City of Huntington Beach

Department of Building & Safety

SEISMIC DESIGN GUIDELINES

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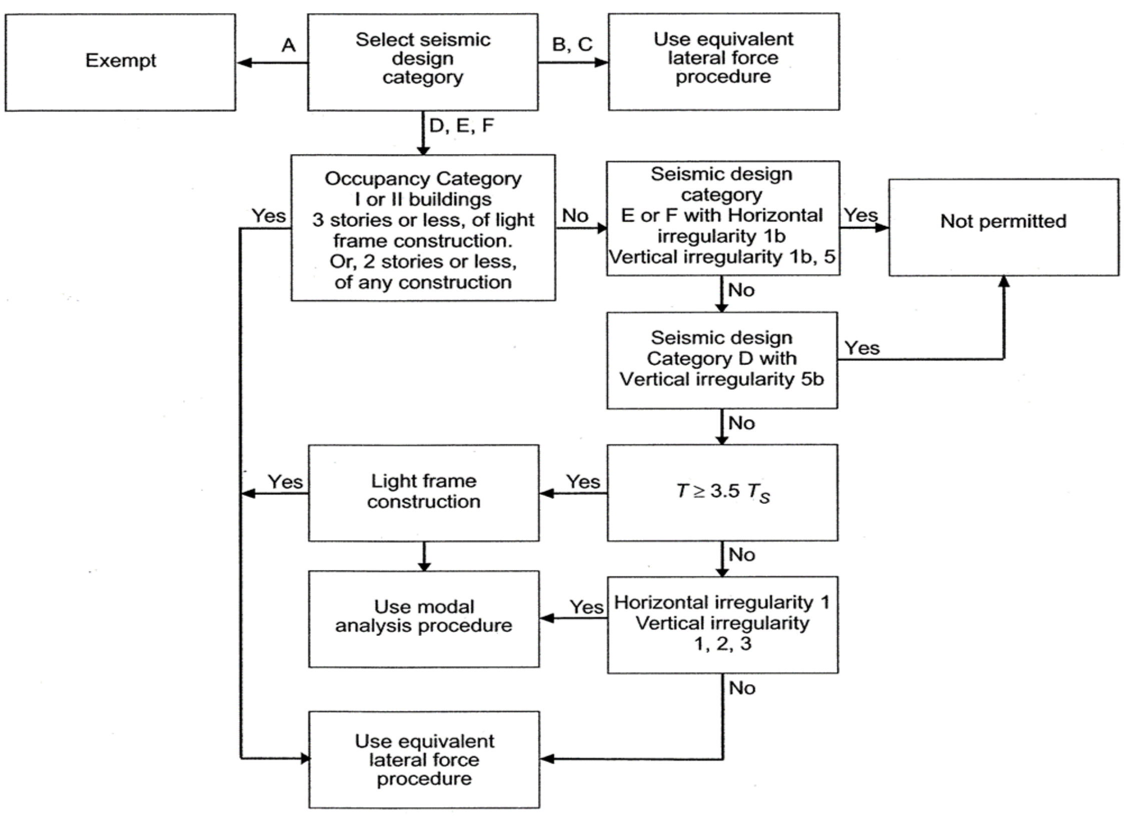
2007 CBC STRUCTURAL PROVISIONS - SEISMIC

The Building Code in general references other standards such as ASCE 7, ACI, AISC, etc. for structural provisions. However, if there are overlaps, the provisions of CBC supersede the standards' provisions (i.e. Occupancy Category tables and Load Combinations).

According to the CBC Section 1613.1, the seismic design of all structures may be accomplished by using the provisions of ASCE with the exception of ASCE Chapter 14 (material-specific seismic design and detailing requirements, which have been mostly incorporated in chapters 18-23 of the CBC) and ASCE Appendix 11A (dealing with quality assurance provisions, which is covered in chapter 17 of CBC).

Seismic Base Shear Determination Steps

Selection of Lateral-Force Procedure:



Selection of analysis procedure

<table>
<tr><td rowspan="5">Step 1.</td><td colspan="2">Determine if exceptions applies:</td><td rowspan="5">CBC Sec. 1613.1</td></tr>
<tr><td>1.</td><td>Detached one- and two-family dwellings, assigned to SDC A, B or C, or located where the mapped short-period spectral response acceleration, Ss ≤ 0.4g.</td></tr>
<tr><td>2.</td><td>The seismic-force-resisting system of wood-frame buildings that conform to the provisions of Section 2308 (Conventional Light Framed Construction).</td></tr>
<tr><td>3.</td><td>Agricultural storage structures intended only for incidental human occupancy.</td></tr>
<tr><td>4.</td><td>Vehicular bridges, electrical transmission tower, hydraulic structures, buried utility lines, etc.</td></tr>
<tr><td>Step 2.</td><td colspan="2">Determine the Occupancy Category of the building
<table>
<tr><th>Occupancy Category</th><th>Nature of Occupancy</th></tr>
<tr><td>I</td><td>Minor storage, agricultural & Temp facilities</td></tr>
<tr><td>II</td><td>Normal buildings</td></tr>
<tr><td>III</td><td>▪ Schools
▪ Public Assembly > 300 occupants
▪ Any building > 5,000 occupants
▪ Hazardous occupancies
▪ Etc...</td></tr>
<tr><td>IV</td><td>Hospitals, Fire / Rescue / Police stations, Emergency preparedness, etc…</td></tr>
</table></td><td>CBC Table 1604.5
<u>Note:</u> Do not use ASCE Table 1-1</td></tr>
<tr><td rowspan="5">Step 3.</td><td colspan="2">MCE - Maximum considered earthquake spectral acceleration - Ss & S₁:</td><td rowspan="5"></td></tr>
<tr><td>Ss =</td><td>Mapped maximum considered earthquake spectral acceleration at 0.2 seconds</td></tr>
<tr><td>S₁ =</td><td>Mapped maximum considered earthquake spectral acceleration at 1.0 seconds</td></tr>
<tr><td>1.</td><td>Get the “Latitude” & “Longitude” for the site from: www.terraserver.microsoft.com or
www.geocoder.us
http://stevemorse.org/jcal/latlon.php</td></tr>
<tr><td>2.</td><td>Go to USGS website at:
http://earthquake.usgs.gov/research/hazmaps/design/
and install "Java Ground Motion Parameter Calculator - Version 5.0.8”
• On the very top right corner use the pull down menu to choose the appropriate Code (in this case IBC 2006)
• Enter the Latitude/Longitude to get the result
• Based on Dr. S.K. Ghosh suggestion, entering the Latitude/Longitude will result in a more accurate output.</td></tr>
</table>

Step 4.	Determine **Site Class** (A → F) • Default Site Class = D (unless B.O. determines Site Class E or F is likely present at the site)		Section 1613.5.2 Table 1613.5.2
Step 5.	**Site coefficients Fa & Fv**: (amplification factors applied to the MCE response parameters):		
	Fa =	Site coefficient at short periods (function of Site Class A-F & Ss)	2007 CBC Table 1613.5.3(1) ASCE 7-05 Table 11.4-1

Site Coefficient Fa corresponding to Ss

Site Class	Response Acceleration, Ss				
	≤ 0.25	0.50	0.75	1.00	≥ 1.25
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	(a)	(a)	(a)	(a)	(a)

Note: (a) Site-specific geotechnical investigation & dynamic site response analysis req'd, except T < 0.5 s

	Fv =	Site coefficient at 1 second period (function of Site Class A - F & S1)	2007 CBC Table 1613.5.3(2) ASCE 7-05 Table 11.4-2

Site Coefficient Fv corresponding to S1

Site Class	Response Acceleration, S1				
	≤ 0.1	0.2	0.3	0.4	≥ 0.5
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	(a)	(a)	(a)	(a)	(a)

Note: (a) Site-specific geotechnical investigation & dynamic site response analysis req'd, except T < 0.5 s

Step 6.	**Adjusted MCE spectral response acceleration - S_{MS} & S_{M1}:**		ASCE 7-05 Eq. 11.4-1 & 11.4-2
	S_{MS} =	MCE spectral response acceleration at 0.2 second period adjusted for Site Class S_{MS} = Fa (Ss)	2007 CBC Equation 16-37 ASCE 7-07 Equation 11.4-1
	S_{M1} =	MCE spectral response acceleration at 1 second period adjusted for Site Class S_{M1} = Fv (S1)	2007 CBC Equation 16-38 ASCE 7-05 Equation 11.4-2
Step 7.	**Design Spectral Response Acceleration Parameters - S_{DS} & S_D:**		
	S_{DS} =	5% damped design spectral response acceleration at 0.2 second period S_{DS} = 2/3 (S_{MS}) = 2/3 (Fa Ss)	ASCE 7-05 Equation 11.4-3

	S_{D1} =	5% damped design spectral response acceleration at 1 second period $S_{D1} = 2/3 (S_{M1}) = 2/3 (Fv\ S_1)$ Note: If $S_1 \geq 0.75$, then structure shall be assigned to SDC "E" or "F" (see Step 8 below)	ASCE 7-05 Equation 11.4-4
Step 8.	Determine the **Seismic Design Category** A thru D *Note:* The more severe of the two SDC governs the design:		
	1.	SDC based on short period accelerations (function of S_{DS} & Occupancy Category)	Table 1613.5.6(1) ASCE Table 11.6-1

Value of S_{DS}	Occupancy Category		
	I or II	III	IV
$S_{DS} < 0.16g$	A	A	A
$0.16g \leq S_{DS} < 0.33g$	B	B	C
$0.33g \leq S_{DS} < 0.50g$	C	C	D
$S_{DS} \geq 0.50g$	D	D	D

	2.	SDC based on 1 second period accelerations (function of S_{D1} & Occupancy Category)	Table 1613.5.6(2) ASCE Table 11.6-2

Value of S_{D1}	Occupancy Category		
	I or II	III	IV
$S_{D1} < 0.067g$	A	A	A
$0.067g \leq S_{D1} < 0.133g$	B	B	C
$0.133g \leq S_{D1} < 0.20g$	C	C	D
$S_{D1} \geq 0.20g$	D	D	D
$S_{D1} \geq 0.75g$	E	E	F

	3.	Determine the Seismic Design Category E or F: • SDC "E" for Occupancy I, II or III with mapped • $S_1 > 0.75g$ • SDC "F" for Occupancy IV with mapped $S_1 > 0.75g$	CBC 1613.5.6 ASCE Sec 11.6

Value of S_1	Occupancy Category		
	I or II	III	IV
$S_1 \geq 0.75g$	E	E	F

__Note:__ Many near-fault sites have $S_1 \geq 0.75g$

Step 9. Determine the *minimum* permissible analysis procedure:

ASCE Table 12.6-1 – Analysis Procedures

SDC	Structure Description	Minimum Analysis
A	All structures	Minimum Lateral Force (ASCE 11.7)
B & C	Occupancy Category I or II • Up to 3-story buildings • Bearing wall or building frame only	Simplified Analysis (ASCE 12.14)
	All other structures	Equivalent-Lateral-Force (ASCE 12.8)
D, E & F	Occupancy Category I or II • Up to 3-story buildings • Bearing wall or building frame only	Simplified Analysis (ASCE 12.14)
	Regular structures with $T < 3.5\ T_s$ All structures of light-frame Irregular structures with $T < 3.5T_s$ & • Vertical irregularity Type 4 or 5 • Plan irregularity Type 2,3,4 or 5	Equivalent-Lateral-Force (ASCE 12.8)
	All other structures	Dynamic Analysis (ASCE 12.9)

Step 10. **A. Simplified Analysis**:

ASCE 7-05
Section 12.14.1.1

I. Seismic Base Shear - ASCE 12.14.8.1

$V = (FS_{DS}/R)\ W$ (ASCE Equation 12.14-11)

$S_{DS} = (2/3)\ F_aS_s$ Where $S_s \leq 1.5g$

- F = 1.0, 1.1 and 1.2 for one-story, two-story and three-story buildings respectively
- R = response modification factors from Table 12.14-1
- W = Effective seismic weight of structure and other loads as follows:
  - Warehouses → minimum of 25% of floor live load
  - Partition load → 10 psf (see ASCE 12.14.8.1)
  - Snow load > 30 psf → 20% (see ASCE 12.14.8.1)
  - Permanent equipment → 100% dead load

II. Vertical Distribution - ASCE 12.14.8.2

$F_x = (W_x/W)\ V$ (ASCE Equation 12.14-11)

- W_x = portion of effective seismic weight at level x

Also for Simplified Design:

- $\rho = 1.0$
- $\Omega = 2.5$

Note: The Simplified Design procedure is permitted to be used if the following limitations are met:

	1. The structure shall qualify for Occupancy Category I or II. 2. The site class shall not be E or F. 3. Structure shall not exceed 3 stories in height above grade. 4. The seismic-force resisting system shall be either a bearing wall system or a building frame system. 5. Structure shall have at least two lines of Lateral resistance in each of two principal axis directions. 6. At least one line of resistance shall be provided on each side of the center of mass in each direction. 7. For structures with flexible diaphragms, overhangs beyond the outside line of shear walls or braced frames shall satisfy: $a \le d/5$ 8. For buildings with diaphragm that is not flexible, distance between the center of rigidity and center of mass parallel to each principal axis shall not exceed 15% of greatest width of diaphragm parallel to that axis. 9. Lines of resistance of the lateral-force-resisting system shall be oriented at angles of no more than 15 degrees from alignment with the principal axes. 10. The simplest design procedure shall be used along each principal axis of building. 11. System irregularities caused by in-plane or out-of-plane offset of lateral-force-resisting elements shall not be permitted (Exception: two-story buildings of light-frame construction). 12. The lateral-load-resistance of any story shall not be less than 89% of that of that of the story above.	
	B. Equivalent-Lateral-Force Procedure **I. Seismic Base Shear** - ASCE 12.8.1 $V = C_s W$ Where… C_s = Seismic response coefficient determined per 12.8.1.1 $C_s = S_{DS} / (R/I_E)$ (ASCE Equation 12.8-2) But need not exceed… $\le S_{DS} / T\ (R/I_E)$ for $T \le T_L$ (ASCE Equation 12.8-3) $\le S_{D1}\ T_L / T^2\ (R/I_E)$ for $T > T_L$ (ASCE Equation 12.8-4) But not less than… ≥ 0.01 (ASCE Equation 12.8-5) $\ge 0.5 S_1 / (R/I_E)$ where $S_1 \ge 0.6g$ (ASCE Equation 12.8-6) S_{DS} = Design spectral response acceleration at short periods I_E = Occupancy importance factor (see Step 11) R = Response modification factor (see Step 12) T = Fundamental period of the structure (see Step 13) $T_s = S_{D1} / S_{DS}$ T_L = Long-period transition period (ASCE Figure 22-15) = 8 or 12 seconds	ASCE 7-05 Section 12.8

	II. Vertical Distribution - ASCE 12.8.3 $Fx = Cvx\ V$ (ASCE Equation 12.8-11) And… $C_{vx} = wx\ hx^{K} / \sum wi\ hi^{K}$ (ASCE Equation 12.8-12) Where… C_{vx} = Vertical distribution factor V = Total design lateral force or shear at the base wi and wx = The portion of the total effective seismic weight of the structure (W) located or assigned to Level i or x hi and hx = The height from the base to Level i or x K = An exponent related to the structure period as follows: K = 1 where T ≤ 0.5 sec K = 2 where T ≥ 2.5 sec K = 2 where 0.5<T< 2.5 = or linear interpolation between 1 & 2 **III. Horizontal Distribution** - ASCE 12.8.4 $Vx = \sum Fi$ (ASCE Equation 12.8-13) Where… Fi = The portion of the seismic base shear (V) induced at Level i *Note:* See ASCE Section 12.8.4: Seismic design story shear to be distributed to vertical elements based on the vertical resisting element and the diaphragm. • "Flexible" Diaphragms: Story shear to be distributed based on the tributary area. • "Rigid" Diaphragm: Story shear to be distributed based on relative stiffness. Rigid diaphragm must include: ▪ Inherent Torsion ASCE Section 12.8.4.1 ▪ Accidental Torsion ASCE Section 12.8.4.2	
Step 11.	**Occupancy Importance Factor (I_E)**	ASCE Table 11.5.1

Occupancy Category	I_E
I or II	1.0
III	1.25
IV	1.5

Step 12.	**Response modification factor**	ASCE Table 12.2-1

Step 13. **Structure Period (T)**

ASCE 7-05
Section 12.8.2

Approximate Formula
$Ta = C_t (h_n)^x$ (ASCE Equation 12.8-7)

Where…
h_n = building height in feet
C_t & x from ASCE 7-05 Table 12.8-2

Structure Type	C_t	x
Steel moment frames	0.028	0.8
Concrete moment frames	0.016	0.9
Eccentrically braced frames	0.03	0.75
All other structural system	0.02	0.75

Alternatively…

- For concrete & steel moment frames ≤12 stories and ≥ 10 ft story height:
  $Ta = 0.1N$ (ASCE Equation 12.8-8)
  Where N = number of stories
- For concrete and masonry shear wall buildings:
  $Ta = (0.0019 / \sqrt{C_w})\ hn$ (Equation 12.8-9)
  Where C_w = …. (Equation 12.8-9)

Upper limit on "T" on calculated period (ASCE 12.8.2)
$T \leq C_u\ Ta$

ASCE Table 12.8-1

Design Spectral Response Acceleration parameter at 1 second, S_{D1}	Coefficient C_u
≥ 0.4	1.4
0.3	1.4
0.2	1.5
0.15	1.6
≤ 0.1	1.7

Note: For drift analysis, the upper limit on calculated (T) does not apply. (ASCE Section 12.8.6.2)

Step 14. **Diaphragms**

ASCE 7-05
Section 12.3.1

Note: Unless a diaphragm can be idealized as either flexible or rigid…, the structural analysis shall explicitly include consideration of the stiffness of the diaphragm.

		1.	**Flexible Diaphragm:** CBC Section 1602: A diaphragm is flexible for the purpose of distribution of story shear and torsional moment where so indicated in Section 12.3.1 of ASCE, as modified in Section 1613.6.1. Diaphragm constructed of wood structural panels or untopped steel decking shall also be permitted to be idealized as flexible, provided *ALL* of the following conditions are met: 1. Topping of concrete are not placed over wood structural panel, except for nonstructural topping no greater than 1-1/2" thick. 2. Each line of vertical elements of the LFRS complies with the allowable story drift of ASCE Table 12.12-1. 3. Vertical elements of the LFRS are light-framed walls sheathed with wood structural panels. 4. Portions of wood structural panel diaphragms that cantilever beyond the vertical elements of the LFRS are designed per CBC 2305.2.5.	ASCE 7-05 Section 12.3.1.1

ASCE Table 12.12-1: Allowable Story Drift

Structure	Occupancy Category		
	I or II	III	IV
Buildings, other than masonry shear wall buildings, of 4 stories or less with fittings designed to accommodate drift	$0.025h_{sx}$	$0.020h_{sx}$	$0.015h_{sx}$
Masonry cantilever shear wall	$0.010h_{sx}$	$0.010h_{sx}$	$0.010h_{sx}$
Other masonry shear walls	$0.007h_{sx}$	$0.007h_{sx}$	$0.007h_{sx}$
All other buildings	$0.020h_{sx}$	$0.015h_{sx}$	$0.010h_{sx}$

Note: Diaphragms of wood structural panels or untopped steel decks in one and two-family residential buildings of light-frame construction shall also be permitted to be idealized as flexible.

<table>
<tr><td></td><td>2.</td><td>Rigid Diaphragm:

CBC Section 1602: A diaphragm is rigid for the purpose of distribution of story shear and torsional moment when the lateral deformation of the diaphragm is ≤ to 2 x the average story drift: $\delta > 2(\Delta)$

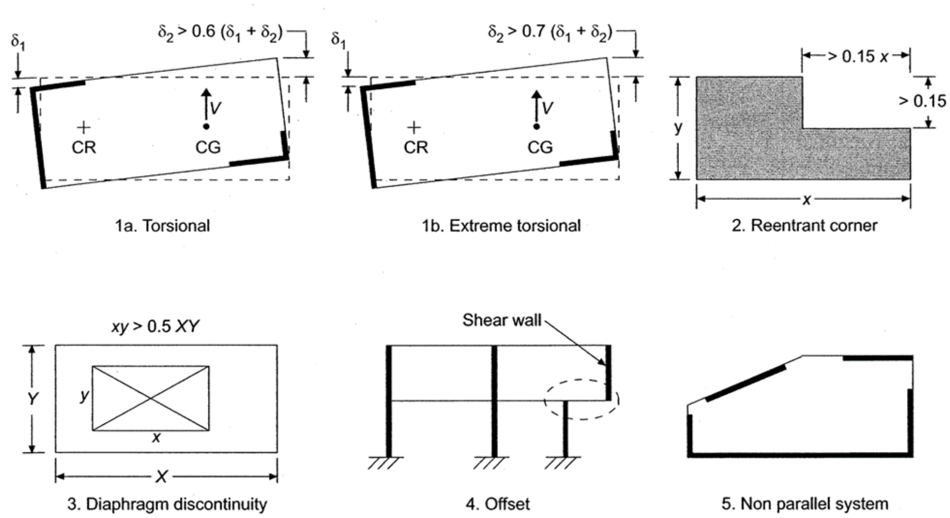
ASCE Section 12.3.1.2: Diaphragms of concrete slabs or concrete filled steel decking, with span-to-depth ratio of ≤ 3, that have no “horizontal irregularities” are permitted to be idealized as “rigid”.</td><td>ASCE 7-05
Section 12.3.1.2</td></tr>
<tr><td>Step 15.</td><td colspan="2">Redundancy Factor, ρ

• Limited to SDC D thru F
• Separate ρ – factor is determined for each direction.
• ρ = 1 if loss or removal of any one element would not result in more than a 33% reduction in story strength, for any story resisting more than 35% of the base shear.
• Otherwise, ρ = 1.3.</td><td>ASCE 12.3.4
ASCE T-12.3.4.1</td></tr>
<tr><td>Step 16.</td><td colspan="3">Horizontal Irregularities: ASCE Section 12.3.2.1

There are six “Horizontal Irregularities” as illustrated below:

1a. Torsional irregularity
1b. Extreme torsional irregularity
2. Re-entrant corners
3. Diaphragm discontinuity
4. Out-of-Plane offsets
5. Nonparallel systems

<u>Note:</u> See ASCE 7-05 for design requirements that are imposed on structures with horizontal irregularities, depending on their design category.



Horizontal structural irregularities</td></tr>
</table>

Step 17. **Vertical Irregularities:** ASCE Section 12.3.2.2

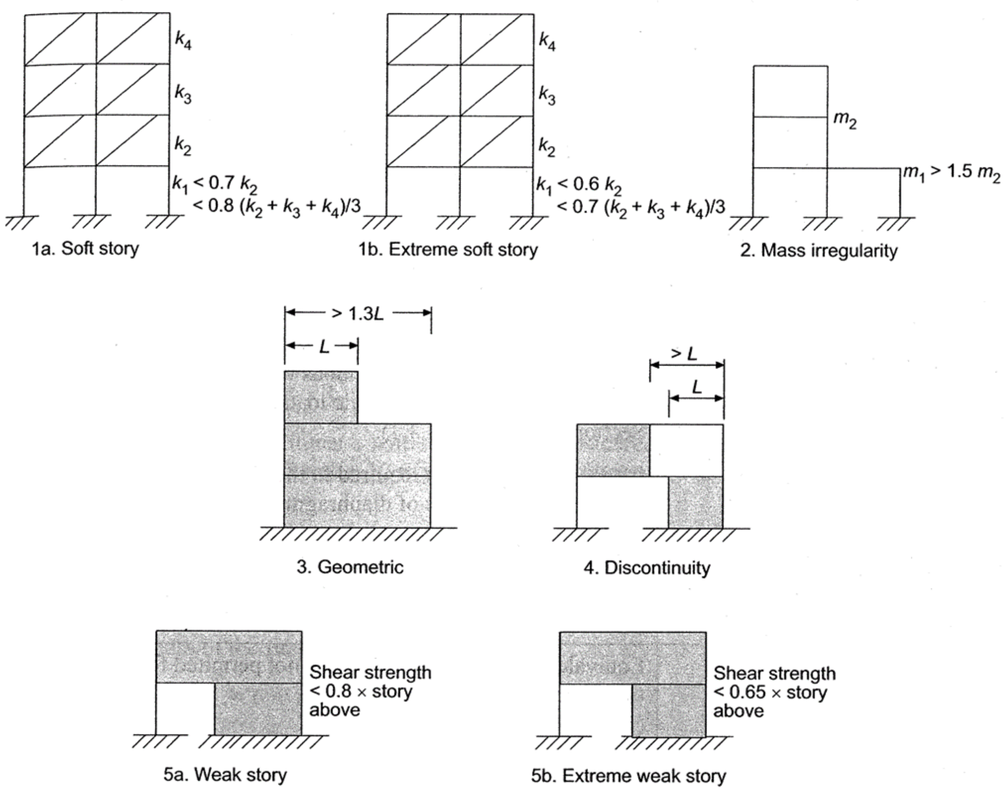
There are six "*Vertical Irregularities*" as illustrated below:

- 1a. Soft story
- 1b. Extreme soft story
- 2. Mass irregularity
- 3. Geometric irregularity
- 4. In-plane discontinuity
- 5a. Weak story
- 5b. Extreme weak story

Note: See ASCE 7-05 for design requirements that are imposed on structures with horizontal irregularities, depending on their design category.

Exceptions:

1. ASCE 12.3.2.2 exempts one-story buildings in any SDC and two-story buildings in SDC A through D from the consideration of vertical irregularity types 1a, 1b, and 2.
2. These irregularities may also be ignored when no story drift ratio is greater than 130% of the story drift ratio of the next story above.



Vertical structural irregularities

Step 18.	**Drift** and **Deformation** Design story drift (ASCE Section 12.8.6) $\Delta = Cd\ \delta xe / I$ Note: ρ applied to drift limit of MRF in Design Category D – F (ASCE 12.12.1.1) Structure separation: Existing UBC "SRSS" equation is being submitted as correction for next cycle of ASCE 7-10.	ASCE 7-05 Section 12.12
Step 19.	Diaphragms, Chords, and Collectors **Diaphragm Forces**: $Fpx = (\sum Fi / \sum Wi)\ Wpx$ ASCE Formula 12.10-1 Where… $0.2\ S_{DS}\ I\ Wpx \leq Fpx = (\sum Fi / \sum Wi)\ Wpx \leq 0.4\ S_{DS}\ I\ Wpx$ Where… Fpx = the diaphragm design force Fi = the deisgn force applied to Level i Wi = the weight tributary to Level i Wpx = the weight tributary to the diaphragm at Level x *Note:* For inertia forces calculated in accordance with Eq. 12.10-1, ρ = 1 For transfer forces, ρ = same as that used for structure For structures having horizontal/vertical structural irregularities, ρ = per Section 12.3.3.4. **Collector Elements**: ASCE 12.10.2 For SDC C – F, collector elements, splices, and their connections to resisting elements shall resist the load combinations with over-strength of Section 12.4.3.2. Exception: In structures or portions thereof braced entirely by light-frame shear walls, use Section 12.10.1.1	ASCE 7-05 Section 12.10.1.1

References:

International Code Council: *2006 IBC & 2007 CBC*
American Society of Civil Engineers: *Minimum Design Loads for Buildings and Other Structures*
CALBO: "*2007 CBC – Structural Plans Examination*"
S. K. Ghosh Associates Inc.: "*Seismic Design Provisions of the California Building Code*"
Ben Yousefi & Martin Johnson: "*Transitioning to the 2007 CBC*"
Alan Williams: "*Seismic and Wind Forces – Structural Design Examples*"