ID # 15343

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Subject : Advanced Design of Reinforced Concrete Structures

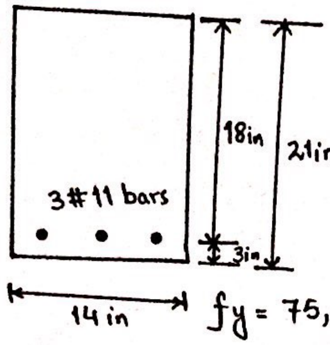
Exam : Mid

Module : 4^{th} Semester

Q.NO(01)(A) :-

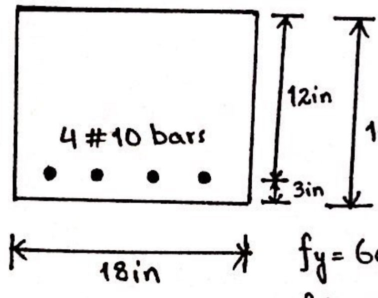
Determine the values of ϵ_t, ϕ and ϕM_n for the Sections shown below :

(a)



$f_y = 75{,}000$ psi
$f_c' = 5000$ psi

(b)



$f_y = 60{,}000$ psi
$f_c' = 4{,}000$ psi

Also discuss the strength analysis. Does the reinforcement is done according to design standard or not. Defend your design analysis.

Solution :-

QNo1(A)(a) :-

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

as $A_s = 4.68\ in^2$

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

$$a = 5.899\ in$$

$C = ?$

$$C = a/\beta_1$$

$$= 5.899/0.85$$

$$= 6.940\ in$$

(1) $\epsilon_t = ?$

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

$$= \frac{18-6.940}{6.940}(0.003) = \boxed{0.00478}$$

$\epsilon_t > 0.004$

$\epsilon_t < 0.005$

Hence Beam is in transition zone.

(2) $\phi = ?$

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

$$= 065 + (0.00478 - 0002)\frac{250}{3}$$

$$= 0.881$$

(3) $\phi M_n = ?$

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

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

$$= 5282.72\ \text{in-k}$$

Convert from in-k to ft-k

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

$$M_n = 440.227\ \text{ft-k}$$

Now $\phi M_n = 0.881(440.227)$

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

QNO1(A)(b) :-

(1) $\varepsilon_t = ?$

$a = A_s \cdot f_y / 0.85 f'_c b$

as → $A_s = 5.06 \ in^2$

$a = 5.06 \times 60 / 0.85 \times 4 \times 18$

$\boxed{a = 4.96 in}$

$C = ?$

$C = a/B_1$

$= 4.96/0.85$

$= 5.835 in$

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

$= \frac{12 - 5.835}{5.835}(0.003)$

$= 0.00316$

$\varepsilon_t = 0.00316 < 0.004$

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

(2) $\phi = ?$

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

$= 0.65 (0.00316 - 0.002) \frac{250}{3}$

$= 0.746$

(3) $\phi M_n = ?$

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

$= 5.06 \times 60 \left(12 - \frac{4.96}{2}\right)$

$= 2890.27 \ in\text{-}k$

Convert in-k to ft-k

$M_n = 2890.27 \ \cancel{in}\text{-}k \times \frac{1 ft}{12 \cancel{in}}$

$= 120.428 \ ft\text{-}k$

Now $\phi M_n = 0.746 \times 120.428$

$= 89.11 \ ft\text{-}k$

Q No 1 (B): Design a doubly reinforced beam for M_D = [First three digits of ID] ft-k and $M_L = 410$ ft-k if $f_c' = 4000$ psi and $f_y = 60{,}000$ psi. Appropriate diagram is must in design.

* Assume the maximum permissible beam dimensions other then done in notes or text book.

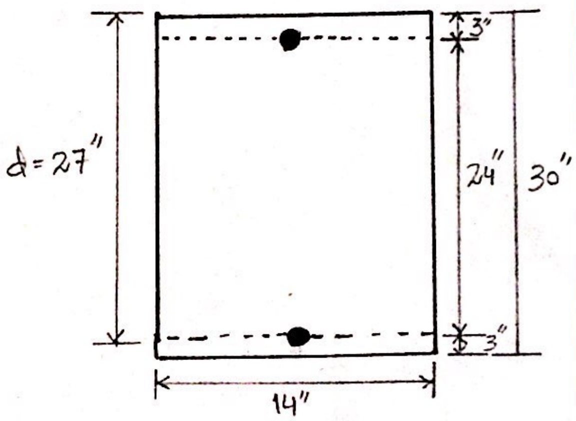
Given Data :

$M_D = 153$ ft-k

$M_L = 410$ ft-k

$f_c' = 4000$ psi

$f_y = 60{,}000$ psi



Solution :

Factored Moment :-

$M_u = 1.2 M_D + 1.6 M_L$

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

$= 839.6$ ft-k

$= \boxed{840 \text{ ft-k}}$

Nominal Moment : (M_n)

$M_n = M_u / \phi$

$= 840 / 0.90$

$\therefore \phi = 0.90$

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

Assuming Maximum-possible Tensile Steel with no compression steel and computing beam nominal strength moment.

ρ_{max} (from Appendix "A", Table A-7)

$= 0.0181$

$A_{s_1} = \rho_{max} \cdot b \cdot d$

$= 0.0181 \times 14 \times 27$

$= \boxed{6.842 \text{ in}^2}$

for

$\rho_{max} = 0.0181$; $\dfrac{M_u}{\phi b d^2} = 912$ psi

$M_u = 912 \times \phi b d^2$

$= 912 \times 0.90 \times 14 \times (27)^2$

$= \boxed{8377084.8 \text{ in-lb}}$

Convert from "inch" to "feet";

$= 8377084.8 / 12$

$= 698090$ ft-lb

Convert from "lb" to "kip"

$= 698090 / 1000$

$M_{u_1} = \boxed{698 \text{ ft-k}}$

* $M_{n_1} = M_{u_1}/\phi = \dfrac{698}{0.90} = 775.55 \text{ ft-k}$
* $M_{n_2} = M_n - M_{n_1} = 933.33 - 698 = 235.33 \text{ ft-k}$

Theoratical As' Required :

$$A_s' = M_{n_2}/f_y(d-d') = \frac{235.33 \times 12}{60\,(27-3)} = 1.96 \approx \boxed{2 in^2}$$

Try 2#9 (2.00 in²)

$$A_s' f_s' = A_{s_2} f_y$$

$$A_{s_2} = A_s' f_s'/f_y = \frac{2 \times 60}{60} = 2 in^2$$

$$A_s = A_{s_1} + A_{s_2}$$
$$= 6.842 + 2$$
$$= \boxed{8.842 \; in^2}$$ Try 8#10 (10.12in²)

Note : The theoratical value of "As'" is exactly the same as the theoratical value.
The actual value of "As" however is higher than the theoratical value by $10.12 - 9.6 = 0.52 in^2$.
if new bar selection for As' is made where by the actual value of "As'" exceeds the theoratical value by about this much (0.52in²), the design will be adequate.
Select 3#8 bars ($A_s = 2.36 \; in^2$) and Repeat the previous step.

Assuming $f_s' = f_y$

(1) $\dfrac{(A_s - A_s')f_y}{0.85 f_c' b \beta_1} = \dfrac{(10.12 - 2.36) \times 60}{0.85 \times 4 \times 14 \times 0.85} = 11.5 \text{ in}$

$\boxed{C = 11.5 in}$

(2) $\epsilon_s' = \left(\dfrac{c-d'}{c}\right)(0.003) = \left(\dfrac{11.5-3}{11.5}\right)(0.003) = 0.00217 > \epsilon_y$

(3) $\epsilon_t = \left(\dfrac{d-c}{c}\right)(0.003) = \left(\dfrac{27-11.5}{11.5}\right)(0.003)$

$= 0.00404 < 0.005$

$\phi \neq 0.90$

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

$$\phi = 0.65 + (0.00404 - 0.002)\frac{250}{3}$$

$$\phi = 0.82$$

$$As_2 = A_s' f_s'/f_y = \frac{236 \times 60}{60} = 2.36\ in^2$$

$$As_1 = A_s - As_2 = 10.12 - 2.36 = 7.76\ in^2$$

$$Mn_1 = As_1 f_y (d - a/2) = 7.76 \times 60\left(27 - \frac{0.85 \times 10.74}{2}\right)$$

$$= 10911.5/12\ in-k$$

$$Mn_1 = \boxed{909.29\ ft-k}$$

$$Mn_2 = As_2 f_y (d - d')$$

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

$$= 3398\ \cancel{in}-k \times 1ft/12\ \cancel{in}$$

$$= \boxed{283\ ft-k}$$

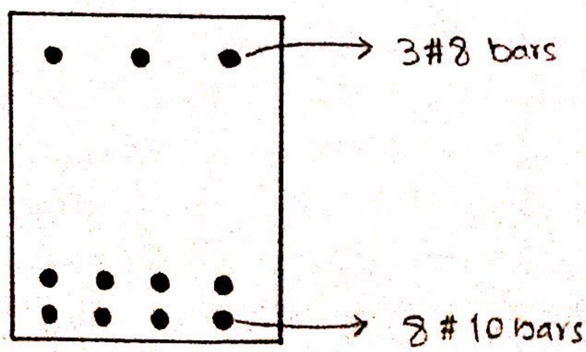
$$M_n = M_{n_1} + M_{n_2} = 909 + 283 = \boxed{1192\ ft-k}$$

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

$$= 977\ ft-k > Mu\ (OK)$$

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

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



QNO-2 :- Design a Short Square column for the following Conditions $P_u = 153\ k$, $M_u = 15\ ft\text{-}k$, $f_c' = 4000\ psi$, $f_y = 60{,}000\ psi$.

Place the bars uniformly around all the four faces of column. Appropriate diagram must in design.

Given data :

$P_u = 153\ K$

$M_u = 15\ ft\text{-}K$

$f_c' = 4000\ psi$

$f_y = 60{,}000\ psi$

Solution :- Assume the column will have average Compression Stress about $0.6 f_c' = 2400\ psi$ $= 2.4\ ksi$

$$A_{g\,(req)} = 153\ k / 2.4\ ksi$$

$$= P_u / 0.6 f_c'$$

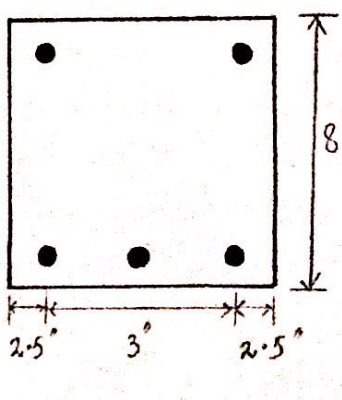
$$= \boxed{63.75\ in^2}$$

Try 8in X 8in Column ($A_g = 64\ in^2$) with the bar arrangement.

$$C = M_u / P_u = \frac{(15\ ft\text{-}k)(12\ in/ft)}{153\ k}$$

$$= \boxed{1.17\ in}$$

$$P_n = P_u / \phi = 153/0.65 = \boxed{235.38\ K}$$



$$K_n = P_n / f_c' A_g = \frac{235.38\ K}{(4\ ksi)(8" \times 8")}$$

$$= \boxed{0.919}$$

$$R_n = P_n \cdot C / f_c' A_g \cdot h = \frac{(235.38\ K)(1.17\ in)}{(4\ ksi)(8" \times 8")(8")}$$

$$= \boxed{0.1344}$$

$$\gamma = 3"/8" = \boxed{0.375}$$

Interpolating between values given in graph 6 & 7 of appendix-A.

$$A_s = (0.0123) \times (8" \times 8")$$

$$= 0.78\ in^2$$

Use 4#4 bar $= 0.78\ in^2$

Q No(3) :- Design a square column for a 16 inch Square tied interior Column that support a dead load $P_D = 153\,K$ and live load of $P_L = 160\,K$. The column is reinforced with #8 bars the base of footing is 5 feet below, the soil weight is $100\,lb/ft^3$. $f_y = 60{,}000\,psi$ and $f_c' = 3000\,psi$ and q_a (first four digit of ID) 1534 psf. Developement length for main bars is also to be done in footing design. Appropriate diagram is must be in design.

Given data :

$P_D = 153\,K$ (First three digits of ID)

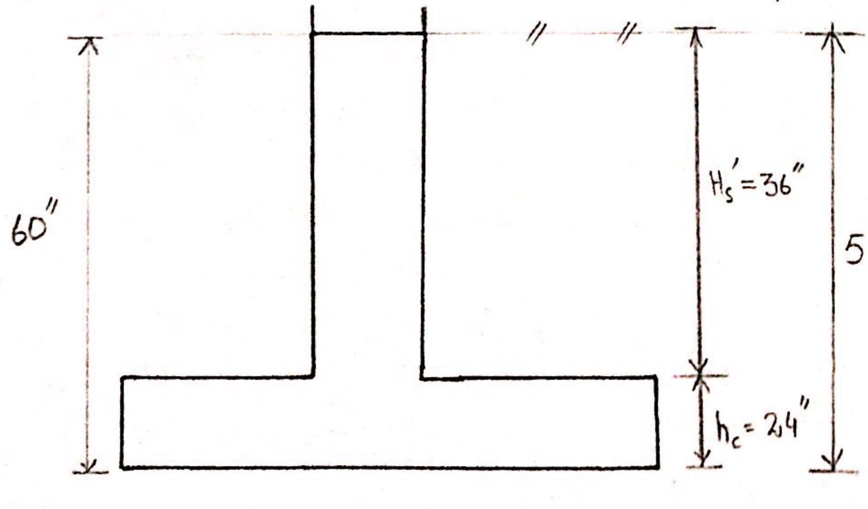
$P_L = 160\,K$

$\gamma_s = 100\,lb/ft^2$

$f_y = 60{,}000\,psi$

$f_c' = 3000\,psi$

$q_a = 1534\,psf$ (first four digits of ID)



Assumed data :

Unit weight of Concrete $= \gamma_c = 150\,lb/ft^3$

$h_c = 24''$

$d = 19.5''$

$H_s' = 36''$

Step # 01 :

Effective Soil pressure "q_e"

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

$$= 1534 - \left(\tfrac{24}{12} \times 150\right) - \left(\tfrac{36}{12}\right) \times 100$$

$$= 934 \text{ psf}$$

$$q_e = \boxed{0.934 \text{ ksf}}$$

Step # 02 : Area of footing

$$\text{Area of footing} = \frac{P_D + P_L}{q_e}$$

$$= \frac{153 + 160}{0.934}$$

$$= \boxed{335 \text{ ft}^2}$$

Use $18.5' \times 18.5'$ footing Area $= 342 \text{ ft}^2$

Step # 03 : Ultimate Bearing Capacity

q_u = Ultimate Bearing Capacity

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

$$= \frac{(1.2 \times 153) + (1.6 \times 160)}{342}$$

$$q_u = \boxed{1.28 \text{ ksf}}$$

Step # 04 : 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) $d = V_{u_2} / \phi 4\sqrt{f_c'}\, b_o$

(ii) $d = V_{u_2} / \phi\left(\frac{\alpha_s d}{b_o} + 2\right)\sqrt{f_c'}\, b_o$

where

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

$b_o \Rightarrow$ perimeter around the punching area $= 4(a+d)$

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

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

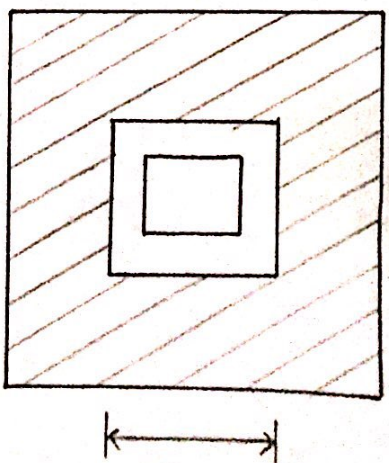
$$V_{u_2} = \{A - (a+d)\} \times q_u$$

$$= \left\{335 - \left(\frac{16 + 19.5}{12}\right)\right\} \times 1.28$$

$$= 433.973 \text{ K}$$

Multiply "1000" to Convert to pound "lb" ←

$$= \boxed{433973 \text{ lb}}$$



16" + 19.5" = 35.5"

Two way shear

(1) $d = V_{u_2} / \phi 4 \sqrt{f_c'}\, b_o$

$= \dfrac{433973}{0.75 \times 4 \times \sqrt{3000} \times 142}$

$= 18.59'' < 19.5''$ (OK)

(2) $d = V_{u_2} / \phi \left(\dfrac{\alpha_s d}{b_o} + 2 \right) \sqrt{f_c'}\, b_o$

$= \dfrac{433973}{0.75 \left(\dfrac{40 \times 19.5}{142} + 2 \right) \sqrt{3000} \times 142}$

$= 9.928'' < 19.5''$ (OK)

Since both value of "d" are less than the assumed valued of 19.5", So punching is OK.

Then use greater of

(1) $\dfrac{153}{60,000} = 0.00255$

(2) $\dfrac{3\sqrt{3000}}{60,000} = 0.00273$

So, $\rho = 0.00273$

Area of Steel

$A_s = \rho . b d$

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

$= 11.81\ in^2$

Use table A-4

8 # 11 bars in both directions

$\boxed{A_s \text{ Selected} = 12.5\ in^2}$

Step # 05 Depth required for Oneway Shear

$V_{u_1} = (18.5 \times 6.958) \times q_u$

$= (18.5 \times 6.958) \times 1.28$

$= 164.576\ k$

$V_{u_1} = \boxed{164576\ lb}$

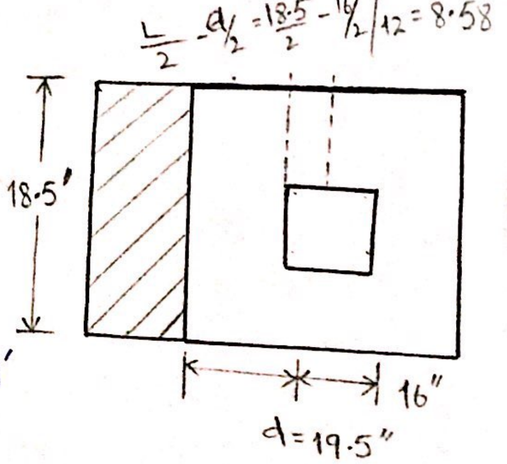
As: $l/2 - 9/2 - d$

$= \dfrac{18.5}{2} - \dfrac{16''}{2} - 19.5''$

$= 9.25 - 8/12 - \dfrac{19.5}{12}$

$= 9.25 - 0.667' - 1.625'$

$= \boxed{6.958'}$



$d = V_u / \phi 2 \sqrt{f_c'}\, b_w = \dfrac{164576}{0.75 \times 2 \times \sqrt{3000} \times (18.5' \times 12)}$

$d = 9.01'' < 19.5$ (OK)

Use $h = 24''$ in total depth

Moment :

$M_u = 8.58 \times 18.5 \times 1.28 \times 8.58/2$

$M_u = \boxed{871\ ft\text{-}k}$

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

Use Appendix "A", table A.12 $\quad \dfrac{M_u}{\phi b d^2} = 139.9 \quad \rho = 0.0024$

$< \rho_{min}$ for flexure

Developement length

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

ψ_t = Reinforcement location factor

ψ_e = Coating factor

ψ_s = Reinforcement size factor

λ = Concrete modification factor

$$\frac{l_d}{d_b} = \frac{3}{40} \frac{f_y}{\lambda\sqrt{f_c'}} \frac{\psi_t \psi_c \psi_s}{C_b/d_b}$$

if $C_b/d_b > 2.5$ then Use 2.5

C_b = Side Cover = 3.5"

d_b = diameter of bar $= 8/8 = 1"$

$C_d/d_b = 3.5/1 = 3.5" > 2.5"$ So Use $\boxed{2.5"}$

Using equation (1)

$$l_b/d_b = 3/40 \times \frac{60000}{1\sqrt{3000}} \times \frac{1\times1\times1}{2.5} = 32.86$$

$$l_b/d_b \frac{A_s(req)}{A_s(selected)} = 32.86 \times \frac{11.81}{12.5} = 31.04$$

$$l_b = 31.04 \times d_b = 31.04 \times 1 \Rightarrow \boxed{l_b = 31"}$$

(OK)