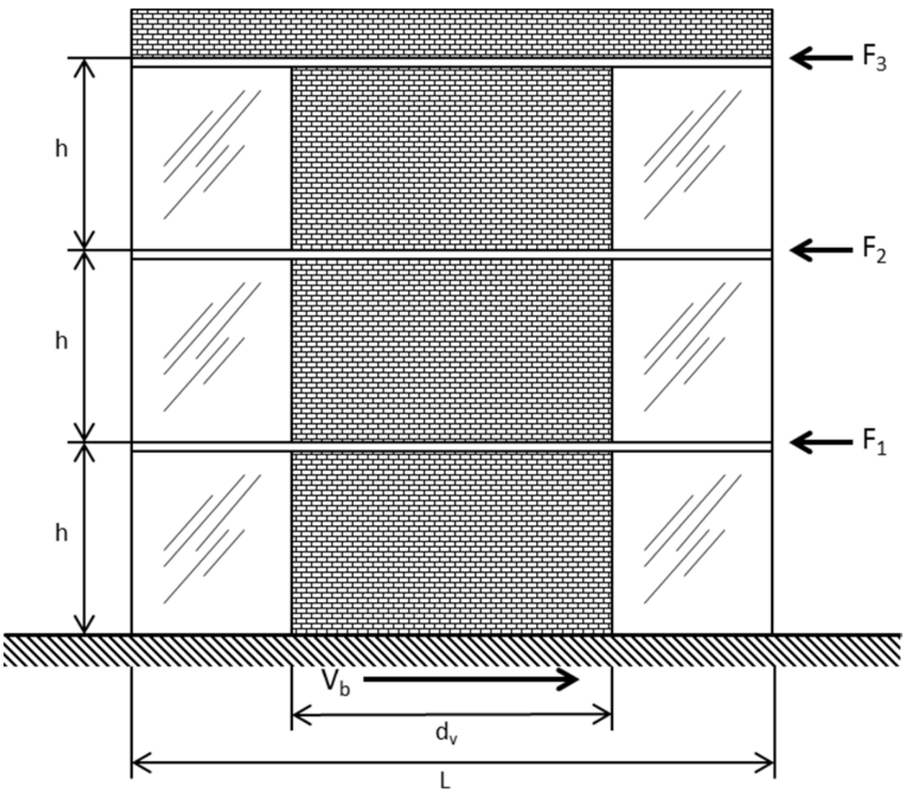
Project 1 – Masonry Shear Wall Analysis

Design the seismic shear walls for the three-story reinforced masonry structure shown below. The plan for the structure is square and doubly symmetric. The length of the structure is 40 feet. The seismic shear walls are to be located at the center of each of the four exterior walls. The wall from the edge of the shear wall to the corner of the building will consist of a glass curtain wall weighing 10 pounds per square foot (psf). The masonry wall density is 135 pounds per cubic foot (pcf). You are to minimize the total weight of the structure. *Note that for this problem, kips (i.e. kilopounds) are repeatedly used (1 kip = 1000 lbs).*



These building parameters are given:

- L = building length = 40 ft
- h = story height = 10 ft
- D_f = floor dead load = 200 psf
- L_f = floor live load = 80 psf
- D_r = roof dead load = 192 psf (includes parapet)
- S = snow load = 48 psf
- γ_m = masonry density = 135 pcf
- w_g = curtain glass weight = 10 psf (wall area)
- f_m = masonry compressive strength = 1200 psi
- f_y = reinforcement yield strength = 60,000 psi

The following variables must be determined by the designer:

- d_v = length of shear wall, ft
- t_1 = thickness of the first story wall, ft
- t_2 = thickness of the first story wall, ft
- t_3 = thickness of the first story wall, ft
- ρ_{v1} = shear reinforcement ratio of the first story wall
- ρ_{v2} = shear reinforcement ratio of the first story wall
- ρ_{v3} = shear reinforcement ratio of the first story wall

Note that the shear wall length, d_v, is constant for the entire height of the structure. The shear wall length must be at least 6 feet less than the length of the structure to allow for windows and exterior doors. The length must be greater than 5 feet. The shear walls must be able to carry both the vertical loads and the lateral seismic loads; no other vertical structural members are to be used.

The masonry units come in sizes ranging from 5.625 inches to 13.625 inches thick in increments of 2 inches. For the purpose of this exercise, assume that the size range is continuous from the minimum to the maximum size. Convert these sizes to feet before using them into your problem. The amount of shear reinforcement in each wall is limited by the following constraints.

- $\rho_v \geq 0.0002$
- $\rho_v \leq \frac{0.064 f_m}{3 f_y}$

Earthquake Loading

The structure is to be located in Provo, UT. The seismic response coefficient and total base shear for the building and location are given by:

$C_s = 0.814g$

and

$V_b = Cs * W$

where:

- V_b = base shear, kip
- W = total dead weight of the building, kip

The dead weight for each floor is given by:

$$w_x = \frac{1}{1000}\left[D_f L^2 + 4t_x h d_v \gamma_m + 4h w_g (L - d_v)\right]$$

where:

- w_x = seismic weight of floor x, kip
- D_f = floor dead weight (note that for floor 3, use the roof dead weight, D_r, instead)
- t_x = shear wall thickness at floor x, ft

The total dead weight, W, is found by summing the dead weight of the three floors.

The equivalent lateral force for each floor is shown on the diagram on the first page. Each is given by the following equations. (Hint: The sum of the lateral seismic force for all the floors should equal the base shear.)

$F_x = C_{vx} V_b$

and

$$C_{vx} = \frac{w_x h_x^k}{\sum_{i=1}^{3} w_i h_i^k}$$

where:

- F_x = the lateral seismic force at floor x, kip
- C_{vx} = vertical distribution factor at floor x
- V_b = base shear, kip
- w_x = dead weight of floor x, kip
- w_i = dead weight of floor i, kip
- h_x = height from base to floor x, ft
- h_i = height from base to floor i, ft
- k = 1 for this scenario

Shear Load

The shear strength resisted by each shear wall is given by:

$$V_{ux} = \frac{1}{2}\sum_{i=x}^{3} F_i$$

where:

- V_{ux} = the shear load resisted by each shear wall at floor x, kip
- F_i = lateral seismic force at floor i, kip

The shear wall strength equation is given by:

$$\varphi_v V_{nx} = \varphi_v \frac{1}{1000}\left[\left(4.0 - 1.75\left(\frac{h}{2d_v}\right)\right)(144) d_v t_x \sqrt{f_m} + 0.25 * P_x + 72 t_x d_v \rho_{vx} f_y\right]$$

and

$$P_x = \frac{1}{4}\sum_{i=x}^{3} 0.9 w_i$$

where:

- $\varphi_v V_{nx}$ = the reduced shear strength of the wall at floor x, kip
- φ_v = shear strength reduction factor = 0.9
- t_x = thickness of the wall at floor x, ft
- ρ_{vx} = shear reinforcement ratio for floor x
- P_x = reduced cumulative vertical load for floor x, kip
- w_i = dead weight of floor i, kip

The reduced shear strength for each wall must be greater than or equal to the respective factored shear load for each wall, i.e.:

$$\varphi_v V_{nx} \geq V_{ux}$$

Axial Load

The factored vertical axial load is given by:

$$P_{ux} = \sum_{i=x}^{3}\left(0.3 w_i + 0.00025 L_{fi} L^2 + F_i \frac{h}{L}\right) + 0.00005 S L^2$$

where:

- w_i = dead weight of floor i, kip
- L_{fi} = floor live load at floor i, kip (note: L_{f3} = 0)
- F_i = lateral seismic force at floor i, kip
- h = story height, ft
- L = building length, ft
- S = snow load

The reduced wall axial strength is given by:

$$\varphi_p P_{nx} = \varphi_p 0.0008\left[0.8 t_x d_v f_m(144)\left[1-\left(\frac{h}{140r}\right)^2\right]\right]$$

and

$$h/_{r_x} = \frac{2h\sqrt{3}}{t_x}$$

where:

- $\varphi_p P_{nx}$ = reduced axial strength for floor x, kip
- φ_p = axial strength reduction factor = 0.9
- d_v = length of shear wall, ft
- $h/_{r_x}$ = slenderness ratio for the wall at floor x
- h = story height, ft
- t_x = thickness of wall at floor x, ft

The reduced wall axial strength must be greater than or equal to the respective factored axial load for each wall, i.e.:

$$\varphi_p V_{nx} \geq V_{ux}$$