Wind Loads:
What's New in ASCE 7-22
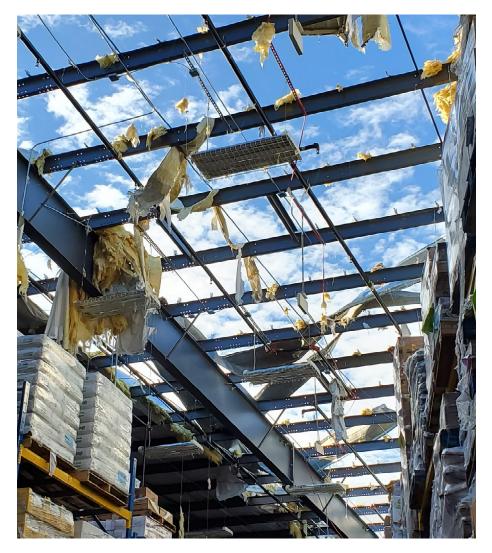
John O'Brien, P.E., S.E.

Agenda

- General
- Chapter 26-31 Change Highlights
- Tornado Loads
- Q&A

Navigating Changes

- Look for grey bars in margins

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.

26.1.2.2 Components and Cla
buildings and other structures
following procedures:

1. Analytical Procedures p appropriate, of Chapter
2. Wind Tunnel Procedure

26.1.3 Performance-Based
buildings and other struct procedures shall be permitted Authority Having Jurisdiction design procedures used shal Section 1.3.1.3.

26.2 DEFINITIONS

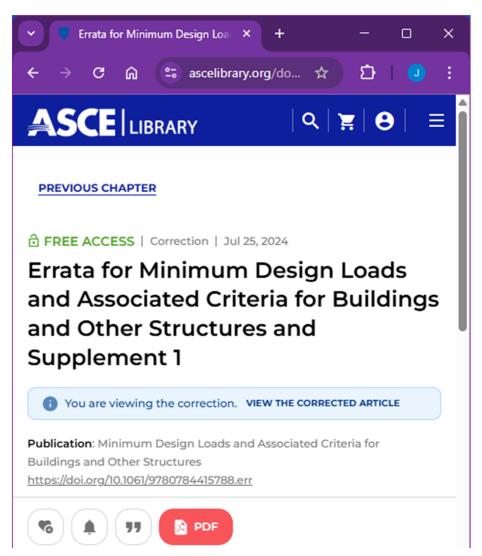The following definitions apply through 31.
APPROVED: Acceptable Jurisdiction.
ASCE WIND DESIGN GI tabase (version 2022-1.0) of g

Errata

- Mistakes happen
- Free download from ASCE Library
- Search "ASCE 7-22 errata"

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Supplements

- Important technical changes
  - Must follow code adoption process
- Free download from ASCE Library
- Supplements #1 & #2 Published

Standard 7-22
Minimum Design Loads and Associated Criteria
for Buildings and Other Structures

SUPPLEMENT 2

Chapter 1: General

1.3.1.3 Performance Based Procedures
Structural and nonstructural components and their connections designed with performance-based procedures shall be demonstrated by analysis in accordance with Section 2.3.5 or by analysis procedures supplemented by testing to provide a reliability that is generally consistent with the target reliabilities stipulated in this section.

Structural and nonstructural components subjected to dead, live, environmental, and other loads except earthquake, tsunami, and loads from extraordinary events shall be based on the target reliabilities in Table 1.3-1. Structural systems subjected to earthquake shall be based on the target reliabilities in Table 1.3-2 and 1.3-3. The design of structures subjected to tsunami loads shall be based on the target reliabilities in Table 1.3-4. Structures, components, and systems that are designed for extraordinary events, using the requirements of Section 2.5 for scenarios approved by the Authority Having Jurisdiction, shall be based on the target reliabilities in Table 1.3-5. The analysis procedures used shall account for uncertainties in loading and resistance.

Chapter 2: Combinations of Loads

2.2 SYMBOLS
A_k = Load or load effect arising from extraordinary event A

D = Dead load

D_i = Weight of ice

E = Earthquake load

F = Load caused by fluids with well-defined pressures and maximum heights

S2-1

Minimum Design Loads and Associated Criteria for Buildings and Other Structures

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General Provisions

Chapter 26

Performance Based Wind Design (PBD)

- 26.1.3: Charging language
  - Design shall conform to 1.3.1.3
- ASCE/SEI *Prestandard for Performance-Based Wind Design* (2019)
  - Prestandard is FREE from ASCE publications
  - Revised prestandard (V1.1) published in 2023

Prestandard for
Performance-Based
Wind Design

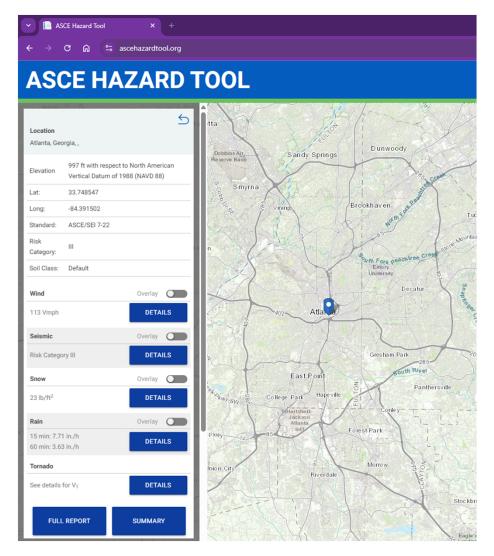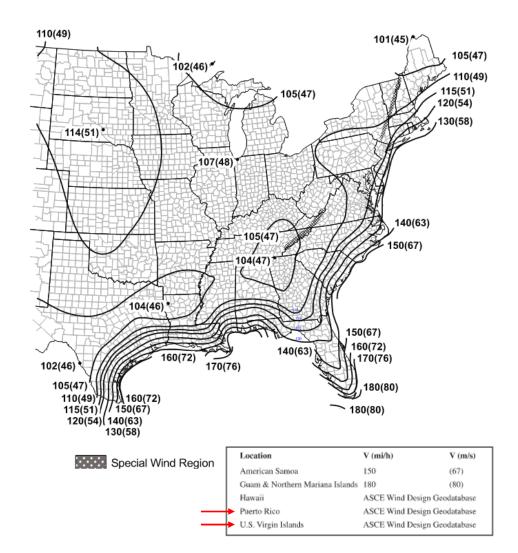**V1.1**

American Society of Civil Engineers

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Wind Hazard Maps

- ASCE Hazard Tool now free
  - https://ascehazardtool.org/
  - No paper maps in the future?

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Wind Hazard Maps

- Special wind regions updated

- Gulf coast hurricane wind speeds revised

- Topographic effects included in Puerto Rico & US Virgin Islands maps
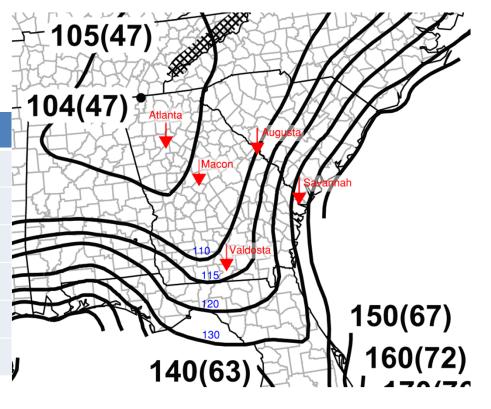

Location	V (mi/h)	V (m/s)
American Samoa	150	(67)
Guam & Northern Mariana Islands	180	(80)
Hawaii	ASCE Wind Design Geodatabase	
Puerto Rico	ASCE Wind Design Geodatabase	
U.S. Virgin Islands	ASCE Wind Design Geodatabase	

Special Wind Region

Wind Hazard Maps

- Georgia:

Risk Category II Basic Wind Speed			
	7-16	7-22	Change
Atlanta	107	105	0.96
Augusta	113	110	0.95
Macon	109	107	0.96
Savannah	135	135	1.00
Valdosta	113	114	1.02

Topographic Effects

- Section 26.8.1
- Conditions 1 & 2 removed
  - 7-16 required isolated & unobstructed, and significant features
  - More sites will require K_{zt} evaluation
- Clarifying language added for table vs equations

Ground Elevation Factor

- Clarified ground elevation above sea level

- z_g -> z_e

- z_g was not intended to be the z_g (gradient height) from velocity pressure coefficient calculations

Table 26.9-1. Ground Elevation Factor, K_e.

Ground Elevation above Sea Level		Ground Elevation Factor, K_e
ft	m	
<0	<0	See note 2
0	0	1.00
1,000	305	0.96
2,000	610	0.93
3,000	914	0.90
4,000	1,219	0.86
5,000	1,524	0.83
6,000	1,829	0.80
>6,000	>1,829	See note 2

Notes:
1. Conservative approximation $K_e = 1.00$ is permitted in all cases.
2. Factor K_e shall be determined from Table 26.9-1 using interpolation or from the following formula for all elevations: $K_e = e^{-0.0000362 z_e}$ (z_e = ground elevation above sea level, ft); or $K_e = e^{-0.000119 z_e}$ (z_e = ground elevation above sea level, m).
3. K_e is permitted to be taken as 1.00 in all cases.

Velocity Pressure Coefficients

- Boundary layer profile adjusted
  - Table 26.10-1 & 26.11-1
- Typical structures:
  - Small reduction in K_z for Exposure B & C
  - No change for Exposure D

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

*Use 0.70 in Chapter 28, Exposure B, when $z < 30$ ft (9.1 m).

Notes:

1. Velocity pressure exposure coefficient K_z may be determined from the following formula:

For $z < 15$ ft	$K_z = 2.41 (15/z_g)^{2/\alpha}$
For $z < 4.6$ m	$K_z = 2.41 (4.6/z_g)^{2/\alpha}$
For 15 ft (4.6 m) $\leq z \leq z_g$	$K_z = 2.41 (z/z_g)^{2/\alpha}$
For $z_g < z \leq 3,280$ ft (1,000 m)	$K_z = 2.41$

2. α and z_g are tabulated in Table 26.11-1.
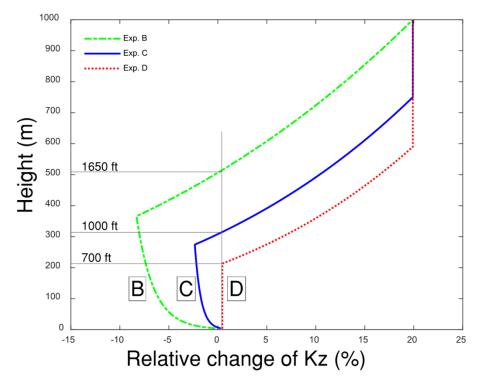3. Linear interpolation for intermediate values of height z is acceptable.
4. Exposure categories are defined in Section 26.7.

Table 26.11-1. Terrain Exposure Constants.

Exposure	Velocity pressure		
	α	z_g (ft)	$\hat{\alpha}$
B	7.5	3,280	1/7.5
C	9.8	2,460	1/9.8
D	11.5	1,935	1/11.5

Exposure	α	z_g (m)	$\hat{\alpha}$
B	7.5	1,000	1/7.5
C	9.8	750	1/9.8
D	11.5	590	1/11.5

* z_{min} = Minimum height used to ensure that the equivalent as z_{min}.

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Velocity Pressure Coefficients

- Boundary layer profile adjusted
  - Table 26.10-1 & 26.11-1
- Typical structures:
  - Small reduction in K_z for Exposure B & C
  - No change for Exposure D
- Very tall structures:
  - K_z increase up to 20%

Directionality Factor

- K_d moved from Velocity Pressure (q_z) to Pressure Equations

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

- MWFRS:

$$p = q K_d G C_p - q_i K_d (G C_{pi}) \qquad (27.3\text{-}1)$$

- C&C: (h<60'):

$$p = q_h K_d [(G C_p) - (G C_{pi})] \text{ (lb/ft}^2\text{)} \qquad (30.3\text{-}1)$$

- C&C (h>60'):

$$p = q K_d (G C_p) - q_i K_d (G C_{pi}) \text{ (lb/ft}^2\text{)} \qquad (30.4\text{-}1)$$

- Tornado MWFRS:

$$p_T = q G_T K_{dT} K_{vT} C_p - q_i (G C_{piT}) \text{ (lb/ft}^2\text{)} \qquad (32.15\text{-}1)$$

- Tornado C&C (h<60'):

$$p_T = q_{hT} [K_{dT} K_{vT} (G C_p) - (G C_{piT})] \text{ (lb/ft}^2\text{)} \qquad (32.17\text{-}1)$$

- Tornado C&C (h>60'):

$$p_T = q K_{dT} K_{vT} (G C_p) - q_i (G C_{piT}) \text{ (lb/ft}^2\text{)} \qquad (32.17\text{-}2)$$

Gust Effect Factor

- Table 26.11-1 adjustments
- 26.11.5 Flexible Buildings
  - Multiple clarifications to flexible gust effect factor, G_f, variables and equations

Table 26.11-1. Terrain Exposure Constants.

	Velocity pressure		Customary Units				Gust effect factor	
Exposure	α	z_g (ft)	$\hat{\alpha}$	$\hat{b}$	$\bar{\alpha}$	$\bar{b}$	c	l (ft)
B	7.5	3,280	1/7.5	0.84	1/4.5	0.47	0.30	320
C	9.8	2,460	1/9.8	1.00	1/6.4	0.66	0.20	500
D	11.5	1,935	1/11.5	1.09	1/8.0	0.78	0.15	650

			SI Units					
Exposure	α	z_g (m)	$\hat{\alpha}$	$\hat{b}$	$\bar{\alpha}$	$\bar{b}$	c	l (m)
B	7.5	1,000	1/7.5	0.84	1/4.5	0.47	0.30	97.54
C	9.8	750	1/9.8	1.00	1/6.4	0.66	0.20	152.40
D	11.5	590	1/11.5	1.09	1/8.0	0.78	0.15	198.12

* z_{min} = Minimum height used to ensure that the equivalent height $\bar{z}$ is the greater of $0.6h$ or z_{min}. For buildings or other structures as z_{min}.

Wind Borne Debris Region

- Definition change in 26.12.3.1
- Areas in hurricane prone region where:
  - $V \geq 140$ mph, or
  - $V \geq 130$ mph & within 1 mile of the ~~coastal~~ mean high water line <u>where an Exposure D condition exists upwind of the water line</u>
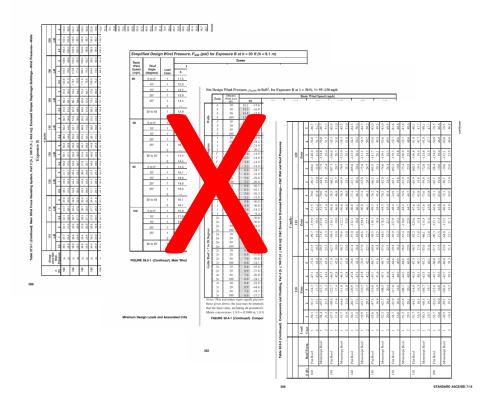
Photo credit: FEMA P-2077 Mitigation Assessment Team Report: Hurricane Michael in Florida

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Main Wind Force Resisting System
Chapter 27 & 28

MWFRS Tabular Methods

- Chapter 27 Part 2: Enclosed Simple Diaphragm Buildings

- Chapter 28 Part 2: Enclosed Simple Diaphragm Low-Rise Buildings

- Removed entirely

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Pressure Equations: K_d

- K_d moved from Velocity Pressure (q_z) to Pressure Equations

$$q_z = 0.00265 K_z K_{zt} \cancel{K_d} K_e V^2 \qquad (26.10\text{-}1)$$

- MWFRS:

$$p = q K_d GC_p - q_i K_d (GC_{pi}) \qquad (27.3\text{-}1)$$

Elevated Buildings

- New in ASCE 7-22!
  - MWFRS
  - C&C

Elevated Buildings
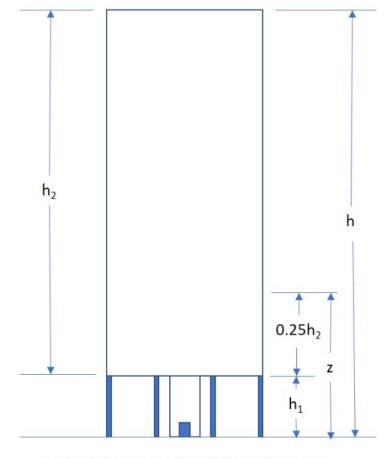
- Check "blocked area" under structure

- Vertical cross section: blocked area less than 75% of gross area?

- Plan area: blocked area less than specified percentages?

- Yes to both:
  - MWFRS Loads per 27.3.1.1.1 – 27.3.1.1.2

- No to either:
  - Assume solid structure for MWFRS loads
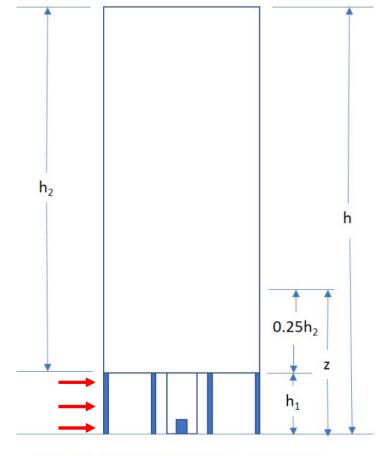
L/B	Plan Area Blocked
<2.5	50%
3.0	45%
3.5	40%
4.0	36%
4.5	33%
5.0	30%

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Elevated Buildings

- Section 27.3.1.1.1:
  Elevated Building Loads
  - Roof & wall loads

Typical Elevated Tall Building - Elevation

Elevated Buildings
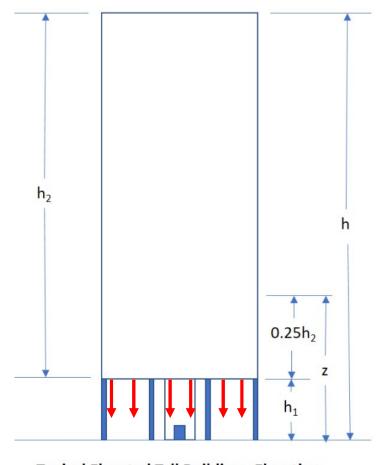
- Section 27.3.1.1.2: **Lateral Loads** on Elements Below Elevated Building
  - Projected area of elements
  - Net force coefficient = 1.3
  - q_z elevation = $h_1 + 0.25h_2$

Typical Elevated Tall Building - Elevation

Elevated Buildings

- Section 27.3.1.1.3: External **Loads on Horizontal Bottom Surfaces** of the Elevated Building

  - Roof pressure coefficients (flat roof)

  - $h = h_1$ for windward edge zone (elevated level height)

  - q_z elevation = $h_1 + 0.25h_2$

Typical Elevated Tall Building - Elevation

Load Cases

- Figure 27.3-8 revised

- Load direction clarified

- Use max, not combined roof load for Case 3 & 4

- Torsional moment application to flexible diaphragms clarified (Note 4)
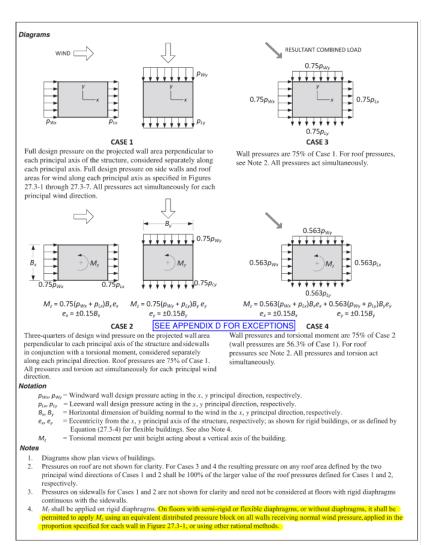
Figure 27.3-8. Main wind force resisting system, design wind load cases.

Building Appurtenances & Other Structures
Chapter 29

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Pressure Equations: K_d

- K_d moved from Velocity Pressure (q_z) to F & P Equations

$$q_z = 0.00265 K_z K_{zt} \cancel{K_d} K_e V^2 \qquad (26.10\text{-}1)$$

$$F = q_h K_d G C_s A_s \qquad\qquad (29.3\text{-}1)$$

$$F = q_z K_d G C_f A_f \qquad\qquad (29.4\text{-}1)$$

$$F_h = q_h K_d (GC_r) A_f \qquad\qquad (29.4\text{-}2)$$
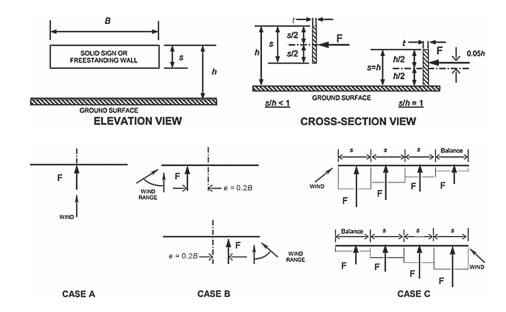
$$F_v = q_h K_d (GC_r) A_f \qquad\qquad (29.4\text{-}3)$$

$$p = q_h K_d \left(GC_p - (GC_{pi}) \right) \qquad (29.4\text{-}4)$$

(not all Chapter 29 equations shown for brevity)

Solid Signs & Walls

- Figure 29.3-1
- Notes cleanup
- Clarify load cases
  - Case A & C: Always
  - Case B: Not required for B/s $\geq$ 2 (ie signs 2x longer than height)

Notes

1. Force coefficients for solid walls or signs with openings less than 30% of gross area shall be permitted to be multiplied by the reduction factor $(1 - (1 - \varepsilon)^{1.5})$.

2. To allow for both normal and oblique wind directions, the following cases shall be considered:
   For $s/h < 1$: (Elevated sign)
   Case A: Resultant force acts normal to the face of the wall or sign through the geometric center.
   Case B: Resultant force acts normal to the face of the wall or sign at a distance from the geometric center toward the windward edge equal to 0.2 times the average width of the wall or sign.
   For double-faced signs with all sides enclosed and $R_{max} \leq 0.4$, it is permitted to use force eccentricity, $e = (0.2 - 0.25R_{max})B$.
   For double-faced signs with all sides enclosed and $R_{min} \leq 0.75$, it is permitted to multiply tabulated C_f values in Cases A and B by the reduction factor, $(1 - 0.133R_{min})$.
   For $B/s \geq 2$, Case B need not be considered, while Case C must be considered;
   Case C: Resultant forces act normal to the face of the wall or sign through the geometric centers of each region.
   For $s/h = 1$: (No legs)
   The same cases as above except that the vertical locations of the resultant forces occur at a distance above the geometric center equal to 0.05 times the average height of the wall or sign.

3. For Case C where $s/h > 0.8$, force coefficients shall be multiplied by the reduction factor $(1.8 - s/h)$. It is permitted to apply this reduction with those specified in Note 2.

4. Linear interpolation is permitted for values of s/h, B/s, and L_r/s other than shown.

Roof Mount Solar

- Parallel to roof
  - Section 29.4.4
  - Pressure equalization reduction for certain conditions (Fig 29.4-8)

Figure 29.4-8. Solar panel pressure equalization factor, γ_a, for enclosed and partially enclosed buildings of all heights.
Note: Bilinear interpolation between the solid line and the dashed line is permitted. Change to = signs for solid line.
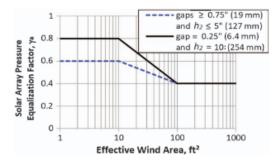
Photo credit: National Park Foundation

Ground Mount Solar

- New section 29.4.5
- Adds guidance for fixed-tilt systems
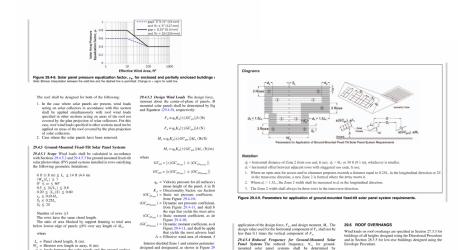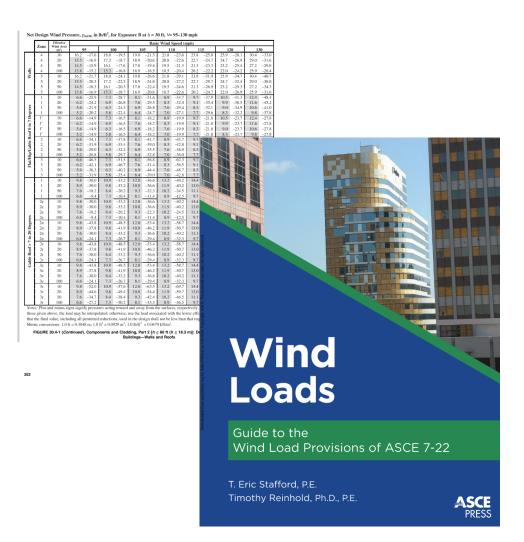
Photo credit: Solar Energy Industries Association

Components & Cladding

Chapter 30

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Tabular Methods

- Removed from ASCE 7-22

- Moved to *Guide to the Wind Load Provisions of ASCE 7-22*

- Spreadsheets / Commercial software

Wind Loads

Guide to the Wind Load Provisions of ASCE 7-22

T. Eric Stafford, P.E.
Timothy Reinhold, Ph.D., P.E.

ASCE PRESS

Pressure Equations: K_d

- K_d moved from Velocity Pressure (q_z) to Pressure Equations

$$q_z = 0.00265 K_z K_{zt} \cancel{K_d} K_e V^2 \qquad \text{(26.10-1)}$$

- C&C:

$$p = q_h K_d \left[(GC_p) - (GC_{pi}) \right] \qquad \text{(30.3-1)}$$

$$p = q K_d (GC_p) - q_i K_d (GC_{pi}) \qquad \text{(30.4-1)}$$

Elevated Buildings

- New in ASCE 7-22!
  - MWFRS
  - C&C

Elevated Buildings
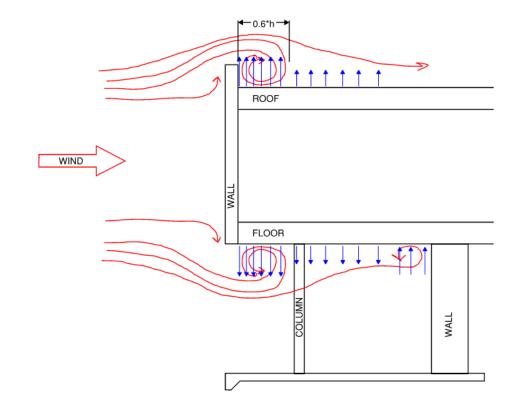
- Bottom Horizontal Surfaces of Elevated Buildings
  - Section 30.3.2.1: h $\leq$ 60 ft
  - Section 30.4.2.1: h > 60 ft

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Elevated Buildings
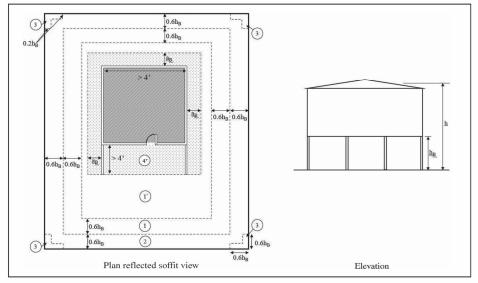
Figure 30.3-1A. Components and cladding [$h \leq 60$ ft (18.3 m)]: external pressure coefficient zones for enclosed, partially enclosed, and partially open elevated buildings with partially enclosed spaces and areas beneath the elevated building—bottom horizontal surface of elevated buildings.
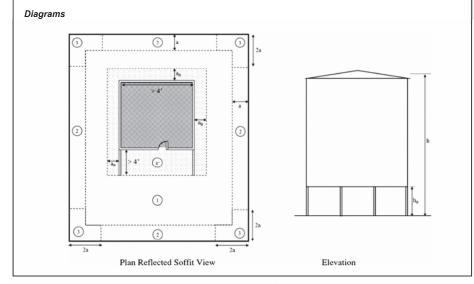
Figure 30.4-1A. Components and cladding, part 3 [$h > 60$ ft ($h > 18.3$ m)]: external pressure coefficient zones for enclosed, partially enclosed, and partially open elevated buildings with partially enclosed spaces and areas beneath the elevated building—bottom horizontal surface of elevated buildings.

Roof External Pressure Coefficients (GC_p)

- Gable: Fig 30.3-2B – 2D

- Hip: Fig 30.3-2E – 2G

- ASCE 7-16: Ridge, eave, corner zones

- ASCE 7-22: Simplified!
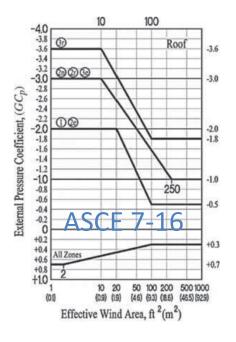
Photo credit: FEMA P-2342 Mitigation Assessment Team Report: Hurricane Ian in Florida

Low-Rise Gable Roofs

- External pressure coefficients, (GC_p)

ASCE 7-16

ASCE 7-22
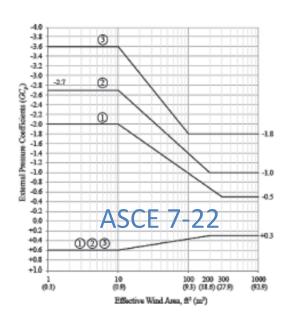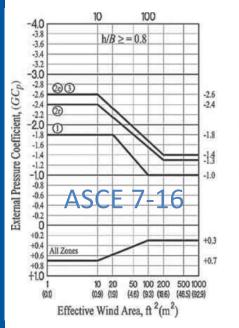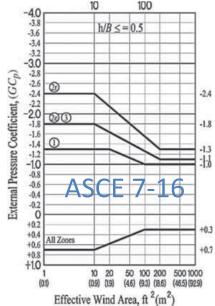
Table C30.3-3. Gable Roof, $7° < \theta \leq 20°$ (Figure 30.3-2B)

	Positive with and without overhang	
All Zones	$(GC_p) = 0.7$	for $A \leq 2$ ft²
	$(GC_p) = 0.7709 - 0.2354 \log A$	for $2 \leq A \leq 100$ ft²
	$(GC_p) = 0.3$	for $A \geq 100$ ft²
	Negative without overhang	
Zones 1 and 2e	$(GC_p) = -2.0$	for $A \leq 20$ ft²
	$(GC_p) = -4.7920 + 2.1460 \log A$	for $20 \leq A \leq 100$ ft²
	$(GC_p) = -0.5$	for $A \geq 100$ ft²
Zones 2n, 2r, and 3e	$(GC_p) = -3.0$	for $A \leq 10$ ft²
	$(GC_p) = -4.4307 + 1.4307 \log A$	for $10 \leq A \leq 250$ ft²
	$(GC_p) = -1.0$	for $A \geq 250$ ft²
Zone 3r	$(GC_p) = -3.6$	for $A \leq 10$ ft²
	$(GC_p) = -5.4000 + 1.800 \log A$	for $10 \leq A \leq 100$ ft²
	$(GC_p) = -1.8000$	for $A \geq 100$ ft²
	Negative with overhang	
Zones 1 and 2e	$(GC_p) = -2.5$	for $A \leq 20$ ft²
	$(GC_p) = -4.3614 + 1.4307 \log A$	for $20 \leq A \leq 100$ ft²
	$(GC_p) = -1.5$	for $A \geq 100$ ft²
Zones 2n and 2r	$(GC_p) = -3.5$	for $A \leq 10$ ft²
	$(GC_p) = -4.5730 + 1.0730 \log A$	for $10 \leq A \leq 250$ ft²
	$(GC_p) = -2.0$	for $A \geq 250$ ft²
Zone 3e	$(GC_p) = -4.1$	for $A \leq 10$ ft²
	$(GC_p) = -5.9599 + 1.8599 \log A$	for $10 \leq A \leq 250$ ft²
	$(GC_p) = -1.5$	for $A \geq 250$ ft²
Zone 3r	$(GC_p) = -4.7$	for $A \leq 10$ ft²
	$(GC_p) = -7.1000 + 2.4000 \log A$	for $10 \leq A \leq 100$ ft²
	$(GC_p) = -2.3$	for $A \geq 100$ ft²

Low-Rise Hip Roofs

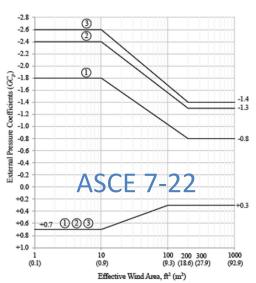- (GC_p) Function of h/B in ASCE 7-16
- ASCE 7-22: Simplified!

ASCE 7-16   ASCE 7-16   ASCE 7-22

Table C30.3-6. Hip Roofs, No Overhang, $7° < \theta \leq 20°$ (Figure 30.3-2E)

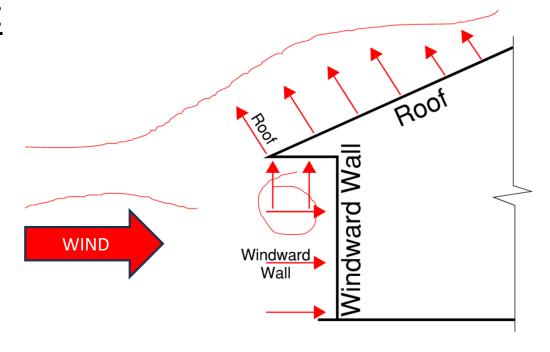|	Positive $h/B \geq 0.8$	
All Zones	$(GC_p) = 0.7$	for $A \leq 10$ ft²
	$(GC_p) = 1.1000 - 0.4000 \log A$	for $10 \leq A \leq 100$ ft²
	$(GC_p) = 0.3$	for $A \geq 100$ ft²
	Negative $h/B \geq 0.8$	
Zone 1	$(GC_p) = -1.8$	for $A \leq 20$ ft²
	$(GC_p) = -3.2891 + 1.1445 \log A$	for $20 \leq A \leq 100$ ft²
	$(GC_p) = -1.0$	for $A \geq 100$ ft²
Zone 2r	$(GC_p) = -2.4$	for $A \leq 10$ ft²
	$(GC_p) = -3.2455 + 0.8455 \log A$	for $10 \leq A \leq 200$ ft²
	$(GC_p) = -1.3$	for $A \geq 200$ ft²
Zones 2e and 3	$(GC_p) = -2.6$	for $A \leq 10$ ft²
	$(GC_p) = -3.5223 + 0.9223 \log A$	for $10 \leq A \leq 200$ ft²
	$(GC_p) = -1.4$	for $A \geq 200$ ft²
	Positive $h/B \leq 0.5$	
All Zones	$(GC_p) = 0.7$	for $A \leq 10$ ft²
	$(GC_p) = 1.1000 - 0.4000 \log A$	for $10 \leq A \leq 100$ ft²
	$(GC_p) = 0.3$	for $A \geq 100$ ft²
	Negative $h/B \leq 0.5$	
Zone 1	$(GC_p) = -1.3$	for $A \leq 20$ ft²
	$(GC_p) = -1.8584 + 0.4292 \log A$	for $20 \leq A \leq 100$ ft²
	$(GC_p) = -1.0$	for $A \geq 100$ ft²
Zone 2r	$(GC_p) = -2.4$	for $A \leq 10$ ft²
	$(GC_p) = -3.2455 + 0.8455 \log A$	for $10 \leq A \leq 200$ ft²
	$(GC_p) = -1.3$	for $A \geq 200$ ft²
Zones 2e and 3	$(GC_p) = -1.8$	for $A \leq 10$ ft²
	$(GC_p) = -2.3380 + 0.5380 \log A$	for $10 \leq A \leq 200$ ft²
	$(GC_p) = -1.1$	for $A \geq 200$ ft²

Low-Rise Hip Roofs

- ASCE 7-22 External pressure coefficients, (GC_p)
  - h/B removed
  - 27°- 45° changed to θ = 45°
    - Interpolate between Figures 30.3-2G and -2F:

$$\frac{\left[GC_p(2G) - GC_p(2F)\right] * (\theta_1 - 27°)}{(45° - 27°)} + GC_p(2F)$$

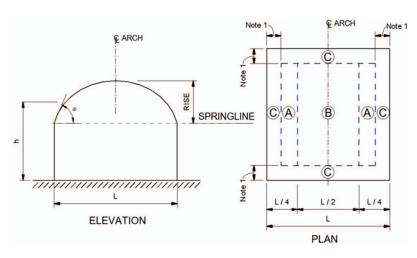Structural Engineers
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Low-Rise Roof Overhangs

- (GC_p) Included only in $\theta \leq 7°$ roof figure
  - Removed from gable & hip
- Section 30.7
  - Wall $+(GC_p)$ on bottom surface
  - Roof $-(GC_p)$ on top surface

Building Section

WIND

Roof

Roof

Windward Wall

Windward Wall

Low-Rise Arched Roofs

- Figure 30.3-8
  - Not new content; previously pointer to Chapter 27

Notation

L = Horizontal dimension of building, ft (m), measured normal to ridge.

r = Rise-to-span ratio = 'rise'/L.

h = Roof height as defined in Chapter 26 for roof angle θ.

θ = Angle of plane of roof from horizontal, in degrees, measured at eave.

External Pressure Coefficient, GC_p
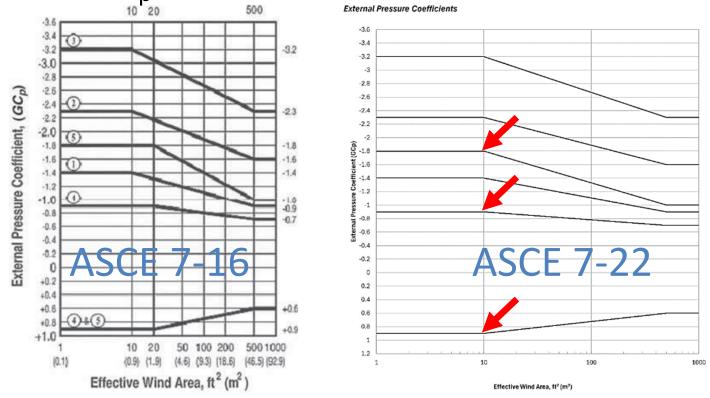
Conditions	Rise-to-Span Ratio, r	(GC_p)	
		Zone A	Zone B
Roof on elevated structure	$0 < r < 0.2$	-1.08 $1.8r-0.36$	$-0.84-1.2r$
	$0.2 \leq r < 0.3$	$7.2r-2.52$ -0.6	$-0.84-1.2r$
	$0.3 \leq r \leq 0.6$	$3.3r-0.84$ -0.6	$-0.84-1.2r$
Roof springing from ground level	$0 < r \leq 0.6$	$1.68r$ -0.6	$-0.84-1.2r$

Notes

1. At roof perimeter Zone C, use the roof zones (Zone 2 and 3) and external pressure coefficients in Fig. 30.3-2A, B, C, and D with "θ" based on springline slope. In the case of Fig. 30.3-2A, use 0.6h as the size of the roof perimeter Zone C. For roof Zones A and B, use external pressure coefficients shown in this table.

2. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.

3. Where multiple values of (GC_p) are listed, the roof zone is subjected to either positive or negative pressures and the structure shall be designed for all conditions.
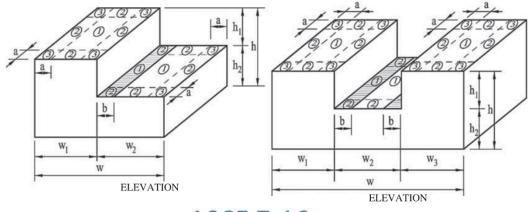

ELEVATION / PLAN diagrams

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h > 60 ft Wall External Pressure Coeff (GC$_p$)

- Small EWA (GC$_p$) aligned with 10 ft^2
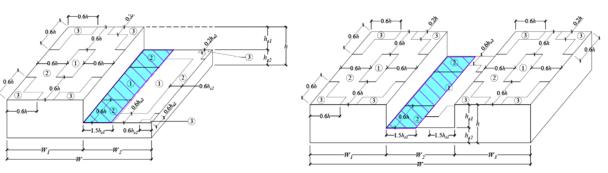

ASCE 7-16

ASCE 7-22

Stepped Roofs

- Low roof at step:
  - Zone 2&3 negative -> Zone 1&2 negative
  - Zone 2 & 3 positive -> Zone 4 & 5 wall positive
- ASCE 7-22:
  - Same process as 7-16
  - Figure will be revised in Supplement
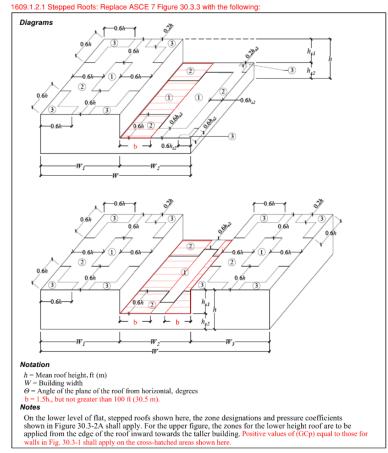
ASCE 7-16

ASCE 7-22

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Stepped Roofs

- Proposed Georgia Amendment

1609.1.2.1 Stepped Roofs: Replace ASCE 7 Figure 30.3.3 with the following:

Notation

h = Mean roof height, ft (m)
W = Building width
Θ = Angle of the plane of the roof from horizontal, degrees
b = 1.5h_1, but not greater than 100 ft (30.5 m).

Notes

On the lower level of flat, stepped roofs shown here, the zone designations and pressure coefficients shown in Figure 30.3-2A shall apply. For the upper figure, the zones for the lower height roof are to be applied from the edge of the roof inward towards the taller building. Positive values of (GCp) equal to those for walls in Fig. 30.3-1 shall apply on the cross-hatched areas shown here.

Figure 30.3-3. Components and cladding [$h \leq$ 60 ft ($h \leq$ 18.3 m)]: external pressure coefficients, (GC_p), for enclosed, partially enclosed, and partially open buildings, $\theta \leq 7°$—stepped roofs.

Attached Canopies
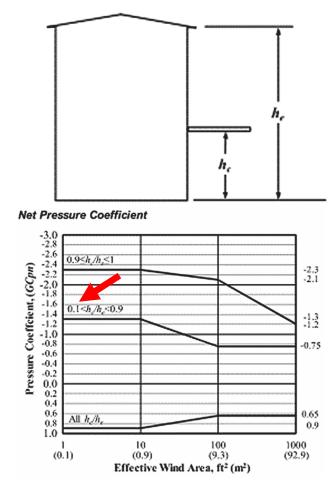
- h $\leq$ 60 ft added in 7-16
- 7-22 adds h > 60 ft
- Separate (upper, lower) surfaces
- Net (combined upper + lower)

Attached Canopies

- h $\leq$ 60 ft added in 7-16

- 7-22 adds h > 60 ft

- Separate (upper, lower) surfaces

- Net (combined upper + lower)
  - Function of h_c/h_e

Diagram

Net Pressure Coefficient

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Roof Pavers

- New in ASCE 7-22!

- Pedestal & loose laid pavers

- Not just "roofs"
  - Elevated amenity spaces
  - Balconies

- $p = q_h K_d C_{L_{net}}$

- $C_{L_{net}}$:
  - Roof (GC_p), wind tunnel data

Figure 1 – View of lifted pavers on the fifth floor roof. The red arrow indicates a paver resting on the top of the parapet.
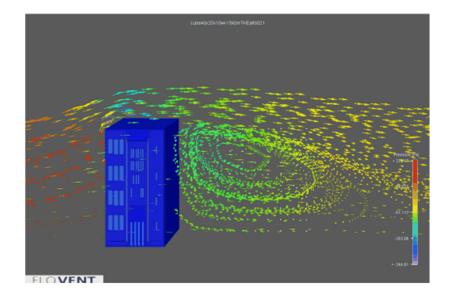
Figure 5 – View of lifted pavers (Irwin 2012, Figure 5).

Wind Tunnel Procedure

Chapter 31

Computational Fluid Dynamics (CFD)

- Section 31.1
  - CFD shall be validated by physical wind tunnel
  - Comply with ASCE 49
  - Peer review per Section 1.3.1.3.4

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Other Changes

- Guidance for:
  - Ground mounted solar – 31.4.5
  - Loads for structures at multiple sites – 31.5.1
  - Rooftop solar – 31.5.2

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Tornado Loads

Chapter 32

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Chapter 32

- New Chapter and Commentary
- Different from wind loads
- Subscript T or Tor
- Point back to Chapters 26-31 for applicable criteria

Chapter 32

- Intended to improve resiliency and life safety
  - EF0 – EF2

- Higher levels of protection?
  - ICC 500 Storm Shelter
  - Longer return period tornado speeds (Appendix G)
  - Performance Based Design

Scope

- Risk Category III or IV

Figure 32.1-2. Flowchart of process for determining when design for tornado loads is required.

Scope

- Risk Category III or IV
- Tornado prone region

Figure 32.1-2. Flowchart of process for determining when design for tornado loads is required.

Scope

- Risk Category III or IV
- Tornado prone region

FIGURE 1609.5—TORNADO-PRONE REGION

Tornado-prone region
Areas outside tornado-prone region

IBC 2024

Tornado-prone region
Areas outside tornado-prone region

Figure 32.1-1. Tornado-prone region.

ASCE 7-22

Scope
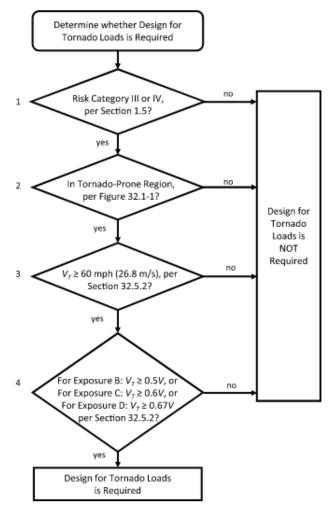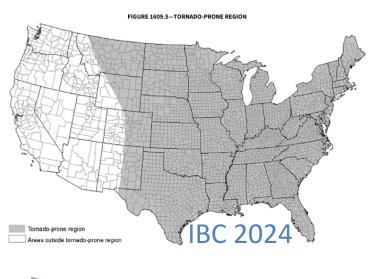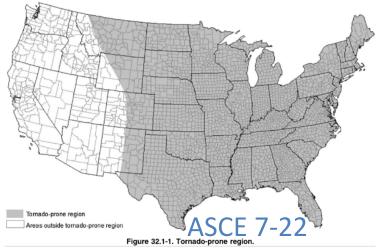
- Risk Category III or IV
- Tornado prone region
- V_T > 60 mph
- V_T >
  - 0.5*V (Exposure B)
  - 0.6*V (Exposure C)
  - 0.67*V (Exposure D)

Figure 32.1-2. Flowchart of process for determining when design for tornado loads is required.

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Tornado Basic Criteria

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_e, see Section 32.9
➤ Tornado velocity pressure exposure coefficients, K_{zTor} and K_{hTor}, 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_{vT}, 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 $h \leq 60$ 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.

Tornado Speed, V_T

- Risk Category
- Effective Plan Area, A_e

Tornado Speed, V_T

- Risk Category
  - III = 1,700 year MRI
  - IV = 3,000 year MRI
- 8 maps for each Risk Category (III & IV):
  - 1 ft^2 (point target), 2,000 ft^2, 10,000 ft^2, 40,000 ft^2, 100,000 ft^2, 250,000 ft^2, 1,000,000 ft^2, 4,000,000 ft^2
- V_T = 50 – 124 mph (Risk Category III)
- V_T = 50 – 138 mph (Risk Category IV)

Tornado Speed, V_T

- Risk Category

- Effective Plan Area, A_e
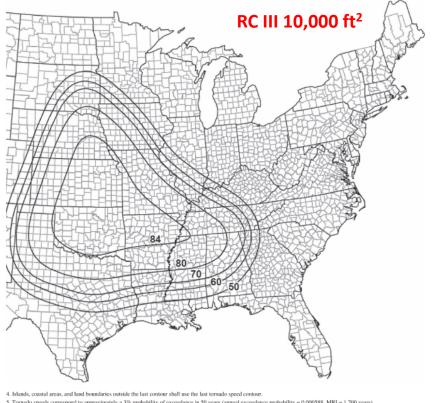
Individual Building
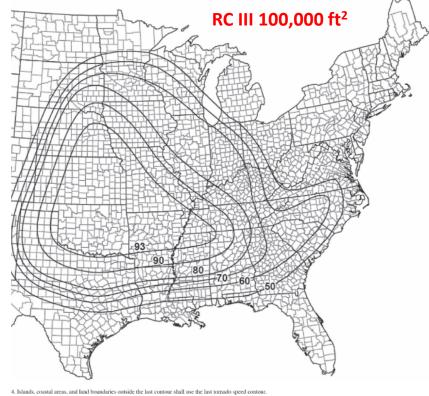
Essential Facilities with
Functionally Dependent Structures

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Tornado Speed, V_T : Risk Category III

RC III 10,000 ft²

RC III 100,000 ft²

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.
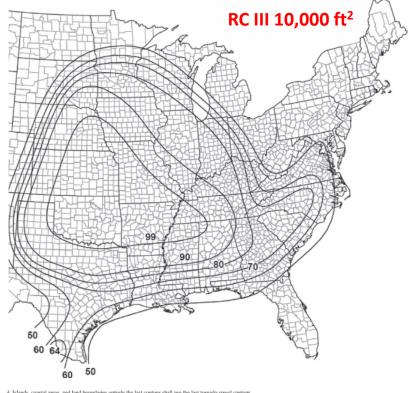
Figure 32.5-1C (Continued). Tornado speeds for Risk Category III buildings and other structures, for effective plan area of 10,000 ft² (929 m²).

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.
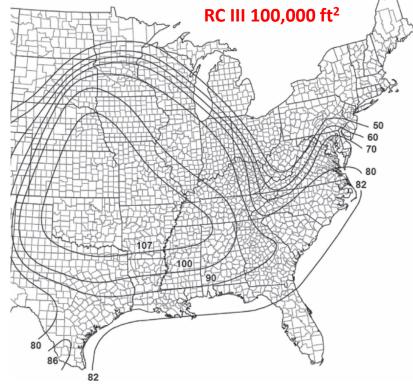
Figure 32.5-1E (Continued). Tornado speeds for Risk Category III buildings and other structures, for effective plan area of 100,000 ft² (9,290 m²).

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Tornado Speed, V_T : Risk Category IV

RC III 10,000 ft²

RC III 100,000 ft²

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 1.7% probability of exceedance in 50 years (annual exceedance probability = 0.00033, MRI = 3,000 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 32.5-2C (Continued). Tornado speeds for Risk Category IV buildings and other structures, for effective plan area of 10,000 ft² (929 m²).

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 1.7% probability of exceedance in 50 years (annual exceedance probability = 0.00033, MRI = 3,000 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 32.5-2E (Continued). Tornado speeds for Risk Category IV buildings and other structures, for effective plan area of 100,000 ft² (9,290 m²).

Tornado Speed, V_T

Tornado Directionality Factor, K_{dT}

- Sec 32.6 & Table 32.6-1
- Main Wind Force Resisting System
  - $K_{dT} = 0.80$
- Components & Cladding
  - $K_{dT} = 1.0$ Essential Facilities & buildings intended to remain operational
  - $K_{dT} = 0.90$ for Roof Zone 1'
  - $K_{dT} = 0.75$ for all other cases

Table 32.6-1. Tornado Directionality Factor, K_{dT}.

Structure Type	Tornado Directio...
Buildings	
Main wind force resisting system	0.80
Components and cladding	
For Essential Facilities and for buildings and other structures required to maintain the functionality of Essential Facilities	1.0
Roof Zone 1' as shown in Figure 30.3-2A	0.90
All other cases	0.75
Arched roofs, circular domes, and all other structures	Use value fro...

Tornado Velocity Pressure

- Sec 32.10 & Table 32.10-1

- No exposure category

- No topographic effects

- K_{zTor} & K_{hTor}
  - Constant up to 200 ft

- Velocity pressure:
  - $q_{zT} = 0.00256*K_{zTor}*K_e*V_T^2$

Table 32.10-1. Tornado Velocity Pressure Exposure Coefficients, K_{zTor} and K_{hTor}

Height above Ground Level, z or h		K_{zTor} and K_{hTor}
ft	m	
0–200	0–61.0	1.0
250	76.2	0.96
300	91.4	0.92
>328	>100	0.90

Notes:

1. The tornado velocity pressure exposure coefficient, K_{zTor}, is permitted to be determined as follows:

   For $0 < z \le 200$ ft (60 m) $K_{zTor} = 1.0$

   For $200 < z \le 328$ ft $K_{zTor} = [(2820 - z)/2620]^2$, where z is in ft

   (For $61 < z \le 100$ m) $K_{zTor} = [(861 - z)/800]^2$, where z is in m

   For $z > 328$ ft (100 m) $K_{zTor} = 0.90$

2. Linear interpolation for intermediate values of height z is permitted.

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Tornado Gust Effects

- Sec 32.11

- G_T = 0.85 permitted for all structures
  - Option to calculate G per Chapter 26, use Exposure C

26.11.4 Rigid Buildings or Other Structures For rigid buildings or other structures as defined in Section 26.2, the gust-effect factor shall be taken as 0.85 or calculated by this formula:

$$G = 0.925\left(\frac{1 + 1.7g_Q I_{\bar{z}}Q}{1 + 1.7g_v I_{\bar{z}}}\right) \qquad (26.11\text{-}6)$$

- G_f does not apply to tornado loads

Tornado Enclosure Classification

- Sec 32.12

- Enclosure per Chapter 26

- Unprotected glazing on windward wall = openings for enclosure classification (32.12.2)

- Impact resistant glazing or impact-protection required for essential facilities (32.12.3)

Photo credit: FEMA

Tornado Internal Pressure Coefficient, GC_{piT}

- Sec 32.13 & Table 32.13-1
- GC_{piT} = +1.0 for sealed structures
- GC_{piT} = +0.55, -0.18 enclosed
- GC_{piT} = +0.55, -0.55 partially enclosed
- GC_{piT} = +0.18, -0.18 partially open
- GC_{piT} = 0.00 open

Table 32.13-1. Main Wind Force Resisting System and Components and Cladding Tornado Internal Pressure Coefficient, (GC_{piT}).
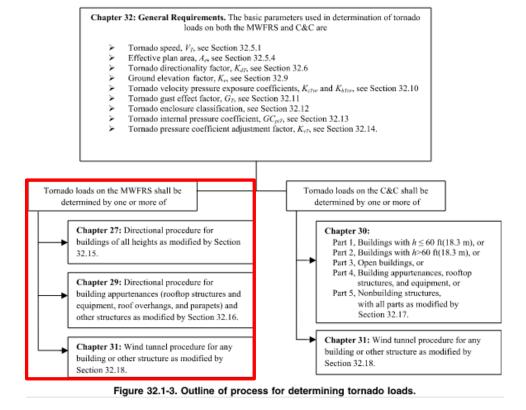
Enclosure Classification	Criteria for Enclosure Classification	Internal Pressure Combined with Atmospheric Pressure Change	Tornado Internal Pressure Coefficient, (GC_{piT})
Sealed other structures	See Section 32.2	Extreme	+1.0
Enclosed buildings and other structures	See Table 26.13-1	High	+0.55 −0.18
Partially enclosed buildings and other structures	See Table 26.13-1	High	+0.55 −0.55
Partially open buildings and other structures	See Table 26.13-1	Moderate	+0.18 −0.18
Open buildings and other structures	See Table 26.13-1	Negligible	0.00

Tornado Pressure Coeff Adjustment Factor, K_{vT}

- Sec 32.14 & Table 32.14-1
- Adjustment factor for vertical (uplift) loads
- K_{vT} = 1.10 for MWFRS Uplift pressure on roof
- K_{vT} = 1.05 - 1.30 for C&C (varies by roof slope and zone)

Table 32.14-1. Tornado Pressure Coefficient Adjustment Factor for Vertical Winds, K_{vT}.

STRUCTURE TYPE	K_{vT}
Buildings	
Negative (Uplift) Pressures on Roofs	
Main Wind Force Resisting System	1.1
Components and Cladding	
Roof slope ≤ 7 degrees	
Zone 1	1.2
Zone 2	1.05
Zone 3	1.05
Roof slope > 7 degrees	
Zone 1	1.2
Zone 2	1.2
Zone 3	1.3
Positive Pressures (Downward Acting) on Roofs	1.0
Wall Pressures	1.0
All Other Cases	1.0
Other Structures	
Negative (Uplift) Pressures on Rooftop Structures and	
Equipment and Rooftop Solar Panels Parallel to the Roof Surface	
Main Wind Force Resisting System	1.1
Components and Cladding	Use values for building C&C
Negative (Uplift) Pressures on Roofs of Bins, Silos, and Tanks	
Main Wind Force Resisting System	1.1
Components and Cladding	See Section 32.17.5
All Other Cases	1.0

Tornado Loads: MWFRS

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_e, see Section 32.9
➤ Tornado velocity pressure exposure coefficients, K_{zTor} and K_{hTor}, 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_{vT}, 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 $h \leq 60$ 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.

Tornado Loads: MWFRS

- 32.15.1 Enclosed, Partially Enclosed, and Partially Open Buildings
  - $p_T = q*G_T*K_{dT}*K_{vT}*C_p - q_i(GC_{piT})$
    - $q = q_{zT}$ External pressure on all walls
    - $q = q_{hT}$ External pressure on roofs
    - $q_i = q_{hT}$ Internal pressure on roofs (enclosed, partially open)
    - $q_i = q_{zT}$ Internal pressure on walls (enclosed, partially open)
    - $q_i = q_{zop}$ Internal pressure on roofs, walls (partially enclosed)
  - **FYI $q_{hT} = q_{zT}$ for h $\leq$ 200 ft!**

Tornado Loads: Components & Cladding

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

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Tornado Loads: Components & Cladding

- 32.17.1 Low-Rise Buildings
  - $p_T = q_{hT} * [K_{dT} * K_{vT} * (GC_p) - (GC_{piT})]$
- 32.17.2 Buildings with h > 60 ft
  - $p_T = q * K_{dT} * K_{vT} * (GC_p) - q_i(GC_{piT})$
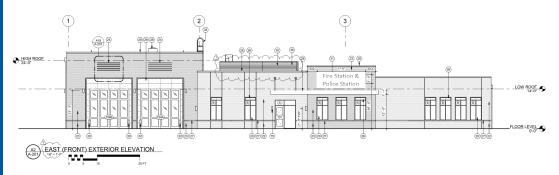
Tornado Load Combos

- Chapter 2

- Strength Design

  - $1.2D + 1.0(W \text{ or } W_T) + L + (0.5L_r \text{ or } \cancel{0.3S} \text{ or } 0.5R)$

  - $0.9D + 1.0(W \text{ or } W_T)$

- Allowable Stress Design

  - $D + 0.6(W \text{ or } W_T)$

  - $D + 0.75L + 0.75(0.6(W \text{ or } W_T)) + 0.75(L_r \text{ or } \cancel{0.7S} \text{ or } R)$

  - $0.6D + 0.6(W \text{ or } W_T)$

Tornado Load Design Example

Design Example
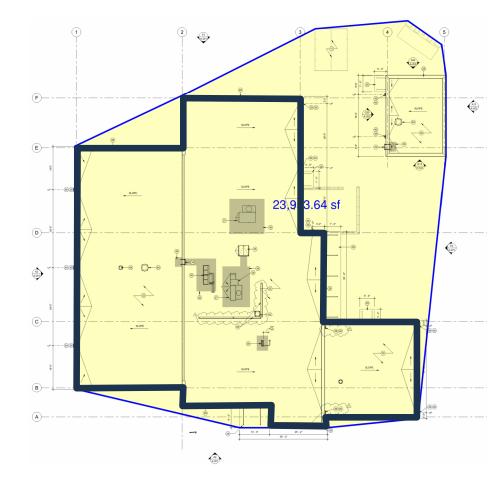
- Fire / Police Station

- Risk Category IV

- Cartersville, GA

- Wind Criteria

  - V = 117 mph

  - Exposure B

  - No Topographic Effects

  - z_e = 750 ft

  - G = 0.85 (Rigid Building)

  - Enclosed Building

  - h = 24 ft

  - Flat roof
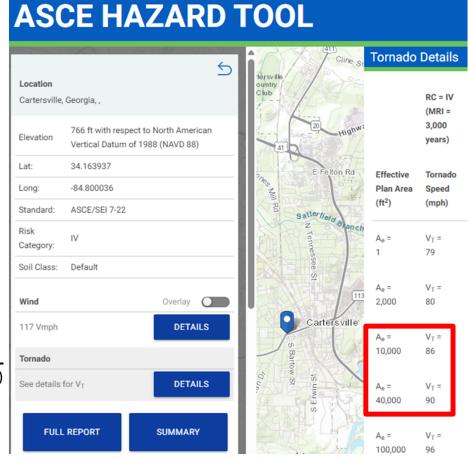
Tornado Criteria

- Effective plan area, A_e = 24,000 ft^2
  - Includes auxiliary buildings that support functions of the essential facility (32.5.4.1)

Tornado Criteria

- Effective plan area, A_e = 24,000 ft^2

  - Includes auxiliary buildings that support functions of the essential facility (32.5.4.1)

- $V_T = 86 + (\log 24{,}000 - \log 10{,}000)\, x\, \dfrac{(90-86)}{(\log 40{,}000 - \log 10{,}000)}$
  $= 88.5\ mph$

ASCE HAZARD TOOL

Location
Cartersville, Georgia, ,

Elevation	766 ft with respect to North American Vertical Datum of 1988 (NAVD 88)
Lat:	34.163937
Long:	-84.800036
Standard:	ASCE/SEI 7-22
Risk Category:	IV
Soil Class:	Default

Wind — Overlay

117 Vmph — DETAILS

Tornado

See details for V_T — DETAILS

FULL REPORT — SUMMARY

Tornado Details

RC = IV
(MRI = 3,000 years)

Effective Plan Area (ft^2)	Tornado Speed (mph)
A_e = 1	V_T = 79
A_e = 2,000	V_T = 80
A_e = 10,000	V_T = 86
A_e = 40,000	V_T = 90
A_e = 100,000	V_T = 96
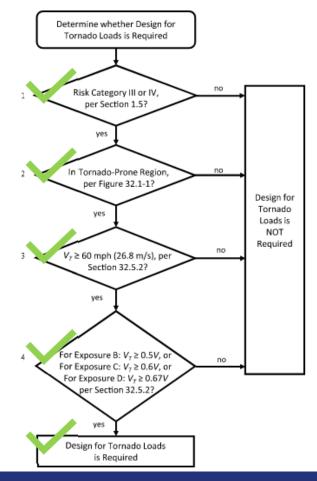
Verify Tornado Design Required

- Figure 32.1-2

Tornado Parameters

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_e, see Section 32.9
- Tornado velocity pressure exposure coefficients, K_{zTor} and K_{hTor}, 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_{vT}, 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 $h \leq 60$ 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.

Tornado Parameters

- A_e = 24,000 ft^2

- V_T = 89 mph

- K_{dT} =
  - 0.80 MWFRS
  - 1.0 C&C (Essential facility)

- K_e = 0.97

- K_{zTor} = K_{hTor} = 1.0

- G_T = 0.85

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_e, see Section 32.9
- Tornado velocity pressure exposure coefficients, K_{zTor} and K_{hTor}, 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_{vT}, see Section 32.14.

Tornado Parameters

- Enclosed structure
  - Impact glazing required for essential facilities
- GC_{piT} = +0.55, -0.18
- K_{vT} =
  - 1.1 MWFRS Roof Uplift
  - 1.2 C&C Zone 1 Uplift
  - 1.05 C&C Zones 2 & 3 Uplift

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_e, see Section 32.9
- Tornado velocity pressure exposure coefficients, K_{zTor} and K_{hTor}, see Section 32.10
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- Tornado enclosure classification, see Section 32.12
- Tornado internal pressure coefficient, GC_{piT}, see Section 32.13
- Tornado pressure coefficient adjustment factor, K_{vT}, see Section 32.14.

Tornado Loads – MWFRS

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

Tornado Loads – MWFRS

		Wind Pressure (psf)	Tornado Pressure (psf)	Tornado / Wind
Net Lateral Pressures (internal cancels)				
Level	Height (ft)			
High Roof	24	21.1	17.4	0.83
Low Roof	14	19.4	17.4	0.9
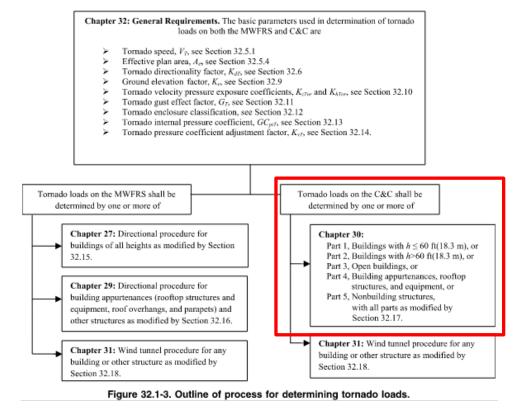
Tornado Loads – MWFRS

Roof Uplift Pressures (positive internal)			
Distance from windward edge	Wind Pressure (psf)	Tornado Pressure (psf)	Tornado / Wind
0 to h/2	-18	-24.1	1.34
h/2 to h	-18.0	-24.1	1.34
h to 2h	-11.5 (-16.0)	-18.2	1.58
> 2h	-8.3 (-16.0)	-15.3 (-16.0)	1.84 (1.0)

Tornado Loads – C&C

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

Tornado Loads – C&C

Wall C&C Pressures				
EWA (ft^2)	Zone	Wind Pressure (psf)	Tornado Pressure (psf)	Tornado / Wind
10	4	-21.2	-30.4	1.44
	5	-26.0	-35.7	1.37
	Positive	19.5	21.3	1.09
100	4	-18.3	-27.3	1.49
	5	-20.3	-29.4	1.45
	Positive	16.7	18.2	1.09

Tornado Loads – C&C
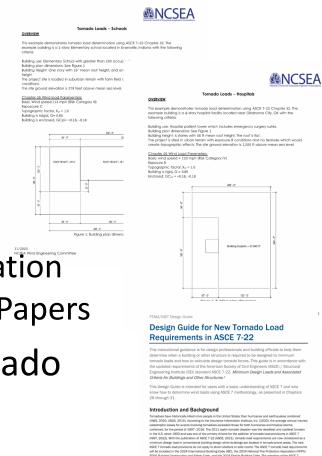
Roof C&C Pressures				
EWA (ft^2)	Zone	Wind Pressure (psf)	Tornado Pressure (psf)	Tornado / Wind
10	1'	-19.5	-32.2	1.65
	1	-34.0	-51.1	1.50
	2	-44.9	-58.5	1.30
	3	-61.1	-77.2	1.26
	Positive	8.7 (16)	9.5 (16)	1.09 (1.0)

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Tornado Loads – C&C

Roof C&C Pressures				
EWA (ft^2)	Zone	Wind Pressure (psf)	Tornado Pressure (psf)	Tornado / Wind
100	1'	-19.5	-32.2	1.65
	1	-26.6	-41.4	1.56
	2	-35.3	-47.5	1.35
	3	-42.0	-55.2	1.32
	Positive	6.9 (16)	7.5 (16)	1.09 (1.0)

Additional Examples
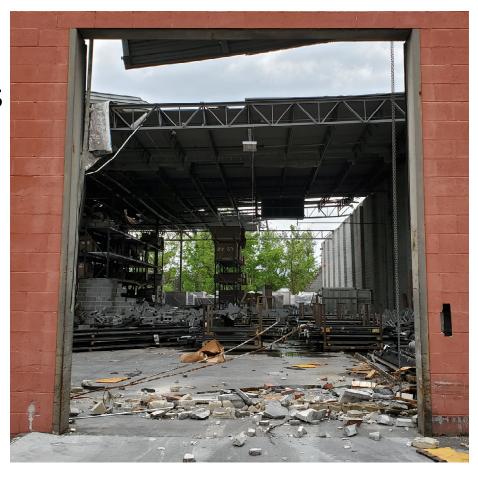
- NCSEA Wind Engineering Committee Example Problems
  - RC III School & RC IV Hospital
  - Free download from NCSEA.COM -> Education & Events-> Publications -> FAQ's & White Papers
- FEMA/NIST Design Guide for New Tornado Load Requirements in ASCE 7-22
  - RC IV Hospital
  - Free download from FEMA.GOV

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Tornado Key Takeaways

- ASCE 7-22 Tornado Provisions
  - Improve resiliency & life safety
  - EF0 – EF2
  - Buildings are **<u>NOT</u>** storm shelters!
- Design Impacts
  - Low rise buildings
  - Interior roof zone uplift
  - Wall C&C pressures

Tornado Key Takeaways

- Construction Cost Impacts:
  - < 0.25% Increase
  - NIST Technical Note 2214

Tornado Loads FAQ

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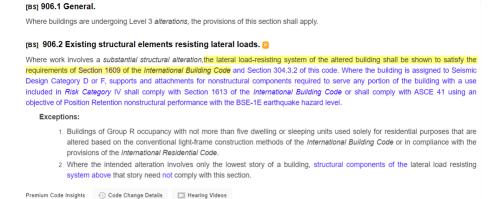
How do I document tornado design?

- IBC 1603.1.4: Wind and tornado design data
  - Tornado speed, V_T
  - Effective plan area, A_e
  - Tornado internal pressure coefficients
  - C&C pressures: "…maximum of wind or tornado…"

GROUND SNOW LOAD, Pg	0 PSF
DESIGN WIND LOAD:	
ULTIMATE DESIGN WIND SPEED (3 SECOND GUST), Vult	201 MPH
NOMINAL DESIGN WIND SPEED, Vasd	156 MPH
RISK CATEGORY	IV
WIND EXPOSURE CATEGORY	D
COMPONENTS AND CLADDING WIND PRESSURE	SEE SCHEDULE
INTERNAL PRESSURE COEFFICIENT	0
DESIGN TORNADO LOAD: (PER FBC REQUIREMENTS)	
TORNADO SPEED (3 SECOND GUST), Vt	113 MPH
EFFECTIVE PLAN AREA FOR TORNADO DESIGN, Ae	4,000,000
RISK CATEGORY	IV
COMPONENTS AND CLADDING TORNADO PRESSURE	SEE SCHEDULE
TORNADO INTERNAL PRESSURE COEFFICIENTS	+1.0
DESIGN SEISMIC LOAD:	
RISK CATEGORY	IV

Renovations: Do tornado loads apply?
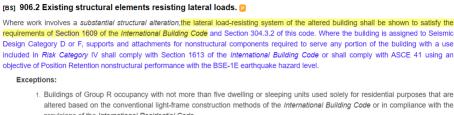
- Follow IEBC requirements associated with scope of work

- No "catch all" requirement

- "...satisfy the requirements of Section 1609 of the IBC..."
  - Includes tornado loads

[BS] 906.1 General.

Where buildings are undergoing Level 3 *alterations*, the provisions of this section shall apply.

[BS] 906.2 Existing structural elements resisting lateral loads.

Where work involves a *substantial structural alteration*, the lateral load-resisting system of the altered building shall be shown to satisfy the requirements of Section 1609 of the *International Building Code* and Section 304.3.2 of this code. Where the building is assigned to Seismic Design Category D or F, supports and attachments for nonstructural components required to serve any portion of the building with a use included in *Risk Category* IV shall comply with Section 1613 of the *International Building Code* or shall comply with ASCE 41 using an objective of Position Retention nonstructural performance with the BSE-1E earthquake hazard level.

Exceptions:

1. Buildings of Group R occupancy with not more than five dwelling or sleeping units used solely for residential purposes that are altered based on the conventional light-frame construction methods of the *International Building Code* or in compliance with the provisions of the *International Residential Code*.

2. Where the intended alteration involves only the lowest story of a building, structural components of the lateral load resisting system above that story need not comply with this section.

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[BS] 906.3 Seismic Design Category F

Renovations: Do tornado loads apply?

- Tornado design may apply for:
  - Major repairs
  - Alterations: Level 2 or 3
  - Substantial structural alterations
  - Change of occupancy (increase risk category)
  - Additions where not structurally independent
  - Relocated buildings

[BS] 906.1 General.

Where buildings are undergoing Level 3 *alterations*, the provisions of this section shall apply.

[BS] 906.2 Existing structural elements resisting lateral loads.

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[BS] 906.3 Seismic Design Category F

Building has a shelter, can I ignore Ch. 32?

- ICC 500:
  - FEMA P-361: …safe room that provides **near-absolute protection**…for occupants.
  - Shelters are often limited to small areas of the overall building

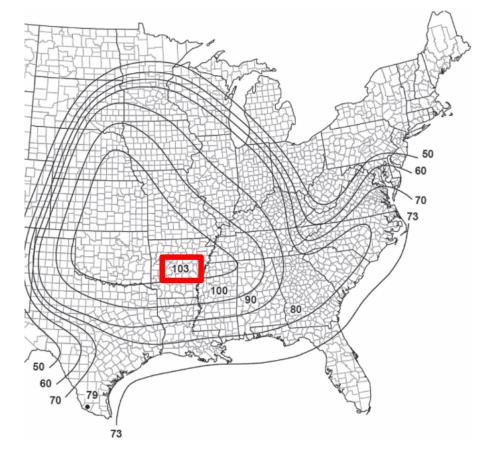# Building has a shelter, can I ignore Ch. 32?

- ASCE 7:
  - Improved resiliency and life safety in lower intensity tornadoes
  - Applies to entire structure
- ASCE 7-22 Chapter 32 applies, even if there is a shelter

What's the deal with the impact glazing?

- ASCE 7 Sec 32.12.3:
  - Use ASTM E1996 Tables 2 & 3
  - Select wind zone using V_T in place of V
- Lowest wind zone is 130 mph, but V_T < 130 ?

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What's the deal with the impact glazing?

- ASCE 7-22 Supplement 3 proposal:
  - Use ASTM E1996 Tables 2 ~~& 3~~
  - ~~Select wind zone using V_T in place of V~~
  - <u>Use missile level D as described in Table 2 of ASTM E1996</u>
  - <u>Comply with impact pass/fail criteria for Enhanced Protection (Section 7 ASTM E1996)</u>

TABLE 2 Applicable Missiles

Missile Level	Missile	Impact Speed (m/s)
A	2 g (31 grains) ± 5 % steel ball	39.62 (130 f/s)
B	910 g ± 100 g (2.0 lb ± 0.25 lb) 2 × 4 in. 52.5 cm ± 100 mm (1 ft – 9 in. ± 4 in.) lumber	15.25 (50 f/s)
C	2050 g ± 100 g (4.5 lb ± 0.25 lb) 2 × 4 in. 1.2 m ± 100 mm (4 ft ± 4 in.) lumber	12.19 (40 f/s)
D	4100 g ± 100 g (9.0 lb ± 0.25 lb) 2 × 4 in. 2.4 m ± 100 mm (8 ft ± 4 in.) lumber	15.25 (50 f/s)
E	4100 g ± 100 g (9.0 lb ± 0.25 lb) 2 × 4 in. 2.4 m ± 100 mm (8 ft ± 4 in.) lumber	24.38 (80 f/s)

TABLE 3 Description Levels

NOTE 1—For Missiles B, C, D, and E, also use Missile A for porous impact protective systems (see 8.5).

Level of Protection	Enhanced Protection (Essential Facilities)		Basic Protection		Unprotected	
Assembly Elevation	≤9.1 m (30 ft)	>9.1 m (30 ft)	≤9.1 m (30 ft)	>9.1 m (30 ft)	≤9.1 m (30 ft)	>9.1 m (30 ft)
Wind Zone 1	D	D	C	C	None	None
Wind Zone 2	D	D	C	A	None	None
Wind Zone 3	E	D	D	A	None	None

Questions?

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