Tuesday, June 18, 2019

ASCE 7-16 and its impact on roof system designs

presented by

NRCA

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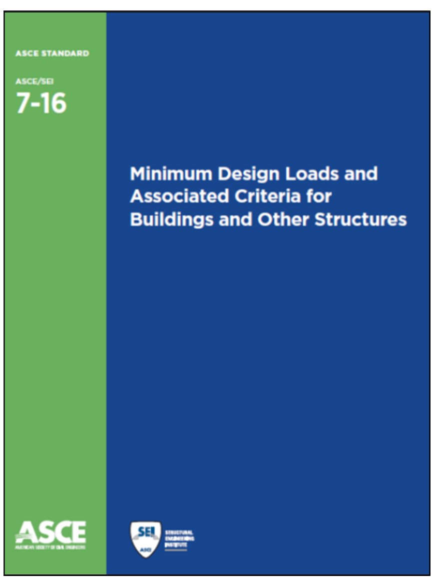
1



- Provisions: 402 pages
- Commentary: 417 pages

- Soft cover
- Electronic file (PDF)

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2

Basic energy equation

$$E = \frac{1}{2} m v^2$$

Fundamental wind pressure equation

$$q = 0.00256 v^2$$

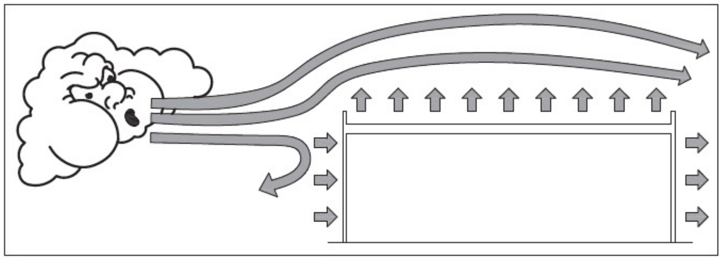
3

Using the fundamental wind pressure equation

Basic wind speed (mph)	Pressure (psf)
85	18.5
90	20.1
100	25.6
110	31.0
120	36.9
130	43.2
140	50.2
150	57.6
160	65.5
170	74.0
180	82.0

4

The fundamental concept of wind design



ASCE 7-16

Wind creates pressures/forces acting on building elements

5

The fundamental concept of wind resistance

Wind resistance ≥ Design wind loads

FM Approvals or UL classification, or engineering analysis

ASCE 7-16

6

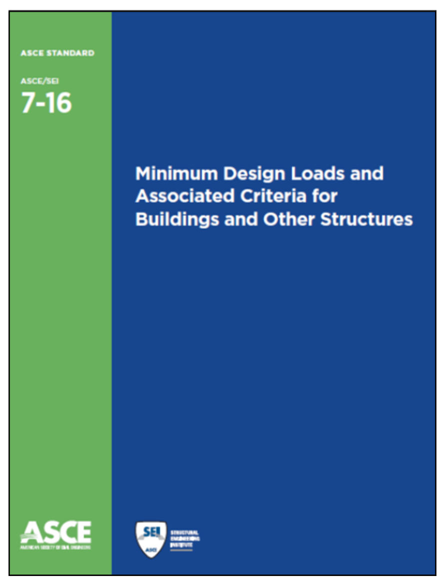
Safety factor

A factor of safety is intended to address possible variances in load determination and normally anticipated variances in materials, including material aging and deterioration, and in application.

Allowable stress design (ASD): Typically 2.0 (per FM and ASTM D6630)
Ultimate strength: - ? -

7

ASCE 7 is referenced in the International Building Code (IBC)



8

Comparing IBC editions to ASCE 7 editions

IBC	ASCE 7
IBC 2006	ASCE 7-05
IBC 2009	ASCE 7-05
IBC 2012	ASCE 7-10
IBC 2015	ASCE 7-10
IBC 2018	ASCE 7-16
IBC 2021	Most likely ASCE 7-16

9

International Building Code, 2018 Edition

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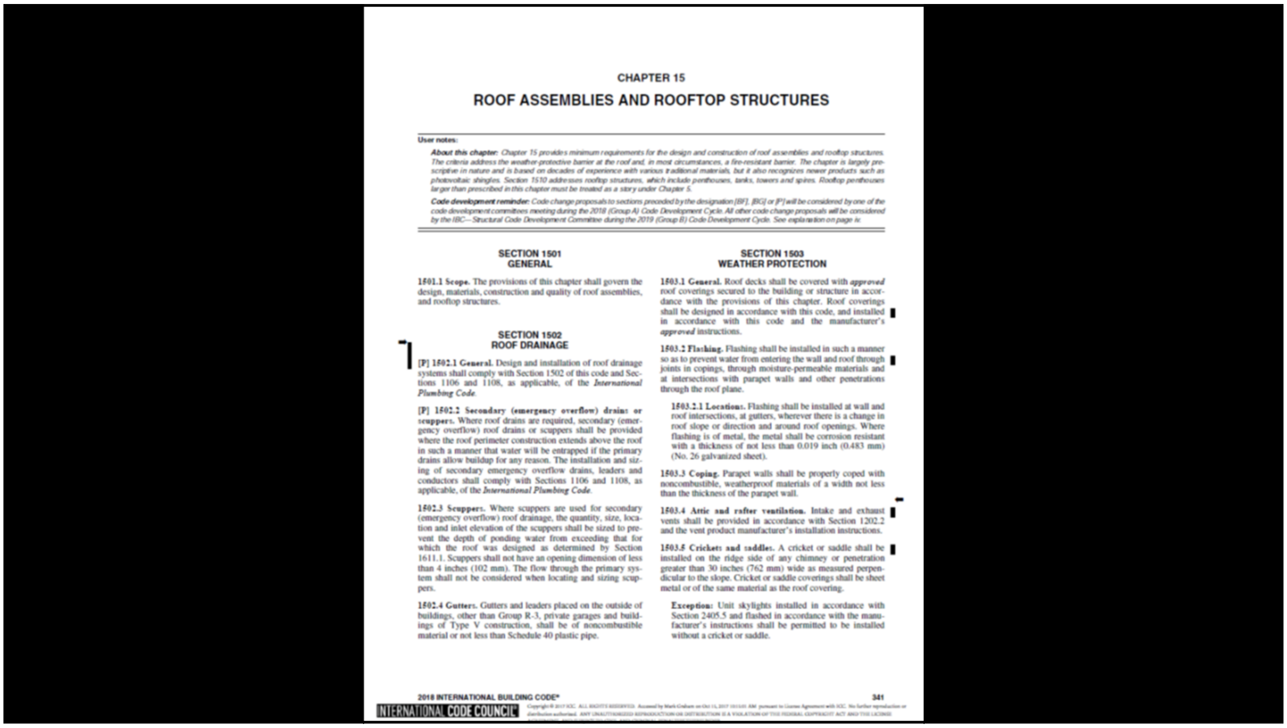
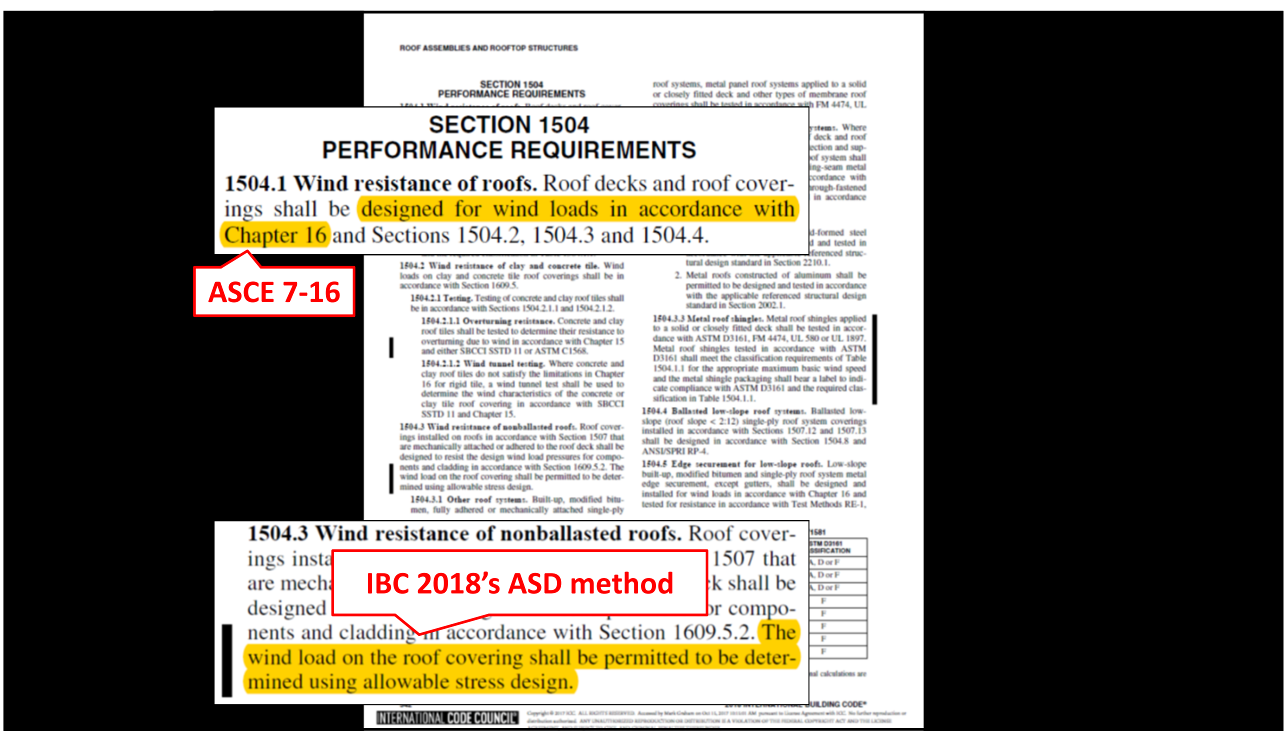
10


CHAPTER 15
ROOF ASSEMBLIES AND ROOFTOP STRUCTURES
SECTION 1501
GENERAL
SECTION 1502
ROOF DRAINAGE
SECTION 1503
WEATHER PROTECTION
2018 INTERNATIONAL BUILDING CODE
341
INTERNATIONAL CODE COUNCIL

11


ROOF ASSEMBLIES AND ROOFTOP STRUCTURES
SECTION 1504
PERFORMANCE REQUIREMENTS
1504.1 Wind resistance of roofs. Roof decks and roof coverings shall be designed for wind loads in accordance with Chapter 16 and Sections 1504.2, 1504.3 and 1504.4.
ASCE 7-16
1504.3 Wind resistance of nonballasted roofs. Roof coverings insta... 1507 that are mech... k shall be designed ... r components and cladding in accordance with Section 1609.5.2. The wind load on the roof covering shall be permitted to be determined using allowable stress design.
IBC 2018's ASD method
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12

CHAPTER 16

STRUCTURAL DESIGN

SECTION 1603 CONSTRUCTION DOCUMENTS

1603.1 General. *Construction documents* shall show the 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*.

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 2.3.6 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 = Roof live load greater than 20 psf (0.96 kN/m^2) and floor live load.

L_r = Roof live load of 20 psf (0.96 kN/m^2) or less.

R = Rain load.

S = Snow load.

Exception: *Construction documents* for buildings constructed in accordance with the *conventional light-frame construction* provisions of Section 2308 shall indicate the following structural design information:

1. Floor and roof dead and live loads.
2. Ground snow load, P_g.
3. Basic design wind speed, V, miles per hour (mph) (km/hr) and allowable stress design wind speed, V_{asd}, as determined in accordance with Section 1609.3.1 and wind exposure.
4. *Seismic design category* and *site class*.
5. Flood design data, if located in *flood hazard areas* established in Section 1612.3.
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 1607.11 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 (Section 1607.13).

determined from Figures 1609.3(1) through 1609.3(8) or ASCE 7.

W = Load due to wind pressure.

W_i = Wind-on-ice in accordance with Chapter 10 of ASCE 7.

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. Snow load importance factor, I_s.

2018 INTERNATIONAL BUILDING CODE® 361

INTERNATIONAL CODE COUNCIL®

13

STRUCTURAL DESIGN

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 20 psf (0.96 kN/m^2).
7. Width of snow drift(s), w.

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,

1603.1.4 Wind design data. The following information related to wind loads shall be shown, regardless of whether wind loads govern the design of the lateral force-resisting system of the structure:

1. Basic design wind speed, V, miles per hour and allowable stress design wind speed, V_{asd}, as determined in accordance with Section 1609.3.1.
2. *Risk category*.
3. Wind exposure. Applicable wind direction if more than one wind exposure is utilized.
4. Applicable internal pressure coefficient.
5. Design wind pressures to be used for exterior component and cladding materials not specifically designed by the *registered design professional* responsible for the design of the structure, psf (kN/m^2).

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.

1604.3.2 Reinforced concrete. The deflection of reinforced concrete structural members shall not exceed that permitted by ACI 318.

1604.3.3 Steel. The deflection of steel structural members shall not exceed that permitted by AISC 360, AISI S100, ASCE 8, SJI CJ or SJI 100, as applicable.

362 2018 INTERNATIONAL BUILDING CODE®

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14

STRUCTURAL DESIGN

SECTION 1608 SNOW LOADS

1608.1 General. Design snow loads shall be determined in accordance with Chapter 7 of ASCE 7, but the design roof load shall be not less than that determined by Section 1607.

1608.2 Ground snow loads. The ground snow loads to be used in determining the design snow loads for roofs shall be determined in accordance with ASCE 7 or Figure 1608.2 for the contiguous United States and Table 1608.2 for Alaska. Site-specific case studies shall be made in areas designated "CS" in Figure 1608.2. Ground snow loads for sites at elevations above the limits indicated in Figure 1608.2 and for all sites within the CS areas shall be *approved*. Ground snow load determination for such sites shall be based on an extreme value statistical analysis of data available in the vicinity of the site using a value with a 2-percent annual probability of being exceeded (50-year mean recurrence interval). Snow loads are zero for Hawaii, except in mountainous regions as *approved* by the *building official*.

1608.3 Ponding instability. Susceptible bays of roofs shall be evaluated for ponding instability in accordance with Chapters 7 and 8 of ASCE 7.

SECTION 1609 WIND LOADS

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 design 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, the provisions of ICC 600 shall be permitted for 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, residential structures using the provisions of AISI S230.
4. Designs using NAAMM FP 1001.
5. Designs using TIA-222 for antenna-supporting structures and antennas, provided that the horizontal extent of Topographic Category 2 escarpments in Section 2.6.6.2 of TIA-222 shall be 16 times the height of the escarpment.
6. Wind tunnel tests in accordance with ASCE 49 and Sections 31.4 and 31.5 of ASCE 7.

The wind speeds in Figures 1609.3(1) through 1609.3(8) are basic design wind speeds, *V*, and shall be converted in accordance with Section 1609.3.1 to allowable stress design wind speeds, V_{asd}, when the provisions of the standards referenced in Exceptions 4 and 5 are used.

1609.1.1.1 Applicability. The provisions of ICC 600 are applicable only to buildings located within Exposure B or C as defined in Section 1609.4. The provisions of ICC 600, AWC WFCM and AISI S230 shall not apply to buildings sited on the upper half of an isolated hill, ridge or escarpment meeting all of the following conditions:

1. The hill, ridge or escarpment is 60 feet (18 288 mm) or higher if located in Exposure B or 30 feet (9144 mm) or higher if located in Exposure C.
2. The maximum average slope of the hill exceeds 10 percent.
3. The hill, ridge or escarpment is unobstructed upwind by other such topographic features for a distance from the high point of 50 times the height of the hill or 2 miles (3.22 km), whichever is greater.

TABLE 1608.2
GROUND SNOW LOADS, p_g, FOR ALASKAN LOCATIONS

LOCATION	POUNDS PER SQUARE FOOT	LOCATION	POUNDS PER SQUARE FOOT	LOCATION	POUNDS PER SQUARE FOOT
Adak	30	Galena	60	Petersburg	150
Anchorage	50	Gulkana	70	St. Paul Islands	40
Angoon	70	Homer	40	Seward	50
Barrow	25	Juneau	60	Shemya	25
Barter Island	35	Kenai	70	Sitka	50
Bethel	40	Kodiak	30	Talkeetna	120
Big Delta	50	Kotzebue	60	Unalakleet	50
Cold Bay	25	McGrath	70	Valdez	160
Cordova	100	Nenana	80	Whittier	300
Fairbanks	60	Nome	70	Wrangell	60
Fort Yukon	60	Palmer	50	Yakutat	150

For SI: 1 pound per square foot = 0.0479 kN/m².

374 — 2018 INTERNATIONAL BUILDING CODE®

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15

STRUCTURAL DESIGN

1609.3.1 Wind speed conversion. Where required, the basic design wind speeds of Figures 1609.3(1) through 1609.3(8) shall be converted to allowable stress design wind speeds, V_{asd}, using Table 1609.3.1 or Equation 16-33.

$$V_{asd} = V\sqrt{0.6} \quad \text{(Equation 16-33)}$$

ASD method permitted (Sec. 1504.3)

1609.3.1 Wind speed conversion. Where required, the basic design wind speeds of Figures 1609.3(1) through 1609.3(8) shall be converted to allowable stress design wind speeds, V_{asd}, using Table 1609.3.1 or Equation 16-33.

$V_{asd} = V\sqrt{0.6}$ (Equation 16-33)

where:

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

V = Basic design wind speeds determined from Figures 1609.3(1) through 1609.3(8).

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.

1609.4.1 Wind directions and sectors. For each selected wind direction at which the wind loads are to be evaluated, the exposure of the building or structure shall be determined for the two upwind sectors extending 45 degrees (0.79 rad) either side of the selected wind direction. The exposures in these two sectors shall be determined in accordance with Sections 1609.4.2 and 1609.4.3 and the exposure resulting in the highest wind loads shall be used to represent winds from that direction.

1609.4.2 Surface roughness categories. A ground surface roughness within each 45-degree (0.79 rad) sector shall be determined for a distance upwind of the site as defined in Section 1609.4.3 from the following categories, for the purpose of assigning an exposure category as defined in Section 1609.4.3.

1609.5 Roof systems. Roof systems shall be designed and constructed in accordance with Sections 1609.5.1 through 1609.5.3, as applicable.

1609.5.1 Roof deck. The roof deck shall be designed to withstand the wind pressures determined in accordance with ASCE 7.

1609.5.2 Roof coverings. Roof coverings shall comply with Section 1609.5.1.

Exception: Rigid tile roof coverings that are air permeable and installed over a roof deck complying with Section 1609.5.1 are permitted to be designed in accordance with Section 1609.5.3.

Asphalt shingles installed over a roof deck complying with Section 1609.5.1 shall comply with the wind-resistance requirements of Section 1504.1.1.

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 design wind speeds determined from Figures 1609.3(1) through 1609.3(8).

378 — 2018 INTERNATIONAL BUILDING CODE®

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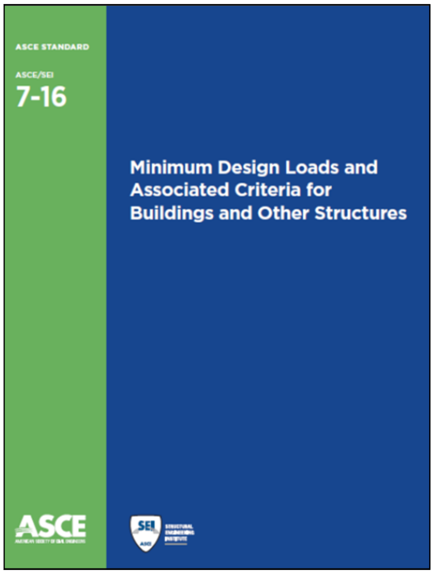
16



American Society of Civil Engineers Standard 7, "Minimum Design Loads and Associated Criteria for Buildings and Other Structures" (ASCE 7-16)

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17

ASCE 7-16's applicable chapters

Design wind load provisions

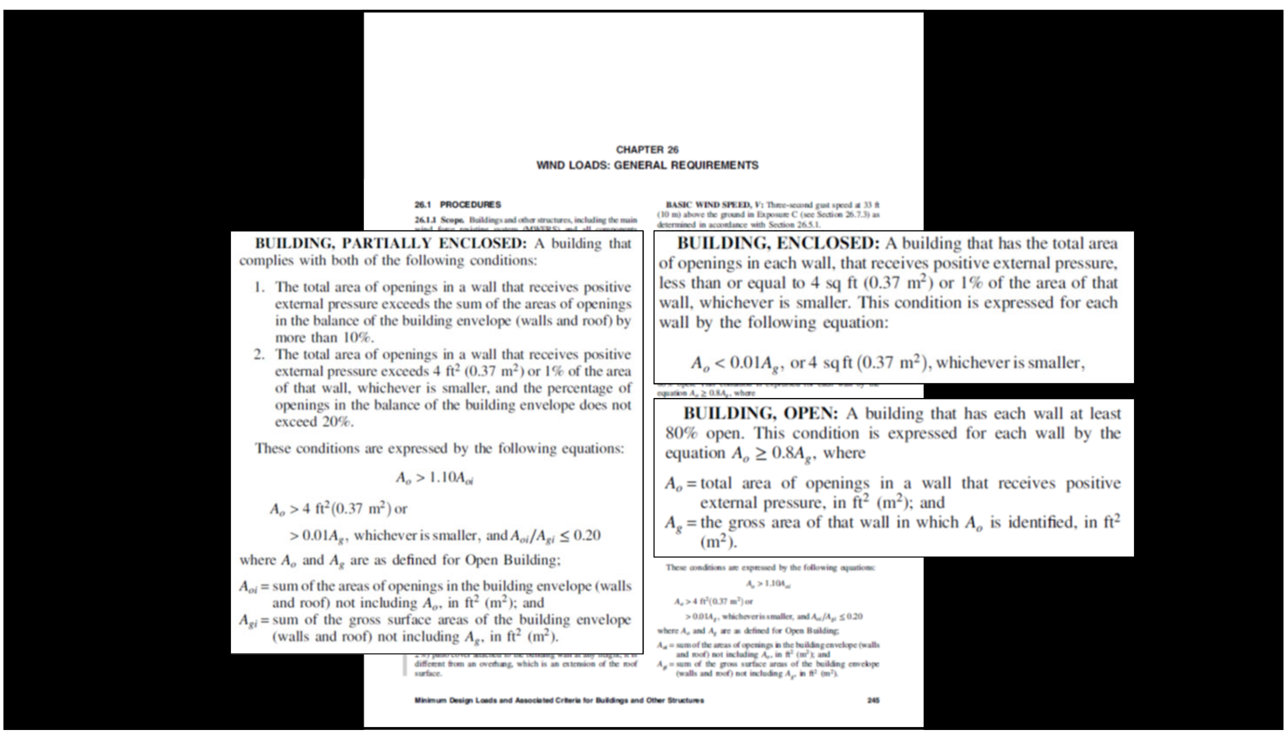
- Ch. 26: Wind loads: General requirements
- Ch. 27: Wind loads on buildings: Main wind force resisting system (Directional procedure)
- Ch. 28: Wind loads on buildings: Main wind force resisting system (Envelope procedure)
- Ch. 29: Wind loads on building appurtenances and other structures: main wind force resisting system (Directional procedure)
- Ch. 30: Components and cladding
- Ch. 31: Wind tunnel procedure

18

ASCE 7-16's Chapter 30 – Components and cladding

- Part 1: Low-rise buildings
- Part 2: Low-rise buildings (Simplified)
- Part 3: Buildings with h > 60 ft
- Part 4: Buildings with 60 ft < h ≤ 160 ft (Simplified)
- Part 5: Open buildings
- …

19



CHAPTER 26

WIND LOADS: GENERAL REQUIREMENTS

26.1 PROCEDURES

BUILDING, PARTIALLY ENCLOSED: A building that complies with both of the following conditions:

1. The total area of openings in a wall that receives positive external pressure exceeds the sum of the areas of openings in the balance of the building envelope (walls and roof) by more than 10%.
2. The total area of openings in a wall that receives positive external pressure exceeds 4 ft² (0.37 m²) 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%.

These conditions are expressed by the following equations:

$$A_o > 1.10A_{oi}$$

$$A_o > 4\ \text{ft}^2 (0.37\ \text{m}^2)\ \text{or}$$

$$> 0.01A_g,\ \text{whichever is smaller, and}\ A_{oi}/A_{gi} \leq 0.20$$

where A_o and A_g are as defined for Open Building;

A_{oi} = sum of the areas of openings in the building envelope (walls and roof) not including A_o, in ft² (m²); and

A_{gi} = sum of the gross surface areas of the building envelope (walls and roof) not including A_g, in ft² (m²).

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 sq ft (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:

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

BUILDING, OPEN: A building that has each wall at least 80% open. This condition is expressed for each wall by the equation $A_o \geq 0.8A_g$, where

A_o = total area of openings in a wall that receives positive external pressure, in ft² (m²); and

A_g = the gross area of that wall in which A_o is identified, in ft² (m²).

Minimum Design Loads and Associated Criteria for Buildings and Other Structures 245

20

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 or partially enclosed
   - 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 a simplified approach and is applicable to an enclosed
   - 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, or hip roof, and the wind pressures are determined directly from a table.
3. Part 3 is applicable to an enclosed or partially enclosed
   - 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.
4. Part 4 is a simplified approach and is applicable to an enclosed
   - Building with 60 ft $< h \leq$ 160 ft (18.3 m $< h \leq$ 48.8 m).

   The building has a flat roof, gable roof, hip roof, monoslope roof, or mansard roof, and the wind pressures are determined directly from a table.
5. Part 5 is applicable to an open building of all heights that has a pitched free roof, monoslope free roof, or troughed free roof.
6. Part 6 is applicable to building appurtenances such as roof overhangs, parapets, and rooftop equipment.
7. Part 7 is applicable to non-building structures – circular bins, silos and tanks; and rooftop solar panels.
   - Circular Bins, Silos and Tanks: $h \leq 120$ 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

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).
- Internal pressure coefficient, (GC_{pi}) (Section 26.13).

Minimum Design Loads and Associated Criteria for Buildings and Other Structures 333

21

PART 1: LOW-RISE BUILDINGS

User Note: Use Part 1 of Chapter 30 to determine wind pressures on C&C of *enclosed and partially enclosed low-rise buildings* that have roof shapes as specified in the applicable figures. The provisions in Part 1 are based on the Envelope Procedure, with *wind pressures calculated using the specified equation* as applicable to each building surface. For buildings for which these provisions are applicable, this method generally yields the lowest wind pressures of all analytical methods contained in this standard.

30.3 BUILDING TYPES

The provisions of Section 30.3 are applicable to an enclosed and partially enclosed

- 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 ($h \leq 18.3$ m) shall be determined from the following equation:

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

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

where

q_h = velocity pressure evaluated at mean roof height h as defined in Section 26.10;

(GC_p) = external pressure coefficients given in:

- Fig. 30.3-1 (walls),
- Figs. 30.3-2A–I (flat roofs, gable roofs and hip roofs),
- Fig. 30.3-3 (stepped roofs),
- Fig. 30.3-4 (multispan gable roofs),
- Figs. 30.3-5A–B (monoslope roofs),
- Fig. 30.3-6 (sawtooth roofs),
- Fig. 30.3-7 (domed roofs),
- Fig. 27.3-3, Note 4 (arched roofs);

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

PART 2: LOW-RISE BUILDINGS (SIMPLIFIED)

User Note: Part 2 of Chapter 30 is a simplified method to determine wind pressures on C&C of *enclosed low-rise buildings* that have flat, gable, or hip roof shapes. The provisions of Part 2 are based on the Envelope Procedure of Part 1 with *wind pressures determined from a table* and adjusted as appropriate.

30.4 BUILDING TYPES

The provisions of Section 30.4 are applicable to an enclosed

- Low-rise building (see definition in Section 26.2); or
- Building with $h \leq 60$ ft (18.3 m).

Table 30.3-1 Steps to Determine C&C Wind Loads for Enclosed and Partially Enclosed Low-Rise Buildings

Step 1: Determine risk category; see Table 1.5-1.
Step 2: Determine the basic wind speed, V, for applicable risk category; see Figs. 26.5-1 and 26.5-2.
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 Fig. 26.8-1.
- Ground elevation factor, K_e; 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_h; see Table 26.10-1.
Step 5: Determine velocity pressure, q_h, Eq. (26.10-1).
Step 6: Determine external pressure coefficient, (GC_p):
- Walls; see Fig. 30.3-1.
- Flat roofs, gable roofs, hip roofs; see Fig. 30.3-2.
- Stepped roofs; see Fig. 30.3-3.
- Multispan gable roofs; see Fig. 30.3-4.
- Monoslope roofs; see Fig. 30.3-5.
- Sawtooth roofs; see Fig. 30.3-6.
- Domed roofs; see Fig. 30.3-7.
- Arched roofs; see Fig. 27.3-3, Note 4.

Step 7: Calculate wind pressure, p; Eq. (30.3-1).

The building has a flat roof, gable roof, or hip 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 design of C&C, the building shall comply with all the following conditions:

1. The mean roof height h must be less than or equal to 60 ft (18.3 m) [$h \leq 60$ ft ($h \leq 18.3$ m)].
2. The building is enclosed as defined in Section 26.2 and conforms to the wind-borne debris provisions of Section 26.12.3.
3. The building is a regular-shaped building as defined in Section 26.2.
4. 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.
5. The building has either a flat roof, a gable roof with $\theta \leq 45°$, or a hip roof with $\theta \leq 27°$.

30.4.2 Design Wind Pressures. Net design wind pressures, p_{net}, for C&C of buildings designed using the procedure specified herein represent the net pressures (sum of internal and external) that shall be applied normal to each building surface as shown in Fig. 30.4-1. p_{net} shall be determined by the following equation:

$$p_{net} = \lambda K_{zt} p_{net30} \quad (30.4\text{-}1)$$

where

λ = adjustment factor for building height and exposure from Fig. 30.4-1;

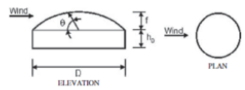
K_{zt} = topographic factor as defined in Section 26.8, evaluated at 0.33 mean roof height, 0.33h; and

p_{net30} = net design wind pressure for Exposure B, at h = 30 ft (h = 9.1 m), from Fig. 30.4-1.

334 STANDARD ASCE/SEI 7-16

22

Diagram



Notation

f = Dome rise, in ft (m).
D = Diameter of a circular structure or member, in ft (m).
h_D = Height to base of dome, in ft (m).
θ = Angle of plane of roof from horizontal, in degrees.

Coefficients for Domes with a Circular Base

External Pressure	Negative Pressures	Positive Pressures	Positive Pressures
θ, degrees	0–90	0–60	61–90
(GC_p)	−0.9	+0.9	+0.5

Notes

1. Values denote (GC_p) to be used with $q_{(h_D+f)}$ where $h_D + f$ is the height at the top of the dome.
2. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
3. Each component shall be designed for the maximum positive and negative pressures.
4. Values apply to $0 \le h_D/D \le 0.5$, $0.2 \le f/D \le 0.5$.
5. θ = 0 degrees on dome springline, θ = 90 degrees at dome center top point. f is measured from springline to top.

FIGURE 30.3-7 Components and Cladding (All Heights): External Pressure Coefficients, (GC_p), for Enclosed and Partially Enclosed Buildings and Structures—Domed Roofs

Table 30.4-1 Steps to Determine C&C Wind Loads for Enclosed Low-Rise Buildings (Simplified Method)

Step 1: Determine risk category; see Table 1.5-1.
Step 2: Determine the basic wind speed, V, for applicable risk category; see Figs. 26.5-1 and 26.5-2.
Step 3: Determine wind load parameters:
- Exposure category B, C, or D; see Section 26.7.
- Topographic factor, K_{zt}; see Section 26.8 and Fig. 26.8-1.

Step 4: Enter figure to determine wind pressures at $h = 30$ ft, p_{net30}; see Fig. 30.4-1.
Step 5: Enter figure to determine adjustment for building height and exposure, λ; see Fig. 30.4-1.
Step 6: Determine adjusted wind pressures, p_{net}; see Eq. (30.4-1).

partially enclosed 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 30.5-1.

30.5.1 Conditions. For the determination of the design wind pressures on the C&C using the provisions of Section 30.5.2, the conditions indicated on the selected figure(s) shall be applicable to the building under consideration.

30.5.2 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:

$$p = q(GC_p) - q_i(GC_{pi})\ (\text{lb/ft}^2) \quad (30.5\text{-}1)$$

$$p = q(GC_p) - q_i(GC_{pi})\ (\text{N/m}^2) \quad (30.5\text{-}1.\text{si})$$

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;
$q_i = q_h$ for windward walls, sidewalls, leeward walls, and roofs of enclosed buildings and for negative internal pressure evaluation in partially enclosed buildings;
$q_i = q_z$ for positive internal pressure evaluation in partially enclosed buildings where height z is defined as the level of the highest opening in the building that could affect the positive internal pressure. For positive internal pressure evaluation, q_i may conservatively be evaluated at height $h (q_i = q_h)$;

360 STANDARD ASCE/SEI 7-16

23

Noteworthy changes in ASCE 7-16

Compared to ASCE 7-10

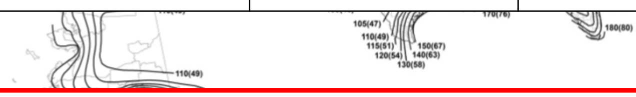
- Revised basic wind speed maps
- Changes (and new) pressure coefficients
- Revised perimeter and corner zones

24

ASCE 7-16 basic wind speed map

Risk Category II Buildings (MRI = 700 years)

MRI		
Risk Category	**ASCE 7-10**	**ASCE 7-16**
I (Low)	300 yrs.	300 yrs.
II (not I, II or IV)	700 yrs.	700 yrs.
Category III (High risk)	1,700 yrs.	1,700 yrs.
Category IV (Essential)	1,700 yrs.	3,000 yrs.



Use of the correct Risk Category/map (i.e., wind speed) is essential

25

Comparing basic wind speeds

City	ASCE 7-05	ASCE 7-10	ASCE 7-16
Miami, FL	150 mph	OC I: 150 mph	Risk Cat. I: 155 mph
		OC II: 160 mph	Risk Cat. II: 165 mph
		OC III & IV: 180 mph	Risk Cat. III: 175 mph
			Risk Cat. IV: 190 mph-
Chicago IL	90 mph	OC I: 105 mph	Risk Cat. I: 100 mph
		OC II: 115 mph	Risk Cat. II: 107 mph
		OC III & IV: 120 mph	Risk Cat. III: 114 mph
			Risk Cat. IV: 119 mph
Los Angeles, CA	85 mph	OC I: 100 mph	Risk Cat. I: 85 mph
		OC II: 110 mph	Risk Cat. II: 90 mph
		OC III & IV: 115 mph	Risk Cat. III: 95 mph
			Risk Cat. IV 100 mph

26

Comparing GC_p pressure coefficients

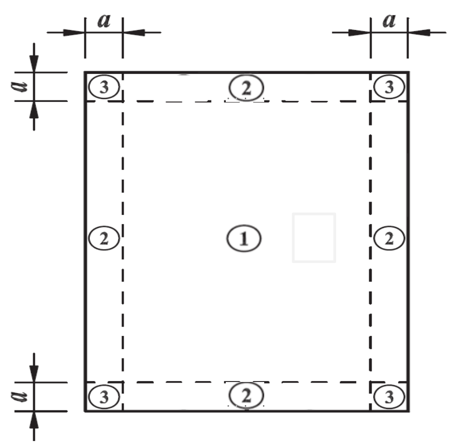
h ≤ 60 ft., gable roofs ≤ 7 degrees

Zone	ASCE 7-10	ASCE 7-16	Change
1'	n/a	0.9	-10%
1 (field)	-1.0	-1.7	+70%
2 (perimeter)	-1.8	-2.3	+28%
3 (corners)	-2.8	-3.2	+14%

27

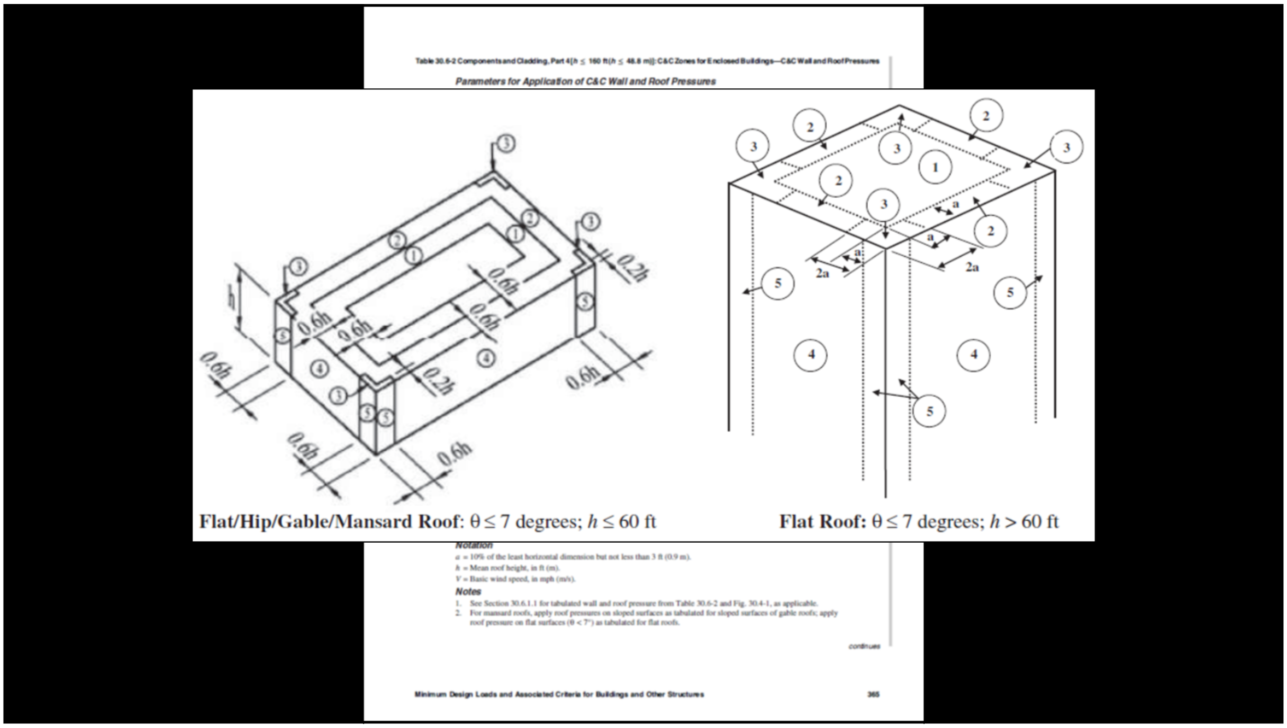
ASCE 7-10's roof zones

h ≤ 60 ft., gable roofs ≤ 7 degrees



a = 10% of the least horizontal direction, or 0.4h, whichever is smaller but not less than either 4% of the least horizontal dimension or 3 ft (0.9 m).

28



29

Noteworthy changes in ASCE 7-16

Compared to ASCE 7-10

- Revised basic wind speed map
- Changes (and new) pressure coefficients
- Revised perimeter and corner zones

While center field pressures may be slightly lower, field, perimeter and corner uplift pressures will generally be greater

30

How the roofing industry will adapt to ASCE 7-16 remains to be seen….

FM Global has indicated they will update their FM 1-28 to be based on ASCE 7-16 (with modifications) in Oct. 2019.

31

Comparing FM 1-28 and ASCE 7-05, -10 & -16

Example: A manufacturing building (Risk Category II) is located in New Orleans, LA. The building is an enclosed structure with a mean roof height of 35 ft. The building is located in an open terrain area that can be categorized as Exposure Category C. An adhered, membrane roof systems is to be installed

Document	Basic wind speed (mph)	Design wind pressure (psf)			
		Zone 1' (Center)	Zone 1 (Field)	Zone 2 (Perimeter)	Zone 3 (Corners)
ASCE 7-05	120	--	38	61	95
FM 1-28	120	--	43	72	109
ASCE 7-10 Strength design	150	--	59	96	148
ASCE 7-10 ASD	116	--	35	59	89
ASCE 7-16 Strength design	150	47	81	107	146
ASCE 7-16 ASD	116	28	49	65	88

32

Allowable stress design (ASD) method

Comparing FM 1-28 and ASCE 7-05, -10 & -16

Example: A manufacturing building (Risk Category II) is located in New Orleans, LA. The building is an enclosed structure with a mean roof height of 35 ft. The building is located in an open terrain area that can be categorized as Exposure Category C. An adhered, membrane roof systems is to be installed

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		Zone 1' (Center)	Zone 1 (Field)	Zone 2 (Perimeter)	Zone 3 (Corners)
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FM 1-28	120	--	43	72	109
ASCE 7-10 Strength design	150	--	59	96	148
ASCE 7-10 ASD	116	--	35	59	89
ASCE 7-16 Strength design	150	47	81	107	146
ASCE 7-16 ASD	116	28	49	65	88

33

Ultimate strength method

Comparing FM 1-28 and ASCE 7-05, -10 & -16

Example: A manufacturing building (Risk Category II) is located in New Orleans, LA. The building is an enclosed structure with a mean roof height of 35 ft. The building is located in an open terrain area that can be categorized as Exposure Category C. An adhered, membrane roof systems is to be installed

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		Zone 1' (Center)	Zone 1 (Field)	Zone 2 (Perimeter)	Zone 3 (Corners)
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FM 1-28	120	--	43	72	109
ASCE 7-10 Strength design	150	--	59	96	148
ASCE 7-10 ASD	116	--	35	59	89
ASCE 7-16 Strength design	150	47	81	107	146
ASCE 7-16 ASD	116	28	49	65	88

34

Comparing FM 1-28 and ASCE 7-05, -10 & -16

Example: A manufacturing building (Risk Category II) is located in New Orleans, LA. The building is an enclosed structure with a mean roof height of 35 ft. The building is located in an open terrain area that can be categorized as Exposure Category C. An adhered, membrane roof systems is to be installed

	Document	Basic wind speed (mph)	Design wind pressure (psf)			
			Zone 1' (Center)	Zone 1 (Field)	Zone 2 (Perimeter)	Zone 3 (Corners)
FM 1-90	ASCE 7-05	120	--	38	61	95
FM 1-90	FM 1-28	120	--	43	72	109
	ASCE 7-10 Strength design	150	--	59	96	148
FM 1-90	ASCE 7-10 ASD	116	--	35	59	89
	ASCE 7-16 Strength design	150	47	81	107	146
FM 1-105	ASCE 7-16 ASD	116	28	49	65	88

35

This comparison illustrates why it is important for Designers to include wind design loads in their Construction Documents (per IBC Sec. 1603.1)…

…It also illustrate why specifying a wind warrantee can create an uneven playing field. Unless the Designer indicates the wind design loads, which design method will the manufacturer use (e.g., in a competitive environment)?

36

37

A brief review…

- Be aware which code/ASCE 7 versions apply
- Use the appropriate Risk Category/map/basic wind speed
- Design loads are required in the *Construction Documents*
- Allowable stress design (ASD) versus ultimate strength
- Consider a safety factor
- Resistance (with any safety factor) ≥ Design wind loads

38

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39