Clarifying Frequently Misunderstood Wind Provisions

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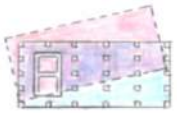
Martin/Martin, Inc.

Frequently Misunderstood Wind Provisions

- Enclosure Classification
- Analysis Methods
- Torsional Effects
- Canopies
- Corner Zones
- Effective Wind Area
- Rooftop Solar/ PV
- ASCE 7-10

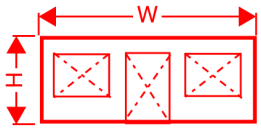


Enclosed, Partially Enclosed, Open?

Enclosure Classification (26.2):

Open Building: A building having *each wall* at least 80% open.

$A_o \geq 0.8A_g$



$A_o = A_1 + A_2 + A_3$

$A_g = W \times H$

Enclosure Classification (26.2):

Partially Enclosed Building: A building that complies with *both* of the following conditions:

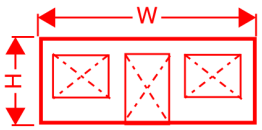
1. The total area of openings in a wall > the sum of the openings in the balance of the building envelope (walls and roof) by >10%.

   $A_o \geq 1.10A_{oi}$

2. The total area of openings in a wall exceeds 4ft² (or 1% of area of that wall), and the % of openings in the balance of the building <20%.

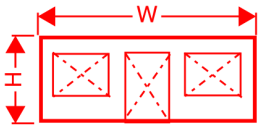
   A_o>4 ft² OR >0.01A_g (Whichever is smaller)

   $\frac{A_o}{A_{gi}} \leq 0.20$



Enclosure Classification (26.2):

Enclosed Building: A building that does not comply with the requirements for open or partially enclosed buildings.



Enclosure Classification (26.2):

Question: What constitutes an opening?

Answer: Doors, operable windows, air intake exhausts, operable louvers, *anything designed to be open during design winds.*

Question: What about windows in wind-borne debris regions?

Answer: Category II, III, IV buildings in wind-borne debris regions to be protected with impact resistant glazing, impact protective systems.

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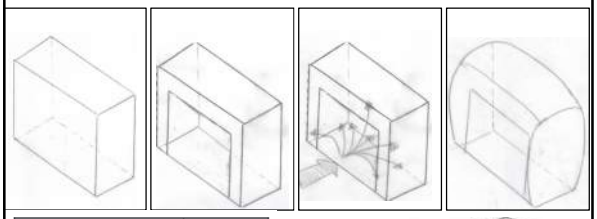
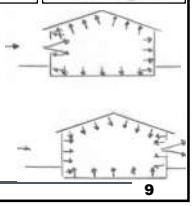


Enclosure Classification	(GC_{pi})
Open Buildings	0.00
Partially Enclosed Buildings	+0.55 -0.55
Enclosed Buildings	+0.18 -0.18



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Enclosed, Partially Enclosed, Open?

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Open Building: A building having each wall at least 80% open.

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Partially Enclosed Building: A building that complies with *both* of the conditions:

1. The total openings in a wall exceeds the sum of the openings in the balance of the building envelope by >10%.
2. The total area of openings in a wall exceeds 4ft² or 1% of area of that wall, *and* the percentage of openings in the balance of the building envelope ≤ 20%.

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Partially Enclosed Building: A building that complies with *both* of the conditions:

1. The total openings in a wall exceeds the sum of the areas of openings in the balance of the building envelope by >10%.

Windward wall Balance of building

$200\,ft \times 25\,ft = 5{,}000\,ft^2$

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Enclosed Building: A building that does not comply with the requirements for open or partially enclosed buildings.

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Partially Enclosed Building: A building that complies with *both* of the conditions:

1. The total openings in a wall exceeds the sum of the areas of openings in the balance of the building envelope by >10%.

$200\,ft \times 25\,ft = 5{,}000\,ft^2 > 1.10[2(75\,ft \times 30\,ft)] = 4{,}950\,ft^2$

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Partially Enclosed Building: A building that complies with *both* of the conditions:

2. The total area of openings in a wall that receives positive external pressure exceeds 4ft² or 1% of area of that wall, and the percentage of openings in the balance of the building envelope is less than 20%.

$$\frac{75\,ft \times 30\,ft \times 2}{75\,ft \times 30\,ft \times 2 + 200\,ft \times 25\,ft + 200\,ft \times 75\,ft} = .18 < .20$$ ✓

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Enclosed, Partially Enclosed, Open?

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Enclosed, Partially Enclosed, Open?

18

Enclosed, Partially Enclosed, Open?

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Enclosed, Partially Enclosed, Open?

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A_c= 10 ft²

A_b= 15 ft²

A_d= 20 ft²

A_a=50 ft²

$$50 ft^2 > 1.10\left[15 ft^2 + 10 ft^2 + 20 ft^2\right] = 49.5 ft^2$$

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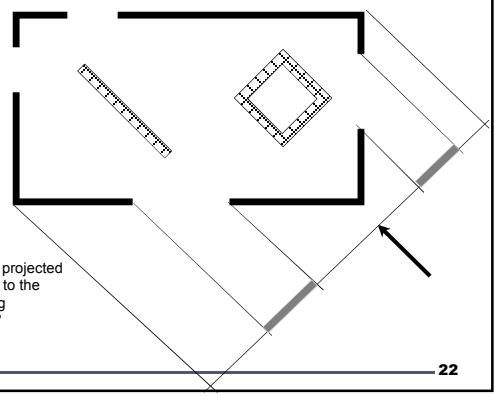
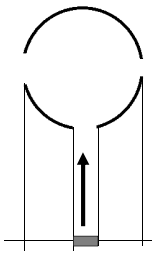
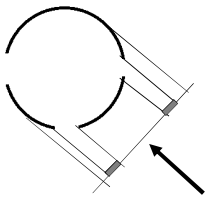


"…on a plane projected perpendicular to the direction being considered…"

22

"…on a plane projected perpendicular to the direction being considered…"





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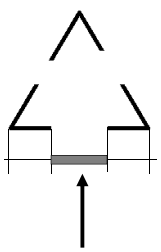
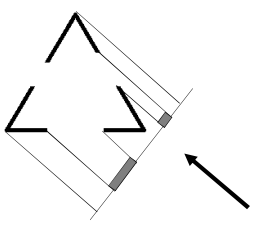
"…on a plane projected perpendicular to the direction being considered…"





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Wind Design Methods

Question: What is the difference between all the Methods (analytical, simplified, directional, envelope, wind tunnel, all-heights) for calculating wind loads? Which one should I use?

Answer:

- Main Wind Force Resisting System (MWFRS) v. Components & Cladding (C&C)
- Building Height < 60 ft v. Building Height > 60 ft
- Enclosed v. Partially Enclosed v. Open
- Flexible v. Rigid Building
- Parapet v. Wall/ Roof
- Building v. Sign/ Mechanical Equipment/ Rooftop Structures
- Regular v. Irregular Building
- Roof Configuration
- Simple Diaphragm

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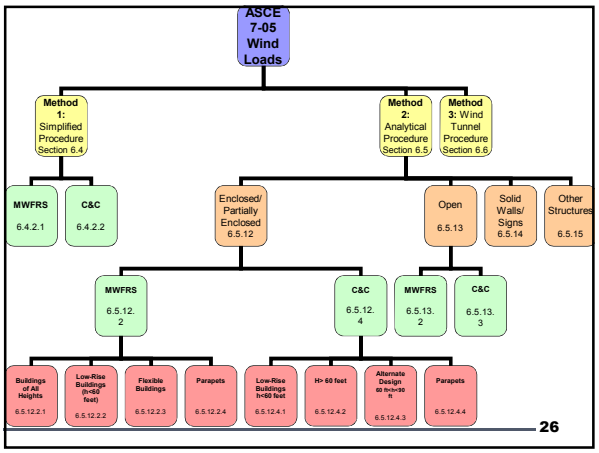

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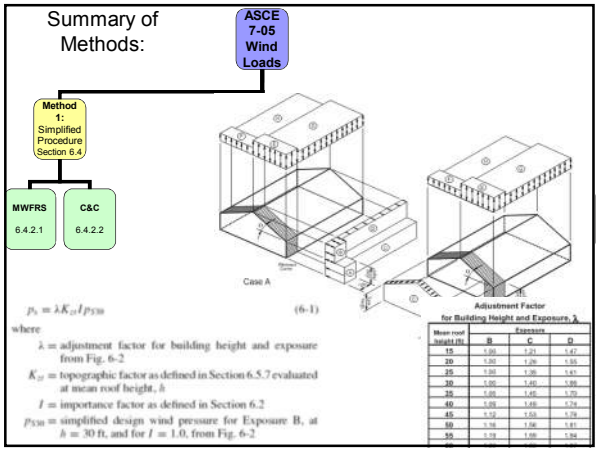
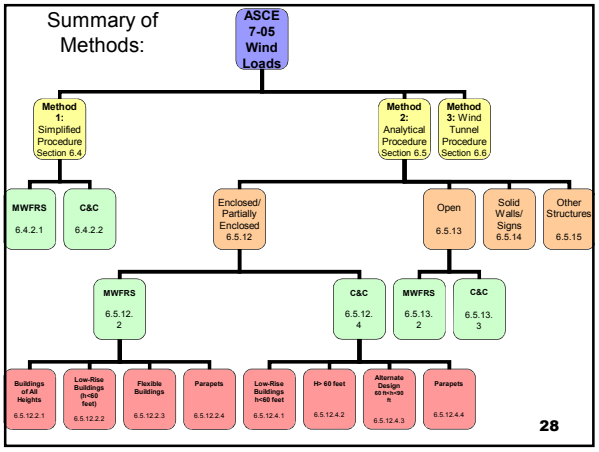
Summary of Methods:



Summary of Methods:



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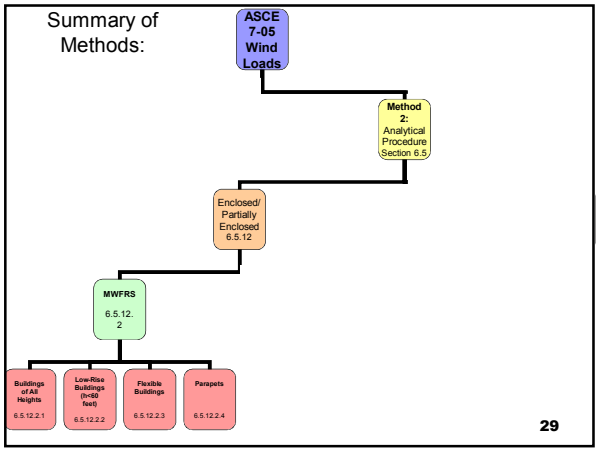
Summary of Methods:



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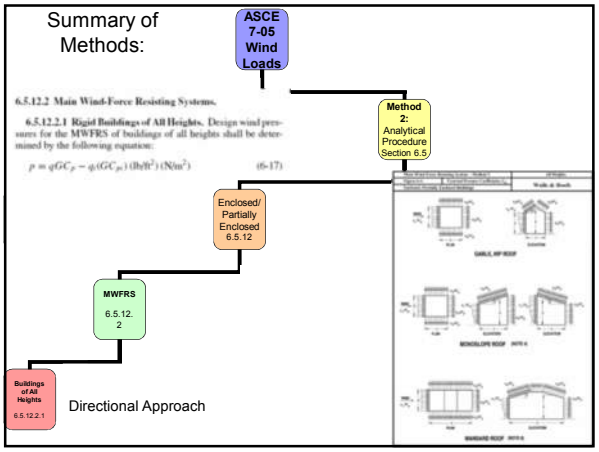
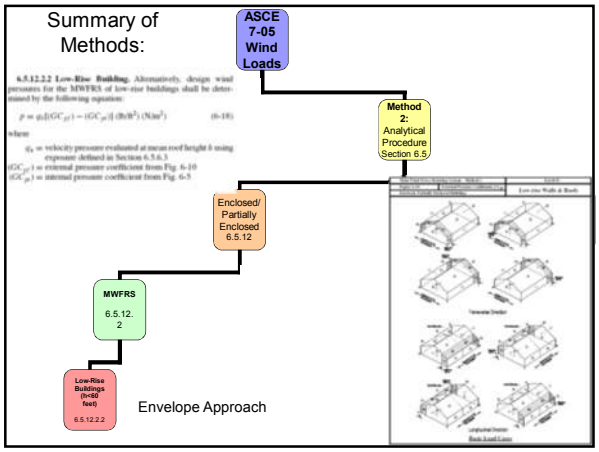
Summary of Methods:



Directional Approach

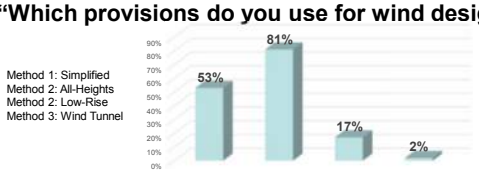
Summary of Methods:



2011 NCSEA provided a survey to 9500 engineers.

→ 980 responses (~10%)

"Which provisions do you use for wind design?"



NCSEA
National Council of Structural Engineers Associations

Responses were consistent across all regions of country

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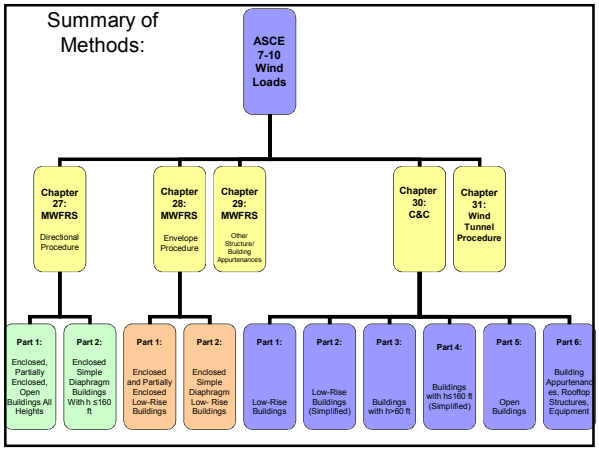
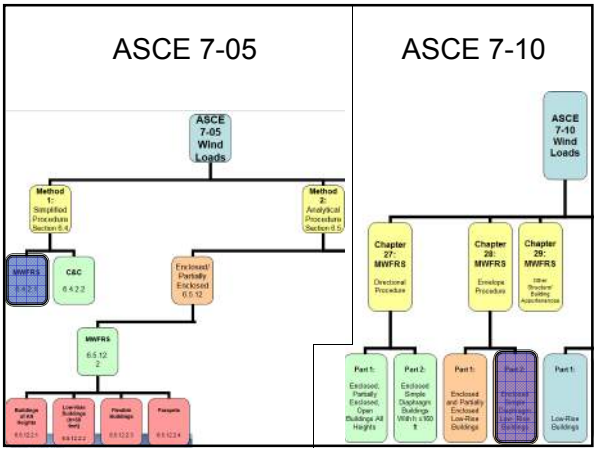
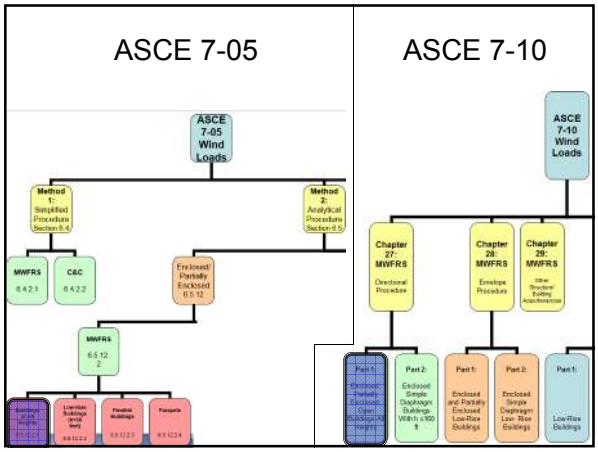
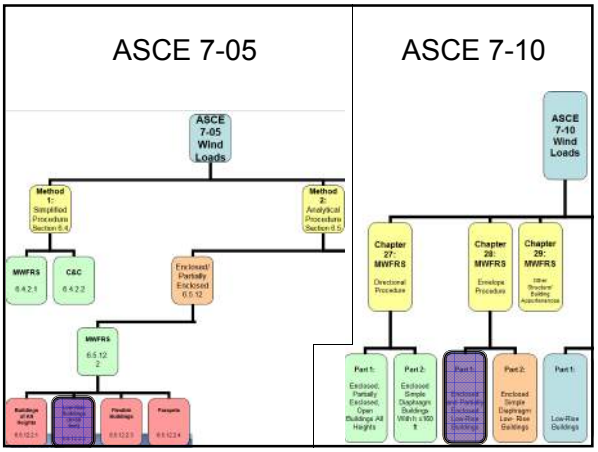
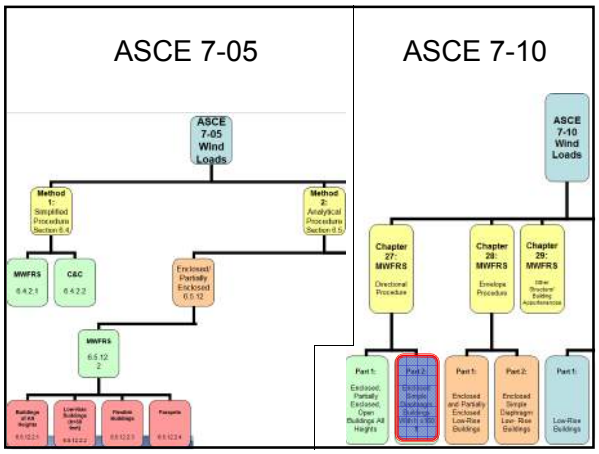
Summary of Methods:











Wind Design Methods

Question: What's the difference between Analytical (Method 2)/ Simplified (Method 1) [ASCE 7-05] and Directional/ Envelope [ASCE 7-10]?

Answer:

Analytical/ Method 2 (ASCE 7-05) = Directional (ASCE 7-10) Chapter 27	Simplified/ Method 1 (ASCE 7-05) = Envelope (ASCE 7-10) Chapter 28
Pressure coefficients reflect actual loading on each surface as a function of wind direction.	Pressure coefficients represent "pseudo" loading that envelope the desired moment, shear…

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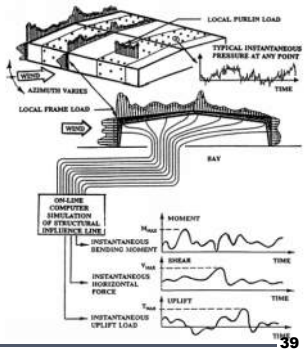
Wind Design Methods

Simplified/ Method 1 (ASCE 7-05) = Envelope (ASCE 7-10) Chapter 28

Pressure coefficients represent "pseudo" loading that envelope the desired moment, shear…



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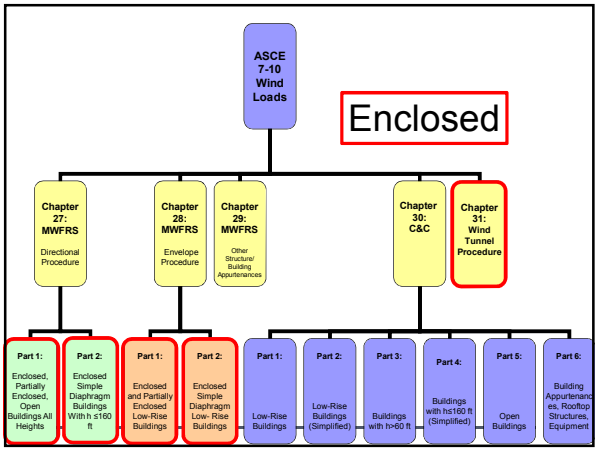
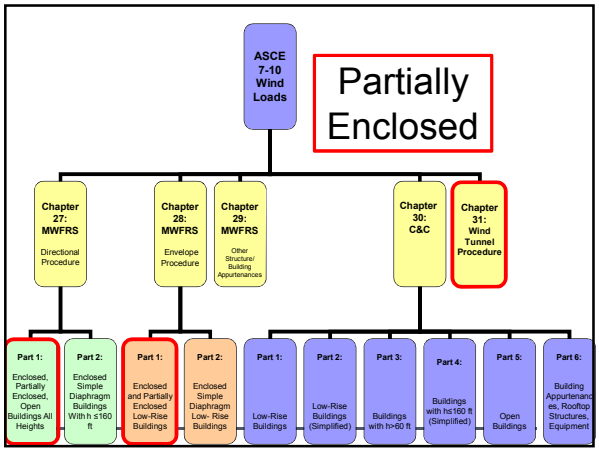
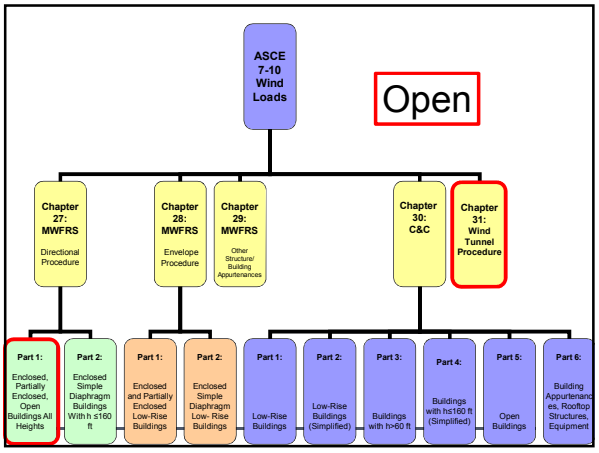
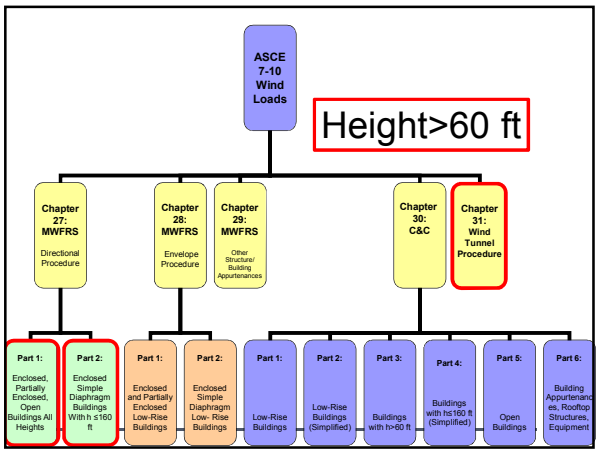
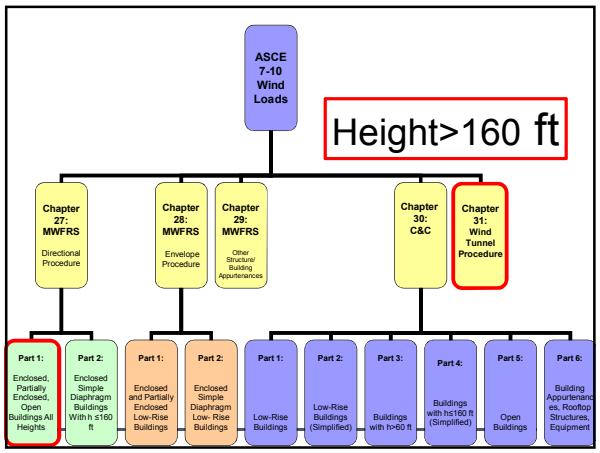
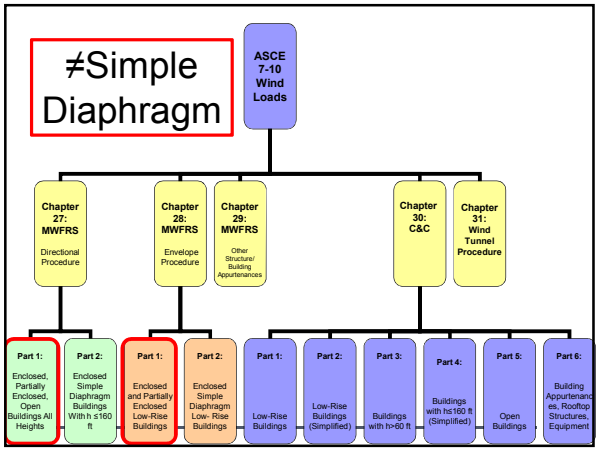


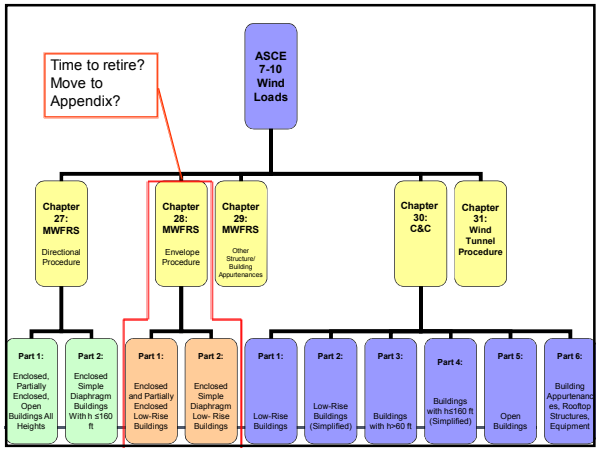






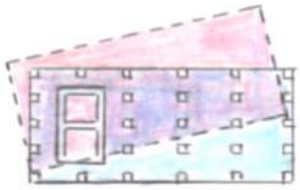






Torsion

Question: When is torsional design required when performing wind load analysis?



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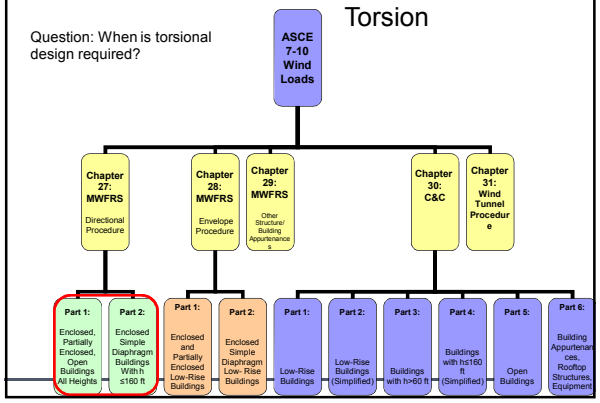
Torsion

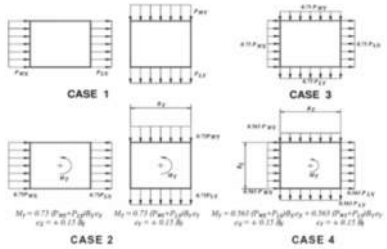
Question: When is torsional design required?



Torsion

Question: When is torsional design required?

Answer: Chapter 27: Directional Procedure → **Required**



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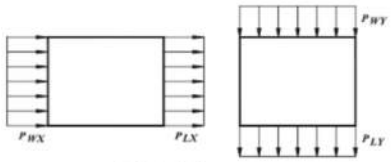
Torsion



CASE 1

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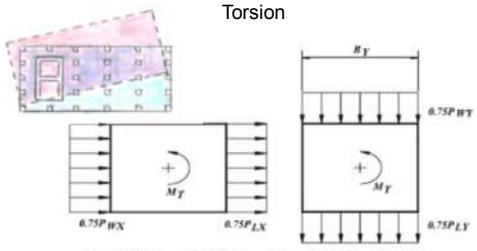
Torsion



$M_T = 0.75\,(P_{WX}+P_{LY})B_X e_X \qquad M_T = 0.75\,(P_{WY}+P_{LY})B_Y e_Y$

$e_X = \pm\,0.15\,B_X \qquad e_Y = \pm\,0.15\,B_Y$

CASE 2

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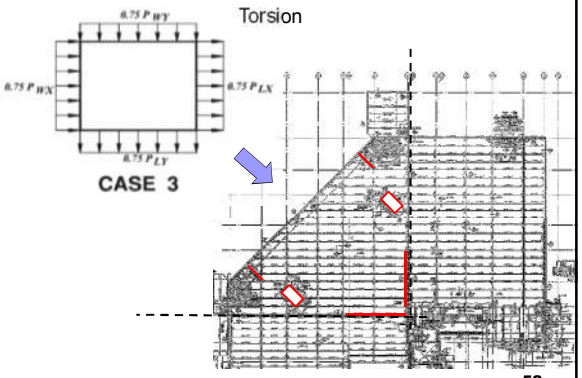
Torsion



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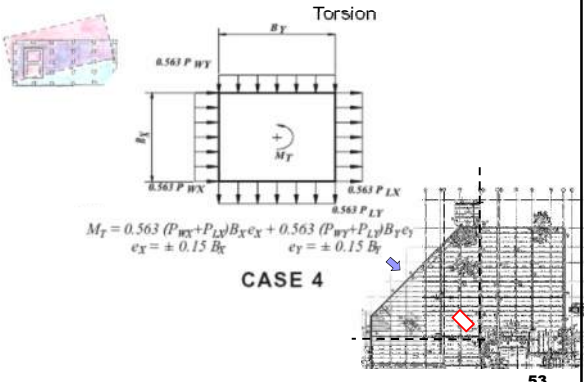
Torsion



$M_T = 0.563\,(P_{WX}+P_{LY})B_X e_X + 0.563\,(P_{WY}+P_{LY})B_Y e_Y$

$e_X = \pm\,0.15\,B_X \qquad e_Y = \pm\,0.15\,B_Y$

CASE 4

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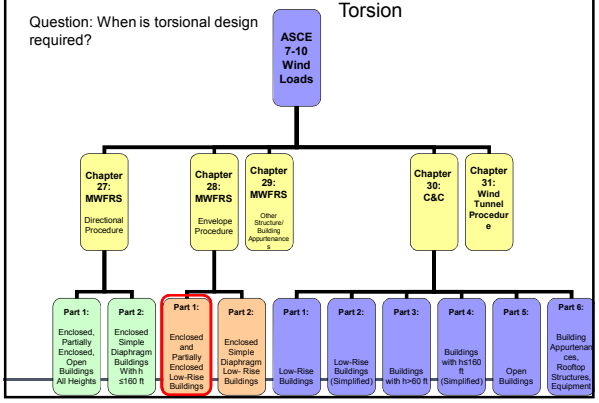
Torsion

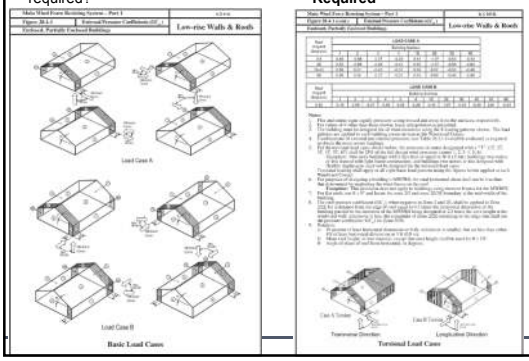
Question: When is torsional design required?



Torsion

Question: When is torsional design required?

Answer: Chapter 28: Part 1→ **Required**



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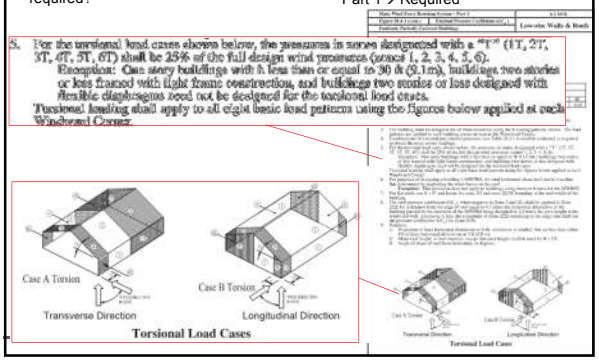
Torsion

Question: When is torsional design required?

Answer: Chapter 28: Part 1→ Required



Torsion

Question: When is torsional design required?

Answer: Chapter 28: Part 1→ Required

5. For the torsional load cases shown below, the pressures in zones designated with a "T" (1T, 2T, 3T, 4T, 5T, 6T) shall be 25% of the full design wind pressures (zones 1, 2, 3, 4, 5, 6).
Exception: Can story buildings with h less than or equal to 30 ft (9.1m), buildings two stories or less framed with light frame construction, and buildings two stories or less designed with flexible diaphragms need not be designed for the torsional load cases.
Torsional loading shall apply to all eight basic load patterns using the figures below applied at each Windward Corner.

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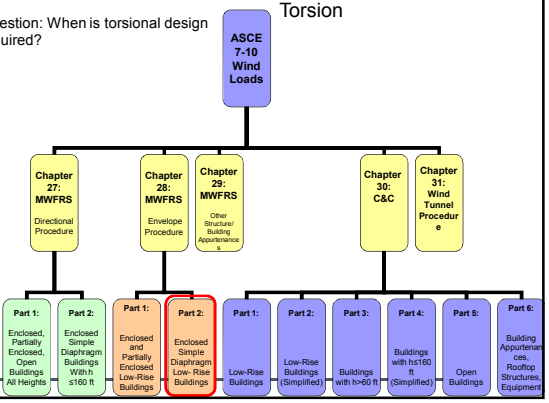
Torsion

Question: When is torsional design required?



Torsion

Question: When is torsional design required?

Answer: Chapter 28: Part 2→ **Not Required**

28.6.2 Conditions
For the design of MWFRS the building shall comply with all of the following conditions:

8. The building is exempted from torsional load cases as indicated in Note 5 of Fig. 28.4-1, or the torsional load cases defined in Note 5 do not control the design of any of the MWFRS of the building.

in the wake of upwind obstructions warrant special consideration.
7. The building has an approximately symmetrical cross-section in each direction with either a flat roof or a gable or hip roof with θ ≤ 45°.

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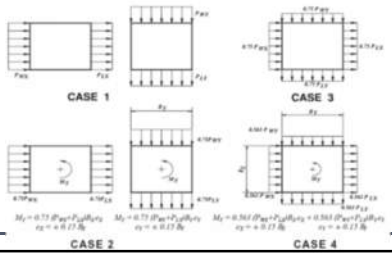
Torsion

Question: When is torsional design required?

Answer: A new option in ASCE 7-10… Appendix D.

Appendix D

BUILDINGS EXEMPTED FROM TORSIONAL WIND LOAD CASES



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Torsion

When can I ignore torsion?

D1.1: One and Two Stories
- One-story buildings h≤30 ft
- Two-story buildings with light-frame construction
- Two-story buildings with flexible diaphragms

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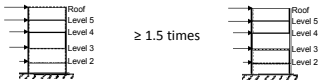
Torsion

When can I ignore torsion?

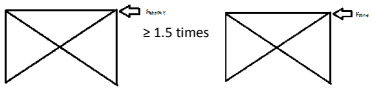
D1.2: Controlled by Seismic Design

D1.2.1 Not flexible diaphragms:
- Center of mass +/-15% geometric center, and
- Seismic story shear > 1.5 Wind story shear

Seismic ≥ 1.5 times Wind



D1.2.2 Flexible diaphragms:
- Seismic forces in LFRS > 1.5 Wind forces in LFRS



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Torsion

When can I ignore torsion?

D1.3: "Torsionally Regular" Structures

BUILDING, TORSIONALLY REGULAR UNDER WIND LOAD: A building with the MWFRS about each principal axis proportioned so that the maximum displacement at each story under Case 2, the torsional wind load case, of Fig. 27.4-8, does not exceed the maximum displacement at the same location under Case 1 of Fig. 27.4-8, the basic wind load case.

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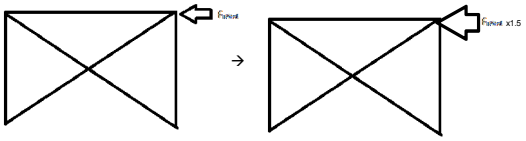
Torsion

When can I ignore torsion?

D1.4: Flexible Diaphragms Designed for Increased Wind Loading
→ Scale MWFRS wind load by 1.5



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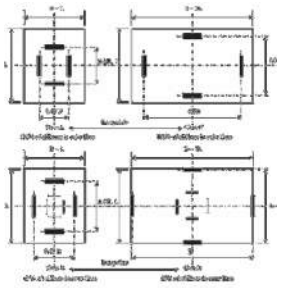
Torsion

When can I ignore torsion?

D1.5: Case A, B, C, D, E, F
(well distributed lateral system)



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Canopies and Awnings
External Pressure Coefficient, C_p

- One of the oldest figures of ASCE 7.
- Helps us understand wind behavior.

Wall Pressure Coefficients, C_p

Surface	L/B	C_p	Use With
Windward Wall	All values	0.8	q_z
Leeward Wall	0-1	-0.5	q_h
	2	-0.3	
	≥4	-0.2	
Side Wall	All values	-0.7	q_h

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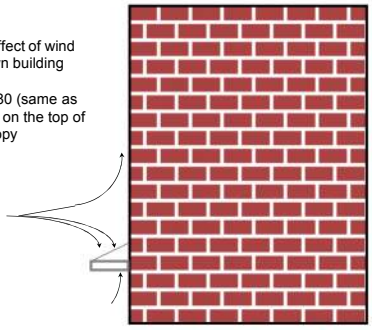
Canopies and Awnings

Down-draft effect of wind flowing down building

→ Use C_p=0.80 (same as windward wall) on the top of canopy



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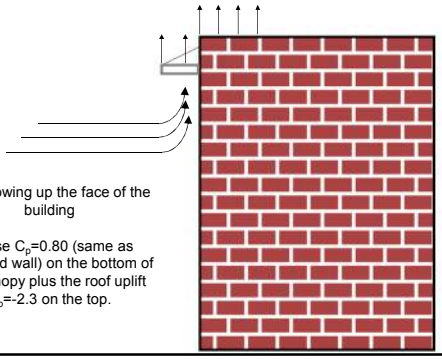
Canopies and Awnings



Wind flowing up the face of the building

→ Use C_p=0.80 (same as windward wall) on the bottom of the canopy plus the roof uplift C_p=-2.3 on the top.

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Local Effects: Wind Around A Corner (Images from FEMA Multi Hazard Seminar)

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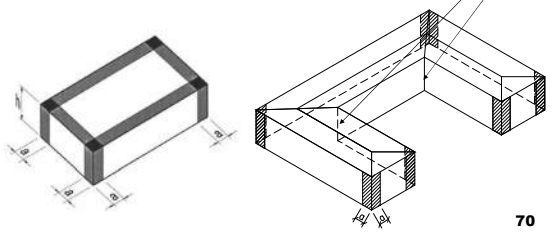
Corner Zones

Not a corner: Inside Corners Do Not Cause Air-Flow Separation

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



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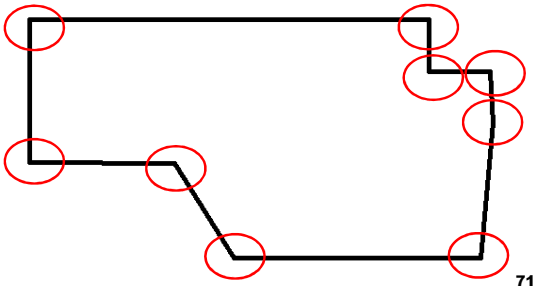
Corner Zones?



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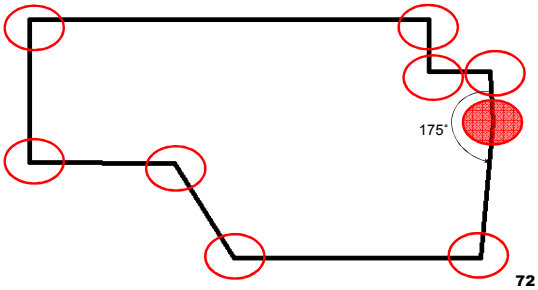
Corner Zones?

Not a corner: Angle is >170°



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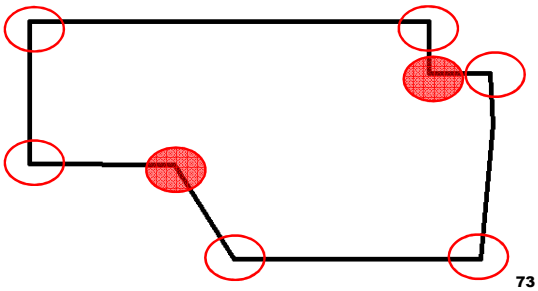
Corner Zones?



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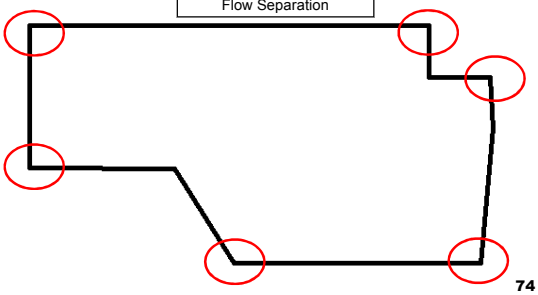
Corner Zones?

Not a corner: Inside Corners Do Not Cause Air-Flow Separation



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Component and Cladding: Effective Wind Area

Question: What's the difference between effective wind area and tributary area?

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Component and Cladding: Effective Wind Area

Question: Roof trusses are 30' long and are 4'-0" OC. What is the effective wind area?

Answer:
A) 30'x4'=120 ft²

B) 30'x30'/3 = 300 ft²

EFFECTIVE WIND AREA, A: The area used to determine GC_p. For component and cladding elements, the effective wind area in Figs. 6-11 through 6-17 and Fig. 6-19 is the span length multiplied by an effective width that need not be less than one-third the span length. For cladding fasteners, the effective wind area shall not be greater than the area that is tributary to an individual fastener.

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Component and Cladding: Effective Wind Area

Question: Roof trusses are 70' long and are 8'-0" OC. What is the effective wind area?

Answer:
A) 70'x8'=560 ft²

B) 70'x70'/3 = 1,633 ft²

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Component and Cladding: Effective Wind Area

Question: Metal decking panels are 20' long and 2' wide supported on beams 5' OC. What is the effective wind area?

Answer:
A) 20'x2'= 40 ft²

B) 5'x2'= 10 ft²

C) 5'x5'/3 = 8.3 ft²

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Component and Cladding: Effective Wind Area

Question: A masonry wall which is grouted and reinforced at 24" OC is 12' tall and 80' long and is supported top and bottom. What is the effective wind area?

Answer:

A) 12'x80'= 960ft^2

B) 12'x1'= 12ft^2

C) 12'x2'= 24ft^2

D) 12'x$\frac{12'}{3}$= 48ft^2

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Component and Cladding: Effective Wind Area

Question: Roof trusses span 75' and are spaced at 10' OC. What is the effective wind area?

Answer:

A) 75'x10'= 750ft^2

B) 75'x$\frac{75'}{3}$= 1,875ft^2

→ The 750 ft^2 tributary area is > 700 ft^2 thus can be designed with MWFRS pressures.

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Rooftop Solar/ PV

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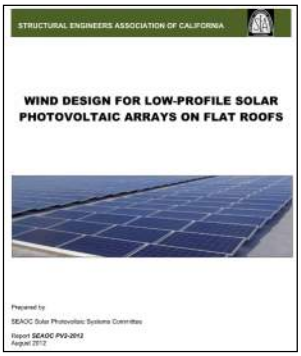
Rooftop Solar/ PV



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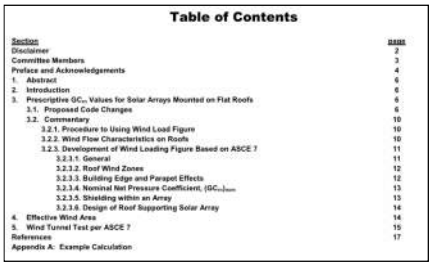
http://www.seaoc.org/bookstore/wind-design-low-profile-solar-photovoltaic-arrays-flat-roofs-seaoc-report-pv2-2012

Rooftop Solar/ PV



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SPOT THE DIFFERENCES

SPOT THE DIFFERENCES

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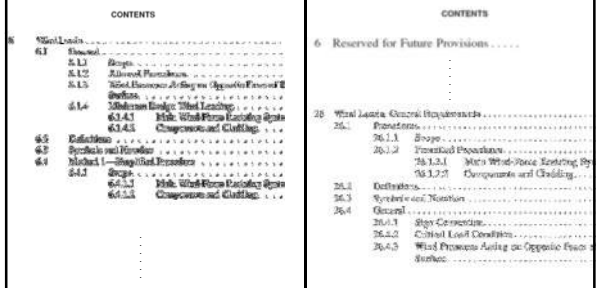
SPOT THE DIFFERENCES

ASCE 7-05 | ASCE 7-10



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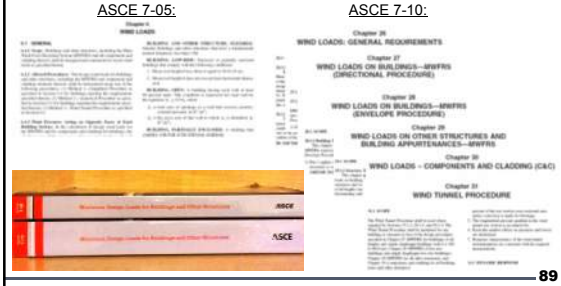
Reorganization

The wind load provisions of ASCE 7-05 (Chapter 6) have been reorganized into 6 Chapters in ASCE 7-10.

ASCE 7-05: | ASCE 7-10:



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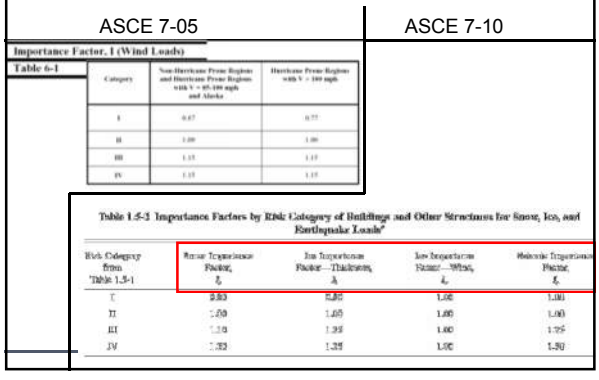
SPOT THE DIFFERENCES

ASCE 7-05 | ASCE 7-10



SPOT THE DIFFERENCES

ASCE 7-05	ASCE 7-10
	

SPOT THE DIFFERENCES

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SPOT THE DIFFERENCES

ASCE 7-05	ASCE 7-10
1. $1.4(D + F)$ 2. $1.2(D + F + T) + 1.6(L + H) + 0.5(L_r \text{ or } S \text{ or } R)$ 3. $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (L \text{ or } 0.8W)$ 4. $1.2D + 1.6W + L + 0.5(L_r \text{ or } S \text{ or } R)$ 5. $1.2D + 1.0E + L + 0.2S$ 6. $0.9D + 1.6W + 1.6H$ 7. $0.9D + 1.0E + 1.6H$	1. $1.4D$ 2. $1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$ 3. $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (L \text{ or } 0.5W)$ 4. $1.2D + 1.0W + L + 0.5(L_r \text{ or } S \text{ or } R)$ 5. $1.2D + 1.0E + L + 0.2S$ 6. $0.9D + 1.0W$ 7. $0.9D + 1.0E$

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Section 26.5: Basic Wind Speeds

New wind speed maps with *2 major changes*:

1. Maps provide wind speeds at strength design level.
2. Maps are provided for different Risk Categories instead of a single map with importance factors to be applied.

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SPOT THE DIFFERENCES

ASCE 7-05	ASCE 7-10
6.5.6.2 Surface Roughness Categories. A ground surface roughness within each 45° sector shall be determined for a distance upwind of the site as defined in Section 6.5.6.3 from the categories defined in the following text, for the purpose of assigning an exposure category as defined in Section 6.5.6.3. Surface Roughness B: Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger. Surface Roughness C: Open terrain with scattered obstructions having heights generally less than 30 ft (9.1 m). This category includes flat open country, grasslands, and all water surfaces in hurricane prone regions. Surface Roughness D: Flat, unobstructed areas and water surfaces outside hurricane prone regions. This category includes smooth mud flats, salt flats, and unbroken ice.	**26.7.2 Surface Roughness Categories** A ground surface roughness within each 45° sector shall be determined for a distance upwind of the site as defined in Section 26.7.3 from the categories defined in the following text, for the purpose of assigning an exposure category as defined in Section 26.7.3. Surface Roughness B: Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger. Surface Roughness C: Open terrain with scattered obstructions having heights generally less than 30 ft (9.1 m). This category includes flat open country and grasslands. Surface Roughness D: Flat, unobstructed areas and water surfaces. This category includes smooth mud flats, salt flats, and unbroken ice.

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Hurricane Zone Changes

- **New Hurricane Simulation Model**
  - Generally lower design wind speeds.
- **Reintroduction of Exposure D in hurricane regions.**
  - Research shows that the roughness of ocean does not continue to increase with increasing wind speed and Exposure D is valid.
- **New windborne debris region results in less areas subject to windborne debris requirements**.

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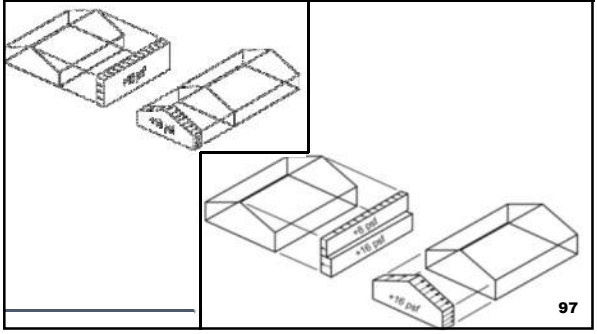
SPOT THE DIFFERENCES

ASCE 7-05	ASCE 7-10



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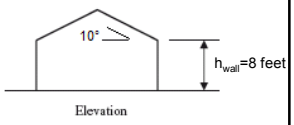
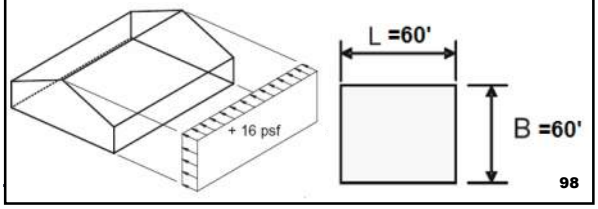
CHANGES TO MINIMUM DESIGN WIND LOADS

Sample Problem:
L=B=60 feet
h_{wall}=8 ft
Roof angle=10˚

→ Minimum wind controls using Directional Procedure for V<158 mph, Envelope Procedure for V<174 mph





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"What modifications or additions would you like to see in the wind design sections of ASCE 7?"

1
2
3
4
5

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NCSEA Recommendations to ASCE 7:

1. Reduce Number of Methods to one (1) Computational Method for All Buildings and one (1) Tabular Method for Buildings < 60' in height.

2. Consolidate Wind Provision currently in both ASCE 7 and IBC to ASCE and simplify the provisions.

3. Provide loading criteria for additional commonly encountered conditions, i.e. Canopies, Tall Parapets, Mechanical Screens and PV Panels.

4. Provide design procedures for RTUs and penthouses on buildings > 60'.

5. Simplify free-standing wall provisions.

6. Provide guidance for irregular building configurations.

ASCE 7-16:

1. Reduce Number of Methods to one Computational Method for All Buildings and one Tabular Method for Buildings < 60' in height (3)
- Remove low-rise provisions from body of code.
- Determine procedure to combine all heights and low rise MWFRS methods.

2. Consolidate Wind Provision currently in both ASCE 7 and IBC and simplify (5)
- Combine low rise and all heights provisions.
- Partially open classification.
- Simplify exposure.
- Clarify C&C load combinations.
- RTU < 60 foot versus > 60 foot

3. Provide loading criteria for additional commonly encountered conditions, i.e. Canopies, Tall Parapets, Mechanical Screens and PV Panels (11)
- Multiple building shapes (commentary).
- Open structures.
- Non-building structures
- PV panel recommendations.
- Mechanical screens versus parapets.
- Garden roofs.
- Tower podium/ stepped buildings.
- Signs

4. Provide design procedures for Roof Top Units and Penthouses on Buildings > 60' (4)
- Establish consistency for <60 feet and >60 feet.
- Mechanical screens.
- C&C versus MWFRS

5. Simplify Free Standing Wall Provisions (0)

6. Provide guidance for Irregular Building configurations (9)
- Multiple building shapes (commentary).
- Open structures.
- Non-building structures.
- Hipped roof slopes.
- Parapets.
- Tower podium/ stepped buildings.
- Buildings with courtyards.

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ASCE 7-16?

Other Items:
- Tornado loads: Commentary
- Topographic effects on low rise.
- Wind tunnel update.
- Parapet provisions.
- Database/ computational fluid mechanics design
- Torsion
- Update on non-hurricane wind speed maps.
- Updated commentary.

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1976 EDITION

23-F, 23-G, 23-H

TABLE NO. 23-F — WIND PRESSURES FOR VARIOUS HEIGHT ZONES ABOVE GROUND[1]

HEIGHT ZONES (in feet)	WIND-PRESSURE-MAP AREAS (pounds per square foot)						
	20	25	30	35	40	45	50
Less than 30	15	20	25	25	30	35	40
30 to 49	20	25	30	35	40	45	50
50 to 99	25	30	40	45	50	55	60
100 to 499	30	40	45	55	60	70	75
500 to 1199	35	45	55	60	70	80	90
1200 and over	40	50	60	70	80	90	100

Summary:

1) Consider the intent of the code before trying to apply the language.
2) Does maintaining all Analysis Methods help or hurt?
3) There are attempts to simplify the code, make it more user friendly.

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415-814-0030

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