Name : Mehran

ID # 15067

Subject : Advanced Design of Reinforced Concrete Structures.

Degree : MS (CEM).

Q.

Sol:

$$a = \frac{A_s f_y}{0.85 \times f_c' \, b}$$

$$= \frac{4.68 \times 75}{0.85 \times 5 \times 14}$$

$$\boxed{a = 5.899 \text{ in}}$$

$c = ?$

$$c = a/\beta_1$$

$$= \frac{5.899}{0.85}$$

$$\boxed{c = 6.940 \text{ in}}$$

$\varepsilon_t = ?$

$$\varepsilon_t = \frac{d-c}{c}(0.003)$$

$$= \frac{18 - 6.940}{6.940}(0.003)$$

$$\boxed{\varepsilon_t = 0.00478}$$

$\varepsilon_t > 0.004$

$\varepsilon_t < 0.005$

The beam is in transition zone.

$\phi = ?$

$$\phi = 0.65 + (\varepsilon_t - 0.002)\frac{250}{3}$$

$$= 0.65 + (0.00478 - 0.002)\frac{250}{3}$$

$$\boxed{\phi = 0.881}$$

$\phi M_n = ?$

$M_n = A_s f_y (d - a/2)$

$= 4.68 \times 75 \left(18 - \frac{5.899}{2}\right)$

$= 5282.72$ in-k

Convert from in-k to ft-k

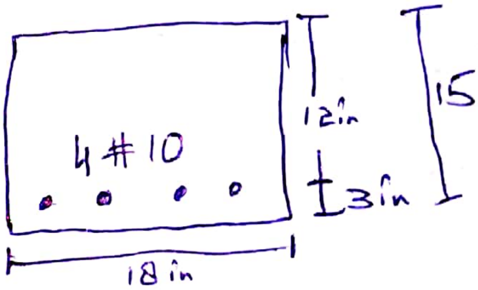
$M_n = 5282.72 \text{ in-k} \times \frac{1 \text{ ft}}{12 \text{ in}}$

$M_n = 440.227$ ft-k

$\phi M_n = 0.881 (440.227)$

$\boxed{\phi M_n = 387.84 \text{ ft-k}}$

Q15 Sol:



$\varepsilon_t = ?$

$$a = \frac{A_s f_y}{0.85 f'_c b}$$

$$= \frac{5.06 \times 60}{0.85 \times 4 \times 18}$$

$\boxed{a = 4.96 \text{ in}}$

$C = a/\beta_1$

$= 4.96/0.85$

$\boxed{c = 5.83 \text{ in}}$

Now

$$\varepsilon_t = \frac{d - c}{c} (0.003)$$

$$= \frac{12 - 5.83}{5.83} (0.003)$$

$\varepsilon_t = 0.00316$

$\varepsilon_t = 0.00316 < 0.004$

Section is not ductile & may not be used as per ACI section 10.3.5.

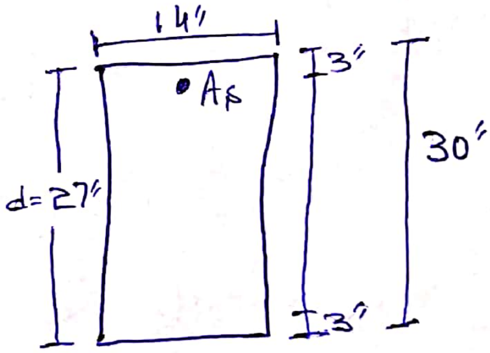
Q1-b) Given Data:

$M_D = 150$ ft-K, $M_L = 410$ ft-K

$f_c' = 4000$ psi, $f_y = 60{,}000$ psi.

Sol:

① Factored Moment:



$M_u = 1.2\,M_D + 1.6\,M_L$

$= 1.2(153) + 1.6(410)$

$= 839.6 \cong 840$ ft-K

② Nominal Moment $(M_n) = ?$

$M_n = M_u/\phi$ $\qquad \phi = 0.90$

$= 840/0.90$

$\boxed{M_n = 933.33 \text{ ft-K}}$

Assuming Max-possible tensile steel with no compression steel & computing beams nominal strength moment.

ρ_{max} (from Appendix A, table A-7)

$= 0.0181$

$As_1 = \rho_{max}\, bd$

$= 0.0181 \times 14 \times 27$

$As_1 = 6.842\ in^2$

for $\rho_{max} = 0.0181 \cdot \frac{M_u}{\phi b d^2} = 912\ Psi$

$M_{u1} = 912 \times \phi b d^2 = 912 \times 0.9 \times 14 \times (27)^2$

$M_{u1} = \frac{8377084.8}{12}$ in-lb

$= \frac{698090}{1000}$ ft-lb

$M_{u1} = 698$ K-ft

$M_{n1} = M_{u1}/\phi = 698/0.9 = 775.55$ K-ft

$M_{n2} = M_n - M_{n1} = 927.77 - 698$

$M_{n2} = 229.77$ K-ft

Theoretical As required

$As = \frac{M_{n2}}{f_y(d-d)}$

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$$= \frac{229.77 \times 12}{60(27-3)}$$

$$= 1.96 \cong \boxed{2 \text{ in}^2}$$

Try 2 #9 (2 in²)

$$A_s' f_s' = A_{s2} f_y$$

$$A_{s2} = \frac{A_s' f_s'}{f_y} = \frac{2 \times 60}{60}$$

$$\boxed{A_{s2} = 2 \text{ in}^2}$$

$$A_s = A_{s1} + A_{s2}$$

$$= 6.84 + 2$$

$$\boxed{A_s = 8.84 \text{ in}^2}$$

Try 8#10 (10.12 in²)

Note:

The actual value of A_s' is exactly the same as theoritical value. The actual value of A_s however is higher than the theoritical value by 10.12 - 9.6 = .52 in² If new bar selection for A_s' exceed the theoritical value by about this much (0.52 in²) the design will be adequate select 5#8 bars (A_s' = 2.36 in²) & repeat the previous step

Assuming $f_s' = f_y$

$$\frac{(A_s - A_s')f_y}{0.85 f_c' b \beta_1} = \frac{(10.12 - 2.36) \times 60}{0.85 \times 4 \times 14 \times 0.85}$$

$c = 11.5$ in

$$\varepsilon_s' = \left(\frac{c-d'}{c}\right)(0.003) = \frac{(11.5-3)}{11.50}(0.003)$$

$= 0.00217 > \varepsilon_y$

$$\varepsilon_t = \frac{(d-c)}{c}(0.003) = \left(\frac{27-11.5}{11.5}\right)(0.003)$$

$= 0.00404 < 0.005$

$\phi \neq 0.90$

$\phi = 0.65 + (\varepsilon_t - 0.002)\ 250/3$

$\phi = 0.65 + (0.00404 - 0.002)\ 250/3$

$\boxed{\phi = 0.82}$

$$A_{s2} = \frac{A_s' f_s'}{f_y} = \frac{2.36 \times 60}{60}$$

$\boxed{A_{s2} = 2.36 \text{ in}^2}$

$A_{s1} = A_s - A_{s2}$

$= 10.12 - 2.36$

$\boxed{A_{s1} = 7.76 \text{ in}^2}$

$M_{n1} = A_{s1} f_y (d - a/2)$

$= 7.76 \times 60 \left[27 - \frac{0.85 \times 10.74}{2}\right]$

$= \frac{10912.5}{12}$ in K

$\boxed{M_{n1} = 909.29 \text{ K-ft}}$

$$M_{n2} = A_{s2} f_y (d - d')$$

$$= (2.36)(60)(27-3)$$

$$= 3398 \text{ in k} \times \frac{ft}{12}$$

$$\boxed{M_{n2} = 283 \text{ ftk}}$$

$$\cancel{\phi} M_n = M_{n1} + M_{n2}$$

$$= 909 + 283$$

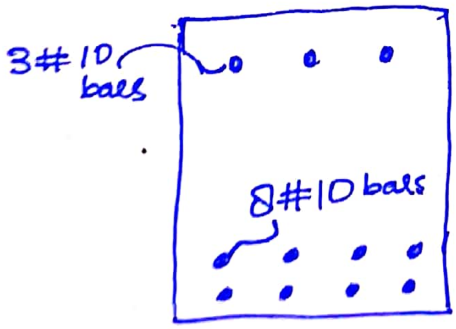
$$\cancel{\phi} M_n = 1192 \text{ ftk}$$

$$\phi M_n = 0.82 \times 1192$$

$$= 977 \text{ ftk} > M_u = OK$$

$A_s' = 2.36 \text{ in}^2$ (3 #8 bars)

$A_s = 10.12 \text{ in}^2$ (8 #10 bars)



Q2) $M_u = 15$ ft-k $\quad P_u = 150$ k

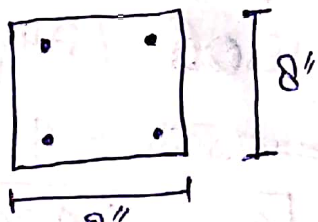
Sol: Assume the column will have average compression stress = about $0.6 f_c' = 2400$ psi $= 2.4$ ksi

$$A_g = 150\text{k} / 2.4\text{ ksi} = P_u / 0.6 f_c'$$

$$= P_u / \text{Av. comp stress}$$

$$= 63.75 \text{ in}^2$$

Try 8″ × 8″ column ($A_g = 64$ in²) with the bar arrangement



$$e = M_u / P_u$$

$$= \frac{15 \text{ ft-k} \times 12 \text{ in/ft}}{150 \text{ k}}$$

$$= 1.17 \text{ in}$$

$$P_n = P_u/\phi = 150\text{k}/0.65 = 230 \text{ k}$$

$$K_n = P_n / f_c' A_g = 230\text{k} / 4 \text{ ksi} \times (8 \times 8) = 0.919$$

$$R_n = \frac{P_n e}{f_c' A_g h} = \frac{230\text{k} \times 1.17 \text{ in}^2}{4 \text{ ksi } (8'' \times 8'') \times 8''}$$

$$\boxed{R_n = 0.1384}$$

$$\gamma = 3''/8'' = 0.375$$

Interpolating b/w values given in graphs 6 & 7 of Appendix A.

$$A_s = 0.0123 \times (8'' \times 8'')$$
$$= 0.78 \text{ in}^2 \qquad \text{use } 4 \, \#4 = 0.78 \text{ in}^2$$

Q 3)

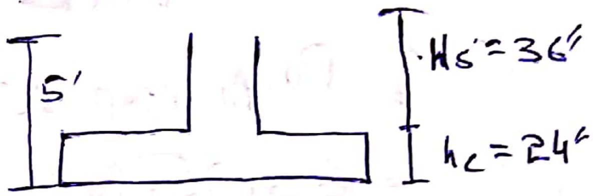
$P_D = 150K$. γ_s, Soil wt $= 100 lb/ft^3$

$P_L = 160K$ $\quad q_a = 1506$

$f_c' = 3000 psi$, $\quad f_y = 60{,}000 psi$.

$\gamma_c = 150 lb/ft^3$, $\quad h_c = 24''$

$d = 19.5''$, $H_s = 36''$



Step#1: effective soil pressure "q_e"

$q_e = q_a - h_c \times \gamma_c - H_s' \times \gamma_s$

$= 1506 - (24/12 \times 150) - (36/12) \times 100$

$= 906 psf$

$\boxed{q_e = 0.906 ksf}$

Step#2: Area of footing

$= \dfrac{P_D + P_L}{q_e}$

$= \dfrac{150 + 160}{0.934} = 336 ft^2.$

use $18.5' \times 18.5'$ footing area $= 342 ft^2$

Step#3: Ultimate Bearing Capacity

$q_u = \dfrac{1.2 P_D + 1.6 P_L}{\text{Area of footing}}$

$= \dfrac{(1.2 \times 150) + (1.6 \times 160)}{342}$

$\boxed{q_u = 1.27 ksf}$

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Step #4: Depth required for two way or punching shear.

The d required for two way shear is the largest value obtained from the following expression.

i) $d = \dfrac{V_{u2}}{\phi 4 \sqrt{f'_c}\, b_o}$

$\alpha_s = 40$ for column where perimeter is four sided square column

ii) $d = \dfrac{V_{u2}}{\phi \left(\frac{\alpha_s d}{b_o} + 2 \right) \sqrt{f'_c}\, b_o}$

b_o = Perimeter around the punching area $= 4(a+d)$

$b_o = 4(a+d) = 4(16+19.5)$

$\boxed{b_o = 142 \text{ in}}$

$V_{u2} = \{A - (a+d)\} \times q_u$

$= \left\{ 336 - \left(\frac{16+19.5}{12} \right) \right\} \times 1.27$

$V_{u2} = 432.672 K$

$\boxed{V_{u2} = 432672 \text{ lb}}$

i) $d = \dfrac{V_{u2}}{\phi 4 \sqrt{f'_c}\, b_o} = \dfrac{432672}{0.75 \times 4 \times \sqrt{3000} \times 142} = 18.58'' < 19.5''$ = OK

ii) $d = \dfrac{V_{u2}}{\phi \left(\frac{\alpha_s d}{b_o} + 2 \right) \sqrt{f'_c} \times b_o} = \dfrac{432672}{0.75 \left(\frac{40 \times 19.5}{142} + 2 \right) \sqrt{3000} \times 142}$

$= 9.653'' < 19.5''$ OK

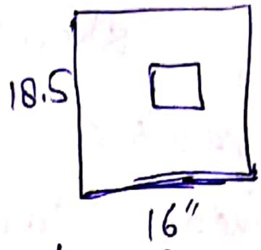
Since both values of d are less than the assumed value of 19.5'' So punching is OK.

Step 5: Depth required for one way shear

$V_{u1} = (18.5 \times 6.958) \times 1.27$

$= 164.101\ K$

$\boxed{V_{u1} = 164101\ lb}$



$\frac{L}{2} - \frac{a}{2} - d$

$\frac{18.5}{2} - \frac{16''}{2} - 19.5$

$= 6.96$

$d = \frac{V_u}{\phi 2 \sqrt{f_c'}\ b_w}$

$= \frac{164101}{0.75 \times 2 \times \sqrt{3000} \times (18.5 \times 12)}$

$d = 9.06 < 19.5 = ok$

use $h = 24''$ in total depth.

Moments:

$M_u = 8.58 \times 18.5 \times 1.28 \times \frac{8.58}{2}$

$= 871\ ft\text{-}K$

$\frac{M_u}{\phi b d^2} = \frac{871 \times 1000 \times 12}{0.9 \times (18.5 \times 12)(19.5)^2} = 137.5\ psi$

using table A-12

$\frac{M_u}{\phi b d^2} = 139.9$

Use the greater

i) $\frac{150}{60{,}000} = 0.00251$

ii) $\frac{3\sqrt{3000}}{60{,}000} = 0.00273$

So, $\rho = 0.00273$

Area of steel:

$A_s = \rho b d$

$A_s = 0.00273 \times (18.5 \times 12) \times 19.5$

$= 11.81\ in^2.$

Using table A-4

8 #11 bars in both direction

$\psi_t = \psi_e = \psi_s = \lambda = 1$

if $\frac{c_b}{d_b} > 2.5$ then use 2.5

c_b = side cover = 3.5"

d_b = dia of bar = 8/8 = 1"

$$\frac{c_d}{d_b} = \frac{3.5}{1} = 3.5 > 2.5$$

using eq (i)

$$\frac{l_b}{d_b} = \frac{3}{40} \times \frac{60{,}000}{1\sqrt{3000}} \times \frac{1 \times 1 \times 1}{2.5} = 32.86$$

$$\frac{l_b}{d_b} = \frac{A_{s\,req}}{A_{s\,sel}} = 32.86 \times \frac{11.81}{12.5} = 31.04$$

$l_b = 3\cancel{1}.30\, d_b = 31.30 \times 1$

$\boxed{l_b = 31''}$ = OK