NCST Investigation of the Champlain Towers Collapse

Invasive Testing of Evidence

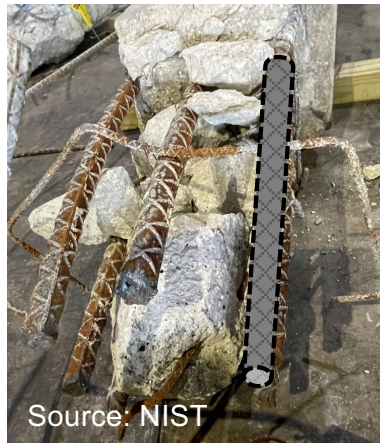
Christopher L. Segura Jr.
Project Leader, Evidence Preservation

Ken Hover
Project Leader, Material Science

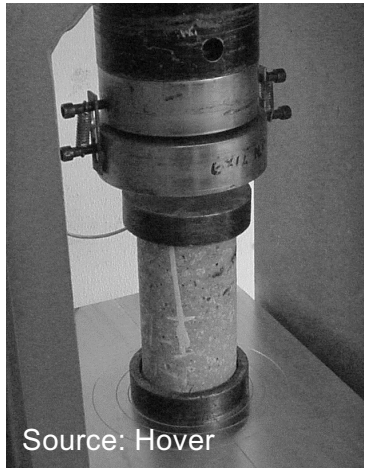
Invasive Testing of Evidence

- Representative **material properties & conditions**
- **As-built** structural details
- Observations & measurements related to **failure hypotheses and failure causes**

Concrete Core and Reinforcing Bar Sample Extraction

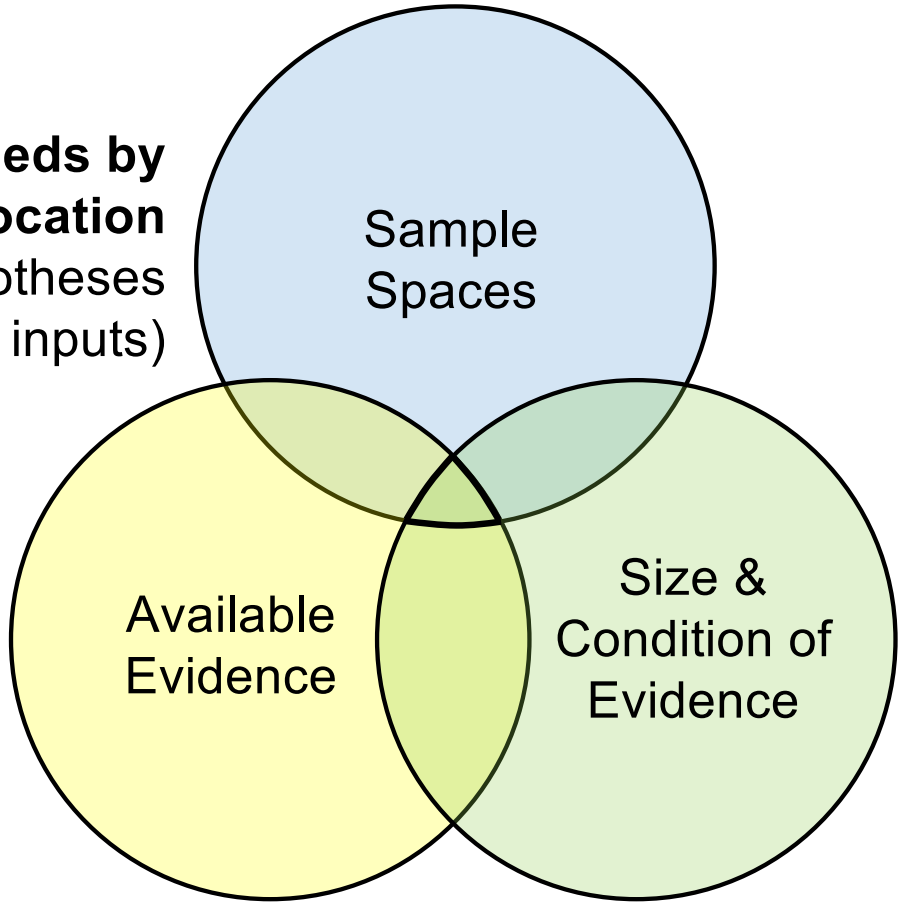


Laboratory Testing of Extracted Samples



Prioritized Plan for Invasive Testing

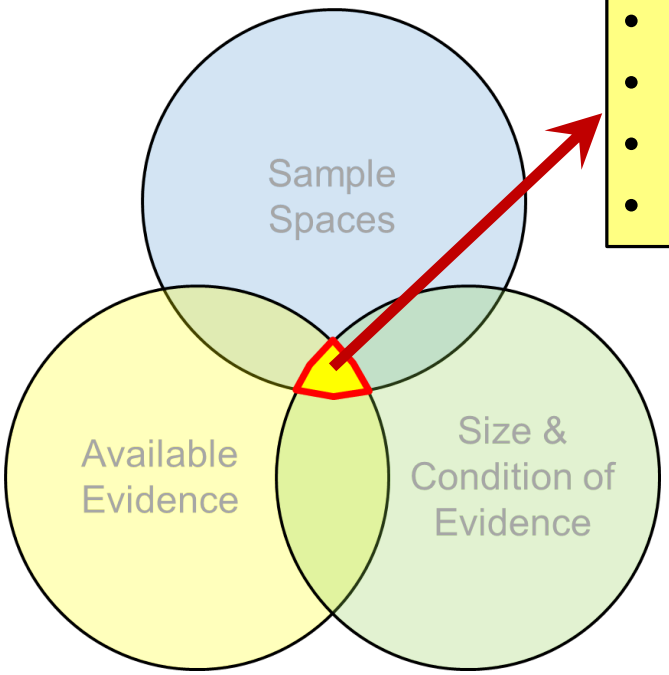
Identify **needs by building location** (failure hypotheses & modeling inputs)



Link evidence to **sample spaces**

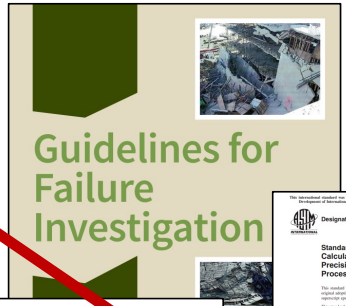
Determine regions of evidence from which to **extract concrete & rebar samples**

Prioritized Plan for Invasive Testing

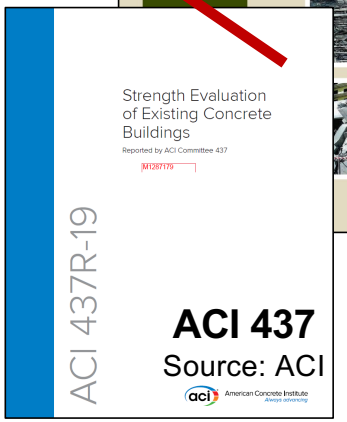


- Which evidence
- How many samples
- Which invasive tests
- In what order

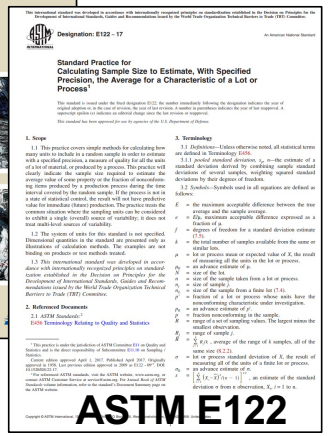
Standards and Guidelines



Source: ASCE
With ASCE permission
https://ascelibrary.org/doi/book/10.1061/9780784415122



ACI 437
Source: ACI

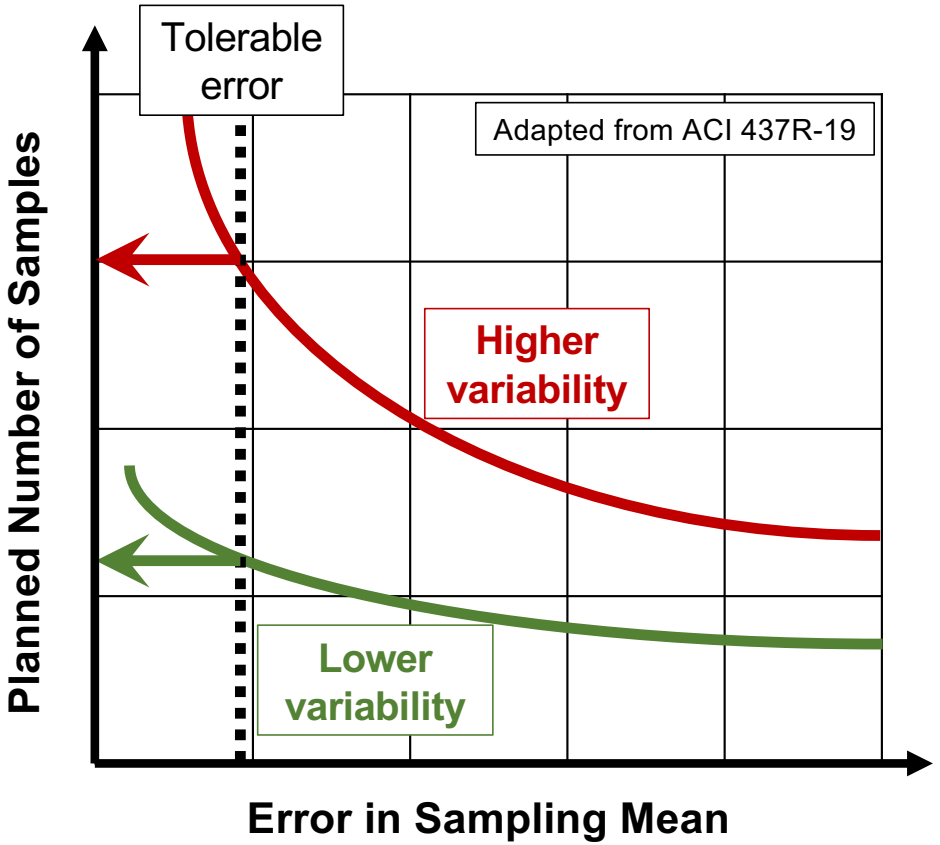


ASTM E122
Source: ASTM*

* Reprinted, with permission, from ASTM E 122-17 *Standard Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process*, copyright ASTM International. A copy of the complete standard may be obtained from www.astm.org

Developing a Sampling Plan

- For **representative material properties and conditions**, sample size influenced by:
  - Variability in material properties
  - Tolerable error
  - Number of intact samples that *could* be extracted



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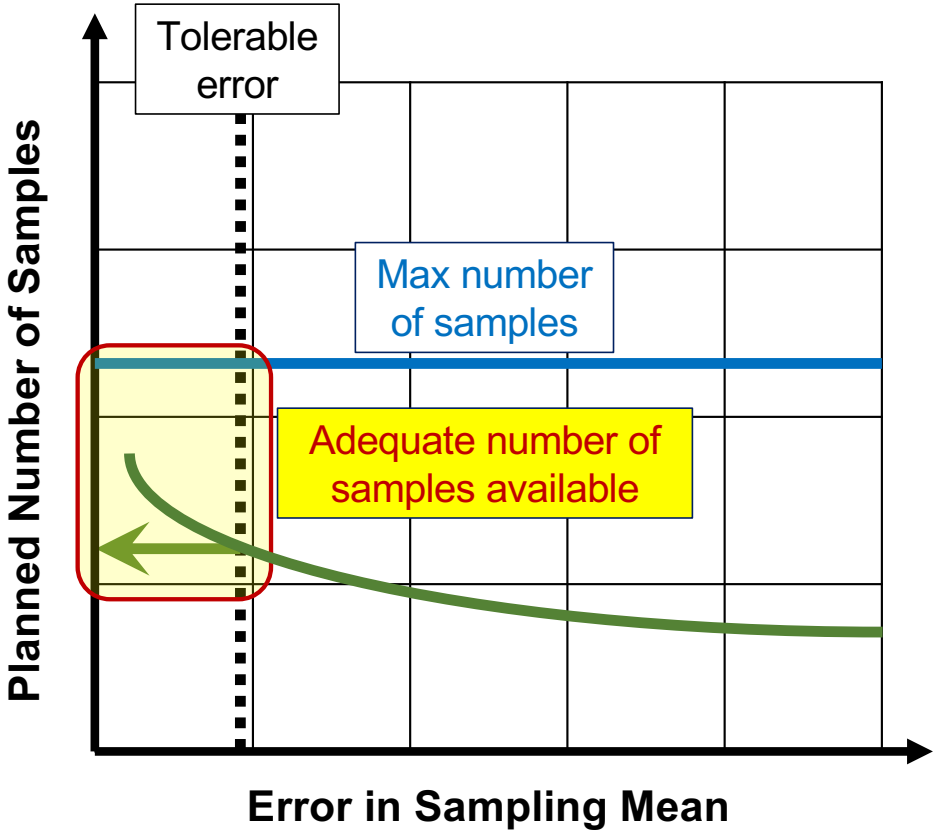
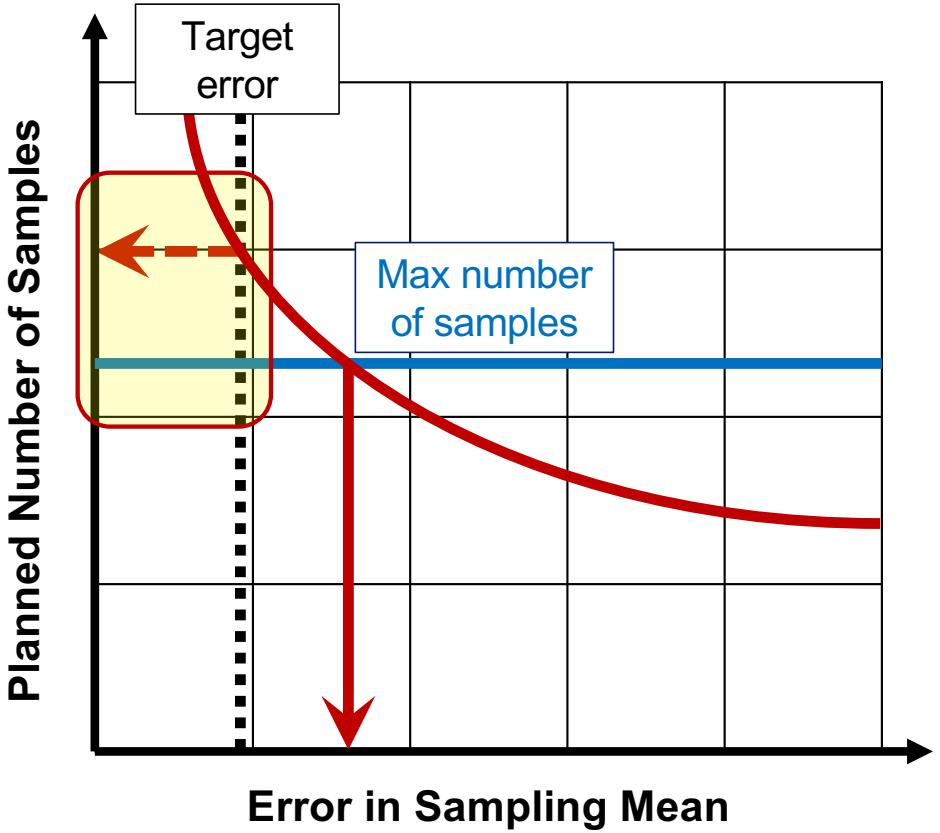


Developing a Sampling Plan

- For **representative material properties and conditions**, sample size influenced by:
  - Variability in material properties
  - Tolerable error
  - Number of intact samples that *could* be extracted
- **Targeted sampling**
  - Specific features/conditions of interest
  - Failure hypotheses & causes



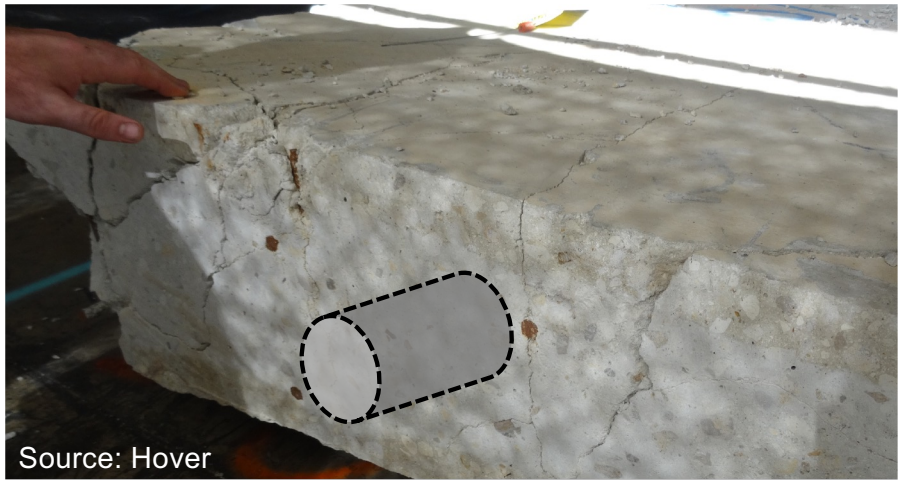
Procedures

Refine sample locations by Non-Destructive Tests

- Ensure intact/uncracked sample
- Detect anomalous regions to avoid or study further
- Avoid rebar in concrete cores

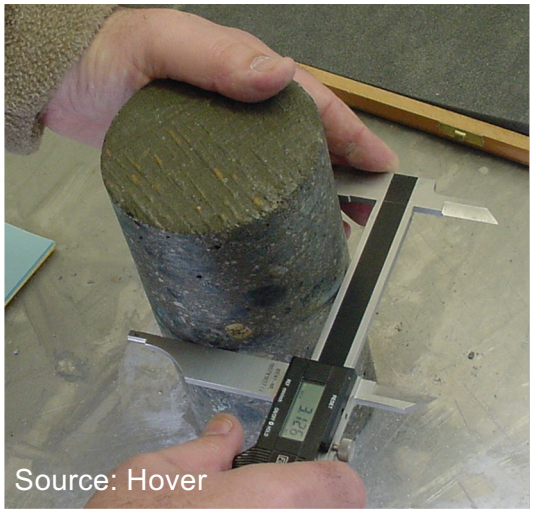
Procedures

- Extract cores (wet-drilling) and reinforcing bar samples
- Expose key features by concrete-sawing (multiple sawing technologies available)



Procedures

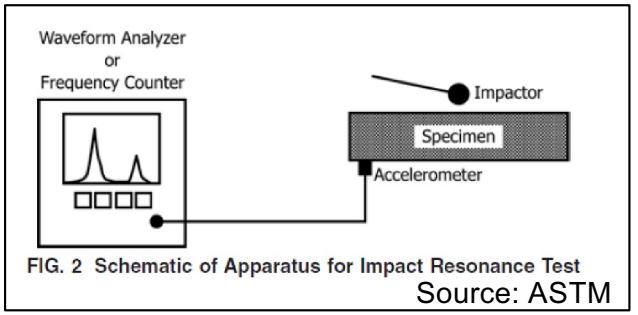
Inspect samples & conduct post-extraction NDT to verify sample viability (detect internal cracks or voids)

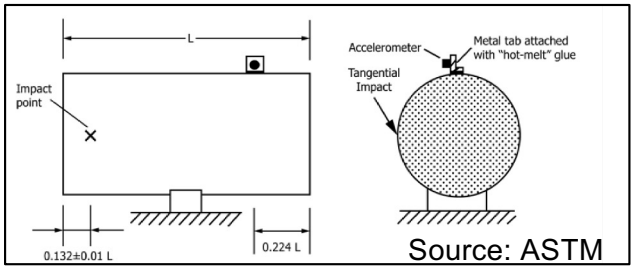


ASTM C597

Ultrasonic Pulse Velocity

Source: Hover



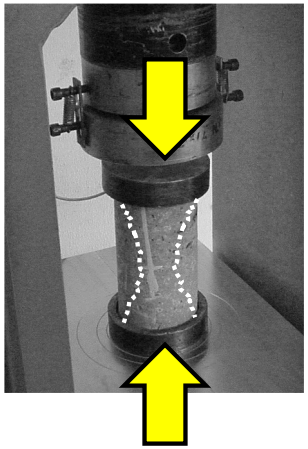


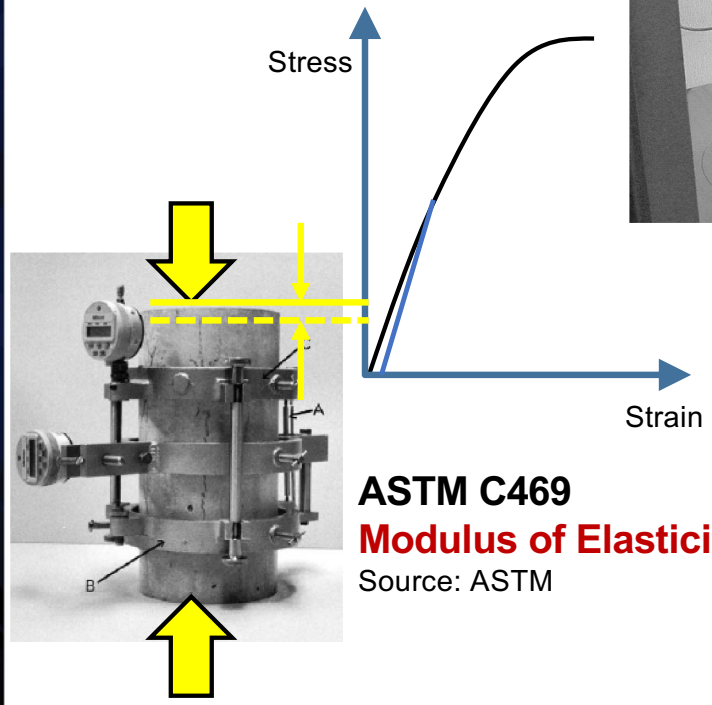
ASTM C215

Resonant Frequency

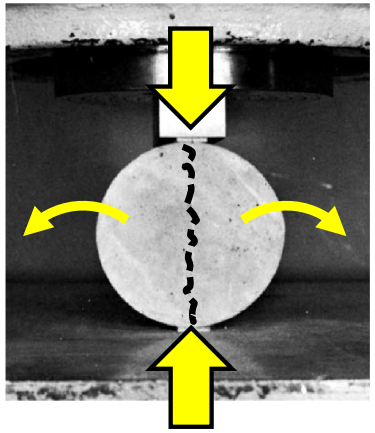
Physical Tests – Mechanical Properties

ASTM C42/39
Compression Strength
Source: Hover



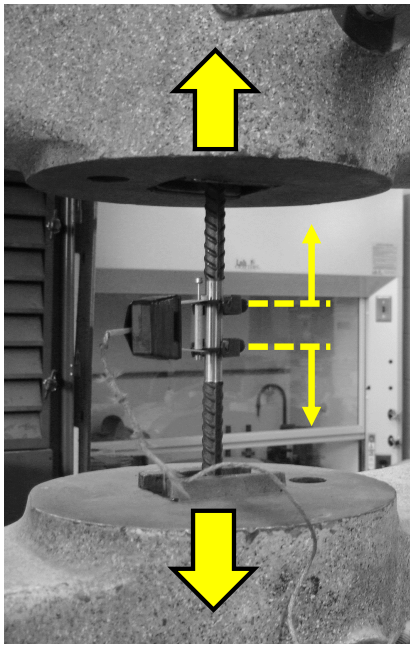


ASTM C469
Modulus of Elasticity
Source: ASTM



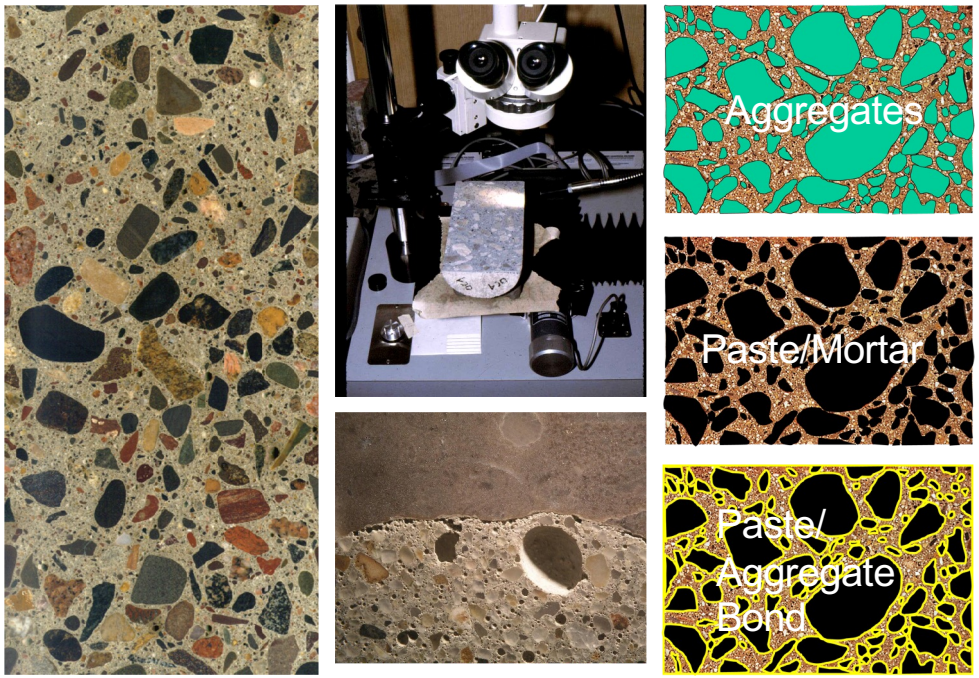
ASTM C496
Splitting Tensile Strength
Source: ASTM

ASTM A370
Rebar Strength & Ductility
Source: Hover



Physical/Chemical Tests – Materials Characteristics

(I) (II) (III)

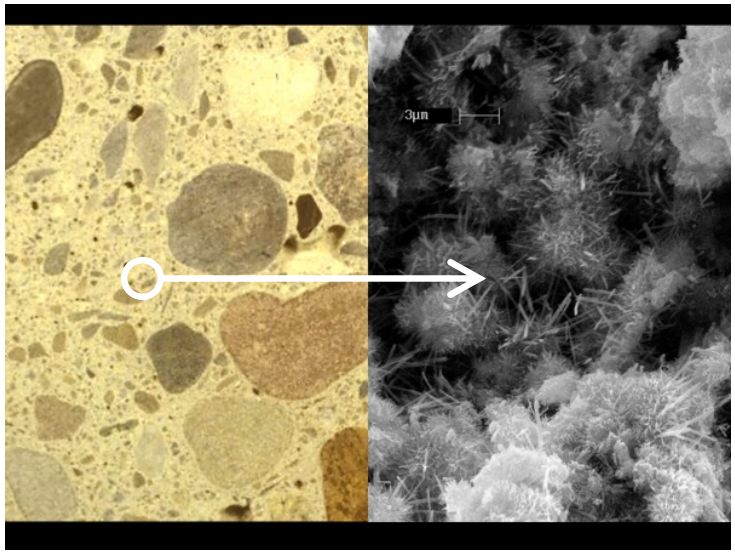


Source: Hover

ASTM C856
Petrographic Analysis

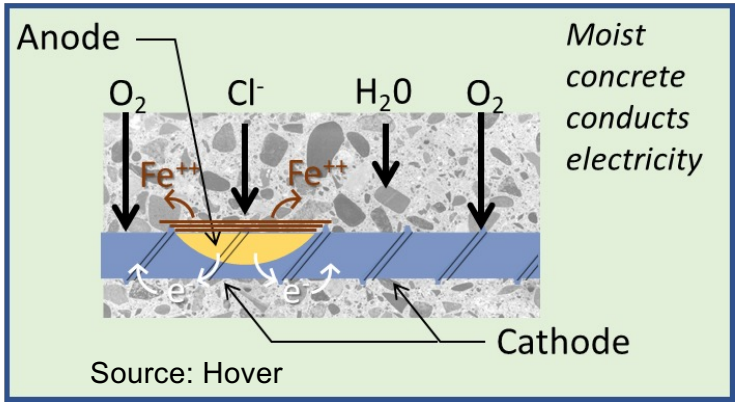
Reconstruct Original
Mixtures

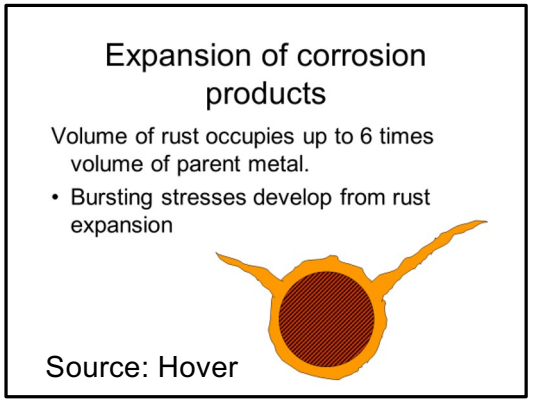
(IV) (V)



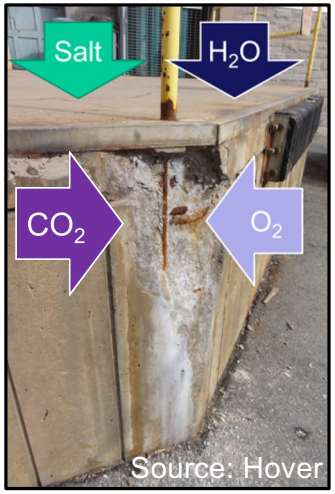
- Density, porosity
- Penetrability to water, chlorides, carbon dioxide

Corrosion-Related Testing



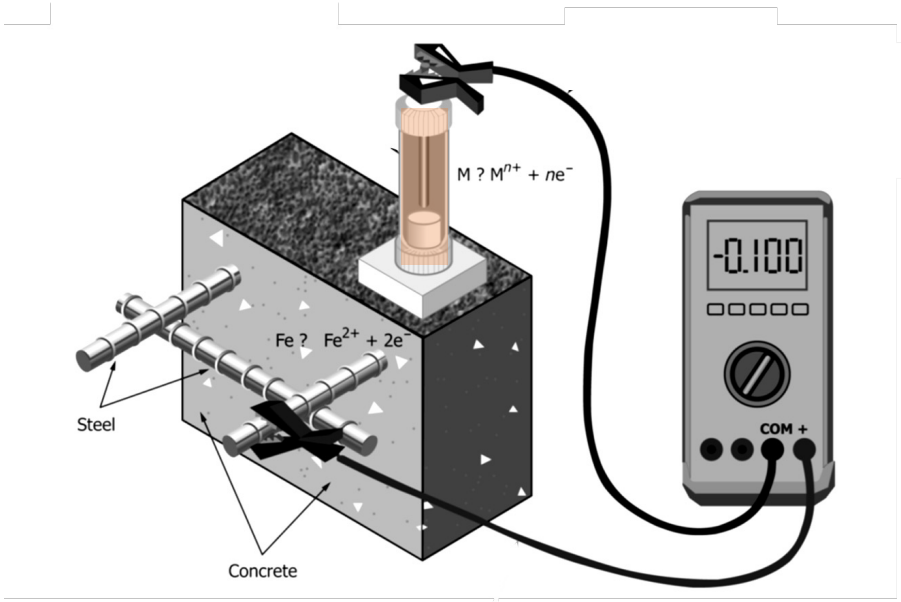


- CO_2 penetration (reduces corrosion resistance)
- Chloride concentration & penetration depth
- Corrosion activity by electrical potential (voltage)
- Corrosion rate by electrical current
- Locate corrosion products via cores & NDT
- Associate corrosion with cracking and rebar bond

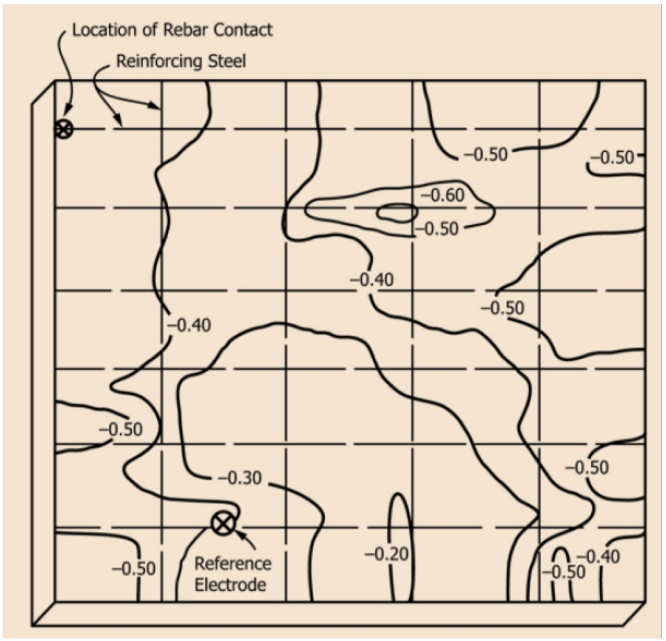


Corrosion-Related Testing

- ASTM C876 Corrosion Potentials of Uncoated Reinforcing Steel in Concrete



Source: ASTM



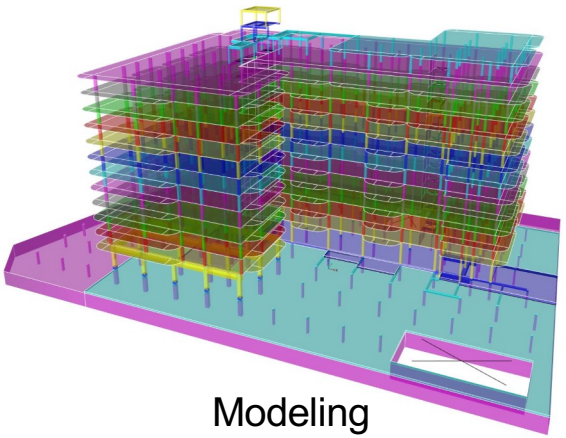
Source: ASTM

Link to Investigation Analysis

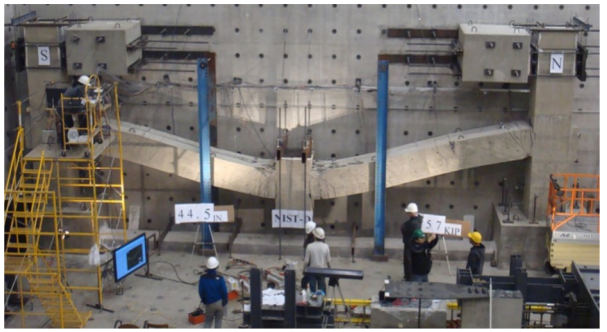
Collect & analyze data → Project-wide database

Sample	Specimen-Location-Exposure	Key Visual Mixture Attributes	Micro Petrographic Characteristics	Key NDT behaviors	Compressive Strength	Tensile Strength	Elastic Modulus	Transport Properties	Corrosion activity & potential
1.									
2.									
3...									
N									

For each sample we obtain test results AND mixture attributes



Modeling
Source: NIST



Representative Structural Component Testing
Source: NIST

Status and Next Steps

- Finalize sample extraction and testing procedures
- Finalize evidence moving & handling protocols
- Finalize specifications for invasive testing equipment

Current evidence layout

Source: NIST

NCST Investigation of the Champlain Towers South Collapse

Invasive Testing of Evidence

Presenters: Christopher Segura
Ken Hover