Advanced Topics and Current Issues in Low-Slope Roofing
The University of Wisconsin Madison
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Wind design

presented by

Mark S. Graham
Vice President, Technical Services
National Roofing Contractors Association
Rosemont, Illinois

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Topics

Wind design

- Design wind loads
  - Code requirements
  - ASCE 7-22 (and earlier versions)
  - RoofWindDesigner.com
  - FM 1-28
    - RoofNav rating calculator
- Wind resistance
  - Code requirements
  - Test methods
  - Safety factors

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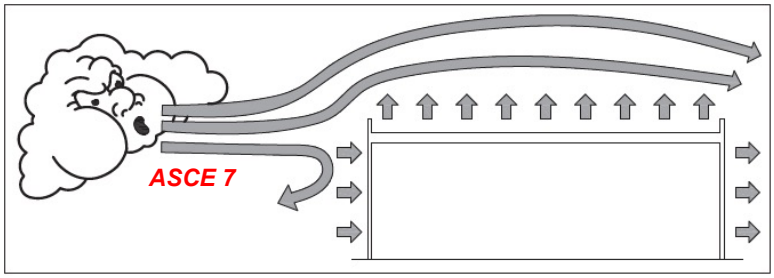
The fundamental concept



Wind creates pressures/forces on building elements…

…these forces are referred to as “Design wind loads”

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The fundamental concept -- continued

A roof system needs to be able to “resist” the design wind loads acting on a building.

- Roof systems are tested for their “resistance” (attachment, adhesion):
  - FM Approvals classifications (FM 1-60, 1-90, 1-120, etc.)
  - UL classifications (UL Class 30, 60, 90)
  - Engineering analysis

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The fundamental concept -- continued

Design wind loads ≤ Tested resistance*

ASCE 7 ≤ FM Approvals classification
or UL classification*
or engineering analysis*

** A "safety factor", typically 2.0 (i.e., 1/2 of tested resistance), is applied to ASD values to account for variations in designs, materials, application and roof system aging/deterioration.*

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Design wind loads

Wind design

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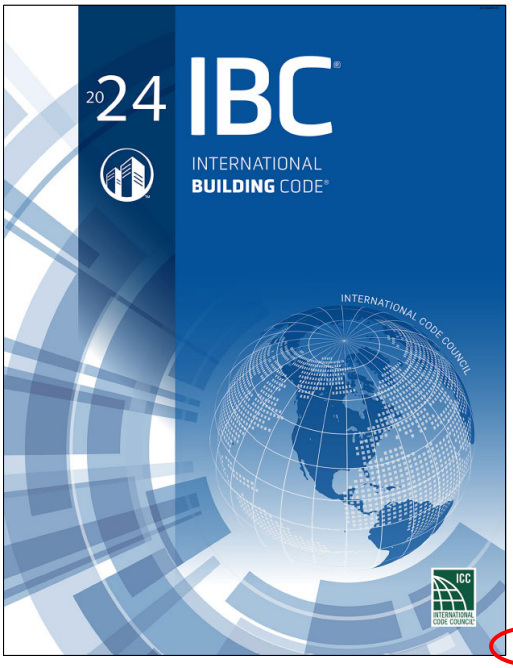

International Building Code, 2024 Edition

Link

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SECTION 1504—PERFORMANCE REQUIREMENTS

1504.1 Wind resistance of roofs. *Roof decks* and *roof coverings* shall be designed in accordance with Section 1504.

1504.2 Wind resistance of asphalt shingles. Asphalt shingles shall be tested in accordance with ASTM D7158. Asphalt shingles shall meet the classification requirements of Table 1504.2 for the appropriate maximum *basic wind speed*. Asphalt shingle packaging shall bear a *label* to indicate compliance with ASTM D7158 and the required classification in Table 1504.2.

Exception: Asphalt shingles not included in the scope of ASTM D7158 shall be tested and *labeled* in accordance with ASTM D3161. Asphalt shingle packaging shall bear a *label* to indicate compliance with ASTM D3161 and the required classification in Table 1504.2.

TABLE 1504.2—CLASSIFICATION OF STEEP SLOPE ROOF SHINGLES TESTED IN ACCORDANCE WITH ASTM D3161 OR D7158

MAXIMUM BASIC WIND SPEED, V, FROM FIGURES 1609.3(1)–(4) OR ASCE 7 (mph)	MAXIMUM ALLOWABLE STRESS DESIGN WIND SPEED, V_{asd}, FROM Table 1609.3.1 (mph)	ASTM D7158 CLASSIFICATION	ASTM D3161 or UL 7103 CLASSIFICATION
110	85	D, G or H	A, D or F
116	90	D, G or H	A, D or F
129	100	G or H	A, D or F
142	110	G or H	F
155	120	G or H	F
168	130	H	F
181	140	H	F
194	150	H	F

For SI: 1 foot = 304.8 mm, 1 mph = 0.447 m/s.
a. The standard calculations contained in ASTM D7158 assume Exposure Category B or C and building height of 60 feet or less. Additional calculations are required for conditions outside of these assumptions.

1504.3 Wind resistance of clay and concrete tile. Wind *loads* on clay and concrete tile *roof coverings* shall be in accordance with Section 1609.6.

1504.3.1 Testing. Testing of concrete and clay roof tiles shall be in accordance with Sections 1504.3.1.1, 1504.3.1.2 and 1504.3.1.3.

1504.3.1.1 Overturning resistance. Concrete and clay roof tiles shall be tested to determine their resistance to overturning due to wind in accordance with Chapter 15 and either SBCCI SSTD 11 or ASTM C1568.

1504.3.1.2 Wind tunnel testing. Where concrete and clay roof tiles do not satisfy the limitations in Chapter 16 for rigid tile, a wind tunnel test shall be used to determine the wind characteristics of the concrete or clay tile *roof covering* in accordance with Chapter 15 and either SBCCI SSTD 11 or ASTM C1569.

1504.3.1.3 Air permeability testing. The lift coefficient for concrete and clay tile shall be 0.2 or shall be determined in accordance with SBCCI SSTD 11 or ASTM C1570.

1504.4 Wind resistance of nonballasted roofs. *Roof coverings* installed on roofs in accordance with Section 1507 that are mechanically attached or adhered to the *roof deck* shall be designed to resist the design wind *load* pressures for components and cladding in accordance with Section 1609.6.2. The wind *load* on the *roof covering* shall be permitted to be determined using *allowable stress design*.

1504.4.1 Other roof systems. Built-up, modified bitumen, fully adhered or mechanically attached single-ply roof systems, metal panel roof systems applied to a solid or closely fitted deck and other types of membrane *roof coverings* shall be tested in accordance with FM 4474, UL 580 or UL 1897.

2. Metal roofs constructed of aluminum shall be permitted to be designed and tested in accordance with the applicable referenced structural design standard in Section 2002.1.

1504.4.3 Metal roof shingles. *Metal roof shingles* applied to a solid or closely fitted deck shall be tested in accordance with ASTM D3161, FM 4474, UL 580 or UL 1897. *Metal roof shingles* tested in accordance with ASTM D3161 shall meet the classification requirements of Table 1504.2 for the appropriate maximum *basic wind speed* and the metal shingle packaging shall bear a *label* to indicate compliance with ASTM D3161 and the required classification in Table 1504.2.

1504.4.4 Slate shingles. Slate shingles shall be tested in accordance with ASTM D3161. Slate packaging shall bear a *label* indicating compliance with ASTM D3161 and the required classification in Table 1504.2.

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ROOF ASSEMBLIES AND ROOFTOP STRUCTURES

1504.5 Ballasted low-slope single-ply roof systems. Ballasted *low-slope* single-ply roof system coverings installed in accordance with Section 1507.12 shall be designed in accordance with ANSI/SPRI RP-4.

1504.6 Edge systems for low-slope roofs. Metal edge systems, except gutters and counterflashing, installed on built-up, modified bitumen and single-ply roof systems on a *low-slope* roof shall be designed and installed for wind *loads* in accordance with Chapter 16 and tested for resistance in accordance with Test Methods RE-1, RE-2 and RE-3 of ANSI/SPRI ES-1, except *basic wind speed, V*, shall be determined from Figures 1609.3(1)through 1609.3(4), as applicable.

1504.6.1 Gutter securement for low-slope roofs. Gutters that are used to secure the perimeter edge of the roof membrane on *low-slope* built-up, modified bitumen, and single-ply roofs, shall be designed, constructed and installed to resist wind loads in accordance with Section 1609 and shall be tested in accordance with Test Methods G-1 and G-2 of SPRI GT-1.

Exception: Ballasted single-ply roof coverings shall be designed and installed in accordance with Section 1504.5.

TABLE 1504.8—MINIMUM REQUIRED PARAPET HEIGHT (INCHES) FOR AGGREGATE SURFACED ROOFS[a, b, c, d, e]

AGGREGATE SIZE	MEAN ROOF HEIGHT (ft)	WIND EXPOSURE AND BASIC WIND SPEED, *V* (MPH)																	
		Exposure B								Exposure C[f]									
		≤ 95	100	105	110	115	120	130	140	150	≤ 95	100	105	110	115	120	130	140	150
ASTM D1863 (No. 7 or No. 67)	15	2	2	2	2	12	12	16	20	24	2	13	15	18	20	23	27	32	37
	20	2	2	2	2	12	14	18	22	26	12	15	17	19	22	24	29	34	39
	30	2	2	2	13	15	17	21	25	30	14	17	19	22	24	27	32	37	42
	50	12	12	14	16	18	21	25	30	35	17	19	22	25	28	30	36	41	47
	100	14	16	19	21	24	27	32	37	42	21	24	26	29	32	35	41	47	53
	150	17	19	22	25	27	30	36	41	46	23	26	29	32	35	38	44	50	56
ASTM D1863 (No. 6)	15	2	2	2	2	12	12	12	15	18	2	2	2	13	15	17	22	26	30
	20	2	2	2	2	12	12	13	17	21	2	2	12	15	17	19	23	28	32
	30	2	2	2	2	12	12	16	20	24	2	12	14	17	19	21	26	31	35
	50	12	12	12	12	14	16	20	24	28	12	15	17	19	22	24	29	34	39
	100	12	12	14	16	19	21	26	30	35	16	18	21	24	26	29	34	39	45
	150	12	14	17	19	22	24	29	34	39	18	21	23	26	29	32	37	43	48

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 mile per hour = 0.447 mph.

a. Parapet height is measured vertically from the top surface of the coping down to the surface of the roof covering in the field of the roof adjacent to the parapet and outbound of any cant strip.

b. Interpolation shall be permitted for wind speed, mean roof height and parapet height. Extrapolation is not permitted.

c. Basic wind speed, *V*, and wind exposure shall be determined in accordance with Section 1609.

d. Where the minimum required parapet height is indicated to be 2 inches (51 mm), a gravel stop shall be permitted and shall extend not less than 2 inches (51 mm) from the roof surface and not less than the height of the aggregate.

e. The tabulated values apply only to conditions where the topographic factor (K_{zt}) determined in accordance with Chapter 26 of ASCE 7 is 1.0 or where K_{zt} is incorporated in the basic wind speed in Section 1609.

f. For Exposure D, add 8 inches (203 mm) to the parapet height required for Exposure C and the parapet height shall not be less than 12 inches (305 mm).

SECTION 1505—FIRE CLASSIFICATION

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[BF] 1505.1 General. Fire classification of roof assemblies shall be in accordance with Section 1505. The minimum fire classification of roof assemblies installed on buildings shall comply with Table 1505.1 based on type of construction of the building. Class A, B and C *roof assemblies* and *roof coverings* required to be *listed* by this section shall be tested in accordance with ASTM E108 or UL 790. In addition, *fire-retardant-treated wood roof coverings* shall be tested in accordance with ASTM D2898.

Exception: *Skylights and sloped glazing* that comply with Chapter 24 or Section 2610.

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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_{gsmin} using Equation 16-17.

Equation 16-17 $p_{gsmin} = 0.7p_g$

where:

p_{gsmin} = *Allowable stress design* ground snow load.

SECTION 1609—WIND LOADS

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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 permitted to be determined in accordance with Section 1609 or ASCE 7. Wind shall be assumed to come from any horizontal direction and wind pressures shall be assumed to act normal to the surface considered.

Exceptions:

1. Subject to the limitations of Section 1609.1.1.1, applicable Group R-2 and R-3 buildings.
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, provisions of AISI S230.
4. Designs using NAAMM FP
5. Designs using TIA-222 for graphic Category 2 escar
6. Wind tunnel tests in accordance with ASCE 7.
7. *Temporary structures* co

The wind speeds in Figures 1609. shall be converted in accordance with Section 1609.3.1 to *allowable stress d* standards referenced in Exceptions 4 and 5 are used.

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

IBC edition vs ASCE 7 edition

IBC 2012: ASCE 7-10
IBC 2015: ASCE 7-10
IBC 2018: ASCE 7-16
IBC 2021: ASCE 7-16
IBC 2024: ASCE 7-22

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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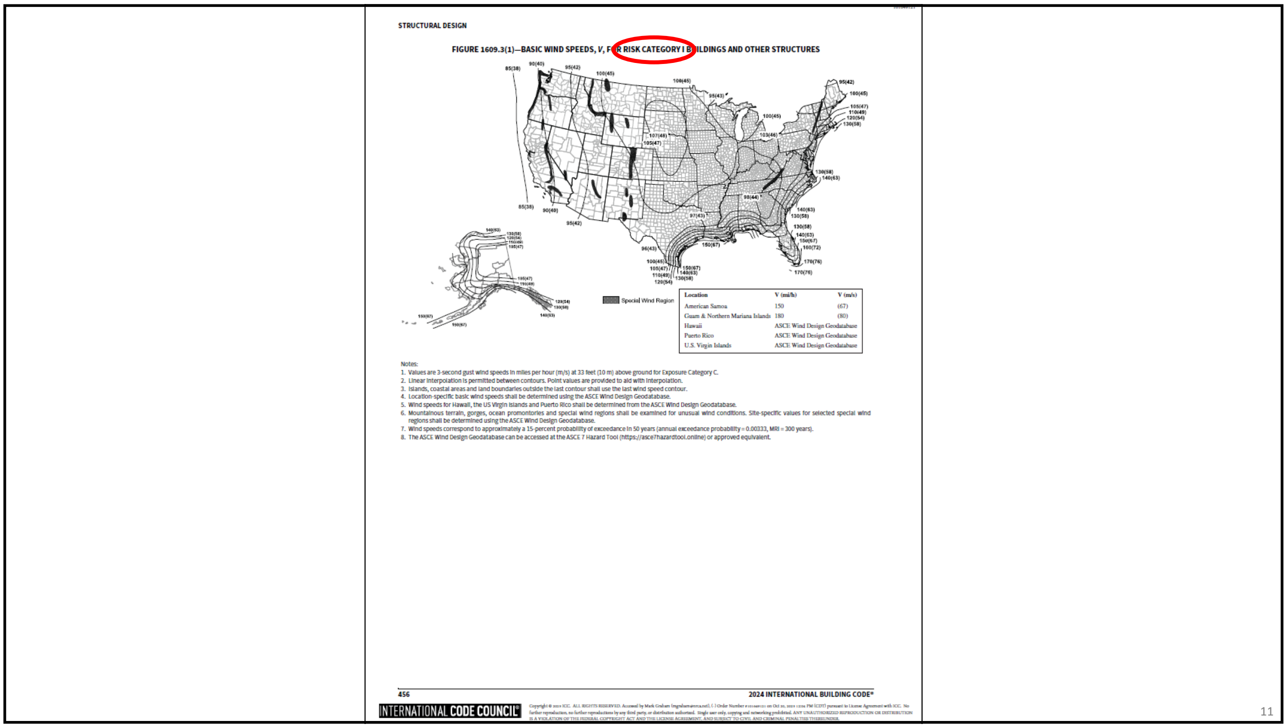

STRUCTURAL DESIGN

FIGURE 1609.3(1)—BASIC WIND SPEEDS, *V*, FOR RISK CATEGORY I BUILDINGS AND OTHER STRUCTURES

Special Wind Region

Location	V (mi/h)	V (m/s)
American Samoa	150	(67)
Guam & Northern Mariana Islands	180	(80)
Hawaii	ASCE Wind Design Geodatabase	
Puerto Rico	ASCE Wind Design Geodatabase	
U.S. Virgin Islands	ASCE Wind Design Geodatabase	

Notes:
1. Values are 3-second gust wind speeds in miles per hour (m/s) at 33 feet (10 m) above ground for Exposure Category C.
2. Linear interpolation is permitted between contours. Point values are provided to aid with interpolation.
3. Islands, coastal areas and land boundaries outside the last contour shall use the last wind speed contour.
4. Location-specific basic wind speeds shall be determined using the ASCE Wind Design Geodatabase.
5. Wind speeds for Hawaii, the US Virgin Islands and Puerto Rico shall be determined from the ASCE Wind Design Geodatabase.
6. Mountainous terrain, gorges, ocean promontories and special wind regions shall be examined for unusual wind conditions. Site-specific values for selected special wind regions shall be determined using the ASCE Wind Design Geodatabase.
7. Wind speeds correspond to approximately a 15-percent probability of exceedance in 50 years (annual exceedance probability = 0.00333, MRI = 300 years).
8. The ASCE Wind Design Geodatabase can be accessed at the ASCE 7 Hazard Tool (https://asce7hazardtool.online) or approved equivalent.

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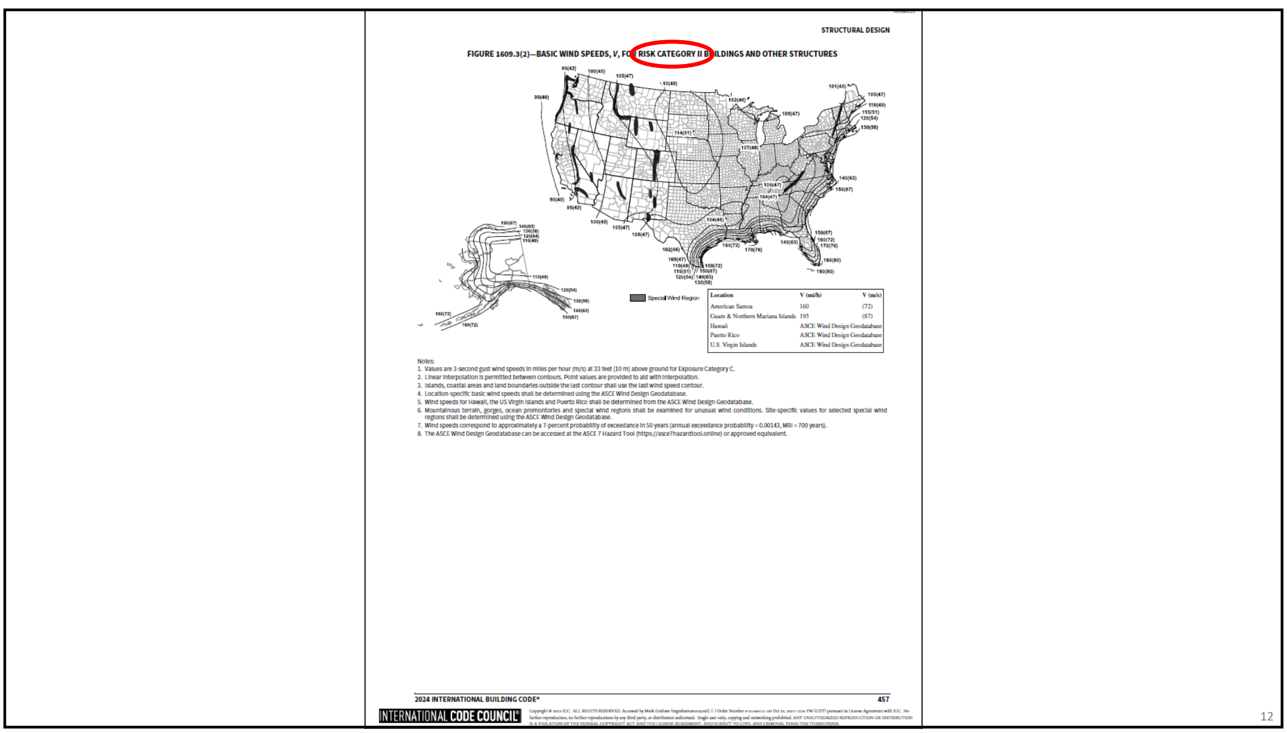

STRUCTURAL DESIGN

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

Special Wind Region

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	

Notes:
1. Values are 3-second gust wind speeds in miles per hour (m/s) at 33 feet (10 m) above ground for Exposure Category C.
2. Linear interpolation is permitted between contours. Point values are provided to aid with interpolation.
3. Islands, coastal areas and land boundaries outside the last contour shall use the last wind speed contour.
4. Location-specific basic wind speeds shall be determined using the ASCE Wind Design Geodatabase.
5. Wind speeds for Hawaii, the US Virgin Islands and Puerto Rico shall be determined from the ASCE Wind Design Geodatabase.
6. Mountainous terrain, gorges, ocean promontories and special wind regions shall be examined for unusual wind conditions. Site-specific values for selected special wind regions shall be determined using the ASCE Wind Design Geodatabase.
7. Wind speeds correspond to approximately a 7-percent probability of exceedance in 50 years (annual exceedance probability = 0.00143, MRI = 700 years).
8. The ASCE Wind Design Geodatabase can be accessed at the ASCE 7 Hazard Tool (https://asce7hazardtool.online) or approved equivalent.

2024 INTERNATIONAL BUILDING CODE® 457

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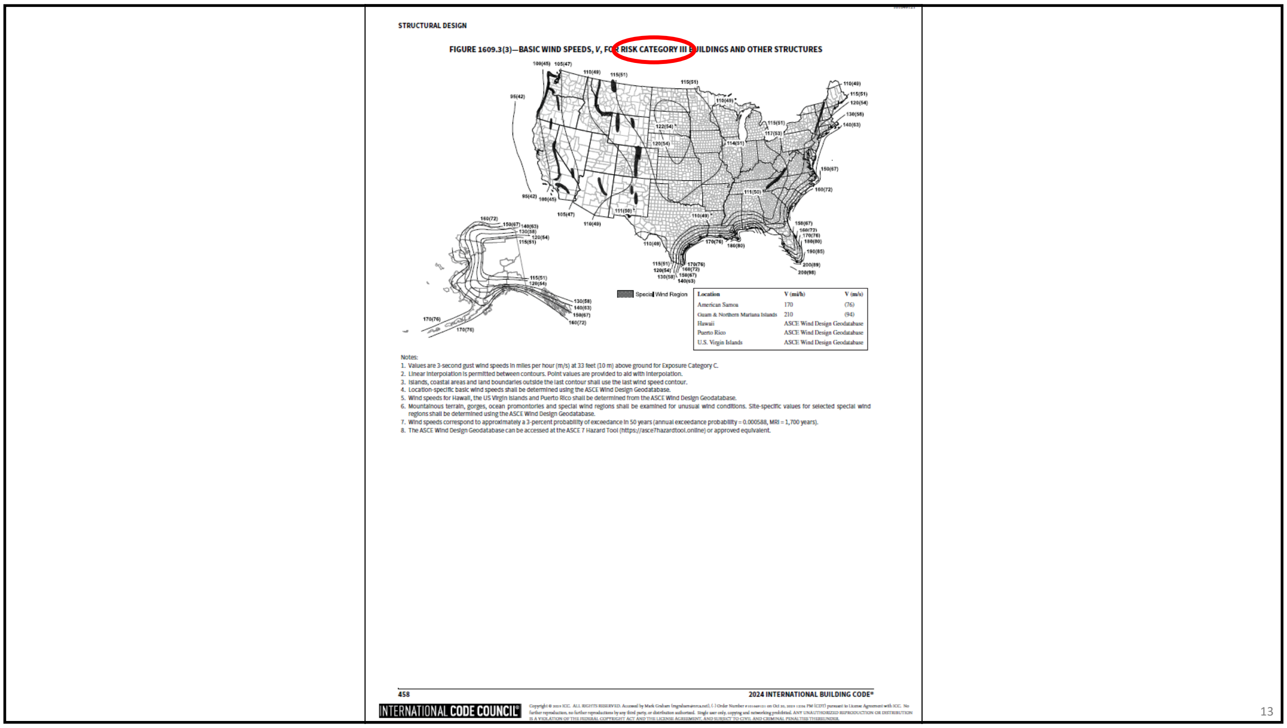

FIGURE 1609.3(3)—BASIC WIND SPEEDS, *V*, FOR RISK CATEGORY III BUILDINGS AND OTHER STRUCTURES

Special Wind Region

Location	V (mi/h)	V (m/s)
American Samoa	170	(76)
Guam & Northern Mariana Islands	210	(94)
Hawaii	ASCE Wind Design Geodatabase	
Puerto Rico	ASCE Wind Design Geodatabase	
U.S. Virgin Islands	ASCE Wind Design Geodatabase	

Notes:
1. Values are 3-second gust wind speeds in miles per hour (m/s) at 33 feet (10 m) above ground for Exposure Category C.
2. Linear interpolation is permitted between contours. Point values are provided to aid with interpolation.
3. Islands, coastal areas and land boundaries outside the last contour shall use the last wind speed contour.
4. Location-specific basic wind speeds shall be determined using the ASCE Wind Design Geodatabase.
5. Wind speeds for Hawaii, the US Virgin Islands and Puerto Rico shall be determined from the ASCE Wind Design Geodatabase.
6. Mountainous terrain, gorges, ocean promontories and special wind regions shall be examined for unusual wind conditions. Site-specific values for selected special wind regions shall be determined using the ASCE Wind Design Geodatabase.
7. Wind speeds correspond to approximately a 3-percent probability of exceedance in 50 years (annual exceedance probability = 0.000588, MRI = 1,700 years).
8. The ASCE Wind Design Geodatabase can be accessed at the ASCE 7 Hazard Tool (https://asce7hazardtool.online) or approved equivalent.

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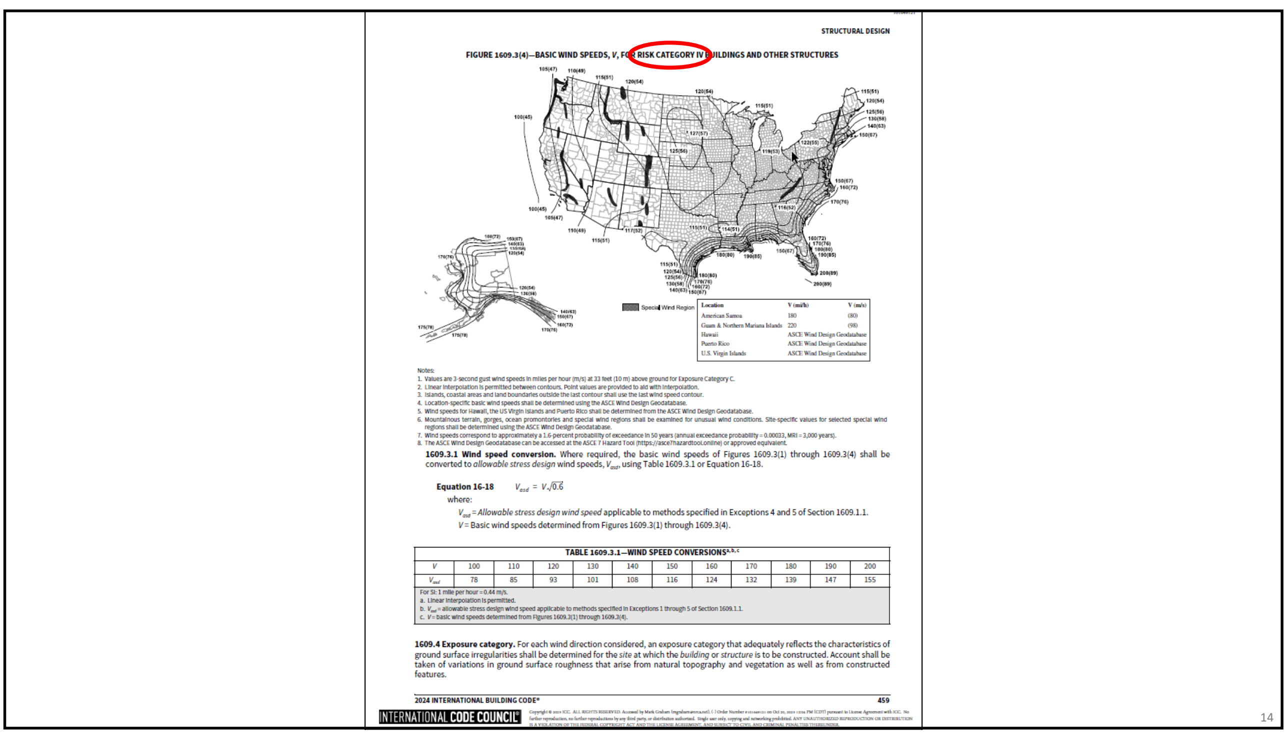

FIGURE 1609.3(4)—BASIC WIND SPEEDS, *V*, FOR RISK CATEGORY IV BUILDINGS AND OTHER STRUCTURES

Special Wind Region

Location	V (mi/h)	V (m/s)
American Samoa	180	(80)
Guam & Northern Mariana Islands	220	(98)
Hawaii	ASCE Wind Design Geodatabase	
Puerto Rico	ASCE Wind Design Geodatabase	
U.S. Virgin Islands	ASCE Wind Design Geodatabase	

Notes:
1. Values are 3-second gust wind speeds in miles per hour (m/s) at 33 feet (10 m) above ground for Exposure Category C.
2. Linear interpolation is permitted between contours. Point values are provided to aid with interpolation.
3. Islands, coastal areas and land boundaries outside the last contour shall use the last wind speed contour.
4. Location-specific basic wind speeds shall be determined using the ASCE Wind Design Geodatabase.
5. Wind speeds for Hawaii, the US Virgin Islands and Puerto Rico shall be determined from the ASCE Wind Design Geodatabase.
6. Mountainous terrain, gorges, ocean promontories and special wind regions shall be examined for unusual wind conditions. Site-specific values for selected special wind regions shall be determined using the ASCE Wind Design Geodatabase.
7. Wind speeds correspond to approximately a 1.6-percent probability of exceedance in 50 years (annual exceedance probability = 0.00033, MRI = 3,000 years).
8. The ASCE Wind Design Geodatabase can be accessed at the ASCE 7 Hazard Tool (https://asce7hazardtool.online) or approved equivalent.

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 $V_{asd} = V\sqrt{0.6}$

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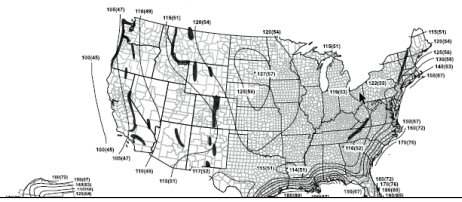
FIGURE 1609.3(4)—BASIC WIND SPEEDS, *V*, FOR RISK CATEGORY IV BUILDINGS AND OTHER STRUCTURES



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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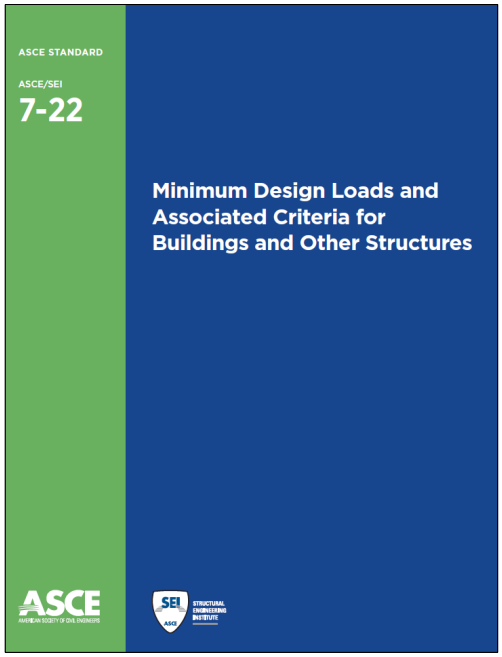

ASCE 7-22

- 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

Link

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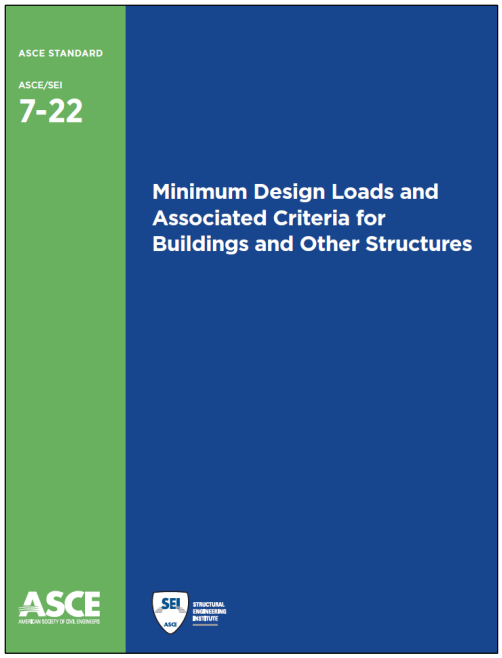

ASCE 7-22 on wind design

- 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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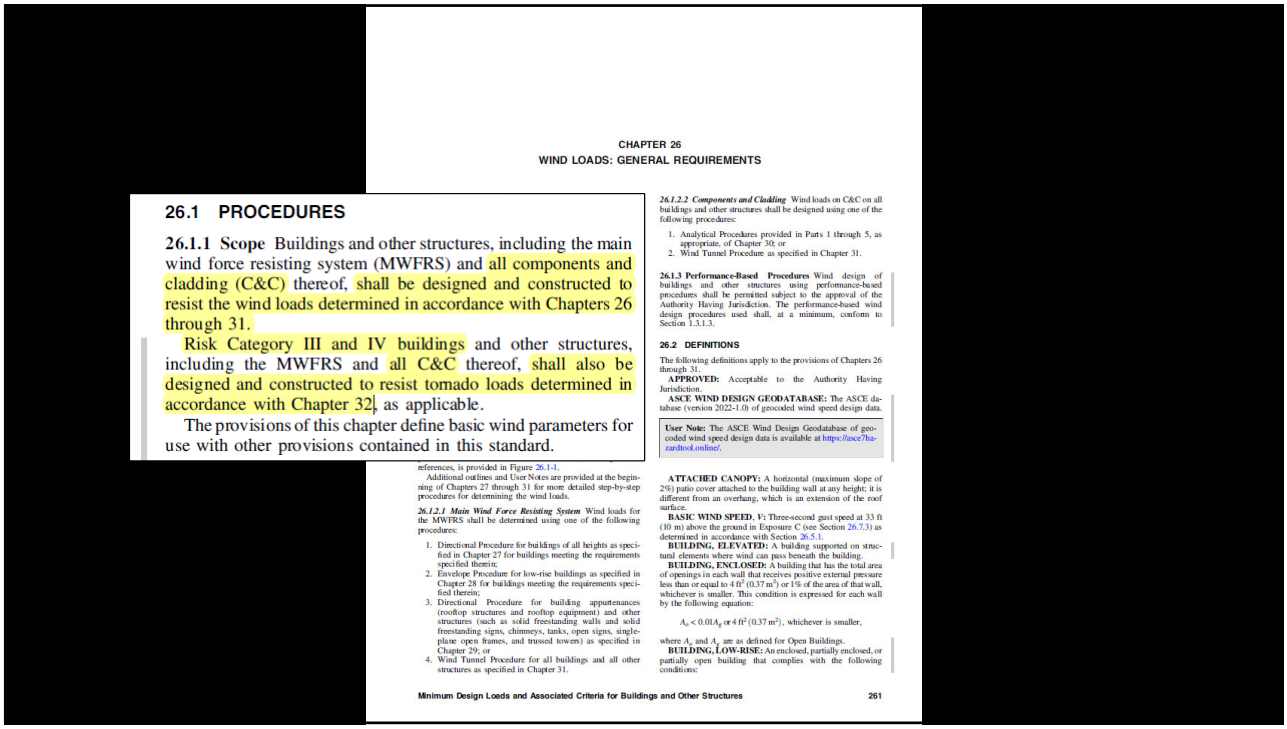

CHAPTER 26
WIND LOADS: GENERAL REQUIREMENTS

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 ft² (0.37 m²) or 1% of the area of that wall, whichever is smaller. This condition is expressed for each wall by the following equation:

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

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:

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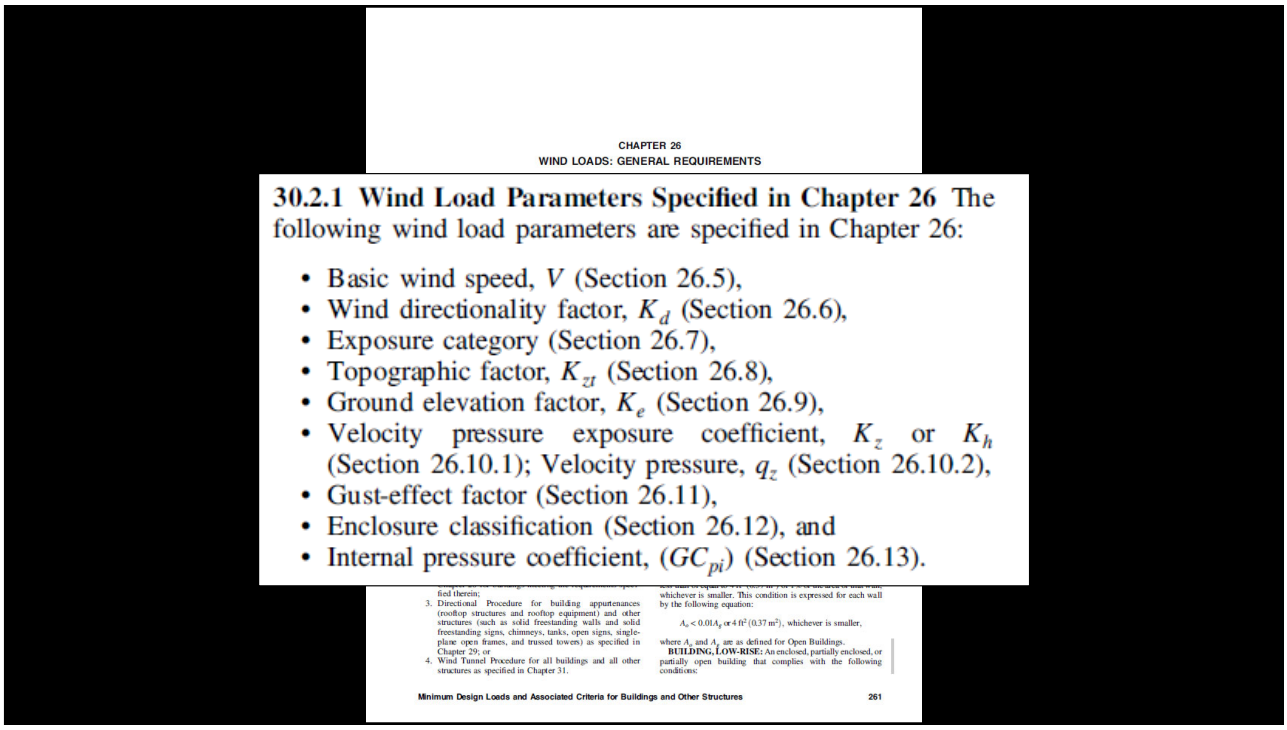

CHAPTER 26
WIND LOADS: GENERAL REQUIREMENTS

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).

fied 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.

whichever is smaller. This condition is expressed for each wall by the following equation:

$A_o < 0.01A_g$ or 4 ft² (0.37 m²), 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:

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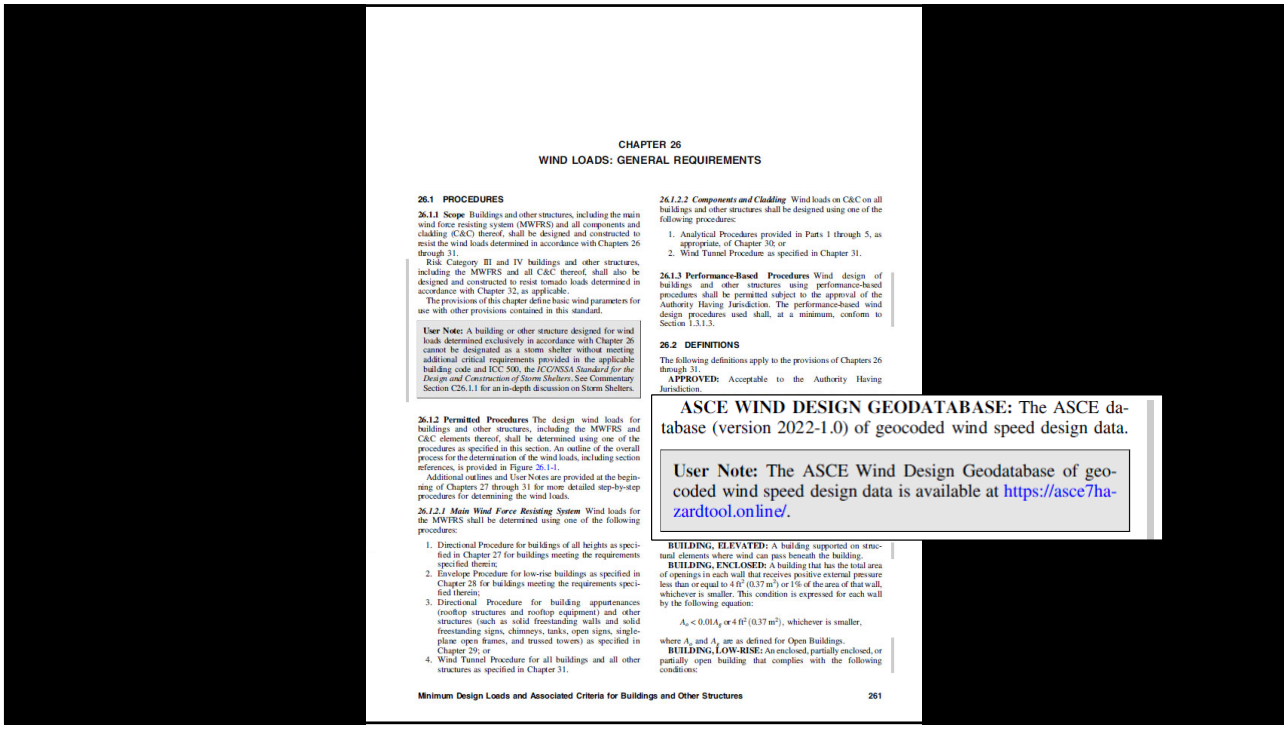

CHAPTER 26
WIND LOADS: GENERAL REQUIREMENTS

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.

User Note: A building or other structure designed for wind loads determined exclusively in accordance with Chapter 26 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 C26.1.1 for an in-depth discussion on Storm Shelters.

26.1.2 Permitted Procedures The design wind 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. An outline of the overall process for the determination of the wind loads, including section 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/.

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 ft² (0.37 m²) or 1% of the area of that wall, whichever is smaller. This condition is expressed for each wall by the following equation:

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

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:

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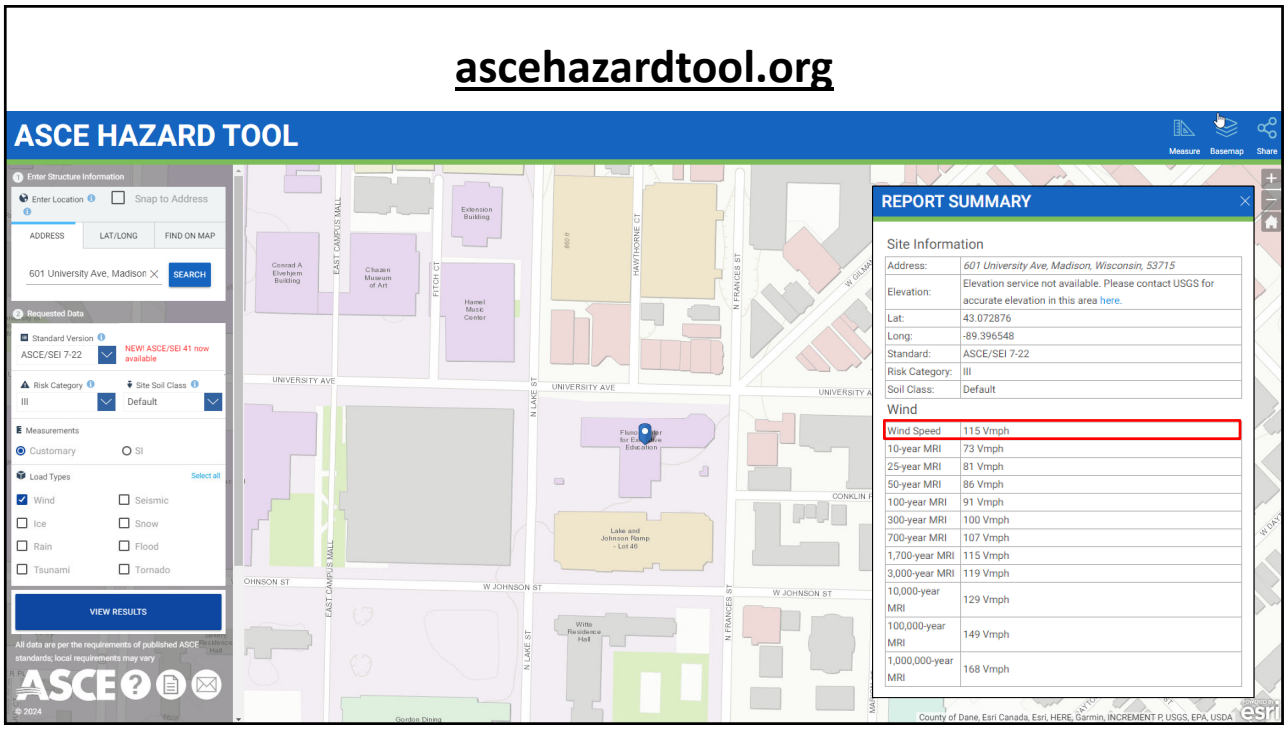

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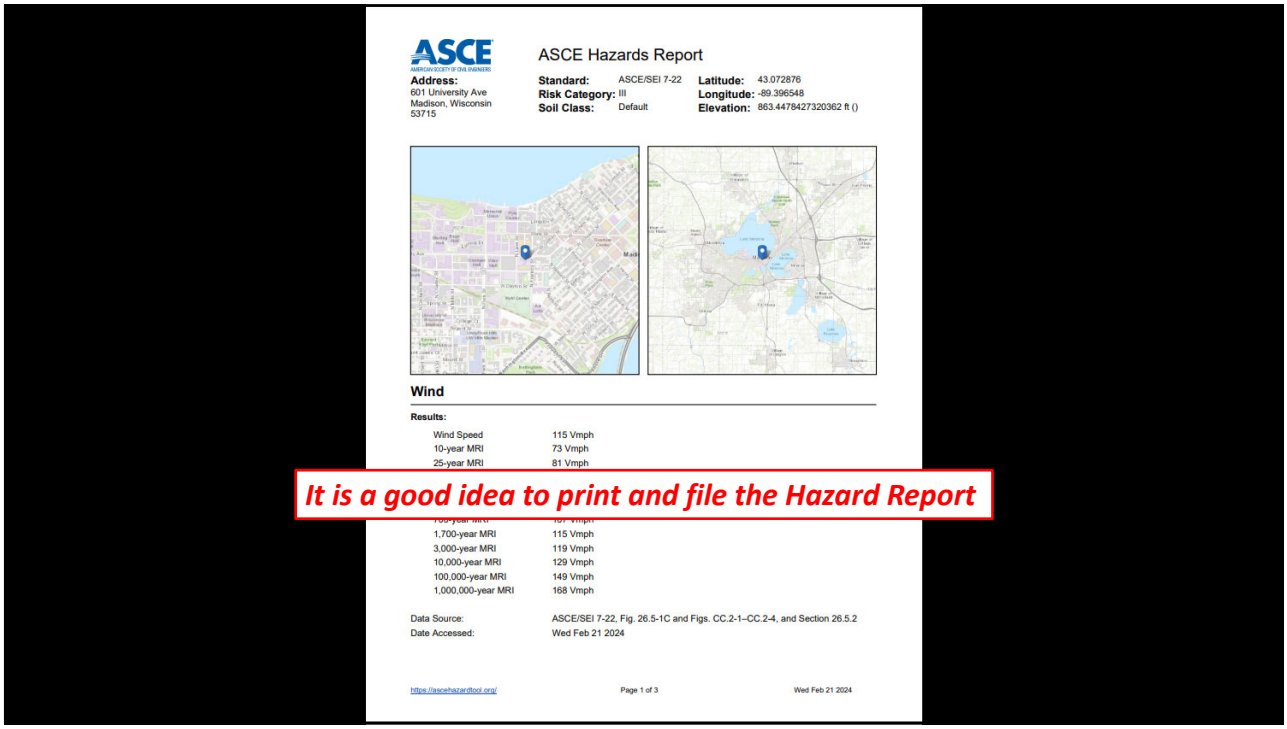

It is a good idea to print and file the Hazard Report

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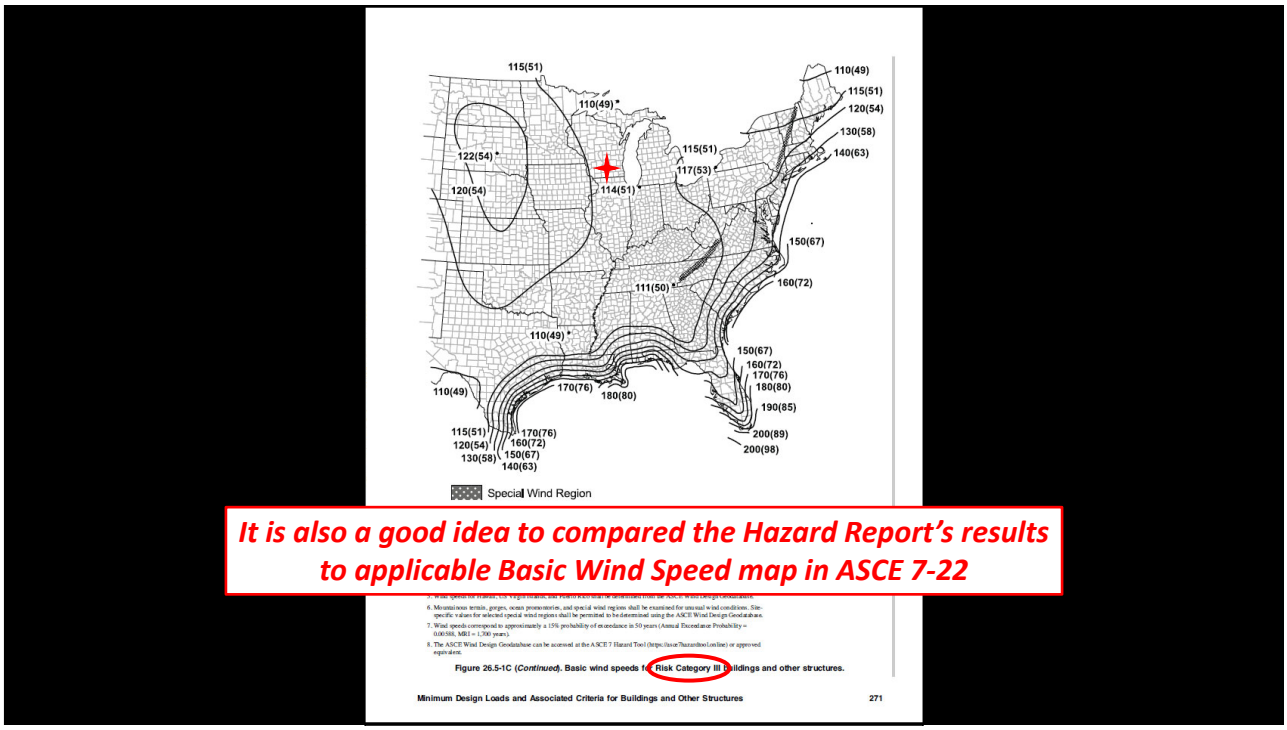

It is also a good idea to compared the Hazard Report's results to applicable Basic Wind Speed map in ASCE 7-22

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$$q_z = 0.00256 K_z K_{zt} K_e V^2 \text{ lb/ft}^2); V, \text{mi/h} \quad (26.10\text{-}1)$$

$$q_z = 0.613 K_z K_{zt} K_e V^2 (\text{N/m}^2); V, \text{m/s} \quad (26.10\text{-}1.\text{SI})$$

where

K_z = Velocity pressure exposure coefficient, see Section 26.10.1
K_{zt} = Topographic factor, see Section 26.8.2;
K_e = Ground elevation factor, see Section 26.9;
V = Basic wind speed, see Section 26.5; and
q_z = Velocity pressure at height z.

The velocity pressure at mean roof height is computed as $q_h = q_z$ evaluated from Equation (26.10-1) using K_z at mean roof height h.

The basic wind speed, V, used in determination of design wind loads on rooftop structures, rooftop equipment, and other building appurtenances shall consider the Risk Category equal to the greater of the following:

1. Risk category for the building on which the equipment or appurtenance is located, or
2. Risk category for any building or other structure to which the equipment or appurtenance provides a necessary service.

$$L_{int} = \frac{\sum_{i=1}^{n} h_i L_i}{\sum_{i=1}^{n} h_i} \quad (26.11\text{-}1)$$

The summations are over the height of the building, where h_i is the height above grade of level i, and L_i is the building length at level i parallel to the wind direction.

26.11.3 Approximate Natural Frequency The approximate lower bound natural frequency (n_a), in Hz, of concrete or structural steel buildings meeting the conditions of

Table 26.10-1. Velocity Pressure Exposure Coefficients, K_h and K_z.

Height above Ground Level, *z* or *h*		Exposure		
ft	m	B	C	D
0–15	0–4.6	0.57 (0.70)*	0.85	1.03
20	6.1	0.62 (0.70)*	0.90	1.08
25	7.6	0.66 (0.70)*	0.94	1.12
30	9.1	0.70	0.98	1.16
40	12.2	0.74	1.04	1.22
50	15.2	0.79	1.09	1.27
60	18.3	0.83	1.13	1.31
70	21.3	0.86	1.17	1.34
80	24.4	0.90	1.21	1.38
90	27.4	0.92	1.24	1.40
100	30.5	0.95	1.26	1.43
120	36.6	1.00	1.31	1.48
140	42.7	1.04	1.34	1.52
160	48.8	1.08	1.39	1.55
180	54.9	1.11	1.41	1.58
200	61.0	1.14	1.44	1.61
250	76.2	1.21	1.51	1.68
300	91.4	1.27	1.57	1.73
350	106.7	1.33	1.62	1.78
400	121.9	1.38	1.66	1.82
450	137.2	1.42	1.70	1.86
500	152.4	1.46	1.74	1.89

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CHAPTER 30
WIND LOADS: COMPONENTS AND CLADDING

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 $h \le 60$ 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 trough 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 $h \le 120$ 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.

30.1.2 Conditions A building that has design wind loads determined in accordance with this chapter shall comply with all of the following conditions:

1. The building is a regular-shaped building as defined in Section 26.2; and
2. The building does not have response characteristics that make it subject to across-wind loading, vortex shedding, or instability caused by galloping or flutter; nor does it have a site location for which channeling effects or buffeting in the wake of upwind obstructions warrant special consideration.

30.1.3 Limitations The provisions of this chapter take into consideration the load magnification effect caused by gusts in 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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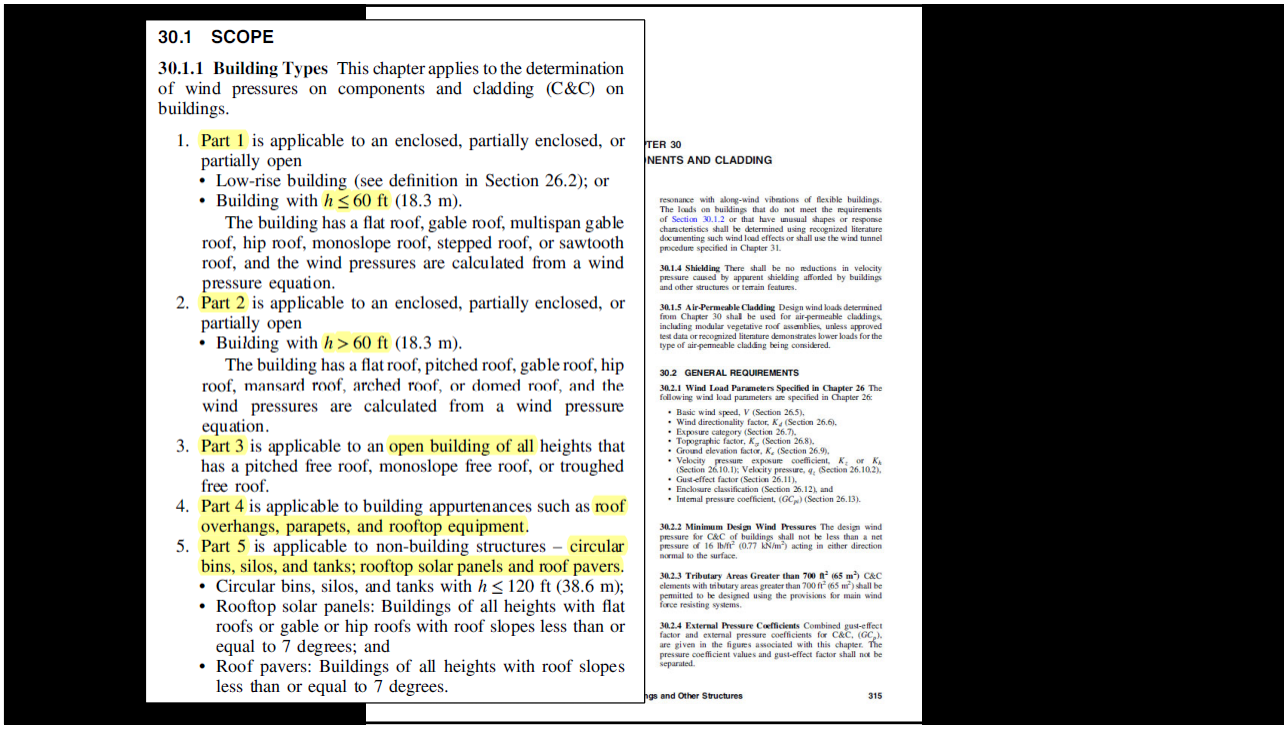

30.1 SCOPE

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.

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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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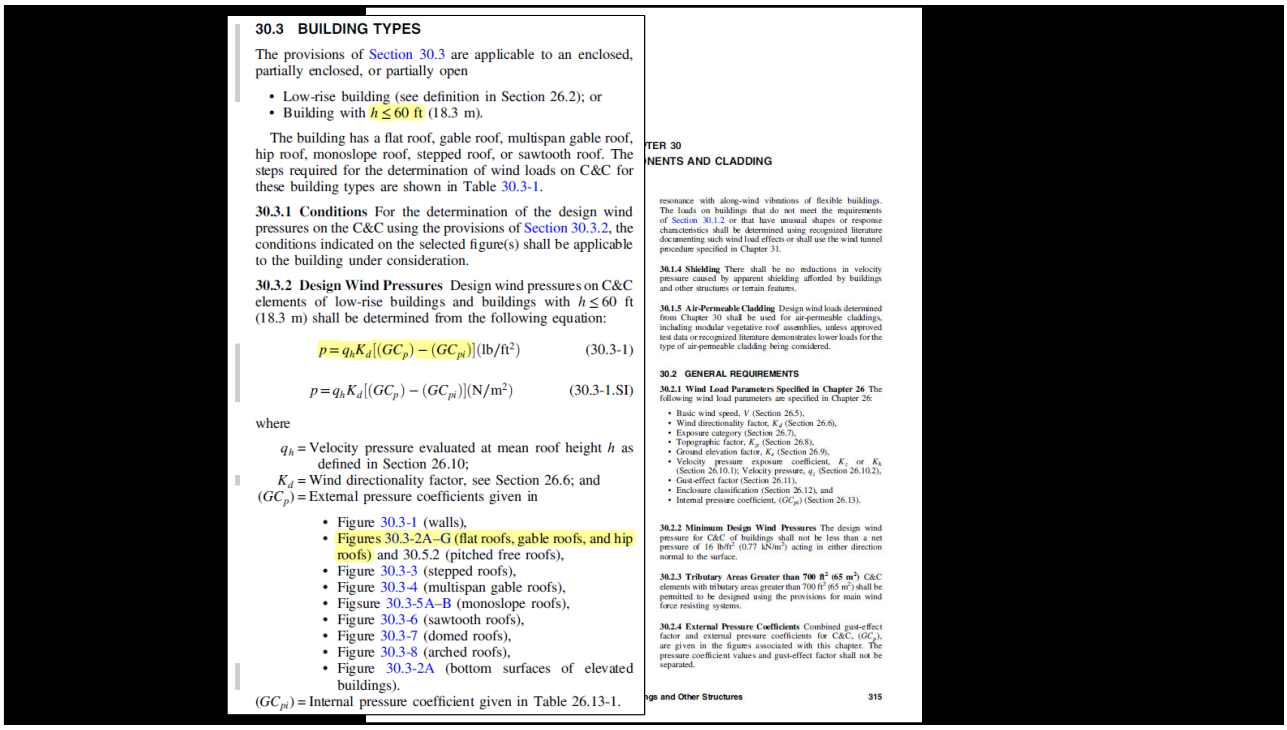

30.3 BUILDING TYPES

The provisions of Section 30.3 are 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. The steps required for the determination of wind loads on C&C for these building types are shown in Table 30.3-1.

30.3.1 Conditions For the determination of the design wind pressures on the C&C using the provisions of Section 30.3.2, the conditions indicated on the selected figure(s) shall be applicable to the building under consideration.

30.3.2 Design Wind Pressures Design wind pressures on C&C elements of low-rise buildings and buildings with $h \leq 60$ ft (18.3 m) shall be determined from the following equation:

$$p = q_h K_d [(GC_p) - (GC_{pi})] \text{ (lb/ft}^2\text{)} \quad (30.3\text{-}1)$$

$$p = q_h K_d [(GC_p) - (GC_{pi})] \text{ (N/m}^2\text{)} \quad (30.3\text{-}1.\text{SI})$$

where

q_h = Velocity pressure evaluated at mean roof height h as defined in Section 26.10;
K_d = Wind directionality factor, see Section 26.6; and
(GC_p) = External pressure coefficients given in

- Figure 30.3-1 (walls),
- Figures 30.3-2A–G (flat roofs, gable roofs, and hip roofs) and 30.5.2 (pitched free roofs),
- Figure 30.3-3 (stepped roofs),
- Figure 30.3-4 (multispan gable roofs),
- Figure 30.3-5A–B (monoslope roofs),
- Figure 30.3-6 (sawtooth roofs),
- Figure 30.3-7 (domed roofs),
- Figure 30.3-8 (arched roofs),
- Figure 30.3-2A (bottom surfaces of elevated buildings).

(GC_{pi}) = Internal pressure coefficient given in Table 26.13-1.

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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),
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- Gust-effect factor (Section 26.11),
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- 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.

gs and Other Structures 315

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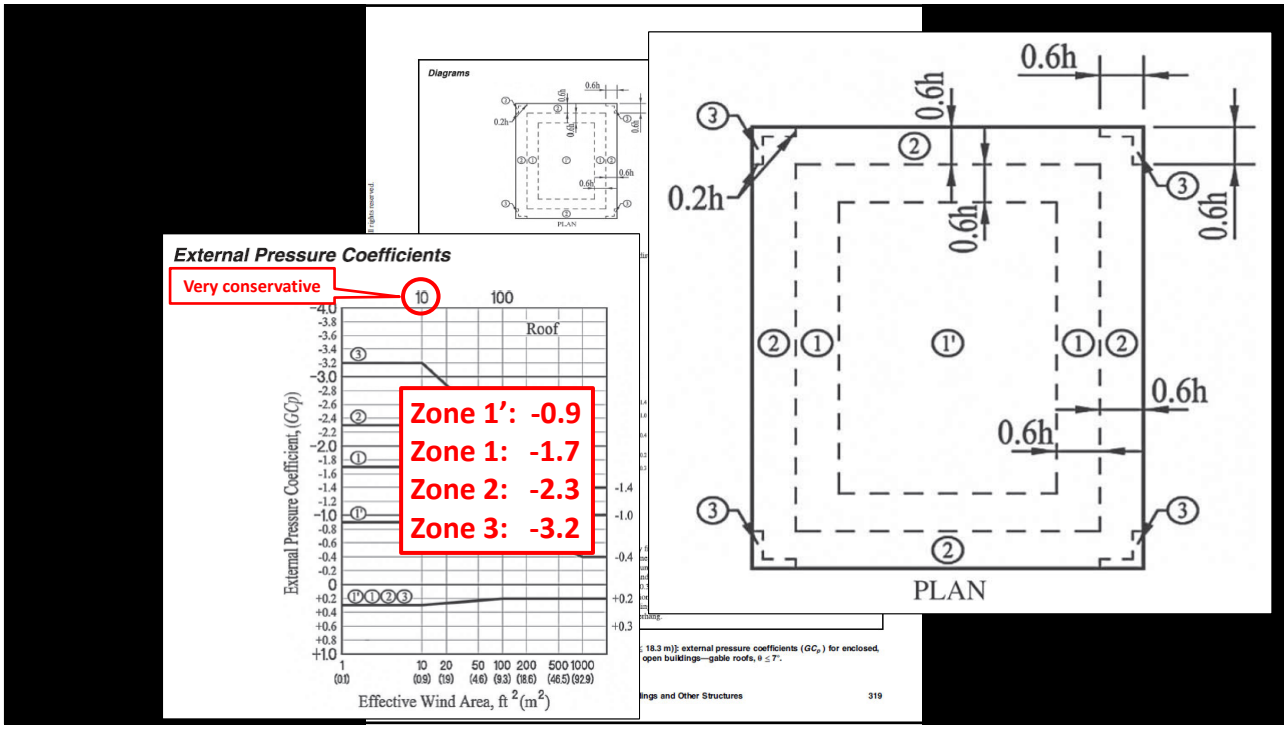

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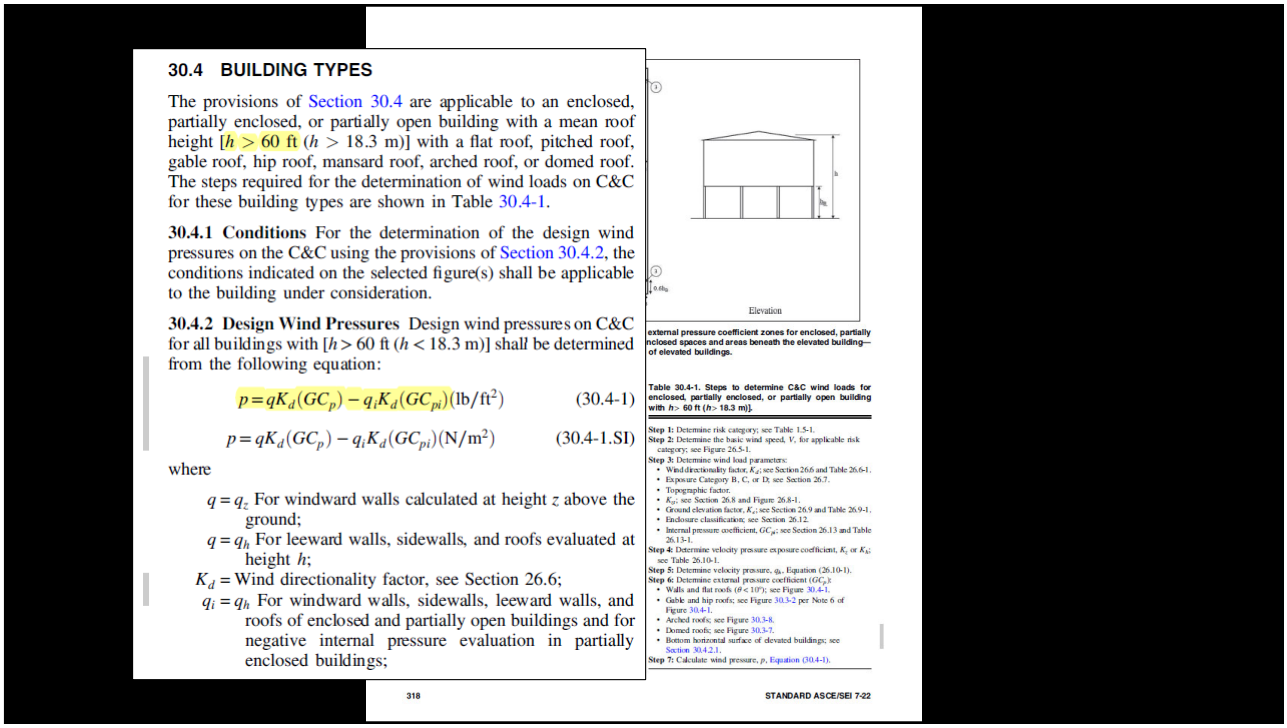

30.4 BUILDING TYPES

The provisions of Section 30.4 are applicable to an enclosed, partially enclosed, or partially open building with a mean roof height [$h > 60$ ft ($h > 18.3$ m)] with a flat roof, pitched roof, gable roof, hip roof, mansard roof, arched roof, or domed roof. The steps required for the determination of wind loads on C&C for these building types are shown in Table 30.4-1.

30.4.1 Conditions For the determination of the design wind pressures on the C&C using the provisions of Section 30.4.2, the conditions indicated on the selected figure(s) shall be applicable to the building under consideration.

30.4.2 Design Wind Pressures Design wind pressures on C&C for all buildings with [$h > 60$ ft ($h < 18.3$ m)] shall be determined from the following equation:

$$p = qK_d(GC_p) - q_iK_d(GC_{pi}) \text{ (lb/ft}^2\text{)} \quad (30.4\text{-}1)$$

$$p = qK_d(GC_p) - q_iK_d(GC_{pi}) \text{ (N/m}^2\text{)} \quad (30.4\text{-}1.SI)$$

where

$q = q_z$ For windward walls calculated at height z above the ground;
$q = q_h$ For leeward walls, sidewalls, and roofs evaluated at height h;
K_d = Wind directionality factor, see Section 26.6;
$q_i = q_h$ For windward walls, sidewalls, leeward walls, and roofs of enclosed and partially open buildings and for negative internal pressure evaluation in partially enclosed buildings;

Elevation

external pressure coefficient zones for enclosed, partially enclosed spaces and areas beneath the elevated building—of elevated buildings.

Table 30.4-1. Steps to determine C&C wind loads for enclosed, partially enclosed, or partially open building with $h >$ 60 ft ($h >$ 18.3 m).

Step 1: Determine risk category; see Table 1.5-1.
Step 2: Determine the basic wind speed, V, for applicable risk category; see Figure 26.5-1.
Step 3: Determine wind load parameters:
- Wind directionality factor, K_d; see Section 26.6 and Table 26.6-1.
- Exposure Category B, C, or D; see Section 26.7.
- Topographic factor, K_{zt}; see Section 26.8 and Figure 26.8-1.
- Ground elevation factor, K_e; see Section 26.9 and Table 26.9-1.
- Enclosure classification; see Section 26.12.
- Internal pressure coefficient, GC_{pi}; see Section 26.13 and Table 26.13-1.

Step 4: Determine velocity pressure exposure coefficient, K_z or K_h; see Table 26.10-1.
Step 5: Determine velocity pressure, q_h, Equation (26.10-1).
Step 6: Determine external pressure coefficient (GC_p):
- Walls and flat roofs ($\theta < 10°$); see Figure 30.4-1.
- Gable and hip roofs; see Figure 30.3-2 per Note 6 of Figure 30.4-1.
- Arched roofs; see Figure 30.3-8.
- Domed roofs; see Figure 30.3-7.
- Bottom horizontal surface of elevated buildings; see Section 30.4.2.1.

Step 7: Calculate wind pressure, p, Equation (30.4-1).

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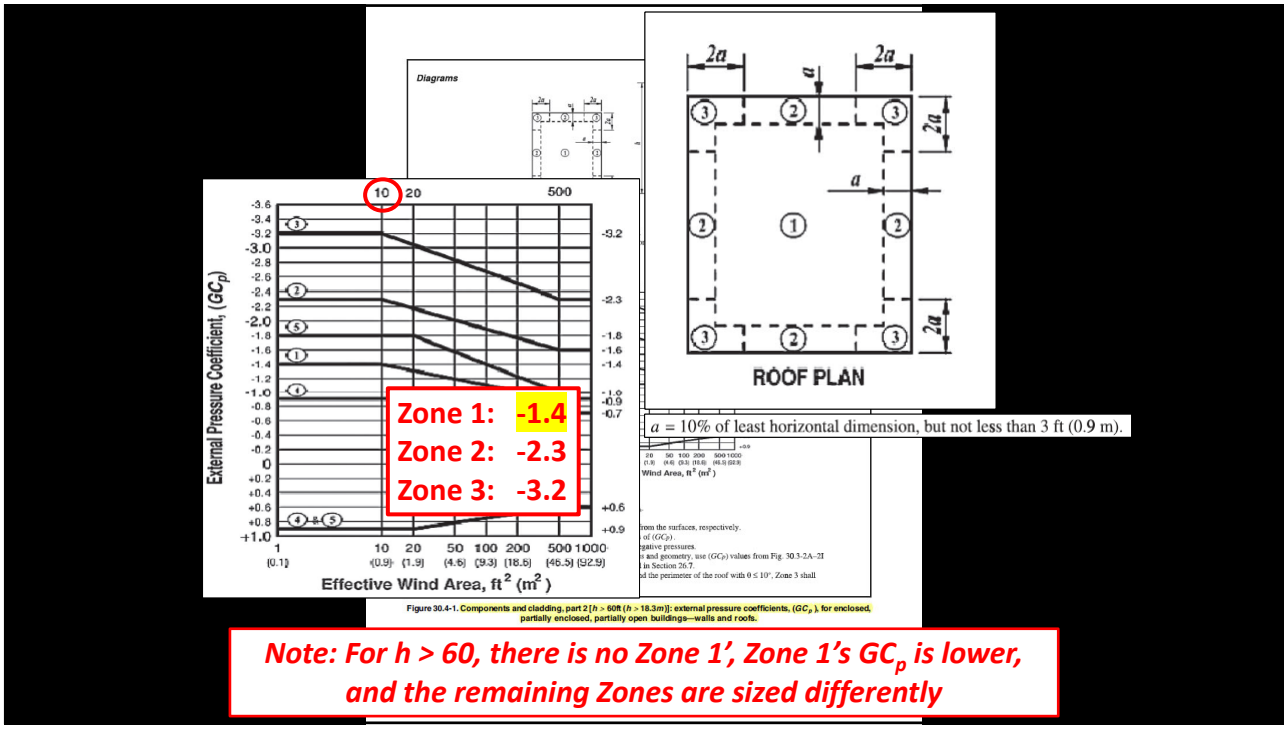

Note: For h > 60, there is no Zone 1', Zone 1's GC_p is lower, and the remaining Zones are sized differently

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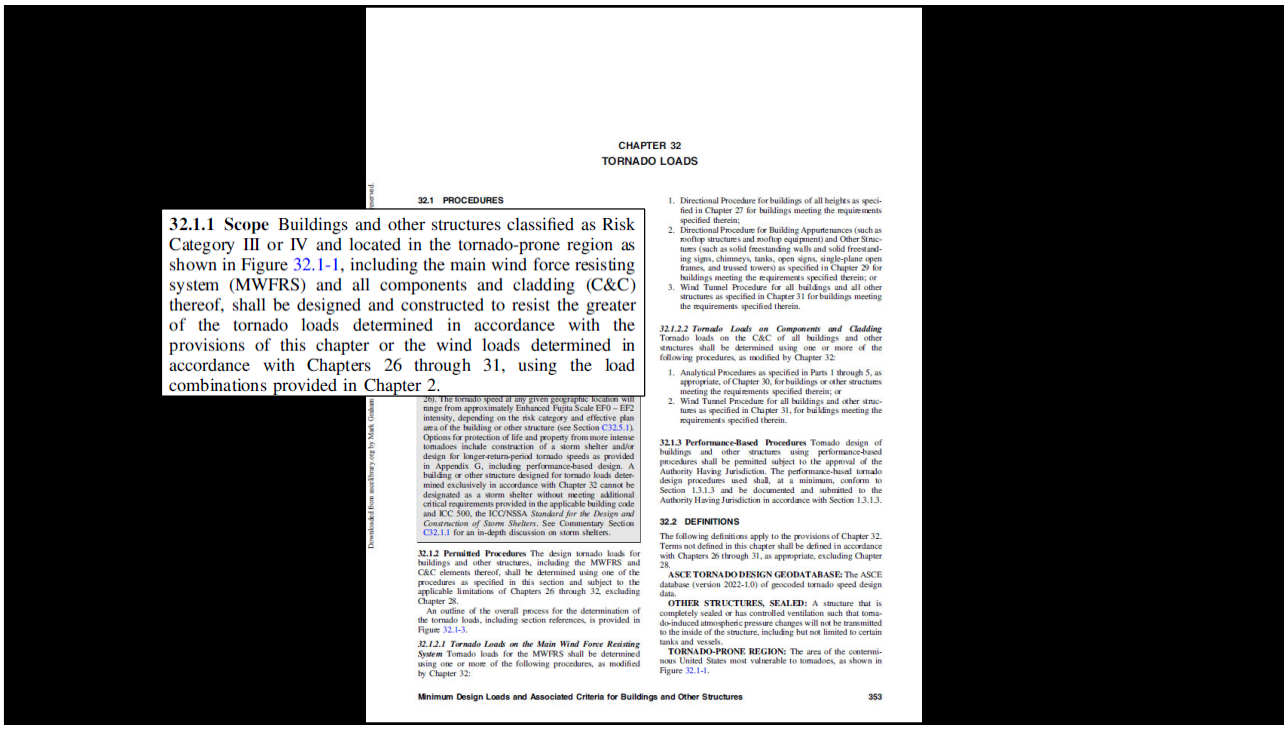

CHAPTER 32
TORNADO LOADS

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 contiguous United States most vulnerable to tornadoes, as shown in Figure 32.1-1.

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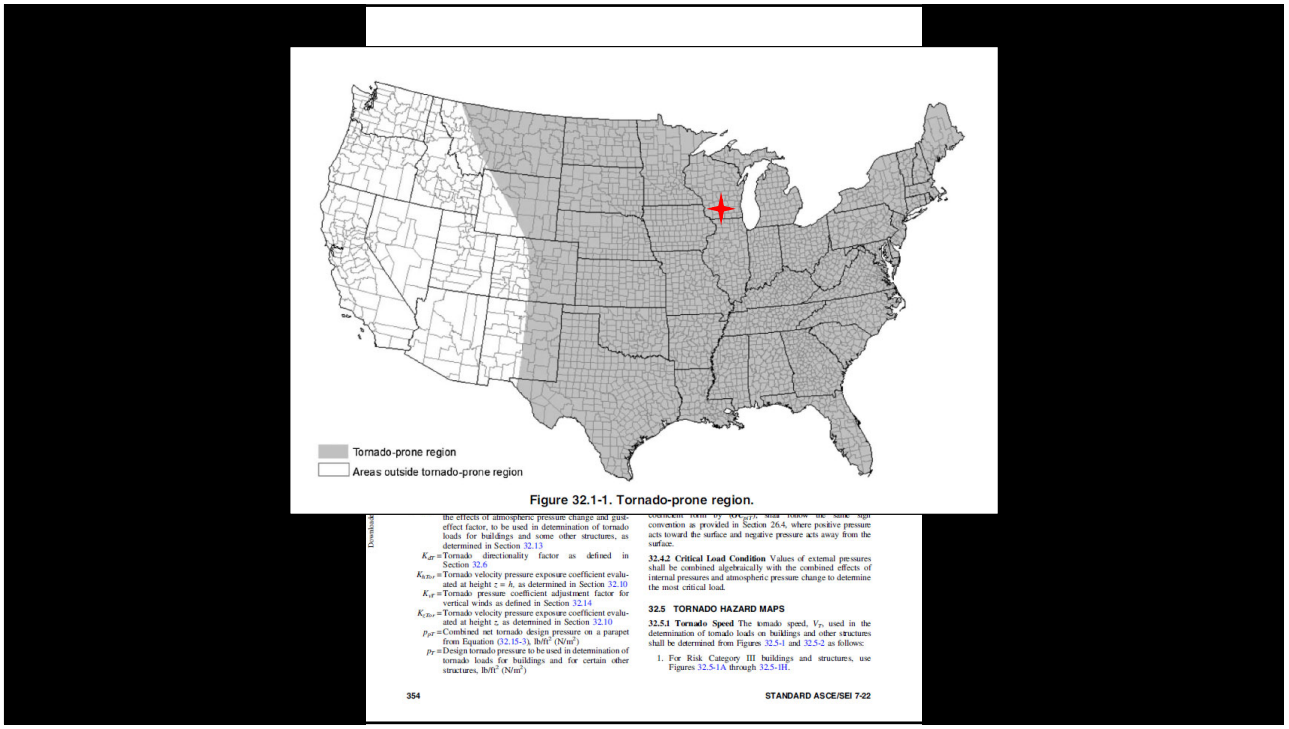

Figure 32.1-1. Tornado-prone region.

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

$K_{h,T_{EF}}$ = 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

$K_{z,T_{EF}}$ = 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.

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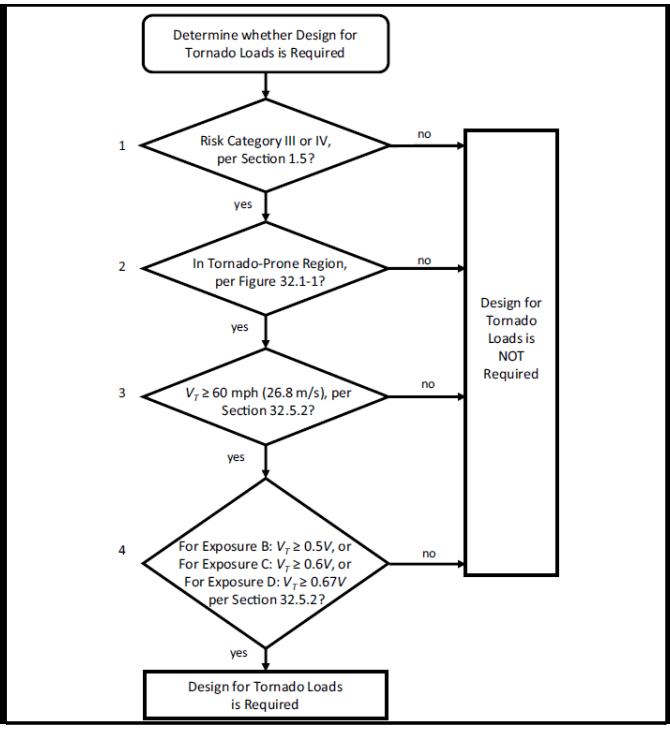

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Chapter 32: General Requirements. The basic parameters used in determination of tornado loads on both the MWFRS and C&C are

- Tornado speed, V_T, see Section 32.5.1
- Effective plan area, A_e, see Section 32.5.4
- Tornado directionality factor, K_{dt}, see Section 32.6
- Ground elevation factor, K_{et}, see Section 32.9
- Tornado velocity pressure exposure coefficients, K_{zt}, and K_{ztop}, see Section 32.10
- Tornado gust effect factor, G_t, see Section 32.11
- Tornado enclosure classification, see Section 32.12
- Tornado internal pressure coefficient, GC_{pit}, see Section 32.13
- Tornado pressure coefficient adjustment factor, K_{zi}, see Section 32.14.

Tornado loads on the MWFRS shall be determined by one or more of

- **Chapter 27:** Directional procedure for buildings of all heights as modified by Section 32.15.
- **Chapter 29:** Directional procedure for building appurtenances (rooftop structures and equipment, roof overhangs, and parapets) and other structures as modified by Section 32.16.
- **Chapter 31:** Wind tunnel procedure for any building or other structure as modified by Section 32.18.

Tornado loads on the C&C shall be determined by one or more of

- **Chapter 30:** Part 1, Buildings with $h \le 60$ ft(18.3 m), or Part 2, Buildings with h>60 ft(18.3 m), or Part 3, Open buildings, or Part 4, Building appurtenances, rooftop structures, and equipment, or Part 5, Nonbuilding structures, with all parts as modified by Section 32.17.
- **Chapter 31:** Wind tunnel procedure for any building or other structure as modified by Section 32.18.

Figure 32.1-3. Outline of process for determining tornado loads.

2. For Risk Category IV buildings and structures, use Figures 32.5-2A through 32.5-2H.

To select the appropriate tornado hazard map to use for the assigned risk category, the effective plan area, A_e, of the building, other structure, or facility, shall be determined in accordance with Section 32.5.4 and shall be rounded up to next available mapped A_e, including 1; 2,000; 10,000; 40,000; 100,000; 250,000; 1,000,000; and 4,000,000 ft^2 (0.1; 186; 929; 3,716; 9,290; 23,226; 92,903; and 371,612 m^2). Alternatively, linear interpolation of tornado speed between maps using the logarithm of the effective plan area size is permitted.

Alternatively, it shall be permitted to use the tornado speeds from the ASCE Tornado Design Geodatabase. The ASCE Tornado Design Geodatabase is available at the ASCE 7 Hazard Tool (https://asce7hazardtool.online) or approved equivalent.

32.5.2 Design for Tornado Loads Not Required For Risk Category III and IV buildings and other structures determined to have tornado speeds V_T < 60 m/h (26.8 m/s), design for tornado loads shall not be required. Where $V_T \ge 60$ m/h (26.8 m/s) but is less than the following threshold speeds then design for tornado loads shall not be required:

1. For Exposure B: $V_T < 0.5V$, or
2. For Exposure C: $V_T < 0.6V$, or
3. For Exposure D: $V_T < 0.67V$,

where V is the basic wind speed determined in accordance with Section 26.5 and the exposure category is determined in accordance with Section 26.7.3, based on the exposure resulting in the greatest wind loads for any wind direction at the site.

32.5.3 Direction of Tornadic Wind The tornadic wind shall be assumed to come from any horizontal direction.

32.5.4 Effective Plan Area The effective plan area, A_e, of the building or other structure shall be determined in accordance with this section.

32.5.4.1 Essential Facilities For Essential Facilities and buildings and other structures required to maintain the functionality of Essential Facilities, the effective plan area shall be equal to the area of the smallest convex polygon enclosing both the Essential Facility and all of the buildings and other structures that maintain the functionality of the Essential Facility.

32.5.4.2 Other than Essential Facilities For buildings and structures that are not designated as Essential Facilities and are not required to maintain the functionality of Essential Facilities, the effective plan area shall be equal to the area of the smallest convex polygon enclosing the plan of the building, other structure, or facility. It is permitted to reduce the effective plan area to that of the effective plan area of the largest structurally independent building or other structure, which does not share structural components with adjacent buildings or other structures.

32.5.4.3 Ground-Mounted Photovoltaic Panel Systems The effective plan area, A_e, of ground-mounted photovoltaic

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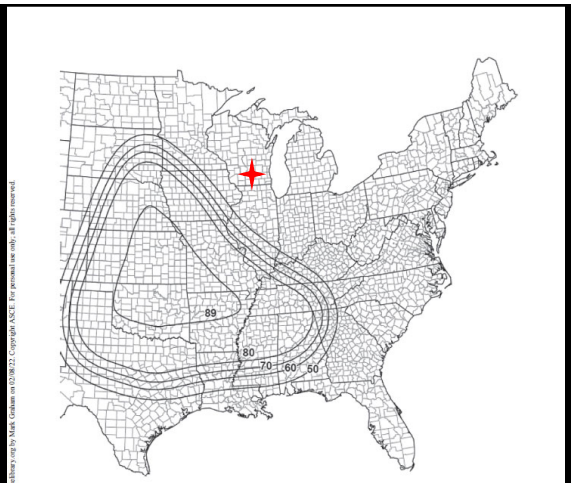

4. Islands, coastal areas, and land boundaries outside the last contour shall use the last tornado speed contour.
5. Tornado speeds correspond to approximately a 3% probability of exceedance in 50 years (annual exceedance probability = 0.000588, MRI = 1,700 years).
6. Location-specific tornado speed 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 32.5-1D (*Continued*). Tornado speeds for Risk Category III buildings and other structures, for effective plan area of 40,000 ft^2 (3,716 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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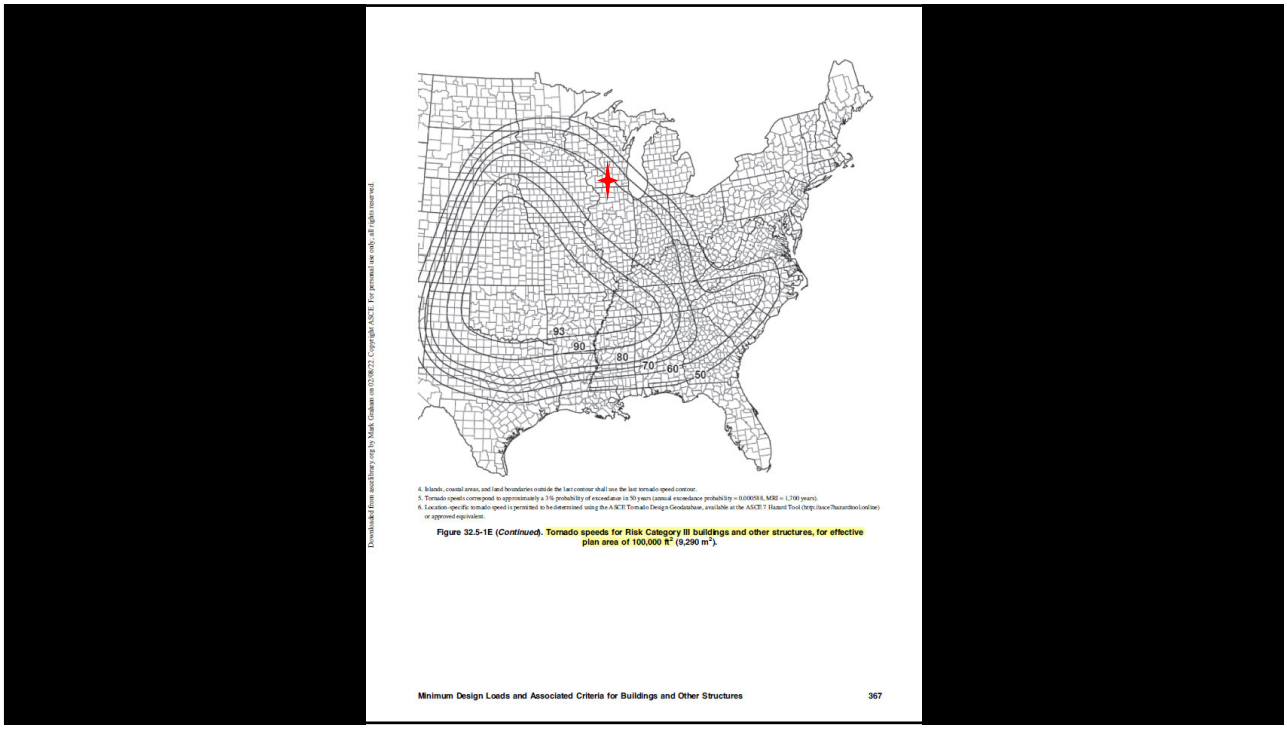

4. Islands, coastal areas, and land boundaries outside the last contour shall use the last tornado speed contour.
5. Tornado speeds correspond to approximately a 3% probability of exceedance in 50 years (annual exceedance probability = 0.000588, MRI = 1,700 years).
6. Location-specific tornado speed 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 ft² (9,290 m²).

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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_{zT}, 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:

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

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

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_{pi}), 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_{pi}), shall be determined from Table 32.13-1 based on building and other structure enclosure classifications determined in accordance with Section 32.12.1.

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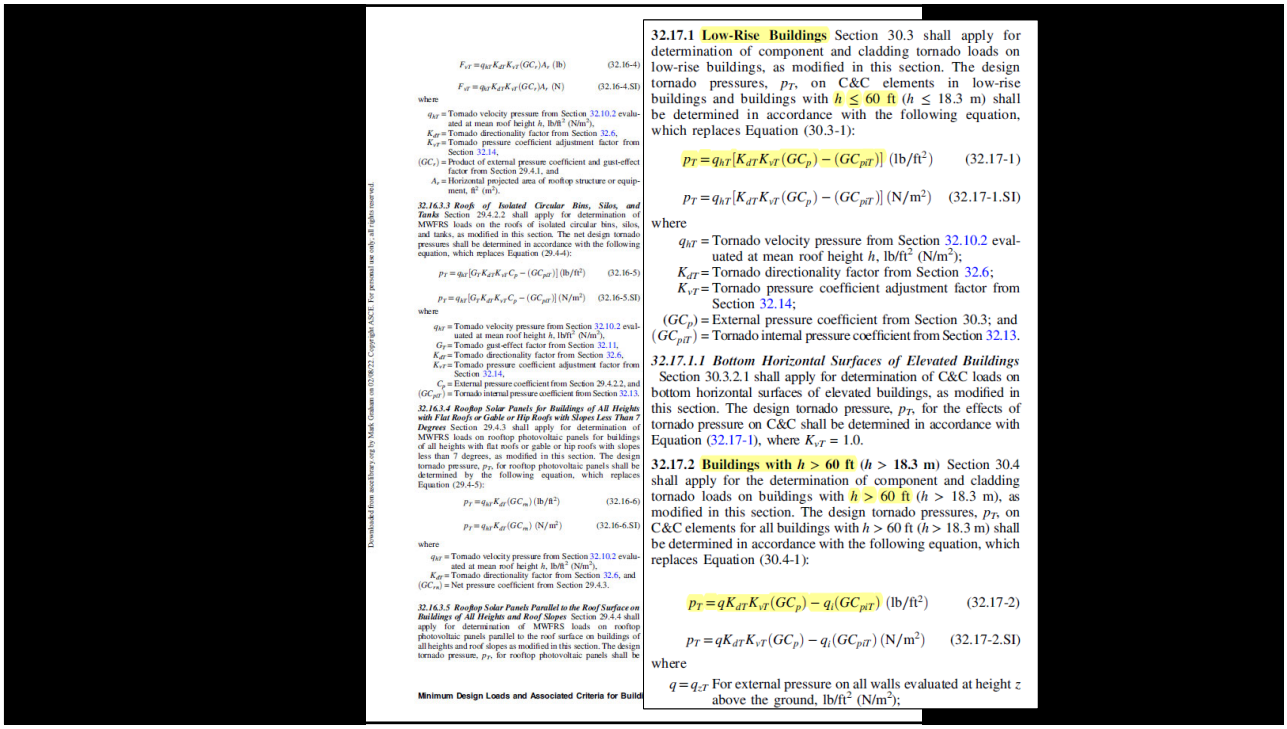

$$F_{rT} = q_{hT} K_{dT} K_{rT} (GC_r) A_r \text{ (lb)} \quad (32.16\text{-}4)$$

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

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_{rT} = 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):

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

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

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_{rT} = 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):

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

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

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_{rn}) = 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):

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

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

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):

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

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

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

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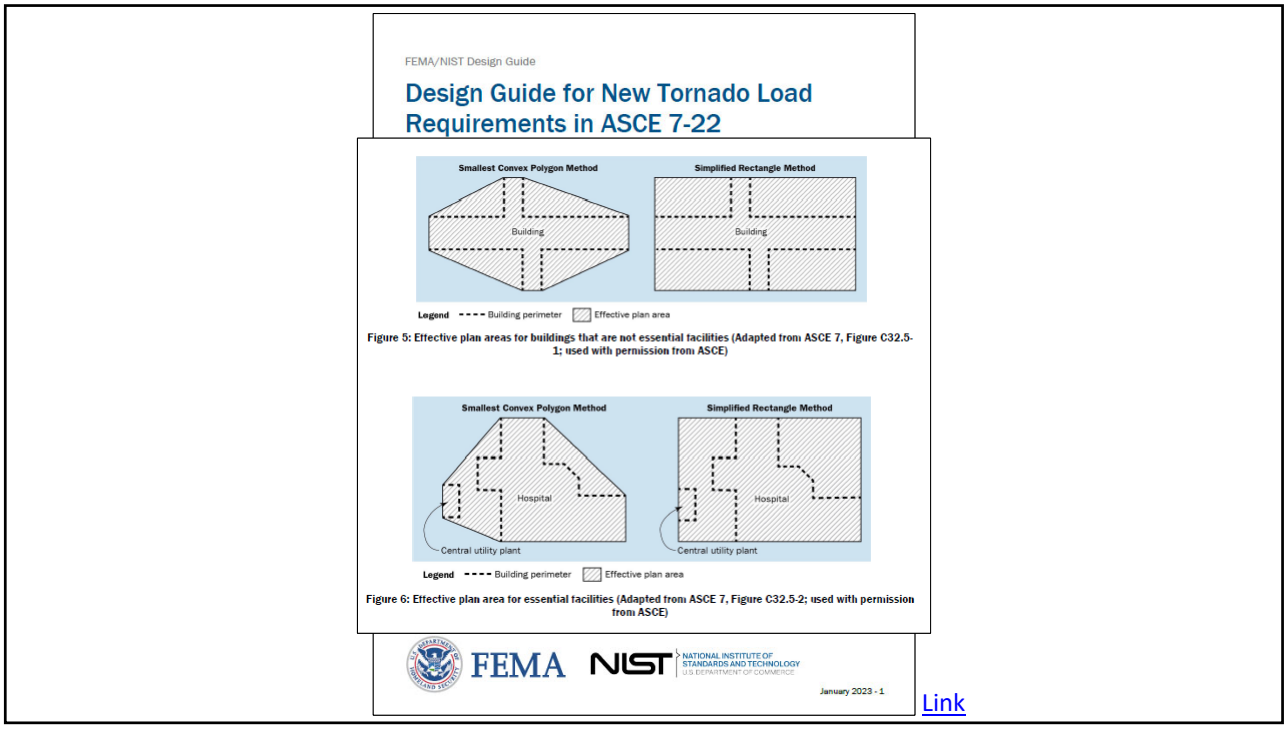

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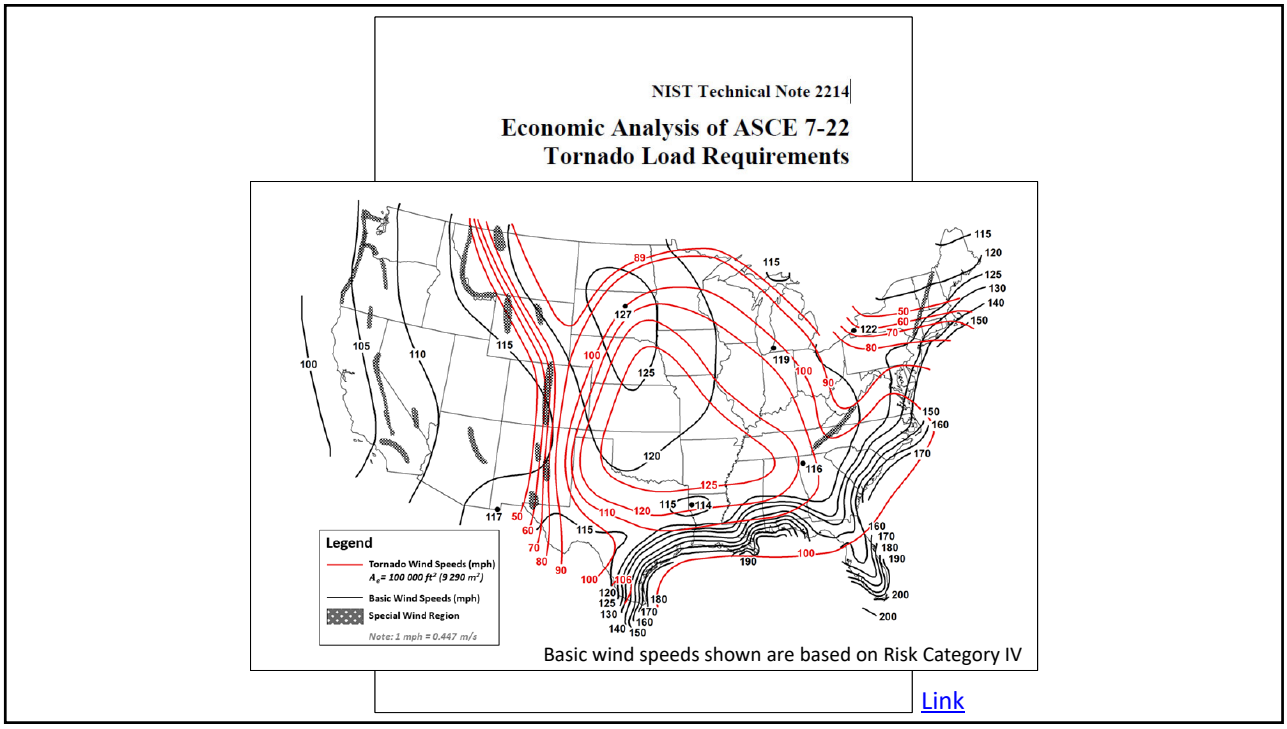

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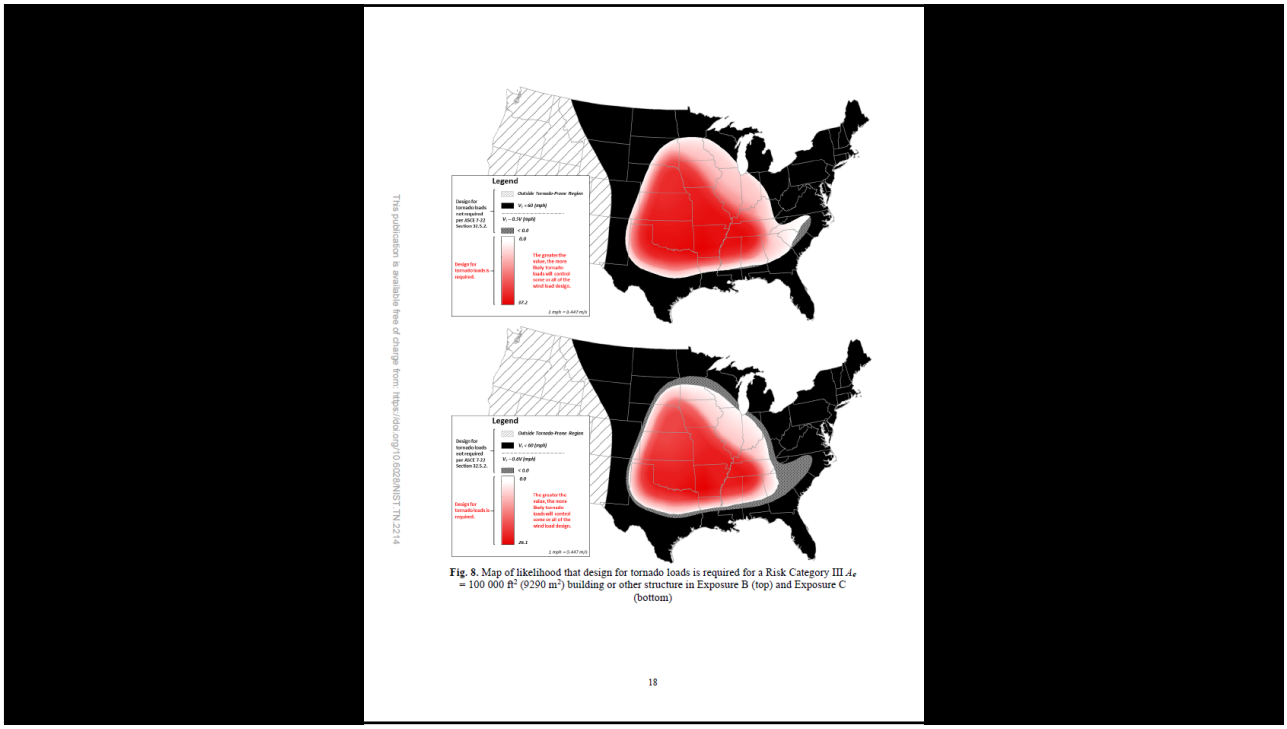

Fig. 8. Map of likelihood that design for tornado loads is required for a Risk Category III A_e = 100 000 ft² (9290 m²) building or other structure in Exposure B (top) and Exposure C (bottom)

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Comparing ASCE 7's versions

Based on a hypothetical building

Assumptions: Building height (h) = 60 ft., low-slope roof, enclosed building configuration, Exposure Category C and Risk Category III in Madison, Wisconsin.

Version	Method	Basic wind speed	Zone 1'	Zone 1	Zone 2	Zone 3
ASCE 7-22	Ult.	115 mph	35.1 psf	61.1 psf	80.6 psf	109.9 psf
	ASD	90 mph	21.1 psf	36.7 psf	48.4 psf	65.9 psf
ASCE 7-16	Ult.	115 mph	35.2 psf	61.4 psf	81.0 psf	110.3 psf
	ASD	90 mph	21.2 psf	36.8 psf	48.6 psf	66.2 psf
ASCE 7-10	Ult.	120 mph	--	42.0 psf	70.5 psf	105.9 psf
	ASD	93 mph	--	25.2 psf	42.3 psf	63.6 psf
ASCE 7-05	Ult.	90 mph	--	27.3 psf	45.4 psf	68.6 psf

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Wind design for FM Global-insured buildings

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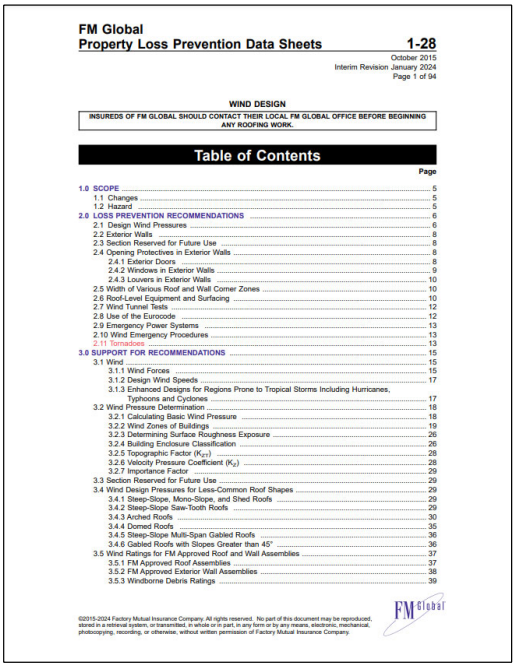

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Property Loss Prevention Data Sheets 1-28

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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

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

Link

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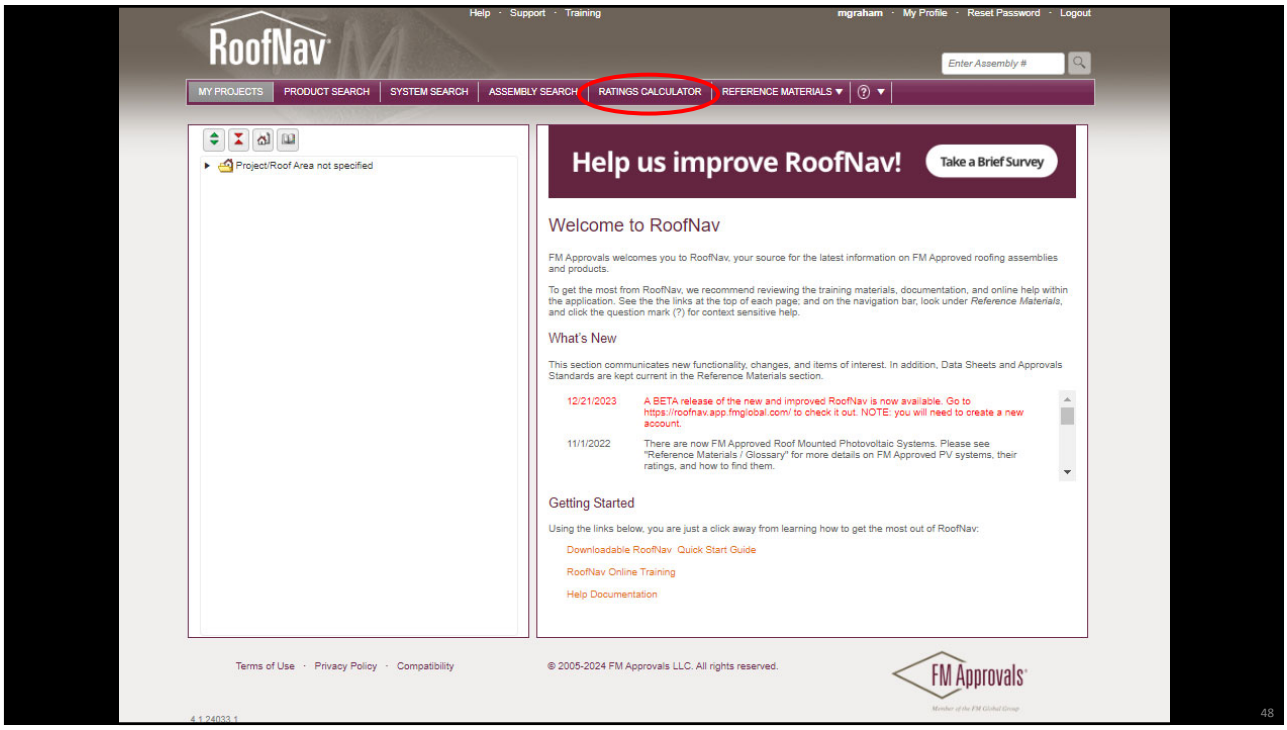

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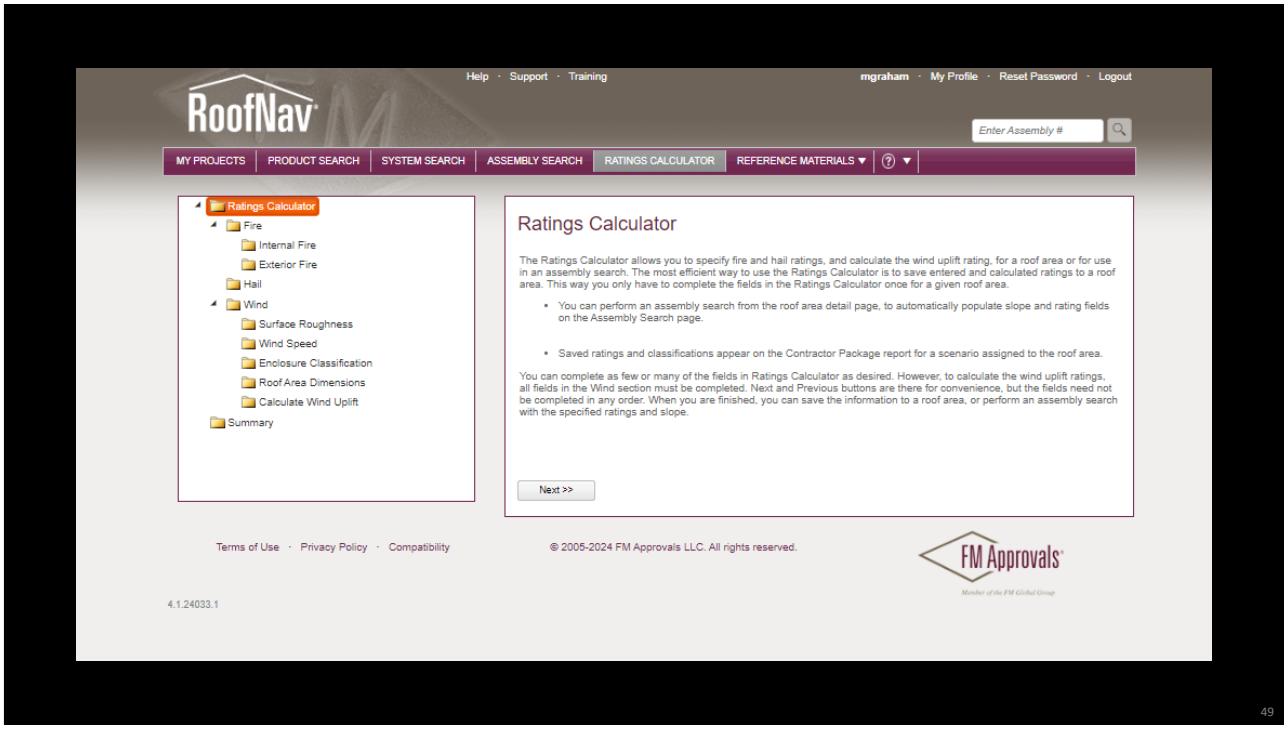
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Ratings Calculator
The Ratings Calculator allows you to specify fire and hail ratings, and calculate the wind uplift rating, for a roof area or for use in an assembly search. The most efficient way to use the Ratings Calculator is to save entered and calculated ratings to a roof area. This way you only have to complete the fields in the Ratings Calculator once for a given roof area.
You can perform an assembly search from the roof area detail page, to automatically populate slope and rating fields on the Assembly Search page.
Saved ratings and classifications appear on the Contractor Package report for a scenario assigned to the roof area.
You can complete as few or many of the fields in Ratings Calculator as desired. However, to calculate the wind uplift ratings, all fields in the Wind section must be completed. Next and Previous buttons are there for convenience, but the fields need not be completed in any order. When you are finished, you can save the information to a roof area, or perform an assembly search with the specified ratings and slope.
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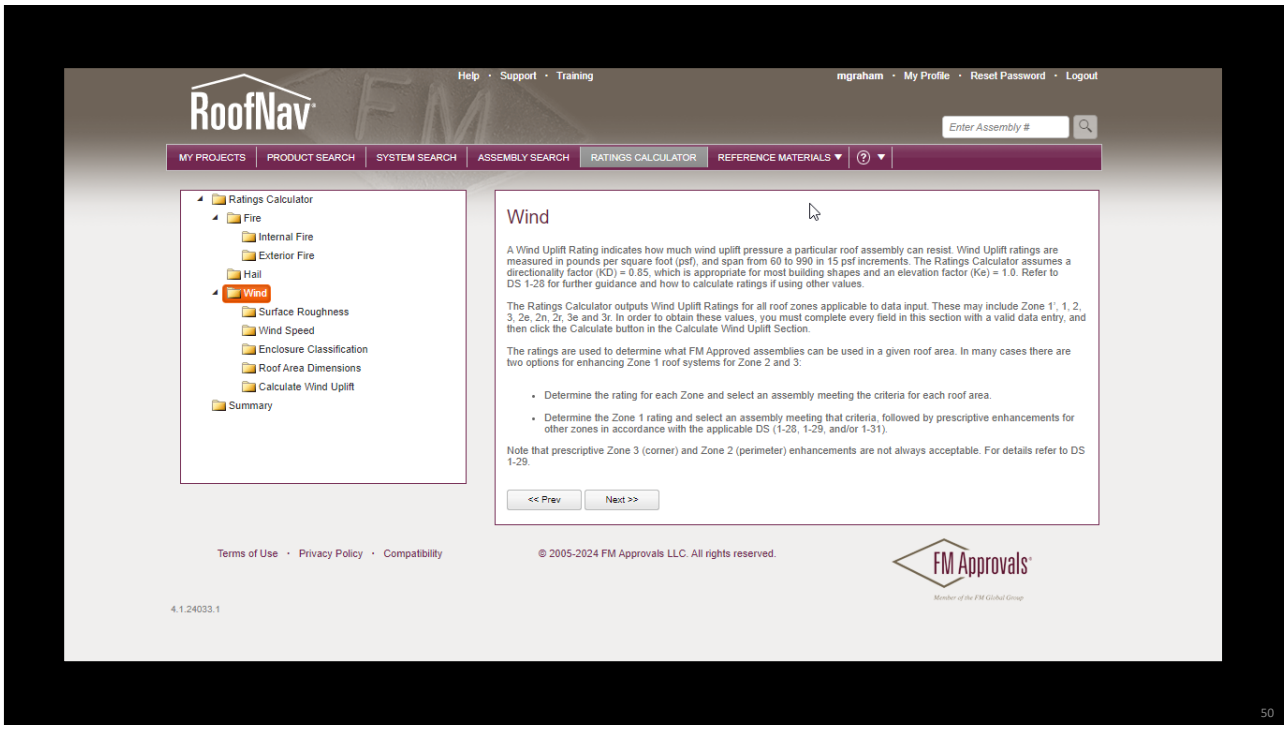
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A Wind Uplift Rating indicates how much wind uplift pressure a particular roof assembly can resist. Wind Uplift ratings are measured in pounds per square foot (psf), and span from 60 to 990 in 15 psf increments. The Ratings Calculator assumes a directionality factor (KD) = 0.85, which is appropriate for most building shapes and an elevation factor (Ke) = 1.0. Refer to DS 1-28 for further guidance and how to calculate ratings if using other values.
The Ratings Calculator outputs Wind Uplift Ratings for all roof zones applicable to data input. These may include Zone 1', 1, 2, 3, 2e, 2n, 2r, 3e and 3r. In order to obtain these values, you must complete every field in this section with a valid data entry, and then click the Calculate button in the Calculate Wind Uplift Section.
The ratings are used to determine what FM Approved assemblies can be used in a given roof area. In many cases there are two options for enhancing Zone 1 roof systems for Zone 2 and 3:
Determine the rating for each Zone and select an assembly meeting the criteria for each roof area.
Determine the Zone 1 rating and select an assembly meeting that criteria, followed by prescriptive enhancements for other zones in accordance with the applicable DS (1-28, 1-29, and/or 1-31).
Note that prescriptive Zone 3 (corner) and Zone 2 (perimeter) enhancements are not always acceptable. For details refer to DS 1-29.
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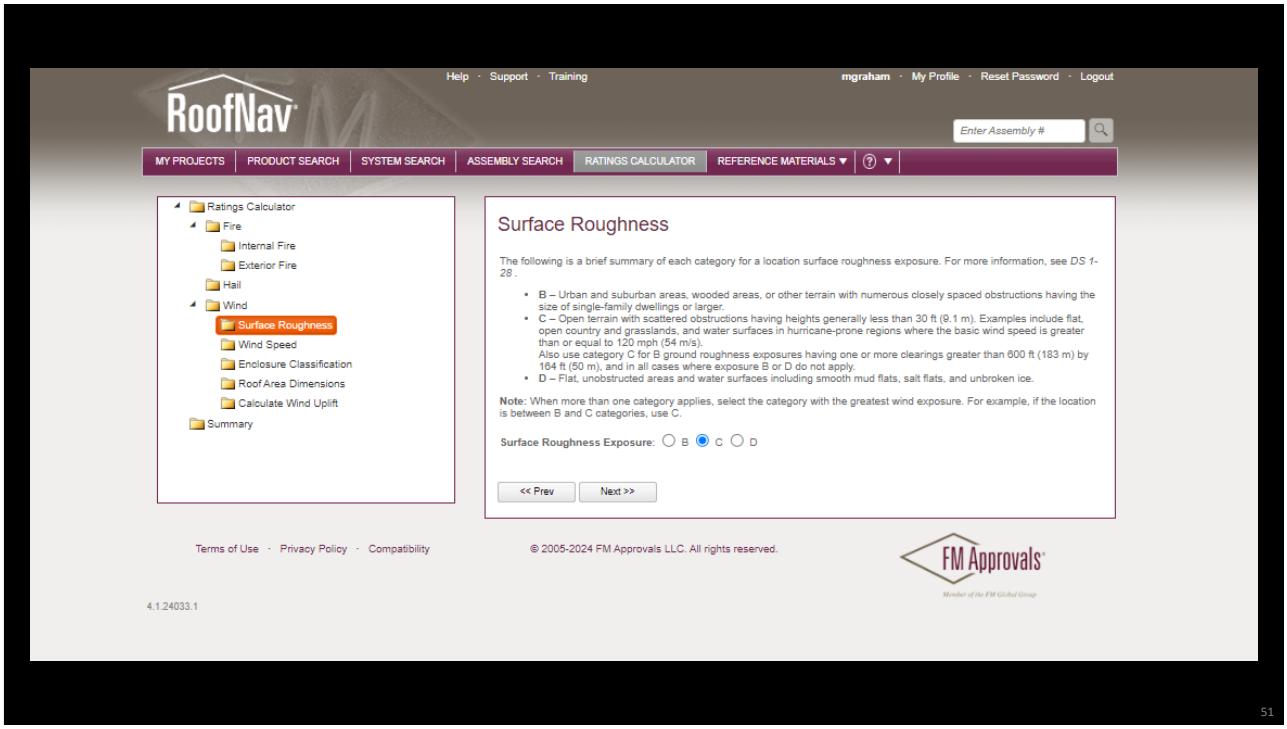
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The following is a brief summary of each category for a location surface roughness exposure. For more information, see DS 1-28 .
B – Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.
C – Open terrain with scattered obstructions having heights generally less than 30 ft (9.1 m). Examples include flat, open country and grasslands, and water surfaces in hurricane-prone regions where the basic wind speed is greater than or equal to 120 mph (54 m/s).
Also use category C for B ground roughness exposures having one or more clearings greater than 600 ft (183 m) by 164 ft (50 m), and in all cases where exposure B or D do not apply.
D – Flat, unobstructed areas and water surfaces including smooth mud flats, salt flats, and unbroken ice.
Note: When more than one category applies, select the category with the greatest wind exposure. For example, if the location is between B and C categories, use C.
Surface Roughness Exposure: B C D
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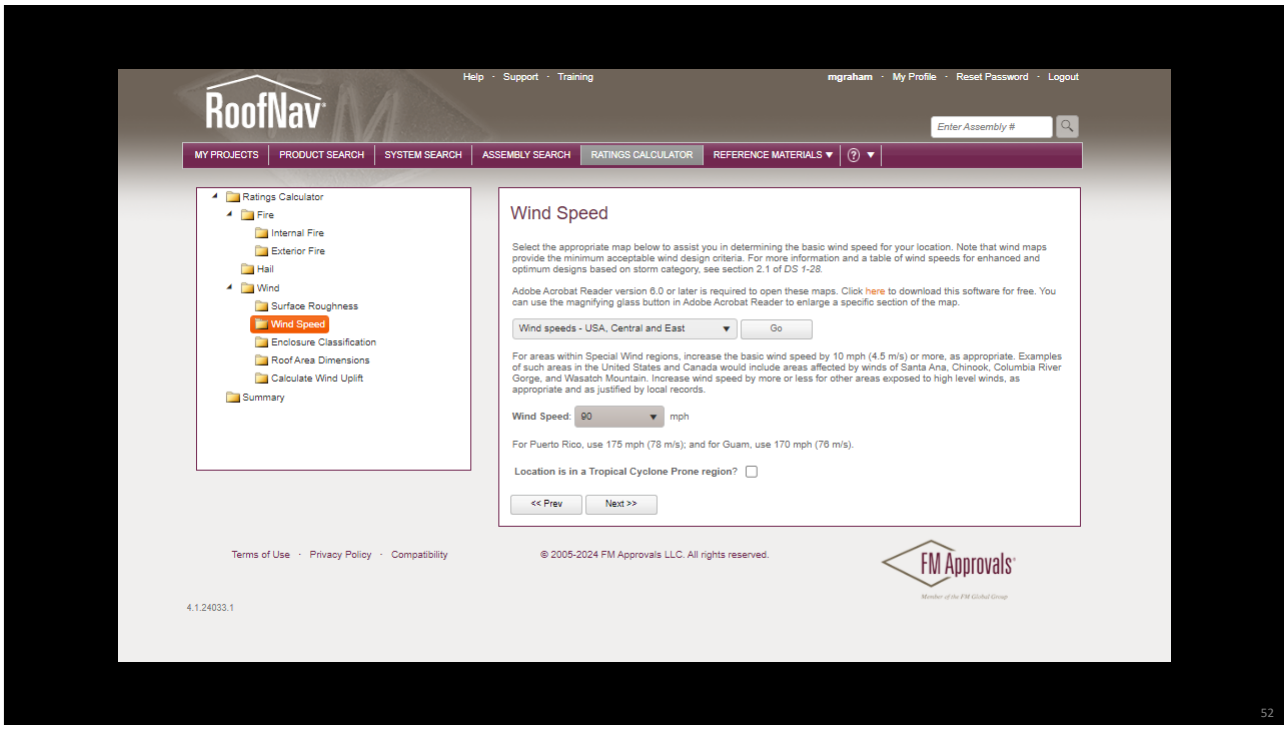
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Wind Speed
Select the appropriate map below to assist you in determining the basic wind speed for your location. Note that wind maps provide the minimum acceptable wind design criteria. For more information and a table of wind speeds for enhanced and optimum designs based on storm category, see section 2.1 of DS 1-28.
Adobe Acrobat Reader version 6.0 or later is required to open these maps. Click here to download this software for free. You can use the magnifying glass button in Adobe Acrobat Reader to enlarge a specific section of the map.
Wind speeds - USA, Central and East
Go
For areas within Special Wind regions, increase the basic wind speed by 10 mph (4.5 m/s) or more, as appropriate. Examples of such areas in the United States and Canada would include areas affected by winds of Santa Ana, Chinook, Columbia River Gorge, and Wasatch Mountain. Increase wind speed by more or less for other areas exposed to high level winds, as appropriate and as justified by local records.
Wind Speed: 90 mph
For Puerto Rico, use 175 mph (78 m/s); and for Guam, use 170 mph (76 m/s).
Location is in a Tropical Cyclone Prone region?
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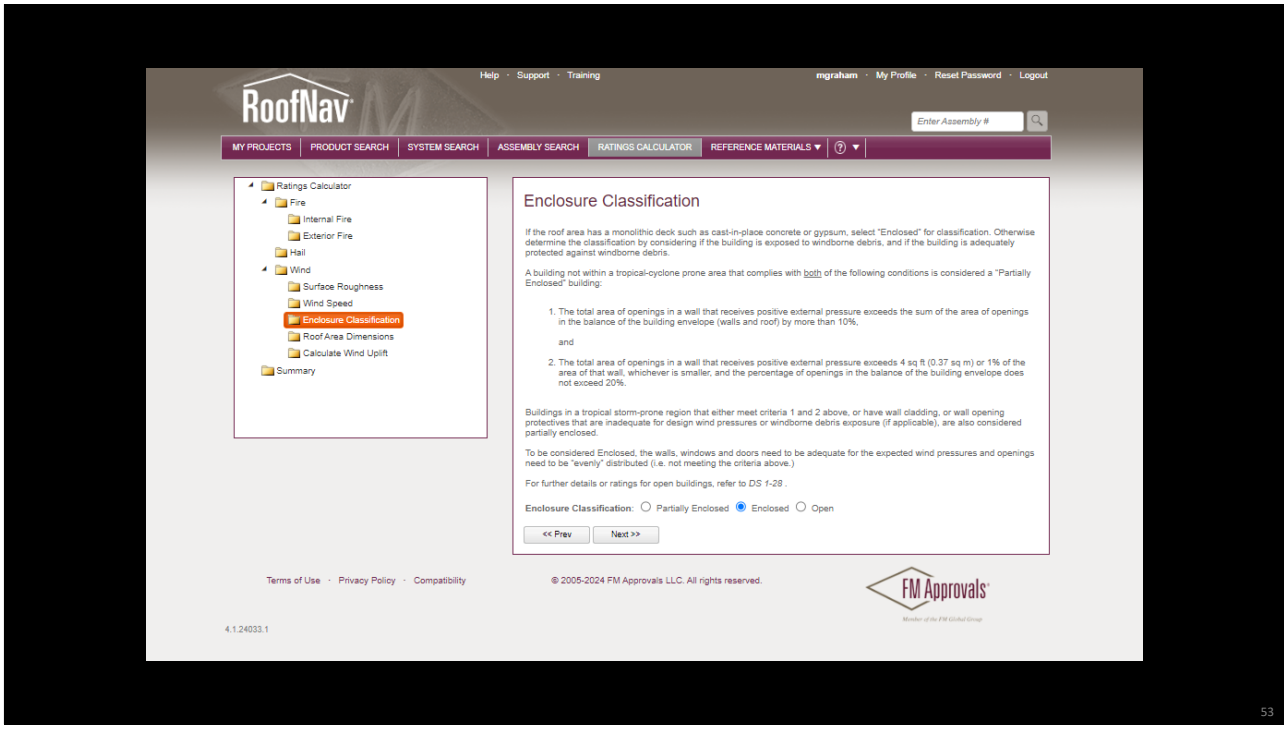
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Enclosure Classification
If the roof area has a monolithic deck such as cast-in-place concrete or gypsum, select "Enclosed" for classification. Otherwise determine the classification by considering if the building is exposed to windborne debris, and if the building is adequately protected against windborne debris.
A building not within a tropical-cyclone prone area that complies with both of the following conditions is considered a "Partially Enclosed" building:
1. The total area of openings in a wall that receives positive external pressure exceeds the sum of the area of openings in the balance of the building envelope (walls and roof) by more than 10%,
and
2. The total area of openings in a wall that receives positive external pressure exceeds 4 sq ft (0.37 sq m) or 1% of the area of that wall, whichever is smaller, and the percentage of openings in the balance of the building envelope does not exceed 20%.
Buildings in a tropical storm-prone region that either meet criteria 1 and 2 above, or have wall cladding, or wall opening protectives that are inadequate for design wind pressures or windborne debris exposure (if applicable), are also considered partially enclosed.
To be considered Enclosed, the walls, windows and doors need to be adequate for the expected wind pressures and openings need to be "evenly" distributed (i.e. not meeting the criteria above.)
For further details or ratings for open buildings, refer to DS 1-28 .
Enclosure Classification: Partially Enclosed Enclosed Open
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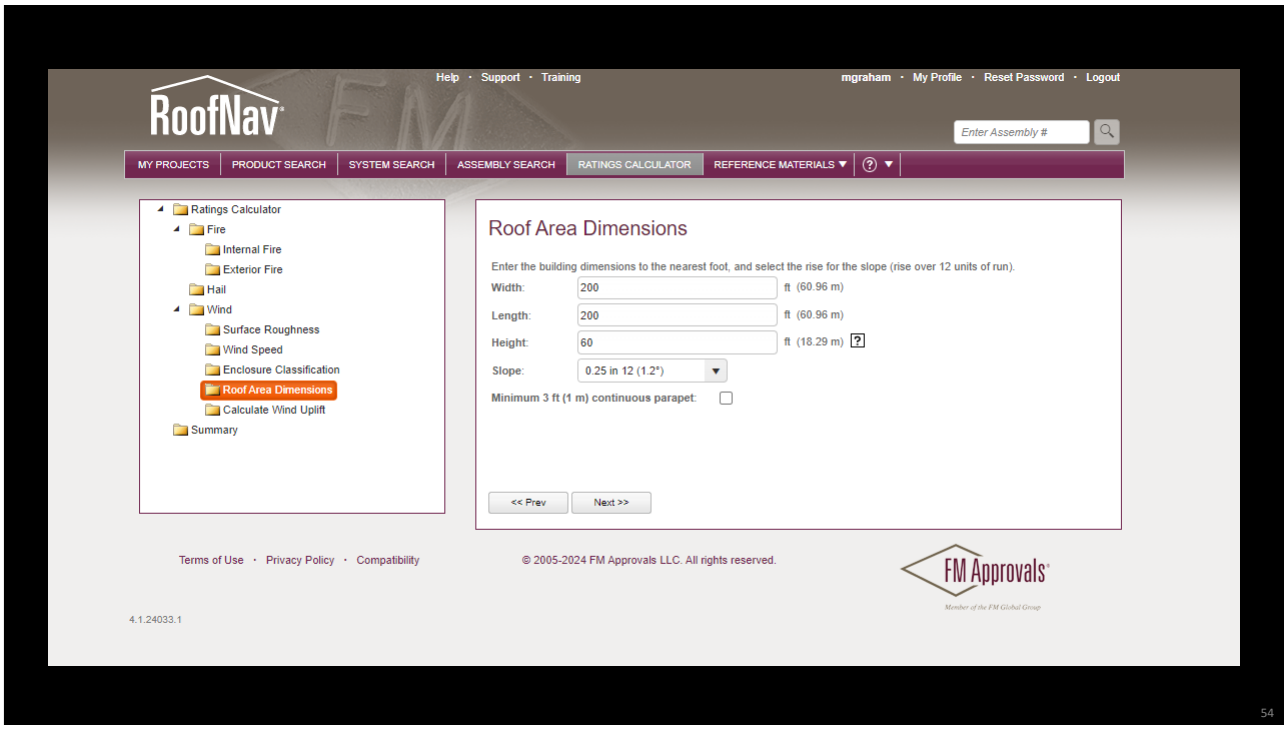
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Roof Area Dimensions
Enter the building dimensions to the nearest foot, and select the rise for the slope (rise over 12 units of run).
Width: 200 ft (60.96 m)
Length: 200 ft (60.96 m)
Height: 60 ft (18.29 m)
Slope: 0.25 in 12 (1.2°)
Minimum 3 ft (1 m) continuous parapet:
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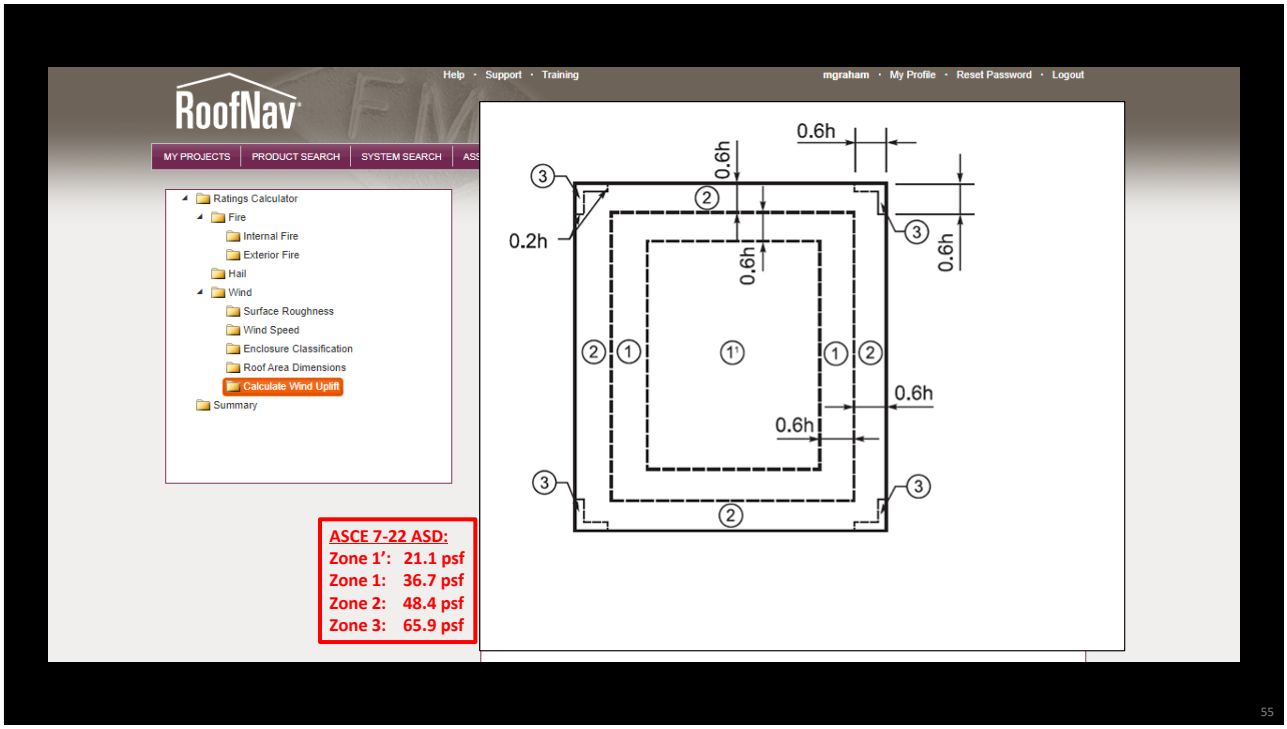

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FM Global's design wind load determination method typically results in higher design wind loads resulting in the need for higher wind resistances compared to ASCE 7-10, -16 and -22

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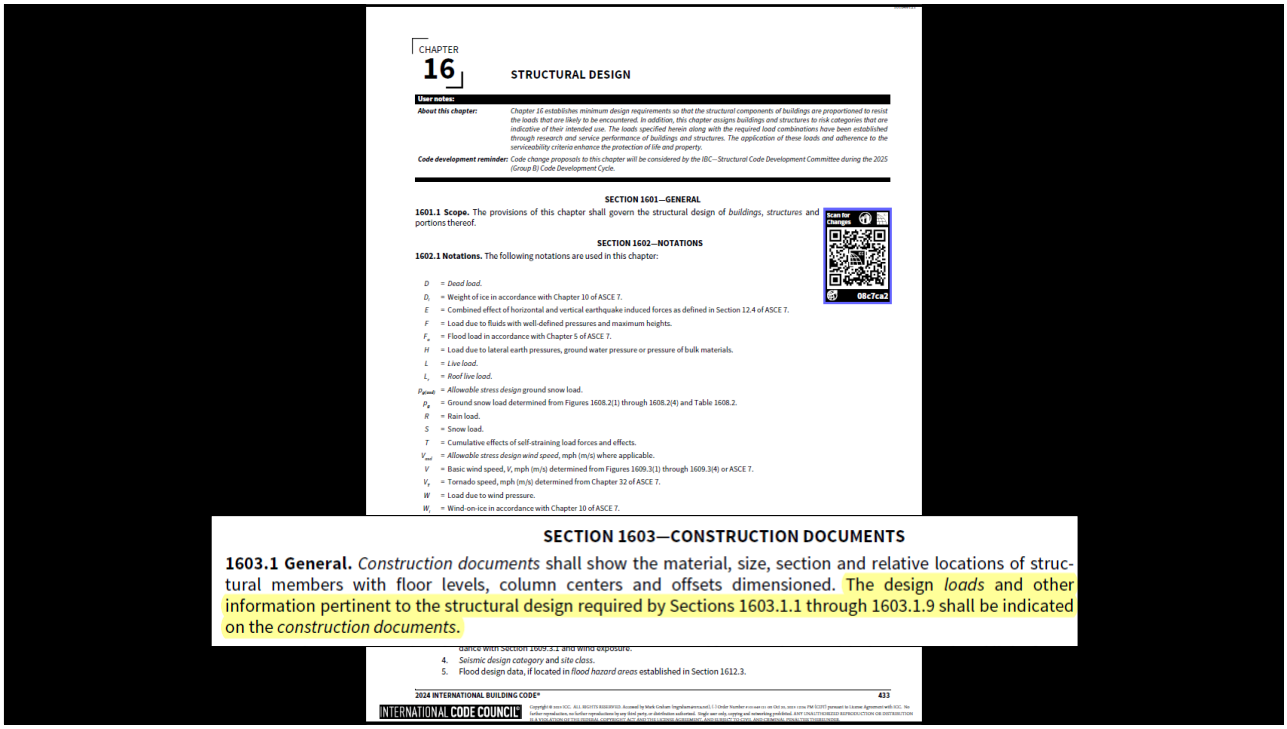

CHAPTER 16 STRUCTURAL DESIGN

User notes:

About this chapter: *Chapter 16 establishes minimum design requirements so that the structural components of buildings are proportioned to resist the loads that are likely to be encountered. In addition, this chapter assigns buildings and structures to risk categories that are indicative of their intended use. The loads specified herein along with the required load combinations have been established through research and service performance of buildings and structures. The application of these loads and adherence to the serviceability criteria enhance the protection of life and property.*

Code development reminder: *Code change proposals to this chapter will be considered by the IBC—Structural Code Development Committee during the 2025 (Group B) Code Development Cycle.*

SECTION 1601—GENERAL

1601.1 Scope. The provisions of this chapter shall govern the structural design of *buildings*, *structures* and portions thereof.

Scan for Changes 08c7ca2

SECTION 1602—NOTATIONS

1602.1 Notations. The following notations are used in this chapter:

D = *Dead load.*
D_i = Weight of ice in accordance with Chapter 10 of ASCE 7.
E = Combined effect of horizontal and vertical earthquake induced forces as defined in Section 12.4 of ASCE 7.
F = Load due to fluids with well-defined pressures and maximum heights.
F_a = Flood load in accordance with Chapter 5 of ASCE 7.
H = Load due to lateral earth pressures, ground water pressure or pressure of bulk materials.
L = *Live load.*
L_r = *Roof live load.*
$P_{allowable}$ = *Allowable stress design* ground snow load.
P_g = Ground snow load determined from Figures 1608.2(1) through 1608.2(4) and Table 1608.2.
R = Rain load.
S = Snow load.
T = Cumulative effects of self-straining load forces and effects.
V_{asd} = *Allowable stress design wind speed*, mph (m/s) where applicable.
V = Basic wind speed, *V*, mph (m/s) determined from Figures 1609.3(1) through 1609.3(4) or ASCE 7.
V_t = Tornado speed, mph (m/s) determined from Chapter 32 of ASCE 7.
W = Load due to wind pressure.
W_i = Wind-on-ice in accordance with Chapter 10 of ASCE 7.

SECTION 1603—CONSTRUCTION DOCUMENTS

1603.1 General. *Construction documents* shall show the material, size, section and relative locations of structural members with floor levels, column centers and offsets dimensioned. The design *loads* and other information pertinent to the structural design required by Sections 1603.1.1 through 1603.1.9 shall be indicated on the *construction documents*.

4. *Seismic design category* and *site class*.
5. Flood design data, if located in *flood hazard areas* established in Section 1612.3.

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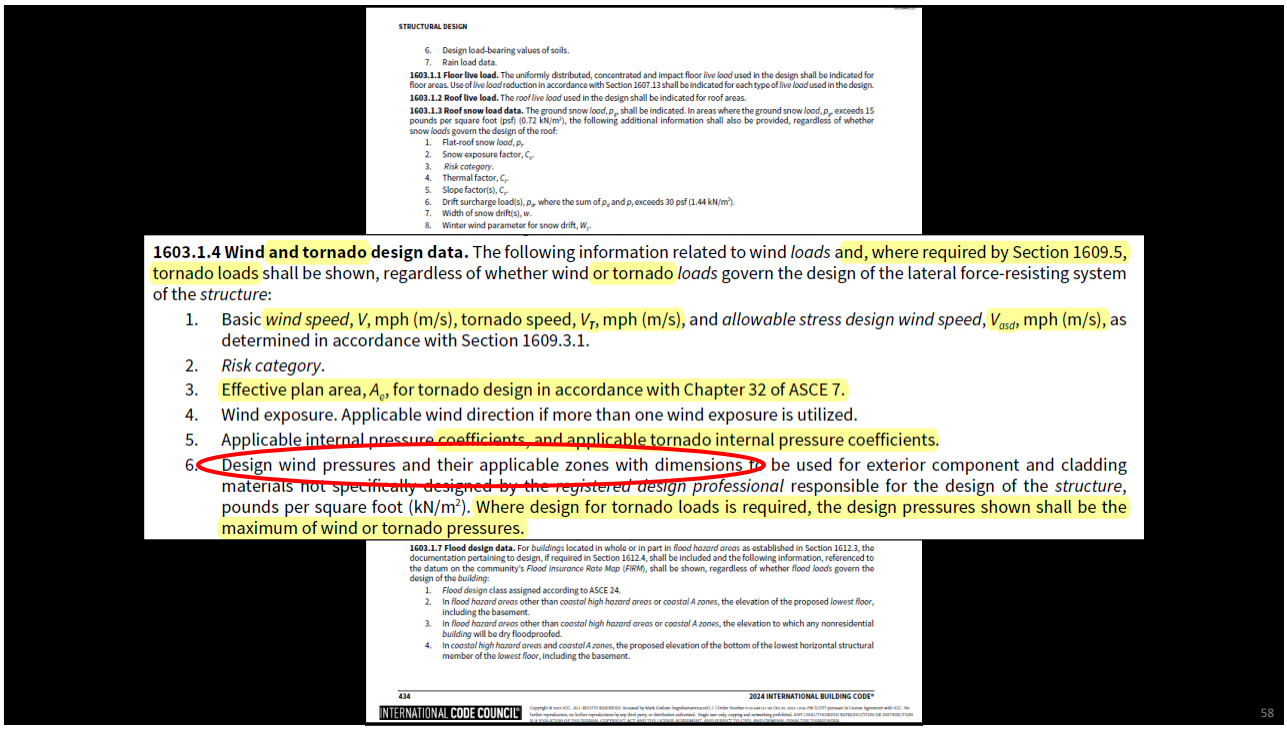

STRUCTURAL DESIGN

6. Design load-bearing values of soils.
7. Rain load data.

1603.1.1 Floor live load. The uniformly distributed, concentrated and impact floor *live load* used in the design shall be indicated for floor areas. Use of *live load* reduction in accordance with Section 1607.13 shall be indicated for each type of *live load* used in the design.

1603.1.2 Roof live load. The *roof live load* used in the design shall be indicated for roof areas.

1603.1.3 Roof snow load data. The ground snow *load*, p_g, shall be indicated. In areas where the ground snow *load*, p_g, exceeds 15 pounds per square foot (psf) (0.72 kN/m^2), the following additional information shall also be provided, regardless of whether snow *loads* govern the design of the roof:

1. Flat-roof snow *load*, p_f.
2. Snow exposure factor, C_e.
3. *Risk category*.
4. Thermal factor, C_t.
5. Slope factor(s), C_s.
6. Drift surcharge load(s), p_d, where the sum of p_d and p_f exceeds 30 psf (1.44 kN/m^2).
7. Width of snow drift(s), *w*.
8. Winter wind parameter for snow drift, W_i.

1603.1.4 Wind and tornado design data. The following information related to wind *loads* and, where required by Section 1609.5, tornado loads shall be shown, regardless of whether wind or tornado *loads* govern the design of the lateral force-resisting system of the *structure*:

1. Basic *wind speed*, *V*, mph (m/s), tornado speed, V_T, mph (m/s), and *allowable stress design wind speed*, V_{asd}, mph (m/s), as determined in accordance with Section 1609.3.1.
2. *Risk category*.
3. Effective plan area, A_e, for tornado design in accordance with Chapter 32 of ASCE 7.
4. Wind exposure. Applicable wind direction if more than one wind exposure is utilized.
5. Applicable internal pressure coefficients, and applicable tornado internal pressure coefficients.
6. Design wind pressures and their applicable zones with dimensions to be used for exterior component and cladding materials not specifically designed by the *registered design professional* responsible for the design of the *structure*, pounds per square foot (kN/m^2). Where design for tornado loads is required, the design pressures shown shall be the maximum of wind or tornado pressures.

1603.1.7 Flood design data. For *buildings* located in whole or in part in *flood hazard areas* as established in Section 1612.3, the documentation pertaining to design, if required in Section 1612.4, shall be included and the following information, referenced to the datum on the community's *Flood Insurance Rate Map* (*FIRM*), shall be shown, regardless of whether *flood loads* govern the design of the *building*:

1. *Flood design class* assigned according to ASCE 24.
2. In *flood hazard areas* other than *coastal high hazard areas* or *coastal A zones*, the elevation of the proposed *lowest floor*, including the basement.
3. In *flood hazard areas* other than *coastal high hazard areas* or *coastal A zones*, the elevation to which any nonresidential *building* will be dry floodproofed.
4. In *coastal high hazard areas* and *coastal A zones*, the proposed elevation of the bottom of the lowest horizontal structural member of the *lowest floor*, including the basement.

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Design wind loads (and, if applicable, tornado loads), zones and zone dimensions are required to be shown on the Construction Documents.

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Wind resistance

Wind design

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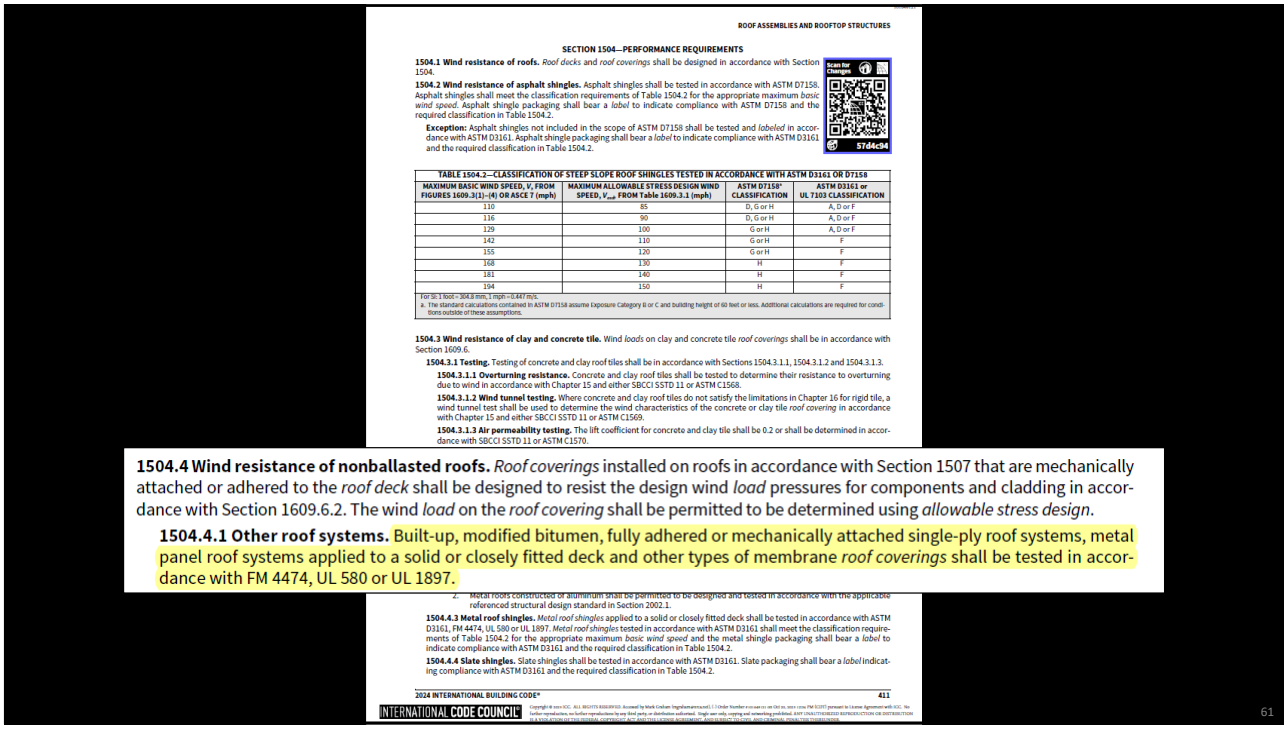

ROOF ASSEMBLIES AND ROOFTOP STRUCTURES

SECTION 1504—PERFORMANCE REQUIREMENTS

1504.1 Wind resistance of roofs. *Roof decks* and *roof coverings* shall be designed in accordance with Section 1504.

1504.2 Wind resistance of asphalt shingles. Asphalt shingles shall be tested in accordance with ASTM D7158. Asphalt shingles shall meet the classification requirements of Table 1504.2 for the appropriate maximum *basic wind speed*. Asphalt shingle packaging shall bear a *label* to indicate compliance with ASTM D7158 and the required classification in Table 1504.2.

Exception: Asphalt shingles not included in the scope of ASTM D7158 shall be tested and *labeled* in accordance with ASTM D3161. Asphalt shingle packaging shall bear a *label* to indicate compliance with ASTM D3161 and the required classification in Table 1504.2.

TABLE 1504.2—CLASSIFICATION OF STEEP SLOPE ROOF SHINGLES TESTED IN ACCORDANCE WITH ASTM D3161 OR D7158

MAXIMUM BASIC WIND SPEED, V, FROM FIGURES 1609.3(1)–(4) OR ASCE 7 (mph)	MAXIMUM ALLOWABLE STRESS DESIGN WIND SPEED, V_{asd}, FROM Table 1609.3.1 (mph)	ASTM D7158[a] CLASSIFICATION	ASTM D3161 or UL 7103 CLASSIFICATION
110	85	D, G or H	A, D or F
116	90	D, G or H	A, D or F
129	100	G or H	A, D or F
142	110	G or H	F
155	120	G or H	F
168	130	H	F
181	140	H	F
194	150	H	F

For SI: 1 foot = 304.8 mm, 1 mph = 0.447 m/s.
a. The standard calculations contained in ASTM D7158 assume Exposure Category B or C and building height of 60 feet or less. Additional calculations are required for conditions outside of these assumptions.

1504.3 Wind resistance of clay and concrete tile. Wind *loads* on clay and concrete tile *roof coverings* shall be in accordance with Section 1609.6.

1504.3.1 Testing. Testing of concrete and clay roof tiles shall be in accordance with Sections 1504.3.1.1, 1504.3.1.2 and 1504.3.1.3.

1504.3.1.1 Overturning resistance. Concrete and clay roof tiles shall be tested to determine their resistance to overturning due to wind in accordance with Chapter 15 and either SBCCI SSTD 11 or ASTM C1568.

1504.3.1.2 Wind tunnel testing. Where concrete and clay roof tiles do not satisfy the limitations in Chapter 16 for rigid tile, a wind tunnel test shall be used to determine the wind characteristics of the concrete or clay tile *roof covering* in accordance with Chapter 15 and either SBCCI SSTD 11 or ASTM C1569.

1504.3.1.3 Air permeability testing. The lift coefficient for concrete and clay tile shall be 0.2 or shall be determined in accordance with SBCCI SSTD 11 or ASTM C1570.

1504.4 Wind resistance of nonballasted roofs. *Roof coverings* installed on roofs in accordance with Section 1507 that are mechanically attached or adhered to the *roof deck* shall be designed to resist the design wind *load* pressures for components and cladding in accordance with Section 1609.6.2. The wind *load* on the *roof covering* shall be permitted to be determined using *allowable stress design*.

1504.4.1 Other roof systems. Built-up, modified bitumen, fully adhered or mechanically attached single-ply roof systems, metal panel roof systems applied to a solid or closely fitted deck and other types of membrane *roof coverings* shall be tested in accordance with FM 4474, UL 580 or UL 1897.

2. Metal roofs constructed of aluminum shall be permitted to be designed and tested in accordance with the applicable referenced structural design standard in Section 2002.1.

1504.4.3 Metal roof shingles. *Metal roof shingles* applied to a solid or closely fitted deck shall be tested in accordance with ASTM D3161, FM 4474, UL 580 or UL 1897. *Metal roof shingles* tested in accordance with ASTM D3161 shall meet the classification requirements of Table 1504.2 for the appropriate maximum *basic wind speed* and the metal shingle packaging shall bear a *label* to indicate compliance with ASTM D3161 and the required classification in Table 1504.2.

1504.4.4 Slate shingles. Slate shingles shall be tested in accordance with ASTM D3161. Slate packaging shall bear a *label* indicating compliance with ASTM D3161 and the required classification in Table 1504.2.

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This wording does not require the testing be conducted solely by FM Approvals or UL.
Other testing laboratories can be used provided they use the prescribed test methods

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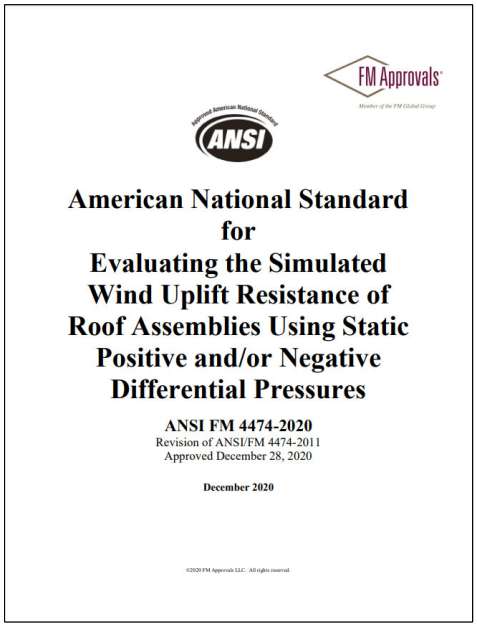

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ANSI

American National Standard for Evaluating the Simulated Wind Uplift Resistance of Roof Assemblies Using Static Positive and/or Negative Differential Pressures

ANSI FM 4474-2020
Revision of ANSI/FM 4474-2011
Approved December 28, 2020

December 2020

ANSI/FM 4474:

- 12 x 24, 5 x 9 or 2 x 2 specimens
- 15 psf test increments to failure
- Class 30, 45, 60, 75, 90, etc. (psf)
- FM typically applies a 2.0 safety factor:
  - e.g., Class 90 is 45 psf allowable
- Tested assemblies identified with individual RoofNav numbers and are shown in RoofNav
- More than 1.1 million assemblies in RoofNav

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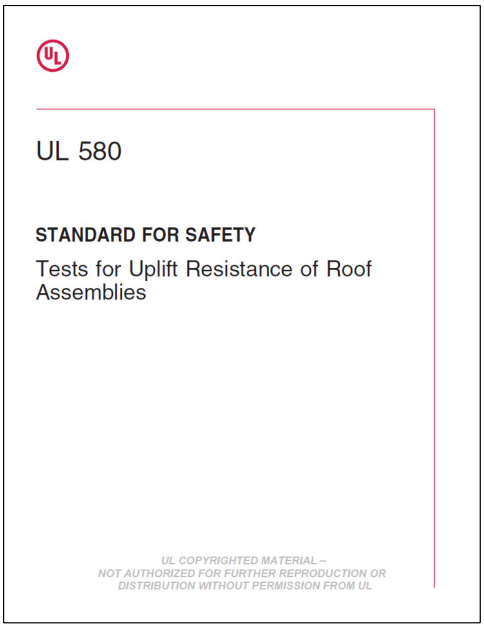

UL 580

STANDARD FOR SAFETY

Tests for Uplift Resistance of Roof Assemblies

UL 580:

- 5th edition, revised March 29, 2019
- 10’ x 10’ chamber
- Oscillating negative and positive pressures applied (80-minute cycles per load classification)
- Class 15, 30, 60 and 90
- Classified assemblies appear in UL Prospector

This is a very stringent test

Link

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UL 580 test apparatus

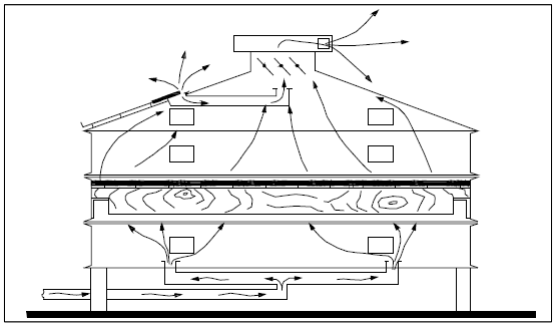

Photo courtesy of Atas International, Inc.

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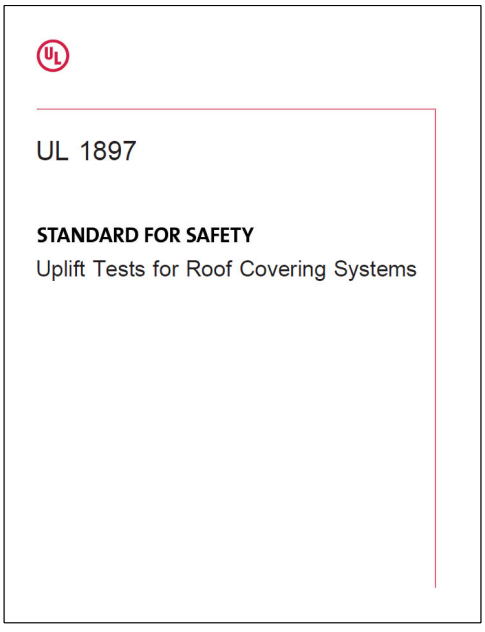

UL 1897:

- 7th edition, revised July 13, 2023
- Part 1: 10’ x 10’ or 5’ x 9’ specimens
  - 15 psf load increments held of 60 seconds each (uniform static pressure)
- Part 2: 2’ x 2’ pull test (adhered systems)
- Class 15, 30, 60 and 90
- Classified assemblies appear in UL Prospector

Link

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1504.8 Wind resistance of aggregate-surfaced roofs. Parapets shall be provided for aggregate surfaced roofs and shall comply with Table 1504.8. Such parapets shall be provided on the perimeter of the roof at all exterior sides except where an adjacent wall extends above the roof to a height at least equivalent to that required for the parapet. For roofs with differing surface elevations due to slope or sections at different elevations, the minimum parapet height shall be determined based on each roof surface elevation, and at no point shall the parapet height be less than that required by Table 1504.8.

Exception: Ballasted single-ply *roof coverings* shall be designed and installed in accordance with Section 1504.5.

TABLE 1504.8—MINIMUM REQUIRED PARAPET HEIGHT (INCHES) FOR AGGREGATE SURFACED ROOFS[a, b, c, d, e]

AGGREGATE SIZE	MEAN ROOF HEIGHT (ft)	WIND EXPOSURE AND BASIC WIND SPEED, *V* (MPH)																	
		Exposure B									Exposure C[f]								
		≤ 95	100	105	110	115	120	130	140	150	≤ 95	100	105	110	115	120	130	140	150
ASTM D1863 (No. 7 or No. 67)	15	2	2	2	2	12	12	16	20	24	2	13	15	18	20	23	27	32	37
	20	2	2	2	2	12	14	18	22	26	12	15	17	19	22	24	29	34	39
	30	2	2	2	13	15	17	21	25	30	14	17	19	22	24	27	32	37	42
	50	12	12	14	16	18	21	25	30	35	17	19	22	25	28	30	36	41	47
	100	14	16	19	21	24	27	32	37	42	21	24	26	29	32	35	41	47	53
	150	17	19	22	25	27	30	36	41	46	23	26	29	32	35	38	44	50	56
ASTM D1863 (No. 6)	15	2	2	2	2	12	12	12	15	18	2	2	2	13	15	17	22	26	30
	20	2	2	2	2	12	12	13	17	21	2	2	12	15	17	19	23	28	32
	30	2	2	2	2	12	12	16	20	24	2	12	14	17	19	21	26	31	35
	50	12	12	12	12	14	16	20	24	28	12	15	17	19	22	24	29	34	39
	100	12	12	14	16	19	21	26	30	35	16	18	21	24	26	29	34	39	45
	150	12	14	17	19	22	24	29	34	39	18	21	23	26	29	32	37	43	48

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 mile per hour = 0.447 m/s.

a. Parapet height is measured vertically from the top surface of the coping down to the surface of the roof covering in the field of the roof adjacent to the parapet and outbound of any cant strip.
b. Interpolation shall be permitted for wind speed, mean roof height and parapet height. Extrapolation is not permitted.
c. Basic wind speed, *V*, and wind exposure shall be determined in accordance with Section 1609.
d. Where the minimum required parapet height is indicated to be 2 inches (51 mm), a gravel stop shall be permitted and shall extend not less than 2 inches (51 mm) from the roof surface and not less than the height of the aggregate.
e. The tabulated values apply only to conditions where the topographic factor (K_{zt}) determined in accordance with Chapter 26 of ASCE 7 is 1.0 or where K_{zt} is incorporated in the basic wind speed in Section 1609.
f. For Exposure D, add 8 inches (203 mm) to the parapet height required for Exposure C and the parapet height shall not be less than 12 inches (305 mm).

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ROOF ASSEMBLIES AND ROOFTOP STRUCTURES

1504.5 Ballasted low-slope single-ply roof systems. Ballasted *low-slope* single-ply roof system coverings installed in accordance with Section 1507.12 shall be designed in accordance with ANSI/SPRI RP-4.

determined from Figures 1609.3(1)through 1609.3(4), as applicable.

1504.6.1 Gutter securement for low-slope roofs. Gutters that are used to secure the perimeter edge of the roof membrane on *low-slope* built-up, modified bitumen, and single-ply roofs, shall be designed, constructed and installed to resist wind loads in accordance with Section 1609 and shall be tested in accordance with Test Methods G-1 and G-2 of SPRI GT-1.

1504.7 Impact resistance. *Roof coverings* installed on *low-slope* roofs in accordance with Section 1507 shall resist impact damage based on the results of tests conducted in accordance with ASTM D3746, ASTM D4272 or the "Resistance to Foot Traffic Test" in FM 4470.

1504.8 Wind resistance of aggregate-surfaced roofs. Parapets shall be provided for aggregate surfaced roofs and shall comply with Table 1504.8. Such parapets shall be provided on the perimeter of the roof at all exterior sides except where an adjacent wall extends above the roof to a height at least equivalent to that required for the parapet. For roofs with differing surface elevations due to slope or sections at different elevations, the minimum parapet height shall be determined based on each roof surface elevation, and at no point shall the parapet height be less than that required by Table 1504.8.

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	20	2	2	2	2	12	12	13	17	21	2	2	12	15	17	19	23	28	32
	30	2	2	2	2	12	12	16	20	24	2	12	14	17	19	21	26	31	35
	50	12	12	12	12	14	16	20	24	28	12	15	17	19	22	24	29	34	39
	100	12	12	14	16	19	21	26	30	35	16	18	21	24	26	29	34	39	45
	150	12	14	17	19	22	24	29	34	39	18	21	23	26	29	32	37	43	48

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e. The tabulated values apply only to conditions where the topographic factor (K_{zt}) determined in accordance with Chapter 26 of ASCE 7 is 1.0 or where K_{zt} is incorporated in the basic wind speed in Section 1609.
f. For Exposure D, add 8 inches (203 mm) to the parapet height required for Exposure C and the parapet height shall not be less than 12 inches (305 mm).

SECTION 1505—FIRE CLASSIFICATION

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[BF] 1505.1 General. Fire classification of roof assemblies shall be in accordance with Section 1505. The minimum fire classification of roof assemblies installed on buildings shall comply with Table 1505.1 based on type of construction of the building. Class A, B and C *roof assemblies* and *roof coverings* required to be *listed* by this section shall be tested in accordance with ASTM E108 or UL 790. In addition, *fire-retardant-treated woodroof coverings* shall be tested in accordance with ASTM D2898.

Exception: *Skylights and sloped glazing* that comply with Chapter 24 or Section 2610.

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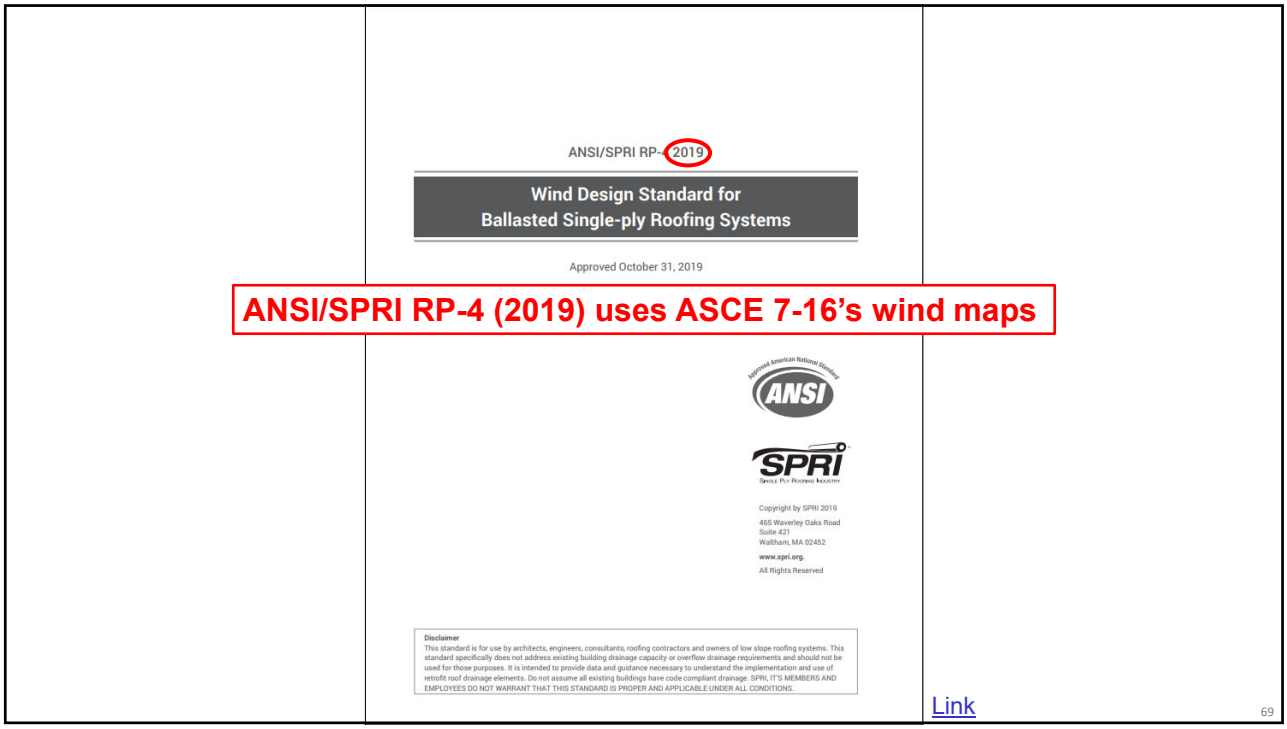
ANSI/SPRI RP-4-2019
Wind Design Standard for
Ballasted Single-ply Roofing Systems
Approved October 31, 2019
ANSI/SPRI RP-4 (2019) uses ASCE 7-16's wind maps
ANSI
SPRI
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Suite 421
Waltham, MA 02452
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Disclaimer
This standard is for use by architects, engineers, consultants, roofing contractors and owners of low slope roofing systems. This standard specifically does not address existing building drainage capacity or overflow drainage requirements and should not be used for those purposes. It is intended to provide data and guidance necessary to understand the implementation and use of retrofit roof drainage elements. Do not assume all existing buildings have code compliant drainage. SPRI, IT'S MEMBERS AND EMPLOYEES DO NOT WARRANT THAT THIS STANDARD IS PROPER AND APPLICABLE UNDER ALL CONDITIONS.
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Now, putting this all together…
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Remember… our fundamental equation

Design wind loads ≤ Tested resistance*

ASCE 7 ≤ Engineering analysis or
FM Approvals classification
or UL classification

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From our hypothetical building calculation

Assumptions: Building height (h) = 60 ft., low-slope roof, enclosed building configuration, Exposure Category C and Risk Category III in Madison, Wisconsin.

Version	Method	Basic wind speed	Zone 1'	Zone 1	Zone 2	Zone 3
ASCE 7-22	Ult.	115 mph	35.1 psf	61.1 psf	80.6 psf	109.9 psf
	ASD	90 mph	21.1 psf	36.7 psf	48.4 psf	65.9 psf

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Remember… our fundamental equation

Design wind loads ≤ Tested resistance*

ASCE 7 ≤ Engineering analysis or
FM Approvals classification
or UL classification

65.9 psf ≤ 131.8 psf (i.e., 65.9 psf x 2.0)
or FM Class 150
UL Class 90

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For FM Global-insured buildings there is an alternative to designing for corner pressures…

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Prescriptive enhancements

Roof Deck Securement and Above-Deck Roof Components 1-29

2.2.10.1 Wind Uplift Resistance

2.2.10.1.1 Provide one of the following options to secure Zones 2 and 3:

A. Use a roof system with an FM Approval wind uplift rating that is acceptable for Zones 1', 1, 2, and 3 per the Ratings Calculator of RoofNav or DS 1-28. That could entail using a system throughout the entire roof that had a wind rating adequate for Zone 3, or using a system that has a varied fastener spacing and multiple wind ratings that are adequate for the respective roof zone.

B. Use the appropriate prescriptive recommendation noted in Section 2.2.10.1.2.

In either case, ensure any whole or partial insulation board or roof cover/base sheet width (when the roll is parallel to the building edge) that falls within the calculated Zone 1, Zone 2, or Zone 3 area has the increased securement applied over the entire board or roof cover/base sheet width.

2.2.10.1.2 Use prescriptive enhancements for Zone 2 and Zone 3 (for all deck types) where roof covers are adhered to some combination of insulation or cover board as long as **one** of the following conditions applies:

A. The recommended Zone 1 rating needed per DS 1-28 in any location does not exceed Class 1-90 (3.6 kPa), or

B. The building is in a non-tropical cyclone-prone region (see Appendix A) and the recommended Zone 1 rating per DS 1-28 does not exceed Class 1-105 (4.3 kPa).

2.2.10.1.2.1 For either of the above conditions, increase the securement over the FM Approved Zone 1 rating as follows:

A. For assemblies using insulation fasteners, enhance the fastening as follows:

1. Increase the number of fasteners per board by 50% minimum in Zone 2, but at least one fastener per 2 ft^2 (1 per 0.19 m^2). It is not necessary to install fasteners closer than one per 1 ft^2 (1 per 0.09 m^2).

2. Install one fastener per 1 ft^2 (1 per 0.09 m^2) in Zone 3.

3. Round up to the next whole number of fasteners, if necessary

B. For components adhered with adhesives applied in ribbons, spots, etc., reduce the spacing between ribbons or spots over the FM Approved spacing for the given wind rating as noted below (round down to a dimension that is practical with respect to board sizes, applicators, etc.):

1. In Zone 2, not more than 67% of the Zone 1 spacing between rows, or area

2. In Zone 3, not more than 50% of the Zone 1 spacing between rows, or area.

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From our fundamental equation

Design wind loads ≤ Tested resistance*

ASCE 7 ≤ Engineering analysis or FM Approvals classification or UL classification

69.4 psf ≤ FM Class 75 with prescriptive Zone 2 and 3 enhancements is permissible for FM Global-insured buildings

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Proper wind design can be a complex undertaking…
but now you know how to do it properly

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Appendix 1—Wind Uplift

Protection against wind forces should be one of the fundamental principles of good roof assembly design. When wind strikes a building, it is deflected around the building's sides and over the roof surface. The result is a positive pressure on the side of the building the wind first contacts (windward side). Lower pressures or negative pressures occur on the building's other sides and over the roof, as shown in Figure A1-1.

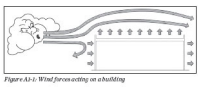

Figure A1-1: Wind forces acting on a building

The fundamental concept of wind design as it applies to roof assemblies is that the wind-resistance (uplift-resistance) capacity of the roof assembly should be greater than the design wind loads that will occur on a building's roof assembly. This is expressed as:

Design uplift-resistance capacity > Design wind load

Typically, these values are measured in pounds per square foot.

If wind loads exceed a roof assembly's resistance capacity, failure (blow-off) of the roof assembly is possible. Therefore, it is important a building's design wind loads and roof assembly's wind resistance accurately be determined.

Design wind loads are mathematical predictions of anticipated maximum wind loads that apply to a specific building (taking into account configuration, height and size, exposure classification and enclosure classification) and location. The widely recognized consensus standard method for determining design wind loads on buildings is ASCE 7, "Minimum Design Loads and Associated Criteria for Buildings and Other Structures." The 2016 edition of ASCE 7, designated ASCE 7-16, is referenced in and serves as the technical basis for wind-load determination in the 2018 edition of the International Building Code.

When designing a building for wind forces, a designer determines theoretical design wind loads using design methods identified in the applicable building code. In the *International Building Code, 2018 Edition* and its previous editions, minimum requirements for design wind loads are identified in Chapter 16—Structural Design. IBC 2018 references ASCE 7-16, "Minimum Design Loads and Associated Criteria for Buildings and Other Structures," for determining design wind loads on buildings, including buildings' roof assemblies.

Using ASCE 7-16, design wind loads of hypothetical 1-square roof areas are determined for each uniquely defined zone using an equation combining velocity pressure caused by wind and specific pressure coefficients. For instance, for low-slope roof assemblies with slopes less than 1½:12, ASCE 7-16 prescribes a pressure coefficient (GCp) of 0.9 for the zone nearest the center and progressively higher GCp values for uniquely defined zones the farther away they are from the center. The highest GCp value of 3.2 occurs at the corner zones. Figure A1-2 illustrates this relationship.

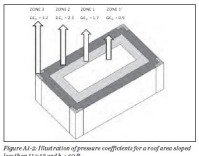

Figure A1-2: Illustration of pressure coefficients for a roof area sloped less than 1½:12 and h ≤ 60 ft.

This relationship shows the premise that design wind loads typically are greater at roof area perimeters and greater still at corners than they are in the field of roofs.

Wind uplift

The NRCA Roofing Manual

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Questions

Wind design

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Mark S. Graham
Vice President, Technical Services
National Roofing Contractors Association
10255 West Higgins Road, 600
Rosemont, Illinois 60018-5607

(847) 299-9070
mgraham@nrca.net
www.nrca.net

Personal website: www.MarkGrahamNRCA.com
LinkedIn: linkedin.com/in/markgrahamnrca

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