Problem #1

A square/rectangular footing supporting a square column is shown below.

(a) Determine the footing dimensions L and B. Use 3 inch increments

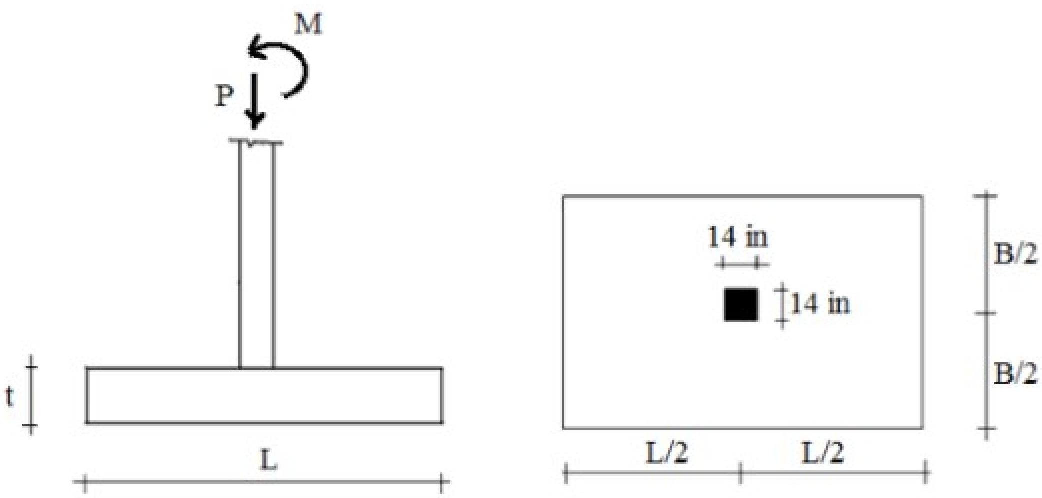
(b) Determine the required t. Use 2 inch increments.

(c) Determine the required reinforcing. Use #8 bars. Show the reinforcing arrangements.

Assume:

$f_c' = 4000$ psi $f_y = 60{,}000$ psi , $q_e = 4.5$ kip/ft^2 .

$P_D = 140$ kip , $P_L = 160$ kip , $M_D = 60$ kip ft , $M_L = 80$ kip ft



Concrete Properties:

fcp := 4000 psi fy := 60000 psi yc := .15 kcf

$\alpha := 40$

$$\beta 1 := \begin{cases} .85 & \text{if } fcp \le 4000 \\ .65 & \text{if } fcp \ge 8000 \\ \left[.85 - (fcp - 4000)\cdot\dfrac{0.05}{1000}\right] & \text{otherwise} \end{cases}$$

$\beta 1 = 0.85$

Soil Properties:

qe := 3.587 ksf ys := .12 kcf

Assumptions:

Footing Thickness: t := 21 in

Soil depth: Df := 3 ft

Loading Conditions:

Pd := 120 kip Pl := 130 kip Md := 0 kip·ft Ml := 0 kip·ft

P := Pd + Pl = 250 kip M := Md + Ml = 0 kip·ft $e := \dfrac{M}{P} = 0$ ft

Factored Loads:

Pu1 := 1.4·Pd kip Pu2 := 1.2·Pd + 1.6·Pl = 35 kip Pu := max(Pu1, Pu2) = 352 kip

Mu1 := 1.4·Md = 0 kip·ft Mu2 := 1.2·Md + 1.6·Ml = 0 kip·ft Mu := max(Mu1, Mu2) = 0 kip·ft

Footing Dimensions:

a1 := 12 in a2 := 12 in

Factors:

$\phi t := .9$ $\phi v := .75$

$ha1 := \frac{a1}{2} = 6 \qquad ha2 := \frac{a2}{2} = 6$

FOOTING DESIGN:

<u>1. Determining L, B, t, As and Id:</u>

$hs := Df \cdot 12 - t = 15$ in

$qe = 3.587$ ksf

$Areqd := \frac{P}{qe} = 69.696$ sf $\qquad Lreqd := \sqrt{Areqd} = 8.348$ ft $\qquad B := 8.5$ ft

Critical Eccentricity: if e < ec, OK.

$ec := \frac{Lreqd}{6} = 1.391$ ft $\qquad A := B \cdot Lreqd = 70.962$ sf $\qquad L := 8.5$

$qu := \frac{Pu}{A} = 4.96$

Reinforcement:

Using #8 bars: $dbar8 := 1 \qquad As8 := 0.79 \qquad cover := 3 + 1.5 \cdot dbar8 \qquad d := t - cover = 16.5$

$b0 := 2 \cdot (a1 + d) + 2 \cdot (a2 + d) = 114$

$$\beta c := \begin{cases} \frac{a1}{a2} & \text{if } a2 \le a1 \\ \left(\frac{a2}{a1}\right) & \text{otherwise} \end{cases}$$

$\beta c = 1$

$Vu1 := qu \cdot B \cdot \left[\left(\frac{L}{2}\right) - \left(\frac{a1}{2 \cdot 12}\right) - \left(\frac{d}{12}\right)\right] = 100.139 \qquad Vu2 := qu \cdot \left[B \cdot L - (a1 + d) \cdot \frac{(a2 + d)}{12 \cdot 12}\right] = 330.411$

$Vu1 := 98.353 \qquad Vu2 := 324.519$

$d1req := Vu1 \cdot \frac{1000}{\phi v \cdot 2 \cdot \sqrt{fcp} \cdot B \cdot 12} = 10.164 \qquad d2a := Vu2 \cdot \frac{1000}{\phi v \cdot 4 \cdot \sqrt{fcp} \cdot b0} = 15.003$

$$d2b := Vu2 \cdot \frac{1000}{\phi v \cdot \left(2 + \frac{4}{\beta c}\right) \cdot \sqrt{fcp} \cdot b0} = 10.002$$

$$d2c := Vu2 \cdot \frac{1000}{\phi v \cdot \left(2 + \frac{\alpha \cdot d}{b0}\right) \cdot \sqrt{fcp} \cdot b0} = 7.704$$

$$d2reqd := \max(d2a, d2b, d2c) = 15.003$$

$$dreqd := \max(d2reqd, d1req) = 15.003$$

Compare Required d1 and d2 with assumed d: $d = 16.5$

Reinforcing

$$Mu := qu \cdot \left[\left(\frac{L}{2}\right) - a1 \cdot \frac{1}{24}\right]^2 \cdot \frac{B}{2} = 296.463$$

$$Rnreq := Mu \cdot \frac{12000}{\phi t \cdot B \cdot 12 \cdot d^2} = 142.345$$

$$\rho req := .85 \cdot \frac{fcp \cdot \left(1 - \sqrt{1 - \frac{2 \cdot Rnreq}{.85 \cdot fcp}}\right)}{fy} = 2.424 \times 10^{-3}$$

$$\rho max := .85 \cdot 0.428 \cdot \beta 1 \cdot \frac{fcp}{fy} = 0.021$$

$$\rho min1 := 3 \cdot \frac{\sqrt{fcp}}{fy} = 3.162 \times 10^{-3}$$

$$\rho min2 := \frac{200}{fy} = 3.333 \times 10^{-3}$$

$$\rho min := \max(\rho min1, \rho min2) = 3.333 \times 10^{-3}$$

Area of Steel Required:

$$Asreq := \begin{cases} \rho req \cdot B \cdot 12 \cdot d & \text{if } \rho req \ge \rho min \\ (\rho min \cdot B \cdot 12 \cdot d) & \text{otherwise} \end{cases}$$

$$Asreq := 5.61$$

Using #8 bars:

$$\frac{Asreq}{As8} = 7.101$$

$$Nbars := 8$$

$$As := Nbars \cdot As8 = 6.32$$

$$\rho := \left(\frac{As}{B \cdot 12 \cdot d}\right) = 3.755 \times 10^{-3}$$

$$a := As \cdot \frac{fy}{0.85 \cdot fcp \cdot B \cdot 12} = 1.093$$

$$c := \frac{a}{\beta 1} = 1.286$$

$$\varepsilon t := (d - c) \cdot \frac{0.003}{c} = 0.035$$

$$\phi t := \begin{cases} .65 & \text{if } \varepsilon t \le 0.002 \\ .9 & \text{if } \varepsilon t \ge 0.005 \\ \left[.65 + (\varepsilon t - 0.002) \cdot \frac{250}{3}\right] & \text{otherwise} \end{cases}$$

$$\phi t = 0.9$$

$$\phi Mn := \phi t \cdot As \cdot fy \cdot \frac{\left(d - \frac{a}{2}\right)}{12000} = 453.711$$

$$Mu := 291.176$$

$$\text{spacing} := \frac{\left[B\cdot 12 - 2\cdot\left(3 + \frac{\text{dbar8}}{2}\right)\right]}{\text{Nbars} - 1} = 13.571$$

$$\text{Cb1} := \frac{\text{spacing}}{2} = 6.786 \qquad \text{Cb2} := \left(3 + \frac{\text{dbar8}}{2}\right) = 3.5 \qquad \text{Cb} := \min(\text{Cb1}, \text{Cb2}) = 3.5$$

ACI Code factors, for bottom reinforcing, non coated bars, for no. 7 and larger bars and normal weight concrete, respectively:

$$\psi t := 1 \qquad \psi e := 1 \qquad \psi s := 1 \qquad \lambda := 1 \qquad \text{Ktr} := 0$$

$$\text{coef} := \begin{vmatrix} 2.5 \ \text{ if } \dfrac{(\text{Ktr} + \text{Cb})}{\text{dbar8}} \geq 2.5 \\ \dfrac{(\text{Ktr} + \text{Cb})}{\text{dbar8}} \ \text{ otherwise} \end{vmatrix}$$

$$\text{coef} = 2.5$$

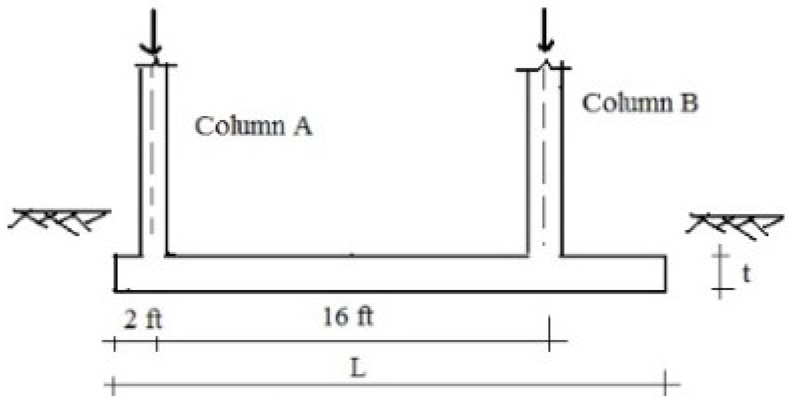
$$\text{ld} := \frac{3\cdot\left(\frac{\text{fy}}{\sqrt{\text{fcp}}}\right)\cdot\left(\psi t\cdot\psi e\cdot\psi s\cdot\frac{\lambda}{\text{coef}}\right)\cdot\text{dbar8}}{40} = 28.46$$

$$\frac{\text{ld}}{12} = 2.372$$

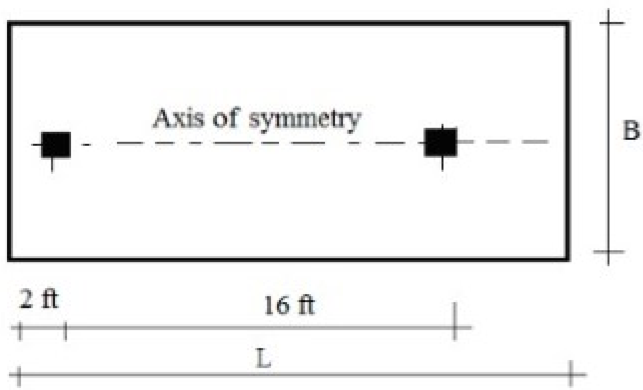
Ana Gouveia

Problem #2

A combined footing supports two square columns. Column A is 14 inches x 14 inches and carries a dead load of 140 kip and a live load of 220 kip. Column B is 16 inches x 16 inches and carries a dead load of 260 kip and a live load of 300 kip. The effective soil pressure is $q_e = 4.0\ \text{kip/ft}^2$. Assume the soil pressure distribution is uniform.



Elevation



Plan

(a) Determine the footing dimensions L and B. Use 3 inch increments.

(b) Establish the shear and moment diagrams corresponding to the factored loading, $P_u = 1.2\ P_D + 1.6\ P_L$.

(c) Determine the required t. Use 2 inch increments.

(d) Determine the required reinforcing. Use #9 bars. Show the reinforcing arrangements.

Assume: $f_c' = 4000\ \text{psi}$ and $f_y = 60{,}000\ \text{psi}$.

Problem #3

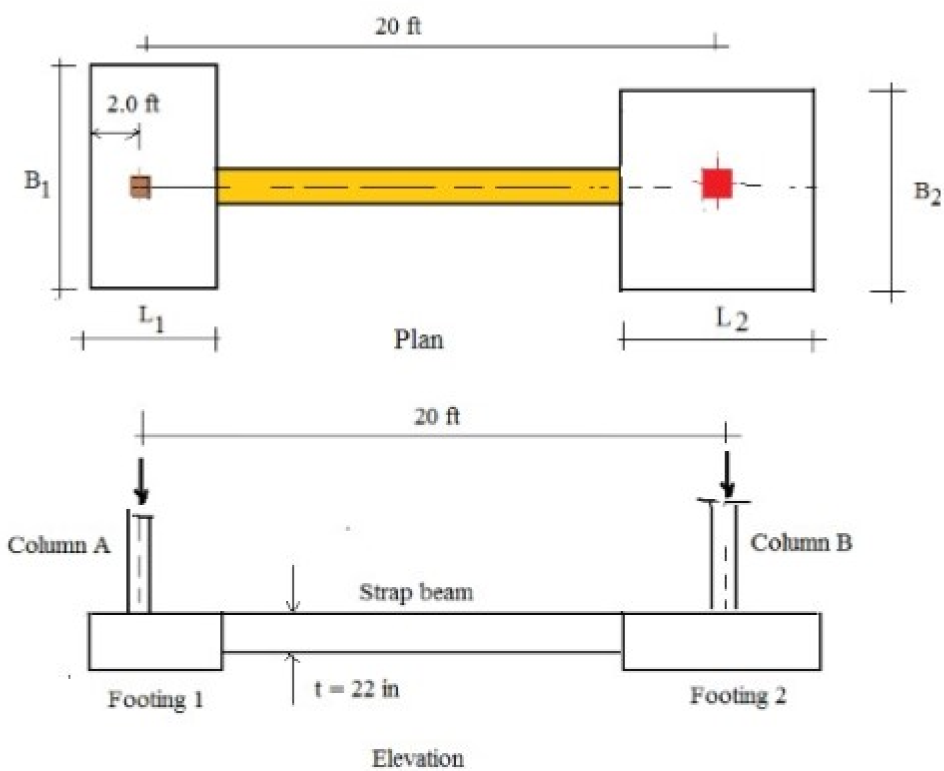
Column A is 14 inches x 14 inches and carries a dead load of 160 kip and a live load of 140 kip. The interior column B is 18 inches x 18 inches and carries a dead load of 230 kip and a live load of 200 kip. The distance between the center lines of the columns is 18 ft. A strap footing is used to support the columns. The center line of column A is 2.ft. from the property line. Assume the strap is placed such that it does not bear directly on the soil. Assume $f_c' = 4000$ psi and $f_y = 60{,}000$ psi.

(a) Determine the dimensions L_1, B_1, B_2 and L_2 for the pad footings that will result in a uniform effective soil pressure not exceeding 4.5 kip/ft^2 under each pad footing. Use ¼ ft. increments.

(b) Establish the shear and moment diagrams corresponding to the factored loading, $P_u = 1.2\,P_D + 1.6\,P_L$.

(c) Design the strap beam (i.e., determine the required width and reinforcing). Use #8 bars. Show the reinforcing arrangements.

(d) Determine the soil pressure profile under the footings determined in part (a) when an additional loading, consisting of an uplift force of 90 kip at the exterior column and an uplift force of 40 kip at the interior column, is applied to the factored loads.

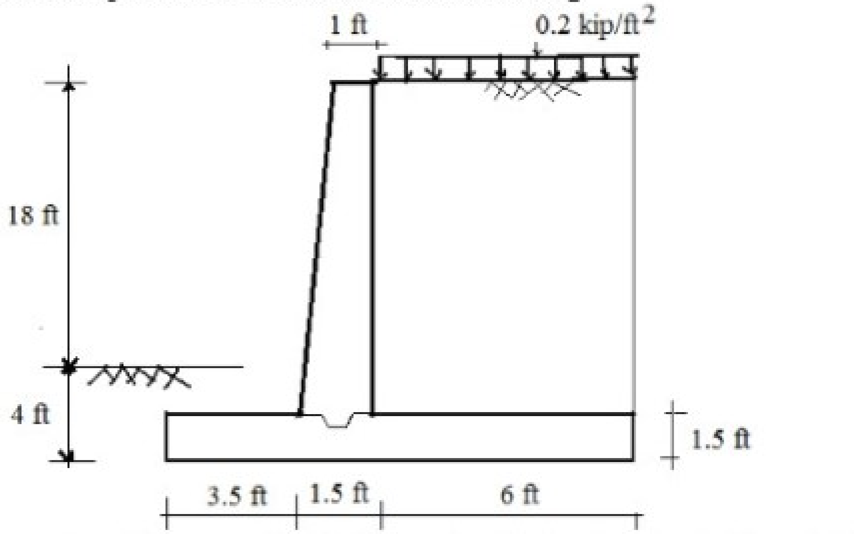


14. **Problem # 4**

Ana Gouveia

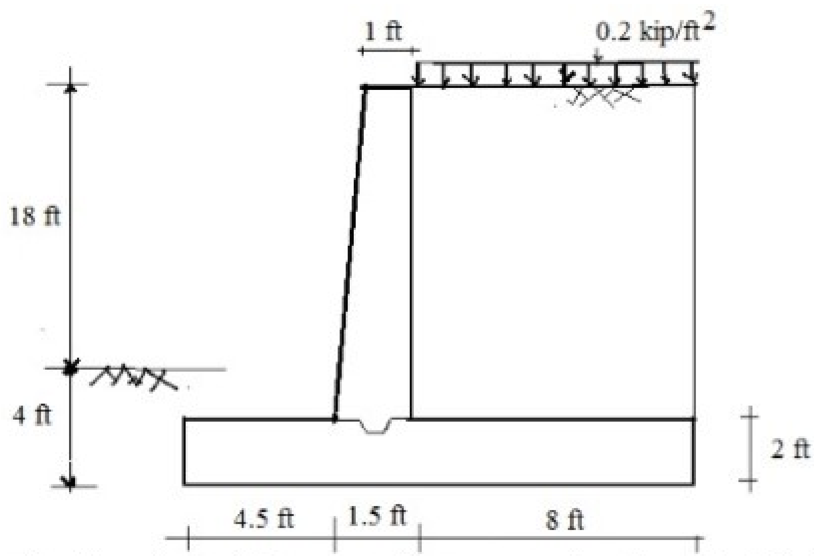
(a) For the cantilever retaining wall shown below, determine the following:

- (i) The soil pressure acting on the wall
- (ii) The factor of safety for overturning
- (iii) The factor of safety for sliding
- (iv) The soil pressure distribution under the footing



(b) To improve the soil pressure distribution under the footing, the footing size is increased as shown below. Select the reinforcing and show the reinforcing details. Use #8 or #4 bars.

Assume: Allowable soil pressure = 4.5 kip/ft^2, $f'_c = 4000$ psi, $f_y = 60{,}000$ psi, $\gamma_{soil} = 0.12$ kip/ft^3, $\gamma_{concrete} = 0.15$ kip/ft^3, $k_a = 1/3$, and $\mu = .58$



(c) Are the dimensions of the stem and base appropriate for optimal design? What is your suggestion?