Summary of Progress on Prior NCST Investigations

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NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
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June 14-15, 2023
NCST Advisory Committee Meeting

World Trade Center Investigation

NOTE – Summaries of the recommendations are included in the following slides for context. The complete recommendations are available in the final report of the NIST Technical Investigation, at https://www.nist.gov/el/final-reports-nist-world-trade-center-disaster-investigation

Progress on Implementation of WTC Recommendations

Recommendation 1	Progress Update: Complete
NIST recommends that progressive collapse be prevented in buildings through the development and nationwide adoption of consensus standards and code provisions, along with the tools and guidelines needed for their use in practice	ASCE 76-23 Standard for Mitigation of Disproportionate Collapse Potential in Buildings and Other Structures published (May 2023) 

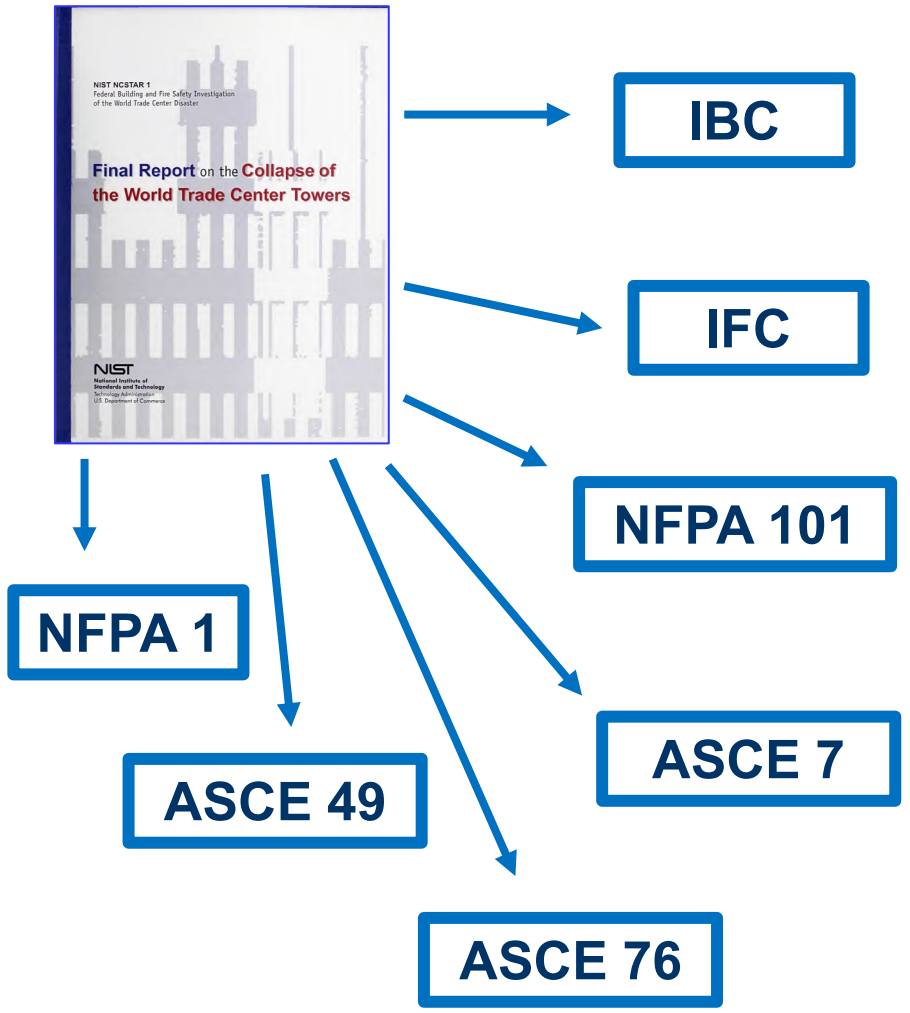
Progress on Implementation of WTC Recommendations

Recommendation 2	Progress Update: Complete
NIST recommends performance standards be developed for: (1) conducting wind tunnel testing of prototype structures that result in repeatable and reproducible results among testing laboratories; and (2) estimating wind loads and their effects on tall buildings, based on wind tunnel testing data and directional wind speed data.	• As reported last year – a revision to wind velocity pressure profiles to better reflect the state-of knowledge on atmospheric boundary-layer flows was incorporated in ASCE 7-22 • ASCE 7-22 wind loads have now been approved for incorporation into the 2024 International Building Code

WTC Recommendations

The implementation of the WTC recommendations is now complete. 30 recommendations have resulted in:

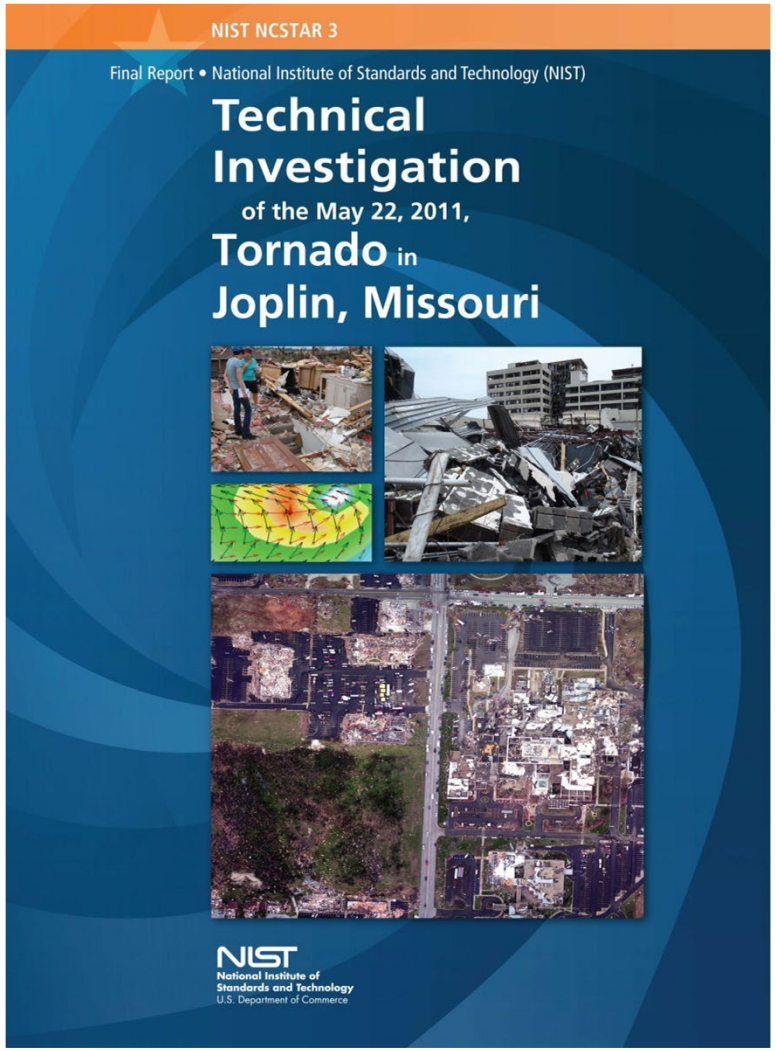
- Adoption of 40 code changes to the I-Codes (International Building Code [IBC] and International Fire Code, [IFC]).
- Adoption of 10 code changes in the Life Safety Code (NFPA 101) and 2 code changes in the Uniform Fire Code (NFPA 1).
- New Standard for *Mitigation of Disproportionate Collapse Potential in Buildings and Other Structures* (ASCE/SEI 76-23).
- Revision to existing standards on wind tunnel testing and estimation of wind loads and effects on buildings (ASCE 49-21 and ASCE 7-22, respectively).



Joplin Tornado Investigation

NOTE – Summaries of the recommendations are included in the following slides for context. The complete recommendations are available in the final report of the NIST Technical Investigation of the Joplin Tornado, at https://dx.doi.org/10.6028/NIST.NCSTAR.3

NIST Joplin Tornado Investigation



The first tornado study to include storm characteristics, building performance, emergency communication and human behavior together - with assessment of the impact of each on fatalities

- **16 recommendations for improving:**
  - Tornado hazard characterization
  - Design and construction of buildings and shelters in tornado–prone regions
  - Emergency communications that warn of threats from tornadoes
- **Implementation of recommendations began in Spring 2014, immediately following publication of final report**

http://dx.doi.org/10.6028/NIST.NCSTAR.3

List of Joplin Recommendations

	R #	RECOMMENDATION SUMMARY
Hazard Characteristics	1	Development and deployment of technology to measure tornado wind fields
	2	Archival of tornado event data
	3	Development of tornado hazard maps
	4	Improvement of EF Scale; means for continued improvement; adoption by NWS
Buildings, Shelters, Designated Safe Areas, and Lifelines	5	Development of performance-based standards for tornado-resistant design
	6	Development of performance-based tornado design methodologies
	7	a) Development of tornado shelter standard for existing buildings; b) Installation of tornado shelters in more buildings in tornado-prone regions
	8	Development of guidelines for public tornado sheltering strategies
	9	Development of guidelines for selection of best available refuge areas
	10	Prohibition of aggregate roof coverings and ballast in tornado-prone regions
	11	Development of requirements for enclosures of egress systems in critical facilities
	12	a) Development of tornado vulnerability assessment guidelines for critical facilities; b) Performance of vulnerability assessments by critical facilities in tornado-prone
Emergency Communication	13	Development of codes, standards, and guidance for emergency communications; Development of joint plan by emergency managers/media/NWS for consistent alerts
	14	Deployment of “push” technologies for transmission of emergency information
	15	Research to identify factors to enhance public perception of personal risk
	16	Develop technology for real-time, spatially-resolved tornado threat information

List of Joplin Recommendations

	R #	RECOMMENDATION SUMMARY – **PROGRESS UPDATES IN THIS BRIEFING**
Hazard Characteristics	1	Development and deployment of technology to measure tornado wind fields
	2	Archival of tornado event data
	3	Development of tornado hazard maps
	4	**Improvement of EF Scale; means for continued improvement; adoption by NWS**
Buildings, Shelters, Designated Safe Areas, and Lifelines	**5**	**Development of performance-based standards for tornado-resistant design**
	6	**Development of performance-based tornado design methodologies**
	7	a) Development of tornado shelter standard for existing buildings; b) Installation of tornado shelters in more buildings in tornado-prone regions
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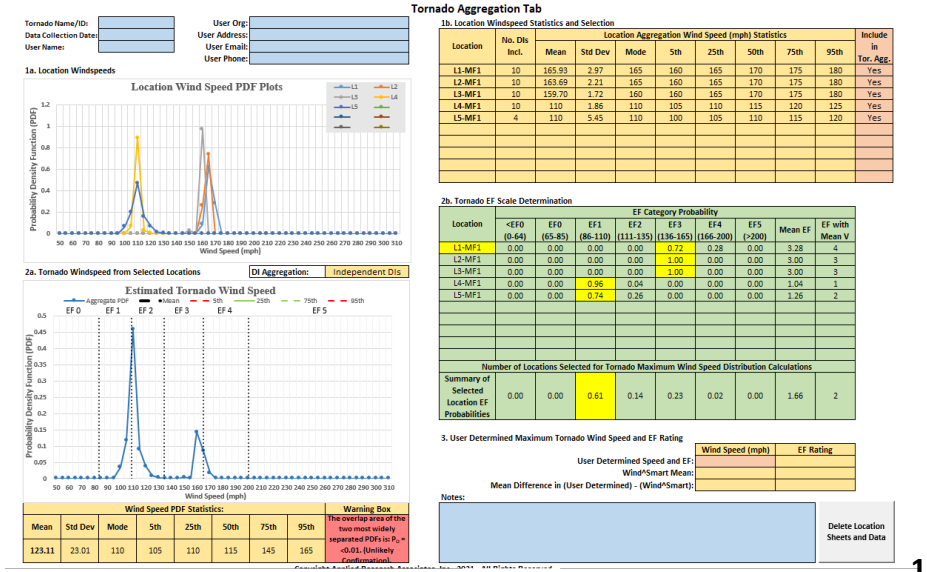
Progress – Improvement of the EF Scale (1/2)

R4: Standardize the Enhanced Fujita (EF) scale and improve through addition of scientific/quantifiable damage indicators, particularly those that distinguish between the most intense tornado events

Smart^DI Advancement

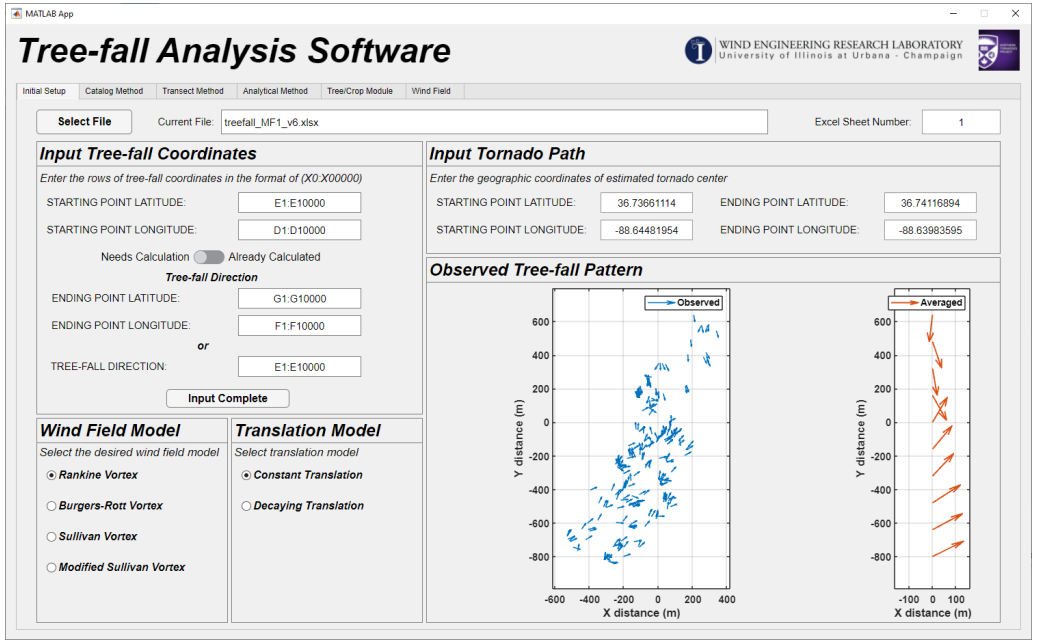
- Initial field data on Quad-State Tornado reported last year
- Collected additional images for more accurate damage assessment/wind speed estimation:
  - Photos from Damage Assessment Toolkit (DAT)
  - Various aerial imageries
  - Street level camera
- Smart^DI tested on Mayfield, KY
  - Acquired year built of residential houses from Graves KY county tax records (year built is an input for Smart^DI tool)
  - Made suggestions for further improvements

Credit: NWS

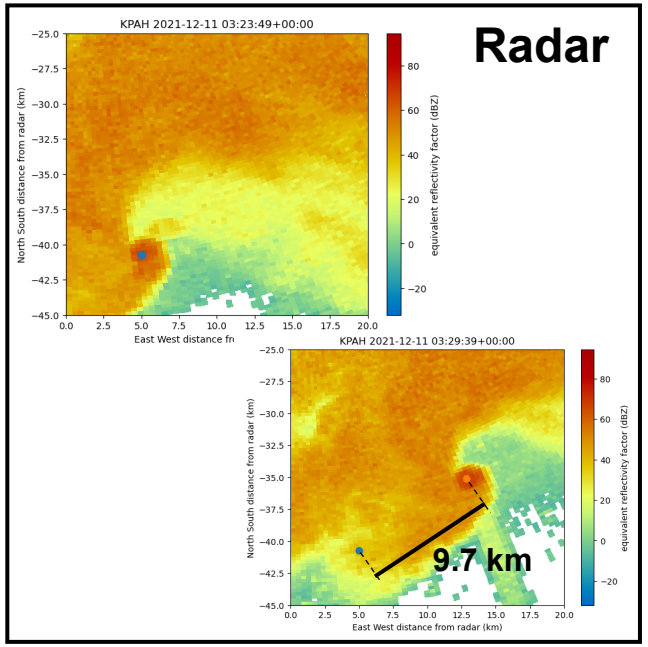


Progress – Improvement of the EF Scale (2/2)

- Independent wind speed estimation of Mayfield, KY using tree damage (i.e., treefall pattern analysis) to validate Smart^DI estimates
  - **Treefall analysis method**: tornado wind field estimation by analyzing the tree-fall pattern
  - Treefall pattern acquired by identifying trees from aerial imagery; analysis by automated software
  - Reduced uncertainties in the parameters from physical evidences (e.g., structural damage, radar)
- Preliminary treefall analysis estimation supports Smart^DI estimation of wind speeds



Credit: NWS. Enhancements by NIST

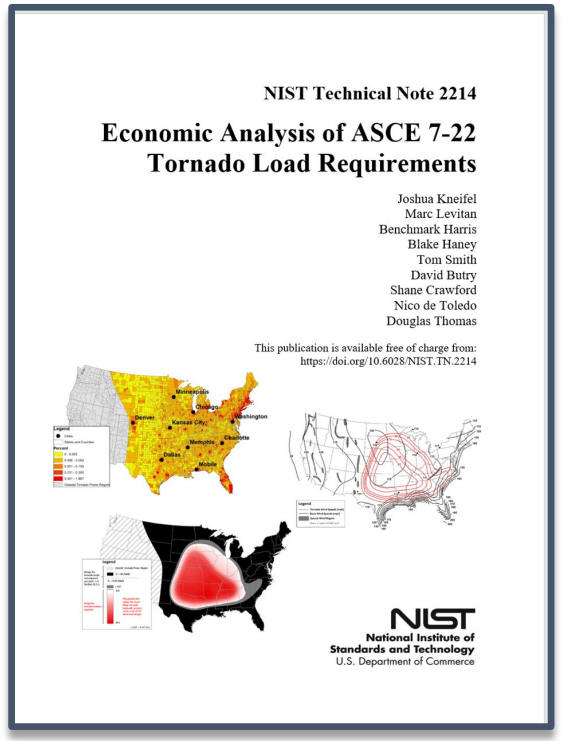


Adoption of Tornado Standard (1/5)

R5: Develop PBD standards for tornado-resistant design and adopt in model codes and local regulations

Multi-part strategy to maximize likelihood of success for incorporation of ASCE 7-22 tornado loads into the 2024 IBC and adoption into federal, state and local codes

1. Documentation of tornado impacts to critical facilities
2. Economic analysis of ASCE 7-22 tornado load provisions
3. Extensive stakeholder communications
4. Develop IBC proposal, in collaboration w/ ASCE and FEMA
5. Develop Tornado Load Design Guide, in collaboration w FEMA


NIST Technical Note 2214

Economic Analysis of ASCE 7-22 Tornado Load Requirements

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Shane Crawford
Nico de Toledo
Douglas Thomas

This publication is available free of charge from: https://doi.org/10.6028/NIST.TN.2214

NIST National Institute of Standards and Technology U.S. Department of Commerce

https://doi.org/10.6028/NIST.TN.2214

Crestview Elementary School, Covington, TN March 2023
Credit: NWS

Wynne High School, Wynne, AR, March 2023
Credit: NWS

Adoption of Tornado Standard (2/5)

Stakeholder Communication Highlights since June 2022

- **15 presentations/webinars/seminars, including:**
  - SEI Standards Series - ASCE 7-22 Preview Session #3 – Wind and Tornado Webinar
  - US Economic Development Administration and US Small Business Administration
  - National Institute of Building Sciences (NIBS) Building Innovation Conference 2022
  - 2022 Storm Shelter Conference
  - Roofing Industry Committee on Wind Issues (RICOWI) Spring Seminar, 2023
  - ASCE Architectural Engineering Conference, 2023
  - 6th International Conference on Protective Structures
  - Metal Building Manufacturers Association Design Seminar
- **8 media interviews, including:**
  - FEMA Video for Building Safety Month, 2023
  - The Infrastructure Show Podcast
  - NewsNation
  - CBC Radio
  - WFLD-TV/Fox 32 Chicago, KTVI St. Louis, KSDK St. Louis
  - YouTube documentary on the Jarrell, Texas Tornado

https://www.nist.gov/news-events/news/2021/06/major-new-building-standard-can-map-out-tornado-threat-first-time

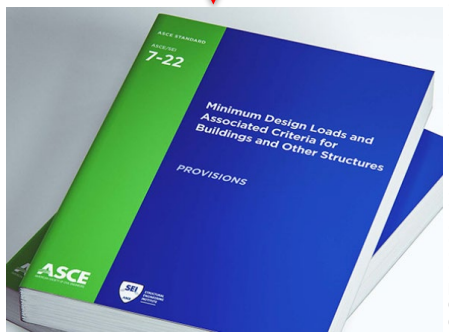
Adoption of Tornado Standard (3/5)

2024 International Building Code

- NIST led development of the proposal to incorporate ASCE 7-22 Tornado Load requirements into the 2024 IBC
  - with ASCE and FEMA, Proposal S63-22
- Coordinated testimony for the Committee Action Hearings
- IBC Structural Committee voted 14-0 to approve

- **Since June 2022 NCSTAC Meeting**
  - Public Comment Period
    – no comments received
  - Online Government Consensus Vote
    – approved via Consent Agenda

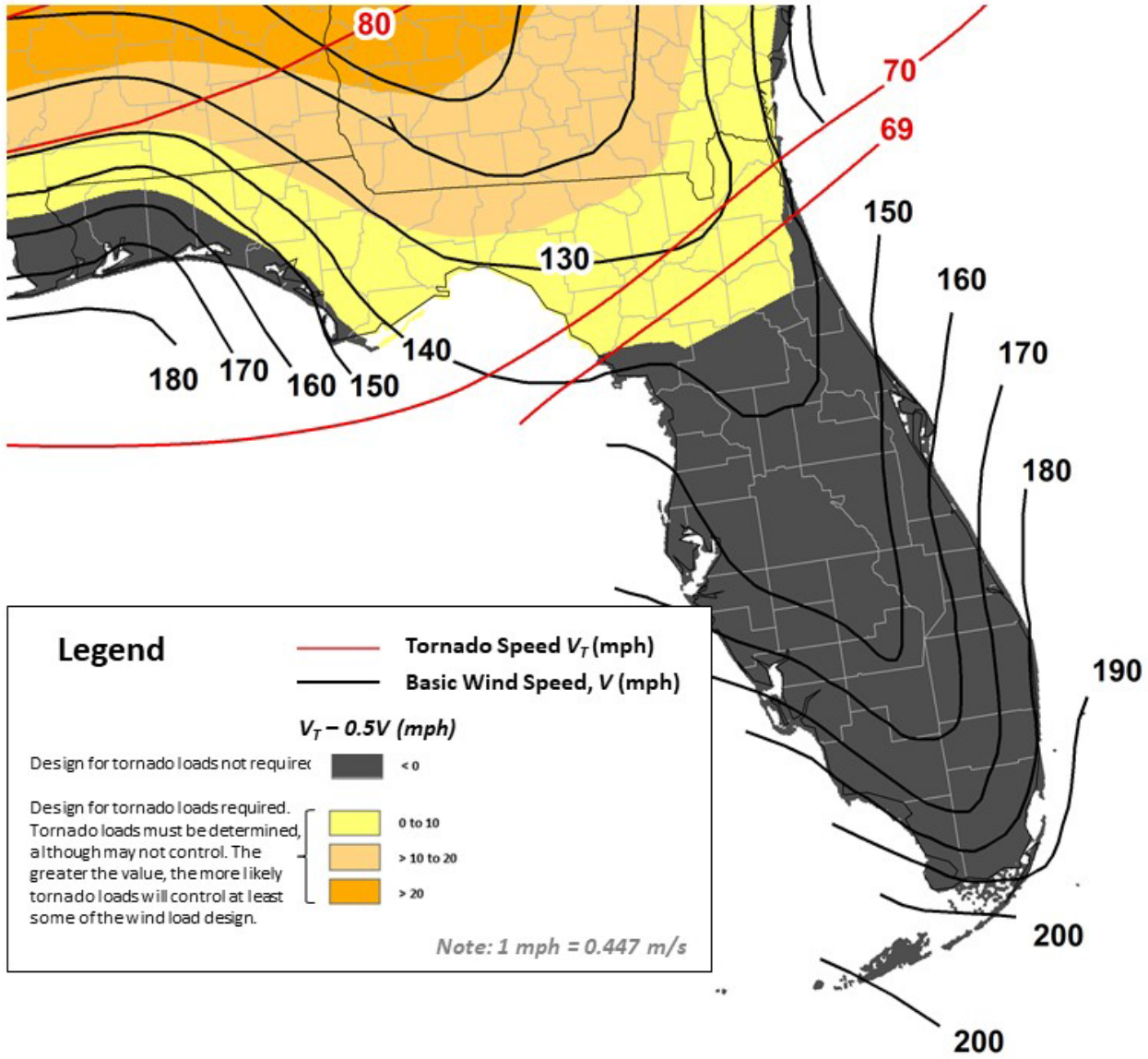
Credit; NOAA/OAR/ERL/NSSL



Approved for the 2024 IBC

Also approved for inclusion in the 2024 NFPA 5000 Building Construction and Safety Code

Adoption of Tornado Standard (4/5)



Comparison of ASCE 7-22 Tornado Speeds and Wind Speeds, and Where Tornado Loads are Required, for

- Risk Category III Building or Structure
- Effective Plan Area = 250,000 ft^2
- Exposure B

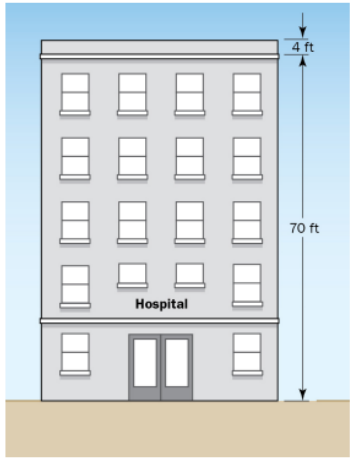
First Local Adoption: 2023 Florida Building Code

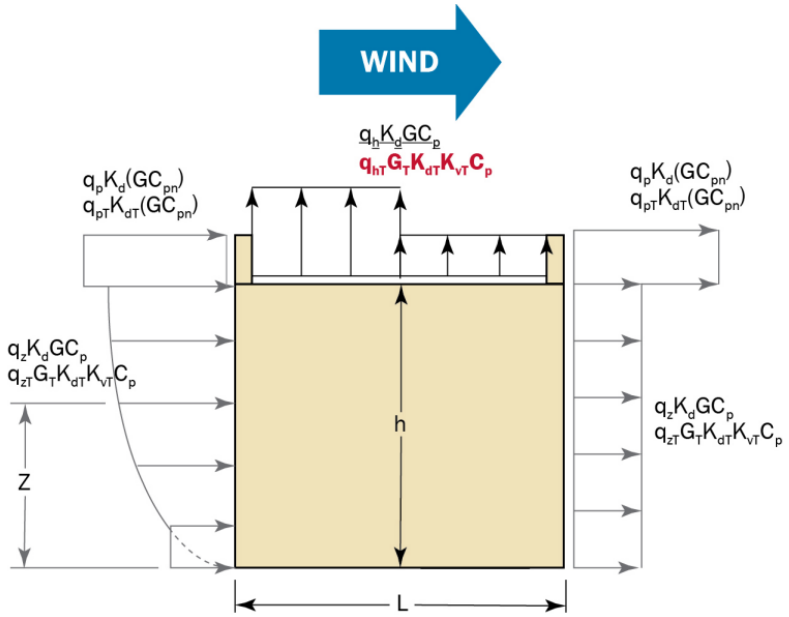
- NIST provided technical input on the proposal submitted to Florida Building Commission
- Tornado loads approved by the Commission in December 2022

Adoption of Tornado Standard (5/5)

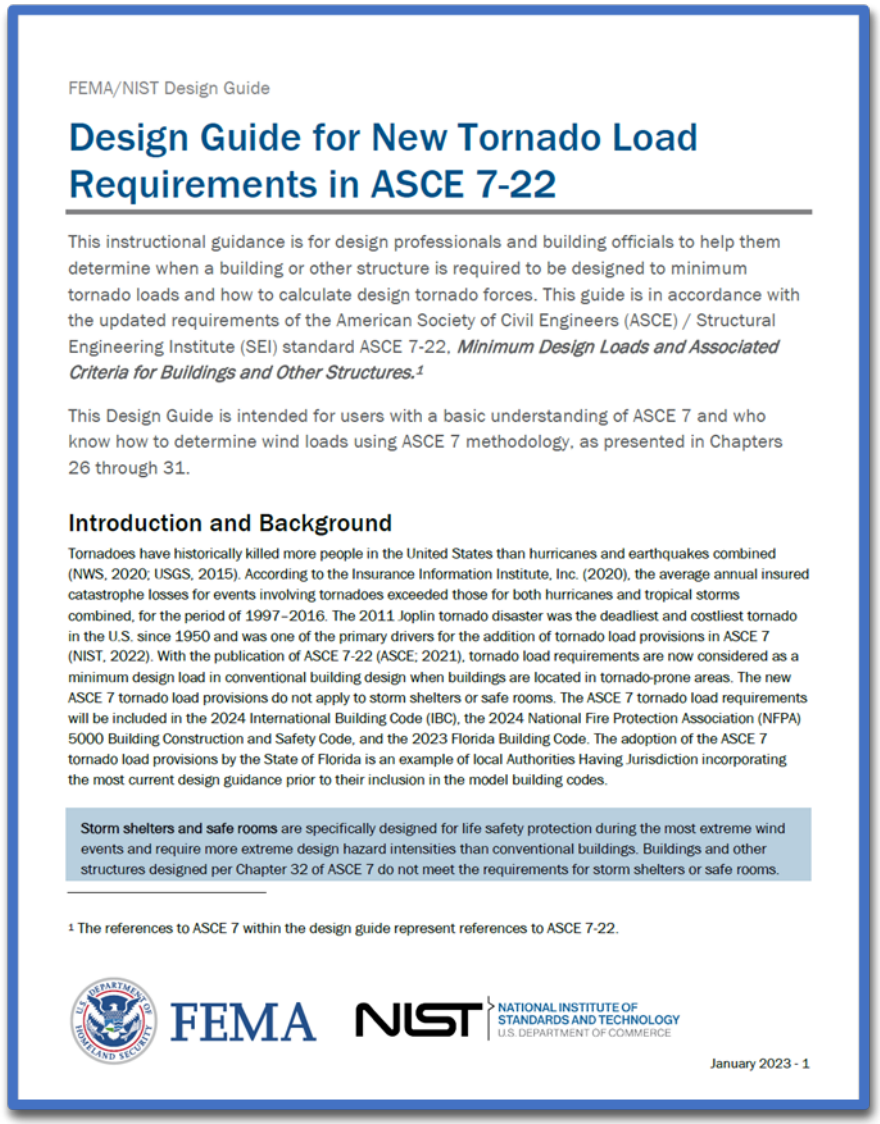
Developed and published joint FEMA/NIST Design Guide for ASCE 7-22 Tornado Loads

- explanation of terminology and procedures
- example tornado load calculations
- comparisons with wind load provisions and calculations





Elevation



FEMA/NIST Design Guide

Design Guide for New Tornado Load Requirements in ASCE 7-22

This instructional guidance is for design professionals and building officials to help them determine when a building or other structure is required to be designed to minimum tornado loads and how to calculate design tornado forces. This guide is in accordance with the updated requirements of the American Society of Civil Engineers (ASCE) / Structural Engineering Institute (SEI) standard ASCE 7-22, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures.*[1]

This Design Guide is intended for users with a basic understanding of ASCE 7 and who know how to determine wind loads using ASCE 7 methodology, as presented in Chapters 26 through 31.

Introduction and Background

Tornadoes have historically killed more people in the United States than hurricanes and earthquakes combined (NWS, 2020; USGS, 2015). According to the Insurance Information Institute, Inc. (2020), the average annual insured catastrophe losses for events involving tornadoes exceeded those for both hurricanes and tropical storms combined, for the period of 1997–2016. The 2011 Joplin tornado disaster was the deadliest and costliest tornado in the U.S. since 1950 and was one of the primary drivers for the addition of tornado load provisions in ASCE 7 (NIST, 2022). With the publication of ASCE 7-22 (ASCE; 2021), tornado load requirements are now considered as a minimum design load in conventional building design when buildings are located in tornado-prone areas. The new ASCE 7 tornado load provisions do not apply to storm shelters or safe rooms. The ASCE 7 tornado load requirements will be included in the 2024 International Building Code (IBC), the 2024 National Fire Protection Association (NFPA) 5000 Building Construction and Safety Code, and the 2023 Florida Building Code. The adoption of the ASCE 7 tornado load provisions by the State of Florida is an example of local Authorities Having Jurisdiction incorporating the most current design guidance prior to their inclusion in the model building codes.

Storm shelters and safe rooms are specifically designed for life safety protection during the most extreme wind events and require more extreme design hazard intensities than conventional buildings. Buildings and other structures designed per Chapter 32 of ASCE 7 do not meet the requirements for storm shelters or safe rooms.

[1] The references to ASCE 7 within the design guide represent references to ASCE 7-22.

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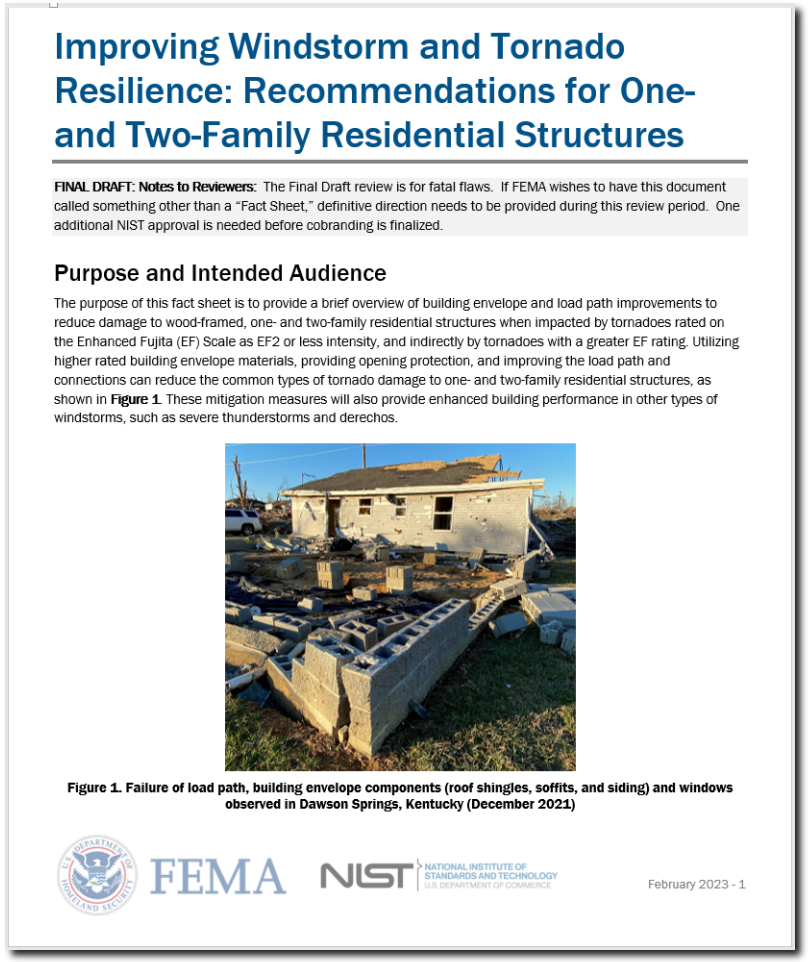
January 2023 - 1

https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=935883

Tornado Resistant Design

R6: Develop risk–balanced, performance–based tornado design methodologies



Improving Windstorm and Tornado Resilience: Recommendations for One- and Two-Family Residential Structures

FINAL DRAFT: Notes to Reviewers: The Final Draft review is for fatal flaws. If FEMA wishes to have this document called something other than a "Fact Sheet," definitive direction needs to be provided during this review period. One additional NIST approval is needed before cobranding is finalized.

Purpose and Intended Audience

The purpose of this fact sheet is to provide a brief overview of building envelope and load path improvements to reduce damage to wood-framed, one- and two-family residential structures when impacted by tornadoes rated on the Enhanced Fujita (EF) Scale as EF2 or less intensity, and indirectly by tornadoes with a greater EF rating. Utilizing higher rated building envelope materials, providing opening protection, and improving the load path and connections can reduce the common types of tornado damage to one- and two-family residential structures, as shown in **Figure 1**. These mitigation measures will also provide enhanced building performance in other types of windstorms, such as severe thunderstorms and derechos.

Figure 1. Failure of load path, building envelope components (roof shingles, soffits, and siding) and windows observed in Dawson Springs, Kentucky (December 2021)

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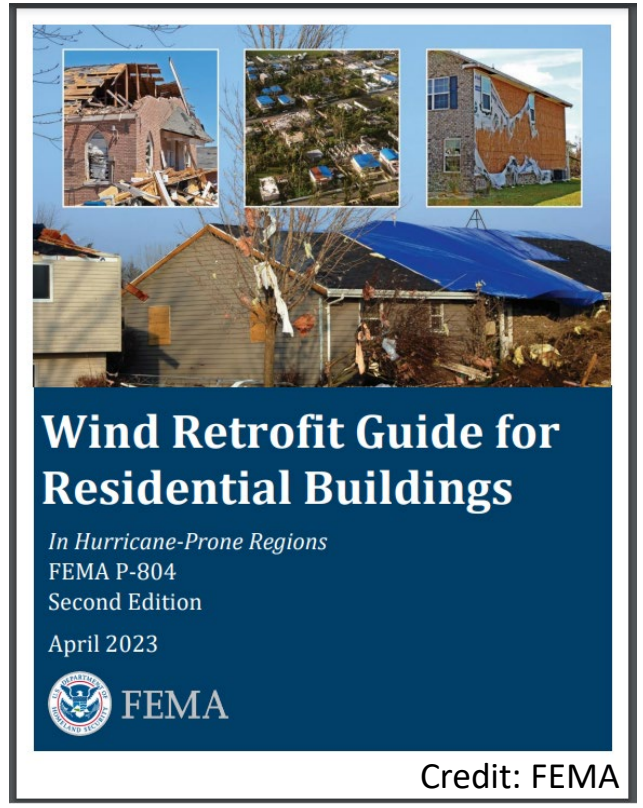
February 2023 - 1

https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=936075

Developed and published FEMA/NIST interim guidance for tornado resistant design and retrofit of one- and two-family residences

Supported FEMA in development of the updated P-804 publication "Wind Retrofit Guide for Residential Buildings"



Credit: FEMA

Impacts/Engagement Summary

- **Existing Standard**
  - **NFPA 1600-2019**, Standard on Continuity, Emergency, and Crisis Management
  - **ICC 500-2020**, Standard for Design and Construction of Storm Shelters
  - **ASCE/SEI 7-22**, Minimum Design Loads and Associated Criteria for Buildings and Structures
  - **ICC 500-2023**, Standard for Design and Construction of Storm Shelters
- **New Standards**
  - **NFPA 1616-2017**, Standard for Mass Evacuation and Sheltering
  - **ASCE/AMS** Standard for Estimation of Wind Speeds in Tornadoes
- **Building Codes**
  - **2018 International Building Code (IBC)**
  - **2018 International Existing Building Code (IEBC)**
  - **2023 Florida Building Code** ← In press
  - **2024 International Building Code (IBC)** ← In press
  - **2024 NFPA 5000 Building Construction and Safety Code** ← In press
- **Guidelines**
  - **FEMA P-320**, Taking Shelter from the Storm, 4th ed.
  - **FEMA P-320**, Taking Shelter from the Storm, 5th ed.
  - **FEMA P-361**, Safe Rooms for Tornadoes and Hurricanes, 3rd ed.
  - **FEMA P-361**, Safe Rooms for Tornadoes and Hurricanes, 4th ed.
  - **ICC 500-2014**, Commentary on the Standard for Design and Construction of Storm Shelters ← Published Sept 2022
  - **ICC 500-2020**, Commentary on the Standard for Design and Construction of Storm Shelters
  - **FEMA P-2062**, Guidelines for Wind Vulnerability Assessments of Existing Critical Facilities
  - **NIST Technical Note,** Alerting under Imminent Threat: Guidance on alerts by outdoor siren & short message alerting systems
  - **Nat. Hazards Rev.**, Alerts and warnings on short messaging channels: guidance from an expert panel process
  - **FEMA P-431**, Tornado Protection: Selecting Refuge Areas in Buildings, 3rd ed.
  - **FEMA/NIST,** Design Guide for New Tornado Load Requirements in ASCE 7-22 ← Published Jan 2023
  - **FEMA/NIST,** Fact Sheet: Improving Windstorm and Tornado Resilience: Recommendations for 1- and 2-Family Residential Structures ← Pub. Feb 2023
  - Guidelines for Tornado Resistant Design of Risk Category II Buildings
  - Guidelines for Public Tornado Sheltering Strategies

Published
In Progress
In Planning / Development
Updates Since June 2022 Briefing

Workshops

- 1st NIST/ASCE Tornado Map Stakeholder Workshop, 2015
- Federal Agency Tornado Map Workshop, 2015
- Workshop on Outdoor Siren Policies, 2016
- Workshop on Short Message Alerting, 2017
- Public Tornado Shelter Workshop: Opportunities and Challenges for Improving Tornado Safety, 2019
- 2nd NIST/ASCE Tornado Map Stakeholder Workshop, 2019
- Quad-State Tornado Outbreak Workshop, 2022

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Remaining Implementation Tasks

Legend
Primarily Completed
Significant Activities/Progress
Modest Progress
Next Steps

	R#	RECOMMENDATION SUMMARY	
Hazard Characteristics	1	Develop and deploy technology to measure tornado wind fields	
	2	Archival of tornado event data	← Linked with efforts for R4
	3	Development of tornado hazard maps	← Propose for ANS 2.3 Std on Tornado Characterization for Nuclear Facility Sites
	4	Improvement of EF Scale; adoption by NWS	← Complete the new ASCE/AMS Standard
Buildings, Shelters, Designated Safe Areas, and Lifelines	5	Develop PBD standard for tornado loads/incl. in model code/local adoption	← Tools and outreach to support local adoption
	6	Develop performance-based tornado design methodologies	← Develop guidance for RC II Buildings
	7	a) Develop tornado shelter standard for existing buildings; b) Installation of tornado shelters in more buildings in tornado-prone regions	← R&D for improvements to ASCE 7-28 tornado load provisions
	8	Develop guidelines for public tornado sheltering strategies	← Develop guidance w/ FEMA and NOAA
	9	Develop guidelines for selection of best available refuge areas	← Complete guidance w/ FEMA
	10	Prohibition of aggregate/ballast roof coverings in tornado-prone regions	← Revise/Resubmit to IBC
	11	Develop req. for enclosures of egress systems in critical facilities	
	12	a) Develop tornado vulnerability assessment guidelines for critical facilities; b) Performance of vulnerability assessments by critical facilities	← Coordinating w/ FEMA
Emergency Communication	13	Develop codes, standards, and guidance for emergency communications; Develop joint plan by emergency mgrs/media/NWS for consistent alerts	
	14	Deploy “push” technologies for transmission of emergency information	
	15	Research to identify factors to enhance public perception of personal risk	
	16	Develop technology for real-time, spatially-resolved tornado threat information	← NOAA

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Progress on Implementation of Past Investigation Recommendations

QUESTIONS?

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