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Subject PRCD I

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Assignment # 1

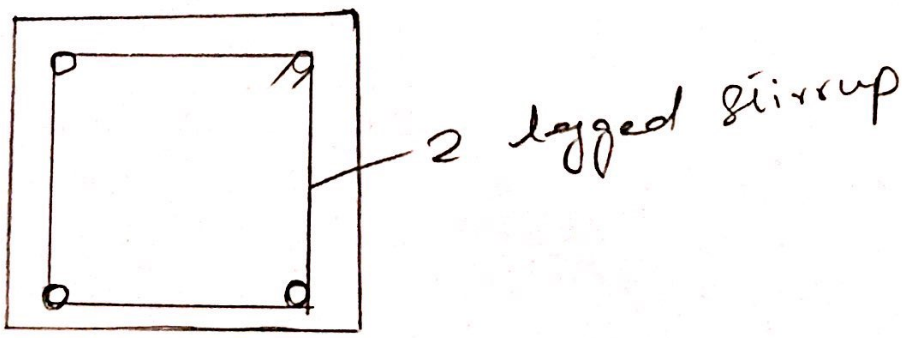
Q1

Stirrup:- Stirrups are closed-loop bars tied at regular intervals in beam reinforcement to hold the bars in position.

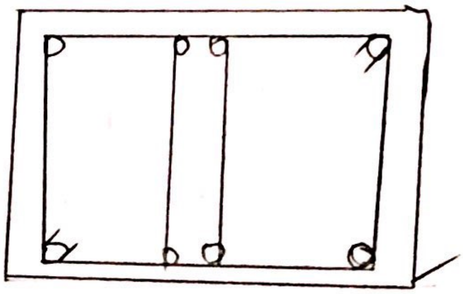
Types of stirrups:-

1) Single legged stirrup:- The single leg stirrups have rarely been used because they are mostly used when binding only two rolls.

2) Two legged stirrup:- It is commonly and widely used stirrup. Minimum 4 bars are required for providing the stirrup.



3) Four legged stirrup:- These stirrups are used in case of web reinforcement.



4 legged Stirrup

ACI Codes for shear design of a beam:-

According to ACI-38 following are the formulas used for shear design of a beam

1) Critical Section:-
Critical section occurs at 45° and is distance (d)" from the face of support which is equal to effective path.

2) Shear strength capacity of concrete is

$$V_c = 2 \times \sqrt{F'c} \times b_w \times d$$

3) Minimum web reinforcement:-

If $V_u \leq \phi V_c$

$\phi = 0.75 \rightarrow$ for shear design

(∵ V_u = Total factored shear applied at a given section)

For Minimum Reinforcement Area:-

$$A_{v\,min} = 0.75 \times \frac{\sqrt{F'c} \times b_w \times s}{f_y}$$

we can get formula for spacing by interchanging the above

$$S_{max} = \frac{A_u \times f_y}{0.75 \times \sqrt{f_c'} \times b_w}$$

4) No web reinforcement is required if

$$V_u < \frac{1}{2} \phi V_c$$

$$S = \frac{\phi \times A_u \times f_y \times d}{V_u - \phi V_c}$$

5) If $V_s \leq 4 \times \sqrt{f_c'} \times b_w \times d$ then

1 — 24"

2 — d/2

3 — $S_{max} = \frac{A_u \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$

4 — $S_{max} = \frac{A_u \times f_y}{50 \times b_w}$

If $V_s > 4 \times \sqrt{f_c'} \times b_w \times d$

↓

Max spacing will be halved

=> If $V_s > 8 \times \sqrt{f_c'} \times b_w \times d$

↓

Then either increase cross-sectional dimensions or increase f_c'

Q No 2

Given

$b_w = 14"$

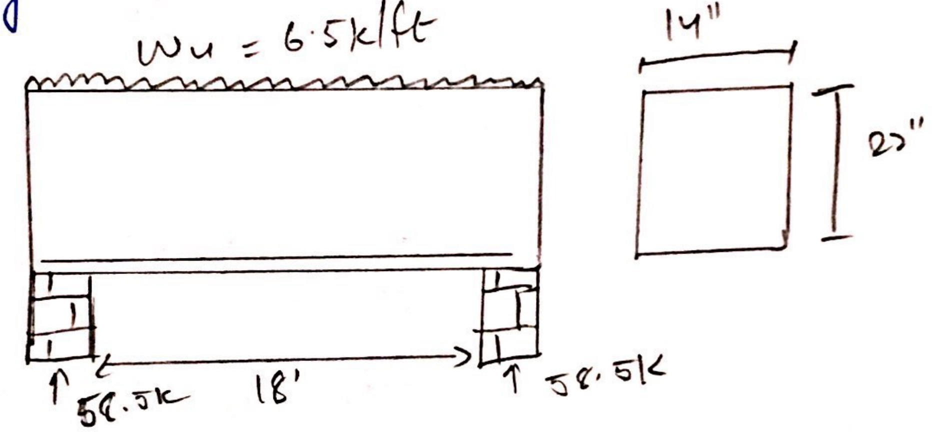
Effective depth $= d = 22"$

Load $= 6.5\ k/ft$

Steel Area $= 7\ in^2$

$f'_c = 4\ ksi$

$f_y = 60\ ksi$



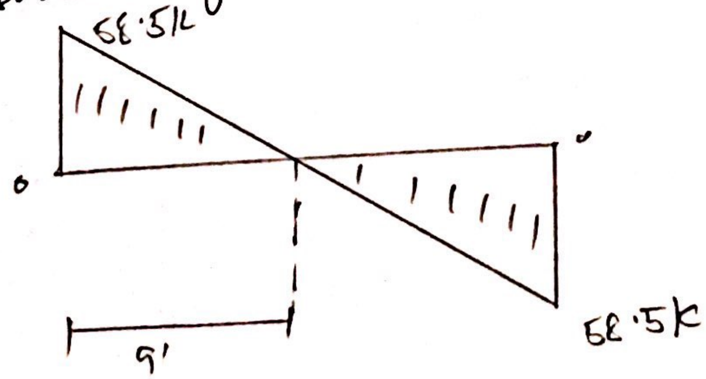
Step 1)

Reactions on supports

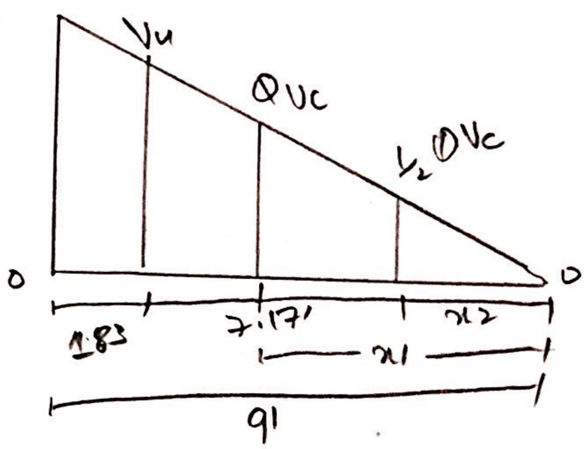
$$\text{Total load} = \frac{6.5 \times 18}{2} = 58.5\ kips$$

Step 2

Shear force diagram



Step 3:-
Finding the critical value of "Vu" and its location
By using similar triangles



From similar triangles

$$\frac{58.5}{9} = \frac{V_u}{8.17}$$

$$V_u = \frac{58.5 \times 7.17}{9}$$

$$\boxed{V_u = 46.61 \text{ kips}}$$

Step 4:-
By formula

$\Rightarrow \phi V_c = \phi \times 2 \times \sqrt{f'_c} \times b_w \times d$

$= 0.75 \times 2 \times \sqrt{4000} \times 14 \times 22 = 29219 \text{ lbs}$
$= 29.21 \text{ kips}$

$\Rightarrow$ location of ϕV_c by similar triangles

$$\frac{58.5}{9} = \frac{\phi V_c}{x_1} \Rightarrow \frac{58.5}{9} = \frac{29.21}{x_1}$$

$\Rightarrow x_1 = 4.49'$

$\Rightarrow$ similarly,

$\frac{1}{2}\phi V_c = \phi V_c/2 \Rightarrow 29.21/2 = 14.60 \text{ kips}$

$\Rightarrow$ location of $\frac{1}{2}\phi V_c$ will be

$$\frac{58.5}{9} = \frac{14.60}{x_2} \Rightarrow \boxed{x_2 = 2.24'}$$

Step (5)

Finding values of ϕV_s

$$V_u = \phi V_s + \phi V_c$$

$$\Rightarrow \phi V_s = V_u - \phi V_c$$

$$= 46.61 - 29.21$$

$$\boxed{\phi V_s = 17.4 \text{ kips}}$$

Step (6)

section adequacy :-

formula

$$= \phi \times 8 \times \sqrt{f'c} \times b_w \times d$$

$$= 0.75 \times 8 \times \sqrt{4000} \times 14 \times 22 = 116877 \text{ lbs}$$

$$= 116.87 \text{ kips}$$

As $\phi \times 8 \times \sqrt{f'c} \times b_w \times d > \phi V_s$

section is adequate!

Step (7)

Max spacing for stirrups

formula

$$\phi \times 4 \times \sqrt{f'c} \times b_w \times d$$

$$0.75 \times 4 \times \sqrt{4000} \times 14 \times 22 = 58438 \text{ lbs}$$

$$= 58.43 \text{ kips}$$

As $\phi \times 4 \times \sqrt{f'c} \times b_w \times d > \phi V_s$

Max will be selected from the following conditions

1- $S_{max} = 24''$

2 - $d/2$ $22/2 = 11''$

3 - $S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$

3 - $S_{max} = \frac{0.22 \times 60000}{0.75 \times \sqrt{4000} \times 14} \times 19.87''$

4 - $S_{max} = \frac{A_v \times f_y}{50 \times b_w} = \frac{0.22 \times 60000}{50 \times 14} \doteq 18.85''$

from above least value of spacing for #3 2 legged stirrup will be selected

$S_{max} = 11''$

Step (8)

By formula

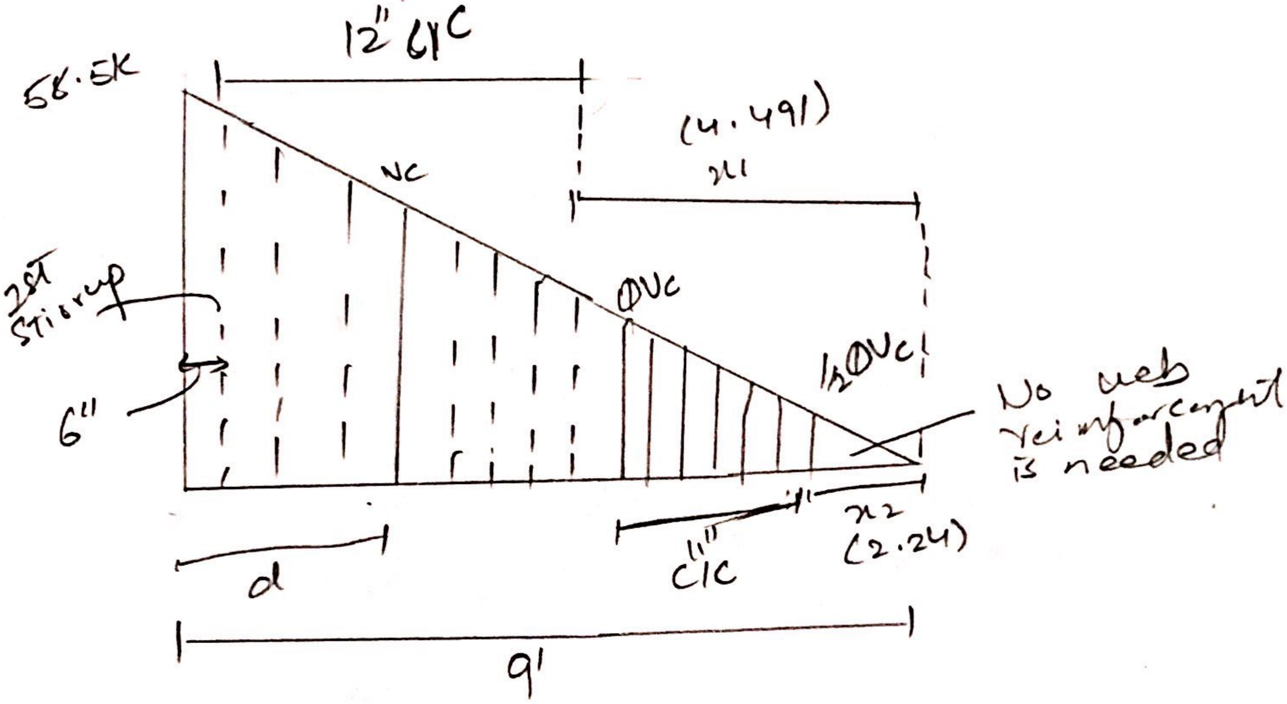
$S = \frac{\phi \times A_v \times f_y \times d}{V_u - \phi V_c} = \frac{0.75 \times 0.22 \times 60 \times 22}{46.61 - 29.21}$

$S = 12.5'' \nless 12''$

So $12''$ c/c

Step 9

Final sketch will be



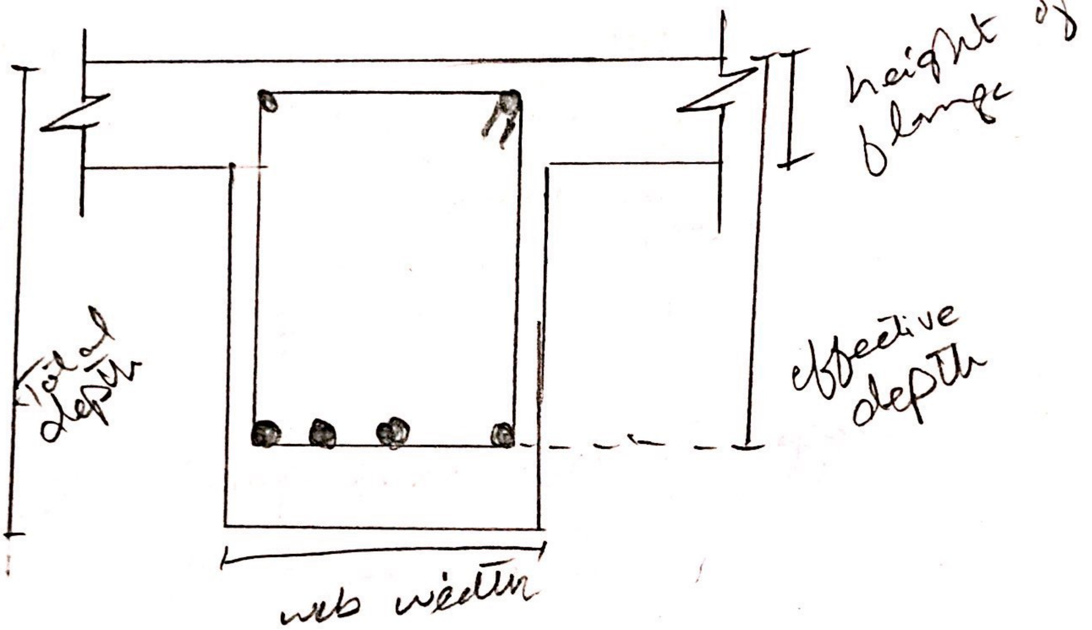
As First stirrup from face of support

$S/2 = 12/2 = 6"$

Q No 3)

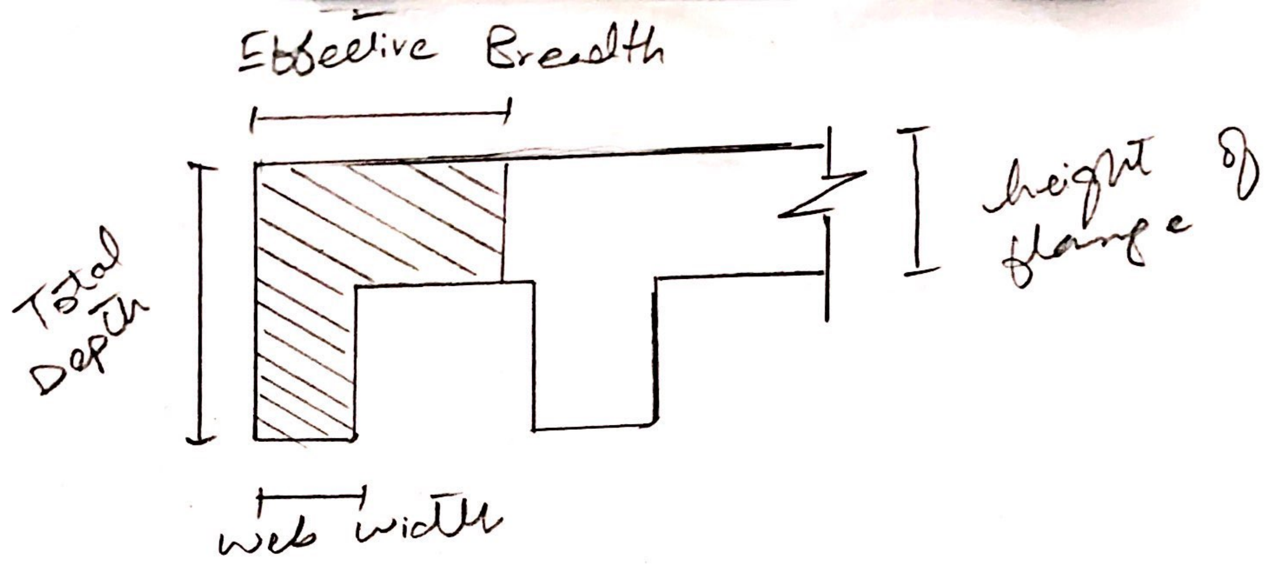
T- Beam:-

In most of the reinforced concrete structures, concrete slabs are cast monolithically with the slab so, in this case the beam that act as an intermediate beam are called T beam.



L - Beam:-

⇒ L. Shaped structure that is in contact with the slab and present at the corner of the floor is called L-Beam.



Flexural Analysis of T-Beam :-

1) For Ultimate factored moment we use

$$M_u = \frac{w_u \times l^2}{8}$$

2) Effective depth

1 — $16(h_f) + b_w$

2 — c/c distance

3 — Span/4

4 — $\frac{CTS}{2} + b_w$

3) Checking whether Rectangular or T-beam analysis is required

i — If $a > h_f$ → Special analysis is req

ii — If $a < h_f$ → Rectangular beam Analysis is required

Scanned with CamScanner

where

a = depth of compression block

hf = Height of flange

4) For finding Area of steel, we have to use:-

$$Ast = \frac{Mu}{\phi \times fy' \times (d - a/2)}$$

where

$$a = \frac{Ast \times fy}{0.85 \times fc' \times bw}$$

5) Checking the reinforcement Ratio

$$\rho_{max} = 0.85 \times B \times \frac{fc'}{fy} \times \left(\frac{\varepsilon u}{\varepsilon u + \varepsilon y}\right)$$

$$\rho_{min} = \frac{200}{fy}$$

$$\rho = \frac{Ast}{b \times d}$$

6) For finding No of bars required

$$\text{No of bars} = \frac{\text{Area of steel}}{\text{Area of bar}}$$

7) Checking min width for bar accomodation:-

b_{min} = 2(cc) + 2(dia of Stirrup) + No of bars (dia of bars) + Spacing b/w bars (dia of bar)

8) Design moment is given by

$Md = \phi \times f_y \times A_{st} \times (d - a/2) \rightarrow$ if $a < h_f$

$Md = \phi \times [A_s + f_y \times (d - h_f/2) + (A_s - A_{st}) + f_y \times (d - a/2)] \rightarrow$ if $a > h_f$

Q no 4)

Case I:-

From the figure $a < h_f$ so in this case, rectangular Beam analysis is required so,

The design Moment formula will be

$Md = \phi \times f_y \times A_{st} \times (d - a/2)$

Case II:-

from the fig

$a > h_f$

so special beam analysis i-e T beam analysis is required

so the required Design Moment will be

$Md = \phi \times [A_s \times f_y \times (d - \frac{h_f}{2}) + (A_s - A_{st}) + f_y \times (d - a/2)]$

QNO 5)

Given:-

height of flange (h_f) = 3.5"

c/c distance = 9'

length /span of the beam = 16'

web width (b_w) = 10"

Effective width (b_w) = 10"

" depth (d) = 18"

h = 23"

M_u = 5800 kip - inch

f_c' = 3ksi

f_y = 60 ksi

Solution:-

Step 1:-

Calculate effective width for T beam

1 - $16(h_f) + b_w = 16(3.5) + 10 = 66"$

2 - c/c distance $= 9 \times 12 = 108"$

3 - Span/4 $= \frac{16}{4} \times 12 = 48"$

Selecting least value

$b_e = 48"$

step 2)

Check if Rectangular or T-beam Analysis is required

Trial # 01 :-

Let $a = h_f = 3.5''$

$$A_{st} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{5800}{0.90 \times 60 \times (18 - \frac{3.5}{2})}$$

$$= 6.61 \text{ in}^2$$

Trial # 02 :-

$$a = \frac{A_{st} \times f_y}{0.85 \times f_c' \times b_e}$$

$$a = \frac{6.61 \times 60}{0.85 \times 3 \times 48} = 3.2''$$

and $A_{st} = 6.55 \text{ in}^2$ => $3.2'' < 3.5''$

Rectangular Beam design is required

Trial 3 :- $a = 3.21''$

and $$A_{st} = \frac{5800}{0.90 \times 60 \left(18 - \frac{3.21}{2}\right)} = 6.55 \text{ in}^2$$

So Area of steel is 6.55 in^2

step 3)

check ρ_{max} and ρ_{min}

$\Rightarrow$ $\rho_{max} = 0.85 \times \beta \times \frac{fc'}{fy} \left(\frac{\varepsilon_u}{\varepsilon_u + \varepsilon_t}\right)$

$= 0.85 \times 0.85 \times \frac{3}{60} \left(\frac{0.003}{0.003 + 0.005}\right)$

$= 0.013$

$\Rightarrow$ $\rho_{min} = \frac{200}{fy} = \frac{200}{60000} = 0.003$

$\Rightarrow$ $\rho = \frac{Ast}{b \times d} = \frac{6.55}{10 \times 18} = 0.036$

$\rho_{min} < \rho < \rho_{max}$

$0.003 < 0.036 < 0.013$

means "doubly Reinforcement Beam"

Find Area of steel against ρ_{max}

$\rho_{max} = \frac{Ast}{b \times d} \Rightarrow Ast = \rho_{max} \times (b \times d)$

$Ast = 0.013 \times (10 \times 18)$

$Ast = 2.34 in^2$

step 4)

Finding value of Mu_2 :-

By formulla

$Mu_2 = \phi \times Ast \times fy \times (d - a/2)$

Find value of "a"

$\Rightarrow \quad a = \dfrac{Ast \times fy}{0.85 \times fcb} = \dfrac{2.43 \times 60}{0.85 \times 5 \times 10}$

$a = 5.72''$

$\Rightarrow \quad Mu_2 = 0.90 \times 2.43 \times 60 \times \left(18 - \dfrac{5.72}{2}\right)$

$Mu_2 = 1986.67$ kip-inch

As $Mu_2 < Mu$

$1986.67 < 5800$

So we have to design the beam in such a way that it resist more bending moment than the applied external moment.

Step 5)

$Mu_1 = Mu - Mu_2$

$= 5800 - 1986.67$

$Mu_1 = 3813.33$ kip-inch

By formula

$Ast = \dfrac{Mu}{\phi \times fy \times (d - d')} = \dfrac{3813.33}{0.90 \times 60 \times (18 - 2.5)}$

$Ast' = 4.56 \, in^2$

Step 6)

$As = Ast + Ast'$

$= 2.43 + 4.56$

$= 6.99 \, in^2$

Step 7)

Selection of bar:-

In Tension zone.-

Use #8 bar

dia $= 8/8 = 1"$, Area $= \frac{\pi}{4}(1)^2 = 0.785 \text{ in}^2$

By formula

No of bars $= \frac{\text{Area of steel}}{\text{Area of single bar}}$

$= \frac{6.99}{0.785} = 8.959$

So 9 #8 bar

In Compression zone :-

Use #7 bar

dia $= (7/8)"$, Area $= \frac{\pi}{4}(7/8)^2 = 0.601 \text{ in}^2$

By formula

No of bar $= \frac{\text{Area of steel}}{\text{Area of single bar}} = \frac{4.56}{0.601} = 7.5 \cong 8$

So 8 #7 bars

Step #8

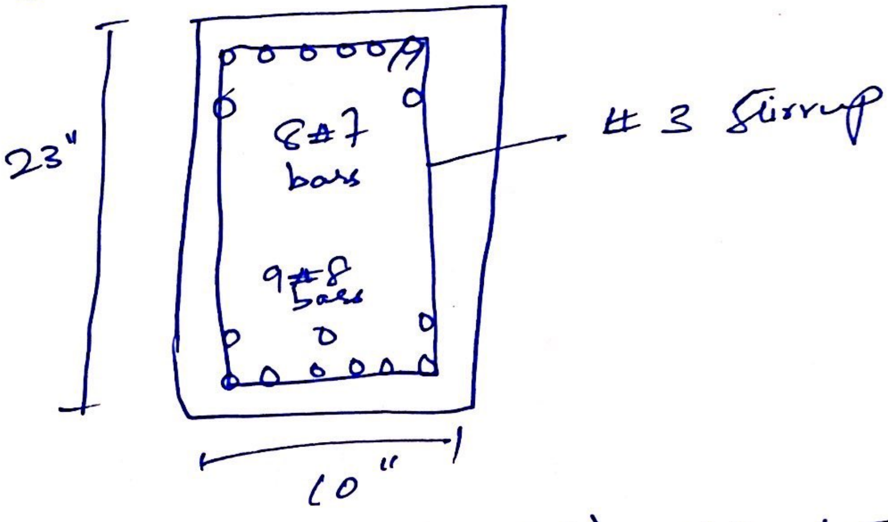
Minimum width for accomodation of bars

$b_{min} = (2 \times 1.5) + (2 \times \frac{3}{8}) + 9(8/8) + 8(8/8)$

$= 20.75"$

As $20.75'' > 10''$

So that bars will be placed in multiple layers



Effective depth $(d) = 23 - 1.5 + \frac{3}{8} + \frac{8}{8} + \frac{1}{2}\left(\frac{8}{8}\right)$

$= 19.6''$

Effective cover $(d') = 1.5 + \frac{3}{8} + \frac{7}{8} + \frac{1}{2}\left(\frac{7}{8}\right) = 3.18''$

Step 9)

Finding the design Moment

$M_d = \phi\left[A_s' \times f_y \times (d-d') + (A_{st} - A_{st}') \times f_y \times (d - \frac{a}{2})\right]$

First $a = \frac{(A_s - A_{st}') \times f_y}{0.85 \times f_c' \times b} = \frac{(9 \times 0.785 - 8 \times 0.601) \times 60}{0.85 \times 3 \times 10}$

$= 5.31''$

$M_d = 0.90\left[(8 \times 0.601) \times 60 \times (19.6 - 3.18) + (9 \times 0.785 - 8 \times 0.601) \times 60 \times 19.6 - \frac{5.31}{2}\right]$

$M_d = 6328.38$

As $6328.38 > 5800 \rightarrow$ so design is ok

Q NO 6)

Given

$b = 14''$

$h = 26''$

$f_c' = 4\,ksi$

$f_y = 60\,ksi$

$M_u = 6000$ kipinches

$d = 22''$

Assume effective cover $(d') = 2.5''$

step # 1

$$\rho_{max} = 0.85 \times \beta \times \frac{f_c'}{f_y} \times \left(\frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y}\right)$$

$$= 0.85 \times 0.65 \times \frac{4}{60} \times \left(\frac{0.003}{0.003 + 0.005}\right)$$

$$\boxed{\rho_{max} = 0.0180}$$

step # 2

$$\rho_{max} = \frac{A_{st}}{bd} \Rightarrow A_{st} = \rho_{max} \times (b \times d)$$

$$\Rightarrow A_{st} = 0.0180 \times (14 \times 22) = \boxed{5.54\ in^2}$$

step # 3

$$M_{u_2} = \phi \times A_{st} \times f_y \times (d - a_{/2})$$

$$\rightarrow a = \frac{A_{st} \times f_y}{0.85 \times f_c b} = \frac{5.54 \times 60}{0.85 \times 4 \times 14}$$

$$= 6.98''$$

so,

$M_{u2} = 0.90 \times 5.54 \times 60 \times (22 - \frac{6.98}{2})$

$= 5537.4$ kip-inch

As

5537.4 < 6000

so "doubly reinforced section"

step # 4

$M_{u1} = M_u - M_{u2}$

$= 6000 - 5537.4$

$M_{u1} = 462.6$ kip inches

step # 5

$M_{u1} = \phi \times A'st \times f_y \times (d - d')$

$= A'st = \frac{M_{u1}}{\phi \times f_y \times (d - d')} = \frac{462.6}{0.90 \times 60 \times (22 - 2.5)}$

$\Rightarrow$ $\boxed{A'st = 0.44 in^2}$

step # 6

$A_s = Ast + A'st$

$= 5.54 + 0.44$

$= 5.9 in^2$

step # 7

1) ~~Steel~~ Steel in Tension zone :-

we use # 7 bar

dia = $(7/8)'' = 0.875''$

Area $= \frac{\pi}{4}(0.875)^2 = 0.601 \text{ in}^2$

so,

No of bars $= \frac{Ast}{\text{Area of single bar}}$

$= \frac{5.98}{0.601} = 9.9 \cong 10$ bars

So 10 # 7 bars

2) Steel in compression zone

we use # 5 bar

dia $= (5/8)'' = 0.625''$, Area $= \frac{\pi}{4}(0.625)^2$

$= 0.306 \text{ in}^2$

so,

No of bars $= \frac{Ast'}{\text{Area of single bar}}$

$= \frac{0.44}{0.306} =$ ~~[illegible]~~ $1.43 \cong 2$ bars

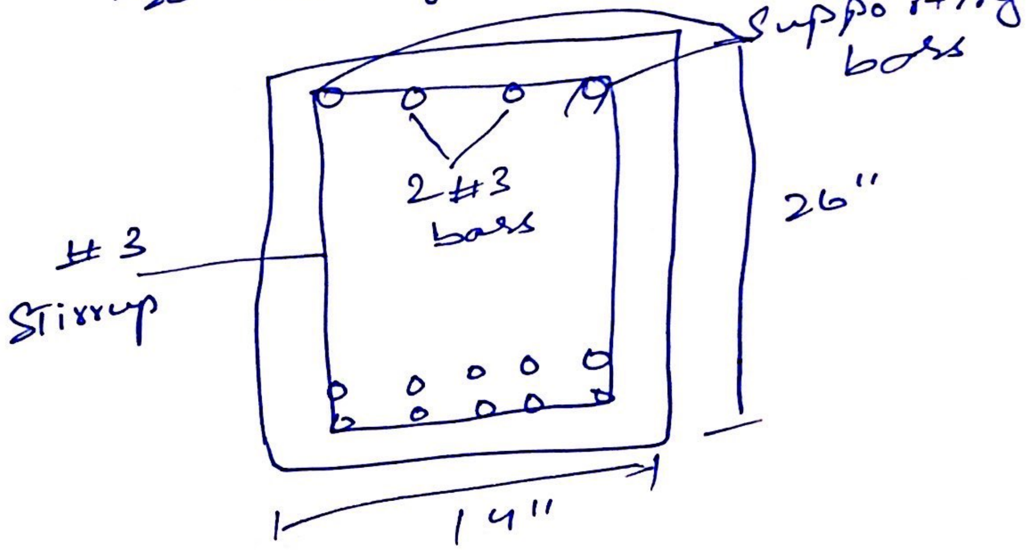
so 2 # 5 bar

Step # 8

$b_{min} = 2(1.5) + 2(3/8) + 10(7/8) + 9(7/8)$

$b_{min} = 20.37 > 14''$

so not good in one layer



Now

=> Effective depth (d) $= 26 - 1.5 - 3/8 - 7/8 - \frac{1}{2}(7/8)$

$= 22.82''$

=> Effective cover (d') $= 1.5 + 3/8 + \frac{1}{2}(5/8)$

$= 2.18''$

Step # 9

$Md = \phi \times [A's \times fy \times (d - d') + (Ast - A's) * fy \times (d - a/2)]$

$a = \frac{(Ast - A's) \times fy}{0.85 \times f'c \times b}$

$= \frac{(10 \times 0.601 - 2 \times 0.306) \times 60}{0.85 \times 4 \times 14}$

$= 6.80''$

$$Md = 0.90\left[(2 \times 0.306) \times 60 \times (22.82 - 2.18) + (10 \times 0.601 - 2 \times 0.306 \times 60 \times \left(22.82 - \frac{6.80}{2}\right)\right]$$

$$Md = 7047.6 \text{ Kip-inches}$$

As $7047.6 > 6000$

Design is OK!