Message from the NIST Director

On September 26, 2022, a NIST staff member on our Gaithersburg, Maryland, campus died after falling from a research structure that partially collapsed during demolition. No similar workplace death had occurred at a NIST facility in nearly 100 years, and it has had a profound effect on us. It has made clear that we must change how we think about and implement safety across the entire organization.

Following the incident, we immediately launched an internal investigation to understand its root cause and any contributing factors. The investigation was conducted by a team of safety experts and engineering staff. They interviewed NIST staff members, reviewed physical evidence, documentation and procedures, and brought in outside expertise to conduct modeling and analysis. The investigation team was also charged with developing corrective actions NIST could take to reduce the likelihood that anything like this would happen again.

This report contains the results of that internal investigation, as well as the results of an executive level review that recommended additional, NIST-wide corrective actions.

The investigation thoroughly evaluated all potential contributing factors and determined that a number of those factors converged on the day of the accident. It revealed critical gaps in our safety program, including the fact that it does not support adequate accountability for all hazardous work performed on the NIST campuses. For example, while a thorough safety hazard review was conducted for the experiment for which the structure was built, there was no safety hazard review performed for demolition of the surrounding structure. This meant the demolition of the part of the structure where the accident occurred was not adequately planned.

While NIST's internal investigation was underway, the Occupational Safety and Health Administration (OSHA) conducted its own investigation. On March 23, 2023, OSHA cited NIST for three serious and five other-than-serious violations, which we are working to correct. These are posted on the NIST website.

The internal investigation also found an insufficient safety culture at all levels. A strong safety culture requires commitment by management and staff, clear roles and responsibilities, accountability, and mechanisms for monitoring and continual improvement.

I also established the NIST Safety Commission to examine NIST safety more broadly and to advise us on actions we can take to improve our safety programs and our safety culture. The commission's interim final recommendations are also posted on the NIST website.

I am committed to ensuring that the factors that converged on the day of this tragedy are addressed, and that the changes we make now are institutionalized and provide a foundation for improvement and a stronger NIST. The NIST leadership team and I have already begun planning for implementation of the recommendations from this investigation and those of the Safety Commission.

This death has shaken all of us. It has revealed weaknesses and gaps in our systems and in our attitudes toward safety. We must do everything we can to prevent other avoidable tragedies. This will require commitment at all levels of the organization. We must make immediate and sustained changes to prioritize safety and make it a core part of everything we do. We must do better for our staff members, their loved ones, and everyone who depends on the work NIST does.

I would like to express my gratitude to the investigation team and all the staff members who supported their work, especially in the NIST Fire Research Laboratory. The many hours they spent making sure this investigation was thorough will have a lasting impact on NIST. We will do right by them and honor the memory of our colleague by becoming a better, safer organization.

Laurie E. Locascio
Under Secretary of Commerce for Standards and Technology &
NIST Director

INVESTIGATION OF THE FATALITY AT THE NATIONAL FIRE RESEARCH LABORATORY

April 7, 2023

National Institute of Standards and Technology
Department of Commerce
Gaithersburg, MD 20899

ABSTRACT

In response to the work-related fatality at the National Fire Research Laboratory on September 26, 2022, the National Institute of Standards and Technology (NIST) initiated a planned, two-step process to understand the causes of the incident and identify actions necessary to prevent future incidents.

- **Incident investigation and development of an incident corrective action plan**. The investigation was conducted by staff from the NIST Office of Safety, Health, and Environment and the NIST Engineering Laboratory. The focus was on identifying the causal factors, root causes, and contributing factors of the specific incident. Corrective actions were developed to address the deficiencies identified, as well as other recommendations for NIST leadership to consider. The results of this effort are presented in Part A of this document.

- **Executive Team review and development of a NIST-level corrective action plan**. Subsequently, a subcommittee of NIST's Executive Safety Committee assessed the report and considered the NIST-wide applicability of the corrective actions identified. The Executive Review Team extended corrective actions and recommendations, as necessary, to ensure sufficient breadth, depth, and sustainability of these actions across NIST. Their work is included in Part B of this report.

Through these two activities, NIST shall strengthen its safety management system and address existing shortcomings in its safety culture to protect the safety and health of all staff.

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EXECUTIVE SUMMARY
OF THE NIST INCIDENT INVESTIGATION REPORT

On September 26, 2022, a National Institute of Standards and Technology (NIST) staff member was performing demolition work on a two-story, steel-framed test structure. The test frame, which is located in the National Fire Research Laboratory (NFRL) on the NIST-Gaithersburg campus, was used in a fire research project over the past three years and was scheduled for demolition with the completion of the experimental work. The staff member was sectioning a large, concrete slab (approximately 12 ft long by 5 ft wide with minimal thickness of 3.25 in.) from a floor which was elevated 13 ft above the lower level of the workspace. The removal process entailed using a walk-behind floor saw to cut the slab from the surrounding floor. An overhead crane would then lift it out with rigging slings, attached via rigging hardware located in the slab corners approximately 1 ft away from each edge, to the lower level for disposal. The staff member used the same technique to remove three other slabs of different shapes and sizes in the two weeks prior.

By lunchtime, the staff member had completed cuts to 3 of the 4 sides and attached the rigging slings to the slab. Upon returning from lunch, the staff member moved the floor saw across the slab and began cutting the last face. With the final cut completed, the slab was now completely free of the surrounding floor and suspended by the rigging slings and overhead crane. The staff member shut the floor saw off and, in an effort to move it out of the way to lift the slab out, pulled the floor saw backwards onto the mid-span (middle) of the slab. This action resulted in an overloading of the suspended slab, with the weight of the staff member and the floor saw, causing the slab to instantaneously and catastrophically fracture beneath him. The staff member fell through the resulting opening in the floor to the level below, suffering fatal injuries.

Within 24 hours of the incident, NIST's Chief Safety Officer authorized an incident investigation team to examine the facts surrounding the incident, determine the causal factors and root causes, identify necessary corrective actions, and provide additional recommendations. The investigation team was composed of staff from NIST's Office of Safety, Health, and Environment (OSHE) and Engineering Laboratory (EL) with the appropriate level of expertise and knowledge to complete the assigned task. The team worked over the next five months reviewing in detail available information and records related to the project work, interviewing NIST staff members and line management, and performing physical and computational analysis of the failed slab.

As a result of this investigation, two actions were identified as causal factors:

1. **Inadequate planning of Slab 4 removal**, specifically, the failed slab was rigged with a very small safety factor. This occurred through a combination of root causes:
    a. The initial hazard review for demolition work on another part of the test frame was inadequately reviewed. There was no evaluation by a demolition safety subject matter expert to identify the appropriate control measures necessary to safely perform the task, and this lack of expertise was carried throughout the multiple stages of demolition work.
    b. The removal technique used during the incident was outside the scope of the approved hazard review. Through its initiation and continued use during earlier demolition work, it

became an acceptable demolition method without an appropriate assessment of the hazards associated with performing the demolition work in that manner.

c. The hazard review for the specific demolition work being performed at the time of the incident was inadequately re-reviewed. Project management was aware of the change in demolition technique compared to what was approved in the original demolition hazard review and erroneously decided not to perform a re-evaluation of the work to assess any new hazards.
d. Work authorization requirements for the demolition work did not have the same rigorous safety scrutiny as the experimental tasks. Many of the attitudes and assumptions made during the approval for demolition work during the incident would not have been acceptable during the testing phase of the project.
e. There was no mechanism to ensure a quality hazard review was developed, approved, and re-viewed and re-approved as necessary. As such, there was a trend in the group's hazard reviews that was not identified, *i.e.*, the focus of hazard reviews was almost exclusively on the experimental activity and less on the "set-up" and "teardown" which is also hazardous work required to perform the experiments.

2. **Accidental loading of Slab 4**, specifically, the staff member pulling the floor saw onto the slab while it was fully suspended by the rigging and crane. This occurred through a combination of root causes:
   a. Standard safe operating procedures were not developed for the demolition work performed at the time of the incident. As a result, the staff member performed numerous unsafe acts while in the process of removing the slab by not properly planning the cuts out in advance, including pulling the floor saw onto the suspended slab.
   b. Staff were authorized to perform this demolition work without the appropriate knowledge of hazards associated with the task. In addition to staff not completing the required training identified by the hazard review, more importantly, there was a gap in the training requirement as no demolition training was identified which would have provided the knowledge on how to plan and perform the work correctly and safely.
   c. Due to project management absence at the worksite, staff became "lax" regarding the implementation of required hazard control measures and the use of safety best practices. The staff member continuously performed unsafe acts, such as walking on a partially or fully suspended slab, as project management was not present to correct this behavior.
   d. In addition to the absence of project management from the worksite, safety responsibilities for the demolition work were consolidated in the staff member performing the work at the time of the incident. Project management failed to ensure adequate division of safety responsibilities between those responsible for overseeing the safety of the work and those performing the work.
   e. Management relied too heavily on the staff member's experience, perceived or otherwise. It was believed the staff member had significant experience from a previous job, and thus, they relied on this individual for both planning and performing the demolition work with no check and balance on either.
   f. Work operations were not continually monitored and updated for compliance by project management. There were multiple opportunities for project management to observe the

work being performed but they did not do so as it appeared project management themselves were not being held accountable for engaging in this responsibility.

The avoidance of these two causal factors was very possible. Through appropriate planning and compliance with established hazard review requirements, in addition to appropriate project management oversight, the slab could have been removed safely by either:

- Rigging it with a higher safety factor through either decreasing the distance between the rigging point locations on the slab or shortening the slab length (which effectively would reduce both the rigging point distance and slab weight); or
- Identifying and implementing hazard control measures to ensure the staff member would not load the slab, such as developing an appropriate cutting and lifting plan or establishing administrative requirements prohibiting the slab from being loaded by any means once it is supported by the rigging and crane.

Multiple other factors contributed to this incident, but not as directly as those described above, and are also documented within this report.

Subsequent to root cause and contributing factor identification, 26 corrective actions were developed to address those issues specifically, as well as prevent any future occurrences. These corrective actions fell into four general categories:

- Strengthening requirements for and improving implementation of EL's policy and procedures for work and worker authorization;
- Improving EL line management oversight of hazardous work;
- Increasing EL line management accountability with respect to safety; and
- Addressing gaps in NIST's safety management system in the areas of:
  - Overhead cranes and rigging; and
  - Audits and assessments.

Further, the Team identified concerns that did not contribute to the incident but should be addressed. As such, eleven recommendations were provided for consideration which focused on weaknesses of the NIST safety management system and insufficiencies of the NIST safety culture.

Acknowledgements

It is with gratitude the NIST Incident Investigation Team acknowledges the contribution of many NIST staff members for their assistance with the conduct of this investigation.

The Team acknowledges NIST Senior Leadership for providing us the resources necessary to perform our work and the autonomy to conduct this investigation in an impartial and objective manner.

The Team acknowledges our direct line management for providing us the time necessary to conduct this investigation.

Our deepest gratitude is reserved for the co-workers of the staff member who without their willingness to participate in this investigation and their candid responses during a very difficult time we would not have been able to complete this work.

1.0 INTRODUCTION

On September 26, 2022, an engineering technician [ENGR TECH 1] in National Fire Research Laboratory (NFRL), was performing demolition work on a two-story, steel-framed test structure. This test frame was used in fire research experiments and is located in Building 205 on the Gaithersburg campus of the National Institute of Standards and Technology (NIST). Through review of video evidence of the incident, ENGR TECH 1 was observed sectioning a slab out of an elevated, steel-concrete composite floor for removal using rigging slings and a crane. After attaching the 12 foot (ft) by 5 ft slab to the rigging and completing the last cut to free it from the surrounding floor, ENGR TECH 1 pulled the walk-behind floor saw onto the mid-span of the slab. This act overloaded the slab resulting in an instantaneous and catastrophic fracture near the mid-span. The failure of the slab beneath ENGR TECH 1 resulted in him falling approximately 13 feet through the floor opening to the level below and sustaining fatal injuries.

Within 24 hours of the incident, NIST's Chief Safety Officer authorized an incident investigation team to:

- Examine the facts surrounding the incident;
- Determine the causal factors, root causes, and contributing factors;
- Identify necessary corrective actions; and
- Provide additional recommendations.

The investigation team was composed of staff from the Office of Safety, Health, and Environment (OSHE) and the Engineering Laboratory (EL) with the appropriate level of expertise and knowledge to complete the assigned task. The team worked over the next five months reviewing in detail available information and records related to the project work, interviewing NIST staff members and line management, and performing physical and computational analysis of the failed slab. Part A of this investigation details the results of the work performed by the NIST Incident Investigation Team.

2.0 TERMINOLOGY AND ACRONYMS

2.1 Terminology

Activity – An experiment, operation, process, or job conducted to achieve a specific outcome.

Causal Factor – A mistake, error, or failure that leads to (or causes) an incident, or fails to mitigate the consequences of the original error.

Contributing Factor – An action or condition not leading directly to the incident but believed to have increased the likelihood of the incident occurring.

Corrective Action – Action taken to eliminate the cause of a detected nonconformity or other undesirable situation.

Corrective Action Plan – A set of planned actions to eliminate the cause of a detected nonconformity or other undesirable situation such as the root cause of an incident.

Deficiency – A deviation from an established NIST requirement, OSHA regulation, or adopted building code or standard. The deficiency categories NIST uses are:

- Imminent danger – Any serious condition or practice that could reasonably be expected to cause death or serious physical harm immediately or before the imminence of the danger can be eliminated through normal procedures.
- Serious – A condition or practice that could be reasonably expected to cause death or serious physical harm to an individual exposed to the condition or practice.
- Other Than Serious/Administrative – A condition or practice that could not reasonably be expected to cause death or serious physical harm

Hazard – Source, situation, or act with a potential for harm in terms of human injury or ill health, adverse impact on the environment, damage or loss of equipment or property, or a combination of these.

Hazardous – Having the potential for harm in terms of human injury or ill health, adverse impact on the environment, damage or loss of equipment or property, or a combination of these.

Hazard Control Measure – Actions taken to reduce the potential of exposure to the hazard. Specific types are:

- Elimination – Action taken to completely remove the source of the hazard from the worker.
- Substitution – Action taken to use a safer alternative to the source of the hazard.
- Engineering – Action taken to reduce or prevent the worker from coming into contact with the hazard.
- Administrative – Action taken with the goal of reducing the duration, frequency, and severity of exposure to the hazard.
- Personal protective equipment – Equipment physically worn by the worker to minimize exposure to hazards that cause serious workplace injuries and illnesses.

Hazard Identification – Process of recognizing that a hazard exists and defining its characteristics.

Hazard Review (Document) – A document describing the results of the hazard review process.

Hazard Review (Process) – The formal process, aspects of which could be iterative, of describing an activity, identifying the hazards associated with the activity, reviewing the physical-location in which the activity will be carried out, assessing the compatibility of the activity with nearby activities, conducting an initial hazard assessment, identifying controls to mitigate the hazards, developing an incident-response plan, conducting a risk assessment, and developing plans for managing wastes generated during the conduct of the activity. This process is typically used by those who perform research-related activities.

Hierarchy of Controls – A range of hazard control measures arranged in order of implementation preference:

- Elimination
- Substitution
- Engineering
- Administrative
- Personal protective equipment

Please see "Hazard Control Measure" for the specific definitions.

Incident – A work-related event in which any of the following, individually or in combination, occurred: an injury or illness; an unauthorized spill or release of hazardous or regulated material to the environment; property damage; exposure; or contamination by radioactive material.

Investigation – The systematic process of analyzing the events leading up to an event, gaining an understanding of what caused it, identifying actions to prevent recurrence, and documenting the results in a written Investigation Report.

Likelihood of a Hazardous Event or Exposure ("Likelihood") – An estimate of the probability of a hazardous event or exposure. The likelihood categories NIST uses are:

- Frequent – Likely to occur frequently or repeatedly.
- Probable – Likely to occur multiple but infrequent times.
- Occasional – Likely to occur at some time.
- Remote – Possible, but not likely to occur.
- Improbable – Very unlikely or can reasonably be assumed not to occur.

Management Observation Process – An element of the NIST safety management system designed to promote safe operations and continual improvement by facilitating an ongoing and frequently occurring conversation about safety between staff and line management.

Relative Hazard Index (RHI) – A measure of the risk of a hazardous event or exposure based on a combination of the severity of the consequences of the hazardous event or exposure to a hazard and its likelihood. The RHI levels NIST uses are:

- 4 – Critical
- 3 – Serious
- 2 – Medium
- 1 – Low
- 0 – Minimal

Requirement (for safety) – A rule established to indicate what actions must be taken or how those actions must be performed in an effort to ensure the safety and health of staff.

Residual Risk – The risk to a staff member subsequent to all identified hazard control measures being implemented.

Risk – Combination of the likelihood of an occurrence of a hazardous event or exposure and the severity of injury or ill health that can be caused by the event or exposure.

Risk Assessment – Process of evaluating the risks arising from hazards, taking into account the adequacy of any existing controls, and deciding whether or not the risks are acceptable.

Root Cause – The absence of a best practice or the failure to apply knowledge that would have prevented the problem, or significantly reduced its likelihood or consequences.

Safety Factor (S_F) – The ratio between the strength of a structure or material, *i.e.*, ability of a structure or material to carry a load, and the load imposed on that structure or material. A value above unity indicates the structure or material is not overloaded and will not fail, but a value of unity or lower indicates the structure or material is loaded at or above its capacity and will fail.

Safety training – Information provide to alert the staff member to the identification, assessment, and control of a specific hazard. Training can be:

- "NIST-level" – Communicating NIST requirements and the associated roles and responsibilities for ensuring those requirements are met; or
- "OU-level" – Communicating activity-specific requirements identified by the hazard review applicable to the work being performed.

Scope Creep – A change in the original boundaries of approved work, *e.g.*, change in the process used or location of where the work is to be performed.

Severity of the Consequences of a Hazardous Event or Exposure to a Hazard (“Severity”) – A qualitative measure of the consequences of the worst credible hazardous event or exposure associated with an identified hazard due to design inadequacies; procedural deficiencies; human error; environmental conditions; or system, subsystem, or component failure or malfunction. The severity categories NIST users are:

- Catastrophic – Death or permanent disability; system or facility loss; major property damage, lasting environmental or public-health impact.
- Severe – Serious injury; temporary total disability (more than 3 months); subsystem loss or significant facility/property damage, temporary environmental or public-health impact.
- Moderate – Medical treatment beyond first aid; lost workdays; more than slight facility/property damage; external reporting requirements; more than routine clean-up.
- Minor – First aid or minor medical treatment; negligible or slight facility/property damage; no external (outside NIST) reporting requirements, routine cleanup.

Standard Operating Procedure – A written step-by-step procedure or operational protocol used to document how a given task must be carried out to ensure safe operation. Standard operating procedures are generally needed when failure to follow a prescribed set of steps results in significant increase in risk.

- EL refers to this document as a Standard Safe Operating Procedure (SSOP) as well.

Task – A component of an activity that provides more specific detail regarding the steps required to complete the work.

2.2 Acronyms

CF – Composite floor

DOC – Department of Commerce

DSR – Division Safety Representative

EL – Engineering Laboratory

ENGR TECH – Engineering Technician

FE – Finite element

FLHR – First-Level Hazard Review

FPG – Fire Protection Group

FRD – Fire Research Division

ft – Foot or Feet

HRC – Hazard Review Committee

KSA – Knowledge, Skills, and Abilities

ksi – Kilopound per Square Inch

kW – Kilowatt

lb – Pound

m – Meter

MOP – Management Observation Process

MW – Megawatt

NFRL – National Fire Research Laboratory

NIST – National Institute of Standards and Technology

OISM – Office of Information Systems Management

OSHE – Office of Safety, Health, and Environment

OU – Organizational Unit

OSY – Office of Security

PACS – Physical Access Control System

PSG – Police Services Group

RHI – Relative Hazard Index

S_F – Safety Factor

sq ft – square feet

SOP – Standard Operating Procedure

SSOP – Standard Safe Operating Procedure

WWR – Welded Wire Reinforcement

3.0 BACKGROUND

3.1 National Fire Research Laboratory Group

The NFRL Group resides within the Fire Research Division (FRD) of the NIST Engineering Laboratory at the National Institute of Standards and Technology – please see Figure 3.1.1. The Group is staffed by federal employees who are engineers (*e.g.*, mechanical, structural, electronics) and engineering technicians. National Research Council postdoctoral fellows, as well as domestic and foreign guest scientists, may also be included as staff members. Depending on project needs, engineers and technicians from other groups in FRD, other divisions within EL, and other organizational units (OUs) within NIST can be temporarily assigned to the NFRL Group.

The NFRL mission is to collaborate with scientists and engineers from industry, academia, and government agencies to address critical technical problems related to fire behavior and structural response to fire. Research areas include:

- Advancement of real-scale fire measurements on habitable structures (*e.g.*, townhouses, offices, and kitchens) and other large objects (*e.g.*, automobiles, buses, and train cars);
- Generation of technical data to improve fire and building codes (*e.g.*, performance testing of cross-laminated timber, light gauge steel-frame structures, and concrete-steel composite floor systems);
- Validation of physics-based models (*e.g.*, the NIST Fire Dynamics Simulator);
- Measurement of heat release rates of a wide variety of items (*e.g.*, crude oils, office and home furnishings, electrical cables, wildfire vegetation, flame retardant foams and plastics);
- Performance of fire suppression systems (*e.g.*, effectiveness of sprinklers, hose streams, and water mist on fires)
- Effectiveness of firefighter equipment technologies (*e.g.*, use of thermal imaging cameras, turnout gear, and self-contained breathing apparatus facemasks) and firefighting tactics (*e.g.*, positive pressure ventilation and wind driven fire suppression techniques); and
- Post-fire investigations (*e.g.*, participation in National Construction Safety Team Investigations such as the World Trade Center Disaster and the Rhode Island Station Nightclub Fire).

3.2 National Fire Research Laboratory Facility – Building 205

The NFRL Group operates the National Fire Research Laboratory located in Building 205 (please see Figure 3.2.1) which is located on the NIST-Gaithersburg campus (please see Figure 3.2.2). The majority of the NFRL fire experiments are performed here. Figure 3.2.3 shows this unique facility in a scale plan view drawing. There are two main laboratories – Room 113 (south high bay of the building – also known as the "fire" or "legacy" side as it was first constructed in 1973) and Room 125 (north high bay of the building – a recent addition commissioned in October 2014). Fire research is performed in both spaces and may involve the use of two natural-gas calibration burners, 8 megawatt (MW) and 16 MW, in order to implement quality control in heat release rate measurements. Other fuels (*e.g.*, household items, office building contents, liquid fuels) can also be used to create and/or sustain the fires. All experiments are conducted under instrumented exhaust hoods that capture smoke and unwanted combustion by-products. Room 113 contains three of these hoods:

- 3 meter (m) x 3 m hood with capacity to handle fire loads up to 750 kilowatt (kW);
- 6 m x 6 m hood with capacity to handle fire loads up to 3 MW; and
- 9 m x 12 m hood with capacity to handle fire loads up to 10 MW.

A fourth hood, the largest at 14 m x 15 m which can handle fire loads up to 20 MW, is located in Room 125. These four hoods are connected to two environmental control systems to treat effluents to meet emission regulations (north and west of the building and shown in Figure 3.2.1).

A variety of instrumentation can be set up for measuring variables such as temperature and pressure in the fire environment, thermal radiation from fires, real-time gas concentrations (*e.g.*, oxygen, carbon dioxide, carbon monoxide, hydrocarbons), and smoke. Sensors can also be employed to measure the mass of the burning materials as well as the structural strain and displacement of the test specimen. A network of precision, high speed data acquisition systems are used for recording signals from these instruments and displaying video outputs.

Since the addition of Room 125, experiments can be performed at a much larger scale (*e.g.*, fully involved building fires fueled by actual building contents or liquid fuels) and allow for controlled loading of structural components during the fires. The latter is done through a test area consisting of a "strong floor" and an adjacent "strong wall" (both are shown in Figures 3.2.3 and 3.2.4) which sit below the 20 MW exhaust hood. The strong wall, 9 m high, acts to stabilize a test specimen to prevent uncontrolled failure, provide lateral restraint, or laterally load a structure (*e.g.*, simulate earthquake or wind effects). The strong floor, 486 m^2 area, provides tie-downs for simulating building foundation constraints and allows for structural reactions to develop in the specimens being tested. Room 125 is also equipped with a configurable hydraulic system and actuators to provide loading to the test structures.

To facilitate carrying out the research in Room 125, several powered industrial vehicles (*e.g.*, forklifts, scissor lift, and boom lift) and two 20-ton bridge cranes are available.

3.3 NFRL Project: Steel-Concrete Composite Floor Systems Subject to Fire Research

Beginning in July 2015, NFRL staff began dialogue with a panel of outside experts – consisting of practicing structural and fire protection engineers from around the world – to develop research concentrated on fire risk reduction in buildings. One focus was on the structural integrity of steel-concrete composite floor systems and factors influencing their fire resistance, including the steel reinforcement used in the floor, the presence or absence of passive fire protection of the steel floor framing, and the types of structural connections. The project was titled *Steel-Concrete Composite Floor Systems Subject to Fire Research* (hereafter referred to as "CF Project").

With the assistance of the outside experts, NFRL staff designed a "reusable" two-story, steel gravity test frame[1] in which a series of fire experiments could be performed to achieve the research objectives. The test frame (please see Figure 3.3.1), constructed underneath the large exhaust hood

[1] Please see Section 6.4 of this report for a full description of the CF Project test frame, including the mechanical properties of the materials used in its construction.

on the strong floor in Room 125, was composed of vertical columns and horizontal girders and beams made of structural steel. The composite steel-concrete floor was then built in place to create an elevated floor 13 feet above the strong floor (from the walking surface of the elevated floor). Underneath a portion of the composite floor, and on the strong floor, a fire test compartment[2] was built in which realistic fires could be created to test the structural integrity of the composite floor directly above it (please see Figure 3.3.2). Both the fire-tested floor and surrounding floor were loaded during the test. Due to the placement of the fire test compartment, the vertical steel columns were not directly exposed to fire, only the composite floor above the compartment. Therefore, after an experiment was completed, the portion of damaged fired-tested floor could be removed without affecting the surrounding composite floor that did not experience damage during the testing. Prior to the next experiment, a new composite floor for testing was rebuilt.

Three experiments[3] were performed using the CF Project test frame on:

- November 14, 2019;
- March 10, 2021; and
- February 3, 2022.

For convenience, they are referred to as CF1, CF2, and CF3, respectively, in this report. CF1 generated baseline data for the real fire resistance and behavior of a full-scale composite floor system designed to achieve a 2-hour fire resistance rating used in the US practice [Choe *et al*., 2021]. CF2 studied fire resistance of the composite floor system with a different slab reinforcement configuration from CF1 [Choe *et al*., 2022]. CF3 was identical to CF2 except no passive fire protection was applied on the exposed secondary steel beam [Ramesh *et al*., 2022]. In all three experiments, the fire-tested floor was loaded using four hydraulic actuators to simulate gravity and fire load combination as prescribed in ASCE 7 [ASCE, 2016]. The surrounding floors were loaded by water-filled drums, providing an imposed load equivalent to 50% of the office live load as also prescribed in ASCE 7 [ASCE, 2016]. After each experiment, a forensic investigation of the fire-tested floor was conducted to visually assess the concrete floor, the structural steel, and the structural steel connections supporting the test floor for fire damage and anomalies. A visual inspection of the surrounding floor was also performed.

While additional tests were envisioned after CF3, the research team decided in May 2022 that future experiments would not be conducted after CF3 and the test frame would be demolished.

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[2] Full design and construction details of the fire test compartment are provided in Choe *et al*. [2021, 2022] and Ramesh *et al*. [2022].

[3] Please see the references noted for a complete description of the experiment and results for each CF Project test.

4.0 NARRATIVE OF THE INCIDENT

The information contained in this section is compiled from the activities identified in Section 5 (Incident Investigation Methodology) and reviewed in Section 6 (Incident Investigation Results), and specifically from videographic evidence, investigation interviews with CF Project staff, and relevant CF Project documents. It is presented here to provide the Reader with knowledge of events leading up to and including the incident as justification for the investigative process used to collect the appropriate evidence and subsequent analysis of that information to arrive at the findings of Section 7 (Incident Investigative Findings) and Section 8 (Causal Factors, Root Causes, Contributing Factors, and Corrective Actions).

4.1 Events Leading up to the Incident

The fire-tested floor of each CF Project experiment was of significant interest from a scientific perspective in terms of the fire resistance of the test floor beams and girders themselves, their connections, and the concrete and steel reinforcement that made up the composite floor. As such, a hazard review was conducted, titled *Composite Floor System Stabilization and Demolition*, that covered work performed as part of the forensic inspection and subsequent removal of the fire-tested floor. The scope of this document was well-defined in that it covered the demolition of a damaged or partially collapsed test section. Various hazards associated with the work were determined and hazard control measures identified to mitigate those hazards.

Prior to any work being performed, the standard operating procedure (SOP) called for a team of structural engineers to analyze the condition of the CF Project test frame as a whole after it reached ambient temperature. Once a determination was made the surrounding bays were safe to work on, under, and around, wood shoring structures were placed inside the fire compartment to support the fire-tested floor during the forensic analysis and ensuing demolition work. The shoring, designed using techniques identified by a Department of Homeland Security field guide[4], was expected to withstand the weight of the test section it was supporting and those working on it. To ensure this requirement was met, the SOP required the design be reviewed and approved by the workspace manager, the principal investigator (leader of the CF Project), and group leader for NFRL. The final constructed shoring was also required to be inspected by a structural engineer. Additional spot shoring, in the form of metal poles, was used at key locations under the surrounding floor in areas directly adjacent to the fire test compartment.

With the shoring in place, the CF Project Team could begin the forensic inspection. This consisted of engineering technicians using a hand-held concrete saw to saw cut around a region of concrete to be removed for evaluation; a walk-behind floor saw was also used even though it was not considered in the hazard review. Concrete outlined by the saw cuts was removed through a combination of jackhammer, hammer drill, and hammer and chisel with the rubble disposed of manually using buckets. Engineers or the engineering technicians took pictures of interest in these locations.

[4] https://www.dhs.gov/science-and-technology/bips-08-field-guide-building-stabilization-and-shoring-techniques

After the forensic inspection, the entire fire-tested floor was demolished by jackhammering the remaining portion of the damaged floor and removal to a dumpster through a combination of buckets and chutes. The steel deck pans were removed using an overhead crane and rigging slings attached to plate lifting clamps or c-clamps. Prior to affected beams and girders being removed, a structural engineer was required to be consulted on their individual weights in order to select the proper rigging. Each structural steel member was rigged one at time, connect to the crane, and then enough tension applied by the crane to support the weight of the beam while the connection bolts were removed to free the beam from the structure. Once lifted out and on the strong floor, the structural steel members were relocated to a storage area outside of Building 205. The demolished area of the test frame was then prepared for re-construction of the next composite floor to be tested. This process was used subsequent to CF1 and CF2 experiments, though a third party was contracted to physically remove the concrete rubble after CF2.

Following CF3, a change in the leader of the CF Project transpired as the previous project leader [CF PROJECT LEADER 1] left for an opportunity outside of NIST. The new project leader [CF PROJECT LEADER 2], coming off a year-long detail in another OU at NIST, was well versed with this work as he was a key project member prior to the detail and was still remotely involved in the project while away. In early May 2022, the CF Project Team made the decision no additional testing was needed, communicated this decision to internal and external stakeholders, and indicated the test frame could be demolished.

Around this time, a management safety observation in the NFRL, which included the CF Project, was performed by EL senior leaders and FRD line management. As a result of this discussion, the *Composite Floor System Stabilization and Demolition* hazard review was amended to account for respiratory and hearing hazards not explicitly called out in the current version. The hazard review and associated documents were reviewed by CF PROJECT LEADER 2 and approved by the group leader for NFRL [NFRL GROUP LEADER], the FRD Division Safety Representative [FRD DSR], and the chief of FRD [FRD CHIEF 2]; the date of approval was May 16, 2022. Forensic inspection of the CF3 fire-tested floor occurred shortly thereafter per practices outlined in the SOP and used after CF1 and CF2.

At the same time the forensic inspection work was conducted, discussion commenced around the method to demolish the remaining portion of the test frame, *i.e.*, the surrounding floor bays consisting of the surrounding composite floor and structural steel members. The activity leader [ENGR TECH 1] proposed removing the surrounding floor by cutting out slabs between the beams and girders with a floor saw and lifting them out with an overhead crane. With the exception of one engineering technician [ENGR TECH 2] who preferred to follow the current process of jackhammering the surrounding floor and removing the rubble to the dumpster, the CF Project team members – other engineering technicians, CF PROJECT LEADER 2, and NFRL GROUP LEADER – agreed this could be an easier and safer process.

With the forensic inspection of the CF3 fire-tested floor completed, the remaining portion of the fire-tested floor could be demolished. Without an official approval of the decision to use the proposed demolition technique, ENGR TECH 1 began “experimenting” using the fire-tested floor through the summer of 2022. He progressively cut larger and larger slabs (starting at ~1 ft by ~4 ft and increasing in size up to ~4 ft by ~4 ft) from the damaged fire-tested floor using the walk-behind floor saw. He then exposed rebar in various locations of the slab, hooked them up to the overhead crane with rigging slings using clevises, and lifted them out to a dumpster. Both CF PROJECT LEADER 2 and NFRL GROUP LEADER stated they were aware of this activity. Performing this work with the new demolition method was not covered under the *Composite Floor System Stabilization and Demolition* hazard review.

On June 15, a meeting was proposed by CF PROJECT LEADER 2 to further discuss the proposed demolition process for the surrounding floor and determine if the existing hazard review for the removal of the fire-tested floor was sufficient to cover the demolition work on the surrounding floor. It is unclear if this meeting was held on this date, but through some series of discussions it was verbally approved by NFRL GROUP LEADER, with the concurrence of CF PROJECT LEADER 2, to perform a "test case" of removing a larger slab from the fire-tested floor. No hazard review was requested or performed for this test case.

ENGR TECH 1, with the assistance of ENGR TECH 2, removed a slab from the damaged fire-tested floor that measured ~9 ft by ~9 ft. This occurred sometime near the middle of August with neither NFRL GROUP LEADER nor CF PROJECT LEADER 2 present for the activity. With the success of this test, a verbal approval was provided by NFRL GROUP LEADER, with no objections from CF PROJECT LEADER 2, to move forward with using the new slab removal process. Further, with the knowledge of:

- The demolition process being completely different; and
- The physical location of the work being performed different (as well as the condition of the material being removed was not the same),

no re-review of the hazard review was conducted as:

- NFRL GROUP LEADER stated this demolition activity (cutting with floor saw and lifting the slab out) was perceived to be less hazardous work when compared to the jackhammering of the fire-tested floor and manual removal of the concrete rubble; and
- CF PROJECT LEADER 2 stated that at the time he believed the information contained in the two previously approved CF Project hazard reviews, the *NFRL Overhead Crane* hazard review, and the general safety training and procedures for the execution of work in the NFRL, had sufficiently covered this method of demolition so there was no need to do a re-review and re-approval.

In preparation for the slab removal process of the surrounding floor, ENGR TECH 1 communicated via email (August 22, 2022) to NFRL GROUP LEADER he was developing a "lifting plan". This plan, later referred to by ENGR TECH 1 as the *Coring and Cutting Plan*, showed the cutlines for each slab to be removed and the locations of the associated core holes where rigging hardware was to be attached (please see Figure 4.1.1). This plan was emailed by ENGR TECH 1 to ENGR TECH 2 on August 23, 2022, indicating the engineering technician could begin transcribing the cutlines and core holes to the surrounding floor. The only specific instructions stipulated were the core holes should be symmetric and no further apart than shown on the plan. While there was an indication the rigging slings could safely support the load (self-weight) of the Slab 1, there were no structural calculations provided indicating the safety factor for each slab lift. Further, there was no indication in the email regarding whether any other individuals had reviewed the plan or if the size or shape of the proposed slabs are a concern – only that the proposed plan would minimize the number of cuts they need to make on the structure. NFRL GROUP LEADER and CF PROJECT LEADER 2 were not provided the *Coring and Cutting Plan* or any related calculations, nor was information of this kind requested by them in advance of the work proceeding. ENGR TECH 2 transcribed the proposed slab cutlines and core hole locations onto the surrounding test floor with chalk during the week of August 29 and drilled the core holes during the following week (September 6 through 9).

As there is no videographic evidence of the cutting of Slab 1 and Slab 2, the following information was compiled from interview statements with multiple engineering technicians who worked in Building 205. ENGR TECH 1 performed the cutting of both slabs sometime between September 12 and September 15. For Slab 1, the walk-behind floor saw was used to make the cuts on each face of the slab, but a jackhammer was needed to free the two southern corners as the cuts did not extend far enough to free the slab completely. Other than this extra step, Slab 1 was removed without complications. The same process was used to cut out and remove Slab 2, however, the jackhammer was not required as ENGR TECH 1 overcut the corners to ensure the slab was completely free from the surrounding floor. For both slabs, no wood shoring was placed beneath them similar to that used for the demolition of the fire-tested floor as it was perceived the surrounding floor was "undamaged". After Slab 2 was removed, wooden shoring used for the fire-tested floor removal was re-positioned under the holes where Slab 1 and Slab 2 had been removed in an effort to provide some fall protection as large, unprotected openings were now created in the surrounding floor.

On the morning of September 23, Slab 3 was removed by ENGR TECH 1 with assistance from ENGR TECH 3. Video evidence was available for this activity. During the cutting, ENGR TECH 1 was observed walking on the slab that was partially and fully cut free from the surrounding floor while the rigging and overhead crane were engaged. Additionally, after the four faces of the slab had been cut and the slab solely supported by the rigging, ENGR TECH 1 was observed walking the floor saw across the mid-span of the slab to relocate it out of the way such that the slab could be lifted out with the crane. Further, while trying to raise the slab out of the surrounding floor using the overhead crane, it was observed to be stuck on the west side of the slab. ENGR TECH 1 was subsequently seen standing on the northeast corner of the slab and bouncing it in an attempt to free it, while at the same time operating the overhead crane with the remote. With additional cuts to the steel decking using a reciprocating saw on the northwest corner of Slab 3 by ENGR TECH 3, the slab was freed from the surrounding floor and placed in the dumpster. After Slab 3 removal, shoring was not placed in the cut bay similar to that for Slab 1 and Slab 2 cut bays. While ENGR TECH 1 installed passive fall protection (cabling) between the Slab 3/4 and Slab 5/6 locations, fall protection measures were not employed to protect the floor opening associated with the removal of Slab 3 from the Slab 4 location even though ENGR TECH 1 and ENGR TECH 2 discussed the need for it on the afternoon of September 23.

Neither NFRL GROUP LEADER nor CF PROJECT LEADER 2 witnessed the cutting or removal of Slabs 1, 2, and 3 as they both indicated they had confidence in ENGR TECH 1 to perform the work.

They both stated they did check in with ENGR TECH 1 on occasion regarding how the work was proceeding or if there were any concerns.

4.2 The Incident

On the morning of September 26, ENGR TECH 1 began the removal process of Slab 4 using the same technique. ENGR TECH 3 was on the surrounding floor performing different demolition activities near the Slab 1 cut bay. Both ENGR TECH 1 and ENGR TECH 3 were observed walking and working around the unprotected floor opening created by Slab 3 removal without any personal fall protection equipment or other fall protection hazard control measure. Around mid-morning, ENGR TECH 1 stopped the cutting process and covered a portion of the unguarded opening with a piece of plywood on the west edge of the hole. Based on the size of the plywood (~2 ft wide), it covered only a small fraction of the Slab 3 floor opening. Afterwards ENGR TECH 1 resumed his cutting of the slab. Prior to lunch, he completed the cutting of the east and west faces of the slab, attached and engaged the rigging, and cut the north face. The floor saw was left on the north side of Slab 4 (please see Figure 4.2.1a).

Upon returning from lunch, ENGR TECH 1 removed the plywood guarding the small section of the floor opening from Slab 3. He positioned a piece of angle iron across the floor opening but did nothing additional to protect it. ENGR TECH 1 obtained the floor saw from the north side of the slab where he left it prior to lunch and walked it across the mid-span of Slab 4, from the north to the south underneath the rigging, in order to cut the south face. This resulted in the cooling water hose attached to the floor saw stretching across the slab, between the east and west rigging points (please see Figure 4.2.1b). During the time ENGR TECH 1 was cutting the south face of the slab, ENGR TECH 3 returned to the surrounding floor and was repairing a piece of equipment on the west side of the test frame. With the final cut of the slab completed (please see Figure 4.2.1c) and the slab solely supported by the rigging, ENGR TECH 1 pulled the saw backwards toward the mid-point of the slab (please see Figure 4.2.1d). He then fully steps on the slab to move the cooling water hose more towards the west and out of the way. ENGR TECH 1 then positioned himself on the slab near the mid-span to turn the floor saw 90º counterclockwise (please see Figure 4.2.1e) so he could pull it backwards across the mid-span of the slab, from the south to the north. As ENGR TECH 1 began to pull the saw backwards and the back wheels of the saw rolled onto the slab, an instantaneous and catastrophic failure of the slab occurred resulting in him falling approximately 13 ft to the strong floor below and sustaining fatal injuries.

5.0 INCIDENT INVESTIGATION METHODOLOGY

5.1 Evaluation and Activities at the Incident Site

On the day of the incident, Room 125 of Building 205 was secured by the NIST Police Services Group (PSG), part of the Office of Security (OSY) in the U.S. Department of Commerce (DOC), and physical access restricted via the electronic badge reader system – Physical Access Control System (PACS). Only PSG staff had physical access to this space while they conducted their investigation. Upon request, a PSG staff member would escort NIST staff into the room. On October 2, 2022, following completion of their investigation, PSG released control of Room 125 to the NIST Incident Investigation Team. Physical access to Room 125 was again restricted using PACS to the Team members, the NIST Chief Safety Officer, and staff from PSG and the NIST Fire Protection Group (FPG). On November 18, 2022, Building 205 access levels were restored to their pre-incident states with the knowledge NFRL staff members could access the space but not the CF Project test frame.

Over the 6 months following the incident, the NIST Incident Investigation Team members accessed Room 125 for the following reasons:

- To secure the pieces of slab which were suspended following the incident;
- To document the incident site, the incident slab (Slab 4), and equipment used during the incident via drone video, still photographs, and physical measurements;
- To reposition pieces of the incident slab (Slab 4);
- To review the incident site with contract staff as part of the finite element modelling and failure analysis work (please see Sections 5.5 and 5.6); and
- To prepare and ship samples of the incident slab to contract staff for petrography, material property analysis, fracture surface review, and failure analysis.

All drone videos and still photographs taken at the incident site were stored in a secure folder accessible only to the NIST Incident Investigation Team.

5.2 Review of Videographic Evidence from the Incident Site

Building 205 is outfitted with six digital video cameras that take continuous feed and store the recordings on a local server in Building 205 for a period of one week. The files are separated into 60-minute intervals starting at the top of each hour. Subsequent to the incident, NIST obtained the video files from NFRL GROUP LEADER and stored them on a secure server. Video was available from these cameras starting at 9:00 am ET on September 20, 2022, through 10:00 am ET on September 27, 2022. Two of the video cameras are located in Room 125 (please see Figure 5.2.1) and are designated by:

- CAMERA 1 – This camera is located in the southwest corner of Room 125 and faces northeast. It provides a view of the west side of the test frame (please see Figure 5.2.2).
- CAMERA 2 – This camera is located in the southeast corner of Room 125 and faces northwest. It provides a view of the east side of the test frame (please see Figure 5.2.3).

Still images were captured from the video and used in this document.

5.3 Interviews of Relevant NIST Staff Members

Current and former EL staff members were interviewed as part of this investigation. All interviewees were NIST staff members at the time of their interview, with the exception of CF PROJECT LEADER 1. Their title at the time of the incident is provided.

- EL Line Management
  - EL DIRECTOR
  - EL DEPUTY DIRECTOR
  - FRD CHIEF 2
  - NFRL GROUP LEADER (two statements)

- NFRL Research Staff for the CF Project
  - CF PROJECT LEADER 1
  - CF PROJECT LEADER 2 (two statements)
  - NFRL ENGINEER 1
  - NFRL ENGINEER 2
  - NFRL ENGINEER 3

- EL Engineering Technicians
  - ENGR TECH 2 (two statements)
  - ENGR TECH 3
  - ENGR TECH 4
  - ENGR TECH 5
  - ENGR TECH 6

- EL Safety Positions
  - EL SAFETY PROFESSIONAL
  - FRD DIVISION SAFETY REPRESENTATIVE (DSR)

- NIST First Responders, FPG staff
  - FIRE FIGHTER 1
  - FIRE FIGHTER 2
  - FIRE FIGHTER 3

The individual interviews were conducted virtually with one NIST Incident Investigation Team member responsible for leading the interview and other Team members manually capturing responses. No audio or video recordings were made.

The interviewees were asked questions in the following areas:

- Roles and responsibilities at NIST;
- Management of safety within EL;
- Accountability of EL staff with respect to safety;
- General thoughts regarding the safety culture within the NFRL Group;
- Relationship and interactions with ENGR TECH 1;

- General roles and responsibilities with respect to the CF Project;
- Involvement with the design of the CF Project test frame;
- Involvement with the construction of the CF Project test frame;
- Procedures and involvement associated with post-experiment work on the CF Project fire-tested floors;
- Procedures and involvement with demolition of the CF Project fire-tested floors, including development and review of hazard reviews and standard operating procedures;
- Procedures and involvement with demolition of the CF Project test frame, including development and review of hazard reviews and standard operating procedures; and
- Knowledge of the incident.

Depending on the individual's role and responsibilities, some areas listed above were not covered with the interviewee.

Following the interview, a document was created from the Team members' notes. The interviewee was then provided with the opportunity to review and edit the document as necessary to ensure clarity and accuracy of their statement. Once the interviewee was satisfied with the content of the document, it was converted to a pdf and electronically signed by the interviewee. In select cases, some staff members were interviewed more than once to gather additional information or obtain clarification on previous responses. Their statements are found in Appendix 5.3.1.

5.4 Evaluation of Relevant Documents and Records

The following documents and records were reviewed as part of this investigation.

- Engineering drawings for the CF Project test frame;
- Construction videos and photos of the CF Project test frame;
- Hazard reviews and standard operating procedures associated with CF Project work;
- Documents and relevant emails related to the demolition of the surrounding floor of the CF Project test frame;
- Published research documents for the CF Project;
- Lab notebooks or working documents;
- Manuals and specifications for equipment used during the incident;
- Workplace inspection records for Room 125;
- Relevant incident investigation reports at NIST which occurred prior to the incident;
- Safety training records for relevant staff members;
- Maryland Medical Examiner's report (Case number 22-12638); and
- NIST PSG police report (G2022-000053)

These reviews were performed by NIST Incident Investigation Team members, and when necessary, assisted by NFRL staff.

5.5 Finite Element Modeling Analysis and 2-D Hand Calculations

An independent structural analysis contractor was contracted to perform high-fidelity, 3-D nonlinear finite element (FE) modeling of steel-concrete composite slabs cut from the surrounding floor and supported by the rigging slings attached to an overhead crane. The model[5] accounted for the self-weight of the slab as well as supplemental or “accidental loads” of the weight of an operator and a walk-behind floor saw. In addition to the as-built and as-cut geometry of the incident slab, two other as-built and as-cut geometry slabs were modelled, as well as scenarios where variation in size, steel reinforcement, and rigging locations of the incident slab were considered. The contractor also performed simplified 2-D calculations of similar slab and loading events. Calculation of the safety factors for these lifts were performed to help explain the results for each scenario in both 2-D and 3-D work.

The contractor visited the NIST-Gaithersburg campus on November 16, 2022, to obtain information related to the incident and review the incident site. Numerous components used in the rigging of the incident slab were requested for analysis as part of the FE modelling effort. These included one of the rigging slings and one set of the rigging hardware (please see Figure 5.5.1). Additionally, a sample of the rebar chair used in the composite floor was provided (Figure 5.5.2). These components were shipped to the contractor.

5.6 Physical Analysis of Slab 4 (Incident Slab)

Concurrent with the FE modeling work described in Section 5.5, the contractor performed an analysis[6] of the concrete sections of the incident slab which included mechanical property testing, petrographic examination, and fracture surface evaluation. The samples to be evaluated were identified during the campus visit, marked, photographed, and sectioned using a wet concrete saw (please see Figures 5.6.1 through 5.6.3). Those samples, along with five core samples with 1 inch diameters (please see Figure 5.6.4) from unknown locations in the surrounding floor, were also shipped to the contractor.

5.7 Identification of Causal Factors, Root Causes, Contributing Factors, Corrective Actions, and Recommendations

The process of identifying causal factors and root causes started by creating a timeline of events and associated conditions from the information obtained during the investigation. Two timelines were created during this process:

- General events leading from the decision to end the CF Project and demolish the test structure; and
- Specific events on the day of the incident.

The NIST Incident Investigation Team used the timelines to identify events and conditions that were causal factors, *i.e.*, conditions and events that if changed would have resulted in avoidance of the incident. For each causal factor, root causes, *i.e.*, the absence of a best practice or the failure to apply knowledge that would have prevented the problem, were then identified using a combination of methods, including:

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[5] Appendix 6.16.1 contains the contractor’s report and provides information on the modelling approach, including major assumptions.

[6] Appendix 6.16.1 contains the contractor’s report and provides information on the methods used for these analyses.

- Open discussion regarding missing hazard control measures that allowed the incident to occur;
- The “5 Why” methodology; and
- The TapRooT methodology.

Additionally, contributing factors, *i.e.*, factors not leading directly to the incident but believed to have increased the likelihood of the incident occurring, were also identified.

The NIST Incident Investigation Team reviewed each root cause and contributing factor and developed corrective actions intended to address the issues identified and prevent recurrence. While the specific corrective actions are described in this report, representatives from the NIST Incident Investigation Team, the NIST Executive Review Team, and EL will meet within one week of the report being finalized to address the following:

- Identification of the organization or individual responsible for implementation of the corrective action;
- Identification of an expected time to complete the corrective action; and
- Identification of the organization or individual responsible for verifying the corrective action is complete.

Finally, other conditions identified that were not directly related to the incident, but which could result in future incidents, were identified and communicated as recommendations for NIST to consider.

6.0 INCIDENT INVESTIGATION RESULTS

6.1 Safety Management in the Engineering Laboratory

The Engineering Laboratory, like most OUs at NIST, has the management structure shown in Figure 6.1.1. Responsibilities flow from the NIST Director through each line manager to the group leader. While not having official line management authority, those shown on the right in blue boxes have safety responsibilities within EL, as discussed below in Section 6.1.1

Management policies and the associated roles and responsibilities in EL are established through a series of Management Memos. Safety is covered in EL Management Memo 01 (MM01): *Safety and Health Management* (please see Appendix 6.1.1). This document establishes basic safety expectations for all EL staff, defines specific roles and responsibilities for each, sets expectations for following emergency protocols, and provides the general framework for how safety training, workplace inspections, hazard reviews, and the management observation process are conducted and managed.

6.1.1 EL Safety Roles and Responsibilities

Appendix A in MM01 details the safety roles and responsibilities for various positions within EL. The following summarizes those in line management which are germane to this investigation.

- The ***EL Director*** is expected to actively support the development and oversee implementation of EL safety policies and procedures that support a positive safety culture and contribute to effective, proactive execution of the EL Safety Management System. Specific responsibilities include continually improving the safety culture of EL and achieving NIST performance objectives through regular inspections, Management Observation Process (MOP) visits, documentation, policy and procedure reviews, and assessments.
- ***EL Division Chiefs*** and ***Office Chiefs***[7] are expected to provide leadership in promoting a positive safety culture throughout the division/office, and implementing, maintaining, and continually improving the effective, proactive execution of the safety management system at the division/office level. Specific responsibilities include ensuring implementation of NIST and EL-wide safety policies and procedures and providing resources as needed to ensure the safety of staff. With respect to hazard reviews, they must review and approve all work that has a relative hazard index[8] (RHI) equal to 2 or greater (please see Section 6.2.2 for all discussion of EL responsibilities for hazard reviews). The standard critical element inserted in all EL division chiefs' and office chiefs' performance plans is found in Appendix 6.1.2.
- ***EL Group Leaders*** are expected to provide leadership in promoting a positive safety culture throughout the group, and implementing, maintaining, and continually improving the effective, proactive execution of the safety management system at the group level. Specific responsibilities include ensuring all potentially hazardous activities within the group have been reviewed in accordance with *EL Hazard Review and Approval Policy and Procedure* (please see Section 6.2.2) and staff have the appropriate knowledge of any potential hazards and associated hazard control measures (please see Section 6.2) necessary to protect

[7] MM01 lists "Office Chief" being on the same level as "Group Leader". However, through discussion with EL Senior Leaders, "Office Chief" is on the same level as "Division Chief".

[8] Please see Section 2.1 for the definition of relative hazard index and Section 6.2 for its use with hazard reviews.

themselves before they begin work. With respect to hazard reviews, they must review and approve all work within their group. The standard critical element inserted in all EL group leaders' performance plans is found in Appendix 6.1.2.

All EL staff members, federal employees and NIST associates and regardless of supervisory responsibilities, are expected to actively support a positive safety culture and contribute to effective, proactive execution of the EL Safety Management System. Specific responsibilities include contributing to a safe, secure, and healthy workplace and continually communicating and emphasizing the importance of safety and holding themselves and each other accountable for ensuring a safe workplace. In doing so, they are given the authority to take actions necessary to ensure a safe workspace, and to report unsafe working conditions or cease work activity if they believe an imminent safety danger exists, without fear of retribution. Accountability is established through the requirement that safety be included as a critical element or activity in each EL staff member's annual performance plan. The standard critical element inserted in all EL non-supervisory ZP and ZT performance plans is found in Appendix 6.1.2.

Separate from line management roles, other roles within EL which have safety responsibilities and are relevant to this investigation are as follows.

- The ***EL Deputy Director*** is not in the direct line management of most EL staff, however, the EL Director has delegated certain safety responsibilities and authorities to this individual. Specific responsibilities include developing and implementing EL safety policies and procedures and ensuring the safety of EL operations and business practices. With respect to hazard reviews, they review and approve all work that has an RHI equal to 3 or greater. The EL Deputy Director may convene an *ad hoc* EL Hazard Review Committees as needed to assist in the review and approval of this work.
- The ***EL Safety Professional*** is expected to proactively assist with and serve as technical resource for EL staff on occupational safety and health issues. Specific responsibilities include providing safety consultation to the EL Senior Leaders and staff, assisting with the creation of hazard reviews, conducting safety training, managing incident reporting and investigation, tracking safety metrics, and participating in workplace inspections. With respect to hazard reviews, the EL Safety Professional provides training on the hazard review requirements and procedures, manages the EL Hazard Review Committee, and provides general advice to the EL Deputy Director for activities with RHI equal to 3.
- ***EL Division Safety Representatives (DSRs)*** are expected to serve as a safety resource for the Division, specifically by participating in workplace inspections, assisting with safety onboarding training, assisting with and leading incident investigations, and communicating safety information. With respect to hazard reviews, they assist with the development of hazard review packages and may serve on the EL Hazard Review Committee.
- ***EL Activity Leaders/Principal Investigators/Project Leaders***[9] are expected to lead activities assigned by the group leader in compliance with all NIST and EL safety policies and procedures. With respect to hazard reviews, they are responsible for:

[9] While not stated in *MM01*, EL DIRECTOR and EL DEPUTY DIRECTOR indicated Project Leaders are equivalent to Principal Investigators.

    - Identifying all potential hazards associated with a given project and taking an active part in hazard reviews as necessary;
    - Ensuring that all potentially hazardous activities under them have been reviewed;
    - Delaying all activities until:
        - The hazard review has been approved at the required levels of NIST/EL management;
        - All project staff members and associates have completed needed safety training;
        - All required controls are in place; and
        - All "Users" of the hazard review are authorized by the group leader;
    - Notifying line management of any planned changes in project activities that could trigger the need for re-review; and
    - Assisting the group leader to ensure that all required engineering controls, administrative controls, and PPE requirements are implemented and that all activities within their projects are in compliance with activity hazard review requirements.
- ***EL Workspace Contacts/Managers*** are expected to coordinate and monitor activities and operations in their assigned workspace(s) and serve as the point of contact for workspace safety issues. With respect to hazard reviews, they:
    - Review documentation as required to determine if the physical location(s) in which the activity is to be conducted is appropriate and adequate for the activity;
    - Conduct compatibility assessments against all activities currently approved for the space to identify any potentially negative or antagonistic interactions, taking into account both planned operations and off-normal conditions that could reasonably be expected to occur; and
    - Monitor workspace activities to ensure that specified hazard control requirements for work in the assigned space are being met, including good housekeeping practices.

With respect to holding line management accountable for safety management, EL Senior Leaders (EL DIRECTOR, EL DEPUTY DIRECTOR, and FRD CHIEF 2) indicated it is difficult to evaluate them in a quantitative manner. They all stated safety was a critical element in yearly performance plans and the language was standardized by level (*i.e.,* group leader and division chief). And while there was overlap between the three in some of the criteria they identified with respect to assessing line managers at the end of the year, there was not a uniform method to do so consistently and fairly. Of note, one criterion not mentioned by EL Senior Leaders was the effectiveness of managing hazardous work in terms of appropriate planning and subsequent oversight of the work being performed.

6.1.2 Safety Management of the CF Project

NFRL Group Leader. NFRL GROUP LEADER had overall line management supervisory and safety responsibility for the CF Project. He participated in the development of the two hazard reviews associated with this work (please see Section 6.3.1 and 6.3.2), as well other as the other NFRL hazard reviews for general operations and use of equipment in Building 205 (please see Section 6.3.4 and 6.3.5). As group leader, NFRL GROUP LEADER was also responsible for approving all the hazard reviews associated with NFRL work. With respect to work conducted in Room 125, NFRL GROUP LEADER stated he performed occasional walkthroughs to monitor progress and periodically reviewed video (live and recorded) of ongoing activities using the video system set-up in Room 125 (please see Section 5.2). He stated he generally left the management of day-to-day operations in Room 125 to ENGR TECH 1 as he trusted his expertise and ability to lead the other engineering technicians. NFRL GROUP LEADER stated he was not present for the cutting or removal of the slabs, whether from the fire-tested floor or the surrounding floor.

Previous CF Project Leader. CF PROJECT LEADER 1 was the leader for the CF Project during the time the CF Project test frame was constructed and through the fire experiments for CF1, CF2, and CF3. In March 2022, she left for an opportunity outside of NIST; this was prior to the forensic investigations of CF3 fire-tested floor. CF PROJECT LEADER 1 was the activity leader for the first hazard review that encompassed the construction of the CF Project test frame and the subsequent fire experiments (please see Section 6.3.1). During the construction of the test frame, she stated she had daily interactions with the engineering technicians constructing the frame (primarily ENGR TECH 1 and ENGR TECH 2) checking on their progress and addressing any issues or concerns they may have had. She also participated in the forensic investigations after CF1 and CF2. While she was not the activity leader for the hazard review that covered the demolition of the fire-tested floor (please see Section 6.3.2), she stated she did participate in developing the document and requested additional shoring underneath various portions of the floor not affected by the experiments. During demolition activities of CF1 and CF2, she conducted walkthroughs in Room 125 to check on progress by the engineering technicians. Further, demolition of CF2 fire-tested floor had a third party perform the concrete rubble removal and she was present periodically to ensure they followed appropriate safety protocols such as wearing the appropriate respiratory protection.

Current Project Leader. CF PROJECT LEADER 2 officially became the leader of the CF Project starting on May 9, 2022. Prior to taking on this role, he was a member of the CF Project Team during the construction of the test frame and for CF1 and CF2 experiments. In May 2021, he was temporarily assigned to another NIST OU for one year. During that time, while he was not an active participant in the CF3 test, he was still remotely engaged in the CF Project work. After being named leader of the CF Project, CF PROJECT LEADER 2 participated in the revision of the hazard review covering the fire-tested floor demolition work in May 2022 (please see Section 6.3.2). With respect to the demolition work itself, CF PROJECT LEADER 2 stated he had intermittent interactions with ENGR TECH 1 to determine if he needed resources or other types of support while the test frame for the CF Project was being demolished, but was not often in Room 125. CF PROJECT LEADER 2 stated he was not present for the cutting or removal of the slabs, whether from the CF3 fire-tested floor or the surrounding floor.

Activity Leader for CF Project demolition work. ENGR TECH 1 was the activity leader of record on the *Composite Floor System Stabilization and Demolition* hazard review (please see Section 6.3.2). Given this role, he was responsible for:

- Identifying the basic process and demolition techniques to be used;
- Establishing the daily work plan; and
- Assigning tasks to the other engineering technicians.

He was also integrally involved with the physical construction of the CF Project test frame. ENGR TECH 1 was considered the "foreman" of Room 125 by staff working in the NFRL. As such, he provided a significant amount of direction to those working in that space, primarily other engineering technicians, regardless of project. ENGR TECH 1 was also the Workspace Manager for Room 125 and had responsibilities for day-to-day oversight of safety in this workspace in general. During the construction and demolition of the CF Project test frame, he was the main point of contact between the project engineers and other engineering technicians. ENGR TECH 1 was integral to all work in Room 125 related to the CF Project.

Other CF Project Staff. Per the MM01, all EL staff have a responsibility for safety in EL workspaces. In general, the engineers and engineering technicians who work in Building 205 stated everyone is responsible for safety at NFRL and believe there is a strong safety culture. With respect to work performed in Building 205, they identified a few examples to support this belief:

- Safety topics are frequently discussed at group meetings every Monday;
- Staff are comfortable raising safety concerns with other NFRL staff as well as with NFRL GROUP LEADER;
- Hazard reviews and standard operating procedures are written for all fire experiments, with the inclusion of a safety briefing prior to testing and naming of a Safety Officer to ensure all participating or witnessing the experiment are aware of safety procedures; and
- Establishment of the “two-person” rule associated with hazardous work in Building 205. (While all were aware of this rule, there was discrepancy regarding its interpretation and implementation, *e.g.*, some thought two people were always required when hazardous work was being performed while others thought one only needed to notify someone else in the building if hazardous work was going to be performed.)

With respect to CF Project, construction and demolition work was generally conducted by the same three technicians, ENGR TECH 1, ENGR TECH 2, and ENGR TECH 3, with occasional assistance from other engineering technicians. The engineering technicians stated daily safety pre-briefs were not conducted for either construction or demolition activities, but rather, ENGR TECH 1 would hold *ad hoc*, informal discussions that covered safety topics like specific strategies or techniques being used. The engineering technicians stated they were comfortable raising safety concerns to him and ENGR TECH 1 would either alleviate safety concerns through explanation of why performing the work in the manner proposed was safe or by taking action to address their safety concerns (*e.g.*, a scaffold staircase replaced the use of a ladder to access the surrounding floor, passive fall protection in the form of cables was added around the perimeter of the surrounding floor). To varying degrees, ENGR TECH 2 and ENGR TECH 3 stated they were present for the cutting or removal of the CF slabs, both from the fire-tested floor and the surrounding floor, with ENGR TECH 3 present for the cutting of the incident slab (Slab 4).

6.2 Risk Assessment Methodology for Approving Work and Worker

NIST uses a graded approach to manage the safety of work performed by staff including those activities that are relatively simple and routine to those that are highly complex one-time projects. For tasks that falls into the following categories, staff can perform work without further evaluation by line management:

- Common everyday tasks performed routinely by members of the general public at work and at home and do not involve extraordinary hazards[10], *e.g.*, working at a computer and using household cleaning products for their intended purpose; and
- Inherently low-risk activities that are considered to present low safety risks without NIST staff having to implement any safety measures to make the work safer[11], *e.g.*, using a scale to weigh non-hazardous materials or working with chemical solutions that are not hazardous.

All other work is considered "hazardous" and must be reviewed and approved by line management prior to the work being performed.

The process of planning work starts with a "thought experiment" where hazards are identified for each task to be performed. This thought experiment can be performed by an individual staff member or a group of staff who are involved in the work or have specialized expertise in the hazards that may be encountered. For each of these hazards, the severity of the consequences to the staff member should they encounter the hazard and the likelihood of the consequence occurring is determined by those developing the document. The intersection of these two is a measure of the risk to the staff member and characterized by the Relative Hazard Index (RHI). Figure 6.2.1 shows RHIs are on the following scale:

- 0 – Minimal
- 1 – Low
- 2 – Medium
- 3 – Serious
- 4 – Critical

Hazardous work can have two RHIs – an initial one before and a second one after a set of hazard controls measures are in place to eliminate or mitigate the hazards the staff member may be exposed to as they conduct the work. These controls are considered in a preferred order of implementation, *i.e.*, a hierarchy of controls, listed here starting with the most effective method of protecting the staff member:

- Elimination (*e.g.*, outsourcing the work to others with the appropriate knowledge, skills, and abilities to perform the hazardous work in a safe manner);
- Substitution (*e.g.*, using a less toxic chemical to achieve the same result);
- Engineering Controls (*e.g.*, installing physical barriers to prevent an individual from entering a hazardous area);
- Administrative Controls (*e.g.*, providing training on the task to be performed, the potential hazard(s) which may be encountered, and the method(s) to protect the staff member from each hazard); and
- Personal Protective Equipment (PPE), *i.e.*, gear worn by the staff member to protect against physical and health hazards (*e.g.*, gloves to protect hands from cuts, earmuffs to protect

[10] NIST recognizes staff members possess the knowledge, skills, and abilities to perform a wide variety of common everyday tasks safely without written hazard reviews.
[11] NIST recognized these types of activities could result in injuries requiring (1) first aid but only on an infrequent basis or (2) medical treatment beyond first aid but are very unlikely to do so.

hearing, dust masks to protect respiratory system, and fall arrest systems to arrest a staff member should they fall from a height).

The RHI after all identified hazard control measures are implemented is considered the "residual risk". This residual risk is agreed upon by those creating the hazard review and line management responsible for authorizing the work to be performed.

6.2.1 NIST Work and Worker Authorization Policy

NIST S 7101.20: *Work and Worker Authorization based on Hazard Reviews* is the policy document that provides the high-level requirements and associated roles and responsibilities for managing the risk assessment process indicated above (please see Appendix 6.2.1). The product of this effort is known as a hazard review[12] and details the following[13]:

- Activity description;
- Activity hazard identification;
- Physical-location review;
- Compatibility assessment of activity with physical location;
- Initial hazard assessment;
- Hazard mitigation;
- Incident-response plan; and
- Risk assessment.

Additional documents such as design drawings, standard operating procedures, safety data sheets, or emergency response procedures may be included as supporting materials.

Prior to allowing the work to be performed, line management must ensure the documentation is sufficiently reviewed by individuals with the knowledge, skills, and abilities to identify, assess, and mitigate the hazards associated with the activity being considered. This must include staff members who are subject matter experts and have received the appropriate training on the hazard(s) which may be encountered during the work. When additional expertise is required, line management should contact staff with safety responsibilities and/or subject matter experts both within and outside their organization. Further, line management must also have similar knowledge, skills, and abilities so they themselves can identify potential hazards and the hazard control measures to mitigate them. A critical component of the hazard review is accurately assessing the RHI of the work to be performed, which is determined by those developing the hazard review and appropriate line management.

For the work process approval, OU line management reviews the hazard review and associated documents and approves according to the RHI level after all hazard control measures have been implemented:

- If all tasks have RHIs of 0 or 1, the work must be approved by the official first-level supervisor (*e.g.*, a group leader) or higher;

[12] Hazard reviews are typically used by those engaged in research at NIST. NIST also allows use of a job hazard analysis to document this process. This is another form primarily used by those performing facilities-related tasks such as plumbing, electrical, and grounds work. As the activity performed at the time of the incident was covered by a hazard review, all further discussion related to risk management methodology will be with respect to the hazard review.

[13] Please see Section 6.b of NIST S 7101.20 for a full description of each of these sections.

- If any task has an RHI of 2, the work must be approved by the official second-level supervisor (*e.g.*, a division chief) or higher;
- If any task has an RHI of 3, the work must be approved by the OU Director; and
- If any task has an RHI of 4, that work shall not be conducted at NIST.

Only after careful evaluation of the work to be performed, the potential hazards the staff member may be exposed to, and an understanding of the proposed hazard control measures used to mitigate those hazards should the responsible line manager sign off on the work to be approved. Subsequently, line management is responsible for ensuring the hazard control measures have been appropriately implemented and assessed to confirm they will effectively reduce risk as intended.

It should be noted the approval of work is a continuous process and requires re-review and re-approval under the following circumstances:

- There is a change in existing activity parameters which would introduce new hazards or increase existing hazards (*e.g.*, changes in the process used, changes in the location of where work will be performed, or the type, condition, or amount of material used);
- There is a change in engineering controls, administrative controls, or PPE which would increase safety risks (*e.g.*, removal of physical barriers or inability of a staff member to wear a specific piece of PPE due to personal medical reasons);
- Previously unrecognized safety issues are identified (*e.g.*, identification of unmarked utilities during excavation); or
- On a pre-determined basis, regardless of any changes, which is not to exceed three years.

The re-approval of the revised hazard review follows the process outlined above with respect to RHIs.

While the work itself may be approved through the hazard review process, a second critical step is line management authorizing individual staff members to perform the work. This authorization should only be granted after:

- The staff member has successfully completed the appropriate NIST-level safety training applicable to the work they are to conduct and the activity-specific training provided at the OU-level, both of which are identified in the hazard review; and
- Line management has an appropriate degree of confidence, based on personal knowledge, observation, or reliable input from others, that the staff member to be authorized:
  - Has the knowledge, skills, and abilities to perform the work safely and correctly; and
  - Fully understands the boundaries/conditions imposed on the activity by the hazard review, the need to work within those boundaries/conditions, and the process for requesting work that falls outside of those boundaries/conditions.

This authorization is typically done by the official first-level supervisor. And similar to the hazard review process, a staff member must be re-authorized if there are changes to the hazard review or there is reason to believe the staff member lacks the knowledge, understanding, or skill necessary to conduct their work safely.

Each OU is required to develop and maintain written procedures to ensure full implementation of the NIST-level requirements within their organization.

6.2.2 EL Work and Worker Authorization Procedure

EL developed an OU policy and procedures document for implementing the NIST-level requirements. Titled *EL Hazard Review and Approval Policy and Procedure* (please see Appendix 6.2.2), this document applies to work at any location performed directly by EL staff members or work conducted by others under the direct supervision of an EL staff member. It is generally aligned with the NIST policy established in NIST S 7101.20 and provides additional details on the roles and responsibilities of EL staff and line management. It also establishes the creation and operation of an OU-level Hazard Review Committee (HRC) which is convened on an *ad hoc* basis by the EL Deputy Director.

According to the EL policy, while the group leader is responsible for ensuring all work conducted in their group involving hazardous activities or materials is covered by an approved hazard review, the following individuals have an active role in the work approval process:

- ***Activity Leader*** is responsible for initiating the hazard review process prior to starting a new activity or changing an activity currently covered by an approved hazard review. Part of this responsibility is to develop a hazard review package which includes:
  - A complete description of the activity (*e.g.*, design plans for new experiments, instruments, or facilities);
  - A step-by-step list of tasks comprising the activity (*e.g.*, work or job instructions, standard operating procedures);
  - A list of hazards identified for each task (*e.g.*, exposure to noise or fall hazards);
  - A list of hazard control measures used to eliminate or mitigate each of the hazards (*e.g.*, safety operating procedures or required PPE); and
  - An incident response plan (*e.g.*, procedures to handle foreseeable emergencies such as failure of control measures or loss of power).

  The activity leader also determines, as a start, the RHI level for each task.
- ***Workspace Manager*** for the space where the activity is to occur is responsible for reviewing the package to identify any issues or concerns with performing the work in that space.
- ***Group Leader*** is responsible for reviewing, and subsequently iterating with the activity leader as necessary, all documentation to ensure safety considerations are sufficiently detailed and hazard control measures are adequate. When all concerns are appropriately addressed and the appropriate RHI level determined, the group leader approves the hazard review package.
- ***Division Safety Representative*** is responsible for reviewing the hazard review package when there is a task or activity with an RHI of 2 or higher and recommending the package move to review by the division chief. They may also serve on an HRC.
- ***Division Chief*** is responsible for reviewing and approving the hazard review package when there is an RHI of 2 or higher.
- ***EL Deputy Director***, as delegated by the EL Director, is responsible for reviewing and approving the hazard review package when there is a task or activity with an RHI of 3. The EL Deputy Director, in consultation with the EL Safety Professional, may convene an HRC to assist in the approval decision. This committee must be comprised of at least two people, one or more who are trained in hazard analysis and control, and one or more subject matter experts as it relates to the work to be performed.
- ***OSHE subject matter experts*** may be consulted at any time in the process, especially when the OU does not have safety expertise in the area of concern.

The EL hazard review policy does not specifically identify the role of a "project leader", and subsequently, does not have responsibilities identified in the document for this individual in terms of hazard reviews. During interviews with EL line management, they specifically stated a project leader is responsible for all aspects of the work that occur within their project, including safety. Specifically with respect to hazard reviews, if the project leader is not the "activity leader" they are expected to review, or re-review, the hazard review package prior to it being submitted to the group leader for consideration.

The EL review and approval process is facilitated using the *MML Hazard Review and Approval System*, an IT application open to all NIST staff. All relevant hazard review documents are required to be uploaded into this system with all EL approvals for the work indicated in the database.

Following the appropriate work authorization, the group leader is required to attest individual staff members are qualified, appropriately trained, and approved to perform the work. Towards this end, authorized users within EL are responsible for:

- Reviewing the content of the hazard review package;
- Completing any required training specified by the hazard review; and
- Working in accordance with the practices and protocols listed in the hazard review [once they are authorized].

Using the *MML Hazard Review and Approval System*, there are no separate verification steps for the group leader to attest to with respect to the staff member having completed the required training and having reviewed the content of the hazard review package. Rather, it is implied the staff member has met these requirements as the system only indicates the staff member as being an "authorized user".

Line management and authorized users are also responsible for identifying any changes to the activities covered by an approved hazard review. When changes to the activity go beyond the scope of the approved hazard review (*e.g.*, the location, the procedures, substances, or quantities differ), the hazard review must be revised and submitted for re-approval.

6.3 Relevant NFRL and CF Project Hazard Reviews and Work Documents

During interviews with NFRL GROUP LEADER and the two leaders of the CF Project (CF PROJECT LEADER 1 and CF PROJECT LEADER 2), they were asked about hazard reviews related to the following work:

- The construction of the CF Project test frame;
- The CF Project fire experiments;
- The demolition of the individual fire-tested floors after each experiment; and
- The demolition of the CF Project test frame.

All three indicated the following hazard review was created to cover the work associated with the construction of the CF Project test frame and the fire experiments:

- *Composite Floor Systems Test* (#733.06.0124 in the *MML Hazard Review and Approval System*).

All three indicated the following hazard review was created to cover the work associated with the demolition of the CF Project fire-tested floors:

- *Composite Floor System Stabilization and Demolition* (#733.06.0148).

NFRL GROUP LEADER and CF PROJECT LEADER 2 indicated the two previously approved CF Project hazard reviews, the *NFRL Overhead Cranes* (#733.06.0052) hazard review, and the general safety training and procedures for the execution of work in the NFRL covered the demolition work for the surrounding floor.

Additionally, other NFRL hazard reviews for general operations and use of equipment in the building were either cited as contributing to the hazard review coverage listed above or incorporated by reference into the two CF Project hazard reviews. Some examples include:

- *National Fire Research Lab General Operations* (#733.06.0132);
- *NFRL Scissor and Boom Lifts* (#733.06.0051);
- *NFRL Industrial Powered Trucks* (#733.06.0047);
- *NFRL General Scaffolding Use* (#733.06.0125);
- *Assembly and Installation of Reaction Yoke* (#733.06.0069); and
- *NFRL Post-Tensioning of High Strength Bars* (#733.06.0071).

These NFRL hazard reviews, as well as the *NFRL Overhead Cranes*, are generic hazard reviews and do not provide specific detail regarding how the information, *i.e.*, hazard control measures, is relevant to the actual work being performed as part of the CF Project.

6.3.1 Composite Floor System Tests Hazard Review

The *Composite Floor System Tests* hazard review package was evaluated. The first approved version of this hazard review and all associated documentation, which was applicable for the construction of the test frame and the first fire experiment (CF1), is provided in Appendix 6.3.1. This document was first drafted by CF PROJECT LEADER 1 in February 2019. The scope of the hazard review, taken directly from the documentation, indicated it was developed to address the experimental aspects of the project:

> *The objective of this test is to measure the response and fire resistance of steel-concrete composite floor assemblies to a compartment fire. A series of tests will be conducted on 6.1 m by 9.1 m composite floor assemblies which will be mechanically loaded to the service gravity load level at ambient temperature and then subjected to a compartment fire.*

Further, the associated SOP stated:

> *This SOP pertains to personnel who have active roles identified during the pre-test safety briefing. Other safety protocols will be also notified during the pre-test safety briefing.*

In accordance with the EL hazard review policy, the hazard review package was approved by NFRL GROUP LEADER on September 11, 2019. Further, as the hazard review contained tasks with an assigned RHI of 2, approval was required by the DSR, FRD DSR (09/25/19), and the chief of FRD, FRD CHIEF 1 (10/24/19), and was provided on the dates indicated.

There were two revisions of this hazard review:

- Revision 1 dated 01/22/2021 – CF PROJECT LEADER 1 revised the scope to provide more detail related to the fire experiment, added COVID-related safety protocols, included "Tear-down" with the "Set-up" task, and added additional information to the SOP. As no new hazards with RHI of 2 or greater were added, only group leader re-approval was required and provided by NFRL GROUP LEADER on January 22, 2021; and
- Revision 2 dated 03/16/2021 – CF PROJECT LEADER 2 added a second SOP to include a "Post-fire loading test" and include additional hazard control measures. As new hazards with RHIs of 2 were added, NFRL GROUP LEADER (03/16/21), FRD DSR (03/22/21), and FRD CHIEF 1 (03/22/21) were required to re-approve the work and did so on the dates indicated. This version of the hazard review and its updated SOP is provided in Appendix 6.3.2.

The hazard review expired on November 16, 2022, and was not renewed.

As stated above, NFRL GROUP LEADER, CF PROJECT LEADER 1, and CF PROJECT LEADER 2, indicated this hazard review package was applicable to:

- Construction of the CF Project test frame; and
- CF Project fire experiments.

When reviewing the *Composite Floor System Tests* hazard review and associated SOP, it was evident the hazard review was primarily focused on the experimental testing and not the construction of the test frame. When interviewed, NFRL GROUP LEADER stated the hazard review was not highly detailed with respect to construction of the test frame and analysis of the documentation bears this out. The following deficiencies were noted when comparing the hazard review and supporting information with the requirements of an EL hazard review package (please see Section 6.2.2):

(1) **A complete description of the activity**. The activity description of the hazard review was focused on the fire experiments to be performed; there is no mention of the construction of the CF Project test frame.

Examples of deficiencies identified, with respect to an appropriate EL hazard review package, are a statement regarding the construction of the CF Project test frame in the scope and attaching the engineering design plans for the test frame.

(2) **A step-by-step list of tasks comprising the activity**. The hazard review and associated SOP include one task titled "Setup". It is unclear as to what "Setup" refers to as there is no additional information explaining this task – was it related to setup of the CF Project test frame (*i.e.*, physical construction) or setup related to performing an experiment (*e.g.*, instrumenting the test frame, loading the test floor with the hydraulic actuators). For the experimental work, there is a detailed SOP which provides step-by-step tasks for conducting the work including pre-test verification steps, safety briefing, loading of the test floor, performance of the fire experiment, and post-test safety measures.

Examples of deficiencies identified, with respect to an appropriate EL hazard review package, are inclusion of a detailed description of the erection steps such as order of the column, girder, and beam installations; rigging of each structural steel member; how the structural steel members were to be connected; installation of the steel decking and steel components in the slab; and pour of the concrete. There is also no mention of the fire compartment construction where the fire for the experiments took place.

(3) A list of hazards identified for each task. For all hazard reviews in the *MML Hazard Review and Approval System*, there is a section titled "Hazards". For the *Composite Floor System Tests* hazard review, it lists three hazards as *Hot Surface*, *Flammable Materials*, and *Toxic*, as well as the NFPA diamond (Health Hazard = 2; Flammability Hazard = 4; Reactivity Hazard = 0; No special symbols). The document also lists a single hazard under the "Setup" task as *Struck by (Mass Acceleration)*. The SOP also identified the *Struck by* hazard, as well as a second one under the general hazards section in "Setup" task titled *Fall (Slip, Trip)*. For the experiments, the hazard review identifies *Struck Against* in relation to the "Mechanical loading" task (denoted as *Struck By* in the SOP) and *Fire/Heat* related to the "Specimen heating" task in both the hazard review and SOP. Due to the nature of experiments performed, there are other hazards which should have been identified associated with the testing, examples include – *Slips, Trips, and Falls* (given the number of wires, cables, and hoses running on the strong floor) and *Overexertion* (related to loading the test floor and surrounding floor prior to the experiment). Hazardous substances, such as the fueling gases and waste product gases, were identified.

Examples of deficiencies identified, with respect to an appropriate EL hazard review package, are identification of hazards typically associated with construction of a steel-framed structure with composite floor decking, such as *Fall from Heights*, *Caught In or Compressed* (while rigging of structural steel components), *Struck Against* (the steel decking edges potentially resulting in lacerations), and *Overexertion.*

(4) A list of controls used to mitigate each of the hazards. The MML Hazard Review Database does not allow for a 1:1 correlation between a specific identified hazard and its corresponding hazard control measures unless those hazards are hazardous substances. Rather, controls are listed for the task as a whole. Required controls related to the "Setup" task are:

- Guard/barrier, other engineering controls;
- Operating procedures;
- Safe practices;
- Review of specified hazard review and procedures[14]; and
- PPE to include head protection, safety glasses with side shields, dust mask (voluntary use), cut resistant gloves, long pants, foot protection, and flame-retardant lab coat.

[14] It is unclear if the authorized user only needs to review the documents associated with the identified hazard review or if they are required to be an authorized user for that specific hazard review as well.

It is unknown when each of these hazard control measures are required to be implemented given neither a step-by-step list of tasks for construction of the test frame nor hazards associated with each task were provided. However, the “Safe Practices” control does include a reference to the construction aspect of the project, *i.e.*, a pre-activity briefing and meeting to discuss steel erection, OSHA steel erection tools link, and use of cranes and lifts.

While the SOP does not offer any additional clarity, there are additional hazard control measures identified in the “Setup” task including:

- All engineering controls listed in the specified hazard reviews [NFRL hazard reviews for equipment use];
- Pre-activity briefing or meeting to discuss the sequence of construction;
- Exclusion zone defined by the workspace manager;
- Buddy system [it is unclear what this buddy system is, *i.e.*, is it related to a two-person lift or the two-person rule instituted by NFRL (please see Section 6.1.2)]; and
- Time limitations (7:30-4:00).

Similar to the hazard review, as the hazard control measures are not tied to a specific task in the SOP, it is unknown when each control must be implemented.

For the experiments, detailed engineering and administrative controls are identified in both the hazard review and SOP. Of note is the requirement for a Safety Officer for the experiment identified in the SOP. This role reviews the “NFRL Fire Test Safety Briefing Checklist” prior to commencing the activity. Further, various control measures were identified in the experiment checklists such as notifying the NIST FPG prior to beginning experiments, wearing specific PPE for certain tasks, and maintaining an exclusion zone around the post-fire test frame until after a safety inspection was performed. For the hazardous substances, required hazard control measures are nested in other NFRL hazard reviews associated with their use.

Examples of deficiencies identified, with respect to an appropriate EL hazard review package, are listing what hazard control measures are required during the specific construction steps of the steel-framed structure.

(5) **An incident response plan.** A reasonable emergency response plan was included in the hazard review package that addressed the most foreseeable emergencies during the construction of the test frame or conduct of the experiments. One note of interest, the emergency response plan identifies ENGR TECH 4 and NFRL GROUP LEADER as the Workspace Managers for Room 125 in Building 205. During interviews with staff working in Building 205, all indicated ENGR TECH 1 was the Workspace Manager for this location.

With respect to approval of the work, per the EL hazard review policy, the group leader is responsible for ensuring all work conducted in their group involving hazardous activities or materials is covered by an approved hazard review. As the initial version of the hazard review was approved on October 24, 2019:

- The CF Project test frame was constructed without appropriate work authorization as the hazard review was not approved until four months after the concrete slab was poured (June 2019 per NFRL staff interviews), and
- The fire experiments were performed with appropriate work authorization as the first fire experiment (CF1) was conducted on November 14, 2019, almost one month after the hazard review was approved by FRD CHIEF 1.

Per the EL hazard review policy, a group leader is required to attest an individual is qualified and appropriately trained to perform the work, *i.e.*, they are an authorized user for the specific hazard review. Additionally, authorized users are responsible for reviewing the content of the hazard review package and completing any required training specified by the hazard review. For this work, staff members were required to:

- Review the *Composite Floor System Tests* hazard review and associated documents;
- Review various NFRL hazard reviews pertaining to general operations and use of equipment in the lab; and
- Complete training specified by the hazard review.

For the first two EL-specific requirements, no documentation was found indicated authorized users reviewed any of the required hazard reviews[15]. From interviews with ENGR TECH 2 and ENGR TECH 3, both indicated they did not review the hazard review documentation. Rather, they took direction from ENGR TECH 1 and he would provide information related to hazards. For the third requirement related to training, the SOP identifies two different sets of training for:

- All participants; and
- Operators,

but does not define who is an "operator" or what their responsibilities are. Further, there is no indication in the hazard review denoting which authorized user is considered an "operator". Regardless, Table 6.3.1 shows the list of authorized users for the first approved version of the hazard review and their training records at the time of their authorization. All those identified as being approved by NFRL GROUP LEADER to perform this work were authorized on the same date FRD CHIEF 1 approved the hazard review, even though none of them had completed all of the required training. Of further note, ENGR TECH 6 stated during his interview he was directed to assist in construction of the test frame, *e.g.*, helping to install the steel pan decking and rebar, building of all three fire compartments. ENGR TECH 6 is not an authorized user on this hazard review, and further, he stated he did not review the *Composite Floor System Tests* hazard review prior to engaging in the work.

6.3.2 Composite Floor System Stabilization and Demolition Hazard Review

The *Composite Floor System Stabilization and Demolition* hazard review package was evaluated. The version of the hazard review and the associated documents applicable at the time of the incident is provided in Appendix 6.3.3. This document was first drafted by ENGR TECH 1 in November 2019. The scope of the hazard review, taken directly from the documentation, indicated it was developed to address the demolition of damaged fire-tested bay:

[15] There is no requirement to separately document these requirements.

The National Fire Research Laboratory (NFRL) conducts a series of experiments on a two-story, multi-bay steel framed structure with steel-concrete composite floors subjected to real fire. This hazard review covers the procedure for demolition of a damaged or partially collapsed test bay for removal. A team of structural engineers will analyze the condition of the damaged structure. Once a determination is made that it is safe to work on, under, and around the surrounding bays, shoring will be placed inside the fire compartment and demolition of the damaged test bay will commence.

The associated SOP had a similar purpose statement. In accordance with the EL hazard review policy, the initial hazard review package was approved by NFRL GROUP LEADER on November 26, 2019. Further, as the hazard review contained tasks with an assigned RHI of 2, approval was required by the DSR, FRD DSR (12/09/19), and the chief of FRD, FRD CHIEF 1 (12/09/19), and was provided on the dates indicated.

There were three revisions of the hazard review:

- Revision 1 dated 09/30/2020 – ENGR TECH 1 added COVID-related safety protocols to the SOP and emergency response plan. As no new hazards with RHI of 2 or greater were added, only group leader re-approval was required and provided by NFRL GROUP LEADER on September 4, 2020;
- Revision 2 dated 05/05/2021 – ENGR TECH 1 updated the SOP to include EL staff oversight of a third party contracted to assist with removal of concrete debris. As no new hazards with RHI of 2 or greater were added, only group leader re-approval was required and provided by NFRL GROUP LEADER on May 6, 2021; and
- Revision 3 dated 05/05/2022 – ENGR TECH 1 updated the hazards to include noise hazard and the SOP to include hearing protection. As new hazards with RHIs of 2 were added, NFRL GROUP LEADER (05/06/22), FRD DSR (05/16/22), and FRD CHIEF 2[16] (05/16/22) were required to re-approve the work and did so on the indicated dates.

The hazard review is current and set to expire on 05/16/2023.

As stated above, NFRL GROUP LEADER and CF PROJECT LEADER 2, indicated this hazard review package was applicable to:

- The demolition of the individual fire-tested floors after each experiment; and
- The demolition of the surrounding floor.

When reviewing the *Composite Floor System Stabilization and Demolition* hazard review and associated SOP, it was evident the hazard review was primarily focused on the demolition of the fire-tested floors and there is no mention of the surrounding floor demolition or the different technique chosen to remove it. Additionally, review of the documents and interviews with engineering technician indicated two other concerns regarding the work:

- While not explicitly stated in the scope, forensic investigations of the fire-tested bays (floor and structural steel components) were performed prior to demolition of each floor; and
- With demolition of the fire-tested floors, the fire compartment was also demolished. This activity is not specifically mentioned in the documents.

[16] FRD CHIEF 1 had retired and FRD CHIEF 2 was acting division chief for FRD.

During interviews with NFRL GROUP LEADER and CF PROJECT LEADER 2, they both stated the original and current version of the hazard review did not include a consideration of the surrounding bays (*i.e.*, the surrounding floor and columns, girders, and beams). As such, a meeting was held with NFRL engineering technicians in late May 2022 to discuss the best method to demolish just the surrounding floor. ENGR TECH 1 recommended saw cutting of large slabs from the composite floor and lifting them out with rigging and an overhead crane, and the remaining portion of the surrounding composite floor could be manually demolished, *e.g.*, jackhammering from a boom or scissor lift. In early August, NFRL GROUP LEADER stated he verbally authorized a "test case" using the proposed demolition technique to determine its viability before proceeding. This decision was made with concurrence from CF PROJECT LEADER 2. After successful removal of a "test case" slab from the damaged fire-tested floor, NFRL GROUP LEADER, CF PROJECT LEADER 2, and ENGR TECH 1 met to discuss the results. ENGR TECH 1 stated the current hazard review for demolition of the fire-tested bays was sufficient for the demolition of the surrounding bays, and with no objection from CF PROJECT LEADER 2, NFRL GROUP LEADER verbally approved the work to commence under that hazard review. The current hazard review focused on the demolition of the fire-tested floors was not updated for the new techniques used during the "test case" nor for moving forward with demolition of the surrounding floor.

The following deficiencies were noted when comparing the *Composite Floor System Stabilization and Demolition* hazard review applicable at the time of the incident (please see Appendix 6.3.3) with the requirements of an EL hazard review package (please see Section 6.2.2):

(1) A complete description of the activity. The activity description of the hazard review was focused on the demolition of the fire-tested floor and there was no mention of the surrounding floor in the approved version of the document at the time of the incident. Further, there was no mention of the forensic investigations which occurred between the experiment and demolition of the fire-tested floor.

Examples of deficiencies identified, with respect to an appropriate EL hazard review package, are inclusion of the activities related to the forensic investigation, the demolition of the fire compartment, and the demolition of the surrounding floor in the scope of the hazard review, as well as to include relevant engineering drawings related to the demolition work.

(2) A step-by-step list of tasks comprising the activity. The hazard review had multiple tasks identified:

- Beam removal;
- Concrete demolition;
- Concrete and deck pan demolition;
- Damaged composite floor system;
- Deck pan removal; and
- Shoring installation.

Given the work proposed for demolition of the fire-tested floor, these are reasonable tasks albeit not in the correct chronological order for performing them. The SOP contained two tasks –

"Setting up support system" and "Demolition of composite slab" with no additional text to provide context. However, the SOP contained a narrative section with the following:

- Set-up or preparation – Addressed the requirement for the structure to cool down before engineers and technicians perform a safety inspection to determine the stability of the fire-tested floor and surrounding floor.
- Forensic investigation – Addressed the conduct of structural engineers during the safety inspection.
- General procedure, shoring – Addressed the general design and installation of shoring to be used in the fire-tested bay, but no explicit details were provided.
- General procedure, demolition – Addressed the procedure to perform the forensic investigation (cut around region of interest using a concrete circular saw), breakup of concrete (jackhammer, hammer drill, or hammer and chisel), removal of concrete (buckets and chutes), removal of steel deck pans (rigging and crane), and removal of structural steel beams (rigging and crane).
- Shutdown/Clean-up – Addressed end of the day inspections to ensure the site is left in a safe and secure manner.

Examples of deficiencies identified, with respect to an appropriate EL hazard review package, are inclusion of a similar narrative for demolition of the fire compartment and the surrounding floor. Minimum expectations for this work would be a detailed description of the demolition process to include:

- An engineering survey of the structure performed by a competent person to determine the condition of the framing, floors, and walls, and possibility of unplanned collapse of any portion of the structure, per OSHA 29 CFR 1926.850(a)[17]. Any adjacent structure where employees may be exposed shall also be similarly checked. Written evidence of this survey is required per the OSHA regulation cited;
- The location of slab removal from the surrounding floor, including size and shape;
- The order of slab removal from the surrounding floor;
- A lifting plan for each slab to include:
  - Rigging hardware;
  - Location of rigging attachment points;
  - Type of rigging with calculations for supporting the load; and
  - Safety factor calculations to ensure the stability of the slab during the removal process; and
- A plan for ensuring fall protection was appropriately afforded as slabs were removed from the surrounding floor.

Some of the tasks listed for the fire-tested floor would be applicable to the demolition of the surrounding floor provided the work was performed in the exact same manner as that for a fire-tested floor (*i.e.*, jackhammering of concrete and manual removal of the rubble).

(3) A list of hazards identified for each task. The "Hazards" section of the hazard review document has no hazards identified, including those in the NFPA diamond (Health Hazard = 0;

[17] https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.850

Flammability Hazard = 0; Reactivity Hazard = 0; No special symbols). Hazards are listed further down the document for each task identified, and in general, they are reasonable for the demolition tasks specified for the fire-tested floor. However, there are additional hazards which could have been identified for fire-tested floor demolition such as *Overexertion* (in relation to physically removing the concrete pieces after breakup) and *Fall from Heights* (as the staff were working on an elevated workspace). Also, the concrete saws are gasoline powered, and thus, there are gasoline canisters in the workspace resulting in *Flammability Hazards*. One hazard identified that wasn't initially understood was *Excavation (Collapse)* listed under the task of "Concrete Demolition" as excavation is associated with extracting material from the ground. It is believed ENGR TECH 1 chose this hazards as it contained the word "collapse", in relation to the possible collapse of the fire-tested floor during demolition. The SOP identified similar hazards as found in the hazard review but provided more explicit detail. Examples include what a worker could be "struck by" (*e.g.*, pieces of concrete slab) or "struck against" (*e.g.*, sharp edges of a deck pan). Further, this document contains the hazards of *Collapse of composite test slab during demolition* and *Fall from elevation during concrete demolition*.

Regarding the forensic investigation and demolition of the fire compartment, many of the hazards identified with respect to the demolition of the fire-tested floor are applicable, but not specifically called out for that exact work. Similarly, for the surrounding floor demolition, the hazards would be comparable if the work was performed in the exact same manner as that for the fire-tested floor, but it was not.

Examples of deficiencies identified, with respect to an appropriate EL hazard review package, are inclusion of hazards associated with:

- The use of a floor saw for cutting of the concrete slab;
- The use of an overhead crane with slings for removal of a large, heavy, non-homogeneous load that has the potential to fail during the lift; and
- Subsequent floor openings once the slabs were removed, *i.e.*, fall hazards.

Further, it is unclear if the following two hazards would have been viewed differently with respect to the demolition of the damaged fire-tested composite floor (which was broken up and removed manually) and the surrounding composite floor (which was saw cut and lifted out with rigging and a crane):

- *Collapse of composite test slab during demolition*; and
- *Fall from elevation during concrete demolition*.

(4) A list of controls used to mitigate each of the hazards. In general, the list of hazard control measures indicated for each identified task in the hazard review document are reasonable with respect to demolition of the fire-tested bays. Of note:

- For the "Beam Removal" task – *Safe Practices* specifies the authorized user is required to "Consult with engineers for estimated weight of beams to ensure use of proper rigging."
- Concrete Demolition – *Safe Practices* specifies "Use caution tape to mark an exclusion zone around the test slab. No activity in compartment during demolition. Use caution tape to mark off exclusion zone around test structure."

Similar to the hazard review document, the SOP contains reasonable engineering and administrative control measures identified for each hazard associated with demolition of the fire-tested bays. As the SOP lists the hazards under a specific task, it is clear what PPE is required to be worn during each task. PPE generally called out for this work is head protection (hard hat), hearing protection (plugs or muffs), eye protection (safety glasses with side shields), respiratory protection (dust mask)[18], foot protection (steel toe boots), and protection against hand cuts (leather or cut resistant gloves). Control measures were also identified in the SOP for these particular hazards:

- Collapse of composite test slab during demolition
  - Use of support system [shoring];
  - Restriction on activity of damaged test slab without shoring in place below entire damaged test slab;
  - Use of caution tape to mark an exclusion zone around the test slab; and
  - Wearing of leather or cut resistant gloves, face shield, and dust mask.
- Fall from elevation during concrete demolition
  - Use of shoring system platform;
  - Use of guardrail in accordance with OSHA standard 1926.502[19];
  - Use of scissor lift or boom lift; and
  - Wearing of [fall protection] harness if other engineering controls are not available.

Three other hazard control measures identified of note:

- During the forensic investigation, the structural engineering team performing the inspection must be under active supervision of a workspace manager and/or group leader during the investigation;
- A team of structural, mechanical, or civil engineers at NIST or by a shoring company will recommend a design for support shoring. The recommended design must be reviewed and approved by the workspace manager, principal investigator (leader of the CF Project), and group leader of NFRL. The final constructed shoring plan shall be inspected by a structural engineer; and
- Before removal of concrete debris by a third-party contractor:
  - A Safety Officer shall ensure that the contractor uses the required PPE; and
  - The Project Representative [undefined who has this role] shall hold a Safety Briefing and review roles and safety procedures with participants.

With respect to demolition of the surrounding floor, the same controls listed above would have been applicable had the demolition process been the same.

Examples of deficiencies identified, with respect to an appropriate EL hazard review package, are inclusion of the following hazard control measures for the new demolition process:

- Specific training required for the demolition of large-scale structures or the safety of staff during that work;

[18] Per OSHA 29 CFR 1926.1153(c)(1), indoor saw cutting of concrete requires respiratory protection, https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.1153.
[19] https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.502

- Structural evaluation of each slab to be removed to ensure an appropriate safety factor during the lift – this may have included a lift plan denoting the location of the rigging points;
- A cutting procedure designed to eliminate situations requiring the operator and/or saw to "load" the slab being cut; and
- Fall protection measures such as covering a floor opening after it is created.

(5) An incident response plan. A reasonable emergency response plan was attached that addressed most foreseeable emergencies during the forensic investigation and subsequent demolition work. For this emergency response plan, the Workspace Managers for Room 125 are identified as NFRL GROUP LEADER, ENGR TECH 1, and ENGR TECH 4.

With respect to approval of work, per the EL hazard review policy, the group leader is responsible for ensuring all work conducted in their group involving hazardous activities or materials is covered by an approve hazard review. As the initial version of the hazard review was approved on December 9, 2019, the following activities were performed with appropriate work authorization:

- The forensic investigation efforts, though not specifically identified in the title or scope of the hazard review, as the hazards were identified and addressed in the hazard review and SOP and there was no indication from interviews this work began prior to approval of the hazard review; and
- The demolition of the fire-tested floor as the hazards were identified and addressed in the hazard review and SOP and there was no indication from interviews this work began prior to approval of the hazard review.

The following activities were performed without appropriate work authorization:

- The demolition of the fire compartments as there is no mention of this activity in the hazard review nor indication of another approved hazard review which would have covered this activity;
- The cutting and removal of the "test case" from the fire-tested floor as there was no consideration of the potential hazards of the new demolition process prior to NFRL GROUP LEADER giving verbal authorization for the "test case" to proceed; and
- The cutting and removal of Slabs 1 through 4 from the surrounding floor as the hazard review was required to be revised and re-approved due to the change in the scope of work, *i.e.*, a complete change in the demolition process, location of the work, and condition of the composite floor material in the surrounding floor.

With respect to authorizing individual staff members, in addition to reviewing the *Composite Floor System Stabilization and Demolition* hazard review, training requirements identified in the SOP were "See references for training specific to other hazard reviews [*NFRL Overhead Cranes; NFRL Scissor and Boom Lifts; and NFRL Industrial Powered Trucks*]". Similar to the *Composite Floor System Tests* hazard review, no documentation was found indicated authorized users reviewed the hazard review that covered demolition work. Both ENGR TECH 2 and ENGR TECH 3 stated they were somewhat familiar with the hazard review, but did not recall reviewing the entire hazard review package. Table 6.3.2 shows the list of authorized users and appropriate training records at the time of their authorization for the approved hazard review. All those identified as being approved to perform this work were authorized by NFRL GROUP LEADER the day after FRD CHIEF 2 approved the hazard review, even though none of them completed all of the required training. NFRL GROUP LEADER stated he did check training records prior to approving those staff members as authorized users. It should also be noted, ENGR TECH 6 stated during his interview he was directed to assisted in some demolition activities, *e.g.*, concrete removal from the CF3 test floor and demolition of CF3 fire compartment. While he recalls reviewing the *Composite Floor System Stabilization and Demolition* hazard review documents, he was not listed as an authorized user.

6.3.3 Coring and Cutting Plan

On August 22, 2022, ENGR TECH 1 emailed NFRL GROUP LEADER advising ENGR TECH 1 would be "managing the demo work from here [home as he was teleworking that week] and creating a lifting plan for the surrounding deck". As such, on August 23, ENGR TECH 1 sent an email titled *Coring and Cutting Plan* with attachment to ENGR TECH 2 (please see Appendix 6.3.4). The attachment detailed the plan ENGR TECH 1 developed to cut the slabs out of the surrounding floor. Shown were the cutlines for each slab to be removed along the east face and most of the north side of the test frame. ENGR TECH 1 indicated the west side of the test frame was a mirror of the east. The attachment also denoted the locations of the associated core holes where rigging was to be attached and indicated the loading of each rigging strap with respect to the overall weight of a typical slab. The only specific instructions were that the core holes should be symmetric and no further apart than shown on the plan. There is no indication in the email regarding whether any other individual reviewed the plan or if the size or shape of the proposed slabs are a concern – only that the plan would minimize the number of cuts they need to make on the structure. NFRL GROUP LEADER and CF PROJECT LEADER 2 were not provided the *Coring and Cutting Plan* or any related calculations, nor were any requested by them, in advance of the work proceeding. As a result, this document was not incorporated into the hazard review package.

NFRL GROUP LEADER stated ENGR TECH 2 forwarded him the email and attachment after the incident. NFRL GROUP LEADER shared this document with the NIST Incident Investigation Team on October 13, 2022. When asked about this document, NFRL GROUP LEADER stated ENGR TECH 1 created it but did not know if concrete reinforcement of the slabs was considered in making the determination for location, size, and shape of the slabs, nor if calculations were performed to determine if the individual slab could support its own weight once the slab was cut free from the test frame. None of the other structural engineers associated with the CF Project (CF PROJECT LEADER 1, CF PROJECT LEADER 2, and NFRL ENGINEER 1) stated they had seen the document prior to the incident. NFRL GROUP LEADER stated he was also not aware of a cutting procedure for each slab, *i.e.*, the specific order the faces of each slab would be cut, or if the corners were to be cut before the long edges, or when the rigging would be installed and engaged.

Prior to the incident there were concerns expressed among the engineering technicians regarding the *Coring and Cutting Plan*:

- ENGR TECH 4 stated he expressed concern to ENGR TECH 1 that the coring holes were located too close to the edges of the slab and not allowing for enough material to prevent a failure in these locations;

- ENGR TECH 2 stated he expressed concern to ENGR TECH 1 that the rigging holes for Slabs 5 through 8 were too far apart. However, as they were not at the point to cut those slabs out, he just let it go at the time for later discussion; and
- ENGR TECH 3 stated ENGR TECH 1 had expressed concerns to him in the days prior to the incident about what could happen when Slabs 5 through 8 were cut and lifted out. ENGR TECH 3 stated ENGR TECH 1 said he was concerned they might break in the middle and "fold" when lifted due to the length of the slabs. ENGR TECH 3 stated ENGR TECH 1 did not express any similar concerns about Slab 4.

6.3.4 NFRL Overhead Cranes Hazard Review

As overhead crane use was a factor contributing to the incident, the hazard review titled *NFRL Overhead Cranes* (#733.06.0052) was also evaluated. The version of the hazard review and the associated documents applicable at the time of the incident is provided in Appendix 6.3.5. The initial version was drafted by ENGR TECH 1 in June 2017. The scope of the hazard review indicated it was developed to address use of the eight cranes in Building 205:

> *NFRL has eight cranes located throughout Bldg. 205 and scrubber bag houses used for heavy lifting. The cranes are used for loading and unloading materials, construction, and moving pit covers for the conditioning pit. This hazard review is for general purpose crane operation and does not cover specific hoisting or rigging that may require additional hazard review.*

A note in the SOP states:

> *This SOP makes references to generic type crane lifts, routine type lifts with no special rigging. Any project that requires unique lifts using special rigging and fixtures or two cranes operating simultaneously for the same lift will have a project FLHR [First-level Hazard Review] detailing these lifts.*

In accordance with the EL hazard review policy, the initial hazard review package was approved by NFRL GROUP LEADER on June 29, 2017. Further, as the hazard review contained tasks with an assigned RHI of 2, approval was required by the DSR, FRD DSR (06/30/17), and the chief for FRD, FRD CHIEF 1 (07/07/17), and was provided on the dates indicated.

There were three revisions of the hazard review prior to the incident:

- 08/29/2017 – ENGR TECH 1 added an addendum to the SOP with new requirements and hazard control measures for using an overhead crane. As no new hazards with RHI of 2 or greater were added, only Group Leader re-approval was required and provided by NFRL GROUP LEADER on August 29, 2017;
- 08/06/2020 – ENGR TECH 1 updated the SOP to include COVID-related protocols. As no new hazards with RHI of 2 or greater were added, only group leader re-approval was required and provided by NFRL GROUP LEADER on August 10, 2020; and

- 05/23/2022 – ENGR TECH 2 added a second addendum to the SOP regarding site specific obstructions to avoid. As no new hazards with RHI of 2 or greater were added, only group leader re-approval was required and provided by NFRL GROUP LEADER on May 23, 2022.

The hazard review is current and set to expire on 05/23/2025.

As the scope clearly identifies the *NFRL Overhead Cranes* hazard review as a general-purpose document and unique crane lifts require a separate hazard review, a direct one to one comparison with the requirements of an EL hazard review package will not be performed as that type of analysis is reserved for a specific activity involving crane use which will have its own separate hazard review. Instead, information of note will be identified here regarding the version applicable at the time of the incident. These are some of the documents uploaded in the MML Hazard Review Database:

- Hazard Review Document
  - Scope indicates any work requiring specific hoisting or rigging may require a separate hazard review detailing the lifts.
  - Related documents include:
    - Overhead crane SOP;
    - Addendum to overhead crane SOP;
    - A daily pre-use inspection checklist for cranes, but there are no requirements for its use or records retention;
    - Crane and sling operator manual covering individual responsibilities, pre-shift safety checklist for cranes, types of lifts, and information to help plan for a safe lift;
    - A presentation covering daily and periodic crane inspections and information to help plan for a safe lift; and
    - Emergency response plan.
- Overhead crane SOP
  - Any project that requires unique lifts using special rigging and fixtures or two cranes operating simultaneously for the same lift will have a project FLHR detailing these lifts. There is no mention of concerns regarding the type of load.
  - Select safety requirements and precautions:
    - At the beginning of each shift, test the upper limit switch of each hoist under no load, while inching the block.
    - Avoid shock loading – move load without sudden acceleration or deceleration.
    - Do not hang from or ride the crane hook, attached load, or attached rigging.
- Addendum to Overhead Crane SOP (08/29/2017)
  - The operator will determine if the lift is routine, complex, or critical and develop a lift plan as needed. The lifting team will discuss any changes to the original lift plan before execution. There is no definition for the type of lifts identified and no mention of consideration of the type of load.
  - Establish a no-entry zone around all crane operations. Only the crane operator and spotters are allowed inside this zone. Evacuate personnel from the open pit areas in the basement if these areas are within the no-entry zone. The no-entry zone should be at least 10 ft from the load. Large loads and complex lifts will require a larger zone. The no-entry zone will be determined during the lifting plan and will be enforced by the operator and spotters.

With respect to approval of work, it is unclear what work this hazard review authorizes. The scope states what the cranes are used for (loading and unloading materials, construction, and moving covers for the conditioning pit) but then states it does not cover specific hoisting or rigging that may require an additional hazard review. Further, the hazard review itself does not address the lifting of a heavy, non-homogenous load that has the potential to fail during the lift.

With respect to authorizing individual staff members, at a minimum, the SOP indicates these training requirements:

- NIST & EL mandatory safety courses;
- Any associated NIST suborders [NIST S 7101.69: *Overhead Cranes and Hoists*];
- EL-733: NFRL Overhead Crane Operation;
- CLC Overhead Crane & Slings; and
- CLC-Indoor Hoisting and Rigging.

Additionally, all "test participants" are required to review related documentation posted in the *MML Hazard Review and Approval System*. While there is no evidence regarding review of the related documentation, Table 6.3.3 shows the list of authorized users and appropriate training records at the time of their authorization for the approved hazard review. All engineer technicians identified as being authorized to perform this work were approved on the same date NFRL GROUP LEADER re-approved the hazard review (05/23/22). NFRL GROUP LEADER himself was approved 8 days later by FRD CHIEF 2. None of those listed as an authorized user had completed all the required training.

6.3.5 Other NFRL Hazard Reviews Related to Construction/Demolition

Through the interview with NFRL GROUP LEADER, several additional projects at NFRL were identified involving significant setup and teardown activities associated with the experiment. The hazard reviews for these projects were evaluated and summarized below with particular focus on how setup and teardown activities were addressed in comparison to experimental activities.

6.3.5.1 NFRL Commissioning Phase III – Ambient Beam Test (#733.06.0002)

Status: Expired on 11/13/18

Activity Leader: ENGR TECH 1

Description: The objective of this test was to conduct commissioning of the load system in Room 125. The tests were focused on a single wide-flange beam supported by a test apparatus constructed of multiple large columns and beams. They were conducted under ambient conditions and did not involve fire.

The hazard review document does not include a set-up or teardown task for the apparatus. The associated SOP contains a section on test set-up which describes the components and basic dimensions of the test apparatus and specimen with a schematic of the test apparatus (please see Figure 6.3.1). There are no procedures provided for erecting the steel columns or beams comprising the apparatus, or for removing/dismantling it. The primary hazard was identified as being struck by falling beams during the tests as well as slip/trip/fall hazards.

6.3.5.2 Structural-Fire Performance of Cold-Formed Steel Shear Walls (HR 733.06.0022)

Status: Expired on 7/16/21

Activity Leader: CF PROJECT LEADER 2

Description: The objective of this test program was to experimentally determine the influence of fire on the lateral load resistance of cold-formed steel shear walls with and without pre-damage. The tests were conducted on 9 ft by 12 ft wall specimens loaded to cause damage, then subjected to fire, and then loaded again until failure.

The hazard review document includes a "Setup/Teardown" task which identifies PPE and a crane training requirement, but no specific steps are provided for either process. The associated SOP does not address construction of the wall specimens, other than to describe their basic composition and indicate they will be fabricated by trained personnel. Construction of the test apparatus is not addressed but a schematic of the test setup was provided (please see Figure 6.3.2). Lifting of the specimens into the test apparatus is described with the statement it must be done by trained personnel. Detailed procedures, including safety information, are provided in the SOP for the experimental aspects of the project. The teardown is documented with a single step stating, "The specimen can be removed using the overhead crane" and it references a FLHR (349) which was not attached.

6.3.5.3 Composite Beam Fire Test (#733.06.0078)

Status: Expired on 11/29/18

Activity Leader: CF PROJECT LEADER 1

Description: The objective of this test program was to study the performance of 12.8 m span composite beams with various beam-to-column connection configurations under fully developed enclosure fire. The tests were conducted using a test apparatus constructed of multiple large columns and beams.

The hazard review document includes a "Setup/Teardown" task and references OSHA safe steel erection practices and other generic NFRL hazard reviews (*e.g.*, *NFRL Overhead Cranes* hazard review) for controls, but no specific steps were provided for either process. The associated SOP contains a section on test setup which describes the components, basic dimensions, and a schematic of the test apparatus (please see Figure 6.3.3). There are no procedures provided for erecting the steel columns or beams comprising the apparatus, or for the removal or dismantling of it. Detailed procedures are provided in the SOP for the experimental aspects of the project. There is a requirement in the SOP to establish a "Specimen Removal Safety Team" after the completion of testing to identify hazards associated with removing the test specimen from the test apparatus. This team was to develop a removal plan. If conducted, this plan was not added to the SOP or hazard review nor was it found in any of the project documentation.

Of note regarding this work – an incident occurred during the setup for this experiment when a large column was knocked over during a crane lift (please see Section 6.12 for additional information related to IRIS Case No. 17-IG-0110). The incident occurred on August 14, 2017, three months prior to the approval of the hazard review for the project, which was given on November 29, 2017.

6.3.5.4 Summary of Other NFRL Hazard Reviews Related to Construction/Demolition

As observed for the CF Project, other NFRL hazard review packages that had a construction, and subsequently demolition, aspect to them focused primarily on the procedures and safety for the experiment with very little information, safety or otherwise, provide with respect to set-up and teardown aspects of the experiment.

6.4 Design and Construction of the CF Project Test Frame

A basic description of the test frame, the structural steel framing system, and the steel-concrete composite floor system, as well as the mechanical properties of the concrete and steels used, are provided in the sections below. The Reader is referred to Choe *et al.* [2021], Choe *et al.* [2022], and Ramesh *et al.* [2022] for additional details regarding the CF test frame, including, but not limited to:

- The design of the fire test floors for each experiment;
- The fire proofing of the structural steel for each experiment; and
- The design of the fire compartment for each experiment.

6.4.1 General Design Information

The test frame used for the CF Project test series is a “reusable” two-story, steel gravity frame designed to be representative of a typical system commonly used in modern U.S. office buildings. While it is considered a “two-story” frame, it actually has three “floors” (please see Figures 6.4.1 and 6.4.2). The strong floor of Room 125 is the ground floor and housed the fire compartment that was a component of the fire experiments. The first floor, and only floor to have a steel-concrete composite floor system, is directly above the ground floor and contained both the fire test floor section – the focus of the experiments – and surrounding floor section. The second floor is located above the first but only contained the steel framing without any composite floor system. The total dimensions are 34 ft wide × 58 ft long with story heights of 12 ft.

6.4.2 Structural Steel Framing System

The test frame was composed of vertical structural steel columns and horizontal structural steel girders and beams (please see Figure 6.4.2). All of the structural steel members were wide-flange sections (W-shapes) of varying sizes (please see Figure 6.4.3).

The vertical columns, which supported reaction forces from the girders, extended the full heigh of the frame and were W12×106 – 12 inches (in.) in depth and weighed 106 lb/ft. There were 12 total for the structure (please see Figure 6.4.4). Each column had a 3 ft wide and 2 in. thick base plate and was anchored to the NFRL strong floor using four 1-3/8 in. diameter steel rods post-tensioned to 100 ksi each.

Figure 6.4.4 also shows the location of the steel girders and beams for both the first and second floors. The girders were either W18×35 or W16×26 and run in the north-south direction; they supported the reaction forces from the steel beams. The steel beams were either W14×22 or W16×31 and run in the east-west direction; they supported the floor loads. For connecting the structural steel members to each other, simple shear connections were used via shear tabs and structural bolts (please see Figure 6.4.5).

When viewed from above, the layout of columns resulted in the test frame divided into 6 bays with each bay bounded by four W12×106 columns at the corners (please see Figure 6.4.6). The matrix was three bays in the east-west direction (with span lengths of 14 ft, 30 ft, and 14 ft) and two bays in the north-south direction (with span widths of 14 ft and 20 ft). For future reference, the “fire test floor” is approximately defined as the southern middle bay, with the remaining five bays adjacent to it referred to as the “surrounding floor”.

6.4.3 Composite Steel-Concrete Floor System

The composite steel-concrete floor system on the first floor consisted of concrete slabs cast in-situ on steel decking with various steel reinforcement components contained in the slab itself.

The steel deck units were 20-gauge Vulcraft 3VLI composite steel decking[20] that was approximately 3 ft wide with varying lengths. The decking has a trapezoidal profile with deck flutes measuring 3 in. deep and spaced roughly 12 in. apart (please see Figure 6.4.7). The steel deck flutes ran continuously in the north-south direction of the test frame and parallel to the girders.

The steel deck units were attached to the top of the steel beams and girders using #10 (5 mm) diameter powder-actuated anchors. These anchors were spaced approximately 1 ft along the perimeter beams and 2 ft along the interior beams. Steel deck units were joined side by side using 0.25 in. diameter sheet metal screws spaced 2 ft along the deck seams.

Subsequent to fastening the steel deck units to the beams and girders, 3/4 in. diameter steel headed shear studs were welded to the top flange of each steel beam or girder, directly burnt through the steel decking. For the beams, the studs were welded at every flute of the steel decking with spacing of 12 in. (please see Figure 6.4.8). For the girders, pairs of headed shear studs were welded on the top flange at 13 in., 14 in., or 18 in. spacing (please see Figure 6.4.9). These headed shear studs were ultimately embedded in the concrete slab and, in combination with the powder-actuated anchors, provided a positive connection between the composite steel-concrete floor system and its supporting steel beams and girders. There was no positive connection between the steel deck and the concrete slab for the portions of the slab between the beams and girders.

The steel reinforcement within the concrete slab varied for different locations of the surrounding floor, but all sections contained some elements of No. 4 rebar and welded wire reinforcement (WWR) mesh (Figure 6.4.10). The steel reinforcement in the concrete slab for CF1 test frame is shown in Figure 6.4.11.

> **NOTE – Figure 6.4.11 shows the steel reinforcement for the first test performed in the CF test series – CF1. While the fire test floor was demolished after this experiments, and**

[20] https://vulcraft.com/Products/Deck

subsequent experiments, the surrounding floor was not. Therefore, the steel reinforcement details shown here for the surrounding floor were present at the time of the incident.

The WWR mesh – 6×6 W1.4×W1.4 (1/8 in. diameter plain steel wires in 6 in. grid) – was used throughout the entire floor slab as the minimum required shrinkage reinforcement, in accordance with the SDI manual [SDI, 2006]. Figure 6.4.12 shows the WWR mesh installed prior to the concrete slab being poured. To ensure continuity across the slab, the sections of WWR mesh were overlapped at their edges. The mesh was placed on rebar chairs to ensure a consistent height in the concrete slab (please see Figure 6.4.13). Some of the chairs were coated with a green epoxy and others were uncoated (black). Whether the chairs were coated or uncoated did not affect the mechanical properties of the slab. Chairs were not continuously used throughout the slab, only in locations to ensure the WWR mesh, and subsequently the No. 4 rebar, was at proper elevation and well-supported prior to the concrete pour.

No. 4 rebar was used as a reinforcement of the surrounding floor concrete slab, but not uniformly. The surrounding floor bays that shared a boundary with the fire test floor, *i.e*., north-middle, southeast, and southwest bay (please see Figure 6.4.14), were reinforced with continuous No. 4 bars spanning the width of the bay. This reinforcement was included to minimize potential concrete damage as the fire-tested floor sagged during the fire experiments. These bars were placed directly above the welded wire reinforcement and at 12 in. spacing on center (please see Figure 6.4.15). For the southeast and southwest bays, these continuous No. 4 bars were perpendicular to the deck flutes, while the bars were parallel to the direction of the steel deck flutes for the north-middle bay. In addition to the continuous rebars, short, hooked No. 4 rebars (please see Figure 6.4.16a) were placed at the perimeter of the bays (please see Figure 6.4.16b) to minimize potential pull-out failures from the edge girders and beams due to the sagging of the fire test floor. They were 38.5 in. in length and also spaced at 12 in.

The two north corner bays (please see Figure 6.4.14) had much lighter reinforcement compared to the other three bays since these corner locations did not play a significant role in the test frame stability and were not an active part of the experiment or research objective. Further, due to the design of the experiment, they were not expected to be affected by the fire-tested floor during the experiments. Only three continuous No. 4 bars were used on the faces adjacent to the other bays (south and west faces for the northeast corner bay and south and east faces for the northwest corner bay). These rebars were spaced at 12 in. At the corners of the bays near the fire test floor, three shorter No. 4 bars were added for additional reinforcement to further prevent possible cracking at these corners. One was in the north-south direction, one was in the east-west direction; and the third one was diagonal. No.4 hooked rebars were also used to minimize potential pull-out failures near the perimeter but with wider spacing at 30 in. on center.

Another steel component added to the concrete floor system was a slab splice (please see Figure 6.4.17). This feature provided continuity between experiments as the fire-tested floor could be demolished after each experiment without affecting the surrounding floor. Subsequent to the second and third fire experiments, the fire-tested floor from the previous experiment was demolished and rebuilt (please see Figure 6.4.18).

Figure 6.4.19 shows an overall view of the composite floor prior to the concrete pour for CF1.

The concrete slab was poured by a third party contractor after all the steel components were installed (please see Figure 6.4.20). Figure 6.4.21 shows a diagram of the floor cross-section. The depth of the concrete slab above the deck flute was 3.25 in., resulting in a maximum slab thickness with the flute of 6.25 in. With the positioning of the rebar chairs, the WWR mesh was approximately 1.6 in. from the top surface of concrete and the rebar was approximately 1 in. from the top surface.

As stated above, the second story level did not have the composite steel deck-concrete floor system. Rather, it had the same steel beams and girders that were used on the first story framing to provide support conditions for the steel columns to simulate column continuity in real buildings. This second-floor framing configuration (*i.e.*, no concrete slabs on the second floor) allowed for the fire test floor (on the first-floor level) to be more easily demolished and replaced for subsequent fire tests.

6.4.4 Concrete and Steel Materials Properties

The floor slabs for the surrounding bays were made of lightweight aggregate concrete (expanded slate lightweight aggregate), with the minimum specified concrete compressive strength at 28-day of 28 MPa (4,000 psi). The concrete mixture also incorporated 4 lb/yd^3 of monofilament polypropylene microfibers to reduce the likelihood of heat-induced concrete spalling during the experiments. For details regarding concrete mixture proportioning, readers are referred to Choe *et al.* [2021]. Table 6.4.1 shows a summary of the measured properties of hardened concrete of the surrounding slabs at 645 days after casting.

All of the structural wide-flange sections were made of ASTM A992 steel, with a minimum specified yield strength of 345 MPa (50 ksi, Grade 50). The 20 gage steel deck units were also specified as having a minimum yield strength of 345 MPa (50 ksi, Grade 50). The headed shear studs were made of ASTM A29 steel and the WWR mesh was made of ASTM A1064 steel. The No. 4 rebar was made from ASTM A615 with a minimum specified yield strength of 345 MPa (50 ksi, Grade 50). The measured mechanical properties of various types of steel used in constructing the test frame were obtained using ASTM E8 tensile testing standard and are as shown in Table 6.4.2.

Additionally, the stress-strain relationships obtained for the WWR, Vulcraft 3VLI steel deck, and the No. 4 rebars are shown in Figure 6.4.22.

6.4.5 General Construction Timeline of the CF Project Test Frame

The structural steel was erected during the spring and into early summer in 2019 by NFRL technicians. They also installed the steel decking and all steel components embedded in the concrete slab. The concrete that composed the surrounding floor was installed in June 2019.

6.5 Methodology for Demolition

6.5.1 Demolition of Fire-Tested Floor

As discussed in the *Composite Floor Stabilization and Demolition* hazard review (please see Section 6.3.2), once the structure had cooled to ambient temperature, a team of structural engineers were required to analyze the condition of the CF Project test frame as a whole. Subsequent to the determination the surrounding bays were safe to work on, under, and around, the following process was used:

- Wood shoring structures were placed inside the fire compartment to support the fire-tested floor during the forensic analysis and ensuing demolition work. This shoring was requirement to be reviewed and approved by the workspace manager, the principal investigator [leader of the CF Project], and the group leader for NFRL. The final constructed shoring was also required to be inspected by a structural engineer. Additional spot shoring, in the form of metal poles, was used at key locations under the surrounding floor in areas directly adjacent to the fire compartment.
- Forensic investigation consisted of engineering technicians using a hand-held concrete saw to saw cut around a region to be removed for evaluation. Concrete outlined by the saw cuts was removed through a combination of jackhammer, hammer drill, and hammer and chisel with the rubble disposed of manually using buckets. Engineers or the engineering technicians took pictures of interest in these locations. It is noted that ENGR TECH 2 stated for CF1 a walk-behind floor saw was rented and used even though it was not considered in the hazard review. With successful use of the floor saw, one was later purchased for use throughout the rest of the CF Project work.
- After the forensic investigation, the entire fire-tested floor was demolished by jackhammering the remaining portion of the damaged floor and removal to a dumpster through a combination of buckets and chutes.
- The steel deck pans were removed using an overhead crane and rigging slings attached to plate lifting clamps or c-clamps.
- Each structural steel beam or girder was rigged one at time, connect to the crane, and then enough tension applied by the crane to support the weight of the beam while the connection bolts were removed to free the beam from the structure. Prior to removed, a structural engineer was required to be consulted on their individual weights in order to select the proper rigging.
- Once lifted out and on the strong floor, the structural steel members were relocated to a storage area outside of Building 205.
- The demolished area of the test frame was then prepared for re-construction of the next composite floor to be tested.

The process described above was used for removal of the CF1 and CF2 fire-tested floors, though a third party was contracted to physically remove the concrete rubble after CF2. For demolition of the CF3 fire-tested floor, ENGR TECH 1 began “experimenting” using the floor saw to cut slabs, starting at ~1 ft by ~4 ft and progressively getting larger (up to ~4 ft by ~4 ft). He then exposed rebar in various locations of the slab, hooked them up to the overhead crane with rigging slings using clevises, and lifted them out to a dumpster. Both CF PROJECT LEADER 2 and NFRL GROUP LEADER stated they were aware of this activity. Performing this work with this new demolition method was not covered under the *Composite Floor System Stabilization and Demolition* hazard review.

6.5.2 Demolition of Surrounding Floor

As discussed in Section 6.3.3, there were no standard operating procedures or narratives developed to demolish the surrounding floor similar to what was found for the demolition of the fire-tested floor. Therefore, the following information was obtained from videographic evidence and statements made by other engineering technicians.

ENGR TECH 1 developed the *Coring and Cutting Plan* (please see Section 6.3.3) which would result in a total of 12 slabs being removed from the surrounding floor: four each along the east and west sides of the test frame (the west side is a mirror of the east) and four from the north-middle bay. ENGR TECH 1 chose the size and shapes of the slabs based upon his desire to reduce the number of cuts while on the surrounding floor, as well as the location of the floor splice and the girders and beams below the surrounding floor (please see Figure 6.5.1). This resulted in:

- Four slabs being square, approximately 9 ft on a side (Slabs 1 and 2 and the corresponding ones on the west side);
- Six slabs being rectangular with lengths of either 12 or 14 ft and widths of either 2 or 5 ft (Slabs 4 through 8 and the corresponding slab in the northwest corner); and
- Two slabs being rectangular with a protruding tab due to the floor splice (Slab 3 and the corresponding one on the west side).

Two slabs had only two rigging points (Slabs 6 and 8) while the remaining ten slabs had four each. The slab removal process was to cut each slab free from the deck using a walk-behind floor saw and then lift them out with an overhead crane (please see Section 6.6 for a description of the specific equipment used). The general steps included:

- Per the *Coring and Cutting Plan*, the slab cutlines and core hole locations were transcribed on the surrounding floor using chalk.
- The core holes for all slabs were drilled in the designated locations on the surrounding floor.
- A walk-behind floor saw was used to cut each side of the slab.
- When the slab was partially cut free, the crane with rigging slings and rigging hardware already attached was positioned over the slab with slack in the slings. The bolt of the rigging hardware was inserted into the core holes in the slab so they extended down and out on the underside of the slab. From below the slab, a washer and nut were attached to the rigging bolt and hand tightened.
- With the rigging hardware attached to the slab, the crane was raised to put enough tension on the rigging slings such that the slab would not drop when all sides were cut. The crane was attempted to be centered in between the rigging points.
- The remaining faces of the slab were cut with the floor saw, freeing it completely from the surrounding structure.
- The slab was lifted out of the surrounding floor using the crane.
- The slab was moved to the strong floor and placed on wood cribbing so the nuts and washers could be removed from the rigging bolts. The rigging hardware was detached from the slab and the crane moved out of the way.

- A forklift was used to either move the slab outside of Building 205 or place it in a dumpster located in Room 125.

The overall plan was for the slab removal to start at the southeast corner of the test frame (with Slab 1) and proceed counterclockwise until all slabs were removed from the surrounding floor. Subsequently, additional steps would have been necessary to demolish the remaining composite floor above each girder and beam (approximately 2 ft widths), as well removal of the as the beams, girders, and columns. This information was also not found in the hazard review documents.

6.6 Documentation of Equipment Used During the Incident

The following equipment were essential to the work being performed when the incident occurred. As such, they were inspected and manuals consulted to help provide information related to the finite element modelling work. From videographic evidence, incident site review, and interviews with first responders, the type of PPE used by ENGR TECH 1 during the incident is also discussed.

6.6.1 Walk-Behind Floor Saw

A gasoline-powered, water-cooled Husqvarna Floor Saw Model FS400LV (20-inch blade version) was procured specifically for cutting the concrete floor sections of the CF Project (please see Figure 6.6.1). This model is a walk-behind, manually propelled “push” style saw designed specifically for sawing concrete slabs using a diamond blade. The cutting depth is adjustable, with a maximum depth 7.5 in. The following information was obtained from the technical specification section of the floor saw operating manual:

- Empty weight is 236 lb;
- Maximum operating weight is 320 lb – dependent on the amount of fuel and cooling water in the onboard tanks; and
- Floor saw dimensions are 44.1 in. in heigh, 24.2 in. in width, and 39 in. in length.

The diamond blade, located on the right side of the saw when viewed from behind, is in line with the back right wheel.

A continuous supply of cooling water is required during operation of the saw. This can be supplied with an integrated tank that must be periodically refilled or by attaching a garden-type hose for a continuous supply. The cooling water hose can be attached so that it feeds the onboard tank or it can be attached to bypass the tank and feed the saw blade directly. There is a valve to turn the water supply on or off.

The specific saw in use at the time of the incident was manufactured and purchased by NFRL in calendar year 2019 (please see Figure 6.6.2).

There were no inspection documents associated with this piece of equipment.

6.6.2 20-Ton Bridge (Overhead) Crane

There are two 20-ton overhead cranes in Room 125. The west crane was used to lift the slabs out of the surrounding floor. The crane is a top running double girder bridge crane manufactured by Platnick Crane and Steel of Bluefield, VA, with a 20-ton capacity (please see Figure 6.6.3). It was installed at the NFRL in 2013, and it spans 85 ft across Room 125 in a north-south orientation. The motorized bridge traverses in an east-west direction. The crane uses a motorized trolley attached to the bridge for north-south positioning and an electric wire rope hoist manufactured by R&M Materials Handling, Inc. for lifting. The hoist utilizes a 15 mm diameter wire rope. The attached hook has a 6.5-in. throat equipped with a hook latch. The crane uses a 460 V, three phase power supply, with controls operating at 115 V. It is operated using a handheld remote-control unit (please see Figure 6.6.4).

The crane has been inspected monthly by an external vendor with a scheduled routine annual inspection conducted post-incident on October 27, 2022, by Crane1 Services of Miamisburg, OH (please see Appendix 6.6.1 for the 2022 inspection records of the west crane). All inspection points were documented as "Satisfactory".

Per statements made by NFRL GROUP LEADER, there were no records available to indicate daily shift inspections were performed as required by the *NFRL Overhead Cranes* hazard review (please see Section 6.3.4).

6.6.3 Rigging Slings

Four textile slings were used to support and lift the slabs once they were cut free of the surrounding floor. The slings were Riggers Choice Roundsling Model RCE90X10, provided by SpanSet, Inc. of Sanford, NC (please see Figure 6.6.5). The slings are constructed with a polyester yarn core covered by a polyester sleeve with dimensions of 10 ft in length, 2.5 in. wide, and approximately 0.3 in. thick. Each sling has a straight lift capacity of 8400 lb and a choke lift capacity of 6700 lb. The slings were all manufactured in 2017. The serial numbers for the slings were:

- 219090-20;
- 219090-32;
- 219090-36; and
- 219090-38.

6.6.4 Rigging Hardware

Figure 6.6.6 shows the rigging hardware assembly used to attach the slab to the slings. The lifting attachment hardware used to attach the rigging slings to the concrete slab consisted of Model 44415 pivot lifting plates manufactured by Actek Manufacturing and Engineering of City of Industry, CA (please see Figure 6.6.7a). The pivot lifting plates were manufactured from heat treated alloy steel and have a rated load of 8,000 lb each. They are designed to allow them to pivot so that they can be aligned with the direction of force from the attached sling. The pivot lifting plates were attached using a threaded 0.875 in. bolt with a nut on each end (please see Figure 6.6.7b). The lifting bolts are marked with the designation "HY B7", indicating a heat-treated chromium-molybdenum low-alloy steel with minimum tensile strength requirement of 861.8 MPa (125 ksi) and yield strength of 724.0 MPa (105 ksi). Based on information provided during interviews, the nuts on the mounting screws were hand tightened.

A steel plate was placed on the threaded bolt on the bottom side of the slab, between the nut and the slab, to function as a washer. The size and condition of the steel plate washers varied (please see Figure 6.6.7c). Two of the washers were approximately 6 in. by 10 in. with a 0.375 in. thickness. They had three 1 in. holes drilled into them and the middle hole was used to attach it to the lifting hardware. Engineering technicians indicated these were likely fabricated from scrap steel in the NFRL machine shop. The other two washers were 4 in. by 4 in. and were 0.25 in. thick with a single 1 in. hole in the center. Engineering technicians indicated these were likely purchased items.

6.6.5 Personal Protective Equipment (PPE)

At the time of the incident, ENGR TECH 1 was wearing the following PPE:

- Type 1 hard hat;
- Earplug style hearing protection; and
- Safety boots.

ENGR TECH 1 was not wearing personal fall protection[21], safety glasses with side shields, or respiratory protection as required by the hazard review.

6.7 Documentation of Videographic Evidence

Videographic evidence was reviewed to determine the procedures used (*e.g.*, order of cutting, when rigging was installed, how crane was operated) and behaviors displayed (*e.g.*, were staff implementing appropriate safety practices and protocols) as work was performed to cut the four slabs from the surrounding floor. Available video recordings obtained from Building 205, Room 125 were from 9:00 am ET on September 20, 2022, through 10:00 am ET on September 27, 2022. As the cutting and removal of Slabs 1 and 2 occurred prior to September 15, 2022, as indicated by ENGR TECH 4 in his statement, there is no video evidence of those events. Slab 3 was cut and removed on September 23 and the cutting of Slab 4 occurred on September 26. Detailed observations and still images from the video evidence are provided in Appendix 6.7.1 and Appendix 6.7.2, respectively. Not all aspects of the activities observed in the video were documented as some tasks were not directly associated with cutting of the slabs, *e.g.*, other activities on the strong floor. The camera providing the best view of these cutting activities was CAMERA 2 located in the southeast corner of the room and looking northwest at the test frame, but the camera identified as CAMERA 1, located in the southwest corner of the room and looking northeast at the test frame, was also used to confirm certain facts (please see Section 5.2).

[21] Per the *Composite Floor System Stabilization and Demolition* hazard review, personal fall protection was required as other fall protection measures were not taken with respect to the Slab 3 floor opening (*e.g.*, covering the floor opening).

6.7.1 Videographic Evidence of Slab 3 Cutting and Removal

The cutting of Slab 3 occurred on Friday, September 23, 2022. Detailed observations with corresponding images of this activity are found in Appendix 6.7.1. The following summarizes the cutting, rigging, and lifting operations for this slab.

- ENGR TECH 1 moves the floor saw near Slab 3. He spends some time moving the saw around looking at how he will cut Slab 3. This may indicate he has not planned out the cutting operation in advance.
- ENGR TECH 1 positions the saw to cut the south face, cutting towards the east (please see Figure 6.7.1 indicating the order of the cuts). As the saw blade is aligned with the outer right side of the saw when viewed operating it from behind, the main weight of the saw is on the slab during Cut 1.
- ENGR TECH 1 stops cutting the south face and positions the saw to cut the north face, cutting towards the east. The main weight of the saw is not on the slab during Cut 2.
- ENGR TECH 1 stops cutting the north face and positions the floor saw to recut the south face, cutting towards the east again. The main weight of the saw is on the slab during Cut 3.
- ENGR TECH 1 stops cutting the south face and hooks up the rigging and engages it. This process involves him moving the crane and slings, which were previously attached, over Slab 3. The rigging hardware is already attached to the slings. ENGR TECH 1 lowers the crane enough so he can extend the rigging bolts through pre-drilled holes in the slab. He then goes below the slab, and using a set of rolling stairs, places a washer and nut on each bolt, fastening them hand tight. ENGR TECH 1 then returns to the surrounding floor and raises the crane until the four slings were engaged under tension. He also attempts to center the crane over the slab.
- ENGR TECH 1 positions the floor saw to cut the east face, cutting towards the south. The main weight of the saw is not on the slab during Cut 4. He makes multiple passes using the saw.
- ENGR TECH 1 stops cutting the east face and positions the saw to cut the west face, cutting towards the south. The main weight of the saw is on the slab during Cut 5.
- After completing the west face cut, ENGR TECH 1 appears to realize the southwest corner of the south face is not fully cut. ENGR TECH 1 walks the floor saw across the mid-span of the slab, from the north to the south, underneath the rigging, and positions it to cut the southwest corner of the south face, cutting towards the west. The main weight of the saw is not on the slab during Cut 6.
- ENGR TECH 1 completes cut of the entire south face and Slab 3 is now fully suspended by the rigging and crane. ENGR TECH 1 walks the floor saw back across the mid-span of the slab, from the south to the north, underneath the rigging, and positions it out of the way for slab removal.
- ENGR TECH 1 attempts to use the crane and rigging to lift the slab out. While the east face is free and rises, the west side of the slab appears to be stuck. After numerous attempts to lift the slab out just using the crane, ENGR TECH 3 joins ENGR TECH 1 next to the slab and uses a reciprocating saw to cut a portion of the steel decking still attached over on the west face. ENGR TECH 1 kicks the tab of Slab 3 and it falls to the strong floor below. Slab 3 is now completely free of the surrounding floor.

- ENGR TECH 1 uses the crane to move Slab 3 to the strong floor.

NOTE – It is unknown when the south and west face of the tab for Slab 3 was cut. Reviewing available videographic evidence starting at 9:00 am on September 20 through until ENGR TECH 1 began the first cut on Slab 3 showed the cuts were not made during this time. Additionally, the cuts made in the east-west direction (Cuts 1, 2, and 3) were long, singular cuts. The same can be said for the north-south cut made on the west side of the tab (Cut 5). It is believed the south and west face of the tab was cut prior to September 20.

6.7.2 Videographic Evidence of Slab 4 Cutting and Incident

The cutting of Slab 4 occurred on Monday, September 26, 2022, and detailed observations of this activity are found in Appendix 6.7.2. The following summarizes the cutting and rigging operations for, and subsequent failure of, this slab.

- ENGR TECH 1 moves the floor saw near Slab 4. He positions it to cut the northwest corner of the north face, cutting towards the west (please see Figure 6.7.2 indicating the order of the cuts). The main weight of the saw is on the slab during Cut 1.
- ENGR TECH 1 stops cutting the north face and positions the saw to cut the southwest corner of the west face, cutting towards the south. The main weight of the saw is on the slab during Cut 2.
- ENGR TECH 1 stops cutting the west face and positions the saw to cut the northwest corner of the west face, cutting towards the north. The main weight of the saw is not on the slab during Cut 3.
- ENGR TECH 1 stops cutting on the west face and positions the saw to cut the middle of the west face, cutting towards the south. The main weight of the saw is on the slab during Cut 4.
- ENGR TECH 1 stops cutting the west face and positions the saw to cut the northeast corner of the east face, cutting towards the north. The main weight of the saw is on the slab during Cut 5.
- ENGR TECH 1 stops cutting the east face and positions the saw to cut the southeast corner of the east face, cutting towards the south. The main weight of the saw is not on the slab during Cut 6.
- ENGR TECH 1 positions the floor saw to cut the middle of the north face, cutting towards the east. The main weight of the saw is not on the slab during Cut 7.
- ENGR TECH 1 stops cutting the north face and hooks up the rigging via a similar process described in Section 6.7.1.
- ENGR TECH 1 begins cutting the northeast corner of the north face, cutting towards the east. The main weight of the saw is not on the slab during Cut 8.
- ENGR TECH 1 stops cutting the north face and positions the saw to cut the middle of the north face, cutting towards the west. The main weight of the saw is on the slab during Cut 9.
- ENGR TECH 1 stops cutting the north face. He leaves the saw on the north side of Slab 4 and goes to lunch.

- ENGR TECH 1 returns from lunch and pushes the saw across Slab 4 from the north to the south underneath the rigging to position the saw to cut the south face, cutting towards the west. The main weight of the saw is not on the slab during Cut 10.
- ENGR TECH 1 completes the cut of the entire south face and Slab 4 is now fully suspended by the rigging and crane.
- ENGR TECH 1 begins to back the floor saw up, moving east towards the mid-span of Slab 4. ENGR TECH 1, fully on the slab underneath the rigging, continues to turn the saw counterclockwise to face the south. ENGR TECH 1 adjusts the location of the cooling water hose used to supply water to the floor saw. ENGR TECH 1 begins to pull the saw back across the slab. As the rear wheels of the saw come onto the slab, Slab 4 experiences an instantaneous and catastrophic failure resulting in the fatal fall of ENGR TECH 1.

6.7.3 Videographic Evidence of Unsafe Acts during Slab 3 and Slab 4 Removal

During review of video evidence related to the cutting and lifting operations of Slabs 3 and 4, unsafe acts were noted by those performing the work. While detailed observations and still images of these acts are found in Appendices 6.7.1 and 6.7.2, the following bullets summarize them.

- Non-compliances with requirements established in NIST S 7101.69: *Overhead Cranes and Hoists Program.*
  - There is no evidence either ENGR TECH 1 or another engineering technician performed a daily pre-use inspection of the overhead crane prior to using it for Slab 3 or Slab 4.
  - ENGR TECH 1 was observed walking on a fully or partially suspended load, *i.e.*, the slab supported by the rigging. Examples provided for Slab 3:
    - With both the north and the majority of the south face of Slab 3 cut, a portion of the east face cut, and the rigging engaged, ENGR TECH 1 walks across the slab underneath the rigging from the north to south to reposition something on the southeast corner of Slab 3.
    - With the north, east, and the majority of the south faces of Slab 3 cut and the rigging engaged, ENGR TECH 1 walks across the slab underneath rigging from the north to south to reposition saw.
    - With the north, east, and the majority of the south faces of Slab 3 cut, a portion of the west face cut, and the rigging engaged, ENGR TECH 1 walks across the slab underneath the rigging from the north to south to retrieve something from the toolbox. Other engineering technicians observe this unsafe act.
    - With the north, east, and west faces of Slab 3 cut, the majority of the south face cut, and the rigging engaged, ENGR TECH 1 walks the floor saw across the slab underneath the rigging from north to south to finish cutting the southwest corner of the south face. Other engineering technicians observe this unsafe act.
    - With all four faces of Slab 3 cut and fully supported by the rigging, ENGR TECH 1 pulls the floor saw across the slab from the south to the north underneath the rigging. Other engineering technicians observe this unsafe act.
    - With all four faces of Slab 3 cut and fully supported by the rigging, ENGR TECH 1 puts his full weight on the northeast corner of Slab 3 in an attempt to “pop” the west

side of the Slab 3 free of the surrounding floor. Other engineering technicians observe this unsafe act.

Examples provided for Slab 4:

- With the east and west faces of Slab 4 cut, the majority of the north face cut, and the rigging engaged, ENGR TECH 1 maneuvers the floor saw to turn it around on the slab underneath the rigging.
- With the north, east, and west faces of Slab 4 cut and the rigging engaged, ENGR TECH 1 first walks the across the slab underneath the rigging from south to north to get the saw. He then walks the floor saw across the slab underneath the rigging from north to south to cut the south face.
- With all four faces of Slab 4 cut and fully supported by the rigging, ENGR TECH 1 puts his full weight on the slab as he attempts to maneuver the saw to pull it across the slab and adjusts the location of the cooling water hose.

– There was no exclusion zone marked off with tape and engineering technicians were observed walking underneath a partially or nearly fully suspended load, *i.e.*, Slab 3 supported by the rigging.

– ENGR TECH 1 was observed employing the following practices, while being observed by other engineering technicians:
  - Operating the crane while he was within a few feet of a fully suspended Slab 3;
  - Using his foot and hand to steady Slab 3 as it was being lifted out;
  - Taking his focus off of a suspended Slab 3 while it was moving; and
  - Leaving Slab 3 suspended in the air while his focus was elsewhere.

– While not in violation of a specific requirement, ENGR TECH 1 was observed walking on a partially cut slab while the rigging was not installed which is not good practice. Examples include:
  - With both the north and south face of Slab 3 cut and the rigging not installed, ENGR TECH 1 walks across the slab once by himself and then a second time while moving the floor saw across the slab.
  - With both the east and west face of Slab 4 cut, a portion of the north face cut, and the rigging not installed, ENGR TECH 1 walks across the slab with the floor saw.

- Non-compliances with requirements established in NIST S 7101.67: *Fall Protection Program.*
  - On the morning of September 26, ENGR TECH 1 and ENGR TECH 3 were walking and working near an unprotected edge (floor opening created by Slab 3) without personal fall protection on.
  - On the afternoon of September 23, ENGR TECH 1 walks within feet of an unprotected edge (floor opening created by Slab 3) without personal fall protection on.
  - On the morning of September 23, ENGR TECH 3 and ENGR TECH 6 violate the verbal exclusion zone, *i.e.*, enter the footprint of the test frame, while ENGR TECH 1 is performing work on an elevated surface with unprotected edges, *i.e.*, nothing to prohibit falling objects.

- Non-compliances with requirements established in NIST S 7101.74: *Powered Industrial Trucks Program.*
  - There is no evidence ENGR TECH 1 performed daily pre-use inspection of the fork truck prior to its use on September 26.
  - ENGR TECH 1 was observed not wearing the seat belt while using the fork truck on September 26.
  - ENGR TECH 1 parks the fork truck with a heavy load elevated approximately 14 ft off the ground.

- Non-compliances with requirements established in NIST S 7401.04: *Fire Prevention During Welding, Cutting, and Other Hot Works Program.*
  - There is no evidence a hot work permit was obtained for using spark-producing tools such as the floor saw or the angle grinder during the demolition activities.

- Non-compliances with NFRL requirements.
  - ENGR TECH 1 was observed numerous times in Room 125 without a hardhat on.
  - ENGR TECH 1 was not fully focused on hazardous activities as he was observed checking his phone while operating the floor saw during the cutting of Slab 3 and Slab 4 and holding onto and drinking from a coffee mug while cutting Slab 4.
  - ENGR TECH 1 was engaged in demolition activities, *e.g.*, cutting the surrounding floor numerous times, without a "buddy" in Room 125.
  - ENGR TECH 1 was observed not to be wearing safety glasses with side shields.

- Non-compliances with OSHA requirements.
  - ENGR TECH 1 was observed not wearing respiratory protection in accordance with OSHA 29 CFR 1926.1153, Respirable Crystalline Silica Standard[22].

6.8 Documentation of the Incident Site

Observations of the incident site (Building 205, Room 125) were document on the day of the incident and during post-incident visits.

6.8.1 Day of the Incident

On the date of the incident, September 26, the following observations were made.

- Lighting: Both roll-up doors were open during the incident and all interior lights were functioning as designed (please see Figure 6.8.1). The room was functionally lit and aided by the roll-up doors being open as it was a clear day with abundant sunlight.

[22] https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.1153

- Mechanical: Mechanical systems, *i.e.*, heating, ventilation, and air conditioning, appeared to be operating as designed. The air in Room 125 was clear with no apparent smells and at ambient temperature (approximately 70 ºF – the same temperature as outside).

- CF Project Test Frame: The perimeter of the test frame area was taped off after the incident by OSHE and PSG personnel using red and yellow tape. There was no indication of a designated exclusion zone prior to this, *e.g.*, physical barrier, which would be warranted given the lack of toeboards or some other control measure to prevent falling objects from the surrounding floor to the strong floor.

  Figure 6.8.2 shows a planar view diagram of the CF Project test frame with the general location of specific items noted. A large, roll-off dumpster was located to the south of the test frame and contained concrete debris and one large slab of concrete (please see Figure 6.8.3). On the southwest corner of the test frame was a set of scaffold stairs for accessing the surrounding floor from the strong floor (please see Figure 6.8.3). The composite floor and fire compartment of the fire-tested bay was demolished, with exception of the two beams running east-west (please see Figure 6.8.4). A forklift with a suspended load of angle iron positioned a few inches above the second level of the test frame was parked in the footprint of the fire compartment (please see Figure 6.8.5). There was a significant amount of water on the strong floor in and around the incident site (please see Figure 6.8.5) due to the use of the floor saw to cut the concrete slab. Multiple metal shoring poles (reddish orange in Figure 6.8.5) were observed supporting the girders (east and west side) and beam (north side) directly adjacent to the fire-tested bay. Four areas from the eastern side of the surrounding floor had been removed. In the northernmost bay, two portions of Slab 4[23] were suspended by the overhead crane with a pile of concrete and a floor saw observed beneath the suspended pieces (please see Figure 6.8.6). In the background of the image is a set of rolling stairs (yellow). To the south of the construction debris on the strong floor and located directly beneath the two southernmost cut bays (Slabs 1 and 2) were structures made of wood (please see Figure 6.8.7).

6.8.2 Subsequent to the Day of the Incident

During subsequent visits to the incident site, the following conditions were noted.

- Lighting: When the roll-up doors are closed, lighting is limited in Room 125. While there is enough lighting to allow for occupancy of the space, it was apparently insufficient to conduct some work if the roll-up doors are not open as task lighting was found on the surrounding floor. Based on review of video evidence, task lighting was minimally used.

- Mechanical: Mechanical systems appeared to be operating as designed and the air in Room 125 was clear with no apparent smells with the roll-up doors closed.

[23] Additional post-incident information regarding the disposition of the incident slab, Slab 4, is found in Section 6.9.4.

- Equipment Used During the Incident: Following the incident, the crane was found positioned over the cut bay where Slab 4 failed. The crane remote was located on the surrounding floor approximately 5 ft west of the Slab 3 cut bay (please see Figure 6.8.8). The rigging slings were still attached to the crane (please see Figure 6.8.9) and supporting two pieces of the slab that were connected using the rigging hardware. The slings were positioned on the hook with some overlap as there was not enough space on the hook to position four slings side-by-side (please see Figure 6.8.10). The opposite ends of the slings were attached to the pivot lifting plates using a girth hitch around the pivot lifting plate shackle (please see Figure 6.8.11). The pivot lifting plates, bolts, nuts, and washers were attached to the two pieces of the slab and in good condition with no evidence of failure. The two smaller washer plates were found on the connection points in the northeast and southeast corners of the slab while the two larger washer plates were found on the connection points in the northwest and southwest corners. Once the two portions of the suspended slab were lowered to the strong floor, the slings were disconnected and inspected. They were found to be in good condition, with no sign of damage or failure.

  The floor saw was found lying on its left side partly underneath debris from the collapsed concrete slab (please Figures 6.8.12). The saw blade was undamaged and both the gasoline and cooling water tanks appeared intact. The cooling water tank contained approximately one gallon of water. A cooling water hose was connected to the bypass connection with the water supply valve in the off position. After removal of the concrete slab pieces, the saw was further inspected. The handle was significantly deformed and the housing was dented in several locations (please see Figure 6.8.13). The saw was weighed using a floor scale at Building 301 and owned by the NIST Shipping and Receiving Department. The weight of the saw (including gasoline and water remaining in the onboard tanks) was 258 lb.

  The positioning of the cooling water hose used to supply the water to the saw was also noted (please see Figure 6.8.14). The main water connection was behind the strong wall with the hose running up the northeast corner of the test frame and secured to the most northeast column (Figure 6.8.14a). It was then suspended across the north face of the test structure and secured to the next column to the west of the most northeast column (Figure 6.8.14b). The hose was then observed on the surrounding floor and dropping down into the cut bay (Figures 6.8.14b and 6.8.14c). It comes back up and is observed draped over the northwest corner of the suspended slab where it was pinched between the two suspended slabs and proceeds down to the floor saw (Figure 6.8.14d).

- Housekeeping on the surrounding floor of the CF Project Test Frame: Figure 6.8.15 shows an overall view of the surrounding floor of the test frame, with Figure 6.8.16 showing closer views in the west, north, and east directions[24]. In general, a lack of care and safety awareness for the working environment was observed on the surrounding floor. Near unprotected edges or partially secured openings there were tripping hazards and object which could fall from the surrounding floor to the strong floor. Figure 6.8.17 shows these objects include jackhammers, powered and manual hand tools, electrical cords, concrete debris, and buckets. Two crowbars were observed

[24] These images were taken after the suspended slabs were secured and the pieces of Slab 4 repositioned.

hooked on the passive fall protection cabling (please see Figure 6.8.18) and extra coiled cabling can be seen on the surrounding floor near the column. Multiple flammable liquid containers (gasoline and 2-cycle fuel) are stored on the surrounding floor (please see Figure 6.8.19).

- Fall Protection on the CF Project Test Frame: Passive fall protection, in the form of cabling, was observed around the entire perimeter of the surrounding floor, except where the scaffold stairs were, as well as around the fire-tested floor (please see Figure 6.8.20). As the floor openings related to the removal of Slabs 1, 2, and 3 existed at the time the work was being performed, adequate fall protection was not provided with respect to their fall hazards, *i.e.*, they were not appropriately covered nor did passive fall protection exist between Slab 3 and Slab 4 bays. Additionally, there was no protection from falling objects along any edge of the surrounding floor, *e.g.*, toeboards or netting.

6.9 Documentation of Removed Composite Floor Slabs

As discussed in Section 6.3.3, ENGR TECH 1 developed a *Coring and Cutting Plan* for removal of slabs from the surrounding floor. The following sections document the as-cut slabs after removal from the surrounding floor.

6.9.1 Slab 1

Figure 6.9.1 shows the portion of the *Coring and Cutting Plan* for Slab 1. The plan was to cut the slab 104.375 in. long by 96 in. wide, with rigging connections in each corner located 1 ft from each cut edge. Figure 6.9.2 shows the approximate slab outline superimposed on the steel reinforcement layout drawing (please see Figure 6.4.11) to indicate the expected location of the No. 4 rebar reinforcement in the cut slab. Not shown on the steel reinforcement layout drawing are the rebar chairs, which were placed on the non-fluted portion of the steel deck and running north and south, and the welded wire fabric which sat on top of the rebar chairs across the entire floor.

After removal of Slab 1 from the surrounding floor, it was moved outside to the parking lot west of Building 205 (Figure 6.9.3). The southeast and southwest corners have damaged edges, matching the statements of ENGR TECH 2 and ENGR TECH 3, *i.e.*, ENGR TECH 1 did not traverse the floor saw far enough in these locations to completely free the slab from the surrounding floor and a jackhammer was needed to break the slab free. The approximate slab dimensions and locations of the rigging holes are shown in Figure 6.9.4.

Figure 6.9.5 shows a typical cross-section of the steel-concrete composite floor. A macroanalysis of the cut faces allowed for observation of the concrete floor and steel components – the steel decking (Figure 6.9.6), the No. 4 rebar reinforcement (Figure 6.9.7), the rebar chair (Figure 6.9.8), and the welded wire fabric (Figure 6.9.9). In general, the depth of the fluting was approximately 3 in. and the slab above the fluting was approximately 3.125 in. The flutes ran north-south.

For Slab 1, as well as the other three slabs discussed below, the welded wire fabric was observed on all cut surfaces and the chairs were observed on the North and South faces of the slabs – these results match the as-built condition. As these two components were not strengthening mechanism of the composite slab, they will not be discussed further in the documentation of the other slabs.

The No. 4 rebar reinforcement was found along the east, south, and west cut faces of Slab 1; no rebar was observed along the north cut face. Figure 6.9.10 shows the approximate locations of the rebar, which matched the steel reinforcement layout drawing shown in Figure 6.9.2.

6.9.2 Slab 2

Figure 6.9.11 shows the portion of the *Coring and Cutting Plan* for Slab 2. The plan was to cut the slab 104.375 in. long by 96 in. wide, with rigging connections in each corner located 1 ft from each cut edge. Figure 6.9.12 shows the approximate slab outline on the steel reinforcement layout drawing to indicate the expected location of the No. 4 rebar reinforcement in the cut slab.

Slab 2 was also moved outside of Building 205 subsequent to removal from the surrounding floor (Figure 6.9.13). The approximate slab dimensions and locations of the rigging holes are shown in Figure 6.9.14. The flutes ran north-south.

A macroanalysis of the cut faces allowed for observation of the placement of the No. 4 rebar reinforcement in the slab. Rebar was found along the east and west cut faces; no rebar was observed along the north or south cut faces. Figure 6.9.15 shows the approximate locations of the rebar, which matched the steel reinforcement layout drawing shown in Figure 6.9.12.

6.9.3 Slab 3

Figure 6.9.16 shows the portion of the *Coring and Cutting Plan* for Slab 3. The plan was to cut the slab in an irregular shape. For the main portion of the slab, the general dimensions were 104.375 in. long by 60 in. wide, with rigging connections in each corner located 12 in. from each cut edge, with the exception of the northwest rigging point. This rigging point was to be aligned with the northeast and southwest rigging points. The general dimensions of the tab in the northwest corner were 39.625 in. long by 21 in. wide. Figure 6.9.17 shows the approximate slab outline on the steel reinforcement layout drawing to indicate the expected location of the No. 4 rebar reinforcement in the cut slab.

Slab 3 was located in the roll-off dumpster inside of Building 205 to the south of the test frame (Figure 6.9.18). While the intent was to cut the slab to the shape shown in Figure 6.9.16 and remove as one piece, in practice, the northwest tab was cut and removed separately (observed through video evidence – please see Section 6.7.1). The approximate dimensions of the individual pieces of the slab and locations of the rigging holes are shown in Figure 6.9.19; the northwest tab was cut shorter in length than planned. The flutes ran north-south.

A macroanalysis of the cut faces allowed for observation of the placement of the No. 4 rebar reinforcement in the slab. Rebar was found along the east, south, and west cut faces of the larger slab portion. Due to its placement in the roll-off, the north cut face was not observable so observations were made on the north cut face of the surrounding floor bay; rebar was found along this face as well.

Figure 6.9.20 shows the approximate locations of the rebar in this piece. These results match the steel reinforcement layout locations shown in Figure 6.9.17 with the exception of the through width piece found along the west face running north and south. While there are no clear construction images showing the rebar reinforcement of the northeast corner of the surrounding floor, there was one image from the northwest corner (Figure 6.9.21). When comparing the steel reinforcement layout drawings to this image, an extra piece of rebar was observed (comparing Figure 6.9.21b to Figure 6.9.21c) so it is assumed this extra piece of rebar was also placed in the northeast corner as well.

For the northwest tab, rebar was found along north and west cut faces; no rebar was observed on the east face. Due to its placement in the roll-off, the south cut face was not observable so observations were made on the south cut face of the surrounding floor bay; rebar was found along this face as well. Figure 6.9.20 shows the approximate locations of the rebar in this piece. The results match the steel reinforcement layout locations shown in Figure 6.9.17 with the exception of the piece of rebar found on the west cut face. Reviewing the steel reinforcement layout drawings and construction images, no explanation could be provided for this piece.

6.9.4 Slab 4

Figure 6.9.22 shows the portion of the *Coring and Cutting Plan* for Slab 4. The plan was to cut the slab 144 in. long by 60 in. wide, with rigging connections in each corner located 1 ft from each cut edge. Figure 6.9.23 shows the approximate slab outline on the steel reinforcement layout drawing to indicate the anticipated location of the No. 4 rebar reinforcement in the cut slab.

As a result of the incident, Slab 4 fractured into numerous pieces. Two large concrete pieces remained suspended in the air by the rigging (Figure 6.9.24), and four large concrete pieces were found on the strong floor directly beneath the location where the slab was cut (Figure 6.9.25). There were multiple smaller concrete fragments (less than 6” in any dimension) located around the larger pieces on the strong floor as well. It is noted the fractures occurred in the north-south direction similar to the orientation of the flutes, *i.e.*, the flutes were parallel to the bending direction and provided no strengthening of the slab in that direction.

For the two suspended pieces, based upon video evidence prior to the incident (please see Section 6.7.2 for discussion of the black bags on the slings as shown in Figure 6.9.26), the east and west portions were identified. Figure 6.9.27 shows the identification of the easternmost (labeled as Piece A) and the westernmost (labeled as Piece E) portions of the slab.

The four pieces on the strong floor were identified by matching up the contours of the fracture surfaces. They were labeled as Pieces B, C1 and C2, and D (Figure 6.9.28).

The individual pieces were secured and repositioned in a manner in which they were located in the slab prior to failure (Figure 6.9.29).

The approximate dimensions of the individual pieces of the slab and locations of the rigging holes are shown in Figure 6.9.30.

A macroanalysis of the cut faces for each piece of Slab 4 allowed for observation of the placement of the No. 4 rebar reinforcement in the slab (Figure 6.9.31).

- Piece A
  - North face – One piece of No. 4 rebar observed 11 in. from the east cut face.
  - East face – Two pieces of No. 4 rebar observed, one 5.5 in. from the north cut face and the other spaced 29.25 in. towards the south cut face.
  - South face – No pieces of No. 4 rebar observed
  - West face – Fracture surface with no rebar observed.

  These results match the as-built rebar locations shown in Figure 6.9.23.

- Piece B
  - North face – One piece of No. 4 rebar observed 10 in. from the east fracture surface.
  - East face – Fracture surface with no rebar observed.
  - South face – No pieces of No. 4 rebar observed
  - West face – Fracture surface with no rebar observed.

  These results match the as-built rebar locations shown in Figure 6.9.23.

- Piece C1 and C2
  - North face – No pieces of No. 4 rebar observed.
  - East face – Fracture surface with no rebar observed.
  - South face – No pieces of No. 4 rebar observed.
  - West face – Fracture surface with no rebar observed.
  - Middle fractured face – Fracture surface with no rebar observed.

  These results match the as-built rebar locations shown in Figure 6.9.23.

- Piece D
  - North face – Two pieces of No. 4 rebar observed, one 3 in. from the east fracture surface and the other spaced 29.25 in. towards the west fracture surface.
  - East face – Fracture surface with no rebar observed.
  - South face – One piece of No. 4 rebar observed 9 in. from the west fracture surface.
  - West face – Fracture surface with no rebar observed.

  The results for the rebar observed on the north cut face match the as-built locations shown in Figure 6.9.23. The piece of rebar observed on the south cut face was not expected per the steel reinforcement layout drawing shown in Figure 6.9.23. This piece of rebar is assumed to be the same piece of rebar unexpectedly found in Slab 3.

- Piece E
  - North face – Two pieces of No. 4 rebar observed, one 0.20 m (7.75 in.) from the west face cut and the other spaced 0.05 m (2 in.) towards the east fracture surface.
  - East face – Fracture surface with no rebar observed.
  - South face – Two pieces of No. 4 rebar observed, one 0.23 m (9 in.) from the west face cut and the other spaced 17” towards the east fracture surface.
  - West face – No pieces of No. 4 rebar observed.

These results match the as-built rebar locations shown in Figure 6.9.23.

The fracture surfaces of from Pieces B and D were examined by the third party contractor and comments provided in Section 6.17.

Figure 6.9.32 shows the suspended portions of Slab 4 (Piece A and Piece E) after they were removed from the cut bay of the surrounding floor and lowered to the strong floor. Portions of the steel decking are observed attached to each piece and were held in place by the rigging hardware. Those decking remnants experienced some deformation from their original shape, specifically that portion of the decking directly beneath Piece C. The decking measure approximately 59 in. in width with lengths of ~90 in. for the section attached to Piece E and 67 in. for the section attached to Piece A. Further analysis revealed there were five separate sections of the decking across the length, as shown in Figure 6.9.33.

6.9.5 Cut Bays of the Surrounding Floor

Figure 6.9.34 shows an aerial view of the four cut bays from the surrounding floor on the east side of CF Project test frame. The different sizes and shapes of the bays are readily evident and match the general sizes and shapes of the cut slabs.

The cut bay on the surrounding floor was observed for Slab 4. Visual observations found a "chip" along the south face on the deck 72.25 in. from the west cut surface (please see Figure 6.9.35). This is approximately at mid-span of Slab 4. It is believed this chip was created by the diamond blade of the floor saw as it fell through the opening during the incident. This matches the general location of the floor saw at the time of the incident observed through the videographic evidence.

6.9.6 Slab Removed from the CF3 Fire-Tested Floor

Through interviews with ENGR TECH 2, it was learned removal of Slab 1 was not the first time the process of saw cutting and then lifting out a slab section of the composite floor had been performed. During demolition of the CF3 fire-tested floor, ENGR TECH 1 began "experimenting" with the technique of cutting sections of the floor out using the floor saw and then lifting it out using the slings and overhead crane. ENGR TECH 2 indicated after the slab was cut, rebar was exposed and clevises attached to them so the slings could be connected to the slab. He also stated the slabs started off small (~1 ft by ~4 ft) and gradual increased in size to ~4 ft by ~4 ft. The last and largest slab removed was the "test case" discussed in Section 6.3.2.

Figure 6.9.36 shows the remnants of the "test case" slab that was cut and lifted out of the fire-tested floor. It was also moved outside of Building 205 next to Slab 1 and Slab 2. The slab edges are not well defined as portions of them have "crumbled" off. The maximum measurement in one direction was 104 in. and 103 in. in the other direction. No rigging holes were observed which matches the information that rebar was exposed and clevises attached. A macroanalysis of the cut faces showed at least three of them were clearly saw cut while the fourth side had a damaged appearance. No. 4 rebar reinforcement was observed throughout the slab on a 1 ft x 1 ft matrix (running both north-south and east-west). These observations align with the reinforcement used in the CF3 fire test floor. There was no steel deck pan underneath the slab.

6.10 Safety Training Records for Relevant Staff Members

Training on potential hazards and their hazard control measures is one element used to authorize a staff member to perform work at NIST per NIST S 7101.20 (please see Section 6.2.1). There are various types of safety training required by NIST including general safety awareness training (applicable to all staff members regardless of their official duties) and specific subject matter area training (applicable only if the staff member will or may be exposed to that hazard).

For subject matter area training, NIST has a number of safety programs covering Occupational Safety and Health, Ionizing Radiation Safety, Environmental Management, and Fire and Life Safety. Examples of subject matter areas in Occupational Safety and Health are Biosafety, Chemical Management, and Personal Protective Equipment. When a subject matter area has an approved requirements document (NIST Directives Management System suborder), NIST-level training is provided for any staff member who will or may be exposed to that hazard to provide them with:

- A baseline understanding of the hazard;
- The hazard control measures to mitigate the hazards; and
- The roles and responsibilities to ensure the appropriate requirements are carried out.

It is a requirement to complete the NIST-level training prior to next performing work involving that hazard. Additionally, the OU is required to provide activity-specific training that is focused on the particular work to be performed. The hazard review for that work identifies the NIST-level and activity-specific training required to be completed prior to the staff member being authorized to perform that work. A staff member may also voluntarily complete additional safety training in the subject matter area if they have a desire to learn more about the hazard and appropriate hazard control measures, but that training is not a requirement to have prior to being authorized to perform work.

6.10.1 Training records for CF Project Staff

Safety training records at NIST are stored in an IT application titled *Safety Education and Training (SET)*. These training records were reviewed for the following engineering technicians who worked within the NFRL and were involved with the CF Project hazard reviews (please see Section 6.3) or participated in the construction and/or demolition of components the CF Project test series (*i.e.*, the test frame in general, the test floors, the surrounding floor, and the fire compartments):

- ENGR TECH 1;
- ENGR TECH 2;
- ENGR TECH 3;
- ENGR TECH 4;
- ENGR TECH 5; and
- ENGR TECH 6.

Safety training records were also reviewed for the following individuals involved with the CF Project:

- NFRL ENGINEER 1;

- FRD DSR
- CF PROJECT LEADER 1 – former leader of the CF Project;
- CF PROJECT LEADER 2 – leader of the CF Project at the time of the incident;
- NFRL GROUP LEADER;
- FRD CHIEF 1 – former chief of FRD; and
- FRD CHIEF 2 – acting chief of FRD at the time of the incident.

All of the training records are found in Appendix 6.10.1

The training records were separated into various categories:

- General safety training which is applicable regardless of the work being performed;
- Safety training related to personal protective equipment;
- Safety training related to construction and demolition work;
- Safety training related to material handling; and
- Other (safety training that may not be directly relevant to the construction and/or demolition of the CF Project).

Within each category, the training is further identified by two sub-categories:

- "NIST-level" training which is provided by NIST and specified by a NIST Suborder to impart baseline understanding of hazards and associated hazard control measures used to eliminate or mitigate those hazards for a specific subject matter area; and
- "OU activity specific" training which is provided by the OU and applicable to the possible hazards encountered engaging in that specific work.

The following two sections contain a review of the training completion records for general safety training (Section 6.10.2) and specific subject matter area trainings (Section 6.10.3). These records may be applicable when NFRL line management authorizes a user for a specific hazard review (please see Section 6.3).

6.10.2 General Safety Training (NIST-level and EL)

The training course titled "NIST P 7100.00: General Safety Training" is a web-based course required to be completed by all new NIST staff members, whether federal employees or associates. This training was reviewed with the following points noted:

- Safety is integrated into everything we [NIST] do.
- Line management is ultimately responsible for safety [at NIST].
- Staff take personal responsibility for their safety.
- Staff also take personal responsibility for the safety of coworkers.
- Hazard reviews are required to determine the potential hazards before a new activity is begun – this process eliminates or reduces hazards by implementing hazard control measures.
- Safe work practices are integrated into jobs from planning an activity to executing.
- Safety incidents and near misses are required to be reported.

- Staff have a responsibility to correct anything they view as hazardous, share safety information, and take action to prevent incidents.
- Staff have a responsibility to report or address working conditions that appear unsafe or unhealthy.
- The supervisor is responsible for identifying required safety training.

Compliance: All NFRL staff indicated above are compliant with the requirement and completed the course.

The training course titled "NIST S 7101.20: Work and Worker Authorization Based on Hazard Review" is a web-based course required to be completed by NIST staff leading hazard reviews and for managers approving hazard reviews. It is optional for others. This training was reviewed with the following points noted:

- Hazard reviews help to uncover hazards in work activities to reduce risk of injury or illness.
- For hazards, one needs to take into consideration severity of consequence and the likelihood of event occurring.
- Hazard reviews are required for all activities: activities with the potential to cause severe or disabling injuries or illnesses; activities that are complex and require written instructions; activities that are performed infrequently; and activities that are new or modified.
- Hazard reviews are not required for activities that are inherently low risk or involve common everyday tasks that don't involve extraordinary hazard.
- Calculations used to characterize or quantify potential hazards associated with the activity are required and should be included.
- Line management approves hazard reviews; the level of approval depends on the relative hazard index.
- Line management authorizes work after ensuring hazard control measures have been implemented to address hazards.
- Line management authorizes workers once they confirm one has the knowledge, skills, and abilities to perform the work safely.
- Re-review of hazard reviews are required every 3 years or whenever a change to existing hazard control measures is made, new hazards are introduced, or a hazard is identified that was overlooked.

Compliance: FRD DSR, NFRL GROUP LEADER, and FRD CHIEF 2 are required to complete this training, which they did. FRD CHIEF 1 was also required to complete the training, but he did not. Additionally, the remainder of the NFRL staff indicated above, with the exception of ENGR TECH 4, ENGR TECH 5, and NFRL ENGINEER 1, completed the course even though it was not required for their responsibilities.

The training course titled "EL General Safety Awareness" is required to be completed by all Engineering Laboratory staff; it is offered either web-based or instructor-led. This training was reviewed with the following points noted:

- EL has staff with various safety roles including division safety representatives and workspace managers.

- Activity hazard reviews are required for all potentially hazardous activities in order to reduce the risks to as low as reasonably practicable. Written Standard Safe Operating Procedures (SSOP's) are an important part of the hazard reviews.
- Staff have a right to refuse to do a job or activity if they have reasonable belief it is unsafe.
- Staff should always be conscious of safety, and not just in the laboratory.
- Staff should follow procedures and not take shortcuts.
- Staff should pay attention at all times and always be aware of what is happening around them.

Compliance: All NFRL staff indicated above are compliant with the requirement and completed the course.

The training course titled "EL-733: NFRL Lab Access and Safety Policies" is a web-based course required to be completed by all staff working in the NFRL (Building 205), and specifically called out in the course description, those working in the fire experiment areas of Rooms 113 and 125. This training was reviewed with the following points noted:

- Workspace managers are identified for each room.
- General hazards found in these locations are identified, which include:
  - Large fires (heat, toxic gases);
  - Large forces and heavy material handling (cranes, forklifts);
  - Flammable liquids, chemicals;
  - Fabrication equipment (band saws, mills, lathes, drill presses);
  - Working at high elevations (ladders, manlifts, platforms, scaffolding);
  - Confined Spaces;
  - Electrical Hazards;
  - Construction Hazards (setup, teardown, modifications); and
  - Pressurized Fluids (compressed gases, cooling lines, hydraulics).
- Various hazard control measures are identified to reduce these hazards:
  - Engineering;
  - Administrative;
  - Personal protective equipment; and
  - Training.
- Activity hazard reviews and SOPs are developed for NFRL general use and specific projects.
- NFRL General Lab Safety Policies:
  - At least two authorized workers are required to be present for all lab activities;
  - Each experimental test series must have an approved hazard review;
  - A safety briefing must be conducted by the activity leader prior to each experiment involving fire or large-scale structure;
  - Fire experiments may be delayed due to extreme hot or cold outdoor temperatures; and
  - Acceptable lab temperatures are 5º C to 35º C when the hood exhaust system is operating.
- Tool use policies are in effect and require specific qualifications including review of hazard reviews and SOPs, training, and demonstrating proficiency.
- Daily safety briefing checklist and pre-test inspection checklists have been developed for fire experiments.
- Key roles and responsibilities for each experiment have been identified.

- Policies are in place for basement and roof access.

Compliance: All NFRL staff indicated above are compliant with the requirement and completed the course.

6.10.3 Training Related to Specific Subject Matter Areas – Demolition

While multiple courses associated with use of powered and hand equipment, use of lifts and booms, and material handling would fall under this category, there are no training records specifically related to demolition or demolition safety found for any staff member associated with the CF Project. This includes CF PROJECT LEADER 1, CF PROJECT LEADER 2, FRD DSR, NFRL GROUP LEADER, FRD CHIEF 1, and FRD CHIEF 2 – all of whom have responsibility for reviewing and approving the demolition work of the CF Project.

6.10.4 Training Related to Specific Subject Matter Areas – Overhead Cranes and Hoists

The training course titled "NIST S 7101.69: Overhead Crane and Hoist" is a web-based course required to be completed by all NIST employees and covered associates whose work activities involve operating overhead cranes and hoists at any site for which NIST has operational jurisdiction. This training was reviewed with the following points noted:

- Different types of inspections are required for crane use – functional inspections are required at the beginning of the workday or shift.
- OUs are required to develop and maintain safe operating procedures for each crane or hoist under their control. The procedures must consider the design and controls of the crane or hoist, the items being lifted, and the conditions, configuration, and construction of the area.
- Operation of the equipment by a competent operator or a trainee who is under the direct supervision of the competent operator must maintain full attention on the task being performed.
- Other minimum considerations include keeping suspended loads as low as possible to the work surface and kept clear of obstructions and personnel and ensuring suspended loads are not left unattended unless provisions have been made to provide auxiliary support.
- OUs shall develop and maintain safe operating procedures in accordance with 29 CFR 1910.184 as part of the hazard review for the use of slings. Procedures must consider the design and construction of the slings, the items being lifted, and the condition, configuration, and construction of the area.
- In addition to the NIST-level training, operators need activity-specific training prior to using the crane or hoist.
- Division chief is responsible for ensuring implementation of the program.
- Supervisors are responsible for ensuring staff complete the required training, ensuring staff conduct inspections at the proper frequency, and providing oversight as necessary to ensure cranes and hoists are operated appropriately.
- Staff using cranes are required to complete the appropriate training and operate the cranes and hoists in accordance with all policies and procedures.

None of the NFRL staff indicated above completed the course.

The training course titled “Overhead Cranes and Slings” is an instructor-led course provided by EL-selected crane training vendors for crane users in their organization. This training, with two presentations available for evaluation, was reviewed with the following points noted:

- Supervisors are responsible for:
  - Ensuring crane operators are trained and certified;
  - Communicating known and potential hazards to crane operators;
  - Enforcing all policies, procedures and legal requirements; and
  - Inspecting what they expect.
- Workers are responsible for:
  - Operating equipment safely, including testing prior to use;
  - Following safety rules, policies, and procedures, and
  - Reporting hazardous conditions, unsafe equipment, accidents, and incidents to supervisor.
- There are different types of “lifts”:
  - Ordinary lifts require a general procedure; and
  - Critical lifts require a plan or procedure for each lift.
- Daily or pre-shift inspections are required.
- Operators need to know the weight of the load and understand stability of load they are going to lift.
- Sling angle affects the sling load capacity and the type of sling used needs to be considered. Synthetic slings need a larger sling angle than a wire rope.
- Synthetic slings need to be inspected and stored properly.
- There is no hoisting, lowering, or traveling while any employee is on the load or hook.
- Operators shall not leave loads suspended in the air unattended.

NFRL GROUP LEADER, CF PROJECT LEADER 1, ENGR TECH 1, ENGR TECH 2, and ENGR TECH 4 completed the course.

The training course titled “EL-733: NFRL Overhead Crane Operation” is a course provided by NFRL for crane users in Building 205. This is an instructor-led course, with NFRL GROUP LEADER as the instructor, to demonstrate operation proficiency as well as knowledge and understanding of workspace specific hazard control measures and comprehension of appropriate guidelines and reference documents. This training has no course materials loaded into the training application, but numerous documents, including the Overhead Crane SOP, were provided to the NIST Incident Investigation Team by NFRL GROUP LEADER. Those documents were reviewed with the following points noted:

- Daily operator inspections are required.
- Operators must not allow themselves to be distracted and they must pay attention to what they are doing.
- There is no hoisting, lowering, or traveling while any employee is on the load or hook.
- Operators shall use a rod to push load or a tag line to pull the load.
- Standard hand signals need to be known.

- The operator will determine if the lift is routine, complex, or critical and develop a lift plan as needed. The lifting team will discuss any changes to the original lift plan before execution. Of note, there are no definitions or examples provided for routine, complex, or critical lifts.
- Use a spotter(s) to assist the crane operator during complex or critical lifts and moves; use additional spotters when necessary. Use clear and recognizable hand signals. Ensure audible communications when visibility is reduced due to obstacles.
- Establish a no-entry zone around all crane operations. Only the crane operator and spotters are allowed inside this zone. The no-entry zone should be at least 10 ft. from the load. Large loads and complex lifts will require a larger zone. The no-entry zone will be determined during the lifting plan and will be enforced by the operator and spotters.
- Crane SOP states any project that requires unique lifts using special rigging and fixtures or two cranes operating simultaneously for the same lift will have a project FLHR detailing these lifts.

ENGR TECH 1 and ENGR TECH 3 completed the course.

The training course titled "CLC S 7101.69: Indoor Hoisting and Rigging" is a web-based course provided by the Commerce Learning Center as an additional resource for staff. This training was reviewed with the following points noted:

- Daily operator inspections are required.
- Safe operating procedures are necessary for complex lifts.

ENGR TECH 1, ENGR TECH 3, and ENGR TECH 5 completed the course.

The training course titled "CLC S 7101.69: Overhead Crane & Slings" was a web-based course provided by the Commerce Learning Center as an additional resource for staff. This training is no longer available for review. All NFRL staff indicated above, with the exception of ENGR TECH 3 and NFRL ENGINEER 1, completed the course.

The training course titled "CLC S 7101.69: Crane Signaling and Communications" is a web-based course provided by the Commerce Learning Center as an additional resource for staff. This training is focused on appropriate communication between crane operator and spotter. ENGR TECH 3 completed the course.

6.10.5 Training Related to Specific Subject Matter Areas – Fall Protection

The training course titled "NIST S 7101.67: Fall Protection Program Training" is a web-based course required to be completed by all NIST employees and covered associates whose work activities may involve them working at heights or expose them to falls from heights. This training was reviewed with the following points noted:

- Falls are considered to be low frequency, but high severity of consequence risks. If risks are not managed adequately, serious injuries or fatalities will most like ensue.
- OU Directors are responsible for designating in writing an OU competent person who assists in identifying, evaluating, and addressing fall protection hazards.
- Division Chiefs are responsible for implementing the program withing their organization according to OU policies and procedures.

- Employees are responsible for completing the training, identifying the need for fall protection hazard control measures, and operating according to OU policies and procedures.
- There is a hierarchy of fall protection measures which include active fall protection systems such as travel restraint and fall arrest.
- Fall protection is required if an unguarded platform is more than 4 feet above the next lower level for non-construction activities or 6 feet for construction activities.
- Fall protection is also about protecting staff from falling objects from heights.
- A competent person should be consulted during the hazard review involving falling object hazards; toeboards or administrative hazard control measures (*e.g.*, restricting storage of materials within 4 feet of the working edge) can be used to protect from falling objects.

CF PROJECT LEADER 1 and ENGR TECH 3 completed the course.

The training course titled "NIST S 7101.67: Fall Protection Authorized Person" is an instructor-led course required to be completed by all NIST employees and covered associates who are required to wear personal fall protection equipment. There were no materials to review for this course. ENGR TECH 2 and ENGR TECH 3 have the course listed in their outstanding training profile, assigned on 04/02/2020 and 08/14/2019, respectively, and have not yet completed it. No other staff members completed the course.

The training course titled "EL - Fall Protection – ILT" is an instructor-led course required to be completed by all EL employees and covered associates working on roofs, scaffolding, and other elevated structures without standard railing. There were no materials to review for this course. NFRL GROUP LEADER, ENGR TECH 1, ENGR TECH 4, and ENGR TECH 6 completed the course.

The training course titled "CLC - Fall Protection (or Working at Heights)" is a web-based course provided by the Commerce Learning Center as an additional resource for staff. This training was reviewed with the following points noted:

- As falling is unpredictable, it is important to take preventative measures.
- OSHA requires workplaces must be setup to prevent employees from falling off of overhead platforms, elevated workstations, or holes in the floor.
- Preventing falls can be done by making use of fall protection systems such as guardrails and personal fall arrest systems.
- There is no acceptable reason for not using fall protection equipment when you are required to do so for your safety.
- Fall protection is required if an unguarded platform is more than 4 feet above the next lower level for non-construction activities or 6 feet for construction activities.
- Toeboards or administrative hazard control measures can be used to protect from falling objects.
- A floor hole must be constantly guarded or protected.
- Personal fall protection equipment can be used to prevent an injury or fatality from fall – there are numerous types and must be selected based upon application.
- Controlled access zones, warning lines, and safety monitoring can also be used.

All but ENGR TECH 3 and ENGR TECH 6 completed the course.

6.11 Workplace Inspections

Per 29 CFR 1960.26, NIST must perform comprehensive safety and health inspections of NIST buildings and worksites. NIST S 7101.26: *Workplace Inspection Program* delineates these requirements (please see Appendix 6.11.1) and establishes work areas where one or more activities are covered by a hazard review need to be inspected at least twice a year and other areas once a year to identify safety and health hazards to workers in those locations. An inspection may be conducted by a single lead inspector or by a team comprising a lead inspector and additional inspectors and/or subject matter experts working under the direction of the lead inspector. Inspections may use checklists to add additional rigor to the inspection process or to focus inspections on particular workplace hazards, provided the use of checklists does not limit the thoroughness of the inspections. Any observed deviation from an established safety or health requirement is referred to as a deficiency. These deficiencies are classified according to their seriousness (*e.g.*, Imminent Danger, Serious, Other than Serious/Administrative) and recorded in and tracked to close (*i.e.*, until the deficiency is fixed) in NIST's IT application titled *Workplace Inspection Recording System (WIRS).*

6.11.1 Workplace Inspection Record for Building 205, Room 125

As Building 205, Room 125 has multiple activities covered under a hazard review, it is required to be inspected at least twice annually. Workplace inspection records for Building 205, Room 125 (please see Appendix 16.11.2) indicate the space was inspected twice in fiscal year 2018 and 2019. For fiscal years 2020 through 2022, due to COVID-related campus access restrictions resulting in the reduction of staff on campus, NIST modified the requirements for these types of spaces to be inspected once per year. The most recent inspection was performed on June 15, 2022.

The inspections were performed by EL lead inspectors, EL support staff, and OSHE staff using standard EL checklists (please see Appendix 6.11.3 for the "EL Laboratory General Checklist" used for the first inspection in 2018 and the "Lab Checklist – Short Version" used for all other inspections). From *WIRS*, a deficiency report was run (please see Appendix 6.11.4). No deficiencies were recorded as "Serious" – a condition or practice that could be reasonably expected to cause death or serious physical harm to an individual exposed to the condition or practice, or "Imminent Danger" – a serious condition or practice that could reasonably be expected to cause death or serious physical harm immediately or before the imminence of the danger can be eliminated through normal procedures. All deficiencies were listed as "closed". There is no indication requirements not included in the EL standard checklists were inspected, nor were any deficiencies recorded for requirements not found on the EL checklists.

6.12 Incident Reporting and Investigation

NIST strives to effectively manage risk by learning as much as possible from workplace incidents that have occurred and to take actions to prevent their recurrence. NIST S 7101.24: *Incident Reporting and Investigation* (IRI) provides policies, procedures, and tools for reporting work-related safety incidents, conducting investigations of their causes, and implementing corrective actions to prevent recurrence (please see Appendix 6.12.1). Each safety incident is categorized as an injury, illness, exposure, contamination by radiation, property damage, spill or release of hazardous materials, or near miss. NIST uses an IT application called the *Incident Reporting and Investigation System (IRIS)* to document the details of each case, including the actions required to remedy any current issues and help prevent the incidents from recurring.

6.12.1 Relevant Incident Investigation Reports Posted Prior to the Incident

Past incidents documented in IRIS were reviewed going back to January 2010 to identify other incidents involving the CF Project, incidents involving structural collapses during demolition activities or otherwise, incidents that occurred in Building 205, and incidents with other similarities.

- Two incidents associated with the CF Project were found (please see Table 6.12.1);
- No incidents were found that involved collapses of structures during demolition activities or otherwise;
- Five incidents that occurred in Building 205 and have aspects related or similar to the current incident were found (please see Table 6.12.2);
- Two incidents that involved falls from a height were found. Both were from a ladder during maintenance work and have no significant similarities to the current incident; and
- One incident that involved the use of a concrete saw was found, but it resulted in dust that set off a fire alarm and has no significant similarities to the current incident.

Appendix 6.12.2 displays the full IRIS reports for the seven cases shown in Tables 6.12.1 and 6.12.2, with a summary of basic findings here:

- Five cases involved concerns with the hazard review in that hazards were not clearly identified in advance and planned for (mitigated) prior to the activity being performed. Three of these involved a large structure or large structural members;
- Three cases involved a scenario where an established procedure was not followed:
  - 1 involved failure to use the correct PPE; and
  - 2 involved failure to correctly use a spotter while operating a crane;
- Three of the incidents occurred during setup of an experiment;
- Two cases involved the use of an overhead crane; and
- None of the prior cases involved:
  - Demolition; or
  - Failure to use Personal Fall Protection.

However, NIST's ability to manage risk through this mechanism depends on whether the appropriate correct action is identified, and then successfully implemented. For the five incidents identified as having insufficient hazard reviews, all from EL, no corrective actions were developed to assess the EL hazard review procedure (please see Section 6.2.2) in an attempt to find deficiencies with its requirements or implementation.

As mentioned above, corrective actions are required to be identified *and implemented* to prevent recurrence of an incident. One of the prior cases identified contained a corrective action that was not implemented, and had aspects relevant to this incident:

- In ***IRIS Case No. 19-IG-0053***, after an employee was cut moving sheet metal while wearing the incorrect type of gloves, *i.e.*, employee was wearing rubber gloves when leather gloves should have been donned, the following root cause and associated corrective action was identified:

  > <u>*Root cause*</u>*: Failure to use proper cut resistant gloves.*
  > <u>*Corrective action*</u>*: The workspace manager or designee will conduct daily checks to assure that PPE is being used.*

  This corrective action was assigned to ENGR TECH 1 as the EL Workspace Manager of Room 125. It was submitted for review by him on May 14, 2019, and certified as implemented by NFRL GROUP LEADER on May 15, 2019. Video evidence of the activities of surrounding floor demolition observed by the investigation team show multiple instances of personnel not wearing the proper PPE, and ENGR TECH 1 was not wearing the proper PPE at the time of the incident, (please see Section 6.7), indicating this corrective action was not being enforced. Engineering technicians working in Building 205 stated these PPE checks were not being conducted.

A second case was identified where a corrective action was completed in a manner that would have made practical and consistent implementation difficult:

- In ***IRIS Case No. 17-IG-0110***, involving a large steel column that was knocked over during a crane operation, the following root cause and associated corrective action was identified:

  > <u>*Root cause*</u>*: The crane operator modified the original lift plan and executed the plan without evaluating the changes.*
  > <u>*Corrective action*</u>*: Revise the overhead crane SOP with instructions to require the operator to determine if the lift is routine, complex or critical; develop an appropriate lift plan; communicate the lift plan to the spotter(s); and evaluate the lift plan in cooperation with the spotter(s) before execution.*

  This corrective action was assigned to ENGR TECH 1 as the EL Workspace Manager of Room 125 and NFRL GROUP LEADER was designated as the person responsible for verifying implementation. The overhead crane SOP was amended to require that lifts be categorized, and lift plans be developed, but no criteria were established for lift types and no requirements for lift plan contents were identified. As such it is not clear how a user would determine the appropriate requirements for a given lift. Through interviews with NFRL GROUP LEADER, it appears that in practice most lifts were considered “routine”, and thus, no lift plans were required to be developed for most of the crane lifts conducted in the NFRL. There were lifts occasionally identified as complex:

  – When conditioning pit covers in Room 125 were lifted and multiple cranes required;
  – When items were lowered into or lifted out of pits in Room 125 and the crane operator could not maintain line of site with the load.

  This case also did not identify a corrective action specifically to address the root cause of making changes to a lift plan without evaluating the changes.

6.13 Electronic Records Review

6.13.1 Review of Outlook Accounts

With the assistance of the Office of Information Systems Management (OISM), the NIST Incident Investigation Team reviewed relevant emails from the Outlook accounts of NIST staff members involved in the CF Project. This review was focused on the following individuals:

- NFRL GROUP LEADER;
- CF PROJECT LEADER 1;
- CF PROJECT LEADER 2;
- FRD DSR;
- ENGR TECH 1;
- ENGR TECH 2; and
- ENGR TECH 3.

The search was bounded between May 1, 2022, to September 26, 2022. OISM searched on the keywords listed in Table 6.13.1 and only provided emails from the above individuals that contained those words.

Based on a review of those files, the following general timeline was established[25]. It should be noted, however, that in most instances there was little or no context to the email communication nor was there a clear link to the project in question (*e.g.*, CF3 was not specifically called out). All emails referenced below can be found in Appendix 6.13.1.

- May 5, 2022
  - An email exchange between FRD DSR and ENGR TECH 1 on the MOP of the CF Project specifically dealing with questions raised by EL SAFETY PROFESSIONAL.
  - An email exchange involving NFRL GROUP LEADER, FRD DSR, and ENGR TECH 1 regarding the MOP. ENGR TECH 1 indicates he disagrees with EL SAFETY PROFESSIONAL's opinion that the demolition activity should be an RHI of 3.

- May 9, 2022
  - An email from CF PROJECT LEADER 2 to multiple staff stating he was now the lead for the CF Project.
  - An email exchange between ENGR TECH 1 and CF PROJECT LEADER 2 regarding the start of the demolition work on CF3 fire-tested floor. CF PROJECT LEADER 2's response indicates he is in charge of the project.

- May 10, 2022
  - An email from CF PROJECT LEADER 2 to NFRL GROUP LEADER stating the hazard review for the CF Project demolition work has been reviewed by himself and ENGR TECH 1, a mention of the RHI = 2 versus RHI = 3 categorization, as well as a request for an internal discussion before responding to EL DEPUTY DIRECTOR and EL SAFETY PROFESSIONAL. In EL SAFETY PROFESSIONAL's communication he indicates the activity should be rated as an RHI = 3 instead of RHI = 2.

[25] Gaps in emails do not indicate zero correspondence, rather no emails meeting the keyword criteria were located.

- An email from ENGR TECH 1 to CF PROJECT LEADER 2 discussing calculations and weight capacity, possibly in relation to the wood shoring underneath the CF3 fire-tested floor, but it could not definitively be determined.

- May 11, 2022
  - An email from ENGR TECH 1 to CF PROJECT LEADER 2 indicating changes to the CF Project demolition hazard review.
  - An email exchange between CF PROJECT LEADER 2 and NFRL ENGINEER 1 regarding calculations of the shoring.

- May 31, 2022
  - An email from ENGR TECH 1 to CF PROJECT LEADER 2 indicating demolition had begun on the west girder on the CF3 fire-tested floor.

- June 15, 2022
  - Meeting request from CF PROJECT LEADER 2 to NFRL GROUP LEADER, ENGR TECH 1, and ENGR TECH 2 for a meeting to discuss amending the current version of the DF Project demolition hazard review to address the surrounding floor.

- August 12, 2022
  - An email from ENGR TECH 1 requesting purchase of the coring rig and drill bits.

- August 22, 2022
  - An email from ENGR TECH 1 to NFRL GROUP LEADER advising of his telework schedule for that week. ENGR TECH 1 indicates he is going to manage demolition from home and develop a lifting plan for the surrounding deck.

- August 23, 2022
  - An email from ENGR TECH 1 to ENGR TECH 2 with the *Coring and Cutting Plan* attached (please see Section 6.3.3).

6.13.2 Review of ENGR TECH 1's Drives

With the assistance of OISM, the NIST Incident Investigation Team reviewed electronic files for information on three topics related to the incident:

- The decision to use the *Composite Floor System Stabilization and Demolition* hazard review package for the surrounding floor;
- The calculations for the slab rigging; and
- The plans for the demolition process.

The three sources were evaluated with the following results:

- Computer 1 (Property Tag 860814)
  - C Drive: A variety of SOP documents were found on this drive but nothing pertaining to the target topics.
  - D Drive: No documents were found pertaining to the target topics.

- Computer 2 (Property Tag G908153): The Coring and Cutting Plan document discussed in Section 6.3.3 was found on this drive, but there were no other documents pertaining to the topics of interest.
- OneDrive: There were no documents pertaining to the topics of interest.

6.14 Report from Maryland Medical Examiner

The State of Maryland requires an examination by the medical examiner in the Office of the Chief Medical Examiner in Baltimore, per Md. Code Ann., Health-Gen § 5-309:

- If the deceased dies suddenly;
- If the deceased was in apparent good health or unattended by a physician; or
- In any suspicious or unusual manner.

As this fatality met the requirement(s) for a medical examiners case (Md. Code Ann., Health-Gen. § 5-301), an autopsy was performed with the report signed on October 3, 2022.

A copy of the medical examiner's report was reviewed by the NIST Incident Investigation Team. Blood screening for comprehensive drug and alcohol test were negative, except for Fluoxetine at 0.2mg/L. No pre-existing condition(s) were noted as contributing factors. The conclusion of the autopsy determined the cause of death was from "multiple injuries" and it was classified as "Accidental."

6.15 Report from NIST Police Service Group

As part of their standard operating procedures, the NIST Police Services Group (OSY, DOC) conducted an investigation of the incident. This effort is required for all work-related fatalities to determine if foul play was involved or if there was criminal cause or involvement. The investigation was conducted per 40 U.S. Code § 1315 and MD Code Ann., Health–Gen. § 5-309. NIST POLICE OFFICER was assigned as the lead investigator which began on September 26, 2022, and concluded on October 28, 2022, with submission of the final report (# G2022-000053).

The conclusion of the investigation indicated this was a work-related accident with no criminal charges deemed appropriate.

6.16 Finite Element Modeling Analysis and 2-D Hand Calculations

The technical cause for the catastrophic failure of Slab 4 was investigated using 3-D high-fidelity, nonlinear finite element (FE) modeling by a third party contractor. This work was driven by the following video evidence:

- 30 seconds prior to the incident Slab 4 did not fail after it was fully cut free from the surrounding floor and suspended by the four rigging slings. This indicates the slab's self-weight, which was uniformly distributed and supported by the four-point rigging, was not significant enough to result in a catastrophic fracture of the slab.
- 10 seconds prior to the incident, Slab 4 did not fail after a concentrated "accidental" load, *i.e.*, ENGR TECH 1's full body weight, was on the slab near the mid-span. This indicates the

slab's self-weight plus the body mass of ENGR TECH 1 was not significant enough to result in a catastrophic fracture of the slab.

- An instantaneous and catastrophic fracture of Slab 4 occurred only after a greater concentrated "accidental" load (the weight of ENGR TECH 1 and the floor saw) was on the slab near the mid-span.
- Slab 3 did not fail after it was fully cut free from the surrounding floor, suspended by the rigging slings, and had the concentrated accidental loads of ENGR TECH 1 and the floor saw on the mid-span of the slab.

Additionally, while there is no video evidence to indicate if a concentrated "accidental" load was placed on Slab 1 or Slab 2, neither catastrophically failed while being removed using the same demolition method. Therefore, in an effort to better understand these observations, finite element modeling was performed to investigate the removals of Slab 2[26], Slab 3, and Slab 4, as well as variations to Slab 4 in terms of the slab length, steel reinforcement in the concrete slab, and location of the rigging location. Calculation of the safety factors for these lifts were performed to help explain the results for each scenario.

Further, simplified 2-D hand calculations, based on well-established design procedures for reinforced concrete sections under flexure, were performed by the contractor to show FE modelling work was not required to reach similar results.

6.16.1 FE Modeling Results

Appendix 6.16.1 contains the complete report regarding the FE modeling and analyses. A summary of the six different lifting scenarios are presented below – three are for the "as is" slab and rigging conditions and three are for hypothetical cases. There were also three loading cases evaluated for each lifting scenario:

- Loading Case 1 – Uniformly distributed load of the slab self-weight;
- Loading Case 2 – Uniformly distributed load of the slab self-weight plus the concentrated load of ENGR TECH 1's weight at the midspan of the slab; and
- Loading Case 3 – Uniformly distributed load of the slab self-weight plus the concentrated loads of the weight of ENGR TECH 1 and the floor saw at the midspan of the slab.

While the WWR 6x6 W1.4 x W1.4 mesh was incorporated in the FE models, discussion of the WWR mesh is not included in this analysis as it was installed throughout the entire floor slab to reduce concrete shrinkage and was not a strengthening mechanism of the steel-concrete composite floor.

Slab 2 "As Is"

Purpose of Analysis: To evaluate the potential for collapse of Slab 2 with the as-removed parameters (geometry, steel deck and steel reinforcement present in the slab, and location of rigging points).

[26] As Slab 1 and Slab 2 were similar (*e.g.*, size, shape, rigging locations, steel reinforcement), only a model of Slab 2 was performed as part of this modelling effort.

Modeling Parameters: The model used visual evidence and physical measurements from Section 6.9.2 to determine the approximate size of the slab, the location of the No. 4 rebar reinforcement in the slab (rebar spanned the slab length spaced 12 in. on center), and the rigging point positions. Key parameters used in the model were the length of the slab (103 inches) and the distance between the east and west rigging positions (79 inches).

Results: Slab 2 did not fail under any of the three loading cases evaluated. This is consistent with the known result of Slab 2 removal, *i.e.*, successful removal without failure of the slab. While it is not known if ENGR TECH 1 walked on the fully suspended slab with or without the floor saw, the FE modelling results indicated the slab would not have failed if he did.

Slab 3 "As Is"

Purpose of Analysis: To evaluate the potential for collapse of Slab 3 with the as-removed parameters (geometry, steel deck and steel reinforcement present in the slab, and location of rigging points).

Modeling Parameters: The model used visual evidence and physical measurements from Section 6.9.3 to determine the approximate size of the slab, the location of the No. 4 rebar reinforcement in the slab (two pieces of rebar spanned its length in east-west direction on the south side of the slab spaced 12 inches on center), and the rigging point positions. Key parameters used in the model were the length of the slab (113 inches) and the distance between the east and west rigging positions (80.6 inches).

Results: Slab 3 did not fail under any of three loading cases evaluated. These results are consistent with the known results of Slab 3 removal, *i.e.*, ENGR TECH 1 successfully walked the floor saw across the slab which was fully supported by the rigging and subsequently removed the slab without its failure.

Slab 4 "As Is"

Purpose of Analysis: To evaluate the potential for collapse of Slab 4 with the as-removed parameters (geometry, steel deck and steel reinforcement present in the slab, and location of rigging points).

Modeling Parameters: The model used visual evidence and physical measurements from Section 6.9.4 to determine the approximate size of the slab, the location of the No. 4 rebar reinforcement in the slab (no rebar spanned its length), and the rigging point positions. Key parameters used in the model were the length of the slab (144 inches) and the distance between the east and west rigging positions (120.6 inches).

Results: Slab 4 did not fail under its self-weight or the combined loading of slab's self-weight and the weight of ENGR TECH 1. These results are consistent with the known results of Slab 4 removal, *i.e.*, the slab did not fail after it was completely cut free of the surrounding floor and fully suspended by the rigging and ENGR TECH 1 successfully walked on the slab fully supported by the rigging without failure in the seconds before pulling the saw onto the slab.

However, the slab did fail with the combined loading of the slab's self-weight, the weight of ENGR TECH 1, and 85.3% of the weight of the floor saw. The failure started as a bending-induced transverse crack forming on the underside of the thin section of the slab directly beneath the accidental load (please see Figure 6.16.1). The crack instantaneously propagated through the slab thickness (less than 0.1 seconds) resulting in an immediate and catastrophic failure of the slab, *i.e.*, the slab instantaneously broke into multiple pieces. These results are consistent with the known results of Slab 4 failure, *i.e.*:

- The slab instantaneously and catastrophically fractured once the back wheels of the saw were on the slab with ENGR TECH 1 (please see Section 6.7.2); and
- Flexural fracture cracks were observed to have formed in the thin section of the concrete near the mid-span of Slab 4 (please see Section 6.17).

Slab 4 "Short"

Purpose of Analysis: To evaluate the potential for collapse of Slab 4 with the same steel reinforcement in the slab as Slab 4 but the slab shortened to have the same length and rigging condition as for Slab 3.

Modeling Parameters: The model used the same slab length (113 inches) and distance between the east and west rigging positions (80.6 inches) as that for Slab 3 but maintained the steel reinforcement as that of Slab 4 (no rebar spanned its length).

Results: Slab 4 "Short" did not fail under any of the three loading cases evaluated.

Slab 4 "Reinforced"

Purpose of Analysis: To evaluate the potential for collapse of Slab 4 with the same length and rigging locations as Slab 4 but similar steel reinforcement for that of Slab 2.

Modeling Parameters: The model used the length (144 inches) and distance between the east and west rigging positions (120.6 inches) as that for the as-removed Slab 4 but had No. 4 rebar reinforcement spanning its length (in the direction of bending) spaced 12 inches on center.

Results: Similar to the Slab 4 "As Is" evaluation, Slab 4 "Reinforced" did not fail under the first two loading cases but did fail with the combined loading of the slab's self-weight, the weight of ENGR TECH 1, and 71% of the weight of the floor saw[27]. This failure started as a bending-induce transverse crack forming on the underside of the thin section of the slab underneath the accidental load, matching the "As Is" condition. However, while the crack propagated through the slab thickness, the rebar reinforcement prevented immediate catastrophic failure. *i.e.*, the slab did not instantaneously break apart. Rather, within the matter of less than 1 second, the slab broke into two major pieces, held together by the rebar, and folded up on itself due to the rigging attachments (please see Figure 6.16.2).

[27] A lower percentage of the saw weight was observed to cause failure as the addition of the No.4 rebar to the slab increased the slab's self-weight.

Slab 4 "Rigging"

Purpose of Analysis: To evaluate the potential for collapse of Slab 4 with the same length and steel reinforcement as Slab 4 but the distance between the east and west rigging positions were closer.

Modeling Parameters: The model used the length (144 inches) and the same location of the No. 4 rebar reinforcement in the slab (no rebar spanned its length), but the east and west rigging positions were 1 ft closer to center resulting in a distance of 96.6 inches.

Results: Slab 4 "Rigging" did not fail under any of the three loading cases.

From these results, it is clear the two factors affecting the failure of Slab 4 was the length of the slab (and concomitantly its self-weight) and the distance between the east and west rigging locations. By shortening the slab length or decreasing the distance between the rigging points, even with the "accidental loading" of the weights of ENGR TECH 1 and the floor saw on the slab, it did not fail. Conversely, while the addition of rebar parallel to the length of the slab did not result in an immediate catastrophic failure, catastrophic failure was observed none-the-less (occurred within 1 second).

6.16.2 Safety Factor of the Lifting Scenarios

A safety factor (S_F) is the ratio between the strength of a structure or material, *i.e.*, ability of a structure or material to carry a load, and the load imposed on that structure or material. A value above unity indicates the structure or material is not overloaded, but a value of unity or lower indicates the structure or material is loaded at or above its capacity and will "fail". Based on current design standards[28], the minimum required safety factor for a load of this nature should be equal to 1.7. General industry recommendations for a reliable structural material (*e.g.*, a steel I-beam) is S_F = 1.5 to 2.0 and for materials that are brittle or have non-homogenous properties (*e.g.*, a concrete slab) is S_F = 2.5 to 3.

With respect to this incident, the concrete slab is the structure or material under load and the imposed loads are the self-weight of the slab and the weights of ENGR TECH 1 and the floor saw. Through the FE modelling evaluations, the safety factors for the six lifting scenarios were calculated and are shown in Table 6.16.1 for the three loading cases.

As seen for Slab 2 and Slab 3 "As Is" evaluations, the safety factor for any of the loading cases is always greater than 2 indicating a good safety margin and structural failure would not occur, even with the "accidental loading" of an operator and the floor saw. This is consistent with observations as both slabs were removed without issue and ENGR TECH 1 was observed walking on Slab 3 with the floor saw without failure (please see Section 6.7.1). Similarly, for Slab 4 "As Is" evaluation, failure did not occur for the loading scenarios of the slab's self-weight and the self-weight plus the weight of ENGR TECH 1. However, this was achieved with a very small safety factor for each case (S_F = 1.12 and 1.03, respectively). For the load case of the slab's self-weight plus the combined weights of

[28] Please see Appendix 6.16.1 for discussion of the derived safety factor for a load of this nature.

ENGR TECH 1 and the floor saw, the safety factor falls below unity indicating failure would occur. The simulation determined the demand exceeded the capacity with 85.3% of the saw's weight on the slab. From the video evidence, it is clear once the back wheels of the floor saw were on the slab, an instantaneous and catastrophic failure occurred.

From the results of the three hypothetical cases for Slab 4, it is evident when looking at the safety factor for the evaluations why modifying the steel reinforcement in the slab did not have an effect on the loading cases while changing the length of the slab (and concomitantly its self-weight) or the location of the rigging points did. The FE modeling results for Slab 4 "Short" (where the slab length – and its self-weight – was decreased by ~20% of that for Slab 4) showed an increase in the safety factor by almost a factor of 2.5 for the slab self-weight case and just under a factor of 2 for the two cases of "accidental" loading. For the FE modeling results for Slab 4 "Rigging" analysis where the rigging locations were moved in towards the center of the slab by 1 ft resulted in an increase of the safety factor by almost a factor of 2 in all three cases. While these safety factor values are not at the 2.5 to 3 range recommended for a material like a concrete slab, they were at or above the current design standards safety factor of 1.7, and well above unity indicating failure would not occur. Conversely, adding the steel reinforcement in the concrete slab in the direction of bending did not change the stability of the slab, and as such, the safety factor values were nearly identical for the "as is" case and the slab failed.

It should be noted here that the weights of ENGR TECH 1 and the floor saw, which combined are the reason for the collapse of Slab 4, are considered "accidental loads" and most likely would not have been anticipated during a formal hazard review. Further, there may be defects in the concrete which could effectively lower the strength of the composite slab from that expected. For these reasons, it is important not to perform lifts that have a safety factor very close to or at unity as there is a greater chance for failure. Lifts of this kind should have a safety factor at or above the current design standards safety factor of 1.7, and more conservatively, near the general recommendations of 2.5 to 3 to ensure the safety of the work being performed.

6.16.3 Simplified 2-D Hand Calculations

It is acknowledged the complex 3-D FE modelling discussed above would not be expected as part of a standard hazard review performed to assess the risk of the surrounding floor demolition. However, 2-D hand calculations, based on well-established engineering principles and accepted structural design procedures for reinforced concrete sections under flexure, could easily and quickly be performed by a structural engineer to ensure the safety of the lift. Towards this end, the contractor also performed these 2-D calculations for the 3 loading cases of the Slab 4 "As Is" lifting scenario to determine the Demand-to-Capacity (D/C) ratios, where the "demand" is the load placed on the structure and the "capacity" is the amount of load the structure can tolerate without failure. These values are presented in Table 6.16.2. The smaller the ratio below unity represents a greater reserve capacity in the structure for additional loading. As the D/C ratio approaches unity, the structure gets closer to failure. At unity or above, theoretically the structure will fail.

The inverse of the D/C ratio is the safety factor, also shown in Table 6.16.2. As noted, there are minor discrepancies between the results of the 2-D hand calculations and those of the 3-D FE modeling results for Slab 4 “As Is” loading cases (please see Table 6.16.1). These discrepancies are the result of assumptions and simplifications required to be made to enable the hand calculations (*e.g.*, simplified linear elastic strain distribution on the concrete cross section assumed in the hand calculations, additional second-order moment in the 3-D FE analysis which adds to the applied bending moment at mid-span due to in-plane reaction force at the rigging points and the slab’s deformation). Regardless of the discrepancies, the importance of these 2-D calculations readily show there is a thin safety margin for the lift of Slab 4 “As Is” under any of the loading conditions and failure would be expected under loading case 3. Similar to above, while the “accidental loading” may not be anticipated during the hazard review process, the knowledge of the small safety factor for a brittle material would initiate the need for hazard control measures such as requiring the use of use of shoring underneath the slab as it was being cut even though it was “undamaged” or indicating the slab shall not be loaded by any means once it is suspended by the rigging.

6.17 Physical Analysis of Slab 4 (Incident Slab)

As part of the FE Modeling analysis, the contractor performed an analysis of the concrete sections of Slab 4 which included mechanical property testing, petrographic examination, and fracture surface evaluation. Appendix 6.16.1 contains the complete analysis with a summary provided here:

- The results of concrete testing and petrography show the quality of concrete used for the fabrication of Slab 4 was acceptable and was not the cause of Slab 4 failure; and

- Flexural fracture surfaces were found across the thin section of the concrete slab near the mid-length of Slab 4. Compression failure marks were observed on the top portion of the slab along the plane of fracture. These observations are consistent with the instantaneous overload failure of a concrete slab that did not have steel reinforcement spanning the length of the slab and perpendicular to the direction of bending.

6.18 Investigation Timelines

Through review of the information obtained as part of this investigation, the NIST Incident Investigation Team developed two event timelines to help determine causal factors and root causes that focused on:

- General events leading from the decision to end the CF Project to the incident; and
- Specific events on the day of the incident.

These are found in Figures 6.18.1 and 6.18.2, respectively.

7.0 INCIDENT INVESTIGATIVE FINDINGS – DISCUSSION OF FACTORS CONTRIBUTING TO THE INCIDENT

The following aspects were evaluated to determine their contribution to the incident:

- Incident – Factors related to the facts of the incident;
- Material and Equipment – Factors related to the materials and equipment used during the incident;
- Activity – Factors related to the method (*i.e.*, demolition process) used to perform the activity at the time of the incident;
- Work Environment – Factors related to the location ENGR TECH 1 was working in at the time of the incident;
- Personnel – Factors related to ENGR TECH 1 as they pertain to the incident;
- Management – Factors related to work planning, work authorization, and supervision as they pertain to the incident; and
- Safety Culture – Factors related to NFRL beliefs, perceptions, and values in relation to risk as they pertain to the incident.

NOTE – This section is not intended to identify causal factors or root causes explicitly, rather, it is to discuss issues that could have contributed to the incident. Causal factors and root causes are discussed in Section 8, along with appropriate corrective actions.

7.1 Incident Factors

Based upon information obtained, the following facts were confirmed by the NIST Incident Investigation Team regarding the incident:

- The incident occurred at 1:04:58 pm ET on September 26, 2022. ENGR TECH 1 was working alone to remove Slab 4 from the surrounding floor of the CF Project test frame located in Building 205. After cutting the slab free from the surrounding floor, and while it was fully suspended by the crane and rigging, ENGR TECH 1 backed the floor saw onto the mid-span of the slab which caused it to fail instantaneously and catastrophically. ENGR TECH 1 fell through the resulting opening to the floor level 13 feet below, sustaining fatal injuries.
- FE modeling confirmed that as planned and implemented Slab 4 was rigged with a very small safety factor given just the self-weight of the slab. The safety factor was reduced further with the additional loading of the slab with the weight of ENGR TECH 1. The slab was loaded beyond its structural capacity when the combined weights of ENGR TECH 1 and the floor saw were added to the self-weight of the slab (safety factor below unity).
- ENGR TECH 1 wore the following PPE during the incident – hard hat, hearing protection, and safety shoes. None of these were designed or intended to protect ENGR TECH 1 from a fall from height.

- ENGR TECH 1 was not wearing safety glasses with side shields, respiratory protection, or personal fall protection[29] as required by the hazard review. The safety glasses and respiratory protection were not designed or intended to protect ENGR TECH 1 from a fall from height. Comments regarding personal fall protection are made below.
- There were no previous incidents or near misses of a similar nature at the NFRL.
- The NIST police report confirmed there was no criminal aspect to the incident.

The following facts remain unconfirmed:

- It could not be determined with certainty why ENGR TECH 1 moved onto the suspended slab with the floor saw. It is believed by this Team he was intending to follow the cooling water hose back between the rigging slings so that it would not interfere with the slab when it was being lifted out with the crane.
- It could not be determined with certainty if a different outcome would have occurred if ENGR TECH 1 had donned personal fall protection equipment as the set-up would have been designed to protect him from a fall through the Slab 3 floor opening and not the opening created when Slab 4 failed.

Given the above information, other than the two unconfirmed facts above, the NIST Incident Investigation Team determined there were no critical facts identified which would preclude the Team from effectively completing this investigation.

7.2 Material and Equipment Factors

Based upon information obtained, the CF Project test frame as a whole was designed to US building codes. In some areas, the structure was built above code requirements for experimental purposes, *e.g.*, the No. 4 rebar in the composite floor placed at 12 in. spacing on center in the bays adjacent to the test floor. The overall design was reviewed internally by NIST engineers as well as a panel of practicing structural and fire protection engineers from around the world who had input on factors such as the size of the structural steel members, the type of connection for the members, the steel reinforcement in the composite steel deck-concrete floor system, and the type of concrete used for the decking. The test floors – the focus of the project objective – may not have followed all required codes (*i.e.*, the CF3 test floor did not have fireproofing material applied to the secondary exposed beam), but that was expressly for experimental purposes. Additionally, the overall stability of the test frame was not affected by the test floor deviations as the structure was designed to account for this and withstand the demolition and rebuilding of a significant portion of the composite floor.

Reviewing construction photographs and performing post-incident analysis on the removed slabs revealed the test frame was generally built per the design drawings. It is noted the test floors were modified from experiment to experiment and were not evaluated.

[29] Per the *Composite Floor System Stabilization and Demolition* hazard review, personal fall protection was required as other fall protection measures were not taken with respect to the Slab 3 floor opening (*e.g.*, covering the floor opening).

Reviewing the materials used in the construction of the test frame (*i.e.*, structural steel members, steel bolts and bolted connections steel decking, and lightweight concrete) showed they either met or exceeded the design specifications.

There were no concerns regarding the equipment used during the incident. The floor saw was in working order and performed as intended. The overhead crane had been inspected annually and monthly by an external contractor with no issues, and while there was no evidence of daily pre-use inspection, there was no indication the crane was not operating correctly on the day of the incident. Post-incident analysis of the rigging slings showed no signs of damage or degradation, and the rigging hardware was still firmly attached to the remaining portions of the slab. Further, review of the site video during the incident revealed the equipment appeared to be functioning properly with no evidence of equipment failure.

Given the above information it was determined there were no safety concerns with the design, actual construction, or materials used in the construction of the CF Project test frame. Additionally, there were no safety concerns with the equipment used during the incident. As such, the NIST Incident Investigation Team concluded material and equipment factors did not contribute to the incident.

7.3 Activity Factors

Based upon information obtained, the general demolition method employed to remove the steel-concrete composite floor slabs from the surrounding floor using a floor saw and rigging with slings and a crane, was a reasonable approach and could have been performed safely. This is evident by the fact that three slabs had successfully been removed from the surrounding floor prior to the incident. Had the proper work planning been conducted (please see Section 7.6.1), and thus the appropriate hazard control measures been identified and implemented (*e.g.*, modifying the rigging to provide a higher safety factor or adding administrative controls prohibiting the loading of the slab), it is believed by this Team Slab 4 could have safely been removed using this method.

Given the above information it was determined there was no safety concerns regarding the demolition method used during the incident (provided the proper work planning had been conducted), and as such, the NIST Incident Investigation Team concluded it did not contribute to the incident.

7.4 Work Environment Factors

Based upon the information obtained:

- The weather conditions on September 26 were sunny and dry with an ambient temperature of approximately 70 ºF. As the location where the incident occurred was inside of Room 125, the NIST Incident Investigation Team concluded the weather conditions did not contribute to the incident.
- With the moderate weather conditions outside, the two large roll-up doors were opened. This resulted in a beneficial effect in that the ambient lighting and cross-ventilation in Room 125 was increased. As such, the NIST Incident Investigation Team concluded temperature, ventilation, and lighting in the space did not contribute to the incident.

- The operation of the floor saw resulted in a noise hazard which required hearing protection by the operator. There was no evidence to indicate noise or the fact that hearing protection was required to be worn created any difficulty or additional safety hazard in performing the work, and as such, the NIST Incident Investigation Team concluded this did not contribute to the incident.
- The working surface, both around and away from the cutting location, had poor housekeeping indicative of a lack of care and safety awareness. Additionally, there was no active or passive fall protection in relation to the Slab 3 floor opening which ENGR TECH 1 was working within six feet of while performing the demolition task associated with Slab 4. While all these details are an indication of a poor safety culture which contributed to the incident (please see Section 7.7), the NIST Incident Investigation Team concluded the fact that there were tripping, fall, and falling object hazards did not contribute to the incident.

7.5 Personnel Factors

Based upon information obtained from the Medical Examiner's report, the NIST Incident Investigation Team concluded there were no physiological factors which contributed to the incident.

Based upon information obtained from CF Project staff members, the NIST Incident Investigation Team concluded there were no stated psychosocial factors (*e.g.*, impending deadlines which rushed the work to be completed, negative work environment) which contributed to the incident.

NOTE – Safety training is associated with the individual who has received the training. While the contribution of this factor to the incident could be evaluated here, this discussion is deferred to Section 7.6.2.1 when worker authorization is evaluated.

7.6 Management Factors

Based upon information obtained, the management of the CF Project demolition activity, specifically in the following areas, was determined to have contributed to the incident:

- Work authorization;
- Worker authorization; and
- Management oversight during performance of work.

7.6.1 Work Authorization

There were multiple instances of failure to follow established procedures related to work authorization which contributed to the incident. They are described below in chronological order.

7.6.1.1 Failure to comply with work authorization procedures – Inadequate review of a hazard review package

Paraphrased from the NIST and EL hazard review policies, prior to allowing hazardous work to be performed, line management must conduct a hazard review and ensure the documentation is sufficiently reviewed by individuals with the knowledge, skills, and abilities to identify, assess, and mitigate the hazards associated with the activity being considered. This must include staff members who are subject matter experts and have received the appropriate training on the hazard(s) which may be encountered during the work. When additional expertise is required, line management should contact staff with safety responsibilities and/or subject matter experts both within and outside their organization. Further, line management must also have similar knowledge, skills, and abilities so they themselves during their review can identify potential hazards and the hazard control measures to mitigate them.

Based upon information obtained, none of the staff members who evaluated the initial hazard review package or the subsequent revisions for the *Composite Floor System Stabilization and Demolition* hazard review had the appropriate safety knowledge, skills, and abilities with respect to demolition to sufficiently appraise the proposed work to ensure it would be performed correctly and safely. There are no training records to indicate those involved with the development, management, or approval of the CF Project demolition activities (activity leader [ENGR TECH 1], either leader of the CF Project, NFRL GROUP LEADER, FRD DSR, or either chief of FRD) received any form of training in demolition or the safety practices required during the work. Further, there is no evidence to indicate a demolition subject matter expert was consulted regarding evaluation of the work planning or the proposed methods. This lack of expertise led to multiple factors not being addressed in the hazard review:

- Identification of appropriate safety training (*e.g.*, demolition and demolition safety);
- Identification of demolition requirements (*e.g.*, engineering demolition survey per 29 CFR 1926.850(a)[30]);
- Identification of demolition best practices (*e.g.*, calculation of safety factors for unique lifts); and
- Identification of all hazards and associated control measures associated with the work.

While this error did not immediately contribute to the incident as the initial version of the hazard review and the subsequent revisions were focused on demolition of the fire-tested floor, this failure to perform an adequate evaluation of the hazard review package was propagated throughout the project, and specifically, when decisions were made regarding the demolition work associated with the surrounding floor (please see Section 7.6.1.3).

7.6.1.2 Failure to comply with work authorization procedures – Scope creep during demolition of fire-tested floors

Paraphrased from the NIST and EL hazard review policies, all hazardous work at NIST begins with appropriate planning in advance of the activities being performed such that all hazards are identified and mitigated to an acceptable risk. An important aspect of this effort is defining the scope of the work such that boundaries are established in which the work can be performed. The scope can either be very narrow and specific to the exact task being performed or it can be broader to allow for variations of the work parameters (*e.g.*, modification of process, location of work, type of materials used). Once established, the authorized users must work within the envelop of identified limits. If work is desired to be performed outside of the approved scope, or if it is recognized work has

[30] https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.850

inadvertently expanded beyond the original scope, re-review and re-approval of the hazard review is required to assess and sufficiently control any new safety risks.

Based upon information obtained, incremental scope creep was observed to occur throughout the CF Project demolition activities of the fire-tested floors which should have prompted a re-review and re-approval of the hazard review prior to the demolition work on the surrounding floor.

First Instance of Scope Creep: Use of a walk-behind floor saw.

The *Composite Floor System Stabilization and Demolition* hazard review lists the use of a concrete circular saw in the "Instruments/Equipment" section. This hand-held saw[31] was initially used to perform the cutting around the areas of interest during the forensic investigations of CF1, but also used during investigations of CF2 and CF3. At some point during the forensic work of the CF1 fire-tested floor, ENGR TECH 2 stated ENGR TECH 1 rented a walk-behind floor saw to facilitate some of the longer cuts. Given the success of this "experiment" using the floor saw, ENGR TECH 1 subsequently purchased a similar model floor saw and used it during the demolition of the CF2 and CF3 fire-tested floors, and later during the demolition activities of the surrounding floor. This change in equipment used was not incorporated into the hazard review at any point, and NFRL GROUP LEADER and CF PROJECT LEADER 2 stated they were unaware the floor saw was not included in the hazard review. While it was justified the walk-behind floor saw performed the same function as the hand-held saw and has similar hazards with respect to cutting concrete (*e.g.*, noise, respiratory), it is a much heavier piece of equipment with increased horsepower compared to the hand-held version. This could lead to increased hazards during its use that were not considered. As a result of the continual usage of the floor saw during demolition of the fire-tested floors, it became an accepted piece of equipment for CF Project demolition work without it being included in the hazard review where an appropriate assessment of the hazards associated with its use could be conducted.

Second Instance of Scope Creep: Experimentation with new demolition technique on the CF3 fire-tested floor.

During demolition of the CF3 fire-tested floor, ENGR TECH 2 stated ENGR TECH 1 began "experimenting" with the removal of small floor slabs (from ~1 ft by ~4 ft extending up to ~4 ft by ~4 ft) via cutting and lifting out with a crane. This method of demolition is not identified in the *Composite Floor System Stabilization and Demolition* hazard review nor in the "Set-up/Teardown" task in the version of the *Composite Floor Systems Tests* hazard review applicable at the time of the incident. Both NFRL GROUP LEADER and CF PROJECT LEADER 2 stated they were aware of this activity and justified it by indicating the work was sufficiently covered under the two previously approved CF Project hazard reviews, the *NFRL Overhead Crane* hazard review, and the general safety training and procedures for the execution of work in the NFRL. No formal assessment was performed to ensure the hazards associated with this new work process were evaluated and controlled. While hazards

[31] The hand-held concrete saw was not used during the demolition of the surrounding floor, specifically as it was broken at the time of surrounding floor removal, but also as the floor saw would have been the preferred piece of equipment for making long, straight cuts on the floor.

associated with the individual use of equipment are covered in these hazard review documents and general training, there is no consideration of the specific hazards associated with the task of lifting a non-homogenous load (with respect to physical structure and mechanical properties of the concrete slab) that had the potential to fail during the lift (as the fire-tested floor was considered to be damaged). As a result of the mistaken beliefs regarding the hazard reviews and training as well as the successful removal of the smaller fire-tested floor slabs, the floor saw and crane removal technique became an acceptable method to perform demolition work without an appropriate assessment of the hazards associated with performing this task.

Third Instance of Scope Creep: Performance of the "test case" on the CF3 fire-tested floor. In an effort to determine if the saw cutting and removal of a large slab using an overhead crane was a viable option for demolition of the surrounding floor, NFRL GROUP LEADER, with concurrence from CF PROJECT LEADER 2, approved the "test case" of removing a more significantly sized floor slab to be performed on the fire-tested floor. NFRL GROUP LEADER justified this decision by stating that while the specifics of the cutting and subsequent lifting with the crane were not explicitly detailed in the *Composite Floor System Stabilization and Demolition* hazard review document, the hazards and controls for using the concrete saw for acquiring forensic samples were included [regardless of the fact the floor saw was not considered in the hazard review and a crane was not used to remove concrete slabs during the forensic investigation]. CF PROJECT LEADER 2 justified his support of this decision by again stating he believed the work was sufficiently covered under the two previously approved CF Project hazard reviews, the *NFRL Overhead Crane* hazard review, and the general safety training and procedures for the execution of work in the NFRL. Again, no formal assessment was performed to ensure the hazards associated with this new work process were evaluated and controlled. The hazard reviews referenced, either separately or considered together, in combination with the NFRL general safety training do not address the specific hazards associated with the lifting of a large, heavy, non-homogeneous load that had the potential to fail during the lift. As a result of the mistaken beliefs regarding the hazard reviews and training as well as the successful removal of the larger slab (~9 ft by ~9 ft) from the fire-tested floor, the confidence in this method being an acceptable demolition technique increased without an appropriate assessment of the hazards associated with performing this task.

Per the NIST hazard review policy, both CF Project management and authorized users are responsible for identifying any changes to the scope of the work covered by an approved hazard review. When changes to the activity go beyond the scope, the hazard review is required to be revised, as necessary, to address any new hazards and submitted for re-approval. It is evident the incremental instances of scope creep described above contributed to the conditions that lead to the incident. There were multiple opportunities for ENGR TECH 1, as the activity leader of the work, and CF Project management (NFRL GROUP LEADER and CF PROJECT LEADER 2) to perform a thorough re-evaluation of the *Composite Floor System Stabilization and Demolition* hazard review to ensure all safety risks associated with the work were identified and sufficiently controlled.

7.6.1.3 Failure to comply with work authorization procedures – Inadequate re-review and re-approve of a hazard review package

As discussed in Section 7.6.1.2, any change to the scope of an approved hazard review requires processes be followed to re-review and re-approve the work to ensure all hazards are appropriately identified and controlled.

Based upon information obtained, following removal of the large "test case" slab from the CF3 fire-tested floor, the decision was made by CF Project Management to use the current hazard review for demolition of the fire-tested floor ***without revision*** for the demolition of the surrounding floor. NFRL GROUP LEADER stated this demolition activity (cutting with floor saw and lifting the surrounding slab out with crane) was perceived to be less hazardous work when compared to the jackhammering of the fire-tested floor and manual removal of the concrete rubble. CF PROJECT LEADER 2 stated again that at the time he believed the information contained in the two previously approved CF Project hazard reviews, the *NFRL Overhead Crane* hazard review, and the general safety training and procedures for the execution of work in the NFRL had sufficiently covered this method of demolition so there was no need to do a re-review and re-approval. Therefore, with:

- ENGR TECH 1, the activity leader, advocating for moving forward with no re-review and re-approval (per statements made by NFRL GROUP LEADER and CF PROJECT LEADER 2);
- No consultation with a demolition subject matter expert regarding the new demolition process to be used; and
- No objections from CF PROJECT LEADER 2,

the verbal approval was provided by NFRL GROUP LEADER to move ahead with demolition work of the surrounding floor under the current version of the hazard review.

Performing a general examination of the *Composite Floor System Stabilization and Demolition* hazard review with respect to the proposed demolition work for the surrounding floor, it was evident this work was outside the scope of the hazard review approved for the demolition of the fire-tested floors. This is based upon the removal method being completely different (*i.e.*, jackhammering and manual removal versus saw cutting slabs and lifting out with a crane) and the location of the work having changed (from the fire-tested floor region to the surrounding floor). Both of these facts, per NIST and EL hazard review policies, require a re-review of the hazard review. However, in place of doing a re-review and re-approval of the hazard review for the surrounding floor demolition activities, CF Project management made their determination based upon:

- Previously accepted practices working (using the floor saw without assessing its hazards in the hazard review);
- Preceding successes (removing smaller slabs from the fire-tested floor and culminating in removal of a slab similar in size to that eventually cut from the surrounding floor);
- Over reliance on generic hazard reviews, general work procedures, and general safety training associated with the NFRL;
- Confidence in the expertise of the CF Project team based upon their experience doing similar demolition work on previous projects (albeit on a mostly smaller scale); and
- The perception that the work was less hazardous (*i.e.*, demolition of the fire-damaged test floor was considered to be the most hazardous aspect of the overall task and the demolition of the essentially undamaged surrounding floor was considered to be easier and safer).

As a result of the hazard review not being re-reviewed and re-approved, and further with no consultation with a demolition subject matter expert, the demolition work of the surrounding floor occurred without the inherent hazards associated with this activity being properly assessed and mitigated. The outcome led to ENGR TECH 1 being unaware of the safety risk associated with the removal of Slab 4 as Slab 4 was rigged in a manner that provided very little safety factor ($S_F = 1.12$). This lack of awareness very likely contributed to ENGR TECH 1's decision to walk across the suspended slab with the saw causing its immediate and catastrophic failure.

Likewise, as a result of there being no assessment of the hazards posed by the cutting and lifting operation, no SOP was developed for the process which could have prevented the unsafe acts observed (*i.e.*, walking on the suspended slab). The process of cutting and lifting each slab from the surrounding floor safely required steps be performed in a specific order to avoid hazards (*e.g.*, walking near unprotected edges, placing concentrated loads on the suspended slab). The lack of a planned approach resulted in multiple instances of ENGR TECH 1 placing himself and the floor saw on the suspended or partially suspended slab and working beneath partially cut slabs (to secure the rigging hardware).

Appendix 7.6.1 contains a list of factors that should have been considered as part of the hazard review that covered the demolition work of the surrounding floor. Further, there is discussion regarding changes in the work planning which could have resulted in the safe and successful removal of composite floor from the Slab 4 location.

It is also worth noting here, based upon simple 2-D calculations, the four slabs planned to be removed from the north-middle bay (Slabs 5 through 8) will collapsed under their own weight if rigged per the original *Coring and Cutting Plan* developed by ENGR TECH 1. This fact is also discussed in Appendix 7.6.1.

7.6.1.4 Other safety concerns related to work authorization identified, but not contributing to the incident

While not directly contributing to the incident, other safety concerns related to NFRL work authorization were identified in general.

- Construction activities of the CF Project test frame were completed prior to the *Composite Floor Systems Test* hazard review being approved. While CF Project management indicated construction tasks were routinely performed by the engineering technicians and the hazards associated with construction were covered under:
  - Generic NFRL hazard reviews for equipment use (*e.g.*, use of cranes and forklifts);
  - NFRL general training; and
  - Staff experience,

  the hazard reviews referenced, either separately or considered together, in combination with the NFRL general safety training do not address the specific hazards associated with the construction of a two-story, steel-framed structure with steel-concrete composite floor.
- There was a requirement to obtain a hot work permit, per NIST S 7101.04: *Fire Prevention During Welding, Cutting, and Other Hot Works*, as welding activities were performed during

construction of the CF Project test frame. This was not identified as part of the *Composite Floor Systems Test* hazard review.

- There was a requirement to don respiratory protection given a material containing crystalline silica was being cut indoors (per OSHA 29 CFR 1926.1153(c)(1) – *OSHA's Respirable Crystalline Silica standard*) during demolition work. This was not identified as part of the *Composite Floor System Stabilization and Demolition* hazard review.
- There was a requirement to obtain a hot work permit, per NIST S 7101.04: *Fire Prevention During Welding, Cutting, and Other Hot Works*, as activities during demolition work involved using equipment that generating sparks in the open air (*e.g.*, concrete floor saw and angle grinder). This was not identified as part of the *Composite Floor System Stabilization and Demolition* hazard review.
- There was significant discussion by the NIST Incident Investigation Team regarding the RHI values documented in both the *Composite Floor Systems Test* and *Composite Floor System Stabilization and Demolition* hazard reviews. Additionally, a review of the current[32] and expired NFRL hazard reviews in the *MML Hazard Review and Approval System* identified only one activity rated as having an RHI of 3. This was concerning given the hazardous work being conducted in the NFRL. And while this Team as a whole believes some activities in the CF Project demolition hazard review should have been rated higher, *i.e.*, RHI of 3, it is also believed this difference would not have changed the outcome of decisions made regarding whether to re-review the hazard review for the demolition of the surrounding floor.
- A review of the prior incidents in Building 205 by the NIST Incident Investigation Team did not identify problems that if corrected, would have prevented this incident. However, multiple incidents involved hazards that were not identified in the hazard review process and in one case a hazard review that had not yet been conducted. This Team believes had there been a periodic review of prior incidents, it is possible that this trend would have been identified and actions taken to improve the implementation of the EL hazard review process.

7.6.1.5 Summary of Work Authorization Failures

The NIST Incident Investigation Team concluded the failure to follow established work authorization procedures, in terms of appropriate review and re-review of a hazard review package at multiple stages during the CF Project demolition work, contributed to the incident.

7.6.2 Worker Authorization

There were multiple instances of failure to follow established procedures related to worker authorization as described below.

7.6.2.1 Failure to comply with worker authorization procedures – Authorization of staff without the appropriate training

Paraphrased from the NIST and EL hazard review policies, the official first-level supervisor is responsible for authorizing individual staff members to perform the work. Part of this authorization requires ensuring the staff member has successfully completed the appropriate NIST-level safety

[32] An assessment was conducted within a week after the incident.

training applicable to the work they are to conduct and the activity-specific training provided at the OU/division-level.

Based upon information obtained, technically all of the staff members listed as authorized users on the *Composite Floor System Stabilization and Demolition* should not have been approved as none of them completed all the required training as specified by the hazard review. This included ENGR TECH 1. Regardless of this fact, with respect to equipment used during the incident, ENGR TECH 1 had completed many training courses in material handling (using overhead cranes and hoists), general construction/demolition work (using powered equipment and machines), and personal protective equipment (using fall protection, hearing protection, and respiratory protection). As such, despite:

- The majority of his training occurring prior to 2018 (with no recent refreshers); and
- The following NIST-level program courses were not completed (but required for the hazards he would be exposed to):
    - NIST S 7101.69: *Overhead Crane and Hoist*; and
    - NIST S 7101.67: *Fall Protection,*

the other trainings he received in these subject matter areas were sufficient for him to have situational and operational awareness of safe practices concerning the equipment being used during the demolition activities and the appropriate personal protective equipment required to be worn.

The more significant issue identified above in Section 7.6.1.1 revolves around the missing activity-specific safety training which should have been identified to specifically address the safety of demolition work. There are no records indicating any staff member had formal training in this subject matter, and previous demolition experience does not equate to being adequately trained to recognize and mitigate safety risks. While ENGR TECH 1 had the knowledge, skills, and abilities to use the individual pieces of equipment to perform the demolition task, it was not established he had the formal demolition training necessary to plan the overall process to demolish the entire CF Project test frame in an appropriate and safe manner. NFRL GROUP LEADER stated ENGR TECH 1 reportedly had extensively, practical hands-on experience with large-scale structural testing when he worked at the Federal Highway Administration. However, there is no indication he had any formal training in the demolition of structures of this nature or the safety requirements necessary during the process while there. ENGR TECH 1's lack of subject matter knowledge was evident as it pertained to his ability to plan the demolition work (please see Section 7.6.2.2).

7.6.2.2 Failure to comply with worker authorization procedures – Authorization of staff without the appropriate knowledge of workplace hazards

The second aspect related to authorizing an individual staff member is for the supervisor to have an appropriate degree of confidence, based on personal knowledge, observation, or reliable input from others, that the staff member to be authorized has the knowledge, skills, and abilities to perform the work safely and correctly.

Based upon information obtained, CF Project management did not have the expertise themselves to make these determinations. Neither NFRL GROUP LEADER nor CF PROJECT LEADER 2 had safety training in demolition and there was no evidence a demolition subject matter expert was consulted to assist with making these judgements. The only staff member who reportedly had any large scale demolition experience was ENGR TECH 1 during his time with the Federal Highway Administration. However, it is unclear as to:

- What type of structures he had experience with;
- His level of participation in demolition of them; or
- If he received any formal safety training regarding demolition.

As a result of the perceived experience and ENGR TECH 1's self-confidence in his ability to perform the work, both CF Project management and the other engineering technicians deferred to ENGR TECH 1 with respect to demolition activities. With no demolition subject matter expert in the review process, this led to no independent check to ensure ENGR TECH 1 had the knowledge, skills, and abilities to plan and carry out the demolition work safely and correctly.

As the activity leader, ENGR TECH 1 was both the creator and modifier of the *Composite Floor System Stabilization and Demolition* hazard review. The version of the document applicable at the time of the incident does not describe the full demolition process for the CF Project test frame. Industry standard is to develop a step-by-step demolition plan for the entire structure in advance to ensure the safety of the work. Reviewing information readily available on the internet yielded a number of demolition plan templates that can be used to formulate the work in an appropriate and safe manner. These templates are very detailed and encompass the entirety of the demolition work – from start to finish. There is no evidence indicating ENGR TECH 1 had fully planned out the demolition work to ensure hazards, whether for the individual demolition tasks or the demolition of the structure as a whole, were identified. Rather, from statements made by NFRL GROUP LEADER and CF PROJECT LEADER 2, the demolition work was being done "piecemeal". Additionally, per OSHA 29 CFR 1926.850(a), there is a requirement for a competent person to perform an engineering survey to assess the condition of the structure in advance of the demolition work to determine the condition of the framing, floors, and walls, and possibility of unplanned collapse of any portion of the structure. Evidence of this engineering survey was not found. And while ENGR TECH 1 did develop the written *Coring and Cutting Plan* for removing slabs from the surrounding floor, this plan was not complete or developed with the appropriate evaluation of the safety factors in mind (*i.e.*, the lifting of a large, heavy, non-homogenous load that has the possibility of failure during the lift).

With respect to the other engineering technicians approved as authorized users, while they indicated they had some on-the-job training from smaller demolition activities in the NFRL (*e.g.*, structures constructed from wood, steel stud framing, and wallboard as well as smaller concrete and steel test set ups from commissioning the new lab space) and previous jobs outside of NIST, they stated they all – including ENGR TECH 1 – had not engaged in demolition work on this large of a scale. As a result, all safety related considerations for the demolition work proposed and performed by ENGR TECH 1 were determined by ENGR TECH 1.

7.6.2.3 Other safety concerns identified related to worker authorization, but not contributing to the incident

While not contributing factors to the incident, other worker authorization failures were identified related to the CF Project in general.

- Authorized users stated they did not review CF Project hazard reviews packages prior to being approved as an authorized user or engaging in construction and demolition work as required by the EL hazard review policy.
- ENGR TECH 6 was not approved as an authorized user on either CF Project hazard review but was directed to perform construction and demolition work related to the CF Project.

7.6.2.4 Summary of Worker Authorization Failures

The NIST Incident Investigation Team concluded the failure to follow established worker authorization procedures, in terms of ensuring the worker had the knowledge, skills, and abilities to perform the work safely and correctly, contributed to the incident.

7.6.3 CF Project Management Oversight during Performance of Work

There were multiple instances of CF Project management failure to provide adequate oversight of the demolition work as described below.

7.6.3.1 Failure to provide adequate management of hazardous work

Paraphrased from the NIST and EL hazard review policies, CF Project management has a responsibility to ensure staff are working in accordance with the practices and protocols listed in the hazard review.

Based upon information obtained, CF Project management was generally absent from the worksite during the demolition activities of the CF Project test frame. Additionally, both NFRL GROUP LEADER and CF PROJECT LEADER 2 stated they were not present during:

- The removal of the smaller slabs from CF3 fire-tested floor;
- The removal of the large "test case" slab from CF3 fire-tested floor; or
- Any portion of the demolition work on the surrounding floor,

regardless of the fact that a new process was being used for demolition. NFRL GROUP LEADER stated he did check in with staff regarding how the work was proceeding or if there were any concerns. CF PROJECT LEADER 2 stated ENGR TECH 1 was leading the demolition activities, and as such, he intermittently checked with the team to inquire about progress, challenges, and needs. It was evident from these and other statements, CF Project management relied on the experience and confidence of ENGR TECH 1 to perform the demolition work as factors to their absence in Room 125 during the demolition activities. While there are safety success measures in performance plans related to "monitoring work operations", and both NFRL GROUP LEADER and CF PROJECT LEADER 2 can state they did so by "verbally checking in" with staff, the expectations of EL Senior Leaders are they would be physical present in the workspace observing the work. Their absence resulted in their failure to enforce personal accountability for CF Project staff members (please see Section 7.7.2).

7.6.3.2 Failure to have adequate management of responsibilities for safety

Adding to the concern of CF Project management absence from the workplace, the management of safety responsibilities for the demolition activities was consolidated in ENGR TECH 1 as:

- The activity leader for CF Project demolition work;

- The workspace manager for Room 125; and
- The person responsible for daily safety during the demolition work (as there was no Safety Officer identified for this work similar to that required for fire experiments).

As such, there was no check and balance regarding the safety of the work performed. It was evident the reliance on ENGR TECH 1 to be the work planner, the work reviewer, the "safety person" with respect to the demolition work, the "safety person" in general for Room 125, and the main person performing the demolition work, combined with the lack of CF Project management oversight, resulted in an overall lack of safety oversight regarding the CF Project demolition work.

7.6.3.3 Other safety concerns identified related to CF Project management absence at the worksite, but not contributing to the incident

While not contributing factors to the incident, other issues were identified related to CF Project management oversight during the CF Project demolition work.

- From OSHA 29 CFR 1926.855(f), there is a requirement to barricade areas beneath the location where the surrounding floor was being removed to prevent access while work was being performed. The *Composite Floor System Stabilization and Demolition* hazard review indicated caution tape was to be used to mark off an exclusion zone around the test structure during demolition. While CF Project staff members indicated there was a "verbal" exclusion zone around the structure, without a physical barrier there as a reminder, staff consistently violated the exclusion zone by walking on the strong floor in the footprint of the test frame while work was being performed above them on the surrounding floor.
- There was a requirement to have adequate fall protection for workers, per NIST S 7101.67: *Fall Protection*, as there were floor openings in a worksurface elevated 13 feet above a lower level during demolition work. While "Fall Protection (In the absence of other controls)" was stated in the *Composite Floor System Stabilization and Demolition* hazard review, CF Project staff were observed working within 6 ft of unprotected floor openings.
- There was a corrective action related to an NFRL incident investigation (***IRIS case number 19-IG-0053***) for the Workspace Manager of Room 125, ENGR TECH 1, to conduct daily checks to ensure PPE is being used as required. NFRL GROUP LEADER attested this corrective action was being implemented. However, due to a lack of CF Project management presence at the worksite:
  - CF Project staff members indicated ENGR TECH 1 was not implementing this corrective action; and
  - ENGR TECH 1 had a history of not abiding by PPE requirements as evidenced by:
    - Not consistently wearing a hard hat in Room 125, per NFRL required PPE to enter Room 125;
    - Not wearing the required fall protection while working near an unprotected floor opening, per NIST S 7101.67; and
    - Not wearing safety glasses during the incident, as required by the *Composite Floor System Stabilization and Demolition* hazard review.

7.6.3.4 Summary of Failures by CF Project Management Oversight during Performance of Work

The NIST Incident Investigation Team concluded the failure of CF Project management oversight, in terms of presence at the worksite and consolidation of safety responsibilities in one individual, contributed to the incident.

NOTE – Neither NFRL GROUP LEADER nor CF PROJECT LEADER 2 stated their ability to telework was a factor contributing to their absence from Room 125 during the demolition activity. As such, no critique should be levied against the current NIST Telework Policy as a result of this incident.

7.6.4 Summary of Management Factors

Given the above information in subsections of Section 7.6, the NIST Incident Investigation Team concluded management of the CF Project, in terms of work and worker authorization and subsequent management oversight of the work being performed, contributed to the incident.

7.7 Safety Culture Factors

In light of past and recent events at NIST, safety culture has become a focus for the Agency. While there is no standard definition of safety culture, two statements often ascribed to it are:

- The way in which safety is managed in a workplace; and
- What we do when no one is watching.

Likewise, many different organizations have endeavored to characterize what a good safety culture looks like by identifying crucial elements, traits, or attributes. Given the lack of consensus around a methodology to define safety culture, it is not the intent of this section to comprehensively analyze how the safety culture in the NFRL contributed to the incident, particularly as many aspects of it have been covered in other subsections of this section (*e.g.*, Section 7.6 related to the process of planning and controlling work activities such that safety is maintained). Rather, factors found to contribute strongly to the incident are considered below.

Based upon information obtained, all staff working in the NFRL, both supervisory and non-supervisory, believe there is a very good safety culture existing in Building 205. While it was found there were pockets of very good safety culture, particularly as it pertained to experimental work, it was not consistent throughout the NFRL. The following documents these instances.

7.7.1 Inconsistent Enforcement of Safety Requirements

Per the NIST and EL hazard review policies, prior to allowing hazardous work to be performed, line management must conduct a hazard review. Like most experimental activities performed at NIST, work in the NFRL generally encompasses the set-up and teardown of an experiment in addition to performing the experiment itself. Both NFRL GROUP LEADER and CF PROJECT LEADER 2 stated set-up and teardown activities related to the CF Project (construction and demolition activities, respectively) are hazardous work and treated on par with experimental work with respect to safety.

Based upon the information obtained, it was evident CF Project construction and demolition activities did not receive the same rigorous safety scrutiny as the experimental tasks.

First considering the experimental work associated with the CF Project and found in the *Composite Floor Systems Tests* hazard review:

- The hazard review was performed and approved in advance of the fire experiments being conducted;
- The hazard review, with respect to the experimental work, met the requirements of a complete EL hazard review package;
- The hazard review contained significant safety requirements with respect to the experiment, including
  - Pre-test verification steps to ensure safety equipment functioned as designed;
  - Naming of a Safety Officer;
  - A required safety briefing prior to the experiments;
  - Step-by-step checklist for performing the experiment;
  - Task specific PPE during the experiment; and
  - Post-test safety measures (while the test frame was cooling to ambient temperature).

Additionally, contained in the hazard review associated with the demolition work (*Composite Floor System Stabilization and Demolition* hazard review) are safety requirements associated with the experimental forensic investigations:

- A team of structural engineers was required to analyze the condition of the CF Protect test frame to determine if it was safe to work on, under, and around. The team was required to wear specific PPE while performing the inspection and be under the active supervision of a workspace manager and/or group leader during the evaluation; and
- A team of structural, mechanical, or civil engineers at NIST or by a shoring company were required to review and approve the shoring underneath the fire-tested floor. It also required approval by the workspace manager, leader for the CF Project, and group leader for NFRL. The final constructed shoring was required to be inspected by a structural engineer.

With respect to conduct of the experiment, there was a higher presence of EL line management in the workspace, including CF Project management and both chiefs of FRD, while the tests were being performed. This type of attention to detail with respect to experimental safety resulted in several safety awards for the NFRL including the 2009 Building and Fire Research Laboratory Safety Award and the 2012 NIST Safety Award

Conversely, with respect to construction work associated with the CF Project, evaluation of the *Composite Floor Systems Tests* hazard review revealed the following facts:

- The hazard review associated with this work was not approved until 4 months after the construction was finished. During their interviews approximately one month after the incident, NFRL GROUP LEADER and the two leaders of CF Project (CF PROJECT LEADER 1 and CF PROJECT LEADER 2) stated the *Composite Floor Systems Tests* hazard review was the document that covered the performance of that work. During his second interview 5 months later, NFRL GROUP LEADER stated work within the NFRL did not always address the hazards of experimental set-up in a dedicated activity hazard review. He stated these hazards were consider through generic activities such as the use of cranes and forklifts and through training and experience as these were tasks the engineering technicians routinely performed. Further, he stated it was a common occurrence for the hazard review to be developed at the same time the team was setting up for an experiment, *i.e.*, in this specific case, the "set-up" was the construction of a two-story, steel-framed structure with steel-concrete composite floor. During his second interview, CF PROJECT LEADER 2[33] stated during construction work the team did their best to lay out appropriate procedures in advance and there were times when work did not proceed as expected and a different method was required. He stated means and methods may need to be adjusted within allowed operating procedures depending on the circumstances and what is deemed safest to achieve the task. CF PROJECT LEADER 2 stated he believes adaption to evolving site conditions is common in construction practice;

- The *Composite Floor Systems Tests* and other generic NFRL hazard reviews together were assumed to meet the requirements of a complete EL hazard review package. However, they did not as the lack of design plans for the test frame, detailed description of erection steps, and identified hazards associated with construction and their corresponding hazard control measures were absent. NFRL GROUP LEADER stated the construction information in the *Composite Floor Systems Tests* was rudimentary and not very detailed. Additionally, the NFRL hazard reviews were generic and did not address the specific hazards associated with the construction of a two-story, steel framed structure;
- There was no Safety Officer identified for construction work;
- While a pre-activity briefing to discuss steel erection was a required control identified in the hazard review, the engineering technicians indicated this meeting did not occur. Rather, *ad hoc*, informal discussions were held by ENGR TECH 1; and
- Unauthorized staff were allowed to participate in construction work.

With respect to CF Project management presence, CF PROJECT LEADER 1 – as the leader of CF Project at the time of the physical construction of the test frame – stated she was present daily in Room 125 and had multiple interactions with ENGR TECH 1 and ENGR TECH 2 during the day checking on their progress and addressing any issues arising from steel member erection.

For demolition work, evaluation of the *Composite Floor System Stabilization and Demolition* hazard review revealed the following facts:

- The hazard review was performed and approved in advance of the demolition of the CF1 fire-tested floor;
- The hazard review in general met the requirements of a complete EL hazard review package with respect to the demolition of the fire-tested floor, but did not cover work related to the fire compartment or the surrounding floor. When discussing the surrounding floor demolition, NFRL GROUP LEADER stated that often during these activities the leader of a project would work closely with the technicians in an attempt to get detailed information for the methods to do the work. He stated many times the work would proceed on a trial and error basis and regularly occurred using a step-by-step process [with no overall plan]. CF PROJECT LEADER 2 stated he believed the demolition work on the surrounding floor was

[33] It is noted CF PROJECT LEADER 2 was not the leader of the CF Project at the time of the test frame construction. His comments are directed at construction work in general performed in the NFRL.

covered under the two previously approved CF Project hazard reviews, the *NFRL Overhead Crane* hazard review, and the general safety training and procedures for the execution of work in the NFRL. These hazard reviews, either separately or taken together, in combination with the NFRL general safety training do not address the hazards associated with the lifting of large, heavy, non-homogeneous loads that have the potential to fail during the lift. Neither NFRL GROUP LEADER nor CF PROJECT LEADER 2 asked to see any type of plan in advance of the demolition work proceeding (even though NFRL GROUP LEADER was aware ENGR TECH 1 was developing a "lifting plan");

- There was no Safety Officer identified for demolition activity ***provided*** NIST staff were performing the demolition work. As discussed in Section 6.3.2, when a third-party contractor was hired to remove concrete rubble from the CF2 fire-tested floor:
  - NFRL GROUP LEADER or CF PROJECT LEADER 1 must request and review a copy of the contractor's safety plan;
  - A project representative was required to hold a Safety Briefing and review roles and safety procedures with the contractors; and
  - A Safety Officer was required to ensure the contractor used the required PPE while performing the work.

  ENGR TECH 2 stated CF PROJECT LEADER 1 performed these tasks during the rubble removal of CF2 fire-tested floor by a third party contractor. However, there was no similar oversight required if NIST staff were performing the exact same work; and
- Unauthorized staff were allowed to participate in demolition work.

With respect to CF Project management presence, neither NFRL GROUP LEADER nor CF PROJECT LEADER 2 were present during the demolition activities associated with the cutting and lifting of any of the composite floor slabs, instead relying on the experience of ENGR TECH 1 to get the work done.

When comparing the hazard review assessment related to the experimental work with the hazard review evaluation of the construction and demolition activities, the difference is evident. Many of the attitudes and assumptions made during the construction and demolition work would not be acceptable during the testing phase of the project. This inconsistent compliance with safety requirements resulted in incomplete hazard assessments and associated controls for setup and teardown activities related to the CF Project. This disparity shows CF Project management does not consistently enforce safety requirements and demonstrate a commitment to safety in their decisions and behaviors.

7.7.2 Enforcement of Personal Accountability

NIST is clear about staff's responsibilities with respect to safety, and specifically:

- Per the *Occupational Safety and Health Order* (NIST O 7100.00), every employee is expected to take personal responsibility for their own safety and the safety of others; and
- Per the NIST hazard review policy (NIST S 7101.20), employees authorized to engage in work shall work within the boundaries/conditions of the hazard review at all times and in accordance with required hazard controls measures and safety training.

Based upon the video evidence reviewed after the incident, ENGR TECH 1 was observed violating numerous safety requirements and safe operating practices during the cutting of Slab 3 and Slab 4. Examples of these include:

- ENGR TECH 1 was not fully focused on hazardous activities being performed (*e.g.*, he was observed numerous times checking his phone while operating the floor saw);
- ENGR TECH 1 was observed not wearing a seat belt while using the fork truck;
- ENGR TECH 1 was observed not wearing personal fall protection when working within 6 ft of an unprotected edge; and
- ENGR TECH 1 was observed "riding" on a suspended load, *i.e.*, when he:
  - Was trying to "bounce" Slab 3 free of the surrounding floor; and
  - Walked either by himself or with the floor saw across Slab 3 and Slab 4 which were fully cut free of the surrounding floor and solely supported by the rigging.

It is unknown why ENGR TECH 1 engaged in these unsafe practices.

NOTE – It is not the intent of this subsection to attribute responsibility for this incident to ENGR TECH 1. Rather, the intent is to show a measure of the safety culture regarding "what we do when no one is watching". It was evident some staff working in Room 125 – not just ENGR TECH 1 – became "lax" regarding the implementation of required hazard control measures and the use of best safety practices and CF Project management did not provide sufficient oversight to correct them. Further, the housekeeping on the surrounding floor around and away from the cutting locations displayed a lack of care and awareness for safety which could easily contribute to the occurrence of other safety-related incidents. It is unknown if the behaviors or conditions observed would have been any different given a more regular presence of CF Project Management during the demolition work, but these issues may have been exacerbated with CF Project Management absence from the workplace.

7.7.3 Summary of Safety Culture Factors

Given the above information, as well as other examples discussed throughout Section 7 in general, the NIST Incident Investigation Team concluded the safety culture in the NFRL was inconsistent and contributed to the incident.

8.0 CAUSAL FACTORS, ROOT CAUSES, CONTRIBUTING FACTORS, AND CORRECTIVE ACTIONS

In Section 7, a number of factors were evaluated to understand which contributed to the incident. Through discussion and careful consideration of the facts, the NIST Incident Investigation Team determined the following two actions were causal factors:

- The inadequate planning of Slab 4 removal, specifically, the slab was rigged with a very small safety factor; and
- The accidental loading of Slab 4, specifically, ENGR TECH 1 pulling the floor saw onto the slab while it was fully suspended by the rigging and crane.

The following sections provide the associated root causes for each causal factor and corrective actions developed to address each root cause in an effort to prevent recurrence. Additionally, other contributing factors identified during the investigation are provided below with appropriate corrective actions.

8.1 Causal Factor 1 – Inadequate Planning of Slab 4 Removal

The *Coring and Cutting Plan* developed for the surrounding floor demolition was not reviewed from the appropriate safety perspective. While it was evident staff in the NFRL were well experienced in crane use with:

- "Reliable" loads (*e.g.*, structural steel members);
- Loads with engineered lift points (*e.g.*, conditioning pit covers); and
- Concrete samples that contained considerable steel reinforcement (*e.g.*, other NFRL projects identified in Section 6.3.5),

this lift was unique in that the load was non-homogenous and had the potential to fail during the task. This fact should have raised concerns regardless of the "experience" staff gained performing lifts of smaller slabs from the CF3 fire-tested floor. Given the size, shape, direction of bending with respect to the deck flutes, and rigging point locations, Slab 4 was rigged in a manner that did not provide a reasonable safety factor (S_F = 1.12). Additionally, not only was this safety factor very low for the lift in general, staff were unaware of how close to failure the slab was with just its own self-weight potentially providing them confidence to engage in unsafe acts.

Root Cause 1.1: The initial hazard review package and subsequent versions were inadequately reviewed

Identified failure: Non-compliance with work authorization procedures

CF Project management failed to have the initial and subsequent versions of the *Composite Floor System Stabilization and Demolition* hazard review package adequately reviewed by a demolition safety subject matter expert. As a result, the following factors were not addressed in the hazard review package:

- Appropriate demolition safety training;
- Safety requirements for demolition work;
- Safety best practices for demolition work; and
- All hazards and associated control measures associated with the demolition work.

While this error did not immediately contribute to the incident, it was propagated throughout the CF Project when decisions were made regarding the demolition work associated with the surrounding floor.

Corrective Action 1: The NFRL Group shall evaluate all current activities covered by a hazard review to ensure a subject matter expert with the appropriate safety knowledge, skills, and abilities (KSAs) for the work being performed has sufficiently reviewed the planning of the work and concurred on the identified control measures. Where appropriate, a stop work order shall be issued until the work is completely covered by an approved hazard review.

Corrective Action 2: EL shall revise the document titled *EL Hazard Review and Approval Policy and Procedure* to include a requirement for an independent evaluation of a hazard review by a subject matter expert with the appropriate safety KSAs related to the work to be performed or potential hazards encountered. The requirement shall identify when this independent evaluation is required, who is responsible for identifying the required KSAs, and state the independent evaluation cannot be performed by the staff member(s) performing the work, the activity leader, the project leader, or other staff member designated to approve the work.

Corrective Action 3: EL shall develop and implement formal training on the *EL Hazard Review and Approval Policy and Procedure* required for those who will create or approve hazard reviews within EL. This training is distinct from the required NIST-level training associated with NIST S 7101.20. This training shall identify who is required to complete the training, the individual roles and responsibilities with respect to creation and approval of the hazard review, and on what frequency this training is required to be completed. This training shall be documented in accordance with NIST S 7101.23: *Safety Education and Training*.

Corrective Action 4: EL shall perform regular audits of their active hazard reviews to assess compliance with the *EL Hazard Review and Approval Policy and Procedure*. These audits shall be conducted independently of the group owning the activity and performed by staff with appropriate knowledge of the NIST and EL hazard review policies. The number and frequency of the audits shall be commensurate with the activities performed within EL. This activity shall be distinct from the safety tabletop exercises currently being performed in EL, but can be conducted in parallel with them.

Root Cause 1.2: Work was performed outside of the approved scope during demolition of fire-tested floors

<u>Identified failure</u>: Non-compliance with work authorization procedures

CF Project management failed to adequately identify scope creep that occurred during the demolition of the fire-tested floors. As a result, equipment use and demolition methods not included in the hazard review became acceptable without an appropriate assessment of the hazards associated with their use.

Corrective Action 5: The NFRL Group shall evaluate all current activities covered by a hazard review to ensure the work being performed is conducted within the boundaries set by the hazard review. Where appropriate, a stop work order shall be issued until the work is completely covered by an approved hazard review.

Corrective Action 6: EL shall revise the document titled *EL Hazard Review and Approval Policy and Procedure* to explicitly indicate what constitutes scope creep and reinforce the requirement for re-review and re-approval. Relevant examples of scope creep that may be observed in EL shall be provided.

Corrective Action 7: EL shall revise the document titled *EL Hazard Review and Approval Policy and Procedure* to establish requirements for appropriate use of generic hazard reviews. The requirements shall state they shall not be used in place of performing a hazard review for an activity unless the generic hazard review explicitly addresses all of the tasks, hazards, and control measures associated with the activity.

Corrective Action 8: EL shall revise the document titled *EL Hazard Review and Approval Policy and Procedure* to establish requirements for appropriate use of general safety training and procedures for the execution of work. The requirements shall state they shall not be used in place of performing a hazard review for an activity but may be incorporated into a generic or specific hazard review.

Corrective Action 9: EL shall revise the document titled *EL Hazard Review and Approval Policy and Procedure* to establish requirements for the project leader. The requirements shall state the roles and responsibilities of this person with respect to planning, approving, and managing the work for the project(s) they lead.

Corrective Action 3: Please see above.

Root Cause 1.3: The hazard review package was inadequately re-reviewed and not re-approved

Identified failure: Non-compliance with work authorization procedures

CF Project management failed to conduct an adequate re-review and subsequent re-approval of the *Composite Floor System Stabilization and Demolition* hazard review package when a new process and hazards were introduced, per NIST and EL requirements. As a result of the failure to reassess the hazards, inadequate planning for Slab 4 removal provided for a very small safety factor and staff were unaware of this safety risk.

Corrective Action 5: Please see above.

Corrective Action 6: Please see above.

Corrective Action 7: Please see above.

Corrective Action 8: Please see above.

Corrective Action 9: Please see above.

Corrective Action 3: Please see above.

Root Cause 1.4: Work authorization requirements were inconsistently applied when comparing teardown activities to the conduct of the experiment itself

Identified failure: Inconsistent enforcement of safety requirements for work authorization

CF Project management failed to consistently enforce work authorization requirements with respect to demolition work associated with the surrounding floor. Many of the attitudes and assumptions made during the work authorization for demolition work of the surrounding floor would not have been acceptable during the testing phase of the project. This inconsistent compliance with safety requirements resulted in an incomplete assessment of the hazards and associated control measures required to mitigate them. As a result, staff were unaware of the safety risk (very small safety factor) associated with Slab 4.

Corrective Action 5: Please see above.

Corrective Action 2: Please see above.

Corrective Action 6: Please see above.

Corrective Action 7: Please see above.

Corrective Action 8: Please see above.

Corrective Action 9: Please see above.

Corrective Action 3: Please see above.

Root Cause 1.5: EL has no mechanism to ensure quality hazard reviews are being developed and approved

Identified failure: Lack of enforcement for line management accountability

While standardized critical elements are required in performance plans for each level of line management, there is no measure for evaluating the quality of hazard reviews within that line manager's organization. This lack of required activity unfortunately led to the activity not being performed which allowed for inadequate hazard reviews to be approved and used by staff.

Corrective Action 10: EL shall develop a proactive safety requirement to measure the safety performance of line managers with respect to quality of hazard reviews.

8.2 Causal Factor 2 – Accidental Loading of Slab 4 while it was Fully Suspended by the Rigging

NFRL staff had sufficient situational and operational awareness of safe practices concerning the equipment being used and the appropriate personal protective equipment required to be worn during the demolition activities. However, there were numerous examples of staff having a "lax" attitude regarding the implementation of required hazard control measures and the use of safety best practices. While it is unknown if the behaviors displayed during the cutting and removal of the slabs would have been any different given a more regular presence[34] of CF Project Management during the demolition work, it is probable these issues were exacerbated with management's absence from the workplace. These issues, compounded with the lack of demolition safety training and inadequate work planning, lead to staff performing numerous unsafe acts. One of these acts was ENGR TECH 1 repeatedly walking on partially and fully cut slabs suspended by the rigging, the latter of which ultimately led to the instantaneous and catastrophic failure of Slab 4 when he attempted to pull the floor saw onto Slab 4.

Root Cause 2.1: Standard safe operating procedures were not developed for demolition work of the surrounding floor

Identified failure: Inconsistent enforcement of safety requirements for work authorization

In addition to the general concerns expressed in the root causes associated with Causal Factor 1 regarding identification and mitigation of the demolition hazards, the inconsistent enforcement of safety requirements specifically resulted in no SOP being developed for the safe cutting and removal of the slabs. Reviewing videographic evidence from the cutting of Slab 3 and Slab 4, it was evident there was no plan in place to ensure the safe performance of work. As a result, the slab cutting process resulted in numerous instances of the following hazards conditions:

- Working beneath a working surface with unprotected edges;
- Cutting near an unprotected floor opening;
- "Entangling" of the cooling water hose with the rigging slings; and
- "Accidental loading" of the partially and fully suspended slabs by ENGR TECH 1 and/or the floor saw.

Corrective Action 11: The NFRL Group shall evaluate all current activities covered by a hazard review to ensure the appropriate standard safe operating procedures have been

[34] From Section 7.6.3, it is noted neither NFRL GROUP LEADER nor CF PROJECT LEADER 2 stated their ability to telework was a factor contributing to their absence from Room 125 during the demolition activity. As such, no critique should be levied against the current NIST Telework Policy as a result of this incident.

developed and are implemented. Where appropriate, a stop work order shall be issued until the work is completely covered by an approved hazard review.

Corrective Action 2: Please see above.

Corrective Action 7: Please see above.

Corrective Action 8: Please see above.

Corrective Action 9: Please see above.

Corrective Action 3: Please see above.

Root Cause 2.2: Staff were authorized without the appropriate knowledge of workplace hazards

Identified failure: Non-compliance with worker authorization procedures

CF Project management authorized staff to perform work without them having the appropriate KSAs to perform the work safely and correctly. Issues identified which led to this determination include:

- Not identifying all necessary training (*e.g.*, demolition safety training);
- Not ensuring staff had reviewed the hazard review package; and
- Not ensuring the required training had actually been completed.

This limited the staff's ability to effectively identify and mitigate all relevant hazards associated with the demolition of the surrounding floor.

Corrective Action 12: The NFRL Group shall evaluate all current activities covered by a hazard review to ensure:

- The appropriate training has been identified for the work to be performed; and
- All staff members approved as authorized users of the hazard review have:
  - Reviewed the hazard review package; and
  - Completed the required training.

Where appropriate, a stop work order shall be issued until the appropriate training has been identified. Further, authorized user status of staff shall be revoked until the appropriate training has been completed.

Corrective Action 2: Please see above.

Corrective Action 13: EL shall revise the document titled *EL Hazard Review and Approval Policy and Procedure* to clarify requirements for safety training, and specifically:

- Having a section in the SOP that explicitly and clearly indicates all required training for various roles identified in the hazard review; and
- Stating previous experience shall not be a substitute for required training.

Corrective Action 14: EL shall revise the document titled *EL Hazard Review and Approval Policy and Procedure* to establish requirements for the second-level supervisor to ensure the first-level supervisor has the appropriate KSAs to effectively authorize staff to perform work.

Corrective Action 9: Please see above.

Corrective Action 3: Please see above.

Root Cause 2.3: Staff continuously performed unsafe acts

Identified failure: Inadequate enforcement of personal responsibility

CF Project management failed to provide adequate oversight of hazardous work being performed, and thus, failed to ensure staff were working in accordance with the practices and protocols listed in the hazard review. As a result, staff became "lax" regarding the implementation of required hazard control measures and the use of safety best practices.

Corrective Action 15: EL shall revise the document titled *EL Hazard Review and Approval Policy and Procedure* to establish requirements for project management and line management on workplace observations when hazardous work is being performed, *i.e.*, management by walking around. This activity shall be distinct from management observations and workplace inspections. The requirements shall state the conditions for which the workplace observations are necessary, the frequency for each management role, and any required outputs (*e.g.*, documentation) as a result of this activity.

Corrective Action 9: Please see above.

Corrective Action 3: Please see above.

Root Cause 2.4: Safety responsibilities were consolidated in a single individual

Identified failure: Inconsistent enforcement of safety requirements for work authorization

CF Project management failed to ensure adequate division of safety responsibilities with respect to the demolition work performed, *e.g.*, a Safety Officer was not identified for the demolition work. While it is acknowledged all staff are responsible for their own safety while performing work, as a result of the consolidated safety responsibilities, ENGR TECH 1 was allowed to engage in unsafe acts in an unchecked manner as he was responsible for overseeing the safety of the work he was performing.

Corrective Action 16: EL shall revise the document titled *EL Hazard Review and Approval Policy and Procedure* to establish requirements for project safety management, and specifically, to ensure there is adequate separation in these responsibilities for those responsible for safety and those performing the work. The requirement shall identify when this is applicable.

Corrective Action 9: Please see above.

Corrective Action 3: Please see above.

Root Cause 2.5: Management relied too heavily on experience, perceived or otherwise

Identified failure: Inadequate enforcement of personal responsibility

CF Project management relied too heavily on ENGR TECH 1's experience with respect to demolition work on the surrounding floor. As a result, this fact in combination with Root Causes 2.1 through 2.4, CF Project management did not enforce personal accountability for those performing the work.

All Corrective Actions associated with Root Causes 2.1 through 2.4.

Root Cause 2.6: Work operations were not continually monitored and updated for compliance

Identified failure: Lack of enforcement for line management accountability

EL group leaders have a success measure under the "Operations" required activity that states, "Supervisor consistently finds work operations are continually monitored and updated for compliance". This success measure was not mentioned by EL line management during interviews when asked "how is line management held accountable for safety". If staff are not evaluated against stated success measures, it can lead to a lack of focus on that activity. In combination with Root Causes 2.4 and 2.5, it resulted in the absence of management from the workspace during demolition work on the surrounding floor.

Corrective Action 17: In coordination with Corrective Action 15, EL shall revise the standard safety critical element for line managers to ensure line management is appropriately engaged with hazardous work being performed.

8.3 Contributing Factors

In addition to the root causes identified above in Sections 8.1 and 8.2 for each causal factor, multiple other issues contributed to this incident and are documented below with their corresponding corrective actions.

Contributing Factor 1: Non-compliance with work authorization procedures – General

NFRL management failed to consistently enforce safety requirements in general during the set-up phase of the CF Project (*i.e.*, construction of the two-story, steel framed structure) as well as the other hazard reviews that had a construction/demolition aspect to the work which were evaluated in Section 6.3.5. Again, an incomplete assessment of the total work to be performed, including set-up and teardown activities of the project, resulted in hazards and associated control measures required to mitigate them not being included. Per statements made by CF Project management, this practice was acceptable which is inconsistent with NIST and EL policies regarding hazardous work.

Corrective Action 18: The NFRL Group shall evaluate all current activities covered by a hazard review to identify cases where "set-up" and "teardown" of an experiment is inadequately assessed. Where appropriate, a stop work order shall be issued until the work is completely covered by an approved hazard review.

Corrective Action 2: Please see above.

Corrective Action 6: Please see above.

Corrective Action 7: Please see above.

Corrective Action 8: Please see above.

Corrective Action 13: Please see above.

Corrective Action 14: Please see above.

Corrective Action 15: Please see above.

Corrective Action 16: Please see above.

Corrective Action 19: EL shall revise the document titled *EL Hazard Review and Approval Policy and Procedure* to reinforce all hazardous work, including "set-up" and "teardown" of an experiment, must be considered for a project and all activities must be covered under an approved hazard review prior to work commencing. A requirements shall also be added to identify when separate hazard reviews are required for the "set-up" and "teardown" activities and the granularity of the tasks to be performed.

Corrective Action 9: Please see above.

Corrective Action 3: Please see above.

Correction Action 4: Please see above.

Contributing Factor 2: Non-compliance with worker authorization procedures – General

CF Project staff members stated they did not review either CF Project hazard review packages prior to being approved as authorized users. Further, staff who were not approved as authorized users stated they were directed to perform construction and demolition work.

Corrective Action 12: Please see above.

Correction Action 4: Please see above.

Contributing Factor 3: Non-compliance with established safety requirements – Fall Protection

Due to the failure to comply with work authorization procedures by not re-reviewing and re-approving the *Composite Floor System Stabilization and Demolition* hazard review package for the surrounding floor (please see Root Cause 1.3), the requirements for fall protection measures were not documented which meant they could not be enforced. It is unknown if completely covering the Slab 3 floor opening or establishing passive fall protection measures between Slab 3 and Slab 4 (*e.g.*, cabling) would have changed ENGR TECH 1's behavior during the incident or if him donning personal fall protection equipment would have resulted in a different outcome of the incident, but some form of fall protection was required.

Corrective Action 20: The NFRL Group shall evaluate all current activities covered by a hazard review for conditions where fall protection is required and ensure the appropriate fall protection control measures are identified by a competent person and implemented prior to engaging in that activity.

Correction Action 4: Please see above.

Contributing Factor 4: Non-compliance with established safety requirements – Implementation of corrective actions

ENGR TECH 1 was assigned a corrective action to conduct daily checks to ensure PPE is being used as required in Room 125 (from ***IRIS case number 19-IG-0053***). These checks were not being performed, specifically evidenced by personal fall protection not worn near the Slab 3 floor opening which was not covered or protected by passive fall protection as well as other examples document in Section 6.7.3. It is unknown if these checks would have resulted in ENGR TECH 1 wearing fall protection or if this would have changed the outcome of the incident, but these checks were required and not being performed.

Corrective Action 21: EL shall ensure corrective actions are implemented and effective.

Corrective Action 22: EL shall reviewed corrective actions on a periodic basis to ensure they are still being implemented and are still effective.

Contributing Factor 5: Failure to identify and communicate safety requirements – Overhead Crane Use

NIST did not adequately identify and communicate safety requirements related to crane use which could have been incorporated in the *Composite Floor System Stabilization and Demolition* hazard review for the surrounding floor demolition.

Corrective Action 23: NIST shall revise and redeploy the safety program titled NIST S 7101.69: *Overhead Cranes and Hoists* to address:

- Standing on suspended loads is prohibited;
- Definitions and requirements for different lift categories, *i.e.*, simple/routine, complex, critical, to include requirements for lift plans as necessary; and
- Requirements for potentially unstable loads.

Contributing Factor 6: Failure to identify and communicate safety requirements – Rigging

NIST did not adequately identify and communicate safety requirements related to rigging which could have been incorporated into the *Composite Floor System Stabilization and Demolition* hazard review package for the surrounding floor demolition.

Corrective Action 24: NIST shall address a gap in its safety management system regarding requirements for rigging and provide regularly scheduled and standardized training for use of rigging. It is noted activity-specific rigging training will also be required.

Contributing Factor 7: Failure to correctly assess the RHI for tasks

There was significant discussion by the NIST Incident Investigation Team regarding the RHI values documented in both the *Composite Floor Systems Test* and *Composite Floor System Stabilization and Demolition* hazard reviews. Additionally, a review of the current and expired NFRL hazard reviews in the *MML Hazard Review and Approval System* identified only one activity rated as having an RHI of 3. This was concerning given the hazardous work being conducted in the NFRL.

Corrective Action 25: The NFRL Group shall evaluate all current activities covered by a hazard review to ensure the tasks have been correctly characterized with respect to RHI. Where appropriate, a stop work order shall be issued until the work is sufficiently reviewed and re-approved by the appropriate line manager.

Contributing Factor 8: Audits and evaluations less than adequate

Audits and evaluations conducted at NFRL were not adequate to identify the observed concerns with hazard review implementation, inconsistent safety compliance, and the failure to implement a prior corrective action.

Corrective Action 26: NIST shall evaluate the overall mechanisms for safety management system auditing, including management system audits, the safety program assessment process, and existing mechanisms (*e.g.*, the Workplace Inspection Program and Management Observation Program) to identify gaps and opportunities for improvement and address them accordingly.

9.0 RECOMMENDATIONS

Through the course of this incident investigation, this Team identified concerns that did not contribute to the incident but should be addressed by NFRL, EL, or NIST. These are provided in no specific order of importance.

9.1 EL Recommitment to Safety

It is recommended EL Senior Leaders and line management take active steps to reaffirm their personal commitment to the safety of all staff. This could include in-person discussions by line management with staff reinforcing their safety rights and responsibilities.

9.2 Revision and Communication of EL MM01

It is recommended the document titled *EL Management Memo 01: Safety and Health Management (EL MM01)* be revised to explicitly document the safety responsibilities of all "management" roles including those of the project leader. A communications plan defining the process and frequency with which this information will be provided to EL staff should also be included.

9.3 Revision and Communication of EL Hazard Review Policy

It is recommended, in addition to the corrective actions identified in Section 8, the document titled *EL Hazard Review and Approval Policy and Procedure* be reviewed and possibly revised with respect to the following considerations:

- Hazard reviews are developed by the appropriate individual with the KSAs to do so (*i.e.*, they should not automatically be delegated to the lowest level);
- Hazard reviews have clearly identified tasks and provide sufficient granularity to describe the work to be performed;
- Identified hazards, and associated hazard control measures, are associated with the specific activity/task that exposes the worker to the hazard;
- For particularly hazardous work, the following are institutionalized:
    - Pre-job safety briefings indicating the method to be used and the frequency with which they are to be performed; and
    - Addition of a Safety Officer role; and
- Adoption of an existing hazard review for new work should go through the formal hazard review process to ensure all hazards of the new work are appropriately identified and controlled.

9.4 EL Review of Incidents

It is recommended EL implement a process for periodic evaluation of incidents in the organization to identify trends and any corrective or preventive actions needed to address them.

9.5 Clarification and Communication of NFRL "Two person" Safety Rule

It is recommended NFRL clarify and re-communicate the "two person" safety rule associated with hazardous work in Building 205. While all staff working in Building 205 were aware of the requirement, there was discrepancy regarding its interpretation and implementation.

9.6 Evaluation for a Safety Program Related to "Set-up" and "Teardown" of Work

It is recommended NIST evaluate the need for a safety program or other resources to address the hazards associated with the set-up and teardown of experiments or other work.

9.7 Evaluation for a Safety Program Related to Construction and Demolition

It is recommended NIST evaluate the need for a safety program to address the hazards associated with construction and demolition work performed by NIST staff members.

9.8 Evaluation for Requirements related to Refresher Training

It is recommended NIST evaluate the need for refresher training beyond those required by regulation (*e.g.*, hearing and respiratory protection, crane use, fall protection).

9.9 Evaluation of the NIST Hazard Review Policy

It is recommended NIST evaluate the effectiveness of the safety program titled NIST S 7101.20: *Work and Worker Authorization based on Hazard Reviews* to identify opportunities for improvement, including consideration of:

- Improved training on the program requirements;
- Addition of instructor-led training on how to develop a quality hazard review;
- Independent assessment of RHIs, as necessary,
- Independent assessment of RHIs if administrative controls are used to reduce the task RHI;
- Design and implementation of the *MML Hazard Review and Approval System*;
- Frequency of re-review for particularly hazardous work;
- Regular audits by the OUs regarding compliance with their OU procedures;
- Periodic NIST-level audit of the program; and
- Assessing the subject matter of the hazard reviews to determine if gaps in NIST's safety management system exists.

9.10 Provision of Standardized NIST-level Crane Training

It is recommended NIST evaluate the need for providing NIST-level practical crane training to standardize the information provided to crane users. This training is distinct from the suborder requirements training and in addition to the requirement for activity-specific crane training.

9.11 Evaluation of the Group Leader Role and Responsibilities

It is recommended NIST evaluate the roles, responsibilities, and expectations of the group leader position. The NIST Incident Investigation Team believes this individual may be set-up to fail given their required hands-on involvement in all aspects of managing their group's activities.

REFERENCES

- L. Choe et al., Fire Resilience of a Steel-Concrete Composite Floor System: Full-Scale Experimental Evaluation for U.S. Prescriptive Approach with a 2-Hour Fire-Resistance Rating (Test #1), Technical Note (NIST TN) - 2165, Gaithersburg, MD, 2021.

- L. Choe et al., Fire Resilience of a Steel-Concrete Composite Floor System: Full-Scale Experimental Evaluation for Influence of Slab Reinforcement (Test #2), Technical Note (NIST TN) - 2203, Gaithersburg, MD, 2022.

- S. Ramesh et al., Fire Resilience of Steel-Concrete Composite Floor Systems, SiF 2022– The 12th International Conference on Structures in Fire, The Hong Kong Polytechnic University, Nov 30 - Dec 2, 2022.

- ASCE (American Society of Civil Engineers), Minimum Design Loads for Buildings and Other Structures, ASCE, Reston, VA, 2016. ASCE 7-16.

- SDI Manual of Construction with Steel Deck, 2nd Edition, Steel Deck Institute, https://www.sdi.org/wp-content/uploads/2013/03/moc2.pdf, 2006.

Table 6.3.1: Training records for Authorized Users of Composite Floor Systems Test Hazard Review (#733.06.0124)

Training required by Composite Floor Systems Test Hazard Review (#733.06.0124)	Authorized Users								
	ENGR TECH 1	ENGR TECH 2	ENGR TECH 3	ENGR TECH 4	ENGR TECH 5	NFRL ENGINEER 1	CF PROJECT LEADER 1	CF PROJECT LEADER 2	NFRL GROUP LEADER
For all participants									
EL-733: NFRL Lab Access and Safety Awareness	Completed	Completed	Completed	Completed	Completed	Completed	Completed	Completed	Instructor
NIST S 7101 21: Personal Protective Equipment Program Training	Completed	Completed	Completed	Completed	Completed	Completed	Completed	Completed	Completed
For operators only									
EL-733: NFRL Emission Control System Training	No	Completed	No	Completed	Completed	No	No	No	Instructor
EL-733: NFRL Natural Gas Fuel Delivery System Training	No	Completed	No	Instructor	No	No	No	No	Instructor
EL-733: NFRL Structural Loading System	Completed	Completed	No	Completed	No	No	No	No	Instructor
EL-733: NFRL Overhead Cranes Training	Completed	Completed	No	Completed	No	No	No	No	Instructor
EL-733 Scissor and Boom Lifts Training	Completed	Completed	Completed	Completed	Completed	No	No	No	Instructor
NIST S 7101 58: Respiratory Protection Program - Training for Voluntary Use of Filtering Facepieces (for fire experiment)	NC at the time*	NC at the time*	Completed	No	No	No	No	NC at the time*	No
NIST S 7101 58: Respiratory Protection Program - Initial Training (for fire experiment)	NC at the time*	Completed	Completed	Completed	Completed	No	Completed	Completed	Completed
NIST S 7101 58: Respiratory Protection Program - Initial or Annual Fit Testing (for fire experiment)	Completed	Completed	Completed	Completed	Completed	No	No	Completed	Completed
NIST S 7101 61: Compressed Gas Safety Program Training (operator only)	Completed	Completed	Completed	Completed	Completed	No	No	Completed	Completed

* Not completed at the time of authorization

Table 6.3.2: Training records for Authorized Users of Composite Floor System Stabilization and Demolition Hazard Review (#733.06.0148)

NFRL Hazard Review	Required Training specified in the NFRL Hazard Review	Authorized Users for Composite Floor System Stabilization and Demolition Hazard Review (#733.06.0148)			
		ENGR TECH 1	ENGR TECH 2	ENGR TECH 3	ENGR TECH 4
NFRL Overhead Cranes (#733.06.0052)	NIST P 7100.00: General Safety Training	Completed	Completed	Completed	Completed
	EL General Safety Awareness - Web Based	Completed	Completed	Completed	Completed
	EL-733: NFRL Lab Access and Safety Policies	Completed	Completed	Completed	Completed
	NIST S 7101.69: Overhead Cranes and Hoists	No	No	No	No
	EL-733: NFRL Overhead Crane Operation	Completed	No	Completed	No
	CLC - Overhead Crane & Slings,	Completed	Completed	No	Completed
	CLC - Indoor Hoisting and Rigging	Completed	No	Completed	No
NFRL Scissor and Boom Lifts (#733.06.0051)	NIST S 7101.67: Fall Protection Authorized Person	No	No	No	No
	CLC - Fall Protection (or Working at Heights),	Completed	Completed	No	Completed
	EL-Fall Protection	Completed	No	No	Completed
	EL-733: NFRL Articulated Boom Lift Operation	Completed	Completed	Completed	Completed
	OFPM Aerial Lift Safety Training	Completed	Completed	Completed	Completed
	EL-733: NFRL Scissor Lift Operation	Completed	Completed	Completed	Completed
	OFPM Scissor lift Training	Completed	Completed	Completed	Completed
NFRL Industrial Powered Trucks (#733.06.0047)	EL-733: NFRL Forklift operation training	Completed	Completed	Completed	Completed
	EL-733: NFRL Skidloader Operation training	Completed	Completed	Completed	Completed

Table 6.3.3: Training records for Authorized Users of NFRL Overhead Cranes (#733.06.0052)

Training required by NFRL Overhead Cranes (#733.06.0052)	Authorized Users for NFRL Overhead Cranes (#733.06.0052)					
	ENGR TECH 1	ENGR TECH 2	ENGR TECH 3	ENGR TECH 4	ENGR TECH 5	NFRL GROUP LEADER
NIST P 7100.00: General Safety Training	Completed	Completed	Completed	Completed	Completed	Completed
EL General Safety Awareness - Web Based	Completed	Completed	Completed	Completed	Completed	Completed
EL-733: NFRL Lab Access and Safety Policies	Completed	Completed	Completed	Completed	Completed	Completed
NIST S 7101.69: Overhead Cranes and Hoists	No	No	No	No	No	No
EL-733: NFRL Overhead Crane Operation	Completed	No	Completed	No	No	Instructor
CLC-Overhead Crane & Slings,	Completed	Completed	No	Completed	Completed	Completed
CLC-Indoor Hoisting and Rigging	Completed	No	Completed	No	Completed	No

Table 6.4.1: Measured properties of hardened concrete of the surrounding slabs at 645 days after casting

Description	Surrounding Slab
Curing period prior to fire testing	645 d (1 yr 9 mo 6d)
Compressive strength (MPa)	63 ± 1
Splitting tensile strength (MPa)	3.0 ± 0.3
Static modulus (GPa)	25 ± 0.2
Bulk density (kg/m^3)	1911 ± 10
Moisture content (% mass)	7.7 ± 0.2
Thermal conductivity, W/m·K	2.2 ± 0.1
Specific heat, J/kg·K	887 ± 47

Table 6.4.2: Measured mechanical properties of various types of steel used in constructing the test frame

Steel part	ASTM	Design		Measured		
		F_y (MPa)	F_u (MPa)	F_y (MPa)	F_u (MPa)	ε_u (%)
W16x31	A992	345	-	382 ± 48	502 ± 27	33 ± 5
W18x35	A992	345	-	360 ± 21	503 ± 6	33 ± 1
Shear tab	A36	250	-	290 ± 1	440 ± 30	37 ± 1
Structural bolt	Gr. A325	-	830	890 ± 12	965 ± 8	19 ± 1
Headed shear stud	A29	-	450	408 ± 2	505 ± 3	-
Steel deck	A653	-	-	403 ± 4	473 ± 2	26 ± 1
WWR	A185	-	-	755 ± 2	790 ± 2	15 ± 1
No. 4 rebar	A615	414	-	478 ± 1	769 ± 2	22 ± 1

Table 6.12.1: Previous incidents associated with the CF Project

IRIS Case	Date of Incident	Description	Similarities with current incident			
			Concern with the hazard review	Established procedure not followed	Occurred during setup of an experiment	Overhead crane used
20-IG-0023	11/14/2019	A full-scale structural fire test of a composite floor assembly using water cooled natural gas burners was being conducted. Approximately 90 minutes into the experiment one of the four water cooling lines began to overheat and hot water vapor was noticed at the vent line entering the floor drain. The hose ruptured at the rear of the compartment and a jet of high-pressure steam was ejected. The burst occurred at the back of the test compartment and was directed toward the wall of the laboratory. The rupture occurred in an exclusion zone where no staff were permitted during the test. The rupture created a loud hissing noise that lasted for less than 30 seconds.	Hazard Review did not identify the potential hazard of bursting water lines.	NA	NA	NA
21-IG-0052	6/16/2021	A scissor lift platform was being positioned to allow photographs to be taken of the Measurement of Structural Performance in Fire Project experimental setup. The handrail of the lift platform contacted a steel beam and was bent.	The general hazard review being used did not address potential hazard of overhead obstructions.	NA	NA	NA

Table 6.12.2: Previous incidents that occurred in Building 205 and have aspects related or similar to the current incident

IRIS Case	Date of Incident	Description	Similarities with current incident			
			Concern with the hazard review	Established procedure not followed	Occurred during setup of an experiment	Overhead crane used
17-IG-0049	1/25/2017	An employee injured their back while lifting and installing gypsum drywall panel in a test enclosure.	Hazard was not identified during project planning.	NA	Yes	NA
17-IG-0110	8/14/2017	A technician was relocating one steel column with an overhead crane, when the crane collided with another crane that was stationary but also carrying a concrete specimen. The collision caused the suspended concrete specimen to sway into a second steel column. The column tipped over onto another concrete test specimen and damaged it.	No Hazard Review was found for this specific activity. Faulty planning / coordination of activity.	No spotter during crane use. Note: The staff member had not taken the training required by the general NFRL Hazard Review for operation of overhead cranes.	Yes	Yes
19-IG-0053	4/19/2019	An employee was moving sheet metal pieces into place for a concrete pour stop. Employee was wearing rubber gloves to protect from oil on steel sheet metal piece. The sheet metal slipped in their hand and cut their finger.	NA	Improper PPE worn (rubber instead of leather).	Yes	NA
21-IG-0029	4/14/2021	A fire experiment was being conducted using a commercially available wooden storage shed. Technicians had assembled the shed per manufacturer's instructions. The shed contained two small pneumatic liftgate cylinders for the lid. Prior to initiating the fire, the Safety Officer reviewed the approved hazard review, completed a checklist required for all burns in NFRL, and conducted a staff safety briefing. The Safety Officer was not aware of the liftgate cylinders until after the structure was on fire and the lid raised exposing the cylinders. The extreme temperature during the fire caused the liftgate cylinders to burst. There were no injuries or property damage.	Hazard Review did not identify the potential hazard of the liftgate cylinders.	NA	NA	NA
22-IG-0027	4/22/2022	A technician was operating one of the 20-ton cranes in Room 125. As they moved the crane, they heard a loud "clank" and some banging from the hook hitting a heat shield mounted on the wall adjacent to the crane.	NA	The crane operator did not have line of sight with the hook and a spotter was not used.	NA	Yes

Table 6.13.1: Keywords Searched on during the Review of Outlook Accounts

Applicable	Concrete	Failure	IRIS	Reinforced	Structure
Bay 1	Core	Fall	Lift	Reinforcement	Surrounding
Break	Coring	FLHR	Lifting	Review	Taco
Calculated	Crack	Floor	Loading	Revise	Tacoing
Calculations	Crane	Fracture	Loads	Rigging	Taco-ing
capacity	Cutting	Hazard	Margin	Safety	Test
CF3	Danger	Hazard Review	Meeting	Safety factor	WIP
CF4	Dangerous	Housekeeping	Plan	Saw	
Collapse	Decking	Husqvarna	PPE	Slab	
Composite	Demolish	Incident	Protection	strength	
Concern	Demolition	Inspection	Rail	Structural	

Table 6.16.1 Safety Factors based on FE Modelling Analyses

Lifting scenario	Safety Factors for a given loading case		
	Weight of slab	Weight of slab and ENGR TECH 1	Weight of slab, ENGR TECH 1, and floor saw
Slab 2 "As Is"	2.77	2.59	2.38
Slab 3 "As Is"	2.71	2.46	2.23
Slab 4 "As Is"	1.12	1.03	0.96
Slab 4 "Short"	2.71	1.89	1.69
Slab 4 "Reinforced"	1.12	1.03	0.96
Slab 4 "Rigging"	2.03	1.85	1.70

Table 6.16.2 Demand to Capacity ratios and Safety Factors determined via 2-D hand calculations for the three loading cases of the Slab 4 "As Is" lifting scenario.

Loading Case	Demand-to-Capacity Ratio	Safety Factor
Case 1: Uniformly distributed load of the slab self-weight	0.700	1.42
Case 2 - Uniformly distributed load of the slab self-weight plus the concentrated load of ENGR TECH 1's weight at the midspan of the slab	0.849	1.18
Case 3 - Uniformly distributed load of the slab self-weight plus the concentrated loads of the weight of ENGR TECH 1 and the floor saw at the midspan of the slab	1.004	0.99

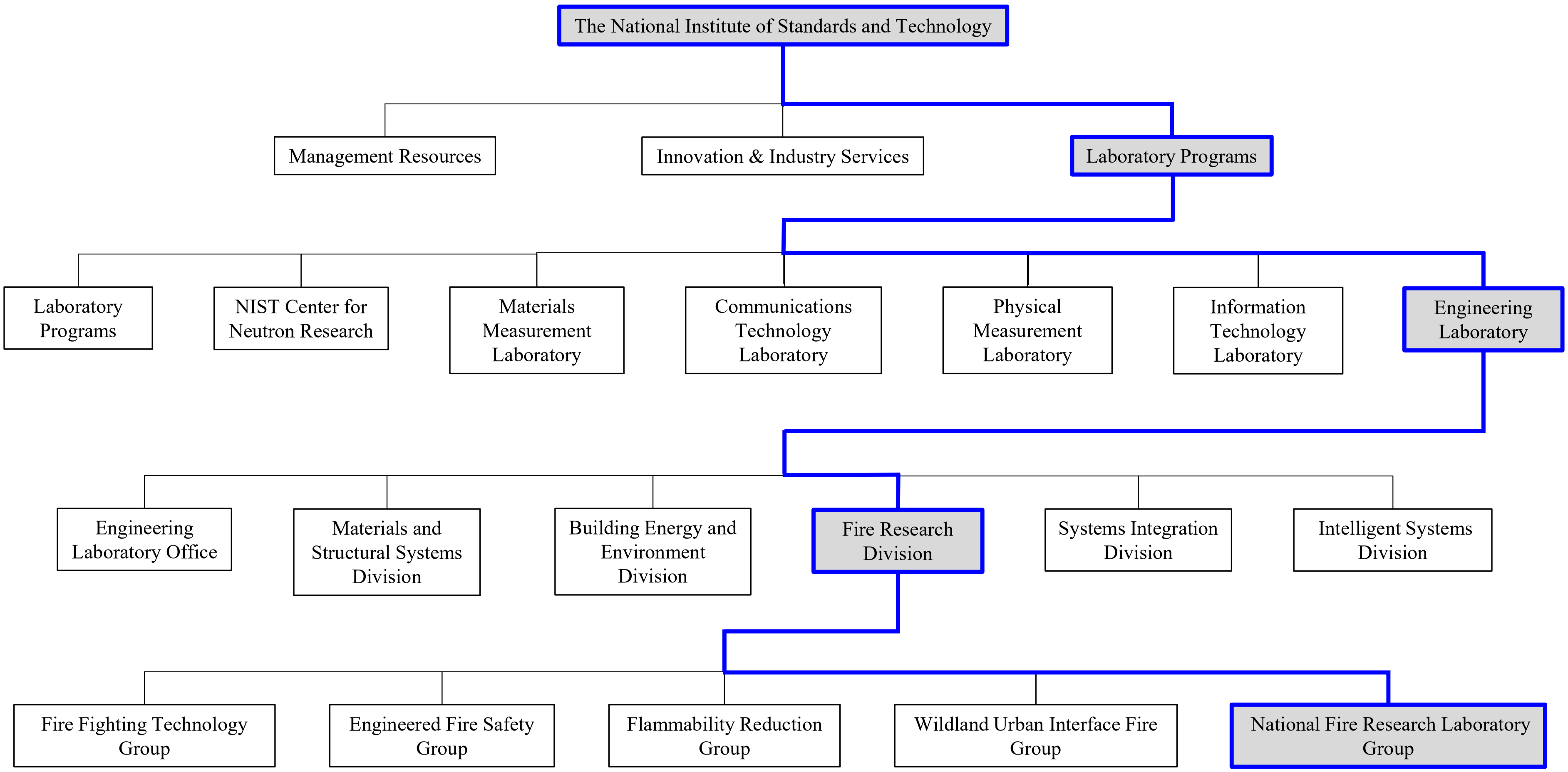


Figure 3.1.1: Organization chart showing the location of the NFRL Group within NIST.

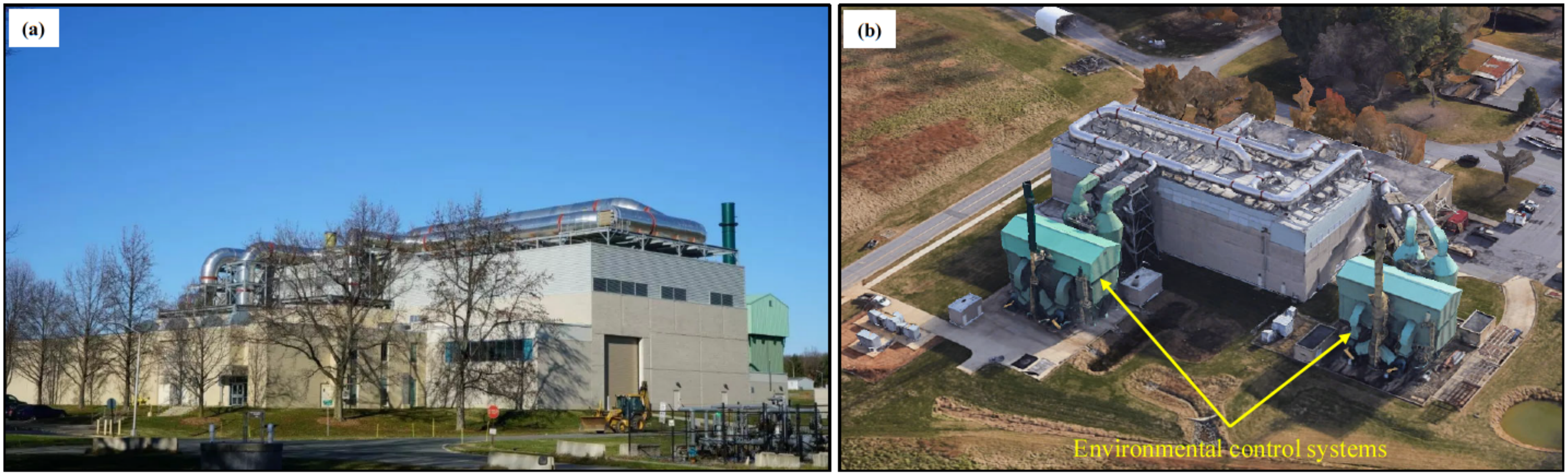


Figure 3.2.1: Images of Building 205 - NFRL. (a) Showing the south and east faces of the building (courtesy of NIST) and (b) showing the north and west faces of the building (courtesy of Google Earth).

Figure 3.2.2: Map of the NIST-Gaithersburg campus showing the location of Building 205 – NFRL (red arrow).

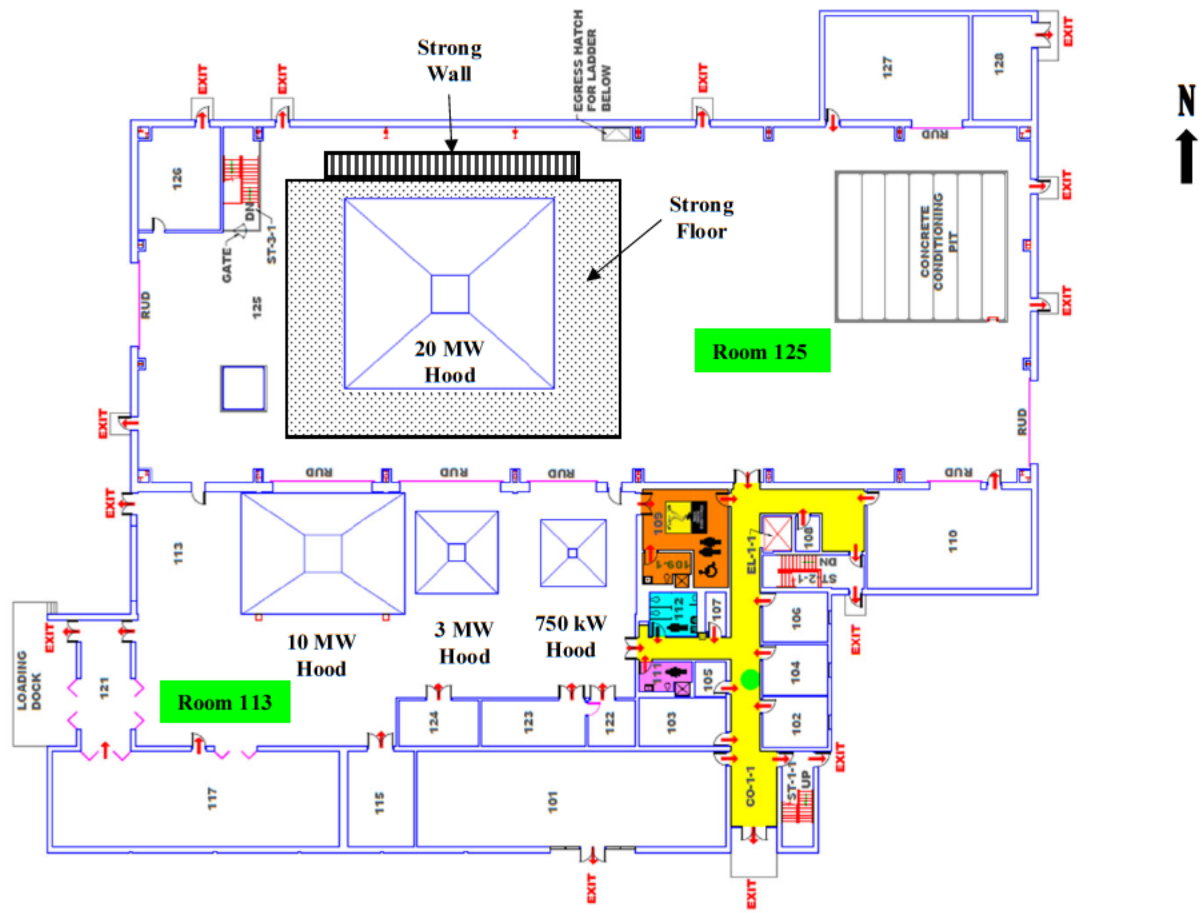


Figure 3.2.3: Scale plan view drawing of the NFRL showing the location of two main laboratory spaces, Rooms 113 and 125.

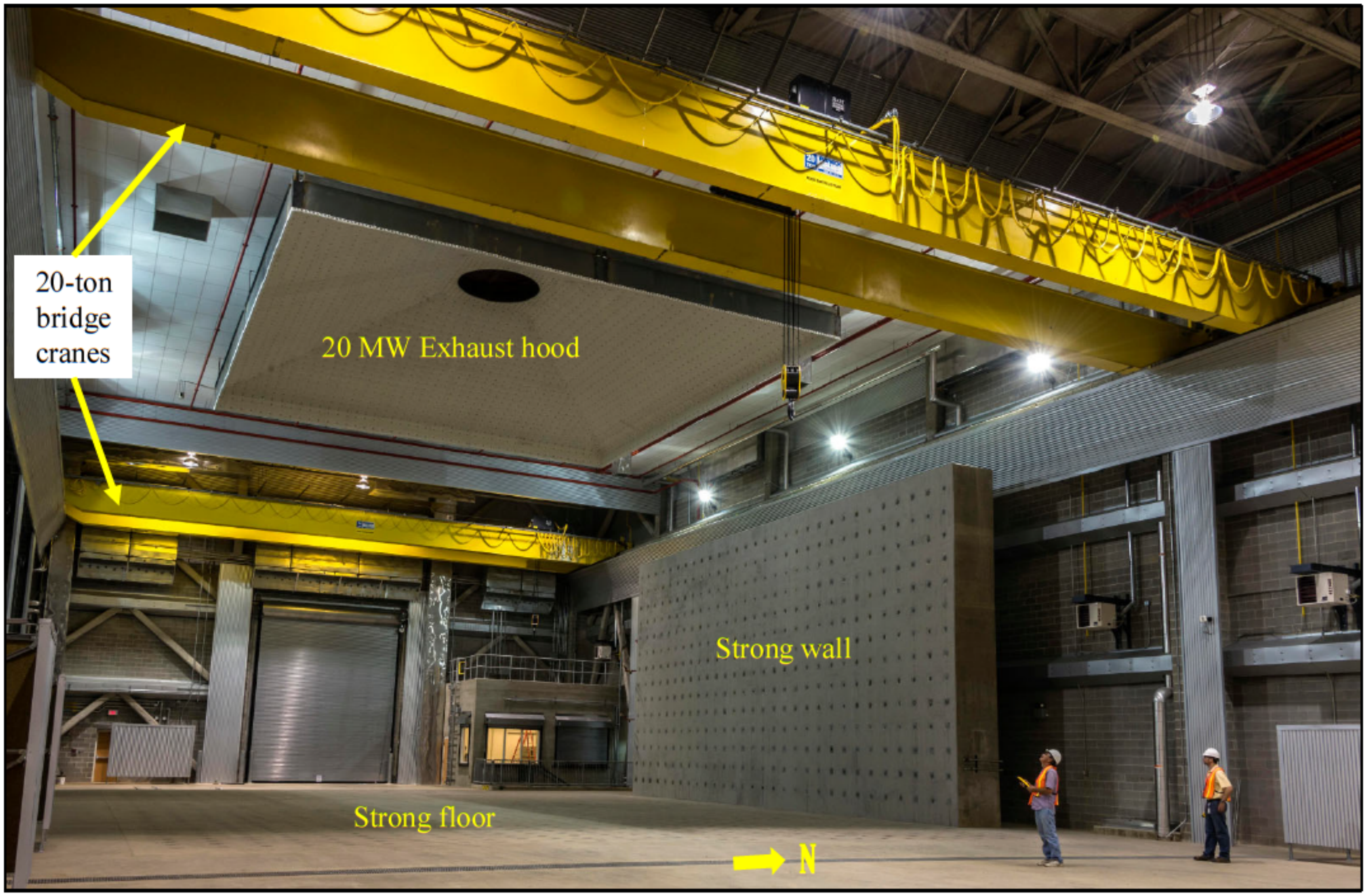


Figure 3.2.4: Image showing the north high bay of Building 205 – Room 125, looking west. The strong wall, strong floor, and exhaust hood are labeled, as well as the two 20-ton bridge cranes.

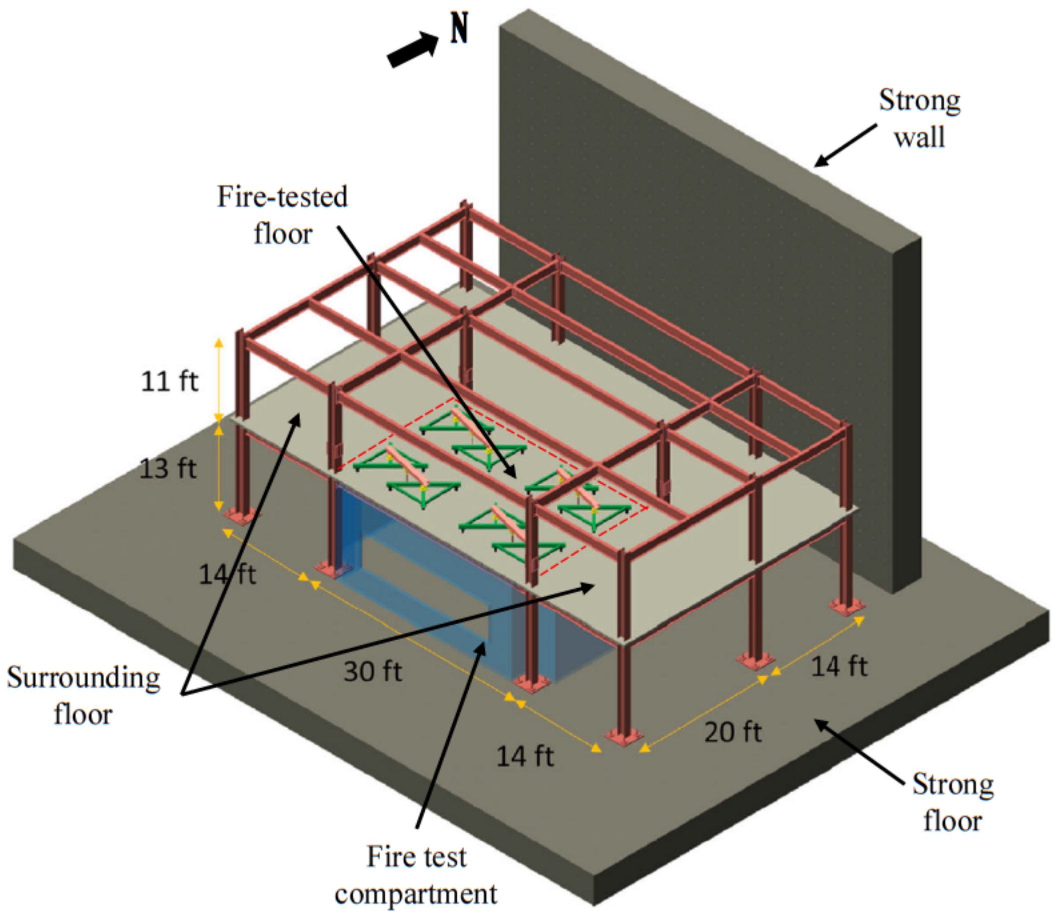


Figure 3.3.1: Diagram showing the CF Project reusable test frame. Not shown are the water drums placed on the surrounding floor for loading during the test.

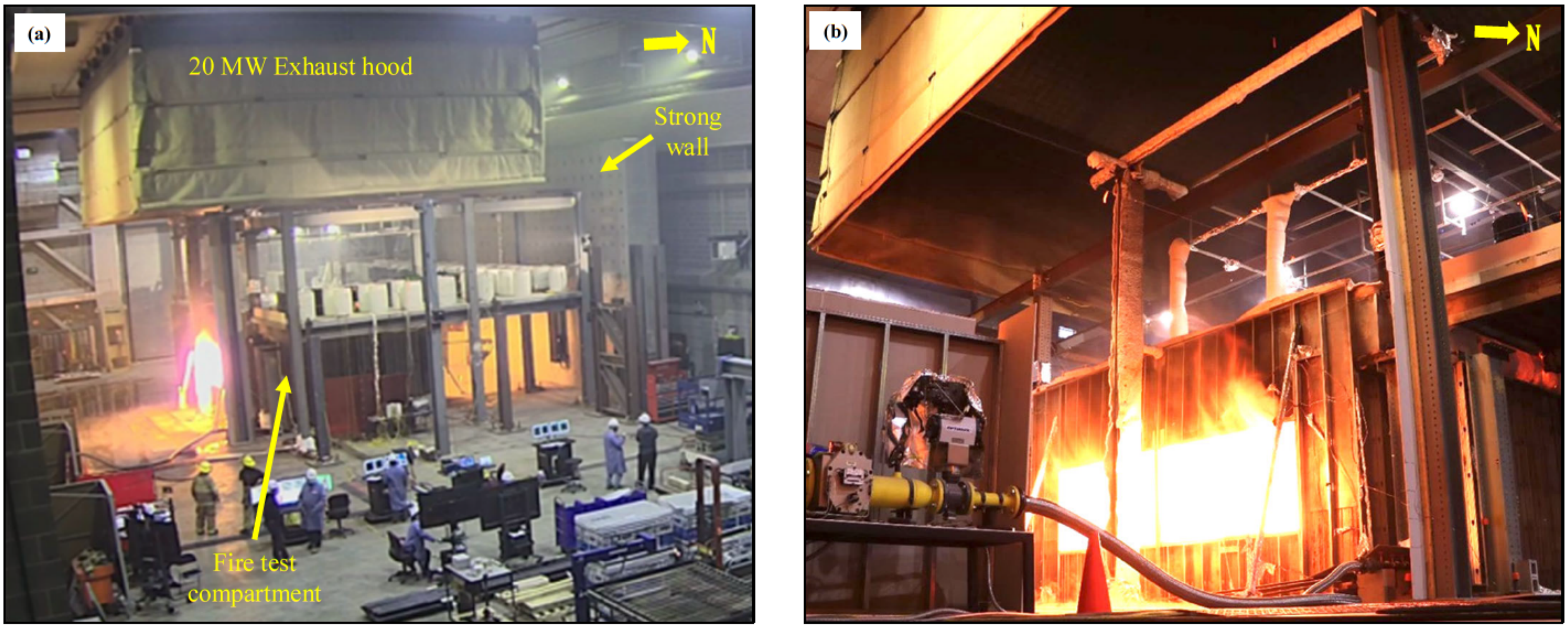


Figure 3.3.2: Image showing a CF Project experiment underway. (a) Shows the test frame as a whole and (b) shows the fire compartment.

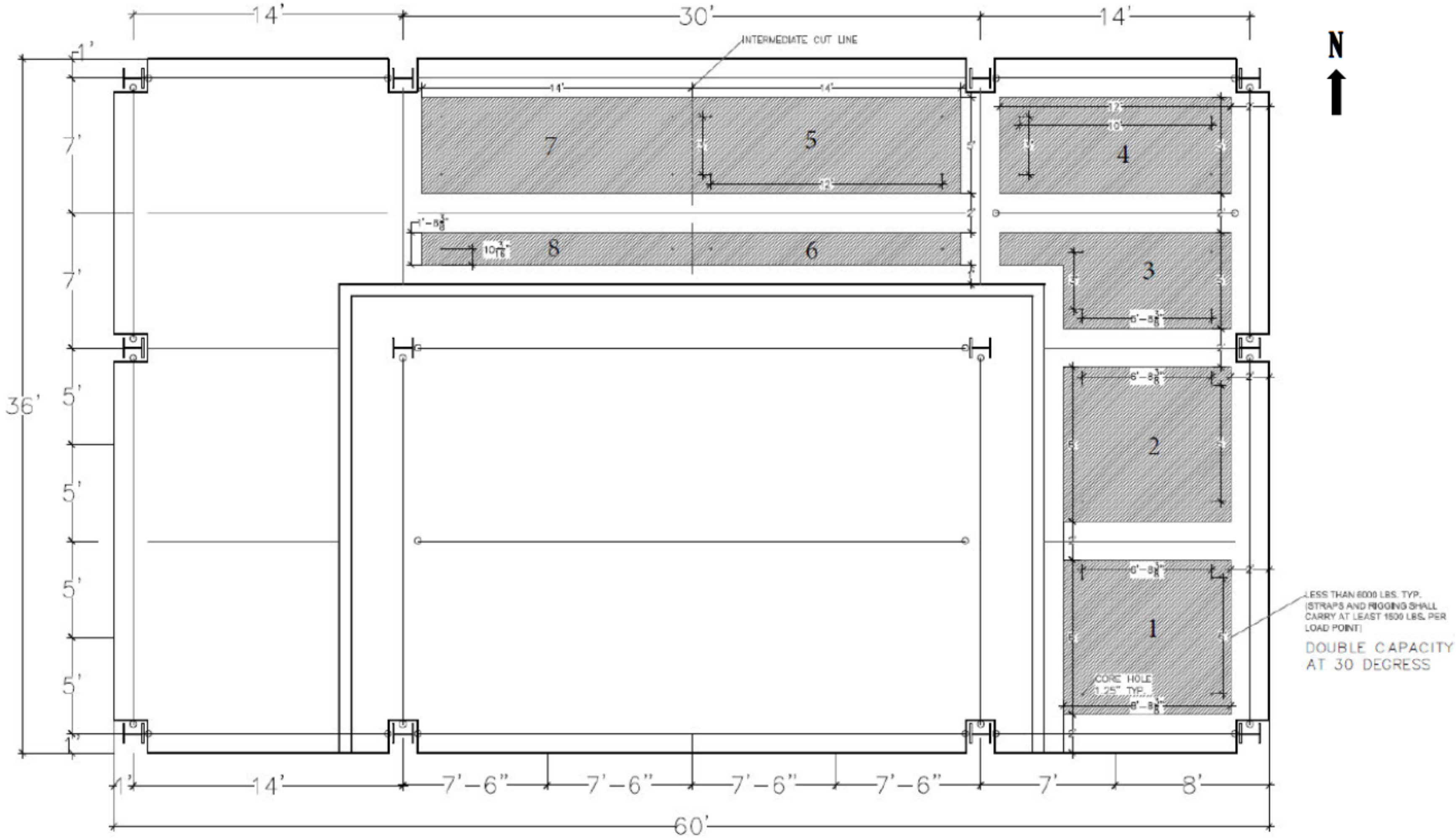


Figure 4.1.1: *Coring and Cutting Plan* developed by ENGR TECH 1 regarding the slabs to be removed from the surrounding floor. This plan is discussed in detail in Section 6.3.3.

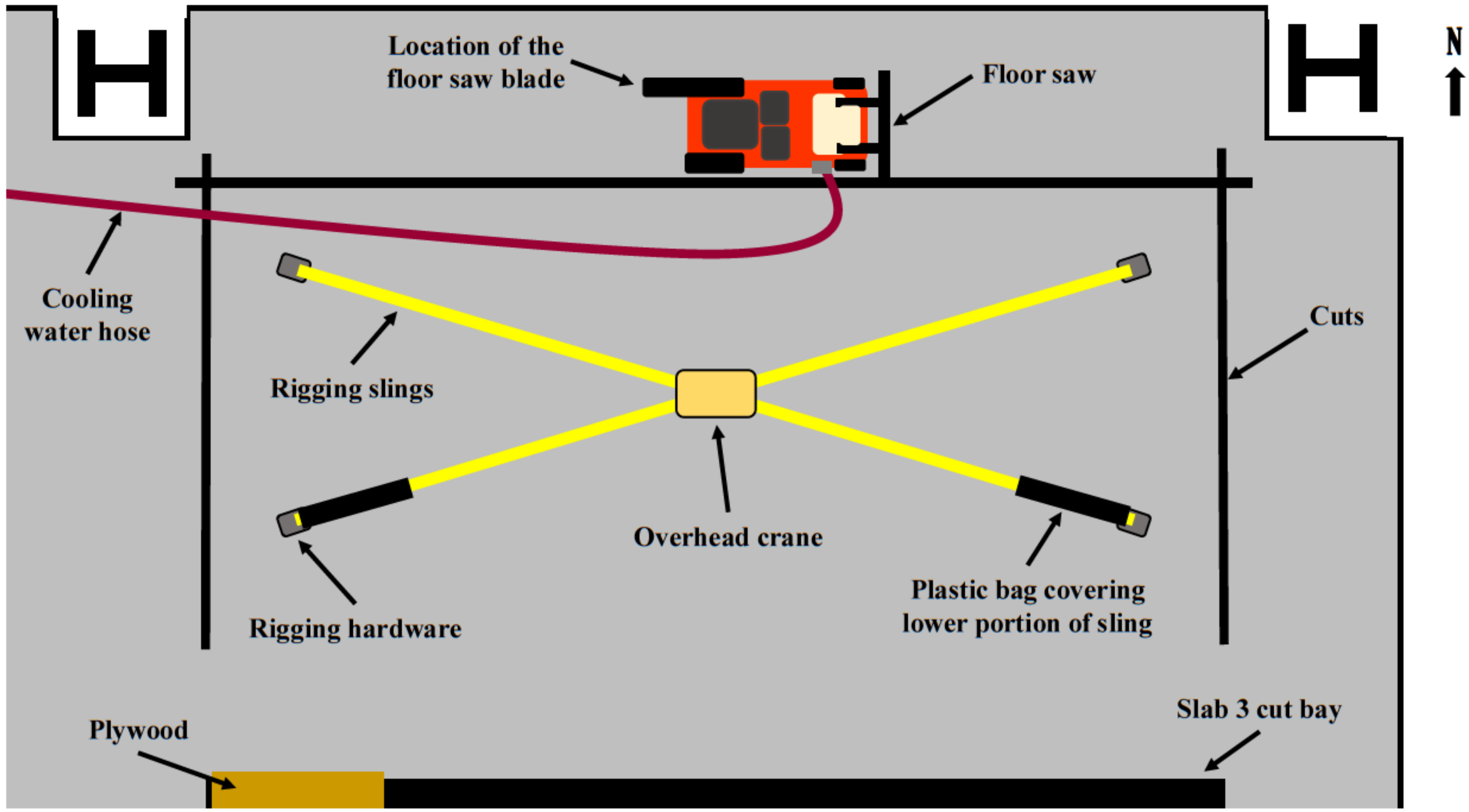


Figure 4.2.1: Planar view diagram of the northeast corner of the CF Project test frame showing the sectioning of Slab 4. (a) North, east, and west faces of Slab 4 were cut prior to lunch and the saw left on the north side of the slab.

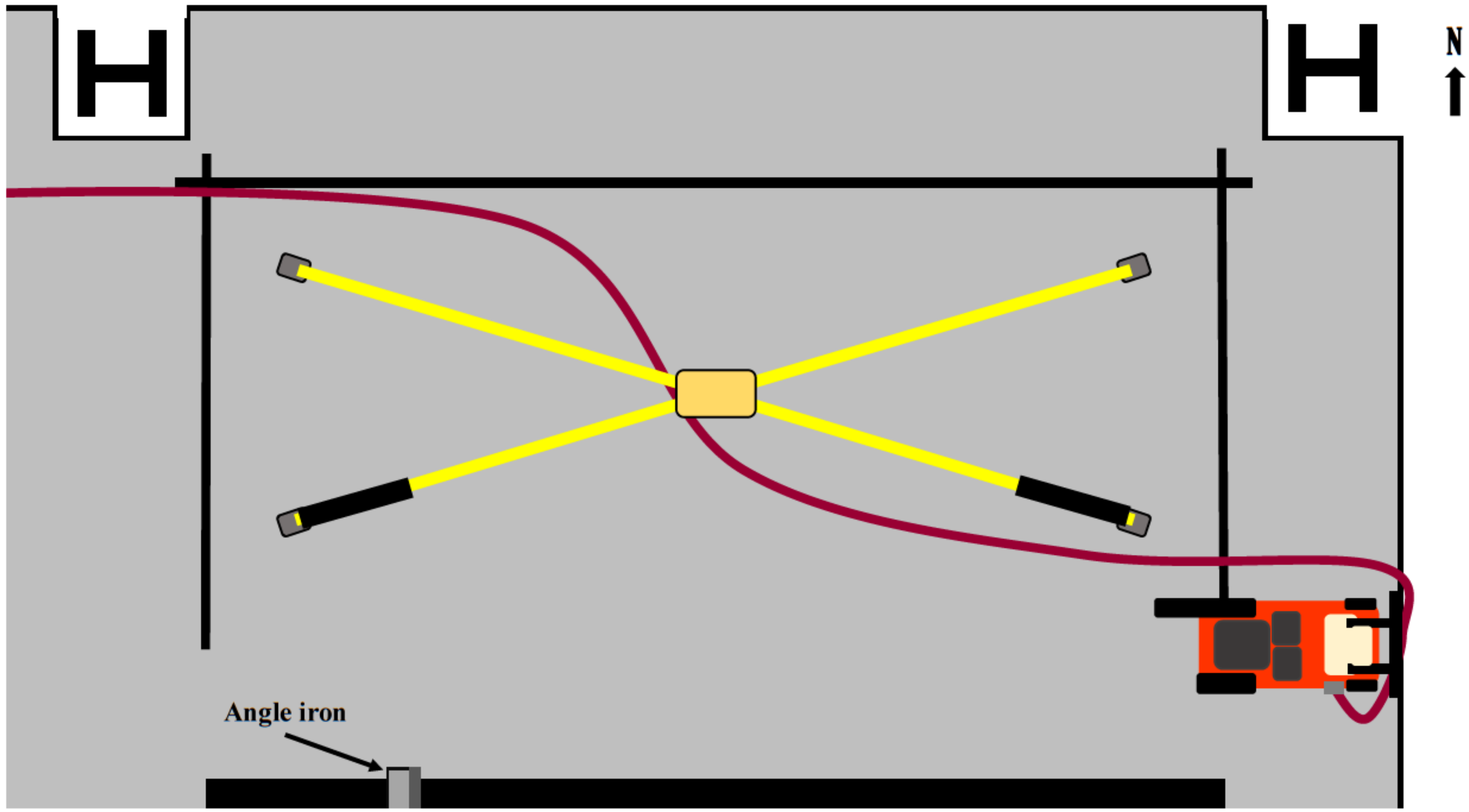


Figure 4.2.1 (cont.): Planar view diagram of the northeast corner of the CF Project test frame showing the sectioning of Slab 4. (b) Position of the floor saw and cooling water hose prior to cutting the south face of Slab 4.

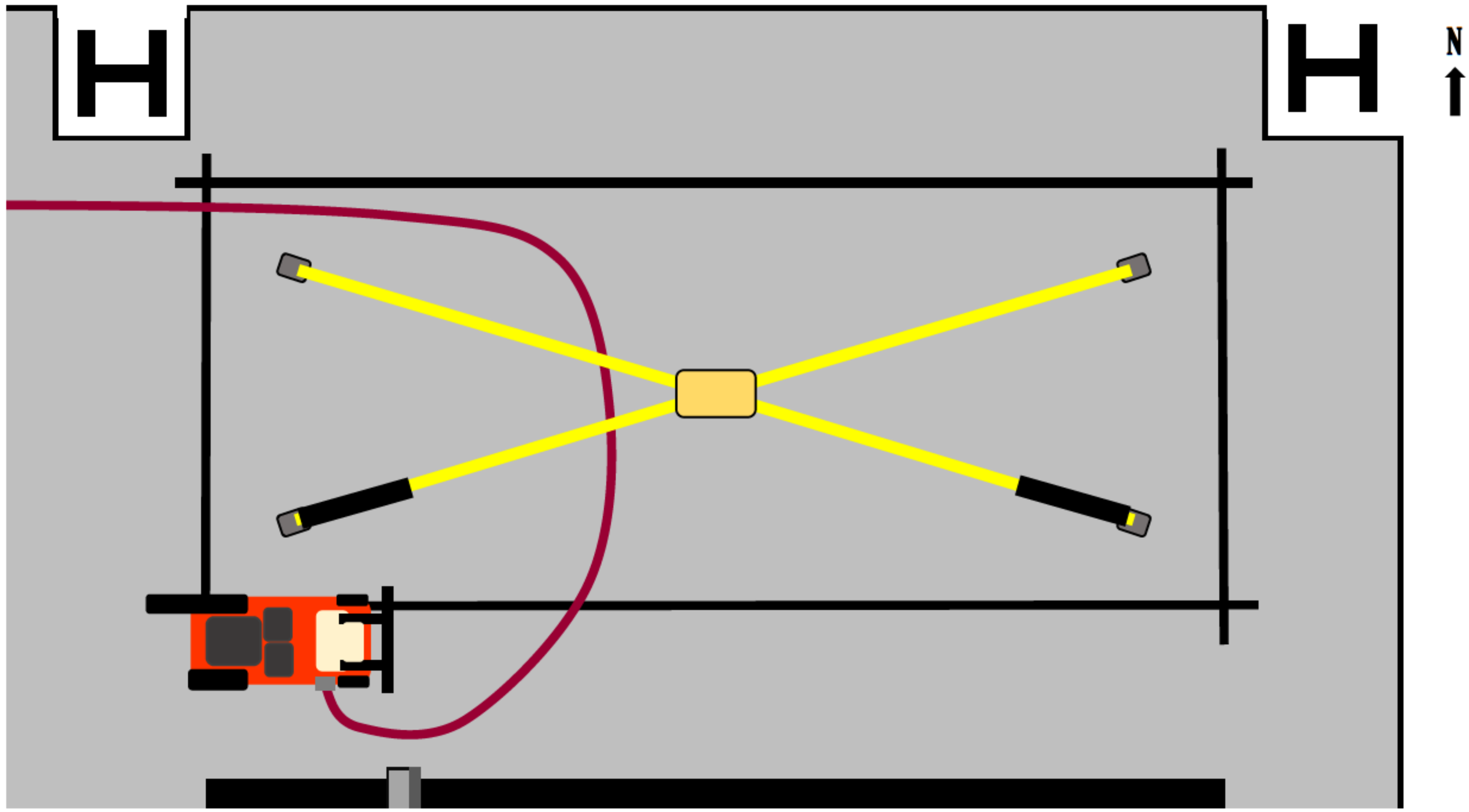


Figure 4.2.1 (cont.): Planar view diagram of the northeast corner of the CF Project test frame showing the sectioning of Slab 4. (c) Position of the floor saw and cooling water hose after cutting the south face of Slab 4.

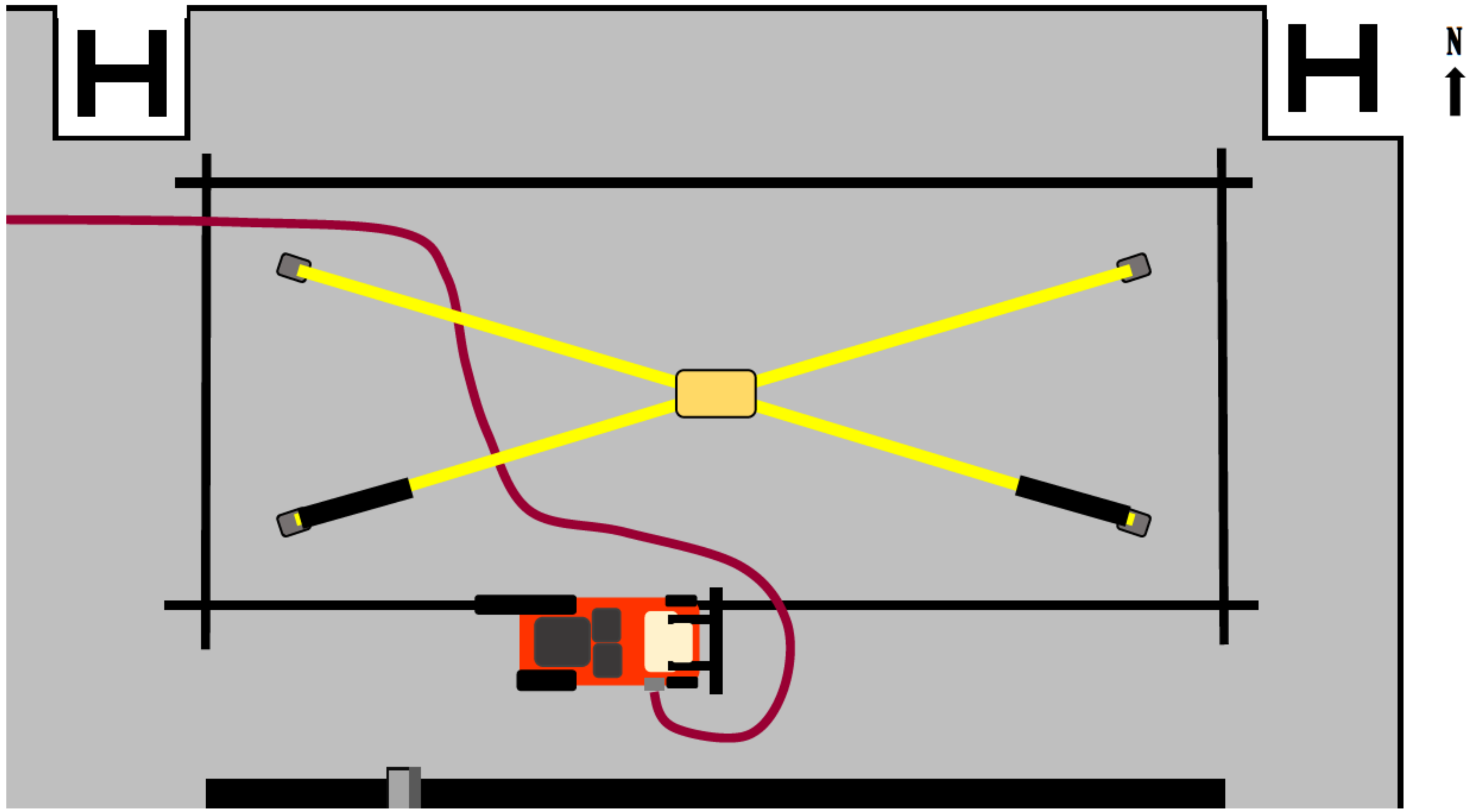


Figure 4.2.1 (cont.): Planar view diagram of the northeast corner of the CF Project test frame. (d) Position of the floor saw and cooling water hose after ENGR TECH 1 pulls it backwards after south face cut.

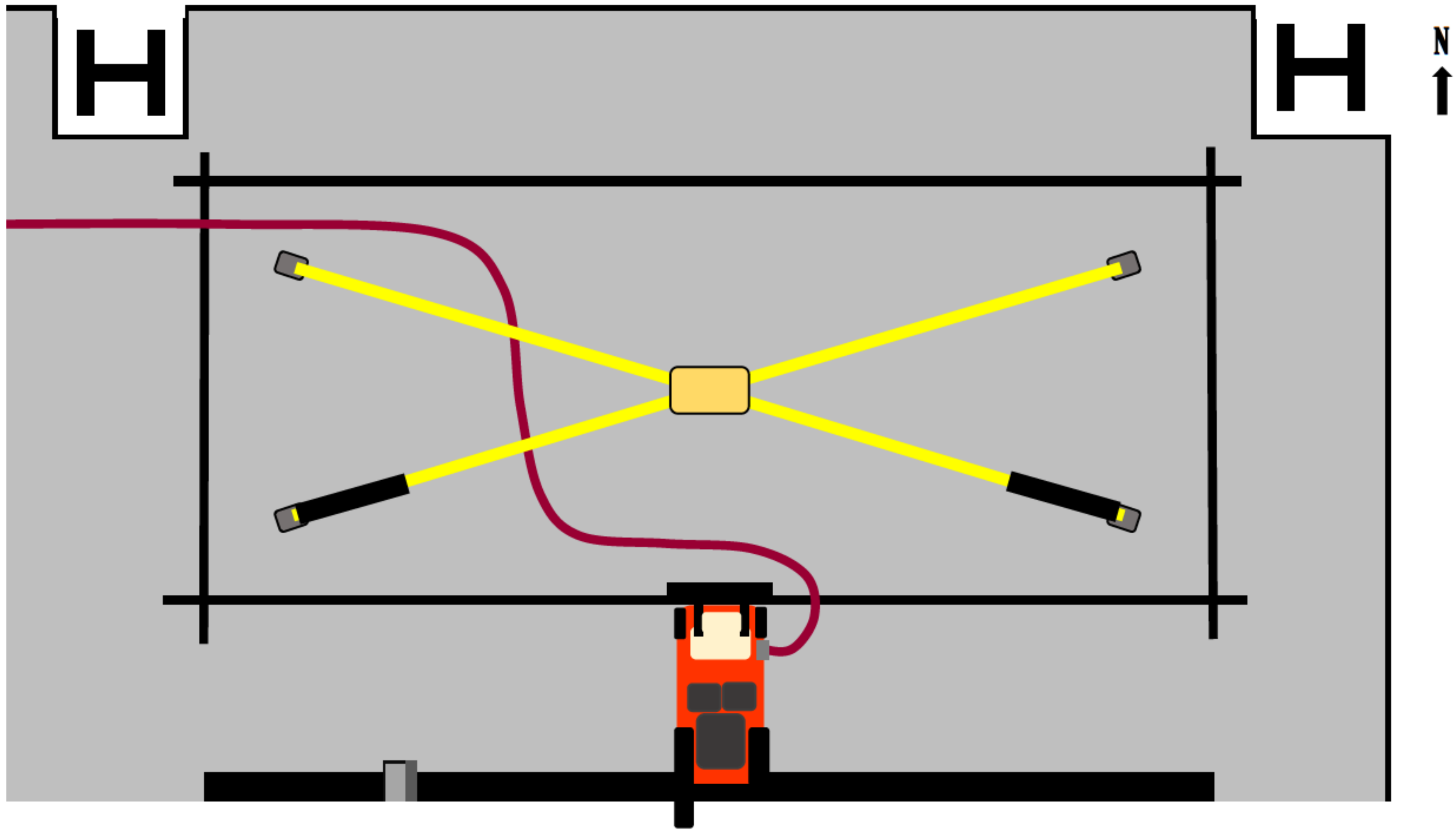


Figure 4.2.1 (cont.): Planar view diagram of the northeast corner of the CF Project test frame. (e) Position of the floor saw and garden hose just prior to ENGR TECH 1 pulling it backwards on to Slab 4.

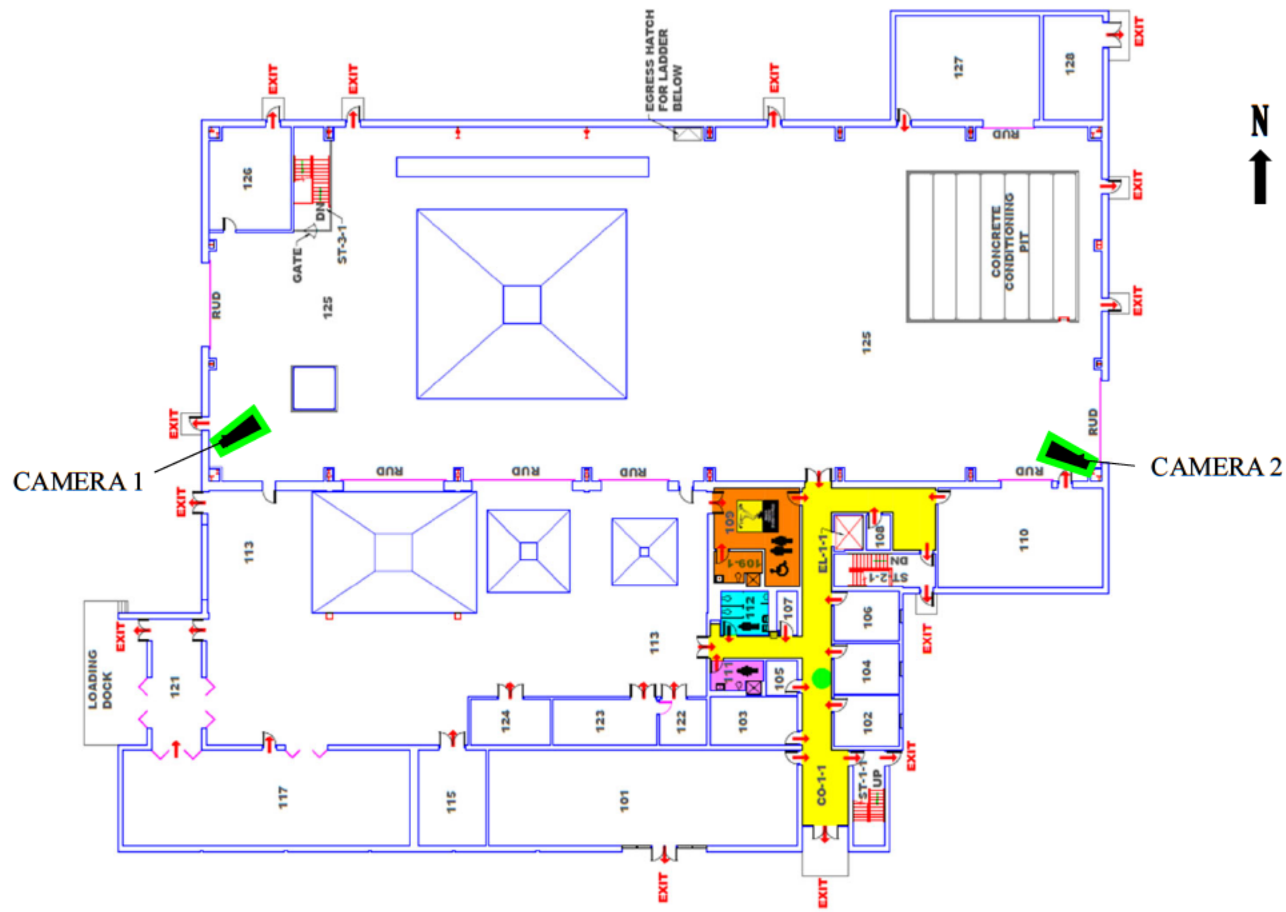


Figure 5.2.1: Scale plan view drawing of the NFRL showing the two camera locations inside of Room 125

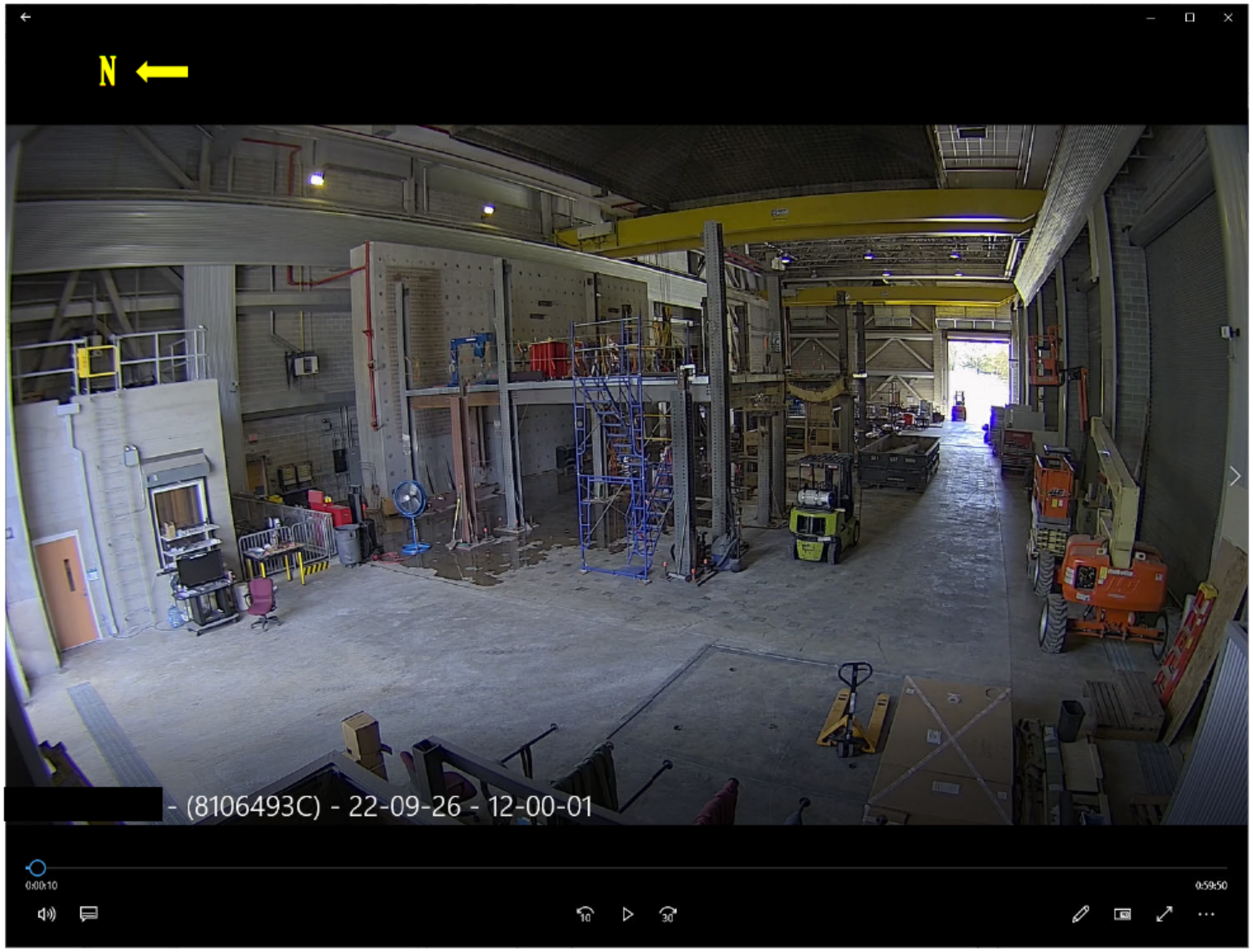


Figure 5.2.2: Image captured from video evidence showing the view from CAMERA 1 located in the southwest corner of Room 125 looking northeast (12:00:10 pm ET on September 26, 2022).

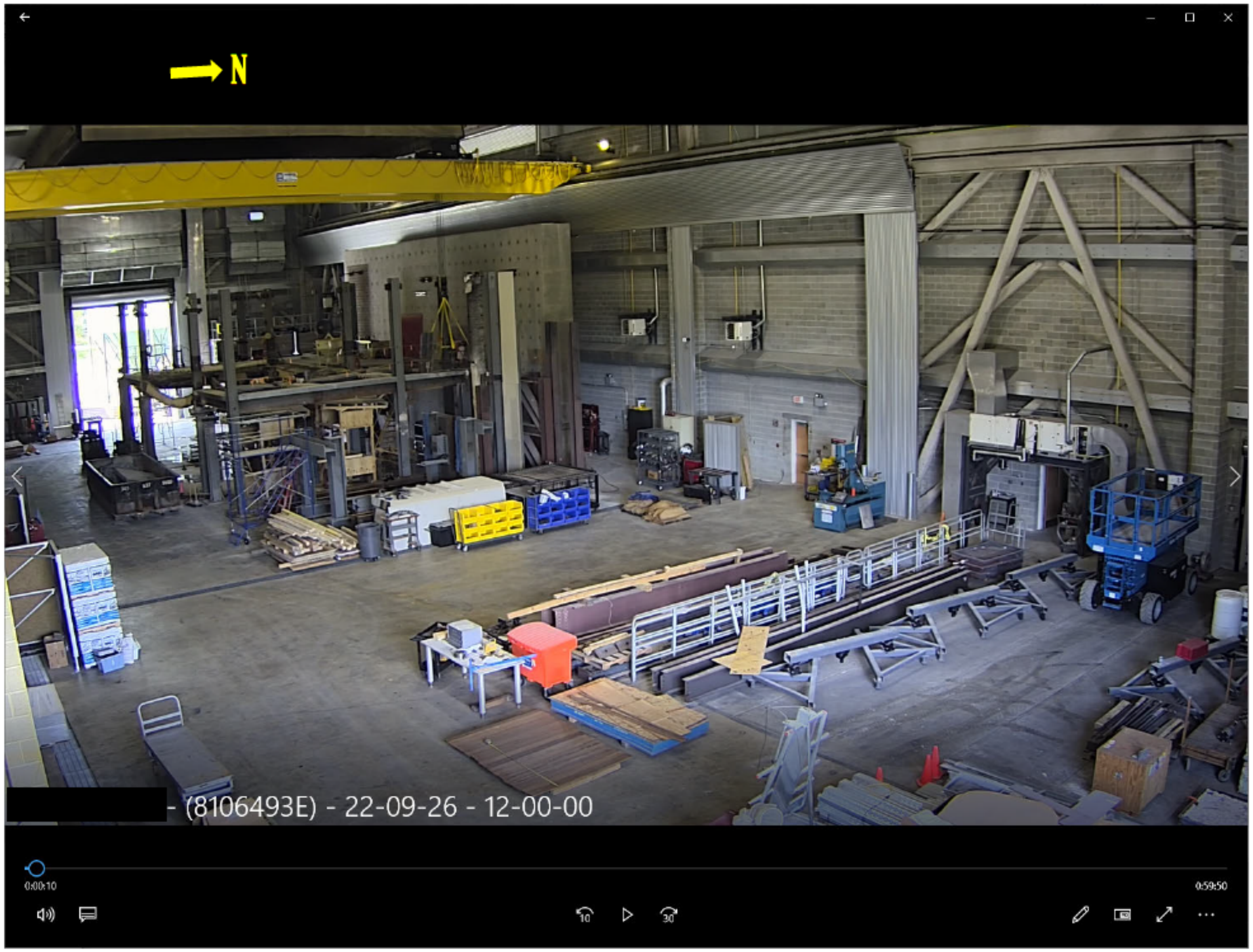


Figure 5.2.3: Image captured from video evidence showing the view from CAMERA 2 located in the southeast corner of Room 125 looking northwest (12:00:10 pm ET on September 26, 2022).

Figure 5.5.1: Components used in the rigging of the incident slab (Slab 4) sent to the contractor for use in the finite element modeling. a) One of the slings and b) one set of the rigging hardware.

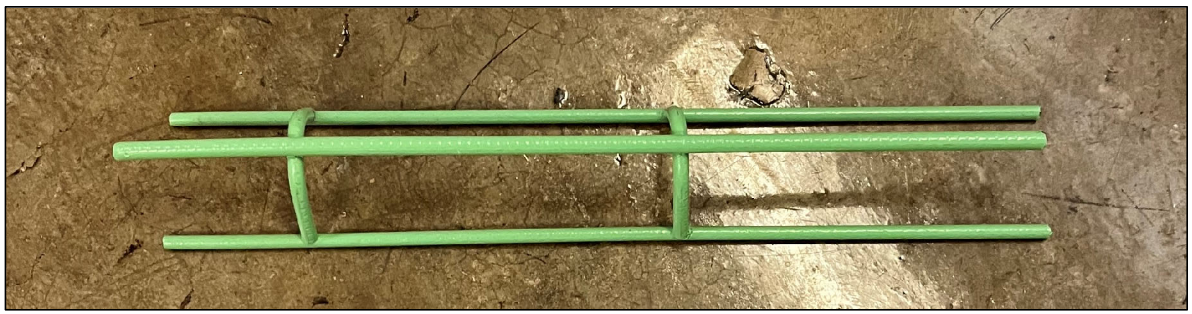


Figure 5.5.2: Piece of rebar chair sent to the contractor for use in the finite element modeling.

Figure 5.6.1: Section of Slab 4 sent to the contractor for analysis – section from Piece B.

Figure 5.6.2: Section of Slab 4 sent to the contractor for analysis – section from Piece D.

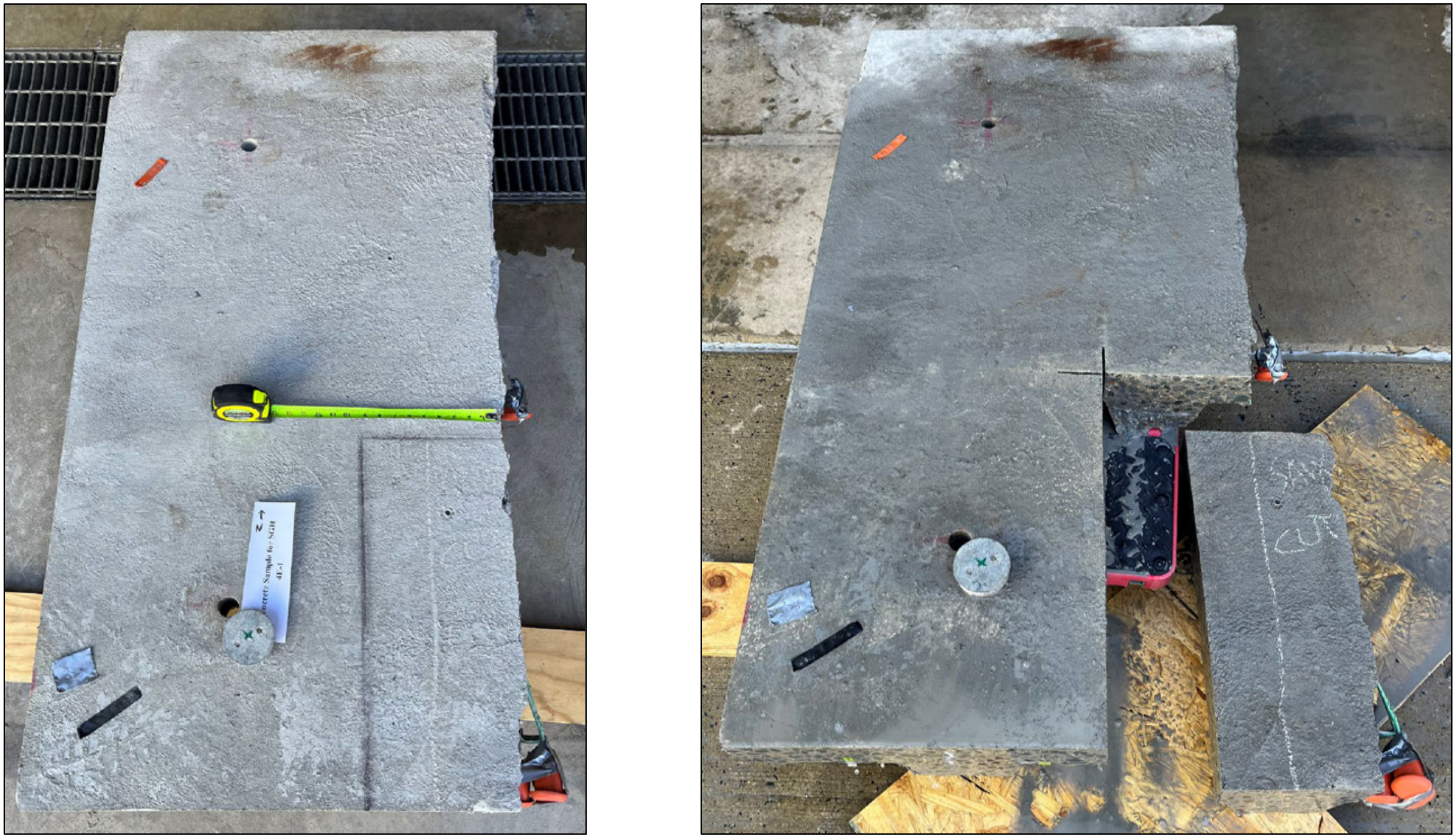


Figure 5.6.3: Section of Slab 4 sent to the contractor for analysis – section from Piece E.

Figure 5.6.4: Core samples with 1 inch diameters from unknown locations in the surrounding floor sent to the contractor for analysis.

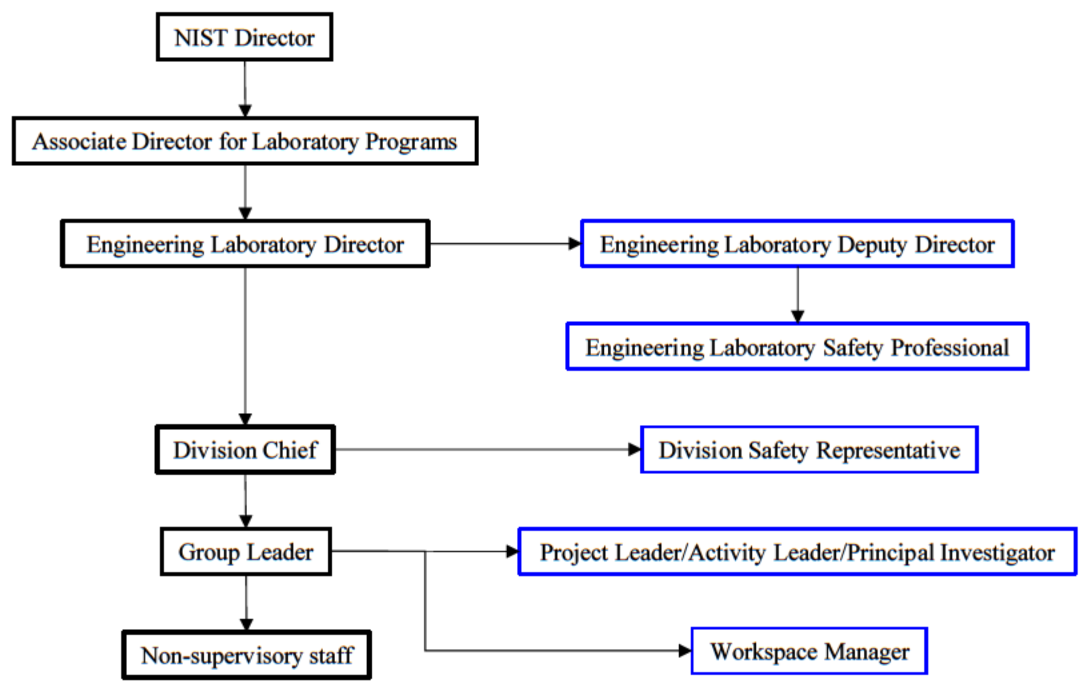


Figure 6.1.1: Line management structure in the Engineering Laboratory is typical of most organizational units at NIST starting at the NIST Director and flowing down to the Group Leader. Those shown in the blue boxes, while not having official line management responsibilities, do have responsibilities for safety.

		POTENTIAL SEVERITY OF THE CONSEQUENCES OF A HAZARDOUS EVENT OR EXPOSURE TO A HAZARD			
		Catastrophic Death or permanent disability System or facility loss Lasting environmental or public-health impact	**Severe** Serious injury; temporary disability Subsystem loss or significant facility/property damage Temporary environmental or public-health impact	**Moderate** Medical treatment beyond first aid; lost-work-day(s) More than slight facility/property damage External reporting requirements; more than routine clean-up	**Minor** First-aid only Negligible or slight facility/property damage No external reporting requirements; routine clean-up
LIKELIHOOD OF OCCURRENCE	**Frequent** Likely to occur repeatedly	**CRITICAL RHI=4**	**CRITICAL RHI=4**	**SERIOUS RHI=3**	**Medium RHI=2**
	Probable Likely to occur multiple but infrequent times	**CRITICAL RHI=4**	**CRITICAL RHI=4**	**SERIOUS RHI=3**	**Medium RHI=2**
	Occasional Likely to occur at some time	**CRITICAL RHI=4**	**SERIOUS RHI=3**	**Medium RHI=2**	**Low RHI=1**
	Remote Possible, but not likely to occur	**SERIOUS RHI=3**	**Medium RHI=2**	**Medium RHI=2**	**Low RHI=1**
	Improbable Very unlikely; can reasonably assume it will not occur	**Medium RHI=2**	**Low RHI=1**	**Low RHI=1**	**Minimal RHI=0**

Figure 6.2.1: Risk-assessment matrix used by NIST to determine the risk level to the work while performing a specific activity. The level of risk is characterized by the RHI. Taken from NIST S 7101.20.

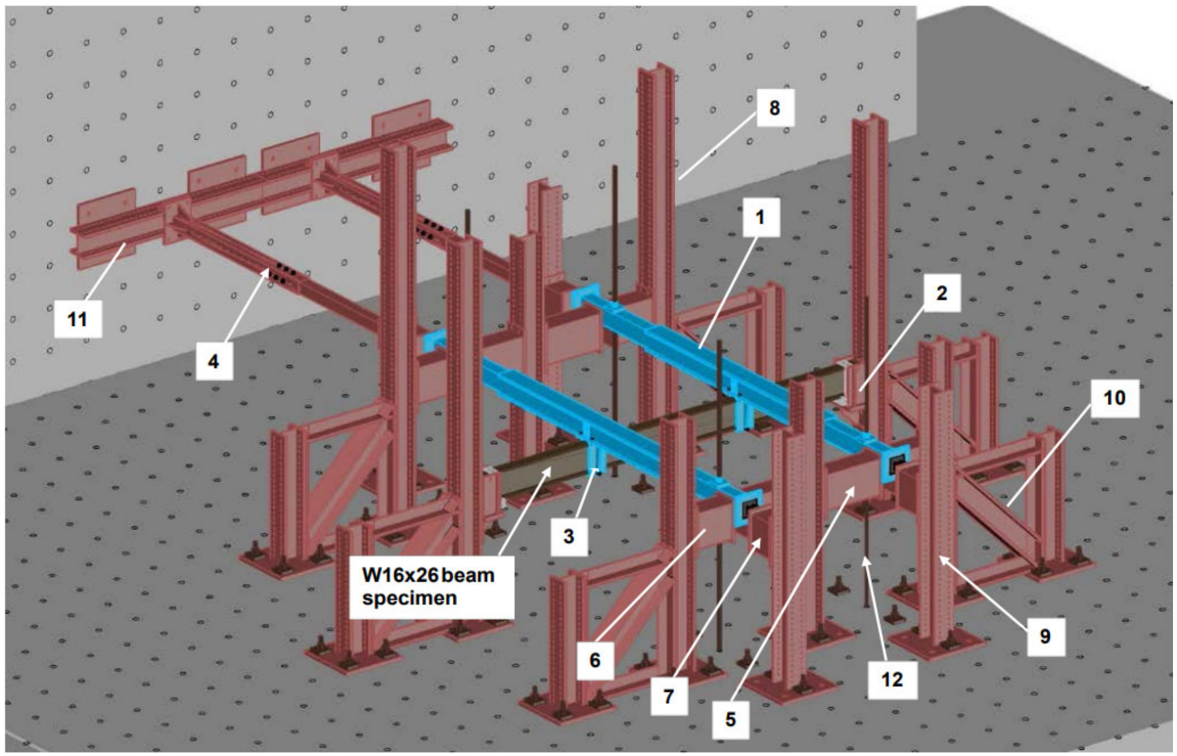


Figure 6.3.1: Schematic of the beam test set-up for the hazard review titled *NFRL Commissioning Phase III – Ambient Beam Test* (#733.06.0002).

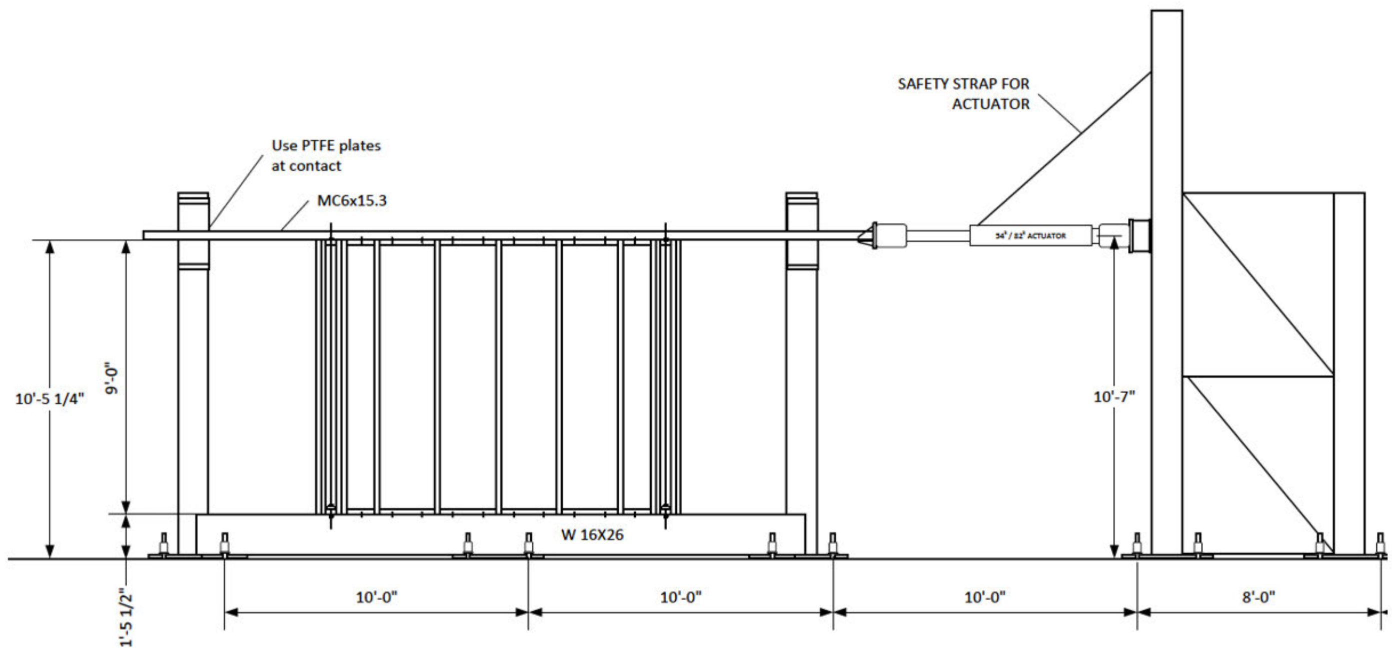


Figure 6.3.2: Schematic of the mechanical loading test setup for the hazard review titled *Structural-Fire Performance of Cold-Formed Steel Shear Walls* (#733.06.0022).

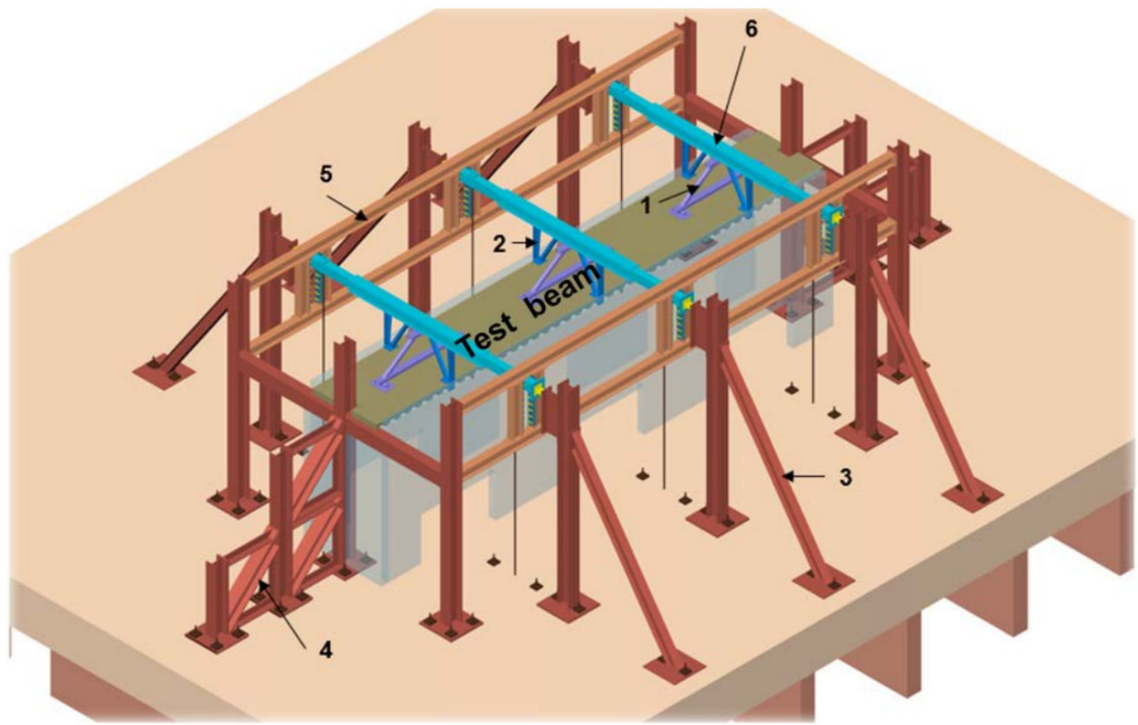


Figure 6.3.3: Schematic of the test apparatus for the hazard review titled *Composite Beam Fire Test* (#733.06.0078).

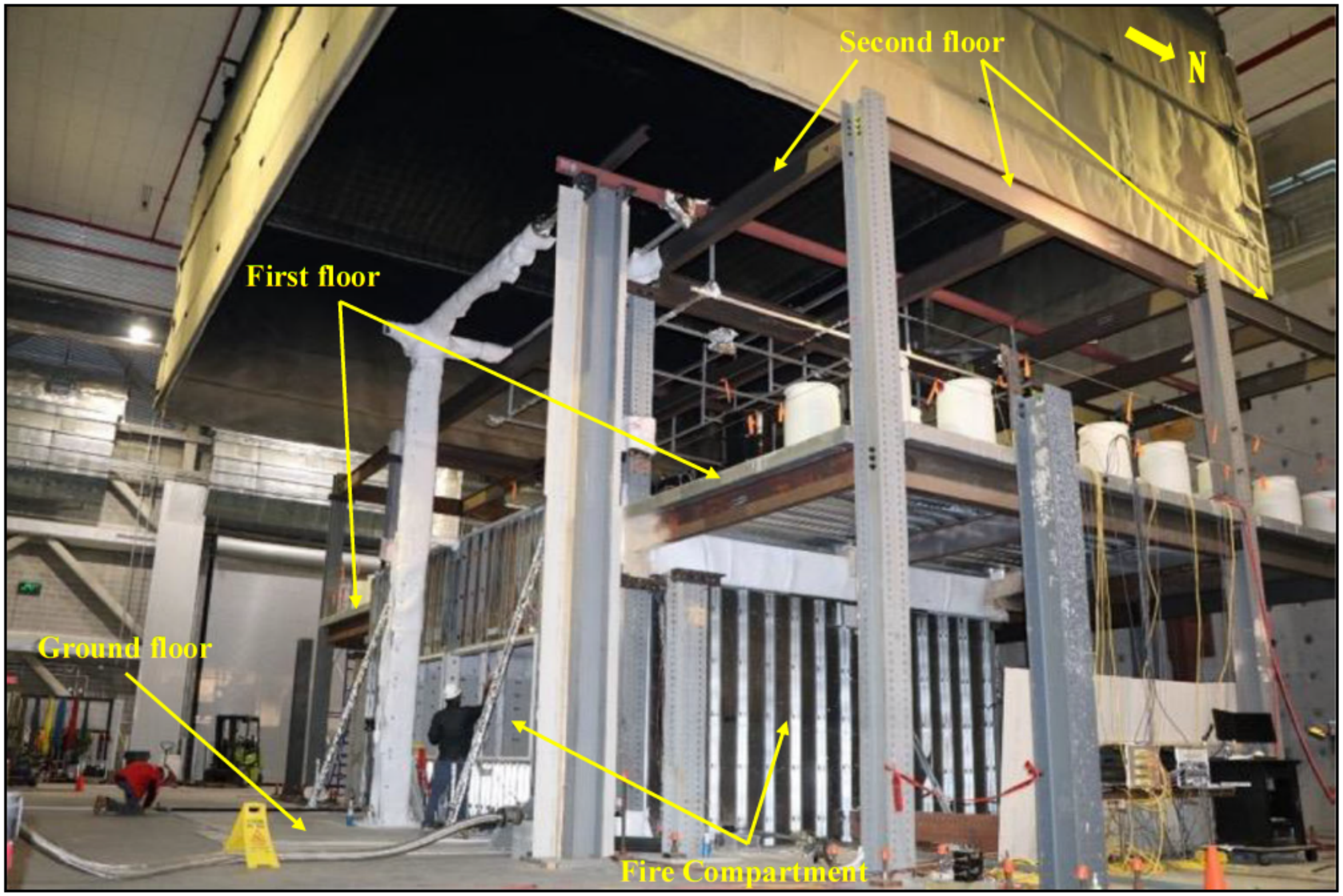


Figure 6.4.1: Construction image of the test frame prior to CF1 experiment.

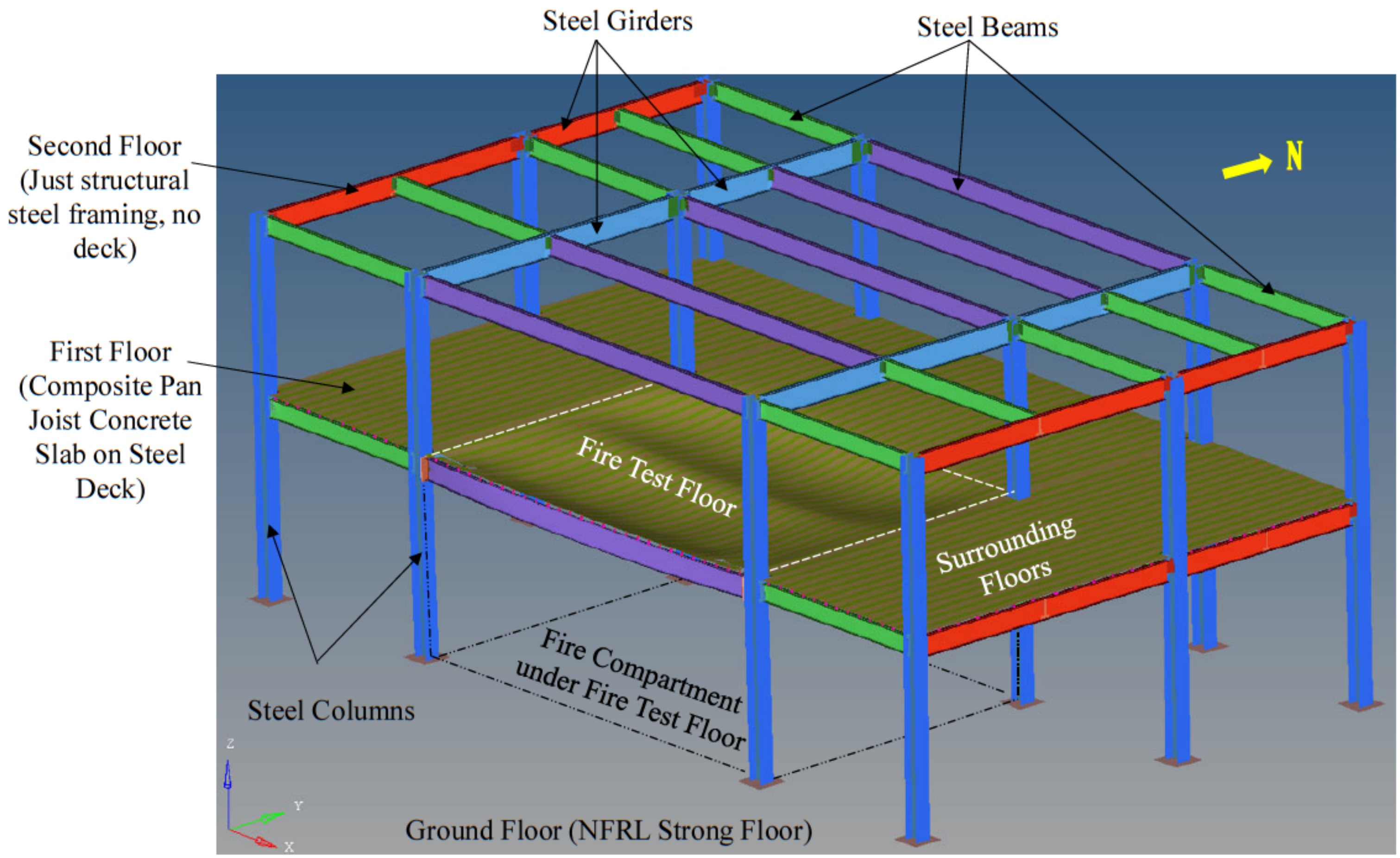
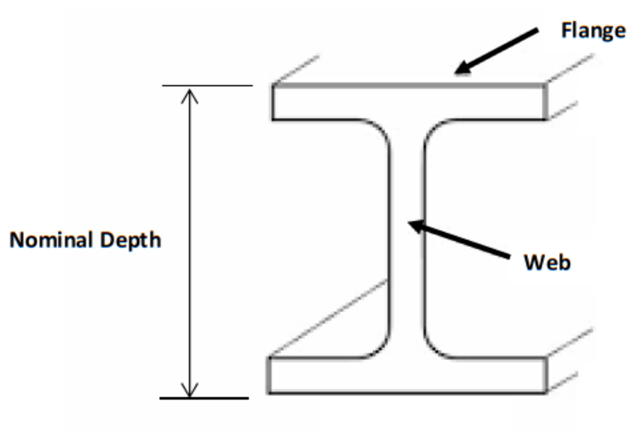


Figure 6.4.2: Isometric view of the test frame showing the overall structural steel system and locations of the Fire Test Floor and Surrounding Floors.



Frame Members	Shapes	Nominal Depth cm (in.)	Weight per Foot kg (lbs)
Beams	W14×22	36 (14)	10 (22)
	W16×31	41 (16)	14 (31)
Girders	W18×35	46 (18)	15.9 (35)
	W16×26	41 (16)	11.8 (26)
Columns	W12×106	30 (12)	48 (106)

Figure 6.4.3: Images showing the cross-section of the structural steel wide-flange (W-shapes) members.

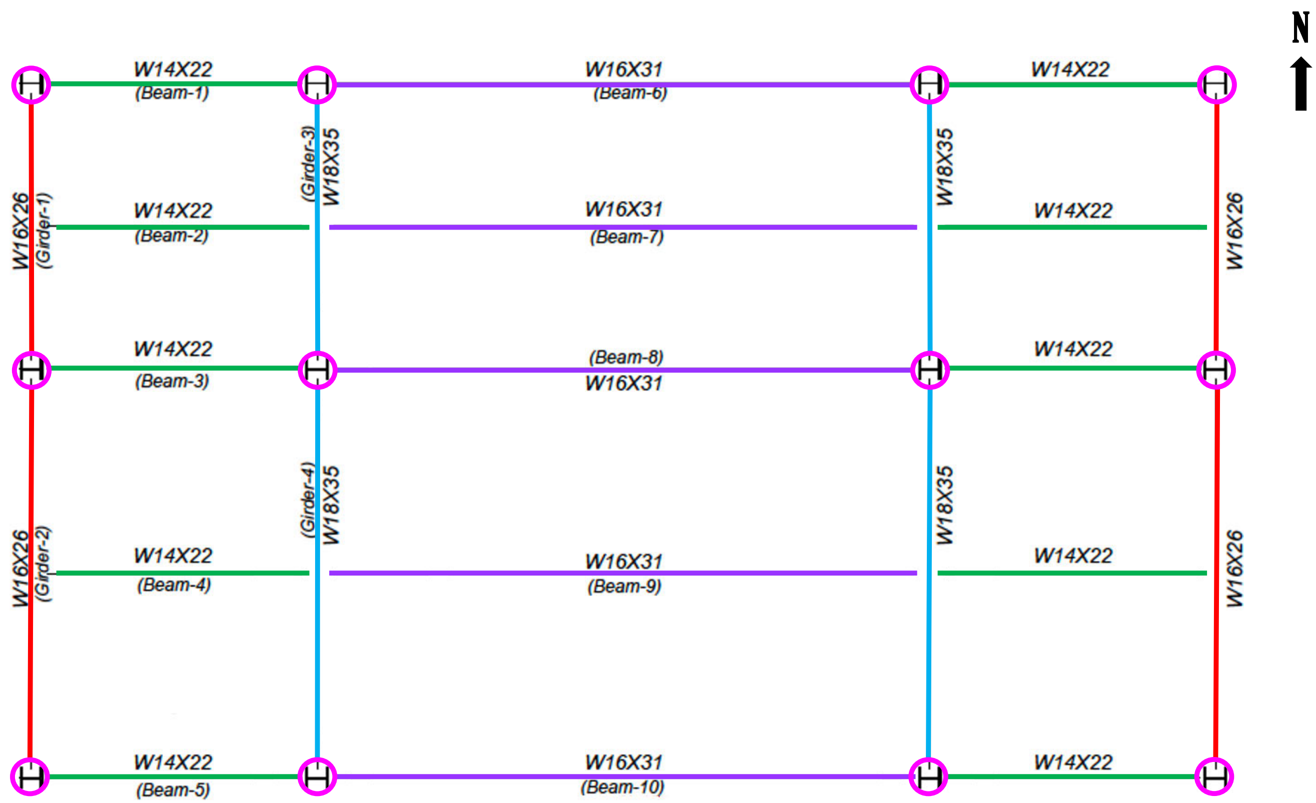
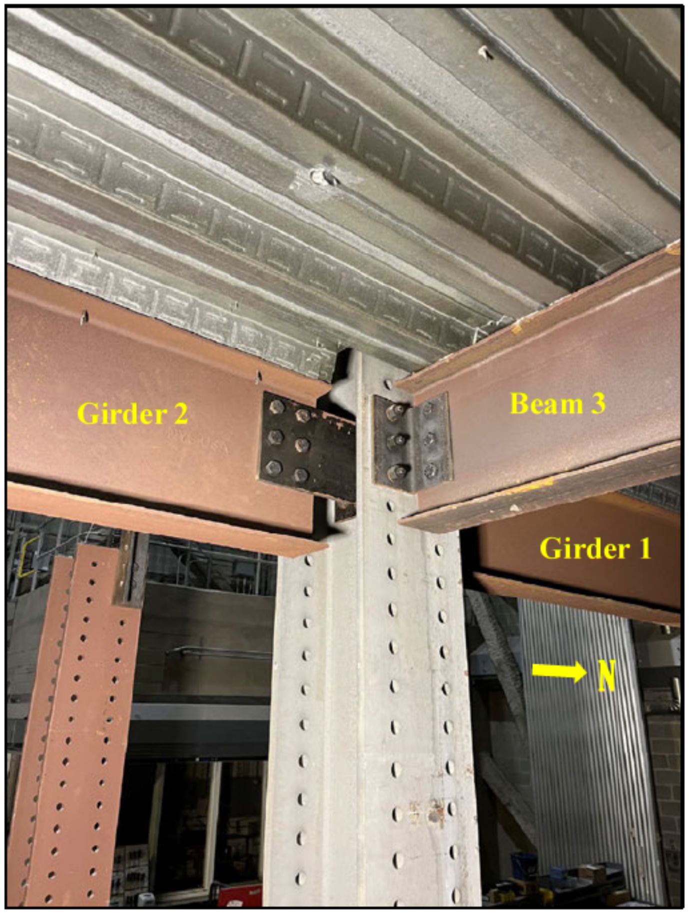


Figure 6.4.4: Planar view of the test frame showing overall structural steel system for first and second floors. The location of vertical columns are denoted by pink circles, horizontal girders are denoted by red and blue lines, and horizontal beams are denoted by green and purple lines.



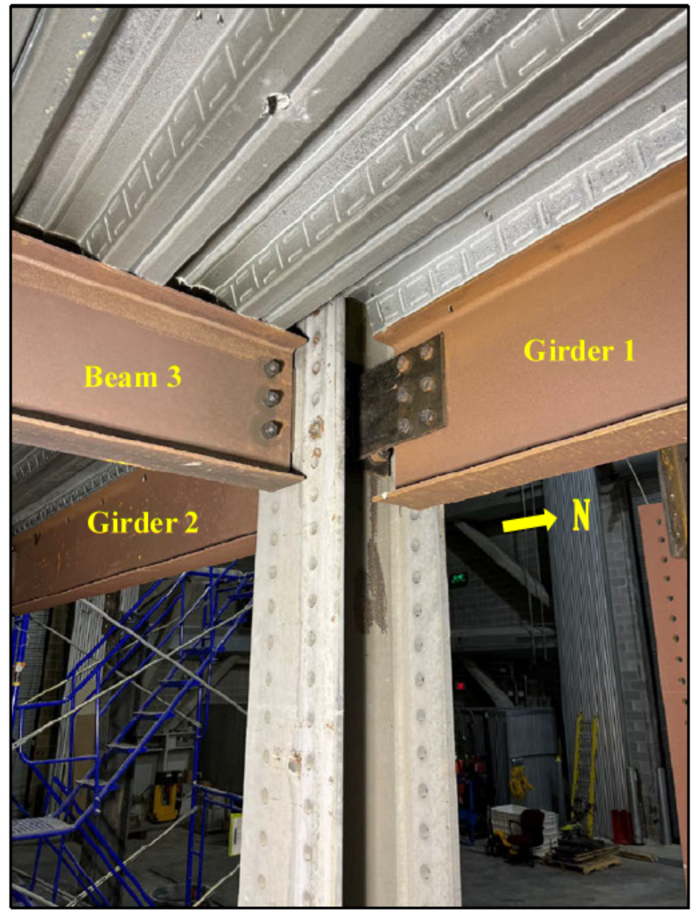


Figure 6.4.5: Image showing the shear tab connections between girder and beam and supporting column.

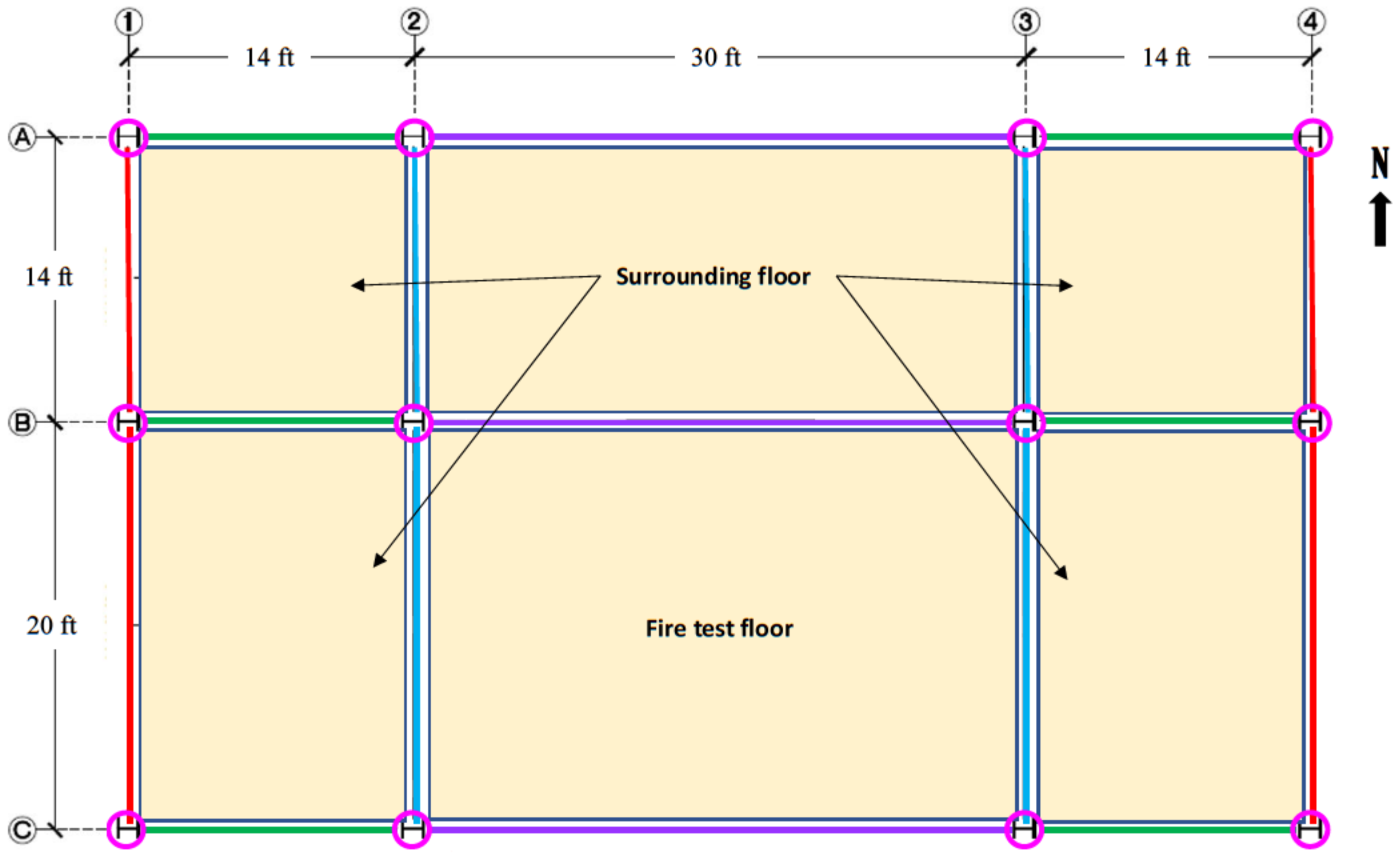


Figure 6.4.6: Planar view of the test frame showing the six bays bounded by the W12×106 columns.

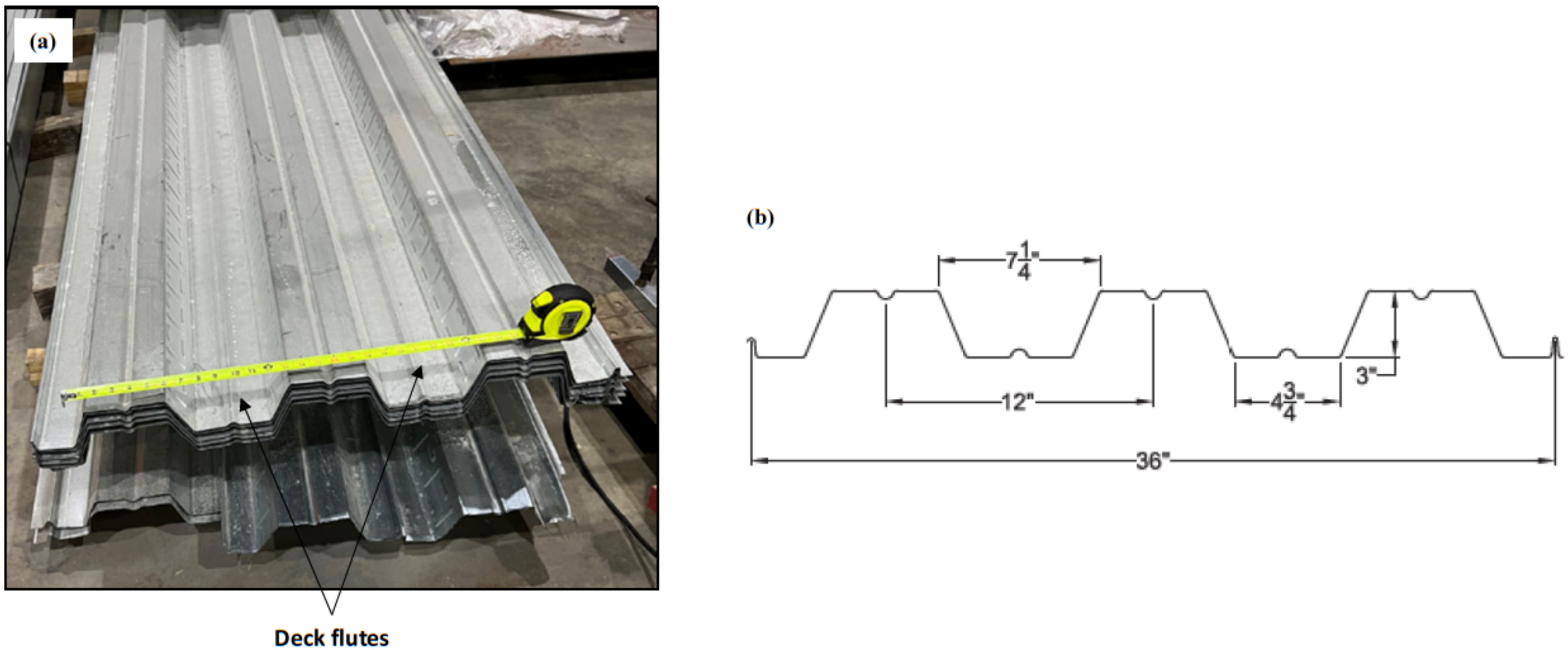
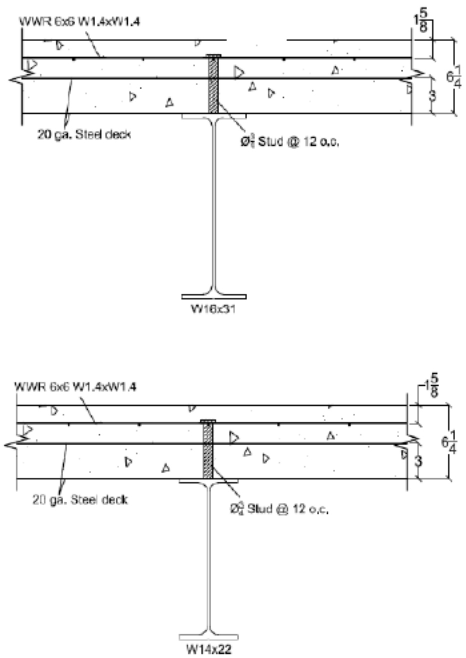


Figure 6.4.7: (a) Image of Vulcraft Composite Steel Deck Units and (b) the dimensions of the units.

(a)



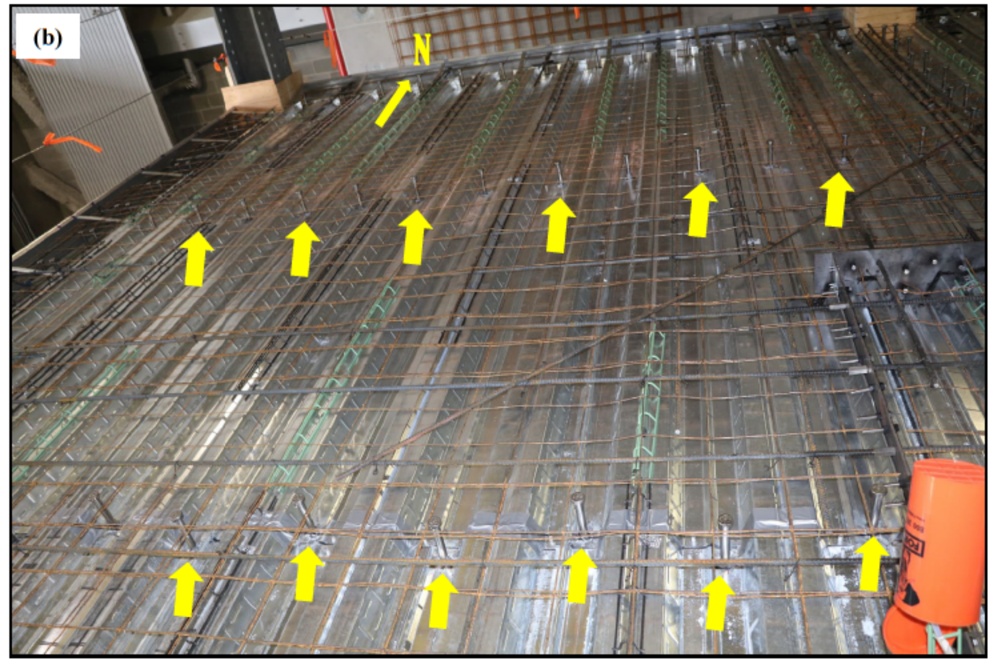


Figure 6.4.8: (a) Images showing the composite beam-concrete sections with headed shear studs and (b) construction photo of the northwest corner of the test frame showing the headed shear studs welded to the W14x22 beams.

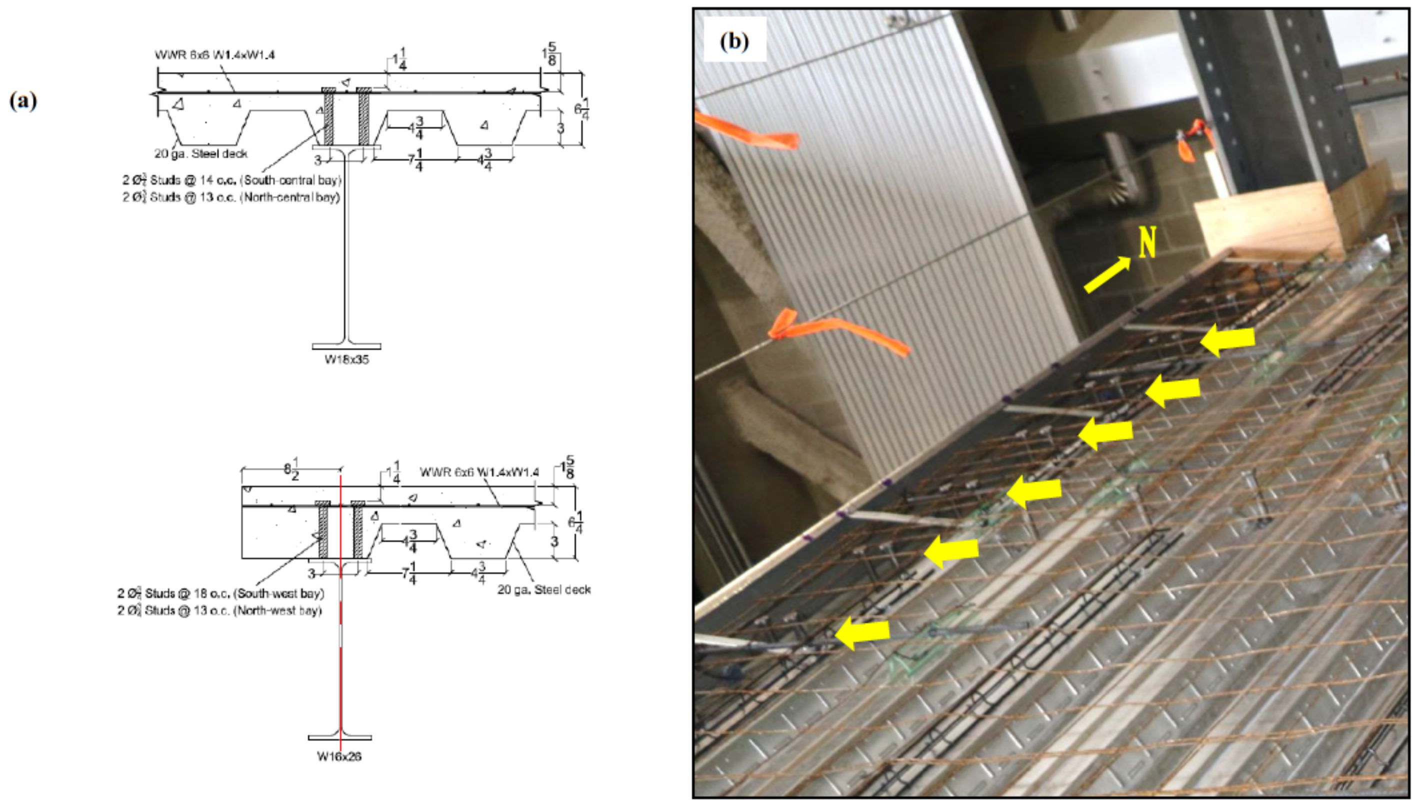


Figure 6.4.9: (a) Images showing the composite girder-concrete sections with pairs of headed shear studs and (b) construction photo of the northwest corner of the test frame showing the pair of headed shear studs welded to the W16x26 girder.

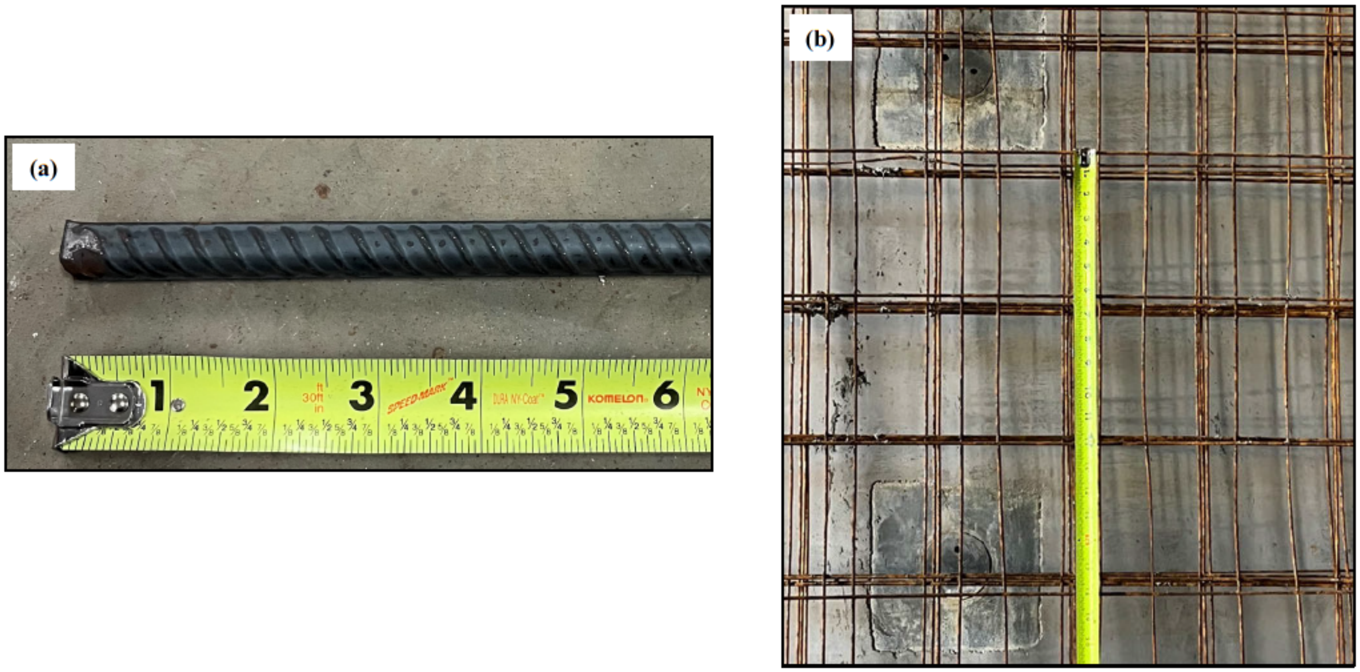


Figure 6.4.10: Images of steel reinforcement found in the concrete slab. (a) No. 4 rebar and (b) WWR mesh.

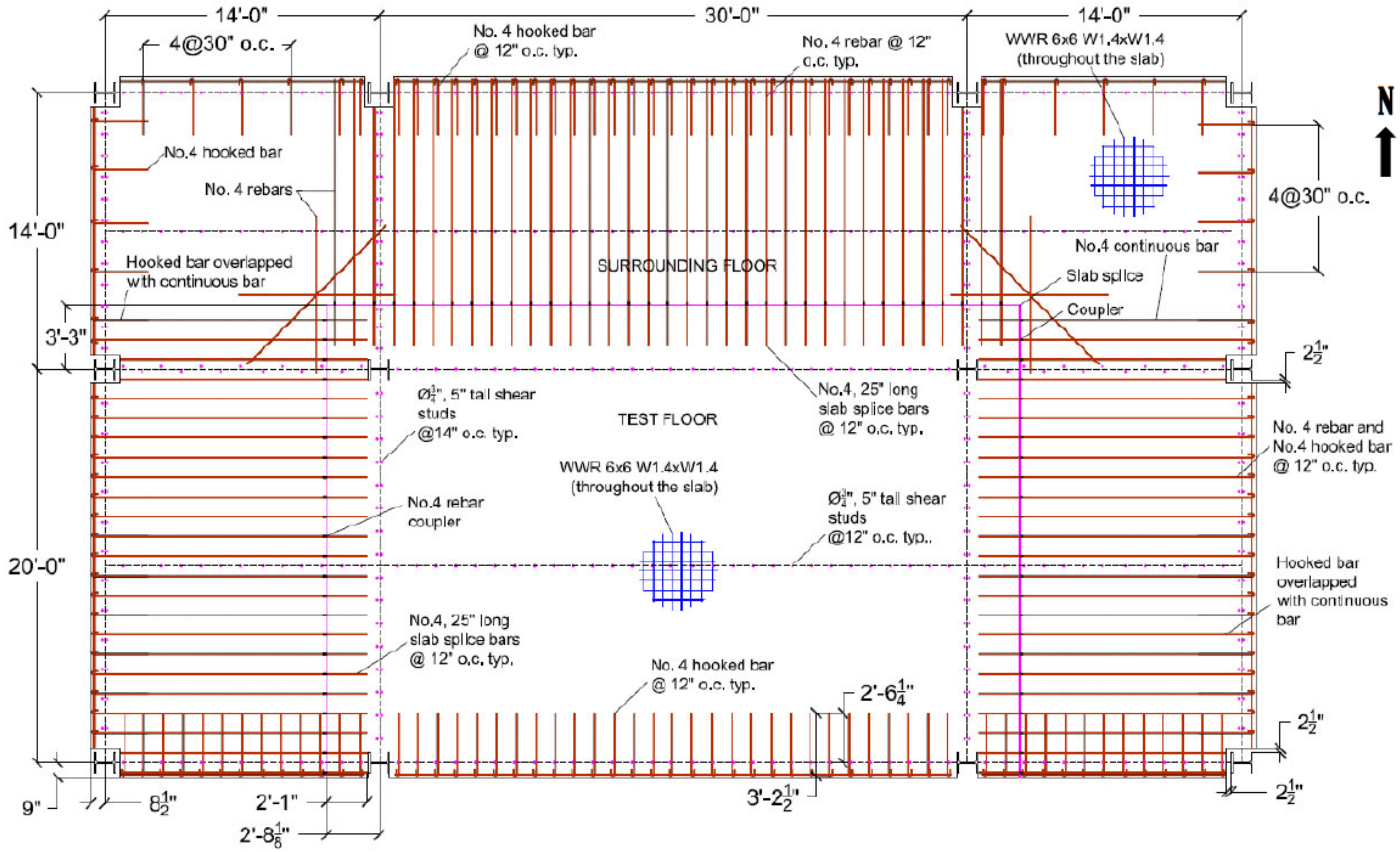


Figure 6.4.11: Steel reinforcement layout for the first floor of the CF1 Test. As the surrounding floor was not demolished between experiments, the steel reinforcement details shown here for the these locations were present at the time of the incident.

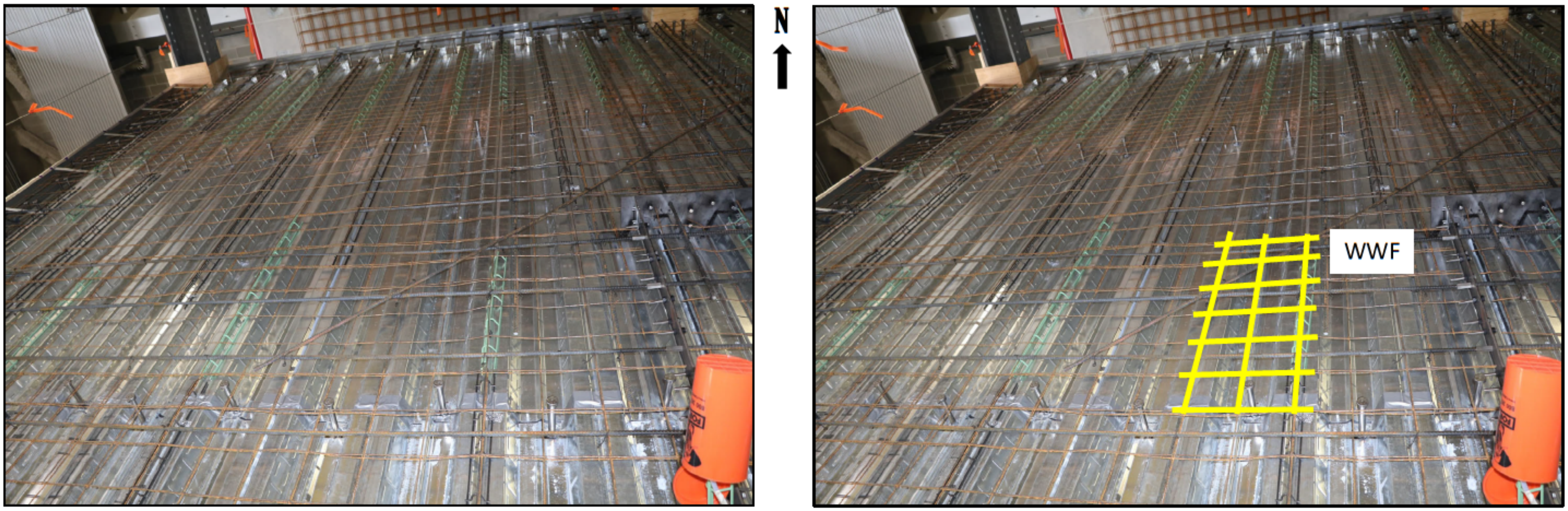


Figure 6.4.12: **Construction photo of the northwest corner of the test frame showing the WWR mesh used as shrinkage reinforcement in the concrete slab.**

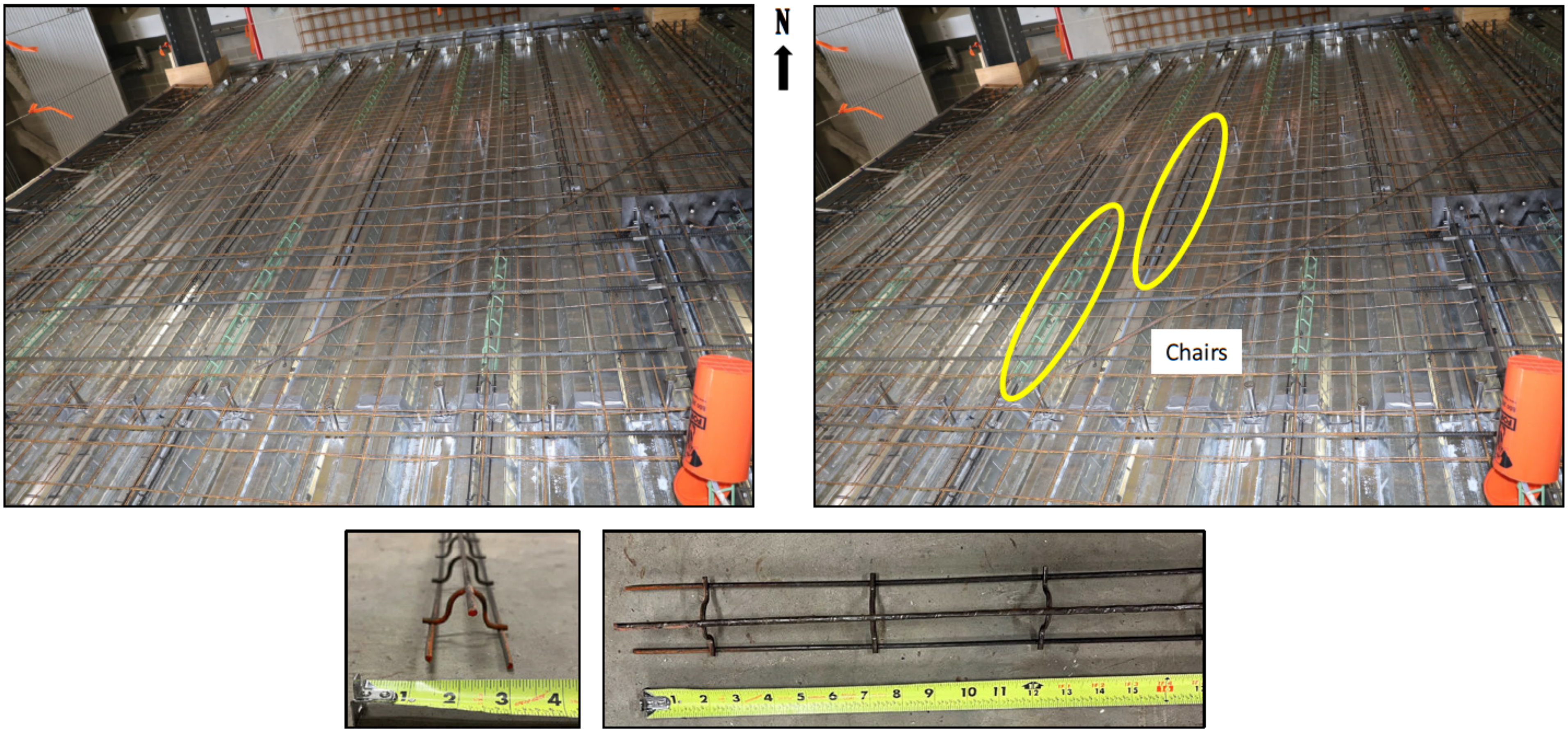


Figure 6.4.13: Construction photo of the northwest corner of the test frame showing the location of the rebar chairs – green were coated and black were uncoated.

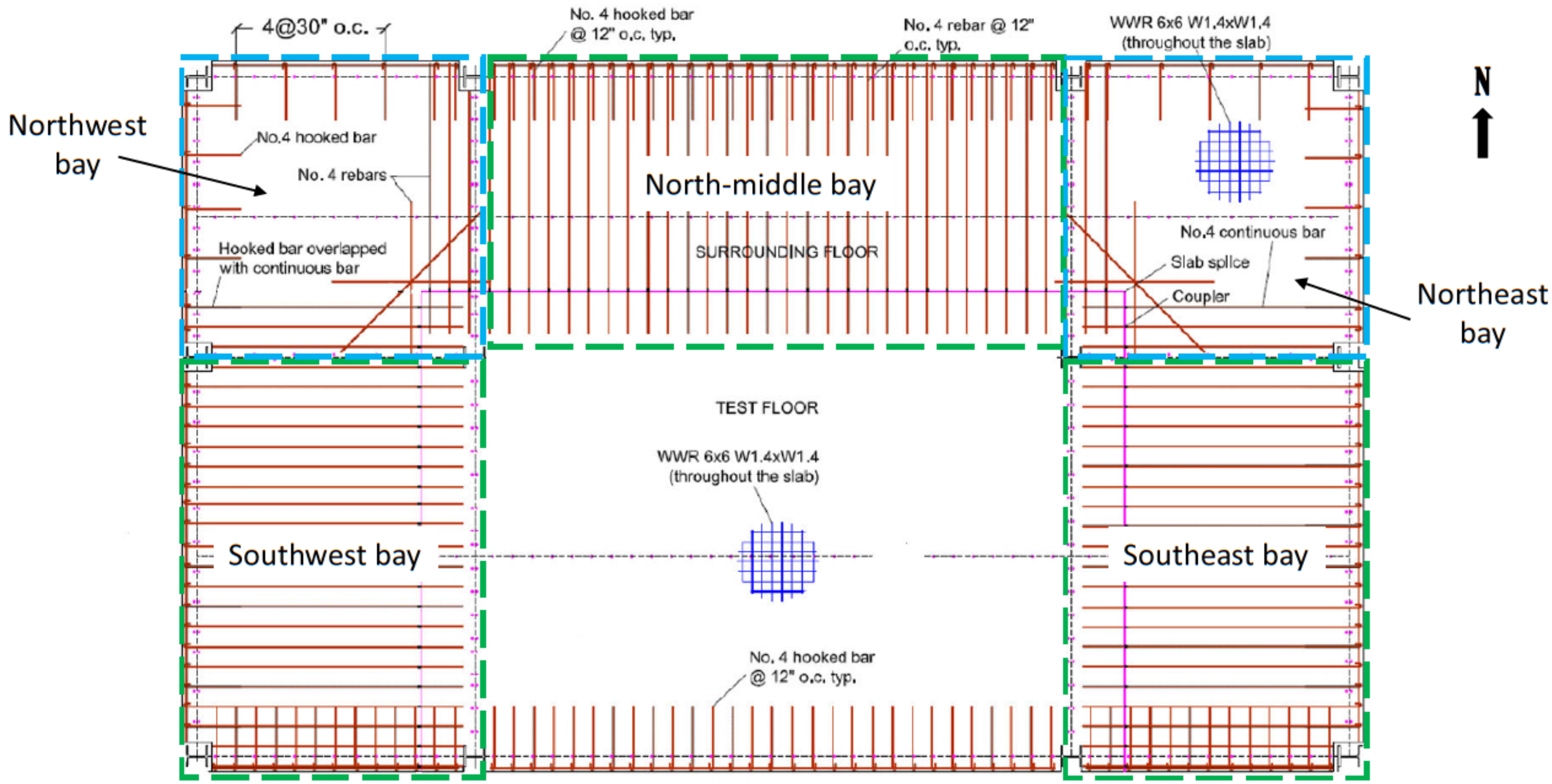


Figure 6.4.14: Steel reinforcement layout for the first floor for the CF1 Test.

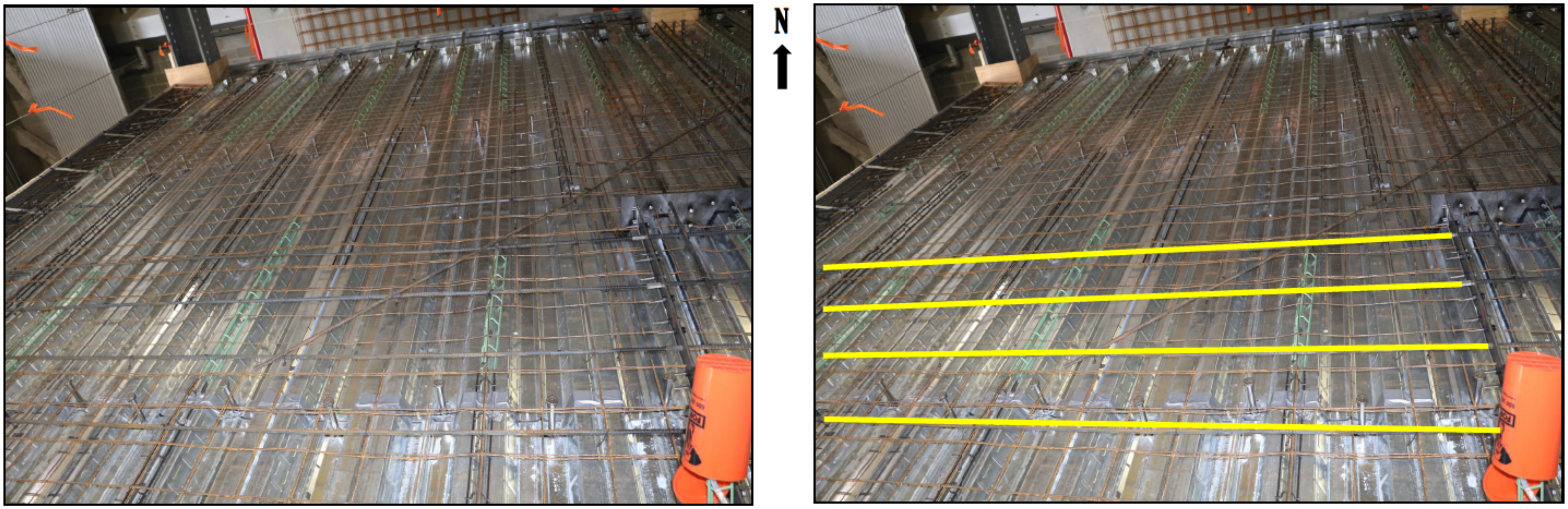


Figure 6.4.15: Construction photo of the northwest corner of the test frame showing the location of the continuous No. 4 rebar in the southwest bay.

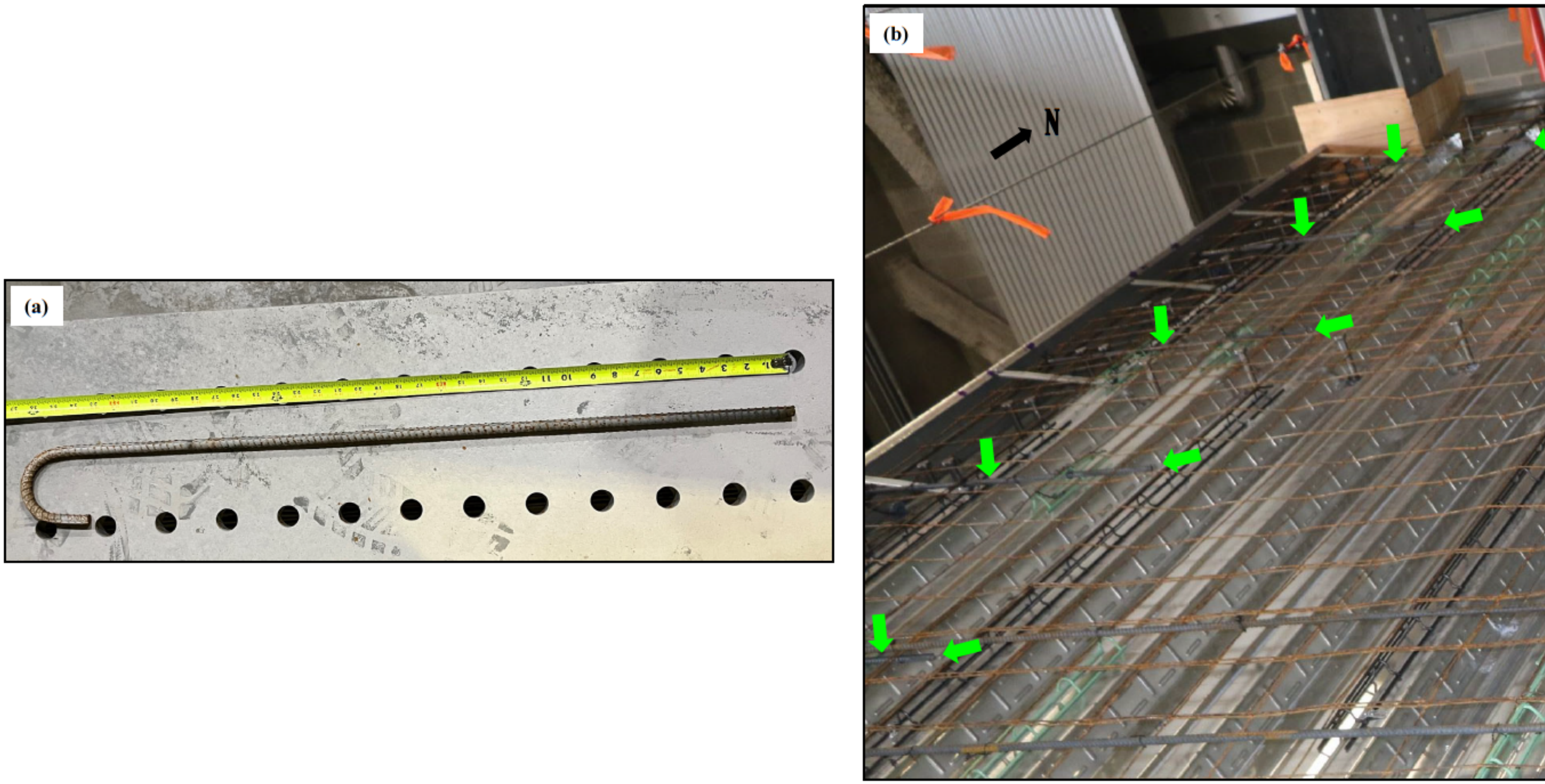


Figure 6.4.16: (a) Image of short, hooked No. 4 rebars used at the perimeter of the bays and (b) Construction photo of the northwest corner of the test frame showing the location hooked rebar.

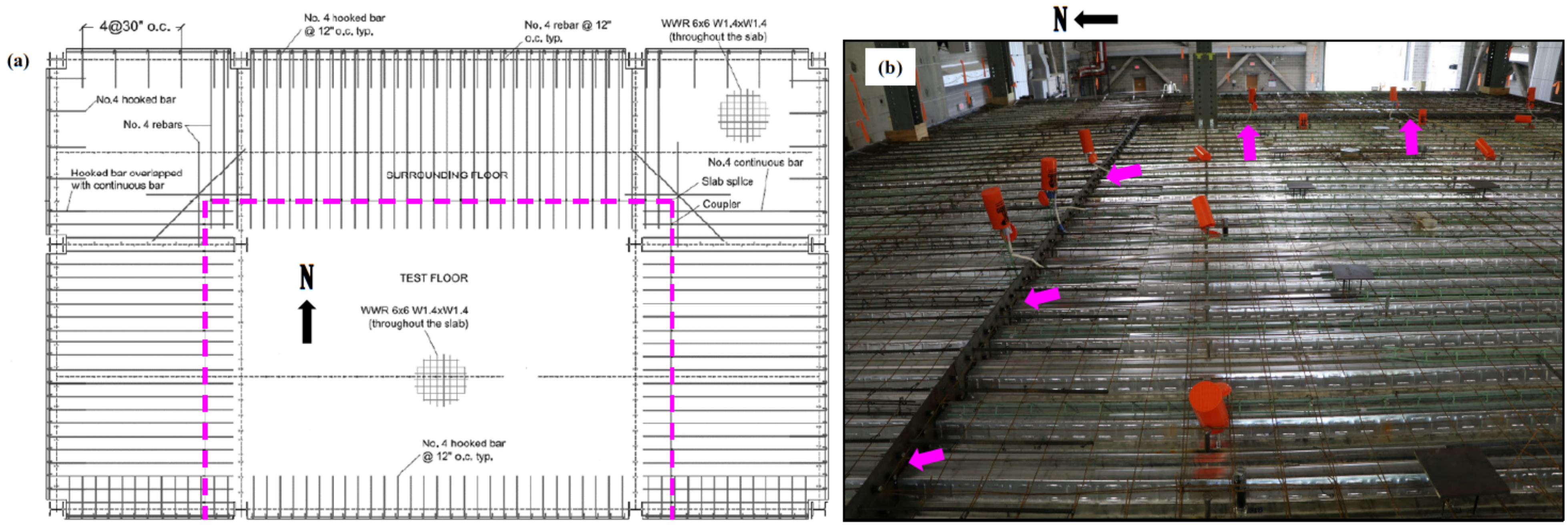


Figure 6.4.17: (a) Image showing the slab splice (pink dashed line) and (b) Construction photo showing the slab splice prior to the first concrete pour.

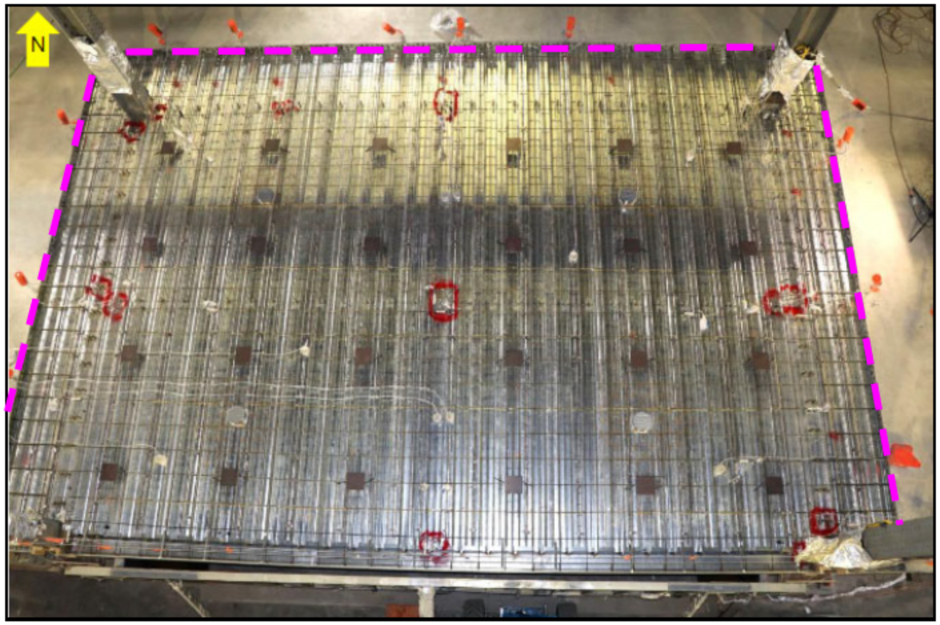


Figure 6.4.18: Construction photo showing the rebuilt test floor prior to the concrete pour for CF2. The fire-tested floor for CF1 was demolished back to the slab splice, without affecting the surrounding floor.

Figure 6.4.19: Overall view of the composite floor prior to concrete pour.

Figure 6.4.20: Construction image showing the concrete decking installation.

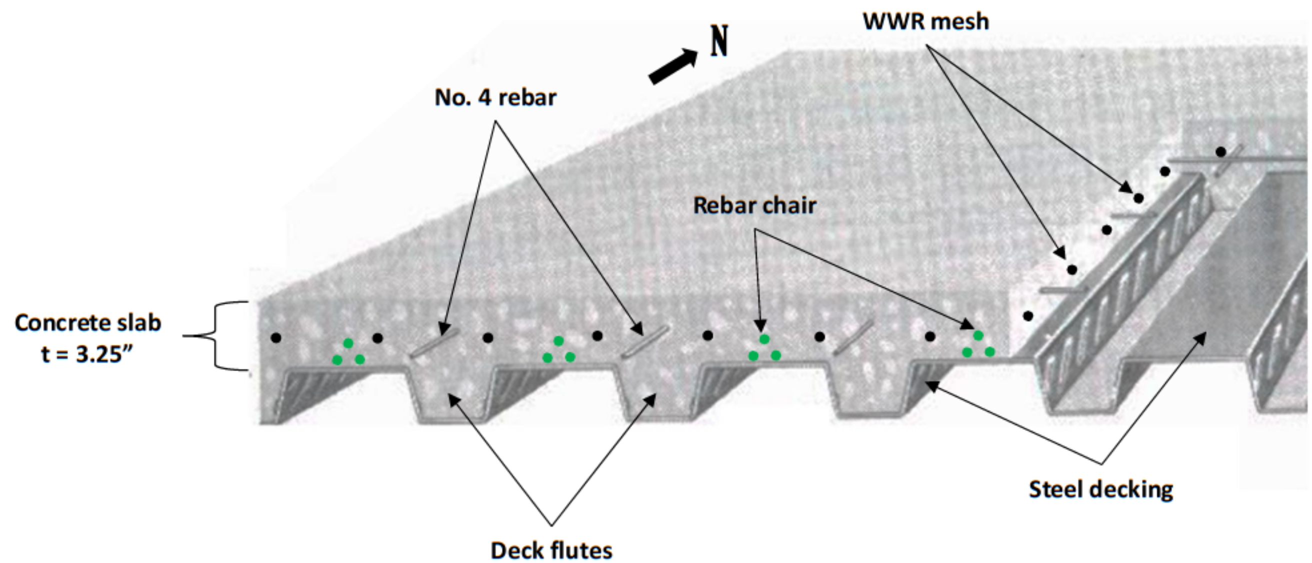


Figure 6.4.21: Representative diagram showing the cross-section of the composite steel deck-concrete floor system, not to scale.

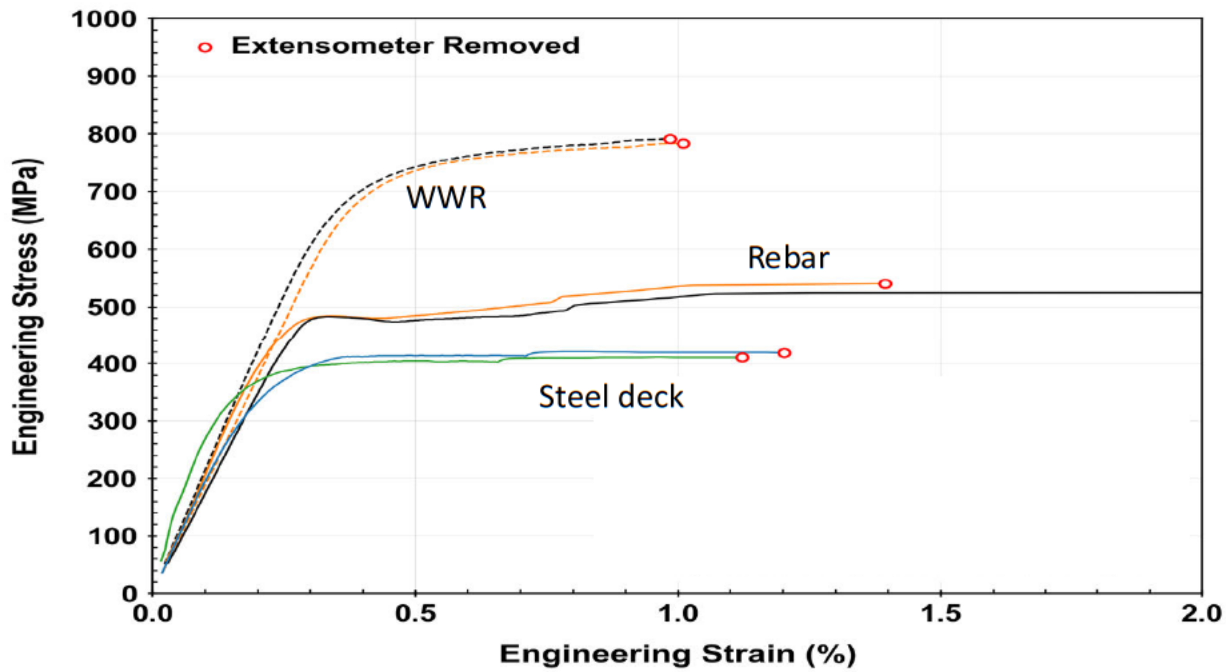


Figure 6.4.22: Engineering stress-strain relationships of steels used in the construction of the composite steel deck-concrete floor slabs.

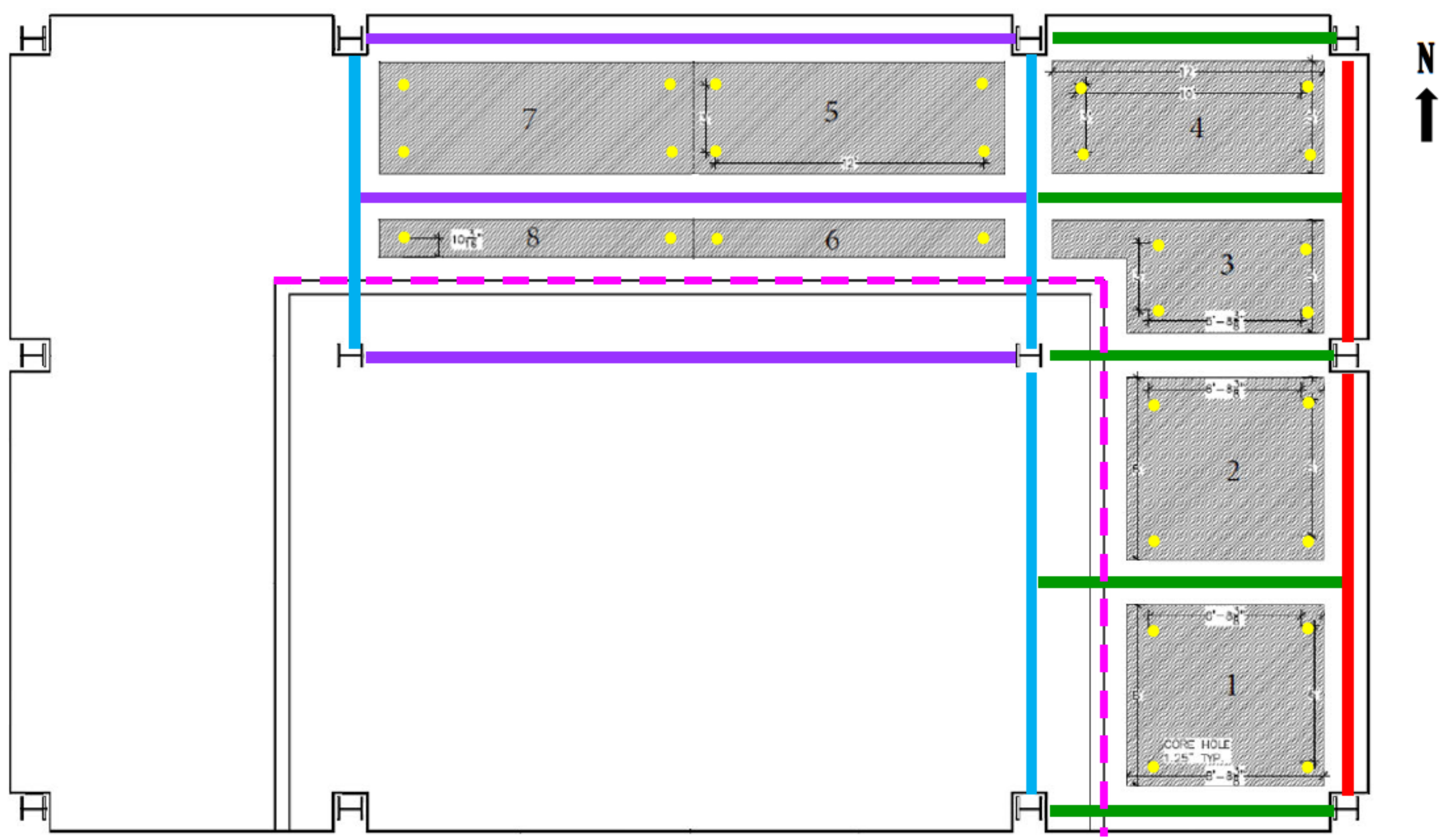


Figure 6.5.1: Coring and cutting diagram from ENGR TECH 1 with the locations of the structural steel girders (blue and red) and beams (purples and green) superimposed on the diagram. Also shown is the floor splice plate (dashed pink) and coring holes (yellow dots).

Figure 6.6.1: Stock image of Husqvarna floor saw Model FS400LV.

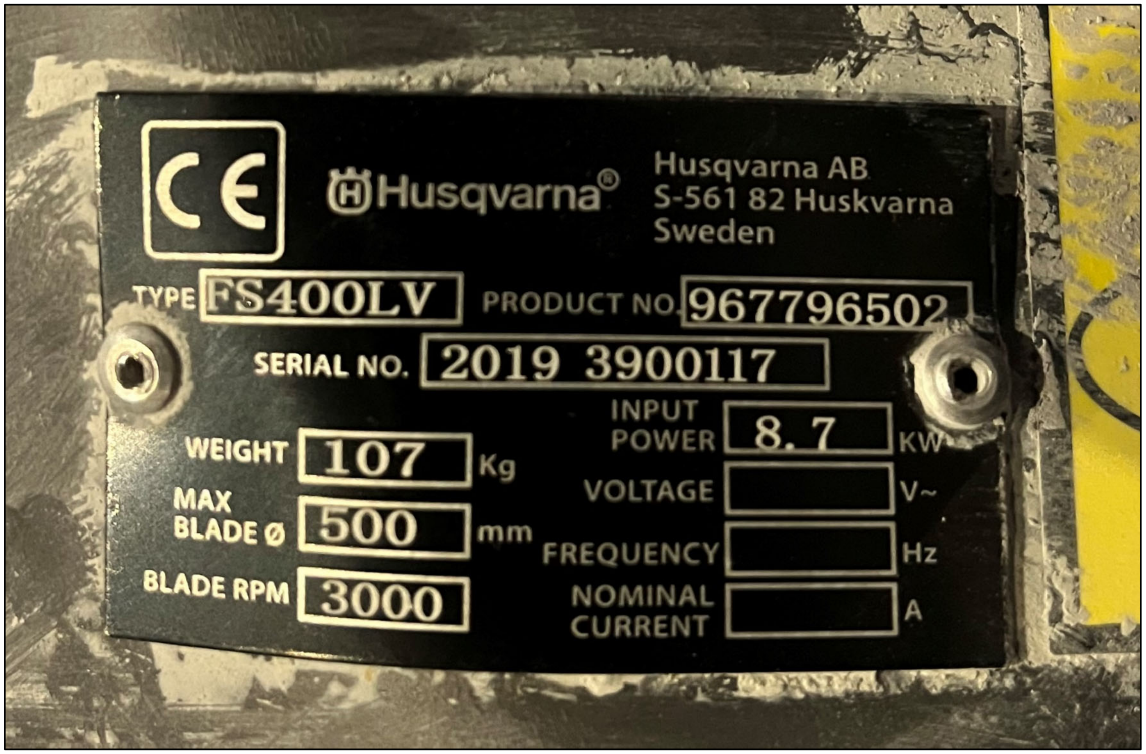


Figure 6.6.2: Information plate on the Husqvarna floor saw used during the incident.

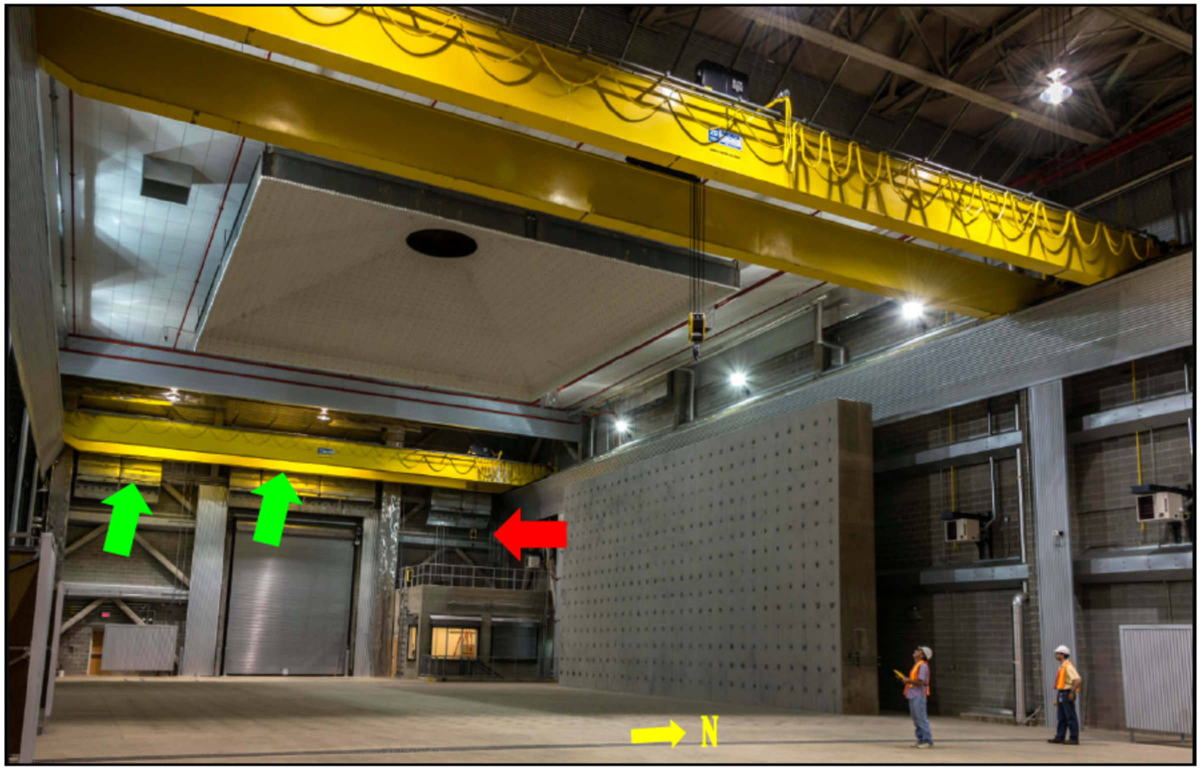


Figure 6.6.3: Image showing the two 20-ton overhead cranes in Room 125. The crane in the background was in operation at the time of the incident (green arrows indicate the double girder bridges and the red arrow shows the hook).

Figure 6.6.4: Crane remote used for the 20-ton overhead cranes in Room 125.

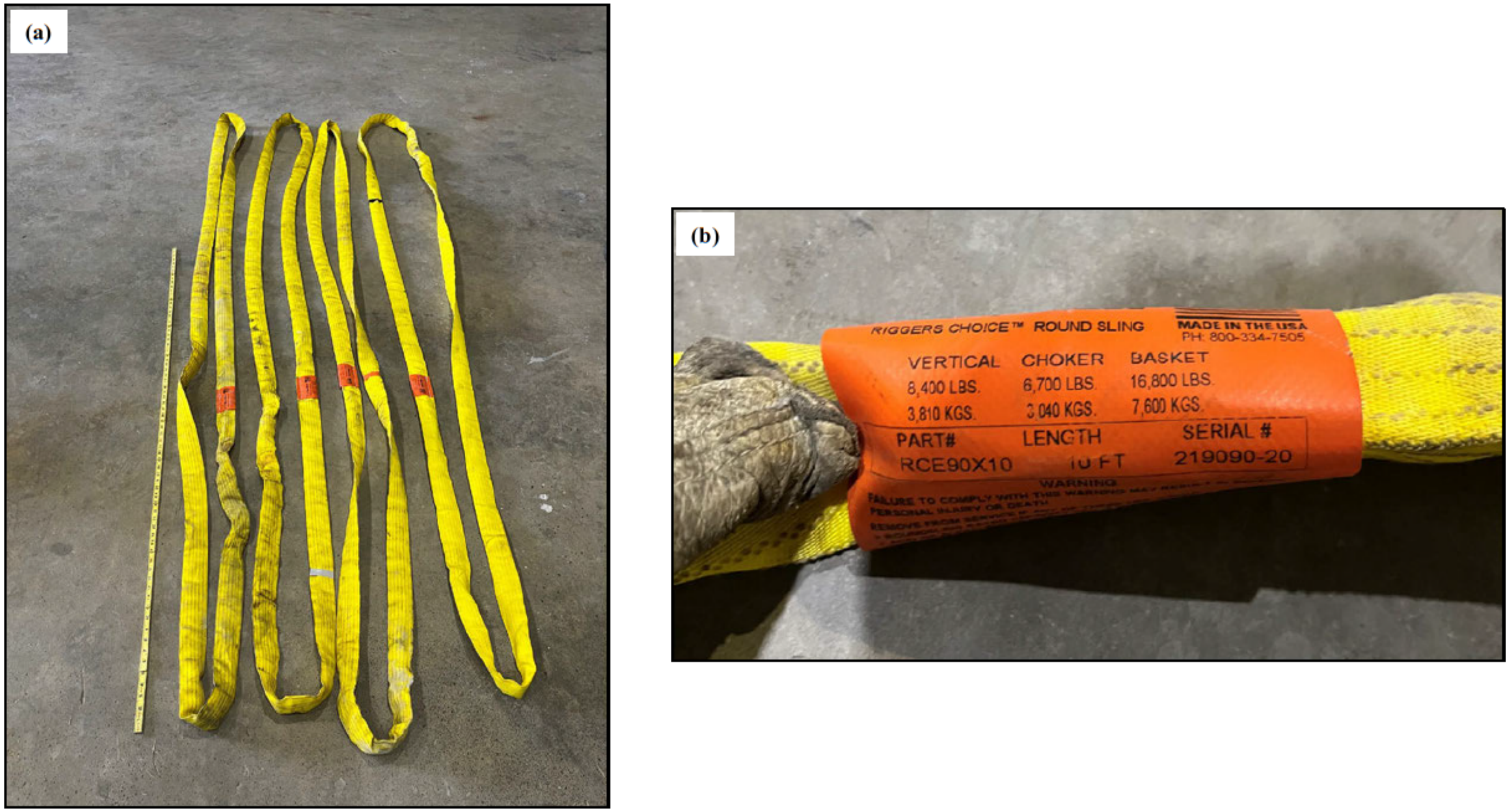


Figure 6.6.5: (a) Rigging slings used during the slab cutting and lifting process. (b) Typical label found on each sling.

Figure 6.6.6: Rigging hardware assembly used to attach the rigging slings to the concrete slab. This specific set was attached to the northeast corner of Slab 4.

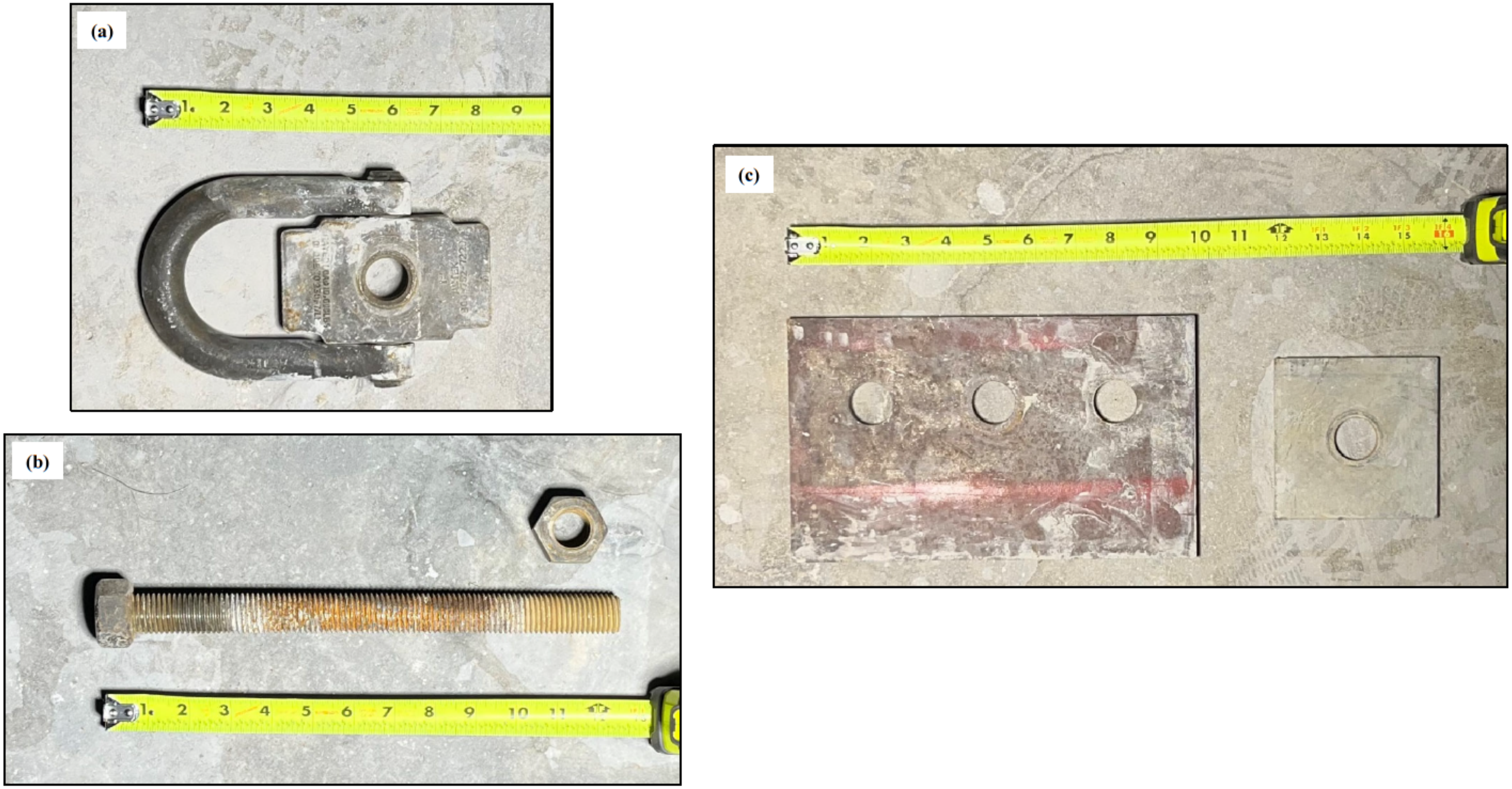


Figure 6.6.7: Images of the washers used as part of the rigging hardware. (a) Pivot lifting plate, (b) Threaded bolt with nuts, and (c) Two steel plates used as washers.

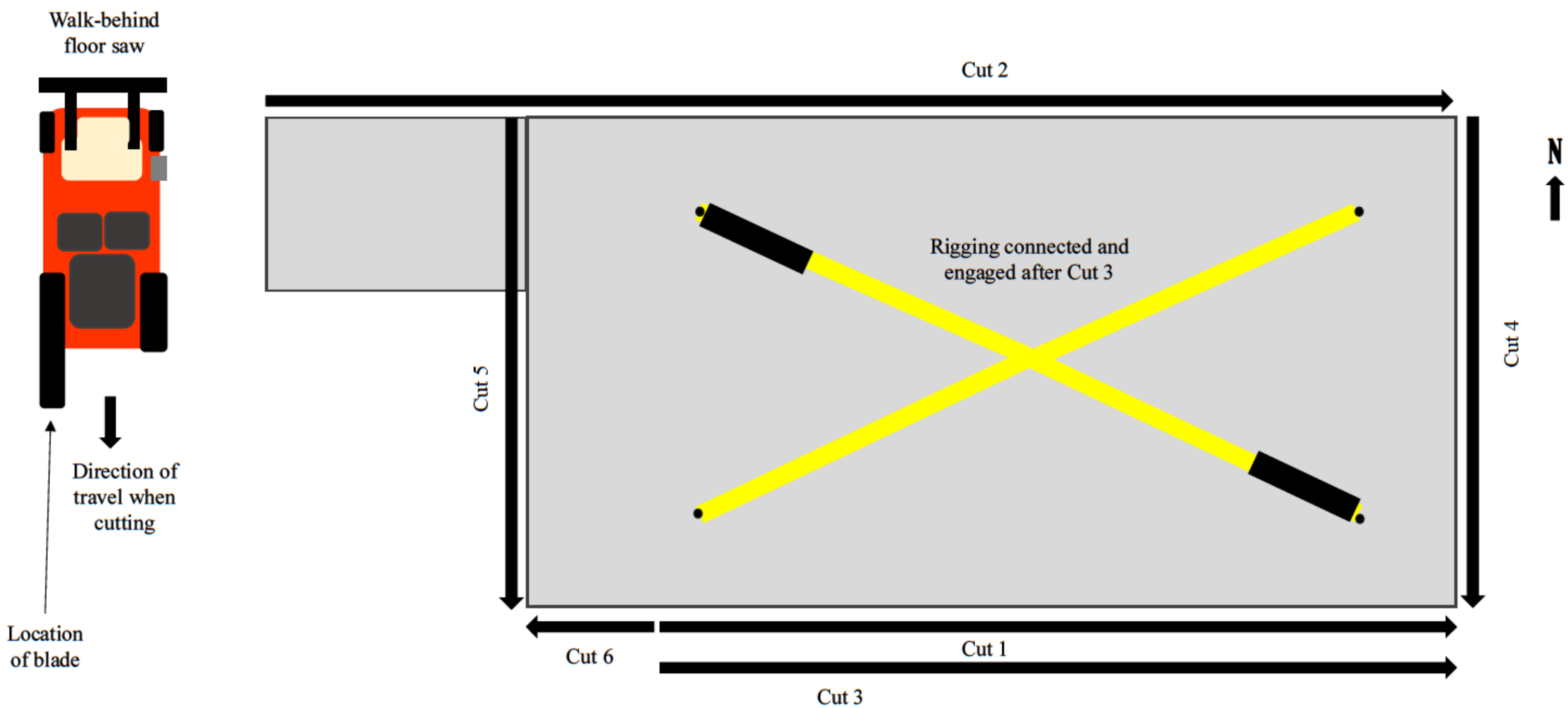


Figure 6.7.1: Schematic of Slab 3 showing the cutting and rigging sequence. The lengths of the cuts are approximate. It is unknown when the south and west faces of the tab was cut. The walk-behind floor saw (roughly to scale) is shown to help the Reader understand when the weight of the saw is on the slab while cutting.

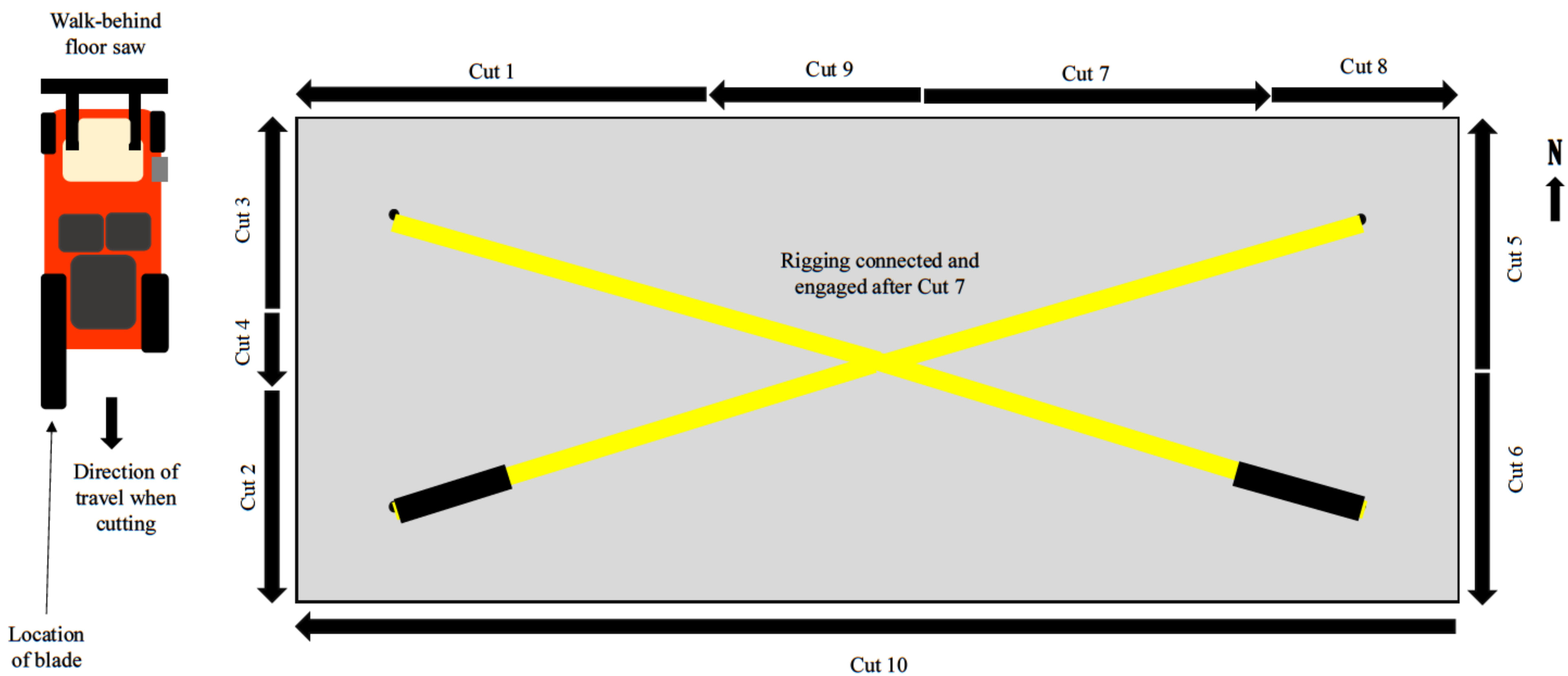


Figure 6.7.2: Schematic of Slab 4 showing the cutting and rigging sequence. The lengths of the cuts are approximate. The walk-behind floor saw (roughly to scale) is shown to help the Reader understand when the weight of the saw is on the slab while cutting.

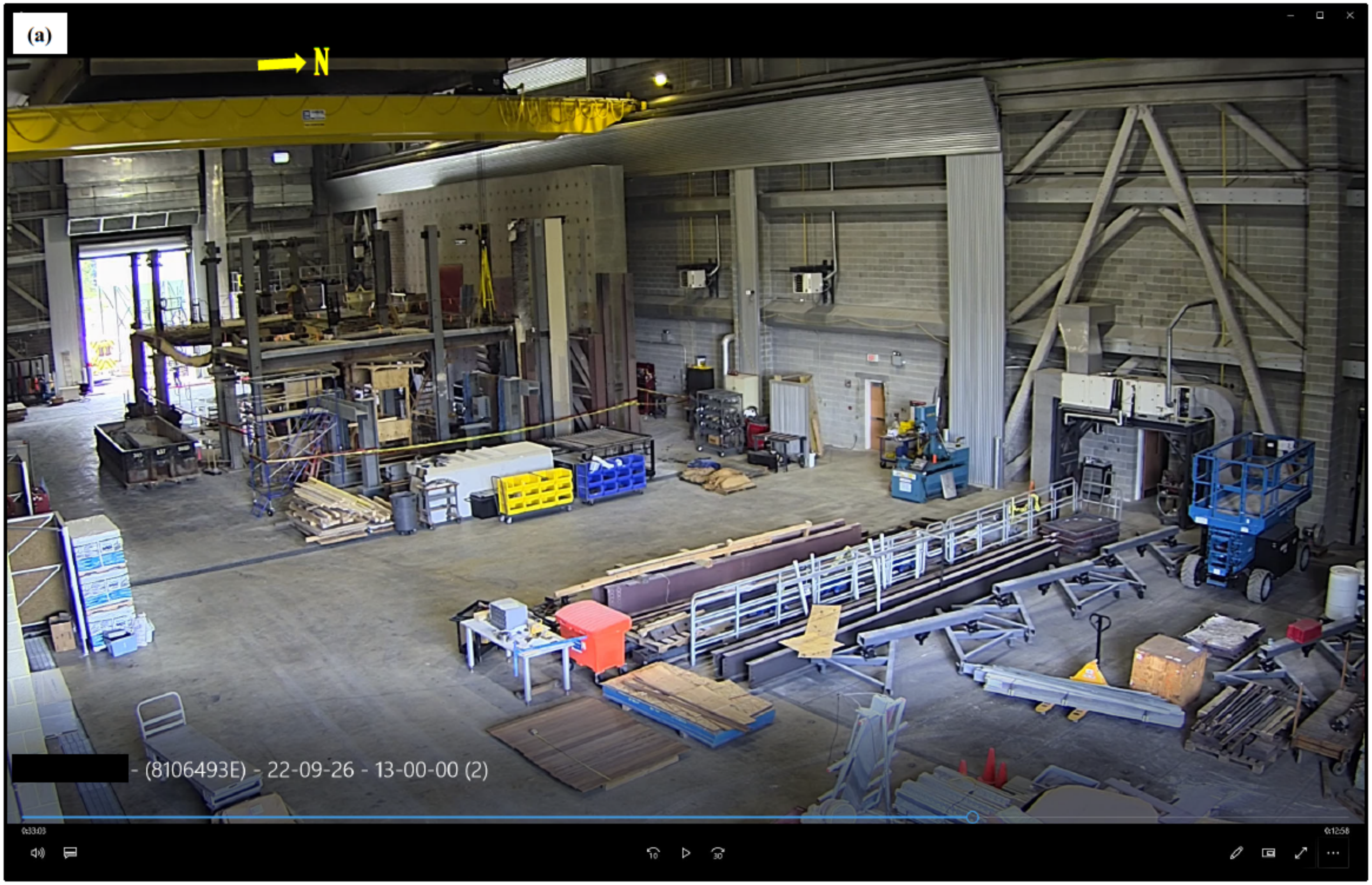


Figure 6.8.1: Image captured from video evidence showing the incident site shortly after the incident occurred. (a) From CAMERA 2 located in the southeast corner of Room 125 looking northwest (September 26 at 1:33:03 pm ET).

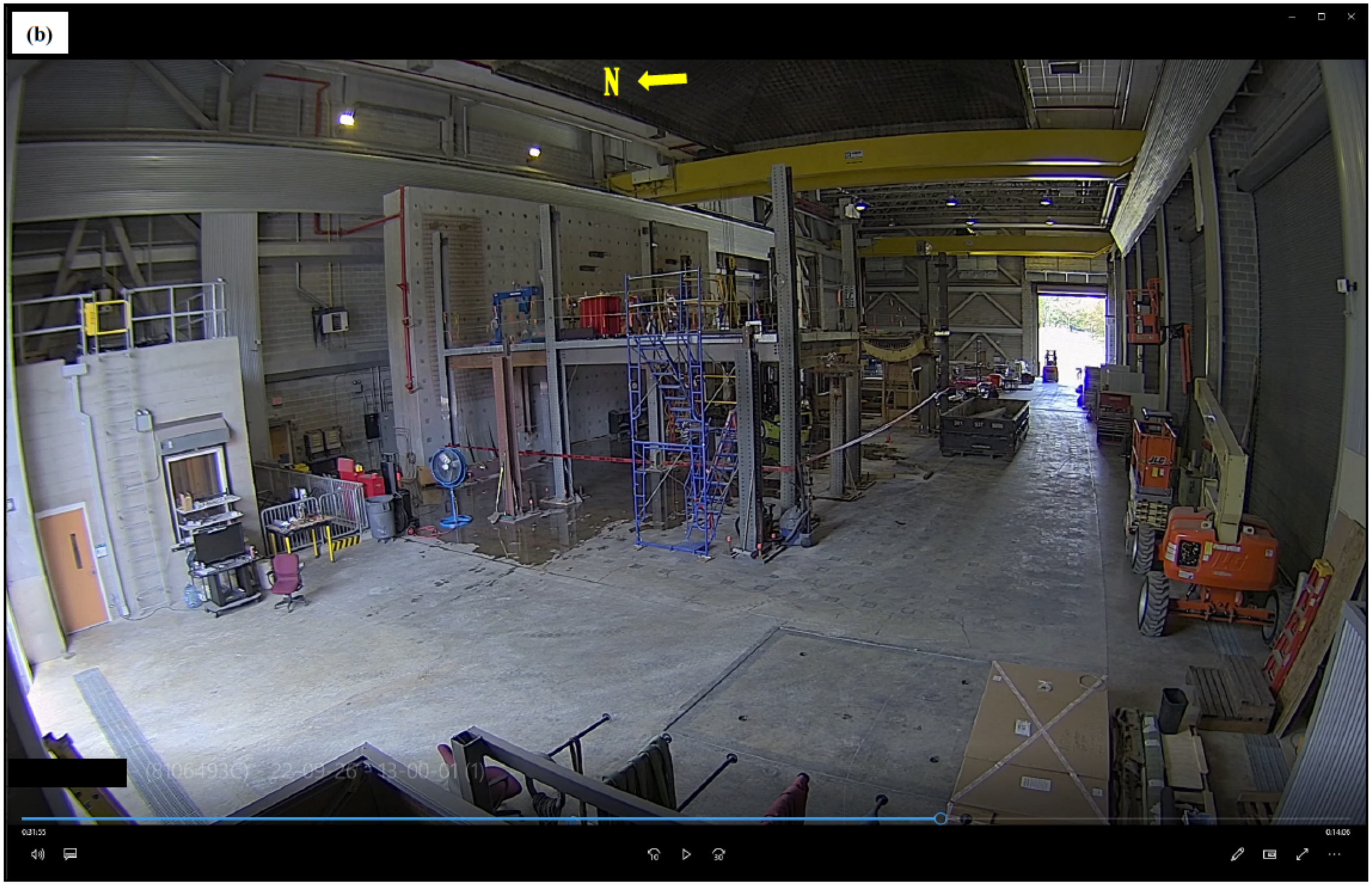


Figure 6.8.1 (cont.): Image captured from video evidence showing the incident site shortly after the incident occurred. (b) From CAMERA 1 located in the southwest corner of Room 125 looking northeast (September 26 at 1:31:55 pm ET).

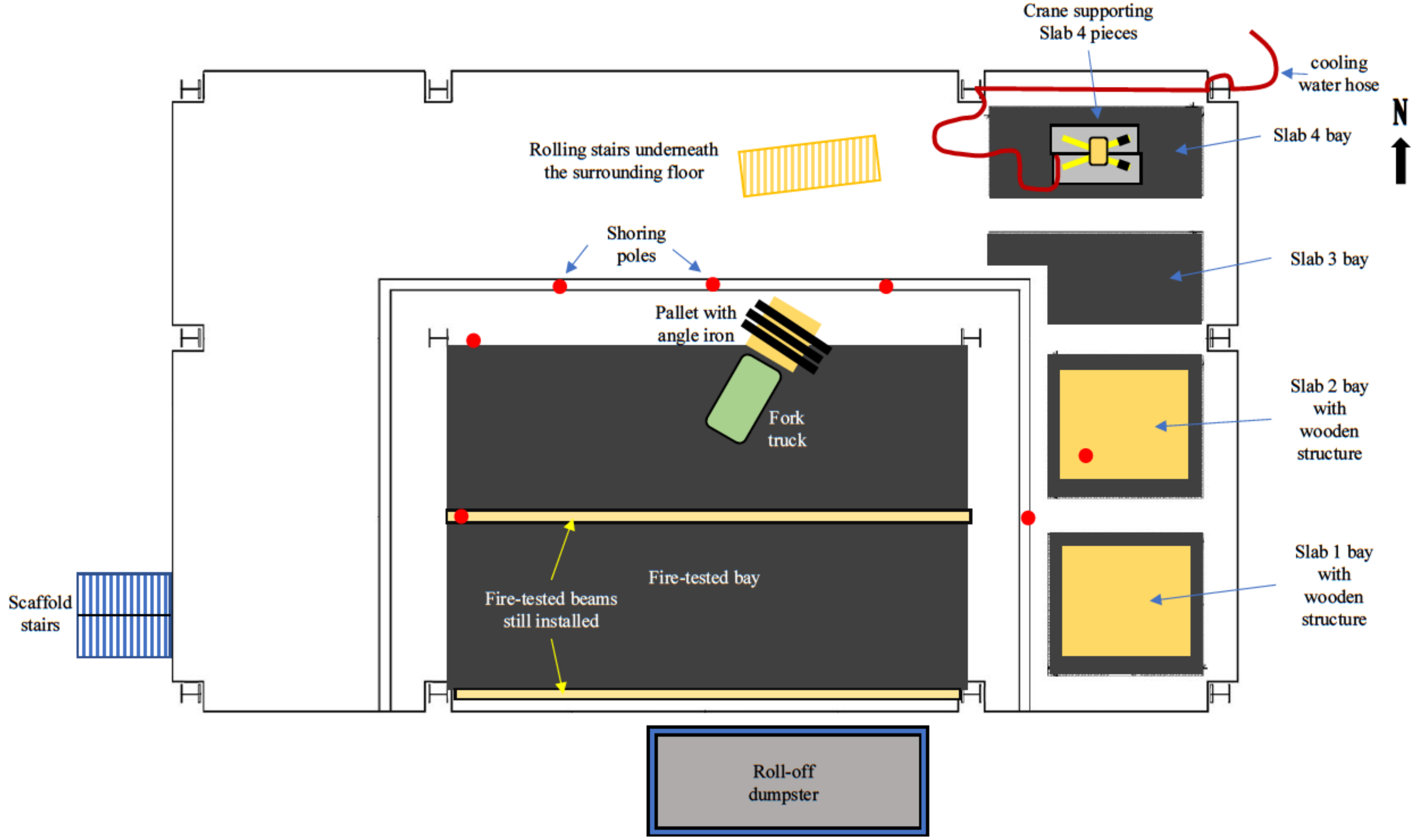


Figure 6.8.2: Diagram of the CF Project test frame showing the location of various items.

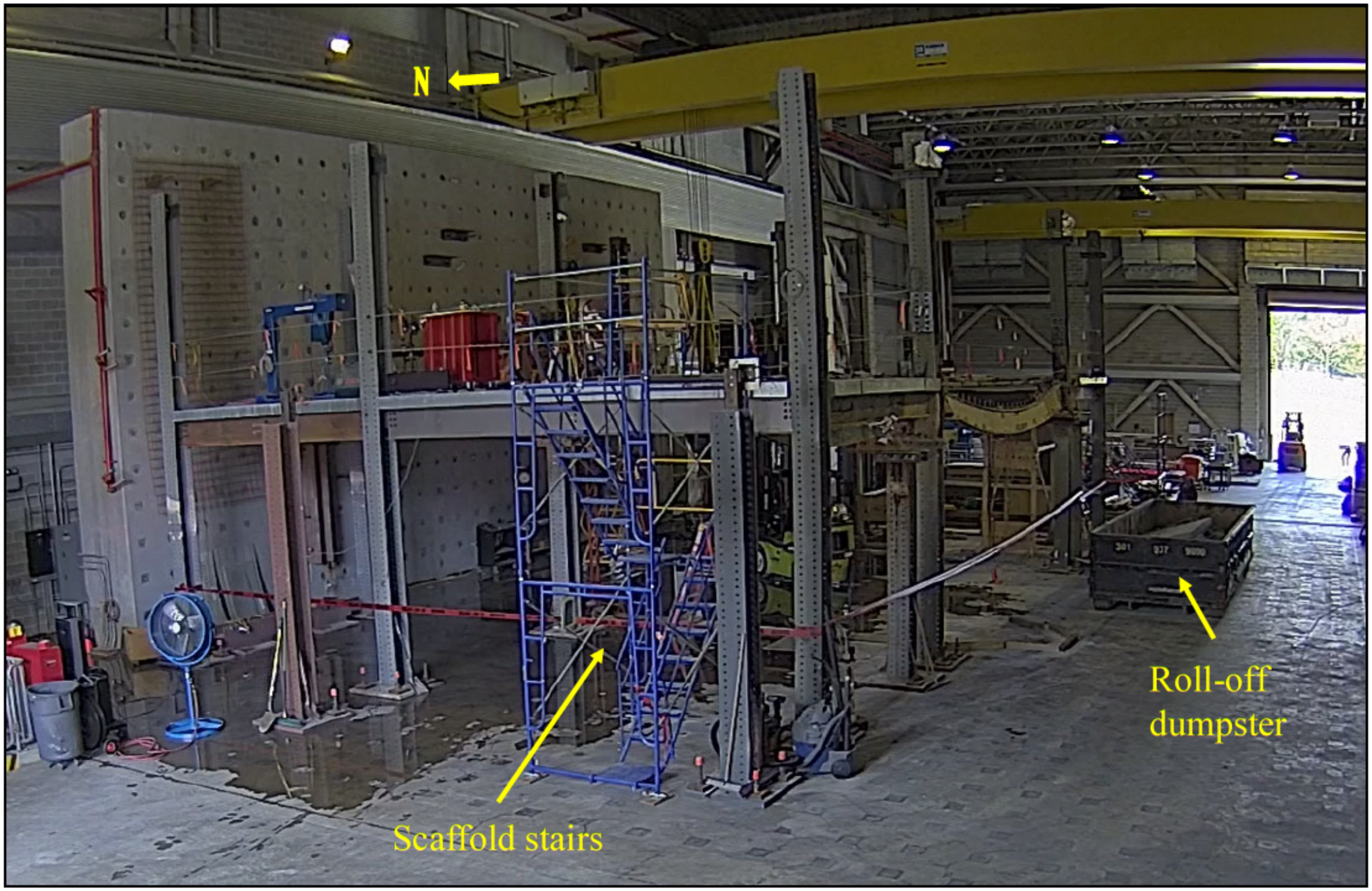


Figure 6.8.3: Image of the roll-off dumpster to the south of the CF Project test frame and the scaffold stairs on the SW corner.

Figure 6.8.4: Image of the test frame showing the fire-tested composite floor and fire compartment have been demolished. Only the two beams running E-W remain of the test floor. Image was taken looking NW.

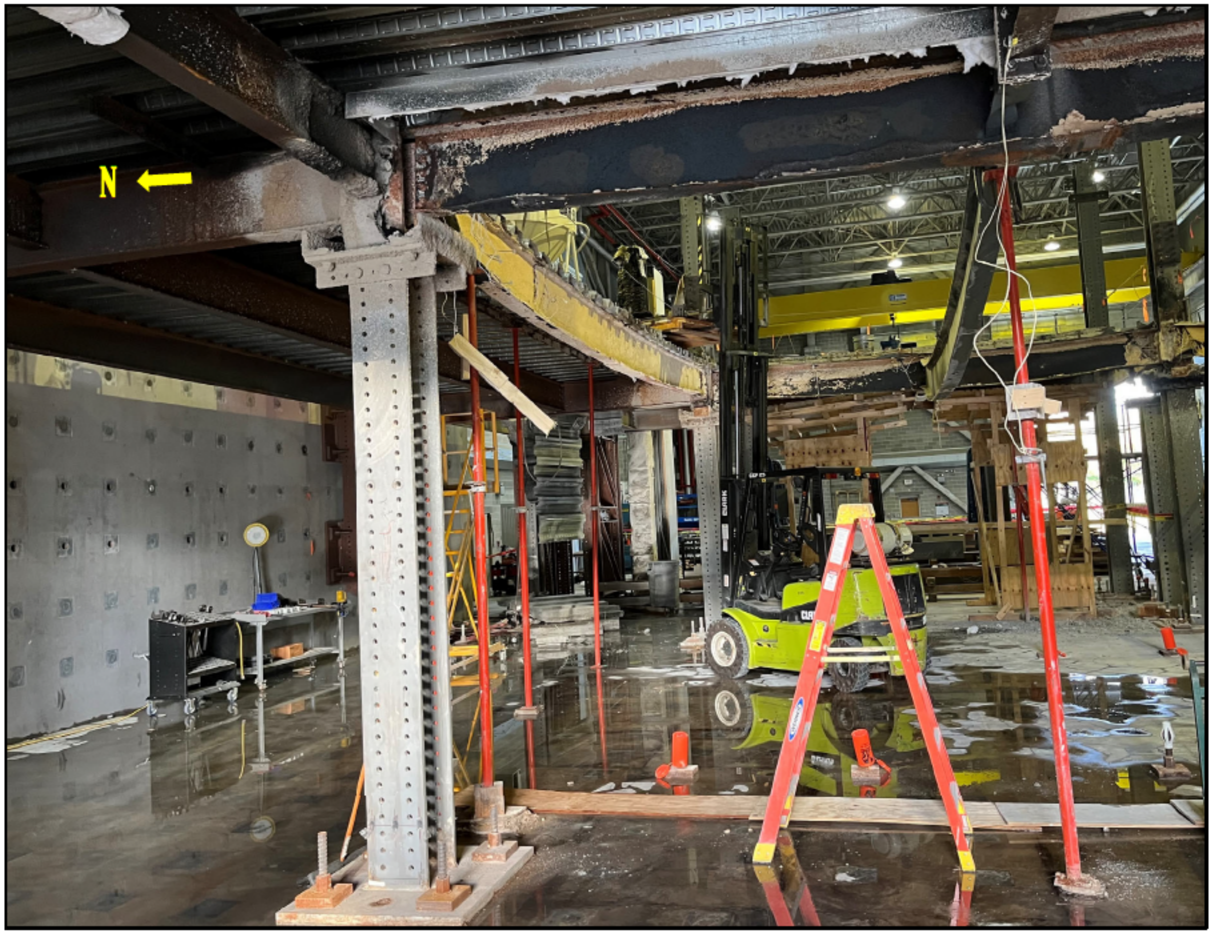


Figure 6.8.5: Image showing the fork truck with elevated load, water on the strong floor, and shoring poles (reddish orange) underneath the surrounding floor. Image taken looking east.

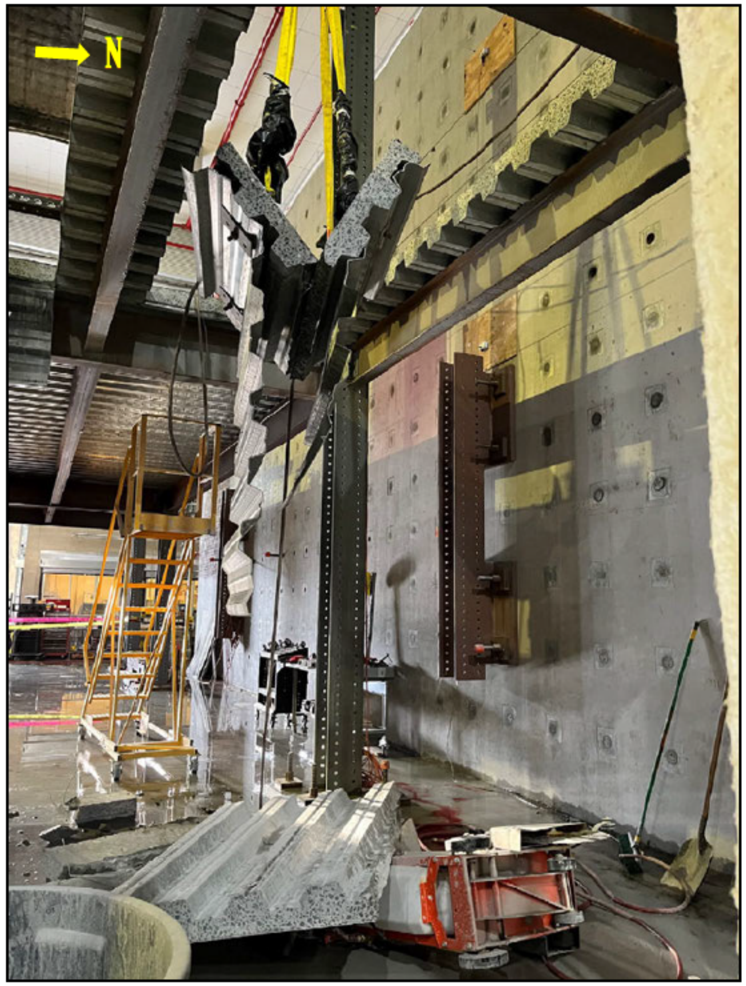


Figure 6.8.6: Image of the suspended concrete debris following the incident. The pile of concrete pieces and floor saw are observed directly below the suspended debris, with the rolling stairs in the background. Image was taken looking west.

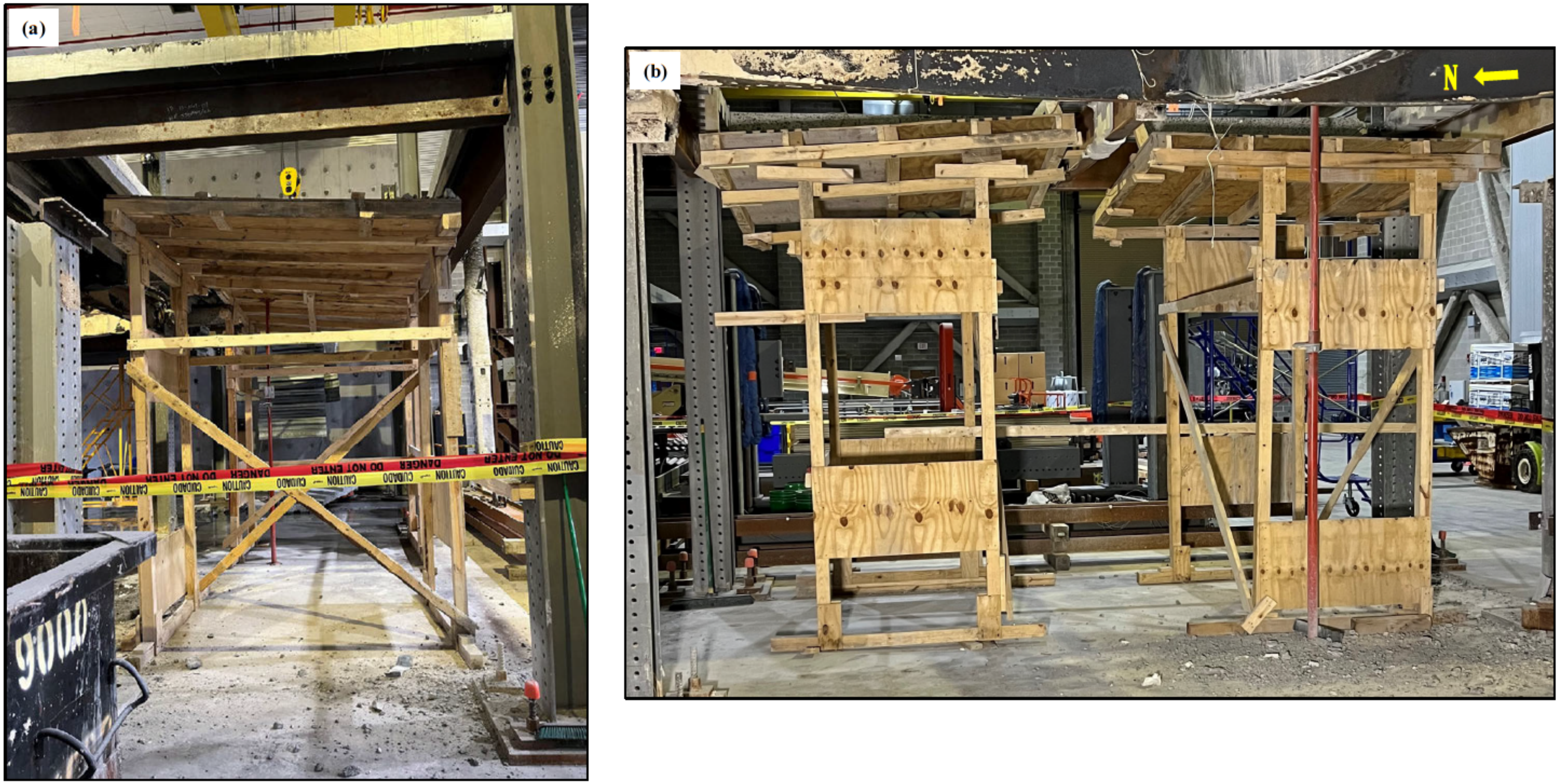


Figure 6.8.7: Image of the wooden structures positioned beneath the two southernmost cut bays (Slabs 1 and 2). (a) Image was taken looking north and (b) image was taken looking east.

Figure 6.8.8: Image showing the location of the crane remote on the surrounding floor post-incident.

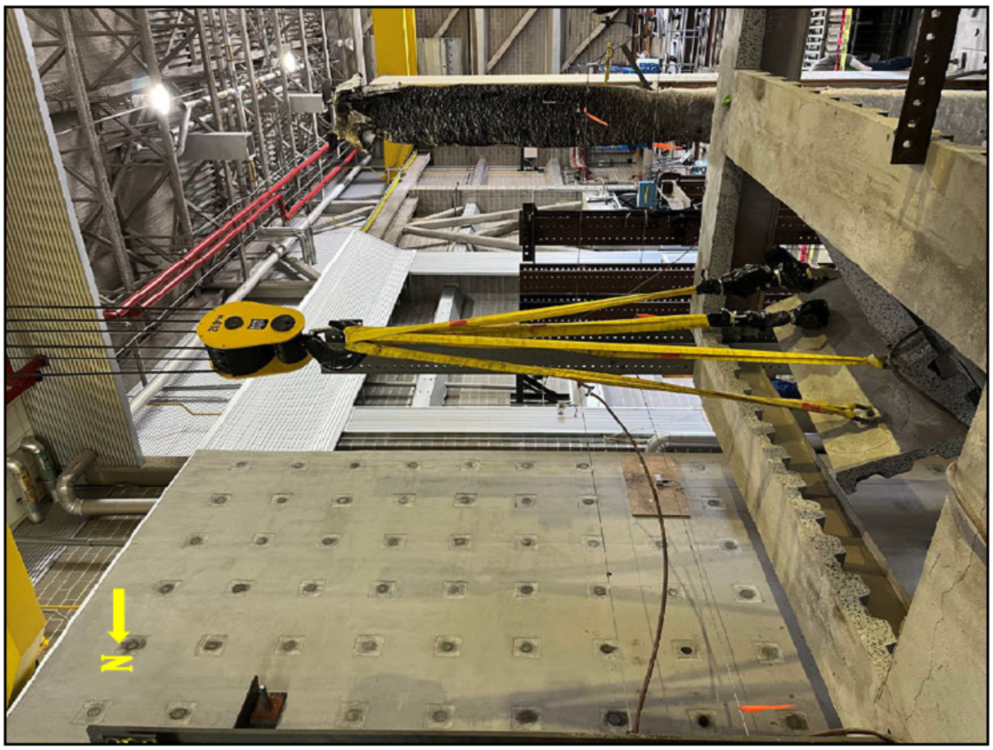


Figure 6.8.9: Post-incident image showing the crane and slings supporting two pieces of the failed slab.

Figure 6.8.10: Post-incident image showing the overlapping of the slings on the crane hook.

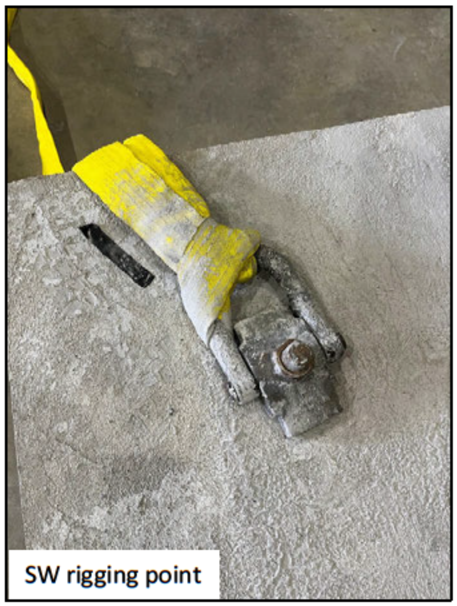


Figure 6.8.11: Images showing the girth hitch configuration of the rigging slings on the pivot lifting plates for Slab 4. Images taken after the suspended Slab 4 pieces were lowered to the strong floor.

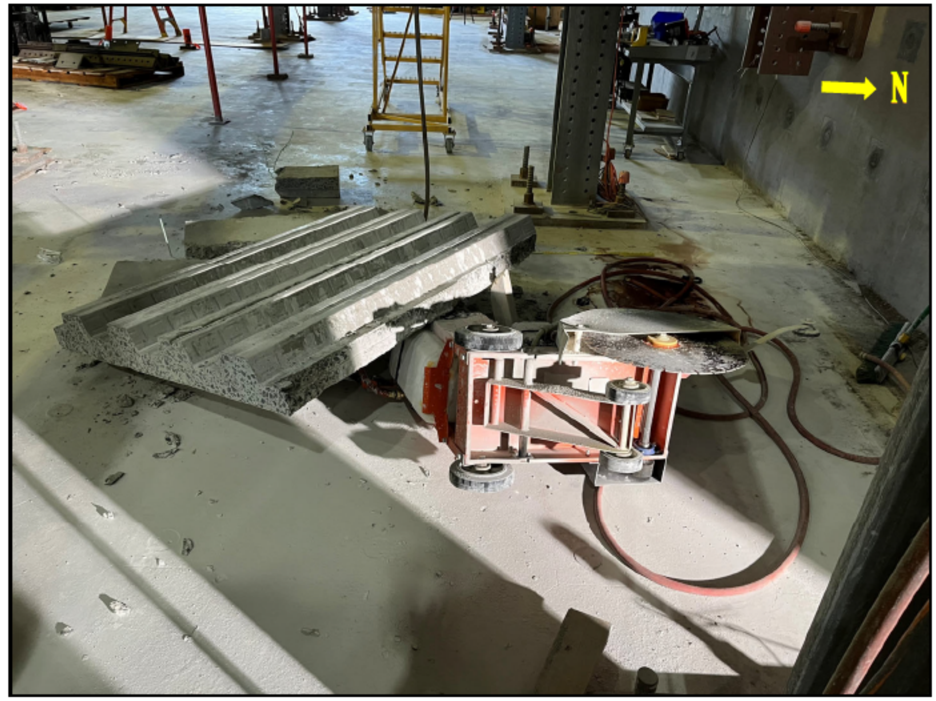


Figure 6.8.12: Husqvarna floor saw trapped under a portion of the collapsed concrete slab.

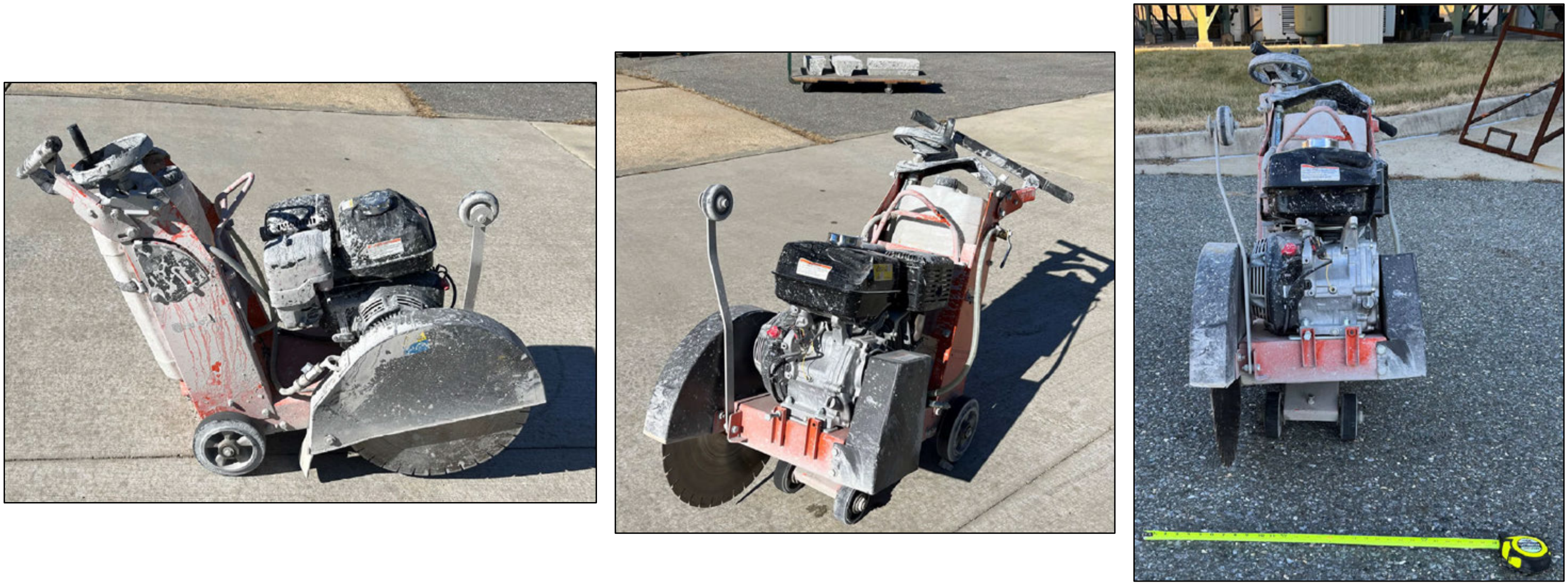


Figure 6.8.13: Husqvarna floor saw Model FS400LV used during the incident.

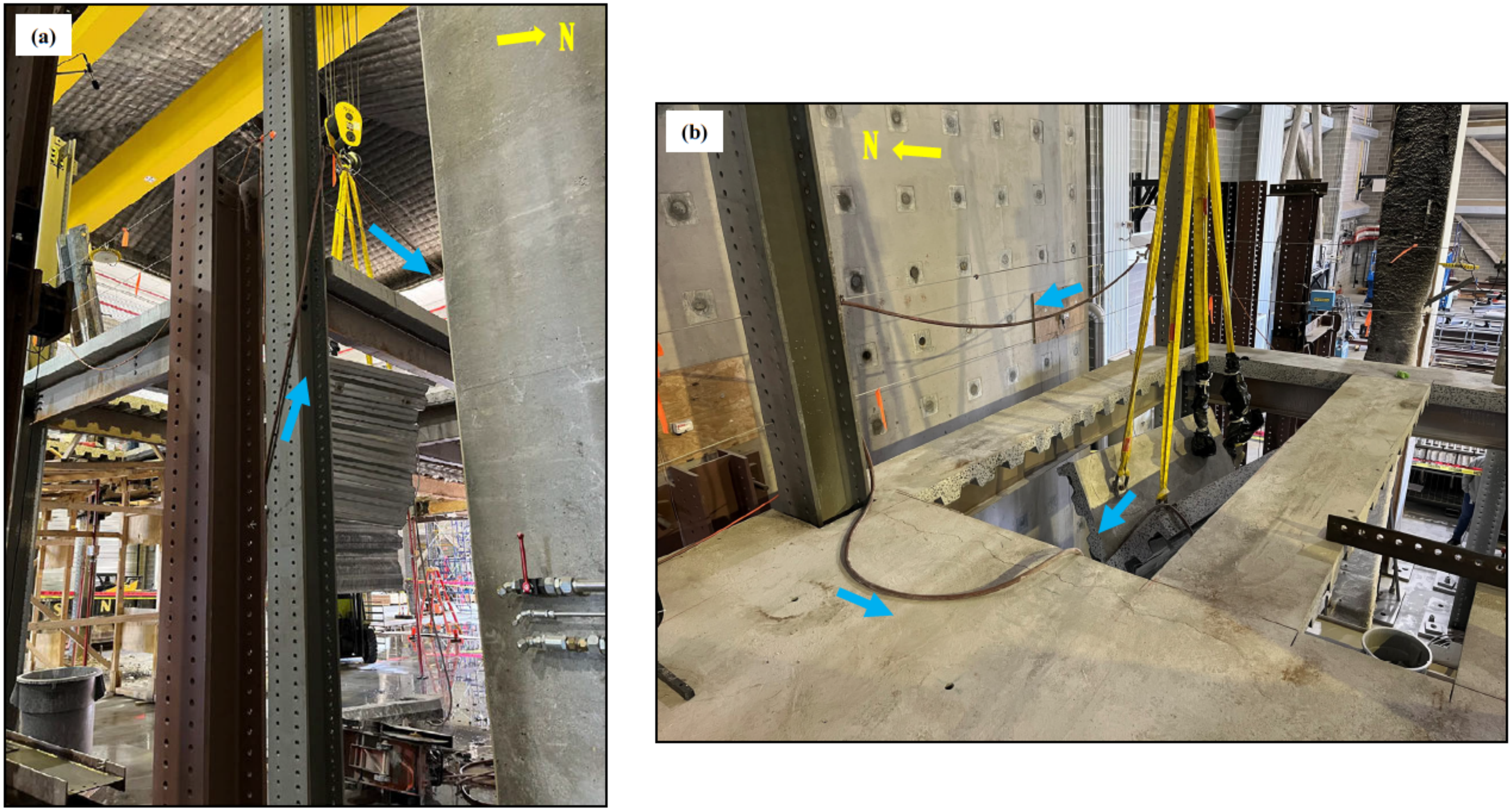


Figure 6.8.14: Positioning of the cooling water hose used to supply water to the floor saw following to the incident. (a) Shows the hose running up the most northeast column of the test frame and secured before running to the west along the north face toward the next column. (b) Shows the hose suspended across the north face of the test frame and secured to two columns. The hose then comes down to rest on the surrounding floor before it goes down towards the strong floor through the cut bay. The blue lines represent the directional flow of water.

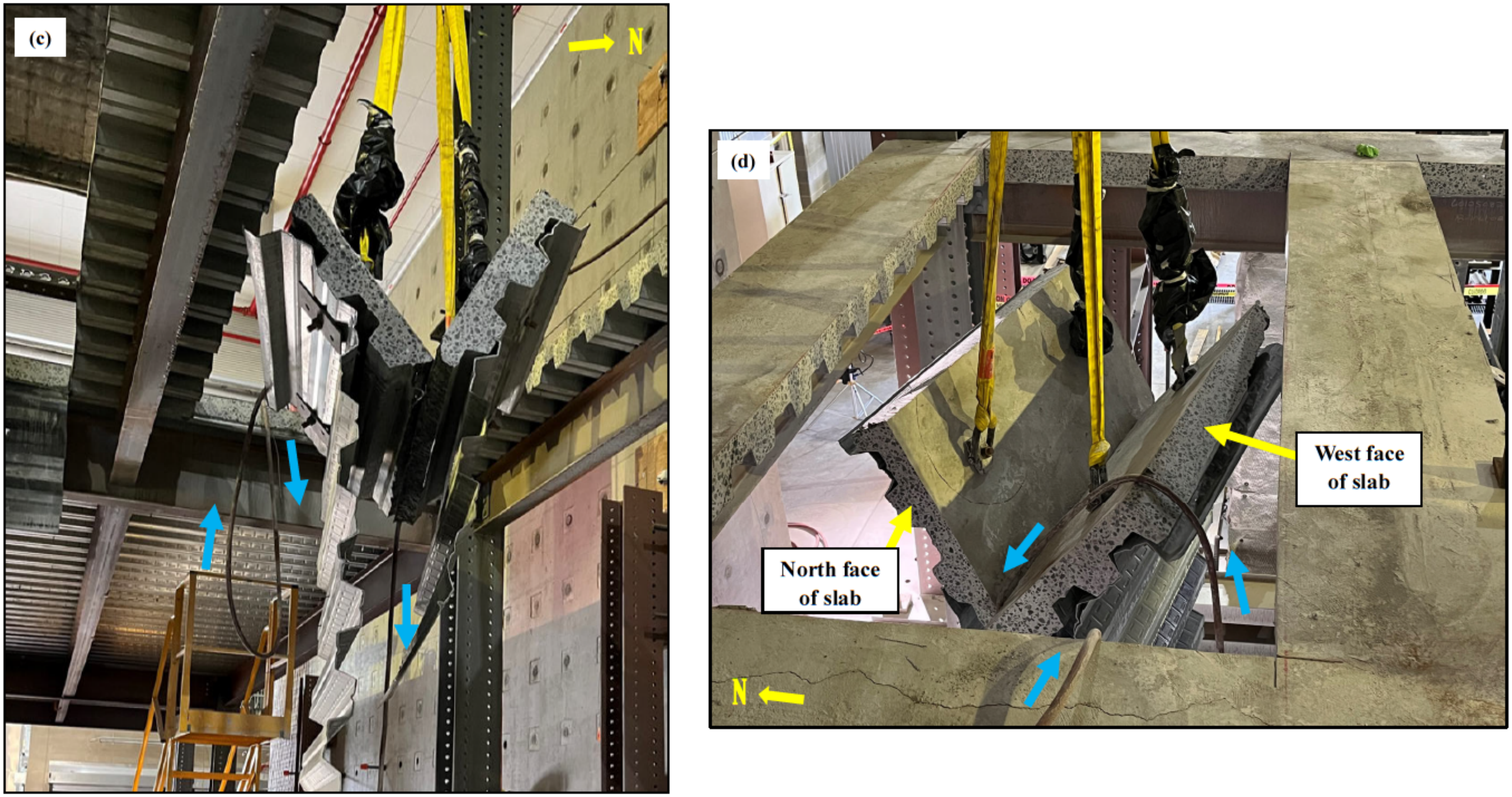


Figure 6.8.14 (cont.): Positioning of the cooling water hose used to supply water to the floor saw following to the incident. (c) Shows the hose looping down in the cut bay and (d) then is draped over the northwest corner of the portion of the cut slab and then back down to the floor saw on the strong floor. The blue lines represent the directional flow of water.

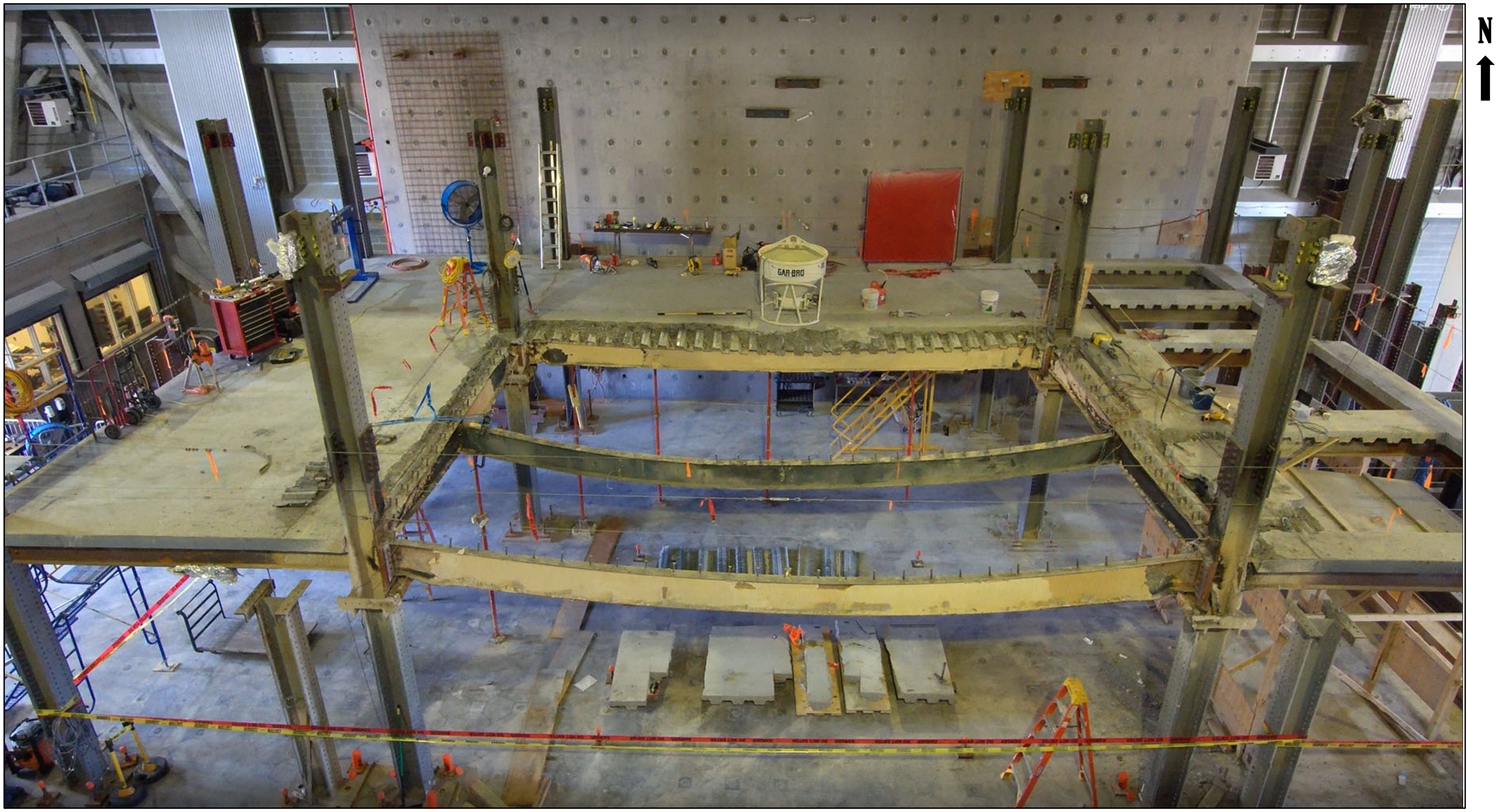


Figure 6.8.15: Overall image (looking north) showing the condition of the test frame. This image was taken after the pieces of Slab 4 were secured and repositioned in a safe manner and the fork truck was moved out of the test frame footprint.

Figure 6.8.16: Images showing the condition of the surrounding floor after the incident. (a) Looking west.

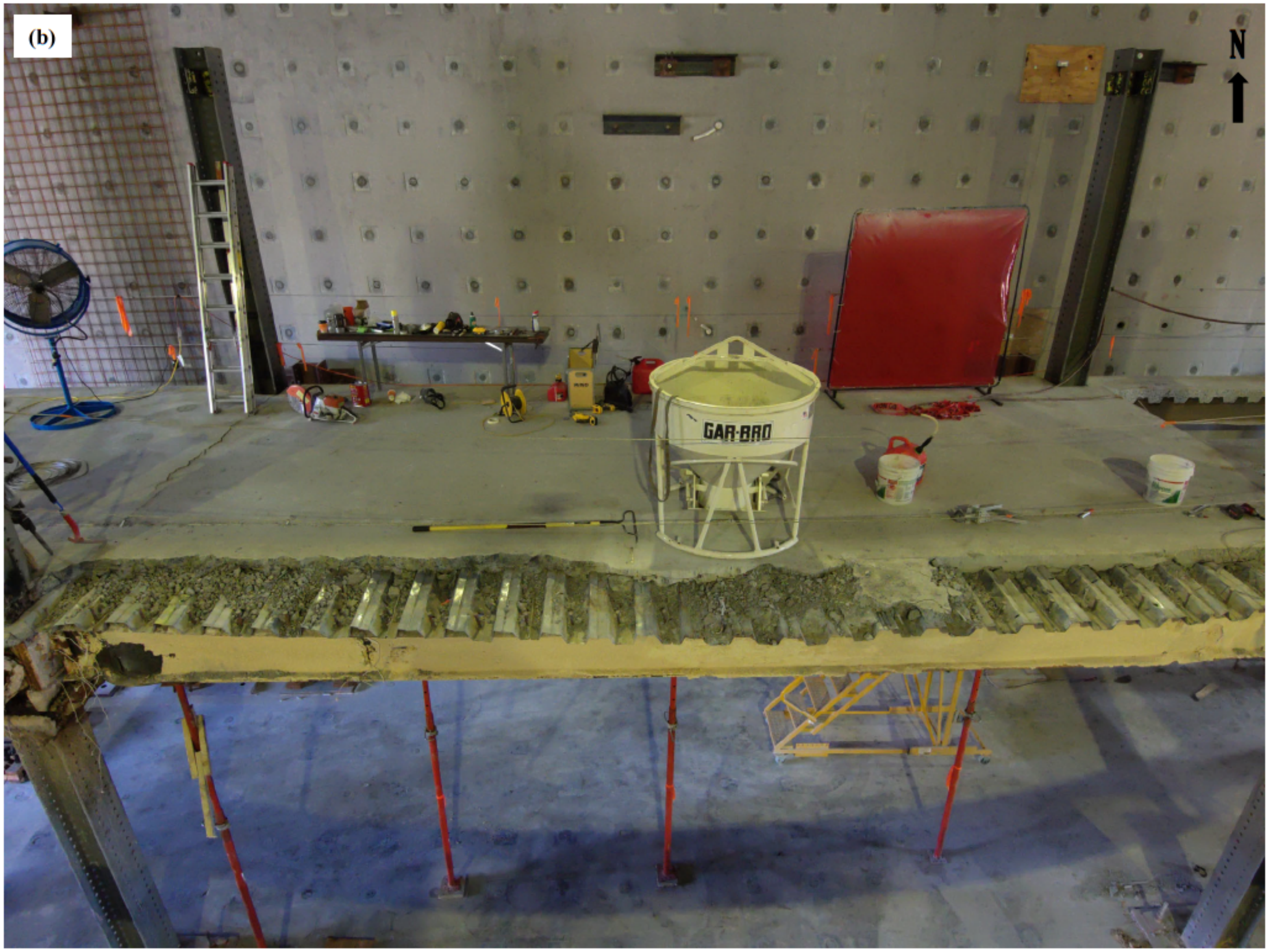


Figure 6.8.16 (cont.): Images showing the condition of the surrounding floor after the incident. (b) Looking north.

Figure 6.8.16 (cont.): Images showing the condition of the surrounding floor after the incident. (c) Looking east.

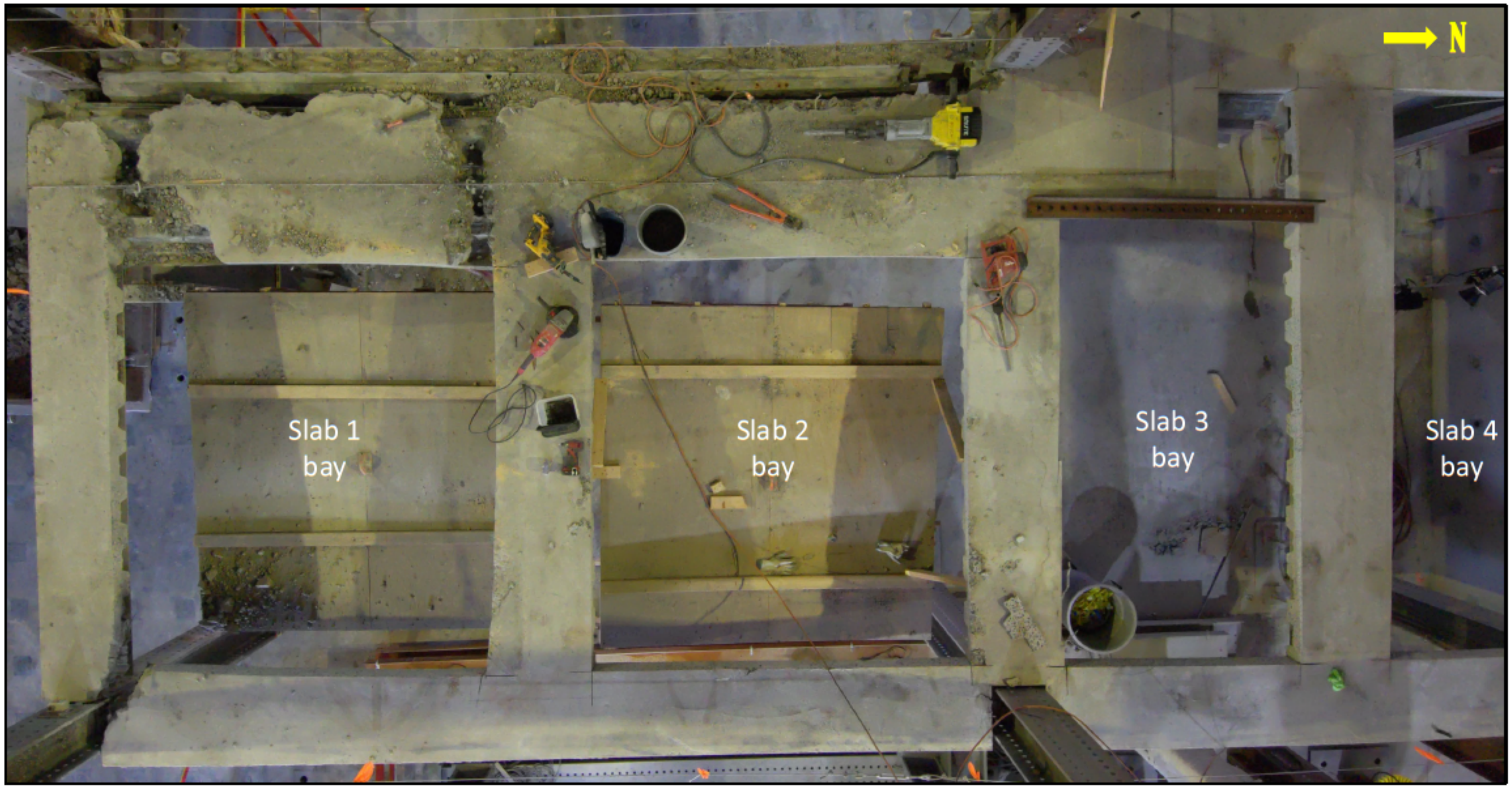


Figure 6.8.17: Image of the east side of the surrounding floor showing tripping hazards and object which could fall from the surrounding floor to the strong floor near unguarded edges.

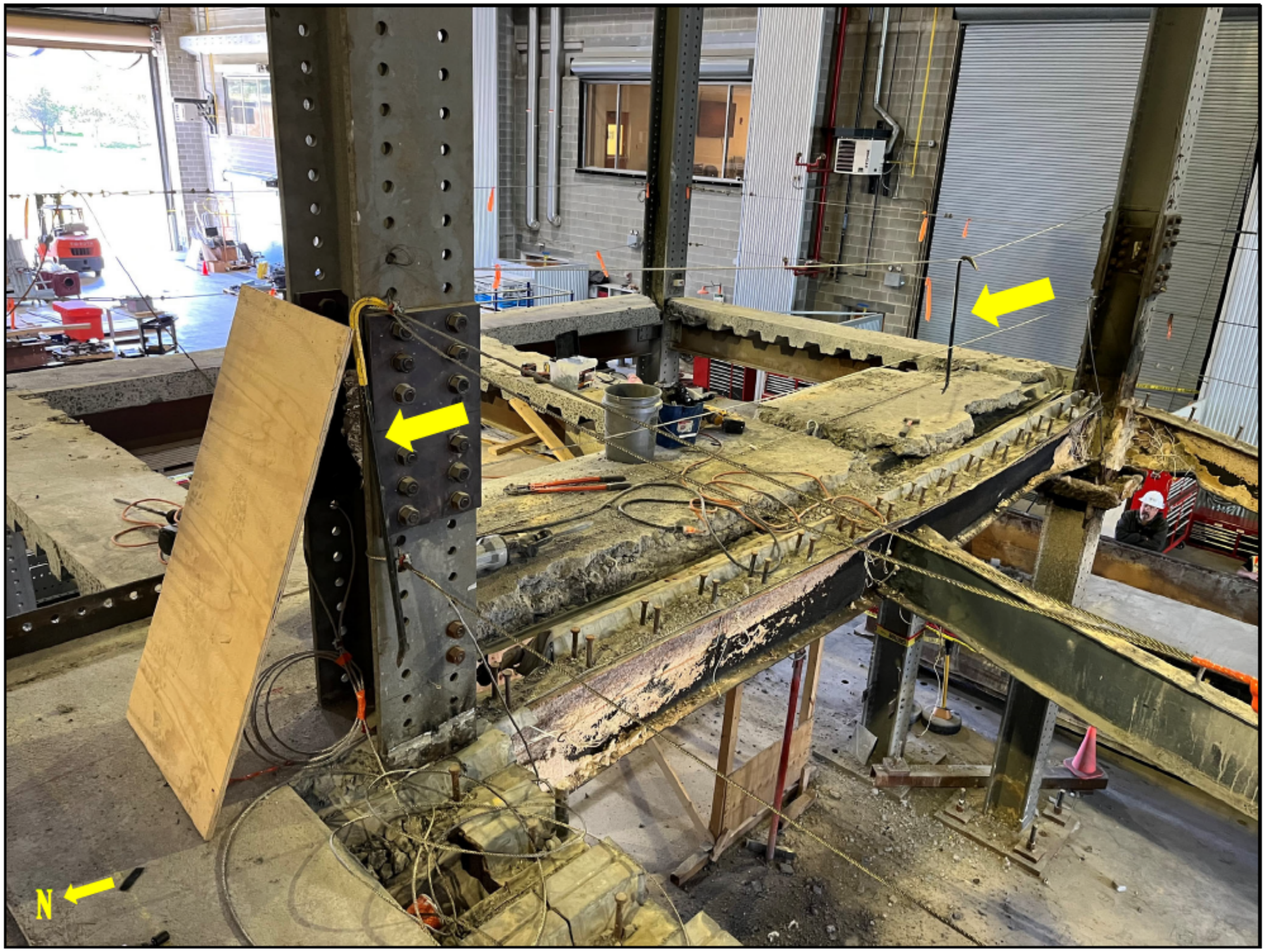


Figure 6.8.18: Images of the surrounding floor showing the conditions after the incident – crowbars are hooked on the passive fall protection cables (yellow arrows) and extra cable is haphazardly found near the column on the concrete slab. Looking southeast.

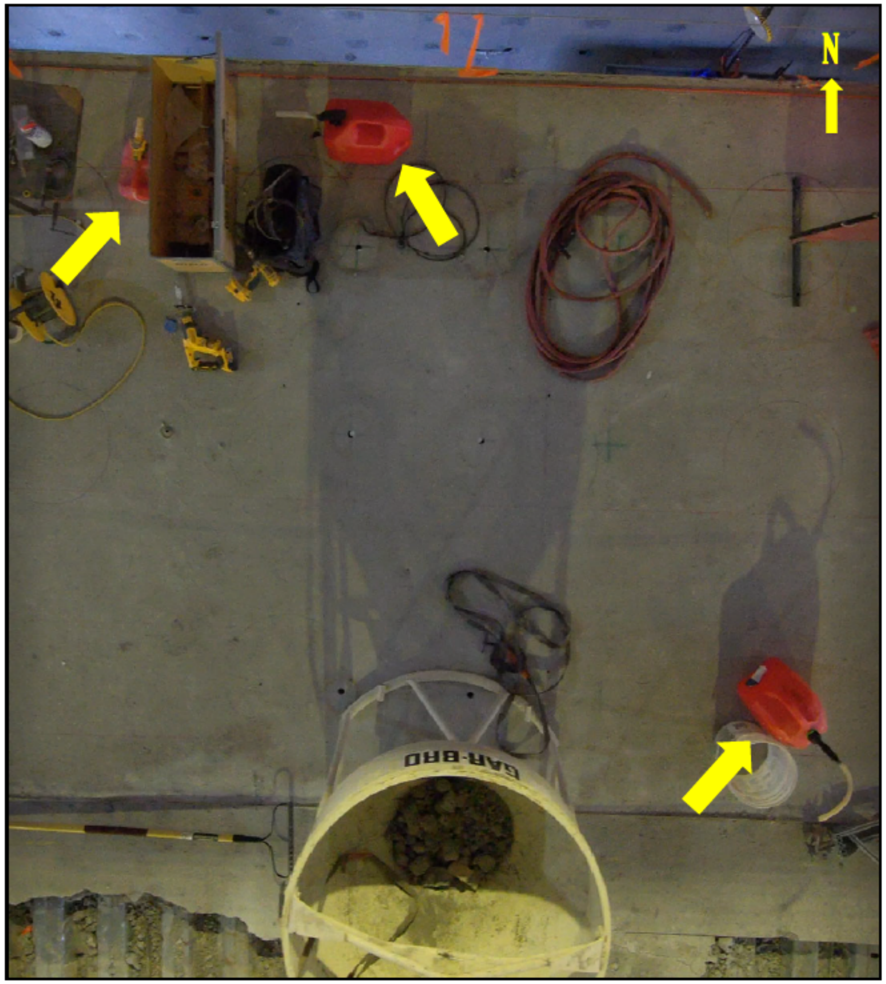


Figure 6.8.19: Images showing the condition of the surrounding floor after the incident – multiple flammable liquid containers are stored on the floor (yellow arrows).

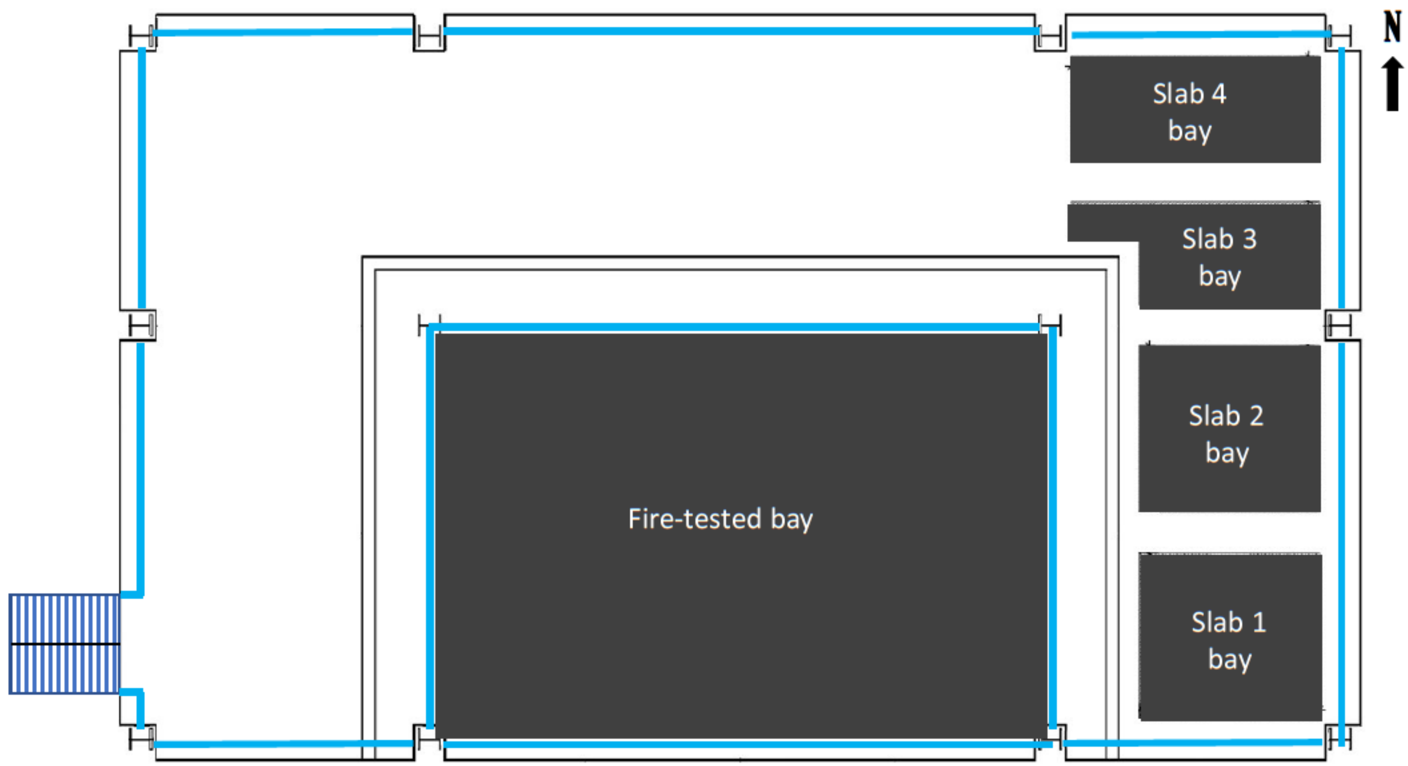


Figure 6.8.20: Diagram of the surrounding floor showing the location of the passive fall protection (blue lines).

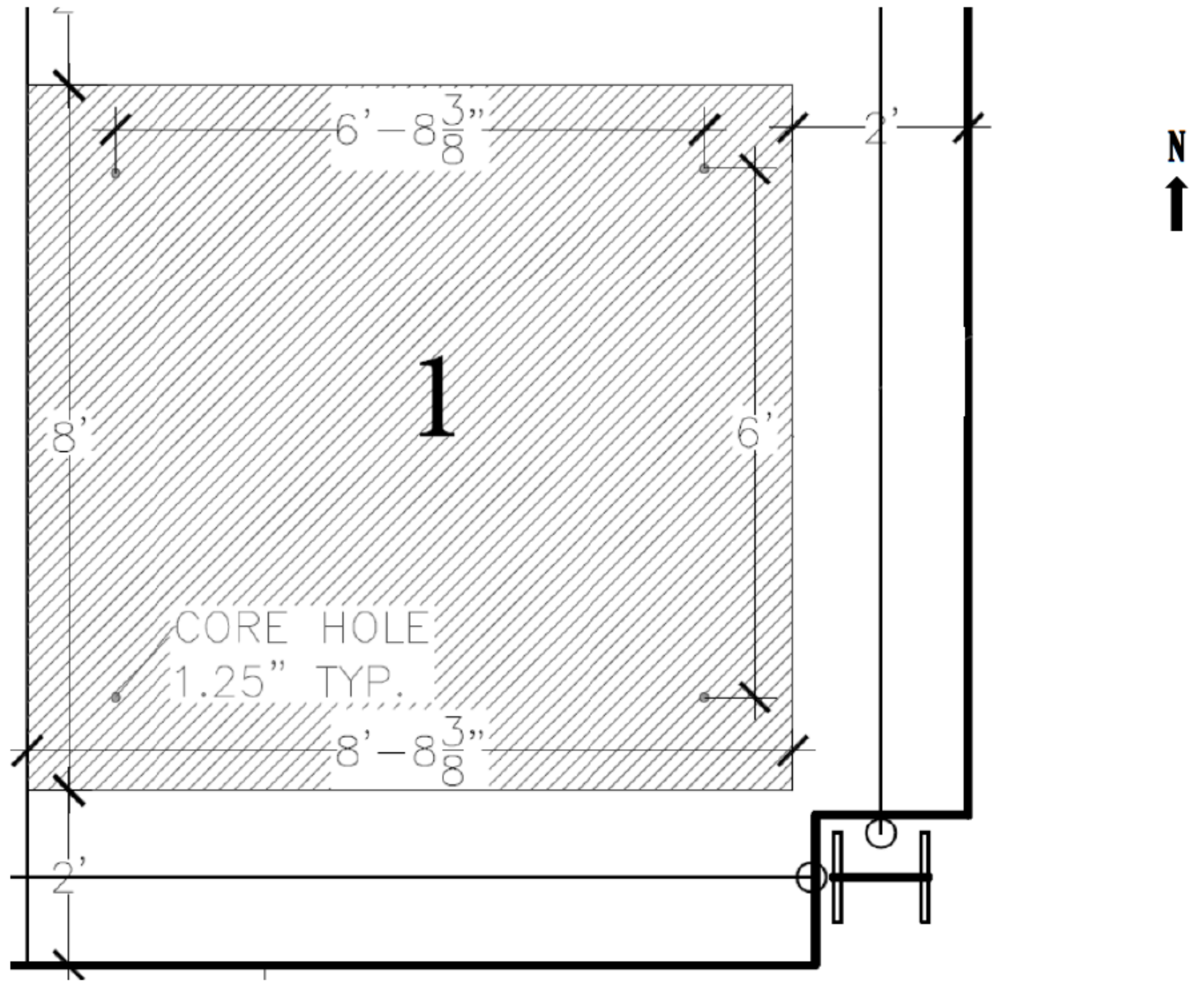


Figure 6.9.1: Coring and cutting plan for Slab 1.

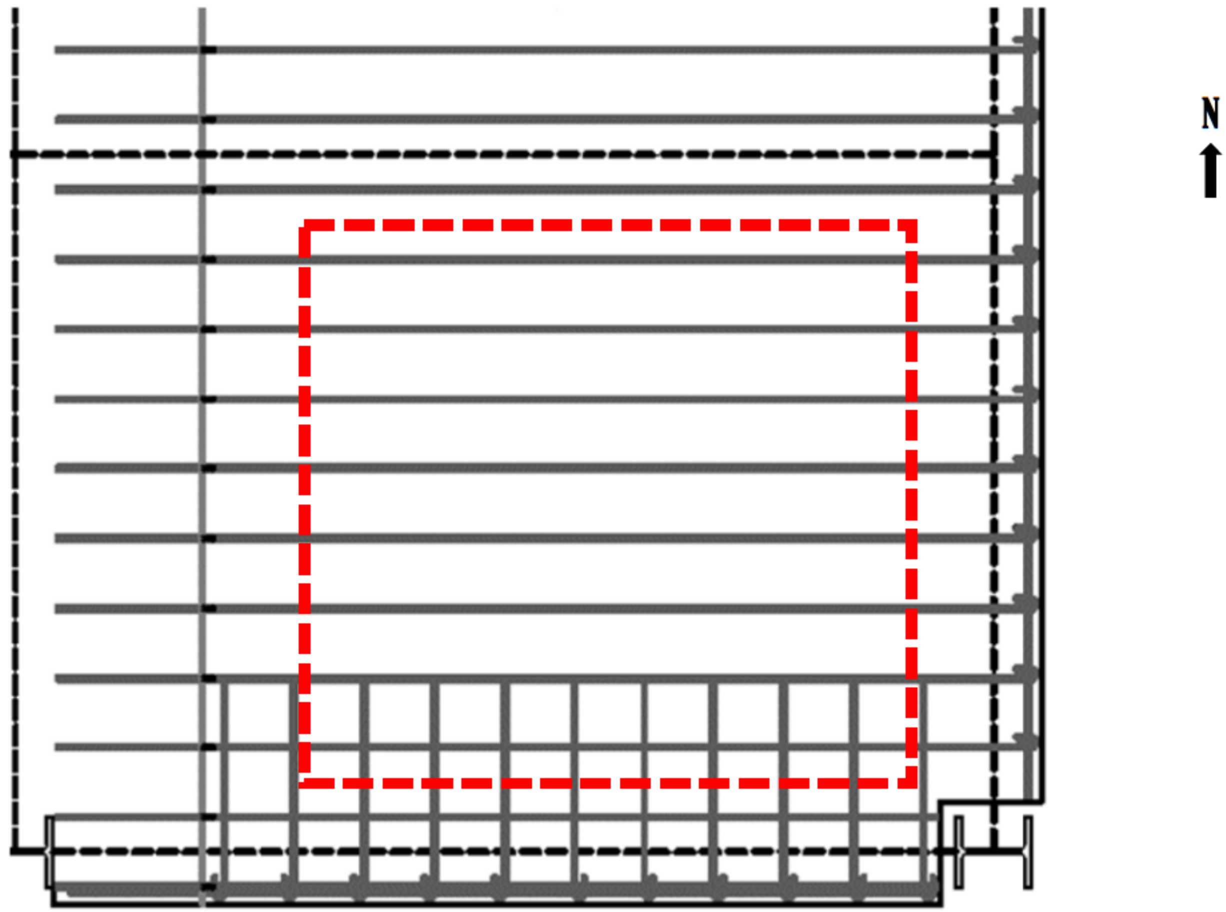


Figure 6.9.2: Approximate Slab 1 outline on the as-built drawing to indicate the anticipated location of the No. 4 rebar reinforcement.

N

Figure 6.9.3: Image of Slab 1.

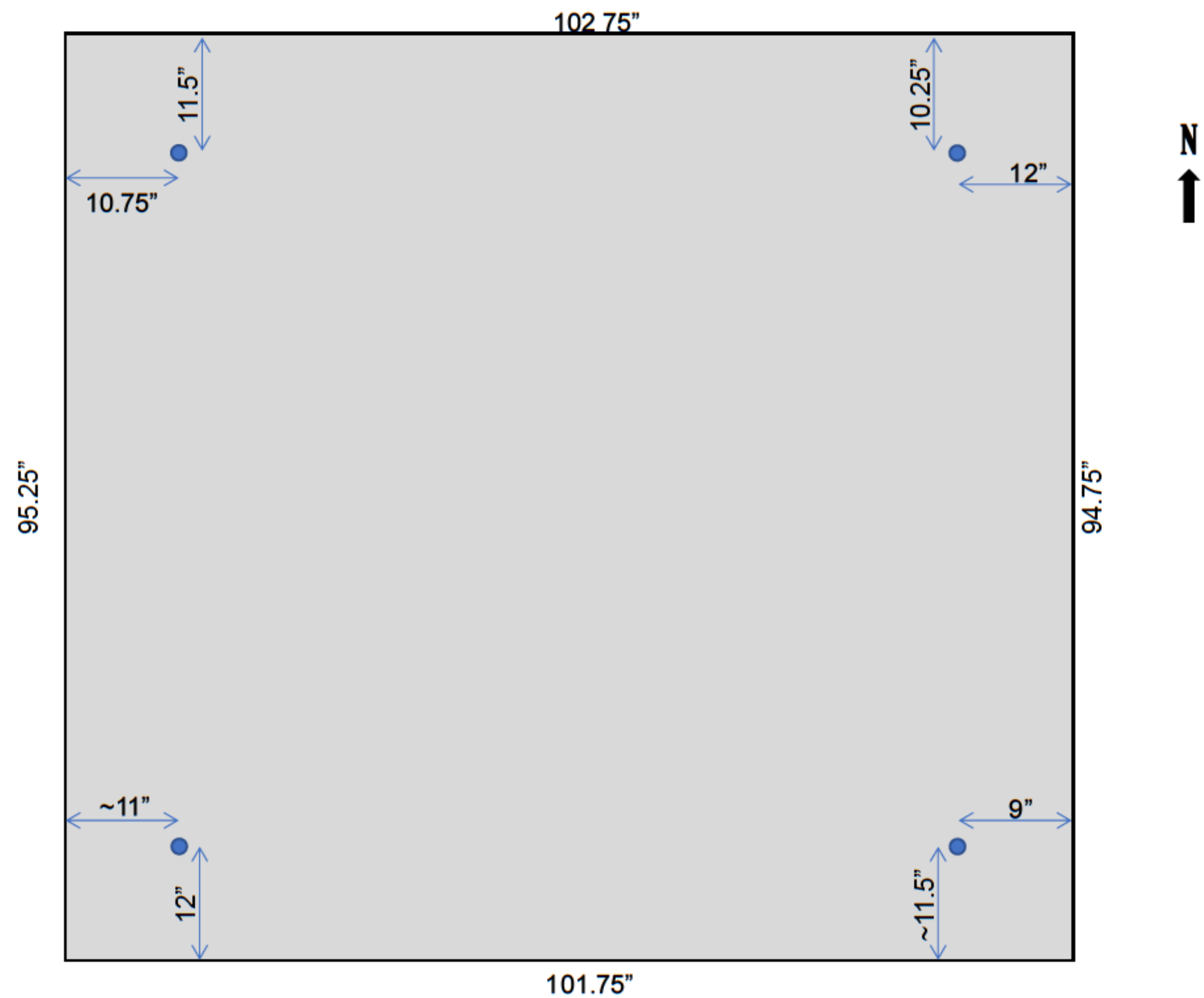


Figure 6.9.4: Slab 1 dimensions and locations of the rigging holes.

Figure 6.9.5: Typical cross-section of the composite floor. Shown in this image is the south cut face of Slab 1.

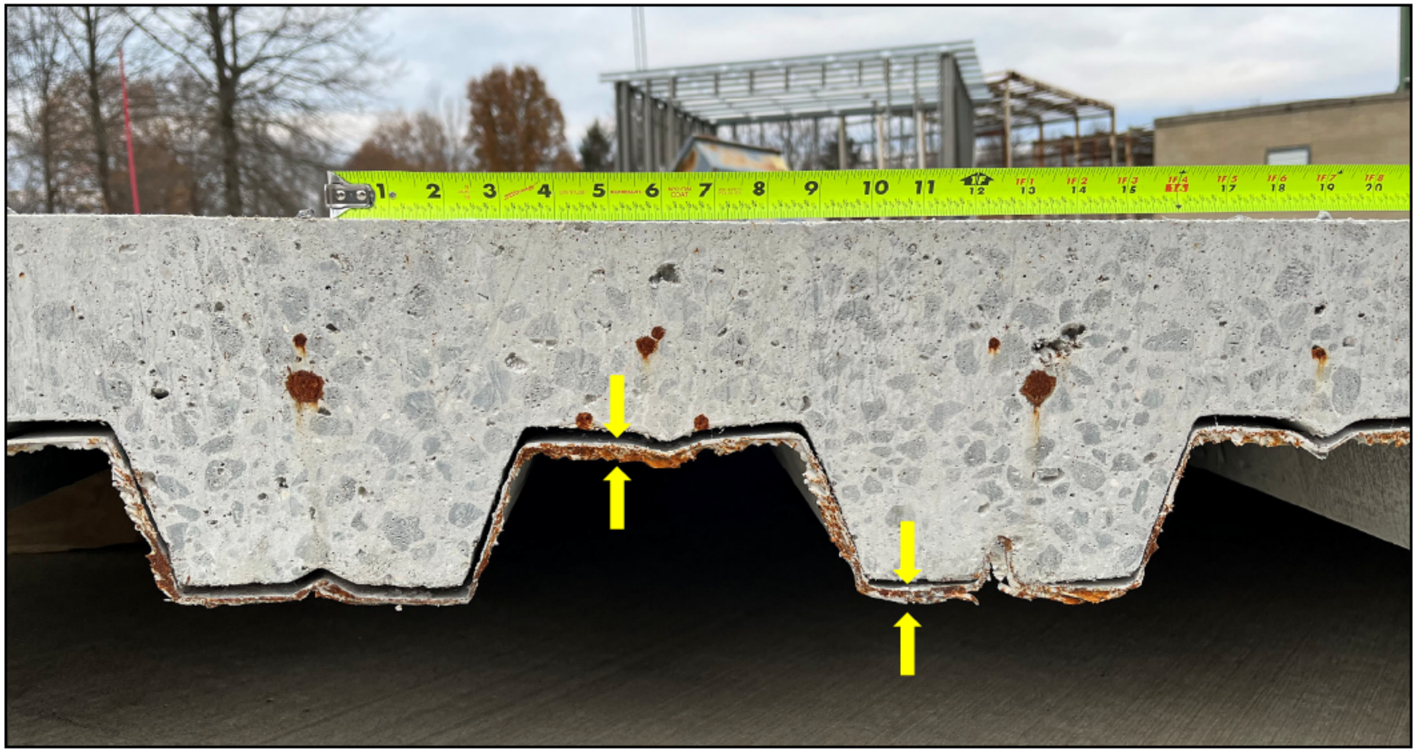


Figure 6.9.6: Typical cross-section of the composite floor showing the steel decking.

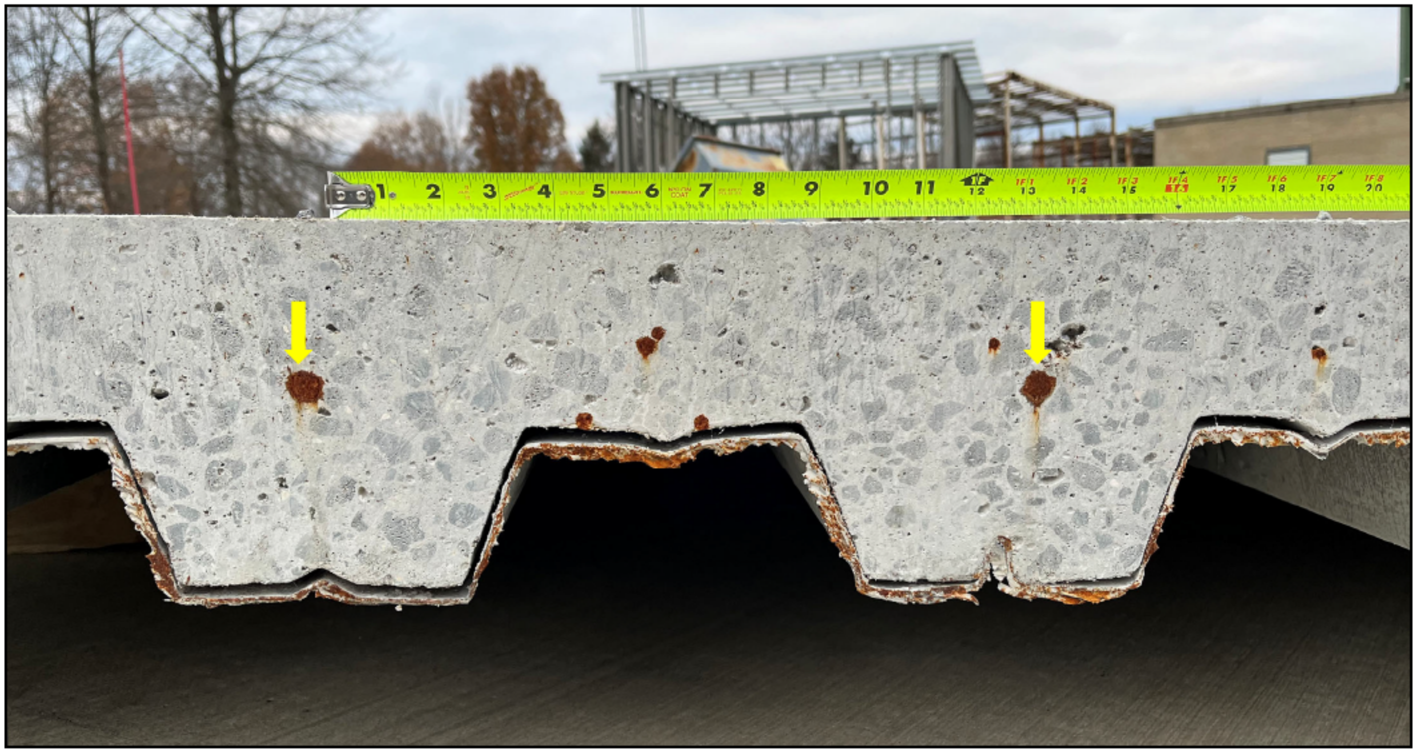


Figure 6.9.7: Typical cross-section of the composite floor showing the No. 4 rebar reinforcement.

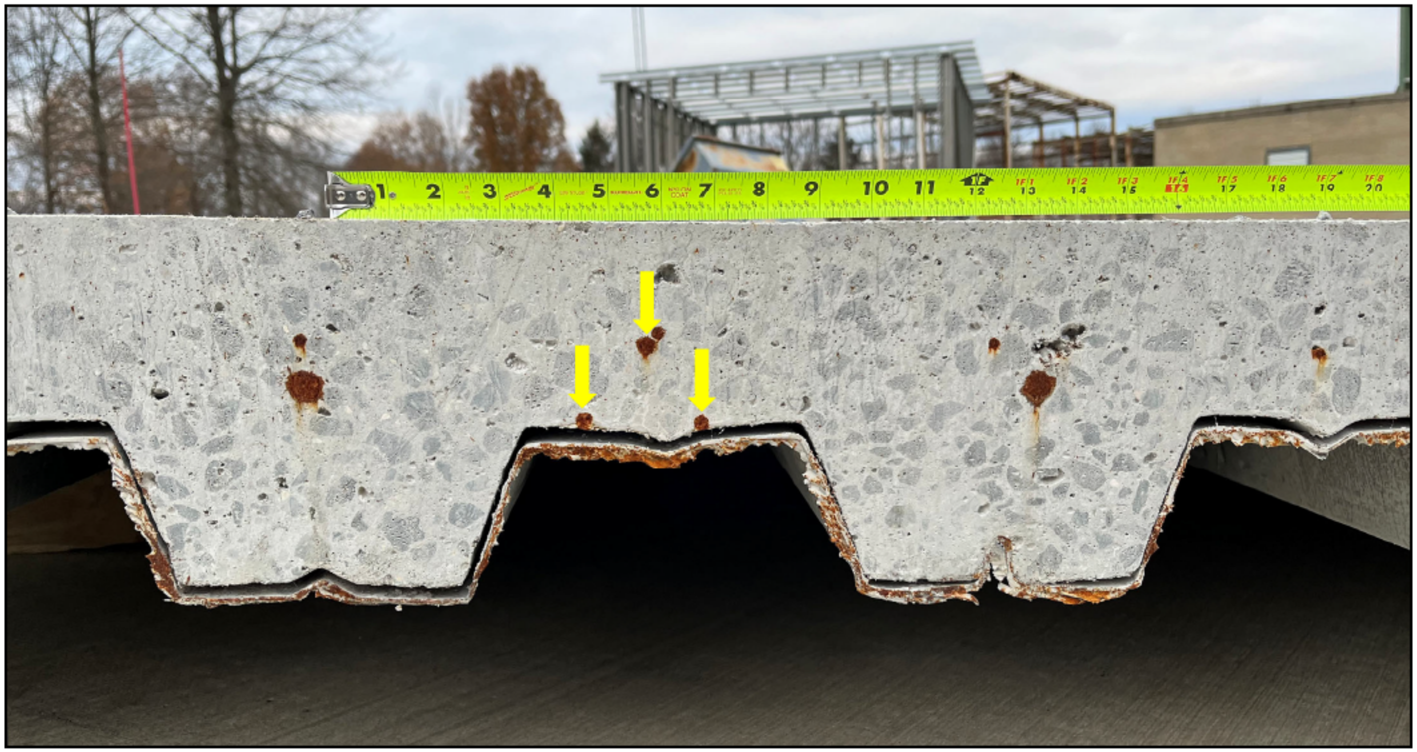


Figure 6.9.8: Typical cross-section of the composite floor showing the chair.

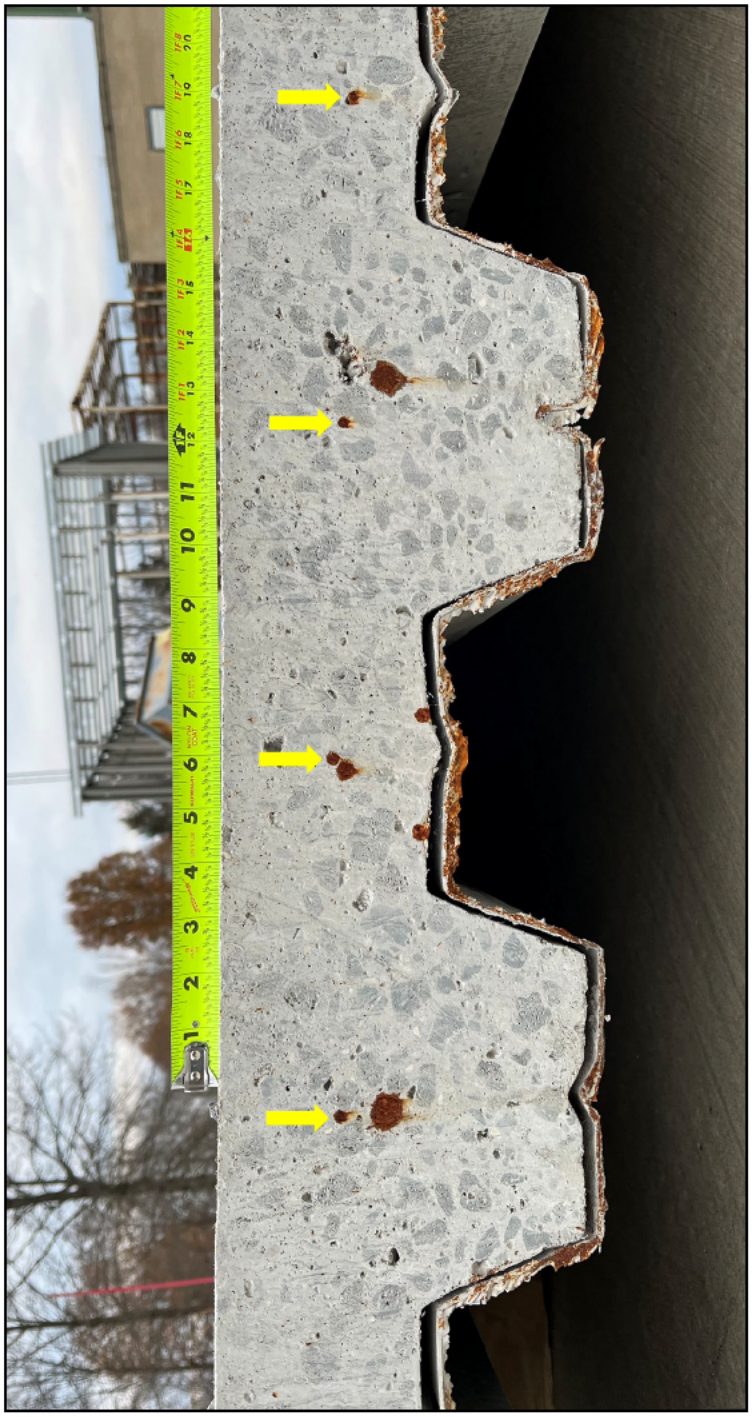


Figure 6.9.9: Typical cross-section of the composite floor showing the welded wire fabric.

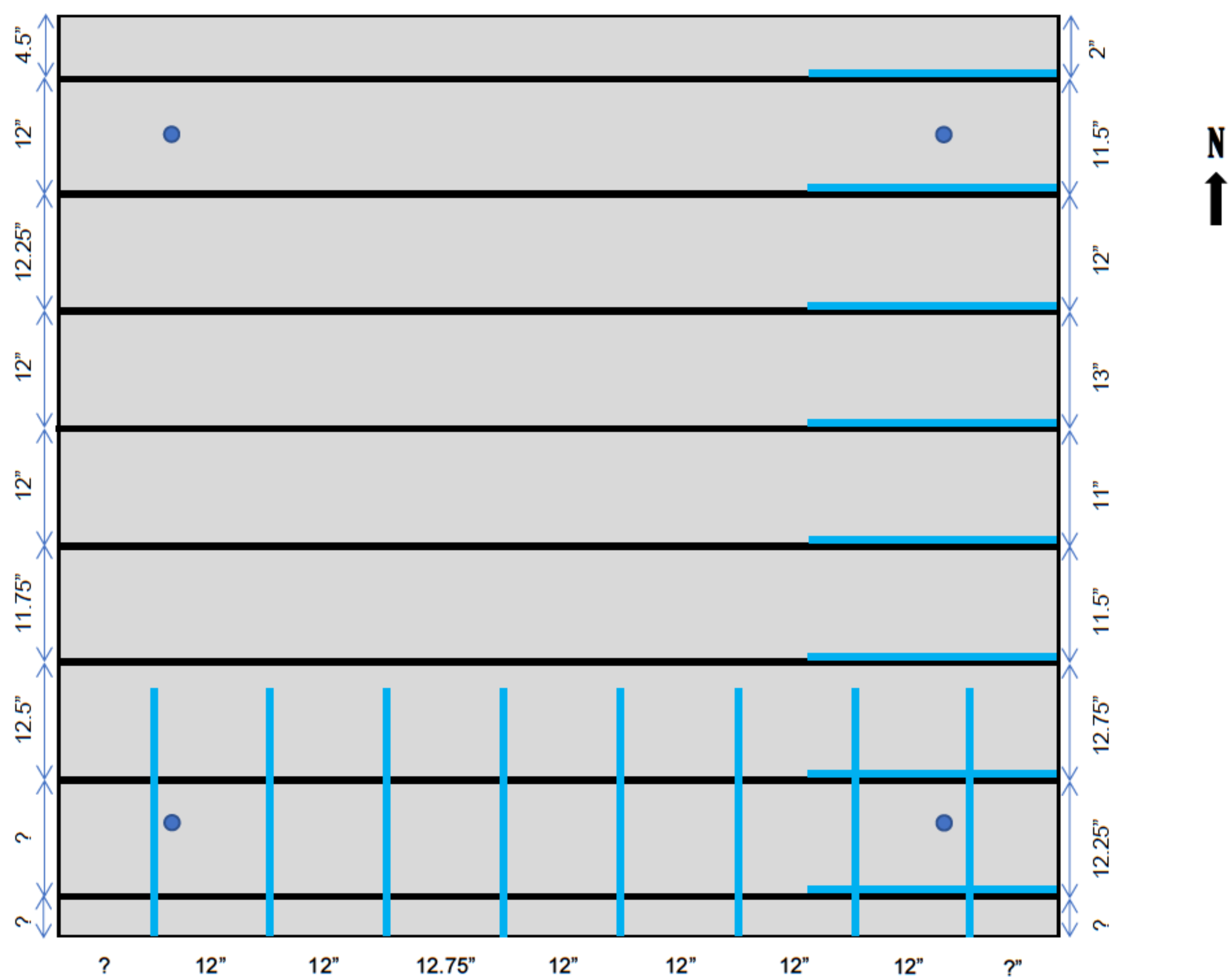


Figure 6.9.10: Observed rebar reinforcement of Slab 1. Some dimensions in the southeast and southwest corners were not obtained due to the damage of the slab. Black line represent No. 4 rebar reinforcement extending through the slab. Blue lines represent the 38" hooked No. 4 rebar and assumed to extend 20" into the slab.

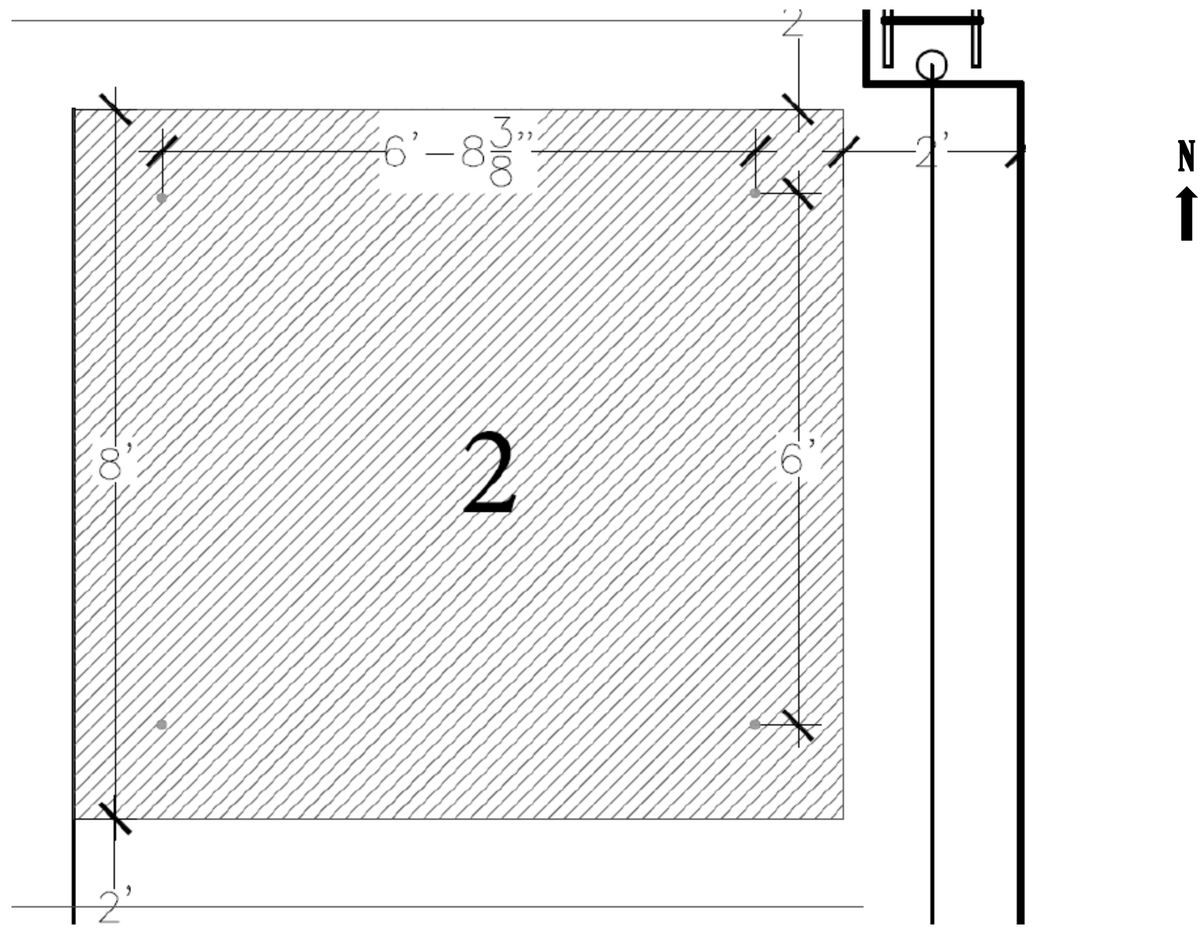


Figure 6.9.11: Coring and cutting plan for Slab 2.

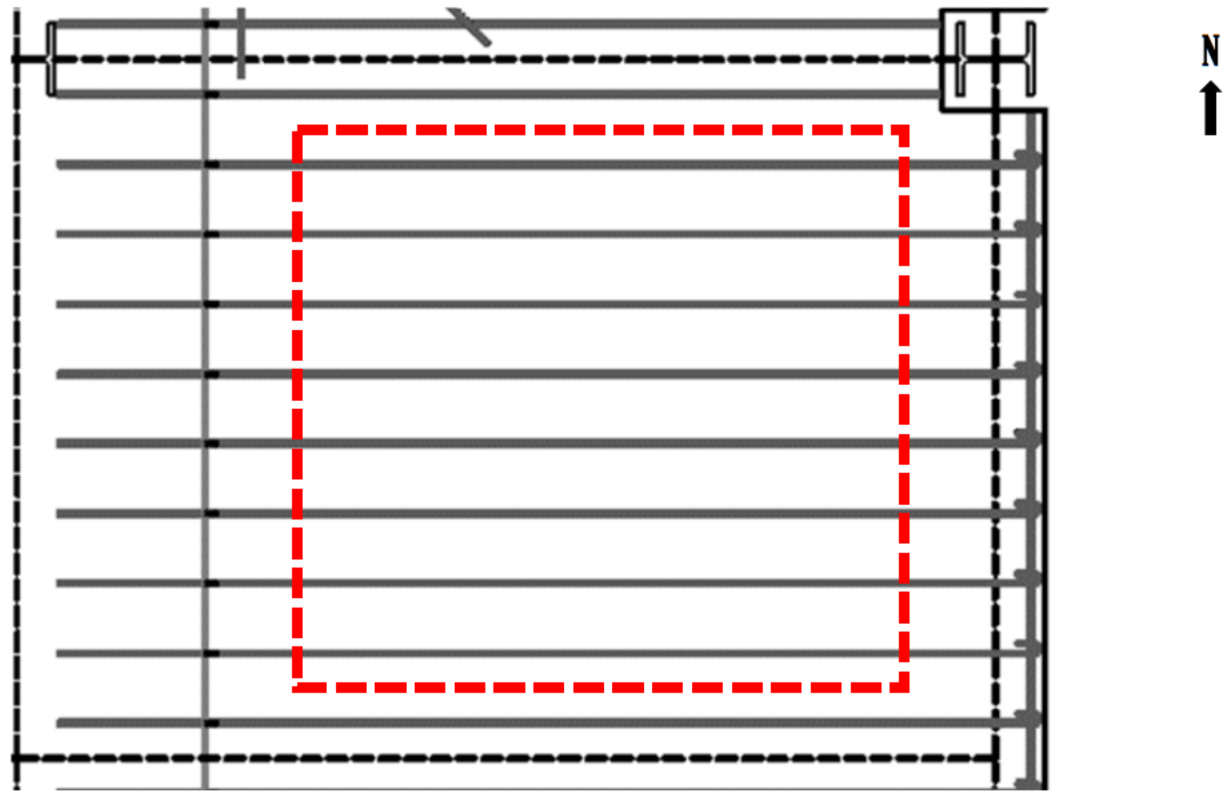


Figure 6.9.12: Approximate Slab 2 outline on the as-built drawing to indicate the anticipated location of the No. 4 rebar reinforcement.

Figure 6.9.13: Image of Slab 2.

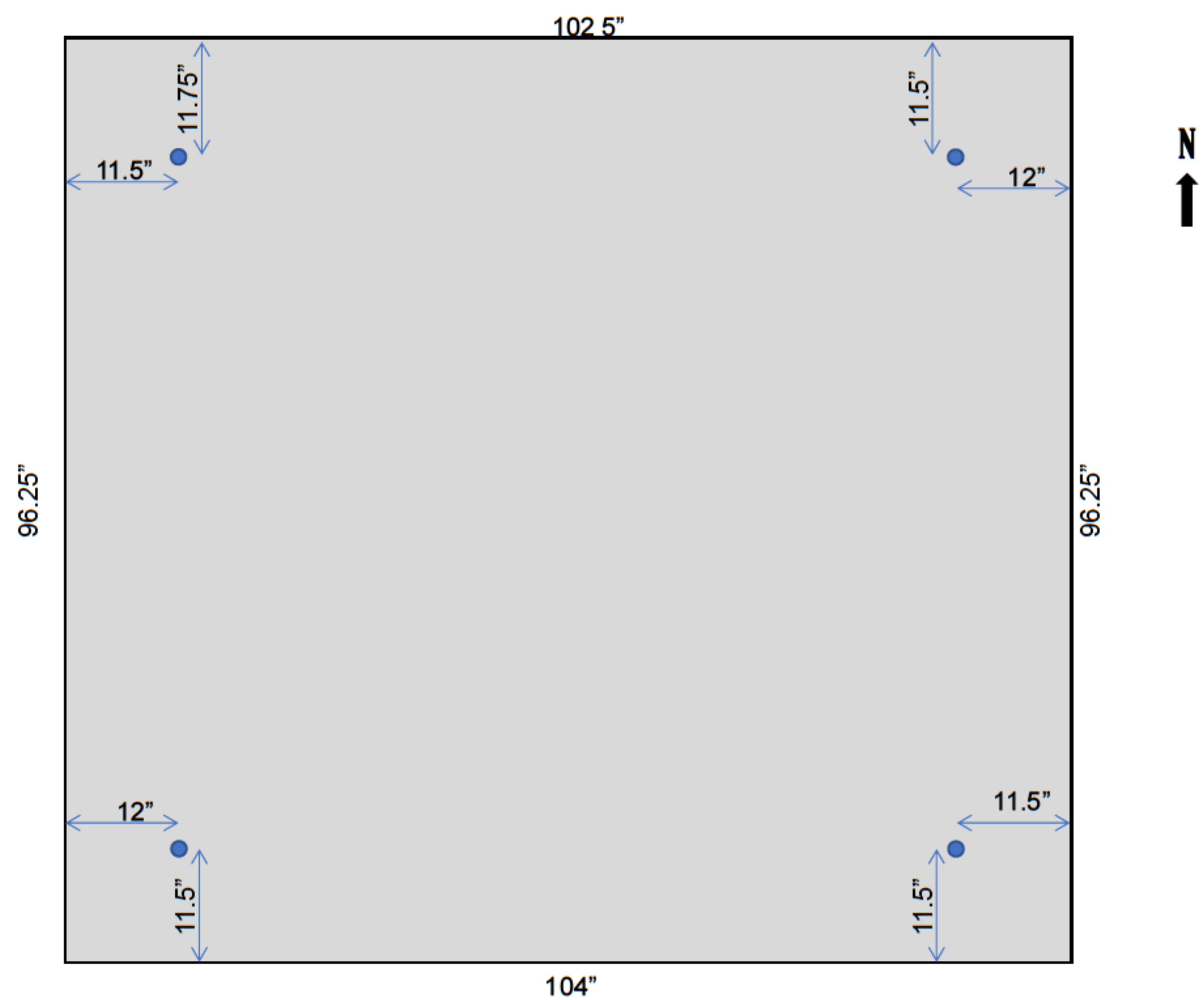


Figure 6.9.14: Slab 2 dimensions and locations of the rigging holes.

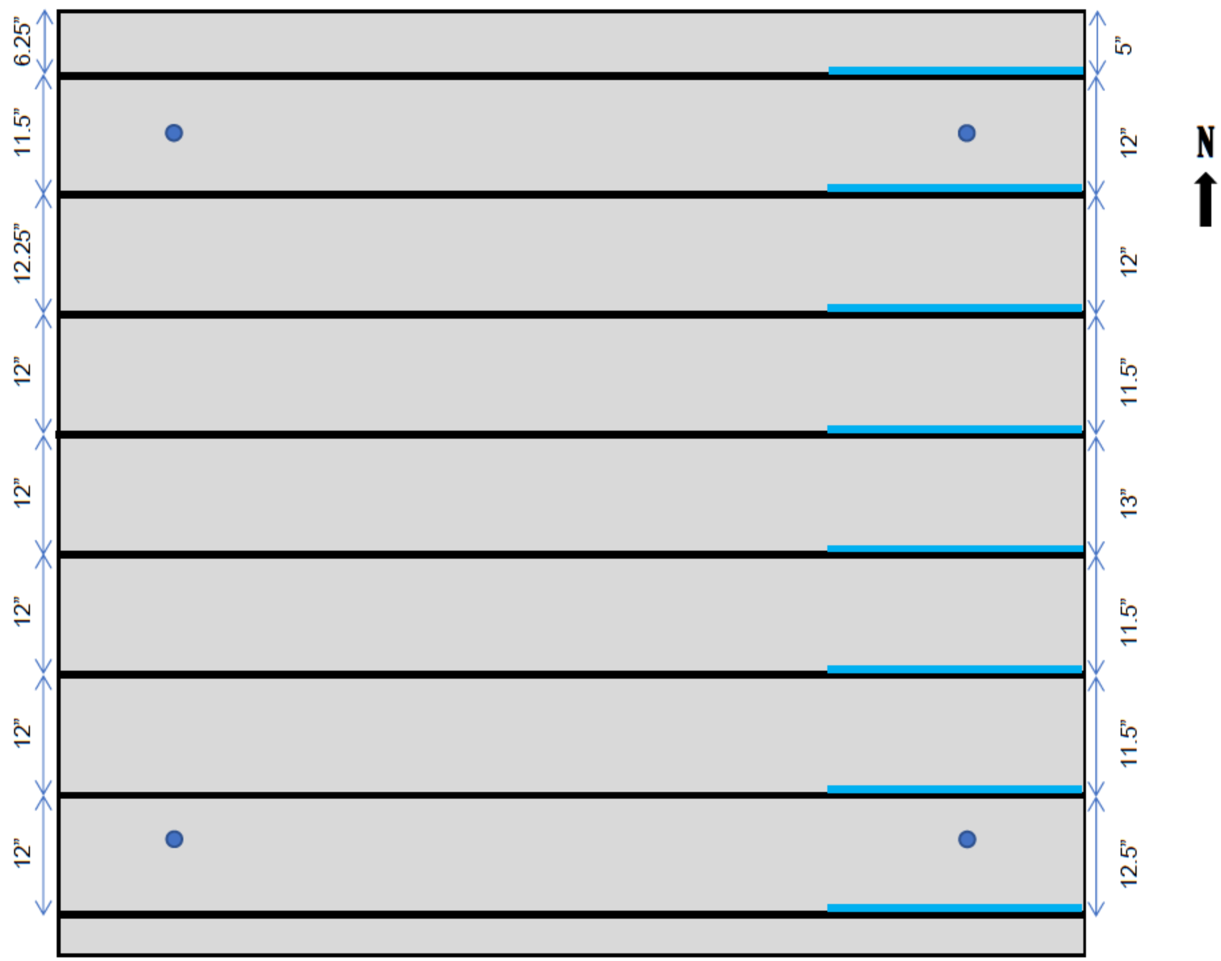


Figure 6.9.15: Observed rebar reinforcement of Slab 2. Black line represent No. 4 rebar reinforcement extending through the slab. Blue lines represent the 38" hooked No. 4 rebar and assumed to extend 20" into the slab.

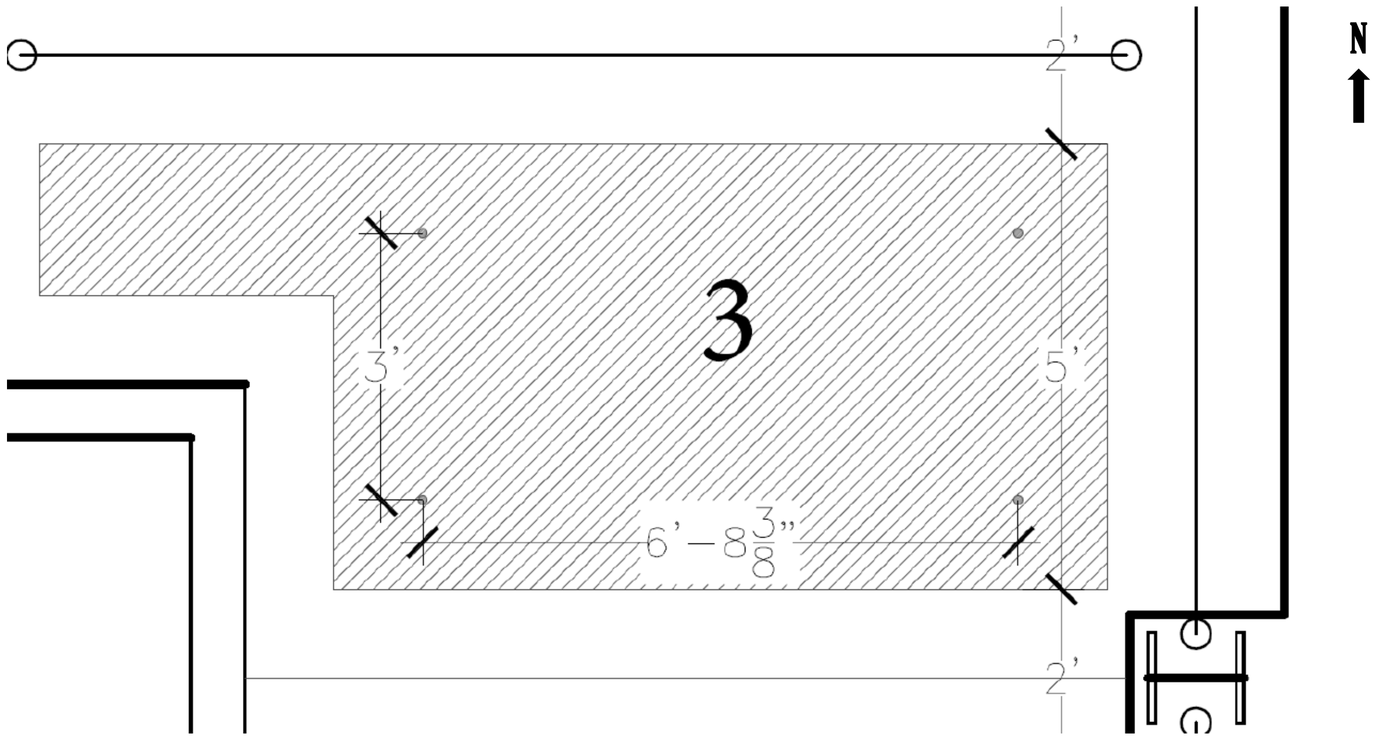


Figure 6.9.16: Coring and cutting plan for Slab 3.

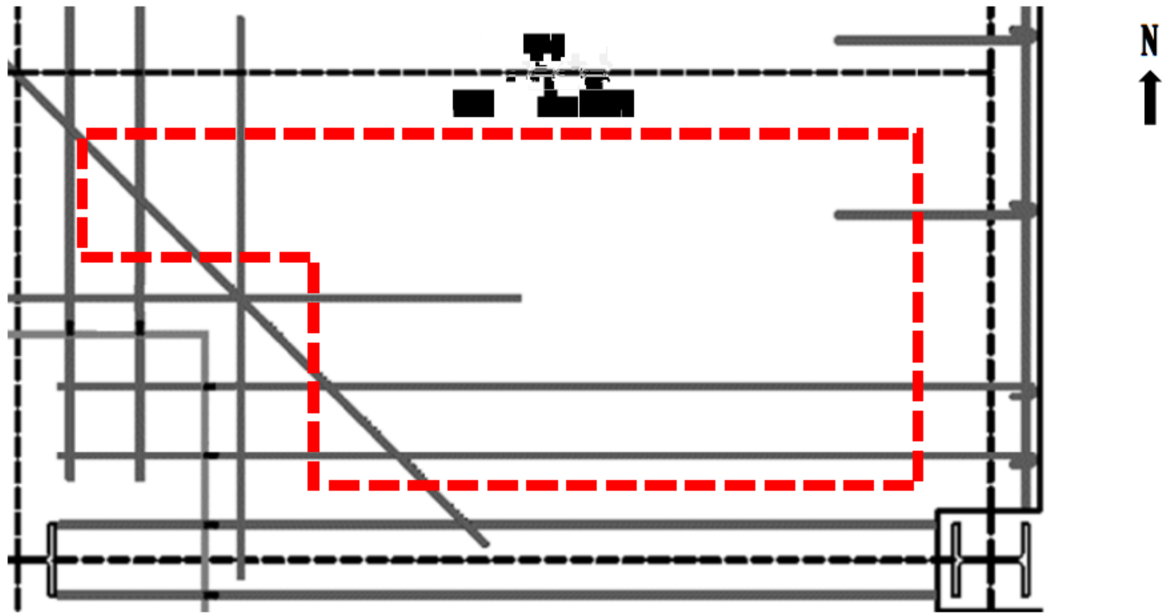


Figure 6.9.17: Approximate Slab 3 outline on the as-built drawing to indicate the anticipated location of the No. 4 rebar reinforcement.

Figure 6.9.18: Image of both pieces of Slab 3. The northwest tab is rotated 90° clockwise in the roll-off and damage of the southeast corner can be seen from it having fallen to the strong floor.

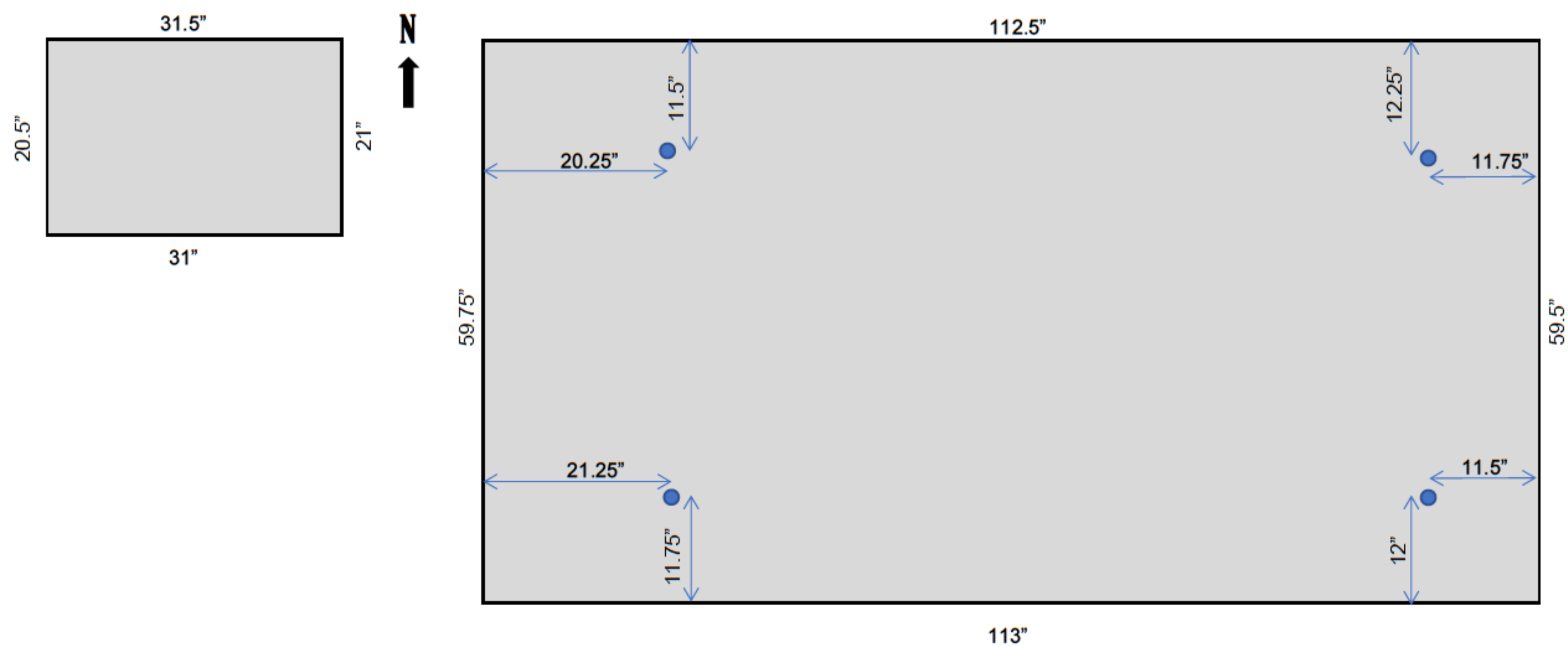


Figure 6.9.19: Slab 3 dimensions and locations of the rigging holes.

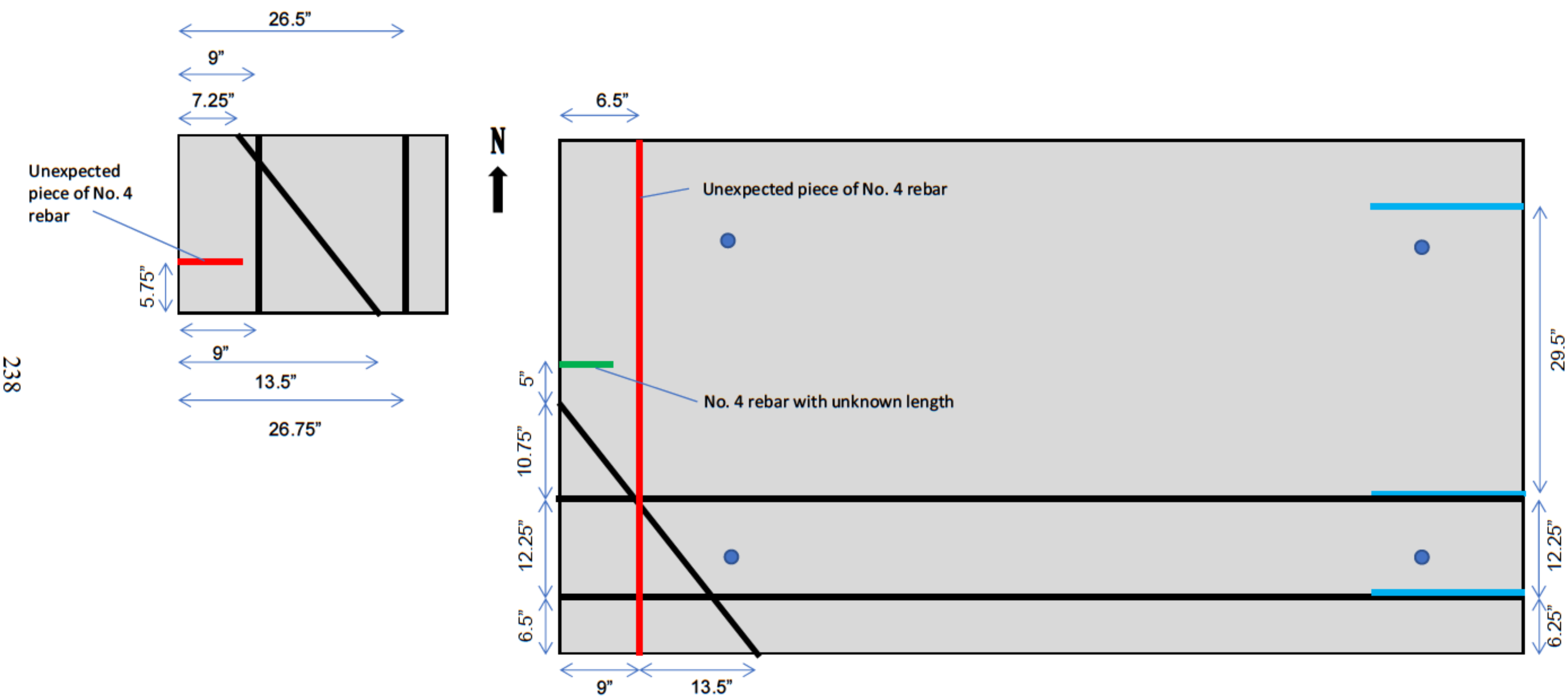


Figure 6.9.20: Observed rebar reinforcement of Slab 3. Blue lines represent the 38" hooked No. 4 rebar and assumed to extend 20" into the slab. The green line represents a piece of rebar with unknown extension into the slab. The red lines represent unexpected rebar observed.

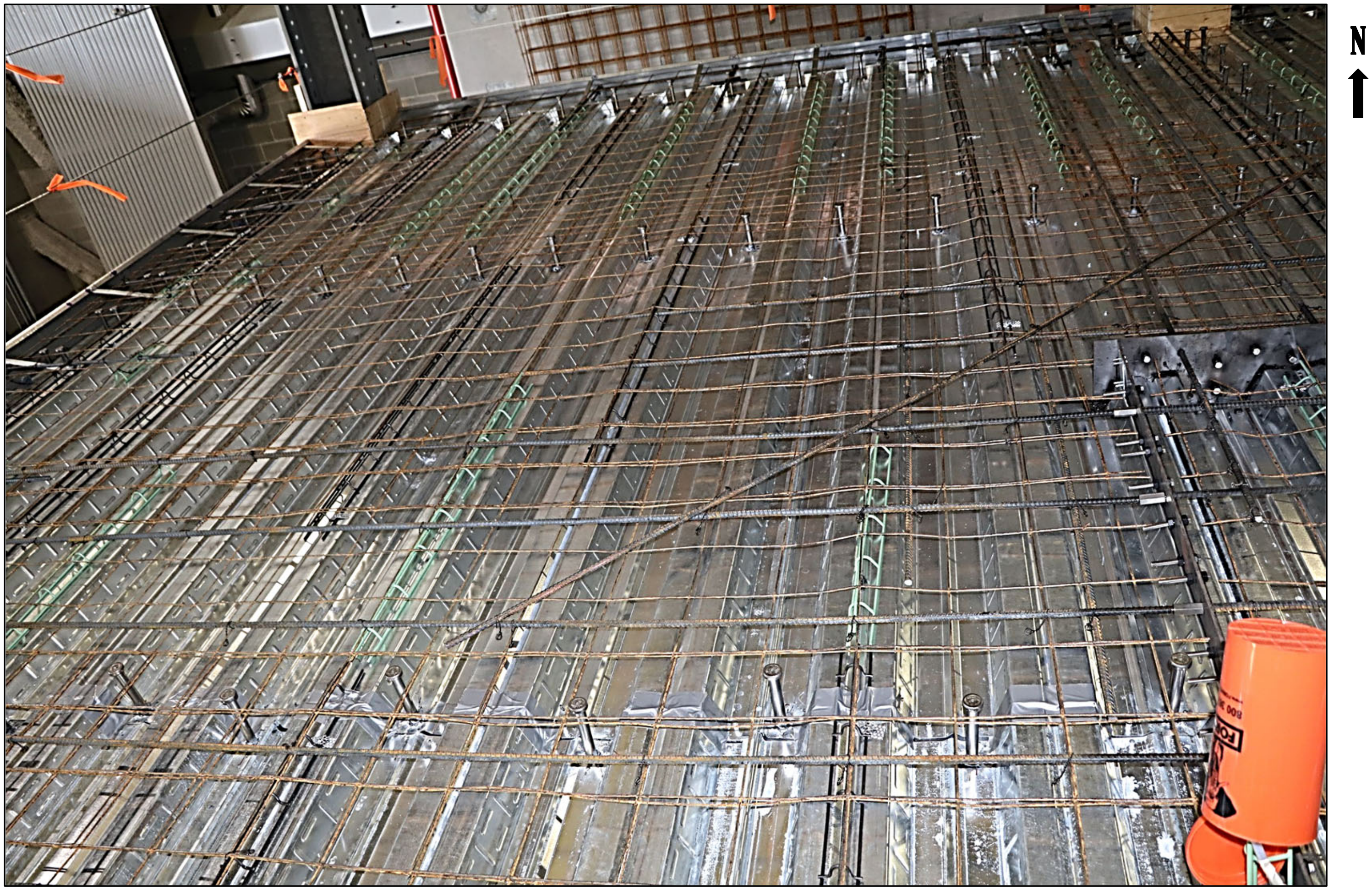


Figure 6.9.21: (a) Construction image showing the rebar reinforcement of the northwest corner of the CF Project test frame.

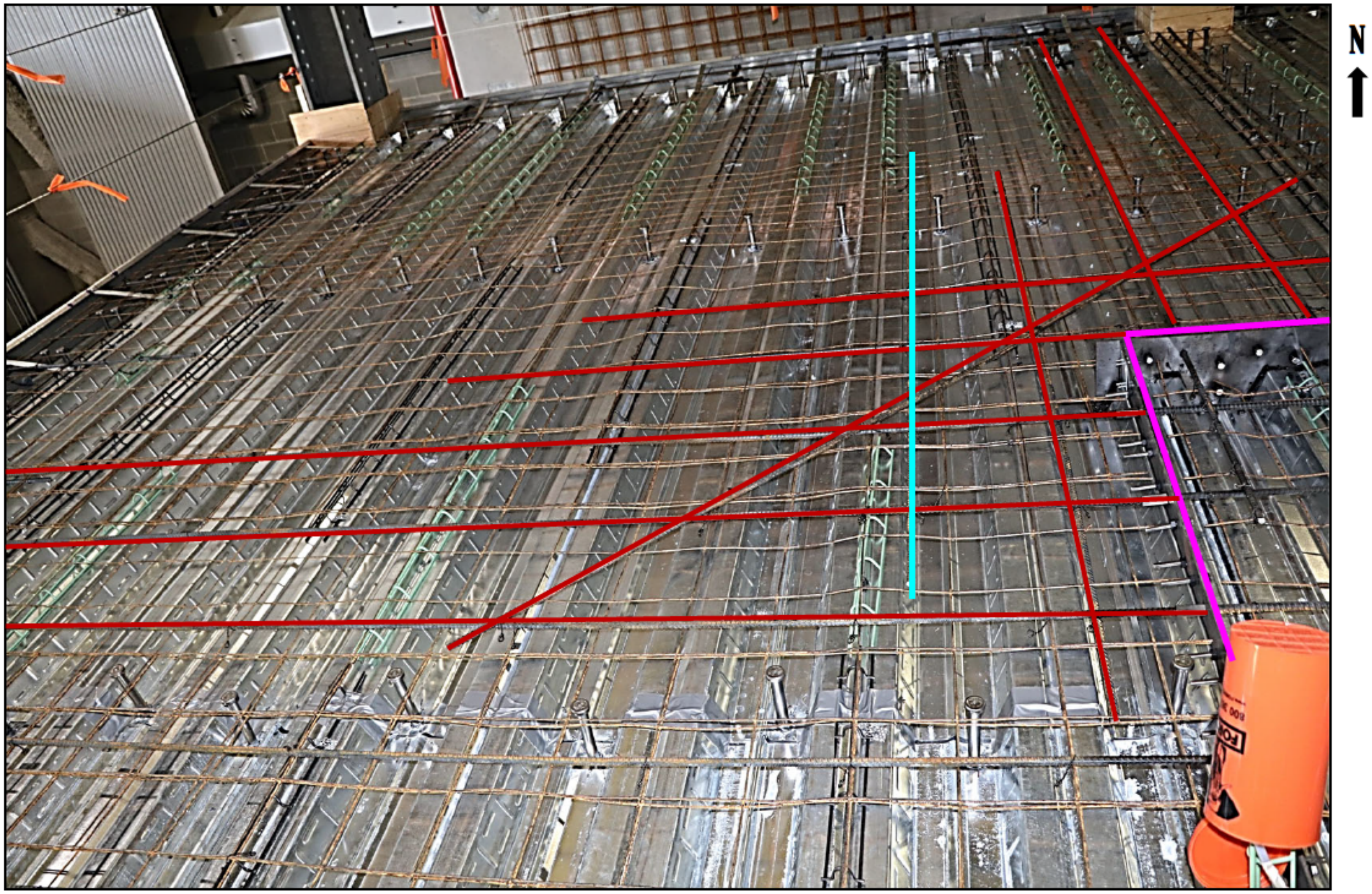


Figure 6.9.21 (cont.): (b) Construction image showing an extra piece of No. 4 rebar (represented by the blue line) running north and south which is not indicated on the as-built drawings.

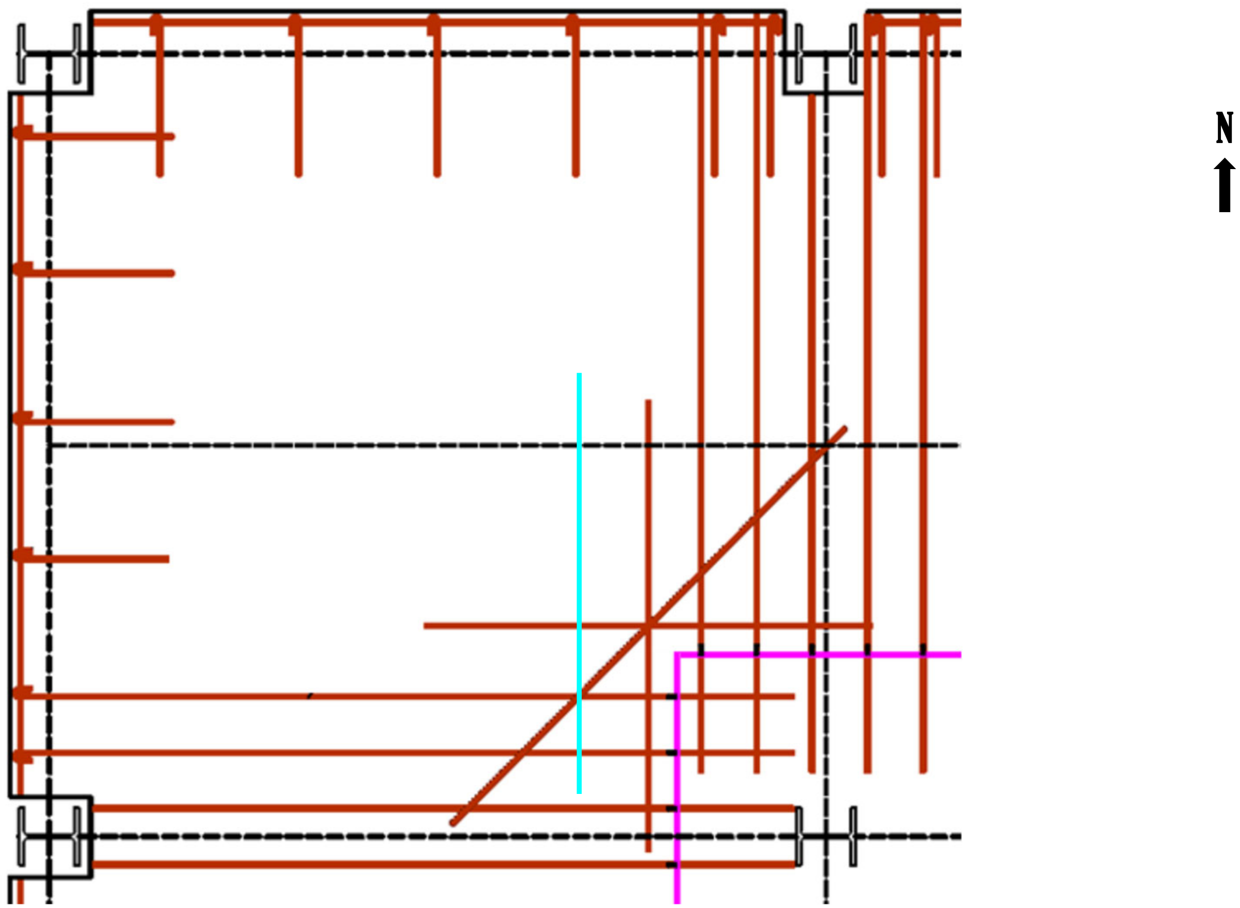


Figure 6.9.21 (cont.): (c) As-built drawing showing the rebar reinforcement of the northwest corner. Blue line represents the piece of rebar observed in the construction image.

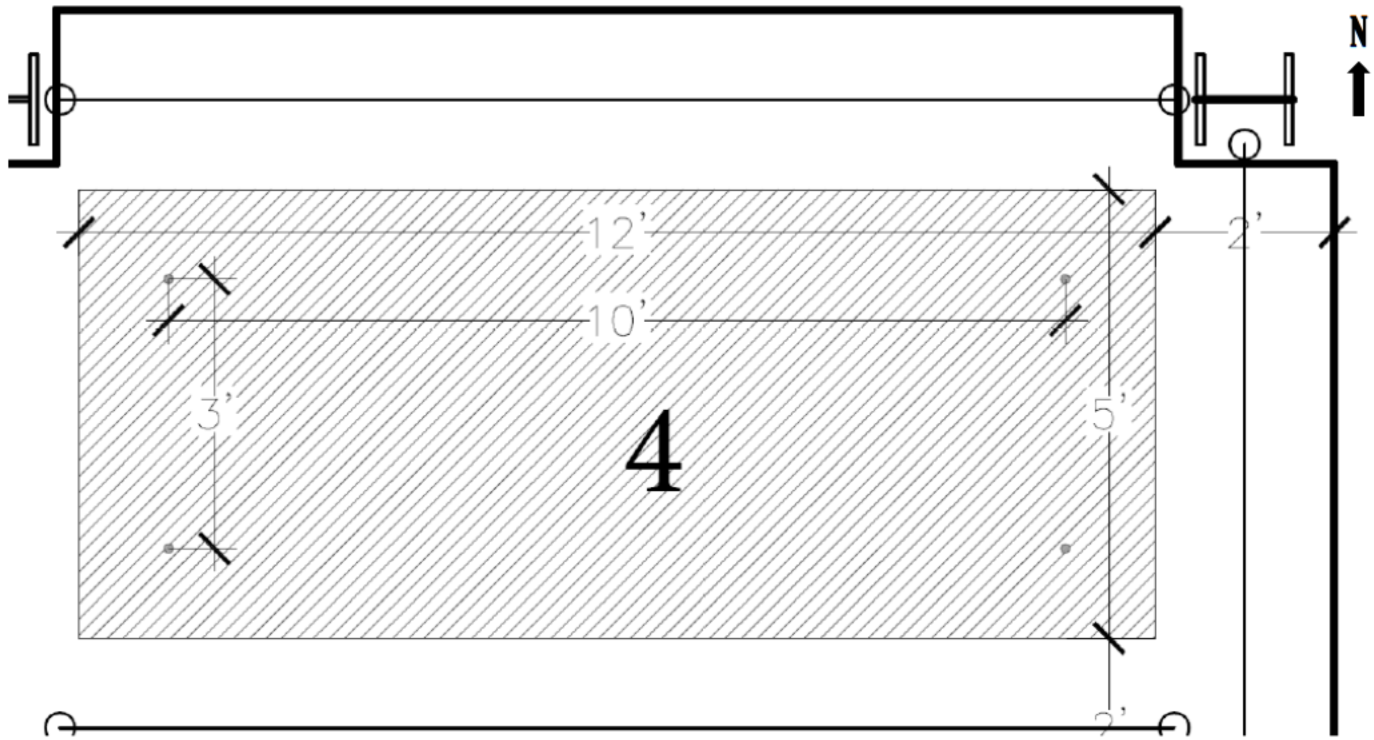


Figure 6.9.22: Coring and cutting plan for Slab 4.

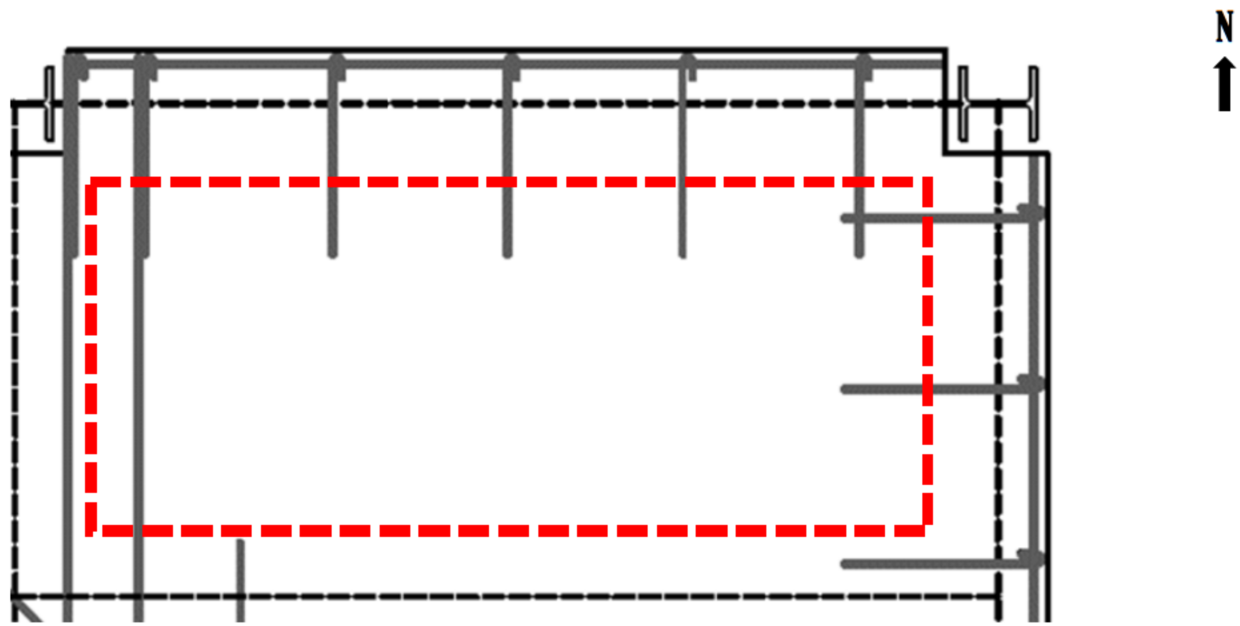


Figure 6.9.23: Approximate Slab 4 outline on the as-built drawing to indicate the anticipated location of the No. 4 rebar reinforcement.

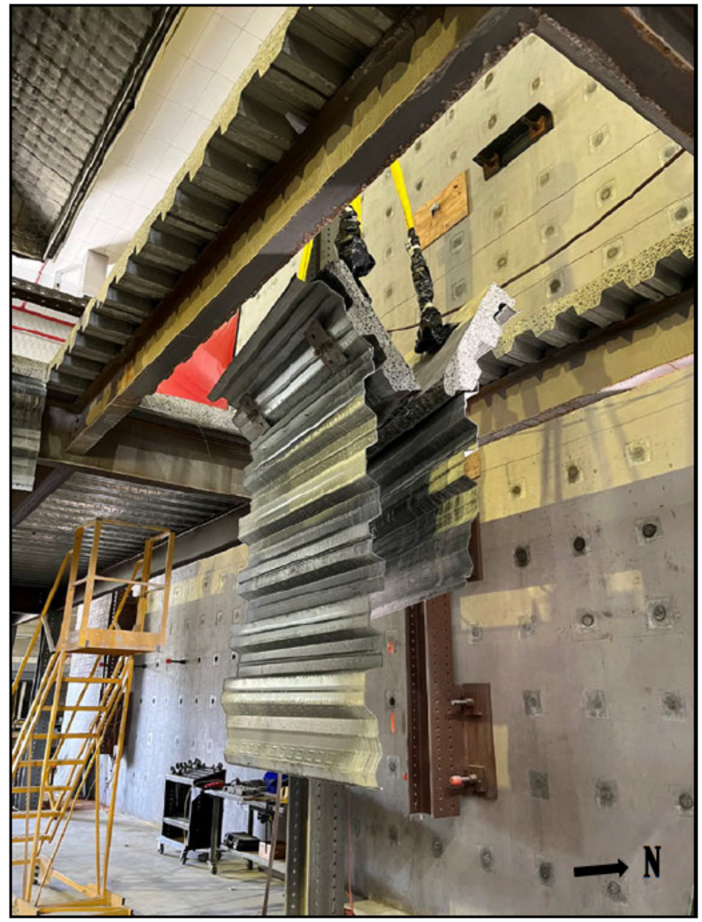


Figure 6.9.24: Two large pieces of Slab 4 were suspended by the rigging after fracture. Viewed from a) the surrounding floor looking east and b) the strong floor looking up and west.

Figure 6.9.25: Four large pieces of Slab 4 found on the strong floor directly beneath the location where the slab was cut. Viewed on the strong floor looking east.

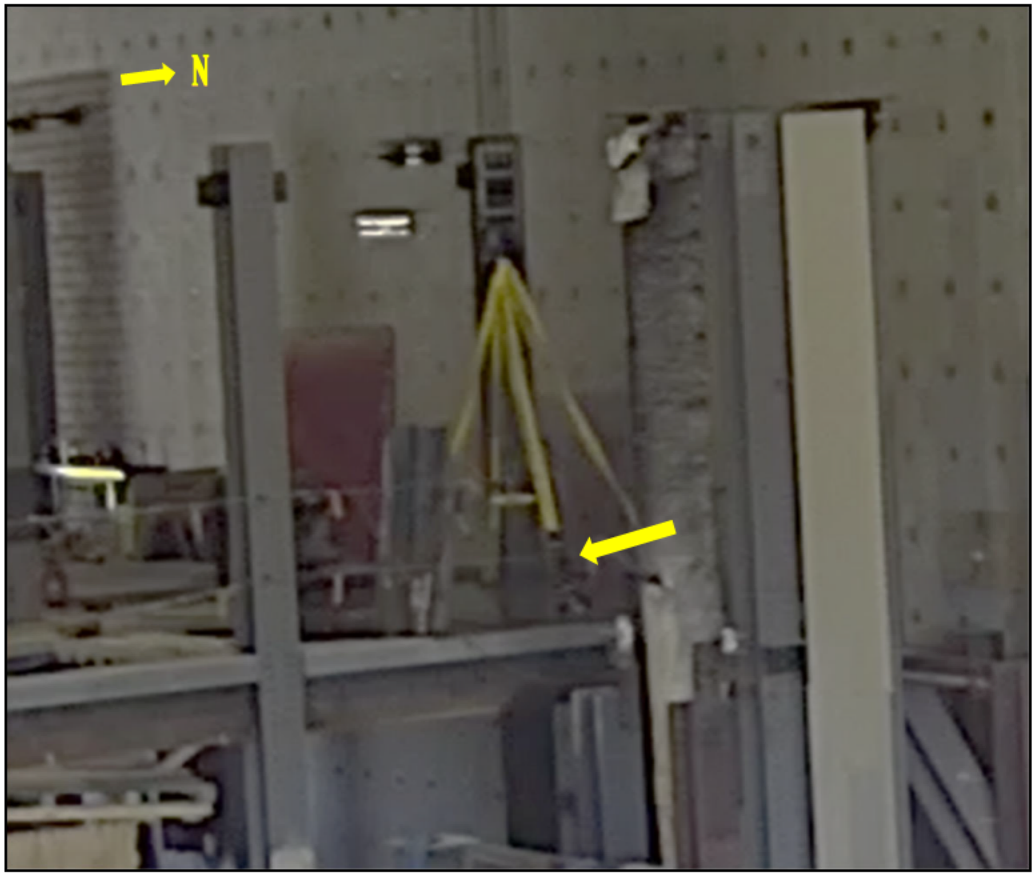


Figure 6.9.26: Image captured from video evidence (CAMERA 2 at 10:42:23 am ET) showing the black bags on south slings. The southeast sling is shown (yellow arrow) while the southwest sling is obscured.

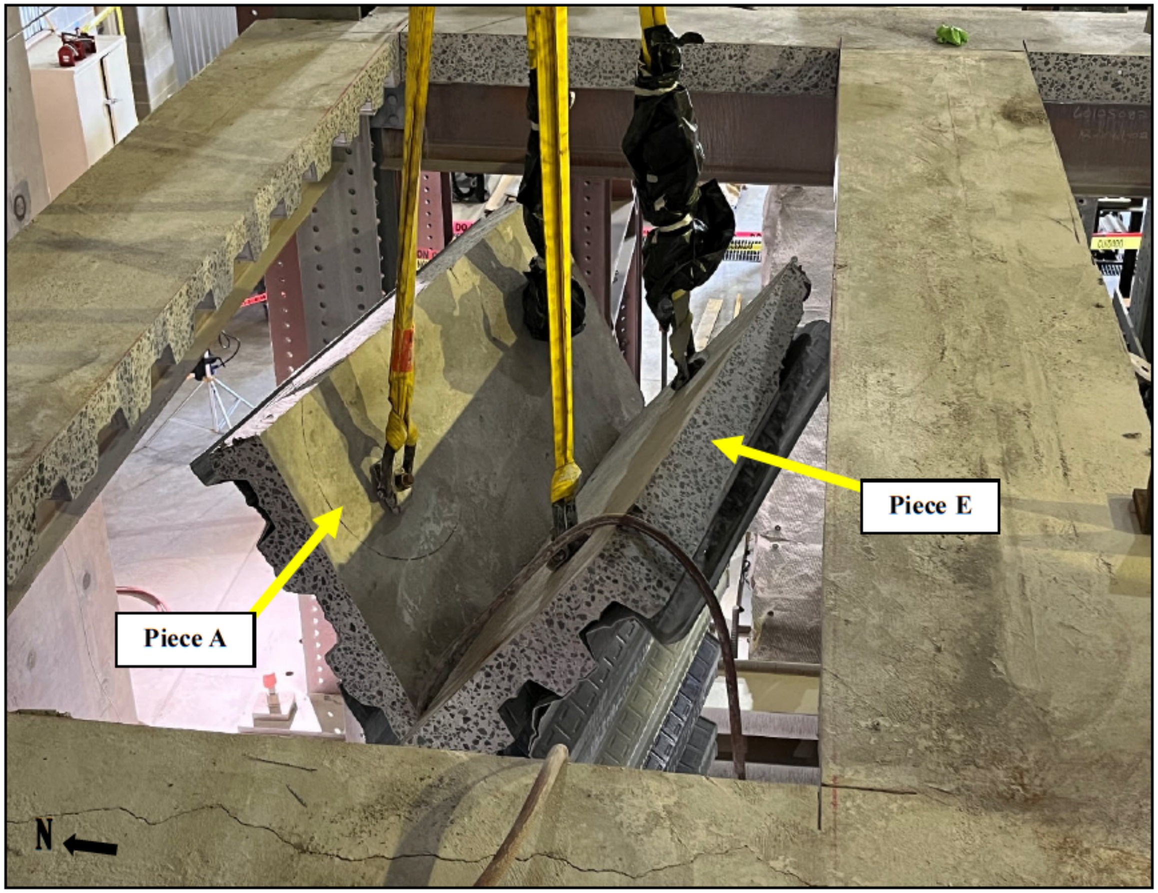


Figure 6.9.27: Two suspended pieces of Slab 4 were identified using the placement of the black bags on the slings. Piece A is the easternmost portion of Slab 4 and Piece E is the westernmost portion. The pieces rotated nearly 90 deg counterclockwise in the bay during the incident. Viewed from the surrounding floor looking east.

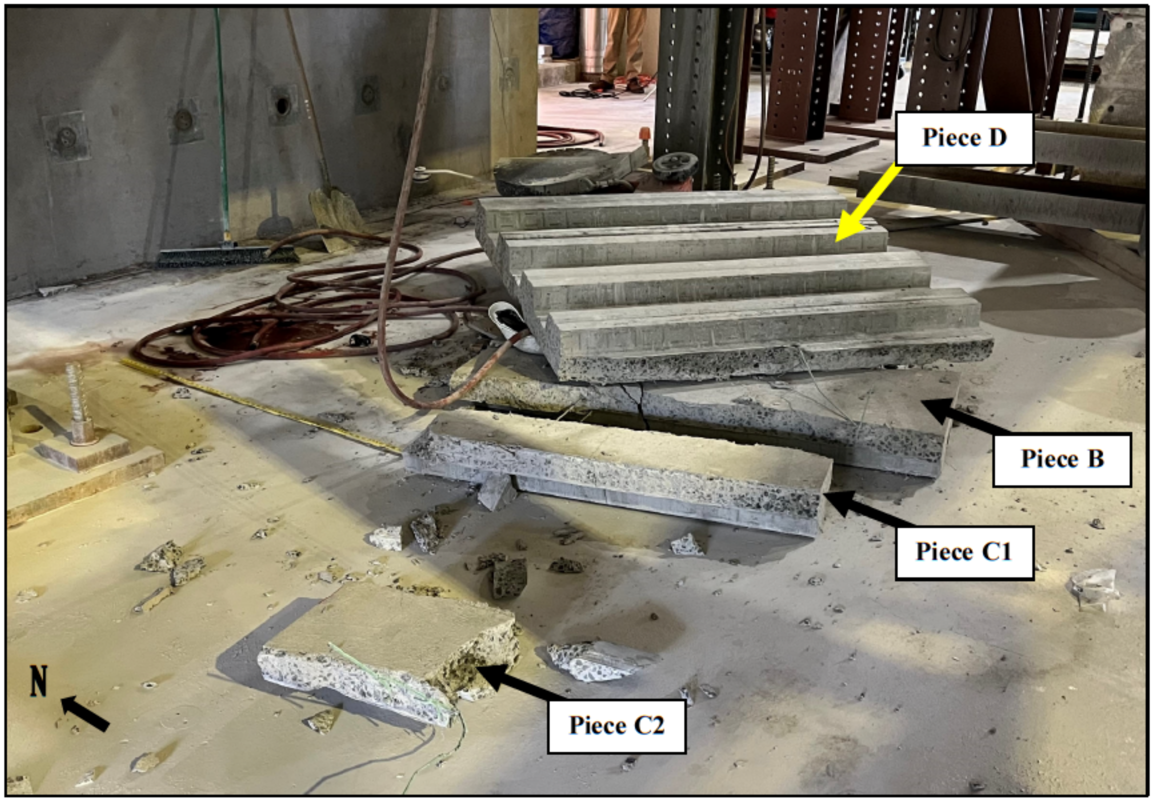


Figure 6.9.28: Four large pieces of Slab 4 were identified by matching up the contours of the fracture surfaces. Viewed on the strong floor looking east.

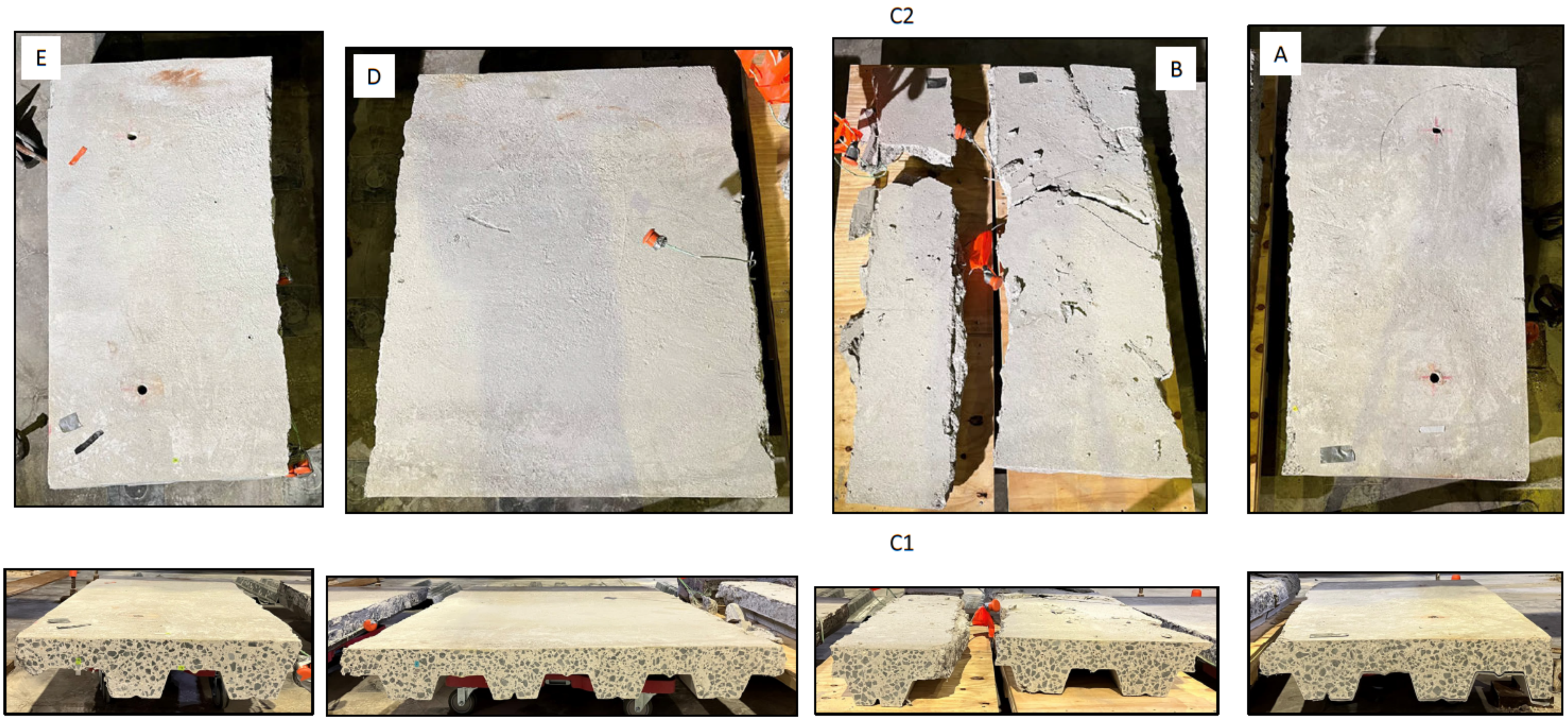
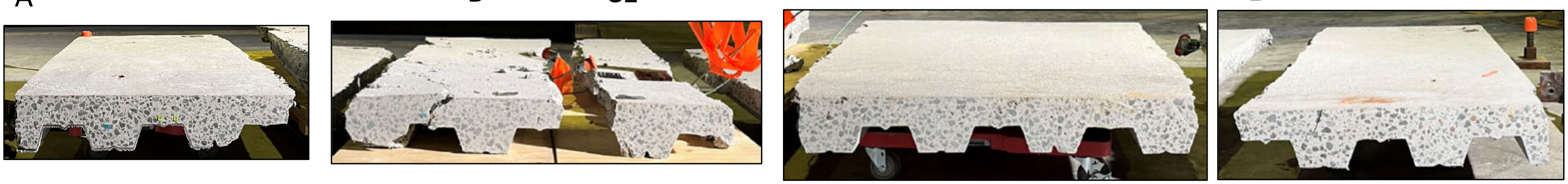


Figure 6.9.29: Slab 4 pieces positioned in a manner in which they were located in the slab prior to fracture. (a) Top view and view of the south cut face.

A B C1 D E



C2

Figure 6.9.29 (cont.): Slab 4 pieces positioned in a manner in which they were located in the slab prior to fracture. (c) View of the north cut face.

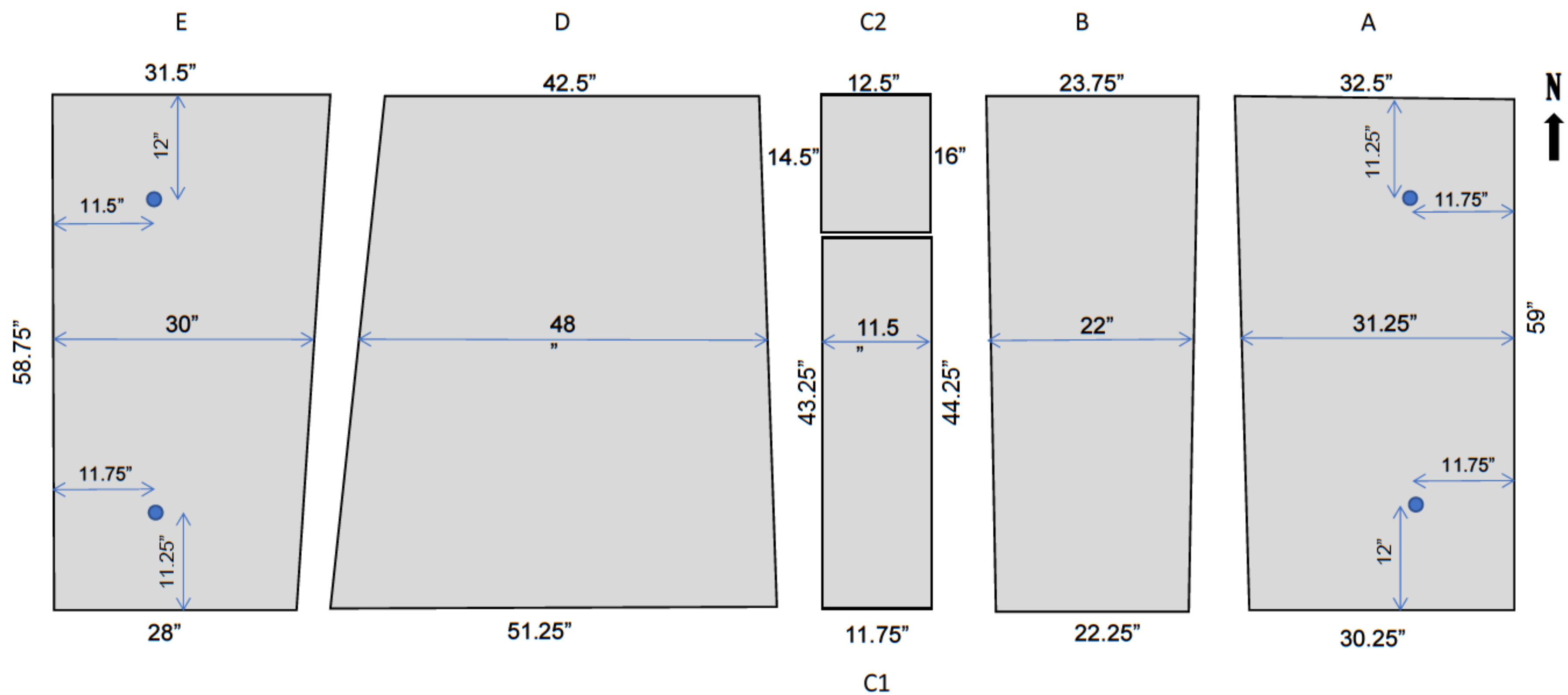


Figure 6.9.30: Slab 4 dimensions (based upon the horizontal top surface) and locations of the rigging holes.

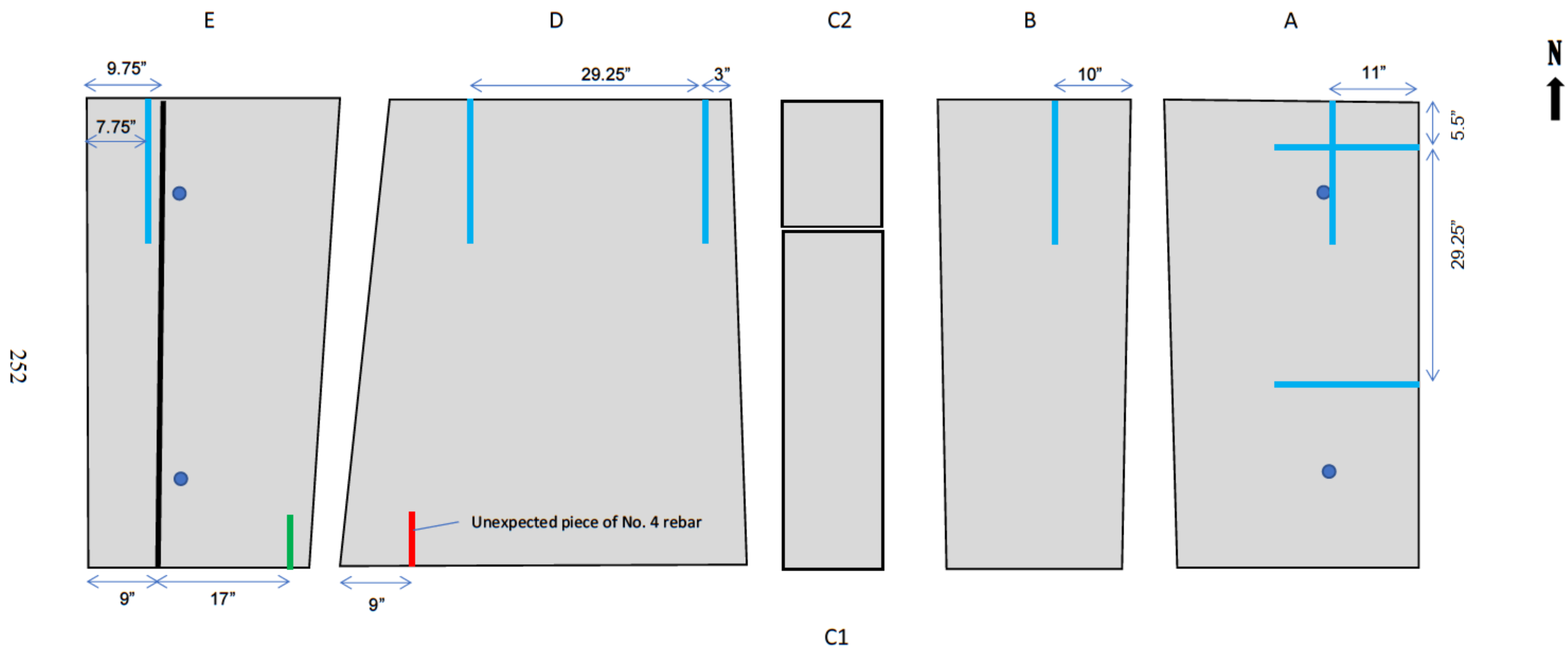


Figure 6.9.31: Observed rebar reinforcement of Slab 4. Blue lines represent the 38" hooked No. 4 rebar and assumed to extend 20" into the slab. Green line represent rebar with unknown extension into the slab. The red line represent unexpected rebar observed with unknown length.

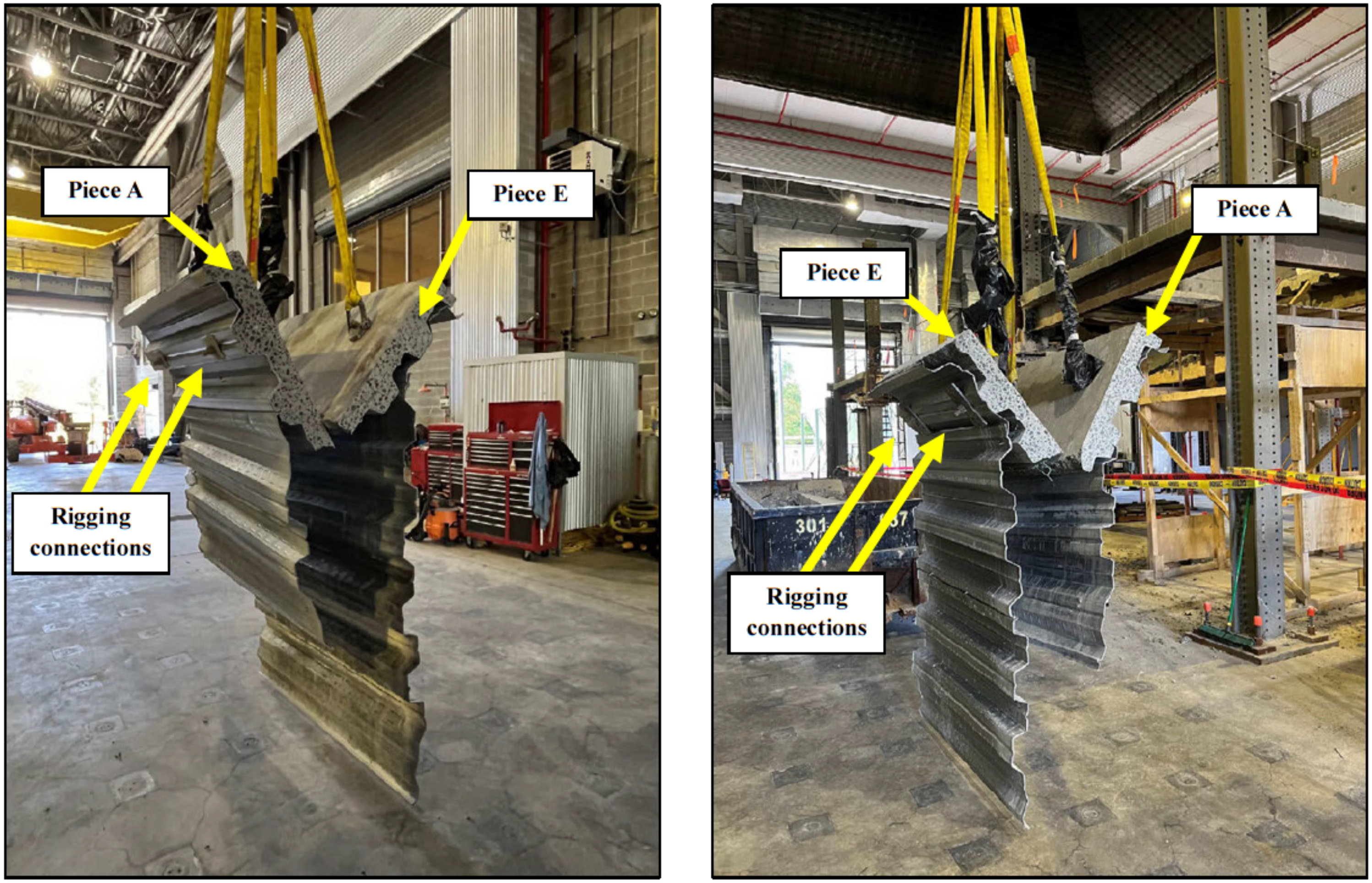


Figure 6.9.32: Two suspended pieces of Slab 4 identified as Piece A and Piece E and the portions of the steel decking being held in place by the rigging connections when viewing a) the north cut face and b) the south cut face.

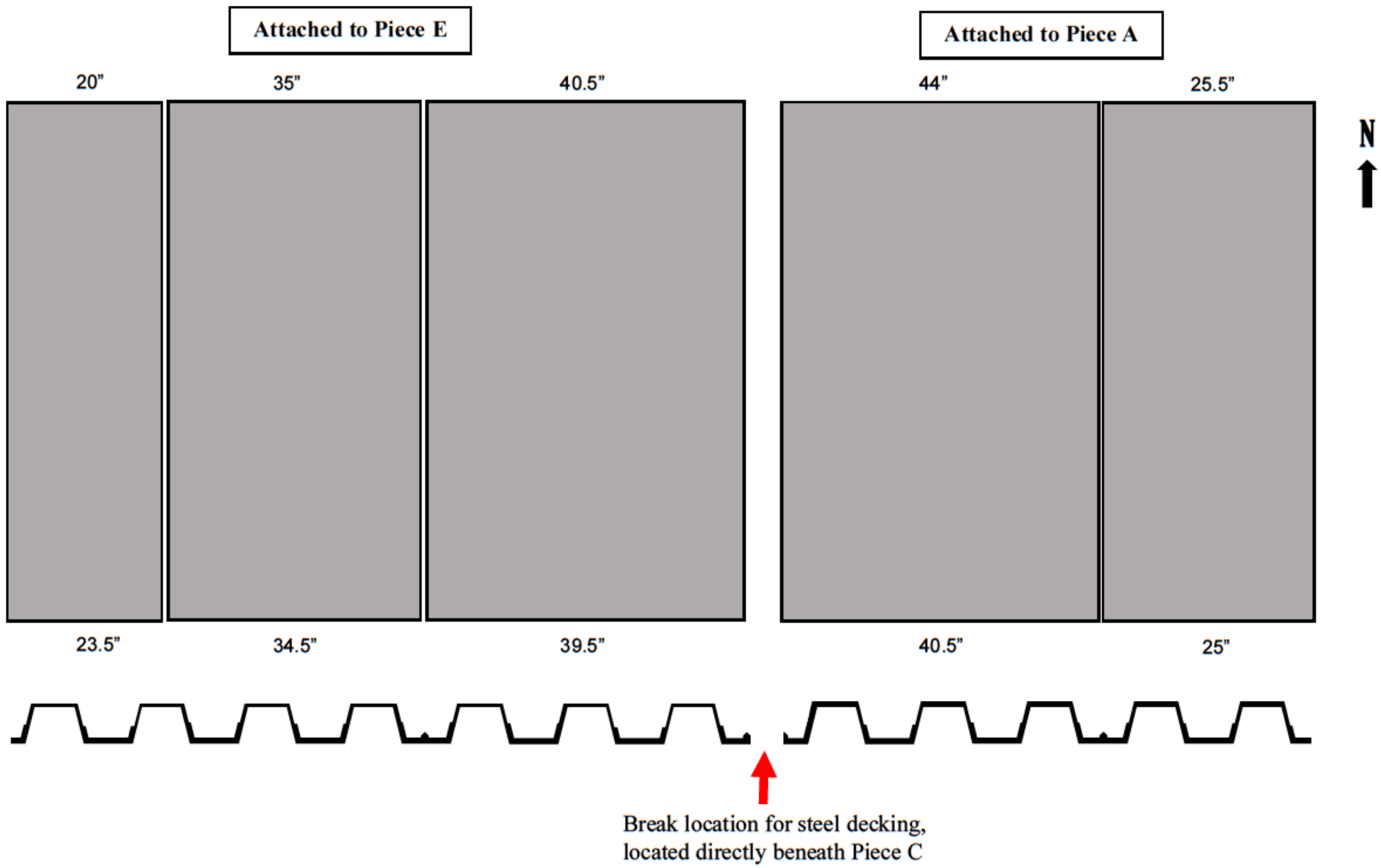


Figure 6.9.33: (a) Measurement for the remnants of the steel decking.

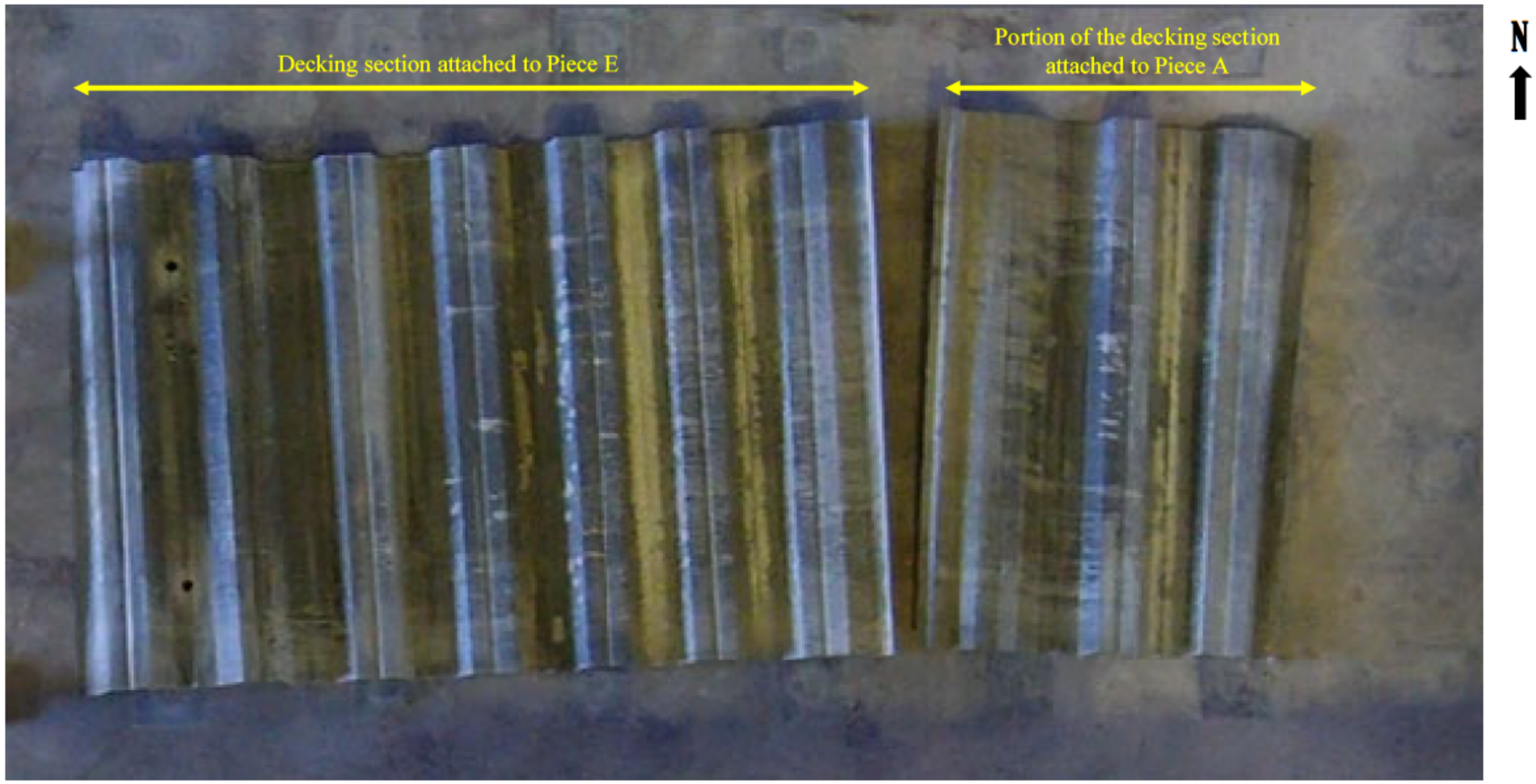


Figure 6.9.33 (cont.): (b) Image of the steel decking. There is a second piece that was attached to Piece A. It is not shown as it is still underneath that portion of the broken slab.

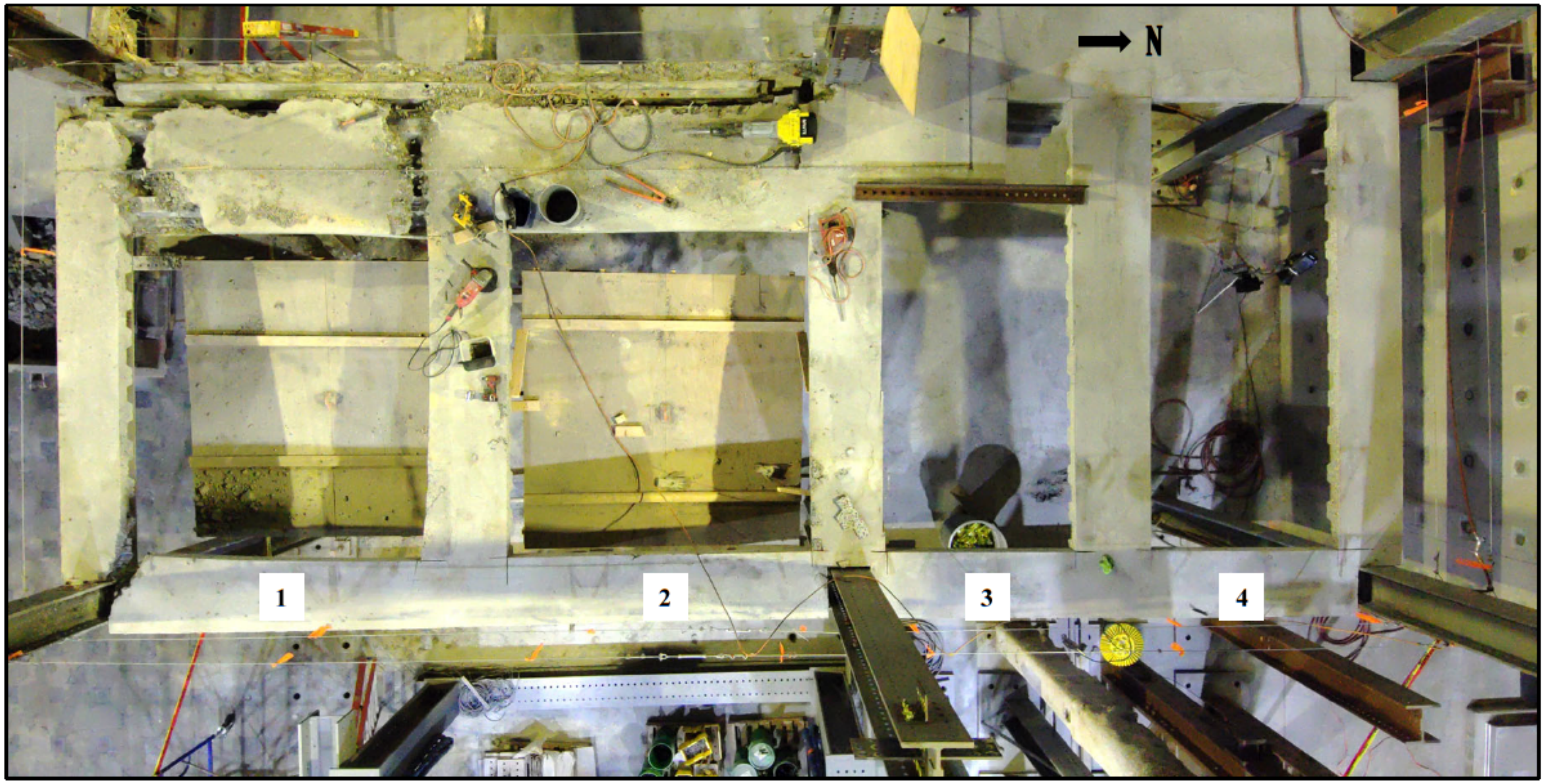


Figure 6.9.34: Aerial view showing the four cut bays in the surrounding floor.

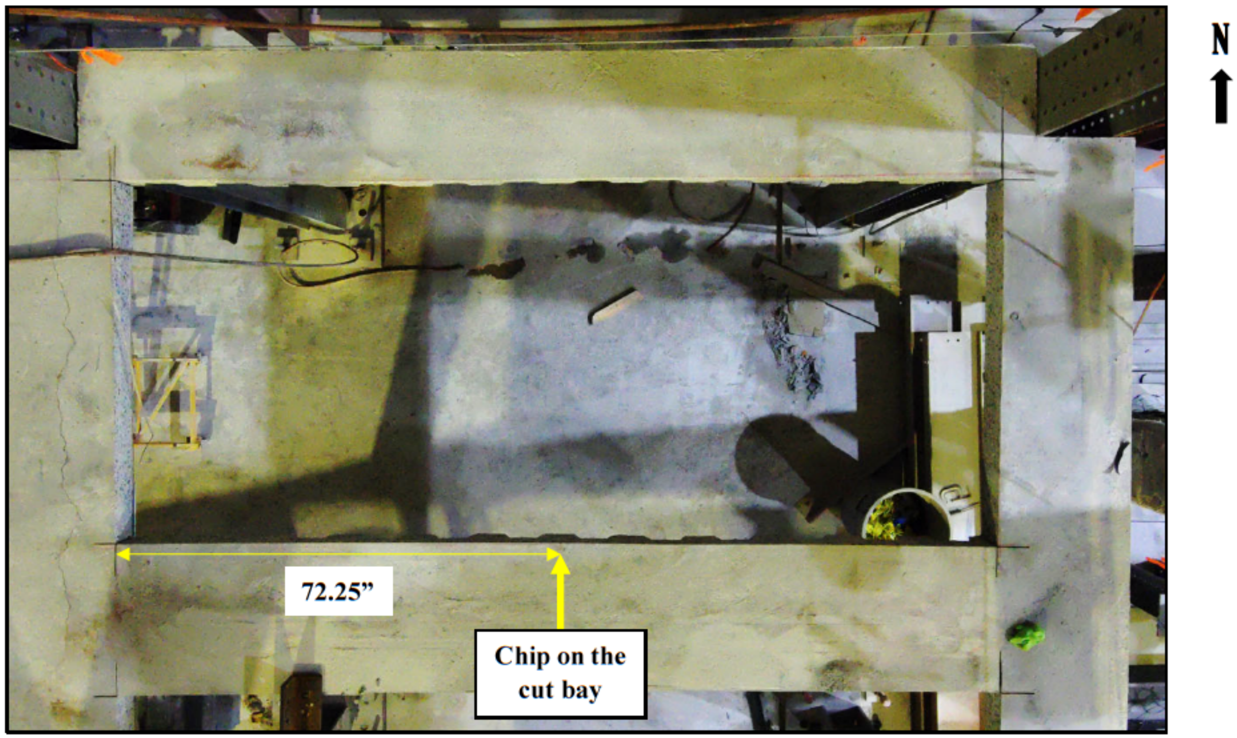
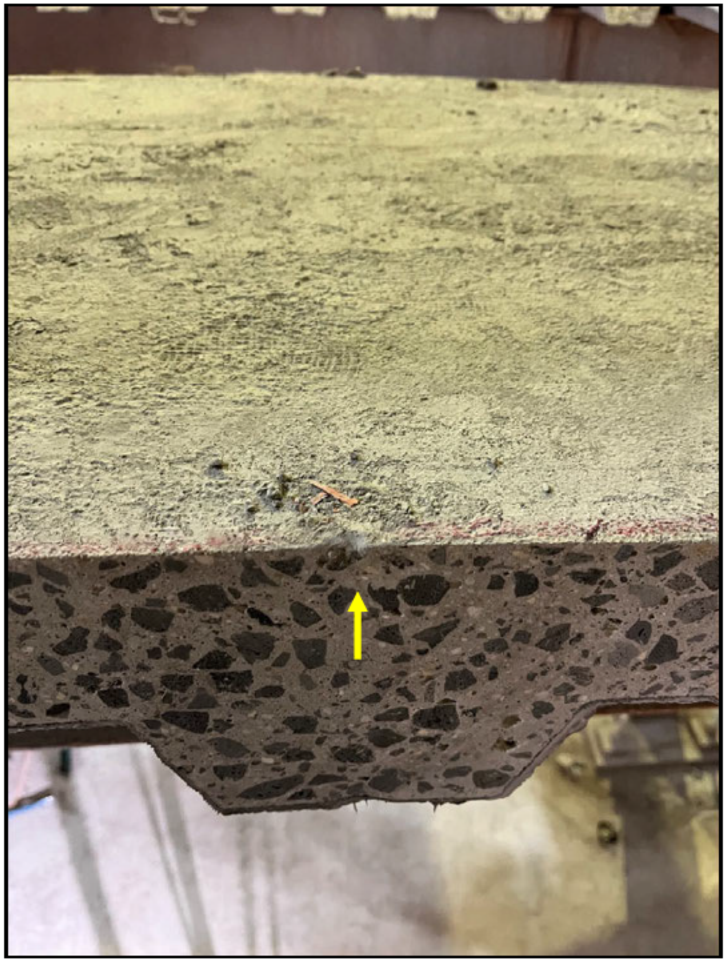


Figure 6.9.35: (a) Aerial view showing the cut bay for Slab 4. Arrow points to a “chip” in the surrounding floor of south cut face.



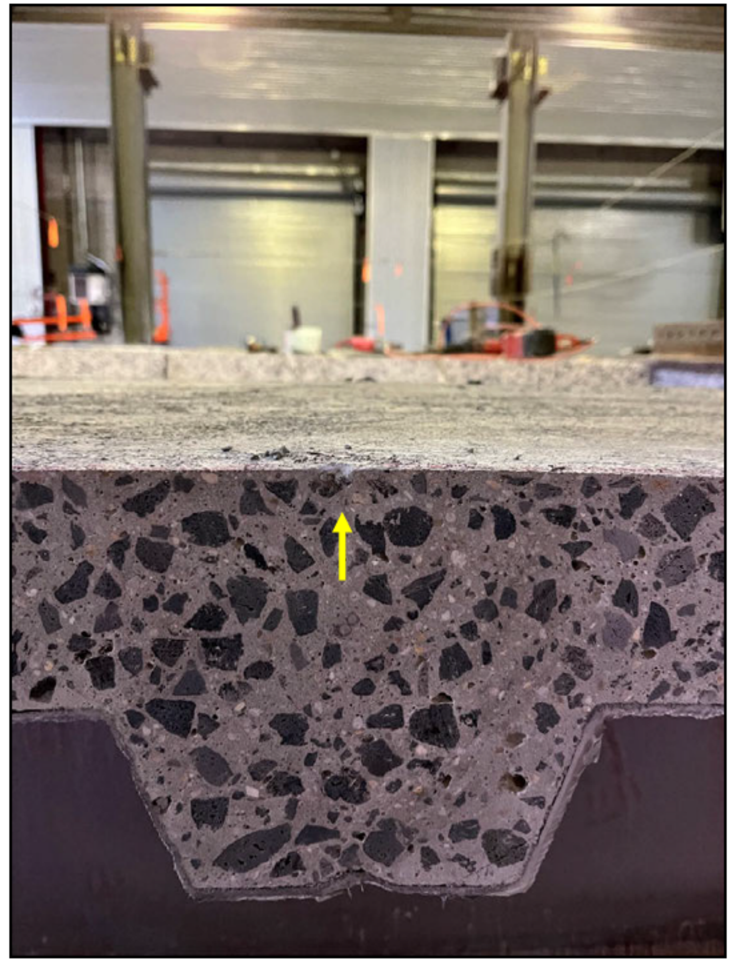
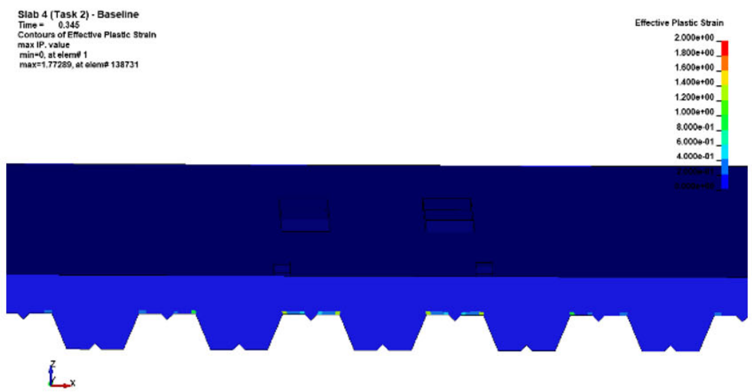
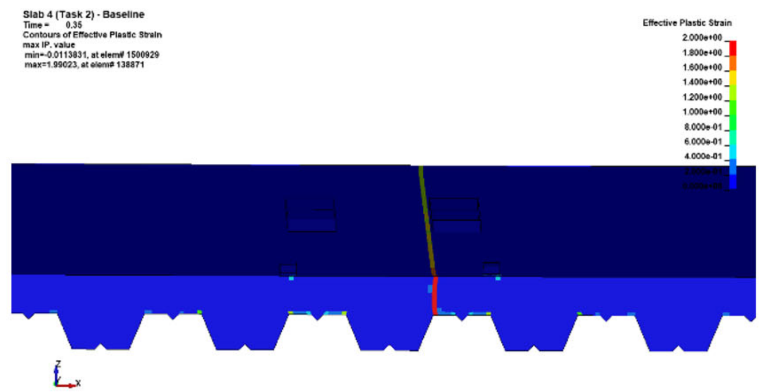


Figure 6.9.35 (cont.): (b) Arrow points to a “chip” in the surrounding floor of south cut face. Images are taken looking south.

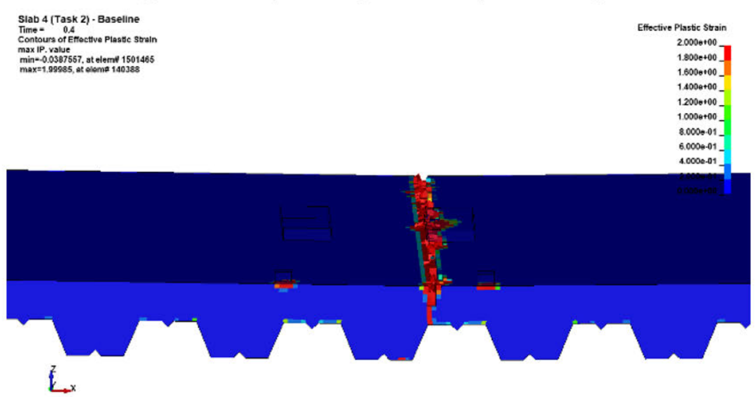
Figure 6.9.36: Images of the slab cut from the CF3 fire-tested floor. Orientation of the slab is unknown.



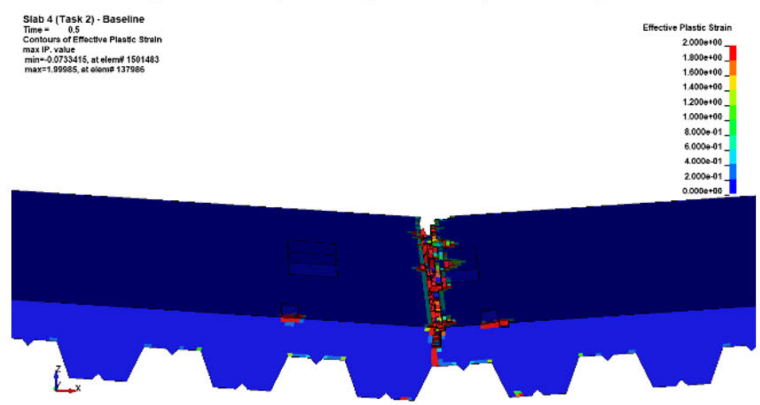
(a) 100% slab + operator weight, 59.2% rotary floor saw weight



(b) 100% slab + operator weight, 85.3% rotary floor saw weight



c) End of gravity loading (100% slab + operator + rotary floor saw weight)



(d) 0.1 seconds after end of gravity loading

Figure 6.16.1: From Appendix 6.17.1, image showing simulation failure of Slab 4 "As Is".

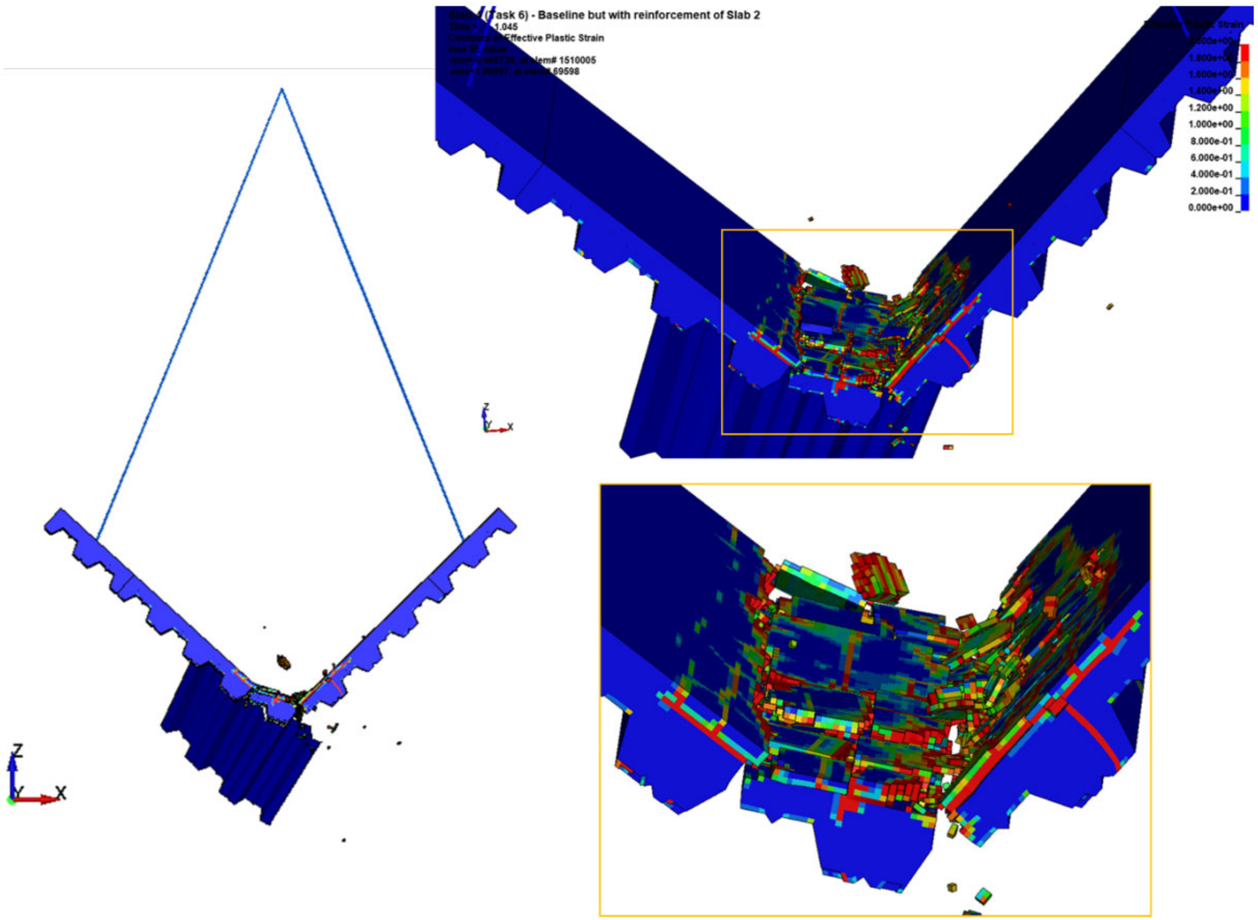


Figure 6.16.2: From Appendix 6.17, image showing simulation failure of Slab 4 "Reinforcement".

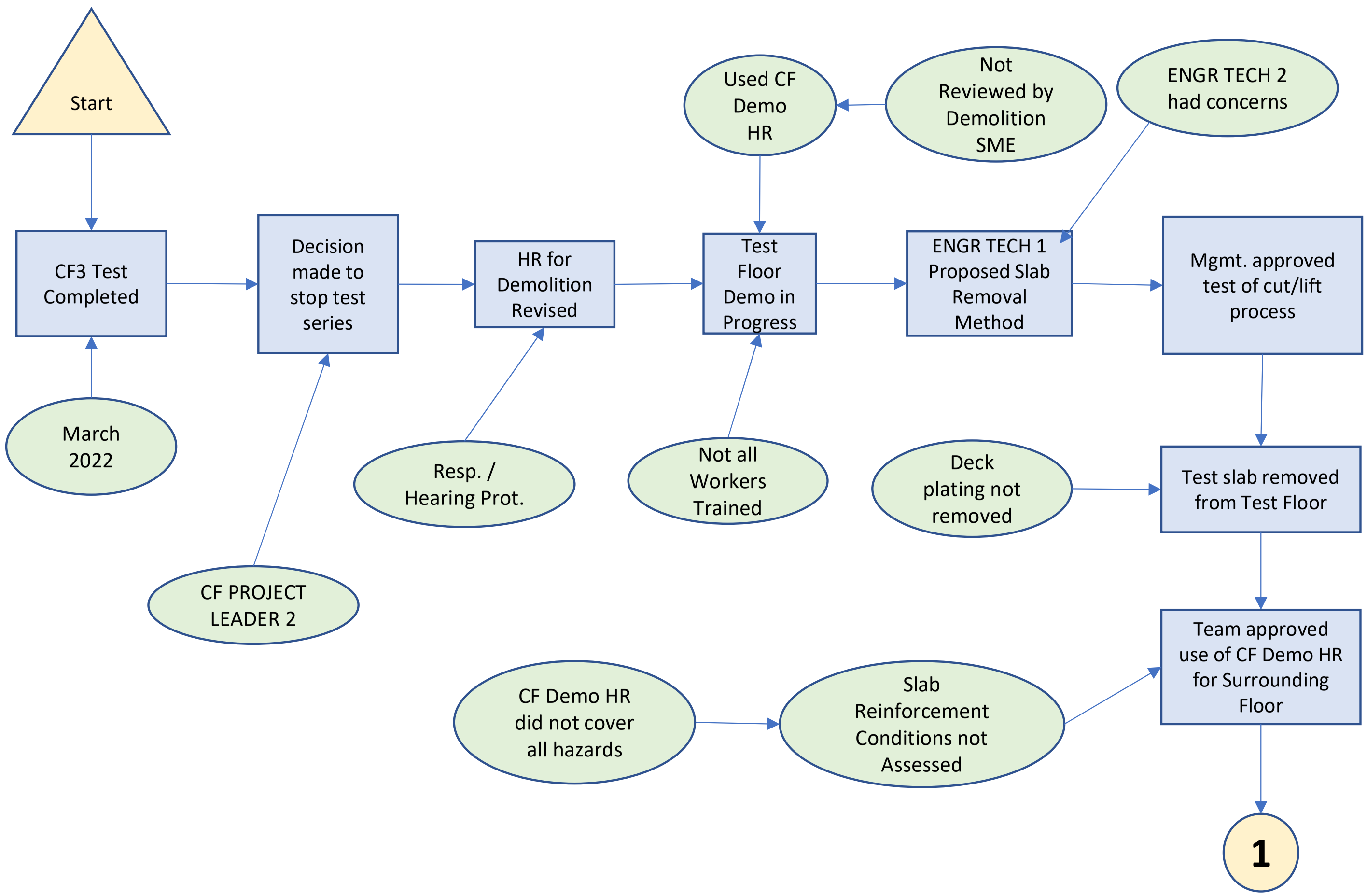


Figure 6.18.1: General events timeline leading from the decision to end the CF Project to the incident.

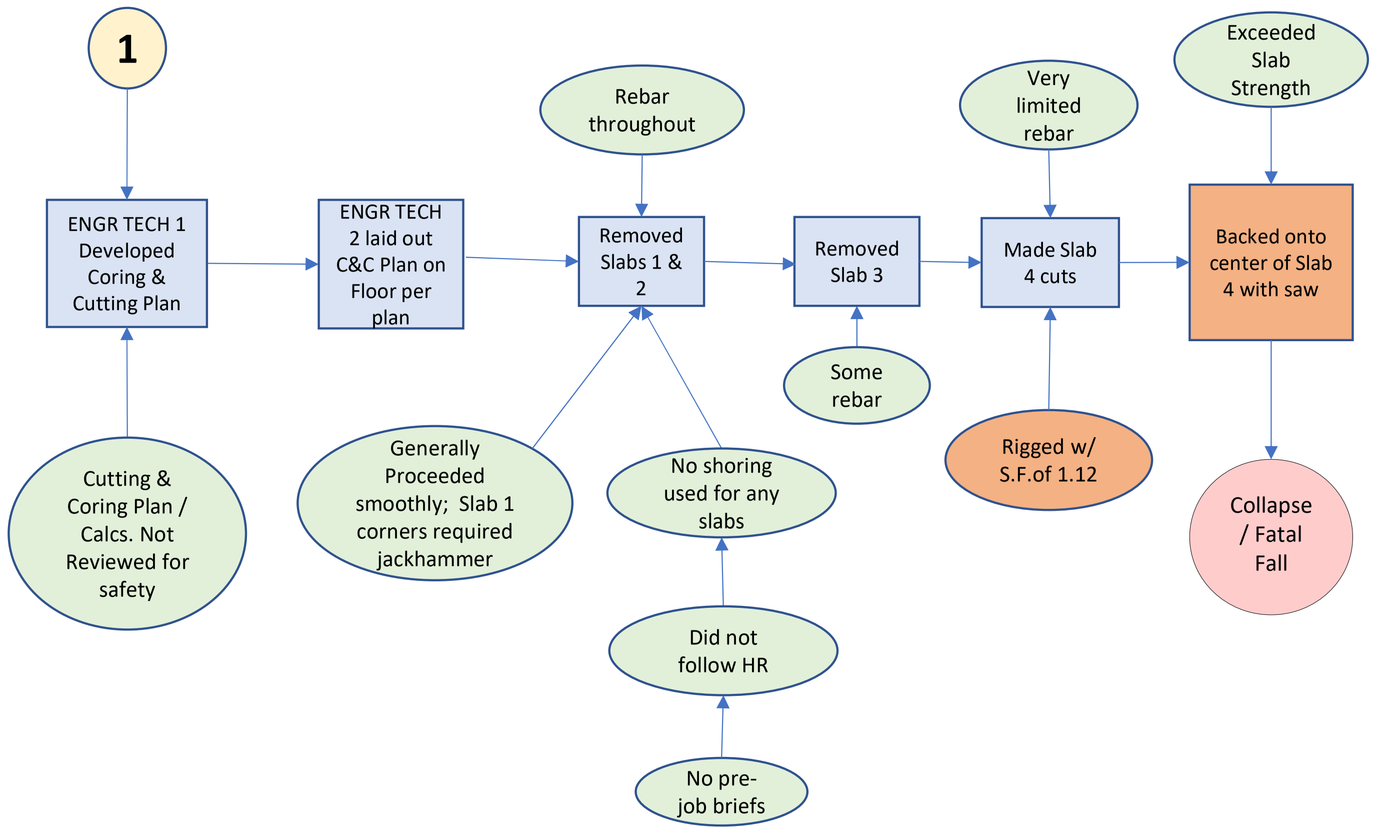


Figure 6.18.1 (cont.): General events timeline leading from the decision to end the CF Project to the incident.

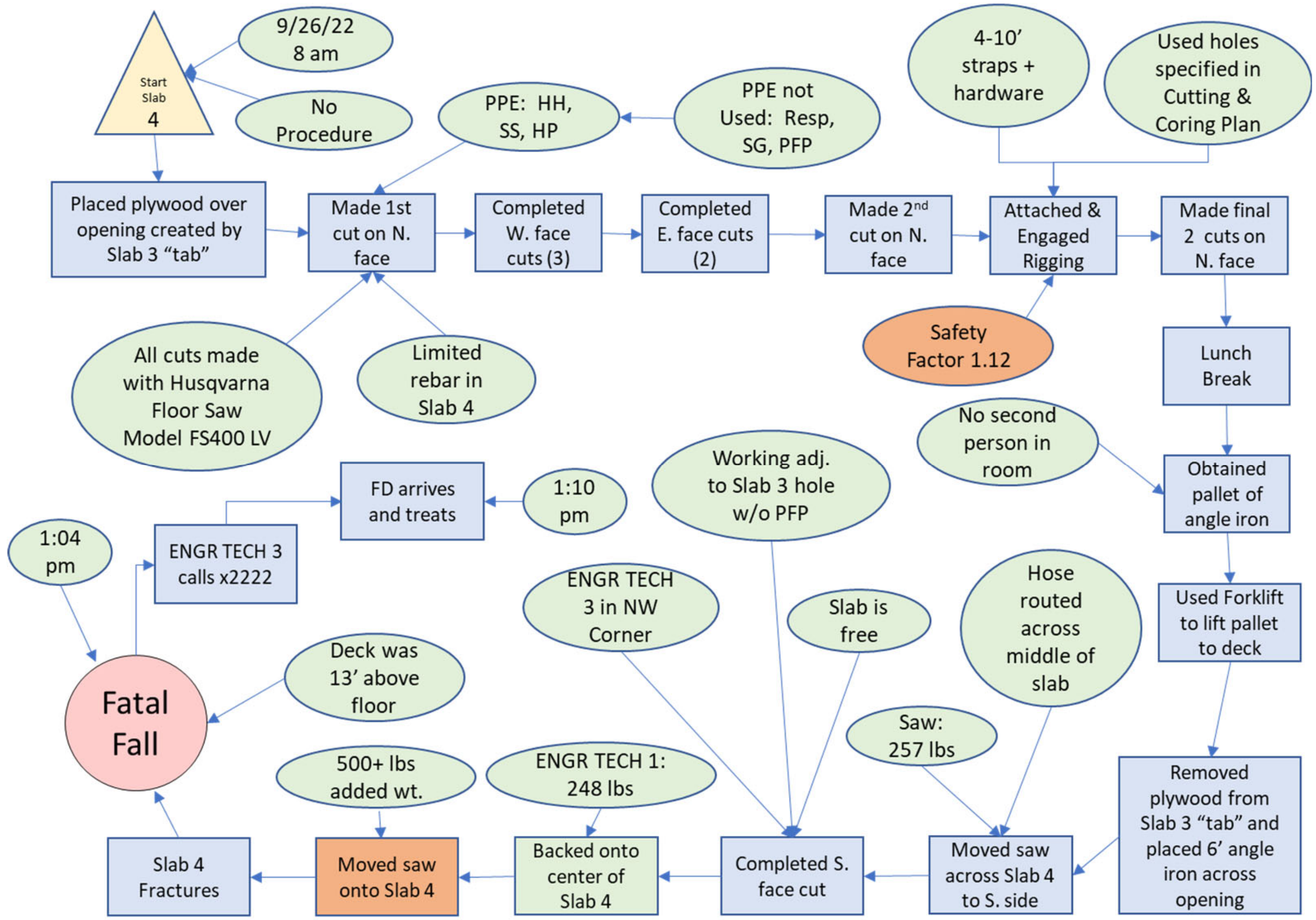


Figure 6.18.2: Specific events timeline for the day of the incident.

Part B: NIST Executive Team Review and NIST-Level Corrective Action Plan

EXECUTIVE SUMMARY
OF THE NIST EXECUTIVE TEAM REVIEW

After the NIST Incident Investigation Team completed its work and a pre-decisional draft report was available, three executive members of the NIST Executive Safety Committee (the Director of the Physical Measurement Laboratory, the Director of the Office of Facilities and Property Management, and the Director of the Office of Safety Health and Environment) convened to review the draft report and develop a NIST-level Corrective Action Plan to ensure that the totality of actions taken, *i.e.*, actions required by the NIST Incident Investigation Team together with those required by the Executive Review Team, have sufficient breadth, depth, and sustainability to prevent similar incidents and help prevent incidents arising from similar root causes at NIST.

The Executive Review Team determined the root causes of this incident pointed to:

1. Fundamental weaknesses in the NIST Safety Management System with respect to completeness and implementation; and
2. Fundamental insufficiencies in the safety culture, with respect to personal commitment and management accountability leading to unsafe actions and complacency.

The Executive Review Team endorsed all corrective actions specified by the NIST Incident Investigation Team, as written and as they apply to EL, NFRL or NIST. For corrective actions specified by the NIST Incident Investigation Team that apply only to NFRL or EL, the Executive Review Team developed new NIST-level corrective actions that require the same or similar measures at the NIST level or NIST-wide. The Executive Review Team also endorsed the NIST Incident Investigation Team's recommendations and elevated these to NIST-level corrective actions. Finally, the Executive Review Team added corrective actions that further address the fundamental weaknesses uncovered by the NIST Incident Investigation Team: Safety Management System gaps, weaknesses safety program implementation and safety culture.

The resulting NIST-level Corrective Action Plan specifies 15 corrective actions and includes an additional three corrective actions, as written by the NIST Incident Investigation Team. Some of these required changes represent improvements in existing processes, others represent fundamental changes to operations. These fundamental changes include the following:

1. New safety programs (*e.g.*, audits and assessments, corrective and preventive actions, construction safety);
2. New requirement to develop appropriate, targeted, refresher safety training, beyond that required by regulations;
3. New requirement to specify when OSHE safety professionals must lead or participate in reviews, assessments, or inspections of work processes, procedures workspaces;
4. Requirement to specify new safety performance plan elements for supervisors; and

New requirement to specify metrics to assess safety culture improvement.

10.0 Purpose of Post-Incident Investigation Executive Review Team

Following the development of a pre-decisional draft report by the NIST Incident Investigation Team, three members of the Executive Safety Committee (the Director of the Physical Measurement Laboratory, the Chief Safety Officer, and the Chief Facilities Management Officer) were asked to review the corrective actions (CA) and recommended actions (RA) specified in the report[35]. The Executive Review Team reviewed the actions and extended or modified these as necessary to ensure that actions taken were of sufficient breadth, depth, and sustainability to address the root causes identified in the report to prevent similar incidents and those arising from similar root causes at NIST. The Executive Review Team included additional corrective actions they deemed necessary and appropriate to address root causes, contributing factors, or fundamental weaknesses revealed by the observations of the investigation team.

10.1 Executive Review Team Categorization of Root Causes and Contributing Factors

The NIST Incident Investigation Team used standard incident investigation methods to identify two fundamental causal factors, determine eleven root causes (RCs), and then identify and assess eight contributing factors (CFs). The NIST Incident Investigation Team then developed a comprehensive set of corrective actions to address root causes and contributing factors in a manner intended to prevent similar incidents, or incidents arising from similar root causes. The Executive Review Team found that these root causes and contributing factors fell into two basic categories:

1. Management System Inadequacies
   a. Gaps (CFs 6,7,8)
   b. Implementation (RCs 1.1, 1.2, 1.3, 2.1, 2.2, 2.4, 2.5)
2. Safety Culture Insufficiencies (RCs 1.4, 1.5, 2.3, 2.6) (CFs 1, 2, 3, 4, 5)
   a. Commitment
   b. Accountability
   c. Complacency

Corrective actions provided by the Executive Review Team are intended to address the management systems inadequacies and safety cultural insufficiencies associated with the root causes and contributing factors. The Executive Review Team:

1. Specified which corrective actions provided by the incident investigation team should be expanded to increase the breadth and applicability;
2. Specified NIST-level programs for development or revision to increase both the breadth and sustainability; and
3. Added detail to some of the incident investigation team's corrective actions or developed new corrective actions to improve the depth of the overall corrective action plan.

[35] The executives did not participate in the investigation and did not contribute to sections 1-9 of this report.

10.2 Executive Review Team Endorsement of Corrective Actions Provided by NIST Incident Investigation Team

The Executive Review Team endorses all corrective actions provided by the NIST Incident Investigation Team, as written and as they apply. Elevation of the corrective actions to the NIST-level should be taken into consideration when developing the specific final action plan as it applies to EL and NFRL.

10.3 Executive Review Team Corrective Actions for Hazard Reviews

Many of the corrective actions specified by the NIST Incident Investigation Team focus on improving implementation of NIST S 7101.20: *Work and Worker Authorization Based on Hazard Reviews Program* (or Hazard Review Program) within EL or for some actions, specifically within NFRL. The Executive Review Team agreed many of the corrective actions focused on Hazard Review Program implementation should be adopted as written, in part, or with modifications and applied NIST-wide. The Executive Review Team corrective actions are listed as E1-E5. References to the NIST Incident Investigation Team corrective actions (CAs) that applied to EL or NFRL are included in parentheses. Additional actions associated with Hazard Review Program improvements that do not tie directly to those specified by the incident investigation team are listed as *"Added by the Executive Review Team."*

Corrective Action E1: OUs must complete the work associated with the FY23 NIST-wide initiative that requires re-review of hazard reviews, including documentation review and activity observation.

This initiative was designed to ensure that all hazardous activities are covered by hazard reviews and meet requirements of NIST S 7101.20. The requirements for re-review of the activity specify that both technical and safety expertise are required, that activities must be observed (at a time when feasible), and hazard reviews revised as necessary to ensure that documentation such as operating procedures, emergency response plans, and the list of hazards, controls (including training) and associated risk assessments cover current practices (see also CA1, CA5, CA11, CA12, CA18, CA25).

Corrective Action E2: All OU hazard review policies must contain the key elements listed below and be communicated as necessary (see also, CA3, RA3) **to affected staff and managers.**

The following key elements must be included in OU policies:

- Roles and responsibilities of those involved in review and approval of hazard reviews, if different from those specified in NIST S 7101.20 (see also CA9, CA16, RA2);
- KSAs (including training) required for those who develop and approve hazard reviews, noting that Subject Matter Experts, internal or external to the OU, may be needed to achieve adequate expertise (see also CA2, CA14);

    Note: The executive team notes that OU's may rely on internal or external subject matter experts to advise supervisors when reviewing and approving activities and workers.

- Requirement to stop work and update hazard reviews when boundary conditions change, or scope creep occurs (see also CA2, CA6, CA8); and
- Scope of activities must be specified as well as boundary conditions, noting that separate hazard reviews may be needed for non-routine activities such as set-up, installation, commissioning, tear-down, decommissioning (see also CA18, RA6).

<u>Corrective Action E3</u>: In addition to assessment of the Hazard Review Program per recommendations in RA9, OSHE shall revise the Hazard Review Program, associated training or tools, as appropriate, to include the following:

- *Added by Executive Review Team. Provide more emphasis on consideration and use of the two top-level controls, elimination and substitution, with examples of each.*
    - *Explicitly require due consideration of substituting external experts or contractors with appropriate KSAs to perform hazardous work when NIST staff have limited expertise or perform the work infrequently.*
- *Added by Executive Review Team. Specify when safety expertise of OSHE staff is required for review of hazardous activities.*
- *Added by Executive Review Team. Specify that reviewers should consider and specify safety improvements deemed necessary to adequately mitigate risk, regardless of funding required.*
- *Added by Executive Review Team. Specify that supervision, pre-job briefings, or posted work plans may be required as hazard controls in specific circumstances, e.g., for construction work, infrequently performed high risker activities.*
- *Added by Executive Review Team. Specify a shorter timeline (than three years) for re-review of high-hazard activities such as many RHI=3 activities.*
- Define the term “boundary condition” and provide more clarity on when a separate hazard review is needed for associated but different work processes such as set-up, commissioning, maintenance, tear-down, decommissioning, *etc*. (see also CA5, CA18, CA19, RA6)
- Specify that supervisors and workers who do not have the KSAs to adequately review safety are required to obtain and rely on Subject Matter Expert review and advice (see also CA14)
- Guidance on how to develop a good quality general or broad-scope hazard review, specifying when this approach is appropriate and when it is not (see also CA7)
- Add a requirement for observing the work conducted according to hazard review specifications as a condition for initial and renewed approvals (see also CA15)
- Clarification on approval of workers based on KSAs, by specifying that supervisors must ensure completion of required program training, activity-specific training, and assess the worker’s level competence. Specify that worker experience may be a condition for approval, or specified as a requirement to work unsupervised but is not a substitute for training (see also CA13)
- Define the “buddy system” and specify requirements that must be met by “buddies” or observers whose presence serves as hazard control (see also RA5)

- Provide more emphasis on "scope creep" and the requirement to stop work, review changes and obtain appropriate approvals (see also CA6)
- The current program does not prohibit the development and safety review of a hazard review by a single individual. Specify how to obtain appropriate safety expertise to achieve an independent review of hazardous work as a condition of approval (see also CA16)

<u>Corrective Action E4</u>: OSHE shall develop and require refresher training for:

- **Staff on how to perform a good quality hazard review including how to assess risk; and**
- **Supervisors and reviewers on conducting a thorough, quality review of the activity and the documented hazard assessment package** (see also CA3, RA8)

<u>Corrective Action E5</u>: OSHE in collaboration with the Executive Safety Committee, Safety Advisory Committee and the Office of Human Resources shall specify safety performance metrics for supervisors, and specifically for those who oversee and authorize hazardous work (see also CA10, CA17)

10.4 Executive Review Team Corrective Actions to Address Safety Management System Gaps and Improvements

The Executive Review Team endorses corrective actions CA23, CA24, CA26 developed by the incident investigation team, as written, to address gaps in the NIST Safety Management System. For completeness, these corrective actions are summarized below:

NIST/OSHE shall revise and re-deploy cranes and hoists as noted in CA23

NIST/OSHE shall develop a new safety program, or modify the cranes and hoists program to address requirements for rigging as noted in CA24

NIST/OSHE shall develop and deploy a comprehensive Audit and Assessment Program as noted in CA26 (see also CA3, CA4)

Executive Team Note: Results from audits and assessments must be included in Management Reviews and used to drive continuous improvement by informing the Safety Objectives that are developed by the Executive Safety Committee, and reviewed, revised as necessary and approved by the NIST Director and Associate Directors; See NIST O 7101.01.

Corrective actions E6-E12 are provided by the Executive Review Team to address gaps and improvements in implementation of specific elements of NIST safety management system. Items that do not tie directly to one of the investigation team CAs, or that are associated with a recommendation by the incident investigation team are preceded with *"Added by the Executive Review Team."*

Corrective Action E6: OSHE, working with the OUs, shall lead a NIST-wide assessment of implementation of NIST S 7101.69: *Fall Protection Program* to ensure control measures have been identified, specified in the applicable hazard reviews, and implemented (see also CA20)

Corrective Action E7: *(Added by Executive Review Team to address recommendation)* OUs with assistance from the Safety Advisory Committee shall develop a process to routinely review incidents and communicate lessons identified to affected staff in their OUs (see also RA4)

Corrective Action E8: NIST/OSHE shall develop a Corrective and Preventive Action Program that specifies the requirement for OUs to review corrective actions for which they are responsible to ensure these actions are tracked, completed in a timely manner, and implemented in a manner that is sustainable if the action, where applicable (CA21, CA22) Note that OSHE shall audit the completeness and efficacy of corrective actions associated with incident prevention as part of CA26.

Corrective Action E9: *(Added by Executive Review Team to address recommendation)* OSHE shall evaluate the need for a Construction Safety Program (that covers demolition) and, if needed, develop the program in collaboration with Subject Matter Experts from the Office of Facilities and Property Management (see RA7)

Corrective Action E10: *(Added by executive team to address recommendation)* OSHE shall evaluate safety program requirements and develop refresher safety training, as necessary, for target audiences, specific to roles and responsibilities and hazards encountered (see RA8)

Corrective Action E11: *(Added by Executive Review Team to address recommendation)* OSHE will work with stakeholders to specify and identify practical crane training course for NIST staff (see RA10)

Corrective Action E12: *(Added by Executive Review Team)* OSHE shall review all NIST safety management system directives and revise as necessary to specify when OSHE safety professionals (or those approved by OSHE, *e.g.*, Division Laser Safety Officers who meet requirements) are required to lead or participate in review hazardous work prior to approval, and in evaluation of processes, procedures, or workspaces to ensure regulatory compliance. (Note: This action will more fully and systemically address factors that indicated insufficient safety KSAs of staff and line managers.)

10.5 Executive Review Team Corrective Actions to Address Safety Culture

Executive Review Team corrective actions E13 and E14 are designed to address NIST Incident Investigation Team recommendations, RA1 and RA11, regarding safety commitment and the responsibilities that fall to first level supervisors.

Corrective Action E13: ***(Added by the Executive Review Team to address recommendation)*** **The NIST Director will communicate the expectation that all NIST staff, supervisors and managers commit to the NIST policy of taking personal responsibility for safety and for implementing the requirements of the NIST Safety Management System as it applies to them (see RA1)**

Corrective Action E14: ***(Added by the Executive Review Team to address recommendation)*** **The ESC will convene a working group, comprised of executive leaders, managers, and supervisors to review safety roles, responsibilities, authorities, and accountabilities (R2A2s) and develop recommendations to revise these as appropriate to ensure clarity, fairness, and balance while preserving the fundamental oversight necessary to maintain safe operations according to the NIST Safety Management System.** This working group should specifically review the burden on first level supervisors for ensuring safety at NIST. **(See RA11)**

The Executive Review Team recognizes that many of the root causes and contributing factors identified by the NIST Incident Investigation Team stem from an insufficiently strong safety culture at NIST. These stem from a culture in which it has become acceptable to disregard safety program requirements or to implement safety requirements inconsistently. Evidence reviewed and described by the NIST Incident Investigation Team indicates that NIST lacks many of the safety culture attributes specified by the Executive Safety Committee. To address these insufficiencies broadly across NIST, in a manner that supports continuous improvement the following Corrective Action is required:

Corrective Action E15: ***(Added by the Executive Review Team)*** **NIST shall implement and continually improve the NIST Safety Culture Program and develop associated metrics to evaluate improvement.**

Note: NIST must develop a culture that encourages, promotes, and accepts safety feedback including requests or instructions to correct unsafe behaviors or conditions. NIST staff members and managers must be willing to accept feedback provided by peers, direction from supervisors, and direction from the CSO and OSHE staff responsible for ensuring regulatory compliance and workplace safety.

10.6 Executive Review Team Corrective Action Summary

In summary, the Executive Review Team has categorized the Root Causes and Contributing Factors associated with this incident into two high-level categories:

- Management Systems; and
- Safety Culture,

to facilitate development of a NIST-level Corrective Action Plan. The NIST level plan will supplement the corrective actions specified by the NIS Incident Investigation Team. The NIST-Level Corrective Action Plan was informed by the corrective actions and recommendations specified by the NIST Incident Investigation Team, includes some of these directly as written, and contains additional corrective actions the executives determined were necessary to fully address management system insufficiencies and safety culture weaknesses identified.

Many NIST-level actions will require changes to the directives that comprise the NIST Safety Management System. These directives and their implementation will be subject to routine audits and assessments, to ensure sustainability of the changes.

Some changes required by the NIST-level corrective action plan represent improvements in existing processes, others represent fundamental changes to operations. Fundamental changes include the following:

1. New safety programs (*e.g.*, audits and assessments; corrective and preventive actions; construction safety);
2. New requirement to develop appropriate, targeted refresher safety training, beyond that required by regulations;
3. New requirement to specify when OSHE safety professionals must participate, review, assess, or inspect work processes, procedures workspaces;
4. New requirement to specify safety performance plan element for supervisors; and
5. New requirement to specify metrics to assess safety.

APPENDICES

Appendix 5.3.1: NIST Staff Interview Statements (Redacted)

Summary of Investigation Interview with EL DIRECTOR

Date: February 27, 2023
Time: 11:00 am to 11:53 am

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members present: [redacted]

SUMARY OF RESPONSES RELATED TO [redacted]
[redacted] stated she is the Director of the Engineering Laboratory (EL) at the National Institute of Standards and Technology (NIST), a position she has held since December 2021. She stated prior to this position, she was a bench scientist, group leader, deputy division chief, and deputy director all in EL.

[redacted] stated she is responsible for all aspects of the management of EL, including:

- Strategic planning;
- Supervising the EL Deputy Director (who is delegated specific safety responsibilities);
- Engaging with NIST Senior Leaders ;
- Interacting with EL stakeholders; and
- Ensuring EL remains focused on its mission.

[redacted] stated her philosophy towards safety is the work will be performed safely or the work will not be performed at all. She stated there is no room for compromise when it comes to safety.

SUMMARY OF RESPONSES RELATED TO SAFETY MANAGEMENT IN EL
[redacted] stated she employs numerous mechanisms to communicate her occupational safety and health expectations to staff, including:

- EL Leadership Meetings, held every two weeks, where safety discussions are always first on the agenda and may be led by the EL Safety Professional;
- EL Safety Meetings, held every two weeks with a smaller team involving the EL Deputy Director, EL Safety Professional, and an administrative staff member, where discussions occur at a high-level and decisions are communicated as appropriate throughout EL;
- Safety Tabletop Exercises, performed each year by EL divisions, where "what if" scenarios are carried out to determine how well safety planning for a project was conducted. Divisions are required to do at least one, but many do more, and subsequently report out to the EL Leadership Team regarding their findings related to the task;
- Quarterly newsletter where safety is always a topic;
- Management observations (MOPs) which she performs at least 12 per year; and
- Many formal and informal discussions directly with EL staff.

[redacted] stated EL line managers are trained on their safety roles and responsibilities and reminded of them 2 to 3 times per year.

[redacted] stated EL division chiefs are responsible for ensuring all activities performed in their portion of the organization are covered by a hazard review. She stated once a year she asks the division chiefs to review hazard reviews in their division that have relative hazard indexes (RHIs) of 0 and 1 to ensure those RHIs are correctly classified. [redacted] stated her expectations are for them to confer with the group leaders regarding both tasks.

[redacted] stated it is difficult to evaluate the safety performance of division chiefs in a quantitative manner. She stated she checks to make sure incidents are reported and investigated in a timely manner and is concerned if it appears staff are not paying attention as a possible factor contributing to the incident or if a cluster of incidents occur within a given group or project. [redacted] stated the EL Safety Professional has a broad view of technical activities in EL and will provide input on any concerns he has regarding work within the divisions as another measure.

[redacted] stated division safety representatives (DSRs) play an important role in EL and are considered "mini-safety professionals". She stated there is no specific qualifications to be a DSR within a specific division. [redacted] stated their responsibilities are assisting with NIST safety program implementation, MOPs, workplace inspections, and hazard reviews, and are an extra set of eyes in general regarding safety. She stated they are expected to contribute to the best of their knowledge, skills, and abilities (KSAs) and should obtain additional assistance if the issue or concern is outside their expertise whether that be from within EL or outside (*e.g.*, OSHE staff member). [redacted] stated for some of the more diverse divisions, there is a "secondary" DSR who assists the first in subject matter areas that may be outside the KSAs of the main DSR.

[redacted] stated the EL Safety Professional plays an important role within EL and has the full support of EL line management. She stated this position is expected to develop good relationships with EL DSRs and OSHE staff such that they can assist with addressing safety issues and concerns broadly across EL. [redacted] stated they are expected to be a strong resource to EL staff, but not expected to be a safety expert in all hazard areas, and will know when and who to bring in to consult on a safety issue or concern. She stated her expectations are for this person is to be present in EL spaces, but not in a random fashion, *i.e.*, they visit spaces based upon the needs of staff or the organization. [redacted] stated the individual who currently holds this position has support from line management and is respected. She stated she has not heard from this person that they receive pushback from staff regarding the activities this person engages in.

[redacted] stated she is familiar with the document *MM01 – Safety and Health Management*.

[redacted] stated the "project leader" role in EL is equivalent to the "principal investigator" role found in *MM01*.

[redacted] stated her expectations for EL projects leaders are they are responsible for all activities that occur within their project, including safety, as they are the ones closest to the work if not performing the work themselves.

[redacted] stated she expects EL project leaders to ensure all activities performed with respect to their project are covered by hazard reviews. She stated regardless of the hazard review being formally routed through them in the MML Hazard Review Database system, EL project leaders are responsible for reviewing the documents for completeness, accuracy, and over all good quality prior to it going to the Group Leader. [redacted] stated she is concerned that the project leaders may not always be consulted since they are not always part of the routing in the MML Hazard Review Database system.

[redacted] stated she expects EL project leaders to have a presence in the workspace when new work or activities are being conducted, but is concerned EL may not have articulated or communicated this strongly or frequently enough . She stated while EL project leaders should expect staff to perform work in accordance with appropriate safety procedures and protocols, they should also follow up to ensure staff are following those safety procedures and protocols.

[redacted] stated she expects the EL project leader to be communicating their safety expectations to staff performing the work and staff performing the work should be communicating back to the EL project leader regarding their safety issues or concerns.

[redacted] stated she is familiar with the document *EL Hazard Review and Approval Policy and Procedure*.

[redacted] stated her current role [as EL Director] in approving hazard reviews within EL is minimal as the majority of those responsibilities have been delegated to the EL Deputy Director. She stated the EL Deputy Director only approves RHI 3 hazard reviews; the RHI 2 and lower are delegated to the Division Chiefs. [redacted] stated when she was in that role [as EL Deputy Director], she was responsible for approving work with RHIs of 3. She stated there is an EL Hazard Review Committee that is *ad hoc* and managed by the EL Safety Professional who assists the EL Deputy Director in making decisions regarding approving work with RHI of 3. [redacted] stated she is not aware of any work recently being approved within EL that had an RHI of 3.

[redacted] stated she relies on EL line management to ensure EL hazard reviews are comprehensive and of good quality. She stated she has communicated this expectation to them. [redacted] stated this is not an optimal method for her to ensure quality of the hazard reviews, but her other roles and responsibilities preclude her from having a more active role.

[redacted] stated a dedicated Safety Officer is required for some instances of work (*e.g.*, fire experiments and field work) and included as a hazard control measure in the hazard review. She stated this role cannot be held by the staff member(s) performing the work, rather, it has to be a staff member who has no other role or responsibility. [redacted] stated she has considered extending this role be required for other types of work, but is also concerned about the practicality of its implementation.

[redacted] stated staff may be relying too much on generic hazard reviews when a separate hazard review should be developed to address the work, and associated hazards, actually being performed.

[redacted] stated based upon feedback she has recently received [subsequent to the incident] EL appears to be more focused on creating hazard reviews for experiments as opposed to the activities required during the set up and teardown of the experiment. She stated this work [set up and teardown] can be just as hazardous as the experiment and may need to be covered by a separate hazard review.

SUMMARY OF RESPONSES RELATED TO THE CF PROJECT

[redacted] stated she was aware of the CF Project prior to the incident.

[redacted] stated she believes she participated in a MOP in Building 205 just prior to starting on the construction of the test frame, but does not recall if they discussed the project while she was there.

[redacted] stated she was not aware of any safety concerns related to the CF Project,

[redacted] stated she did not review either hazard review associated with the CF Project prior to the incident.

[redacted] stated she was not present during any activities involving the construction of the CF Project test frame.

[redacted] stated she was not present during any of the three CF Project experiments, but believes she may have watched a portion of one via live streaming.

[redacted] stated she was not present during any of the activities involving demolition work associated with the CF Project test frame, either the fire-tested floor or the surrounding floor.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interview held on February 27, 2023, by the NIST Team investigating the Building 205 incident.

[redacted]

[redacted]

Date

Summary of Investigation Interview with EL DEPUTY DIRECTOR

Date: February 28, 2023
Time: 3:00 pm to 4:01 pm

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members present: [redacted]

SUMARY OF RESPONSES RELATED TO [redacted]

[redacted] stated he is the Engineering Laboratory (EL) Deputy Director for Planning and Operations at the National Institute of Standards and Technology (NIST), a position he has held since January 2021 (starting as Acting Deputy Director). He stated prior to this position, he was the Chief of the Intelligent Systems Division in EL.

[redacted] stated some of his responsibilities are:

- Overseeing administrative support and operations staff within EL headquarters, *e.g.*, those responsible for safety, facilities, property, grants, contracts, acquisitions, IT systems and security;
- Assisting in the implementation of NIST safety programs within EL;
- Assisting in the development of EL strategic planning with respect to technical programs;
- Developing and implementing various policies approved by the EL Director; and
- Consulting with the EL Director on all matters related to the organization.

SUMMARY OF RESPONSES RELATED TO SAFETY MANAGEMENT IN EL

[redacted] stated EL line managers are held accountable for safety through a critical element in their performance plan. He stated the language [required activities and success measures] is similar between positions, *i.e.*, all division chiefs have the same critical element and all group leaders have same critical element.

[redacted] stated it is a challenge to quantitatively rate line managers with respect to safety. He stated some measures currently used to evaluate safety performance are to assess whether activities are being conducted and/or performed in a timely manner, *e.g.*, safety inspections, management observations (MOPs), incident reports, safety training. [redacted] stated they [EL] need to identify more proactive measures to quantitatively assess the safety performance of line managers.

[redacted] stated EL requires each division with lab activities to perform a yearly safety tabletop exercise, "what if" scenarios related to a project, and assess their overall safety readiness. He stated the results of that exercise are presented to the EL Leadership Team.

[redacted] stated EL division safety representatives (DSRs) are expected to serve as a safety resource to EL staff. He stated they assist in performing various safety activities including development of hazard reviews and conduct of MOPs and IRIS investigations. [redacted] stated EL does not have qualifications for DSRs beyond having a certain degree of expertise with respect to the work being performed within the division. He stated this can be a challenge given the diverse nature of the technical work in some of the divisions. [redacted] stated in these situations, some divisions may have "co-DSRs" to help cover all the hazards. He stated the DSRs are expected to complete the appropriate safety training related to the hazards within the division they serve.

[redacted] stated the EL Safety Professional is similar to the DSRs but is expected to work at a higher level and support EL as a whole. He stated this person is expected to develop good relationships with OSHE and EL DSRs. [redacted] stated the EL Safety Professional is expected to be knowledgeable and provide expert consultation on safety policies, practices, procedures, and controls or be able to know who can appropriately assist. He stated this person has the full support of EL line management and has the authority to enter EL spaces to address safety issues or concerns or have safety discussions with staff. [redacted] stated he has not heard of the EL Safety Professional receiving pushback from staff beyond having appropriate and respectful discussions regarding safety control measures and working towards an acceptable solution to resolve the concern.

[redacted] stated he is familiar with the document *MM01 – Safety and Health Management*.

[redacted] stated the "project leader" role in EL is equivalent to the "principal investigator" role found in *MM01*.

[redacted] stated his expectations for EL project leaders are they are responsible for all activities that occur within their project, including planning technical activities, reviewing hazard reviews (if not leading the effort to create them), ensuring control measures are in place, and monitoring safe execution of the work (*i.e.*, observing staff to ensure they are working in accordance with the appropriate safety practices and protocols).

[redacted] stated he is familiar with the document *EL Hazard Review and Approval Policy and Procedure*.

[redacted] stated his role [as delegated by the EL Director] is to participate in hazard reviews that have a relative hazard index (RHI) of 3. He stated the EL Safety Professional, in consultation with himself, establishes an EL Hazard Review Committee for the specific work to be performed for their consultation on whether the hazard review needs modification and when it should or should not be approved. [redacted] stated on occasion he does review hazard reviews with RHI levels of 2 if it is determined that an OU-level review should be conducted for that work to be approved.

[redacted] stated he also monitors the overall EL hazard review process ensuring they are completed and of good quality. He stated this is a challenging responsibility given the breadth of work performed within EL. [redacted] stated he relies heavily on division chiefs and group leaders to ensure the quality of hazard reviews as the majority of the EL hazard review portfolio have RHI levels of 2 or lower.

He stated he does review hazard reviews that have RHIs below 3 during MOPs and the safety tabletop exercises performed by the divisions.

[redacted] stated there is the possibility staff could be biasing RHI determinations on the lower side to avoid the process of having to go through the OU-level hazard review process. He stated they strive to ensure the OU-level hazard reviews are not too onerous (in terms of delays) to encourage staff to be objective when determining RHI levels.

[redacted] stated he has heard concerns about the difficulties associated with timely approval of RHI-3 hazard reviews in the past, but has not heard of any recent concerns or issues.

[redacted] stated he believes [since the incident] some staff are having a hard time figuring out the best way to structure hazard reviews to incorporate experimental set-up and teardown activities.

[redacted] stated he believes [since the incident] there have been more questions and discussion with staff regarding equipment-specific versus activity-specific structuring of hazard reviews. He stated EL may need to consider using more of a job hazard analysis (JHA) approach to performing some work. [redacted] stated this may lead to concerns regarding how to appropriately document and record the efforts resulting from the JHA approach as this does not fit into the implementation of the MML Hazard Review Database IT system.

SUMMARY OF RESPONSES RELATED TO THE CF PROJECT

[redacted] stated he was aware of the CF Project prior to the incident.

[redacted] stated he participated in a MOP in the National Fire Research Laboratory (NFRL) in April 2022 where they discussed numerous aspects of work performed in the building. He stated others participating in the MOP were [redacted] [NFRL Group Leader], [redacted] [Fire Research Division DSR], [redacted] (NFRL engineering technician], and [redacted] [NFRL engineering technician]. He stated some safety issues discussed with respect to the CF project included ergonomic issues related to debris removal [post-jackhammer break up] and repositioning of the hydraulic actuators located in the basement of Room 125. [redacted] stated they had shored and begun demolition of the fire-tested (deformed) floor but to his knowledge they had not yet begun demolition work on the surrounding floor when he was present in Building 205 for the MOP.

[redacted] stated with respect to demolition of the CF Project test frame, he learned of two main issues which precluded a contractor performing the demolition work:

- The time delay associated with the NIST process for getting a contractor in to perform the work; and
- The removal of experimental sensors embedded in the concrete they wanted to recover.

[redacted] stated they did discuss the crane incident [IRIS case number 22-IG-0027] where a heat shield was damaged. He stated this led to discussion of other crane-related concerns such as limitations on testing of the lower limit due to the need for the load hook to sometimes drop below the strong floor, and inspections of equipment used in rigging.

[redacted] stated there was discussion related to concerns over the loss of institutional knowledge with technicians taking other positions outside of NIST or retiring.

[redacted] stated he had not reviewed the demolition hazard review associated with the CF Project [*Composite Floor System Stabilization and Demolition*] as part of the MOP activities in April, but has reviewed it since the incident. He stated he believes [since the incident] that performing the demolition work piecemeal, and not having an overall demolition plan for the structure as a whole, is an issue. [redacted]. [redacted] stated he believes attention was paid with respect to the safety of the construction and experimentation, and on shoring and demolition of the damaged fire-tested floor section, but less attention was perhaps given to the demolition of the surrounding floor as they were not expecting it to have been compromised. He stated he believes there can be a tendency to rely on experience of staff as opposed to planning the work from start to finish.

[redacted] stated he was not aware of any safety concerns related to the CF Project beyond those discussed during the April 2022 MOP visit.

[redacted] stated he was not present during any activities involving the construction of the CF Project test frame.

[redacted] stated he was not present during any of the three CF Project experiments.

[redacted] stated he was not present during any of the activities involving demolition work associated with the CF Project test frame, either the fire-tested floor or the surrounding floor.

[redacted] stated he is looking forward to the recommendations from the incident investigation report so they can implement and better ensure the safety and health of staff.

[redacted] stated he believes we [NIST] tend to think about serious injuries and fatalities as improbable events. He stated we should look at other organizations and industries with higher risk exposure and more experience and expertise in reducing fatalities and serious injuries to help determine the best focus of energy to ensure the safety and health of staff.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interview held on February 28, 2023, by the NIST Team investigating the Building 205 incident.

[redacted] [redacted]

[redacted]

Date

Summary of Investigation Interview with FRD CHIEF 2

Date: February 15, 2023
Time: 8:00 am to 8:40 am

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members present: [redacted]

SUMMARY OF RESPONSES RELATED TO [redacted]

[redacted] stated he is the Acting Division Chief of the Fire Research Division (FRD) in the Engineering Laboratory (EL) at the National Institute of Standards and Technology. He stated he has held this role since early October 2021. [redacted] stated prior to being named Acting Division Chief, he was the Deputy Division Chief and the Leader of the Wildland Urban Interface Fire Group. He stated his roles and responsibilities as the Acting Division Chief are the management of all aspects of the division and oversee day-to-day operations.

SUMMARY OF RESPONSES RELATED TO SAFETY MANAGEMENT

[redacted] stated he communicates his occupational safety and health expectations to FRD staff through both quarterly division meetings and weekly group leader meetings. He stated safety is always the first agenda item, and many times the Division Safety Representative (DSR) will have a significant amount of time to discuss safety concerns and review safety metrics.

[redacted] stated he takes safety very seriously. He stated since NIST began efforts to return more staff to campus beginning in June 2022, he will make almost daily rounds in Building 224. [redacted] stated if he notices an unsafe condition or unsafe act, he will immediately address the concern (*e.g.*, asking staff to close drawers left open that could be tripped over and directing staff to wear the appropriate personal protective equipment when required. He stated if it is a serious concern or one that appears to be repeated, he will have a discussion with the group leader about it.

[redacted] stated there is still very little activity occurring in Building 224. He stated he does not normally make a daily round in Building 205 due to the distance between his office and that building.

[redacted] stated group leaders are evaluated with respect to safety by having a specific critical element in their performance plan which focuses on safety. He stated the weighting of the critical element is 2. [redacted] stated as part of the end of year performance plan evaluation, he reviews open corrective actions in each group as well as trends in the workplace inspection data and near miss reporting. He stated only one group leader received an "E" in safety, while the other three group leaders received an "S" this year for that critical element.

[redacted] stated his expectations of FRD project leaders are to interface with stakeholders, secure funding for the project, plan out the project work, create or participate in project-related hazard reviews, ensure day-to-day work is performed safely, and ensure deliverables are met. He stated, to his knowledge, these responsibilities are not formalized in an EL document.

[redacted] stated his expectations of the FRD DSR is to be a resources to division staff regarding safety. He stated some of the roles of this position are:

- Participate or review all hazard reviews, *i.e.*, "be an extra set of eyes on the document";
- Participate in workplace inspections for both offices and laboratories;
- Help obtaining necessary safety-related supplies; and
- "Impromptu" inspections of spaces by walking around and checking in on staff and work being performed.

[redacted] stated his role in the work authorization process is to assess hazard reviews with an RHI = 2 or higher. He stated he would not typically see hazard reviews with lower RHIs. [redacted] stated for the hazard reviews with RHIs lower than 2 he has seen, the hazards are appropriately characterized to provide the correct RHI.

[redacted] stated NFRL has numerous generic hazard reviews for standard activities performed in Building 205, *e.g.*, use of overhead cranes and fork trucks. He stated these hazard reviews do not cover the specific work to be performed while using this equipment.

[redacted] stated over the past few months he has re-approved a handful of hazard reviews. He stated as part of his evaluation prior to re-approving is how detailed is the document or supporting documents. [redacted] stated he recently rejected a hazard review for work to be performed in Building 224 as the staff members proposing the work did not fully understand the limitations of the system to be used and the size of the sample was too large described in the HR.

[redacted] stated he did re-approve the *Composite Floor Systems Stabilization and Demolition* hazard review on May 16, 2022. He stated the changes primarily focused on noise and respiratory hazards. [redacted] stated as the hazard review had been successfully used to conduct demolition work of the fire-tested floor in the past and only changes were to PPE requirements, he approved it.

[redacted] stated he was not informed or aware of any changes to the type of work being performed under the *Composite Floor Systems Stabilization and Demolition* hazard review.

[redacted] stated that he does perform MOPs and recently conducted one with [redacted], [redacted] and [redacted]. He stated that very few had been conducted in the prior two years due to COVID-related mandatory telework.

[redacted] stated he does participate in EL Tabletop Exercises. He stated an activity is chosen to focus on and the division chief, group leader, relevant staff, the DSR, and sometimes [redacted] will run through "what if" scenarios to determine if the hazard review, standard operating procedures, and emergency response procedures are sufficient. [redacted] stated this is a very useful activity as it can identify weaknesses in the documents.

[redacted] stated he is subscribed to receive IRIS reports and will review them. He stated relevant reports will be discussed in quarterly division mtgs by the DSR.

[redacted] stated he does review workplace inspection data and has noticed many of the deficiencies are related to poor housekeeping and blocked electrical panels. He stated he does review late corrective actions and will notify staff about them.

[redacted] stated FRD staff take safety very seriously and will take action to remediate issues when they are made aware of concerns.

INTERVIEWEE STATEMENT
I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interview held on February 10, 2023, by the NIST Team investigating the Building 205 incident.

[redacted]

2/19/2023

[redacted]

Date

Summary of Investigation Interview with NFRL GROUP LEADER

Date: October 17, 2022
Time: 9:00 am to 11:30 am ET

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members present: [redacted]

SUMMARY OF RESPONSES RELATED TO [redacted]

[redacted] stated he is the Group Leader for the National Fire Research Laboratory (NFRL) in the Fire Research Division of the Engineering Laboratory (EL) at the National Institute of Standards and Technology (NIST). He has held this supervisory role since 2007, which was prior to the NFRL becoming an official "group" in the NIST organizational architecture. [redacted] has supervisory responsibilities including but not limited to managing group solvency, supervising staff, scheduling of experiments, and providing oversight for safety.

[redacted] stated the group as a whole has been very proactive with respect to safety and have won several safety awards including the 2009 BFRL Safety Award and the 2012 NIST Safety Award. He stated the NFRL was conducting work risk assessments (*i.e.*, hazard reviews) prior to NIST as an organization requiring this activity in 2009. In addition to hazard reviews, the NFRL has general safety policies established for all workers in Building 205 rooms 113 and 125 fire experiment areas. The training (EL-733: *NFRL Lab Access and Safety Awareness* in NIST's SET IT application) must be completed prior to beginning work in those locations and covers basic policies, access, PPE, and fire protection systems. Further, a safety officer is named for each experiment who is responsible for developing a safety checklist to consult prior to the activity and providing safety briefings for those involved with the activity. The safety checklist includes tasks such as reviewing hazards associated with the activity, reminding those involved with the activity of their individual roles and responsibilities, and coordinating with the NIST Fire Protection Group if they were performing experiments involving open flames or performing activities that could result in a fire such as welding or flame cutting. Safety briefings are required at the beginning of each day when experiments are planned. For similar experiments on the same day, a new safety briefing may not be required. But safety briefings were routinely held if the activity changed or if new personnel were added to ensure all involved were aware of the change in the work or their roles and responsibilities.

[redacted] stated he was not necessarily in the area at all times while work is being performed.

[redacted] stated the NFRL had submitted incidents in the past into NIST's Incident Reporting and Investigation System (IRIS) and they incorporated lessons identified into their work practices.

SUMMARY OF RESPONSES RELATED TO [redacted]

[redacted] stated [redacted] held the title of Engineering Technician since he joined NIST in 2012. [redacted] stated he was [redacted]'s supervisor for his full employment at NIST and [redacted]'s interactions with [redacted] depended upon what activities were occurring – they could be daily or weekly. [redacted] stated prior to joining NIST, [redacted] worked at the [redacted] ([redacted]) where he gained extensive, practical hands-on experience with large-scale structural testing. [redacted] was also with the [redacted] prior to joining [redacted]. [redacted] has a Bachelor of Science degree in Civil Engineering from [redacted] and had taken courses in fire protection engineering towards a master's degree.

[redacted] stated [redacted]'s responsibilities at the NFRL included, but are not limited to, activity leader for construction and demolition of large-scale test structures, activity leader for hydraulic loading equipment, activity leader for material handling (*e.g.*, overhead cranes and fork trucks), and workspace manager. The latter role is responsible for safety-related issues in the assigned workspace to include implementation of proper safety practices while work is performed and completion of workplace inspections and follow-ups. [redacted] was the workspace manager for the following rooms in Building 205:

- 01 (Strong Floor Basement);
- 02 (Basement Pump Room);
- 125 (Structure Fire Test Bay);
- 126 (Structure Fire Lab Control Room).

[redacted] was also a credit card holder and Contracting Officer's Representative.

[redacted] stated [redacted] did not have official supervisory responsibilities, but he did direct the work, *i.e.*, assign day-to-day tasks, for other NFRL technicians ([redacted] and [redacted]) working in Room 125. [redacted] also provided safety oversight and training for guest researchers, PREP students, and contractors working in Room 125.

[redacted] stated [redacted] was responsible for authoring hazard reviews, standard operating procedures, and safety operating procedures in various areas including material handling, construction, and demolition. For NIST staff, he was not responsible for authorizing those documents as that is a line management function. [redacted] did review and provide feedback on safety plans for contractors working in the NFRL and accepted final product (*e.g.*, concrete work). [redacted] did not authorize other NIST staff to perform work, but as activity leader, he would bring concerns to [redacted] if performance issues developed.

SUMMARY OF RESPONSES RELATED TO THE DESIGN AND CONSTRUCTION OF THE TWO-STORY TEST FRAME

[redacted] stated [redacted] (now at [redacted]) was the initial Project Leader for the two-story test frame. Other NIST staff members involved in the design of the initial test frame were [redacted], [redacted], [redacted], [redacted], and other members from the Structures Group in the Materials and Structural Systems Division. All are staff members in EL, with the exception of [redacted] who is a PREP associate. [redacted] was involved at the latter half of the test frame design stages and provided input on the proposed design and constructability of the test frame. [redacted] also stated the final design was vetted with a panel of outside experts. He believes the initial test frame design was approved sometime in 2018.

[redacted] stated building codes were utilized in the design of the test frame, and to his knowledge, it met code – noting that the test floor area may not have met code as part of the designed experimental objective. He also stated the surrounding floor was not designed for occupancy, *i.e.*, this area may not have needed to meet all the codes. [redacted] stated the building codes could be found in the NIST Technical Note 2165: *Fire Resilience of a Steel-Concrete Composite Floor System: Full-Scale Experimental Evaluation for U.S. Prescriptive Approach with a 2-Hour Fire-Resistance Rating (Test #1)* published in October 2021.

[redacted] stated the slab splice separated the test floor from the surrounding floor of the test frame. It facilitated reuse of the test frame as the test floor could be demolished while the surrounding floor remained intact, thus providing continuity from experiment to experiment. A new test floor could then be built for the next experiment.

[redacted] stated continuous rebar reinforcement was not required for the surrounding floor in the NE and NW corners of the test frame. These locations did not play a significant role in the test frame stability and were not an active part of the experiment or research objective. The rebar in the East, West, and North sections of the surrounding floor was required for the slab splice and not a design code requirement.

[redacted] stated there was a hazard review conducted for the project, which included the construction of the test frame, but it was not highly detailed. The hazard review is #733.06.0124.031621 – *Composite Floor Systems Test* in the MML Hazard Review Database. The hazard review specifically addressed construction hazards under Task 1. Setup

[redacted] stated NFRL technicians, including [redacted], installed the structural steel columns, beams, and girders for the test frame. He believes a staff member from the Fabrication Technology Office in Management Resources, and possibly an external contractor, assisted in some of the welding. NFRL technicians were also responsible for installing the steel pans, chairs, welded wire fabric, and #4 rebar reinforcement prior to the concrete pour. Shear studs were used in some locations to attach the steel pans to the beams and girders. An external contractor was responsible for pouring the concrete decking. He believes shoring was used underneath the steel deck during the concrete pour but was unsure if shoring was required prior to the pour. The initial test frame was built in 2018 and 2019.

[redacted] stated there was no formal "commissioning" of the test frame, *i.e.*, an individual verifying the structure was fully operational and ready for experimental work to commence. There were numerous walk throughs performed with hands-on inspections. [redacted] and [redacted] were responsible for reviewing aspects of the structural systems of the test frame whereas he and [redacted] (NFRL technician) were responsible for the fire systems.

[redacted] stated to his knowledge the surrounding floor of the test frame was built according to the engineering/design drawings.

[redacted] stated to his knowledge there were no safety concerns related to the initial construction of the test frame.

SUMMARY OF RESPONSES RELATED TO PROCEDURES ASSOCIATED WITH POST-EXPERIMENTAL WORK AND REMOVAL OF THE TEST FLOOR CF1 AND CF2

[redacted] stated after each experiment [designated as Composite Floor (CF)], the test floor and surrounding floor was inspected with results presented to an external panel for review. Subsequently, discussions were held between [redacted], [redacted], and other NFRL technicians to determine the best way to remove the test floor and prepare for the next experiment. [redacted] stated there is a hazard review for this work in the MML Hazard Review Database (#733.06.0148.050522 – *Composite Floor System Stabilization and Demolition*). [redacted] also stated there is a written demolition plan and standard operating procedures for demolition of the test floor. [redacted] was primarily responsible for authoring these documents, with input from [redacted]. The demolition plan covered specific methods for demolishing the test floor which included methods of shoring, removal of concrete and steel, complex lifting scenarios with a crane, and fall protection. [redacted] stated these documents were influenced by a division tabletop exercise conducted in 2017-2018 for long span of similar flooring construction. Subsequent to the CF2 experiment, the safety documents were reviewed to determine if they were still applicable for the demolition work of the test floor to be performed. As demolition of the test floor did not change, the same safety documents used for demolition of CF1 was used for CF2.

[redacted] stated market research was conducted after CF1 to have the demolition of the test floor performed by an external contractor but ultimately determined the work could be performed by NFRL technicians.

[redacted] stated the demolition of the test floor after CF1 and CF2 was performed by [redacted], [redacted], [redacted], and [redacted]. [redacted] provided oversight at times. He believes [redacted] and [redacted] may have also assisted. The work was not required to be supervised by line management. As activity leader, [redacted] was responsible for the scheduling the day-to-day work and providing updates on the progress. [redacted] stated he occasionally visited the work site and discussed challenges and safety concerns regarding removal of the test floor. These topics included the strenuous physical nature of the work and fatigue of staff, whether other methods for removal could be employed (*e.g.*, using a saw to cut the concrete out versus jackhammering), respiratory protection from the dust being created, hearing protection related to the use of demolition equipment, and the use of misting equipment for cooling of staff performing the work during warmer ambient temperatures. He stated he also reviewed videos from the cameras set-up in Room 125 on a periodic basis.

SUMMARY OF RESPONSES RELATED TO PLANNING DEMOLITION OF THE FULL TEST FRAME AFTER CF3

[redacted] stated that [redacted] was the Project Leader up until the time she left for an appointment at [redacted], after which [redacted] became the new project leader. [redacted] began this role sometime in mid to late May 2022. It was determined around this time that CF4 would not be conducted and the test frame could be demolished.

[redacted] stated removal of the test floor after CF3 was performed similarly to the demolition after CF1 and CF2 with one exception. After a management observation process (MOP) discussion with [redacted] (EL Deputy Director), a recommendation was made to formally include hearing protection in the hazard review which subsequently done.

[redacted] stated the hazard review previously referenced for demolition of the test floor after each experiment did not include a consideration of the surrounding floor. As such, he discussed with NFRL technicians ([redacted], [redacted], [redacted], and [redacted]) the best method to remove the surrounding floor concrete. [redacted], having previous experience with demolition, recommended saw cutting sections and lifting them out with rigging and a crane. It was agreed to try the removal of one first using this technique and then discuss before proceeding to the other sections. After successful removal of the southernmost slab on the East side of the test frame, [redacted], [redacted], and [redacted] agreed the hazard review for demolition of the test floor was sufficient for the removal of the remaining surrounding floor.

[redacted] stated he did not see a full demolition plan for removal of the surrounding floor prior to the work starting. Based upon verbal discussions with [redacted], he was under the assumption engineering/design drawings were consulted with respect to slab removal locations. He also believed calculations were performed for determining the location of the rigging points on each slab.

After the incident and prior to the interview with [redacted], [redacted] sated he received a forwarded email from [redacted] with a file attached titled *Coring and Cutting Plan*; the original email, with a similar subject line to the name of the file and dated August 23, 2022, was from [redacted] to [redacted]. [redacted] shared this document with the Incident Investigation Team on October 13, 2022. The document indicated the following for the surrounding floor along the East and North sides of the test frame:

- The size of the slab;
- The location of the slab cuts;
- The location of the rigging points for each slab; and
- An estimation of the load for each "strap" of the rigging for the southernmost slab cut from the East side of the test frame.

[redacted] stated [redacted] created this document. [redacted] did not know if concrete reinforcement was considered in making the determination for location, size, and shape of the slabs, nor if calculations were performed to determine if the individual slab could support its own weight once the slab was cut free from the test frame. He stated it is possible that [redacted] or [redacted] could have reviewed calculations, but he does not know for sure. [redacted] stated from a previous conversation with [redacted], there was 3-5 safety factor built in. [redacted] stated he assumed this safety factor was determined using the calculated design strength of the cut slab relative to the self-weight using the maximum separation distance of the pick points for the lift. He did not know if this calculation assumed a distributed load or a point load. [redacted] also stated in the email body used to provide this document, [redacted] indicated:

- The sizes and shapes of the slabs to be removed would:
  - Not exceed crane capacity;
  - Fit between the columns when moved; and

    - Fit in the dumpster; and
- The rigging points indicated were the "maximum" distances to be used.

[redacted] stated he was not aware of a cutting plan for each slab, *i.e.*, the specific order the faces of each slab would be cut, or if the corners were to be cut before the long edges, or when the rigging would be installed and engaged. He stated the holes for attaching the rigging were drilled in advance.

[redacted] stated [redacted] made the determination for what rigging to use and most likely used the rigging that was on-hand which met the necessary capacity and length requirements.

[redacted] stated he was not aware of a schedule for slab removal, *i.e.*, if there was an order for which slab would be cut first or if a slab was planned to be cut on a given day. He stated there was no overarching schedule or rush to get the full test frame demolished beyond being completed by spring of 2023. He believes [redacted] had a self-imposed goal of removing one slab per day from the test frame.

[redacted] stated discussions were held between [redacted] and the other NFRL technicians regarding the use of shoring underneath the surrounding floor slabs to be cut but does not know if the decisions were documented.

[redacted] stated [redacted] made the determination for what demolition equipment was to be used. For cutting of the surrounding floor slabs, a wet floor saw was indicated with jackhammering required for the remaining portion of the surrounding floor. The structural steel was to be unbolted, where possible, or torch cut. [redacted] stated he does not know if these decisions were documented.

[redacted] stated the following personal protective equipment (PPE) was called out to perform demolition activities of the surrounding floor:
- Steel-toed boots;
- Gloves;
- Hard hat;
- Safety glasses;
- Hearing protection;
- Respiratory protection (dust mask); and
- Personal fall protection equipment if working near an exposed edge.

[redacted] stated the NFRL technicians had some latitude when it came to wearing the PPE, depending on the activity they were performing.
[redacted] stated there was no specific requirement for the number of persons to participate in the cutting of the slabs, but a general lab policy imposed for hazardous activities in Room 125 was to have at least two people in the space, within close proximity and aware of the activities being performed. The expectation was staff would respectfully challenge each other if they observed unsafe activities. [redacted] stated he observed staff challenging others on numerous occasions and referenced a time when [redacted] had concerns about how work was being performed and stopped the activity.

[redacted] stated there was no specific safety protocols identified with respect to behavior during or after a slab was cut, but general training indicated an individual shall not stand on, ride on, or walk underneath a suspended load. These requirements are found in the standard operating procedure associated with hazard review #733.06.0052.052322 – *NFRL Overhead Cranes*. [redacted] was not aware of NFRL technicians violating these policies prior to the incident, whether through direct observation or informed by another person. He stated he did observe a NFRL technician violating these protocols in the review of video from Room 125 just prior to the incident.

[redacted] stated passive fall protection was discussed and implemented through cabling along exposed edges. [redacted] stated toe boards may have been considered but determined not to be required due to exclusion zones when staff were working on the structure. [redacted] stated barriers may not have been erected to indicate an exclusion zone as there were very few people working in that location and all staff that were had knowledge of the exclusion zones.

[redacted] stated the following training was required for performing surrounding floor slab removal:

- Crane;
- Fork truck; and
- "On-the-job" for using various pieces of demolition equipment (*e.g.*, floor saw and jackhammer).

[redacted] stated line management supervision was not required for this work to be performed. He relied on the experience of NFRL technicians to monitor themselves. [redacted] stated he periodically visited Room 125 during the demolition work of the test floor for previous experiments.

[redacted] stated he is responsible for "global safety" with respect to work performed in Room 125, but [redacted], through his role as workplace manager and activity leader, was responsible for the day-to-day safety of the work site while the surrounding floor was being demolished. [redacted] was not aware of safety briefings being conducted with respect to the demolition work of the surrounding floor as no safety officer was designated for this activity.

SUMMARY OF RESPONSES RELATED TO DEMOLITION OF THE FIRST THREE SLABS REMOVED FROM THE EAST SIDE OF THE TEST FRAME

[redacted] stated the test floor (CF3) was demolished prior to work involving removal of the surrounding floor. He also stated an inspection of the surrounding floor for damage resulting from the CF3 experiment was performed by [redacted] and [redacted] as there were plans to have a fourth experiment (CF4). He believes [redacted] may have documentation of this inspection.
[redacted] stated [redacted], with input from other NFRL technicians, determined where passive fall protection (cabling) was required while performing slab removal; this should have been continually reassessed as work progressed. [redacted] also stated [redacted] indicated he did not want to use personal fall protection measures but would evaluate the need for it "on the fly". [redacted] does not know if these decisions were documented by [redacted].

[redacted] stated he did not know when the first two slabs, *i.e.*, those located southernmost on the East side of the test frame, were removed or who performed the work; he believes it occurred in the week or two prior to the in incident. [redacted] stated the third slab, north of the first two, was removed by [redacted] on September 23, 2022. [redacted] did not specifically authorize [redacted] to perform this specific work as [redacted] was previously authorized for demolition work with respect to the test floor. Further, [redacted] was comfortable with this work being performed as it was less physically demanding than removal of the test floor. [redacted] stated a floor saw, hand saw, crane, and slings were required for this work. [redacted] was not in Room 125 while any of the first three slabs were being cut and removed.

[redacted] stated slab remove was being performed on an opportunistic schedule, *i.e.*, as the NFRL technicians' schedule allowed for it. He was receiving weekly progress updates from [redacted]. Again, [redacted] stated there was no set schedule for slab removal or external influences necessitating the work proceed faster than it was.

[redacted] stated he did not know exactly when rigging was installed and engaged for each slab, but it was done prior to the completion of the cuts.

[redacted] stated he did not know if the third slab removed which had an irregular shape, *i.e.*, not rectangular, was intended to be cut and removed in that shape. [redacted] was not aware of any issues with the cutting of this slab.

[redacted] stated he was not aware of NFRL technicians standing on or walking across the first three slabs after being cut, whether partially or fully free of the test frame.

[redacted] stated wooden shoring previously used underneath the CF3 test floor was moved into the cut bays for the two southernmost slabs cut from the East side of the test frame after the slabs were removed. He stated it was most likely in an effort to provide fall protection while working around the exposed edges of the surrounding floor after the slabs were removed. [redacted] did not know why something similar was not used for the third bay after the slab was removed on September 23.

[redacted] is only aware of a post-job debrief after the cutting and removal of the first slab. [redacted] indicated he was "happy" with the way the process went and felt it was safer than removing the test floor.

[redacted] stated [redacted] notified him of an issue with the cutting and removal of one of the slabs with respect to ensuring the corners were completely cut prior to trying to lift the slab out.

SUMMARY OF RESPONSES RELATED TO THE INCIDENT

[redacted] stated he was teleworking on the day of the incident.

[redacted] stated he did not know if a pre-job briefing was held prior to cutting the northernmost slab on the East side of the test frame.

[redacted] stated at the time of the incident he was not aware of a discussion regarding the exposed edge to the south of the slab that was to be cut. He also did not know why passive fall protection (cabling) was not installed or the hole protected by some other means (*e.g.*, covered). He believes [redacted] was attempting to do something along these lines with the angle iron located on the elevated pallet but did not complete whatever the planned task was. Subsequent to the incident, [redacted] told [redacted] they did briefly discuss protecting the hole to the south of the slab to be removed; this discussion between [redacted] and [redacted] occurred on September 23, 2022.

[redacted] stated he did not know if a discussion was had regarding the lack of reinforcement in the northernmost slab, *i.e.*, no rebar parallel to the slab's length.

[redacted] stated he was not aware of a change in procedure for cutting the northernmost slab as opposed to the first three slabs.

[redacted] stated he was not aware of any concerns regarding the demolition equipment used on that day.

[redacted] stated he assumed toe boards were not used as an exclusion zone was in effect.

[redacted] stated he did not know why shoring was not used under the slab that was to be cut that day and speculated it may not have been required as the surrounding floor was not compromised similar to the test floor and had sufficient structural integrity to be cut and lifted out for disposal.

[redacted] stated he did not know if [redacted] was performing work as planned that day.

[redacted] stated he did not know why personal fall protection equipment was not used by [redacted] even though he was working within feet of an exposed edge.

[redacted] stated he believes [redacted] was aware of the requirement prohibiting individuals from standing on, walking on, or riding on supported loads as the information is stated in the NFRL training. The specific training course is EL-733: *NFRL Overhead Crane Operation* in NIST's SET IT application and is also stated in the standard operating procedure associated with hazard review #733.06.0052.052322 – *NFRL Overhead Cranes*. He is also not aware of [redacted] exhibiting these behaviors previously.

[redacted] had no concerns regarding [redacted] performing this work.

REQUEST FOR INFORMATION

At the end of the interview, [redacted] was informed the Incident Investigation Team would reach out to him later in the day with requests for documentation.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interviewed held on October 17, 2022, by the NIST Team investigating the Building 205 incident.

[redacted]

11/01/2022

Date

[redacted]

Summary of Second Investigation Interview with NFRL GROUP LEADER

Date: February 14, 2023
Time:1:00 pm to 2:00 pm

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members present: [redacted]

SUMARY OF RESPONSES RELATED TO THE TIMELINE OF EVENTS

[redacted] stated a meeting with multiple NFRL technicians was held in the May 2022 timeframe to discuss different methods to remove the surrounding floor. He stated he could not identify a specific date or if the discussion occurred over numerous group meetings and/or informal discussions. [redacted] stated there were two main options discussed either using the previous method of jackhammering and manually removing the rubble to a dumpster or using the floor saw to cut slabs and lift them out with an overhead crane. He stated no decisions were made during this time frame.

[redacted] stated he could not recall if the June 15, 2022, meeting requested by [redacted] (Project Leader) was held on that day, but it was on his Outlook calendar. He stated if the meeting was held [to discuss whether the concrete removal hazard review *Composite Floor System Stabilization and Demolition* should be revised for use on the surrounding floor] he could not remember specifics of the discussion. [redacted] stated he does recall, whether it was at this meeting or another, [redacted] advocating for the cutting and lifting method as he believed it was the safer option.

[redacted] stated he believes the meeting to discuss [redacted] performing a "test case" occurred within a month or so of the incident [August timeframe].

[redacted] stated he believes the first "test case" was not Slab 1. He stated it was most likely a large slab cut out of the fire-tested floor of CF3. [redacted] stated he believed the initial decision to use the current demolition hazard review [*Composite Floor System Stabilization and Demolition*] to cover removal of surrounding floor slabs was made prior to Slab 1 being removed . [redacted] stated this decision would be revisited if any complications were discovered during the removal of Slab 1.

> **NOTE** This statement is different from [redacted]'s first interview where Slab 1 was identified as the "test case".

SUMMARY OF RESPONSES RELATED TO THE ROLE AND RESPONSIBLITIES OF THE PROJECT LEADER

[redacted] stated project leaders in his group have the primary responsibility for the following tasks with respect to the project they lead:

- Conception and planning of work;
- Creation, review [of others work], and re-review of hazard reviews; and
- Execution or direction of work.

[redacted] stated project leaders in his group are responsible for observing the work performed related to their project, but on an as needed basis. He stated he would not expect them to be "on the floor" all the time. [redacted] stated, with respect to [redacted], they treated him as a job foreman and supervision was not always required for work he performed.

[redacted] stated project leaders in his group, to some extent, are responsible for ensuring the implementation of safety practices and protocols while work is being performed. He stated this function is primarily the responsibility of himself as the supervisor so he does not lean as heavily on them for this responsibility.

SUMMARY OF QUESTIONS RELATED TO GENERAL IMPLEMENTATION OF THE HAZARD REVIEW PROCESS IN EL

[redacted] stated he was familiar with the document titled *EL Hazard Review and Approval Policy and Procedure*, but he had not reviewed it in a few years. He stated he more recently reviewed the EL document titled *MM01 – Safety and Health Management*.

[redacted] stated all of the following statements were true regarding EL implementation of the NIST Hazard Review policy:

- Group Leaders are responsible for ensuring all work conducted in their group involving hazardous activities or materials is covered by an approved hazard review.
- Group Leaders are required to authorize staff members to conduct work. In order to do that, the Group Leader is required to ensure the staff member has:
  - Reviewed the content of the hazard review package; and
  - Completed any required training specified by the hazard review.
- A hazard review must be revised and submitted for re-approval when changes to the activity go beyond the scope of the approved hazard review (*e.g.*, there is a change in the location, the procedures, substances, or quantities).

[redacted] stated Authorized Users have a responsibility to perform work in accordance with the practices and protocols listed in the hazard review. He stated others [co-workers] also have a responsibility for the safety of those working around them and should address unsafe behavior if it is observed. [redacted] stated group leaders have a responsibility to ensure Authorized Users are working in accordance with the practices and protocols listed in the hazard review, but it is not normal practice to "police" staff in any formal manner.

SUMMARY OF QUESTIONS RELATED TO THE USE OF OVERHEAD CRANES IN NFRL

[redacted] stated while he is the instructor for the course titled *EL-733: NFRL Overhead Crane Operation* with the course description of:

> *Verification of overhead crane operation proficiency. Operators must demonstrate knowledge and understanding of workspace specific safety controls and comprehension of appropriate guidelines and reference documents (EL-FLHR 349, OSHA 29 CFR 1910.184, OSHA 29 CFR 1910.179, ASME B30.17 and B30.9). Completion of training must be verified by WSM and FLHR Activity Leader.*

he himself is not an experienced crane operator, but rather, he coordinates external instructors teach it to his staff.

[redacted] stated he could not easily provide a definition for what would constitute a "routine" lift.

[redacted] stated for defining a "complex" lift he would denote specific scenarios such as:

- A lift involving the tandem use of two cranes;
- A lift where the load has an unusual shape or if the load was off-center;
- A lift where there is difficulty strapping or securing the load; or
- A lift where sight lines are obstructed or if the hook goes below the floor into the basement.

[redacted] stated he believed a "critical" lift was one where the load was greater than 75-80% of the rated capacity of the crane.

[redacted] stated some of the components of a lift plan are:

- Location of pick points;
- Structural calculations;
- Sequence of steps; and
- Location of barriers for exclusion zone.

[redacted] stated developing a lift plan is not a formal process that requires review and approval. He stated he was very comfortable with [redacted] developing a lift plan. [redacted] stated he would have hoped [redacted] would have checked with [redacted] (previous Project Leader) or [redacted] ([redacted] Guest Researcher) prior to a lift which required a lift plan, but he did not check to see if he had.

[redacted] stated he believed it was correct that any project which requires unique lifts using special rigging and fixtures or two cranes operating simultaneously for the same lift would be required to have a project first level hazard review detailing these lifts. He stated this would be different from a lift plan. [redacted] provided an example of a distinct hazard review for lifting the concrete pit covers off of the conditioning pits in Building 125 (*Removal and Installation of Concrete Pit Covers* hazard review - #733.06.0126).

[redacted] stated daily inspections are required of crane use and consist of:

- Examining the hook and cables;
- Sounding the horn;
- Running the hook up and down;

- Running the crane along the trolley; and
- Checking the surrounding area where the crane will run for to ensure safe operation.

[redacted] stated these requirements have been communicated to those who are approved to use overhead cranes [*NFRL Overhead Cranes* hazard review – #733.06.0052].

[redacted] stated there are no requirements for records retention for daily crane inspections.

[redacted] stated it is the responsibility of the operator to ensure the daily crane inspections are occurring.

SUMMARY OF RESPONSES RELATED TO A PREVIOUS INCIDENT

[redacted] stated the hazard review under which the work associated with IRIS Case Number 17-IG-0110 was *Composite Beam Fire Test* hazard review - #733.06.0078]

SUMMARY OF RESPONSES RELATED TO CF PROJECT WORK

[redacted] stated the *Composite Floor Systems Tests* hazard review covered the work required to constructure two-story, steel-framed test structure used during the CF Project experiments, even though the information contained within was rudimentary and not very detailed.

[redacted] stated construction work is a hazardous activity and the NFRL has numerous general hazard reviews that are used to cover the specific tasks (*e.g.*, use of crane use, lifts, and fork truck). He stated these documents are generic.

[redacted] stated they have performed similar construction work in previous projects:

- EL FLHR546 – *Demonstration Test of NFRL Reaction Columns*;
- *NFRL Phase III Commissioning – Ambient Beam Test* - #733.06.0002
- *Composite Beam Fire Test* - #733.06.0078; and
- *Structural-Fire Performance of Cold-Formed Steel Shear Walls* - #733.06.0022]

[redacted] stated it was a common occurrence for the hazard review to be developed at the same time the team was setting up for an experiment, *i.e.*, in this specific case, the construction of the two-story, steel-framed structure. He stated this as the reasoning for the *Composite Floor Systems Tests* hazard review being approved four months after the test frame was constructed.

[redacted] stated they did not always address the hazards of set-up and tear-down of an experiment in a dedicated activity hazard review. He stated that these hazards were consider though generic activities such and the use of cranes and forklifts and through training and experience.

[redacted] stated crane lifts during installation of the columns, girders, and beams would be considered a fairly routine task. He stated this opinion was based largely on the feedback from the technicians performing the lift. [redacted] stated as a result a lift plan would not be required.

[redacted] stated the construction of the fire compartments was also covered by the *Composite Floor Systems Tests* hazard review in a general sense. He stated while it was not explicitly stated in the hazard review, there were components of the construction activities, a listing of the hazards, and identified control measures. [redacted] stated the generic hazard reviews would also cover this work. [redacted] stated he ensured all staff members re-authorized on the *Composite Floor System Stabilization and Demolition* hazard review after the re-approval on May 16, 2022, met the requirements to be authorized (*e.g.*, they had reviewed the content of the hazard review package and completed any required training specified by the hazard review).

[redacted] stated he knew [redacted] was experimenting with saw cutting on the fire tested floor, however the condition of the concrete was very different. [redacted] stated Slab 1 was also a test case as he was checking in at each stage to see if the method was working.

[redacted] stated the approval to perform the "test case" to remove a floor slab using the floor saw cutting and crane was covered under the *Composite Floor System Stabilization and Demolition* hazard review. He stated the specifics of the cutting and subsequent lifting with the crane is not explicitly detailed in the document. However, the hazards and controls for using the concrete saw for acquiring forensic samples are included.

[redacted] stated the reasoning to use the *Composite Floor System Stabilization and Demolition* hazard review for the surrounding floor is this activity (cutting with floor saw and lifting the slab out) was perceived to be less hazardous work when compared to the jackhammering of the fire-tested floor and manual removed of the concrete rubble. He stated [redacted] advocated for this method. [redacted] stated there was no objection from [redacted] regarding using the *Composite Floor System Stabilization and Demolition* hazard review for the surrounding floor demolition.

[redacted] stated the use of a crane to first support a steel-concrete composite slab being cut and then subsequently lifted out would be considered a routine lift. He stated the slab shapes were uniform and well below the rated capacity of the crane. [redacted] stated only one crane was required for this lift and it could be done by one operator.

[redacted] stated he does not recall witnessing first-hand the cutting or removal of the test case slab or any of the surrounding floor slabs. He stated he did check in with staff regarding how the work was proceeding or if there were any concerns. [redacted] stated his ability to telework had a minimal affect the amount of time he was able to directly observe work.

[redacted] stated he did occasionally review both the live stream and recorded video, but he did not watch it all the time.

[redacted] stated he did observe staff members becoming lax regarding some safety requirements (*e.g.*, not wearing the appropriate PPE while in Room 125). He stated he did talk to staff regarding his concerns, and while for the most part they complied, he did receive some "pushback".

[redacted] stated he did not have any concerns about cutting concrete slabs, with thin sections of 3", out of a floor and lifting them out with rigging and a sling.

[redacted] stated there were no plans in place to revise the *Composite Floor System Stabilization and Demolition* hazard review to address the demolition of the remaining portion of the test frame after the slabs were removed. He stated that often during construction and demolition activities the project leader would work closely with the technicians in an attempt to get detailed information for the methods to do the work. [redacted] stated many times the work would proceed on a trial and error basis and work like this regularly occurred on a step-by-step basis.

[redacted] stated he was aware [redacted] had begun "experimenting" using the fire-tested floor to cut and lift slabs out. He stated he was aware of the large slab (now identified as the "test case") but did not know about the smaller slabs being cut and lifted out.

[redacted] stated "experimenting" outside the scope of a hazard review was not acceptable behavior.

[redacted] stated there was often a distinction between the ideal way to do work versus the how the work was actually performed. He stated many times using the hazard review system [MML Hazard Review Database] made it difficult or slow to get work done.

[redacted] stated his expectations are staff will perform work they are comfortable with doing given their experience and training.

[redacted] stated he did not know if [redacted] had any formal demolition training, but he did have significant experience from his previous job at the [redacted]. He stated many of the NFRL technicians have had "real world" experience with construction and demolition.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interview held on February 14, 2023, by the NIST Team investigating the Building 205 incident.

[redacted]

[redacted]

2/27/2023

Date

Summary of Investigation Interview with CF PROJECT LEADER 1

Date: November 1, 2022
Time: 4:00 pm to 4:40 pm ET

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members present: [redacted]

SUMMARY OF RESPONSES RELATED TO [redacted]

[redacted] stated she is currently a senior principal research engineer at [redacted]. She has held this position since March 2022. [redacted] stated prior to that position she was a research structural engineer for the National Fire Research Laboratory (NFRL) in the Fire Research Division of the Engineering Laboratory (EL) at the National Institute of Standards and Technology (NIST). She held this position from August 2012 until she took the position at [redacted]. [redacted] stated her main duties at NIST were to perform structural fire research. She was also assigned the role of Project Leader for the Steel-Concrete Composite Floor (CF) Systems Subject to Fire research project (hereafter referred to as "CF Project"). She stated she did not have supervisory responsibilities in this role.

SUMMARY OF QUESTIONS RELATED TO MR. STORY

[redacted] stated she had interactions with [redacted] and the frequency of them depended upon the phase of the CF Project. She stated during the design phase there was very little interaction, but during the construction phase interactions were daily – sometimes multiple times in a day. [redacted] stated she would check on the progress of the CF test frame construction or consult with [redacted] if there were issues with the structural steel frame assemblies or connections. She stated she also had interactions with him during experiment preparation and teardown.

SUMMARY OF RESPONSES RELATED TO THE DESIGN AND CONSTRUCTION OF THE TWO-STORY TEST FRAME

[redacted] stated she was part of the NIST design team responsible for developing a two-story test frame. She stated other NIST team members were [redacted] [retired] and [redacted] [redacted] stated the team first considered the maximum size of the test structure, which was ultimately dictated by the size of the fire exhaust hood located in Building 205, room 125. She stated [redacted] developed a preliminary design using AISC 360 – *Specifications for Structural Steel Buildings* and other applicable standards for the steel structure. [These standards are referenced in Section 2.1.1 in NIST Technical Note 2165: *Fire Resilience of a Steel-Concrete Composite Floor System: Full-Scale Experimental Evaluation for U.S. Prescriptive Approach with a 2-Hour Fire-Resistance Rating (Test #1)* published in October 2021.] [redacted] stated the test structure was designed as a gravity frame commonly used in an office building, with the exception of support columns (W12 x 106). She stated the support columns used in this structure are conservatively designed and supported by semi-rigid connections at their bases to provide a safe load path to the strong floor during construction/deconstruction and experimental testing. [redacted] stated in addition to her checking [redacted] calculations, staff from [redacted] also provided an independent check of the design using their own calculations to confirm the beams and floor slabs designed were appropriate. She also stated she presented a summary of the structural engineering and fire protection design of the test structure to an expert panel consisting of 13 structural and fire protection engineers who subsequently provided feedback. [redacted] stated the test frame was built to code; this is documented in Section 2.1.1 of NIST Technical Note 2165.

[redacted] stated the continuous #4 rebar, perpendicular to the slab splice, found in the East, North, and West sections of the surrounding floor was not required for code compliance, rather, it was added to reinforce the slab splice to provide restraint from expansion of the test floor during the fire experiments. She stated #4 rebar reinforcement was not required in the NE and NW sections of the surrounding floor as these locations were not directly connected to the test floor slab or expected to be affected during the fire experiments so only wire mesh reinforcement was included for code compliance. [redacted] stated the composite floor sections in the NE and NW corners of the test frame would meet code requirements; as documented in Section 2.1.1 of NIST Technical Note 2165.

[redacted] stated [redacted] was not involved with the design of the structure.

[redacted] stated a hazard review was conducted for erecting the structure and performing the fire experiments. [Subsequent to the interview, [redacted] was provided with a copy of the hazard review titled *Composite Floor Systems Test* - #733.06.0124.031621 in the MML Hazard Review Database. She confirmed this was the hazard review she was referring to in this portion of her statement.]

[redacted] stated the structural steel frame was fabricated by a third party and assembled by NFRL Technicians, specifically [redacted] and [redacted], as well as some assistance from [redacted] at times. She stated during the physical construction of the test frame, she had daily interactions with [redacted] and [redacted] checking on their progress and addressing any tolerance issues as the structural steel members (beams and columns) was connected.

[redacted] stated the steel pan decking was installed by the NFRL technicians using screws along their length to connect adjacent pieces. She stated they were nailed to the beams and shear studs were installed as well. [redacted] stated the steel pan decking was part of the composite floor system and provided some strength from loading during the construction. She stated shoring was used at slab splices during the concrete placement.

[redacted] stated a third party poured the concrete floor slabs.

[redacted] stated there was no formal "commissioning" of the structure, rather, "shakedown" tests were performed by the team as a whole to determine if the structure and all instrumentation were operational.

[redacted] stated to her knowledge the surrounding floor of the test frame was built according to the engineering/design drawings.

[redacted] stated to her knowledge there were no safety concerns related to the initial construction of the test frame.

SUMMARY OF RESPONSES RELATED TO PROCEDURES ASSOCIATED WITH POST-EXPERIMENTAL WORK AND REMOVAL OF THE TEST FLOOR CF1 AND CF2

[redacted] stated there were three tests performed using the test frame – CF1, CF2, and CF3.

[redacted] stated after CF1 she performed a forensic analysis, consisting of visual inspections, of the composite test floor and structural steel and structural steel connections supporting the test floor surveying for fire damage and anomalies. She stated she also performed a visual inspection of the surrounding floor and noted cracks in the surrounding floor slab in the North section, running N-S in the portion reinforced by #4 rebar. [redacted] stated these cracks posed no safety concern.

[redacted] stated a hazard review was conducted for demolishing the test floor, which included a demolition plan. [Subsequent to the interview, [redacted] was provided with a copy of the hazard review titled *Composite Floor System Stabilization and Demolition* - #733.06.0148.050522 in the MML Hazard Review Database. She confirmed this was the hazard review she was referring to in this portion of her statement.] [redacted] stated [redacted] created the hazard review but approval from the Group Leader [[redacted]] was required to perform this work. She stated [redacted] proposed the shoring locations within the test floor bay and after consultation with [redacted], she added shoring at slab splices to the surrounding floors. [redacted] stated the NFRL technicians were responsible for determining the method of demolition as well as performing the work. She stated there was a brief discussion of a third party performing the demolition work, but it was not pursued due to extended timeframes associated with the NIST procurement process.

[redacted] stated after CF2 she and [redacted] performed a similar forensic analysis as conducted after CF1 of the test floor and structural steel and connections. She stated during visual inspection of the surrounding floor new cracks were noted in the East and West sections, running E-W in the portion reinforced by #4 rebar. [redacted] stated these cracks posed no safety concern.

[redacted] stated demolition work of CF2 test floor was similar to CF1 with the exception being a third party was brought in to physically remove the concrete decking after the NFRL technicians had jackhammered and broken up the floor.

SUMMARY OF RESPONSES RELATED TO PLANNING THE DEMOLITION OF THE FULL TEST STRUCTURE AFTER CF3

[redacted] stated after CF3 a fourth experiment was planned, but she took her position at [redacted] prior to any further decisions being made. She stated she had no interactions with [redacted] regarding his plans to demolish the test frame. [redacted] did not review any drawings [specifically shown an image from the file titled *Coring and Cutting Plan* created by [redacted]] or calculations related to the demolition of the test frame made by [redacted].

SUMMARY OF RESPONSES RELATED TO THE INCIDENT

[redacted] stated she did not have facts regarding the incident that led to the fatal injuries of [redacted].

[redacted] was shown an image from the file titled *Coring and Cutting Plan* and she stated she would be concerned about the stability of the portion of the remaining surrounding floor between Slab 3 and Slab 4 once those slabs were removed from the test frame. She stated if shoring or braces were not used under this section and any small load was imposed (*e.g.*, human weight), it may be "wobbly".

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interviewed held on November 1, 2022, by the NIST Team investigating the Building 205 incident.

[redacted] ______________________ 11/21/2022

[redacted] Date

Summary of Investigation Interview with CF PROJECT LEADER 2

Date: October 17, 2022
Time: 1:00 pm to 2:40 pm ET

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members present: [redacted]

SUMMARY OF RESPONSES RELATED TO [redacted]

[redacted] stated he is a Research Structural Engineer for the National Fire Research Laboratory (NFRL) in the Fire Research Division of the Engineering Laboratory (EL) at the National Institute of Standards and Technology (NIST). He has held this position since January 2014 when he first joined NIST as a member of the Materials and Structural Systems Division; he moved into the NFRL in October 2014. [redacted] was on detail to the Program Coordination Office (PCO) in the NIST Director's Office from May 2021 to May 2022. Upon his return to the NFRL in May 2022, [redacted] was assigned the Project Leader role for Steel-Concrete Composite Floor (CF) Systems Subject to Fire Research Project (hereafter referred to as "CF Project"). [redacted] has no formal supervisory responsibilities in this role. He is also a Contracting Officer's Representative, Level II.

[redacted] stated before going on detail to the PCO, he was involved with the conception, planning, and execution of work related to CF Project since about 2015. He supported the project in many ways, including, but not limited to:

- Concrete design and placement;
- Metrology;
- Camera set-up; and
- Advanced imaging techniques.

[redacted] stated he assisted with the drafting of publications and presentations for the first two experiments – referred to as CF1 and CF2 – but did not have much involvement with CF3 as he was in the PCO at the time. Upon his return from the PCO and taking on the role of Project Leader, it was determined the planned experiment CF4 would not be conducted and the test frame used for these experiments was to be demolished.

[redacted] stated he feels the safety culture in the NFRL is very strong.

SUMMARY OF RESPONSES RELATED TO [redacted]

[redacted] stated he had regular interactions with [redacted] while working in the NFRL. The nature of his interactions depended on the project and the type of work being performed. [redacted] stated he had frequent to daily interactions with [redacted] on several past projects as the two worked closely on procurements, test procedures, and hazard reviews (*i.e.*, work risk assessments). With respect to his role as Project Leader for the CF Project, [redacted] stated he had intermittent interactions with [redacted] to determine if he needed resources or other types of support while the test frame for the CF Project was being demolished. He also stated he worked with [redacted] on updating the hazard review used for the demolition of the test frame. This change was necessitated after a Management Observation Process (MOP) discussion with [redacted] (EL Deputy Director) and other EL staff prior to surrounding floor demolition. It was recommended to formally include hearing protection and amend other items in the hazard review.

SUMMARY OF RESPONSES RELATED TO THE DESIGN AND CONSTRUCTION OF THE TWO-STORY TEST FRAME

[redacted] stated [redacted] was instrumental in the early development of the concept for the two-story test frame. Many other NIST staff members participated in the design including [redacted] (now at [redacted]) and [redacted] (EL Guest Researcher), as well as a panel of outside experts consisting of structural and fire protection engineers from around the world. [redacted] stated [redacted] was involved in the design but was unsure of his contributions.

[redacted] stated building codes were utilized in the design of the test frame, and to his knowledge, it met or possibly went above code requirements. [redacted] stated the building codes could be found in Section 2 of the NIST Technical Note 2165: *Fire Resilience of a Steel-Concrete Composite Floor System: Full-Scale Experimental Evaluation for U.S. Prescriptive Approach with a 2-Hour Fire-Resistance Rating (Test #1)* published in October 2021. [redacted] noted that it is his understanding that while the building nominally followed code requirements for the structural design, the building was a research specimen and not intended for service use.

[redacted] stated the outside experts recommended adding elements including:

- Hooked rebar around the perimeter of the test frame to facilitate the research objectives; and
- Polypropylene microfibers to the concrete for both the test floor and surrounding floor to resist spalling from heat during the fire experiments.

[redacted] stated he did not explicitly investigate how adding polypropylene to the concrete would affect its mechanical properties.

[redacted] stated he did not know when the test frame design was approved or who would have approved it.

[redacted] stated the slab splice demarcated the test floor from the surrounding floor of the test frame and facilitated replacement of the test floor, *i.e.*, the splice allowed the test floor to be demolished while not impacting the surrounding floor.

[redacted] stated he did not know why the continuous rebar reinforcement was not used in the surrounding floor in the NE and NW corners of the test frame as he was not part of that discussion. He stated he believed the provided welded wire mesh in the composite slab is to code and additional No. 4 rebar reinforcement used in the surrounding floor would not be required under normal load design conditions for occupancy.

[redacted] stated there was a hazard review conducted for the overall project which included "set-up" and "teardown" of the test frame. This hazard review can be found in the MML Hazard Review Database (#733.06.0124.031621). Standard operating procedures (SOPs) are also associated with this document.

[redacted] stated NFRL technicians ([redacted], [redacted], [redacted], [redacted], and [redacted] – a technician in another group in the Fire Research Division) performed the physical construction of the structural steel, including the steel pan which was connected to the beams using welded shear studs on the beams. The lap joints of the steel pans were secured with screws. An external contractor was responsible for placing the concrete and another external contractor sprayed on the fire proofing material. [redacted] stated he did not know if shoring was used under the steel deck prior to or during the concrete pour. He stated the placement of the concrete for the initial test frame occurred in June of 2019.

[redacted] stated he did not know if there was a formal "commissioning" of the test frame, *i.e.*, an individual(s) verifying the structure was fully operational and ready for experimental work to commence.

[redacted] stated he did not know if the surrounding floor of the test frame was built according to the engineering/design drawings.

[redacted] stated to his knowledge there were no safety concerns related to the initial construction of the test frame.

SUMMARY OF RESPONSES RELATED TO PROCEDURES ASSOCIATED WITH POST-EXPERIMENTAL WORK AND REMOVAL OF THE TEST FLOOR CF1 AND CF2

[redacted] stated he does not recall being significantly involved in the demolition of the test floor after CF1 or CF2.

SUMMARY OF RESPONSES RELATED TO PLANNING DEMOLITION OF THE FULL TEST FRAME AFTER CF3

[redacted] stated [redacted] had primary responsibility for demolition of the test frame after CF3 as he had previous experience in demolishing large-scale test structures in the NFRL and at the [redacted] – his previous job.

[redacted] stated he believed the removal of the test floor after CF3 was performed similarly to the demolition of the test floor for CF1 and CF2. He stated there was a separate hazard review for demolition of the test floor that was used for CF1 and CF2 and that same hazard review was used for CF3 test floor demolition. This hazard review can be found in the MML Hazard Review Database - #733.06.0148.050522 – *Composite Floor System Stabilization and Demolition*. It was determined by [redacted] (Group Leader of NFRL), [redacted], and the NFRL technicians that the hazard review used for test floor removal after CF1 and CF2 as updated and approved on 5/16/2022 was appropriate for demolition of CF3 test floor. [redacted] stated an SOP was developed to address the hazards of removing the test floor that included evaluation of the condition of the test frame and test floor, as well as specific provisions for shoring of the test floor due to damage during the experiments. He stated [redacted] [redacted] developed this document.

[redacted] stated NFRL technicians primarily did the demolition work after CF3. This included [redacted] [redacted], [redacted] and [redacted] [redacted] [redacted], and [redacted] assisted in aspects of the test structure demolition as well.

[redacted] stated to his knowledge there was no specific requirement in the hazard review or SOP for the number of persons to participate in the cutting of the slabs, but a general rule for conducting hazardous work in Room 125 was to have at least two people in the space. He stated line management supervision was not required for this work.

[redacted] stated there was no separate hazard review for demolition of the surrounding floor beyond what was written in the original hazard review for set-up and teardown of the test frame (#733.06.0124.031621). [redacted] stated there was discussion around removal of the surrounding floor prior to the work being conducted and the primary focus was on finding the safest and least physically taxing method to do so.

[redacted] stated he was not aware of a specific demolition plan for the removal of the surrounding floor.

[redacted] stated he was aware of the file titled *Coring and Cutting Plan* as [redacted] had showed it to him on the same day Occupational Safety and Health Administration (OSHA) visited in response to the incident (October 13, 2022). He stated he assumed [redacted] created the document and made the determinations of size, shape, and location of the slabs to be cut from the surrounding floor. He was not aware of the following regarding the document:

- How the size, shape, and location of the slabs were determined;
- How the location of the rigging points were determined;
- If there was a sectioning plan for each slab, *i.e.*, which face to cut first, second, third, fourth; or
- If calculations were made to determine if the individual slabs could support their own weight once cut free of the test frame and supported by the rigging.

[redacted] was not aware of these decisions being documented by [redacted] He also did not have knowledge of whether [redacted] reviewed engineering/design drawings as part of this effort.

[redacted] did not know if shoring was considered for each slab to be cut.

[redacted] stated [redacted] and possibly some of the other NFRL technicians, made the determination for what demolition equipment was to be used. For cutting of the surrounding floor slabs, a floor saw was to be used and the slab would then be lifted out with rigging and a crane.

[redacted] stated the following personal protective equipment (PPE) was called out to perform demolition activities of the surrounding floor:

- Steel-toed boots;
- Gloves;
- Hard hat;
- Respiratory protection (dust mask); and
- Personal fall protection equipment if working near an exposed edge.

[redacted] stated to his knowledge there is no mention in the hazard review regarding specific safety protocols identified with respect to behavior during or after a slab was cut, but there are requirements in the NFRL Crane SOP indicating that an individual shall not stand on, ride on, or walk underneath a suspended load. These requirements are found in the standard operating procedure associated with hazard review #733.06.0052.052322 – NFRL Overhead Cranes.

[redacted] stated everyone is responsible for safety at the work location.

[redacted] was not aware of safety briefings being conducted with respect to the demolition work of the surrounding floor as he was not directly involved with the physical work being performed.

SUMMARY OF RESPONSES RELATED TO DEMOLITION OF THE FIRST THREE SLABS REMOVED FROM THE EAST SIDE OF THE TEST FRAME

[redacted] stated the test floor for CF3 was demolished prior to work involving removal of the surrounding floor. He believes [redacted] was primarily responsible for oversight of the demolition work.

[redacted] stated he did not participate in an inspection of the surrounding floor after CF3 and does not know if one was conducted. He stated in the few times he was on the structure prior to demolition work beginning, through casual observation, he did not notice anything out of the ordinary or looking unusual with respect to the surrounding floor.

[redacted] stated there were multiple options for fall protection available to the NFRL technicians during this work. An example is cabling used around the perimeter of the test floor and the edge of the surrounding floor. He stated during the cutting of the slabs, the decision to use personal fall protection would have been determined by the person performing the work and it may not have been deemed to be a reasonable option by the operator if it impeded the work. He stated these decisions should have been reassessed as the work progressed.

[redacted] stated he did not know when or who performed the slab removals for the first three cut out of the surrounding floor. He stated he believed a walk behind floor saw and crane was used but does not know for certain.

[redacted] stated there was no schedule for demolishing the test frame beyond it needed to be completed by Spring 2023. The NFRL technicians were working at their pace with the primary drivers of safety, efficiency, and the least amount of physical strain on the staff performing the work.

[redacted] stated he did not know if there were any issues during removal of Slab 3.

[redacted] stated prior to the incident he was not aware of NFRL technicians standing on, walking on, or walking underneath the slabs once they were either partially or fully cut free from the test frame. He stated after reviewing some of the video from Room 125 he did observe [redacted] standing on the attached load at the time of the incident.

[redacted] stated he was aware of the wooden structures observed in the bays for Slab 1 and Slab 2. He stated they were used to shore up the test floor but was not sure why or when they were placed in the bays for Slab 1 and Slab 2.

[redacted] stated he asked [redacted] if there were any problems with the cutting of Slab 1 and [redacted] indicated it worked great. [redacted] was not aware of post-job debriefs after the cutting of Slabs 2 or 3, or if there were any concerns raised.

SUMMARY OF RESPONSES RELATED TO THE INCIDENT

[redacted] stated he was teleworking on the day of the incident and could not provide detail about the specific work that was being performed that day.

[redacted] stated he had no concerns about [redacted] performing the work as he believes he had received all required training and was experienced in performing demolition work.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interview held on October 17, 2022, by the NIST Team investigating the Building 205 incident.

[redacted]

Date

Summary of Second Investigation Interview with CF PROJECT LEADER 2

Date: February 13, 2023
Time: 10:00 am to 10:40 am

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members present: [redacted]

SUMMARY OF RESPONSES RELATED TO ROLES AND RESPONSIBILITIES AS CF PROJECT LEADER (beginning on May 9, 2022)

[redacted] stated he has responsibilities with respect to decision making regarding the reporting and logistics related to the CF Project. He stated this includes having technical and organizational discussions within the CF Project group, coordination and communication with the exterior panel, and oversight for the remainder of the work required to be performed (*e.g.*, writing of research papers, demolition).

[redacted] stated he was involved with review of relevant CF Project hazard reviews for work performed. He stated when he returned from his detail, there were two approved hazard reviews in place that covered the work performed [*Composite Floor Systems Test* - #733.06.0124.031621 and *Composite Floor System Stabilization and Demolition* – #733.06.0148.050522]. [redacted] stated after a MOP, he worked with [redacted] (NFRL technician) and the CF Project Team to update the latter hazard review to cover the noise and respiratory hazards not explicitly called out in the document.

[redacted] stated once the issues raised during the MOP were addressed and it was perceived by the team that adequate hazard review had been performed (two CF HRs and related NFRL HRs for Crane operation, etc.), he coordinated between the research and demolition activities for the CF3 fire-tested floor. [redacted] stated [redacted] would reach out to him occasionally for decisions about storage or disposal of materials, removal of instrumentation, *etc*.

[redacted] stated for the surround floor and remaining structure, he intermittently checked with the team to inquire about progress, challenges, and needs. He stated they were slowly moving to close the project out and [redacted] was leading the demolition activities.

[redacted] stated he had responsibilities with respect to execution or direction of work to be performed as part of the CF Project. He stated this included working with the subject matter experts regarding data collection ([redacted]), demolition ([redacted]), and research communications (himself).

[redacted] stated he had responsibilities with respect to observing work performed as part of the CF Project. He stated these interactions were intermittent. They took place in person, by phone, or occasionally during the weekly group meeting. He physically met with [redacted] to discuss the data collection and with [redacted] regarding the demolition of the test frame. [redacted] stated his ability to telework did not affect the amount of time he was able to observe work.

[redacted] stated he had responsibilities with respect to the safety of work performed as part of the CF Project. He stated he ensured the appropriate hazard reviews were in place. [redacted] stated he was primarily concerned about the structural stability of the fire-tested floor given the damage it had sustained during the CF3 experiment. He stated to the best of his recollection he was involved with discussions about the best way, in terms of safety and effectiveness, of removing the surrounding floor, but he relied on the staff who were performing the operations to determine the best means/methods to accomplish the work.

SUMARY OF RESPONSES RELATED TO THE TIMELINE OF EVENTS

[redacted] stated he was unsure of actual dates for the following events:

- A general meeting [redacted] (NFRL Group Leader) held with multiple NFRL technicians to discuss different methods to remove the surrounding floor. [redacted] stated he was unsure if the specific meeting referenced was the meeting with the project team held in early May to follow-up on the MOP for which he was present, or if this was in reference to an additional meeting (or meetings) and he had knowledge of these discussions through informal subsequent discussions with NFRL staff.
- A meeting titled "Concrete removal Haz Review" scheduled for June 15, 2022, to include [redacted], [redacted], [redacted], and [redacted] (NFRL technician). The text in the invite stated:

  Decision item: Do we need to amend the concrete removal Haz Review to facilitate removal of large sections of the undamaged structure with the crane (assuming this is viable and we want to do it)

  [redacted] stated he is unsure if this meeting was held as he thought schedule conflicts and/or staff using leave may have precluded it.
- A meeting where it was agreed by himself, [redacted], and [redacted] that a "test case" can be performed using the floor saw cutting and removal of the slab to determine if the method is a viable option. [redacted] stated [redacted] had been using this method to remove pieces of the CF3 fire-tested floor already so it is unclear why this meeting would have been necessary.
- A meeting, subsequent to the "test case" being performed, where himself, [redacted], and [redacted] decided to use the *Composite Floor System Stabilization and Demolition* hazard review of the fire-tested floor for demolition of the surrounding floor. [redacted] stated that at the time he believed that the information contained in the two previously approved CF Project hazard reviews, together with the general safety training and procedures for the execution of work in the NFRL, had sufficiently covered this method of demolition so there was no need to do a re-review and re-approval.

SUMMARY OF RESPONSES RELATED TO THE DEMOLITION WORK PERFORMED AFTER CF3

[redacted] stated he was aware [redacted] was cutting slabs of the CF3 fire-tested floor and lifting them out with the crane. He stated he believed this work was covered under the two previously approved CF Project hazard reviews, the crane operation hazard review, and the general safety training and procedures for the execution of work in the NFRL. [redacted] stated he did not know exact details of how the work was being performed as he largely relied on [redacted], [redacted], and [redacted] (NFRL technician) to determine the safest and most effective method for demolishing the CF3 fire-tested floor because they were proficient in and closest to the execution of the work.

[redacted] stated he believed the work conducting the "test case" was covered under the two previously approved CF Project hazard reviews and the general safety training and procedures for the execution of work in the NFRL. He stated he trusted the judgement of [redacted] regarding this demolition work as he knew [redacted] had used the floor saw during the previous post-experimental forensic inspections of CF3 fire-tested floor and it was not apparent at that time that new hazards were being introduced. [redacted] stated while the cutting of the larger rectangular sections of the undamaged floor was new, he believed the perception was this was a subset of work [redacted] had been doing. He stated he was not aware the use of the concrete floor saw was not called out in the hazard reviews, but rather that concrete cutting in general as a hazard was covered.

[redacted] stated he did not observe the "test case" work being performed.

[redacted] stated during construction and demolition work the team did their best to lay out appropriate procedures in advance. He stated the two previously approved CF Project hazard reviews, as well as the NFRL hazard reviews for general work in Room 125 [*e.g.*, overhead cranes, scissor and boom lift, powered industrial trucks], were used for the demolition work. [redacted] stated there were times when work did not proceed as expected and a different method was required with a hypothetical example provided of using a cutting torch to remove a shear tab where bolts had seized preventing extraction with an impact driver. He stated means and methods may need to be adjusted within allowed operating procedures depending on the circumstances and what is deemed safest to achieve the task. [redacted] stated he believes adaption to evolving site conditions is common in construction practice.

[redacted] stated that at the time he did not have concerns regarding the proposed method for removing the surrounding floor using a floor saw to cut the slab and then lifting out with the crane that would prohibit its use if done safely.

[redacted] stated he did not see or review the Coring and Cutting Plan in advance of the work commencing. He stated he did not know why it was not provided or why he did not ask to review something similar in advance, but presumably [redacted] did not feel it was necessary given the hazard reviews that were in place, his past experience on the project demolition, and type of lift being performed. [redacted] stated he heard after the incident that [redacted] had performed the calculations and there was a "good" safety factor.

[redacted] stated previous lifts in the NFRL that had involved interaction with the project engineers had been critical or complicated lifts involving situations with large mass, two cranes, irregular support geometries, or sensitive experimental components. He stated such critical lifts are defined in the crane hazard review.

[redacted] stated he visited the worksite during the timeframe the demolition work was occurring but does not recall being present for any of the slab cutting or lifting out. He stated he believes he was on the surrounding floor with [redacted] after Slab 2 was cut and prior to Slab 3 being cut. [redacted] stated he does not recall the topic(s) of their conversation.

[redacted] stated he believed at that time that the combination of the two previously approved CF Project hazard reviews and the general NFRL hazard reviews [*e.g.*, use of overhead cranes, lifts, and fork trucks] together with the experience of [redacted] are sufficient for the complete demolition of the entire CF Project test frame.

[redacted] stated he did not think that he or the team differentiated with respect to 'safety' for the demolition of the surrounding floor compared to the fire-tested floor, but rather the fire tested portion was complicated by the damage and deformation it had sustained.

[redacted] stated that at the time he perceived the lift of the slabs out of the surrounding floor as uncomplicated lifts as they did not involve high utilization of the crane capacity, multiple cranes, or irregular support geometries. He stated he did not believe the lift operator was required to submit a lift plan for this work. [redacted] stated it is up to the crane operator to determine how the lift will be performed and if a lift plan is required, in many instances.

[redacted] stated with respect to the corrective action identified in IRIS Case Number 19-IG-0053:

The workspace manager or designee will conduct daily checks to assure that PPE is being used

he does not know which checks were performed and with what frequency. He stated he is aware of instances of staff checking each other on their use of hard hats, gloves, safety glasses, *etc*.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interview held on February 13, 2023, by the NIST Team investigating the Building 205 incident.

[redacted]

[redacted]

____
Date

Summary of Investigation Interview with NFRL ENGINEER 1

Date: November 2, 2022
Time: 9:00 am to 9:40 am ET

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members present: [redacted]

SUMMARY OF RESPONSES RELATED TO [redacted]

[redacted] stated he is a foreign guest researcher for the National Fire Research Laboratory (NFRL) in the Fire Research Division of the Engineering Laboratory at the National Institute of Standards and Technology (NIST). He has held this position from December 2013 to present with short breaks around the start of 2019 (December 2018 to January 2019) and in 2022 (January to September). [redacted] stated his main duties at NIST are to perform structural fire research in which he designs experiments and instrumentation plans to collect data for the Steel-Concrete Composite Floor (CF) Systems Subject to Fire Research Project (hereafter referred to as "CF Project"); he is also involved with data analysis, publications, and presentations for this work. He stated he does not have supervisory responsibilities.

[redacted] stated he feels safety at the NFRL is very good and more strict than other places he has worked. He stated he felt very comfortable bringing up safety concerns to [redacted] [NFRL Group Leader] and [redacted] [current CF Project Leader].

SUMMARY OF QUESTIONS RELATED TO [redacted]

[redacted] stated he had frequent interactions with [redacted] during the construction phase of the CF Project where they would discuss questions about the design drawings or installation of instrumentation. He stated there were discussions related to post-test investigation of the test floor during its demolition after the three experiments.

SUMMARY OF RESPONSES RELATED TO THE DESIGN AND CONSTRUCTION OF THE TWO-STORY TEST FRAME

[redacted] stated he was part of the NIST design team responsible for developing the two-story test frame. He stated they surveyed leading US firms regarding typical building parameters such as beam spacing, reinforcement layout, and typical dead and live loads. [redacted] stated he designed the test structure with both [redacted] [previous CF Project Leader] and outside firms ([redacted] and [redacted]) who verified his calculations for the girder and beam sizes, slab thickness, and the connections to meet the strength and serviceability requirements. He stated the building was built to code with the exception of the slab splice which would not normally be found in a building. [redacted] stated the design was then presented to a panel of experts from around the world to get their feedback. He stated they recommended adding the shorter, hooked rebar around the exterior perimeter of the test frame to minimize pulling out failure of slabs along edges, but this is not required by code.

[redacted] stated the continuous #4 rebar found in the East, North, and West sections of the surrounding floor was not required for code compliance. He stated it was added for scientific reasons to help transmit forces from the test floor through the slab splice to the surrounding structure during the experiment.

[redacted] stated the #4 rebar reinforcement was not required in the NE and NW sections of the surrounding floor as these locations were not connected to the slab splice and would not be affected during the fire experiments as they are not adjacent to the test floor.

[redacted] stated he provided the technical drawings to [redacted] as he led the effort to physically construct the test frame with assistance from [redacted] and [redacted] – two other NFRL engineer technicians. He stated he believed a hazard review was conducted for the construction, but he was not involved with its development and presumes it would have been developed by [redacted] or [redacted].

[redacted] stated during the construction he would check on progress of the work; standard personal protective equipment for him to do so was a hard hat and safety glasses. He stated he did use a scissor lift, run by one of the NFRL technicians, to inspect structural steel connections.

[redacted] stated the steel pan decking installed by the NFRL technicians did provide strength to the floor but was unsure as to how much contribution compared to the concrete once it was cured. He stated each section of decking was screwed to the adjacent section along their edges, and they were screwed to the beams as well as anchored to the beams using shear studs that were welded to the steel beams through the steel decks.

[redacted] stated during the initial pour of the concrete (CF1), shoring was used under the steel pan decking, even though it was not required.

[redacted] stated the test floor was pre-tested by the CF team members through mechanically loading the floor, *i.e.*, a "shakedown" test, as well as subjecting the test floor to natural gas fire, to ensure the loading system, natural gas burners, and instrumentation and data acquisition systems were operational before the CF experiments.

[redacted] stated to his knowledge the surrounding floor of the test frame was built according to the engineering/design drawings.

[redacted] stated to his knowledge there were no safety concerns related to the initial construction of the test frame.

SUMMARY OF RESPONSES RELATED TO PROCEDURES ASSOCIATED WITH POST-EXPERIMENTAL WORK AND REMOVAL OF THE TEST FLOOR CF1 AND CF2

[redacted] stated there were three tests performed using the test frame – CF1, CF2, and CF3.

[redacted] stated after CF1, he performed visual inspections of the composite test floor and the surrounding floor. He stated he observed cracks in the surrounding floor slab in the North section, running N-S in the portion reinforced by #4 rebar. [redacted] stated they consulted with the panel of experts and did not perform repairs of the surrounding floor as the cracks were not a safety concern, nor would they affect the performance of future tests.

[redacted] stated he believes a hazard review was performed for the demolition of the test floor. He stated he believes [redacted] developed the hazard review, but he did not have any input into the document. [redacted] stated he and [redacted] determined where the shoring would need to be placed under the test floor, and specifically, in the location of the slab splice.

[redacted] stated after CF2 he performed a similar visual inspection of the test floor and surrounding floor. He stated he observed new cracks in the East and West sections, running E-W in the portion reinforced by #4 rebar. [redacted] stated these cracks were not a safety concern either.

[redacted] stated he did not have any information related to the shoring or hazard review for demolition of the test floor after CF2.

SUMMARY OF RESPONSES RELATED TO PLANNING THE DEMOLITION OF THE FULL TEST STRUCTURE AFTER CF3

[redacted] stated after CF3 it was determined to end the series of CF experiments as [redacted] had taken a position at [redacted] and [redacted]. He also stated the team felt they had learned more than enough from the first three experiments.

[redacted] stated prior to that decision, he had performed visual observations of the test floor and surrounding floor and did not note any new cracking.

[redacted] stated at the request of [redacted], he performed independent calculations for the shoring used under the test floor to ensure the capacity was adequate to support the load. He stated he did not see any other documents related to hazard review for the demolition of the test floor.

[redacted] stated he did not have any involvement with the plans for demolishing the test frame as a whole. He stated he had not seen the file titled *Coring and Cutting Plan* created by [redacted] until after the incident occurred. [redacted] also stated he did not review any other drawings or calculations related to the demolition of the test frame made by [redacted] nor did [redacted] discuss his plans for demolition with [redacted].

SUMMARY OF RESPONSES RELATED TO THE INCIDENT

[redacted] stated he was in his office in Building 205 when the incident occurred. He stated he went out to the lab floor [Room 125] after he was told what happened. [redacted] stated he watched the video of the incident shortly thereafter.

[redacted] stated once the slab was cut free from the test frame, the load transfer mechanism would completely change and the steel pan decking would have provided no strength to the slab.

[redacted] stated if he had reviewed the calculations performed by [redacted], he may have had concerns about the cutting of the slabs, but probably would not have factored in the possibility of someone stepping on to the suspended slab. He also stated, after reviewing the *Coring and Cutting Plan* figure showing the location of all the slabs to be cut, he would have had concerns about the cutting of the longer slabs (#5 and #7) due to their length and would have wanted to check the safety factor for lifting them out of the surrounding floor.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interviewed held on November 2, 2022, by the NIST Team investigating the Building 205 incident.

[redacted] 11/16/2022

[redacted] Date

Summary of Investigation Interview with NFRL ENGINEER 2

Interview Date: November 3, 2022
Time: 9:00 AM to 9:35 AM ET

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members Present: [redacted]

SUMMARY OF RESPONSES RELATED TO [redacted] AND SAFETY CULTURE AT NFRL

[redacted] stated he is a Mechanical Engineer for the National Fire Research Laboratory (NFRL) in the Fire Research Division of the Engineering Laboratory at the National Institute of Standards and Technology (NIST). He stated he has held this role for 24 years at NIST. [redacted] stated he started in the NFRL in 2014 and his supervisor is [redacted], Group Leader. [redacted] stated he is responsible for metrology and calorimetry measurements of gas species and flow measurements in exhaust ducts. He stated he is a principal investigator for his own projects and also assists others with instrumentation of their projects.

[redacted] stated NFRL does its best to comply with the NIST Safety Management System. He stated all projects need to have hazard reviews. [redacted] stated hazard reviews are conducted and standard operating procedures are developed for projects and workspaces. He stated hazards are identified and staff are made aware of what the hazards are. [redacted] stated safety checklists are used prior to experiments. He also stated staff are encouraged to complete assigned training and they are mindful of hazards and try to operate in a safe manner.

[redacted] stated he is comfortable raising safety concerns to [redacted] as well as his peers and has not received pushback when expressing them. He stated staff talk about activities that may be unsafe and the potential consequences of not being safe. [redacted] stated if he saw someone doing something unsafe, he would say something.

[redacted] stated in general he does not participate in safety meetings being held regarding the setup or teardown of an experiment as he is mostly involved in design and installation of the instrumentation.

[redacted] stated he participated in management observation process discussions with the latest one occurring in mid to late summer with the division safety representative [[redacted]] and the division chief [[redacted]]. He stated he found these activities worthwhile because everyone can talk and hear each other's concerns and, in some cases, might lead them to rethink how to operate more safely.

SUMMARY OF RESPONSES RELATED TO [redacted]

[redacted] stated he interacted with [redacted] from a scientific perspective and was interested in discussing the monitoring of the MTS Hydraulic System readouts by [redacted].

[redacted] stated he did not need to raise safety concerns to [redacted] and did not feel that safety took a back seat. He stated [redacted] did not express any safety concerns to him.

SUMMARY OF [redacted]'S RESPONSES REGARDING COMPOSITE FLOOR EXPERIMENTS

[redacted] stated he had a small role in the experiment which involved flow/ventilation measurements only. He stated he made sure the instrumentation was performing well and also took some still photographs for documentary purposes. [redacted] stated he did not raise any safety concerns during setup, performance of experiment, or during teardown. He stated he did not know if safety was managed differently during the different stages of the experiment but he knew they had discussions about demolition of the test area. [redacted] stated he believes there is a hazard review, for the demolition of the test floor and did observe the area being roped off [around the fire compartment] and shoring underneath the test floor.

[redacted] did not observe anyone displaying poor safety behaviors but did state he had very limited involvement in the various stages of the composite floor experiment.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interviewed held on November 3, 2022, by the NIST Team investigating the Building 205 incident.

[redacted]

[redacted] Date ____________________

Summary of Investigation Interview with NFRL ENGINEER 3

Interview Date: November 3, 2022
Time: 11:00 am to 11:55 am ET

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members Present: [redacted]

SUMMARY OF RESPONSES RELATED TO [redacted] AND SAFETY CULTURE AT NFRL

[redacted] stated he is an Electronics Engineer for the National Fire Research Laboratory (NFRL) in the Fire Research Division of the Engineering Laboratory at the National Institute of Standards and Technology (NIST). He stated he has held this role for 13 years. [redacted] stated he started in the NFRL around 2009 and his supervisor is [redacted] [NFRL Group Leader]. [redacted] stated he is responsible for software development, IT support, electronics, sensors, data/video acquisition and management, data storage, and coordination with IT Security.

[redacted] stated from his perspective, having worked previously in private industry (*e.g.*, automotive, [redacted], [redacted]), he thinks NFRL has an extra layer of safety. He stated the process is very good for doing hazard reviews and hazards are assessed proactively for all projects. [redacted] stated it could slow things down but safety was addressed. He stated one could not just rush in to do things and there would always be 2 people on site when work was being conducted. [redacted] stated safety briefings were held before every experiment in order to ensure everyone was aware of and familiar with the hazards. He stated everyone was required to participate and one had to be authorized to participate in experiments. [redacted] stated PPE enforcement was a priority with management and the safety officers.

[redacted] stated he was comfortable with raising safety concerns to [redacted] and did not experience pushback or a feeling that safety took a back seat. He stated he also felt comfortable raising safety concerns to his peers and they were always considered and addressed through re-engineering or other means.

[redacted] stated project safety started by defining the project, identifying the PI and the team, establishing a project plan, and conducting a hazard review to incorporate safety. He stated the hazard review must be reviewed and approved at multiple levels. [redacted] stated training is a typical requirement and would be taken by all participants even if their particular role did not require it.

[redacted] stated he does not do the physical installation of instrumentation and that is left up to the NFRL technicians. He stated he does not participate in demolition work, and therefore, did not participate or have knowledge if safety briefings were included.

[redacted] stated he was not included in Management Observation Process (MOPs) visits, other than some issues identified in MOPs have been brought to his attention for resolution (*e.g.*, extension cords).

[redacted] stated he was not involved in "Toolbox" meetings but observed the NFRL technicians would gather for group discussions. He stated he was not aware of the contents of the discussions.

SUMMARY OF RESPONSES RELATED TO [redacted]

[redacted] stated he relied on [redacted]'s structural engineering expertise to know what to do with his sensors, and on aspects of projects involving structures or hydraulic systems. He stated [redacted] also did CAD drawings for [redacted]. [redacted] stated [redacted] would often come to him for assistance video needs. He stated [redacted] had safety concerns about staff being in the basement during fire tests on the strong floor so [redacted] setup cameras of the equipment in the basement. [redacted] stated he never experienced pushback from [redacted] on safety issues and [redacted] appeared to be very proactive and respectful of others' concerns.

SUMMARY OF [redacted]'S RESPONSES REGARDING COMPOSITE FLOOR EXPERIMENTS

[redacted] stated he was responsible for data/video collection, thermal imaging, data processing, setting up and reviewing live feedback that included things like early warning systems. He stated there were 600 channels of data including thermocouples, strain gauges, video, and audio.

[redacted] stated he did not have any safety concerns about the different stages of the experiment. He stated he did feel uneasy about going up on the scissor lift but was always accompanied by one of the NFRL technicians.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interview held on November 3, 2022, by the NIST Team investigating the Building 205 incident.

[redacted]

11/16/2022

Date

Summary of Investigation Interview with ENGR TECH 2

Date: October 27, 2022
Time: 1:00 pm to 4:00 pm ET

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members present: [redacted]

SUMMARY OF RESPONSES RELATED TO [redacted] AND SAFETY CULTURE AT NFRL

[redacted] stated he is an Engineering Technician for the National Fire Research Laboratory (NFRL) Group in the Fire Research Division of the Engineering Laboratory at the National Institute of Standards and Technology. He stated he has held this role for 15 years, all of it in the Fire Research Division. [redacted] stated he spent 8 months working as a mason prior to working at NIST.

[redacted] stated he works primarily on the "structural" side of the NFRL (Building 205) in Room 125. He stated his responsibilities include setup and teardown of experimental apparatus, instrumentation, loading systems, and emissions control systems. [redacted] stated he will also assist with running tests and serves as a backup staff resource for activities in the older "fire" section of the lab in Room 113.

[redacted] stated safety in the NFRL was managed differently depended on what was going on. He stated for any difficult tasks, they always had conversations about determining the safest way to do them. [redacted] stated [redacted] authored hazard reviews (HRs) and standard operating procedures (SOPs) with input from himself and other team members. He stated if there was a concern while work was being performed, they always stopped and talked about it before moving forward.

[redacted] stated safety concerns were handled different ways. He stated if it was related to a day-to-day activity, they handled it between technicians, but larger issues would be brought to [redacted] [NFRL Group Leader]. [redacted] stated, as an example, the original plan for construction of the Composite Floor (CF) experiments test floor was to pre-cast it and then lift it into place in the test frame with the crane. He stated he was not comfortable with this plan and recommended they cast the test floor in place in the test frame as it would be safer. [redacted] stated [redacted] listened to the concern and the plan was subsequently modified.

[redacted] stated the two-person rule in effect at NFRL requires that there always be someone else around if you are doing hazardous work or working outside of normal business hours.

SUMMARY OF RESPONSES RELATED TO [redacted]

[redacted] stated he worked with [redacted] on a daily basis and that they worked well together. He stated [redacted] generally functioned as a foreman, but they worked alongside each other as a team. [redacted]

[redacted] stated they performed the majority of the work together on CF Project. He stated he was being mentored by [redacted] regarding the structural aspects of the set-up and he was mentoring [redacted] regarding the fire aspects of the experiment.

[redacted] stated he felt comfortable raising safety concerns to [redacted] and he often did. He stated [redacted] never dismissed him outright and he would either provide a reasonable explanation for not changing the process or they modified procedure.

[redacted] stated [redacted] did express some safety concerns to him but [redacted] usually had a solution and would explain how they were going to do something.

[redacted] stated [redacted]'s interactions with his line management [[redacted]] and project managers [former – [redacted] and current – [redacted]] were good and if concerns were raised, they would listen. He stated he never felt that safety "took a back seat" to other priorities at NFRL.

SUMMARY OF RESPONSES RELATED TO THE DESIGN AND CONSTRUCTION OF THE TWO-STORY TEST FRAME

[redacted] stated he was not involved in the design of the CF test frame.

[redacted] stated he did not have any safety concerns with the design of the CF test frame, subsequent to the change regarding casting the test floor in place, but there were often changes in the design during construction [*e.g.*, modification of structural steel connections]. He stated he did not know there was limited reinforcement in the NE and NW corners of the structures, and even thought there was rebar in a grid pattern in these locations.

[redacted] stated he assisted with the construction of the CF test frame through installation of the columns, beams, girders, steel deck, rebar chairs, and welded wire mesh. He stated he was on extended leave during the installation of the rebar [citing this as the reason he was not aware of the limited reinforcement in the NE and NW corners].

[redacted] stated hazards associated with construction were communicated to him by [redacted] as he would communicate what steps were necessary and what hazards might be encountered. He stated he was aware of a hazard review for the work to be performed but he did not personally review it as he took instruction from [redacted] and [redacted] regarding how to do the work safely. [redacted] stated there was no special training for the task, only the training they had previously received such as rigging and crane training and other safety program trainings.

[redacted] stated he assisted with the installation of the steel deck. He stated the individual pans were screwed together along their length about every 2 feet, and then fastened to beams using powder-actuated fasteners and shear studs. [redacted] stated shoring wasn't used during the initial construction with exception of shoring the two beams at the spliced section on the east and west.

[redacted] stated during the construction of the test frame they needed to have better access to the floor than what they previously used, *e.g.*, ladders to access elevated floors. He stated based upon his concern [redacted] obtained a stair scaffold to address this issue.
[redacted] stated fall protection was identified as being a need and steel cabling was installed around the perimeter of the test frame.

[redacted] stated there were some self-imposed frustrations on the CF project related to construction, but not related to safety. He stated they would set goals for themselves that were tough to meet, or the NFRL engineers would switch things up on them after they had completed a task, *e.g.*, changing the structural steel connections on beams they had just finished installing.

SUMMARY OF RESPONSES RELATED TO PROCEDURES ASSOCIATED WITH POST-EXPERIMENTAL WORK AND REMOVAL OF THE TEST FLOOR CF1 AND CF2

[redacted] stated he did not participate in the official inspection of the test frame after CF1 or CF2 experiment and these were conducted by the NFRL engineers [[redacted] and [redacted]]. He stated he would take them in the manlift to review the bays and connections. [redacted] stated he was instructed to saw-cut some test floor locations so the engineers could take pictures. He stated he made casual observations and saw some cracks in the surrounding floor but [redacted] told him the cracks were not an issue.

[redacted] was involved in the demolition work of the test floor after the CF1 and CF2 experiments, and the subsequent reconstructions of the test floor. He stated he had experience with demolition of smaller structures at his previous job and in the past at NFRL (*e.g.*, structures constructed from wood, steel stud framing, and wallboard). [redacted] stated this was the first time the technician team had performed large scale demolition work like this at NFRL. He stated they did have experience in demolishing smaller concrete and steel test set ups from commissioning the new lab space. [redacted] stated he did not receive any formal training on demolition methods or safety associated with demolition.

[redacted] stated it took about 2 to 3 months to determine the safest way to demolish the test floor and get the HR approved [*Composite Floor System Stabilization and Demolition* - #733.06.0148.050522 in the MML Hazard Review Database]. He stated there was some discussion about having a contractor do the work, but it was decided it would be done in-house. [redacted] stated he did not know who made that decision.

[redacted] stated he did not see a demolition plan, just post-test inspection drawings for where to remove pieces of the test floor for observation.

[redacted] stated he and [redacted] reviewed a FEMA document related to shoring of damaged structures. He stated he and [redacted] both liked this plan as they could custom build the shoring to match the contour of the damaged floor. [redacted] stated they built the shoring close to the contour of the underside of the test floor decking and then use wedges underneath the shoring to get it snug with the decking. He stated [redacted] made the calculations for how much of a load the shoring they were building could hold.

[redacted] stated hazards associated with the demolition work were communicated through day-to-day informal discussion held on the floor. He stated he doesn't believe he reviewed any documents but was involved in meetings and discussions to mitigate the hazards. [redacted] stated specific safety requirements were the installation of cabling for fall protection and installing shoring of the floor from the outside in. He stated that he wore personal fall protection as needed when demolishing the test floor.

[redacted] stated demolition was conducted by jackhammering the concrete floor and removing it in 5-gallon buckets. He stated the steel deck and damaged beams would then be removed.

[redacted] stated for the CF2 test floor demolition, a contractor assisted with concrete removal after they jackhammered the test floor. He stated [redacted] was there occasionally to provide oversight of the contractors. [redacted] stated he talked with the contractors about removing both the test floor and the surrounding floor using saw-cutting and they said it would be an acceptable technique.

[redacted] stated they reused the shoring from CF1 test floor demolition for CF2 test floor demolition except they added plywood to the underside as the steel deck was in bad shape after the CF2 experiment.

[redacted] stated when rebuilding the test floor for CF3 experiment they needed to jack up some of the beams in the surrounding floor to be able to install new ones.

[redacted] stated [redacted] was the "foreman" of the team conducting demolition work, but everyone had input on decisions.

SUMMARY OF RESPONSES RELATED TO PLANNING DEMOLITION OF THE FULL TEST FRAME AFTER CF3

[redacted] stated for demolition of the surrounding floor he did not want to saw-cut sections of the slab out. He stated he preferred to jackhammer the floor similar to the test floors as he was worried about the saw blade getting stuck while cutting or the slabs getting wedged when being lifted out. [redacted] stated he was also concerned the work of removing the remaining concrete attached to the beams was going to be more difficult using the jackhammer. He stated he expressed these concerns to [redacted], but [redacted] convinced him the technique was safe. [redacted] stated [redacted] was more confident in how he was doing things related to structural issues and had far more experience than him and didn't think he was nervous doing the saw cutting and lifting.

[redacted] stated there was an informal discussion involving himself, [redacted], [redacted], [redacted], and maybe others to determine the need for a new HR for the removal of the surrounding floor, but [redacted] felt the HR for the test floor was sufficient. [redacted] stated he did not stay for the entire discussion.

[redacted] stated he had seen the drawing showing the location and size of the slabs to be cut and the coring locations for the associated rigging [this drawing hereafter referred to as the *Coring and Cutting Plan*]. He stated [redacted] drew the diagram and he was not involved in any calculations that may have been done nor did he ever see any evidence of calculations being performed. [redacted] stated he assumed [redacted] had referenced design drawings and [redacted] knew that the NW and NE corners of the surrounding floor had limited rebar, but this fact was never discussed.

[redacted] stated he told [redacted] they should start with smaller slab sizes. He stated [redacted] most likely laid out the slab sizes and shapes to minimize cuts in the air and maximize the amount of material being removed. [redacted] stated no discussions were held about the weight of slabs or if the slab weights may be close to the load limit. He stated he did not see calculations indicating the slabs could support their own weight once cut free from the surrounding floor, but [redacted] told him he had used a “2 to 3 safety factor”.

[redacted] stated [redacted] made the determinations where the rigging points were located. He stated [redacted] indicated the drawing showed the maximum distances the holes could be apart, but in practice [redacted] marked them at the exact locations shown on the *Cutting and Coring Plan*. [redacted] stated [redacted] said he calculated the strap angle to make sure it wasn’t too far apart.

[redacted] stated [redacted] selected the rigging straps and he believed the slings chosen were more than adequate to support the loads.

[redacted] stated he was not aware of any discussions for using shoring under the surrounding floor.

[redacted] stated he was not aware of a specific schedule for when each slab would be removed.

[redacted] stated he believed the plan was to cut the east and west faces first, hook up rigging, and then do the north and south faces. He stated this was determined so [redacted] would not end up on a narrow section once the final cut was made or have to stand on the piece he was cutting.

[redacted] stated [redacted] bought the walk behind floor saw for use on the long cuts of both the test floor and the surrounding floor. He stated he did not have any safety concerns with the floor saw. [redacted] stated the ring saw was possibly going to be used to cut the corners of the surrounding floor slabs, but it broke while being used on the test floor and was never used on the surrounding floor.

[redacted] stated to his knowledge the slab removal task was a single person task.

[redacted] stated once a slab was cut out and being lifted the safety protocol was to keep a safe distance from it. He stated the team was to ensure no one was under the structure and then ensure no one entered the area where the slab was suspended.

[redacted] stated that he expressed concern to [redacted] that the rigging holes for Slabs 5, 6, 7, & 8 were too far apart, but as they were not at the point to cut those slabs out, he just let it go at the time for later discussion.

SUMMARY OF RESPONSES TO DEMOLITION OF CF3 TEST FLOOR AND REMOVAL OF SLABS 1, 2, AND 3 FROM THE SURROUNDING FLOOR

[redacted] stated he participated in the demolition of the test floor after CF3 experiment. He stated the process was basically the same as for CF1 and CF2, except that they did not use a contractor for concrete debris removal. [redacted] stated [redacted] and [redacted] did calculations to ensure the shoring would hold the weight of the CF3 test floor as an action item resulting from a Management Observation Process discussion. He stated they used a ring saw for some of the floor removal process.

[redacted] stated he drew the cutlines on the surrounding floor.

[redacted] stated he did all of the core drills for the rigging points in each slab.

[redacted] stated [redacted] was responsible for oversight of the slab removal, but that they worked together as a team to get things done.

[redacted] stated he was not aware of pre-job safety briefings during the slab removal but stated safety issues were discussed on normal "floor discussions" between the team.

[redacted] stated [redacted] did all of the saw cutting on the surround floor.

[redacted] stated he did not feel any pressure from [redacted] or other staff in regard to the schedule.

[redacted] stated he could not recall when Slabs 1 and 2 were removed.

[redacted] stated he observed [redacted] cutting Slab 1 but did not see it get lifted out. He stated he believes [redacted] made some saw cuts prior to hooking up and engaging rigging for Slab 1. [redacted] stated [redacted] told him Slab 1 was a little tough to lift out as the corners were not fully cut so they had to use a jackhammer to free some of them. He stated [redacted] learned from this and began to "over cut" the sides to ensure the corners were free.

[redacted] stated he did observe the cutting of Slab 2 and was present when it was lifted out. He stated during the lifting activity he told [redacted] to move because he was in an unsafe location (between the slab and a steel column).

[redacted] stated he was not initially comfortable with lifting the slabs out but became more comfortable after the first two were successfully removed.

[redacted] stated [redacted] told them they should be wearing personal fall protective equipment prior to Slab 3 being cut. He stated at that point they decided to move the old cribbing into the bays for Slabs 1 and 2. [redacted] stated this was not the greatest plan but that it was better than nothing and it would help with the jackhammering that would have to be done to remove the concrete remaining on the beams after the slabs were removed.

[redacted] stated while cutting Slab 3 [redacted] became worried the saw blade was getting dull, but then he realized he was cutting longitudinally on a piece of rebar, so he moved the saw a few inches and started a new cut.

[redacted] stated [redacted] intended for Slab 3 to be removed as shown on the *Cutting and Coring Plan*, in an irregular shape, but that it was too difficult in practice, so it was cut out as two rectangular pieces. He stated [redacted] and [redacted] helped with spotting when Slab 3 was removed.

[redacted] was not aware of post-job debriefs after each slab removal, but the morning after removing Slab 1 he recalls a conversation with [redacted] where they realized that they had created a big fall hazard.

[redacted] stated on Friday September 23, in the afternoon after Slab 3 was removed, he and [redacted] discussed fall protection for the Slab 4 removal. He stated they talked about placing steel beams across the hole (created by Slab 3 removal) and then laying plywood down over the top, but that would've created a step, and possible trip, hazard and was too much bother. [redacted] stated [redacted] was going to put cabling up to protect the hole created by Slab 3 removal. He stated he didn't realize at the time given the column locations this would not be possible.

[redacted] stated he had never seen anyone standing on Slab 1, 2, or 3 during the removal process after they had been partially or fully cut, and that he recalled having a conversation with [redacted] about not having the saw or their person on the slab.

[redacted] stated to his knowledge neither [redacted] nor [redacted] visited Room 125 during the slab removal process.

SUMMARY OF RESPONSES RELATED TO THE INCIDENT

[redacted] stated he was not at work on the day of the incident.

[redacted] stated he was not aware of any safety discussion regarding specific hazards of Slab 4 (*e.g.*, the lack of rebar).

[redacted] stated the black plastic bags on two of the slings used to lift the slabs were placed there to protect them from the cooling water used for the floor saw.

[redacted] stated he did not know what [redacted] was planning to do with the angle iron found on the forklift the day of the incident but believes he may have been planning to cover the Slab 3 hole using it and some plywood.

[redacted] stated they did try and use the saw without the hose and only filling the tank, but that didn't work to keep dust down due to low water pressure as the tank is gravity fed. He stated when the garden hose was hooked up, they had great water pressure and it kept dust down.

[redacted] stated he did not know why shoring was not used underneath Slab 4, but recalls [redacted] indicating it wasn't necessary for the entirety of the surrounding floor as the steel deck was not damaged like it was for the test floor.

[redacted] stated he did not know why [redacted] was not wearing fall protection on the day of the incident. He stated in the past [redacted] had justified not using personal fall protection because there was no good place to tie off and he was relying on the cables for passive fall protection.

[redacted] stated he did not know why [redacted] pulled the floor saw back onto the suspended slab after the final cut was made. He stated it may have been due to a piece of angle iron situated in a way that would prevent the saw from being moved west onto the remaining solid deck or possibly because the water hose was tangled in the rigging.

[redacted] stated he did not have concerns about how [redacted] performed his work but felt [redacted] was sometimes overly confident that the work he was doing was safe. He stated he would question [redacted] sometimes about the way work was being performed because he had less experience on the structure side than [redacted] did. [redacted] stated he never saw him do any intentionally unsafe acts.

[redacted] stated he wonders if anyone checked calculations or if [redacted] had asked anyone to check the calculations related to slab size and location of cuts. He stated sometimes [redacted] could be prideful and perhaps didn't want to ask someone to check calculations. [redacted] stated [redacted] also didn't like wasting other people's time.

[redacted] stated after the incident [redacted] mentioned to him that [redacted] was planning on shortening the slabs for removal in the North section of the surrounding floor so instead of cutting and removing four slabs (Slabs 5, 6, 7, and 8) there would be 8 slabs removed.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interviewed held on October 27, 2022, by the NIST Team investigating the Building 205 incident.

11/29/2022

____

[redacted]

Date

Summary of Second Investigation Interview with ENGR TECH 2

Date: February 13, 2023
Time: 2:00 pm to 2:40 pm

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members present: [redacted]

SUMMARY OF QUESTIONS RELATED TO DEMOLITION ACTIVITIES AFTER MAY 2022
[redacted] stated he and [redacted] talked frequently during the spring and early summer of 2022 about the best way to demolish the surrounding floor. He stated he could not identify the date of a specific meeting where [redacted] (NFRL Group Leader) met with the NFRL technicians to discuss the best method to do so.

[redacted] stated [redacted] began "experimenting" with removing floor slabs from the CF3 fire-tested floor to see how big of a piece they could lift out of the floor. He stated 5 or 6 "slabs" were cut out of the floor starting with a small piece (1 ft by 4 ft) and progressively getting larger (4 ft by 4 ft). [redacted] stated the last slab they cut and lifted out is the one currently in the Building 205 parking lot which measures ~8.5 ft by ~8.5 ft.

[redacted] stated the hand-held concrete saw was primarily used for the smaller cuts but the floor saw was used for the longer cuts. He stated the saw depth for both was set so they did not cut into the steel decking.

[redacted] stated they would expose rebar on the slab and use a clevis to connect the sling to the rebar. He stated for the smaller slabs they would expose rebar near the center of the slab and use one sling to lift it out. [redacted] stated as the slabs got bigger, they increased the number of slings used to lift the slab out. He stated they did not lift out the steel decking with the slab.

[redacted] stated he did not know if [redacted] or [redacted] (Project Leader) were aware of [redacted] "experimenting" on cutting and lifting the slabs out, but he acknowledged he was not aware of all the conversations [redacted] had with them.

[redacted] stated [redacted] had previously engaged in "experimenting" during other projects, but it was never with the intent to "get away with something". He stated it was more about determining if a task could be performed and they would typically err on the side of being "comfortable" with the activity.

[redacted] stated a meeting was held on June 15, 2022, where he met with [redacted], [redacted], and [redacted] regarding use of the hazard review titled *Composite Floor System Stabilization and Demolition* (#733.06.0148.050522) for the surrounding floor demolition. He stated [redacted] and [redacted] provide verbal permission to perform a "test case" to see if the method of using the crane and slings to lift out a pre-cut slab would work.

[redacted] stated he does not believe Slab 1 was the "test case" referenced to determine if the *Composite Floor System Stabilization and Demolition* hazard review (#733.06.0148.050522) could be utilized to cover the surrounding floor demolition. He stated he believes the "test case" was the largest slab pulled out of the CF3 fire-tested floor.

[redacted] stated he could not identify the date of a specific meeting where [redacted] and [redacted] gave verbal permission to use the *Composite Floor System Stabilization and Demolition* hazard review for the surrounding floor.

[redacted] stated the beams and girders of the second floor were removed after the CF3 test floor had been demolished and prior to him transcribing the cut lines on the surrounding floor – so this was most likely done in early August 2022.

[redacted] stated he transcribed the cut lines and coring marks on the surround floor the week of August 29, 2022.

[redacted] stated he drilled the coring holes for the rigging hardware the week of September 5, 2022.

[redacted] stated he and [redacted] discussed not walking on the slab while it was being cut and the importance of having the saw on the outside of the slab when performing the long cuts [North and South faces of the slab]. He stated he did not know why [redacted] walked on Slab 3 when it was fully suspended by the rigging and subsequently walked on Slab 4 under the same condition. [redacted] stated he believes [redacted] may have been comfortable with doing this even though they had discussed not to do so.

[redacted] stated it was the crane operator who determined if a lift plan was required. He stated a complex lift would encompass an activity like using two cranes at once with an example provided being lifting off the tops off the concrete conditioning pit on the East side of Building 205. [redacted] stated if the surrounding floor slab was rigged correctly, he would consider the lift a "simple" lift not requiring a lifting plan.

[redacted] stated he did not know the exact date when the Husqvarna floor saw was purchased. He stated they had rented one initially and most likely purchased this one in calendar year 2019.

[redacted] stated the dumpster present at the time of the incident of was delivered on August 15, 2022.

SUMMARY OF OTHER QUESTIONS ASKED

[redacted] stated [redacted] (Fire Research Division Safety Representative) passed through Room 125 a few times while the CF Project was on-going but does not believe she was there to specifically discuss the work performed as part of the project.

[redacted] stated with respect to the corrective action identified in IRIS Case Number 19-IG-0053:

The workspace manager or designee will conduct daily checks to assure that PPE is being used the checks were not performed daily, but rather depended on the activity.

[redacted] stated while staff recognize the importance of doing the hazard reviews, they did not and do not "enjoy" writing them up. He stated in working with [redacted] on a few, [redacted] would put in what was necessary to get the hazard review completed but they did not always cover what was done in practice. [redacted] stated if [redacted] had a major concern about a task they would explicitly follow the written standard operating procedure.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interviewed held on February 13, 2023, by the NIST Team investigating the Building 205 incident.

[redacted]

02/15/2023

Date

Summary of Investigation Interview with ENGR TECH 3

Date: October 27, 2022
Time: 9:00 am to 10:30 am ET

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members present: [redacted]

SUMMARY OF RESPONSES RELATED TO [redacted] AND SAFETY CULTURE AT NFRL

[redacted] stated he is an Engineering Technician for the National Fire Research Laboratory (NFRL) Group in the Fire Research Division of the Engineering Laboratory at the National Institute of Standards and Technology. He stated he has over 17 years of federal service (NIST Plant Division from October 2005 through February 2015, Department of Defense from February 2015 through January 2017, and NIST NFRL from January 2017 to present). [redacted] stated he has prior experience in the construction industry as well. He stated his main responsibilities are the setup and teardown of experimental apparatus and other structures at NFRL.

[redacted] stated safety is managed at the NFRL through group meetings every Monday where general safety topics were discussed. He stated there is a basic understanding that everyone is responsible for safety at NFRL. [redacted] stated when he worked in Room 125 of Building 205 he would go to [redacted] for specific job or task safety issues.

[redacted] stated the two-person rule in effect at NFRL requires people to always work with someone when doing hazardous work. He stated each partner would discuss what they were doing that day so the other understood what was going on and would be there for emergencies.

SUMMARY OF RESPONSES RELATED TO [redacted]

[redacted] stated he worked with [redacted] every day when performing construction or demolition on the Composite Floor (CF) test frame. He stated [redacted] generally directed his work and was easy to work with. [redacted] stated he was comfortable raising safety concerns to him and felt [redacted] always listened and would consider his safety concerns. He stated, as an example, [redacted] provided suggestions on rigging configurations for lifting and moving pieces and [redacted] accepted these suggestions.

[redacted] stated there was significant collaboration between [redacted] and his supervisor [[redacted]] and project manager [[redacted]]. He stated he never felt [redacted] or line management pushed back on safety requirements or concerns, and never felt safety "took a back seat" to other priorities at NFRL. [redacted] stated safety is the responsibility of each specific person doing the work .

SUMMARY OF RESPONSES RELATED TO THE DESIGN AND CONSTRUCTION OF THE TWO-STORY TEST FRAME

[redacted] stated he was not involved in the design of the CF test frame.

[redacted] stated he did not have any safety concerns about the design of the CF test frame.

[redacted] stated he assisted with the assembly of the initial CF test frame, including installing the decking and rebar. He stated construction hazards were communicated through informal discussion held on the floor as things happened where work was being conducted. [redacted] stated he assumed there was an approved hazard review or they would not be doing the work. He stated he did not review a hazard review before performing the work as all the hazards were apparent and communicated on the job. [redacted] stated he recalls back and forth discussions on safety issues during construction but does not recall any major safety concerns.

[redacted] stated that there were often changes in the design during construction. He stated, as an example, the initial design was for the tab to be bolted on for the connection for the beams and the girders, but the engineers changed it to a wielded-on tab in the middle of the construction.

[redacted] stated the steel decking pans were screwed together along their length about every 1 to 2 feet, and then fastened to beams using powder-actuated fasteners. He stated chairs for supporting the rebar were screwed to the pans and rebar was tied to the chairs. [redacted] stated he believes they used some shoring underneath the test floor when the concrete was poured, but not underneath the surrounding floor as the spans were short enough that shoring wouldn't have been required.

SUMMARY OF RESPONSES RELATED TO PROCEDURES ASSOCIATED WITH POST-EXPERIMENTAL WORK AND REMOVAL OF THE TEST FLOOR CF1 AND CF2

[redacted] stated he did not participate in the official inspections of the test frame after CF1 or CF2 as that was conducted by the NFRL engineers [[redacted] and [redacted]], but he did make casual observations about the surrounding floor. He stated he observed some cracks in the surrounding floor [along the North side, running N-S, near the NE and NW corners of the test floor], but he did not have safety concern about them but more about how those cracks might affect future experiments.

[redacted] stated he was involved in the demolition work of the test floor after the CF1 and CF2 tests, and the construction of the test floor for subsequent experiments. He stated he had experience conducting demolition work in his prior construction job and while working for DOD. [redacted] stated NFRL provided high-level training on specific aspects of the activity (*e.g.*, crane training) but nothing specific on demolition as it was all on the job training.

[redacted] stated he was familiar with the hazard review prepared for the demolition of the test floor [*Composite Floor System Stabilization and Demolition* - #733.06.0148.050522 in the MML Hazard Review Database] and knew it contained some planning aspects but felt that it mainly stayed on the computer and did not provide information about hazards and safety requirements in a practical format such as safety toolbox meetings would have. He stated he was concerned the hazard review did not cover inhalation hazards created by the dust. [redacted] stated they did wear dust masks and sprayed water while they were jackhammering in an attempt to keep the dust down. He stated he was concerned about the long-term health issues breathing in the silica dust.

[redacted] stated there was no official meeting or toolbox talk about the hazards, rather, [redacted] would informally talk in the morning about safety issues to be aware of. He stated prior to experiments they always had a formal safety briefing, but nothing similar was held for the demolition work. [redacted] stated his understanding of safety requirements for the test floor removal consisted of typical PPE – hard hat, safety boots, safety glasses and hearing protection, and water was used for dust suppression.

[redacted] stated he reviewed a FEMA document discussing the use of cribbing/shoring underneath compromised floors. He stated prior to demolition of the test floor, the cribbing/shoring was added underneath the test floor and then they would use jackhammers to break up the concrete and remove it using buckets.

[redacted] does not recall a test floor demolition plan but sometimes saw drawing from NFRL engineers indicating locations they wanted small sections of floor removed and pictures obtained.

[redacted] stated he felt the demolition proceeded at a good pace, but he perceived pressure from the project engineers to have it done faster. [redacted] would supervise day-to-day work, and [redacted] would check on progress but generally seemed content to let them do their job without him having to check on them.

[redacted] stated [redacted] was considered the lead technician during these activities but that it was a team effort by the technician group to demolish the test floor. He stated the NFRL engineers would occasionally come out to see the test floor and check on progress and other aspects of the project.

SUMMARY OF RESPONSES RELATED TO PLANNING DEMOLITION OF THE FULL TEST FRAME AFTER CF3

[redacted] stated he was not aware of [redacted] writing a new hazard review for the CF3 test frame demolition activity, but safety issues were discussed during informal discussions each day.

[redacted] stated [redacted] was responsible for oversight of the slab removal.

[redacted] stated he was not aware of a separate hazard review for demolition of the surrounding floor, but he had less involvement with this part of the project beyond informal "on the floor" activity planning sessions.

[redacted] stated he saw the drawing showing the location and the slab sizes to be removed from the surrounding floor, as well as the coring locations for rigging (this drawing hereafter referred to as the *Coring and Cutting Plan*). He stated he did not see any other documentation related to demolition of the surrounding floor. [redacted] assumed the *Cutting and Coring Plan* had been approved and provided by the NFRL engineers, and that appropriate calculations had been done to determine the slab sizes and verify the slabs could support their own weight. [redacted] stated he recalled hearing that a safety factor of 3 to 5 had been used for the rigging calculations and he assumed [redacted] had determined the rigging hole locations but later learned that it was [redacted]

[redacted] stated he did not recall specific discussions about new hazards associated with removing the surrounding floor, but it did occur to him that water from the floor saw could create new hazards. He stated there was the potential for slipping hazards, but they were able to clean up the floor with squeegees. [redacted] stated cutting of the slab using the walk-behind floor saw was a single person task and there was always a second person there assisting as a spotter or helper.

[redacted] stated he was not aware of a specific schedule for when each slab would be removed.

[redacted] stated he was not aware of any discussions for using shoring under the surrounding floor during the removal process.

[redacted] stated equipment for the slab removal was selected primarily by [redacted] with input from the rest of the team. He stated he did not have any safety concerns about the equipment used.

[redacted] stated, in general, he felt the use of a saw to remove the slabs was a good idea as it would result in less physically demanding work and less dust. He stated they discussed using the ring saw to make the corner cuts and because it could make bevel cuts, whereas the floor saw could not. [redacted] stated they used the ring saw on some of the test floor, but it was never used to make any cuts on the surrounding floor slabs because it was broken and had not yet been repaired. He stated there was never any discussion about the weight of the floor saw.

[redacted] stated [redacted] chose the rigging straps to be used and verified they were rated for the weight of the loads. He stated they probably could have used lower-rated straps. [redacted] stated the threaded eyebolts used for the rigging were hardware they had used before.

[redacted] stated he did not know when the rigging was going to be attached with respect to sectioning of the faces of each slab. He stated he assumed the rigging would be hooked up first, prior to any cuts, but he knows [redacted] did not do that in practice as he typically made a few cuts before installing rigging.

[redacted] stated he was not aware of specific decisions about the order in which the faces of each slab would be cut, he just knew that the last cut would be "dicey" since at that point the slab would be suspended solely by the crane. He stated he does not know if the plan was to cut the corners first.

[redacted] stated PPE for the demolition activity included steel toed shoes and a hard hat. He also stated they should have been wearing personal fall protection, but they weren't as they just relied on the cabling. [redacted] stated [redacted] had concerns about the lanyards for personal fall protection getting tangled up and they only used personal fall protection on manlifts.

[redacted] stated once a slab was cut out and being lifted the safety protocol was to keep a safe distance from it. He stated a spotter would assist the crane operator.

SUMMARY OF RESPONSES TO DEMOLITION OF CF3 TEST FLOOR AND REMOVAL OF SLABS 1, 2, AND 3 FROM THE SURROUNDING FLOOR

[redacted] did not participate in an official inspection of the test structure after CF3 but he made casual observations similar to those after CF1 and CF2.

[redacted] stated he provided limited assistance with the demolition of the test floor after CF3 experiment as he was working on a different project.

[redacted] stated he was not aware of pre-job safety briefings during the slab removal, like would be conducted during experiments, but stated safety issues were discussed on normal "floor discussions" between the team.

[redacted] stated a verbal exclusion zone was used to ensure no one on the floor would be exposed to falling debris or materials from the deck. He stated he knew not to go underneath the structure while cutting was occurring.

[redacted] stated during some of the slab removal process he was working on another experiment on the "fire" side of Building 205 [room 113].

[redacted] stated he did not receive any additional training for the slab removal process other than what he had already received.

[redacted] stated he thought the slab cutlines and coring hole locations were marked by [redacted] and [redacted] and [redacted] drilled the core holes.

[redacted] stated he never used the floor saw but it seemed to work well for the slab cutting task. He stated [redacted] was unhappy about the saw's brake so he adjusted it.

[redacted] stated he assisted in attaching the rigging hardware for a couple of the slabs. He stated the only specific precautions or direction he recalled related to the installation of rigging hardware was that [redacted] told him the nuts on the bolts just needed to be hand tight.

[redacted] stated he does not remember the exact dates when Slabs 1 and 2 were removed.

[redacted] stated [redacted] ran the floor saw for all of the slabs removed. He stated a jackhammer was used around the corners of Slab 1 and a reciprocating saw was used on a couple of the slabs to help complete cuts through the steel decking pan.

[redacted] stated the wooden cribbing observed beneath the cutouts for Slabs 1 and 2 were put in the bays after the slabs were cut and removed. He stated they were placed there for fall protection while working around the holes left by Slabs 1 and 2.

[redacted] stated he felt the demolition was proceeding at a good pace but thought the engineers and other principal investigators who wanted to use the space may have thought they were too slow.

[redacted] stated he did not recall when the rigging was installed for the slabs he helped with (Slabs 3 and 4), but he thinks some cuts were made prior to it being attached.

[redacted] stated [redacted] intended for Slab 3 to be removed as shown on the *Cutting and Coring Plan*, in an irregular shape, but in practice it was too difficult so it was cut out as two rectangular pieces. He stated during the cutting of Slab 3, [redacted] called him up on structure to use a reciprocating saw to cut the steel decking associated with the smaller piece to be removed. [redacted] stated once the steel decking was cut, [redacted] "kicked it" and it fell through to the ground. He stated prior to cutting the steel decking, he had put plywood down on the strong floor to protect the floor.

[redacted] stated he did not observe anyone standing on Slabs 1, 2, or 3 during the removal process after they had been partially or fully cut.

[redacted] stated that he never liked the saw cuts on the north and south sides of the slabs.

[redacted] stated he was not aware of post-job debriefs after each slab removal. He stated after Slab 1 was cut, one safety issue that was emphasized was that it was important to cut the corners cleanly so the jackhammer would not be needed. [redacted] stated there was also some discussion of being aware of where you were standing after the last cut.

[redacted] stated he felt line management did not make any efforts to ensure the safety of the staff during the removal of the surrounding floor slabs. He stated safety was left to those performing the work and his primary safety concern during slab removal was making the final cut and ensuring they were in a safe location when that cut was made, since after that the slab would be fully suspended.

[redacted] stated he thinks perhaps [redacted] was too confident as slabs were coming out relatively easy.

SUMMARY OF RESPONSES RELATED TO THE INCIDENT

[redacted] stated he never thought about the fact there was very little rebar in the NE and NW corners of the surrounding floor, and he assumed [redacted] would have known about the lack of reinforcement in that area. He stated he did not review any design drawings prior to the start of demolition. [redacted] also stated he was not aware of any other safety discussion regarding specific hazards of Slab 4 (*e.g.*, the lack of rebar) and [redacted] did not express any concern to him with respect to Slab 4.

[redacted] stated [redacted] had expressed concerns to him in the days prior to the incident about what could happen when Slabs 5, 6, 7, and 8 were lifted out. He stated [redacted] said he was concerned they might break in the middle and "fold" when lifted due to the length of the slabs.

[redacted] stated a pre-job safety briefing was not held prior to cutting Slab 4, beyond normal discussion about the days' work. He stated on the morning of the incident, they discussed the possibility of the slabs in the middle of the test frame (Slabs 5, 6, 7, and 8) breaking apart when lifted.

[redacted] stated the black plastic bags on two of the slings used to lift the slabs were placed there to protect them from the cooling water used for the floor saw.

[redacted] stated he did not know what [redacted] was planning to do with the angle iron found on the forklift the day of the incident, but thinks he was planning to cover the Slab 3 hole using it.

[redacted] stated he was not aware of any discussions regarding hazard created by the water supply hose for the floor saw, but he knows it can be bothersome. He stated it was the responsibility of the operator to manage it.

[redacted] stated on the morning of September 26, 2022, [redacted] worked on making floor cuts for Slab 4 while he worked on removing concrete from around the Slab 1 bay. He stated when he returned from lunch [redacted] had already resumed cutting Slab 4.

[redacted] stated at the time of the incident he was on the upper floor of the test frame, in the NW corner, working on a saw.

[redacted] stated he did not know why [redacted] was not wearing fall protection and they should have been using it that day.

[redacted] stated he did not know why [redacted] pulled the floor saw back onto the suspended slab after the final cut was made. He stated he did not know if [redacted] had done this previously and did not know if line management was aware that it had occurred.

[redacted] stated [redacted] was confident in the work he was performing and [redacted] had confidence in him as well.

[redacted] stated he did not raise any safety concerns specific to the CF Test Project to [redacted]. He stated [redacted] had conducted numerous lifts of large items in the past and he was not concerned about his ability to do it safely.

[redacted] stated he was not aware of any similar incident ever occurring at the NFRL.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interviewed held on October 27, 2022, by the NIST Team investigating the Building 205 incident.

[redacted]

[redacted]

11/18/2022

Date

Summary of Investigation Interview with ENGR TECH 4

Date: October 26, 2022
Time: 8:00 am to 10:00 am ET

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members present: [redacted]

SUMMARY OF RESPONSES RELATED TO [redacted] AND SAFETY CULTURE AT NFRL

[redacted] stated he is an Engineering Technician for the National Fire Research Laboratory (NFRL) in the Fire Research Division of the Engineering Laboratory at the National Institute of Standards and Technology (NIST). He stated he has held this role for almost 33 years at NIST, all of it in the Fire Research Division. [redacted] stated he is responsible for day-to-day project management of projects related to fire research and has limited involvement with activities on the structural side of Building 205 [Room 125]. He stated he also serves as the Safety Officer for fire experiments.

[redacted] stated the NFRL has done a very good job of managing safety over the past 10 to 15 years with respect to fire experiments. He stated hazard reviews (HRs) and standard operating procedures (SOPs) are written for all fire experiments. [redacted] stated there is plenty of discussion with respect to these documents, but he personally is not responsible for authoring the documents.

[redacted] stated prior to all fire experiments, the Principal Investigator provides a briefing to ensure everyone knows what is going on for a given experiment and what their responsibilities are; the Safety Officer ensures the information provided is correct. He stated if there were multiple fire experiments on a given day, and hazards were similar, a briefing may not be held before each separate experiment. [redacted] stated if the hazards changed or new people were involved or observing the experiment, a shorter version of the briefing is provided. He stated it is very important for visitors to know where exits are prior to the experiments and to follow directions during the experiments.

[redacted] stated he is comfortable raising safety concerns with other NFRL staff while work is being performed in Building 205, and if necessary, raising those concerns with [redacted] [NFRL Group Leader]. He stated [redacted] always addressed his concerns.

[redacted] stated the two-person rule in effect at NFRL requires anyone performing hazardous work to ensure someone else is in the facility. He stated the second person is supposed to be the "level-headed" person should something go wrong as the person involved may not be thinking clearly. [redacted] stated he had an incident at home with a skill saw injury and he did not think clearly during that incident [provided as an example]. He also stated some work would require two staff members be directly involved while the work was being performed and provided use of an overhead crane as an example – they always had two people involved and sometimes 3 if they were doing a complex lift.

SUMMARY OF RESPONSES RELATED TO [redacted]

[redacted] stated he typically had daily interactions with [redacted] where they would discuss early in the morning what each was working on that day. He stated he did not work directly with [redacted] most of the times as they typically worked on different sides of Building 205 (*i.e.*, [redacted] worked on the "structural" side in Room 125 and he worked on the "fire" side in Room 113).

[redacted] stated if their work overlapped, they did their own thing and [redacted] did not direct the work [redacted] was performing.

[redacted] stated he had a good working relationship with [redacted] and could raise safety concerns to him if necessary.

[redacted] stated he did not have any specific knowledge of interactions between [redacted] and his supervisor [[redacted] or project manager [[redacted] and assumed the interactions were similar to his own. He stated he never felt [redacted] or line management pushed back on safety requirements or concerns, and never felt that safety "took a back seat" to other priorities at NFRL.

SUMMARY OF RESPONSES RELATED TO THE DESIGN AND CONSTRUCTION OF THE TWO-STORY TEST FRAME

[redacted] stated he was not involved in the design of the test frame used for the Composite Floor (CF) Project.

[redacted] stated he did not know why the surrounding floor in the NE and NW sections was designed with limited rebar. He stated he had forgotten about this design characteristic until he was shown an image of the rebar detailing during the interview.

[redacted] stated he helped very little with assembly of the structural steel or steel related to the composite floor as this was done primarily by NFRL technicians ([redacted], [redacted], and [redacted]). He stated he believed [redacted] was responsible for day-to-day safety during structural steel construction.

[redacted] did not have specific safety concerns about the initial structure but did recall how after the steel decking was installed, he told [redacted] they needed cabling around the perimeter of the test frame [for passive fall protection]. He stated based upon his suggestion [redacted] put up cabling for the top and central "rail" that met requirements based off the steel decking. [redacted] stated once the concrete floor was installed, [redacted] realized they had to move cabling up several inches to meet OSHA requirements and did so.

[redacted] stated he participated in the construction of the fire compartments used during each experiment. He stated construction of these compartments was more complex than for the typical fire experiments as the fires were planned to be 2 to 3 hours long instead of the more typical 20 to 30 minutes of other experiments.

SUMMARY OF RESPONSES RELATED TO PROCEDURES ASSOCIATED WITH POST-EXPERIMENTAL WORK AND REMOVAL OF THE TEST FLOOR CF1 AND CF2

[redacted] stated his main concern during the actual CF Project experiments was the safety of personnel involved and the safety of equipment used, with test results a secondary consideration. He stated prior to each fire experiment, [redacted] provided a safety briefing and [redacted] covered emergency egress and where staff could and could not be located during the experiments.

[redacted] stated he believes [redacted], [redacted] [previous project leader], and [redacted] inspected the test floor after each test. He stated he was up on the surrounding floor after each test and made casual observations but saw nothing out of the ordinary regarding the surrounding floor after CF1 and CF2 experiments. [redacted] stated he never used personal fall protection when he was up on the surrounding floor as he relied on the cable system installed around the perimeter of the test frame.

[redacted] stated to his knowledge a Safety Officer was not named for the demolition activities, and [redacted] – by default as the activity lead – was responsible for day-to-day safety. He stated has no knowledge of "official" safety briefings occurring, but he is aware of "floor" discussions between the NFRL technicians that covered work to be performed for the day.

[redacted] stated he did raise a safety concern to [redacted] regarding the degraded nature of the test floor and their efforts to remove it. His stated he was involved in the discussion to use cribbing under the test floor and was primarily concerned they [NFRL technicians] installed it from the outside in so they would be protected from any accidental collapse or other overhead hazards. [redacted] stated [redacted], [redacted], and [redacted] installed the cribbing.

[redacted] stated he also suggested removing the concrete debris during demolition using a concrete chute.

[redacted] stated he does not recall seeing a demolition plan for the test floor removal beyond the SOP referenced in the HR for demolition of the test floors [*Composite Floor System Stabilization and Demolition* - #733.06.0148.050522 found in the MML Hazard Review Database]. He stated safety protocols included dust masks, a hard hat, safety boots, safety glasses, and hearing protection. [redacted] stated fall protection may not have been required for demolition of the test floor as cribbing was installed underneath the test floor prior to demolition.

[redacted] stated falling object protection was provided using a verbal exclusion zone and also relied on people knowing not to work on the strong floor when others were working on the deck area above them.

[redacted] stated he had no concerns about [redacted] performing the demolition work on the test floors as he appeared confident in what he was doing and never expressed any safety concerns to him beyond their discussion about how to shore the test floor for demolition.

SUMMARY OF RESPONSES RELATED TO PLANNING DEMOLITION OF THE FULL TEST FRAME AFTER CF3

[redacted] stated the same HR that was used for test floor demolition was used for the surrounding floor demolition but believes it may have been revised a few times prior to demolition of the CF3 test floor.

[redacted] stated [redacted] was responsible for the surrounding floor demolition activity. He stated he believes [redacted] made the determination to use a floor saw instead of the jackhammering technique used during removal of the test floor.

[redacted] stated there was a discussion with [redacted] about the saw blade possibly getting pinched while cutting the slabs, but [redacted] did not consider it a safety issue.

[redacted] stated he was concerned that removing slabs from the surrounding floor with a saw would make removal of the remaining slab material more difficult since a jackhammer would need to be used from a manlift to break it up.

[redacted] stated he had seen the image from the *Coring and Cutting Plan* created by [redacted] showing the slab cuts and coring locations for rigging. [redacted] stated his impression of the plan was simply to allow for the largest pieces possible to be taken out. He stated he did not know if the intent was to cut Slab 3 as a single piece or two smaller rectangular pieces. [redacted] stated he thought it would have been difficult to cut Slab 3 as a single piece.

[redacted] stated he believed [redacted] determined the rigging point locations as well as determined what specific rigging would be used. He stated he did ask [redacted] if there was enough "meat" between the contact point and edges such that they wouldn't break off when being lifted. [redacted] stated [redacted] told him "yes" and he did not pursue the issue further.

[redacted] was not aware of specific decisions about the order in which the faces of each slab would be cut and did not know if there was a plan to cut the corners first. He stated he would not have recommended cutting the corners first.

[redacted] stated he remembers a discussion between [redacted] and [redacted] regarding ending up on a "hard surface" after the cuts were completed and not to be on a narrow edge.

[redacted] stated he did have concerns about what were they going to do with the last slab to be cut out of the West section as there would be no place to end up with the saw - the only option would be the scaffolding stairwell. He stated as it was still a way off before those cuts would occur he did not bring it up at the time.

[redacted] was not aware of any discussions for using shoring under the surrounding floor.

SUMMARY OF RESPONSES TO DEMOLITION OF CF3 TEST FLOOR AND REMOVAL OF SLABS 1, 2, AND 3 FROM THE SURROUNDING FLOOR

[redacted] stated the test floor after CF3 was in worse condition than after previous tests in that the test floor had incurred more damage. He stated he also observed cracks in the surrounding floor near Slab 6 and Slab 8 [as seen in the *Coring and Cutting Plan* document] running N-S. [redacted] did not consider them to be a safety issue but felt they could affect experimental results if future experiments were to be conducted.

[redacted] stated he did not assist with any of the physical demolition (jackhammering) of the test floor after the CF3 experiment but helped a little with removal of the concrete after it was jackhammered. He stated he did not assist with demolition of the fire compartment walls as he was on annual leave (September 15 through 23).

[redacted] did not participate in the removal of the slabs from the surrounding floor.

[redacted] stated he assumed the other NFRL technicians ([redacted], [redacted], and [redacted]) lined out the cutlines and core hole locations on the floor.

[redacted] does not know who drilled the core holes.

[redacted] stated he knows [redacted] did not use personal fall protection during some of the cutting. He stated [redacted] may have made this decision as it wouldn't have been helpful, *i.e.*, if it was too long, you would hit the ground before it caught you or if too short, you couldn't get work done. [redacted] did recall that the NFRL technicians discussed "roping off" sections after cutting out slabs to protect them from the newly created fall hazard.

[redacted] stated he observed Slab 1 being cut with a floor saw but did not observe it being removed from the test frame with the rigging and crane. He also stated he thinks the rigging was hooked up to Slab 1 prior to any of the edges of the slab being cut with the floor saw but wasn't really sure. [redacted] also observed Slab 2 being removed from the test frame with the rigging and crane but did not observe it being cut. [redacted] stated both of these activities occurred prior to September 15, 2022. He stated he believed they "came out nicely".

[redacted] was not present for Slab 3 cutting or removal.

[redacted] stated he did not know why the cribbing used under the test floor was moved into the bays where Slab 1 and Slab 2 were removed. He stated it may have been moved there to act as fall protection after the slabs were removed. [redacted] stated he is not sure how the cribbing was put there as they are taller than the horizontal beams on the underside of the surrounding floor.

[redacted] stated he was not aware of pre-job safety briefings occurring prior to slab removal similar to what would have been conducted during experiments. He stated he believes the safety issues may have been discussed on normal "floor discussions" between the team. [redacted] stated he was not aware of post-job debriefs after slab removal.

[redacted] stated he knew discussions were had regarding the saw method working well and statements that straight saw cuts were important since angled cuts would make lifting the slab out more difficult.

[redacted] stated he was not aware of any safety concerns identified after removal of Slabs 1, 2, or 3.

[redacted] stated he did not know of a specific schedule for the removal of the slabs beyond what they [NFRL technicians] wanted to do. He stated he did not feel any schedule pressure when he was working on the project.

[redacted] stated he believed NFRL line management was on the floor occasionally during demolition. He stated he was not sure if this was during any of the actual slab removal process but was sure they were aware the activity was being performed.

SUMMARY OF RESPONSES RELATED TO THE INCIDENT

[redacted] stated he was teleworking on the day of the incident, and he was on annual leave the prior week.

[redacted] stated he did not know of any prior incidents at the NFRL similar to the one that occurred.

[redacted] stated he is not aware of any discussion of the specific hazards of removing Slab 4 (*e.g.*, the hole created when Slab 3 was removed) and is not aware if the process for cutting Slab 4 was changed from the previous slabs.

[redacted] stated he thinks [redacted] may have been planning to cover the Slab 3 hole using the angle iron that was found on the forklift after the incident.

[redacted] stated he assumes the black plastic bags on two of the slings used to lift the slabs were placed there to protect them from the cooling water used for the floor saw.

[redacted] stated he is not sure why shoring was not placed under Slab 4.

[redacted] stated he is unaware of anything unusual that happened during the Slab 4 removal (prior to the incident).

[redacted] stated he was aware of how the accident occurred and does not know why [redacted] would have placed himself and the floor saw on the suspended slab after it had been fully cut free of the test structure.

[redacted] stated he is not sure why [redacted] was not wearing fall protection, other than he may not have been able to find a good tie-off point to allow him to conduct the slab cutting.

[redacted] stated he is not aware of any discussions regarding issues created by the water sup

ply hose for the floor saw, but he knows it can be aggravating to maneuver the saw around with it attached. He stated the floor saw has a water supply tank, but the supply capacity wasn't enough for doing the long cuts they were doing.

[redacted] stated he had no concerns with how [redacted] performed his work, but he was concerned about the slabs once they were cut and being lifted out. He stated he was not sure how stable the slabs would have been and if they broke at height, it would be a major hazard. [redacted] stated using a contractor wouldn't necessarily have made a difference as demolition is a different activity with different hazards.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interviewed held on October 26, 2022, by the NIST Team investigating the Building 205 incident.

__[redacted]__ 11/16/2022

[redacted] Date

Summary of Investigation Interview with ENGR TECH 5

Date: October 26, 2022
Time: 11:00 pm to 11:50 pm am ET

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members present: [redacted]

SUMMARY OF RESPONSES RELATED TO [redacted] AND SAFETY CULTURE AT NFRL

[redacted] stated he is an Engineering Technician for the National Fire Research Laboratory (NFRL) in the Fire Research Division of the Engineering Laboratory at the National Institute of Standards and Technology (NIST). He stated he has held this role for over 27 years, all while at NIST. [redacted] stated most of his career at NIST was spent in the Wildland Urban Interface Fire Group. He stated during this time he would occasionally help out on large projects in Building 205. [redacted] stated he permanently joined the NFRL Group about 4 years ago. He stated he usually works on the "fire" side of Building 205 [Room 113] on small-scale experiments where he does a variety of tasks such as setting up data acquisition systems, running wires and plumbing, and setting up gas controls.

[redacted] stated from his perspective safety training was an important aspect of safety at NFRL and noted several programs such as crane training and forklift training that are required for work he performs. He stated another important aspect was the development of hazards reviews (HRs) and associated standard operating procedures (SOPs) for each project that would establish safety requirements and personal protective equipment (PPE). [redacted] stated safety inspections were conducted regularly and any safety issues were followed up on. He stated he believes NFRL has made significant strides in improving safety over the years.

[redacted] stated he could bring safety concerns to the attention of the line management at NFRL, particularly [redacted] [NFRL Group Leader]. He stated there were regular inspections and discussions about safety, and from his perspective safety concerns were addressed when raised.

[redacted] stated he felt the two-person rule was very important at NFRL. He stated it was emphasized to always make people aware of what you are doing, particularly if it is hazardous, *e.g.*, staff would leave the stairwell chain unhooked if going up to roof so others would know someone was up there. [redacted] stated when working together, the other person should be aware of what emergency procedures might be necessary, *e.g.*, knowing where the emergency shut off is.

SUMMARY OF RESPONSES RELATED TO [redacted]

[redacted] stated he did not work extensively with [redacted] as they typically worked on different sides of Building 205 (*i.e.*, [redacted] worked on the "structural" side in Room 125 and he worked on the "fire" side in Room 113). [redacted] and [redacted] had recently begun working together to review the new files added to the Fire Calorimetry Database (FCD).

[redacted] stated when he worked in Room 125, he recognized [redacted] as the "lead" and took direction from him even though he wasn't a supervisor.

[redacted] stated he could raise safety concerns with [redacted]. He stated he never had a reason to raise a safety concern with him.

[redacted] stated [redacted] never raised any safety concerns to him either.

[redacted] stated he did not have any specific knowledge of safety-related interactions between [redacted] and his supervisor [[redacted]] or project manager [[redacted]], but his general impression was that the relationships were collaborative. He stated he never felt safety "took a back seat" to other priorities at NFRL and he felt safety was a priority.

SUMMARY OF RESPONSES RELATED TO THE DESIGN AND CONSTRUCTION OF THE TWO-STORY TEST FRAME

[redacted] stated he was not involved in the design of the test frame used for the Composite Floor (CF) Project.

[redacted] stated he was not involved with the initial construction of the test frame. He stated he was also not familiar with safety briefings related to the construction as he was not involved in those aspects of the project.

SUMMARY OF RESPONSES RELATED TO THE CF PROJECT EXPERIMENTS

[redacted] stated his involvement with the CF Project was primarily setting up and testing the gas control systems, thermocouples, strain gauges, and associated data collection systems.

[redacted] stated safety briefings were held before each experiment to review hazards, roles, and responsibilities. He stated [redacted] was in attendance for each briefing, as well as [redacted] who was an active participant regarding hazard discussion.

SUMMARY OF RESPONSES RELATED TO PROCEDURES ASSOCIATED WITH POST-EXPERIMENTAL WORK AND REMOVAL OF THE TEST FLOOR CF1 AND CF2

[redacted] stated he was not involved in the demolition work of the test floors after CF1 and CF2.

[redacted] stated he remembers a group discussion about having contractors perform the demolition work because the work was “messy” but was not sure why it was determined NFRL technicians would conduct the work.

[redacted] stated he was not involved with any of the construction work to prepare the test frame for the subsequent experiments beyond assisting with loading the test and surrounding floor and testing some circuitry for strain gauges.

SUMMARY OF RESPONSES RELATED TO PLANNING DEMOLITION OF THE FULL TEST FRAME AFTER CF3

[redacted] stated he was not involved in the demolition of the test floor or the surrounding floor after CF3.

SUMMARY OF RESPONSES RELATED TO THE INCIDENT

[redacted] stated he worked in Building 205 in the morning on the day of the incident, in Rooms 110 and the SE corner of Room 125. He stated when he returned from lunch the emergency vehicles and personnel were present.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interviewed held on October 26, 2022, by the NIST Team investigating the Building 205 incident.

________________________________ 11/10/2022

[redacted] Date

Summary of Investigation Interview with ENGR TECH 6

Date: October 26, 2022
Time: 1:00 pm to 1:55 pm am ET

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members present: [redacted]

SUMMARY OF RESPONSES RELATED TO [redacted] AND SAFETY CULTURE AT NFRL

[redacted] stated he is an Engineering Technician for the Engineered Fire Safety Group in the Fire Research Division of the Engineering Laboratory at the National Institute of Standards and Technology. He stated he has held this role for over 25 years. [redacted] stated prior to the COVID-19 pandemic he worked primarily in Building 224. He stated in August 2020, he began working in Building 205 primarily in the original portion of the building he referred to as the "fire side" [Room 113]. [redacted] stated he spent his time setting up and running experiments, building test set-ups, running instrumentation wiring, machining items for tests, and assisting on the "structural side" [Room 125] when needed.

[redacted] stated from his perspective safety is always a priority for experiments conducted at the NFRL. He stated the team has a good working relationship and would communicate freely if someone had a safety concern or wanted to offer ideas about safer ways to do things. [redacted] stated he felt he could bring safety concerns to the attention of NFRL line management [[redacted], NFRL Group Leader].

[redacted] stated the two-person rule in effect at NFRL required anyone performing hazardous work to ensure someone else was with them so they could check on them periodically and provide assistance if needed.

SUMMARY OF RESPONSES RELATED TO [redacted]

[redacted] stated he did not work extensively with [redacted] as they typically worked on different sides of Building 205 (*i.e.*, [redacted] worked on the "structural" side in Room 125 and he worked on the "fire" side in Room 113). He stated when they worked together, they had a good working relationship.

[redacted] stated when he worked in Room 125 he recognized [redacted] as the "lead" and took direction from him; he could also rely on the other engineering technicians for direction as needed. [redacted] stated when the NFRL technicians were working in Room 113, they would take direction from him.

[redacted] stated he felt comfortable raising safety concerns to [redacted], although he did not raise any in regard to the work he performed on the Composite Floor (CF) Project.

[redacted] stated he did not have any specific knowledge of interactions between [redacted] and his supervisor [[redacted]] or project leader [[redacted]]. He stated he never felt safety "took a back seat" to other priorities at NFRL.

SUMMARY OF RESPONSES RELATED TO THE DESIGN AND CONSTRUCTION OF THE TWO-STORY TEST FRAME

[redacted] stated he was not involved in the design of the test structure used for the CF Project. He stated he was not aware that continuous rebar reinforcement was not used in the NE and NW corners of the surrounding floor of the test structure.

[redacted] stated he had some involvement with the construction of the initial test structure with tasks like installing the steel pan decking and rebar. He stated there was a hazard review created for this work [*Composite Floor Systems Test* - #733.06.0124.031621 in the MML Hazard Review Database], but he did not review that document as the work he performed was general construction work.

[redacted] stated he assisted with the construction of the fire compartments of the test structure. He stated there was a hazard review created for this work [*Composite Floor Systems Test* - #733.06.0124.031621 in the MML Hazard Review Database], but he did not review that document as the work he performed was general construction work.

[redacted] stated [redacted] managed the day-to-day safety aspects of the work he performed as part of the CF Project. He stated safety hazards were typically communicated to him prior to starting work through informal discussions between himself and other team members. [redacted] stated he heard general discussions about how to do things safely, but not with respect to them [NFRL technicians] being worried or afraid of doing a specific activity. He stated [redacted] appeared comfortable with the work he was performing.

[redacted] stated he did not have any specific safety concerns related to the initial structure and he felt comfortable with the fall protection system in place [cabling].

SUMMARY OF RESPONSES RELATED TO PROCEDURES ASSOCIATED WITH POST-EXPERIMENTAL WORK AND REMOVAL OF THE TEST FLOOR CF1 AND CF2

[redacted] stated he was not involved with the demolition of the test floor after CF1 and CF2 experiments.

[redacted] stated he was not involved with the demolition of the fire compartments after the CF1 and CF2 experiments.

[redacted] stated he was involved with the rebuilding of the fire compartments after the CF1 and CF2 experiments. He stated there was a hazard review created for this work [*Composite Floor Systems Test* - #733.06.0124.031621 in the MML Hazard Review Database], but he did not review that document as the work he performed was general construction work.

SUMMARY OF RESPONSES RELATED TO PLANNING DEMOLITION OF THE FULL TEST FRAME AFTER CF3

[redacted] stated he was not involved with the planning for demolition of the full test frame.

SUMMARY OF RESPONSES TO DEMOLITION OF CF3 TEST FLOOR AND REMOVAL OF SLABS 1, 2, AND 3 FROM THE SURROUNDING FLOOR

[redacted] stated he assisted with removal of some of the concrete after it was jackhammered from CF3 test floor. He stated he recalled reviewing a hazard review for the removal of the test floor [*Composite Floor System Stabilization and Demolition* - #733.06.0148.050522 in the MML Hazard Review Database] which included personal protective equipment such as dust masks, “bunny” suits, and the more obvious things like a hard hat, safety glasses, and steel-toed shoes. [redacted] stated he never used personal fall protection when he was up on the structure as he always relied on the cable system.

[redacted] stated he assisted with removing some of the cribbing used to support the CF3 test floor while it was being demolished.

[redacted] stated he participated in the demolition of the fire compartment after the CF3 experiment. He stated his experience with demolition was from having a general construction background and his training on demolition methods and safety was also from this experience [redacted] stated [redacted] was the leader of the demolition team, but some decisions about how to do activities were made as a team.

[redacted] stated he did not participate in the removal of the slabs from the surrounding floor.

[redacted] stated he did not know why the cribbing was placed under the locations of Slabs 1 and 2.

[redacted] stated that he did not feel any schedule pressure when he was working on the project.

[redacted] stated he had no specific safety concerns about the slab removal process other than a general concern about lifting and moving large pieces of concrete with the crane.

SUMMARY OF RESPONSES RELATED TO THE INCIDENT

[redacted] stated he worked in Building 205 in the morning on the day of the incident. He stated he went to Building 224 around 9:30 am to complete some paperwork and then returned to Building 205 sometime shortly after the incident.

[redacted] stated he did not know of any prior incidents at the NFRL similar to this one.

[redacted] stated he had full confidence in how [redacted] performed his work.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interviewed held on October 26, 2022, by the NIST Team investigating the Building 205 incident.

[redacted]

[redacted]

11/16/2022

Date

Summary of Investigation Interview with EL SAFETY PROFESSIONAL

Date: February 10, 2023
Time: 11:00 am to 12:15pm

Interview was conducted via Teams

Interviewer: [redacted]
Interview panel: [redacted]

SUMMARY OF RESPONSES RELATED TO [redacted]

[redacted] stated he is the Safety Professional for the Engineering Laboratory at the National Institute of Standards and Technology (NIST). He has held this role as a federal employee since September 24, 2012. [redacted] stated his responsibilities within EL include:

- Consulting and advising EL line management and staff regarding occupational safety and health matters;
- Providing occupational safety and health support to division safety representatives;
- Participating in hazard reviews (discussed in detail later in this statement);
- Participating in workplace inspections;
- Serving as the OU-level administrator for all NIST Safety IT applications (*e.g.*, IRIS and SET);
- Conducting some safety trainings (*e.g.*, instructor-led orientation training to SHIP and SURF students, orientation for use of the MML Hazard Review Database);
- Creating and distributing safety reports for EL line management (*e.g.*, workplace inspection deficiencies and safety training status reports);
- Collaborating with other OU Safety Program Managers and OSHE staff regarding best practices;
- Serving as the EL representative on the Safety Advisory Committee; and
- Serving as the Safety Advisory Committee Liaison to the Executive Safety Committee.
- Organizing instructor led training by external vendors on topics such as scaffold, forklift and crane operation safety.

[redacted] believes he has the highest level of support for his activities from EL line management

SUMMARY OF RESPONSES RELATED TO THE EL HAZARD REVIEW POLICY

[redacted] is familiar with the document titled "EL Hazard Review and Approval Policy and Procedure". With respect to specific roles identified for the EL Safety Professional:

- [redacted] stated he believes the EL policy document does meet the requirements of the NIST Hazard Review suborder (NIST S 7101.20: *Work and Worker Authorization Based on Hazard Reviews*). There was an effort to keep the language in the EL document as similar as possible to the NIST suborder, but there are some minor differences between the NIST document and other OU policies (*e.g.*, the EL Director delegates their responsibilities for OU level Hazard Review approvals to the EL Deputy Director).

- [redacted] stated he does chair the EL Hazard Review Committee and, in consultation with the EL Deputy Director and the relevant Division Chief , Group Leader, and Project Leader, determines the members for each committee based upon the work and associated hazards identified. He stated he will often bring in outside experts from other OUs and on average 5-6 committees are called a year. [redacted] indicated the MML Hazard Review Database will notify him if a hazard review contains an RHI = 3. The Division Chief may also request a formal review by the committee for RHI less than 3. Separately from his official role as the Committee Chair, he may also be contacted to consult on hazard reviews during their development. [redacted] stated the Committee provides benefit and is effective in that it puts "fresh eyes" on the work and identified safety control measures.

- [redacted] stated he provides training to staff on the use of the MML Hazard Review Database, but does not include information related to roles, responsibilities, or other requirements. He does not recall providing training to [redacted] (NFRL Group Leader) or [redacted] (Acting Division Chief at the time of the incident), but he also stated he does not maintain training records of these sessions.

- [redacted] stated the EL hazard review policy document was not reviewed in FY22 and is unsure of the last time it was formally reviewed. He stated it may have been the dated listed on the document [12/01/16]. He stated there is another document that was recently reviewed and updated titled "EL Management Memo 01: Safety and Health Management". This document does cover some aspects of hazard reviews and was last approved for use on January 22, 2021.

[redacted] stated there is no documented definition for who is the "Activity Leader" called out in the EL hazard review policy. He stated he believes it is usually the lab PhD performing the work or for more "industrial" type work it would be the technician responsible for running the equipment or tool.

[redacted] stated there is no defined role in the EL hazard review process for a "Project Leader" unless that individual is identified as the "Activity Leader".

[redacted] stated he is periodically contacted by EL staff to consult on hazard reviews outside of his role as Chair of the EL Hazard Review Committee. Prior to the incident, he stated he did not receive "too many" requests.

[redacted] stated EL performs tabletop exercises where once a year each division will do a deep dive on an existing or new hazard review and present the results to the EL Management Council. He stated this practice was initiated in 2017 when it was recognized that emergency response procedures were lacking. There were two tabletop exercises conducted in the past few years that involved NFRL staff or facilities:

- November 27, 2017 – involved connection failure scenarios and response during a test performed as part of the Structural Fire Experiment of Composite Floor Beam (MML Hazard Review Database #733.06.0078).

- January 25, 2022 – involved procedures to handle various emergency or unexpected occurrences during reduced-scale compartment backdraft experiments (MML Hazard Review Database #733.01.0158).

[redacted] stated these exercise are beneficial as it is another opportunity to have "fresh eyes" on the work to be performed and identifies actions that need to be taken to strength the hazard review. He stated he is sometimes asked to participate on the tabletop teams, and he contributes during the management review of the results.

[redacted] stated he does have the authority to request changes to a hazard review and provided a few recent examples of this including the most recent revision to the NFRL Ladder Use hazard review (MML Hazard Review Database #733.06.0207).

SUMMARY OF RESPONSES RELATED TO WORK IN NFRL

[redacted] stated prior to the incident while he did not feel resistance to his assistance, he was not often consulted on NFRL hazard reviews. He stated when he did have interactions with NFRL staff regarding hazard reviews they were cooperative and amenable to his recommendations.

[redacted] stated prior to the incident he had very little if any awareness of the CF Project work. He was not involved with the creation or revision of the *Composite Floor Systems Tests* hazard review (MML Hazard Review Database #733.06.0124). He also stated while he did not participate in the creation of the *Composite Floor System Stabilization and Demolition* (MML Hazard Review Database #733.06.0148), he did have a brief phone meeting on May11 to discuss the last revision of the document prior to the incident. [redacted] stated had no input on the following aspects of the CF Project:

- Design of the test frame;
- Construction of the test frame;
- Demolition of the fire-tested floors and fire compartment;
- Rebuilding of the test floor and fire compartment; or
- Demolition of the test frame itself.

[redacted] stated he had interactions with NFRL staff in early May 2022 regarding the CF Project work. After an NFRL crane incident (IRIS Case Number 22-IG-0027), he visited Building 205, Room 125 to see where it occurred to review what had happened. While there, he stated he had some questions regarding the demolition of the CF3 fire-tested floor and attempted to set-up a meeting with [redacted] for May 5, 2022. [redacted] stated his specific concerns were ensuring staff had some form of :

- Fall protection due to the demolition work performed on the CF3 fire-tested floor; and
- Hearing protection given the jackhammering of the composite test floor.

He stated that meeting was canceled due to scheduling conflicts, and on May 9, he rescheduled the meeting for May 11. He stated [redacted] forwarded the meeting request to among others [redacted]. [redacted] stated he received emails from [redacted][1] later in the day first stating:

[1] Please see attached email thread for the referenced statements.

> *As of this morning, I am back from the Program Office. With [redacted] departure, I have taken over the lead for the Composite Floor project.*
>
> [redacted] *asked that* [redacted], [redacted], *and I join this meeting because we have responsibilities for the workspace, safety, and project management. If our participation is not desired/needed for this meeting, let me know.*
>
> *Could you let me know the specific topic(s) for discussion and/or desired outcome of the meeting so we can prep accordingly?*

and later:

> *I will review the Hazard Review [Composite Floor System Stabilization and Demolition] before our meeting.*

[redacted] stated the meeting did occur on May 11, and subsequently, [redacted] sent an email to him later in the day indicating [redacted] had made changes to the hazard review [*Composite Floor System Stabilization and Demolition*] based upon the conversation.

[redacted] stated there was no discussion regarding the demolition of the surrounding floor during those meetings or at any other meetings prior to the incident.

SUMMARY OF RESPONSES RELATED TO CORRECTIVE ACTIONS ASSOCIATED WITH INCIDENT REPORTING AND INVESTIGATION

[redacted] stated he has no responsibilities related to verifying whether or not corrective actions identified as part of an incident investigation are implemented. He stated that is typically the responsibility of the EL line manager assigned that task in IRIS.

[redacted] stated he has no knowledge of whether the corrective action associated with IRIS Case Number 17-IG-0110, requiring the development of lift plans for complex lifts, was appropriately implemented within the NFRL.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interview held on February 10, 2023, by the NIST Team investigating the Building 205 incident.

[redacted]

[redacted]

Date

Summary of Investigation Interview with FRD DSR

Date: November 7, 2022
Time: 1:00 pm to 1:45 pm ET

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members present: [redacted]

SUMMARY OF RESPONSES RELATED TO [redacted] AND SAFETY CULTURE AT NFRL

[redacted] stated she is a Physical Science Technician for the Flammability Reduction Group in the Fire Research Division (FRD) of the Engineering Laboratory (EL) at the National Institute of Standards and Technology (NIST). She stated she has held this position since April 2015. [redacted] stated prior to this position she worked for the [redacted] on the NIST campus starting in 1989. She stated she has a Bachelor of Science degree in biology. [redacted] stated she has held the role of Division Safety Representative (DSR) for five years. She stated in this role she assists with such activities as creating and reviewing hazard reviews (HRs), performing chemical inventories, conducting workplace safety inspections, and responding to general safety issues that arise. [redacted] is also the Division Laser Safety Representative.

[redacted] stated management of safety in the NFRL depends on the activity and how the HRs are developed. She stated sometimes the HRs originate with the NFRL engineers and sometimes from the technicians. [redacted] stated the technicians do not always agree with the engineers about how things should be done. She stated the NFRL technicians have told her [redacted] [NFRL Group Leader] has stepped in on their behalf. [redacted] stated [redacted], in her opinion, would never ask someone to perform an unsafe activity and he was very conscientious of safety implementation during the work. She stated, based upon her observations and conversations, when it came to performing the work, the NFRL technicians have the "final say" regarding safety.

[redacted] stated she was told by [redacted] that the most hazardous activity in NFRL was related to the transport of the hydraulic loading system in the basement. She stated the NFRL basement is a very tight space and [redacted] stated that modifying the piping in the area might give a little more room to maneuver. [redacted] stated this has been discussed with EL line management.

[redacted] stated she has participated in the management observation process discussions in the NFRL. She stated two recent discussion were very good – one with [redacted] [EL Deputy Director] in March and another with most of the NFRL Group in September. [redacted] stated both went well and were productive with great input and feedback from staff involved.

[redacted] stated she has participated in workplace inspections in the NFRL, both "official" using the WIRS application and "non-official" since they were working during COVID. She stated [redacted]

[redacted] [Engineering Technician in the Engineered Fire Safety Group] typically leads these and has done a great job keeping up with these during COVID. [redacted] stated minor issues have been found and resolved.

[redacted] stated she has participated in incident investigations involving the NFRL. She stated she believes incidents are taken very seriously in the NFRL and they report incidents that might not be reported by other groups.

[redacted] stated she has participated in the NFRL hazard review process. [Please see next section.]

SUMMARY OF RESPONSES RELATED TO EL HAZARD REVIEW PROCESS

[redacted] stated FRD does not have an official policy for what activities require HRs as FRD will do a HR for "everything".

[redacted] stated when staff want to perform new work, they usually come to her first to discuss the activity before putting it into the IT application titled "MML Hazard Review Database". She stated she obtains the background information, primarily from the principal investigator (PI), and works with staff to develop standard operating procedures (SOPs) and emergency response plans (ERPs) outside of the IT application. [redacted] stated it is her preference that principal investigators (PIs) send her a draft SOP and ERP before submitting the HR. She stated after they agree on a final copy, the PI adds the SOP, ERP, and other pertinent documents and information to the MML Hazard Review Database. [redacted] stated the PI will then submit the HR for approval. She stated not all HRs are done this way though, as some staff submit the HRs through the IT application without any editing from her beforehand. [redacted] stated if corrections or additions need to be made to the HR, it would be rejected and returned to the PI through the IT application. [redacted] stated the entire HR then needs to be approved. She stated for a relative hazard index (RHI) of 0 or 1, only the group leader needs to approve and she may not see them although she does frequently look through HRs with those RHIs. [redacted] stated for an RHI of 2 or 3, the group leader, DSR, and DC need to approve through the IT application, specifically in that order. She stated she encourages staff to print the SOPs and ERPs out and put them near the activity area.

[redacted] stated if there is a change to the work, *e.g.*, modification to procedure or use of a new hazardous material, a revision to the original HR is required. She stated she was not aware of an official revision process, *i.e.,* sometimes the PI will notify her or get her advice but sometimes, if only a minor change is made, she will not get a notification as it may only need group leader approval.

[redacted] stated she is not aware of a completely new HR being required due to changes in current work, typically its just a revision of the current HR. An exception might be if certain staff were approved for the original HR but not approved to do the work in the revision, then a different HR would be required.

[redacted] stated that, in the last year or so, she and [redacted] have communicated more frequently about the requirements for a HR. She stated her perception is that [redacted] recognizes that an approved HR is a requirement for work, but his priority is not the documentation in the HR. [redacted] stated that [redacted] appears to be very concerned for the safety of the staff but relies heavily on the knowledge and experience of his technicians. She stated that she does not know that amount of input he provides to the HR before it is submitted. [redacted] stated she does not recall him ever rejecting a submitted HR and approves them very quickly.

SUMMARY OF RESPONSES RELATED TO THE HAZARD REVIEWS ASSOCIATED WITH THE CF EXPERIMENTS

[redacted] stated she was familiar with the hazard review titled *Composite Floor Systems Test* - #733.06.0124.031621 in the MML Hazard Review Database. She stated she could not remember if this HR covered the construction of the test frame or if it covered the construction of the fire compartments used during the experiments. [redacted] stated she could not recall the revision history of this HR document, either.

[redacted] stated she was familiar with the hazard review titled *Composite Floor System Stabilization and Demolition* - #733.06.0148.050522 in the MML Hazard Review Database. She stated this document covered the demolition of the test floor but did not include the demolition of the surrounding floor.

[redacted] stated that she, [redacted], and [redacted] discussed the respiratory hazards (from dust). She stated they planned to wet down the cement to reduce dust while cutting. [redacted] stated [redacted] believed the respiratory protection (*e.g.*, a half-face respirator) to be too bulky and might be more of a safety hazard, so they chose to wear N95s. She stated that she recommended that they bring water up onto the deck in case they needed to wash their eyes, they later said they did. [redacted] stated [redacted] and [redacted] agreed that the most hazardous part of this activity was walking on the rebar.

[redacted] stated she is not aware of a separate HR that covered the demolition of the surrounding floor.

[redacted] stated she was not aware a decision was made to use the HR associated with the demolition of the test floor for the demolition of the surrounding floor. She stated if changes to the HR were submitted and the MML Hazard Review Database considered the changes to be minor, she may not have been notified about it.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interview held on November 7, 2022, by the NIST Team investigating the Building 205 incident.

[redacted] ______

11/18/2022
Date

Summary of Investigation Interview with FIRE FIGHTER 1

Date: October 24, 2022
Time: 8:00 am to 8:17 am

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other Team Members Present: [redacted]

SUMMARY OF INTERVIEW

Firefighter (FF) [redacted] stated he has been at NIST for the past 13 years and has been a FF/Emergency Medical Technician since he was 17 years old.

FF [redacted] stated on the date of the incident, September 26, 2022, he was working at the NIST Fire Department (FD) and assigned as the Engine Driver. To the best of his recollection, the call for service in Building 205 was received at the firehouse via the NIST emergency number (x2222) just a little after 1:00 pm.

FF [redacted] stated he drove the NIST FD utility vehicle to building 205 to help as he had a feeling the ambulance crew would need assistance for the "unknown emergency". The NIST FD ambulance was already on scene when he arrived. He stated FF [redacted] was with the patient and FF [redacted] was retrieving additional supplies and the cot from the ambulance. FF [redacted] stated he retrieved the Reeves stretcher from the ambulance and went to the patient. FF [redacted] stated he observed the patient laying in a large pool of water. The patient was on his back, with his head oriented to the NE corner of the building – near the large floor saw. The patient had his legs on top of a piece of concrete debris pieces [when shown a picture from the accident site, it was identified as Piece C1 from Slab 4]. FF [redacted] stated no debris was on top of the patient. FF [redacted] stated he moved a small piece of concrete debris [when shown a picture from the accident site, it was identified as Piece C2 from Slab 4] to allow for better access to the patient. FF [redacted] stated he assisted with movement of the patient to the Reeves stretcher and to the back of the ambulance where his contact with the patient ended. FF [redacted] stated he did not recall seeing any personal protective equipment other than the patient's hard hat which was crushed between the two (2) large pieces of concrete debris. FF [redacted] stated that he did not observe a fall protection harness.

INTERVIEWEE STATEMENT

I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interviewed held on October 24, 2022, by the NIST Team investigating the Building 205 incident.

_______________________________ 11/08/2022
[redacted] Date

Summary of Investigation Interview with FIREFIGHTER 2

Date: October 20, 2022
Time: 11:00 am to 11:30 am

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other team members present: [redacted]

SUMMARY OF INTERVIEW
Firefighter [redacted] stated he has been at NIST for the past 12 years and has been a FF/Emergency Medical Technician for the past 25 years.

[redacted] stated on the date of the incident, September 26, 2022, he was working at the NIST Fire Department and assigned as Aide on the ambulance. To the best of his recollection, the call for service in Building 205 was received at the firehouse via the NIST emergency number (x2222) just after lunch at approximately 1:00 pm. [redacted] stated the initial call received at the firehouse was for an "unknown emergency." [redacted] stated while enroute to Bldg 205 he received updated call information that it was traumatic injuries from a fall.

[redacted] stated he recalls the ambulance was waved down at the large roll-up door to Building 205. [redacted] stated he instructed his driver [[redacted]] to position the ambulance for a rapid departure. [redacted] stated he believed the scene was dangerous as a large amount of water was near the patient (approximately 0.5 inches deep) and he was concerned about potential electrical hazards and hanging overhead debris. [redacted] stated the patient was lying face-up on the floor, head oriented towards the NE near the strongwall and his legs to the SW on a piece of concrete debris [when shown a picture from the accident site, it was identified as Piece B from Slab 4]. He stated nothing was on top of the patient. [redacted] stated he was advised by [redacted] the patient had no pulse and CPR was being initiated. [redacted] stated he went back to the ambulance to retrieve additional equipment (AED) and requested ALS support from Montgomery County Fire and EMS for a trauma arrest. [redacted] stated he assisted [redacted] and [redacted] in placing the patient onto a Reeves stretcher for transport to the cot and back of the ambulance for further patient care. [redacted] stated he did not immediately notice any personal protective equipment but did recall later finding hearing protection in place on the patient. He stated he did not notice any fall protection equipment.

INTERVIEWEE STATEMENT
I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interviewed held on October 20, 2022, by the NIST Team investigating the Building 205 incident.

[redacted] ______________________   11/07/2022
Date

Summary of Investigation Interview with FIRE FIGHTER 3

Date: October 24, 2022
Time: 8:20 am to 8:30

Interview was conducted via Teams with no video or audio recording.

Interviewer: [redacted]
Other team members present: [redacted]

SUMMARY OF INTERVIEW
Firefighter (FF) [redacted] stated he has been at NIST for just over 2 years and has been a FF/Emergency Medical Technician for the past 11 years.

FF [redacted] stated on the date of the incident, September 26, 2022, he was working at the NIST Fire Department. He stated he was originally assigned to the engine, but also covered as the ambulance driver for a few hours during the day due to other needs on campus. FF [redacted] stated to the best of his recollection, the call for service in Building 205 was received at the firehouse via the NIST emergency number (x2222) at approximately 1:00 pm.

FF [redacted] stated he believed the incident scene was dangerous to providers as a substantial amount of water was on the floor and hanging overhead debris. FF [redacted] stated the patient was laying on his left side/back approximately 2 feet away from the large concrete debris pieces with his head to the NE (nearest to the floor saw) and feet SW [when shown a picture from the accident site, he identified the patient's feet as being near Pieces C1 and C2 from Slab 4]. He stated no debris was on top of the patient. FF [redacted] stated he did not observe any injuries to the patient aside from obvious head trauma. FF [redacted] stated he checked the patient for a pulse, and finding none, began CPR while FF [redacted] went back to the ambulance to retrieve the AED and other additional equipment. FF [redacted] stated he did see the patient's hard hat wedged between 2 pieces of concrete debris, but did not recall seeing any other personal protective equipment used by the patient, to include fall protection devices.

INTERVIEWEE STATEMENT
I have reviewed and amended this document and it accurately and completely summarizes my responses provided during an interviewed held on October 24, 2022, by the NIST Team investigating the Building 205 incident.

______________________________ ______________
[redacted] Date

Appendix 6.1.1: EL Management Memo 01 - *Safety and Health Management*

	EL Management Memo 01	
	Document Title: Safety and Health Management	
	Category: Safety and Health Management	**Management Owner:** [redacted]
	Effective Date: 1-22-2021	**Admin. Owner:** [redacted]
	https://eli.nist.gov/sites/Safety/	

Safety and Health Management

Contents

1. Introduction

This memorandum provides general safety and health information along with overall policy and guidance regarding the Engineering Laboratory (EL) Safety Management System (SMS) and shall be communicated to all EL employees and associates (including students, post docs, and guest researchers). All EL employees and associates should also be familiar with National Institute of Standards and Technology (NIST) safety policy for specific topics, as set forth in the NIST Safety Programs.

The EL SMS is comprised of policies, procedures, tools, and oversight designed to manage the safety of all EL staff, associates, and visitors.

2. Policy

All EL staff and associates shall actively contribute to a safe, secure, and healthy workplace. EL staff and associates shall continually communicate and emphasize the importance of safety and hold themselves and each other accountable for ensuring a safe workplace.

3. Roles and Responsibilities

All staff and associates are responsible for their own safe behavior. Safety is included as a critical element or an activity for EL employees as part of each individual's annual performance agreement. The EL Director, Deputy Director, Division/Office Chiefs, Group Leaders and other supervisors are accountable for communicating safety and health information to their staff in a timely fashion. All employees and associates are responsible for communicating unsafe working conditions to their supervisors or sponsors.

ROLE: All staff and associates shall actively support a positive safety culture and contribute to effective, proactive execution of the EL Safety Management System.

RESPONSIBILITIES

All EL staff and associates are responsible for**:**

- Understanding and supporting NIST's safety culture, values, and policies as well as EL's Safety and Health (S&H) programs and practices.
- Contributing to an open and supportive work environment where all staff members and associates are knowledgeable about S&H programs and practices and free to report S&H issues and concerns without fear of retribution.
  Completing all role and activity-specific S&H training required to perform assigned activities and roles (https://eli.nist.gov/safety/Lists/Safety%20Training/AllItems.aspx), before being exposed to work-related hazards.
- Carrying out all work in compliance with applicable safety regulations, policies, directives, and other requirements, including:
    - adhering to instructions on warning signs and postings;
    - responding to emergency situations and training drills in an appropriate manner, consistent with any established policies, procedures, and expectations;
    - contributing to hazard reviews conducted by the Work Space Managers and Activity Leaders as needed;
    - utilizing required personal protective equipment;
    - alerting management to environmental, safety, or health risks and hazards encountered while performing work or any other unsafe condition observed;
    - issuing cease work activity directions upon observing imminent danger; and
- Attending periodic safety meetings.
- Reporting incidents and near-misses to their supervisor and/or sponsor as soon as practically possible (see Section 4.4).

AUTHORITIES

All EL staff and associates are **authorized to** act and interact with each other as necessary to complete their general and role-specific EH&S responsibilities, and to ensure safe and effective operations including:

- Performing work and making decisions within established safety policies and guidelines.
- Taking any and all necessary actions to ensure a safe, secure, and healthy workplace within EL for themselves and others.
- Reporting unsafe working conditions, without fear of retribution.
- Ceasing work activity if an imminent safety or health danger exists, without fear of retribution.
- Helping to identify training, information, equipment, and facility needs to perform work safely.

- Escalating issues up the management chain if safety problems are not addressed.

ACCOUNTABILITIES

All EL staff and associates are **accountable to:**

- Each other, for contributing to a safe, secure, and healthy workplace.
- Their supervisors, for completion of their general and role-specific EH&S responsibilities, implementing the EL Safety Management System within their workplace activities, and for contributing to the establishment of an effective Safety Management System in EL.

See *Appendix A – Roles, Responsibilities, Accountabilities and Authorities* for a list of roles for which additional responsibilities have been assigned ***beyond those*** that apply to all EL staff and associates.

4. Responding to Emergencies and Unsafe Conditions

On the NIST Gaithersburg campus:

- To report a fire or other emergency, call x2222 (or 301-975-2222 from a mobile phone)
- To speak to the fire department about a non-emergency workplace accident, call x6190.
- To speak to police about a non-emergency security incident, call x2805.
- For safety, health and environmental concerns and potential hazards, contact the NIST Safety Office at x5375 (option 3).
    - For facility related concerns or non-emergency safety concerns contact the Plant Trouble Desk at x6928, or submit a service ticket (M-Slip).

4.1. Building Alarms

In the event of a fire or life-safety hazard, the building alarm will sound, and a public announcement will be made as to the nature of the emergency, and the response required of the staff. When building occupants are instructed to evacuate, they must use the *nearest* exit, and meet at a predetermined location. Each hallway has a trained Evacuation Coordinator to assist the evacuation process.
The public announcement following the building alarm may indicate that you are to shelter-in-place. In that case, you should not evacuate the building; instead, gather at the nearest "shelter-in-place" location (indicated by a yellow sign with those words), or in an interior room or corridor located on the lowest floor of the building. An announcement made over the public address will indicate when it is safe to leave the "shelter-in-place" location.

In case of fire or life safety hazard:

1. Pull fire alarm;
2. Evacuate building;
3. Call x2222 (or 301-975-2222 if using a mobile phone).

When instructed to EVACUATE the building:

1. Place equipment in a secure state, if you can do so safely following pre-determined shutdown procedures;
2. Place “Evacuated” magnet on outside of room door and close door as you exit;
3. Close the door
4. Exit the building through the closest exit;
5. Assemble at your predetermined evacuation assembly area outside the building; and

6. Do not re-enter until given instructions to do so by the NIST Police or Fire Department.
7. When instructed to SHELTER-IN-PLACE:
   1. Place equipment in a secure state, if you can do so safely;
   2. Place "Evacuated" magnet on outside of room door and close door as you exit;
   3. Close the door;
   4. Assemble at your predetermined shelter-in-place assembly area inside the building; and
   5. Do not leave the shelter-in-place area until given instructions to do so by the NIST Police, Fire Department, or public address system announcement.

4.2. Egress Paths

In offices and regularly occupied portions of laboratories, pathways must be at least 0.71 m (28 in.) wide and kept clear of all obstacles. Stairways should never be used for storage. Exit paths must be clear, including hallways, stairwells, and lobbies. Anyone who notices that an exit door or pathway is obstructed should report the obstruction to their supervisor for appropriate action.

4.3. Accident or Injury

In the event of a work-related incident, injury, or illness requiring emergency assistance on the NIST Gaithersburg campus, call x2222 (or 301-975-2222 from a mobile device) immediately. An EL employee, associate or visitor who has an incident, is injured, or becomes ill due to work related activities[2] while on the NIST Gaithersburg campus between 8:30 a.m. and 5 p.m., Monday through Friday, *and does not require emergency assistance*, should seek assistance at the NIST Health Unit in the basement of Building 101, Room C33 (x5131), even if the incident or injury requires only minor first aid. Outside of normal working hours on the NIST Gaithersburg campus, staff should call x2222 (or 301-975-2222 from a mobile device) for emergency and first aid assistance.

4.4. Identified Action Items and Incident Reporting

If any of the following occur, they must be reported to the appropriate Supervisor/GL, Division Chief, EL Safety Professional, EL Senior Safety Officer, and EL Director as soon as practically possible (The injured or ill staff member should not delay obtaining medical assistance if these officials are not available):

- any fatality;
- any medical treatment or first aid for an individual or group (including medical treatment obtained off campus when due to a work-related incident or while on duty);
- any loss of consciousness;
- any incident that involves an emergency room visit by an individual or group;
- any incident that involves a request for assistance from off-campus resources, *e.g.*, from the city, county, or another agency, such as NIH;
- any incident that involves a potential violation of any license or permit
- an incident that *had the potential* for causing injury or harming the health of a NIST employee, associate, or visitor (referred to as a "near miss"); or
- any incident that has the potential to raise significant questions or concerns amongst the staff

The employee's Group Leader is responsible for submitting an initial report to the Incident Reporting and Investigation System (IRIS) within two business days of the accident or injury. All safety incidents require a Final Incident Investigation Report to be completed within 20 business days, approved by the appropriate Division Chief and the EL Deputy Director. For additional details see EL Incident Reporting and Investigation (IRIS) Procedure.

In addition to the above communications, an individual's supervisor shall assist reporting of work-related injuries and occupational disease/illness caused or aggravated by employment to the NIST Office of Human Resources (OHRM) when advised by the OSHE IRIS recordkeeper or the NIST Health Unit. Department of Labor forms are available on-line, and assistance in filling out the forms is available in the NIST Health Unit (x5131).

4.5. First Aid Kits

The following guidance is provided for the restricted use of first aid kits. First aid kits are required for field work, welding/cutting/brazing operations, and can be also obtained for laboratory use on an as-approved basis. The requirements for use of these kits are as follows:

Laboratory First Aid Kits

Because NIST has a Health Unit on the Gaithersburg campus to dispense professional medical services, first aid kits are not routinely distributed outside of the Emergency Services Division. However, OSHA specifically cites the need for first aid equipment for welding, cutting, and brazing operations [29 CFR 1910.252 (c)(13)]. The EL Director also has the authority, delegated to the EL Deputy Director, to approve the distribution and use of first aid kits for other laboratory staff at his/her discretion. For either of the above-mentioned scenarios, it must be ensured that:

The first aid kit contents are limited to the recommendations of ANSI standard (Z308.1) for general indoor use, office, or manufacturing environments.

- A staff member is designated to maintain the contents of the first aid kit, replenishing components when necessary due to use or the expiration date of any contents.
- The designated staff member that provides first aid using the kit has an up to date first aid certification from the EL First Aid Instructor or other recognized training organization (i.e. NIST Fire Department, National Safety Council, American Heart Association, Red Cross, etc.)
- A log sheet is provided with the kit to capture information on when and how the kit is used.
- Staff follow-up with a visit to the NIST Health Unit whenever first aid has been applied and file an incident report in IRIS. *Under no circumstances should staff make medical judgments to bypass a visit to the Health Unit in favor of a first aid procedure.*
- All staff that are working in the laboratory where the first aid kit is located are made aware of the kit and of the requirements described above, by the Workspace Manager.

To obtain a laboratory first aid kit, staff should send an email to the EL Deputy Director explaining the need for a kit and designating the responsible staff person. If the Deputy Director concurs, approved laboratory first aid kits can be obtained by contacting the EL Safety Professional and providing a cost center number. The kit(s) will be ordered following Deputy Director approval and provided to the requester when the appropriate first aid certification is provided.

Field First Aid Kits

Some activities in EL involve field work, which may not be performed in close proximity to on-site professional medical services. For any EL field work assignments, the project leader is responsible for ensuring that:

- A first aid kit, developed in consultation with the NIST Health Unit, is in the field with the project team at all times.
- At least one member of the field project team has an up to date first aid certification. Contact the EL Safety Professional for information on availability of first aid training.
- Contents of the kit are maintained and replenished when necessary due to use or expiration date of any components.
- Staff follow up with a visit to the NIST Health Unit or local medical facility whenever first aid

has been applied and file an incident report in IRIS. *Under no circumstances should staff make medical judgments to bypass a visit to the Health Unit or a local medical facility in favor of a first aid procedure*.

Standard operating procedures for field study teams must be incorporated into the first level hazard review (FLHR) of the specific study, including roles and responsibilities regarding first aid.

5. Role-and Activity-Specific Training

All new EL employees and associates that will be at NIST for 6 months or longer are required to attend the *NIST Onboarding Orientation,* which includes a one-hour segment on safety and physical security. In addition to the awareness training provided during orientation, all EL staff and all associates must also complete the EL Safety Awareness for All Personnel - Web Based course or the equivalent instructor led course when available usually during SURF/SHIP onboarding. Supervisors should review the EL Safety Training Requirements with all new employees or associates under their supervision within the first week of their appointment and assign training using the Safety Education and Training Application.

Many staff and associates may be exposed to hazards and safety issues specific to the activity(s) assigned. Activity-specific safety training is identified during the conduct of activity hazard reviews (see section 8). All employees and associates shall complete and remain current on training that is required to work on their activities, to perform their job safely, and to comply with regulations. Training requirements are developed by the individual's supervisor and the leaders of activities to which the employee is assigned.

EL staff members who are assigned to serve in specific safety related roles shall complete the additional role-specific training courses listed in EL Safety Training Requirements.

Completion of required safety training is tracked using the NIST Safety Education and Training (SET) Application (maintained by NIST's Office of Safety, Health, and Environment (OSHE) – contact the EL Safety Professional for more information or assistance with this application).

6. Safety Inspections

Periodic safety inspections are required for all EL Work Spaces using the Workplace Inspection Reporting System (WIRS). EL Lead Inspectors conduct the safety inspections with OSHE. Offices are inspected once a year and laboratories twice a year. Details for the conduct of safety inspection in EL are in EL Workplace Inspection Program Procedure and NIST S 7101-26 Workplace Inspection Program.

7. Activity Hazard Reviews

All non-office type (laboratory, shop, or field) activities to be performed by EL staff or associates shall be assessed and reviewed according to the EL Hazard Review and Approval Policy and Procedure using the MML Hazard Review Tool. Hazard reviews are an integral part of designing and planning for such activities and must occur up front, to the greatest extent possible or feasible, before construction, renovation, or procurement of equipment or materials are initiated. The risks associated with all laboratories, shop, or field activity hazards shall be eliminated or mitigated, using the procedures defined in the above-mentioned document.

8. Management Observation Process (MOP) Visits

The Management Observation Process (MOP) is an element of the NIST safety management system designed to promote safe operations and continual improvement by facilitating an ongoing and frequently occurring conversation about safety between staff and line management. The requirement for MOPs is detailed in the **NIST 7101-05 Management Observation Process 080819.docx** sub-order. The purpose of the MOP is to: (1) help prevent injuries, illnesses, and incidents by increasing dialogue with workers on creating a safe workplace; (2) observe workers' behaviors without threat of punishment; and (3) provide positive reinforcement of safe work practices and behavior. The MOP also provides an opportunity for managers to demonstrate commitment to safety by regularly engaging staff in conversations about safety and by supporting improvements to workplace safety. Additional details on the Engineering Labs MOP program is in Appendix B.

Approved:

[redacted] [redacted]

[redacted]
Acting Director, Engineering Laboratory

Appendix A – Roles, Responsibilities, Accountabilities and Authorities

Contents

All Staff and Associates

ROLE: Actively support a positive safety culture and contribute to effective, proactive execution of the EL Safety Management System.

RESPONSIBILITIES: All EL staff and associates are responsible for reading and understanding this memorandum. All EL staff and associates are held responsible for their own safe behavior. All EL staff and associates shall be familiar with the National Institute of Standards and Technology (NIST) *Occupational Safety and Health Policy*

All EL staff and associates are **responsible for**:

- Understanding and supporting NIST's safety policies, culture and values and EL's S&H programs and practices.
- Contributing to an open and supportive work environment where all staff members and associates are knowledgeable about S&H policies and practices and free to report S&H issues and concerns without fear of retribution.
- Completing all role- and activity-specific S&H training required to perform assigned activities and roles, before being exposed to work-related hazards.
- Carrying out all work in compliance with applicable safety regulations, policies, directives, and other requirements, including:
    - adhering to instructions on warning signs and postings;
    - responding to emergency situations and training drills in an appropriate manner, consistent with any established policies, procedures, and expectations;
    - contributing to hazard reviews conducted by the Workspace Managers and Project Leaders as needed;
    - utilizing required personal protective equipment;
    - alerting management to environmental, safety, or health risks and hazards encountered while performing work or any other unsafe condition observed;
    - issuing cease work activity directions upon observing imminent danger; and
- Attending periodic safety meetings.
- Reporting incidents and near misses to their supervisor and/or sponsor as soon as practically possible.

AUTHORITIES: All EL staff and associates are **authorized to** act and interact with each other as necessary to complete their general and role-specific EH&S responsibilities and ensure safe and effective operations including:

- Performing work and making decisions within established safety policies and guidelines.
- Taking any and all necessary actions to ensure a safe, secure, and healthy workplace within EL for themselves and others.
- Reporting unsafe working conditions, without fear of retribution.
- Ceasing and reporting work activity if an imminent safety or health danger exists, without fear of retribution.
- Help to identify training, information, equipment, and facility needs to perform work safely.
- Escalating issues up the management chain if safety problems are not addressed.

ACCOUNTABILITIES: All EL staff and associates are **accountable to:**

- Each other, for contributing to a safe, secure, and healthy workplace.
- Their supervisors, for completion of their general and role-specific EH&S responsibilities, implementing the EL Safety Management System within their workplace activities, and for contributing to the establishment of an effective Safety Management System in EL.

The following is a list of roles, for which additional responsibilities have been assigned ***beyond those*** that apply to all EL staff and associates:

EL Director and Deputy Director

ROLE: Actively support the development and implementation EL EH&S policies and procedures that support a positive safety culture and contribute to effective, proactive execution of the EL Safety Management System.

RESPONSIBILITIES: The EL Director is responsible for overseeing development and implementation of EL policies and procedures for environmental health, safety, hazard analysis and control within EL that conform to the requirements of NIST Occupational Safety and Health Policy and all NIST Safety, Health and Environmental Programs[23] including:

- Exercising leadership and actions needed in EL to achieve established safety performance objectives, including implementing a Safety Management System that meets established requirements.
- Approving the EL Safety Program (this document).
- Serving as an active member of the NIST Executive Safety Committee (ESC).
- Communicating the agency's safety culture and values to EL Staff.
- Leading and ensuring management commitment to EH&S.
- Committing EL resources as necessary to ensure the health and safety of EL staff and associates and continually improve safety performance.
- Continually improving the safety culture of EL and achieving NIST performance objectives through regular inspections, Management Observation Process (MOP) visits, documentation, policy and procedure reviews, and assessments.

The EL Director may delegate certain responsibilities and authorities to the EL Deputy Director and/or EL Senior Safety Officer (SSO) (see section below).

EL Senior Safety Officer/Deputy Director (OU Safety Coordinator)

ROLE: In conjunction with the EL Director, The EL Senior Safety Officer (SSO) acts to carry out EL's environmental, safety and health (S&H) activities under the overall leadership and oversight of the EL Director.

RESPONSIBILITIES: The EL Senior Safety Officer is responsible for developing and implementing EL policies and procedures for environmental health, safety, hazard analysis and control within EL that conform to the requirements of the NIST *Occupational Safety and Health Policy* including:

- Ensuring the safety of EL operations and business practices by:
  - ensure implementation of EL's activity hazard review policies and procedures;
  - approval of RHI 3 EL activity hazard reviews;
  - ensure EL's implementation of NIST-wide and other applicable safety procedures and practices (e.g., signage, chemical labeling and inventory, workplace safety inspections, emergency preparation and response);
  - making resource recommendations to the EL Director to address cross cutting EL safety issues and needs and continually improve safety performance; and
  - ensure thorough investigations and root cause analyses of all S&H incidents and near-misses and the implementation of both near-term and long-term corrective actions.
- Overseeing an internal website with EL - specific safety information that complements the

NIST Office of Safety, Health and Environment (OSHE) website.
- Ensuring the identification, availability, completion, and tracking of EH&S training by all EL staff and associates required by NIST and/or EL.
- Continually improving the safety culture and performance of EL through:
  - the Management Observation Process;
  - timely improvements to EL's EH&S policies and procedures;
  - evaluation and recognition of safety performance of managers, staff, and associates; and
  - assessments of EL's safety operations and business practices by qualified safety professionals.
- Periodically assessing the effective implementation of the EL Hazard Review program.,.

EL Safety Professional (SP)

ROLE: Proactively assist EL staff, associates and management in all aspects of EH&S and serving as a technical resource on occupational safety and health issues.

RESPONSIBILITIES: The EL Safety Professional (SP) is responsible for:

- Providing EL staff, associates and management with assistance in identifying and implementing hazard controls, appropriate required training, and needed upgrades to facilities and equipment.
- Assisting EL Staff to implement NIST Occupational Safety and Health Policy
- Participate in activity hazard assessments and the reviews in accordance with the EL Hazard Review and Approval Policy and Procedure .
- Organize and chair OU Level Hazard Review Committee reviews for EL for RHI 3 activities and submit recommendations to Deputy Director for approval.
- Tracking safety metrics and monitoring completion of required training, completion of activity hazard reviews, workplace inspection and corrective action data and other assigned action items.
- Serve as OU Admin for WIRS, MML Hazard review tool IRIS and SET.
- Ensure thorough investigations and root cause analyses of all S&H incidents and near-misses.
- Oversee the Workplace Inspection Program for EL and participate in safety inspections as needed.
- Represent EL on the Safety Advisory Council (SAC)
- Communicating safety information to EL DSRs

Division Chief

ROLE: Provide leadership in promoting a positive safety culture throughout the Division, and implement, maintain, and continually improve the effective, proactive execution of the safety management system at the Division level.

RESPONSIBILITIES: The Division Chief is responsible for:

- Ensuring Division implementation of NIST-wide and EL safety procedures and practices, (including hazards signage, chemical labeling and inventory, and activity hazard reviews, space inspections, and emergency preparation and response).
- Committing Division resources as necessary to ensure the health and safety of EL staff and associates and continually improve safety performance.
- Promoting and communicating a safety culture throughout the Division that embodies and exemplifies safe work practices.
- Ensuring effective communication of necessary safety and health information to Division staff

and associates.

- Informing the EL Director and Deputy Director of any significant incident or injury as soon as practically possible, (see details in Section 4.4). and ensuring that incidents and investigations are reported through IRIS in a timely manner.
- Ensuring that reported incidents and near misses are investigated, appropriate actions taken, and lessons shared as appropriate.
- Actively overseeing that safety training is made available to enable staff and associates to safely perform their jobs before they are exposed to hazards associated with their work assignments, and ensuring the completion and tracking of EH&S training by Division staff and associates as required by NIST and/or EL.
- Making effective appointments of Division staff to key collateral EH&S positions, as applicable: Division Safety Representative, Division Laser Safety Representative, Radiation Source Custodians, Radiation Source Users, Chemical Inventory Database Manager, and Evacuation Coordinators.
- Ensuring that Division staff and associates are aware of and perform EH&S responsibilities (including stopping work in case of unsafe practices or conditions) in a timely manner, and that the performance agreements of Division staff reflect their safety responsibilities and performance expectations.
- Ensuring that safety performance is adequately evaluated and recognized.
- Regularly monitoring, audits, reviews, and analyses of the Division safety performance and culture.
- Ensuring that event-driven activity hazard reviews occur as required in accordance with the EL Hazard Review and Approval Policy and Procedure
- Reviewing RHI 2 and RHI 3 hazard review documentation in accordance with requirements, ensuring that the hazards have been properly identified and characterized by the Group Leader and Activity Leader and that the assigned severity and RHI are consistent with EL requirements (approval signifying that the RHIs associated with the activity represent an acceptable level of risk).
- Participating in project/activity Management Observation Process (MOP) visits as necessary (Each lab must have a MOP once a year with visits shared between DC, Director and Deputy Director as further detailed in the EL MOP Procedure).
- Ensuring implementation of applicable OSHE sub-orders in a timely manner.
- Ensuring that labs and offices within the division are inspected in accordance with the EL Workplace Inspection Program Procedure.
- Conducting MOPs on a monthly basis and ensuring all Division labs are visited once a year with lab staff.

Group Leader or Office Chief

ROLE: Provide leadership in promoting a positive safety culture throughout the Group/Office, and implement, maintain, and continually improve the effective, proactive execution of the safety management system at the Group/Office level.

RESPONSIBILITIES: Group Leaders and Office Chiefs are responsible for:

- Promoting and communicating a safety culture throughout the Group/Office that embodies and exemplifies safe work practices.
- Ensuring effective communication of necessary safety and health information to Group/Office staff and associates, including:
    - providing this memorandum (EL Management Memo #1) to all new employees and associates within two days of their arrival; and

- o ensuring that all new staff and associates are provided a tour of all appropriate lab space(s) in which he/she will work, that includes a discussion of any potential hazards and associated control measures (e.g., personal protective equipment, standard operating procedures, required training) as soon as possible after arrival and before appointee begins work in that space(s).Ensuring that Group/Office staff and associates are aware of and perform EH&S responsibilities (including stopping work in case of unsafe practices or conditions) in a timely manner, and that the performance agreements of Group staff reflect their safety responsibilities and performance expectations.
- Actively overseeing that safety training is made available to enable Group/Office staff and associates to safely perform their jobs <u>before</u> they are exposed to hazards associated with their work assignments, and ensuring the completion and tracking of S&H training by Group/Office staff and associates as required by NIST and/or EL.
- Ensuring that safety performance is adequately evaluated and recognized.
- Regularly monitoring, audits, reviews, and analyses of the Division safety performance and culture.
- Reporting all EH&S incidents and near misses to the Division Chief as soon as practically possible
- Submitting an initial incident report in the NIST Safety Incident Reporting Information System (IRIS), within two calendar days of any accident or injury, and a Final Incident Investigation Report within 20 business days; investigating, determining root cause, and implementing near-term and long-term follow up corrective actions as necessary.
- Taking action to correct unsafe working conditions within ability of Group/Office resources or escalating to upper management. Ensuring that all potentially hazardous activities within the Group have been reviewed in accordance with EL Hazard Review and Approval Policy and Procedure (including predefined research activities; routine maintenance or service of equipment or instruments; ad hoc use of equipment or instruments; construction, building or facility renovations; and/or transport, handling, or disposal of potentially hazardous materials, supplies or equipment).

With regard to ensuring the safety of workspaces within the Group, the Group Leader is responsible for:

- Appointing Workspace Contacts for all non-office or office-like spaces where Group activities take place.
- Completing Work Space safety inspections in accordance with EL Workplace Inspection Program Procedure and NIST S 7101-26 Workplace Inspection Program

Activity Leaders/PI’s

<u>ROLE</u>: Lead activities assigned by the Group Leader in compliance with all NIST and EL EH&S policies and procedures.

<u>RESPONSIBILITIES</u>: Activity Leaders/PI’s are responsible for:

- Fully implementing EL Hazard Review and Approval Policy and Procedure by:
    - o Delaying all activities until (1) the hazard review has been approved at the required levels of NIST/EL management, (2) all project staff members and associates have completed needed safety training, and (3) all required controls are in place, all “Users” of the hazard review are authorized by the group leader.
    - o Identifying all potential hazards associated with a given project activity and taking an active part in hazard reviews as necessary.
    - o Ensure that all potentially hazardous activities under the have been reviewed.
    - o Notifying line management of any planned changes in project activities that could

trigger the need for re-review.

  - Assisting the Group Leader to ensure that all required engineering controls, administrative controls, and PPE requirements are implemented and that all activities within their projects are in compliance with activity hazard review requirements.

Division Safety Representative (DSR)

ROLE: Support Division safety efforts including making contributions to the planning, development, and implementation of the NIST and EL Hazard Review policies and procedures and serving as a resource for Division staff and associates with regard to EH&S issues.

RESPONSIBILITIES: Division Safety Representatives are responsible for:

- Acting as liaison and coordinating with the EL Safety Professional and NIST OSHE on Division EH&S issues.
- Assisting Division management in investigating and documenting accidents, injuries, and near misses.
- Assisting supervisors with onboarding of new staff and associates, as requested, including:
  - ensuring that all new staff and associates are provided a tour of all appropriate lab space(s) in which he/she will work, that includes a discussion of any potential hazards and associated control measures (e.g., personal protective equipment, standard operating procedures, required training) as soon as possible after arrival and before appointee begins work in that space(s).
- Serving as Lead Safety Inspector and supporting implementation of the NIST Workplace Inspection Program for the Division
- Communicating information on identified hazards, alerts, precautions, and required corrective actions throughout the Division.
- Assisting the Division Chief with Division safety meetings and associated reporting.
- Assisting supervisors with the evaluation and recognition of safety performance, as requested.
- Assisting supervisors with actions to improve safety performance.
- Assisting in developing, implementing, and communicating Division, EL, and NIST safety policies and programs.
- Assisting supervisors in coordinating responses to employee occupational health and safety related complaints and concerns within Division.
- Participating in activity hazard reviews in accordance with EL Hazard Review and Approval Policy and Procedure .
- Assisting Division Chief with maintaining Division files for injuries, departmental safety meetings, hazard corrections, employee safety training, and Safety Data Sheets if applicable.

Workspace Contact

ROLE: Coordinate and monitor activities and operations in their assigned workspace(s) and serve as the point of contact for workspace S&H issues.

RESPONSIBILITIES: Developing and ensuring enforcement of access requirements for assigned Work Spaces.

- Participating in safety inspections of assigned workspaces with the Lead Inspector and OSHE.
- Coordinating activities among activity participants conducting work in the space they manage as well as in adjacent workspaces.

- Working with the Division Chemical Inventory Database Manager to ensure that the chemical inventory is correct, hazardous materials have satisfactory safety controls in place, and all excess and unused chemicals are disposed properly and in a timely manner.
- Working with Radiation Source Custodians to ensure that all radioactive sources are properly accounted for and secured.
- Ensuring that door signs for assigned workspace(s) conform to NIST Hazard Signage Program requirements and that the information is updated annually for laboratories.
- Ensuring that routine PPE as determined by the space hazard review (e.g., safety glasses, hard hats) are available as appropriate (including for visitors).
- Reviewing hazard review documentation as required to determine if the physical location(s) in which the activity is to be conducted is appropriate and adequate for the activity (taking into account security and access control, quantities and classes of hazardous materials, containers and storage for hazardous wastes, ventilation, fire and life-safety systems, emergency response equipment including eyewashes and safety showers, utilities, compatibility with materials of construction, and location on the site, as applicable).
- Conducting compatibility assessments against all activities currently approved for the space (and when applicable, neighboring spaces) to identify any potentially negative or antagonistic interactions, taking into account both planned operations and off-normal conditions that could reasonably be expected to occur.
- Monitoring workspace activities to ensure that specified hazard control requirements for work in the assigned space are being met, including good housekeeping practices.

EL Hazard Review Committee (HRC) Member

ROLE: Contribute to the effective operation of the EL Hazard Review Committee (HRC) and its role in implementing the EL safety management system.

RESPONSIBILITIES: EL Hazard Review Committee Members are responsible for:

- Attending HRC meetings when called by the HRC Chair.
- Participating in activity hazard reviews and other related activities as assigned by the HRC Chair.
- Providing technical advice within their area of expertise to as warranted.

Building Facilitator

ROLE: Oversee and manage activities of building evacuation coordinators

RESPONSIBILITIES: The Building Facilitator is responsible for:

- Overseeing the building Evacuation Coordinators, ensuring that all areas are covered, assignments are filled, and lists are current.
- Working with Activity Leaders, Project Leaders and DSRs to identify and maintain lists of critical experiments/activities within the building and informing NIST Fire Protection Group and/or Emergency Services as appropriate.
- Working with Activity Leaders, Project Leaders and DSRs to identify building activities where possible unusual/extreme hazardous conditions could exist during an emergency and notifying NIST Fire Protection Group / Emergency Services as appropriate.
- Serve as a liaison between NIST Fire Protection Group / Emergency Services and the Evacuation Coordinators and EL management.
- Communicating construction, maintenance activities and scheduled utility outages to building occupants.

Evacuation Coordinator

ROLE: Coordinate the orderly evacuation of their assigned areas of responsibility.

RESPONSIBILITIES: The Evacuation Coordinator is responsible for:

- Maintaining a current Evacuation Coordinator Checklist for his/her assigned area.
- Maintaining a current list of individuals with special needs within his/her assigned area.
- Coordinate efforts with assigned backup person as necessary.
- During an evacuation:
    - Maintaining order and providing instruction to evacuees.
    - Completing the Evacuation Coordinator Checklist for his/her assigned area and submitting it to the NIST Fire Protection Group / Emergency Services staff on scene.
    - Assisting evacuees and those with special needs where possible without jeopardizing his/her own safety.

CIMS (Chemical Inventory Management System) Administrator

ROLE: Oversee the NIST Chemical Inventory Management System (CIMS) for the Engineering Laboratory

RESPONSIBILITIES: The CIMS Administrator is responsible for performing the following tasks as necessary:

- Provide support to OU CIMS Power Users.
- Perform CIMS Power User responsibilities, when applicable.
- Provide updates to OU/division CIMS Power Users, Employee Users, and Associate Users regarding guidance or changes to the NIST hazardous chemical inventory database, when provided by OSHE or the OU.
- Organize the annual Reconciliation Phase with OU/division CIMS Power Users, Employee Users, and Associate Users.
- Request NIST CIMS Administrator assistance as needed for user account promotion and training, questions or comments pertaining to the CIMS application.

CIMS Division/Office Power User

ROLE: Serve as the Division representative and administrator for the NIST Chemical Inventory System (CIMS).

RESPONSIBILITIES: The CIMS Power User is responsible for performing the following tasks as necessary:

- Create/edit container, location, material, package, reconciliation, and vendor records for records associated with divisions assigned to the division.
- Create/edit/execute reports;
- Perform container reconciliations for divisional locations;
- Transfer/dispose containers assigned to divisional user accounts.

- Ensure that each hazardous chemical container associated with his/her OU/division has been entered in CIMS in a timely manner, when applicable.
- Ensure for each hazardous chemical container assigned to his/her OU/division that a CIMS container label has been printed and provided to the associated container owner.
- Ensure that each hazardous chemical container record associated with his/her OU/division has been:
  - Updated in CIMS in a timely manner to ensure that the associated chemical owner and storage location information is current; or,
  - Marked "disposed" in CIMS in a timely manner, if the chemical container has been disposed of in accordance with the requirements of the NIST Hazardous Waste Accumulation program or if the chemical contents of the container are no longer present at NIST.
- Ensure that each hazardous chemical storage location record associated with his/her OU/division has been entered into CIMS in a timely manner and has been updated, when applicable.
- Participate in the annual Reconciliation Phase (To be performed during the 1st quarter of each fiscal year and completed prior to December 31st each year).
  - Perform any needed updates to CIMS records to ensure that records accurately reflect the identity, quantity, owner, and storage location for each hazardous chemical container stored in/owned by his/her OU/division, when applicable.
- Perform updates to CIMS records in timely manner, when requested by OU/division CIMS users.
- Provide CIMS support to other CIMS Power Users in his/her OU/division.
- Correct any erroneous information in CIMS, if found and not affecting other CIMS container, location, material, or user records.
- Notify Line Management in a timely manner when a new storage location record needs to be added to the CIMS database to:
  - Ensure that the new storage location has been reviewed and approved for hazardous chemical storage prior to creating the new location record in CIMS.
- Notify Line Management in a timely manner (e.g., 2 weeks prior to departure) that a CIMS user will be permanently leaving NIST to:
  - Ensure that the hazardous chemical containers owned by the departing CIMS user will be re-assigned to a new owner or disposed of in accordance with the requirements of the NIST Hazardous Waste Accumulation program;
  - Ensure that CIMS records (e.g., user, container, and location) associated with the departing CIMS user will be updated in CIMS; and
  - Ensure that CIMS responsibilities assigned to the departing CIMS user will be re-assigned, when applicable.
- Notify the CIMS Administrator (Michael Dinderman) in a timely manner regarding any questions or comments pertaining to the CIMS application.

CIMS User

ROLE: Use material defined as hazardous during their assigned duties.

RESPONSIBILITIES: The CIMS User is responsible for performing the following tasks as necessary:

- Review container, location, material, and container CIMS records for accuracy.
- Execute reports.
- Ensure that each hazardous chemical container that he/she is responsible for has been inventoried in CIMS, when applicable.
- Ensure that each hazardous chemical container inventoried in CIMS and that he/she is

responsible for has been labeled with a CIMS label that contains accurate and current information.

- Participate in the annual Reconciliation Phase (To be performed during the 1st quarter of each fiscal year and completed prior to December 31st each year).
- Notify Line Management in a timely manner when a new storage location is to be created in CIMS to:
    - Ensure that the new storage location will be reviewed and approved for hazardous chemical storage prior to having the new location record created in CIMS.
- Notify Line Management and the CIMS OU Administrator in a timely manner (e.g., 2 weeks prior to departure) when a CIMS user will be permanently leaving NIST to:
    - Ensure that the hazardous chemical containers owned by the departing CIMS user will be re-assigned to a new owner or disposed of in accordance with the requirements of the NIST Hazardous Waste Accumulation program;
    - Ensure that CIMS records (e.g., user, container, and location) associated with the departing CIMS user will be updated in CIMS; and,
    - Ensure that CIMS responsibilities assigned to the departing CIMS user will be re-assigned, when applicable.
- Notify the CIMS OU Administrator to:
    - Request a CIMS user account (Associate and Employee roles) [Requests for higher roles must be forwarded to the NIST CIMS Administrator].
- Notify the OU/division CIMS Power User in a timely manner when a hazardous chemical is to be purchased by or received at his/her NIST work area.
- If the hazardous chemical is not currently in the CIMS database, then the employee responsible for the hazardous chemical container shall:
    - Ensure that the vendor specific MSDS/SDS will be readily available in the work area where the hazardous chemical will be stored;
    - Communicate the information contained in the vendor specific MSDS/SDS to all workers in the work area where the chemical will be stored to inform anyone who may be exposed to the chemical of the hazards they may be exposed to; and,
    - Provide the vendor specific MSDS/SDS to the OU/division CIMS Power User so that it may be uploaded into the CIMS database.
- Notify the OU/division CIMS Power User when a CIMS-inventoried hazardous chemical container that he/she owns will be moved to a new storage location and ensure that the CIMS container record has been updated to reflect the correct storage location (Note: See above bullet regarding communicating chemical hazards to workers who may be exposed to the hazardous chemical.).
- Notify the OU/division CIMS Power User in a timely manner when a CIMS-inventoried hazardous chemical container that he/she owns has been disposed of or completely used and ensure that the associated CIMS container record has been marked "disposed".
- Notify the OU/division CIMS Power User in a timely manner when a CIMS-inventoried hazardous chemical container that he/she owns will change ownership.
- Notify the OU/division CIMS Power User to request a CIMS container label, when applicable.

Radiation Source Custodian

ROLE: Control, use, or otherwise manipulate ionizing radiation sources and to be responsible for the primary control and accountability of ionizing radiation sources.

RESPONSIBILITIES: The Radiation Source Custodian is responsible for:

- Working with Workspace Managers, Activity Leaders and Project Leaders to contribute to the development of standard safe operating procedures (including emergency preparation, response, and evacuation procedures) to eliminate, control, or provide personal protection

from safety risks associated with ionizing radiation sources that may expose employees, associates, or visitors to hazards, in accordance with [NIST Directive 7200.00 - Ionizing Radiation Safety] including:
  - Ensuring, prior to any use of a source, that Radiation Source Users are informed of the terms and conditions specified in the NIST-364, Radioactive Material Request form and associated documents, and in any applicable NIST-365, Change to Radioactive Material Request forms , specific to the use of the source.
  - When appropriate, initiating requests using the NIST-365 form for changes in the utilization of radioactive material, and/or in Radiation Source User(s), use location(s), or storage location.
  - Coordinating with the Gaithersburg Radiation Safety Division any transfers of custodianship, changes in utilization, receipt of materials, shipments of sources to off-site entities, or disposal of waste.
  - Authorizing sources for use only by RSO authorized Radiation Source Users approved by the EL Director.
- Participating in routine audits performed by the Gaithersburg Radiation Safety Division to:
  - ensure that ionizing radiation sources on their inventory are used safely and in accordance with regulatory and NIST radiation safety program requirements;
  - ensure that their sources are used by only approved Source Users with approved procedures having approved hazard reviews; and
  - provide appropriate oversight of their Source Users to ensure their sources are used safely and in accordance with all requirements.
- Informing their supervisor and the EL Senior Safety Officer of any known discrepancies in the inventory or practices that deviate from NIST Health Physics guidance.
- Notify the NIST Radiation Safety Office (RSO) and EL Management of any known incidents involving radioactive materials.
- If requested, serve as an OU representative of the NIST Ionizing Radiation Safety Committee (IRSC)[33].

Radiation Source User

ROLE: Control, use, or otherwise manipulate ionizing radiation sources in the pursuit of measurement science to accomplish the EL agenda.

RESPONSIBILITIES: The Radiation Source User is responsible for:

- Using, handling, or manipulating only sources for which they have been approved by the NIST Radiation Safety Officer (RSO) or designee and authorized by the EL Director, in compliance with NIST Order 7201 - Ionizing Radiation Safety – Radioactive Material and Ionizing-Radiation-Producing Machines, NIST Policy 7200 - Ionizing Radiation Safety Policy.
  - Using ionizing radiation sources in a manner that complies with the terms and conditions specified in the NIST-364 form and associated documents, and any applicable NIST-365 forms, specific to the source being used, including use protocols and hazard mitigation and emergency response plans.
  - When appropriate, initiating requests using the NIST-365 form for changes in the utilization of radioactive material, and/or in Source User, use location(s), or storage location.
  - Maintaining the security of, and access to, ionizing radiation sources; and recognizing and responding appropriately to incidents involving ionizing radiation sources to prevent the spread of contamination.
  - Identifying to their respective Source Custodian any issues that have, or may have,

radiological safety significance or regulatory compliance implications.
  - Certifying that all relevant NIST and EL policies, procedures and regulations regarding ionizing radiation sources have been read, understood, and are followed.
  - Notify the NIST Radiation Safety Office (RSO), EL Source Custodian and EL Management of any known incidents involving radioactive materials.

Division Laser Safety Representative

ROLE: Serve as the Division safety contact for activities and operations involving class 3 and class 4 lasers and laser systems, and to provide leadership and act as a consultant to staff with regard to the safe use of lasers.

RESPONSIBILITIES: The Division Laser Safety Representative is responsible for:

- Supporting actions needed in the Division to achieve established laser safety performance objectives, including supporting the implementation of the NIST Laser Safety Program[35].
- Communicating NIST's safety culture and values and EL's policies and procedures regarding the use of lasers to staff and associates.
- Supporting the Division's efforts to comply with applicable laser safety regulations, policies, directives, and other requirements, including:
  - informing the NIST Laser Safety Officer (LSO) of any known changes in the division's laser inventory;
  - requests/arranges review of new (or location change) class 3B and 4 lasers/laser systems by the NIST LSO;
  - as part of the activity hazard review process, reviewing safety plans for Class 3B and 4 lasers and laser systems as well as lab environment to ensure that all requirements in NIST S 7101-72 Laser Safety sub-order are followed;
  - provides Division hands-on laser safety training to new laser users; and
  - working with the relevant Work Space Contact and Activity Leaders, contribute to the development of standard operating procedures (including emergency preparation, response, and evacuation procedures) to eliminate, control, or provide personal protection from safety risks associated with laser systems that may expose staff and associates to hazards.

NIST Executive Safety Council (ESC) OU Representative

ROLE: To assure the effective implementation of the NIST Order 7100.01, Occupational Safety and Health (OSH).

RESPONSIBILITIES: The NIST ESC OU Representative is responsible for actively participating and providing input to the Committee including:

- Participating in the development, deployment, and maintenance of OSH directives in accordance with the requirements of the OSH program development, and maintenance program.
- Supporting the NIST Director and Associate Directors in conducting management reviews.
- Identifying to the NIST Director and Associate Directors opportunities for improvement and the need for possible changes to the OSH management system.
- Establishing and maintaining OSH objectives and plans for achieving those objectives, taking into account the results of management reviews.
- Reviewing and revising OSH objectives and plans for achieving those objectives no less frequently than every two years, taking into account:

    - compliance with regulatory and other requirements;
    - OSH risks;
    - incident history;
    - technological options;
    - financial, operational, and business requirements; and
    - the views of relevant interested parties.
- Providing a forum for sharing OSH-related information pertinent to the OSH management system and for identifying and addressing issues warranting NIST-level attention.
- Providing a venue for members to provide input and feedback on the plans, priorities, programs, and services of OSHE.
- Advising the NIST Director and Associate Directors on OSH-related issues warranting their attention.

NIST Safety Advisory Council (SAC) OU Representative

ROLE: To foster top-down and bottom-up communication across NIST OUs and with NIST OSHE regarding all safety related topics.

RESPONSIBILITIES: The NIST SAC OU Representative is responsible for:

- Raising important safety issues or concerns to NIST management and the NIST Executive Safety Committee (ESC).
- Disseminating important safety information to their OU management, for ultimate dissemination to all staff and associates.
- As requested, work with OSHE staff to review and roll-out new or updates policies and procedures, regulatory requirements, best work practices, training opportunities, etc., in consultation with OU management, fellow DSRs, and appropriate subject-matter experts.
- As requested, assist the Divisions/OUs to identify candidates and/or subject matter experts to participate in NIST safety working groups concerned with specific safety activities, and review and provide feedback on proposed and implemented policies and procedures.
- Communicate information to OU DSRs
- Assist in planning and conducting DSR Summits

NIST Laser Safety Advisory Committee (LSAC) OU Representative

ROLE: To assure the effective implementation of the NIST laser-safety policy and program on an ongoing basis.

RESPONSIBILITIES: The NIST LSAC OU Representative is responsible for:

Actively participating and providing input to the Committee in order to:

- Report annually to the NIST Chief Safety Officer and NIST Deputy Director on current program status, the past year's accomplishments, long-range plans, and needs for improving or updating the NIST laser-safety program.
- Advise the NIST Chief Safety Officer and subordinate managers and personnel on matters pertaining to laser-safety policy and practices to ensure compliance with ANSI standards and laser-safety best practices.
- Assist NIST Divisions with technical information and guidance related to laser safety.
- Provide a pool of laser-safety experts to participate in laser-safety inspections; to review and

suggest corrections for inspection deficiencies; to take part in the investigation of laser injuries, accidents, and near misses; and to assist with laser calculations and evaluations.
- Provide a forum for laser-safety personnel to assist one another with laser calculations and evaluations and to share lessons learned, best practices, and training opportunities.
- Develop, define, and communicate training procedures and opportunities for Division Laser Safety Representatives (DLSRs) and assist DLSRs in identifying and communicating training opportunities for other personnel.

NIST Nanoparticle Safety Committee (NSC) OU Representative

ROLE: The role of the Nanoparticle Safety Representative (NSC) OU Representative is to monitor and to advise on activities and operations using nanomaterials within EL.

RESPONSIBILITIES: The NSC OU Representative is responsible for:

- Actively participating and providing input to the NSC.
- Working with Work Space Contacts and Project Leaders to contribute to the development of standard safe operating procedures (including emergency preparation, response, and evacuation procedures) to eliminate, control, or provide personal protection from safety risks associated with nanomaterials that may expose employees, associates, or visitors to hazards, in accordance with regulatory documents (NIOSH, EPA, CDC, etc.) and NIST OSHE Dispersible Engineered Nanomaterials sub-order including:
  - Identifying training, guidance, equipment and facility needs to:
    - maintain the security of and access to nanomaterials within EL,
    - perform nanomaterials work safely; and
    - recognize and respond appropriately to incidents/accidents involving nanomaterials to prevent the spread of contamination.
  - Coordinating with the Safety Health and Environment Division and members of NIST's Nanoparticle Safety Committee on any new applications using nanomaterials, changes in utilization, shipments of nanomaterials to off-site entities or disposal of waste.
  - Ensuring that nanomaterials received from outside companies are logged into CIMS.

Appendix B - EL Management Observation Process

The purpose of this document is to provide additional guidance on responsibilities of EL line managers on the **NIST 7101-05 Management Observation Process 080819.docx** . This process applies to the EL Director and all subordinate line managers.

REQUIREMENTS

All EL line managers shall participate in scheduled MOPs to ensure that there is communication with staff on safety issues in their assigned workspaces at least annually. MOP's should be conducted for both lab and office spaces.

Director and Deputy Director shall schedule 6-12 MOPS each annually at the beginning of the fiscal year covering all of the EL Divisions. This should be done in coordination with Division Chiefs to avoid overlapping of MOPS.

Division Chiefs and Group Leaders shall schedule MOPS for the remainder of their EL occupied spaces occupied by staff.

Scheduling and Documentation - MOP visits for labs and lab like spaces shall be scheduled separate from safety inspections and documented using the spreadsheet linked below.
https://docs.google.com/open?id=16biDbpJWk_kgUk4w8ZTSVyP5mNC2XPdn4FJ4dC079kc&authuser=laslo.varadi%40nist.gov&usp=drive_fs
MOP visits for offices should be conducted in conjunction with annual office inspections and documented using the WIRS safety inspection application https://wirs.nist.gov/ .

METHODOLOGY

(1) MOPs are NOT workplace safety inspections but are visits to promote open discussion without fear of reprisal among staff and managers regarding safety of operations and workspaces, and should lead to better understanding of the safety aspects of the specific work being conducted and the workplace in which the work is conducted. Note-taking should be kept to a minimum and only cover follow-up on safety items or concerns.

(2) MOPs shall be performed in work locations where managers can observe (as allowed by the relevant FLHR) and discuss work practices and workplace conditions.
- For labs and lab-like spaces, ensure the hazardous work is covered by a hazard review and discuss adequacy of hazard mitigation.
- Where work is primarily office-based, managers should discuss implementation of office safety and general safety requirements.
- When a weakness or poor practice is observed, managers should recommend or require, as appropriate, safety improvements without taking punitive measures.
- Managers shall recognize and promote best safety practices and behaviors observed and provide positive feedback to MOP participants.

MOP TOOLS

The following are some useful tools to facilitate performance of effective MOPs.

HR Guide: https://rise.articulate.com/share/KOsTjo4skNTlNCcFYrWIxySAm_IWBFQM
Office Environment Guide: https://rise.articulate.com/share/XKXCetcHk7BeTq6uLqSzSrSk_gGo-h7B
MOP Questions (Optional): NIST Safety Cards - Examples of questions to use during a MOP.pdf

Appendix 6.1.2: EL Safety Critical Elements for Line Managers and Staff

Division Chief/Office Chief Critical Element
Objective: Provide leadership in promoting a positive safety culture throughout EL and implement, maintain, and monitor an effective, proactive execution of the safety management system at the Division/Office level.
Weight: 2

Required Activities/Results:	Success Measures:
Safety Culture - Promote, encourage and communicate a safety culture throughout the Division, which ensures safe work practices. • Promote communication of safety culture • Communicate NIST/EL safety policies • Promote safe work practices by reviewing specific safety incidents	Supervisor consistently finds an improvement in promotion, encouragement, and communication of safety culture as evidenced by: • Quality safety discussions at 75% of division meetings • Quarterly meetings held to review safety NIST/EL safety policies • Quality reviews of 75% of all EL incidents and 75% of NIST incidents that are immediately relevant to Division work • Funding is made available to execute additional safety controls of hazards, and improve work environments ergonomically.
Training - Actively oversee safety training, including making resources available to enable staff and associates to perform their jobs safely.	Supervisor consistently finds an improvement in safety training as evidenced by: • Position appropriate training courses reviewed and identified for each group member at least once per year. • Timely availability and completion of safety training by Division staff as required to meet the requirements of the EL Safety Management System. • Evidence that staff is held accountable to meet training requirements necessary to perform their duties resulting in 85% of staff trained on a timely basis. • Appropriate funding is made available to accomplish necessary safety training.
Accountability - Ensure that safety performance is adequately evaluated and recognized. • all safety performance elements contain appropriate safety responsibilities and measures • Evaluate and recognize group and division staff safety participation	Supervisor consistently finds an improvement in safety accountability as evidenced by: • Division staff safety contributions are reviewed, and top 3 performers are recognized, • 90% of all initial investigation reports are filed within 3 business days. • 90% of all incident investigations are completed and entered into IRIS within 20 business days.

Hazard Identification and Control - Ensure that hazard identification and control system responsibilities are performed in the Group/Team, including review by the OU Hazard Review Committee, when necessary. • Hazards are identified and risks are assessed for work activities (job hazard analysis). • Safety incidents and corrective actions are reported timely to supervisor. • Lab inspections are conducted regularly • Management Observation Process (MOP) is conducted annually for all (STRS and OA) projects led by division staff	Supervisor consistently finds an improvement in hazard identification and control as evidenced by: • Corrective actions are taken within 24 hours for acute risks and 30 days for chronic risks to prevent future incidents. Work stoppages are utilized, when appropriate. • Unless otherwise justified, 90% of all corrective actions will be completed within timeframe identified by incident investigation. • Incidents and near misses are investigated, appropriate actions taken, and lessons shared at the ELMC, and throughout EL, as appropriate. • Incident investigations to determine root cause are consistent with established policies and completed in a timely manner. • Division Chief implements at least one new idea to encourage incident reporting. • Lab inspections happen quarterly at a minimum. Unless otherwise justified, corrective actions are taken and documented on 90% of all items cited for improvement during lab inspections • Unless otherwise justified, corrective actions are taken and documented on 90% of all items cited for improvement during MOPs
Continuous Improvement - Contribute to implementation of the Division and/or OU safety management system, as required; Contribute to OU/Division safety analyses and reviews for the continuous improvement of safety performance.	Supervisor consistently finds that: • Useful input to the safety management system is submitted in a timely manner; contributions to reports and reviews are complete and of high qualify, submitted in a timely manner, and support continuous improvement. • Evidence of effective and efficient implementation of the safety management system.
Security - The baseline security requirements in the NIST Security Policy are met.	Actions are taken to ensure at least 95% of their employees and associates complete training on the baseline security requirements by January 2018 and consistently demonstrate the baseline security requirements in the performance of their duties. Employee consistently demonstrates the baseline security requirements in the performance of their own duties.

Group Leader Critical Element

Objective: Provide leadership in promoting a positive safety culture throughout EL and implement, maintain, and monitor an effective, proactive execution of the safety management system at the Group level.

Weight: 2

Required Activity/Results	Success Measures
Safety Culture - Promote, encourage and communicate a safety culture throughout the Division, which ensures safe work practices.	Supervisor consistently finds that: • Frequent communications to staff and associates regarding the importance of safety have occurred. • Employee survey results show employees feel safe at work, and understand and support safety initiatives.
Training - Actively oversee safety training, including making resources available to enable staff and associates to perform their jobs safely.	Supervisor consistently finds that: • Appropriate position-based safety training has been made available. • Group/Team staff and associates have completed offered safety training within assigned deadlines.
Accountability - Ensure that safety performance is adequately evaluated and recognized.	Supervisor consistently finds that: • Employee performance plans contain appropriate safety responsibilities and measures; performance is evaluated commensurate with stated guidelines and measures. • Positive, proactive steps toward supporting safety rules and practices are appropriately rewarded and reinforced.
Operations - Ensure that staff and associates in the Group/Team are aware of and implement Environmental Safety and Health (ESH) responsibilities, including stopping work because of unsafe practices or conditions; conduct and/or coordinate regular workplace inspections.	Supervisor consistently finds that: • Clear and timely safety expectations have been delineated. • Preventative measures targeted toward mitigating hazards and risk have been instituted. • Staff and associates participate in regular safety meetings. • Work operations are continually monitored and updated for compliance. • Safety walks are conducted and completed per established NIST/OU/Division guidelines. • Regular workplace safety inspections and associated reports are timely; safety concerns are discovered and properly addressed.

Risk Assessment - Ensure that hazard identification and risk assessment system responsibilities are performed in the Group/Team, including review by the OU Hazard Review Committee, when necessary.	Supervisor consistently finds that: • Hazards are identified and risks are assessed for work activities (job hazard analysis). • Safety incidents and corrective actions are reported timely to supervisor. • Safety incidents are documented timely per established NIST procedures. • Incidents and near misses are investigated, appropriate actions taken, and lessons shared as appropriate. • Incident investigations to determine root cause are consistent with established policies and completed in a timely manner. • Corrective actions are swiftly taken to prevent future incidents and to ensure safe work practices.
Planning, Monitoring and Reporting - Contribute to implementation of the Division and/or OU safety management system, as required; Contribute to OU/Division safety analyses and reviews for the continuous improvement of safety performance.	Supervisor consistently finds that: • Useful input to the safety system is submitted in a timely manner. • Contributions to reports and reviews are complete, of high quality, submitted in a timely manner, and support continuous improvement.

ZP – Non-Supervisory

Objective: Conduct research safely, actively support a positive safety culture throughout the Division, EL, and NIST, and work toward effective, proactively execute the safety management and security systems.

Weight: 1 - 2

Required Activity/Results	Success Measures
Safety Culture - Support the vision of a safety culture throughout the Division. Participate in regular monitoring and analyses of the Division safety practices and contribute to the overall safety culture.	Supervisor consistently finds that: • Ideas and suggestions for improving the organization's safety culture is provided to Division/OU in a timely fashion. • Responsibility for safety in the division is understood and demonstrated. • Commitment to safety in conducting job-related activities is demonstrated. • Organization's safety practices are modeled.
Training - Take appropriate safety training needed to accomplish job responsibilities and comply with NIST safety requirements.	Supervisor consistently finds that: • Appropriate training is identified and taken within established deadlines.
Incident Reporting- Promptly report incidents and near misses as well as unsafe and/or unhealthful working conditions or practices.	Supervisor consistently finds that: • Incidents and near misses are reported promptly; paperwork completed as requested and required.
Operations - Comply with Environmental, Safety and Health (ES&H) responsibilities for division, including stopping work in case of unsafe practices or conditions. Carry out all responsibilities of a staff member as provided in the EL ES&H R2A2s	Supervisor consistently finds that: • Work operations are continually monitored and updated for compliance. • Safety walks are conducted and completed per established NIST/OU/Division guidelines. • Relevant ESH responsibilities are accomplished within established deadlines and are compliant with established policies. • Evidence of carrying out additional responsibilities in a timely and useful manner • FLHRs and WSHRs are completed in a timely manner
Hazard Assessment - Systematically identify hazards and/or unsafe situations or practices and contribute to hazard control system responsibilities relevant to the job.	Supervisor consistently finds that: • Hazards and risks are identified; proper precautions are taken and controls followed • PPE requirements for the job are followed.

Contribute to implementation of the Division and/or OU safety management system, as required; Contribute to OU/Division safety analyses and reviews for the continuous improvement of safety performance.	Supervisor consistently finds that: • Useful input to the plan is submitted in a timely manner; contributions to reports and reviews are complete and of high qualify, submitted in a timely manner, and support continuous improvement.

ZT (non-supervisory), for all levels
Objective: Not stated in EL template.
Weight: Not provided in EL template.

Required Activity/Results	**Success Measures**
Safety Culture - Support the vision of a safety culture throughout the Division. Participate in regular monitoring and analyses of the Division safety practices and contribute to the overall safety culture. The vision of safety culture throughout the Division/OU is supported.	Supervisor consistently finds that: • New ideas and suggestions for improving the organization's safety culture are provided to Division/OU. • Responsibility for safety in the division is understood and demonstrated. • Commitment to safety in conducting job-related activities is demonstrated. • Organization's safety practices are modeled. • Employee consistently models the organization's safety practices and performs duties in accordance with NIST safety requirements. Incidents, near-misses, or unsafe working conditions or practices are promptly reported, when necessary, and follow-up paperwork is accurately completed as requested or required.
Training - Take appropriate safety training needed to accomplish job responsibilities and comply with NIST safety requirements.	Supervisor consistently finds that: • Appropriate training is identified and taken within established deadlines.
Incident Reporting- Promptly report incidents and near misses as well as unsafe and/or unhealthful working conditions or practices.	Supervisor consistently finds that: • Incidents and near misses are reported promptly; paperwork completed as requested and required.
Operations - Comply with Environmental, Safety and Health (ES&H) responsibilities for division, including stopping work in case of unsafe practices or conditions.	Supervisor consistently finds that: • Work operations are continually monitored and updated for compliance. • Safety walks are conducted and completed per established NIST/OU/Division guidelines. • Relevant ESH responsibilities are accomplished within established deadlines and are compliant with established policies.
Hazard Assessment - Systematically identify hazards and/or unsafe situations or practices and contribute to hazard control system responsibilities relevant to the job.	Supervisor consistently finds that: • Hazards and risks are identified; proper precautions are taken and controls followed • PPE requirements for the job are followed.

Planning, Monitoring and Reporting - Contribute to generation, dissemination, and implementation of the annual OU safety improvement plan.	Supervisor consistently finds that: • Contribution to the safety plan is complete, of high quality, and submitted within deadline provided by project leader.

Appendix 6.2.1: NIST S 7101.20: *Work and Worker Authorization based on Hazard Reviews*

National Institute of Standards and Technology • U.S. Department of Commerce

WORK AND WORKER AUTHORIZATION BASED ON HAZARD REVIEWS (“HAZARD REVIEW”)

NIST S 7101.20
Approval Date: 12/23/2020
Effective Date: 06/05/2020

1. PURPOSE

The purpose of this suborder is to define the requirements and associated roles and responsibilities for authorizing both hazardous activities (“work”) and workers based on a systematic level of work planning and control commensurate to the hazards, job complexities, and physical location, *i.e.*, based on hazard reviews.

2. BACKGROUND

a. This suborder describes NIST’s graded approach to managing the safety of a wide range of hazardous activities, from those that are relatively simple and routine to those that are highly complex one-time projects. The graded approach is based on the severity of the consequences of hazardous events or exposures to hazards and the likelihood of such events or exposures.

b. While this suborder primarily focuses on hazardous activities performed under normal and off-normal operating conditions, there are provisions for authorizing work and workers under abnormal operating conditions in which external factors may alter the risk assessment or present additional hazards to those directly associated with performance of the activity.

c. This suborder supersedes NIST Administrative Manual Subchapter 12.06, *Hazard Analysis and Control*.

3. APPLICABILITY

a. The requirements of this suborder apply to all activities conducted by NIST employees and associates as part of their assigned duties under normal operating conditions except for the following:

(1) *Common Everyday Tasks Performed Routinely by Members of the General Public at Work and Home and that Do Not Involve Extraordinary Hazards.* This exception recognizes that NIST staff members possess the knowledge, skills, and abilities to perform a wide variety of common everyday tasks safely without written hazard reviews. Examples of such common everyday tasks include working at a computer, reviewing documents, walking, climbing stairs, picking up objects, and using scissors or short step stools.

(2) *Inherently Low-Risk Activities.* This exception applies to activities that are considered to present low safety risks without NIST personnel having to implement any safety controls to mitigate those risks.[1,2] The following activities are considered to present low safety risks:

(a) Activities that could result in injuries requiring first aid but only infrequently; and

(b) Activities that could result in injuries requiring medical treatment beyond first aid but are very unlikely to do so.

Examples of inherently low-risk activities include calibrating a balance, preparing non-hazardous solutions, and using an optical microscope to examine non-hazardous samples.

b. The requirements of this suborder apply to any activity, regardless of the hazardous nature of the activity itself, when performed under abnormal operating conditions (see Section 2.b) where external factors may present hazards or pose additional risk beyond those associated with performance of the activity, except when:

(1) Following the general requirements and/or guidance associated with the abnormal condition provides sufficient protection from the hazards associated with the abnormal condition;

(2) No activity-specific instructions are needed to implement the general requirements and/or guidance associated with the abnormal operating conditions; and

(3) The activity-specific risks do not change as a result of the abnormal conditions.

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[1] This presumes that if such an activity involves the use of equipment with built-in safety features, these features do not require written safe work practices, are not easily defeated, and will not be intentionally defeated or separated from the equipment.

[2] The requirements of this suborder apply to any activity for which PPE is *required* to mitigate the activity's safety risks. They do not apply to the following uses of PPE: PPE required solely for entry into the space in which the inherently low-risk activity is conducted, not for protection from the hazards associated with the activity; PPE used *voluntarily* as an additional layer of protection; and PPE worn solely to protect equipment or materials.

c. The exemptions provided in Section 3a do not relieve NIST staff members or management from their responsibility to manage the safety risks associated with common everyday tasks and inherently low-risk activities. NIST focuses on these using a variety of mechanisms, including general safety training, safety-related communications, and incident awareness and reduction efforts. In addition, the exemptions do not relieve NIST of its responsibility to evaluate the compatibility of such activities with more hazardous activities in the same spaces.

4. REFERENCES

a. 29 Code of Federal Regulations 1910.132, Personnel Protective Equipment.

5. APPLICABLE OCCUPATIONAL SAFETY AND HEALTH (OSH) SUBORDERS

a. NIST S 7101.04: Safety and Health Requirements for Minors;

b. NIST S 7101.21: Personal Protective Equipment;

c. NIST S 7101.58: Respiratory Protection;

d. NIST S 7101.55: Hearing Protection;

e. NIST S 7101.22: Hazard Signage;

f. Other OSH suborders that contain sections focused on the identification, assessment, and mitigation (*i.e.*, control) of hazards in specific OSH areas, *e.g.*, chemical hazard communication, chemical management, cryogen safety, dispersible engineered nanomaterials, hearing protection, and magnetic-field safety, to name several; and

g. NIST S 7101.23: Safety Education and Training.

6. REQUIREMENTS

Requirements are provided for the risk-assessment methodology to be used in conducting hazard reviews; the content, conduct, and approval of hazard reviews; the authorization of work and workers; the re-review, and re-approval, of hazard reviews and the re-authorization of work that falls outside the scope of current hazard reviews; retraining and reauthorization of workers according to updated hazard reviews; records; activities involving workers from multiple OUs; and Organizational Unit (OU) implementing procedures. Appendix B illustrates the processes for authorizing work and workers and the role of hazard reviews.

a. Risk-Assessment Methodology

Procedures for implementing this suborder shall use the risk-assessment matrix in Appendix C as the basis for conducting risk assessments. Once a hazard has been identified, the risk of a hazardous event or exposure associated with that hazard shall be characterized, as indicated in Appendix C and below, by a Relative Hazard Index (RHI) based on the severity of the consequences of a hazardous event or exposure to a hazard and the likelihood of such an event or exposure.

(1) Severity of the consequences of a hazardous event or exposure to a hazard ("Severity")

(a) The severity categories in Appendix C provide qualitative measures of the consequences of the worst credible hazardous event (see definition of "Worst Credible Hazardous Event") or exposure associated with an identified hazard due to design inadequacies; procedural deficiencies; human error; environmental conditions; or system, subsystem, or component failure or malfunction. The severity categories that shall be used are:

i. CATASTROPHIC: Death or permanent disability; system or facility loss; major property damage, lasting environmental or public-health impact.

ii. SEVERE: Serious injury; temporary total disability (more than 3 months); subsystem loss or significant facility/property damage, temporary environmental or public-health impact.

iii. MODERATE: Medical treatment beyond first aid; lost workdays; more than slight facility/property damage; external reporting requirements; more than routine clean-up.

iv. MINOR: First aid or minor medical treatment; negligible or slight facility/property damage; no external (outside NIST) reporting requirements, routine cleanup.

(2) Likelihood of a hazardous event or exposure ("Likelihood")

(a) The likelihood categories in Appendix C broadly estimate the probability that a hazardous event or exposure involving an identified hazard will occur in carrying out an activity. The likelihood categories that shall be used are:

i. FREQUENT: Likely to occur frequently or repeatedly.

ii. PROBABLE: Likely to occur multiple but infrequent times.

iii. OCCASIONAL: Likely to occur at some time.

iv. REMOTE: Possible, but not likely to occur.

v. IMPROBABLE: Very unlikely: can reasonably be assumed not to occur.

To the extent practical, likelihood should be assigned based on research, analysis, experience, or evaluation of historical safety data from work with similar hazards.

(3) RHIs

(a) RHIs shall be associated with identified hazards by assigning both severity and likelihood categories as indicated above and by identifying the corresponding RHIs at the intersection of the severity column and likelihood row in the risk-assessment matrix in Appendix C. The RHI levels that shall be used are:

i. Critical (RHI = 4)

ii. Serious (RHI = 3)

iii. Medium (RHI = 2)

iv. Low (RHI = 1)

v. Minimal (RHI = 0)

The RHI for an identified hazard provides a measure of the risk associated with that hazard *assuming* that some set of controls has been implemented, where that set of controls could range from inherent/built-in controls only to inherent/built-in controls plus additional controls. In this sense, *RHIs are based on mitigated hazards*.[3]

b. Hazard-Review Process

Hazard reviews shall consist of the following primary elements, each of which must be documented: (1) activity description, (2) activity hazard identification, (3) physical-location review, (4) compatibility assessment, (5) initial hazard assessment, (6) hazard mitigation, (7)

[3] RHIs are sometimes conceptualized as being based on (a) severity *taking into account inherent/built-in controls only* and (b) likelihood *after the implementation of additional controls.* This is valid to the extent that additional controls reduce, or are considered to reduce, *only* likelihood, *not* severity.

incident-response plan, and (8) risk assessment. Appendix D provides a flowchart illustrating the relationship of these elements.

(1) Activity Description
Hazard reviews shall:

(a) Fully and accurately describe the activity being reviewed, including its intended outcome or expected result, in a way that is detailed enough for someone outside of the division or group to understand it;[4]

(b) Define the activity boundaries by identifying what is included in the activity as well as what is specifically excluded from the activity, *e.g.*, commissioning, normal operations, and maintenance of an instrument could be considered separate activities with their own hazard reviews, depending on how different the hazards and associated controls are in the three phases;

(c) Identify distinct subtasks within an activity based on significant differences in the nature of the work and associated hazards (hazards may differ from task to task and must be managed accordingly);

(d) Specify the physical location in which the activity is to be conducted; if the activity is to be conducted in multiple locations, describe the general environment in which the activity will be conducted and describe any specific restrictions, if applicable. When the restrictions vary from location to location, subtasks should be assigned by location.

(2) Activity Hazard Identification
The activity hazard identification shall:

(a) Identify the hazards associated with the activity, or, if the activity comprises distinct subtasks, the hazards associated with each of those subtasks; and

(b) Note, reference, or include as attachments to the hazard review the results of any exposure assessments or calculations conducted to characterize or quantify identified potential hazards associated with the activity.

(3) Physical-Location Review
The physical-location review shall determine if the venue in which the activity is to be conducted is appropriate and adequate. Routine laboratory, shop, or mechanical activities

[4] An activity description similar to a scientific abstract would represent a best management practice.

are typically acceptable in spaces intended for such activities. OSHE should be consulted, however, when unique, atypical, or unusual activities may not be consistent with the proposed venue, and the results of the consultation should be noted in the review. For example, OSHE should be consulted when the activity involves unusual quantities or classes of hazardous materials or requires specialized fire and life-safety systems or emergency-response equipment, and the results should be noted in the review.

(4) Compatibility Assessment

The compatibility assessment shall examine the hazard reviews associated with the totality of activities conducted in the proposed physical location, both in the actual space itself and, when applicable, neighboring spaces, to identify any potentially negative or antagonistic interactions, taking into account both planned operations and off-normal conditions that could reasonably be expected to occur.

(5) Initial Hazard Assessment

The initial hazard assessment shall:

(a) Identify for each identified hazard the key stages in the activity, or its subtasks, at which a hazardous event or exposure could occur, focusing on those stages essential to safe conduct of the activity or its subtasks; and

(b) Assign severity levels to each of the identified hazards, taking into account inherent/built-in controls only, *i.e.*, prior to identifying any other controls (see definition of "Inherent/Built-In Controls");

(c) Consider any synergistic, negative, or antagonistic interactions identified in the compatibility assessment.

(6) Hazard Mitigation

(a) Hazard mitigation shall employ the following "hierarchy of controls" (*i.e.*, preferred order of implementation of controls) to mitigate each of the identified hazards, with each subsequent control category being less effective and reliable than the previous category:

i. Elimination;

ii. Substitution;

iii. Engineering controls;

iv. Administrative controls (including signage, warnings, alarms, and training), and;
v. Personal protective equipment (PPE).

Hierarchy of controls shall be employed until enough controls have been identified to mitigate the hazards to acceptable levels; in some cases, a combination of controls may be necessary, *e.g.*, engineering controls such as machine guarding and local exhaust ventilation could be used in conjunction with training and PPE to mitigate a hazard. There must be a clear connection between the hazards, the controls, and the mitigation of the hazards.

(b) Hazard mitigation shall stipulate the engineering controls required for an activity, *e.g.*, chemical fume hood, gas cabinet, enclosures, interlocks, blast wall, safety interlock.

(c) Hazard mitigation shall specify the alarms and other warnings required for an activity, *e.g.*, toxic gas alarms, oxygen sensors, warning lights, hazard signage.

(d) When engineering controls and alarms and other warnings must be integrated into the building infrastructure, the hazard review shall confirm that the physical location in which the activity is to be conducted contains, or will contain, such equipment.

(e) Hazard mitigation shall specify safe operating guidelines, as applicable (see definition of "Safe Operating Guidelines"), and incorporate these explicitly in the hazard review, either in their entirety or by reference.

(f) Hazard mitigation shall specify any restrictions on employees conducting activities alone or out of hours, and if there are such restrictions, the additional safety measures that must be implemented, e.g., buddy system, safe operating guideline.

(g) Hazard mitigation shall specify any ongoing direct supervision required for employees to engage in the activity when ongoing direct supervision is deemed a necessary administrative control.

(h) Hazard mitigation *should* specify any restrictions on:

i. The number of hours employees spends on the activity during a workday;

ii. The time of day employees conduct the activity; and

iii. The environmental conditions under which employees conduct the activity.

(i) Hazard mitigation shall specify the PPE required for conduct of the activity or subtasks of the activity.

i. All PPE, including employee-owned PPE, shall be of safe design and construction for the work to be performed.

ii. PPE shall be selected in accordance with the requirements in the PPE and other OSH suborders (*e.g.*, Biosafety, Cryogen Safety, Hearing Protection, Respiratory Protection, *etc.*), as applicable.

iii. PPE that properly fits each affected employee shall be selected.

(j) Hazard mitigation shall, based on the physical-location review, identify any additional controls necessary to conduct the activity safely in the proposed physical location.

(k) Hazard mitigation shall, based on the compatibility assessment, identify any additional controls necessary to conduct the proposed activity safely in proximity to other activities in the space and, when applicable, neighboring spaces.

(l) Hazard mitigation shall specify the activity-specific training, to be provided by the OU, required for employees to engage in the activity, or distinct subtasks of the activity, in the proposed physical location, and, when applicable, in proximity to other activities in the space and neighboring spaces.

i. The Safety Education and Training suborder requires employees to complete the training specified in OSH suborders (*e.g.*, Biosafety, Cryogen Safety, Magnetic Fields, *etc.*) applicable to the work they are to conduct. This training is documented and recorded in accordance with the requirements of the Safety Education and Training suborder and need not be specified in the hazard review.

ii. When activities involve the use of PPE, the activity-specific training must result in employees being able to demonstrate an understanding of the following requirements, and any special activity-specific abilities needed to use the applicable PPE properly, before they are permitted to perform work with that PPE:

(i) What PPE is necessary;

(ii) When PPE is necessary;

(iii) How to properly don, doff, adjust, and wear the PPE;

(iv) The limitations of the PPE; and

(v) The proper care, maintenance, useful life, and disposal of the PPE.

This activity-specific training must address only those activity-specific aspects of the PPE not covered in either (1) the training provided by OSHE on the PPE program, or (2) the training completed previously by affected employees for other activities. This training shall be provided by OU employees, or others, who have demonstrated an understanding of the activity-specific aspects of the applicable PPE and any activity-specific ability to use that PPE properly.

(m) Voluntary use of controls should be documented in the hazard mitigation section of the Hazard Review when such use is subject to requirements in other OSH suborders.[5]

(7) Incident-Response Plan (Activity Specific)
Planning for incidents, including off-normal conditions[6], as applicable, is a critical element of the hazard review process. In addition to providing guidance during an emergency, the development of incident-response plans may result in the identification of hazardous conditions that could aggravate or compound an emergency situation. Additionally, the planning process may bring to light deficiencies, such as the lack of resources (equipment, trained personnel, supplies) or adequate controls that can be rectified before an emergency occurs. Hazard reviews shall include activity-specific incident-response plans that:

(a) Stipulate any activity-specific equipment and supplies required for incident response, *e.g.*, emergency shut-off switch, spill containment, special-purpose vacuum cleaner;

(b) Include the following when necessary to protect employee safety and health, the physical location, and the environment:

[5] For example, the voluntary use of respiratory protection is governed by specific requirements in the Respiratory Protection suborder.
[6] Examples of off-normal conditions, *i.e.*, conditions outside of expected operating limits, include over or under pressure, over or under temperature, over or under flow rates, and loss of electrical power.

i. Procedures for shutting down or placing systems in a safe configuration;

ii. Plans for responding to off-normal conditions resulting from the failure of one or more controls in the activity itself and, when necessary, other activities conducted in the same space or neighboring spaces;

iii. Plans for responding to events such as utility losses, *e.g.*, power or water, and building evacuations; and

iv. The identification of additional controls deemed necessary to reduce risks to acceptable levels;

(c) Ensure that decisions regarding employees working alone or out of hours fully consider the need to respond promptly, if necessary, to incidents that threaten employee safety and health or the environment; and

(d) Specify the activity-specific incident-response training, to be provided by the OU, required for employees to engage in the activity or distinct subtasks of the activity.

(8) Risk Assessment

(a) Hazard Reviews shall include an assessment of the risks by assigning RHIs to each of the identified hazards subsequent to the application of controls.

(b) If the risk assessment subsequent to hazard mitigation results in RHIs that feasibly could be lower, additional steps to mitigate the hazards shall be taken to reduce the RHIs to those lower levels.

(9) Additional Requirements

(a) Hazard reviews shall meet the additional requirements established in other OSH suborders, when applicable;[7]

(b) Hazard reviews shall flag, *e.g.*, using checkboxes, activities requiring the control of hazardous energy (lockout/tagout), confined-space entry, hearing protection,

[7] For example, hazard reviews of activities involving the use of biohazardous materials must include a Biohazardous Materials Registration and Authorization Form approved by the NIST Biosafety Officer; hazard reviews of activities involving the use of radioactive material at NIST Gaithersburg must include (among other things) a specific hazard assessment and hazard mitigation plan whose safety evaluation by the NIST Gaithersburg Radiation Safety Officer has been approved by the NIST Ionizing Radiation Safety Committee.

respiratory protection, fall protection, and assessments of exposure to carcinogenic chemicals;

(c) Hazard reviews shall be readily available in hard-copy or electronic form in or near the space in which the associated activities are to be conducted; and

(d) Hazard reviews shall identify hazardous wastes generated in the conduct of the activity and include management of those wastes, as applicable. Arrangements for disposal shall be coordinated with OSHE.

c. Conduct of Hazard Reviews

Hazard reviews shall be conducted by, or in consultation with, individuals with the knowledge, skills, and abilities to identify, assess, and mitigate the hazards associated with the activity under review, to conduct the physical-location review and compatibility assessment, and to develop plans for incident response.

(1) Hazard reviews shall be conducted by individuals who collectively[8] have taken the training provided by OSHE on the Hazard Review program and on all OSH programs pertinent to the activity under review.

(2) Hazard reviews should include subject matter experts from OSHE, the Office of Facilities and Property Management (OFPM), and other OUs when the OU conducting the hazard review requires additional safety or facilities expertise.

(3) Hazard reviews shall include consultation with the relevant groups in OSHE, ESO, and OFPM (*e.g.*, Fire and Facilities Safety Group, Police Services Group, Fire Protection Group, Facilities Maintenance Division) when activity-specific alarms must be tied into building or facility alarm systems.

d. Approval of Hazard Reviews[9, 10]

Completed hazard reviews shall be approved by line management, with the approval signifying that the RHIs associated with the activity represent an acceptable level of safety risk.[11]

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[8] At least one member of the team must have taken the required training.

[9] Sections 6d-i focus on activities that involve workers from a single OU. Section 6j indicates how Sections 6d-i apply to activities that involve workers from multiple OUs.

[10] OUs may approve hazard reviews and authorize work at one time provided that the requirements in this section and Section 6e, respectively, are met.

[11] The approved hazard review serves as the Certification of Hazard Assessment required by 29 CFR 1910.132, *Personal Protective Equipment*.

(1) Hazard reviews shall be approved by line managers who have taken the training provided by OSHE on the Hazard Review program.

(2) Activities with any RHI = 4 shall not be conducted at NIST.

(3) Hazard reviews of activities involving minors (individuals under age 18) that could result in their being exposed to hazards with RHI = 2 shall be approved by OU Directors.[12, 13]

(4) With the exceptions noted in items (5) and (6) below, all other hazard reviews shall be approved at the following *or higher* levels of the line management of the OU responsible for the activity (see NIST 7101.00):[14]

(a) Group Leaders:

i. Activities with all RHIs ≤ 1.

(b) Division Chiefs:

i. Activities with some RHIs = 2 but no RHIs = 3.

(c) OU Directors:[15]

i. Activities with at least one RHI = 3.

(5) Activities for which the highest hazards have RHI = 2 and these are fully controlled to industry standards (see definition of "Fully Controlled to Industry Standards"), as determined by OSHE, may be approved by Group Leaders.

(6) Activities for which the highest hazards have RHI = 3 and these are fully-controlled to industry standards (see definition of "Fully Controlled to Industry Standards"), as determined by OSHE in consultation with experts in the OUs, may be approved by Division Chiefs.

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[12] As indicated in Section 10. AUTHORITIES, OU Directors may delegate the authority to approve such hazard reviews to OU Deputy Directors or Division Chiefs.

[13] Activities with RHIs > 2 and a list of other specific activities are prohibited for minors; see the Safety and Health Requirements for Minors suborder.

[14] OUs may require lower levels of line management (and others, e.g., chairs of hazard review committees, OU/division safety personnel, and project leaders) to sign off on hazard reviews prior to those hazard reviews being approved at the levels of line management indicated.

[15] OU Directors may wish to establish (standing or *ad hoc*) Hazard Review Committees to conduct (or review) hazard reviews for such activities and recommend their approval or disapproval.

e. Authorization of Work[16]

Activities covered by approved hazard reviews shall be authorized to commence by line management, with the authorization signifying that controls other than training[17] have been verified to have been implemented and that the controls will continue to be implemented as a condition for the ongoing conduct of the work.[18]

(1) Activities shall be authorized by line managers who have taken the training provided by OSHE on the Hazard Review program.

(2) Activities with any RHI =4 shall not be authorized by NIST.

(3) With the exceptions noted in item (4) below, activities covered by all other hazard reviews shall be authorized at the following *or higher* levels of line management:[19]

(a) Group Leaders:

i. Activities with all RHIs ≤ 2.

(b) Division Chiefs:

i. Activities with at least one RHI = 3.

(4) Activities for which the highest hazards have RHI = 3 and these are fully-controlled to industry standards (see definition of "Fully Controlled to Industry Standards"), as determined by OSHE, may be authorized by Group Leaders.

(5) If an activity of one OU is to be conducted in space assigned to another OU, access to that space must be authorized by the line management of the second OU subject to any conditions established by that OU to protect other employees working in the space from the hazards associated with the activity. These conditions must be included as part of the formal authorization of work (see NIST 7101.00).

[16] OUs may approve hazard reviews and authorize work at one time provided that the requirements in this section and Section 6e, respectively, are met.

[17] Training is addressed not in the authorization of work, but in the authorization of workers; see Section 6f.

[18] So, for example, if a chemical fume hood is a required control, and the chemical fume hood is out of service or suspected to be functioning improperly, the work must stop until the fume hood is fully operational or an equivalent control is identified and implemented. Similarly, PPE must be in good working condition; defective or damaged PPE shall not be used.

[19] OUs may require lower levels of line management (and others, such as chairs of hazard review committees, OU/division safety personnel, and project leaders) to sign off on authorizations of work prior to work being authorized at the level of line management indicated.

f. Authorization of Workers

To engage in activities that have been authorized by line management, workers must themselves be authorized to perform that work by line management. This authorization signifies that:

- The workers have taken the training specified in the OSH suborders applicable to the work they are to conduct and the activity-specific training identified in Sections 6b(6)(i) (Hazard Mitigation) and 6b(7)(c) (Incident-Response Plan);

- Line-management has an appropriate degree of confidence, based on personal knowledge, observation, or reliable input from others, that the workers to be authorized:

    - Have the knowledge, skills, and abilities to perform the work safely and correctly; and

    - Fully understand the boundaries/conditions imposed on the activity by the activity hazard review, the need to work within those boundaries/conditions, and the process for requesting work that falls outside of those boundaries/conditions.

(1) Workers shall be authorized by line managers who have taken the training provided by OSHE on the Hazard Review program and, in the case of official first-level supervisors, on all OSH programs applicable to the work to be conducted;[20] and

(2) Workers shall be authorized by their official first-level supervisors, *or at that level and higher*.[21, 22]

g. Re-Review and Re-Approval of Hazard Reviews and Re-Authorization of Work and Workers

[20] The Safety Education and Training suborder requires official first-level supervisors to complete training on the OSH suborders applicable to the work to be conducted by employees they supervise. This training is documented and recorded in accordance with the requirements of the Safety Education and Training suborder and need not be specified in the hazard review.

[21] If a worker is to be authorized to carry out only a specified set of subtasks of a larger activity, that worker need only take the training applicable to that specified set of subtasks.

[22] If an activity involves workers from one or more groups or divisions within a single OU, the OU may wish to establish additional requirements for authorizing workers across organizational lines. For example, if an activity owned by one group involves workers from a second group and the two Group Leaders are the official first-level supervisors, the OU may wish to have the workers from the second group authorized first by their Group Leader and then by the Group Leader of the group that owns the activity.

(1) Hazard reviews shall be re-reviewed whenever:

(a) Changes in existing activity parameters would introduce new hazards or increase existing hazards; [23]

(b) Changes in engineering controls, administrative controls, or PPE would increase safety risks; or

(c) Previously unrecognized safety issues are identified, *e.g.*, through direct observation or discussion, relating to an incident or audit that indicates inadequate controls, or abnormal operating conditions which affect availability or efficacy of documented, planned controls.

(2) Hazard reviews shall be re-reviewed on a predetermined basis to verify that the hazards have not changed substantially since the hazard review was last approved or reviewed, and that existing controls are adequate. Predetermined review periods:

(a) Shall be established when hazard reviews are initially reviewed and approved and when they are re-reviewed;

(b) Shall not exceed three years;

(c) Shall be included in the hazard review documentation;

(d) Shall be based on risk and the potential for change, with higher-risk, more potentially variable activities being reviewed more frequently; and

(e) May be more frequent based on the likelihood for change within an activity.

(3) When re-reviews indicate that hazards *have not* changed *and* that existing controls are *adequate*, the re-reviewed hazard reviews shall include the date of the re-review, the signature(s) of the individual(s) conducting the re-review, and the signature of the responsible line manager.

(4) When re-reviews indicate that hazards *have* changed *or* that existing controls are *inadequate*:

[23] For example, changes in equipment, equipment operation, materials, maximum quantities of materials, concentrations, operating temperatures and pressures, power levels, or process rates, or changes in permit conditions for permit-required activities, that would introduce new hazards or increase existing hazards.

(a) The re-reviewed hazard reviews shall be re-approved in accordance with the requirements in Section 6d; and

(b) Work and workers shall be re-authorized in accordance with the requirements in Sections 6e and 6f, respectively.

The re-approval of the hazard review and the re-authorization of work shall take place at the levels of line management determined by the hazards that have changed or for which the existing controls are inadequate, or at a higher level of line management.

h. Retraining and Re-Authorization of Workers

(1) Employees who have been authorized to conduct work shall, as a condition of their authorization, complete retraining identified by the OUs whenever there is reason to believe that employees lack the knowledge, understanding, or skill necessary to conduct their work safely. Individual OSH suborders list specific circumstances under which such retraining is required. General circumstances under which retraining is required include, but are not limited to:

(a) An observation or other condition reveals that a worker lacks the necessary knowledge understanding or skill; or

(b) An inspection or audit points to a systemic deficiency warranting retraining.

i. Records

(1) Copies of all current hazard reviews and work and worker authorizations shall be maintained in hard copy or electronic form.

(2) Copies of hazard reviews and work and worker authorizations for activities that have ceased shall be maintained in hard copy or electronic form for at least one (1) year unless the hazard assessment involved exposure monitoring, in which case the hazard review and work and worker authorizations shall be submitted to OSHE for retention in accordance with the requirements of the Industrial Hygiene program.

(3) Training shall be documented and recorded in accordance with the requirements, roles, and responsibilities in the Safety Education and Training suborder.

j. Activities Involving Workers from Multiple OUs

(1) The activity shall be owned by the *de facto* lead OU or, if it is not obvious which OU is the *de facto* lead OU, by the OU determined to be the lead OU by discussion among the involved OUs.

(2) The hazard review shall be approved by the lead OU in accordance with the requirements in Section 6d, Approval of Hazard Reviews.

(3) Work shall be authorized by the lead OU in accordance with the requirements in Section 6e, Authorization of Work.

(4) Workers from the lead OU shall be authorized by the lead OU in accordance with the requirements in Section 6f, Authorization of Workers.

(5) Workers from OUs other than the lead OU shall be authorized by their respective OUs in accordance with the requirements in Section 6f *and* by the lead OU ("final authorization") in accordance with its own requirements.

(a) In authorizing workers from their OUs, OUs other than the lead OU should determine that the hazard review is adequate, that the safety risk to workers from their OUs is acceptable, and that the work has been authorized by the lead OU.

(6) Hazard reviews shall be re-reviewed and re-approved and work and workers from the lead OU shall be re-authorized by the lead OU in accordance with the requirements in Section 6g, Re-Review and Re-Approval of Hazard Reviews and Re-Authorization of Work and Workers.

(7) Workers from OUs other than the lead OU shall be re-authorized by their respective OUs in accordance with the requirements in Section 6g *and* by the lead OU ("final re-authorization") in accordance with its own requirements.

(8) Workers from the lead OU shall be retrained and re-authorized by the lead OU in accordance with the requirements in Section 6h, Retraining and Re-Authorization of Workers.

(9) Workers from other than the lead OU shall be retrained and re-authorized by their respective OUs in accordance with the requirements in Section 6h *and* by the lead OU in accordance with its own requirements.

(10) Records related to hazard-review documentation, the authorization of work, and the authorization of workers from the lead OU shall be maintained by the lead OU in accordance with the requirements in Section 6i, Records.

(11) Records of the authorization of workers from OUs other than the lead OU shall be maintained as follows:

(a) Records of the authorization of workers from OUs other than the lead OU shall be maintained by the workers' respective OUs; and

(b) Records of the final authorizations of such workers by the lead OU shall be maintained by the lead OU.

k. OU Hazard Review and Work and Worker Authorization Procedures
Written procedures, which, if followed, would result in the requirements in Sections 6a-j being met, shall be developed and maintained by each OU.

7. DEFINITIONS

a. Abnormal Conditions – Operational occurrences caused by external factors which are not expected to occur as part of normal and off-normal conditions and may alter the risk assessment or present additional hazards to those directly associated with performance of the activity. Examples include restricted access to campus or need to work in close contact with another staff member during pandemic conditions.

b. Activity – An experiment, operation, process, or job, often comprising subtasks, conducted to achieve a specific outcome.

c. Direct Supervision – Relative to an employee, a term meaning that a second employee, proficient in the activity being conducted by the first employee, shall be either present in the work area while the activity is being conducted or available for consultation within a reasonable amount of time commensurate with the need for consultation, based on the proficiency of the first employee.

d. Fully Controlled to Industry Standards (Used in Reference to Hazards) – Controlled by a device, apparatus, or system being designed in accordance with applicable regulatory and consensus standards and predicated upon that device, apparatus, or system being used in a prescribed manner. The mitigation of hazards that are fully controlled to industry standards relies primarily on built-in/engineering controls or inherent design features but may, in some cases, rely upon best practices. In either case, the control should be traceable to a broad industry, consensus-based set of controls.

e. Hazard – Source, situation, or act with a potential for harm in terms of human injury or ill health, adverse impact on the environment, damage or loss of equipment or property, or a combination of these (from NIST 7101.00).[24]

f. Hazard Identification – Process of recognizing that a hazard exists and defining its characteristics (from NIST 7101.00).

g. Hazard Review (Document) – A document describing the results of the hazard-review process.

h. Hazard Review (Process) – The formal process, aspects of which could be iterative, of describing an activity, identifying the hazards associated with the activity, reviewing the physical-location in which the activity will be carried out, assessing the compatibility of the activity with nearby activities, conducting an initial hazard assessment, identifying controls to mitigate the hazards, developing an incident-response plan, conducting a risk assessment, and developing plans for managing wastes generated during the conduct of the activity.

i. Hierarchy of Controls – A range of hazard control methods arranged in order of implementation preference from elimination to substitution, engineering controls, administrative controls, and personal protective equipment.

j. Inherent/Built-In Controls – Features of a system's design that prevent or limit the severity of the consequences of system failure. Inherent/built-in controls cannot be defeated or separated from the system without conscious or willful effort.

k. Likelihood of a Hazardous Event or Exposure ("Likelihood") – An estimate of the probability of a hazardous event or exposure.

l. Line Management – For the purposes of this suborder, the OU Director, Division Chief, and Group Leader, or equivalent.

m. Office-Like Space – A space, such as a conference room, copier room, break room, or ordinary computer room that has the same types of hazards as a typical office or office environment.

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[24] This definition parallels that in *Occupational Health and Safety Assessment Series (OHSAS) Standard 18001:2007, Occupational Health and Safety Management Systems – Requirements*. For comparison, *OSHA 3071, Job Hazard Analysis, 2002 (revised)* defines a hazard as "the potential for harm, often associated with a condition or activity that, if left uncontrolled, can result in injury, illness or damage to property or the environment", and *American National Standard for Occupational Safety and Health Management Systems, ANSI/AIHA Z10-2005,* defines a hazard as "a condition, set of circumstances, or inherent property that can cause injury, illness or death".

n. Off-Normal Conditions – Operational occurrences which may be expected to occur that are generally outside routine or planned operations. For example, loss of cooling water would be an "off-normal" condition which could cause a heat-sink to overheat and combust. Other examples include power failure, error at power-up or power-down, loss of cryogen containment, human error, *etc.*

o. Relative Hazard Index (RHI) – A measure of the risk of a hazardous event or exposure based on a combination of the severity of the consequences of the hazardous event or exposure to a hazard and its likelihood.

p. Risk – Combination of the likelihood of an occurrence of a hazardous event or exposure and the severity of injury or ill health that can be caused by the event or exposure (from NIST 7101.00).

q. Risk Assessment – Process of evaluating the risks arising from hazards, taking into account the adequacy of any existing controls, and deciding whether or not the risks are acceptable (from NIST 7101.00).

r. Safe Operating Guideline – A written set of requirements or practices developed or designed to enable a task to be carried out safely. Safe operating guidelines can include, but are not limited to, standard operating procedures, job hazard analyses, and instrument/equipment instruction manuals.

s. Severity of the Consequences of a Hazardous Event or Exposure to a Hazard ("Severity") – A qualitative measure of the consequences of the worst credible hazardous event or exposure associated with an identified hazard due to design inadequacies; procedural deficiencies; human error; environmental conditions; or system, subsystem, or component failure or malfunction.

t. Standard Operating Procedure – A written step-by-step procedure or operational protocol used to document how a given task **must** be carried out to ensure safe operation. Standard operating procedures are generally needed when failure to follow a prescribed set of steps results in significant increase in risk.

u. Worst Credible Hazardous Event – Most severe or serious event capable of being believed, taking into account all relevant considerations.

8. ACRONYMS

a. HR – Hazard Review

b. OSH – Occupational Safety and Health

c. OSHE – Office of Safety, Health, and Environment

d. OU – Organizational Unit

e. PPE – Personal Protective Equipment

f. RHI – Relative Hazard Index

9. ROLES AND RESPONSIBILITIES

a. NIST Director and Associate Directors:

(1) Concur or non-concur on approvals by OU Directors of hazard reviews of activities elevated to the directorship level.

b. OU Directors:

(1) Ensure that written OU procedures are developed, maintained, and implemented to ensure that the requirements of Sections 6a-j are met within their respective OUs.

c. Line Management:

(1) Take the training provided by OSHE on the Hazard Review program;

(2) Ensure that hazard reviews are conducted for all new activities;

(3) Involve employees in the conduct of hazard reviews as appropriate;

(4) Ensure that hazard reviews are conducted by individuals who collectively have taken the training provided by OSHE on the Hazard Review program and on all NIST OSH programs pertinent to the activity under review;

(5) Approve hazard reviews in accordance with the requirements of Section 6d, with the approval signifying that the RHIs associated with the activity represent an acceptable level of risk;

(6) Authorize activities in accordance with the requirements of Section 6e, with the authorization signifying that controls other than training have been verified to have been

implemented and that required safety equipment shall be maintained in proper working order in accordance with manufacturers' specifications and all applicable standards;

(7) Authorize workers in accordance with the requirements of Section 6f, with the authorization signifying that (a) the workers have taken the training provided by OSHE on all NIST OSH programs pertinent to the activity to be conducted and the training identified in Sections 6b(6)(l) and 6b(7)(d), (b) line management has an appropriate degree of confidence, based on personal knowledge, observation, or reliable input from others, that the workers to be authorized have the knowledge, skills, and abilities to perform the work safely and correctly, and (c) the workers fully understand the activity boundaries/conditions, the need to work within those established boundaries/conditions, and the process for requesting work that falls outside those boundaries/conditions;

(8) Re-review and re-approve hazard reviews and re-authorize work and workers in accordance with the requirements of Section 6g;

(9) While visiting laboratories, discussing work, or conducting management observations:

(a) Be vigilant for "scope creep", i.e., advertent or inadvertent changes in activity boundaries/conditions or controls that introduce new hazards, increase existing hazards, or otherwise increase safety risk; and

(b) If scope creep is identified, stop work and require re-review and re-approval of the hazard review and re-authorization of work and workers, as per Section 6g;

(10) Maintain records in accordance with the requirements of Section 6h.

d. Official First-Level Supervisors Authorizing Work (in addition to their responsibilities as part of Line Management):

(1) Complete the training provided by OSHE on all NIST OSH programs pertinent to the work to be authorized; and

e. Employees Conducting Hazard Reviews:

(1) Take the training provided by OSHE on the Hazard Review program.

f. Employees Authorized to Engage in Work:

(1) Complete the training provided by OSHE on all NIST OSH programs pertinent to the work to be conducted and the training provided by the OU identified in Sections 6b(6)(i) (Hazard Mitigation) and 6b(7)(c) (Incident-Response Plan), as applicable; and

(2) Work within the boundaries/conditions of the hazard review at all times and in accordance with required controls and training;

(2) If it is necessary or desirable to work outside the boundaries/conditions of a hazard review or change existing controls, request line management re-review of the hazard review as per Section 6g; and

(3) Be vigilant for scope creep, and if scope creep is identified, stop work and request line management re-review of the hazard review, as per Section 6g.

g. Employees Assigned Responsibility for Safety Equipment:

(1) Ensure that required safety equipment is maintained in proper working order in accordance with manufacturers' specifications and all applicable standards.

h. Employees:

(1) Participate in the conduct of hazard reviews as appropriate.

i. Chief Safety Officer:

(1) Maintain this suborder;
(2) Develop and maintain any necessary supporting NIST directives, including procedures, guidance, and notices;

(3) Review the efficacy of written OU procedures for meeting the requirements of this suborder and provide the results of those reviews to the respective OU Directors; and

(4) Support, through the OSHE staff, OU implementation of this suborder.

j. OSH Program Manager for the Hazard Review program:

(1) Make determinations that particular hazards are controlled to industry standards and maintain and make available to the OUs a list of such hazards and their associated RHIs;

(2) Develop and maintain any necessary deployment tools, including forms, instructions, IT applications, training, and user guides;

(3) Serve as the primary point of contact and subject matter expert on:

(a) Federal, State and local regulatory requirements and guidelines; and

(b) Consensus industry standards and best practices.

(4) Ensure effective communication with management and staff on program-related issues.

10. AUTHORITIES

For authorities applicable to all NIST OSH suborders, see NIST 7101.00. There are no authorities specific to this suborder alone.

11. DIRECTIVE OWNER

Chief Safety Officer

12. APPENDICES

Appendix A. Revision History

Appendix B. Processes for Authorizing Work and Workers

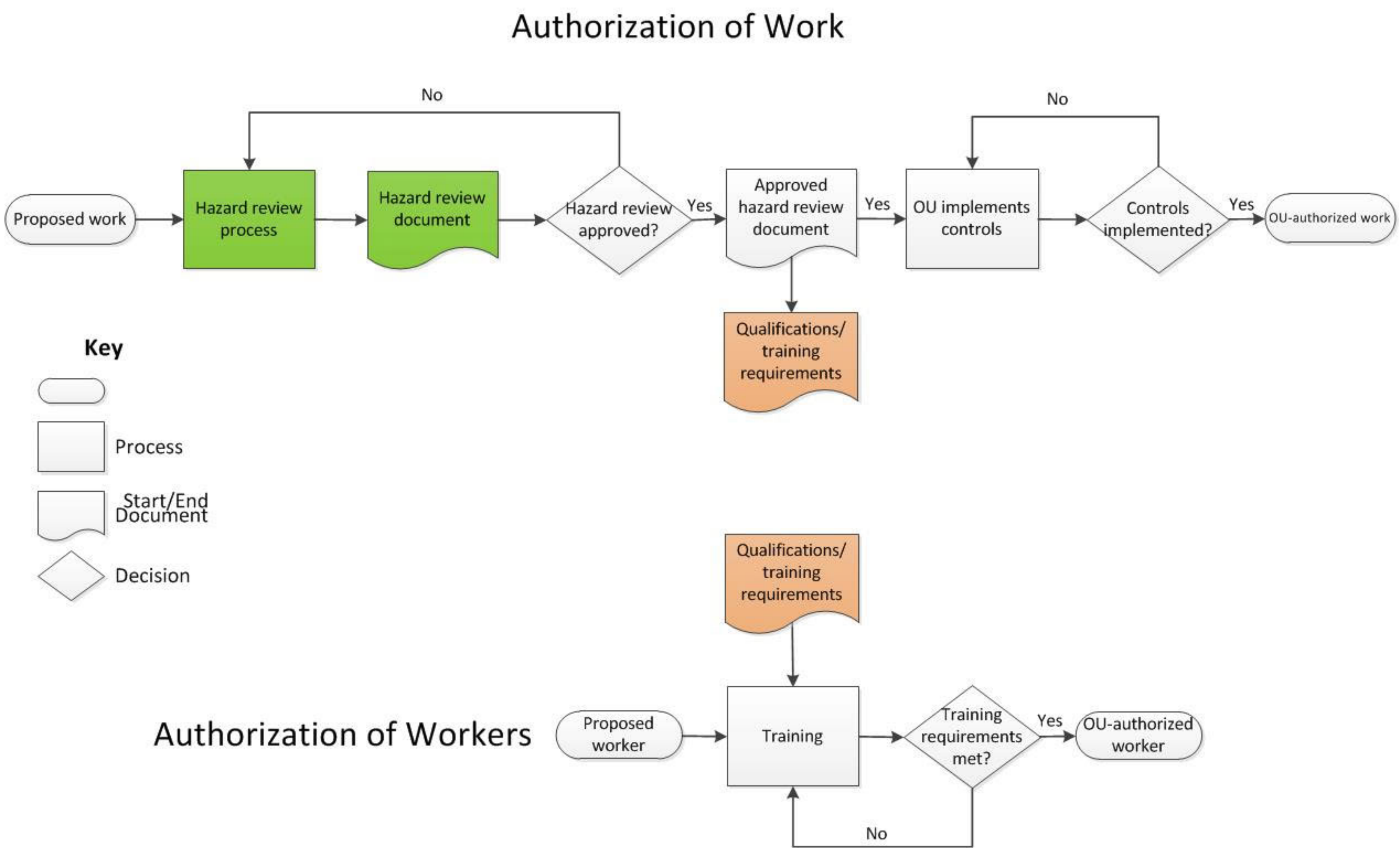
Appendix C. Risk-Assessment Matrix

Appendix D. Elements of the Hazard Review Process

Appendix A. Revision History

Revision	Date	Responsible Person	Description of Change
1	01/23/15	[redacted]	Modifications made to Section 3. Applicability, subsequent to Executive Safety Committee review.
2	11/07/17	[redacted]	Modified Section 6 to make more explicit the need for workers to understand the requirements of hazard reviews and the need to stay within scope or request re-review. Modified Section 9 to reflect the responsibilities necessary to fulfil the modified requirements in Section 6.
3	05/05/2020		• Modified Section 2.b to include abnormal conditions • Modified Section 3.b to include applicability of abnormal conditions. • Modified Section 6g(1)(c) to include abnormal conditions
4	12/23/2020	[redacted]	Updated links under References and Applicable Suborders.

Appendix B. Processes for Authorizing Work and Workers (for details on the hazard-review process, see Appendix D)

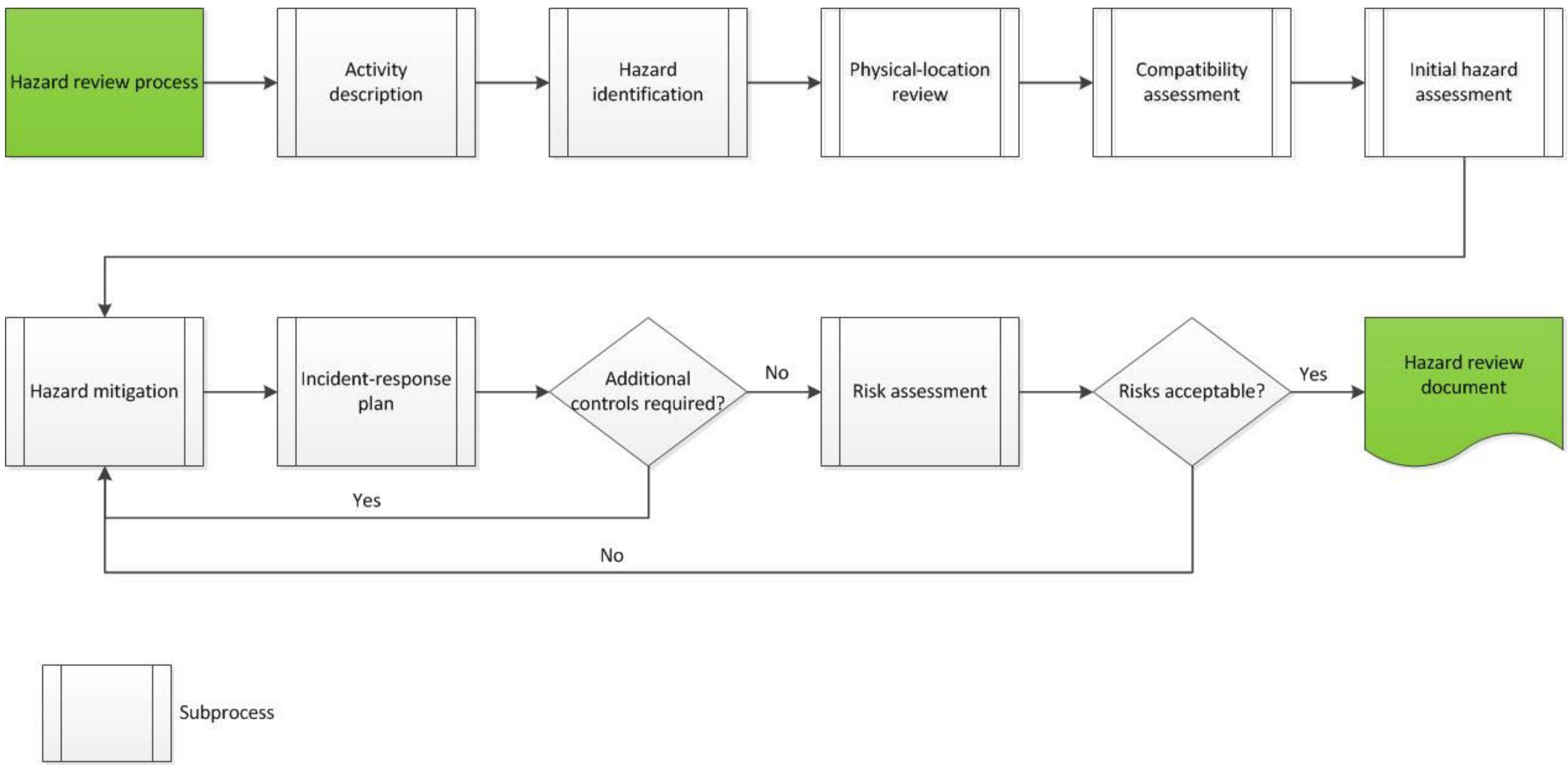


Appendix C. Risk-Assessment Matrix

This matrix is used to determine the risk level, or Relative Hazard Index (RHI), for a given hazard.

		POTENTIAL SEVERITY OF THE CONSEQUENCES OF A HAZARDOUS EVENT OR EXPOSURE TO A HAZARD			
		Catastrophic Death or permanent disability System or facility loss Lasting environmental or public-health impact	**Severe** Serious injury; temporary disability Subsystem loss or significant facility/property damage Temporary environmental or public-health impact	**Moderate** Medical treatment beyond first aid; lost-work-day(s) More than slight facility/property damage External reporting requirements; more than routine clean-up	**Minor** First-aid only Negligible or slight facility/property damage No external reporting requirements; routine clean-up
LIKELIHOOD OF OCCURRENCE	**Frequent** Likely to occur repeatedly	**CRITICAL RHI=4**	**CRITICAL RHI=4**	**SERIOUS RHI=3**	**Medium RHI=2**
	Probable Likely to occur multiple but infrequent times	**CRITICAL RHI=4**	**CRITICAL RHI=4**	**SERIOUS RHI=3**	**Medium RHI=2**
	Occasional Likely to occur at some time	**CRITICAL RHI=4**	**SERIOUS RHI=3**	**Medium RHI=2**	**Low RHI=1**
	Remote Possible, but not likely to occur	**SERIOUS RHI=3**	**Medium RHI=2**	**Medium RHI=2**	**Low RHI=1**
	Improbable Very unlikely; can reasonably assume it will not occur	**Medium RHI=2**	**Low RHI=1**	**Low RHI=1**	**Minimal RHI=0**

Appendix D. Elements of the Hazard Review Process (see Section 6b)



Appendix 6.2.2: ***EL Hazard Review and Approval Policy and Procedure***

EL Hazard Review and Approval Policy and Procedure

Revision Date: December 1, 2016

Background: This document describes the EL Hazard Review and Approval Policy and Procedure. These documents are intended to meet the requirements of NIST[1] S 7101-20, Work and Worker Authorization Based on Hazard Reviews (Hazard Review), Version 041814, which became effective March 31, 2015.

Scope: The EL Hazard Review and Approval Policy applies to all EL staff, associates and those under the direct supervision of EL staff, at all locations, and covers potentially hazardous, work-related activities for workspaces that present hazards **beyond those encountered in a typical office**. Low-risk activities (where the potential severity is either moderate or minor and where the likelihood of an incident or exposure is improbable) that do not require the use of personal protective equipment or administrative controls such as procedures, signs, alarms and are exempt from this requirement.

Policy: It is EL policy to conduct hazard assessments for all potentially hazardous work covered by the scope of this document, to implement controls that mitigate hazards to an acceptable level of risk, and for line-management to review and approve hazard assessments and controls prior to commencement of work.

Roles and Responsibilities:

EL Director and Deputy Director: The EL Director is responsible for establishing, reviewing, and ensuring compliance with the EL Hazard Review and Approval Policy. The EL Director delegates to the EL Deputy Director: convening *ad hoc* Hazard Review Committees as needed, and reviewing and approving (or rejecting) activities that require OU-level review, as described in this document.

EL Safety Program Coordinator (SPC): The EL Safety Program Coordinator (a.k.a EL Safety Professional) is responsible for ensuring that the EL Hazard Review and Approval policy and procedure meets the requirements of Ref. 1 (above) and other applicable OSHE Safety Programs; for managing the Hazard Review Committee review process; and for providing training on this policy and procedure for EL Leadership, Division Safety Representatives, and EL management and staff (as requested).

Division Chiefs (DCs): Division Chiefs are responsible for implementing this policy and procedure in their Divisions; ensuring that subordinate managers and Division Safety Representatives have appropriate training on hazard assessment and control; and for reviewing and approving (or rejecting) hazard reviews for activities that require Division-level review as described in this document, using the MML Hazard Review tool https://mmlweb.nist.gov/safety/. Division Chiefs are also responsible for determining whether hazards may impact another Division or OU and notifying the appropriate Division Chief or OU Director of the nature of any such impacts. Division Chiefs are responsible for ensuring that Group Leaders are trained to recognize and identify mitigation strategies to address the hazards presented by work conducted in their groups.

Division Safety Representatives (DSRs): Division Safety Representatives are responsible for completing training on the Hazard Review Suborder; reviewing hazard review packages as needed using the MML Hazard Review tool; and for serving on Hazard Review Committees as needed.

Group Leaders (GLs): Group Leaders (or designated first-level supervisors) are responsible for completing training on the Hazard Review Suborder; and ensuring that all work conducted in their group involving hazardous activities or materials is covered by approved Hazard Reviews. Group Leaders also are responsible for reviewing and approving (or rejecting) all hazard review packages for work conducted in their group and authorizing workers, utilizing the MML Hazard Review tool

Hazard Review Committee (HRC): The hazard review committee is an *ad hoc* committee convened on a case-by-case basis with the concurrence of the EL Deputy Director to review activities that require EL-level review, in accordance with the process and procedure described in this document. The HRC must comprise of at least two members, one or more who are trained in hazard analysis and control, and one or more subject matter experts.

The HRC is responsible for reviewing the hazard review package, for performing a site inspection of the workspace and, when acceptable, for recommending the hazard review activity for approval by the EL Deputy Director.

EL Workspace Managers: EL Workspace managers are responsible for reviewing all hazard review packages for work conducted in their laboratory or shop and for identifying and informing line management when activities may not be suitable for that space, or may be incompatible with other activities in that space.

Activity Leader: The activity leader is the person responsible for initiating the hazard assessment and review process prior to initiation of a new activity, or prior to changing an activity covered by an approved hazard review. The activity leader is also responsible for updating the information in the hazard review package in a timely manner when changes occur, and as necessary for scheduled reviews, and for submitting the revised hazard review package for approval.

Authorized Users: Authorized users are those who have been approved by their Group Leader to do the work described in the hazard review. They are responsible for completing any required training, reviewing the content of the hazard review package, and implementing all controls listed in the hazard review whenever the activity is conducted. **Division Chief approval is required to work alone and out-of-hours (before 7 AM and after 7 PM) to perform work for which the Risk Hazard Index values are greater than two (>2).**

MML Web Developer: The MML Web Developer is responsible for ensuring that the MML Hazard Review and Approval System (HRAS) is fully functional and that the information contained in the database is maintained, regularly backed up, and archived according to applicable NIST requirements.

Hazard Review Process

The general process for hazard review and approval is described in this section. Hazard assessment and control as well as review and approval are accomplished through use of an MML-developed, web-based database system. A detailed procedure is included as Appendix A, EL Hazard Review and Approval Procedure, and instructions for use of the database system are provided on-line.

Hazard Assessment and Control: Hazard assessment and control is accomplished through:

1. Identification and description of activities that involve hazardous substances or hazardous procedures;
2. Assessment of the type and potential severity of hazards associated with the substances, work environment, equipment and work procedures as described in Ref. 1;
3. Mitigation of hazards through application of controls, considering the hierarchy of controls (elimination, substitution, engineering and administrative controls, and personal protective equipment); see Ref.1;
4. Evaluation of the residual risk using the risk hazard index matrix described in Appendix B of Ref. 1.

Hazard Review Package: For each activity the hazard review package includes a complete description of the activity, a step-by-step list of tasks comprising the activity, a list of the hazards identified for each task, together with controls used to mitigate each of the hazards, and an incident response plan. The hazard review package consists of a web-based form and supporting documents that adequately describe the activity and the safety-related precautions and procedures.

1. The web-based form contains: the activity name and unique (system-generated) identifier, a brief activity description, location(s), activity duration and frequency, staff who will be performing the work, a list of the hazardous substances, tasks and equipment used, and an evaluation of the hazards associated with each, together with the proposed controls to mitigate each hazard.
2. Supporting documents (uploaded into the database record for that activity) include:

a. An emergency response plan that addresses emergency shut-down procedures, failure of controls, responses to materials releases or exposures, and other foreseeable off-normal and emergency conditions, as applicable;
b. Any procedures or instructions needed to ensure safe operation; and
c. Any authorizations needed for specific hazardous materials work such as a Biohazard Registration form for work with biohazards, approved NIST 364/5 or BL100/1 forms or Safety Evaluation for work with Radioactive Material (RAM).

Hazard Review and Approval: After the hazard review package is completed, it is submitted for review and approval. Activities for which the residual risk, after all controls have been implemented, is minimal or low (RHI = 0 or 1) require only GL approval. Division-level review is required for activities for which the residual risk is medium, serious or critical, corresponding to RHI values of 2, 3 and 4, respectively. Division level review consists of review by the Group Leader, followed by the Division Safety Representative (or a designated safety or subject matter expert), and finally, by the Division Chief. If the residual risk after all controls have been applied is serious (RHI = 3)), the activity also will be subject to EL-Level Review. In such cases, the process consists of review and approval by the OU Deputy Director or referral to the EL Hazard Review Committee, and review and approval by the EL Deputy Director. Some exceptions to the requirement for EL-level review are described in the EL Procedure for Hazard Review and Approval, included as Appendix A to this Policy. Work may not commence until all required approvals are obtained.

Authorization for Work to Commence and Authorization of Workers. Approval of the hazard review package constitutes authorization for work to commence. A separate approval by the Group Leader is required to attest that individual staff or workers are qualified, appropriately trained and approved to perform the work. Similarly, a separate approval by the Division Chief is required for staff to work alone and/or after hours. A list, containing the authorized users and those approved to work alone after hours, is associated with the hazard review record in the MML Hazard Review and Approval System. Staff approvals are maintained separately so that staff may be changed (added or deleted) without re-approval of the entire HR package.

Scheduled Reviews of Approved Hazard Reviews. Approved hazard reviews will be re-evaluated no less than every three years. These re-evaluations will assure that the documents accurately reflect current practices, the work is appropriate for the space, there are no additional potentially incompatible activities for that workspace, all controls are adequate, and practices are compliant with applicable OSHE program requirements. For additional information see Appendix A, Section 9.

Records and Documentation: The MML Hazard Review and Approval System maintains the documentation that comprises each hazard review package and the associated records of approval or rejection from each stage of the review process. The hazard review package may be revised during development and in response to reviewer comments. However, the final approved hazard review package may not be edited and any subsequent revisions will be assigned a new version number. Staff authorizations serve as the record that staff have completed the associated task-specific training and are approved to do the work. These approvals are associated with hazard review activity records, but are maintained separately within the system.

Review and Revision: This policy will be reviewed annually by the EL Director, EL Deputy Director, and Safety Program Coordinator and revised as necessary to improve the effectiveness of the hazard review process. Recommendations for changes to the Policy and /or the MML tool shall be submitted to the EL Safety Program Coordinator.

References:

1.) NIST S 7101-20, Work and Worker Authorization Based on Hazard Reviews, Version 041814.

2.) ANSI/AIHA Z10-2005, American National Standard for Occupational Health and Safety Management Systems, American Industrial Hygiene Association, 60 pp., 2005.

Purpose: This Appendix describes the EL Hazard Review and Approval Procedure, consistent with the requirements of Ref 1.

Abbreviations:

DC: Division Chief
DSR: Division Safety Representative
GL: Group Leader
HR: Hazard Review
HRC: Hazard Review Committee
OSHE: Office of Safety Health and Environment
PI: Principal Investigator or activity leader
PPE: Personal Protective Equipment

Procedure: In EL, hazard review and approvals are documented through use of an MML-developed, web-based database system. The system is used to document the activity, the associated hazards, the proposed controls, and the residual risk upon applying the controls. The system routes the information to the reviewers and maintains records of all approvals, changes requested, and any rejections. Final approved HR packages are locked. An approved HR package may be revised by the PI or copied (cloned) by another person who wishes to use an existing HR package as a starting point to build a new HR package. Revisions are assigned the same HR identification number with a new version number, and clones are assigned entirely new identification and version numbers. Both revisions and clones must be routed for approval.

The database system assigns unique identifiers to each HR package and provides version tracking for revised HR packages. The procedure for initiating a HR consists of filling out the web-based form and uploading the supporting documents to create a HR package, as described below in Sections 1-6. Once the package is complete, it is submitted for review and approval, as described in Sections 7-8. All approved hazard reviews are scheduled for regular evaluation as described in Section 9. Instructions for use of the database system are available online, within the database system, under references. Note that the database system relies on the information on people and locations contained in the internal web application, NIST Org, found at https://mmlweb.nist.gov/org/. Contact your office manager to update this as needed.

Create a Hazard Review Package

1. **Identify Activities**-- Individual staff members, in consultation with GL's, DSR's, PI's and lab or shop contacts, as necessary, are responsible for identifying activities that involve hazardous substances or tasks. GL's are responsible for ensuring that all work performed by members of their Group has been evaluated. An activity may be a discrete task, multiple tasks or, related tasks,.
2. **Describe the Activity: General Information** -- To create a hazard review package, information about the activity is entered into the web-based form: the activity name, a brief activity description, the location(s), the activity duration and frequency, and the staff who will be performing the work. Documents needed to adequately describe the activity are submitted (uploaded) as part of the hazard review package; these may include design plans (for new instruments, experiments or facilities), standard operating procedures, safe operating procedures, work or job instructions, instrument manuals, etc. An **Emergency Response Plan must be included** as part of the hazard review package and must describe the actions required to handle foreseeable emergencies such as failure of controls, power outages, and spills or releases of hazardous materials. Work with radioactive material (RAM) requires a copy of the associated approved NIST 364/5. These documents must be uploaded as well.

Note: Staff members are also responsible for identifying any changes to activities covered by approved HRs. When changes to the activity go beyond the scope of the approved HR (e.g., the location, the procedures, substances or quantities differ) the HR must be revised and submitted for approval. The MML hazard review database system allows the activity to be revised and provides version tracking of the HR package. See Section 9, for review and approval of revised HRs.

3. **Describe the Activity: Identify Tasks, Equipment, and Substances** --**The next requirement is to identify each step or task in the activity,** and the associated temperature and pressure range (if applicable). Steps in an activity might include startup or setup activities, sample preparation, reagent preparation, laser alignment, set-up or tear-down of an instrument or experiment, operating a piece of equipment, or performing maintenance on an instrument, etc. The last step in describing the activity is to identify the substances and quantities used and created in the activity, and describing the material properties (e.g., health hazard, fire hazard, reactive, cryogenic, biohazardous, radioactive, nanomaterial, acid/base, etc.) and any associated storage requirements. Each of these properties appears as a field on the form.

4. **Assess Hazards** -- The PI identifies the potential hazards inherent to the materials and equipment used and associated with each step of the activity. In identifying the potential hazards, the PI should consider what could go wrong (within reason), e.g., if the procedure were not followed, if controls failed, if the power or ventilation failed, if any substance amounts or procedural limits (temperature, pressure, etc.) are exceeded, etc. A list of potential hazards is included as a drop-down menu in the web-based form and shown in Table 1.

5. **Propose Controls to Mitigate Hazards** -- Hazards are mitigated to reduce risks to an acceptable level. This is achieved by applying the "hierarchy of controls" which ranks the effectiveness of controls based on the following priority: elimination of the hazard; substitution with a lesser hazard; use of engineering controls; alarms and warnings; implementation of administrative controls (including training, use of procedures, time limitations, access restrictions, teamwork, etc.); use of personal protective equipment (PPE). The first two elements, elimination and substitution should be considered first. The PI should determine whether performing the work is necessary and then determine whether a less hazardous substance or procedure may be used to do the work. For example, determine whether a less toxic material could be substituted or whether a dilute solution may be purchased rather than prepared in the lab. After these have been considered, engineering controls, alarms and warnings, administrative controls are applied as appropriate, in that order. When necessary to mitigate hazards, the appropriate PPE is specified. A list of controls is included as a drop-down menu in the web-based form, and shown in Table 2. There is also Glove Selection Guide provided under references on the database system home page.

   Note: When selecting PPE, the PI must enter *the type PPE that is specific to that hazard* and must specify the type of glove (coat, apron, or other barrier type) needed to protect against the specific chemical(s) used or hazards encountered in the activity. When hearing protection or respirators are used, the user must indicate whether use is "required" or "voluntary" after consulting with the EL Safety Program Coordinator (Safety Professional). See footnotes of Table 2 for more information. Documenting the type of PPE used to mitigate a specific hazard is a requirement of Occupational Safety and Health Administration (federal) regulations.

6. **Evaluate the Risk**-- Risk evaluation includes assessment of both the severity and likelihood of exposure to a given hazard. The risk for each hazard will be qualified using the Risk Hazard Index (RHI matrix shown in Table 3). To determine the RHI value, the severity of the hazard is evaluated based on the inherent properties of the hazardous material (taking into consideration material quantity and concentration) equipment, or hazardous process (without applying any controls). Then,

the likelihood of exposure to that hazard is estimated based on the premise that all controls are in place, taking into consideration factors such as the frequency and duration of exposure to the hazard, and the "reasonable and prudent person" rule. That is, the likelihood of being exposed to that hazard is what a prudent person could reasonably expect based the nature of the work, foreseeable off-normal conditions and reasonable incident scenarios, and with all controls implemented. The severity and frequency are selected from drop-down menus in the web-based form and the RHI calculated automatically based on those selections.

7. Routing and Approval of Hazard Review Packages

Review and Approval by Line Management. Once all information has been entered into the web-based form and all supporting documents uploaded, the PI submits the HR package for review and approval. The HR package is routed electronically and automatically by the database system. All activities are subject to Group Leader review and approval as the first level of review. Division-level review and approval is required as the second level of review for all activities for which the RHI ≥2. Activities for which the RHI = 3 will subsequently be subjected to EL- level review, though some RHI =3 activities may qualify as exempt; see Section 7c below. In addition, the Division Chief may request EL-level review for lower risk, RHI=2 activities. This may be appropriate, for example, when there are multiple hazard types and greater expertise is needed to ensure that controls are adequate. **Activities for which the RHI=4 are not permitted at NIST.** Review and approval processes are described below:

a. **Group Level Review and Approval**. All hazard reviews for activities covered by the scope of this policy must be reviewed and approved by the Group Leader. **The activity may not begin without this approval.** The Group Leader must:

   i. Review the HR package documentation describing the activity.

   ii. Reject activities for which the RHI=4. (Determine whether the work is necessary, and if so, whether more controls can be implemented to reduce the risk).

   iii. Iterate with the P.I. as necessary to ensure that all safety considerations are documented and controls are adequate (or the activity will not be approved).

   iv. Approve the activity, request changes or additional information, or reject the activity.

   v. Group Leader approval is the final approval for activities for which the RHI = 0 or 1. No further review is required until the activity is due for regularly scheduled re-review, or activity changes require the package to be revised accordingly and submitted for a new review.

b. **Division Level Hazard Review and Approval.** Activities for which the RHI ≥ 2 must also be reviewed and approved by the Division Chief. The activity may not begin without this approval. Activities for which the RHI = 2 or 3 must be reviewed by the DSR who is responsible for recommending the activity for Division Chief review. The DSR may name a proxy (OSHE staff, Group Safety Representative or Subject Matter Expert) to perform the review.

   i. Each reviewer must review the HR package documentation describing the activity.

ii. Each reviewer must iterate with the P.I. as necessary to ensure that all safety considerations are documented and controls are adequate (or the activity will not be approved).

iii. The DSR must recommend the activity for review by the Division Chief, request changes or additional information, or indicate that they do not recommend the activity for review by the Division Chief.

iv. The Division Chief must approve the activity, request changes or additional information, or reject the activity.

v. Division Chief approval is the final approval for activities for which the RHI=2. No further review is required until the activity is due for regularly scheduled re-review, or activity changes require the package to be revised accordingly and submitted for a new review.

vi. Where the Activity Leader has requested an exemption from EL-level review for RHI 3 activities, reviewers must agree that the activity is consistent with requirements listed below in 7.f.

c. EL-Level Hazard Review and Approval. Activities for which the RHI = 3 must be reviewed at the EL-level unless the activity qualifies as exempt as described in Section 7.f, below. The EL-level hazard review process consists of the following steps:

i. The EL Deputy Director, in consultation with the EL Safety Program Coordinator, decides whether convening an *ad hoc* HRC is necessary or if the Deputy Director will review and approve that hazard review without the HRC.If it is decided that an HRC is needed then the following steps will be followed.

Note: HRCs must have at least two members; at least one member must be a Subject Matter Expert for the work involved, and at least one member must be trained in hazard assessment and control. The HRC should include subject matter on laser safety, cryogen safety, or nanomaterials and a safety subject matter expert from EL and/or OSHE, when relevant.

ii. The HRC reviews the HR package describing the activity and proposed controls.

iii. The HRC iterates with the Activity Leader as necessary to ensure that all safety considerations are documented and controls are adequate (or the activity will not be approved).

iv. The HRC inspects the workspace to ensure that controls are in place and there are no other safety-related concerns related to conduct of that work in that space.

v. The HRC recommends for approval or rejection by the EL Deputy Director.

vi. The EL Deputy Director reviews the HR package documentation describing the activity.

vii. The EL Deputy Director iterates with HRC to ensure safety considerations are documented and controls are adequate (or the activity will not be approved).

viii. The EL Deputy Director approval (or rejection). EL Director approval is the final approval for RHI= 3 activities.

d. Reviewers are responsible for assessing:

i. Whether the activity description is complete and sufficiently thorough to allow an assessment of hazards and the mitigation strategies employed.

ii. Whether the activity is compatible with and appropriate for the space(s) for which it is proposed.

iii. Whether the activity is compatible with other activities that occur in that space.

iv. Whether all hazards have been identified and assessed.

v. Whether elimination of the hazard is feasible.

vi. Whether substitution with a less hazardous substance or process has been considered.

vii. Whether the engineering controls and administrative controls including training, PPE and other mitigation strategies identified in the HR are sufficient.

viii. Whether the risk hazard index reflects the residual risk after all controls have been implemented.

ix. Whether the incident response plan is adequate to cover foreseeable off-normal and emergency conditions.

x. And Division Chiefs must additionally assess whether the activity presents hazards that could materially affect those in another Division or OU and to inform them of the hazards if this is the case.

e. Consultation with OSHE safety area experts may be requested for any hazard review. Consultation with OSHE is required when unusual or atypical activities are proposed and the OU does not have safety expertise in the area of concern. Assessments by OSHE may be accomplished by requesting OSHE review and uploading any associated reports as an attachment to the HR, or by requesting that OSHE serve as a proxy for the DSR in review of activities for which the RHI=2 or 3, or as a member of the HRC for those with RHI=3.

i. Consultation with OSHE should be considered for the following:

1. Evaluation of noise hazards and recommendations for hearing protection
2. Evaluation of airborne contaminants and recommendations respiratory protection

f. **Exemptions to the requirement for EL-level review may be granted for RHI values of 3 for activities that OSHE deems fully controlled to industry** standards by virtue of the device or system design controls being in accordance with applicable regulatory and consensus standards. The DC and DSR must concur that EL-level review is not necessary, and attest that the activity is on a list of activities deemed by OSHE to be fully controlled to industry standards and employs controls as described.

i. The RHI value of 3 is due only to work with compressed gas cylinders, or cryogens and the work will only be performed by appropriately trained (through successful completion of required training) and qualified staff, and done in accordance with the requirements of the Compressed Gas Safety or Cryogen Safety Program. There is no exemption for toxic or flammable gases.

ii. The RHI value of 3 is due only to work with Class IIIb or IV lasers and the work is done in accordance with the OSHE Laser Safety Program and the hazard review package and controls have been reviewed and deemed adequate by the EL Division Laser Safety Representative and he/she agrees that the activity is exempt from EL-level review.

8. **Authorization for Work and Approved Users.** Approval of the HR package constitutes authorization for the work to commence. An additional, separate approval by the Group Leader is required to attest that users are qualified and appropriately trained to perform the work. Similarly, an additional, separate approval by the Division Chief is required for staff to work alone, after hours. A list, containing the authorized users and those approved to work alone and after hours, is associated with the hazard review record in database system. Where work is performed after-hours and alone, additional safety precautions to address out-of-hours work alone should be included in the HR package (e.g., in the SOP, ERP or activity description).

9. **Scheduled Re-evaluation of Approved Hazard Reviews.** HRs will be re-evaluated at least every three years to assure that the documents accurately reflect the current practices, that there are no additional potentially incompatible activities for that workspace, and that all controls are adequate and compliant with applicable OSHE program requirements. Activities will expire 3 years from the activity approval date. The Hazard Review and Approval system will display expiration dates.

   Notices. The PI will receive four notices prior to the expiration date. Six months and three months prior to the expiration date, the principal investigator will receive an email reminder to review the activity, update it if necessary, and submit it for re-review. At one month and one week prior to expiration, the Principal Investigator, Authorized Users, Division Safety Representative, and Group Leader will receive notices that the activity will expire unless it is submitted for re-review. ***Note: If your activity is already more than 3 years old, you will also have 6 months to complete the re-review.***

   When you receive the email notice:

   1. review the activity described in the hazard review form and attachments, the list of hazards and associated controls, and risk assessment
   2. update the information as necessary to reflect current practices and safety requirements
   3. submit the hazard review package for review

   Level of Re-Review and Approval. There are three basic types of updates that will meet the requirement for re-review and extend the expiration date. These are described below.

   Renew. If the principal investigator determines that no changes are needed, the principal investigator may click on renew, and the activity will be routed to the Group Leader for review and approval. Group Leader approval is all that is necessary for a renewal, regardless of Relative Hazard Index (RHI) level.

   Minor Revisions. Minor revisions may be approved by the Group Leader, regardless of the RHI level. Minor revisions are limited to the following: changes to attached documents; changes to activity name, description or frequency; removing rooms, substances, tasks or equipment; adding or modifying RHI=0 and RHI=1 substances, tasks, or equipment.

All Other Revisions. All other revisions are reviewed based on the RHI level of the change. For example, adding rooms to RHI=2 activities, adding or modifying RHI=2 tasks or substances, or deleting controls from existing RHI=2 tasks or substances are reviewed by the Group Leader, Division Safety Representative, and final approval is by the Division Chief. Similarly, adding rooms

to RHI=3 activities, adding or modifying RHI=3 tasks or substances, or deleting controls from existing RHI=3 tasks or substances are reviewed by the Group Leader, Division Safety Rep, Division Chief, Hazard Review Committee and final approval is by the MML Director.

Note that work may not be conducted on activities for which the hazard reviews have expired.

Change Log. The new system displays a change log so that reviewers can see, at a glance, what changes were made to the hazard review.

Records and Documentation: The HRA system assigns a unique identifier for each HR package (and revised package), maintains the documentation that comprises each hazard review package, and the records of approvals, recommended changes, and rejections for all activities. Although staff authorizations are associated with each HR package, approvals are maintained separately within the database system so that authorized users may be added or removed without re-approval of the entire hazard review package.

Review and Improvement: This policy will be reviewed annually by the EL Director, EL Deputy Director, and Safety Program Coordinator and revised as necessary to improve the effectiveness of the hazard review process. Revisions will be reviewed by the EL Management Council.

References:

1.) NIST Administrative Manual Chapter 12.06 Hazard Analysis and Control
Nota bene: The list of hazard types in the MML Hazard Review and Approval System includes those listed in Appendix A of AdMan 12.06, and the following additional hazards: biological, chemical carcinogen, chemical teratogen, dispersible engineered nanomaterial, and dust/particles.

2.) ANSI/AIHA Z10-2005, American National Standard for Occupational Health and Safety Management Systems, American Industrial Hygiene Association, 60 pp, 2005.

Table 1. List of Hazards from NIST Administrative Manual 12.06 Appendix A supplemented with additional hazards marked with an asterisk (*).

Hazard	Description
Asphyxiation/Oxygen Displacement	Lack of breathable oxygen resulting from the displacement of air in a room by sudden release of cryogenic fluids such as liquid nitrogen or liquid helium or in confined spaces such as manholes by the accumulation of noxious gases.
Biological*	Biological material or condition that presents potential risk to the health of humans or other organisms, either directly through infection or indirectly through damage to the environment.
Chemical (Carcinogen) *	A chemical that is capable of causing cancer
Chemical (Corrosive)	A chemical that, when it comes into contact with skin, metal, or other materials, damages the materials. Acids and bases are examples of corrosives.
Chemical (Flammable)	A chemical that when exposed to a heat ignition source results in combustion. Typically, the lower a chemical's flashpoint and boiling point, the more hazardous the chemical. Check MSDS for flammability/combustibility information. In general, flammable (combustible) materials are those with flash points lower than 100 °F (38 °C)
Chemical (Teratogen) *	A chemical that is capable of damaging fetuses. (Mutagens are capable of damaging chromosomes.)
Chemical (Toxic)	A chemical that when absorbed through the skin, inhaled, or ingested causes illness, disease, or death. The amount of chemical exposure is critical in determining hazardous effects. Check Material Safety Data Sheets (MSDS), and/or OSHA 1910.1000 for chemical hazard information.
Dispersible Engineered Nanomaterial*	Intentionally-produced, dispersible material with one or more dimensions between approximately 1 nm and 100 nm
Dust/Particles (Irritant) *	Any solid material in powdered form with particles that may irritate eyes, or the respiratory tract.
Explosion (Chemical Reaction)	Sudden and violent release of a large amount of gas/energy due to a chemical reaction.
Explosion (Over Pressurization)	Sudden and violent release of a large amount of gas/energy due to a significant pressure difference such as rupture in a boiler or compressed gas cylinder.
Electrical (Shock/Short-Circuit)	Contact with exposed conductors or a device incorrectly or inadvertently grounded. Contact with high voltages. Contact with 60 Hz alternating current (common house current) is very dangerous because it can stop the heart.
Electrical (Fire)	Use of electrical power that results in electrical overheating or arcing to the point of combustion or ignition of flammable material, or electrical component damage.
Electrical (Static/ESD)	The moving or rubbing of wool, nylon, other synthetic fibers, and even flowing liquids can generate static electricity. This creates an excess or deficiency of electrons on the surface of

	material, which discharges (spark) to the ground resulting in the ignition of flammables or damage to electronics or the body's nervous system.
Electrical (Loss of Power)	Safety-critical equipment failure as a result of loss of power.
Ergonomics (Strain)	Damage of tissue due to overexertion (strains and sprains) or repetitive motion.
Ergonomics (Human Factor)	A system design, procedure, or equipment that is error-provocative. (A switch goes up to turn something off).
Excavation (Collapse)	Soil collapse in a trench or excavation as a result of improper or inadequate shoring. Soil type is critical in determining the hazard likelihood.
Fall (Slip, Trip)	Conditions that result in falls (impacts) from height or traditional walking surfaces (such as slippery floors, poor housekeeping, uneven walking surfaces, exposed ledges, etc.)
Fire/Heat	Temperatures that can cause burns to the skin or damage to other organs. Fires require a heat source, fuel, and oxygen.
Mechanical/Vibration (Chaffing/Fatigue)	Vibration that can cause damage to nerve endings, or material fatigue that results in a safety-critical failure. (Examples are abraded slings and ropes, weakened hoses and belts.)
Mechanical Failure	Self-explanatory; typically occurs when devices exceed designed capacity or are inadequately maintained.
Mechanical	Skin, muscle, or body part exposed to crushing, caught-between, cutting, tearing, shearing items or equipment.
Noise	Noise levels (>85 dBA, 8 hr TWA) that result in hearing damage or inability to communicate safety-critical information.
Radiation (Ionizing)	Alpha, Beta, Gamma, neutral particles, and X-rays that cause injury (tissue damage) by ionization of cellular components.
Radiation (Non-Ionizing)	High power lasers and ultraviolet, visible, infrared, and microwave radiation that cause injury to tissue or eyes by thermal, photochemical, or other means.
Struck By (Mass Acceleration)	Accelerated mass that strikes the body causing injury or death. (Examples are falling objects and projectiles.)
Struck Against	Injury to a body part as a result of coming into contact of a surface when the action was initiated by that person. (An example is when a screwdriver slips.)
Temperature Extreme Cold	Temperatures that result in hypothermia, frostbite, or burns as may occur upon exposure to cryogens.
Temperature Extreme Heat	Temperatures that result in heat stress or exhaustion.
Visibility	Lack of lighting or obstructed vision that results in an error or other hazard.
Weather (Snow/Rain/Wind/Ice)	Self-explanatory

Table 2. Examples of Built-in Engineering, Applied, Alarms, Administrative, and PPE Controls

Built-in Engineering Controls	Enclosure/Isolation
	Ergonomic Design
	Interlock/Auto-shutoff
	Guard/Barrier
	Ventilation
Applied Engineering Control	Fume Hood
	Glove Box
	Biosafety Cabinet
	Nanomaterial ventilated enclosure
	Work behind shielding
Alarms and Warnings	Sensors with Alarms (e.g. O_2 sensor)
	Hood Alarms (hood height, face velocity, etc.)
	Proximity Alarms
	Signs (Danger, Warning, Caution, Radioactive material, etc.)
Administrative Controls	Training ▪ Review hazards, controls and procedures ▪ Read MSDS ▪ Instructor led course ▪ On-line course ▪ Training for PPE use (respirator, hearing protection ▪ Training on specific instrument ▪ Training on specific hazards ▪ Hands-on training by PI
	Procedures or instructions
	Work Permits
	Safe Practices
	Time Limitations
	Buddy system
	Industrial hygiene practices
	Monitoring
Personal Protective Equipment	Eye protection: ▪ Safety glasses with side shields ▪ Safety goggles ▪ Laser-safety glasses ▪ Face Shield
	Clothing: ▪ High Visibility clothing ▪ Lab coat
	Gloves (e.g, nitrile; insulated, etc. See glove selection guide.)
	Hearing Protection: Specify Type (e.g., Earplugs, Headphones) Specify Required or Voluntary*
	Head Protection (e.g. Bump cap, Hard Hat, etc.)
	Foot Protection (e.g., Steel-toed boots, slip resistant, etc.)
	Respirator: Specify Type (e.g., SCBA, PAPR, etc.) Specify Required or Voluntary*
	Dust Mask (Specify required or voluntary)*

- Required Use: The PPE must be flagged as “Required” when there is a potential during normal operations, for exposures that meet or exceed a regulatory limit. When use is required an exposure assessment is also required.
- Voluntary Use: PPE must be flagged as “Voluntary” when there is no potential during normal operations, for exposures that meet or exceed a regulatory limit, but the user would like additional protection.

Table 3. Risk Hazard Index Matrix based on ANSI/AIHA Z10-2005, American National Standard for Occupational Health and Safety Management Systems.

		POTENTIAL SEVERITY OF HAZARD			
		Catastrophic Death or permanent disability System or facility loss Lasting environmental or public health impact	**Severe** Serious injury; temporary disability Subsystem loss or facility damage Temporary environmental or public health impact	**Moderate*** Medical treatment; lost-work-day(s) Minor facility damage External reporting/cleanup requirements	**Minor**** First-aid only Negligible or slight damage Routine cleanup
LIKELIHOOD OF OCCURRENCE	**Frequent** Likely to occur repeatedly	**CRITICAL** **RHI=4**	**CRITICAL** **RHI=4**	**SERIOUS** **RHI=3**	**Medium** **RHI=2**
	Probable Likely to occur multiple but infrequent times	**CRITICAL** **RHI=4**	**CRITICAL** **RHI=4**	**SERIOUS** **RHI=3**	**Medium** **RHI=2**
	Occasional Likely to occur at some time	**CRITICAL** **RHI=4**	**SERIOUS** **RHI=3**	**Medium** **RHI=2**	**Low** **RHI=1**
	Remote Possible, but not likely to occur	**SERIOUS** **RHI=3**	**Medium** **RHI=2**	**Medium** **RHI=2**	**Low** **RHI=1**
	Improbable Very unlikely; can reasonably assume it will not occur	**Medium** **RHI=2**	**Low** **RHI=1**	**Low** **RHI=1**	**Minimal** **RHI=0**

*The ANSI/AIHA Z10-2005 standard uses “Marginal” rather than Moderate to describe this severity.
** The ANSI/AIHA Z10-2005 standard uses “Negligible” rather than Minor to describe this severity.

Appendix 6.3.1: *Composite Floor Systems Test* Hazard Review (#733.06.0124) and All Associated Documentation approved on 10/24/19

View Activity

733.06.0124.021919i - Composite Floor Systems Tests (Replaced)

Contacts:
Principal Investigator: [redacted]
Division: Fire Research Division **Division Chief:** [redacted]
Group: National Fire Research Laboratory **Group Leader:** [redacted]

Activity description: The objective of this test is to measure the response and fire resistance of steel-concrete composite floor assemblies to a compartment fire. A series of tests will be conducted on 6.1 m by 9.1 m composite floor assemblies which will be mechanically loaded to the service gravity load level at ambient temperature and then subjected to a compartment fire.

Parameters: **Activity Frequency:** Limited Duration **Times Repeated:** less than 10

Hazards:


Hot surface


Flammable materials


Toxic

Required PPE:


Safety Glasses with side shields


Head Protection


Foot Protection

Other PPE (Please Specify) (long pants)


Lab Coat (flame retardant lab coat)


Gloves (specify type or types) (Cut resistant gloves)


Dust mask (Voluntary Use)

Storage requirements: None specified

Locations (Contact): 205/125[redacted])

Authorized Users:

User Name	Authorized By	Authorization Date	Approved for Out of Hours Work By	Out of Hours Approval Date
[redacted]	Activity Replaced	October 24, 2019	--	--
	Activity Replaced	October 24, 2019	--	--
	Activity Replaced	October 24, 2019	--	--
	Activity Replaced	October 24, 2019	--	--
	Activity Replaced	October 24, 2019	--	--
	Activity Replaced	October 24, 2019	--	--
	Activity Replaced	October 24, 2019	--	--
	Activity Replaced	October 24, 2019	--	--
	Activity Replaced	October 24, 2019	--	--

Required Training: Review of Hazard Review and Procedures (Operation of NFRL Structural Loading Systems (733.06.0073)), Review of Hazard Review and Procedures (NFRL Large Fire Experiments (733.06.0132); Enclosure Fire Test using Natural Gas Burners (733.06.0120);), Other (Please Specify) (Refer to SOP), Review of Hazard Review and Procedures (NFRL Large Fire Experiments (733.06.0132)), Other (Please Specify) (NIST S 7101.61: Compressed Gas Safety Program Training (operator only)), Review of Hazard Review and Procedures (Refer to NFRL Large Fire Experiments (733.06.0132)), Other (Please Specify) (EL-733: NFRL Emission Control System Training for Operators), Review of Hazard Review and Procedures (NFRL Overhead Cranes (733.06.0052); NFRL Scissor and Boom Lifts (733.06.0051); Assembly and Installation of Reaction Yoke (733.06.0069); NFRL Post-Tensioning of High Strength Bars (733.06.0071); NFRL General Scaffolding Use (733.06.0125))

Incident/Emergency Response Plan Location: ERP

Expiration Date: October 24, 2022

History: **Created:** [redacted] 2019-02-19 13:36:44 -0500 **Updated:** [redacted] 2021-01-22 14:04:15 -0500

Reviews: **Review Level:** Division Chief

Related Documentation

Title	Filename	Attachment Type	Description
Safety Briefing Checklist	NFRL_Generic_Safety_Briefing_Checklist_7-14-2016__3_.docx	Other	
natural gas	SDS-natrual-gas.pdf	Safety Data Sheet (previously MSDS)	
propane	SDS-portable-propane.PDF	Safety Data Sheet (previously MSDS)	
carbon dioxide	SDS-carbon-dioxide.pdf	Safety Data Sheet (previously MSDS)	
carbon monoxide	SDS-carbon-monoxide.pdf	Safety Data Sheet (previously MSDS)	
ERP	CompositeFloorTest_ERP.docx	Incident/Emergency Response Plan	Revised after DSR review
SOP	CompositeFloorTest_SOPmb_kh_rev2_nb2.docx	Standard Operating Procedure	Revised after Division Chief review
SOP with comments	CompositeFloorTest_SOPmb.docx	Review Attachment Group Leader review [redacted] September 2019	markup of SOP

Approval/Review History

Activity	Status	Review level	Reviewing Official	Modified
733.06.0124 - Composite Floor Systems Tests	Review Completed	Group Leader	[redacted]	[redacted] 2019-09-11 13:03:20 -0400
733.06.0124 - Composite Floor Systems Tests	Returned to PI	Division Safety Representative	[redacted]	[redacted] - 2019-09-19 12:09:10 -0400
733.06.0124 - Composite Floor Systems Tests	Returned to PI	Division Safety Representative	[redacted]	[redacted] - 2019-09-25 11:29:09 -0400
733.06.0124 - Composite Floor Systems Tests	Review Completed	Division Safety Representative	[redacted]	[redacted] - 2019-09-25 16:17:20 -0400
733.06.0124 - Composite Floor Systems Tests	Returned to PI	Division Chief	[redacted]	[redacted] 2019-10-18 10:41:14 -0400
733.06.0124 - Composite Floor Systems Tests	Review Completed	Division Chief	[redacted]	[redacted] 2019-10-24 11:23:28 -0400

Tasks/Equipment

1. Setup (Tasks/Equipment)

Signage Required N/A

Required Controls

Guard/Barrier, **Other Engineering Controls (Please Specify)** (Rated structural braces and shoring), **Operating Procedures** (OHSA 1926.502- Fall protection systems criteria and practices; OHSA 1926.759 - Falling object protection; 1926.302 Power-operated hand tools), **Safe Practices** (pre-activity briefing & meeting to discuss steel erection; OHSA steel erection tools (https://www.osha.gov/SLTC/etools/steelerection/index.html)), **Review of Hazard Review and Procedures** (NFRL Overhead Cranes (733.06.0052); NFRL Scissor and Boom Lifts (733.06.0051); Assembly and Installation of Reaction Yoke (733.06.0069); NFRL Post-Tensioning of High Strength Bars (733.06.0071); NFRL General Scaffolding Use (733.06.0125)), **Dust mask (Voluntary Use)**, **Foot Protection**, **Gloves (specify type or types)** (Cut resistant gloves), **Head Protection**, **Safety Glasses with side shields**

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Struck By (Mass Acceleration)	Set-up and/or Tear Down	Catastrophic	Improbable	2 - Medium

2. Mechanical loading (Tasks/Equipment)

Signage Required N/A

Required Controls

Enclosure/Isolation (Actuators are located at the basement), **Interlock/Auto-shutoff** (Actuators will be automatically depressurized with preset load and displacement limits; Emergency stop), **Other Engineering Controls (Please Specify)** (Rated loading frames and support frames with safety factors; instrumentation to monitor structural integrity), **Operating Procedures** (Refer to SOP), **Safe Practices** (Exclusion zone of 5 m will significantly reduced struck by hazard), **Review of Hazard Review and Procedures** (Operation of NFRL Structural Loading Systems (733.06.0073)), **Foot Protection**, **Head Protection**, **Other PPE (Please Specify)** (long pants), **Safety Glasses with side shields**

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Struck Against	Normal Operations	Severe	Remote	2 - Medium

3. Specimen heating (Tasks/Equipment)

Hot surface

Signage Required hot_surface

Required Controls

Interlock/Auto-shutoff (Maxon safety shutoff switch), **Other Engineering Controls (Please Specify)** (Automatic deluge and monitor, and manual hose fire suppression system., Methyl Mercaptan addative. Odor threshold .002 (ppm)), **Ventilation** (20 MW exhaust hood), **Safe Practices** (safety briefing; 5 m exclusion zone; leak checks), **Other (Please Specify)** (Refer to SOP), **Review of Hazard Review and Procedures** (NFRL Large Fire Experiments (733.06.0132); Enclosure Fire Test using Natural Gas Burners (733.06.0120);), **Foot Protection**, **Head Protection**, **Lab Coat** (flame retardant lab coat), **Other PPE (Please Specify)** (long pants), **Safety Glasses with side shields**

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Fire/Heat	Normal Operations	Catastrophic	Improbable	2 - Medium

Principal Substances

Concrete projectiles by spalling (Principal Substances)

Signage Required	N/A
Health	Moderate (2)
Flammable	None (0)
Reactive	None (0)
Storage Required	N/A

Required Controls

Other Engineering Controls (Please Specify) (polypropylene fibers (as crack arresters) in concrete mix), **Safe Practices** (5 m Exclusion zone during test), **Foot Protection**, **Head Protection**, **Safety Glasses with side shields**

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Struck By (Mass Acceleration)	Normal Operations	Moderate	Improbable	1 - Low

Natural gas (Principal Substances)

Signage Required	N/A
Quantity	20
Units	psig
Health	Slight (1)
Flammable	Extreme (4)
Reactive	None (0)
Storage Required	N/A

Required Controls

Other Engineering Controls (Please Specify) (Refer to NFRL Large Fire Experiments (733.06.0132)), **Other Device Use (Please Specify)** (Refer to NFRL Large Fire Experiments (733.06.0132)), **Operating Procedures** (Refer to NFRL Large Fire Experiments (733.06.0132)), **Review of Hazard Review and Procedures** (NFRL Large Fire Experiments (733.06.0132))

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Chemical (Flammable)	Normal Operations	Catastrophic	Improbable	2 - Medium

Propane gas (Principal Substances)

Signage Required	N/A
Quantity	< 0.5
Units	L
Health	Moderate (2)
Flammable	Extreme (4)
Reactive	None (0)
Storage Required	N/A

Required Controls

Other Engineering Controls (Please Specify) (No hazards are listed because the hazards have been accounted for elsewhere or there are no associated hazards.), **Other (Please Specify)** (NIST S 7101.61: Compressed Gas Safety Program Training (operator only))

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Chemical (Flammable)	Normal Operations	Catastrophic	Improbable	2 - Medium

Waste Products

Carbon Dioxide Waste Products)

Signage Required N/A
Health Moderate (2)
Flammable None (0)
Reactive None (0)
Storage Required N/A

Required Controls

Other Engineering Controls (Please Specify) (Refer to NFRL Large Fire Experiments (733.06.0132)), **Operating Procedures** (Refer to NFRL Large Fire Experiments (733.06.0132)), **Review of Hazard Review and Procedures** (Refer to NFRL Large Fire Experiments (733.06.0132))

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Asphyxiation/Oxygen displacement	Normal Operations	Minor	Remote	1 - Low

Carbon Monoxide (Waste Products)

Signage Required N/A
Health Moderate (2)
Flammable Extreme (4)
Reactive None (0)
Storage Required N/A

Required Controls

Other Engineering Controls (Please Specify) (Refer to NFRL Large Fire Experiments (733.06.0132)), **Ventilation** (20 MW exhaust hood), **Alarms** (CO monitors in the high bay), **Use Monitoring** (CO measurement inside the compartment), **Other (Please Specify)** (EL-733: NFRL Emission Control System Training for Operators), **Review of Hazard Review and Procedures** (Refer to NFRL Large Fire Experiments (733.06.0132))

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Chemical (Toxic)	Normal Operations	Catastrophic	Improbable	2 - Medium

Version History

Initial Version: 733.06.0124.021919i

Subsequent Version (1 of 2): 733.06.0124.012221

Type of Change and Resulting Level of Review for this Version

Change Type:	Minor change(s); see table below for detailed list of changes. Review and final approval by first-level Supervisor, regardless of activity RHI value.
Primary reasons for this change type:	• Any changes to the activity result in the classification of the changes as minor

Detailed list of changes (compared to prior version)

Description or documentation Field	Change Type	Previous Version	This Version
Attachment: NFRL Safety Briefing Checklist	Added		
Description for attachment: SOP	Changed	Revised after Division Chief review	Added COVID-19 requirements Revised PPE, exclusion zone, and testing criteria
Disk filename for attachment: SOP	Changed	191021102514_CompositeFloorTest_SOPmb_kh_rev2_nb2.docx	210122125712_CompositeFloorTest_Rev1_lc.docx
Filename for attachment: SOP	Changed	CompositeFloorTest_SOPmb_kh_rev2_nb2.docx	CompositeFloorTest_Rev1_lc.docx
Filesize for attachment: SOP	Changed	737623	969110
Attachment: Safety Briefing Checklist	Removed		
Experiment description	Changed	The objective of this test is to measure the response and fire resistance of steel-concrete composite floor assemblies to a compartment fire. A series of tests will be conducted on 6.1 m by 9.1 m composite floor assemblies which will be mechanically loaded to the service gravity load level at ambient temperature and then subjected to a compartment fire.	The objective of this test is to measure the structural and temperature responses of steel-concrete composite floor assemblies to a natural gas-fueled compartment fire. A series of tests will be conducted on 6.1 m by 9.1 m composite floor assemblies which will be mechanically loaded to the service gravity load level at ambient temperature and then subjected to a compartment fire simulating the ASTM E119 fire environment.

Subsequent Version (2 of 2): 733.06.0124.031621

Type of Change and Resulting Level of Review for this Version

Change Type:	Minor change(s); see table below for detailed list of changes. Review and final approval by first-level Supervisor, regardless of activity RHI value.
Primary reasons for this change type:	• Any changes to the activity result in the classification of the changes as minor

Detailed list of changes (compared to prior version)

Description or documentation Field	Change Type	Previous Version	This Version
Attachment: SOP	Removed		
Attachment: SOP Version1 Original	Added		
Attachment: SOP Version2 including PostFireLoadingTest	Added		

Title: Compartment Fire Test on Composite Floor System

Building & room number: Building 205; Room 125

Test Director:

Workspace manager(s):

Purpose and Scope: The purpose of this test program is to measure thermal and structural responses of the composite floor assemblies subjected to combined mechanical loading and compartment fires. This experimental test involves a two-story multi-bay structural steel frame with concrete floor slabs constructed at the NFRL. The fire compartment measures 6.1 m (20 ft) by 9.1 m (30 ft) in plan and 4.0 m (13 ft) in height, situated at the middle bay of the test frame on the ground level (Refer to Figure 1). The test fire will be produced using four 1.5 m by 1 m natural gas-fueled burners distributed inside the test compartment. Four hydraulic actuators mounted at the basement are be connected to loading frames above the test floor assembly via water-cooled high-strength steel pipes to apply the code-required gravity loads during fire exposure. The composite floor assembly resisting mechanical loads will be exposed to a compartment fire (with heat release rate up to 11.4 MW) until a structural failure condition is reached.

This SOP pertains to personnel who have active roles identified during the pre-test safety briefing. Other safety protocols will be also notified during the pre-test safety briefing.

After consultation with the NFRL group leader and the workspace manager, the principle investigator (Test director) of each activity shall provide an approved hazard review for final review by the NFRL group leader before the activity can commence.

Hazardous Materials:

- Chemical (Flammable): Natural gas, propane
- Chemical (Toxic): Carbon monoxide

Special containment, containers or handling equipment:

- 20 MW exhaust hood will capture hot gases and combustibles.
- Four actuators will be mounted at the basement to protect from fire exposure.

Required Personal Protective Equipment (PPE):

1. **Setup**
   - Closed toe shoes
   - Hard hat
   - Safety glasses
   - Long pants
   - Cut resistant gloves
   - Dust mask (voluntary use)

- Half-mask air-purifying respirator equipped with high efficiency particulate air (HEPA) filter cartridges (for installation and removal of ceramic fiber blanket)

2. **Experiment**
    - Closed toed shoes
    - Fire resistant lab coat
    - Hard hat
    - Safety glasses
    - Long pants
    - Heat resistant gloves (voluntary use)
    - Firefighter turn out gear and heat resistant gloves (only for an operator who ignites the pilot flame)

Training Requirements:

1. **For all participants:**
    - EL-733: NFRL Lab Access and Safety Awareness
    - NIST S 7101.21: Personal Protective Equipment Program Training
2. **For operators only:**
    - EL-733: NFRL Emission Control System Training
    - EL-733: NFRL Natural Gas Fuel Delivery System Training
    - EL-733: NFRL Structural Loading System (733.06.0073)
    - EL-733: NFRL Overhead Cranes Training (733.06.0052)
    - EL-733 Scissor and Boom Lifts Training (733.06.0051)
    - NIST S 7101.58: Respiratory Protection Program - Training for Voluntary Use of Filtering Facepieces
    - NIST S 7101.58: Respiratory Protection Program - Initial Training (Web-based)
    - NIST S 7101.58: Respiratory Protection Program - Initial or Annual Fit Testing

Hazards and Controls:

1. Set-up

a) General Hazards: Stuck by (Mass Acceleration), Fall (Slip, Trip)
- Specific Hazards:
    - Refer to Hazard Review on NFRL Overhead Cranes (733.06.0052)
    - Refer to Hazard Review on NFRL Scissor and Boom Lifts (733.06.0051)
    - Refer to Hazard Review on NFRL General Scaffolding Use (733.06.0125)
    - Refer to Hazard Review on Assembly and Installation of Reaction Yoke (733.06.0069)
    - Refer to Hazard Review on NFRL Post-Tensioning of High Strength Bars (733.06.0071)
- Engineering Controls:
    - All engineering controls listed in hazard reviews above.

- Administrative Controls:
  - Pre-activity briefing or meeting to discuss the sequence of construction
  - Guard/barrier/signs
  - Exclusion zone defined by the workspace manager
  - Buddy system
  - Time limitations (7:30-4:00)
  - PPE (see PPE list above)

2. Experiment

a) General Hazard: Stuck by (Mass Acceleration)

- Engineering Controls
  - Emergency stop switch integrated with the MTS computer located in the NFRL test bay.
  - The loading frames are designed to transfer the maximum force up to 34,000 lbs. per actuator. The force applied in this test will be 7,000 lbs. per actuator. Safety factor, SF, (the ratio of the design strength of loading frames to the applied load during the test) is about 5.
  - Entire floor assembly is designed for SF=3 or greater (at ambient temperature).
  - Support columns are designed for SF=3 or greater and anchored to the strong floor (providing a reliable load path to the strong floor)
  - Rated structural braces or catch systems that prevent damages to the strong floor
  - Concrete mixture design with polypropylene fibers to lower the likelihood of explosive spalling
  - Instrumentation to monitor the structural integrity of the test structure
- Administrative Controls
  - Pre-test safety briefing
  - Exclusion zone (See Figure 2)
  - PPE (hard hat, close toe shoes, safety glasses, gloves, long pants)

b) General Hazards: Fire and Heat

- Specific Hazards
  - Refer to Hazard Review on NFRL Large Fire Experiments (733.06.0132)
  - Refer to Hazard Review on Enclosure Fire Test using Natural Gas Burners (733.06.0120)
- Engineering Controls
  - All engineering controls listed in the hazard reviews above
  - Maxon safety shutoff switch
  - Automatic deluge and monitor as well as manual hose fire suppression system
  - NFRL exhaust hood for ventilation
  - Combustible gas leak detector
  - Flame barriers outside the test compartment (gypsum or concrete boards, ceramic fiber blanket, and heat shield)

- Water cooling of burner frames
- MTS actuators mounted at the basement to protect from fire
- Instrumentation to monitor temperatures of the test floor and surrounding structures

- Administrative Controls
  - Pre-test safety briefing
  - Routine inspection and leak checks for natural gas burners and pipework
  - Operator who ignites the pilot flames should wear turnout gear and heat resistant gloves.
  - PPE (hard hat, close toe shoes, safety glasses, long pants, flame retardant lab coat)
  - Exclusion zone (See Figure 2)

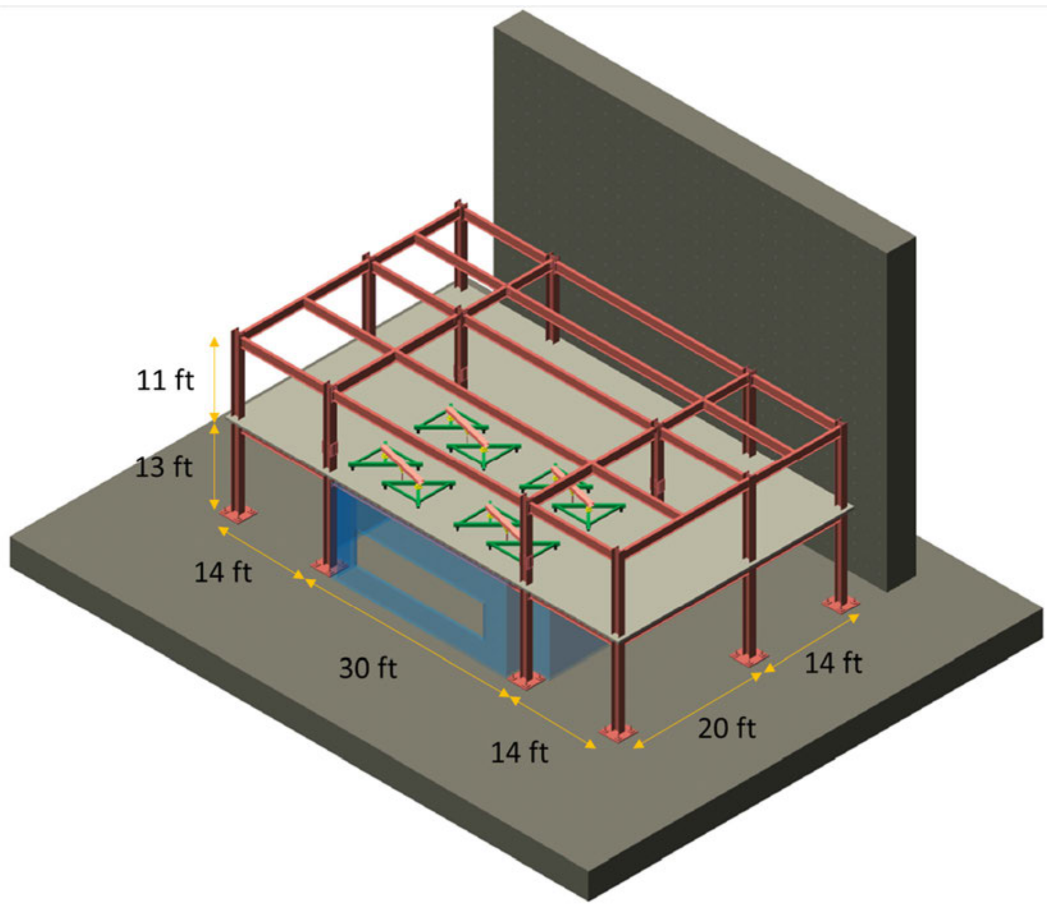


Figure 1. Test Structure

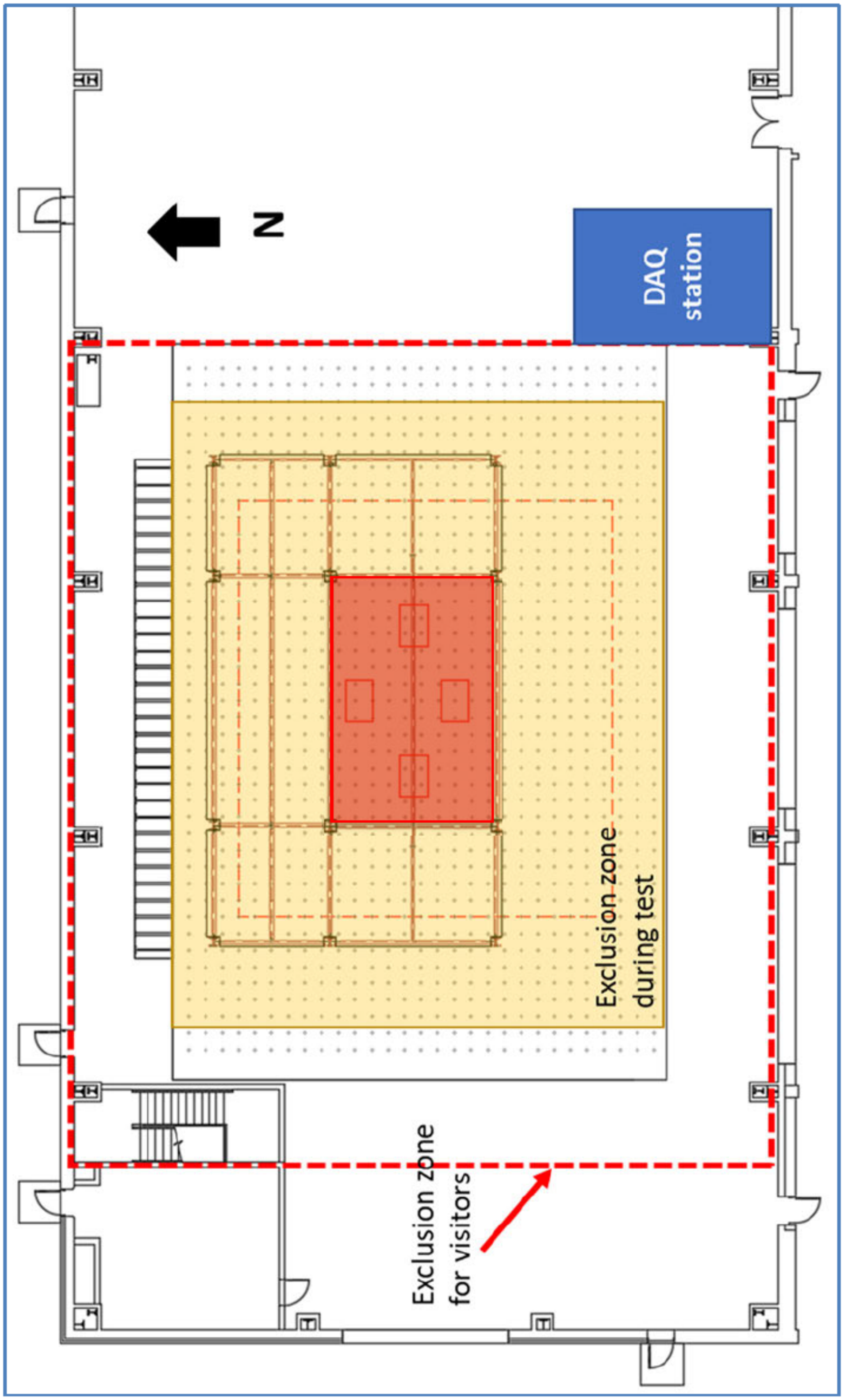


Figure 2 Exclusion zone during experiment (Bldg. 205 / Rm 125)

Standard Operating Procedure (SOP):

Experiments shall not be conducted if the outside temperature is below -10 °C or above 45 °C or if extreme weather is expected.

1. **Pre-test**
   - ☐ Turn on exhaust fans and open makeup air dampers.
   - ☐ Verify no desired combustible materials within 5 m of the hood skirt
   - ☐ Deactivate automatic fire suppression systems
   - ☐ Verify all fire suppression water lines are functioning.
   - ☐ Notify NIST fire department
   - ☐ Turn on measurement systems and verify that they are functioning.
   - ☐ Turn on lighting and verify camera settings if used.
   - ☐ Verify MTS actuator load rate, displacement limit and interlocks setting
2. **Test director conducts safety briefing**
   The Safety Briefing is limited to individuals identified by the Test Director. Personnel who do not attend the safety briefly shall not enter the test area after this point. Refer to Figure 2 for exclusion zone
3. **Start data acquisition**
4. **Apply the specified mechanical loads to the test floor assembly at ambient temperature**
   a. Extend the actuator piston to maintain the 1-inch gap between the ceiling of the basement and the top of the actuator coupler.
   b. Apply a preload of 1000 lbs. per actuator at a rate of 250 lbs./min. Verify force distributions over the test floor and structural measurements.
   c. Increase a force to 6000 lbs. per actuator at a rate of 250 lbs./min. The total mechanical force applied using four actuators is approximately equal to 28,000 lbs. which should be maintained using the MTS force control. Set the displacement limit of the actuators (approximately equal to 20 inches).
5. **Acquire background data for heat release rate**
6. **Ignite pilot flame and burner performed by qualified NIST staff**
   a. A pilot flame is installed on each test burner and is comprised of copper gas line fed by a small propane bottle outside of the compartment.
   b. Technician wearing turnout gear checks for gas in compartment with sniffer, ignites the pilot flame with a portable propane bottle and 1 m copper wand and then exits the compartment.
   c. NFRL natural gas operator starts the flow of natural gas to the test burner.
   d. After the fire ignition is confirmed by an assigned observer, the test protocol is begun.
7. **Increase gas flow to bring fire to desired test magnitude.**
   Refer to the table below for a target magnitude of the burner heat release rate.

Time (min)	Target Burner HRR (kW)
0	870
1	870
6	5800
11	7,000
22	8,000
44	9,000
75	10,000
135	11,400
180 -	11,400

8. **Run test until any of the following criteria is reached.**
    - Actuator displacement limit (20 inches),
    - Failure of the test floor connections,
    - Loss of slab continuity at critical locations,
    - Significant flame leakages above the concrete slab,
    - Loss of exhaust hood flow,
    - Significant damage to the fire compartment, or
    - Failure of critical safety monitoring systems (i.e., data acquisition and/or cameras not returning to satisfactory operation within a reasonable time, 5 minutes)

    If at any time unsafe conditions exist, the Safety Officer, the Test Director, and the Lab Director will have authority to stop the experiment.

9. **Shut off the natural gas fuel delivery system and remove mechanical loads applied using actuators.**

10. **Stop data acquisition system when the temperature of the specimen (both steel and concrete) drops below 100 °C.**

11. **Maintain exclusion area (Figure 2) until the wall surface cooled down below 50 C as determined by thermocouple or handheld FLIR camera and CO measured in the compartment drops below 50 PPM.**

Specimen removal and clean-up procedure:

- Within a week after completion of the test, a Specimen Removal Safety Team, consisting of NFRL technician(s) and engineer(s), will meet to assess damage level of the tested specimen and to identify hazard(s) associated with removing process. A separate hazard review will be submitted for tear-down tasks completed by NFRL staff.

Plans for Out-of-Hours Operation: Out-of-hours operation is not permitted.

Compartment Fire Test on Composite Floor System
Emergency Response Plan

Building & room number: Building 205; Room 125

Test Director:

Workspace manager(s):

Emergency Response Plan: Scenarios listed below.

Power outage
During a power outage, all participants shall follow the directions from the Safety Officer designated during the pre-test Safety Briefing. NIST staff will suppress the fire prior to exiting the building if feasible. Testing will be performed during daylight hours, so the rollup door can be manually raised to provided natural light, as required.

Shelter-in-place
During a shelter-in-place (SIP), all test participants shall follow the directions from the Safety Officer designated during the pre-test Safety Briefing (SIP location, first floor locker room 109). The Safety Officer will decide whether to suppress the fire prior to retreating to the shelter-in-place location.

Loss of ventilation
In case of loss of ventilation from the exhaust hood, all test participants shall follow the directions from the Safety Officer designated during the pre-test Safety Briefing. NFRL staff will turn off fuel supply or suppress the fire prior to exiting the building. In some cases, the fire will be allowed to self-extinguish when fuel is depleted. This will be decided before the start of the test.

Loss of critical monitoring system
In the case that critical safety monitoring systems, such as cameras and/or data acquisition, should fail, the Safety Officer in consultation with the Test Director shall determine whether the experiment can be safely continued. If no immediate hazard is identified, the Safety Officer may allow experiment to continue If the monitoring systems can be returned to satisfactory operation within a reasonable time, 5 minutes. If at any time, the Safety Officer or the Test Director determine that unsafe conditions exist, the experiment must be shut down.

Hydraulic leak
In case of hydraulic leak or spill, all test participants shall follow the directions from the Safety Officer and MTS operator designated during the pre-test Safety Briefing. The Safety Officer will decide when it is safe to enter the spilled zone to eliminate sources of ignition, to stop source of leak, to prevent entry into waterways and sewer systems, and to take necessary actions for clean-up.

Uncontrolled fire or natural gas leak:
In the case that and uncontrolled fire or uncontrolled natural gas leak occurs, the fire alarm should be activated and all staff in building 205 should leave the building and proceed to

grassy areas across from the main entrance. Call x2222 as soon as possible. Report incident to line management.

Injury

If the injury requires emergency medical attention, contact NIST Emergency Services at ext. 2222. The individual must immediately notify (or have someone notify) his/her group leader, division chief, and division safety representative. Supervisor will arrange transportation to the health unit in a non-emergency incident. All injuries must be reported.

NFRL Fire Test Safety Briefing Checklist

Project Name:___________________________________

Date: ___________________________

Test File Name:____________________________________

1) Roles and Responsibilities
   a. PI/Test Director: ___________________________
   b. CoPI: ______________________________________
   c. Safety Officer: ______________________________
   d. DAQ Operator: ______________________________
   e. ECS Operator: ______________________________
   f. NG Control System Operator: _________________
   g. Ignition/Suppression: ________________________
2) Test description
   a. Fuel:____________ Peak HRR: ___________ Ignition: _________________
   b. What's new:_______________ What's expected: _____________________
3) Hazards (circle)
   a. Smoke, heat, hot objects, heavy lifting, tripping
   b. Other hazards___________________________
4) Mitigation
   a. FLHR#__________ (briefly review major controls)
   b. Emergency procedures and evacuation and Incident reporting
   c. Review Rules for Guests and Visitors (exclusion zones and exits)
5) Review Immediate Timeline ____
6) Verify Tasks:
   a. ☐ - NIST FD Notified and Water Deluge System in Bypass
   b. ☐ - Exhaust Hood Dampers Set (3 m, 6 m, 9 m, 15 m)
   c. ☐ - Exhaust Fresh Air Intakes Open
   d. ☐ - Hood Air Mass Flow Rate _______ kg/s
   e. ☐ - Visible Emission Required? (yes/no). Observer ___________________
   f. ☐ - Restricted Access Signs and Barriers at Doors
   g. ☐ - Safety Briefing Completed

NATURAL GAS

ChemWatch Review SDS

Chemwatch Hazard Alert Code: **4**

Chemwatch: **4074-09**
Version No: **12.1.1.1**
Safety Data Sheet according to OSHA HazCom Standard (2012) requirements

Issue Date: **01/13/2016**
Print Date: **09/17/2016**
L.GHS.USA EN

SECTION 1 IDENTIFICATION

Product Identifier

Product name	NATURAL GAS
Chemical Name	natural gas
Synonyms	gas sweet, natural gas C1-4, natural gas, sweet, raw gas, sweet natural gas, sweet raw gas, synthetic natural gas, wellhead natural
Proper shipping name	Methane, compressed or Natural gas, compressed (with high methane content)
Other means of identification	Not Available
CAS number	8006-14-2

Recommended use of the chemical and restrictions on use

Relevant identified uses	The use of a quantity of material in an unventilated or confined space may result in increased exposure and an irritating atmosphere developing. Before starting consider control of exposure by mechanical ventilation. Operators should be trained in correct use. Commercial heating and cooking gas fuel. Fractionated and used as base raw material for the manufacture of many chemicals ammonia, acetylene. etc..

Name, address, and telephone number of the chemical manufacturer, importer, or other responsible party

Registered company name	Vector (Vector Gas)
Address	101 Carlton Gore Road Auckland Newmarket New Zealand
Telephone	+64 9 978 7788
Fax	Not Available
Website	Not Available
Email	Not Available

Emergency phone number

Association / Organisation	Not Available
Emergency telephone numbers	Not Available
Other emergency telephone numbers	Not Available

SECTION 2 HAZARD(S) IDENTIFICATION

Classification of the substance or mixture

Considered a Hazardous Substance by the 2012 OSHA Hazard Communication Standard (29 CFR 1910.1200). Classified as Dangerous Goods for transport purposes.

CHEMWATCH HAZARD RATINGS

Continued...

		Min / Max
Flammability	4	
Toxicity	0	
Body Contact	1	
Reactivity	1	
Chronic	0	

0 = Minimum
1 = Low
2 = Moderate
3 = High
4 = Extreme

NFPA 704 diamond

Note: The hazard category numbers found in GHS classification in section 2 of this SDSs are NOT to be used to fill in the NFPA 704 diamond. Blue = Health Red = Fire Yellow = Reactivity White = Special (Oxidizer or water reactive substances)

CANADIAN WHMIS SYMBOLS

CANADIAN WHMIS CLASSIFICATION

Ingredient	CAS number	Classification Description	Classification Code
methane	74-82-8	Compressed Gas, Flammable Gas	A, B1

Classification	Simple Asphyxiant, Flammable Gas Category 1, Gas under Pressure (Compressed gas)

Label elements

GHS label elements	

SIGNAL WORD	DANGER

Hazard statement(s)

H220	Extremely flammable gas.
H280	Contains gas under pressure; may explode if heated.
	May displace oxygen and cause rapid suffocation

Hazard(s) not otherwise specified

Not Applicable

Supplementary statement(s)

Not Applicable

Precautionary statement(s) Prevention

P210	Keep away from heat/sparks/open flames/hot surfaces. - No smoking.

Precautionary statement(s) Response

P377	Leaking gas fire: Do not extinguish, unless leak can be stopped safely.
P381	Eliminate all ignition sources if safe to do so.

Precautionary statement(s) Storage

P410+P403	Protect from sunlight. Store in a well-ventilated place.

Precautionary statement(s) Disposal

Not Applicable

SECTION 3 COMPOSITION / INFORMATION ON INGREDIENTS

Substances

CAS No	%[weight]	Name
8006-14-2		natural gas
		as
74-82-8	85-95	methane

Continued...

Mixtures

See section above for composition of Substances

SECTION 4 FIRST-AID MEASURES

Description of first aid measures

Eye Contact	▸ If product comes in contact with eyes remove the patient from gas source or contaminated area. ▸ Take the patient to the nearest eye wash, shower or other source of clean water. ▸ Open the eyelid(s) wide to allow the material to evaporate. ▸ Gently rinse the affected eye(s) with clean, cool water for at least 15 minutes. Have the patient lie or sit down and tilt the head back. Hold the eyelid(s) open and pour water slowly over the eyeball(s) at the inner corners, letting the water run out of the outer corners. ▸ The patient may be in great pain and wish to keep the eyes closed. It is important that the material is rinsed from the eyes to prevent further damage. ▸ Ensure that the patient looks up, and side to side as the eye is rinsed in order to better reach all parts of the eye(s) ▸ Transport to hospital or doctor. ▸ Even when no pain persists and vision is good, a doctor should examine the eye as delayed damage may occur. ▸ If the patient cannot tolerate light, protect the eyes with a clean, loosely tied bandage. ▸ Ensure verbal communication and physical contact with the patient. **DO NOT** allow the patient to rub the eyes **DO NOT** allow the patient to tightly shut the eyes **DO NOT** introduce oil or ointment into the eye(s) without medical advice **DO NOT** use hot or tepid water.
Skin Contact	If skin contact occurs: ▸ Immediately remove all contaminated clothing, including footwear. ▸ Flush skin and hair with running water (and soap if available). ▸ Seek medical attention in event of irritation.
Inhalation	▸ Following exposure to gas, remove the patient from the gas source or contaminated area. ▸ NOTE: Personal Protective Equipment (PPE), including positive pressure self-contained breathing apparatus may be required to assure the safety of the rescuer. ▸ Prostheses such as false teeth, which may block the airway, should be removed, where possible, prior to initiating first aid procedures. ▸ If the patient is not breathing spontaneously, administer rescue breathing. ▸ If the patient does not have a pulse, administer CPR. ▸ If medical oxygen and appropriately trained personnel are available, administer 100% oxygen. ▸ Summon an emergency ambulance. If an ambulance is not available, contact a physician, hospital, or Poison Control Centre for further instruction. ▸ Keep the patient warm, comfortable and at rest while awaiting medical care. ▸ **MONITOR THE BREATHING AND PULSE, CONTINUOUSLY.** ▸ Administer rescue breathing (preferably with a demand-valve resuscitator, bag-valve mask-device, or pocket mask as trained) or CPR if necessary.
Ingestion	▸ Not considered a normal route of entry. ▸ If spontaneous vomiting appears imminent or occurs, hold patient's head down, lower than their hips to help avoid possible aspiration of vomitus. ▸ Avoid giving milk or oils. ▸ Avoid giving alcohol.

Most important symptoms and effects, both acute and delayed

See Section 11

Indication of any immediate medical attention and special treatment needed

For gas exposures:

BASIC TREATMENT

- Establish a patent airway with suction where necessary.
- Watch for signs of respiratory insufficiency and assist ventilation as necessary.
- Administer oxygen by non-rebreather mask at 10 to 15 l/min.
- Monitor and treat, where necessary, for pulmonary oedema .
- Monitor and treat, where necessary, for shock.
- Anticipate seizures.

ADVANCED TREATMENT

- Consider orotracheal or nasotracheal intubation for airway control in unconscious patient or where respiratory arrest has occurred.
- Positive-pressure ventilation using a bag-valve mask might be of use.
- Monitor and treat, where necessary, for arrhythmias.
- Start an IV D5W TKO. If signs of hypovolaemia are present use lactated Ringers solution. Fluid overload might create complications.

Continued...

- Drug therapy should be considered for pulmonary oedema.
- Hypotension with signs of hypovolaemia requires the cautious administration of fluids. Fluid overload might create complications.
- Treat seizures with diazepam.
- Proparacaine hydrochloride should be used to assist eye irrigation.

BRONSTEIN, A.C. and CURRANCE, P.L.
EMERGENCY CARE FOR HAZARDOUS MATERIALS EXPOSURE: 2nd Ed. 1994
For acute or short term repeated exposures to petroleum distillates or related hydrocarbons:

- Primary threat to life, from pure petroleum distillate ingestion and/or inhalation, is respiratory failure.
- Patients should be quickly evaluated for signs of respiratory distress (e.g. cyanosis, tachypnoea, intercostal retraction, obtundation) and given oxygen. Patients with inadequate tidal volumes or poor arterial blood gases (pO2 50 mm Hg) should be intubated.
- Arrhythmias complicate some hydrocarbon ingestion and/or inhalation and electrocardiographic evidence of myocardial injury has been reported; intravenous lines and cardiac monitors should be established in obviously symptomatic patients. The lungs excrete inhaled solvents, so that hyperventilation improves clearance.
- A chest x-ray should be taken immediately after stabilisation of breathing and circulation to document aspiration and detect the presence of pneumothorax.
- Epinephrine (adrenalin) is not recommended for treatment of bronchospasm because of potential myocardial sensitisation to catecholamines. Inhaled cardioselective bronchodilators (e.g. Alupent, Salbutamol) are the preferred agents, with aminophylline a second choice.
- Lavage is indicated in patients who require decontamination; ensure use of cuffed endotracheal tube in adult patients. [Ellenhorn and Barceloux: Medical Toxicology]

SECTION 5 FIRE-FIGHTING MEASURES

Extinguishing media

DO NOT EXTINGUISH BURNING GAS UNLESS LEAK CAN BE STOPPED SAFELY:
OTHERWISE: LEAVE GAS TO BURN.
FOR SMALL FIRE:

- Dry chemical, CO_2 or water spray to extinguish gas (only if absolutely necessary and safe to do so).
- **DO NOT** use water jets.

FOR LARGE FIRE:

- Cool cylinder by direct flooding quantities of water onto upper surface until well after fire is out.

Special hazards arising from the substrate or mixture

Fire Incompatibility	▸ Avoid contamination with oxidising agents i.e. nitrates, oxidising acids, chlorine bleaches, pool chlorine etc. as ignition may result

Special protective equipment and precautions for fire-fighters

Fire Fighting	FOR FIRES INVOLVING MANY GAS CYLINDERS: ▸ To stop the flow of gas, specifically trained personnel may inert the atmosphere to reduce oxygen levels thus allowing the capping of leaking container(s). ▸ Reduce the rate of flow and inject an inert gas, if possible, before completely stopping the flow to prevent flashback. ▸ **DO NOT extinguish the fire until the supply is shut off** otherwise an explosive re-ignition may occur. ▸ If the fire is extinguished and the flow of gas continues, used increased ventilation to prevent build-up, of explosive atmosphere. --- GENERAL --- ▸ Alert Fire Brigade and tell them location and nature of hazard. ▸ May be violently or explosively reactive. ▸ Wear breathing apparatus plus protective gloves. ▸ Consider evacuation ▸ Fight fire from a safe distance, with adequate cover.
Fire/Explosion Hazard	▸ HIGHLY FLAMMABLE: will be easily ignited by heat, sparks or flames. ▸ Will form explosive mixtures with air ▸ Fire exposed containers may vent contents through pressure relief valves thereby increasing fire intensity and/ or vapour concentration. ▸ Vapours may travel to source of ignition and flash back. ▸ Containers may explode when heated - Ruptured cylinders may rocket ▸ Fire may produce irritating, poisonous or corrosive gases. Combustion products include; carbon monoxide (CO) carbon dioxide (CO_2) other pyrolysis products typical of burning organic material**Contains low boiling substance:** Closed containers may rupture due to pressure buildup under fire conditions.

SECTION 6 ACCIDENTAL RELEASE MEASURES

Personal precautions, protective equipment and emergency procedures

See section 8

Continued...

Environmental precautions

See section 12

Methods and material for containment and cleaning up

Minor Spills	▸ Avoid breathing vapour and any contact with liquid or gas. Protective equipment including respirator should be used. ▸ **DO NOT** enter confined spaces where gas may have accumulated. ▸ Shut off all sources of possible ignition and increase ventilation.
Major Spills	▸ Clear area of all unprotected personnel and move upwind. ▸ Alert Emergency Authority and advise them of the location and nature of hazard. ▸ May be violently or explosively reactive. ▸ Wear full body clothing with breathing apparatus. ▸ Remove leaking cylinders to a safe place. ▸ Fit vent pipes. Release pressure under safe, controlled conditions ▸ Burn issuing gas at vent pipes. ▸ **DO NOT** exert excessive pressure on valve; **DO NOT** attempt to operate damaged valve. |Gas will immediately disperse.|Leaks with no fire will disperse upwards quickly

Personal Protective Equipment advice is contained in Section 8 of the SDS.

SECTION 7 HANDLING AND STORAGE

Precautions for safe handling

Safe handling	The conductivity of this material may make it a static accumulator., A liquid is typically considered nonconductive if its conductivity is below 100 pS/m and is considered semi-conductive if its conductivity is below 10 000 pS/m., Whether a liquid is nonconductive or semi-conductive, the precautions are the same., A number of factors, for example liquid temperature, presence of contaminants, and anti-static additives can greatly influence the conductivity of a liquid. ▸ Containers, even those that have been emptied, may contain explosive vapours. ▸ Do NOT cut, drill, grind, weld or perform similar operations on or near containers. ▸ Electrostatic discharge may be generated during pumping - this may result in fire. ▸ Ensure electrical continuity by bonding and grounding (earthing) all equipment. ▸ Restrict line velocity during pumping in order to avoid generation of electrostatic discharge (<=1 m/sec until fill pipe submerged to twice its diameter, then <= 7 m/sec). ▸ Avoid splash filling. Natural gases contain a contaminant, radon-222, a naturally occurring radioactive gas. During subsequent processing, radon tends to concentrate in liquefied petroleum streams and in product streams having similar boiling points. Industry experience indicates that the commercial product may contain small amounts of radon-222 and its radioactive decay products (radon daughters). The actual concentration of radon-222 and radioactive daughters in process equipment (IE lines, filters, pumps and reactor units) may reach significant levels and produce potentially damaging levels of gamma radiation. Consider use in closed pressurised systems, fitted with temperature, pressure and safety relief valves which are vented for safe dispersal. Use only properly specified equipment which is suitable for this product, its supply pressure and temperature The tubing network design connecting gas cylinders to the delivery system should include appropriate pressure indicators and vacuum or suction lines. Fully-welded types of pressure gauges, where the bourdon tube sensing element is welded to the gauge body, are recommended. Before connecting gas cylinders, ensure manifold is mechanically secure and does not containing another gas. ▸ Avoid generation of static electricity. Earth all lines and equipment. ▸ **DO NOT** transfer gas from one cylinder to another.
Other information	▸ Store in an upright position. ▸ Outside or detached storage is preferred. Rotate all stock to prevent ageing. Use on FIFO (First In-First Out) basis ▸ Cylinders should be stored in a purpose-built compound with good ventilation, preferably in the open. ▸ Such compounds should be sited and built in accordance with statutory requirements. ▸ The storage compound should be kept clear and access restricted to authorised personnel only. ▸ Cylinders stored in the open should be protected against rust and extremes of weather. |Not applicable to pipeline supplies.

Conditions for safe storage, including any incompatibilities

Suitable container	▸ Cylinder: ▸ Ensure the use of equipment rated for cylinder pressure. ▸ Ensure the use of compatible materials of construction. ▸ Valve protection cap to be in place until cylinder is secured, connected. ▸ Cylinder must be properly secured either in use or in storage.
Storage incompatibility	Methane: ▸ reacts violently with oxidizing agents such as chlorine, bromine pentafluoride, oxygen trifluoride and nitrogen trifluoride in the presence of catalysts or sources of ignition.

Continued...

	- contact with chlorine dioxide causes spontaneous explosion. - contact with liquid fluorine causes spontaneous explosion, even at very low temperatures (-19 deg.C). A mixture of liquid methane and liquid oxygen is an explosive. - Explosion hazard may follow contact with incompatible materials - Compressed gases may contain a large amount of kinetic energy over and above that potentially available from the energy of reaction produced by the gas in chemical reaction with other substances - Avoid reaction with oxidising agents

SECTION 8 EXPOSURE CONTROLS / PERSONAL PROTECTION

Control parameters

OCCUPATIONAL EXPOSURE LIMITS (OEL)

INGREDIENT DATA

Source	Ingredient	Material name	TWA	STEL	Peak	Notes
US ACGIH Threshold Limit Values (TLV)	natural gas	Natural gas	Not Available	Not Available	Not Available	TLV® Basis: Asphyxia; See Appendix F: Minimal Oxygen Content
US ACGIH Threshold Limit Values (TLV)	methane	Methane	Not Available	Not Available	Not Available	TLV® Basis: Asphyxia; See Appendix F: Minimal Oxygen Content

EMERGENCY LIMITS

Ingredient	Material name	TEEL-1	TEEL-2	TEEL-3
methane	Methane	2,900 ppm	2900 ppm	17000 ppm

Ingredient	Original IDLH	Revised IDLH
natural gas	Not Available	Not Available
methane	Not Available	Not Available

MATERIAL DATA

TLV TWA: 1000 ppm as aliphatic hydrocarbon gases, alkane C1-C4 ES TWA: simple asphyxiant

Exposure controls

Appropriate engineering controls	Engineering controls are used to remove a hazard or place a barrier between the worker and the hazard. Well-designed engineering controls can be highly effective in protecting workers and will typically be independent of worker interactions to provide this high level of protection. The basic types of engineering controls are: Process controls which involve changing the way a job activity or process is done to reduce the risk. Enclosure and/or isolation of emission source which keeps a selected hazard "physically" away from the worker and ventilation that strategically "adds" and "removes" air in the work environment. |Ventilation should ensure that work place atmospheres do not reach 25% of lower explosive limit.|Provide supplied air respirators if oxygen concentration in the air is suspected to be less than 19%. Cartridge respirator do NOT give protection and may result in rapid suffocation.
Personal protection	
Eye and face protection	- Safety glasses with side shields. - Chemical goggles. - Contact lenses may pose a special hazard; soft contact lenses may absorb and concentrate irritants. A written policy document, describing the wearing of lenses or restrictions on use, should be created for each workplace or task.
Skin protection	See Hand protection below
Hands/feet protection	- When handling sealed and suitably insulated cylinders wear cloth or leather gloves.
Body protection	See Other protection below
Other protection	- The clothing worn by process operators insulated from earth may develop static charges far higher (up to 100 times) than the minimum ignition energies for various flammable gas-air mixtures. This holds true for a wide range of clothing materials including cotton. - Avoid dangerous levels of charge by ensuring a low resistivity of the surface material worn outermost. BRETHERICK: Handbook of Reactive Chemical Hazards. - Protective overalls, closely fitted at neck and wrist. - Eye-wash unit. **IN CONFINED SPACES:**

	‣ Non-sparking protective boots ‣ Static-free clothing. ‣ Ensure availability of lifeline. · Some plastic personal protective equipment (PPE) (e.g. gloves, aprons, overshoes) are not recommended as they may produce static electricity. · For large scale or continuous use wear tight-weave non-static clothing (no metallic fasteners, cuffs or pockets). · Non sparking safety or conductive footwear should be considered. Conductive footwear describes a boot or shoe with a sole made from a conductive compound chemically bound to the bottom components, for permanent control to electrically ground the foot an shall dissipate static electricity from the body to reduce the possibility of ignition of volatile compounds.
Thermal hazards	Not Available

Respiratory protection

Cartridge respirators should never be used for emergency ingress or in areas of unknown vapour concentrations or oxygen content. The wearer must be warned to leave the contaminated area immediately on detecting any odours through the respirator. The odour may indicate that the mask is not functioning properly, that the vapour concentration is too high, or that the mask is not properly fitted. Because of these limitations, only restricted use of cartridge respirators is considered appropriate.

- Positive pressure, full face, air-supplied breathing apparatus should be used for work in enclosed spaces if a leak is suspected or the primary containment is to be opened (e.g. for a cylinder change)
- Air-supplied breathing apparatus is required where release of gas from primary containment is either suspected or demonstrated.

SECTION 9 PHYSICAL AND CHEMICAL PROPERTIES

Information on basic physical and chemical properties

Appearance	Invisible, highly flammable gas which readily forms explosive mixtures in air. Supplied in bulk to consumers by pipeline at pressures up to 1000 kPa|Odourant in form of ethyl mercaptan added to allow detection, recognition. Odour threshold 20 ppm|Gas is less dense than air. Burns with a pale, luminous flame. Practically insoluble in water. Soluble in alcohol, ether, hydrocarbons Packed as a gas under pressure.

Physical state	Compressed Gas	**Relative density (Water = 1)**	0.58-0.63
Odour	Not Available	**Partition coefficient n-octanol / water**	Not Available
Odour threshold	Not Available	**Auto-ignition temperature (°C)**	540
pH (as supplied)	Not Applicable	**Decomposition temperature**	Not Applicable
Melting point / freezing point (°C)	-182 as CH4	**Viscosity (cSt)**	Not Applicable
Initial boiling point and boiling range (°C)	-162 as CH4	**Molecular weight (g/mol)**	16.04 as CH4
Flash point (°C)	-218	**Taste**	Not Available
Evaporation rate	Fast	**Explosive properties**	Not Available
Flammability	HIGHLY FLAMMABLE.	**Oxidising properties**	Not Available
Upper Explosive Limit (%)	15.0	**Surface Tension (dyn/cm or mN/m)**	Not Available
Lower Explosive Limit (%)	5.0	**Volatile Component (%vol)**	100
Vapour pressure (kPa)	Not Available	**Gas group**	Not Available
Solubility in water (g/L)	Immiscible	**pH as a solution (1%)**	Not Applicable
Vapour density (Air = 1)	0.55	**VOC g/L**	Not Available

SECTION 10 STABILITY AND REACTIVITY

Reactivity	See section 7
Chemical stability	‣ Unstable in the presence of incompatible materials. ‣ Product is considered stable. ‣ Hazardous polymerisation will not occur. ‣ Presence of elevated temperatures. ‣ Presence of heat source and ignition source

Continued...

Possibility of hazardous reactions	See section 7
Conditions to avoid	See section 7
Incompatible materials	See section 7
Hazardous decomposition products	See section 5

SECTION 11 TOXICOLOGICAL INFORMATION

Information on toxicological effects

Inhaled	The material is not thought to produce adverse health effects or irritation of the respiratory tract (as classified by EC Directives using animal models). Nevertheless, good hygiene practice requires that exposure be kept to a minimum and that suitable control measures be used in an occupational setting. Inhalation of vapours may cause drowsiness and dizziness. This may be accompanied by narcosis, reduced alertness, loss of reflexes, lack of coordination and vertigo. Common, generalised symptoms associated with non-toxic gas inhalation include : ▸ central nervous system effects such as headache, confusion, dizziness, progressive stupor, coma and seizures; ▸ respiratory system complications may include tachypnoea and dyspnoea; ▸ cardiovascular effects may include circulatory collapse and arrhythmias; ▸ gastrointestinal effects may also be present and may include mucous membrane irritation and nausea and vomiting. Acute effects from inhalation of high concentrations of vapour are pulmonary irritation, including coughing, with nausea; central nervous system depression - characterised by headache and dizziness, increased reaction time, fatigue and loss of co-ordination Central nervous system (CNS) depression may include nonspecific discomfort, symptoms of giddiness, headache, dizziness, nausea, anaesthetic effects, slowed reaction time, slurred speech and may progress to unconsciousness. Serious poisonings may result in respiratory depression and may be fatal. Material is highly volatile and may quickly form a concentrated atmosphere in confined or unventilated areas. The vapour may displace and replace air in breathing zone, acting as a simple asphyxiant. This may happen with little warning of overexposure. The use of a quantity of material in an unventilated or confined space may result in increased exposure and an irritating atmosphere developing. Before starting consider control of exposure by mechanical ventilation. The paraffin gases C1-4 are practically nontoxic below the lower flammability limit, 18,000 to 50,000 ppm; above this, low to moderate incidental effects such as CNS depression and irritation occur, but are completely reversible upon cessation of the exposure. |In small dose may cause dizziness or anaesthesia.
Ingestion	Not normally a hazard due to physical form of product. Considered an unlikely route of entry in commercial/industrial environments
Skin Contact	Skin contact is not thought to have harmful health effects (as classified under EC Directives); the material may still produce health damage following entry through wounds, lesions or abrasions. Limited evidence exists, or practical experience predicts, that the material either produces inflammation of the skin in a substantial number of individuals following direct contact, and/or produces significant inflammation when applied to the healthy intact skin of animals, for up to four hours, such inflammation being present twenty-four hours or more after the end of the exposure period. Skin irritation may also be present after prolonged or repeated exposure; this may result in a form of contact dermatitis (nonallergic). The dermatitis is often characterised by skin redness (erythema) and swelling (oedema) which may progress to blistering (vesiculation), scaling and thickening of the epidermis. At the microscopic level there may be intercellular oedema of the spongy layer of the skin (spongiosis) and intracellular oedema of the epidermis. Open cuts, abraded or irritated skin should not be exposed to this material Entry into the blood-stream through, for example, cuts, abrasions, puncture wounds or lesions, may produce systemic injury with harmful effects. Examine the skin prior to the use of the material and ensure that any external damage is suitably protected.
Eye	Although the material is not thought to be an irritant (as classified by EC Directives), direct contact with the eye may produce transient discomfort characterised by tearing or conjunctival redness (as with windburn). Direct contact with the eye may not cause irritation because of the extreme volatility of the gas; however concentrated atmospheres may produce irritation after brief exposures.. |Eyes should be protected against dust stirred up by release of high gas pressure.
Chronic	There is some evidence that human exposure to the material may result in developmental toxicity. This evidence is based on animal studies where effects have been observed in the absence of marked maternal toxicity, or at around the same dose levels as other toxic effects but which are not secondary non-specific consequences of the other toxic effects. Principal route of occupational exposure to the gas is by inhalation. Daily exposure of animals to 0.1-0.4 Gray produces anaemia which may be fatal. Protracted exposures below 0.1 Gray per day may produce myeloproliferative disease, potentially producing leukemia. If the total dose of radiation is sufficient, radiation sickness may ensue. Possible disorders resulting from chronic exposure to gamma-radiation include lung cancer, sterility, anaemia, leukemia, or bone cancer.

Continued...

	TOXICITY	IRRITATION
natural gas	Not Available	Not Available
methane	Inhalation (mouse) LC50: >15.6-<17.9 mm/l/2hr>[1]	Not Available
	Inhalation (mouse) LC50: 326 mg/L/2hr[2]	
	Inhalation (mouse) LC50: 410000 ppm/2hr[1]	
	Inhalation (mouse) LC50: 500000 ppm/2hr[2]	
	Inhalation (rat) LC50: >800000 ppm15 min[1]	
	Inhalation (rat) LC50: 1354.944 mg/L15 min[1]	
	Inhalation (rat) LC50: 1355 mg/l15 min[1]	
	Inhalation (rat) LC50: 1442.738 mg/L15 min[1]	
	Inhalation (rat) LC50: 1443 mg/l15 min[1]	
	Inhalation (rat) LC50: 570000 ppm15 min[1]	
Legend:	*1. Value obtained from Europe ECHA Registered Substances - Acute toxicity 2.* Value obtained from manufacturer's SDS. Unless otherwise specified data extracted from RTECS - Register of Toxic Effect of chemical Substances*	

NATURAL GAS	for Petroleum Hydrocarbon Gases: In many cases, there is more than one potentially toxic constituent in a refinery gas. In those cases, the constituent that is most toxic for a particular endpoint in an individual refinery stream is used to characterize the endpoint hazard for that stream. The hazard potential for each mammalian endpoint for each of the petroleum hydrocarbon gases is dependent upon each petroleum hydrocarbon gas constituent endpoint toxicity values (LC50, LOAEL, etc.) and the relative concentration of the constituent present in that gas. It should also be noted that for an individual petroleum hydrocarbon gas, the constituent characterizing toxicity may be different for different mammalian endpoints, again, being dependent upon the concentration of the different constituents in each, distinct petroleum hydrocarbon gas.
NATURAL GAS & METHANE	No significant acute toxicological data identified in literature search.

Acute Toxicity	⃠	**Carcinogenicity**	⃠
Skin Irritation/Corrosion	⃠	**Reproductivity**	⃠
Serious Eye Damage/Irritation	⃠	**STOT - Single Exposure**	⃠
Respiratory or Skin sensitisation	⃠	**STOT - Repeated Exposure**	⃠
Mutagenicity	⃠	**Aspiration Hazard**	⃠

Legend: ✖ *– Data available but does not fill the criteria for classification*
✔ *– Data required to make classification available*
⃠ *– Data Not Available to make classification*

SECTION 12 ECOLOGICAL INFORMATION

Toxicity

Ingredient	Endpoint	Test Duration (hr)	Species	Value	Source
methane	LC50	96	Fish	24.11mg/L	2
methane	EC50	96	Algae or other aquatic plants	7.71mg/L	2
methane	EC50	96	Algae or other aquatic plants	8.57mg/L	2
Legend:	*Extracted from 1. IUCLID Toxicity Data 2. Europe ECHA Registered Substances - Ecotoxicological Information - Aquatic Toxicity 3. EPIWIN Suite V3.12 - Aquatic Toxicity Data (Estimated) 4. US EPA, Ecotox database - Aquatic Toxicity Data 5. ECETOC Aquatic Hazard Assessment Data 6. NITE (Japan) - Bioconcentration Data 7. METI (Japan) - Bioconcentration Data 8. Vendor Data*				

for Petroleum Hydrocarbon Gases:
Environmental fate:
The environmental fate characteristics of petroleum hydrocarbon gases are governed by these physical-chemical attributes. All components of these gases will partition to the air where interaction with hydroxyl radicals is an important fate process. Hydrocarbons having molecular weights represented in these streams are inherently biodegradable, but their tendency to partition to the atmosphere would prevent their biotic degradation in water and soils. However, if higher molecular weight fractions of these streams enter the aquatic or terrestrial environment, biodegradation may be an important fate

Continued...

mechanism.
For methane:
log Kow : 1.09
Koc : 753
Half-life (hr) air : 21600
Half-life (hr) H_2O surface water : 1.17-14
Half-life (hr) soil : 1680
ThOD : 3.99

Environmental Fate

Terrestrial fate: An estimated Koc value of 90, determined from a log Kow of 1.09 indicates that methane is expected to have high mobility in soil Volatilisation is expected to be the most important fate process for methane in soil based on its vapor pressure of 4.7x10+5 mm Hg at 25 deg C. Volatilisation of methane from moist soil surfaces is expected to be an important fate process given an estimated Henry's Law constant of 0.66 atm-cu m/mole derived from its vapor pressure, and water solubility, 22 mg/l. Utilisation of methane by soil microorganisms has been detected from five soil samples collected from sites near Adelaide, South Australia(6).

Aquatic fate: The estimated Koc value indicates that methane is not expected to adsorb to suspended solids and sediment(. Volatilisation from water surfaces is expected to be the dominant fate process in aqueous systems based upon an estimated Henry's Law . Using this Henry's Law constant volatilisation half-lives for a model river and model lake are both 2 hrs. An estimated BCF of 1, derived from its log Kow suggests the potential for bioconcentration in aquatic organisms is low. The biodegradation half-life of methane was estimated to range from 70 days to infinity based on gas exchange biodegradation experiments conducted in model estuarine ecosystems.

Atmospheric fate:: Methane exists in the gas-phase in the ambient atmosphere with a vapor pressure of 4.7x10+5 mm Hg. Gas-phase methane is very slowly degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be about 6 yrs, calculated from its rate constant of 6.9x10-15 cu cm/molecule-sec at 25 deg C.

DO NOT discharge into sewer or waterways.

Persistence and degradability

Ingredient	Persistence: Water/Soil	Persistence: Air
	No Data available for all ingredients	No Data available for all ingredients

Bioaccumulative potential

Ingredient	Bioaccumulation
methane	LOW (LogKOW = 1.09)

Mobility in soil

Ingredient	Mobility
	No Data available for all ingredients

SECTION 13 DISPOSAL CONSIDERATIONS

Waste treatment methods

Product / Packaging disposal	▸ Evaporate or incinerate residue at an approved site. ▸ Return empty containers to supplier. ▸ Ensure damaged or non-returnable cylinders are gas-free before disposal. |Not applicable to gas supplies delivered on demand by pipeline.

SECTION 14 TRANSPORT INFORMATION

Labels Required

Marine Pollutant	NO

Land transport (DOT)

UN number	1971
UN proper shipping name	Methane, compressed or Natural gas, compressed (with high methane content)
Transport hazard class(es)	Class: 2.1 Subrisk: Not Applicable

Continued...

Packing group	Not Applicable
Environmental hazard	Not Applicable
Special precautions for user	Hazard Label: 2.1 Special provisions: Not Applicable

Air transport (ICAO-IATA / DGR)

UN number	1971
UN proper shipping name	Methane, compressed; Natural gas, compressed with high methane content
Transport hazard class(es)	ICAO/IATA Class: 2.1 ICAO / IATA Subrisk: Not Applicable ERG Code: 10L
Packing group	Not Applicable
Environmental hazard	Not Applicable
Special precautions for user	Special provisions: A1 Cargo Only Packing Instructions: 200 Cargo Only Maximum Qty / Pack: 150 kg Passenger and Cargo Packing Instructions: Forbidden Passenger and Cargo Maximum Qty / Pack: Forbidden Passenger and Cargo Limited Quantity Packing Instructions: Forbidden Passenger and Cargo Limited Maximum Qty / Pack: Forbidden

Sea transport (IMDG-Code / GGVSee)

UN number	1971
UN proper shipping name	METHANE, COMPRESSED or NATURAL GAS, COMPRESSED with high methane content
Transport hazard class(es)	IMDG Class: 2.1 IMDG Subrisk: Not Applicable
Packing group	Not Applicable
Environmental hazard	Not Applicable
Special precautions for user	EMS Number: F-D, S-U Special provisions: Not Applicable Limited Quantities: 0

Transport in bulk according to Annex II of MARPOL and the IBC code

Not Applicable

SECTION 15 REGULATORY INFORMATION

Safety, health and environmental regulations / legislation specific for the substance or mixture

NATURAL GAS(8006-14-2) IS FOUND ON THE FOLLOWING REGULATORY LISTS

International Air Transport Association (IATA) Dangerous Goods Regulations - Prohibited List Passenger and Cargo Aircraft
US ACGIH Threshold Limit Values (TLV)
US Toxic Substances Control Act (TSCA) - Chemical Substance Inventory

METHANE(74-82-8) IS FOUND ON THE FOLLOWING REGULATORY LISTS

International Air Transport Association (IATA) Dangerous Goods Regulations - Prohibited List Passenger and Cargo Aircraft
US - California Permissible Exposure Limits for Chemical Contaminants
US - Oregon Permissible Exposure Limits (Z-1)
US - Washington Permissible exposure limits of air contaminants
US ACGIH Threshold Limit Values (TLV)
US Spacecraft Maximum Allowable Concentrations (SMACs) for Airborne Contaminants
US Toxic Substances Control Act (TSCA) - Chemical Substance Inventory

Continued...

Federal Regulations

Superfund Amendments and Reauthorization Act of 1986 (SARA)

SECTION 311/312 HAZARD CATEGORIES

Immediate (acute) health hazard	No
Delayed (chronic) health hazard	No
Fire hazard	Yes
Pressure hazard	Yes
Reactivity hazard	No

US. EPA CERCLA HAZARDOUS SUBSTANCES AND REPORTABLE QUANTITIES (40 CFR 302.4)

None Reported

State Regulations

US. CALIFORNIA PROPOSITION 65

None Reported

National Inventory	Status
Australia - AICS	Y
Canada - DSL	Y
Canada - NDSL	N (natural gas; methane)
China - IECSC	Y
Europe - EINEC / ELINCS / NLP	Y
Japan - ENCS	N (natural gas)
Korea - KECI	Y
New Zealand - NZIoC	Y
Philippines - PICCS	N (natural gas)
USA - TSCA	Y
Legend:	*Y = All ingredients are on the inventory* *N = Not determined or one or more ingredients are not on the inventory and are not exempt from listing(see specific ingredients in brackets)*

SECTION 16 OTHER INFORMATION

Other information

Classification of the preparation and its individual components has drawn on official and authoritative sources as well as independent review by the Chemwatch Classification committee using available literature references.
A list of reference resources used to assist the committee may be found at:
www.chemwatch.net

The SDS is a Hazard Communication tool and should be used to assist in the Risk Assessment. Many factors determine whether the reported Hazards are Risks in the workplace or other settings. Risks may be determined by reference to Exposures Scenarios. Scale of use, frequency of use and current or available engineering controls must be considered.

Definitions and abbreviations

Continued...

PC—TWA: Permissible Concentration-Time Weighted Average
PC—STEL: Permissible Concentration-Short Term Exposure Limit
IARC: International Agency for Research on Cancer
ACGIH: American Conference of Governmental Industrial Hygienists
STEL: Short Term Exposure Limit
TEEL: Temporary Emergency Exposure Limit。
IDLH: Immediately Dangerous to Life or Health Concentrations
OSF: Odour Safety Factor
NOAEL :No Observed Adverse Effect Level
LOAEL: Lowest Observed Adverse Effect Level
TLV: Threshold Limit Value
LOD: Limit Of Detection
OTV: Odour Threshold Value
BCF: BioConcentration Factors
BEI: Biological Exposure Index

SAFETY DATA SHEET

1. Identification

Product identifier	**Propane**
Other means of identification	
SDS number	WC002
Product code	UN1978
Recommended use	Portable fuel.
Recommended restrictions	None known.

Manufacturer/Importer/Supplier/Distributor information

Manufacturer/Supplier	Worthington Cylinder Corporation
Address	300 E. Breed St., Chilton, WI 5301 United States
Contact person	Ann Stiefvater
E-mail address	Ann.Stiefvater@worthingtonindustries.com
Telephone number	1-920-849-1740
Emergency telephone number	1-703-527-3887 International / CHEMTREC 1-800-424-9300 Domestic

2. Hazard(s) identification

Physical hazards	Flammable gases	Category 1
	Gases under pressure	Liquefied gas
Health hazards	Not classified.	
OSHA defined hazards	Simple asphyxiant	

Label elements

Signal word	Danger
Hazard statement	Extremely flammable gas. Contains gas under pressure; may explode if heated. May displace oxygen and cause rapid suffocation.
Precautionary statement	
Prevention	Keep away from heat/sparks/open flames/hot surfaces. - No smoking. Keep container tightly closed. Use only outdoors or in a well-ventilated area. Wear respiratory protection.
Response	Leaking gas fire: Do not extinguish, unless leak can be stopped safely. Eliminate all ignition sources if safe to do so.
Storage	Protect from sunlight. Store in a well-ventilated place.
Disposal	Dispose of waste and residues in accordance with local authority requirements.
Hazard(s) not otherwise classified (HNOC)	None known.
Supplemental information	None.

3. Composition/information on ingredients

Mixtures

Chemical name	CAS number	%
Propane	74-98-6	87.5-100
Propylene	115-07-1	0-10

Ethane	74-84-0	0-7
Butane	106-97-8	0-2.5

Additives

Chemical name	CAS number	%
Ethyl Mercaptan	75-08-1	<0.005

Composition comments Gas concentrations are in percent by volume.

4. First-aid measures

Inhalation Remove from further exposure. For those providing assistance, avoid exposure to yourself or others. Use adequate respiratory protection. If respiratory tract irritation, dizziness, nausea, or unconsciousness occurs, seek immediate medical assistance. If breathing has stopped, assist ventilation with a mechanical device or use mouth-to-mouth resuscitation.

Skin contact Not likely, due to the form of the product. If frostbite occurs, immerse affected area in warm water (not exceeding 105°F/41°C). Keep immersed for 20 to 40 minutes. Get medical attention immediately.

Eye contact Not likely, due to the form of the product. If frostbite occurs, immediately flush eyes with plenty of warm water (not exceeding 105°F/41°C) for at least 15 minutes. If easy to do, remove contact lenses. Get medical attention promptly if symptoms persist or occur after washing.

Ingestion This material is a gas under normal atmospheric conditions and ingestion is unlikely.

Most important symptoms/effects, acute and delayed Exposure to rapidly expanding gas or vaporizing liquid may cause frostbite ("cold burn"). Very high exposure can cause suffocation from lack of oxygen. Symptoms may include loss of mobility/consciousness. Victim may not be aware of asphyxiation. Asphyxiation may bring about unconsciousness without warning and so rapidly that victim may be unable to protect themself.

Indication of immediate medical attention and special treatment needed Exposure may aggravate pre-existing respiratory disorders. Provide general supportive measures and treat symptomatically.

General information If you feel unwell, seek medical advice (show the label where possible). Ensure that medical personnel are aware of the material(s) involved, and take precautions to protect themselves.

5. Fire-fighting measures

Suitable extinguishing media Dry chemical powder. Carbon dioxide (CO_2). Water fog. Foam.

Unsuitable extinguishing media Do not use water jet as an extinguisher, as this will spread the fire.

Specific hazards arising from the chemical Extremely flammable gas. Vapors may form explosive mixtures with air. Vapors may travel considerable distance to a source of ignition and flash back. During fire, gases hazardous to health may be formed.

Special protective equipment and precautions for firefighters Self-contained breathing apparatus and full protective clothing must be worn in case of fire.

Fire fighting equipment/instructions Do not extinguish fires unless gas flow can be stopped safely; explosive re-ignition may occur. Promptly isolate the scene by removing all persons from the vicinity of the incident. No action shall be taken involving any personal risk or without suitable training. For fires involving this material, do not enter any enclosed or confined fire space without proper protective equipment, including self-contained breathing apparatus. Stop flow of material. Use water to keep fire exposed containers cool and to protect personnel effecting shutoff. If a leak or spill has not ignited, use water spray to disperse the vapors and to protect personnel attempting to stop leak. Prevent runoff from fire control or dilution from entering streams, sewers or drinking water supply.

Specific methods Use standard firefighting procedures and consider the hazards of other involved materials. Cool containers exposed to flames with water until well after the fire is out.

General fire hazards Extremely flammable gas. Contents under pressure. Pressurized container may explode when exposed to heat or flame.

6. Accidental release measures

Personal precautions, protective equipment and emergency procedures Evacuate the area promptly. No action shall be taken involving any personal risk or without suitable training. In the event of a leak evacuate all personnel until ventilation can restore oxygen concentrations to safe levels. Keep unnecessary personnel away. Eliminate all ignition sources (no smoking, flares, sparks, or flames in immediate area). Do not touch damaged containers or spilled material unless wearing appropriate protective clothing. Ventilate closed spaces before entering them. Wear appropriate personal protective equipment (See Section 8).

Methods and materials for containment and cleaning up	Eliminate all ignition sources (no smoking, flares, sparks, or flames in immediate area). Keep combustibles (wood, paper, oil, etc.) away from spilled material. Stop leak if you can do so without risk. If possible, turn leaking containers so that gas escapes rather than liquid. Isolate area until gas has dispersed. For waste disposal, see section 13 of the SDS.
Environmental precautions	Should not be released into the environment. Prevent further leakage or spillage if safe to do so.

7. Handling and storage

Precautions for safe handling	Keep away from heat/sparks/open flames/hot surfaces. - No smoking. Do not handle, store or open near an open flame, sources of heat or sources of ignition. Protect material from direct sunlight. All equipment used when handling the product must be grounded. Do not breathe gas. Avoid prolonged exposure. Do not enter storage areas or confined spaces unless adequately ventilated. Use only outdoors or in a well-ventilated area. Oxygen concentration should not fall below 19.5 % at sea level (pO2 = 135 mmHg). Mechanical ventilation or local exhaust ventilation may be required. Wear appropriate personal protective equipment. Observe good industrial hygiene practices.
Conditions for safe storage, including any incompatibilities	Store at temperatures not exceeding 49°C/120°F. Keep away from heat, sparks and open flame. Prevent electrostatic charge build-up by using common bonding and grounding techniques. Store in a cool, dry place out of direct sunlight. Cylinders should be stored upright, with valve protection cap in place, and firmly secured to prevent falling or being knocked over. Protect cylinders from damage. Stored containers should be periodically checked for general condition and leakage. Store in original tightly closed container. Keep container tightly closed. Store in a well-ventilated place. Use care in handling/storage. Store away from incompatible materials (see Section 10 of the SDS).

8. Exposure controls/personal protection

Occupational exposure limits

US. OSHA Table Z-1 Limits for Air Contaminants (29 CFR 1910.1000)

Components	Type	Value
Propane (CAS 74-98-6)	PEL	1800 mg/m3
		1000 ppm
Additives	**Type**	**Value**
Ethyl Mercaptan (CAS 75-08-1)	Ceiling	25 mg/m3
		10 ppm

US. ACGIH Threshold Limit Values

Components	Type	Value
Butane (CAS 106-97-8)	STEL	1000 ppm
Propylene (CAS 115-07-1)	TWA	500 ppm
Additives	**Type**	**Value**
Ethyl Mercaptan (CAS 75-08-1)	TWA	0.5 ppm

US. NIOSH: Pocket Guide to Chemical Hazards

Components	Type	Value
Butane (CAS 106-97-8)	TWA	1900 mg/m3
		800 ppm
Propane (CAS 74-98-6)	TWA	1800 mg/m3
		1000 ppm
Additives	**Type**	**Value**
Ethyl Mercaptan (CAS 75-08-1)	Ceiling	1.3 mg/m3
		0.5 ppm

Biological limit values	No biological exposure limits noted for the ingredient(s).
Appropriate engineering controls	Provide adequate ventilation and minimize the risk of inhalation of gas. Use process enclosures, local exhaust ventilation, or other engineering controls to control airborne levels below recommended exposure limits.

Individual protection measures, such as personal protective equipment

Eye/face protection	Wear approved safety glasses or goggles.

Skin protection	
Hand protection	Wear appropriate chemical resistant gloves. Neoprene or nitrile gloves are recommended.
Skin protection	
Other	Wear protective clothing appropriate for the risk of exposure.
Respiratory protection	If engineering controls do not maintain airborne concentrations below recommended exposure limits (where applicable) or to an acceptable level (in countries where exposure limits have not been established), an approved respirator must be worn.
Thermal hazards	Contact with liquefied gas might cause frostbites, in some cases with tissue damage. Wear appropriate thermal protective clothing, when necessary.
General hygiene considerations	Do not eat, drink or smoke when using the product. Wash thoroughly after handling. Provide eyewash station and safety shower. Handle in accordance with good industrial hygiene and safety practices.

9. Physical and chemical properties

Appearance	Colorless gas.
Physical state	Gas (Liquefied).
Form	Compressed liquefied gas.
Color	Colorless.
Odor	Rotten egg.
Odor threshold	Not available.
pH	Not applicable.
Melting point/freezing point	-306.4 °F (-188 °C)
Initial boiling point and boiling range	-43.6 °F (-42 °C) 14.7 psia
Flash point	-155.2 °F (-104.0 °C)
Evaporation rate	Not applicable.
Flammability (solid, gas)	Extremely flammable gas.
Upper/lower flammability or explosive limits	
Explosive limit - lower (%)	2.15 %
Explosive limit - upper (%)	9.6 %
Vapor pressure	127 psig (21°C / 70°F)
Vapor density	Not available.
Relative density	0.504 (liquid) 1.5 (vapor) (air=1) @ 15°C / 60°F
Solubility(ies)	
Solubility (water)	Slightly soluble in water.
Partition coefficient (n-octanol/water)	1.77
Auto-ignition temperature	809.6 °F (432 °C)
Decomposition temperature	Not available.
Viscosity	Not applicable.
Other information	
Explosive properties	Not explosive.
Molecular weight	45 g/mol
Oxidizing properties	Not oxidizing.
Percent volatile	100 %

10. Stability and reactivity

Reactivity	Reacts violently with strong oxidants, nitrites, inorganic chlorides, chlorites and perchlorates causing fire and explosion hazard.
Chemical stability	Stable under normal temperature conditions and recommended use.
Possibility of hazardous reactions	Polymerization will not occur. May form explosive mixture with air.

Conditions to avoid	Avoid heat, sparks, open flames and other ignition sources. Avoid temperatures exceeding the flash point. Contact with incompatible materials.
Incompatible materials	Strong oxidizing agents. Strong acids. Halogens. Nitrates.
Hazardous decomposition products	Thermal decomposition of this product can generate carbon monoxide and carbon dioxide. Hydrocarbons.

11. Toxicological information

Information on likely routes of exposure

Inhalation	High concentrations: Suffocation (asphyxiant) hazard - if allowed to accumulate to concentrations that reduce oxygen below safe breathing levels. Breathing of high concentrations may cause dizziness, light-headedness, headache, nausea and loss of coordination. Continued inhalation may result in unconsciousness.
Skin contact	Contact with liquefied gas may cause frostbite.
Eye contact	Contact with liquefied gas may cause frostbite.
Ingestion	This material is a gas under normal atmospheric conditions and ingestion is unlikely.
Symptoms related to the physical, chemical and toxicological characteristics	Exposure to rapidly expanding gas or vaporizing liquid may cause frostbite ("cold burn"). Very high exposure can cause suffocation from lack of oxygen. Victim may not be aware of asphyxiation. Asphyxiation may bring about unconsciousness without warning and so rapidly that victim may be unable to protect themself.

Information on toxicological effects

Acute toxicity Not expected to be acutely toxic.

Components	Species	Test Results
Propane (CAS 74-98-6)		
Acute		
Inhalation		
LC50	Rat	1355 mg/l
Propylene (CAS 115-07-1)		
Acute		
Inhalation		
LC50	Mouse	680 mg/l, 2 Hours
	Rat	658 mg/l, 4 Hours

Skin corrosion/irritation	Not classified.
Serious eye damage/eye irritation	Not classified.
Respiratory or skin sensitization	
Respiratory sensitization	Not a respiratory sensitizer.
Skin sensitization	This product is not expected to cause skin sensitization.
Germ cell mutagenicity	No data available to indicate product or any components present at greater than 0.1% are mutagenic or genotoxic.
Carcinogenicity	This product is not considered to be a carcinogen by IARC, ACGIH, NTP, or OSHA.

IARC Monographs. Overall Evaluation of Carcinogenicity

Propylene (CAS 115-07-1) 3 Not classifiable as to carcinogenicity to humans.

NTP Report on Carcinogens

Not listed.

OSHA Specifically Regulated Substances (29 CFR 1910.1001-1050)

Not regulated.

Reproductive toxicity	This product is not expected to cause reproductive or developmental effects.
Specific target organ toxicity - single exposure	Not classified.
Specific target organ toxicity - repeated exposure	Not classified.
Aspiration hazard	Not likely, due to the form of the product.
Further information	Exposure over a long period of time may cause central nervous system effects.

12. Ecological information

Ecotoxicity	The product is not expected to be hazardous to the environment.
Persistence and degradability	The product is readily biodegradable.
Bioaccumulative potential	The product is not expected to bioaccumulate.

Partition coefficient n-octanol / water (log Kow)

Propane	1.77
Propylene (CAS 115-07-1)	1.77

Mobility in soil	Not relevant, due to the form of the product.
Other adverse effects	The product contains volatile organic compounds which have a photochemical ozone creation potential.

13. Disposal considerations

Disposal instructions	Use the container until empty. Do not dispose of any non-empty container. Empty containers have residual vapor that is flammable and explosive. Cylinders should be emptied and returned to a hazardous waste collection point. Do not puncture or incinerate even when empty. Dispose in accordance with all applicable regulations.
Local disposal regulations	Dispose of in accordance with local regulations.
Hazardous waste code	D001: Waste Flammable material with a flash point <140 °F The waste code should be assigned in discussion between the user, the producer and the waste disposal company.
Waste from residues / unused products	Dispose in accordance with all applicable regulations.
Contaminated packaging	Empty containers should be taken to an approved waste handling site for recycling or disposal.

14. Transport information

DOT

UN number	UN1978
UN proper shipping name	Propane
Transport hazard class(es)	
Class	2.1
Subsidiary risk	-
Label(s)	2.1
Packing group	Not applicable.
Environmental hazards	
Marine pollutant	No
Special precautions for user	Read safety instructions, SDS and emergency procedures before handling.
Special provisions	19, T50
Packaging exceptions	306
Packaging non bulk	304
Packaging bulk	314, 315

IATA

UN number	UN1978
UN proper shipping name	Propane
Transport hazard class(es)	
Class	2.1
Subsidiary risk	-
Packing group	Not applicable.
Environmental hazards	No
ERG Code	10L
Special precautions for user	Read safety instructions, SDS and emergency procedures before handling.

IMDG

UN number	UN1978
UN proper shipping name	PROPANE
Transport hazard class(es)	
Class	2.1
Subsidiary risk	-
Packing group	Not applicable.
Environmental hazards	
Marine pollutant	No

EmS F-D, S-U

Special precautions for user Read safety instructions, SDS and emergency procedures before handling.

Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code Not applicable.

General information Avoid transport on vehicles where the load space is not separated from the driver's compartment. Ensure vehicle driver is aware of the potential hazards of the load and knows what to do in the event of an accident or an emergency. Before transporting product containers: Ensure that containers are firmly secured. Ensure cylinder valve is closed and not leaking. Ensure valve outlet cap nut or plug (where provided) is correctly fitted. Ensure valve protection device (where provided) is correctly fitted. Ensure adequate ventilation. Ensure compliance with applicable regulations.

15. Regulatory information

US federal regulations This product is a "Hazardous Chemical" as defined by the OSHA Hazard Communication Standard, 29 CFR 1910.1200.
All components are on the U.S. EPA TSCA Inventory List.

TSCA Section 12(b) Export Notification (40 CFR 707, Subpt. D)

Not regulated.

OSHA Specifically Regulated Substances (29 CFR 1910.1001-1050)

Not regulated.

CERCLA Hazardous Substance List (40 CFR 302.4)

Butane (CAS 106-97-8)	LISTED
Ethyl Mercaptan (CAS 75-08-1)	LISTED
Propane (CAS 74-98-6)	LISTED
Propylene (CAS 115-07-1)	LISTED

Superfund Amendments and Reauthorization Act of 1986 (SARA)

Hazard categories Immediate Hazard - Yes
Delayed Hazard - No
Fire Hazard - Yes
Pressure Hazard - Yes
Reactivity Hazard - No

SARA 302 Extremely hazardous substance

Not listed.

SARA 311/312 Hazardous chemical Yes

SARA 313 (TRI reporting)

Chemical name	CAS number	% by wt.
Propylene	115-07-1	0-10

Other federal regulations

Clean Air Act (CAA) Section 112 Hazardous Air Pollutants (HAPs) List

Not regulated.

Clean Air Act (CAA) Section 112(r) Accidental Release Prevention (40 CFR 68.130)

Butane (CAS 106-97-8)
Ethyl Mercaptan (CAS 75-08-1)
Propane (CAS 74-98-6)
Propylene (CAS 115-07-1)

Safe Drinking Water Act (SDWA) Not regulated.

US state regulations

US. Massachusetts RTK - Substance List

Butane (CAS 106-97-8)
Ethyl Mercaptan (CAS 75-08-1)
Propane (CAS 74-98-6)
Propylene (CAS 115-07-1)

US. New Jersey Worker and Community Right-to-Know Act

Butane (CAS 106-97-8)
Ethyl Mercaptan (CAS 75-08-1)

Propane (CAS 74-98-6)
Propylene (CAS 115-07-1)

US. Pennsylvania Worker and Community Right-to-Know Law

Butane (CAS 106-97-8)
Ethyl Mercaptan (CAS 75-08-1)
Propane (CAS 74-98-6)
Propylene (CAS 115-07-1)

US. Rhode Island RTK

Butane (CAS 106-97-8)
Ethyl Mercaptan (CAS 75-08-1)
Propane (CAS 74-98-6)
Propylene (CAS 115-07-1)

US. California Proposition 65

California Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65): This material is not known to contain any chemicals currently listed as carcinogens or reproductive toxins.

International Inventories

Country(s) or region	Inventory name	On inventory (yes/no)*
Australia	Australian Inventory of Chemical Substances (AICS)	Yes
Canada	Domestic Substances List (DSL)	Yes
Canada	Non-Domestic Substances List (NDSL)	No
China	Inventory of Existing Chemical Substances in China (IECSC)	Yes
Europe	European Inventory of Existing Commercial Chemical Substances (EINECS)	Yes
Europe	European List of Notified Chemical Substances (ELINCS)	No
Japan	Inventory of Existing and New Chemical Substances (ENCS)	Yes
Korea	Existing Chemicals List (ECL)	Yes
New Zealand	New Zealand Inventory	Yes
Philippines	Philippine Inventory of Chemicals and Chemical Substances (PICCS)	Yes
United States & Puerto Rico	Toxic Substances Control Act (TSCA) Inventory	Yes

*A "Yes" indicates this product complies with the inventory requirements administered by the governing country(s).
A "No" indicates that one or more components of the product are not listed or exempt from listing on the inventory administered by the governing country(s).

16. Other information, including date of preparation or last revision

Issue date 05-May-2014

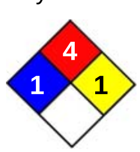
Revision date 09-August-2016

Version # 02

Further information The classification for health and environmental hazards is derived by a combination of calculation methods and test data, if available.

HMIS® ratings
Health: 1
Flammability: 4
Physical hazard: 1

NFPA ratings



List of abbreviations
STEL: Short term exposure limit.
TWA: Time weighted average.
PEL: Permissible Exposure Limit.
LC50: Lethal Concentration, 50%.

References
EPA: AQUIRE database
NLM: Hazardous Substances Data Base
HSDB® - Hazardous Substances Data Bank
IARC Monographs. Overall Evaluation of Carcinogenicity
National Toxicology Program (NTP) Report on Carcinogens
ACGIH Documentation of the Threshold Limit Values and Biological Exposure Indices

Disclaimer	All information in this Safety Data Sheet is believed to be accurate and reliable. However, no guarantee or warranty of any kind is made with regard to the accuracy of information or the suitability of the recommendations contained herein. It is the user's responsibility to assess the safety and toxicity of this product under their own conditions of use and to comply with all applicable laws and regulations.
This SDS contains revisions in the following section(s):	1 - 16

SAFETY DATA SHEET

Carbon Dioxide

Section 1. Identification

GHS product identifier : Carbon Dioxide

Chemical name : Carbon dioxide, gas

Other means of identification : Carbonic, Carbon Dioxide, Carbonic Anhydride, R744, Carbon Dioxide USP

Product type : Gas.

Product use : Synthetic/Analytical chemistry and Medical use.

Synonym : Carbonic, Carbon Dioxide, Carbonic Anhydride, R744, Carbon Dioxide USP

SDS # : 001013

Supplier's details : Airgas USA, LLC and its affiliates
259 North Radnor-Chester Road
Suite 100
Radnor, PA 19087-5283
1-610-687-5253

24-hour telephone : 1-866-734-3438

Section 2. Hazards identification

OSHA/HCS status : This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).

Classification of the substance or mixture : GASES UNDER PRESSURE - Liquefied gas
Simple asphyxiant.

GHS label elements

Hazard pictograms :

Signal word : Warning

Hazard statements : Contains gas under pressure; may explode if heated.
May displace oxygen and cause rapid suffocation.
May increase respiration and heart rate.

Precautionary statements

General : Read and follow all Safety Data Sheets (SDS'S) before use. Read label before use. Keep out of reach of children. If medical advice is needed, have product container or label at hand. Close valve after each use and when empty. Use equipment rated for cylinder pressure. Do not open valve until connected to equipment prepared for use. Use a back flow preventative device in the piping. Use only equipment of compatible materials of construction. Always keep container in upright position.

Prevention : Use and store only outdoors or in a well ventilated place.

Response : Not applicable.

Storage : Protect from sunlight. Store in a well-ventilated place.

Disposal : Not applicable.

Hazards not otherwise classified : In addition to any other important health or physical hazards, this product may displace oxygen and cause rapid suffocation.
May cause frostbite.

Section 3. Composition/information on ingredients

Substance/mixture : Substance

Chemical name : Carbon dioxide, gas

Other means of identification : Carbonic, Carbon Dioxide, Carbonic Anhydride, R744, Carbon Dioxide USP

Product code : 001013

CAS number/other identifiers

CAS number : 124-38-9

Ingredient name	%	CAS number
Carbon Dioxide	100	124-38-9

Any concentration shown as a range is to protect confidentiality or is due to batch variation.

There are no additional ingredients present which, within the current knowledge of the supplier and in the concentrations applicable, are classified as hazardous to health or the environment and hence require reporting in this section.

Occupational exposure limits, if available, are listed in Section 8.

Section 4. First aid measures

Description of necessary first aid measures

Eye contact : Immediately flush eyes with plenty of water, occasionally lifting the upper and lower eyelids. Check for and remove any contact lenses. Continue to rinse for at least 10 minutes. Get medical attention if irritation occurs.

Inhalation : Remove victim to fresh air and keep at rest in a position comfortable for breathing. If not breathing, if breathing is irregular or if respiratory arrest occurs, provide artificial respiration or oxygen by trained personnel. It may be dangerous to the person providing aid to give mouth-to-mouth resuscitation. Get medical attention if adverse health effects persist or are severe. If unconscious, place in recovery position and get medical attention immediately. Maintain an open airway. Loosen tight clothing such as a collar, tie, belt or waistband.

Skin contact : Flush contaminated skin with plenty of water. Remove contaminated clothing and shoes. Get medical attention if symptoms occur. Wash clothing before reuse. Clean shoes thoroughly before reuse.

Ingestion : As this product is a gas, refer to the inhalation section.

Most important symptoms/effects, acute and delayed

Potential acute health effects

Eye contact : No known significant effects or critical hazards.

Inhalation : No known significant effects or critical hazards.

Skin contact : No known significant effects or critical hazards.

Frostbite : Try to warm up the frozen tissues and seek medical attention.

Ingestion : As this product is a gas, refer to the inhalation section.

Over-exposure signs/symptoms

Eye contact : No specific data.

Inhalation : No specific data.

Skin contact : No specific data.

Ingestion : No specific data.

Indication of immediate medical attention and special treatment needed, if necessary

Notes to physician : Treat symptomatically. Contact poison treatment specialist immediately if large quantities have been ingested or inhaled.

Specific treatments : No specific treatment.

Section 4. First aid measures

Protection of first-aiders : No action shall be taken involving any personal risk or without suitable training. It may be dangerous to the person providing aid to give mouth-to-mouth resuscitation.

See toxicological information (Section 11)

Section 5. Fire-fighting measures

Extinguishing media

Suitable extinguishing media : Use an extinguishing agent suitable for the surrounding fire.

Unsuitable extinguishing media : None known.

Specific hazards arising from the chemical : Contains gas under pressure. In a fire or if heated, a pressure increase will occur and the container may burst or explode.

Hazardous thermal decomposition products : Decomposition products may include the following materials:
carbon dioxide
carbon monoxide

Special protective actions for fire-fighters : Promptly isolate the scene by removing all persons from the vicinity of the incident if there is a fire. No action shall be taken involving any personal risk or without suitable training. Contact supplier immediately for specialist advice. Move containers from fire area if this can be done without risk. Use water spray to keep fire-exposed containers cool.

Special protective equipment for fire-fighters : Fire-fighters should wear appropriate protective equipment and self-contained breathing apparatus (SCBA) with a full face-piece operated in positive pressure mode.

Section 6. Accidental release measures

Personal precautions, protective equipment and emergency procedures

For non-emergency personnel : No action shall be taken involving any personal risk or without suitable training. Evacuate surrounding areas. Keep unnecessary and unprotected personnel from entering. Avoid breathing gas. Provide adequate ventilation. Wear appropriate respirator when ventilation is inadequate. Put on appropriate personal protective equipment.

For emergency responders : If specialized clothing is required to deal with the spillage, take note of any information in Section 8 on suitable and unsuitable materials. See also the information in "For non-emergency personnel".

Environmental precautions : Ensure emergency procedures to deal with accidental gas releases are in place to avoid contamination of the environment. Inform the relevant authorities if the product has caused environmental pollution (sewers, waterways, soil or air).

Methods and materials for containment and cleaning up

Small spill : Immediately contact emergency personnel. Stop leak if without risk.

Large spill : Immediately contact emergency personnel. Stop leak if without risk. Note: see Section 1 for emergency contact information and Section 13 for waste disposal.

Section 7. Handling and storage

Precautions for safe handling

Protective measures : Put on appropriate personal protective equipment (see Section 8). Contains gas under pressure. Avoid breathing gas. Do not puncture or incinerate container. Use equipment rated for cylinder pressure. Close valve after each use and when empty. Protect cylinders from physical damage; do not drag, roll, slide, or drop. Use a suitable hand truck for cylinder movement.
Avoid contact with eyes, skin and clothing. Empty containers retain product residue and can be hazardous.

Section 7. Handling and storage

Advice on general occupational hygiene : Eating, drinking and smoking should be prohibited in areas where this material is handled, stored and processed. Workers should wash hands and face before eating, drinking and smoking. Remove contaminated clothing and protective equipment before entering eating areas. See also Section 8 for additional information on hygiene measures.

Conditions for safe storage, including any incompatibilities : Store in accordance with local regulations. Store in a segregated and approved area. Store away from direct sunlight in a dry, cool and well-ventilated area, away from incompatible materials (see Section 10). Cylinders should be stored upright, with valve protection cap in place, and firmly secured to prevent falling or being knocked over. Cylinder temperatures should not exceed 52 °C (125 °F). Keep container tightly closed and sealed until ready for use. See Section 10 for incompatible materials before handling or use.

Section 8. Exposure controls/personal protection

Control parameters

Occupational exposure limits

Ingredient name	Exposure limits
Carbon Dioxide	**ACGIH TLV (United States, 3/2017). Oxygen Depletion [Asphyxiant].** STEL: 54000 mg/m³ 15 minutes. STEL: 30000 ppm 15 minutes. TWA: 9000 mg/m³ 8 hours. TWA: 5000 ppm 8 hours. **NIOSH REL (United States, 10/2016).** STEL: 54000 mg/m³ 15 minutes. STEL: 30000 ppm 15 minutes. TWA: 9000 mg/m³ 10 hours. TWA: 5000 ppm 10 hours. **OSHA PEL (United States, 6/2016).** TWA: 9000 mg/m³ 8 hours. TWA: 5000 ppm 8 hours. **OSHA PEL 1989 (United States, 3/1989).** STEL: 54000 mg/m³ 15 minutes. STEL: 30000 ppm 15 minutes. TWA: 18000 mg/m³ 8 hours. TWA: 10000 ppm 8 hours.

Appropriate engineering controls : Good general ventilation should be sufficient to control worker exposure to airborne contaminants.

Environmental exposure controls : Emissions from ventilation or work process equipment should be checked to ensure they comply with the requirements of environmental protection legislation. In some cases, fume scrubbers, filters or engineering modifications to the process equipment will be necessary to reduce emissions to acceptable levels.

Individual protection measures

Hygiene measures : Wash hands, forearms and face thoroughly after handling chemical products, before eating, smoking and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location.

Eye/face protection : Safety eyewear complying with an approved standard should be used when a risk assessment indicates this is necessary to avoid exposure to liquid splashes, mists, gases or dusts. If contact is possible, the following protection should be worn, unless the assessment indicates a higher degree of protection: safety glasses with side-shields.

Skin protection

Section 8. Exposure controls/personal protection

Hand protection	: Chemical-resistant, impervious gloves complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates this is necessary. Considering the parameters specified by the glove manufacturer, check during use that the gloves are still retaining their protective properties. It should be noted that the time to breakthrough for any glove material may be different for different glove manufacturers. In the case of mixtures, consisting of several substances, the protection time of the gloves cannot be accurately estimated.
Body protection	: Personal protective equipment for the body should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product.
Other skin protection	: Appropriate footwear and any additional skin protection measures should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product.
Respiratory protection	: Based on the hazard and potential for exposure, select a respirator that meets the appropriate standard or certification. Respirators must be used according to a respiratory protection program to ensure proper fitting, training, and other important aspects of use. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator.

Section 9. Physical and chemical properties

Appearance

Physical state	: Gas. [Compressed gas.]
Color	: Colorless.
Odor	: Odorless.
Odor threshold	: Not available.
pH	: Not available.
Melting point	: Sublimation temperature: -79°C (-110.2 to °F)
Boiling point	: Not available.
Critical temperature	: 30.85°C (87.5°F)
Flash point	: [Product does not sustain combustion.]
Evaporation rate	: Not available.
Flammability (solid, gas)	: Not available.
Lower and upper explosive (flammable) limits	: Not available.
Vapor pressure	: 830 (psig)
Vapor density	: 1.53 (Air = 1) Liquid Density@BP: Solid density = 97.5 lb/ft3 (1562 kg/m3)
Specific Volume (ft^3/lb)	: 8.7719
Gas Density (lb/ft^3)	: 0.114
Relative density	: Not applicable.
Solubility	: Not available.
Solubility in water	: Not available.
Partition coefficient: n-octanol/water	: 0.83
Auto-ignition temperature	: Not available.
Decomposition temperature	: Not available.
Viscosity	: Not applicable.
Flow time (ISO 2431)	: Not available.
Molecular weight	: 44.01 g/mole

Section 10. Stability and reactivity

Reactivity	: No specific test data related to reactivity available for this product or its ingredients.
Chemical stability	: The product is stable.
Possibility of hazardous reactions	: Under normal conditions of storage and use, hazardous reactions will not occur.
Conditions to avoid	: No specific data.
Incompatible materials	: No specific data.
Hazardous decomposition products	: Under normal conditions of storage and use, hazardous decomposition products should not be produced.
Hazardous polymerization	: Under normal conditions of storage and use, hazardous polymerization will not occur.

Section 11. Toxicological information

Information on toxicological effects

Acute toxicity

Not available.

Irritation/Corrosion

Not available.

Sensitization

Not available.

Mutagenicity

Not available.

Carcinogenicity

Not available.

Reproductive toxicity

Not available.

Teratogenicity

Not available.

Specific target organ toxicity (single exposure)

Not available.

Specific target organ toxicity (repeated exposure)

Not available.

Aspiration hazard

Not available.

Information on the likely routes of exposure : Not available.

Potential acute health effects

Eye contact	: No known significant effects or critical hazards.
Inhalation	: No known significant effects or critical hazards.
Skin contact	: No known significant effects or critical hazards.

Section 11. Toxicological information

Ingestion : As this product is a gas, refer to the inhalation section.

Symptoms related to the physical, chemical and toxicological characteristics

Eye contact : No specific data.
Inhalation : No specific data.
Skin contact : No specific data.
Ingestion : No specific data.

Delayed and immediate effects and also chronic effects from short and long term exposure

Short term exposure

Potential immediate effects : Not available.
Potential delayed effects : Not available.

Long term exposure

Potential immediate effects : Not available.
Potential delayed effects : Not available.

Potential chronic health effects

Not available.

General : No known significant effects or critical hazards.
Carcinogenicity : No known significant effects or critical hazards.
Mutagenicity : No known significant effects or critical hazards.
Teratogenicity : No known significant effects or critical hazards.
Developmental effects : No known significant effects or critical hazards.
Fertility effects : No known significant effects or critical hazards.

Numerical measures of toxicity

Acute toxicity estimates

Not available.

Section 12. Ecological information

Toxicity

Not available.

Persistence and degradability

Not available.

Bioaccumulative potential

Product/ingredient name	$LogP_{ow}$	BCF	Potential
Carbon Dioxide	0.83	-	low

Mobility in soil

Soil/water partition coefficient (K_{OC}) : Not available.

Other adverse effects : No known significant effects or critical hazards.

Section 13. Disposal considerations

Disposal methods : The generation of waste should be avoided or minimized wherever possible. Disposal of this product, solutions and any by-products should at all times comply with the requirements of environmental protection and waste disposal legislation and any regional local authority requirements. Dispose of surplus and non-recyclable products via a licensed waste disposal contractor. Waste should not be disposed of untreated to the sewer unless fully compliant with the requirements of all authorities with jurisdiction. Empty Airgas-owned pressure vessels should be returned to Airgas. Waste packaging should be recycled. Incineration or landfill should only be considered when recycling is not feasible. This material and its container must be disposed of in a safe way. Empty containers or liners may retain some product residues. Do not puncture or incinerate container.

Section 14. Transport information

	DOT	TDG	Mexico	IMDG	IATA
UN number	UN1013	UN1013	UN1013	UN1013	UN1013
UN proper shipping name	CARBON DIOXIDE	CARBON DIOXIDE	CARBON DIOXIDE	CARBON DIOXIDE	CARBON DIOXIDE
Transport hazard class(es)	2.2 	2.2 	2.2 	2.2 	2.2 
Packing group	-	-	-	-	-
Environmental hazards	No.	No.	No.	No.	No.

"Refer to CFR 49 (or authority having jurisdiction) to determine the information required for shipment of the product."

Additional information

DOT Classification : **Limited quantity** Yes.
Quantity limitation Passenger aircraft/rail: 75 kg. Cargo aircraft: 150 kg.

TDG Classification : Product classified as per the following sections of the Transportation of Dangerous Goods Regulations: 2.13-2.17 (Class 2).
Explosive Limit and Limited Quantity Index 0.125
Passenger Carrying Road or Rail Index 75

IATA : **Quantity limitation** Passenger and Cargo Aircraft: 75 kg. Cargo Aircraft Only: 150 kg.

Special precautions for user : **Transport within user's premises:** always transport in closed containers that are upright and secure. Ensure that persons transporting the product know what to do in the event of an accident or spillage.

Transport in bulk according to Annex II of MARPOL and the IBC Code : Not available.

Section 15. Regulatory information

U.S. Federal regulations : **TSCA 8(a) CDR Exempt/Partial exemption**: This material is listed or exempted.

Clean Air Act Section 112 (b) Hazardous Air Pollutants (HAPs) : Not listed

Section 15. Regulatory information

Clean Air Act Section 602 Class I Substances : Not listed

Clean Air Act Section 602 Class II Substances : Not listed

DEA List I Chemicals (Precursor Chemicals) : Not listed

DEA List II Chemicals (Essential Chemicals) : Not listed

SARA 302/304

Composition/information on ingredients

No products were found.

SARA 304 RQ : Not applicable.

SARA 311/312

Classification : Refer to Section 2: Hazards Identification of this SDS for classification of substance.

State regulations

Massachusetts : This material is listed.

New York : This material is not listed.

New Jersey : This material is listed.

Pennsylvania : This material is listed.

International regulations

Chemical Weapon Convention List Schedules I, II & III Chemicals

Not listed.

Montreal Protocol (Annexes A, B, C, E)

Not listed.

Stockholm Convention on Persistent Organic Pollutants

Not listed.

Rotterdam Convention on Prior Informed Consent (PIC)

Not listed.

UNECE Aarhus Protocol on POPs and Heavy Metals

Not listed.

Inventory list

Australia : This material is listed or exempted.

Canada : This material is listed or exempted.

China : This material is listed or exempted.

Europe : This material is listed or exempted.

Japan : **Japan inventory (ENCS)**: This material is listed or exempted.
Japan inventory (ISHL): This material is listed or exempted.

Malaysia : Not determined.

New Zealand : This material is listed or exempted.

Philippines : This material is listed or exempted.

Republic of Korea : This material is listed or exempted.

Taiwan : This material is listed or exempted.

Thailand : Not determined.

Turkey : This material is listed or exempted.

United States : This material is listed or exempted.

Viet Nam : Not determined.

Section 16. Other information

Hazardous Material Information System (U.S.A.)

Health	/	1
Flammability		0
Physical hazards		3

Caution: HMIS® ratings are based on a 0-4 rating scale, with 0 representing minimal hazards or risks, and 4 representing significant hazards or risks. Although HMIS® ratings and the associated label are not required on SDSs or products leaving a facility under 29 CFR 1910.1200, the preparer may choose to provide them. HMIS® ratings are to be used with a fully implemented HMIS® program. HMIS® is a registered trademark and service mark of the American Coatings Association, Inc.

The customer is responsible for determining the PPE code for this material. For more information on HMIS® Personal Protective Equipment (PPE) codes, consult the HMIS® Implementation Manual.

National Fire Protection Association (U.S.A.)

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Copyright ©2001, National Fire Protection Association, Quincy, MA 02269. This warning system is intended to be interpreted and applied only by properly trained individuals to identify fire, health and reactivity hazards of chemicals. The user is referred to certain limited number of chemicals with recommended classifications in NFPA 49 and NFPA 325, which would be used as a guideline only. Whether the chemicals are classified by NFPA or not, anyone using the 704 systems to classify chemicals does so at their own risk.

Procedure used to derive the classification

Classification	Justification
GASES UNDER PRESSURE - Liquefied gas	Expert judgment

History

Date of printing : 2/12/2018

Date of issue/Date of revision : 2/12/2018

Date of previous issue : 4/25/2017

Version : 0.03

Key to abbreviations : ATE = Acute Toxicity Estimate
BCF = Bioconcentration Factor
GHS = Globally Harmonized System of Classification and Labelling of Chemicals
IATA = International Air Transport Association
IBC = Intermediate Bulk Container
IMDG = International Maritime Dangerous Goods
LogPow = logarithm of the octanol/water partition coefficient
MARPOL = International Convention for the Prevention of Pollution From Ships, 1973 as modified by the Protocol of 1978. ("Marpol" = marine pollution)
UN = United Nations

References : Not available.

Notice to reader

Section 16. Other information

To the best of our knowledge, the information contained herein is accurate. However, neither the above-named supplier, nor any of its subsidiaries, assumes any liability whatsoever for the accuracy or completeness of the information contained herein.
Final determination of suitability of any material is the sole responsibility of the user. All materials may present unknown hazards and should be used with caution. Although certain hazards are described herein, we cannot guarantee that these are the only hazards that exist.

SAFETY DATA SHEET

Carbon Monoxide

Section 1. Identification

GHS product identifier : Carbon Monoxide

Chemical name : carbon monoxide

Other means of identification : Carbon oxide (CO); CO; Exhaust gas; Flue gas; Carbonic oxide; Carbon oxide; Carbone (oxyde de); Carbonio (ossido di); Kohlenmonoxid; Kohlenoxyd; Koolmonoxyde; NA 9202; Oxyde de carbone; UN 1016; Wegla tlenek; Carbon monooxide

Product type : Gas.

Product use : Synthetic/Analytical chemistry.

Synonym : Carbon oxide (CO); CO; Exhaust gas; Flue gas; Carbonic oxide; Carbon oxide; Carbone (oxyde de); Carbonio (ossido di); Kohlenmonoxid; Kohlenoxyd; Koolmonoxyde; NA 9202; Oxyde de carbone; UN 1016; Wegla tlenek; Carbon monooxide

SDS # : 001014

Supplier's details : Airgas USA, LLC and its affiliates
259 North Radnor-Chester Road
Suite 100
Radnor, PA 19087-5283
1-610-687-5253

24-hour telephone : 1-866-734-3438

Section 2. Hazards identification

OSHA/HCS status : This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).

Classification of the substance or mixture : FLAMMABLE GASES - Category 1
GASES UNDER PRESSURE - Compressed gas
ACUTE TOXICITY (inhalation) - Category 3
TOXIC TO REPRODUCTION (Fertility) - Category 1
TOXIC TO REPRODUCTION (Unborn child) - Category 1
SPECIFIC TARGET ORGAN TOXICITY (REPEATED EXPOSURE) - Category 1

GHS label elements

Hazard pictograms :

Signal word : Danger

Hazard statements : Extremely flammable gas.
Contains gas under pressure; may explode if heated.
Toxic if inhaled.
May damage fertility or the unborn child.
Causes damage to organs through prolonged or repeated exposure.

Precautionary statements

General : Read and follow all Safety Data Sheets (SDS'S) before use. Read label before use. Keep out of reach of children. If medical advice is needed, have product container or label at hand. Close valve after each use and when empty. Use equipment rated for cylinder pressure. Do not open valve until connected to equipment prepared for use. Use a back flow preventative device in the piping. Use only equipment of compatible materials of construction. Approach suspected leak area with caution.

Section 2. Hazards identification

Prevention : Obtain special instructions before use. Do not handle until all safety precautions have been read and understood. Wear protective gloves. Wear eye or face protection. Wear protective clothing. Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. No smoking. Use only outdoors or in a well-ventilated area. Do not breathe gas. Do not eat, drink or smoke when using this product. Wash hands thoroughly after handling.

Response : Get medical attention if you feel unwell. IF exposed or concerned: Get medical attention. IF INHALED: Remove person to fresh air and keep comfortable for breathing. Call a POISON CENTER or physician. Leaking gas fire: Do not extinguish, unless leak can be stopped safely. Eliminate all ignition sources if safe to do so.

Storage : Store locked up. Protect from sunlight. Store in a well-ventilated place.

Disposal : Dispose of contents and container in accordance with all local, regional, national and international regulations.

Hazards not otherwise classified : In addition to any other important health or physical hazards, this product may displace oxygen and cause rapid suffocation.

Section 3. Composition/information on ingredients

Substance/mixture : Substance

Chemical name : carbon monoxide

Other means of identification : Carbon oxide (CO); CO; Exhaust gas; Flue gas; Carbonic oxide; Carbon oxide; Carbone (oxyde de); Carbonio (ossido di); Kohlenmonoxid; Kohlenoxyd; Koolmonoxyde; NA 9202; Oxyde de carbone; UN 1016; Wegla tlenek; Carbon monooxide

Product code : 001014

CAS number/other identifiers

CAS number : 630-08-0

Ingredient name	%	CAS number
carbon monoxide	100	630-08-0

Any concentration shown as a range is to protect confidentiality or is due to batch variation.

There are no additional ingredients present which, within the current knowledge of the supplier and in the concentrations applicable, are classified as hazardous to health or the environment and hence require reporting in this section.

Occupational exposure limits, if available, are listed in Section 8.

Section 4. First aid measures

Description of necessary first aid measures

Eye contact : Immediately flush eyes with plenty of water, occasionally lifting the upper and lower eyelids. Check for and remove any contact lenses. Continue to rinse for at least 10 minutes. Get medical attention.

Inhalation : Remove victim to fresh air and keep at rest in a position comfortable for breathing. If it is suspected that fumes are still present, the rescuer should wear an appropriate mask or self-contained breathing apparatus. If not breathing, if breathing is irregular or if respiratory arrest occurs, provide artificial respiration or oxygen by trained personnel. It may be dangerous to the person providing aid to give mouth-to-mouth resuscitation. Get medical attention. If necessary, call a poison center or physician. If unconscious, place in recovery position and get medical attention immediately. Maintain an open airway. Loosen tight clothing such as a collar, tie, belt or waistband.

Skin contact : Flush contaminated skin with plenty of water. Remove contaminated clothing and shoes. To avoid the risk of static discharges and gas ignition, soak contaminated clothing thoroughly with water before removing it. Continue to rinse for at least 10 minutes. Get medical attention. Wash clothing before reuse. Clean shoes thoroughly before reuse.

Ingestion : As this product is a gas, refer to the inhalation section.

Most important symptoms/effects, acute and delayed

Section 4. First aid measures

Potential acute health effects

Eye contact	: Contact with rapidly expanding gas may cause burns or frostbite.
Inhalation	: Toxic if inhaled.
Skin contact	: Contact with rapidly expanding gas may cause burns or frostbite.
Frostbite	: Try to warm up the frozen tissues and seek medical attention.
Ingestion	: As this product is a gas, refer to the inhalation section.

Over-exposure signs/symptoms

Eye contact	: No specific data.
Inhalation	: Adverse symptoms may include the following:, reduced fetal weight, increase in fetal deaths, skeletal malformations
Skin contact	: Adverse symptoms may include the following:, reduced fetal weight, increase in fetal deaths, skeletal malformations
Ingestion	: Adverse symptoms may include the following:, reduced fetal weight, increase in fetal deaths, skeletal malformations

Indication of immediate medical attention and special treatment needed, if necessary

Notes to physician	: Treat symptomatically. Contact poison treatment specialist immediately if large quantities have been ingested or inhaled.
Specific treatments	: No specific treatment.
Protection of first-aiders	: No action shall be taken involving any personal risk or without suitable training. If it is suspected that fumes are still present, the rescuer should wear an appropriate mask or self-contained breathing apparatus. It may be dangerous to the person providing aid to give mouth-to-mouth resuscitation. Wash contaminated clothing thoroughly with water before removing it, or wear gloves.

See toxicological information (Section 11)

Section 5. Fire-fighting measures

Extinguishing media

Suitable extinguishing media	: Use an extinguishing agent suitable for the surrounding fire.
Unsuitable extinguishing media	: None known.
Specific hazards arising from the chemical	: Contains gas under pressure. Extremely flammable gas. In a fire or if heated, a pressure increase will occur and the container may burst, with the risk of a subsequent explosion.
Hazardous thermal decomposition products	: Decomposition products may include the following materials: carbon dioxide carbon monoxide
Special protective actions for fire-fighters	: Promptly isolate the scene by removing all persons from the vicinity of the incident if there is a fire. No action shall be taken involving any personal risk or without suitable training. Contact supplier immediately for specialist advice. Move containers from fire area if this can be done without risk. Use water spray to keep fire-exposed containers cool. If involved in fire, shut off flow immediately if it can be done without risk. If this is impossible, withdraw from area and allow fire to burn. Fight fire from protected location or maximum possible distance. Eliminate all ignition sources if safe to do so.
Special protective equipment for fire-fighters	: Fire-fighters should wear appropriate protective equipment and self-contained breathing apparatus (SCBA) with a full face-piece operated in positive pressure mode.

Section 6. Accidental release measures

Personal precautions, protective equipment and emergency procedures

For non-emergency personnel : Accidental releases pose a serious fire or explosion hazard. No action shall be taken involving any personal risk or without suitable training. Evacuate surrounding areas. Keep unnecessary and unprotected personnel from entering. Shut off all ignition sources. No flares, smoking or flames in hazard area. Do not breathe gas. Provide adequate ventilation. Wear appropriate respirator when ventilation is inadequate. Put on appropriate personal protective equipment.

For emergency responders : If specialized clothing is required to deal with the spillage, take note of any information in Section 8 on suitable and unsuitable materials. See also the information in "For non-emergency personnel".

Environmental precautions : Ensure emergency procedures to deal with accidental gas releases are in place to avoid contamination of the environment. Inform the relevant authorities if the product has caused environmental pollution (sewers, waterways, soil or air).

Methods and materials for containment and cleaning up

Small spill : Immediately contact emergency personnel. Stop leak if without risk. Use spark-proof tools and explosion-proof equipment.

Large spill : Immediately contact emergency personnel. Stop leak if without risk. Use spark-proof tools and explosion-proof equipment. Note: see Section 1 for emergency contact information and Section 13 for waste disposal.

Section 7. Handling and storage

Precautions for safe handling

Protective measures : Put on appropriate personal protective equipment (see Section 8). Contains gas under pressure. Avoid exposure - obtain special instructions before use. Avoid exposure during pregnancy. Do not handle until all safety precautions have been read and understood. Do not get in eyes or on skin or clothing. Do not breathe gas. Use only with adequate ventilation. Wear appropriate respirator when ventilation is inadequate. Do not enter storage areas and confined spaces unless adequately ventilated. Store and use away from heat, sparks, open flame or any other ignition source. Use explosion-proof electrical (ventilating, lighting and material handling) equipment. Use only non-sparking tools. Empty containers retain product residue and can be hazardous. Do not puncture or incinerate container. Use equipment rated for cylinder pressure. Close valve after each use and when empty. Protect cylinders from physical damage; do not drag, roll, slide, or drop. Use a suitable hand truck for cylinder movement.

Advice on general occupational hygiene : Eating, drinking and smoking should be prohibited in areas where this material is handled, stored and processed. Workers should wash hands and face before eating, drinking and smoking. Remove contaminated clothing and protective equipment before entering eating areas. See also Section 8 for additional information on hygiene measures.

Conditions for safe storage, including any incompatibilities : Store in accordance with local regulations. Store in a segregated and approved area. Store away from direct sunlight in a dry, cool and well-ventilated area, away from incompatible materials (see Section 10). Store locked up. Eliminate all ignition sources. Keep container tightly closed and sealed until ready for use. Cylinders should be stored upright, with valve protection cap in place, and firmly secured to prevent falling or being knocked over. Cylinder temperatures should not exceed 52 °C (125 °F).

Section 8. Exposure controls/personal protection

Control parameters

Occupational exposure limits

Section 8. Exposure controls/personal protection

Ingredient name	Exposure limits
carbon monoxide	**California PEL for Chemical Contaminants (*Table AC-1*) (United States).** PEL: 25 ppm 8 hours. CEIL: 200 ppm **ACGIH TLV (United States, 3/2017).** TWA: 25 ppm 8 hours. TWA: 29 mg/m³ 8 hours. **OSHA PEL 1989 (United States, 3/1989).** TWA: 35 ppm 8 hours. TWA: 40 mg/m³ 8 hours. CEIL: 200 ppm CEIL: 229 mg/m³ **NIOSH REL (United States, 10/2016).** TWA: 35 ppm 10 hours. TWA: 40 mg/m³ 10 hours. CEIL: 200 ppm CEIL: 229 mg/m³ **OSHA PEL (United States, 6/2016).** TWA: 50 ppm 8 hours. TWA: 55 mg/m³ 8 hours.

Appropriate engineering controls : Use only with adequate ventilation. Use process enclosures, local exhaust ventilation or other engineering controls to keep worker exposure to airborne contaminants below any recommended or statutory limits. The engineering controls also need to keep gas, vapor or dust concentrations below any lower explosive limits. Use explosion-proof ventilation equipment.

Environmental exposure controls : Emissions from ventilation or work process equipment should be checked to ensure they comply with the requirements of environmental protection legislation. In some cases, fume scrubbers, filters or engineering modifications to the process equipment will be necessary to reduce emissions to acceptable levels.

Individual protection measures

Hygiene measures : Wash hands, forearms and face thoroughly after handling chemical products, before eating, smoking and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location.

Eye/face protection : Safety eyewear complying with an approved standard should be used when a risk assessment indicates this is necessary to avoid exposure to liquid splashes, mists, gases or dusts. If contact is possible, the following protection should be worn, unless the assessment indicates a higher degree of protection: safety glasses with side-shields.

Skin protection

Hand protection : Chemical-resistant, impervious gloves complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates this is necessary. Considering the parameters specified by the glove manufacturer, check during use that the gloves are still retaining their protective properties. It should be noted that the time to breakthrough for any glove material may be different for different glove manufacturers. In the case of mixtures, consisting of several substances, the protection time of the gloves cannot be accurately estimated.

Body protection : Personal protective equipment for the body should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product. When there is a risk of ignition from static electricity, wear anti-static protective clothing. For the greatest protection from static discharges, clothing should include anti-static overalls, boots and gloves.

Section 8. Exposure controls/personal protection

Other skin protection	: Appropriate footwear and any additional skin protection measures should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product.
Respiratory protection	: Based on the hazard and potential for exposure, select a respirator that meets the appropriate standard or certification. Respirators must be used according to a respiratory protection program to ensure proper fitting, training, and other important aspects of use. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator.

Section 9. Physical and chemical properties

Appearance	
Physical state	: Gas. [Compressed gas.]
Color	: Colorless.
Odor	: Odorless.
Odor threshold	: Not available.
pH	: Not available.
Melting point	: -211.6°C (-348.9°F)
Boiling point	: -191.52°C (-312.7°F)
Critical temperature	: -140.15°C (-220.3°F)
Flash point	: Not available.
Evaporation rate	: Not available.
Flammability (solid, gas)	: Extremely flammable in the presence of the following materials or conditions: open flames, sparks and static discharge and oxidizing materials.
Lower and upper explosive (flammable) limits	: Lower: 10.9% Upper: 74.2%
Vapor pressure	: Not available.
Vapor density	: 0.97 (Air = 1)
Specific Volume (ft^3/lb)	: 13.8889
Gas Density (lb/ft^3)	: 0.072
Relative density	: Not applicable.
Solubility	: Not available.
Solubility in water	: Not available.
Partition coefficient: n-octanol/water	: Not available.
Auto-ignition temperature	: 607°C (1124.6°F)
Decomposition temperature	: Not available.
Viscosity	: Not applicable.
Flow time (ISO 2431)	: Not available.
Molecular weight	: 28.01 g/mole
Aerosol product	
Heat of combustion	: -10101818 J/kg

Section 10. Stability and reactivity

Reactivity	: No specific test data related to reactivity available for this product or its ingredients.
Chemical stability	: The product is stable.
Possibility of hazardous reactions	: Under normal conditions of storage and use, hazardous reactions will not occur.

Section 10. Stability and reactivity

Conditions to avoid : Avoid all possible sources of ignition (spark or flame). Do not pressurize, cut, weld, braze, solder, drill, grind or expose containers to heat or sources of ignition.

Incompatible materials : Oxidizers

Hazardous decomposition products : Under normal conditions of storage and use, hazardous decomposition products should not be produced.

Hazardous polymerization : Under normal conditions of storage and use, hazardous polymerization will not occur.

Section 11. Toxicological information

Information on toxicological effects

Acute toxicity

Product/ingredient name	Result	Species	Dose	Exposure
carbon monoxide	LC50 Inhalation Gas.	Rat	3760 ppm	1 hours

Irritation/Corrosion

Not available.

Sensitization

Not available.

Mutagenicity

Not available.

Carcinogenicity

Not available.

Reproductive toxicity

Not available.

Teratogenicity

Not available.

Specific target organ toxicity (single exposure)

Not available.

Specific target organ toxicity (repeated exposure)

Name	Category	Route of exposure	Target organs
carbon monoxide	Category 1	Not determined	Not determined

Aspiration hazard

Not available.

Information on the likely routes of exposure : Routes of entry anticipated: Inhalation.

Potential acute health effects

Eye contact : Contact with rapidly expanding gas may cause burns or frostbite.
Inhalation : Toxic if inhaled.
Skin contact : Contact with rapidly expanding gas may cause burns or frostbite.
Ingestion : As this product is a gas, refer to the inhalation section.

Symptoms related to the physical, chemical and toxicological characteristics

Section 11. Toxicological information

Eye contact : No specific data.

Inhalation : Adverse symptoms may include the following:, reduced fetal weight, increase in fetal deaths, skeletal malformations

Skin contact : Adverse symptoms may include the following:, reduced fetal weight, increase in fetal deaths, skeletal malformations

Ingestion : Adverse symptoms may include the following:, reduced fetal weight, increase in fetal deaths, skeletal malformations

Delayed and immediate effects and also chronic effects from short and long term exposure

Short term exposure

Potential immediate effects : Not available.

Potential delayed effects : Not available.

Long term exposure

Potential immediate effects : Not available.

Potential delayed effects : Not available.

Potential chronic health effects

Not available.

General : Causes damage to organs through prolonged or repeated exposure.

Carcinogenicity : No known significant effects or critical hazards.

Mutagenicity : No known significant effects or critical hazards.

Teratogenicity : May damage the unborn child.

Developmental effects : No known significant effects or critical hazards.

Fertility effects : May damage fertility.

Numerical measures of toxicity

Acute toxicity estimates

Not available.

Section 12. Ecological information

Toxicity

Not available.

Persistence and degradability

Not available.

Bioaccumulative potential

Not available.

Mobility in soil

Soil/water partition coefficient (K_{OC}) : Not available.

Other adverse effects : No known significant effects or critical hazards.

Section 13. Disposal considerations

Disposal methods : The generation of waste should be avoided or minimized wherever possible. Disposal of this product, solutions and any by-products should at all times comply with the requirements of environmental protection and waste disposal legislation and any regional local authority requirements. Dispose of surplus and non-recyclable products via a licensed waste disposal contractor. Waste should not be disposed of untreated to the sewer unless fully compliant with the requirements of all authorities with jurisdiction. Empty Airgas-owned pressure vessels should be returned to Airgas. Waste packaging should be recycled. Incineration or landfill should only be considered when recycling is not feasible. This material and its container must be disposed of in a safe way. Empty containers or liners may retain some product residues. Do not puncture or incinerate container.

Section 14. Transport information

	DOT	TDG	Mexico	IMDG	IATA
UN number	UN1016	UN1016	UN1016	UN1016	UN1016
UN proper shipping name	CARBON MONOXIDE, COMPRESSED	CARBON MONOXIDE, COMPRESSED	CARBON MONOXIDE, COMPRESSED	CARBON MONOXIDE, COMPRESSED	CARBON MONOXIDE, COMPRESSED
Transport hazard class(es)	2.3 (2.1)	2.3 (2.1)	2.3 (2.1)	2.3 (2.1)	2.3 (2.1)
Packing group	-	-	-	-	-
Environmental hazards	No.	No.	No.	No.	No.

"Refer to CFR 49 (or authority having jurisdiction) to determine the information required for shipment of the product."

Additional information

DOT Classification : Toxic - Inhalation hazard Zone D
Limited quantity Yes.
Quantity limitation Passenger aircraft/rail: Forbidden. Cargo aircraft: 25 kg.
Special provisions 4

TDG Classification : Product classified as per the following sections of the Transportation of Dangerous Goods Regulations: 2.13-2.17 (Class 2), 2.13-2.17 (Class 2).
Explosive Limit and Limited Quantity Index 0
ERAP Index 500
Passenger Carrying Ship Index Forbidden
Passenger Carrying Road or Rail Index Forbidden

IATA : **Quantity limitation** Passenger and Cargo Aircraft: Forbidden. Cargo Aircraft Only: Forbidden.

Special precautions for user : **Transport within user's premises:** always transport in closed containers that are upright and secure. Ensure that persons transporting the product know what to do in the event of an accident or spillage.

Transport in bulk according to Annex II of MARPOL and the IBC Code : Not available.

Section 15. Regulatory information

U.S. Federal regulations : **TSCA 8(a) CDR Exempt/Partial exemption**: Not determined

Clean Air Act Section 112 (b) Hazardous Air Pollutants (HAPs) : Not listed

Clean Air Act Section 602 Class I Substances : Not listed

Clean Air Act Section 602 Class II Substances : Not listed

DEA List I Chemicals (Precursor Chemicals) : Not listed

DEA List II Chemicals (Essential Chemicals) : Not listed

SARA 302/304

Composition/information on ingredients

No products were found.

SARA 304 RQ : Not applicable.

SARA 311/312

Classification : Refer to Section 2: Hazards Identification of this SDS for classification of substance.

State regulations

Massachusetts : This material is listed.

New York : This material is not listed.

New Jersey : This material is listed.

Pennsylvania : This material is listed.

California Prop. 65

⚠ **WARNING**: This product can expose you to Carbon monoxide, which is known to the State of California to cause birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov.

Ingredient name	No significant risk level	Maximum acceptable dosage level
Carbon monoxide	-	-

International regulations

Chemical Weapon Convention List Schedules I, II & III Chemicals

Not listed.

Montreal Protocol (Annexes A, B, C, E)

Not listed.

Stockholm Convention on Persistent Organic Pollutants

Not listed.

Rotterdam Convention on Prior Informed Consent (PIC)

Not listed.

UNECE Aarhus Protocol on POPs and Heavy Metals

Not listed.

Inventory list

Australia : This material is listed or exempted.

Canada : This material is listed or exempted.

China : This material is listed or exempted.

Section 15. Regulatory information

Europe	:	This material is listed or exempted.
Japan	:	**Japan inventory (ENCS)**: This material is listed or exempted. **Japan inventory (ISHL)**: Not determined.
Malaysia	:	Not determined.
New Zealand	:	This material is listed or exempted.
Philippines	:	This material is listed or exempted.
Republic of Korea	:	This material is listed or exempted.
Taiwan	:	This material is listed or exempted.
Thailand	:	Not determined.
Turkey	:	Not determined.
United States	:	This material is listed or exempted.
Viet Nam	:	Not determined.

Section 16. Other information

Hazardous Material Information System (U.S.A.)

Health	*	3
Flammability		4
Physical hazards		3

Caution: HMIS® ratings are based on a 0-4 rating scale, with 0 representing minimal hazards or risks, and 4 representing significant hazards or risks. Although HMIS® ratings and the associated label are not required on SDSs or products leaving a facility under 29 CFR 1910.1200, the preparer may choose to provide them. HMIS® ratings are to be used with a fully implemented HMIS® program. HMIS® is a registered trademark and service mark of the American Coatings Association, Inc.

The customer is responsible for determining the PPE code for this material. For more information on HMIS® Personal Protective Equipment (PPE) codes, consult the HMIS® Implementation Manual.

National Fire Protection Association (U.S.A.)

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Copyright ©2001, National Fire Protection Association, Quincy, MA 02269. This warning system is intended to be interpreted and applied only by properly trained individuals to identify fire, health and reactivity hazards of chemicals. The user is referred to certain limited number of chemicals with recommended classifications in NFPA 49 and NFPA 325, which would be used as a guideline only. Whether the chemicals are classified by NFPA or not, anyone using the 704 systems to classify chemicals does so at their own risk.

Procedure used to derive the classification

Classification	Justification
FLAMMABLE GASES - Category 1	Expert judgment
GASES UNDER PRESSURE - Compressed gas	According to package
ACUTE TOXICITY (inhalation) - Category 3	On basis of test data
TOXIC TO REPRODUCTION (Fertility) - Category 1	Expert judgment
TOXIC TO REPRODUCTION (Unborn child) - Category 1	Expert judgment
SPECIFIC TARGET ORGAN TOXICITY (REPEATED EXPOSURE) - Category 1	Expert judgment

History

Date of printing : 11/29/2017

Section 16. Other information

Date of issue/Date of revision	:	11/29/2017
Date of previous issue	:	2/20/2017
Version	:	1
Key to abbreviations	:	ATE = Acute Toxicity Estimate BCF = Bioconcentration Factor GHS = Globally Harmonized System of Classification and Labelling of Chemicals IATA = International Air Transport Association IBC = Intermediate Bulk Container IMDG = International Maritime Dangerous Goods LogPow = logarithm of the octanol/water partition coefficient MARPOL = International Convention for the Prevention of Pollution From Ships, 1973 as modified by the Protocol of 1978. ("Marpol" = marine pollution) UN = United Nations
References	:	Not available.

Indicates information that has changed from previously issued version.

Notice to reader

To the best of our knowledge, the information contained herein is accurate. However, neither the above-named supplier, nor any of its subsidiaries, assumes any liability whatsoever for the accuracy or completeness of the information contained herein.
Final determination of suitability of any material is the sole responsibility of the user. All materials may present unknown hazards and should be used with caution. Although certain hazards are described herein, we cannot guarantee that these are the only hazards that exist.

Appendix 6.3.2: C*omposite Floor System Tests* Hazard Review (#733.06.0124) and SOP approved on 03/22/21

View Activity

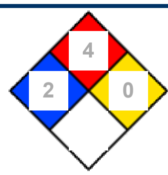
733 06 0124 031621 Composite Floor Systems Tests (Approved)

Contacts	**Principal Investigator**	[redacted]		
	Division	Fire Research Division	**Division Chie**	[redacted]
	Group	National Fire Research Laboratory	**Group Leader**	[redacted]

Activity description
The objective of this test is to measure the structural and temperature responses of steel concrete composite floor assemblies to a natural gas fueled compartment fire A series of tests will be conducted on 6 1 m by 9 1 m composite floor assemblies which will be mechanically loaded to the service gravity load level at ambient temperature and then subjected to a compartment fire simulating the ASTM E119 fire environment

Parameters
Activity Frequency Limited Duration **Times Repeated** less than 10

Hazards




Flammable materials


Toxic

Required PPE


Safety Glasses with side shields


Head Protection


Foot Protection

Other PPE (Please Specify) (long pants)


Lab Coat (flame retardant lab coat)


Gloves (specify type or types) (Cut resistant gloves)


Dust mask (Voluntary Use)

Storage requirements None specified

Locations (Contact) 205/125[redacted])

Authorized Users

View Revoked/Denied Approvals

User Name	Authorized By		Authorization Date	Approved for Out of Hours Work By	Out of Hours Approval Date
[redacted]	[redacted]	Revoke Authorization	March 22 2021	No Approval Required	
[redacted]	[redacted]	-- Revoke Authorization	March 22, 2021	No Approval Required	--
[redacted]	[redacted]	Revoke Authorization	March 22 2021	No Approval Required	
[redacted]	[redacted]	-- Revoke Authorization	March 22, 2021	No Approval Required	--
[redacted]	[redacted]	Revoke Authorization	March 22 2021	No Approval Required	
[redacted]	[redacted]	-- Revoke Authorization	March 22, 2021	No Approval Required	--
[redacted]	[redacted]	Revoke Authorization	March 22 2021	No Approval Required	
[redacted]	[redacted]	-- Revoke Authorization	March 22, 2021	No Approval Required	--

Required Training
Review of Hazard Review and Procedures (Operation of NFRL Structural Loading Systems (733.06 0073)), Review of Hazard Review and Procedures (NFRL Large Fire Experiments (733.06.0132); Enclosure Fire Test using Natural Gas Burners (733.06.0120);), Other (Please Specify) (Refer to SOP), Review of Hazard Review and Procedures (NFRL Large Fire Experiments (733.06 0132)), Other (Please Specify) (NIST S 7101.61: Compressed Gas Safety Program Training (operator only)), Review of Hazard Review and Procedures (Refer to NFRL Large Fire Experiments (733 06.0132)), Other (Please Specify) (EL-733: NFRL Emission Control System Training for Operators), Review of Hazard Review and Procedures (NFRL Overhead Cranes (733 06.0052); NFRL Scissor and Boom Lifts (733 06.0051); Assembly and Installation of Reaction Yoke (733.06.0069); NFRL Post-Tensioning of High Strength Bars (733.06 0071); NFRL General Scaffolding Use (733.06.0125))

Incident/Emergency Response Plan Location ERP

E piration Date November 16 2022

History **Created** [redacted] 2021 03 16 13 19 25 0400 **Updated** [redacted] 2022 11 09 11 20 15 0500

Reviews **Review Level** Division Chief

Related Documentation

Title	Filename	Attachment Type	Description
natural gas	SDS natrual gas pdf	Safety Data Sheet (previously MSDS)	
propane	SDS-portable-propane.PDF	Safety Data Sheet (previously MSDS)	
carbon dioxide	SDS carbon dioxide pdf	Safety Data Sheet (previously MSDS)	
carbon monoxide	SDS-carbon-monoxide pdf	Safety Data Sheet (previously MSDS)	
ERP	CompositeFloorTest ERP docx	Incident/Emergency Response Plan	Revised after DSR review
NFRL Safety Briefing Checklist	NFRL Fire Test Safety Briefing Checklist 01 19 2020 docx	Other	Replaced with the current version (01 19 2020)
SOP Version1 Original	CompositeFloorTest Original docx	Standard Operating Procedure	This is an original version
SOP_Version2_including_PostFireLoadingTest	CompositeFloorTest_IncludingPostFireLoadingTest_Cleaned.docx	Standard Operating Procedure	This is the revised version including a post fire loading test All mark ups are cleaned

Approval/Review History

Activity	Status	Review level	Reviewing Official	Modified
733.06.0124 - Composite Floor Systems Tests	Review Completed	Group Leader	[redacted]	[redacted] - 2021-03-16 13:47:06 -0400
733 06 0124 Composite Floor Systems Tests	Returned to PI	Division Safety Representative	[redacted]	[redacted] 2021 03 19 11 22 21 0400
733.06.0124 - Composite Floor Systems Tests	Review Completed	Division Safety Representative	[redacted]	[redacted] - 2021-03-22 06:31 09 -0400
733 06 0124 Composite Floor Systems Tests	Review Completed	Division Chief	[redacted]	[redacted] 2021 03 22 15 03 29 0400

Tasks/Equipment

1. Setup (Tasks/Equipment)

Signage Required N/A

Required Controls

Guard/Barrier, **Other Engineering Controls (Please Specify)** (Rated structural braces and shoring), **Operating Procedures** (OHSA 1926.502- Fall protection systems criteria and practices; OHSA 1926.759 - Falling object protection; 1926.302 Power-operated hand tools), **Safe Practices** (pre-activity briefing & meeting to discuss steel erection; OHSA steel erection tools (https //www.osha.gov/SLTC/etools/steelerection/index.html)), **Review of Hazard Review and Procedures** (NFRL Overhead Cranes (733 06.0052); NFRL Scissor and Boom Lifts (733 06.0051); Assembly and Installation of Reaction Yoke (733 06.0069); NFRL Post-Tensioning of High Strength Bars (733 06.0071); NFRL General Scaffolding Use (733.06.0125)), **Dust mask (Voluntary Use)**, **Foot Protection**, **Gloves (specify type or types)** (Cut resistant gloves), **Head Protection**, **Safety Glasses with side shields**

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Struck By (Mass Acceleration)	Set-up and/or Tear Down	Catastrophic	Improbable	2 - Medium

2. Mechanical loading (Tasks/Equipment)

Signage Required N/A

Required Controls

Enclosure/Isolation (Actuators are located at the basement), **Interlock/Auto-shutoff** (Actuators will be automatically depressurized with preset load and displacement limits; Emergency stop), **Other Engineering Controls (Please Specify)** (Rated loading frames and support frames with safety factors; instrumentation to monitor structural integrity), **Operating Procedures** (Refer to SOP), **Safe Practices** (Exclusion zone of 5 m will significantly reduced struck by hazard), **Review of Hazard Review and Procedures** (Operation of NFRL Structural Loading Systems (733 06.0073)), **Foot Protection**, **Head Protection**, **Other PPE (Please Specify)** (long pants), **Safety Glasses with side shields**

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Struck Against	Normal Operations	Severe	Remote	2 - Medium

3. Specimen heating (Tasks/Equipment)

Signage Required N/A

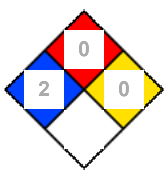
Required Controls

Interlock/Auto-shutoff (Maxon safety shutoff switch), **Other Engineering Controls (Please Specify)** (Automatic deluge and monitor, and manual hose fire suppression system., Methyl Mercaptan addative. Odor threshold .002 (ppm)), **Ventilation** (20 MW exhaust hood), **Safe Practices** (safety briefing; 5 m exclusion zone; leak checks), **Other (Please Specify)** (Refer to SOP), **Review of Hazard Review and Procedures** (NFRL Large Fire Experiments (733.06 0132); Enclosure Fire Test using Natural Gas Burners (733 06.0120);), **Foot Protection**, **Head Protection**, **Lab Coat** (flame retardant lab coat), **Other PPE (Please Specify)** (long pants), **Safety Glasses with side shields**

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Fire/Heat	Normal Operations	Catastrophic	Improbable	2 - Medium

Principal Substances

Concrete projectiles by spalling (Principal Substances)



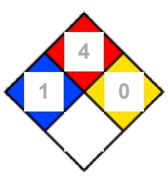
Signage Required N/A
Health Moderate (2)
Flammable None (0)
Reactive None (0)
Storage Required N/A

Required Controls

Other Engineering Controls (Please Specify) (polypropylene fibers (as crack arresters) in concrete mix), **Safe Practices** (5 m Exclusion zone during test), **Foot Protection**, **Head Protection**, **Safety Glasses with side shields**

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Struck By (Mass Acceleration)	Normal Operations	Moderate	Improbable	1 - Low

Natural gas (Principal Substances)



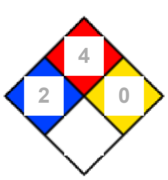
Signage Required N/A
Quantity 20
Units psig
Health Slight (1)
Flammable Extreme (4)
Reactive None (0)
Storage Required N/A

Required Controls

Other Engineering Controls (Please Specify) (Refer to NFRL Large Fire Experiments (733.06.0132)), **Other Device Use (Please Specify)** (Refer to NFRL Large Fire Experiments (733 06.0132)), **Operating Procedures** (Refer to NFRL Large Fire Experiments (733.06 0132)), **Review of Hazard Review and Procedures** (NFRL Large Fire Experiments (733 06.0132))

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Chemical (Flammable)	Normal Operations	Catastrophic	Improbable	2 - Medium

Propane gas (Principal Substances)



Signage Required N/A
Quantity < 0 5
Units L
Health Moderate (2)
Flammable Extreme (4)
Reactive None (0)
Storage Required N/A

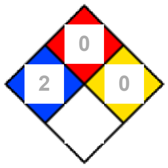
Required Controls

Other Engineering Controls (Please Specify) (No hazards are listed because the hazards have been accounted for elsewhere or there are no associated hazards.), **Other (Please Specify)** (NIST S 7101.61: Compressed Gas Safety Program Training (operator only))

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Chemical (Flammable)	Normal Operations	Catastrophic	Improbable	2 - Medium

Waste Products

Carbon Dioxide (Waste Products)



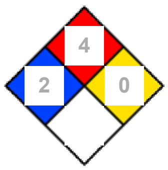
Signage Required	N/A
Health	Moderate (2)
Flammable	None (0)
Reactive	None (0)
Storage Required	N/A

Required Controls

Other Engineering Controls (Please Specify) (Refer to NFRL Large Fire Experiments (733.06.0132)), **Operating Procedures** (Refer to NFRL Large Fire Experiments (733 06.0132)), **Review of Hazard Review and Procedures** (Refer to NFRL Large Fire Experiments (733.06 0132))

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Asphyxiation/Oxygen displacement	Normal Operations	Minor	Remote	1 - Low

Carbon Monoxide (Waste Products)



Signage Required	N/A
Health	Moderate (2)
Flammable	Extreme (4)
Reactive	None (0)
Storage Required	N/A

Required Controls

Other Engineering Controls (Please Specify) (Refer to NFRL Large Fire Experiments (733.06.0132)), **Ventilation** (20 MW exhaust hood), **Alarms** (CO monitors in the high bay), **Use Monitoring** (CO measurement inside the compartment), **Other (Please Specify)** (EL-733: NFRL Emission Control System Training for Operators), **Review of Hazard Review and Procedures** (Refer to NFRL Large Fire Experiments (733.06 0132))

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Chemical (Toxic)	Normal Operations	Catastrophic	Improbable	2 - Medium

Version History

Initial Version: 733.06.0124.021919i

Previous Version (2 of 2): 733.06.0124.012221

Type of Change and Resulting Level of Review for this Version

Change Type	Minor change(s); see table below for detailed list of changes. Review and final approval by first-level Supervisor, regardless of activity RHI value.
Primary reasons for this change type	• Any changes to the activity result in the classification of the changes as minor

Detailed list of changes (compared to prior version)

Description or documentation Field	Change Type	Previous Version	This Version
Attachment: NFRL Safety Briefing Checklist	Added		
Description for attachment: SOP	Changed	Revised after Division Chief review	Added COV D-19 requirements Revised PPE, exclusion zone, and testing criteria
Disk filename for attachment: SOP	Changed	191021102514_CompositeFloorTest_SOPmb_kh_rev2_nb2 docx	210122125712_CompositeFloorTest_Rev1_lc.docx
Filename for attachment: SOP	Changed	CompositeFloorTest_SOPmb_kh_rev2_nb2 docx	CompositeFloorTest_Rev1_lc.docx
Filesize for attachment: SOP	Changed	737623	969110
Attachment: Safety Briefing Checklist	Removed		
Experiment description	Changed	The objective of this test is to measure the response and fire resistance of steel-concrete composite floor assemblies to a compartment fire. A series of tests will be conducted on 6.1 m by 9.1 m composite floor assemblies which will be mechanically loaded to the service gravity load level at ambient temperature and then subjected to a compartment fire.	The objective of this test is to measure the structural and temperature responses of steel-concrete composite floor assemblies to a natural gas-fueled compartment fire. A series of tests will be conducted on 6.1 m by 9.1 m composite floor assemblies which will be mechanically loaded to the service gravity load level at ambient temperature and then subjected to a compartment fire simulating the ASTM E119 fire environment.

This Version: 733.06.0124.031621

Type of Change and Resulting Level of Review for this Version

Change Type	Minor change(s); see table below for detailed list of changes. Review and final approval by first-level Supervisor, regardless of activity RHI value.
Primary reasons for this change type	• Any changes to the activity result in the classification of the changes as minor

Detailed list of changes (compared to prior version)

Description or documentation Field	Change Type	Previous Version	This Version
Attachment: SOP	Removed		
Attachment: SOP Version1 Original	Added		
Attachment: SOP Version2 including PostFireLoadingTest	Added		

Title: Compartment Fire Test on Composite Floor System

Building & room number: Building 205; Room 125

Test Director: [redacted]

Workspace manager(s): [redacted]

Purpose and Scope: The purpose of this test program is to measure thermal and structural responses of the composite floor assemblies subjected to combined mechanical loading and compartment fires. This experimental test involves a two-story multi-bay structural steel frame with concrete floor slabs constructed at the NFRL. The fire compartment measures 6.1 m (20 ft) by 9.1 m (30 ft) in plan and 4.0 m (13 ft) in height, situated at the middle bay of the test frame on the ground level (Refer to Figure 1). The test fire will be produced using four 1.5 m by 1 m natural gas-fueled burners distributed inside the test compartment. Four hydraulic actuators mounted at the basement are be connected to loading frames above the test floor assembly via water-cooled high-strength steel pipes to apply the code-required gravity loads during fire exposure. The composite floor assembly resisting mechanical loads will be exposed to a compartment fire simulating ASTM E119 temperature-time relationship.

Post-fire loading test: If the test floor assembly is deemed stable after it sufficiently cools down from this fire experiment, a mechanical loading test will be conducted using the same loading arrangement to measure the post-fire residual strength of the test floor assembly. This testing will be performed at room temperature and run until any of failure criteria is achieved (See page 9 bullet 4).

This SOP pertains to personnel who have active roles identified during the pre-test safety briefing. Other safety protocols will be also notified during the pre-test safety briefing.

After consultation with the NFRL group leader and the workspace manager, the principle investigator (Test director) of each activity shall provide an approved hazard review for final review by the NFRL group leader before the activity can commence.

COVID-19 Work Requirements

All activities in this hazard review have been assessed for the ability to comply with NIST directives to adequately reduce the potential spread of COVID-19. General Hazard Review 733.04.0164 (Requirements to Mitigate COVID-19 Exposure) describes NIST requirements along with suggestions for additional engineering and/or administrative controls, and personal protective equipment to prevent the possible spread of COVD-19.

An assessment of the work described in this hazard review determined that these activities are in the Medium Risk Group. The assessment determined that the minimum

NIST COVID-19 precautions for medium risk activities are adequate to reduce the potential spread of COVID-19.

Hazardous Materials during Fire Experiment:

- Chemical (Flammable): Natural gas, propane
- Chemical (Toxic): Carbon monoxide

Special containment, containers or handling equipment:

- 20 MW exhaust hood will capture hot gases and combustibles.
- Four actuators will be mounted at the basement to protect from fire exposure.

Required Personal Protective Equipment (PPE):

1. **Setup or tear-down**
   - Closed toe shoes
   - Hard hat
   - Safety glasses
   - Long pants
   - Cut resistant gloves
   - Face mask
   - Half-mask air-purifying respirator equipped with high efficiency particulate air (HEPA) filter cartridges (for installation and removal of ceramic fiber blanket)
2. **Experiment**
   - Face mask
   - Closed toed shoes
   - Fire resistant lab coat – during fire experiment
   - Hard hat
   - Safety glasses
   - Long pants
   - Heat resistant gloves (voluntary use) – during fire experiment
   - Firefighter turnout gear and heat resistant gloves for NFRL staff who perform
     - Burner ignition during fire experiment
     - Active cooling (water spraying) of the north rollup door and strong floor during fire experiment

Training Requirements:

1. **For all participants:**
   - EL-733: NFRL Lab Access and Safety Awareness
   - NIST S 7101.21: Personal Protective Equipment Program Training
2. **For operators only:**
   - EL-733: NFRL Emission Control System Training
   - EL-733: NFRL Natural Gas Fuel Delivery System Training
   - EL-733: NFRL Structural Loading System (733.06.0073)
   - EL-733: NFRL Overhead Cranes Training (733.06.0052)
   - EL-733 Scissor and Boom Lifts Training (733.06.0051)

- NIST S 7101.58: Respiratory Protection Program - Training for Voluntary Use of Filtering Facepieces (for fire experiment)
- NIST S 7101.58: Respiratory Protection Program - Initial Training (for fire experiment)
- NIST S 7101.58: Respiratory Protection Program - Initial or Annual Fit Testing (for fire experiment)

Hazards and Controls:

1. Setup or Tear-down

a) General Hazards: Stuck by (Mass Acceleration), Fall (Slip, Trip)
- Specific Hazards:
  - NFRL Overhead Cranes (733.06.0052)
  - NFRL Scissor and Boom Lifts (733.06.0051)
  - NFRL General Scaffolding Use (733.06.0125)
  - Assembly and Installation of Reaction Yoke (733.06.0069)
  - NFRL Post-Tensioning of High Strength Bars (733.06.0071)
  - Composite Floor System Stabilization and Demolition (733.06.0148)
- Engineering Controls:
  - All engineering controls listed in the hazard reviews above.
  - Catch system (e.g., 6x6 lumber cribbing) in the middle of the test bay for post-fire loading testing
- Administrative Controls:
  - Pre-activity briefing or meeting to discuss the sequence of construction
  - Guard/barrier/signs
  - Exclusion zone defined by the workspace manager
  - Buddy system
  - Time limitations (7:30-4:00)
  - PPE (see PPE list above)

2. Experiment

a) General Hazard: Stuck by (Mass Acceleration)
- Engineering Controls
  - Emergency stop switch integrated with the MTS computer located in the NFRL test bay.
  - For fire testing, MTS displacement limit was set to 24 inches for automatic depressurization of hydraulic fluid. For post-fire loading test, this displacement limit will be set to approx.15 inches.
  - The structural steel loading frames are designed to safely transfer the maximum force up to 34,000 lbs. per actuator. Applied load will be fraction of the capacity of loading system (34,000 lbs.). For post-fire loading testing, the actuator load limit will be set to 30,000 lbs. to automatically remove hydraulic pressure in the actuators.

  - Surrounding floor assembly is designed for Safety Factor of 3 or greater at ambient temperature.
  - Structural steel columns are designed for Safety Factor of 3 or greater and anchored to the strong floor. These columns are protected from fire exposure and will provide a reliable load path to the strong floor during and after the experiment.
  - Rated structural steel braces or catch systems that prevent damages to the strong floor
  - Concrete mixture design with polypropylene fibers to lower the likelihood of explosive spalling – during fire testing
  - Instrumentation and cameras to monitor structural responses (displacements and strains) of the test building
- Administrative Controls
  - Pre-test safety briefing
  - Exclusion zone (See Figure 2)
  - PPE (hard hat, close toe shoes, safety glasses, gloves, long pants)

b) General Hazards: Fire and Heat
- Specific Hazards
  - NFRL Large Fire Experiments (733.06.0132)
- Engineering Controls
  - All engineering controls listed in the hazard reviews above
  - Maxon safety shutoff switch
  - Automatic deluge and monitor as well as manual hose fire suppression system
  - NFRL exhaust hood for ventilation
  - Combustible gas leak detector
  - Flame barriers outside the test compartment (gypsum or concrete boards, ceramic fiber blanket, and heat shield)
  - MTS actuators mounted at the basement to protect from fire
  - Instrumentation to monitor temperatures of the test floor and surrounding structures
- Administrative Controls
  - Pre-test safety briefing
  - Routine inspection and leak checks for natural gas burners and pipework
  - Operator who ignites the pilot flames should wear turnout gear and heat resistant gloves.
  - PPE (hard hat, close toe shoes, safety glasses, long pants, flame retardant lab coat)
  - Passive protection of the strong floor with concrete or gypsum boards in front of the south vent opening of the test bay
  - Active cooling (water spraying) of the north rollup door and strong floor near the south vent opening of the test bay.
  - Exclusion zone (See Figure 2)

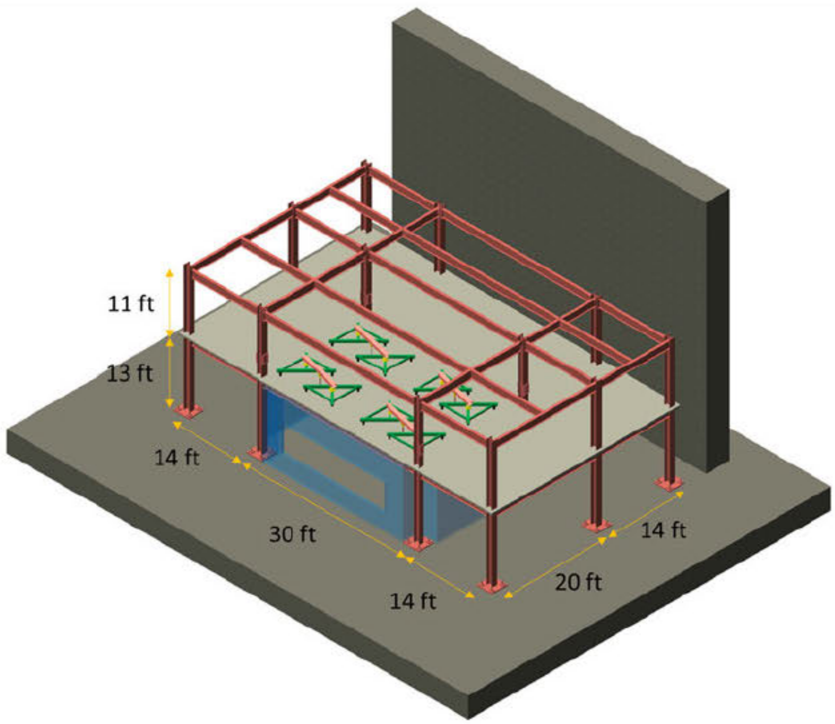


Figure 1. Test Structure (a large vent opening on the south wall)

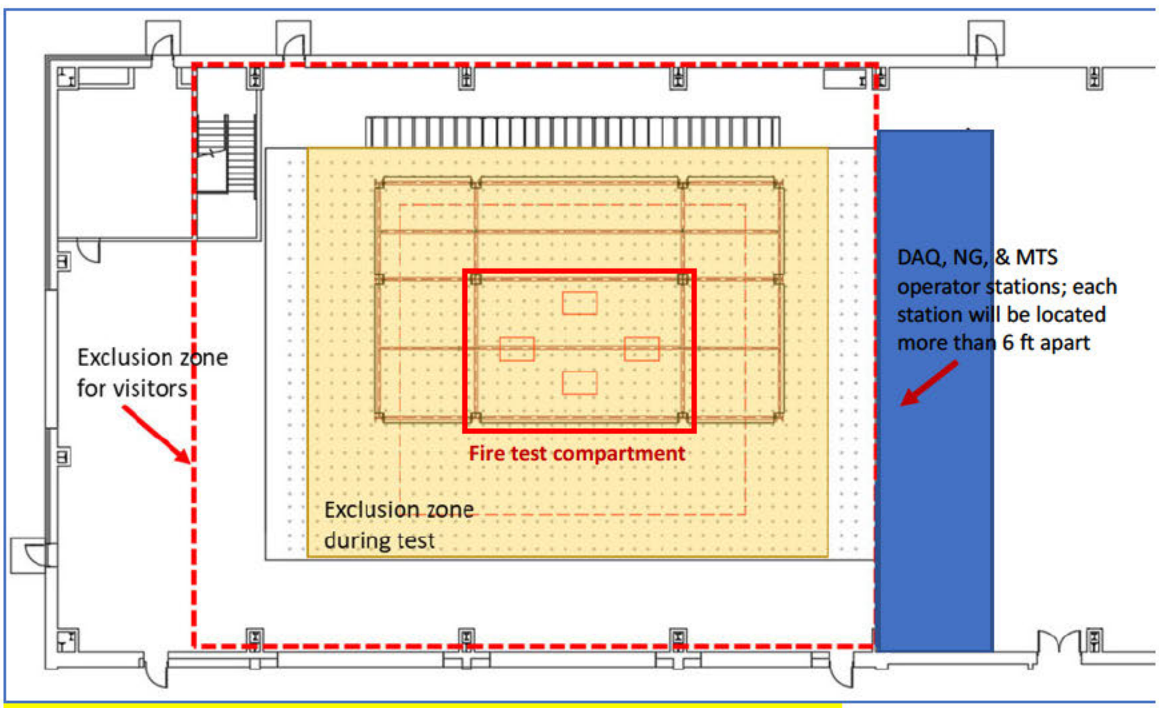


Figure 2 Exclusion zone during experiment (Bldg. 205 / Rm 125)

Standard Operating Procedure (SOP) for Structural Fire Experiment:
Experiments shall not be conducted if the outside temperature is below -10 °C or above 45 °C or if extreme weather is expected.

1. **Pretest**
- ☐ Turn on exhaust fans and open makeup air dampers.
- ☐ Verify no desired combustible materials within 5 m of the hood skirt
- ☐ Deactivate automatic fire suppression systems
- ☐ Verify all fire suppression water lines are functioning
- ☐ Notify NIST fire department
- ☐ Verify NFRL data acquisition and recording systems are functioning
- ☐ Turn on lighting and verify camera settings
- ☐ Verify all settings required for safe operation of MTS hydraulic system
  - ☐ Chilled water temperature
  - ☐ Basement cameras
  - ☐ Pre-set displacement and load limits that trigger unloading of a test structure

2. **Test director conducts safety briefing**

The Safety Briefing is limited to individuals identified by the Test Director. Personnel who do not attend the safety briefly shall not enter the test area after this point.

3. **Start data acquisition and recording system**
  - ☐ Complete offset nulling of strain and displacement output (Vout = 0 V)
  - ☐ Verify MTS readings transferred via NFRL data bridge program

4. **Open valves for water cooled loading pipes**

5. **Increase mechanical loads to a target magnitude (7000 lbs. per actuator)**

6. **Switch MTS control mode to 'Force' and verify actuator forces and stroke displacements are unchanged up to 30 min.**

7. **Acquire background data for heat release rate and repeat offset nulling of strain and displacement output**

8. **Ignite four test burners inside the test compartment by qualified NFRL staff**

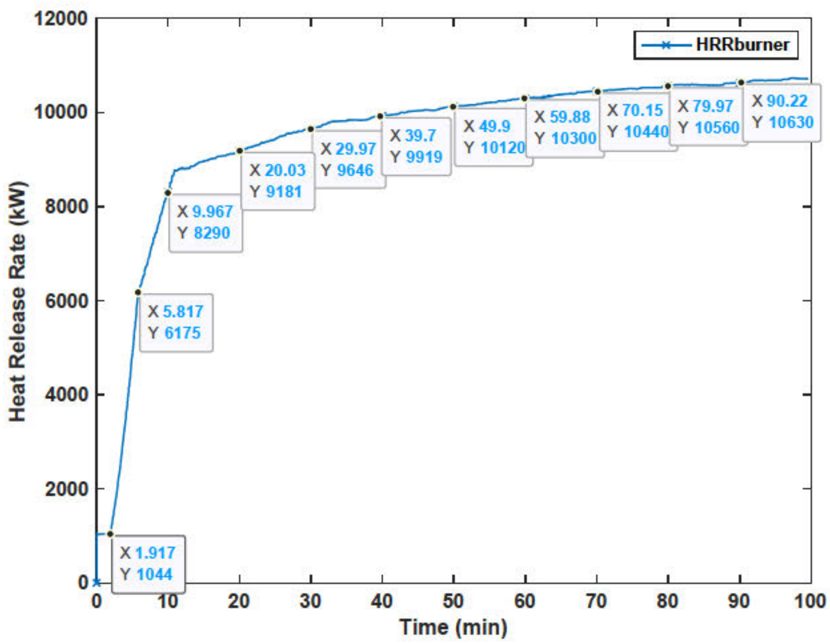
a. Verify gas leakage at the burner pipework connected to NFRL fuel delivery system with sniffer.

b. Ignite pilot flames of the test burners with a portable propane bottle and exit the test compartment. *Burner pilots are fed by a small propane bottle outside the test compartment via copper gas lines.* <u>*A NFRL technician who performs this task must wear firefighter turnout gear.*</u>

c. Increase gas flow to ignite all four test burners. *NFRL natural gas operator may set the burner HRR less than or equal to 1000 kW.*
d. Confirm ignition of the test burners by an assigned observer
e. Verify uniformity of gas distribution in the test burners. Regulate globe valves of the burner pipelines outside the test compartment if necessary.

9. Increase gas flow to simulate the ASTM E119 temperature-time relationship.

a. Run the prescribed burner ramp shown below.
b. Check the average upper layer temperatures every 15 min. If the temperature is more than 100 C off from the ASTM E119 prescribed temperatures, then make an adjustment on the values of HRRburner.



10. Run a structural fire test until any of the following criteria is reached

a. Remove a test fire only. Turn off gas supply to the test burners if any of the following scenarios occurs:
   - Failure of the fire test compartment
     i. Wall breach,
     ii. Detachment of Kaowool drapes above the east, west, and/or north walls,
     iii. Structural failure of the south wall due to excessive thermal expansion of a test floor assembly, or
     iv. Significant flame leakage above the test floor assembly
   - Loss of exhaust hood flow
b. Remove hydraulic loading only. Release hydraulic pressure in the MTS system if any of the following scenarios occurs:
   - Actuator displacement limit (approx. 24 inches)

- Failure of water-cooled steel loading pipes connected to actuators, or
- Water outlet temperature of water-cooled loading pipes in excess of 60 C,

c. Remove both fire and hydraulic loading immediately if any of the following scenarios occurs:
- Failure of critical safety monitoring systems longer than 5 min
- Rupture of rebars in the middle of the test floor slab
- Failure of the beam-to-column connection(s) of the test floor assembly,
- Failure of the beam-to-column connection(s) of the second-story south beam framing, or
- At any time, unsafe conditions exist. The Safety Officer, the Test Director, and the Lab Director will have authority to stop the experiment.

11. Close valves for water cooled loading pipe when the compartment temperature is below 200 °C

12. Stop data acquisition system when the temperature of the specimen (both steel and concrete) drops below 100 °C.

13. Maintain exclusion area (footprint of 15 m hood) until

- ☐ **Wall surfaces cooled down below 50 °C as determined by thermocouple or handheld FLIR camera,**
- ☐ **CO measured in the compartment drops below 50 PPM, and**
- ☐ **Initial structural safety inspections are performed by NFRL structural engineer(s)**

14. Perform a safety debriefing

Standard Operating Procedure (SOP) for Post-fire Loading Experiment:

1. **Pretest**

- ☐ Verify NFRL data acquisition and recording systems are functioning
- ☐ Turn on lighting and verify camera settings
- ☐ Verify all settings required for safe operation of MTS hydraulic system
    - ☐ Chilled water temperature
    - ☐ Basement cameras
    - ☐ Pre-set displacement and load limits used for automatic depressurization of hydraulic system

2. **Test director conducts safety briefing**

The Safety Briefing is limited to individuals identified by the Test Director. Personnel who do not attend the safety briefly shall not enter the test area after this point.

3. **Start data acquisition, recording, and camera system**
    - Complete offset nulling of strain and displacement output
    - Verify MTS readings on MIDAS

4. **Increase mechanical loads at 500 lbs./min or lower per actuator until any of the following criteria is reached**

    i. Pre-set actuator displacement limit (approx. 15 inches per actuator),
    ii. Pre-set actuator load limit (approx. 30,000 lbs. per actuator),
    iii. Rupture of rebar(s) at critical locations (e.g., south of the north primary beam and around the secondary beam, north of the south primary beam), or
    iv. Failure of the beam-to-column connection(s) of the test floor assembly
    v. At any time, unsafe conditions exist. The Safety Officer, the Test Director, and the MTS operator will have authority to stop the experiment.

    -Case i might occur with or without collapse of the test floor assembly and hydraulic forces will be removed automatically.
    -Case ii might occur without collapse and hydraulic forces will be removed automatically.
    -For Cases iii and iv, the actuator load is no longer increasing at a programed load rate while the vertical displacement and rebar strains of the test floor assembly increase rapidly. Loud noise might occur simultaneously. For Cases iii, iv, and v, press the MTS E-stop button to manually remove hydraulic forces.

5. **Stop DAQ recording and camera systems**

6. **Maintain exclusion area (footprint of 15 m hood) until initial structural safety inspections are performed by NFRL structural engineer(s)**

7. **Perform a safety debriefing**

Plans for Out-of-Hours Operation: Out-of-hours operation is not permitted.

Specimen removal and clean-up procedure:
Within a week after completion of the experiment, a Specimen Removal Safety Team, consisting of NFRL staff, will meet to assess damage level of the tested specimen and to identify hazard(s) associated with removing process. Refer to Composite Floor System Stabilization and Demolition (733.06.0148) for generic deconstruction activities of a tested floor assembly and associated hazard review. If necessary, this hazard review may be revised based upon the initial visual inspections performed by NIST structural engineers.

Appendix 6.3.3: ***Composite Floor System Stabilization and Demolition*** **Hazard Review (#733.06.0148) and All Associated Documentation approved on 05/16/22**

View Activity

733 06 0148 050522 Composite Floor System Stabilization and Demolition (Approved)

Contacts

Principal Investigator [redacted]
Division Fire Research Division **Division Chie** [redacted]
Group National Fire Research Laboratory **Group Leader** [redacted]

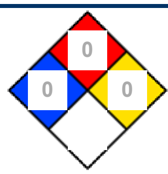
Activity description

The National Fire Research Laboratory (NFRL) conducts a series of experiments on a two story multi bay steel framed structure with steel concrete composite floors subjected to real fire This hazard review covers the procedure for demolition of a damaged or partially collapsed test bay for removal A team of structural engineers will analyze the condition of the damaged structure Once a determination is made that it is safe to work on under and around the surrounding bays shoring will be placed inside the fire compartment and demolition of the damaged test bay will commence

Parameters

Activity Frequency Indefinite Use **Times Repeated**

Hazards



Required PPE

Safety Glasses with side shields
Head Protection (Hard Hat)
Foot Protection (Steel Toe)
Dust mask (Required Use)
Fall Protection (In absence of other controls)
Other PPE (Please Specify) (Face shield)
Other PPE (Please Specify) (Leather or cut resistant gloves)
Head Protection (Hard hat)
Foot Protection (Steel toe)
Hearing Protection (Voluntary Use) (Ear Plugs and Ear Muffs)
Hearing Protection (Required Use) (Ear Plugs)

torage requirements: None specified

Locations (Contact): 205/125 [redacted])

Authorized Users

User Name	Authorized By		Authorization Date	Approved for Out of Hours Work By	Out of Hours Approval Date
[redacted]	[redacted]	Revoke Authorization	May 17 2022	No Approval Required	
[redacted]	[redacted]	-- Revoke Authorization	May 17, 2022	No Approval Required	--
[redacted]	[redacted]	Revoke Authorization	May 17 2022	No Approval Required	
[redacted]	[redacted]	-- Revoke Authorization	May 17, 2022	No Approval Required	--

Required Training

Other (Please Specify) (Structure survey team members must have a structural engineering degree.), Review of Hazard Review and Procedures (733.06.0051 NFRL Scissor and Boom Lifts), Review of Hazard Review and Procedures (NFRL Overhead Cranes; NFRL Industrial Powered Trucks (Forklifts and Skidloader)), Other (Please Specify) (Hearing Protection)

Incident/Emergency Response Plan Location: ERP Composite Floor System Stabilization and Demolition

E piration Date: May 16 2023 Set earlier expiration date (1 week from today)

History: **Created** [redacted] 2022 05 05 14 46 38 0400 **Updated** [redacted] 2022 05 16 16 27 21 0400

Reviews: **Review Level** Division Chief

Related Documentation

Title	Filename	Attachment Type	Description
ERP-Composite Floor System Stabilization and Demolition	ERP__Composite_Deck_Removal_v2.docx	Incident/Emergency Response Plan	
SSOP Composite Floor System Stabilization and Demolition	SOP Composite Deck Removal kmh rev1 1 lc 2 docx	Safe Operating Procedure	

Approval/Review History

Activity	Status	Review level	Reviewing Official	Modified
733.06.0148 - Composite Floor System Stabilization and Demolition	Review Completed	Group Leader	[redacted]	[redacted] - 2022-05-06 14:13:18 -0400
733.06.0148 - Composite Floor System Stabilization and Demolition	Returned to PI	Division Safety Representative	[redacted]	[redacted] - 2022-05-11 12:08:11 -0400
733.06.0148 - Composite Floor System Stabilization and Demolition	Review Completed	Division Safety Representative	[redacted]	[redacted] - 2022-05-16 14 38:20 -0400
733.06.0148 - Composite Floor System Stabilization and Demolition	Review Completed	Division Chief	[redacted]	[redacted] - 2022-05-16 16:27:21 -0400

Tasks/Equipment

Beam Removal (Tasks/Equipment)

Signage Required N/A

Required Controls

Other Device Use (Please Specify) (Crane with rigging; forklift), **Safe Practices** (Consult with engineers for estimated weight of beams to ensure use of proper rigging.), **Review of Hazard Review and Procedures** (NFRL Overhead Cranes; NFRL Industrial Powered Trucks (Forklifts and Skidloader)), **Foot Protection** (Steel Toe), **Head Protection** (Hard Hat), **Safety Glasses with side shields**

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Struck By (Mass Acceleration)	Normal Operations	Catastrophic	Improbable	2 - Medium

Concrete Demolition (Tasks/Equipment)

Signage Required N/A

Required Controls

Other Engineering Controls (Please Specify) (Water feed), **Other Device Use (Please Specify)** (Portable Fans, Shoring System, Shoring system platform; guardrail; scissor or boom lift, Shoring system platform; transfer chute or bucket), **Safe Practices** (Avoid exposure when not directly involved in cutting operation, No activity on damaged test slab without shoring; Use caution tape to mark an exclusion zone around the test slab, No activity in compartment during demolition; Use caution tape to mark off exclusion zone around test structure.), **Other (Please Specify)** (Structure survey team members must have a structural engineering degree.), **Review of Hazard Review and Procedures** (733.06 0051 NFRL Scissor and Boom Lifts), **Dust mask (Required Use)**, **Fall Protection** (In absence of other controls), **Foot Protection** (Steel Toe), **Head Protection** (Hard Hat), **Other PPE (Please Specify)** (Face shield), **Safety Glasses with side shields**

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Dust/Particles (Respiratory Irritant)	Normal Operations	Minor	Occasional	1 - Low
Excavation (Collapse)	Normal Operations	Catastrophic	Improbable	2 - Medium
Fall (Slip, Trip)	Normal Operations	Catastrophic	Improbable	2 - Medium
Struck By (Mass Acceleration)	Normal Operations	Moderate	Remote	2 - Medium
Struck By (Mass Acceleration)	Normal Operations	Catastrophic	Improbable	2 - Medium

Concrete and Deck Pan Demolition (Tasks/Equipment)

Signage Required N/A

Required Controls

Other (Please Specify) (Hearing Protection), **Hearing Protection (Required Use)** (Ear Plugs), **Hearing Protection (Voluntary Use)** (Ear Plugs and Ear Muffs)

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Noise	Multi-Stages	Moderate	Occasional	2 - Medium

Damaged Composite Floor System (Tasks/Equipment)

Signage Required N/A

Required Controls

Other Device Use (Please Specify) (Beam arrest angles; Beam arrest columns; Shoring system), **Safe Practices** (No activity in compartment without shoring; Use caution tape to block entrance to compartment; Preassemble shoring to reduce time and exposure; Begin shoring immediately upon entering the compartment and shore from outside in or from safe to unsafe regions.), **Foot Protection** (Steel toe), **Head Protection** (Hard hat), **Safety Glasses with side shields**

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Struck By (Mass Acceleration)	Normal Operations	Catastrophic	Improbable	2 - Medium

Deck Pan Removal (Tasks/Equipment)

Signage Required N/A

Required Controls

Other Device Use (Please Specify) (Plate lifting clamps or c-clamps for lifting points), **Safe Practices** (Handle with c-clamps where possible), **Foot Protection** (Steel Toe), **Head Protection** (Hard Hat), **Other PPE (Please Specify)** (Leather or cut resistant gloves), **Safety Glasses with side shields**

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Struck Against	Normal Operations	Severe	Remote	2 - Medium
Ergonomics (Strain)	Normal Operations	Moderate	Remote	2 - Medium

Shoring Installation (Tasks/Equipment)

Signage Required N/A

Required Controls

Buddy System (Two man carry), **Foot Protection** (Steel Toe), **Head Protection** (Hard Hat), **Safety Glasses with side shields**

Hazard	Stage	Severity	Controlled Likelihood	Controlled RHI
Struck By (Mass Acceleration)	Normal Operations	Minor	Remote	1 - Low

Version History

Initial Version: 733.06.0148.112219i

Previous Version (2 of 3): 733.06.0148.090320

Type of Change and Resulting Level of Review for this Version

Change Type	Minor change(s); see table below for detailed list of changes. Review and final approval by first-level Supervisor, regardless of activity RHI value.
Primary reasons for this change type	• Any changes to the activity result in the classification of the changes as minor

Detailed list of changes (compared to prior version)

Description or documentation Field	Change Type	Previous Version	This Version
Disk filename for attachment: ERP-Composite Floor System Stabilization and Demolition	Changed	191206111920_ERP__Composite_Deck_Removal_v2.docx	200903092715_ERP__Composite_Deck_Removal_v2 docx
Filesize for attachment: ERP-Composite Floor System Stabilization and Demolition	Changed	16001	16426
Disk filename for attachment: SSOP-Composite Floor System Stabilization and Demolition	Changed	191206100840_SOP_Composite_Deck_Removal_kmh_rev1 docx	200903092654_SOP_Composite_Deck_Removal_kmh_rev1__1_.docx
Filename for attachment: SSOP-Composite Floor System Stabilization and Demolition	Changed	SOP_Composite_Deck_Removal_kmh_rev1.docx	SOP_Composite_Deck_Removal_kmh_rev1__1_ docx
Filesize for attachment: SSOP-Composite Floor System Stabilization and Demolition	Changed	18213785	18214048

Previous Version (3 of 3): 733.06.0148.050521

Type of Change and Resulting Level of Review for this Version

Change Type	Minor change(s); see table below for detailed list of changes. Review and final approval by first-level Supervisor, regardless of activity RHI value.
Primary reasons for this change type	• Any changes to the activity result in the classification of the changes as minor

Detailed list of changes (compared to prior version)

Description or documentation Field	Change Type	Previous Version	This Version
Disk filename for attachment: SSOP-Composite Floor System Stabilization and Demolition	Changed	200903092654_SOP_Composite_Deck_Removal_kmh_rev1__1_ docx	210505134345_SOP_Composite_Deck_Removal_kmh_rev1__1_lc.docx
Filename for attachment: SSOP-Composite Floor System Stabilization and Demolition	Changed	SOP_Composite_Deck_Removal_kmh_rev1__1_.docx	SOP_Composite_Deck_Removal_kmh_rev1__1_lc docx
Filesize for attachment: SSOP-Composite Floor System Stabilization and Demolition	Changed	18214048	18219347

This Version: 733.06.0148.050522

Type of Change and Resulting Level of Review for this Version

Change Type	There has been a change to one or more RHI=2 tasks, equipment or substances. See Table of changes below. Review as an RHI=2 activity (GL, DSR, and final Approval by Division Chief, or equivalent).
Primary reasons for this change type	• New hazard Noise (associated with Concrete and Deck Pan Demolition) added 2 - Medium

Detailed list of changes (compared to prior version)

Description or documentation Field	Change Type	Previous Version	This Version
Disk filename for attachment: SSOP-Composite Floor System Stabilization and Demolition	Changed	210505134345_SOP_Composite_Deck_Removal_kmh_rev1__1_lc.docx	220511125201_SOP_Composite_Deck_Removal_kmh_rev1__1_lc__2_.docx
Filename for attachment: SSOP-Composite Floor System Stabilization and Demolition	Changed	SOP_Composite_Deck_Removal_kmh_rev1__1_lc docx	SOP_Composite_Deck_Removal_kmh_rev1__1_lc__2_.docx
Filesize for attachment: SSOP-Composite Floor System Stabilization and Demolition	Changed	18219347	18219040

Task or Equipment	Associated Parameter	Change Type	Previous Version	This Version
Concrete and Deck Pan Demolition		Added		
Concrete and Deck Pan Demolition	Hazard	Added		Noise

Composite Floor System Stabilization and Demolition
Safe Operating Procedure

Title: NFRL Composite Floor System Stabilization and Demolition

Activity ID: 733.06.0148 **Version:** 112219i

Building & room number: Building 205; Room 125

Principle Investigator: [redacted]

Contact person(s): [redacted], GL (x 6880)

Workspace manager(s): [redacted] (x 6880), [redacted] (x2590), [redacted] (x8118)

Date: 05/11/2022

After consultation with the NFRL group leader and the workspace manager, the principle investigator (Test Director) of each activity shall provide an approved hazard review for final review by the NFRL group leader before the activity can commence.

This SOP for setting up support system (Task 1) and concrete demolition (Task 2) pertains to NIST personnel only.
If the removal of concrete debris is performed by a third-party contractor (Task 3), Group Leader of Principle Investigator must request and review a copy of the contractor's safety plan. The contractor must perform the job with the PPE listed below.

Scope and Purpose: A previous approved hazard review (Hazard Review- Composite Floor Systems Tests, ID 733.06.0124 Revision 021919i) covered a series of experiments, conducted by the National Fire Research Lab (NFRL), on a two-story, steel framed structure with steel-concrete composite floors subjected to real fire test in order to measure thermal and structural responses of composite floor assemblies subjected to combined mechanical loading and compartment fires.

This hazard review, A Composite Floor System Stabilization and Demolition, is a hazard review that covers procedure for demolition of a damaged or partially collapsed test section for removal.

Brief Summary of Procedure: A team of structural engineers, will analyze the condition of the damaged structure. Once a determination is made that the structure is safe to work on, under, and around the surrounding bays, shoring be placed inside the fire compartment. After proper support is in place, demolition of the 20 x 20-foot test section will commence.

References*:*

Commented [redacted] [redacted], I think one of us should be on site if a contractor performs the removal of concrete debris.

Composite Floor System Stabilization and Demolition
Safe Operating Procedure

Department of Homeland Security Field Guide for Building Stabilization and Shoring Techniques
733.06.0052 NFRL Overhead Cranes
733.06.0051 NFRL Scissor and Boom Lifts
733.06.0047 NFRL Industrial Powered Trucks (Forklifts and Skid loader)

Instruments/Equipment:

NIST designed shoring system
Hilti Hammer Drill
Bosch Electric Jackhammer
Hammer and Chisel
Angle Grinder
Concrete Circular Saw

PPE Required:

Steel Toe Footwear- for all tasks
Hard Hat- for all tasks
Safety Glasses with Side Shields- for all tasks
Face Shield
Dust mask
Leather or cut resistant gloves

Training Requirements:

See references for training specific to other hazard reviews.
Structure survey team members must have a structural engineering degree.
The staff member inspecting the shoring each day must be competent for that task.

COVID-19 Work Requirements
All activities in this hazard review have been assessed for the ability to comply with NIST directives to adequately reduce the potential spread of COVID-19. General Hazard Review 733.04.0164 (Requirements to Mitigate COVID-19 Exposure) describes NIST requirements along with suggestions for additional engineering and/or administrative controls, and personal protective equipment to prevent the possible spread of COVD-19.

An assessment of the work described in this hazard review determined that these activities are in the High Risk Group. The assessment determined that the minimum NIST COVID-19 precautions for high risk activities are adequate to reduce the potential spread of COVID-19.

In addition to the minimum NIST COVID-19 precautions, staff may select additional engineering and/or administrative controls, and personal protective equipment found in HR 733.04.0164 to augment, but not to degrade NIST minimum requirements.

Composite Floor System Stabilization and Demolition
Safe Operating Procedure

Hazards and Controls:

Task 1: Setting up Support System

Hazard: Struck by falling composite slab or supporting members.

- Engineering Controls
  - Beam arrest angles bolted to columns under connections.
  - Beam arrest columns.
  - Support system.
  - Two man carry

- Administrative Controls
  - No activity in compartment without support system in place.
  - Use caution tape to mark exclusion zones where access to the compartment is possible.
  - Reduce time and exposure by preassembling support system.
  - Support system

Hazard: Collapse of composite while setting up the support system

- Engineering Control
  - Begin shoring immediately upon entering the compartment and shore from the outside in or from safe to unsafe regions.

- PPE
  - Leather or cut resistant gloves

Task 2: Demolition of composite slab

Hazard: Noise

- Administrative Controls
  - Participants must wear hearing protection during sawing and jackhammering of concrete or steel decking.
- PPE
  - Ear plugs or ear muffs (mandatory)
  - Ear plugs with ear muffs (optional)

Composite Floor System Stabilization and Demolition
Safe Operating Procedure

Hazard: Collapse of composite test slab during demolition

- Engineering Controls
    - Support system
- Administrative Controls
    - No activity on damaged test slab without shoring in place below entire damaged test slab.
    - Use caution tape to mark an exclusion zone around the test slab.
- PPE
    - Leather or cut resistant gloves
    - Face Shield
    - Dust mask

Hazard: Fall from elevation during concrete demolition

- Engineering Controls
    - Shoring system platform
    - Guardrail in accordance with OSHA standard 1926.502
    - Scissor lift or boom lift
- PPE
    - Harness if other engineering controls are not available

Hazard: Concrete dust inhalation during concrete sawing

- Engineering Controls
    - Portable fans
    - Water feed
- Administrative Controls
    - Avoid exposure when not directly involved in cutting operation
- PPE
    - Face Shield
    - Dust mask

Hazard: Struck by spalling concrete during demolition

- PPE
    - Face Shield

Hazard: Struck by falling concrete during demolition

- Engineering Controls
  - Chute or concrete bucket
  - Shoring system platform

- Administrative Controls
  - No activity in compartment during demolition.
  - Use caution tape to mark off an exclusion zone.

Hazard: Struck against sharp deck pan edges

- PPE
  - Leather or cut resistant gloves

Hazard: Deck pan lifting strain

- Engineering Controls
  - Plate lifting clamps or c-clamps rigged to crane

- Administrative Controls
  - Two man carry

- PPE
  - Leather or cut resistant gloves

Hazard: Struck by falling beam

- Engineering Controls
  - Crane with rigging and forklift

- Administrative Controls
  - Consult with engineers for estimated weight of beams to ensure use of proper rigging.

Before removal of concrete debris by a third-party contractor

- Safety Officer shall ensure that the contractor uses the required PPE.
- The Project Representative shall hold a Safety Briefing and review roles and safety procedures with participants.

Set-up or Preparation:

Leave time for structure to cool and monitor its behavior. Engineers and technicians perform a structure survey to identify condition of beams, columns, connections, deck pans, reinforcement, and concrete. Inspect beam arrest angles for damage, where applicable. Identify residual strength of structure. Identify load paths should a failure occur. Identify sequence of demolition if demolition of a particular region will affect the stability of the structure.

Forensic Investigation:

The investigation team may only consist of structural engineers. Keep the number of team members as small as possible. All others must remain outside the perimeter of the structure until the team has determined the structure is safe to approach. The inspection must be performed outside of the compartment. The team must wear hard hat, steel toe footwear, and safety glasses with side shields. The team must be under active supervision of a workspace manager and/or group leader during the investigation.

Figure 1-Top View of Damaged Test Section

Figure 2-Bottom View of Damaged Test Section (Location of Shoring Installation)

General Procedure:

Shoring

Repairing or restraining a damaged section (i.e. casting concrete supports, welding plates across a damaged joint) to strengthen or support the structure should be considered as an alternative to a spot shore. No activity in compartment or on damaged test bay without shoring. No activity on deck during shoring operations. Shoring should be preassembled as much as possible to reduce time in compartment and avoid exposure to hazards. Begin shoring immediately upon entering the compartment and shore from the outside in or from safe to unsafe regions. Shoring should also be placed outside the test bay where an undamaged supporting member ties into a damaged supporting member. If a connection is broken shoring should begin in the direction of the broken connection and a spot shore or other support must be placed beneath it until the floor system is completely shored. If a connection should fail during shoring exit the compartment and assemble the team to reassess and identify potential new hazards. Shoring should be able to withstand the weight of the test section of the structure. A team of structural, mechanical, or civil engineers at NIST or by a shoring company will recommend a design for support shoring. The recommended design must be reviewed and approved by the workspace manager, principal investigator, and group leader. The final constructed shoring plan shall be inspected by a structural engineer. Shoring should be equipped with platforms to catch falling debris and support workers where the floor has been removed. The shoring system design will be constructed using the Department of Homeland Security Field Guide for Building Stabilization and Shoring Techniques.

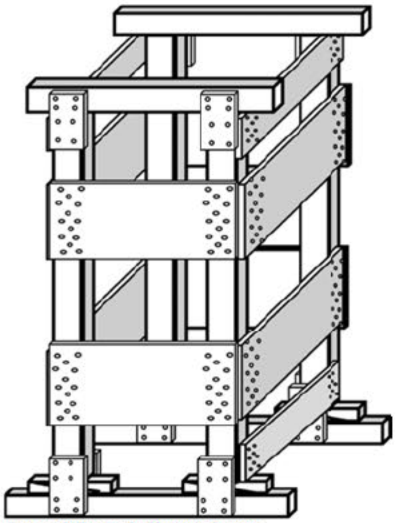


Figure 3-Example Shoring System

Structural Performance

Design Load 4 x 4 posts: 32,000 lb
Design Load 6 x 6 posts: 80,000 lb
Safety Factors: 2 to 1 (Minimum)
Failure Mechanism: Buckling of posts
Material Compatibility: Intact, solid Surfaces
Tested and Documented: Yes
Safe Haven: Yes

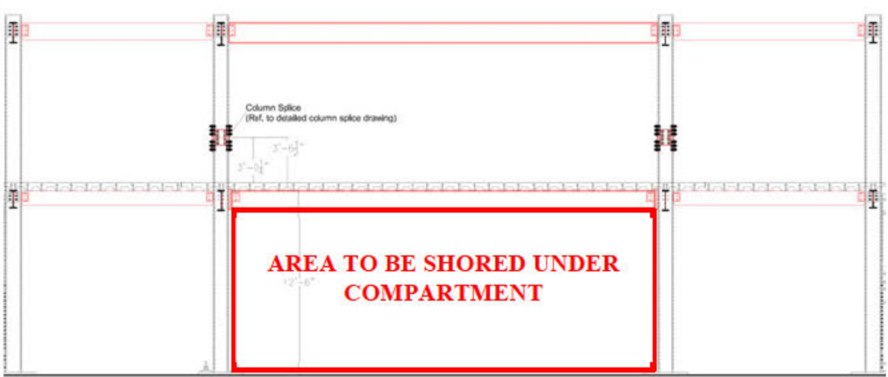


Figure 4-View of Shoring Area (Elevation View from South Looking North)

Composite Floor System Stabilization and Demolition
Safe Operating Procedure

Demolition

No activity in compartment during demolition operation. Saw cut around a region to be removed and where forensic investigation will occur. Remove concrete using a combination of jackhammer, hammer drill, or hammer and chisel. Move debris to a dumpster using a chute or by lowering with buckets. Remove deck pans using plate lifting clamps or c-clamps as lifting points with straps and crane. Remove two second story beams directly above test bay. Estimate beam weights. Select proper rigging. Strap damaged beams one at a time. Connect rigging to crane. Apply enough tension to support the weight of the beam. Remove connection bolts to free beam from structure. Relocate beams to outside storage area using forklift.

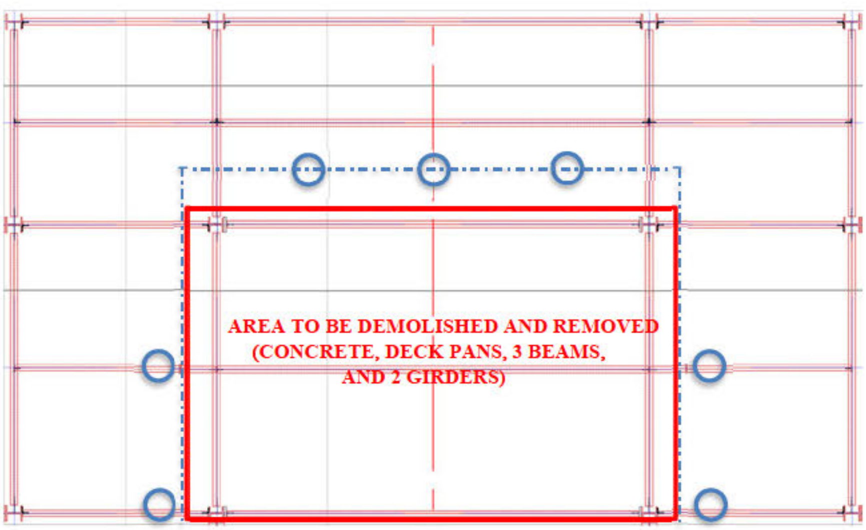


Figure 5-View of Demolition Area (Top Plan View-Circles Indicate Location of Existing Shores; Dashed Line Indicates Splice)

Shut-down/Clean-up Procedure: When stopping work for the day inspect the area to ensure tools are unplugged and secured from falling. Ensure there is no loose debris that could fall.

Plans for Out of Hours Operation: Out of hours work is prohibited.

Emergency Response Plan for Composite Floor System Stabilization and Demolition

Building and Room Number: Building 205/ Room 125

Contact person: [redacted]

Workspace manager: [redacted]

1) Emergency shutdown procedures.
   - Secure loose equipment, tools, and debris
   - Evacuate demolition area
2) Structural collapse
   - Follow emergency shutdown procedures
   - Evacuate structure
   - Mark off an exclusion zone around structure
   - Gather the structure survey team to re-assess and identify new hazards
3) In the event of a power failure:
   - Follow emergency shutdown procedures
4) Cuts, abrasions, or Injury:
   - Follow emergency shutdown procedures.
   - If minor; seek medical attention from the NIST Health Unit.
   - Notify supervisor of injury.
   - If catastrophic; call Emergency Services at 2222.
5) In the event of a weather emergency, building evacuation, natural gas leak, or other type of emergency:
   - Follow emergency shutdown procedures.
   - Follow evacuation instructions provided by NIST Emergency Response or Building Staff.
6) Shelter in Place
   - Follow emergency shutdown procedures.
   - Proceed to Shelter in Place gathering area
7) COVID Exposure
   1. If a staff member is alerted to the possibility that they have been exposed to COVID, they must report the possible exposure to their supervisor immediately. They must begin a 14-day period of self-isolation.
   2. If a staff member develops COVID or COVID like symptoms, the must report those symptoms to their supervisor immediately. Staff exhibiting the symptoms should seek medical attention to address symptoms.
   3. Disinfection of the site and equipment should be initiated. Equipment may also be secured and isolated for minimum of 72 hours.

Appendix 6.3.4: *Coring and Cutting Plan* - Email and Diagram

From: [redacted]
To: [redacted]
Subject: FW: Coring and Cutting Plan
Date: Thursday, October 13, 2022 8:35:47 AM
Attachments: Coring and Cutting Plan.pdf

[redacted]
National Fire Research Lab
Cell: [redacted]

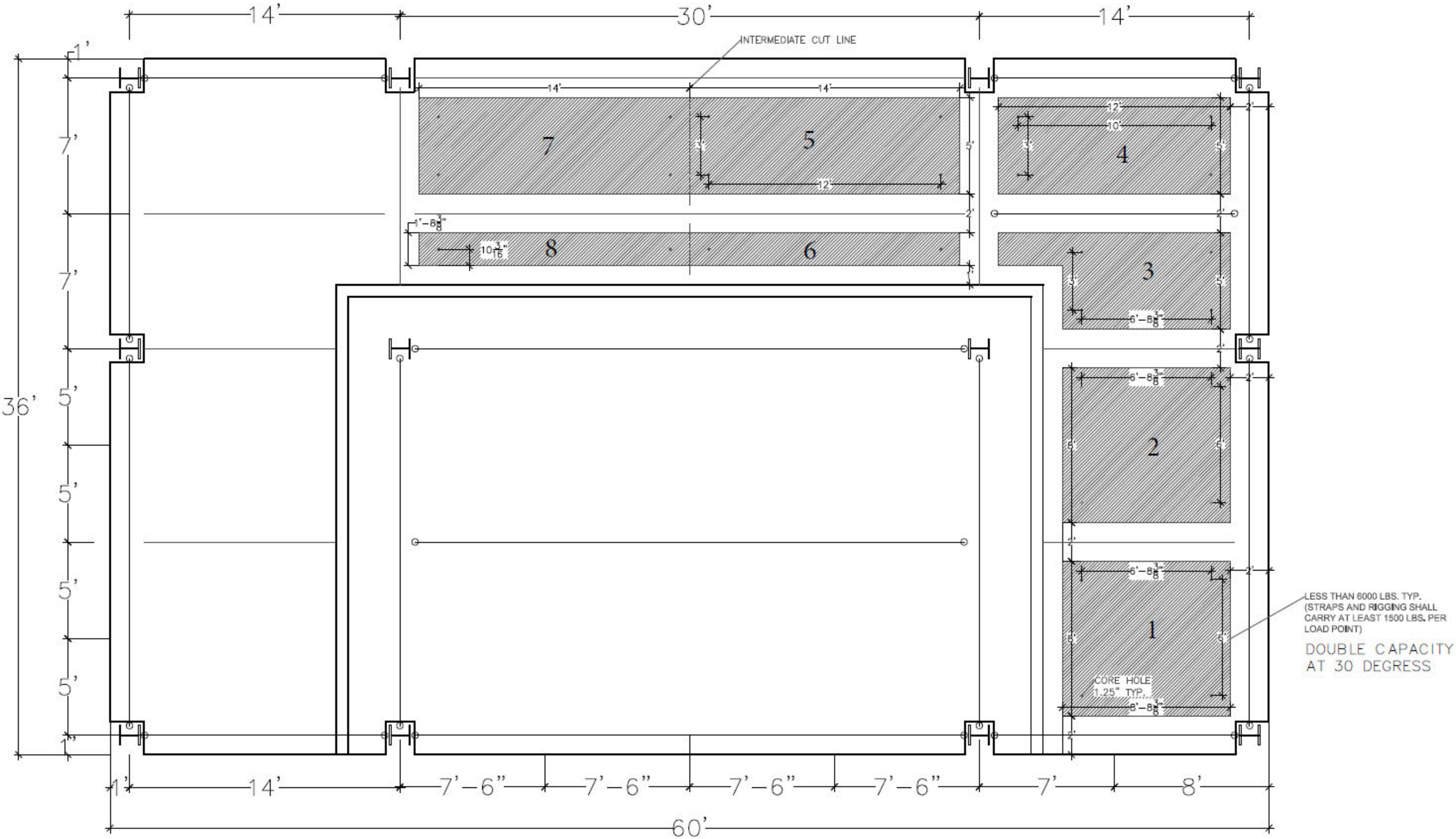
From: [redacted]
Sent: Tuesday, August 23, 2022 1:50 PM
To: [redacted]
Subject: Coring and Cutting Plan

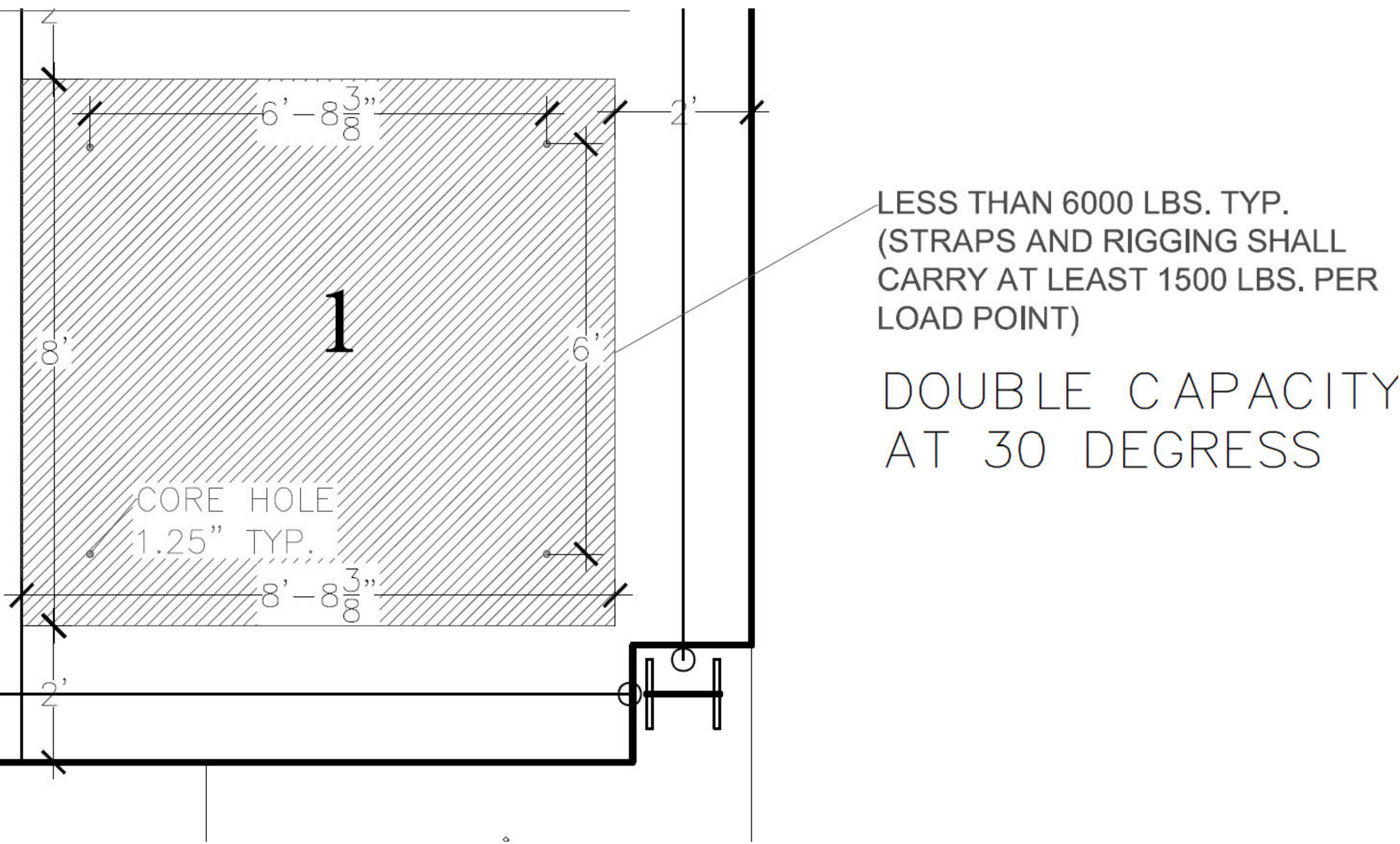
Yo,

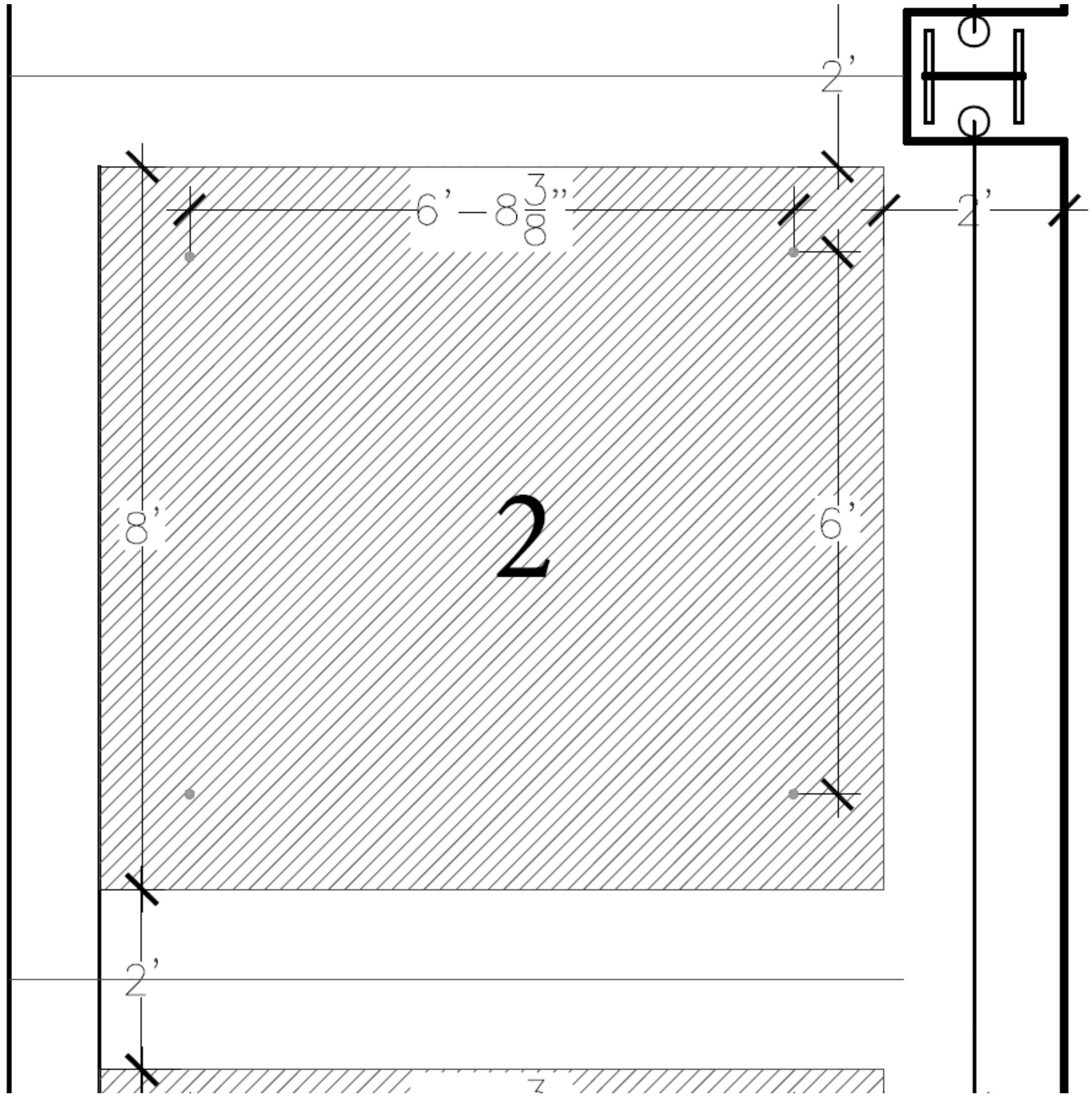
I'm sure you are helping [redacted] this week but if not take a look at the attached. If you feel like it you can start laying this out because it's a relatively easy job. Let me know if you have any suggestions or there is a missing dimension. The core hole locations don't have to be perfect as long as they are symmetric and are not spaced further apart than they are in the drawing (that is the max dimension). I know they all won't fit in the dumpster this way but this minimizes the amount of cuts in the air. The west is a mirror of the east.

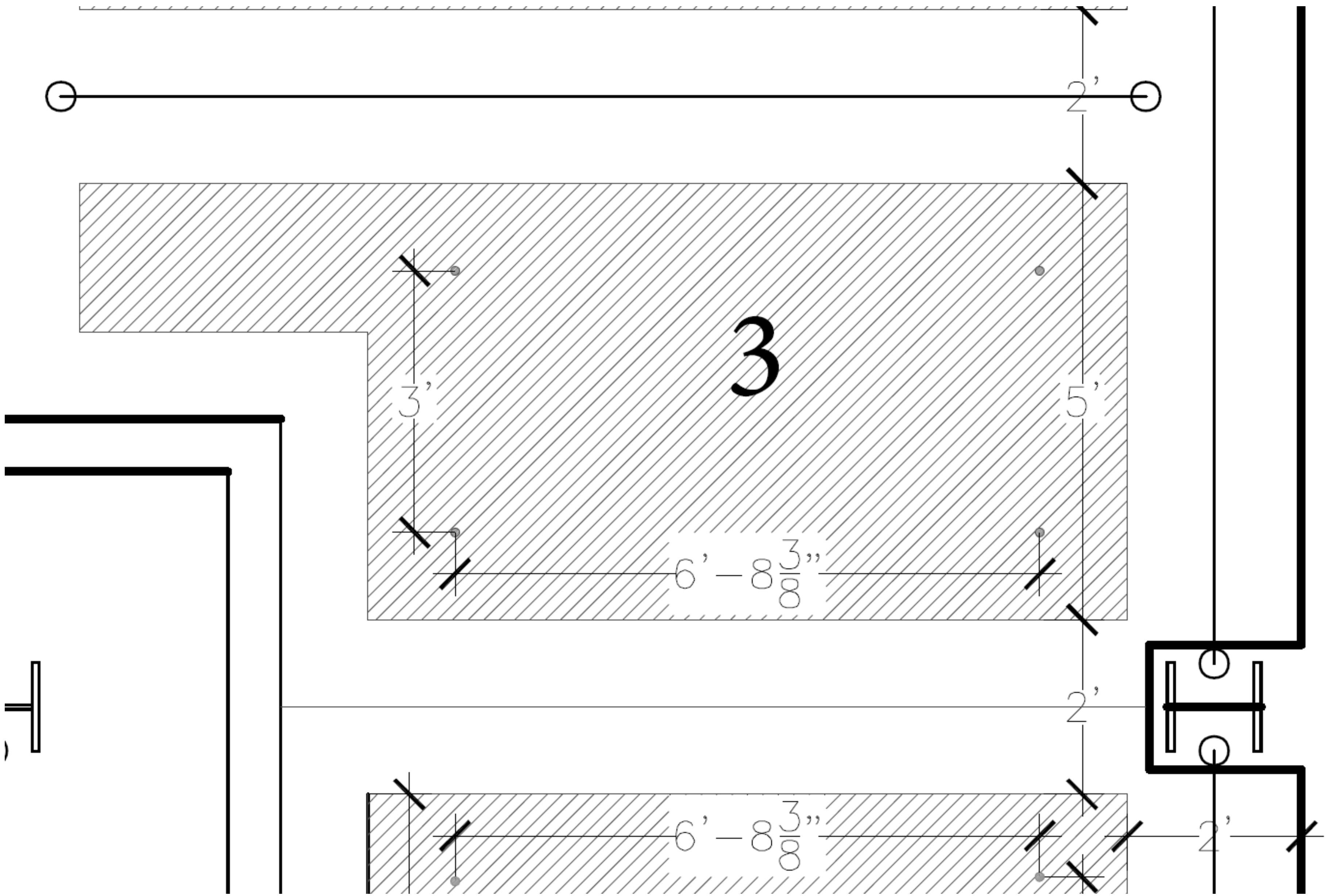
Best Regards,

[redacted], Engineering Technician
National Fire Research Laboratory (NFRL)
National Institute of Standards and Technology
100 Bureau Drive, Stop 8666, Building 205
Gaithersburg, MD 20899-8666
Office: [redacted]
Cell: [redacted]
Lab: [redacted]
Fax: [redacted]
E-mail: [redacted]

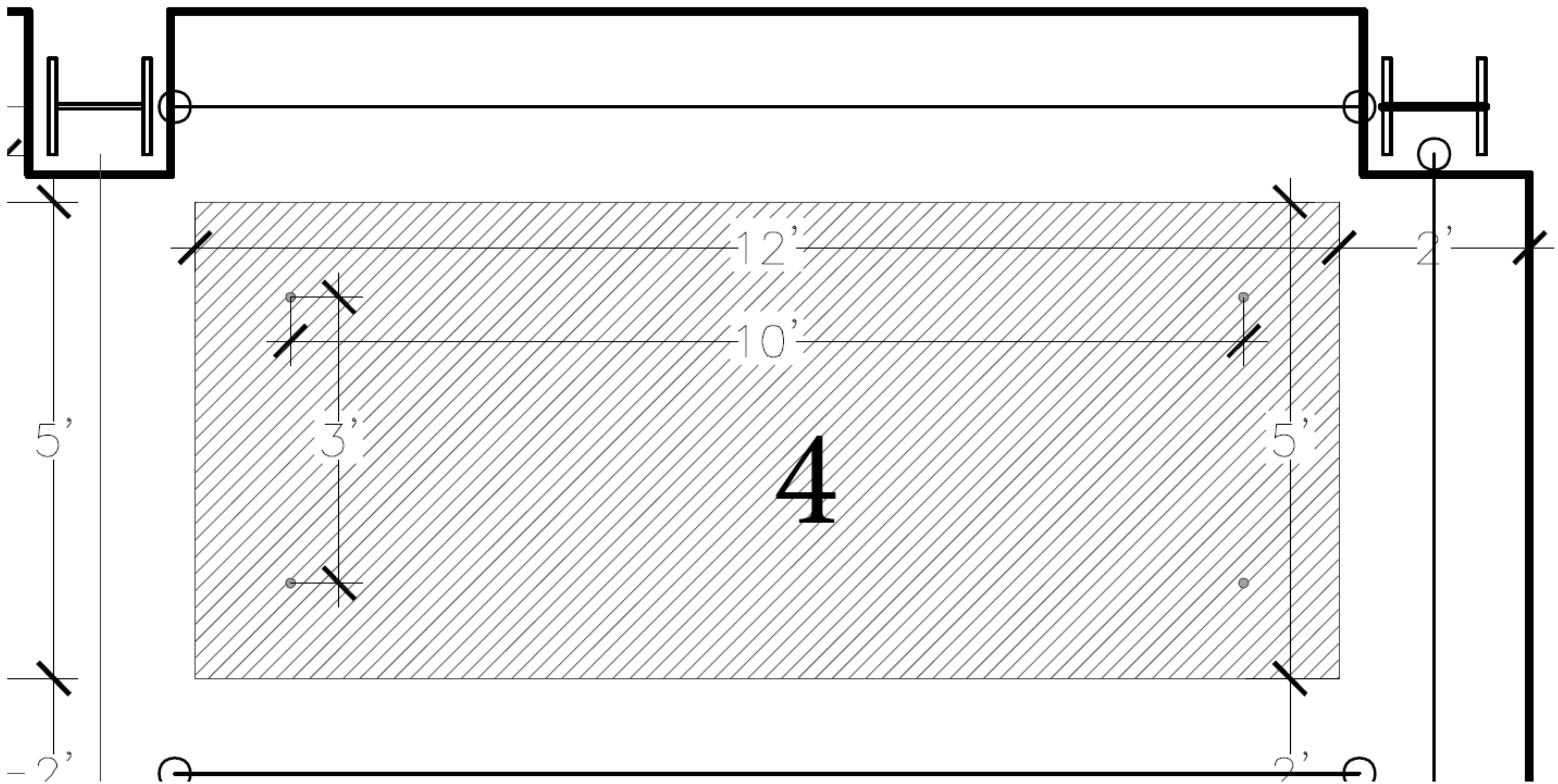

14'
30'
14'
INTERMEDIATE CUT LINE
36'
60'
7'
5'
7'-6"
8'
1
2
3
4
5
6
7
8
CORE HOLE 1.25" TYP.
LESS THAN 6000 LBS. TYP. (STRAPS AND RIGGING SHALL CARRY AT LEAST 1500 LBS. PER LOAD POINT)
DOUBLE CAPACITY AT 30 DEGRESS

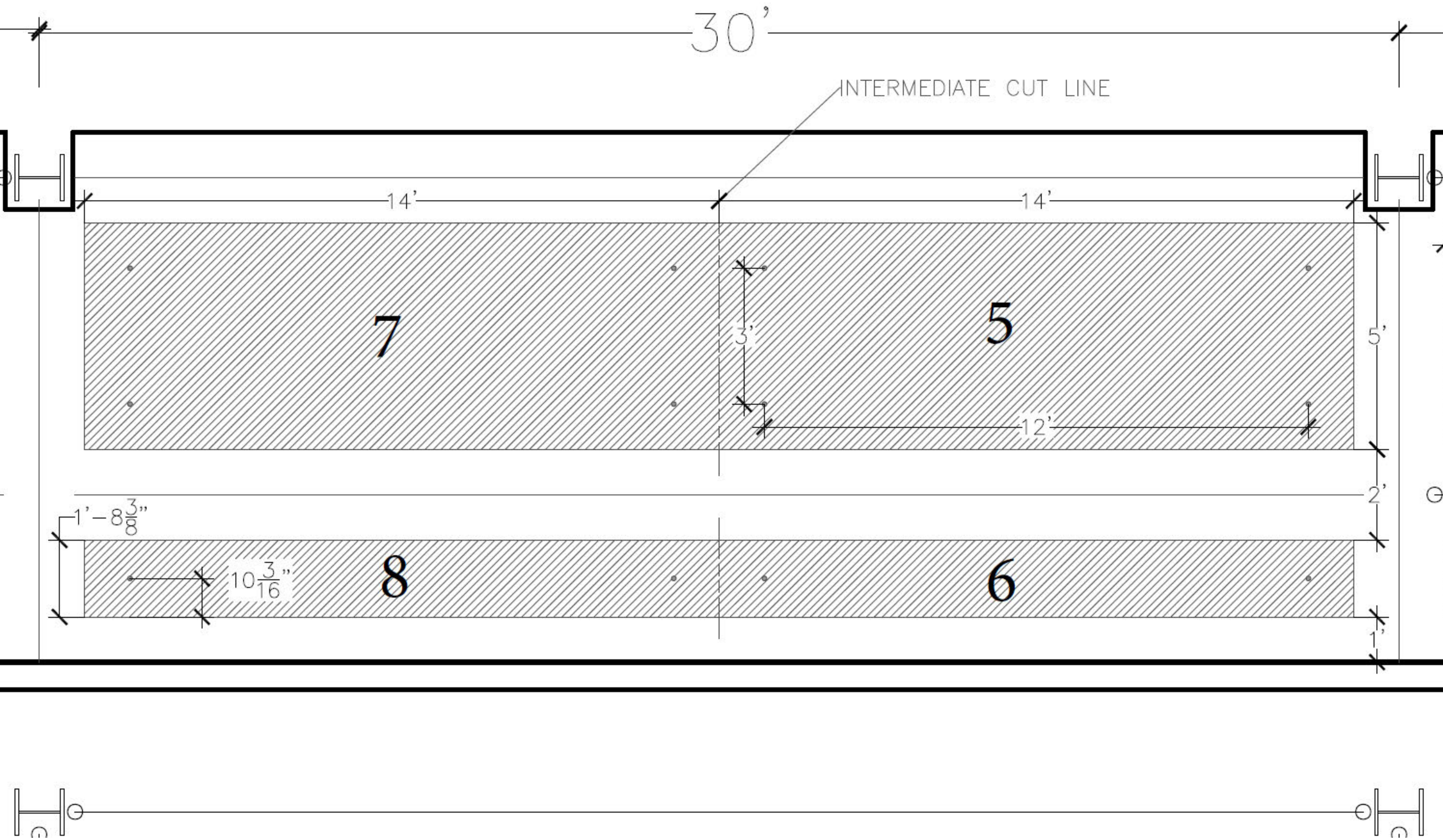

6'-8 3/8"
2'
1
8'
6'
CORE HOLE
1.25" TYP.
8'-8 3/8"
2'
LESS THAN 6000 LBS. TYP.
(STRAPS AND RIGGING SHALL
CARRY AT LEAST 1500 LBS. PER
LOAD POINT)
DOUBLE CAPACITY
AT 30 DEGRESS


2'
6'-8 3/8"
2'
8'
2
6'
2'



2'
3
3'
5'
6'-8 3/8"
2'
6'-8 3/8"
2'


12'
2'
10'
5'
3'
4
5'
2'
2'


30'
INTERMEDIATE CUT LINE
14'
14'
7
5
3'
5'
12'
2'
1'-8 3/8"
10 3/16"
8
6
1'

Appendix 6.3.5: *NFRL Overhead Cranes* Hazard Review (#733.06.0052) and All Associated Documents approved on 05/23/22

View Activity

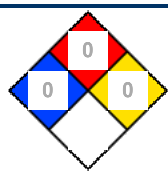
733 06 0052 052322 NFRL Overhead Cranes (Approved)

Contacts	**Principal Investigator**	[redacted]		
	Division	Fire Research Division	**Division Chie**	[redacted]
	Group	National Fire Research Laboratory	**Group Leader**	[redacted]

Activity description: NFRL has eight cranes located throughout Bldg 205 and scrubber bag houses used for heavy lifting The cranes are used for loading and unloading materials construction and moving pit covers for the conditioning pit This hazard review is for general purpose crane operation and does not cover specific hoisting or rigging that may require additional hazard review

Parameters: **Activity Frequency** Indefinite Use **Times Repeated**

Hazards



Required PPE

Safety Glasses with side shields Head Protection (Hard Hat) Foot Protection (Safety toed shoes or boots)

Storage requirements: None specified

Locations (Contact): [redacted]

Authorized Users

User Name	Authorized By	Authorization Date	Approved or Out o Hours Work By	Out o Hours Approval Date
[redacted]	[redacted] -- Revoke Authorization	May 23, 2022	No Approval Required	--
[redacted]	[redacted] Revoke Authorization	May 23 2022	No Approval Required	
[redacted]	[redacted] -- Revoke Authorization	May 23, 2022	No Approval Required	--
[redacted]	[redacted] Revoke Authorization	May 23 2022	No Approval Required	
[redacted]	[redacted] -- Revoke Authorization	May 31, 2022	No Approval Required	--
[redacted]	[redacted] Revoke Authorization	May 23 2022	No Approval Required	

Required Training: Crane Training (CLC Overhead Crane & Slings EL 733 NFRL Overhead Crane Operation CLC Indoor Hoisting and Rigging) Crane Training (CLC Overhead Crane & Slings EL 733 NFRL Overhead Crane Operation CLC Indoor Hoisting and Rigging)

Incident/Emergency Response Plan Location: I/ERP

Expiration Date: May 23, 2025 Set earlier expiration date (1 week from today)

History: **Created** [redacted] 2022-05-23 12:46:37 -0400 **Updated** [redacted] 2022-05-23 13 27:57 -0400

Reviews: **Review Level** Group Leader

Related Documentation

Title	Filename	Attachment Type	Description
I/ERP	NFRLCranesEmergencyPlan docx	Incident/Emergency Response Plan	
Crane and Sling Operator Manual	CraneandSlingOperatorTraining.pdf	Other	
Crane Daily Checklist	Crane Safety Daily Check Sheet pdf	Other	
Overhead Crane Safety	OverheadCraneSafety.pdf	Other	
Overhead Crane SOP	CraneSOP docx	Standard Operating Procedure	
Addendum to Overhead Crane SOP	Addendum_to_Overhead_Crane_SOP.docx	Standard Operating Procedure	

Approval/Review History

Activity	tatus	Review level	Reviewing O icial	Modi ied
733 06 0052 NFRL Overhead Cranes	Review Completed	Group Leader	[redacted]	[redacted] 2022 05 23 13 27 57 0400

Tasks/Equipment

Crane (Tasks/Equipment)

Signage Required N/A

Required Controls

Alarms (When cranes in room 125 are powered up, When cranes in room 125 are powered on), **Buddy System**, **Operating Procedures**, **Safe Practices**, **Crane Training** (CLC-Overhead Crane & Slings, EL-733: NFRL Overhead Crane Operation, CLC-Indoor Hoisting and Rigging, CLC Overhead Crane & Slings, EL-733: NFRL Overhead Crane Operation, CLC-Indoor Hoisting and Rigging), **Foot Protection** (Safety toed shoes or boots), **Head Protection** (Hard Hat), **Safety Glasses with side shields**

Hazard	tage	everity	Controlled Likelihood	Controlled RHI
Struck Against	Normal Operations	Severe	Remote	2 Medium
Struck By (Mass Acceleration)	Normal Operations	Severe	Remote	2 - Medium

Version History

Initial Version 733 06 0052 062717i

Previous Version (2 of 3) 733 06 0052 082917

Type o Change and Resulting Level o Review or this Version

Change Type Minor change(s) see table below for detailed list of changes
Review and final approval by first level Supervisor regardless of activity RHI value

Primary reasons or this change type
- Any changes to the activity result in the classification of the changes as minor

Detailed list o changes (compared to prior version)

Description or documentation Field	Change Type	Previous Version	This Version
Attachment: Addendum to Overhead Crane SOP	Added		

Previous Version (3 of 3) 733 06 0052 080620

Type o Change and Resulting Level o Review or this Version

Change Type Minor change(s) see table below for detailed list of changes
Review and final approval by first level Supervisor regardless of activity RHI value

Primary reasons or this change type
- Any changes to the activity result in the classification of the changes as minor

Detailed list o changes (compared to prior version)

Description or documentation Field	Change Type	Previous Version	This Version
Disk filename for attachment: Overhead Crane SOP	Changed	170707142850_CraneSOP.docx	200806131832_CraneSOP_COVID.docx
Filename for attachment Overhead Crane SOP	Changed	CraneSOP docx	CraneSOP COVID docx
Filesize for attachment: Overhead Crane SOP	Changed	806234	807275
Updated by for attachment Overhead Crane SOP	Changed	[redacted]	[redacted]

This Version: 733.06.0052.052322

Type of Change and Resulting Level of Review for this Version

Change Type Minor change(s); see table below for detailed list of changes.
Review and final approval by first-level Supervisor, regardless of activity RHI value.

Primary reasons for this change type
- Any changes to the activity result in the classification of the changes as minor

Detailed list of changes (compared to prior version)

Description or documentation Field	Change Type	Previous Version	This Version
Disk filename for attachment Addendum to Overhead Crane SOP	Changed	170829115609_Addendum_to_Overhead_Crane_SOP.pdf	220523125321_Addendum_to_Overhead_Crane_SOP.docx
Filename for attachment: Addendum to Overhead Crane SOP	Changed	Addendum to Overhead Crane SOP pdf	Addendum to Overhead Crane SOP docx
Filesize for attachment Addendum to Overhead Crane SOP	Changed	59161	17279
Mime type for attachment: Addendum to Overhead Crane SOP	Changed	application/pdf	application/vnd openxmlformats-officedocument.wordprocessingml.document
Disk filename for attachment Overhead Crane SOP	Changed	200806131832 CraneSOP COV D docx	220523124952 CraneSOP docx
Filename for attachment: Overhead Crane SOP	Changed	CraneSOP_COVID.docx	CraneSOP docx
Filesize for attachment Overhead Crane SOP	Changed	807275	24400
Attachment: Overhead Cranes and Slings at NFRL	Removed		
205/117 for rooms	Removed	205/117	

Overhead Cranes
Standard Operating Procedure (SOP)

Title: NFRL Overhead Cranes

Activity ID#: 733.06.0052

Building & room number: Bldg. 205; Rms 125, 113, and baghouses

Principle Investigator: [redacted]

Workspace manager(s): [redacted]

After consultation with the NFRL group leader and the workspace manager, the principle investigator (Test director) of each activity shall provide an approved hazard review for final review by the NFRL group leader before the activity can commence.

This SOP pertains to NIST personnel only.

Purpose and Scope:

The NFRL has eight cranes located throughout Bldg. 205 and scrubber bag houses used for heavy lifting. The cranes are used for loading and unloading materials, construction, and moving pit covers for the conditioning pit. This hazard review is for general purpose crane operation and does not cover specific hoisting or rigging.

Equipment Description:

1. One ten ton crane is located in west side of the Fire Test Bay (room 113) and only traverses from north to south on a fixed rail. This crane is mainly used for unloading heavy equipment and materials off vehicles that have come in through the roll-up door on the west side of the building. The electrical disconnect box is located on the west wall of 113 to the left of the roll-up door.
2. Out of Service - A second ten ton crane is typically parked in room 117 but is capable of traversing via rail into room 113, 121 and out onto the loading dock. The large bifold doors to these rooms must be opened adequately and the area cleared before any loads are moved into or out of the building. The electrical disconnect box for this crane is located on the west wall of 113 to the left of the exit door.
3. Two 20 ton cranes are located in the Structure Fire Test By (room 125). These cranes can be operated individually or simultaneously. Extreme caution must be used when both cranes are operating together for one lift or simultaneously for two lifts. Electrical disconnects for these cranes are located on the east wall of 125 and also on the north wall
4. Two two-ton cranes are located, one in each ECS bag house for lifting the hopper lids for maintenance access. . The electrical disconnect for the older bag house is located inside the bag house door to the left. The disconnect for the newest bag house is located inside the bag house door in the southeast corner.
5. Two half ton jib cranes are located, one outside each ECS bag house for lifting materials and equipment up to the work area. To use this crane, there is a removable rail to facilitate loads being placed at that level. A safety harness tied off must be worn when doing this type of work. The electrical disconnect for these cranes are just behind the crane.

Overhead Cranes
Standard Operating Procedure (SOP)

Note: This SSOP makes references to generic type crane lifts, routine type lifts with no special rigging. Any project that requires unique lifts using special rigging and fixtures or two cranes operating simultaneously for the same lift will have a project FLHR detailing these lifts.

PPE Required:

Personal protective equipment (PPE) in the normal operating procedures of the National Fire Research Laboratory is required:

- Closed toed shoes
- Hard hat
- Safety glasses

Training Requirements:

In addition to NIST & EL **mandatory** safety courses, all test participants must complete/review:

- Any associated NIST suborders.
- All related documentation posted in the MML hazard review.
- CLC-Overhead Crane & Slings, EL-733: NFRL Overhead Crane Operation
- CLC-Indoor Hoisting and Rigging
- CLC Overhead Crane & Slings
- EL-733: NFRL Overhead Crane Operation
- CLC-Indoor Hoisting and Rigging

Suggested Reading Material:

- IRIS reports from previous incidents
- Addendums attached to MML hazard review
- OSHA 29 CFR 1910.179
- ANSI B30.16 Overhead hoists
- ANSI B30.2 Overhead and Gantry Cranes
- ANSI B30.9 Slings
- ANSI B30.26 Rigging Hardware
- ANSI B30.10 Hooks
- The ANSI standards are available through the NIST Library.

Overhead Cranes
Standard Operating Procedure (SOP)

COVID-19 Work Requirements

All activities in this hazard review have been assessed for the ability to comply with NIST directives to adequately reduce the potential spread of COVID-19. General Hazard Review 733.04.0164 (Requirements to Mitigate COVID-19 Exposure) describes NIST requirements along with suggestions for additional engineering and/or administrative controls, and personal protective equipment to prevent the possible spread of COVD-19.

An assessment of the work described in this hazard review determined that these activities are in the Low Risk Group. The assessment determined that the minimum NIST COVID-19 precautions for low risk activities are adequate to reduce the potential spread of COVID-19.

Safety Requirements and Precautions:

- Load must be within crane capacity.
- Hoist chain/rope free from kinks/twists and not wrapped around load.
- Multiple part lines, if used, are not twisted around each other.
- Bring hook over load to prevent swinging.
- At the beginning of each shift, test the upper limit switch of each hoist under no load, while inching the block.
- Do not use the limit switch as an operating control.
- Load attached to load block hook by slings or other approved devices.
- Pad sharp edges to protect slings.
- Make certain sling clears all obstacles.
- Load shall be well secured and properly balanced.
- In sling or other lifting device before lifted more than a few inches.
- Do not use side pulls under any circumstance.
- Avoid shock loading – move load without sudden acceleration or deceleration.
- Move load without hitting obstructions.
- There is no hoisting, lowering, or traveling while personnel are attaching or detaching rigging.
- Do not carry loads over people.
- Do not hang from or ride the crane hook, attached load, or attached rigging.
- Test brakes each time a load approaches the rated load of the crane.
- Do not lower load below the point where two wraps of rope remain on the hoisting drum.
- When two cranes are involved, one qualified person shall be in charge.
- Operator shall not leave the area where they have line of sight to a suspended load.
- When starting the bridge, and when hook or load approaches near or over people, the warning signal shall be sounded.

Addendum to Overhead Crane SOP – 8/29/2017

a. The operator will determine if the lift is routine, complex, or critical and develop a lift plan as needed. The lifting team will discuss any changes to the original lift plan before execution.
b. Use a spotter(s) to assist the crane operator during complex or critical lifts and moves; use additional spotters when necessary. Use clear and recognizable hand signals. Ensure audible communications when visibility is reduced due to obstacles.
c. Plan the connect/disconnect procedures for structural members; plan the lift path and the path of travel; review and discuss the plan (operator and spotter(s)) prior to execution.
d. Inform everyone in the area that crane operations will occur.
e. Establish a no-entry zone around all crane operations. Only the crane operator and spotters are allowed inside this zone. Evacuate personnel from the open pit areas in the basement if these areas are within the no-entry zone. The no-entry zone should be at least 10 ft. from the load. Large loads and complex lifts will require a larger zone. The no-entry zone will be determined during the lifting plan and will be enforced by the operator and spotters.
f. Keep all structural members anchored/secured while not in translation.

Addendum to Overhead Crane SOP – 5/9/2022

Site specific obstructions to avoid – contact workspace manager before operating in these areas

a. Heat shields
    - Angled heat shields are located at the top of the north and south walls of the test bay. The hook block can come in contact with these shields. Operators should use the heat shields located at the floor level as a boundary line. If the operator must operate beyond this boundary line, they must consult the workspace manager.

b. Hood Curtains
    - The 15m hood curtain upper limits can be tripped before the curtain has reached its upper limit. The crane can come in contact with the curtains if they have not been lifted properly. Consult the workspace manager to ensure the last user to lift the curtains ensured proper curtain elevation.

c. Crane to Crane Contact
    - There is an electrical box located at the north end of the east crane and a piece of Unistrut that sticks out in the east direction on the west crane. These items can come in contact if the trolley of the west crane is positioned all the way north and the crane bumpers are touching. Contact the workspace manager if you must operate cranes in close proximity.

NFRL Overhead Cranes

Incident/Emergency Response Plan

In the event of an emergency where personnel are injured, call x2222 immediately. Assist anyone injured if possible, notify supervisor immediately. In the event of a power failure during a lift, the trolley is designed to drift to a stop to prevent excessive swinging of the load and the cable brake will activate. Personnel must leave the area with the load suspended and rope off the area if safe to do so. All lifts are to be carried out with the least amount of load height possible. If the load does happen to shift or break loose during the operators' absence, the situation will be dealt with upon power being restored.

INDUSTRIAL SAFETY TRAINERS inc.

DAILY PRE-USE INSPECTION FOR CRANES.

ENSURE THAT THE FOLLOWING ITEMS ARE CHECKED BEFORE USING CRANES. REGISTER YOUR INSPECTION BELOW.

NOTE: EACH OPERATOR USING CRANE MUST PERFORM A PRE-USE INSPECTION

Crane____________ **Capacity:** ______________________ **Location:** ______________________________

CAUTION: Operators are responsible for ensuring that the crane is in proper operating condition and to report any defects to their supervisor. IF NECESSARY – LOCK OUT EQUIPMENT TO PREVENT ACCIDENTAL USE

PRE-OPERATIONAL CHECKS	OK	NOT OK	PRE-OPERATIONAL CHECKS	OK	NOT OK
Test run unit, Check Operation of:	☐	☐	**Chains**: excessive Wear, Twist and Stretch	☐	☐
Emergency Stop	☐	☐	**Rope**: Crushing, Kinking and Broken Wires	☐	☐
Pendant or Joystick	☐	☐	Check Load Attachments	☐	☐
Correct Direction	☐	☐	Capacity Rating	☐	☐
Brakes of all Motions	☐	☐	End Connectors	☐	☐
Check Load Hook for Wear and Cracks	☐	☐	**Chains**: excessive Wear, Twist and Stretch	☐	☐
Saddle Wear	☐	☐	**Rope**: Crushing, Kinking and Broken Wires	☐	☐
Twist	☐	☐	Check Upper Limit with No Load	☐	☐
Throat	☐	☐	Listen for Unusual Noises	☐	☐
Safety Latch	☐	☐	Look at the Crane While in Operation For:	☐	☐
Check Hoist Ropes or Chains	☐	☐	Crabbing	☐	☐
End connections	☐	☐	Jerky Movements	☐	☐
			OTHER	☐	☐

DATE	TIME	OPERATORS SIGNATURE	COMMENTS

To be completed by designated operators and when form is completed IT MUST be forwarded to your Shift Supervisor.

Overhead Crane Safety and Inspection Requirements

Notice

- It is the responsibility of the Owner/User to install, inspect, test, maintain, and operate a crane or associated lifting equipment in accordance with the applicable volume of the ANSI/ASME B30 Safety Standard, OSHA Regulations, and ANSI-NFPA 70, National Electric Code and local regulations and laws. If the crane or associated ifting equipments is installed as part of a total lifting system, it is also the responsibility of the owner/user to comply with the applicable ANSI/ASME B30 volumes that address other types of equipment used in the system.

  Further, it is a responsibi ity of the Owner/User to require all personnel who install, inspect, test, maintain, and operate a crane or associated lifting equipment to read and to comply with the contents of the instruction manuals furnished by the manufacturer of the crane or associated lifting equipment, and the applicable portions of the volume of the ANSI/ASME B30 Safety Standard, OSHA Regulations, and the ANSI/NFPA 70, National Electric Code. If the crane or associated lifting equipment is installed as part of a total lifting system, the applicable ANSI/ASME B30 volumes that address other types of equipment used in the systems must also be read and followed by a l personnel.

Daily Operator Inspection Requirements

- Tagged Crane or Hoist
- Control Devices
- Brakes
- Hook
- Hook Latch
- Reeving
- Limit Switches
- Oil Leakage
- Unusual Sounds

Daily Operator Inspection Reuirements

- Tagged Crane or Hoist
  - Check that the crane or hoist is not tagged with an out-of-order sign.

Daily Operator Inspection Requirements

- Control Devices
  - Check that all motions agree with control device markings e.g., Up/Down/Fwd/Rev.

Daily Operator Inspection Requirements

- Brakes (Travel)
  - Check that all motions do not have excessive drift and that stopping distances are normal (approx. 10% of high speed travel.
- **Hoist Brakes**
  - **No drift permitted**.

Daily Operator Inspection Requirements

- Hook
  - Check for damage, cracks, nicks, gouges, deformity of the throat opening, wear on saddle or load bearing point, and twist. Refer to the manual furnished by the original manufacturer of the crane or hoist.

Daily Operator Inspection Requirements

- Hook Latch
  - Check that hook latch, if provided, is not missing and that it operates properly.

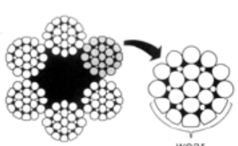
Daily Operator Inspection Requirements

- **Wire Rope**
  - **Broken Wires**
  - **Excessive Wear**
  - **Kinks**
  - **Crushing**
  - **Stretching**
  - **Birdcaging**
  - **Rope Measurement**

Wire Rope Inspection – Broken Wires

- 10 wires in one rope lay
- 5 wires in one strand in one rope lay

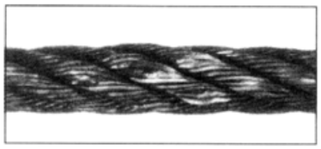
Wire Rope Inspection – Excessive Wear



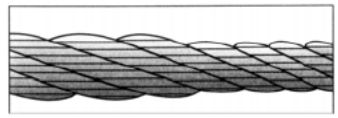
- Loss of 1/3 of the rope diameter of individual wires.

Wire Rope Inspection – Kinks

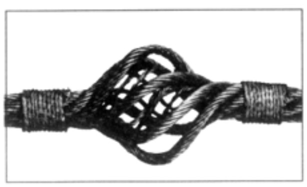
Wire Rope Inspection – Crushing



Wire Rope Inspection – Stretching

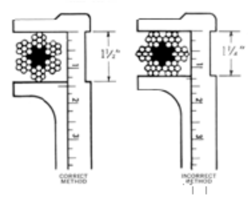


Wire Rope Inspection – Birdcaging



Wire Rope Inspection – How to Measure

- The components of a wire rope each have a small but definite size tolerance. Therefore, the rope itself must have a diameter at least equal to the nominal, or catalog, size – **never smaller**.



Wire Rope Inspection

- Replace any wire rope or red tag if you observe any of these conditions!

Daily Operator Inspection Requirements

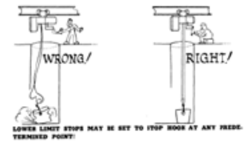
- Load Chain
  - Check load chain, including end connections for excessive wear, twist, distorted links or stretch, beyond the manufacturer's recommendations.

Daily Operator Inspection Requirements

- Reeving
  - Check that the wire rope or load chain is properly reeved and that rope or load chain parts are not twisted about each other. Make sure wire rope is properly seated in drum grooves.

Daily Operator Inspection Requirements

- **Limit Switches**
  - **Check that the upper limit device stops lifting motions of the hoist load block before striking any part of the hoist or crane.**
  - **Caution exercise extreme care during this test to avoid striking any part of the hoist or trolley with the hoist load block or lift beam in the event of a faulty limit switch.**



Daily Operator Inspection Requirements

- Oil Leakage
  - Check for any sign of oil leakage on the crane and on the floor area beneath the crane.

Daily Operator Inspection Requirements

- Unusual Sounds
  - Check for any unusual sounds such as
    - S ,uealing
    - Grinding
    - Unusual vibration
  - from the crane or hoist mechanism while operating the crane and hoist.

Daily Operator Inspection Requirements

- Warning and Safety Labels and Warning Devices
  - Check that warning and other safety labels are not missing and that they are legible. Check that audible and visual warning devices are operational.

Periodic Inspection

- A Periodic Inspection is a detailed visual and operational inspection whereby individual components are examined to determine their condition. The Periodic Inspection is performed as often as quarterly based on service, environmental and application factors as determined by a qualified person or as outline in the following table.

Periodic Inspection Chart
(as required by OSHA)

ASME B30.2 Service Class	Number of Shifts Operated per Day		
	1 Shift	2 Shifts	3 Shifts
	Frequency of Inspection		
Normal	ANNUAL	ANNUAL	ANNUAL
Heavy	ANNUAL	SEMI-ANNUAL TO ANNUAL	SEMI-ANNUAL
Severe	QUARTERLY	QUARTERLY	QUARTERLY

Periodic Inspection Items Required by OSHA

A. Structural Members
B. Signs and Labels
C. Connection Points
D. Sheaves and Drums
E. Shafts, Axles, Wheels, Couplings
F. Brakes _holdin_ and control_
G. Indicators, Gauges
H. Self-contained Electric, Hydraulic, or Gasoline Powered Generating Units
I. Transmissions
J. Electrical Components
K. Covers and Guards
L. Bumpers and End Stops
M. Trolley and Runway Rail
N. Runway Structure
O. Conductor System
P. Below-the-Hook Devices

Periodic Inspection Items Required by OSHA

A. Structural members, such as girders, end trucks, footwalks, trap doors, ladders, handrails, trolley frame, cab, etc.
- Check for deformed, cracked, corroded or unsecured members. Are foot walks free of debris, grease, etc.?
- Does cab have a fire extinguisher, proper type?

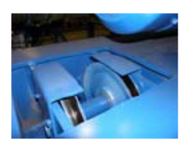
Periodic Inspection Items Required by OSHA

B. Signs and Labels
- Check for proper capacity labels. Are they legible from the floor? Are warning signs in place and legible?
- Was cranes test loaded? Did you record in your records?

Periodic Inspection Items Required by OSHA

C. Connection Points
- Check for loose/broken bolts or rivets. Check for cracked or insufficient welds.

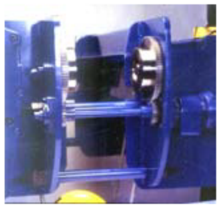
Periodic Inspection Items Required by OSHA



D. Sheaves and Drums
- Check for worn _rooves, worn _roove lands, sharp edges, and cracks.

Periodic Inspection Items Required by OSHA

E. Shafts, Axles, Wheels, Couplings
- Check for worn, cracked bent or broken parts. Check for loose/missing hardware.



Periodic Inspection Items Required by OSHA

F. Brakes (Holding and Control)
- Check for excessive wear and proper adjustment on brake system parts, linings, pawls and ratchets. Check for proper functioning of electric control brake.

Periodic Inspection Items Required by OSHA

G. Indicators, Gauges or Other Devices
- Check for load, wind, and other indicators over their full range, re-calibrate as required.

Periodic Inspection Items Required by OSHA

H. Transmissions
- Check for excessive wear of chain drive sprockets and excessive chain stretch. Open gearbox inspection covers and check for gear teeth wear and proper lubrication.

Periodic Inspection Items Required by OSHA

Electrical Components
- Check all electrical apparatus for signs of pitting or any deterioration of controller contactors, limit switches, pushbutton stations, motor slip rings, brushes, resistors.
- Check for any loose wire connections for damaged wiring.
- Check for evidence of overheating.
- Make sure door or cover closed properly.

Periodic Inspection Items Required by OSHA

- Electrical Components
  - Controller contactors
  - Limit switches
  - Push button stations

Periodic Inspection Items Required by OSHA

- Electrical Components
  - Motor slip rings
  - Brushes
  - Resistors

Periodic Inspection Items Required by OSHA

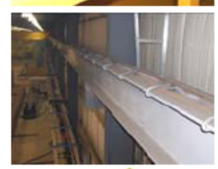
J. Covers and Guards
- Check that all covers or _uards are in _ lace, secure, and undamaged.

Periodic Inspection Items Required by OSHA

K. Bumpers and End Stops
- Check all bumpers and end stops for damage. Check for proper restraints and obvious under sizing or improper energy absorption capabilities.

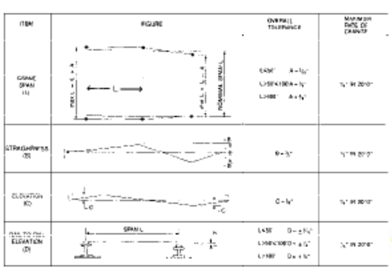
Periodic Inspection Items Required by OSHA

L. Trolley and Runway Rail
- Check rails and fastening devices for looseness, gaps, misalignment, wear.



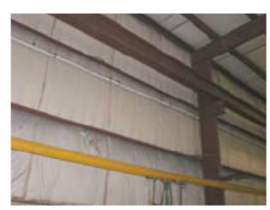
Periodic Inspection Items Required by OSHA

L. Trolley and Runway Rail



Periodic Inspection Items Required by OSHA

M. Runway Structures
- Check runway structure for proper anchors, loose bolted connections, corrosion, cracked or deformed members.



Periodic Inspection Items Required by OSHA

N. Conductor System

- Check the conductor systems for:
  - Alignment
  - Fastening
  - Splices
  - Power feeds
  - Conductor shoes for wear.

Periodic Inspection Items Required by OSHA

O. Below-the-Hook Devices

- Check for cracks or structural damage. Check mechanical components for wear, alignment, and missing/loose hardware. Check all motors, controls, wiring. Check that all guards are in place and secure.

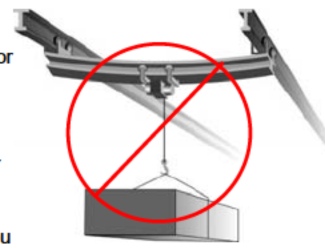
- For details, see below-the-hook presentation

Operational Safety – Before Lifting

- Lifters must only be used by trained operators.
- Do not allow yourself to be distracted. Pay attention to what you are doing.
- Test operation of moving lifter parts and controls at the beginning of each shift.

Operational Safety – Before Lifting

- Do not overload crane or hoist. Make sure the combined weight of the lifter and load does not exceed the rated load capacity of the crane or hoist.
- Refuse to make lift if you are unsure of any issues. Do not proceed until all issues are resolved.

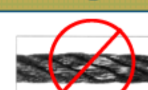


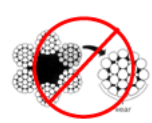
Operational Safety – Before Lifting

- To ensure load is balanced and stable, make a preliminary lift of a few inches.
- Do not overload lifter. Do not try to lift a load that is too big for the lifter.
- Do not pick up hot loads unless the lifter is specially designed for high temperature service.

Operational Safety – Before Lifting

- Make sure hoist rope or chain is free from twists, knots and kinks. Multiple part lines should not be twisted around each other.





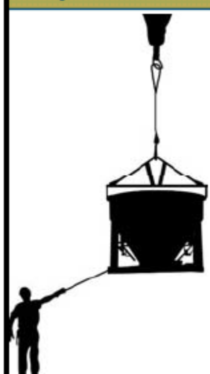
Operational Safety – Moving a Load

- Take instructions only from the person designated to give signals.
- Do not ride or allow other people to do so.
- Do not lift load higher than necessary to avoid obstructions in its path.

Operational Safety – Moving a Load

- Do not allow loads to come in contact with other objects. Make sure the path of travel is free of obstructions before moving the load.
- Do not lift loads over eople. Sta out from under the load and make sure other people remain at a distance.
- Avoid sudden starts and stops. This prevents shock loading which can stress the system beyond its capacity.

Operational Safety – Moving a Load



- Stay clear while moving load. Do not allow load to swing. Use a rod to push load or a tag line to pull the load. Exercise particular caution with sheet lifters. Be sure to keep load level. Tilting the lifter could cause the load to slide off the lifter.
- Always lower load to ground and check its stability before leaving the area.

Operational Safety – Moving a Load

- Make sure the lifter is properly stored after use. Lifters are big and heavy and can cause personal injury or property damage if they fail. Some lifter require a specially designed stand. Others may be stored on a level surface.

Crane Inspector – Definition

- **Any person engaging in the testing, examination and/or certification of cranes, including but no limited to top running and under-running bridge and gantry type, single or double irder overhead travelin cranes and associated hoisting equipment.**

Crane Inspector – Work Experience

- **Shall have a minimum of 2,000 field hours of experience related to maintaining, servicing, repairing, modifying and functional testing of cranes and associated hoisting equipment.**
- **Experience should provide a working knowledge of how to identify deficiencies in mechanical, structural, electrical systems and components of cranes.**

Crane Inspector – Physical Qualifications

- Vision of at least 20/30 in one eye and 20/50 in the other with or without correction.
- Normal depth perception, field of vision, hand-eye coordination, and no tendencies to dizziness or similar conditions.
- Not have evidence of physical restrictions not be subject to seizures or loss of physical control, or emotional instability that could render a hazard to the technician or others.

NPCA

Crane Inspector – Physical Qualifications

- Be able to hear, with or without hearing aid, adequately for a specific task.
- Have sufficient strength, endurance agility, coordination, manual dexterity and speed of reaction to meet the demands of the job.
- Be capable of working at extended heights in a safe manner under varying environmental and adverse physical conditions.

NPCA

Crane Inspector – Other Qualifications

- Should demonstrate proficiency to read and write in English.
- Should demonstrate proficient oral and written communication skills.
- Should be subject to other safety, drug or other specific Seller and/or Purchaser's requirements.
- Should be able to distinguish colors, if color differentiation is required for the task.

NPCA

Crane Inspector – Required Training

- Should have received formal training in the areas of safety and design codes related to cranes Federal, State and local codes and regulations safe operating practices of cranes report writing and documentation and communication skills.
- An inspector should receive additional formal training every two years as a minimum and be able to provide documentation of such training.

NPCA

Crane Inspector – Required Training

- Additional training should include, but not be limited to the following areas:
  - Trade skills
  - Products
  - Safety
  - Tolls & Equipment
  - Job-site Conduct

NPCA

Crane Inspector – Required Training

- Testing
  - Inspector shall be required to demonstrate proficiency by passing both a written and practical examination. Inspector should be able to present documentation of successful completion of above qualifications.
- Certification/Licensing
  - If local code bodies or governments mandate, additional testing and registration for inspector certification or licensing may be required.

NPCA

Recommended Forms – OSHA Crane Inspection Report

- □Maintenance Log
- □OSHA Crane Inspection Report
- □Trouble Shooting Guide

Recommended Forms – Maintenance Log


Maintenance Log

- Click on picture to open .pdf file.

Recommended Forms – OSHA Crane Inspection Report


OSHA Crane Inspection Report

- Click on picture to open .pdf file.

Recommended Forms – OSHA Crane Inspection Report – Alternate Version

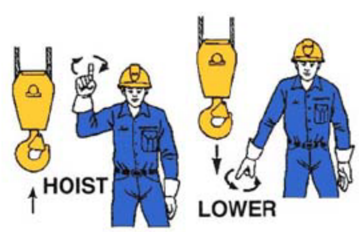
- Click on picture to open .pdf file.

Recommended Forms – Trouble Shooting Guide

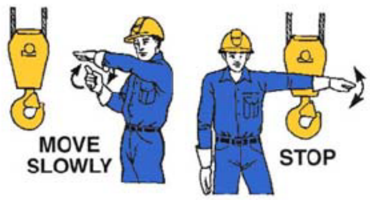

Troubleshooting Guide

- Click on picture to open .pdf file.

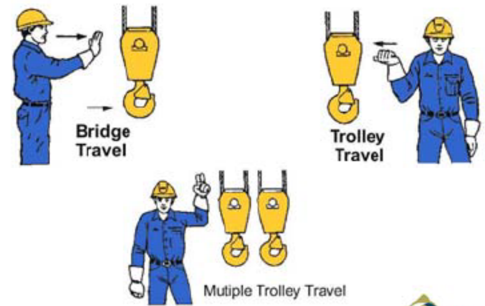
Standard Hand Signals



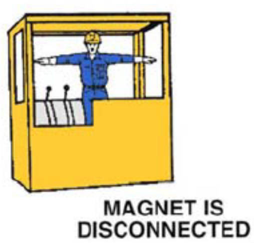
Standard Hand Signals



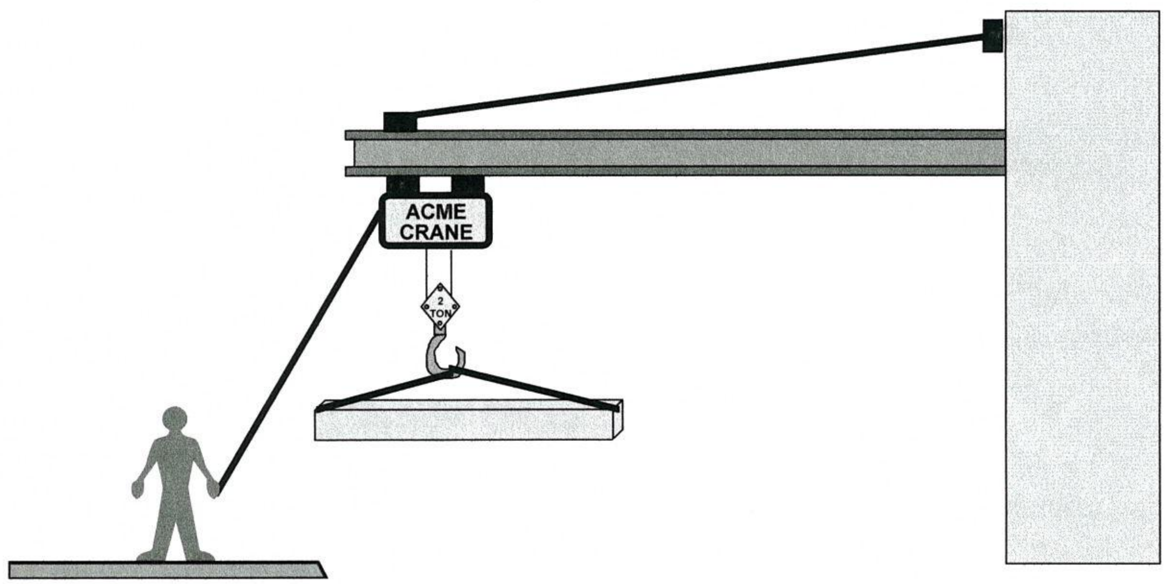
Standard Hand Signals



Standard Hand Signals



INDUSTRIAL CRANE & SLING OPERATOR TRAINING



NIST – APRIL 2013

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INDUSTRIAL CRANE & SLING OPERATOR TRAINING

United States Department of Labor
Occupational Safety and Health Administration

Overhead and Gantry Cranes (29 CFR 1910.179)

- Design and construction criteria
- Safety features
- Brakes
- Electrical and operational control requirements
- Hoisting equipment
- Inspections
- Preventative maintenance
- Handling the Load

Slings (29 CFR 1910.184)

- Safe operating practices and inspections
- Types of slings – alloy chain, wire rope, metal mesh, natural and synthetic fiber rope, synthetic web
- Sling identification/marking, attachments, inspections, proof testing, proper sling use, safe operating temperature, repairing/reconditioning, effects of wear, deformed attachments, minimum sling lengths, rated capacities, removal from service, sling coatings.

(ASME B30)
(Crane Manufacturers Association of America)

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Responsibilities

Corporations and Employers

- Enforce Safety Laws.
  Overhead and Gantry Cranes (29 CFR 1910.179)
  Slings (29 CFR 1910.184)
- Ensure operators are trained
- Equipment meets codes, is maintained and inspected
- Fines/Penalties – subject to maximum fines of $70,000 per violation and criminal charges

Supervisor's Responsibilities

- Ensure all personnel operating a crane and using slings are trained & certified to the company standard
- Communicate known & potential hazards in the workplace to the operators
- Enforce all policies, procedures, and legal requirements
- Inspect what you Expect
- Fines/Penalties – subject to fines and criminal charges

Worker's Responsibilities

- Operate a crane and use slings safely, including testing prior to use
- Possess physical qualifications based on specific job requirements
- Follow company's safety rules, policies & procedures
- Report hazardous conditions and/or defective machinery/equipment to the supervisor or employer
- Personal Injury

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The BRight Group USA LLC
Practical Training Solutions

INDUSTRIAL CRANE & SLING OPERATOR TRAINING

Here are some of the items that should be included on a **Pre-Shift Inspection** of a crane.

Date __________ Crane # __________ Time__________

Inspection	OK	Not OK	N/A	**Explanation**
POWER OFF				
Ladder and safety gate				
Footwalks and hand rails				
Check for loose bolts, nuts and fittings				
Check drums for proper spooling				
General crane housekeeping				
Air leakage				
Hydraulic fluid leakage				
Twisted, broken, kinked cables or ropes				
Load capacity stenciling				
POWER ON				
Hoist upper limit switch				
If provided, lower limit switch				
Wire rope condition				
Hoist brake				
Trolley operation (brakes, controller, etc.)				
Bridge operation (brakes, controller, etc.)				
Horn				
Safety latch				
Hook				
Emergency stop				
Check Manufacturer's manual for other items included in Pre-Shift Inspection				

Inspected by: ____________________ Supervisor: ____________________

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Crane Service and Inspections

Crane Service
- Normal
- Heavy
- Severe

Inspections
- Daily (Pre-shift)
- Frequent
- Periodic

Class of Lift and Procedures

Class of Lift
- Critical
- Pre-engineered Production
- Ordinary

Critical
- Plan or procedure for each lift

Pre-engineered Production
- Repetitive lifts, general procedure

Ordinary
- General procedure, highly trained riggers/operators

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Center Of Gravity

What is meant by the center of gravity of the load?

____

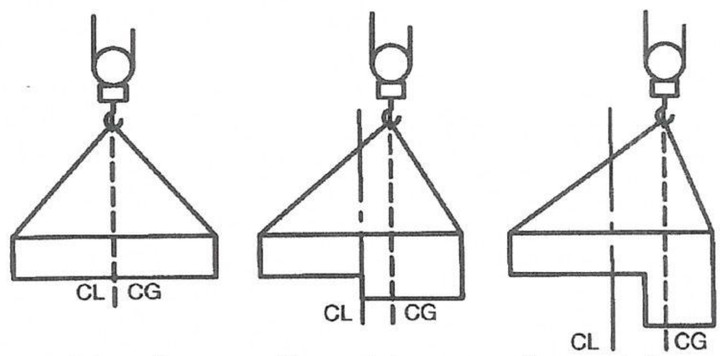
What is meant by center of gravity above point of attachment?

____

Why is this important to know before lifting the load?

____

Balancing a Load



Balanced — Some unbalance — Severe unbalance

Note:
CL = Centerline
CG = Center of Gravity

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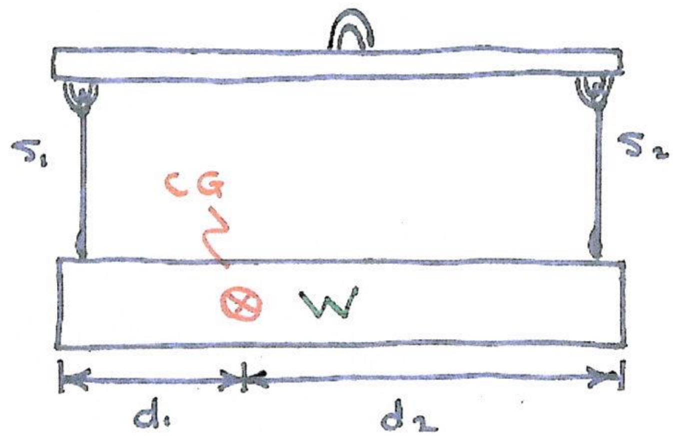
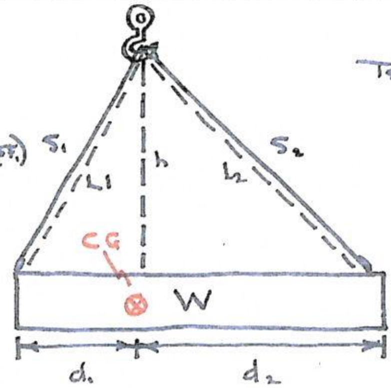


$T_{S1} = W\left(d_2/d_1+d_2\right)$ $T_{S2} = W\left(d_1/d_1+d_2\right)$

$T_{S2} = W\left(\frac{d_1}{d_1+d_2}\right)(SF_2)$

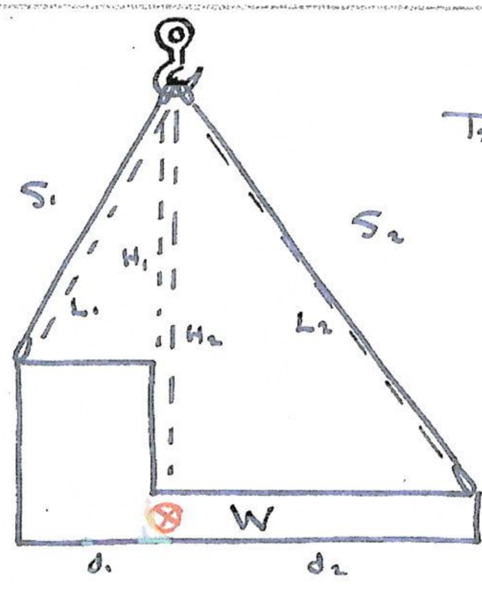
$T_{S1} = W\left(d_2/d_1+d_2\right)(SF_1)$



$S.F._1 = L_1/h$ $SF_2 = L_2/h$

or

Estimate Angle & use chart

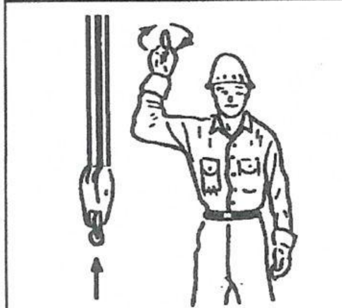


$T_{S2} = \frac{W d_1 L_2}{(d_2 h_1)+(d_1 h_2)}$

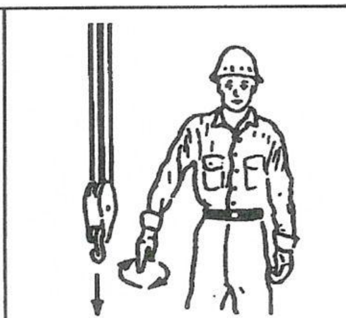
$T_{S1} = \frac{W d_2 L_1}{(d_2 h_1)+(d_1 h_2)}$

INDUSTRIAL CRANE & SLING OPERATOR TRAINING

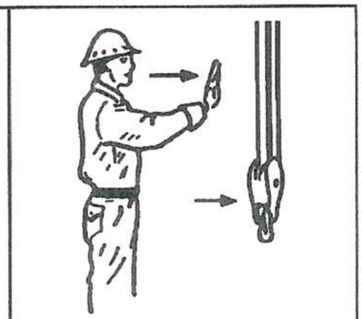
Standard Hand Signals for Overhead Crane Operation



HOIST. With forearm vertical, forefinger pointing up, move hand in small horizontal circles.

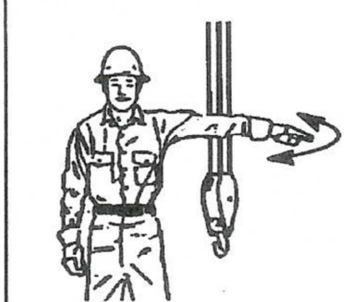


LOWER. Extend arm downward, forefinger pointing down, and move hand in small horizontal circles.

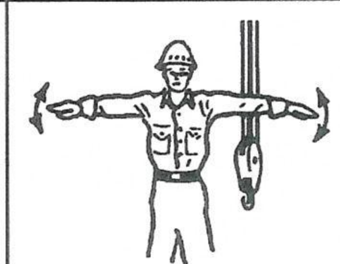


BRIDGE. Arm extended forward, hand open and slightly raised, make pushing motion in direction of travel.

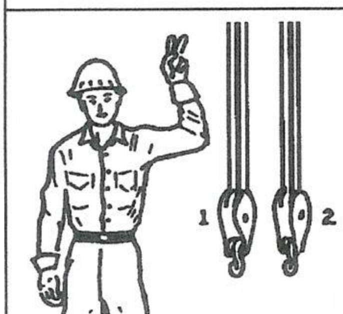
TROLLEY TRAVEL. Palm up, finger closed, thumb pointing in direction of motion, jerk hand horizontally.



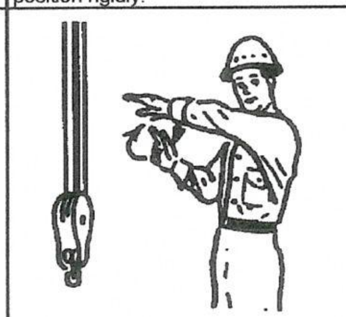
STOP. Extend arm, palm down, hold position rigidly.



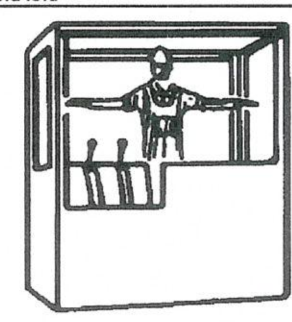
EMERGENCY STOP. Extend arm, palm down, moving hand rapidly right and left.



MULTIPLE TROLLEYS. Hold up one finger for block marked "1" and two fingers for block marked "2." Regular signals follow.



MOVE SLOWLY. Use one hand to give any motion signal and place other hand motionless above hand giving the motion signal. (Hoist slowly shown as example.)



MAGNET IS DISCONNECTED. Crane operator spreads both hands apart, palms up.

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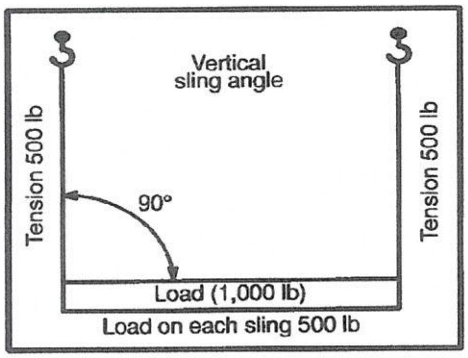
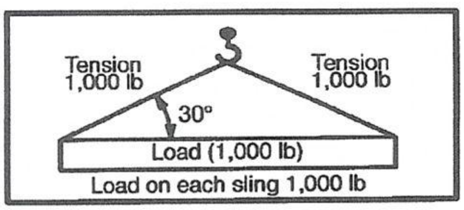
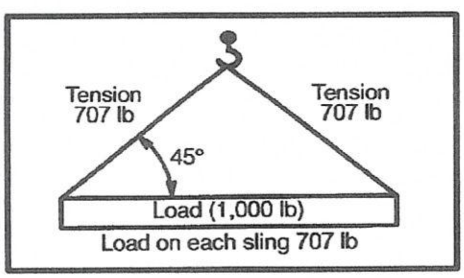
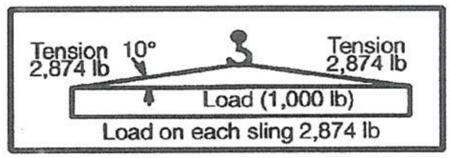
INDUSTRIAL CRANE & SLING OPERATOR TRAINING

Load Angle and Lifting Efficiency









Sling angle	Load angle factor
90°	1.000
85°	1.004
80°	1.015
75°	1.035
70°	1.064
65°	1.104
60°	1.155
55°	1.221
50°	1.305
45°	1.414
40°	1.555
35°	1.742
30°	2.000
25°	2.364
20°	2.924
15°	3.861
10°	5.747
5°	11.490

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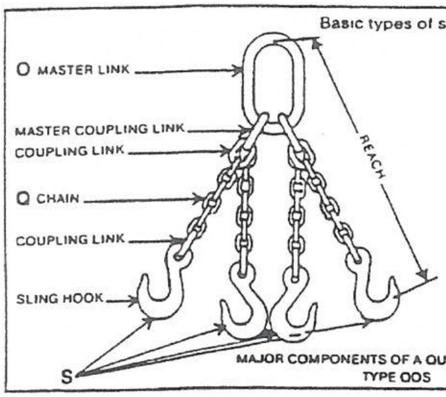
INDUSTRIAL CRANE & SLING OPERATOR TRAINING

CHAIN SLINGS



Basic types of sling chains are designated throughout the industry, by standard symbols as follows:

FIRST SYMBOL (Basic Type)

- **S** Single Sling Chain with master link and hook, or hook each end.
- **C** Single Choker Sling Chain with master link each end. No hooks.
- **D** Double Sling Chain with standard master link and hooks
- **T** Triple Sling Chain with standard master link and hooks.
- **Q** Quadruple Sling Chain with standard master link and hooks.

SECOND SYMBOL (Type of master link or end link)

- **O** Standard Oblong Master Link
- **P** Standard Pear Shaped Master Link
- **R** Master Ring

THIRD SYMBOL (Type of hook)

- **S** Sling Hook
- **G** Grab Hook
- **F** Foundry Hook
- **P** Plate Hook

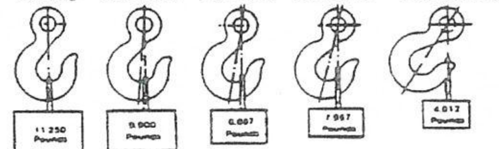
GRADE 8 ALLOY SLING CHAIN WORKING LOAD LIMITS* (lbs.)

TRADE SIZE INCHES	SINGLE SLING TYPE S	DOUBLE SLINGS TYPE D			TRIPLE TYPE T AND QUADRUPLE TYPE Q SLINGS		
	90°	60°	45°	30°	60°	45°	30°
7/32	2,100	3,700	3,000	2,100	5,500	4,500	3,200
9/32	3,500	6,100	4,900	3,500	9,100	7,400	5,200
5/16	4,100	7,100	5,800	4,100	10,700	8,600	6,200
3/8	7,100	12,300	10,000	7,100	18,400	15,100	10,600
1/2	12,000	20,800	17,000	12,000	31,200	25,500	18,000
5/8	18,100	31,300	25,600	18,100	47,000	38,400	27,100
3/4	28,300	49,000	40,000	28,300	73,500	60,000	42,400
7/8	34,200	59,000	48,400	34,200	88,900	72,500	51,300
1	47,700	82,600	67,400	47,700	123,900	101,200	71,500
1¼	72,300	125,200	102,200	72,300	187,800	153,400	108,400
1½	80,000	138,600	113,100	80,000	207,600	168,000	120,000

*CAUTION: This working load limit should not be exceeded.

HOW HOOK LOADING EFFECTS THE WORKING LOAD LIMIT

True Loading	1/4" Off Center	1/2" Off Center	3/4" Off Center	Point Loading



100% Of Rating	88% Of Rating	79% Of Rating	71% Of Rating	41% Of Rating

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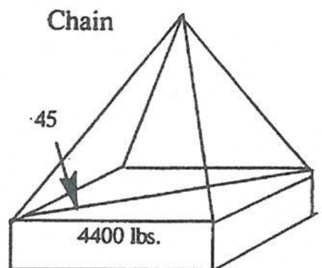
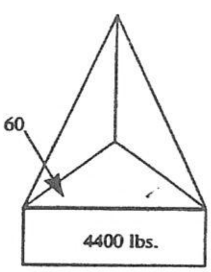
CAN YOU LIFT THESE LOADS SAFELY?

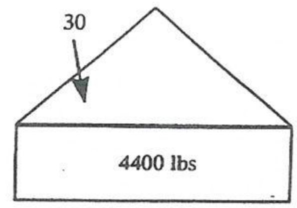
Using the sling chart provided answer if you could lift the loads pictured below.



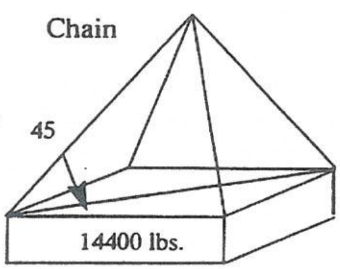
QOS 7/32" Yes
No



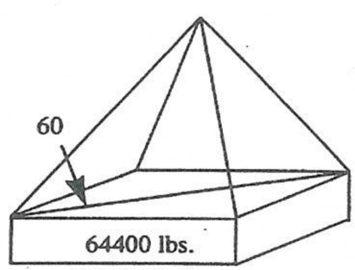
TOS 7/32" Yes
No



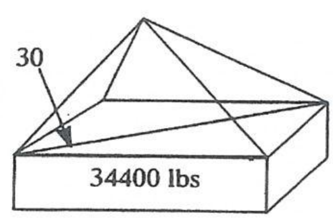
DOS 3/8" Yes
No



Q05 3/8" Yes
No



Q05 3/4" Yes
No



Q05 5/8" Yes
No

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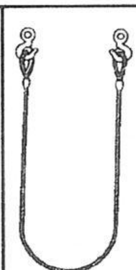
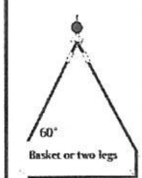
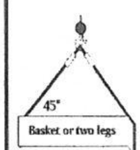
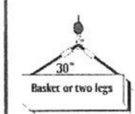
INDUSTRIAL CRANE & SLING OPERATOR TRAINING

Load Capacity of Wire Rope Slings

Mechanical Splice (IWRC) in pounds. Design factor = 5:1

Dia. in inches	 Vertical	 Choker	 Basket or two legs				Dia. in inches
1/4	1,100	840	2,200	1,940	1,580	1,100	1/4
5/16	1,700	1,300	3,400	3,000	2,400	1,700	5/16
3/8	2,400	1,860	4,800	4,200	3,600	2,400	3/8
7/16	3,400	2,500	3,800	5,800	4,800	3,400	7/16
½	4,400	3,200	8,800	7,600	6,200	4,400	½
9/16	5,500	4,200	11,000	9,600	7,700	5,500	9/16
5/8	6,800	5,000	13,600	11,800	9,600	6,800	5/8
3/4	9,700	7,200	19,400	16,800	13,600	9,700	3/4
7/8	13,000	9,800	26,000	22,000	18,300	13,000	7/8
1	17,000	12,800	34,000	30,000	24,000	17,000	1
1 1/8	20,000	15,600	40,000	36,000	30,000	20,000	1 1/8
*1 1/4	25,000	18,400	50,000	42,000	34,000	25,000	*1 1/4
*1 3/8	30,000	24,000	60,000	52,000	42,000	30,000	*1 3/8
*1 ½	36,000	28,000	72,000	64,000	50,000	32,000	*1 ½
*1 5/8	42,000	32,000	84,000	70,000	58,000	42,000	*1 5/8
*1 3/4	50,000	38,000	100,000	82,000	66,000	50,000	*1 3/4
*2	64,000	48,000	128,000	106,000	86,000	64,000	*2

(CFR 1910.184/ANSI/ASME B30.9)

Notes:

(1) These values only apply when the D/d ratio is 25 or greater (choker and basket hitches)

D = Diameter of curvature around which the body of the sling is bent

d = Diameter of rope

(2) Choker hitch values apply only to choke angles greater than 120 degrees.

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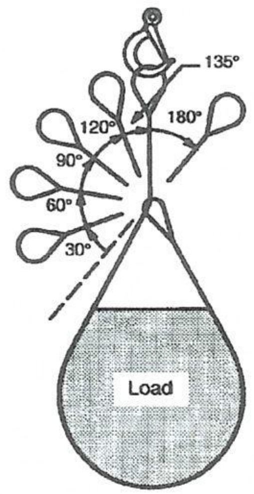
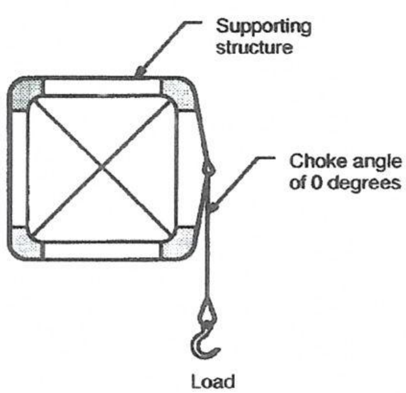
INDUSTRIAL CRANE & SLING OPERATOR TRAINING

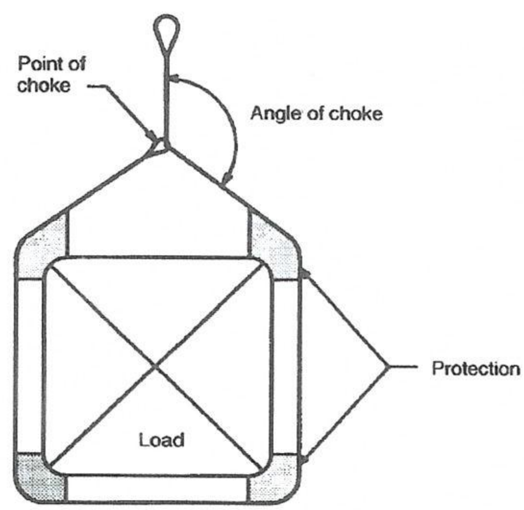
Choker Hitch Rated Capacity Adjustment



Angle of choke in degrees	Rated capacity IWRC and FC rope percent **
Over 120	100
90–120	87
60–89	74
30–59	62
0–29	49

**Percent of sling rated capacity in a choker hitch





Angle of choke

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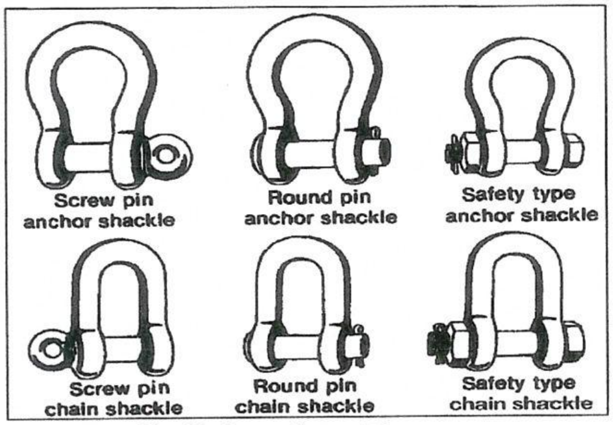
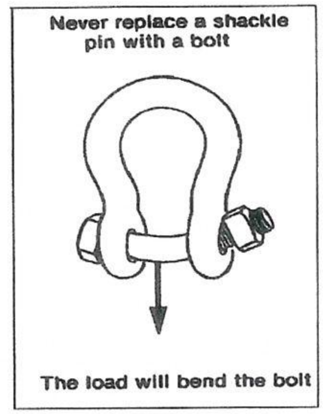
Shackles

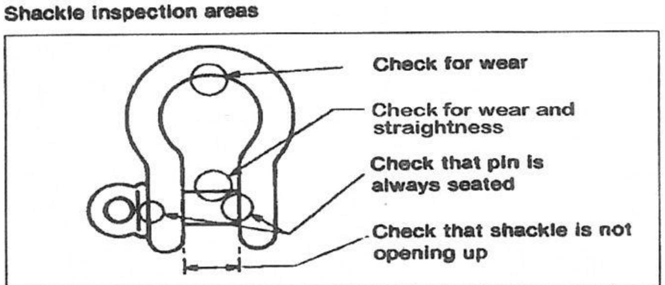
Typical shackles



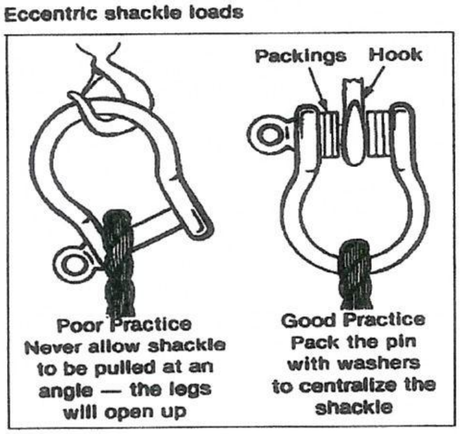
Replacing shackle pins



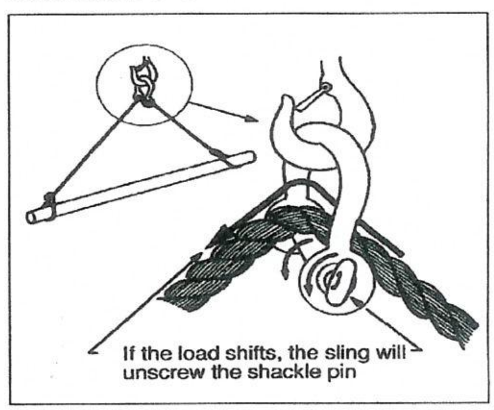
Shackle inspection areas



Eccentric shackle loads



Do not use screw pin shackles if the pin can roll under load and unscrew



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Handling the Load

Load must be within crane capacity.
Hoist chain/rope free from kinks/twists and not wrapped around load.
Multiple part lines, if used, are not twisted around each other.
Bring hook over load to prevent swinging.
At beginning of each shift, test the upper limit switch of each hoist under no load, while inching the block.
Do not use the limit switch as an operating control.
Load attached to load block hook by slings or other approved devices.
Pad sharp edges to protect slings.
Make certain sling clears all obstacles.
Load shall be well secured and properly balanced in sling or other lifting device before lifted more than a few inches.
Do not use side pulls unless an authorized person determines crane will be stable and parts not overstressed.
Avoid shock loading - move load without sudden acceleration or deceleration.
Move load without hitting obstructions.
There is no hoisting, lowering, traveling while any employee is on the load or hook.
Employer requires operator to avoid carrying loads over people.
Test brakes each time a load approaches the rated load.
Do not lower load below the point where two wraps of rope remain on the hoisting drum.
When two cranes are involved, one qualified person shall be in charge.
Employer ensures no employee leaves position at controls while load is suspended.
When starting the bridge and when hook or load approaches near or over people, the warning signal shall be sounded.

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SPECIFIC RULES FOR USING THE CRANE AT YOUR WORKPLACE

Lists specific safety rules for Crane use in your workplace?

____

____

____

____

____

What additional safety rules for crane use would you suggest to add to the current Company standards?

____

____

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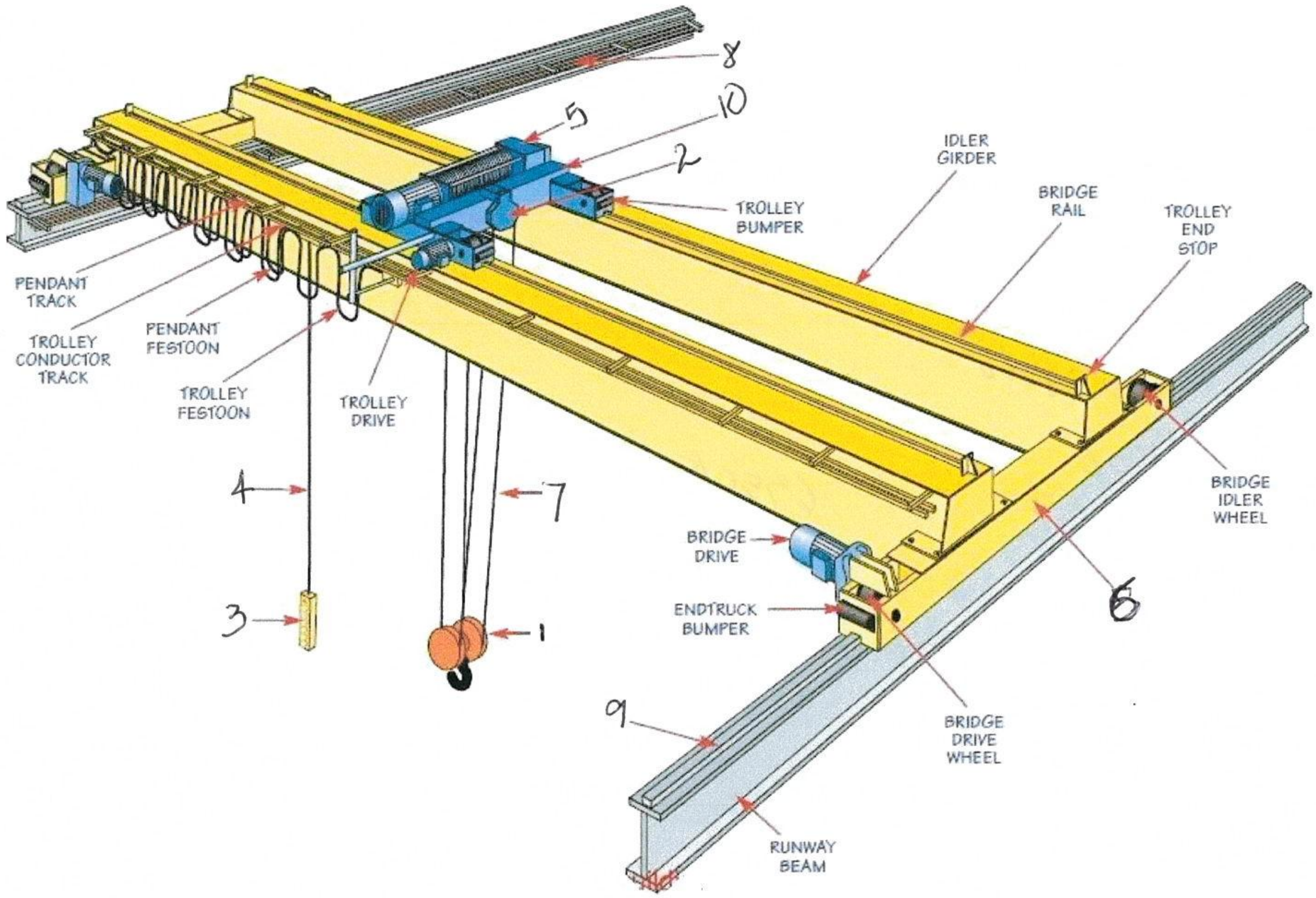
PARTS OF AN OVERHEAD CRANE



Identify:

1. Load Block (Hook Block, Running Block)
2. Upper Block (Head Block)
3. Pendant Control
4. Pendant Cable
5. Trolley Frame
6. End Truck
7. Wire Rope (Running Rope)
8. Conductors
9. Runway Rail
10. Hoist

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Appendix 6.6.1: Annual and Monthly Inspection Records for the 20-Ton Crane (west side) in Building 205, Room 125

CRANE 1

888-658-1212

CRANE 1

SERVICE • SAFETY • SYSTEMS

FolderID: J09-07277
FormID: 12558196

Frequent Inspection - Overhead Crane & Hoist - CRANE 1 V1

National Institute of Standards & Technology (nist)
100 Bureau Drive
Gaithersburg, MD 20899

Overhead Crane	
Completed by: 09-[redacted] **on 01/12/2022**	
Location:	Bldg 205
Area:	Room 125
CRANE 1 UNIT ID:	WESTSIDE
QR Code:	C12045416
Status:	In Service

Customer Unit ID:	West side
Equipment Type:	Top Running Double Girder Bridge with Runway
Initial Load Test Date:	Load Test Document Confirmed
Capacity:	20 Tons
Power Type:	460/3/60
Crane Manufacturer:	Platnick
Crane Serial Number:	13015
Hoist Quantity:	Main
Hoist Type, Hoist 1:	Wire Rope
Capacity, Hoist 1:	20 Ton
Manufacturer, Hoist 1:	R&M
Model Number, Hoist 1:	SX60610200P66FGD0F
Serial Number, Hoist 1:	HNX03187
Hoist 1 Chain or Wire Rope: Length, Diameter & End Fittings:	.15.20mm
Hoist Lifting Height:	35'
Hoist Type, Hoist 2:	N/A
Hoist Type, Hoist 3:	N/A
Trolley Type:	Motorized
Operator Control Type:	Pendant & Remote
Pendant Brand:	Telemecanique
Access to Equipment:	66' Working Height Lift

Priorities Found: **12 - Good**

General Inspection Items		
1.	Tagged Crane or Hoist	**(SAT) Satisfactory**
2.	Control Devices	**(SAT) Satisfactory**
3.	Brakes	**(SAT) Satisfactory**
4.	Hoist Limit Switches	**(SAT) Satisfactory**
5.	Travel Limits	**(SAT) Satisfactory**
6.	Oil Leakage	**(SAT) Satisfactory**
7.	Unusual Sounds	**(SAT) Satisfactory**
8.	Warning and Safety Labels and Warning Devices	**(SAT) Satisfactory**
Lifting Medium		
9.	Hook	**(SAT) Satisfactory**
10.	Hook Latch	**(SAT) Satisfactory**
11.	Wire Rope	**(SAT) Satisfactory**
12.	Reeving	**(SAT) Satisfactory**
13.	Date of Inspection	**01/12/2022**

14. Inspector Name	[redacted]

CRANE 1

SERVICE • SAFETY • SYSTEMS

Frequent Inspection - Overhead Crane & Hoist - CRANE 1 V1

National Institute of Standards & Technology (nist)
100 Bureau Drive
Gaithersburg, MD 20899

FolderID: J09-07163
FormID: 12835267

Overhead Crane

Completed by: 09-[redacted] **on 02/15/2022**

Location:	Bldg 205
Area:	Room 125
CRANE 1 UNIT ID:	WESTSIDE
QR Code:	C12045416
Status:	In Service

Customer Unit ID:	West side
Equipment Type:	Top Running Double Girder Bridge with Runway
Initial Load Test Date:	Load Test Document Confirmed
Capacity:	20 Tons
Power Type:	460/3/60
Crane Manufacturer:	Platnick
Crane Serial Number:	13015
Hoist Quantity:	Main
Hoist Type, Hoist 1:	Wire Rope
Capacity, Hoist 1:	20 Ton
Manufacturer, Hoist 1:	R&M
Model Number, Hoist 1:	SX60610200P66FGD0F
Serial Number, Hoist 1:	HNX03187
Hoist 1 Chain or Wire Rope: Length, Diameter & End Fittings:	.15.20mm
Hoist Lifting Height:	35'
Hoist Type, Hoist 2:	N/A
Hoist Type, Hoist 3:	N/A
Trolley Type:	Motorized
Operator Control Type:	Pendant & Remote
Pendant Brand:	Telemecanique
Access to Equipment:	66' Working Height Lift

Priorities Found: **12 - Good**

General Inspection Items

1.	Tagged Crane or Hoist	**(SAT) Satisfactory**
2.	Control Devices	**(SAT) Satisfactory**
3.	Brakes	**(SAT) Satisfactory**
4.	Hoist Limit Switches	**(SAT) Satisfactory**
5.	Travel Limits	**(SAT) Satisfactory**
6.	Oil Leakage	**(SAT) Satisfactory**
7.	Unusual Sounds	**(SAT) Satisfactory**
8.	Warning and Safety Labels and Warning Devices	**(SAT) Satisfactory**

Lifting Medium

9.	Hook	**(SAT) Satisfactory**
10.	Hook Latch	**(SAT) Satisfactory**
11.	Wire Rope	**(SAT) Satisfactory**
12.	Load Chain	**(NA) Not Applicable**
13.	Reeving	**(SAT) Satisfactory**

14.	Date of Inspection	**02/15/2022**
15.	Inspector Name	[redacted]

CRANE 1

SERVICE • SAFETY • SYSTEMS

CRANE 1

888-658-1212

FolderID: J09-07161
FormID: 13132899

Frequent Inspection - Overhead Crane & Hoist - CRANE 1 V1

National Institute of Standards & Technology (nist)
100 Bureau Drive
Gaithersburg, MD 20899

Overhead Crane

Completed by: 09-[redacted] on 03/21/2022

Location:	Bldg 205
Area:	Room 125
CRANE 1 UNIT ID:	WESTSIDE
QR Code:	C12045416
Status:	In Service

Customer Unit ID:	West side
Equipment Type:	Top Running Double Girder Bridge with Runway
Initial Load Test Date:	Load Test Document Confirmed
Capacity:	20 Tons
Power Type:	460/3/60
Crane Manufacturer:	Platnick
Crane Serial Number:	13015
Hoist Quantity:	Main
Hoist Type, Hoist 1:	Wire Rope
Capacity, Hoist 1:	20 Ton
Manufacturer, Hoist 1:	R&M
Model Number, Hoist 1:	SX60610200P66FGD0F
Serial Number, Hoist 1:	HNX03187
Hoist 1 Chain or Wire Rope: Length, Diameter & End Fittings:	.15.20mm
Hoist Lifting Height:	35'
Hoist Type, Hoist 2:	N/A
Hoist Type, Hoist 3:	N/A
Trolley Type:	Motorized
Operator Control Type:	Pendant & Remote
Pendant Brand:	Telemecanique
Access to Equipment:	66' Working Height Lift

Priorities Found: **12 - Good**

General Inspection Items		
1.	Tagged Crane or Hoist	**(SAT) Satisfactory**
2.	Control Devices	**(SAT) Satisfactory**
3.	Brakes	**(SAT) Satisfactory**
4.	Hoist Limit Switches	**(SAT) Satisfactory**
5.	Travel Limits	**(SAT) Satisfactory**
6.	Oil Leakage	**(SAT) Satisfactory**
7.	Unusual Sounds	**(SAT) Satisfactory**
8.	Warning and Safety Labels and Warning Devices	**(SAT) Satisfactory**
Lifting Medium		
9.	Hook	**(SAT) Satisfactory**
10.	Hook Latch	**(SAT) Satisfactory**
11.	Wire Rope	**(SAT) Satisfactory**
12.	Reeving	**(SAT) Satisfactory**
13.	Date of Inspection	**03/21/2022**

14. Inspector Name [redacted]

CRANE 1

888-658-1212

CRANE 1

SERVICE • SAFETY • SYSTEMS

FolderID: j09-07167
FormID: 13486892

Frequent Inspection - Overhead Crane & Hoist - CRANE 1 V1

National Institute of Standards & Technology (nist)
100 Bureau Drive
Gaithersburg, MD 20899

Overhead Crane	
Completed by: 09-[redacted] on 05/04/2022	
Location:	Bldg 205
Area:	Room 125
CRANE 1 UNIT ID:	WESTSIDE
QR Code:	C12045416
Status:	In Service

Customer Unit ID:	West side
Equipment Type:	Top Running Double Girder Bridge with Runway
Initial Load Test Date:	Load Test Document Confirmed
Capacity:	20 Tons
Power Type:	460/3/60
Crane Manufacturer:	Platnick
Crane Serial Number:	13015
Hoist Quantity:	Main
Hoist Type, Hoist 1:	Wire Rope
Capacity, Hoist 1:	20 Ton
Manufacturer, Hoist 1:	R&M
Model Number, Hoist 1:	SX60610200P66FGD0F
Serial Number, Hoist 1:	HNX03187
Hoist 1 Chain or Wire Rope: Length, Diameter & End Fittings:	.15.20mm
Hoist Lifting Height:	35'
Hoist Type, Hoist 2:	N/A
Hoist Type, Hoist 3:	N/A
Trolley Type:	Motorized
Operator Control Type:	Pendant & Remote
Pendant Brand:	Telemecanique
Access to Equipment:	66' Working Height Lift

Priorities Found: **12 - Good**

General Inspection Items	
1. Tagged Crane or Hoist	**(SAT) Satisfactory**
2. Control Devices	**(SAT) Satisfactory**
3. Brakes	**(SAT) Satisfactory**
4. Hoist Limit Switches	**(SAT) Satisfactory**
5. Travel Limits	**(SAT) Satisfactory**
6. Oil Leakage	**(SAT) Satisfactory**
7. Unusual Sounds	**(SAT) Satisfactory**
8. Warning and Safety Labels and Warning Devices	**(SAT) Satisfactory**
Lifting Medium	
9. Hook	**(SAT) Satisfactory**
10. Hook Latch	**(SAT) Satisfactory**
11. Wire Rope	**(SAT) Satisfactory**
12. Reeving	**(SAT) Satisfactory**
13. Date of Inspection	**05/04/2022**

14. Inspector Name	[redacted]

CRANE 1

888-658-1212

CRANE 1

SERVICE • SAFETY • SYSTEMS

Frequent Inspection - Overhead Crane & Hoist - CRANE 1 V1

FolderID: j09-07166
FormID: 13890378

National Institute of Standards & Technology (nist)
100 Bureau Drive
Gaithersburg, MD 20899

Overhead Crane	
Completed by: 09-[redacted] on 06/21/2022	
Location:	Bldg 205
Area:	Room 125
CRANE 1 UNIT ID:	WESTSIDE
QR Code:	C12045416
Status:	In Service

Customer Unit ID:	West side
Equipment Type:	Top Running Double Girder Bridge with Runway
Initial Load Test Date:	Load Test Document Confirmed
Capacity:	20 Tons
Power Type:	460/3/60
Crane Manufacturer:	Platnick
Crane Serial Number:	13015
Hoist Quantity:	Main
Hoist Type, Hoist 1:	Wire Rope
Capacity, Hoist 1:	20 Ton
Manufacturer, Hoist 1:	R&M
Model Number, Hoist 1:	SX60610200P66FGD0F
Serial Number, Hoist 1:	HNX03187
Hoist 1 Chain or Wire Rope: Length, Diameter & End Fittings:	.15.20mm
Hoist Lifting Height:	35'
Hoist Type, Hoist 2:	N/A
Hoist Type, Hoist 3:	N/A
Trolley Type:	Motorized
Operator Control Type:	Pendant & Remote
Pendant Brand:	Telemecanique
Access to Equipment:	66' Working Height Lift

Priorities Found: ● **12 - Good**

General Inspection Items		
1.	Tagged Crane or Hoist	**(SAT) Satisfactory**
2.	Control Devices	**(SAT) Satisfactory**
3.	Brakes	**(SAT) Satisfactory**
4.	Hoist Limit Switches	**(SAT) Satisfactory**
5.	Travel Limits	**(SAT) Satisfactory**
6.	Oil Leakage	**(SAT) Satisfactory**
7.	Unusual Sounds	**(SAT) Satisfactory**
8.	Warning and Safety Labels and Warning Devices	**(SAT) Satisfactory**
Lifting Medium		
9.	Hook	**(SAT) Satisfactory**
10.	Hook Latch	**(SAT) Satisfactory**
11.	Wire Rope	**(SAT) Satisfactory**
12.	Reeving	**(SAT) Satisfactory**
13.	Date of Inspection	**06/21/2022**

14. Inspector Name [redacted]

CRANE 1

888-658-1212

CRANE 1

SERVICE • SAFETY • SYSTEMS

FolderID: J09-07169
FormID: 14166483

Frequent Inspection - Overhead Crane & Hoist - CRANE 1 V1

National Institute of Standards & Technology (nist)
100 Bureau Drive
Gaithersburg, MD 20899

Overhead Crane	
Completed by: 09-[redacted] on 07/26/2022	
Location:	Bldg 205
Area:	Room 125
CRANE 1 UNIT ID:	WESTSIDE
QR Code:	C12045416
Status:	In Service

Customer Unit ID:	West side
Equipment Type:	Top Running Double Girder Bridge with Runway
Initial Load Test Date:	Load Test Document Confirmed
Capacity:	20 Tons
Power Type:	460/3/60
Crane Manufacturer:	Platnick
Crane Serial Number:	13015
Hoist Quantity:	Main
Hoist Type, Hoist 1:	Wire Rope
Capacity, Hoist 1:	20 Ton
Manufacturer, Hoist 1:	R&M
Model Number, Hoist 1:	SX60610200P66FGD0F
Serial Number, Hoist 1:	HNX03187
Hoist 1 Chain or Wire Rope: Length, Diameter & End Fittings:	.15.20mm
Hoist Lifting Height:	35'
Hoist Type, Hoist 2:	N/A
Hoist Type, Hoist 3:	N/A
Trolley Type:	Motorized
Operator Control Type:	Pendant & Remote
Pendant Brand:	Telemecanique
Access to Equipment:	66' Working Height Lift

Priorities Found: **12 - Good**

General Inspection Items	
1. Tagged Crane or Hoist	**(SAT) Satisfactory**
2. Control Devices	**(SAT) Satisfactory**
3. Brakes	**(SAT) Satisfactory**
4. Hoist Limit Switches	**(SAT) Satisfactory**
5. Travel Limits	**(SAT) Satisfactory**
6. Oil Leakage	**(SAT) Satisfactory**
7. Unusual Sounds	**(SAT) Satisfactory**
8. Warning and Safety Labels and Warning Devices	**(SAT) Satisfactory**
Lifting Medium	
9. Hook	**(SAT) Satisfactory**
10. Hook Latch	**(SAT) Satisfactory**
11. Wire Rope	**(SAT) Satisfactory**
12. Reeving	**(SAT) Satisfactory**
13. Date of Inspection	**07/26/2022**

14. Inspector Name [redacted]

CRANE 1

SERVICE • SAFETY • SYSTEMS

FolderID: J09-08353
FormID: 14612619

Frequent Inspection - Overhead Crane & Hoist - CRANE 1 V1

National Institute of Standards & Technology (nist)
100 Bureau Drive
Gaithersburg, MD 20899

Overhead Crane

Completed by: 09-[redacted] on 09/20/2022

Location:	Bldg 205
Area:	Room 125
CRANE 1 UNIT ID:	WESTSIDE
QR Code:	C12045416
Status:	In Service

Customer Unit ID:	West side
Equipment Type:	Top Running Double Girder Bridge with Runway
Initial Load Test Date:	Load Test Document Confirmed
Capacity:	20 Tons
Power Type:	460/3/60
Crane Manufacturer:	Platnick
Crane Serial Number:	13015
Hoist Quantity:	Main
Hoist Type, Hoist 1:	Wire Rope
Capacity, Hoist 1:	20 Ton
Manufacturer, Hoist 1:	R&M
Model Number, Hoist 1:	SX60610200P66FGD0F
Serial Number, Hoist 1:	HNX03187
Hoist 1 Chain or Wire Rope: Length, Diameter & End Fittings:	,15,20mm
Hoist Lifting Height:	35'
Hoist Type, Hoist 2:	N/A
Hoist Type, Hoist 3:	N/A
Trolley Type:	Motorized
Operator Control Type:	Pendant & Remote
Pendant Brand:	Telemecanique
Access to Equipment:	66' Working Height Lift

Priorities Found: **12 - Good**

General Inspection Items

1.	Tagged Crane or Hoist	**(SAT) Satisfactory**
2.	Control Devices	**(SAT) Satisfactory**
3.	Brakes	**(SAT) Satisfactory**
4.	Hoist Limit Switches	**(SAT) Satisfactory**
5.	Travel Limits	**(SAT) Satisfactory**
6.	Oil Leakage	**(SAT) Satisfactory**
7.	Unusual Sounds	**(SAT) Satisfactory**
8.	Warning and Safety Labels and Warning Devices	**(SAT) Satisfactory**

Lifting Medium

9.	Hook	**(SAT) Satisfactory**
10.	Hook Latch	**(SAT) Satisfactory**
11.	Wire Rope	**(SAT) Satisfactory**
12.	Reeving	**(SAT) Satisfactory**
13.	Date of Inspection	**09/20/2022**

14. Inspector Name [redacted]

CRANE 1

SERVICE • SAFETY • SYSTEMS

CRANE 1

888-658-1212

FolderID: J09-07163
FormID: 14928050

Periodic Crane & Hoist Inspection Report

National Institute of Standards & Technology (nist)
100 Bureau Drive
Gaithersburg, MD 20899

Overhead Crane

Completed by: 09-[redacted]	on 10/27/2022
Location:	Bldg 205
Area:	Room 125
CRANE 1 UNIT ID:	WESTSIDE
QR Code:	C12045416
Status:	In Service

Customer Unit ID:	West side
Equipment Type:	Top Running Double Girder Bridge with Runway
Initial Load Test Date:	Load Test Document Confirmed
Capacity:	20 Tons
Power Type:	460/3/60
Crane Manufacturer:	Platnick
Crane Serial Number:	13015
Hoist Quantity:	Main
Hoist Type, Hoist 1:	Wire Rope
Capacity, Hoist 1:	20 Ton
Manufacturer, Hoist 1:	R&M
Model Number, Hoist 1:	SX60610200P66FGD0F
Serial Number, Hoist 1:	HNX03187
Hoist 1 Chain or Wire Rope: Length, Diameter & End Fittings:	.15.20mm
Hoist Lifting Height:	35'
Hoist Type, Hoist 2:	N/A
Hoist Type, Hoist 3:	N/A
Trolley Type:	Motorized
Operator Control Type:	Pendant & Remote
Pendant Brand:	Telemecanique
Access to Equipment:	66' Working Height Lift

Priorities Found: **59 - Good**

Documentation		
1.	Initial Load Test Records	**(SAT) Satisfactory**
2.	Monthly Inspection of Hook, Wire Rope, Load Chain	**(SAT) Satisfactory**
3.	Periodic Inspections	**(SAT) Satisfactory**
4.	PM Program	**(SAT) Satisfactory**
General		
5.	Manufacturer's Markings (Photo Required)	**(SAT) Satisfactory**
6.	Operation Warning Labels	**(SAT) Satisfactory**
7.	Required Clearances	**(SAT) Satisfactory**
8.	Capacity Markings	**(SAT) Satisfactory**
9.	Disconnect and Markings	**(SAT) Satisfactory**
10.	Control Station & Markings	**(SAT) Satisfactory**
11.	General House Keeping	**(SAT) Satisfactory**
12.	Warning Light or Device	**(SAT) Satisfactory**
13.	Lubrication	**(SAT) Satisfactory**

14.	Operation Test Performed	(SAT) Satisfactory
Hoist(s)		
15.	Hook and Latch	(SAT) Satisfactory
16.	Hook Throat Opening Dimension	6.5"
17.	Load Cable (Wire Rope) or Load Chain	(SAT) Satisfactory
18.	Wire Rope or Chain Dimension	15mm
19.	Load Block Frame & Guards	(SAT) Satisfactory
20.	Lower Sheaves, Pins and Bearings	(SAT) Satisfactory
21.	Load Cable or Chain Reeving	(SAT) Satisfactory
22.	Load Cable or Chain End Connections	(SAT) Satisfactory
23.	Idler Sheave and Pin	(SAT) Satisfactory
24.	Running Sheaves and Pins	(SAT) Satisfactory
25.	Hoist Frame and Suspension	(SAT) Satisfactory
26.	Hoist Gear Box	(SAT) Satisfactory
27.	Hoist Shafts & Couplings	(SAT) Satisfactory
28.	Motors & Motor Pinions	(SAT) Satisfactory
29.	Hoist Motor Brake	(SAT) Satisfactory
30.	Control Brake	(SAT) Satisfactory
31.	Hoist Drum or Chain Liftwheel	(SAT) Satisfactory
32.	Upper & Lower Limits	(SAT) Satisfactory
Trolley(s)		
33.	Frame & Bumper	(SAT) Satisfactory
34.	Rail Sweeps / Drop Lugs	(SAT) Satisfactory
35.	Wheels & Bearings	(SAT) Satisfactory
36.	Wheel Shafts / Axle, Couplings	(SAT) Satisfactory
37.	Gears & Coupling Guards	(SAT) Satisfactory
38.	Gear Box(s), Open Gears	(SAT) Satisfactory
39.	Motors & Pinions	(SAT) Satisfactory
40.	Trolley Brake(s) Linings and Discs	(SAT) Satisfactory
Electric Controls		
41.	Control Panel & Cover	(SAT) Satisfactory
42.	Wiring Cables & Fittings	(SAT) Satisfactory
43.	Control Station & Buttons	(SAT) Satisfactory
44.	Contactors & Contactor Tips	(SAT) Satisfactory
45.	Mainline Contactor	(SAT) Satisfactory
46.	Resistors / Soft Start	(SAT) Satisfactory
47.	Main Line Conductor	(SAT) Satisfactory
48.	Collector Shoes	(SAT) Satisfactory
Crane		
49.	End Trucks, Bumpers, Buffers	(SAT) Satisfactory
50.	Wheels, Axles, Bearings	(SAT) Satisfactory
51.	Rail Sweeps, Drop Lugs	(SAT) Satisfactory
52.	Shafts, Couplings	(SAT) Satisfactory
53.	Girder, Connection, Structure	(SAT) Satisfactory
54.	Gear & Coupling Guards	(SAT) Satisfactory
55.	Gear Boxes, Open Gears	(SAT) Satisfactory
56.	Motors & Pinions	(SAT) Satisfactory

57.	Brake (s) Linings & Discs	(SAT) Satisfactory
Structure / Runway		
58.	Runway Beams & Stops	(SAT) Satisfactory
59.	Rail, Attachment, Splices	(SAT) Satisfactory
60.	Runway, Alignment / Span	(SAT) Satisfactory
61.	Columns / Tiebacks	(SAT) Satisfactory
Date & Signature:		
62.	Date of the Inspection	10/27/2022
63.	Lead Inspector Name	[redacted]

Appendix 6.7.1: Videographic Evidence of Slab 3 Demolition Activities

SLAB 3: The cutting of the main portion of Slab 3 occurred on Friday, September 23, 2022.

7:04:50	ENGR TECH 1 arrives in Room 125 and enters Room 126.
7:06:25	ENGR TECH 1 emerges walks towards the east high bay door and opens it. He then walks west and opens the west high bay door.
7:15:10	ENGR TECH 1 ascends the scaffold stairs to the surrounding floor; he is wearing a hard hat.
7:15:25	ENGR TECH 1 walks east over to where Slab 3 is to be cut and looks around at the area where he is to be cutting. There is passive fall protection between Slab 2 cut bay and where Slab 3 is to be cut.
7:16:45	ENGR TECH 1 begins to clear the area of Slab 3 by repositioning cords and tools.
7:19:40	ENGR TECH 1 obtains the floor saw and moves it near Slab 3. He spends the next few minutes moving the saw around looking at how he will cut Slab 3.
7:23:25	ENGR TECH 1 positions the floor saw to cut the south face, cutting towards the east. The main weight of the saw is on the slab during Cut 1. Please see Figure A6.7.1 indicating the order of cutting.
7:24:40	ENGR TECH 1 inserts hearing protection and starts floor saw. He is not wearing respiratory protection. He begins to cut the south face, moving the saw in an eastern direction.
7:48:40	ENGR TECH 1 walks away from the saw to grab the gas can located near the scaffold stairs.
7:49:20	ENGR TECH 1 begins to fill the gas tank of the saw.
7:50:40	ENGR TECH 2 enters Room 125 through the west high bay and enters Room 126.
7:52:00	ENGR TECH 1 puts the gas can down and reinserts hearing protection. He starts up the floor saw again and continues to cut the South face, moving the saw in an eastern direction.
7:54:30	ENGR TECH 2 obtains the crane remote and begins moving the crane to the southwest corner of Room 125; he is wearing a hard hat.
7:58:10	The crane with rigging now attached is moving back towards the test frame. There is no evidence a functional inspection of the crane was performed.
7:58:45	ENGR TECH 2 ascends the scaffold stairs to the surrounding floor. He continues to move the crane until he stops it at the east edge of the strong wall, appears to be above the Slab 2 cut bay.
7:59:45	ENGR TECH 2 walks over to ENGR TECH 1 and appears to exchange some words with ENGR TECH 1.
8:02:45	ENGR TECH 2 walks back towards the worktable.
8:07:30	ENGR TECH 1 stops cutting the south face.
8:07:45	ENGR TECH 1 walks over toward ENGR TECH 2 and they appear to be talking on the west side of the test frame.
8:09:20	ENGR TECH 3 arrives in Room 125 and ascends the scaffold stairs to the surrounding floor to talk with ENGR TECH 1 and ENGR TECH 2.
8:24:00	All three technicians walk down the scaffold stairs and enter Room 126.

8:48:00 ENGR TECH 6 arrives in Room 125 and enters Room 126.
9:28:50 ENGR TECH 1 ascends the scaffold stairs to the surrounding floor and walks over to the floor saw.
9:29:40: ENGR TECH 1 appears to put on disposable gloves.
9:30:00 ENGR TECH 1 obtains the floor saw and positions it to cut the north face, cutting towards the east. The main weight of the saw is not on the slab during Cut 2.
9:30:50 ENGR TECH 1 starts the floor saw and begins cutting the north face, moving the saw in an eastern direction. He makes multiple cuts with the saw.

9:59:55 ENGR TECH 1 completes cut of the entire north face.

10:00:00 ENGR TECH 1 positions the floor saw to cut the south face again, cutting towards the east. The main weight of the saw is on the slab during Cut 3.

10:10:10 ENGR TECH 1 appears to complete the cut of the entire south face.

10:10:20 ENGR TECH 1 walks on the slab to turn the saw off. At this time, both the north and south faces of the slab are cut. He then walks over to the worktable to grab the crane remote. He walks back towards Slab 3 with remote in hand.
10:10:50 ENGR TECH 1 grabs the floor saw and walks it across the slab to position it on Slab 4, again, the north and south faces of the slab are cut free of the surrounding floor.
10:11:00 ENGR TECH 1 uses the crane remote to bring the rigging in over Slab 3 to hook up the rigging.
10:11:20 ENGR TECH 1 removes the bolts and plates from the rigging connections.
10:12:30 ENGR TECH 1 grabs one sling with the black plastic bag on it and positions it in the northwest rigging location.
10:12:40 ENGR TECH 1 grabs one sling without the black plastic bag on it and positions it in the northeast rigging location.
10:13:00 ENGR TECH 1 grabs one sling with the black plastic bag on it and positions it in the southeast rigging location.
10:13:15 ENGR TECH 1 grabs one sling without the black plastic bag on it and positions it in the southwest rigging location.
10:13:52 ENGR TECH 1 leaves the surrounding floor via the scaffold stairs to connect the rigging from below using the rolling stairs.
10:19:05 ENGR TECH 1 ascends the scaffold stairs after connecting the rigging from below to the surrounding floor. He walks over towards Slab 3, inserts his hearing protection, grabs the remote, and engages rigging.
10:20:30 ENGR TECH 1 positions the floor saw to cut the east face, cutting towards the south. The main weight of the saw is not on the slab during Cut 4.
10:20:55 ENGR TECH 1 starts the floor saw begins cutting east face, moving the saw in a southern direction.

10:23:00 ENGR TECH 1 stops cutting and walks across slab underneath rigging from north to south to reposition something on the southeast corner of Slab 3. He returns to the saw and continues cutting the east face, making multiple cuts.

10:33:35 ENGR TECH 1 completes cut of the entire East face.

10:33:45 ENGR TECH 1 begins to position the saw to cut the west face, cutting towards the north.

10:34:40 ENGR TECH 1 walks across slab underneath rigging from the north to south to reposition saw (Figure A6.7.2). At this time, the north, east, and south faces of the slab are cut.

10:34:50 ENGR TECH 1 realizes the passive fall protection will not allow him to cut close enough to south face, He pushes the saw forward (north) and then turns the floor saw around 180º and positions it to face south. The main weight of the saw is on the slab during Cut 5.

10:35:25 ENGR TECH 1 begins to cut the west face, moving the saw in a southern direction. He makes multiple cuts, sparks are observed underneath the slab falling to the strong floor.

10:36:25 ENGR TECH 3 ascends the scaffold stairs to the surrounding floor. He walks over near ENGR TECH 1 and they appear to talk.

10:40:50 ENGR TECH 3 begins walking towards the scaffold stairs and descends.

10:41:15 The saw blade appears to get wedged in the cut and ENGR TECH 1 struggles to free it over the next few minutes.

10:42:10 ENGR TECH 3 walks into the test frame footprint and underneath slab as ENGR TECH 1 struggles to free the saw blade.

10:42:15 ENGR TECH 6 ascends the scaffold stairs and walks over to talk with ENGR TECH 1.

10:42:20 ENGR TECH 1 is able to free the saw.

10:43:30 ENGR TECH 1 and ENGR TECH 6 appear to talk about cutting the west face. For the next few minutes, they use a light to look at the cut.

10:45:55 ENGR TECH 6 leaves the surrounding floor via the scaffold stairs.

10:46:05 ENGR TECH 1 tells ENGR TECH 3 to get some plywood and put it underneath Slab 3.

10:46:25 ENGR TECH 6 walks into the test frame footprint and underneath slab to begin removing equipment from underneath Slab 3.

10:47:20 ENGR TECH 3 walks into the test frame footprint and underneath slab to position the plywood underneath Slab 3.

10:48:00 ENGR TECH 1 appears to be stomping on the northwest tab of Slab 3. He is unable to kick it through. ENGR TECH 3 and ENGR TECH 6 have moved near the dumpster. ENGR TECH 6 is outside of the test frame footprint, but ENGR TECH 3 is still inside the footprint.

10:48:30 ENGR TECH 3 grabs two more pieces of plywood from near the dumpster and walks into the test frame footprint and underneath Slab 3 to position the plywood underneath it.

10:49:20	ENGR TECH 1 inserts hearing protection, starts saw, and resumes cutting of the West face. ENGR TECH 3 and ENGR TECH 6 have moved near the dumpster.
10:57:20	**ENGR TECH 1 completes cut of the entire West face.**
10:58:00	ENGR TECH 1 realizes the southwest corner of the south face is not fully cut. He walks the saw across slab underneath rigging from North to South (please see Figure A6.7.3). At this time the slab is almost completely free of the surrounding floor and suspended by the rigging. ENGR TECH 3 and ENGR TECH 6 watch from the west side of the dumpster.
10:58:15	ENGR TECH 1 positions the floor saw to cut the southwest corner of the south face, cutting towards the west. The main weight of the saw is not on the slab during Cut 6.
10:59:50	ENGR TECH 1 stops cutting. He walks across slab underneath rigging from the south to north (Figure A6.7.4) to retrieve something from the toolbox. ENGR TECH 3 and ENGR TECH 6 watch from the west side of the dumpster.
11:02:35	ENGR TECH 1 resumes cutting the southwest corner of the south face.
11:07:10	**ENGR TECH 1 completes cut of the entire South face. Slab 3 is now fully supported by the rigging.**
11:07:25	ENGR TECH 1 pulls the floor saw across the slab from the south to the north (Figure A6.7.5). At this time, the slab is completely free of the surrounding floor and fully suspended by the rigging. ENGR TECH 3 and ENGR TECH 6 watch from the west side of the dumpster.
11:08:15	ENGR TECH 1 grabs the crane remote and begins to lift slab out. The east face appears to be free, but the west face is not.
11:08:40	ENGR TECH 1 walks over to the northeast corner of Slab 3 and steps on it, first with one foot, then he puts his full weight on the slab (Figure A6.7.6). He tries to "rock" the slab while using the crane remote to lift the slab out for about 10 seconds. ENGR TECH 3 watches from the west side of the dumpster and ENGR TECH 6 watches from the east side of the dumpster.
11:09:00	ENGR TECH 1 walks over to northwest corner of Slab 3 and begins "stomping", presumably on the northwest tab. He appears to be using the crane remote at the same time.
11:09:40	ENGR TECH 1 returns to the northeast corner of the slab and again steps on it with his full weight while using the crane remote to lift the slab (Figure A6.7.7). ENGR TECH 3 watches from the west side of the dumpster and ENGR TECH 6 watches from the east side of the test frame.
11:09:50	ENGR TECH 1 heads back over to west face of Slab 3 and bends down to look at the cut. He appears to be using the crane remote as the slab is moving.
11:10:20	ENGR TECH 1 lowers the crane as the east face goes back down and slack can be seen in slings.

11:10:30	ENGR TECH 1 attempts to lift the slab again with the crane, but it still appears to be stuck on the west face.
11:11:05	ENGR TECH 3 ascends the scaffold stairs with a Sawzall.
11:11:10	With the rigging engaged and the slab sticking up and out of the East side, ENGR TECH 1 begins stomping again, presumably on the northwest tab.
11:11:35	ENGR TECH 3 joins ENGR TECH 1 near the west side of the slab. With the rigging engaged, ENGR TECH 3 uses the Sawzall to cut a portion of the steel decking in between the northwest tab and the main piece of Slab 3.
11:11:55	ENGR TECH 3 completes the cut and the northwest tab falls to the strong floor below. This matches the visual evidence at the incident site showing the steel decking underneath the northwest tab bent downwards (Figure A6.7.8). As the tab falls to the floor, Slab 3 moves in an uncontrolled fashion towards the east. ENGR TECH 1 and ENGR TECH 3 are less than a few feet from the slab.
11:12:10	ENGR TECH 1 uses the crane remote to lift the slab out.
11:12:35	ENGR TECH 1, near the northeast corner of Slab 3, uses his right foot to steady the slab as he is trying to lift it out.
11:12:45	ENGR TECH 1 moves over to west side of Slab 3 to assess why the slab is still stuck.
11:13:05	ENGR TECH 1 continues to use the crane to get the slab free. At 11:16:09, Slab 3 is clearly free.
11:13:15	ENGR TECH 1 moves north of the slab (standing on Slab 4) and continues lifting.
11:13:25	ENGR TECH 1, still north of the elevated Slab 3, moves the slab north in his direction. He is only a few feet from the slab. Both ENGR TECH 1 and ENGR TECH 3 are near an unprotected edge – the floor opening created by removing Slab 3.
11:13:30	ENGR TECH 1 uses his hand to steady the northwest corner of Slab 3 and walks over to stand near Slab 6 (Figure A6.7.9).
11:13:45	With Slab 3 in the air at least 3-4 feet, and twisting, ENGR TECH 1 uses his hand to steady the southwest corner, which has rotated towards him, and talks with ENGR TECH 3 who is over by the workbench.
11:14:15	ENGR TECH 1 begins moving Slab 3 south over the Slab 2 and Slab 1 cut bays.
11:14:35	With Slab 3 still moving south between the two columns to the south of Slab 1 cut bay, ENGR TECH 1 begins to walk away, taking his eyes off the load (Figure A6.7.10).
11:14:45	ENGR TECH 1 stops the crane before he and ENGR TECH 3 descend the scaffold stairs. Slab 3 remains suspended in the air while he is walking down the scaffolding. ENGR TECH 6, on the strong floor, is to the southeast of the slab (Figure A6.7.11). If the slab was to come down to the floor, he is within 15 feet of it.
11:15:10	ENGR TECH 1, now on the strong floor, begins to bring Slab 3 west and down.
11:15:30	ENGR TECH 1 stops the crane while Slab 3 is still positioned well off the ground (appears to be at the height of the surrounding floor) and swinging over the dumpster and goes to look at the strong floor area under the Slab 3 cut bay

	with ENGR TECH 3 (Figure A6.7.12). ENGR TECH 6 is at the southeast corner of the dumpster.
11:16:10	While still over by the Slab 3 cut bay, ENGR TECH 1 begins to lower Slab 3 while moving it towards the west side of the dumpster.
11:16:25	ENGR TECH 1 and ENGR TECH 3 are now near the northwest corner of the dumpster with the slab still at least 8 to 10 ft off the ground and near them.
11:17:30	After putting cribbing underneath the slab, it is now on the ground.
1:50:15	ENGR TECH 1 returns to the surrounding floor to install passive fall protection between Slabs 3 and 4 and Slabs 5 and 6. He is not wearing a hard hat.
1:51:50	ENGR TECH 1 walks within a few feet of the Slab 3 cut bay with no fall protection (Figure A6.7.13). He continues to install the passive fall protection for the next few minutes working within feet of the Slab 3 cut bay

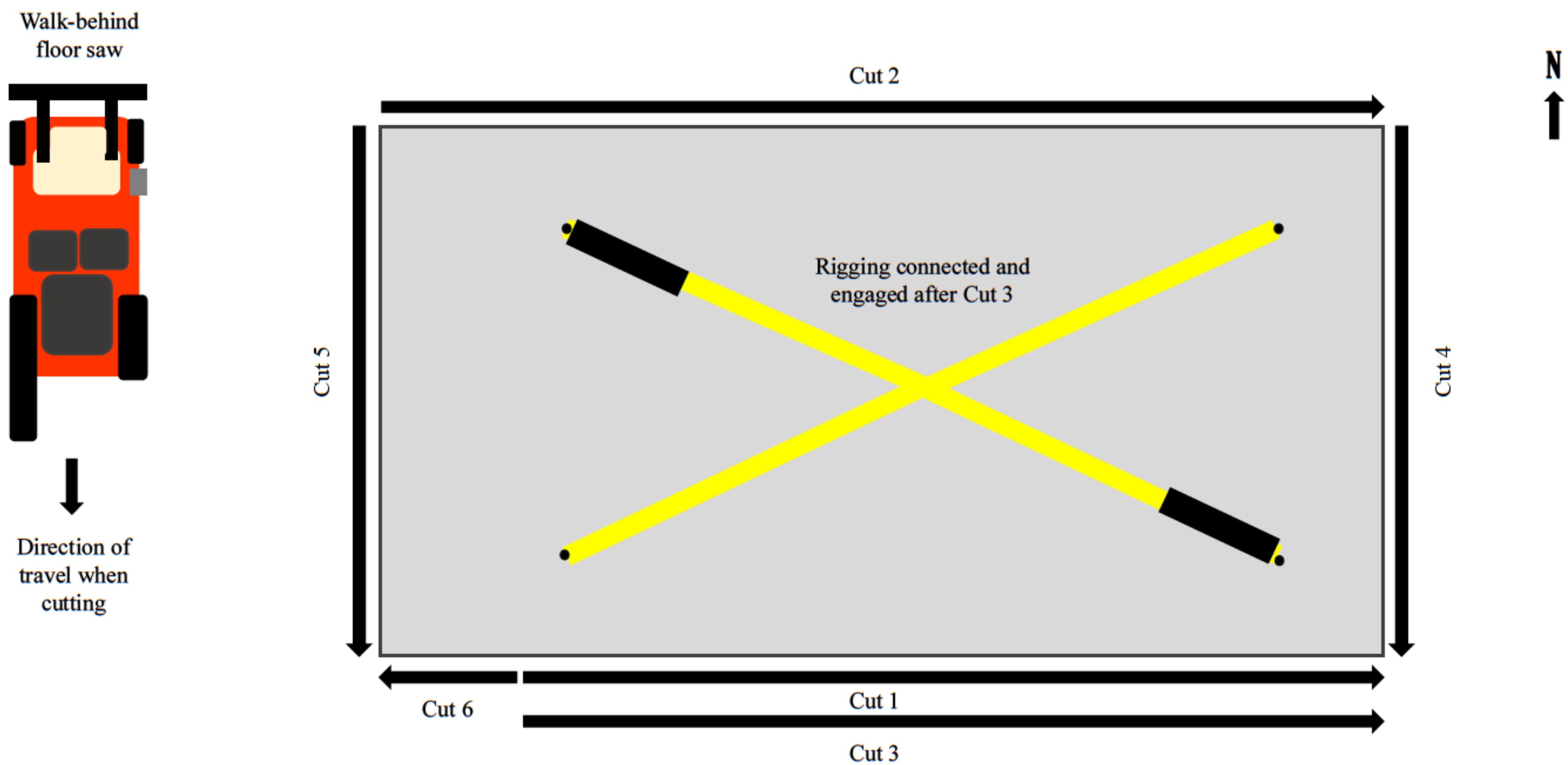


Figure A6.7.1: Schematic of Slab 3 showing the cutting and rigging sequence. The lengths of the cuts are approximate. The walk-behind floor saw (roughly to scale) is shown to help the Reader understand when the weight of the saw is on the slab while cutting.

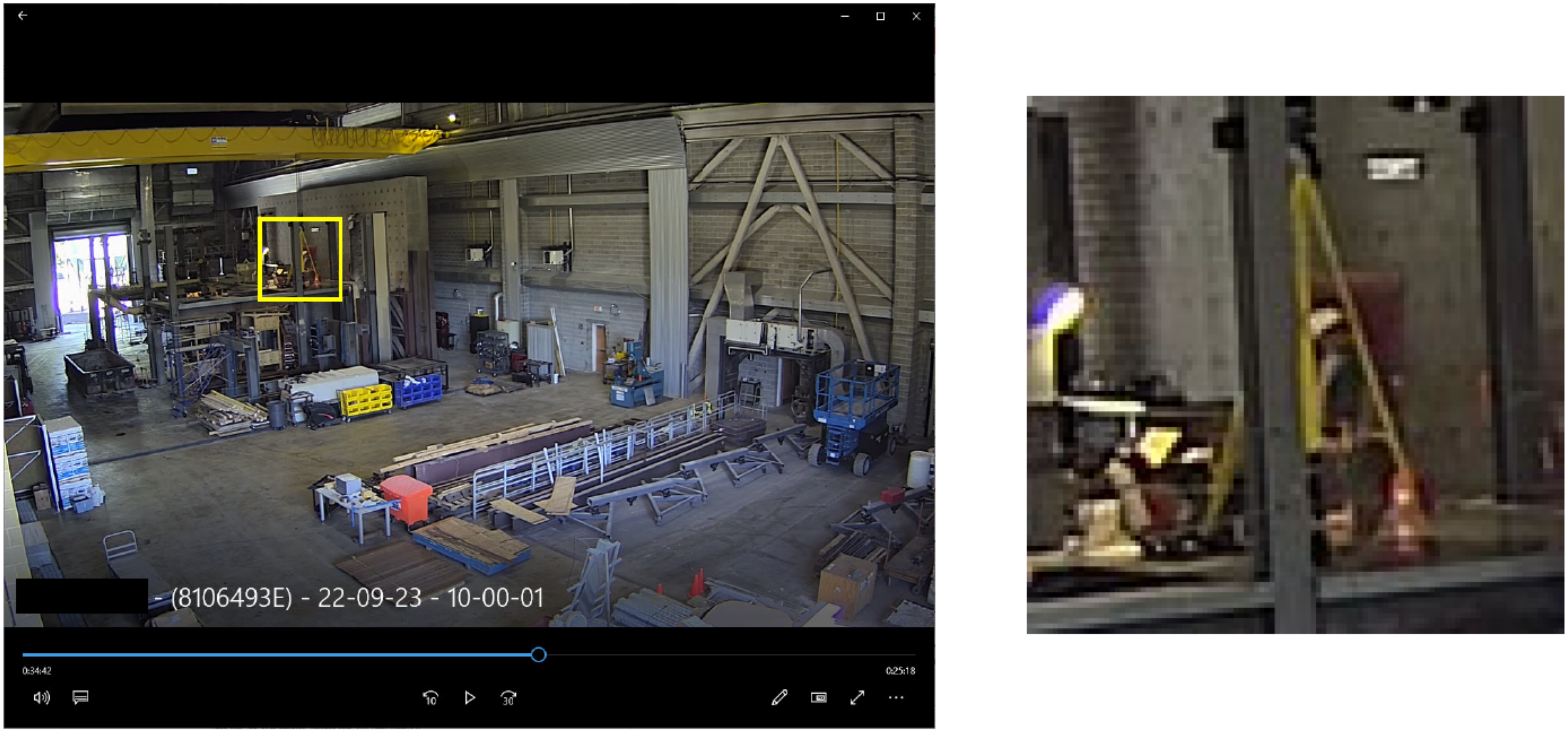
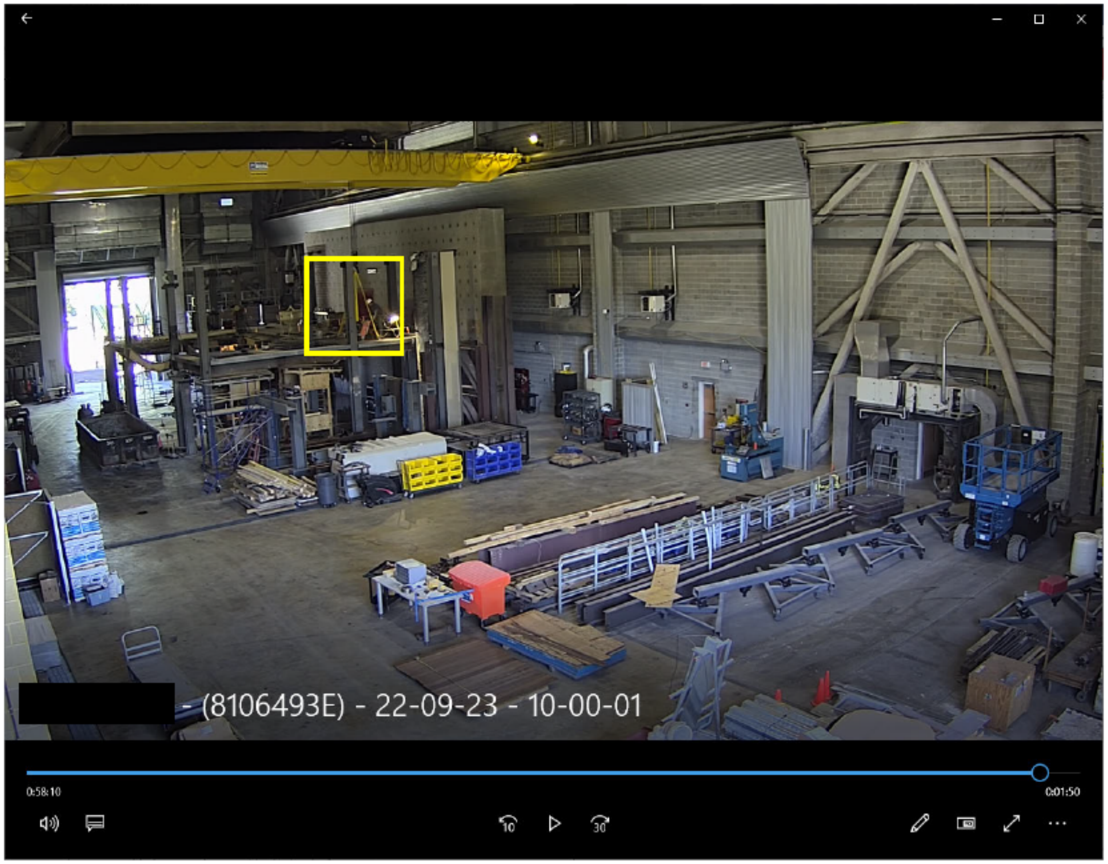


Figure A6.7.2: Image captured from video evidence (10:34:42 am ET) showing ENGR TECH 1 walking across Slab 3 from the north to the south. At this time, the north, east, and south faces of the slab are cut



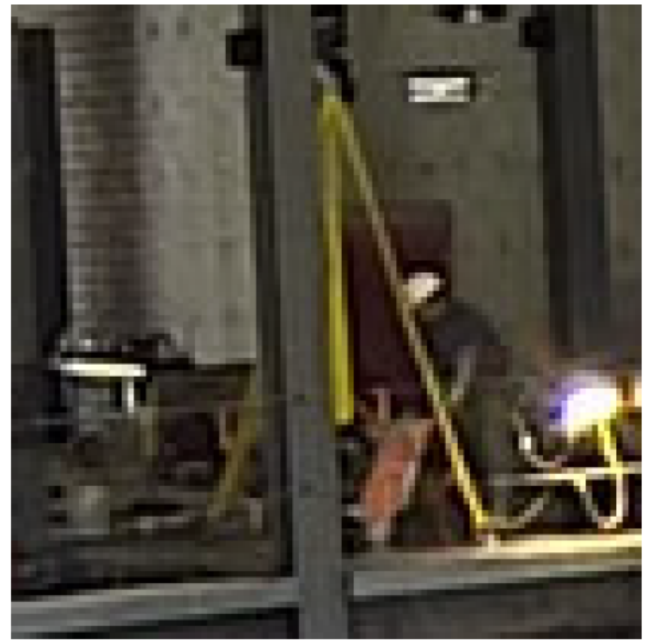
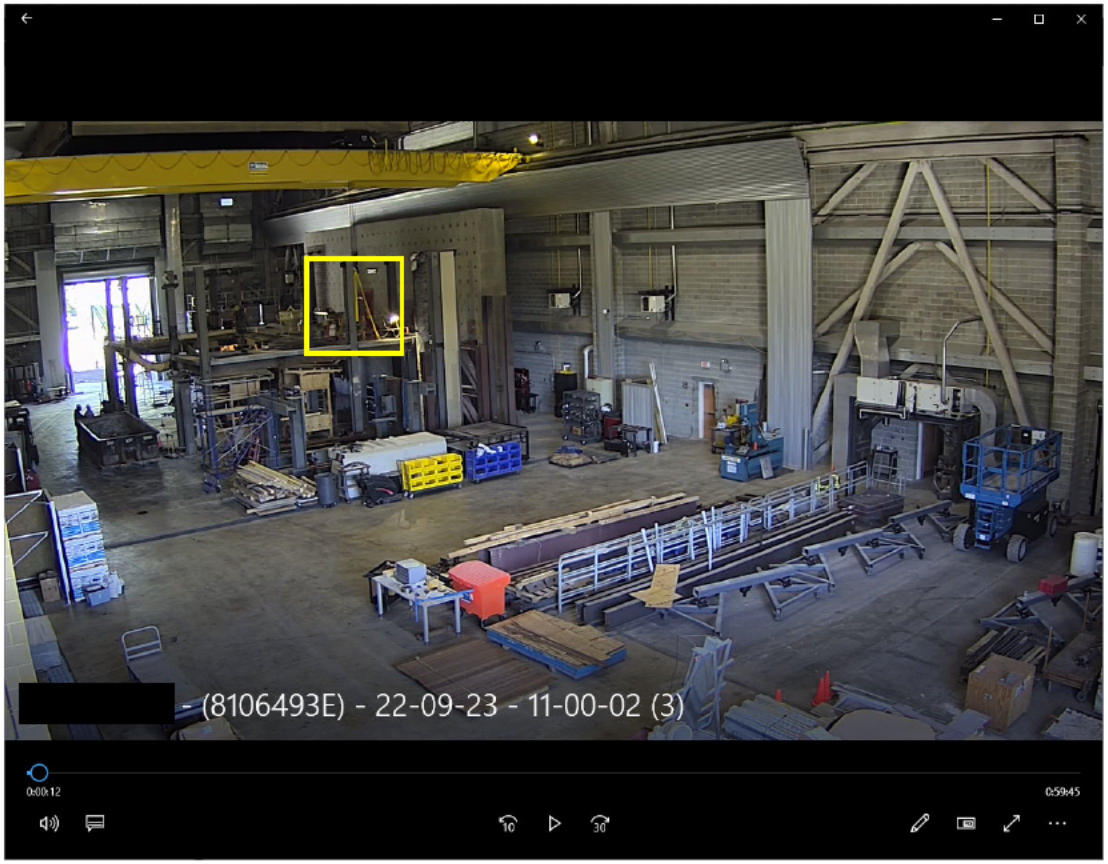


Figure A6.7.3: Image captured from video evidence (10:58:10 am ET) showing ENGR TECH 1 walking the saw across Slab 3 from the north to the south. At this time, the slab is almost completely free of the surrounding floor and suspended by the rigging.



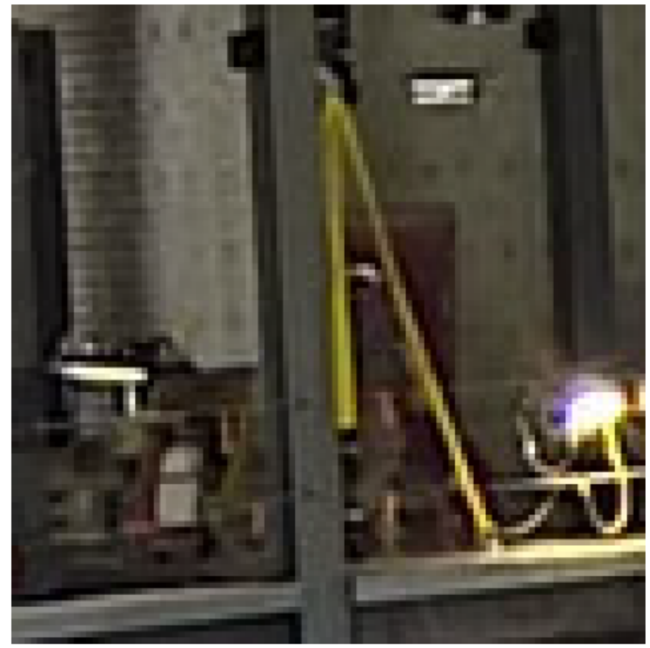
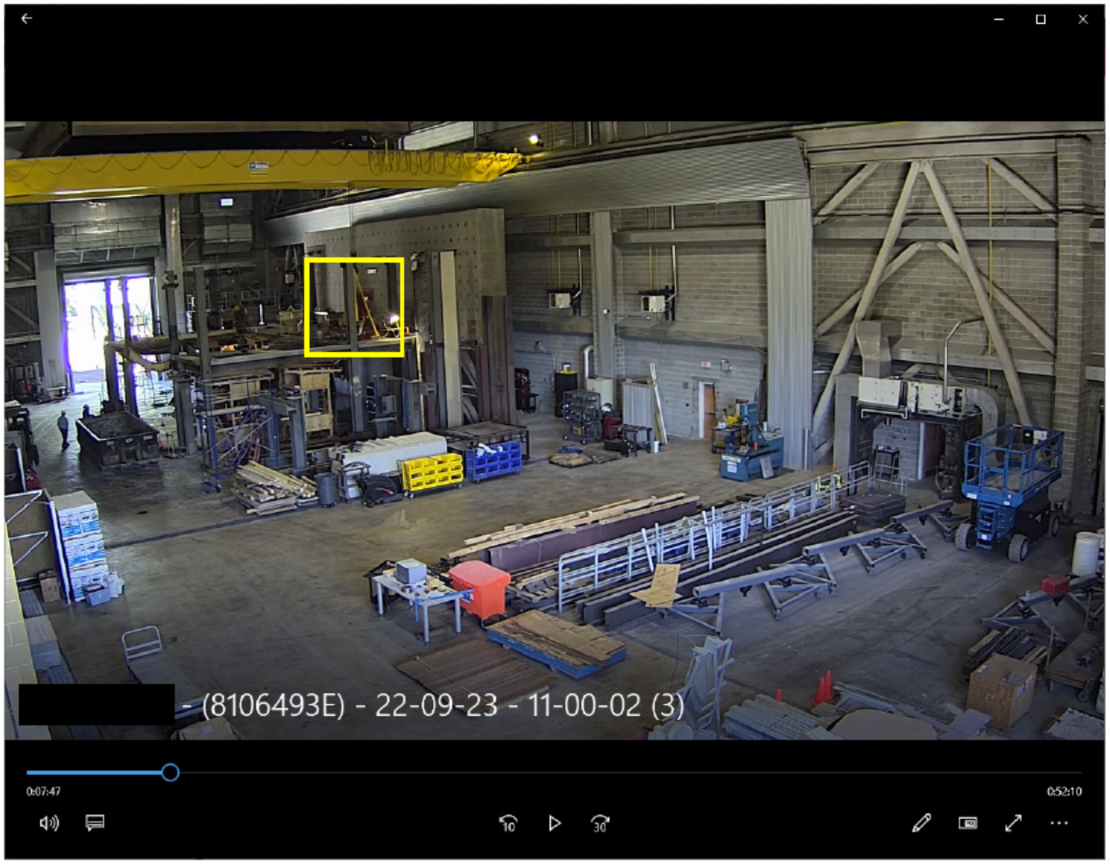


Figure A6.7.4: Image captured from video evidence (11:00:12 am ET) showing ENGR TECH 1 walking across Slab 3 from the south to the north. At this time, the slab is almost completely free of the surrounding floor and suspended by the rigging.



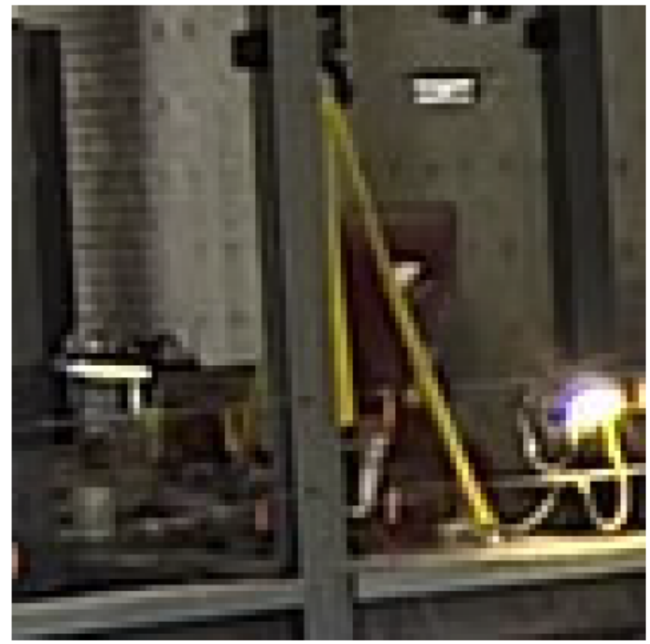


Figure A6.7.5: Image captured from video evidence (11:07:47 am ET) showing ENGR TECH 1 pulls the floor saw across Slab 3 from the south to the north. At this time, the slab is completely free of the surrounding floor and fully suspended by the rigging.

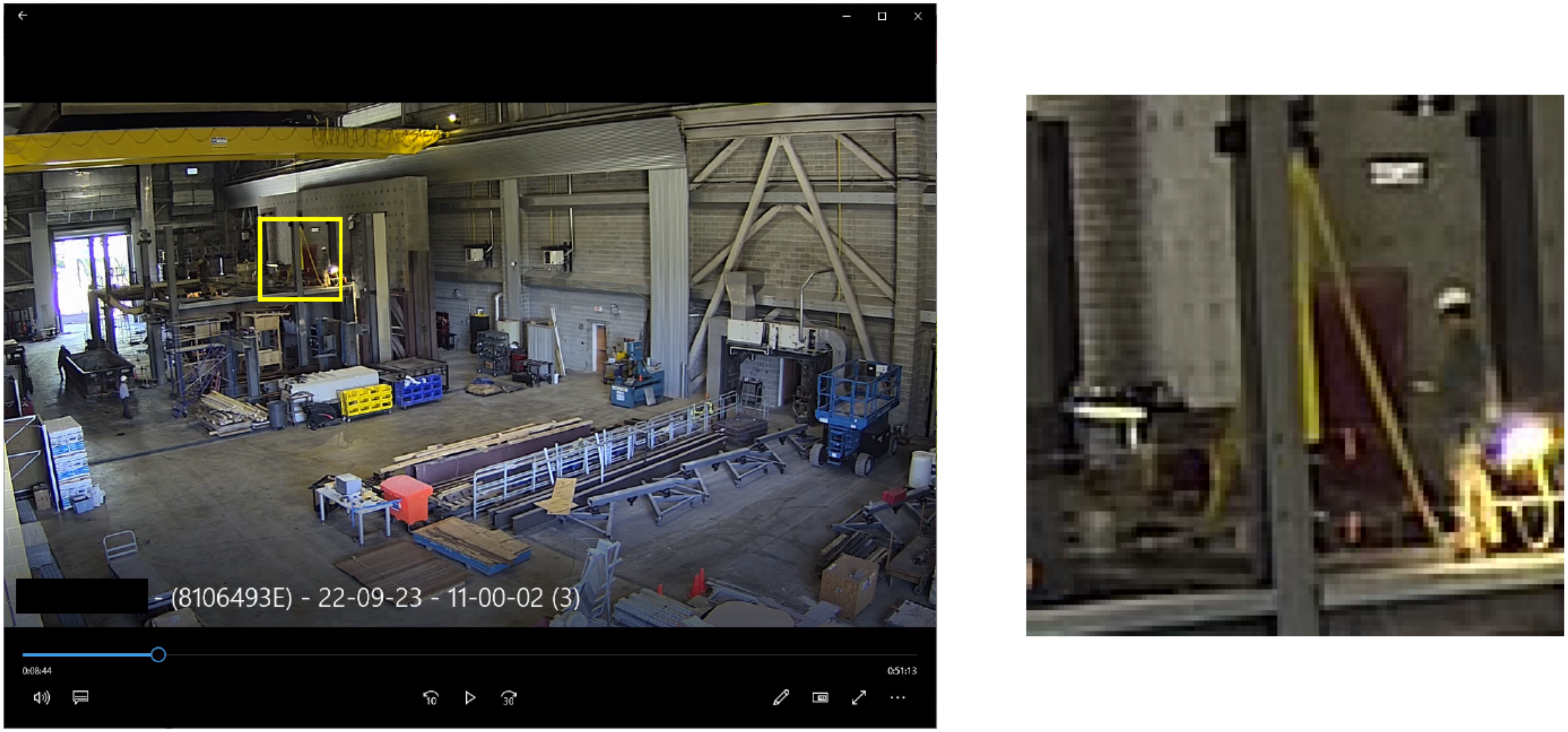
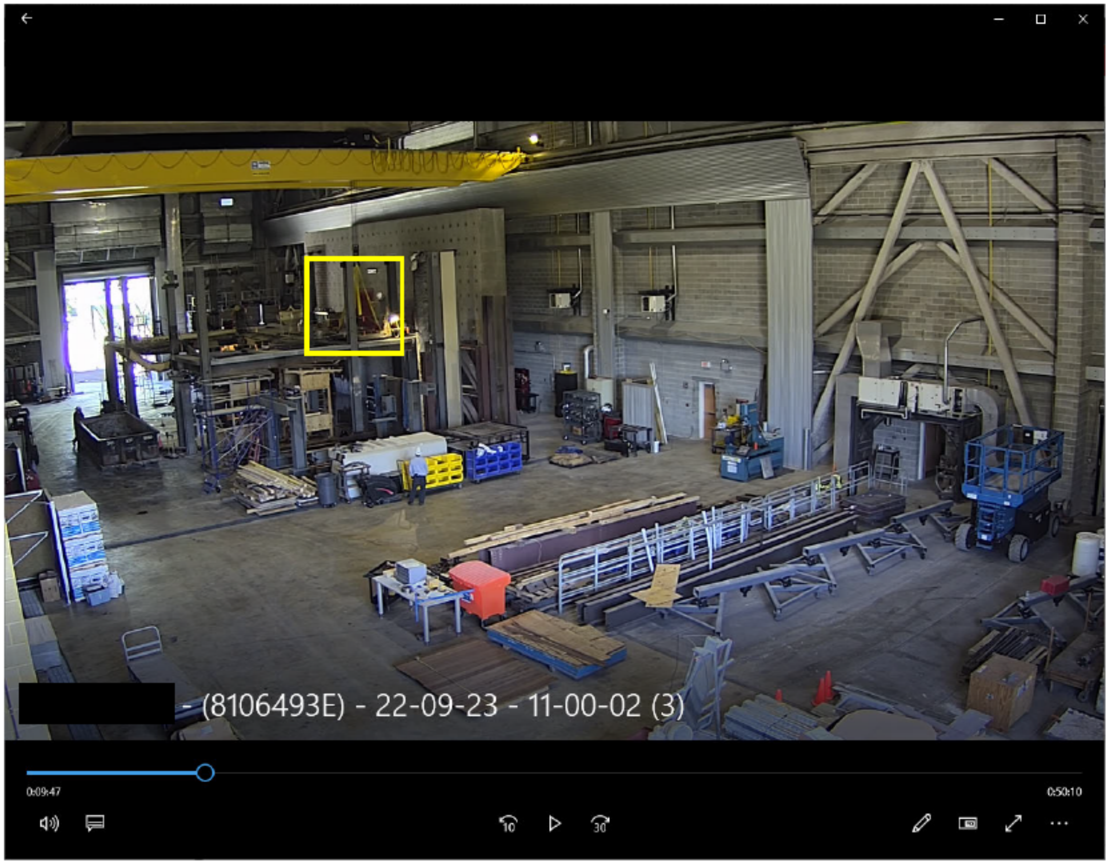


Figure A6.7.6: Image captured from video evidence (11:08:44 am ET) showing ENGR TECH 1 stepping on the northeast corner of Slab 3 with his full weight while operating the crane.



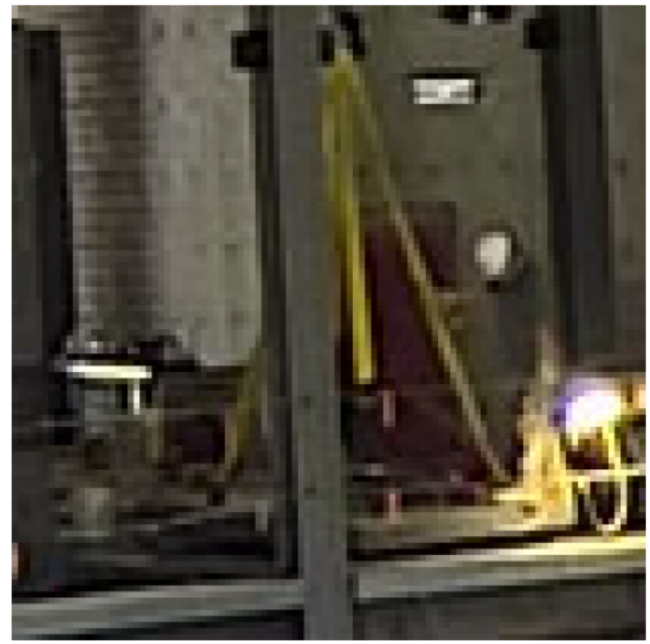
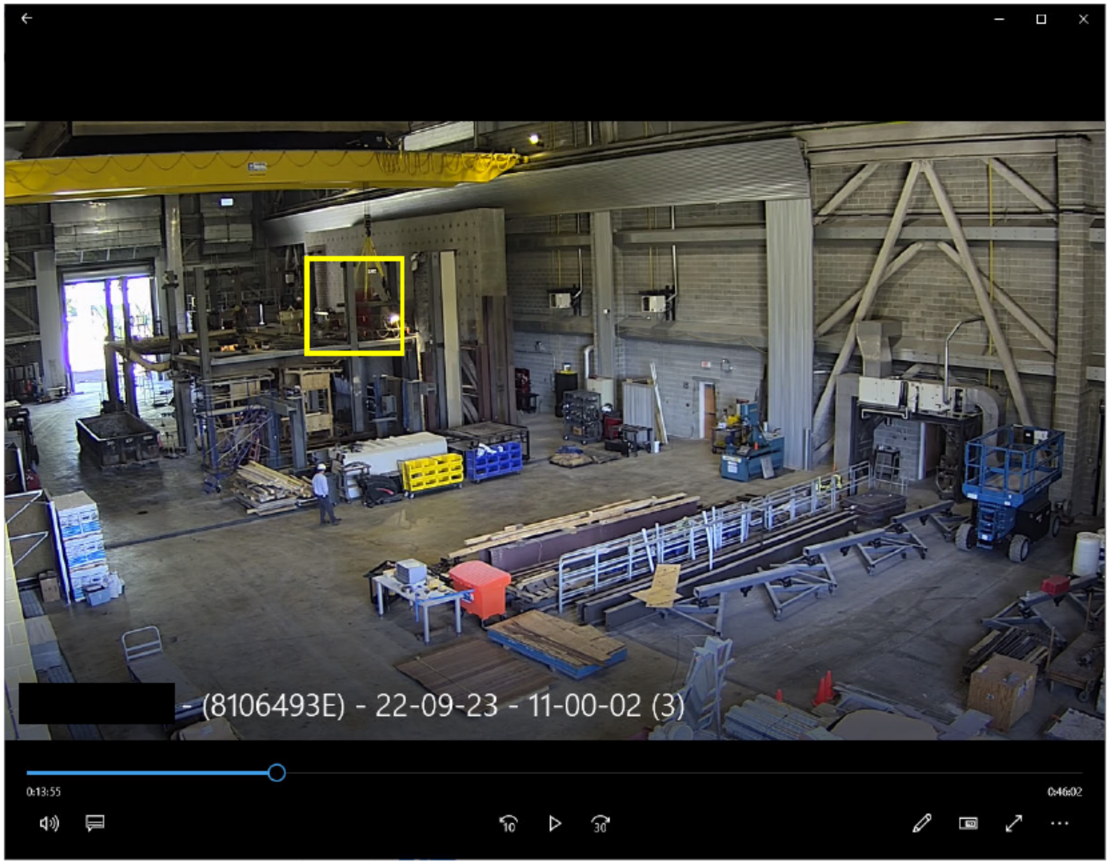


Figure A6.7.7: Image captured from video evidence (11:09:47 am ET) showing ENGR TECH 1 again stepping on the northeast corner of Slab 3 with his full weight while operating the crane.


Figure A6.7.8: Images of the Slab 3 cut bay showing the steel decking under the northwest tab being pushed downward after ENGR TECH 1 kicks the tab through the floor.



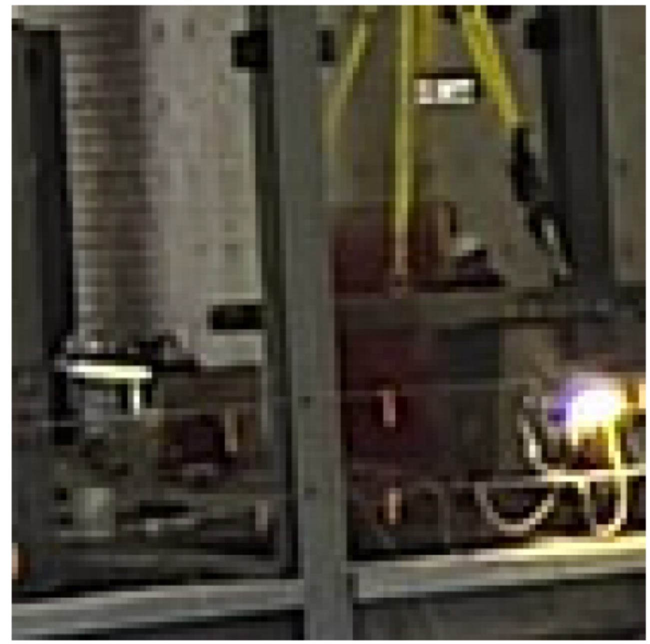


Figure A6.7.9: Image captured from video evidence (11:13:32 am ET) showing ENGR TECH 1 using his hand to steady the elevated Slab 3 while operating the crane.

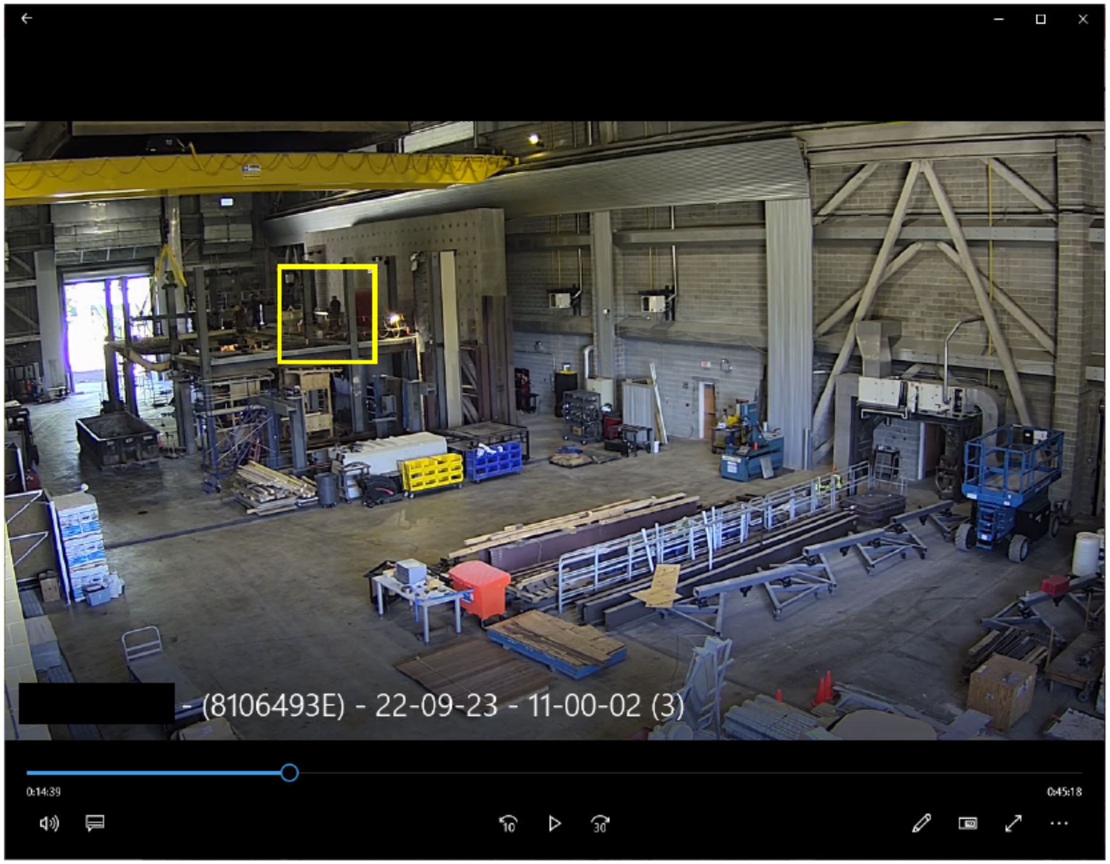


Figure A6.7.10: Image captured from video evidence (11:14:39 am ET) showing ENGR TECH 1 operating the crane while not observing the load.

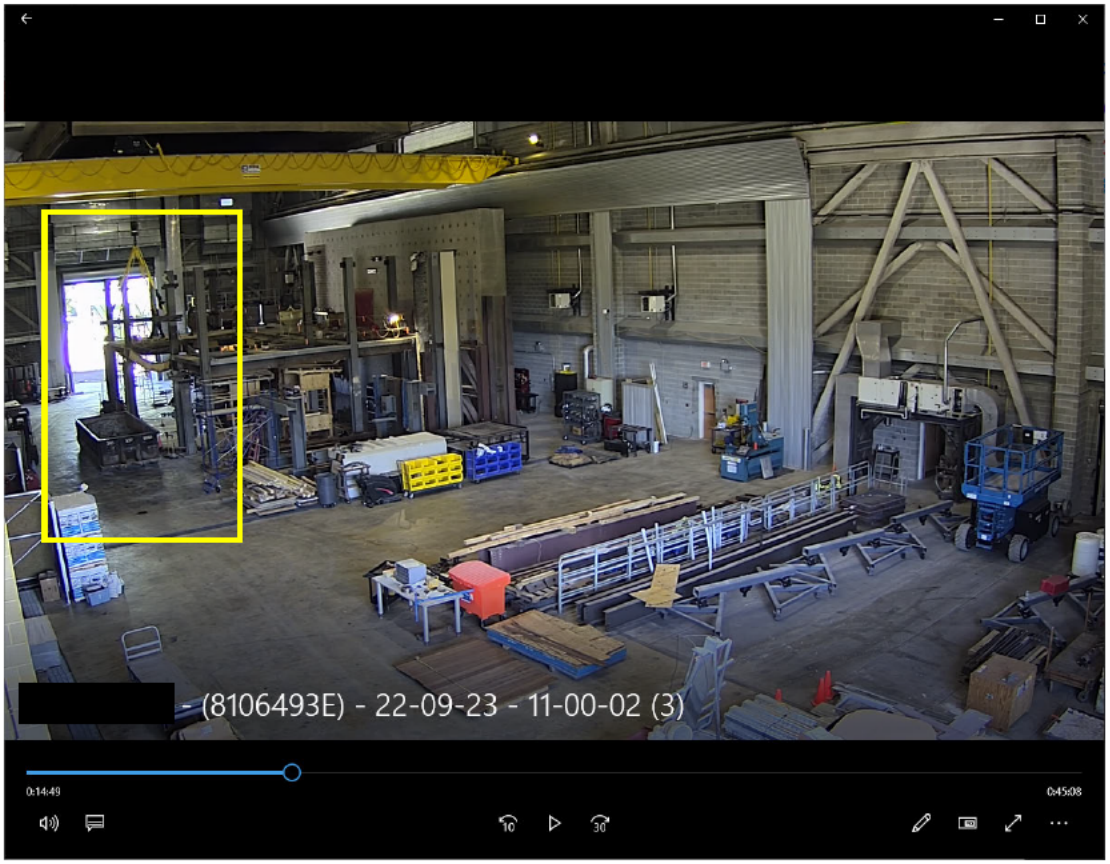


Figure A6.7.11: Image captured from video evidence (11:14:49 am ET) showing ENGR TECH 1 leaving the suspended load in the air while he descends the stairs. ENGR TECH 6, on the strong floor (arrow), is to the southeast of the slab. If the slab was to come down to the floor (hatched area), he is within 15 feet of it.

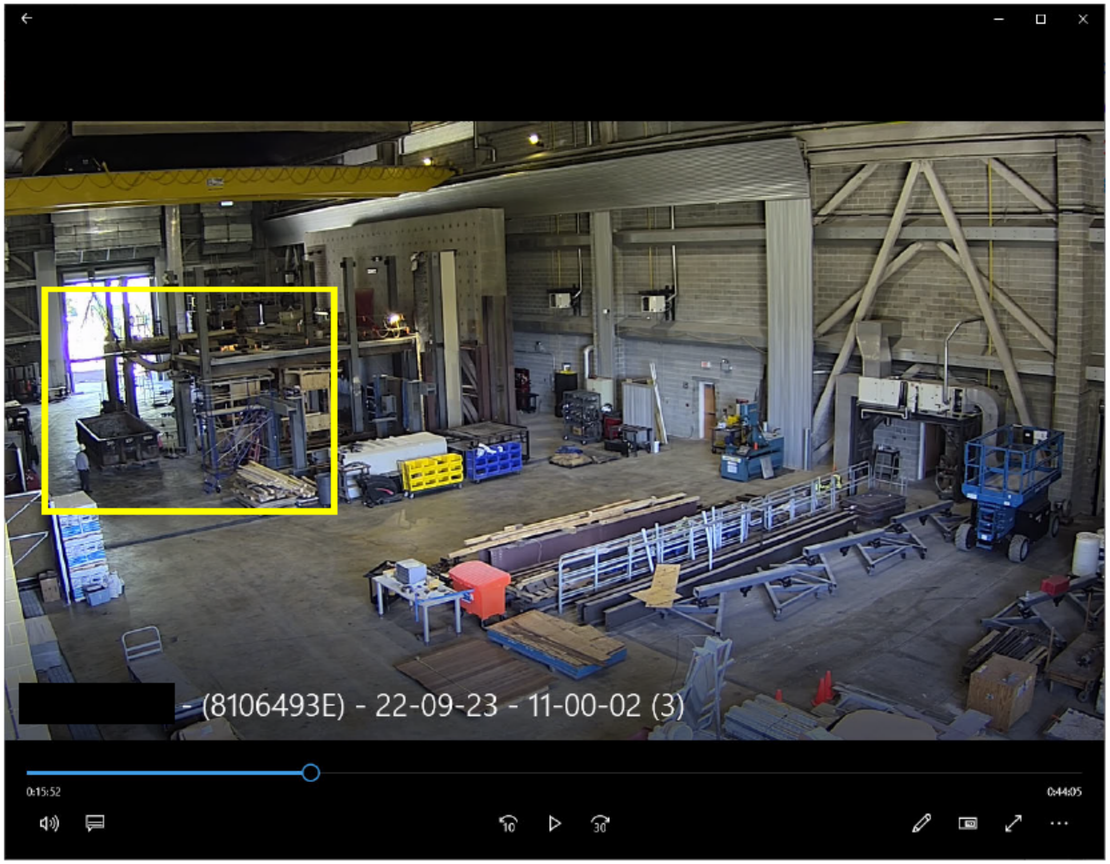


Figure A6.7.12: Image captured from video evidence (11:15:52 am ET) showing ENGR TECH 1 leaving the suspended load in the air while reviews the strong floor near the Slab 3 cut bay. ENGR TECH 6, on the strong floor (arrow), is to the southeast of the slab which is over the roll-off (hatched area).

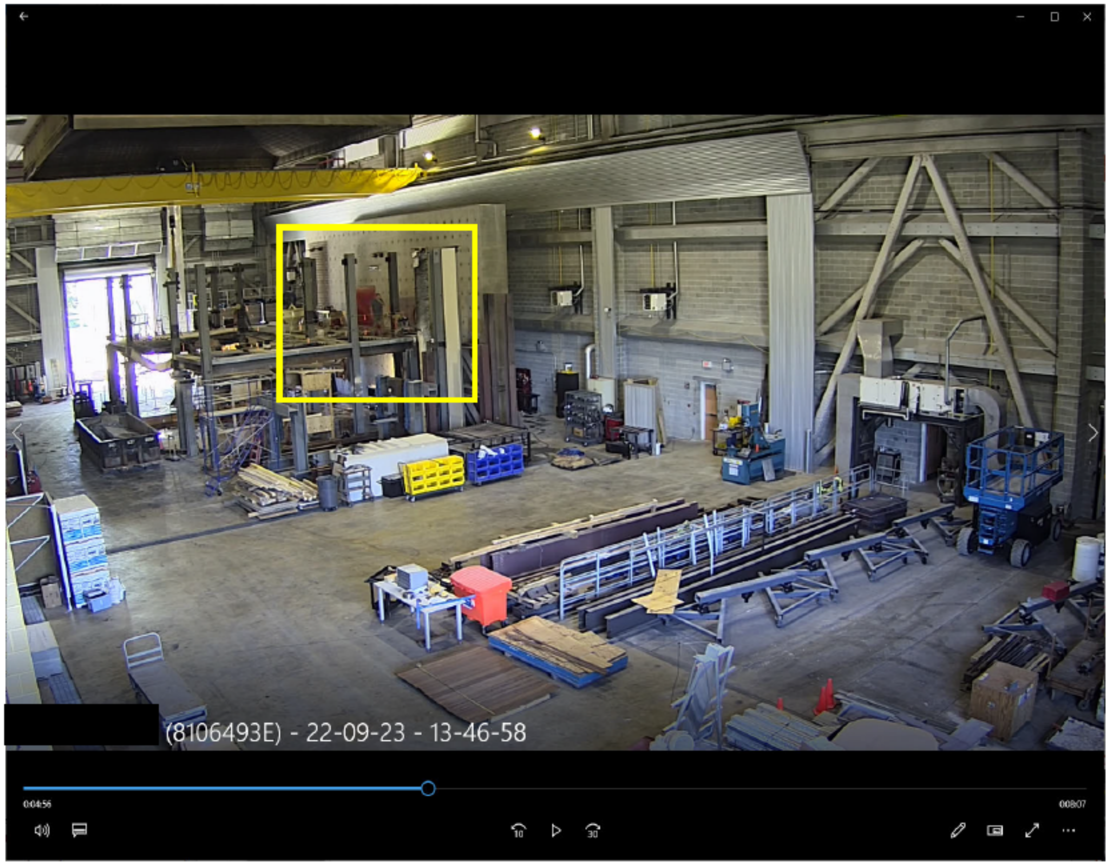


Figure A6.7.13: Image captured from video evidence (1:51:54 pm ET) showing ENGR TECH 1 walking within a few feet of the Slab 3 cut bay with no fall protection.

Appendix 6.7.2: Videographic Evidence of Slab 4 Demolition Activities

SLAB 4: The cutting of Slab 4 occurred on Monday, September 26, 2022.

8:01:00	ENGR TECH 1 arrives in Room 125 and enters Room 126.
8:06:40	ENGR TECH 1 ascends the scaffold stairs to the surrounding floor; he is wearing a hardhat.
8:07:10	ENGR TECH 1 dunks under passive fall protection to get from the Slab 5/6 area to the Slab 3/4 area. There is no fall protection for the Slab 3 cut bay and he is not wearing personal fall protection.
8:08:00	ENGR TECH 1 inserts hearing protection.
8:09:50	ENGR TECH 1 obtains the floor saw located on the eastern side of Slab 4 and positions it to cut the north face, cutting towards the west. The main weight of the saw is on the slab during Cut 1. Please see Figure A6.7.14 indicating the order of cutting.
8:10:30	ENGR TECH 1 starts the floor saw and begins to cut the north face, moving the saw in a western direction.
8:14:55	ENGR TECH 1 stops cutting; he appears to have cut only the northwest corner of the north face.
8:15:55	ENGR TECH 1 positions the floor saw to cut the west face, cutting towards the south. The main weight of the saw is on the slab during Cut 2.
8:16:30	ENGR TECH 1 starts cutting west face, moving the saw in a southern direction.
8:20:30	ENGR TECH 3 arrives in Room 125 and ascends the scaffold stairs to the surrounding floor; he is wearing a hardhat.
8:21:55	ENGR TECH 3 dunks under the passive fall protection to get from Bay 5/6 area to Bay 3/4 area. He walks by the Slab 3 cut bay where there is no passive fall protection. ENGR TECH 3 is not wearing personal fall protection.
8:24:05	ENGR TECH 1 stops cutting. He walks past the Slab 3 cut bay and joins ENGR TECH 3 near the Slab 1 cut bay to talk.
9:11:40	ENGR TECH 1 walks over to southwest corner of the Slab 3 cut bay. He and ENGR TECH 3 appear to be talking about the bay as ENGR TECH 1 points to it numerous times.
9:12:30	ENGR TECH 1 walks past the Slab 3 cut bay to perform small tasks near Slab 4. ENGR TECH 3 joins him. They are working north of Slab 3 cut bay, near the edge, with no fall protection.
9:12:45	ENGR TECH 3 is working directly to the west at the edge of the Slab 3 cut bay with no fall protection.
9:14:35	ENGR TECH 3 leaves the Slab 3/4 area soon joined by ENGR TECH 1 near the Slab 5/7 bays. They talk.
9:30:45	ENGR TECH 3 dunks under the passive fall protection going from Slab 5/6 area to the Slab 3 cut bay carrying a large hand tool. There is no fall protection for Slab 3 cut bay.
9:31:25	ENGR TECH 3 dunks under the passive fall protection going from Slab 5/6 area to the Slab 3 cut bay carrying a large jackhammer (Figure A6.7.15). There is no fall protection for Slab 3 cut bay. He carries it to the west of the Slab 2 and Slab 1 cut bays.

9:34:15	ENGR TECH 1 removes the passive fall protection between the Slab 5/6 area and the Slab 3/4 area.
9:35:25	ENGR TECH 1 inserts hearing protection, starts the floor saw, and restarts cutting the west face.
9:37:20	ENGR TECH 1 stops cutting; he appears to have cut only the southwest corner of the west face of Slab 4. He turns the floor saw around 180º and positions it to cut the west face, cutting towards the north. The main weight of the saw is not on the slab during Cut 3.
9:37:45	ENGR TECH 1 begins to cut the west face, moving the saw in a northern direction. He makes multiple cuts in this location.
9:39:15	ENGR TECH 3 walks from the Slab 5/6 area to the Slab 3 cut bay carrying two buckets. There is no fall protection for Slab 3 cut bay. He carries them to the west of the Slab 2 and Slab 1 cut bays.
9:39:25	ENGR TECH 3 walks along the thin concrete slab, approximately 60 cm (24 inches), between the Slab 2 and Slab 3 cut bays with no fall protection (Figure A6.7.16).
9:41:25	ENGR TECH 3 begins jackhammering the surrounding floor in the southeast corner of Slab 1 cut bay. He is wearing hearing protection but not wearing respiratory protection, it could not be determined if ENGR TECH 3 was wearing any type of eye or face protection.
9:49:00	ENGR TECH 1 stops cutting on the northwest corner of the west face of Slab 4. He turns the floor saw around 180º and positions it to cut the west face, cutting towards the south. The main weight of the saw is on the slab during Cut 4.
9:50:10	**ENGR TECH 1 completes cut of the entire west face.**
9:51:15	ENGR TECH 1 works to attach the cooling water hose to the passive fall protection on the North face of the test frame.
9:54:35	ENGR TECH 3 begins using an angle grinder on the surrounding floor in the southeast corner of Slab 1 cut bay. He is wearing hearing protection but does not appear to be wearing a face shield or respiratory protection. Larger showers of sparks are observed (Figure A6.7.17).
9:59:10	ENGR TECH 1 positions the floor saw to cut the east face, cutting towards the north. The main weight of the saw is on the slab during Cut 5.
10:00:45	ENGR TECH 1 starts the floor saw and begins cutting the east face, moving the saw in a northern direction.
10:05:25	ENGR TECH 1 stops cutting the slab. He then leaves the surrounding floor via the scaffold stairs and obtains a piece of plywood over on the east side of Room 125.
10:09:05	ENGR TECH 1 ascends the scaffold stairs to the surrounding floor carrying the piece of plywood. He walks over and places the piece of plywood over the northwest tab section of Slab 3 cut bay. ENGR TECH 1 then walks over and talks with ENGR TECH 3 near the Slab 1 cut bay.
10:10:50	ENGR TECH 1 obtains a gas can and begins filling up the floor saw.

10:13:15	ENGR TECH 1 starts the floor saw and finishes the cut of the northeast corner of the east face.
10:18:55	ENGR TECH 1 turns the floor saw around 180º and positions it to cut the east face, cutting towards the south. The main weight of the saw is not on the slab during Cut 6.
10:20:20	ENGR TECH 1 begins to cut the east face, moving the saw in a southern direction.

10:26:05 ENGR TECH 1 completes cut of the entire east face.

10:26:15	ENGR TECH 1 positions the floor saw to cut the north face, cutting towards the east. The main weight of the saw is not on the slab during Cut 7. In order to do this, he maneuvers the floor saw on the slab which has its east and west faces fully cut and a portion of the north face cut (Figure A6.7.18).
10:27:10	ENGR TECH 1 begins to cut the north face, moving the saw in an eastern direction.
10:34:25	ENGR TECH 1 stops cutting the north face.
10:35:20	ENGR TECH 1 leaves the surrounding floor via the scaffold stairs and obtains the crane remote.
10:36:20	ENGR TECH 1 opens up the west high bay door.
10:37:15	ENGR TECH 1 opens up the east high bay door.
10:37:55	ENGR TECH 1 ascends the scaffold stairs to the surrounding floor with the crane remote. When he gets onto the surrounding floor, he begins operating the crane to move it and the rigging over to the Slab 4 area. There is no evidence a functional inspection of the crane was performed.
10:38:55	ENGR TECH 1 moves the floor saw so it is positioned over Slab 4.
10:39:35	ENGR TECH 1 grabs one sling with the black plastic bag on it and positions it in the southeast rigging location.
10:40:00	ENGR TECH 1 grabs one sling with the black plastic bag on it and positions it in the southwest rigging location.
10:40:55	ENGR TECH 1 grabs one sling without the black plastic bag on it and positions it in the northwest rigging location.
10:41:15	ENGR TECH 1 grabs one sling without the black plastic bag on it and positions it in the northeast rigging location (Figure A6.7.19).
10:42:35	ENGR TECH 1 leaves the surrounding floor via the scaffold stairs to connect the rigging from below.
10:48:40	ENGR TECH 1 ascends the scaffold stairs to the surrounding floor and walks over to the Slab 4 area where he engages the rigging.
10:49:35	ENGR TECH 1 obtains the floor saw and positions it to finish cutting the north face in the northeast corner, cutting towards the east. The main weight of the saw is not on the slab during Cut 8.
10:50:50	ENGR TECH 1 starts the floor saw and begins to cut the north face, moving the saw in an eastern direction.

11:19:35	ENGR TECH 1 stops cutting and turns the floor saw around 180º and positions it to face the north face, cutting towards the west. In order to do this, he maneuvers the floor saw on the slab which has its east and west faces fully cut and a major portion of the north face cut (Figure A6.7.20). During the final cut on the north face, the main weight of the saw is on the slab during Cut 9.
11:20:00	ENGR TECH 1 begins to cut the north face, moving the saw in a western direction.
11:21:05	**ENGR TECH 1 completes cut of the entire North face.**
11:21:15	ENGR TECH 1 leaves the saw on the north side of Slab 4 and walks across Slab 4 from the north to the south underneath the rigging to talk with ENGR TECH 3 (Figure A6.7.21). At this time, the north, east, and west faces are completely cut.
11:25:20	ENGR TECH 1 leaves the surrounding floor via the scaffold stairs, followed by ENGR TECH 3.
12:27:55	ENGR TECH 1 obtains a pallet jack and begins moving boxes and pallets along the east side of the Room 125. He is not wearing a hard hat.
12:30:45	ENGR TECH 1 ascends the scaffold stairs to the surrounding floor and begins measuring the Slab 3 cut bay width.
12:31:45	ENGR TECH 1 leaves the surrounding floor via the scaffold stairs and walks back over to the east side of Room 125 where he makes measurements and continues using the pallet jack.
12:36:30	ENGR TECH 1 obtains the fork truck to use over on the east side of Room 125. It is evident no daily pre-use inspection was performed.
12:37:35	ENGR TECH 1 exits the fork truck. It is evident he did not put his seatbelt on before operating the fork truck.
12:38:45	ENGR TECH 1 obtains a pallet with angle iron on it. He transports the pallet into the fire compartment area of the test frame and raises it up to the surrounding floor.
12:41:00	ENGR TECH 1 leaves the fork truck and ascends the scaffold stairs to the surrounding floor.
12:41:50	ENGR TECH 1 puts on a hard hat.
12:43:15	ENGR TECH 1 grabs a piece of angle iron and puts down over Slab 3 cut bay (Figure A6.7.22).
12:43:45	ENGR TECH 1 removes the piece of plywood he put down earlier in the day over the NW tab of the Slab 3 cut bay. There is no fall protection for Slab 3 cut bay.
12:44:05	ENGR TECH 1 inserts hearing protection.
12:44:15	ENGR TECH 1 walks across Slab 4 from the south to the north underneath the rigging to obtain the floor saw. He obtains the saw and pushes it across Slab 4 from the north to the south underneath the rigging (Figure A6.7.23). This results in the cooling water hose attached to the saw running across the slab from the north to the south between the east and west rigging locations. ENGR TECH 1

	then pulls the saw to the east side of Slab 4 to position it to cut the south face, cutting towards the West. The main weight of the saw is not on the slab during Cut 10.
12:45:00	ENGR TECH 1 begins to cut the south face, moving the saw in a western direction.
1:04:30	**ENGR TECH 1 completes cut of the entire south face. Slab 4 is now fully supported by the rigging.**
1:04:40	ENGR TECH 1 begins to back the floor saw up, moving east. In the process he puts his full weigh on the suspended slab near the mid-point of the slab (Figure A6.7.24).
1:04:50	ENGR TECH 1 bends down to move the cooling water hose to the west.
1:04:55	ENGR TECH 1, fully on the slab underneath the rigging, continues to turn the saw counterclockwise to face the south so he can drag it north across the slab.
1:04:58	ENGR TECH 1 has turned the saw to the south and begins to pull it back across the slab (Figure A6.7.25).
1:04:59	Slab 4 sustains catastrophic failure as the rear wheels of the saw come onto the slab resulting in the fatal fall of ENGR TECH 1.

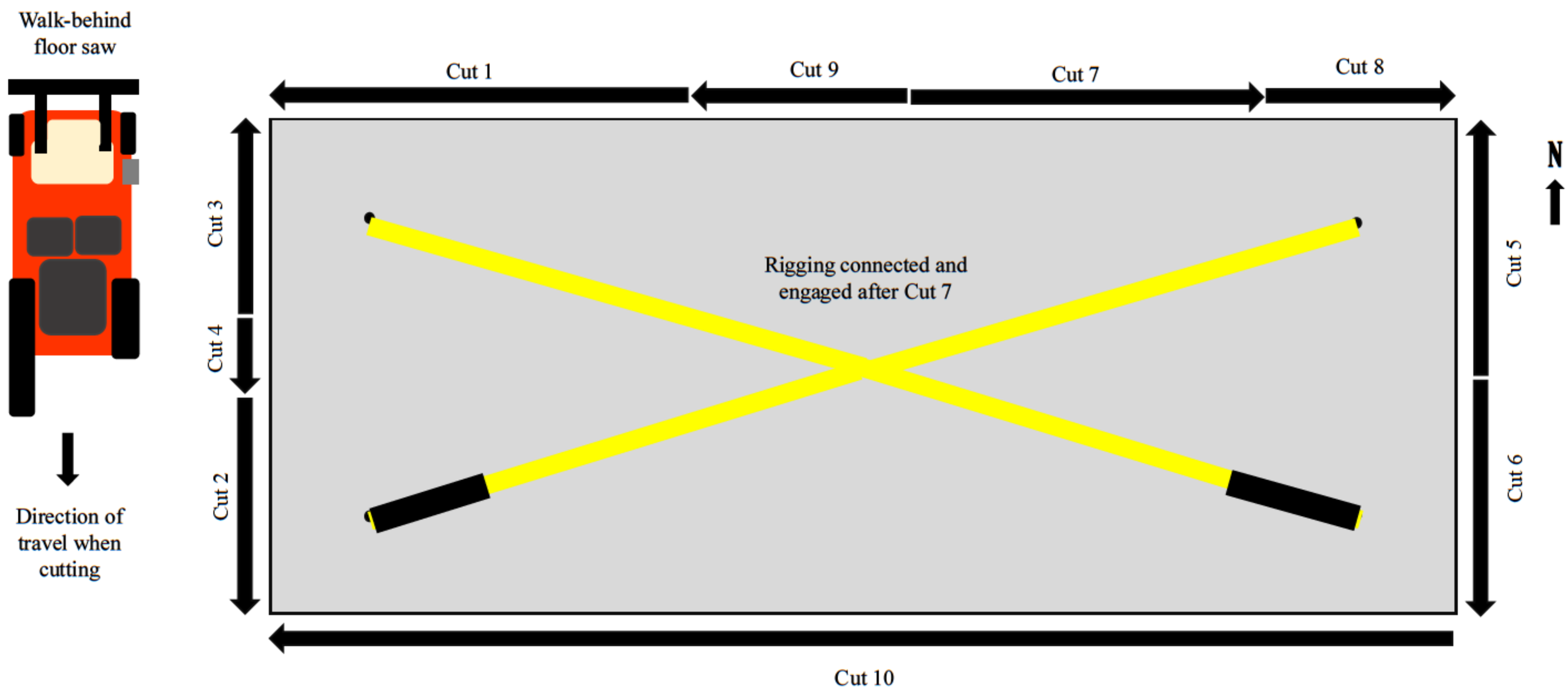
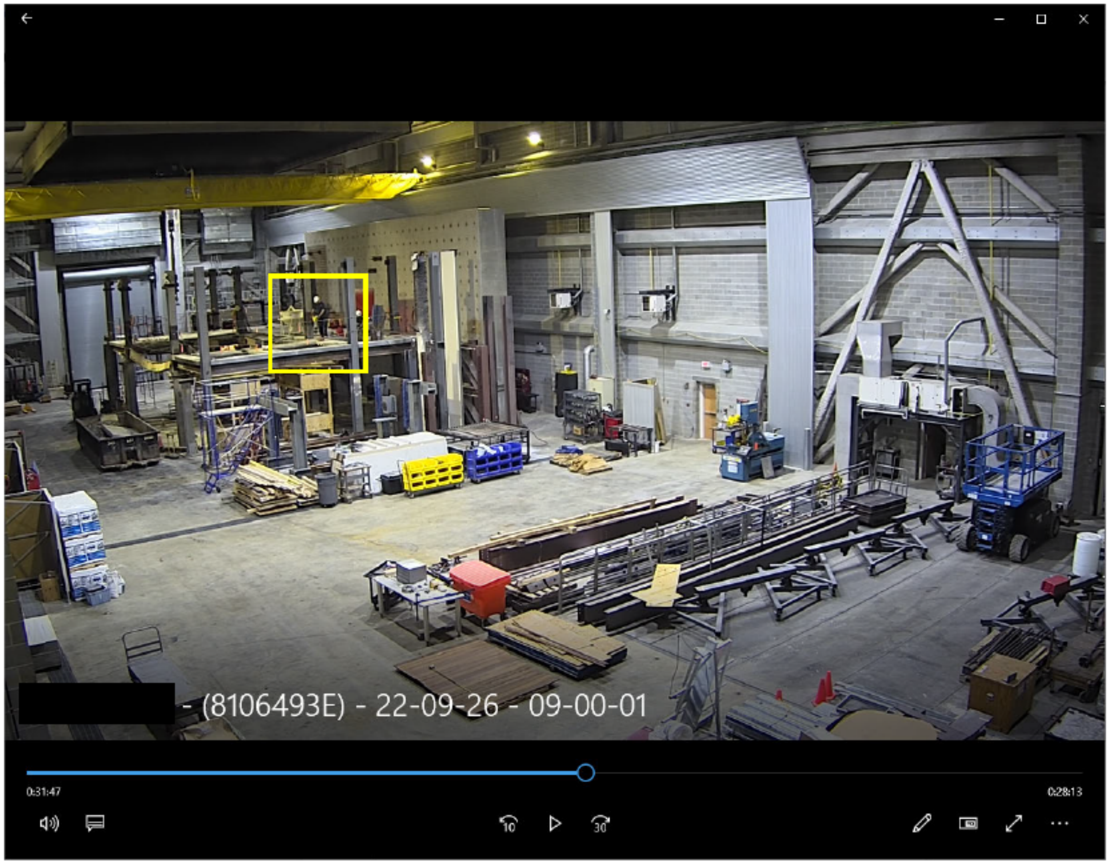


Figure A6.7.14: Schematic of Slab 4 showing the cutting and rigging sequence. The lengths of the cuts are approximate. The walk-behind floor saw (roughly to scale) is shown to help the Reader understand when the weight of the saw is on the slab while cutting.



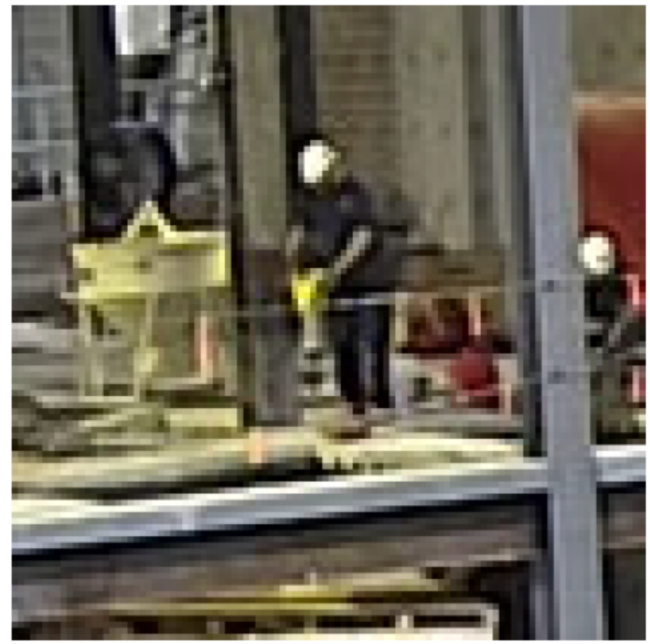


Figure A6.7.15: Image captured from video evidence (9:31:47 am ET) showing ENGR TECH 3 carrying a large jackhammer to the west of the Slab 3 cut bay with no fall protection.

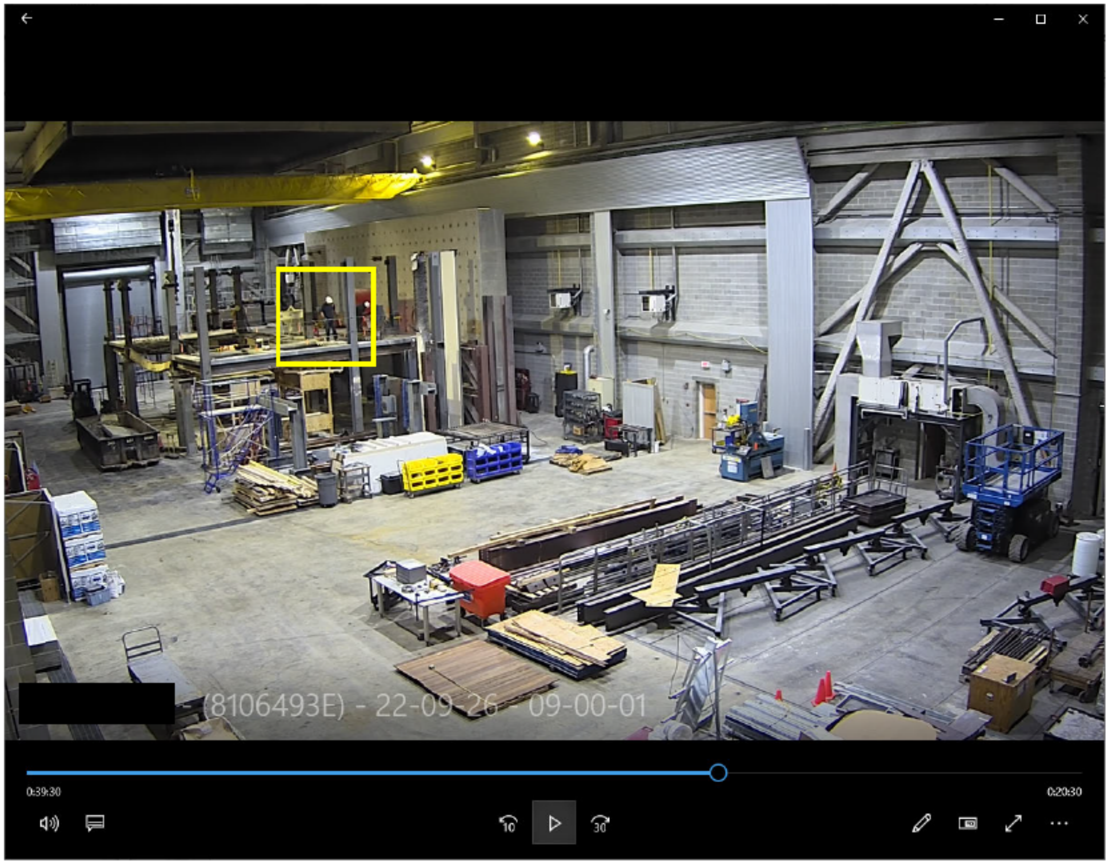


Figure A6.7.16: Image captured from video evidence (9:39:30 am ET) showing ENGR TECH 3 walking on the narrow concrete slab between the cut bays for Slab 2 and 3.

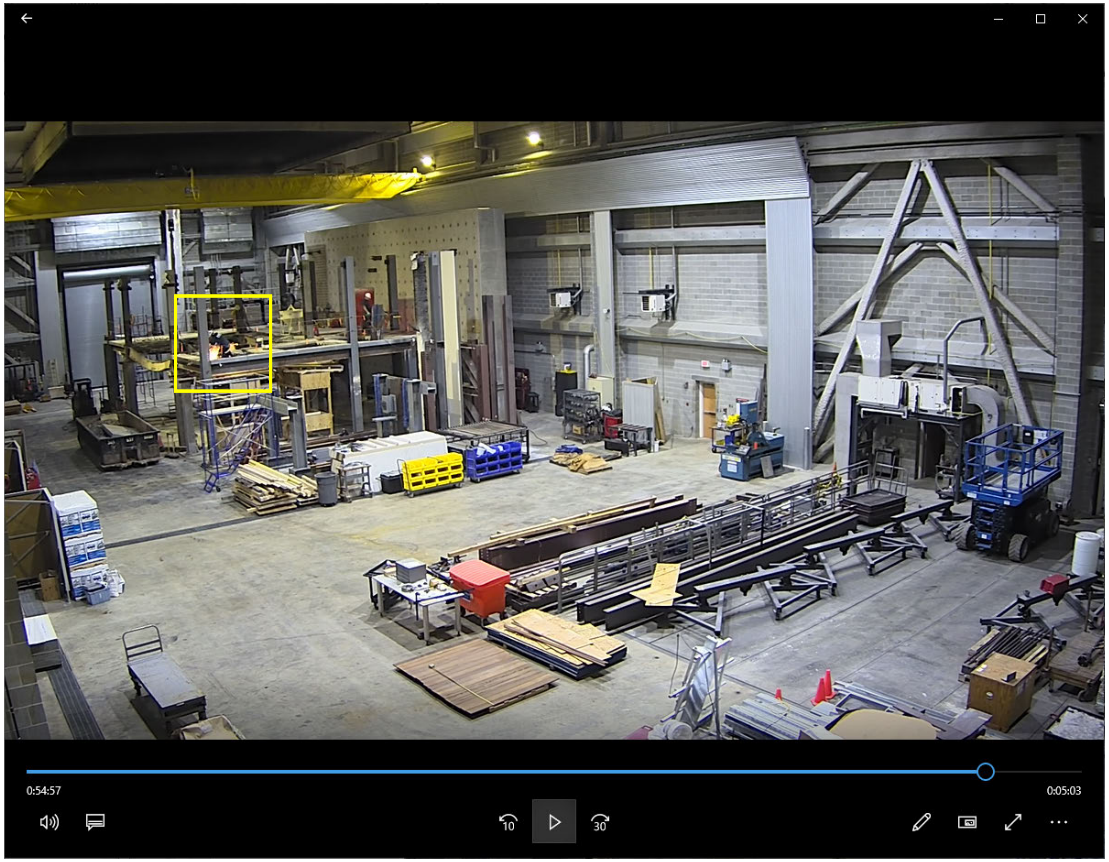
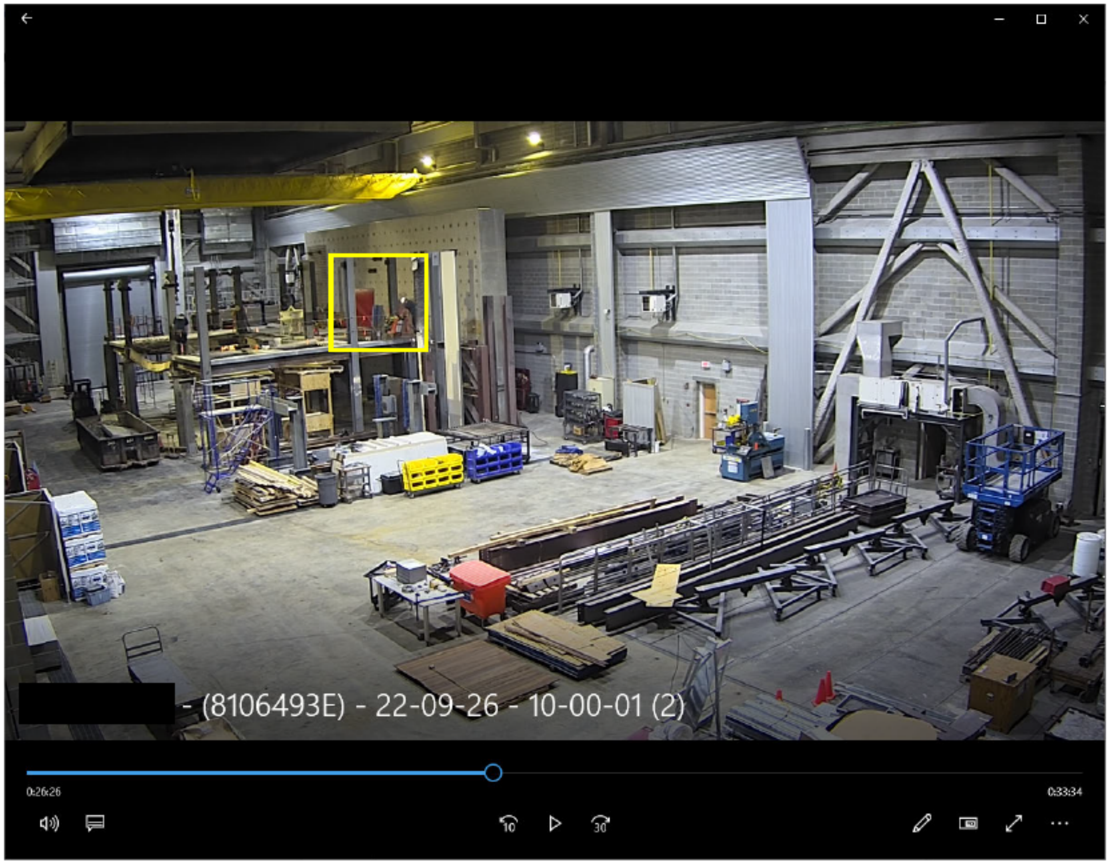


Figure A6.7.17: Image captured from video evidence (9:54:57 am ET) showing ENGR TECH 3 using an angle grinder with no apparent face shield or respiratory protection.



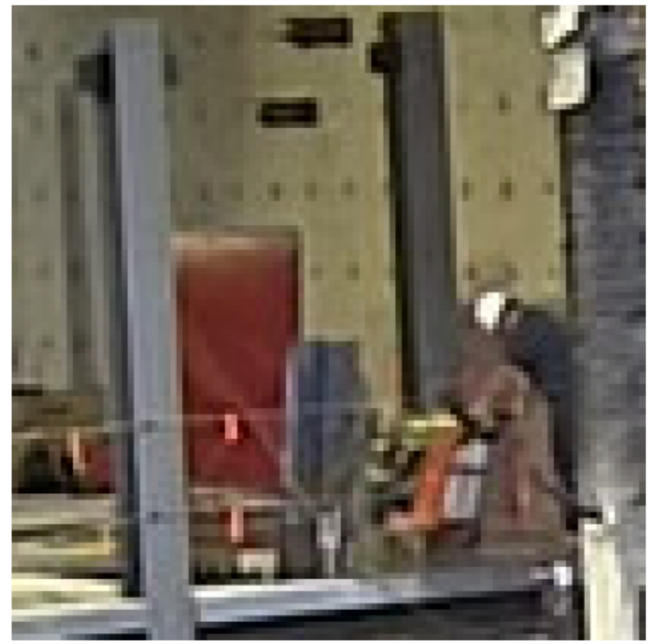


Figure A6.7.18: Image captured from video evidence (10:26:26 am ET) showing ENGR TECH 1 repositioning the floor saw by maneuvering it on Slab 4 while the east and west faces and a portion of the north face are cut. Rigging has not yet been connected.

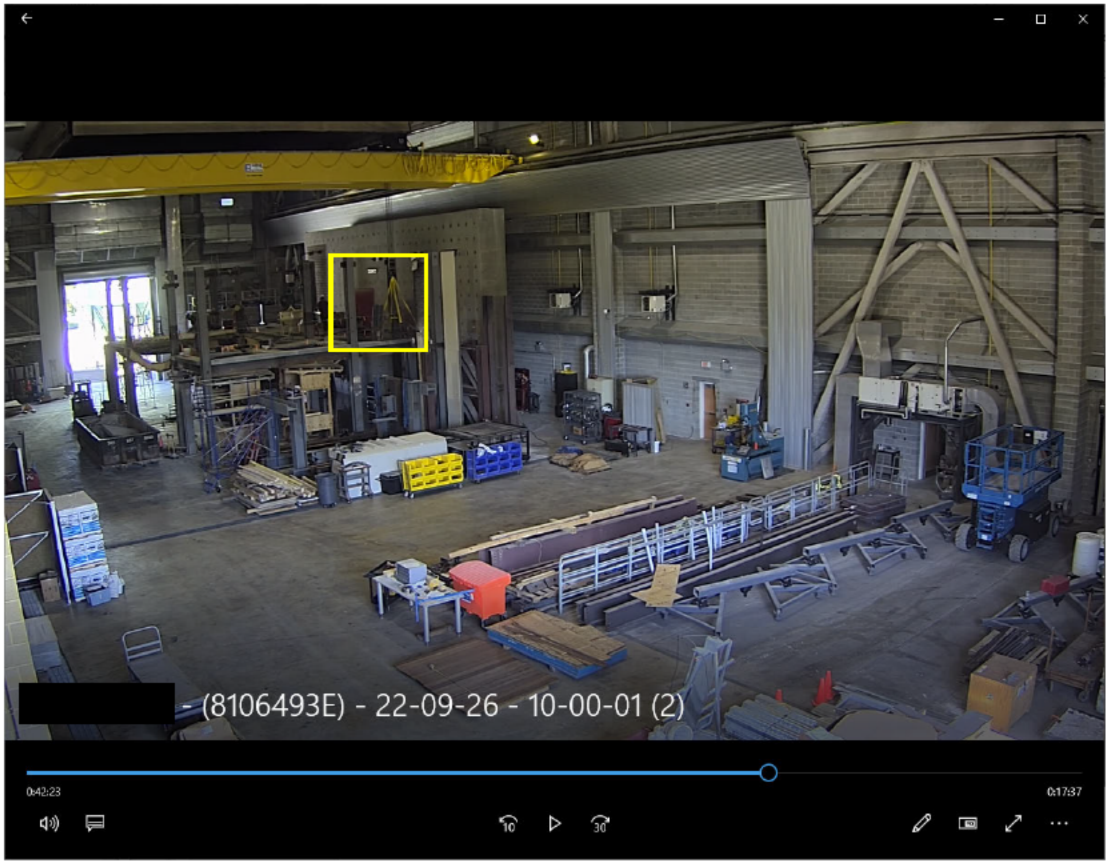


Figure A6.7.19: Image captured from video evidence (10:42:23 am ET) showing the black bags on south slings. The southeast sling is shown (yellow arrow) while the southwest sling is obscured.

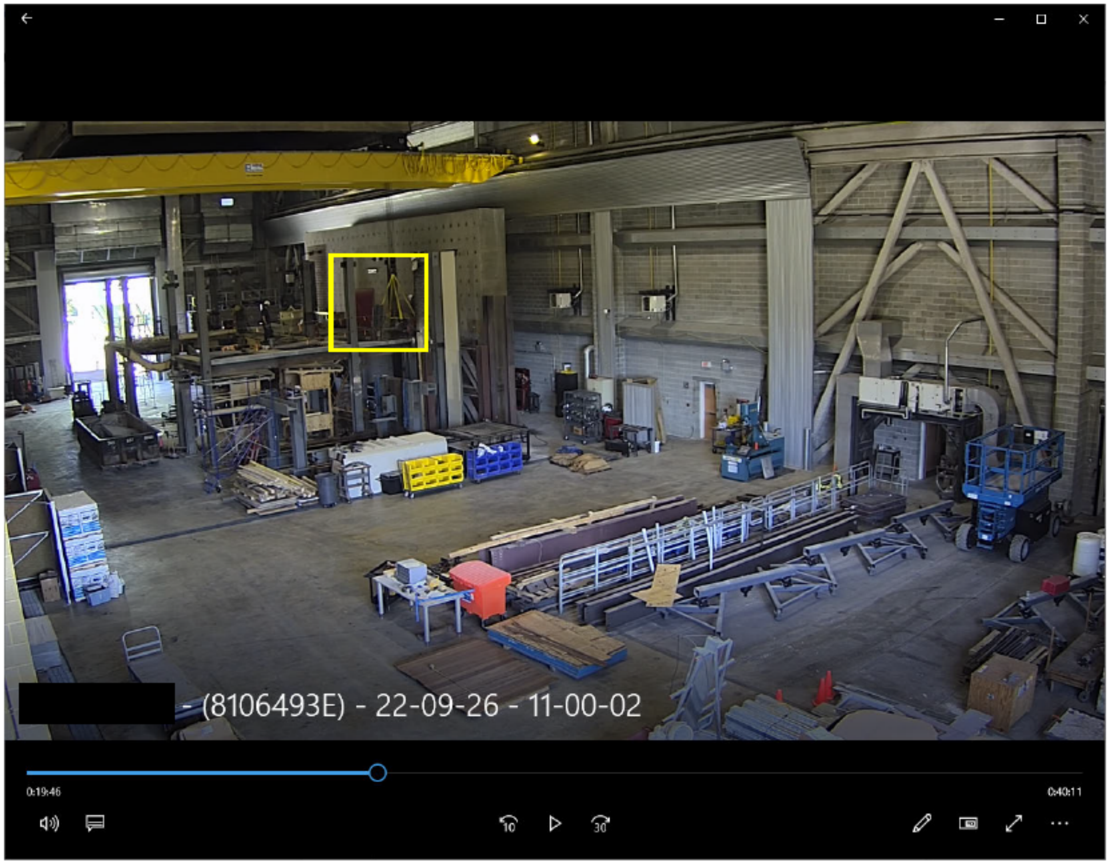
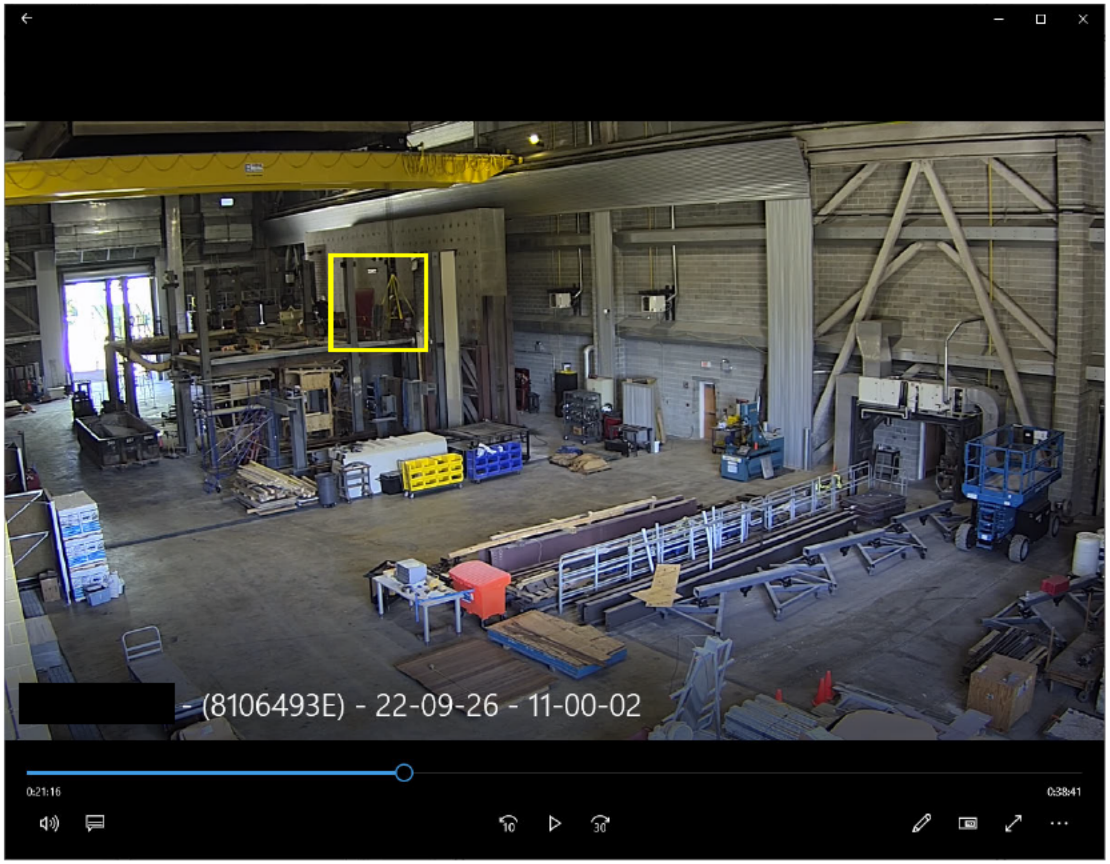


Figure A6.7.20: Image captured from video evidence (11:19:46 am ET) showing ENGR TECH 1 repositioning the floor saw by maneuvering it on Slab 4 while the east and west faces and a major portion of the north face are cut. Rigging is connected.



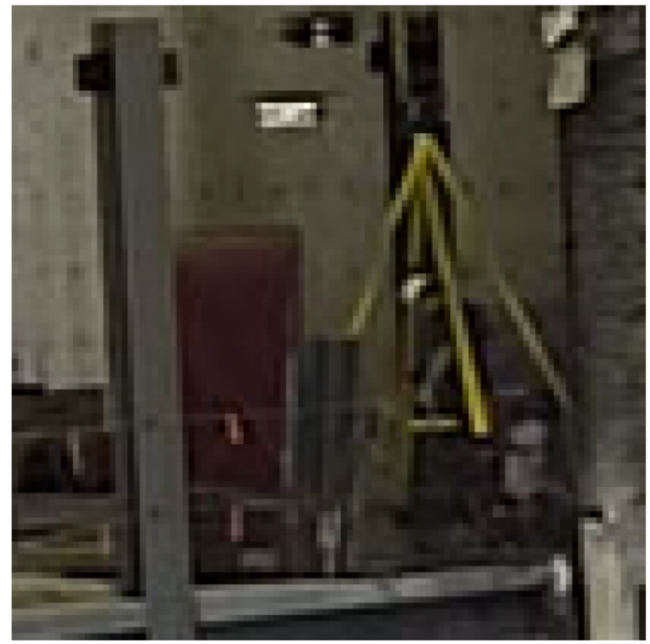


Figure A6.7.21: Image captured from video evidence (11:21:16 am ET) showing ENGR TECH 1 walking across Slab 4 while the north, east, and west faces are cut. Rigging is connected.

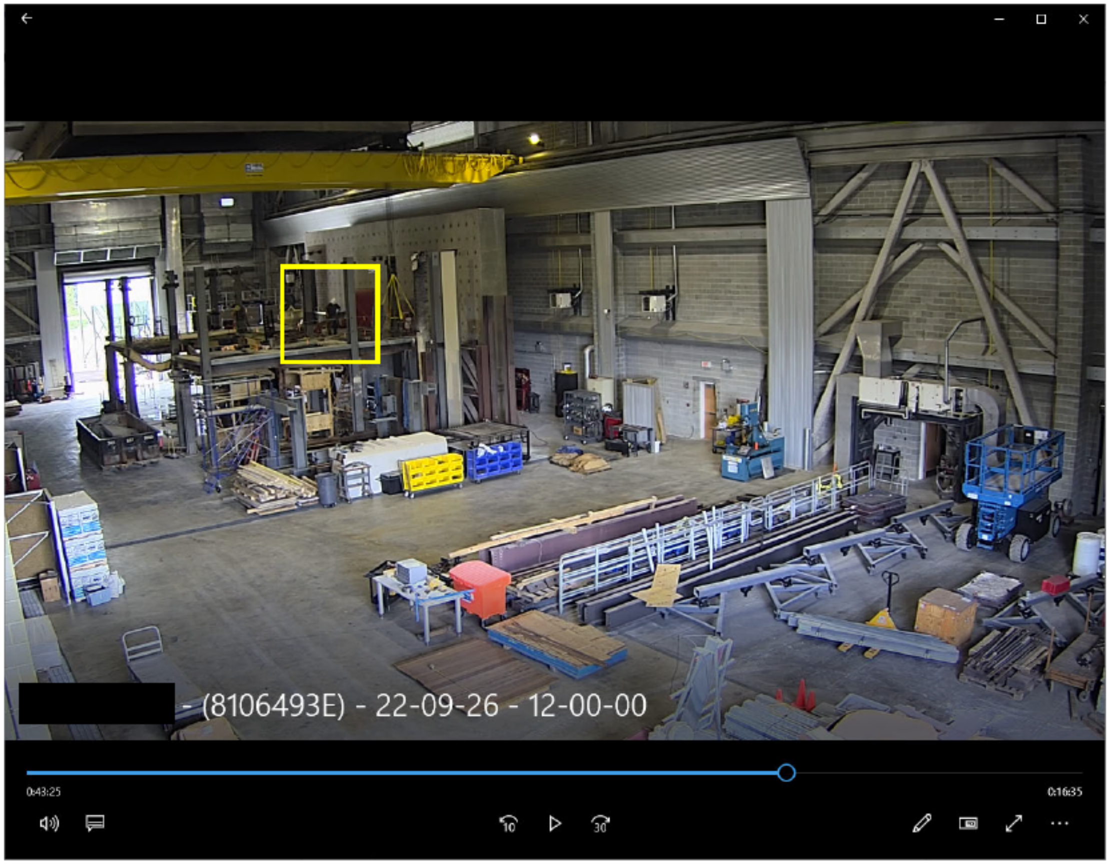


Figure A6.7.22: Image captured from video evidence (12:43:25 pm ET) showing ENGR TECH 1 laying a piece of heavy angle iron across the width of the Slab 3 cut bay.

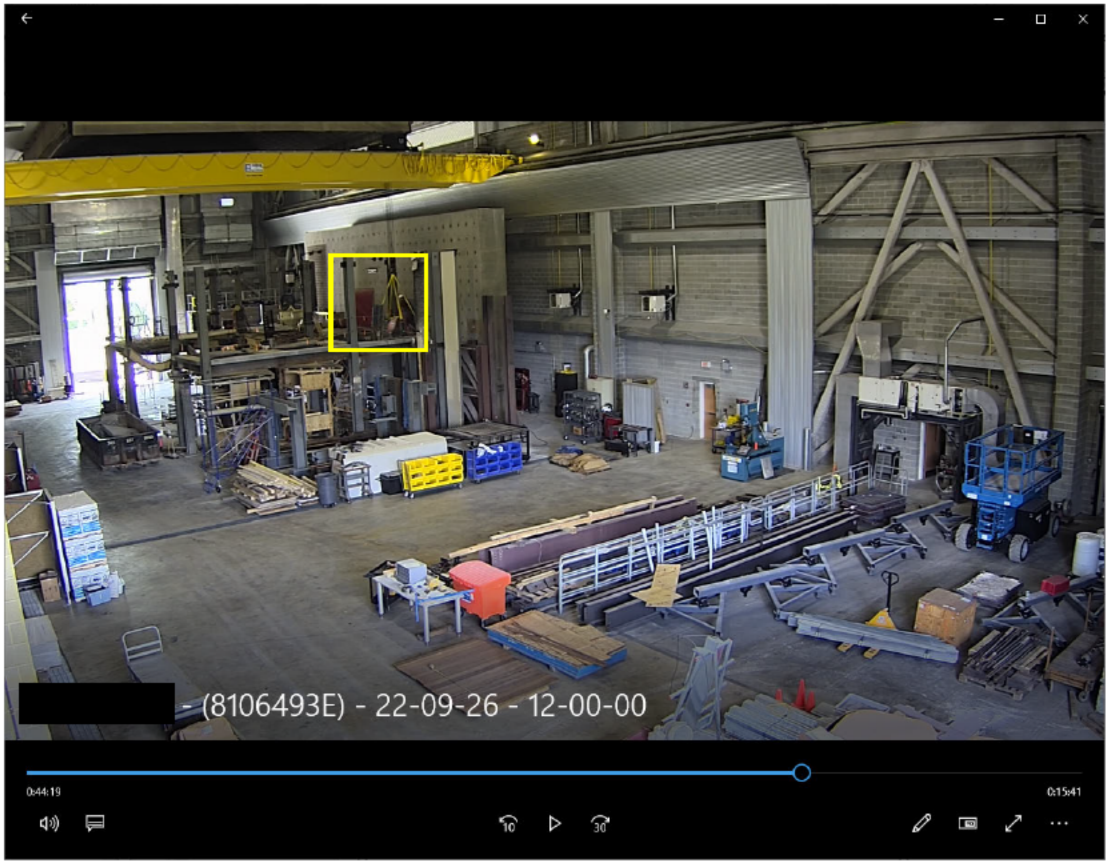


Figure A6.7.23: Image captured from video evidence (12:44:19 pm ET) showing ENGR TECH 1 pushing the floor saw across Slab 4 prior to cutting the south face.

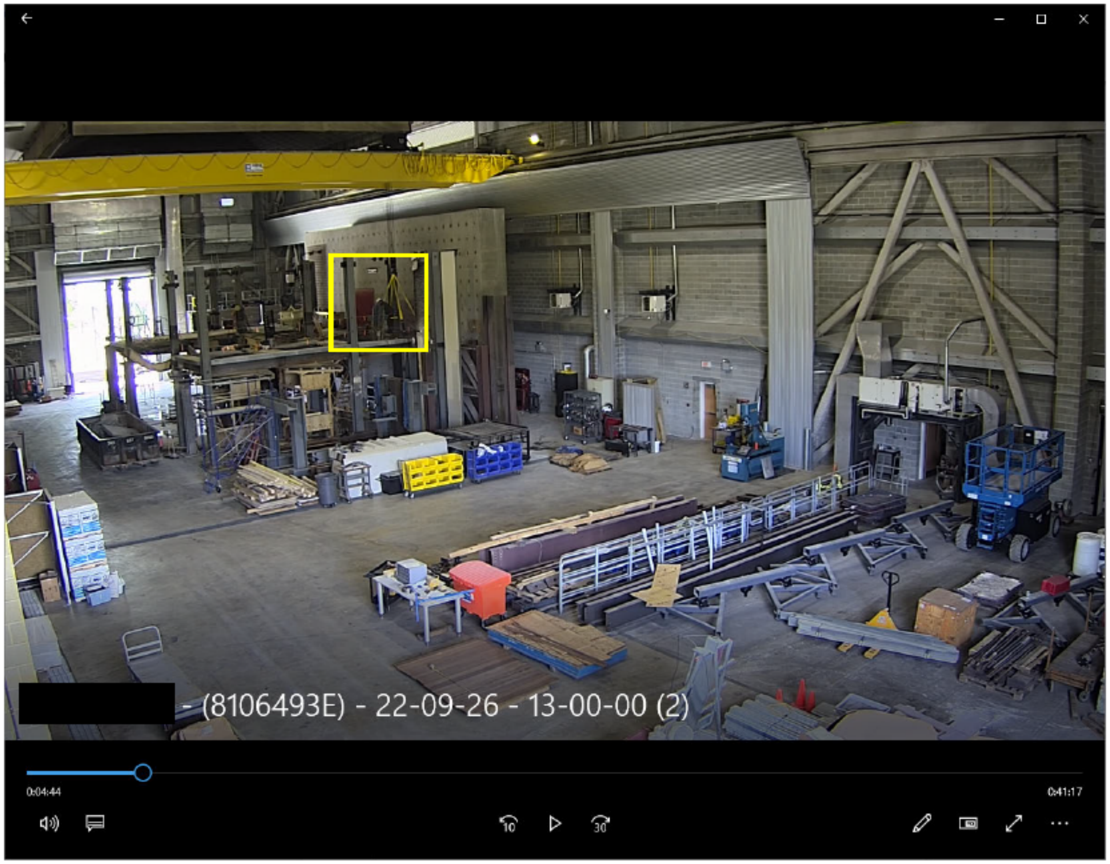


Figure A6.7.24: Image captured from video evidence (1:04:44 pm ET) showing ENGR TECH 1 backing up the floor saw to pull it back across Slab 4. In the process, his full body weight is on the slab, but the saw weight is not.

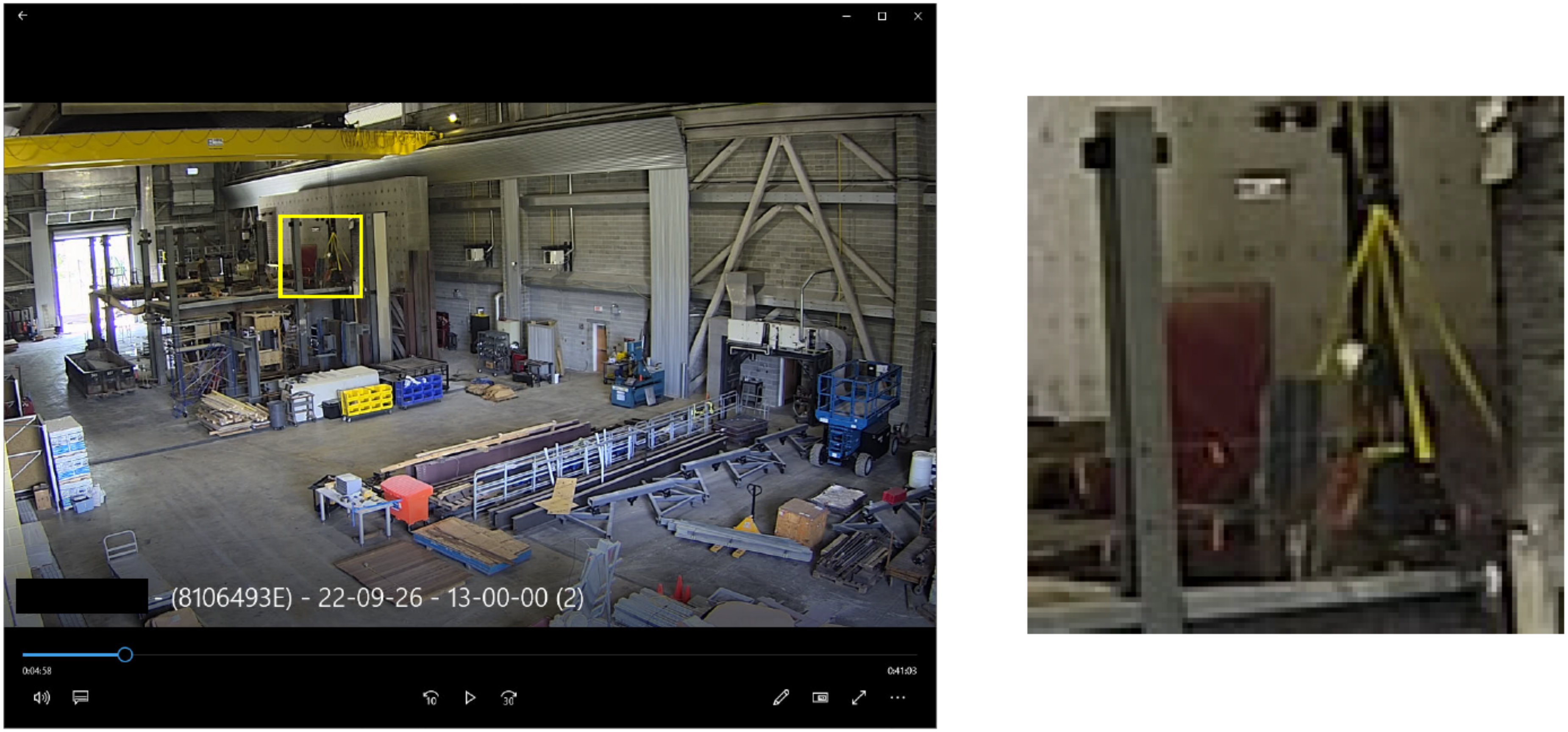


Figure A6.7.25: Image captured from video evidence (1:04:58 pm ET) showing ENGR TECH 1, with the saw facing south, as he begins to pull it back across the slab.

Appendix 6.10.1: Safety Training Records for CF Project Staff

ENGR TECH 1				
Category	Course Name	Category	Date Assigned	Date Completed
General Safety Training	NIST P 7100.00: General Safety Training	NIST Level	1/15/2014	1/21/2014
	NIST S 7101.20: Work and Worker Authorization Based on Hazard Review	NIST Level	2/12/2015	3/12/2015
	EL General Safety Awareness - Web Based	OU/Division Level	6/22/2020	6/22/2020
	EL Safety Awareness for All Personnel ILT	OU/Division Level	8/19/2013	1/24/2013
	EL Safety Awareness for Laboratory Personnel - ILT	OU/Division Level	8/19/2013	1/24/2013
	EL-733: NFRL Lab Access and Safety Policies	OU/Division Level	12/29/2014	1/20/2015
Personal Protective Equipment	NIST S 7101.21: Personal Protective Equipment Program Training	NIST Level	2/12/2015	3/12/2015
	NIST S 7101.21: Personal Protective Equipment Program 2019 Gap Training	NIST Level	8/14/2019	8/14/2019
	CLC - Fall Protection (or Working at Heights)	OU/Division Level	8/22/2013	10/1/2012
	EL - Fall Protection - ILT	OU/Division Level	8/12/2015	8/11/2015
	NIST S 7101.58: Respiratory Protection Program - Training for Voluntary Use of Filtering Facepieces	NIST Level	6/25/2020	6/25/2020
	NIST S 7101.58: Respiratory Protection Program - Initial Training (Web-based)	NIST Level	6/25/2020	6/25/2020
	NIST S 7101.58: Respiratory Protection Program - FY17 Refresher Training (Web-based)	NIST Level	2/12/2017	2/28/2017
	NIST S 7101.58: Respiratory Protection Program - FY18 Refresher Fit Testing	NIST Level	5/10/2018	4/27/2018
	NIST S 7101.58: Respiratory Protection Program - FY18 Refresher Training (Web-based)	NIST Level	1/26/2018	5/15/2018
	NIST S 7101.58: Respiratory Protection Program - FY19 Refresher Training (Web-based)	NIST Level	2/6/2019	2/12/2019
	NIST S 7101.58: Respiratory Protection Program - FY20 Refresher Training (Web-based)	NIST Level	1/14/2020	3/17/2020
	NIST S 7101.58: Respiratory Protection Program - FY21 Refresher Training (Web-based)	NIST Level	3/9/2021	5/6/2021
	NIST S 7101.58: Respiratory Protection Program - 2022 Refresher Training (Web-based)	NIST Level	2/3/2022	3/28/2022
	CLC - Using Respiratory Protection	NIST Level	8/14/2013	9/28/2012
	NIST S 7101.55: Hearing Protection Program - Initial Training (Web-based)	NIST Level	6/22/2020	6/22/2020
	NIST S 7101.21: Protective Footwear	NIST Level	1/13/2015	1/20/2015
	NIST S 7101.21: Eye Protection Training	NIST Level	1/13/2015	1/20/2015
	NIST S 7101.21: Hand Protection	NIST Level	1/13/2015	1/20/2015
	NIST S 7101.21: Head Protection	NIST Level	1/10/2015	1/20/2015
	CLC - Personal Protective Equipment: Head Protection	NIST Level	8/14/2013	10/1/2012
Construction/Demolition Work	CLC - Hand and Power Tool Safety	NIST Level	8/22/2013	10/1/2012
	NIST S 7101.64: Electrical Safety for Laboratory Workers	NIST Level	6/22/2020	6/22/2020
	NIST S 7101.65: Basic Machine Shop Safety	NIST Level	6/25/2020	6/26/2020
	EL-733: NFRL Machine and Fabrication Shop Safety Awareness	OU/Division Level	6/2/2014	6/6/2014
	CLC S 7401.04: Welding, Cutting, and Brazing	NIST Level	8/14/2013	10/2/2012
	EL-733: NFRL Welding and Torch Cutting for Operators	OU/Division Level	2/26/2014	2/28/2014
	CLC - Slips, Trips, and Falls	NIST Level	8/14/2013	9/28/2012
	EL 733: NFRL Articulated Boom Lift Operation	OU/Division Level	7/31/2014	7/31/2014
	EL-733: NFRL Scissor Lift Operation	OU/Division Level	7/31/2014	7/31/2014
	OFPM Aerial Lift Safety Training	OU/Division Level	9/7/2021	9/15/2021
	OFPM Scissor lift Training	OU/Division Level	6/22/2021	6/22/2021
	CLC - Ladder Safety	NIST Level	1/29/2016	2/1/2016
	CLC - Scaffolding and Ladder Safety	NIST Level	8/14/2013	10/4/2012
	EL - Scaffold Training for Competent Person	OU/Division Level	4/17/2019	4/9/2019

ENGR TECH 1 (continued)				
Category	**Course Name**	**Category**	**Date Assigned**	**Date Completed**
Material Handling	CLC S 7101.69: Overhead Crane & Slings	NIST Level	10/23/2014	4/15/2013
	CLC S 7101.69: Overhead Crane & Slings	NIST Level	11/3/2014	4/15/2014
	CLC S 7101.69: Overhead Crane & Slings	NIST Level	8/21/2013	4/15/2013
	CLC S 7101.69: Indoor Hoisting and Rigging	NIST Level	8/22/2013	10/1/2012
	Overhead Cranes and Slings	OU/Division Level	5/7/2013	4/15/2013
	EL-733: NFRL Overhead Crane Operation	OU/Division Level	6/25/2020	6/25/2020
	NIST S 7101.74: Powered Industrial Trucks	NIST Level	3/27/2019	3/17/2020
	CLC - Powered Industrial Trucks: Forklift	NIST Level	8/21/2013	4/18/2013
	CLC - Powered Industrial Trucks: Forklift	NIST Level	6/5/2014	4/18/2013
	CLC S 7101.74: Powered Industrial Truck Safety	NIST Level	8/14/2013	10/2/2012
	CLC S 7101.74: Forklift Safety Awareness 2.0	NIST Level	8/22/2013	10/1/2012
	EL - Forklift training	OU/Division Level	11/3/2021	10/20/2021
	EL - Forklift training	OU/Division Level	6/20/2017	6/19/2017
	EL-733: NFRL Forklift Operation	OU/Division Level	5/2/2014	6/6/2014
	EL-733: NFRL Skidloader Operation	OU/Division Level	6/6/2014	6/6/2014
	644 & 645 FY18Q3 Electrical Safety & Crane Incident (web)	OU/Division Level	5/8/2020	6/25/2020
Other	CLC - Defensive Driving Fundamentals	NIST Level	6/25/2020	6/25/2020
	CLC - Electrical Safety	NIST Level	8/22/2013	9/28/2012
	CLC - Fire and Explosion Hazards	NIST Level	8/27/2013	2/5/2013
	CLC - Fire and Explosion Hazards	NIST Level	8/27/2013	10/1/2012
	CLC - Fire Safety and Prevention	NIST Level	8/27/2013	10/1/2012
	CLC - Hazard Communication: An Employee''s Right to Know	NIST Level	8/28/2013	10/3/2012
	CLC - Laser Safety Training	NIST Level	8/27/2013	10/1/2012
	CLC - Material Safety Data Sheets	NIST Level	8/28/2013	9/28/2012
	CLC - Office Safety	NIST Level	8/28/2013	9/28/2012
	CLC S 7101.56: Lockout/Tagout for Authorized Persons 2.0	NIST Level	8/22/2013	10/4/2012
	CLC S 7101.57: Confined Spaces 2.0	NIST Level	8/16/2013	10/1/2012
	CLC S 7101.61: Compressed Gas Safety	NIST Level	8/15/2013	9/28/2012
	CLC S 7101.62: Back Safety and Injury Prevention 2.0	NIST Level	8/12/2013	9/27/2012
	CLC S 7101.62: Computer Ergonomics	NIST Level	8/16/2013	9/28/2012
	CLC S 7101.62: Office Ergonomics	NIST Level	8/13/2013	9/28/2010
	CLC S 7101.xx: Lead Awareness in General Industry	NIST Level	8/22/2013	10/4/2012
	CLC S 7200.00: Radiation Safety	NIST Level	6/25/2020	6/26/2020
	CLC S 7401.04: Portable Fire Extinguishers 2.0	NIST Level	6/26/2020	6/26/2020
	NIST P 7100: Safety and Health Training for Staff Accessing and Working on NIST Campuses during the COVI	NIST Level	10/19/2021	10/19/2021
	NIST P 7100: Safety and Health Training for Staff Accessing and Working on NIST Campuses during the COVI	NIST Level	3/31/2022	4/8/2022
	NIST S 7101.22: Hazard Signage Training - Program Requirements	NIST Level	6/22/2020	6/22/2020
	NIST S 7101.51: Bloodborne Pathogens Web-based User Training 2020	NIST Level	6/25/2020	6/26/2020
	NIST S 7101.56: Control of Hazardous Energy (Lockout/Tagout (LOTO))	NIST Level	3/11/2015	3/12/2015
	NIST S 7101.56: Control of Hazardous Energy (Lockout/Tagout (LOTO)) - Gap training	NIST Level	8/15/2019	8/15/2019
	NIST S 7101.57: Permit-Required Confined Spaces	NIST Level	6/25/2020	6/25/2020
	NIST S 7101.59: Chemical Hazard Communication Program Training	NIST Level	3/7/2016	3/8/2016
	NIST S 7101.59: HCS - New Label Elements and New Safety Data Sheet Format	NIST Level	11/25/2013	11/25/2013

ENGR TECH 1 (continued)				
Category	**Course Name**	**Category**	**Date Assigned**	**Date Completed**
Other	NIST S 7101.60: Chemical Management Program Training	NIST Level	6/22/2020	6/22/2020
	NIST S 7101.61: Compressed Gas Safety Program Training	NIST Level	1/29/2016	2/1/2016
	NIST S 7101.61: Compressed Gas Safety Program Training	NIST Level	1/31/2022	1/31/2022
	NIST S 7101.62: Office Safety Program Training	NIST Level	6/22/2020	6/22/2020
	NIST S 7101.64: Safe Electrical Work Practices – Comprehensive Course	NIST Level	7/26/2018	7/25/2018
	NIST S 7101.64: Safe Electrical Work Practices – Limited Scope Course	NIST Level	9/22/2016	9/21/2016
	NIST S 7101.72: Laser Safety Awareness - Non-User (Web-Based)	NIST Level	7/18/2022	7/18/2022
	NIST S 7301.06: NIST Gaithersburg Chemical Waste Accumulation and Disposal	NIST Level	11/29/2019	11/29/2019
	NIST S 7401.04: NIST Fire Extinguisher Training	NIST Level	6/25/2020	6/25/2020
	EL Chemical Waste Disposal - Web Based	OU/Division Level	6/25/2020	6/25/2020
	EL First Aid/CPR/AED	OU/Division Level	8/20/2013	5/14/2013
	EL-733: NFRL Structural Loading for Operators	OU/Division Level	4/28/2014	4/28/2014

ENGR TECH 2				
Category	**Course Name**	**Category**	**Date Assigned**	**Date Completed**
General Safety Training	NIST P 7100.00: General Safety Training	NIST-Level	2014/01/15	2014/01/21
	NIST S 7101 20: Work and Worker Authorization Based on Hazard Review	NIST-Level	2015/02/12	2015/03/24
	EL General Safety Awareness - Web Based	OU Activity-Specific	2020/06/29	2020/06/29
	EL Safety Awareness Combined Course - ILT	OU Activity-Specific	2013/08/19	2012/09/04
	EL-733: NFRL Lab Access and Safety Policies	OU Activity-Specific	2014/12/29	2015/01/13
Personal Protective Equipment	NIST S 7101 21: Personal Protective Equipment Program Training	NIST Level	2015/02/12	2015/02/25
	NIST S 7101 21: Personal Protective Equipment Program 2019 Gap Training	NIST Level	2019/08/14	2019/08/14
	CLC S 7101.21: Personal Protective Equipment 2.0	NIST Level	2021/07/12	2021/07/12
	NIST S 7101.67: Fall Protection Authorized Person	**NIST Level**	**2020/04/09**	**Not Started**
	CLC - Fall Protection (or Working at Heights)	OU/Division Level	2013/08/22	2010/04/08
	NIST S 7101 58: Respiratory Protection Program - Training for Voluntary Use of Filtering Facepieces	NIST Level	2021/07/12	2021/07/12
	NIST S 7101 58: Respiratory Protection Program - Initial Training (Web-based)	NIST Level	2014/07/15	2014/07/02
	NIST S 7101.58: Respiratory Protection Program - FY17 Refresher Fit Testing	NIST Level	2017/02/16	2017/02/03
	NIST S 7101.58: Respiratory Protection Program - FY17 Refresher Training (Web-based)	NIST Level	2017/02/01	2017/02/01
	NIST S 7101.58: Respiratory Protection Program - FY20 Refresher Training (Web-based)	NIST Level	2020/04/09	2020/04/09
	NIST S 7101.58: Respiratory Protection Program - FY21 Refresher Fit Testing	NIST Level	2021/08/06	2021/07/09
	NIST S 7101.58: Respiratory Protection Program - FY21 Refresher Training (Web-based)	NIST Level	2021/03/09	2021/05/21
	NIST S 7101.58: Respiratory Protection Program - 2022 Refresher Training (Web-based)	NIST Level	2022/02/03	Not Started
	CLC - Using Respiratory Protection	NIST Level	2013/08/14	2013/02/05
	EL Respirator Training and Fit Testing	OU/Division Level	2013/08/21	2012/03/06
	EL SCBA Training and Fit Testing	OU/Division Level	2013/08/22	2010/08/24
	NIST S 7101.55: Hearing Protection Program - Initial Training (Web-based)	NIST Level	2020/06/29	2020/06/29
	NIST S 7101.21: Protective Footwear	NIST Level	2015/01/13	2015/01/13
	NIST S 7101.21: Eye Protection Training	NIST Level	2015/01/13	2015/01/13
	NIST S 7101.21: Hand Protection	NIST Level	2015/01/13	2015/01/13
	NIST S 7101.21: Head Protection	NIST Level	2015/01/10	2015/01/13
Construction/Demolition Work	CLC - Hand and Power Tool Safety	NIST Level	2013/08/22	2009/09/28
	NIST S 7101.64: Electrical Safety for Laboratory Workers	NIST Level	2020/06/29	2020/06/29
	NIST S 7101.65: Basic Machine Shop Safety	NIST Level	2014/07/15	2020/04/09
	EL Machine Shop Safety	OU/Division Level	2013/08/21	2010/04/28
	CLC S 7401.04: Welding, Cutting, and Brazing	NIST Level	2013/08/14	2009/02/26
	EL-733: NFRL Welding and Torch Cutting for Operators	OU/Division Level	2014/02/26	2014/02/28
	CLC - Slips, Trips, and Falls	NIST Level	2013/08/14	2009/10/02
	EL 733: NFRL Articulated Boom Lift Operation	OU/Division Level	2014/07/31	2014/07/31
	EL-733: NFRL Scissor Lift Operation	OU/Division Level	2014/07/31	2014/07/31
	OFPM Aerial Lift Safety Training	OU/Division Level	2021/09/07	2021/09/15
	OFPM Scissor lift Training	OU/Division Level	2021/06/22	2021/07/14, 2021/09/15
	CLC - Ladder Safety	NIST Level	2016/01/29	2016/02/01
	CLC - Scaffolding and Ladder Safety	NIST Level	2013/08/22	2009/09/25
	EL - Scaffold Training for Competent Person	OU/Division Level	2019/04/17	2019/04/09
Material Handling	CLC S 7101.69: Overhead Crane & Slings	NIST Level	2014/10/23	2013/04/15
	Overhead Cranes and Slings	OU/Division Level	2013/05/07	2013/04/04
	NIST S 7101.74: Powered Industrial Trucks	NIST Level	2019/03/27	2020/06/26
	CLC - Powered Industrial Trucks: Forklift	NIST Level	2013/08/21	2013/04/18, 2013/04/18
	CLC S 7101.74: Powered Industrial Truck Safety	NIST Level	2013/08/14	2009/11/25
	EL - Forklift training	OU/Division Level	2017/06/20	2017/06/19, 2021/10/20
	EL-733: NFRL Forklift Operation	OU/Division Level	2014/05/02	2014/06/06
	EL-733: NFRL Skidloader Operation	OU/Division Level	2014/06/06	2014/06/06

ENGR TECH 2 (continued)				
Category	**Course Name**	**Category**	**Date Assigned**	**Date Completed**
Other	CLC - Fire Safety and Prevention	NIST Level	2013/08/27	2010/04/08
	CLC - Hazard Communication: An Employee''s Right to Know	NIST Level	2013/08/28	2011/12/12
	CLC - Laboratory Safety	NIST Level	2013/08/22	2010/10/05
	CLC - Material Safety Data Sheets	NIST Level	2013/08/28	2009/10/02
	CLC - Office Safety	NIST Level	2013/08/28	2011/12/12
	CLC S 7101.50: Bloodborne Pathogen Awareness 2.0	NIST Level	2021/07/11	2021/07/18
	CLC S 7101.56: Lockout/Tagout for Authorized Persons 2.0	NIST Level	2013/08/22	2011/05/17
	CLC S 7101.62: Computer Ergonomics	NIST Level	2020/06/29	2020/06/29
	CLC S 7101.62: Office Ergonomics	NIST Level	2020/06/29	2020/06/29
	CLC S 7101.xx: Lead Awareness in General Industry	NIST Level	2013/08/22	2010/12/06
	CLC S 7200.00: Radiation Safety	NIST Level	2013/08/14	2011/06/01
	NIST 7101-61_Compressed Gas Safety GAP Training_070821	NIST Level	2022/02/07	2022/02/17
	NIST P 7100: Safety and Health Training for Staff Accessing and Working on NIST Campuses during the COVID	NIST Level	2022/03/31	2022/04/11
	NIST P 7100: NIST Safe Return to Campus Training for Phase 1	NIST Level	2020/06/26	2020/06/26
	NIST S 7101 22: Hazard Signage Training - Program Requirements	NIST Level	2020/06/29	2020/06/29
	NIST S 7101 50: Infectious Diseases training for HOT response team	NIST Level	2021/07/12	2021/07/12
	NIST S 7101 56: Control of Hazardous Energy (Lockout/Tagout (LOTO))	NIST Level	2015/03/11	2015/03/24
	NIST S 7101 56: Control of Hazardous Energy (Lockout/Tagout (LOTO)) - Gap training	NIST Level	2019/08/14	2019/08/14
	NIST S 7101 59: Chemical Hazard Communication Program Training	NIST Level	2016/03/07	2016/03/08, 2021/07/18
	NIST S 7101 59: HCS - New Label Elements and New Safety Data Sheet Format	NIST Level	2013/11/25	2013/11/25
	NIST S 7101.60: Chemical Management Program Training	NIST Level	2020/06/29	2020/06/29
	NIST S 7101.61: Compressed Gas Safety Program Training	NIST Level	2016/01/29	2016/02/01
	NIST S 7101.62: Office Safety Program Training	NIST Level	2020/06/29	2020/06/29
	NIST S 7101.64: Safe Electrical Work Practices – Limited Scope Course	NIST Level	2016/09/22	2016/09/21
	NIST S 7101.72: Laser Safety Awareness - Non-User (Web-Based)	NIST Level	2022/07/18	2022/07/18
	EL Confined Space Entry Safety	OU/Division Level	2013/08/21	2010/04/20
	EL Office Safety and Ergonomics	OU/Division Level	2013/08/20	2009/09/29
	EL-733: NFRL Emission Control System Training for Operators	OU/Division Level	2014/02/28	2014/03/19
	EL-733: NFRL Natural Gas Fuel Delivery System Training	OU/Division Level	2018/11/15	2018/11/15
	EL-733: NFRL Structural Loading for Operators	OU/Division Level	2014/02/25	2014/04/28
	First Aid/CPR/AED	OU/Division Level	2022/02/07	2022/05/31

ENGR TECH 3				
Category	Course Name	Category	Date Assigned	Date Completed
General Safety Training	NIST P 7100.00: General Safety Training	NIST Level	2014/01/15	2017/01/11
	NIST S 7101.20: Work and Worker Authorization Based on Hazard Review	NIST Level	2020/06/30	2020/06/30
	CLC S 7101.23: Job Hazard Analysis	NIST Level	2022/11/10	2022/11/10
	CLC S 7101.23: Safe Work Practices	NIST Level	2022/11/16	2022/11/16
	EL General Safety Awareness - Web Based	OU/Division Level	2017/01/09	2017/01/11
	EL-733: NFRL Lab Access and Safety Policies	OU/Division Level	2017/01/09	2017/01/11, 2022/11/08
Personal Protective Equipment	NIST S 7101.21: Personal Protective Equipment Program Training	NIST Level	2017/01/09	2019/10/22, 2022/11/17
	NIST S 7101.21: Personal Protective Equipment Program 2019 Gap Training	NIST Level	2020/06/22	2020/06/22
	CLC S 7101.21: Personal Protective Equipment 2.0	NIST Level	2020/06/22	2020/06/22
	NIST S 7101.67: Fall Protection Program Training	NIST Level	2022/11/02	2022/11/02
	NIST S 7101.67: Fall Protection Authorized Person	NIST Level	2019/08/14	Not Started
	NIST S 7101.58: Respiratory Protection Program - Training for Voluntary Use of Filtering Facepieces	NIST Level	2017/01/09	2017/01/11
	NIST S 7101.58: Respiratory Protection Program - Initial Training (Web-based)	NIST Level	2017/01/09	2017/01/11
	NIST S 7101.58: Respiratory Protection Program - FY17 Refresher Fit Testing	NIST Level	2017/02/16	2017/02/03
	NIST S 7101.58: Respiratory Protection Program - FY19 Refresher Training (Web-based)	NIST Level	2019/02/06	2019/03/28
	NIST S 7101.58: Respiratory Protection Program - FY20 Refresher Training (Web-based)	NIST Level	2020/04/10	2020/04/10
	NIST S 7101.58: Respiratory Protection Program - FY20 Refresher Training and Fit Testing for the Fire Protect	NIST Level	2020/06/29	2020/06/29
	NIST S 7101.58: Respiratory Protection Program - 2022 Refresher Fit Testing	NIST Level	2022/06/09	2022/05/18
	NIST S 7101.58: Respiratory Protection Program - 2022 Refresher Training (Web-based)	NIST Level	2022/02/03	2022/02/11
	NIST S 7101.55: Hearing Protection Program - Initial Training (Web-based)	NIST Level	2017/01/09	2017/01/11, 2022/11/17
	NIST S 7101.55: Hearing Protection Program - FY20 Refresher Training (Web-based)	NIST Level	2020/06/30	2020/06/30
	NIST S 7101.55 Hearing Protection Program-FY22 Refresher Training v2-Web-based	NIST Level	2022/11/17	2022/11/17
	NIST S 7101.21: Protective Footwear	NIST Level	2020/06/22	2020/06/22
	CLC S 7101.21: PPE: Head Protection	NIST Level	2022/12/01	2022/12/01
	NIST S 7101.21: Eye Protection Training	NIST Level	2020/06/22	2020/06/22
	CLC S 7101.21: PPE: Eye and Face Protection	NIST Level	2022/12/01	2022/12/01
	CLC S 7101.21: Personal Protective Equipment: Eye and Face Protection	NIST Level	2020/06/22	2020/06/22
	NIST S 7101.21: Hand Protection	NIST Level	2020/06/30	2020/06/30
	CLC S 7101.21: Personal Protective Equipment: Hand Protection	NIST Level	2020/06/23	2020/06/23
	NIST S 7101.21: Head Protection	NIST Level	2020/06/22	2020/06/22, 2022/11/17
Construction/Demolition Work	NIST S 7101.64: Electrical Safety for Laboratory Workers	NIST Level	2017/01/09	2017/01/11
	NIST S 7401.04: NIST Hot Works Safety Training	NIST Level	2020/06/30	2020/06/30
	CLC S 7401.04: Welding, Cutting, and Brazing	NIST Level	2020/06/22	2020/06/22
	NIST S 7101.65: Basic Machine Shop Safety	NIST Level	2020/06/29	2020/06/29, 2022/11/17
	EL Machine Shop Safety	OU/Division Level	2017/01/09	2017/01/16
	OFPM Hand and Power tools safety training	OU/Division Level	2020/06/30	2020/06/30, 2022/11/17
	NIST S 7101.75: Slips, Trips, and Falls	NIST Level	2020/06/30	2020/06/30
	CLC S 7101.62: Slips, Trips, and Falls 2.0	NIST Level	2022/11/03	2022/11/03
	EL 733: NFRL Articulated Boom Lift Operation	OU/Division Level	2020/04/02	2020/04/02
	EL-733: NFRL Scissor Lift Operation	OU/Division Level	2020/04/02	2020/04/02
	OFPM Aerial Lift Safety Training	OU/Division Level	2021/08/26	2021/08/26
	OFPM Scissor lift Training	OU/Division Level	2021/06/22	2021/06/29
	EL - Scaffold Training for Competent Person	OU/Division Level	2019/04/17	2019/04/09
Material Handling	CLC S 7101.69: Crane Signaling and Communications	NIST Level	2022/05/09	2022/05/11
	CLC S 7101.69: Indoor Hoisting and Rigging	NIST Level	2020/06/29	2020/06/29

ENGR TECH 3 (continued)				
Category	**Course Name**	**Category**	**Date Assigned**	**Date Completed**
Material Handling	644 & 645 FY18Q3 Electrical Safety & Crane Incident (web)	OU/Division Level	2020/04/13	2020/04/13
	EL-733: NFRL Overhead Crane Operation	OU/Division Level	2020/04/02	2020/04/02
	NIST S 7101.74: Powered Industrial Trucks	NIST Level	2019/03/27	2019/03/28
	CLC S 7101.74: Forklift Safety Awareness 2.0	NIST Level	2020/06/29	2020/06/29
	CLC S 7101.74: Powered Industrial Truck Safety	NIST Level	2020/06/29	2020/06/29
	EL - Forklift training	OU/Division Level	2017/06/20	2017/06/19, 2021/10/20
	EL-733: NFRL Forklift Operation	OU/Division Level	2020/04/02	2020/04/02
	EL-733: NFRL Skidloader Operation	OU/Division Level	2020/04/02	2020/04/02
Other	CLC - Defensive Driving Fundamentals	NIST Level	2020/07/14	2020/07/14
	CLC - Electrical Safety	NIST Level	2020/06/22	2020/06/22
	CLC O 7101.00: Behavior-based safety for Supervisors	NIST Level	2020/06/22	2020/06/22, 2022/12/01
	CLC S 7101.24: Access to Medical and Exposure Records	NIST Level	2020/04/14	2020/06/22, 2020/07/28
	CLC S 7101.24: Accident Investigation and Reporting – Cal/OSHA	NIST Level	2021/10/07	2021/10/07
	CLC S 7101.24: Incident Investigation and Reporting	NIST Level	2022/11/04	2022/11/04
	CLC S 7101.51: Bloodborne Pathogen Awareness	NIST Level	2020/06/29	2020/06/29
	CLC S 7101.52: Cryogenic Safety	NIST Level	2020/06/25	2020/06/25
	CLC S 7101.56: Lockout/Tagout 2.0	NIST Level	2020/06/25	2020/06/25
	CLC S 7101.56: Lockout/Tagout for Authorized Persons 2.0	NIST Level	2020/06/25	2020/06/25
	CLC S 7101.57: Confined Spaces 2.0	NIST Level	2020/06/25	2020/06/25
	CLC S 7101.60: Carcinogen Safety	NIST Level	2020/06/22	2020/06/22
	CLC S 7101.60: Liquefied Petroleum Gas (LPG)	NIST Level	2020/06/22	2020/06/22
	CLC S 7101.61: Compressed Gas Safety	NIST Level	2020/06/25	2020/06/25
	CLC S 7101.62: Back Safety and Injury Prevention 2.0	NIST Level	2020/06/29	2020/06/29
	CLC S 7101.62: Computer Ergonomics	NIST Level	2020/06/22	2020/06/22
	CLC S 7101.62: Ergonomics in the Workplace 2.0	NIST Level	2020/06/29	2020/06/29
	CLC S 7101.62: Office Ergonomics	NIST Level	2020/06/22	2020/06/22
	CLC S 7101.xx: Heat Stress Recognition and Prevention	NIST Level	2020/06/22	2020/06/22
	CLC S 7101.xx: Lead Awareness in General Industry	NIST Level	2020/06/22	2020/06/22
	CLC S 7200.00: Radiation Safety	NIST Level	2020/06/22	2020/06/22
	CLC S 7401.04: Portable Fire Extinguishers 2.0	NIST Level	2020/06/22	2020/06/22
	NIST 7101-61_Compressed Gas Safety GAP Training_070821	NIST Level	2022/02/07	2022/02/11
	NIST O 7101.00: Safety Leadership Training	NIST Level	2020/06/29	2020/06/29
	NIST P 7100: Safety and Health Training for Staff Accessing and Working on NIST Campuses during the COV	NIST Level	2022/03/31	2022/03/31
	NIST P 7100: NIST Safe Return to Campus Training for Phase 1	NIST Level	2020/06/23	2020/06/23, 2021/07/06
	NIST S 7101.22: Hazard Signage Training - Program Requirements	NIST Level	2017/01/09	2017/01/11
	NIST S 7101.23: Safety Education and Training Program Training	NIST Level	2020/06/30	2020/06/30
	NIST S 7101.24: Incident Reporting and Investigation Training - Program Requirements	NIST Level	2020/06/30	2020/06/30
	NIST S 7101.24: IRIS Investigation Submitter Training	NIST Level	2020/06/30	2020/06/30
	NIST S 7101.24: IRIS Report Submitter Training	NIST Level	2020/06/30	2020/06/30
	NIST S 7101.24: OU IRIS Administrator Training	NIST Level	2020/06/30	2020/06/30
	NIST S 7101.26: Workplace Inspection Program Training	NIST Level	2020/06/30	2020/06/30, 2020/10/22
	NIST S 7101.26: Workplace Inspector Training	NIST Level	2020/06/30	2020/10/22
	NIST S 7101.50: Biological Toxin Training 2020	NIST Level	2020/04/13	2020/04/13
	NIST S 7101.50: Infectious Diseases training for HOT response team	NIST Level	2020/04/10	2020/04/10
	NIST S 7101.51: Bloodborne Pathogens Web-based User Training 2020	NIST Level	2020/06/30	2020/06/30
	NIST S 7101.52: Cryogen Safety Suborder Training_043013	NIST Level	2020/06/30	2020/06/30
	NIST S 7101.52: Cryogen User Safety Training	NIST Level	2020/06/30	2020/06/30

ENGR TECH 3 (continued)				
Category	**Course Name**	**Category**	**Date Assigned**	**Date Completed**
Other	NIST S 7101.54: Dispersible Engineered Nanomaterials (DENMs) Safety Training	NIST Level	2020/06/30	2020/06/30
	NIST S 7101.56: Control of Hazardous Energy (Lockout/Tagout (LOTO))	NIST Level	2017/01/09	2017/01/11, 2017/01/11
	NIST S 7101.56: Control of Hazardous Energy (Lockout/Tagout (LOTO)) - Gap training	NIST Level	2019/10/22	2019/10/22
	NIST S 7101.57: Permit-Required Confined Spaces	NIST Level	2017/01/09	2017/01/11
	NIST S 7101.59: Chemical Hazard Communication Program Training	NIST Level	2017/01/09	2017/01/11
	NIST S 7101.59: HCS - New Label Elements and New Safety Data Sheet Format	NIST Level	2013/12/16	2013/12/16
	NIST S 7101.60: Chemical Management Program Training	NIST Level	2020/06/22	2020/06/22
	NIST S 7101.60: Receiving Hazardous Chemicals	NIST Level	2020/06/30	2020/06/30
	NIST S 7101.61: Compressed Gas Safety Program Training	NIST Level	2017/01/09	2017/01/11
	NIST S 7101.62: Office Safety Program Training	NIST Level	2017/01/09	2017/01/11
	NIST S 7101.64: Electrical Cord Hazards	NIST Level	2020/06/30	2020/06/30
	NIST S 7101.72: Laser Safety Awareness - Non-User (Web-Based)	NIST Level	2020/06/29	2020/06/29, 2022/07/11
	NIST S 7101.xx: Soldering Awareness Training	NIST Level	2020/06/30	2020/06/30
	NIST S 7201.01: Initial Radiation Safety - Online Modules	NIST Level	2020/06/30	2020/06/30
	NIST S 7301.06: NIST Gaithersburg Chemical Waste Accumulation and Disposal	NIST Level	2020/06/30	2020/06/30
	NIST S 7401.04: NIST Fire Extinguisher Training	NIST Level	2020/04/14	2020/04/14
	CLC S 7101.64: NFPA 70E Electrical Safety in the Workplace 2018 Edition	OU/Division Level	2020/06/22	2020/06/22
	Cryogen Transfer	OU/Division Level	2020/04/15	2020/04/15
	EL Chemical Waste Disposal - Web Based	OU/Division Level	2020/06/29	2020/06/29
	EL-730: Laser Safety Training	OU/Division Level	2020/06/29	2020/06/29
	EL-733: NFRL Roof Access Safety Awareness	OU/Division Level	2020/04/02	2020/04/02
	NCNR Cryogen Safety Awareness	OU/Division Level	2020/06/29	2020/06/29

ENGR TECH 4				
Category	Course Name	Category	Date Assigned	Date Completed
General Safety Training	NIST P 7100.00: General Safety Training	NIST Level	2014/01/15	2014/01/21
	EL Safety Awareness Combined Course - ILT	OU/Division Level	2013/08/19	2012/09/04
	EL-733: NFRL Lab Access and Safety Policies	OU/Division Level	2014/12/30	2015/01/13
Personal Protective Equipment	NIST S 7101.21: Personal Protective Equipment Program Training	NIST Level	2015/02/12	2015/02/19
	NIST S 7101.21: Personal Protective Equipment Program 2019 Gap Training	NIST Level	2020/01/10	2020/01/10
	CLC - Fall Protection (or Working at Heights)	OU/Division Level	2013/08/22	2010/04/08
	EL - Fall Protection - ILT	OU/Division Level	2015/08/12	2015/08/11
	NIST S 7101.58: Respiratory Protection Program - Initial Training (Web-based)	NIST Level	2015/03/11	2015/03/27
	NIST S 7101.58: Respiratory Protection Program - FY16 Refresher Training (Web-based)	NIST Level	2016/04/19	2016/11/04
	NIST S 7101.58: Respiratory Protection Program - FY17 Refresher Fit Testing	NIST Level	2017/02/16	2017/02/03
	NIST S 7101.58: Respiratory Protection Program - FY20 Refresher Training (Web-based)	NIST Level	2020/01/30	2020/04/23
	NIST S 7101.58: Respiratory Protection Program - FY21 Refresher Training (Web-based)	NIST Level	2021/03/09	2021/06/08
	NIST S 7101.58: Respiratory Protection Program - 2022 Refresher Training (Web-based)	NIST Level	2022/02/03	Not Started
	CLC - Using Respiratory Protection	NIST Level	2013/08/14	2013/02/05
	EL Respirator Training and Fit Testing	OU/Division Level	2013/08/21	2012/03/06
	EL SCBA Training and Fit Testing	OU/Division Level	2013/08/22	2010/08/24
	NIST S 7101.55: Hearing Protection Program - Initial Training (Web-based)	NIST Level	2015/03/11	2015/03/27
	NIST S 7101.21: Protective Footwear	NIST Level	2015/01/13	2015/01/13
	NIST S 7101.21: Head Protection	NIST Level	2015/01/10	2015/01/13
	NIST S 7101.21: Eye Protection Training	NIST Level	2015/01/13	2015/01/13
	NIST S 7101.21: Hand Protection	NIST Level	2015/01/13	2015/01/13
Construction/Demolition Work	NIST S 7101.64: Electrical Safety for Laboratory Workers	NIST Level	2020/06/23	2020/06/23
	CLC S 7401.04: Welding, Cutting, and Brazing	NIST Level	2013/08/14	2010/04/09
	EL-733: NFRL Welding and Torch Cutting for Operators	OU/Division Level	2014/02/26	2014/02/28
	EL Machine Shop Safety	OU/Division Level	2013/08/21	2010/04/28
	CLC - Hand and Power Tool Safety	NIST Level	2013/08/22	2010/04/09
	EL 733: NFRL Articulated Boom Lift Operation	OU/Division Level	2014/07/31	2014/07/31
	EL-733: NFRL Scissor Lift Operation	OU/Division Level	2014/07/31	2014/07/31
	OFPM Aerial Lift Safety Training	OU/Division Level	2021/09/07	2021/09/14
	OFPM Scissor lift Training	OU/Division Level	2021/06/22	2021/06/23
	CLC - Ladder Safety	NIST Level	2016/01/29	2016/02/03
	CLC - Scaffolding and Ladder Safety	NIST Level	2013/08/22	2010/04/07
	EL - Scaffold Training for Competent Person	OU/Division Level	2019/04/17	2019/04/09
Material Handling	CLC S 7101.69: Overhead Crane & Slings	NIST Level	2014/10/23	2013/04/15
	Overhead Cranes and Slings	OU/Division Level	2013/05/07	2013/04/15
	CLC - Powered Industrial Trucks: Forklift	NIST Level	2013/08/21	2013/04/18, 2013/04/18
	NIST S 7101.74: Powered Industrial Trucks	NIST Level	2019/03/27	2020/04/30
	EL - Forklift training	OU/Division Level	2017/06/20	2017/06/19, 2021/10/20
	EL-733: NFRL Forklift Operation	OU/Division Level	2014/05/02	2014/06/06
	EL-733: NFRL Skidloader Operation	OU/Division Level	2014/06/06	2014/06/06
Other	CLC - Fire Safety and Prevention	NIST Level	2013/08/27	2010/04/07
	CLC - Hazard Communication: An Employee"s Right to Know	NIST Level	2013/08/28	2011/12/12
	CLC - Hazard Recognition & Controls	NIST Level	2013/08/20	2009/08/20
	CLC - Laboratory Safety	NIST Level	2013/08/22	2010/10/05

ENGR TECH 4 (continued)				
Category	**Course Name**	**Category**	**Date Assigned**	**Date Completed**
Other	CLC - Material Safety Data Sheets	NIST Level	2013/08/28	2009/10/05
	CLC - Office Safety	NIST Level	2013/08/28	2011/12/12
	CLC S 7101.56: Lockout/Tagout for Authorized Persons 2.0	NIST Level	2013/08/22	2011/05/17
	CLC S 7101.62: Computer Ergonomics	NIST Level	2020/06/23	2020/06/23
	CLC S 7101.62: Office Ergonomics	NIST Level	2020/06/23	2020/06/23
	CLC S 7101.xx: Lead Awareness in General Industry	NIST Level	2013/08/22	2010/12/06
	CLC S 7200.00: Radiation Safety	NIST Level	2013/08/14	2011/06/01
	NIST 7101-61_Compressed Gas Safety GAP Training_070821	NIST Level	2022/02/07	2022/07/20, 2022/07/20
	NIST P 7100.00: OSHA 6000 - Collateral Duty Course for Federal Employees	NIST Level	2013/08/15	2010/09/13
	NIST P 7100: Safety and Health Training for Staff Accessing and Working on NIST Campuses during the COVID	NIST Level	2022/03/31	2022/03/28
	NIST P 7100: NIST Safe Return to Campus Training for Phase 1	NIST Level	2020/06/24	2020/06/24
	NIST S 7101.56: Control of Hazardous Energy (Lockout/Tagout (LOTO))	NIST Level	2015/03/11	2015/03/27
	NIST S 7101.56: Control of Hazardous Energy (Lockout/Tagout (LOTO)) - Gap training	NIST Level	2019/08/15	2019/08/15
	NIST S 7101.59: Chemical Hazard Communication Program Training	NIST Level	2016/03/07	2016/03/21
	NIST S 7101.59: HCS - New Label Elements and New Safety Data Sheet Format	NIST Level	2013/11/25	2013/11/25
	NIST S 7101.61: Compressed Gas Safety Program Training	NIST Level	2016/01/29	2016/02/04
	NIST S 7101.64: Safe Electrical Work Practices – Limited Scope Course	NIST Level	2016/09/22	2016/09/21
	NIST S 7101.72: Laser Safety Awareness - Non-User (Web-Based)	NIST Level	2022/07/19	2022/07/19
	EL Confined Space Entry Safety	OU/Division Level	2013/08/21	2010/04/20
	EL First Aid/CPR/AED	OU/Division Level	2013/08/20	2013/05/14
	EL Office Safety and Ergonomics	OU/Division Level	2013/08/20	2009/09/29
	EL-733: NFRL Emission Control System Training for Operators	OU/Division Level	2014/02/28	2014/03/19
	EL-733: NFRL Natural Gas Fuel Delivery System Training	OU/Division Level	2018/11/15	2018/11/15
	EL-733: NFRL Structural Loading for Operators	OU/Division Level	2014/04/28	2014/04/28

ENGR TECH 5				
Category	Course Name	Category	Date Assigned	Date Completed
General Safety Training	NIST P 7100.00: General Safety Training	NIST Level	2014/01/15	2014/01/21
	NIST P 7100.00: OSHA 6000 - Collateral Duty Course for Federal Employees	NIST Level	2013/08/15	2010/10/18
	EL Safety Awareness Combined Course - ILT	OU/Division Level	2013/08/19	2012/09/04
	EL-733: NFRL Lab Access and Safety Policies	OU/Division Level	2015/03/25	2015/03/25, 2023/01/05
Personal Protective Equipment	CLC - Fall Protection (or Working at Heights)	OU/Division Level	2013/08/22	2011/06/08
	NIST S 7101.21: Personal Protective Equipment Program Training	NIST Level	2015/02/12	2015/03/25
	NIST S 7101.21: Personal Protective Equipment Program 2019 Gap Training	NIST Level	2019/08/14	2019/08/14
	NIST S 7101.67: Fall Protection Authorized Person	NIST Level	2019/08/14	2020/08/24
	NIST S 7101.58: Respiratory Protection Program - Initial Training (Web-based)	NIST Level	2014/08/14	2014/08/14
	NIST S 7101.58: Respiratory Protection Program - FY17 Refresher Training (Web-based)	NIST Level	2017/02/12	2018/01/18
	NIST S 7101.58: Respiratory Protection Program - FY18 Refresher Fit Testing	NIST Level	2018/07/27	2018/07/06
	NIST S 7101.58: Respiratory Protection Program - FY19 Refresher Training (Web-based)	NIST Level	2019/02/06	2019/02/06
	NIST S 7101.58: Respiratory Protection Program - FY20 Refresher Training (Web-based)	NIST Level	2020/01/14	2020/07/01
	NIST S 7101.58: Respiratory Protection Program - FY21 Refresher Training (Web-based)	NIST Level	2021/03/09	2021/04/27
	NIST S 7101.58: Respiratory Protection Program - 2022 Refresher Training (Web-based)	NIST Level	2022/02/03	2022/05/20
	NIST S 7101.58: Respiratory Protection Program - 2023 Refresher Training (Web-based)	NIST Level	2023/01/19	Not Started
	CLC - Using Respiratory Protection	NIST Level	2013/08/14	2013/02/05
	EL Respirator Training and Fit Testing	OU/Division Level	2013/08/21	2012/03/06
	EL SCBA Training and Fit Testing	OU/Division Level	2013/08/22	2008/09/05
	NIST S 7101.55: Hearing Protection Program - Initial Training (Web-based)	NIST Level	2015/06/24	2015/06/24
	NIST S 7101.55: Hearing Protection Program - FY16 Refresher Training (Web-based)	NIST Level	2015/12/31	2016/02/12
	NIST S 7101.55: Hearing Protection Program - FY21 Refresher Training (Web-based)	NIST Level	2021/07/21	2021/07/21
Construction/Demolition Work	NIST S 7101.64: Electrical Safety for Laboratory Workers	NIST Level	2020/07/01	2020/07/01
	NIST S 7101.65: Basic Machine Shop Safety	NIST Level	2014/03/27	2015/03/25
	CLC - Hand and Power Tool Safety	NIST Level	2013/08/22	2011/10/05
	EL-733: NFRL Machine and Fabrication Shop Safety Awareness	OU/Division Level	2014/06/02	2015/03/25
	EL Machine Shop Safety	OU/Division Level	2013/08/22	2008/03/03
	CLC - Slips, Trips, and Falls	NIST Level	2013/08/14	2011/10/04
	OFPM Aerial Lift Safety Training	OU/Division Level	2021/09/07	2021/09/07
	OFPM Scissor lift Training	OU/Division Level	2021/06/22	2021/06/22
	EL 733: NFRL Articulated Boom Lift Operation	OU/Division Level	2014/07/31	2014/07/31
	EL-733: NFRL Scissor Lift Operation	OU/Division Level	2014/07/31	2014/07/31
	CLC - Scaffolding and Ladder Safety	NIST Level	2013/08/22	2013/03/14
	EL - Scaffold Training for Competent Person	OU/Division Level	2019/04/17	2019/04/09
Material Handling	CLC S 7101.69: Overhead Crane & Slings	NIST Level	2013/08/21	2010/11/10, 2014/11/18
	CLC S 7101.69: Indoor Hoisting and Rigging	NIST Level	2013/08/22	2011/10/05
	NIST S 7101.74: Powered Industrial Trucks	NIST Level	2019/03/27	2019/03/28
	CLC - Powered Industrial Trucks: Forklift	NIST Level	2014/12/04	2014/11/19
	EL - Forklift training	OU/Division Level	2021/11/03	2021/10/20
	EL-733: NFRL Forklift Operation	OU/Division Level	2014/05/02	2020/08/24

ENGR TECH 5 (continued)				
Category	**Course Name**	**Category**	**Date Assigned**	**Date Completed**
Other	CLC - Defensive Driving Fundamentals	NIST Level	2013/08/27	2012/02/21
	CLC - Fire and Explosion Hazards	NIST Level	2013/08/27	2010/11/23
	CLC - Fleet Safety: Accident Procedures Involving Large Vehicles	NIST Level	2021/10/26	2021/10/26
	CLC - Fleet Safety: Distracted Driving	NIST Level	2021/10/26	2021/10/26
	CLC - Fleet Safety: Urban Driving	NIST Level	2021/10/26	In Progress
	CLC - Job Hazard Analysis	NIST Level	2013/08/22	2011/06/27
	CLC - Laboratory Safety	NIST Level	2013/08/22	2010/11/09
	CLC - Material Safety Data Sheets	NIST Level	2013/08/28	2009/10/15
	CLC - Office Safety	NIST Level	2013/08/28	2010/11/23
	CLC S 7101.60: Beryllium	NIST Level	2021/10/26	In Progress
	CLC S 7101.62: Back Safety and Injury Prevention 2.0	NIST Level	2013/09/19	2013/08/05
	CLC S 7200.00: Radiation Safety	NIST Level	2013/08/14	2012/02/21
	NIST 7101-61 Compressed Gas Safety GAP Training 070821	NIST Level	2022/02/07	2022/02/07
	NIST P 7100: Safety and Health Training for Staff Accessing and Working on NIST Campuses during the COVID	NIST Level	2021/10/25	2021/10/25, 2022/04/21
	NIST P 7100: NIST Safe Return to Campus Training for Phase 1	NIST Level	2020/07/17	2020/07/17, 2021/07/12
	NIST S 7101.22: Hazard Signage Training - Program Requirements	NIST Level	2020/07/01	2020/07/01
	NIST S 7101.50: Infectious Diseases training for HOT response team	NIST Level	2015/12/31	2016/02/12
	NIST S 7101.59: Chemical Hazard Communication Program Training	NIST Level	2016/03/07	2016/04/06
	NIST S 7101.59: CIMS OU/Division Administrator Role	NIST Level	2018/09/27	2018/09/27
	NIST S 7101.59: HCS - New Label Elements and New Safety Data Sheet Format	NIST Level	2013/11/19	2013/11/19
	NIST S 7101.61: Compressed Gas Safety Program Training	NIST Level	2016/02/04	2016/02/11
	NIST S 7101.62: Office Safety Program Training	NIST Level	2020/07/01	2020/07/01
	NIST S 7101.64: Safe Electrical Work Practices – Limited Scope Course	NIST Level	2016/09/22	2016/09/21
	NIST S 7101.72: Laser Safety Awareness - Non-User (Web-Based)	NIST Level	2022/07/11	2022/07/11
	NIST S 7301.06: NIST Gaithersburg Chemical Waste Accumulation and Disposal	NIST Level	2019/11/13	2019/11/15
	EL Confined Space Entry Safety	OU/Division Level	2013/08/21	2010/04/20
	EL First Aid/CPR/AED	OU/Division Level	2013/08/20	2011/11/28
	EL Hazard Communications	OU/Division Level	2013/08/20	2010/12/07
	EL Office Safety and Ergonomics	OU/Division Level	2013/08/20	2009/09/29
	EL Radiation Safety for New Users	OU/Division Level	2013/08/21	2008/07/23
	EL Responder Safety Awareness	OU/Division Level	2013/08/22	2011/01/19
	EL-733: NFRL Emission Control System Training for Operators	OU/Division Level	2014/03/10	2020/08/24

ENGR TECH 6				
Category	Course Name	Category	Date Assigned	Date Completed
General Safety Training	NIST P 7100.00: General Safety Training	NIST Level	2014/01/15	2014/01/21
	NIST S 7101.20: Work and Worker Authorization Based on Hazard Review	NIST Level	2015/03/27	2015/03/27
	EL Safety Awareness Combined Course - ILT	OU/Division Level	2013/08/19	2012/09/04
	EL-733: NFRL Lab Access and Safety Policies	OU/Division Level	2015/03/26	2015/03/27
Personal Protective Equipment	NIST S 7101 21: Personal Protective Equipment Program Training	NIST Level	2015/02/12	2015/03/24
	NIST S 7101 21: Personal Protective Equipment Program 2019 Gap Training	NIST Level	2019/10/24	2019/10/24
	EL - Fall Protection - ILT	OU/Division Level	2015/08/12	2015/08/11
	NIST S 7101 58: Respiratory Protection Program - Training for Voluntary Use of Filtering Facepieces	NIST Level	2014/12/22	2014/12/22, 2014/12/22
	NIST S 7101.58: Respiratory Protection Program - Initial Training (Web-based)	NIST Level	2015/04/09	2016/04/21
	NIST S 7101.58: Respiratory Protection Program - Initial Fit Testing FY16	NIST Level	2015/01/09	2014/04/15
	NIST S 7101.58: Respiratory Protection Program - FY15 Refresher Fit Testing	NIST Level	2015/01/27	2015/07/10
	NIST S 7101.58: Respiratory Protection Program - FY15 Refresher Training (Web-based)	NIST Level	2015/04/09	2015/04/09
	NIST S 7101.58: Respiratory Protection Program - FY16 Refresher Fit Testing	NIST Level	2016/05/27	2016/07/19
	NIST S 7101.58: Respiratory Protection Program - FY17 Refresher Fit Testing	NIST Level	2017/03/30	2017/03/28
	NIST S 7101.58: Respiratory Protection Program - FY17 Refresher Training (Web-based)	NIST Level	2017/02/12	2017/02/13
	NIST S 7101.58: Respiratory Protection Program - FY18 Refresher Fit Testing	NIST Level	2018/04/19	2018/04/10
	NIST S 7101.58: Respiratory Protection Program - FY18 Refresher Training (Web-based)	NIST Level	2018/01/26	2018/02/08
	NIST S 7101.58: Respiratory Protection Program - FY19 Refresher Fit Testing	NIST Level	2019/03/20	2019/06/20
	NIST S 7101.58: Respiratory Protection Program - FY19 Refresher Training (Web-based)	NIST Level	2019/02/06	2019/02/21
	NIST S 7101.58: Respiratory Protection Program - FY20 Refresher Training (Web-based)	NIST Level	2020/01/14	2020/01/16
	NIST S 7101.58: Respiratory Protection Program - FY21 Refresher Training (Web-based)	NIST Level	2021/03/09	2021/04/02
	NIST S 7101.58: Respiratory Protection Program - 2022 Refresher Training (Web-based)	NIST Level	2022/02/03	2022/02/14
	CLC - Using Respiratory Protection	NIST Level	2013/08/14	2013/02/04
	EL Respirator Training and Fit Testing	OU/Division Level	2013/08/21	2012/02/23
	EL SCBA Training and Fit Testing	OU/Division Level	2013/08/22	2008/09/05
	NIST S 7101.55: Hearing Protection Program - Initial Training (Web-based)	NIST Level	2014/04/28	2014/04/28, 2014/04/28
	NIST S 7101.21: Protective Footwear	NIST Level	2014/10/02	2014/10/02
	NIST S 7101.21: Head Protection	NIST Level	2014/10/02	2014/10/02
	NIST S 7101.21: Eye Protection Training	NIST Level	2014/10/02	2014/10/02
	NIST S 7101.21: Hand Protection	NIST Level	2014/10/02	2014/10/02
Construction/Demolition Work	CLC - Hand and Power Tool Safety	NIST Level	2013/08/22	2009/09/21
	EL Machine Shop Safety	OU/Division Level	2013/08/21	2010/02/25
	NIST S 7101.75: Slips, Trips, and Falls	NIST Level	2014/10/02	2014/10/02, 2020/03/26
	CLC - Slips, Trips, and Falls	NIST Level	2013/08/14	2010/12/09, 2020/03/26
	OFPM Aerial Lift Safety Training	OU/Division Level	2021/09/16	2021/09/17
	OFPM Scissor lift Training	OU/Division Level	2021/06/22	2021/06/22
	CLC - Scaffolding and Ladder Safety	NIST Level	2013/08/22	2009/09/21
	EL - Scaffold Training for Competent Person	OU/Division Level	2019/04/17	2019/04/09
Material Handling	CLC S 7101.69: Overhead Crane & Slings	NIST Level	2013/08/21	2009/03/18
	NIST S 7101.74: Powered Industrial Trucks	NIST Level	2019/03/27	2019/04/03
	CLC - Powered Industrial Trucks: Forklift	NIST Level	2014/12/04	2014/12/04
	EL - Forklift training	OU/Division Level	2017/06/20	2017/06/19, 2021/10/20
Other	CLC - Defensive Driving Fundamentals	NIST Level	2017/10/16	2017/10/17
	CLC - Hazard Communication: An Employee''s Right to Know	NIST Level	2013/08/28	2011/09/20
	CLC - Hazard Recognition & Controls	NIST Level	2013/08/20	2009/08/18

ENGR TECH 6 (continued)				
Category	**Course Name**	**Category**	**Date Assigned**	**Date Completed**
Other	CLC - Office Safety	NIST Level	2013/08/28	2011/12/16
	CLC S 7101.56: Lockout/Tagout 2.0	NIST Level	2020/04/06	2020/04/24
	CLC S 7101.60: Liquefied Petroleum Gas (LPG)	NIST Level	2013/08/22	2013/03/28
	CLC S 7101.61: Compressed Gas Safety	NIST Level	2014/10/03	2014/10/03
	CLC S 7101.xx: Heat Stress Recognition and Prevention	NIST Level	2017/10/16	2017/10/17
	CLC S 7101.xx: Lead Awareness in General Industry	NIST Level	2013/08/22	2011/09/20
	CLC S 7200.00: Radiation Safety	NIST Level	2013/08/14	2010/10/08
	CLC S 7401.04: Portable Fire Extinguishers 2.0	NIST Level	2013/08/27	2010/12/09
	NIST P 7100.00: 2019 NIST Safety Day Opening Presentations	NIST Level	2019/10/28	2019/10/28
	NIST P 7100.00: Electrical Safety at Home	NIST Level	2019/10/28	2019/10/28
	NIST P 7100: Safety and Health Training for Staff Accessing and Working on NIST Campuses during the COVI	NIST Level	2021/10/22	2021/10/22, 2022/04/01
	NIST P 7100: NIST Safe Return to Campus Training for Phase 1	NIST Level	2020/07/06	2020/07/06, 2021/07/09
	NIST S 7101.26: Workplace Inspection Program Training	NIST Level	2018/07/25	2018/07/25
	NIST S 7101.26: Workplace Inspector Training	NIST Level	2018/07/10	2018/08/23
	NIST S 7101 50: Bloodborne Pathogens Web-based User Training 2016	NIST Level	2017/10/16	2017/10/20
	NIST S 7101 50: Infectious Diseases training for HOT response team	NIST Level	2017/10/16	2017/10/18
	NIST S 7101.51: Bloodborne Pathogens Web-based User Training 2020	NIST Level	2020/02/19	2020/03/04
	NIST S 7101.59: Chemical Hazard Communication Program Training	NIST Level	2016/04/04	2016/04/04
	NIST S 7101.59: HCS - New Label Elements and New Safety Data Sheet Format	NIST Level	2013/11/12	2013/11/12
	NIST S 7101.61: Compressed Gas Safety Program Training	NIST Level	2016/01/29	2016/02/04, 2022/01/28
	NIST S 7101.64: Electrical Cord Hazards	NIST Level	2020/03/26	2020/03/26
	NIST S 7101.64: Safe Electrical Work Practices – Limited Scope Course	NIST Level	2016/06/07	2016/09/21
	NIST S 7101.72: Laser Safety Program Training, Part 2 - Laser Safety Awareness - Laser Users (Instructor-led)	NIST Level	2013/08/21	2015/04/15
	NIST S 7201.01 2016 Refresher Training for Source Users of Radioactive Materials--November sessions.	NIST Level	2016/10/25	2016/11/15
	NIST S 7201.01 2018 Radiation Safety Refresher Training for Source Users, Source Custodians and their Line M	NIST Level	2018/11/01	2018/12/11
	NIST S 7201.01 2022 Radiation Safety Refresher Training for Source Users and their Line Management	NIST Level	2022/11/01	2022/11/21
	NIST S 7201.01 Radiation Safety Training for Source Custodians - Inventory Reconciliation 2018	NIST Level	2018/05/03	2018/05/14
	NIST S 7201.01: 2020 Radiation Safety Refresher Training for Source Users, Source Custodians and their Line	NIST Level	2020/10/20	2020/11/10
	NIST S 7301.06: NIST Gaithersburg Chemical Waste Accumulation and Disposal	NIST Level	2019/11/18	2019/11/18
	DSR Summit - Spring 2020	OU/Division Level	2020/06/05	2020/05/28
	EL Asbestos Awareness Training	OU/Division Level	2015/07/15	2015/07/15
	EL Bloodborne Pathogen Training	OU/Division Level	2013/08/16	2012/02/23
	EL First Aid/CPR/AED	OU/Division Level	2013/08/23	2011/11/29
	EL Lathe Safety	OU/Division Level	2013/08/21	2010/02/24
	EL Milling Machine Safety	OU/Division Level	2013/08/21	2010/02/24
	EL Office Safety and Ergonomics	OU/Division Level	2013/08/20	2009/09/29
	EL Radiation Safety for New Users	OU/Division Level	2013/08/21	2010/11/19

NFRL ENGINEER 1				
Category	**Course Name**	**Category**	**Date Assigned**	**Date Completed**
General Safety Training	NIST P 7100.00: General Safety Training	NIST Level	2014/01/15	2014/01/21
	EL Safety Awareness Combined Course - ILT	OU/Division Level	2020/07/01	2020/07/01
	EL-733: NFRL Lab Access and Safety Policies	OU/Division Level	2015/01/13	2015/02/18, 2023/01/06
Personal Protective Equipment	CLC - Fall Protection (or Working at Heights)	OU/Division Level	2016/01/29	2016/04/08
	NIST S 7101.21: Personal Protective Equipment Program Training	NIST Level	2015/02/12	2015/02/18
	NIST S 7101.21: Personal Protective Equipment Program 2019 Gap Training	NIST Level	2019/09/11	2019/09/11
	NIST S 7101.55: Hearing Protection Program - Initial Training (Web-based)	NIST Level	2020/07/01	2020/07/01
	NIST S 7101.21: Protective Footwear	NIST Level	2015/01/13	2015/02/18
	NIST S 7101.21: Eye Protection Training	NIST Level	2015/01/13	2015/02/18
	NIST S 7101.21: Head Protection	NIST Level	2015/01/10	2015/01/12
Construction/Demolition Work	NIST S 7101.64: Electrical Safety for Laboratory Workers	NIST Level	2020/07/01	2020/07/01
	OFPM Scissor lift Training	OU/Division Level	2021/06/22	2021/08/30
	CLC - Ladder Safety	NIST Level	2016/01/29	2016/04/07
Material Handling	None			
Other	CLC S 7101.62: Computer Ergonomics	NIST Level	2020/07/02	2020/07/02
	NIST P 7100.00: 2019 NIST Safety Day Opening Presentations	NIST Level	2019/10/25	2019/10/25
	NIST P 7100.00: Electrical Safety at Home	NIST Level	2019/10/25	2019/10/25
	NIST P 7100: NIST Safe Return to Campus Training for Phase 1	NIST Level	2020/07/01	2020/07/01
	NIST S 7101.22: Hazard Signage Training - Program Requirements	NIST Level	2020/07/01	2020/07/01
	NIST S 7101.56: Control of Hazardous Energy (Lockout/Tagout (LOTO))	NIST Level	2019/10/24	2019/10/24
	NIST S 7101.59: Chemical Hazard Communication Program Training	NIST Level	2016/03/07	2016/04/08
	NIST S 7101.60: Chemical Management Program Training	NIST Level	2020/07/01	2020/07/01
	NIST S 7101.62: Office Safety Program Training	NIST Level	2020/07/02	2020/07/02

FRD DSR				
Category	**Course Name**	**Category**	**Date Assigned**	**Date Completed**
General Safety Training	NIST P 7100.00: General Safety Training	NIST Level	2014/01/15	2014/01/21
	NIST S 7101.20: Work and Worker Authorization Based on Hazard Review	NIST Level	2015/03/27	2015/03/27
	EL General Safety Awareness - Web Based	OU/Division Level	2015/04/22	2015/04/24
	EL-733: NFRL Lab Access and Safety Policies	OU/Division Level	2020/05/18	2020/06/05
Personal Protective Equipment	NIST S 7101.21: Personal Protective Equipment Program Training	NIST Level	2014/11/04	2015/03/27
	NIST S 7101.21: Personal Protective Equipment Program 2019 Gap Training	NIST Level	2019/07/11	2019/07/10
	NIST S 7101.58: Respiratory Protection Program - Initial Training (Web-based)	NIST Level	2014/11/05	2014/11/05, 2020/06/25
	NIST S 7101.55: Hearing Protection Program - Initial Training (Web-based)	NIST Level	2019/10/16	2020/03/03
	NIST S 7101.21: Eye Protection Training	NIST Level	2016/06/27	2018/06/25
General Construction Work	OFPM Hand and Power tools safety training	OU/Division Level	2022/02/14	2022/02/14
	NIST S 7101.64: Electrical Safety for Laboratory Workers	NIST Level	2019/10/15	2019/08/21
Material Handling				
Other	NIST 7101-61 Compressed Gas Safety GAP Training 070821	NIST Level	2022/02/04	2022/02/04
	NIST P 7100.00: 2019 NIST Safety Day Opening Presentations	NIST Level	2019/10/25	2019/10/25
	NIST P 7100: Safety and Health Training for Staff Accessing and Working on NIST Campuses during the COVID Pandemic	NIST Level	2022/01/21	2022/01/21, 2022/04/08
	NIST P 7100: NIST Safe Return to Campus Training for Phase 1	NIST Level	2020/06/24	2020/06/24, 2020/07/09, 2020/08/24
	NIST S 7101.23: Safety Education and Training Program Training	NIST Level	2020/03/24	2020/03/24
	NIST S 7101.24: Incident Investigation - Principles and Methods	NIST Level	2017/11/15	2017/11/14
	NIST S 7101.26: LIVE Workplace Inspector Series, Fire Safety Systems	NIST Level	2021/10/19	2021/10/21
	NIST S 7101.26: LIVE Workplace Inspector Series, Walking and Working Surfaces Safety	NIST Level	2021/11/22	2021/11/18
	NIST S 7101.26: WIRS Introduction for Lead Inspectors	NIST Level	2016/10/13	2016/10/12
	NIST S 7101.26: Workplace Inspection Program Training	NIST Level	2016/07/20	2016/07/20
	NIST S 7101.26: Workplace Inspector Training	NIST Level	2016/07/20	2016/07/20
	NIST S 7101.50: Biosafety and Bloodborne Pathogens Combo Training	NIST Level	2014/02/23	2013/06/18
	NIST S 7101.52: Cryogen Safety 2021 GAP Training	NIST Level	2021/04/26	2021/04/26
	NIST S 7101.52: Cryogen User Safety Training	NIST Level	2014/03/31	2014/03/31
	NIST S 7101.54: Dispersible Engineered Nanomaterials (DENMs) Safety Training	NIST Level	2015/04/22	2015/04/24
	NIST S 7101.56: Control of Hazardous Energy (Lockout/Tagout (LOTO))	NIST Level	2019/08/13	2019/08/13
	NIST S 7101.56: Control of Hazardous Energy (Lockout/Tagout (LOTO)) - Gap training	NIST Level	2019/08/14	2019/09/16
	NIST S 7101.59: CIMS Division Administrator Role	NIST Level	2018/11/02	2019/03/27
	NIST S 7101.59: Chemical Hazard Communication Program Training	NIST Level	2016/03/24	2016/03/24
	NIST S 7101.59: Hazardous Chemical Container Labeling Requirements	NIST Level	2015/04/29	2015/04/29
	NIST S 7101.59: HCS - New Label Elements and New Safety Data Sheet Format	NIST Level	2013/11/27	2014/05/27
	NIST S 7101.60: Chemical Management Program Training	NIST Level	2020/04/06	2020/04/23
	NIST S 7101.61: Compressed Gas Safety Program Training	NIST Level	2016/02/04	2016/02/08, 2022/04/28
	NIST S 7101.72: DLSR Laser Hazard Analysis Training (2022)	NIST Level	2022/01/25	2022/01/07
	NIST S 7101.72: Laser Safety Awareness - Non-User (Web-Based)	NIST Level	2019/04/02	2019/04/02
	NIST S 7101.72: Laser Safety Program Training, Part 2 - Laser Safety Awareness - Laser Users (Instructor-led)	NIST Level	2018/05/17	2019/09/23
	NIST S 7101.75: Slips, Trips, and Falls	NIST Level	2016/06/27	2018/06/25
	NIST S 7301.06: NIST Gaithersburg Chemical Waste Accumulation and Disposal	NIST Level	2019/11/14	2019/11/14, 2021/04/19
	Cryogen Transfer	OU/Division Level	2020/04/30	2020/06/05
	DSR Summit -- Spring 2017	OU/Division Level	2017/03/16	2017/03/13
	DSR Summit -- Spring 2018	OU/Division Level	2018/03/14	2018/03/12
	DSR Summit - Spring 2020	OU/Division Level	2020/06/05	2020/05/28
	DSR Summit - Spring 2021	OU/Division Level	2021/04/22	2021/04/21
	DSR Summit - Spring 2022	OU/Division Level	2022/04/21	2022/04/20
	EL-730: Laser Safety Training	OU/Division Level	2018/06/25	2019/10/28
	First Aid/CPR/AED	OU/Division Level	2016/04/18	2016/04/27
	From MSQA to Imaging Gently and Wisely	OU/Division Level	2020/09/16	2020/09/16
	Machine Shop Safety - Basic course	OU/Division Level	2017/10/24	2017/11/14
	MML Safety Stand Down: Focus on Legacy Materials	OU/Division Level	2014/12/19	2014/11/18
	NCNR: Cryogenic Safety Webinar	OU/Division Level	2020/05/07	2020/04/24
	NIST S 7101.67: Fall Protection Training for General Industry	OU/Division Level	2020/04/30	2020/04/30

CF PROJECT LEADER 1				
Category	Course Name	Category	Date Assigned	Date Completed
General Safety Training	NIST P 7100.00: General Safety Training	NIST Level	1/15/2014	1/21/2014
	EL Safety Awareness Combined Course - ILT	OU/Division Level	8/19/2013	9/4/2012
	EL Safety Awareness for All Personnel ILT	OU/Division Level	8/19/2013	9/4/2012
	EL General Safety Awareness - Web Based	OU/Division Level	7/2/2020	7/2/2020
	EL-733: NFRL Lab Access and Safety Policies	OU/Division Level	1/12/2015	1/12/2015
Personal Protective Equipment	NIST S 7101.21: Personal Protective Equipment Program 2019 Gap Training	NIST Level	8/14/2019	8/14/2019
	NIST S 7101.21: Personal Protective Equipment Program Training	NIST Level	2/12/2015	2/18/2015
	NIST S 7101.67: Fall Protection Program Training	NIST Level	9/8/2021	9/8/2021
	CLC - Fall Protection (or Working at Heights)	OU/Division Level	1/29/2016	3/15/2016
	NIST S 7101.58: Respiratory Protection Program - FY20 Refresher Training (Web-based)	NIST Level	1/21/2020	1/30/2020
	NIST S 7101.58: Respiratory Protection Program - FY21 Refresher Training (Web-based)	NIST Level	3/9/2021	5/6/2021
	CLC - Personal Protective Equipment / Respiratory Protection (HAZWOPER)	NIST Level	8/14/2013	11/6/2012
	NIST S 7101.55: Hearing Protection Program - Initial Training (Web-based)	NIST Level	6/16/2020	6/18/2020
	NIST S 7101.21: Protective Footwear	NIST Level	1/13/2015	1/23/2015
	NIST S 7101.21: Head Protection	NIST Level	1/10/2015	1/12/2015
	NIST S 7101.21: Eye Protection Training	NIST Level	1/13/2015	1/23/2015
Construction/Demolition Work	NIST S 7101.64: Electrical Safety for Laboratory Workers	NIST Level	7/2/2020	7/2/2020
	CLC - Ladder Safety	NIST Level	1/29/2016	3/15/2016
Material Handling	CLC S 7101.69: Overhead Crane & Slings	NIST Level	8/21/2013	4/15/2013
	Overhead Cranes and Slings	OU/Division Level	5/7/2013	4/15/2013
	OFPM Scissor lift Training	OU/Division Level	6/22/2021	6/22/2021
Other	CLC - Electrical Safety	NIST Level	8/22/2013	10/31/2012
	CLC - Hazard Communication: An Employee"s Right to Know	NIST Level	8/28/2013	11/7/2012
	CLC - Material Safety Data Sheets	NIST Level	8/28/2013	11/5/2012
	NIST P 7100: Safety and Health Training for Staff Accessing and Working on NIST Campuses during the COVID	NIST Level	10/18/2021	10/18/2021
	NIST P 7100: NIST Safe Return to Campus Training for Phase 1	NIST Level	7/2/2020	7/2/2020
	NIST P 7100: NIST Safe Return to Campus Training for Phase 1	NIST Level	7/12/2021	7/12/2021
	NIST S 7101.22: Hazard Signage Training - Program Requirements	NIST Level	6/18/2020	7/2/2020
	NIST S 7101.56: Control of Hazardous Energy (Lockout/Tagout (LOTO))	NIST Level	10/21/2019	10/21/2019
	NIST S 7101.56: Control of Hazardous Energy (Lockout/Tagout (LOTO)) - Gap training	NIST Level	10/21/2019	10/21/2019
	NIST S 7101.59: Chemical Hazard Communication Program Training	NIST Level	3/7/2016	3/15/2016
	NIST S 7101.59: HCS - New Label Elements and New Safety Data Sheet Format	NIST Level	11/25/2013	11/25/2013
	NIST S 7101.60: Chemical Management Program Training	NIST Level	7/2/2020	7/2/2020
	NIST S 7101.62: Office Safety Program Training	NIST Level	7/2/2020	7/2/2020

CF PROJECT LEADER 2				
Category	Course Name	Category	Date Assigned	Date Completed
General Safety Training	NIST P 7100.00: General Safety Training	NIST Level	2014/01/15	2014/01/21
	NIST S 7101.20: Work and Worker Authorization Based on Hazard Review	NIST Level	2015/02/12	2015/02/18
	EL Safety Awareness for All Personnel - Web Based	OU/Division Level	2014/05/07	2014/05/30
	EL-733: NFRL Lab Access and Safety Policies	OU/Division Level	2015/01/13	2015/04/06, 2022/10/17
Personal Protective Equipment	NIST S 7101.21: Personal Protective Equipment Program 2019 Gap Training	NIST Level	2019/08/26	2019/08/26
	NIST S 7101.21: Personal Protective Equipment Program Training	NIST Level	2014/11/06	2014/11/06
	CLC - Fall Protection (or Working at Heights)	OU/Division Level	2014/10/23	2014/10/23
	NIST S 7101.58: Respiratory Protection Program - Initial Fit Testing FY16	NIST Level	2015/01/09	2014/03/11
	NIST S 7101.58: Respiratory Protection Program - Initial Training (Web-based)	NIST Level	2014/07/03	2014/07/02
	NIST S 7101.58: Respiratory Protection Program - Training for Voluntary Use of Filtering Facepieces	NIST Level	2020/06/16	2020/06/16
	NIST S 7101.58: Respiratory Protection Program - 2022 Refresher Training (Web-based)	NIST Level	2022/02/03	2022/02/03
	NIST S 7101.58: Respiratory Protection Program - FY15 Refresher Fit Testing	NIST Level	2015/02/18	2016/02/24
	NIST S 7101.58: Respiratory Protection Program - FY15 Refresher Training (Web-based)	NIST Level	2015/12/22	2015/12/22
	NIST S 7101.58: Respiratory Protection Program - FY16 Refresher Fit Testing	NIST Level	2016/04/19	2016/02/24
	NIST S 7101.58: Respiratory Protection Program - FY17 Refresher Fit Testing	NIST Level	2017/04/14	2017/03/31
	NIST S 7101.58: Respiratory Protection Program - FY17 Refresher Training (Web-based)	NIST Level	2017/02/12	2017/03/23
	NIST S 7101.58: Respiratory Protection Program - FY18 Refresher Fit Testing	NIST Level	2018/04/19	2018/04/17
	NIST S 7101.58: Respiratory Protection Program - FY18 Refresher Training (Web-based)	NIST Level	2018/01/26	2018/01/29
	NIST S 7101.58: Respiratory Protection Program - FY19 Refresher Training (Web-based)	NIST Level	2019/02/06	2019/02/07
	NIST S 7101.58: Respiratory Protection Program - FY20 Refresher Fit Testing	NIST Level	2020/01/24	2020/01/24
	NIST S 7101.58: Respiratory Protection Program - FY20 Refresher Training (Web-based)	NIST Level	2020/01/14	2020/01/14
	NIST S 7101.58: Respiratory Protection Program - FY21 Refresher Fit Testing	NIST Level	2022/02/07	Not Started
	NIST S 7101.58: Respiratory Protection Program - FY21 Refresher Training (Web-based)	NIST Level	2021/03/09	2021/03/22
	NIST S 7101.58: Respiratory Protection Program - Initial Respirator Medical Evaluation	NIST Level	2015/12/31	2016/02/03
	NIST S 7101.55: Hearing Protection Program - Initial Training (Web-based)	NIST Level	2014/11/10	2014/11/10
	NIST S 7101.55: Hearing Protection Program - FY16 Refresher Training (Web-based)	NIST Level	2015/12/22	2015/12/22
	NIST S 7101.21: Protective Footwear	NIST Level	2015/01/13	2015/01/13
	NIST S 7101.21: Head Protection	NIST Level	2015/01/10	2015/01/12
	NIST S 7101.21: Eye Protection Training	NIST Level	2015/01/13	2015/01/13
	NIST S 7101.21: Hand Protection	NIST Level	2022/12/06	2022/12/06
	CLC S 7101.21: Personal Protective Equipment: Hand Protection	NIST Level	2020/06/24	2020/06/24
Construction/Demolition Work	CLC - Hand and Power Tool Safety	NIST Level	2015/03/11	2015/03/11
	OFPM Hand and Power tools safety training	OU/Division Level	2022/12/06	2022/12/06
	NIST S 7101.64: Electrical Safety for Laboratory Workers	NIST Level	2020/06/16	2020/06/16
	NIST S 7101.65: Basic Machine Shop Safety	NIST Level	2015/04/06	2015/04/06
	EL-733: NFRL Machine and Fabrication Shop Safety Awareness	OU/Division Level	2015/04/06	2015/04/06
	OFPM Scissor lift Training	OU/Division Level	2021/06/22	2021/06/25
	CLC - Ladder Safety	NIST Level	2016/01/29	2016/02/01
Material Handling	CLC S 7101.69: Overhead Crane & Slings	NIST Level	2014/12/04	2014/12/04
Other	CLC - Defensive Driving Fundamentals	NIST Level	2016/03/24	2016/04/20, 2020/06/18
	CLC - Fire Safety and Prevention	NIST Level	2014/10/23	2014/10/23
	CLC - Laboratory Safety	NIST Level	2014/07/29	2014/07/29

CF PROJECT LEADER 2 (continued)				
Category	**Course Name**	**Category**	**Date Assigned**	**Date Completed**
Other	CLC - Material Safety Data Sheets	NIST Level	2014/10/23	2014/10/23
	CLC S 7101.57: Confined Spaces 2.0	NIST Level	2014/10/23	2014/10/23
	CLC S 7101.61: Compressed Gas Safety	NIST Level	2014/07/29	2014/07/29, 2020/06/18
	CLC S 7101.62: Back Safety and Injury Prevention 2.0	NIST Level	2020/06/24	2020/06/24
	CLC S 7101.62: Computer Ergonomics	NIST Level	2020/06/18	2020/06/18
	CLC S 7101.62: Office Ergonomics	NIST Level	2020/06/18	2020/06/18
	CLC S 7101.xx: Heat Stress Recognition and Prevention	NIST Level	2016/03/24	2016/04/20
	CLC S 7101.xx: Lead Awareness in General Industry	NIST Level	2020/06/24	2020/06/24
	NIST 7101-61_Compressed Gas Safety GAP Training_070821	NIST Level	2022/02/07	2022/02/16
	NIST P 7100.00: 2019 NIST Safety Day Opening Presentations	NIST Level	2019/10/25	2019/10/25
	NIST P 7100: Safety and Health Training for Staff Accessing and Working on NIST Campuses during the COVID	NIST Level	2021/10/18	2021/10/18, 2022/04/07
	NIST P 7100: NIST Safe Return to Campus Training for Phase 1	NIST Level	2020/06/24	2020/06/24
	NIST S 7101.22: Hazard Signage Training - Program Requirements	NIST Level	2020/06/16	2020/06/16
	NIST S 7101.50: Bloodborne Pathogens Web-based User Training 2016	NIST Level	2017/03/23	2017/03/23
	NIST S 7101.50: Bloodborne Pathogens Web-based User Training 2017	NIST Level	2017/03/23	2017/04/28
	NIST S 7101.50: Infectious Diseases training for HOT response team	NIST Level	2015/12/22	2015/12/22
	NIST S 7101.51: Bloodborne Pathogens User Training (2015 Refresher)	NIST Level	2015/12/22	2015/12/22
	NIST S 7101.51: Bloodborne Pathogens Web-based User Training 2020	NIST Level	2020/02/19	2020/02/20
	NIST S 7101.56: Control of Hazardous Energy (Lockout/Tagout (LOTO))	NIST Level	2020/06/24	2020/06/24
	NIST S 7101.56: Control of Hazardous Energy (Lockout/Tagout (LOTO)) - Gap training	NIST Level	2019/08/26	2019/08/26
	NIST S 7101.59: Chemical Hazard Communication Program Training	NIST Level	2016/03/07	2016/03/07
	NIST S 7101.59: Hazardous Chemical Container Labeling Requirements	NIST Level	2015/12/31	2016/01/08
	NIST S 7101.59: HCS - New Label Elements and New Safety Data Sheet Format	NIST Level	2015/12/22	2015/12/22
	NIST S 7101.60: Chemical Management Program Training	NIST Level	2020/06/16	2020/06/16, 2020/06/16
	NIST S 7101.61: Compressed Gas Safety Program Training	NIST Level	2016/01/29	2016/02/01
	NIST S 7101.62: Office Safety Program Training	NIST Level	2020/06/16	2020/06/16
	NIST S 7101.72: Laser Safety Program Training, Part 1 - Introduction to the NIST Laser Safety Program for Lase	NIST Level	2022/07/11	2022/07/11
	NIST S 7101.72: Laser Safety Program Training, Part 2 - Laser Safety Awareness - Laser Users (Instructor-led)	NIST Level	2014/07/30	2014/06/03
	NIST S 7401.04: NIST Fire Extinguisher Training	NIST Level	2020/06/16	2020/06/16
	EL 731: Hot Disk Thermal Constants Analyzer	OU/Division Level	2014/12/17	2014/12/18
	EL Chemical Waste Disposal - Web Based	OU/Division Level	2020/06/24	2020/06/24
	First Aid/CPR/AED	OU/Division Level	2014/04/01	2016/04/13, 2016/04/13

NFRL GROUP LEADER				
Category	**Course Name**	**Category**	**Date Assigned**	**Date Completed**
General Safety Training	NIST P 7100.00: General Safety Training	NIST Level	2014/01/15	2014/01/21
	NIST P 7100.00: OSHA 6000 - Collateral Duty Course for Federal Employees	NIST Level	2013/08/15	2009/03/16
	NIST S 7101.20: Work and Worker Authorization Based on Hazard Review	NIST Level	2015/02/12	2015/02/15
	CLC - Hazard Recognition & Controls	NIST Level	2013/08/20	2009/08/18
	NIST O 7101.00: Safety Leadership Training	NIST Level	2015/03/22	2015/04/27
	NIST S 7101 27: Management Observation Process - Recommended Training	NIST Level	2020/12/21	2020/12/16
	CLC O 7101.00: Behavior-based safety for Supervisors	NIST Level	2013/08/12	2010/10/05
	EL General Safety Awareness - Web Based	OU/Division Level	2020/06/23	2020/06/23
	EL-733: NFRL Lab Access and Safety Policies	OU/Division Level	2015/01/12	2015/01/12, 2021/11/09
	EL Safety Awareness Combined Course - ILT	OU/Division Level	2013/08/19	2012/09/04
Personal Protective Equipment	NIST S 7101.21: Personal Protective Equipment Program Training	NIST Level	2015/01/09	2015/02/16
	NIST S 7101.21: Personal Protective Equipment Program 2019 Gap Training	NIST Level	2019/08/14	2019/08/14
	EL - Fall Protection - ILT	OU/Division Level	2015/08/12	2015/08/11
	CLC - Fall Protection (or Working at Heights)	OU/Division Level	2013/08/22	2014/10/09
	NIST S 7101.58: Respiratory Protection Program - Initial Training (Web-based)	NIST Level	2014/07/07	2014/07/02
	NIST S 7101.58: Respiratory Protection Program - FY17 Refresher Fit Testing	NIST Level	2017/02/16	2017/02/03
	NIST S 7101.58: Respiratory Protection Program - FY17 Refresher Training (Web-based)	NIST Level	2017/01/30	2017/02/01
	NIST S 7101.58: Respiratory Protection Program - FY19 Refresher Training (Web-based)	NIST Level	2019/02/06	2019/04/02
	NIST S 7101.58: Respiratory Protection Program - FY20 Refresher Fit Testing	NIST Level	2020/01/24	2020/02/11
	NIST S 7101.58: Respiratory Protection Program - FY20 Refresher Training (Web-based)	NIST Level	2020/01/14	2020/01/14
	NIST S 7101.58: Respiratory Protection Program - FY21 Refresher Training (Web-based)	NIST Level	2021/03/09	2021/03/15
	NIST S 7101.58: Respiratory Protection Program - 2022 Refresher Training (Web-based)	NIST Level	2022/02/03	2022/02/09
	CLC - Using Respiratory Protection	NIST Level	2013/08/14	2013/02/05
	EL SCBA Training and Fit Testing	OU/Division Level	2013/08/22	2010/08/24
	EL Respirator Training and Fit Testing	OU/Division Level	2013/08/21	2012/03/06
	NIST S 7101.55: Hearing Protection Program - Initial Training (Web-based)	NIST Level	2014/10/02	2014/10/02
	NIST S 7101.21: Protective Footwear	NIST Level	2015/01/10	2015/01/10
	NIST S 7101.21: Head Protection	NIST Level	2015/01/09	2015/01/09
	NIST S 7101.21: Eye Protection Training	NIST Level	2015/01/10	2015/01/10
	CLC S 7101.21: Personal Protective Equipment: Hand Protection	NIST Level	2019/05/13	2019/10/21
	NIST S 7101.21: Hand Protection	NIST Level	2015/01/10	2015/01/10
Construction/Demolition Work	CLC - Hand and Power Tool Safety	NIST Level	2013/08/22	2009/12/30
	OFPM Hand and Power tools safety training	OU/Division Level	2022/11/23	2022/11/23
	NIST S 7101.64: Electrical Safety for Laboratory Workers	NIST Level	2020/06/18	2020/06/18
	EL-733: NFRL Machine and Fabrication Shop Safety Awareness	OU/Division Level	2015/03/25	2017/08/02
	OFPM Aerial Lift Training	OU/Division Level	2021/06/22	In Progress
	OFPM Scissor lift Training	OU/Division Level	2021/06/22	2021/06/22
	EL 733: NFRL Articulated Boom Lift Operation	OU/Division Level	2014/07/31	2014/07/31
	EL-733: NFRL Scissor Lift Operation	OU/Division Level	2014/07/31	2014/07/31
	EL - Scaffold Training for Competent Person	OU/Division Level	2019/04/17	2019/04/09
	CLC - Scaffolding and Ladder Safety	NIST Level	2013/08/22	2010/04/07
	CLC - Ladder Safety	NIST Level	2016/01/29	2016/01/29

NFRL GROUP LEADER (continued)				
Category	**Course Name**	**Category**	**Date Assigned**	**Date Completed**
Material Handling	CLC S 7101.69: Overhead Crane & Slings	NIST Level	2013/08/21	2013/04/15
	Overhead Cranes and Slings	OU/Division Level	2013/05/07	2013/04/15
	NIST S 7101-74: Powered Industrial Truck Deployment Briefing	NIST Level	2019/03/28	2019/03/27
	NIST S 7101.74: Powered Industrial Trucks	NIST Level	2019/03/27	2019/03/28
Other	CLC - Fire and Explosion Hazards	NIST Level	2013/08/27	2010/10/01
	CLC - Fire Safety and Prevention	NIST Level	2013/08/27	2010/04/07
	CLC - Hazard Communication: An Employee''s Right to Know	NIST Level	2013/08/28	2010/11/09
	CLC - Laboratory Safety	NIST Level	2013/08/22	2010/10/05
	CLC - Material Safety Data Sheets	NIST Level	2013/08/28	2009/11/16
	CLC - Office Safety	NIST Level	2013/08/28	2011/12/13
	CLC S 7101.56: Lockout/Tagout for Authorized Persons 2.0	NIST Level	2013/08/22	2014/08/03
	CLC S 7101.61: Compressed Gas Safety	NIST Level	2014/06/25	2014/07/29
	CLC S 7101.62: Computer Ergonomics	NIST Level	2020/06/18	2020/06/18
	CLC S 7101.62: Office Ergonomics	NIST Level	2020/06/19	2020/06/19, 2020/08/24
	CLC S 7101.xx: Lead Awareness in General Industry	NIST Level	2013/08/22	2010/12/17
	NIST 7101-61_Compressed Gas Safety GAP Training_070821	NIST Level	2022/02/07	2022/02/09
	NIST P 7100: Safety and Health Training for Staff Accessing and Working on NIST Campuses during the COVI	NIST Level	2022/03/31	2022/04/04
	NIST P 7100: NIST Safe Return to Campus Training for Phase 1	NIST Level	2020/06/25	2020/06/25, 2021/07/06
	NIST P7100.00: Distracted Driving and Walking	NIST Level	2019/10/25	2019/10/25
	NIST S 7101.22: Hazard Signage Training - Program Requirements	NIST Level	2020/06/23	2020/06/23
	NIST S 7101.24: Equivalent Training for Incident Investigation - Principles and Methods	NIST Level	2020/06/26	2010/09/10
	NIST S 7101 24: IRIS Investigation Submitter Training	NIST Level	2017/09/12	2017/09/18
	NIST S 7101 24: IRIS Report Submitter Training	NIST Level	2017/09/12	2017/09/18
	NIST S 7101.26: LIVE Workplace Inspector Series, Fire Safety Systems	NIST Level	2021/10/20	2021/10/21
	NIST S 7101.26: Workplace Inspector Training	NIST Level	2021/02/05	2021/02/25
	NIST S 7101.52: Cryogen User Safety Training	NIST Level	2016/11/15	2016/11/15
	NIST S 7101.56: Control of Hazardous Energy (Lockout/Tagout (LOTO))	NIST Level	2015/03/11	2015/03/11
	NIST S 7101.56: Control of Hazardous Energy (Lockout/Tagout (LOTO)) - Gap training	NIST Level	2019/08/14	2019/08/14
	NIST S 7101.57: Permit-Required Confined Spaces	NIST Level	2020/04/21	2020/05/08
	NIST S 7101.59: Chemical Hazard Communication Program Training	NIST Level	2016/03/07	2016/03/17
	NIST S 7101.59: HCS - New Label Elements and New Safety Data Sheet Format	NIST Level	2013/11/23	2013/11/23
	NIST S 7101.60: Chemical Management Program Training	NIST Level	2020/06/23	2020/06/23
	NIST S 7101.61: Compressed Gas Safety Program Training	NIST Level	2016/01/29	2016/01/29
	NIST S 7101.62: Office Safety Program Training	NIST Level	2020/06/25	2020/06/25
	NIST S 7101.64: Safe Electrical Work Practices – Limited Scope Course	NIST Level	2016/09/22	2016/09/21
	NIST S 7101.72: Laser Safety Program Training, Part 2 - Laser Safety Awareness - Laser Users (Instructor-led)	NIST Level	2021/10/15	Not Started
	NIST S 7201.01 2018 Radiation Safety Refresher Training for Source Users, Source Custodians and their Line N	NIST Level	2018/11/01	2019/03/11
	NIST S 7301.06: NIST Gaithersburg Chemical Waste Accumulation and Disposal	NIST Level	2019/11/13	2019/11/13
	NIST S 7401.04: NIST Fire Extinguisher Training	NIST Level	2020/06/16	2020/06/16
	EL Asbestos Awareness Training	OU/Division Level	2015/07/15	2015/07/15
	EL Bloodborne Pathogen Training	OU/Division Level	2013/08/16	2012/03/06
	EL Confined Space Entry Safety	OU/Division Level	2013/08/21	2010/04/20
	EL First Aid/CPR/AED	OU/Division Level	2013/08/20	2013/05/14
	EL Hazard Communications	OU/Division Level	2013/08/20	2010/12/07
	EL Incident Investigation Training - NSC/OSHE	OU/Division Level	2013/08/22	2010/09/10
	EL Office Safety and Ergonomics	OU/Division Level	2013/08/20	2009/09/29
	EL Responder Safety Awareness	OU/Division Level	2013/08/22	2010/12/07
	EL-730: OSHE Safety Training Database Tool	OU/Division Level	2014/01/15	2014/01/14

NFRL GROUP LEADER (continued)				
Category	**Course Name**	**Category**	**Date Assigned**	**Date Completed**
Other	EL-733: NFRL Emission Control System Training for Operators	OU/Division Level	2014/02/28	2014/03/19
	EL-733: NFRL Natural Gas Fuel Delivery System Training	OU/Division Level	2018/11/15	2018/11/15

FRD CHIEF 1				
Category	**Course Name**	**Category**	**Date Assigned**	**Date Completed**
General Safety Training	NIST P 7100.00: General Safety Training	NIST Level	1/15/2014	1/21/2014
	NIST P 7100.00: OSHA 6000 - Collateral Duty Course for Federal Employees	NIST Level	8/15/2013	3/16/2009
	CLC - Hazard Recognition & Controls	NIST Level	8/20/2013	9/15/2009
	NIST O 7101.00: Safety Leadership Training	NIST Level	3/24/2017	3/24/2017
	EL-733: NFRL Lab Access and Safety Policies	OU/Division Level	5/18/2020	7/23/2020
	EL Safety Awareness Combined Course - ILT	OU/Division Level	8/19/2013	9/17/2012
	EL Safety Awareness for All Personnel - Web Based	OU/Division Level	12/31/2015	1/5/2016
	EL Safety Awareness for All Personnel ILT	OU/Division Level	8/19/2013	9/4/2012
Personal Protective Equipment	NIST S 7101 21: Personal Protective Equipment Program Training	NIST Level	2/12/2015	3/25/2015
	NIST S 7101 21: Personal Protective Equipment Program 2019 Gap Training	NIST Level	1/28/2020	1/28/2020
	NIST S 7101 58: Respiratory Protection Program - Initial Training (Web-based)	NIST Level	12/31/2015	NULL
	NIST S 7101 58: Respiratory Protection Program - FY17 Refresher Fit Testing	NIST Level	2/12/2017	NULL
	NIST S 7101 58: Respiratory Protection Program - Training for Voluntary Use of Filtering Facepieces	NIST Level	6/25/2020	6/25/2020
	CLC - Using Respiratory Protection	NIST Level	8/14/2013	8/15/2013
	NIST S 7101 55: Hearing Protection Program - Initial Training (Web-based)	NIST Level	6/24/2015	1/5/2016
	EL Respirator Training and Fit Testing	OU/Division Level	8/21/2013	2/23/2012
General Construction Work	CLC - Hand and Power Tool Safety	NIST Level	8/22/2013	2/25/2009
	NIST S 7101.64: Electrical Safety for Laboratory Workers	NIST Level	5/5/2016	5/5/2016
	CLC - Scaffolding and Ladder Safety	NIST Level	8/22/2013	12/9/2009
Material Handling				
Other	NIST P 7100.00: 2019 NIST Safety Day Opening Presentations	NIST Level	10/28/2019	10/28/2019
	NIST P 7100.00: Electrical Safety at Home	NIST Level	10/28/2019	10/28/2019
	NIST P 7100: Safety and Health Training for Staff Accessing and Working on NIST Campuses during the COVID Pandemic	NIST Level	10/18/2021	10/18/2021
	NIST P 7100: NIST Safe Return to Campus Training for Phase 1	NIST Level	6/23/2020	6/23/2020
	NIST S 7101 24: Equivalent Training for Incident Investigation - Principles and Methods	NIST Level	6/26/2020	8/27/2012
	NIST S 7101 24: Incident Reporting and Investigation Training - Program Requirements	NIST Level	8/20/2013	8/27/2012
	NIST S 7101 52: Cryogen Safety Suborder Training_043013	NIST Level	4/8/2020	7/23/2020
	NIST S 7101 52: Cryogen User Safety Training	NIST Level	4/8/2020	7/23/2020
	NIST S 7101 56: Control of Hazardous Energy (Lockout/Tagout (LOTO))	NIST Level	1/29/2020	1/29/2020
	NIST S 7101 58: Respiratory Protection Program - FY16 Refresher Training (Web-based)	NIST Level	4/19/2016	NULL
	NIST S 7101 59: Chemical Hazard Communication Program Training	NIST Level	3/7/2016	3/18/2016
	NIST S 7101 59: HCS - New Label Elements and New Safety Data Sheet Format	NIST Level	11/19/2013	11/19/2013
	NIST S 7101.61: Compressed Gas Safety Program Training	NIST Level	2/4/2016	2/5/2016
	NIST S 7101.64: Safe Electrical Work Practices – Limited Scope Course	NIST Level	3/30/2020	6/14/2021
	NIST S 7201.01 2016 Refresher Training for Source Users of Radioactive Materials--December Sessions.	NIST Level	1/13/2017	12/2/2016
	NIST S 7201.01 2018 Radiation Safety Refresher Training for Source Users, Source Custodians and their Line Management	NIST Level	11/1/2018	11/19/2018
	NIST S 7201.01: 2015 Refresher Training For Source Users	NIST Level	11/10/2015	11/13/2015
	NIST S 7201.01: 2020 Radiation Safety Refresher Training for Source Users, Source Custodians and their Line Management	NIST Level	10/20/2020	11/18/2020
	CLC - Office Safety	NIST Level	8/28/2013	12/13/2011
	CLC - Slips, Trips, and Falls	NIST Level	8/14/2013	12/9/2009
	CLC S 7101.60: Carcinogen Safety	NIST Level	8/15/2013	12/13/2011
	CLC S 7200.00: Radiation Safety	NIST Level	8/14/2013	12/13/2011
	EL Bloodborne Pathogen Training	OU/Division Level	8/16/2013	2/23/2012
	EL Hazard Communications	OU/Division Level	8/20/2013	12/7/2010
	EL Incident Investigation Training - NSC/OSHE	OU/Division Level	10/3/2017	8/27/2012
	EL Radiation Safety for New Users	OU/Division Level	8/21/2013	1/13/2009
	EL Responder Safety Awareness	OU/Division Level	8/21/2013	12/7/2010
	First Aid/CPR/AED	OU/Division Level	1/27/2016	1/19/2016

FRD CHIEF 2				
Category	**Course Name**	**Category**	**Date Assigned**	**Date Completed**
General Safety Training	NIST P 7100.00: General Safety Training	NIST Level	2014/01/15	2014/01/21
	NIST S 7101 20: Work and Worker Authorization Based on Hazard Review	NIST Level	2014/12/09	2014/12/09
	CLC - Hazard Recognition & Controls	NIST Level	2013/08/20	2009/07/01
	NIST O 7101.00: Safety Leadership Training	NIST Level	2015/03/22	2015/03/23
	EL-733: NFRL Lab Access and Safety Policies	OU/Division Level	2015/03/12	2015/03/12
	EL Safety Awareness Combined Course - ILT	OU/Division Level	2013/08/19	2012/09/04
Personal Protective Equipment	NIST S 7101 21: Personal Protective Equipment Program Training	NIST Level	2019/08/12	2019/08/12
	NIST S 7101 21: Personal Protective Equipment Program 2019 Gap Training	NIST Level	2015/01/13	2015/01/13
	NIST S 7101 58: Respiratory Protection Program - Initial Training (Web-based)	NIST Level	2014/10/01	2014/10/02
	NIST S 7101 58: Respiratory Protection Program - Training for Voluntary Use of Filtering Facepieces	NIST Level	2015/02/18	2015/02/18
	NIST S 7101 55: Hearing Protection Program - Initial Training (Web-based)	NIST Level	2014/12/09	2014/12/09
	NIST S 7101 21: Protective Footwear	NIST Level	2015/01/13	2015/01/13
	NIST S 7101 21: Head Protection	NIST Level	2015/01/13	2015/01/13
	NIST S 7101 21: Eye Protection Training	NIST Level	2015/01/13	2015/01/13
	NIST S 7101 21: Hand Protection	NIST Level	2015/01/13	2015/01/13
General Construction Work	NIST S 7101.64: Electrical Safety for Laboratory Workers	NIST Level	2016/04/28	2016/04/28
Material Handling				
Other	NIST P 7100.00: 2019 NIST Safety Day Opening Presentations	NIST Level	2019/10/25	2019/10/25
	NIST P 7100: Safety and Health Training for Staff Accessing and Working on NIST Campuses during the COVID Pandemic	NIST Level	2021/10/19	2021/10/19, 2022/04/01
	NIST P 7100: NIST Safe Return to Campus Training for Phase 1	NIST Level	2020/06/23	2020/06/23, 2021/07/05
	NIST S 7101 22: Hazard Signage Training - Program Requirements	NIST Level	2020/10/27	2020/10/27
	NIST S 7101 24: Equivalent Training for Incident Investigation - Principles and Methods	NIST Level	2020/06/26	2010/10/04
	NIST S 7101 24: IRIS Investigation Submitter Training	NIST Level	2017/09/15	2017/09/15
	NIST S 7101 24: IRIS Report Submitter Training	NIST Level	2017/09/15	2017/09/15
	NIST S 7101 26: WIRS Introduction for Lead Inspectors	NIST Level	2016/10/07	2016/10/06
	NIST S 7101 26: Workplace Inspection Program Training	NIST Level	2016/07/06	2016/07/06
	NIST S 7101 26: Workplace Inspector Training	NIST Level	2016/07/20	2016/07/20
	NIST S 7101 54: Dispersible Engineered Nanomaterials (DENMs) Safety Training	NIST Level	2015/12/10	2015/12/10
	NIST S 7101 57: Permit-Required Confined Spaces	NIST Level	2015/02/18	2015/02/18
	NIST S 7101 59: Chemical Hazard Communication Program Training	NIST Level	2016/02/17	2016/02/17
	NIST S 7101 59: HCS - New Label Elements and New Safety Data Sheet Format	NIST Level	2013/11/12	2013/11/15
	NIST S 7101.60: Chemical Management Program Training	NIST Level	2020/10/27	2020/10/27
	NIST S 7101.61: Compressed Gas Safety Program Training	NIST Level	2016/01/28	2016/01/28
	NIST S 7101.72: Laser Safety Program Training, Part 2 - Laser Safety Awareness - Laser Users (Instructor-led)	NIST Level	2015/04/23	2020/01/23
	NIST S 7101.75: Slips, Trips, and Falls	NIST Level	2018/03/15	2019/09/26
	NIST S 7201.01 2021 Radiation Safety Refresher Training for Source Users and their Line Management	NIST Level	2021/11/22	2021/11/22
	CLC - Office Safety	NIST Level	2013/08/28	2010/11/15
	CLC - Protection from Occupational Noise	NIST Level	2014/05/08	2014/05/09
	CLC S 7200.00: Radiation Safety	NIST Level	2013/08/14	2010/11/08
	EL Chemical Waste Disposal	OU/Division Level	2013/08/21	2009/01/21
	EL Incident Investigation Training - NSC/OSHE	OU/Division Level	2013/08/22	2010/10/04
	Hazard Review Database Primer & Review	OU/Division Level	2018/04/25	2018/02/20

Appendix 6.11.1: NIST S 7101.26: W*orkplace Inspection Program*

National Institute of Standards and Technology • U.S. Department of Commerce

WORKPLACE INSPECTION PROGRAM

NIST S 7101.26
Approval Date: 01/05/2021
Effective Date:[1,2] 04/01/2017

1. PURPOSE

The purpose of this program is to provide a uniform approach for NIST organizational units (OUs) to ensure that comprehensive safety and health inspections of NIST buildings and worksites are conducted; ensure inspectors have the necessary training and experience; establish a deficiency hazard classification process; establish processes for informing employees and covered associates of serious and imminent-danger unsafe or unhealthful working conditions (UWCs) identified through the inspection process; and identify common safety deficiencies for targeted reduction approaches.

2. BACKGROUND

a. NIST P 7100.00 articulates NIST's commitment to making occupational safety and health an integral core value and vital part of the NIST culture by, in part:

(1) Complying with applicable laws, regulations, and other promulgated safety and health requirements; and

(2) Abating deficiencies and taking actions to prevent incidents from occurring.

b. NIST must meet the requirements of 29 CFR 1960.25, Qualifications of Safety and Health Inspectors and Agency Inspections, which establishes minimum inspection frequency and inspector qualifications. Implementation of this suborder through the requirements in Section 6 and the roles and responsibilities in Section 9 fulfills those requirements.

c. NIST must meet the requirements of 29 CFR 1960.26, Conduct of Inspections, which establishes minimum inspection and reporting requirements, employee and management

[1] For revision history, see Appendix A.
[2] Some of requirements of this suborder will be effective on October 1, 2016, the remainder (those noted in comment boxes) on October 1, 2017.

participation, and inspector authorities. Implementation of this suborder through the requirements in Section 6, the roles and responsibilities in Section 9, and authorities in Section 10 fulfills those requirements.

d. NIST must meet the requirements of 29 CFR 1960.30, Abatement of Unsafe or Unhealthful Working Conditions, which establishes minimum posting and abatement requirements. Implementation of this suborder through the requirements in Section 6 and the roles and responsibilities in Section 9 fulfills those requirements.

3. APPLICABILITY

a. The requirements of this suborder apply to all NIST-owned facilities.

b. The requirements of this suborder apply to all off-site non-residential workplaces where NIST employees and covered associates conduct work activities [*e.g.*, Hollings Marine Laboratory, Institute for Bioscience and Biotechnology Research (IBBR), JILA] for periods of six months or more.

c. The requirements of this suborder do not apply to residential work locations (*e.g.*, telework) or to off-site locations where NIST activities are conducted for less than six months.

4. REFERENCES

a. 29 CFR Part 1960, Basic Program Elements for Federal Employee Occupational Safety and Health Programs and Related Matters, specifically Subparts 1960.1, 1960.25, 1960.26, 1960.30, 1960.57, and 1960.59.

b. OHSAS 18001:2007, Occupational Health and Safety Management Systems – Requirements, specifically Section 4.5.2.

5. APPLICABLE NIST OCCUPATIONAL SAFETY AND HEALTH SUBORDERS

a. NIST S 7101.20: Work and Worker Authorization Based on Hazard Reviews

b. NIST S 7101.23: Safety Education and Training

c. NIST S 7101.02: Employee Reporting of Unsafe or Unhealthful Working Conditions

d. NIST S 7101.03: Stop Work

e. All NIST suborders related to occupational safety and health, fire and life safety, and environmental management.

6. REQUIREMENTS

a. Inspection Frequency

(1) All work areas shall be inspected at the following frequencies:

(a) At least annually for offices, office-like spaces, and other spaces where a hazard review is not required by NIST S 7101.20: Work and Worker Authorization Based on Hazard Reviews.

(b) At least twice annually for work areas where one or more activities are required to have hazard reviews in accordance with NIST S 7101.20: Work and Worker Authorization Based on Hazard Reviews.

b. Equivalency for Inspections of Off-site Locations

(1) For off-site locations not owned by NIST, OUs may accept equivalent inspections conducted by or on behalf of the site owners, provided:

(a) Affected NIST employees and covered associates and the OSHE Workplace Inspection Program Manager are provided a copy of the inspection results; and

(b) OUs verify, to the extent necessary, that abatement actions adequately eliminate UWCs impacting NIST employees and covered associates.

(2) For serious and imminent danger UWCs that are the responsibility of the host organization and are not adequately addressed, the OU shall take appropriate action to ensure the safety and health of potentially impacted NIST employees and covered associates. These actions may include, if necessary, relocation of potentially impacted NIST employees and covered associates to a safe work environment.

(3) UWCs that are the responsibility of the OU to abate shall be addressed in accordance with Sections 6i and 6j.

c. Inspector and Inspection Team Qualifications

(1) A lead inspector shall be assigned for each inspection.

(2) An inspection may be conducted by a single lead inspector or by a team comprising a lead inspector and additional inspectors and/or subject matter experts working under the direction of the lead inspector.

(3) Inspectors of offices, office-like spaces, and other spaces where a hazard review is not required must meet the training requirements specified in Section 6l(1).

(4) Inspectors of workplaces where one or more activities are required to have hazard reviews must meet the training requirements specified in Sections 6l(1) and 6l(2) and meet the qualifications of an Occupational Safety and Health Inspector as defined in Section 7h.

(5) All inspectors, including lead inspectors, shall be NIST employees.

(6) Covered associates may serve on inspection teams as subject matter experts.

d. Inspection Scope

(1) Inspections during any given year shall be conducted such that all workplace hazards are considered at the frequencies specified in Section 6a.

(a) OUs may choose to conduct limited-scope inspections on a more frequent basis provided that all workplace hazards are considered annually at the frequencies specified in Section 6a.

e. Inspection Checklists

(1) OUs may use checklists to add additional rigor to the inspection process or to focus inspections on particular workplace hazards, provided that the use of checklists for other than limited-scope inspections does not limit the thoroughness of the inspections or the recording of deficiencies not included on the checklists.

(2) OSHE Program Managers shall develop and maintain question sets aligned with the requirements of assigned suborders. OUs may use these question sets, in whole or in part, to develop question and inspection checklists. OUs may also develop their own question sets and inspection checklists.

(3) The use of question sets and inspection checklists is at the discretion of the OUs.

f. Pre-inspection Planning[3]

(1) Prior to inspection, the following shall be available to the lead inspector:

(a) If requested, all available relevant information which pertains to the occupational safety and health of the workplace to be inspected;

(b) Name and contact information of the workplace supervisor (typically the lowest level of line management) with responsibility for the workplace to be inspected;

(c) Name and contact information of the union representative,[4] if any, of employees assigned to the workplace to be inspected; and

(d) Any special requirements or precautions necessary to enter the workplace, such as escort requirements, minimum personal protective equipment required for entry, or safeguards necessary to protect research activities.

(2) Inspectors and team members should understand, in advance, the general types of work activities and conditions to be inspected, in order to have the proper equipment (*e.g.*, personal protective equipment, flashlight, circuit tester) available to conduct an effective inspection.

(3) OSHE shall be notified of all OU inspections conducted under this program and will participate on inspection teams as resources permit.

(4) Notifications of OU inspections should be provided to OSHE by submitting an electronic meeting invitation or sending an email to *"WIP@nist.gov"* at least 14 calendar days in advance of planned inspections to facilitate OSHE participation.

(a) Notification should include the following:

i. Timeframe for the inspections [date(s) and times(s) to the extent they can be specified];

ii. Point of contact for the inspection;

[3] For workplaces requiring a security clearance for entry, contact the OSHE Workplace Inspection Program manager for further instruction.

[4] Although most NIST employees are not represented by unions, several groups are.

iii. Brief listing of the type(s) of spaces to be included in the inspections (*e.g.*, offices, chemical labs, laser labs, biological labs, mechanical spaces, mechanical testing, machine shops). This does not need to be an exhaustive listing; if most of the spaces fall into several categories, each outlier doesn't need to also be listed;

iv. Whether the scope of the inspection will be broad-based or focused on particular type(s) of hazards; and

v. Any preferences on specialized expertise the OSHE participant(s) should have.

(b) OSHE shall coordinate participation with the point of contact for the inspection and will participate to the extent that resources are available, with priority given to inspections of work areas in which hazardous activities are conducted, e.g., laboratories, shops.

g. Conduct of Inspections

(1) Every effort will be made by the inspection team to conduct inspections as scheduled, during normal work hours, and to avoid interference or adverse impact on laboratory, shop, or office operations. Inspections may be announced or unannounced to the workplace supervisor and employees and covered associates of the workplace to be inspected. Where access to a workplace is restricted by regulation or policy, the lead inspector will arrange for an escort or obtain permission from the space owner for entry for the purpose of each inspection.

(2) When, in the opinion of an inspection team member, it is necessary to conduct personal monitoring (sampling) of an employee's or covered associate's work environment, the lead inspector shall record the need for such monitoring as a deficiency and recommend as an abatement action arranging for such sampling through OSHE or by a non-OSHE competent person.

(3) Inspectors shall identify any deficiencies observed in the workplace [see Section 6e pertaining to the use of inspection checklists].

(4) If an identified deficiency presents a potential hazard to employee or covered associates safety and health, the lead inspector shall classify it using written guidance provided by OSHE.

(5) Whenever and as soon as an inspection team member makes a determination that an imminent danger exists, the lead inspector shall urge affected employees and covered associates to stop work in a manner that does not increase the danger, provide interim

instructions to secure the work area or activity (*e.g.*, using signage or barriers) to prevent exposure to the danger and inadvertent restart of the activity, and notify the workplace supervisor of the concern. If the lead inspector is not satisfied with the response to protect employees and covered associates, the lead inspector[5] shall contact OSHE for the possible issuance of a Stop Work Order (SWO). If a SWO is issued, subsequent actions to address the imminent danger will be in accordance with NIST S 7101.03: Stop Work.

(6) During the course of an inspection, any employee or covered associate has the right to bring to the attention of an inspection team member any UWC which the employee or covered associate has reason to believe exists in the workplace.

(7) The workplace supervisor and employees and covered associates are strongly encouraged to accompany the inspection team during the physical inspection of any workplace to aid the inspection, and, if an employee-designated representative is accompanying the inspection team, to provide that representative with more detailed knowledge of any existing or potential UWCs in the workplace.

(a) Additional representatives of OU management and employees may accompany the inspection team if the lead inspector or the OU determines that such additional representatives will further aid the inspection.

(b) Different representatives may be allowed to accompany the inspection team during different portions of an inspection.

(8) The lead inspector, with input from the inspection team members, will identify all observed deficiencies, observations, or recommendations within the scope of the inspection.

(9) The lead inspector should advise the workplace supervisor on establishing abatement dates, with due consideration of achievability and interim employee and covered associate safety.

(10) At the conclusion of an inspection, the workplace supervisor may meet with the lead inspector to request informal advice on any apparent deficiencies identified during the inspection and to provide the lead inspector with any pertinent information regarding conditions in the workplace.

[5] OSHE staff members are authorized to issue oral Stop Work Orders in accordance with NIST S 7101.03: Stop Work. The participation of OSHE staff members in inspections will facilitate the issuance of oral Stop Work Orders.

h. Inspection Reports

(1) The lead inspector shall enter newly identified deficiencies into the Workplace Inspection Reporting System (WIRS) no later than 15 calendar days following an inspection. If there are compelling reasons why this cannot be completed within 15 days, the inspector shall notify the workplace supervisor of the reason for the delay.

(2) WIRS shall notify the workplace supervisor when inspection result entry has been completed.

(3) The inspection report shall contain the following information:

(a) Names of inspection team members;

(b) Name of workplace supervisor;

(c) Organizational information (OU, Division, and Group);

(d) Date of inspection;

(e) Location(s) inspected (*e.g.*, building, room);

(f) Information pertaining to deficiencies identified, including:

i. Description of deficiency;

(i) Existing deficiencies recorded during previous inspections that remain unabated should not be duplicated in WIRS.

ii. Deficiency classification (imminent danger, serious, other than serious/ administrative);

iii. For serious and imminent-danger conditions, reference to suborder or other standard; and

iv. Whether deficiency was fully abated during the inspection (optional).

(g) For deficiencies classified as serious or imminent danger that are not fully abated during the inspection:

i. Recommended abatement actions;

ii. Recommended interim protective measures; and

iii. Comments (*e.g.*, observations, recommendations).

i. Notices of Unsafe or Unhealthful Working Conditions

(1) If an inspection results in a finding of an imminent-danger or serious UWC, the workplace supervisor shall establish an abatement date in WIRS and generate a UWC notice.

(a) The UWC notice shall characterize and describe the nature of the UWC, reference the suborder or other standard it violates, and provide a timeframe for abatement.

(b) The UWC notice, or a copy of it, shall be posted immediately by the workplace supervisor, either at or near the location where the UWC exists or existed; if that is not possible, it shall be posted in a prominent place where all affected employees and covered associates can read it.

i. An electronic copy of the notice may be provided to employees and covered associates via email in lieu of posting in situations where all of the following conditions are met:

(i) Each employee and covered associate conducting activities in the workplace is provided an electronic copy;

(ii) Each employee and covered associate routinely accesses a computer (to ensure they have timely access to the notice);

(iii) The UWC(s) addressed by the notice does not present a risk to other employees or covered associates who may intermittently access the workplace (*e.g.*, to perform maintenance); and

(iv) The UWC(s) addressed by the notice are fully abated within 30 calendar days.

(c) Any additional notices describing special measures in effect during abatement of the UWC shall also be posted by the workplace supervisor.

(d) Each posted notice shall remain posted until the UWC has been abated or for 3 business days, whichever is longer.

j. Abatement of Deficiencies

(1) Other-Than-Serious UWCs and Administrative Deficiencies

(a) Upon receipt by a workplace supervisor of an inspection report confirming the existence of an other-than-serious UWC or administrative deficiency, actions to abate the UWC shall be promptly developed and implemented.

(b) Once the deficiency has been abated, the deficiency shall be recorded as closed in WIRS.

(2) Serious or Imminent-Danger UWCs

(a) Upon receipt by a workplace supervisor of an inspection report confirming the existence of an imminent-danger or serious UWC, abatement actions to eliminate the UWC, including any interim protective measures necessary to protect employees and covered associates, shall be promptly developed and implemented.

(b) If it is determined by the workplace supervisor that the abatement actions cannot be completed within 30 calendar days of receipt of the inspection report, an abatement plan shall be developed, shared with affected employees and covered associates, and recorded in WIRS. The estimated completion dates shall be replaced by actual completion dates when the plan has been fully implemented.

(3) It shall be verified, to the extent necessary, that abatement actions adequately eliminate serious and imminent danger UWCs. Abatement actions determined to be inadequate shall remain open in WIRS until UWCs have been satisfactorily abated.

(4) When a deficiency cannot be abated within NIST's authority, the OU shall request assistance from appropriate higher authority. The CSO and all personnel subject to the hazard from the deficiency shall be advised of this action and of interim protective measures in effect, and shall be kept informed of subsequent progress on the abatement plan.

(5) When applicable, if a deficiency cannot be abated without assistance of the General Services Administration or other Federal lessor agency, the OU shall act with the lessor agency to secure abatement.

k. Inspections by the Occupational Safety and Health Administration (OSHA)

(1) OSHA has the authority to conduct announced and unannounced safety and health inspections of federal workplaces and operations. All NIST personnel will cooperate fully during any such inspection. The Chief Safety Officer (CSO) shall be notified whenever OSHA inspectors request access to NIST facilities and will assign an OSHE representative to coordinate the inspection process, including:

(a) Notifying the affected OU(s) of the inspection, when permitted to do so by OSHA;

(b) Accompanying[6] the OSHA inspector(s), along with an OU representative whenever practical, while on-site;

(c) Documenting the observations of the OSHA inspectors, including photographing areas photographed by OSHA; and

(d) Entering the results of the inspection into WIRS.

(2) OUs, in coordination with the CSO, will abate any UWCs identified during the inspection in accordance with OSHA instructions and the requirements of this suborder.

(3) The CSO, in coordination with affected OUs, will take the lead on all inspection-related correspondence with OSHA.

l. Training

(1) Individuals who will serve as inspectors[7] shall complete:

(a) Inspector training provided by OSHE on:

i. How to conduct inspections, evaluate hazards, and suggest general abatement procedures and interim protective measures;

ii. Procedures for classifying UWCs as imminent danger, serious, or other-than-serious;

[6] For workplaces outside of Gaithersburg and Boulder, OSHE will coordinate with the responsible OU to ensure an OU representative addresses the requirements of Sections 6k(1)(b) and 6k(1)(c).
[7] This training is also available to union representatives who will assist in conducting workplace safety and health inspections.

iii. Inspector authorities;

iv. Inspection procedures and techniques;

v. Handling differing opinions of team members;

vi. Considerations for establishing abatement dates; and

vii. Preparation of reports and other documentation to support the inspection findings.

(2) Inspection team members, including the lead inspector, shall complete the training specified in safety and health suborders applicable to the hazard(s) in the work areas they are to inspect.[8]

(3) OU managers and supervisors shall complete the training on the Workplace Inspection Program provided by OSHE for managers and supervisors.

m. Recordkeeping

(1) WIRS shall maintain the following records for at least five years after deficiency abatement:

(a) Inspection results;

(b) Notices of UWCs;

(c) Abatement plans, when required;

(d) Description of abatement actions taken, when required; and

(e) Date abatement actions were completed.

(2) Records will be made available to an Authorized Representative of the Secretary of Labor upon request.

[8] If an inspection team approach is used, the composite qualifications of the team may be considered in meeting this requirement. It is not necessary for each team member to complete training on a particular applicable suborder as long as someone on the team has done so.

n. Summary Reports

(1) The Workplace Inspection Program Manager shall prepare and submit an annual report to the CSO for distribution to the Executive Safety Committee (ESC).

(2) The annual report shall include the following information:

(a) Summary of the inspection results reported through WIRS;

(b) Summary of abatement action status on inspection findings tracked through WIRS;

(c) Prevalence and trending of common safety issues currently incorporated in the NIST Shared Standard of Safety Performance (3SP) initiative; and

(d) Recommendations of common safety issues to be considered for inclusion in the 3SP initiative or other safety improvement efforts.

(3) The Workplace Inspection Program Manager will compile, analyze, and report inspection data periodically at the direction of the CSO.

7. DEFINITIONS

Definitions common to all NIST safety and health suborders can be found in Section 6 of NIST O 7100.00. The definitions specific to this suborder are as follows:

a. **Abatement** – Action by an employer to comply with a cited standard or regulation or to eliminate a recognized hazard identified during an inspection.

b. **Abatement Plan** – A set of planned actions to abate a recognized **deficiency** and their estimated completion dates.

c. **Administrative Deficiency** – A deviation from established requirements that does not create an unsafe or unhealthful working condition.

d. **Authorized Representative of the Secretary of Labor** – A person or agent of the Secretary of Labor whose authority and jurisdiction originates from the Secretary of Labor; routinely a Department of Labor employee.

e. **Deficiency** - A deviation from established requirements. NOTE: A **deficiency** may be an **unsafe or unhealthful working condition** if it presents a hazard (*e.g.*, unguarded pinch point) or an **administrative deficiency** if it does not (*e.g.*, missing "emergency contact" sticker on telephone).

f. **<u>Imminent Danger (Condition or Practice)</u>** – Any **serious condition or practice** that could reasonably be expected to cause death or serious physical harm immediately or before the imminence of the danger can be eliminated through normal procedures.

g. **<u>Inspector</u>** – A NIST employee having the training and qualifications required to conduct assigned workplace inspections on their own or as a member of an inspection team.

h. **<u>Occupational Safety and Health Inspector</u>** – An **occupational safety and health specialist**, Certified Safety Professional, or Certified Industrial Hygienist possessing competence to recognize and evaluate **workplace** hazards and identify mitigation options.

i. **<u>Occupational Safety and Health Specialist</u>** – A person meeting the Office of Personnel Management standards for one of the following classifications:

(1) Safety and Occupational Health Manager/Specialist GS-018;

(2) Engineer GS-800;

(3) Industrial Hygienist GS-690;

(4) Fire Protection and Prevention Specialist/Marshal GS-081;

(5) Health Physicist GS-1306;

(6) Occupational Medicine Physician GS-602;

(7) Occupational Health Nurse GS-610;

(8) Safety Technician GS-019;

(9) Physical Science Technician GS-1311;

(10) Environmental Health Technician GS-699;

(11) Chemist GS-1320;

(12) Health Technician GS-645;

(13) Physicist GS-1310; or

(14) Equally qualified person.[9]

j. **Office-Like Space** – A space, such as a conference room, copier room, break room, or ordinary computer room that has the same types of hazards as a typical office or office environment.

k. **Other Than Serious (Condition or Practice)** – A condition or practice that could not reasonably be expected to cause death or serious physical harm.

l. **Serious[10] (Condition or Practice)** – A condition or practice that could be reasonably expected to cause death or **serious physical harm** to an individual exposed to the condition or practice.

m. **Serious Physical Harm** – Impairment of the body in which part of the body is made functionally useless or is substantially reduced in efficiency on or off the job. Such impairment may be permanent or temporary, chronic or acute. Injuries involving such impairment would usually require treatment by a medical doctor or other licensed health care professional. Injuries that constitute serious physical harm include, but are not limited to, amputations (loss of all or part of a bodily appendage);[11] concussion; crushing (internal, even though skin surface may be intact); fractures (simple or compound); burns or scalds, including electric and chemical burns, likely to require medical treatment; cuts, lacerations, or punctures involving significant bleeding and/or requiring suturing; and sprains and strains likely to require medical treatment. Illnesses that constitute serious physical harm include, but are not limited to, cancer; respiratory illnesses (silicosis, asbestosis, byssinosis, etc.); hearing impairment; central nervous system impairment; visual impairment; poisoning; and musculoskeletal disorders.

n. **Stop Work Order** – Formal notification to cease work activities that present an **imminent danger**.

[9] The OU Director shall be responsible for determining that an individual is an equally qualified person and for documenting that determination. The OU Director may delegate this responsibility.
[10] NOTE: The key determination is the likelihood that death or serious harm will result **IF** an accident or exposure occurs. **The likelihood of an accident occurring is not addressed in making this determination.**
[11] An amputation is the traumatic loss of a limb or other external body part. Amputations include a part, such as a limb or appendage that has been severed, cut off, amputated (either completely or partially); fingertip amputations with or without bone loss; medical amputations resulting from irreparable damage; and amputations of body parts that have since been reattached.

o. **<u>Unsafe or Unhealthful Working Condition</u>** – Any condition or practice in any **workplace** that could have a direct or immediate adverse impact on safety or health.

p. **<u>Workplace</u>** – A physical location where NIST work is performed.

q. **<u>Workplace Supervisor</u>** – First-level supervisor, or other designated OU line manager, with primary responsibility for ensuring a safe and healthful work environment in their specific **workplace**.[12] In most cases, the **workplace supervisor** is the Group Leader.

8. ACRONYMS

Acronyms common to all NIST safety and health suborders can be found in Section 7 of NIST O 7100.00. The acronyms specific to this suborder are as follows:

a. 3SP – Shared Standard of Safety Performance

b. CFR – Code of Federal Regulations

c. CSO – Chief Safety Officer

d. ESC – Executive Safety Committee

e. OSHA – Occupational Safety and Health Administration

f. OSHE – Office of Safety, Health, and Environment

g. OU – Organizational Unit

h. SWO – Stop Work Order

i. UWC – Unsafe or Unhealthful Working Condition

j. WIRS – Workplace Inspection Reporting System

[12] Note that where NIST workers perform work in workplaces not owned and operated by NIST, the **workplace** will not be under the complete control of the NIST **workplace supervisor**. When the NIST **workplace supervisor** requires changes within the physical location, the **workplace supervisor** should work with the owners of the **workplace** to effect the necessary changes, or modify NIST work practices as necessary to ensure the safety and health of NIST workers.

9. RESPONSIBILITIES

Roles and responsibilities common to all NIST safety and health suborders can be found in Section 8 of NIST O 7100.00. The roles and responsibilities specific to this suborder are as follows:

a. All Employees and Covered Associates:

(1) Cooperate fully during the conduct of occupational safety and health inspections;

(2) Bring to the attention of inspectors any UWCs they have reason to believe exist in the workplace; and

(3) Abate deficiencies when directed to do so by their workplace supervisor.

b. OU Management:

(1) Assign lead inspectors;

(2) Manage the assignments of inspection team members;

(3) Ensure that all workplaces and operations are inspected at the required intervals;

(4) Ensure OSHE is notified of inspections in advance;

(5) Ensure that the information detailed in Section 6f is made available to lead inspectors to plan inspections; and

(6) For workplaces with employees represented by unions, ensure that union representatives are provided the opportunity to accompany inspection teams.

c. OU Management above the Level of the Workplace Supervisor:

(1) Support workplace supervisors in abating deficiencies, as necessary; and

(2) Verify, to the extent necessary, that abatement actions adequately eliminate serious and imminent danger UWCs.

d. Workplace Supervisor:

(1) Ensure that deficiencies in their respective workplaces are abated in accordance with program requirements;

(2) Upon receiving inspection reports identifying serious or imminent-danger UWCs:

   (a) Establish abatement dates in WIRS for those UWCs not fully abated during the inspection;

   (b) Generate UWC notices and ensure they are posted/distributed in accordance with program requirements;

   (c) Ensure that abatement actions to eliminate the UWCs, including any interim protective measures necessary to protect employees and covered associates, are promptly developed and implemented; and

   (d) If abatement actions cannot be completed within 30 calendar days of receipt of the inspection report, ensure that abatement plans are developed, shared with affected employees and covered associates, and recorded in WIRS; and

(3) Ensure that WIRS is updated to reflect abatement status, including dates that serious and imminent danger UWCs are abated.

e. Lead Inspectors:

(1) Manage the assignments of inspection team members, when applicable;

(2) Resolve differing opinions;

(3) Complete assigned workplace inspections and ensure that inspection reports containing the information detailed in Section 6h(3) are completed and recorded in WIRS within the timeframe described in Section 6h(1); and

(4) If an imminent-danger UWC is identified:

   (a) Urge affected employees and covered associates to stop work in a manner that does not increase the danger;

   (b) Provide interim instructions to secure the work area or activity (*e.g.*, using signage or barriers) to prevent exposure to the danger and inadvertent restart of the activity; and

   (c) Notify the workplace supervisor of the concern.

f. Inspection Team Members:

(1) Assist the lead inspector in completing inspection reports containing the information detailed in Section 6h(3), especially in:

(a) Identifying and classifying deficiencies; and

(b) Recommending abatement actions and interim protective measures for serious and imminent-danger deficiencies not fully abated during the inspection.

g. OSHE Program Managers:

(1) Develop and maintain inspection question sets aligned with assigned suborders.

h. Workplace Inspection Program Manager:

(1) Provide written guidance on classifying UWCs;

(2) Prepare and submit an annual summary report to the CSO; and

(3) Compile, analyze, and report inspection data periodically at the direction of the CSO.

10. AUTHORITIES

Authorities common to all NIST safety and health suborders can be found in Section 9 of NIST O 7100.00. The authorities specific to this suborder are as follows:

a. Lead Inspectors[13] and Inspection Team Members:

(1) To have access, at reasonable times, to any building, installation, facility, construction site, or other area, workplace, or environment where work is performed in order to conduct an assigned inspection; and

(2) To interview and or consult with management and employees and covered associates separately, privately, or as a group concerning matters of occupational safety and health to aid the conduct of effective and thorough inspections.

[13] These authorities also apply to OSHA compliance officers.

b. Lead Inspectors:

(1) To restrict participation on an inspection if necessary to ensure a fair and orderly inspection.

11. DIRECTIVE OWNER

Chief Safety Officer

12. APPENDICES

a. Revision History

Appendix A. Revision History

Revision No.	Approval Date	Deployment Start Date	Effective Date	Brief Description of Change; Rationale
0	05/18/15	04/01/16	04/01/17	• None – Initial document
1	11/30/15	04/01/16	10/01/16 for first set of requirements 10/01/17 for remaining requirements (those noted in comment boxes) See Footnote 2.	• Added Footnote 2 to indicate more clearly that some of the requirements of this suborder will be effective on October 1, 2016, the remainder (those noted in comment boxes) on October 1, 2017. • Changed effective date of first set of requirements from 04/01/16 to 10/01/16. • Changed effective date of remaining requirements (those noted in comment boxes) 04/01/17 to 10/01/17 • Revised dates in comment boxes to reflect these changes. • Rationale for changes in effective dates: (1) Allow more time to develop the iPad application module of the Workplace Inspection Reporting System; (2) allow more time to develop and provide inspector training; and (3) align the effective date of the Workplace Inspection Program with the beginning of a fiscal year.
2	07/29/16	07/29/16	07/29/16	• Made numerous edits solely for clarity • Made program applicable to covered associates • Added training requirement for managers and supervisors • Added a responsibility under employees and covered associates to abate deficiencies when directed to do so by their workplace supervisor • Added responsibilities for "OU Management above the Level of the

Revision No.	Approval Date	Deployment Start Date	Effective Date	Brief Description of Change; Rationale
				• Workplace Supervisor" to (a) support workplace supervisors in abating deficiencies, as necessary, and (b) verify, to the extent necessary, that abatement actions adequately eliminate serious and imminent danger UWCs [NOTE: The second responsibility was associated with the requirement in Section 6i(3). As originally worded, Section 6i(3) assigned this responsibility to the "OUs"; it should have been more specific and assigned it to management above the level of the workplace supervisor.] • Removed Appendix B; will provide stand-alone tool instead
3	04/19/17	NA	04/19/17	• Made minor edits • Added requirement that all inspectors, including lead inspectors, be NIST employees • Indicated that covered associates may serve on inspection teams as subject matter experts • Added comments in Section 9 to indicate that certain responsibilities will not take effect until October 1, 2017 • Clarified the responsibilities of OU management and Lead Inspectors regarding managing the assignments of inspection team members
4	03/22/18	10/01/17	10/01/17	• Removed the comments indicating that requirements related to the following would be effective on 10/01/17: classification of deficiencies, use of WIRS, posting of UWC notices, recording of suborder/regulatory references.

Revision No.	Approval Date	Deployment Start Date	Effective Date	Brief Description of Change; Rationale
5	1/5/21	1/5/21	[redacted]	• Updated suborder links.

Appendix 6.11.2: Workplace Inspection Records for Building 205, Room 125

Inspection

73 - EL

Inspection ID	Status	Site	Building	Room	Sub Space	Inspector	Inspection Date	Submission Date	OU	Division	Group	Workplace Supervisor	Space Contacts	# Questions	# Deficiency	% Deficiencies	# Comments	Comments	Checklist Name
35509	submitted	GBURG	205	125		[redacted]	03/19/2018	03/22/2018	73 - EL	733	733.06	[redacted]	[redacted]	176	10	10.64	0		EL Laboratory General Checklist - 20171213
39776	submitted	GBURG	205	125		[redacted]	10/17/2018	10/19/2018	73 - EL	733	733.06	[redacted]	[redacted], [redacted]	19	4	21.05	1	Fall Protection (PPE)/ Lifting Slings & Straps - It would be a good practice to have the full body harnesses used on the boom lift, lifting slings/straps, lanyards inspected on a regular (annual) bases or as recommended by the manufacturer. It was noticed during the inspection that some of this devices have older manufacture dates (5 years or more). The manufactures should be contacted to ascertain whether of not there is a shelf life of such devices. It is a requirement that these devices be inspected by the user before use and taken out of service if any deficiencies are found.	Lab Checklist - Short Version 9-5-2018
42217	submitted	GBURG	205	125		[redacted]	04/04/2019	04/05/2019	73 - EL	733	733.06	[redacted]	[redacted], [redacted]	19	3	15.79	1	Consult with [redacted] and/or other to determine the frequency of	Lab Checklist - Short Version 9-5-2018

																		inspection of the rigging devices such as straps, slings, cables etc.	
46560	submitted	GBURG	205	125		[redacted]	10/16/2019	10/16/2019	73 - EL	733	733.06	[redacted]	[redacted]	19	3	15.79	1	Consult with [redacted] (OU Safety rep.) as to the acceptable documentation and record keeping needed for the daily/ shift inspections of the fork trucks and man lifts.	Lab Checklist - Short Version 9-5-2018
48567	submitted	GBURG	205	125		[redacted]	12/16/2020	12/16/2020	73 - EL	733	733.06	[redacted]	[redacted]	19	2	10.53	1	The 4 Lift Trucks need yearly inspection done.	Lab Checklist - Short Version 9-5-2018
49937	submitted	GBURG	205	125		[redacted]	07/22/2021	07/22/2021	73 - EL	733	733.06	[redacted]	[redacted]	19	3	15.79	0		Lab Checklist - Short Version 9-5-2018
52816	submitted	GBURG	205	125		[redacted]	06/15/2022	06/16/2022	73 - EL	733	733.06	[redacted]	[redacted]	19	2	10.53	0		Lab Checklist - Short Version 9-5-2018

Appendix 6.11.3: Workplace Inspection Checklists used in Building 205, Room 125

EL Laboratory General Checklist - 20171213

Publish Date: 12/14/2017 Expire Date: 12/14/2027

Question	Question Type	Program	Reference Type	Reference	Fail Condition	Labels	Options
4941 - Does the lab have an approved door sign at the entrance?	yes/no	Hazard Signage Program	NIST requirement	12.08.08	No	Hazard Signage	
7673 - If there is a telephone present, is it operational?	yes/no/na	No Program	NIST requirement	none	No		
7829 - Are chemicals present in the work area that are within the scope of the Chemical Hazard Communication (CHC) suborder?	yes/no	Chemical Hazard Communication Program	None	None	None	CHC	
7833 - Are all non-hazardous chemical containers labeled, tagged, or marked with: 1) Product identifier; and, 2) NIST Chemical Owner Name?	yes/no/na	Chemical Hazard Communication Program	NIST requirement	S 7101.59 (6)(c)(4)	No	CHC	
7830 - Are all hazardous chemical containers shipped to the NIST work area labeled, tagged, or marked with the Shipped Container Label Information and labels received with incoming containers have not been defaced or removed and labels are prominently displayed, in English, legible, and contain information that is current?	yes/no/na	Chemical Hazard Communication Program	NIST requirement	7101.59(6)(c)(1), 7101.59(6)(c)(2)(a)(i), 7101.59(6)(c)(2)(b)	No	CHC	

7831 - Are all hazardous chemical containers prepared at the NIST work area labeled, tagged, or marked with Workplace Container Label Information or represented by an Alternate Method of Labeling that meets the CHC requirements for Alternate Methods of Labeling and labels and other forms of warning prominently displayed, in English, legible, and contain information that is current?	yes/no/na	Chemical Hazard Communication Program	NIST requirement	7101.59(6)(c)(1), 7101.59(6)(c)(2)(a)(ii), 7101.59(6)(c)(2)(c)	No	CHC	
7832 - Do you want to perform an SDS screening at this time? (Optional)	yes/no	Chemical Hazard Communication Program	NIST requirement	7101.59(6)(b)(1)(f), 7101.59(6)(b)(2)(a), 7101.59(6)(b)(3)(a)	None	CHC	
7836 - Is the Hazardous Chemical Inventory List readily available, and is there an SDS for each hazardous chemical that was checked against the List (a spot-check)?	yes/no	Chemical Hazard Communication Program	NIST requirement	7101.59(6)(b)(1)(f), 7101.59(6)(b)(2)(a), 7101.59(6)(b)(3)(a)	None		
7834 - Are SDSs in English and include the same product identifier and supplier information used on the hazardous chemical container labels in the work area?	yes/no	Chemical Hazard Communication Program	NIST requirement	7101.59(6)(b)(1)(a), 7101.59(6)(b)(1)(b)	None	CHC	

7835 - Have SDSs been developed and revised in accordance with the CHC requirements, when applicable?	yes/no/na	Chemical Hazard Communication Program	NIST requirement	7101.59(6)(b)(1)(a), 7101.59(6)(b)(2)(b), 7101.59(6)(b)(3)(b), 7101.59(6)(b)(1)(b); 7101.59(6)(b)(2)(c); 7101.59(6)(b)(3)(c), 7101.59(6)(b)(1)(c), 7101.59(6)(b)(1)(d), 7101.59(6)(b)(1)(e)	None	CHC	
7680 - If isopropyl alcohol (IPA) is present, is the expiration date labeled on the container?	yes/no/na	Chemical Hazard Communication Program	None	None	No		
7707 - Does the work area contain chemical waste or a chemical waste Satellite Accumulation Area (SAA)?	yes/no	Chemical Waste Accumulation/Disposal at NIST Gaithersburg Program	None	None	None		
7708 - Has a satellite accumulation area (SAA) been established?	yes/no	Chemical Waste Accumulation/Disposal at NIST Gaithersburg Program	NIST requirement	7301.04.6.b(1)	None	SAA	

7709 - Is there a sign indicating the location of the SAA?	yes/no	Chemical Waste Accumulation/Disposal at NIST Gaithersburg Program	NIST requirement	7301.04.6.b (3)(a)	No	SAA	
7710 - Does the SAA appear to have been inspected on a weekly basis and is documentation of inspections up-to-date and available?	yes/no	Chemical Waste Accumulation/Disposal at NIST Gaithersburg Program	NIST requirement	7301.04 (draft), 6 CFR 1007-3,262.34(g) and 265.174	No	SAA	
7711 - Is all chemical waste that is present being stored in the SAA container?	yes/no/na	Chemical Waste Accumulation/Disposal at NIST Gaithersburg Program	NIST requirement	None	No	Chem Waste/SAA	
7712 - Is chemical waste present in the SAA container?	yes/no	Chemical Waste Accumulation/Disposal at NIST Gaithersburg Program	None	None	None	Chem Waste	
7713 - Are chemical wastes being stored in containers that are in good condition and compatible with the chemical constituents?	yes/no	Chemical Waste Accumulation/Disposal at NIST Gaithersburg Program	NIST requirement	7301.04.6.c (1)	No	Chem Waste	
7714 - Are chemical waste containers labeled with all of the following: A list of the constituents, An estimate of the volume or percent volume of each constituent, and Contact information for the individual generating the waste?	yes/no	Chemical Waste Accumulation/Disposal at NIST Gaithersburg Program	NIST requirement	7301.04.6.c (5)	No	Chem Waste	

7715 - Are the chemical waste containers closed?	yes/no	Chemical Waste Accumulation/Disposal at NIST Gaithersburg Program	NIST requirement	7301.04.6.c (3)	No	Chem Waste	
7716 - Are chemical waste containers stored within spill (secondary) containment (e.g. bins, trays)?	yes/no	Chemical Waste Accumulation/Disposal at NIST Gaithersburg Program	NIST requirement	7301.04.6.b (3)(d)	No	Chem Waste	
7717 - If corrosive chemicals (acids/bases) are being used in the lab, or if there is a battery charging station in the lab, is there an emergency eyewash unit in the space?	yes/no/na	Chemical Management Program	Federal regulatory requirement	29 CFR 1910.151(c)	No		
7674 - Is a permanently installed emergency eyewash unit present?	yes/no	Chemical Management Program	NIST requirement	NIST S 7101.60	None		
7675 - What type of eyewash unit is present?	checkboxes	Chemical Management Program	NIST requirement	NIST S 7101.60	None		Pedestal mount, Drench Hose/eyewash, Swinging,
7677 - Is the eyewash freely accessible, without obstruction?	yes/no	Chemical Management Program	NIST requirement	NIST S 7101.60	No		
7678 - Is the eyewash operating temperature within the appropriate range?	yes/no	Chemical Management Program	NIST requirement	NIST S 7101.60	No		
7679 - Have task eye wash bottles been labeled with an expiration date?	yes/no/na	Chemical Management Program	NIST requirement	NIST S 7101.60	No		
6482 - Are compressed gases present in this workspace?	yes/no	Compressed Gas Safety Program	None	None	None	compressed gases	

6483 - Are cylinders labeled with product identifiers and information regarding the hazards of the compressed gas?	yes/no	Compressed Gas Safety Program	NIST requirement	7101.61.6.b (2)(a)	No	compressed gases	
6484 - Are cylinders free of visible signs of damage?	yes/no	Compressed Gas Safety Program	NIST requirement	7101.61.6.b (2)(b)	No	compressed gases	
6485 - Are cylinders secured to prevent them from falling or being knocked over?	yes/no	Compressed Gas Safety Program	NIST requirement	7101.61.6.b (5)(a)(i)	No	compressed gases	
6486 - Are valve protection caps securely attached to all cylinders that are not attached to a regulator or manifold?	yes/no	Compressed Gas Safety Program	NIST requirement	7101.61.6.b (5)(a)(vi)	No	compressed gases	
6487 - Are all cylinders that are present currently IN USE (either attached to a regulator/manifold or a single reserve cylinder secured alongside the first cylinder)?	yes/no	Compressed Gas Safety Program	NIST requirement	7101.61.6.b (5)(c)(i)	No	compressed gases	
6488 - If toxic or highly toxic gases are present in this workspace, is a continuous, alarming, gas-detection system present for all toxic and highly toxic compressed gases, with gas detection at the point of use, at the source container, in the storage area, and at the point of discharge?	yes/no/na	Compressed Gas Safety Program	NIST requirement	7101.61.6.a (4)	No	compressed gases	
6489 - If corrosive gases are present, is an eyewash station and safety shower provided?	yes/no/na	Compressed Gas Safety Program	NIST requirement	7101.61.6.a (6)(a)	No	compressed gases	

6492 - Are compressed gas cylinders containing gases with NFPA 704 health hazard ratings of 3 or 4, or a health hazard rating of 2 without physiological warning properties, or pyrophoric gases kept in a ventilated gas cabinet?	yes/no/na	Compressed Gas Safety Program	NIST requirement	7101.61.6.b (6)(b)	No	compressed gases	
6493 - Is each compressed gas line labeled with the gas name and direction of flow?	yes/no/na	Compressed Gas Safety Program	NIST requirement	7101.61.6.c (3)	No	compressed gases	
6640 - Are cryogens present in this workspace?	yes/no	Cryogen Safety Program	None	None	None		
6642 - Does this space have mechanical exhaust ventilation?	yes/no	Cryogen Safety Program	None	None	None		
6655 - Have additional controls been applied to reduce the risk of oxygen deficiency where ventilation is inadequate or non-existent?	yes/no/na	Cryogen Safety Program	NIST requirement	7101.52.6.c (2)	No		
6643 - Does this space have a potential or known oxygen deficiency hazard?	yes/no	Cryogen Safety Program	None	None	None		
6654 - Has hazard signage been posted at every entrance to the space?	yes/no	Cryogen Safety Program	NIST requirement	7101.52.6.c (3)	No		
6644 - Has an oxygen monitor been installed in the space?	yes/no	Cryogen Safety Program	None	None	None		
6652 - Are all oxygen sensors are within their calibration time frame or service life?	yes/no	Cryogen Safety Program	NIST requirement	7101.52.6.c (4)(a)	No		

6653 - Are calibration and maintenance records kept near the monitor?	yes/no	Cryogen Safety Program	NIST requirement	7101.52.6.c (4)(b)	No		
6648 - Are pressure-relief devices provided throughout the cryogen system?	yes/no	Cryogen Safety Program	NIST requirement	7101.52.6.c (5)(g)	No		
6650 - Is PPE available that is specifically made for cryogens?	yes/no	Cryogen Safety Program	NIST requirement	7101.52.6.c (8)	No		
7737 - Are dispersible engineered nano-materials (DENMs) handled in this workspace?	yes/no/na	Dispersible Engineered Nanomaterials (DENMs) Program	NIST requirement	DENMS program	None	Screening	
7738 - Is there a nano-enclosure or hood used for work with DENMS?	yes/no	Dispersible Engineered Nanomaterials (DENMs) Program	NIST requirement	7101.54.6.b (2), (3), (4)	None		
7743 - Has the hood or enclosure been certified within 12 mo, and is it under negative pressure?	yes/no	Dispersible Engineered Nanomaterials (DENMs) Program	NIST requirement	7101.54.6.b (2), (3), (4)	No		
7744 - If the hood has a readout, is it within 90%-120% of the recommended flow?	yes/no/na	Dispersible Engineered Nanomaterials (DENMs) Program	NIST requirement	7101.54.6.b (2), (3), (4)	No		
7739 - If a DENM is present that has been found to be potentially hazardous, has a Caution sign been posted? Select NA if unknown.	yes/no/na	Dispersible Engineered Nanomaterials (DENMs) Program	NIST requirement	7101.54.6.h	No		

7740 - Are materials contaminated with DENMs placed in a proper waste container and disposed of as hazardous waste? (Select NA if indeterminate.)	yes/no/na	Dispersible Engineered Nanomaterials (DENMs) Program	NIST requirement	7101.54.6.f	No		
7741 - Are all DENMs segregated and stored according to the hazards associated with constituent chemical properties?	yes/no	Dispersible Engineered Nanomaterials (DENMs) Program	NIST requirement	7101.54.6.c (3)	No		
7742 - Are all forms of DENMs kept in tightly-closed, chemically-compatible containers when not in use?	yes/no	Dispersible Engineered Nanomaterials (DENMs) Program	NIST requirement	7101.54.6.c (2)	No		
7718 - Is there a hood in this space?	yes/no/na	Chemical Management Program	Other	ANSI Z9.5	None		
7719 - Is the hood labeled that it has passed inspection and testing within the last 12 months?	yes/no	Chemical Management Program	Other	ANSI Z9.5	No		
7720 - Does the hood have flow sensor that shows the current face velocity of the hood?	yes/no	Chemical Management Program	NIST requirement	ANSI Z9.5	No		
7721 - If the flow sensor indicated less than 90% or greater than 120% of the proper velocity, as stated on the most recent hood testing label, has the hood been marked as being out of service?	yes/no	Chemical Management Program	NIST requirement	ANSI Z9.5	No		

7745 - Are there observable processes that create hot surfaces or generate airborne contaminants?	yes/no	No Program	None	None	None		
7746 - Are thermally hot surfaces isolated from contact with flammable materials, and are measures in place (e.g. controls, signage) to protect workers from incidental exposure to hot surfaces?	yes/no	No Program	Other	PML best practice	No		
7747 - Are processes capable of generating airborne contaminants conducted in an appropriate hood (chemical fume, nano, BSL, etc.)?	yes/no	Chemical Management Program	Federal regulatory requirement	OSHA Section 5(a)(1)	No		
5296 - Does the space contain hazardous incoherent optical radiation sources (e.g. welding torches, furnaces, UV and intense non-collimated light sources, arcs and plasmas)?	yes/no	Incoherent Optical Radiation Safety Program	None	None	None	Incoherent Optical Radiation, screening question	
5297 - Does the red-bordered door sign indicate the hazards associated with the sources (e.g. non-ionizing radiation, hot surfaces) and the required PPE for entry?	yes/no	Hazard Signage Program	NIST requirement	NIST 12.08.08	No	Incoherent Optical Radiation, Hazard Signage	
5298 - Is the appropriate PPE available to protect workers from the hazards of each particular source in the space (e.g. welding goggles, filter glasses, thermally protective gloves, goggles/face shields)?	yes/no/na	Personal Protective Equipment (PPE)	NIST requirement	7101.21.6.a., b.	No	Inchoherent Optical Radiaition, PPE	

5299 - Is the space free of leaks and condensation (e.g. from cooling water) that could cause flooding or electrical hazards?	yes/no/na	No Program	Other	PML best practice	No	Incoherent Optical Radiation	
5300 - If a UV source is running, is the space free of the smell of ozone?	yes/no/na	No Program	Other	PML best practice	No	Incoherent Optical Radiation	
5301 - Are thermally hot surfaces isolated from contact with flammable materials, and are measures in place (e.g. contols, signage) to protect workers from incidental exposure to hot surfaces?	yes/no/na	No Program	Other	PML best practice	No	Incoherent Optical Radiation	
5302 - Is the direct and scattered light from the source(s) contained as much as possible by engineering controls (e.g. barriers, baffling) and blocked to prevent incidental exposure?	yes/no/na	Laser Safety Program	Other	PML best practice	No	Incoherent Optical Radiation	
6551 - Are lasers operated in the space?	yes/no	Laser Safety Program	None	None	None	Laser	
6552 - Are class 3R Invisible, Class 3B, or Class 4 lasers operated in the space?	yes/no	Laser Safety Program	None	None	None	Laser	
6553 - Is a yellow caution sign (optional) posted at the entrance to the space?	yes/no	Hazard Signage Program	NIST requirement	Recommen dation only for Class 2 and Class 2M - HSI No. 13, section 10.3	None	Laser	

6554 - Is the laser hazard icon included on the red general hazard door sign?	yes/no	Laser Safety Program	None	None	No	Laser	
6555 - Does the laser door signage contain the required information (a danger sign posted with the type, wavelength, and power of each laser along with the OD for protective eyewear)?	yes/no	Laser Safety Program	NIST requirement	HSI No. 13, section 10.3	No	Laser	
6556 - Is laser eye protection of the appropriate OD present?	yes/no	Laser Safety Program	NIST requirement	HSI No. 13, section 8.3.2	No	Laser	
6557 - Is access limited when the laser is operating?	yes/no	Laser Safety Program	NIST requirement	HSI No. 13, section 8.3.6	No	Laser	
6558 - Is there a red laser light outside the door, and is it functioning properly?	yes/no	Laser Safety Program	NIST requirement	HSI No. 13, section 8.3.4	No	Laser	
7787 - Is there a persistent noise source in this space that seems loud, eg. You need to raise your voice to be heard by people near you?	yes/no	Hearing Protection Program	None	None	None		
7788 - Has hazard signage been posted at the entrances that clearly indicates the noise hazard, the required administrative controls and/or hearing protection devices (HPDs) needed.	yes/no	Hearing Protection Program	NIST requirement	7101.55.6.j.1	No		
7790 - Are hearing protection devices, earplugs, muffs, canal caps, available for use	yes/no	Hearing Protection Program	NIST requirement	7101.55.9.a.7	No		

7789 - Has a noise monitoring been completed?	yes/no	Hearing Protection Program	NIST requirement	7101.55.9.a.5	No		
7791 - Do the activities conducted in the space require the use of PPE?	yes/no	Personal Protective Equipment (PPE)	None	None	None	Screening question	
7792 - Is the appropriate minimum PPE for entry readily available?	yes/no/na	Personal Protective Equipment (PPE)	NIST requirement	7101.21.6.d (1)	No		
7793 - Does appropriate task-specific PPE appear to be available? If not observed, select N/A.	yes/no/na	Personal Protective Equipment (PPE)	NIST requirement	7101.21.6.a, b	No		
7794 - If observed, is PPE used, maintained and disposed of properly? If not observed select NA.	yes/no/na	Personal Protective Equipment (PPE)	NIST requirement	7101.21.6.a, b	No		
6301 - Are respirators stored in this space?	yes/no	Respiratory Protection Program	None	None	None		
6302 - Are the respirators stored in this space clean and protected from damage and contamination?	yes/no	Respiratory Protection Program	NIST requirement	7101.58.6.h	No		
6303 - If an airborne hazard exists that requires a respirator, is hazard signage posted on the door?	yes/no/na	Respiratory Protection Program	NIST requirement	7101.58.6.n.1	No		
6305 - Are SCBA respirators stored in this space?	yes/no	Respiratory Protection Program	None	None	None		

6310 - Are annual flow testing records available for all SCBAs?	yes/no	Respiratory Protection Program	NIST requirement	7101.58.6.i.1.d.i	No		
6311 - Do all SCBAs have inspection, maintenance and service records?	yes/no	Respiratory Protection Program	NIST requirement	7101.58.6.l.2	No		
6312 - Do the inspection records contain all the required elements: Date of inspection, name of inspector, findings, any required remedial actions, respirator identification?	yes/no	Respiratory Protection Program	NIST requirement	7101.58.6.h.3.c.iv	No		
6313 - Are SCBAs used for purposes other than firefighting inspected monthly?	yes/no/na	Respiratory Protection Program	NIST requirement	7101.58.6.h.3.d.i.i	No		
6315 - Does the air in the cylinders meet the requirements of being ANSI/Grade D air?	yes/no	Respiratory Protection Program	NIST requirement	7101.58.6.j.1	No		
6316 - Are SCBA parts, that are broken or out of service, tagged or marked to prevent use?	yes/no/na	Respiratory Protection Program	NIST requirement	7101.58.6.h.4.a	No		
6307 - Are users of these respirators enrolled in the NIST Respiratory Protection Program and have they completed retraining and fit testing within the last 12 months?	yes/no/na	Respiratory Protection Program	NIST requirement	7101.58.6.m.1	No		
5022 - Does the facility have an overhead crane?	yes/no	Overhead Cranes and Hoists	Federal regulatory requirement	1910.179	None		

5023 - Is the rated load of the crane plainly marked on each side of the crane, and each hoist if more than one hoist?	yes/no	Overhead Cranes and Hoists	Federal regulatory requirement	1910.179(b)(5)	No		
5024 - Are inspections of the crane and rigging equipment conducted frequently or periodically as required?	yes/no	Overhead Cranes and Hoists	Federal regulatory requirement	1910.179(j)	No		
7748 - Are Powered Industrial Vehicle (i.e. forklifts, bucket lifts) used at the facility?	yes/no	Powered Industrial Trucks (PITs) Program	Federal regulatory requirement	1910.178	None		
7749 - Are all nameplates and markings are in place and are maintained in a legible condition and does the nameplate indicate that the truck meets ANSI B56.1 requirements?	yes/no	Machines, Tools, and Associated Equipment Safety Program	Federal regulatory requirement	1910.178(a)(3), 1910.178(a)(6)	No		
7750 - Are High Lift Rider trucks fitted with an overhead guard unless operating conditions do not permit.	yes/no/na	Fall Protection Program	Federal regulatory requirement	1910.178(e)(1)	No		
7751 - Is there an eyewash unit located near the battery charging station?	yes/no/na	Powered Industrial Trucks (PITs) Program	Federal regulatory requirement	1910.178(g)(2)	No		
7752 - Is there machining equipment in the space?	yes/no	Machines, Tools, and Associated Equipment Safety Program	None	None	None	Equipment & Machine	
7753 - Is the equipment properly guarded?	yes/no	Machines, Tools, and Associated Equipment Safety Program	Federal regulatory requirement	29 CFR 1910.212(a)(1)	No	Equipment & Machine	

7754 - Is machinery installed to prevent unintentional moving or tipping?	yes/no/na	Machines, Tools, and Associated Equipment Safety Program	Federal regulatory requirement	29 CFR 1910.212(b)	No	Equipment & Machine	
7755 - Are start, stop, emergency, and other operating controls within the operator's reach?	yes/no	Machines, Tools, and Associated Equipment Safety Program	None	None	No	Equipment & Machine	
7756 - Is adequate PPE available in areas with tools?	yes/no/na	Personal Protective Equipment (PPE)	NIST requirement	NIST S 7101.21.6.a.(1)	No	Equipment & Machine	
7757 - If Restricted Access devices are being used to restrict usage by unauthorized personnel, have all the unused equipment been rendered inoperable?	yes/no/na	No Program	None	None	No		
5245 - Are portable electrical tools or hand-operated tools in the space?	yes/no	Machines, Tools, and Associated Equipment Safety Program	None	None	None	Equipment & Machine	
5246 - Are electrically powered tools double insulated or grounded?	yes/no/na	Machines, Tools, and Associated Equipment Safety Program	Federal regulatory requirement	29 CFR 1910.243(a)(5) & 29 CFR 1926.302(a)(1)	No	Equipment & Machine	

5247 - Are tools properly maintained?	yes/no	Machines, Tools, and Associated Equipment Safety Program	Federal regulatory requirement	29 CFR 1910.242(a)	No	Equipment & Machine	
7795 - Does the space contain electrical appliances, that are not intented for research purposes? e.g., space heaters, coffee makers.	yes/no	Office Safety Program	None	None	None	Office Safety, appliance screening	
7796 - Do appliances with heating elements bear the marks of a Nationally Recognized Testing Laboratory, such as Underwriters Laboratories (UL) or Factory Mutual?	yes/no	Office Safety Program	NIST requirement	S7101.62.6. d.(4)(c)	No	Office Safety, Electrical Safety	
7797 - Are appliances with current loads greater than 12 amperes plugged directly into wall outlets or into an OSHE approved power strip that is listed for commercial or industrial uses, has a master circuit breaker, a master on/off switch, and a metal case?	yes/no/na	Office Safety Program	NIST requirement	S7101.62.6. d.(4)(b)	No	Office Safety	
5001 - Are electrical plugs un-damaged, fully inserted into receptacles, and not connected using 3-prong to 2-prong adapters?	yes/no	Electrical Safety Program	NIST requirement	S7101.62.6. d.(1)(a), S7101.62.6. d.(1)(b), S7101.62.6. d.(1)(g)	No		

5002 - Are cords free of tension, not pinched, not permanently attached to building surfaces, and free of cracks and exposed wires?	yes/no	Electrical Safety Program	NIST requirement	S7101.62.6. d.(1)(c), S7101.62.6. d.(1)(d), S7101.62.6. d.(1)(e), S7101.62.6. d.(1)(g)	No		
5003 - Is the space free of overloaded permanently installed electrical outlets?	yes/no	Electrical Safety Program	NIST requirement	S7101.62.6. d.(2)(a)	No		
5004 - Is the space free of broken, missing, or cracked electrical outlet cover plates?	yes/no	Electrical Safety Program	NIST requirement	S7101.62.6. d.(2)(b)	No		
7767 - Does the space require GFCI outlets due to the presence of electrical outlets in proximity to water sources?	yes/no	Electrical Safety Program	NIST requirement	S7101.62.6. d.(2)(c)	None		
7768 - Are all electrical outlets within 6 feet of a water source equipped with GFCI protections?	yes/no	Electrical Safety Program	NIST requirement	S7101.62.6. d.(2)(c)	No		
7769 - Are all the tested GFCI outlets operating correctly?	yes/no/na	Electrical Safety Program	NIST requirement	S7101.62.6. d.(2)(c)	No		
5006 - Are electrical panels unobstructed with moveable objects and does the space around the panels permit the panel door to open at least a 90-degrees?	yes/no/na	Electrical Safety Program	NIST requirement	S7101.62.6. d.(3)(k).i.	No		
5007 - Does the space contain supplemental devices such as power strips, surge suppressors, uninterruptible power supplies, or extension cords?	yes/no	Electrical Safety Program	None	None	None		

5008 - Are/do all supplemental power devices grounded, bear the mark of a NRTL, connected directly to wall outlets, not attached to building structures that require tools to remove, and not routed through walls or ceiling?	yes/no/na	Electrical Safety Program	NIST requirement	S7101.62.6. d.(3)(a), S7101.62.6. d.(3)(b), S7101.62.6. d.(3)(c), S7101.62.6. d.(3)(f), S7101.62.6. d.(3)(h)	No		
5009 - Extension cords are not used in place of permanent wiring?	yes/no/na	Electrical Safety Program	NIST requirement	S7101.62.6. d.(3)(g)	No		
5010 - Are equipment with current loads greater than 12 amperes plugged directly into wall outlets or into an OSHE approved power strip that is listed for commercial or industrial uses, has a master circuit breaker, a master on/off switch, and a metal case?	yes/no/na	Electrical Safety Program	NIST requirement	S7101.62.6. d.(4)(b)	No		
7758 - Is lockout or tagout used in use in this space?	yes/no	Control of Hazardous Energy (Lockout/Tagout or LOTO)	NIST requirement	None	None		
7760 - Are the locks red colored?	yes/no	Control of Hazardous Energy (Lockout/Tagout or LOTO)	NIST requirement	7101.56.6.i	No		
7759 - Do tags contain the required information and of the proper design, construction and affixed properly?	yes/no	Control of Hazardous Energy (Lockout/Tagout or LOTO)	NIST requirement	S7101.56.6. i	No		

7764 - Is LOTO conducted by an Authorized Worker?	yes/no	Control of Hazardous Energy (Lockout/Tagout or LOTO)	NIST requirement	7101.56.6.c	No		
7761 - Does the LOTO require a written procedure based on 7101.56.6.b(1) ?	yes/no	Control of Hazardous Energy (Lockout/Tagout or LOTO)	NIST requirement	7101.56.6.b (1)	None		
7762 - Are LOTO Energy Control Procedures (both written and verbal) inspected annually?	yes/no	Control of Hazardous Energy (Lockout/Tagout or LOTO)	NIST requirement	7101.56.6.k	No		
7763 - Are the written LOTO procedures appropriate for the equipment being serviced?	yes/no	Control of Hazardous Energy (Lockout/Tagout or LOTO)	NIST requirement	7101.56.6.b (2)(b)	No		
7765 - If the LOTO involves coordination with another Division, are written procedures available, and have they been shared with the other Division?	yes/no/na	Control of Hazardous Energy (Lockout/Tagout or LOTO)	NIST requirement	7101.56.6.c	No		
7766 - Are all walking and working surfaces (i.e., passageways, storerooms, and service rooms) kept clean, orderly, sanitary, dry, and free of protruding objects and loose materials?	yes/no	Walking/Working Surface Program	Federal regulatory requirement	29 CFR 1910.22(a)	No		
5272 - Do all overhead catwalks or mezzanines have standard guardrails and toe-boards?	yes/no/na	Walking/Working Surface Program	Federal regulatory requirement	29 CFR 1910.23(a) (2)	No	Walking/Working	

7780 - Are stairs present?	yes/no	Walking/Working Surface Program	None	None	None		
7781 - Are fixed stairs having four or more risers present in this space?	yes/no	Walking/Working Surface Program	None	None	None		
7782 - Do exposed stairways and platforms have railings on all open sides?	yes/no/na	Walking/Working Surface Program	Federal regulatory requirement	29 CFR 1910.24(h)	No		
7783 - Do enclosed stairways have a handrail on at least one side?	yes/no/na	Walking/Working Surface Program	Federal regulatory requirement	29 CFR 1910.24(h)	No		
7784 - Are stairways at least 22 inches wide?	yes/no	Walking/Working Surface Program	Federal regulatory requirement	29 CFR 1910.24(d)	No		
7785 - Are stair treads slip-resistant?	yes/no	Walking/Working Surface Program	Federal regulatory requirement	29 CFR 1910.24(f)	No		
7786 - Are all stair treads in good condition?	yes/no	Walking/Working Surface Program	Federal regulatory requirement	29 CFR 1910.24(f)	No		
7824 - Are ladders present?	yes/no	Walking/Working Surface Program	None	None	None		
7825 - Is the ladder load capacity clearly marked on each ladder?	yes/no	Walking/Working Surface Program	Other	ANSI 14.1 (Wooden Ladders); 14.2 (Metal Ladders); 14.5 (Reinforced Plastic Ladders)	No		

7826 - Are they in good condition with no worn parts or sharp edges?	yes/no	Walking/Working Surface Program	Federal regulatory requirement	29 CFR 1910 Subpart D	No		
7827 - Are steps not spaced more than 12 inches apart?	yes/no	Walking/Working Surface Program	Federal regulatory requirement	29 CFR 1910 Subpart D	No		
7828 - Do they have a metal spreader or locking device?	yes/no	Walking/Working Surface Program	Federal regulatory requirement	29 CFR 1910 Subpart D	No		
7770 - Are step stools (self-supporting, portable, non-adjustable ladder having a top step that is no more than 32 inches high and is designed to be stepped on) present?	yes/no	Walking/Working Surface Program	Federal regulatory requirement	29 CFR 1926.1050 (b)	None		
7771 - Do all step stools or small step ladders have anti-slip feet and are they in good working condition overall?	yes/no	Walking/Working Surface Program	NIST requirement	S7101.62.6.c.(2, 4)	No		
7772 - If more than two steps high, is there a hand rail or safety bar? (Recommended)	yes/no	Walking/Working Surface Program	NIST requirement	S7101.62.6.c.(3)	None		
7773 - Is heavy shelving (greater than 200 lb per shelf) used in the space?	yes/no	No Program	None	None	None		
7774 - Is the heavy shelving load capacity clearly marked?	yes/no	No Program	None	None	No		
7813 - Screening for Fire Safety.	yes/no	Impairment of Fire Protection and Life Safety Systems Program	None	None	None		

7814 - Are materials stored at least 24 inches from the ceiling?	yes/no/na	Impairment of Fire Protection and Life Safety Systems Program	NIST requirement	S7101.62.6. e.(2)(b)	No		
7815 - Are materials stored at least 18 inches from the sprinkler heads?	yes/no/na	Impairment of Fire Protection and Life Safety Systems Program	NIST requirement	S7101.62.6. e.(2)(c)	No		
7816 - Are exit paths at least 28 inches wide?	yes/no	Impairment of Fire Protection and Life Safety Systems Program	NIST requirement	S7101.62.6. e.(3)	No		
7817 - Are flammable or combustible liquids being utilized in the laboratory?	yes/no	Chemical Management Program	None	None	None		
7821 - Are Class I flammable liquids being utilized under a chemical fume hood? Are Class I flammable liquids being utilized under a chemical fume hood, in an area where ventilation is adequate to prt accumulation of vapor in excess of 25% of the LFL, or in a Class I Division 1 or 2 location?	yes/no	Chemical Management Program	Other	NFPA 45-9.3.1	No		

7822 - Are heating operations involving flammable and combustible liquids being performed under a chemical fume hood or in a safe location to adequately vent and control vapors?	yes/no	Chemical Management Program	Other	NFPA 45-9.5.4	No		
7823 - Are ignition hazards absent where flammable and combustible liquids are used?	yes/no	Chemical Management Program	Other	NFPA 30-6.5.1	No		
7818 - Are hot works conducted inside the laboratory?	yes/no	Fire Prevention During Welding, Cutting, and Other Hot Works	None	None	None		
7819 - Are hot works being performed in a designated hot works area or has a permit been acquired to perform the work outside of a designated hot works area?	yes/no	Fire Prevention During Welding, Cutting, and Other Hot Works	Other	NFPA 51B-5.2.2	No		
7820 - Is the designated hot works area clear of all combustible and flammable materials?	yes/no	Fire Prevention During Welding, Cutting, and Other Hot Works	Other	NFPA 51B-5.2.1	No		
5303 - Is tall/heavy furniture that could topple secured to the wall?	yes/no/na	Office Safety Program	NIST requirement	S7101.62.6.f.(5)	No	Office Safety	
7722 - Are all the overhead lights operating correctly?	yes/no	Walking/Working Surface Program	None	None	No		

7723 - Are there overhead doors in the space?	yes/no	No Program	None	None	None		
7724 - Are the overhead door safety stops malfunctioning?	yes/no/na	No Program	None	None	None		
7725 - Is there signage warning that the overhead door safety stops are not functioning correctly?	yes/no	No Program	None	None	No		
5307 - Are there any other deficiencies not in this list?	yes/no	No Program	None	None	Yes		
5359 - Deficiency #1 ?	yes/no	No Program	Other	NA	Yes		
5360 - Deficiency #2 ?	yes/no	No Program	Other	NA	Yes		
5361 - Deficiency #3 ?	yes/no	No Program	Other	NA	Yes		
5362 - Deficiency #4 ?	yes/no	No Program	Other	NA	Yes		
5363 - Deficiency #5 ?	yes/no	No Program	Other	NA	Yes		

Checklist Questions

Lab Checklist - Short Version 9-5-2018

Publish Date: 09/06/2018 Expire Date: 09/06/2023

Question	Question Type	Program	Reference Type	Reference	Fail Condition	Labels	Options
8226 - Is the space free of deficiencies in the Hazard Signage Program?	yes/no/na	Hazard Signage Program	NIST requirement	NIST Admin Manual Subchapter 12.08	No	Hazard Signage	
8249 - Are walking/working surfaces free of deficiencies?	yes/no	Walking/Working Surface Program	Federal regulatory requirement	OSHA 1910 Subpart D	No		
8238 - Is the space free of work environment (storage/lighting) safety deficiencies?	yes/no	No Program	NIST requirement	NIST S 7101.62	No		
8050 - Are compressed gas systems properly designed, installed, and maintained and are compressed gas cylinders properly labeled, secured, and stored?	yes/no/na	Compressed Gas Safety Program	NIST requirement	NIST S 7101.61	No		
8224 - Is the lab free of Cryogen program deficiencies?	yes/no/na	Cryogen Safety Program	NIST requirement	NIST S7101.52	No		
8239 - Is the potential for surface and airborne contamination by dispersible engineered nanomaterials (DENMs) adequately controlled?	yes/no/na	Dispersible Engineered Nanomaterials (DENMs) Program	NIST requirement	NIST S 7101.54	No		
8362 - Is the lab free of Chemical Hazard Communications Deficiencies?	yes/no/na	Chemical Hazard Communication Program	NIST requirement	NIST S 7101.59	No		

8363 - Is the lab free of Chemical Management Program deficiencies?	yes/no/na	Chemical Management Program	NIST requirement	NIST S 7101.60	No		
8227 - Are all hazadrous chemical wastes properly contained, labeled, segregated, and stored?"	yes/no/na	Chemical Waste Accumulation/Disposal at NIST Gaithersburg Program	NIST requirement	NIST S 7301.04	No		
8235 - Is space/activity free of laser safety deficiencies? (for class 3R invisible, 3B and 4 lasers only)	yes/no/na	Laser Safety Program	NIST requirement	NIST S 7101.72	No		
8231 - Is space or observed activity free of Personal Protection Equipment (PPE) program deficiencies?	yes/no/na	Personal Protective Equipment (PPE)	NIST requirement	NIST S 7101.21	No		
8323 - Are respirators properly stored and appropriate for the hazard in the lab?	yes/no/na	Respiratory Protection Program	NIST requirement	NIST S 7101.58	No		
8228 - In high noise environments, are adequate warning signs and hearing protection devices in place?	yes/no/na	Hearing Protection Program	NIST requirement	NIST S 7101.55	No		
8232 - Is space free of electrical safety deficiencies?	yes/no	Electrical Safety Program	Federal regulatory requirement	OSHA 1910 Subpart S, NIST S 7101.64	No		
8236 - Is the room/lab free of fire and life safety deficiencies?	yes/no	Impairment of Fire Protection and Life Safety Systems Program	NIST requirement	NIST S 7401.01	No		

8229 - Is the space free of any lockout tagout deficiencies (when lockout tagout is observed)?	yes/no/na	Control of Hazardous Energy (Lockout/Tagout or LOTO)	NIST requirement	NIST S 7101.56	No		
8237 - Are overhead cranes and powered industrial trucks free from recognized deficiencies?	yes/no/na	Material Handling Program	Federal regulatory requirement	OSHA 1910.178, 1910.179	No		
8234 - Are powered machines and tools free of deficiencies?	yes/no/na	Machines, Tools, and Associated Equipment Safety Program	Federal regulatory requirement	OSHA 1910 Subpart O	No		
8230 - Are Permit Required Confined Spaces labeled with hazard warning signage that reads "DANGER - Permit-Required Confined Space - Entry by authorized personnel only"?	yes/no/na	Permit-Required Confined Spaces	NIST requirement	NIST S 7101.57	No		

Appendix 6.11.4: Workplace Inspection Deficiency Report for Building 205, Room 125

Deficiency Report

Deficiency ID	Status	Site	Building	Room	Inspection Date	Inspector	Deficiency Description	Program	Question ID	Reference	Classification	Corrected Onsite	On Site Abatement Action	Recommended Abatement Action	Recommended Interim Controls	Workplace Supervisor	Deficiency Owner	Planned Abatement Action	Planned Abatement Date	Abatement Action Taken	Abatement Submitter	Actual Abatement Date	Inspection Submitted Date
1059322	Closed	Gaithersburg	205	125	03/19/2018	[redacted]	The fire extinguishers used for welding or fire testing that are currently on the floor in various places should be relocated to storage and secured from tipping over.	No Program	5360	NA	Other-than-serious UWC/Administrative	No				[redacted]	[redacted]	[redacted] will move to cylinder storage area and secure	03/30/2018	moved		03/30/2018	03/22/2018
1059264	Closed	Gaithersburg	205	125	03/19/2018	[redacted]	Electrical disconnect switch for roll up door is blocked	No Program	5362	NA	Other-than-serious UWC/Administrative	No				[redacted]	[redacted]	unblock ([redacted])	03/30/2018	cleared		03/30/2018	03/22/2018
1059269	Closed	Gaithersburg	205	125	03/19/2018	[redacted]	CO2 compressed gas cylinder on cart should be placed in storage rack and chained.	Compressed Gas Safety Program	6485	7101.61.6.b(5)(a)(i)	Other-than-serious UWC/Administrative	No				[redacted]	[redacted]	[redacted] will move gas bottle to cylinder storage area and secure.	03/30/2018	moved		03/30/2018	03/22/2018
1059310	Closed	Gaithersburg	205	125	03/19/2018	[redacted]	Power strip powering computer monitor on east end was connected to extension cord. Daisy chained	Electrical Safety Program	5002	S7101.62.6.d.(1)(c), S7101.62.6.d.(1)(d), S7101.62.6.d.(1)(e), S7101.62.6.d.(1)(g)	Other-than-serious UWC/Administrative	No				[redacted]	[redacted]			Removed extension cord		03/19/2018	03/22/2018
1059274	Closed	Gaithersburg	205	125	03/19/2018	[redacted]	Electrical disconnect switch for roll up door on south wall, near east end is blocked	No Program	5359	NA	Other-than-serious UWC/Administrative	No				[redacted]	[redacted]	unblock [redacted]	03/30/2018	cleared		03/30/2018	03/22/2018

Deficiency Report

Supervisor Initial Response Date	Inspection ID	OU	Division	Group	Space Contacts	Checklist Name	M Slip	M Slip Entered Date	Updated By	Updated Date
3/23/2018 4:43:14 PM	35509	73 - EL	733	733.06	[redacted],	EL Laboratory General Checklist - 20171213			[redacted]	03/30/2018
3/23/2018 4:40:45 PM	35509	73 - EL	733	733.06	[redacted],	EL Laboratory General Checklist - 20171213			[redacted]	03/30/2018
3/23/2018 4:44:41 PM	35509	73 - EL	733	733.06	[redacted]	EL Laboratory General Checklist - 20171213			[redacted]	03/30/2018
3/23/2018 4:40:20 PM	35509	73 - EL	733	733.06	[redacted],	EL Laboratory General Checklist - 20171213			[redacted]	03/23/2018
3/23/2018 4:41:12 PM	35509	73 - EL	733	733.06	[redacted]	EL Laboratory General Checklist - 20171213			[redacted]	03/30/2018

Deficiency Report

Deficiency ID	Status	Site	Building	Room	Inspection Date	Inspector	Deficiency Description	Program	Question ID	Reference	Classification	Corrected Onsite	On Site Abatement Action	Recommended Abatement Action	Recommended Interim Controls	Workplace Supervisor	Deficiency Owner	Planned Abatement Action	Planned Abatement Date	Abatement Action Taken	Abatement Submitter	Actual Abatement Date	Inspection Submitted Date
1059296	Closed	Gaithersburg	205	125	03/19/2018	[redacted]	Band saw guard should be lowered completely when not in use	No Program	7753	29 CFR 1910.212(a)(1)	Other-than-serious UWC/Administrative	No				[redacted]	[redacted]	lower band saw guard	03/30/2018	lowered guard. Does not go flush with deck		03/30/2018	03/22/2018
1059279	Closed	Gaithersburg	205	125	03/19/2018	[redacted]	Hawg wash liquid needs a chemical hazard label	Chemical Hazard Communication Program	7833	S 7101.59(6)(c)(4)	Other-than-serious UWC/Administrative	No				[redacted]	[redacted]	[redacted] will add to Cispro and print label (see [redacted]). Coolant for band saw will be disposed as waste ([redacted]	04/06/2018	proper label applied		05/01/2018	03/22/2018
1060833	Closed	Gaithersburg	205	125	03/19/2018	[redacted]	The electrical cutoff switch for the cranes were blocked.	No Program		OSHE	Other-than-serious UWC/Administrative	No	0			[redacted]	[redacted]	unblock ([redacted])	03/30/2018	cleared		03/30/2018	03/22/2018
1060822	Closed	Gaithersburg	205	125	03/19/2018	Kathleen [redacted]	Extension cord powering the radio should not be routed through the bottom of the wall on the west end of the building.\u201D	Electrical Safety Program		NA	Other-than-serious UWC/Administrative	No	0			[redacted]	[redacted]	reroute electrical cord ([redacted])	03/30/2018	rerouted		03/30/2018	03/22/2018
1059257	Closed	Gaithersburg	205	125	03/19/2018	[redacted]	\u2022\tOperator was observed without fall protection while using scissor lift with midrail that was not secured.	No Program	5361	NA	Other-than-serious UWC/Administrative	Yes	Worker was notified and he was not observed using lift again during inspection	N/A		[redacted]	[redacted]			N/A		03/19/2018	03/22/2018

Deficiency Report

Supervisor Initial Response Date	Inspection ID	OU	Division	Group	Space Contacts	Checklist Name	M Slip	M Slip Entered Date	Updated By	Updated Date
3/23/2018 4:31:06 PM	35509	73 - EL	733	733.06	[redacted]	EL Laboratory General Checklist - 20171213			[redacted]	03/30/2018
3/23/2018 4:36:55 PM	35509	73 - EL	733	733.06	[redacted]	EL Laboratory General Checklist - 20171213			[redacted]	05/14/2018
3/23/2018 4:39:29 PM	35509	73 - EL	733	733.06	[redacted]	EL Laboratory General Checklist - 20171213			[redacted]	03/30/2018
3/23/2018 4:38:55 PM	35509	73 - EL	733	733.06	[redacted]	EL Laboratory General Checklist - 20171213			[redacted]	03/30/2018
N/A	35509	73 - EL	733	733.06	[redacted]	EL Laboratory General Checklist - 20171213			[redacted]	03/22/2018

Deficiency Report

Deficiency ID	Status	Site	Building	Room	Inspection Date	Inspector	Deficiency Description	Program	Question ID	Reference	Classification	Corrected Onsite	On Site Abatement Action	Recommended Abatement Action	Recommended Interim Controls	Workplace Supervisor	Deficiency Owner	Planned Abatement Action	Planned Abatement Date	Abatement Action Taken	Abatement Submitter	Actual Abatement Date	Inspection Submitted Date
1136667	Closed	Gaithersburg	205	125	10/17/2018	[redacted]	The lanyard used for the Boom truck should not have a shock absorber.	Personal Protective Equipment (PPE)	8231	NIST S 7101.21	Other-than-serious UWC/Administrative	No		1) Replace with a short lanyard that is used for fall restraint.		[redacted]	[redacted]	Replace shock absorbing lanyard with a retractable locking lanyard.	11/06/2018	Replaced shock absorbing lanyard with a retractable locking lanyard.	[redacted]	11/06/2018	10/19/2018
1136672	Closed	Gaithersburg	205	125	10/17/2018	[redacted]	The Powered Air Purifying Respirator (PAPR) should be stored in a plastic bag when not in use to avoid contamination of the face piece.	Respiratory Protection Program	8323	NIST S 7101.58	Other-than-serious UWC/Administrative	No				[redacted]	[redacted]			Stored facepiece in plastic bag on 10/30/2018.	[redacted]	10/30/2018	10/19/2018
1136675	Closed	Gaithersburg	205	125	10/17/2018	[redacted]	The forklifts should be maintained annually by an authorized service provider. The last inspection seems to be in January 2016. ANSI B56.1 has guidelines. This also pertains to scissor lifts and boom lifts. The manufactures recommend a scheduled / annual inspection.	Material Handling Program	8237	OSHA 1910.178, 1910.179	Other-than-serious UWC/Administrative	No		Have lifts serviced by an authorized provider as soon as reasonably possible.	Daily inspections or prior to to first use should be conducted by equipment operator as recommended by manufacturer. If any deficiencies are observed, the lift must be taken out of service until it has been repaired/ serviced by an authorized provider.	[redacted]	[redacted]			The two lifts where all serviced and inspected on 10/24/2018, Waiting on the bill for that to see how much and when this comes I can make payment decision on the lifts meaning using another vender or them.	[redacted]	11/08/2018	10/19/2018

Deficiency Report

Supervisor Initial Response Date	Inspection ID	OU	Division	Group	Space Contacts	Checklist Name	M Slip	M Slip Entered Date	Updated By	Updated Date
11/8/2018 3:36:38 PM	39776	73 - EL	733	733.06	[redacted],	Lab Checklist - Short Version 9-5-2018			[redacted]	11/08/2018
10/30/2018 2:00:53 PM	39776	73 - EL	733	733.06	[redacted]	Lab Checklist - Short Version 9-5-2018			[redacted]	10/30/2018
11/8/2018 3:38:31 PM	39776	73 - EL	733	733.06	[redacted],	Lab Checklist - Short Version 9-5-2018			[redacted]	11/08/2018

Deficiency Report

Deficiency ID	Status	Site	Building	Room	Inspection Date	Inspector	Deficiency Description	Program	Question ID	Reference	Classification	Corrected Onsite	On Site Abatement Action	Recommended Abatement Action	Recommended Interim Controls	Workplace Supervisor	Deficiency Owner	Planned Abatement Action	Planned Abatement Date	Abatement Action Taken	Abatement Submitter	Actual Abatement Date	Inspection Submitted Date
1136680	Closed	Gaithersburg	205	125	10/17/2018	[redacted]	1) Router on top of partition and extension cord, wrapped around nearby. 2) Daisy chained UPS on North wall	Electrical Safety Program	8232	OSHA 1910 Subpart S, NIST S 7101.64	Other-than-serious UWC/Administrative	No		1) Remove router & extension cord. 2) Remove daisy chain.		[redacted]	[redacted]		10/29/2018	Router and extension cord were removed until needed for next Livestream action.	[redacted]	10/29/2018	10/19/2018
1175557	Closed	Gaithersburg	205	125	04/04/2019	[redacted]	Rubber electrical cord from switch needs to be in a conduit.	Electrical Safety Program	8232	OSHA 1910 Subpart S, NIST S 7101.64	Other-than-serious UWC/Administrative	No				[redacted]	[redacted]	Remove from Service. Contact electric shop.	04/10/2019	Removed from service. Submitted M-Slip	[redacted]	04/10/2019	04/05/2019
1175565	Closed	Gaithersburg	205	125	04/04/2019	[redacted]	Open pail/container of oil used for band saw. Near large band saw.	Chemical Management Program	8363	NIST S 7101.60	Other-than-serious UWC/Administrative	No		Seal or cover container to prevent spillage.		[redacted]	[redacted]	Cover pail with lid.	04/10/2019	Covered pail with lid.	[redacted]	04/10/2019	04/05/2019
1175564	Closed	Gaithersburg	205	125	04/04/2019	[redacted]	Aisle way to crane electrical disconnect is less than 28".	Walking/Working Surface Program	8249	OSHA 1910 Subpart D	Other-than-serious UWC/Administrative	No		Clear a path to disconnect.		[redacted]	[redacted]	Move pallets blocking walk way to disconnect.	04/09/2019	Moved pallets blocking walk way to disconnect. Confirmed by supervisor.	[redacted]	04/09/2019	04/05/2019
1237600	Closed	Gaithersburg	205	125	10/16/2019	[redacted]	Male electrical plug coming out of electrical box that powers lighting.	Electrical Safety Program	8232	OSHA 1910 Subpart S, NIST S 7101.64	Other-than-serious UWC/Administrative	No		Install a male receptacle in electrical box.		[redacted]	[redacted]			Light power cord plugged directly into receptacle. conduit and junction box no longer needed	[redacted]	10/21/2019	10/16/2019
1237604	Closed	Gaithersburg	205	125	10/16/2019	[redacted]	Empty sign holder.	No Program	8226	NIST Admin Manual Subchapter 12.08	Other-than-serious UWC/Administrative	No		Have proper sign installed.		[redacted]	[redacted]			sign installed	[redacted]	10/18/2019	10/16/2019

Deficiency Report

Supervisor Initial Response Date	Inspection ID	OU	Division	Group	Space Contacts	Checklist Name	M Slip	M Slip Entered Date	Updated By	Updated Date
10/29/2018 1:56:22 PM	39776	73 - EL	733	733.06	[redacted]	Lab Checklist - Short Version 9-5-2018			[redacted]	10/29/2018
4/10/2019 3:31:17 PM	42217	73 - EL	733	733.06	[redacted]	Lab Checklist - Short Version 9-5-2018	RITM0418505	04/10/2019	[redacted]	04/10/2019
4/10/2019 3:32:03 PM	42217	73 - EL	733	733.06	[redacted],	Lab Checklist - Short Version 9-5-2018			[redacted]	04/10/2019
4/9/2019 3:42:46 PM	42217	73 - EL	733	733.06	[redacted]	Lab Checklist - Short Version 9-5-2018			[redacted]	04/09/2019
10/21/2019 10:33:01 AM	46560	73 - EL	733	733.06	[redacted]	Lab Checklist - Short Version 9-5-2018			[redacted]	10/21/2019
10/21/2019 10:30:00 AM	46560	73 - EL	733	733.06	[redacted],	Lab Checklist - Short Version 9-5-2018			[redacted]	10/21/2019

Deficiency Report

Deficiency ID	Status	Site	Building	Room	Inspection Date	Inspector	Deficiency Description	Program	Question ID	Reference	Classification	Corrected Onsite	On Site Abatement Action	Recommended Abatement Action	Recommended Interim Controls	Workplace Supervisor	Deficiency Owner	Planned Abatement Action	Planned Abatement Date	Abatement Action Taken	Abatement Submitter	Actual Abatement Date	Inspection Submitted Date
1237602	Closed	Gaithersburg	205	125	10/16/2019	[redacted]	1) Fall protection cabling on elevated concrete deck not at proper heights. 2) Hole in floor large enough for someone to possibly step into.	Walking/Working Surface Program	8249	OSHA 1910 Subpart D	Other-than-serious UWC/Administrative	No		1) Move fall protection cabling to 42 +/- 3" and 21" above concrete floor / deck. 2) Guard hole in floor.		[redacted]	[redacted]			cable moved and hole blocked	[redacted]	10/21/2019	10/16/2019
1265364	Closed	Gaithersburg	205	125	12/16/2020	[redacted]	Acetylene Cylinder needs Cyspro Label	Compressed Gas Safety Program	8050	NIST S 7101.61	Other-than-serious UWC/Administrative	No		Apply Label		[redacted]	[redacted]			label applied		01/05/2021	12/16/2020
1265351	Closed	Gaithersburg	205	125	12/16/2020	[redacted]	1) Power cords hanging in walkways- Northeast & Northwest corners of structure 2) Unused power cords laying in walkway. 3) Cart blocking Fire Extinguisher	Walking/Working Surface Program	8249	OSHA 1910 Subpart D	Other-than-serious UWC/Administrative	No		1) Reroute cords. 2) Wrap up cords when not in use 3) Move cart		[redacted]	[redacted]			[redacted] moved cords and cart		12/29/2020	12/16/2020

Deficiency Report

Supervisor Initial Response Date	Inspection ID	OU	Division	Group	Space Contacts	Checklist Name	M Slip	M Slip Entered Date	Updated By	Updated Date
10/21/2019 10:29:16 AM	46560	73 - EL	733	733.06	[redacted]	Lab Checklist - Short Version 9-5-2018			[redacted]	10/21/2019
1/5/2021 2:03:51 PM	48567	73 - EL	733	733.06	[redacted]	Lab Checklist - Short Version 9-5-2018			[redacted]	01/05/2021
1/5/2021 2:08:43 PM	48567	73 - EL	733	733.06	[redacted]	Lab Checklist - Short Version 9-5-2018			[redacted]	01/05/2021

Deficiency Report

Deficiency ID	Status	Site	Building	Room	Inspection Date	Inspector	Deficiency Description	Program	Question ID	Reference	Classification	Corrected Onsite	On Site Abatement Action	Recommended Abatement Action	Recommended Interim Controls	Workplace Supervisor	Deficiency Owner	Planned Abatement Action	Planned Abatement Date	Abatement Action Taken	Abatement Submitter	Actual Abatement Date	Inspection Submitted Date
1282173	Closed	Gaithersburg	205	125	07/22/2021	[redacted]	Incorrect dates on inspection sticker-applies to all cranes in bldg 205	Material Handling Program	8237	OSHA 1910.178, 1910.179	Other-than-serious UWC/Administrative	No		Consult with [redacted] to update inspection stickers		[redacted]	[redacted]			confirmed inspection dates are correct and cranes and overdue. [redacted] form OFPM informed us that the inspection contract will be in place soon		07/28/2021	07/22/2021
1282181	Closed	Gaithersburg	205	125	07/22/2021	[redacted]	No clear pathway to crane disconnect-northeast wall. Torch cart blocking electrical disconnect-roll up door on east side	Electrical Safety Program	8232	OSHA 1910 Subpart S, NIST S 7101.64	Other-than-serious UWC/Administrative	No		Clear pathway		[redacted]	[redacted]			area cleared		07/27/2021	07/22/2021
1282178	Closed	Gaithersburg	205	125	07/22/2021	[redacted]	Acetylene cylinder needs a cis-pro label	Compressed Gas Safety Program	8050	NIST S 7101.61	Other-than-serious UWC/Administrative	No		Attach a label		[redacted]	[redacted]			labeled		07/28/2021	07/22/2021
1317307	Closed	Gaithersburg	205	125	06/15/2022	[redacted]	Electrical disconnect blocked.	Electrical Safety Program	8232	OSHA 1910 Subpart S, NIST S 7101.64	Other-than-serious UWC/Administrative	No		Remove items from in front of disconnect.		[redacted]	[redacted]			items removed		06/22/2022	06/16/2022
1317289	Closed	Gaithersburg	205	125	06/15/2022	[redacted]	Waste coolant for saw improperly stored.	Chemical Management Program	8363	NIST S 7101.60	Other-than-serious UWC/Administrative	No		Have waste coolant removed.		[redacted]	[redacted]			chemical waste pickup scheduled		06/22/2022	06/16/2022

Deficiency Report

Supervisor Initial Response Date	Inspection ID	OU	Division	Group	Space Contacts	Checklist Name	M Slip	M Slip Entered Date	Updated By	Updated Date
7/29/2021 10:37:37 AM	49937	73 - EL	733	733.06	[redacted]	Lab Checklist - Short Version 9-5-2018			[redacted]	07/29/2021
7/27/2021 2:37:01 PM	49937	73 - EL	733	733.06	[redacted]	Lab Checklist - Short Version 9-5-2018			[redacted]	07/27/2021
7/29/2021 10:38:29 AM	49937	73 - EL	733	733.06	[redacted]	Lab Checklist - Short Version 9-5-2018			[redacted]	07/29/2021
6/22/2022 2:45:50 PM	52816	73 - EL	733	733.06	[redacted]	Lab Checklist - Short Version 9-5-2018			[redacted]	06/22/2022
6/22/2022 2:49:19 PM	52816	73 - EL	733	733.06	[redacted]	Lab Checklist - Short Version 9-5-2018			[redacted]	06/22/2022

Appendix 6.12.1: NIST S 7101.24: ***Incident Reporting and Investigation***

National Institute of Standards and Technology • U.S. Department of Commerce

INCIDENT REPORTING AND INVESTIGATION

NIST S 7101.24
Approval Date: 01/04/2021
Deployment Start Date: 07/26/2017
Effective Date[1]: 10/01/2017

1. PURPOSE

This suborder establishes the requirements and roles and responsibilities for the reporting and investigation of work-related safety incidents and near misses to determine why these events occurred and what actions must be taken to prevent their recurrence, and for the dissemination throughout the organization of the related incident information and lessons identified. In addition, this suborder provides administrative requirements for complying with Federal Occupational Safety and Health Administration (OSHA) Injury and Illness Recordkeeping and Reporting Requirements.

2. BACKGROUND

NIST management is committed to the safety of everyone who works for, works at, or visits NIST. As part of this commitment, NIST strives to prevent safety incidents by effectively managing risk in all its activities. Essential to effectively managing risk is to learn as much as possible from incidents that have occurred and to take actions to prevent their recurrence. Success in this depends, in turn, on the prompt reporting of incidents and on the timely completion and use of the results of comprehensive incident investigations. Therefore, NIST shall report and investigate incidents in a thorough and timely manner, and share incident reports and lessons identified effectively throughout the organization. This incident data will be analyzed to identify systemic weaknesses in the NIST occupational safety and health (OSH) management system, leading to corrective actions to address those weaknesses.

[1] For revision history, see Appendix A.

3. APPLICABILITY

a. The provisions of this suborder apply to NIST employees and covered associates[2] engaged in **work-related** activities (see Section 7, DEFINITIONS).

b. The requirements of this Suborder apply to the following types of events, as defined in Section 7:

(1) Incidents:

(a) Injury;

(b) Illness;

(c) Exposure;

(d) Contamination by radioactive material;

(e) Spill / release;

(f) Property damage; and

(g) Other events with actual safety or environmental impacts; and

(2) Near misses.

c. The requirements of this suborder do not apply to unsafe conditions or practices, unless they result in an incident or near miss event.[3]

d. This suborder does not address the following topics:

(1) Emergency communications from staff members and first responders, other than communications for reporting of Immediate Notification Incidents as outlined in Section 6d of this suborder, through Organizational Unit (OU) management and emergency

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[2] As per NIST O 7101.00: Occupational Safety and Health Management System, a NIST associate permitted to perform work at a NIST workplace and subject to NIST policies and procedures to the extent allowed by law and the terms of the associate's agreement. Covered associates include Foreign and Domestic Guest Researchers (including contractors who perform NIST R&D/technical work); Research Associates; Intergovernmental Agency Personnel Act assignees; Facility Users; Volunteer Students; and other federal employees who perform work at NIST workplaces.

[3] Unsafe conditions and practices should be reported through appropriate channels in accordance with procedures established in NIST S 7101.02: *Employee Reporting of Unsafe or Unhealthful Working Conditions*.

communication channels, to the NIST Director and Associate Directors, the Department of Commerce, and others pursuant to an emergency or potentially serious incident. Employees should refer to the Office of Facilities and Property Management web page for guidance: https://inet.nist.gov/ofpm;

(2) Specific steps that employees and covered associates should take pursuant to sustaining work-related occupational injuries or illnesses. Employees should refer to the Office of Human Resources Management Workers Compensation Program at https://inet.nist.gov/ohrm/services/owcp; and

(3) Requirements associated with consequence management, *i.e.*, policies, procedures, and forms related to workers' compensation, automobile accidents, and personal property claims.

4. EXTERNAL REFERENCES

a. 29 Code of Federal Regulations (CFR) Part 1904, Recording and Reporting Occupational Injuries and Illnesses

b. 29 CFR Part 1960, Basic Program Elements for Federal Employee Occupational Safety and Health Programs and Related Matters

5. APPLICABLE NIST OCCUPATIONAL SAFETY AND HEALTH DIRECTIVES

a. NIST O 7101.00: Occupational Safety and Health Management System

b. NIST Suborder (S) 7101.23: Safety Education and Training

c. NIST S 7101.02: Employee Reporting of Unsafe or Unhealthful Working Conditions

d. NIST S 7101.55: Hearing Protection

6. REQUIREMENTS

a. General Requirements

(1) All **incidents** and near misses shall be reported by employees and covered associates to their OU line management using OU implementation procedures established per the requirements of Section 6f.

(2) Each such incident or near miss (“event”) shall be documented and investigated to identify why it occurred and what actions are needed to prevent recurrence.

(3) The NIST web-based application titled ***Incident Reporting and Investigation System*** (***IRIS***) shall be used to document events subject to this Suborder, including the relevant investigations. The following general requirements shall apply:

(a) Report Format - Events will be documented using one of two formats, based generally on the complexity and seriousness of the event (see Section 7, Definitions):

i. Streamlined Format (Streamlined Report only); or

ii. Standard Format (Initial Report followed by Investigation Report).

(b) Reporting Timeframes

i. Streamlined and Initial Reports shall be submitted into the ***IRIS*** application within two (2) business days of line management being notified[4], if possible.

ii. Investigation Reports shall be recorded in ***IRIS*** within 20 (twenty) business days of line management being notified, if possible.

b. Initial Evaluation and Information Gathering
As per OU implementation procedures, OU Line Management shall evaluate each event reported to:

(1) Verify the applicability of this Suborder;

(2) Classify each event as an incident or near miss, based on the definitions in Section 7.

(3) Evaluate each incident to determine if it meets the definition of an **Immediate Notification Incident** (see Section 7, Definitions).

(a) When an Immediate Notification Incident is identified, the reporting procedure outlined in Section 6c below shall be followed immediately and OSHE shall assume responsibility for subsequent reporting and investigation requirements.

[4] Cases involving OSHA Recordable Standard Threshold Shift hearing losses shall be entered into IRIS within two (2) business days of line management being notified by letter that the case has either been confirmed by retest, or that a retest will not be taken. Please see NIST S 7101.55: *Hearing Protection* for additional information regarding these types of incidents.

(4) Determine which IRIS report format (Streamlined or Standard) will be used and collect information needed to submit a Streamlined or Initial Report, as appropriate.

(a) OU management shall consider the significance of the circumstances of the event to determine which format is required to be used.

(b) The Standard Format shall be used for the following:

i. Immediate Notification Incidents;

ii. Incidents known by the OU to be **OSHA Recordable cases** (see Section 7, Definitions) unless the OU has received prior approval from the Incident Reporting and Investigation (IRI) Program Manager (PM) to use the Streamlined Format; and

iii. Incidents that result in contamination with or exposure to radioactive material.

(c) The **OU IRIS Administrator** and the **Incident Reporting and Investigation (IRI) Program Manager (PM)** (see Section 7, Definitions) have the authority to require the use of the Standard Format for an event.

(5) Identify OUs involved in the event, specifically:

(a) Identify all OUs with employees involved;

(b) Identify the OU with responsibility for the space where the event occurred; and

(c) Identify the OU with responsibility for the equipment involved.

c. Immediate Notification Incident Procedure

(1) Immediate Notification Incidents shall be reported to OSHE as soon as possible as per the following procedure:

(a) During normal business hours:

i. Call OSHE at x5375, Option 3.

ii. If no one picks up, send an email to serious.injury@nist.gov.

(b) Outside of normal business hours, send an email to serious.injury@nist.gov.

(2) For each Immediate Notification Incident, the following information shall be provided to OSHE:

(a) A brief description of the incident;

(b) The location of the incident;

(c) The time of the incident;

(d) The category of incident, as follows:

i. Fatality;

ii. In-patient hospitalization;

iii. Amputation; or

iv. Loss of an eye;

(e) The number of employees and/or covered associates who suffered the incident;

(f) The names of the employee(s) and/or covered associate(s) who suffered the incident;

(g) An OU point of contact with phone number; and

(h) Periodic updates of the status of the employees(s) or covered associate(s) involved and/or changes to previously provided information.

(3) The NIST CSO shall confirm the reported incident meets the definition of an Immediate Notification Incident.

(4) The NIST CSO shall report confirmed Immediate Notification Incidents to the 24-Hour OSHA hotline at (800) 321-OSHA, within the following timeframes:

(a) Work-related fatality – within 8 hours of finding out; and

(b) Work-related amputation, loss of an eye, or in-patient hospitalization of one or more employees or covered associates – within 24 hours of finding out.

(5) The NIST CSO shall report the following information to OSHA, for each Immediate Notification Incident:

(a) The establishment name (e.g. NIST Gaithersburg, NIST Boulder, etc.)

(b) The NIST contact person and phone number

(c) The information in items 6c(2)(a)-(f) above.

(6) After notifying OSHA of an Immediate Notification Incident, the NIST CSO shall submit the following reports into IRIS:

(a) An Initial Report per the requirements of Sections 6a(3)(b)i and 6d; and

(b) An Investigation Report per the requirements of Sections 6a(3)(b)ii and 6e.

d. Submittal of Streamlined and Initial Reports

A Streamlined or Initial Report shall be submitted for each event, based upon the format selected in Section 6b above, and subject to the following requirements:

(1) OU Responsibility for Streamlined or Initial Report Submittal

(a) For an Immediate Notification Incident, OSHE, with participation from the OU(s) involved, shall develop and submit the required report.

(b) For an event that involves individuals, space, and equipment from only one OU, that OU shall submit the required report.

(c) For an event involving multiple individuals and/or space and/or equipment from different OUs, the OU IRIS Administrators from all OUs involved shall coordinate with each other to identify the OU to develop and submit the required report, with appropriate support from the other OU(s).

(d) For an event where no individuals are involved (*e.g.*, a fire that occurred in a building after hours or a chemical spill in a laboratory when no one was present), the OU responsible for the space in which the event occurred shall submit the required report.

(2) IRIS Submitter Requirements

(a) Streamlined and Initial Reports shall be entered into IRIS only by employees designated and trained as OU IRIS Report Submitters.

(b) Streamlined and Initial Reports should not be submitted by employees directly involved in the event.

(3) Streamlined Report Content
Streamlined Reports shall include the following information:

(a) General Information:

i. Name, OU, Division, and Group of the individual submitting the report;

ii. Type of event (*e.g.*, Injury, Near Miss, Property Damage, *etc.*);

iii. Date and time of event, if known;

iv. Location of the event and type of space (*e.g.*, laboratory, office, hallway); and

v. When OU line management was first notified of the event;

(a) Individuals Involved - For each person involved in an event, the following information shall be included:

i. Name;

ii. Position;

iii. Employment Status:

(i) Employee;

(ii) Associate; or

(iii) Visitor;

iv. Status of the individual as a result of the event:

(i) Injured;

(ii) Became Ill;

(iii) Exposed; or

(iv) Combination of i-iii above; or

(v) None of the above;

v. If injured, ill, or exposed:

(i) A description of the injury, illness, or exposure;

(ii) A description of the immediate care given;

(iii) If the individual will miss any days of work, if known; and

(iv) If the individual will be restricted or transferred to another job because of the event, if known.

(c) Event Description

i. A brief description of the activity leading up to or taking place at the time of the event;

ii. A description of what happened, or for a near miss, what could have happened;

iii. A description of any immediate measures taken to respond to the event, including any actions taken to prevent workers from exposure to hazards;

iv. A description of why the event occurred, including identification of any hazard(s) that directly caused or almost caused the event;

v. A description of the measures taken to prevent recurrence, including the abatement actions taken or planned to address any hazard(s) identified in Step iv above;

(i) For abatement actions that will take 30 calendar days or longer to implement, an abatement plan must be uploaded, including the planned completion date and the name of the individual(s) responsible for implementing the plan.

(d) Property Damage

i. A brief description of any damage to government property, other than motorized vehicles;

ii. A brief description of any damage to personal property, other than motorized vehicles; and

iii. A brief description of any damage to motorized vehicles.

(4) Initial Report Content for Standard Format shall include the following information:

(a) General Information:

i. Name, OU, Division, and Group of the individual submitting the report;

ii. Type of event (*e.g.*, Injury, Near Miss, Property Damage, etc.);

iii. Date and time of event, if known;

(i) For cases involving OSHA Recordable Standard Threshold Shift (STS) hearing losses, the date the STS is confirmed by letter shall be entered.

iv. Location of the event and type of space (*e.g.*, hallway);

v. When OU line management was first notified of the event;

vi. The OU responsible for the space where the event occurred;

vii. The OU responsible for any equipment involved in the event, if applicable; and

viii. The OU responsible for leading the investigation, based on the guidelines contained in Section 6(e)(1).

(i) If an OU other than the OU submitting the Initial Report is designated to lead the investigation, the name of the individual in Line Management from the designated OU who accepted responsibility for the investigation must be documented.

(b) Individuals Involved - For each person involved in an event, the following information shall be included:

i. Name;

ii. Position;

iii. Employment Status:

(i) Employee;

(ii) Associate; or

(iii) Visitor;

iv. Status of the individual as a result of the event:

(i) Injured;

(ii) Became Ill;

(iii) Exposed;

(iv) Contaminated by radioactive material;

(v) Combination of i-iv above; or

(vi) None of the above;

v. If injured, ill, or exposed:

(i) A description of the injury, illness, or exposure;

(ii) A description of the immediate care given;

(iii) If the individual will miss any days of work, if known; and

(iv) If the individual will be restricted or transferred to another job because of the event, if known.

(c) Event Description

i. A brief description of the activity leading up to or taking place at the time of the event;

ii. A description of what happened, or for a near miss, what could have happened;

iii. A description of any immediate measures taken to respond to the event, including any actions taken to protect workers from exposure to hazards;

(d) Property Damage

i. A brief description of any damage to government property, other than motorized vehicles;

ii. A brief description of any damage to personal property, other than motorized vehicles; and

iii. A brief description of any damage to motorized vehicles;

(5) OU Review of Streamlined and Initial Reports

(a) Prior to submittal to IRIS, the OU IRIS Administrator shall review the Streamlined and Initial Reports submitted from within their OU for:

i. Appropriate selection of format;

ii. Appropriate selection of event type;

iii. Completeness of report; and

iv. Quality of report.

(b) If the Submitter of an Initial Report has designated a different OU to lead the investigation, that designated OU shall have the opportunity to review and comment on the Initial Report during the OU Review step.

(c) During the OU Review step, the OU IRIS Administrator shall designate one of the following two notification options for how the report will be communicated:

i. Post Only

(i) Streamlined Reports, Initial Reports and Investigation Reports designated as "Post Only" shall be posted to ***IRIS*** where they will be viewable by the NIST staff.

(ii) An email containing a summary of the Streamlined Report, Initial Report, or Investigation Report shall be sent only to the OU IRIS Report Submitter, the OU IRIS Administrator, all investigators (for an Investigation Report), and the IRI PM.

ii. Post with Notification

(i) Streamlined Reports, Initial Reports, and Investigation Reports designated as "Post with Notification" shall be posted to ***IRIS*** where they will be viewable by the NIST staff.

(ii) An email containing a summary of the Streamlined Report, Initial Report, or Investigation Report shall be sent to the OU IRIS Report Submitter, the OU IRIS Administrator, all investigators (for an Investigation Report), the IRI PM, and notification subscribers as per their subscription service preferences.

e. Conduct and Documentation of Incident Investigations
For each event utilizing the Standard Report Format, an investigation shall be conducted and an Investigation Report submitted, per the following requirements.

(1) OU Responsibility for Leading Investigations

(a) For Immediate Notification Incidents, OSHE, with participation from the OU(s) involved, shall lead the investigation.

(b) For events that involve individuals and space from only one OU, that OU shall lead the investigation. Please note Section 6e(1)(e) for additional clarification.

(c) For events involving multiple individuals and/or space(s) and/or equipment from different OUs, the OU IRIS Administrators from all OUs involved shall identify the OU that will lead the investigation, with appropriate participation from the other OU(s). The OU leading the investigation shall provide the Lead Investigator.

i. If an agreement cannot be reached, the IRI PM shall designate the OU responsible for leading the investigation. Please note Section 6e(1)(e) for additional clarification.

ii. If multiple OUs are involved in the investigation, each OU shall have the opportunity to review and comment on the Investigation Report prior to its submission by the lead OU.

(d) For events where no individuals are involved (*e.g.*, flooding that occurred in a laboratory after hours or collapse of a bookshelf in an office when no one was present in the room), the OU responsible for the space in which the incident or near miss occurred shall lead the investigation. Please note Section 6e(1)(e) for additional clarification.

(e) If at any time it is determined that another OU is responsible for the activity in which the event occurred, or for the apparent cause of the event, or will be assigned a corrective action, that OU will participate in or lead the investigation, or, if the investigation is already underway, participate for the remainder of the investigation, as necessary and appropriate.

(2) Investigator Requirements

(a) Investigations shall be led and documented in IRIS by an OU Lead Investigator designated by the OU leading the investigation, and trained per the requirements of Section 6g.

(b) An individual should not serve as an OU Lead Investigator for an event where there is a conflict of interest (e.g. for an event that directly involved them or for an event involving their direct supervisor.).

(3) OSHE Participation in Investigations

(a) Based on the nature of an incident or near miss, OSHE may require the inclusion of OSHE subject matter experts on the investigation team. This requirement will apply, at a minimum, to incidents related to the following NIST Safety Programs:

i. Biosafety;

ii. Electrical Safety;

iii. Ergonomics;

iv. Fire and Life Safety suborders;

v. Hazardous Waste Accumulation;

vi. Hearing Protection;

vii. Ionizing Radiation Safety;

viii. Laser Safety; and

ix. Other programs on a case-by-case basis.

(b) OSHE shall aid in conducting investigations upon request.

(4) Investigation Reports shall include the following information:

(a) Name and OU of the Lead Investigator;

(b) Name and OU of other members of the investigation team;

(c) A brief description of the investigative process;

(d) The essential findings of the investigation and supporting information, including;

i. A general (narrative) description of what happened and why;

ii. Any updates to information provided in the Initial Report;

iii. Pictures, sketches, videos, etc. (as needed);

iv. The causal factor(s); and

v. The root cause(s).

(e) At least one corrective action per root cause, including:

i. A description of each specific corrective action, including interim steps as needed;

ii. Identification of persons responsible for implementation of corrective actions;

iii. Identification of the expected time to complete corrective actions;

(i) For corrective actions expected to require more than 30 calendar days to complete, a corrective action plan must be uploaded and approval from line management documented;

iv. Identification of individuals in line management responsible for verifying that corrective actions are complete; and

(f) Any lessons identified, as defined in Section 7, for sharing with the broader NIST community, including recommendations for follow-up by OSHE.

(5) OU Review of Investigation Reports

(a) Prior to submittal to IRIS for posting, the responsible OU IRIS Administrator shall review Investigation Reports for completeness and quality.

(b) Each OU represented on the investigation team shall have the opportunity to review and comment on the Investigation Report during the OU Review step.

(c) The OU IRIS Administrator shall designate a notification method for the Investigation Report per Section 6d(5)(c).

f. OU Implementation Procedures

Each OU shall establish implementation procedures and responsibilities for carrying out the requirements of this suborder including, but not limited to, the following:

(1) Reporting of incidents and near misses to OU management by employees and covered associates, *e.g.*, whom they must contact and by what means;

(2) Evaluating and classifying reported events per Section 6b above;

(3) Reporting of Immediate Notification Incidents to the NIST CSO;

(4) Determining the recording format for the event (*i.e.*, Streamlined or Standard format), per Section 6b(4) and the notification method per Section 6d(5)(c);

(5) Designating staff members with the following roles:

  (a) OU IRIS Submitter(s);

  (b) Lead Investigator(s); and

  (c) OU IRIS Administrator(s).

(6) Training of OU staff members to meet the OU Implementation Procedures and the requirements of a Lead Investigator per Section 6g;

(7) Drafting and vetting of Streamlined Reports and Initial Reports;

(8) Drafting and vetting of Investigation Reports, including determination that corrective actions are appropriate to prevent recurrence of the incident or near miss while not inadvertently introducing other hazards;

(9) Ensuring corrective actions are:

  (a) Implemented in a timely fashion;

  (b) Implemented in such a manner as to prevent recurrence of the incident or near miss while not inadvertently introducing other hazards; and

  (c) Tracked to closure;

(10) Sharing lessons identified, as appropriate, within the OU and identifying lessons to OSHE that should be shared to a wider audience;

(11) Ensuring information required for regulatory documentation of injuries and illnesses (*e.g.*, OSHA 301 Forms for each OSHA Recordable injury or illness) is provided to OSHE within seven calendar days of it being requested by the IRI PM; and

(12) For each OSHA Recordable case resulting in days away from work, restricted work, and/or transfer to another job (**OSHA Recordable DART case**, as defined in Section 7), ensuring work duty status information (*e.g.*, full duty, restricted, unable to work) is maintained and provided to the IRI PM as requested.

g. Training and Information

(1) All training shall be conducted and recorded in accordance with the requirements of the NIST S 7101.23: Safety Education and Training.

(2) OU IRIS Report Submitters and OU IRIS Administrators shall complete training provided by OSHE on the use of the IRIS application.

(3) Lead investigators shall complete training regarding incident investigation principles and methods from either OSHE or equivalent training provided by an outside source approved by the OSHE IRI PM[5].

(4) OU staff shall be informed by the OU of those aspects of the OU Implementation Procedures (see Section 6f) applicable to their roles in incident reporting and investigation.

h. OSHE Management of IRI

(1) Processing of Streamlined and Initial Reports

(a) The IRI PM shall ensure that Streamlined and Initial Reports to be posted publicly to ***IRIS*** do not contain information that can be used to identify specific individuals or that can be used with other sources to identify such individuals;

(b) The IRI PM shall review submitted Streamlined and Initial Reports for appropriate selection of the reporting format selected (Streamlined or Standard) per Section 6b(4) and notification method selected per Section 6d(5)(c).

[5] OSHE shall maintain a list of currently approved equivalent incident investigation courses provided by outside sources.

(c) The IRI PM shall post Streamlined and Initial Reports to ***IRIS*** within 2 business days of submission, if possible.

(2) Processing of Investigation Reports

(a) The IRI PM shall ensure that Investigation Reports to be posted publicly to ***IRIS*** do not contain information that can be used to identify specific individuals or that can be used with other sources to identify such individuals;

(b) The IRI PM shall review submitted Investigation Reports for appropriate selection of notification method per Section 6d(5)(c).

(c) The IRI PM shall post Investigation Reports to ***IRIS*** within 2-3 business days of submission; if possible.

(3) IRI Notifications

(a) Notifications of Streamlined Reports, Initial Reports, and related Investigation Reports shall be communicated to the NIST staff using the ***IRIS*** application.

i. NIST employees in a supervisory role shall receive notifications when Streamlined Reports, Initial Reports, and Investigation Reports are posted.

ii. NIST staff shall be afforded the opportunity to receive email notifications when Streamlined Reports, Initial Reports, and Investigation Reports are posted, utilizing the ***IRIS*** application subscription service.

(b) For each NIST establishment identified in Section 6h(6)(b)(i) below, the CSO shall sign and post the OSHA Form 300A – *Summary of Work-related Injuries and Illnesses* ("annual summary") from the previous calendar year on the NIST Safety Web Page and in at least one conspicuous physical location at the establishment. The annual summary shall be posted from February 1 to April 30.

(c) The IRI PM shall provide a weekly summary of IRI Program activity to the NIST Director, Associate Directors, and OU Directors.

(d) The NIST CSO shall provide a monthly summary of IRI Program activity to the NIST Leadership Board.

(4) Monitoring and Measurement

(a) The IRI PM shall collect data and compile metrics necessary to evaluate the effectiveness of this program, including, but not limited to:

i. Number and types of events reported;

ii. Length of time for staff to report to line management;

iii. Time taken to submit Streamlined and Initial Reports into ***IRIS***;

iv. Percentage of Streamlined and Initial Reports submitted within 2 business days;

v. Time taken to submit Investigation Reports into IRIS;

vi. Percentage of Investigation Reports submitted within 20 business days;

vii. Backlog of investigations open longer than 20 business days; and

viii. Total number of OSHA Recordable cases and OSHA Recordable DART cases.

(5) IRI Compliance Evaluation

(a) The IRI PM shall conduct an internal compliance evaluation of the regulatory recordkeeping requirements outlined in Section 6h(6)(b) of this program on at least an annual basis. A standard checklist shall be developed and used.

(b) Results of internal compliance evaluations shall be documented and maintained as a record per Section 6h(6)(a).

(c) Corrective actions shall be implemented as soon as practical to address findings of non-compliance.

(6) IRI Recordkeeping

(a) NIST-Required Recordkeeping

i. Personal information that is collected in reports and investigations shall be maintained securely in the ***IRIS*** application.

ii. Personal information that is collected in reports and investigations shall be accessible to the IRI Program Manager, OSHE IRIS Administrator, OU IRIS Administrator(s), the OU Submitter, members of the Investigation Team, the relevant supervisor(s), and the employee(s) directly involved.

iii. For each injury and illness incident, the IRI PM shall classify the event using the U.S. Department of Labor Bureau of Labor Statistics (BLS) Occupational Injury and Illness Classification System. This will include classification of:

(i) Nature of Event or Exposure;

(ii) Nature of Injury or Illness;

(iii) Part of Body Affected; and

(iv) Source of Injury or Illness.

iv. The IRI PM shall retain training records as identified in Section 6g using the IT application supporting the NIST Safety Education and Training Program.

v. The IRI PM shall retain results of annual internal compliance evaluations as described in Section 6h(5).

(b) OSHA Required Recordkeeping

i. The IRI PM shall maintain a list of NIST establishments for which separate OSHA records will be maintained, pursuant to 29 CFR 1904.30.

ii. For injuries and illnesses resulting from an incident, the IRI PM shall document case details, including medical treatment, sufficient to make and record a determination of the OSHA status of each case as one of the following:

(i) OSHA Recordable;

(ii) OSHA Recordable DART; and

(iii) Not an OSHA Recordable.

iii. For each injury or illness determined to be an OSHA Recordable, the IRI PM shall send a request for a completed OSHA 301 Form – *Injury and Illness Incident Report* to the OU IRIS Administrator of the employee. Completed OSHA 301 Forms shall be retained by the IRI PM for each OSHA Recordable case.

iv. For each OSHA Recordable DART case, the IRI PM shall utilize the ***IRIS*** application to obtain (from the supervisor of the employee), update, and document DART information.

v. For the establishments identified in Section 6h(6)(b)(i), the IRI PM shall maintain the OSHA Form 300 – *Log of Work-Related Injuries and Illnesses*.

vi. For the establishments identified in Section 6h(6)(b)(i), the IRI PM shall maintain the OSHA Form 300A – *Summary of Work-related Injuries and Illnesses*.

vii. The IRI PM shall maintain a record of all information initially provided to OSHA for each Immediate Notification Incident, and all subsequent correspondence related to the incident.

viii. The IRI PM shall provide any information described in this section to external entities (*e.g.*, DOC, BLS) as requested.

(c) The retention period for the records identified in this section shall be not less than five years from the end of the calendar year that these records cover.

7. DEFINITIONS

a. Abatement – Action taken to eliminate a recognized safety hazard or deficiency.

b. Abatement Plan – A set of planned actions to abate a recognized hazard and their estimated completion dates.

c. Causal Factor – An action or condition, or lack thereof, related to equipment, people, management, or the environment that an event occurred in, that caused or contributed to the severity or likelihood of an event.

d. Condition – Any state, as found, whether or not it resulted from an event, that may have adverse safety, health, environmental, or operational implications.

e. Contamination by Radioactive Material – The unintended/unexpected presence of radioactive material on, or in, an individual.

f. Corrective Action – Action to eliminate the cause of a detected nonconformity or other undesirable situation.

g. Corrective Action Plan – A set of planned actions to eliminate the cause of a detected nonconformity or other undesirable situation such as the root cause of an incident.

h. Event – For the purposes of this suborder, a real-time occurrence.

i. Exposure – Contact by an individual through touching, breathing, or consuming a harmful chemical or biological substance; or unintended / unexpected dose to an individual from an ionizing radiation field. Any exposure that results in an injury or illness shall be classified as an injury or illness.

j. Hazard – Source, situation, or act with a potential for harm in terms of human injury or ill health, adverse impact on the environment, damage or loss of equipment or property, or a combination of these.

k. Illness – Any abnormal condition or disorder, other than one resulting from a work-related injury, caused by one-time, continued, or repeated exposure to environmental factors associated with employment, including acute and chronic illnesses or diseases that may be caused by inhalation, absorption, ingestion, or direct contact. OSHA Recordable STS hearing loss cases are included in this definition.

l. Immediate Notification Incident – A work-related incident that results in any of the following to one or more employees or covered associates (reference 29 CFR 1904.39):

(1) Death, within 30 (thirty) calendar days of the incident;

(2) In-patient hospitalization within 24 hours of the incident; or

(3) An amputation or loss of an eye within 24 hours of the incident.

m. Incident – A work-related event in which any of the following, individually or in combination, occurred: an injury or illness; an unauthorized spill or release of hazardous or regulated material to the environment; property damage; exposure; or contamination by radioactive material.

n. Initial Report – A report that contains the items listed in Section 6d(4).

o. Injury – Any wound or condition of the body caused by external force, including physical stress or strain that results from a work accident or from exposure in the work environment, *e.g*., amputation, bruise, burn, contusion, cut, fracture. The injury is identifiable as to time and place of occurrence and member or function of body affected, and is caused by a specific event or incident, or series of events or incidents, within a single day or work shift.

p. Investigation – The systematic process of analyzing the events leading up to an event, gaining an understanding of what caused it, identifying actions to prevent recurrence, and documenting the results in a written Investigation Report.

q. Investigation Report – A report that contains the items listed in Section 6e(4).

r. Lessons Identified – Information (such as Extent of Condition Reviews) resulting from an investigation that, if acted upon by an organization and the individuals therein, will reduce the probability of recurrence of that and similar events.

s. Near Miss – Also known as a "near hit," "near-accident," or "close call," a work-related event that did not result in any of the following, either individually or in combination, but had a plausible likelihood of doing so: an injury or illness; a spill or release of hazardous or regulated material to the environment; property damage; exposure; or contamination by radioactive material.

t. OSHA Recordable case – Any injury or illness that meets the general recording criteria established by OSHA at 29 CFR 1904.7. In general, this includes any work-related injury or illness that results in death, days away from work, restricted work or transfer to another job, medical treatment beyond first aid, or loss of consciousness. Work-related cases involving cancer, chronic irreversible disease, a fractured or cracked bone, or a punctured eardrum are always OSHA Recordable.

u. OSHA Recordable DART case – Any OSHA Recordable case that results in death, days away from work, restricted work or transfer to another job, as established by OSHA at 29 CFR 1904.7.

v. OU Responsible for the Space – OU to which the space has been assigned by the Office of Facilities and Property Management.

w. Property Damage – Incident resulting in loss or harm to property.

x. Root Cause – A causal factor of an event that, if corrected, would prevent the recurrence of that and similar events.

y. Spill / Release – An unauthorized spill or release of hazardous or regulated material to the environment.

z. Streamlined Format – Format used for relatively simple and generally minor events that can be resolved without significant corrective actions. (*Abatement actions* may be necessary.) These cases will be documented in a single Streamlined Report containing information on what happened, why it occurred, and how it can be prevented from happening again. A separate Investigation Report is not required.

aa. Streamlined Report - A report containing the items listed in Section 6d(3).

bb. Standard Format – Format used to document more significant and/or more complex events that require a higher level of investigation and significant corrective actions. This can include near misses. These cases will be documented in an Initial Report, followed by an Investigation Report that establishes the root cause(s) of the incident or near miss, and the corrective actions.

cc. Work-Related – A condition wherein an injury, illness, or fatality was caused, contributed to, or significantly aggravated, or could have been, by an event or exposure at work or on official business away from work (reference 29 CFR 1904.5).

8. ACRONYMS

a. BLS – United States Bureau of Labor Statistics

b. CFR – Code of Federal Regulations

c. DART – Days away from work, restricted work, or transfer to another job

d. DOC – Department of Commerce

e. EOC – Extent of Condition

f. IRI PM – Incident Reporting and Investigation Program Manager

g. IRIS – Incident Reporting and Investigation System

h. OSH – Occupational Safety and Health

i. OSHA – Occupational Safety and Health Administration

j. OU – Organizational Unit

k. STS – Standard Threshold Shift

9. RESPONSIBILITIES

a. OU Directors are responsible for:

(1) Ensuring the establishment of OU procedures, the implementation of which will result in the requirements of Section 6 applicable to the OU being met

(2) Ensuring the OU procedures are implemented;

(3) Ensuring the quality and timeliness of Streamlined, Initial, and Investigation Reports;

(4) Ensuring that applicable lessons identified are shared within their OU, as appropriate; and

(5) Ensuring that all-required follow-up actions are completed and effective.

b. OU IRIS Administrators are responsible for:

(1) Coordinating efforts with other OUs when multiple OUs are involved in an incident through personnel, space, or equipment, to ensure that the reporting and investigation requirements of this program are met;

(2) Reviewing incident reports and incident investigations for completeness, quality, accuracy, and appropriateness of the selected format (Streamlined or Standard);

(3) Designating the notification method that will be used for each incident; and

(4) Designating OU Submitters and OU Lead Investigators for their respective OUs.

c. Lead Investigators are responsible for organizing, conducting and documenting incident investigations, including EOC reviews as assigned, to effectively identify causal factors and root cause(s) of incidents and near misses, and appropriate corrective actions necessary to prevent recurrence.

d. Supervisors are responsible for:

(1) Reporting all incidents as soon as practically possible to their management in accordance with OU policies and procedures;

(2) Ensuring that equipment and facilities involved in incidents are shut down if necessary and restored to use only after hazards have been mitigated;

(3) Preserving the scenes of incidents intact to the extent possible to facilitate incident investigations;

(4) Supporting incident investigations as prescribed by their OU-level policies;

(5) Reviewing IRIS incidents, evaluating and communicating lessons learned applicable to activities under their span of control, and taking appropriate actions to prevent similar incidents;

(6) Completing required documentation for OSHA Recordable injury and illness cases, including OSHA 301 Forms and other relevant information as requested by the OSHE IRI PM; and

(7) Providing the OSHE IRI PM with updated case information (*e.g.*, current duty status, days away, *etc.*) for employees that incur OSHA Recordable injuries.

e. NIST Employees and Covered Associates are responsible for:

(1) Reporting (or having someone else report) incidents and near misses immediately to their supervisor or sponsor; and

(2) Providing complete and accurate information in support of incident investigations and recordkeeping, as necessary and as prescribed by the OU-level policies.

f. IRI PM is responsible for:

a. Maintaining this suborder and providing guidance as requested by NIST personnel;

b. Reviewing IRIS cases and data to identify trends indicative of systemic issues, facilitating identification of tactics to address them.

c. Facilitating the communication of lessons learned across the NIST community.

d. Ensuring NIST-level training as required by this suborder is available;

e. Maintaining a list of incident investigation courses provided by external sources that meet the equivalent training requirement established at 6g(3); and

f. Carrying out duties as established within this suborder to maintain compliance with OSHA Injury and Illness Recordkeeping regulations.

10. AUTHORITIES

There are no authorities specific to this suborder alone.

11. DIRECTIVE OWNER

Chief Safety Officer

12. APPENDICES

None

Appendix A. Revision History

Revision No.	Approval Date	Responsible Person	Brief Description of Change; Rationale
0			• None – Initial document
1	07/26/17	07/26/17	• Revised order of document for clarity and flow. • Added regulatory injury and illness recordkeeping requirements. • Added incident types for radiation events • Incorporated changes designed to differentiate near miss events from incidents. • Added a streamlined process for less complex events. • Added options for how notifications for events are made, based on relevance of events to NIST staff. • Added ownership of equipment involved in an event as a criterion for determining OU responsibility. • Added process for review of reports at the OU level prior to submittal to OSHE for posting. • Added requirements for abating direct hazards. • Added requirements for IRIS Submitters and Lead Investigators to be designated and trained. • Updated and clarified the process for submitting Immediate Notification Incidents. • Added requirement for OSHE to conduct an annual compliance evaluation.
2	1/4/2021	[redacted]	• Updated links to suborders.

Appendix 6.12.2: Relevant Incident Investigation Reports Posted Prior to the Incident

Incident Reporting & Investigation System

View Incident Report

INCIDENT TITLE:	Employee Injures Back Installing Drywall
CASE NUMBER:	17-IG-0049
EVENT TYPE:	Injury
REPORTING ORGANIZATIONAL UNIT:	(73) Engineering Laboratory
LOCATION:	Gaithersburg
DATE/TIME OF INCIDENT	1/25/2017 11:30 AM

DESCRIPTION OF INCIDENT:

Briefly describe the activity leading up to and / or taking place at the time of the incident? (Do not include measures taken after the incident.)

Employee installing gypsum drywall panel in test enclosure.

Briefly describe the outcome or result of the incident (e.g what happened – slip and fall, description of the injury) and basic information about what caused it.

Employee experienced pain in back.

Briefly describe the immediate actions taken to respond to the incident – e.g. how the scene was secured, employee was taken to the Health Unit, etc.

Notified management and reported to health unit.

BASIC DESCRIPTION OF INVESTIGATIVE PROCESS:

SUMMARY OF THE INVESTIGATION FINDINGS:

ATTACHED INVESTIGATION REPORT, PICTURES, SKETCHES OR OTHER RELATED FILE(S): IRIS Incident Investigation Report-BackInjuryDrywall - Final.docx

CORRECTIVE ACTION

Causes

CAUSAL FACTOR: EMPLOYEE WAS LIFTING MODERATELY HEAVY SECTIONS OF DRYWALL (< 40 LBS.). HE WAS ON AN EXTENSION LADDER IN AN AWKWARD TWISTING POSITION AS IT WAS HANDED TO HIM BY ANOTHER INDIVIDUAL. EMPLOYEE MAY HAVE HAD PRE-EXISTING, UNREPORTED BACK PAIN ISSUES. PREVIOUS WORK ACTIVITIES MAY HAVE CONTRIBUTED TO THE INJURY. READ LESS

CATS #	Estimated Due Date	Assigned To	Status
CATS-17-IG-0049-002	06/01/2017		Archived
CATS-17-IG-0049-001	03/06/2017		Archived

ROOT CAUSE: AVAILABLE MECHANICAL EQUIPMENT OR ADDITIONAL STAFF TO LIFT SHEETROCK PANELING INTO PLACE WERE NOT USED SINCE NO ISSUES OR DIFFICULTIES WERE ENCOUNTERED IN PREVIOUS SHEETROCK INSTALLATION ACTIVITIES.

CATS #	Estimated Due Date	Assigned To	Status
CATS-17-IG-0049-003	02/13/2017		Archived

LESSONS IDENTIFIED

Lessons Identified
1) Encourage staff to report physical issues to supervisor, project leader or NIST Health Unit. 2) Do not assume that employees will volunteer pre-existing medical conditions, either acute or chronic, that may impair their performance.

Action Tracking System

View a Corrective Action

Corrective Action Number: CATS-17-IG-0049-001

Corrective Action: Hold an NFRL staff and project team meeting to remind staff to consider use of mechanical methods when positioning building materials whenever possible. Remind staff to coordinate hando of materials to reduce potential bending or twisting that could lead to a muscle strain injury.

Assigned To:

Individual Responsible for Closing Out the Corrective Action:

Estimated Completion Date: 03/06/2017

Status: Archived

Created By:

Action Tracking System

View a Corrective Action

Corrective Action Number:	CATS-17-IG-0049-002
Corrective Action:	Hold a quarterly division technician meeting to remind staff that any staff involved in work activities that require physical exertion notify group and project leaders of any existing physical limitations that could increase risk of injury.
Assigned To:	
Individual Responsible for Closing Out the Corrective Action:	
Estimated Completion Date:	06/01/2017
Status:	Archived
Created By:	

Action Tracking System

View a Corrective Action

Corrective Action Number:	CATS-17-IG-0049-003
Corrective Action:	1) During planning phase, identify possible physical activities and consider mechanical equipment or additional labor resources that might be needed to avoid or reduce physical exertion. 2) During test-day safety briefings, encourage staff to discuss in private any acute or chronic conditions with the supervisor, project leader or the NIST Health Unit.
Assigned To:	
Individual Responsible for Closing Out the Corrective Action:	
Estimated Completion Date:	02/13/2017
Status:	Archived
Created By:	

IRIS Incident Investigation Report

IRIS Case Number: 17-IG-0049

1. <u>**Information about Investigators**</u>
   a. **Investigator's name and organizational unit.**
   b. **If more than one investigator, please indicate who was the lead investigator.**

2. <u>**Information pertaining to the Incident Report submitted**</u>

   a. **Does the data in the Incident Report need to be updated?** No, the Incident Report was correct, the initial report and additional details are included to provide clarification of the investigation findings.
   Activity leading up to and/or taking place at time of the incident: On Wednesday Jan 25th 2017 at 11:30 AM, the employee was installing pieces of drywall on the outside of a project test structure at the National Fire Research Lab (NFRL). The employee handled about 6 pieces of drywall that day all less than 4ft in length and weighing less than 40 lbs. The employ was on an extension ladder while a piece of drywall was handed to him by another employee standing on the ground. The employee on the ladder was reaching out and twisting as he received the material and sustained an injury

Immediate impact of the incident: As soon as the employee lifted the material into place he felt a sharp pain in his back. He stopped performing the activity and continued performing light duty work. He was still experiencing pain later in the day and went to the NIST health unit as advised by a supervisor. The employee visited his personal physician the next day. He returned to work Monday Jan 30th 2017 and was placed on light duty assignment until Feb 6th 2017 per doctor's order.

3. <u>**Information pertaining to the Causal Factor(s) associated with the Incident**</u>

   a. Describe the causal factor.
      1) Employee was lifting moderately heavy sections of drywall (< 40 lbs.). He was on an extension ladder in an awkward twisting position as it was handed to him by another individual. Employee may have had pre-existing, unreported back pain issues. Previous work activities may have contributed to the injury.

b. Describe the corrective action(s) associated with this causal factor and add the following information.

1) Hold an NFRL staff and project team meeting to remind staff to consider use of mechanical methods when positioning building materials whenever possible. Remind staff to coordinate handoff of materials to reduce potential bending or twisting that could lead to a muscle strain injury.
   i. Name of the individual responsible for completing the corrective action.
   ii. The date the corrective action should be completed. 3/6/2017
   iii. Name and organizational unit of individual responsible for verifying that the corrective action is completed.
   iv. Was an interim measure(s) required? Yes. A safety briefing was conducted with the immediate project team on 1/26/2017 before the activity was resumed. The team had an open dialog about safe practices for material handling. They were also reminded to be careful and avoid injuries related to over-exertion.

2) Hold a quarterly division technician meeting to remind staff that any staff involved in work activities that require physical exertion notify group and project leaders of any existing physical limitations that could increase risk of injury.
   v. Name of the individual responsible for completing the corrective action.
   vi. The date the corrective action should be completed. 6/1/2017
   vii. Name and organizational unit of individual responsible for verifying that the corrective action is completed.
   viii. Was an interim measure(s) required? No.

4. Information pertaining to the Root Cause(s) associated with the Incident

1. Available mechanical equipment or additional staff to lift sheetrock paneling into place were not used since no issues or difficulties were encountered in previous sheetrock installation activities.
   a. Describe the corrective action(s) associated with this root cause and add the following information.

1) During planning phase, identify possible physical activities and consider mechanical equipment or additional labor resources that might be needed to avoid or reduce physical exertion.
   Individual responsible:
   Date to be completed: 2/13/2017
   Verifying individual:

2) During test-day safety briefings, encourage staff to discuss in private any acute or chronic conditions with the supervisor, project leader or the NIST Health Unit.
   Individual responsible:
   Date to be completed: 2/13/2017
   Verifying individual:

5. <u>Information pertaining to Lesson Identified</u>

a. Indicate all lessons identified to be shared with the NIST community.
   1) Encourage staff to report physical issues to supervisor, project leader or NIST Health Unit.
   2) Do not assume that employees will volunteer pre-existing medical conditions, either acute or chronic, that may impair their performance.

Incident Reporting & Investigation System

View Incident Report

INCIDENT TITLE:	Overhead Crane Collision Results in Property Damage
CASE NUMBER:	17-IG-0110
EVENT TYPE:	Property Damage
REPORTING ORGANIZATIONAL UNIT:	(73) Engineering Laboratory
LOCATION:	Gaithersburg
DATE/TIME OF INCIDENT	8/14/2017 02:30 PM

DESCRIPTION OF INCIDENT:

Briefly describe the activity leading up to and / or taking place at the time of the incident? (Do not include measures taken after the incident.)

Technician was relocating one steel column with overhead crane, when the crane collided with another crane that was stationary but carrying a concrete specimen . The collision caused the suspended concrete specimen to sway into a another steel column. The column tipped over onto another concrete test specimen.

Briefly describe the outcome or result of the incident (e.g what happened – description of property damage, description of chemical spill, etc.) and basic information about what caused it.

The concrete test specimen sustained some damage.

Briefly describe the immediate actions taken to respond to the incident – e.g. how the scene was secured, OSHE Spill Team was called and cleaned up the spill; damaged equipment was locked out of service, etc.

Steel column was uprighted. Steel column was bolted to the floor.

BASIC DESCRIPTION OF INVESTIGATIVE PROCESS:

SUMMARY OF THE INVESTIGATION FINDINGS:

ATTACHED INVESTIGATION REPORT, PICTURES, SKETCHES OR OTHER RELATED FILE(S): IncidentSummary-CraneCollision.docx

CORRECTIVE ACTION

Causes

CAUSAL FACTOR: LARGE STRUCTURAL MEMBERS WERE TEMPORARILY UNANCHORED/UNSECURED. (THE WEST COLUMN WAS NOT ANCHORED TO THE FLOOR AND THE CONCRETE FLOOR SPAN WAS LEFT SUSPENDED ON THE OVERHEAD CRANE). ONE OF THE STRUCTURAL COLUMNS WAS KNOCKED OVER BY THE SUSPENDED FLOOR SPAN WHEN TWO OVERHEAD CRANES BUMPED INTO EACH OTHER. READ LESS

CATS #	Estimated Due Date	Assigned To	Status
CATS-17-IG-0110-001	08/30/2017		Archived
CATS-17-IG-0110-002	08/31/2017		Archived

CAUSAL FACTOR: COLLISION OF THE OVERHEAD CRANES.

CATS #	Estimated Due Date	Assigned To	Status
CATS-17-IG-0110-003	12/20/2017		Archived

ROOT CAUSE: **THE CRANE OPERATOR MODIFIED THE ORIGINAL LIFT PLAN AND EXECUTED THE PLAN WITHOUT EVALUATING THE CHANGES. THE MODIFIED PLAN LEFT THE SECOND OVERHEAD CRANE IN THE PATH OF THE MOVING CRANE, RESULTING IN A COLLISION OF THE OVERHEAD CRANES.** READ LESS

CATS #	Estimated Due Date	Assigned To	Status
CATS-17-IG-0110-004	08/30/2017		Archived
CATS-17-IG-0110-005	08/30/2017		Archived

LESSONS IDENTIFIED

Lessons Identified
i. Plan complex crane operations, and review and discuss the plans with others before execution. ii. Anchor/secure all large and massive items that have the potential to sway or topple on impact. iii. Install and utilize collision avoidance systems whenever multiple overhead cranes share the same track. iv. Establish a no-entry zone around ... Read More

Action Tracking System

View a Corrective Action

Corrective Action Number:	CATS-17-IG-0110-001
Corrective Action:	Revise the overhead crane standard operating procedures (SOP) with instructions to keep all structural members anchored/secured while not in translation.
Assigned To:	
Individual Responsible for Closing Out the Corrective Action:	
Estimated Completion Date:	08/30/2017
Status:	Archived
Created By:	

Action Tracking System

View a Corrective Action

Corrective Action Number:	CATS-17-IG-0110-002
Corrective Action:	Reposition structural members that are stored in the laboratory away from the path of the overhead crane operations and anchor/secure them to reduce the potential for toppling.
Assigned To:	
Individual Responsible for Closing Out the Corrective Action:	
Estimated Completion Date:	08/31/2017
Status:	Archived
Created By:	

Action Tracking System

View a Corrective Action

Corrective Action Number:	CATS-17-IG-0110-003
Corrective Action:	Install a collision avoidance system on the cranes to provide an audible warning to the operator.
Assigned To:	
Individual Responsible for Closing Out the Corrective Action:	
Estimated Completion Date:	12/20/2017
Status:	Archived
Created By:	

Action Tracking System

View a Corrective Action

Corrective Action Number:	CATS-17-IG-0110-005
Corrective Action:	Revise the overhead crane SOP with instructions to require the operator to determine if the lift is routine, complex or critical; develop an appropriate lift plan; communicate the lift plan to the spotter(s); and evaluate the lift plan in cooperation with the spotter(s) before execution.
Assigned To:	
Individual Responsible for Closing Out the Corrective Action:	
Estimated Completion Date:	08/30/2017
Status:	Archived
Created By:	

Action Tracking System

View a Corrective Action

Corrective Action Number:	CATS-17-IG-0110-004
Corrective Action:	Revise the overhead crane SOP with the instructions to require an operator and spotter(s) (use multiple spotters when necessary) for complex lifts.
Assigned To:	
Individual Responsible for Closing Out the Corrective Action:	
Estimated Completion Date:	08/30/2017
Status:	Archived
Created By:	

Incident Summary – Crane Collision

Background

Five test specimens of concrete floor sections, referred to here as lightweight aggregate composite beams (LWACB), are arranged on the strong floor of building 205 (Fig. 1). Each LWACB is 6' x 42' and is supported by two 24' tall columns, each with an I-beam cross section of 1' x 1'. The columns are anchored to the floor using high strength rods and the LWACB is bolted to the columns. The specimens are arranged to allow for installation of sensors and fireproofing while allowing for the assembly of the test set up. The south specimen and supporting columns were being prepared for relocation to the test set up. The plan was to lower the LWACB to the floor, support the LWACB with wood cribbing, and relocate the columns to the appropriate position in the test set up. This lift is unique in that the LWACB wraps partially around the columns requiring the use of two cranes. One crane is used to support the LWACB while another crane is used to remove a column. Once one column is removed the LWACB can be moved away from the other column.

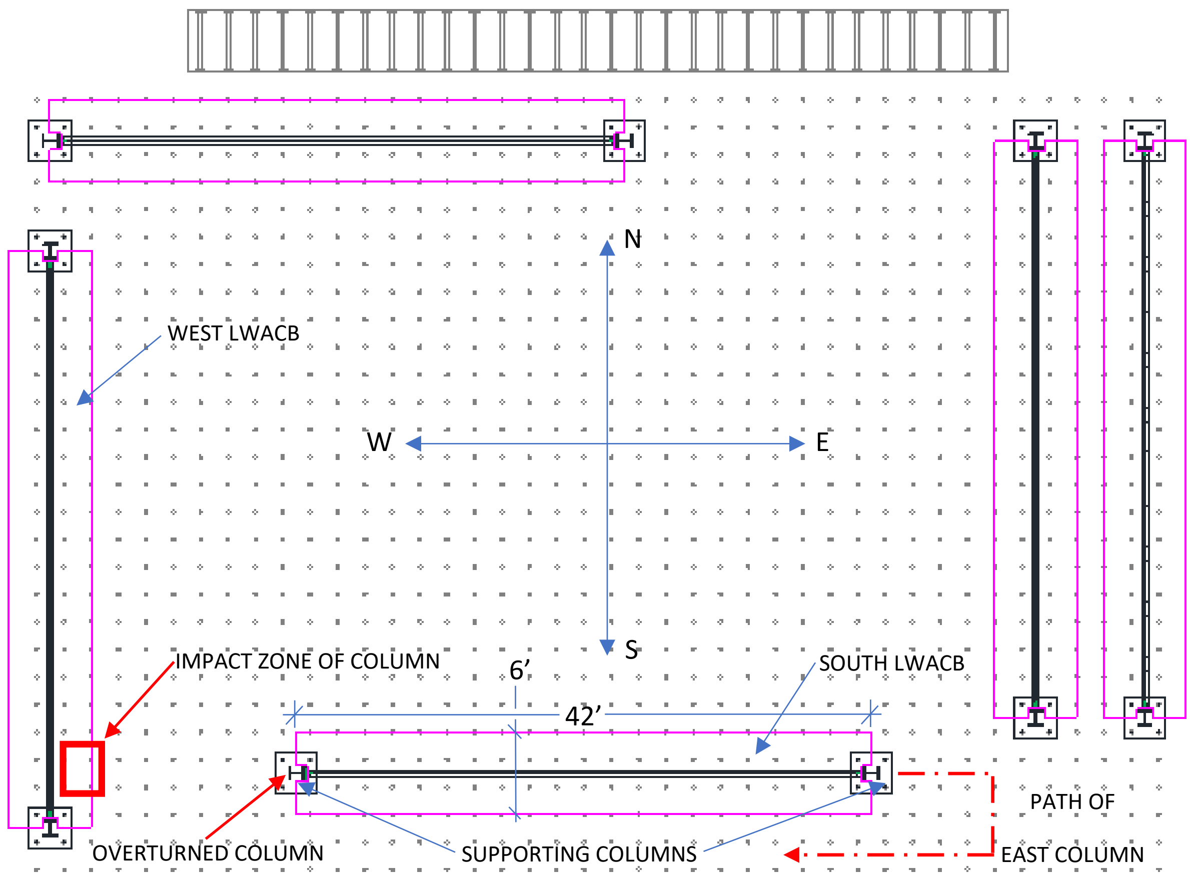


Figure 1 – Plan View - Arrangement of LWACB Test Specimens

Incident

The west crane was used to support the south LWACB (Fig. 2). The anchor rods and bolts were removed leaving both of the columns free-standing.

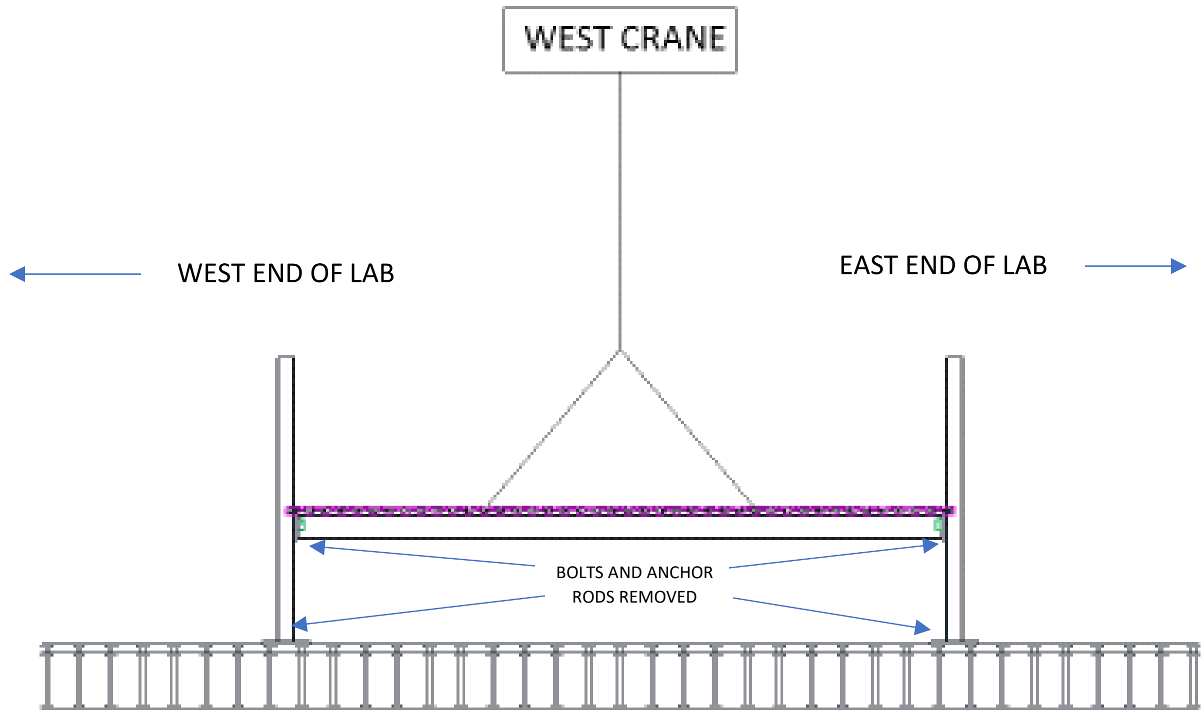


Figure 2 - Elevation View of South LWACB Connected to West Crane

While the west crane remained stationary the east crane was brought over to remove the east column (Fig. 3.)

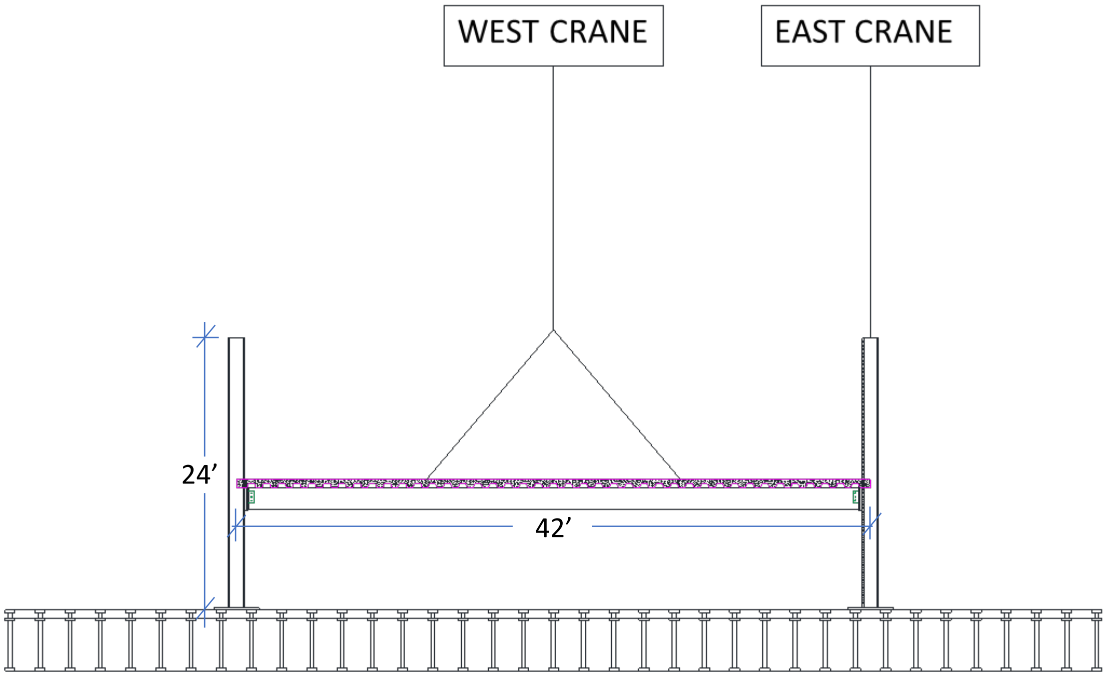


Figure 3 - Elevation View of East Column Connected to East Crane

While moving the east column in the west direction the east crane collided with the west crane causing the LWACB to begin to sway (Fig. 4).

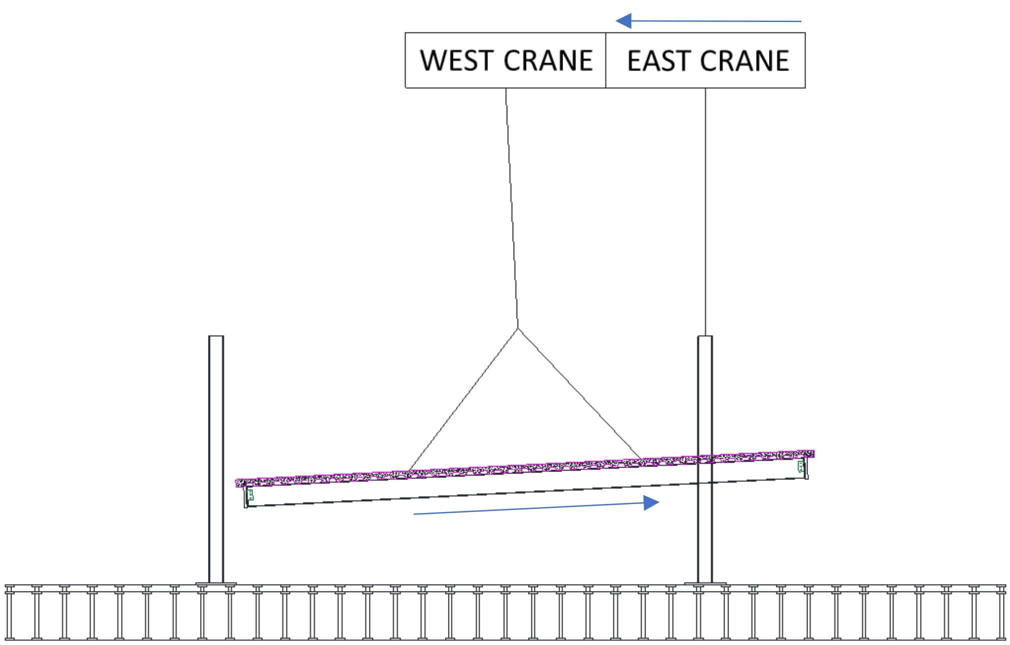


Figure 4 - Elevation View of Crane Impact and LWACB Sway

The LWACB collided with the west column causing it to overturn onto the west LWACB (Fig. 5).

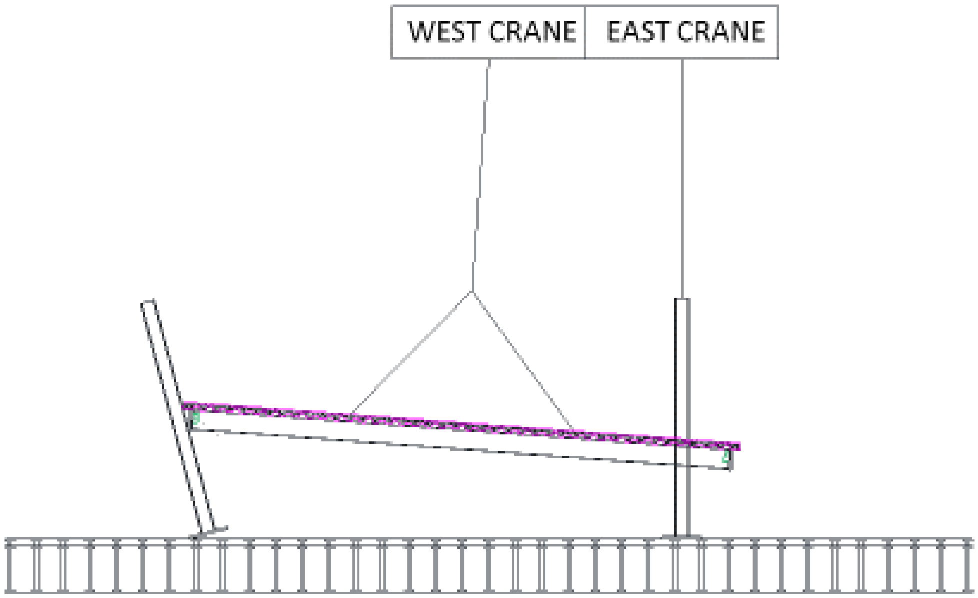
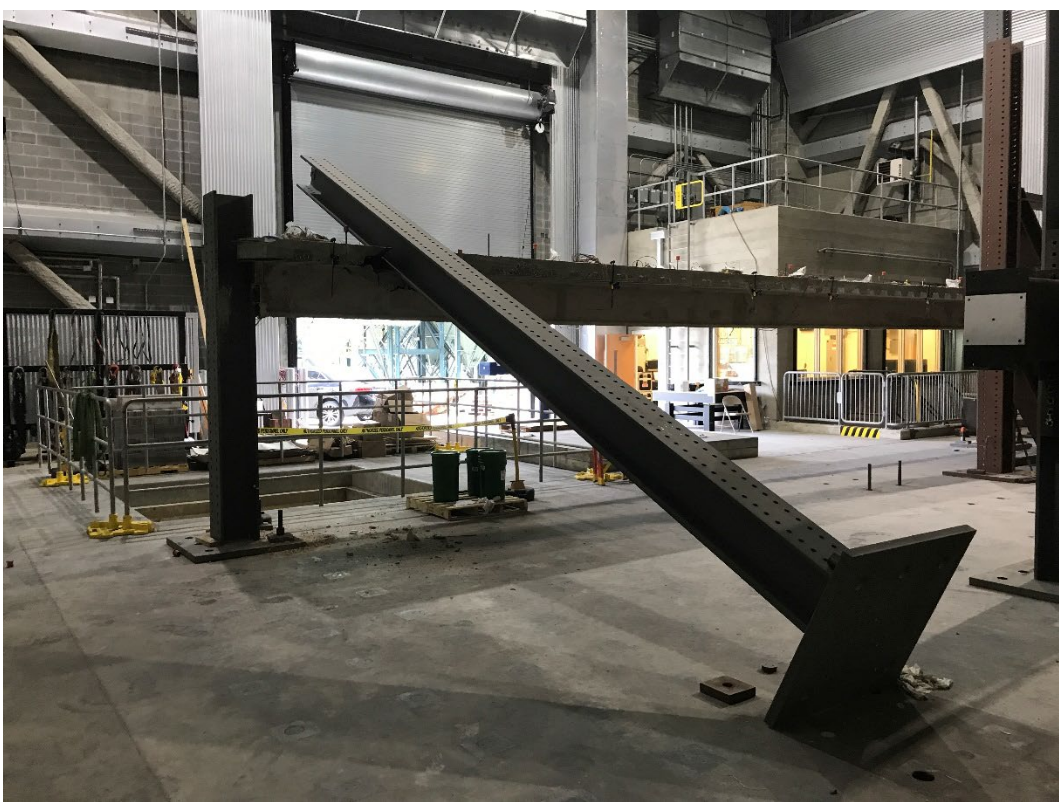


Figure 5 - Elevation View of LWACB Impacting West Column

The impact of the column and the west LWACB caused damage to the west LWACB concrete deck (see images below).



The crane operator was the only person in the area where the incident occurred. The crane operator was located near the southeast corner of the south LWACB.

Post Incident

The east column was lowered immediately upon crane impact. The east column was disconnected from the east crane and the east crane was relocated to the far east end of the lab. The south LWACB was lowered, supported by wood cribbing, and disconnected from the west crane. The west crane was used to return the overturned column to the upright position. Loose concrete was removed to prevent injury to investigators or lab personnel. The principal investigator, WSM, and acting group leader were notified of the incident immediately after securing the lab. Crane operation was suspended.

Proposed Corrective Actions

1) Revise the overhead crane standard operating procedures to include the following:
    a. Use a spotter(s) to assist the crane operator during complex lifts and moves; use additional spotters when necessary. Use clear and recognizable hand signals. Ensure audible communications when visibility is reduced due to obstacles.
    b. Determine if the lift is routine, complex or critical; develop an appropriate lift plan; communicate the lift plan to the spotter(s); and evaluate the lift plan in cooperation with the spotter(s) before execution.
    c. Inform everyone in the area that crane operations will occur.
    d. Establish a no-entry zone around all crane operations. Only the crane operator and spotters are allowed inside this zone. Evacuate personnel from the open pit areas in the basement if these areas are within the no-entry zone. The no-entry zone should encompass the lift path and establish a perimeter greater than the maximum dimension of the load and other items involved in the lift. The no-entry zone will be determined during the lifting plan and will be enforced by the operator and spotters.
    e. Keep all structural members anchored/secured while not in translation.

2) Anchor or secure structural members that are stored in the laboratory to reduce the potential for toppling.
    a. Develop a strategy on where to store structural members to reduce the number of obstacles for crane operations and how to anchor or secure them.

3) Install a collision avoidance system on the overhead cranes to provide an audible warning to the operator and prevent collision.
    a. Research collision avoidance systems
    b. List minimum requirements
    c. Submit work order to NIST Plant Division to purchase and install

Lesson Learned

1) Plan complex crane operations, and review and discuss the plans with others before execution.
2) Anchor/secure all large and massive items that have the potential to sway or topple on impact.
3) Install collision avoidance systems whenever multiple overhead cranes share the same track.
4) Establish a no-entry zone around overhead crane operations to reduce the potential for personal injury; only the crane operator and spotters are allowed inside this zone.

Incident Reporting & Investigation System

View Incident Report

INCIDENT TITLE:	Employee Cuts Finger on Sheet Metal
CASE NUMBER:	19-IG-0053
EVENT TYPE:	Injury
REPORTING ORGANIZATIONAL UNIT:	(73) Engineering Laboratory
LOCATION:	Gaithersburg
DATE/TIME OF INCIDENT	4/19/2019 02:20 PM

DESCRIPTION OF INCIDENT:

Briefly describe the activity leading up to and / or taking place at the time of the incident? (Do not include measures taken after the incident.)

Employee was moving sheet metal pieces into place for a concrete pour stop. Employee was wearing rubber gloves to protect from oil on steel sheet metal piece.

Briefly describe the outcome or result of the incident (e.g what happened – slip and fall, description of the injury) and basic information about what caused it.

The sheet metal slipped in their hand and cut their finger.

Briefly describe the immediate actions taken to respond to the incident – e.g. how the scene was secured, employee was taken to the Health Unit, etc.

Employee immediately notified their supervisor and was taken to the health unit by another employee. The health unit administered first aid and the employee returned to work.

BASIC DESCRIPTION OF INVESTIGATIVE PROCESS:

The Group Leader (Lead Investigator) interviewed the injured worker and the other worker who was present at the time of the injury. Both were interviewed on the day of the incident. The work space where the injury occurred was inspected was observed within minutes of the incident.

SUMMARY OF THE INVESTIGATION FINDINGS:

Employee was moving sheet metal pieces into place for a concrete pour stop. Employee was wearing rubber gloves to protect from oil on steel sheet metal piece. Sharp unfinished edge of sheet metal caused a cut to the employees finger. Employee was properly trained and understood the need for cut resistant gloves. Proper gloves would have likely prevented the injury. Additional finishing to create a smooth edge on the sheet metal part could have also prevented the injury, but was not practical in this application.

CORRECTIVE ACTION

Causes

CAUSAL FACTOR: PERSONAL PROTECTIVE EQUIPMENT FAILED TO PREVENT SKIN LACERATION DURING HANDLING OF SHEET METAL

CATS #	Estimated Due Date	Assigned To	Status
19-IG-0053-CA04	05/10/2019		Closed
19-IG-0053-CA05	05/10/2019		Closed

ROOT CAUSE: FAILURE TO USE PROPER CUT RESISTANT GLOVES

CATS #	Estimated Due Date	Assigned To	Status
19-IG-0053-CA01	04/22/2019		Closed
19-IG-0053-CA02	05/10/2019		Closed

CATS #	Estimated Due Date	Assigned To	Status
19-IG-0053-CA03	05/10/2019		Closed

LESSONS IDENTIFIED

Lessons Identified
The injured staff member was properly trained but chose to use a less protective glove to increase feel and comfort. The main lesson is that the Group Leader, Project Leader and Lab Safety Officer should be attentive and insist that established safety controls are properly implemented.

Action Tracking System

View a Corrective Action

Corrective Action Number: 19-IG-0053-CA01

Corrective Action: Hold project team meeting and remind all staff members to wear proper PPE

Assigned To:

Individual Responsible for Closing Out the Corrective Action:

Estimated Completion Date: 04/22/2019

Status: Closed

Created By:

Comments:

Date	Name	Note Category	Comments
5/14/2019		Review	
5/14/2019		Implement	Meeting Held

Action Tracking System

View a Corrective Action

Corrective Action Number: 19-IG-0053-CA02

Corrective Action: Workspace manager or designee will conduct daily checks to assure that proper PPE is being used

Assigned To:

Individual Responsible for Closing Out the Corrective Action:

Estimated Completion Date: 05/10/2019

Status: Closed

Created By:

Comments:

Date	Name	Note Category	Comments
5/15/2019		Review	
5/14/2019		Implement	Conducts daily checks to assure that proper PPE is being used.

Action Tracking System

View a Corrective Action

Corrective Action Number:	19-IG-0053-CA03
Corrective Action:	Group Leader conduct unannounced checks on a regular basis to verify that proper PPE is being used
Assigned To:	
Individual Responsible for Closing Out the Corrective Action:	
Estimated Completion Date:	05/10/2019
Status:	Closed
Created By:	
Comments:	

Date	Name	Note Category	Comments
5/15/2019		Review	unannouced checks have be implemented to verify that proper PPE is being used.
5/14/2019		Implement	periodic unannounced checks by the group leader have begun

Action Tracking System

View a Corrective Action

Corrective Action Number: 19-IG-0053-CA05

Corrective Action: review mechanical and magnetic clamps for handling of sheet metal

Assigned To:

Individual Responsible for Closing Out the Corrective Action:

Estimated Completion Date: 05/10/2019

Status: Closed

Created By:

Comments:

Date	Name	Note Category	Comments
5/15/2019		Review	
5/14/2019		Implement	Uses clamps when handling sheet metal.

Action Tracking System

View a Corrective Action

Corrective Action Number: 19-IG-0053-CA04

Corrective Action: review other types of gloves for handling sheet metal, including Kevlar and Chain Mail

Assigned To:

Individual Responsible for Closing Out the Corrective Action:

Estimated Completion Date: 05/10/2019

Status: Closed

Created By:

Comments:

Date	Name	Note Category	Comments
5/15/2019		Review	
5/14/2019		Implement	Uses cut resistant gloves when handling sheet metal.

Incident Reporting & Investigation System

View Incident Report

INCIDENT TITLE:	Overheated Cooling Water Line Bursts, Releasing Pressurized Steam
CASE NUMBER:	20-IG-0023
EVENT TYPE:	Near Miss
REPORTING ORGANIZATIONAL UNIT:	(73) Engineering Laboratory
LOCATION:	Gaithersburg
DATE/TIME OF INCIDENT	11/14/2019 10:30 AM

DESCRIPTION OF INCIDENT:

Briefly describe the near miss incident including events leading up to and / or taking place at the time of the incident? (Do not include measures taken after the incident.)

A full scale structural fire test of a composite floor assembly using water cooled natural gas burners was being conducted. At approximately 90 minutes into the experiment one of the four water cooling lines began to overheat and hot water vapor was noticed at the vent line entering the floor drain. The hose ruptured at the rear of the compartment and a jet of high pressure steam was ejected. The burst occurred at the back of the test compartment and was directed toward the wall of the laboratory. The rupture occurred in an exclusion zone where no staff were permitted during the test. The rupture created a loud hissing noise that lasted for less than 30 seconds.

Briefly describe what could have happened if circumstances had been slightly different.

Had a staff member been in the exclusion zone, where the hose ruptured, they could have been severely burned from the high-pressure steam.

Briefly describe the immediate actions taken to respond to the incident – e.g. how the scene was secured, how the hazard was abated, etc.

A technician turned off the cooling water supply to the burners, abating the high-pressure steam. The experiment continued without the cooling water, which was not needed to safely continue and complete the test.

BASIC DESCRIPTION OF INVESTIGATIVE PROCESS:

The group leader and technicians discussed the events and actions taken during the burn when pressurized steam was released. They examined the design of the cooling water lines and discussed the root cause. The DSR spoke to the GL and met with the technicians to discuss and examine the current design and possible solutions to keep the water lines from overheating again. The Division Chief was informed and offered input. A description of the incident was presented at a division safety meeting.

SUMMARY OF THE INVESTIGATION FINDINGS:

A water-cooling line that supplied one of the burners overheated and caused hot water vapor to rupture a hose leading from the vent line.

CORRECTIVE ACTION

Causes

ROOT CAUSE: THE CURRENT DESIGN DOES NOT PROVIDE ADEQUATE PROTECTION TO THE WATER-COOLING LINE TO KEEP IT FROM OVERHEATING. AS A RESULT THE WATER-COOLING LINE THAT LEAD TO ONE OF THE BURNERS OVERHEATED AND CAUSED HOT WATER VAPOR TO RUPTURE A HOSE LEADING FROM THE VENT LINE.

READ LESS

CATS #	Estimated Due Date	Assigned To	Status
20-IG-0023-CA01	01/01/2020		Closed

LESSONS IDENTIFIED

Lessons Identified
The current design does not provide adequate protection to the water-cooling line to keep it from overheating. The design needs to be carefully examined and modified before any additional experiments with these burners.

Action Tracking System

View a Corrective Action

Corrective Action Number: 20-IG-0023-CA01

Corrective Action: Redesign and revise the the cooling water line location or insulation for the natural gas burners

Assigned To:

Individual Responsible for Closing Out the Corrective Action:

Estimated Completion Date: 01/01/2020

Status: Closed

Created By:

Comments:

Date	Name	Note Category	Comments
1/2/2020		Review	Burners are currently offline in storage. new design will be implemented during test planned later in the 2020. We will also consider the option of eliminating the cooling line.
1/2/2020		Implement	Cooling water line redesign to increase water flow and add insulation

Incident Reporting & Investigation System

View Incident Report

INCIDENT TITLE:	Unanticipated Hazard -Small Liftgate Cylinders Burst
CASE NUMBER:	21-IG-0029
EVENT TYPE:	Other
REPORTING ORGANIZATIONAL UNIT:	(73) Engineering Laboratory
LOCATION:	Gaithersburg
DATE/TIME OF INCIDENT	4/14/2021 Incident Time Unknown

DESCRIPTION OF INCIDENT:

Briefly describe the activity leading up to and / or taking place at the time of the incident? (Do not include measures taken after the incident.)

This activity involved a fire experiment using a commercially available wooden storage shed. Technicians assembled the shed per manufacturer's instructions. The shed included two small pneumatic liftgate cylinders for the lid. Prior to initiating the fire, the Safety Officer reviewed the approved hazard review, completed a checklist required for all burns in NFRL, and conducted a staff safety briefing. The Safety Officer was not aware of the liftgate cylinders until after the structure was on fire and the lid raised exposing the cylinders.

Briefly describe the outcome or result of the incident (e.g what happened – description of property damage, description of chemical spill, etc.) and basic information about what caused it.

The extreme temperature during the fire caused the liftgate cylinders to burst. There were no injuries or property damage.

Briefly describe the immediate actions taken to respond to the incident – e.g. how the scene was secured, OSHE Spill Team was called and cleaned up the spill; damaged equipment was locked out of service, etc.

Having previous experience with the behavior of pneumatic cylinders in fires, the Safety Officer and an engineer determined that with the mitigation controls that were already in place, there was no obvious safety hazard. The team was notified that they should expect the cylinders to fail shortly. As the test progressed there were two loud pop sounds (similar to gunshot or firework) when the cylinders burst.

BASIC DESCRIPTION OF INVESTIGATIVE PROCESS:

The safety officer and an engineer that were on the scene discussed the incident with the NFRL Group Leader (GL). The same day, the engineer and GL notified the Division Chief and DSR (IRIS submitter and trained investigator) to give a detailed account of the incident.

SUMMARY OF THE INVESTIGATION FINDINGS:

A commercially available shed included two small pneumatic liftgate cylinders for the lid. The Safety Officer was not aware of the liftgate cylinders until after the structure was on fire and the lid raised, exposing the cylinders. The extreme temperature during the fire caused the liftgate cylinders to burst.

CORRECTIVE ACTION

Causes

CAUSAL FACTOR: THE EXTREME TEMPERATURE DURING THE FIRE CAUSED THE LIFTGATE CYLINDERS TO BURST.

ROOT CAUSE: THE SAFETY OFFICER WAS NOT AWARE OF THE LIFTGATE CYLINDERS UNTIL AFTER THE STRUCTURE WAS ON FIRE AND THE LID RAISED EXPOSING THE CYLINDERS.

CATS #	Estimated Due Date	Assigned To	Status
21-IG-0029-CA02	06/24/2021		Closed

LESSONS IDENTIFIED

Lessons Identified
A more thorough inspection of the shed would have revealed the cylinders. The cylinders could have been removed, mitigating the hazard.

Action Tracking System

View a Corrective Action

Corrective Action Number:	21-IG-0029-CA02
Corrective Action:	The Safety Briefing Checklist contained in Hazard Review 733.06.0132.030220 - NFRL Large Fire Experiments, will be modified to include identification of components that could become over-pressurized, and verification that they have been removed or controlled.
Assigned To:	
Individual Responsible for Closing Out the Corrective Action:	06/24/2021 Closed
Estimated Completion Date:	
Status:	
Created By:	
Attached corrective action plan(s):	PreTestSafetyInspection06172021.docx

Comments:

Date	Name	Note Category	Comments
6/21/2021		Review	New checklist has been developed and implemented
6/21/2021		Implement	Please review the attached checklist. Note the following addition: "Pressurized fluids have been identified and removed or controlled".

NFRL Pre-Test Inspection Checklist

Performed by Test Safety Officer prior to Safety Briefing

Safety Officer____________________

Date___________________________

Project___________________________

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1) Verify Following Safety Conditions:
   a. ☐ - NIST FD notified and water deluge system in bypass
   b. ☐ - Restricted access signs placed at lab entrance doors
   c. ☐ - Carbon monoxide monitors in place
   d. ☐ - Tripping hazards identified and mitigated
   e. ☐ - Exclusion zones clearly identified
   f. ☐ - Flammable items have been identified and removed or controlled
   g. ☐ - Pressurized fluids have been identified and removed or controlled
   h. ☐ - Fire hoses, handheld extinguishers and sprinklers are in place

Incident Reporting & Investigation System

View Incident Report

INCIDENT TITLE:	Scissor Lift Damaged While Being Operated
CASE NUMBER:	21-IG-0052
EVENT TYPE:	Property Damage
REPORTING ORGANIZATIONAL UNIT:	(73) Engineering Laboratory
LOCATION:	Gaithersburg
DATE/TIME OF INCIDENT	6/16/2021 Incident Time Unknown

DESCRIPTION OF INCIDENT:

Briefly describe the activity leading up to and / or taking place at the time of the incident? (Do not include measures taken after the incident.)

A scissor lift platform was being positioned to allow photographs to be taken of an experimental setup.

Briefly describe the outcome or result of the incident (e.g what happened – description of property damage, description of chemical spill, etc.) and basic information about what caused it.

The handrail of the lift platform came into contact with a steel beam, as a result the handrail was bent.

Briefly describe the immediate actions taken to respond to the incident – e.g. how the scene was secured, OSHE Spill Team was called and cleaned up the spill; damaged equipment was locked out of service, etc.

The lift was lowered and taken out of service.

Attached incident report, pictures, sketches or other related file(s):

scissor lift bent railing.png

BASIC DESCRIPTION OF INVESTIGATIVE PROCESS:

The NFRL lift operator discussed the incident with the NFRL Group Leader (GL). The same day, the GL notified the Division Chief and DSR (IRIS submitter and trained investigator) to give a detailed account of the incident.

SUMMARY OF THE INVESTIGATION FINDINGS:

The scissor lift platform was being positioned to allow photographs to be taken of an experimental setup. The handrail of the lift platform came into contact with a steel beam, as a result the handrail was bent. It was determined that the Hazard Review for the activity (NFRL Scissor and Boom Lifts), did not include sufficient safety checks and training.

ATTACHED INVESTIGATION REPORT, PICTURES, SKETCHES OR OTHER RELATED FILE(S): scissor lift bent railing.jpg

CORRECTIVE ACTION

Causes

CAUSAL FACTOR: THE SCISSOR LIFT PLATFORM OPERATOR WAS POSITIONING THE LIFT TO ALLOW PHOTOGRAPHS TO BE TAKEN OF AN EXPERIMENTAL SETUP. THE HANDRAIL OF THE LIFT PLATFORM CAME INTO CONTACT WITH A STEEL BEAM, AS A RESULT THE HANDRAIL WAS BENT. READ LESS

ROOT CAUSE: HAZARD REVIEW 733.06.08241- NFRL SCISSOR AND BOOM LIFTS DID NOT INCLUDE SUFFICIENT SAFETY CHECKS AND TRAINING.

CATS #	Estimated Due Date	Assigned To	Status
21-IG-0052-CA01	09/06/2021		Closed

LESSONS IDENTIFIED

Lessons Identified
Safety procedures and training requirements should be periodically reviewed and updated, if needed.

Action Tracking System

View a Corrective Action

Corrective Action Number: 21-IG-0052-CA01

Corrective Action: The Standard Operation Procedure (SOP) of Hazard Review 733.06.0051.082421 - NFRL Scissor and Boom Lifts will be updated with additional safety measures, new training requirements for users and operators, and the addition of ANSI/SAIA A92.3 - 2006 (R2014) documents.

Assigned To:

Individual Responsible for Closing Out the Corrective Action: 09/06/2021

Closed

Estimated Completion Date:

Status:

Created By:

Comments:

Date	Name	Note Category	Comments
11/17/2021		Review	training requirements and documentation have been reviewed and implemented
11/17/2021		Implement	The Standard Operation Procedure (SOP) of Hazard Review 733.06.0051.082421 - NFRL Scissor and Boom Lifts was updated with additional safety measures, new training requirements for users and operators, ... Read More


WARNING

Incident Reporting & Investigation System

View Incident Report

INCIDENT TITLE:	Near Miss During Operation of Overhead Bridge Crane
CASE NUMBER:	22-IG-0027
EVENT TYPE:	Near Miss
REPORTING ORGANIZATIONAL UNIT:	(73) Engineering Laboratory
LOCATION:	Gaithersburg
DATE/TIME OF INCIDENT	4/22/2022 01:15 PM

DESCRIPTION OF INCIDENT:

Briefly describe the near miss incident including events leading up to and / or taking place at the time of the incident? (Do not include measures taken after the incident.)

A technician operating the crane looked up to ensure the path was clear for travel and noted that the hook was completely retracted before moving the crane bridge. As they moved the crane, they heard a loud "clank" and some banging from the hook hitting a heat shield mounted on the wall adjacent to the crane.

Briefly describe what could have happened if circumstances had been slightly different.

The hook could have damaged the heat shield, possibly resulting in additional hazards to personnel.

Briefly describe the immediate actions taken to respond to the incident – e.g. how the scene was secured, how the hazard was abated, etc.

The technician stopped the crane, moved it back to it's original position, and took it out of service.

Attached incident report, pictures, sketches or other related file(s):

LRFL Bridge Crane.jpg

BASIC DESCRIPTION OF INVESTIGATIVE PROCESS:

The NFRL Acting Group Leader immediately reported the incident to the Acting Deputy Division Chief and followed it up with a written summary of the incident. The DSR (IRIS submitter and investigator) subsequently interviewed the crane operator and a witness.

SUMMARY OF THE INVESTIGATION FINDINGS:

Before moving the crane bridge, the crane operator looked to ensure the path was clear for travel and noted that the hook was completely retracted. From a location not in line of sight of the hook, the operator used a remote control to move the bridge. When the bridge was moved, the hook hit a heat shield mounted on the wall adjacent to the crane. The operator misjudged the initial position of the hook and could not see it as it neared the heat shield.

ATTACHED INVESTIGATION REPORT, PICTURES, SKETCHES OR OTHER RELATED FILE(S): Crane investigation.jpg

CORRECTIVE ACTION

Causes

CAUSAL FACTOR: THE CRANE HOOK MADE CONTACT WITH THE ADJACENT HEAT SHIELD.

CATS #	Estimated Due Date	Assigned To	Status
22-IG-0027-CA03	06/13/2022		Closed

ROOT CAUSE: THE CRANE OPERATOR DID NOT FOLLOW THE CLASSROOM TRAINING TO BE IN LINE OF SIGHT OF THE HOOK OR HAVE A SPOTTER..

CATS #	Estimated Due Date	Assigned To	Status
22-IG-0027-CA01	06/03/2022		Closed
22-IG-0027-CA02	06/03/2022		Closed

LESSONS IDENTIFIED

Lessons Identified
Crane operators must follow the required procedure when moving the crane.

20
TON

Action Tracking System

View a Corrective Action

Corrective Action Number: 22-IG-0027-CA01

Corrective Action: Crane operator will retake crane safety course EL-733: NFRL Overhead Crane Operation

Assigned To:

Individual Responsible for Closing Out the Corrective Action: 06/03/2022

Estimated Completion Date: Closed

Status:

Created By:

Attached corrective action plan(s): accedited crane course.docx

Comments:

Date	Name	Note Category	Comments
6/27/2022		Review	
6/27/2022		Implement	I am in the process of registering for the Nist crane safety course taught by an accredited certifying body prior to EL-733 NFRL Overhead Crane Operation.

Safety Education Training

View a Course

VIEW

Course Description

Course Title:	Overhead Cranes and Slings
Course Description:	Classroom and hands-on safety training for the use of Overhead Cranes and Slings
Course Instructor(s):	Varadi, Laslo
Course Category:	OU/Division Level
Course Sub Category:	Activities Specific
Course Type:	Instructor Led
Duration:	5 Hours
NIST SET Course ID:	766
Number of Days to Complete:	1
Is this a Refresher Course?	No

Course Additional Information

Location:	Gaithersburg
Recommended Program Name(s):	Machines, Tools, and Associated Equipment Safety Program
Exam Required?	No
Should Staff be able to Take the Exam Without Taking the Course?	No
Notes:	Course instructor/vendor varies. Royal Arc, Crane 1, NSC
IsAlwaysAssignable:	Yes
IsAlwaysActive:	Yes
Records for this course are pushed to CLC?	Yes

Course Session(s)

There are no sessions currently scheduled for this course. Please contact the instructor directly for this training.

Course Materials

Uploaded Material(s):

Overhead Cranes and Slings.ppt

Crane Safety - Royal Arc

Action Tracking System

View a Corrective Action

Corrective Action Number:	22-IG-0027-CA02
Corrective Action:	The PI of approved hazard review 733.06.0052 NFRL Overhead Cranes will edit the SOP to include the requirement to not move the crane without line of sight or a spotter.
Assigned To:	
Individual Responsible for Closing Out the Corrective Action:	06/03/2022
	Closed
Estimated Completion Date:	
Status:	
Created By:	
Comments:	

Date	Name	Note Category	Comments
7/1/2022		Review	
7/1/2022		Implement	Edited SOP

Action Tracking System

View a Corrective Action

Corrective Action Number:	22-IG-0027-CA03
Corrective Action:	Having a beam stop is not practical for the needs of NFRL. They have added a new administrative control for crane operation and have updated their SOP… "Operators should use the heat shields located at the floor level as a boundary line. If the operator must operate beyond this boundary line, they must consult the workspace manager."
Assigned To:	
Individual Responsible for Closing Out the Corrective Action:	06/13/2022
Estimated Completion Date:	Closed
Status:	
Created By:	
Comments:	

Date	Name	Note Category	Comments
6/27/2022		Review	
6/27/2022		Implement	Added administrative controls and will review procedures with users.

Appendix 6.13.1: Relevant Emails from the Review of CF Project Team Member Outlook Accounts (Redacted)

From: [redacted]
Sent: Thursday, May 5, 2022 11:32 AM
To: [redacted]
Subject: RE: MOP

Thanks! I will bring this up in the group leader meeting and see what [redacted] thinks. I briefly mentioned it to [redacted] just now.

[redacted] just called me with questions about the demolition and the hazard review. I am sure that [redacted] put him up to this after the MOP.

From: [redacted]
Sent: Wednesday, May 04, 2022 1:59 PM
To: [redacted]
Subject: RE: MOP

The inventory is attached. Thanks for your help.

Best Regards,

[redacted], Engineering Technician
National Fire Research Laboratory (NFRL)
National Institute of Standards and Technology
100 Bureau Drive, Stop 8666, Building 205
Gaithersburg, MD 20899-8666
Office: [redacted]
Cell: [redacted]
Lab: [redacted]
Fax: [redacted]
E-mail: [redacted]

From: [redacted]
Sent: Tuesday, May 3, 2022 11:38 AM
To: [redacted]
Subject: MOP

[redacted],

You guys did a really great job with [redacted]!! The best MOP I have been to. He seemed really impressed. I told [redacted] how well you guys did.

Other than the fall protection harnesses, what is the name of the other straps we want inspected?

I am going to email [redacted].

From: [redacted]
Sent: Thursday, May 5, 2022 11:59 AM
To: [redacted]
Subject: RE: heads up

I was explaining what we were doing and the process for making sure the shoring was good which is covered in the HR. He did have a look of concern but I thought we made him comfortable enough to move on. The only thing that was identified as a potential issue was dust. We said we used a filtered fan, opened doors, and hosed down the concrete. Maybe this was his concern. With the controls we have in place this is not a level 3.

Best Regards,

[redacted], Engineering Technician
National Fire Research Laboratory (NFRL)
National Institute of Standards and Technology
100 Bureau Drive, Stop 8666, Building 205
Gaithersburg, MD 20899-8666
Office: [redacted]
Cell: [redacted]
Lab: [redacted]
Fax: [redacted]
E-mail: [redacted]

From: [redacted]
Sent: Thursday, May 5, 2022 11:41 AM
To: [redacted]
Subject: FW: heads up

Did something come up in the MOP?

From: [redacted]
Sent: Thursday, May 5, 2022 11:28 AM
To: [redacted]
Subject: heads up

[redacted] is on the phone now asking questions about the demolition. He's going to call you… He's thinking of moving it up to a hazard level 3.

I think [redacted] is driving this and having [redacted] look into it.

From: [redacted]
Sent: Thursday, May 5, 2022 12:04 PM
To: [redacted]
Subject: RE: heads up

Also,

[redacted] wasn't at the MOP but I did see him asking [redacted] questions during the crane inspection.

Best Regards,

[redacted], Engineering Technician
National Fire Research Laboratory (NFRL)
National Institute of Standards and Technology
100 Bureau Drive, Stop 8666, Building 205
Gaithersburg, MD 20899-8666
Office: [redacted]
Cell: [redacted]
Lab: [redacted]
Fax: [redacted]
E-mail: [redacted]

From: [redacted]
Sent: Thursday, May 5, 2022 11:41 AM
To: [redacted]
Subject: FW: heads up

Did something come up in the MOP?

From: [redacted]
Sent: Thursday, May 5, 2022 11:28 AM
To: [redacted]
Subject: heads up

[redacted] is on the phone now asking questions about the demolition. He's going to call you… He's thinking of moving it up to a hazard level 3.

I think [redacted] is driving this and having [redacted] look into it.

From: [redacted]
Sent: Monday, May 9, 2022 11:46 AM
To: [redacted]
Cc:
Subject: RE: Composite Floor Demolition

[redacted],

As of this morning, I am back from the Program Office. With [redacted] departure, I have taken over the lead for the Composite Floor project.

[redacted] asked that [redacted], and I join this meeting because we have responsibilities for the workspace, safety, and project management. If our participation is not desired/needed for this meeting, let me know.

Could you let me know the specific topic(s) for discussion and/or desired outcome of the meeting so we can prep accordingly?

Cheers,
[redacted]

-----Original Appointment-----
From: [redacted]
Sent: Monday, May 9, 2022 11:34 AM
To: [redacted].
Cc: [redacted]
Subject: Composite Floor Demolition
When: Wednesday, May 11, 2022 11:30 AM-12:00 PM (UTC-05:00) Eastern Time (US & Canada).
Where: Microsoft Teams Meeting

-----Original Appointment-----
From: [redacted]
Sent: Thursday, May 05, 2022 4:22 PM
To: [redacted]
Cc: [redacted]
Subject: Composite Floor Demolition
When: Wednesday, May 11, 2022 11:30 AM-12:00 PM (UTC-05:00) Eastern Time (US & Canada).
Where: Microsoft Teams Meeting

Microsoft Teams meeting

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From: [redacted]
Sent: Monday, May 9, 2022 12:08 PM
To: [redacted]
Subject: Re: Composite Floor

No worries. I totally understand.

On: 09 May 2022 12:06,
"[redacted]> wrote:

I trust your judgement if you need to proceed in the meantime. In principle, I am in close-out mode for this phase of the project. I just want to get some situational awareness before committing to any large moves.

[redacted]

From: [redacted]
Sent: Monday, May 9, 2022 12:04 PM
To: [redacted]
Subject: RE: Composite Floor

All good. We can talk Wednesday.

Best Regards,

[redacted], Engineering Technician
National Fire Research Laboratory (NFRL)
National Institute of Standards and Technology
100 Bureau Drive, Stop 8666, Building 205
Gaithersburg, MD 20899-8666
Office: [redacted]
Cell: [redacted]
Lab: [redacted]
Fax: [redacted]
E-mail: [redacted]

From: [redacted]
Sent: Monday, May 9, 2022 12:03 PM
To: [redacted]
Subject: RE: Composite Floor

can that decision wait until we talk Wednesday morning? If not, call me after 1 pm today @ [redacted].

From: [redacted]
Sent: Monday, May 9, 2022 11:59 AM
To: [redacted]
Subject: Composite Floor

[redacted],

Since you are back I want to ask for an official answer on whether or not we can begin to dismantle everything but the surrounding bay (instrumentation, etc.). I want to keep busy while we are waiting around for safety and guest researcher decisions.

Best Regards,

[redacted], Engineering Technician
National Fire Research Laboratory (NFRL)
National Institute of Standards and Technology
100 Bureau Drive, Stop 8666, Building 205
Gaithersburg, MD 20899-8666
Office: [redacted]
Cell: [redacted]
Lab: [redacted]
Fax: [redacted]
E-mail: [redacted]

From: [redacted]
Sent: Tuesday, May 10, 2022 12:23 PM
To: [redacted]
Cc: [redacted]
Subject: RE: Composite Floor Demolition

Ok sure

-------- Original Message --------
From: "[redacted]
Date: Tue, May 10, 2022 12:18 PM -0400
To: [redacted]
CC: [redacted]
Subject: RE: Composite Floor Demolition

[redacted],

I went through the HazReview and chatted with [redacted]. I think that we are good to go on all points, but question of RHI 2 vs 3 requires some internal discussion before we meet with [redacted] and Co. Perhaps the four of us (you, me, [redacted]) could briefly discuss this around 10am before you and I have our 1-on-1.

[redacted]

From: [redacted]
Sent: Monday, May 9, 2022 1:39 PM
To: [redacted]
Cc: [redacted]
Subject: Re: Composite Floor Demolition

Hi [redacted],
I left you a message on your phone. Please call me on [redacted] so we can discuss in more detail if you wish. The meeting will be to specifically discuss the Hazard Review for the demolition. The review while quite detailed and thorough may be missing a few things that should be addressed and detailed before work starts. Also I would have rated the activity as an RHI 3 instead of 2. As far as who should be on the call, I'll leave that to you all but I think you as the PI, [redacted]? [redacted] can be at your option at this time but he is welcome to participate. I don't expect our meeting to take more than 30 minutes.

[redacted]

On: 09 May 2022 11:45, "[redacted]> wrote:

> [redacted],
>
> As of this morning, I am back from the Program Office. With [redacted]'s departure, I have taken over the lead for the Composite Floor project.

[redacted] asked that [redacted], and I join this meeting because we have responsibilities for the workspace, safety, and project management. If our participation is not desired/needed for this meeting, let me know.

Could you let me know the specific topic(s) for discussion and/or desired outcome of the meeting so we can prep accordingly?

Cheers,
[redacted]

-----Original Appointment-----
From: [redacted]
Sent: Monday, May 9, 2022 11:34 AM
To: [redacted]
Cc: [redacted]
Subject: Composite Floor Demolition
When: Wednesday, May 11, 2022 11:30 AM-12:00 PM (UTC-05:00) Eastern Time (US & Canada).
Where: Microsoft Teams Meeting

-----Original Appointment-----
From: [redacted]
Sent: Thursday, May 05, 2022 4:22 PM
To: [redacted]
Cc: [redacted]
Subject: Composite Floor Demolition
When: Wednesday, May 11, 2022 11:30 AM-12:00 PM (UTC-05:00) Eastern Time (US & Canada).
Where: Microsoft Teams Meeting

Microsoft Teams meeting

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From: [redacted]
Sent: Tuesday, May 10, 2022 10:43 AM
To: [redacted]
Subject: Meetings Tomorrow

[redacted],

I won't be in until 8:30 tomorrow. Is 9 a good start time? Also, if it comes up in the safety meeting, we have about 232,000 lb. supporting, conservatively, about 45,000 lb. for a safety factor of about 5. If we need span information for the 4 x 4 platforms above supports I can get that but I think we are good. Welcome back!

Best Regards,

[redacted], Engineering Technician
National Fire Research Laboratory (NFRL)
National Institute of Standards and Technology
100 Bureau Drive, Stop 8666, Building 205
Gaithersburg, MD 20899-8666
Office: [redacted]
Cell: [redacted]
Lab: [redacted]
Fax: [redacted]
E-mail: [redacted]

From: [redacted]
Sent: Wednesday, May 11, 2022 12:57 PM
To: [redacted]
Subject: Demolition HR

Here is a list of the recent changes.

Added Source 'Concrete and Deck Pan Demolition' with hazard 'noise'. Added controls for training and PPE.

Added hearing protection to SSOP.

Added OSHA standard reference for guardrail design to SSOP.

Added two deep review on structural design.

Resolved comments and uploaded clean document.

Best Regards,

[redacted], Engineering Technician
National Fire Research Laboratory (NFRL)
National Institute of Standards and Technology
100 Bureau Drive, Stop 8666, Building 205
Gaithersburg, MD 20899-8666
Office: [redacted]
Cell: [redacted]
Lab: [redacted]
Fax: [redacted]
E-mail: [redacted]

From: [redacted]
Sent: Wednesday, May 11, 2022 5:25 PM
To: [redacted]
Cc: [redacted]
Subject: RE: Vertical Load Capacity of Shoring

Thank you [redacted] for putting a second set of eyes on this.

[redacted]

From: [redacted]
Sent: Wednesday, May 11, 2022 3:36 PM
To: [redacted]
Subject: Re: Vertical Load Capacity of Shoring

Hi [redacted],

I have put the calculation sheet of vertical load capacity of shoring and references I used for the calculations in the following share folder.

\\nfrl1\NFRL_Projects\Steel_Frame_Structure_Fire\COMPOSITE_FLOOR_TEST\Experimental_Plan\Deconstruction\CF_TEST3_Shoring

[redacted].

On Wed, May 11, 2022 at 2:04 PM [redacted] wrote:

> Hi [redacted],
>
> Please see the attached files for the calculation of vertical load capacity of shoring and references I used for the calculations.
>
> The vertical load capacity of vertical members has a factor of safety of 3.8.
>
> When I calculated the flexural capacity of the top 4 x 4 (3.5" x 3.5") wood planks, the factor of safety is 1.5 assuming a Modulus of Rupture of 12,400 psi for the Douglas Fir wood plank used. We can chat.
>
> Thanks.

[redacted].

From: [redacted]
Sent: Tuesday, May 31, 2022 3:36 PM
To: [redacted]
Subject: Slab Demo

[redacted],

I started removing concrete from the west girder today. [redacted] had said that was the first point of interest. Would it make sense to start demo on the undamaged sections on days that [redacted] is unable to be in the lab?

[redacted]

From: [redacted]
To: [redacted]
Subject: Concrete removal Haz Review
Start: Wednesday, June 15, 2022 9:00:00 AM
End: Wednesday, June 15, 2022 9:30:00 AM
Location: Microsoft Teams Meeting

This is a placeholder if [redacted] is back.

Decision item:

1. do we need to amend the concrete removal Haz Review to facilities removal of large sections of the undamaged structure with the crane (assuming this is viable and we want to do it).

[redacted]

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Click here to join the meeting <https://teams.microsoft.com/l/meetup-join/19%3ameeting_NzU1NTE2YzktYzEyOC00NzJiLThkYTktMDRmOTkzYzFlMmM4%40thread.v2/0?context=%7b%22Tid%22%3a%222ab5d82f-d8fa-4797-a93e-054655c61dec%22%2c%22Oid%22%3a%228ab596a1-fb96-45e0-a8cf-8657f2232984%22%7d>

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From: [redacted]
Sent: Friday, August 12, 2022 3:42 PM
To: [redacted]
Subject: Re: Purchase Request

Not 20,000 but 2,000.

On: 12 August 2022 15:41,
[redacted]> wrote:

[redacted],

Can we purchase a coring rig with coring bits for the outer slab demo? This will be used to core holes for lifting anchors. Cost is $20571.41.

[redacted]

From:	[redacted]
Sent:	Monday, August 22, 2022 10:01 AM
To:	[redacted]
Subject:	RE: Telework/Leave Request

[redacted],

This is just a reminder that I am out this week. I will be managing the demo from here and creating a lifting plan for the surrounding deck. I also have a ton of credit card paperwork to catch up on. I may take some leave this week. I will let you know what days if I do.

Best Regards,

[redacted], Engineering Technician
National Fire Research Laboratory (NFRL)
National Institute of Standards and Technology
100 Bureau Drive, Stop 8666, Building 205
Gaithersburg, MD 20899-8666
Office: [redacted]
Cell: [redacted]
Lab: [redacted]
Fax: [redacted]
E-mail: [redacted]

From: [redacted]
Sent: Thursday, August 4, 2022 2:02 PM
To: [redacted]
Subject: RE: Telework/Leave Request

That's fine with me.

From: [redacted]
Sent: Thursday, August 04, 2022 1:20 PM
To: [redacted]
Subject: Telework/Leave Request

[redacted],

I know the timing of this request isn't ideal because I have been out all week. But is it possible for me to telework or use a combination of leave and telework the week of the 22nd? My wife goes back to work that week.

Best Regards,

[redacted], Engineering Technician
National Fire Research Laboratory (NFRL)
National Institute of Standards and Technology
100 Bureau Drive, Stop 8666, Building 205
Gaithersburg, MD 20899-8666
Office: [redacted]
Cell: [redacted]
Lab: [redacted]
Fax: [redacted]
E-mail: [redacted]

From: [redacted]
Sent: Tuesday, August 23, 2022 1:50 PM
To: [redacted]
Subject: Coring and Cutting Plan
Attachments: Coring and Cutting Plan.pdf

Yo,

I'm sure you are helping [redacted] this week but if not take a look at the attached. If you feel like it you can start laying this out because it's a relatively easy job. Let me know if you have any suggestions or there is a missing dimension. The core hole locations don't have to be perfect as long as they are symmetric and are not spaced further apart than they are in the drawing (that is the max dimension). I know they all won't fit in the dumpster this way but this minimizes the amount of cuts in the air. The west is a mirror of the east.

Best Regards,

[redacted], Engineering Technician
National Fire Research Laboratory (NFRL)
National Institute of Standards and Technology
100 Bureau Drive, Stop 8666, Building 205
Gaithersburg, MD 20899-8666
Office: [redacted]
Cell: [redacted]
Lab: [redacted]
Fax: [redacted]
E-mail: [redacted]

Appendix 6.16.1: 3D High-Fidelity, Nonlinear Finite Element Modeling and Failure Analysis of Composite One-Way Pan Joist Concrete Slab on Steel Deck

3D High-Fidelity, Nonlinear Finite Element Modeling and Failure Analysis of Composite One-Way Pan Joist Concrete Slab on Steel Deck

Prepared for

National Institute of Standards and Technology
Gaithersburg, MD 20899

Submitted by

Strativia LLC
1401 Mercantile Lane, Suite 501
Largo, MD 20774

Prepared by

Mehdi Zarghamee, Robert MacNeill,
Keng-Wit Lim, Steven Palkovic, and Nicholas Catella
Simpson Gumpertz & Heger Inc.
480 Totten Pond Road
Waltham, MA 02451

16 March 2023

16 March 2023

Dr. Long T. Phan
National Institute of Standards and Technology
Gaithersburg, MD 20899

Project 221564 – 3D High Fidelity, Nonlinear Finite Element Modeling and Failure Analysis of Composite One-Way Pan Joist Concrete Slab on Steel Deck

Subject: Final Report

Dear Dr. Phan:

We are pleased to submit hereby our final report on the above project. Our 3D high-fidelity, nonlinear finite element model of Slab 4 simulates the performance of the slab through failure. Analysis of the other slabs shows no failure under the dead and live loads of operator and rotary floor saw for all other cases except Slab 4 with added reinforcement, which also fails.

It has been our pleasure to work with you and your team on this interesting and challenging project.

Sincerely yours,
SIMPSON GUMPERTZ & HEGER INC.

Mehdi S. Zarghamee

Mehdi S. Zarghamee, P.E., Ph.D.
Senior Principal
MD License No. 56200

Robert A. MacNeill
Associate Principal

EXECUTIVE SUMMARY

To determine the technical cause of the failure of a rectangular concrete slab that was being suspended by a lifting crane at the National Fire Research Laboratory (NFRL) of the National Institute of Standards and Technology (NIST), NIST has issued a contract for Simpson Gumpertz & Heger Inc. (SGH), through Strativia LLC., to perform three-dimensional (3D) nonlinear finite element modeling and failure analysis of the failed slab as well as five other slabs with similar configuration but with different dimensions, reinforcements, and span lengths between rigging points. All six slabs to be modeled are composite one-way pan joist concrete on steel deck slabs with approximate plan dimensions of: 3.66 m x 1.52 m (144 in. × 60 in.), three slabs; 2.87 m x 1.52 m (113 in. × 60 in.), two slabs; and 2.62 m x 2.44 m (103 in. × 96 in.), one slab. Three of the six slabs, including the failed 3.66 m x 1.52 m (144 in. × 60 in.) slab, are cut-out sections from the test floor of the NFRL two-story test frame. The remaining three slabs are variations of the failed slab (failed slab but with shorter overall length, with added reinforcement, or with shortened rigging distance). Finite element analysis (FEA) was utilized to determine whether the loads that were observed to have been placed on the failed slab just prior to its failure, including the self-weight of the slab, the weight of a walk-behind floor saw that was being used to cut the slab, and the weight of the saw operator, would be sufficient to cause the observed failure in any of the slabs. This report presents the details of our 3D finite element analysis of the slabs and corresponding results.

We received and reviewed the available information gathered by NIST and conveyed to us by Dr. Long Phan. We visited the site, received additional information about the slabs and their loading and boundary conditions from the presentations by Dr. Stephen W. Banovic, and reviewed the events that led to the failure of Slab 4. We then performed a thorough inspection of the fracture surfaces of Slab 4 and all components of the rigging system and loadings related to Slab 4 failure. We made measurements of the geometry and took photographs of the concrete slab, steel deck, slings and their anchor systems, and reinforcements, including the rebars, welded wire fabric, and rebar chairs of Slab 4. We also inspected the successfully removed and intact Slab 3. During the visit, we also identified concrete samples to be cut from the Slab 4 remnants and a lifting sling, a lifting anchor, and a section of the rebar chair to be sent to the SGH laboratory for testing and evaluation. We performed petrographic examination; extracted cores from the concrete samples received; and tested concrete modulus, tensile and compressive strength, and stiffness of the sling.

Using the collected and verified data and the measured material properties, we developed 3D nonlinear finite element models of six composite concrete-steel deck slabs with varying configurations, reinforcement details, and support conditions and performed LS-DYNA analyses to determine whether the resulting stress conditions in these slabs would lead to their failure under loading conditions that included the slab self-weight and the weights of the operator and the FS400 LV rotary floor saw. The purposes and results of these analyses are summarized below:

> **Model 1 (Task2)**, **Failure Analysis of Slab 4:** To examine whether Slab 4, in as-is condition, would fail under the combined weights of Slab 4, the operator, and the rotary floor saw, we constructed a detailed finite element model of Slab 4 and its four-sling support and subjected it to the sum of self-weight of the slab and weights of the operator and rotary floor saw. The analysis showed that flexural failure of Slab 4 occurred when the load reached 100% of slab self-weight and weight of operator and 85.3% of the weight of the rotary floor saw with an ultimate capacity-to-demand ratio of 0.96. This is consistent with the observation that Slab 4 collapsed as soon as the weights of the operator and the rotary floor saw were placed on it. Additionally, the analysis also accurately captured Slab 4's failure mode, which included (1) the formation of a primary flexural crack and fracture surface at mid-span of the slab and (2) crushing failure of concrete in the compression zone along the plane of the fracture surface. These numerical results are consistent with physical evidence obtained from examination of the remnants and fracture surfaces of Slab 4.
>
> **Model 2 (Task 3)**, **Failure Analysis of Slab 3**: To examine whether Slab 3, in as-is condition, would fail under the combined weights of Slab 3, the operator, and the rotary floor saw, we constructed a detailed finite element model of Slab 3, similar to that developed for Slab 4 in Task 2 but with Slab 3 geometry, reinforcement details, and rigging distance subjected to four-sling support and self-weight of the slab and weights of the operator and rotary floor saw. The analysis results showed that failure of Slab 3 does not occur with an ultimate capacity-to-demand ratio of 2.23. The results are consistent with the response observed at NIST.
>
> **Model 3 (Task 4)**, **Failure Analysis of Slab 2**: To examine whether Slab 2, in as-is condition, would fail under the combined weights of Slab 2, the operator, and the rotary floor saw, we made appropriate changes in the geometry, reinforcement details,

and rigging distance of the Slab 4 model to match Slab 2's design and performed finite element analysis to assess damage and failure potential in Slab 2 when subjected to the same loading and support conditions. The analysis led to no failure of the slab with an ultimate capacity-to demand ratio of 2.38. The results are consistent the response observed at NIST.

Model 4 (Task 5), **Failure Analysis of Shortened Slab 4**: To answer the hypothetical question of whether Slab 4 would have failed similarly to the Model 1 failure if it had been shortened to have the same length and rigging condition as Slab 3, we constructed a detailed finite element model of Slab 4, shortened it to match the length of Slab 3, and subjected it to four-sling support and self-weight of the slab and weights of the operator and rotary floor saw. The analysis led to no failure of the slab with an ultimate capacity-to-demand ratio of 1,69.

Model 5 (Task 6), **Failure Analysis of Slab 4 with Added Reinforcement:** To answer the hypothetical question of whether Slab 4 would have failed similarly to the Model 1 failure if it had been reinforced similarly to Slab 2 (#4 bars at 12 in. on center), we added steel reinforcement to the concrete slab considered in Model 1, Slab 4. The analysis results show increased capacity of Slab 4 to resist the loads, but Slab 4 will develop a deep crack and concrete will crush and disintegrate at the mid-length of the slab, with separate halves of the slab joined together along the fractured surface by the longitudinal reinforcements bridging the crack. As the vertical deflection of the slab continues to increase, the two halves of the concrete slab that are hinging about the yielding rebars rapidly fold and close on themselves. At this point, the slab has failed and continues to deform, and the ultimate capacity-to-demand ratio is 0.96.

Model 6 (Task7), **Failure Analysis of Slab 4 with Closer Rigging Points:** To answer the hypothetical question of whether Slab 4 would have failed similarly to the Model 1 failure if the distance between rigging points in the primary direction of bending for Slab 4 had been shortened by 0.61 m (2 ft), we considered a different rigging configuration compared to Model 1 (Task 2) in which the anchor points of slings are moved inward toward the center by 0.305 m (12 in.). The results of the analysis indicate no failure of slab with an ultimate capacity-to-demand ratio of 1.70, but it also shows that concrete tensile strain at the corners of the slab are high enough to cause microcracking, but not high enough to produce a visible crack, and that the concrete stress does not exceed the tensile strength.

We examined the fracture surfaces of Slab 4. Our examination revealed no anomaly that differed from the expected features of flexural failure of the slab. The results of concrete testing and petrography show that the quality of concrete used for fabrication of Slab 4 was acceptable and was not the cause of Slab 4's failure, although air voids may have contributed to lowering the tensile strength of concrete.

We used the tested properties of the sling to evaluate the impact of slack in one of the slings on the stresses in the slab. For this purpose, we ran the model of Slab 4 assuming elastic slab material properties and using test-determined properties for the slings. We made two runs: a baseline run in which all slings had equal length of 3.05 m (120 in.) and a second run in which one of the slings had 50.8 mm (2 in.) slack, i.e., a length of 3.10 m (122 in.). 50.8 mm (2 in.) slack is much greater than our expected slack of a fraction of an inch. The result of our analysis showed that for an expected slack of a fraction of an inch, the stress demand in the slab is not appreciably different; therefore, we conclude that the expected differences in the length of slings were not a major contributing factor to the failure of Slab 4.

During the process of performing numerical analysis, we observed that the results of our 3D FE analysis, regarding failure occurrence, are sensitive to (i) the axial tensile strength of concrete used in the FE model (as expected) and (ii) impact of dynamic response of the slab after flexural cracking has developed. We also noted the discrepancies between hand calculations of flexural strength of the slabs and the FEA results. The analyses we performed use a value of concrete axial tensile strength between the results of split-disk tensile strength performed by SGH and NIST. Given its minor influence, the analyses do not account for differences in effective length of the four supporting slings. The discrepancies between hand calculations and FEA results are all related to assumptions and simplifications made for hand calculations.

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APPENDICES

1. INTRODUCTION

To determine the technical cause of the failure of a rectangular concrete slab that was being suspended by a lifting crane using four-point rigging at the National Fire Research Laboratory (NFRL) of the National Institute of Standards and Technology (NIST), NIST has issued a contract for Simpson Gumpertz & Heger Inc. (SGH), through Strativia LLC., to perform three-dimensional (3D) nonlinear finite element modeling and failure analysis of the failed slab as well as five other slabs with similar configuration but with different dimensions, reinforcements, and span lengths between rigging points. All six slabs to be modeled are composite one-way pan joist concrete on steel deck slabs with approximate plan dimensions of 3.66 m x 1.52 m (144 in. × 60 in.), three slabs; 2.87 m x 1.52 m (113 in. × 60 in.), two slabs; and 2.62 m x 2.44 m (103 in. × 96 in.), one slab. Three of the six slabs, including the failed, 3.66 m x 1.52 m (144 in. × 60 in.) slab, are cut-out sections from the test floor of the NFRL two-story test frame. The remaining three slabs are variations of the failed slab (failed slab but with shorter overall length, with added reinforcement, or with shortened rigging distance). Finite element analysis (FEA) was used to determine whether the loads that were observed to have been placed on the failed slab just prior to its failure, including the self-weight of the slab, the weight of a walk-behind floor saw that was being used to cut the slab, and the weight of the saw operator, would be sufficient to cause the observed failure in any of the slabs. This report presents the details of our 3D finite element analysis of the slabs and corresponding results.

We received and reviewed the available information gathered by NIST and conveyed to us by Dr. Long Phan. We visited the site, received additional information about the slabs and their loading and boundary conditions from the presentations by Dr. Stephen W. Banovic, and reviewed the events that led to the failure of Slab 4. We then performed a thorough inspection of the fracture surfaces of Slab 4 and all components of the rigging system and loadings related to Slab 4 failure. We made measurements of the geometry and took photographs of the concrete slab, steel deck, slings and their anchor systems, and reinforcements, including the rebars, welded wire fabric, and rebar chairs of Slab 4. We also inspected the successfully removed and intact Slab 3. During the visit, we also identified concrete samples to be cut from the Slab 4 remnants and a lifting sling, a lifting anchor, and a section of the rebar chair to be sent to the SGH laboratory for testing and evaluation. We performed petrographic examination; extracted cores from the concrete samples received; and tested concrete modulus, tensile and compressive strength, and stiffness of the sling.

Using the collected and verified data and the measured material properties, we developed 3D nonlinear finite element models of six composite concrete-steel deck slabs, with varying configurations, reinforcement details, and support conditions, and performed LS-DYNA analyses to determine whether the resulting stress conditions in these slabs would lead to their failure under loading conditions that included the slab self-weight and the weights of the operator and the FS400 LV rotary floor saw.

2. SCOPE OF WORK

2.1 Purpose

The purpose of this report is to present the results of our 3D high-fidelity finite element modeling and failure analysis of composite one-way pan joist concrete slab on steel deck.

The scope of work consists of a site visit (Task 1), using the collected and verified data to develop six finite-element models and performing analyses as listed below (Tasks 2 through 7), preparing a draft report to be submitted to NIST for review and comment, and preparing a final report that addresses all comments received from NIST (Task 8).

The modeling tasks are as follows:

- **Model 1 (Task 2)** – 3D nonlinear finite element modeling and failure analysis of Slab 4. For failure analysis of Slab 4, we constructed a detailed finite element model using material properties obtained from NIST and from testing of core samples from the remnants of the failed Slab 4 at SGH and subjected the model to the combined loading of the slab self-weight and the weights of the operator and the rotary floor saw that was being used to cut the slab to evaluate its potential for failure.
- **Model 2 Slab 3 (Task 3)** – 3D nonlinear finite element modeling of Slab 3. For structural evaluation of this slab, we adapted the Slab 4 model, incorporated the dimensions, reinforcement details, and support conditions of Slab 3, and subjected it to the same combined load of Slab 3's self-weight and weights of the operator and the rotary floor saw.
- **Model 3 Slab 2 (Task 4)** – 3D nonlinear finite element modeling of Slab 2. For finite element analysis, we made appropriate changes in the geometry, reinforcement details, and rigging distance of the Slab 4 model to match Slab 2 design, and we performed analysis to assess the damage and the failure likelihood of Slab 2 when subjected to the same loading and boundary conditions as Slab 4.
- **Model 4 Slab 4 Short (Task 5)** – 3D nonlinear finite element modeling of Slab 4-Short. To evaluate whether Slab 4 would still have failed had it been shortened to have the same length and rigging condition as for Slab 3, we shortened the Slab 4 model and subjected it to the same combined load of self-weight and weights of operator and rotary floor saw to evaluate its likelihood of failure
- **Model 5 Slab 4 Reinforced (Task 6) –** 3D nonlinear finite element modeling of Slab 4-reinforced. To evaluate whether Slab 4 would still have failed had it been reinforced similarly to Slab 2 (#4 bars at 0.305 m (12 in.) on center), we added steel

reinforcement to the concrete slab considered in the original Slab 4 model (Model 1, Task 2) and subjected it to the combined load of the slab's self-weight and weights of the operator and the rotary floor saw.

- **Model 6 Slab 4 Rigging (Task 7) –** 3D nonlinear finite element modeling of Slab 4 rigging. To evaluate whether Slab 4 would still have failed had the distance between rigging points in the primary direction of bending been shortened by 0.610 m (2 ft), we modified the rigging configuration of the original Slab 4 model (Model 1 (Task 2)) by moving the anchor points of the slings in the east and west sides toward the center of the slab by 0.305 m (12 in.) and subjected it to the combined load of the slab's self-weight and weights of the operator and the rotary floor saw.

The objective of the site visit was to gather information and to discuss the planned analysis with key NIST personnel on the following subjects:

- understand construction details,
- obtain material properties,
- understand the sequence of events that led to failure,
- inspect failed components and the structure from which they came, and
- identify failure modes, if possible.

3. REVIEWED DOCUMENTS

SGH received the following materials from NIST prior to our Task 1 site visit.

NIST Rebar: Test certificate of tensile testing of Coupon 1 using ASTM E8 test method and stress-strain data for#3 Rebar (ASTM A615), Element Materials Technology, Newton, Massachusetts (MA), 6 January 2021.

NIST Rebar: Test certificate, Export Administration Regulations (EAR) Controlled Data of tensile testing of Coupon 2 using ASTM E8 test method and stress-strain data for #3 Rebar (ASTM A615), and stress-strain data of #3 Rebar (ASTM A615), Element Materials Technology, Newton, MA, 6 January 2021.

NIST Steel Deck: Test Certificate, EAR Controlled Data of Coupon 1 using ASTM E8 test method and stress-strain data for 20 gage Steel Deck (C6-Steel Deck 1), Element Materials Technology, Newton, MA, 6 January 2021.

NIST Steel Deck: Test Certificate, EAR Controlled Data of Coupon 2 using ASTM E8 test method and stress-strain data for 20 gage Steel Deck (C6-Steel Deck 2), Element Materials Technology, Newton, MA, 6 January 2021.

Vulcraft, “Steel Roof & Floor Deck” Nucor Vulcraft/Verco Group brochure, 2018.

NIST Wire Mesh: Test Certificate – EAR-Controlled Data of coupon 1 using ASTM E8 test method and stress-strain data for wire from welded wire mesh (C10-Wiremesh 1), element materials Technology, Newton, MA, 6 January 2021.

NIST Wire Mesh: Test Certificate – EAR-Controlled Data of coupon 1 using ASTM E8 test method and stress-strain data for wire from welded wire mesh (C10-Wiremesh1), Element Materials Technology, Newton, MA, 6 January 2021.

NIST Wire Mesh: Test Certificate – EAR-Controlled Data of coupon 2 using ASTM E8 test method and stress-strain data for wire from welded wire mesh (C10-Wiremesh2), Element Materials Technology, Newton, MA, 6 January 2021.

Banovic, Stephen, “Direct Cause of Incident Presentation,” November 2022.

Phan, Long T. “Material Properties and Information for 3D- FE Modelling” November 2022.

4. SITE INSPECTION

On 16 November 2022, Mehdi Zarghamee and Robert MacNeill travelled from Boston to the NIST campus in Gaithersburg, Maryland, for a firsthand inspection of the failed slab, the details of loading at the time of failure, and the tools and equipment used for supporting and lifting the slab. During our inspection at NIST headquarters, Dr. Long T. Phan and Dr. Stephen W. Banovic of NIST accompanied us. Our visit included an initial presentation by Dr. Banovic followed by our inspections of the two-story fire test frame in the NFRL where the fire test was conducted.

4.1 Slab Removal Process

In his presentation, Dr. Banovic told us the following:

- The fire test frame was built in 2019.
- Three tests were completed; these tests are identified as CF1, CF2, and CF3.
- At the end of test CF3, the fire test floor was demolished and removed piece by piece.
- Later, the peripheral slabs on the surrounding floor were also removed. Each peripheral slab was removed through a sequence of through-thickness cuts around its edge using a rotary floor saw. Before the slabs were completely cut, their weight was supported by four 3.05 m (10 ft) long circular slings that were anchored to points near the corners of the slabs. The slings were supported by an overhead crane. The operator and rotary floor saw's weights remained supported by the floor structure until perimeter cutting was completed and the slab's weight was supported by the slings.
- Slabs 1 and 2 were successfully removed, but there is no video evidence of those efforts. Slab 3 was first removed successfully by drilling holes near the corners, attaching circular slings, and making the perimeter cuts to lower the slab onto the floor of the laboratory. We understand that the fully cut and sling-suspended Slab 3 remained intact after the operator and rotary floor saw traversed its shorter length.
- Slab 4 removal occurred on 26 September 2022 using the same process that had been successfully used to remove Slab 3. After cutting the entire perimeter of Slab 4 so that it became solely supported by the slings and overhead crane, the operator moved onto the center of the suspended slab from the southern edge. He then began to back the rotary floor saw onto the slab, also from the southern edge. Slab 4 failed as soon as the rotary floor saw weight was rolled onto the slab. The details of the failure were documented by NIST.

- Figure 4-1 shows the location of the test floor (south central) and perimeter slabs to be cut and removed (designated 1 to 8) on the surrounding floor of the test frame.

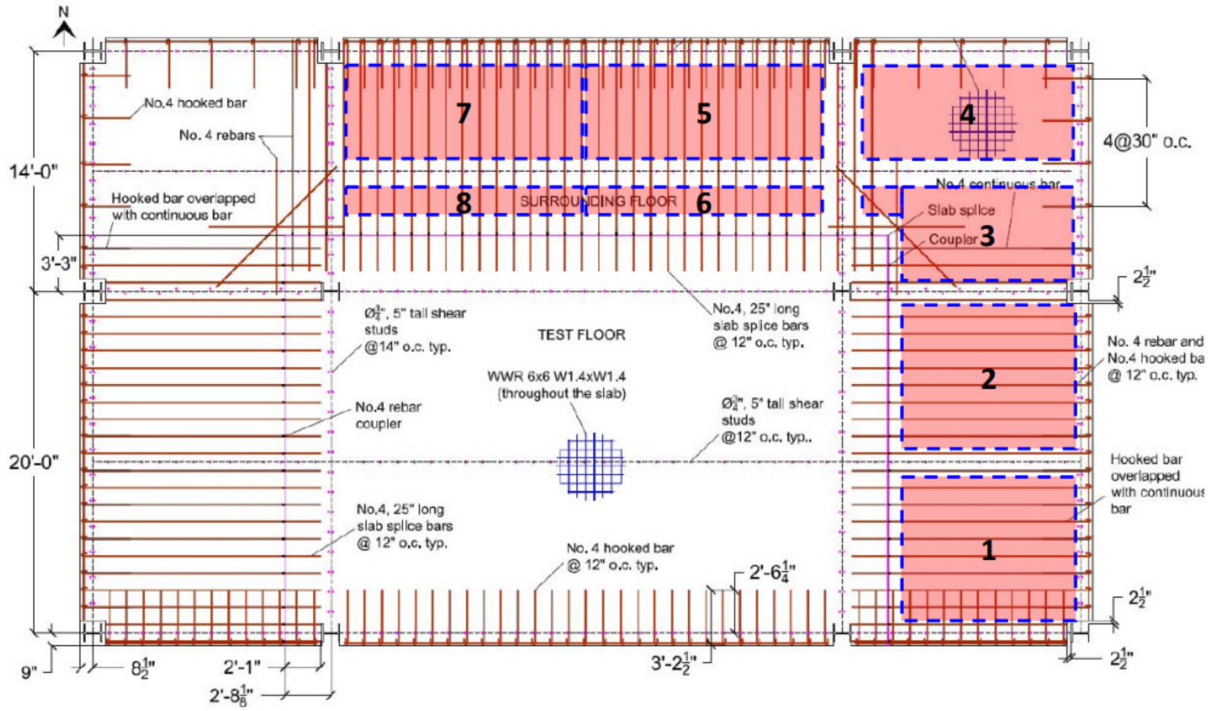


Figure 4-1 – Plan view of test floor, surrounding floor, and perimeter slab removal areas. (1 in. = 25.4 mm and 1 ft = 0.305 m)

4.2 Slings

- The slings are completely circular slings 3.05 m (10 ft) in length. The sling in flat position is approximately 7.6 mm (0.3 in.) thick and 63.5 mm (2.5 in.) wide.
- After drilling the holes near the corners of a slab, the anchors were installed; the anchors consist of a steel bolt with a plate placed on the underside of the slab with a nut.
- The sling was tied using a choker method to the anchor. The other end of the circular sling was placed in the hook of a crane. The four slings that connect the crane hook to the slab anchors ended up on top of each other. As a result, the effective lengths of the four slings are different, and the lengths of the four slings are off by 0 mm (0.0 in,), 7.6 mm (0.3 in.), 15.2 mm (0.6 in.), and 22.9 mm (0.9 in.).
- No failure of any sling or anchor was experienced.
- Figure 4-2 shows a drilled hole and sling anchor, load capacity markings on the anchor, sling configured for a choker attachment, and load capacity markings on the sling.

Figure 4-2 – Drilled hole for anchoring sling, load capacity marking on anchor, sling attachment as choker, marking on sling showing a capacity of 3,040 kg (6,700 lbf).

4.3 Rotary Floor Saw

- Saw cutting of Slab 4 occurred on 26 September using a Husqvarna FS400 LV rotary floor saw. When the saw cuts were completed, the weights of the slab, rotary floor saw, and the operator were supported by the four circular slings. The rotary floor saw containing water and gasoline was moved on the slab. The operator moved toward the center of the slab from south to north.

- As soon as the weights of operator and the rotary floor saw were on Slab 4, the slab failed. The failure mode of Slab 4 was flexure, with a transverse crack forming though the thin part of the slab (in N-S direction) just near the mid-length of the long side of slab.

- The rotary floor saw rear wheels are approximately 0.43 m (17 in.) apart, and the front wheels are 0.20 m (8 in.) apart, with the front and rear wheel axles spaced 0.38 m (15 in.).

- The rotary floor saw without water or gasoline is 106 kg (234 lbf), and with water and gasoline it increases by 39 kg (86 lbf) for a fully loaded 145.1 kg (320 lbf). At the time of failure, we assume that the total weight of the rotary floor saw was 116.8 kg (257.5 lbf) based on the rotary floor saw weight measured by NIST after the slab failure event.

- The sequence of cutting is shown in the NIST presentation of Cause of Failure (Appendix D).

- Figure 4-3 shows the rotary floor saw used for cutting slabs.

Figure 4-3 – Husqvarna FS400 LV Rotary Floor Saw.

4.4 Slab

- The total concrete slab thickness is 159 mm (6.25 in.), consisting of a 76 mm (3 in.) thick joist (rib, or flute) and 83 mm (3.25 in.) thick concrete topping.

- The steel deck (Vulcraft 3VLI) is 20 ga (0.909 mm (0.0358 in.) thick) with geometry shown in Figure 4-4. The concrete mix description is a lightweight concrete mix with high polymer fiber content dated 16 April 2019 with mix design shown in Table 4-1.

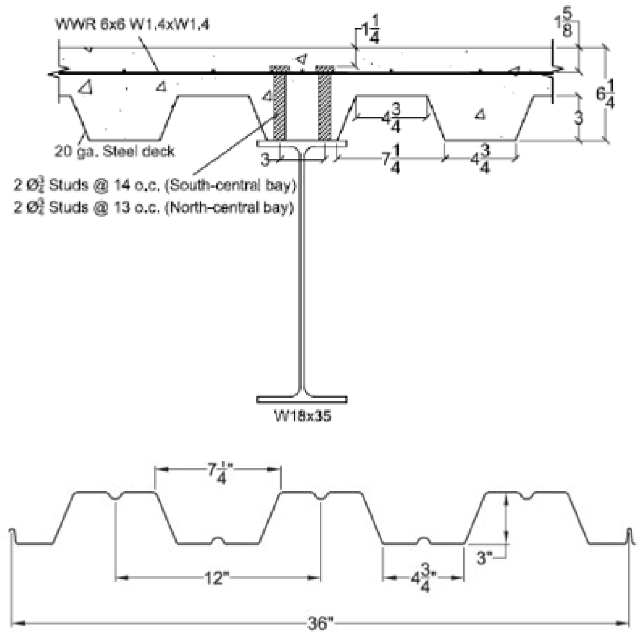


Figure 4-4 – Steel deck geometry. (1 in. = 25.4 mm and 1 ft = 0.305 m)

Table 4-1 – Mix Design of Concrete (1 in. = 25.4 mm, 1 lb. 0.454 Kg, and 1 oz = 29.6 ml)

w/cm: 0.41 **Slump:** 5.5 ± 1.0 inch

	Material	SSD
Cement:	ASTM C-150: Type I/II Lehigh	560
Fly Ash:	ASTM C-618: Separation Technologies Class F	140
Aggregate:	ASTM C-33: Carolina Stalite LTWT	890
Sand:	ASTM C-33: Chaney Sand	1372
Air:	2.5%	
Water:	ASTM C-1602; ASTM C-1603	284
Admixture:	See Below	10
	Total	3256
	Unit Weight (pcf)	120.6
	Calculated Equilibrium Dry Density (pcf)	115.7

Admixtures

FRC MONO-150 - 4 lb/cy
Sika Viscocrete 2100 - 3 ± 3 oz/cwt
Sika Plastocrete 161 - 5 ± 2 oz/cwt
SikaTard 440 - 2 ± 2 oz/cwt
Sika ViscoFlow 2020 - 4 ± 2 oz/cwt

The mechanical properties of concrete as measured by NIST are shown in Table 4-2.

Table 4-2 – Mechanical Properties of Concrete Measured by NIST (1 MPa =145.04 psi)

Lightweight concrete with design f'c = 4000 psi (28 MPa)
+ monofilament polypropylene microfibers (2.37 kg/m^3)

Measured within one week after fire testing

Description	Test #1 Slab	Test #2 Slab	Surrounding Slab
Curing period prior to fire testing	163 d (5 mo 10 d)	140 d (4 mo 17 d)	645 d (1 yr 9 mo 6d)
Compressive strength (MPa)	**67 ± 3**	**78 ± 1**	63 ± 1
Splitting tensile strength (MPa)	3.4 ± 0.4	3.6 ± 0.4	3.0 ± 0.3
Static modulus (GPa)	27 ± 1	25 ± 1	25 ± 0.2
Bulk density (kg/m^3)	1930 ± 7	1948 ± 22	1911 ± 10
Moisture content (% mass)	**7.5 ± 0.5**	**5.7 ± 0.3**	7.7 ± 0.2
Thermal conductivity, W/m·K	2.2 ± 0.2	2.2 ± 0.3	2.2 ± 0.1
Specific heat, J/kg·K	963 ± 62	797 ± 65	887 ± 47

4.5 Reinforcement Properties

The following are test methods and mechanical properties of the steels provided by NIST. For the rebars, #3 bars were tested, and the properties obtained are used for modeling of #4 rebars in the slabs.

- The steel rebars are ASTM A615. Two #3 rebars were tested in accordance with ASTM E8 and found to have an average 0.2% offset yield strength of 477.5 MPa (69.25 ksi), an average ultimate strength of 768.8 MPa (111.5 ksi), an average elongation of 21.5% and an average reduction in cross-section area of 51.5%, and an average modulus of elasticity of 187.9 GPa (27.246 msi).

- The steel deck steel samples were tested, and the average 0.2% offset yield strength is 403 MPa (58.5 ksi), average ultimate strength is 472 MPa (68.5 ksi), average elongation 25.7%, and average modulus of elasticity 196.2 GPa (28.453 msi).

- Samples of the wire mesh were also tested and found to have an average 0.2% yield strength of 755 MPa (109.5 ksi) and ultimate tensile strength of 789.5 MPa (114.5 ksi), with 15% elongation and 56.5% reduction in cross-sectional area and a modulus of elasticity of 138.0 GPa (20.010 msi).

4.6 Observations and Measurements

We performed detailed observations and measurements on the following items:

- We observed all pieces of the failed reinforced concrete Slab 4 and the intact and removed Slab 3, verifying the dimensions shown on drawings provided by Drs. Phan and Banovic.

- We observed flexural fracture surfaces across the thin section of the concrete slab at mid-length of the failed Slab 4. Our examination of fracture surface revealed no anomaly that differed from the expected features of flexural failure of the slab. Compression failure marks were observed along the top of the fracture surfaces that run in the north-south direction. Parts of the rebar chairs were visible at all fracture surfaces near the bottom surface of the slab in the tensile side of the slab. We performed detailed measurements of the geometry and locations of rebar chairs.

- We observed and made measurements of the relative locations of all wheels and axles of the rotary floor saw.

- We made detailed observations and verifying measurements on samples of the slings. The slings did not show any sign of distress. Their circular length when flattened was 3.05 m (10 ft) long. We measured their thickness when flattened and we obtained a value of 7.6 mm (0.3 in.).

- We observed welded wire fabric and rebar reinforcement used in fabrication of slabs.

- We marked three pieces of concrete on fractured parts of Slab 4 and a complete sling and requested NIST to cut and ship them to SGH laboratory for mechanical testing and petrography.

5. LABORATORY TESTING AT SGH

5.1 Samples Received by SGH

We received a pallet of materials from NIST on 29 November 2022, which included three concrete slab samples cut from Slab 4 identified as 4B-1 (Photo 5-1), 4D-1 (Photo 5-2), and 4E-1 (Photo 5-3), a sling manufactured by SpanSet for lifting the slab (Photo 5-4), a lifting anchor (Photo 5-5), a reinforcement chair (Photo 5-6), and multiple small-diameter concrete core sections (Photo 5-7). Appendix A presents photographs of the slab samples received at SGH and the specimens at various stages of the testing process. Due to structural failure and subsequent additional damage after the failure, Slab 4 broke into five pieces, along the line of transverse (north-south) cracks, which are marked as A, B, C, D, and E in Figure 5-1. The approximate location of the Slab 4 concrete slab samples in the overall slab layout is also shown in Figure 5-1.

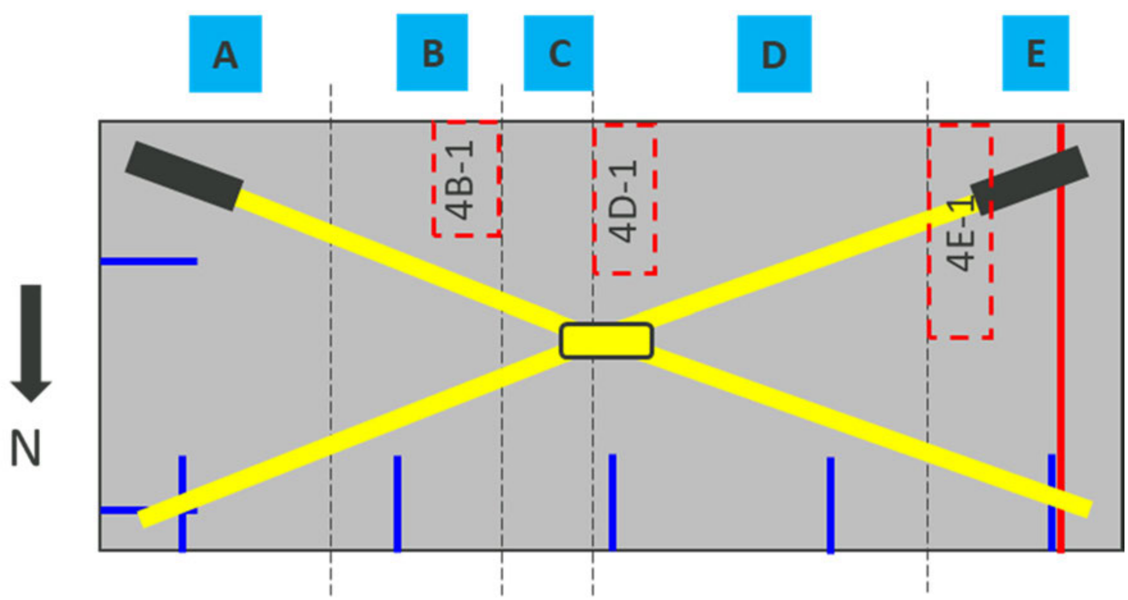


Figure 5-1 – Plan view looking down at the incident slab and indicating the location of slab samples 4B-1, 4D-1, and 4E-1 with respect to the incident failure pattern.

The scope of our physical testing and material evaluation work in support of this effort included the following:

- Mechanical testing of the lifting sling to obtain the tensile stiffness for constitutive models in FEA (see Section 5.2). We used a hot knife to cut a 0.61 m (24 in.) long section from the 3.05 m (10 ft) long looped sling for tension testing (Photo 5-8).

- Mechanical testing of concrete core specimens to obtain material property inputs for constitutive models in FEA (see Sections 5.3 and 5.4). We used a 79.4 mm (3-1/8 in.) outer diameter coring bit to extract an approximately 0.305, (12 in.) long cylindrical specimen from sample 4B-1, 4D-1, and 4E-1 (Photos 5-9 through 5-11). A schematic illustrating the cutting and core procedure for a representative concrete slab sample is shown in Figure 5-2. The core locations were positioned in regions of the slab that would not include any steel reinforcement. From each 0.305 m (12 in.) long core, we prepared two core specimens that were approximately 0.152 m (6 in.) long for mechanical testing. One core specimen was used for splitting tensile testing per ASTM C496 [1], and the other core specimen was used for compression testing to measure the elastic modulus and ultimate compressive strength per ASTM C469 [2] and ASTM C39 [3], respectively. As a result, six core specimens were tested: three in compression and three in split disk tension.

- Petrographic analysis of concrete was performed on 102 mmx 152 mm (4 in. x 6 in.) petrographic specimens removed from Slab 4 pieces 4D-1 and 4E-1 (see Section 5.5). We conducted our petrographic examinations in accordance with the applicable procedures outlined in ASTM C856 [4] From each petrographic specimen, we prepared:

    - A polished sample of 25 mm to 38 mm (0.98 in. to 1.5 in.) thickness that encompassed the entire slab depth for evaluating the general features, overall condition, and composition of the hardened concrete. We examined the polished sections with the aid of a reflected-light stereomicroscope at magnifications of 6.5X to 50X.
    - A blue-dyed epoxy-impregnated ultrathin (20μm to 25μm thick) section for a more detailed assessment of the composition and quality of the hardened concrete. In addition, we identified any materials-related distress mechanisms, such as alkali-silica reactivity (ASR) or sulfate attack, if present. We examined the prepared ultrathin sections using a transmitted-light polarizing microscope at magnifications of 25X to 400X.
    - A remnant section that was broken using a small sledgehammer to produce freshly fractured surfaces for microscopic examination. We examined the laboratory-induced fractured surfaces with the aid of a reflected-light stereomicroscope at magnifications of 6.5X to 50X.

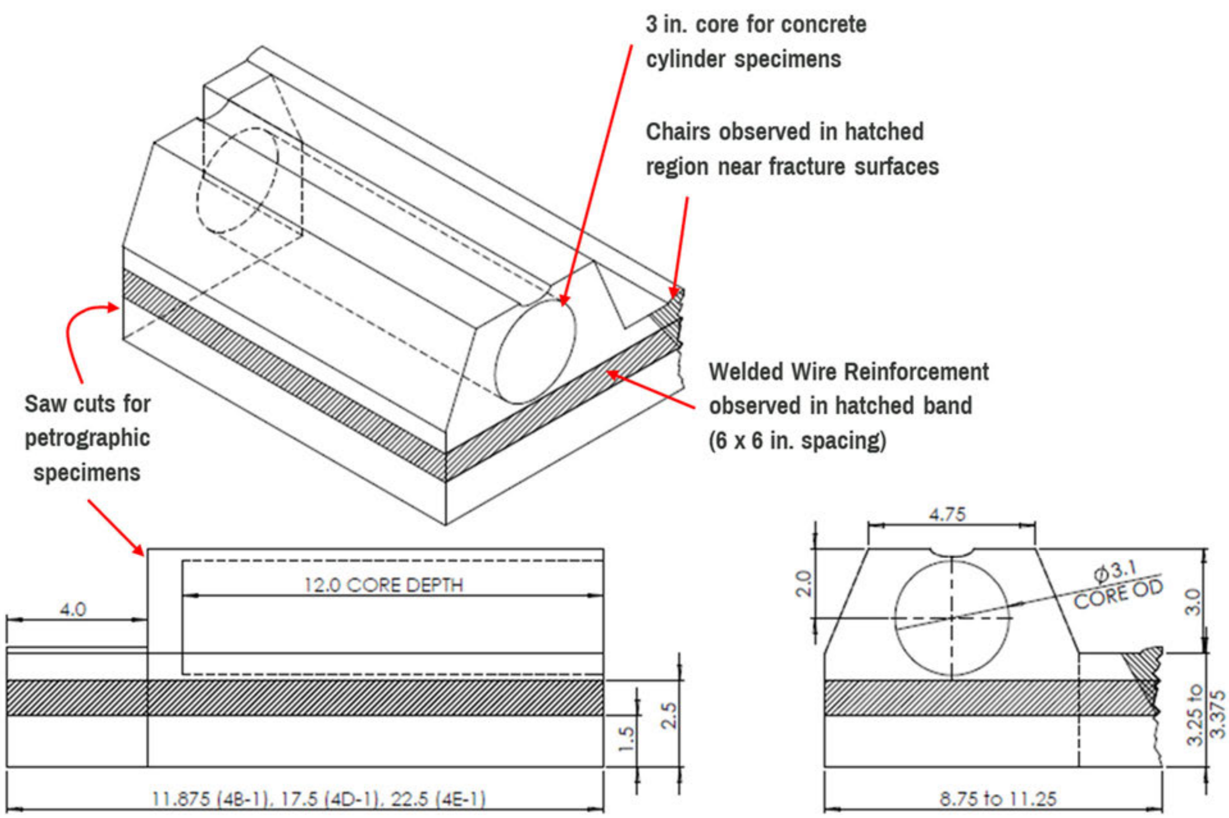


Figure 5-2 – Schematic of concrete cores and saw cuts used to extract specimens for mechanical testing and petrography from Slab 4 samples. (1 in. = 25.4 mm)

5.2 Stiffness Test of Slings

The ends of the sling were gripped with hydraulic wedge action grips using our Instron testing machine, resulting in an 18.125 in. long gauge section between the grips for tension testing (Photo 5-12). We loaded the sling section from 0 to 20 kN (4,500 lbf). This process was repeated four times, with two cycles at 2.54 mm (0.1 in.) per minute and two cycles at 25.4 mm (1.0 in.) per minute. Deflection was measured by the displacement of the machine crosshead and was adjusted to be zero at 44 N (10 lbf) to remove the initial slack in the sling. The resulting load-deflection behavior is shown in Figure 5-3 and Figure 5-4, which both show little sensitivity to loading rate in the range tested.

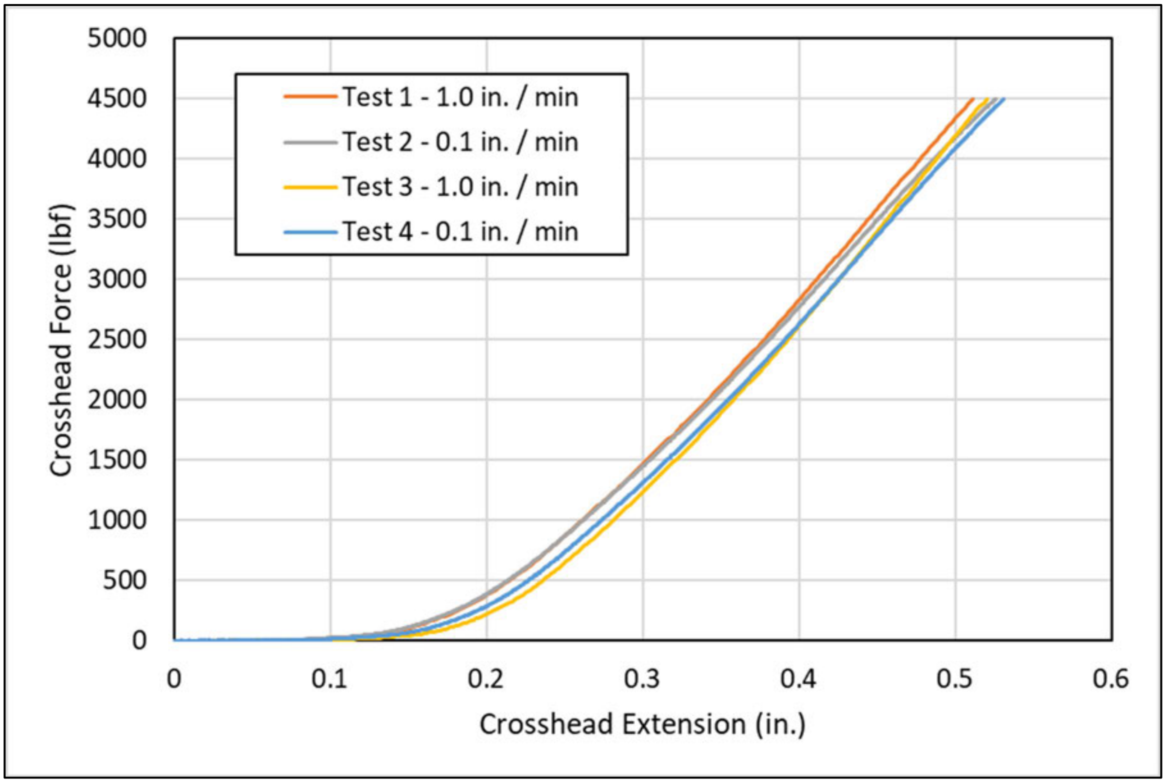


Figure 5-3 – Tension force versus cross head extension. (1 in. = 25.4 mm, 1 lbf = 0.454 kg)

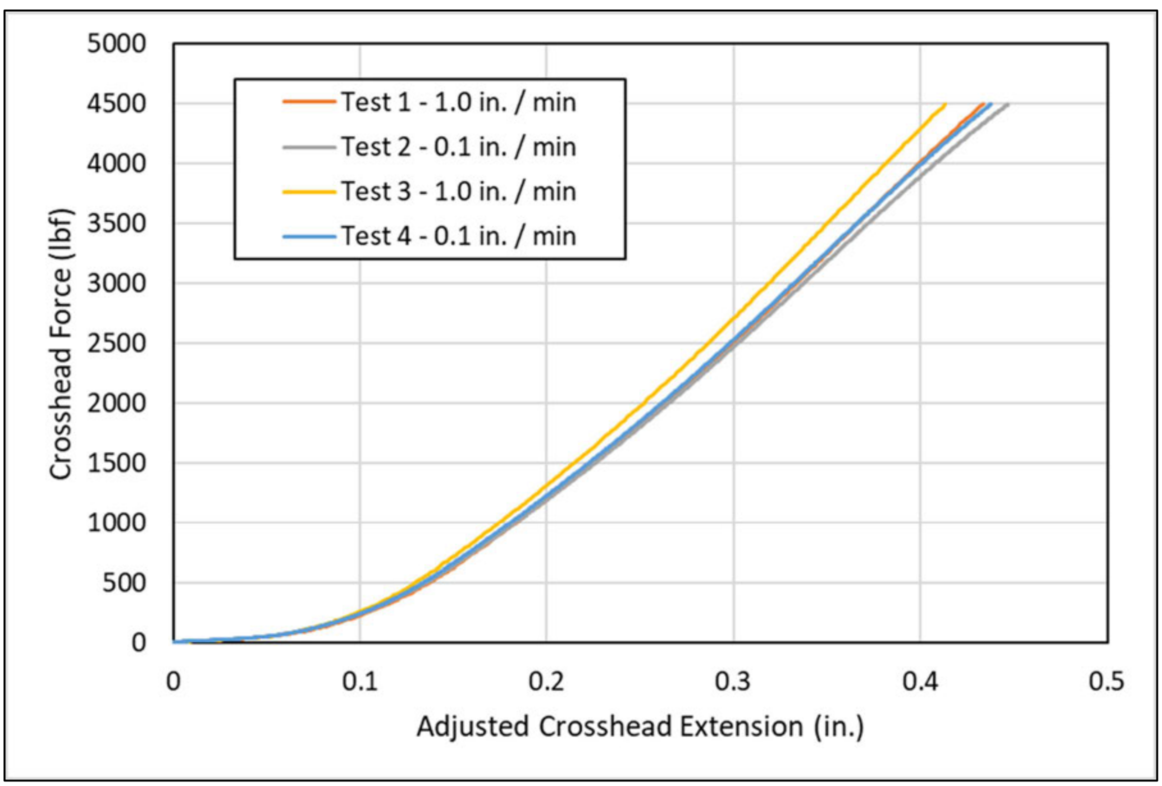


Figure 5-4 – Tension force versus cross head extension after adjustment to read zero displacement at 4.535 kg (10 lbf) tensile force. (1 in. = 25.4 mm, 1 lbf = 0.454 kg)

5.3 Split Tensile Strength of Concrete

We performed split tensile testing according to ASTM C496 [1] for the core specimens extracted from slab samples 4B-1, 4D-1, and 4E-1. Testing was performed with a Forney compression testing machine at a loading rate of 1.0 MPa (145 psi) per min. The splitting tensile strength (T) of the specimen was evaluated using:

$$T = \frac{2P}{\pi l D} \qquad \text{(Eq. 1)}$$

where P is the maximum applied load, l is the average measured specimen length, and D is the average measured specimen diameter. Photo 5-13 shows a representative core specimen prior to testing, and Photos 5-14 through 5-16 show the three core specimens after the peak load was achieved. Fibers in the concrete mix prevented the complete separation of the cracked specimens at peak load, but we applied further loading to core specimen 4D-1 to separate the broken halves as shown in Photo 5-17. We observed the fracture surface and found more than 80% of the aggregates fractured, indicating good bonding between the matrix and aggregate. A summary of the split tensile results is provided in Table 5-1, with an average split tensile strength of 70.6 kN (15.9 kip), resulting in an average split tensile strength of 4.5 MPa (650 psi).

Table 5-1 – Summary of Split Tension Core Specimen Testing by SGH
(1 MPa =145 psi, 1kN = 225 lb., and 1 mm =0.0394 in.)

Specimen ID	Avg. Dimensions		ASTM C496 Split Tensile			
	Diameter (mm)	Length (mm)	Peak Load (kN)	Split Tensile Strength (MPa)	Break Type	Estimated Fractured Aggregate
4B-1	68.53	136.4	71.1	4.84	Diagonal	>80%
4D-1	68.45	151.4	70.6	4.33	Vertical	
4E-1	68.45	147.0	70.1	4.43	Vertical	

5.4 Unconfined Compression Testing of Concrete Strength and Modulus

We performed unconfined compression testing to measure the elastic modulus per ASTM C469 [2] and ultimate compressive strength per ASTM C39 [3] from core specimens extracted from slab samples 4B-1, 4D-1, and 4E-1. Testing was performed with a Forney compression testing machine at a loading rate of 0.25 MPa (36 psi) per sec.

We measured longitudinal compressive strain using a Humboldt compressometer with a linear variable displacement transducer (LVDT) for continuously measuring deformation. The compressometer had a gauge length of 101.6 mm (4 in.) and rotating yoke design where the specimen deformation was one-half of the recorded LVDT displacement. Elastic modulus testing of each specimen consisted of three loading cycles ranging from 0 MPa up to 40% of the ultimate compressive strength, with the first cycle used to verify compressometer performance and specimen alignment, and stress-strain measurements are recorded in the two subsequent loading cycles. We calculated the chord modulus of elasticity (E) from loading cycles 2 and 3 data using:

$$E = \frac{S_2 - S_1}{\varepsilon_2 - 50\ \mu\varepsilon} \qquad \text{(Eq. 2)}$$

where S_2 is the stress corresponding to 40% of ultimate load, ε_2 is the strain at 40% of ultimate load, and S_1 is the stress corresponding to the strain of 50 με. Photo 5-18 shows a representative specimen with attached compressometer for elastic modulus evaluation.

After elastic modulus testing was performed, we removed the compressometer and loaded the specimen to failure in uniaxial compression to measure the ultimate compressive strength. We calculated the compressive strength ($f'c$) using:

$$f'c = \frac{4P}{\pi D^2} \qquad \text{(Eq. 3)}$$

where P was the maximum load and D was the average measured diameter of the specimen. No correction factor for the ultimate load was applied because the length-to-diameter ratio exceeded 1.75. Photos 5-19 through 5-21 show the three core specimens after the peak load was obtained.

For each concrete core specimen, we measured the dry density using the procedure defined in ASTM C39 [3]. A summary of the physical specimen measurements for the three compression specimens is provided in Table 5-2, and a summary of the compressive elastic modulus and ultimate compressive strength is provided in Table 5-3. For the Slab 4 concrete material, we measured an average elastic modulus of 25.3 GPa (3.67 msi) and ultimate compressive strength of 54.7 MPa. (7.93 ksi) The average dry density of the three specimens tested was 1,861 kg/m^3 (116.2 pcf).

Table 5-2 – Physical Properties of Compressive Concrete Core Specimens (1mm = 0.0394 in., 1 Kg = 2.20 lb. and 1 Kg/m^3 = 0.0624 pcf)

Specimen ID	Diameter (mm)	Length (mm)	Length / Diameter	Area (mm.^{2})	Mass (kg)	Density (kg/m^3)
4B-1	67.8	150.1	2.21	3612	1.005	1853
4D-1	68.6	150.1	2.19	3694	1.030	1858
4E-1	68.7	150.4	2.19	3708	1.044	1873
Average	68.4	150.2	2.20	3671	1.026	1861

Table 5-3 – Mechanical Properties from Uniaxial Compression Testing of Concrete Core Specimens (1 kN = 225 lb. and 1 MPa = 145 psi)

Specimen ID	ASTM C469 Modulus of Elasticity			ASTM C39 Compressive Strength	
	Cycle 2 (GPa)	Cycle 3 (GPa)	Average (GPa)	Peak Load (kN)	f'c (MPa)
4B-1	26.1	26.0	26.1	208	57.5
4D-1	24.9	25.1	25.0	197	53.4
4E-1	25.1	24.8	24.9	198	53.4
Average	25.4	25.3	25.3	201	54.8

5.5 Concrete Petrography

A detailed description of our concrete petrography procedures, images, and observations is included in Appendix B. A summary of the results of our examination of petrographic specimens extracted from the Slab 4 concrete is as follows:

- The concrete contains 19 mm (3/4 in.) maximum-sized crushed, lightweight, expanded shale and/or expanded slate as coarse aggregate and natural sand composed of quartz, chert, and quartzite as fine aggregate. The aggregate particles are well distributed throughout the samples (Photo 5-22).

- The paste is well-hydrated and contains portland cement, fly ash, and typical hydration products (Photo 5-23). The concrete exhibits a moderate water/cementitious material (w/cm) ratio of 0.40 to 0.50.

- The concrete also contains polymeric microfibers that are well distributed throughout the concrete mix with no observed regions of fiber clumping (Photo 5-24).

- The paste-to-aggregate bond is tight, as laboratory-induced fractures extend primarily through aggregate particles and not along the boundaries of the aggregates (Photo 5-25).

- The concrete contains entrapped and entrained air voids, with an estimated total air content of 4% to 7%. The air voids are not uniformly distributed (Photo 5-26). We also observed localized zones that exhibit large (between 3.18 mm to 6.35 mm (1/8 in. to 1/4 in.) diameter, irregularly shaped voids. These larger voids may represent localized zones of less-than-optimal consolidation and weaker tensile strength. However, areas of widespread, large, interconnected voids (i.e., honeycomb), were not observed.

- We observed a porous zone in the uppermost 1.59 mm to 9.53 mm (1/16 in. to 3/8 in.) of concrete, where the paste is lighter gray in color, marginally softer, and exhibits a higher water-to-cementitious materials (w/cm) ratio compared to the interior portions of concrete (Photo 5-27). Bleed water channels extend through this surface paste zone. The presence of bleed-water channels extending through this zone indicates that the concrete was finished before bleeding ended.

5.6 Summary

Based on the results of the tests performed at the SGH laboratory on the samples we identified during our site visit to NIST, including petrographic examination, concrete modulus test, tensile strength test, and compressive strength test, we can conclude that the quality of concrete used for fabrication of Slab 4 was acceptable and was not the cause of Slab 4's failure. We observed air voids and other anomalies that may have contributed to lowering the tensile strength of concrete compared to the expected tensile strength from the measured compressive strength.

6. STRUCTURAL ANALYSIS

6.1 Slab Bending Capacity

We performed hand calculations per ACI 318 [5] to evaluate the flexural capacity of the different slab designs that would be modeled using finite element analysis. For this purpose, we modelled the slab as a beam subjected to the distributed self-weight and concentrated loads at midspan equal to the weights of operator and rotary floor slab, as shown in Figure 6-1. The critical section of this beam is the thin reinforced concrete section, between the joists, over the top of the steel deck. Table 6-1 summarizes the unfactored demand, unfactored capacity, and unfactored demand-to-capacity (D/C) ratios for the different slab conditions that were analyzed. Our hand calculations approximate the lifted slab as a simply supported beam with total length L, distance between the edge-of-slab and sling anchors in the east-west direction L_a and L_c, width in the north-south direction b_w, thickness $t = 8.25\ cm$ (3.25 in.), and depth of steel reinforcement from the top surface $d = 4.13\ \mathrm{cm}$ (1.625 in.). For each slab configuration, we calculate the cross-sectional area of steel reinforcement A_s, the minimum steel reinforcement required by ACI 318 for ensuring a tension-controlled failure $A_{s,min}$, the total unfactored demand at the slab mid-span from self-weight of slab and concentrated loads from the rotary floor saw and operator M_u, the capacity of the concrete above the steel deck in tension $\mathbf{M_{cr}}$, and the capacity of the slab at yielding M_y. Concrete crushing is assumed to occur simultaneously with yielding of tensile reinforcement for all six models due to the limited depth of the compression zone, which results in high compressive stress that is equivalent to the tensile force required to yield the rebars in the tension zone. The details of different slab geometry and reinforcement layouts are described in Section 6.2, with detailed hand calculations provided in Appendix C.

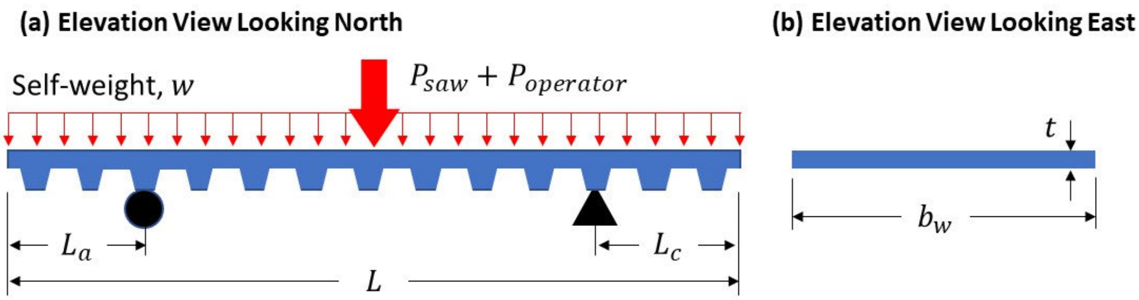


Figure 6-1 – Slab modeled as a beam used for hand calculation of flexural capacity.

Table 6-1 – Summary of Slab Capacity Hand Calculations
(1 in. = 25.4 mm, 1 kip-ft = 1.356 kN-m)

Task No.	Model Description	Slab Properties					Demand	Capacity			D/C Ratio		Comment
		L (in.)	L_a (in.)	L_c (in.)	b_w (in.)	A_s (in.^{2})	M_u (Kip-ft)	$A_{s,min}$ (in.^{2})	M_{cr} (Kip-ft)	M_y (Kip-ft)	$\frac{M_u}{M_{cr}}$	$\frac{M_u}{M_y}$	
2	Baseline Slab 4	144	11.63	11.75	60	0.14	4.19	0.43	4.18	1.16	1.00	3.63	[1]
3	Slab 3	113	20.75	11.63	60	0.53	1.97	0.43	4.18	4.29	0.47	0.46	[2,3]
4	Slab 2	103	12.0	12.0	96.5	1.80	2.73	0.69	6.71	14.06	0.41	0.19	[2,3]
5	Slab 4 short	113	20.75	11.63	60	0.14	1.97	0.43	4.18	1.16	0.47	1.70	[1,3]
6	Slab 4 reinforced	144	11.63	11.75	60	1.12	4.19	0.43	4.18	8.78	1.00	0.48	[2]
7	Slab 4 rigging	144	23.63	23.75	60	0.14	2.50	0.43	4.18	1.16	0.60	2.16	[1,3]

[1] Slab does not meet ACI 318 requirements for minimum flexural steel reinforcement. If the concrete cracks in tension ($M_u > M_{cr}$), i.e., demand is greater than cracking moment, the steel reinforcement yielding capacity is significantly exceeded ($M_u \gg M_y$), i.e., demand is greater than yield moment, and a sudden brittle failure is expected.

[2] Slab has additional #4 steel reinforcement ($A_s > A_{s,min}$), ensuring a ductile tension-controlled failure mode. No failure occurs for given loading because $M_y \gg M_u$.

[3] Ultimate demand has been reduced by changing the slab geometry and boundary locations. The concrete is less likely to crack in tension because $M_{cr} \gg M_u$.

6.2 Finite Element Modeling

6.2.1 Modeling Approach

An explicit nonlinear dynamic finite element (FE) modeling approach using LS-DYNA [6] was selected. This approach accounts for quickly changing conditions or discontinuous events, such as concrete cracking and crushing that may be expected in the slab under the given loads. In the following sections, the major modeling assumptions are listed, and the slab model's components are described in detail.

6.2.2 Major Modeling Assumptions

Major modeling assumptions used in the finite element model include:

- Regions around sling anchor points were not modeled in detail since no failure was observed in the slings or in the concrete around the anchor points; each sling was attached to a single node on top of the concrete slab, and the concrete material surrounding anchor points was made elastic.

- Slab rebars and chairs were assumed to have mechanical properties of #3 rebar which was tested by NIST [7]. Steel mechanical properties were simplified to an elastic-plastic bilinear response with post-yield strain hardening. Steel elastic properties and mass density selected are elastic modulus E_{steel} = 200 GPa (29 msi), Poisson's ratio ν = 0.3, and mass density ρ_{steel} = 7,800 kg/m^3 .(487 pcf). Plastic properties were established using the yield strength, ultimate strength, and ultimate strain from test data provided by NIST [7], resulting in a plastic tangent modulus of 1.1 GPa (159 ksi) for the welded wire mesh, 2.3 GPa (334 ksi) for the chairs and rebar, and 0.8 GPa (116 ksi) for the deck.

- Concrete tensile failure strain ϵ_f was taken as 11 times $\epsilon_t = f_t/E_{concrete}$ where f_t is the uniaxial tensile strength (see discussion on variability of split-disk tensile strength in Sec. 6.2.3.1) and $E_{concrete}$ is the concrete elastic modulus [8].

- Analysis of Slab 4 (Model 1, Task 2) showed that differential sling lengths introduced by slacking did not significantly change the maximum tensile stress at minimum slab thickness near the midspan (Appendix E). Therefore, differential sling tension among the four slings is not considered a primary factor contributing to failure. We assumed that all slings were exactly 3.05 m (10 ft) long when unloaded and with zero slack. Any differential sling slack will increase the demand on one or more slings.

- We assumed that there is no positive connection between the concrete slab and steel deck [9], except for a limited number of nodal vertical translation constraints that were applied between the steel deck and concrete slab on the north and south sides to prevent the steel deck from artificially separating from the concrete slab during gravity loading. The effect of screws between steel deck and concrete slab was ignored.

6.2.3 Model Components

6.2.3.1 Slab

Concrete slab mechanical properties were based on laboratory tests performed by NIST and by SGH as described in Section 4 and 5. The slab is divided into two material zones:

- A mid-span zone over which damage and cracking were determined to occur. Here, the Karagozian and Case (K&C) concrete damage or MAT72_REL3 model [10] is applied. The material parameters correspond to a compressive strength f'_c of 54.7 MPa (7,933 psi) and uniaxial tensile strength f_t of 3.27 MPa (474 psi). The differences in split tensile strength of concrete measured independently by NIST as 3.0 MPa (435 psi), see Table 4-2) and SGH (653 psi (4.5 MPa), see Table 5-1 and Section 5.3) and the results of petrographic observations are indicative of variability in the tensile strength of concrete. The split disk tensile strength provides values that are greater than the uniaxial tensile strength, and a reduction factor of 0.9 is used to adjust the split disk test results to equivalent uniaxial tensile strength [11]. The value of uniaxial tensile strength of 3.27 MPa (474 psi) was selected for the material model, which inferred a tensile splitting strength of 3.63 MPa (526.5 psi). This tensile splitting strength value falls midway between the split tensile strengths provided by NIST [7] (3.0 MPa (435 psi), see Table 4-2) and from tests performed by SGH (4.5 MPa (653 psi), see Table 5-1 and Section 5.3).

Following Assumption 4, the localization width parameter of the MAT72_REL3 model was calibrated to 4.6 cm (1.81 in). to produce a tensile failure strain ε_f of approximately 11 times $\varepsilon_t = f_t/E$ where E is 35 GPa (5.08 msi), calculated from the ACI 318 formula $E = 57{,}000\sqrt{f_c'}$ with f'c in psi and converted to SI units; we obtain $E = 4{,}734\sqrt{f_c'}$ with f'_c in (MPa). Calibration was performed under unconfined uniaxial tension of a single 1 cm^3 (0.3937 in.^{3}) element, which is the discretization size used in the middle of the slab. The calibrated material responses under the unconfined uniaxial tension and compression are shown in Figure 6-2 and Figure 6-3, respectively.

- Areas outside of the mid-span zone to which the anchor points of the slings were connected (see Assumption 1). Here, a linear elastic material with elastic modulus E = 35 GPa (5.08 msi) and a Poisson's ratio of 0.17 was used.

Mass density of 1,861 kg/m^3(116.2 pcf) as determined from SGH laboratory testing (see Section 5.4) was assigned to both material zones.

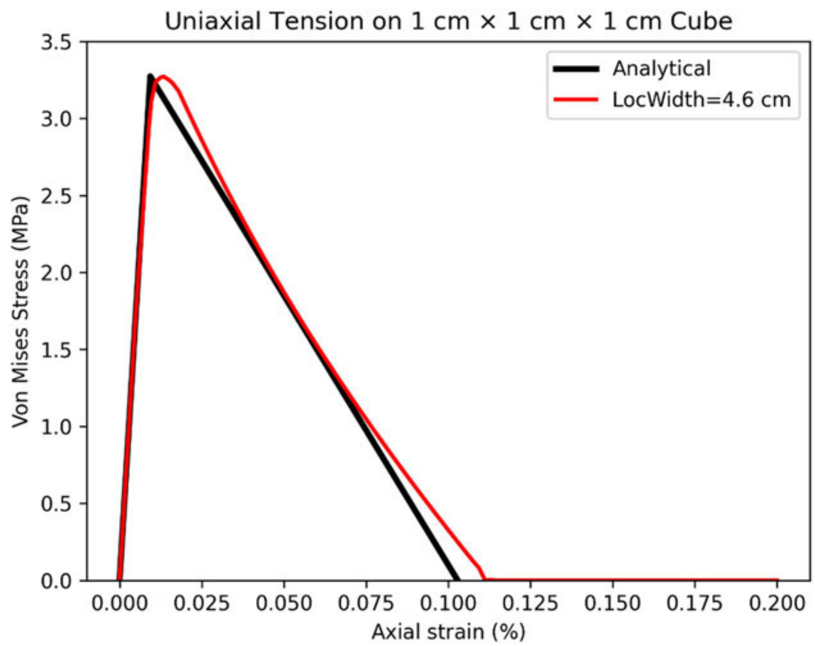


Figure 6-2 Calibrated concrete damage material response under unconfined uniaxial tension. (1 MPa = 145 psi, 1 cm = 0.3937 in.)

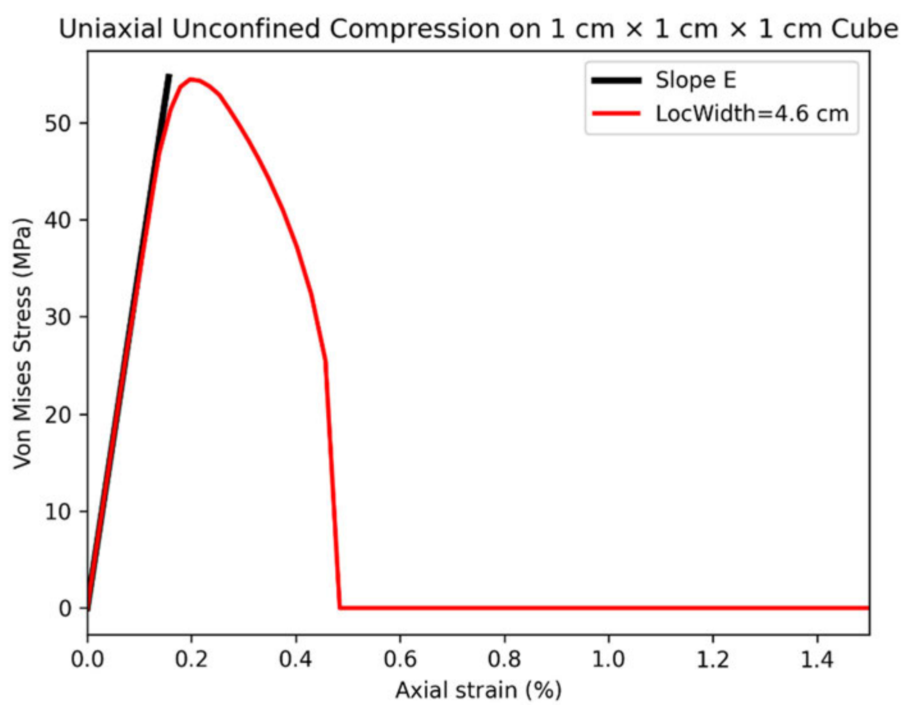


Figure 6-3 Calibrated concrete damage material response under unconfined uniaxial compression. (1 MPa = 145 psi, 1 cm = 0.3937 in.)

The FE model slab planar dimensions are shown in Figure 6-4 through Figure 6-8. Measured planar dimensions of Slab 4 and Slab 3 provided in [9] showed slight deviation from an exact rectangular geometry. For FE modeling, these slabs were idealized such that their planar dimensions were exactly rectangular.

The FE mesh of the slab consists of hexahedral elements (fully integrated formulation, ELFORM -1). Elements were set to be eroded under severe distortion or when the maximum principal strain exceeds 50%. The FE meshes for all the model cases are shown in Figure 6-4 through Figure 6-8.

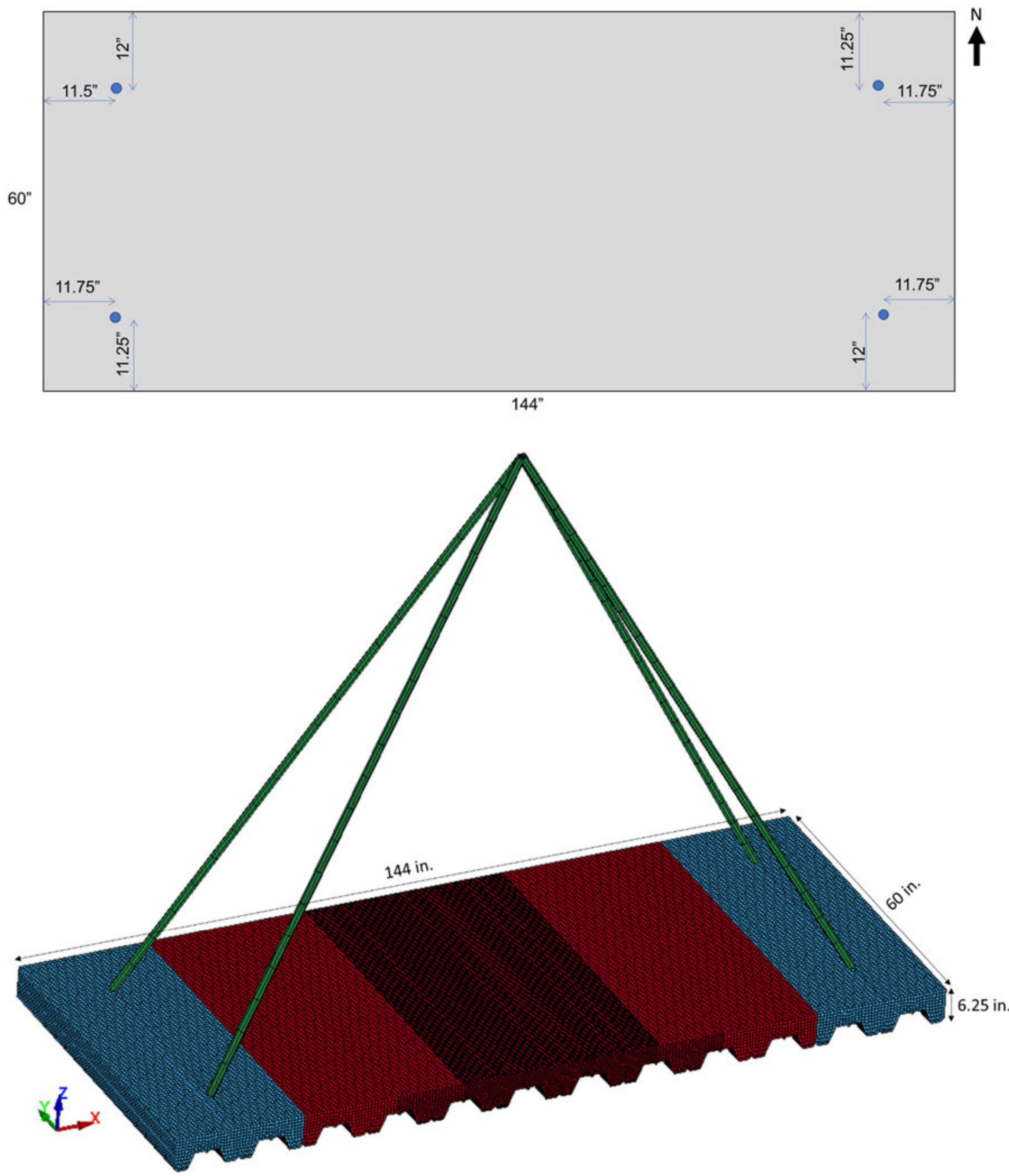


Figure 6-4 – FE model plan dimensions and mesh of Slab 4 (Model 1, Task 2) and Slab 4-Reinforced (Model 5, Task 6). Red elements are those having nonlinear concrete damage response and blue elements are those with linear elastic response. Anchor points were placed relative to slab corners using measurements provided in [9]. (1 in. = 25.4 mm)

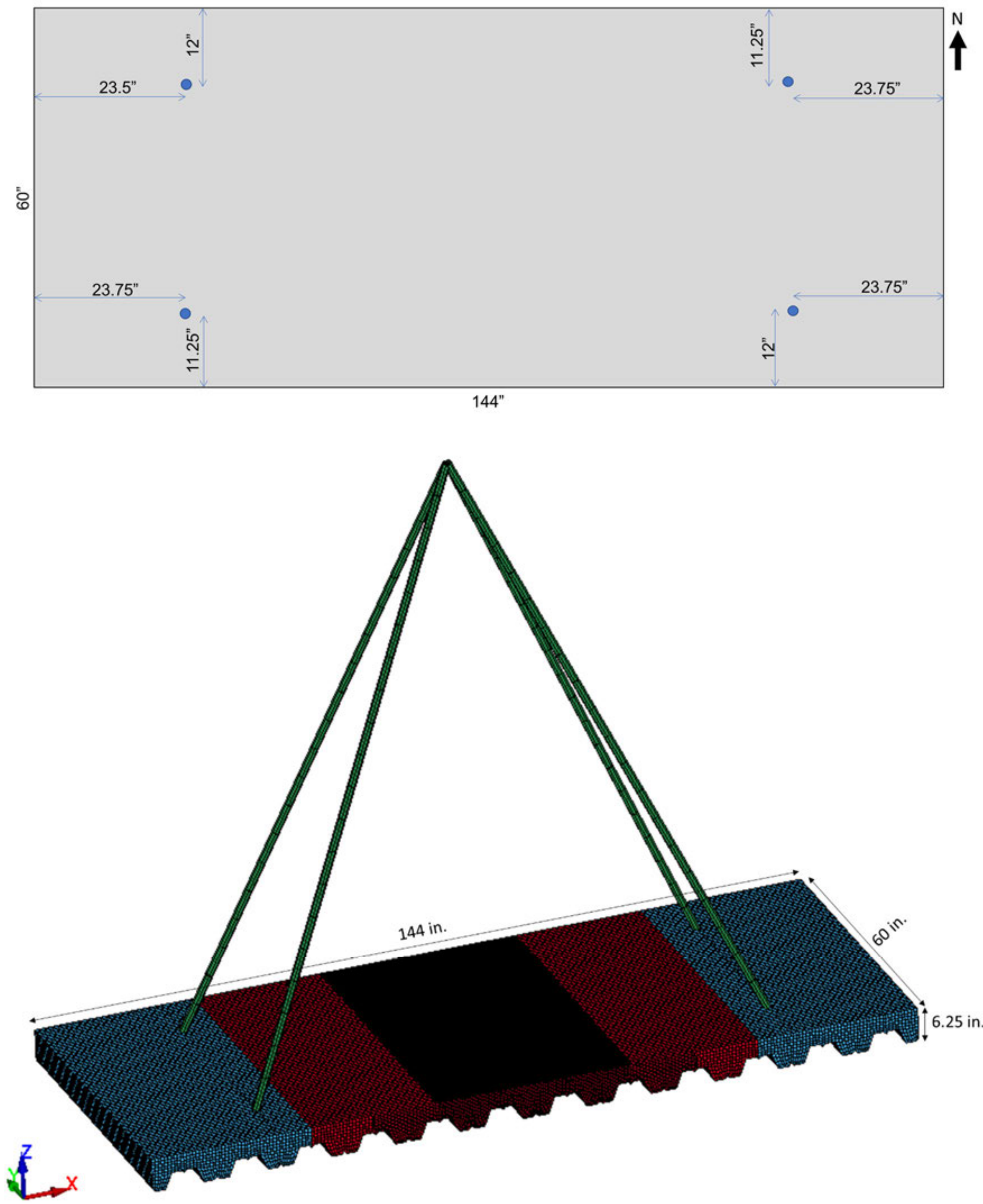


Figure 6-5 – FE model plan dimensions and slab mesh of Slab 4-Rigging (Model 6, Task 7). Red elements are those having nonlinear concrete damage response and blue elements are those with linear elastic response. Anchor points were placed relative to slab corners using measurements provided in [9]. (1 in. =25.4 mm)

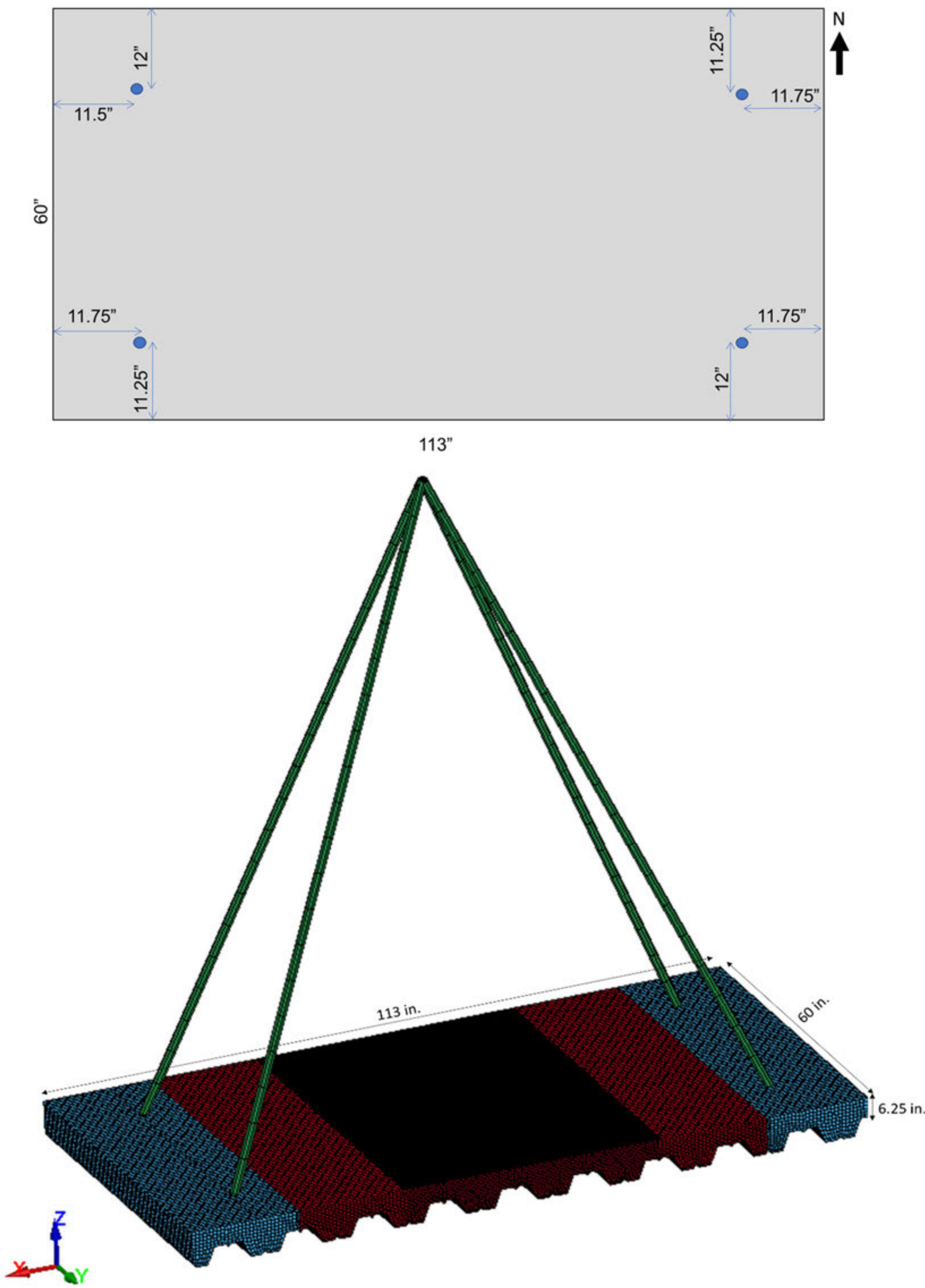


Figure 6-6 – FE model plan dimensions and slab mesh of Slab 4-Short (Model 4, Task 5). Red elements are those having nonlinear concrete damage response and blue elements are those with linear elastic response. Anchor points were placed relative to slab corners using measurements provided in [9]. (1 in. = 25.4 mm)

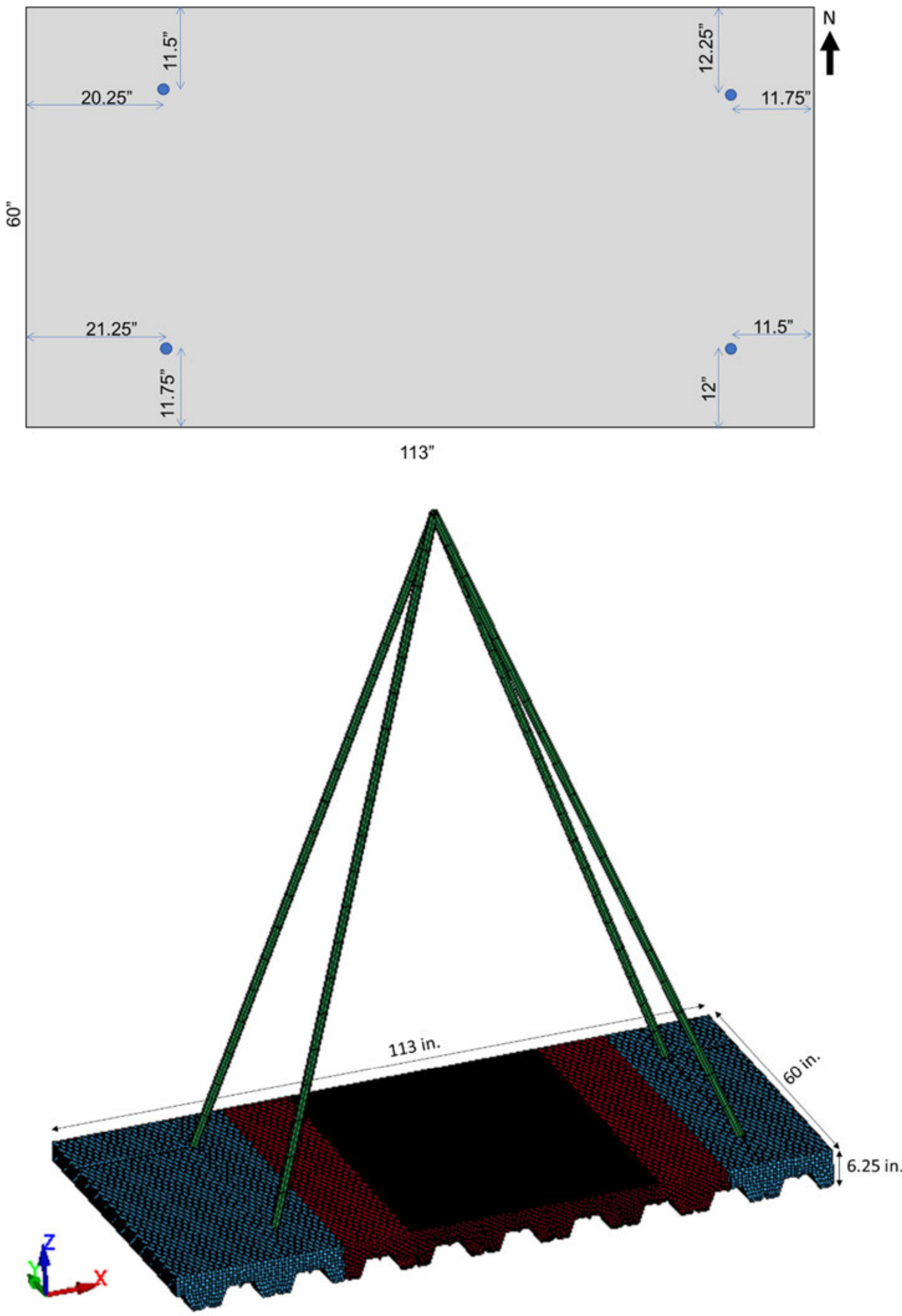
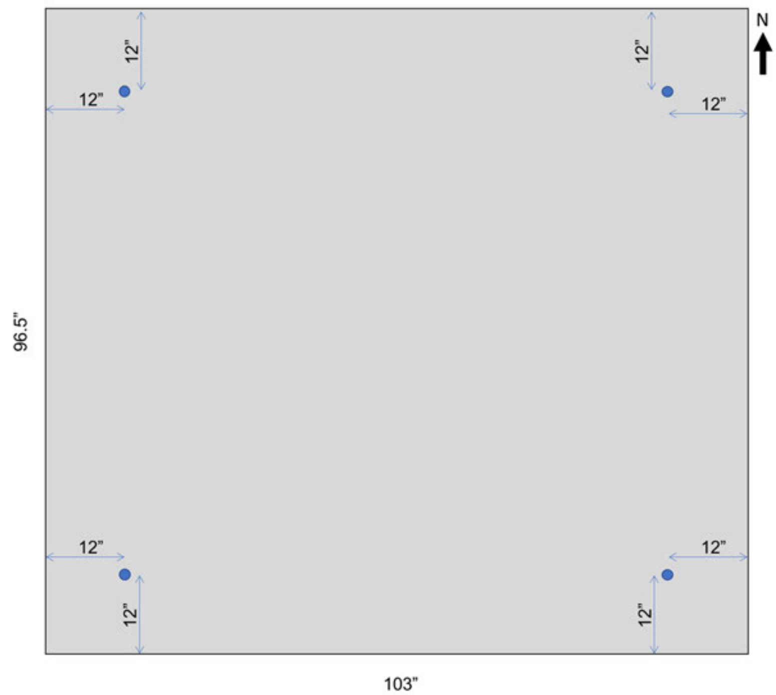


Figure 6-7 – FE model plan dimensions and slab mesh of Slab 3 (Model 2, Task 3). Red elements are those having nonlinear concrete damage response and blue elements are those with linear elastic response. Anchor points were placed relative to slab corners using measurements provided in [9]. (1 in. = 25.4 mm)



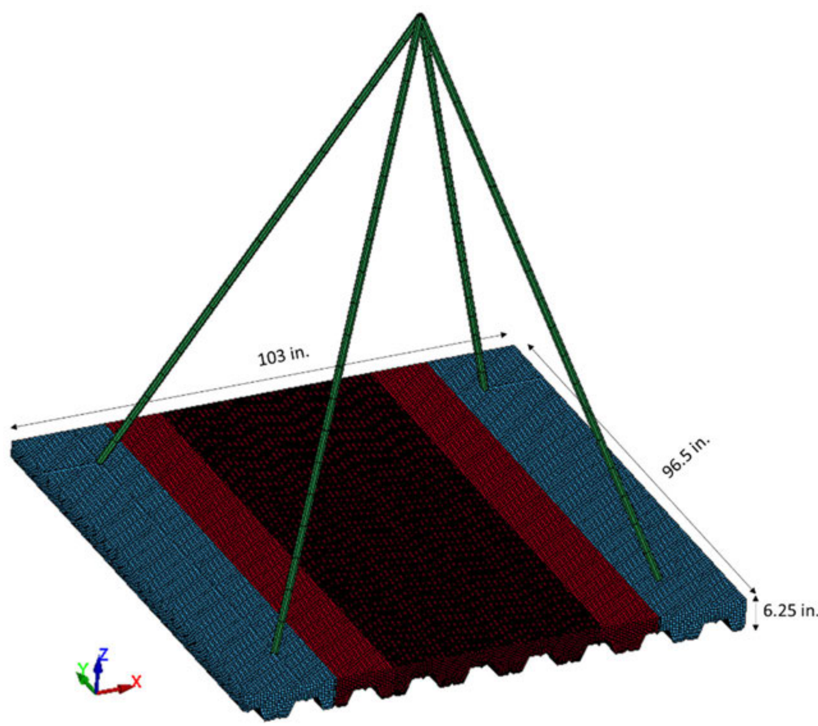


Figure 6-8 – FE model plan dimensions and slab mesh of Slab 2 (Model 3, Task 4). Red elements are those having nonlinear concrete damage response and blue elements are those with linear elastic response. Anchor points were placed relative to slab corners using measurements provided in [9]. (1 in. = 25.4 mm)

6.2.3.2 Steel Deck

The steel deck was Vulcraft Gage 20 [12]. The deck was modeled using shell elements (Belytschko-Tsay, ELFORM 2) with shell thickness of 0.9093 mm (0.0358 in).

Following Assumption 3, an elastic-plastic bilinear material response was used with post-yield strain hardening. Plastic properties occur at the onset of yield at stress of 403 MPa (58.4 ksi) and ultimate strength at 473 MPa (68.6 ksi), with corresponding ultimate strain of 26%. The latter is converted to a true strength of 596 MPa (86.4 ksi) and true ultimate strain (also failure strain) of 23%, which results in a tangent modulus of 0.8 GPa (116.0 ksi) that is used in the LS-DYNA material card.

The steel deck was connected to the concrete slab as described in Assumption 6. Frictionless contact was specified between the steel deck and concrete slab.

The shell elements representing the steel decks are shown in Figure 6-9.

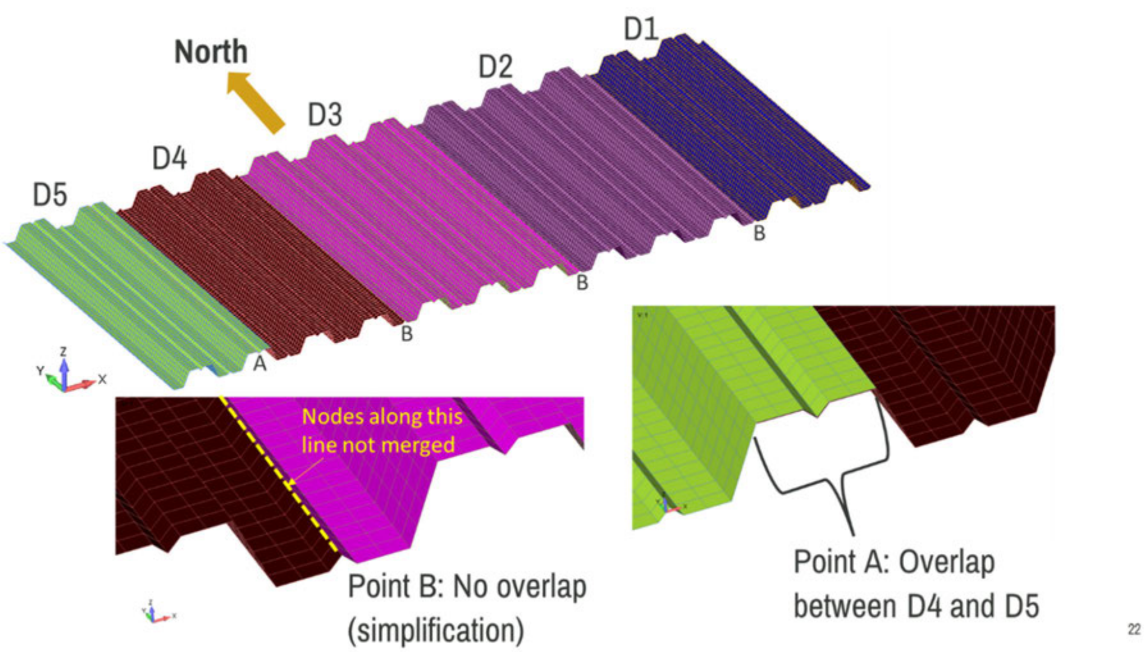


Figure 6-9 – Steel deck mesh, shown for Slab 4 (Model 1, Task 2), Slab 4-Reinforced (Model 5, Task 6), and Slab 4-Rigging (Model 6, Task 7); similar for other model cases.

6.2.3.3 Wire Mesh

The wire mesh was WWR 6x6 W1.4 x W1.4 [12], which is a 0.1524 m x 0.1524 m (6 in x 6 in) grid of wire with nominal diameter of 3.4036 mm (0.134 in). The wire mesh was positioned at 41.275 mm (1.625 in) from the top surface as shown in Figure 6-10.

Following Assumption 3, an elastic-plastic bilinear material response was used with post-yield strain hardening. Plastic properties are a yield stress of 755 MPa (109.5 ksi) and an ultimate strength of 790 MPa (114.6 ksi), with corresponding ultimate strain of 15%. The latter is converted to a true ultimate strength of 909 MPa (131.8 ksi) and true ultimate strain (also failure strain) of 14%, which results in a tangent modulus of 1.1 GPa (159.5 ksi) that is used in the LS-DYNA material card.

The beam elements representing the wire mesh are shown in Figure 6-11 through Figure 6-14. The different slab property zones are also indicated in these figures: red is the mid-span slab with nonlinear properties and blue is the outer slab with elastic properties.

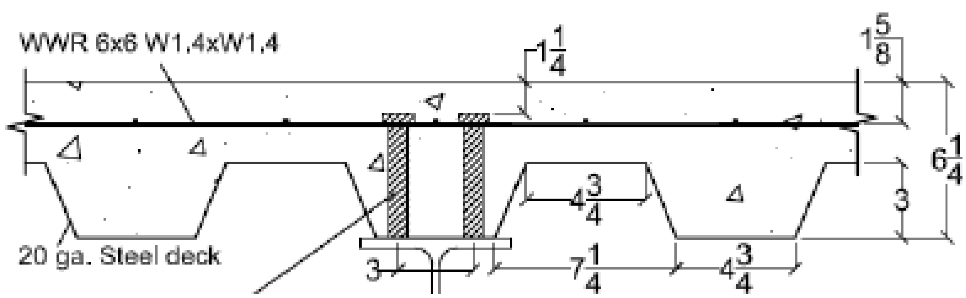


Figure 6-10 – WWR 6x6 W1.4 x W1.4 wire mesh [12]. (1 in. = 25.4 mm)

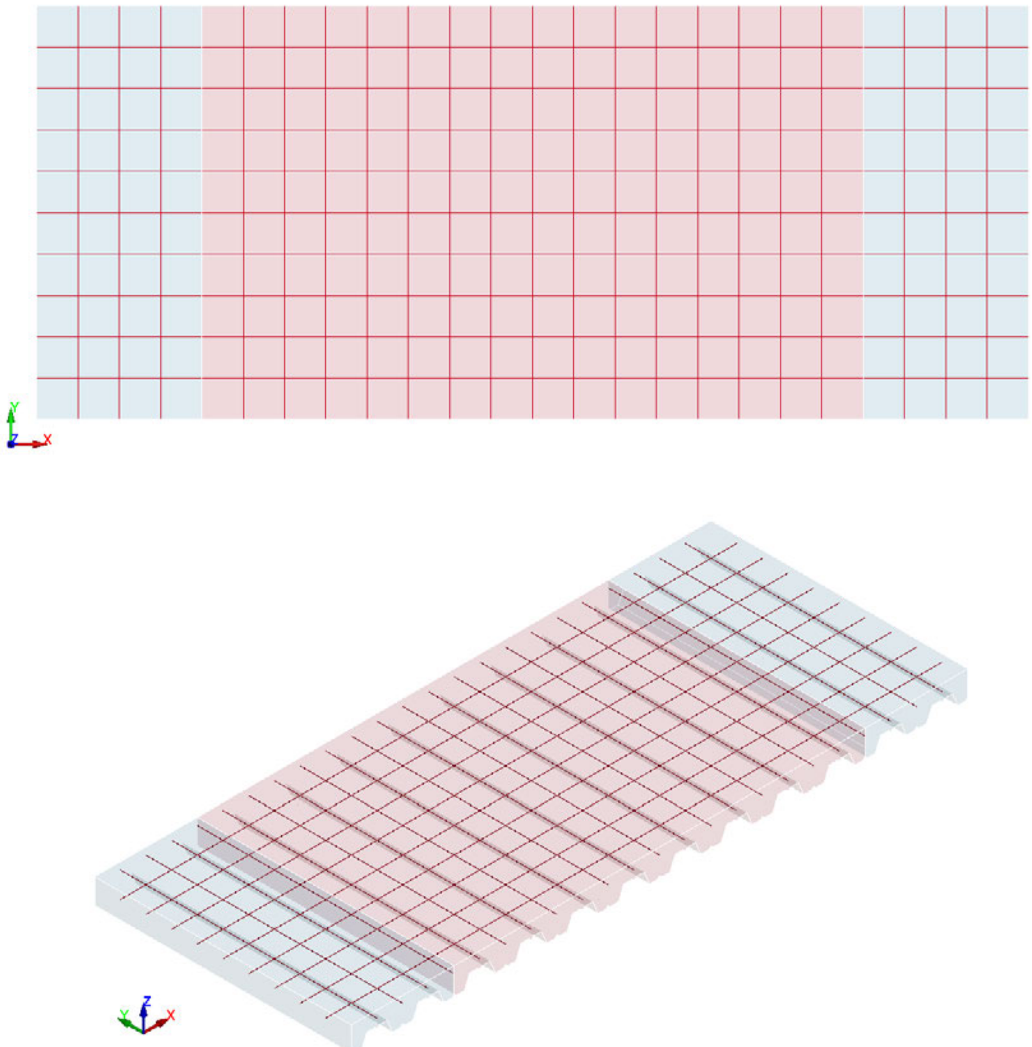


Figure 6-11 – Beam elements representing wire mesh for Slab 4 (Model 1, Task 2), Slab 4-Reinforced (Model 5, Task 6), and Slab 4-Rigging (Model 6, Task 7).

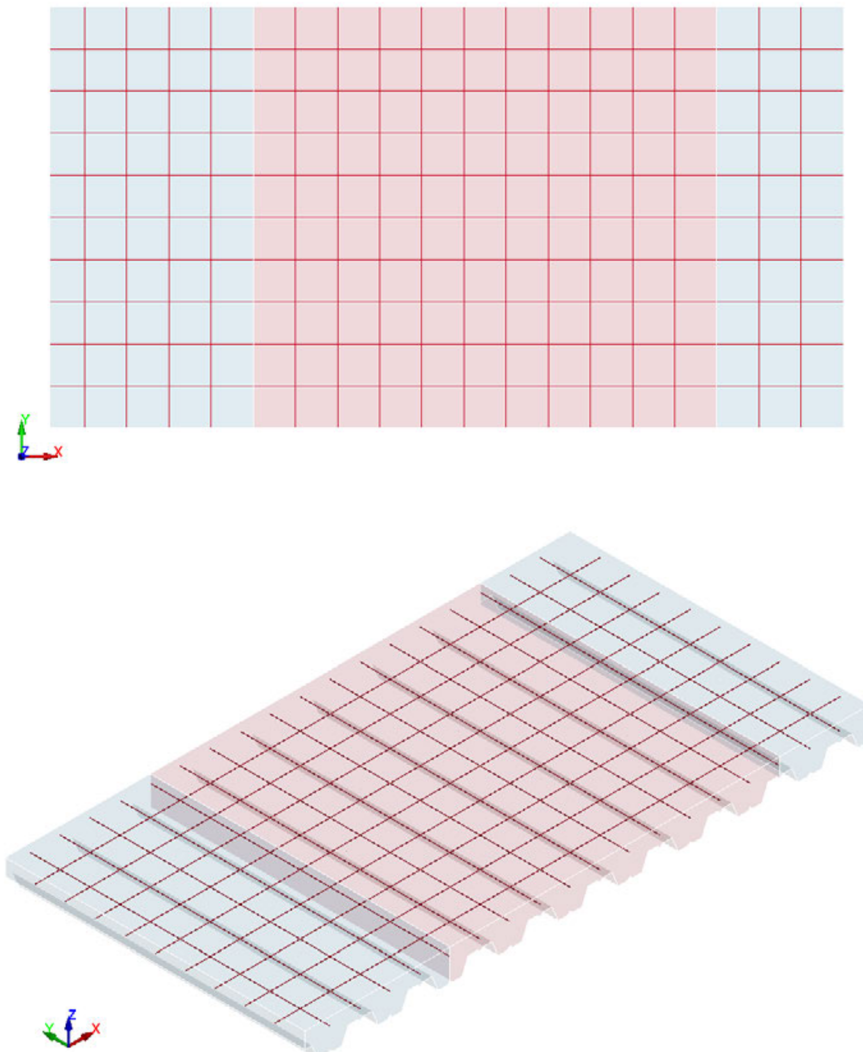


Figure 6-12 – Beam elements representing wire mesh for Slab 4-Short (Model 4, Task 5).

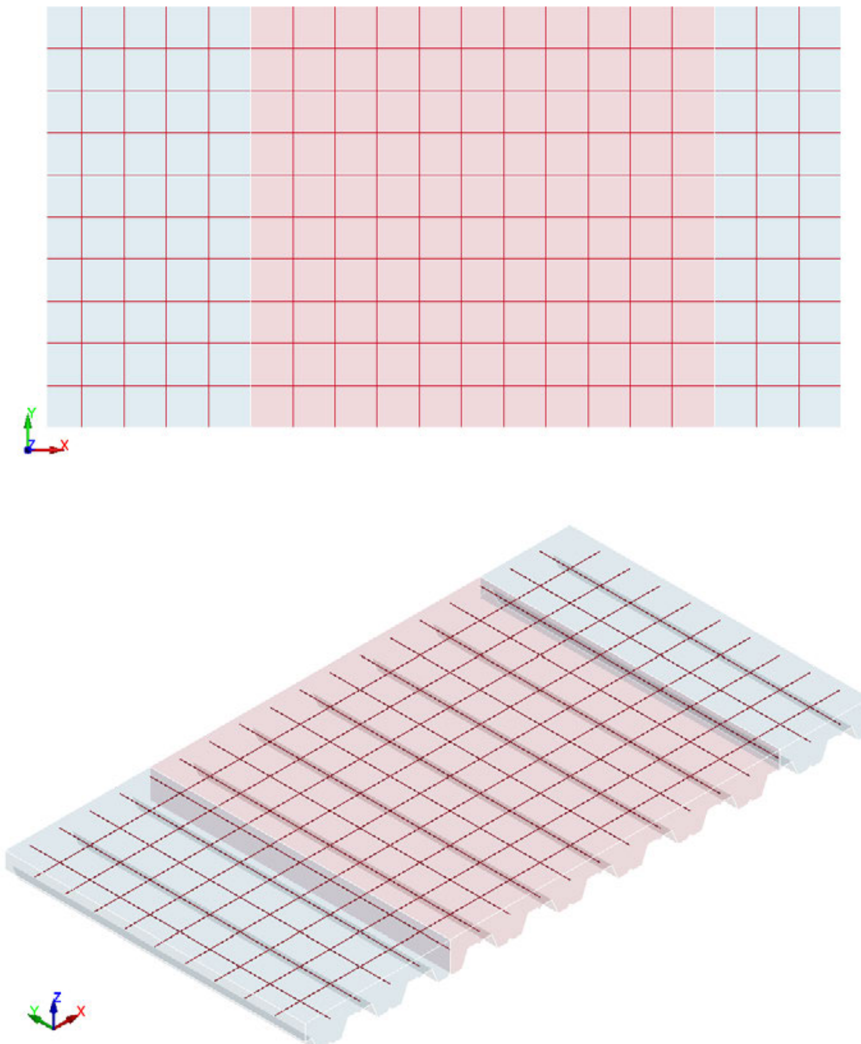


Figure 6-13 – Beam elements representing wire mesh for Slab 3 (Model 2, Task 3).

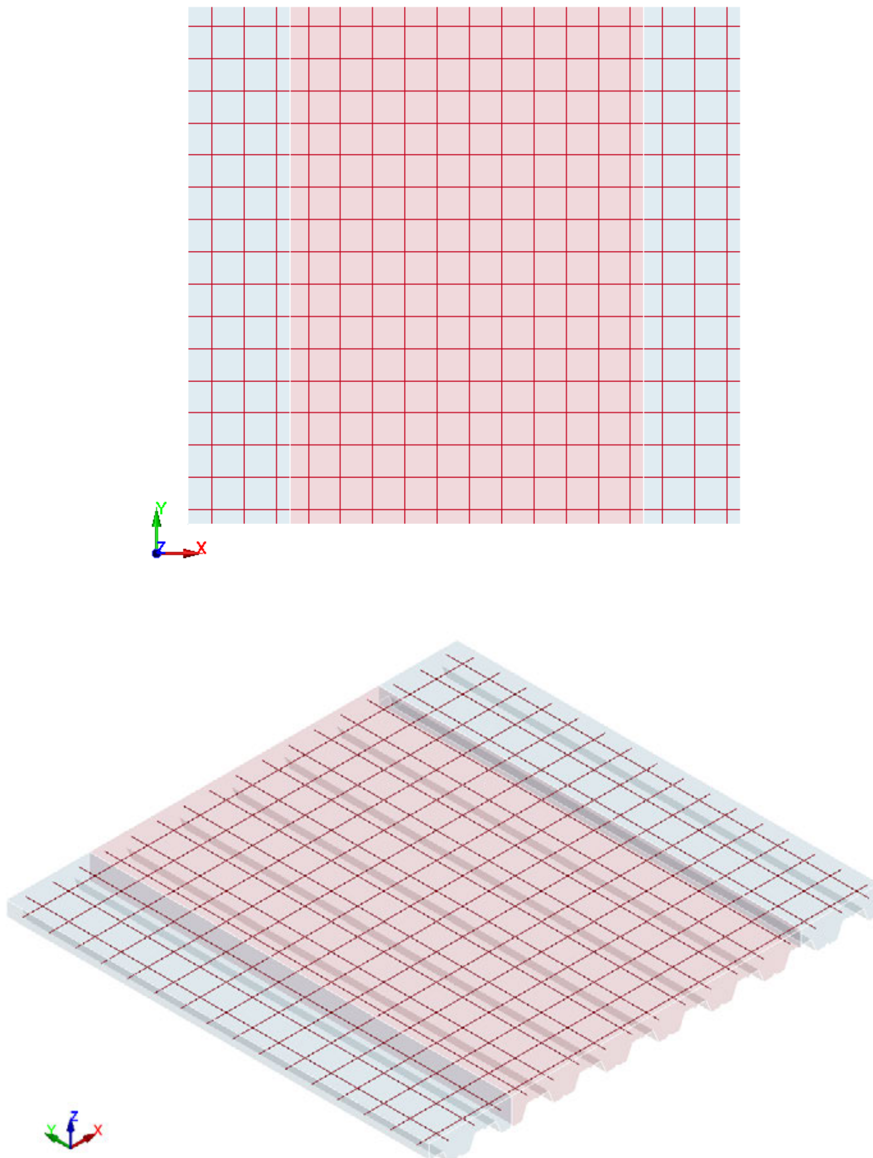


Figure 6-14 – Beam elements representing wire mesh for Slab 2 (Model 3, Task 4).

6.2.3.4 Rebars

Rebars were modeled using beam elements (Hughes-Liu, ELFORM 1), which were embedded in the solid elements representing the concrete slab.

The rebars are #4 type rebars with nominal bar diameter of 12.7 mm (0.5 in). Rebar lengths and planar positions were provided in [9]. The following rebar lengths were assumed:

- Slab 4 (Model 1, Task 2), Slab 4 (Model 5, Task 6), and Slab 4 (Model 6, Task 7): “#4 rebar with unknown length” and “#4 rebar” were assumed to be 0.3048 m (1 ft).
- Slab 4 (Model 4, Task 5): “#4 rebar” were assumed to be 0.3048 m (1 ft).
- Slab 3 Task 3: “#4 rebar with unknown length” was assumed to be 1.2192 m (4 ft)

Rebar planar positions in the FE model are shown in Figure 6-15 through Figure 6-18. Based on photos in [13], north-south running rebars were positioned below wire mesh and east-west running rebars above wire mesh.

Following Assumption 3, an elastic-plastic bilinear material response was used with post-yield strain hardening. Plastic properties are a yield stress of 478 MPa (69.3 ksi) and an ultimate strength of 769 MPa (111.5 ksi), with corresponding ultimate strain of 22% (see Assumption 2). The latter is converted to a true ultimate strength of 938 MPa (136.0 ksi) and true ultimate strain (also failure strain) of 20%, which results in a tangent modulus of 2.3 GPa (333.6 ksi) that is used in the LS-DYNA material card.

The beam elements representing the rebars are shown in Figure 6-19 through Figure 6-23.

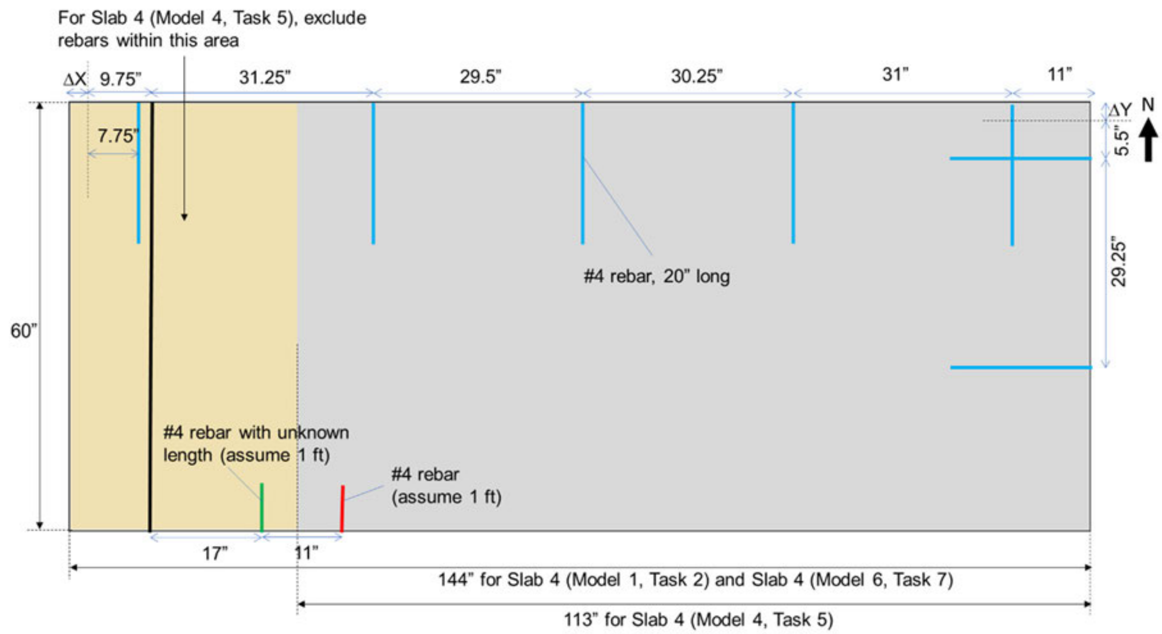


Figure 6-15 – Rebar planar positions in the FE model for Slab 4 (Model 1, Task 2), Slab 4-Short (Model 4, Task 5), and Slab 4-Rigging (Model 6, Task 7). Rebars were centered within the idealized slab dimensions by shifting the N/S bars by ΔX = +0.625 in. and E/W bars by ΔY = -0.5 in. (1 in. = 25.4 mm)

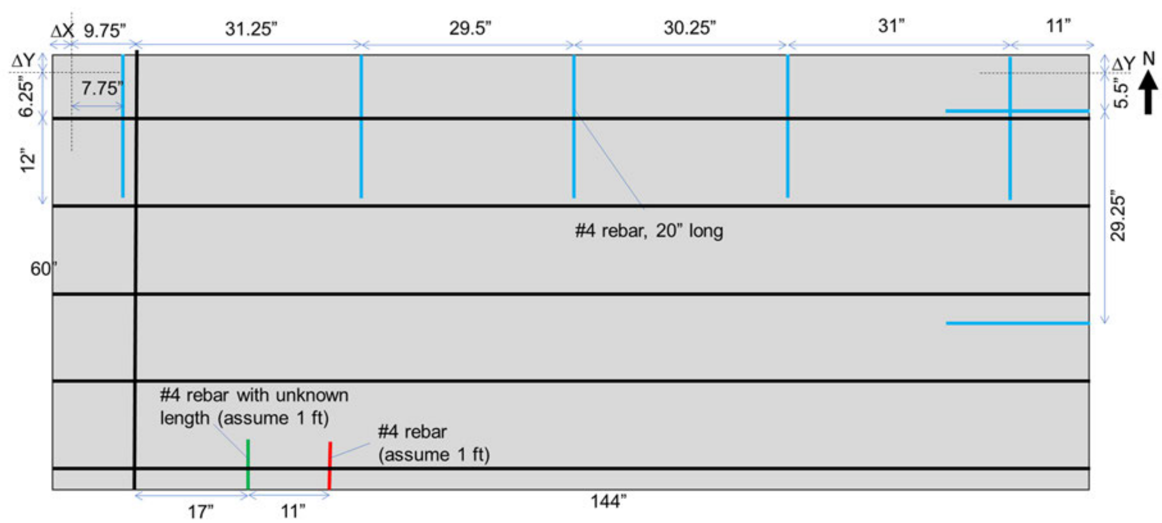


Figure 6-16 – Rebar planar positions in the FE model for Slab 4-Reinforced (Model 5, Task 6). Rebars were centered within the idealized slab dimensions by shifting the N/S bars by ΔX = +0.625 in. and E/W bars by ΔY = -0.5 in. (1 in. = 25.4 mm)

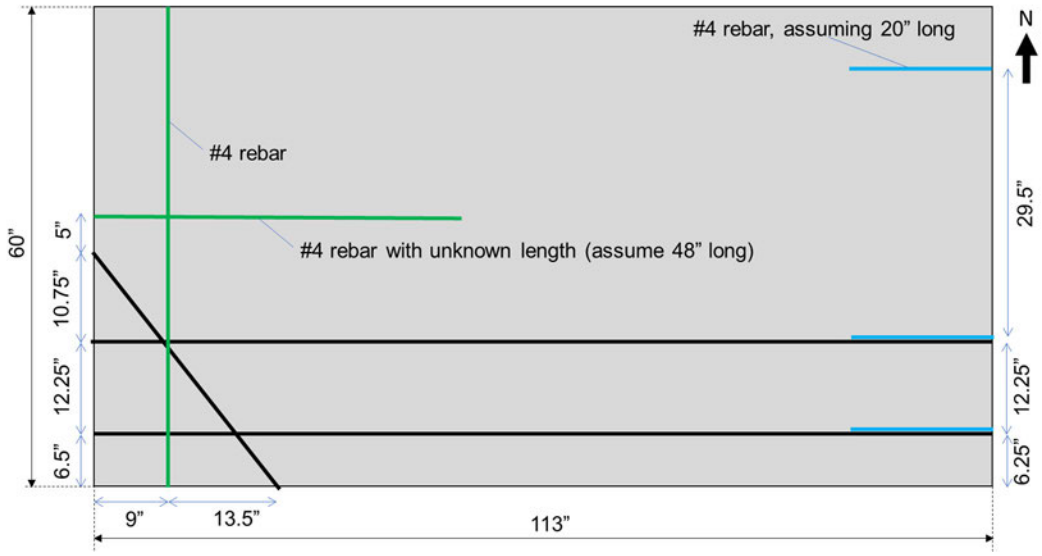


Figure 6-17 – Rebar planar positions in the FE model for Slab 3 (Model 2, Task 3). (1 in. = 25.4 mm)

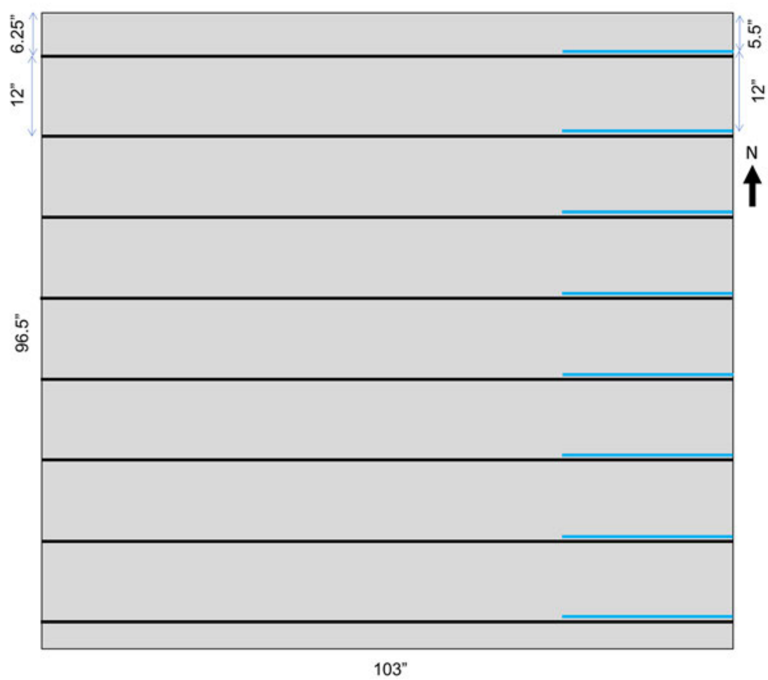


Figure 6-18 – Rebar planar positions in the FE model for Slab 2 (Model 3, Task 4). (1 in. = 25.4 mm)

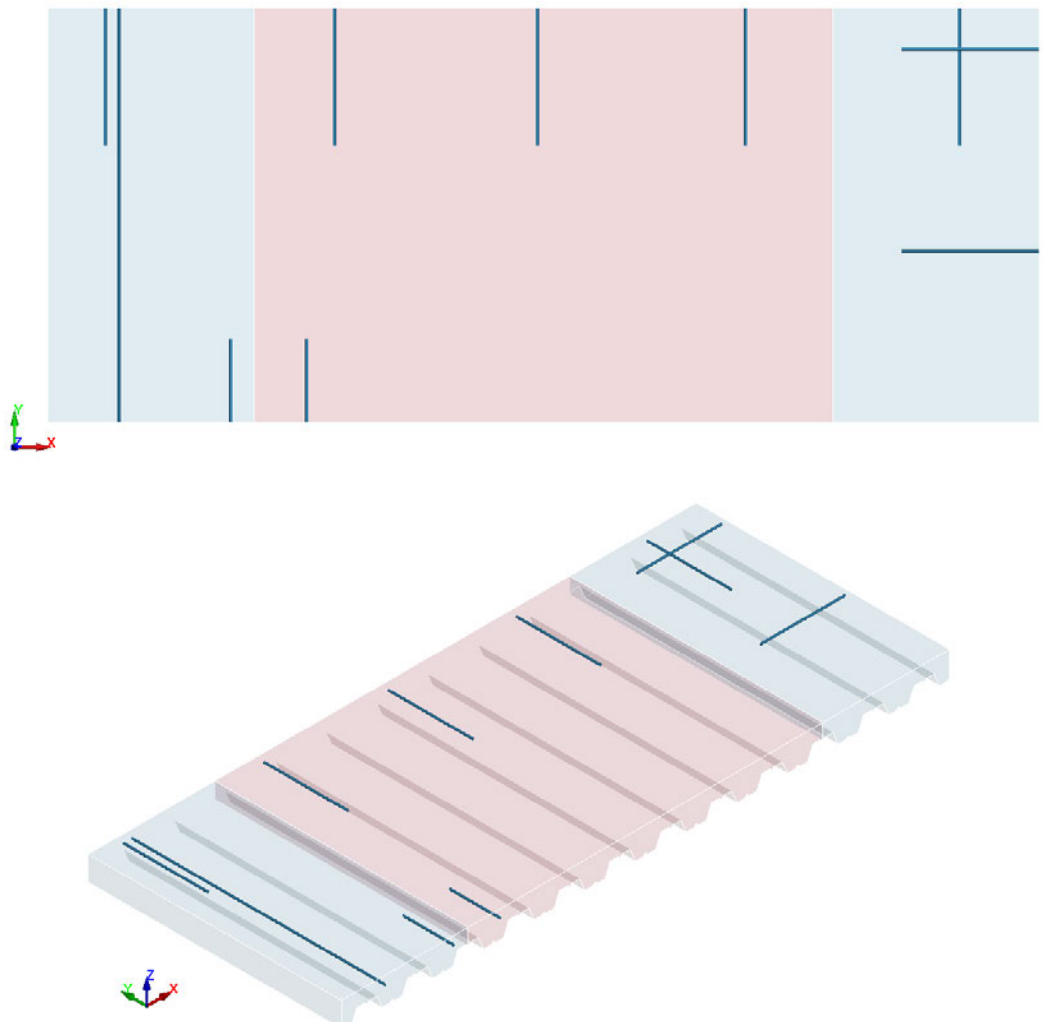


Figure 6-19 – Beam elements representing rebars for Slab 4 (Model 1, Task 2) and Slab 4-Rigging (Model 6, Task 7).

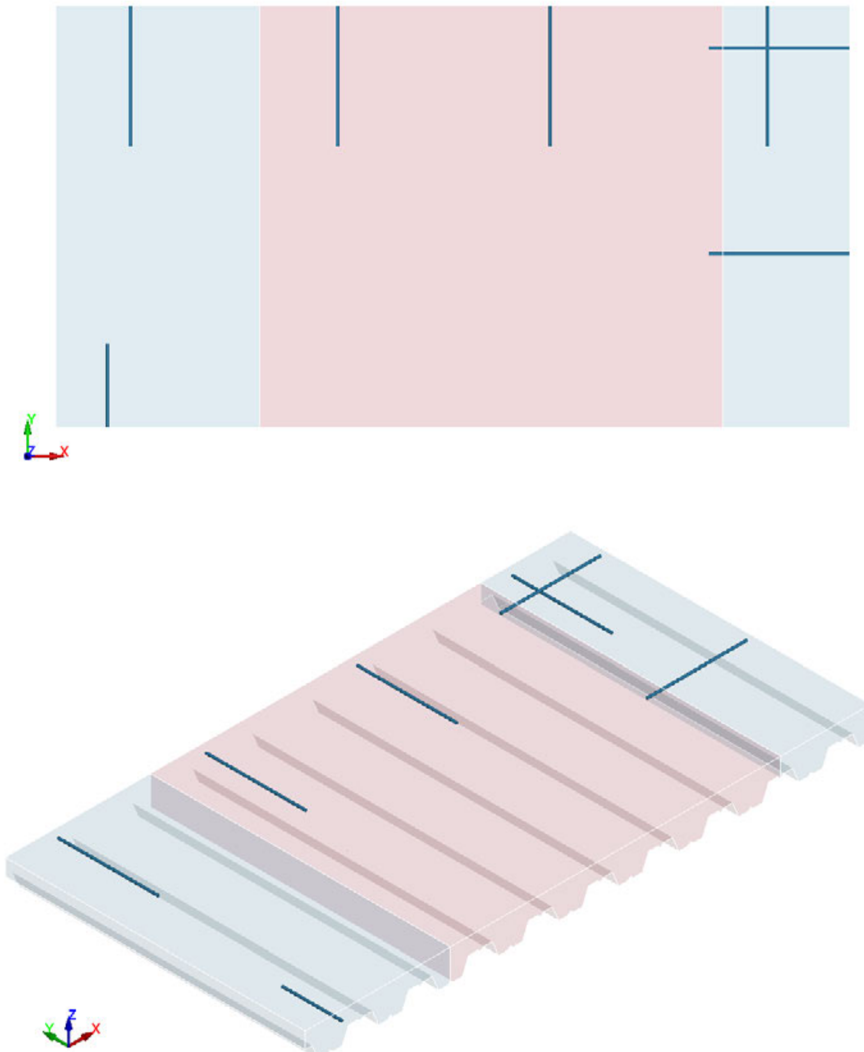


Figure 6-20 – Beam elements representing rebars for Slab 4-Short (Model 4, Task 5).

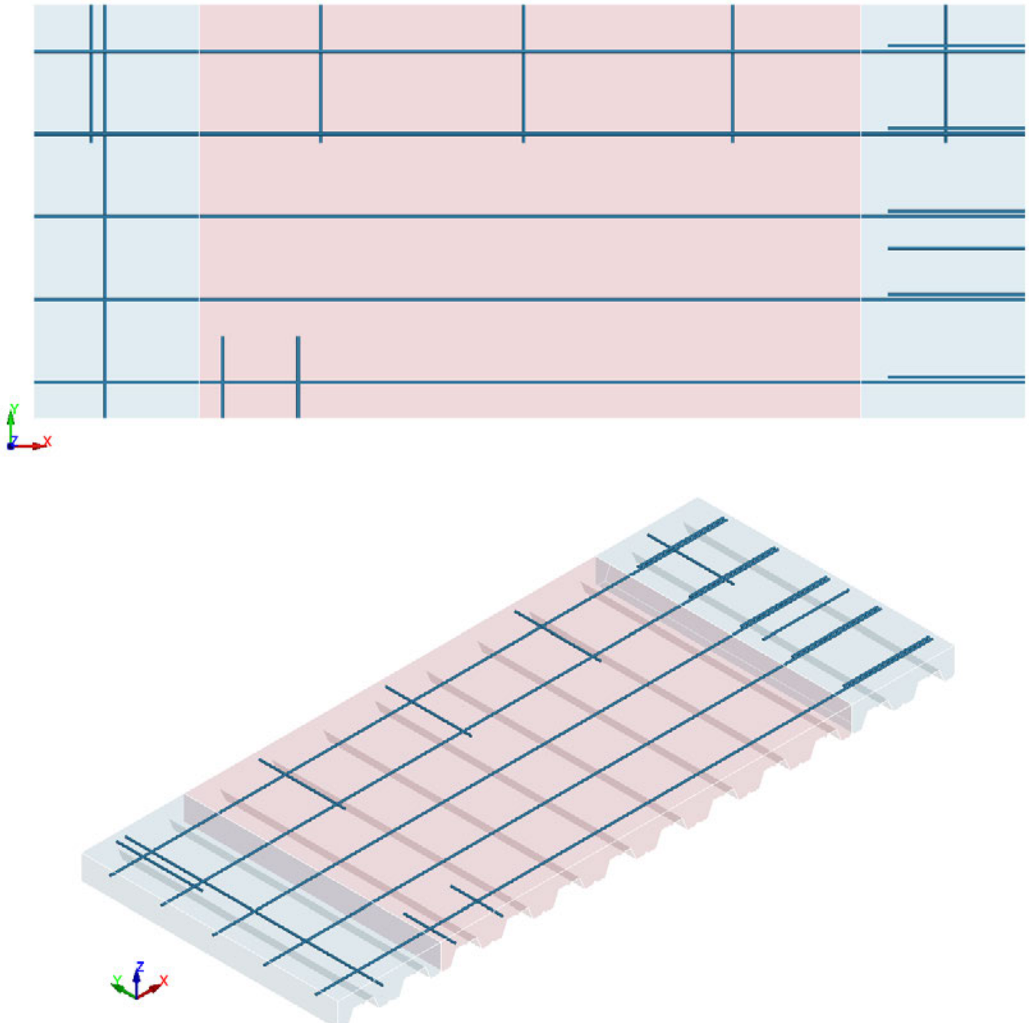


Figure 6-21 – Beam elements representing rebars for Slab 4-Reinforced (Model 5, Task 6).

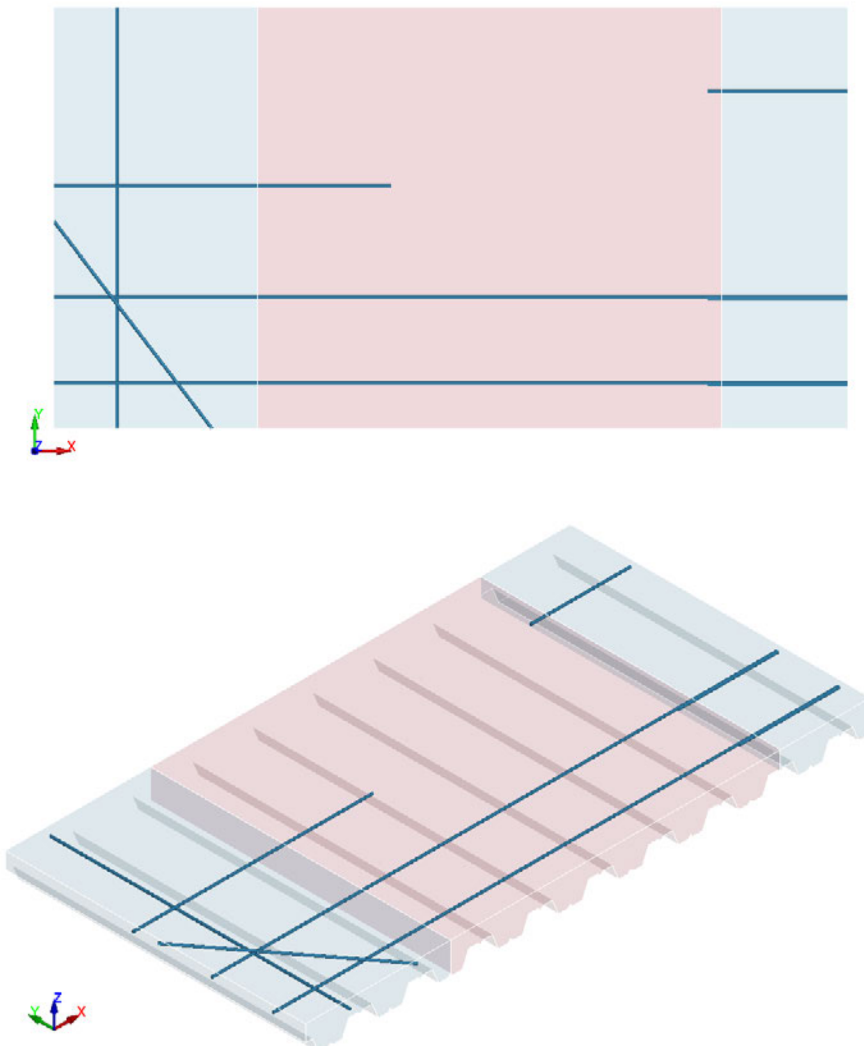


Figure 6-22 – Beam elements representing rebars for Slab 3 (Model 2, Task 3).

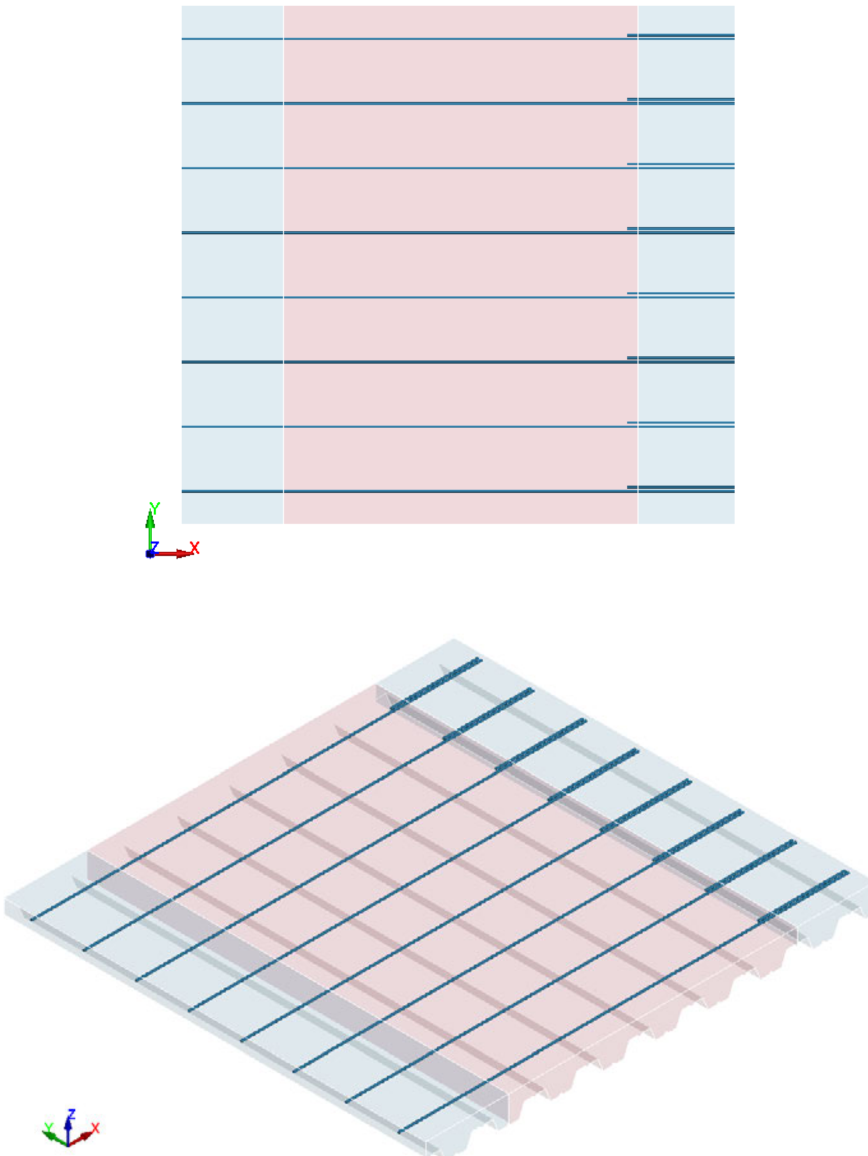


Figure 6-23 – Beam elements representing rebars for Slab 2 (Model 3, Task 4).

6.2.3.5 Rebar Chairs

Rebar chairs were modeled using beam elements (Hughes-Liu, ELFORM 1), which were embedded in the solid elements representing the slab. The chair dimensions were based on SGH field notes [14]:

- Assume epoxy coated for all bars
- Top bar diameter = 6.35 mm (0.25 in)
- Bottom bar diameter = 4.953 mm (0.195 in)
- Spacer diameter = 4.0132 mm (0.158 in)

Rebar chair material properties were assumed to be the same as those used for rebars. The beam elements representing the chairs are shown in Figure 6-24.

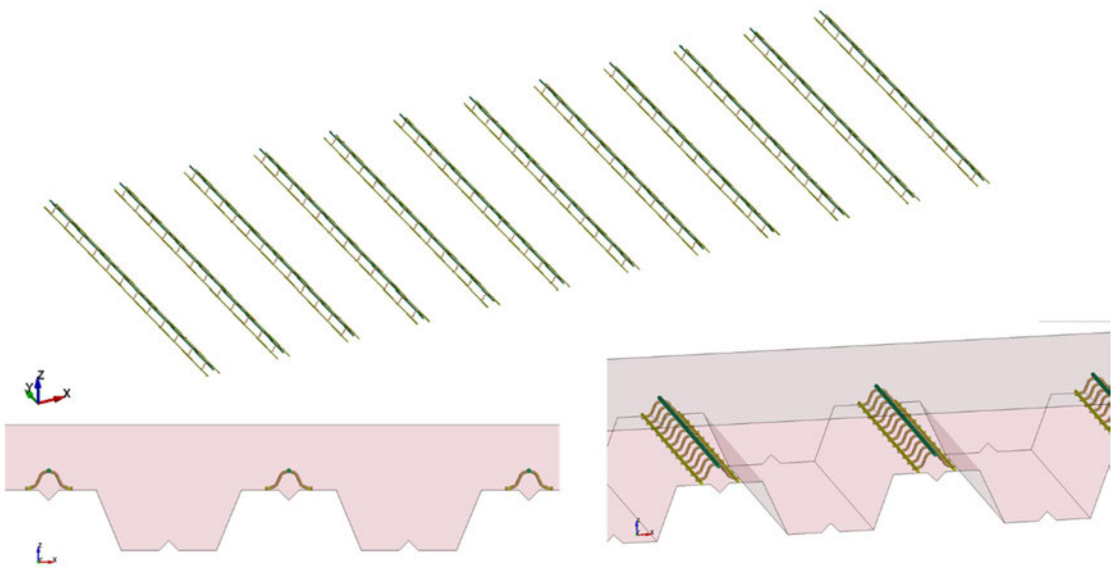


Figure 6-24 – Beam elements representing rebar chairs, shown for Slab 4 (Model 1, Task 2), Slab 4 (Model 5, Task 6), and Slab 4 (Model 6, Task 7); similar for other model cases.

6.2.3.6 Operator Mass

Operator weight was prescribed to be 1,103 N (248 lbf) [15]. The operator mass was distributed over 0.605 m (2 ft). Each foot was represented by a rectangular block:

- Block dimensions are 101.6 mm x 304.8 mm (4 in. x 12 in.) and thickness is 25.4 mm (1 in.) (assumed).
- The block is 10,000 times softer than E of the elastic concrete slab assuming rubber-type modulus of about 1 MPa.
- Mass density of each block is calculated as half of operator weight divided by block volume.
- The base of the block is tied to the top of the concrete slab.
- The block is discretized with hexahedral elements (fully integrated formulation, ELFORM -1).

The operator mass was placed at the center determined by the intersection of the diagonals formed by diagonally opposing anchor points, which corresponds to slab center, except for Slab 4 (Task 5) and Slab 3 (Task 3), which have the east side anchor points moved inwards by an additional (approximately) 0.3048 m (12 in). The locations of the operator mass in the models are shown in Figure 6-25 through Figure 6-30.

6.2.3.7 Rotary Floor Saw Mass

Rotary floor saw weight (with partially full water tank) was prescribed to be 1,145 N (257.5 lbf) [15]. We assumed that the rotary floor saw mass was distributed on the slab over two (rear) wheels. Each wheel load was represented by a rectangular block the approximate size of the wheel-ground contact area:

- Patch area of 38.1 mm x 34.93 mm (1.5 in. x 1.375 in.) and thickness of 25.4 mm (1 in.) [14].
- 10,000 times softer than E of elastic concrete slab (assume rubber-type modulus of about 1 MPa).
- Mass density of each block was calculated as half of rotary floor saw weight divided by block volume.
- The base of the block was tied to the top of the concrete slab.
- Block was discretized with hexahedral elements (fully integrated formulation, ELFORM -1).

For the baseline Slab 4 (Task 2) model, the two rear wheels of the rotary floor saw were placed on the south edge of the slab, while the maximum loading condition was assumed for all other cases, namely, the rear wheels were placed at the same center determined for the operator mass. The locations of the two rear wheels of the rotary floor saw in the models are shown in Figure 6-25 through Figure 6-30.

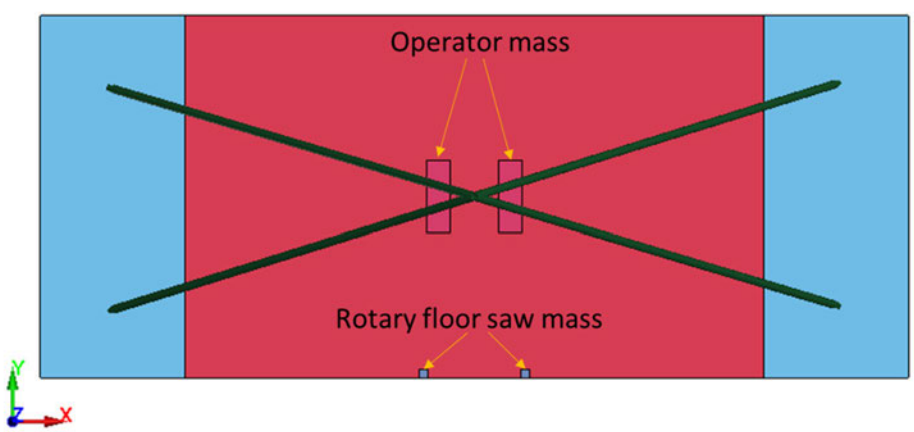


Figure 6-25 – Operator and rotary floor saw positions for Slab 4 (Model 1, Task 2).

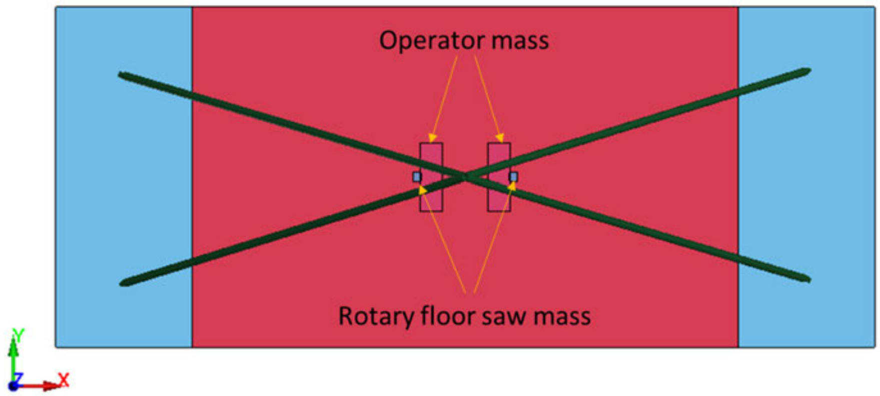


Figure 6-26 – Operator and rotary floor saw positions for Slab 4-Reinforced (Model 5, Task 6).

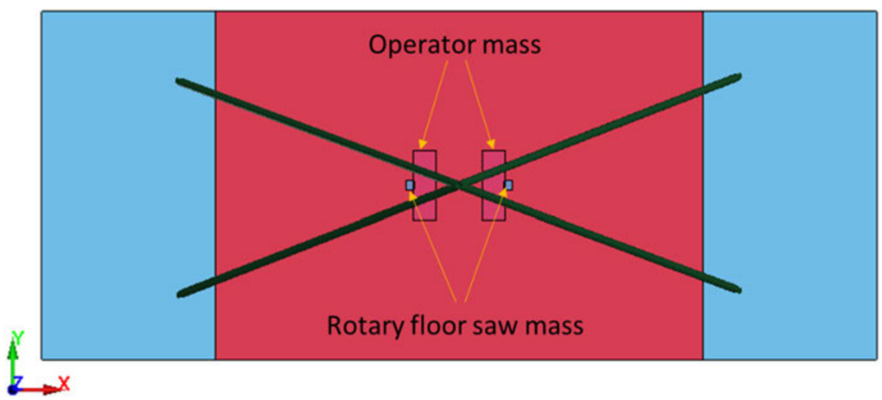


Figure 6-27 – Operator and rotary floor saw positions for Slab 4-Rigging (Model 6, Task 7).

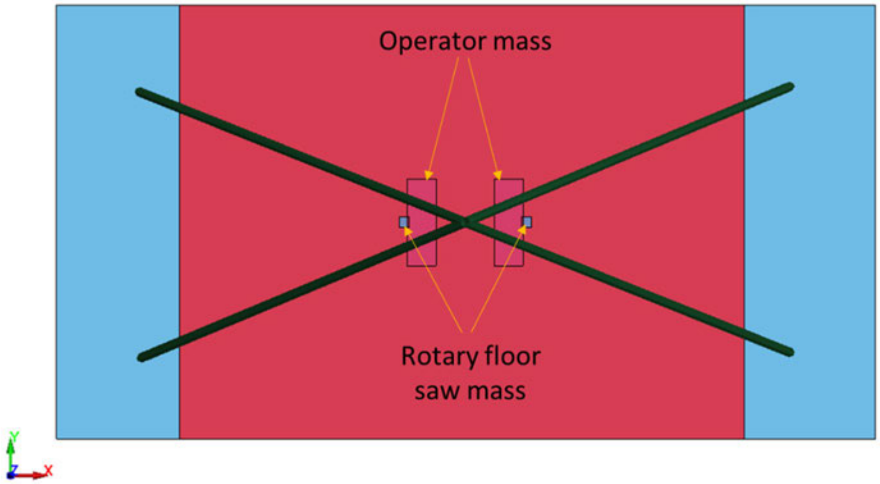


Figure 6-28 – Operator and rotary floor saw positions for Slab 4-Short (Model 4, Task 5).

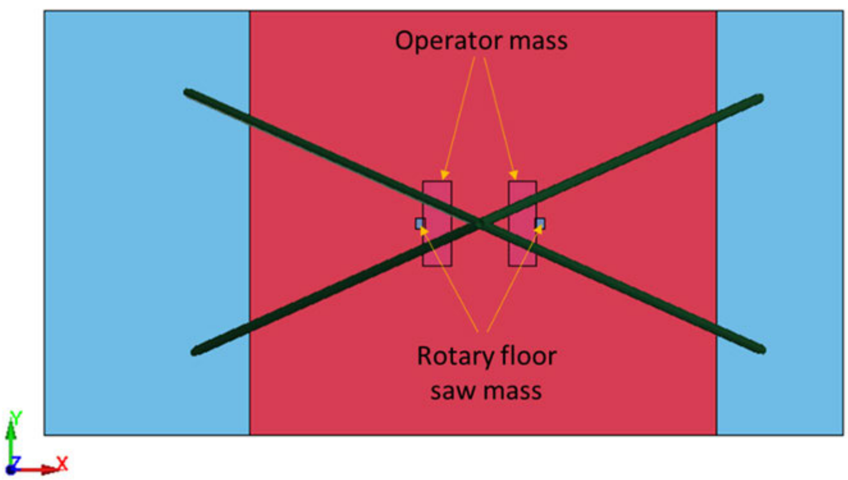


Figure 6-29 – Operator and rotary floor saw positions for Slab 3 (Model 2, Task 3).

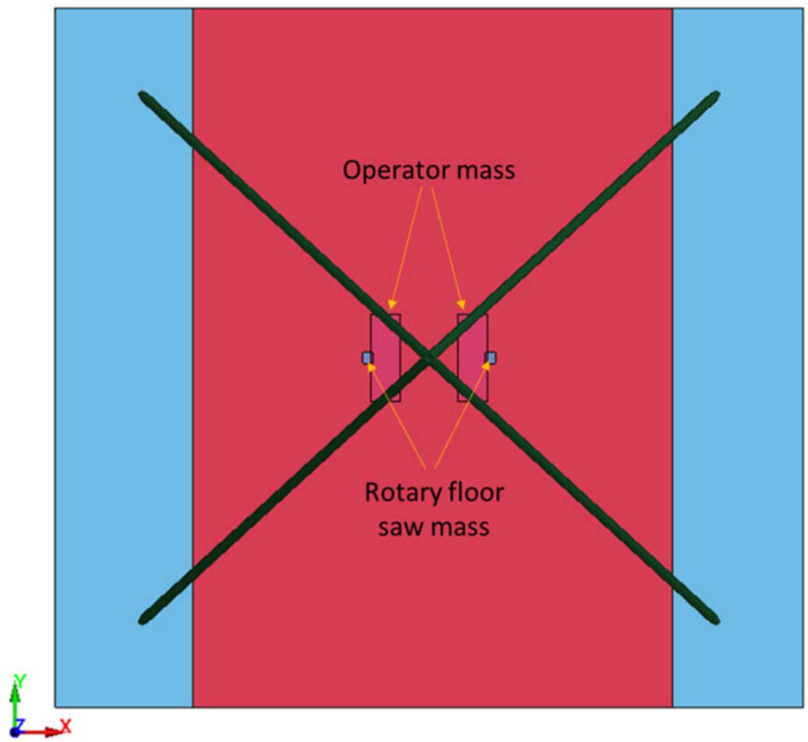


Figure 6-30 – Operator and rotary floor saw positions for Slab 2 (Model 3, Task 4).

6.2.3.8 Slings

Four slings were connected to each slab at anchor points that were positioned relative to slab corners using the measurements made by NIST in [9]. The other (top) end of each sling was adjusted so that an exact length of 3.048 m (10 ft) was obtained [7]. The node on this end was fixed in all translation degrees of freedom. The slings were assumed to initially have zero slack prior to application of gravity loading (Assumption 5).

Slings were modeled using cable beam elements (ELFORM 6). We assumed that the cross-sectional area of each sling is equivalent to that of two 1 in. diameter bars (double legs of a circular sling). Based on information in [16] and [17], the mass density was set to 734 kg/m^3 (45.8 pcf) to match the weight of a 3.048 m (10 ft) circular sling of 22.24 N (5 lbf). The weight of the plates, bolts, and nuts at the anchor points are ignored since these weights are not resisted by the slabs and are not modeled (Assumption 1). Using data obtained from SGH testing of slings described in Section 5.2, the average sling modulus was estimated to be 2.21 GPa (321 ksi) – see Figure 6-31. This modulus was used in the *MAT_CABLE_DISCRETE_BEAM material card of the cable beam element. The sling anchor points relative to slab corners and the cable elements representing the slings are shown in Figure 6-4 through Figure 6-8.

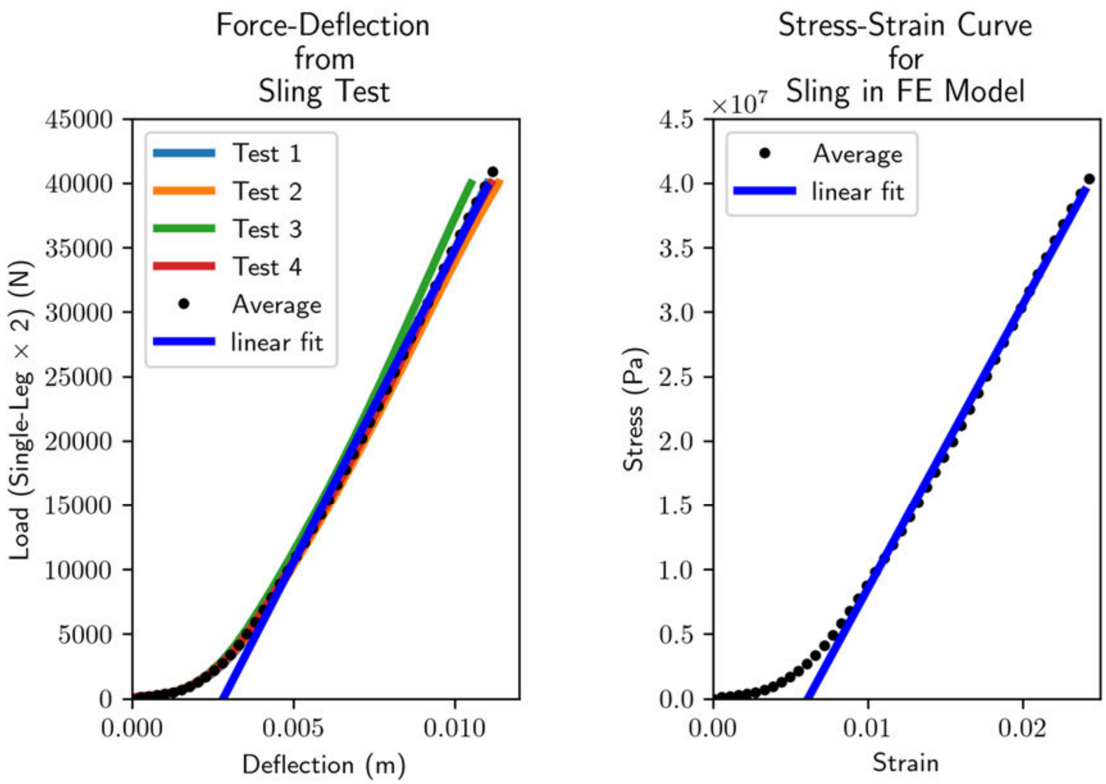


Figure 6-31 – Estimated average sling stiffness and modulus from SGH testing of slings.

6.2.3.9 Loading and Model Initialization

For each model, gravity was ramped up smoothly between 0 and 0.4 sec (see Figure 6-32). Gravity influences the weights of the slab, its reinforcement, the steel deck, and the weights of the operator and rotary floor saw simultaneously. Global damping was applied between 0 and 0.4 sec to minimize inertial effects and prevent premature overloading of the slab; thereafter, damping was turned off. Dynamic response is expected to occur during cracking and failure of the concrete slab.

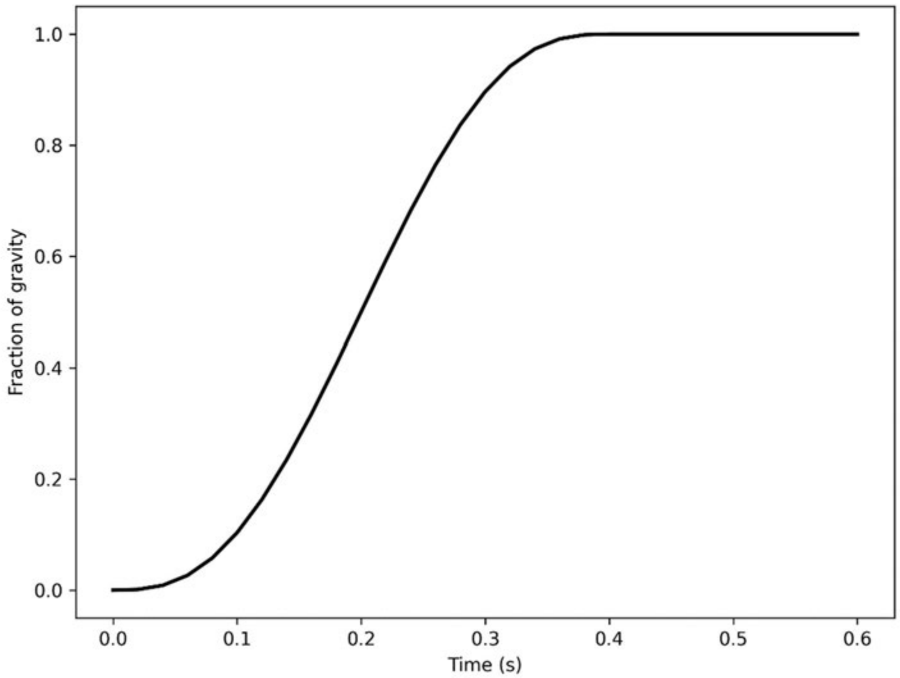


Figure 6-32 – Smooth scaling function for gravity ramp.

6.2.4 3D Nonlinear Finite Element Analysis Results

The following main quantities are plotted to assess the survivability of the slab:

1. The sum of the vertical reactions at the top ends of the slings. Three horizontal reference lines are also shown corresponding to the full weight of each of the following three components of the load that were on Slab 4 just prior to its failure:

   - Slab self-weight (including weights of reinforcement and deck) (green line)
   - Slab self-weight + weight of operator (blue line)
   - Slab self-weight+ weights of operator and rotary floor saw (red line)

2. Concrete damage variable contours showing the formation and propagation of transverse flexural cracks. The damage contours vary as follows:

   - Between 0 to 1: Concrete goes through a linear elastic stress-strain relationship followed by initial microcracking (resulting in nonlinearity of stress-strain relationship) until the stress reaches the maximum strength.
   - Between 1 to 2: Concrete softens, and stress decreases monotonically with increasing strain beyond the strain corresponding to peak stress until the strain reaches a value at which microcracks are fully coalesced, forming a visible crack where stress can no longer be transferred across the crack.
   - The damage variable describes the stress state with respect to initial, maximum, and residual yield surfaces. Damage can occur under multiaxial stress states; the damage variable does not differentiate between tensile and compressive states. Note that the quantity labeled "effective plastic strain" in the plots is the damage variable for the K&C concrete model per LS-DYNA manual [6].

A detailed description of the response of Slab 4 (Model 1, Task 2), which is the baseline model, is provided in Section 6.2.4.1 below to highlight how the above quantities are used to assess the slab condition. Brief summaries for the other slab models (Models 2 to 6) are provided in Sections 6.2.4.2 through 0.

6.2.4.1 Slab 4 (Model 1, Task 2)

This is the baseline model. As mentioned in Section 6.2.3.1, with uniaxial tensile strength of 3.27 MPa (474.3 psi), Slab 4 (Model 1, Task 2) fails when the weights of rotary floor saw and operator are added to the slab self-weight. We calculated the capacity-to-demand (C/D) ratios. The demand was determined from a linear elastic analysis by computing the bending moment across the width of the slab at the minimum thickness section by integrating the stresses in the concrete and steel elements making up the cross section cut that passes through the concrete element with the maximum damage variable. The capacity was calculated in the same way as for the demand using the stresses from the nonlinear model corresponding to the maximum capacity of the same cross section cut. The results of our analysis are the C/D ratios, i.e., safety factors, with M_U being the ultimate moment capacity of the slab, just before visible cracking appears, and M_D the moment demand. After initiation of visible cracking, the capacity drops rapidly.

$$S_F = \frac{C}{D} = \frac{M_U}{M_D\ (self\ weight)} = 1.12 \qquad \text{Eq. 4.1}$$

$$S_F = \frac{C}{D} = \frac{M_U}{M_D(self\ weight + Operator)} = 1.03 \qquad \text{Eq. 4.2}$$

$$S_F = \frac{C}{D} = \frac{M_U}{M_D(self\ weight + Operator + saw)} = 0.96 \qquad \text{Eq. 4.3}$$

The calculated factor of safety should be compared with the required safety factor by the current codes. The required safety factor is determined from the load factor of 1.4 based on the requirements of ASCE 7 Minimum Design Loads and Associated criteria for Buildings and Other Structures (2022), the resistance factor against failure in bending of 0.9 Based on the requirements of ACI 318-19 (22) Standard Building Code Requirements for Structural Concrete, and a dynamic amplification of loads due to the impact in the lifting operation. The minimum impact factor of the very gradual lifting operation is an amplification factor of 10% as specified by AASHTO's LRFD Design Specification (2020)and 15 % as specified by the AASHTO's Guide Design Specification for Bridge Temporary Works (2017) for manually operated lift, both by AASHTO. The resulting required safety factors has a minimum value of 1.7.

Figure 6-33 shows the sling vertical reactions at the anchor points. We observe that Slings 2 and 3 carried more load than Slings 1 and 4. This is expected as the rear wheels were placed on the south edge of the slab. The vertical reactions at the anchor points showed a drop just after failure due to the slacking of the slings. Figure 6-34 shows the sum of the vertical sling reactions, and this is compared with the three weights listed in Item 1 of Section 6.2.4. The sum indicates that the slab was able to support its self-weight without failure. When the load level reached the slab + operator + rotary floor saw stage, with 100% slab and operator weight, and 85.3% rotary floor saw weight, a bending-induced transverse crack formed on the bottom of Slab 4 and subsequently propagated upward through the slab thickness. The development of this crack is shown in Figure 6-35 through Figure 6-37. Just prior to slab failure (Figure 6-35), tensile principal stresses were seen to be concentrated at the minimum slab thickness corners. Damage propagation was first initiated at a minimum slab thickness corner on the south end of the slab (Point A in Figure 6-35).

Compressive or tensile strains in the top and bottom fibers of the slab were plotted. ACI 318 [5] states that the nominal strength of a member that is subjected to moment and axial force is determined when compressive fiber strain reaches 0.3%. Tensile cracking strain (11 times tensile strain at peak strength) corresponding to the calibrated uniaxial tensile strength described in Section 6.2.3.1 is approximately 0.11%. Close-ups of the damage and global X--strain contours are shown in Figure 6-38 and Figure 6-39. The global X-strain contours show that strains reaching or exceeding the tensile cracking strain of 0.l% were developed within a narrow band, and the corresponding damage levels were at the maximum value of 2.0. Physically, this corresponds to initially formed microcracks coalescing into a macrocrack and separation of concrete (i.e., a fully visible crack) that propagates through the slab thickness. Following the development of a fully visible crack, concrete crushing (compressive strains reaching 0.3%) occurred at the top surface of the slab due to block arching; severely distorted elements were numerically eroded.

The wire mesh showed that the equivalent plastic strains were concentrated along the crack plane – see Figure 6-40. At the time the simulation was terminated (at approximately 0.56 seconds, corresponding to 0.16 seconds after 100% gravity was reached – see Figure

6-33), the maximum equivalent plastic strain is approximately 2%. There was a rapid rise in kinetic energy following slab failure as shown in Figure 6-41. The slab is considered failed since the damage value of 2.0 was reached with macrocrack in the tension zone under the slab and concrete crushing occurred in the compression zone at the top surface of the slab.

The response of Slab 4 (Model 1, Task 2) predicted by this model is consistent with the reported observations by NIST [13].

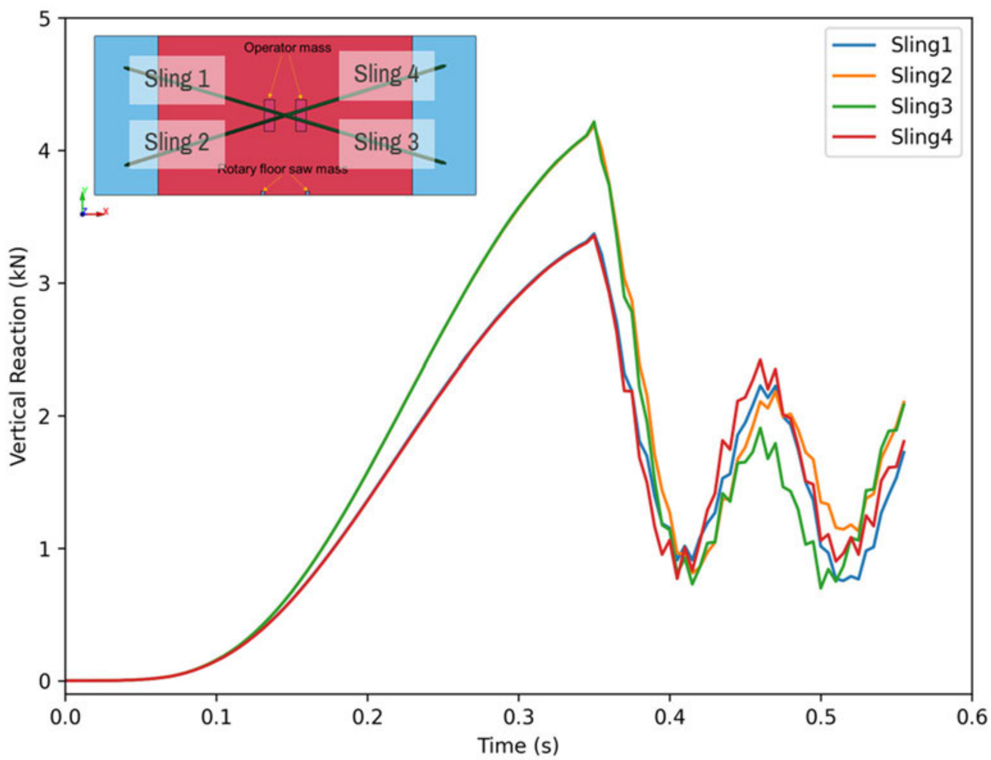


Figure 6-33 – Slab 4 (Model 1, Task 2): sling vertical reactions at anchor points.

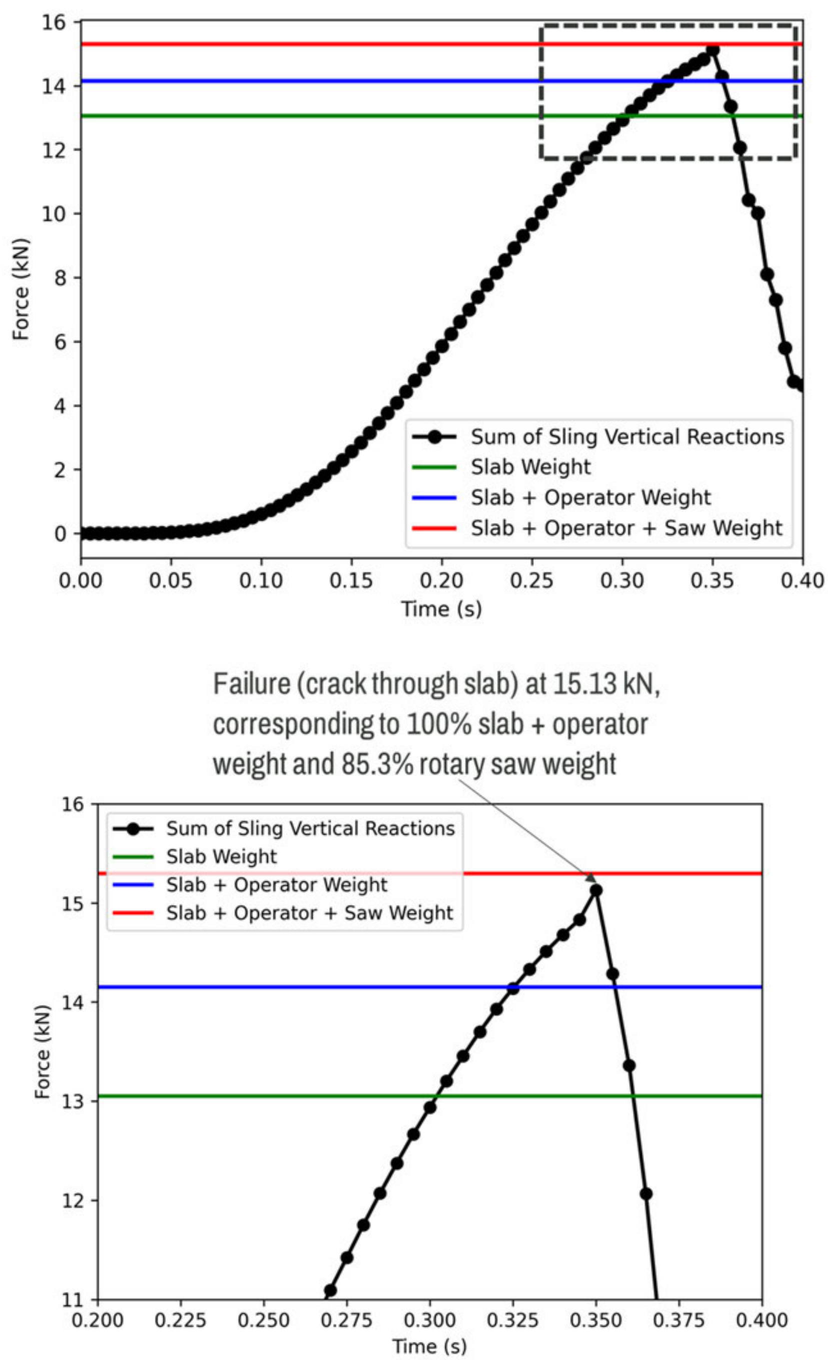


Figure 6-34 – Slab 4 (Model 1, Task 2): sum of sling vertical reactions and close-up of load history near the peak. (1 kN = 225 lb.)

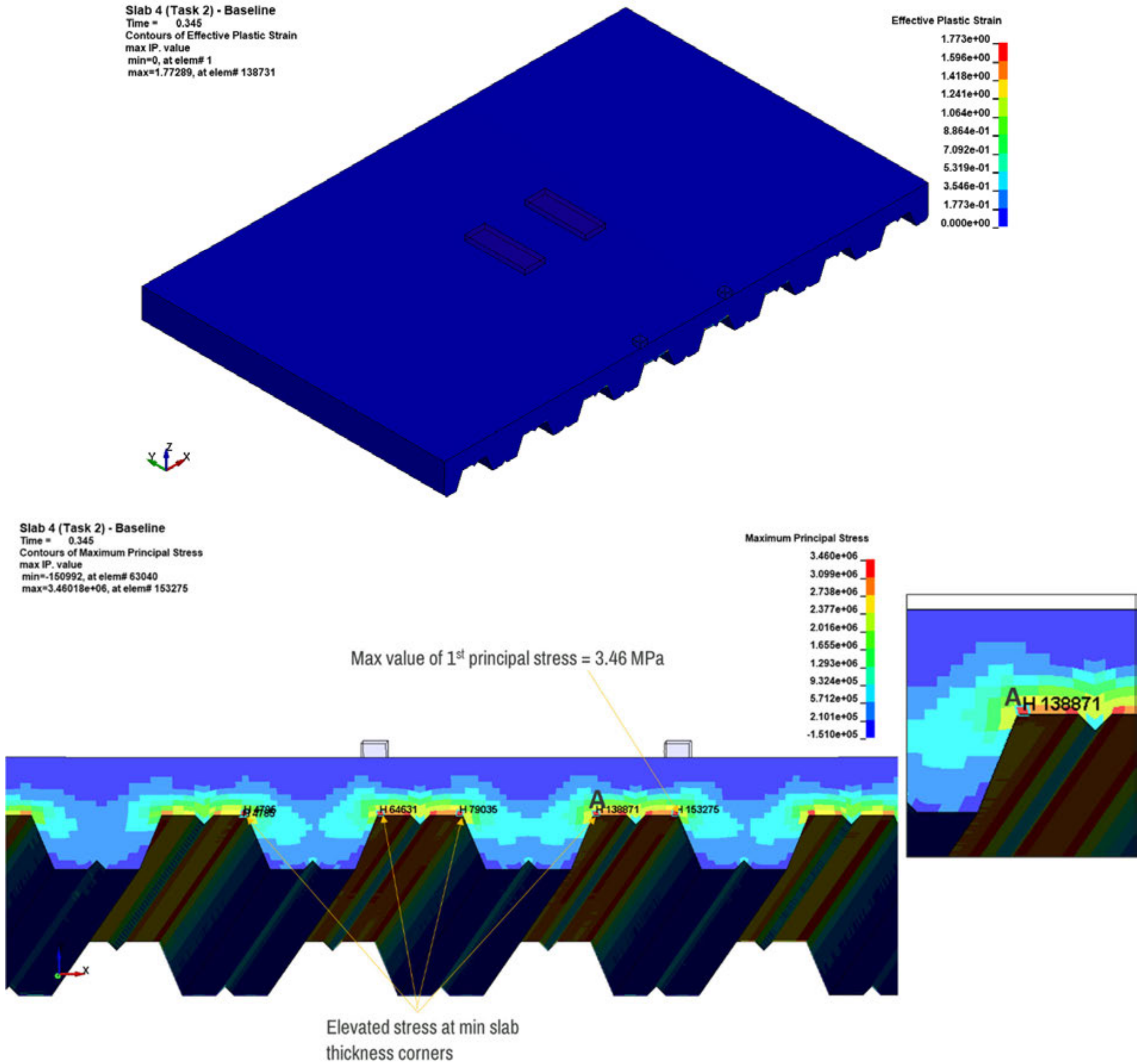


Figure 6-35 – Slab 4 (Model 1, Task 2): damage and maximum principal stress contours at 100% slab + operator weight and 59.2% rotary floor saw weight. The insert figure shows close-up of point A with maximum value of maximum principal stress. Note that under multi-axial stress state that results in confinement, the maximum principal stress can be higher than the uniaxial tensile strength (which is obtained under an unconfined tensile test). (1 MPa = 145.04 psi)

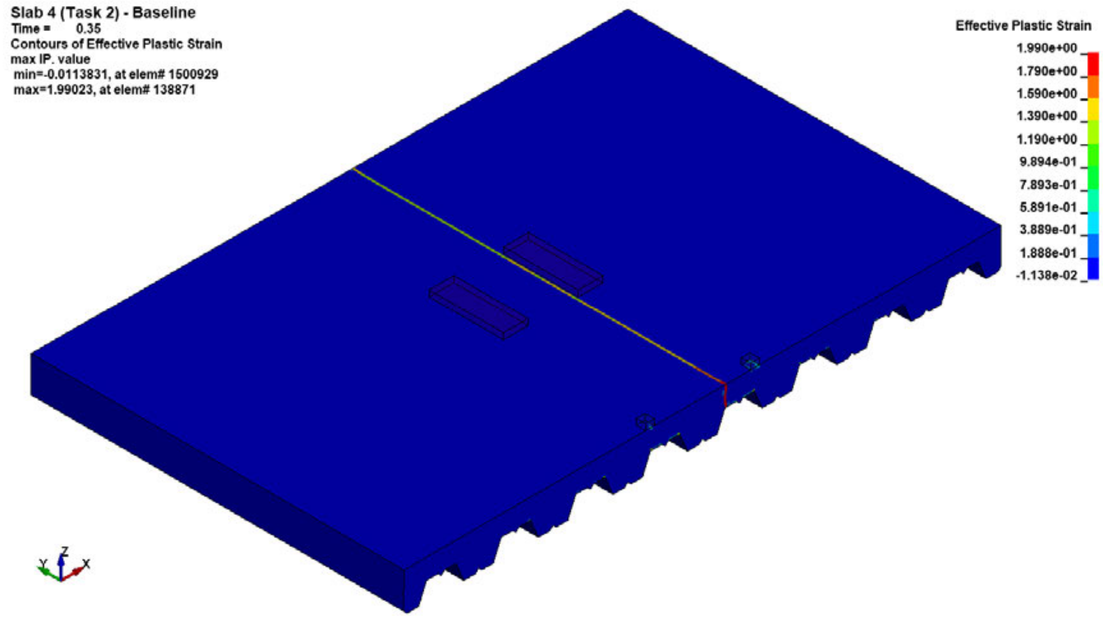


Figure 6-36 – Slab 4 (Model 1, Task 2): damage contour at 100% slab + operator weight and 85.3% rotary floor saw weight.

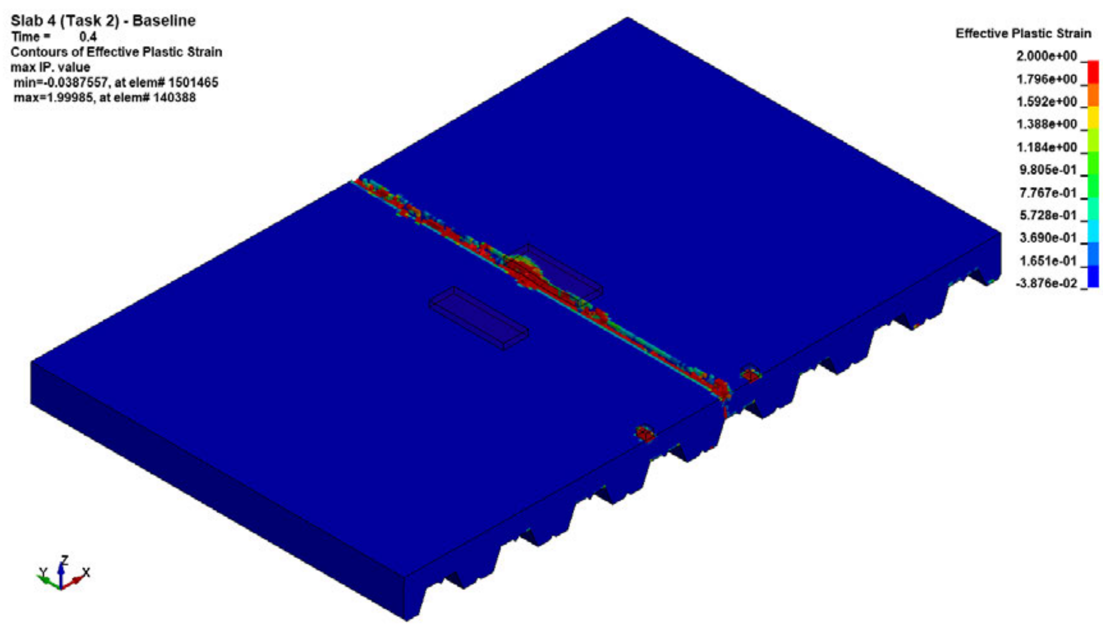
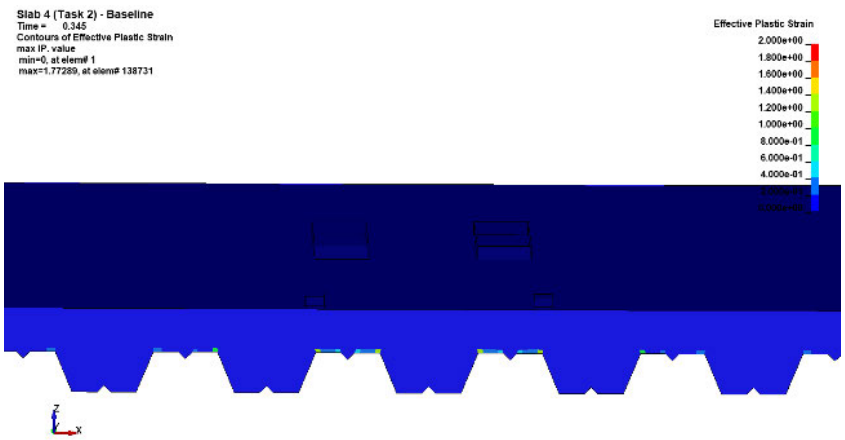
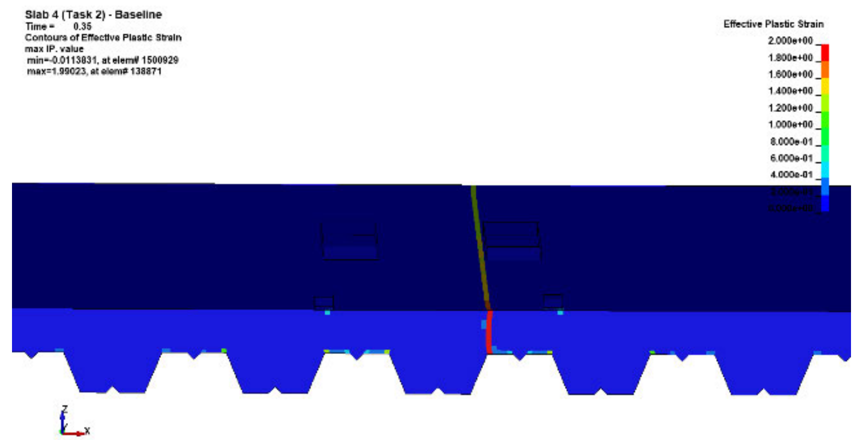


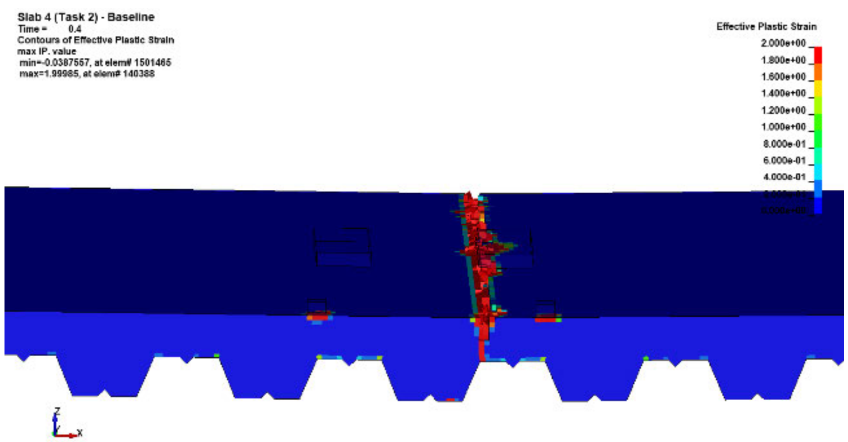
Figure 6-37 – Slab 4 (Model 1, Task 2): damage contour at 100% slab + operator + rotary floor saw weight (full weight).



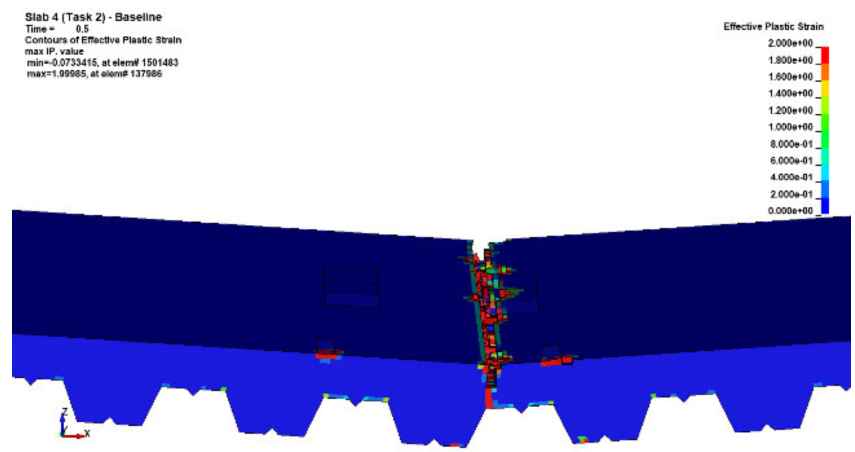
(a) 100% slab + operator weight, 59.2% rotary floor saw weight



(b) 100% slab + operator weight, 85.3% rotary floor saw weight

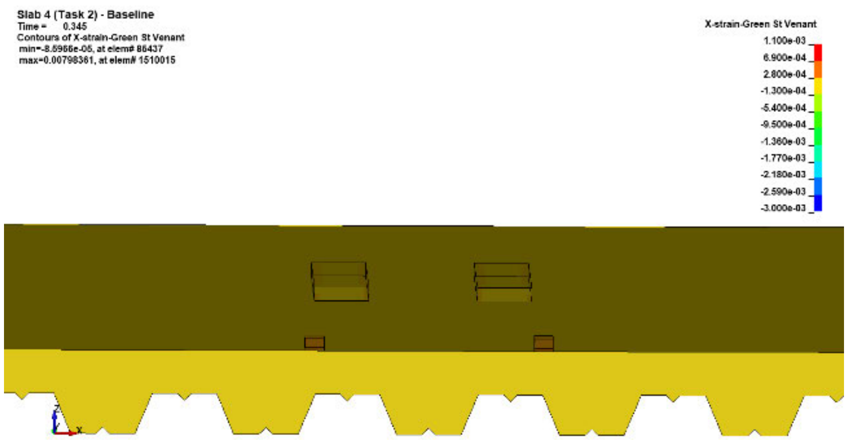


c) End of gravity loading (100% slab + operator + rotary floor saw weight)

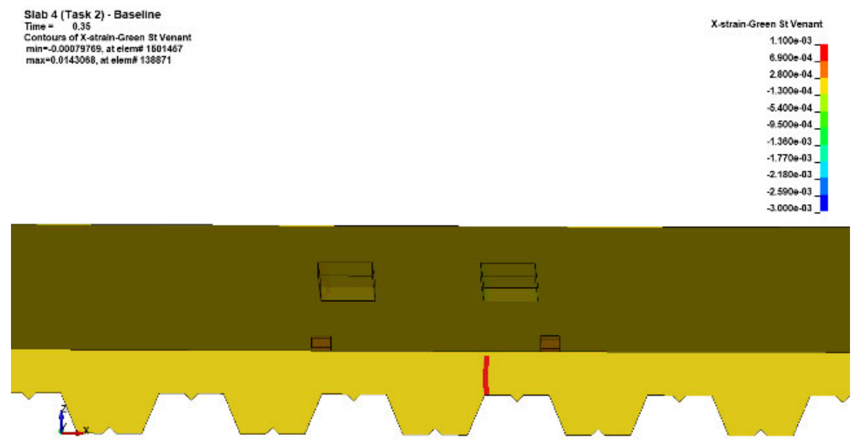


(d) 0.1 sec after end of gravity loading

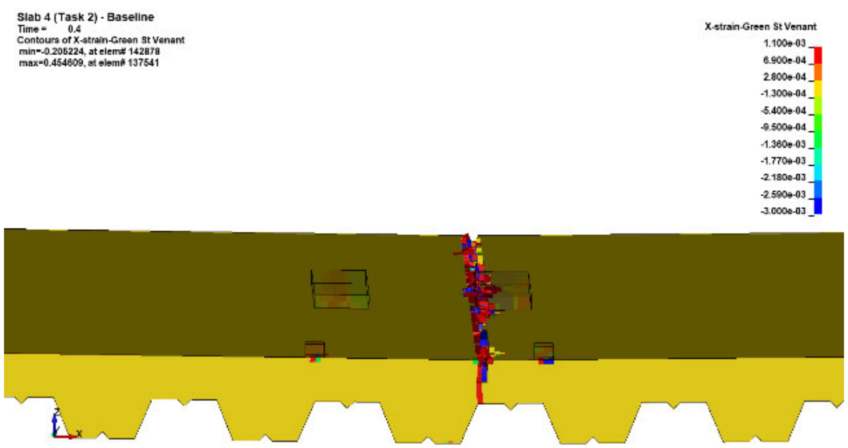
Figure 6-38 – Slab 4 (Model 1, Task 2), close-ups of damage contour seen from south end of slab.



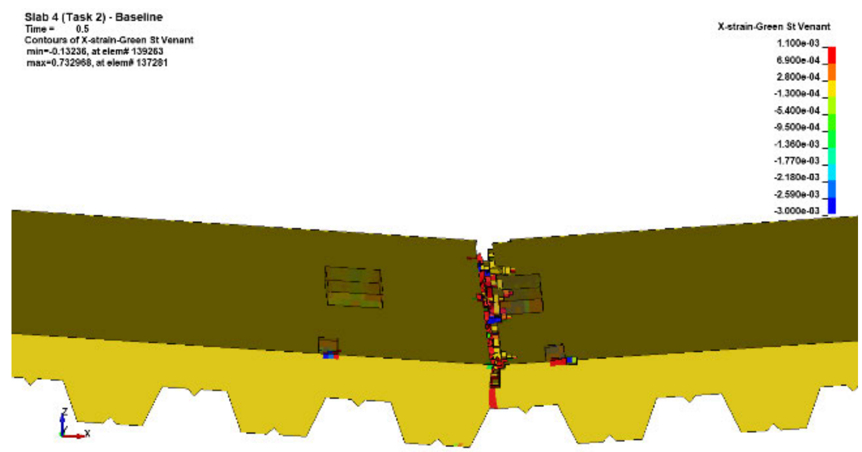
(a) 100% slab + operator weight, 59.2% rotary floor saw weight



(b) 100% slab + operator weight, 85.3% rotary floor saw weight



(c) End of gravity loading (100% slab + operator + rotary floor saw weight)



(d) 0.1 seconds after end of gravity loading

Figure 6-39 – Slab 4 (Model 1, Task 2), close-ups of global X-strain contour seen from south end of slab. The lower contour threshold is -0.3% (blue, concrete crushing) and the upper contour threshold is +0.11% (red, the tensile failure strain).

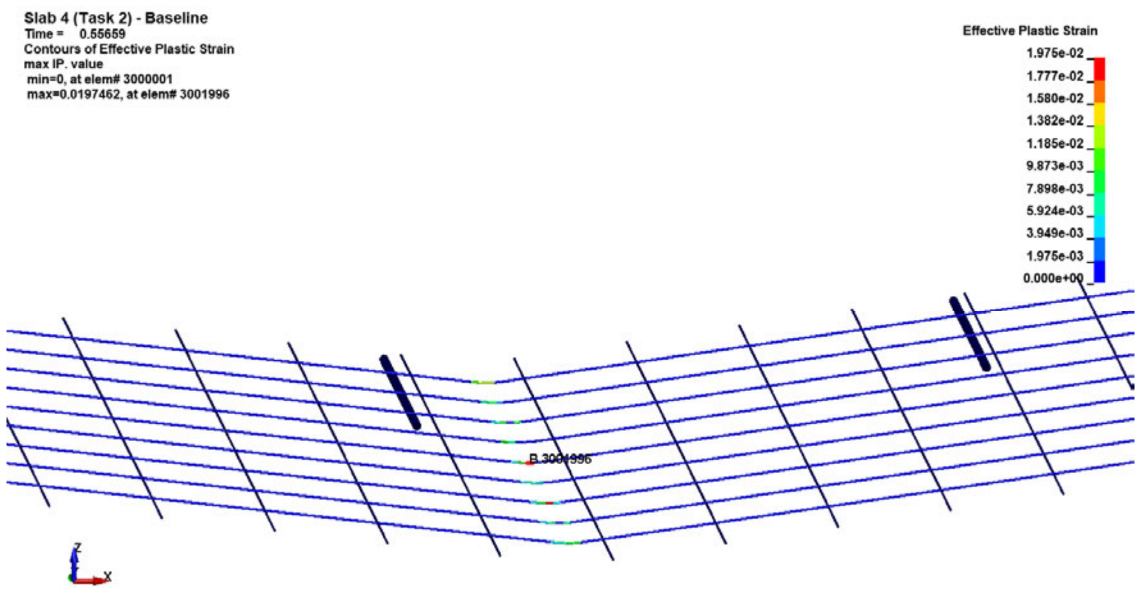


Figure 6-40 – Slab 4 (Model 1, Task 2), plastic strain contour in wire mesh at end of simulation (Note that maximum plastic strain reaches 2%).

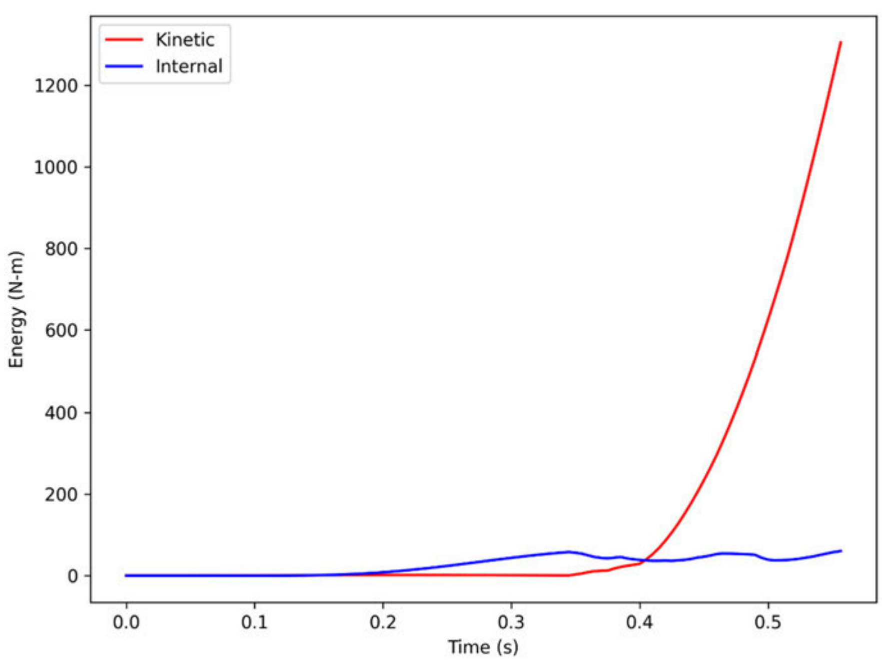


Figure 6-41 – Slab 4 (Model 1, Task 2), energy history (Note the increase in kinetic energy as the slab fails).

6.2.4.2 Slab 3 (Model 2, Task 3)

We modified the model developed for Slab 4 to incorporate the geometry, reinforcement and rigging point distances of Slab 3 and subjected it to self-weight of the slab and weights of the operator and rotary floor saw. We calculated the C/D ratios. The demand was determined from a linear elastic analysis by computing the bending moment across the width of the slab at the minimum thickness section by integrating the stresses in the concrete and steel elements making up the cross section that passes through the concrete. We then extended the nonlinear analysis to capture the ultimate strength of the slab. At failure, the maximum principal strain was 262 micro strains, which is larger than 93 micro strains corresponding to the tensile strength of concrete, and a damage variable equal to 1.79. The capacity was calculated in the same way as for the demand, using the stresses from the nonlinear model corresponding to the maximum capacity of the same cross section. The results show a C/D ratio of 2.23. The results of our analysis are the C/D ratios, i.e., safety factors S_F:

$$S_F = \frac{C}{D} = \frac{M_U}{M_D\,(self\ weight)} = 2.71 \qquad \text{Eq. 5.1}$$

$$S_F = \frac{C}{D} = \frac{M_U}{M_D(self\ weight + Operator)} = 2.46 \qquad \text{Eq. 5.2}$$

$$S_F = \frac{C}{D} = \frac{M_U}{M_D(self\ weight + Operator + saw)} = 2.23 \qquad \text{Eq. 5.3}$$

The calculated safety factor exceeds the minimum required safety factor of 1.7.

The sum of the vertical reactions of slings is shown in Figure 6-42, which shows that the slab does not fail (total weight of slab + operator + saw, shown as horizontal red line, is less than the sum of the sling vertical reactions). There was damage accumulated in the slab as shown in Figure 6-43. The maximum damage variable is less than 1.0, which means that material response did not produce a stress that exceeds the tensile strength of concrete, but the material was no longer linear elastic and had material nonlinearity. Nonlinearity implies that microcracking had developed but had not coalesced to form a macrocrack through the slab thickness. The maximum damage variable is about 0.29, but these were highly localized at the connection points between slab and the deck. At the minimum slab thickness near the midspan, the maximum value is about 0.04, which is significantly smaller than 1.0.

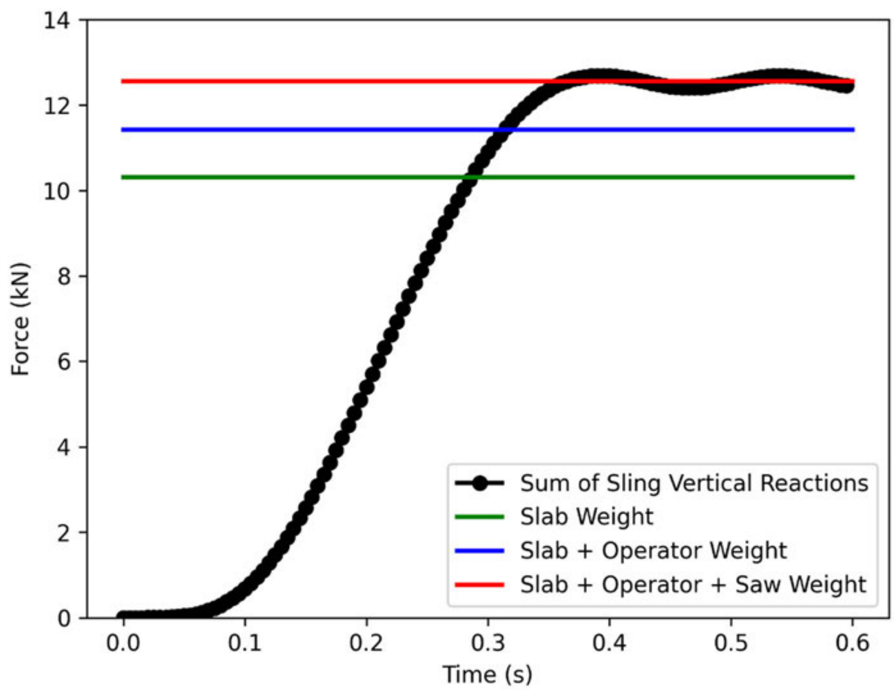


Figure 6-42 – Slab 3 (Model 2, Task 3), sum of sling vertical reactions.

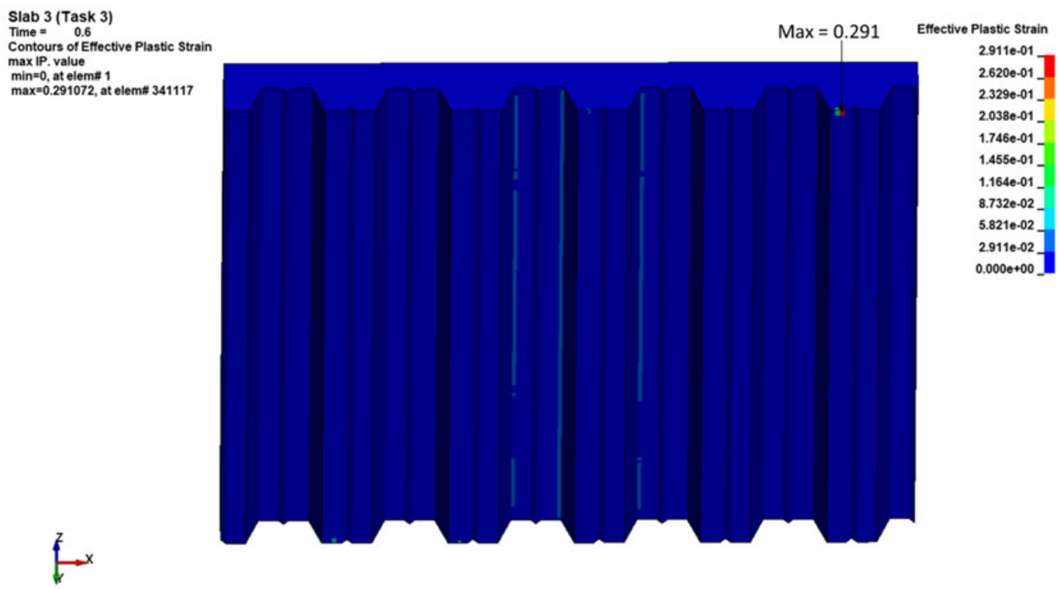


Figure 6-43 – Slab 3 (Model 2, Task 3), damage contour, view from under the slab. Note absence of cracking or crushing of concrete. Note: maximum damage variable is about 0.29, at a connection point between slab joist and deck, maximum (tensile) damage variable at the minimum slab thickness corners is about 0.04 (maximum principal strain of approximately 56 micro strain).

6.2.4.3 Slab 2 (Model 3, Task 4)

For Slab 2, we modified the model developed for Slab 4 to incorporate the geometry, reinforcement and rigging point distances of Slab 2 and subjected it to self-weight of the slab and weights of the operator and rotary floor saw. We calculated the C/D ratios. The demand was determined from a linear elastic analysis by computing the bending moment across the width of the slab at the minimum thickness section by integrating the stresses in the concrete and steel elements making up the cross section that passes through the concrete. We then extended the nonlinear analysis to capture the ultimate strength of the slab. At failure, the maximum principal strain was 244 micro strains, which is larger than 93 micro strains corresponding to the tensile strength of concrete, and a damage variable equal to 1.76. The capacity was calculated in the same way as for the demand, using the stresses from the nonlinear model corresponding to the maximum capacity of the same cross section. The results show a C/D ratio of 2.38. The results of our analysis are the C/D ratios, i.e., safety factors S_F:

$$S_F = \frac{C}{D} = \frac{M_U}{M_D\ (self\ weight)} = 2.77 \qquad \text{Eq. 6.1}$$

$$S_F = \frac{C}{D} = \frac{M_U}{M_D(self\ weight+Operator)} = 2.59 \qquad \text{Eq. 6.2}$$

$$S_F = \frac{C}{D} = \frac{M_U}{M_D(self\ weight+Operator+saw)} = 2.38 \qquad \text{Eq. 6.3}$$

The calculated safety factor exceeds the minimum required safety factor of 1.7.

The sum of the vertical reactions of the four slings presented in Figure 6-44 shows that the slab does not fail. There was damage accumulated in the slab as shown in Figure 6-45. The damage levels were less than 1.0, which implies that material response was no longer linear elastic and had experienced material nonlinearity, but the stresses had not yet reached the peak tensile strength. Physically, this means that microcracking had developed but had not yet coalesced to form a transverse macrocrack through the slab thickness. The maximum damage is about 0.96, but this damage was highly localized at the connection points between slab and the deck. At the minimum slab thickness corners near the midspan, the maximum damage value is about 0.03, which is significantly smaller than 1.0.

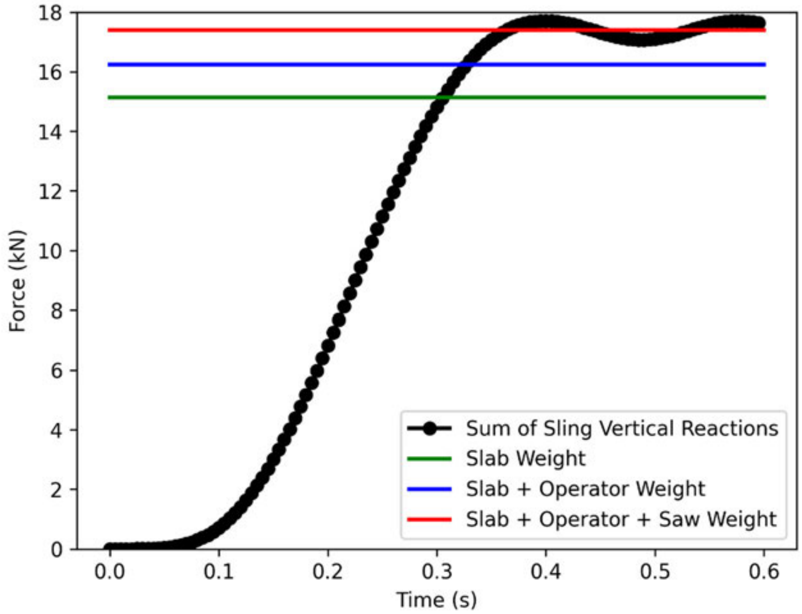


Figure 6-44 – Slab 2 (Model 3, Task 4), sum of sling vertical reactions.

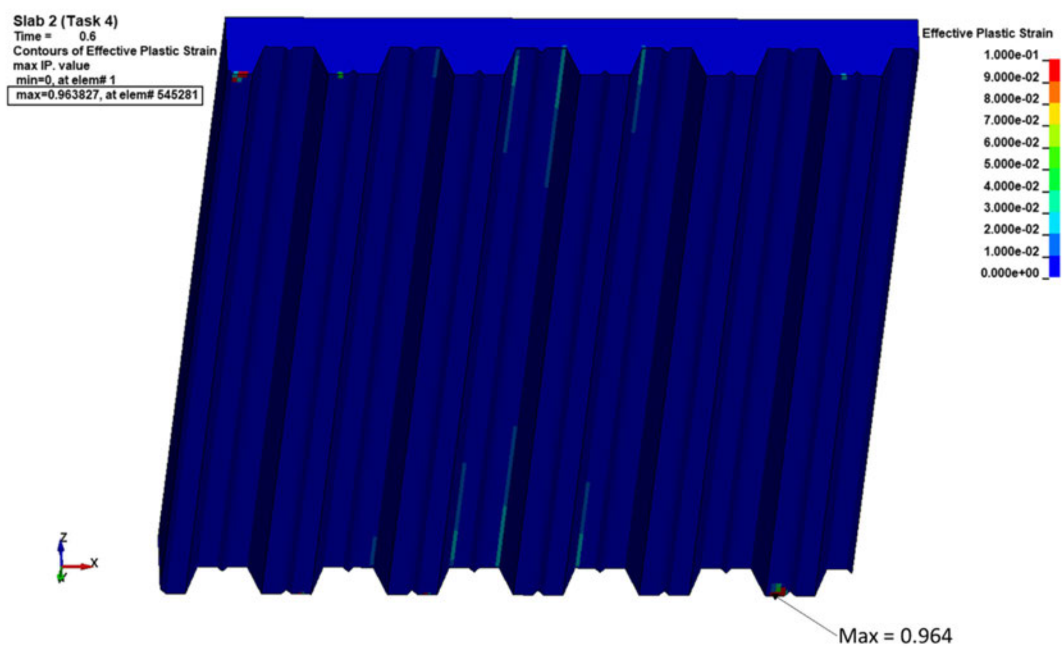


Figure 6-45 – Slab 2 (Model 3, Task 4), damage contour, view from under the slab. Note absence of cracking or crushing of concrete. Note: upper threshold of 0.1 is applied to highlight damage levels at the minimum slab thickness corners near the midspan – maximum damage value is about 0.96, at a connection point between slab joist

and deck, the maximum (tensile) damage variable at the minimum slab thickness corners is about 0.03 (maximum principal strain of approximately 51 micro strains).

6.2.4.4 Slab 4 Short (Model 4, Task 5)

This model is designated as Slab 4 Short, indicating that the length of the Slab 4 is cut short to match the length of Slab 3. The rigging points relative to the slab corners are the same as those of Slab 4 (Model 1, Task 2). The reinforcement is also the same as in Slab 4 (Model 1, Task 2) (wire mesh only, no longitudinal rebars). We calculated the C/D ratios. The demand was determined from a linear elastic analysis by computing the bending moment across the width of the slab at the minimum thickness section by integrating the stresses in the concrete and steel elements making up the cross section that passes through the concrete. We then extended the nonlinear analysis to capture the ultimate strength of the slab. At failure, the maximum principal strain was 244 micro strains, which is larger than 93 micro strains corresponding to the tensile strength of concrete, and a damage variable equal to 1.76. The capacity was calculated in the same way as for the demand, using the stresses from the nonlinear model corresponding to the maximum capacity of the same cross section. The results show a C/D ratio of 2.38. The results of our analysis are the C/D ratios, i.e., safety factors S_F:

$$S_F = \frac{C}{D} = \frac{M_U}{M_D\ (self\ weight)} = 2.71 \qquad \text{Eq. 7.1}$$

$$S_F = \frac{C}{D} = \frac{M_U}{M_D(self\ weight + Operator)} = 1.89 \qquad \text{Eq. 7.2}$$

$$S_F = \frac{C}{D} = \frac{M_U}{M_D(self\ weight + Operator + saw)} = 1.69 \qquad \text{Eq. 7.3}$$

The calculated safety factor barely meets the minimum required safety factor of 1.7.

The sum of the vertical reactions of slings is shown in Figure 6-46, which shows that the slab did not fail. There was damage accumulated in the slab as shown in Figure 6-47. The damage levels were less than 1.0, which means that material response had transitioned past the linear elastic regime into the nonlinear damage-accumulating regime, but the stresses had not yet reached the peak tensile strength. Physically, this means that microcracking had developed but had not yet coalesced to form a transverse macrocrack through the slab thickness. The maximum damage is about 0.47, but this damage was highly localized at the connection points between the slab and the deck. At the minimum slab thickness corners near the midspan, the maximum damage value is about 0.13, which is significantly smaller than 1.0.

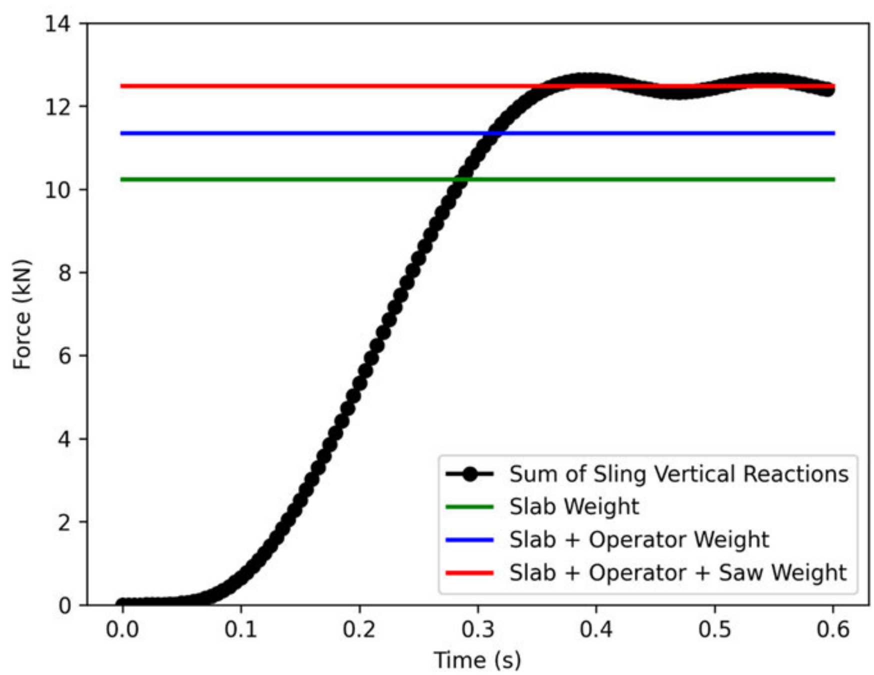


Figure 6-46 – Slab 4 Short (Model 4, Task 5), sum of sling vertical reactions.

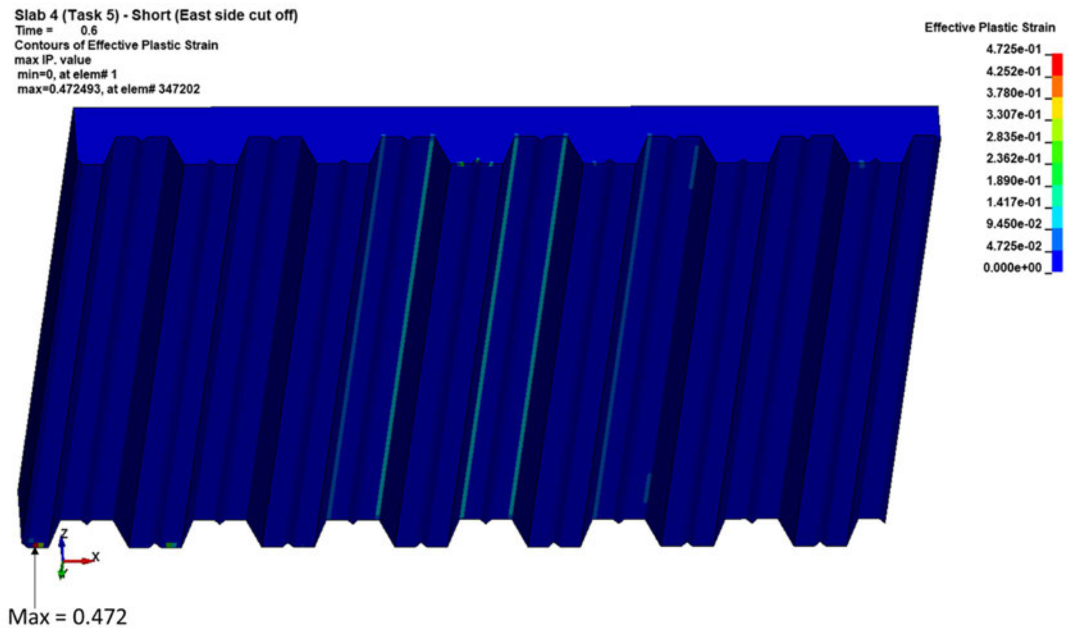


Figure 6-47 – Slab 4 Short (Model 4, Task 5), damage contour, view from under the slab. Note absence of cracking or crushing of concrete. Note: maximum damage value is about 0.47, localized at a connection point between slab joist and deck, maximum (tensile) damage at the minimum slab thickness corners is about 0.13 (maximum principal strain of approximately 70 micro strain).

6.2.4.5 Slab 4 Reinforced (Model 5, Task 6)

This model is the same as that of Slab 4, but with the reinforcement of Slab 2, which provides additional #4 rebars that run in the E/W direction. We calculated the C/D ratios. The demand was determined from a linear elastic analysis by computing the bending moment across the width of the slab at the minimum thickness section by integrating the stresses in the concrete and steel elements making up the cross section cut that passes through the concrete element with the maximum damage value. The capacity was calculated in the same way as for the demand, using the stresses from the nonlinear model corresponding to the maximum capacity of the same cross section. As shown below, the results of our analysis are the C/D ratios, i.e., safety factors S_F. After initiation of visible cracking, the capacity drops rapidly.

$$S_F = \frac{C}{D} = \frac{M_U}{M_D\ (self\ weight)} = 1.12 \qquad \text{Eq. 8.1}$$

$$S_F = \frac{C}{D} = \frac{M_U}{M_D(self\ weight + Operator)} = 1.03 \qquad \text{Eq. 8.2}$$

$$S_F = \frac{C}{D} = \frac{M_U}{M_D(self\ weight + Operator + saw)} = 0.96 \qquad \text{Eq.8.3}$$

The calculated safety factor is much less than the minimum required safety factor of 1.7.

The sum of the sling vertical reactions is shown in Figure 6-48, which shows that the maximum load carried by the slab when the first flexural transverse crack formed is 100% slab and operator weight plus 71.4% of the rotary floor saw weight.

The damage evolution in the slab is shown in Figure 6-49 and Figure 6-50. Tensile cracking and damage still occurred at minimum slab thickness corners like in the Slab 4 (Model 1, Task2) baseline model described in Section 6.2.4.1. Here, however, crack propagation was first initiated at the minimum slab thickness under the operator and rotary floor saw masses as shown in Figure 6-50. The additional #4 rebars carried the weight following the loss of concrete modulus. Initially, the additional rebars did arrest and prevent the damage from reaching the top surface, as intended in reinforced concrete, but damage continued to accumulate along the rebars.

There is an overloading of the slab due to inertial effects that ensued from the first cracking as can be seen in the sum of the sling vertical reactions (see Figure 6-48). The slab continues to deform and at approximately 0.64 sec after full gravity, the slab configuration is as shown in Figure 6-51. Two macrocracks propagated through the entire slab, splitting the slab into major pieces, with significant crushing and disintegration of concrete near the low point of the deformed slab. Other cracks also appear parallel to the two macrocracks. The rebars crossing the cracked surfaces begin to yield. As deformation of the slab increases, the yielding of the rebar increases; in Figure 6-52, the maximum plastic strain reached is about 4.9%. Note that the damage and failure processes mentioned above are occurring while the kinetic energy of the system is still increasing (see Figure 6-53). As the vertical deflection of the slab continues to increase, the two halves of concrete slab that are hinging about the yielding rebars would close very rapidly. At this point, the slab has failed and continues to deform.

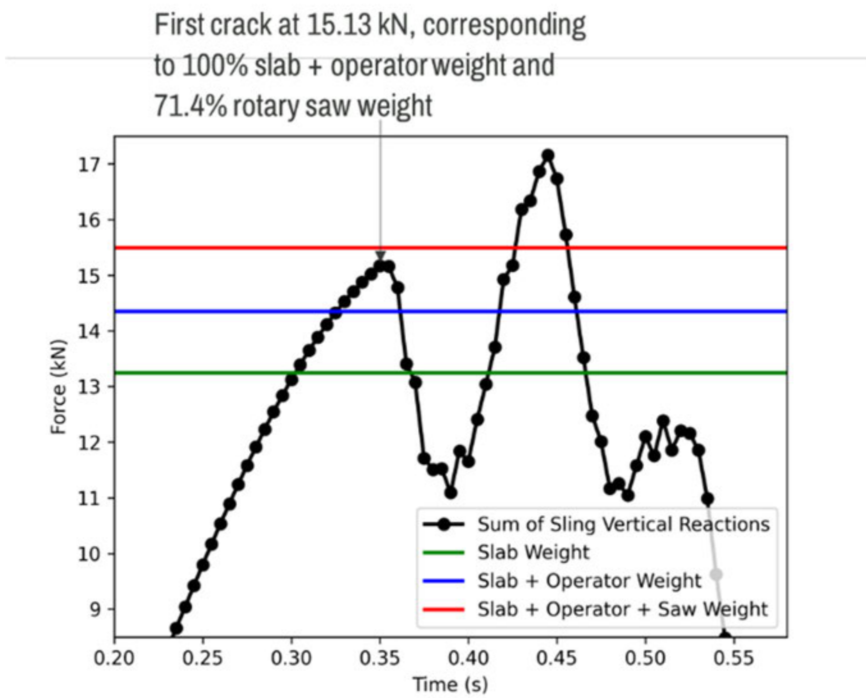
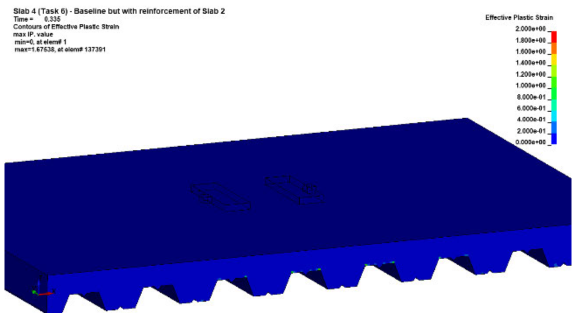
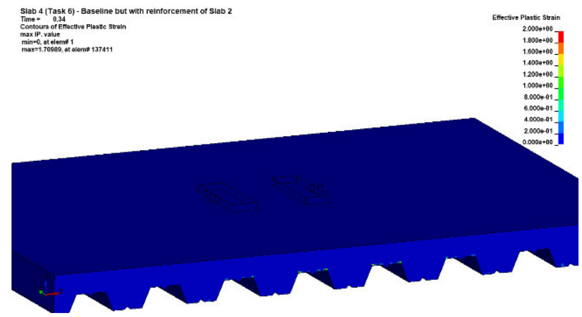


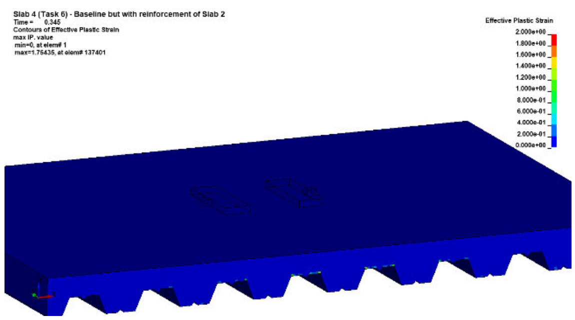
Figure 6-48 – Slab 4 Reinforced (Model 5, Task 6): sum of sling vertical reactions and close-up of load history near the peak.



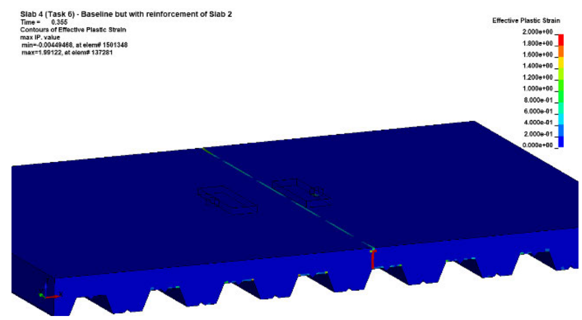
(a) 100% slab + Operator weight, 31.5% rotary floor saw weight



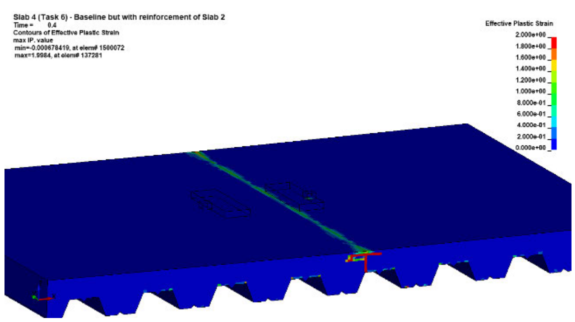
(b) 100% slab + operator weight, 45.9% rotary floor saw weight



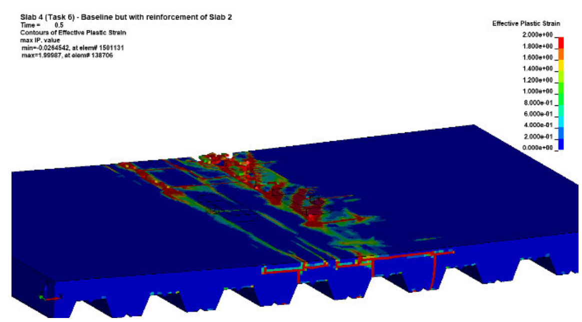
(c) 100% slab + operator weight, 59.1% rotary floor saw weight



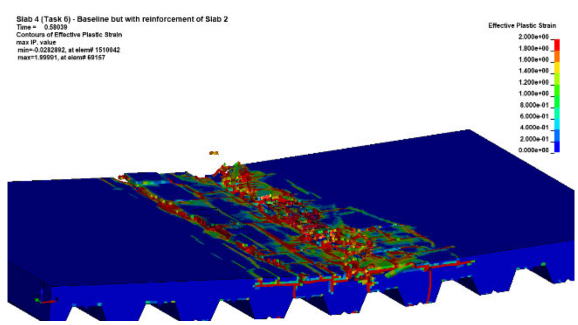
(d) 100% slab + operator weight, 71.4% rotary floor saw weight



(e) At full gravity (100% slab + operator + rotary floor saw weight)

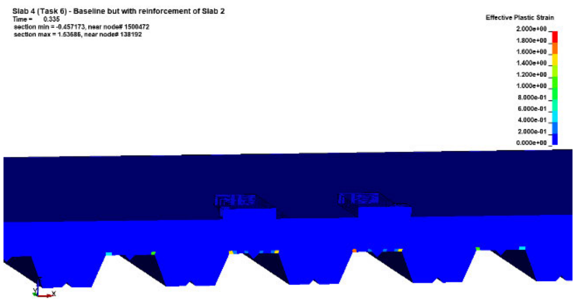


(f) 0.1 sec after full gravity



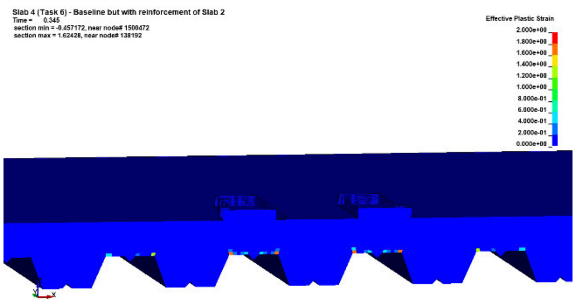
(g) 0.18 sec after full gravity

Figure 6-49 – Slab 4 Reinforced (Model 5, Task 6), damage contour, view from south end of slab.

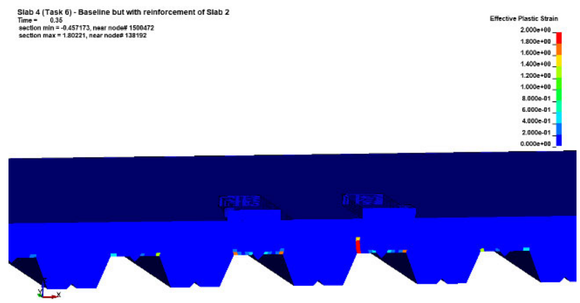


(a) 100% slab + operator weight, 31.5% rotary floor saw weight

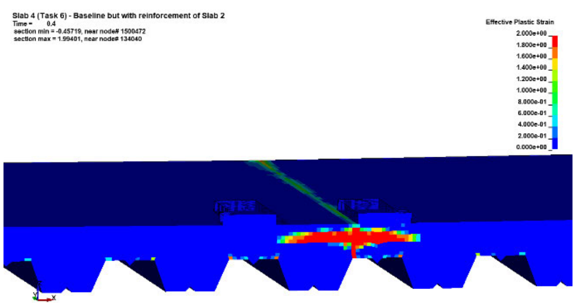
(b) 100% slab + operator weight, 45.9% rotary floor saw weight



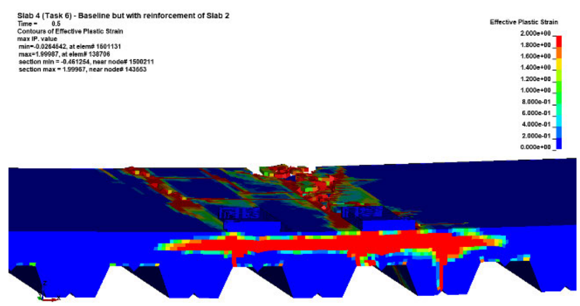
(c) 100% slab + operator weight, 59.1% rotary floor saw weight



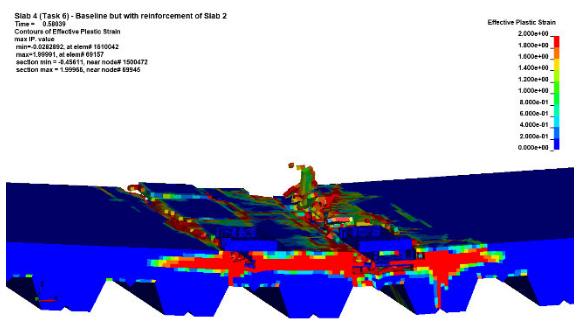
(d) 100% slab + operator weight, 71.4% rotary floor saw weight



(e) At full gravity (100% slab + operator + rotary floor saw weight)



(f) 0.1 seconds after full gravity



(g) 0.18 seconds after full gravity

Figure 6-50 – Slab 4 Reinforced (Model 5, Task 6), damage contour, section cut through operator and rotary floor saw masses.

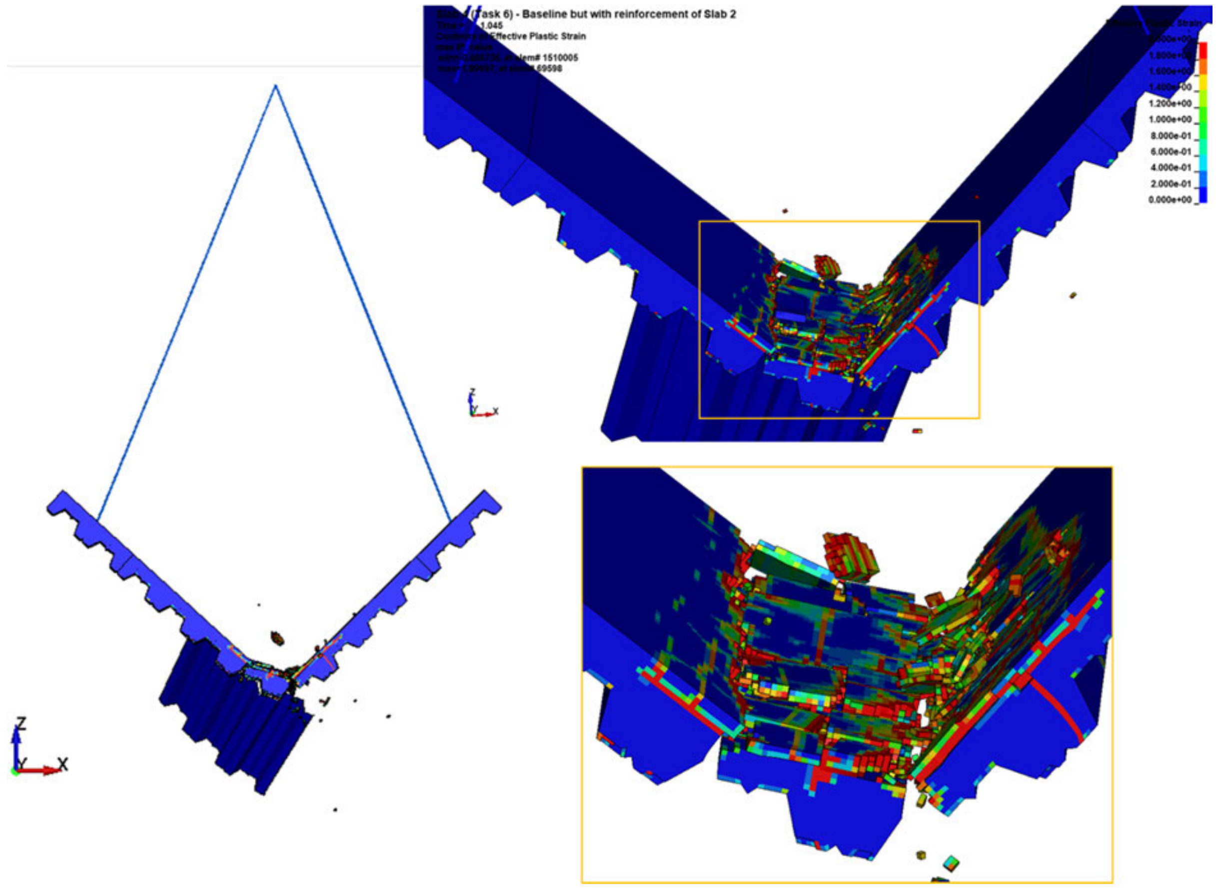


Figure 6-51 – Slab 4 Reinforced (Model 5, Task 6), damage contour at 0.645 seconds after full gravity.

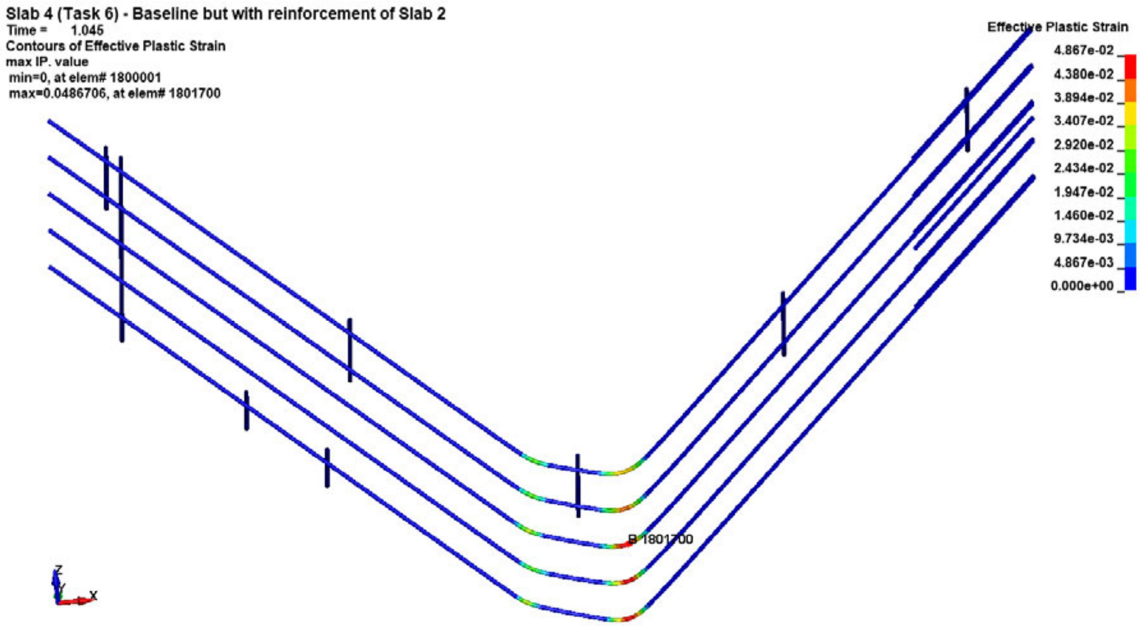


Figure 6-52 – Slab 4 Reinforced (Model 5, Task 6), plastic strain contour of rebars. Maximum plastic strain is about 4.9%.

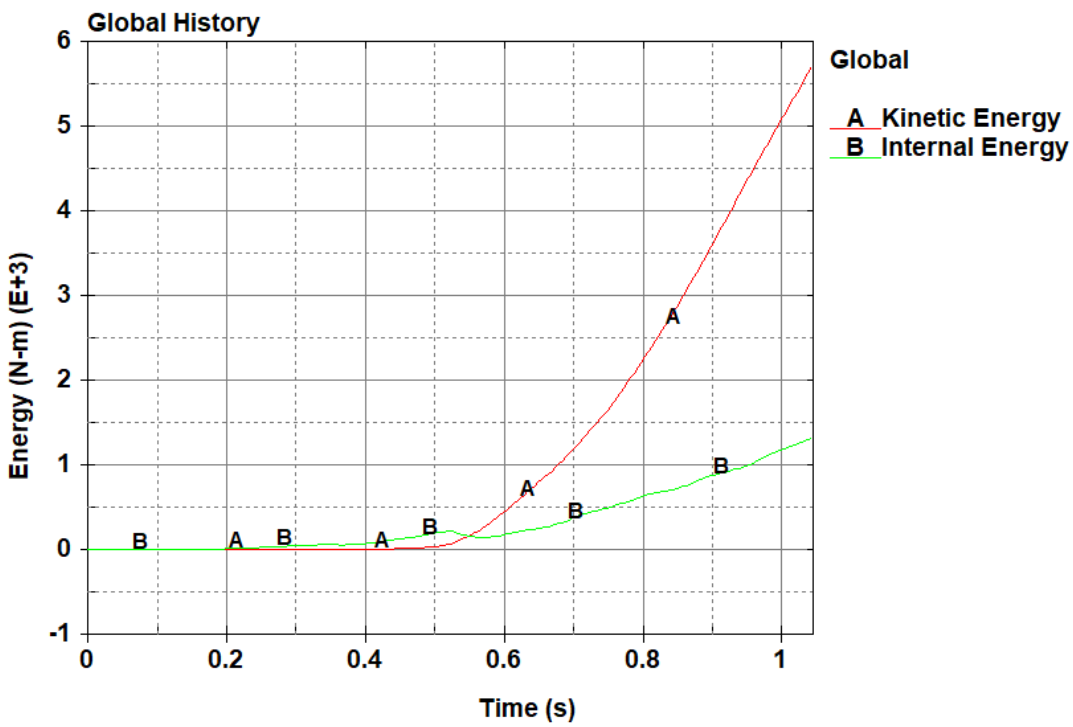


Figure 6-53 – Slab 4 Reinforced (Model 5, Task 6), global kinetic and internal energy histories.

6.2.4.6 Slab 4 Rigging (Model 6, Task 7)

This model is designated as Slab 4 Rigging, indicating that the rigging points of Slab 4 are changed by moving them inward, toward the center, by 305 mm (12 in). We calculated the C/D ratios. The demand was determined from a linear elastic analysis by computing the bending moment across the width of the slab at the minimum thickness section by integrating the stresses in the concrete and steel elements making up the cross section that passes through the concrete. We then extended the nonlinear analysis to capture the ultimate strength of the slab. At failure, the maximum principal strain was 247 micro strains, which is larger than 93 micro strains corresponding to the tensile strength of concrete, and a damage variable equal to 1.77. The capacity was calculated in the same way as for the demand, using the stresses from the nonlinear model corresponding to the maximum capacity of the same cross section. The results show a C/D ratio of 2.38. The results of our analysis are the C/D ratios, i.e., safety factors S_F:

$$S_F = \frac{C}{D} = \frac{M_U}{M_D\ (self\ weight)} = 2.03 \qquad \text{Eq. 9.1}$$

$$S_F = \frac{C}{D} = \frac{M_U}{M_D(self\ weight + Operator)} = 1.85 \qquad \text{Eq. 9.2}$$

$$S_F = \frac{C}{D} = \frac{M_U}{M_D(self\ weight + Operator + saw)} = 1.70 \qquad \text{Eq. 9.3}$$

The calculated safety factor barely meets the minimum required safety factor of 1.7.

The sum of the sling vertical reactions is shown in Figure 6-54, which shows that the slab did not fail. There was damage accumulated in the slab as shown in Figure 6-55. The damage levels were less than 1.0, which means that material response was no longer elastic and had yielded, but the stresses had not yet reached the peak tensile strength. Physically, this means that microcracking had developed but has not yet coalesced to form a transverse macrocrack through the slab thickness. The maximum damage is about 0.33, but this damage was highly localized at the connection points between slab and the deck. At the minimum slab thickness corners near the midspan, the maximum damage value is about 0.13, which is significantly smaller than 1.0.

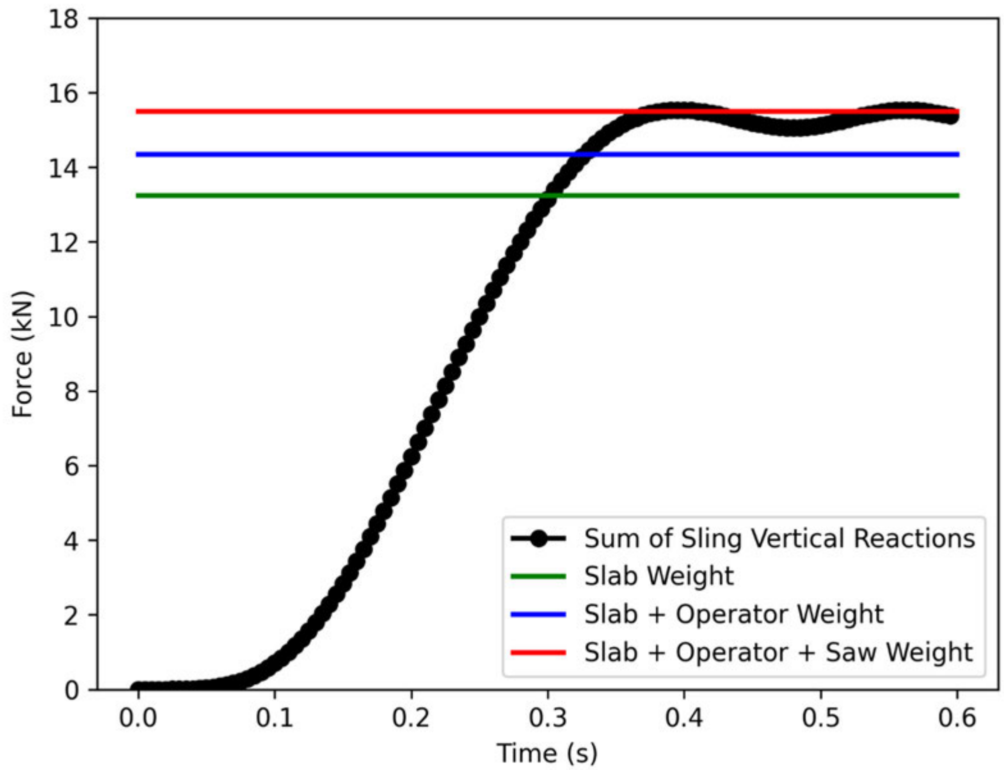


Figure 6-54 – Slab 4 Rigging (Model 6, Task 7), sum of sling vertical reactions.

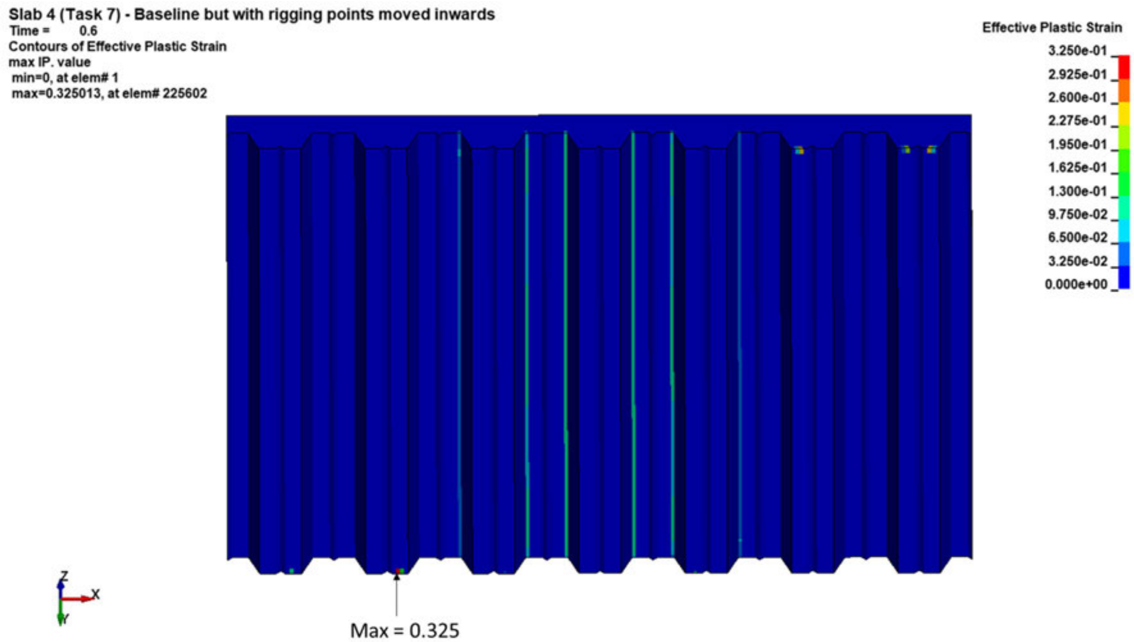


Figure 6-55 – Slab 4 Rigging (Model 6, Task 7), damage contour, view from under the slab. Note absence of cracking or crushing of concrete. Note: maximum damage value is about 0.33, localized at a connection point between slab joist and deck, maximum tensile damage at the minimum slab thickness corners is about 0.13 (maximum principal strain of approximately 70 micro strains).

6.3 Quality Assurance

We performed this work in accordance with the SGH Corporate Quality Manual. All analyses and calculations were performed by qualified staff members who were selected by and supervised by the project's Principal in Charge (PIC), Mehdi Zarghamee and the Project Manager (PM), Robert MacNeill. All analyses and calculations were independently verified by qualified staff members (other than those performing the tasks) who were assigned by the PIC and the PM. An independent quality review was performed by Nicholas Catella and Steven Palkovic, the Quality Assurance Reviewers.

7. DISCUSSION OF THE RESULTS

In this chapter, we will discuss several issues of significance including (i) sensitivity of the results of our 3D finite element analysis and failure occurrence to the axial tensile strength of concrete, (ii) impact of dynamic response of the slab after visible cracking of concrete, (iii) impact of differences in the effective length of slings on failure of slab, and (iv) comparison of hand calculations in Section 6.1 and FEA results.

7.1 Failure Criteria

Flexural failure of a reinforced concrete slab under increasing load requires tensile cracking of concrete in tension zone and either compression failure of concrete in the compression zone or tensile rupture of rebars. When two of these conditions are met, the slab is unable to carry the load and continues to deform.

To capture failure, in addition to the nonlinear stress-strain relationship in compression, we set up a compressive failure criterion of 0.3% strain at the extreme fiber of concrete in compression. At strains less than 0.3%, the stress-strain relationship is initially linear, and changes to nonlinear as stress approaches the compressive strength of concrete. For strains greater than 0.03%, the stress drops rapidly with increasing strain. For tension, we consider a bilinear stress-strain relationship for concrete in which stress is initially linear function of strain until it reaches the tensile strength, followed by a linear strain softening branch where stress decreases with strain with a modulus of E/10. For strains in the entire strain softening zone, the concrete experiences microcracking and the microcracks tend to coalesce and form the first visible crack when tensile stress reaches zero at a strain of $11\epsilon_t$ where ϵ_t is strain corresponding to maximum tensile strength. We also calculate a damage factor that is 0 when stress is so small that there is no material nonlinearity from microcracking or cracking of concrete or plasticity of steel. The damage factor is greater than 0 and less than 1 when there is nonlinearity from microcracking of concrete and plasticity of steel. It reaches 2 when strain in concrete reaches the visible cracking strain of $11\epsilon_t$ in tension, failure strain of 0.3% in compression, or failure of steel in tension or compression.

For failure to occur, we must have a damage factor of 2 with a macrocrack (i.e., a crack that separates concrete masses and is visible to the naked eye, also referred to as a crack) in the tension zone and either concrete crushing in the compression zone or yielding and fracturing of tension bars. For cases where maximum sustained damage is below 2, the slab is not in a state of failure, but damage may exist in the form of microcracking in tension or compression. When the damage factor is less than 1, the slab does not manifest any sign of damage to the naked eye.

7.2 Sensitivity of 3D Finite Element Analysis Results on Tensile Strength of Concrete

We found that the results of the 3D finite element analysis performed to determine the structural safety of Slab 4 (Task 2), supported by four slings and subjected to the self-weight of slab and the weights of the operator and the rotary floor saw, are sensitive to the value of uniaxial tensile strength of concrete. A value for uniaxial tensile strength of 3 MPa (435 psi), as reported by the split disk test performed for NIST, resulted in failure while a value of 4.096 MPa (594 psi), as tested by SGH, did not. Our petrographic examination of polished and thin sections of concrete indicated several reasons for the variability of the split-disk test results, including, but not limited to, weaker concrete near the exposed surfaces from carbonation and existence of large air voids in the mix caused by inadequate compaction of concrete. Furthermore, the uniaxial tensile strength of concrete is expected to be about 90% of the split disk tensile strength. Therefore, we elected to use a value for uniaxial tensile strength of 3.27 MPa (474 psi), corresponding to a split disk tensile strength of 3.63 MPa (526 psi), which is midway between the NIST measured and SGH measured splitting tensile strength) and results in failure of the baseline Slab 4 (Task 2) in our finite element analysis.

7.3 Impact of Dynamic Response on Failure Prediction

We found that once concrete at midspan of Slab 4 cracks while the slab is supported by four slings, a dynamic situation occurs as the cracked slab responds to the abrupt change. The dynamic response of the slab increases the load effects and thus can result in failure of the slab in cases where static analysis does not result in failure.

Lifting a rigid plate with four slings may not result in expected load distribution, and differences in length among the four slings may result in significant changes in load distribution. The circular slings have a well-controlled length of 3.05 m (10 ft) when stretched between two points. A carefully installed anchorage system of slings may not result in differences in the effective lengths between the four slings. However, the use of the choker attachment of the sling to the anchors may result in differences in the lengths of the slings and give rise to changes in the load distribution on the slab and impact the load at which the failure of the slab initiates. We performed a study to evaluate the impact of slack in one of the slings on stresses in the slab. The results presented in Appendix E show that the expected slack in one of the slings does not impact the stresses in the slab appreciably.

7.4 Differences between Hand Calculations and 3D Finite Element Analysis

The results of our hand calculations of the ultimate strength of the slab do not always agree with the results obtained from the 3D finite element analysis of the same problem. An example is Slab 4 with additional reinforcement, i.e., Slab 4 (Task 6), where hand calculation shows that the additional reinforcement will provide sufficient extra capacity to withstand the load effects without failure, but 3D finite element analysis shows that the slab is subject to failure. The sources for this observed discrepancy are as follows:

- Assumption of rigid vertical support in hand calculation instead of flexible slings in tension and zero stiffness in compression can result in different load distributions on the slab.
- Absence of consideration of dynamic response of slab after concrete cracking in hand calculation as opposed to our 3D finite element analysis that treats the problem as a dynamic system that results in the finite element model predicting failure at a lower load due to additional inertial forces.
- Hand calculation typically involves neglecting the effects of stress risers in concrete resulting from the geometry of the concrete slab. The 3D finite element analysis of the slab accounts fully for the geometry of the slab.
- In hand calculation, the strength of the slab is computed assuming a slab of uniform thickness, thus neglecting the complex geometry of the concrete slab that conforms to

the geometry of steel deck. The 3D finite element analysis of the slab considers the complex geometry of the concrete slab.

- Hand calculation typically involves linear elastic analysis or simplified ultimate capacity calculations. The 3D finite element analysis of the slab accounts for the 3D nonlinearity of the materials.

8. CONCLUSIONS

We received and reviewed the available information gathered by NIST and conveyed to us by Dr. Long Phan. We visited the site, received additional information about the slabs and their loading and boundary conditions from presentations by Dr. Stephen W. Banovic, and reviewed the events that led to the failure of Slab 4. We then performed a thorough inspection of the fracture surfaces of the concrete slab and all components of the system and loadings related to Slab 4 failure. We examined the fracture surfaces of Slab 4. Our examination revealed no anomaly that differed from the expected features of flexural failure of the slab. We made measurements of the geometry and took photographs of concrete slab, steel deck, slings and their anchor systems, and reinforcements, including the rebars, welded wire fabric, and chairs of Slab 4. We also briefly inspected the intact Slab 3. During the visit, we also marked samples to be cut from the Slab 4 remnants and identified slings and other hardware to be sent to the SGH laboratory for testing. We performed petrographic examination and tested concrete modulus, tensile and compressive strength, and the stiffness of the sling. The results of concrete testing and petrography show that the quality of concrete used for fabrication of Slab 4 was acceptable and was not the cause of Slab 4's failure, although air voids may have contributed to lowering the tensile strength of concrete.

We used the tested properties of the sling to evaluate the impact of slack in one of the slings on the stresses in the slab. For this purpose, we ran the model of Slab 4 assuming elastic slab material properties and using test-determined properties for the slings. We made two runs: a baseline run in which all slings had equal length of 3.05 m (120 in.) and a second run in which one of the slings had 50.8 mm (2 in.) slack, i.e., 3.10 m (122 in.) length. 50.8 mm (2 in.) slack is much greater than our expected slack of a fraction of an inch. The result of our analysis is provided in Appendix E and shows that 50.8 mm (2 in.) slack increases the maximum tensile stress in the slab by 17.5%. Therefore, for expected slack of a fraction of an inch, the difference in stress demand is expected to be of the order of 2% to 4%. Therefore, we conclude that the expected differences in the length of slings was not a major contributing factor to the failure of Slab 4.

Using the collected and verified data and the measured material properties, we performed a series of six 3D nonlinear finite element analyses that can correctly simulate the failure of slabs under varying assumptions as follows:

Model 1 (Task 2), **Failure Analysis of Slab 4:** We constructed a detailed finite element model of Slab 4 and its four-sling support and subjected it to the sum of self-weight of the slab and weights of the operator and rotary floor saw. The analysis led to failure of the slab when the load reached 100% self-weight and weight of operator and 85.3% of the rotary floor saw weight, with an ultimate capacity-to-demand ratio of 0.96.

Model 2 (Task 3), **Failure Analysis of Slab 3**: We constructed a detailed finite element model of Slab 3, similar to that developed for Slab 4 (Task 2) but with Slab 3 dimensions, reinforcement details, and rigging locations subjected to four-sling support and self-weight of the slab and weights of the operator and rotary floor saw. The analysis results show that failure of Slab 3 (Task 3) does not occur with an ultimate capacity-to-demand ratio of 2.23.

.

Model 3 (Task 4), **Failure Analysis of Slab 2**: We made appropriate changes in the geometry, reinforcement details, and rigging locations of Slab 4 to match the Slab 2 design and performed finite element analysis to assess damage and failure potential of Slab 2 when subjected to the same loading and support conditions. The analysis led to no failure of Slab 2 with an ultimate capacity-to-demand ratio of 2.38.

Model 4 (Task 5), **Failure Analysis of Slab 4 Shortened**: We constructed a detailed finite element model of Slab 4, shortened to match the length of Slab 3 while maintaining the rigging points of Slab 4, and subjected it to the four-sling support, self-weight of the slab, and weights of the operator and rotary floor saw. The analysis led to no failure of the slab with an ultimate capacity-to-demand ratio of 1.69.

Model 5 (Task 6), **Failure Analysis of Slab 4 with Added Reinforcement:** We added steel reinforcement to the concrete slab considered in Model 1, Slab 4. The analysis results show increased capacity of Slab 4 to resist the loads, but Slab 4 will develop a deep crack and fractured and disintegrated concrete at the mid-length of slab, with separate halves of slab joined together along the fractured surface by the longitudinal reinforcement bridging the crack. As the vertical deflection of the slab continues to increase, the two halves of the concrete slab that are hinging about the yielding rebars close and confine both the operator and rotary floor saw. At this point, the slab has failed and continues to deform. The calculated ultimate capacity-to-demand ratio of this slab is 0.96.

Model 6 (Task 7), Failure Analysis of Slab 4 with Closer Rigging Points: We considered different rigging configurations compared to the baseline Slab 4 configuration (Task 2) in which the anchor points of slings are moved inward toward the center by 0.305m (12 in.) The result of the analysis indicates no failure of the slab with an ultimate capacity-to-demand ratio of 1.70 but shows that concrete tensile strain at the corners of the slab is high enough to cause microcracking, but not high enough to produce a visible crack, and that the concrete stress does not exceed the tensile strength.

During the process of performing numerical analysis, we observed that the results of our 3D FE analysis, regarding failure occurrence, are sensitive to (i) the axial tensile strength of concrete used in the FE model (as expected) and (ii) impact of dynamic response of the slab after flexural cracking has developed. We also noted the discrepancies between hand calculations of flexural strength of the slabs and the FEA results. The analyses we performed use a value of concrete axial tensile strength between the results of split-disk tensile strength tests performed by SGH and NIST. Given its minor influence, the analyses do not account for differences in effective length of the four supporting slings. The discrepancies between hand calculations and FEA results are all related to assumptions and simplifications made for hand calculations.

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APPENDIX A – PHOTOS OF LABORATORY TESETING AT SGH

Photo 5-1 – Received slab Sample 4B-1 (note direction indicated as North is actually South).

Photo 5-2 – Received slab sample 4D-1 (note direction indicated as North is actually South).

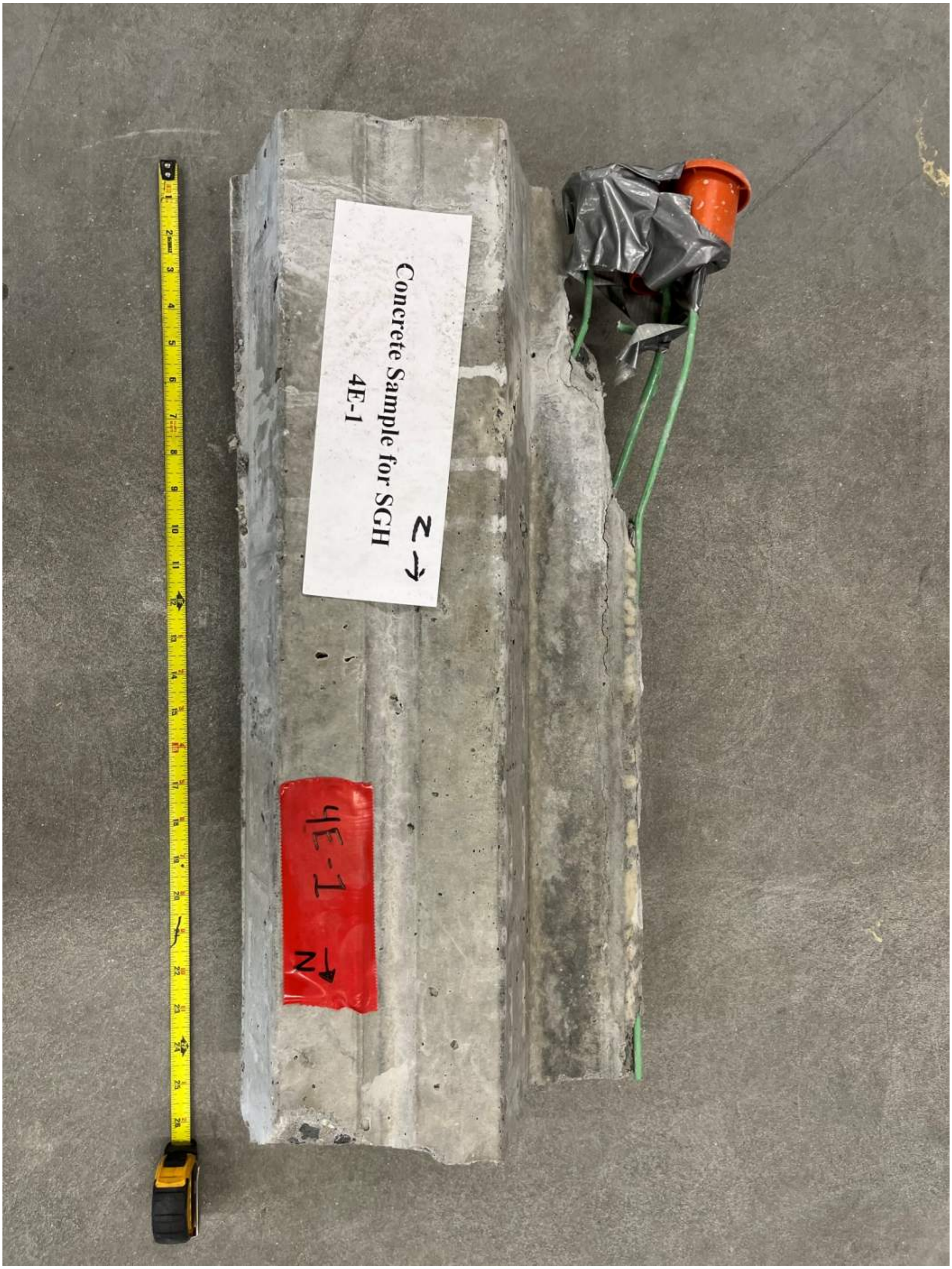


Photo 5-3 – Received slab sample 4E-1.

Photo 5-4 – Received SpanSet lifting sling.

Photo 5-5 – Received lifting anchor.

Photo 5-6 – Received reinforcement chair.

Photo 5-7 – Received concrete core sections.

Photo 5-8 – Looped lifting sling with section removed for tensile stiffness testing.

Photo 5-9 – Core extracted from sample 4B-1 with compression and tension halves identified.

Photo 5-10 – Core extracted from sample 4D-1 with compression and tension halves identified.

Photo 5-11 – Core extracted from sample 4E-1.

Photo 5-12 – Section of lifting sling used for tension testing in Instron machine

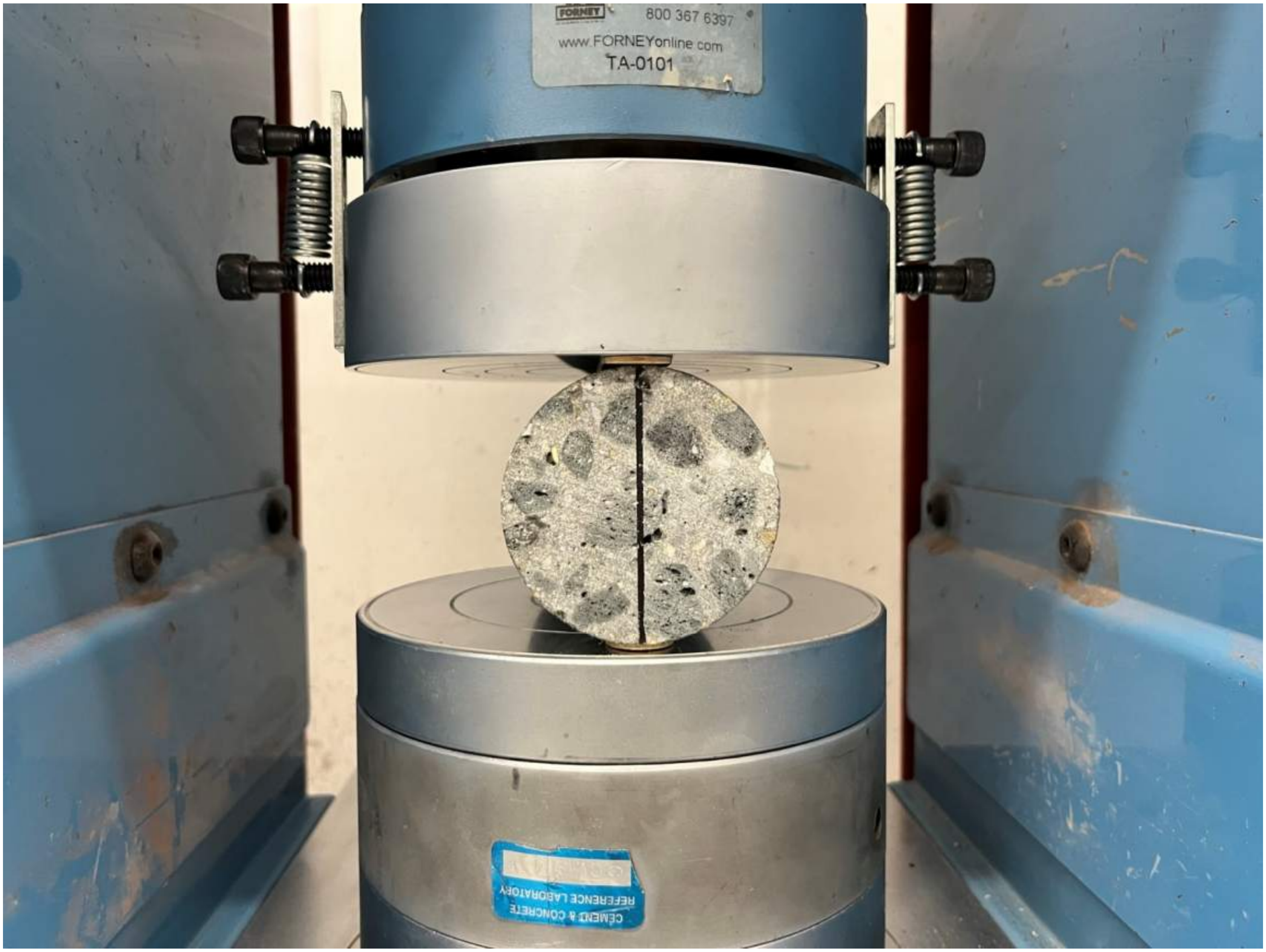


Photo 5-13 – Split tensile testing setup for specimen 4D-1.

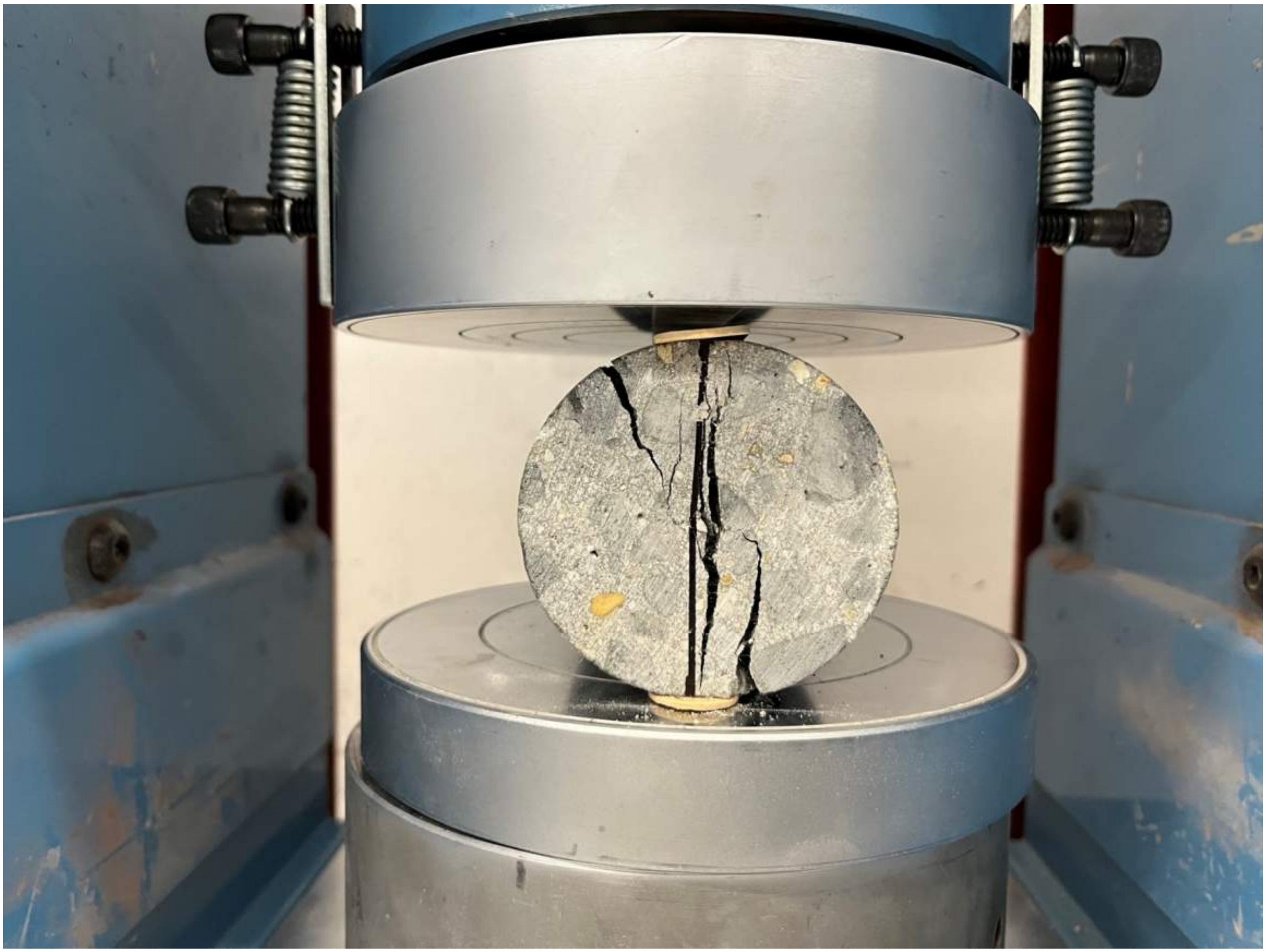


Photo 5-14 – Split tension testing of specimen 4B-1 after peak load

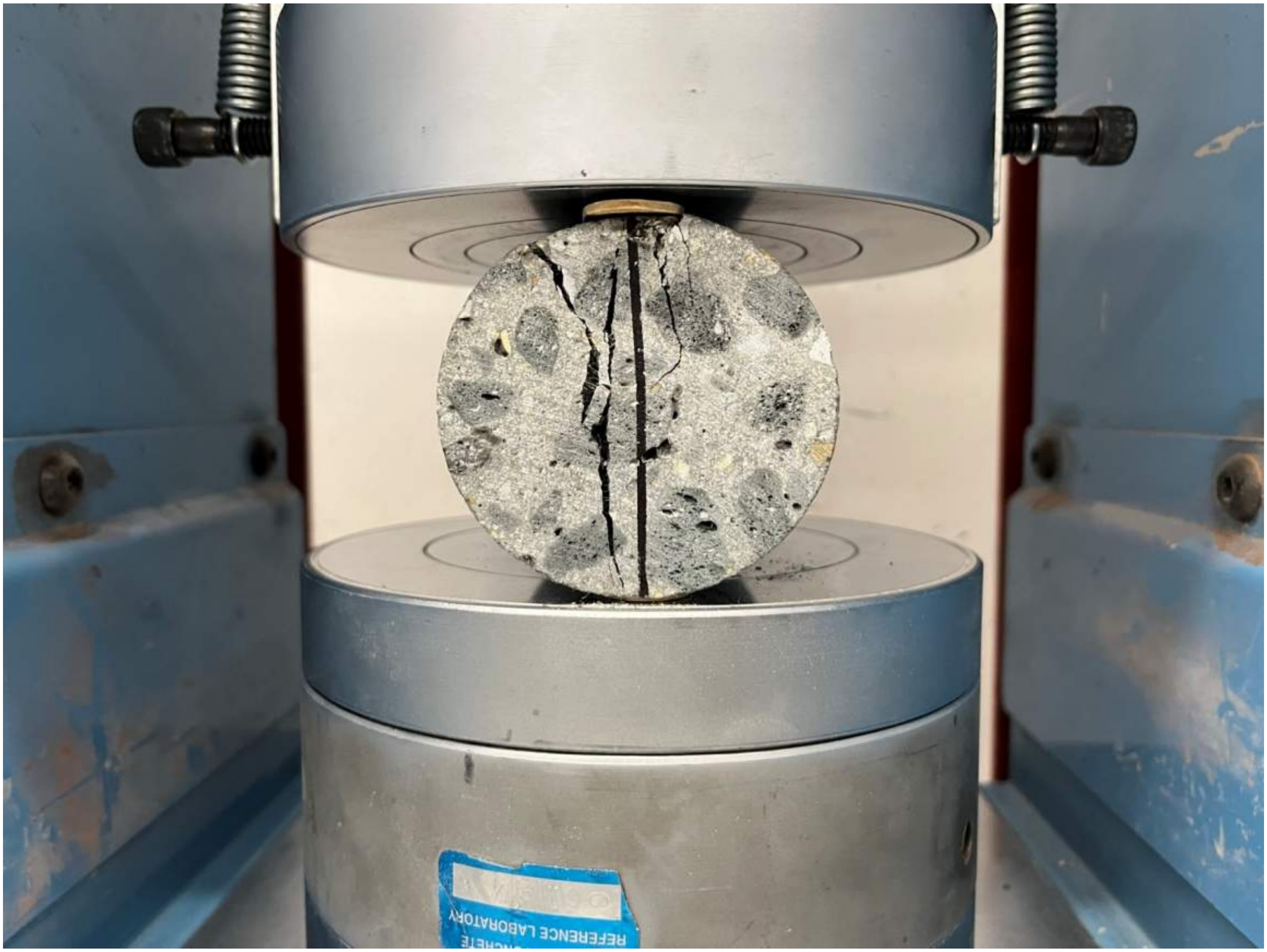


Photo 5-15 – Split tension testing of specimen 4D-1 after peak load.

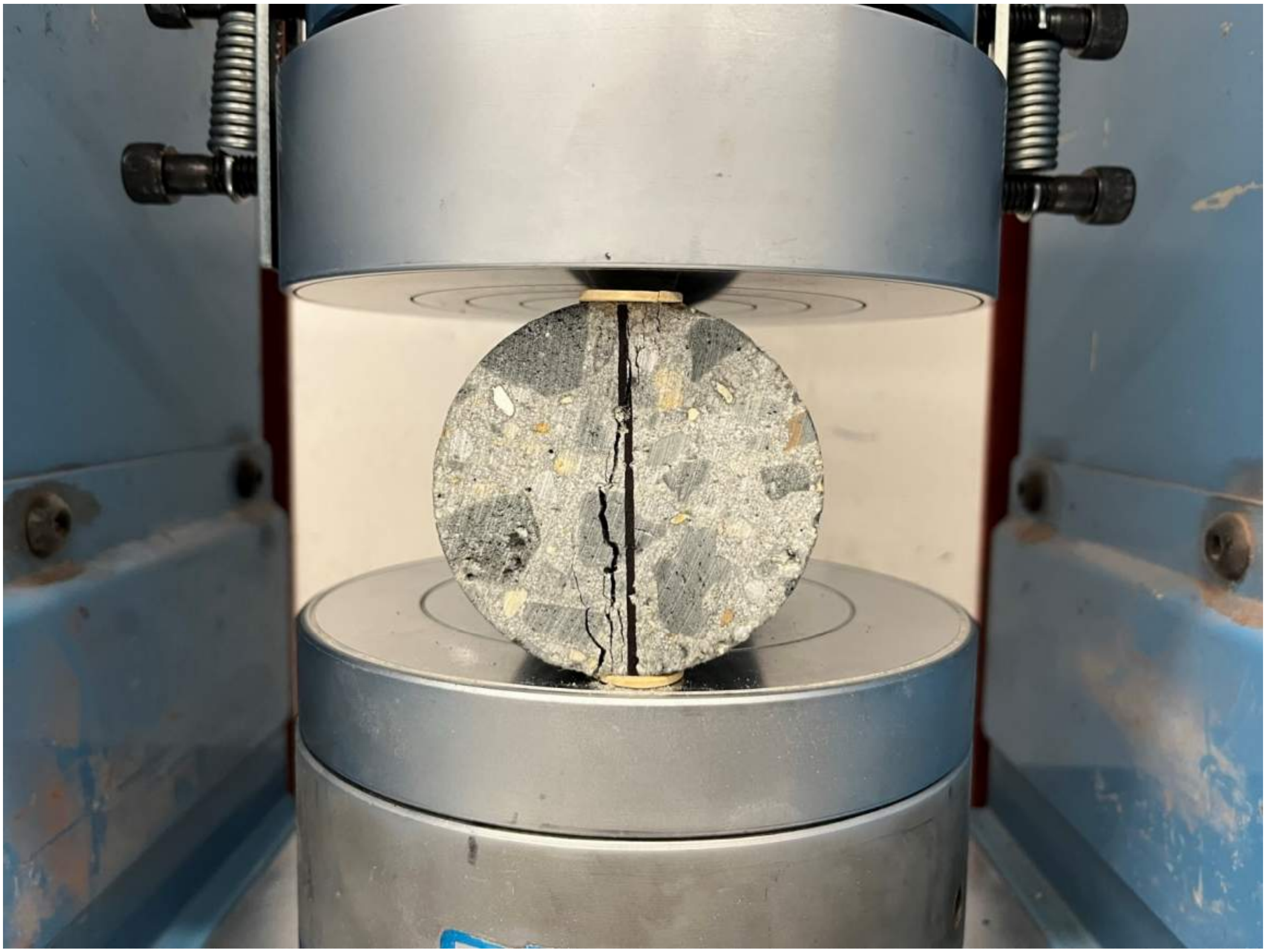


Photo 5-16 – Split tension testing of specimen 4E-1 after peak load.

Photo 5-17 – Fracture surfaces of specimen 4D-1 after tension splitting.

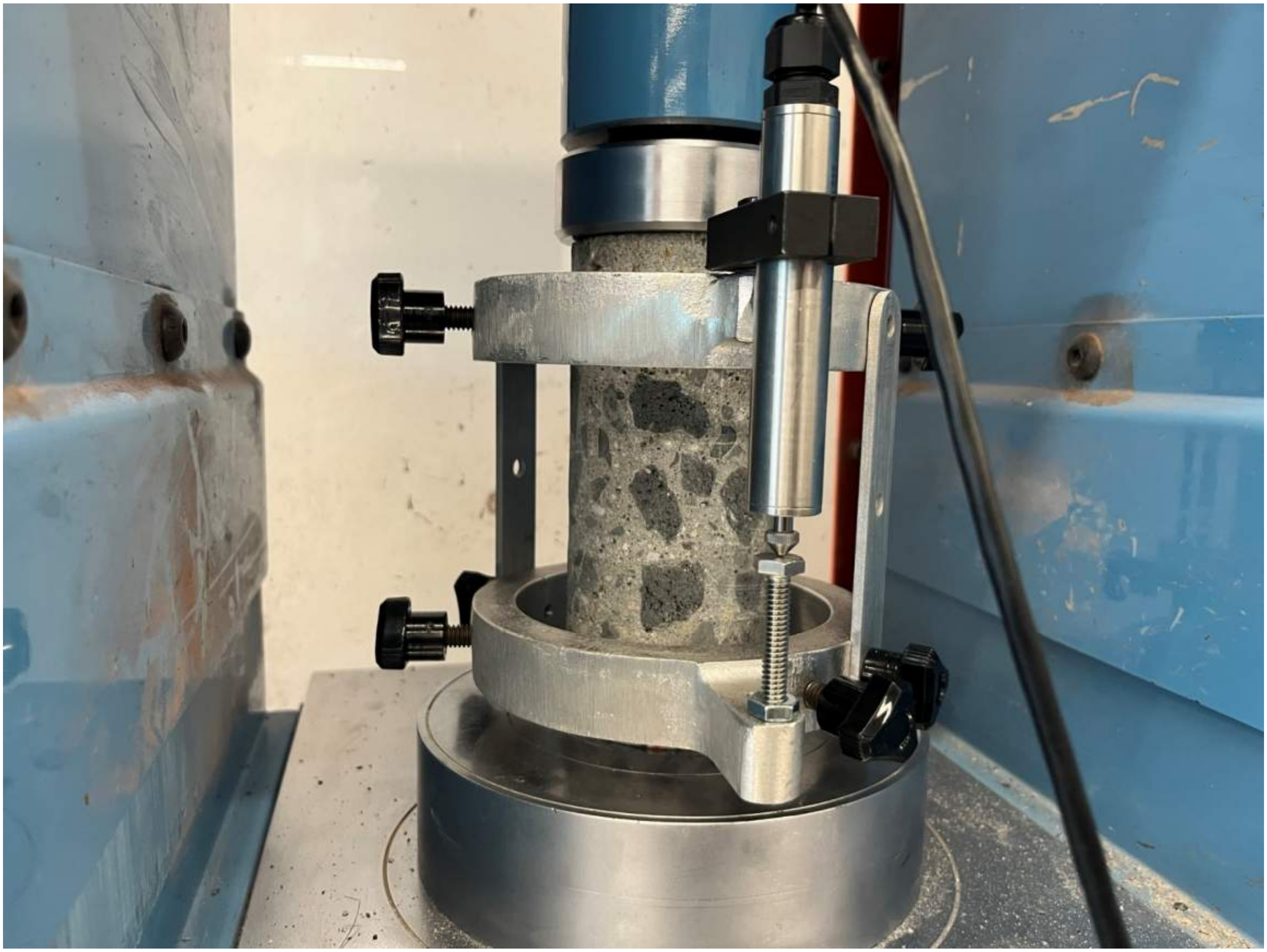


Photo 5-18 – Specimen 4D-1 with compressometer for elastic modulus testing.

Photo 5-19 – Compression testing of specimen 4B-1 after peak load.

Photo 5-20 – Compression testing of specimen 4D-1 after peak load.

Photo 5-21 – Compression testing of specimen 4E-1 after peak load.

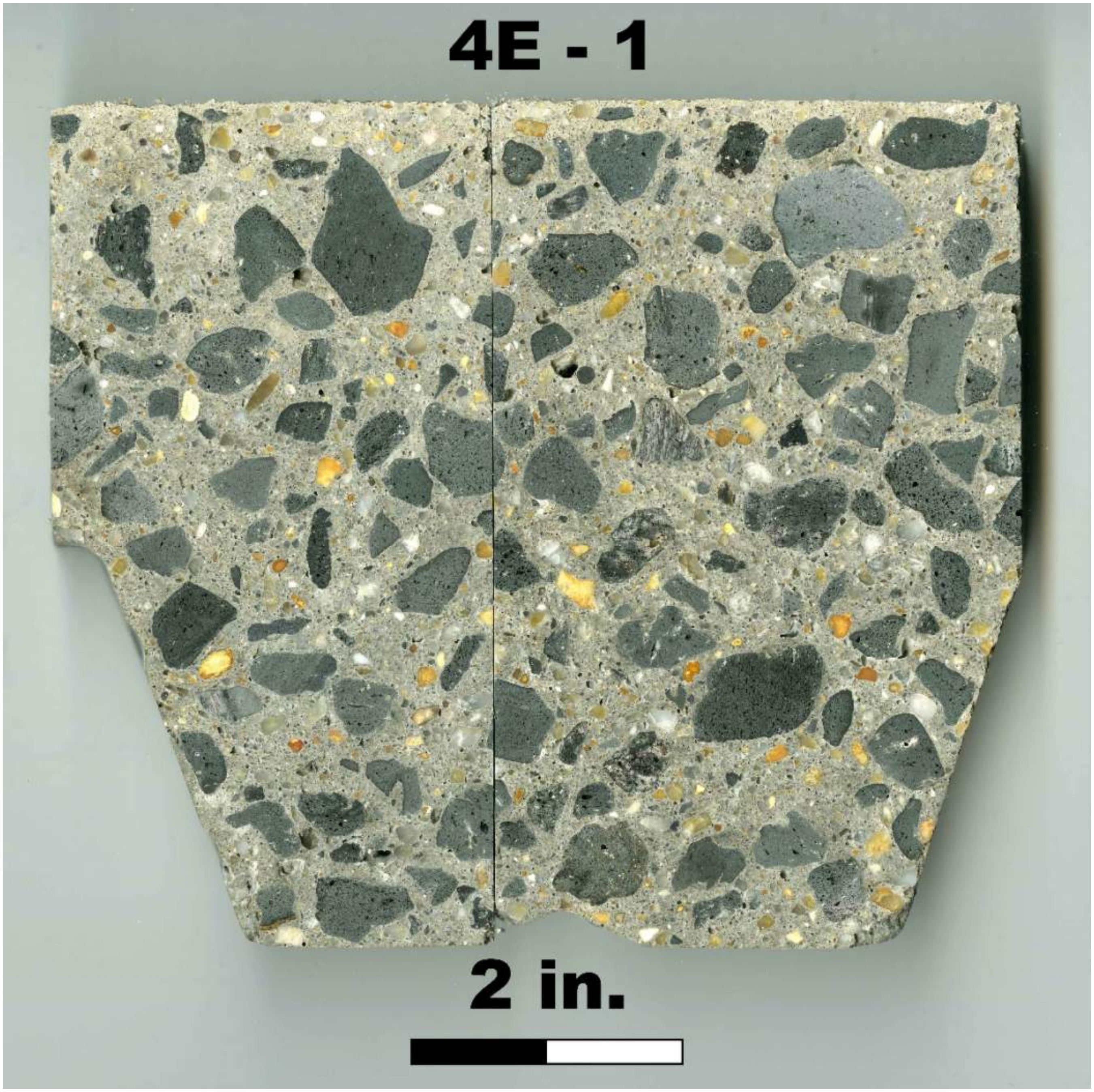


Photo 5-22 – Polished concrete section from sample 4E-1.

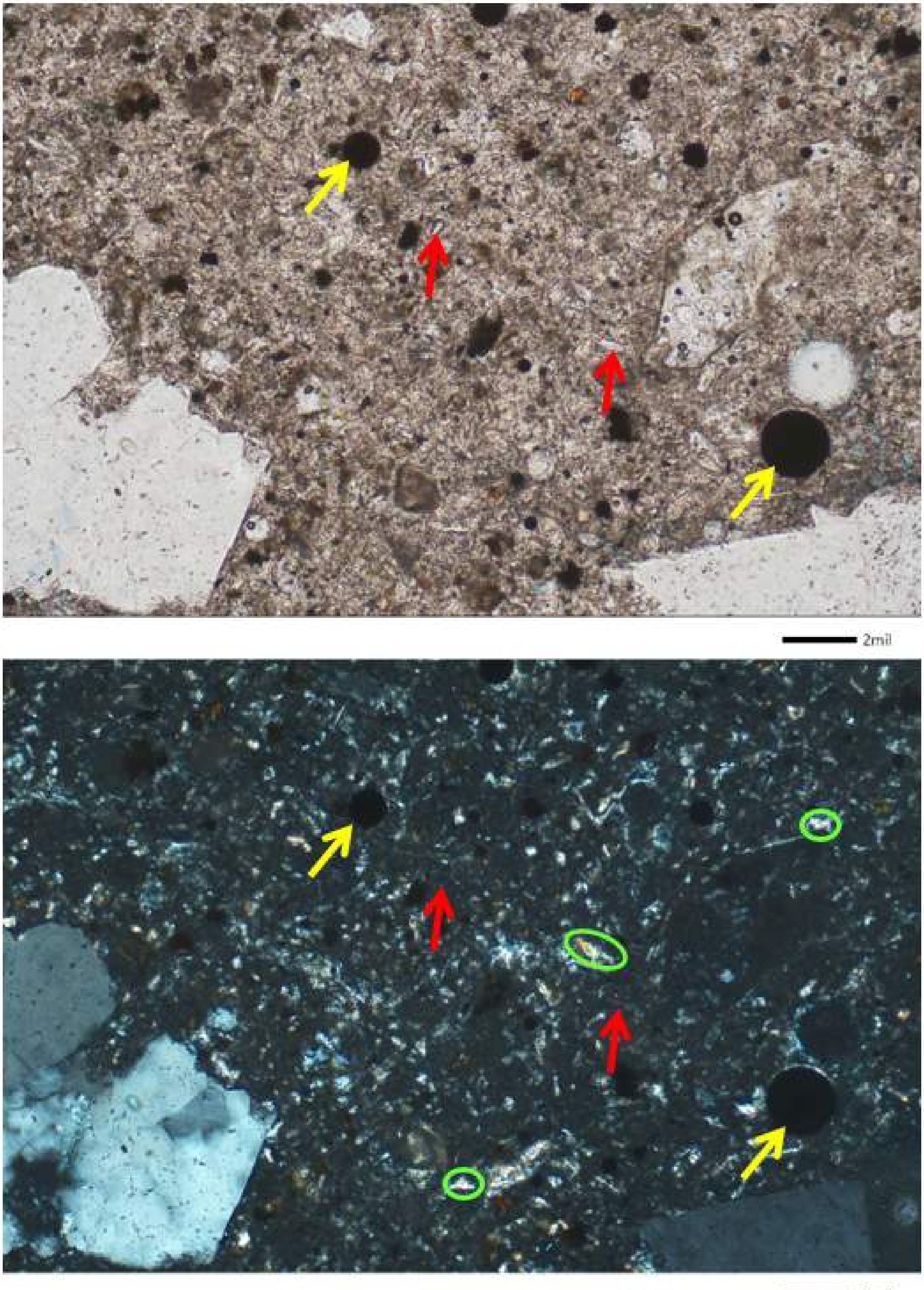
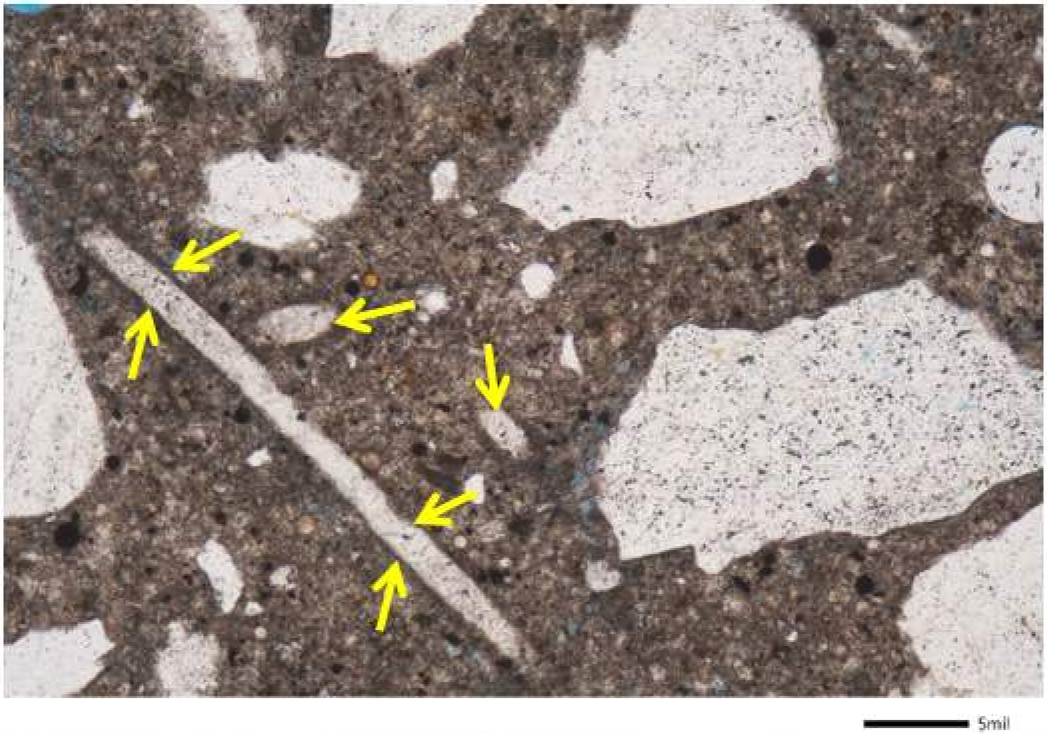


Photo 5-23 – Ultrathin section from Sample 4D-1 showing the typical paste microstructure. Yellow arrows mark examples of residual fly ash particles and red arrows mark examples of residual portland cement particles. The green ovals mark examples of calcium hydroxide (typical portland cement hydration product) observed in the lower image.

(Plane polarized light in the upper image and cross polarized light in the lower image). .



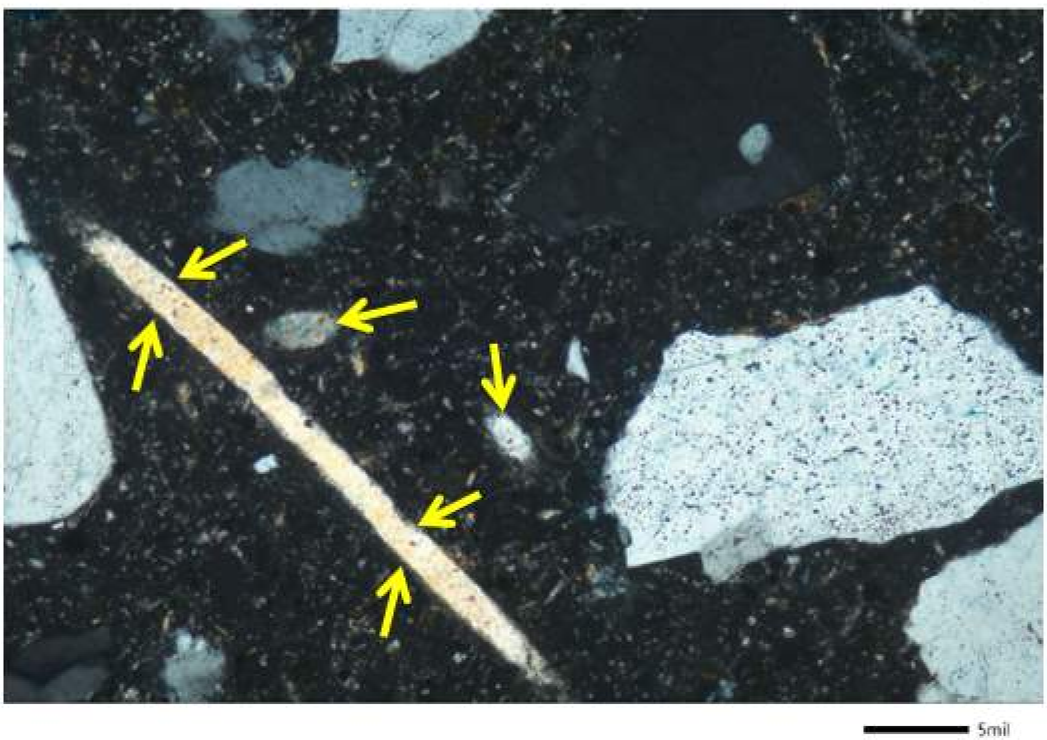


Photo 5-24 – Ultrathin section from Sample 4E-1 showing polymeric microfibers (yellow arrows) in the paste microstructure.

(Plane polarized light in the upper image and cross polarized light in the lower image).

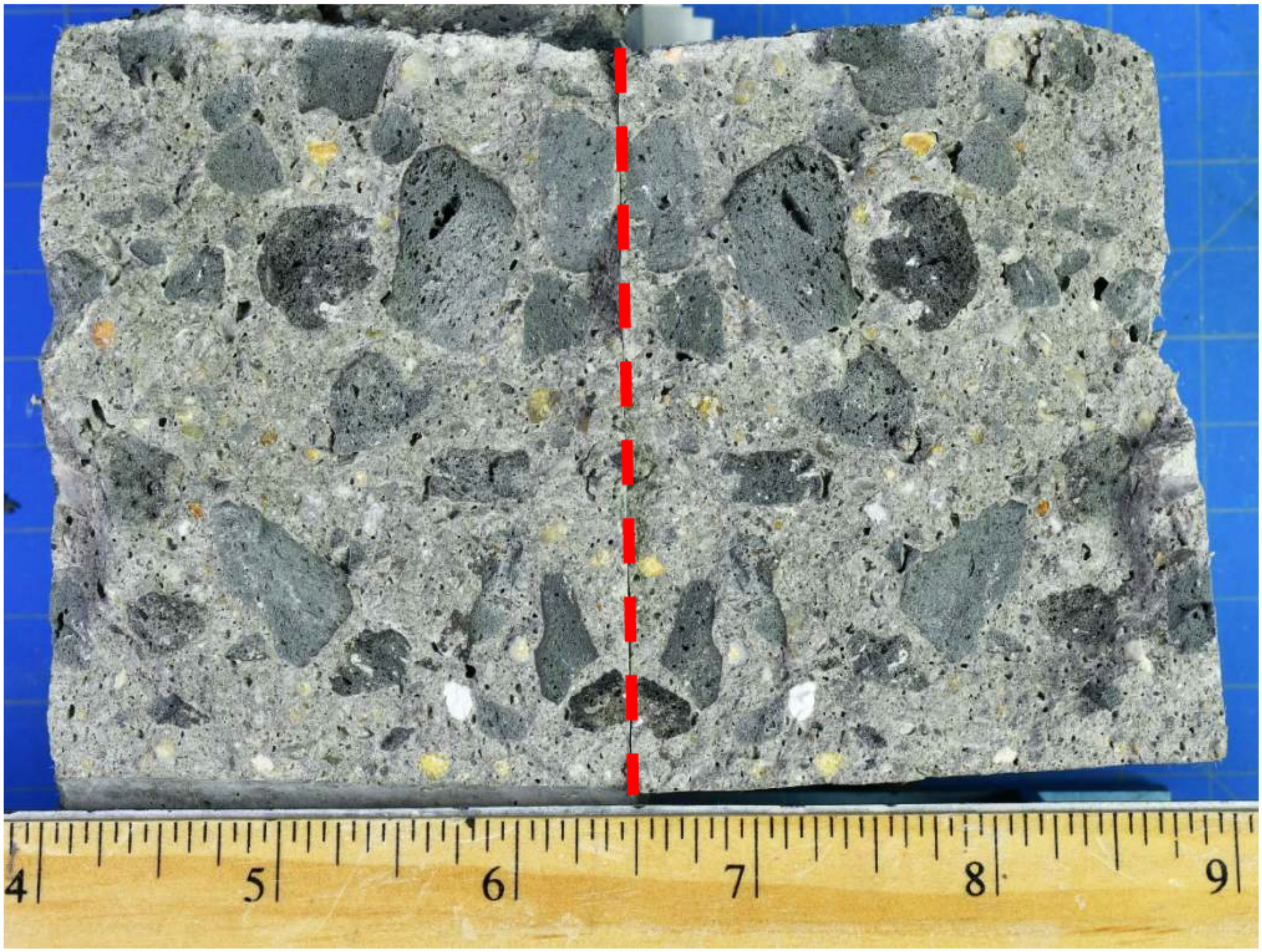


Photo 5-25 – Opposing surfaces along a lab-created fracture plane on a section of Sample 4E-1. Most of the coarse aggregate particles are broken through along this fracture plane, which indicates a well-developed paste-to-aggregate bond. The red dashed line marks the division between the opposing surfaces.

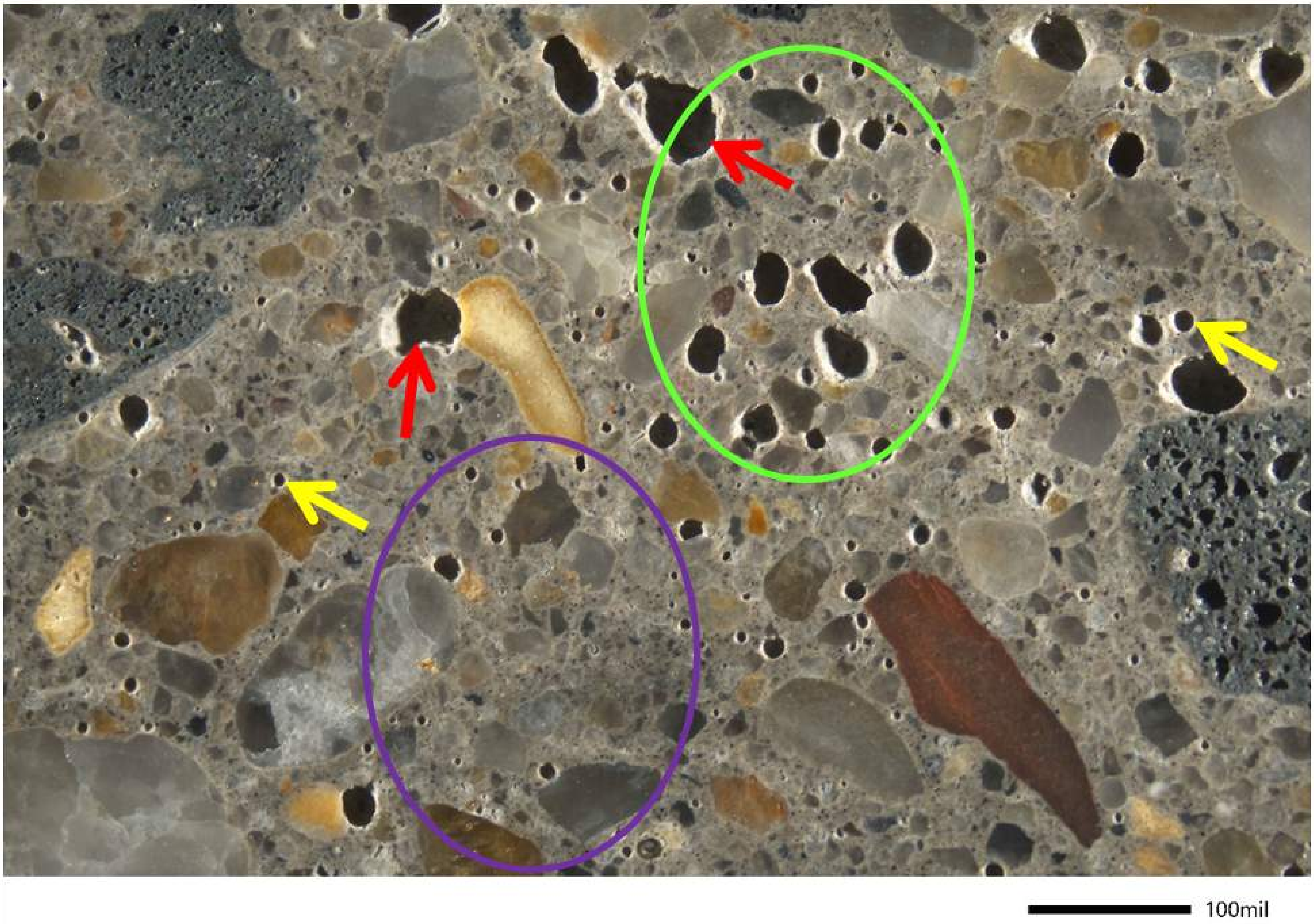


Photo 5-26 – Polished section from Sample 4D-1 showing the air void system in the interior portion of concrete. Red arrows mark examples of semi-spherical entrapped air voids and yellow arrows mark examples of tiny, spherical, entrained air voids. The green oval marks a high air content zone and the purple oval marks a low air content zone.

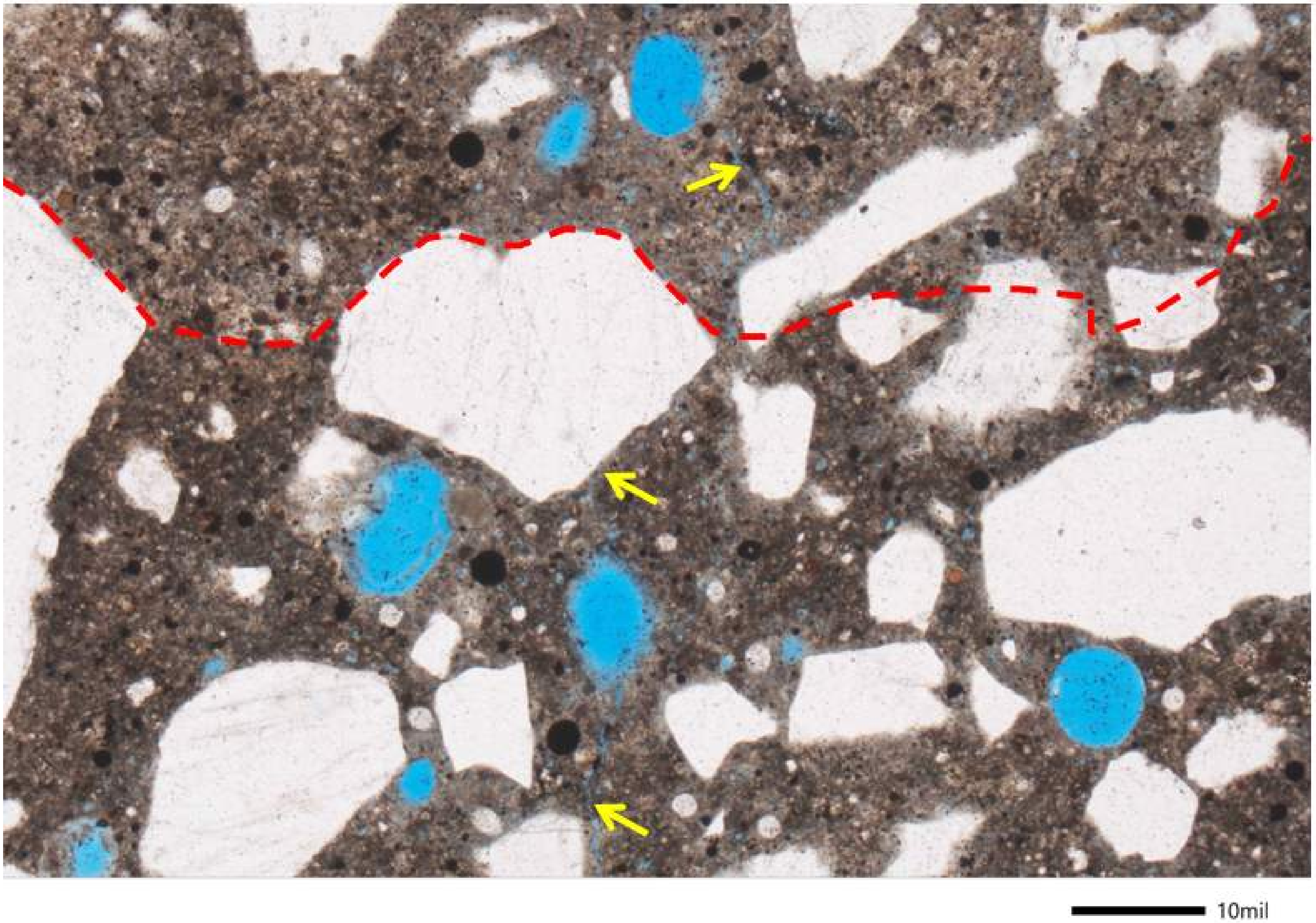


Photo 5-27 – Ultrathin section from Sample 4E-1 showing a bleed water channel (yellow arrows) in the near surface region of concrete. The cementitious paste above the red dashed line is more porous than the cementitious paste below the red dashed line.

(Plane polarized light).

APPENDIX B – PETROGRAPHIC EXAMINATION RESULTS

PETROGRAPHIC EXAMINATION RESULTS

Date: 14 December 2022

Material: Concrete Test: ASTM C856 Conducted by: Kyle L. Schusler
Reviewed by: James W. Schmitt

Project: 221564 –Failure Analysis of a Composite One-Way Pan Joist Concrete Slab on Steel Deck

Subject: Petrographic Examination of Concrete Samples

SAMPLE DESCRIPTION

We received two remnant full-depth samples of concrete. One sample was labeled as "4D-1" and the other sample was labeled as "4E-1" (Photos 1 – 4). The sections are approximately 3-1/2 in. to 6-1/2 in. thick. We understand the sections were extracted from an interior, elevated slab that was placed on a corrugated metal deck. We were asked to perform petrographic examinations on both samples to evaluate the attributes and overall condition of the concrete.

TEST METHODS

We cut a 1-in. to 1-1/2 in. thick section from a representative area from each sample that encompassed the entire slab thickness (Photos 1 and 3). We then ground and polished the cut sections to produce smooth, flat surfaces for microscopic examination (Photos 5 and 6). We examined the prepared polished sections to evaluate the general features, overall condition, and composition of the hardened concrete. We examined the polished sections with the aid of a reflected-light stereomicroscope at magnifications of 6.5X to 50X.

In addition, we prepared a blue-dyed epoxy-impregnated ultrathin (20 to 25 μm) section from a representative area of each sample. We examined the ultrathin sections to provide a more detailed assessment of the composition and quality of the hardened concrete. In addition, we identified any materials-related distress mechanisms, such as alkali-silica reactivity (ASR) or sulfate attack, if present. We examined the prepared ultrathin sections using a transmitted-light polarizing microscope at magnifications of 25X to 400X.

We also broke remnant sections from each sample using a small sledgehammer to produce freshly fractured surfaces for microscopic examination. We examined the laboratory-induced fractured surfaces with the aid of a reflected-light stereomicroscope at magnifications of 6.5X to 50X.

We conducted our petrographic examinations in accordance with the applicable procedures outlined in ASTM C856 – Standard Practice for Petrographic Examination of Hardened Concrete.

DETAILED PETROGRAPHIC EXAMINATION

The concrete composition and properties represented by Samples 4D-1 and 4E-1 are similar and will be described collectively in this report except where specifically noted below.

GENERAL CONDITION

The top surface is relatively flat, rough, and rich in cementitious paste, which is consistent with a lightly troweled surface. The bottom surface is smooth, rich in cementitious paste, and exhibits a few voids, which is consistent with the imprint of a formed surface.

Cracking

There are a few vertical microcracks in the uppermost 1/2 in. of concrete (Photo 7). The vertical microcracks are generally less than 1 mil in width. These microcracks intersect the top surface, taper with depth, pass primarily around aggregate particles, appear to follow relict bleed water channels, and eventually dissipate. The properties of these microcracks are generally consistent with minor drying shrinkage.

Carbonation Depth

We observed a carbonation front in the uppermost 3/16 in. to 7/16 in. of concrete.

REINFORCING STEEL

The samples contain nominal 0.134 in. diameter steel reinforcing wires approximately 2 in. below the top surface (Photos 5 and 6).

CONCRETE COMPOSITION AND STRUCTURE

AGGREGATE DESCRIPTION

Coarse Aggregate

Coarse aggregate consists of 3/4 in. maximum-sized, crushed lightweight aggregate. The lightweight aggregate is composed of expanded shale and/or expanded slate. Individual aggregate particles are subangular to subrounded and equant to slightly elongated in shape. Individual particles are evenly distributed throughout the concrete with no evidence of coarse aggregate segregation (Photos 5 and 6).

Fine Aggregate

Fine aggregate consists of natural sand primarily composed of quartz, chert, and quartzite. Individual aggregate particles are subangular to subrounded and equant to elongated in shape. Fine aggregate is uniformly distributed throughout the concrete.

PASTE STRUCTURE

Color

The concrete exhibits a relatively uniform medium gray cementitious paste color, except in the uppermost 1/16 in. to 3/8 in. where the cementitious paste is lighter gray in color (Photo 7) and marginally softer compared to the interior portion of concrete.

Texture

Examination of freshly fractured surfaces reveals a translucent to opaque cementitious paste structure having a dull to subvitreous luster and microgranular texture throughout the interior of the concrete.

Paste-To-Aggregate Bond

Most coarse aggregate particles were broken through when the concrete was fractured in the laboratory, which indicates that the concrete exhibits a well-developed paste-to-aggregate bond (Photos 8 and 9).

Composition

The cementitious paste contains well-hydrated portland cement particles (Photo 10). We observed several residual partially hydrated alite particles with hydration rims and well-distributed anhedral laths of calcium hydroxide in the cementitious paste.

The cementitious paste also contains fly ash as a supplementary cementitious material (Photo 10). Based on comparison with known laboratory standards, we estimated that the residual fly ash content is 15% to 25% by weight of total residual cementitious materials.

The concrete also contains polymeric microfibers (Photo 11) that are well distributed throughout the concrete mix.

Bleeding

We observed a few bleed-water channels in the uppermost portion of concrete (Photos 12 and 13). These bleed-water channels often intersect the top surface.

Water/Cementitious Material Ratio (w/cm)

Based on the paste color, paste texture, and overall composition of the paste structure, the extent of hydration of cement grains, and the amount and distribution of cement hydration products, we estimated that the concrete generally contains a moderate w/cm in the range of 0.40 to 0.50.

We observed a light gray-colored zone in the uppermost 1/16 in. to 3/8 in. of concrete (as previously described), where the paste structure is marginally softer and exhibits a dull luster. This surface paste zone exhibits higher levels of porosity (Photo 13) and fewer residual cementitious particles compared to the interior portion of concrete. These properties indicate this lighter colored, softer cementitious paste zone exhibits a higher w/cm than cementitious paste in the interior of the concrete.

AIR-VOID SYSTEM

The concrete contains entrapped air voids and entrained air voids (Photos 14 and 15). Based on comparisons with known laboratory standards, we estimated a total air content of approximately 4% to 7%. The air voids are not uniform in distribution. We observed areas of paste with high air content adjacent to areas of low air content (Photo 14).

We also observed a few localized zones that exhibit relatively large (between 1/8 in. to 1/4 in. diameter), irregularly-shaped voids (Photos 16 and 17). These larger voids may represent localized zones of less-than-optimal consolidation; however, areas of widespread, large, interconnected voids (i.e., honeycomb), were not observed.

DETERIORATION MECHANISMS

Freeze-Thaw

Not observed.

Sulfate Attack

Not observed.

Alkali-Aggregate Reactivity

We did not observe evidence for alkali-aggregate reactivity. However, some of the chert fine aggregate particles contain potentially reactive microcrystalline quartz.

Corrosion

Not observed.

SUMMARY

The concrete represented by Samples 4D-1 and 4E-1 is intact without major cracking or deterioration.

The concrete contains 3/4 in. maximum-sized crushed, lightweight, expanded shale and/or expanded slate as coarse aggregate and natural sand composed of quartz, chert, and quartzite as fine aggregate. The aggregate particles are well distributed throughout the samples.

The paste is well-hydrated and contains portland cement, fly ash, and typical hydration products. The concrete exhibits an overall moderate w/cm in the range of 0.40 to 0.50.

The concrete also contains polymeric microfibers that are well distributed throughout the concrete mix.

The paste-to-aggregate bond is tight, as laboratory-induced fractures extend primarily through aggregate particles.

The concrete contains entrapped and entrained air voids, with an estimated total air content of 4% to 7%. The air voids are not uniformly distributed. We also observed a few localized zones that exhibit relatively large (between 1/8 in. to 1/4 in. diameter), irregularly-shaped voids. These larger voids may represent localized zones of less-than-optimal consolidation; however, areas of widespread, large, interconnected voids (i.e., honeycomb), were not observed.

We observed a porous zone in the uppermost 1/16 in. to 3/8 in. of concrete, where the paste is lighter gray in color, marginally softer, and exhibits a higher w/cm compared to the interior portions of concrete. Bleed water channels extend through this surface paste zone. The presence of bleed-water channels extending through this zone indicates that the concrete was finished prior to the cessation of bleeding.

Photo 1

Bottom surface of Sample 4D-1. The red box outlines the section provided to us for petrographic examination.

Photo 2

Top surface of Sample 4D-1.

Photo 3

Bottom surface of Sample 4E-1. The red box outlines the section provided to us for petrographic examination.

Photo 4

Top surface of Sample 4E-1.

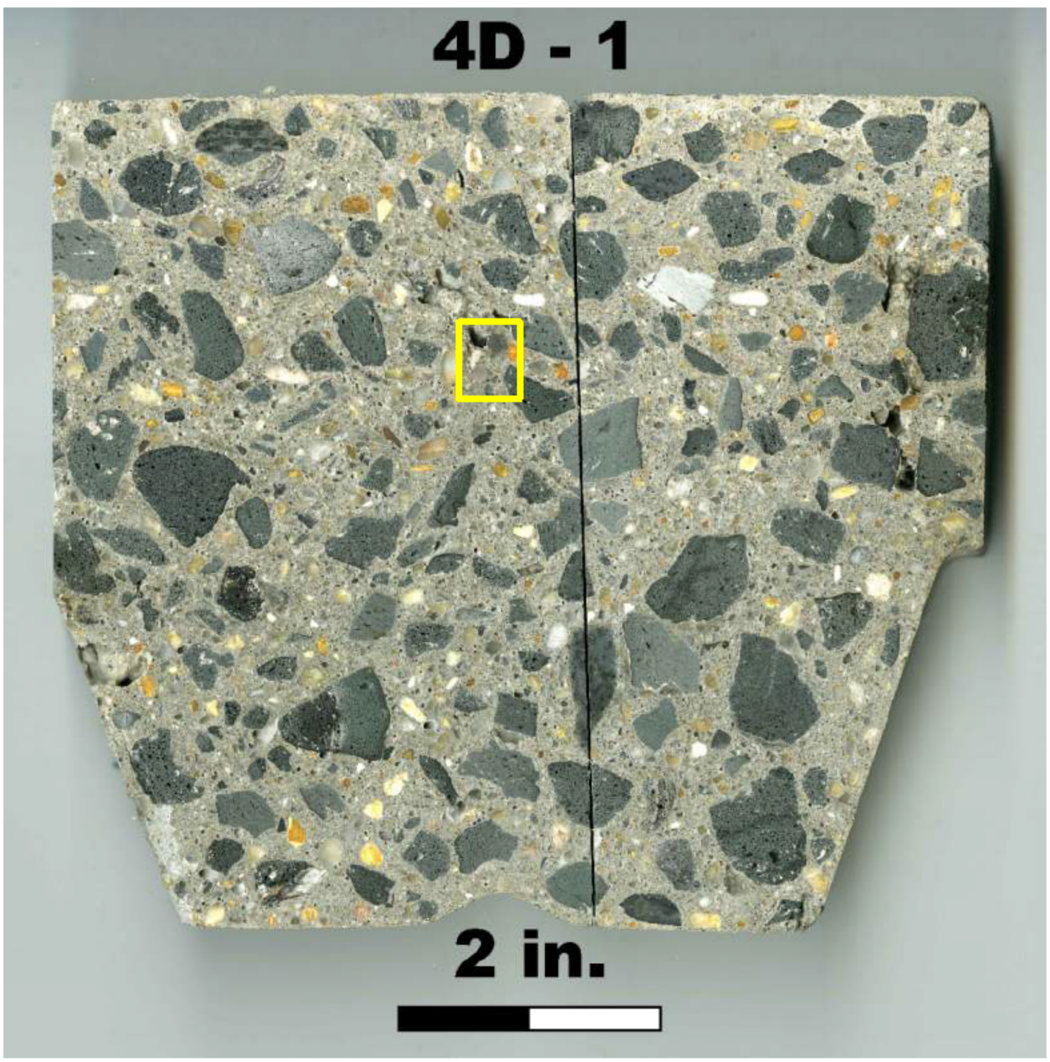


Photo 5

Polished section from Sample 4D-1 with its top surface towards the top of the image. The yellow box marks the locations of two 1/8 in. thick steel reinforcing wires.

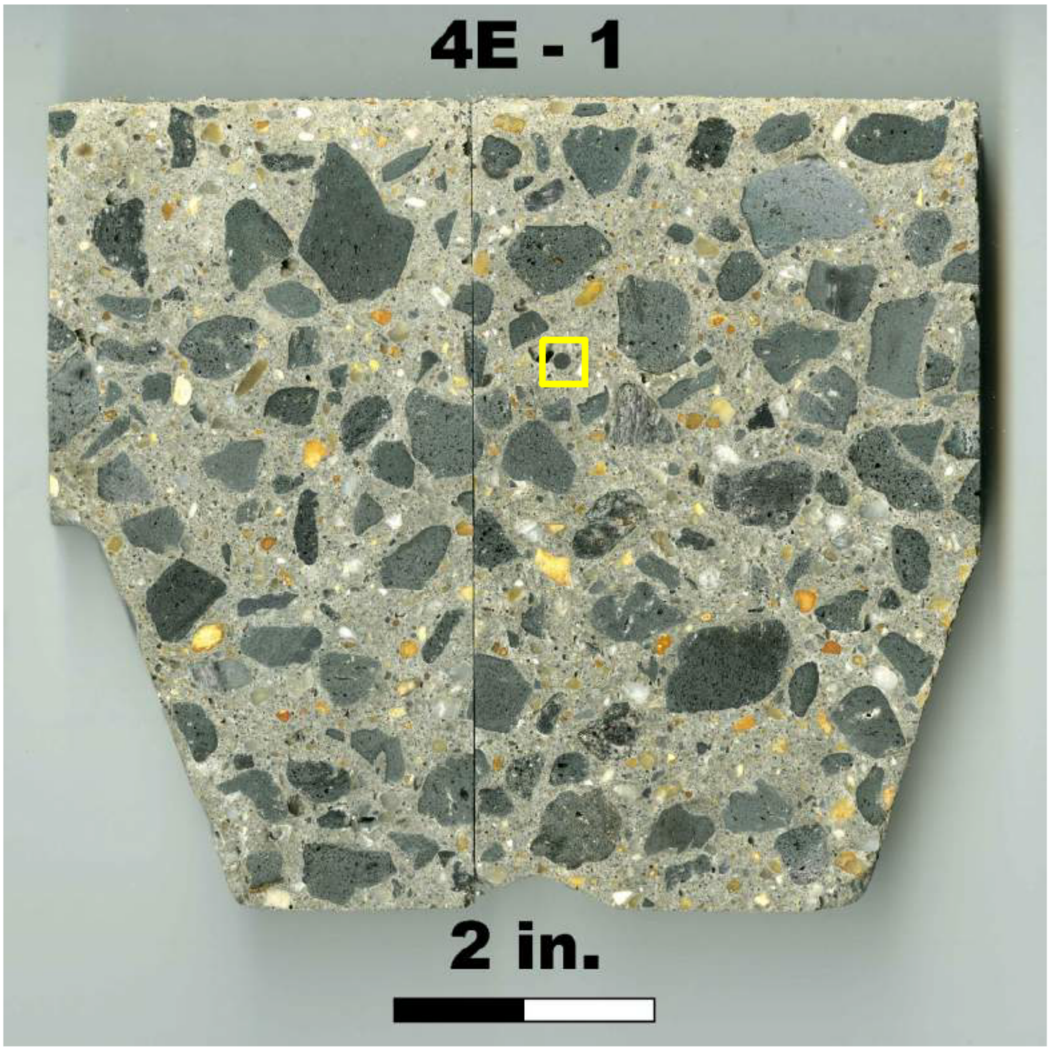


Photo 6

Polished section from Sample 4D-1 with its top surface towards the top of the image. The yellow box marks the location of one 1/8 in. thick steel reinforcing wire.

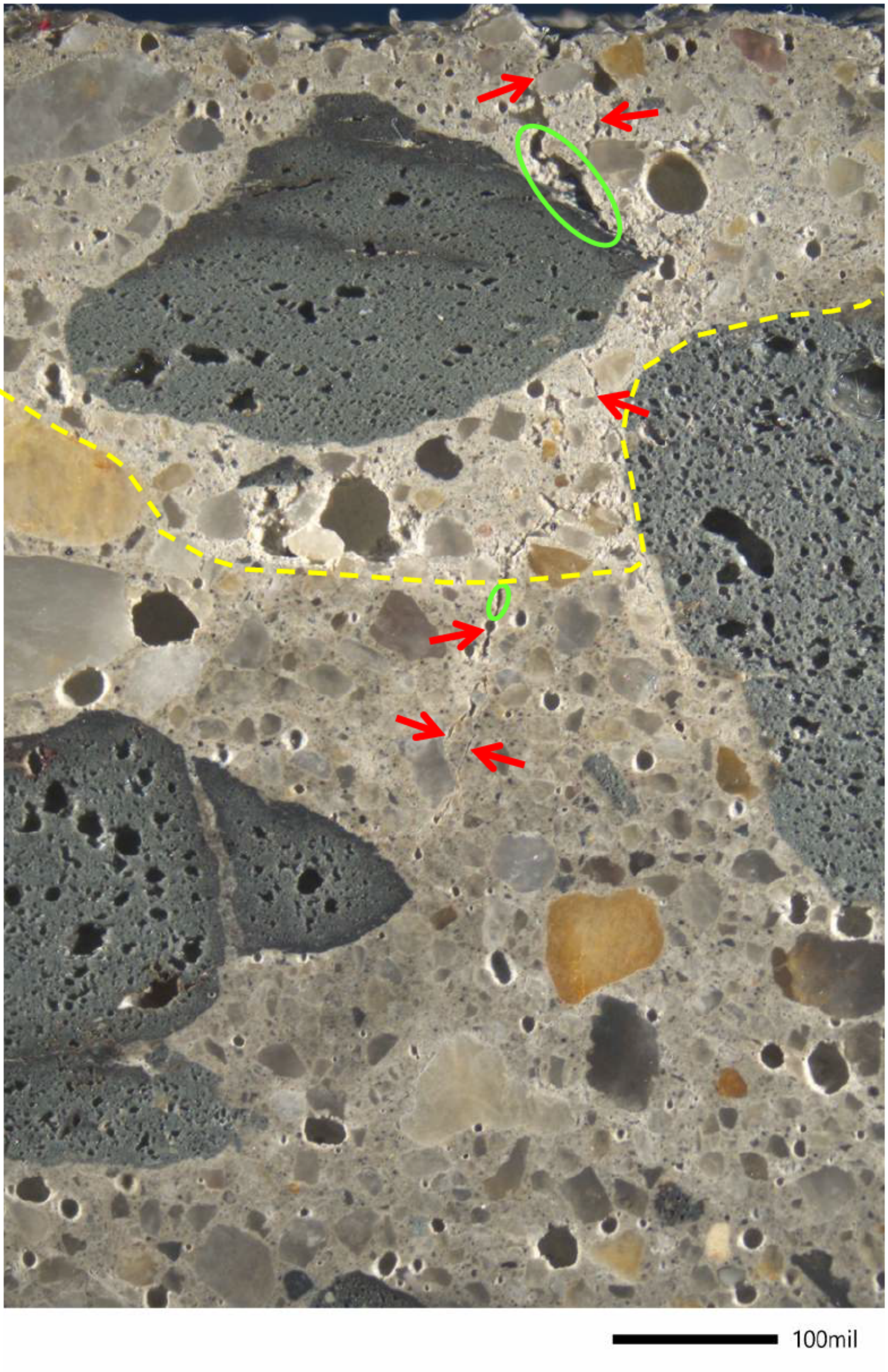
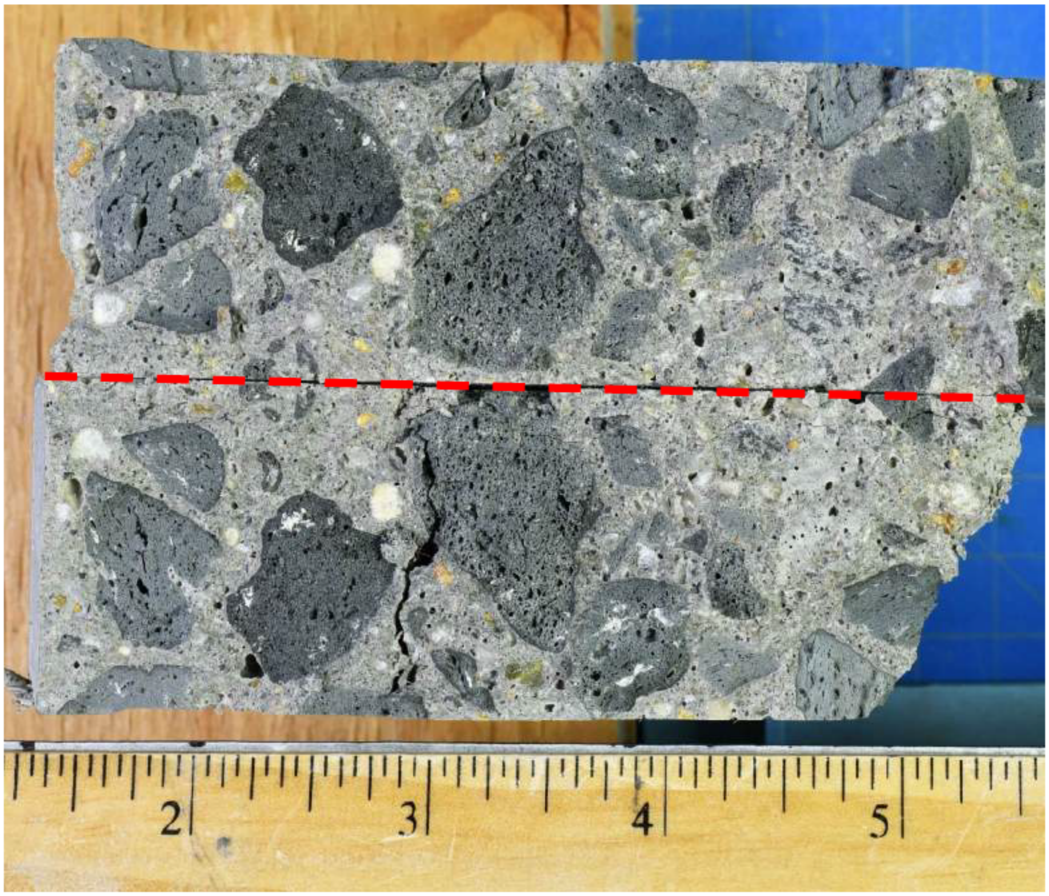


Photo 7

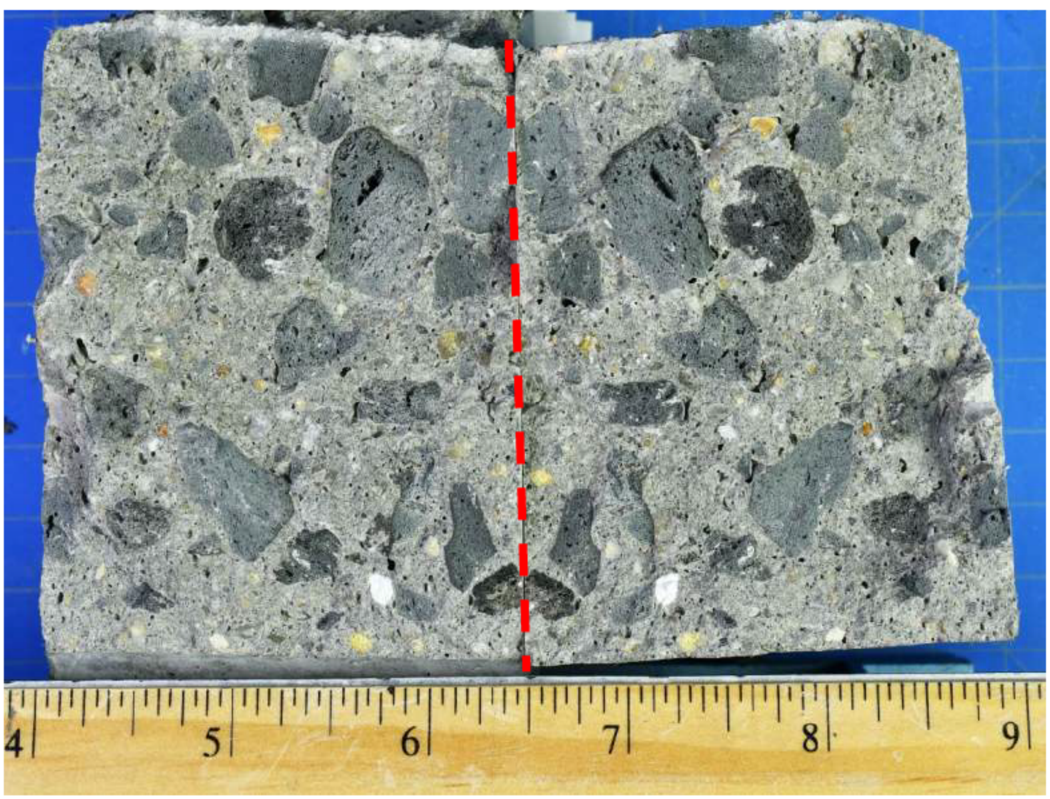
Polished section from Sample 4D-1 showing the uppermost portion of concrete. The cementitious paste matrix above the yellow dashed line is lighter gray in color and marginally softer compared to the cementitious paste below the yellow dashed line. The red arrows mark vertical microcracks following and intersecting relict bleed water channels (green ovals).

Photo 8

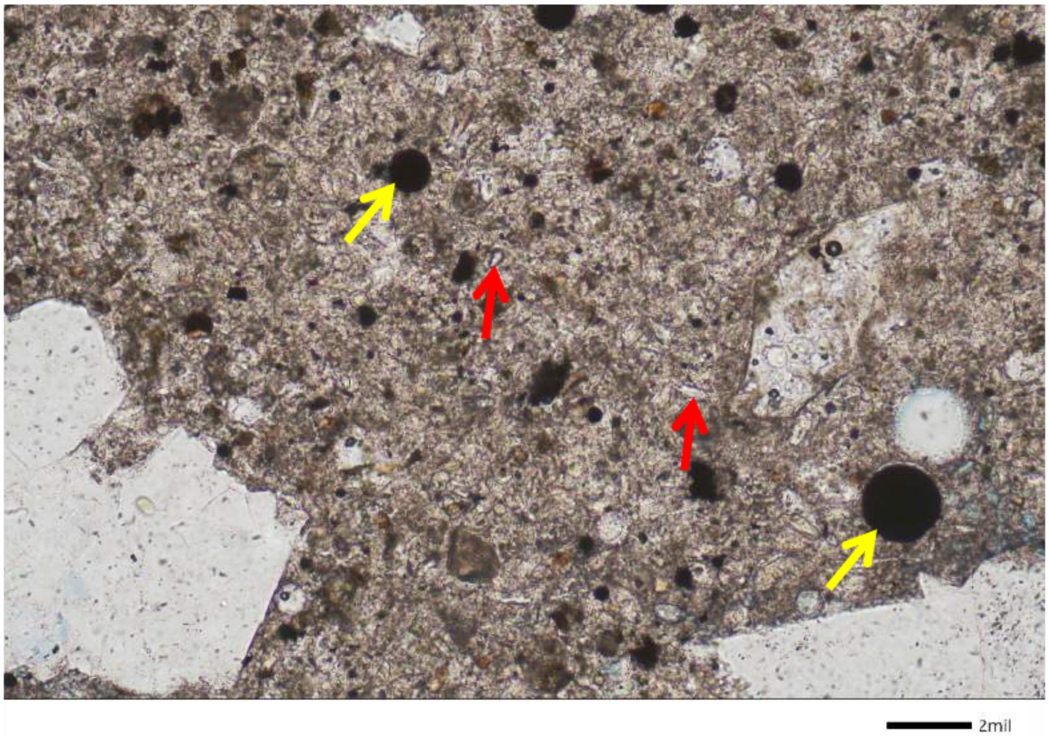


Opposing surfaces along a lab-created fracture plane on a section of Sample 4D-1. Most of the coarse aggregate particles are broken through along this fracture plane, which indicates a well-developed paste-to-aggregate bond. The red dashed line marks the division between the opposing surfaces.

Photo 9



Opposing surfaces along a lab-created fracture plane on a section of Sample 4E-1. Most of the coarse aggregate particles are broken through along this fracture plane, which indicates a well-developed paste-to-aggregate bond. The red dashed line marks the division between the opposing surfaces.



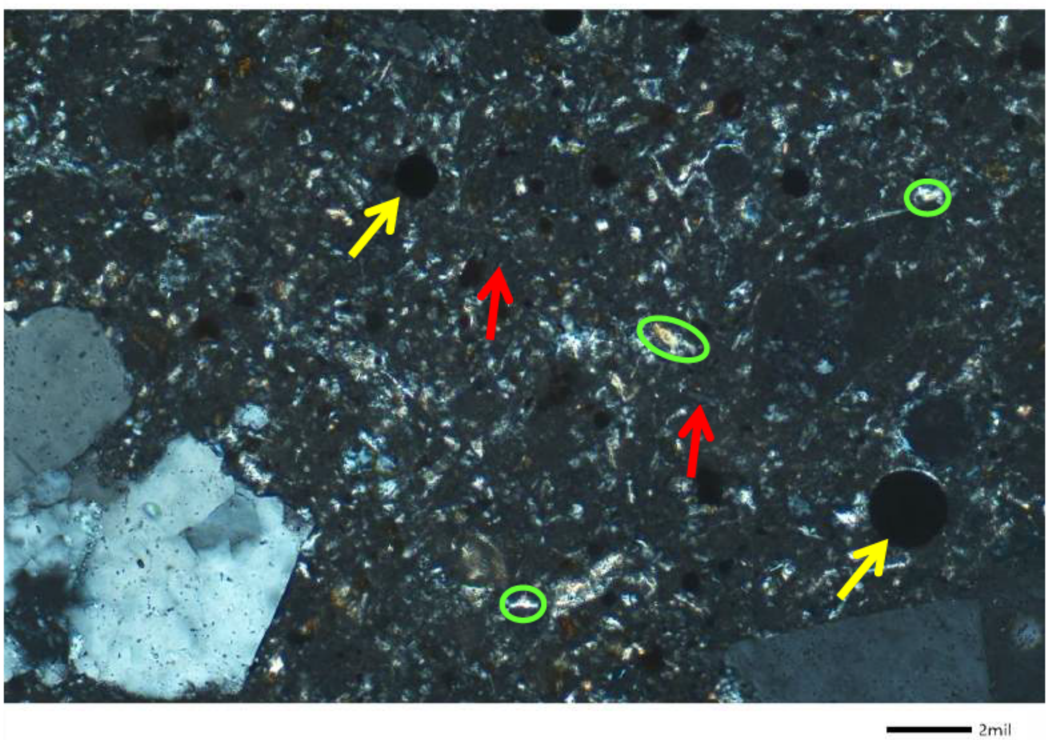


Photo 10

Ultrathin section from Sample 4D-1 showing the typical paste microstructure. Yellow arrows mark examples of residual fly ash particles and red arrows mark examples of residual portland cement particles. The green ovals mark examples of calcium hydroxide (typical portland cement hydration product) observed in the lower image.

(Plane polarized light in the upper image and cross polarized light in the lower image).

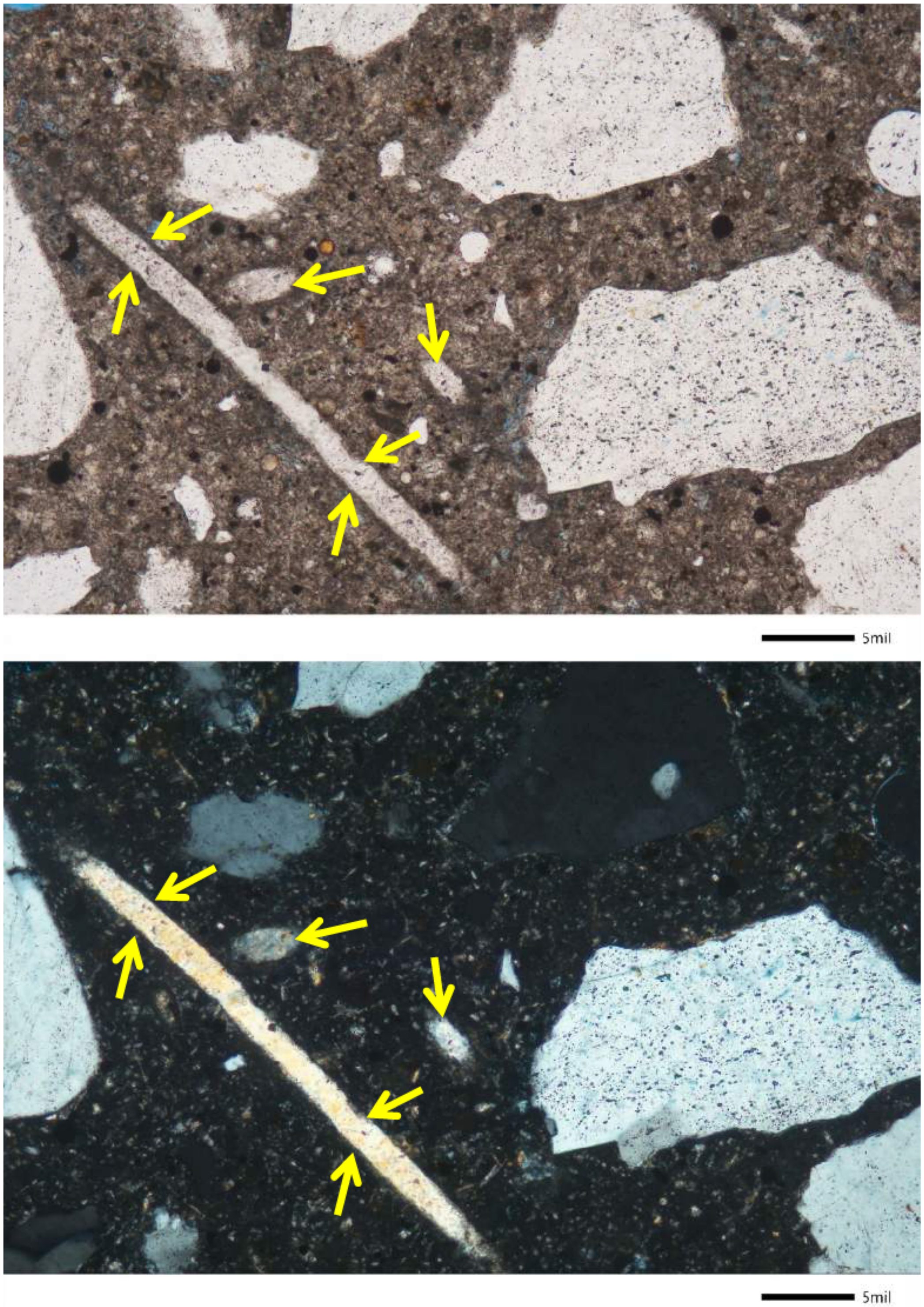


Photo 11

Ultrathin section from Sample 4E-1 showing polymeric microfibers (yellow arrows) in the paste microstructure.

(Plane polarized light in the upper image and cross polarized light in the lower image).

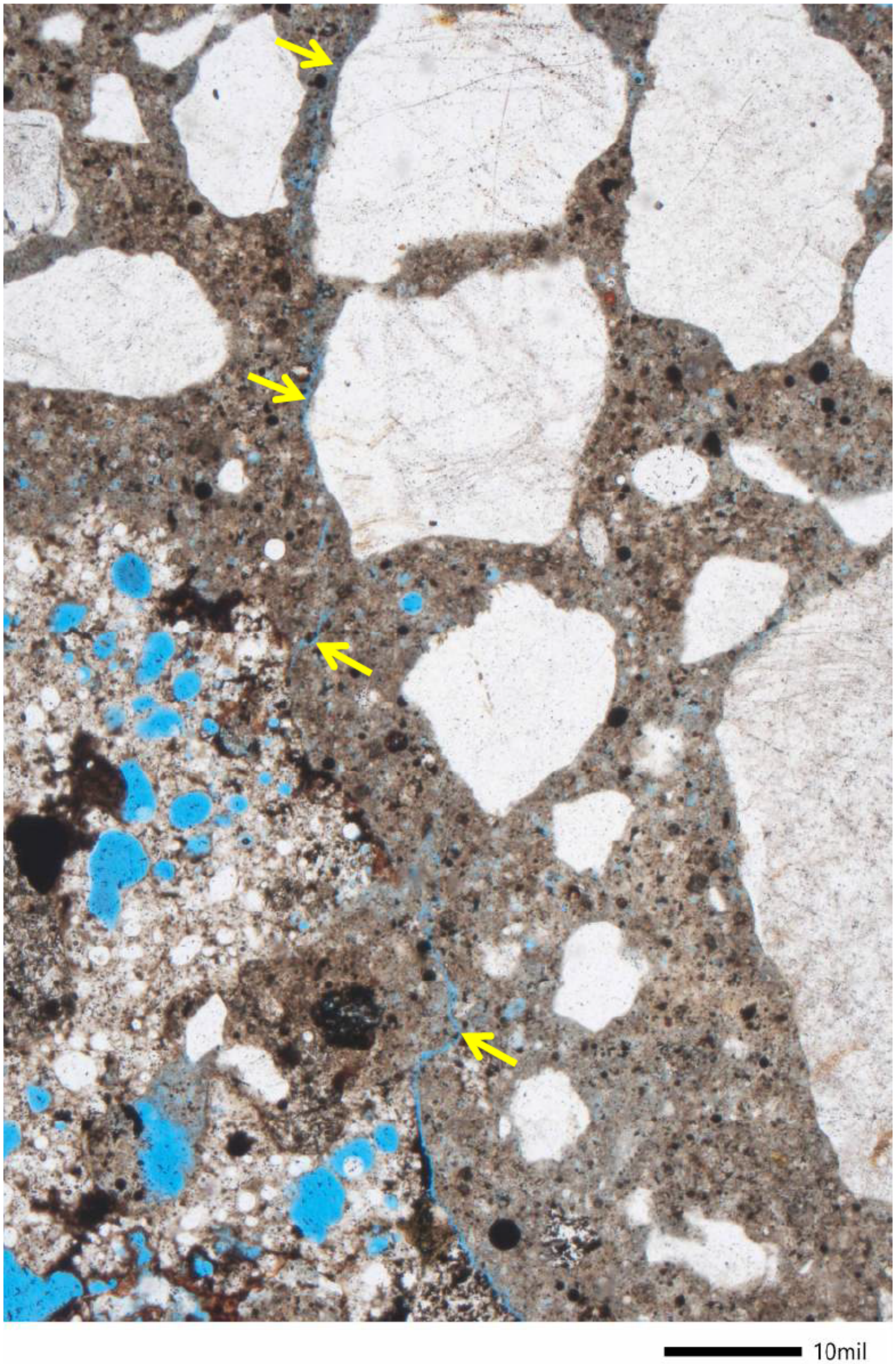


Photo 12

Ultrathin section from Sample 4D-1 showing a bleed-water channel (yellow arrows) in the near surface region of concrete.

(Plane polarized light).

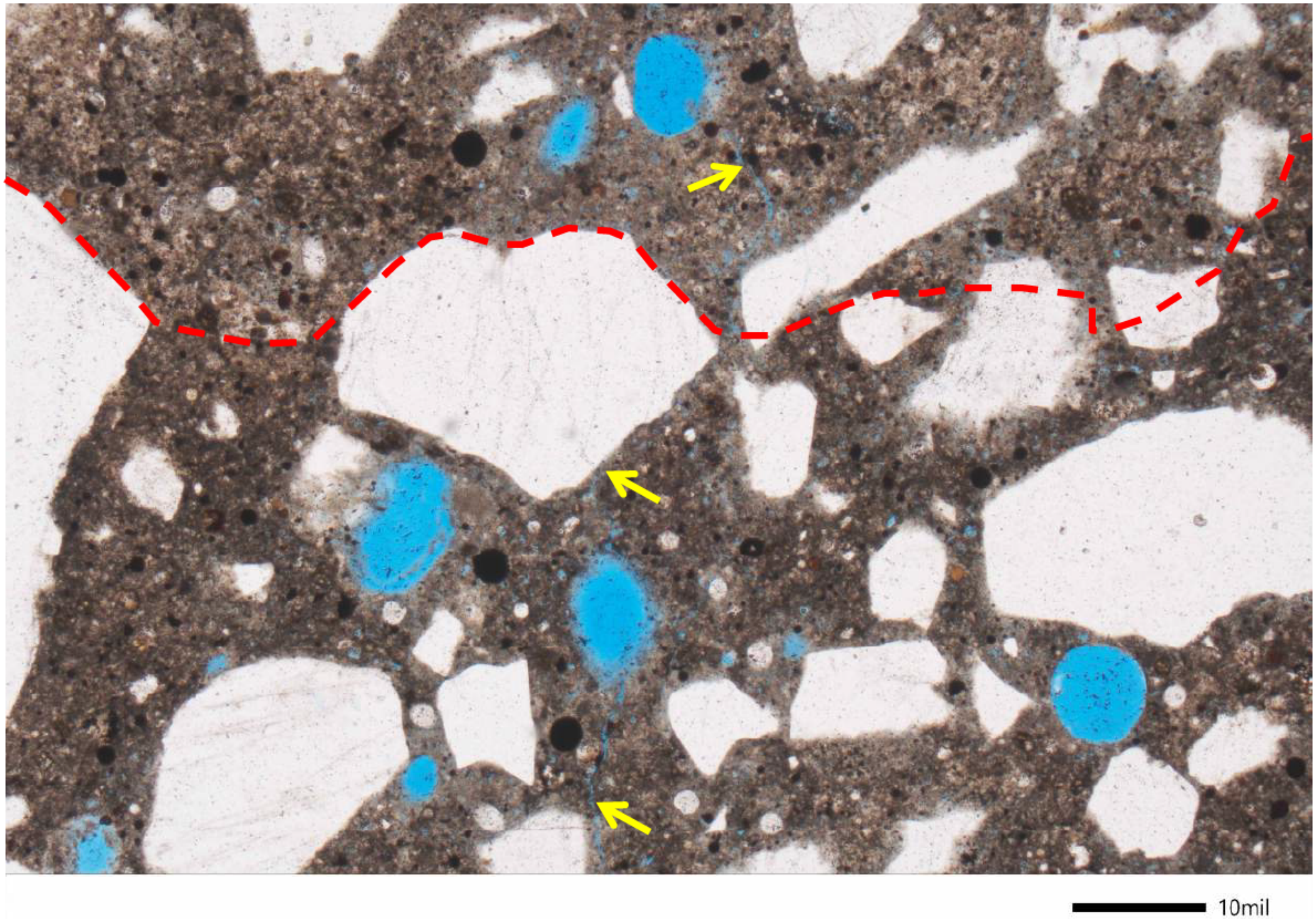


Photo 13

Ultrathin section from Sample 4E-1 showing a bleed water channel (yellow arrows) in the near surface region of concrete. The cementitious paste above the red dashed line is more porous than the cementitious paste below the red dashed line.

(Plane polarized light).

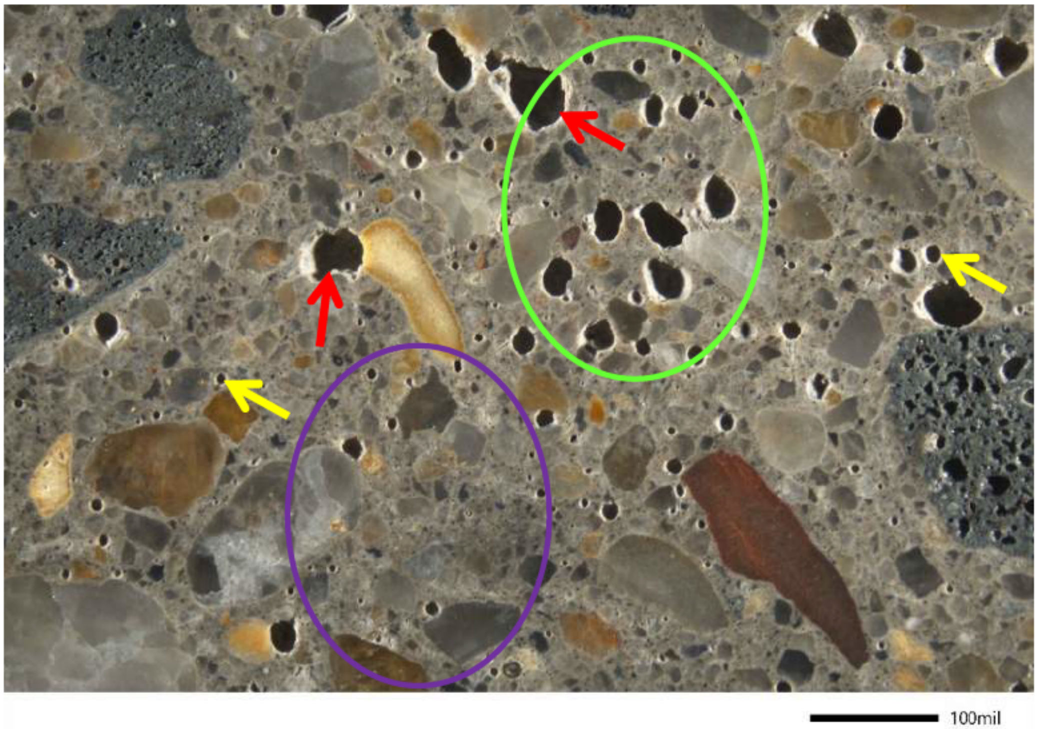


Photo 14

Polished section from Sample 4D-1 showing the air void system in the interior portion of concrete. Red arrows mark examples of semi-spherical entrapped air voids and yellow arrows mark examples of tiny, spherical, entrained air voids. The green oval marks a high air content zone and the purple oval marks a low air content zone.

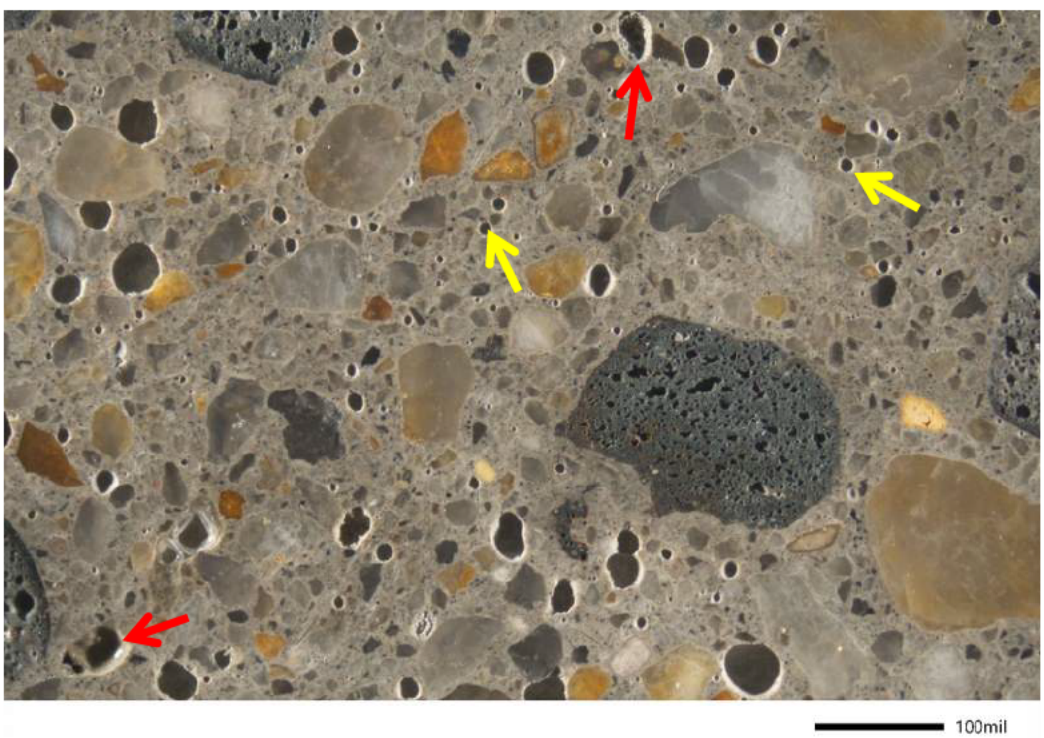


Photo 15

Polished section from Sample 4E-1 showing the air void system in the interior portion of concrete. Red arrows mark examples of semi-spherical entrapped air voids and yellow arrows mark examples of tiny, spherical, entrained air voids.

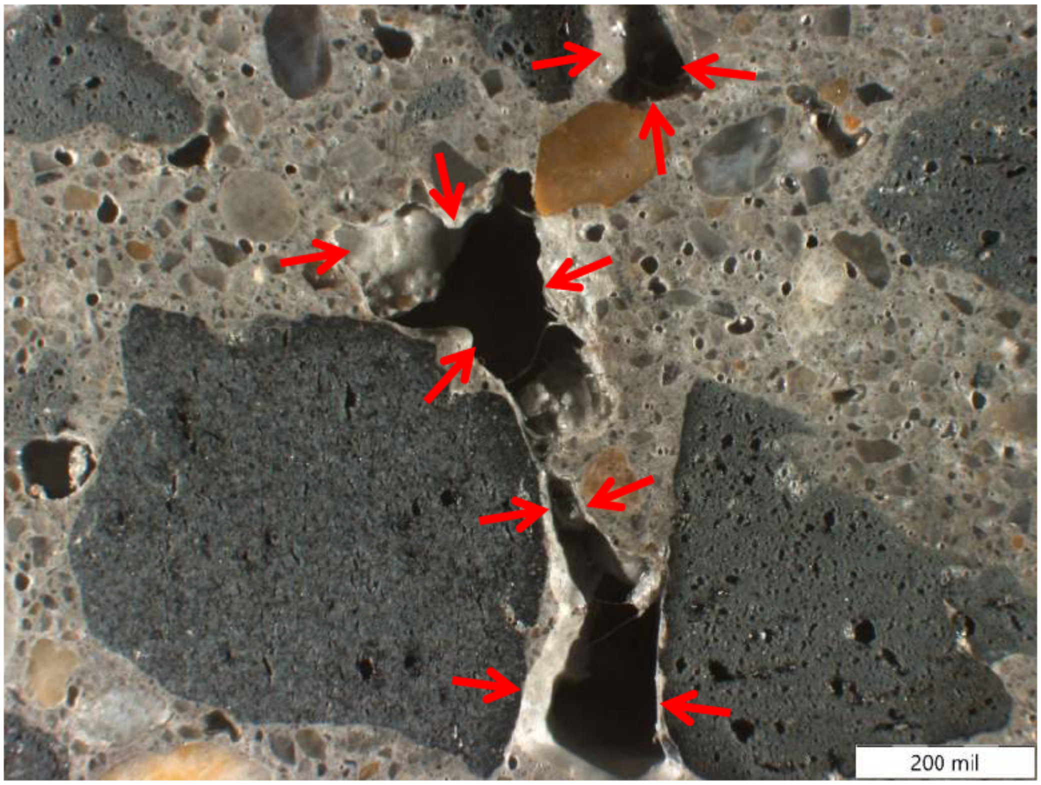


Photo 16

Polished section from Sample 4D-1 showing large, irregularly-shaped voids (red arrows) in the interior portion of concrete.

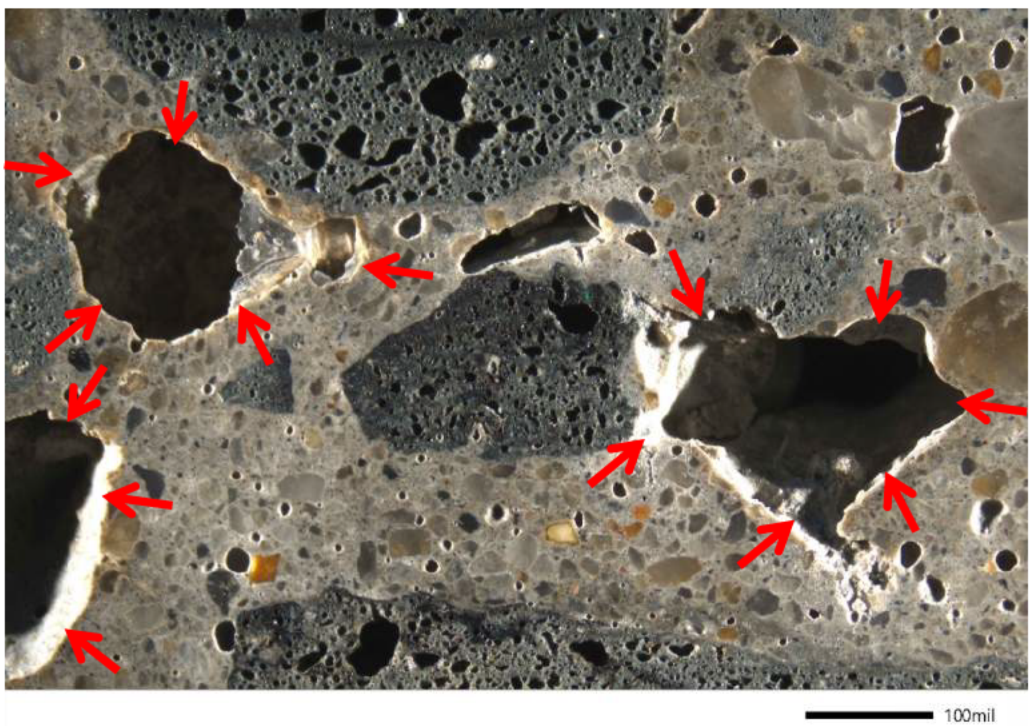


Photo 17

Polished section from Sample 4E-1 showing large, irregularly-shaped voids near the base of the section.

APPENDIX C – HAND CALCULATIONS OF SLAB CAPACITY

Appendix C-1: Slab Capacity of Task 2 Model Configuration (Slab 4 Baseline)

Appendix C-2: Slab Capacity of Task 3 Model Configuration (Slab 3)

Appendix C-3: Slab Capacity of Task 4 Model Configuration (Slab 2)

Appendix C-4: Slab Capacity of Task 5 Model Configuration (Slab 4 Short)

Appendix C-5: Slab Capacity of Task 6 Model Configuration (Slab 4 Reinforced)

Appendix C-6: Slab Capacity of Task 7 Model Configuration (Slab 4 Rigging)

CLIENT	National Institute of Standards and Technology
SUBJECT	Hand calculation of slab capacity for FEA comparison
SHEET NO.	
PROJECT NO.	221564.00
DATE	19 December 2022
BY	SDPalkovic
CHECKED BY	NDCatella

Appendic C-1: Slab Capacity of Task 2 Model Configuration (Slab 4 Baseline)

References: *[1] ACI318-19(22): Building Code Requirements for Structural Concrete*
[2] Vulcraft, "Steel Roof and Floor Deck," August 2018.
[3] Geometry and slab reinforcement layout for SGH SOW

Inputs

Concrete compressive strength:	$f'_c := 54.7\text{MPa}$	Measured concrete properties
Concrete uniaxial strength:	$f_t := 3.27\text{MPa}$	
Concrete bulk density	$\rho_c := 1861\,\frac{\text{kg}}{\text{m}^3}$	
Steel yield strength	$f_y := 420\text{MPa}$	Grade 60 yield strength
Steel deck depth	$d_{deck} := 3\text{in}$	Vulcraft manual for 3C Conform with 20 gauge thickness
Steel deck channel widths	$w_{deck\ top} := 7.25\text{in}$ $w_{deck\ bot} := 4.75\text{in}$	
Spacing between deck channels	$s_{deck} := 12\text{in}$	
Steel deck mass per unit area	$m_{deck} := 2.07\,\frac{\text{lbm}}{\text{ft}^2}$	
Slab length:	$L_{slab} := 144\text{in}$	Slab geometry dependent on task model description
Slab width:	$b_{slab} := 60\text{in}$	
Deck thickness (total)	$t_{slab} := 6.25\text{in}$	
Left anchor edge distance	$L_a := \frac{(11.5\text{in} + 11.75\text{in})}{2} = 11.625 \cdot \text{in}$	
Right anchor edge distance	$L_c := \frac{(11.75\text{in} + 11.75\text{in})}{2} = 11.75 \cdot \text{in}$	
Wire mesh diameter:	$d_b := 0.134\text{in}$	WWR 6x6 W1.4x1.4
Wire mesh bar spacing:	$s_{bar} := 6\text{in}$	
Number of EW #4 rebar	$n_{rb} := 0$	#4 steel reinforcement dependent on task model description
Diameter of #4 rebar	$d_{rb} := 0.5\text{in}$	
Distance from top of concrete to center of steel reinforcement	$d := 1.625\text{in}$	Place all reinforcement at centerline of WWR for capacity calculations
Weight of operator:	$P_{op} := 248\text{lbf}$	
Weight of saw:	$P_{saw} := 257.5\text{lbf}$	

Demand Calculations

Depth of concrete slab for critical flexure	$d_c := t_{slab} - d_{deck}$	$d_c = 3.25 \cdot in$
Area of concrete deck channel	$A_{channel} := \frac{1}{2} \cdot (w_{deck\,top} + w_{deck\,bot}) \cdot d_{deck}$	$A_{channel} = 18 \cdot in^2$
Mass of channel per unit area:	$m_{channel} := A_{channel} \cdot \frac{1}{s_{deck}} \cdot \rho_c$	$m_{channel} = 14.522 \cdot \frac{lbm}{ft^2}$
Mass of concrete deck per unit area	$m_{conc} := d_c \cdot \rho_c$	$m_{conc} = 31.465 \cdot \frac{lbm}{ft^2}$
Total mass of slab per unit area:	$m_{slab} := m_{channel} + m_{conc} + m_{deck}$	$m_{slab} = 48.057 \cdot \frac{lbm}{ft^2}$
Slab self-weight per unit length	$w_{dl} := m_{slab} \cdot b_{slab} \cdot g$	$w_{dl} = 240.286 \cdot \frac{lbf}{ft}$
Distance between slig supports	$L_b := L_{slab} - L_a - L_c$	$L_b = 10.052\ ft$
Left sling vertical reaction force from slab self-weight	$R_a := w_{dl} \cdot \frac{L_{slab} \cdot (L_{slab} - 2L_c)}{2L_b}$	$R_a = 1.44 \cdot kip$

Demand at slab location with peak self-weight moment

distance from left anchor to peak self-weight moment	$x_1 := \frac{R_a}{w_{dl}} - L_a$	$x_1 = 5.025 \cdot ft$
Distance from peak self-weight moment to concentrated loads	$dx := \left\lvert x_1 - \frac{L_b}{2} \right\rvert$	$dx = 1.009 \times 10^{-3}\ ft$
Moment from self-weight at x_1	$M_{dl\,x1} := R_a \cdot x_1 - \frac{w_{dl}}{2} \cdot (L_a + x_1)^2$	$M_{dl\,x1} = 2.921 \cdot kip \cdot ft$
Moment from operator at x_1	$M_{op\,x1} := \frac{P_{op}}{2} \cdot \left(\frac{L_b}{2} - dx\right)$	$M_{op\,x1} = 0.623 \cdot kip \cdot ft$
Moment from saw at x_1	$M_{saw\,x1} := \frac{P_{saw}}{2} \cdot \left(\frac{L_b}{2} - dx\right)$	$M_{saw\,x1} = 0.647 \cdot kip \cdot ft$
Total moment at x_1	$M_{u\,x1} := M_{dl\,x1} + M_{op\,x1} + M_{saw\,x1}$	$M_{u\,x1} = 4.191 \cdot kip \cdot ft$

Demand at slab mid-span

Moment from self-weight at Lb/2	$M_{dl\,x2} := R_a \cdot \frac{L_b}{2} - \frac{w_{dl}}{2} \cdot \left(L_a + \frac{L_b}{2}\right)^2$	$M_{dl\,x2} = 2.921 \cdot kip \cdot ft$
Moment from operator at Lb/2	$M_{op\,x2} := P_{op} \cdot \frac{L_b}{4}$	$M_{op\,x2} = 0.623 \cdot kip \cdot ft$
Moment from saw at Lb/2	$M_{saw\,x2} := P_{saw} \cdot \frac{L_b}{4}$	$M_{saw\,x2} = 0.647 \cdot kip \cdot ft$
Total moment at Lb/2	$M_{u\,x2} := M_{dl\,x2} + M_{op\,x2} + M_{saw\,x2}$	$M_{u\,x2} = 4.191 \cdot kip \cdot ft$

Maximum demand moment on slab

Total unfactored moment due to dead and live loads	$M_u := \max(M_{u\,x1}, M_{u\,x2})$	$M_u = 4.191 \cdot kip \cdot ft$

Capacity Calculations

Elastic section modulus for critical section of concrete deck

$$S_c := \frac{b_{slab} \cdot d_c^2}{6} \qquad S_c = 105.625 \cdot in^3$$

Area of wire mesh:

$$A_{mesh} := \frac{b_{slab}}{s_{bar}} \cdot \frac{\pi}{4} \cdot d_b^2 \qquad A_{mesh} = 0.141 \cdot in^2$$

Area of EW rebar:

$$A_{rb} := n_{rb} \cdot \frac{\pi}{4} \cdot d_{rb}^2 \qquad A_{rb} = 0 \cdot in^2$$

Total area of steel reinrforcement

$$A_{total} := A_{mesh} + A_{rb} \qquad A_{total} = 0.141 \cdot in^2$$

Check Minimum Required Reinforcement

Minimum required reinforcement ACI Eq. 10-3

$$A_{min\ 1} := 3 \cdot b_{slab} \cdot \frac{d}{f_y} \cdot \left(psi \sqrt{\frac{f'_c}{psi}} \right) \qquad A_{min\ 1} = 0.428 \cdot in^2$$

$$A_{min\ 2} := 200 \cdot b_{slab} \cdot \frac{d \cdot psi}{f_y} = 0.32 \cdot in^2 \qquad A_{min\ 2} = 0.32 \cdot in^2$$

$$A_{min} := \max\left(A_{min\ 1}, A_{min\ 2}\right) \qquad A_{min} = 0.428 \cdot in^2$$

Flexural Capacity

Depth of equivalent concrete stress block for rebar yielding:

$$a_y := \frac{A_{total} \cdot f_y}{0.85 \cdot f'_c \cdot b_{slab}} \qquad a_y = 0.021 \cdot in$$

Moment capacity of reinforced concrete section with steel reinforcing yielding

$$M_y := A_{total} \cdot f_y \cdot \left(d - \frac{a_y}{2} \right) \qquad M_y = 1.156 \cdot kip \cdot ft$$

Concrete cracking moment

$$M_k := f_t \cdot S_c \qquad M_k = 4.175 \cdot kip \cdot ft$$

Demand-to-Capacity (D/C) Calculations

D/C ratio for steel rebar yielding

D/C ratio for steel yielding with all loads applied:

$$DC_{My} := \frac{M_u}{M_y} \qquad DC_{My} = 3.627$$

D/C ratio for concrete cracking in tension

D/C ratio for dead load alone:

$$DC_{Mk\ DL} := \frac{M_{dl\ x1}}{M_k} \qquad DC_{Mk\ DL} = 0.7$$

D/C ratio with operator added:

$$DC_{Mk\ op} := \frac{\max\left(M_{dl\ x1} + M_{op\ x1}, M_{dl\ x2} + M_{op\ x2}\right)}{M_k} \qquad DC_{Mk\ op} = 0.849$$

D/C ratio with all loads

$$DC_{Mk\ saw} := \frac{M_u}{M_k} \qquad DC_{Mk\ saw} = 1.004$$

SHEET NO. ______

PROJECT NO. 221564.00

DATE 19 December 2022

CLIENT National Institute of Standards and Technology

BY SDPalkovic

SUBJECT Hand calculation of slab capacity for FEA comparison

CHECKED BY NDCatella

Appendix C-2: Slab Capacity of Task 3 Model Configuration (Slab 3)

References: *[1] ACI 318-19(22): Building Code Requirements for Structural Concrete*
[2] Vulcraft, "Steel Roof and Floor Deck," August 2018.
[3] Geometry and slab reinforcement layout for SGH SOW

Inputs

Concrete compressive strength:	$f'_c := 54.7\text{MPa}$	Measured concrete properties
Concrete uniaxial strength:	$f_t := 3.27\text{MPa}$	
Concrete bulk density	$\rho_c := 1861\frac{\text{kg}}{\text{m}^3}$	
Steel yield strength	$f_y := 420\text{MPa}$	Grade 60 yield strength
Steel deck depth	$d_{deck} := 3\text{in}$	Vulcraft manual for 3C Conform with 20 gauge thickness
Steel deck channel widths	$w_{deck\ top} := 7.25\text{in}$ $w_{deck\ bot} := 4.75\text{in}$	
Spacing between deck channels	$s_{deck} := 12\text{in}$	
Steel deck mass per unit area	$m_{deck} := 2.07\frac{\text{lbm}}{\text{ft}^2}$	
Slab length:	$L_{slab} := 113\text{in}$	Slab geometry dependent on task model description
Slab width:	$b_{slab} := 60\text{in}$	
Deck thickness (total)	$t_{slab} := 6.25\text{in}$	
Left anchor edge distance	$L_a := \frac{(20.25\text{in} + 21.25\text{in})}{2} = 20.75\cdot\text{in}$	
Right anchor edge distance	$L_c := \frac{(11.75\text{in} + 11.5\text{in})}{2} = 11.625\cdot\text{in}$	
Wire mesh diameter:	$d_b := 0.134\text{in}$	WWR 6x6 W1.4x1.4
Wire mesh bar spacing:	$s_{bar} := 6\text{in}$	
Number of EW #4 rebar	$n_{rb} := 2$	#4 steel reinforcement dependent on task model description
Diameter of #4 rebar	$d_{rb} := 0.5\text{in}$	
Distance from top of concrete to center of steel reinforcement	$d := 1.625\text{in}$	Place all reinforcement at centerline of WWR for capacity calculations
Weight of operator:	$P_{op} := 248\text{lbf}$	
Weight of saw:	$P_{saw} := 257.5\text{lbf}$	

Demand Calculations

Depth of concrete slab for critical flexure	$d_c := t_{slab} - d_{deck}$	$d_c = 3.25 \cdot in$
Area of concrete deck channel	$A_{channel} := \frac{1}{2} \cdot \left(w_{deck\ top} + w_{deck\ bot}\right) \cdot d_{deck}$	$A_{channel} = 18 \cdot in^2$
Mass of channel per unit area:	$m_{channel} := A_{channel} \cdot \frac{1}{s_{deck}} \cdot \rho_c$	$m_{channel} = 14.522 \cdot \frac{lbm}{ft^2}$
Mass of concrete deck per unit area	$m_{conc} := d_c \cdot \rho_c$	$m_{conc} = 31.465 \cdot \frac{lbm}{ft^2}$
Total mass of slab per unit area:	$m_{slab} := m_{channel} + m_{conc} + m_{deck}$	$m_{slab} = 48.057 \cdot \frac{lbm}{ft^2}$
Slab self-weight per unit length	$w_{dl} := m_{slab} \cdot b_{slab} \cdot g$	$w_{dl} = 240.286 \cdot \frac{lbf}{ft}$
Distance between slig supports	$L_b := L_{slab} - L_a - L_c$	$L_b = 6.719\,ft$
Left sling vertical reaction force from slab self-weight	$R_a := w_{dl} \cdot \frac{L_{slab} \cdot \left(L_{slab} - 2L_c\right)}{2L_b}$	$R_a = 1.259 \cdot kip$

Demand at slab location with peak self-weight moment

distance from left anchor to peak self-weight moment	$x_1 := \frac{R_a}{w_{dl}} - L_a$	$x_1 = 3.512 \cdot ft$
Distance from peak self-weight moment to concentrated loads	$dx := \left\vert x_1 - \frac{L_b}{2} \right\vert$	$dx = 0.153\,ft$
Moment from self-weight at x_1	$M_{dl\ x1} := R_a \cdot x_1 - \frac{w_{dl}}{2} \cdot \left(L_a + x_1\right)^2$	$M_{dl\ x1} = 1.123 \cdot kip \cdot ft$
Moment from operator at x_1	$M_{op\ x1} := \frac{P_{op}}{2} \cdot \left(\frac{L_b}{2} - dx\right)$	$M_{op\ x1} = 0.398 \cdot kip \cdot ft$
Moment from saw at x_1	$M_{saw\ x1} := \frac{P_{saw}}{2} \cdot \left(\frac{L_b}{2} - dx\right)$	$M_{saw\ x1} = 0.413 \cdot kip \cdot ft$
Total moment at x_1	$M_{u\ x1} := M_{dl\ x1} + M_{op\ x1} + M_{saw\ x1}$	$M_{u\ x1} = 1.933\,kip \cdot ft$

Demand at slab mid-span

Moment from self-weight at Lb/2	$M_{dl\ x2} := R_a \cdot \frac{L_b}{2} - \frac{w_{dl}}{2} \cdot \left(L_a + \frac{L_b}{2}\right)^2$	$M_{dl\ x2} = 1.12 \cdot kip \cdot ft$
Moment from operator at Lb/2	$M_{op\ x2} := P_{op} \cdot \frac{L_b}{4}$	$M_{op\ x2} = 0.417 \cdot kip \cdot ft$
Moment from saw at Lb/2	$M_{saw\ x2} := P_{saw} \cdot \frac{L_b}{4}$	$M_{saw\ x2} = 0.433 \cdot kip \cdot ft$
Total moment at Lb/2	$M_{u\ x2} := M_{dl\ x2} + M_{op\ x2} + M_{saw\ x2}$	$M_{u\ x2} = 1.969\,kip \cdot ft$

Maximum demand moment on slab

Total unfactored moment due to dead and live loads	$M_u := \max\left(M_{u\ x1}, M_{u\ x2}\right)$	$M_u = 1.969 \cdot kip \cdot ft$

Capacity Calculations

Elastic section modulus for critical section of concrete deck $S_c := \frac{b_{slab} \cdot d_c^2}{6}$ $S_c = 105.625 \cdot in^3$

Area of wire mesh: $A_{mesh} := \frac{b_{slab}}{s_{bar}} \cdot \frac{\pi}{4} \cdot d_b^2$ $A_{mesh} = 0.141 \cdot in^2$

Area of EW rebar: $A_{rb} := n_{rb} \cdot \frac{\pi}{4} \cdot d_{rb}^2$ $A_{rb} = 0.393 \cdot in^2$

Total area of steel reinrforcement $A_{total} := A_{mesh} + A_{rb}$ $A_{total} = 0.534 \cdot in^2$

Check Minimum Required Reinforcement

Minimum required reinforcement ACI Eq. 10-3 $A_{min\,1} := 3 \cdot b_{slab} \cdot \frac{d}{f_y} \cdot \left(psi \sqrt{\frac{f'_c}{psi}} \right)$ $A_{min\,1} = 0.428 \cdot in^2$

$A_{min\,2} := 200 \cdot b_{slab} \cdot \frac{d \cdot psi}{f_y} = 0.32 \cdot in^2$ $A_{min\,2} = 0.32 \cdot in^2$

$A_{min} := \max\left(A_{min\,1}, A_{min\,2}\right)$ $A_{min} = 0.428 \cdot in^2$

Flexural Capacity

Depth of equivalent concrete stress block for rebar yielding: $a_y := \frac{A_{total} \cdot f_y}{0.85 \cdot f'_c \cdot b_{slab}}$ $a_y = 0.08 \cdot in$

Moment capacity of reinforced concrete section with steel reinforcing yielding $M_y := A_{total} \cdot f_y \cdot \left(d - \frac{a_y}{2} \right)$ $M_y = 4.294 \cdot kip \cdot ft$

Concrete cracking moment $M_k := f_t \cdot S_c$ $M_k = 4.175 \cdot kip \cdot ft$

Demand-to-Capacity (D/C) Calculations

D/C ratio for steel rebar yielding

D/C ratio for steel yielding with all loads applied: $DC_{My} := \frac{M_u}{M_y}$ $DC_{My} = 0.459$

D/C ratio for concrete cracking in tension

D/C ratio for dead load alone: $DC_{Mk\,DL} := \frac{M_{dl\,x1}}{M_k}$ $DC_{Mk\,DL} = 0.269$

D/C ratio with operator added: $DC_{Mk\,op} := \frac{\max\left(M_{dl\,x1} + M_{op\,x1}, M_{dl\,x2} + M_{op\,x2}\right)}{M_k}$ $DC_{Mk\,op} = 0.368$

D/C ratio with all loads $DC_{Mk\,saw} := \frac{M_u}{M_k}$ $DC_{Mk\,saw} = 0.472$

Appendix C-3: Slab Capacity of Task 4 Model Configuration (Slab 2)

References: *[1] ACI 318-19(22): Building Code Requirements for Structural Concrete*
[2] Vulcraft, "Steel Roof and Floor Deck," August 2018.
[3] Geometry and slab reinforcement layout for SGH SOW

Inputs

Concrete compressive strength:	$f'_c := 54.7\text{MPa}$	Measured concrete properties
Concrete uniaxial strength:	$f_t := 3.27\text{MPa}$	
Concrete bulk density	$\rho_c := 1861\,\dfrac{\text{kg}}{\text{m}^3}$	
Steel yield strength	$f_y := 420\text{MPa}$	Grade 60 yield strength
Steel deck depth	$d_{deck} := 3\text{in}$	Vulcraft manual for 3C Conform with 20 gauge thickness
Steel deck channel widths	$w_{deck\ top} := 7.25\text{in}$ $w_{deck\ bot} := 4.75\text{in}$	
Spacing between deck channels	$s_{deck} := 12\text{in}$	
Steel deck mass per unit area	$m_{deck} := 2.07\,\dfrac{\text{lbm}}{\text{ft}^2}$	
Slab length:	$L_{slab} := 103\text{in}$	Slab geometry dependent on task model description
Slab width:	$b_{slab} := 96.5\text{in}$	
Deck thickness (total)	$t_{slab} := 6.25\text{in}$	
Left anchor edge distance	$L_a := \dfrac{(12\text{in} + 12\text{in})}{2} = 12\cdot\text{in}$	
Right anchor edge distance	$L_c := \dfrac{(12\text{in} + 12\text{in})}{2} = 12\cdot\text{in}$	
Wire mesh diameter:	$d_b := 0.134\text{in}$	WWR 6x6 W1.4x1.4
Wire mesh bar spacing:	$s_{bar} := 6\text{in}$	
Number of EW #4 rebar	$n_{rb} := 8$	#4 steel reinforcement dependent on task model description
Diameter of #4 rebar	$d_{rb} := 0.5\text{in}$	
Distance from top of concrete to center of steel reinforcement	$d := 1.625\text{in}$	Place all reinforcement at centerline of WWR for capacity calculations
Weight of operator:	$P_{op} := 248\text{lbf}$	
Weight of saw:	$P_{saw} := 257.5\text{lbf}$	

Demand Calculations

Depth of concrete slab for critical flexure $d_c := t_{slab} - d_{deck}$ $d_c = 3.25 \cdot in$

Area of concrete deck channel $A_{channel} := \frac{1}{2} \cdot (w_{deck\ top} + w_{deck\ bot}) \cdot d_{deck}$ $A_{channel} = 18 \cdot in^2$

Mass of channel per unit area: $m_{channel} := A_{channel} \cdot \frac{1}{s_{deck}} \cdot \rho_c$ $m_{channel} = 14.522 \cdot \frac{lbm}{ft^2}$

Mass of concrete deck per unit area $m_{conc} := d_c \cdot \rho_c$ $m_{conc} = 31.465 \cdot \frac{lbm}{ft^2}$

Total mass of slab per unit area: $m_{slab} := m_{channel} + m_{conc} + m_{deck}$ $m_{slab} = 48.057 \cdot \frac{lbm}{ft^2}$

Slab self-weight per unit length $w_{dl} := m_{slab} \cdot b_{slab} \cdot g$ $w_{dl} = 386.461 \cdot \frac{lbf}{ft}$

Distance between slig supports $L_b := L_{slab} - L_a - L_c$ $L_b = 6.583\ ft$

Left sling vertical reaction force from slab self-weight $R_a := w_{dl} \cdot \frac{L_{slab} \cdot (L_{slab} - 2L_c)}{2L_b}$ $R_a = 1.659 \cdot kip$

Demand at slab location with peak self-weight moment

distance from left anchor to peak self-weight moment $x_1 := \frac{R_a}{w_{dl}} - L_a$ $x_1 = 3.292 \cdot ft$

Distance from peak self-weight moment to concentrated loads $dx := \left| x_1 - \frac{L_b}{2} \right|$ $dx = 2.185 \times 10^{-15}\ ft$

Moment from self-weight at x_1 $M_{dl\ x1} := R_a \cdot x_1 - \frac{w_{dl}}{2} \cdot (L_a + x_1)^2$ $M_{dl\ x1} = 1.9 \cdot kip \cdot ft$

Moment from operator at x_1 $M_{op\ x1} := \frac{P_{op}}{2} \cdot \left(\frac{L_b}{2} - dx \right)$ $M_{op\ x1} = 0.408 \cdot kip \cdot ft$

Moment from saw at x_1 $M_{saw\ x1} := \frac{P_{saw}}{2} \cdot \left(\frac{L_b}{2} - dx \right)$ $M_{saw\ x1} = 0.424 \cdot kip \cdot ft$

Total moment at x_1 $M_{u\ x1} := M_{dl\ x1} + M_{op\ x1} + M_{saw\ x1}$ $M_{u\ x1} = 2.732\ kip \cdot ft$

Demand at slab mid-span

Moment from self-weight at Lb/2 $M_{dl\ x2} := R_a \cdot \frac{L_b}{2} - \frac{w_{dl}}{2} \cdot \left(L_a + \frac{L_b}{2} \right)^2$ $M_{dl\ x2} = 1.9 \cdot kip \cdot ft$

Moment from operator at Lb/2 $M_{op\ x2} := P_{op} \cdot \frac{L_b}{4}$ $M_{op\ x2} = 0.408 \cdot kip \cdot ft$

Moment from saw at Lb/2 $M_{saw\ x2} := P_{saw} \cdot \frac{L_b}{4}$ $M_{saw\ x2} = 0.424 \cdot kip \cdot ft$

Total moment at Lb/2 $M_{u\ x2} := M_{dl\ x2} + M_{op\ x2} + M_{saw\ x2}$ $M_{u\ x2} = 2.732\ kip \cdot ft$

Maximum demand moment on slab

Total unfactored moment due to dead and live loads $M_u := \max(M_{u\ x1}, M_{u\ x2})$ $M_u = 2.732 \cdot kip \cdot ft$

Capacity Calculations

Elastic section modulus for critical section of concrete deck	$S_c := \frac{b_{slab} \cdot d_c^2}{6}$	$S_c = 169.88 \cdot in^3$
Area of wire mesh:	$A_{mesh} := \frac{b_{slab}}{s_{bar}} \cdot \frac{\pi}{4} \cdot d_b^2$	$A_{mesh} = 0.227 \cdot in^2$
Area of EW rebar:	$A_{rb} := n_{rb} \cdot \frac{\pi}{4} \cdot d_{rb}^2$	$A_{rb} = 1.571 \cdot in^2$
Total area of steel reinrforcement	$A_{total} := A_{mesh} + A_{rb}$	$A_{total} = 1.798 \cdot in^2$

Check Minimum Required Reinforcement

Minimum required reinforcement ACI Eq. 10-3	$A_{min\,1} := 3 \cdot b_{slab} \cdot \frac{d}{f_y} \cdot \left(psi \sqrt{\frac{f'_c}{psi}} \right)$	$A_{min\,1} = 0.688 \cdot in^2$
	$A_{min\,2} := 200 \cdot b_{slab} \cdot \frac{d \cdot psi}{f_y} = 0.515 \cdot in^2$	$A_{min\,2} = 0.515 \cdot in^2$
	$A_{min} := \max\left(A_{min\,1}, A_{min\,2}\right)$	$A_{min} = 0.688 \cdot in^2$

Flexural Capacity

Depth of equivalent concrete stress block for rebar yielding:	$a_y := \frac{A_{total} \cdot f_y}{0.85 \cdot f'_c \cdot b_{slab}}$	$a_y = 0.168 \cdot in$
Moment capacity of reinforced concrete section with steel reinforcing yielding	$M_y := A_{total} \cdot f_y \cdot \left(d - \frac{a_y}{2} \right)$	$M_y = 14.061 \cdot kip \cdot ft$
Concrete cracking moment	$M_k := f_t \cdot S_c$	$M_k = 6.714 \cdot kip \cdot ft$

Demand-to-Capacity (D/C) Calculations

D/C ratio for steel rebar yielding

D/C ratio for steel yielding with all loads applied:	$DC_{My} := \frac{M_u}{M_y}$	$DC_{My} = 0.194$

D/C ratio for concrete cracking in tension

D/C ratio for dead load alone:	$DC_{Mk\,DL} := \frac{M_{dl\,x1}}{M_k}$	$DC_{Mk\,DL} = 0.283$
D/C ratio with operator added:	$DC_{Mk\,op} := \frac{\max\left(M_{dl\,x1} + M_{op\,x1}, M_{dl\,x2} + M_{op\,x2}\right)}{M_k}$	$DC_{Mk\,op} = 0.344$
D/C ratio with all loads	$DC_{Mk\,saw} := \frac{M_u}{M_k}$	$DC_{Mk\,saw} = 0.407$

CLIENT National Institute of Standards and Technology

SUBJECT Hand calculation of slab capacity for FEA comparison

Appendic C-4: Slab Capacity of Task 5 Model Configuration (Slab 4 Short)

References: *[1] ACI318-19(22): Building Code Requirements for Structural Concrete*
[2] Vulcraft, "Steel Roof and Floor Deck," August 2018.
[3] Geometry and slab reinforcement layout for SGH SOW

Inputs

Concrete compressive strength:	$f'_c := 54.7\text{MPa}$	Measured concrete properties
Concrete uniaxial strength:	$f_t := 3.27\text{MPa}$	
Concrete bulk density	$\rho_c := 1861\,\frac{\text{kg}}{\text{m}^3}$	
Steel yield strength	$f_y := 420\text{MPa}$	Grade 60 yield strength
Steel deck depth	$d_{deck} := 3\text{in}$	Vulcraft manual for 3C Conform with 20 gauge thickness
Steel deck channel widths	$w_{deck\ top} := 7.25\text{in}$ $w_{deck\ bot} := 4.75\text{in}$	
Spacing between deck channels	$s_{deck} := 12\text{in}$	
Steel deck mass per unit area	$m_{deck} := 2.07\,\frac{\text{lbm}}{\text{ft}^2}$	
Slab length:	$L_{slab} := 113\text{in}$	Slab geometry dependent on task model description
Slab width:	$b_{slab} := 60\text{in}$	
Deck thickness (total)	$t_{slab} := 6.25\text{in}$	
Left anchor edge distance	$L_a := \frac{(20.25\text{in} + 21.25\text{in})}{2} = 20.75 \cdot \text{in}$	
Right anchor edge distance	$L_c := \frac{(11.75\text{in} + 11.5\text{in})}{2} = 11.625 \cdot \text{in}$	
Wire mesh diameter:	$d_b := 0.134\text{in}$	WWR 6x6 W1.4x1.4
Wire mesh bar spacing:	$s_{bar} := 6\text{in}$	
Number of EW #4 rebar	$n_{rb} := 0$	#4 steel reinforcement dependent on task model description
Diameter of #4 rebar	$d_{rb} := 0.5\text{in}$	
Distance from top of concrete to center of steel reinforcement	$d := 1.625\text{in}$	Place all reinforcement at centerline of WWR for capacity calculations
Weight of operator:	$P_{op} := 248\text{lbf}$	
Weight of saw:	$P_{saw} := 257.5\text{lbf}$	

Demand Calculations

Depth of concrete slab for critical flexure	$d_c := t_{slab} - d_{deck}$	$d_c = 3.25 \cdot in$
Area of concrete deck channel	$A_{channel} := \frac{1}{2} \cdot \left(w_{deck\ top} + w_{deck\ bot}\right) \cdot d_{deck}$	$A_{channel} = 18 \cdot in^2$
Mass of channel per unit area:	$m_{channel} := A_{channel} \cdot \frac{1}{s_{deck}} \cdot \rho_c$	$m_{channel} = 14.522 \cdot \frac{lbm}{ft^2}$
Mass of concrete deck per unit area	$m_{conc} := d_c \cdot \rho_c$	$m_{conc} = 31.465 \cdot \frac{lbm}{ft^2}$
Total mass of slab per unit area:	$m_{slab} := m_{channel} + m_{conc} + m_{deck}$	$m_{slab} = 48.057 \cdot \frac{lbm}{ft^2}$
Slab self-weight per unit length	$w_{dl} := m_{slab} \cdot b_{slab} \cdot g$	$w_{dl} = 240.286 \cdot \frac{lbf}{ft}$
Distance between slig supports	$L_b := L_{slab} - L_a - L_c$	$L_b = 6.719\,ft$
Left sling vertical reaction force from slab self-weight	$R_a := w_{dl} \cdot \frac{L_{slab} \cdot \left(L_{slab} - 2L_c\right)}{2L_b}$	$R_a = 1.259 \cdot kip$

Demand at slab location with peak self-weight moment

distance from left anchor to peak self-weight moment	$x_1 := \frac{R_a}{w_{dl}} - L_a$	$x_1 = 3.512 \cdot ft$
Distance from peak self-weight moment to concentrated loads	$dx := \left\lvert x_1 - \frac{L_b}{2} \right\rvert$	$dx = 0.153\,ft$
Moment from self-weight at x_1	$M_{dl\ x1} := R_a \cdot x_1 - \frac{w_{dl}}{2} \cdot \left(L_a + x_1\right)^2$	$M_{dl\ x1} = 1.123 \cdot kip \cdot ft$
Moment from operator at x_1	$M_{op\ x1} := \frac{P_{op}}{2} \cdot \left(\frac{L_b}{2} - dx\right)$	$M_{op\ x1} = 0.398 \cdot kip \cdot ft$
Moment from saw at x_1	$M_{saw\ x1} := \frac{P_{saw}}{2} \cdot \left(\frac{L_b}{2} - dx\right)$	$M_{saw\ x1} = 0.413 \cdot kip \cdot ft$
Total moment at x_1	$M_{u\ x1} := M_{dl\ x1} + M_{op\ x1} + M_{saw\ x1}$	$M_{u\ x1} = 1.933 \cdot kip \cdot ft$

Demand at slab mid-span

Moment from self-weight at Lb/2	$M_{dl\ x2} := R_a \cdot \frac{L_b}{2} - \frac{w_{dl}}{2} \cdot \left(L_a + \frac{L_b}{2}\right)^2$	$M_{dl\ x2} = 1.12 \cdot kip \cdot ft$
Moment from operator at Lb/2	$M_{op\ x2} := P_{op} \cdot \frac{L_b}{4}$	$M_{op\ x2} = 0.417 \cdot kip \cdot ft$
Moment from saw at Lb/2	$M_{saw\ x2} := P_{saw} \cdot \frac{L_b}{4}$	$M_{saw\ x2} = 0.433 \cdot kip \cdot ft$
Total moment at Lb/2	$M_{u\ x2} := M_{dl\ x2} + M_{op\ x2} + M_{saw\ x2}$	$M_{u\ x2} = 1.969 \cdot kip \cdot ft$

Maximum demand moment on slab

Total unfactored moment due to dead and live loads	$M_u := \max\left(M_{u\ x1}, M_{u\ x2}\right)$	$M_u = 1.969 \cdot kip \cdot ft$

Capacity Calculations

Elastic section modulus for critical section of concrete deck
$$S_c := \frac{b_{slab} \cdot d_c^{\,2}}{6} \qquad S_c = 105.625 \cdot in^3$$

Area of wire mesh:
$$A_{mesh} := \frac{b_{slab}}{s_{bar}} \cdot \frac{\pi}{4} \cdot d_b^{\,2} \qquad A_{mesh} = 0.141 \cdot in^2$$

Area of EW rebar:
$$A_{rb} := n_{rb} \cdot \frac{\pi}{4} \cdot d_{rb}^{\,2} \qquad A_{rb} = 0 \cdot in^2$$

Total area of steel reinrforcement
$$A_{total} := A_{mesh} + A_{rb} \qquad A_{total} = 0.141 \cdot in^2$$

Check Minimum Required Reinforcement

Minimum required reinforcement ACI Eq. 10-3
$$A_{min\,1} := 3 \cdot b_{slab} \cdot \frac{d}{f_y} \cdot \left(psi \sqrt{\frac{f'_c}{psi}}\right) \qquad A_{min\,1} = 0.428 \cdot in^2$$

$$A_{min\,2} := 200 \cdot b_{slab} \cdot \frac{d \cdot psi}{f_y} = 0.32 \cdot in^2 \qquad A_{min\,2} = 0.32 \cdot in^2$$

$$A_{min} := \max\left(A_{min\,1}, A_{min\,2}\right) \qquad A_{min} = 0.428 \cdot in^2$$

Flexural Capacity

Depth of equivalent concrete stress block for rebar yielding:
$$a_y := \frac{A_{total} \cdot f_y}{0.85 \cdot f'_c \cdot b_{slab}} \qquad a_y = 0.021 \cdot in$$

Moment capacity of reinforced concrete section with steel reinforcing yielding
$$M_y := A_{total} \cdot f_y \cdot \left(d - \frac{a_y}{2}\right) \qquad M_y = 1.156 \cdot kip \cdot ft$$

Concrete cracking moment
$$M_k := f_t \cdot S_c \qquad M_k = 4.175 \cdot kip \cdot ft$$

Demand-to-Capacity (D/C) Calculations

D/C ratio for steel rebar yielding

D/C ratio for steel yielding with all loads applied:
$$DC_{My} := \frac{M_u}{M_y} \qquad DC_{My} = 1.704$$

D/C ratio for concrete cracking in tension

D/C ratio for dead load alone:
$$DC_{Mk\,DL} := \frac{M_{dl\,x1}}{M_k} \qquad DC_{Mk\,DL} = 0.269$$

D/C ratio with operator added:
$$DC_{Mk\,op} := \frac{\max\left(M_{dl\,x1} + M_{op\,x1}, M_{dl\,x2} + M_{op\,x2}\right)}{M_k} \qquad DC_{Mk\,op} = 0.368$$

D/C ratio with all loads
$$DC_{Mk\,saw} := \frac{M_u}{M_k} \qquad DC_{Mk\,saw} = 0.472$$

CLIENT National Institute of Standards and Technology

SUBJECT Hand calculation of slab capacity for FEA comparison

Appendic C-5: Slab Capacity of Task 6 Model Configuration (Slab 4 Reinforced)

References: *[1] ACI 318-19(22): Building Code Requirements for Structural Concrete*
[2] Vulcraft, "Steel Roof and Floor Deck," August 2018.
[3] Geometry and slab reinforcement layout for SGH SOW

Inputs

Concrete compressive strength:	$f'_c := 54.7\text{MPa}$	Measured concrete properties
Concrete uniaxial strength:	$f_t := 3.27\text{MPa}$	
Concrete bulk density	$\rho_c := 1861\,\dfrac{\text{kg}}{\text{m}^3}$	
Steel yield strength	$f_y := 420\text{MPa}$	Grade 60 yield strength
Steel deck depth	$d_{deck} := 3\text{in}$	Vulcraft manual for 3C Conform with 20 gauge thickness
Steel deck channel widths	$w_{deck\ top} := 7.25\text{in}$ $w_{deck\ bot} := 4.75\text{in}$	
Spacing between deck channels	$s_{deck} := 12\text{in}$	
Steel deck mass per unit area	$m_{deck} := 2.07\,\dfrac{\text{lbm}}{\text{ft}^2}$	
Slab length:	$L_{slab} := 144\text{in}$	Slab geometry dependent on task model description
Slab width:	$b_{slab} := 60\text{in}$	
Deck thickness (total)	$t_{slab} := 6.25\text{in}$	
Left anchor edge distance	$L_a := \dfrac{(11.5\text{in} + 11.75\text{in})}{2} = 11.625\cdot\text{in}$	
Right anchor edge distance	$L_c := \dfrac{(11.75\text{in} + 11.75\text{in})}{2} = 11.75\cdot\text{in}$	
Wire mesh diameter:	$d_b := 0.134\text{in}$	WWR 6x6 W1.4x1.4
Wire mesh bar spacing:	$s_{bar} := 6\text{in}$	
Number of EW #4 rebar	$n_{rb} := 5$	#4 steel reinforcement dependent on task model description
Diameter of #4 rebar	$d_{rb} := 0.5\text{in}$	
Distance from top of concrete to center of steel reinforcement	$d := 1.625\text{in}$	Place all reinforcement at centerline of WWR for capacity calculations
Weight of operator:	$P_{op} := 248\text{lbf}$	
Weight of saw:	$P_{saw} := 257.5\text{lbf}$	

Demand Calculations

Depth of concrete slab for critical flexure	$d_c := t_{slab} - d_{deck}$	$d_c = 3.25 \cdot in$
Area of concrete deck channel	$A_{channel} := \frac{1}{2} \cdot \left(w_{deck\ top} + w_{deck\ bot}\right) \cdot d_{deck}$	$A_{channel} = 18 \cdot in^2$
Mass of channel per unit area:	$m_{channel} := A_{channel} \cdot \frac{1}{s_{deck}} \cdot \rho_c$	$m_{channel} = 14.522 \cdot \frac{lbm}{ft^2}$
Mass of concrete deck per unit area	$m_{conc} := d_c \cdot \rho_c$	$m_{conc} = 31.465 \cdot \frac{lbm}{ft^2}$
Total mass of slab per unit area:	$m_{slab} := m_{channel} + m_{conc} + m_{deck}$	$m_{slab} = 48.057 \cdot \frac{lbm}{ft^2}$
Slab self-weight per unit length	$w_{dl} := m_{slab} \cdot b_{slab} \cdot g$	$w_{dl} = 240.286 \cdot \frac{lbf}{ft}$
Distance between slig supports	$L_b := L_{slab} - L_a - L_c$	$L_b = 10.052\ ft$
Left sling vertical reaction force from slab self-weight	$R_a := w_{dl} \cdot \frac{L_{slab} \cdot \left(L_{slab} - 2L_c\right)}{2L_b}$	$R_a = 1.44 \cdot kip$

Demand at slab location with peak self-weight moment

distance from left anchor to peak self-weight moment	$x_1 := \frac{R_a}{w_{dl}} - L_a$	$x_1 = 5.025 \cdot ft$
Distance from peak self-weight moment to concentrated loads	$dx := \left| x_1 - \frac{L_b}{2} \right|$	$dx = 1.009 \times 10^{-3}\ ft$
Moment from self-weight at x_1	$M_{dl\ x1} := R_a \cdot x_1 - \frac{w_{dl}}{2} \cdot \left(L_a + x_1\right)^2$	$M_{dl\ x1} = 2.921 \cdot kip \cdot ft$
Moment from operator at x_1	$M_{op\ x1} := \frac{P_{op}}{2} \cdot \left(\frac{L_b}{2} - dx\right)$	$M_{op\ x1} = 0.623 \cdot kip \cdot ft$
Moment from saw at x_1	$M_{saw\ x1} := \frac{P_{saw}}{2} \cdot \left(\frac{L_b}{2} - dx\right)$	$M_{saw\ x1} = 0.647 \cdot kip \cdot ft$
Total moment at x_1	$M_{u\ x1} := M_{dl\ x1} + M_{op\ x1} + M_{saw\ x1}$	$M_{u\ x1} = 4.191 \cdot kip \cdot ft$

Demand at slab mid-span

Moment from self-weight at Lb/2	$M_{dl\ x2} := R_a \cdot \frac{L_b}{2} - \frac{w_{dl}}{2} \cdot \left(L_a + \frac{L_b}{2}\right)^2$	$M_{dl\ x2} = 2.921 \cdot kip \cdot ft$
Moment from operator at Lb/2	$M_{op\ x2} := P_{op} \cdot \frac{L_b}{4}$	$M_{op\ x2} = 0.623 \cdot kip \cdot ft$
Moment from saw at Lb/2	$M_{saw\ x2} := P_{saw} \cdot \frac{L_b}{4}$	$M_{saw\ x2} = 0.647 \cdot kip \cdot ft$
Total moment at Lb/2	$M_{u\ x2} := M_{dl\ x2} + M_{op\ x2} + M_{saw\ x2}$	$M_{u\ x2} = 4.191 \cdot kip \cdot ft$

Maximum demand moment on slab

Total unfactored moment due to dead and live loads	$M_u := \max\left(M_{u\ x1}, M_{u\ x2}\right)$	$M_u = 4.191 \cdot kip \cdot ft$

Capacity Calculations

Elastic section modulus for critical section of concrete deck

$$S_c := \frac{b_{slab} \cdot d_c^2}{6} \qquad S_c = 105.625 \cdot in^3$$

Area of wire mesh:

$$A_{mesh} := \frac{b_{slab}}{s_{bar}} \cdot \frac{\pi}{4} \cdot d_b^2 \qquad A_{mesh} = 0.141 \cdot in^2$$

Area of EW rebar:

$$A_{rb} := n_{rb} \cdot \frac{\pi}{4} \cdot d_{rb}^2 \qquad A_{rb} = 0.982 \cdot in^2$$

Total area of steel reinrforcement

$$A_{total} := A_{mesh} + A_{rb} \qquad A_{total} = 1.123 \cdot in^2$$

Check Minimum Required Reinforcement

Minimum required reinforcement ACI Eq. 10-3

$$A_{min\,1} := 3 \cdot b_{slab} \cdot \frac{d}{f_y} \cdot \left(psi \sqrt{\frac{f'_c}{psi}} \right) \qquad A_{min\,1} = 0.428 \cdot in^2$$

$$A_{min\,2} := 200 \cdot b_{slab} \cdot \frac{d \cdot psi}{f_y} = 0.32 \cdot in^2 \qquad A_{min\,2} = 0.32 \cdot in^2$$

$$A_{min} := \max\left(A_{min\,1}, A_{min\,2}\right) \qquad A_{min} = 0.428 \cdot in^2$$

Flexural Capacity

Depth of equivalent concrete stress block for rebar yielding:

$$a_y := \frac{A_{total} \cdot f_y}{0.85 \cdot f'_c \cdot b_{slab}} \qquad a_y = 0.169 \cdot in$$

Moment capacity of reinforced concrete section with steel reinforcing yielding

$$M_y := A_{total} \cdot f_y \cdot \left(d - \frac{a_y}{2} \right) \qquad M_y = 8.78 \cdot kip \cdot ft$$

Concrete cracking moment

$$M_k := f_t \cdot S_c \qquad M_k = 4.175 \cdot kip \cdot ft$$

Demand-to-Capacity (D/C) Calculations

D/C ratio for steel rebar yielding

D/C ratio for steel yielding with all loads applied:

$$DC_{My} := \frac{M_u}{M_y} \qquad DC_{My} = 0.477$$

D/C ratio for concrete cracking in tension

D/C ratio for dead load alone:

$$DC_{Mk\,DL} := \frac{M_{dl\,x1}}{M_k} \qquad DC_{Mk\,DL} = 0.7$$

D/C ratio with operator added:

$$DC_{Mk\,op} := \frac{\max\left(M_{dl\,x1} + M_{op\,x1}, M_{dl\,x2} + M_{op\,x2}\right)}{M_k} \qquad DC_{Mk\,op} = 0.849$$

D/C ratio with all loads

$$DC_{Mk\,saw} := \frac{M_u}{M_k} \qquad DC_{Mk\,saw} = 1.004$$

CLIENT National Institute of Standards and Technology

SUBJECT Hand calculation of slab capacity for FEA comparison

Appendic C-6: Slab Capacity of Task 7 Model Configuration (Slab 4 Rigging)

References: *[1] ACI 318-19(22): Building Code Requirements for Structural Concrete*
[2] Vulcraft, "Steel Roof and Floor Deck," August 2018.
[3] Geometry and slab reinforcement layout for SGH SOW

Inputs

Concrete compressive strength:	$f'_c := 54.7\text{MPa}$	Measured concrete properties
Concrete uniaxial strength:	$f_t := 3.27\text{MPa}$	
Concrete bulk density	$\rho_c := 1861 \frac{\text{kg}}{\text{m}^3}$	
Steel yield strength	$f_y := 420\text{MPa}$	Grade 60 yield strength
Steel deck depth	$d_{deck} := 3\text{in}$	Vulcraft manual for 3C Conform with 20 gauge thickness
Steel deck channel widths	$w_{deck\ top} := 7.25\text{in}$ $w_{deck\ bot} := 4.75\text{in}$	
Spacing between deck channels	$s_{deck} := 12\text{in}$	
Steel deck mass per unit area	$m_{deck} := 2.07 \frac{\text{lbm}}{\text{ft}^2}$	
Slab length:	$L_{slab} := 144\text{in}$	Slab geometry dependent on task model description
Slab width:	$b_{slab} := 60\text{in}$	
Deck thickness (total)	$t_{slab} := 6.25\text{in}$	
Left anchor edge distance	$L_a := \frac{(23.5\text{in} + 23.75\text{in})}{2} = 23.625 \cdot \text{in}$	
Right anchor edge distance	$L_c := \frac{(23.75\text{in} + 23.75\text{in})}{2} = 23.75 \cdot \text{in}$	
Wire mesh diameter:	$d_b := 0.134\text{in}$	WWR 6x6 W1.4x1.4
Wire mesh bar spacing:	$s_{bar} := 6\text{in}$	
Number of EW #4 rebar	$n_{rb} := 0$	#4 steel reinforcement dependent on task model description
Diameter of #4 rebar	$d_{rb} := 0.5\text{in}$	
Distance from top of concrete to center of steel reinforcement	$d := 1.625\text{in}$	Place all reinforcement at centerline of WWR for capacity calculations
Weight of operator:	$P_{op} := 248\text{lbf}$	
Weight of saw:	$P_{saw} := 257.5\text{lbf}$	

Demand Calculations

Depth of concrete slab for critical flexure — $d_c := t_{slab} - d_{deck}$ — $d_c = 3.25 \cdot in$

Area of concrete deck channel — $A_{channel} := \frac{1}{2} \cdot (w_{deck\ top} + w_{deck\ bot}) \cdot d_{deck}$ — $A_{channel} = 18 \cdot in^2$

Mass of channel per unit area: — $m_{channel} := A_{channel} \cdot \frac{1}{s_{deck}} \cdot \rho_c$ — $m_{channel} = 14.522 \cdot \frac{lbm}{ft^2}$

Mass of concrete deck per unit area — $m_{conc} := d_c \cdot \rho_c$ — $m_{conc} = 31.465 \cdot \frac{lbm}{ft^2}$

Total mass of slab per unit area: — $m_{slab} := m_{channel} + m_{conc} + m_{deck}$ — $m_{slab} = 48.057 \cdot \frac{lbm}{ft^2}$

Slab self-weight per unit length — $w_{dl} := m_{slab} \cdot b_{slab} \cdot g$ — $w_{dl} = 240.286 \cdot \frac{lbf}{ft}$

Distance between slig supports — $L_b := L_{slab} - L_a - L_c$ — $L_b = 8.052\,ft$

Left sling vertical reaction force from slab self-weight — $R_a := w_{dl} \cdot \frac{L_{slab} \cdot (L_{slab} - 2L_c)}{2L_b}$ — $R_a = 1.44 \cdot kip$

Demand at slab location with peak self-weight moment

distance from left anchor to peak self-weight moment — $x_1 := \frac{R_a}{w_{dl}} - L_a$ — $x_1 = 4.023 \cdot ft$

Distance from peak self-weight moment to concentrated loads — $dx := \left| x_1 - \frac{L_b}{2} \right|$ — $dx = 2.554 \times 10^{-3}\,ft$

Moment from self-weight at x_1 — $M_{dl\ x1} := R_a \cdot x_1 - \frac{w_{dl}}{2} \cdot (L_a + x_1)^2$ — $M_{dl\ x1} = 1.479 \cdot kip \cdot ft$

Moment from operator at x_1 — $M_{op\ x1} := \frac{P_{op}}{2} \cdot \left(\frac{L_b}{2} - dx \right)$ — $M_{op\ x1} = 0.499 \cdot kip \cdot ft$

Moment from saw at x_1 — $M_{saw\ x1} := \frac{P_{saw}}{2} \cdot \left(\frac{L_b}{2} - dx \right)$ — $M_{saw\ x1} = 0.518 \cdot kip \cdot ft$

Total moment at x_1 — $M_{u\ x1} := M_{dl\ x1} + M_{op\ x1} + M_{saw\ x1}$ — $M_{u\ x1} = 2.496 \cdot kip \cdot ft$

Demand at slab mid-span

Moment from self-weight at Lb/2 — $M_{dl\ x2} := R_a \cdot \frac{L_b}{2} - \frac{w_{dl}}{2} \cdot \left(L_a + \frac{L_b}{2} \right)^2$ — $M_{dl\ x2} = 1.479 \cdot kip \cdot ft$

Moment from operator at Lb/2 — $M_{op\ x2} := P_{op} \cdot \frac{L_b}{4}$ — $M_{op\ x2} = 0.499 \cdot kip \cdot ft$

Moment from saw at Lb/2 — $M_{saw\ x2} := P_{saw} \cdot \frac{L_b}{4}$ — $M_{saw\ x2} = 0.518 \cdot kip \cdot ft$

Total moment at Lb/2 — $M_{u\ x2} := M_{dl\ x2} + M_{op\ x2} + M_{saw\ x2}$ — $M_{u\ x2} = 2.497 \cdot kip \cdot ft$

Maximum demand moment on slab

Total unfactored moment due to dead and live loads — $M_u := \max(M_{u\ x1}, M_{u\ x2})$ — $M_u = 2.497 \cdot kip \cdot ft$

Capacity Calculations

Elastic section modulus for critical section of concrete deck

$$S_c := \frac{b_{slab} \cdot d_c^{\,2}}{6} \qquad S_c = 105.625 \cdot in^3$$

Area of wire mesh:

$$A_{mesh} := \frac{b_{slab}}{s_{bar}} \cdot \frac{\pi}{4} \cdot d_b^{\,2} \qquad A_{mesh} = 0.141 \cdot in^2$$

Area of EW rebar:

$$A_{rb} := n_{rb} \cdot \frac{\pi}{4} \cdot d_{rb}^{\,2} \qquad A_{rb} = 0 \cdot in^2$$

Total area of steel reinrforcement

$$A_{total} := A_{mesh} + A_{rb} \qquad A_{total} = 0.141 \cdot in^2$$

Check Minimum Required Reinforcement

Minimum required reinforcement ACI Eq. 10-3

$$A_{min\,1} := 3 \cdot b_{slab} \cdot \frac{d}{f_y} \cdot \left(psi \sqrt{\frac{f'_c}{psi}} \right) \qquad A_{min\,1} = 0.428 \cdot in^2$$

$$A_{min\,2} := 200 \cdot b_{slab} \cdot \frac{d \cdot psi}{f_y} = 0.32 \cdot in^2 \qquad A_{min\,2} = 0.32 \cdot in^2$$

$$A_{min} := \max\left(A_{min\,1}, A_{min\,2}\right) \qquad A_{min} = 0.428 \cdot in^2$$

Flexural Capacity

Depth of equivalent concrete stress block for rebar yielding:

$$a_y := \frac{A_{total} \cdot f_y}{0.85 \cdot f'_c \cdot b_{slab}} \qquad a_y = 0.021 \cdot in$$

Moment capacity of reinforced concrete section with steel reinforcing yielding

$$M_y := A_{total} \cdot f_y \cdot \left(d - \frac{a_y}{2} \right) \qquad M_y = 1.156 \cdot kip \cdot ft$$

Concrete cracking moment

$$M_k := f_t \cdot S_c \qquad M_k = 4.175 \cdot kip \cdot ft$$

Demand-to-Capacity (D/C) Calculations

D/C ratio for steel rebar yielding

D/C ratio for steel yielding with all loads applied:

$$DC_{My} := \frac{M_u}{M_y} \qquad DC_{My} = 2.16$$

D/C ratio for concrete cracking in tension

D/C ratio for dead load alone:

$$DC_{Mk\,DL} := \frac{M_{dl\,x1}}{M_k} \qquad DC_{Mk\,DL} = 0.354$$

D/C ratio with operator added:

$$DC_{Mk\,op} := \frac{\max\left(M_{dl\,x1} + M_{op\,x1}, M_{dl\,x2} + M_{op\,x2}\right)}{M_k} \qquad DC_{Mk\,op} = 0.474$$

D/C ratio with all loads

$$DC_{Mk\,saw} := \frac{M_u}{M_k} \qquad DC_{Mk\,saw} = 0.598$$

APPENDIX D – SLAB 4 REMOVAL STEPS

Step 1 – Drill Holes

Step 2 – Saw Cut a Part of North Edge

Step 3 – Saw Cut a Part of East Edge

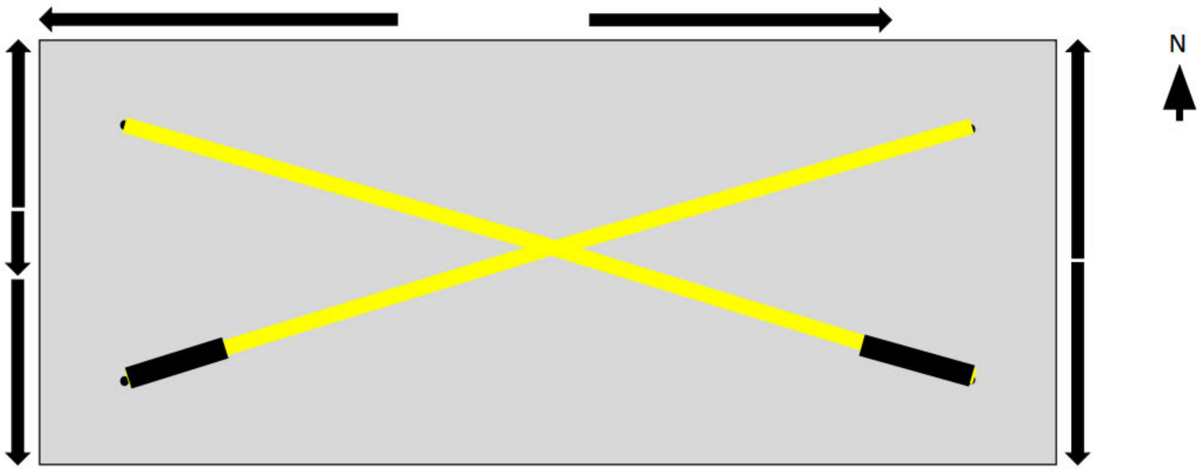
Step 4 – Saw Cut a Part of East Edge

Step 5 – Saw Cut the Rest of East Edge

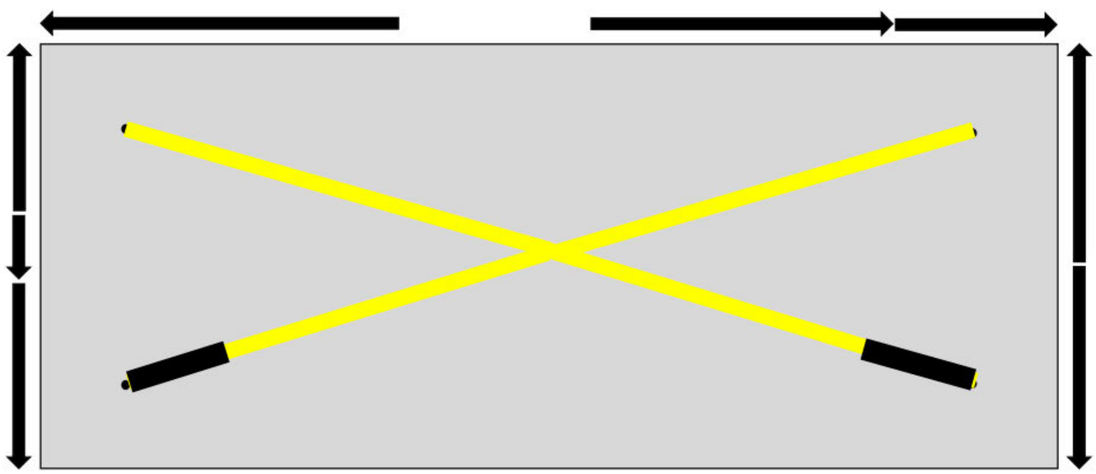
Step 6 – Saw Cut a Part of West Edge

Step 7 – Saw Cut the Rest of West Edge

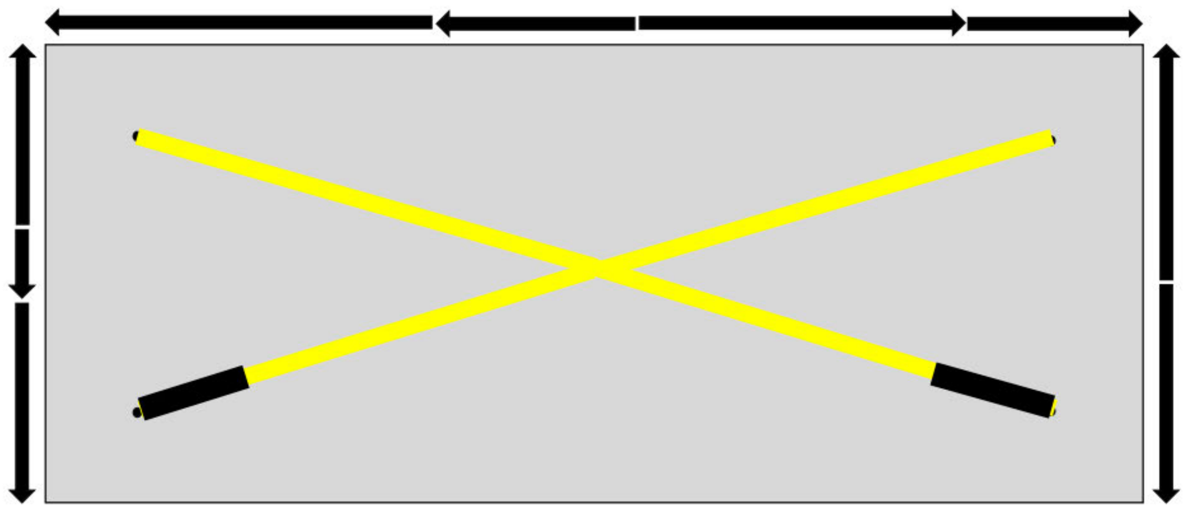
Step 8 – Saw Cut a Part of North Edge



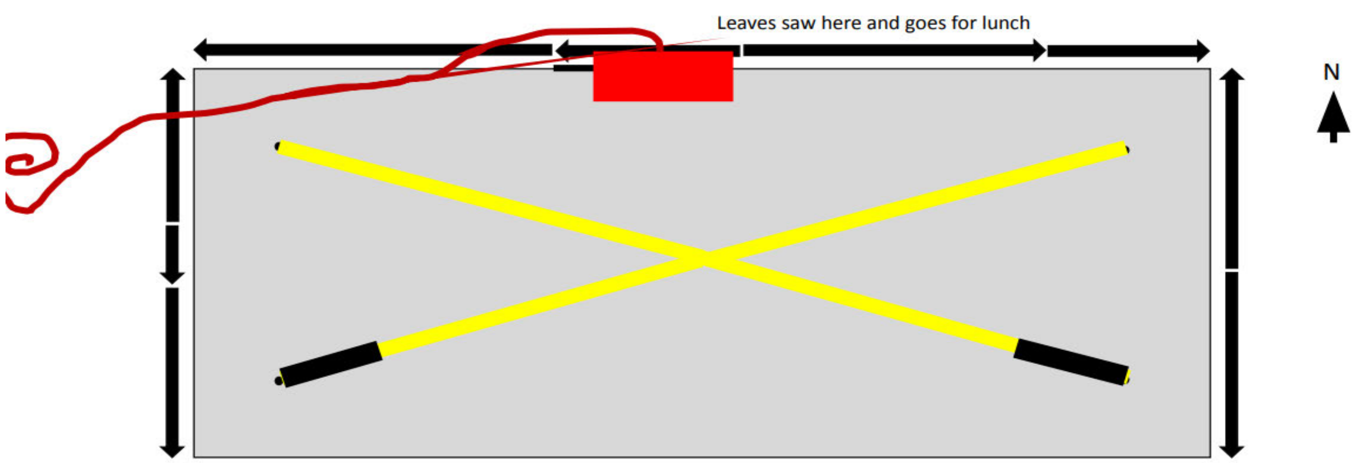
Step 9 – Attach Slings



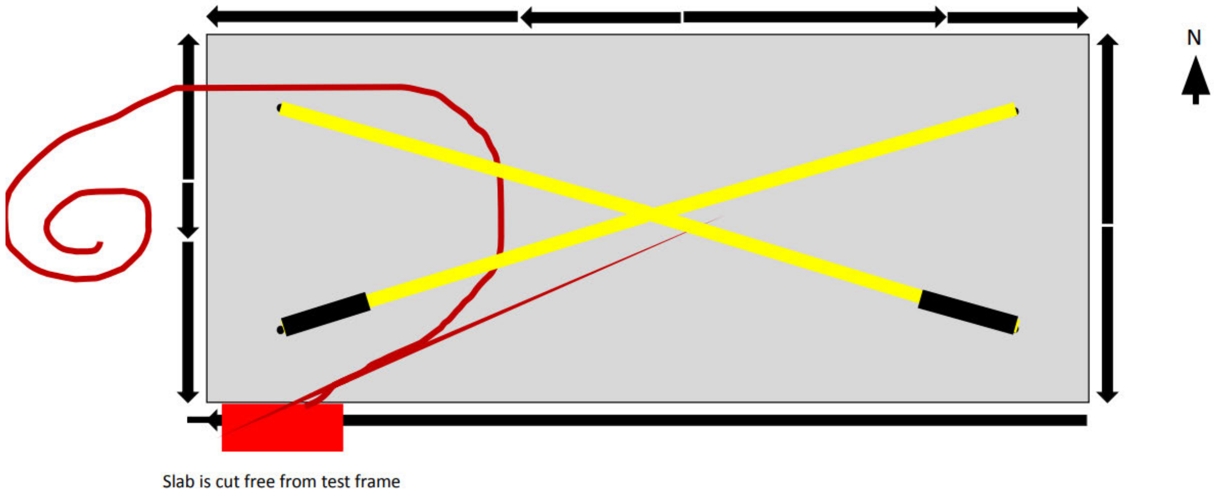
Step 10 – Saw Cut more Along North Edge



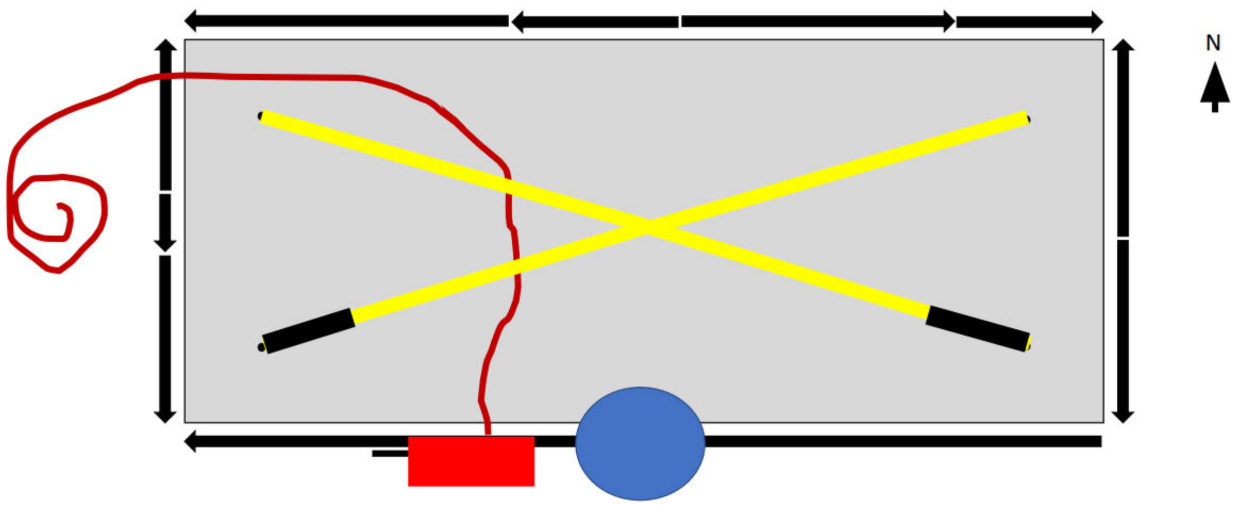
Step 11 – Complete Saw Cutting of North edge



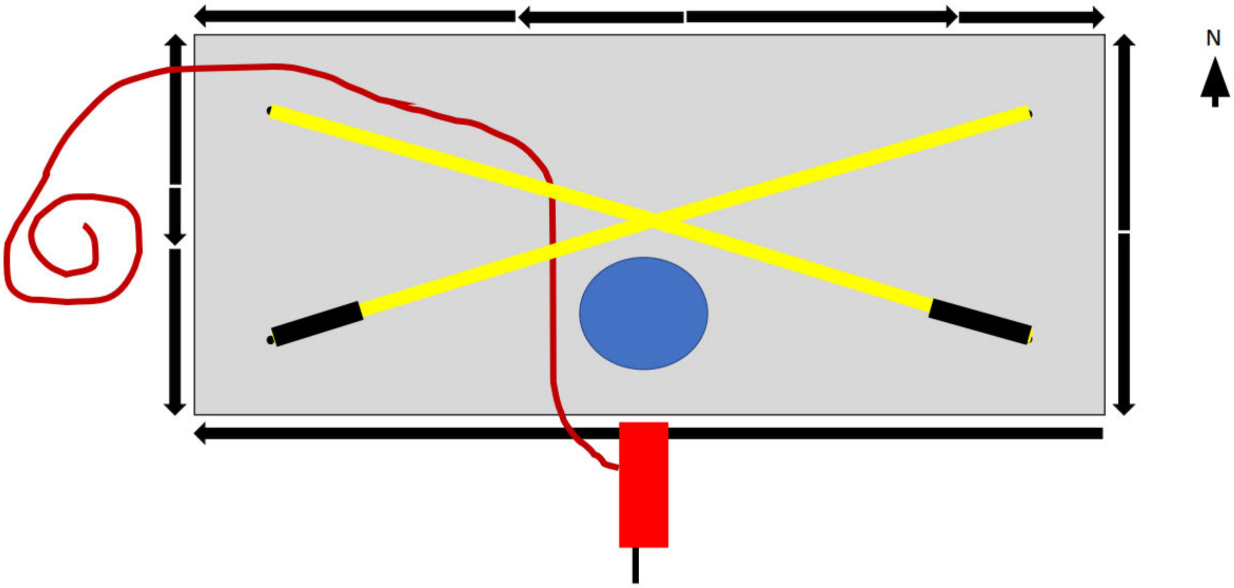
Step 12 – Leave Saw at North Edge Go for Lunch



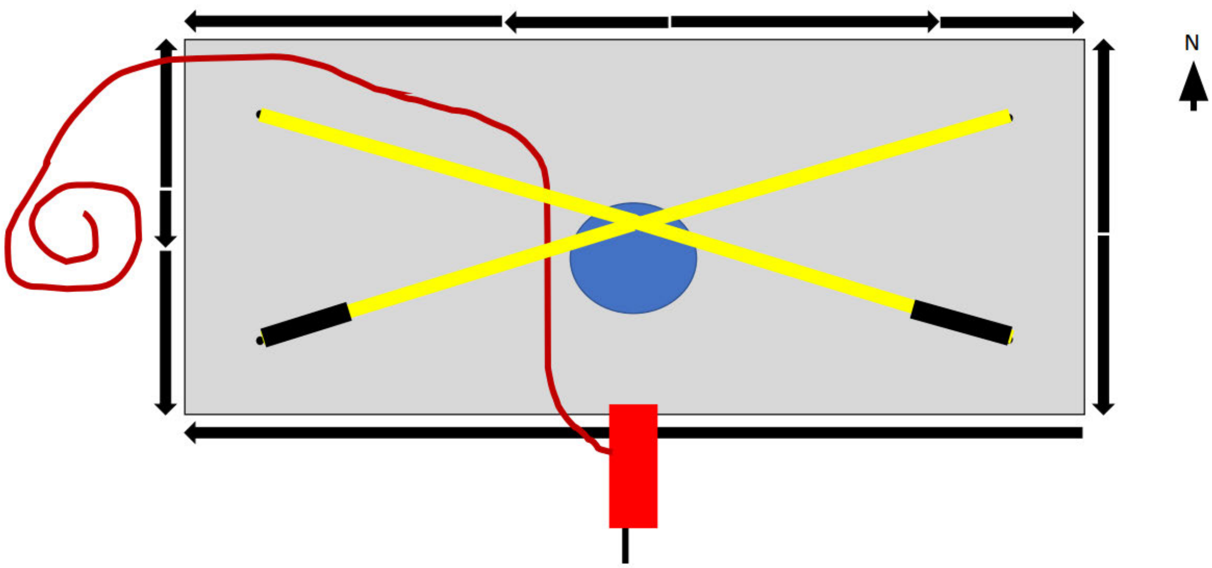
Step 13 – Cut South Edge and Free Slab from Test Frame



Step 14 – Free Slab with Weights of Saw and Operator on Adjacent Beam



Step 15 – Operator on Slab



Step 16 – Slab 4 Prior to Failure with Weights of Operator and Part of rotary saw on the edge of Slab 4

APPENDIX E

IMPACT OF SLACK IN A SLING ON STRESSES IN SLAB 4

SUMMARY

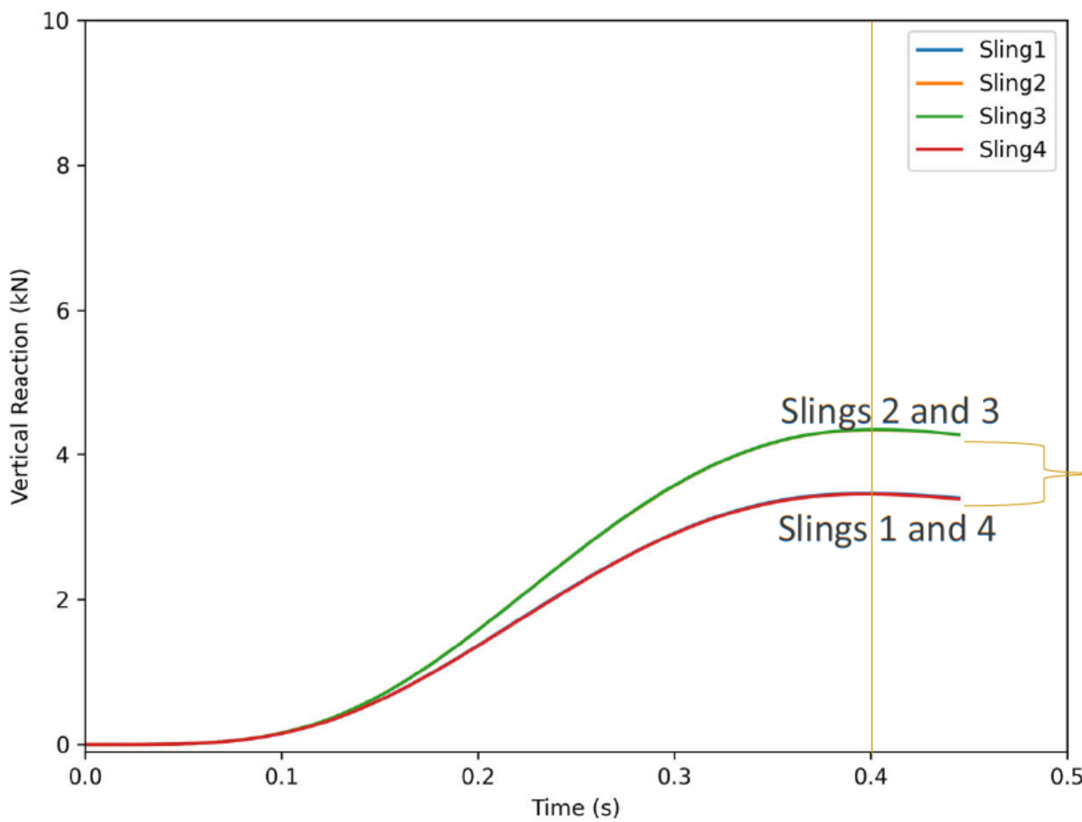
- Baseline model (Slab 4, Task 2) with material properties all set to linear elastic
- Two cases:
  - No slacked
  - Slacked case (Sling 2 slacked by approximately 2 in.)
- Change in maximum value of max principal stress:

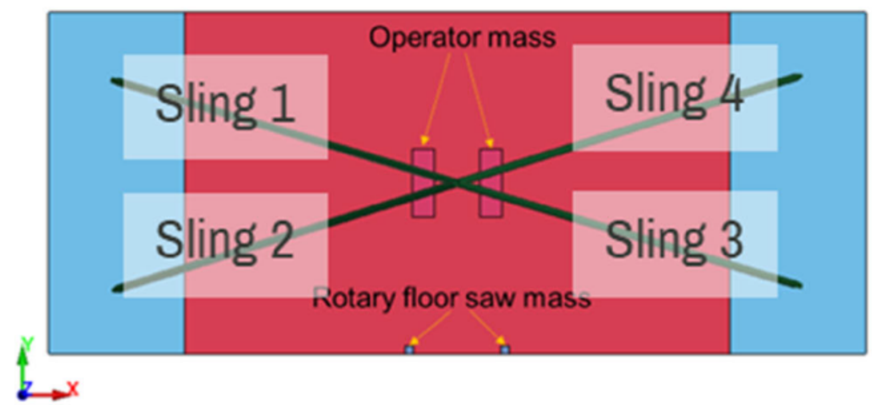
Case	Maximum value of max principal stress (MPa)
No slacked	4.45
Slacked	5.23

17.5% increase

NO SLACK CASE

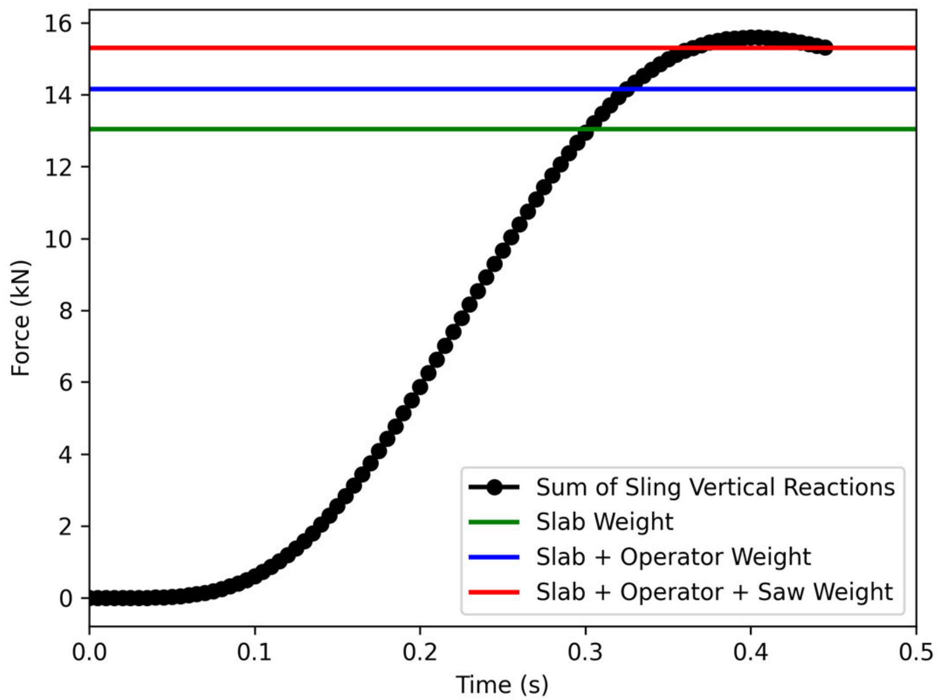
SUM OF VERTICAL REACTIONS OF INDIVIDUAL SLINGS

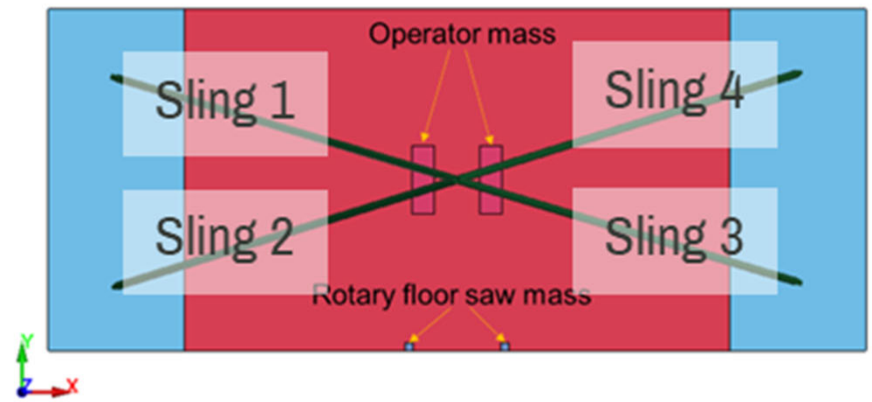




Difference because rotary floor saw mass was on south edge

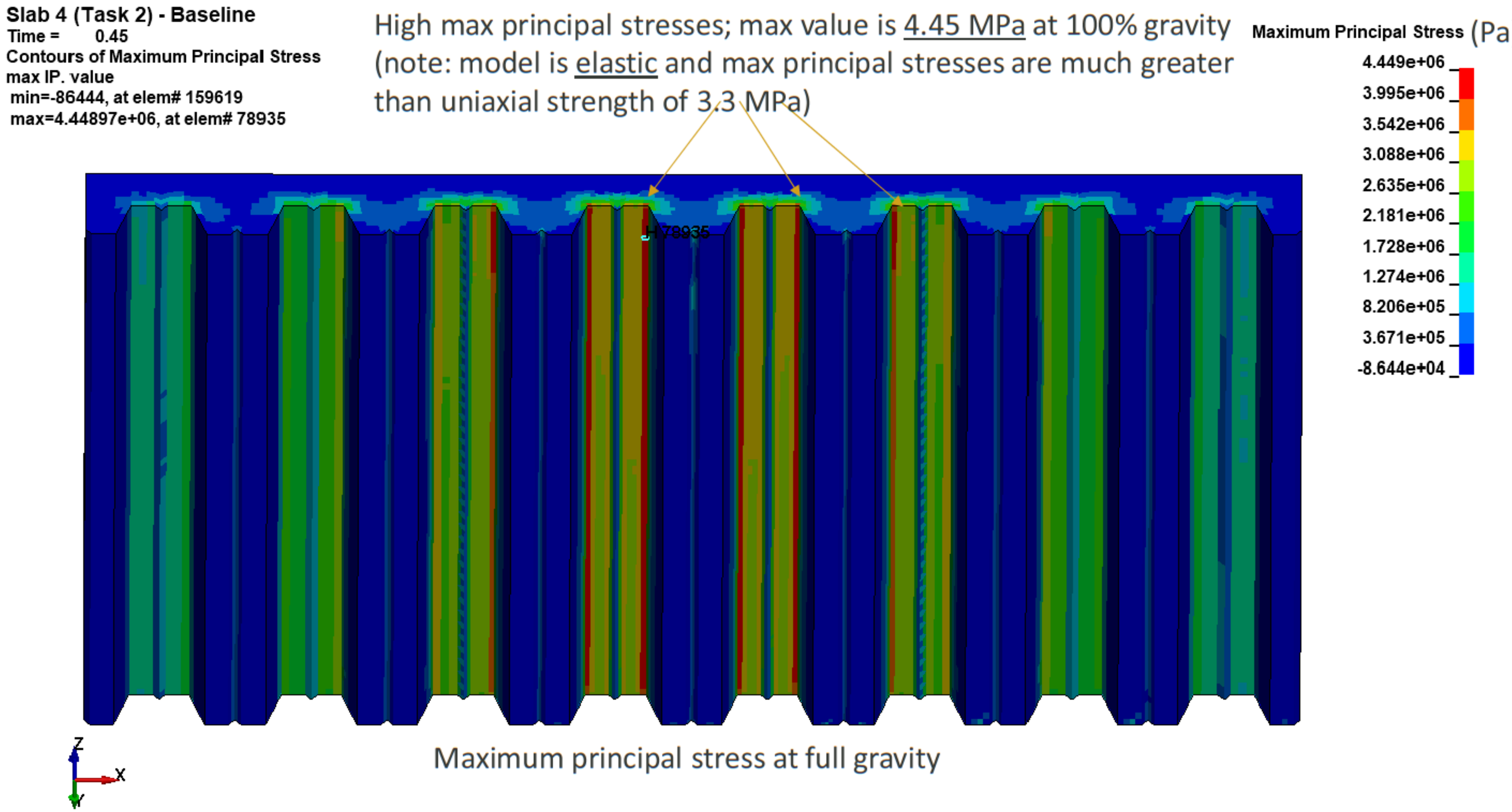
SUM OF SLING VERTICAL REACTIONS





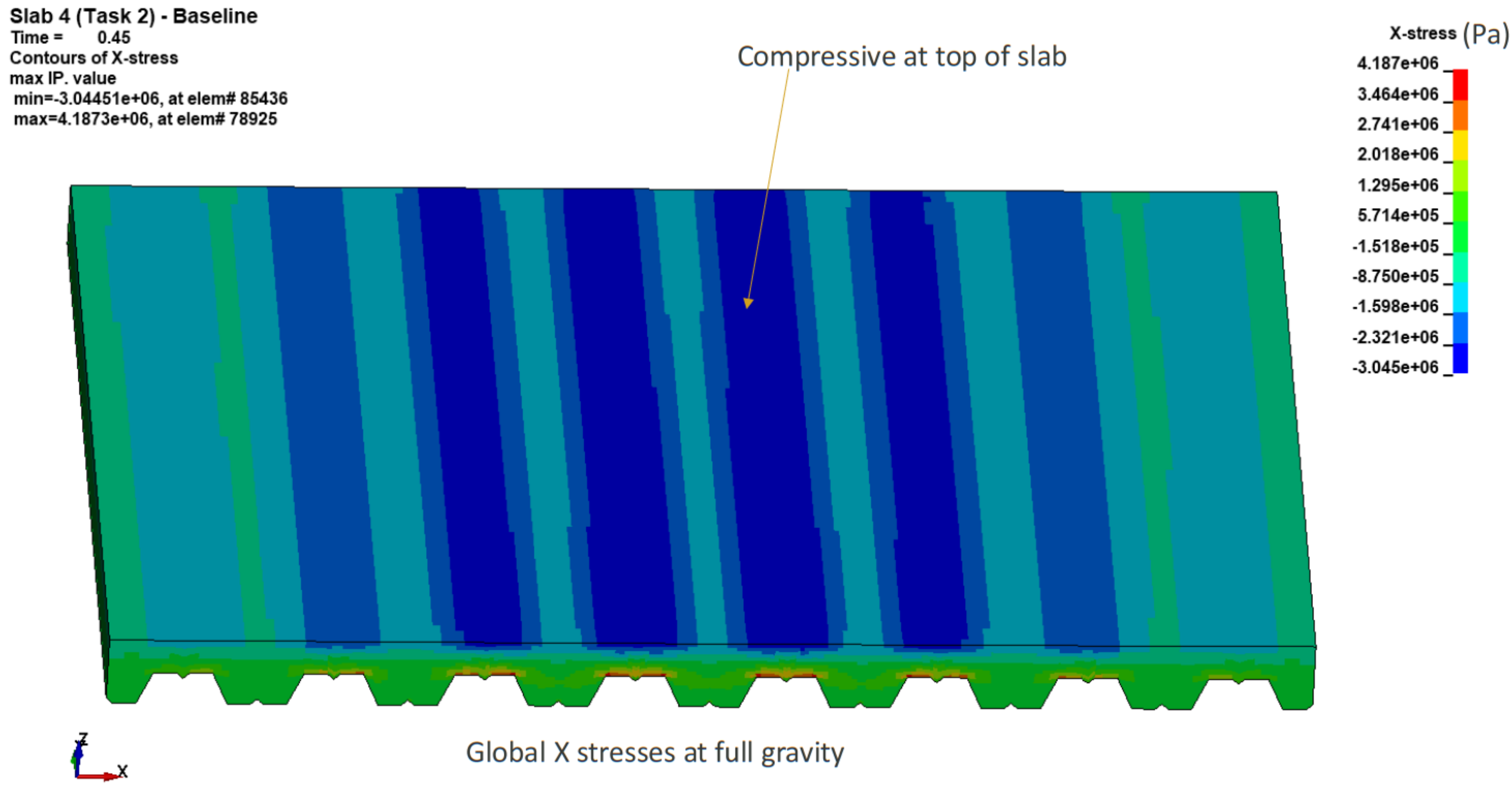
MAX PRINCIPAL STRESSES

High max principal stresses; max value is 4.45 MPa at 100% gravity (note: model is elastic and max principal stresses are much greater than uniaxial strength of 3.3 MPa)



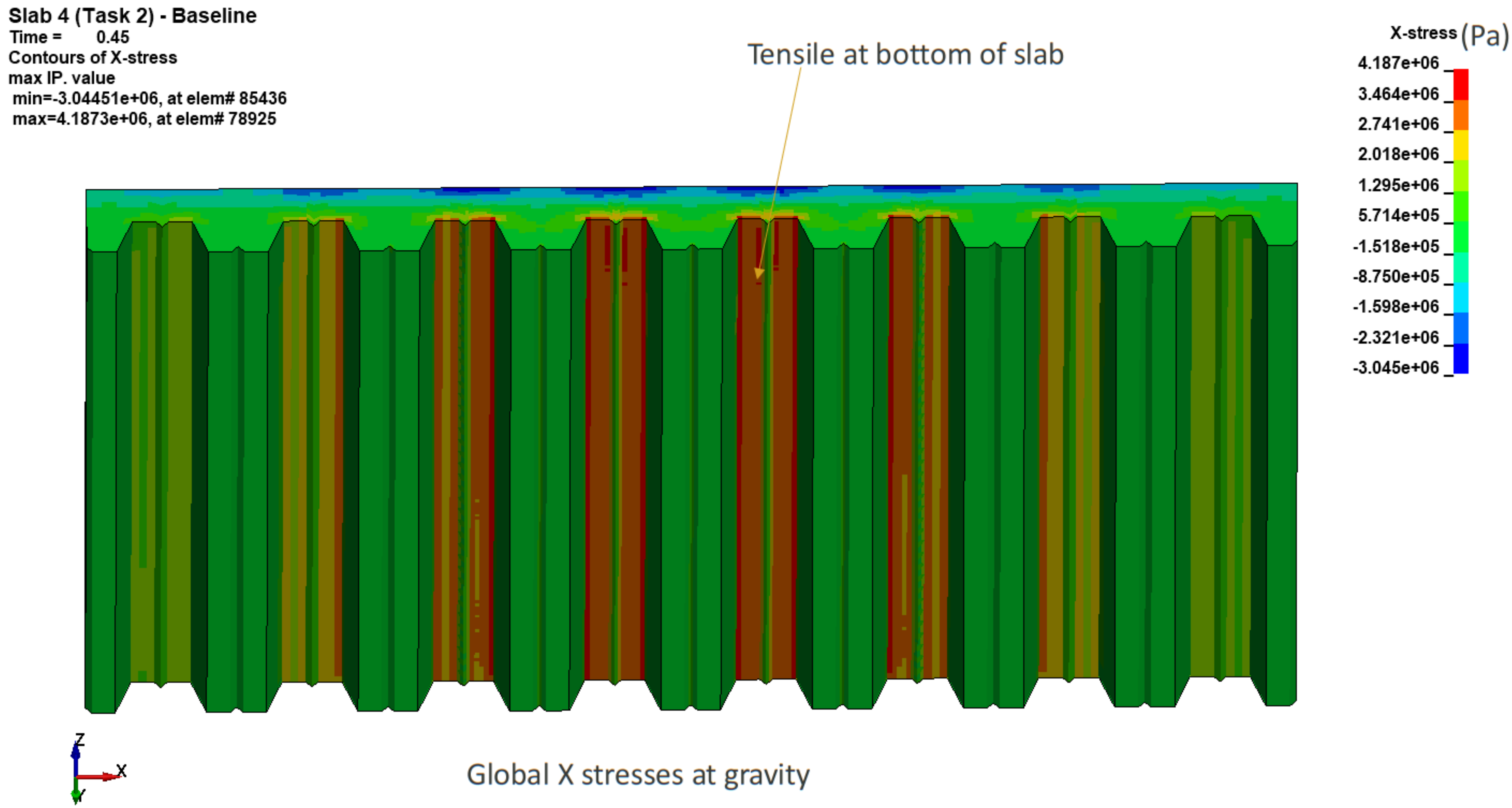
Maximum principal stress at full gravity

GLOBAL X STRESSES



Global X stresses at full gravity

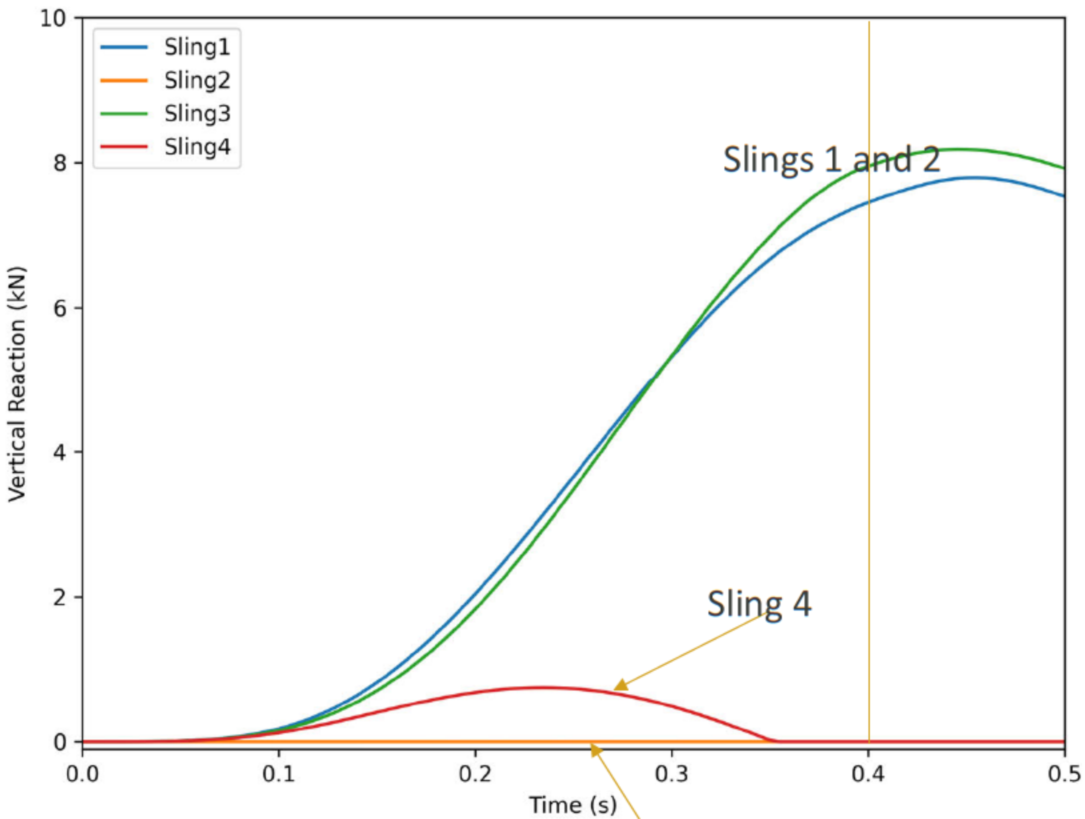
GLOBAL X STRESSES



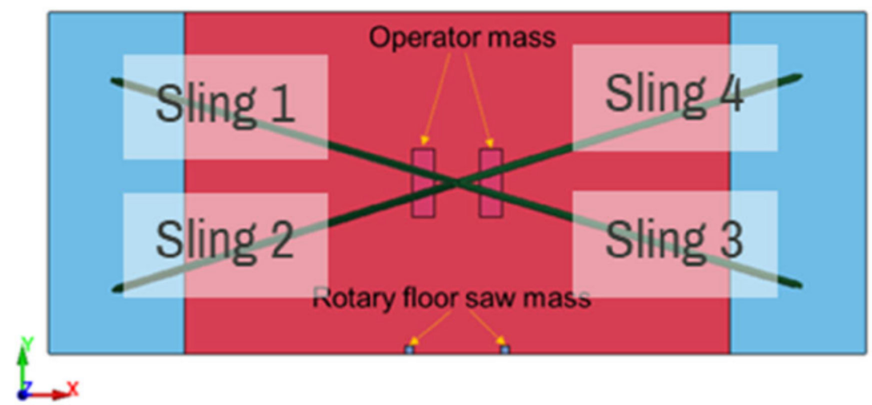
Global X stresses at gravity

2-INCH SLACK IN SLING 2

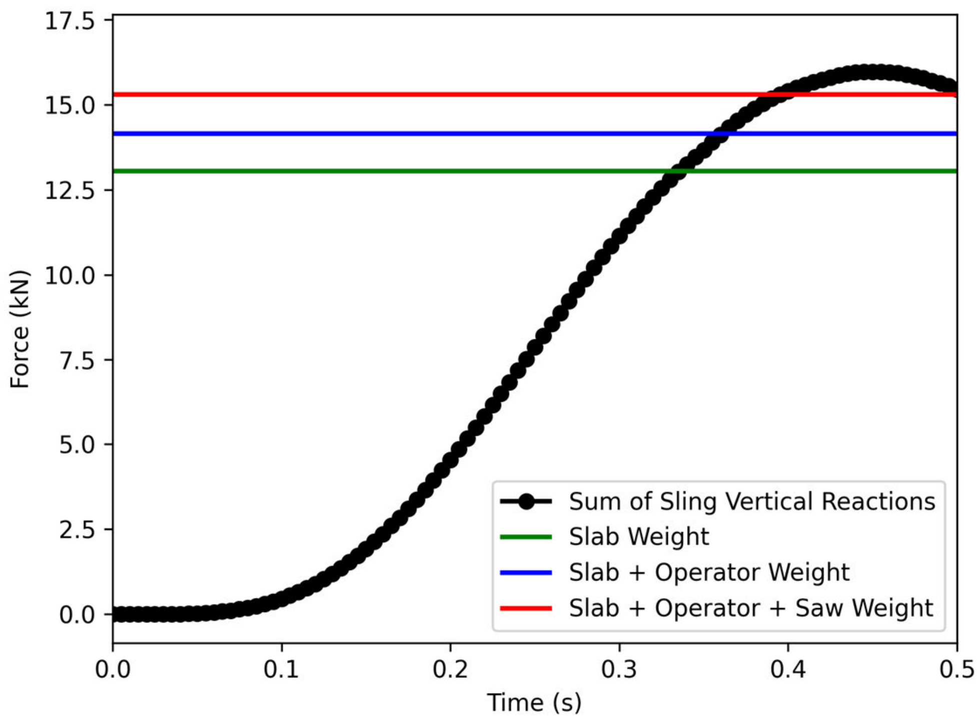
SUM OF VERTICAL REACTIONS OF INDIVIDUAL SLINGS

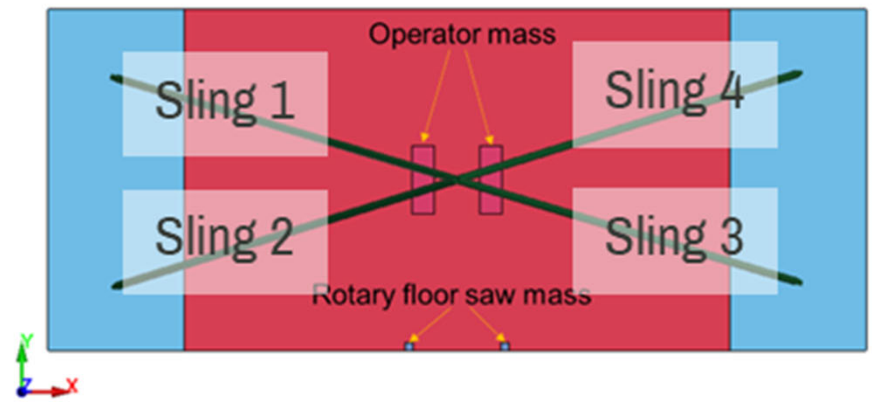


Sling 2 is slacked from beginning



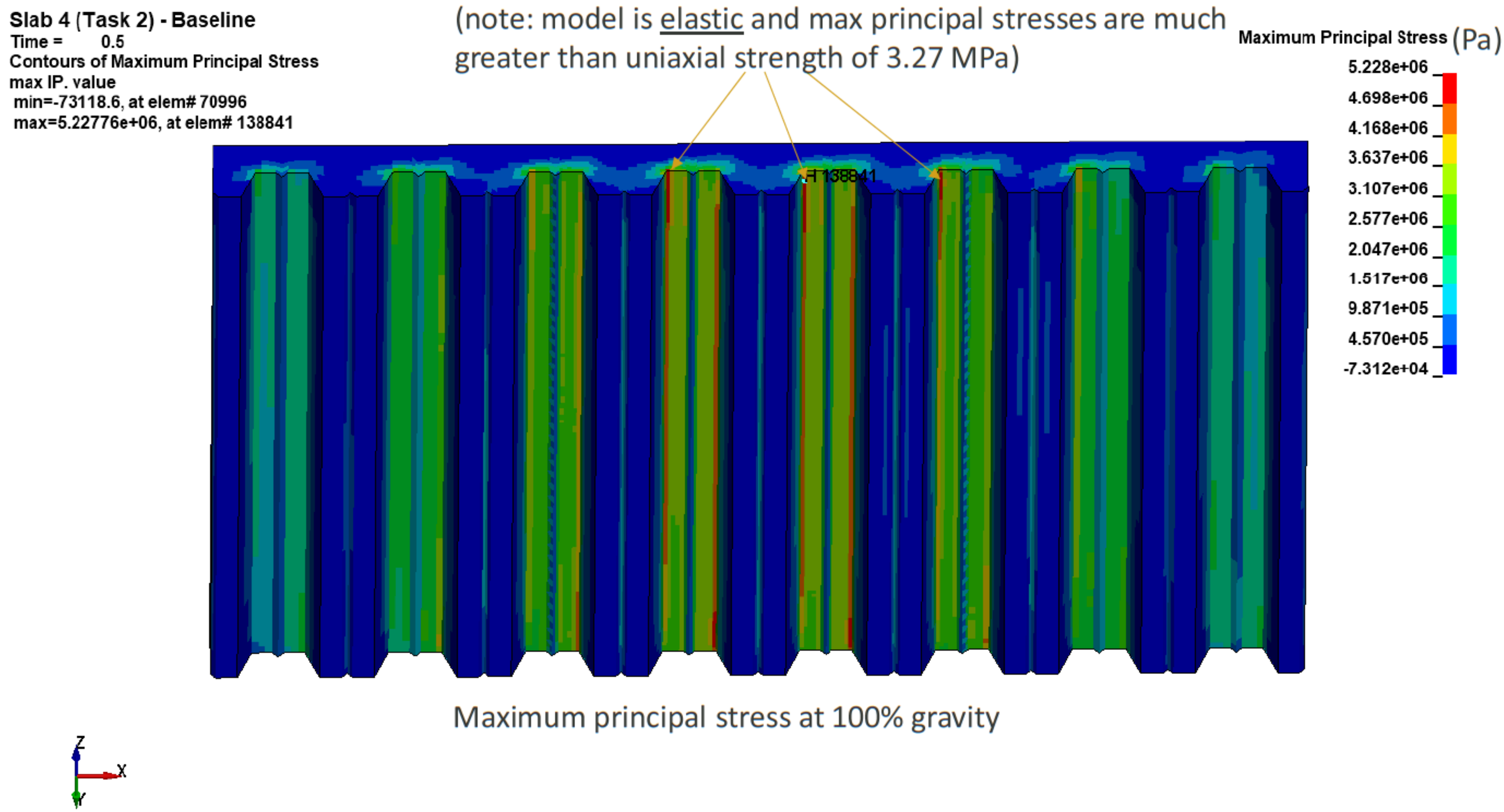
SUM OF SLING VERTICAL REACTIONS





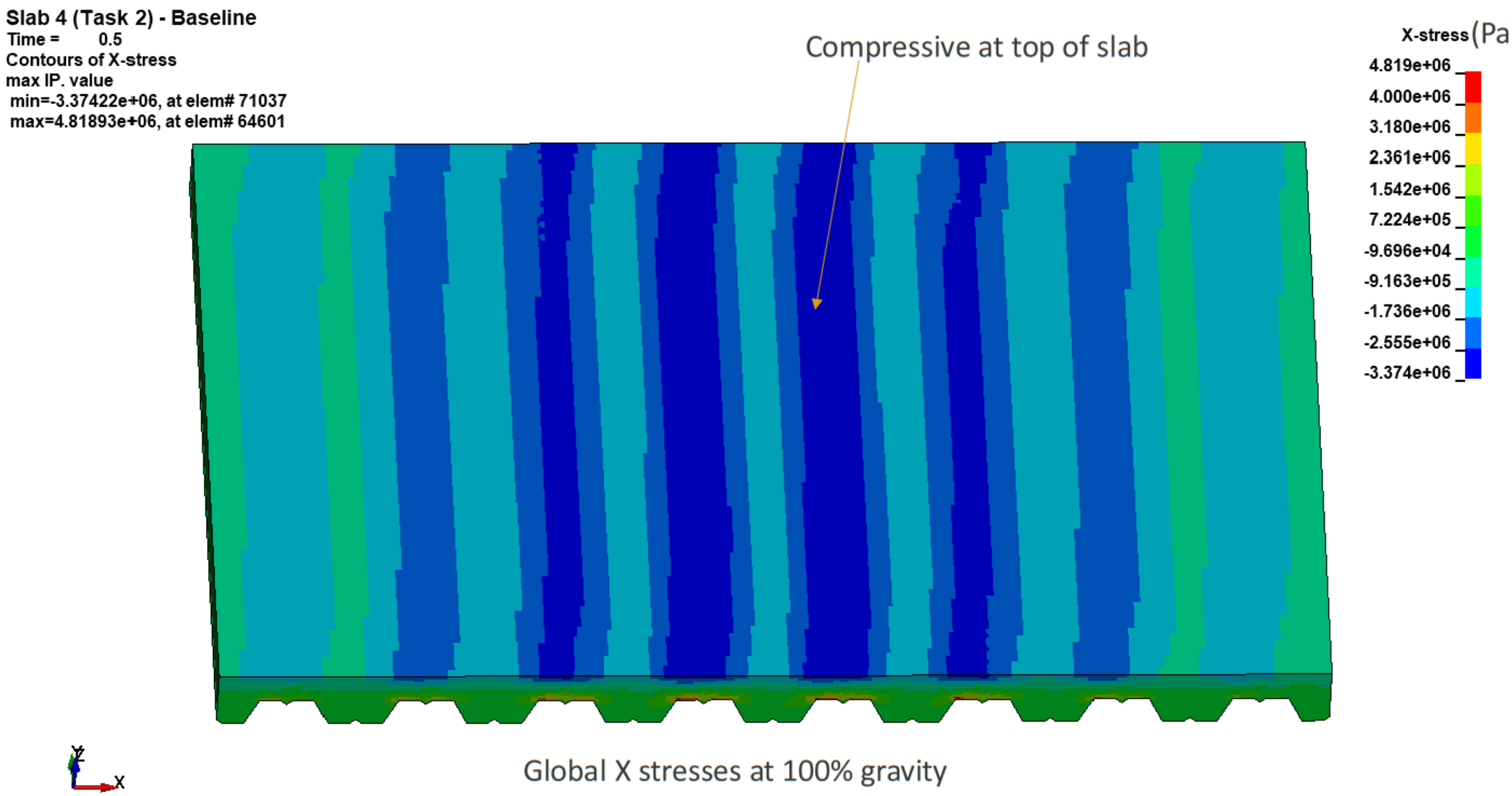
MAX PRINCIPAL STRESSES

High max principal stresses; max value is 5.23 MPa at full gravity (note: model is elastic and max principal stresses are much greater than uniaxial strength of 3.27 MPa)



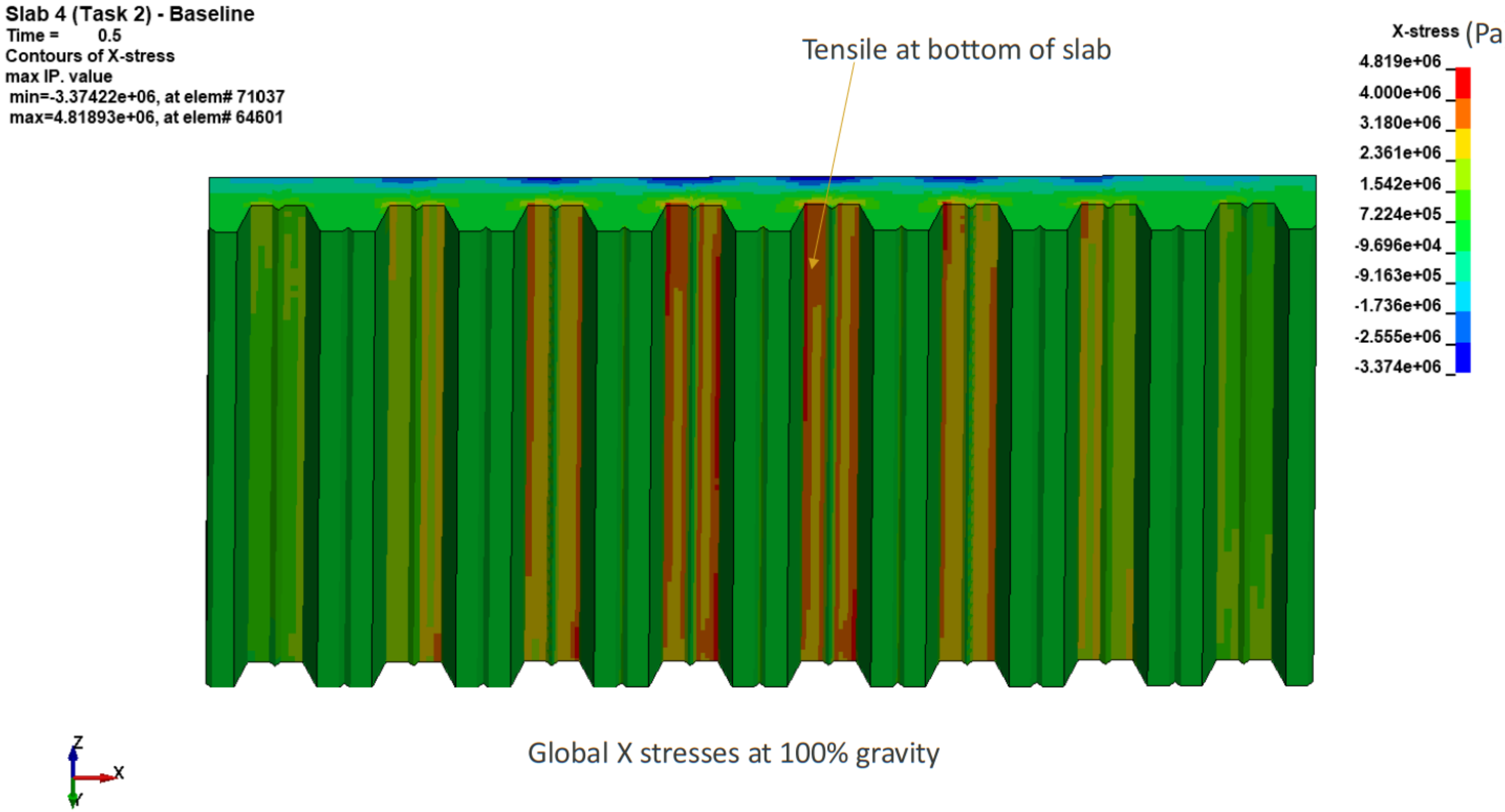
Maximum principal stress at 100% gravity

GLOBAL X STRESSES



Global X stresses at 100% gravity

GLOBAL X STRESSES



Global X stresses at 100% gravity

Appendix 7.6.1: Missing Considerations for the Demolition of the Surrounding Floor

Missing considerations for the demolition of the surrounding floor

Based on an evaluation of the work being conducted, the NIST Incident Investigation Team identified the following factors should have been included as part of a hazard review package for demolition of the surrounding floor, whether in a revision of the current version of the *Composite Floor System Stabilization and Demolition* hazard review or as a new, separate hazard review.

- Engineering survey to determine the condition of the structure in advance of the demolition
  As stated in OSHA 29 CFR 1926 Subpart T[1], and specifically 29 CFR 1926.850(a)[2], a documented survey of the condition of the as-is structure performed by a competent person is required for demolition work. This information is critical as demolition work is particularly hazardous due to unknown hazards that may either have been forgotten or have developed over time. Full knowledge of the as-is structure provides the opportunity to evaluate the demolition job in its entirety, plan the demolition work properly from start to finish, and can offer insight into possible issues or challenges as the demolition work progresses.

- Safety evaluation of each slab to be removed
  CF Project management consistently referred to the two previously approved CF Project hazard reviews, the *NFRL Overhead Crane* hazard review, and the general safety training and procedures for the execution of work in the NFRL as the reason no re-evaluation of this work was required. However, these documents, and previous crane lifting experience in Room 125, do not consider the activity of lifting a large, heavy, non-homogeneous load that has the potential to fail during the lift. The majority of the lifting experience in NFRL was with:
    - "Reliable" loads (*e.g.*, structural steel members);
    - Loads with engineered lift points (*e.g.*, conditioning pit covers); and
    - Concrete samples that contained considerable steel reinforcement (*e.g.*, other projects identified in Section 6.3).

  The slabs removed from the surrounding floor had thin cross-sections (thickness of 3.125 in., without the flutes) and minimal (Slabs 1, 2, and 3) or no (Slab 4) steel reinforcement in the bending direction. Review of the steel reinforcement layout drawing and overlaying the proposed cuts, as done in Section 6.9 for the individual slabs, would have readily led to the understanding the slabs being sectioned from the various locations had different amounts of steel reinforcement (No. 4 rebar). This knowledge in total would have required additional safety considerations for the work beyond "minimizing the number of cuts in the air" (per the email from ENGR TECH 1, please see Section 6.3.4).

  Additionally, the differences in size and shape of the proposed slabs to be cut should have raised other concerns regarding the integrity of the individual slabs during the lifting process. Slab 4, being longer in length (12 ft) and with the shorter width (5 ft), and without any steel reinforcement in the direction of bending, would be more vulnerable to bending failure under its own self-weight compared to the other three previously cut slabs, which were shorter and/or of different shape. A simple 2D hand calculation, as discussed in Section 6.16.3,

[1] https://www.osha.gov/demolition/standards
[2] https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.850

could easily and quickly be computed by a structural engineering staff member to determine the safety factor against bending failure of the lift. While the FE modelling[3] was a more rigorous method to determine these safety factor values, the results show that just the self-weight of Slab 4 alone had a very small margin of safety ($S_F = 1.12$, where a safety factor at or below unity will result in failure). Industry practice for safety factors when working with brittle materials such as concrete is typically at 2.5 or higher. Had an appropriate evaluation of the hazards been performed, the very thin safety margin for Slab 4 could have been identified, and initiated the following:

- Change in the cutting plan (*e.g.*, cutting a shorter slab);
- Change in the lifting plan (*e.g.*, reducing the lifting span length - distance between east and west rigging points);
- Implementation of additional engineering controls (*e.g.*, requiring the use of shoring underneath the slab as it was being cut even though it was "undamaged"); and/or
- Implementation of additional administrative controls (*e.g.*, indicating the slab shall not be loaded by any means once it is partially or fully suspended by the rigging).

Finally, it is important to note that even if Slab 4 had not failed as a result of accidental overloading, the next set of slabs to be removed (Slabs 5 through 8) would have failed under their own self-weight once fully cut free of the surrounding floor and suspended by the rigging. As shown in Section 6.3.4, Slab 5 was to have the same width as Slab 4 but with 2 ft longer in both the overall length and the lifting span length (12 ft distance between east and west rigging points instead of 10 ft as for Slab 4). This 2 ft increase in lifting span length would translate into a 44% increase in applied bending moment (demand) in Slab 5 compared to that of Slab 4. Since the bending moment capacities of Slab 4 and Slab 5 are the same, the 44% increase in bending moment demand for Slab 5 meant Slab 5 would have a safety factor of 0.78 under just its own self-weight (original safety factor of 1.12 divided by an addition bending moment increase of 1.44). In short, the *Coring and Cutting Plan* developed by ENGR TECH 1, to maximize the amount of material removed with the fewest cuts, and with no technical review by a structural engineer, was flawed and would ultimately lead to failure.

- Development of a cutting plan

  There were two factors identified concerning the cutting of the slabs. The first factor was the motivation to remove as much material as possible from the surrounding floor while minimizing the number of cuts to be made while on the structure (per the email from ENGR TECH 1 to ENGR TECH 2 as well as statements made by ENGR TECH 2 after the incident). As discussed in Section 6.5.2, the location, and subsequently the sizes and shapes, of the slabs as determined by ENGR TECH 1 was dictated by the underlying steel components of the CF Project test frame (*i.e.*, the girders, beams, and slab splice). There were no considerations given to the individual safety factors associated with each lift. Had this been a factor, as discussed in Section 6.16.2 with the cutting of a shorter slab (Slab 4 "Short" where the slab length, and accordingly the lifting span length, was decreased by ~20% of that for

[3] 2D hand calculations provided slightly higher values for the safety factor given their assumptions, but these values were still well below the acceptable industry practice of 2.5 and would have brought awareness to the high risks associated with the work.

Slab 4), the safety factor could have been increased by almost a factor of 2.5 for the slab self-weight case (due to reduce self-weight and closer rigging points) and just under a factor of 2 for the two cases of “accidental” loading (please see Table 6.16.1).

The second factor was with respect to the safest manner to cut the slab such that the slab was not loaded by the saw, the operator, or both during the work. Reviewing the video evidence after the incident strongly indicated there was no pre-work planning regarding the cutting of Slabs 3 and 4:

- Just prior to starting the cuts on Slab 3, ENGR TECH 1 was observed spending time moving the saw around in the area where Slab 3 was to be cut in an attempt to determine which way and in which order to perform the cuts; and
- There were major differences noted in the order and manner of the face cutting between Slab 3 and Slab 4 (please see Section 6.7.1 and 6.7.2, respectively).

As a result of the lack of planning, there were many times during the process to cut Slab 3 and Slab 4 where the partially or fully cut slab was loaded with either the weight of the floor saw, the weight of ENGR TECH 1, or the weight of both. Further, as discussed in the next subsection regarding potential development of a lift plan, there was no consideration for the location of the cooling water hose attached to the floor saw with respect to the rigging to prevent the need for ENGR TECH 1 and/or the floor saw to traverse and load the slab.

- <u>Development of a lifting plan</u>

  NFRL GROUP LEADER and CF PROJECT LEADER 2 stated a lifting plan would not have been required as the lifting of the steel-concrete composite floor slabs were considered routine and uncomplicated. However, given the very thin margin of safety for Slab 4, a lifting plan should have been developed for at least that slab. The FE modeling results for Slab 4 “Rigging” analysis where the rigging locations were moved in towards the center of the slab by 1 ft resulted in an increase of the safety factor by almost a factor of 2 in all three loading scenarios (please see Table 6.16.1). A simplified 2-D hand calculation could also have easily been performed to show the increase in safety factor as a result of the shorter lifting span length.

  Further, given there was no apparent plan for when to hook up and engage the rigging:

  - Slab 3 rigging installed after the north and south faces were cut; and
  - Slab 4 rigging installed after the east, west, and at least half of the north face was cut,

  as well as a cut plan developed in advance, this resulted in the cooling water hose attached to the floor saw to become “entangled” in the rigging during the cutting. This was clearly the issue with the cutting of Slab 4. When ENGR TECH 1 returned from lunch, he had only the south face to cut. Instead of moving the saw, which was on the north face of the slab, around the rigging to the west and then backing the saw up on the south face to make the cut, he walked the saw across the mid-span of the slab from the north to the south underneath the rigging. This resulted in the hose laying on the slab between the east and west rigging points. When ENGR TECH 1 had completed the cut of the south face, instead of pushing the saw forward towards the west and onto the location near Slabs 5 and 6, he walked it back across the slab at midspan – which has been cut free from the surrounding floor and was fully supported by the rigging at this point – perhaps in order to "untangle" the hose. This ultimately overloaded the slab and resulted in the incident. Unfortunately, this was not the only time a lack of planning resulted in ENGR TECH 1 walking on a suspended slab with the floor saw as this behavior was also observed during the cutting of Slab 3. However, in that case the slab did not fail as its safety factor was 2.23 (please see Table 6.16.1) due to its shorter length (and resulting lower self-weight) and closer rigging points.

- Safety training related to demolition work
  As with any training, the goal is to educate individuals regarding the hazards they may face during the performance of work, as well as the hazard controls measures used to mitigate the safety risks. With respect to demolition work, some key objectives are to:
  - Identify hazards related to the layout and structural integrity of the structure being demolished;
  - Explain how to manage fall hazards during demolition using the hierarchy of controls;
  - Describe hazards that are associated with equipment or process use during demolition work; and
  - Discuss how environmental hazards related to demolition work can cause health issues for those exposed.

  No demolition safety training was identified in the hazard review as being required for those performing the work or those authorizing the work to be performed.

- Review of safety requirements for crane use
  While it is acknowledged there is no formal "refresher training" requirements for the majority of NIST safety program, a regular review of requirements and safety practices associated with crane use could have prevented some unsafe acts which were observed during the lifting of Slab 3 and Slab 4 (please see Section 6.7.3).

- Review of hazard control measures for fall protection
  Fall protection is required if an unguarded edge is more than 6 feet above the next lower level for construction activities, per OSHA CFR 1926.501(b)(1). While it is not known if ENGR TECH 1 would have survived the incident had he been wearing personal fall protection, the requirement for him to do so was evident given he was working within 6 feet of the Slab 3 cut bay, which was 13 feet above ground level, while cutting Slab 4. This concern was previously discussed among the engineering technicians prior to the incident, and specifically between ENGR TECH 1 and ENGR TECH 2 on September 23 after Slab 3 had been removed. ENGR TECH 2 stated ENGR TECH 1 had justified not using personal fall protection because there was no good place to tie off and he was relying on the cables placed around the outer perimeter for passive fall protection. Further, after the incident, ENGR TECH 3 stated they knew they should have been wearing personal fall protection on the day of the incident due to the Slab 3 floor opening being unprotected.

  Regardless of the desire to forego wearing personal fall protection, advance planning could have identified the hazard control measure of covering the floor opening, per OSHA 29 CFR

1926.850(i). It was clear from the actions of ENGR TECH 1 on the day of the incident he was at least partially distracted and concerned by the unprotected floor opening associated with Slab 3. First, he attempted to cover a small portion of the hole (the small tab in the NW corner) using a 2 ft piece of plywood in the morning. It appeared this action was random, *i.e.*, not planned in advance, as both ENGR TECH 1 and ENGR TECH 3 had been walking and working near the floor opening for approximately 2 hours prior to him laying the plywood. Second, upon returning from lunch, ENGR TECH 1 spent nearly 15 minutes trying to address this issue by obtaining several large pieces of angle iron. He ultimately removed the piece of plywood he had placed that morning and put down one piece of angle iron. He made no further attempt to protect the opening. It is unknown if this led to inattentiveness or frustration on the part of ENGR TECH 1 and if that contributed to the actions he took later in the day.