number of well-defined fault systems, so deterministic MCE_R ground motions are used to estimate the levels of ground shaking in those regions.

S_S shall be determined from the 0.2 second (i.e., short period) mapped MCE_R spectral response accelerations, and S_1 shall be determined from the 1-second mapped MCE_R spectral response accelerations shown on *IBC Figures 1613.2.1(1)* through *1613.2.1(10)* which are based on the national seismic hazard study conducted by the United States Geologic Survey (USGS).

NOTE: where $S_S \leq 0.15$ and $S_1 \leq 0.04$, the structure may be assigned to *Seismic Design Category* A.

Earthquake Ground Motion Parameters are most easily, and more accurately, determined utilizing the *ASCE 7 Hazard Tool* at - https://asce7hazardtool.online/ with the input of street address, or Latitude and Longitude, or Find on the Map, to calculate the appropriate response parameters (S_S & S_1, F_a & F_v, S_{MS} & S_{M1}, and S_{DS} & S_{D1}), MCE_R response spectrum, design response spectrum, etc.

Site Class Definitions *IBC §1613.2.2*

Based on the site soil properties, the site shall be classified as either *Site Class* A, B, C, D, E or F in accordance with *ASCE 7-16 – Chapter 20.*

Site Classification *ASCE 7 – §20.1*

The *Site Class* shall be determined in accordance with *ASCE 7-16 – Table 20.3-1* and *§20.3* based on the upper 100 feet of the site profile.

Site class definitions are dependent on one or more of the following average soil properties:

- ✓ shear wave velocity ($\bar{v}_s$)
- ✓ standard penetration resistance ($\bar{N}$ or $\bar{N}_{ch}$)
- ✓ undrained shear strength ($\bar{s}_u$)

Site Class

A = Hard Rock (extremely rare in California … East coast only) with $\bar{v}_s > 5{,}000$ ft/second

B = Rock with $2{,}500 \leq \bar{v}_s \leq 5{,}000$ ft/second

C = Very dense soil & soft rock with $1{,}200 \leq \bar{v}_s \leq 2{,}500$ ft/second, etc.

D* = Stiff soil with $600 \leq \bar{v}_s \leq 1{,}200$ ft/second, etc. ←

E = Soft clay soil with $\bar{v}_s < 600$ ft/second, etc. … **or** any profile with > 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 = Soil (requiring site-specific evaluation per *ASCE 7-16 – §20.3.1*) with the following characteristics:
1. Soils vulnerable to potential failure or collapse under seismic loading (e.g., liquefiable soils, quick and highly sensitive clays, and collapsible weakly cemented soils)
2. Peats and/or highly organic clays, where thickness of peat and/or highly organic clay $H > 10$ feet
3. Very high plasticity clays ($H > 25$ feet with $PI > 75$)
4. Very thick soft/medium stiff clay ($H > 120$ feet) with $s_u < 1{,}000$ psf

3.7 ASCE 7 Seismic Design Criteria — *ASCE 7 – Chapter 11*

Scope — *ASCE 7 – §11.1.2*

Every structure (e.g., buildings and nonbuilding structures) and portion thereof, including nonstructural components, shall be designed and constructed to resist the effects of earthquake motions as prescribed by the seismic requirements of *ASCE 7-16*.

Applicability — *ASCE 7 – §11.1.3*

Structures and their nonstructural components shall be designed and constructed in accordance with the requirements of the following chapters based on the type of structure or component:

- Buildings: *ASCE 7-16 – Chapter 12*
- Nonbuilding Structures: *ASCE 7-16 – Chapter 15*
- Nonstructural Components: *ASCE 7-16 – Chapter 13*
- Seismically Isolated Structures: *ASCE 7-16 – Chapter 17*
- Structures with Damping Systems: *ASCE 7-16 – Chapter 18*

Seismic Importance Factor, I_e — *ASCE 7 – §11.5.1*

Each structure shall be assigned an *importance factor* (I_e) in accordance with *ASCE 7-16 – Table 1.5-2* … based on the *Risk Category* of the building (or other structure) from *IBC – Table 1604.5*.

- *Risk Category* I → $I_e = 1.0$
- *Risk Category* II → $I_e = 1.0$
- *Risk Category* III (high occupancy) → $I_e = 1.25$*
- *Risk Category* IV (essential facilities) → $I_e = 1.5$*

The seismic *importance factor* (I_e) is used in the *Seismic Response Coefficient* (C_S) equations with the intent to raise the yield level for important structures (e.g., hospitals, fire stations, emergency operation centers, hazardous facilities, etc.).

Use of an *importance factor* greater than one is intended to provide for a lower inelastic demand on a structure which should result in lower levels of structural and nonstructural damage.

**Risk Category* III and IV structures will require *Structural Observations* for structures per *IBC §1704.6.1*

Seismic Design Category A — *ASCE 7 – §11.7*

Structures may be assigned to *Seismic Design Category* A (i.e., *SDC* = A) under any of the following two conditions:

1. $S_S \leq 0.15$ and $S_1 \leq 0.04$ … per *IBC §1613.2.1*, **OR**
2. $S_{DS} < 0.167$ and $S_{D1} < 0.067$ … per *IBC Tables 1613.2.5(1) & 1613.2.5(2)*

Structures assigned to *Seismic Design Category* A need only comply with the requirements of *ASCE 7-16 – §1.4* (i.e., *ASCE 7-16 – Chapter 12* does not apply).

Nonstructural components assigned to *Seismic Design Category* A are exempt from seismic design requirements (i.e., *ASCE 7-16 – Chapter 13* does not apply).

Tanks assigned to *Risk Category* IV shall satisfy the freeboard requirement in *ASCE 7-16 – §15.6.5.1*.

Load Combinations for Allowable Stress Design *ASCE 7 – §2.4*

All applicable *Allowable Stress Design* (ASD) load combinations must be considered since the most critical load effect may occur when one or more of the contributing loads (e.g., D, E, L, L_r, S) are not acting.

- D *ASCE 7 (2.4-1)*
- $D + L$ *ASCE 7 (2.4-2)*
- $D + (L_r \text{ or } S \text{ or } R)$ *ASCE 7 (2.4-3)*
- $D + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$ *ASCE 7 (2.4-4)*
- $D + 0.6W$ *ASCE 7 (2.4-5)*
- $D + 0.75L + 0.75(0.6W) + 0.75(L_r \text{ or } S \text{ or } R)$ *ASCE 7 (2.4-6)*
- $0.6D + 0.6W$ *ASCE 7 (2.4-7)*

ASD Load Combinations with Seismic Load Effects *ASCE 7 – §2.4.5*

When a structure is subject to seismic load effects, the following load combinations shall be considered in addition to the basic ASD load combinations of *ASCE 7 – §2.4.1*:

- $1.0D + 0.7E_v + 0.7E_h$ *ASCE 7 (2.4-8)*

  or … $(1.0 + 0.14S_{DS})D + 0.7\rho Q_E$
- $1.0D + 0.525E_v + 0.525E_h + 0.75L + 0.75S$ *ASCE 7 (2.4-9)*

  or … $(1.0 + 0.105S_{DS})D + 0.525\rho Q_E + 0.75L + 0.75S$
- $0.6D – 0.7E_v + 0.7E_h$ *ASCE 7 (2.4-10)*

  or … $(0.6 – 0.14S_{DS})D + 0.7\rho Q_E$

NOTE: See *ASCE 7-16 – §2.4.5 - Exception 1 & 2* for additional requirements on the equations above (e.g., S in *ASCE 7 (2.4-9)*, $0.9D$ in lieu of $0.6D$ in *ASCE 7 (2.4-10)* for special masonry shear walls, etc.).

Alternative ASD Load Combinations *IBC §1605.2*

In lieu of the *Basic ASD Load Combinations* of *ASCE 7 – §2.4*, structures and portions thereof shall be permitted to be designed for the most critical effects resulting from the following load combinations:

- $D + L + (L_r \text{ or } S \text{ or } R)$ *IBC (16-1)*
- $D + L + 0.6W$ *IBC (16-2)*
- $D + L + 0.6W + S/2$ *IBC (16-3)*
- $D + L + S + 0.6W/2$ *IBC (16-4)*
- $D + L + S + E/1.4$ *IBC (16-5)*

  or … $(1.0 + 0.14S_{DS})D + L + S + \rho Q_E/1.4$
- $0.9D + E/1.4$ *IBC (16-6)*

  or … $(0.9 – 0.14S_{DS})D – \rho Q_E/1.4$

NOTE: See *IBC §1605.2 - Exception 1 & 2* for crane hook loads, flat roof snow loads ≤ 30 psf, roof live loads ≤ 30 psf, and flat roof snow loads > 30 psf.

NOTE: When using the *Alternative ASD Load Combinations* that include wind or seismic loads, allowable stresses are permitted to be increased, or load combinations reduced, where permitted by the appropriate material chapter or the referenced standards. See *IBC §1605.2* for requirements and conditions when considering wind loads (W) and/or foundations for loadings considering vertical seismic load effects (i.e., $E_v = 0$, etc.).

Load Combinations with Overstrength Factor

Where the seismic load effect with overstrength (Ω_0) is combined with the effects of other loads, the following seismic load combination for structures (not subject to flood or atmospheric ice loads) shall be used.

SD/LRFD Load Combinations with Seismic Overstrength — *ASCE 7 – §2.3.6*

When a structure is subject to seismic load effects, the following load combinations shall be considered in addition to the basic SD/LRFD load combinations of *ASCE 7 – §2.3.1*:

- $1.2D + E_v + E_{mh} + L + 0.2S$ — *ASCE 7 (2.3-6*)*

  or … $(1.2 + 0.2S_{DS})D + \Omega_0 Q_E + L + 0.2S$

- $0.9D - E_v + E_{mh}$ — *ASCE 7 (2.3-7*)*

  or … $(0.9 - 0.2S_{DS})D - \Omega_0 Q_E$

NOTE: See *ASCE 7-16 – §2.3.6 - Exception 1 & 2* for additional requirements on the equations above (e.g., use of $0.5L$ in *ASCE 7 (2.3-6)* where $L_o \leq 100$ psf except for garages or areas occupied as places of public assembly, etc.).

ASD Load Combinations with Seismic Overstrength — *ASCE 7 – §2.4.5*

When a structure is subject to seismic load effects, the following load combinations shall be considered in addition to the basic ASD load combinations of *ASCE 7 – §2.4.1*:

- $1.0D + 0.7E_v + 0.7E_{mh}$ — *ASCE 7 (2.4-8*)*

  or … $(1.0 + 0.14S_{DS})D + 0.7\Omega_0 Q_E$

- $1.0D + 0.525E_v + 0.525E_{mh} + 0.75L + 0.75S$ — *ASCE 7 (2.4-9*)*

  or … $(1.0 + 0.105S_{DS})D + 0.525\Omega_0 Q_E + 0.75L + 0.75S$

- $0.6D - 0.7E_v + 0.7E_{mh}$ — *ASCE 7 (2.4-10*)*

  or … $(0.6 - 0.14S_{DS})D - 0.7\Omega_0 Q_E$

NOTE: See *ASCE 7-16 – §2.4.5 - Exception 1 & 2* for additional requirements on the equations above (e.g., S in *ASCE 7 (2.4-9)*, $0.9D$ in lieu of $0.6D$ in *ASCE 7 (2.4-10)* special masonry shear walls, etc.).

Cantilever Column Systems — *ASCE 7 – §12.2.5.2*

Foundations and other elements used to provide overturning resistance at the base of cantilever column elements shall be designed to resist the seismic load effects, including overstrength (Ω_0) of *ASCE 7-16 – §12.4.3.*

Elements Supporting Discontinuous Walls or Frames — *ASCE 7 – §12.3.3.3*

Structural elements (e.g., columns, beams, trusses, slabs) supporting discontinuous walls or frames shall be designed to resist the seismic load effects, including overstrength (Ω_0) of *ASCE 7-16 – §12.4.3 …*for structures having either of the following:

- **Horizontal Structural Irregularity Type 4 –** Out-of-Plane Offset per *ASCE 7-16 – Table 12.3-1*
- **Vertical Structural Irregularity Type 4 –** In-Plane Discontinuity in Vertical Lateral Force-Resisting Element per *ASCE 7-16 – Table 12.3-2*

Using the load combinations from *ASCE 7-16* and recognizing that horizontal diaphragms are specifically designed to resist only lateral loads (e.g., not vertical gravity loads) … therefore, typically only earthquake (or wind) loads are considered for the design of the diaphragm to resist shear forces (e.g., D, L, L_r, S, etc. do not apply a lateral load on the diaphragm):

- **Allowable Stress Design (ASD) –**

$$\text{Maximum shear} = 0.7E = 0.7\ V_1 = 0.7(w_s L/2)$$

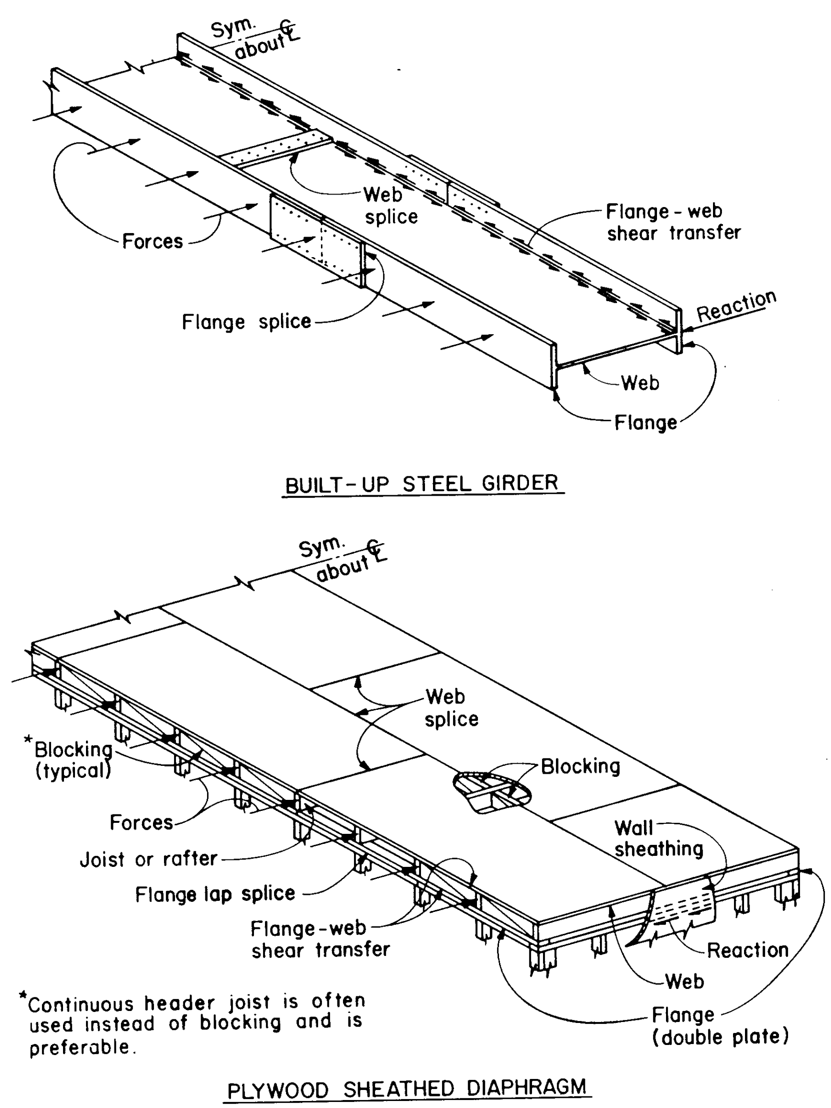
$$\text{Maximum unit diaphragm shear, } v_{max} = \frac{0.7(\text{max. shear})}{\text{diaphragm depth}} = \frac{0.7\ V_1}{d} \text{ (units of plf)}$$

- **Strength Design (SD or LRFD) –**

$$\text{Maximum shear} = 1.0E = 1.0\ V_1 = 1.0(w_s L/2)$$

$$\text{Maximum unit diaphragm shear, } v_{max} = \frac{\text{max. shear}}{\text{diaphragm depth}} = \frac{V_1}{d} \text{ (units of plf)}$$

Figure 8.8 – Diaphragm & Beam Analogy (Ref. 2)



(Applied Technology Council ATC-7 Report)

- **Diagonal Brace A**

$D = 0$
$L_r = 0$
$Q_E = \pm\, 33$ kips
$E_h = 1.3Q_E = 1.3(\pm\, 33 \text{ kips}) = \pm\, 42.9$ kips
$E_v = 0.13D = 0.13(0) = 0$

Column B
$D = 50$ kips
$L_r = 12$ kips
$Q_E = \pm 17$ kips
$E_h = 1.3Q_E = 1.3(\pm\, 17 \text{ kips}) = \pm\, 22.1$ kips
$E_v = 0.13D = 0.13(50 \text{ kips}) = 6.5$ kips

A.) STRENGTH DESIGN (SD/LRFD) BASIC LOAD COMBINATIONS:

1. Maximum Axial Force in Brace A

By inspection - since there are no gravity load effects in the brace, eqn *ASCE 7 (2.3-1)* through *(2.3-5)* will not govern and only the basic load combinations with seismic load effects need to be calculated.

$1.2D + E_v + E_h + L + 0.2S$ *ASCE 7 (2.3-6)*
$1.2\,(0) + 0 + 42.9 \text{ kips} + 0 + 0.2\,(0) = \underline{+\,42.9 \text{ kips}}$ (compression)

$0.9D - E_v + E_h$ *ASCE 7 (2.3-7)*
$1.2\,(0) - 0 + (-\,42.9 \text{ kips}) = \underline{-\,42.9 \text{ kips}}$ (tension)

$\therefore$ Maximum SD/LRFD axial force, $P = \boxed{\pm\, 42.9 \text{ kips}}$ compression or tension

2. Maximum Axial Force in Column B

By inspection - since there are only dead load (D) and roof live load (L_r) gravity load effects in the column, eqn *ASCE 7 (2.3-1) & (2.3-3)* will be calculated in addition to basic load combination with seismic load effects eqn *ASCE 7 (2.3-6)* to determine the maximum axial force in the column.

$1.4\,D$ *ASCE 7 (2.3-1)*
$1.4\,(50 \text{ kips}) = +\,70.0$ kips (compression)

$1.2\,D + 1.6\,(L_r \text{ or } S \text{ or } R) + 0.5\,(L \text{ or } 0.5\,W)$ *ASCE 7 (2.3-3)*
$1.2\,(50 \text{ kips}) + 1.6\,(12 \text{ kips}) + 0.5\,(0) = +\,79.2$ kips (compression)

$1.2\,D + E_v + E_h + L + 0.2\,S$ *ASCE 7 (2.3-6)*
$1.2\,(50) + 6.5 \text{ kips} + 22.1 \text{ kips} + 0 + 0.2\,(0) = \underline{+\,88.6 \text{ kips}}$ (compression)

$\therefore$ Maximum SD/LRFD axial force, $P = \boxed{+\,88.6 \text{ kips}}$ compression

3. Minimum Axial Force in Column B

By inspection - *ASCE 7 (2.3-1)* through *(2.3-5)* will not govern and the minimum axial force in the column will be governed by basic load combination with seismic load effects eqn *ASCE 7 (2.3-7)*.

$0.9\,D - E_v + E_h$ *ASCE 7 (2.3-7)*
$0.9\,(50) - 6.5 \text{ kips} + (-22.1 \text{ kips}) = \underline{+\,16.4 \text{ kips}}$ (compression)

$\therefore$ Minimum SD/LRFD axial force, $P = \boxed{+\,16.4 \text{ kips}}$ compression

By inspection, the maximum drag force will occur on line 3 (i.e., 25′ > 10′) -

- Wall Line 1: roof $v_1 = 175$ plf

  max. $F_d = v_1\,(10') = (175 \text{ plf})(10') = 1{,}750$ lbs (SD/LRFD force level)

- Wall Line 2: total "combined" roof $v_2 = 175 + 175 = 350$ plf, wall $v_2 = 350$ plf

  max. $F_d = 0$ lbs (SD/LRFD force level)

- Wall Line 3: roof $v_3 = 175$ plf

  max. $F_d = v_3\,(25') = (175 \text{ plf})(25') = \boxed{4{,}375 \text{ lbs}}$ ← governs (SD/LRFD force level)

  From Part A.4 - drag force $F_d = 8{,}750$ lbs → $\boxed{\therefore\ 50\% \text{ reduction in maximum drag force}}$

NOTE: When a flexible diaphragm building consists of two perimeter lines of lateral resistance (i.e., shear walls on lines 1 & 3) and one interior line of lateral resistance (i.e., shear wall on line 2), the total shear to the interior line of lateral resistance will theoretically be equal to one-half of the base shear (i.e., $V_2 = V/2$) even when the interior line of resistance is not located at the center of the building plan (i.e., $L = L_1 + L_2$ and $L_1 \neq L_2$).

$$V_2 = w_s\,(L_1/2) + w_s\,(L_2/2)$$
$$= w_s\,(L_1 + L_2)/2 = w_s\,L/2 = V/2$$

3.27 Determine the *Site Class* adjusted maximum considered earthquake (MCE_R) spectral acceleration parameters (S_{MS} & S_{M1}) for the previous problem.

a. $S_{MS} = 1.20$ & $S_{M1} = 0.84$
b. $S_{MS} = 0.85$ & $S_{M1} = 0.66$
c. $S_{MS} = 0.70$ & $S_{M1} = 0.44$
d. $S_{MS} = 0.65$ & $S_{M1} = 0.30$

3.28 Given $S_S = 1.82$ & $S_1 = 0.68$, and a geotechnical report identifying the average soil properties of the upper 100 feet as a "very dense soil", determine the appropriate site coefficients F_a & F_v.

a. $F_a = 1.0$ & $F_v = 1.7$
b. $F_a = 1.2$ & $F_v = 1.7$
c. $F_a = 1.2$ & $F_v = 1.4$
d. Site-specific ground motion must be used per *ASCE 7-16 – §11.4.8*

3.29 Determine the *site class* adjusted maximum considered earthquake (MCE_R) spectral acceleration parameters (S_{MS} & S_{M1}) for the previous problem.

a. $S_{MS} = 2.18$ & $S_{M1} = 0.95$
b. $S_{MS} = 1.82$ & $S_{M1} = 1.74$
c. $S_{MS} = 1.82$ & $S_{M1} = 1.16$
d. Site-specific ground motion must be used per *ASCE 7-16 – §11.4.8*

3.30 Given a soil profile of "soft rock", $S_S = 0.40$ & $S_1 = 0.15$, determine the appropriate site coefficients F_a & F_v.

a. $F_a = 1.0$ & $F_v = 1.0$
b. $F_a = 1.3$ & $F_v = 1.5$
c. $F_a = 1.2$ & $F_v = 1.65$
d. $F_a = 1.48$ & $F_v = 2.3$

3.31 Determine the site adjusted maximum considered earthquake (MCE_R) spectral acceleration parameters (S_{MS} & S_{M1}) for the previous problem.

a. $S_{MS} = 0.59$ & $S_{M1} = 0.35$
b. $S_{MS} = 0.48$ & $S_{M1} = 0.25$
c. $S_{MS} = 0.52$ & $S_{M1} = 0.23$
d. $S_{MS} = 0.40$ & $S_{M1} = 0.15$

3.32 The <u>design</u> spectral response acceleration parameters (i.e., S_{DS} & S_{D1}) are a function of:

I. *Site Class*
II. *Risk Category*
III. Mapped MCE_R spectral accelerations parameters (S_S & S_1)

a. I
b. I & II
c. I & III
d. II & III

3.46 What would be the most appropriate MCE$_R$ spectral response acceleration parameters (S_S & S_1) for a building project proposed at 35º00′00″ Latitude and -120º00′00″ Longitude?

a. $S_S = 1.50$ & $S_1 = 0.70$
b. $S_S = 1.25$ & $S_1 = 0.50$
c. $S_S = 1.00$ & $S_1 = 0.40$
d. $S_S = 0.75$ & $S_1 = 0.30$

3.47 MCE$_R$ mapped spectral response acceleration parameters S_S & S_1 are determined based on which *site class*?

a. B
b. C
c. D
d. None of the above

3.48 Given $S_S = 0.63$ & $S_1 = 0.25$, with no soils report, what site coefficients F_a & F_v would be most appropriate per the *IBC?*

a. $F_a = 1.2$ & $F_v = 2.0$
b. $F_a = 1.3$ & $F_v = 2.1$
c. $F_a = 1.4$ & $F_v = 2.2$
d. Site-specific ground motion procedure is required to determine F_a & F_v

3.49 Given $S_S = 0.63$ & $S_1 = 0.25$, with no soils report, what design spectral response acceleration parameters would be most appropriate (i.e., S_{DS} & S_{D1})?

a. Site-specific ground motion procedure is required to determine S_{DS} & S_{D1}
b. $S_{DS} = 0.59$ & $S_{D1} = 0.37$
c. $S_{DS} = 0.55$ & $S_{D1} = 0.53$
d. $S_{DS} = 0.55$ & $S_{D1} = 0.35$

3.50 Given a 3-story State Emergency Operations Center (EOC) with $S_S = 1.92$, $S_1 = 0.80$, $S_{DS} = 1.29$ & $S_{D1} = 0.80$, what is the *Seismic Design Category*?

a. C
b. D
c. E
d. F

3.51 Which of the following occupancies types would <u>never</u> be assigned to *Seismic Design Category* E (*SDC* = E)?

a. Police station
b. Apartment building
c. County jail
d. Medical office building

3.52 Which of the following would be considered a *Risk Category* III structure?

a. 2-story Group E classroom building with an occupant load of 250
b. Multiplex cinema with 10 theaters each with an occupant load of 320
c. State University classroom building with an occupant load of 500
d. High-rise apartment building with an occupant load of 5,000

Problem	Answer	Reference / Solution
3.27	b	p. 1-33 & *2021 IBC* p. 16-41 - *§1613.2.3* $S_{MS} = F_a S_S$ *IBC (16-20)* $= 1.7\ (0.50) = 0.85$ $S_{M1} = F_v S_1$ *IBC (16-21)* $= 3.3\ (0.20) = 0.66$ $\therefore S_{MS} = \underline{0.85}$ & $S_{M1} = \underline{0.66}$ ←
3.28	c	1-33 & *2021 IBC* p. 16-42 - *Tables 1613.2.3(1) & 1613.2.3(2)* "very dense soil" → *ASCE 7-16* p. 204 - *Table 20.3-1* → *Site Class* C *Site Class* C & $S_S = 1.82 > 1.5$ → *Table 1613.2.3(1)* → $F_a = 1.2$ *Site Class* C & $S_1 = 0.68 > 0.6$ → *Table 1613.2.3(2)* → $F_v = 1.4$ $\therefore F_a = \underline{1.2}$ & $F_v = \underline{1.4}$ ←
3.29	a	p. 1-33 & *2021 IBC* p. 16-41 - *§1613.2.3* $S_{MS} = F_a S_S$ *IBC (16-20)* $= 1.2\ (1.82) = 2.18$ $S_{M1} = F_v S_1$ *IBC (16-21)* $= 1.4\ (0.68) = 0.95$ $\therefore S_{MS} = \underline{2.18}$ & $S_{M1} = \underline{0.95}$ ←
3.30	b	p. 1-33 & *2021 IBC* p. 16-42 - *Tables 1613.2.3(1) & 1613.2.3(2)* "soft rock" → *ASCE 7-16* p. 204 - *Table 20.3-1* → *Site Class* C *Site Class* C & $S_S = 0.40$ → *Table 1613.2.3(1)* → $F_a = 1.3$ *Site Class* C & $S_1 = 0.15$ → *Table 1613.2.3(2)* → $F_v = 1.5$ $\therefore F_a = \underline{1.3}$ & $F_v = \underline{1.5}$ ←
3.31	c	p. 1-33 & *2021 IBC* p. 16-41 - *§1613.2.3* $S_{MS} = F_a S_S$ *IBC (16-20)* $= 1.3\ (0.40) = 0.52$ $S_{M1} = F_v S_1$ *IBC (16-21)* $= 1.5\ (0.15) = 0.23$ $\therefore S_{MS} = \underline{0.52}$ & $S_{M1} = \underline{0.23}$ ←
3.32	c	p. 1-34 & *2021 IBC* p. 16-41 - *§1613.2.4* S_{DS} & S_{D1} are equal to 2/3 of the S_{MS} & S_{M1} respectively, which means they all are a function of the the *Site Class* (i.e., F_a & F_v) <u>and</u> mapped MCE_R spectral acceleration parameters S_S & S_1 ∴ <u>I & III</u> ←
3.33	b	p. 1-34 & *2021 IBC* p. 16-41 - *§1613.2.4* $S_{DS} = 2/3\ S_{MS}$ *IBC (16-22)* $= 2/3\ (0.90) = 0.60$ $S_{D1} = 2/3\ S_{M1}$ *IBC (16-23)* $= 2/3\ (0.74) = 0.49$ $\therefore S_{DS} = \underline{0.60}$ & $S_{D1} = \underline{0.49}$ ←

Problem	Answer	Reference / Solution
3.42	c	p. 1-37 - Table 3.3 *Seismic Design Category* C = <u>Moderate</u> seismic hazard level ←
3.43	d	p. 1-37 & *2021 IBC* p. 16-41 - *§1613.2.5* a. Hospital (Group I-2, Condition 2) → *IBC Table 1604.5* → *RC* = IV b. Single-family residence (Group R-3) → *IBC Table 1604.5* → *RC* = II c. County jail (Group I-3) → *IBC Table 1604.5* → *RC* = III *Seismic Design Category* F applies <u>only</u> to *Risk Category* IV structures (i.e., essential facilities, etc.) *SDC* = F <u>does not</u> apply to *Risk Category* I, II or III structures … ∴ <u>Both b & c</u> ←
3.44	d	*2021 IBC* p. 16-4 & 5 - *§1604.5.1* & *Table 1604.5* Where a building or structure is occupied by <u>two or more occupancies</u> not included in the same *Risk Category,* it shall be assigned the classification of the <u>highest</u> *Risk Category* corresponding to the various occupancies. Office building → *IBC Table 1604.5* → *RC* = II Fire station → *IBC Table 1604.5* → *RC* = IV ← governs ∴ use *Risk Category* <u>IV</u> ←
3.45	c	*2021 IBC* p. 16-44 & 46 - *Figures 1613.2.1(1)* & *1613.2.1(3)* At 45º00′00″ Latitude and -120º00′00″ Longitude … *Figure 1613.2.1(1)* → $S_S \approx 36\% = \underline{0.36}$ *Figure 1613.2.1(3)* → $S_1 \approx 15\% = \underline{0.15}$ ∴ $S_S = \underline{0.36}$ & $S_1 = \underline{0.15}$ ←
3.46	c	*2021 IBC* p. 16-44 & 46 - *Figures 1613.2.1(1)* & *1613.2.1(3)* At 35º00′00″ Latitude and -120º00′00″ Longitude … *Figure 1613.2.1(1)* → $S_S \approx 100\% = \underline{1.00}$ *Figure 1613.2.1(3)* → $S_1 \approx 40\% = \underline{0.40}$ ∴ $S_S = \underline{1.00}$ & $S_1 = \underline{0.40}$ ←
3.47	d	*2021 IBC* p. 16-44 & 46 - *Figures 1613.2.1(1)* & *1613.2.1(3)* Unlike the *2015 IBC* and *ASCE 7-10* where the S_S & S_1 maps were based on a *Site Class* B soil profile, the S_S & S_1 maps for the *2021 IBC* and *ASCE 7-16* are based on a soil profile interface <u>between</u> *Site Class* B and *Site Class* C (i.e., average shear wave velocity = 2,500 ft/sec) ∴ <u>None of the above</u> ←
3.48	b	1-33 - NOTE & *2021 IBC* p. 16-41 - *Table 1613.2.3(1)* & *Table 1613.2.3(2)* No soils report → assume *Site Class* D (default) Using linear interpolation … for intermediate values of S_S and S_1 per Note *Site Class* D & $S_S = 0.63$ → *Table 1613.2.3(1)* → $F_a = 1.3$ *Site Class* D & $S_1 = 0.25$ → *Table 1613.2.3(2)* → $F_v = 2.1$ ∴ $F_a = \underline{1.3}$ & $F_v = \underline{2.1}$ ←

Problem	Answer	Reference / Solution
3.49	c	1-33 to 34 & *2021 IBC* p. 16-41 & 42 - *§1613.2.3, §1613.3.4, Table 1613.2.3(1) & Table 1613.2.3(2)*, and *ASCE 7-16 Supplement 3* to *§11.4.8* From Problem 3.48 – $F_a = 1.3$ & $F_v = 2.1$ $S_{MS} = F_a S_S$ *IBC (16-20)* $= 1.3\,(0.63) = 0.82$ ***NOTE**:* per Exception for *Site Class* D sites w/ $S_1 \geq 0.2$ … a GMHA is <u>not required</u> where S_{M1} is increased by 50% for all applications of S_{M1}, etc. $S_{M1} = {}^*1.5\,F_v S_1$ *IBC (16-21)* $= 1.5\,(2.1)(0.25) = 0.79$ $S_{DS} = 2/3\, S_{MS}$ *IBC (16-22)* $= 2/3\,(0.82) = \underline{0.55}$ $S_{D1} = 2/3\, S_{M1}$ *IBC (16-23)* $= 2/3\,(0.79) = \underline{0.53}$ $\therefore S_{DS} = \underline{0.55}$ & $S_{D1} = \underline{0.53}$ $\leftarrow$
3.50	d	1-37 - Table 3.4 & *2021 IBC* p. 16-41 - *§1613.2.5* Emergency Operations Center (EOC) $\rightarrow$ *IBC Table 1604.5* $\rightarrow$ *RC* = IV $S_1 = 0.80 > 0.75$ $\rightarrow$ for *Risk Category* IV $\rightarrow$ *Seismic Design Category* F ∴ <u>*SDC* = F</u> $\leftarrow$
3.51	a	p. 1-37 - Table 3.4 & *2021 IBC* p. 16-41 - *§1613.2.5* Police station $\rightarrow$ *IBC Table 1604.5* $\rightarrow$ *RC* = IV Apartment building (Group R-2) $\rightarrow$ *IBC Table 1604.5* $\rightarrow$ *RC* = II County jail (Group I-3) $\rightarrow$ *IBC Table 1604.5* $\rightarrow$ *RC* = III Medical office building (Group B) $\rightarrow$ *IBC Table 1604.5* $\rightarrow$ *RC* = II *Seismic Design Category* E applies <u>only</u> to *Risk Category* I, II or III structures … *SDC* = E <u>does not</u> apply to *Risk Category* IV structures ∴ <u>Police station</u> $\leftarrow$
3.52	b	p. 1-28 & *2021 IBC* p. 16-5 - *Table 1604.5* Group E classroom bldg. w/ occupant load (OL) = 250 $\ngtr$ 250 $\rightarrow$ *RC* = II Multiplex cinema bldg. OL = 10 (300) = 3,200 > 2,500 $\rightarrow$ <u>*RC* = III</u> State University classroom bldg. w/ OL = 500 $\ngtr$ 500 $\rightarrow$ *RC* = II High-rise apartment bldg. w/ OL = 5,000 $\ngtr$ 5,000 $\rightarrow$ *RC* = II ∴ <u>Multiplex cinema w/ 10 theaters each with an occupant load of 320</u> $\leftarrow$
3.53	d	p. 1-31 - Mapped MCE_R Acceleration Parameters, S_S & S_1 The MCE_R ground motions are expected to result in structures with a <u>1% probability of collapse in 50 years</u>, which is assumed to be an acceptable level of seismic safety. ∴ <u>1% probability of collapse in 50 years</u> $\leftarrow$
3.54	c	p. 1-28 & *2021 IBC* p. 3-9 - *§308.4* Group I-3 occupancies include correctional centers, detention centers, <u>jails</u>, prerelease centers, <u>prisons</u>, reformatories, etc. ∴ <u>Group I-3</u> $\leftarrow$

Problem	Answer	Reference / Solution
7.6	b	Horizontal force per brace: H = 6.0 kips / 2 frames = 3.0 kips per frame (horizontal component in brace) Length of brace, $L_b = \sqrt{(8')^2 + (6')^2} = 10'$ By similar triangles (or trigonometry), the resultant axial force in brace: $Q_E = R$ = (3.0 kips)(10′) / (8′) = 3.8 kips per brace ←
7.7	b	Dead load effect: Tank is supported by 4 columns D = (20 kips) / 4 columns = 5 kips per column ←
7.8	b	p. 1-80 - Vertical Seismic Load Effect, E_v & *ASCE 7-16* p. 99 - *§12.4.2.2* $E_v = 0.2 S_{DS} D$ *ASCE 7 (12.4-4a)* E_v = 0.2(0.60)(5 kips) = ± 0.6 kips per column ←
7.9	d	p. 1-28 to 29 - Risk Category & *2021 IBC* p. 16-5 - *Table 1604.5* Power-generating stations ... required as emergency backup facilities for *Risk Category* IV structures (e.g., EOC) – *Risk Category* IV ←
7.10	b	1-37 to 38 & *2021 IBC* p. 16-41 - *§1613.2.5* & *Tables 1613.2.5(1)* & *(2)* $S_1 < 0.75$ … therefore, determine *SDC* from *Tables 1613.2.5(1)* & *(2)* only S_{DS} = 0.60 & *RC* = IV → *Table 1613.2.5(1)* → *SDC* = D S_{D1} = 0.24 & *RC* = IV → *Table 1613.2.5(2)* → *SDC* = D ∴ *SDC* = D ←
7.11	a	p. 1-39 - Seismic Importance Factor, I_e & *ASCE 7-16* p. 5 - *Table 1.5-2* *Risk Category* IV – *2021 IBC Table 1604.5* ∴ I_e = 1.5 ←
7.12	b	p. 1-106 to 107 & *ASCE 7-16* p. 147 - *Table 15.4-1* – Nonbuilding Structures Similar to Buildings Steel ordinary concentrically braced frames (steel OCBF) – R = 3¼ ←
7.13	b	p. 1-106 - Rigid Nonbuilding Structures & *ASCE 7-16* p. 149 - *§15.4.2* T = 0.05 second < 0.06 second → Rigid nonbuilding structure $V = 0.30 S_{DS} W I_e$ *ASCE 7 (15.4-5)* = 0.30(0.60)(20 kips)(1.5) = 5.4 kips ←
7.14	d	p. 1-110 to 111 - Tanks and Vessels & *ASCE 7-16* p. 153 - *§15.7.1* This section applies to all tanks, vessels, bins and silos, and similar containers storing liquids, gases, and granular solids supported at the base. ∴ I, II & III ←
7.15	d	p. 1-106 to 107 & *ASCE 7-16* p. 150 - *§15.5* Nonbuildings structures similar to buildings include pipe racks, steel storage racks, electrical power generating facilities, structural towers for tanks and vessels, and piers and wharves. ∴ All of the above ←

Problem	Answer	Reference / Solution
9.8	b	p. 1-122 - Drag Force Maximum drag force occurs on right (i.e., East) wall line at 20′ from South end of collector (i.e., South end of 30′ shear wall) – From Problem 9.7, ASD roof $v = 240$ plf for ASD, max F_d = roof $v(20') = (240\text{ plf})(20') = 4{,}800$ lbf = 4.8 kips ←
9.9	b	p. 1-155 to 158 - Shear Wall Overturning / Hold-Downs $\rho = 1.0$ (given) $V_1 = V_2 = V/2 = 33.6\text{ kips}/2 = 16.8$ kips $T = \dfrac{-0.7\rho(V_1\,h)}{b} = \dfrac{-0.7(1.0)(16.8)(10')}{30'} = -3.92$ kips ∴ for ASD, uplift T = 4.0 kips ←
9.10	b	p. 1-144 - Wood Structural Panel Diaphragms $V = C_S W = 0.196\,W$ (given) For a single-story building – $w_s = f_{p1} = F_{p1}/L = C_S w_{p1}$ E-W direction: $w_s = 0.196\,[(25\text{ psf})(75') + (15\text{ psf})(12'/2)\,4\text{ walls}] = 438$ plf $V_{max} = w_s L/2 = (438\text{ plf})(40')/2 = 8{,}760$ lbf for ASD, roof $v = (0.7\,V_{max})/d = 0.7\,(8{,}760\text{ lbf})/75' = 82\text{ plf} \approx$ 80 plf ←
9.11	c	p. 1-152 - Table 9.5 & *SDPWS-2021* p. 40 - *Table 4.3A* 3/8″ rated sheathing w/ 8d common @ 2″ o.c. → $v_n = 1485$ plf 15/32″ Structural I w/ 10d common @ 6″ o.c. → $v_n = 950$ plf **NG!** 15/32″ Structural I w/ 10d common @ 4″ o.c. → $v_n = 1430$ plf **NG!** 15/32″ Structural I w/ 10d common @ 3″ o.c. → $v_n = 1860$ plf **OK** 15/32″ Structural I w/ 10d common @ 2″ o.c. → $v_n = 2435$ plf **OK** ∴ use 15/32″ Structural I w/ 10d common @ 3″ o.c. = 1860 plf > 1485 plf ←
9.12	d	p. 1-145/146 - Table 9.2 & 9.3, *SDPWS-2021* p. 25/26 - *Table 4.2A* & *4.2C* Load parallel to continuous panel joints = CASE 3 (weak direction) 15/32″ sheathing w/ 8d @ 6″ o.c. unblocked → Table 9.3 (*4.2C*) → $v_n = 505$ plf → ASD $v_s = v_n/2.8 = (505\text{ plf})/2.8 = 180\text{ plf} < 275$ plf **NG!** 15/32″ sheathing w/ 10d @ 6″ o.c. unblocked → Table 9.3 (*4.2C*) → $v_n = 530$ plf → ASD $v_s = v_n/2.8 = (530\text{ plf})/2.8 = 189\text{ plf} < 275$ plf **NG!** 15/32″ sheathing w/ 8d @ 6″ o.c. blocked → Table 9.2 (*4.2A*) → $v_n = 755$ plf → ASD $v_s = v_n/2.8 = (755\text{ plf})/2.8 = 270\text{ plf} < 275$ plf **NG!** 15/32″ sheathing w/ 10d @ 6″ o.c. blocked → Table 9.2 (*4.2A*) → $v_n = 810$ plf → ASD $v_s = v_n/2.8 = (810\text{ plf})/2.8 = 289\text{ plf} > 275$ plf **OK** ∴ use 15/32″ sheathing w/ 10d common @ 6″ o.c. ←
9.13	d	p. 1-118 - Flexible Diaphragm Analysis $V = C_S W$ and $C_S = 0.20$ (given) For a single-story building – $w_s = f_{p1} = F_{p1}/L = C_S w_{p1}$ *(continued)*