IBC Seismic Force Procedure Lab Problem

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IBC Base Shear Expression

$$V = \left[\frac{I_e(S_{DS})}{R}\right]W \quad \text{for} \quad T \leq T_S$$

$$T = C_t h_n^x$$

$$V = \left[\frac{I_e(S_{D1})}{TR}\right]W \quad \text{for} \quad T > T_S$$

$$T_S = \frac{S_{D1}}{S_{DS}}$$

Seismic Base Shear (V) depends on:

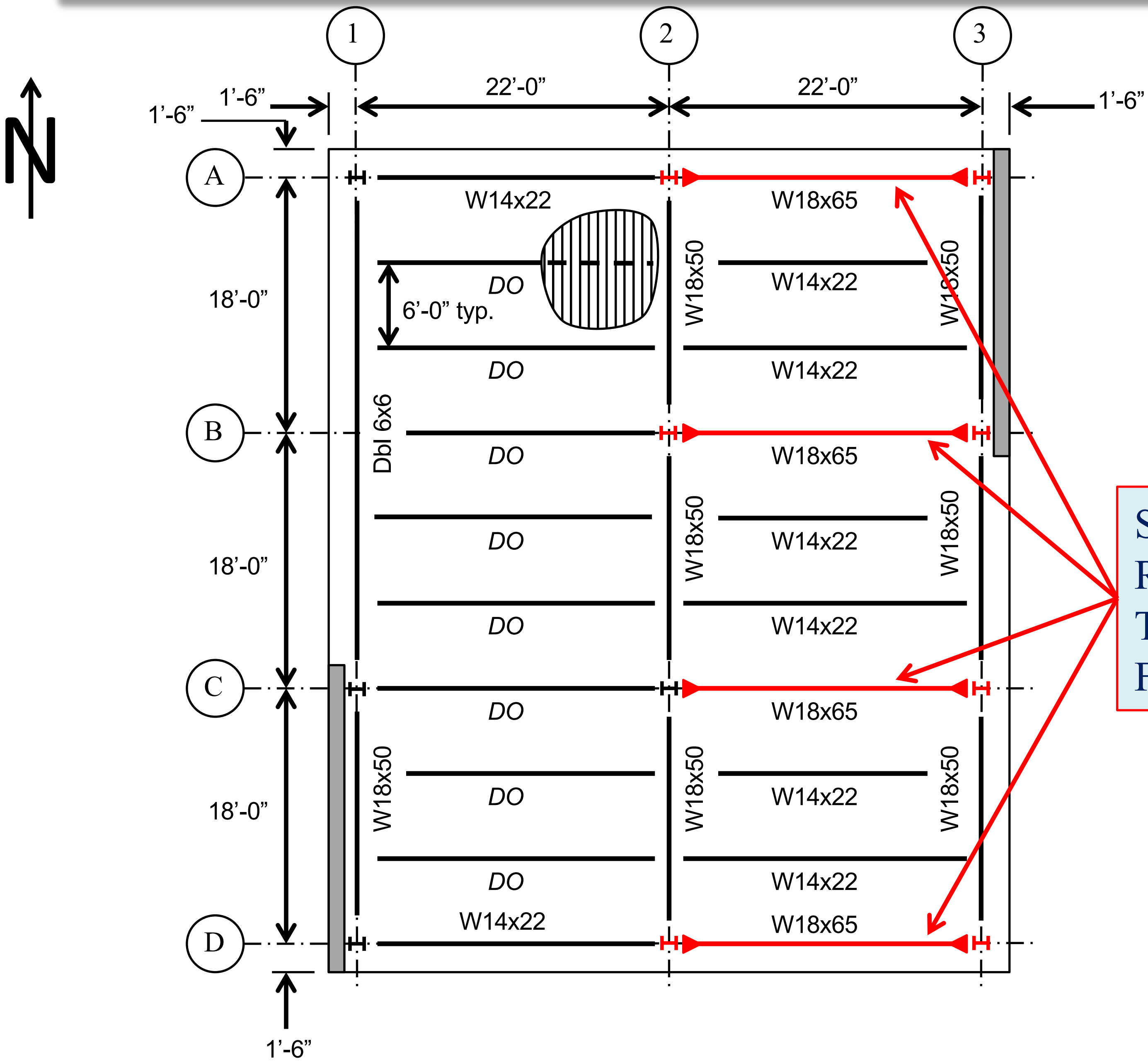
1. The seismic weight of the building (W);
2. The fundamental period of vibration of the building (T);
3. The earthquake acceleration at the base of the building (S_{DS} and S_{D1});
4. The energy dissipating capacity of the lateral force resisting system (R);
5. The desired performance level of the building (I_e).

Example Problem to Illustrate the Process of Finding the IBC Base Shear

Our CE 160 Lab example building is a planned retail building that will house a daycare facility. The building is located near Sacramento, CA. The geotechnical engineer has determined that the soil at the site can be classified as Site Class C. Recall that the roof weight was determined in Lab 4 to be 29 psf. In addition, the average weight of the non-structural exterior curtain walls is 15 psf (including the concrete walls). The building has 170 linear feet of interior interior partition walls weighing 10 psf.

Determine the IBC base shear for earthquake acceleration in the East-West direction for our example building.

Moment Resisting Frames Resist Seismic Force in the East-West Direction



Special Moment Resisting Frames To Resist E-W Seismic Forces

IBC Estimate of the Fundamental Period of Vibration of a Building

$$T = C_t h_n^x$$

h_n = average roof height of the building

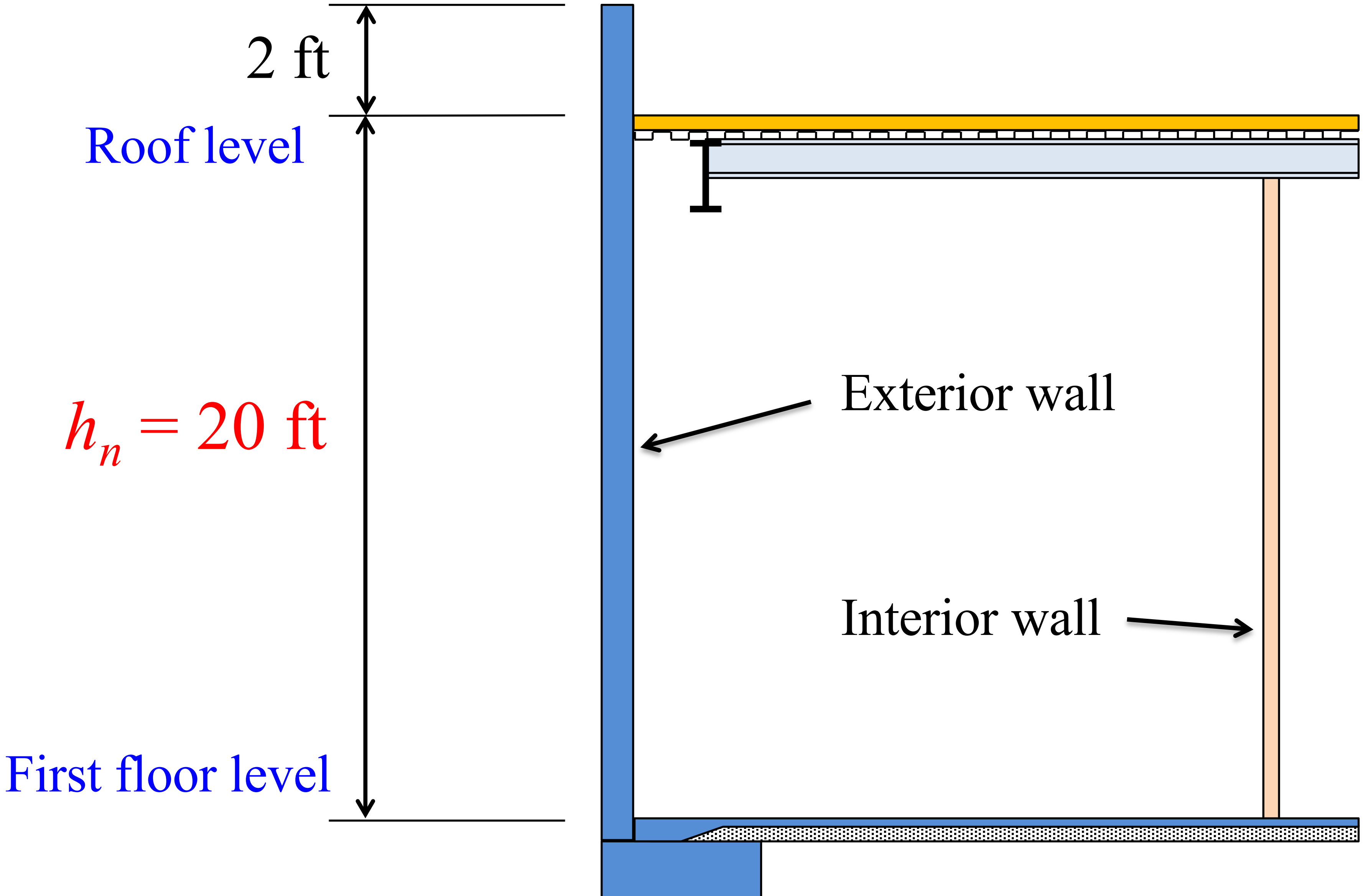
C_t =

= 0.028 for steel moment resisting frames
= 0.016 for concrete moment resisting frames
= 0.030 for eccentrically braced frames
= 0.020 for all other systems (shear walls, concentric braced frames, etc.

x =

= 0.8 for steel moment resisting frames
= 0.9 for concrete moment resisting frames
= 0.75 for eccentrically braced frames
= 0.75 for all other systems (shear walls, concentric braced frames, etc.

Estimate the Fundamental Period of the Building



$$T = (0.028)(20)^{0.8} = 0.308 \text{ sec}$$

Find the Importance Factor

TABLE 1604.5
OCCUPANCY CATEGORY OF BUILDINGS AND OTHER STRUCTURES

OCCUPANCY CATEGORY	NATURE OF OCCUPANCY
I	Buildings and other structures that represent a low hazard to human life in the event of failure, including but not limited to: • Agricultural facilities. • Certain temporary facilities. • Minor storage facilities.
II	Buildings and other structures except those listed in Occupancy Categories I, III and IV
III	Buildings and other structures that represent a substantial hazard to human life in the event of failure, including but not limited to: • Covered structures whose primary occupancy is public assembly with an occupant load greater than 300. • Buildings and other structures with elementary school, secondary school or day care facilities with an occupant load greater than 250. • Buildings and other structures with an occupant load greater than 500 for colleges or adult education facilities. • Health care facilities with an occupant load of 50 or more resident patients, but not having surgery or emergency treatment facilities. • Jails and detention facilities. • Any other occupancy with an occupant load greater than 5,000. • Power-generating stations, water treatment for potable water, waste water treatment facilities and other public utility facilities not included in Occupancy Category IV. • Buildings and other structures not included in Occupancy Category IV containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released.
IV	Buildings and other structures designated as essential facilities, including but not limited to: • Hospitals and other health care facilities having surgery or emergency treatment facilities. • Fire, rescue and police stations and emergency vehicle garages. • Designated earthquake, hurricane or other emergency shelters. • Designated emergency preparedness, communication, and operation centers and other facilities required for emergency response. • Power-generating stations and other public utility facilities required as emergency backup facilities for Occupancy Category IV structures. • Structures containing highly toxic materials as defined by Section 307 where the quantity of the material exceeds the maximum allowable quantities of Table 307.1.(2). • Aviation control towers, air traffic control centers and emergency aircraft hangars. • Buildings and other structures having critical national defense functions • Water treatment facilities required to maintain water pressure for fire suppression.

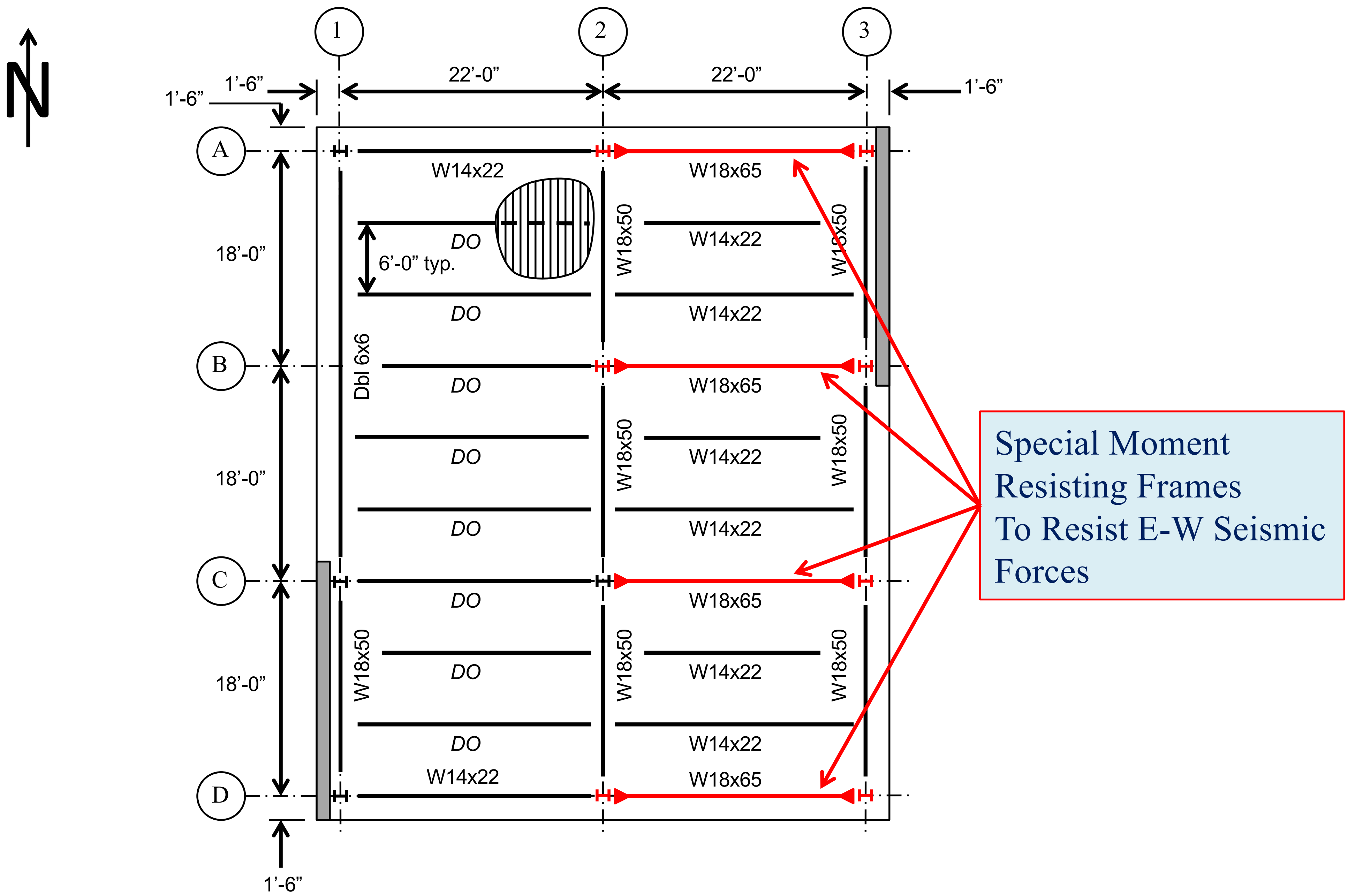
Table 1.5-2 Importance Factors by Risk Category of Buildings and Other Structures for Snow, Ice, and Earthquake Loads[a]

Risk Category from Table 1.5-1	Snow Importance Factor, I_s	Ice Importance Factor—Thickness, I_i	Ice Importance Factor—Wind, I_w	Seismic Importance Factor, I_e
I	0.80	0.80	1.00	1.00
II	1.00	1.00	1.00	1.00
III	1.10	1.25	1.00	1.25
IV	1.20	1.25	1.00	1.50

[a]The component importance factor, I_p, applicable to earthquake loads, is not included in this table because it is dependent on the importance of the individual component rather than that of the building as a whole, or its occupancy. Refer to Section 13.1.3.

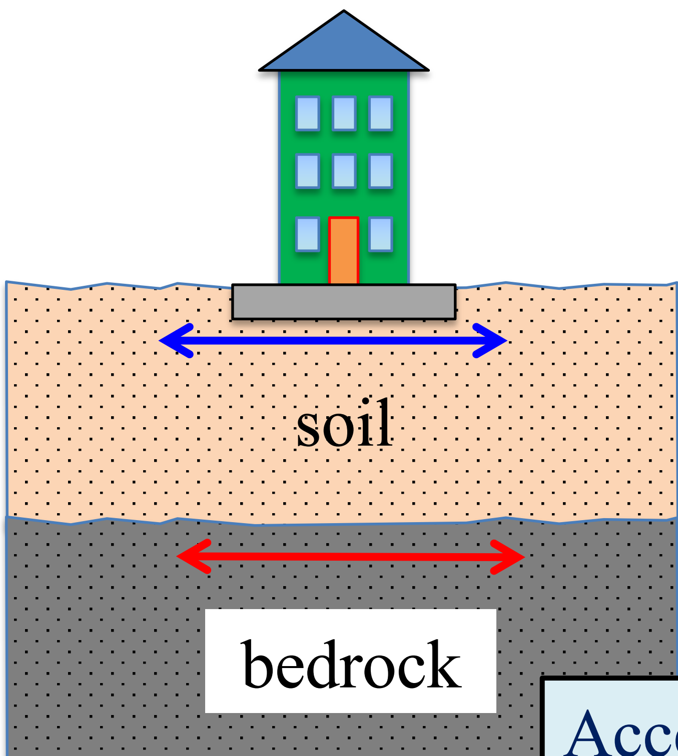
$$I_e = 1.25$$

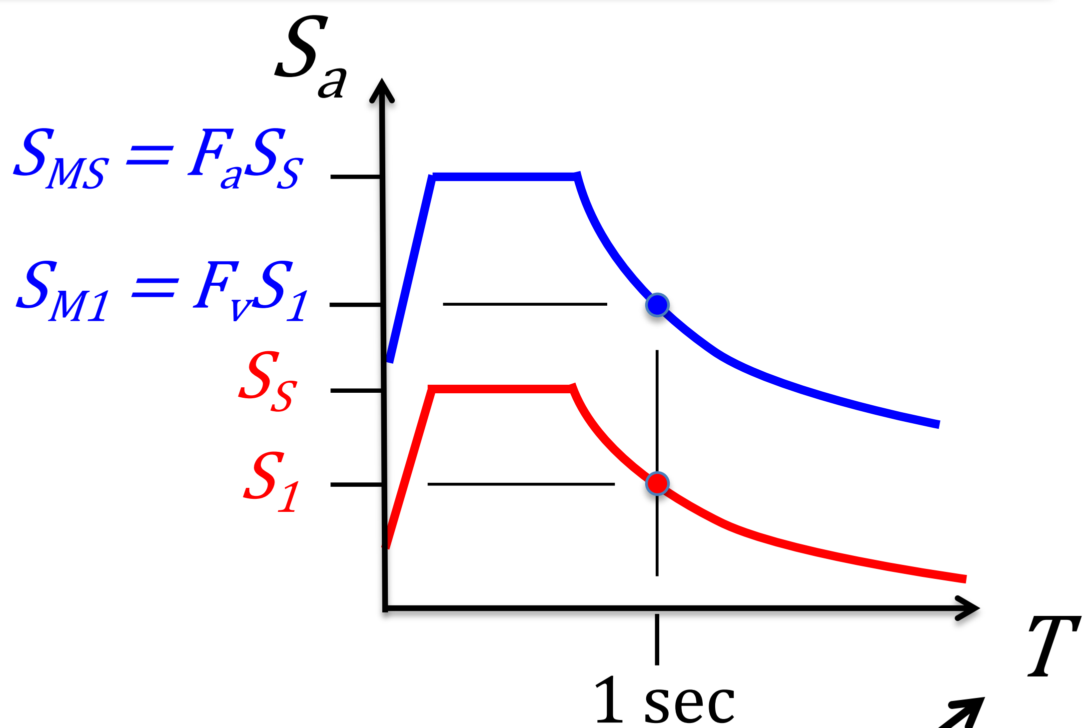
Estimate the Fundamental Period of the Building



Earthquake Acceleration at the Base of the Building

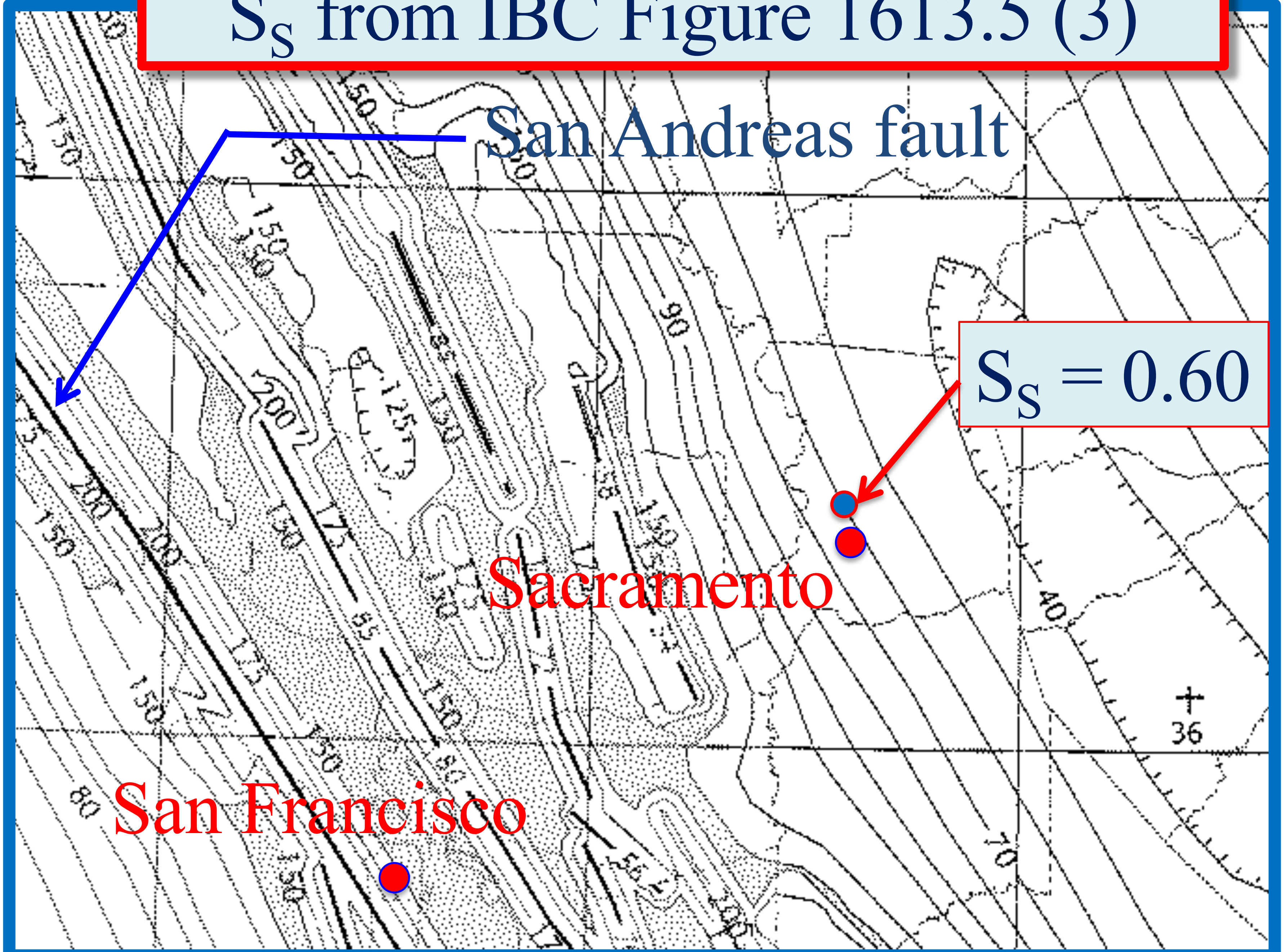
Maximum acceleration at the base of the building depends on the seismicity of the site and the soil at the site



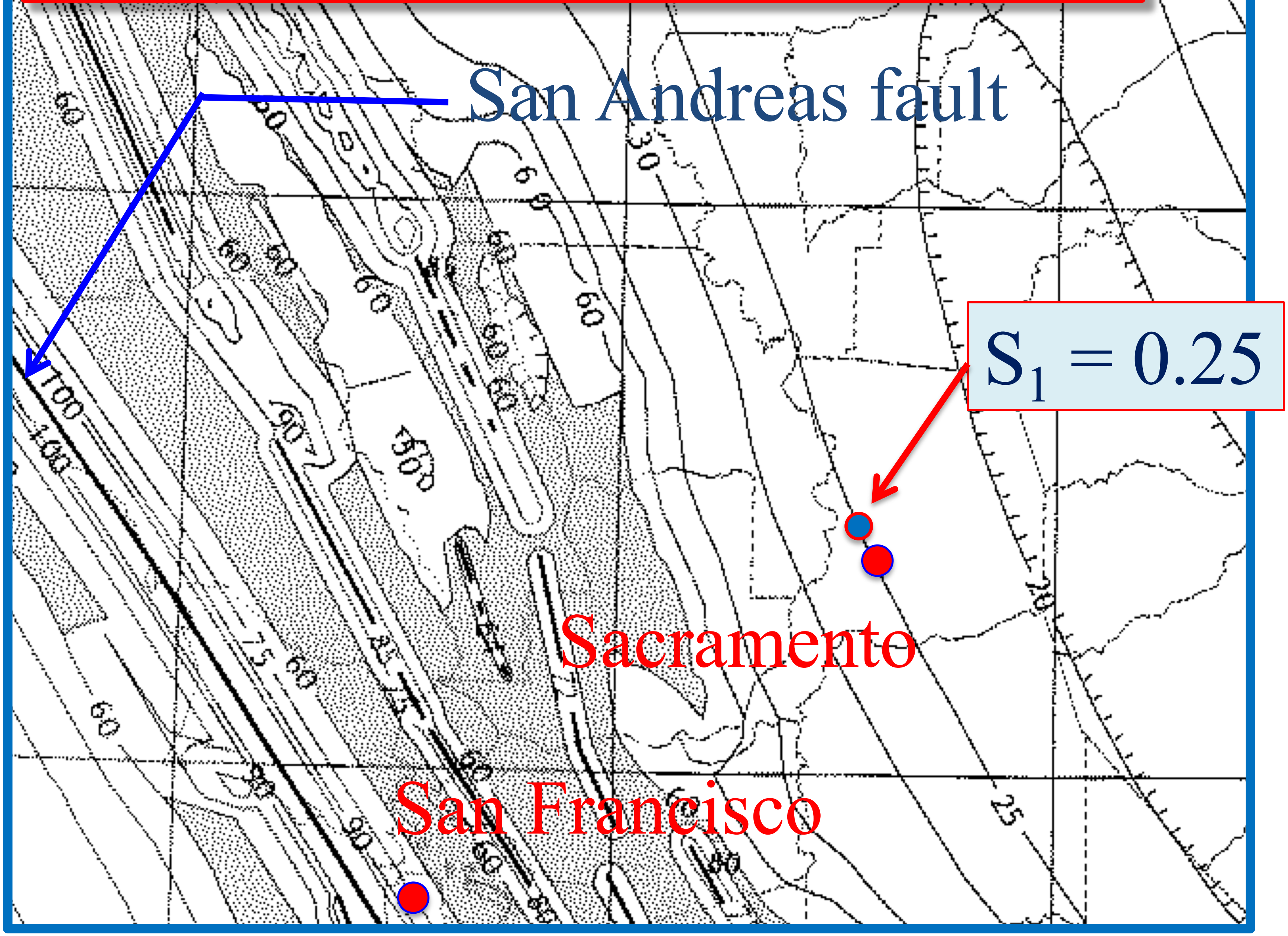


Acceleration is a function of the fundamental period of the building

S_S from IBC Figure 1613.5 (3)



S_1 from IBC Figure 1613.5 (4)



Site Class from Table 1613.5.2

TABLE 1613.5.2
SITE CLASS DEFINITIONS

SITE CLASS	SOIL PROFILE NAME	AVERAGE PROPERTIES IN TOP 100 feet, SEE SECTION 1613.5.5		
		Soil shear wave velocity, $\bar{v}_s$, (ft/s)	Standard penetration resistance, $\bar{N}$	Soil undrained shear strength, $\bar{s}_u$, (psf)
A	Hard rock	$\bar{v}_s > 5,000$	N/A	N/A
B	Rock	$2,500 < \bar{v}_s \leq 5,000$	N/A	N/A
C	Very dense soil and soft rock	$1,200 < \bar{v}_s \leq 2,500$	$\bar{N} > 50$	$\bar{s}_u \geq 2,000$
D	Stiff soil profile	$600 \leq \bar{v}_s \leq 1,200$	$15 \leq \bar{N} \leq 50$	$1,000 \leq \bar{s}_u \leq 2,000$
E	Soft soil profile	$\bar{v}_s < 600$	$\bar{N} < 15$	$\bar{s}_u < 1,000$
E	—	Any profile with more than 10 feet of soil having the following characteristics: 1. Plasticity index $PI > 20$, 2. Moisture content $w \geq 40\%$, and 3. Undrained shear strength $\bar{s}_u < 500$ psf		
F	—	Any profile containing soils having one or more of the following characteristics: 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays ($H >$ 10 feet of peat and/or highly organic clay where H = thickness of soil) 3. Very high plasticity clays ($H >$25 feet with plasticity index $PI >$75) 4. Very thick soft/medium stiff clays ($H >$120 feet)		

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m^2, 1 pound per square foot = 0.0479 kPa. N/A = Not applicable

Find F_a from Table 1613.5.3 (1)

$S_S = 0.6$

TABLE 1613.5.3(1)
VALUES OF SITE COEFFICIENT F_a [a]

SITE CLASS	MAPPED SPECTRAL RESPONSE ACCELERATION AT SHORT PERIOD				
	$S_s \le 0.25$	$S_s = 0.50$	$S_s = 0.75$	$S_s = 1.00$	$S_s \ge 1.25$
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

a. Use straight-line interpolation for intermediate values of mapped spectral response acceleration at short period, S_s.
b. Values shall be determined in accordance with Section 11.4.7 of ASCE 7.

$$\frac{0.75 - 0.6}{0.75 - 0.5} = \frac{1.1 - F_a}{1.1 - 1.2}$$

$$F_a = 1.16$$

Find F_v from Table 1613.5.3 (2)

$S_1 = 0.25$

TABLE 1613.5.3(2)
VALUES OF SITE COEFFICIENT F_V [a]

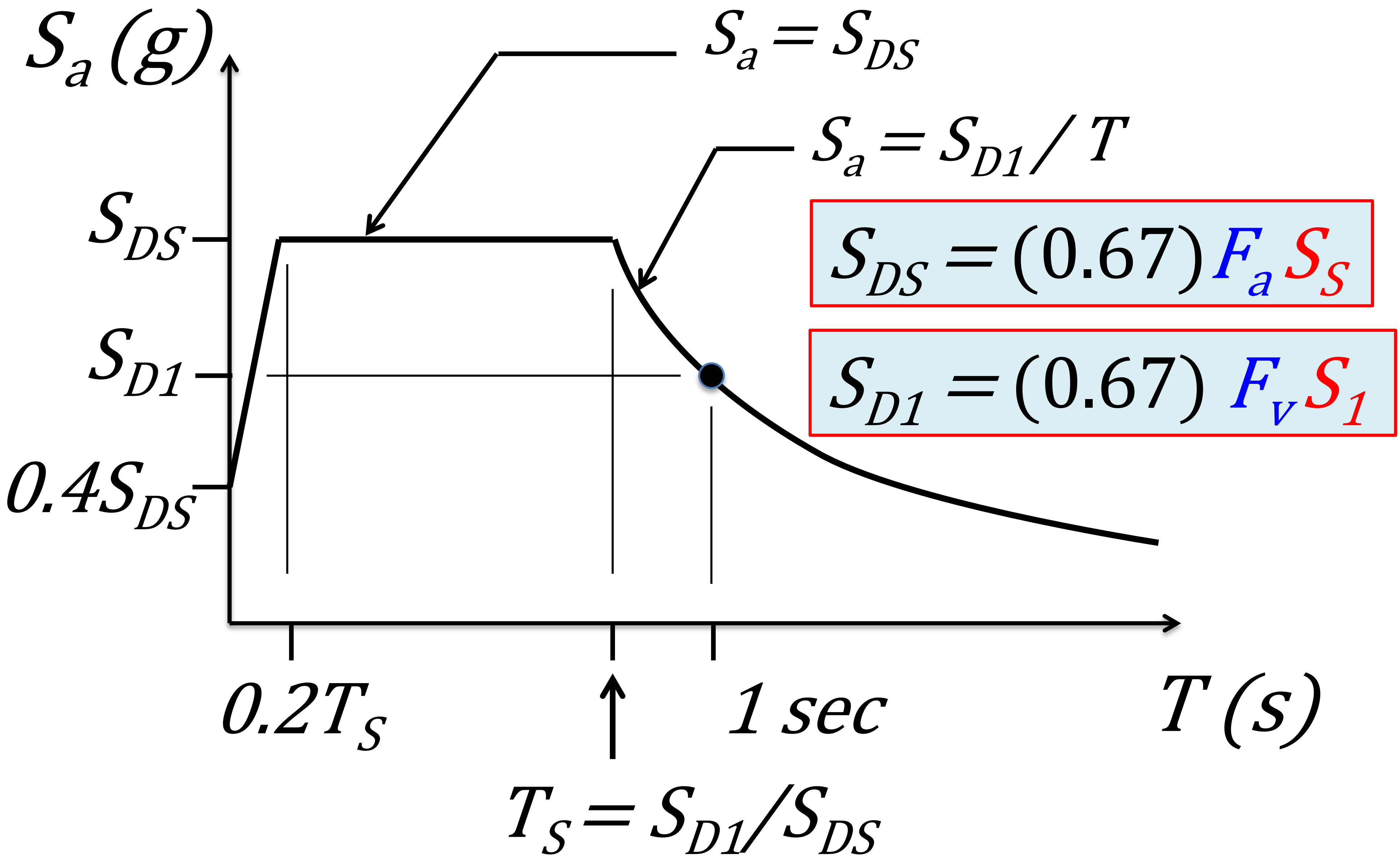
SITE CLASS	MAPPED SPECTRAL RESPONSE ACCELERATION AT 1-SECOND PERIOD				
	$S_1 \le 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 \ge 0.5$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	Note b	Note b	Note b	Note b	Note b

a. Use straight-line interpolation for intermediate values of mapped spectral response acceleration at 1-second period, S_1.
b. Values shall be determined in accordance with Section 11.4.7 of ASCE 7.

$$\frac{0.30 - 0.25}{0.30 - 0.20} = \frac{1.5 - F_v}{1.6 - 1.5}$$

$$F_V = 1.55$$

IBC Design Response Spectrum



Calculate Design Accelerations S_{DS} and S_{D1}

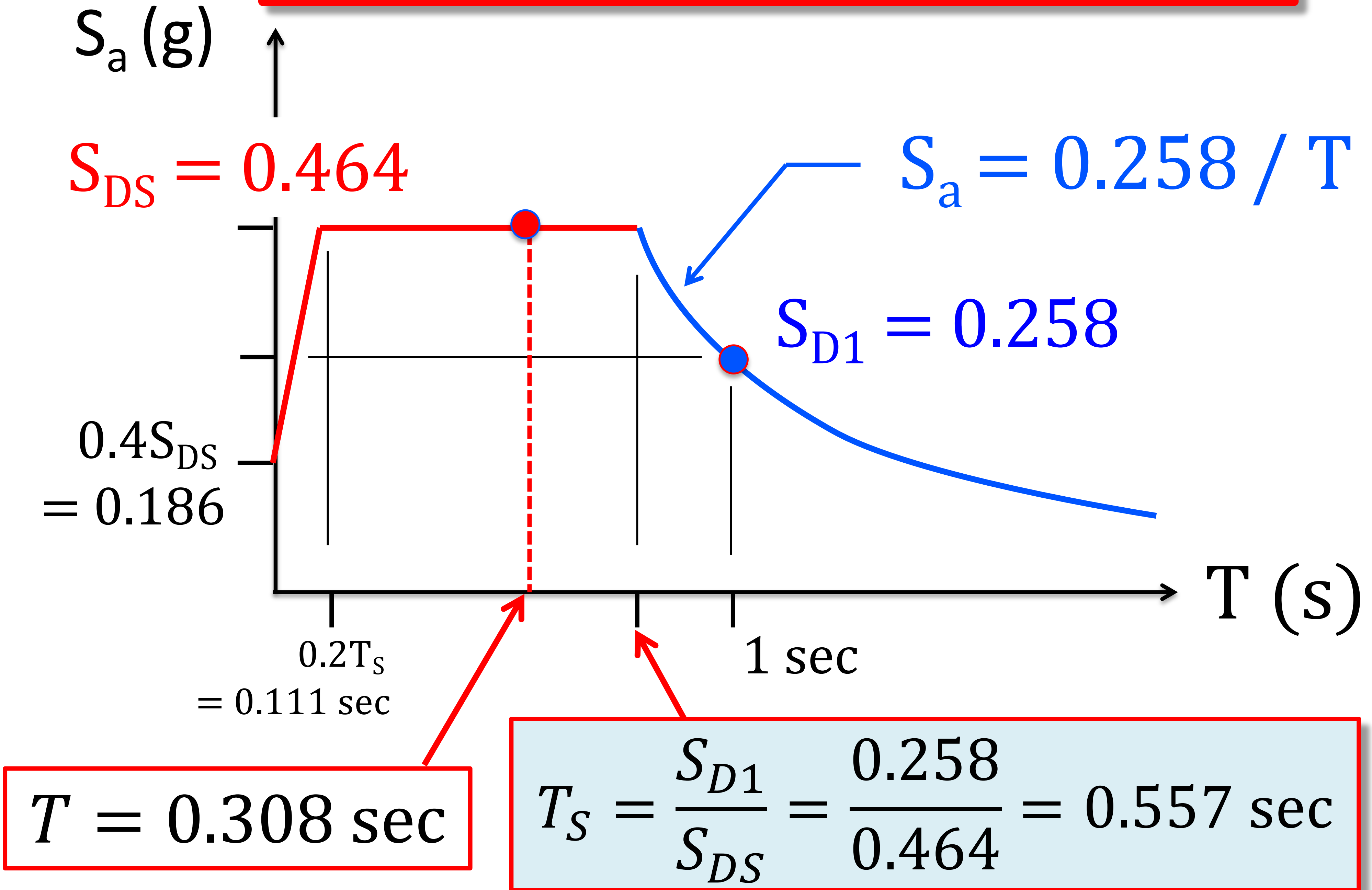
$$S_{DS} = (0.67)\,F_a\,S_S$$

$$S_{DS} = (0.67)(1.16)(0.6) = 0.464$$

$$S_{D1} = (0.67)\,F_v\,S_1$$

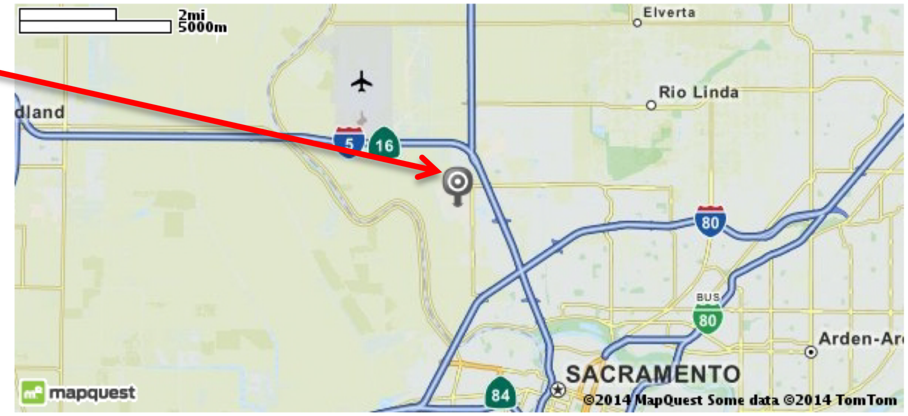
$$S_{DS} = (0.67)(1.55)(0.25) = 0.258$$

IBC Design Response Spectrum



Can Verify Accelerations and Spectra from USGS Website

38.6475°N, 121.54589°W

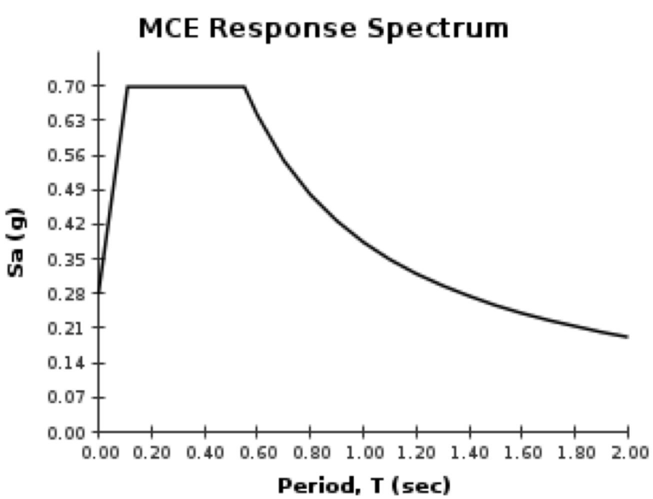


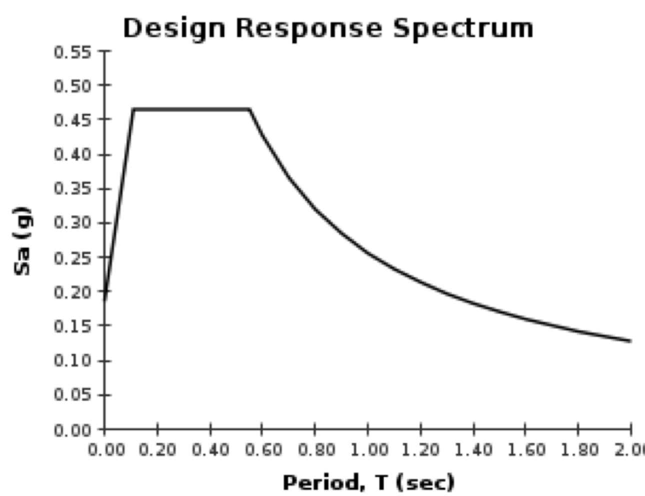
Site Class C – "Very Dense Soil and Soft Rock"
I/II/III

USGS–Provided Output

S_S = 0.602 g S_{MS} = 0.698 g S_{DS} = 0.465 g
S_1 = 0.248 g S_{M1} = 0.384 g S_{D1} = 0.256 g

Although this information is a product of the U.S. Geological Survey, we provide no warranty, expressed or implied, as to the accuracy of the data contained therein. This tool is not a substitute for technical subject-matter knowledge.





Energy Dissipating Capacity of the Lateral Force Resisting System

The base shear is adjusted for the earthquake energy dissipation of the Lateral Force Resisting System by dividing by a Response Modification Coefficient, R;

The Response Modification Coefficient is a measure of the energy dissipating characteristics of lateral force resisting system based on test results and performance in past earthquakes.

A high R value is assigned to systems that have performed well in past earthquakes and can effectively dissipate earthquake energy.

Find the Response Modification Coefficient

Table 12.2-1 (*Continued*)

Seismic Force-Resisting System	ASCE 7 Section Where Detailing Requirements Are Specified	Response Modification Coefficient, R[a]	Overstrength Factor, Ω_0[g]	Deflection Amplification Factor, C_d[b]	Structural System Limitations Including Structural Height, h_n (ft) Limits[c] — Seismic Design Category B	C	D[d]	E[d]	F[e]
C. MOMENT-RESISTING FRAME SYSTEMS									
1. Steel special moment frames	14.1 and 12.2.5.5	8	3	5½	NL	NL	NL	NL	NL
2. Steel special truss moment frames	14.1	7	3	5½	NL	NL	160	100	NP
3. Steel intermediate moment frames	12.2.5.7 and 14.1	4½	3	4	NL	NL	35[h]	NP[h]	NP[h]
4. Steel ordinary moment frames	12.2.5.6 and 14.1	3½	3	3	NL	NL	NP[i]	NP[i]	NP[i]
5. Special reinforced concrete moment frames[n]	12.2.5.5 and 14.2	8	3	5½	NL	NL	NL	NL	NL
6. Intermediate reinforced concrete moment frames	14.2	5	3	4½	NL	NL	NP	NP	NP
7. Ordinary reinforced concrete moment frames	14.2	3	3	2½	NL	NP	NP	NP	NP
8. Steel and concrete composite special moment frames	12.2.5.5 and 14.3	8	3	5½	NL	NL	NL	NL	NL
9. Steel and concrete composite intermediate moment frames	14.3	5	3	4½	NL	NL	NP	NP	NP
10. Steel and concrete composite partially restrained moment frames	14.3	6	3	5½	160	160	100	NP	NP
11. Steel and concrete composite ordinary moment frames	14.3	3	3	2½	NL	NP	NP	NP	NP
12. Cold-formed steel—special bolted moment frame[p]	14.1	3½	3[o]	3½	35	35	35	35	35
D. DUAL SYSTEMS WITH SPECIAL MOMENT FRAMES CAPABLE OF RESISTING AT LEAST 25% OF PRESCRIBED SEISMIC FORCES	12.2.5.1								
1. Steel eccentrically braced frames	14.1	8	2½	4	NL	NL	NL	NL	NL
2. Steel special concentrically braced frames	14.1	7	2½	5½	NL	NL	NL	NL	NL
3. Special reinforced concrete shear walls[l]	14.2	7	2½	5½	NL	NL	NL	NL	NL
4. Ordinary reinforced concrete shear walls[l]	14.2	6	2½	5	NL	NL	NP	NP	NP
5. Steel and concrete composite eccentrically braced frames	14.3	8	2½	4	NL	NL	NL	NL	NL
6. Steel and concrete composite special concentrically braced frames	14.3	6	2½	5	NL	NL	NL	NL	NL

Continued

$$R = 8$$

Calculate the East–West Seismic Coefficient

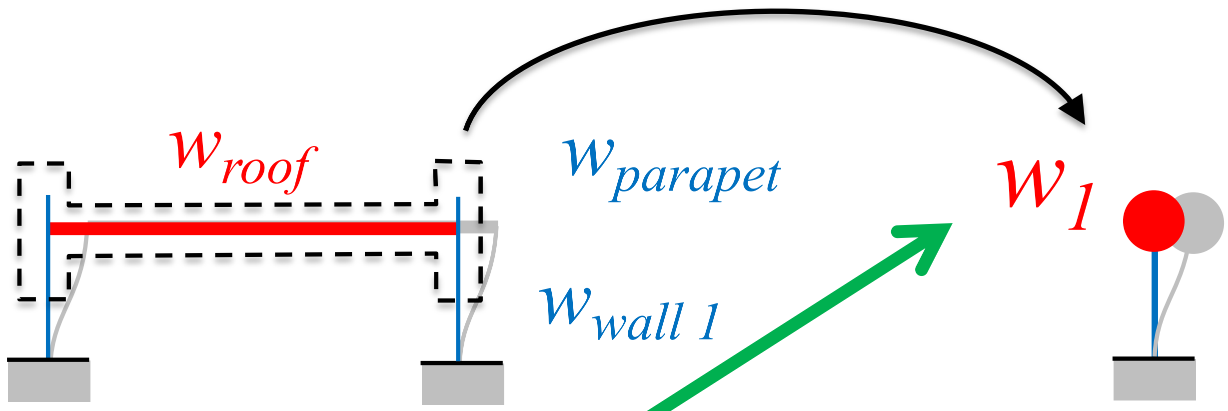
0.308 sec < 0.557 sec

$$V = \left[\frac{I_e(S_{DS})}{R}\right]W \quad \text{for} \quad T \le T_S$$

$$V = \left[\frac{(1.25)(0.464)}{(8)}\right]W$$

$$V = (0.0725)W$$

Dynamic Model of the Building



Weight of the building is lumped at the roof level

$$w_1 = w_{roof} + \frac{1}{2}(w_{wall\ 1}) + w_{parapet}$$

Total Seismic Weight of Building

$$W = w_1$$