15 Question Seismic Design Quiz for the California PE Exam

This document contains 15 seismic design questions with complete solutions and code references to help anyone in their studies for the California State Specific Seismic Exam required for PE licensure. Visit www.structural.wiki, for more resources and study tips.

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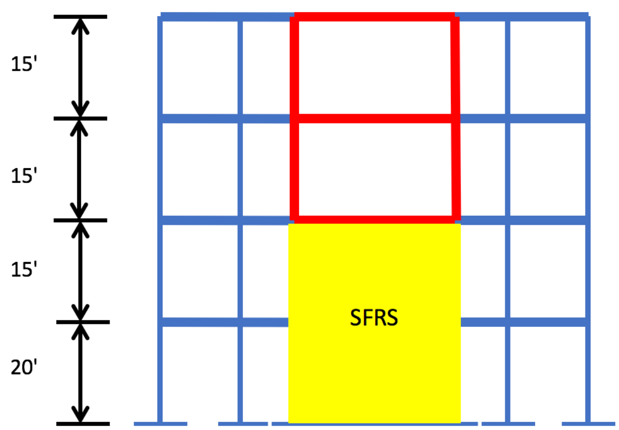
www.structural.wiki
Rev.0 - March 2021

1. The four-story structure shown falls under Seismic Design Category E and utilizes a Steel Special Moment Frame at the third and fourth stories. The Special Moment Frame is to be discontinued at the third floor and an alternate system is to be used for the first and second stories of the structure. What systems are acceptable for use at the first and second stories?



ELEVATION

A. Steel Special Concentrically Braced Frame
B. Steel Eccentrically Braced Frame
C. Special Reinforced Concrete Moment Frame
D. Steel Buckling-Restrained Braced Frame

2. A two-story police station is being designed to resist seismic forces per *ASCE 7-16*. Based off the following parameters, determine the appropriate Seismic Design Category:

$$F_a = 1.0 \qquad F_v = 1.7 \qquad S_{DS} = 1.32\ g \qquad S_{D1} = 0.85\ g$$

A. Seismic Design Category A
B. Seismic Design Category B
C. Seismic Design Category C
D. Seismic Design Category D
E. Seismic Design Category E
F. Seismic Design Category F

3. Consider a single-story emergency shelter which carries a roof dead load of 10 PSF and utilizes a Steel Ordinary Concentric Braced Frame Seismic Force-Resisting System.

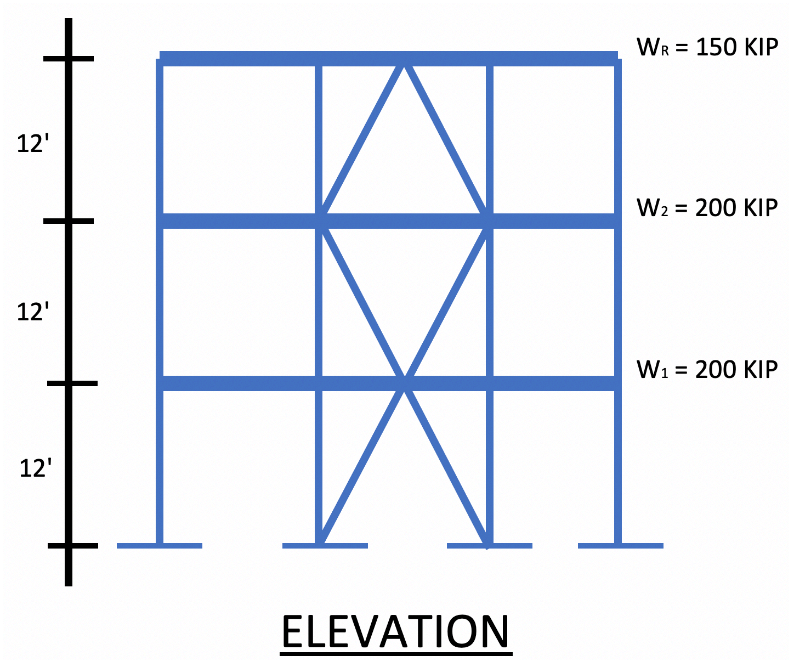
Given the following parameters, what is the maximum height allowed by *ASCE 7-16*?

$$S_{DS} = 0.45g \qquad S_1 < 0.75g$$

A. 35 ft
B. 60 ft
C. 160 ft
D. 240 ft

4. You are to design a 3-story Steel Special Concentrically Braced Frame building with an occupancy load of 200. Determine the seismic base shear, based on the following parameters:

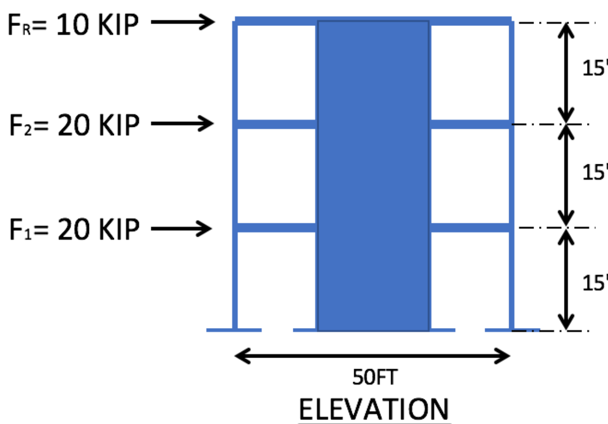
$$S_{DS} = 1.25g \qquad S_{D1} = 0.82g \qquad S_1 = 0.82g \qquad T_L = 8s$$

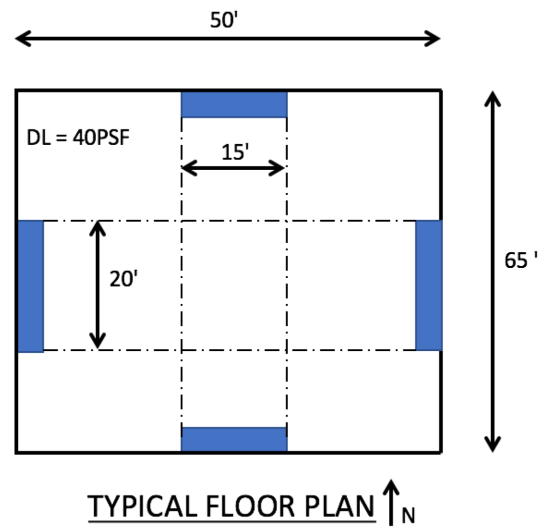


A. $V = 145.1\ kip$
B. $V = 59.8\ kip$
C. $V = 55.7\ kip$
D. $V = 111.3\ kip$

5. A 3-story art studio building designed by architects who dislike circular shapes utilizes a Concrete Special Shear Wall System in each direction to resist seismic forces. The building was designed for story forces shown and has 18" concrete shear walls. Determine the diaphragm force in the North-South Direction at Level 2 based on the floor dead load and weight of concrete shear walls; assume dead load includes weight of building framing tributary to floor.

$$\gamma_{concrete} = 150\ pcf,\ \ DL = 40\ psf$$



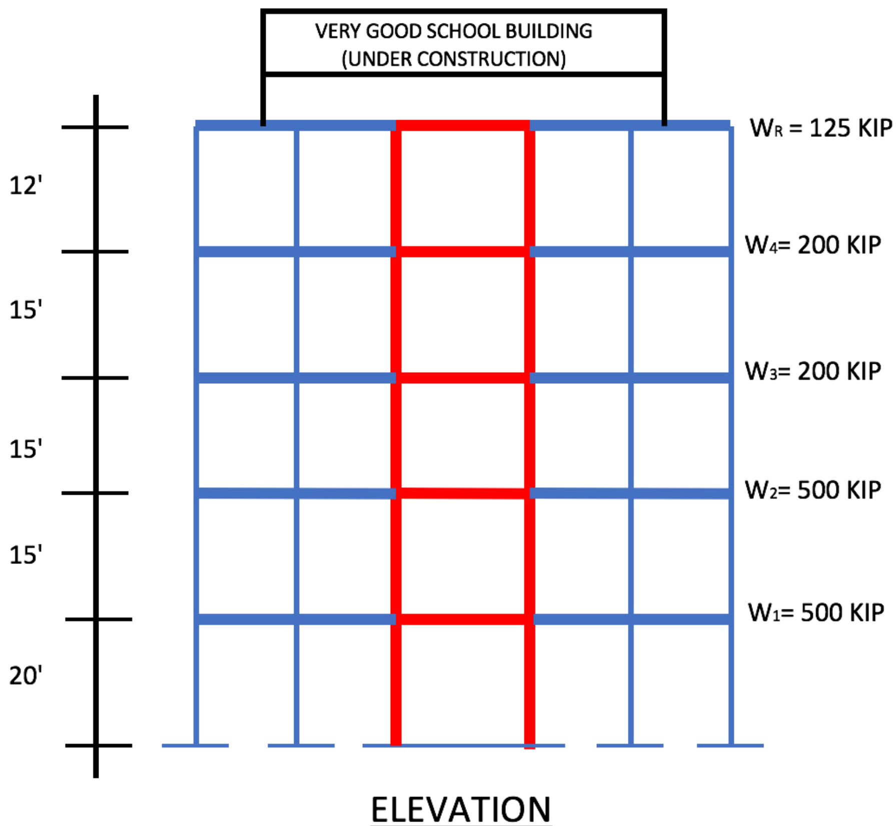


A. $F_{p2} = 13.6\ kip$
B. $F_{p2} = 18.3\ kip$
C. $F_{p2} = 12.6\ kip$
D. $F_{p2} = 19.0\ kip$

6. You are to design a community college building with an occupant load of 750 people. The building is to utilize a Steel Special Moment Frame. Based on the following seismic parameters, determine the base shear:

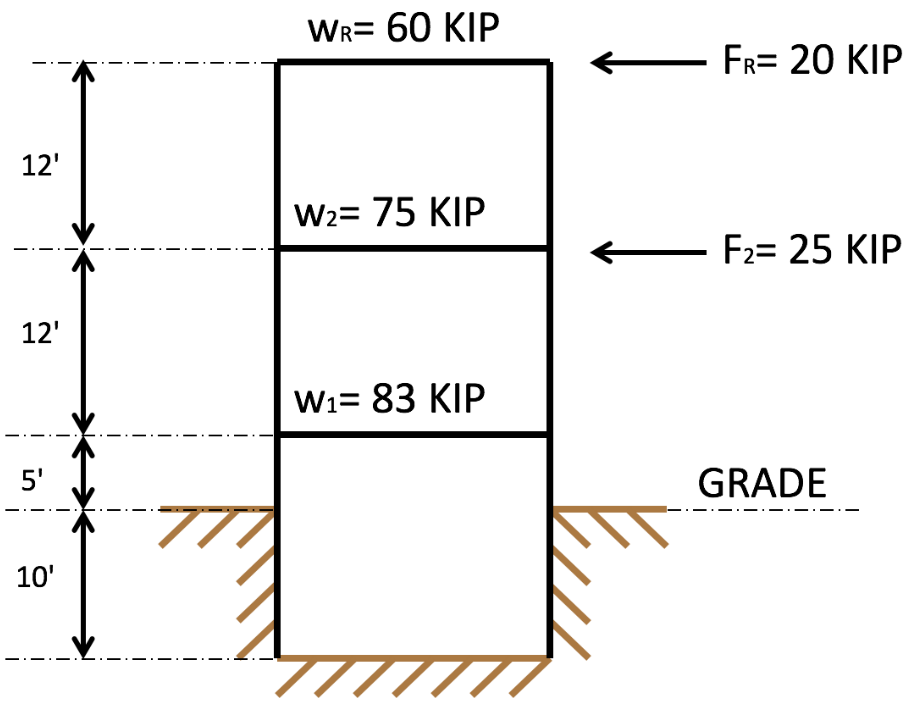
$$S_1 < 0.6g \qquad S_{DS} = 1.30g \qquad S_{D1} = 0.92g$$

$$T = 0.6s \qquad T_L = 8s$$



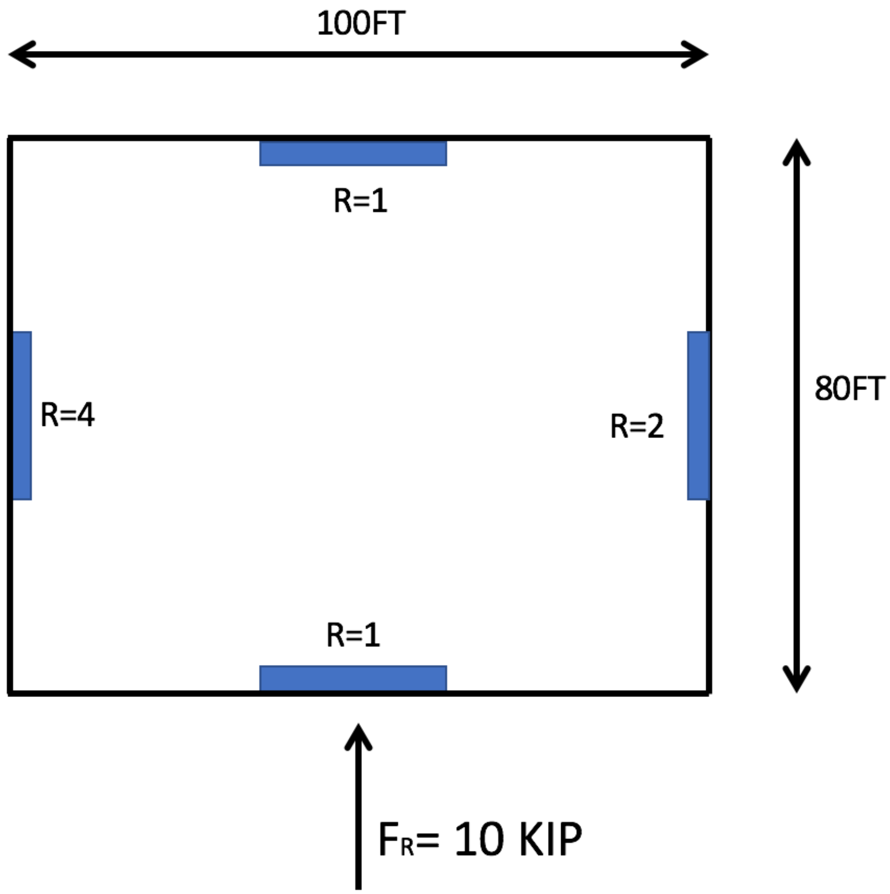
A. $V = 175\ kip$
B. $V = 305\ kip$
C. $V = 610\ kip$
D. $V = 730\ kip$

7. A 3-story apartment building with Ordinary Reinforced Masonry Shear Walls has been designed for forces shown using the simplified design method of *ASCE 7-16 Chapter 12*. Determine the Spectral Response Acceleration used in design:



A. $S_{DS} = 0.85g$
B. $S_{DS} = 0.43g$
C. $S_{DS} = 0.61g$
D. $S_{DS} = 1.03g$

8. A roof plan for a 3-story wood frame apartment building with metal deck floors is shown. Based on the given roof story force, find the accidental torsional moment associated with the roof diaphragm.

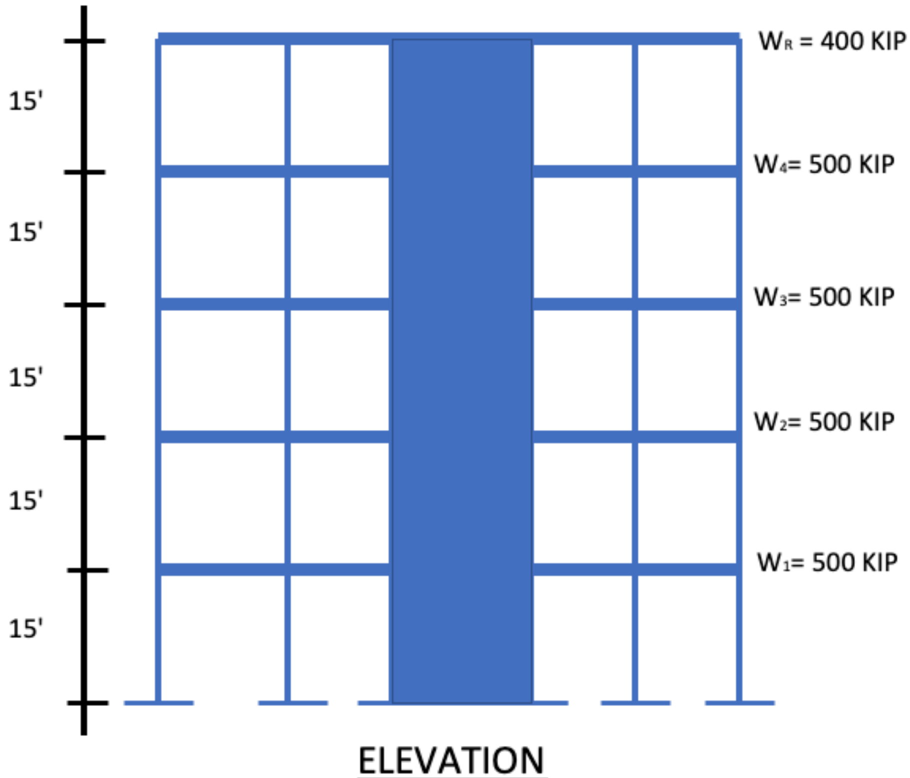


ROOF PLAN

A. 0 kip-ft
B. 10.7 kip-ft
C. 15.3 kip-ft
D. 13.2 kip-ft

9. You are analyzing an existing 5 story jail with a Special Reinforced Concrete Shear Wall Seismic Force-Resisting System in each direction. Given the following parameters, what is the seismic story force at Level 1?

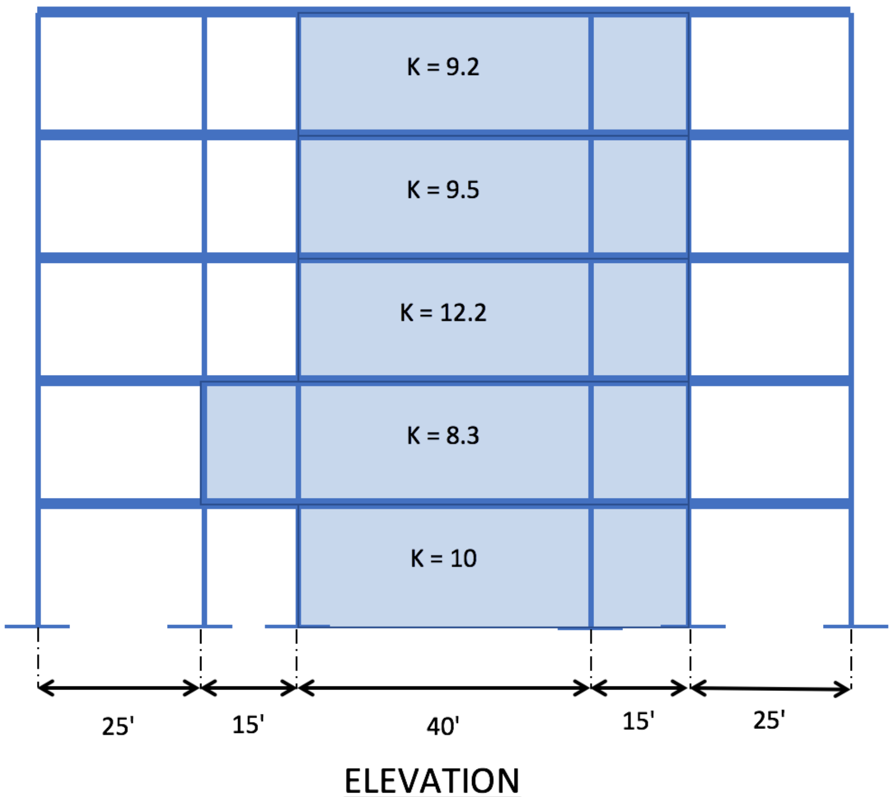
$$S_S = 2.44g \quad S_1 = 0.86g \quad T_L = 8s$$



Assume that no ground motion hazard analysis is available and take utilize code exceptions as required.

A. $F_1 = 58.3\ kip$
B. $F_1 = 35.0\ kip$
C. $F_1 = 233.1\ kip$
D. $F_1 = 116.6\ kip$

10. The structure shown is a five-story shear wall building with relative lateral stiffnesses noted at each level. Determine the type of Vertical Irregularity associated with this structure:

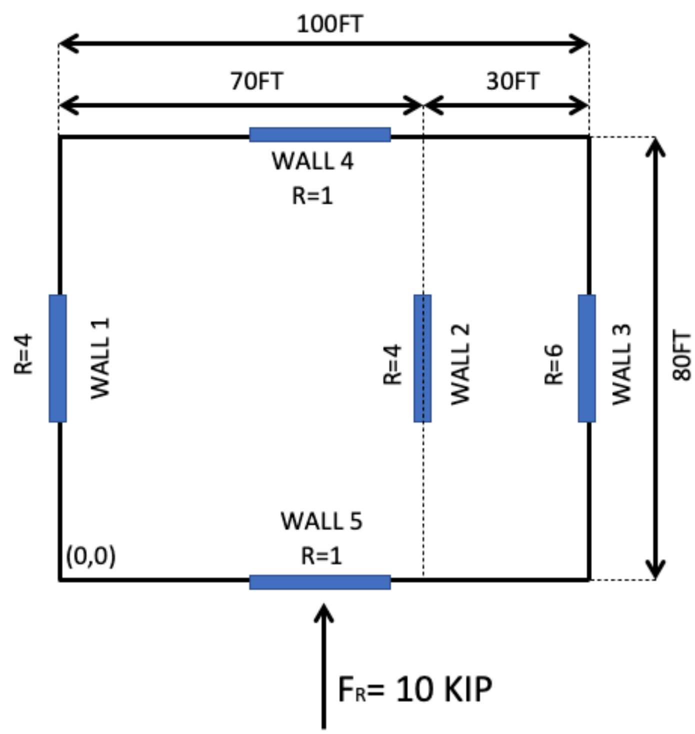


A. Stiffness-Extreme Soft Story Irregularity
B. Vertical Geometric Irregularity
C. Discontinuity in Lateral Strength–Weak Story Irregularity
D. Stiffness-Soft Story Irregularity
E. Discontinuity in Lateral Strength–Extreme Weak Story Irregularity

11. Determine the approximate fundamental period T_a of a 70 ft tall building the utilizes Ordinary Reinforced Concrete Moment Frame as the Seismic Force-Resisting System.

A. $T_a = 0.73\ s$
B. $T_a = 0.13\ s$
C. $T_a = 0.52\ s$
D. $T_a = 0.89\ s$

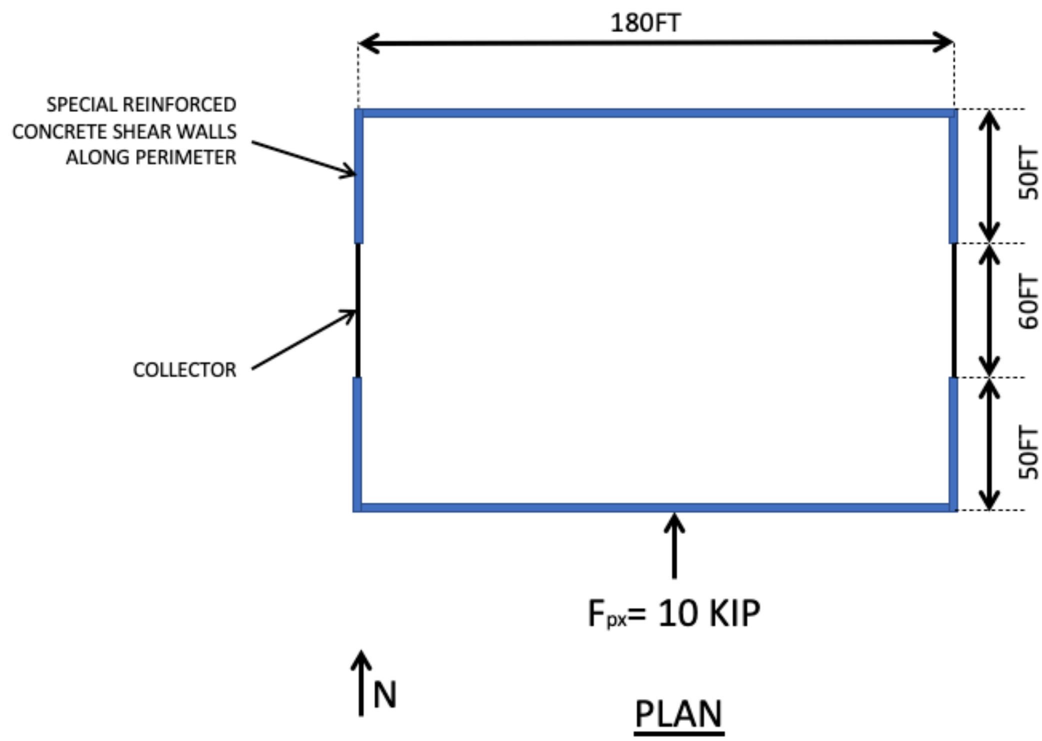
12. The plan pictured below shows the relative rigidities of concrete shear walls located directly below a 6" concrete roof slab. Given the loading shown, determine the location of the center of rigidity and the load at Wall 1.



ROOF PLAN

A. (63 ft, 40 ft); 3 kip
B. (63 ft, 35ft); 5 kip
C. (72 ft, 40 ft); 5 kip
D. (72 ft, 35ft); 3 kip

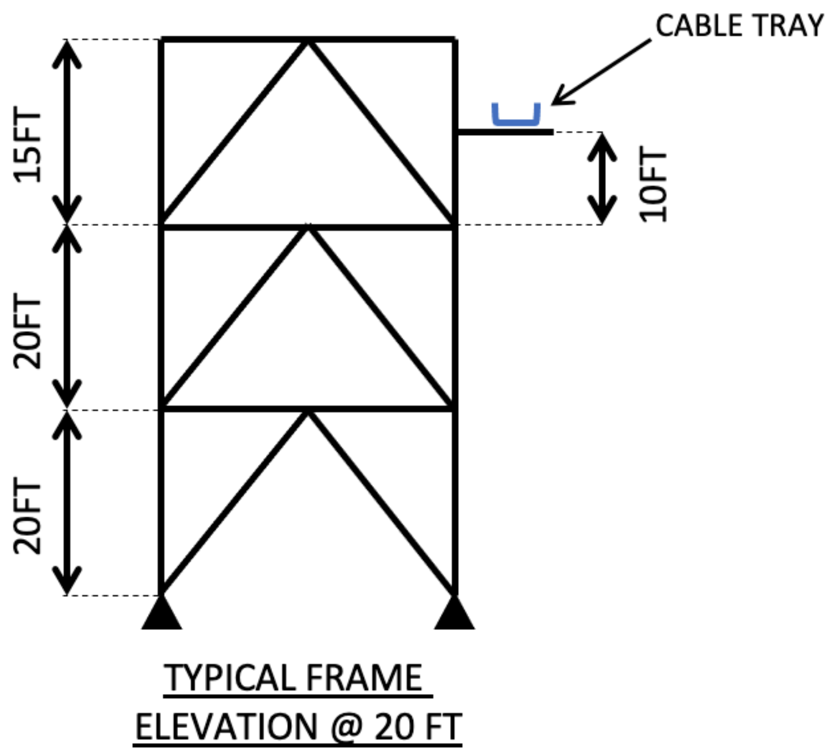
13. Pictured below is the plan view of a structure with special reinforced concrete shear walls along the perimeter. The shear walls are discontinuous in the North-South direction and connected with a collector element. Given a seismic diaphragm force F_{px}, calculate the maximum force in the collector element.



A. $F_{collector} = 7.5\ kip$
B. $F_{collector} = 0.9\ kip$
C. $F_{collector} = 3.9\ kip$
D. $F_{collector} = 2.3\ kip$

14. Find the horizontal seismic design force for a cable tray attached to the storage rack structure pictured below given the following parameters:

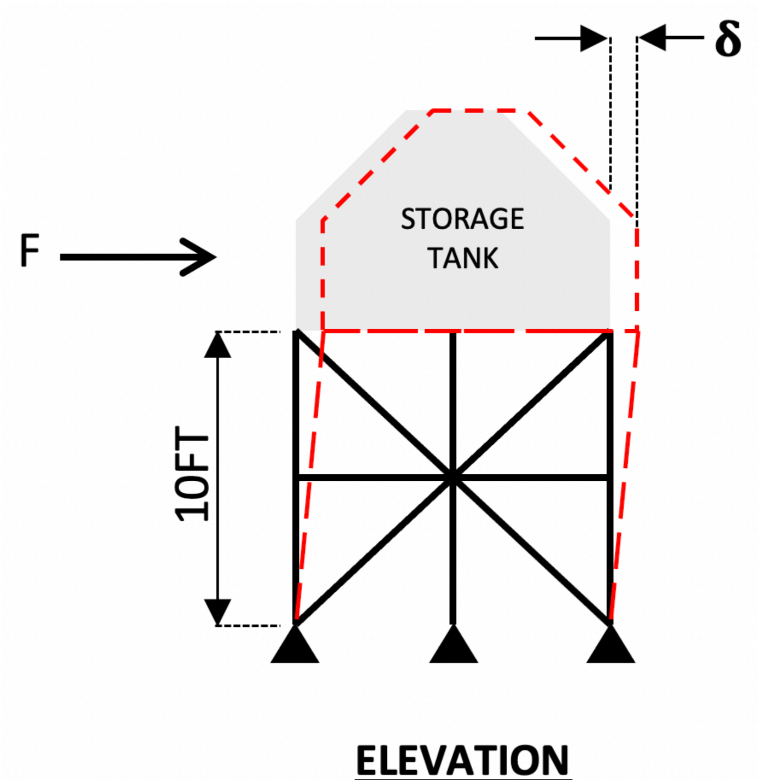
- $W_{tray} = 20\ plf$
- $S_{DS} = 1.25$
- Risk Category I Structure
- Tray Powers Ice Cream Room at New Start-Up



A. $F_P = 0.23\ kip$
B. $F_P = 0.80\ kip$
C. $F_P = 0.15\ kip$
D. $F_P = 0.46\ kip$

15. The trussed tower supported storage tank pictured below experience a deflection $\delta = 0.02\ in$ when loaded with lateral force $F = 10\ kip$. Given the following parameters, find the seismic base shear for this non-building structure:

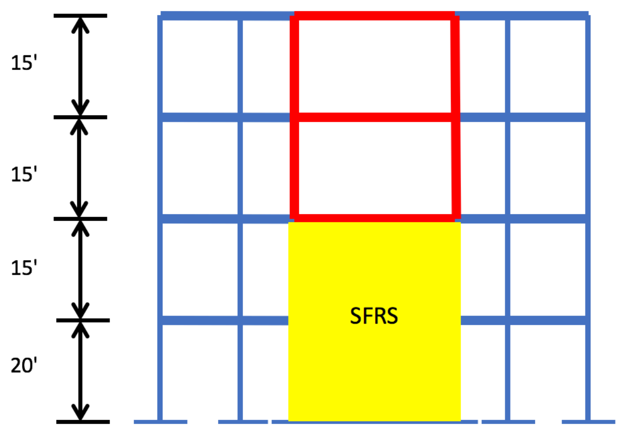
$$S_{DS} = 0.61g \qquad W = 10\ kip \qquad I_e \coloneqq 1.25$$



A. $V = 7.0\ kip$
B. $V = 4.6\ kip$
C. $V = 3.5\ kip$
D. $V = 2.3\ kip$

SOLUTIONS

1. The four-story structure shown falls under Seismic Design Category E and utilizes a Steel Special Moment Frame at the third and fourth stories. The Special Moment Frame is to be discontinued at the third floor and an alternate system is to be used for the first and second stories of the structure. What systems are acceptable for use at the first and second stories?



ELEVATION

E. Steel Special Concentrically Braced Frame
F. Steel Eccentrically Braced Frame
G. Special Reinforced Concrete Moment Frame
H. Steel Buckling-Restrained Braced Frame

Answer: A) Steel Special Concentrically Braced Frame

ASCE 7-16 Section 12.2.5.5 requires a special moment frame to be supported by a more rigid system with a lower response modification coefficient, R, when discontinued above the base of a structure.

For a Steel Special Concentrically Braced Frame - R = 6. ⇐ **Acceptable**
For a Steel Eccentrically Braced Frame - R = 8.
For a Special Reinforced Concrete Moment Frame - R = 8.
For a Steel Buckling-Restrained Braced Frame - R = 8.

2. A two-story police station is being designed to resist seismic forces per *ASCE 7-16*. Based off the following parameters, determine the appropriate Seismic Design Category:

$$F_a = 1.0 \qquad F_v = 1.7 \qquad S_{DS} = 1.32\ g \qquad S_{D1} = 0.85\ g$$

G. Seismic Design Category A
H. Seismic Design Category B
I. Seismic Design Category C
J. Seismic Design Category D
K. Seismic Design Category E
L. Seismic Design Category F

Answer: F) Seismic Design Category F

Police stations are considered Risk Category IV structures per *IBC 2018 Table 1604.5*

Assume Site Class D per *ASCE 7-16 Section 11.4.3*.

Site Modified Maximum Considered Response Acceleration at 1-s period:

$$S_{M1} = \frac{3}{2} * S_{D1} = 1.275$$

Long-Period Site Coefficient:

$$F_v = 1.7$$

Maximum Considered Response Acceleration at 1-s period:

$$S_1 = \frac{S_{M1}}{F_v} = 0.75$$

Per *ASCE 7-16 Section 11.6* this structure will fall under Seismic Design Category F

3. Consider a single-story emergency shelter which carries a roof dead load of 10 PSF and utilizes a Steel Ordinary Concentric Braced Frame Seismic Force-Resisting System.

   Given the following parameters, what is the maximum height allowed by *ASCE 7-16*?

$$S_{DS} = 0.45g \qquad S_1 < 0.75g$$

   E. 35 ft
   F. 60 ft
   G. 160 ft
   H. 240 ft

   Answer: B) 60 ft

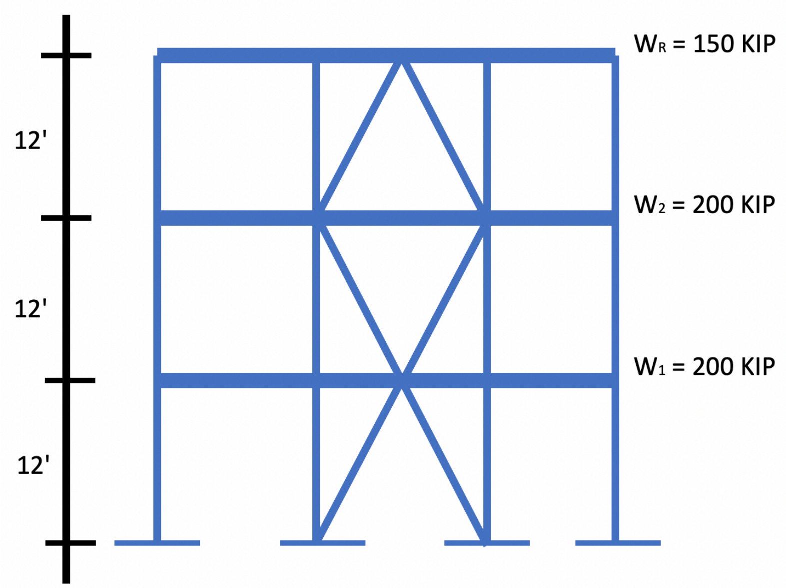
   Per *IBC 2018 Table 1604.5* emergency shelters are classified as Risk Category IV structures.

   Based on *ASCE 7-16 Section 11.6* and the Design Spectral Response Acceleration $\mathbf{S_{DS}}$, this structure is assigned Seismic Design Category D.

   Based on *Table 12.2-1 of ASCE 7-16,* the maximum height of a structure utilizing a Steel Ordinary Concentric Braced Frame where the structure is a single story and has a dead load of less than 20 PSF is 60 ft (*see footnote j*).

4. You are to design a 3-story Steel Special Concentrically Braced Frame building with an occupancy load of 200. Determine the seismic base shear, based on the following parameters:

$$S_{DS} = 1.25g \qquad S_{D1} = 0.82g \qquad S_1 = 0.82g \qquad T_L = 8s$$



ELEVATION

E. $V = 145.1\ kip$
F. $V = 59.8\ kip$
G. $V = 55.7\ kip$
H. $V = 111.3\ kip$

Answer: D) $\boldsymbol{111.3\ kip}$

Long-Period Transition Period: $T_L = 8s$

Maximum Considered Spectral Response at 1-s Period: $S_1 = 0.82g$

Design Spectral Response Acceleration at Short Period: $S_{DS} = 1.25g$

Design Spectral Acceleration at 1-s Period: $S_{D1} = 0.82g$

Structural Height: $h_n = 36\ ft$

Per *IBC 2018 Table 1604.5*, since the occupancy load is 200, the structure is assigned to Risk Category II.

Therefore, the Seismic Importance Factor is $I_e = 1.0$ per *ASCE 7-16 Table 1.5-2*.
Since $S_1 > 0.75$, the structure is assigned to Seismic Design Category E per *ASCE 7-16 Section 11.6*.

Per *ASCE 7-16 Table 12.2-1*, the maximum allowable height of the structure $h_{max} = 160\ ft > h_n = 36\ ft$, therefore height of the structure is adequate for the Seismic Force-Resisting System.

Per *ASCE 7-16 Table 12.2-1*, the Response Modification Factor *R=6*.

The Seismic Coefficient C_s and Seismic Weight of the structure W are required to solve for the base shear per *ASCE 7-16 EQ. 12.8-1*: $V = C_s * W$

Seismic Weight of the structure:

$$W = W_1 + W_2 + W_R = 550\ kip$$

To solve for the Seismic Coefficient C_s of the structure, we must first find the Approximate Fundamental Period, T_a:

$T_a = C_t h_n^x$ [ASCE 7-16 EQ. 12.8-7]

$C_t = 0.02,\ x = 0.75$ [ASCE 7-16 Table 12.8-2]

$$T_a = C_t * h_n^x = 0.02 * (36ft)^{0.75} = 0.29s$$

Seismic Coefficient of the structure:

$C_s = \frac{S_{DS}}{\left(\frac{R}{I_e}\right)} = \frac{1.25g}{\left(\frac{6}{1.0}\right)} = 0.21$ [ASCE 7-16 EQ. 12.8-2]

Since $T_a < T_L$, we check the maximum seismic coefficient as follows:

$C_{s-max} = \frac{S_{D1}}{T\left(\frac{R}{I_e}\right)} = \frac{0.82g}{\left(0.29s*\left(\frac{6}{1.0}\right)\right)} = 0.47$ [ASCE 7-16 EQ. 12.8-3]

We check the minimum seismic coefficient as follows:

$C_{s-min} = 0.044 * S_{DS} * I_e > 0.01 = 0.06$ [ASCE 7-16 EQ. 12.8-5]

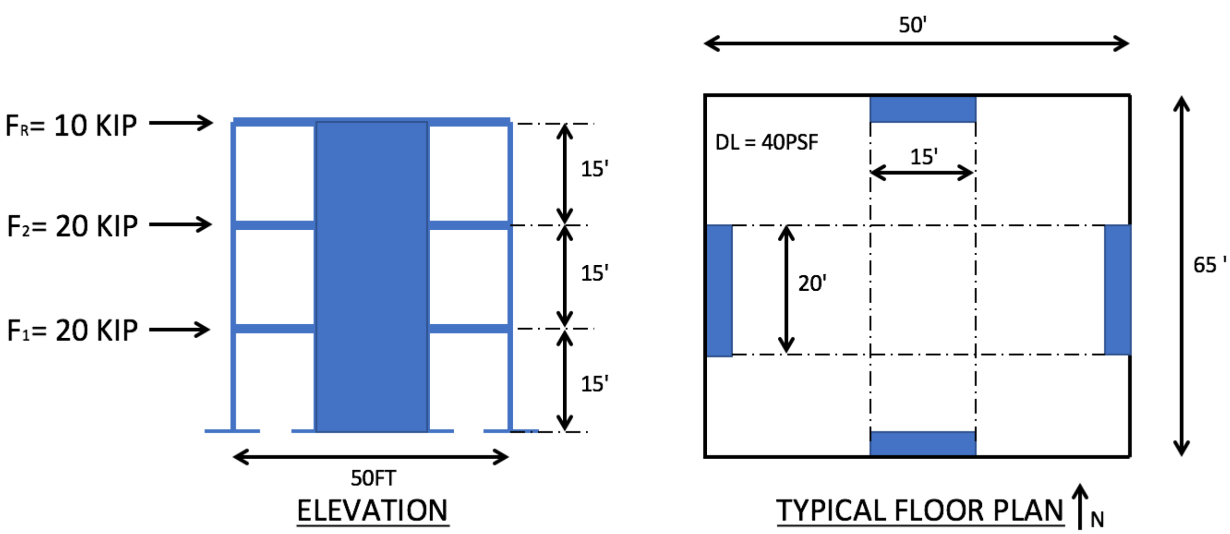
Additionally, since $S_1 > 0.6$, we also check:

$C_{s-min} = \frac{(0.5*S_1)}{\left(\frac{R}{Ie}\right)} = 0.5 * \frac{(0.82g)}{\left(\frac{6}{1.0}\right)} = 1.0$ [ASCE 7-16 EQ. 12.8-6]

$$\textbf{Therefore, } \boldsymbol{C_s = 0.21}$$
$$\boldsymbol{\Rightarrow V = C_s * W = 115.5\ kip}$$

5. A 3-story art studio building designed by architects who dislike circular shapes utilizes a Concrete Special Shear Wall System in each direction to resist seismic forces. The building was designed for story forces shown and has 18" concrete shear walls. Determine the diaphragm force in the North-South Direction at Level 2 based on the floor dead load and weight of concrete shear walls; assume dead load includes weight of building framing tributary to floor.

$$\gamma_{concrete} = 150\ pcf,\ \ DL = 40\ psf$$



E. $F_{p2} = 13.6\ kip$
F. $F_{p2} = 18.3\ kip$
G. $F_{p2} = 12.6\ kip$
H. $F_{p2} = 19.0\ kip$

Answer: C) $\mathbf{12.6}\ \boldsymbol{kip}$

Weight of North-South Shear Walls:
$$2 * \gamma_{concrete} * 15\ ft * 20\ ft * 1.5\ ft = 135\ kip$$

Weight of East-West Shear Walls:
$$2 * \gamma_{concrete} * 15\ ft * 15\ ft * 1.5\ ft = 101.25\ kip$$

Weight of Typical Floor:
$$40\ psf * 65\ ft * 50\ ft = 130\ kip$$

Weight Tributary to Level 2:
$$w_2 = 135\ kip + 101.25\ kip + 130\ kip = 366.25\ kip$$

Weight Tributary to Level 2 Diaphragm:

$$w_{p2} = 101.25\,kip + 130\,kip = 231.25\,kip$$

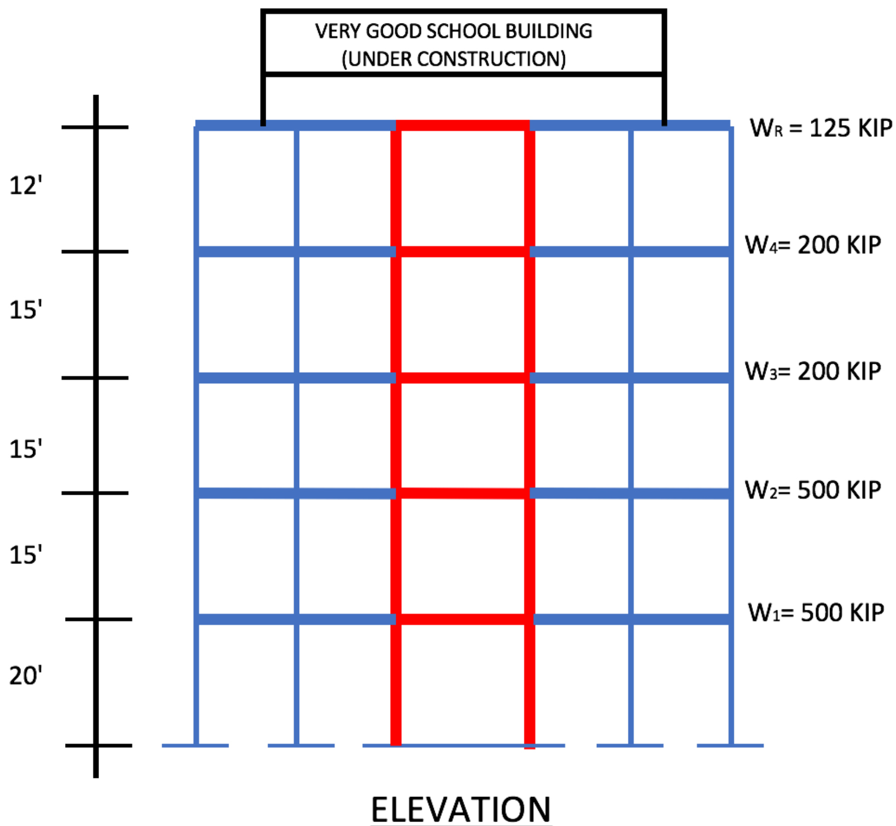
Per *ASCE 7-16 EQ. 12.10-1*, the diaphragm design force is:

$$\Rightarrow F_{p2} = \frac{\Sigma F_i}{\Sigma w_i} * w_{px} = \frac{20\,kip}{366.25\,kip} * 231.25\,kip = 12.6\,kip$$

6. You are to design a community college building with an occupant load of 750 people. The building is to utilize a Steel Special Moment Frame. Based on the following seismic parameters, determine the base shear:

$$S_1 < 0.6g \qquad S_{DS} = 1.30g \qquad S_{D1} = 0.92g$$

$$T = 0.6s \qquad T_L = 8s$$



E. $V = 175\ kip$
F. $V = 305\ kip$
G. $V = 610\ kip$
H. $V = 730\ kip$

Answer: B) $\boldsymbol{V = 305\ kip}$

Long-Period Transition Period: $T_L = 8s$

Short Period Design Spectral Acceleration: $S_{DS} = 1.30g$

1-s Period Design Spectral Acceleration: $S_{D1} = 0.92g$

Structural Height: $h_n = 77ft$

Since the occupancy load is greater than 500, the structure falls under Risk Category III per *IBC 2018 Table 1604.5*.

Therefore, the Seismic Importance Factor $I_e = 1.25$ per *ASCE 7-16 Table 1.5-2*.

Per *ASCE 7-16 Section 11.6*, the structure is assigned to Seismic Design Category D.

Per *ASCE 7-16 Table 12.2-1*, Steel Special Moment Frames have no limits on height.

Per *ASCE 7-16 Table 12.2-1*, the Response Modification Factor $R = 8$.

The Seismic Coefficient C_s and Seismic Weight of the structure W are required to solve for the Base Shear per *ASCE 7-16 EQ. 12.8-1*: $V = C_s * W$

Seismic Weight of the structure:

$$W = W_1 + W_2 + W_3 + W_4 + W_R = 1525kip$$

Seismic Coefficient of the structure:

$$C_s = \frac{S_{DS}}{\left(\frac{R}{I_e}\right)} = \frac{1.30g}{\left(\frac{8}{1.25}\right)} = 0.20 \qquad \text{[ASCE 7-16 EQ. 12.8-2]}$$

Since $T_a < T_L$, we check the maximum seismic coefficient as follows:

$$C_{s-max} = \frac{S_{D1}}{T\left(\frac{R}{I_e}\right)} = \frac{0.92g}{0.6\ s*\left(\frac{8}{1.25}\right)} = 0.24 \qquad \text{[ASCE 7-16 EQ. 12.8-3]}$$

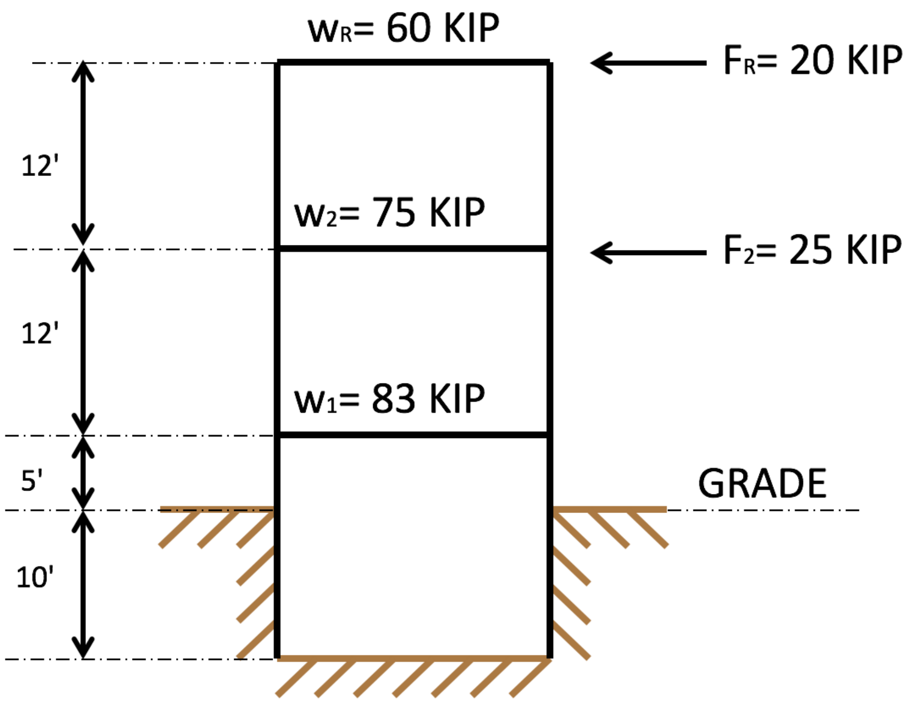
We check the minimum seismic coefficient as follows:

$$C_{s-min} = 0.044 * S_{DS} * I_e > 0.01 \qquad \text{[ASCE 7-16 EQ. 12.8-5]}$$

Therefore, $\boldsymbol{C_s = 0.20}$

⇒ and $\boldsymbol{V = C_s * W = 305kip}$

7. A 3-story apartment building with Ordinary Reinforced Masonry Shear Walls has been designed for forces shown using the simplified design method of *ASCE 7-16 Chapter 12*. Determine the Spectral Response Acceleration used in design:



E. $S_{DS} = 0.85g$
F. $S_{DS} = 0.43g$
G. $S_{DS} = 0.61g$
H. $S_{DS} = 1.03g$

Answer: C) $S_{DS} = 0.61g$

Per *ASCE 7-16 Chapter 11* Definitions, a story above grade plane is that which has a roof that extends more than 6 feet above grade.

Sum story forces of 2nd & 3rd story:

$$V = F_2 + F_R = 45\ kip$$

Sum seismic weights of 2nd & 3rd story:

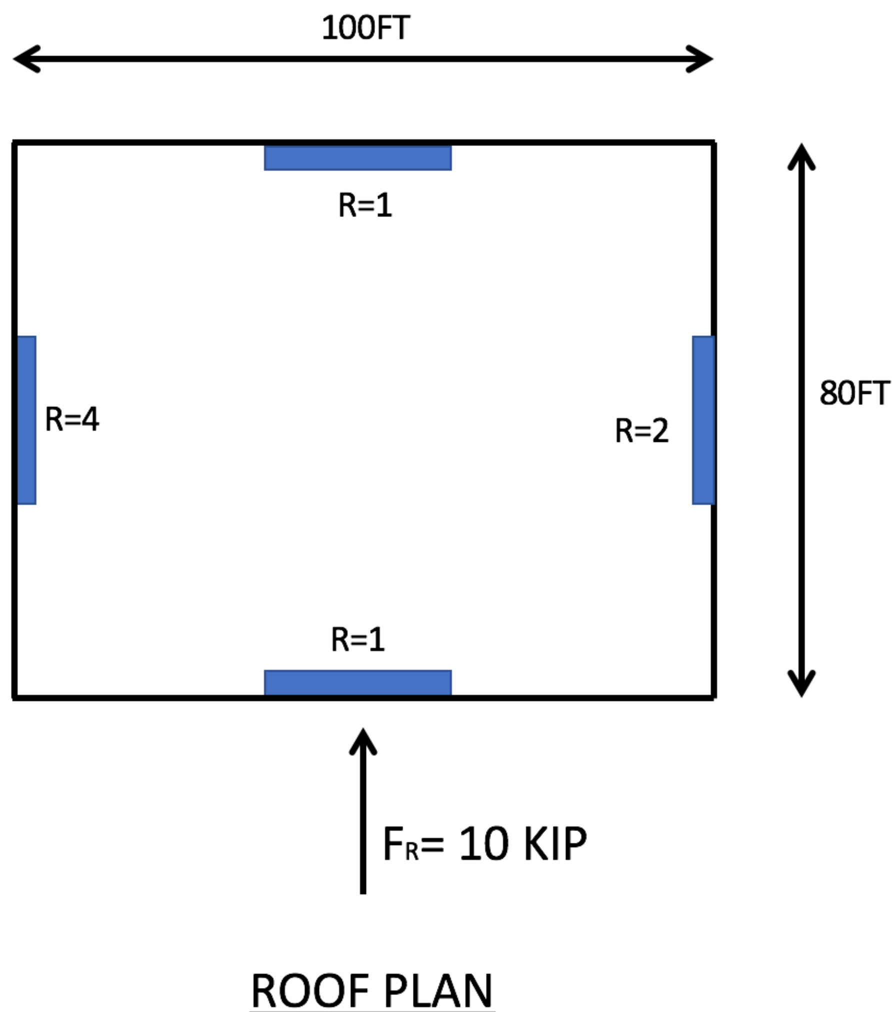
$$W = w_2 + w_R = 135\ kip$$

$F = 1.1$ (2 stories above grade)

Response Modification Factor: $R = 2$ [ASCE 7-16 Table 12.14-1]

$S_{DS} = \frac{V*R}{F*W} = \frac{45\ kip*2}{1.1*135\ kip} = 0.61g$ [ASCE 7-16 EQ. 12.14-12]

8. A roof plan for a 3-story wood frame apartment building with metal deck floors is shown. Based on the given roof story force, find the accidental torsional moment associated with the roof diaphragm.



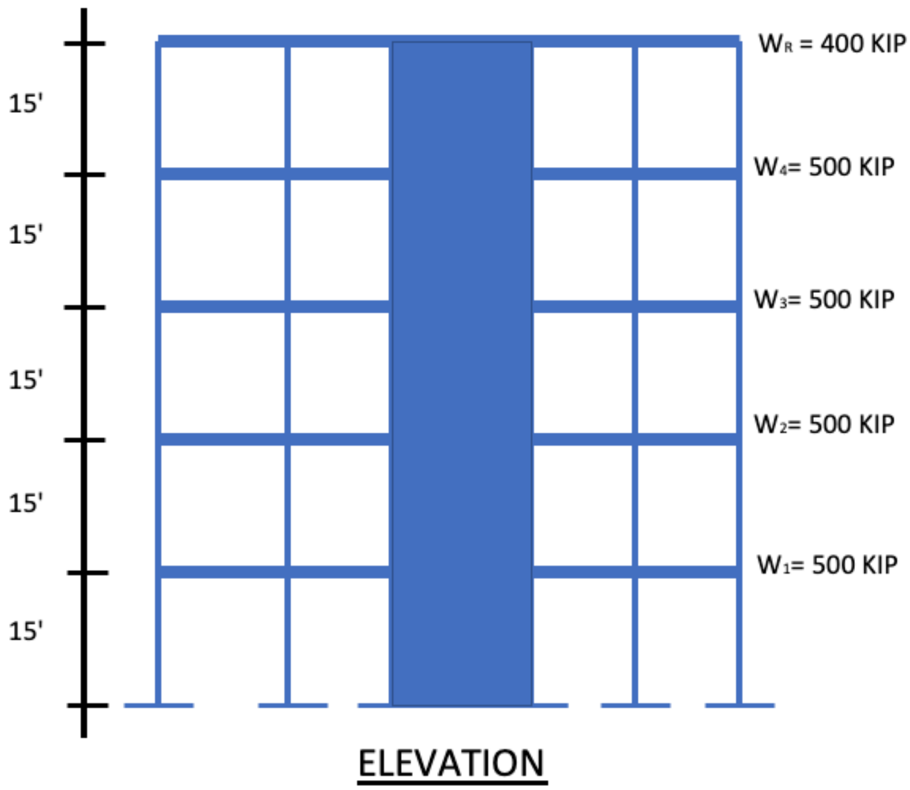
E. 0 kip-ft
F. 10.7 kip-ft
G. 15.3 kip-ft
H. 13.2 kip-ft

Answer: A) 0 kip-ft

Trick question! Per *ASCE 7-16 Section 12.14.5* diaphragms made of untopped metal decking are considered flexible. Therefore, there is no torsion considered.

9. You are analyzing an existing 5 story jail with a Special Reinforced Concrete Shear Wall Seismic Force-Resisting System in each direction. Given the following parameters, what is the seismic story force at Level 1?

$$S_S = 2.44g \quad S_1 = 0.86g \quad T_L = 8s$$



Assume that no ground motion hazard analysis is available and take utilize code exceptions as required.

E. $F_1 = 58.3\ kip$
F. $F_1 = 35.0\ kip$
G. $F_1 = 233.1\ kip$
H. $F_1 = 116.6\ kip$

Answer: A) $\boldsymbol{F_1 = 58.3\ kip}$

Assume Site Class D per *ASCE 7-16 Section 11.4.3*

Long-Period Transition Period: $T_L = 8s$

Maximum Considered Spectral Response at 1-s Period: $S_1 = 0.86g$

Maximum Considered Spectral Response at Short Period: $S_S = 2.44g$
Site Coefficient F_a per *ASCE 7-16 Table 11.4-1*:

$$S_S >= 1.25g$$
$$F_a = 1.0$$

Site Coefficient F_v per *ASCE 7-16 Table 11.4-2*:

$$S_1 >= 0.5g$$
$$F_v = 1.5$$

Note, footnote **a** of *Table 11.4-2* requires us to obtain a ground motion hazard analysis unless we follow *Exception 2:* determine the seismic coefficient per *Equation 12.8-2* for $\boldsymbol{T \le 1.5T_s}$ and 1.5 times the values of either *Equation 12.8-3* for $\boldsymbol{T_L \ge T > 1.5T_S}$ or *Equation 12.8-4* for $\boldsymbol{T > T_L}$.

Adjusted Maximum Considered Spectral Response at Short Period:

$$S_{MS} = F_a * S_S = 1.0 * 2.44g = 2.44g$$

Adjusted Maximum Considered Spectral Response at 1-s Period:

$$S_{M1} = F_v * S_1 = 1.5 * 0.86g = 1.29g$$

Design Spectral Response Acceleration at Short Period:

$$S_{DS} = 2/3 * S_{MS} = 1.63g$$

Design Spectral Response Acceleration at 1-s Period:

$$S_{D1} = 2/3 * S_{M1} = 0.86g$$

$$T_s = \frac{S_{D1}}{S_{DS}} = \frac{0.86\ g}{1.63\ g} = 0.5\ s$$

Structural Height: $h_n = 75\ ft$

Since the structure is being used as a jail it falls under Institutional Group I-3 Occupancy per *IBC 2018 Section 308.4*, and therefore is assigned to Risk Category III per *IBC 2018 Table 1604.5*.

Accordingly, the Seismic Importance Factor $I_e = 1.25$ per *ASCE 7-16 Table 1.5-2*.

Since $S_1 > 0.75$, the structure is assigned to Seismic Design Category E per *ASCE 7-16 Section 11.6*.

Per *ASCE 7-16 Table 12.2-1*, the maximum allowable height of the structure $h_{max} = 160\ ft > h_n = 36\ ft$ for Special Reinforced Concrete Shear Walls, therefore the height of the structure is acceptable for the Seismic Force-Resisting System.

Per *ASCE 7-16 Table 12.2-1*, the Response Modification Factor $R = 6$.

To find the force at Level 2 we must first find the base shear of the structure.

The Seismic Coefficient C_s and Seismic Weight of the structure W are required to solve for the base shear per *ASCE 7-16 EQ. 12.8-1*: $V = C_s * W$

Seismic Weight of the structure:

$$W = W_1 + W_2 + W_3 + W_4 + W_R = 2400\ kip$$

To solve for the Seismic Coefficient of the structure, we must first find the Approximate Fundamental Period:

Approximate Fundamental Period:

$T_a = C_t h_n^x$ [ASCE 7-16 EQ. 12.8-7]

$C_t = 0.02, x = 0.75$ [ASCE 7-16 Table 12.8-2]

$$T_a = C_t h_n^x = 0.02 * (75\ ft)^{0.75} = 0.5\ s$$

$$1.5 * T_s = 0.8\ s$$

Since $\boldsymbol{T_a \leq 1.5T_s}$, the Seismic Coefficient is calculated as follows:

$C_s = \frac{S_{DS}}{\left(\frac{R}{I_e}\right)} = \frac{1.63g}{\left(\frac{6}{1.25}\right)} = 0.34$ [ASCE 7-16 EQ. 12.8-2]

We check the minimum seismic coefficient as follows:

$C_{s-min} = 0.044 * S_{DS} * I_e \geq 0.01 = 0.09$ [ASCE 7-16 EQ. 12.8-5]

Additionally, since $S_1 \geq 0.6\ g$ we also check:

$C_{s-min} = 0.5 * \frac{S_1}{\frac{R}{I_e}} = 0.5 * \frac{0.86g}{\frac{6}{1.25}} = 0.09$ [ASCE 7-16 EQ. 12.8-6]

Therefore, $C_s = 0.34$

and $V = C_s * W = 816\ kip$

Solve for the force at Level 1 based on the vertical distribution of seismic forces per *ASCE 7-16 Section 12.8.3*:

$F_x = C_{vx} * V$ [ASCE 7-16 EQ. 12.8-11]

$C_{vx} = \frac{w_x h_x^k}{\Sigma w_i h_i^k}$ [ASCE 7-16 EQ. 12.8-12]

Since $T_a = 0.5\ s,\ k = 1$

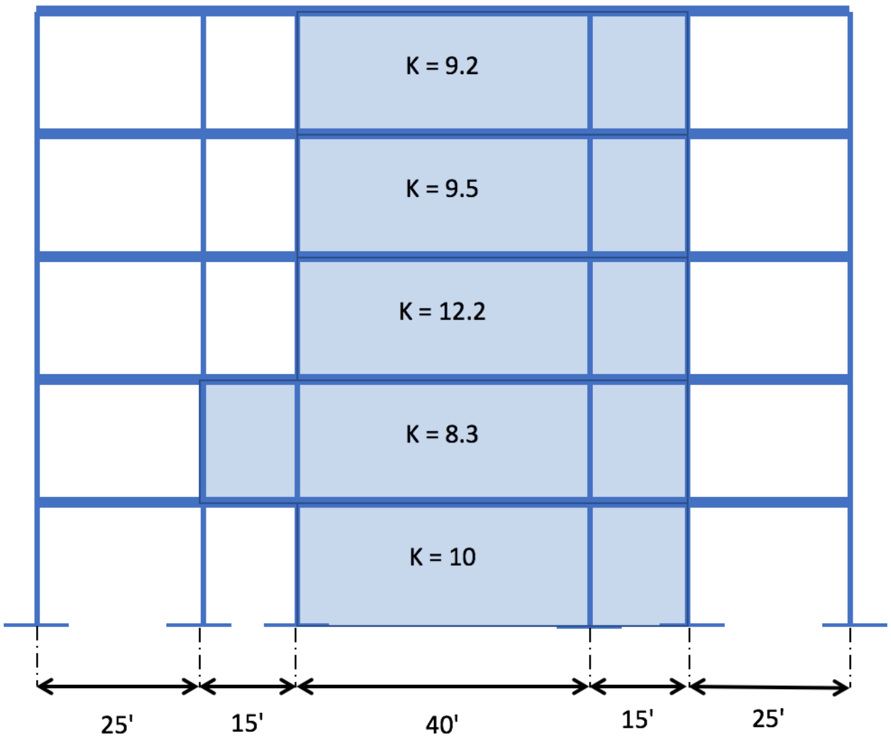
$$w_R h_R^k = 400\ kip * (75\ ft)^{1.0} = 30000$$
$$w_5 h_5^k = 500\ kip * (60\ ft)^{1.0} = 30000$$
$$w_4 h_4^k = 500\ kip * (45\ ft)^{1.0} = 22500$$
$$w_3 h_3^k = 500\ kip * (30\ ft)^{1.0} = 15000$$
$$w_2 h_2^k = 500\ kip * (15\ ft)^{1.0} = 7500$$

$$\Sigma w_i h_i^k = 105{,}000$$

The Seismic Story Force at Level 1 is:

$$F_1 = C_{v1} * V = \frac{w_1 h_1^k}{\Sigma w_i h_i^k} * V = \frac{7500}{105{,}000} * 816kip = 58.3kip$$

10. The structure shown is a five-story shear wall building with relative lateral stiffnesses noted at each level. Determine the type of Vertical Irregularity associated with this structure:



ELEVATION

F. Stiffness-Extreme Soft Story Irregularity
G. Vertical Geometric Irregularity
H. Discontinuity in Lateral Strength–Weak Story Irregularity
I. Stiffness-Soft Story Irregularity
J. Discontinuity in Lateral Strength–Extreme Weak Story Irregularity

Answer: D) Stiffness-Soft Story Irregularity

Per *ASCE 7-16 Table 12.3-2*, Stiffness-Soft Story Irregularity is defined to exist when the lateral stiffness of a story is less than that 70% of the story above.

Consider the relative stiffness of level 3: $K_3 = 12.2$
Consider the relative stiffness of level 2: $K_2 = 8.3$

$$\frac{K_2}{K_3} = 0.68 < 0.70$$

Therefore, the structure shown has a Stiffness-Soft Story Irregularity.

11. Determine the approximate fundamental period T_a of a 70 ft tall building the utilizes Ordinary Reinforced Concrete Moment Frame as the Seismic Force-Resisting System.

E. $T_a = 0.73\ s$
F. $T_a = 0.13\ s$
G. $T_a = 0.52\ s$
H. $T_a = 0.89\ s$

Answer: A) $T_a = 0.73\ s$

Given a Structural Height of $h_n = 70\ ft$

The Approximate Fundamental Period is found based on *ASCE 7-16 Section 12.8.2.1*:

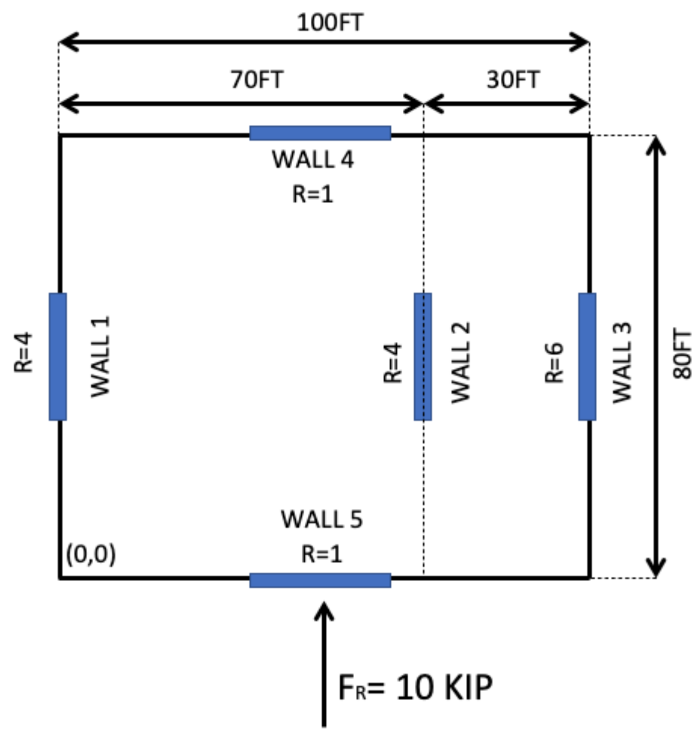
$T_a = C_t * h_n^x$ [ASCE 7-16 EQ. 12.8-3]

$C_t = 0.016, x = 0.9$ [ASCE 7-16 Table 12.8-2]

$$T_a = C_t * h_n^x = 0.016 * (70\ ft)^{0.9} = 0.73\ s$$

$$\Rightarrow \boldsymbol{T_a = 0.73\ s}$$

12. The plan pictured below shows the relative rigidities of concrete shear walls located directly below a 6” concrete roof slab. Given the loading shown, determine the location of the center of rigidity and the load at Wall 1.



ROOF PLAN

E. (63 ft, 40 ft); 3 kip
F. (63 ft, 35ft); 5 kip
G. (72 ft, 40 ft); 5 kip
H. (72 ft, 35ft); 3 kip

Answer: A) (63ft, 40 ft); 3 kip

Considering the bottom left corner of the roof plan as our origin point. The following equations can be used to find coordinates for the center of rigidity:

$$x_r = \frac{\sum R_i x_i}{\sum R_i}, y_r = \frac{\sum R_i y_i}{\sum R_i}$$

$$x_r = \frac{4*(0\ ft)+4*(70\ ft)+6*(100\ ft)}{4+4+6} \approx 63\ ft$$

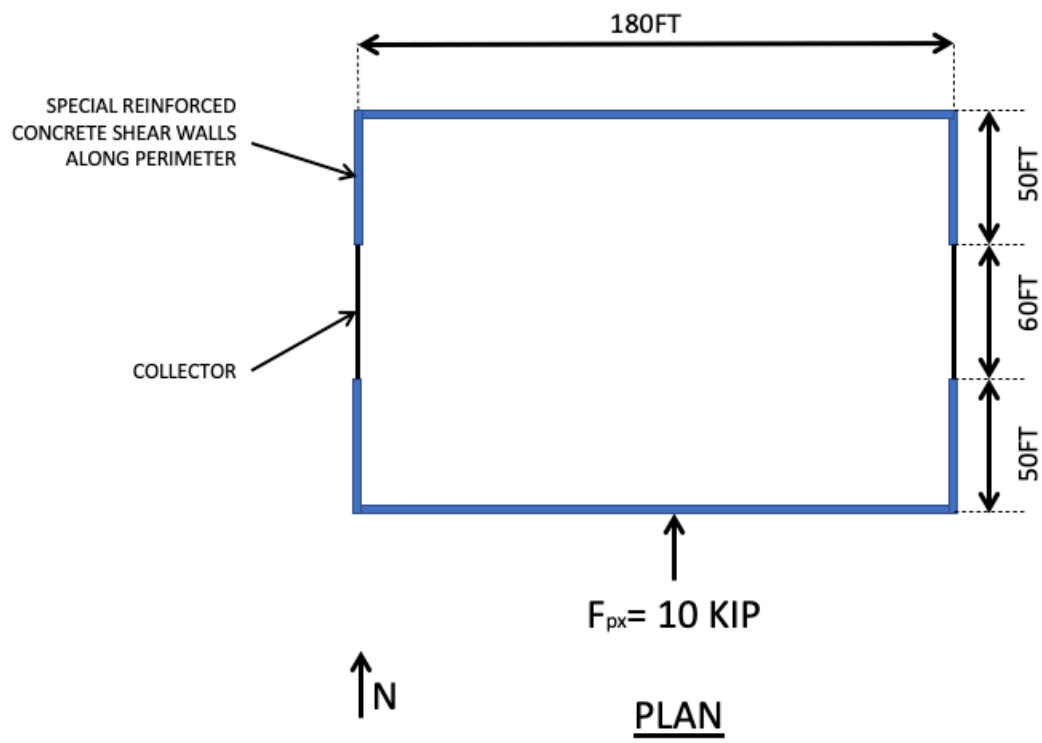
$$y_r = \frac{1*(80\ ft)+1*(0\ ft)}{1+1} = 40\ ft$$

⇒ **Therefore, the center of rigidity is located at (63 ft, 40 ft).**

Next, we calculate the load on Wall 1 based on the roof seismic force multiplied by the wall's rigidity relative to Walls 2 and 3 which resist load in the same direction.

$$\Rightarrow \boldsymbol{F_{wall-1} = 10\ kip * \frac{4}{4+4+6} \approx 3.0\ kip}$$

13. Pictured below is the plan view of a structure with special reinforced concrete shear walls along the perimeter. The shear walls are discontinuous in the North-South direction and connected with a collector element. Given a seismic diaphragm force F_{px}, calculate the maximum force in the collector element.



E. $F_{collector} = 7.5\ kip$
F. $F_{collector} = 0.9\ kip$
G. $F_{collector} = 3.9\ kip$
H. $F_{collector} = 2.3\ kip$

Answer: D) $F_{collector} = 2.3\ kip$

Find the diaphragm shear force v_D based on plan dimensions:

$$v_D = \frac{10\ kip}{2 * 160ft} = 31.25\ plf$$

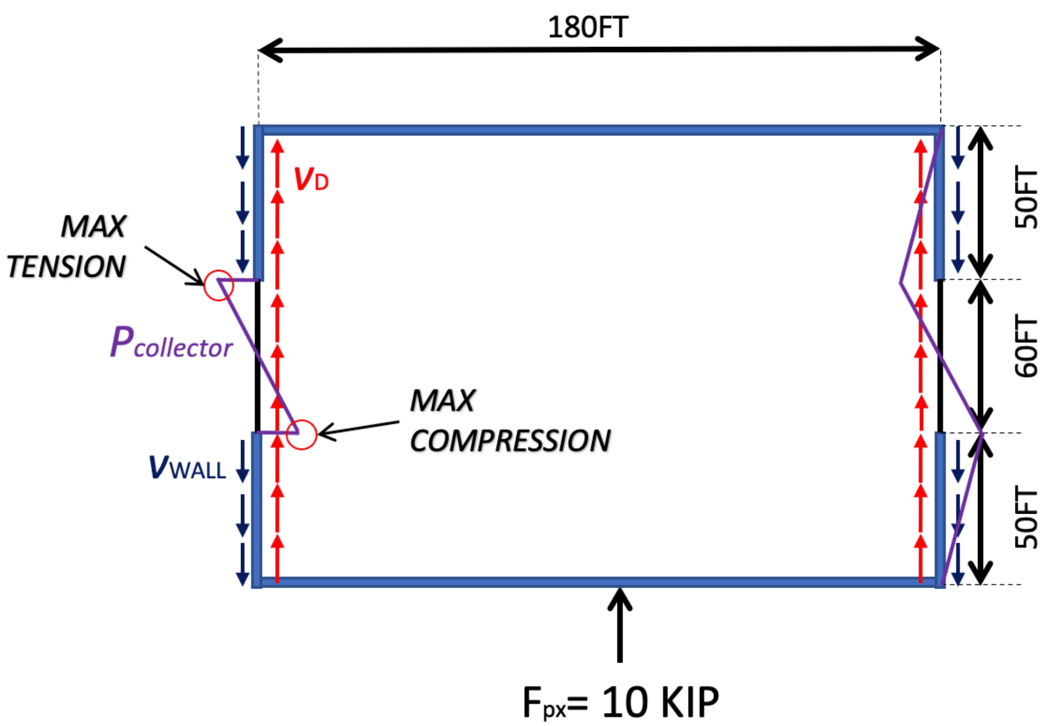
Find the wall shear force v_{WALL} based on wall length:

$$v_{WALL} = \frac{10\ kip}{2 * 100ft} = 50\ plf$$

Determine the overstrength factor based on *Table 12.2-1 of ASCE 7-16:*

$$\Omega = 2.5$$

As illustrated in the force diagram below, the maximum force in the collector occurs at the boundary where the collector interfaces with the shear wall. The collector force can be calculated by taking the difference between the shear transferred to the wall and the diaphragm shear over the wall's length. In this situation, the collector has equal and opposite tension and compression forces at either end because the length of wall is equal on both sides of the collector.

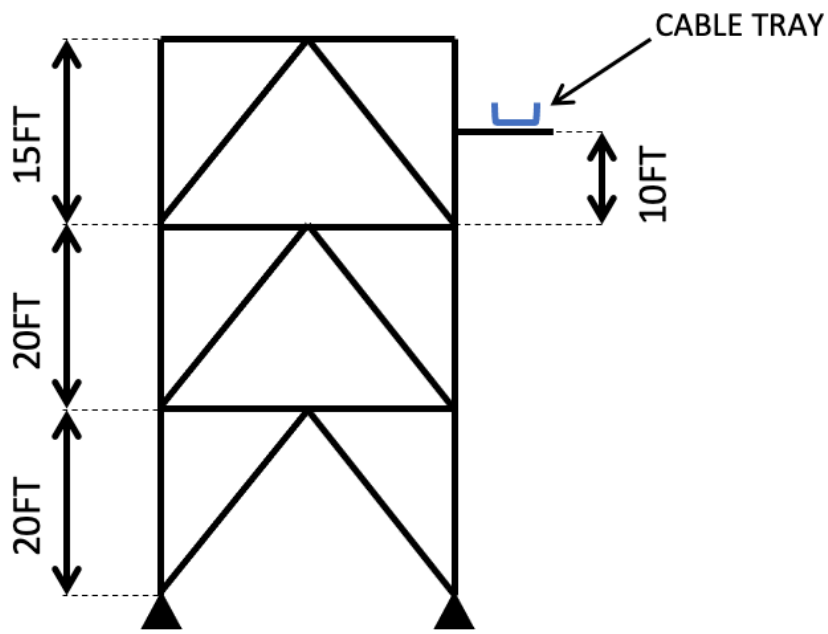


Calculate the maximum collector force based on the difference of v_{wall} and v_d:

$$\Rightarrow F_{collector} = 50\,ft * (v_{WALL} - v_D) * \Omega = 2.3\,kip$$

14. Find the horizontal seismic design force for a cable tray attached to the storage rack structure pictured below given the following parameters:

- $W_{tray} = 20\ plf$
- $S_{DS} = 1.25$
- Risk Category I Structure
- Tray Powers Ice Cream Room at New Start-Up



TYPICAL FRAME
ELEVATION @ 20 FT

E. $F_P = 0.23\ kip$
F. $F_P = 0.80\ kip$
G. $F_P = 0.15\ kip$
H. $F_P = 0.46\ kip$

Answer: A) $F_P = 0.23\ kip$

The seismic design force for a non-building structure is determined based on the guidelines of *Chapter 13 of ASCE 7*.

Per *Equation 13.3-1 of ASCE 7-16* the seismic design force is as follows:

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

Based on elevation and given weight:

$$W_p = 20\, plf * 20\, ft = 0.4\, kip$$
$$z = 50\, ft$$
$$h = 55\, ft$$

The importance factor is found based on *ASCE 7-16 Section 13.1*:

$$I_p = 1.0$$

The amplification factor and response modification factor are based on *Table 13.6-1 of ASCE 7-16 Chapter 13*:

$$a_p = 2.5$$
$$R_p = 6.0$$

$$F_p = \frac{0.4 * 2.5 * 1.25 * 0.4\, kip}{\left(\frac{6.0}{1.0}\right)} * \left(1 + 2 * \frac{50}{55}\right) = 0.23\, kip$$

Per Equations 13.3-2 and 13.3-3, maximum and minimum forces must be checked:

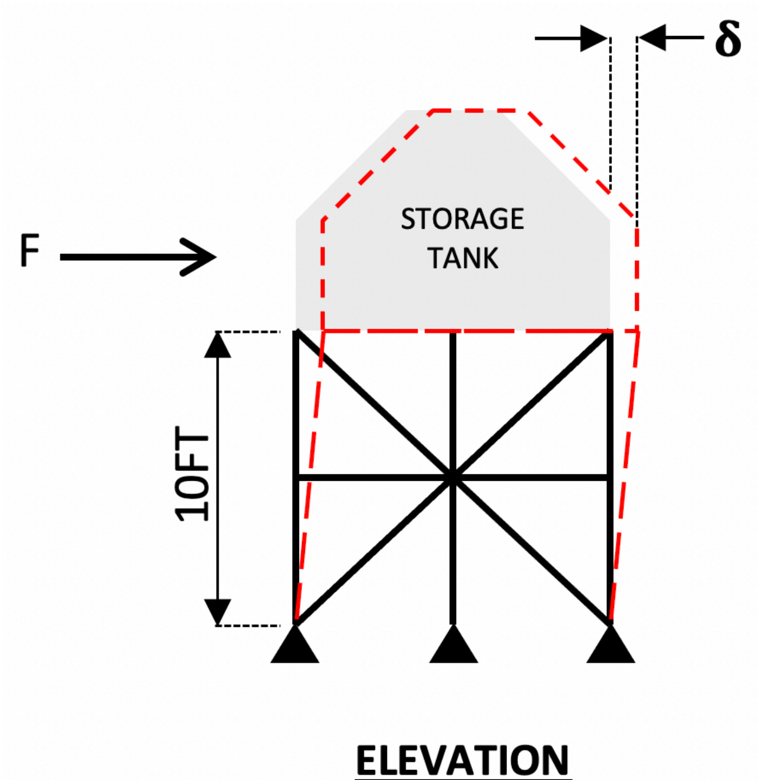
$$F_{p-max} = 1.6 * S_{DS} * I_p * W_p = 0.8\, kip$$

$$F_{p-min} = 0.3 * S_{DS} * I_p * W_p = 0.15\, kip$$

$$\Rightarrow F_p = 0.23\, kip$$

15. The trussed tower supported storage tank pictured below experience a deflection $\delta = 0.02\ in$ when loaded with lateral force $F = 10\ kip$. Given the following parameters, find the seismic base shear for this non-building structure:

$$S_{DS} = 0.61g \qquad W = 10\ kip \qquad I_e := 1.25$$



E. $V = 7.0\ kip$
F. $V = 4.6\ kip$
G. $V = 3.5\ kip$
H. $V = 2.3\ kip$

Answer: D) $V = 2.3\ kip$

The seismic base shear for a non-building structure is calculated based on *ASCE 7-16 Chapter 15*.

First, determine if this structure may be considered rigid based on the period. Per *ASCE 7-16 Section 15.3.2* if the period is less 0.06 seconds, the structure may be considered rigid.

The period is calculated based on the stiffness as follows:

$$K = \frac{F}{\delta} = \frac{10\ kip}{0.02\ in} = 500\ kip/in$$

$$T = 2\pi\sqrt{\frac{m}{K}} = 2\pi\sqrt{\frac{\frac{10\ kip}{386\frac{in}{s^2}}}{500\frac{kip}{in}}} = 0.045\ s < 0.06\ s$$

$$\therefore Consider\ Structure\ Rigid$$

Per *ASCE 7-16 Section 15.4.2*, rigid nonbuilding structures shall be designed for the following seismic base shear:

$$V = 0.30 * S_{DS} * W * I_e$$

$$V = 0.30 * 0.61\ g * 10\ kip * 1.25 = 2.3\ kip$$