Building Codes – 1997 UBC to 2000/2003 IBC

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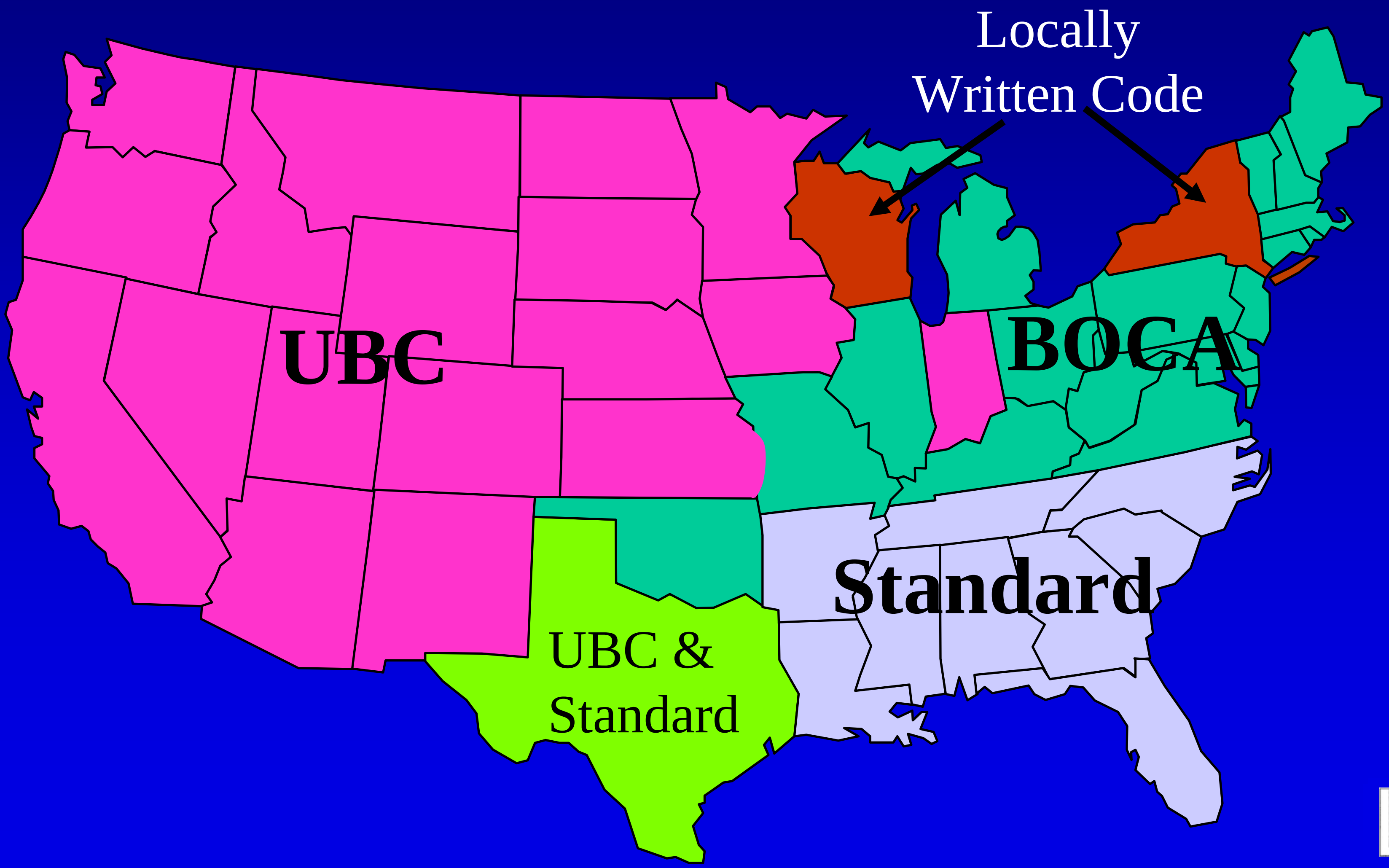
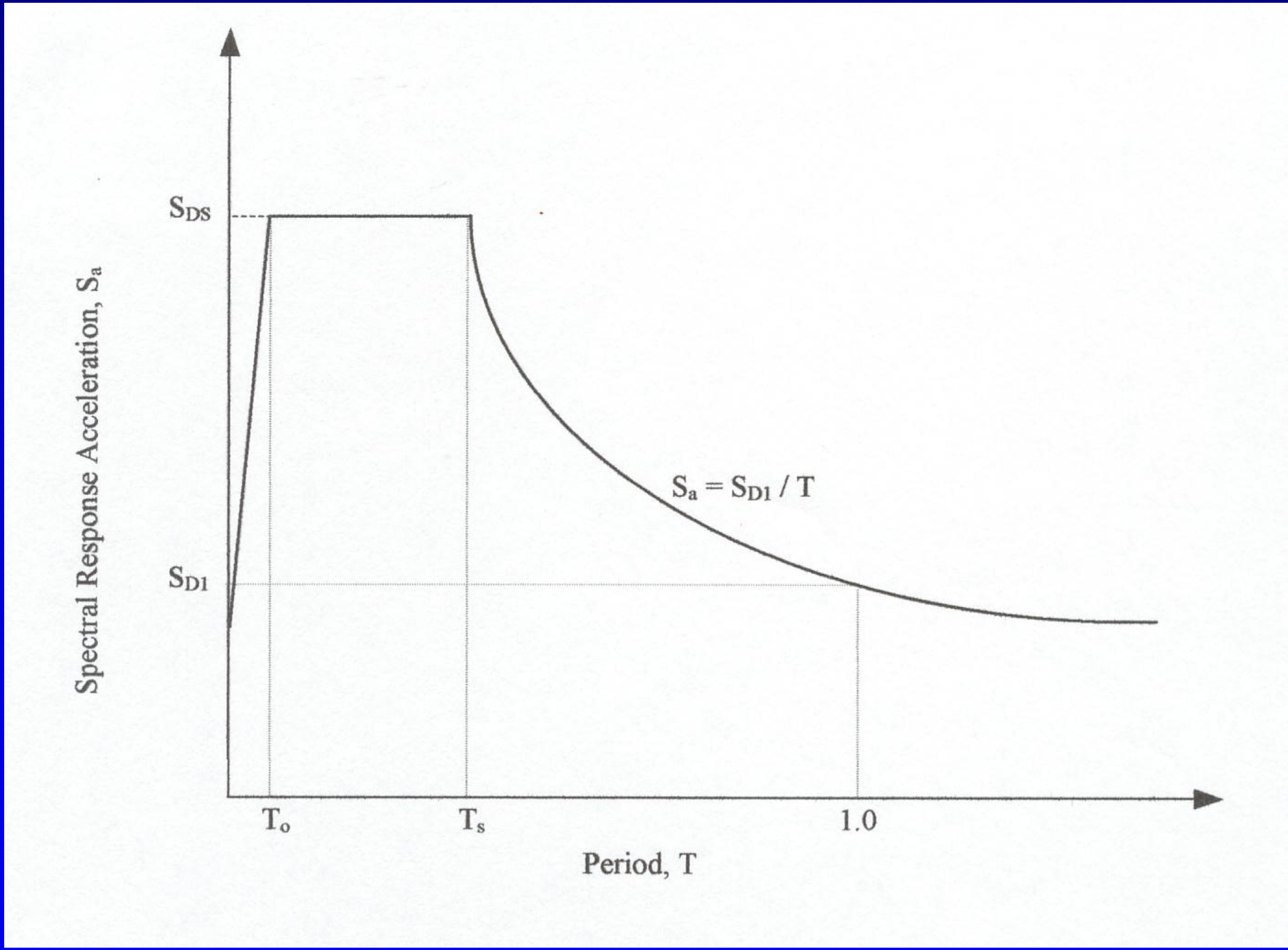
Approximate Area of Code Influences



SEISMIC INPUT PARAMETERS

General Procedure Design Spectrum



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IBC Design Ground Motion

- S_S = mapped (MCE) spectral response acceleration at short periods for Site Class B
- S_1 = mapped (MCE) spectral response acceleration at 1.0-second period for Site Class B
- ASCE 7 Figs. 9.4.1.1(a) through (j)/ IBC Figs. 1615(1) through 1615(10) give contour maps for S_S and S_1
- S_S and S_1 are also available on CD-ROM

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IBC Design Ground Motion

- **Site Class Definitions (Table 9.5.1.1/ 1615.1.1)**
  - Class A: Hard rock
  - Class B: Rock
  - Class C: Very dense soil and soft rock
  - Class D: Stiff soil
  - Class E: Soft soil
  - Class F: Soils requiring site-specific evaluations

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IBC Design Ground Motion

- Site Class D must be used when the soil properties are not known in sufficient detail, unless the building official determines that Site Class E or F is likely to be present at the site

IBC Design Ground Motion

- S_{MS} = soil-modified MCE spectral response acceleration at short periods

  $= F_a S_S$

- S_{M1} = soil-modified MCE spectral response acceleration at 1.0-second period

  $= F_v S_1$

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Table 9.4.1.2.4a/1615.1.2(1) Values of Site Coefficient F_a[a]

Site Class	Mapped Spectral Response Acc. at Short Periods				
	$S_S \leq 0.25$	$S_S = 0.5$	$S_S = 0.75$	$S_S = 1.00$	$S_S \geq 1.25$
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	Note b	Note b	Note b	Note b	Note b

Table 9.4.1.2.4b/1615.1.2(2) Values of Site Coefficient F_v[a]

Site Class	Mapped Spectral Response Acc. at 1 Second Period				
	$S_1 \le 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 \ge 0.5$
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	Note b	Note b	Note b	Note b	Note b

IBC Ground Motion

- S_{DS} = design spectral response acceleration at short periods

  $= (2/3)\ S_{MS}$

- S_{D1} = design spectral response acceleration at 1.0-second period

  $= (2/3)\ S_{M1}$

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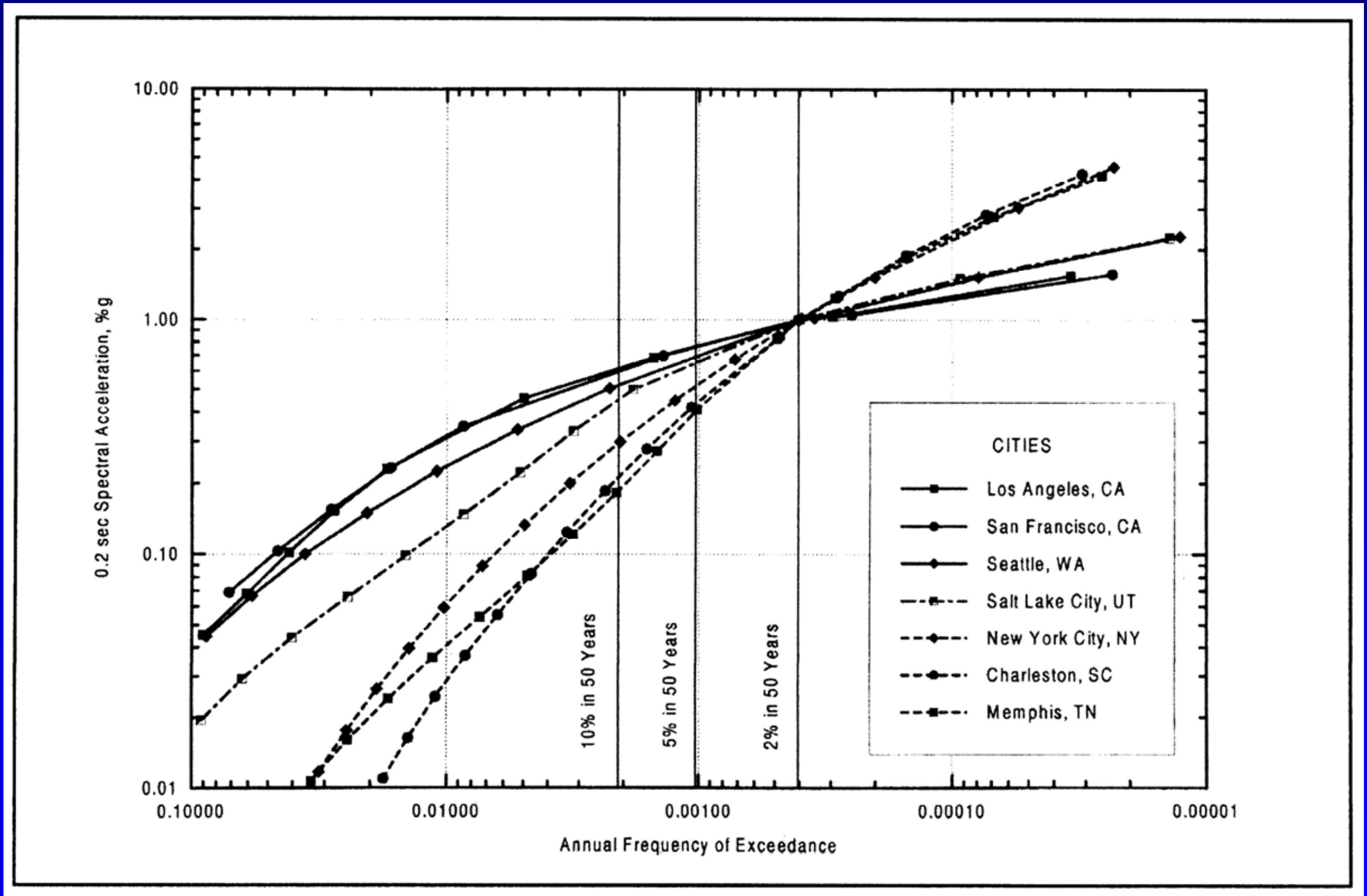
Relative Hazard at Selected Sites for 0.2s Spectral Response Acceleration



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IBC Ground Motion

- **Maximum Considered Earthquake (MCE)**
  - Maximum level of earthquake ground shaking that is considered reasonable to design buildings to resist

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IBC Ground Motion

- **Maximum Considered Earthquake (MCE):**
  - » Deterministic earthquakes (in coastal California)- best estimate of ground motion from maximum magnitude earthquakes on seismic faults with high probabilities of occurrence.

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IBC Ground Motion

- **Maximum Considered Earthquake (MCE)**
  - 2% probability of exceedance in 50 years (approximately 2,500 year return period) where deterministic approach is not used

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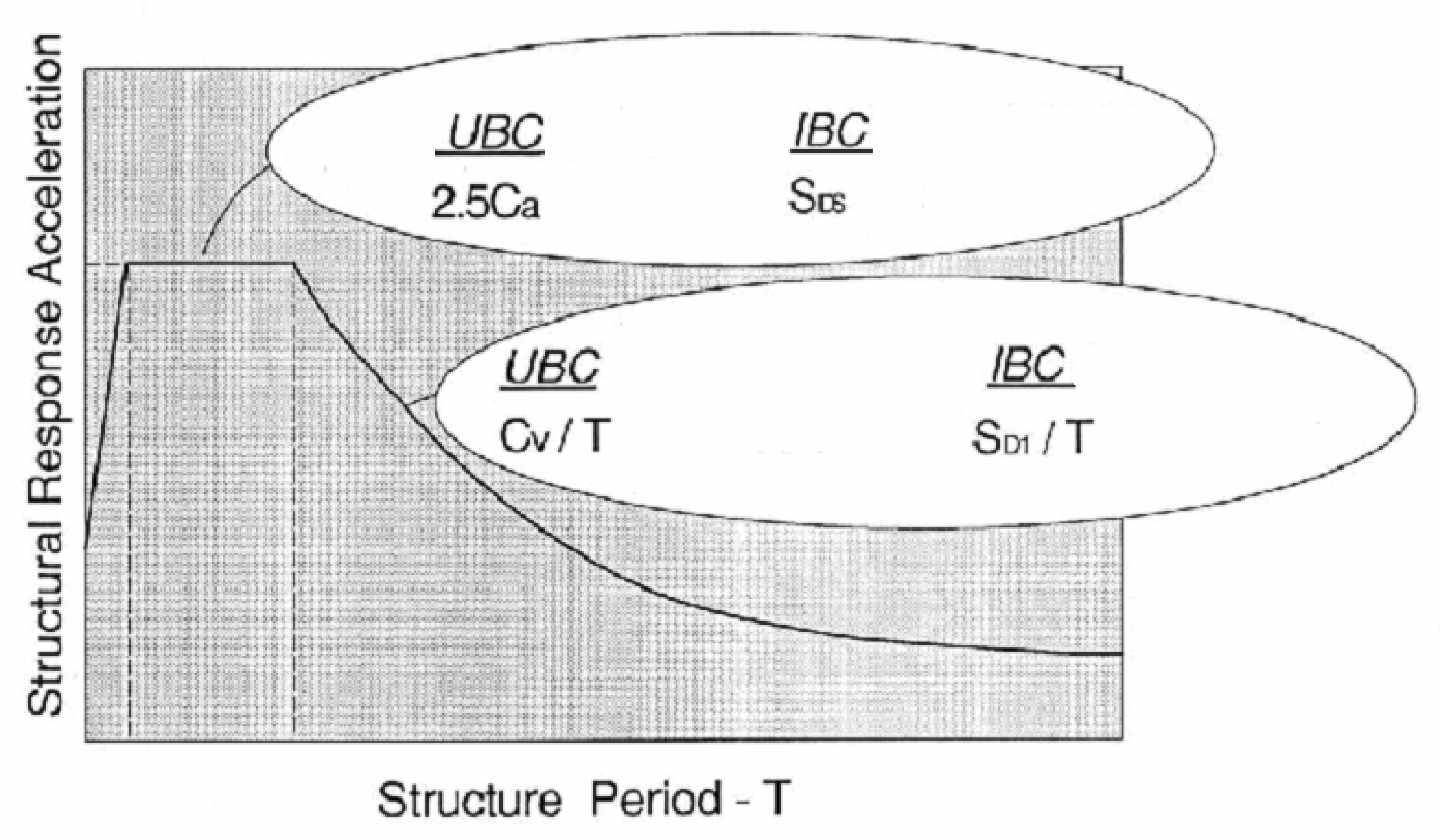
Design Spectrum



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SHORT- AND LONG-PERIOD SEISMIC INPUT 1997 UBC vs. IBC

*Site	UBC			IBC	
	Zone	$2.5C_a$	C_v	S_{DS}	S_{D1}
West Los Angeles (Inglewood Fault)	4	1.3	0.64	1.37	0.54
Downtown San Francisco (4th & Market)	4	1	0.45	1	0.43
U.C. Berkeley Memorial Stadium	4	1.5	0.8	1.33	0.62
Denver	1	0.2	0.08	0.17	0.04
Sacramento	3	0.75	0.3	0.4	0.17
St Paul	0	0	0	0.07	0.01
Seattle	3	0.75	0.3	1	0.4
Portland	3	0.75	0.3	0.8	0.26
Houston	0	0	0	0.07	0.03

* S_D soil profile

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SEISMIC ZONE VS. SEISMIC DESIGN CATEGORY

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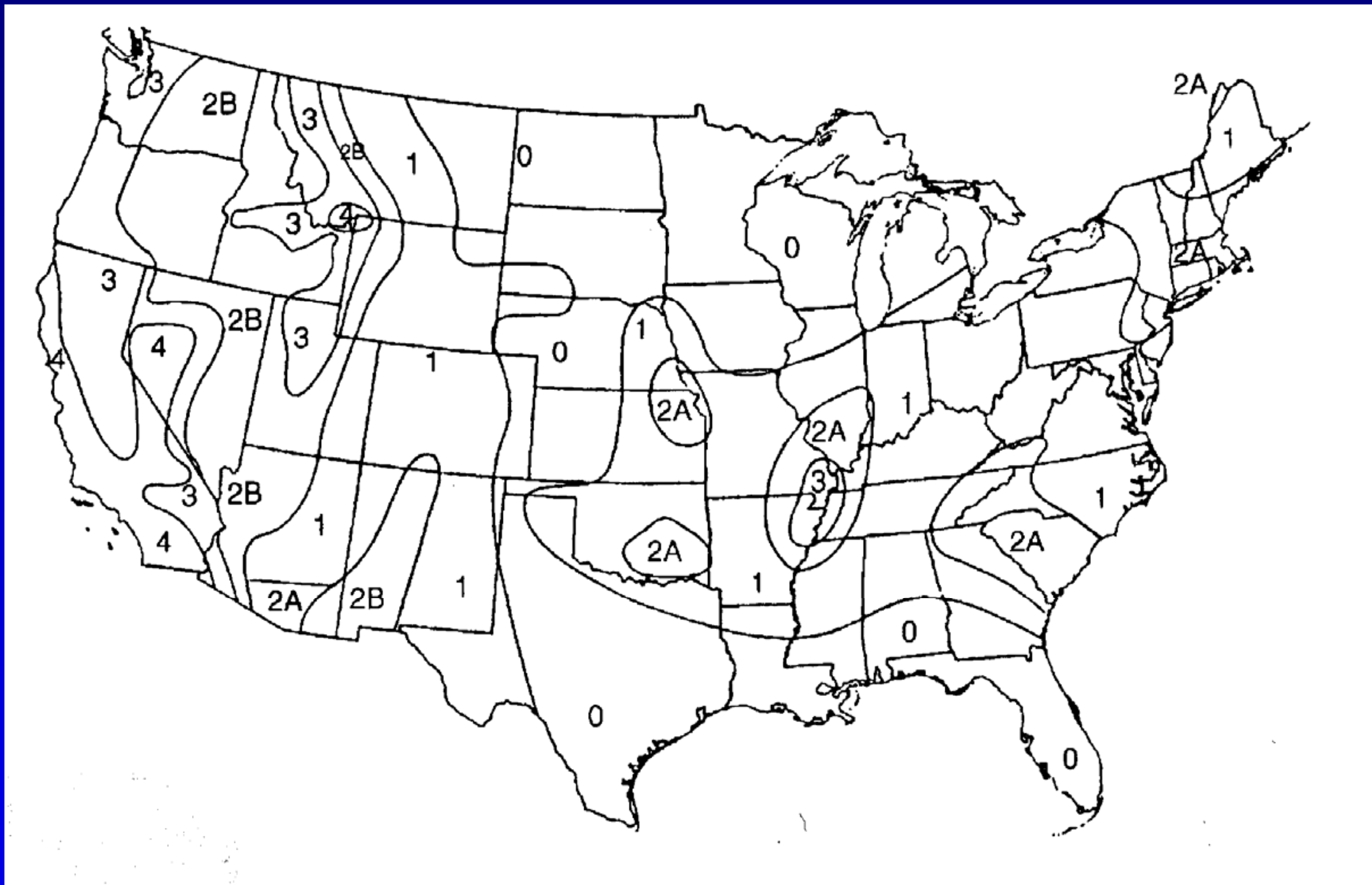
UBC Seismic Zones



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Occupancy Categories

IBC Occupancy Category	IBC Seismic Use Group	1997 UBC Occupancy Category	General Description
I	I	5	Low-hazard facility
II	I	4	Standard-occupancy building
III	II	3	High-occupancy building
IV	III	2,1	Essential Or hazardous facility

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SDC Based on Short Period Response Acceleration – IBC

Values of S_{DS}	SEISMIC GROUP		
	I	II	III
$S_{DS} < 0.167$ g	A	A	A
$0.167g \le S_{DS} < 0.33g$	B	B	C
$0.33g \le S_{DS} < 0.50g$	C	C	D
$0.50g \le S_{DS}$	D[a]	D[a]	D[a]

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SDC Based on 1 sec. Period Response Acceleration – IBC

Values of S_{D1}	SEISMIC GROUP		
	I	II	III
$S_{D1} < 0.067g$	A	A	A
$0.067g \le S_{D1} \le 0.133g$	B	B	C
$0.133g \le S_{D1} \le 0.20g$	C	C	D
$0.20g \le S_{D1}$	D[a]	D[a]	D[a]

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SDC of IBC
(Note a)

Value of S_1	SEISMIC GROUP		
	I	II	III
$S_1 \geq 0.75g$	E	E	F

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Approximate Equivalency between UBC Seismic Zones and IBC SDC's

1997 UBC Seismic Zone	0,1	2A,2B	3,4
IBC Seismic Design Category	A,B	C	D,E,F

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SDC OF IBC vs. UBC Seismic Zone

LOCATION	97 UBC	IBC				
	Zone	SITE CLASS				
		A	B	C	D	E
West LA	4	E	E	E	E	E
San Francisco	4	D	D	D	D	D
Berkeley	4	E	E	E	E	E
Phoenix	1	A	A	B	B	C
Denver	1	A	B	B	B	C
Sacramento	3	C	C	D	D	D
Seattle	3	D	D	D	D	D
Portland	3	D	D	D	D	D
Houston	0	A	A	A	B	C

[1] On Newport-Inglewood Fault; [2]Downtown, 4th & Market; [3]UC Memorial Stadium

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EXEMPTIONS FROM SEISMIC DESIGN

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IBC Exemptions from Seismic Design

- SDC A structures
- Detached one- and two-family dwellings in SDC A, B, and C, or located where $S_S \leq 0.4g$
- Conventional light-frame construction (need only conform to IBC Sec. 2308 or the IRC)
- Agricultural storage structures – incidental human occupancy
- Structures located where $S_S \leq 0.15g$ and $S_1 \leq 0.04g$

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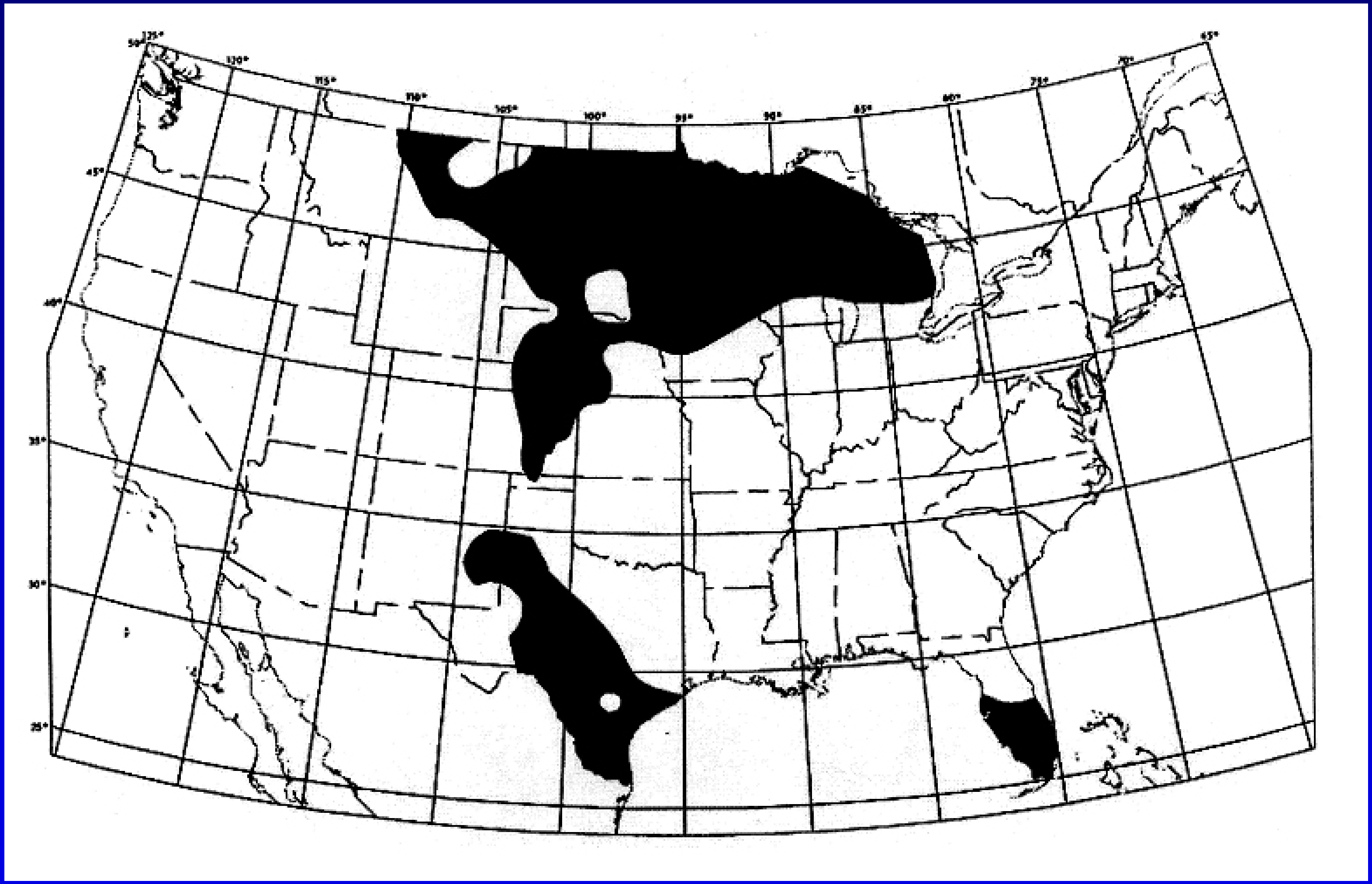
$S_S \leq 0.15g$ and $S_1 \leq 0.04g$



EQUIVALENT LATERAL FORCE PROCEDURE

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Design Base Shear

Base Shear	1997 UBC	2003 IBC
$V \leq$	$\frac{2.5C_a I}{R} W$	$\frac{S_{DS} I_E}{R} W$
$V =$	$\frac{C_V I}{RT} W$	$\frac{S_{D1} I_E}{RT} W$

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Minimum Design Base Shear

- All Seismic Zones / Seismic Design Categories

$V_{min} = 0.11\ C_a\ I\ W$ 1997 UBC

$V_{min} = 0.044\ S_{DS}\ I_E\ W$ IBC

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Minimum Design Base Shear

- Seismic Zone 4 / SDC E, F

$$V_{min} = \frac{0.8ZN_vI}{R}W$$ 1997 UBC

$$V_{min} = \frac{0.5S_1I_E}{R}W$$ IBC

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Seismic Importance Factor (I_E), (I)

Seismic Use Group (Occupancy Category)	Importance Factor	
	IBC (I_E)	UBC (I)
I (4, 5)	1.00	1.00
II (2, 3)	1.25	1.00
III (1)	1.50	1.25

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IBC vs. UBC
Vertical Force Distribution

IBC	1997 UBC
$F_x = \frac{w_x h_x^k}{\sum wh^k} V$	$F_x = \frac{w_x h_x}{\sum wh} (V - F_t)$
where	where
$T \leq 0.5 \sec....k = 1$	$T \leq 0.7 \sec....F_t = 0$
$T \geq 2.5 \sec....k = 2$	$T > 0.7 \sec....F_t = 0.07TV$

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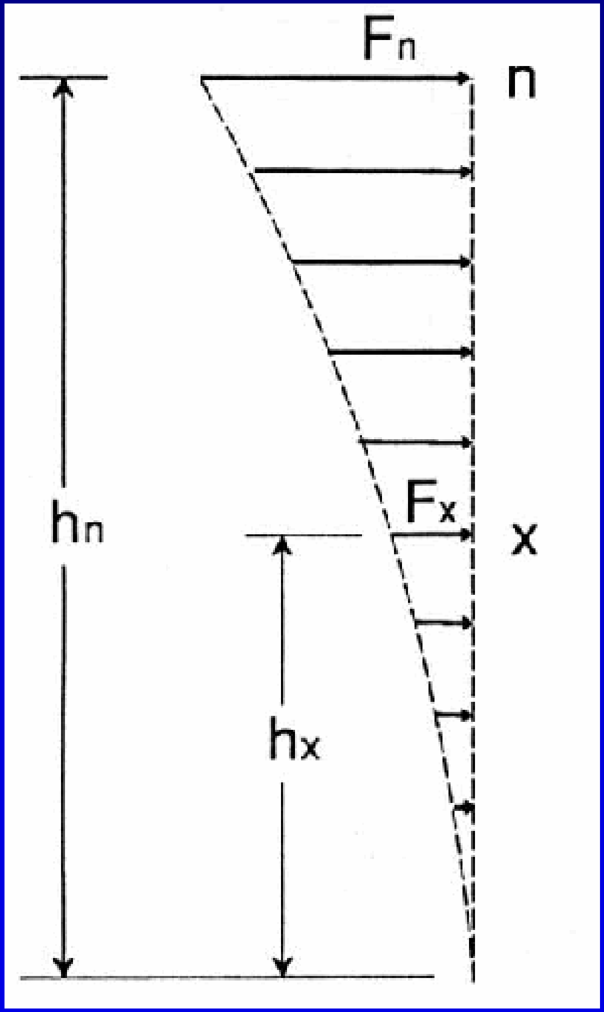
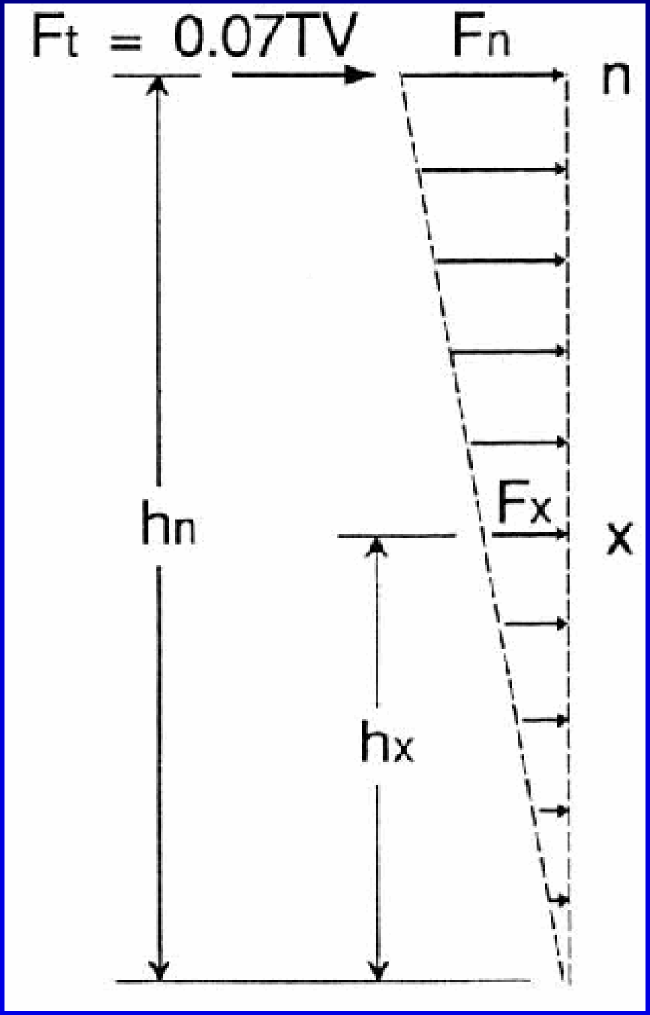
IBC vs. UBC
Vertical Force Distribution

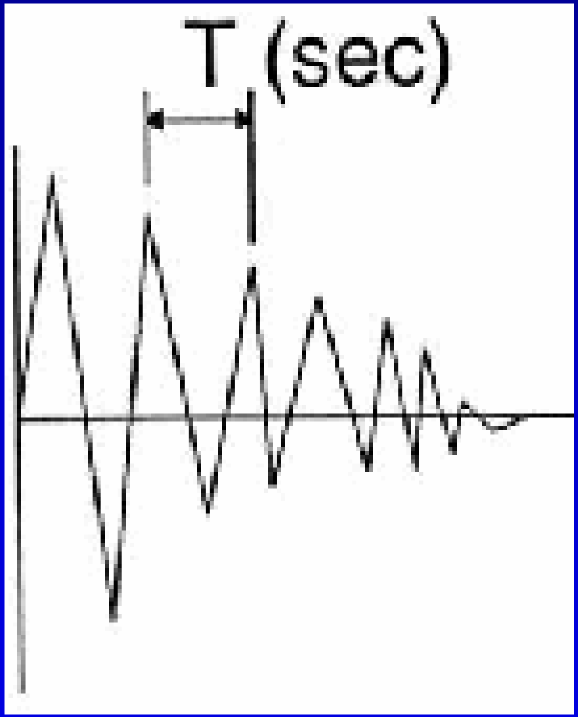
IBC



1997 UBC



Structure Period



Calculated by……

1) Approximate Formulae

2) Rational Analysis using structural properties and deformational characteristics of resisting elements in a properly substantiated analysis

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Approximate Period Formulae

$T_a = C_T (h_n)^{3/4}$ UBC (30-8)

Lateral Force Resisting System	C_T
Steel Moment Frames	0.035
Steel Moment Frames Eccentrically Braced Steel Frames	0.030
All other buildings	0.020

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Upper Limit on T by "Rational Analysis"

IBC	1997 UBC
$T \leq C_U T_a$	$T \leq 1.3\ T_a$, Zone 4 $\leq 1.4\ T_a$, Zones 1,2,3

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Upper Limit on T by "Rational Analysis"

Table 9.5.5.3.1 (ASCE 7-02)

Coefficient for Upper Limit on Calculated Period

Design Spectral Response Acceleration (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
≤ 0.05	1.7

Note: For drift analysis, upper limit on calculated (T) does not apply (Section 9.5.5.7.1)

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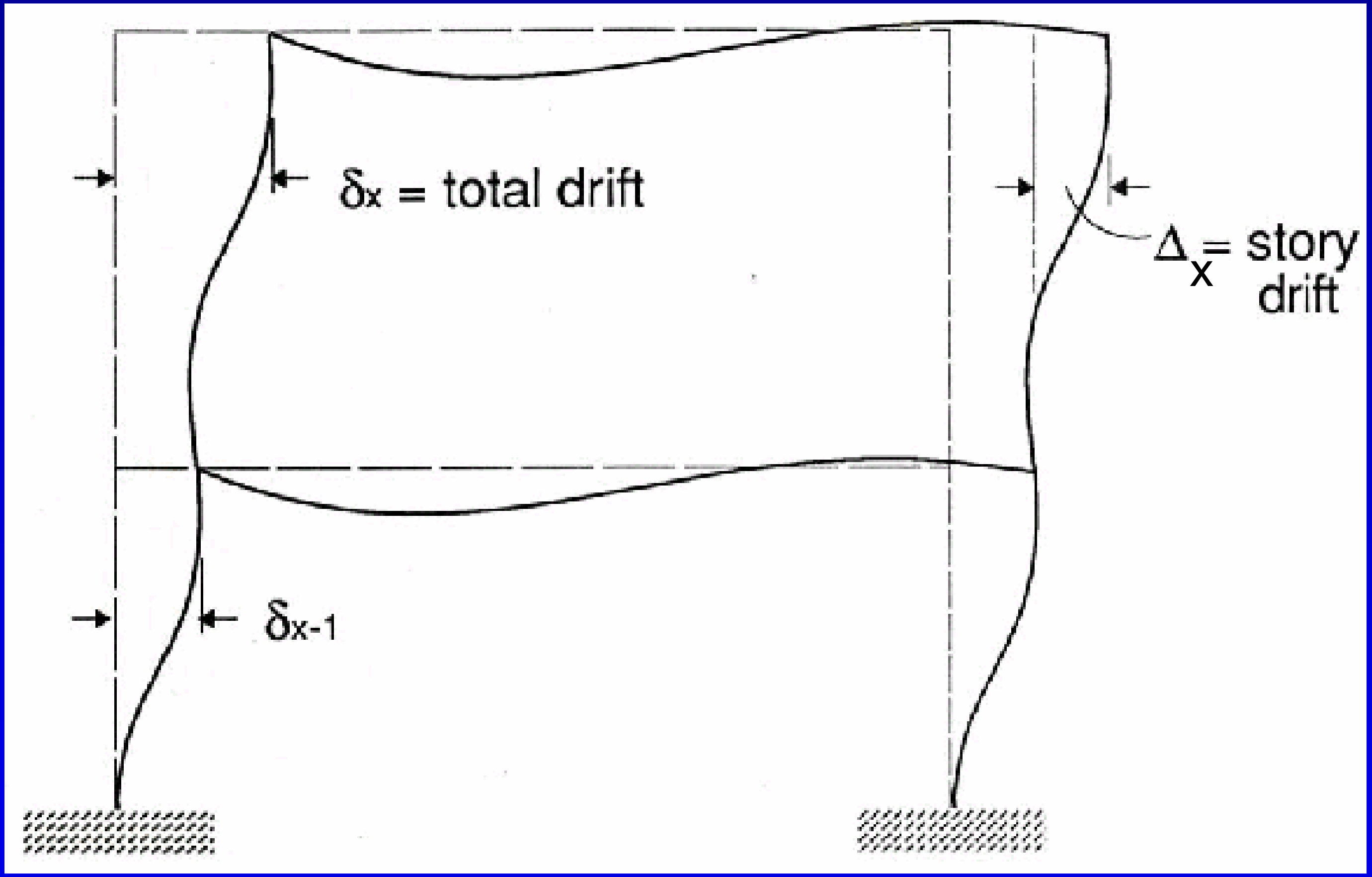
ASCE 7-02 9.5.5.7.1 Interstory Drift (Δ)

Lateral displacement of one level relative to the other level above or below



1617.3 (ASCE 7-02 9.5.5.7.1) Interstory Drift (Δ)

$$\Delta_x = \delta_x - \delta_{x-1} \leq \Delta_a$$

where….

IBC	1997 UBC
$\delta_x = C_d \, \delta_{xe} / I_E$	$\delta_x = 0.7R \, \delta_{xe}$

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Allowable Story Drift (Δ_a)
ASCE 7-02 Table 9.5.2.8

Building	Seismic Use Group		
	I	II	III
Buildings ≤ 4 stories in height (other than masonry)	$0.025h_{sx}$	$0.020h_{sx}$	$0.015h_{sx}$
Masonry cantilever shear wall buildings	$0.010h_{sx}$	$0.010h_{sx}$	$0.010h_{sx}$
Other masonry shear walls buildings	$0.007h_{sx}$	$0.007h_{sx}$	$0.007h_{sx}$
Masonry wall frame buildings	$0.013h_{sx}$	$0.013h_{sx}$	$0.010h_{sx}$
All other buildings	$0.020h_{sx}$	$0.015h_{sx}$	$0.010h_{sx}$

h_{sx} = Story height below level x

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Allowable Story Drift (Δ_a)
1997 UBC

Δ_a = **0.020** h_{sx} for $T \geq 0.7$ sec.

= **0.025** h_{sx} for $T < 0.7$ sec.

h_{sx} = Story height below level x

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Earthquake Effect

1997 UBC	IBC
$E = \rho E_h + E_v$ $= \rho E_h + 0.5 C_a I D$	$E = \rho Q_E + 0.2 S_{DS} D$

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Effect of Vertical Earthquake Ground Motion

- **Gravity and Earthquake Effects Additive**

$$U = 1.2D + 1.0E + 0.5L + 0.2S$$

$$= 1.2D + (\rho E_h + 0.5C_a ID) + 0.5L + 0.2S$$

$$= (1.2 + 0.5C_a I)D + \rho E_h + 0.5L + 0.2S \quad \text{....1997 UBC}$$

$$U = 1.2D + 1.0E + 0.5L + 0.2S$$

$$= 1.2D + (\rho Q_E + 0.2S_{DS}D) + 0.5L + 0.2S$$

$$= (1.2 + 0.2S_{DS})D + \rho Q_E + 0.5L + 0.2S \text{ .... IBC}$$

Effect of Vertical Earthquake Ground Motion

- Gravity and Earthquake Effects Counteractive

$$U = 0.9D - 1.0E$$
$$= 0.9D - (\rho E_h + 0.5C_a ID)$$
$$= (0.9 - 0.5C_a I)D - \rho E_h \quad \text{..........1997 UBC}$$

$$U = 0.9D - 1.0E$$
$$= 0.9D - (\rho Q_E + 0.2S_{DS}D)$$
$$= (0.9 - 0.2S_{DS})D - \rho Q_E \quad \text{........... IBC}$$

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Special Seismic Load Combinations

- Elements supporting discontinuous systems
- Collector elements

$$U = 1.2D + f_1 L + 1.0E_m$$

$$U = 0.9D \pm 1.0E_m$$

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Special Seismic Load Combinations

1997 UBC	IBC
$E_m = \Omega_0 E_h$	$E_m = \Omega_0 Q_E \pm 0.2S_{DS}D$
Ω_0 = 2.0, 2.2 or 2.8 depending on structural system	Ω_0 = 2.0, 2.5 or 3.0 depending on structural system

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REDUNDANCY

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Redundancy Factor (ρ)

1997 UBC	IBC
ρ = max ρ_I over lower two thirds of building height $1.0 \leq \rho \leq 1.5$	ρ = max ρ_I over entire building height $1.0 \leq \rho \leq 1.5$
$\rho_i = 2 - \dfrac{20}{r_{max,i}\sqrt{A_B}}$	$\rho_i = 2 - \dfrac{20}{r_{max,i}\sqrt{A_i}}$
A_B = area of ground floor in sq.ft.	A_i= area of diaphragm supported by lateral force resisting elements in story i in sq.ft
$r_{max,I}$ = maximum element to story shear ratio in story i	

Redundancy Factor (ρ)

- For structures with seismic-force-resisting system consisting entirely of special moment frames,

1997 UBC		IBC	
Zone 4	$\rho \leq 1.25$	SDC D	$\rho \leq 1.25$
		SDC E,F	$\rho \leq 1.10$