Assignment

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Section : A

Semester : 6th

Subject : PRCD-I

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Question -1 :-

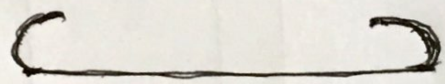
Explain in detail Type of Stirrups with figure and Also explain ACI code for shear design.

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

TYPES OF STIRRUPS :-

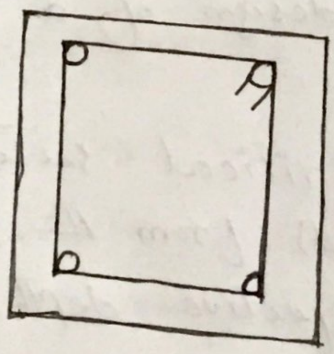
① Single Legged Stirrup :-

The single-leg stirrups have rarely been used b/c they are mostly used when binding only two rods.



② Two Legged Stirrup :-

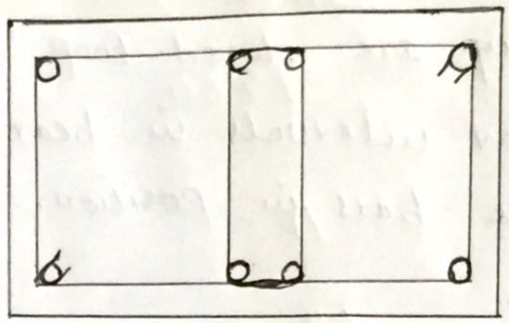
It is most commonly and widely used stirrups. Minimum 4 bars are required for providing this stirrup.



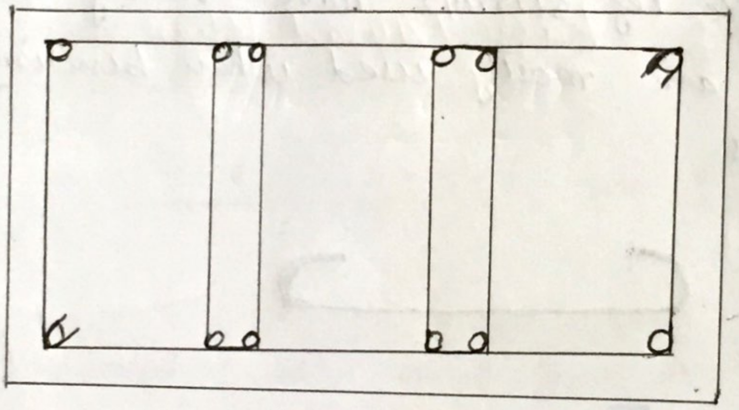
2 Legged Stirrup

③ Four Legged Stirrup :-

These stirrup are used in case of web reinforcement.



④ Six Legged Stirrup :-



ACI Codes for Shear Design of A Beam :

According to ACI-318, following the formulas used for the shear design of a beam.

① Critical Section :-

Critical section occurs at 45° and is at distance (d) from the face of support which is equal to effective depth.

② Shear strength capacity of concrete :-

$$V_c = 2 \times \sqrt{f_c} \times b_w \times d$$

③ Minimum Web Reinforcement :-

If $V_u \leq \phi V_c$, then theoritically no web reinforcement is required. However ACI code require provision of atleast a minimum area of web reinforcement equal to.

$\phi = 0.75 \rightarrow$ For shear design

V_u = total factored shear applied at given section

For Minimum Reinforcement Area:-

$$A_{v\,min} = \frac{0.75 \times \sqrt{f_c'} \times b_w \times S}{f_y} \quad \text{or} \quad \frac{50 \times b_w \times S}{f_y}$$

By interchanging the above formula, we can obtain the formula for maximum spacing.

$$S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{f_c'} \times b_w} \quad \text{or} \quad \frac{A_v \times f_y}{50 \times b_w}$$ (lesser value is selected)

⇒ No web Reinforcement is required if

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

b/w between critical section "V_u" and "ϕV_c" spacing between web reinforcement can be found by

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

$\Rightarrow$ if $V_s \le 4 \times \sqrt{f'_c} \times b_w \times d$:-

Then maximum spacing for stirrup will be the smallest of the following.

(1) 24" (2) $d/2$

(3) $S_{max} = \dfrac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$ (4) $S_{max} = \dfrac{A_v \times f_y}{50 \times b_w}$

$\Rightarrow$ if $V_s > 4 \times \sqrt{f'_c} \times b_w \times d$:-

then max spacing will be halved.

$\Rightarrow$ If $V_s > 8 \times \sqrt{f'_c} \times b_w \times d$:-

then either increase cross-sectional dimension or increase f'_c

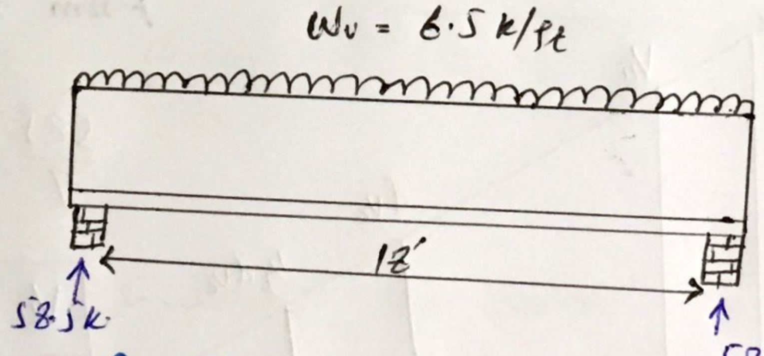
QUESTION - 2

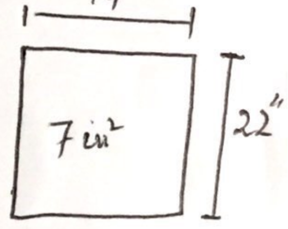
A simply supported rectangular beam 14" wide having an effective depth of 22" to carry a lateral load of 6.5 K/ft on a 18' simple span. It is reinforced with 7 in² of Tensile steel area, if f'c = 4 ksi and fy = 60 ksi. Then design the beam for shear.

GIVEN DATA :-

- ★ Breath of web of beam = bw = 14"
- ★ Effective depth = d = 22"
- ★ Load = 6.5 k/ft
- ★ Steel Area = 7 in²
- ★ f'c = 4 ksi
- ★ fy = 60 ksi

Solution :-





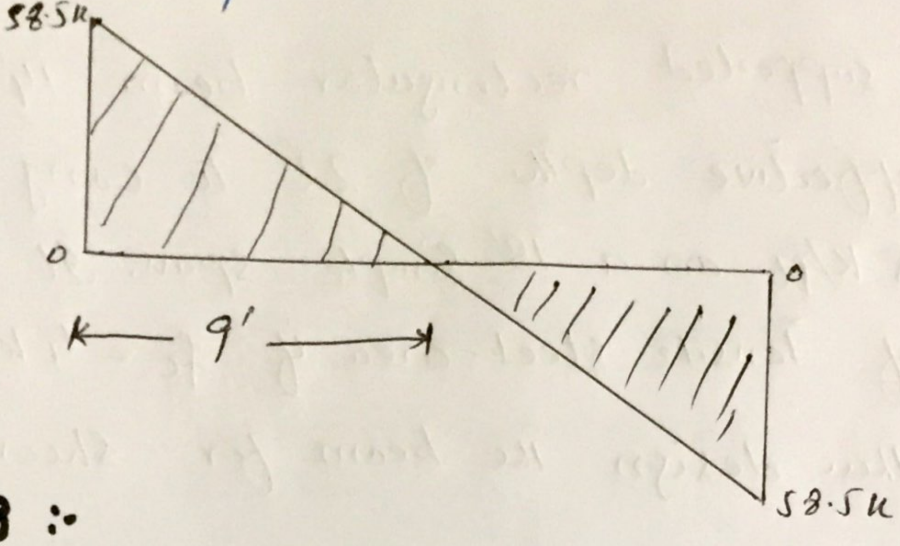
Step # 1 Rection on supports

Reection due to Applied load

Total Load = $\frac{6.5 \times 18}{2}$ = 58.5 Kips

Step # 02

Shear Force Diagram



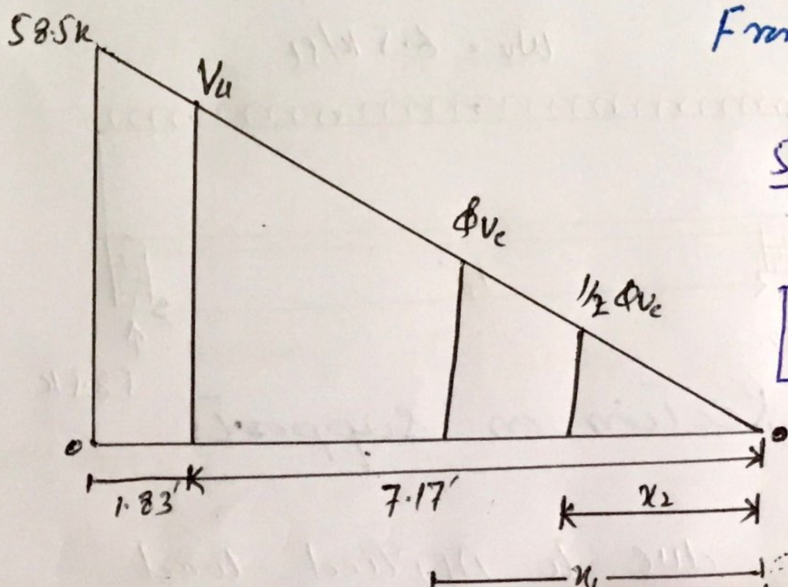
Step # 03 :-

We have Two same Triangle Now we take left sid Triangle To find critical shear "V_u" and its location

As we know that, the critical shear is located at ~~diagram~~ distance "d" ~~by~~ from face of support d.

$$d = 22'' = 1.83'$$

we will find the value of critical shear at distance by use of similar triangles.



From similar Triangle

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

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

Step #04 :-

Find the value of "ϕV_c" and "$1/2\,\phi V_c$" and also its distance from zero shear to right side.

As we know that

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

$$\phi V_c = 0.75 \times 2\sqrt{4000} \times 14 \times 22 = 29219 \text{ lbs}$$

$$\boxed{\phi V_c = 29.219 \text{ kips}}$$

⇒ location of ϕV_c By Similar Triangles.

$$\frac{58.5}{9} = \frac{29.21}{x_1} \qquad \boxed{x_1 = 4.49'}$$

⇒ Similarly

$$1/2\,\phi V_c = \frac{29.219}{2} = \boxed{14.60 \text{ kips}}$$

⇒ location of $1/2\,\phi V_c$ will be,

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

Step #05

Finding the value of ϕV_s

By formula,

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

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

$$\phi V_s = 46.61 - 29.21$$

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

Step #06

Check on Section Adequacy

By formula

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

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

$$= 116877 \text{ lbs}$$

$$= \boxed{116.87 \text{ kips}}$$

As

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

So Section is Adequate.

Step #07

Maximum Spacing for Stirrup

By formula

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

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

$$\boxed{58.44 \text{ kips}}$$

As

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

So maximum will be selected from four conditions

1) $S_{max} = 24''$
2) $S_{max} = d/2 = \frac{22}{2} = 11''$
3) $S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$

Using #3 Stirrup

dia = 0.375''

Area = 0.11 in^2

For 2legged

$0.11 \times 2 = 0.22 \ in^2$

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

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

From above four conditions, lest value of spacing for #3, 2 leg stirrups will be selected that as $\boxed{S_{max} = 11''}$

Step # 8 Stirrup Spacing

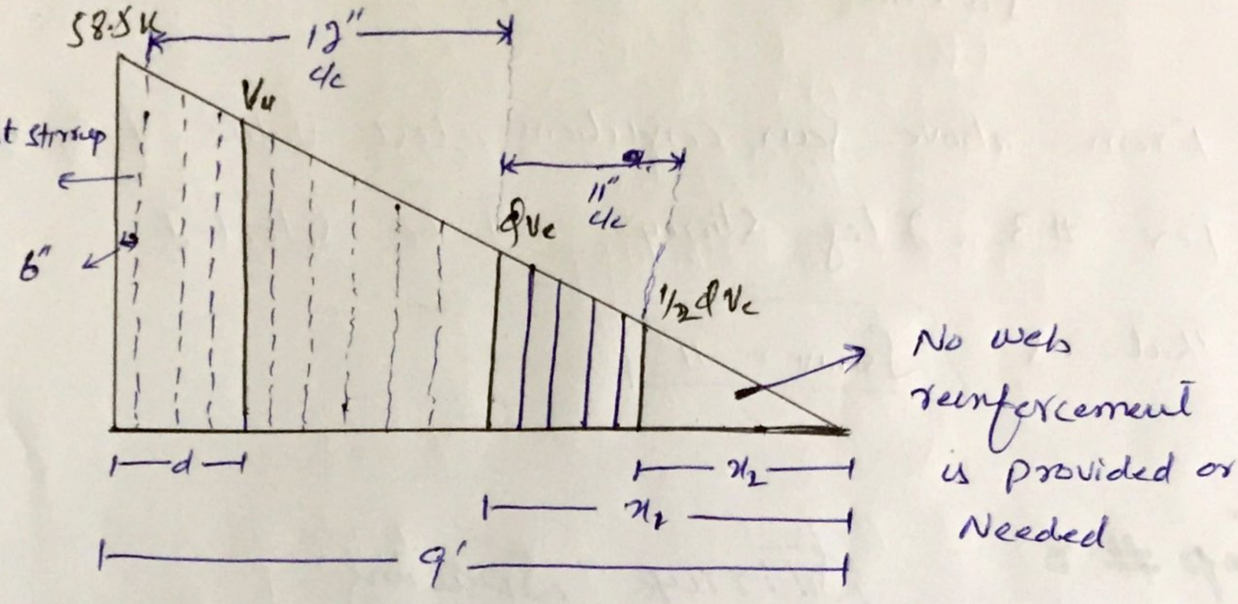
Stirrup spacing from at critical section will be

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

$S = 12.5'' \cong 12''$

$\boxed{\text{so c/c } 12''}$

Step #09 Final Sketch



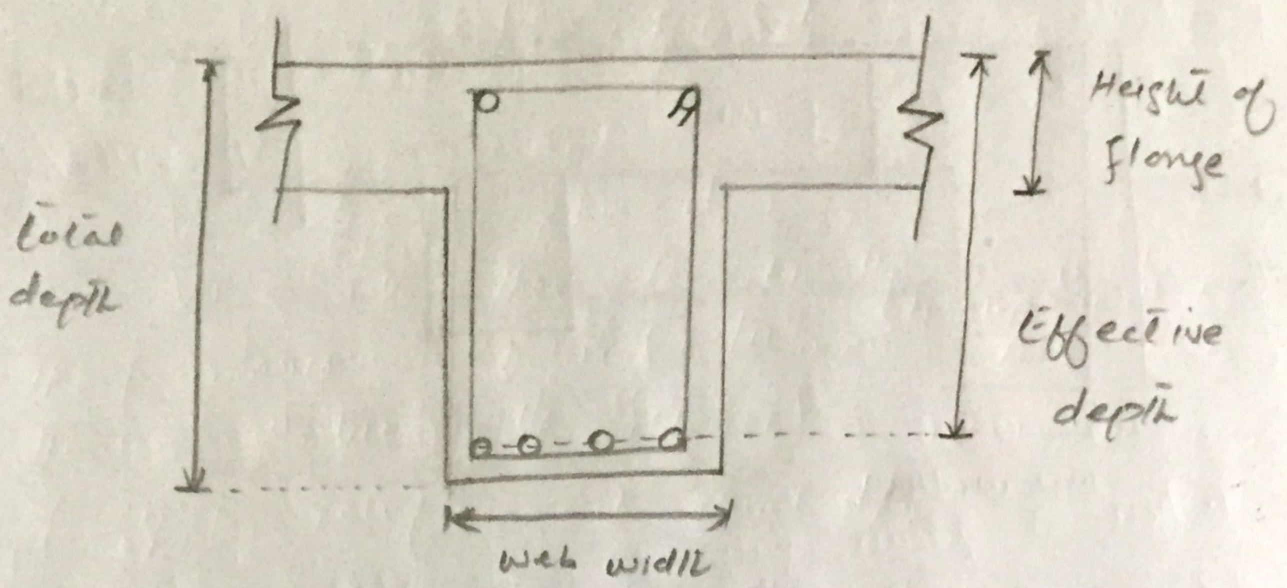
Question 03 :-

Define both the T-Beam and L-Beam with help of diagram. Also explain general analysis of T-beam.

T-Beam :-

In most of the reinforcement 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.

★ Because of their T-Shape, these beam are called T-beam



=> It is provided at the center of the slab to resists the load.

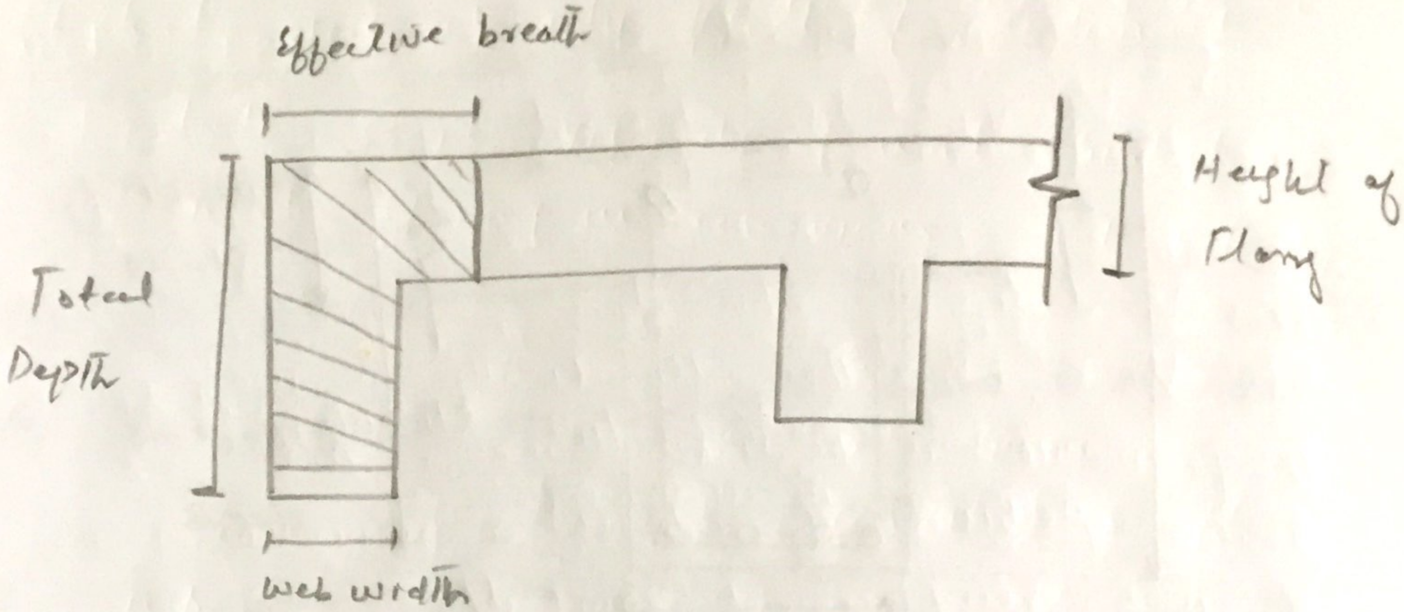
=> The upper most area of the beam attached to the slab called Flange.

=> The bottom rectangular portion of the beam is called web of the beam.

L-Beam :- L-Shaped Structure that is in contact with the slab and present at corner of the floor is called L-Beam

=> L-Beam are also called Edge beam

=> It is always provided at the corner of the slab



⇒ L-Beam are typical structure depth, the beam are in presented or reinforced Concrete

Flexural Analysis of T-Beam :-

① For finding the ultimate factored moment we use following formule.

$$Mu = \frac{Wu \times L^2}{8}$$

② Effective with (be) for T-Beam is calculated

① $16(hf) + bw$

② c/c distance

③ span/4

④ $\frac{CTS}{2} + bw$

we have selected the least value from above formula

(3) Checking wether Rectangular or T-Beam Analysis is required.

(i) If $a > h_f$ → Special Analysis is required

(ii) If $a < h_f$ → Rectangular beam Analysis

(4) For finding Area of Steel.

$$A_{sT} = \frac{M_u}{\phi \times f_y \times (d - \frac{a}{2})}$$

(5) For checking the range of Reinforcement Ratio

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

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

$$\rho = \frac{A_{st}}{b \times d}$$

(6) Formula for Finding No. of bar.

$$\text{No. of Bar} = \frac{\text{Area of Steel}}{\text{Area of single bar}}$$

(1) For checking minimum width for bar

$$b_{min} = 2(\text{clear cover}) + 2\begin{pmatrix}\text{dia of} \\ \text{Stirrup}\end{pmatrix} + (\text{No of bar}) \times (\text{dia of bar}) +$$

$$\text{spacing b/w bar}\,(\text{dia of bar})$$

(2) Design moment is given by

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

$$M_d = \phi \left[A_s \times f_y \times \left(d - \frac{h_f}{2}\right) + (A_{st} - A_{si})(d - a/2) \right.$$

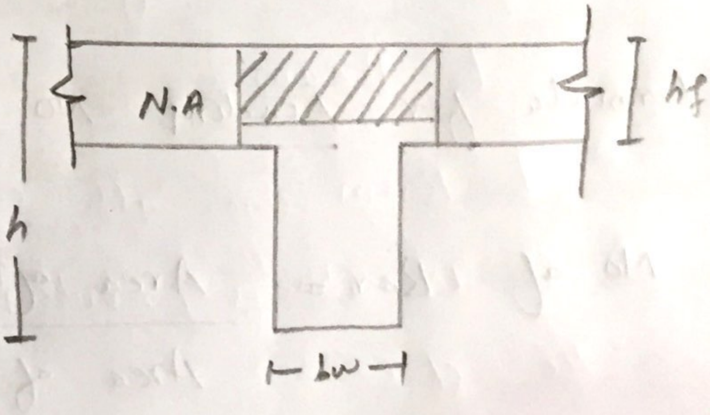
if $a > h_f$

Question 4 :-

What is the different b/w CASE-I and CASE-2 in the design of T-Beam.

CASE-I :-

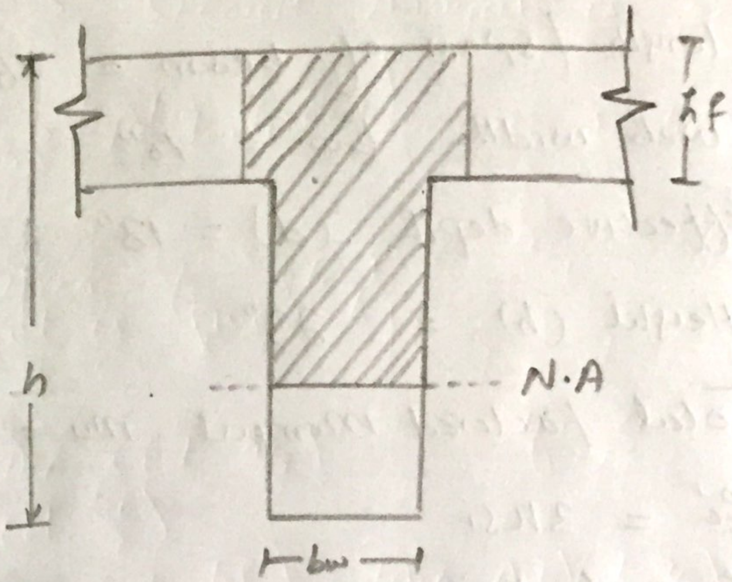
From the figure
$a < h_f$
So in this case, Rectangular Beam Analysis is Required.



So,
the Design moment formula will be

$$Md = \phi * fy * Ast * (d - a/2)$$

Case II :-



From the figure
$a > hf$
So in this, Special beam analysis, i.e
T-Beam Analysis is required
So, the required Design moment will be

$$Md = \phi \left[As * fy * \left[d - \frac{hf}{2} \right] + (As - Ast) * fy (d - a/2) \right)$$

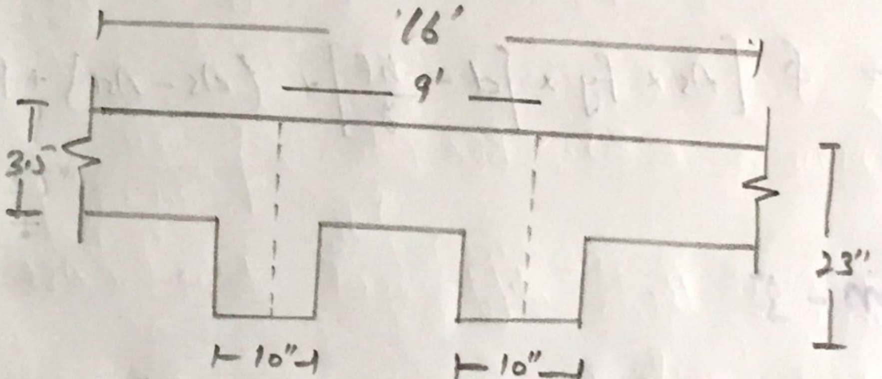
Question - 5

A floor system consists of 3.5" concrete slab supported by 16' simple span speed at 9' c/c, the beam having a web width of 10" and effective depth of 18" and Total height is 23". Calculate the necessary flexural reinforcement of the factored applied moment is 5800 k-in. Use $f'c = 3ksi$ & $fy = 60ksi$

Given Data :-

* Height of flange (h_f) = 3.5"
* c/c distance = 9'
* length / span of beam = 16'
* web width b_w = 10"
* Effective depth (d) = 18"
* Height (h) = 23"
* Total factored moment M_u = 5800 kip-inch
* f'_c = 3 ksi
* f_y = 60 ksi

Solution :-



Step-1 Calculate the effective width (be) for T-beam

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

2) c/c distance = 9×12 = 108"

3) span/4 = $\frac{16}{4} \times 12$ = 48"

Selecting the least value of be as

be = 48"

Step = 2

Check whether Rectangular or T- Beam Analysis is required.

Trial # 01 : Let $a = hf = 3.5''$

$$Ast = \frac{Mu}{\phi \times fy \times (d - \frac{a}{2})} = \frac{5800}{0.90 \times 60 (18 - \frac{3.5}{2})}$$

$$\boxed{Ast = 6.61 \ in^2}$$

Trial # 02

$$a = \frac{Ast \times fy}{0.85 \times f'c \times be} = \frac{6.61 \times 60}{0.85 \times 3 \times 48}$$

$$\boxed{a = 3.2''}$$

&

$$\boxed{Ast = 6.55 \ in^2}$$

Trial # 03

$$a = 3.2$$

$$Ast = \frac{5800}{0.90 \times 60 (18 - \frac{3.2}{2})}$$

$$\boxed{Ast = 6.55 \ in^2}$$

So Area of steel is $6.55 \ in^2$

Step = 03

Check ρmax & ρmin

$$\rho max = 0.85 \times B \times \frac{f'c}{fy} \left(\frac{\varepsilon u}{\varepsilon u + \varepsilon t} \right)$$

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

$$\boxed{\rho_{max} = 0.013}$$

$\Rightarrow$ $$\rho_{min} = \frac{200}{f_y} = \frac{200}{60000}$$

$$\boxed{\rho_{min} = 0.003}$$

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

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

As the value of ρ_{max} is less then ρ.
So we have to design it as (Doubly Reinforcement Beam)

$\Rightarrow$ First we have to find the Area of Steel against ρ_{max}.

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

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

$$\boxed{Ast = 2.34\ in^2}$$

Step = 4

Find the value of Mu_2:

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

First Find the value of "a"

$$a = \frac{Ast \times fy}{0.85 \times f'c \times b} = \frac{2.34 \times 60}{0.85 \times 3 \times 10}$$

$$\boxed{a = 5.72"}$$

$$Mu_2 = 0.90 \times 2.34 \times 60 \times (18 - 5.72/2)$$

$$\boxed{Mu_2 = 1986.67 \text{ kip-inch}}$$

As $Mu_2 < Mu$

So we have to design the beam in such away at that it can resist more bending moment then the applied external moment.

Step = 5

Finding Difference in moment and Area of steel.

$$Mu_1 = Mu - Mu_2 \Rightarrow 5800 - 1986.67$$

$$\boxed{Mu_1 = 3813.33 \text{ kip-inch}}$$

Now

$$A's_t = \frac{Mu}{\phi \times fy \times (d - d')} = \frac{3813.33}{0.90 \times 60 \times (18 - 2.5)}$$

$$\boxed{A'st = 4.56 \text{ in}^2}$$

Step = 06 Finding Total Area of Steel.

$A_s = A_{st} + A'_{st} \Rightarrow 2.43 + 4.56$

$\boxed{A_s = 6.99 \ in^2}$

Step = 07 :- Section of Bar

In Tension zone :- Let we use #8 bar

$dia = 8/8 = 1"$ Area $= 0.785 \ in^2$

$$\text{No. of Bar} = \frac{\text{Area of Steel}}{\text{Area of single bar}} = \frac{6.99}{0.785} = 8.9 \cong 9$$

So 9 #8 bar

In Compression zone :- Let we use #7 bar

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

$Area = 0.601 \ in^2$

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

So 8 #7 bar.

Step #08

Minimum width for Accomodation bars.

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

$$b_{min} = 20.75''$$

As $20.75'' > 10''$

So the bars will be placed in multiple layers.

Effective depth :(d)

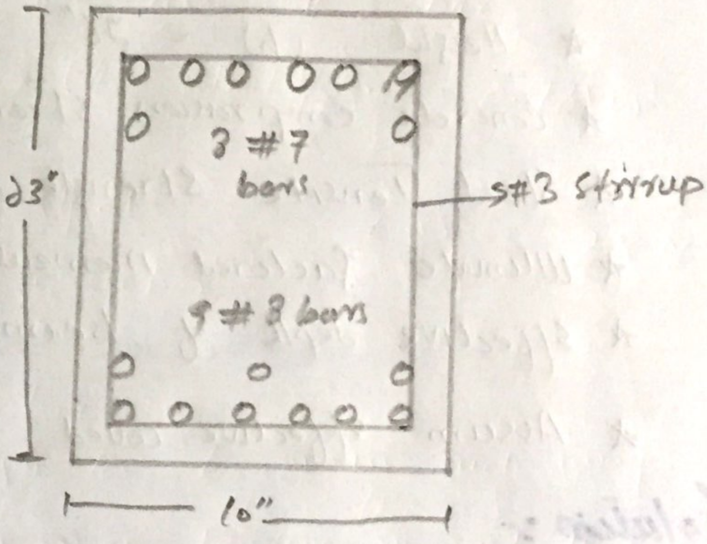
$$d = 23 - 1.5 + \frac{3}{8} + \frac{8}{8} + \frac{1}{2}(8/8)$$

$$d = 19.6''$$

Effective cover (d')

$$d' = 1.5 + 3/8 + 7/8 + 1/2(7/8)$$

$$\boxed{d' = 3.18''}$$



Step = 9

Finding the Design moment

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

$$a = \frac{(A_s - A_s') \times f_y}{0.85 \times f_c' \times b} = \frac{(9 \times 0.785 - 8 \times 0.60) \times 60}{0.85 \times 3 \times 10} = 5.31''$$

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

$$\boxed{M_d = 6328.33}$$

As $6328.33 > 5800$ So design is OK!

Question - 06

A beam is revised to developed and ultimate moment of 6000 kip-inches to 14×26 inch size. Use $f'c = 4ksi$ and $fy = 60ksi$. Determine flexural reinforcement assume two rows of tensile reinforcement & effective depth of beam is 22 inch.

Given Data :-

- ★ Breath (b) = 14"
- ★ Height (h) = 26"
- ★ Concrete compression strength $f'c = 4ksi$
- ★ Steel Tensile strength $fy = 60ksi$
- ★ Ultimate factored moment $Mu = 6000$ kis-inch
- ★ Effective depth of beam $d = 22"$
- ★ Assum Effective coved $d' = 2.5"$

Solution :-

Step - 1 Reinforcement Ratio

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

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

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

Step = 2 Area of Steel

$$\rho_{max} = \frac{Ast}{b \times d} = Ast = \rho_{max}(b \times d) = 0.0180(14 \times 22)$$

$$\boxed{Ast = 5.54 \, in^2}$$

Step = 3 Design Moment

$$M_{u2} = \phi \times A_{st} \times f_y \times (d - a/2)$$

$$a = \frac{A_{st} \times f_y}{0.85 \times f'_c \times b} = \frac{5.54 \times 60}{0.85 \times 4 \times 14} = \boxed{6.98''}$$

Then

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

$$\boxed{M_{u2} = 5537.4 \text{ kip-inch}}$$

As

$$5537.4 < 6000$$

So we design a section as doubly reinforced.

Step = 4 : Difference in Moments

$$M_{u1} = M_u - M_{u2} = 6000 - 5537.4$$

$$\boxed{M_{u1} = 462.6 \text{ kip-inch}}$$

Step = 5 Area of Steel

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

So Area of steel in compression zone will be

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

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

Step = 6 Total Steel Area

$A_s = A_{s1} + A_{s}' \Rightarrow 5.54 + 0.44$

$\boxed{A_s = 5.98\ in^2}$

Step = 07 Selection & No. of bar used

① Steel in Tension Zone:

We use #7 bar

dia = $7/8 = 0.875"$ Area = $0.601\ in^2$

So

No. of bars = $\dfrac{A_s}{\text{Area of sigal bar}} = \dfrac{5.98}{0.601} = 9.9$

$\boxed{\text{No. of bar} = 10\ \text{bars}}$

So 10 #7 bars

② Steel in Compression Zone:

Use #5 bar

dia = $(5/8)" = 0.625"$ Area = $0.306\ in^2$

So

No. of bars = $\dfrac{A_{s1}}{\text{Area of single bar}} = \dfrac{0.44}{0.306} = 1.43$

No. of bars = 2

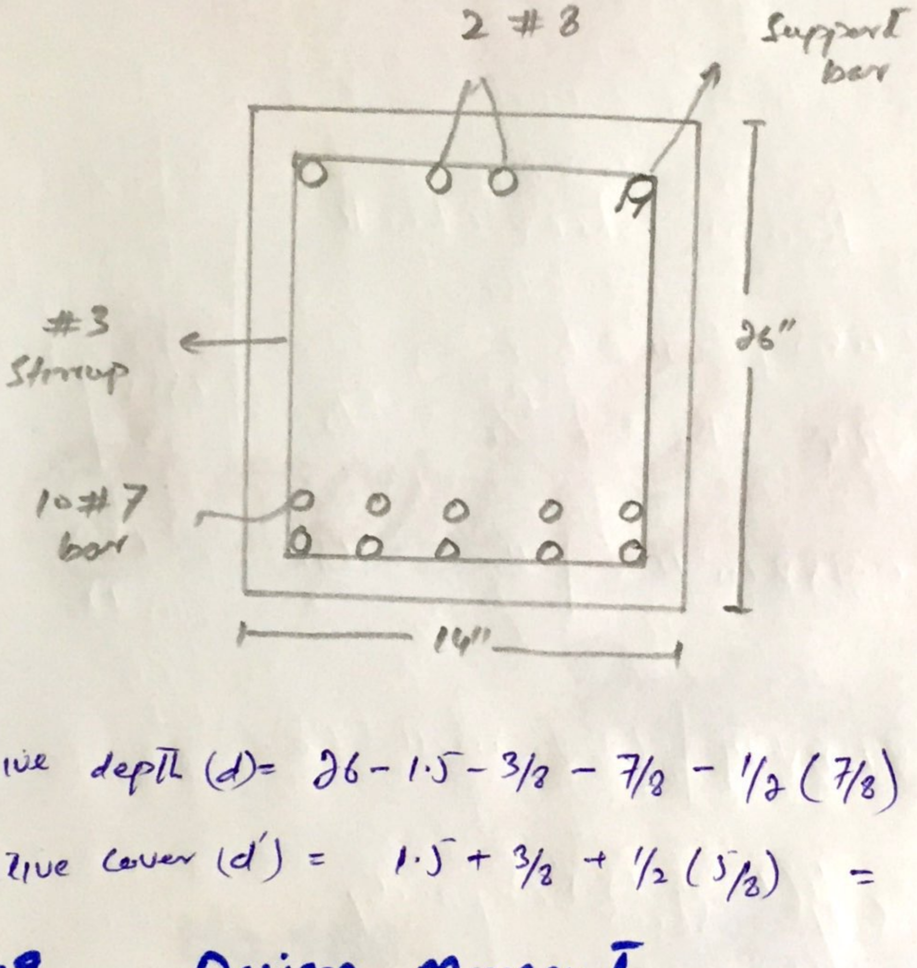
So 2 #5 bar

Step = 8 Minimum width of Beam

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

$b_{min} = 20.37 > 14"$

So not good in one laye.



⇒ Effective depth (d) $= 26 - 1.5 - 3/8 - 7/8 - 1/2(7/8) = 22.82"$

⇒ Effective cover (d') $= 1.5 + 3/8 + 1/2(5/8) = 2.18"$

Step = 9 Design Moment

$Md = \phi\left[A's \times f_y (d - d') + (As - A's) \times f_y (d - a/2)\right)$

$a = \dfrac{(As - A's)\, f_y}{0.85 \times f'c \times b} = \dfrac{[(10 \times 0.601) - (2 \times 0.306)]\, 60}{0.85 \times 4 \times 14} = \boxed{6.80"}$

$Md = 0.90\left[(2 \times 0.306) \times 60 \times (22.82 - 2.18) + (10 \times 0.601 - 2 \times 0.306) \times 60 \times (22.82 - 6.8/2)\right)$

$\boxed{Md = 7047.6 \text{ Kips-inch}}$ As $7047.6 > 6000$

Design is OK!