Advanced Design Of Reinforced Concrete Structure Design

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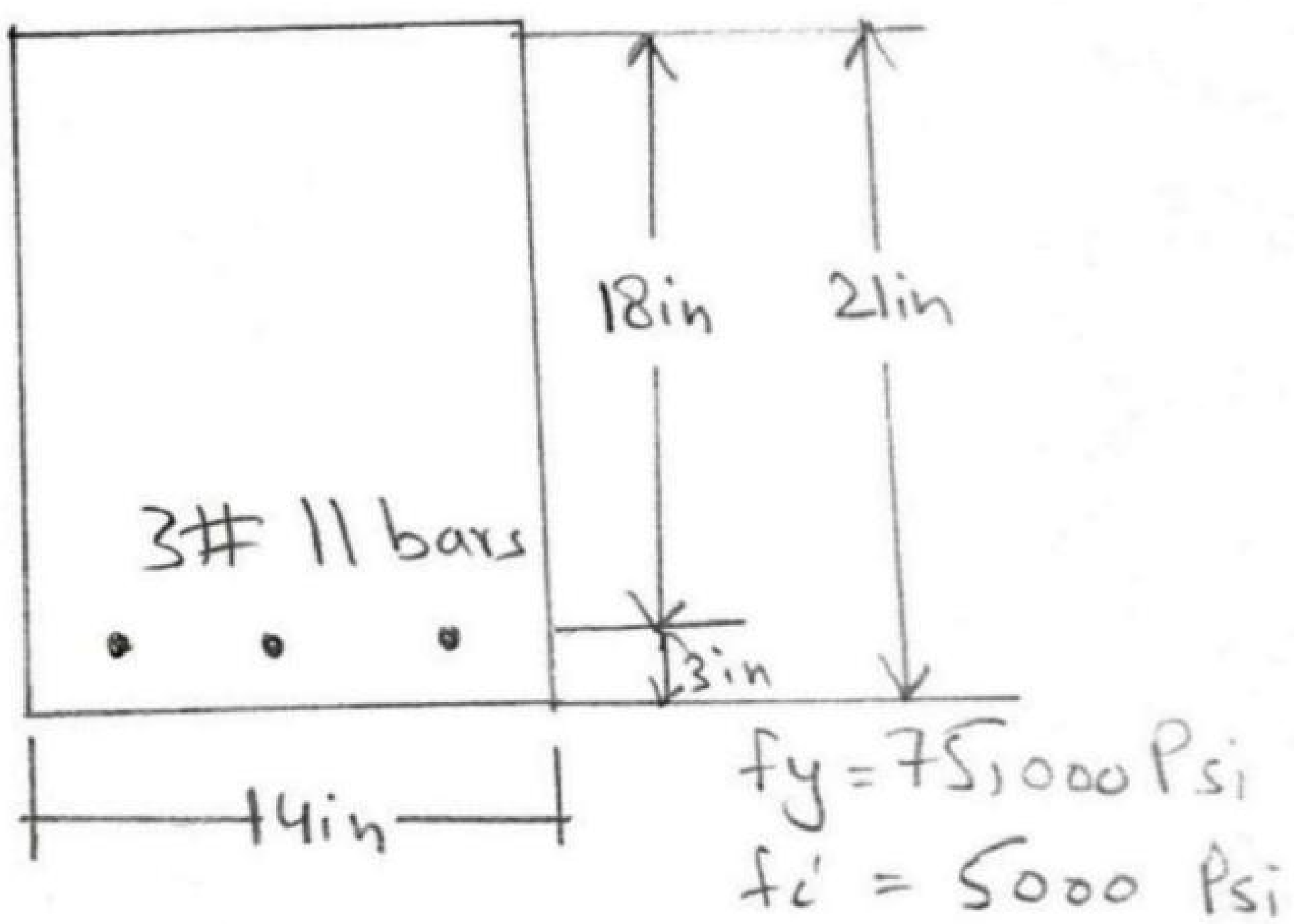
Semester : 4th (Mid Term)

QNo.1 :

Determine the value of ε_t, ϕ & ϕM_n for the section show below

(A)



Sol:-

$$a = \frac{A_s f_y}{0.85 f_c' b} \longrightarrow \text{(A)}$$

(A_s) is taken from table (4.68) put in eq. (A)

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

$$\boxed{a = 5.899}$$

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$c = ?$

$c = a/\beta_1 \rightarrow$ (B)

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

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

$\Rightarrow$ 1) $\epsilon_t = ?$

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

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

$$\boxed{\epsilon_t = 0.00478}$$

$$\epsilon_t > 0.004$$

$$\epsilon_t < 0.005$$

Hence beam is in transition zone.

$\Rightarrow$ 2) $\phi = ?$

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

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

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

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⇒ 3) $\phi M_n = ?$

$$M_n = A_s f_y \left(d - \frac{a}{2}\right)$$

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

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

Convert from in-k to ft-k

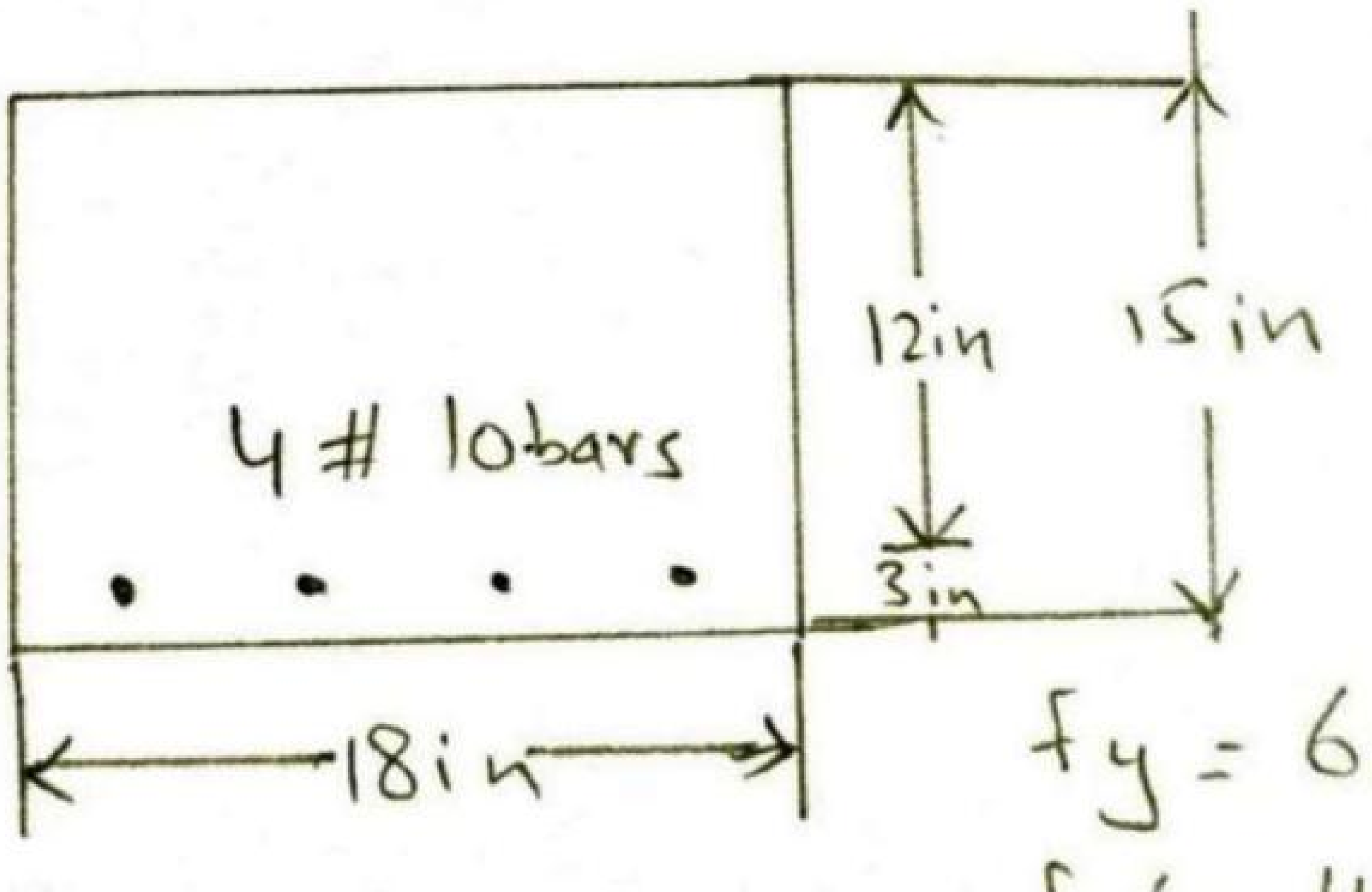
$$M_n = 5282.72\ \cancel{\text{in}}\ \text{k} \times \frac{1 \text{ ft}}{12\ \cancel{\text{in}}}$$

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

Now,

$$\phi M_n = 0.881\,(440.227)$$

$$\boxed{\phi M_n = 387.89 \text{ ft-k}}$$



$f_y = 60{,}000$ psi

$f_c' = 4000$ psi

Sol:-

$\epsilon_t = ?$

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{5.06 \times 60}{0.85 \times 4 \times 18}$$

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

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$c = a/\beta_1 = \frac{4.96}{0.85}$

$\boxed{c = 5.835 \text{ in}}$

Now,

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

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

$\boxed{\epsilon_t = 0.00316}$

$\epsilon_t = 0.00316 < 0.004$

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

$\Rightarrow$ 2) $\phi = ?$

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

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

$\boxed{\phi = 0.746}$

3) $\phi M_n = ?$

$M_n = A_s f_y (d - a/2) = 5.06 \times 60 \left(12 - \frac{4.96}{2}\right)$

$M_n = \frac{2890.27 \text{ in-k}}{12} \boxed{= 120.428 \text{ ft}\cdot\text{k}}$

Now,

$\phi M_n = 0.746 \times 120.428$

$\boxed{\phi M_n = 89.11 \text{ ft}\cdot\text{k}}$

Hence Proved

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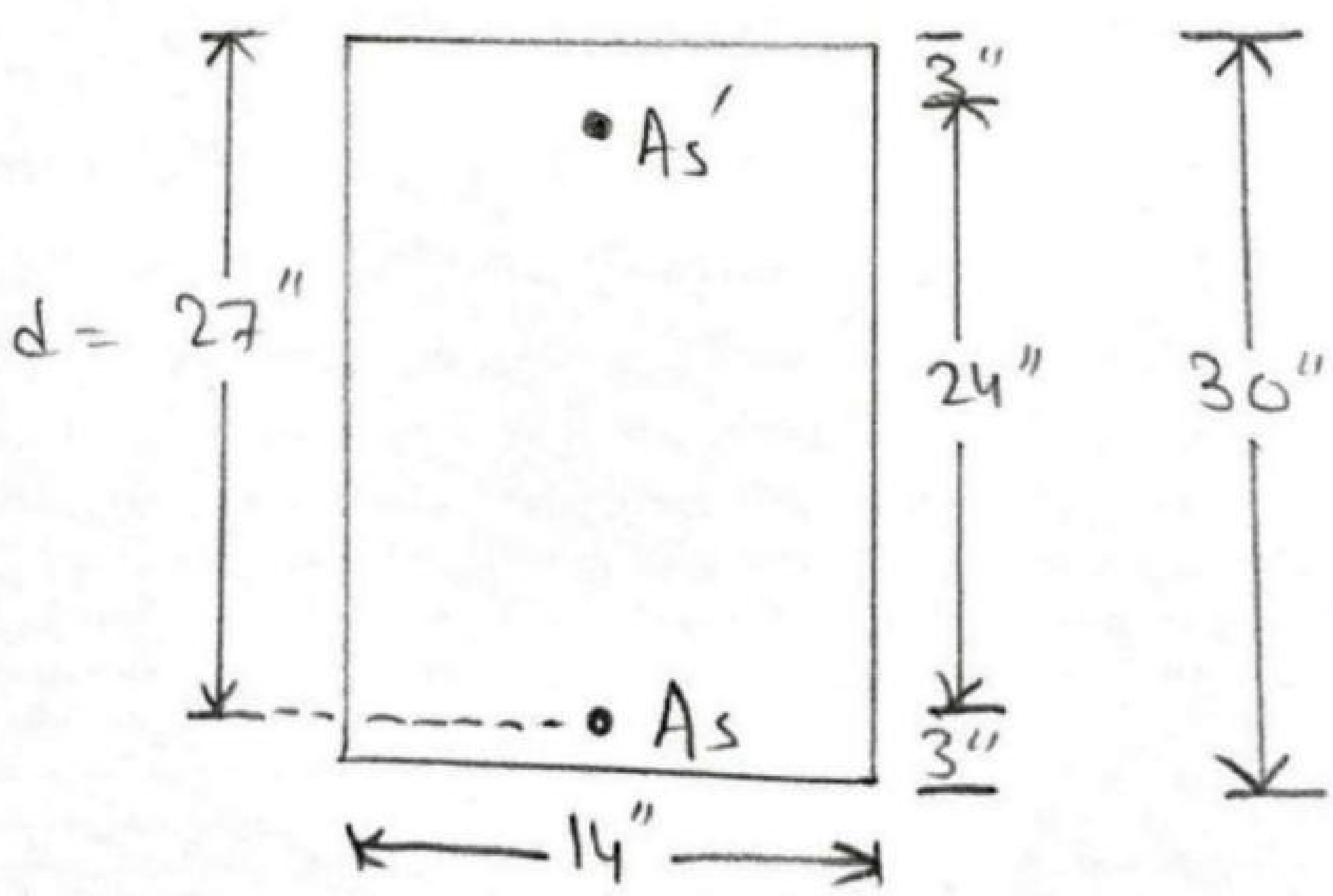
QNo. 1 (B)

Design a doubly reinforced beam for M_D = [first three digits of R] 153 ft·k & M_L = 410 ft-k, if $f_c' = 4000$ Psi & f_y = 60000 Psi. Appropiate diagram is must in design. ⑤

Assume the max. permissible beam diamensian other then done in notes.

<u>Given data</u>

$M_D = 153$ ft-k
$M_L = 410$ ft-k
$f_c' = 4000$ Psi
$f_y = 60{,}000$ Psi



Sol:-

1) Factored Moment

$$M_U = 1.2 M_D + 1.6 M_L$$
$$= 1.2(153) + 1.6(410)$$
$$= 839.6 \approx 840 \text{ ft·k}$$

$$\boxed{M_U = 840 \text{ ft·k}}$$

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2) Nominal Moment $(M_n) = ?$

$$M_n = M_u / \phi$$

$$= 840/0.90 \qquad \phi = 0.90$$

$$= 933.33 \text{ ft·k}$$

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

ρ_{max} (from Appendix A. table A.7)
$\underline{(0.0181)}$

$$A_{s1} = \rho_{max}\, b\, d$$

$$= 0.0181 \times 14 \times 27$$

$$\boxed{A_{s1} = 6.842 \text{ in}^2}$$

for

$$\rho_{max} = 0.0181, \quad \frac{M_u}{\phi b d^2} \boxed{= 912 \text{ psi}}$$

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

$$M_{u1} = \frac{837084.8 \text{ in-lb}}{12}$$

$$= \frac{698090 \text{ ft·lb}}{1000}$$

$$\boxed{M_{u1} = 698 \text{ ft·k}}$$

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$$M_{n1} = M_{u1}/\phi = 698/0.9$$

$$\boxed{M_{n1} = 775.55 \text{ ft·k}}$$

$$M_{n2} = M_n - M_{n1} = 933.33 - 698$$

$$\boxed{M_{n2} = 235.33 \text{ ft-k}}$$

3) Theoretical As' required:

$$A_s' = \frac{M_{n2}}{f_y(d-d')} = \frac{235.33 \times 12}{60(27-3)}$$

$$= 1.96 \approx 2 \text{ in}^2$$

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

Try 2 # 9 bars (2.000 in^2)

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

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

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

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

$$= 6.842 + 2$$

$$\boxed{A_s = 8.842 \text{ in}^2}$$

Try 8 # 10 bars (10.12 in^2)

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Note :

The actual value of As' is exactly the same as the theoretical value. The actual value of As however is higher than the theoretical value by 10.12 − 9.6 = 0.52 in² if new bar selection for As' is made where by the actual value of As' ~~exceeds~~ exceeds the theoretical value by about this much (0.52 in²) the design will be adequate.

Select 3 # 8 bars ($A_s' = 2.36 \text{ in}^2$) & repeat the previous steps.

Assuming $f_s' = f_y$

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

$$\boxed{C = 11.5 \text{ in}}$$

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

$$\varepsilon_s' = 0.00217 > \epsilon_y$$

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

$$= 0.00404 < 0.005$$

$$\phi \neq 0.90$$

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

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

$$\boxed{\phi = 0.82}$$

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

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

$$A_{s1} = A_s - A_{s2} = 10.12 - 2.36$$

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

$$M_{n1} = A_{s1} f_y \left(d - \frac{a}{2}\right) = 7.76 \times 60 \left(27 - \frac{0.85 \times 10.74}{2}\right)$$

$$= \frac{10912.5 \text{ in-k}}{12}$$

$$\boxed{M_{n1} = 909.29 \text{ ft}\cdot\text{k}}$$

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

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

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

$$\boxed{M_{n2} = 283 \text{ ft-k}}$$

$$M_n = M_{n1} + M_{n2} = 909 + 283$$

$$\boxed{M_n = 1192 \text{ ft}\cdot\text{k}}$$

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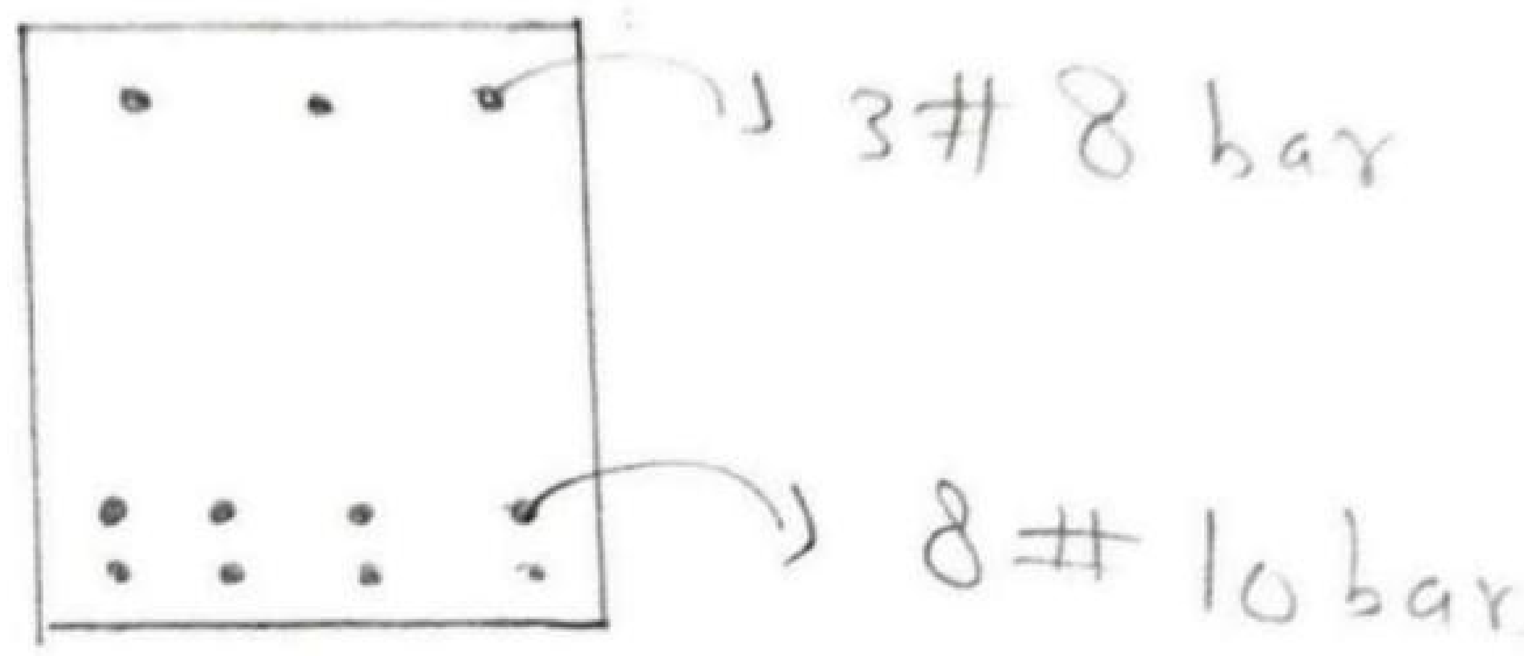
$\phi M_n = 0.82 \times 1192$

$= 977 \text{ ft.k} > M_u$

ok

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

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



QNo.2

Design a short square column for the following Conditions $P = 153$ k, $M_u = 15$ ft-k $f_c' = 4000$ psi, $f_y = 60,000$ psi. Place the bars uniformly around all four faces of column. Appropiate diagrame must in design.

Sol:- Assume the column will have Average Compression stress = about $0.6 f_c' = 2400$ psi

$= 2.4$ ksi

$A_g = \dfrac{153\text{k}}{2.4 \text{ ksi}} = \dfrac{P_u}{0.6 f_c'}$

$\boxed{A_g = 63.75 \text{ in}^2}$ $\quad P_u =$ Avg. Compression stress

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Try 8in x 8in Column ($A_g = 64 \text{ in}^2$)
with the bar arrangement

$$e = M_u / P_u$$

$$= \frac{15 \cancel{ft} \times 12 \text{ in}/\cancel{ft}}{153 \text{ k}}$$

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

$$P_n = P_u / \phi = 153 \text{ k} / 0.65$$

$$\boxed{P_n = 235.38 \text{ k}}$$

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

$$\boxed{K_n = 0.919}$$

$$R_n = \frac{P_n e}{f'c \cdot A_g \cdot h} = \frac{(235.38 \text{k})(1.17 \text{ in})}{4 \text{ksi } (8'' \times 8'')(8'')}$$

$$\boxed{R_n = 0.1344}$$

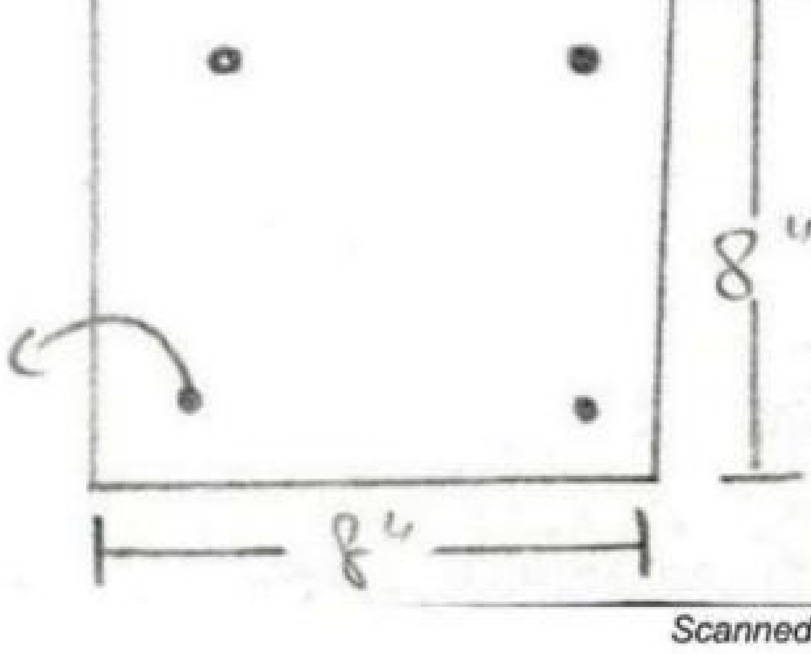
$$\gamma = 3''/8 \Rightarrow \boxed{\gamma = 0.375}$$

So,

$$A_s = 0.0123 \times (8'' \times 8'')$$
$$= 0.78 \text{ in}^2$$

Use 4 # 4 bars $= 0.78 \text{ in}^2$

4#4 bars
(0.78in^2)



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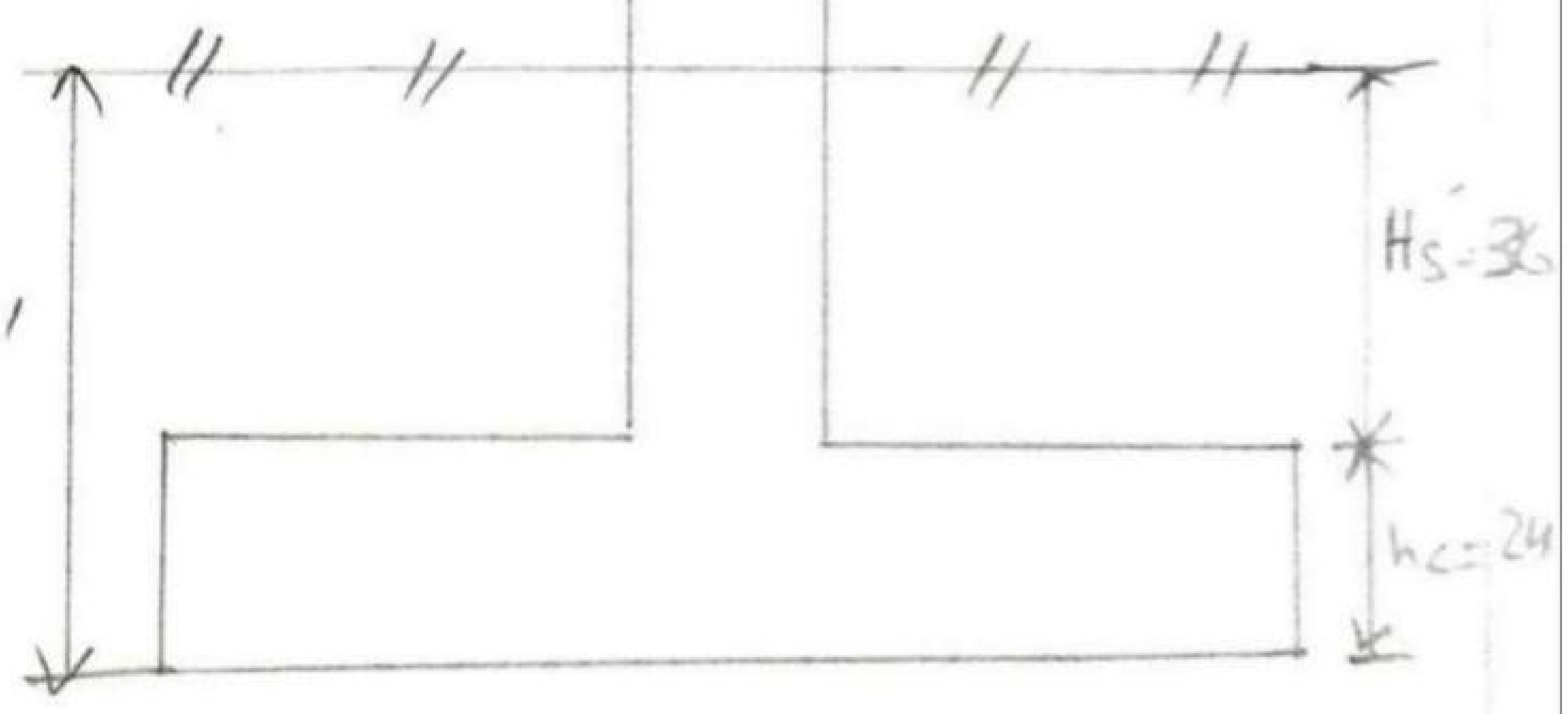
Q No. 3

Design a square column footing for a 16in square tied interior column, the supports are deed load P_D = (first three digits of R) = 153k & live load of $P_L = 160k$, The column is reinforced with #8 bars, the base of footing is 5 feet below, the soil weight is 100 lb/ft³. $f_y = 60{,}000$ Psi, & $f_c' = 3000$ Psi & q_a = first four digits of R) = 1534 Psf

=) Development of length for main bars & also to be design in footing.

Appropiate diagrame is must in design.

Given data



$P_D = 153k$

$P_L = 160k$

unit weigh of soil $\gamma_s = 100 lb/ft^3$

$f_y = 60{,}000$ Psi

$f_c' = 3000$ Psi

$q_a = 1534$ Psi

Assumed data

unit weight for Concrete = $\gamma_c = 150 lb/ft^3$

$h_c = 24''$

$d = 19.5''$

$H_s' = 36''$

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Step # 01 effective soil pressure "q_e"

$$q_e = q_a - h_c \times \gamma_c - H_s' \times \gamma_s$$
$$= 1534 - \left(\frac{24}{12} \times 150\right) - \left(\frac{36}{12}\right) \times 100$$

$$q_e = \frac{934 \text{ Psf}}{1000}$$

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

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

$$q_u = \frac{1.2 P_D + 1.6 P_L}{342}$$

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

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

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 expressions

i) $d = \dfrac{V_{U2}}{\phi 4 \sqrt{f_c'}\, b_o}$

ii) $d = \dfrac{V_{U2}}{\phi \left(\dfrac{\alpha_s d}{b_o} + 2\right)\sqrt{f_c'}\, b_o}$

$\alpha_s = 40$ for column where Perimeter is four sided $\Rightarrow$ Square column

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

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

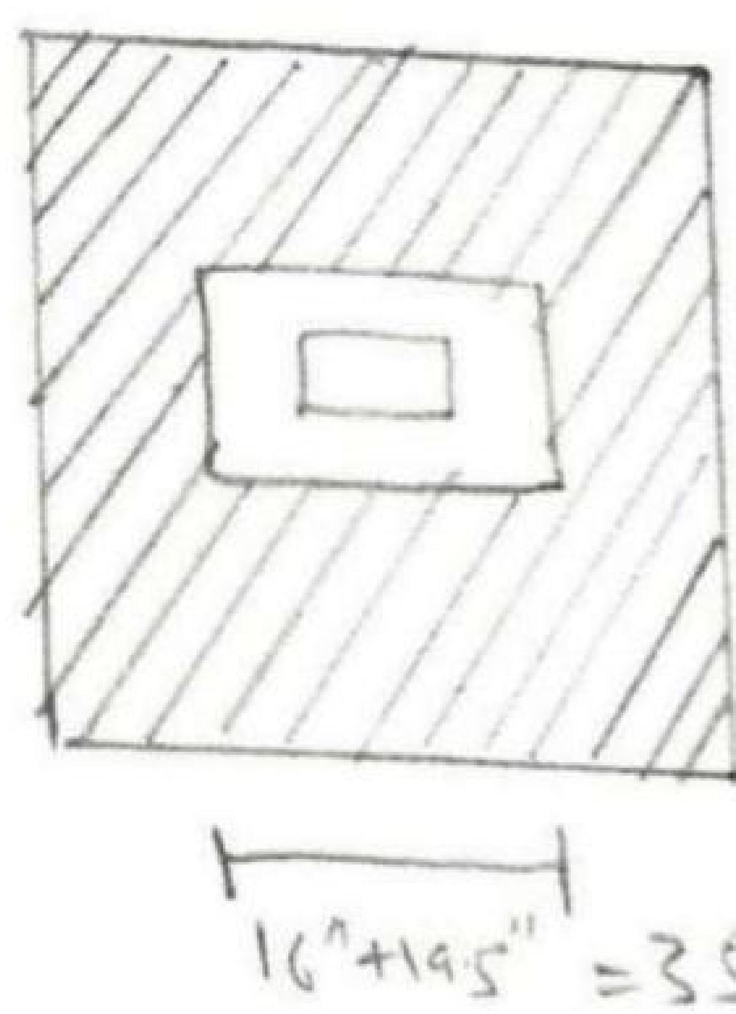
$\boxed{b_o = 142 \text{ in}}$

$V_{U2} = \{A - (a+d)\} \times q_u$

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

$V_{U2} = 933.973 \text{ k} \times 1000$

$\boxed{V_{U2} = 433973 \text{ lb}}$



Two way shear

① $d = \dfrac{V_{U2}}{\phi 4 \sqrt{f_c'}\, b_o} = \dfrac{433973}{0.75 \times 4\sqrt{3000} \times 142}$

$\boxed{d = 18.59'' < 19.5''}$ OK

② $d = \dfrac{V_{U2}}{\phi \left(\dfrac{\alpha_s d}{b_o} + 2\right)\sqrt{f_c'}\, b_o} = \dfrac{433973}{0.75 \left(\dfrac{40 \times 19.5}{142} + 2\right)\sqrt{3000} \times 142}$

$\boxed{d = 9.928'' < 19.5''}$ OK

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

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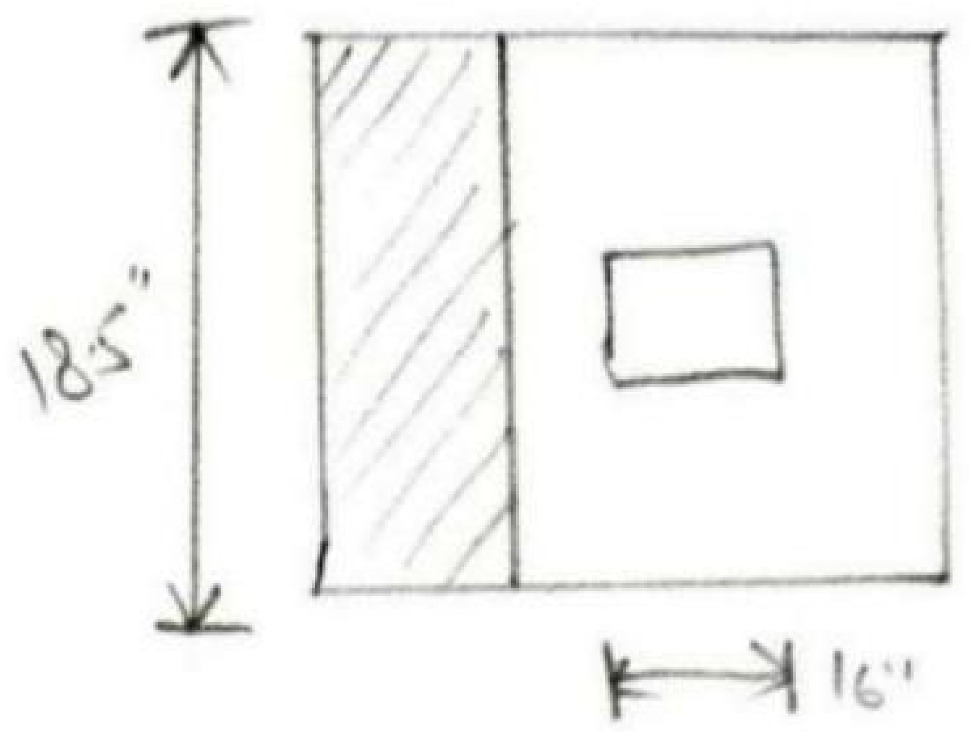
Step #05 Depth required for one way sheer

$$\frac{L}{2}-\frac{a}{2}=\frac{18.5}{2}-\frac{16}{2}/_{12}=8.58'$$

$$V_{u1}=(18.5\times 6.958)\times 1.28$$

$$V_{u1}=164.576k\times 1000$$

$$\boxed{V_{u1}=164576\,lb}$$



$d=19.5''$

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

$$=\frac{164576}{0.75\times 2\sqrt{3000}\times(18.5\times 12)}$$

$$\boxed{d=9.01''<19.5''\ \text{ok}}$$

use $h=24''$ in total depth

$$=\frac{l}{2}-\frac{a}{2}-d$$

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

$$=9.25-\frac{8}{12}-\frac{19.5}{12}$$

$$=9.25'-0.667'-1.625'$$

$$\boxed{=6.958'}$$

Moment:

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

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

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

$$M_u\ \boxed{=137.5\,psi}$$

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Then use of greater of

① $\frac{153}{60,000} = 0.00255$

② $\frac{3\sqrt{3000}}{60,000} = 0.00273$ $\boxed{\text{So, } \rho = 0.00273}$

Area of steel :-

$A_s = \rho b d = 0.00273 \times (18.5 \times 12)(19.5)$

$A_s = 11.81 \text{ in}^2$

Use table A4

8 #11 bars in both directions

$A_{s(\text{selected})} = 12.5 \text{ in}^2$

Development 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

$$\frac{l_d}{d_b} = \frac{3}{40} \times \frac{f_y}{\lambda\sqrt{f_c'}} \times \frac{\Psi_t \Psi_e \Psi_s}{C_b/d_b}$$

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

C_b = Side Cover $= 3.5''$

d_b = dia of bar $= \frac{8}{8} = 1''$

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$$\frac{C_d}{d_b} = \frac{3.5}{1} = 3.5 > 2.5 \text{ so use } 2.5$$

using eq 1

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

$$\boxed{\frac{l_b}{d_b} = 32.86}$$

$$\frac{l_b}{d_b} = \frac{A_{s(req)}}{A_{s(selected)}} = 32.86 \times \frac{11.81}{12.5}$$

$$\boxed{\frac{l_b}{d_b} = \cancel{87.64}\ 31.04}$$

$$l_b = 32.30 \times d_b = 31.04 \times 1$$

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

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