ASCE 7 and IBC Wind and Seismic Provisions

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CMS Código Modelo Sísmico
América Latina y El Caribe

8ª JORNADA
COMISIÓN PERMANENTE
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Agenda:

Seismic:
- Basic Principles
- Irregularities
- Redundancy
- Nonstructural
- Functional Recovery

Wind:
- Analysis Procedures
- Drift
- MWFRS v C&C
- Tornados

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"In dealing with earthquakes, we must contend with appreciable probabilities that ***failure*** will occur… Otherwise, all the ***wealth*** of the world would prove insufficient.. the most modest structures would be ***fortresses***. We must also face ***uncertainty*** on a large scale, for it is our task to design engineering systems – about whose pertinent ***properties we know little*** – to resist future earthquakes– whose characteristics we ***know even less***…"

Fundamentals of Earthquake Engineering, Newmark and Rosenblueth (1971):

".. Earthquake engineering is a ***cartoon***. . . Earthquakes systematically bring out the ***mistakes*** made in design and construction."

Response Modification Coefficient, R

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- Red line is the force vs. displacement if the structure responded elastically.
- Green line is the actual force vs. displacement of the structure.
- Blue line is the code force per ASCE 7.

Illustrates design parameters:
- Response modification coefficient, R
- Deflection amplification factor, C_d
- System overstrength factor, Ω_o.

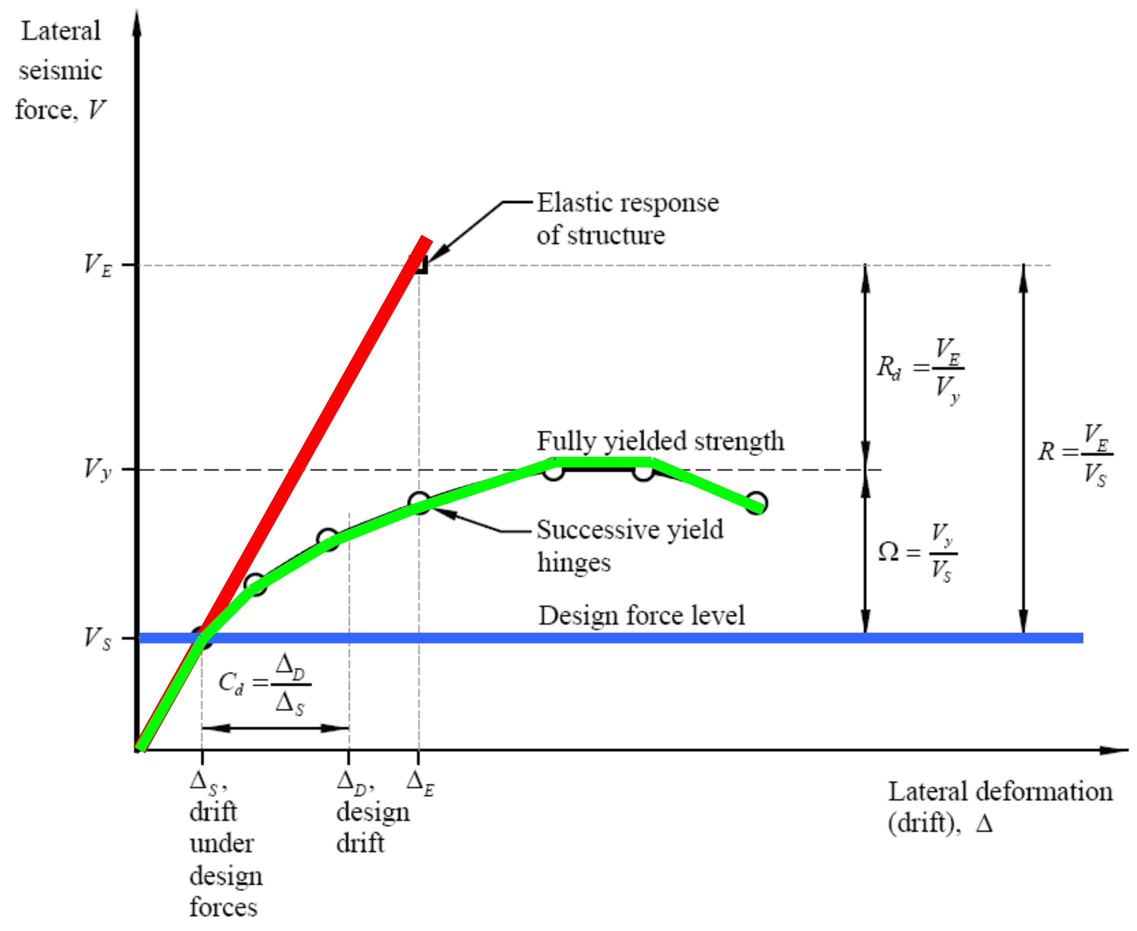

Figure C12.1-1 Inelastic force-deformation curve.

Response Modification Coefficient, R

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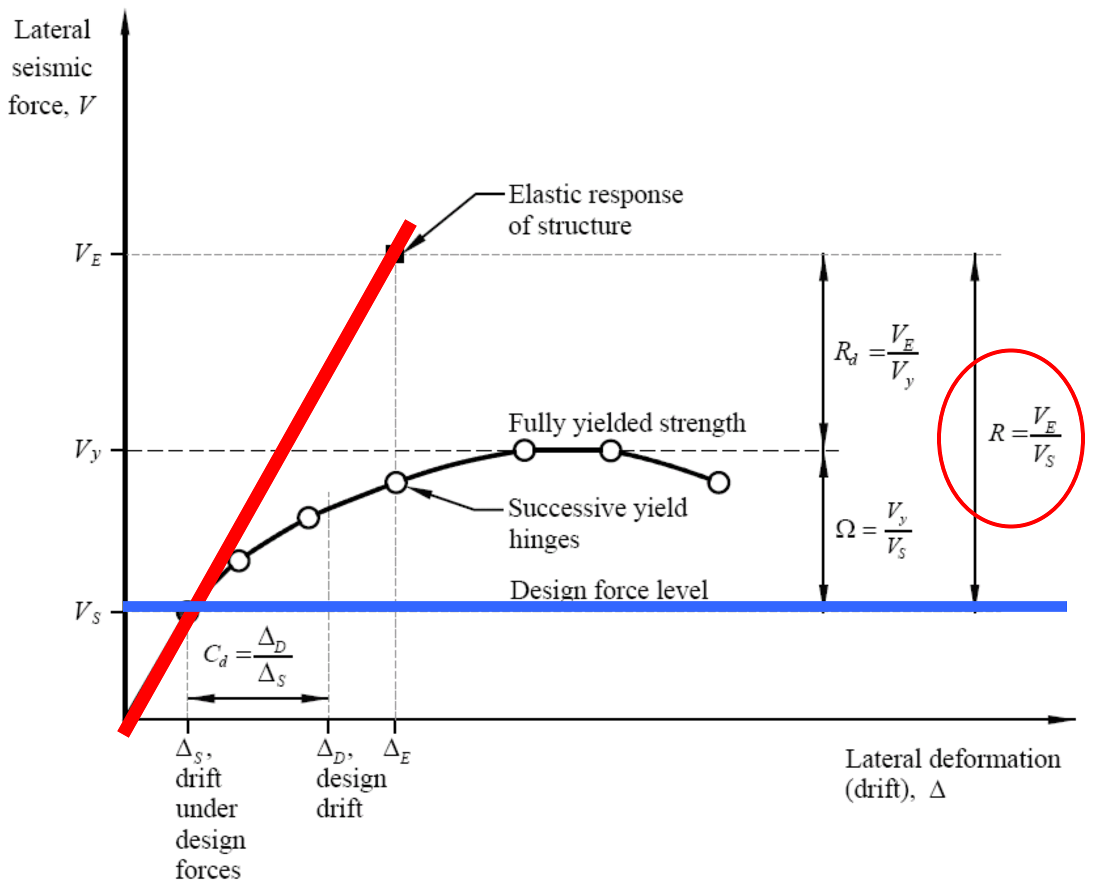

"In dealing with earthquakes, we must contend with appreciable probabilities that failure will occur in the near future. Otherwise, all the wealth of the world would prove insufficient to fill our needs: the most modest structures would be fortresses."

In ASCE 7, seismic design forces are calculated by dividing the force from a linear response when subjected to the design ground motion by the response modification coefficient, *R*.

$$C_s = \frac{S_{DS}}{\left(\frac{R}{I_e}\right)}$$

Response Modification Coefficient, R

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New Systems (ASCE 7-22):

- Composite shear walls
- Coupled special concrete
- CLT shear walls

New Systems (ASCE 7-28):

- CLT Rocking Shear Walls
- Damped Steel Moment Frame

Table 12.2-1. Design Coefficients and Factors for Seismic Force-Resisting Systems.

	ASCE 7 Section Where Detailing Requirements Are Specified	Response Modification Coefficient, R^a	Overstrength Factor, $\Omega_0{}^b$	Deflection Amplification Factor, $C_d{}^c$	Seismic Design Category				
					B	C	D[e]	E[e]	F[f]
A. BEARING WALL SYSTEMS									
2. Reinforced concrete ductile coupled walls[g]	14.2	8	2 ½	8	NL	NL	160	160	100
20. Cross-laminated timber shear walls	14.5	3	3	3	65	65	65	65	65
21. Cross-laminated timber shear walls with shear resistance provided by high-aspect-ratio panels only	14.5	4	3	4	65	65	65	65	65
B. BUILDING FRAME SYSTEMS									
5. Reinforced concrete ductile coupled walls[g]	14.2	8	2 ½	8	NL	NL	160	160	100
28. Steel and concrete coupled composite plate shear walls	14.3	8	2½	5½	NL	NL	160	160	100

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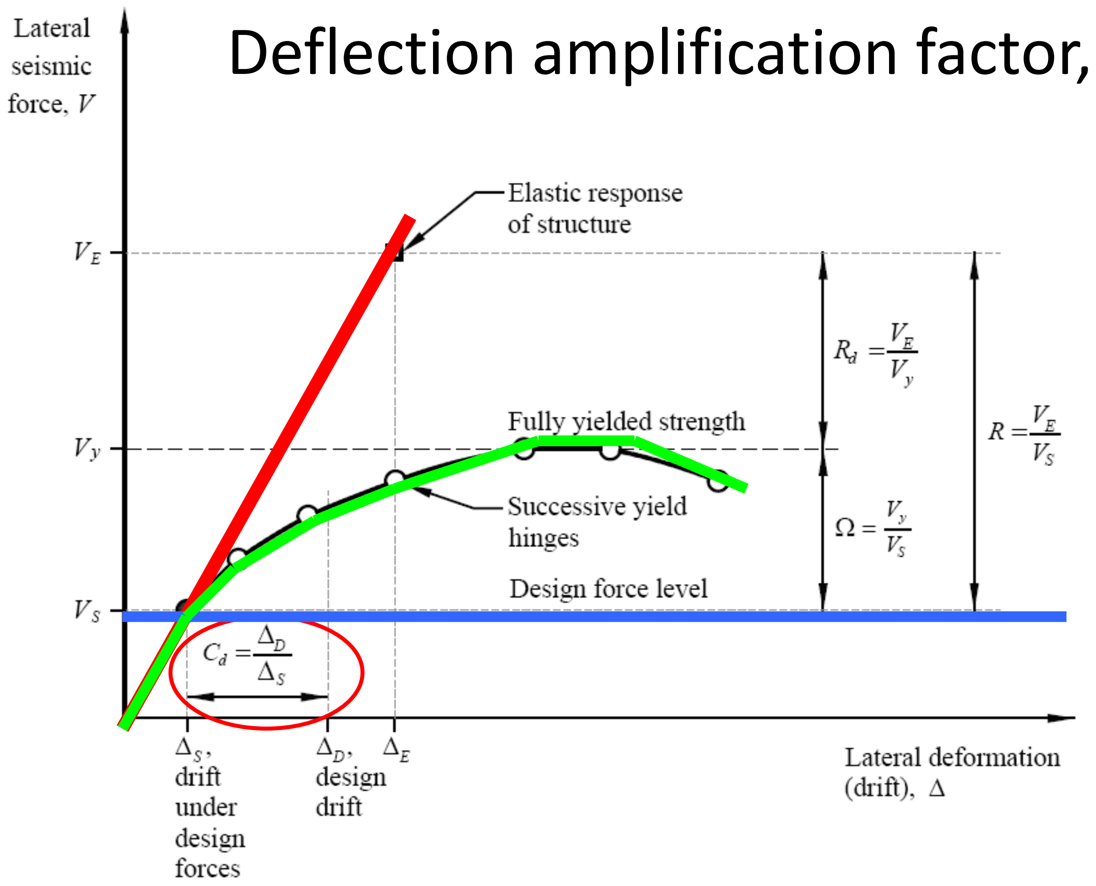
Drift

Deflection amplification factor, C_d



In ASCE 7, the elastic deformations (Δ_S) calculated under reduced forces are multiplied by C_d to estimate the actual inelastic deflections.

$$\delta_M = \frac{C_d \delta_{max}}{I_e}$$

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Drift

$$\delta_x = \frac{C_d \delta_{xe}}{I_e} \quad (12.8\text{-}15) \quad < \Delta_a$$

Table 12.12-1 Allowable Story Drift, Δ_a[a,b]

Structure	Risk Category I or II	Risk Category III	Risk Category IV
Structures, other than masonry shear wall structures, 4 stories or less above the base as defined in Section 11.2, with interior walls, partitions, ceilings, and exterior wall systems that have been designed to accommodate the story drifts.	$0.025h_{sx}$[c]	$0.020h_{sx}$	$0.015h_{sx}$
Masonry cantilever shear wall structures[d]	$0.010h_{sx}$	$0.010h_{sx}$	$0.010h_{sx}$
Other masonry shear wall structures	$0.007h_{sx}$	$0.007h_{sx}$	$0.007h_{sx}$
All other structures	$0.020h_{sx}$	$0.015h_{sx}$	$0.010h_{sx}$

[a] h_{sx} is the story height below Level x.
[b] For seismic force-resisting systems comprised solely of moment frames in Seismic Design Categories D, E, and F, the allowable story drift shall comply with the requirements of Section 12.12.1.1.
[c] There shall be no drift limit for single-story structures with interior walls, partitions, ceilings, and exterior wall systems that have been designed to accommodate the story drifts. The structure separation requirement of Section 12.12.3 is not waived.
[d] Structures in which the basic structural system consists of masonry shear walls designed as vertical elements cantilevered from their base or foundation support which are so constructed that moment transfer between shear walls (coupling) is negligible.

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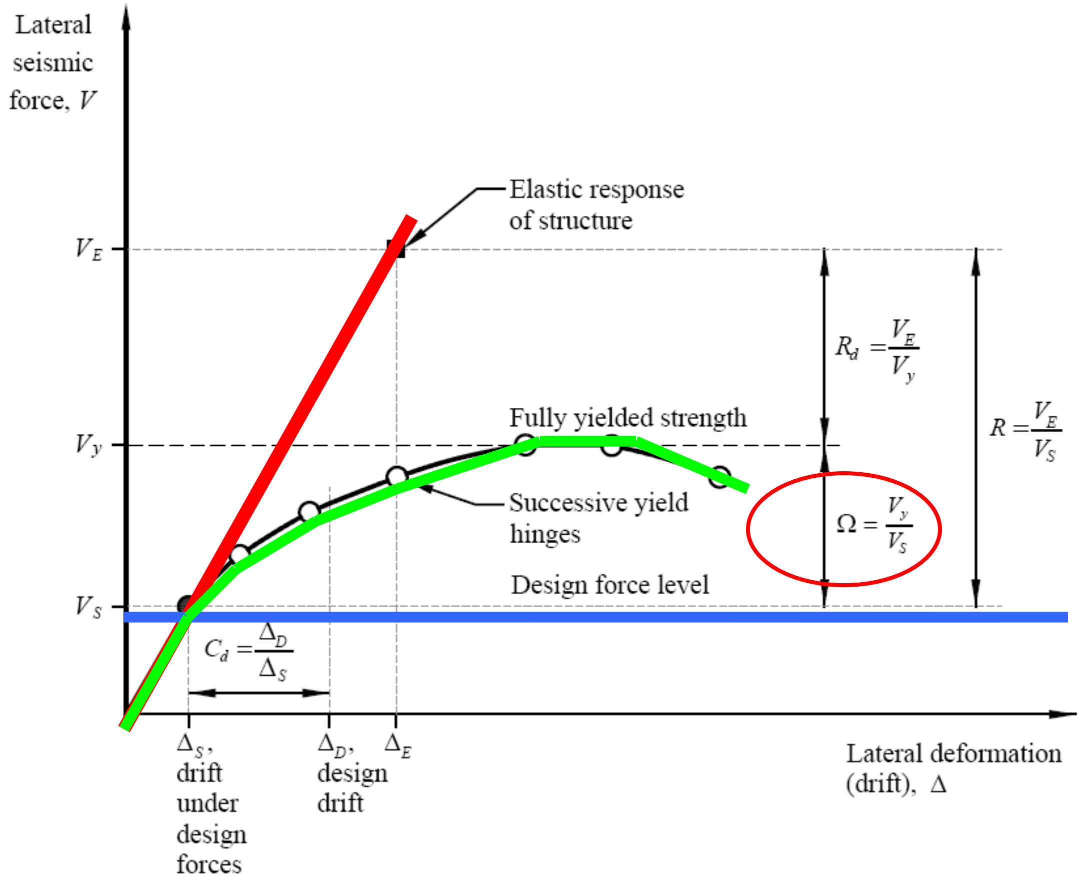
Overstrength Factor, Ωo



The Ω_o coefficient approximates the inherent overstrength and can be broken down into several components:

$$\Omega_o = \Omega_D \Omega_M \Omega_S$$

Overstrength Factor, Ωo

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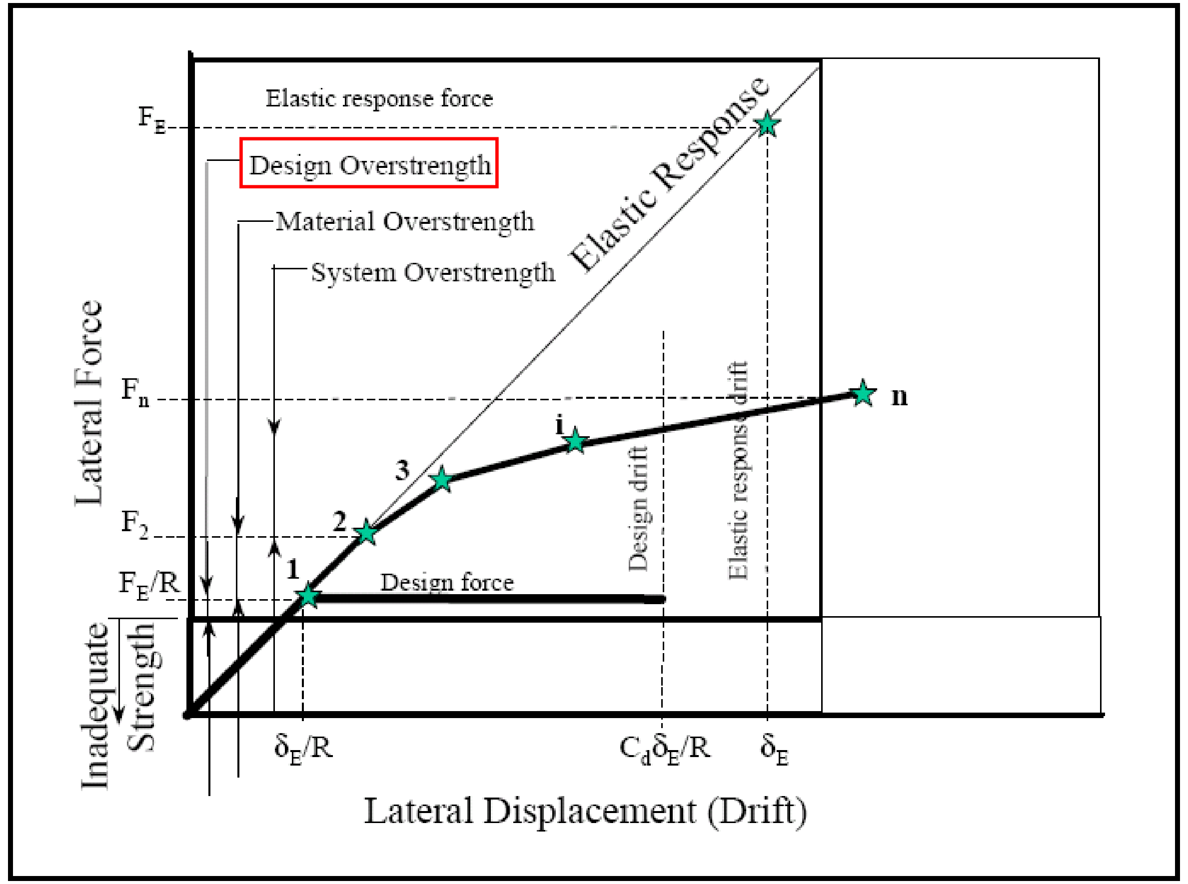
DESIGN OVERSTRENGTH

- Ω_D is the overstrength provided by the design engineer and/ or code.

EXAMPLES:

- Load and resistance factors.
- Design controlled by stiffness.
- Architectural requirements.



Overstrength Factor, Ωo

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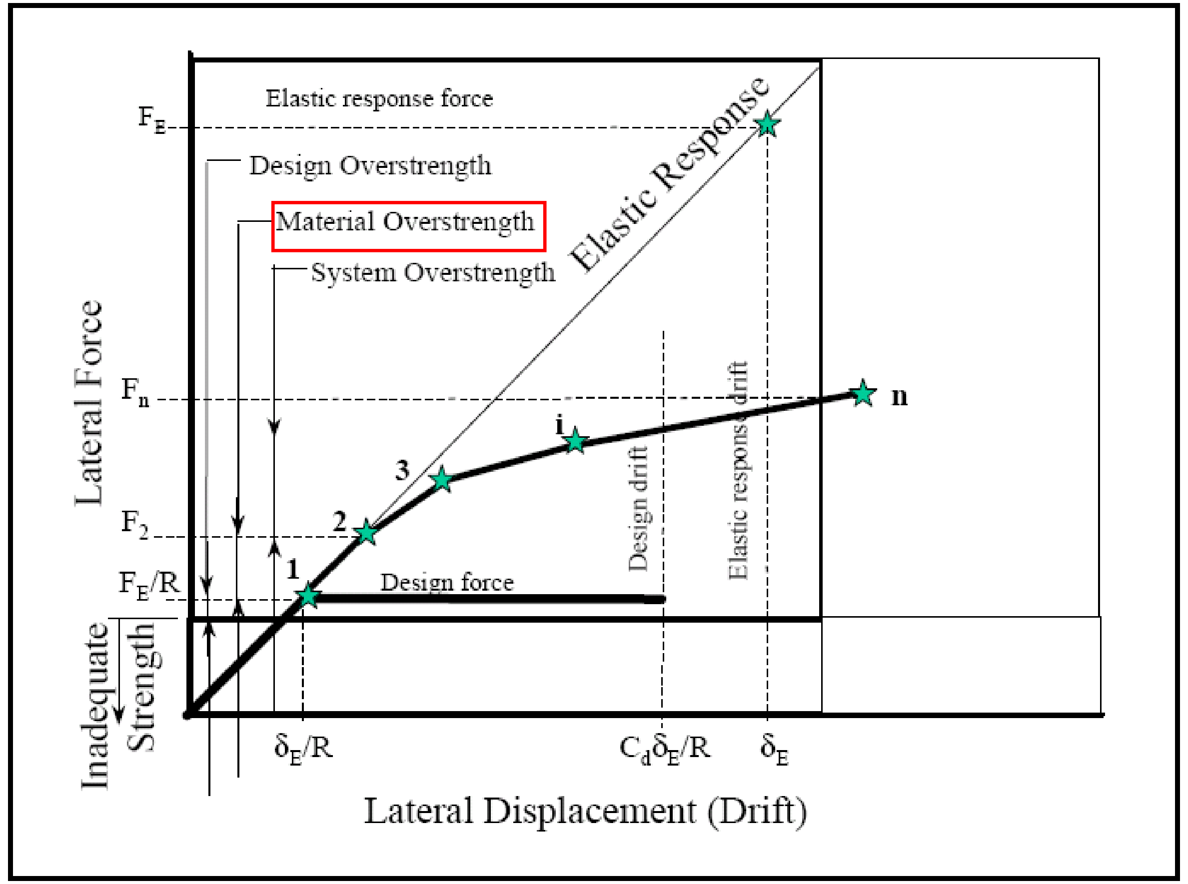
MATERIAL OVERSTRENGTH

• Ω_M represents material overstrength.

EXAMPLES:

Reinforced masonry, concrete, and steel provisions have historically used a factor of ~1.25 to account for the ratio of mean to specified strengths.

- • A survey of WF steel: Ratios = 1.37 and 1.15 for A36 and A572 Gr. 50.



Overstrength Factor, Ωo

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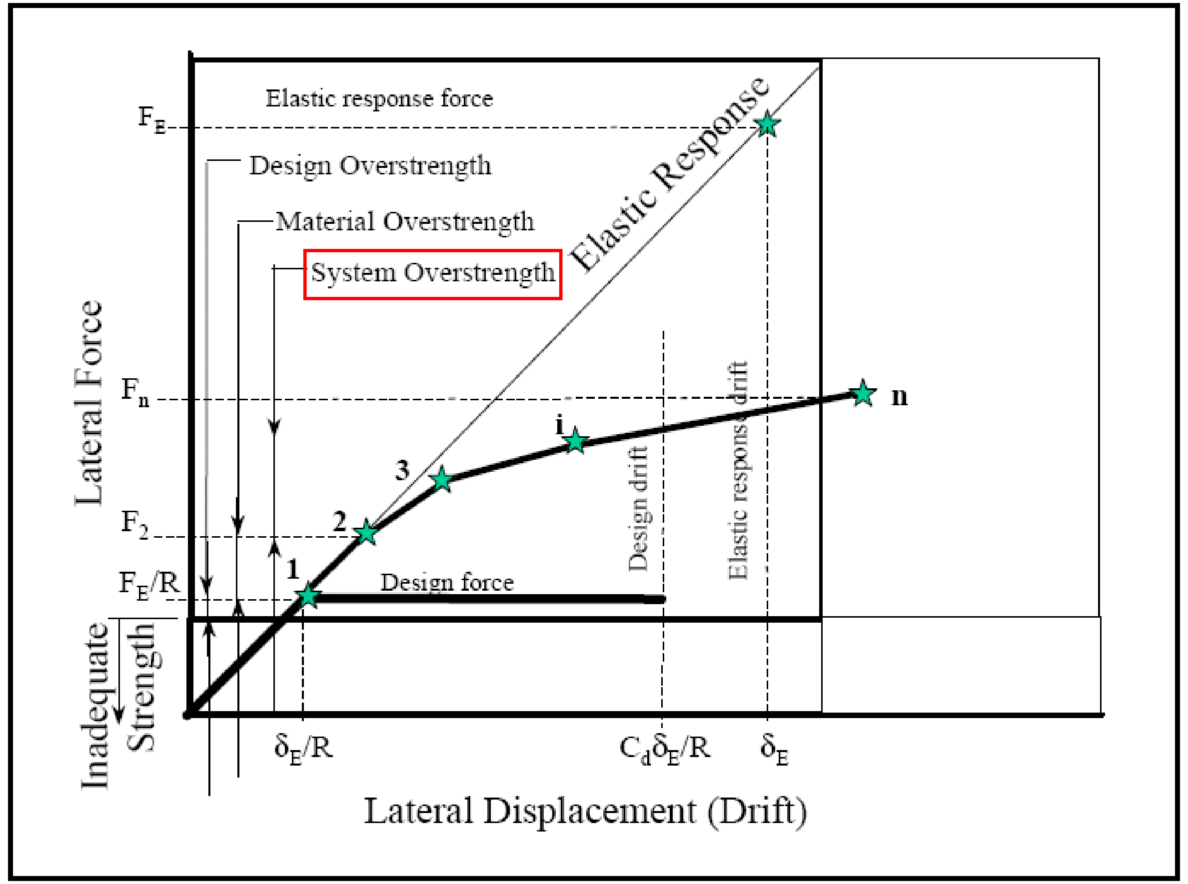
SYSTEM OVERSTRENGTH

- Ω_S represents the system overstrength.

EXAMPLES:

- Redundancy.
- The degree to which non-LFRS elements provide resistance after LFRS has yielded.



Overstrength Factor, Ωo

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ASCE 7 Section 12.4.3.2

Basic Combinations for Strength Design with Overstrength Factor (see Sections 2.3.2 and 2.2 for notation).

5. $(1.2 + 0.2S_{DS})D + \Omega_o Q_E + L + 0.2S$
7. $(0.9 - 0.2S_{DS})D + \Omega_o Q_E + 1.6H$

Overstrength Factor, Ωo

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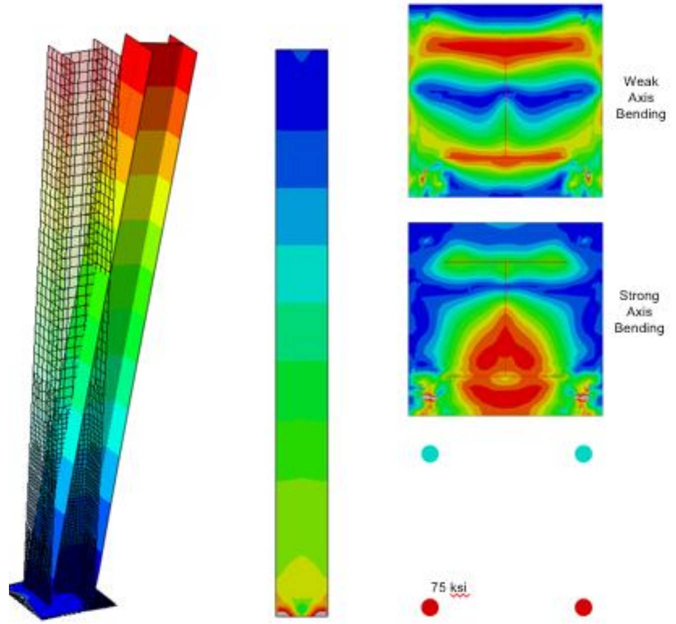
12.2.5.2: Cantilever Column Systems, SDC B-F

Foundations and other elements used to provide overturning resistance at the base of cantilever column elements shall have the strength to resist the load combinations with overstrength factors of Section 12.4.3.2.



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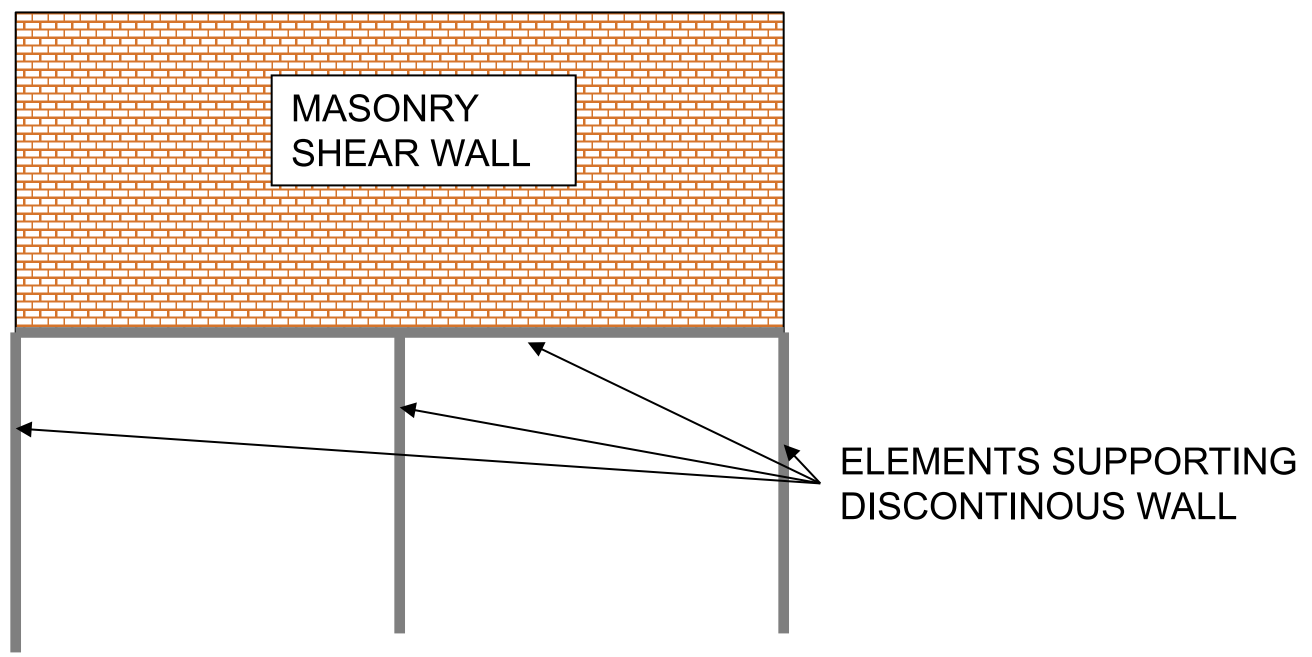
Overstrength Factor, Ωo

12.3.3.3: Elements Supporting Discontinuous Walls or Frames, SDC B-F

Columns, beams, trusses, or slabs supporting discontinuous walls or frames shall have the strength to resist the maximum axial force that can develop in accordance with the load combinations with overstrength factors of Section 12.4.3.2.



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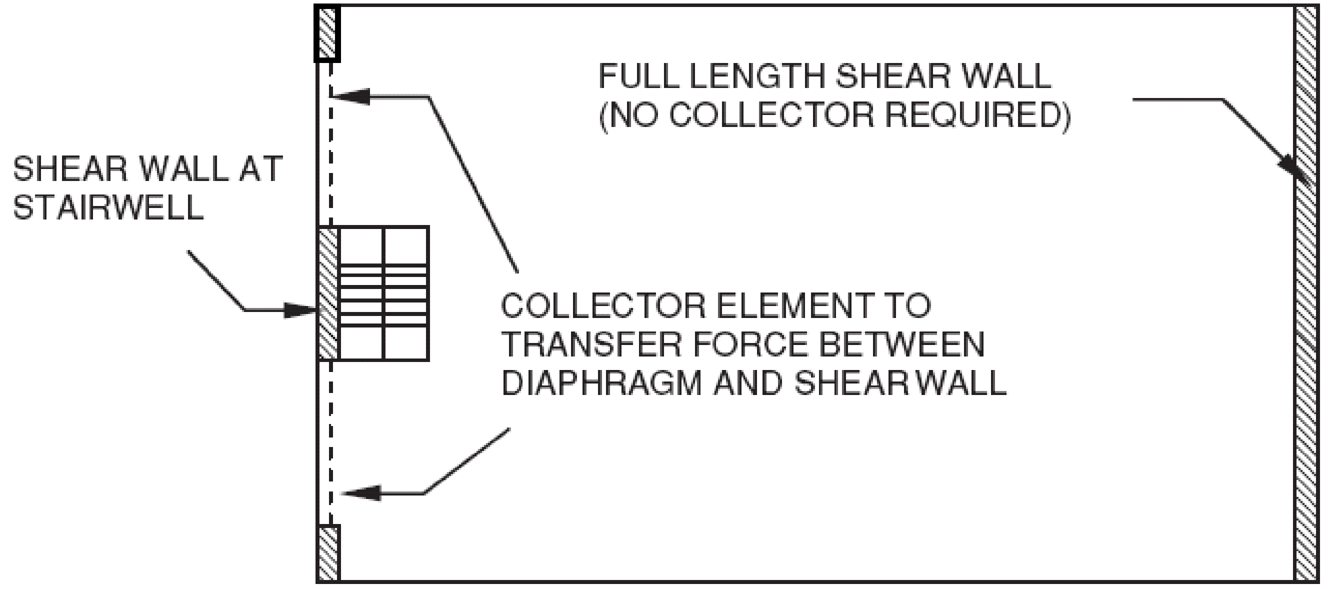
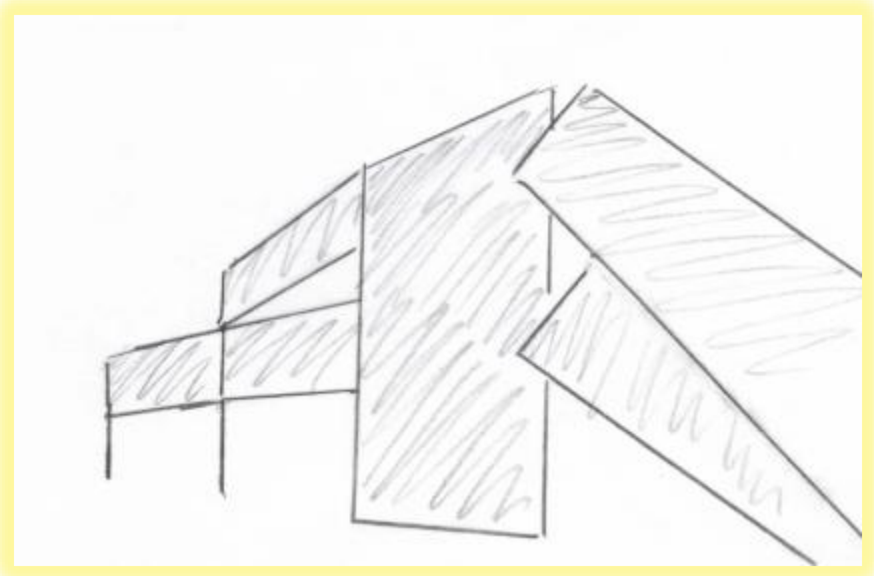
Overstrength Factor, Ωo

12.10.2.1: Collector Elements, SDC C-F

Collector elements, splices, and their connections to resisting elements shall resist the load combinations of Section 12.4.3.2.





"In a way, earthquake engineering is a cartoon . . . Earthquake effects on structures systematically bring out the mistakes made in design and construction, even the minutest mistakes."

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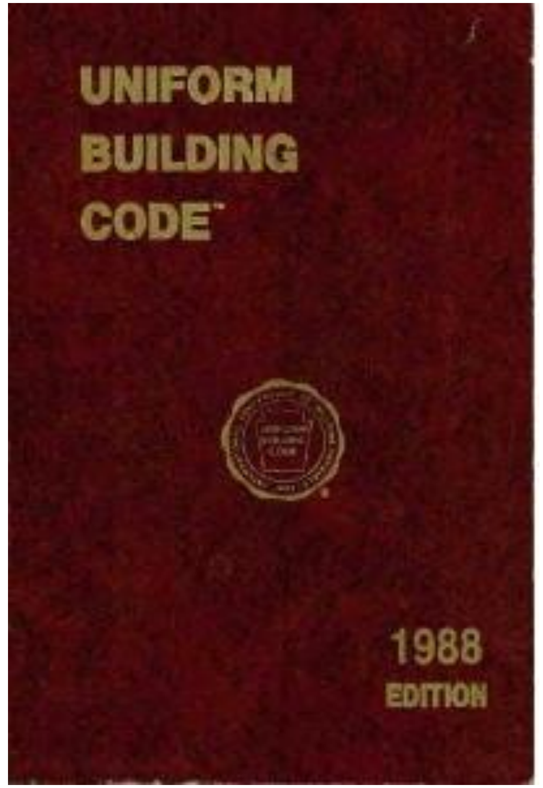
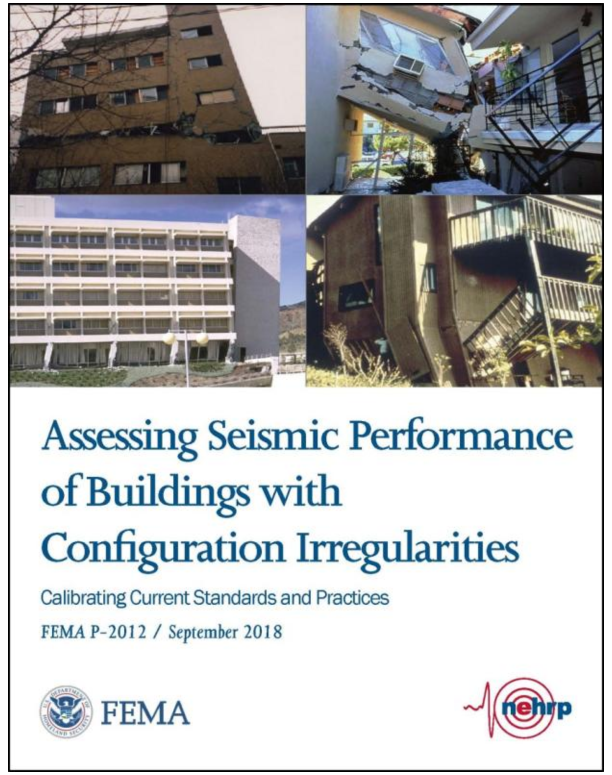
Irregularities

- Code provisions developed for regular buildings.
- Earthquakes show that irregular configurations lead to greater damage.
- Irregularity code provisions first introduced in 1988 UBC.





Irregularities (Horizontal)

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Table 12.3-1 Horizontal Structural Irregularities

Type	Description	Reference Section	Seismic Design Category Application
1a.	**Torsional Irregularity:** Torsional irregularity is defined to exist where the maximum story drift, computed including accidental torsion with $A_x = 1.0$, at one end of the structure transverse to an axis is more than 1.2 times the average of the story drifts at the two ends of the structure. Torsional irregularity requirements in the reference sections apply only to structures in which the diaphragms are rigid or semirigid.	12.3.3.4 12.7.3 12.8.4.3 12.12.1 Table 12.6-1 16.3.4	D, E, and F B, C, D, E, and F C, D, E, and F C, D, E, and F D, E, and F B, C, D, E, and F
1b.	**Extreme Torsional Irregularity:** Extreme torsional irregularity is defined to exist where the maximum story drift, computed including accidental torsion with $A_x = 1.0$, at one end of the structure transverse to an axis is more than 1.4 times the average of the story drifts at the two ends of the structure. Extreme torsional irregularity requirements in the reference sections apply only to structures in which the diaphragms are rigid or semirigid.	12.3.3.1 12.3.3.4 12.3.4.2 12.7.3 12.8.4.3 12.12.1 Table 12.6-1 16.3.4	E and F D D B, C, and D C and D C and D D B, C, and D
2.	**Reentrant Corner Irregularity:** Reentrant corner irregularity is defined to exist where both plan projections of the structure beyond a reentrant corner are greater than 15% of the plan dimension of the structure in the given direction.	12.3.3.4 Table 12.6-1	D, E, and F D, E, and F
3.	**Diaphragm Discontinuity Irregularity:** Diaphragm discontinuity irregularity is defined to exist where there is a diaphragm with an abrupt discontinuity or variation in stiffness, including one that has a cutout or open area greater than 50% of the gross enclosed diaphragm area, or a change in effective diaphragm stiffness of more than 50% from one story to the next.	12.3.3.4 Table 12.6-1	D, E, and F D, E, and F
4.	**Out-of-Plane Offset Irregularity:** Out-of-plane offset irregularity is defined to exist where there is a discontinuity in a lateral force-resistance path, such as an out-of-plane offset of at least one of the vertical elements.	12.3.3.3 12.3.3.4 12.7.3 Table 12.6-1 16.3.4	B, C, D, E, and F D, E, and F B, C, D, E, and F D, E, and F B, C, D, E, and F
5.	**Nonparallel System Irregularity:** Nonparallel system irregularity is defined to exist where vertical lateral force-resisting elements are not parallel to the major orthogonal axes of the seismic force-resisting system.	12.5.3 12.7.3 Table 12.6-1 16.3.4	C, D, E, and F B, C, D, E, and F D, E, and F B, C, D, E, and F

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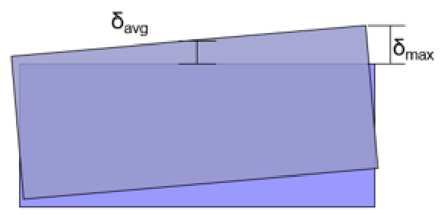
Irregularities (Horizontal)

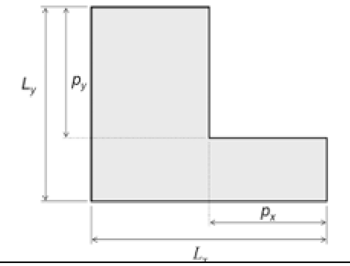
1a/1b: Torsional



Torsional Irregularity:
No Irregularity: $\delta_{max}<1.2\delta_{avg}$
Irregularity: $1.2\delta_{avg}\le\delta_{max}\le1.4\delta_{avg}$
Extreme Irregularity: $\delta_{max}>1.4\delta_{avg}$

ASCE Section	Penalty	SDC
12.3.3.4	25% increase in seismic forces in connections for diaphragms and collectors	D, E, F
Table 12.6-1	Permitted Analytical Procedure	D, E, F
12.7.3	3D structural model required	B, C, D, E, F
12.8.4.3	Amplification of accidental torsion	C, D, E, F
12.12.1	Story drift: largest difference in deflection	C, D, E, F
16.3.4	Torsion: Accidental Eccentricity	B, C, D, E, F
12.3.3.1	Extreme: Prohibited	E, F

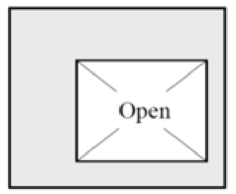
2: Reentrant Corner



Reentrant Corner Irregularity:
$P_y>0.15L_y$ AND
$P_x>0.15L_x$

ASCE Section	Penalty	SDC
12.3.3.4	25% increase in seismic forces for connections in diaphragms and collectors	D, E, F
Table 12.6-1	Permitted Analytical Procedure	D, E, F

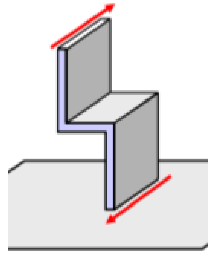
3: Diaphragm



Diaphragm Discontinuity Irregularity:
Cutout, open > 50% gross area, or Changes in effective diaphragm stiffness >50% from one story to next.

ASCE Section	Penalty	SDC
12.3.3.4	25% increase in seismic forces for connections in diaphragms and collectors	D, E, F
Table 12.6-1	Permitted Analytical Procedure	D, E, F

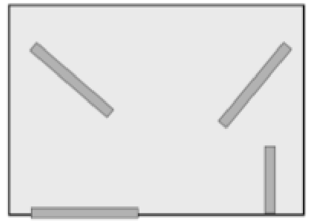
4: Out-of-Plane



Out-of-Plane Offsets Irregularity:
Discontinuities in a lateral force-resistance path, such as out-of-plane offsets of the vertical elements.

ASCE Section	Penalty	SDC
12.3.3.3	Axial force using load combinations with overstrength for discontinuous elements.	B, C, D, E, F
12.3.3.4	25% increase in seismic forces for connections in diaphragms and collectors	D, E, F
Table 12.6-1	Permitted Analytical Procedure	D, E, F
12.7.3	3D structural model required	B, C, D, E, F
16.3.4	Torsion: Accidental Eccentricity	B, C, D, E, F

5: Non-Parallel



Nonparallel Systems-Irregularity:
Vertical lateral force-resisting elements not parallel to or symmetric about the major orthogonal axes.

ASCE Section	Penalty	SDC
12.5.3	Orthogonal load combinations	C, D, E, F
Table 12.6-1	Permitted Analytical Procedure	D, E, F
12.7.3	3D structural model required	B, C, D, E, F
16.3.4	Torsion: Accidental Eccentricity	B, C, D, E, F

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Irregularities (Vertical)

Table 12.3-2 Vertical Structural Irregularities

Type	Description	Reference Section	Seismic Design Category Application
1a.	**Stiffness–Soft Story Irregularity:** Stiffness–soft story irregularity is defined to exist where there is a story in which the lateral stiffness is less than 70% of that in the story above or less than 80% of the average stiffness of the three stories above.	Table 12.6-1	D, E, and F
1b.	**Stiffness–Extreme Soft Story Irregularity:** Stiffness–extreme soft story irregularity is defined to exist where there is a story in which the lateral stiffness is less than 60% of that in the story above or less than 70% of the average stiffness of the three stories above.	12.3.3.1 Table 12.6-1	E and F D, E, and F
2.	**Weight (Mass) Irregularity:** Weight (mass) irregularity is defined to exist where the effective mass of any story is more than 150% of the effective mass of an adjacent story. A roof that is lighter than the floor below need not be considered.	Table 12.6-1	D, E, and F
3.	**Vertical Geometric Irregularity:** Vertical geometric irregularity is defined to exist where the horizontal dimension of the seismic force-resisting system in any story is more than 130% of that in an adjacent story.	Table 12.6-1	D, E, and F
4.	**In-Plane Discontinuity in Vertical Lateral Force-Resisting Element Irregularity:** In-plane discontinuity in vertical lateral force-resisting element irregularity is defined to exist where there is an in-plane offset of a vertical seismic force-resisting element resulting in overturning demands on supporting structural elements.	12.3.3.3 12.3.3.4 Table 12.6-1	B, C, D, E, and F D, E, and F D, E, and F
5a.	**Discontinuity in Lateral Strength–Weak Story Irregularity:** Discontinuity in lateral strength–weak story irregularity is defined to exist where the story lateral strength is less than 80% of that in the story above. The story lateral strength is the total lateral strength of all seismic-resisting elements sharing the story shear for the direction under consideration.	12.3.3.1 Table 12.6-1	E and F D, E, and F
5b.	**Discontinuity in Lateral Strength–Extreme Weak Story Irregularity:** Discontinuity in lateral strength–extreme weak story irregularity is defined to exist where the story lateral strength is less than 65% of that in the story above. The story strength is the total strength of all seismic-resisting elements sharing the story shear for the direction under consideration.	12.3.3.1 12.3.3.2 Table 12.6-1	D, E, and F B and C D, E, and F

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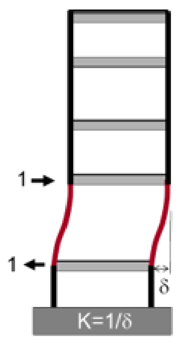
Irregularities (Vertical)

1a/1b: Soft Story

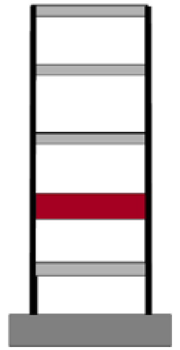


Stiffness-Soft Story Irregularity:
Lateral stiffness <70% story above or <80% average stiffness of 3 stories above

Extreme: Lateral stiffness <60% story above or <70% average stiffness of 3 stories above

ASCE Section	Penalty	SDC
Table 12.6-1	Permitted Analytical Procedure	D, E, F
12.3.3.1	Extreme: Prohibited	E, F

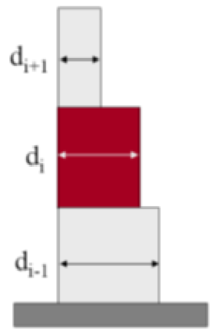
2: Weight (Mass)



Weight (Mass) Irregularity:
Mass of any story >150% of mass of an adjacent story.
(Excluded: Roof lighter than floor below)

ASCE Section	Penalty	SDC
Table 12.6-1	Permitted Analytical Procedure	D, E, F

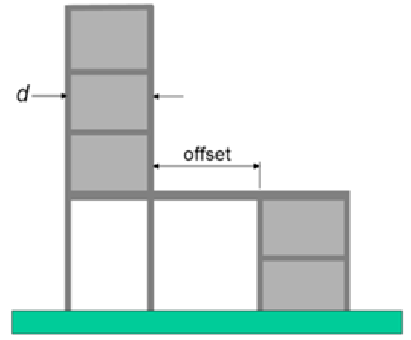
3: Geometric



Vertical Geometric Irregularity:
Horizontal dimension of the seismic force–resisting system >130% of adjacent story.

ASCE Section	Penalty	SDC
Table 12.6-1	Permitted Analytical Procedure	D, E, F

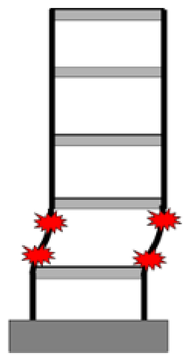
4: In-Plane



In-Plane Discontinuity in Vertical Lateral Force-Resisting Element Irregularity:
In-plane offset of lateral force-resisting elements> length of elements, or Reduction in stiffness of resisting element in the story below.

ASCE Section	Penalty	SDC
12.3.3.3	Axial force using load combinations with overstrength for discontinuous elements.	B, C, D, E, F
12.3.3.4	25% increase in seismic forces in connections in diaphragms and collectors	D, E, F
Table 12.6-1	Permitted Analytical Procedure	D, E, F

5a/5b: Weak Story



Discontinuity in Lateral Strength–Weak Story Irregularity:
Lateral strength < 80% story above.

Extreme: Lateral strength < 65% story above.

ASCE Section	Penalty	SDC
12.3.3.1	Prohibited	E, F
Table 12.6-1	Permitted Analytical Procedure	D
12.3.3.1	Extreme: Prohibited	D, E, F
12.3.3.2	Extreme: Cannot exceed 2 stories or 30 feet (see exception)	B, C

Irregularities (ASCE 7-22)

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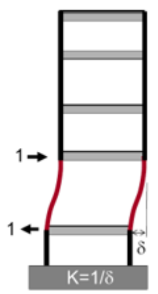
1a/1b: Soft Story

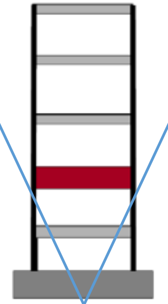


Stiffness-Soft Story Irregularity:
Lateral stiffness <70% story above or <80% average stiffness of 3 stories above

Extreme: Lateral stiffness <60% story above or <70% average stiffness of 3 stories above

ASCE Section	Penalty	SDC
Table 12.6-1	Permitted Analytical Procedure	D, E, F
12.3.3.1	Extreme: Prohibited	E, F

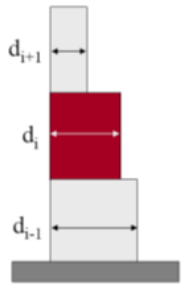
2: Weight (Mass)



Weight (Mass) Irregularity:
Mass of any story >150% of mass of an adjacent story.
(Excluded: Roof lighter than floor below)

ASCE Section	Penalty	SDC
Table 12.6-1	Permitted Analytical Procedure	D, E, F

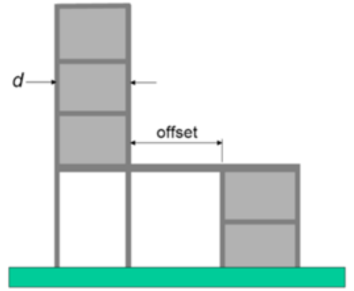
3: Geometric



Vertical Geometric Irregularity:
Horizontal dimension of the seismic force–resisting system >130% of adjacent story.

ASCE Section	Penalty	SDC
Table 12.6-1	Permitted Analytical Procedure	D, E, F

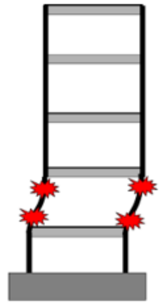
4: In-Plane



In-Plane Discontinuity in Vertical Lateral Force-Resisting Element Irregularity:
In-plane offset of lateral force-resisting elements> length of elements, or Reduction in stiffness of resisting element in the story below.

ASCE Section	Penalty	SDC
12.3.3.3	Axial force using load combinations with overstrength for discontinuous elements.	B, C, D, E, F
12.3.3.4	25% increase in seismic forces in connections in diaphragms and collectors	D, E, F
Table 12.6-1	Permitted Analytical Procedure	D, E, F

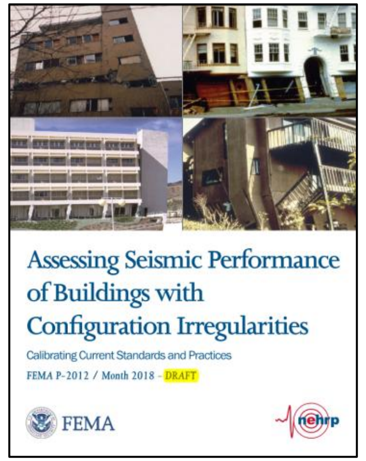
5a/5b: Weak Story



Discontinuity in Lateral Strength–Weak Story Irregularity:
Lateral strength < 80% story above.

Extreme: Lateral strength < 65% story above.

ASCE Section	Penalty	SDC
12.3.3.1	Prohibited	E, F
Table 12.6-1	Permitted Analytical Procedure	D
12.3.3.1	Extreme: Prohibited	D, E, F
12.3.3.2	Extreme: Cannot exceed 2 stories or 30 feet (see exception)	B, C



Irregularities (ASCE 7-22)

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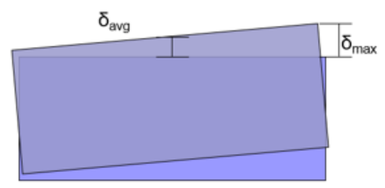
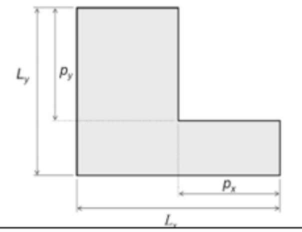
1a/1b: Torsional



Torsional Irregularity:
No Irregularity: $\delta_{max}<1.2\delta_{avg}$
Irregularity: $1.2\delta_{avg}\leq\delta_{max}\leq1.4\delta_{avg}$
Extreme Irregularity: $\delta_{max}>1.4\delta_{avg}$

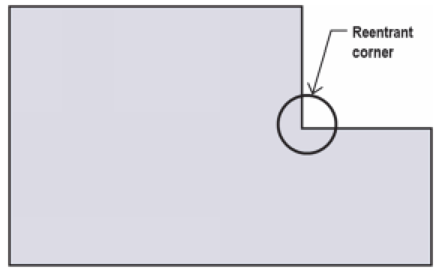
ASCE Section	Penalty	SDC
12.3.3.4	25% increase in seismic forces in connections for diaphragms and collectors	D, E, F
Table 12.6-1	Permitted Analytical Procedure	D, E, F
12.7.3	3D structural model required	B, C, D, E, F
12.8.4.3	Amplification of accidental torsion	C, D, E, F
12.12.1	Story drift: largest difference in deflection	C, D, E, F
16.3.4	Torsion: Accidental Eccentricity	B, C, D, E, F
12.3.3.1	Extreme: Prohibited	E, F

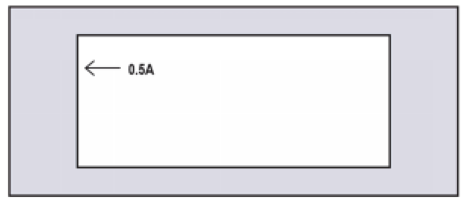
2: Reentrant Corner



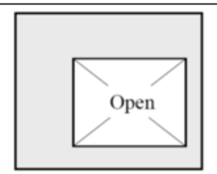
Reentrant Corner Irregularity:
$P_y>0.15L_y$ AND
$P_x>0.15L_x$

ASCE Section	Penalty	SDC
12.3.3.4	25% increase in seismic forces for connections in diaphragms and collectors	D, E, F
Table 12.6-1	Permitted Analytical Procedure	D, E, F





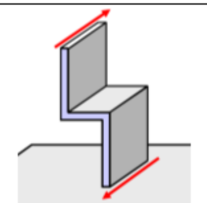
3: Diaphragm



Diaphragm Discontinuity Irregularity:
Cutout, open > 50% gross area, or Changes in effective diaphragm stiffness >50% from one story to next.

ASCE Section	Penalty	SDC
12.3.3.4	25% increase in seismic forces for connections in diaphragms and collectors	D, E, F
Table 12.6-1	Permitted Analytical Procedure	D, E, F

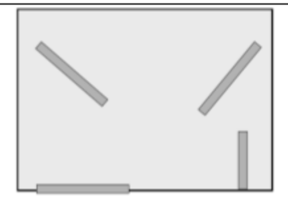
4: Out-of-Plane



Out-of-Plane Offsets Irregularity:
Discontinuities in a lateral force-resistance path, such as out-of-plane offsets of the vertical elements.

ASCE Section	Penalty	SDC
12.3.3.3	Axial force using load combinations with overstrength for discontinuous elements.	B, C, D, E, F
12.3.3.4	25% increase in seismic forces for connections in diaphragms and collectors	D, E, F
Table 12.6-1	Permitted Analytical Procedure	D, E, F
12.7.3	3D structural model required	B, C, D, E, F
16.3.4	Torsion: Accidental Eccentricity	B, C, D, E, F

5: Non-Parallel



Nonparallel Systems-Irregularity:
Vertical lateral force-resisting elements not parallel to or symmetric about the major orthogonal axes.

ASCE Section	Penalty	SDC
12.5.3	Orthogonal load combinations	C, D, E, F
Table 12.6-1	Permitted Analytical Procedure	D, E, F
12.7.3	3D structural model required	B, C, D, E, F
16.3.4	Torsion: Accidental Eccentricity	B, C, D, E, F

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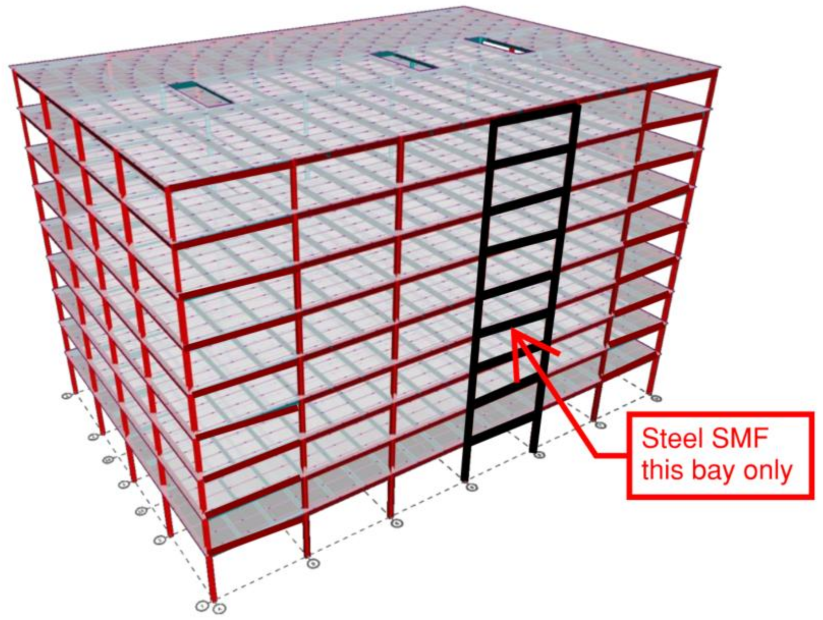
Redundancy Factor, ρ

- 1994 Northridge earthquake damage higher in low redundancy structures.
- Code updated to encourage redundancy (SDC D, E, F).
- For structures with low redundancy, design forces amplified

→ increase strength and resistance to damage.



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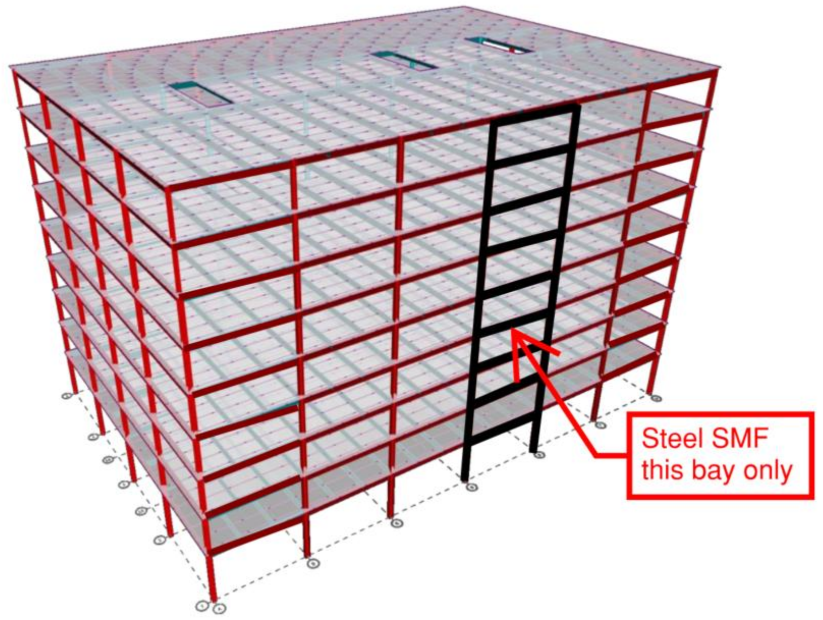
Redundancy Factor, ρ

12.3.4.1: Conditions Where ρ = 1.0.

12.3.4.2: Redundancy Factor, ρ, for SDC D, E, F

- ρ = 1.0 or 1.3



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Redundancy Factor, ρ

1. Structures assigned to Seismic Design Category B or C.
2. Drift calculation and P-delta effects.
3. Design of nonstructural components (Chapter 13).

Examples: Mechanical/ electrical components, ceilings, cabinets.

4. Design of non-building structures that are *not* similar to buildings (Chapter 15).

Examples: Tanks, amusement structures/ monuments, signs and billboards, cooling towers.

Redundancy Factor, ρ

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5. Design of collector elements, splices and their connections when overstrength factor is used.

6. Design of members or connections when overstrength of 12.4.3.2 is required.

Basic Combinations for Strength Design with Overstrength Factor (see Sections 2.3.2 and 2.2 for notation).

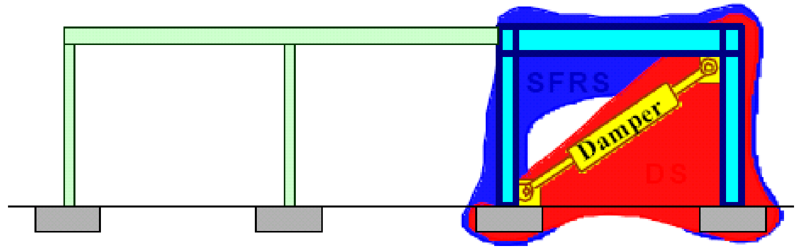
5. $(1.2 + 0.2S_{DS})D + \Omega_o Q_E + L + 0.2S$

7. $(0.9 - 0.2S_{DS})D + \Omega_o Q_E + 1.6H$

7. Diaphragm loads determined using Eq. 12.10-1.

$$F_{px} = \frac{\sum_{i=x}^{n} F_i}{\sum_{i=x}^{n} w_i} w_{px} \qquad (12.10\text{-}1)$$

8. Structures with damping systems designed in accordance with Chapter 18.



9. Out-of-plane wall anchorage (including connections).

$$F_p = 0.4 S_{DS} k_a I_e W_p \qquad (12.11\text{-}1)$$

Redundancy Factor, ρ

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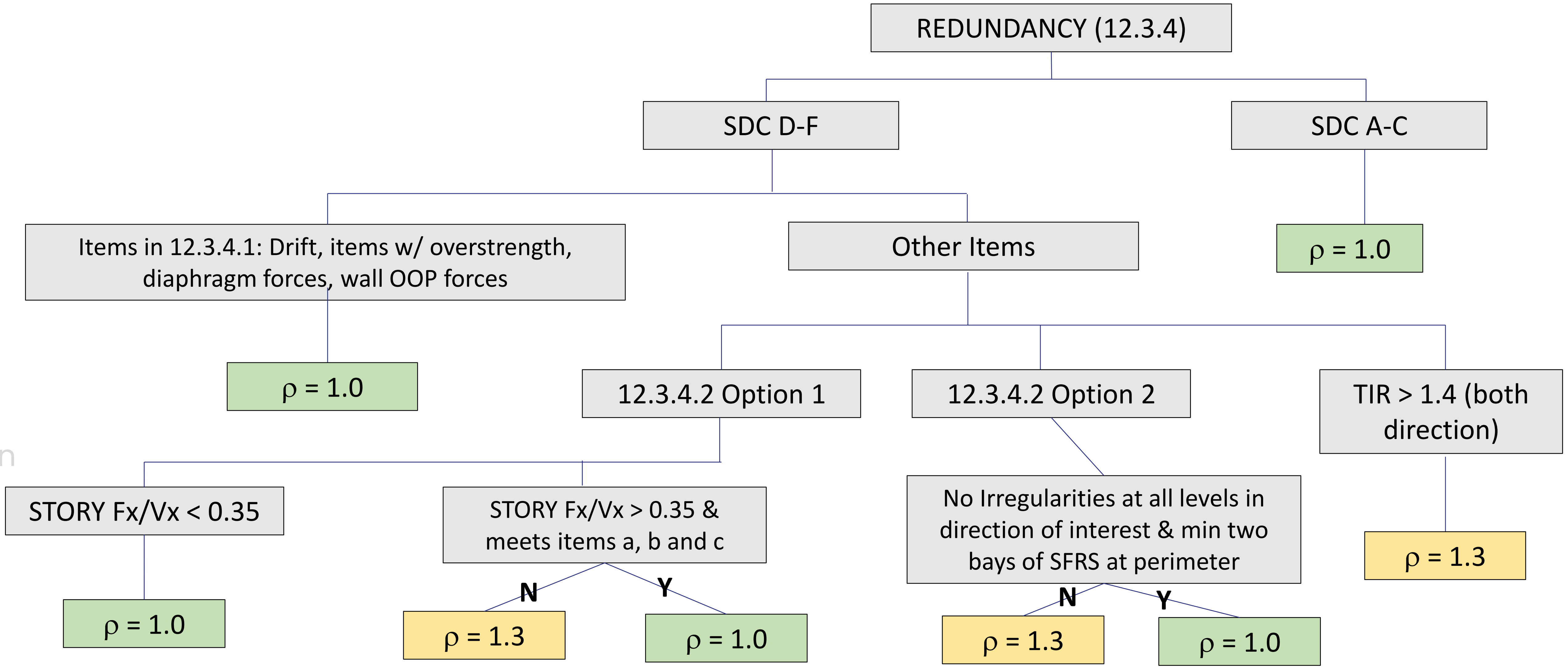

Agenda:

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Redundancy Factor, ρ

ASCE 7 12.3.4.2

ρ = 1.0 or 1.3

ρ = 1.3 unless ONE of the following conditions is met:

Condition 1: Can an individual element be removed from the lateral force resisting system without:

- Causing the remaining structure to suffer a reduction in story strength > 33%, or
- Creating an extreme torsional irregularity?

Redundancy Factor, ρ

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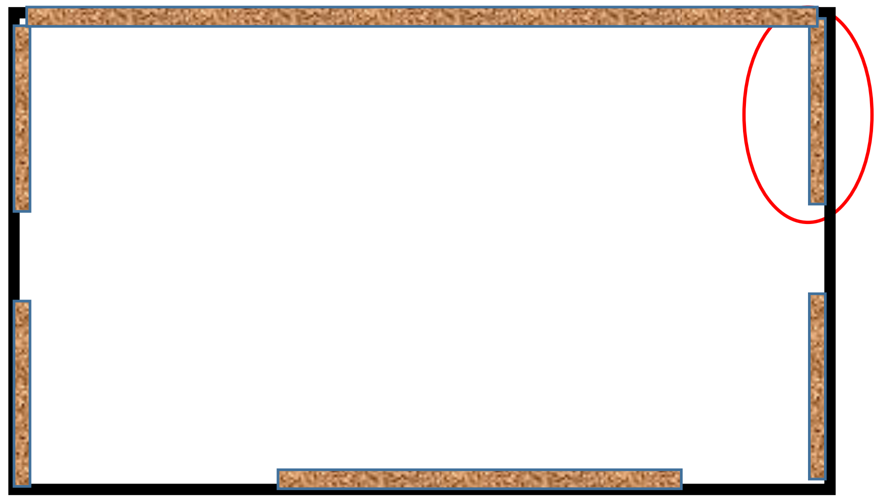
Condition 1:



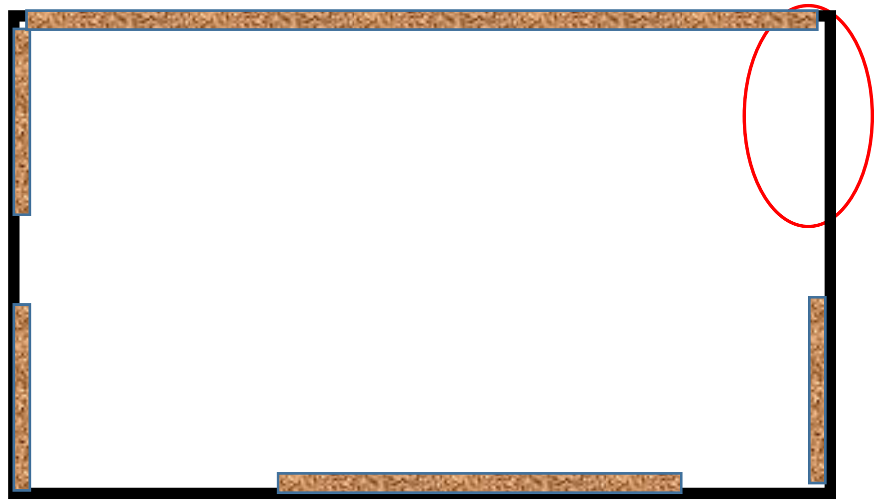


TABLE 12.3-3 REQUIREMENTS FOR EACH STORY RESISTING MORE THAN 35% OF THE BASE SHEAR

Lateral Force-Resisting Element	Requirement
Braced Frames	Removal of an individual brace, or connection thereto, would not result in more than a 33% reduction in story strength, nor does the resulting system have an extreme torsional irregularity (horizontal structural irregularity Type 1b).
Moment Frames	Loss of moment resistance at the beam-to-column connections at both ends of a single beam would not result in more than a 33% reduction in story strength, nor does the resulting system have an extreme torsional irregularity (horizontal structural irregularity Type 1b).
Shear Walls or Wall Pier with a height-to-length ratio of greater than 1.0	Removal of a shear wall or wall pier with a height-to-length ratio greater than 1.0 within any story, or collector connections thereto, would not result in more than a 33% reduction in story strength, nor does the resulting system have an extreme torsional irregularity (horizontal structural irregularity Type 1b).
Cantilever Columns	Loss of moment resistance at the base connections of any single cantilever column would not result in more than a 33% reduction in story strength, nor does the resulting system have an extreme torsional irregularity (horizontal structural irregularity Type 1b).
Other	No requirements

Redundancy Factor, ρ

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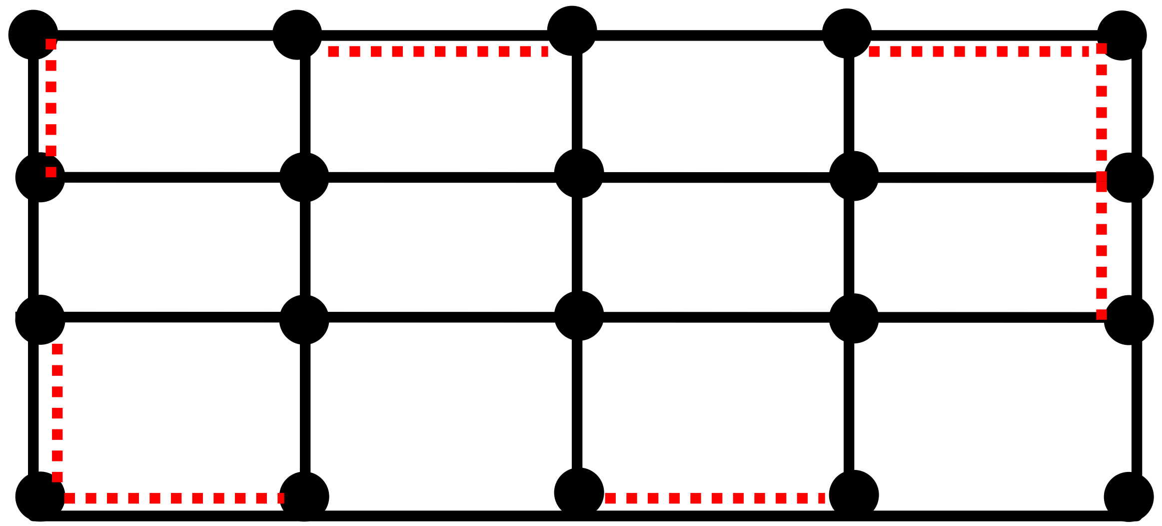
Condition 2:

ρ = 1.0 or 1.3

ρ = 1.3 unless ONE of the following conditions is met:

Condition 2: If a structure is *regular in plan* and there are at least *2 bays* of seismic force resisting *perimeter framing on each side* of the structure in *each orthogonal direction* at each *story resisting > 35%* of the base shear.



Nonstructural

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ASCE 7-16

13.1.4 Exemptions. The following nonstructural components are exempt from the requirements of this chapter:

1. Furniture except storage cabinets, as noted in Table 13.5-1;
2. Temporary or movable equipment;
3. Architectural components in Seismic Design Category B, other than parapets, provided that the component Importance Factor, I_p, is equal to 1.0;
4. Mechanical and electrical components in Seismic Design Category B;
5. Mechanical and electrical components in Seismic Design Category C provided that either
   a. The component Importance Factor, I_p, is equal to 1.0 and the component is positively attached to the structure; or
   b. The component weighs 20 lb (89 N) or less or, in the case of a distributed system, 5 lb/ft (73 N/m) or less.
6. Discrete mechanical and electrical components in Seismic Design Categories D, E, or F that are positively attached to the structure, provided that either
   a. The component weighs 400 lb (1,779 N) or less, the center of mass is located 4 ft (1.22 m) or less above the adjacent floor level, flexible connections are provided between the component and associated ductwork, piping, and conduit, and the component Importance Factor, I_p, is equal to 1.0; or
   b. The component weighs 20 lb (89 N) or less or, in the case of a distributed system, 5 lb/ft (73 N/m) or less; and.
7. Distribution systems in Seismic Design Categories D, E, or F included in the exceptions for conduit, cable tray, and raceways in Section 13.6.5, duct systems in 13.6.6 and piping and tubing systems in 13.6.7.3. Where in-line components, such as valves, in-line suspended pumps, and mixing boxes require independent support, they shall be addressed as discrete components and shall be braced considering the tributary contribution of the attached distribution system.

ASCE 7-22

Seismic Design Category (SDC)	Nonstructural Components Exempt from the Requirements of this Chapter
All Categories	• Furniture (except storage cabinets, as noted in Table 13.5-1) • Temporary or movable equipment
A	• All components
B	• Architectural Components, other than parapets, provided that the component Importance Factor, I_p, is equal to 1.0 • Mechanical and Electrical Components

C	• Mechanical and Electrical Components, provided that either
	  ○ the component Importance Factor, I_p, is equal to 1.0 and the component is positively attached to the structure; or
	  ○ the component weighs 20 lb (89 N) or less

D, E, F	• Mechanical and electrical components positively attached to the structure, provided that
	  ○ For discrete mechanical and electrical components, the component weighs 400 lb (1,779 N) or less, the center of mass is located 4 ft (1.22 m) or less above the adjacent floor level, flexible connections are provided between the component and associated ductwork, piping, and conduit, and the component Importance Factor, I_p, is equal to 1.0; or
	  ○ For discrete mechanical and electrical components, the component weighs 20 lb (89 N) or less; or
	  ○ For distribution systems, the component Importance Factor, I_p, is equal to 1.0 and the operating weight of the system is 5 lb/ft (73 N/m) or less.
	• Distribution systems included in the exceptions for conduit, cable tray, and raceways in Section 13.6.5, duct systems in 13.6.6, and piping and tubing systems in 13.6.7.3. Where in-line components, such as valves, in-line suspended pumps, and mixing boxes, require independent support, they shall be addressed as discrete components and shall be braced considering the tributary contribution of the attached distribution system.

Nonstructural

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$$F_p = \frac{0.4 a_p S_{DS} W_p}{\left(\frac{R_p}{I_p}\right)}\left(1 + 2\frac{z}{h}\right) \qquad (13.3\text{-}1)$$

ASCE 7-16

The horizontal seismic design force shall be calculated as

$$F_p = 0.4 S_{DS} I_p W_p \left[\frac{H_f}{R_\mu}\right]\left[\frac{C_{AR}}{R_{po}}\right] \qquad (13.3\text{-}1)$$

F_p is not required to be taken as greater than

$$F_p = 1.6 S_{DS} I_p W_p \qquad (13.3\text{-}2)$$

and shall not be taken as less than

$$F_p = 0.3 S_{DS} I_p W_p \qquad (13.3\text{-}3)$$

ASCE 7-22

Nonstructural

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The horizontal seismic design force shall be calculated as

$$F_p = 0.4 S_{DS} I_p W_p \left[\frac{H_f}{R_\mu}\right]\left[\frac{C_{AR}}{R_{po}}\right] \qquad (13.3\text{-}1)$$

F_p = Seismic design force;

S_{DS} = Spectral acceleration, short period, as determined in accordance with Section 11.4.5; — SAME

I_p = Component Importance Factor as determined in accordance with Section 13.1.3; — SOME MODIFICATIONS TO I_P FROM 7-16

W_p = Component operating weight;

H_f = Factor for force amplification as a function of height in the structure as determined in Section 13.3.1.1;

R_μ = Structure ductility reduction factor as determined in Section 13.3.1.2; — FUNCTION OF SUPPORTING STRUCTURE - REPLACES (Z/H)

C_{AR} = Component resonance ductility factor that converts the peak floor or ground acceleration into the peak component acceleration, as determined in Section 13.3.1.3; and — OLD a_P

R_{po} = Component strength factor as determined in Section 13.3.1.4. — OLD R_P

Nonstructural

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New factor H_f = height amplification

Requires fundamental period of structure

For the purposes of computing H_f, T_a is determined using Equation (12.8-8) for buildings. Where the SFRS is unknown, T_a is permitted to be determined by Equation (12.8-8) using the approximate period parameters for "all other structural systems."

12.8.2.1 Approximate Fundamental Period The approximate fundamental period (T_a), in seconds, shall be determined from the following equation:

$$T_a = C_t h_n^x \qquad (12.8\text{-}8)$$

13.3.1.1 Amplification with Height, H_f For nonstructural components supported at or below grade plane, the factor for force amplification with height H_f, is 1.0. For components supported above grade plane by a building or nonbuilding structure, H_f is permitted to be determined by Equation (13.3-4) or Equation (13.3-5). Where the approximate fundamental period of the supporting building or nonbuilding structure is unknown, H_f is permitted to be determined by Equation (13.3-5).

$$H_f = 1 + a_1\left(\frac{z}{h}\right) + a_2\left(\frac{z}{h}\right)^{10} \qquad (13.3\text{-}4)$$

$$H_f = 1 + 2.5\left(\frac{z}{h}\right) \qquad (13.3\text{-}5)$$

where

$a_1 = 1/T_a \le 2.5$;

$a_2 = [1 - (0.4/T_a)^2] \ge 0$;

z = Height above the base of the structure to the point of attachment of the component. For items at or below the base, z shall be taken as 0. The value of $\frac{z}{h}$ need not exceed 1.0;

h = Average roof height of structure with respect to the base; and

T_a = Lowest approximate fundamental period of the supporting building or nonbuilding structure in either orthogonal direction. For structures with combinations of seismic force-resisting systems (SFRSs), the SFRS that produces the lowest value of T_a shall be used.

Nonstructural

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New factor R_μ = Structure ductility reduction factor

Requires "R" and Ω_o of building LFRS

(Taken as 1.3 if LFRS is not known)

13.3.1.2 Structure Ductility Reduction Factor, R_μ For components supported by a building or nonbuilding structure, the reduction factor for ductility of the supporting structure, R_μ, is calculated as

$$R_\mu = [1.1R/(I_e\Omega_0)]^{1/2} \geq 1.3 \qquad (13.3\text{-}6)$$

where

I_e = Importance Factor as prescribed in Section 11.5.1 for the building or nonbuilding structure supporting the component;

R = Response modification factor for the building or nonbuilding structure supporting the component, from Table 12.2-1, 15.4-1, or 15.4-2; and

Ω_0 = Overstrength factor for the building or nonbuilding structure supporting the component, from Table 12.2-1, 15.4-1, or 15.4-2.

For components supported at or below grade plane, R_μ shall be taken as 1.0. When the SFRS of the building or nonbuilding structure is not specified, R_μ shall be taken as 1.3 for components above grade plane. When the SFRS of the building or nonbuilding structure is not listed in Table 12.2-1, 15.4-1, or 15.4-2, R_μ shall be taken as 1.3 for components above grade plane, unless seismic design parameters for the SFRS have been approved by the Authority Having Jurisdiction.

Functional Recovery

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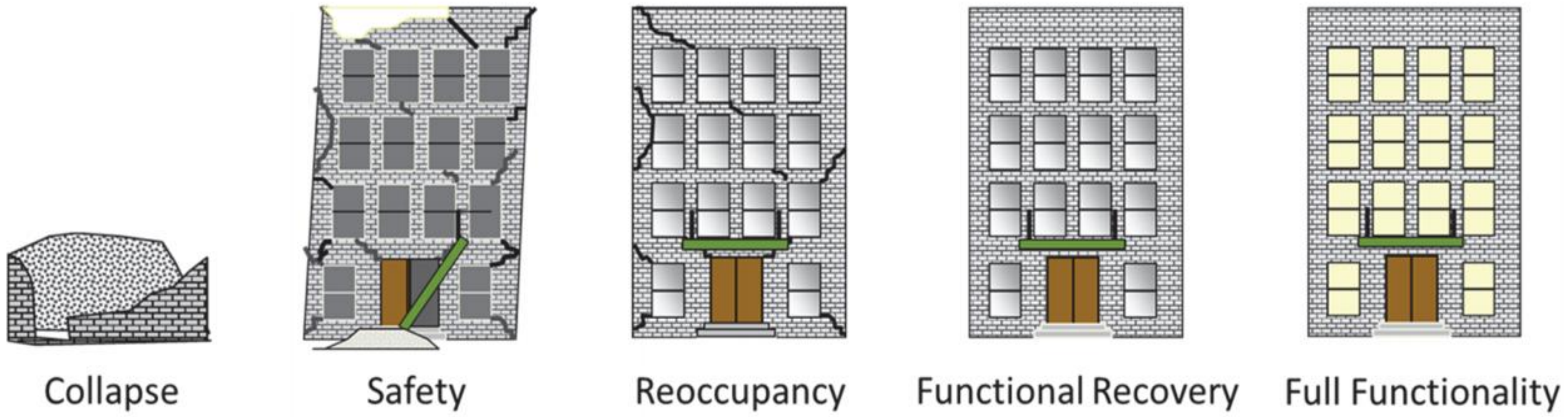

Analysis Procedures

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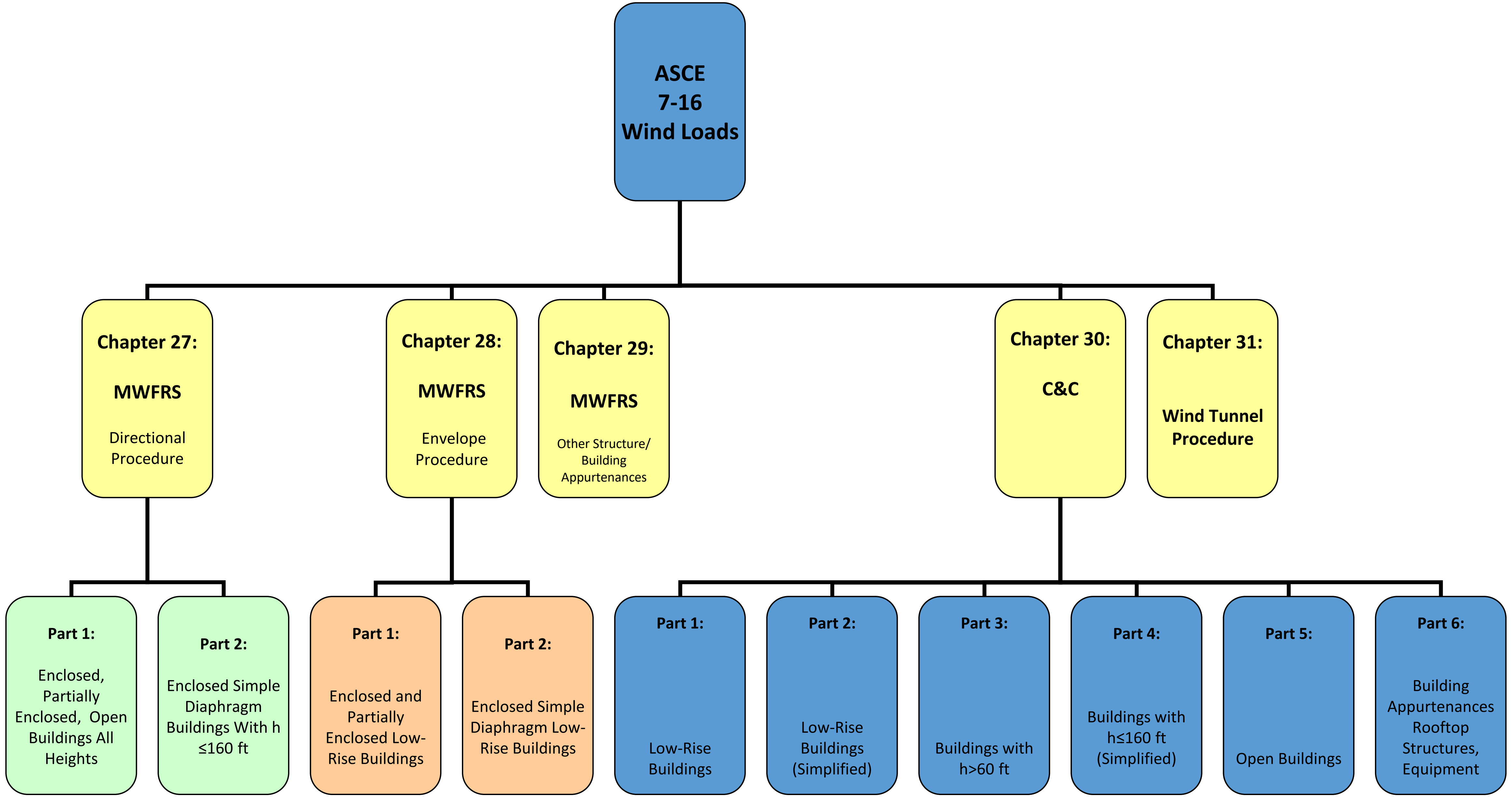

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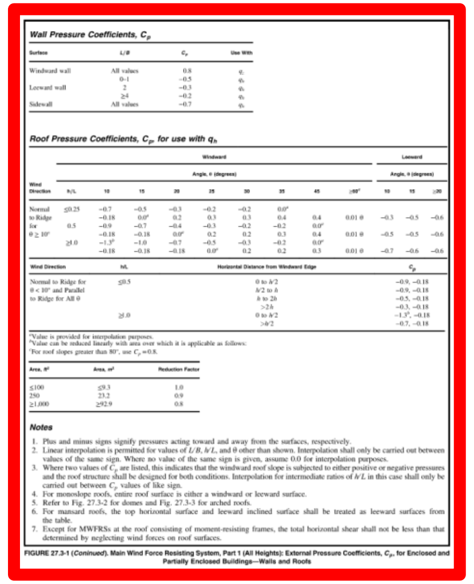
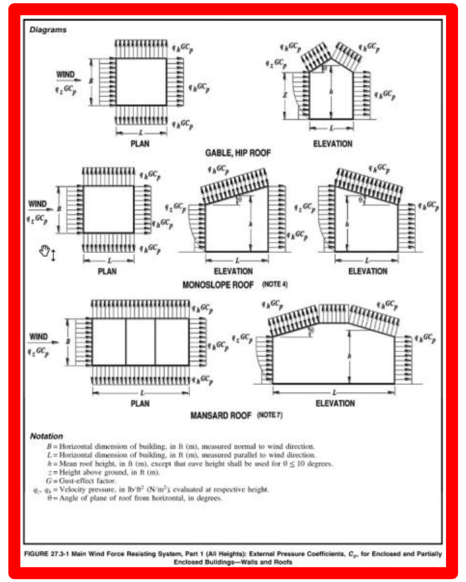
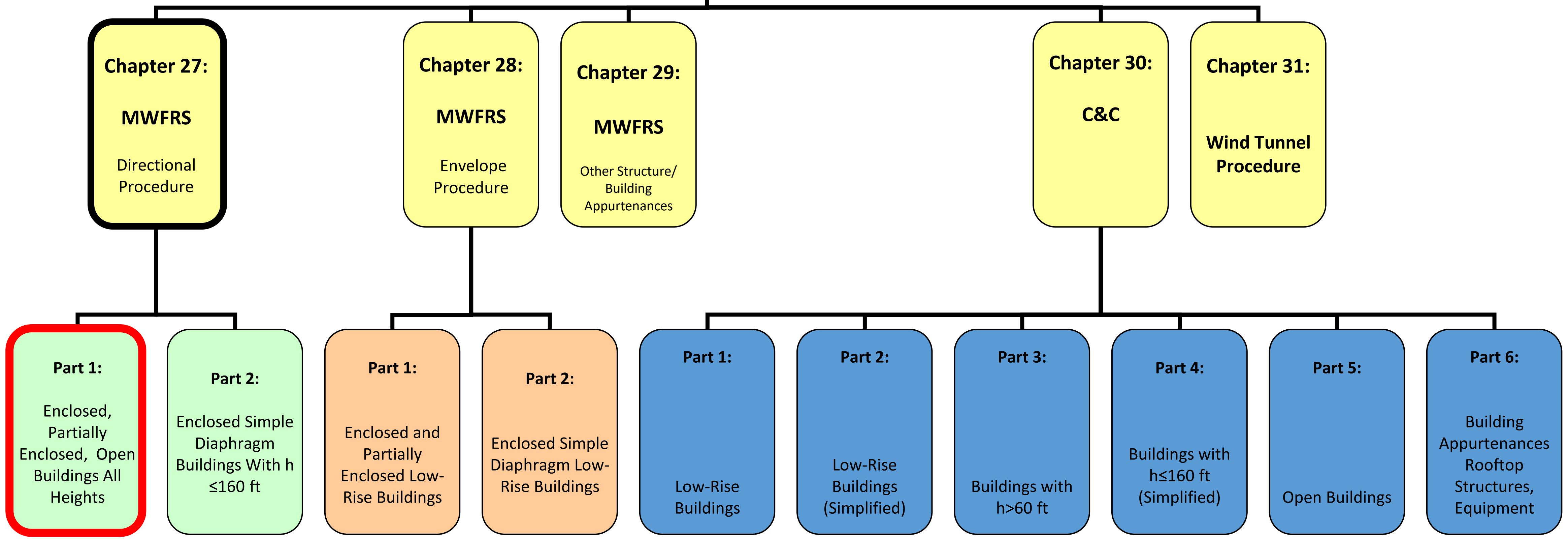


$$p = qGC_p - q_i(GC_{pi})$$





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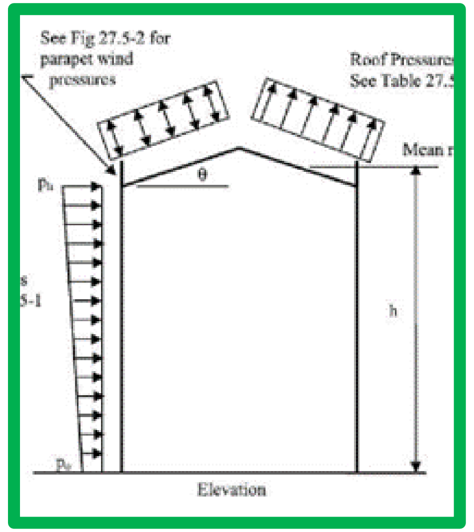
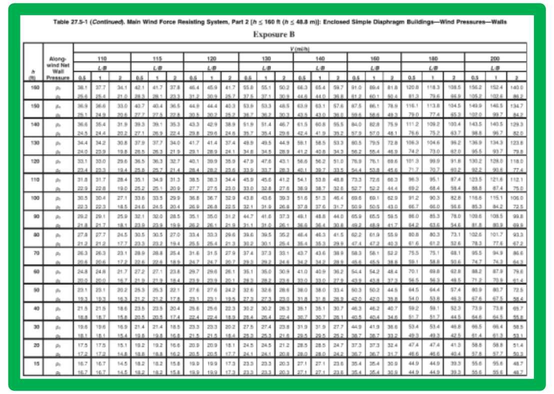
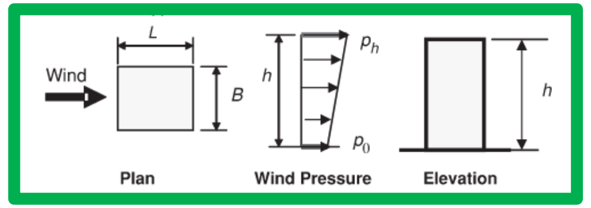
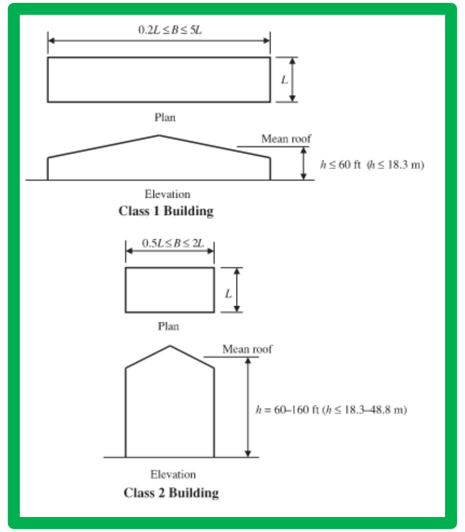




Analysis Procedures





ASCE 7-16 Wind Loads

- **Chapter 27: MWFRS** Directional Procedure
  - **Part 1:** Enclosed, Partially Enclosed, Open Buildings All Heights
  - **Part 2:** Enclosed Simple Diaphragm Buildings With h ≤160 ft
- **Chapter 28: MWFRS** Envelope Procedure
  - **Part 1:** Enclosed and Partially Enclosed Low-Rise Buildings
  - **Part 2:** Enclosed Simple Diaphragm Low-Rise Buildings
- **Chapter 29: MWFRS** Other Structure/ Building Appurtenances
- **Chapter 30: C&C**
  - **Part 1:** Low-Rise Buildings
  - **Part 2:** Low-Rise Buildings (Simplified)
  - **Part 3:** Buildings with h>60 ft
  - **Part 4:** Buildings with h≤160 ft (Simplified)
  - **Part 5:** Open Buildings
  - **Part 6:** Building AppurtenancesRooftop Structures, Equipment
- **Chapter 31: Wind Tunnel Procedure**

Analysis Procedures

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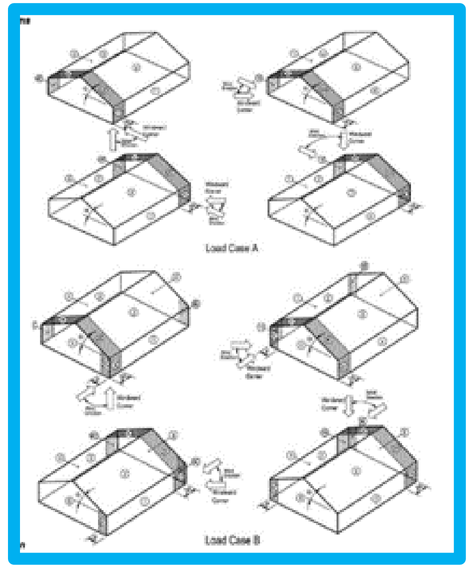

$$p = q_h[(GC_{pf}) - (GC_{pi})]$$

- **ASCE 7-16 Wind Loads**
  - **Chapter 27: MWFRS** Directional Procedure
    - **Part 1:** Enclosed, Partially Enclosed, Open Buildings All Heights
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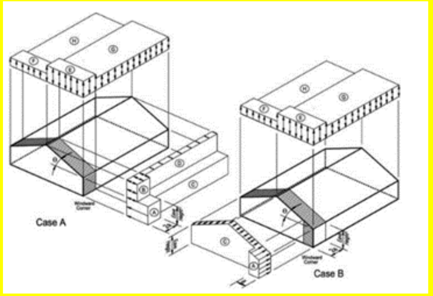

$$p_s = \lambda K_{zt} p_{s30}$$

Adjustment Factor for Building Height and Exposure, λ

Mean roof height (ft)	Exposure B	Exposure C	Exposure D
15	1.00	1.21	1.47
20	1.00	1.29	1.55
25	1.00	1.35	1.61
30	1.00	1.40	1.66
35	1.05	1.45	1.70
40	1.09	1.49	1.74
45	1.12	1.53	1.78
50	1.16	1.56	1.81
55	1.19	1.59	1.84
60	1.22	1.62	1.87

Note: Unit conversions for tables: 1.0 ft = 0.3048 m; 1.0 lb/ft^2 = 0.0479 kN/m^2; 1 mph = 1.6 km/h

ASCE 7-16 Wind Loads

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Analysis Procedures

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Question: What's the difference between Chapter 27 and Chapter 28?

Answer:

Chapter 27: Directional	Chapter 28: Envelope
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…

Analysis Procedures

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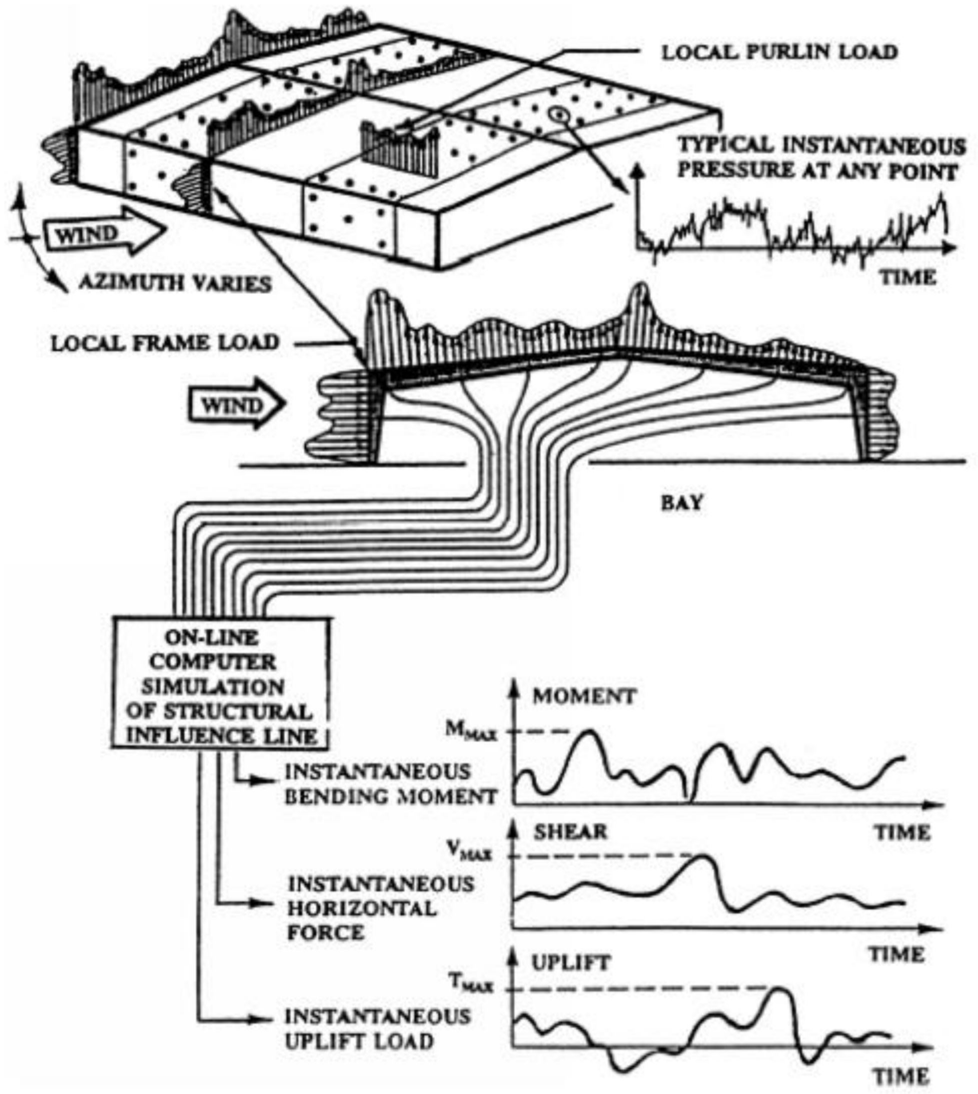
Chapter 28

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



Analysis Procedures

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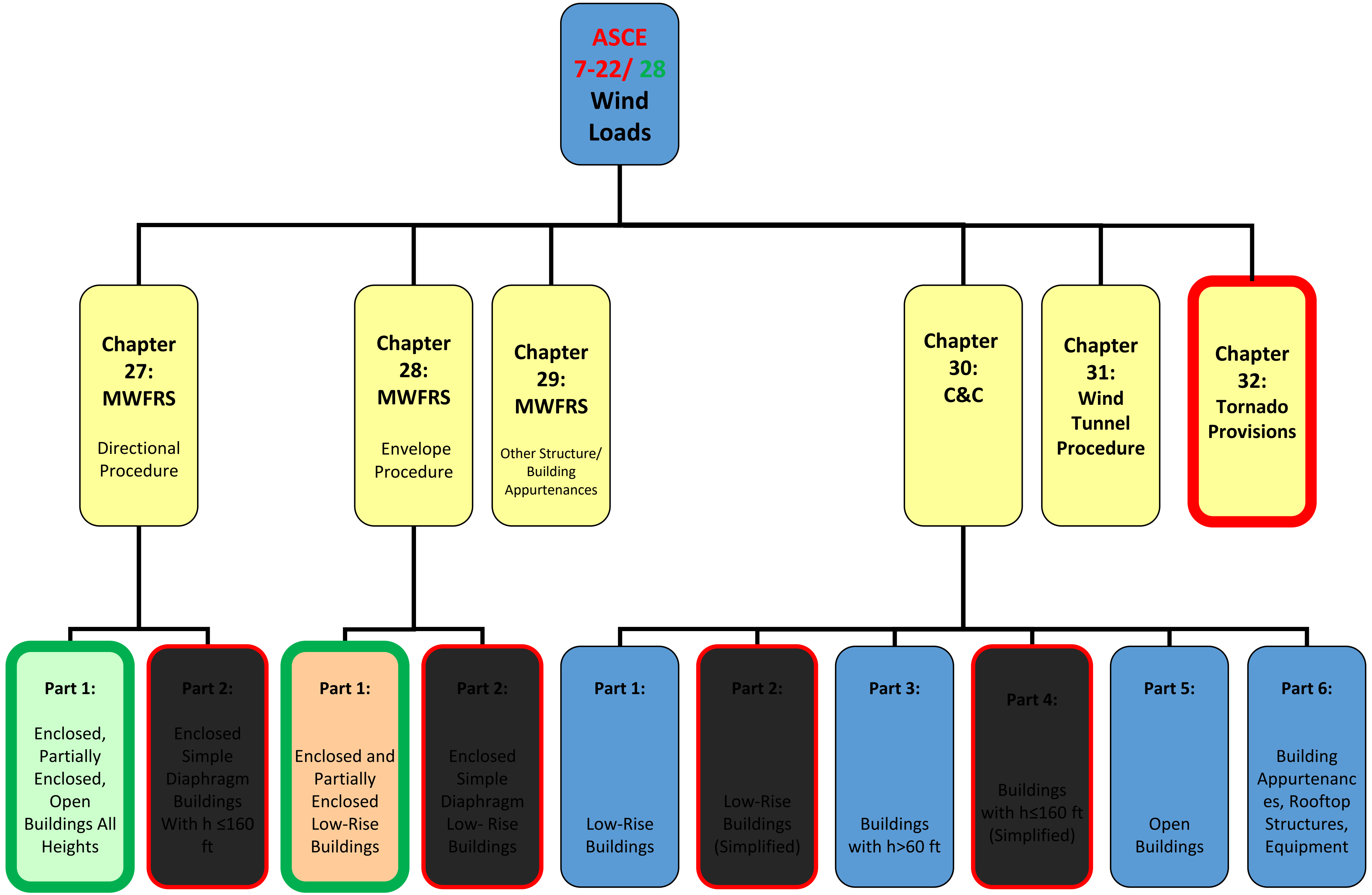

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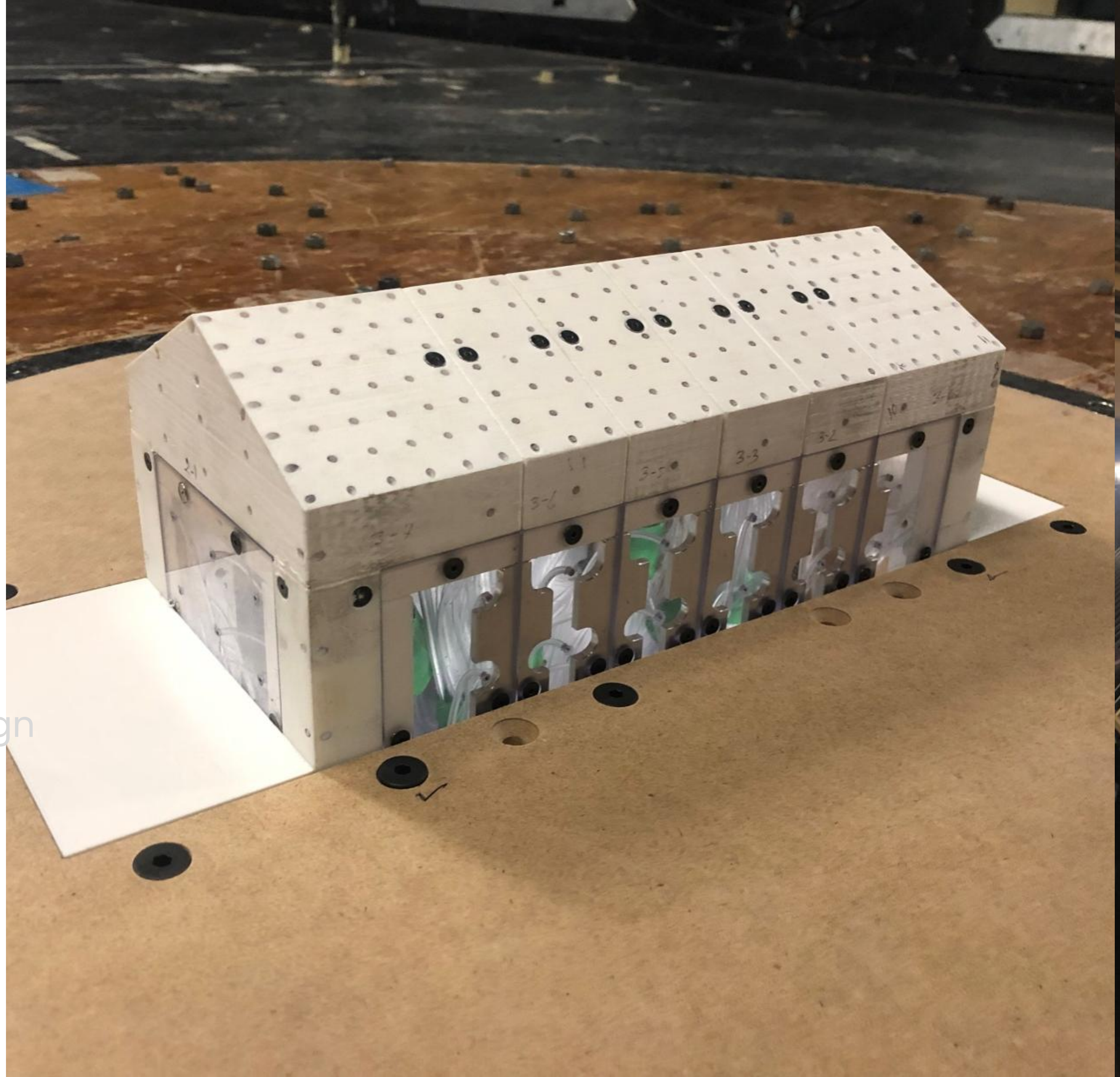

Drift

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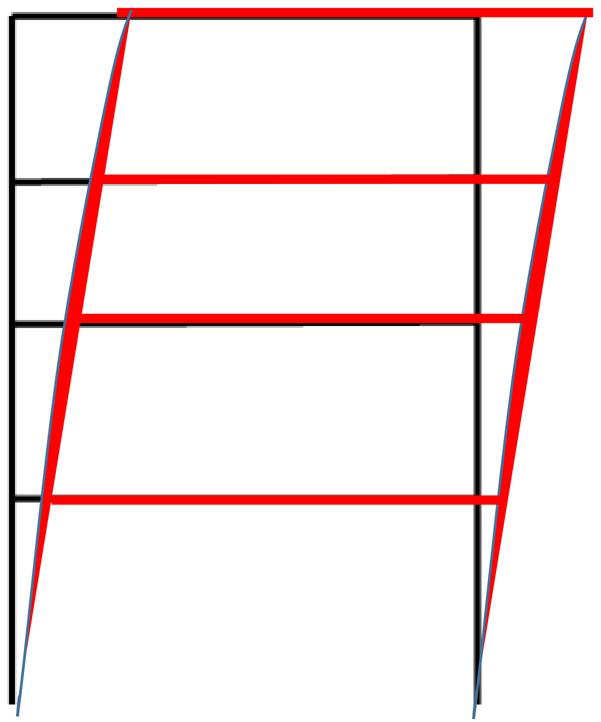
- Drift limits in common usage for building ~**1/600 to 1/400** of the *building* or *story* height.
- Absolute limit on *story drift* may be needed to reduce damage (nonstructural partitions, cladding, and glazing) which may occur if the story drift > **3/8 in.**



Drift

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Appendix C
SERVICEABILITY CONSIDERATIONS

C. SERVICEABILITY CONSIDERATIONS

This appendix is not a mandatory part of the standard but provides guidance for design for serviceability in order to maintain the function of a building and the comfort of its occupants during normal usage. Serviceability limits (e.g., maximum static deformations, accelerations, etc.) shall be chosen with due regard to the intended function of the structure.

Serviceability shall be checked using appropriate loads for the limit state being considered.

C.1 DEFLECTION, VIBRATION, AND DRIFT

C.1.1 Vertical Deflections

Deformations of floor and roof members and systems due to service loads shall not impair the serviceability of the structure.

C.1.2 Drift of Walls and Frames

Lateral deflection or drift of structures and deformation of horizontal diaphragms and bracing systems due to wind effects shall not impair the serviceability of the structure.

C.1.3 Vibrations

Floor systems supporting large open areas free of partitions or other sources of damping, where vibration due to pedestrian traffic might be objectionable, shall be designed with due regard for such vibration.

Mechanical equipment that can produce objectionable vibrations in any portion of an inhabited structure shall be isolated to minimize the transmission of such vibrations to the structure.

Building structural systems shall be designed so that wind-induced vibrations do not cause occupant discomfort or damage to the building, its appurtenances, or contents.

C.2 DESIGN FOR LONG-TERM DEFLECTION

Where required for acceptable building performance, members and systems shall be designed to accommodate long-term irreversible deflections under sustained load.

C.3 CAMBER

Special camber requirements that are necessary to bring a loaded member into proper relations with the work of other trades shall be set forth in the design documents.

Beams detailed without specified camber shall be positioned during erection so that any minor camber is upward. If camber involves the erection of any member under preload, this shall be noted in the design documents.

C.4 EXPANSION AND CONTRACTION

Dimensional changes in a structure and its elements due to variations in temperature, relative humidity, or other effects shall not impair the serviceability of the structure.

Provision shall be made either to control crack widths or to limit cracking by providing relief joints.

C.5 DURABILITY

Buildings and other structures shall be designed to tolerate long-term environmental effects or shall be protected against such effects.

Commentary Appendix C
SERVICEABILITY CONSIDERATIONS

CC. SERVICEABILITY CONSIDERATIONS

Serviceability limit states are conditions in which the functions of a building or other structure are impaired because of local damage, deterioration, or deformation of building components, or because of occupant discomfort. Although safety generally is not an issue with serviceability limit states (one exception would be for cladding that falls off a building due to excessive story drift under wind load), they nonetheless may have severe economic consequences. The increasing use of the computer as a design tool, the use of stronger (but not stiffer) construction materials, the use of lighter architectural elements, and the uncoupling of the nonstructural elements from the structural frame may result in building systems that are relatively flexible and lightly damped. Limit state design emphasizes the fact that serviceability criteria (as they always have been) are essential to ensure functional performance and economy of design for such building structural systems (Ad Hoc Committee on Serviceability Research 1986, National Building Code of Canada 1990, and West and Fisher 2003).

In general, serviceability is diminished by

1. Excessive deflections or rotation that may affect the appearance, functional use, or drainage of the structure or may cause damaging transfer of load to nonload supporting elements and attachments;
2. Excessive vibrations produced by the activities of building occupants, mechanical equipment, or the wind, which may cause occupant discomfort or malfunction of building service equipment; and
3. Deterioration, including weathering, corrosion, rotting, and discoloration.

In checking serviceability, the designer is advised

a small probability of being exceeded in 50 years.) Appropriate service loads for checking serviceability limit states may be only a fraction of the nominal loads.

The response of the structure to service loads normally can be analyzed assuming linear elastic behavior. However, members that accumulate residual deformations under service loads may require examination with respect to this long-term behavior. Service loads used in analyzing creep or other long-term effects may not be the same as those used to analyze elastic deflections or other short-term or reversible structural behavior.

Serviceability limits depend on the function of the building and on the perceptions of its occupants. In contrast to the ultimate limit states, it is difficult to specify general serviceability limits that are applicable to all building structures. The serviceability limits presented in Sections CC.1.1, CC.1.2, and CC.1.3 provide general guidance and have usually led to acceptable performance in the past. However, serviceability limits for a specific building should be determined only after a careful analysis by the engineer and architect of all functional and economic requirements and constraints in conjunction with the building owner. It should be recognized that building occupants are able to perceive structural deflections, motion, cracking, and other signs of possible distress at levels that are much lower than those that would indicate that structural failure was impending. Such signs of distress may be taken incorrectly as an indication that the building is unsafe and diminish its commercial value.

CC.1.1 Vertical Deflections

Excessive vertical deflections and misalignment

Drift

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Use of the nominal (700-year mean recurrence interval (MRI) or 1,700-year MRI) wind load in checking serviceability is excessively conservative. The following load combination, derived similarly to Eqs. CC-1a and CC-1b, can be used to check short-term effects:

$$\boxed{D + 0.5L + W_a} \quad \text{(CC-3)}$$

in which W_a is wind load based on serviceability wind speeds in Figs. CC-1 through CC-4. Some designers have used a 10-year MRI (annual probability of 0.1) for checking drift under wind loads for typical buildings (Griffis 1993), whereas others have used a 50-year MRI (annual probability of 0.02) or a 100-year MRI (annual probability of 0.01) for more drift-sensitive buildings. The selection of the MRI for serviceability evaluation is a matter of engineering judgment that should be exercised in consultation with the building client.

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Risk Category I

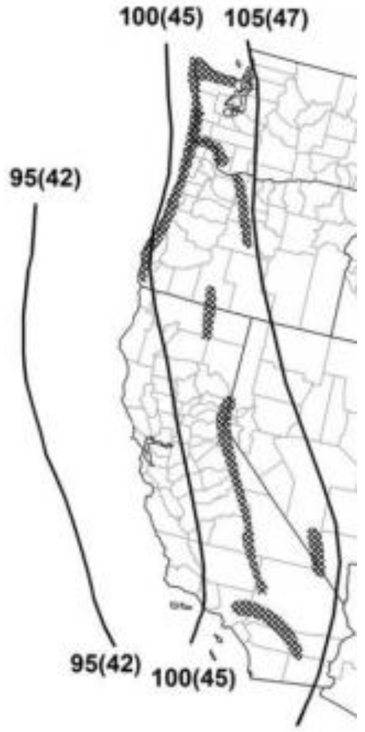
300-year return period

Risk Category II

700-year return period

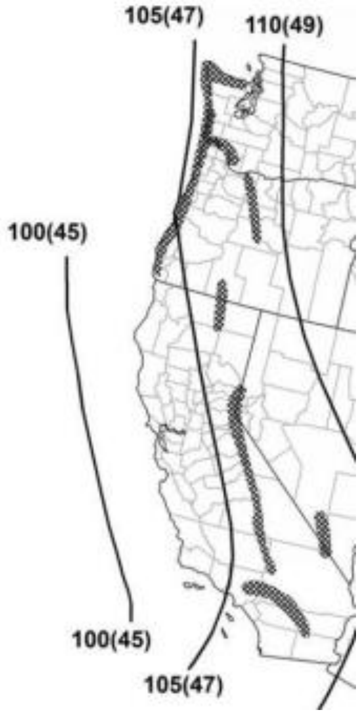
Risk Category III

1,700-year return period



Risk Category IV

3,000-year return period



Drift

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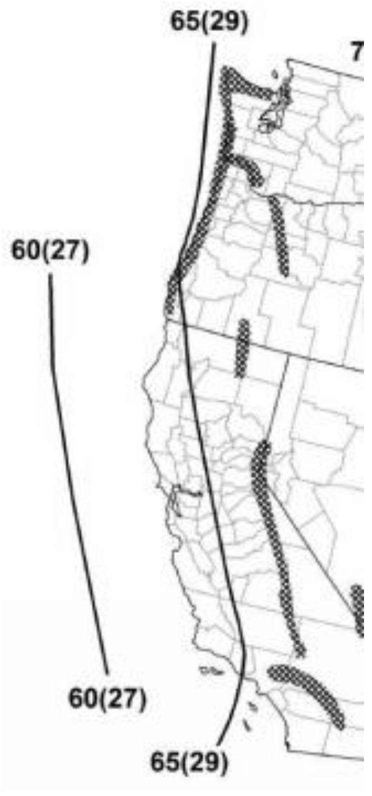
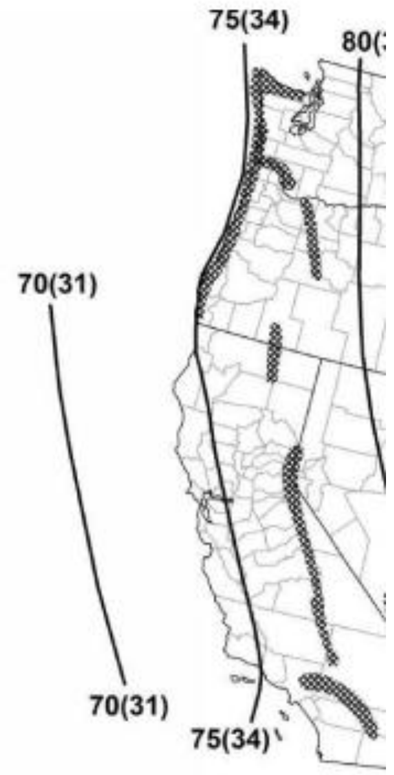
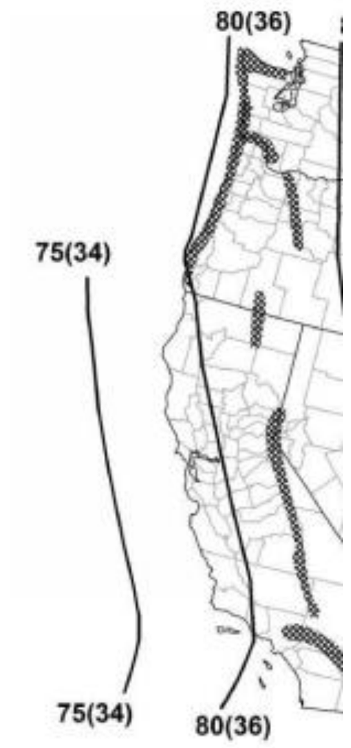


10-year return period

25-year return period



50-year return period



100-year return period

Drift

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TABLE 1604.3
DEFLECTION LIMITS[a, b, c, h, i]

CONSTRUCTION	L	E, S or W[f]	$D + L$[d, g]
Roof members:[e]			
Supporting plaster or stucco ceiling	l/360	l/360	l/240
Supporting nonplaster ceiling	l/240	l/240	l/180
Not supporting ceiling	l/180	l/180	l/120
Floor members	l/360	—	l/240
Exterior walls:			
With plaster or stucco finishes	—	l/360	—
With other brittle finishes	—	l/240	—
With flexible finishes	—	l/120	—
Interior partitions:[b]			
With plaster or stucco finishes	l/360	—	—
With other brittle finishes	l/240	—	—
With flexible finishes	l/120	—	—
Farm buildings	—	—	l/180
Greenhouses	—	—	l/120

For SI: 1 foot = 304.8 mm.

a. For structural roofing and siding made of formed metal sheets, the total load deflection shall not exceed l/60. For secondary roof structural members supporting formed metal roofing, the live load deflection shall not exceed l/150. For secondary wall members supporting formed metal siding, the design wind load deflection shall not exceed l/90. For roofs, this exception only applies when the metal sheets have no roof covering.

b. Flexible, folding and portable partitions are not governed by the provisions of this section. The deflection criterion for interior partitions is based on the horizontal load defined in Section 1607.14.

c. See Section 2403 for glass supports.

d. The deflection limit for the $D+L$ load combination only applies to the deflection due to the creep component of long-term dead load deflection plus the short-term live load deflection. For wood structural members that are dry at time of installation and used under dry conditions in accordance with the AWC NDS, the creep component of the long-term deflection shall be permitted to be estimated as the immediate dead load deflection resulting from $0.5D$. For wood structural members at all other moisture conditions, the creep component of the long-term deflection is permitted to be estimated as the immediate dead load deflection resulting from D. The value of $0.5D$ shall not be used in combination with AWC NDS provisions for long-term loading.

e. The above deflections do not ensure against ponding. Roofs that do not have sufficient slope or camber to ensure adequate drainage shall be investigated for ponding. See Section 1611 for rain and ponding requirements and Section 1503.4 for roof drainage requirements.

f. The wind load is permitted to be taken as 0.42 times the "component and cladding" loads for the purpose of determining deflection limits herein. Where members support glass in accordance with Section 2403 using the deflection limit therein, the wind load shall be no less than 0.6 times the "component and cladding" loads for the purpose of determining deflection.

g. For steel structural members, the dead load shall be taken as zero.

h. For aluminum structural members or aluminum panels used in skylights and sloped glazing framing, roofs or walls of sunroom additions or patio covers not supporting edge of glass or aluminum sandwich panels, the total load deflection shall not exceed l/60. For continuous aluminum structural members supporting edge of glass, the total load deflection shall not exceed l/175 for each glass lite or l/60 for the entire length of the member, whichever is more stringent. For aluminum sandwich panels used in roofs or walls of sunroom additions or patio covers, the total load deflection shall not exceed l/120.

i. For cantilever members, l shall be taken as twice the length of the cantilever.

"Wind load 0.42 C&C for deflection"

MWFRS or C&C

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Main Wind-Force Resisting System (MWFRS)

An assemblage of structural elements assigned to provide support and stability for the overall building or other structure. The system generally receives wind loading from more than one surface

- Examples: Moment frames, braced frames, shear walls, diaphragms.

Components and Cladding (C&C)

Elements of the building envelope or elements of building appurtenances and rooftop structures and equipment that do not qualify as part of the MWFRS.

Elements of the structure that support local peak loads.

The magnitude of the force is dependent on the wind area.

tributary to the component.

- The smaller the tributary area of a component the more
  likely to see relatively high pressures on their tributary areas.
- Examples: Metal studs, fasteners, purlins, girts.

MWFRS or C&C

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- Tornados
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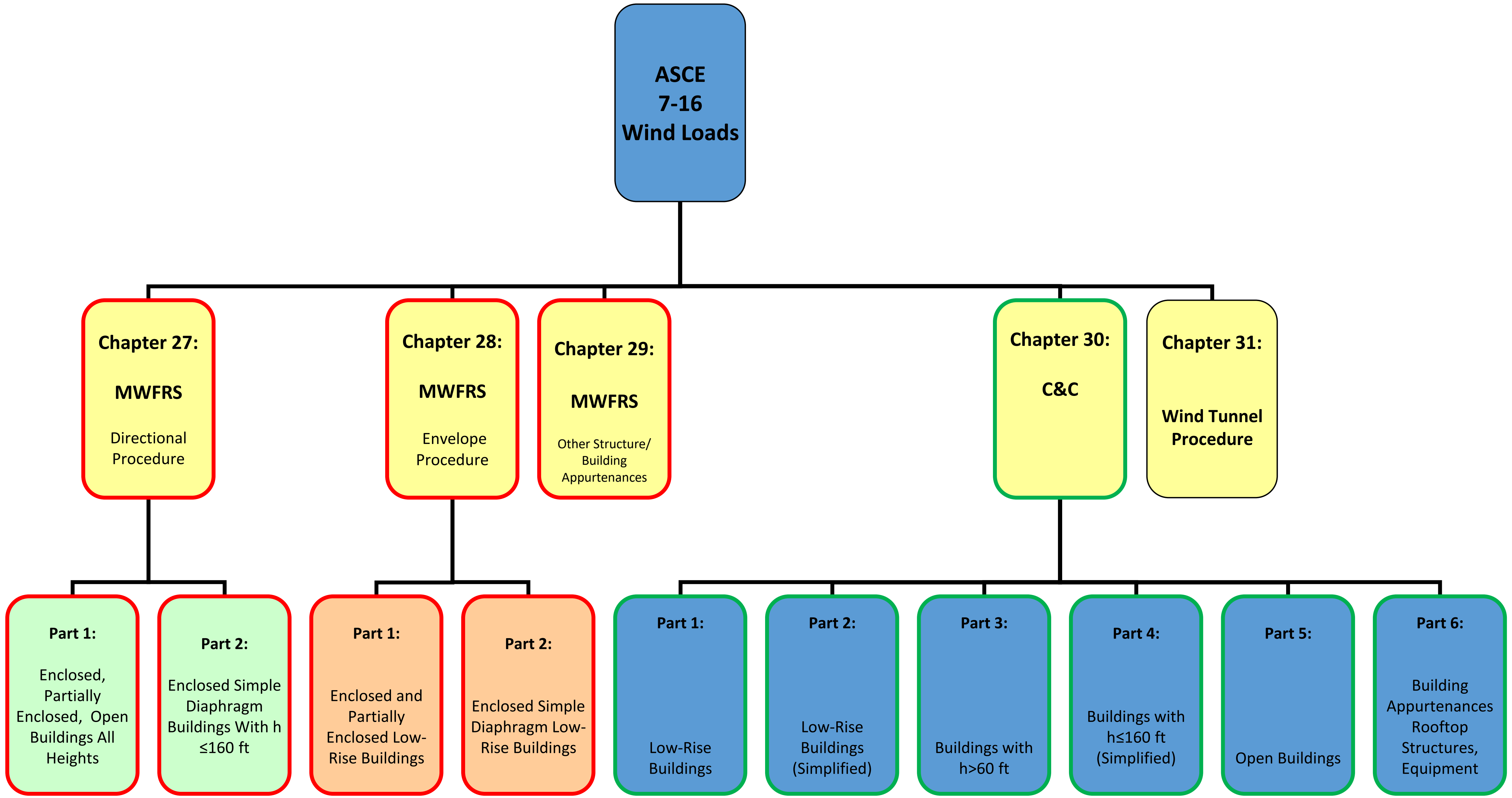

Tornados

Agenda:

Seismic:
- Basic Principles
- Irregularities
- Redundancy
- Nonstructural
- Functional Recovery

Wind:
- Analysis Procedures
- Drift
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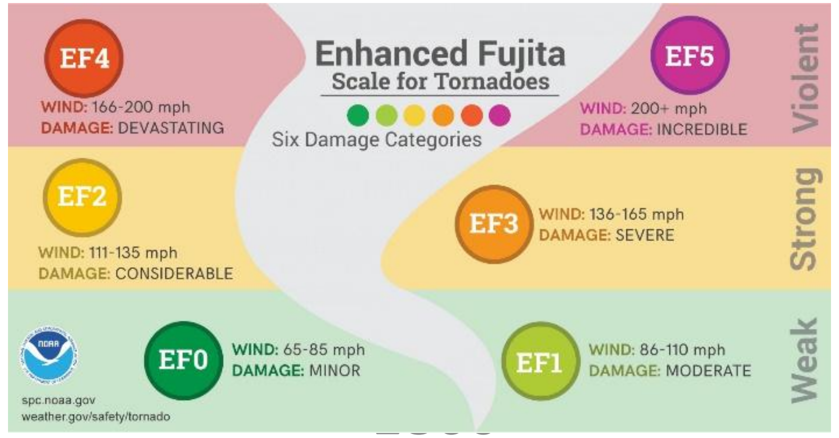
- Joplin tornado → NIST research
- EF 2 intensity or less.
- Not for storm shelters, safe room
- Tornado loads ≠ Straight line wind loads
    - Vertical updrafts
    - Atmospheric pressure changes
    - Rate of change of wind direction
    - Combine differently with other environmental loads
    - Dependent on the plan size
    - Glazing protection

Two tornadoes over the Great Plains.
(NOAA Legacy Photo; OAR/ERL/Wave Propagation Laboratory)



Agenda:

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Tornados

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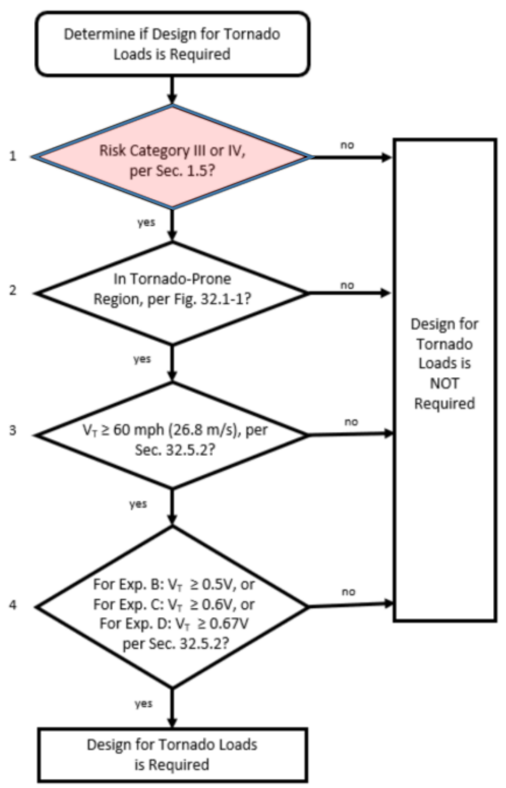

FIGURE 32.1-2 Flowchart of Process for Determining when Design for Tornado Loads is Required

Risk Category I and II structures.

Tornados

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Seismic:
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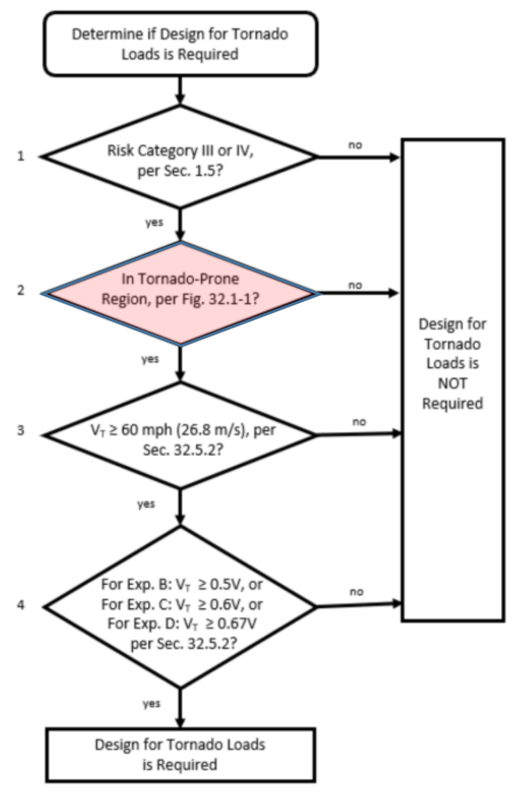

FIGURE 32.1-2 Flowchart of Process for Determining when Design for Tornado Loads is Required

Outside tornado-prone region?

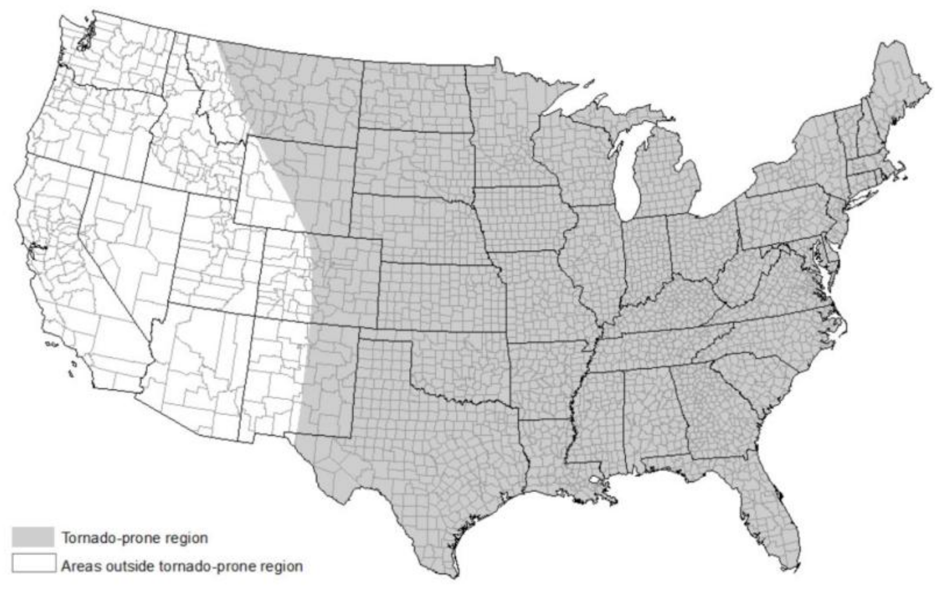

Figure 32.1-1 Tornado-Prone Region

Agenda:

Seismic:
- Basic Principles
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Tornados

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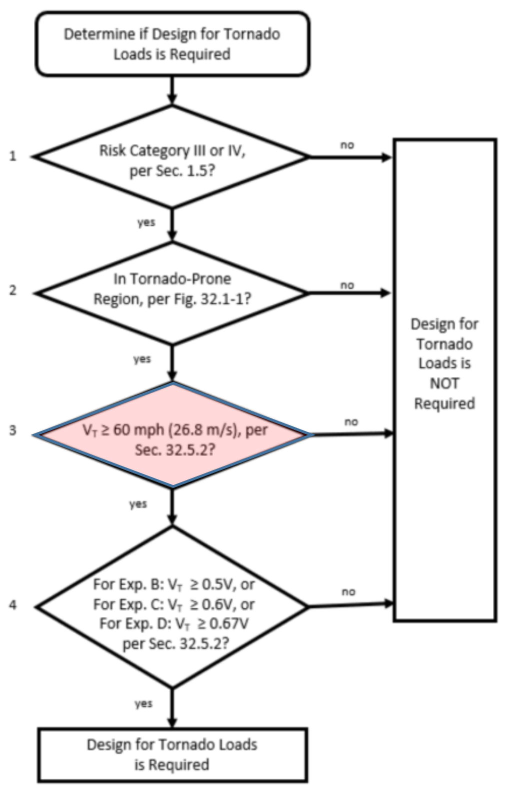


FIGURE 32.1-2 Flowchart of Process for Determining when Design for Tornado Loads is Required

V_T <60 mph (function of location, RC, plan area).

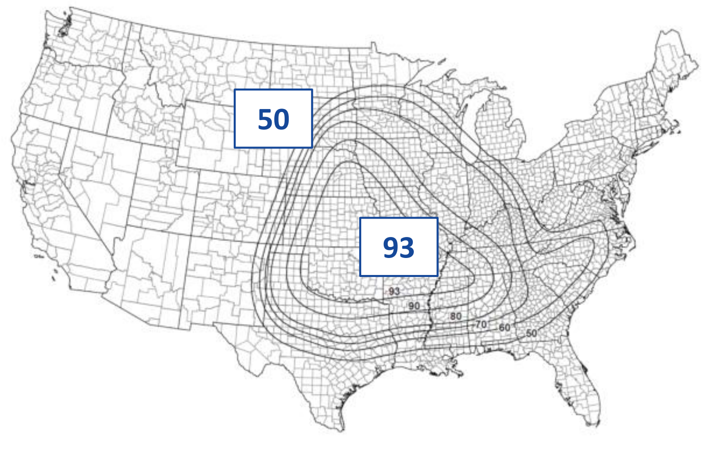


FIGURE 32.5-1E Tornado Speeds for Risk Category III Buildings and Other Structures, for Effective Plan Area of 100,000 ft² (9,290 m²)

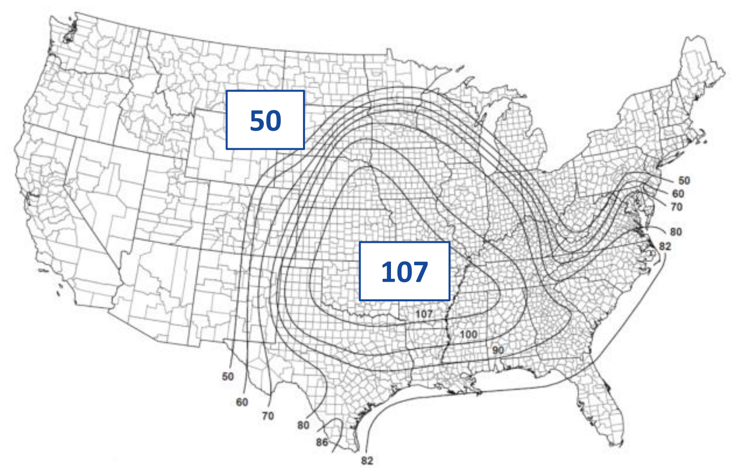
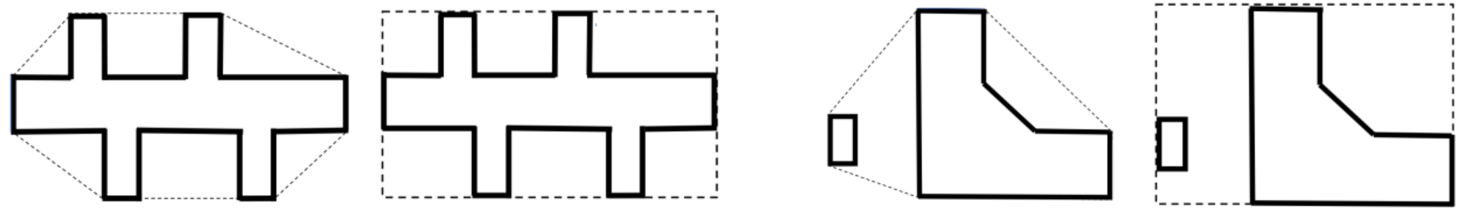


FIGURE 32.5-1E Tornado Speeds for Risk Category IV Buildings and Other Structures, for Effective Plan Area of 100,000 ft² (9,290 m²)



Agenda:

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Tornados

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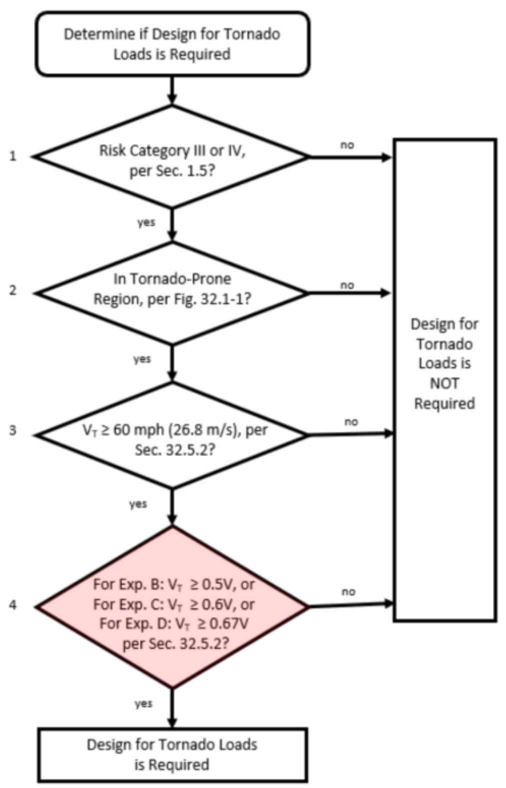

FIGURE 32.1-2 Flowchart of Process for Determining when Design for Tornado Loads is Required

Compare V_T to V.

- Exp. B: $V_T < 0.5V$
- Exp. C: $V_T < 0.6V$
- Exp. D: $V_T < 0.67V$

Tornados

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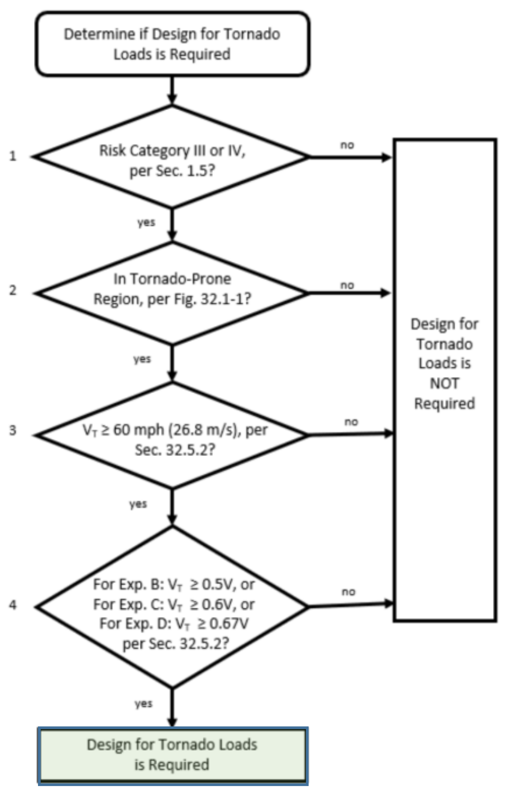

FIGURE 32.1-2 Flowchart of Process for Determining when Design for Tornado Loads is Required

- **Tornado velocity pressure**

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

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

- **MWFRS loads**

$$p_T = q G_T K_{dT} K_{vT} C_p - q_i (GC_{piT}) \quad (\text{lb/ft}^2)$$

$$p_T = q G_T K_{dT} K_{vT} C_p - q_i (GC_{piT}) \quad (\text{N/m}^2)$$

Performance Based Design

Agenda:

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- Nonstructural
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- Drift
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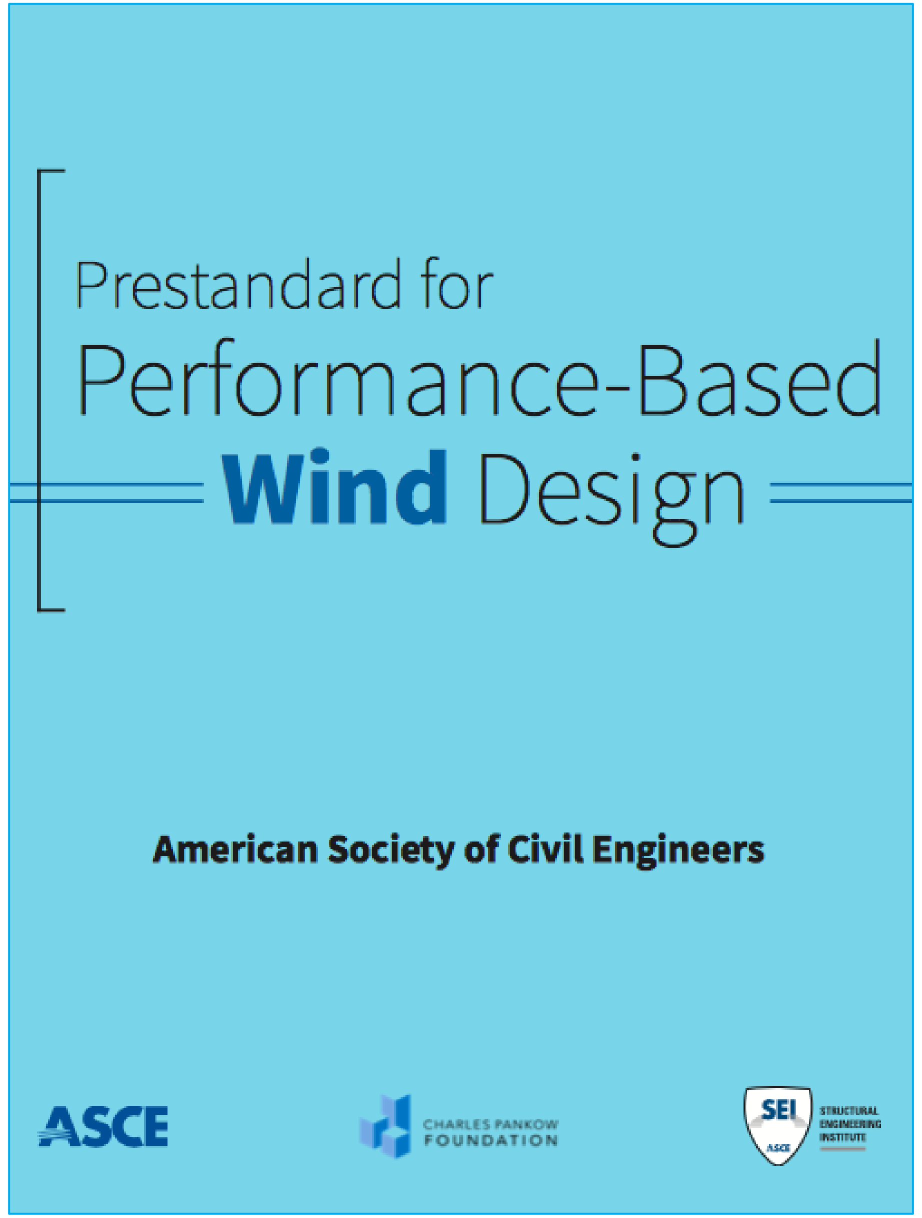
- Performance Based Design



Gracias por su atención

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INSTITUTO DE LA CONSTRUCCIÓN

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