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COLORADO ROOFING ASSOCIATION

Denver, Colorado -- December 12, 2024

Roofing Technical Update

presented by

Mark S. Graham
Vice President, Technical Services
National Roofing Contractors Association (NRCA)

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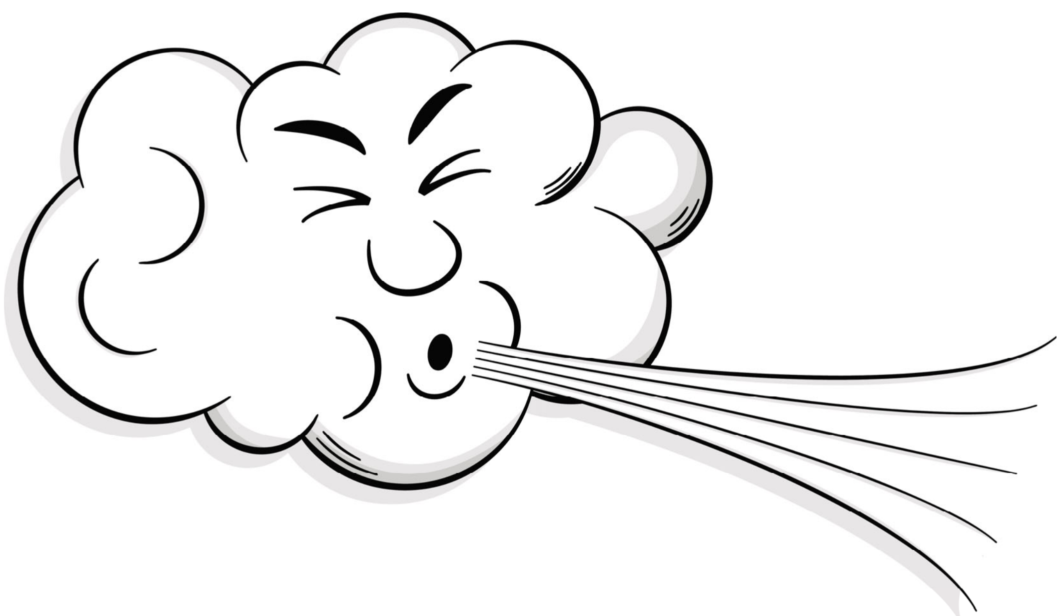
<u>Wind design, high winds, hurricanes and tornados</u>

3



4

Beaufort wind scale

Force	Wind Speed (mph)	Description	Characteristics
0	0-1	Calm	Smoke rises vertically
1	1-3	Light air	Direction of smoke drift
2	4-7	Light breeze	Wind felt of face; leaves rustle
3	8-12	Gentle breeze	Wind extends a light flag
4	13-18	Moderate breeze	Small branches are moved
5	19-24	Fresh breeze	Small trees in leaf begin to sway
6	25-31	Strong breeze	Large branches in motion
7	32-38	Near gale	Whole trees in motion
8	39-46	Gale	Breaks twigs off trees
9	47-54	Severe gale	Slight structural damage occurs
10	55-63	Storm	Trees uprooted; structural damage
11	64-72	Violent storm	Wide-spread damage
12	73-83	Hurricane	See Saffir-Simpson Hurricane Scale

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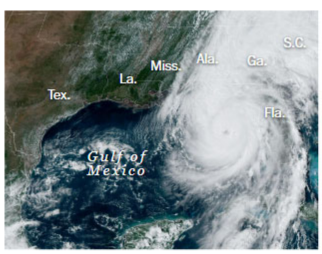
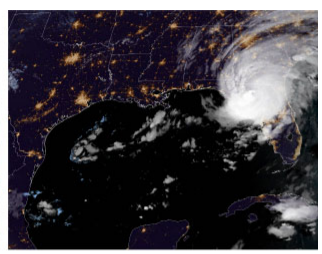
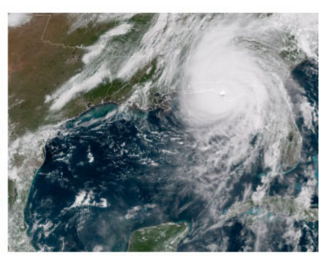
Hurricanes



HELENE (Sept. 26)
420 miles wide


IDALIA (2023)
219 miles


IDA (2021)
247 miles


MICHAEL (2018)
272 miles

6

Saffir-Simpson Hurricane Wind Scale

Category	Wind Speed (mph)	Characteristics
1	74-95	Very dangerous winds produce some damage
2	96-110	Extremely dangerous winds will cause extensive damage
3	111-129	Devastating damage will occur
4	130-156	Catastrophic damage will occur
5	157 and higher	Catastrophic damage will occur

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Tornados

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Enhanced Fujita Scale (EF scale)

Category	Wind Speed (mph)
0	65-85
1	86-110
2	111-135
3	136-165
4	166-200
5	Over 200

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Joplin, MO

May 22, 2011

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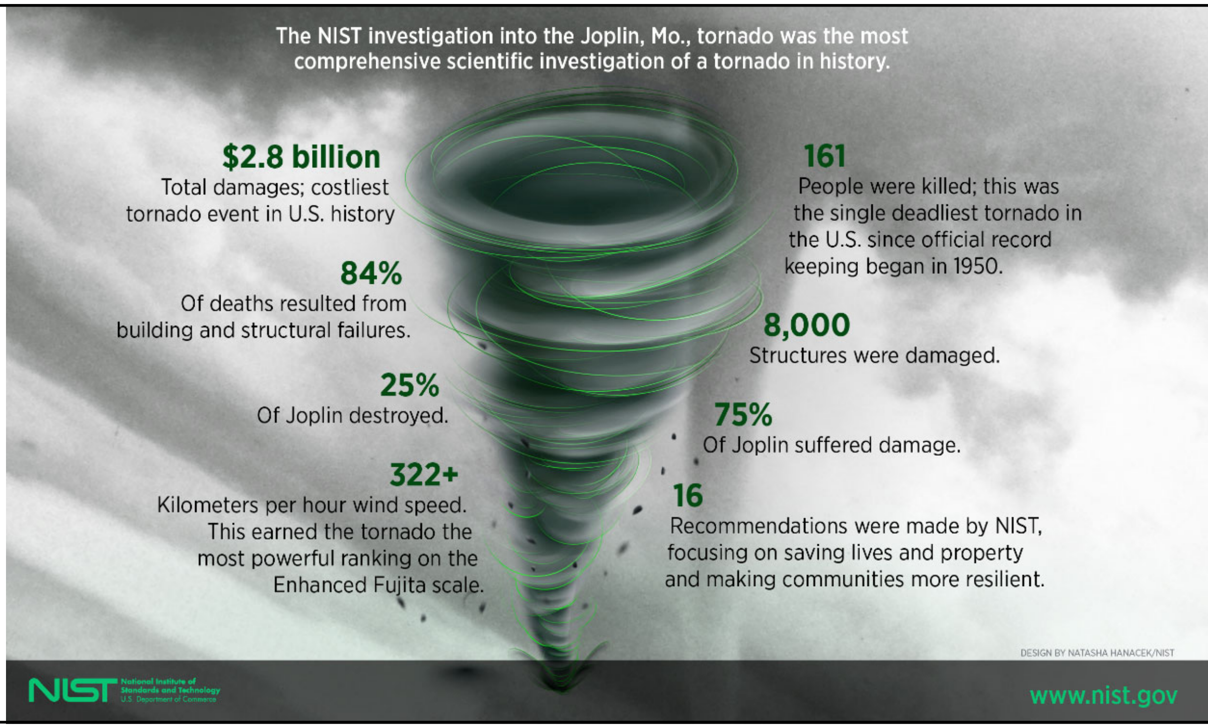

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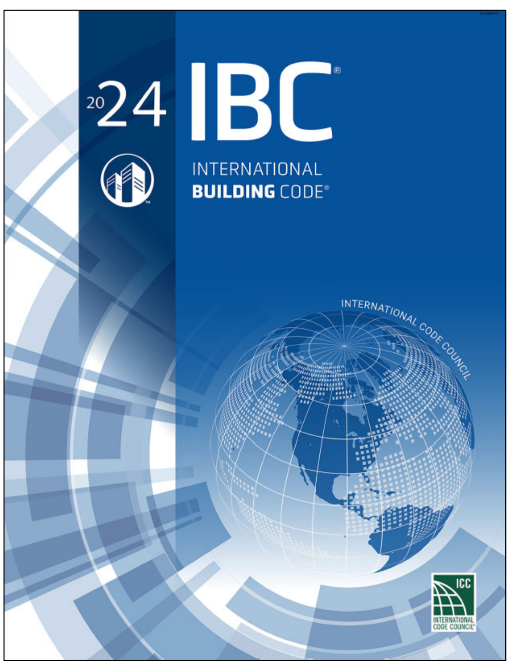

International Building Code, 2024 Edition

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STRUCTURAL DESIGN

1608.2.1 Ground snow conversion. Where required, the ground snow loads, p_g, of Figures 1608.2(1) through 1608.2(4) and Table 1608.2 shall be converted to *allowable stress design* ground snow loads, $p_{g(asd)}$, using Equation 16-17.

Equation 16-17 $p_{g(asd)} = 0.7p_g$

where:

$p_{g(asd)}$ = *Allowable stress design* ground snow load.

SECTION 1609—WIND LOADS

Scan for Changes

ccb96a8

1609.1 Applications. *Buildings*, *structures* and parts thereof shall be designed to withstand the minimum wind *loads* prescribed herein. Decreases in wind *loads* shall not be made for the effect of shielding by *other structures*.

1609.1.1 Determination of wind loads. Wind *loads* on every *building* or *structure* shall be determined in accordance with Chapters 26 to 30 of ASCE 7. The type of opening protection required, the basic wind speed, *V*, and the exposure category for a *site* is permi[...] be determined in accordance with Section 1609 or ASCE 7. Wind shall be assumed to come from any hor[...]tion and wind pressures shall be assumed to act normal to the surface considered.

IBC 2024 Ch. 35-References Standards identifies ASCE 7-22's edition as being applicable

Exceptions:

1. Subject to the limitations [...] applicable Group R-2 and [...]
2. Subject to the limitations of Section 1609.1.1.1, residential *structures* using the provisions of AWC WFCM.
3. Subject to the limitations of Section 1609.1.1.1, residential *structures* using the provisions of AISI S230.
4. Designs using NAAMM FP 1001.
5. Designs using TIA-222 for antenna-supporting *structures* and antennas, provided that the horizontal extent of Topographic Category 2 escarpments in Section 2.6.6.2 of TIA-222 shall be 16 times the height of the escarpment.
6. Wind tunnel tests in accordance with ASCE 49 and Sections 31.4 and 31.7 of ASCE 7.
7. *Temporary structures* complying with Section 3103.6.1.2.

The wind speeds in Figures 1609.3(1) through 1609.3(4) are basic wind speeds, *V*, and shall be converted in accordance with Section 1609.3.1 to *allowable stress design* wind speeds, V_{asd}, when the provisions of the standards referenced in Exceptions 4 and 5 are used.

attachment hardware provided and anchors permanently installed on the *building*. Attachment in accordance with Table 1609.2 with corrosion-resistant attachment hardware provided and anchors permanently installed on the *building* is permitted for *buildings* with a mean roof height of 45 feet (13 716 mm) or less where V_{asd} determined in accordance with Section 1609.3.1 does not exceed 140 mph (63 m/s).

2. Glazing in *Risk Category I buildings*, including *greenhouses* that are occupied for growing plants on a production or research basis, without public access shall be permitted to be unprotected.

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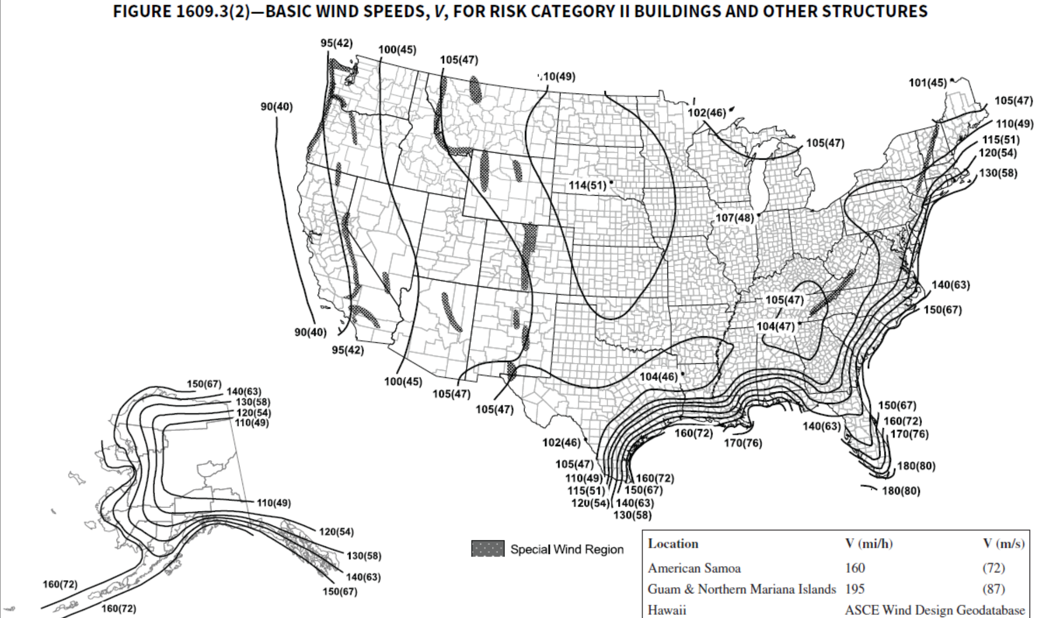
FIGURE 1609.3(2)—BASIC WIND SPEEDS, *V*, FOR RISK CATEGORY II BUILDINGS AND OTHER STRUCTURES



Location	V (mi/h)	V (m/s)
American Samoa	160	(72)
Guam & Northern Mariana Islands	195	(87)
Hawaii	ASCE Wind Design Geodatabase	
Puerto Rico	ASCE Wind Design Geodatabase	
U.S. Virgin Islands	ASCE Wind Design Geodatabase	

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TABLE 1604.5—RISK CATEGORY OF BUILDINGS AND OTHER STRUCTURES

RISK CATEGORY	NATURE OF OCCUPANCY
I	Buildings and other structures that represent a low hazard to human life in the event of failure, including but not limited to: • Agricultural facilities. • Certain temporary facilities. • Minor storage facilities.
II	Buildings and other structures except those listed in Risk Categories I, III and IV.
III	Buildings and other structures that represent a substantial hazard to human life in the event of failure, including but not limited to: • Buildings and other structures whose primary occupancy is public assembly with an occupant load greater than 300. • Buildings and other structures containing one or more public assembly spaces, each having an occupant load greater than 300 and a cumulative occupant load of these public assembly spaces of greater than 2,500. • Buildings and other structures containing Group E or Group I-4 occupancies or combination thereof, with an occupant load greater than 250. • Buildings and other structures containing educational occupancies for students above the 12th grade with an occupant load greater than 500. • Group I-3, Condition 1 occupancies. • Any other occupancy with an occupant load greater than 5,000.[a] • Power-generating stations with individual power units rated 75 MW_{AC} (megawatts, alternating current) or greater, water treatment facilities for potable water, wastewater treatment facilities and other public utility facilities not included in Risk Category IV. • Buildings and other structures not included in Risk Category IV containing quantities of toxic or explosive materials that: • Exceed maximum allowable quantities per control area as given in Table 307.1(1) or 307.1(2) or per outdoor control area in accordance with the *International Fire Code*; and • Are sufficient to pose a threat to the public if released.[b]
IV	Buildings and other structures designated as essential facilities and buildings where loss of function represents a substantial hazard to occupants or users, including but not limited to: • Group I-2, Condition 2 occupancies. • Ambulatory care facilities having emergency surgery or emergency treatment facilities. • Group I-3 occupancies other than Condition 1. • Fire, rescue, ambulance and police stations and emergency vehicle garages • Designated earthquake, hurricane or other emergency shelters. • Designated emergency preparedness, communications and operations centers and other facilities required for emergency response. • Public utility facilities providing power generation, potable water treatment, or wastewater treatment. • Power-generating stations and other public utility facilities required as emergency backup facilities for *Risk Category* IV structures. • Buildings and other structures containing quantities of highly toxic materials that: • Exceed maximum allowable quantities per control area as given in Table 307.1(2) or per outdoor control area in accordance with the *International Fire Code*; and • Are sufficient to pose a threat to the public if released.[b] • Aviation control towers, air traffic control centers and emergency aircraft hangars. • Buildings and other structures having critical national defense functions. • Water storage facilities and pump structures required to maintain water pressure for fire suppression.

a. For purposes of occupant load calculation, occupancies required by Table 1004.5 to use *gross floor area* calculations shall be permitted to use *net floor areas* to determine the total occupant load. The floor area for vehicular drive aisles shall be permitted to be excluded in the determination of net floor area in parking garages.

b. Where approved by the building official, the classification of buildings and other structures as Risk Category III or IV based on their quantities of toxic, highly toxic or explosive materials is permitted to be reduced to Risk Category II, provided that it can be demonstrated by a hazard assessment in accordance with Section 1.5.3 of ASCE 7 that a release of the toxic, highly toxic or explosive materials is not sufficient to pose a threat to the public.

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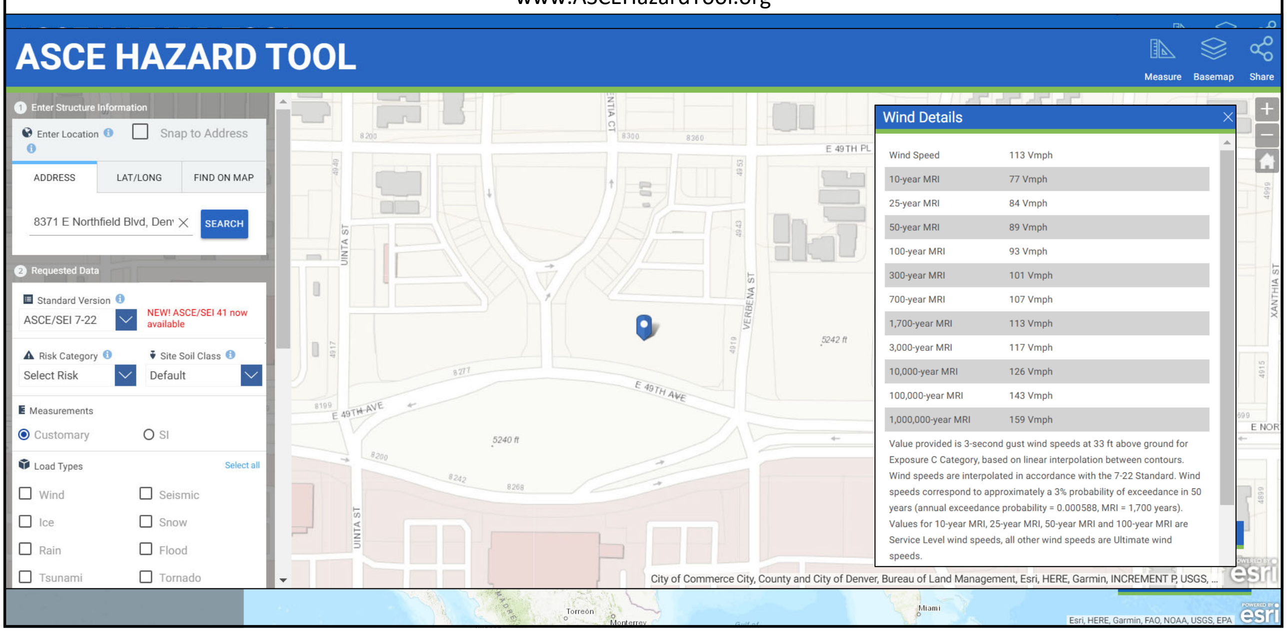
ASCE Hazard Tool

www.ASCEHazardTool.org



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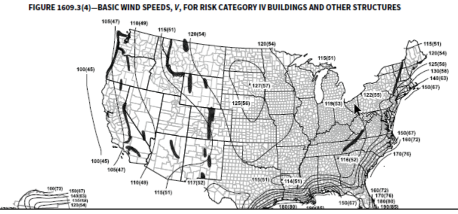
STRUCTURAL DESIGN

FIGURE 1609.3(4)—BASIC WIND SPEEDS, *V*, FOR RISK CATEGORY IV BUILDINGS AND OTHER STRUCTURES



1609.3.1 Wind speed conversion. Where required, the basic wind speeds of Figures 1609.3(1) through 1609.3(4) shall be converted to *allowable stress design* wind speeds, V_{asd}, using Table 1609.3.1 or Equation 16-18.

Equation 16-18 $V_{asd} = V\sqrt{0.6}$ ← **i.e., $V_{ASD} = V \times 0.78$**

where:

V_{asd} = *Allowable stress design wind speed* applicable to methods specified in Exceptions 4 and 5 of Section 1609.1.1.

V = Basic wind speeds determined from Figures 1609.3(1) through 1609.3(4).

TABLE 1609.3.1—WIND SPEED CONVERSIONS[a, b, c]

V	100	110	120	130	140	150	160	170	180	190	200
V_{asd}	78	85	93	101	108	116	124	132	139	147	155

For SI: 1 mile per hour = 0.44 m/s.

a. Linear interpolation is permitted.

b. V_{asd} = allowable stress design wind speed applicable to methods specified in Exceptions 1 through 5 of Section 1609.1.1.

c. V = basic wind speeds determined from Figures 1609.3(1) through 1609.3(4).

1609.4 Exposure category. For each wind direction considered, an exposure category that adequately reflects the characteristics of ground surface irregularities shall be determined for the *site* at which the *building* or *structure* is to be constructed. Account shall be taken of variations in ground surface roughness that arise from natural topography and vegetation as well as from constructed features.

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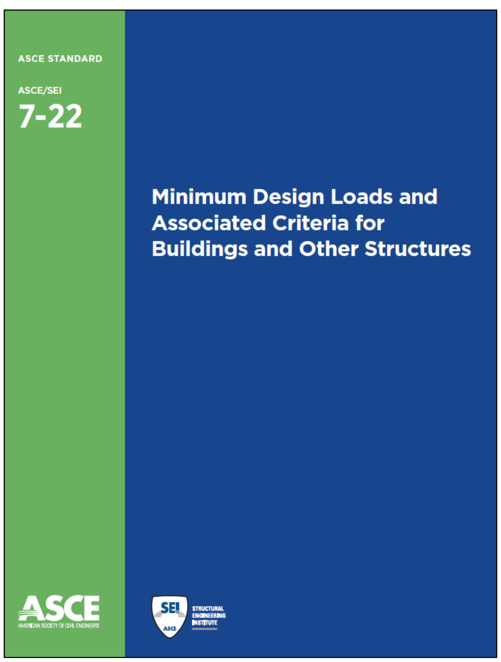

Link

ASCE 7-22

- All loads on buildings and structures
- 482 pages + commentary (1046 pages total)
- 32 chapters
- 7 appendixes
- Referenced in IBC 2024 Ch. 16- Wind Design as the basis for wind design

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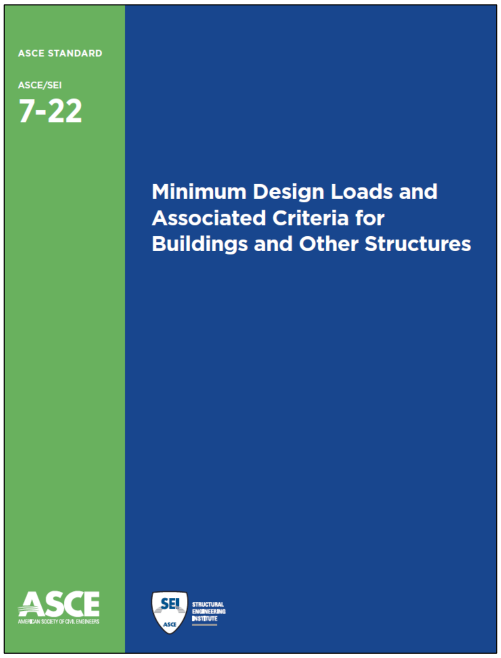

ASCE 7-22 on wind design

- Ch. 26: Wind loads: General requirements
- Ch. 30: Wind loads: Components and cladding
- Ch. 31: Wind tunnel procedure
- Ch. 32: Tornado loads

99 pages

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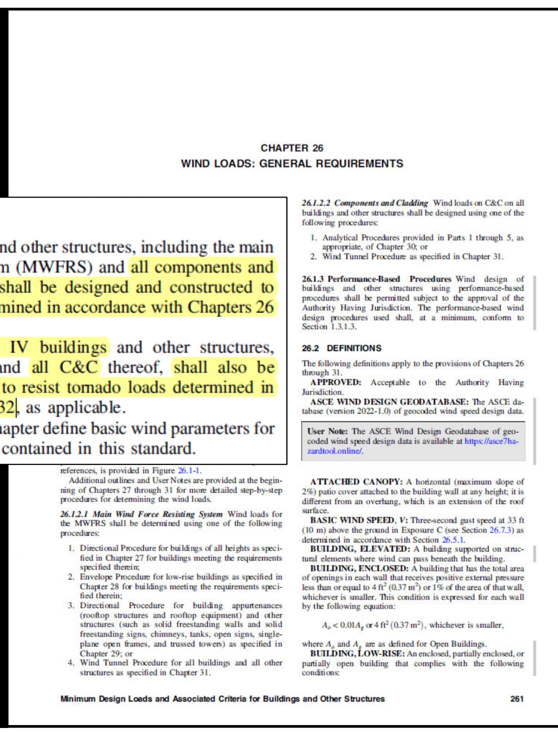

CHAPTER 26
WIND LOADS: GENERAL REQUIREMENTS

26.1 PROCEDURES

26.1.1 Scope Buildings and other structures, including the main wind force resisting system (MWFRS) and all components and cladding (C&C) thereof, shall be designed and constructed to resist the wind loads determined in accordance with Chapters 26 through 31.

Risk Category III and IV buildings and other structures, including the MWFRS and all C&C thereof, shall also be designed and constructed to resist tornado loads determined in accordance with Chapter 32, as applicable.

The provisions of this chapter define basic wind parameters for use with other provisions contained in this standard.

references, is provided in Figure 26.1-1.

Additional outlines and User Notes are provided at the beginning of Chapters 27 through 31 for more detailed step-by-step procedures for determining the wind loads.

26.1.2.1 Main Wind Force Resisting System Wind loads for the MWFRS shall be determined using one of the following procedures:

1. Directional Procedure for buildings of all heights as specified in Chapter 27 for buildings meeting the requirements specified therein;
2. Envelope Procedure for low-rise buildings as specified in Chapter 28 for buildings meeting the requirements specified therein;
3. Directional Procedure for building appurtenances (rooftop structures and rooftop equipment) and other structures (such as solid freestanding walls and solid freestanding signs, chimneys, tanks, open signs, single-plane open frames, and trussed towers) as specified in Chapter 29; or
4. Wind Tunnel Procedure for all buildings and all other structures as specified in Chapter 31.

26.1.2.2 Components and Cladding Wind loads on C&C on all buildings and other structures shall be designed using one of the following procedures:

1. Analytical Procedures provided in Parts 1 through 5, as appropriate, of Chapter 30; or
2. Wind Tunnel Procedure as specified in Chapter 31.

26.1.3 Performance-Based Procedures Wind design of buildings and other structures using performance-based procedures shall be permitted subject to the approval of the Authority Having Jurisdiction. The performance-based wind design procedures used shall, at a minimum, conform to Section 1.3.1.3.

26.2 DEFINITIONS

The following definitions apply to the provisions of Chapters 26 through 31.

APPROVED: Acceptable to the Authority Having Jurisdiction.

ASCE WIND DESIGN GEODATABASE: The ASCE database (version 2022-1.0) of geocoded wind speed design data.

User Note: The ASCE Wind Design Geodatabase of geocoded wind speed design data is available at https://asce7hazardtool.online/.

ATTACHED CANOPY: A horizontal (maximum slope of 2%) patio cover attached to the building wall at any height; it is different from an overhang, which is an extension of the roof surface.

BASIC WIND SPEED, V: Three-second gust speed at 33 ft (10 m) above the ground in Exposure C (see Section 26.7.3) as determined in accordance with Section 26.5.1.

BUILDING, ELEVATED: A building supported on structural elements where wind can pass beneath the building.

BUILDING, ENCLOSED: A building that has the total area of openings in each wall that receives positive external pressure less than or equal to 4 ft^2 (0.37 m^2) or 1% of the area of that wall, whichever is smaller. This condition is expressed for each wall by the following equation:

$$A_o < 0.01A_g \text{ or } 4\ ft^2\ (0.37\ m^2), \text{ whichever is smaller,}$$

where A_o and A_g are as defined for Open Buildings.

BUILDING, LOW-RISE: An enclosed, partially enclosed, or partially open building that complies with the following conditions:

Minimum Design Loads and Associated Criteria for Buildings and Other Structures 261

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30.1 SCOPE

30.1.1 Building Types This chapter applies to the determination of wind pressures on components and cladding (C&C) on buildings.

1. Part 1 is applicable to an enclosed, partially enclosed, or partially open
   - Low-rise building (see definition in Section 26.2); or
   - Building with $h \leq 60$ ft (18.3 m).

   The building has a flat roof, gable roof, multispan gable roof, hip roof, monoslope roof, stepped roof, or sawtooth roof, and the wind pressures are calculated from a wind pressure equation.
2. Part 2 is applicable to an enclosed, partially enclosed, or partially open
   - Building with $h > 60$ ft (18.3 m).

   The building has a flat roof, pitched roof, gable roof, hip roof, mansard roof, arched roof, or domed roof, and the wind pressures are calculated from a wind pressure equation.
3. Part 3 is applicable to an open building of all heights that has a pitched free roof, monoslope free roof, or troughed free roof.
4. Part 4 is applicable to building appurtenances such as roof overhangs, parapets, and rooftop equipment.
5. Part 5 is applicable to non-building structures – circular bins, silos, and tanks; rooftop solar panels and roof pavers.
   - Circular bins, silos, and tanks with $h \leq 120$ ft (38.6 m);
   - Rooftop solar panels: Buildings of all heights with flat roofs or gable or hip roofs with roof slopes less than or equal to 7 degrees; and
   - Roof pavers: Buildings of all heights with roof slopes less than or equal to 7 degrees.

TER 30
NENTS AND CLADDING

resonance with along-wind vibrations of flexible buildings. The loads on buildings that do not meet the requirements of Section 30.1.2 or that have unusual shapes or response characteristics shall be determined using recognized literature documenting such wind load effects or shall use the wind tunnel procedure specified in Chapter 31.

30.1.4 Shielding There shall be no reductions in velocity pressure caused by apparent shielding afforded by buildings and other structures or terrain features.

30.1.5 Air-Permeable Cladding Design wind loads determined from Chapter 30 shall be used for air-permeable claddings, including modular vegetative roof assemblies, unless approved test data or recognized literature demonstrates lower loads for the type of air-permeable cladding being considered.

30.2 GENERAL REQUIREMENTS

30.2.1 Wind Load Parameters Specified in Chapter 26 The following wind load parameters are specified in Chapter 26:

- Basic wind speed, V (Section 26.5),
- Wind directionality factor, K_d (Section 26.6),
- Exposure category (Section 26.7),
- Topographic factor, K_{zt} (Section 26.8),
- Ground elevation factor, K_e (Section 26.9),
- Velocity pressure exposure coefficient, K_z or K_h (Section 26.10.1); Velocity pressure, q_z (Section 26.10.2),
- Gust-effect factor (Section 26.11),
- Enclosure classification (Section 26.12), and
- Internal pressure coefficient, (GC_{pi}) (Section 26.13).

30.2.2 Minimum Design Wind Pressures The design wind pressure for C&C of buildings shall not be less than a net pressure of 16 lb/ft^2 (0.77 kN/m^2) acting in either direction normal to the surface.

30.2.3 Tributary Areas Greater than 700 ft^2 (65 m^2) C&C elements with tributary areas greater than 700 ft^2 (65 m^2) shall be permitted to be designed using the provisions for main wind force resisting systems.

30.2.4 External Pressure Coefficients Combined gust-effect factor and external pressure coefficients for C&C, (GC_p), are given in the figures associated with this chapter. The pressure coefficient values and gust-effect factor shall not be separated.

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CHAPTER 32
TORNADO LOADS

32.1 PROCEDURES

32.1.1 Scope Buildings and other structures classified as Risk Category III or IV and located in the tornado-prone region as shown in Figure 32.1-1, including the main wind force resisting system (MWFRS) and all components and cladding (C&C) thereof, shall be designed and constructed to resist the greater of the tornado loads determined in accordance with the provisions of this chapter or the wind loads determined in accordance with Chapters 26 through 31, using the load combinations provided in Chapter 2.

26). The tornado speed at any given geographic location will range from approximately Enhanced Fujita Scale EF0 – EF2 intensity, depending on the risk category and effective plan area of the building or other structure (see Section C32.5.1). Options for protection of life and property from more intense tornadoes include construction of a storm shelter and/or design for longer-return-period tornado speeds as provided in Appendix G, including performance-based design. A building or other structure designed for tornado loads determined exclusively in accordance with Chapter 32 cannot be designated as a storm shelter without meeting additional critical requirements provided in the applicable building code and ICC 500, the ICC/NSSA *Standard for the Design and Construction of Storm Shelters*. See Commentary Section C32.1.1 for an in-depth discussion on storm shelters.

32.1.2 Permitted Procedures The design tornado loads for buildings and other structures, including the MWFRS and C&C elements thereof, shall be determined using one of the procedures as specified in this section and subject to the applicable limitations of Chapters 26 through 32, excluding Chapter 28.

An outline of the overall process for the determination of the tornado loads, including section references, is provided in Figure 32.1-3.

32.1.2.1 Tornado Loads on the Main Wind Force Resisting System Tornado loads for the MWFRS shall be determined using one or more of the following procedures, as modified by Chapter 32:

1. Directional Procedure for buildings of all heights as specified in Chapter 27 for buildings meeting the requirements specified therein;
2. Directional Procedure for Building Appurtenances (such as rooftop structures and rooftop equipment) and Other Structures (such as solid freestanding walls and solid freestanding signs, chimneys, tanks, open signs, single-plane open frames, and trussed towers) as specified in Chapter 29 for buildings meeting the requirements specified therein; or
3. Wind Tunnel Procedure for all buildings and all other structures as specified in Chapter 31 for buildings meeting the requirements specified therein.

32.1.2.2 Tornado Loads on Components and Cladding Tornado loads on the C&C of all buildings and other structures shall be determined using one or more of the following procedures, as modified by Chapter 32:

1. Analytical Procedures as specified in Parts 1 through 5, as appropriate, of Chapter 30, for buildings or other structures meeting the requirements specified therein; or
2. Wind Tunnel Procedure for all buildings and other structures as specified in Chapter 31, for buildings meeting the requirements specified therein.

32.1.3 Performance-Based Procedures Tornado design of buildings and other structures using performance-based procedures shall be permitted subject to the approval of the Authority Having Jurisdiction. The performance-based tornado design procedures used shall, at a minimum, conform to Section 1.3.1.3 and be documented and submitted to the Authority Having Jurisdiction in accordance with Section 1.3.1.3.

32.2 DEFINITIONS

The following definitions apply to the provisions of Chapter 32. Terms not defined in this chapter shall be defined in accordance with Chapters 26 through 31, as appropriate, excluding Chapter 28.

ASCE TORNADO DESIGN GEODATABASE: The ASCE database (version 2022-1.0) of geocoded tornado speed design data.

OTHER STRUCTURES, SEALED: A structure that is completely sealed or has controlled ventilation such that tornado-induced atmospheric pressure changes will not be transmitted to the inside of the structure, including but not limited to certain tanks and vessels.

TORNADO-PRONE REGION: The area of the conterminous United States most vulnerable to tornadoes, as shown in Figure 32.1-1.

Minimum Design Loads and Associated Criteria for Buildings and Other Structures 353

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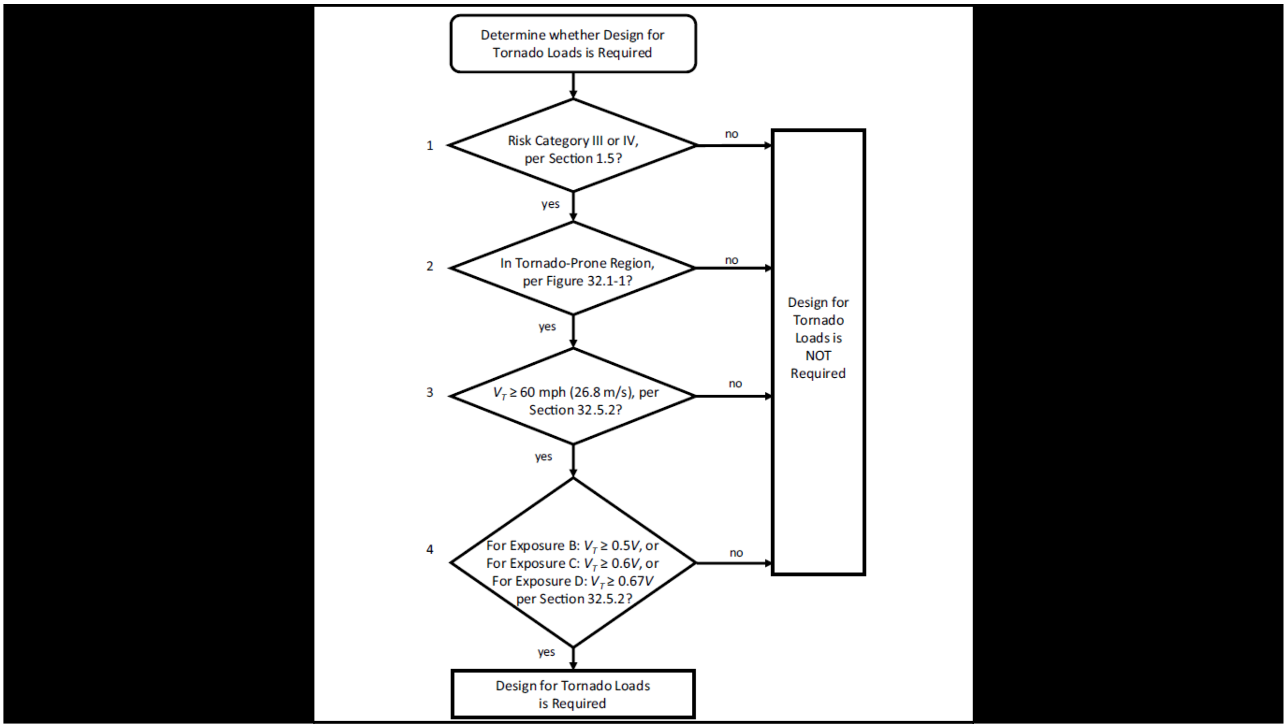

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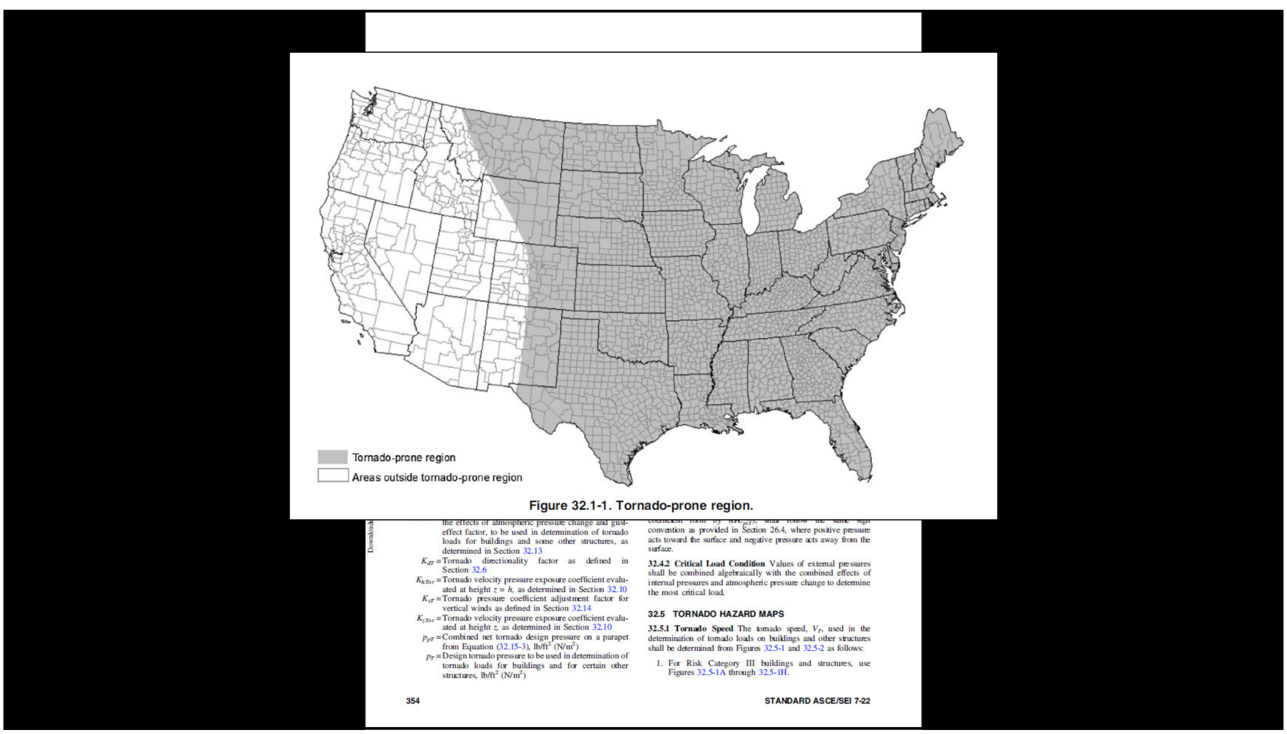

Figure 32.1-1. Tornado-prone region.

the effects of atmospheric pressure change and gust-effect factor, to be used in determination of tornado loads for buildings and some other structures, as determined in Section 32.13

K_{dT} = Tornado directionality factor as defined in Section 32.6

K_{hTor} = Tornado velocity pressure exposure coefficient evaluated at height $z = h$, as determined in Section 32.10

K_{vT} = Tornado pressure coefficient adjustment factor for vertical winds as defined in Section 32.14

K_{zTor} = Tornado velocity pressure exposure coefficient evaluated at height z, as determined in Section 32.10

p_{pT} = Combined net tornado design pressure on a parapet from Equation (32.15-3), lb/ft^2 (N/m^2)

p_T = Design tornado pressure to be used in determination of tornado loads for buildings and for certain other structures, lb/ft^2 (N/m^2)

convention as provided in Section 26.4, where positive pressure acts toward the surface and negative pressure acts away from the surface.

32.4.2 Critical Load Condition Values of external pressures shall be combined algebraically with the combined effects of internal pressures and atmospheric pressure change to determine the most critical load.

32.5 TORNADO HAZARD MAPS

32.5.1 Tornado Speed The tornado speed, V_T, used in the determination of tornado loads on buildings and other structures shall be determined from Figures 32.5-1 and 32.5-2 as follows:

1. For Risk Category III buildings and structures, use Figures 32.5-1A through 32.5-1H.

354 STANDARD ASCE/SEI 7-22

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FEMA/NIST Design Guide

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

"Effective area" for tornado design purposes

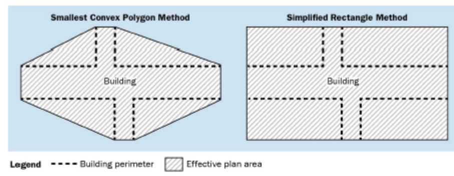

Figure 5: Effective plan areas for buildings that are not essential facilities (Adapted from ASCE 7, Figure C32.5-1; used with permission from ASCE)

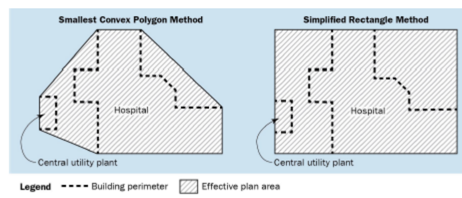

Figure 6: Effective plan area for essential facilities (Adapted from ASCE 7, Figure C32.5-2; used with permission from ASCE)

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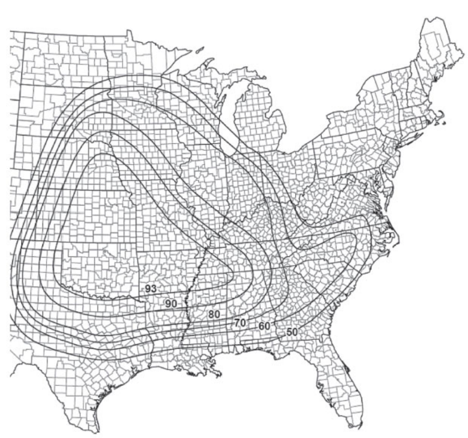

4. Islands, coastal areas, and land boundaries outside the last contour shall use the last tornado speed contour.
5. Tornado speeds correspond to approximately a 3% probability of exceedance in 50 years (annual exceedance probability = 0.000588, MRI = 1,700 years).
6. Location-specific tornado speed is permitted to be determined using the ASCE Tornado Design Geodatabase, available at the ASCE 7 Hazard Tool (http://asce7hazardtool.online) or approved equivalent.

Figure 32.5-1E (*Continued*). Tornado speeds for Risk Category III buildings and other structures, for effective plan area of 100,000 ft^2 (9,290 m^2).

Separate tornado speed maps based on Risk Category III and IV, and effective plan areas of 1; 2,000; 10,000; 40,000; 100,000; 250,000; 1,000,000 and 4,000,000 sq. ft.

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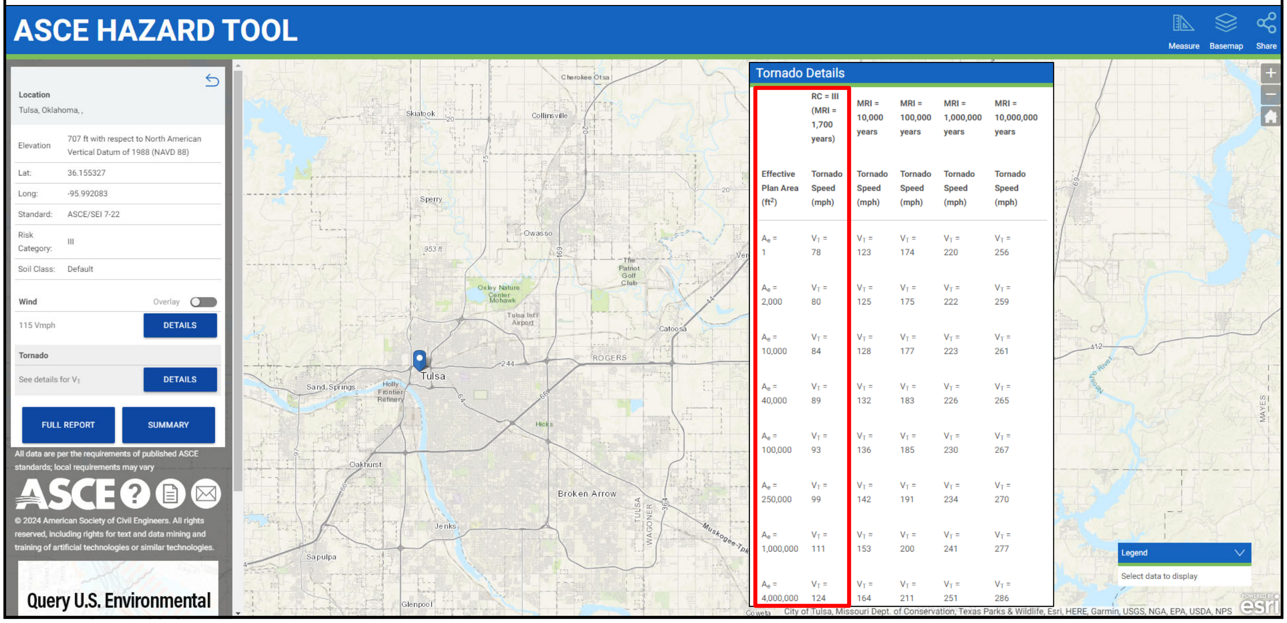
ASCE Hazard Tool

www.ASCEHazardTool.org



Effective Plan Area (ft²)	RC = III (MRI = 1,700 years) Tornado Speed (mph)	MRI = 10,000 years Tornado Speed (mph)	MRI = 100,000 years Tornado Speed (mph)	MRI = 1,000,000 years Tornado Speed (mph)	MRI = 10,000,000 years Tornado Speed (mph)
A_e = 1	V_T = 78	V_T = 123	V_T = 174	V_T = 220	V_T = 256
A_e = 2,000	V_T = 80	V_T = 125	V_T = 175	V_T = 222	V_T = 259
A_e = 10,000	V_T = 84	V_T = 128	V_T = 177	V_T = 223	V_T = 261
A_e = 40,000	V_T = 89	V_T = 132	V_T = 183	V_T = 226	V_T = 265
A_e = 100,000	V_T = 93	V_T = 136	V_T = 185	V_T = 230	V_T = 267
A_e = 250,000	V_T = 99	V_T = 142	V_T = 191	V_T = 234	V_T = 270
A_e = 1,000,000	V_T = 111	V_T = 153	V_T = 200	V_T = 241	V_T = 277
A_e = 4,000,000	V_T = 124	V_T = 164	V_T = 211	V_T = 251	V_T = 286

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panel systems shall be equal to the effective plan area of the largest structurally independent photovoltaic support structure that does not share structural components with other adjacent structures.

32.6 TORNADO DIRECTIONALITY FACTOR

The tornado directionality factor, K_{dT}, shall be determined from Table 32.6-1 and shall be used to determine the tornado loads in accordance with Sections 32.15 through 32.17.

32.7 TORNADO EXPOSURE

Tornado velocity pressure exposure coefficients K_{zTor} and K_{hTor} are determined in Section 32.10.1. Exposure requirements in Section 26.7 shall not apply to the determination of K_{zTor} and K_{hTor}.

32.10 TORNADO VELOCITY PRESSURE

32.10.1 Tornado Velocity Pressure Exposure Coefficient A tornado velocity pressure exposure coefficient, K_{zTor} or K_{hTor}, as applicable, shall be determined from Table 32.10-1.

32.10.2 Tornado Velocity Pressure Tornado velocity pressure, q_{zT}, evaluated at height z above ground, shall be determined in accordance with the following equation:

$$q_{zT} = 0.00256 K_{zTor} K_e V_T^2 \text{ (lb/ft}^2\text{)}; V_T \text{ in mi/h} \quad (32.10\text{-}1)$$

$$q_{zT} = 0.613 K_{zTor} K_e V_T^2 \text{ (N/m}^2\text{)}; V_T \text{ in m/s} \quad (32.10\text{-}1.\text{SI})$$

where

K_{zTor} = Tornado velocity pressure exposure coefficient, see Section 32.10.1;
K_e = Ground elevation factor, see Section 32.9;
V_T = Tornado speed, see Section 32.5; and
q_{zT} = Tornado velocity pressure at height z.

The velocity pressure at mean roof height shall be computed as $q_{hT} = q_{zT}$ evaluated from Equation (32.10-1) using K_{zTor} at mean roof height h.

32.12 TORNADO ENCLOSURE CLASSIFICATION

32.12.1 General For the purpose of determining internal pressure coefficients for tornadoes, buildings and other structures for which tornado internal pressure coefficients, (GC_{piT}), apply shall have an enclosure classification assigned in accordance with this section. If a building or other structure satisfies both the "open" and "partially enclosed" tornado enclosure classification definitions, it shall be classified as a "partially open" building or other structure.

32.12.2 Openings To assign the tornado enclosure classification, the amount of openings in the building envelope shall be determined by taking each wall of the building or other structure, assuming it functions as the windward wall, and summing the total area of openings present with respect to the area of the remaining building envelope. Buildings shall be classified as enclosed, partially enclosed, partially open, or open as defined in Section 26.2. Other structures shall be classified as sealed, as defined in Section 32.2, or enclosed, partially enclosed, partially open, or open as defined in Section 26.2.

Where not required by Section 32.12.3 to protect glazed openings, enclosed buildings and other structures shall either (1) be reevaluated for classification as partially enclosed, with all unprotected glazed openings on each assumed windward wall considered as openings; or (2) be protected in accordance with Section 32.12.3.1.

32.12.3 Protection of Glazed Openings Glazed openings shall be protected as specified in this section for Essential Facilities and for buildings and other structures required to maintain the functionality of Essential Facilities.

32.12.3.1 Protection Requirements for Glazed Openings Glazing in buildings requiring protection shall be protected with an impact-protective system or shall be impact-resistant glazing. Impact-protective systems shall be either (a) permanently affixed non-operable systems or (b) permanently affixed operable systems capable of being fully deployed from inside the building within five minutes and used in buildings that are staffed 24 hours per day.

Impact-protective systems and impact-resistant glazing shall be subjected to missile tests in accordance with ASTM E1996 using missile level D or E as described in Table 2 of ASTM E1996. Testing to demonstrate compliance with ASTM E1996 shall be in accordance with ASTM E1886. Impact-resistant glazing and impact-protective systems shall comply with the pass/fail criteria of Section 7 of ASTM E1996. Glazing in sectional doors, rolling doors, and flexible doors shall be subjected to missile tests in accordance with ANSI/DASMA 115 as applicable. Glazing and impact-protective systems shall comply with the "Enhanced Protection" requirements of Table 3 of ASTM E1996, with tornado speed used in place of basic wind speed for determination of wind zone.

EXCEPTION: Other testing methods and/or performance criteria are permitted to be used where approved.

32.13 TORNADO INTERNAL PRESSURE COEFFICIENTS

Tornado internal pressure coefficients, (GC_{piT}), shall be determined from Table 32.13-1 based on building and other structure enclosure classifications determined in accordance with Section 32.12.1.

Minimum Design Loads and Associated Criteria for Buildings and Other Structures 357

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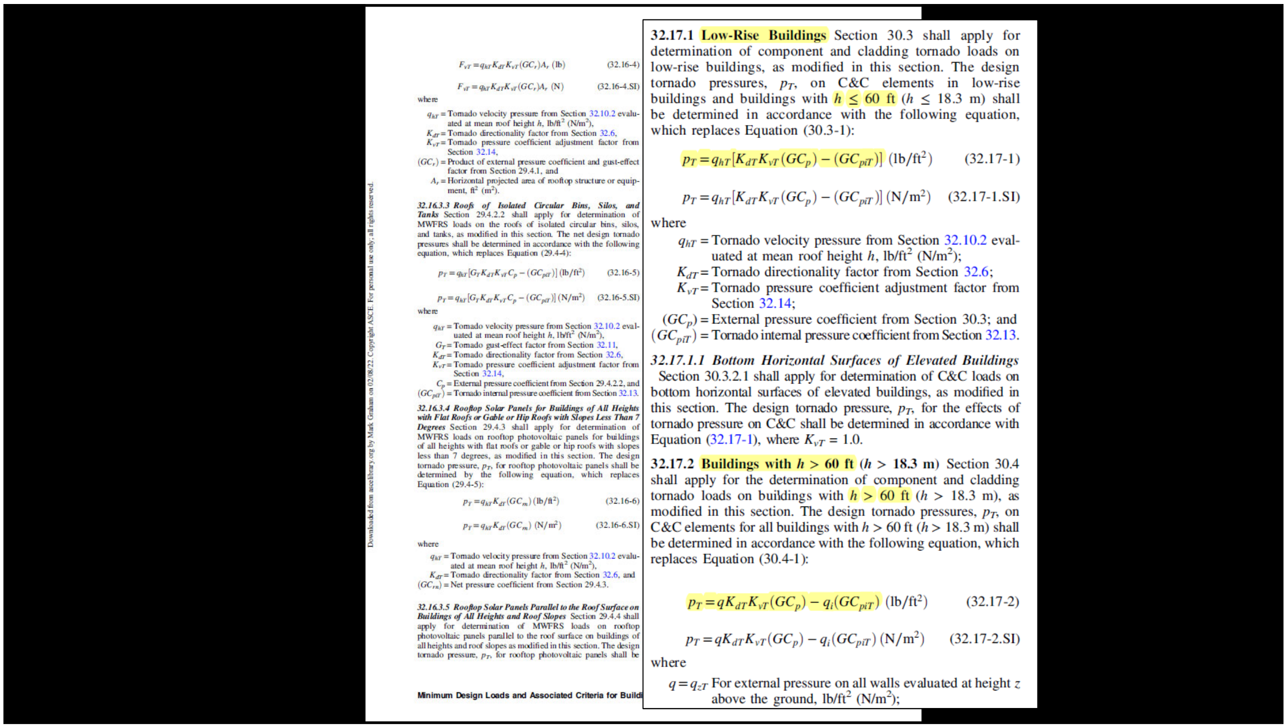

$$F_{vT} = q_{hT} K_{dT} K_{vT} (GC_r) A_r \text{ (lb)} \quad (32.16\text{-}4)$$

$$F_{vT} = q_{hT} K_{dT} K_{vT} (GC_r) A_r \text{ (N)} \quad (32.16\text{-}4.\text{SI})$$

where

q_{hT} = Tornado velocity pressure from Section 32.10.2 evaluated at mean roof height h, lb/ft^2 (N/m^2),
K_{dT} = Tornado directionality factor from Section 32.6,
K_{vT} = Tornado pressure coefficient adjustment factor from Section 32.14,
(GC_r) = Product of external pressure coefficient and gust-effect factor from Section 29.4.1, and
A_r = Horizontal projected area of rooftop structure or equipment, ft^2 (m^2).

32.16.3.3 Roofs of Isolated Circular Bins, Silos, and Tanks Section 29.4.2.2 shall apply for determination of MWFRS loads on the roofs of isolated circular bins, silos, and tanks, as modified in this section. The net design tornado pressures shall be determined in accordance with the following equation, which replaces Equation (29.4-4):

$$p_T = q_{hT}[G_T K_{dT} K_{vT} C_p - (GC_{piT})] \text{ (lb/ft}^2) \quad (32.16\text{-}5)$$

$$p_T = q_{hT}[G_T K_{dT} K_{vT} C_p - (GC_{piT})] \text{ (N/m}^2) \quad (32.16\text{-}5.\text{SI})$$

where

q_{hT} = Tornado velocity pressure from Section 32.10.2 evaluated at mean roof height h, lb/ft^2 (N/m^2),
G_T = Tornado gust-effect factor from Section 32.11,
K_{dT} = Tornado directionality factor from Section 32.6,
K_{vT} = Tornado pressure coefficient adjustment factor from Section 32.14,
C_p = External pressure coefficient from Section 29.4.2.2, and
(GC_{piT}) = Tornado internal pressure coefficient from Section 32.13.

32.16.3.4 Rooftop Solar Panels for Buildings of All Heights with Flat Roofs or Gable or Hip Roofs with Slopes Less Than 7 Degrees Section 29.4.3 shall apply for determination of MWFRS loads on rooftop photovoltaic panels for buildings of all heights with flat roofs or gable or hip roofs with slopes less than 7 degrees, as modified in this section. The design tornado pressure, p_T, for rooftop photovoltaic panels shall be determined by the following equation, which replaces Equation (29.4-5):

$$p_T = q_{hT} K_{dT} (GC_m) \text{ (lb/ft}^2) \quad (32.16\text{-}6)$$

$$p_T = q_{hT} K_{dT} (GC_m) \text{ (N/m}^2) \quad (32.16\text{-}6.\text{SI})$$

where

q_{hT} = Tornado velocity pressure from Section 32.10.2 evaluated at mean roof height h, lb/ft^2 (N/m^2),
K_{dT} = Tornado directionality factor from Section 32.6, and
(GC_m) = Net pressure coefficient from Section 29.4.3.

32.16.3.5 Rooftop Solar Panels Parallel to the Roof Surface on Buildings of All Heights and Roof Slopes Section 29.4.4 shall apply for determination of MWFRS loads on rooftop photovoltaic panels parallel to the roof surface on buildings of all heights and roof slopes as modified in this section. The design tornado pressure, p_T, for rooftop photovoltaic panels shall be

Minimum Design Loads and Associated Criteria for Buildi

32.17.1 Low-Rise Buildings Section 30.3 shall apply for determination of component and cladding tornado loads on low-rise buildings, as modified in this section. The design tornado pressures, p_T, on C&C elements in low-rise buildings and buildings with $h \le 60$ ft ($h \le 18.3$ m) shall be determined in accordance with the following equation, which replaces Equation (30.3-1):

$$p_T = q_{hT}[K_{dT} K_{vT} (GC_p) - (GC_{piT})] \text{ (lb/ft}^2) \quad (32.17\text{-}1)$$

$$p_T = q_{hT}[K_{dT} K_{vT} (GC_p) - (GC_{piT})] \text{ (N/m}^2) \quad (32.17\text{-}1.\text{SI})$$

where

q_{hT} = Tornado velocity pressure from Section 32.10.2 evaluated at mean roof height h, lb/ft^2 (N/m^2);
K_{dT} = Tornado directionality factor from Section 32.6;
K_{vT} = Tornado pressure coefficient adjustment factor from Section 32.14;
(GC_p) = External pressure coefficient from Section 30.3; and
(GC_{piT}) = Tornado internal pressure coefficient from Section 32.13.

32.17.1.1 Bottom Horizontal Surfaces of Elevated Buildings Section 30.3.2.1 shall apply for determination of C&C loads on bottom horizontal surfaces of elevated buildings, as modified in this section. The design tornado pressure, p_T, for the effects of tornado pressure on C&C shall be determined in accordance with Equation (32.17-1), where $K_{vT} = 1.0$.

32.17.2 Buildings with $h > 60$ ft ($h > 18.3$ m) Section 30.4 shall apply for the determination of component and cladding tornado loads on buildings with $h > 60$ ft ($h > 18.3$ m), as modified in this section. The design tornado pressures, p_T, on C&C elements for all buildings with $h > 60$ ft ($h > 18.3$ m) shall be determined in accordance with the following equation, which replaces Equation (30.4-1):

$$p_T = qK_{dT} K_{vT} (GC_p) - q_i (GC_{piT}) \text{ (lb/ft}^2) \quad (32.17\text{-}2)$$

$$p_T = qK_{dT} K_{vT} (GC_p) - q_i (GC_{piT}) \text{ (N/m}^2) \quad (32.17\text{-}2.\text{SI})$$

where

$q = q_{zT}$ For external pressure on all walls evaluated at height z above the ground, lb/ft^2 (N/m^2);

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If the tornado loads are greater than the conventional wind loads, use the tornado loads as the basis for wind design

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A wind and tornado design example…

Hypothetical situation: A hospital (Risk Category IV) building with a 70 ft. mean roof height 343 square low-slope roof area is located in an urban (Exposure B) Tulsa, OK

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Solution:

Wind design:

	Wind Speed	Z_1 (Field)	Z_2 (Perimeter)	Z_3 (Corner)
Ult. method	120 mph	53 psf	77 psf	101 psf
ASD method	93 mph	**FM Class 75**		

Tornado design:

A_e=40,000 sq. ft.

	Wind Speed	Z_1 (Field)	Z_2 (Perimeter)	Z_3 (Corner)
Ult. method	107 mph	61 psf	81 psf	107 psf
ASD method	--	**FM Class 75**		

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Impact of effective area (A_e)

A_e=40,000 sq. ft.

	Wind Speed	Z_1 (Field)	Z_2 (Perimeter)	Z_3 (Corner)
Ult. method	103 mph	61 psf	81 psf	107 psf
ASD method	--	**FM Class 75**		

A_e=100,000 sq. ft.

	Wind Speed	Z_1 (Field)	Z_2 (Perimeter)	Z_3 (Corner)
Ult. method	107 mph	65 psf	87 psf	115 psf
ASD method	--	**FM Class 90**		

A_e=250,000 sq. ft.

	Wind Speed	Z_1 (Field)	Z_2 (Perimeter)	Z_3 (Corner)
Ult. method	113 mph	73 psf	97 psf	128 psf
ASD method	--	**FM Class 90**		

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Impact of effective area (A_e) - continued

A_e=1,000,000 sq. ft.

	Wind Speed	Z_1 (Field)	Z_2 (Perimeter)	Z_3 (Corner)
Ult. method	125 mph	89 psf	119 psf	156 psf
ASD method	--	**FM Class 120**		

A_e=4,000,000 sq. ft.

	Wind Speed	Z_1 (Field)	Z_2 (Perimeter)	Z_3 (Corner)
Ult. method	138 mph	109 psf	145 psf	191 psf
ASD method	--	**FM Class 135**		

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While ASCE 7-22's wind load provisions are relatively manageable, the tornado provisions, where applicable, can get rather complex.

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Roof Wind Designer

www.roofwinddesigner.com

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What about FM Global-insured buildings?

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FM Global
Property Loss Prevention Data Sheets **1-28**

October 2015
Interim Revision January 2024
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WIND DESIGN

INSUREDS OF FM GLOBAL SHOULD CONTACT THEIR LOCAL FM GLOBAL OFFICE BEFORE BEGINNING ANY ROOFING WORK.

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FM Global

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FM 1-28, "Wind design"

- Intended to apply to FM Global-insured buildings
- ASD basic wind speed maps and design method
- Some ultimate design concepts (e.g., zones)
- Importance Factor = 1.15
- Tornado provisions added

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WIND DESIGN

INSUREDS OF FM GLOBAL SHOULD CONTACT THEIR LOCAL FM GLOBAL OFFICE BEFORE BEGINNING ANY ROOFING WORK.

Table of Contents

1.1 Changes

January 2024. Interim revision. The following changes were made:

A. The tornado guidance formerly in Appendix D has been transferred to new Sections 2.11 and 3.12, and to existing Section 4.2. All tables, figures and equations have been re-numbered to the new sections. Appendix D has been deleted in its entirety.

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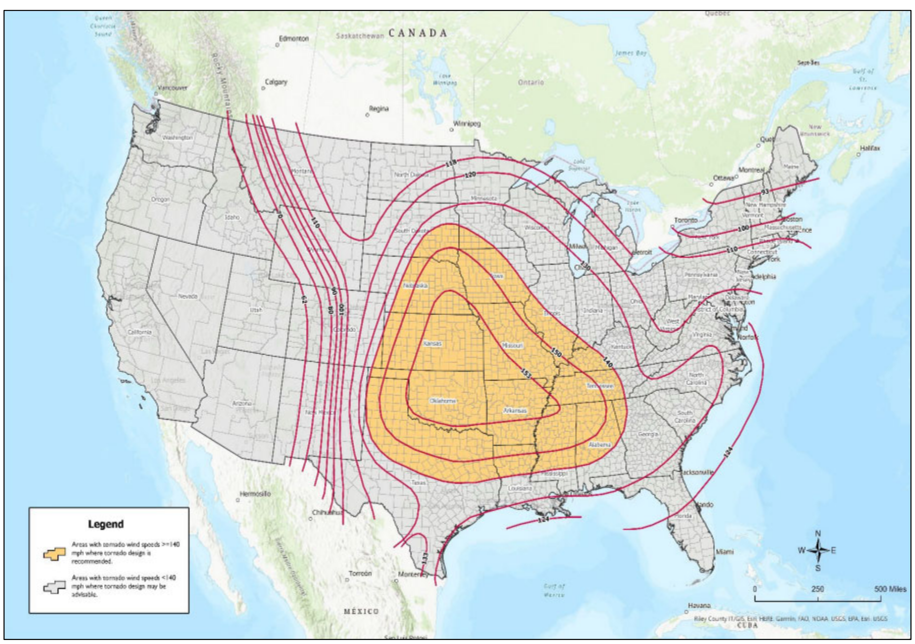

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Tornado design recommendations

FM 1-28, Sec. 2.11-Tornados

- Assume “partially enclosed” and Exposure C
- Avoid the use of windows
  - When windows are provided, use FM 4350 Level D or E impact-resistant glazing
- Limit other exterior wall openings (e.g., doors)
  - Doors should open outward and have positive latching
- Do not use aggregate on roofs
- Consider full-time QAO during exterior wall and roof application

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Wind Design 1-28

FM Global Property Loss Prevention Data Sheets Page 45

3.12.4.5 Design Wind Speeds and Wind Pressures

The guidance in this document is primarily for locations on the map in Figure 2.11.1 with wind speeds of 140 mph (62 m/s) and greater. If desired by the client or account team, design guidance can be given for locations on the map with wind speeds less than 140 mph (62 m/s).

Note: The cost increase to change from a 90 mph (40 m/s) design wind speed (as is the case with the majority of the central United States) to a higher tornado wind design will vary, depending on geography, the specific design criteria, percentage of windows, etc. Increased construction costs for components and cladding are expected in areas not normally designed for increased wind speeds. This cost increase could be as high as 50%.

Similar to what occurs with hurricanes, most tornado damage is much greater to the building envelope than to the building frame. Using an importance factor of 1.15 (based on ASCE 7-05), some larger structures designed for more typical code-required wind speeds (≥ 90 mph [40 m/s]), have experienced considerable damage to the building envelope, yet limited damage to the structural frame. One cost-effective approach would be to provide a limited increase in design strength for the building frame, but a considerable increase in resistance for the building envelope.

GC_{piT} = Tornado Internal pressure coefficient (use +/- 0.55 for partially enclosed)

Since the value of p_T is based off of an ultimate 10,000-year MRI wind speed, convert to an allowable/design pressure by multiplying by 0.6. For plan review/new construction, a safety factor of 2.0 should be applied.

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FM Global's tornado design provisions are more stringent than IBC 2024's and ASCE 7-22's

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Some useful references

Tornado design

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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.

FEMA NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY U.S. DEPARTMENT OF COMMERCE

January 2023 - 1

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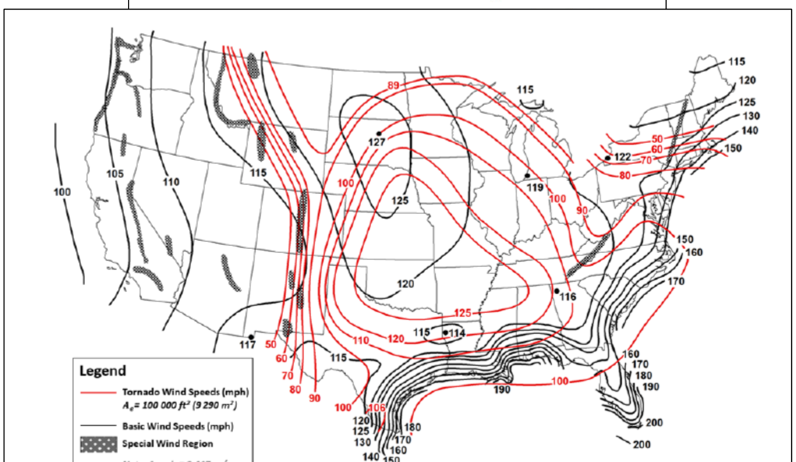
NIST Technical Note 2214

Economic Analysis of ASCE 7-22 Tornado Load Requirements



Basic wind speeds shown are based on Risk Category IV

Link

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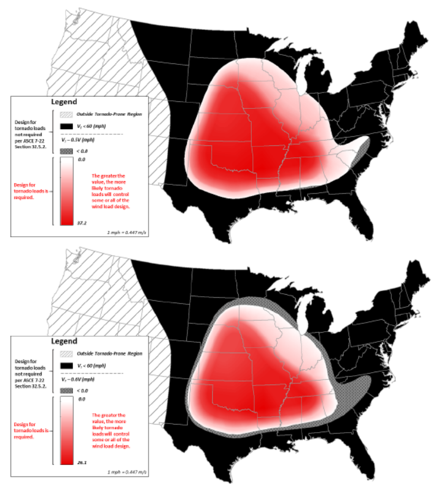

Fig. 8. Map of likelihood that design for tornado loads is required for a Risk Category III A_e = 100 000 ft^2 (9290 m^2) building or other structure in Exposure B (top) and Exposure C (bottom)

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LinkedIn: linkedin.com/in/MarkGrahamNRCA

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COLORADO ROOFING ASSOCIATION

Denver, Colorado -- December 12, 2024

Roofing Technical Update

presented by

Mark S. Graham
Vice President, Technical Services
National Roofing Contractors Association (NRCA)

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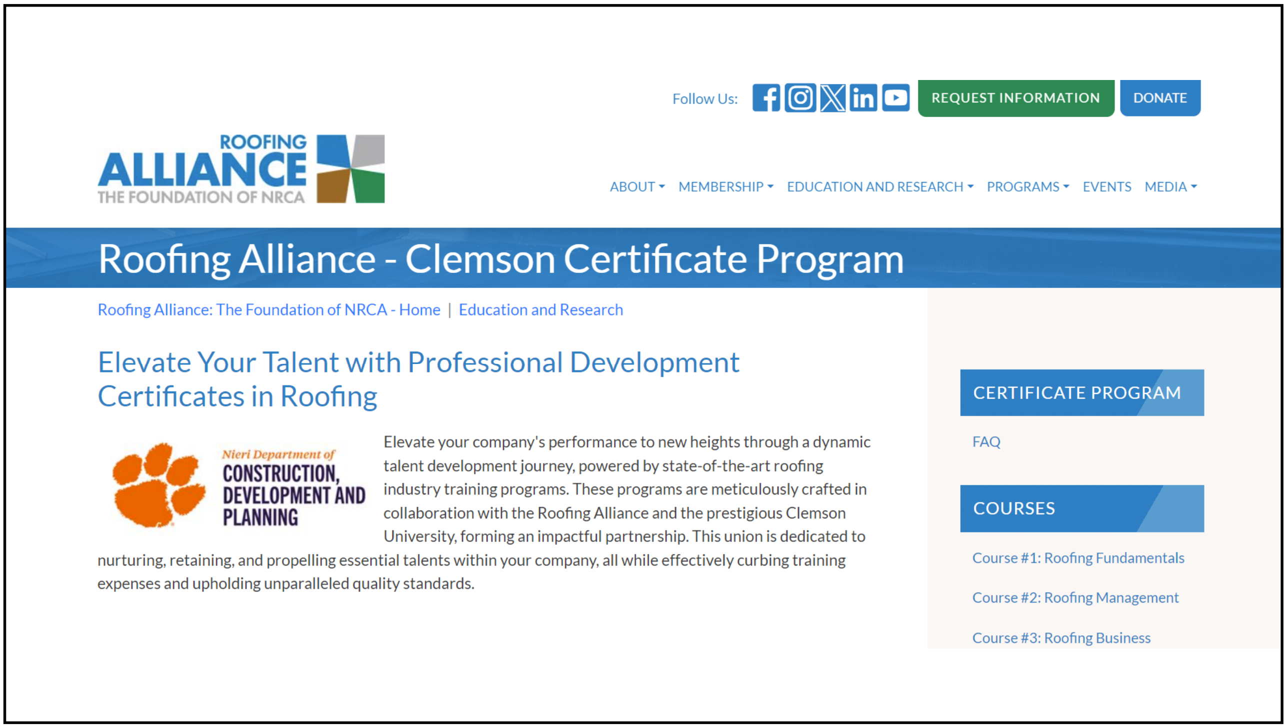
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Course #2: Roofing Management
Course #3: Roofing Business

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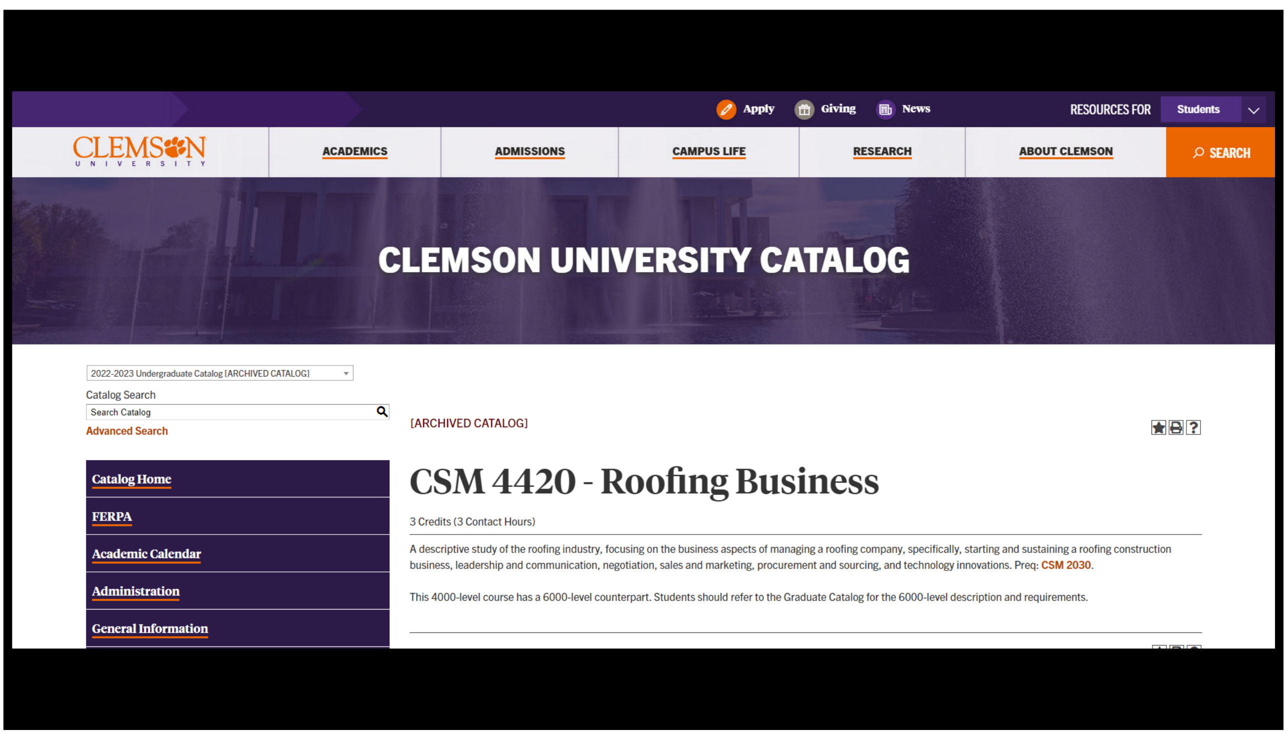
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CSM 4420 - Roofing Business
3 Credits (3 Contact Hours)
A descriptive study of the roofing industry, focusing on the business aspects of managing a roofing company, specifically, starting and sustaining a roofing construction business, leadership and communication, negotiation, sales and marketing, procurement and sourcing, and technology innovations. Preq: CSM 2030.
This 4000-level course has a 6000-level counterpart. Students should refer to the Graduate Catalog for the 6000-level description and requirements.

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"Fully" adhered

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TECH TODAY

The fully adhered misnomer

Terminology can create unrealistic expectations within the roofing industry

by Mark S. Graham

The term "fully adhered" is used by some manufacturers and specifiers to identify adhered single-ply membrane roof system configurations or refer to the adhesion of rigid board insulation to underlying substrates. But this terminology can create application and performance expectations that are unrealistic and likely cannot be achieved.

NRCA recommends the term "fully adhered" be avoided

Definitions

When considering the term "fully adhered," it is important to realize it is not specifically defined by the U.S. roofing industry.

The industry's consensus-based terminology standard, ASTM D1079, "Standard Terminology Relating to Roofing and Waterproofing," does not include terms or definitions for fully adhered, adhered or adhesion.

Similarly, the glossary contained in the appendix of *The NRCA Roofing Manual: Architectural Metal Flashing, Condensation and Air Leakage Control, and Reroofing—2014* does not contain a specific definition for the term fully adhered. The manual defines "adhere" as: "To cause two surfaces to be held together by the combined strength of the molecular forces and the mechanical interlocking achieved between adhesive and the bonded surface … ."

Merriam-Webster defines adhere (and its derivatives adhered and adhering) as "to hold fast or stick by or as if by gluing, suction, grasping, or fusing." Similarly, the term "fully" is defined as "in a full manner or degree; complete."

Although not specifically defined, the implication of fully adhered is 100 percent adhesion between two surfaces or materials.

Realistic expectations

Experienced roofing industry professionals realize the expectation of complete adhesion between two surfaces such as a single-ply membrane and underlying rigid board insulation is unrealistic and likely cannot be achieved in field applications.

Taken at its most literal sense, complete adhesion between a single-ply membrane and a rigid board insulation substrate is impossible because there will not be membrane adhesion at the insulation boards' joints.

Also, thickness variability in insulation boards and its effect on adhesion needs to be considered. For example, the U.S. product standard for polyisocyanurate insulation, ASTM C1289, "Standard Specification for Faced Rigid Cellular Polyisocyanurate Thermal Insulation Board," permits a board thickness tolerance of ±1/8-inch and crushing and depressions up to 1/8 of an inch in depth on up to 10 percent of a polyisocyanurate insulation board's surface area. Because reinforced single-ply membranes tend to lay relatively flat, having an adhered membrane application readily conform to and remain completely adhered to the recognized irregularities in insulation boards is unlikely.

Irregular, nonsmooth roof deck surfaces create similar situations. Because board-type insulation is relatively rigid, it generally will not readily conform to irregularities in roof deck substrates. Individual rigid boards tend to rest on the high points in a roof deck's finished surface and span the low points.

As a result, rigid board insulation seldom is completely adhered to roof deck substrates. It generally is adhered at the relative high points in the roof deck's surface and may be partially or marginally adhered and even unadhered at the relative low points. Specifying smaller insulation board sizes (4 by 4 feet instead of 4 by 8 feet) generally is suggested to minimize rigid insulation boards from spanning substrate low-point irregularities.

In practice

The concept of lacking 100 percent, complete adhesion between two adhered surfaces is not new to the roofing industry; it has long been recognized in the application of built-up roof membranes where voids between plies can occur. To address this, NRCA's *Quality Control Guidelines for the Application of Built-up Roofing* indicates interply moppings are intended to be continuous; however, voids of limited size are permitted provided overlapping voids do not occur between two or more plies. NRCA has maintained this position since the late 1970s, and it has become well-accepted by the roofing industry.

As it applies to adhering rigid board insulation in continuously applied adhesive applications, actual adhesion rates of about 60 to 90 percent are common (even less in some specific instances) in successfully performing adhered roof systems.

On this basis, NRCA recommends the term "fully adhered" be avoided and suggests the term "adhered" for field applications because it is more realistic.

MARK S. GRAHAM is NRCA's vice president of technical services.

Professional Roofing

January 2017

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Nighttime tie-in and night seal considerations

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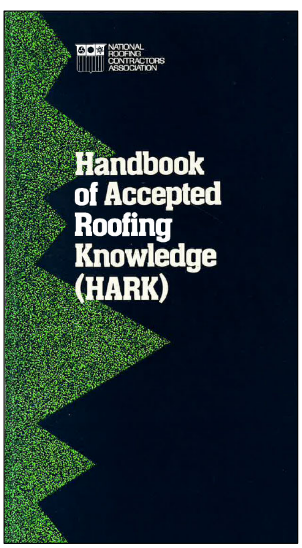

XXI. WATER CUTOFFS AND WEATHER PROTECTION

Water cutoffs are temporary felt courses that are installed to prevent moisture from entering the insulation and membrane during construction. They should be applied at the end of each day's work and whenever work is halted for an indefinite period to protect the membrane from precipitation. They must be removed prior to installing additional insulation.

Temporary flashings should be installed as weather protection if permanent flashings are not in place. All openings in the membrane should be sealed to prevent any moisture from entering the roof system before completing membrane application.

Specifications requiring gravel installation each day are unrealistic and sometimes detrimental to the quality of the completed roof. Where working conditions permit, roofing felts should be "glazed" and sealed at the end of each day's work if final surfacing is not installed.

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With single-ply membrane systems, nighttime tie-ins and night seals have gotten more difficult…

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Some considerations

Nighttime tie-ins and night seals

- Project specific planning…
- Get back to the basics…
  - Water cut-off
  - Night seals
- SA underlayment and base sheet products can work well for cut-offs

Concepts to share?

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Roof deck loading considerations

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Some examples of roof loading

- Pallet of asphalt shingles (42 bundles): 2,500 to 4,200 lbs.
- Pallet of TPO membrane rolls: 1,400 to 3,450 lbs.
- Pallet of MB cap sheet (20 rolls): About 2,500 lbs.
- Pallet of glass-faced gypsum board (4 x 4): 1,600 to 2,400 lbs.
- Pallet of bonding adhesive (45 pails): 1,800 lbs.
- Bundle of polyiso. (4 x 8): 250 to 500 lbs.

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University of Massachusetts – Amherst

"Roof Live Loads for Low-Slope Roofs"

Joint research

Metal Building Manufacturers Association

National Roofing Contractors Association

Steel Deck Institute

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Some initial considerations

Roof deck loading concerns

- Roofing operations may exceed live load capacity
- Note joist/framing orientation
- Consider avoiding adjacent load placement
- Position loads across joists/framing
- Consider added dunnage across framing
- Also consider rooftop equipment weight

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Radio frequency radiation

Rooftop cell phone transmitters

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CRCA Advisory Bulletin

JUNE 2023

Radiofrequency Radiation and Electromagnetic Fields

The increased number of cellular antennas and other communication equipment that generates radiofrequency radiation (RF) and electromagnetic fields (EMF) may be exposing roofers and other contractors to harmful levels of radiations when working on rooftops, sides of buildings and other locations where RF generating antennas are located. This bulletin will focus on radiation types, safety limits and mitigating exposure.

With the ever-increasing use and development of communication technology, there is an increased risk for those working in and around communication devices and equipment that emit radiofrequency electromagnetic fields (EMF) such as smart meters, cell phone towers and equipment using 5G technology. Roof areas are often prime locations for this type of equipment and anyone accessing these roof areas for any reason should be aware of the Occupational Health and Safety requirements and the Safety Code 6. Consult with provincial and/or federal authorities having jurisdiction for further information/guidance for most stringent requirements.

What is Radiofrequency (RF) Radiation?

There are two types of radiation – ionizing radiation and non-ionizing radiation. Both are forms of electromagnetic energy, but ionizing radiation has more energy than non-ionizing radiation. Ionizing radiation, like x-rays or gamma rays, has enough energy to cause chemical changes by breaking chemical bonds. Sources of this type of radiation can be found in hospitals, nuclear energy plants, and nuclear weapons facilities. Non-ionizing radiation causes molecules to vibrate, which generates heat. RF radiation is a type of non-ionizing radiation and is the energy used to transmit wireless information. RF radiation is invisible and power levels of equipment and amount of RF radiation can fluctuate without warning.

About Safety Code 6

Health Canada publishes Safety Code 6[1] which sets out recommended safety limits for human exposure to radiofrequency electromagnetic fields (EMF) in the frequency range from 3 kHz to 300 GHz. This range covers the frequencies used by communications devices and equipment that emit radiofrequency EMF such as: Wi-Fi, cell phones, smart meters, cell phone towers, those using 5G technology.

Safety Code 6 is reviewed on a regular basis to confirm that it continues to provide protection against all known potentially adverse health effects. If new scientific evidence were to show that exposure to radiofrequency EMF below the levels found in Safety Code 6 poses a risk, the Government of Canada would take steps to protect the health of Canadians.

[1] https://www.canada.ca/en/health-canada/services/health-risks-safety/radiation/occupational-exposure-regulations/safety-code-6-radiofrequency-exposure-guidelines.html

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June 2023

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How protect yourself from RF radiation
The risks associated with RF radiation increases with the number of devices present, the closer a worker is to the equipment/device(s), and the more time that is spent in the area. Workers can protect themselves by the following:

How protect yourself from RF radiation

The risks associated with RF radiation increases with the number of devices present, the closer a worker is to the equipment/device(s), and the more time that is spent in the area. Workers can protect themselves by the following:

- Complete a visual assessment of the area to determine if cellular antennas or other RF radiation generating antennas are present. If you are not sure, ask your supervisor, the building owner, or the property manager if RF-generating antennas are present where you need to work. The building owner or property manager should have the information, or know whom to contact for information about antennas, their locations, and the RF radiation levels.
- Look for warning signs posted near RF antennas; the signs should identify the hazard and tell you where to get more information.
- Contact the building owner/manager and the antenna licensee to have the equipment temporarily powered down or moved.

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Recognize the signage

Photos courtesy of Peter Shackford—Hettrick, Cyr & Associates, Inc.

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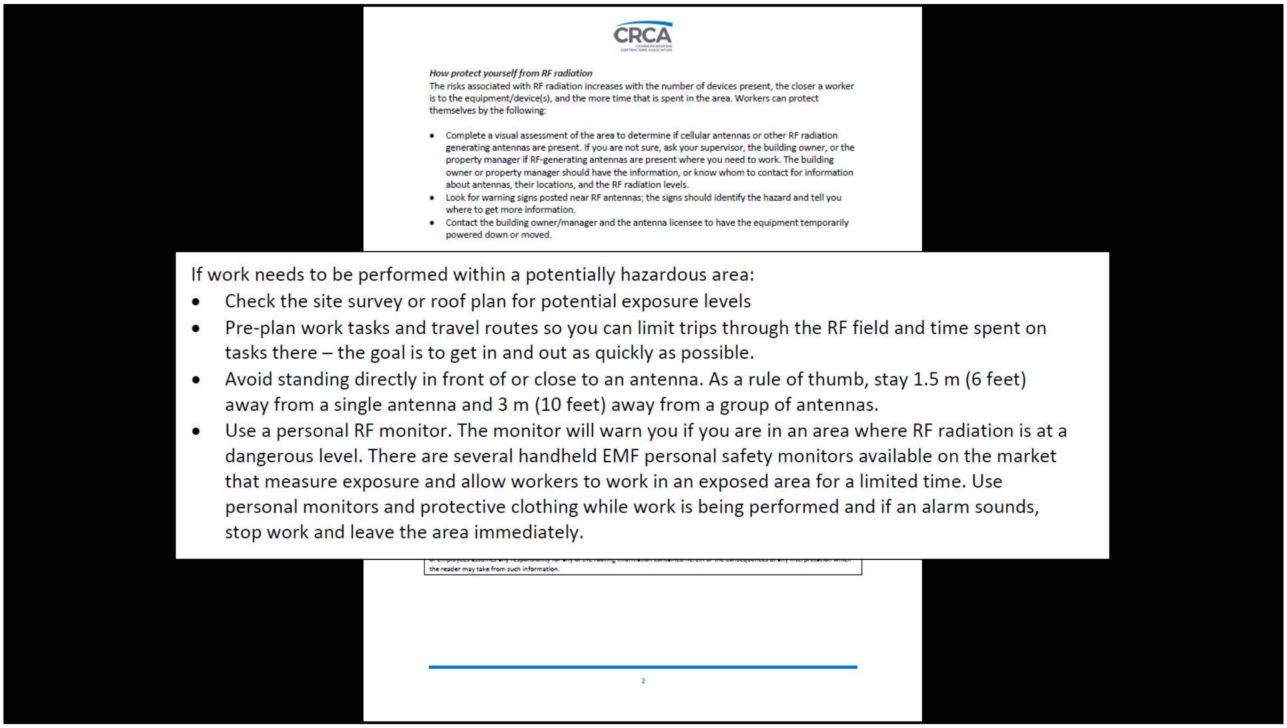

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How protect yourself from RF radiation

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- Look for warning signs posted near RF antennas; the signs should identify the hazard and tell you where to get more information.
- Contact the building owner/manager and the antenna licensee to have the equipment temporarily powered down or moved.

If work needs to be performed within a potentially hazardous area:

- Check the site survey or roof plan for potential exposure levels
- Pre-plan work tasks and travel routes so you can limit trips through the RF field and time spent on tasks there – the goal is to get in and out as quickly as possible.
- Avoid standing directly in front of or close to an antenna. As a rule of thumb, stay 1.5 m (6 feet) away from a single antenna and 3 m (10 feet) away from a group of antennas.
- Use a personal RF monitor. The monitor will warn you if you are in an area where RF radiation is at a dangerous level. There are several handheld EMF personal safety monitors available on the market that measure exposure and allow workers to work in an exposed area for a limited time. Use personal monitors and protective clothing while work is being performed and if an alarm sounds, stop work and leave the area immediately.

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TOOLBOXTALKS

Radio frequency (RF) hazards

According to the Federal Communications Commission (FCC), radio waves and microwaves emitted by transmitting antennae are one form of electromagnetic energy that harm people. Harm from RF exposure will vary according to power levels, length of exposure time and distance from the antennae. Sources of RF energy on a rooftop often are not obvious and usually are not properly marked or defined as danger zones by warning signs. In many cases, antennae are hidden by building elements so workers may not be aware of their presence. Here are some important facts about RF energy and things that you can do to avoid it:

- High levels of RF may heat body tissue and increase body temperature, causing tissue damage because the body cannot cool quickly enough to prevent damage. This is called RF's thermal effects, and your eyes are the most vulnerable part of your body. Actual contact may cause a shock or burn.
- At lower, nonthermal levels of RF exposure, nervous system and immune system problems, kidney damage, neurological disorders and even some cancers may occur.
- Become familiar with what RF transmitters or antennae look like and the dangers of working near them. Be aware that warning signs for RF transmitters may not always be present on a roof.
- Your employer must inquire as to the presence of RF equipment and whether it may be shut down or shielded or other barrier device installed for the duration of the work period roofing workers will be in proximity to the transmitter.
- Symptoms of RF exposure often seem the same as physical exertion and can become heat exhaustion or heat stroke. Removing a worker from the area and cooling the body is important. Trained, professional medical care of the symptoms is critical.

National Roofing Contractors Association TOOLBOXTALKS www.nrca.net 219

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Some useful references

- CRCA Advisory Bulletin (Link)
- Health Canada's Safety Code 6 (Link)
- Federal Communications Commission (Link)
- Center for Construction Research and Training (Link)

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RESEARCH+TECH

Plywood or OSB?

Moisture-related concerns exist with wood structural panels

by Mark S. Graham

NRCA's technical services staff continues to hear from roofing contractors experiencing moisture-related dimensional stability problems with plywood and oriented strand board structural panel sheathing used with steep-slope roof systems. Following is a brief discussion of moisture mechanics, linear expansion and thickness swell testing, and NRCA's recommendations for plywood and OSB structural panel sheathing roof decks.

Moisture mechanics

Plywood and OSB sheathing, similar to all wood products, are hygroscopic, meaning they tend to absorb and release moisture from their surroundings.

When not exposed to direct wetting, structural panel sheathing's moisture content is a function of its environment's relative humidity and temperature. During construction and its service life, panels may be exposed to direct moisture. When exposed to direct wetting, structural panel sheathing's moisture content is influenced by wetting time and panel variables that affect capillarity, such as veneer species of plywood and wax additives in OSB.

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Standards for wood structural panels

International Residential Code, 2021 Edition

Plywood:

- U.S. Department of Commerce PS-1, "Structural Plywood"
- CSA Group O325, "Construction Sheathing"

Oriented-strand board (OSB):

- U.S. Department of Commerce PS-2, "Performance Standard for Wood-based Structural-use Panels"
- CSA Group O437, "Standards for OSB and Waferboard"

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Common, but not referenced in the Code

Plywood and OSB:

- APA-The Engineered Wood Association Standard PRP-108, "Performance Standards and Policies for Structural-Use Panels"

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Attachment of Wood Panels: The *International Residential Code, 2024 Edition's* Table R602.3(1)-Fastening Schedule provides minimum fastener and fastener spacing requirements for wood structural panels into roof framing shown in Figure 6.1.

Item	Description of building elements	Number and type of fasteners	Spacing of fasteners	
			Edges (inches)	Intermediate supports (inches)
Wood structural panels, roof sheathing to framing and particle board wall sheathing to framing				
31	3/8- to ½-inch-thick	6d common or deformed nail (2" x 0.113" x 0.281" head)	6	6
		8d common nail (2½" x 0.131" x 0.281" head), or RSRS-01 nail (2⅜" x 0.113" x 0.281" head)	6	6
32	19/32- to ¾-inch thick	8d common nail (2½" x 0.131" x 0.281" head), or RSRS-01 nail (2⅜" x 0.113" x 0.281" head)	6	6
33	7/8- to 1¼-inch thick	10d common nail (3" x 0.148" x 0.281" head), or 2½" x 0.131" x 0.281" head deformed nail	6	12

Figure 6-1. Roof sheathing-specific excerpt from International Residential Code, 2024 Edition's Table R602.3(1)-Fastening Schedule

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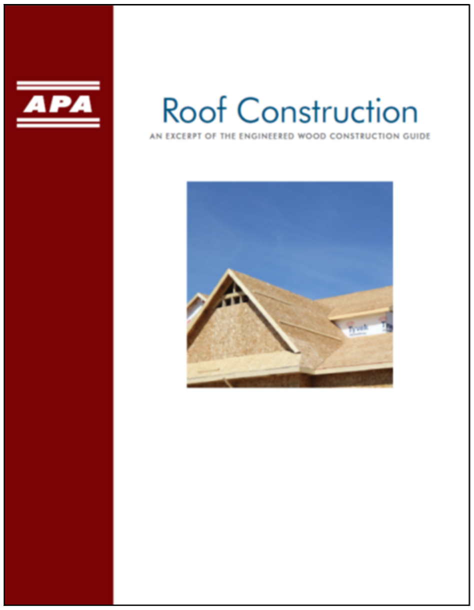

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APA Form E30, "Roof Construction"
--Roofing-specific excerpts from APA's *Engineered Wood Construction Guide* (102 pages)

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A Not-So-Perfect Storm:
The Convergence of Large Buildings, Wood Decks, and Mechanically Attached Low-Slope, Single-Ply Roofing Systems

ABSTRACT

Recent indicators suggest the potential need for additional design considerations when installing mechanically attached, low-slope, single-ply roof systems over oriented strand board (OSB) decking in large warehouse applications. Specifically, sustained wind uplift forces, building pressurization, or a combination of the two can sometimes coincide to subject the roof system to excessive stress. This, in turn, may cause the mechanical fasteners securing the roof to loosen or withdraw.

To gain a deeper understanding of the potential concerns associated with employing standard fastening patterns in such systems, we conducted a limited sampling of cyclic and dynamic testing. This limited sampling allowed us to formulate prospective conclusions on the potential effects of wind uplift and building pressurization on mechanical fastener pullout values.

This white paper is dedicated to exploring the potential performance of in-seam mechanical fastening patterns in OSB decking systems within large warehouse building environments when they are exposed to a variety of environmental conditions. Furthermore, we aim to provide suggestions for design professionals to consider when choosing to use a mechanically fastened single-ply roofing system over an OSB deck in large warehouse applications.

LEARNING OBJECTIVES

- Identify wind uplift and building pressurization issues with wood decks on large warehouse and industrial structures and the resulting effects on mechanically attached, single-ply roofing systems.
- Describe wind and pressure-related failures of single-ply roof systems on distribution centers in the western United States.
- Recognize variability in wood decking materials as well as the effect of pressure, cycling, and eccentric uplift forces in the acceleration of roof system failures.
- Explain design and installation best practices along with repair recommendations to reinforce roof system reliability.

SPEAKERS

Richard Gustin
Johns Manville, Denver, Colorado

Rick Gustin started his career as a roofing contractor before coming to Johns Manville (JM) in 1998, where he served as a field technical representative. He then held various roles, including technical services specialist, Six Sigma Black Belt, and application engineer before assuming responsibility as manager of Guarantee Services. In 2013, he became the EPDM product manager focusing on developing JM's offering. Today, Rick is the Owner Services Technical Manager responsible for large claims and technical marketing support. He holds a degree in mechanical engineering from Rensselaer Polytechnic Institute.

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March 8-11, 2024

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Considerations

Lumber, plywood and OSB

- Be extra cautious of plywood and OSB roof decks
- Limit your deck acceptance responsibilities
- Consider more proactive plywood and OSB deck replacement
- Consider pull tests for plywood and OSB roof decks when using mechanically-attached membrane systems

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Nailbase insulation considerations

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Nailbase insulation considerations

- Double layer design and application
- Taped joints can control vapor leaks/underlayment wrinkling at board joints
- Pressure-tested and FRT nailbase are not good ideas for nailbase

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RESEARCH + TECH

Photo courtesy of Atlas Roofing, Atlanta

Know the options

Proper specification is essential for nail-base insulation

by Mark S. Graham

In roof assembly configurations with nailable roof coverings, such as asphalt shingles and metal panels, factory-fabricated, nail-base insulation is becoming more common as a component of insulation entirely above the roof deck. Because nail-base insulation serves multiple functions, including being a roof covering substrate and thermal insulation layer, proper design and specification are essential for roof assembly performance.

The basics

Nail-base insulation is composed of a layer of rigid board insulation factory-adhered or laminated to a layer of structural wood panel sheathing, such as plywood or oriented strand board.

The U.S. product standard for nail-base insulation is ASTM C1289, "Standard Specification for Faced Rigid Cellular Polyisocyanurate Thermal Insulation Board," Type V. It provides requirements for a polyisocyanurate insulation foam core

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September 2024

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Questions submitted

- Are you good with the new synthetic underlayment standards? Should we be concern about moisture being trapped at the sheathing/decking.
- A couple of years ago you talked about doing an experiment, where you sealed a water container on top of asphalt shingles, and you couldn't believe how much water went through the shingle. Any follow up on that test?
- How many nail penetrations to OSB/plywood before you need to replace. Any code references to help with insurance claims or other?

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Additional questions

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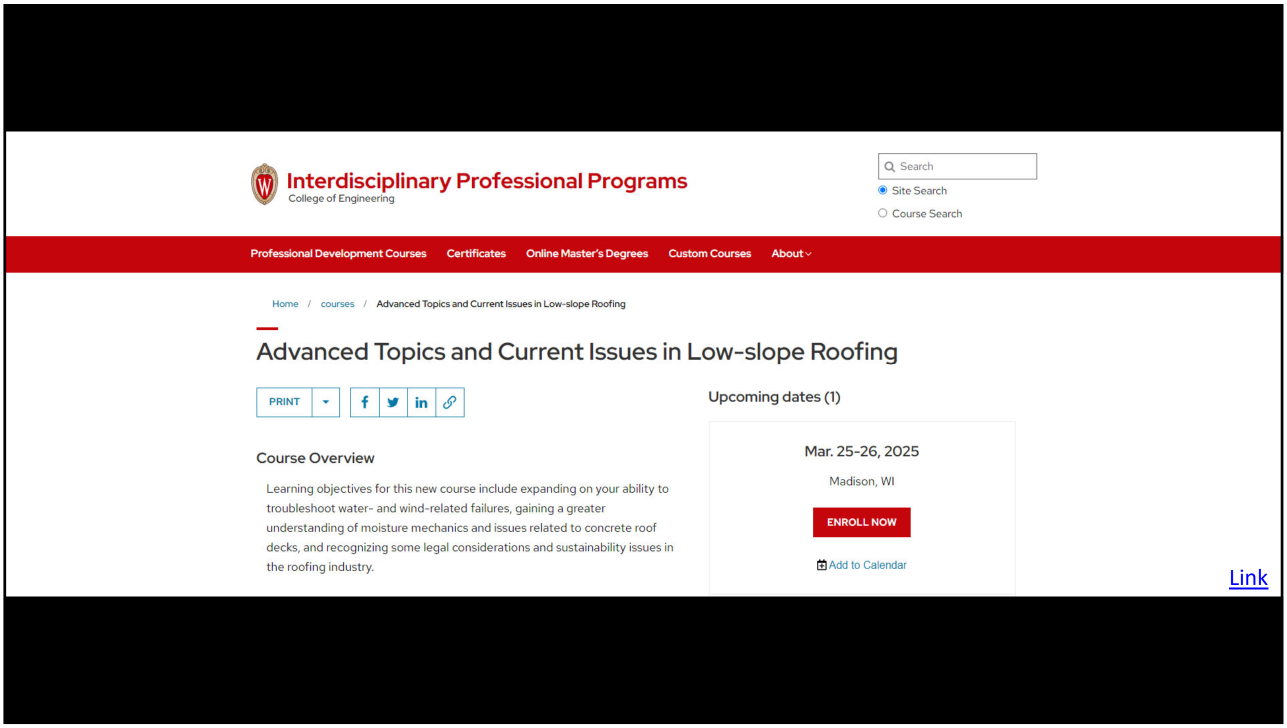

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Final reminders!

CRA
COLORADO
ROOFING ASSOCIATION

- Please fill out the survey and drop it at the registration desk with your badge when you leave today.
- If you did not sign-in, please be sure to stop and sign the check-in sheet so we can issue your CIUs appropriately for this event.

Thank You for attending!

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