Final term ~~Paper~~ Assignment

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Section — 'A'

Semester — 6th

Subject — PRCD-I

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Q:- 1

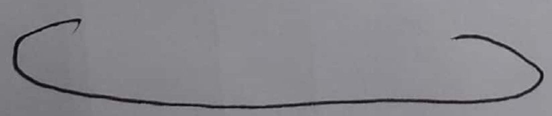
Stirrup:-

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

Types of stirrups:-

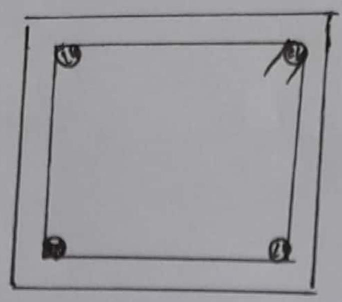
1- Single legged stirrup:-

The single leg stirrups have rarely been used ~~Stirrup. Minimum 4 bars are~~ because they are mostly used when binding only two rods.



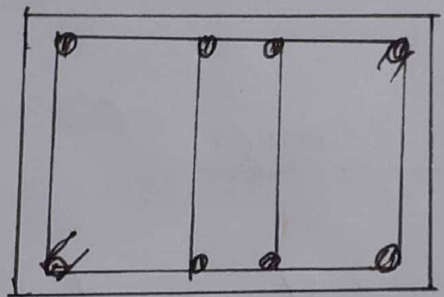
2) Two legged Stirrup:-

It is most commonly and widly using stirrups. Minimum 4 bars are required for providing this stirrups.

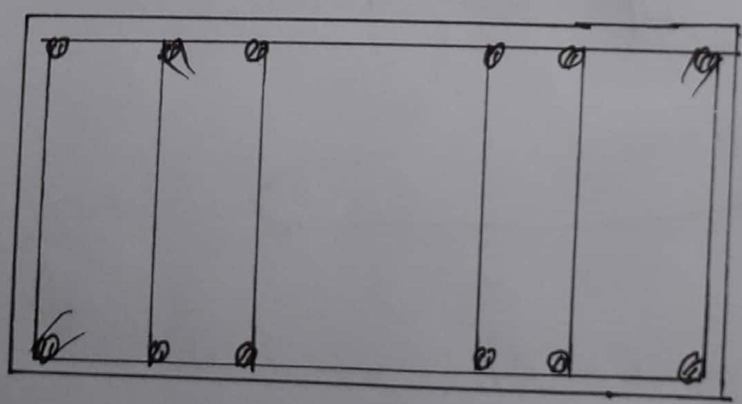


3/ Four legged stirrups:-

These stirrups are used in case of web reinforment.



4/ Six legged Stirrups:-



ACI Codes For Shear Design of a Beam

According to ACI-318, following are 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 theoratically no web reinforcement is requirement 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 a 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 formulas, we can obtain the formula for maximum

$$S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w} \quad \text{or} \quad \frac{A_v \times f_y}{50 \times b_w}$$

4- No web reinforcement is required if

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

⇒ Between Critical Section "V_u" and "ϕV_c", spacing b/w web reinforcement can be find by

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

5 - if $V_s \leq 4 \times \sqrt{f'_c} \times b_w \times d$, then max spacing for stirrups 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 - $S_{max} = \dfrac{A_v \times f_y}{50 \times b_w}$

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

$\downarrow$

max spacing will be halved.

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

Then either increase cross-sectional dimension or increase f'_c.

Question - 02 :-

Given data:-

Effective depth = 22"

Breadth of web beam (b_w) = 14"

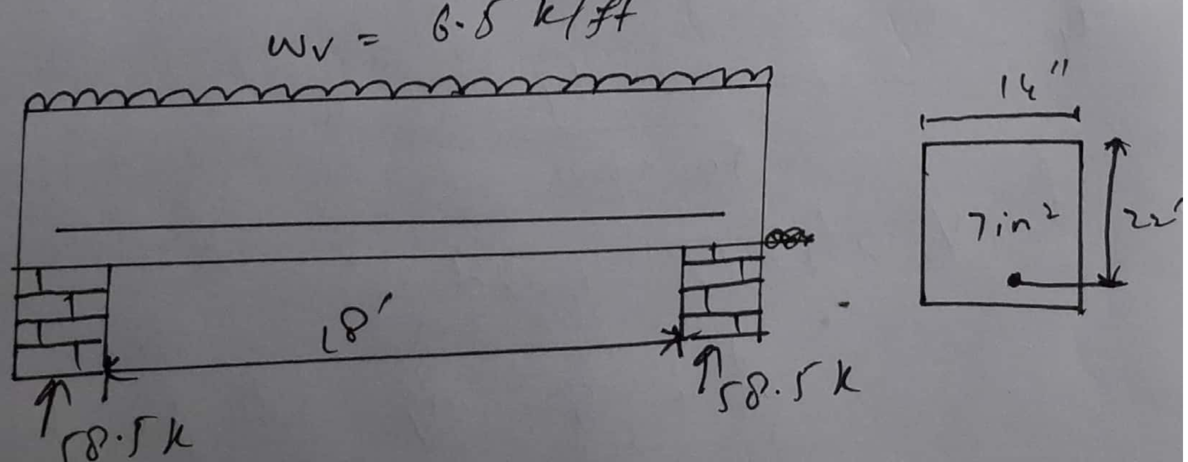
Given load = 6.5 k/ft

Steel area = 7 in^2

f'_c = 4 ksi

f_y = 60 ksi

Solution :-



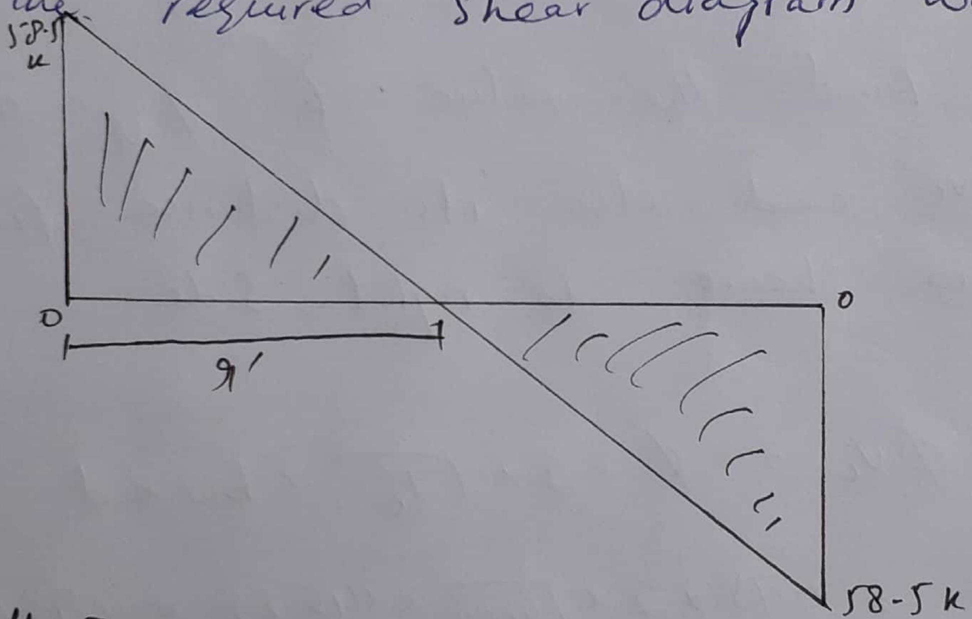
Step # 1 Reactions on Supports:

Finding the reactions due to applied load.

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

Step # 2 Shear force diagram:-

The required Shear diagram will be

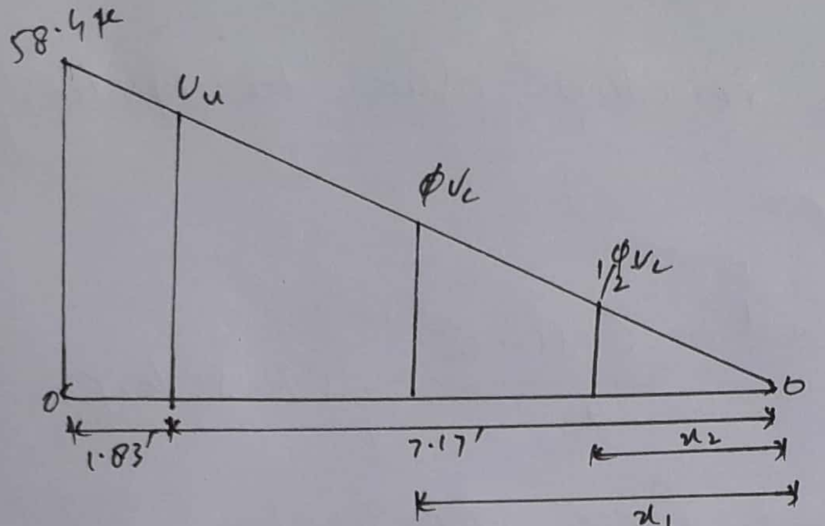


Step # 3 :-

Now find the value of "V_u" and location.

Critical Shear is located at distance "d" from force of Support $(d) = 22'' = 1.83'$

we can find the values using Similar Δs.



From Single Δs

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

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

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

Step # 4 :-

Find the value of "ϕV_c" and 1/2 "ϕV_c" and also its distance from zero shears to right side.

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

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

$$= 29.21 \text{ kips}$$

Locations by Similar Δs.

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

$$\boxed{x_1 = 4.49'}$$

Similarly,

$\frac{1}{2}\phi V_c = \phi V_c/2 \Rightarrow 29.21/2 = 14.60\,kip$

→ Location of $\frac{1}{2}\phi V_c$

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

Step # 5:-

Finding the value of ϕV_s

$V_u = \phi V_s + \phi V_c$

$\phi V_s = V_u - \phi V_c$

$= 46.61 - 29.21$

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

Step # 06:-

Check section adequency

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

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

$= 116.87\ kips.$

As $\phi \times 8 \times \sqrt{f'_c} \times b \times d > \phi V_s \Rightarrow \boxed{Adequate}$

Step # 7 :-

Max: Spacing for Stirrups

By formula,

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

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

$= 58.43$ kips.

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

So max will selected by following 4 conditions.

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

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

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

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

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

From above least value of ~~Stirrup~~ spacing for #3 2 legged Stirrup

$S_{max} = 11''$

Step # 8 :-

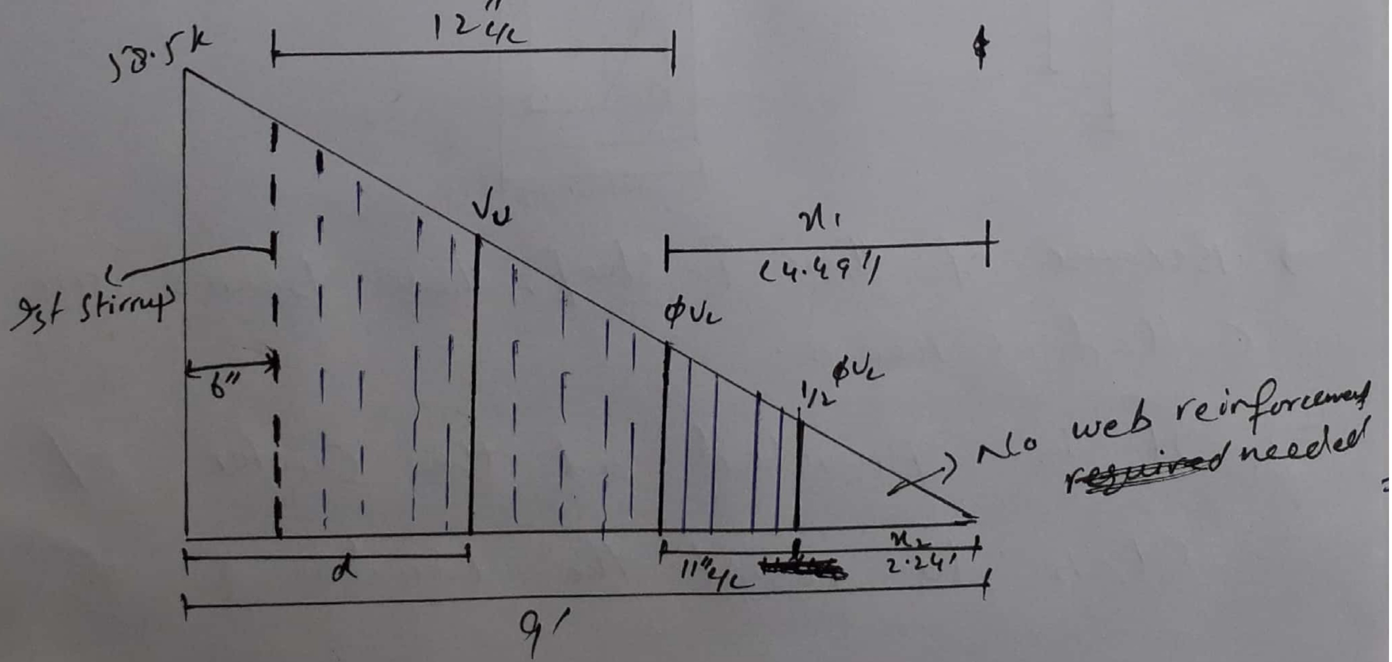
Stirrup Spacing from Critical Section

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

$S = 12.5'' \simeq 12''$

So $12''$ c/c

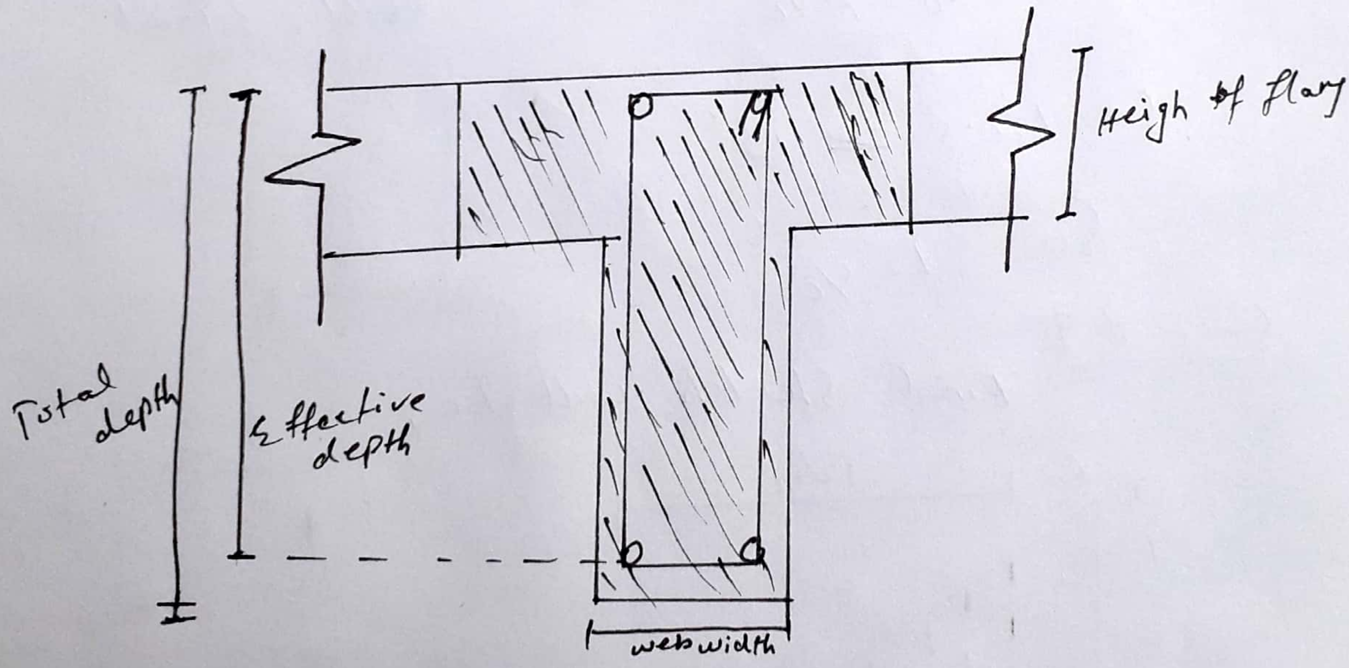
Step # 9 Final Sketch will be,



Question # 03:-

T-Beam:-

In most of the reinforced concrete structures, concret slabs are cast monoliticaly with the slab so, in this case the beam that act as an intermediat beam are called T-Beam.

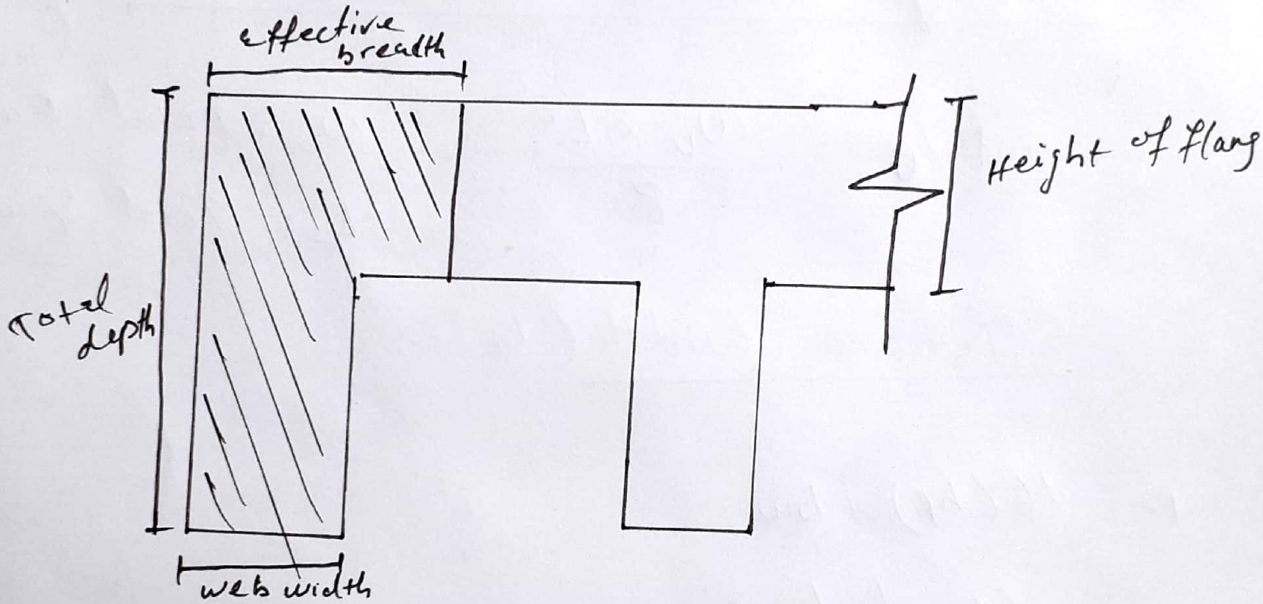


⇒ Because of their T-shap, these beams are called T-Beam.

⇒ It is provided at the center of slab to resist the loads.

L- Beams :-

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



⇒ L-Beam are also called Edge Beam.

⇒ It is always provided at the Corners of the slab.

⇒ L. Beam are typical floor Beams b/c of their reduced over all Structural depth, the beams are in Prestressed or R.Concrete

Flexural Analysis of T-Beam:-

Flexural analysis of T-Beam consist of the following steps:-

1- Finding ultimat factered moment

$$M_u = \frac{W_u \times L^2}{8}$$

W_u = Total Factor load
L = Total span

2- Effective width (b_e):-

1- $16(h_f) + b_w$

2- c/c distance

3- Span/4

4- $\frac{CTS}{2} + b_w$

we will select the least value.

3- Checking wethear rectangular or T-Beam:-

i- If $a > h_f \Rightarrow$ Special analysis is required.

ii - If $a < h_f \Rightarrow$ Rectangular beam analysis.

4- Finding Area of Steel:

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

ϕ = Strength reduction
d = Effective depth
a = Compression block depth
bw = web width

where

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

5- Check 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 Bars:

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

7- Checking Minimum width for bars:

$$b_{min} = 2(\text{Clear Cover}) + 2\left(\text{dia of Stirrups}\right) + \text{No. of bar}\left(\text{dia of bar}\right) + \text{Spacing b/w bars}\left(\text{dia of bars}\right)$$

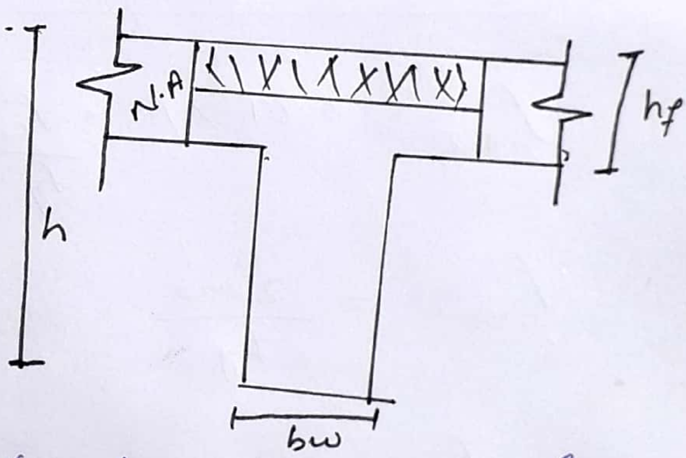
8- Design moment :-

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

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

if $a > h_f$.

Question - 04



Case - I :-

From the figure

$a < h_f$

So in this case, Rectangular Beam analysis is required.

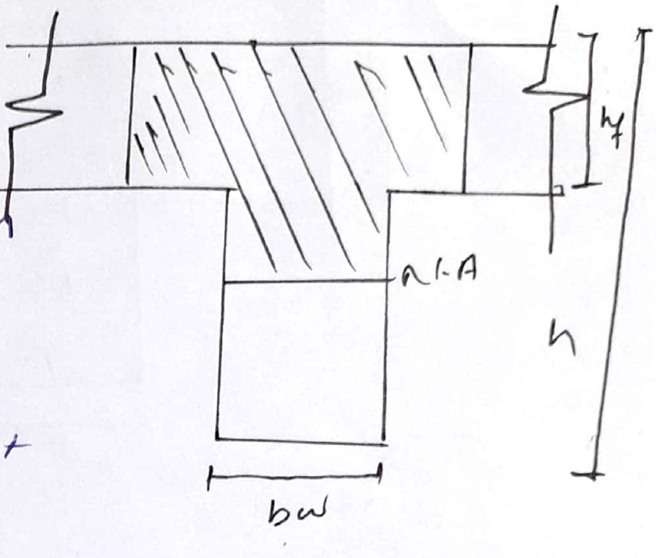
So, the design moment formula will be

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

Case - II :-

From figure $a > h_f$, so in this special beam analysis i.e

T- beam analysis is required.
So the required Design moment will be



$$M_d = \phi \times \{A_{sf} \times f_y \times (d - \frac{h_f}{2}) + (A_s - A_{sf}) \times f_y \times (d - a/2)\}.$$

Question - 05 :-

Given data :-

Height of flange (h_f) = 3.5"

c/c distance = 9'

Span of beam = 16'

b_w = 10"

d = 18"

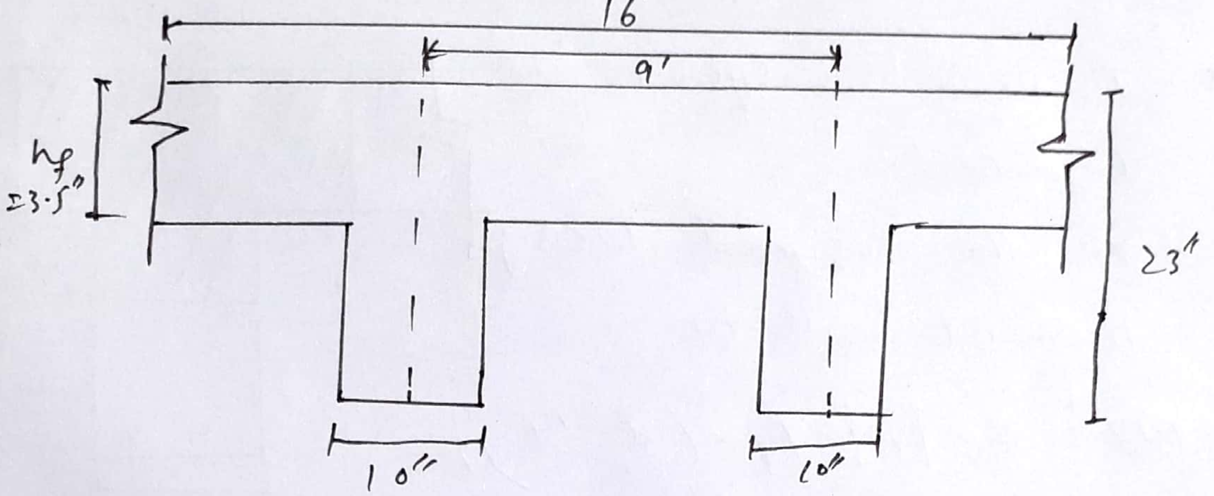
h = 23"

M_u = 5800 kip-inch

f_y = 60 ksi

f'_c = 3 ksi

Solution:-



Step # 01

Effective width (b_e) of T-beam.

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

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

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

Least value $\Rightarrow \boxed{b_e = 48''}$

Step # 2

Checking wether rectangular or T-beam analysis required.

Trial # 01

$a = h_f = 3.5''$

$$A_{st} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{5800}{0.90 \times 60 \times (18 - 8.5/2)} = 6.61 \text{ in}^2$$

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 $\boxed{A_{st} = 6.55 \, in^2} \Rightarrow 3.2'' < 3.5''$

So Rectangular Beam analysis Required.

Step # 03

Check ρ_{max} & ρ_{min}

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

$$0.85 \times 0.85 \times \frac{3}{60} \left(\frac{0.003}{0.003 + 0.005} \right) = 0.013$$

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

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

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

$$0.003 < 0.036 < 0.013$$

Now ρ_{max} is less then ρ, so design doubly Reinforced beam.

First find the Area of Steel against ρ_{max}

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

$$A_{st} = 0.013 \times (10 \times 18)$$

$$\boxed{A_{st} = 2.34 \text{ in}^2}$$

Step # 4 :-

Finding the value of M_{U_2}

$$M_{U_2} = \phi \times A_{st} \times f_y \times (d - a/2)$$

Find the value of "a"

$$\Rightarrow a = \frac{A_{st} \times f_y}{0.85 \times f'_c \times b} = \frac{2.43 \times 60}{0.85 \times 3 \times 10}$$

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

$$\Rightarrow M_{U_2} = 0.90 \times 2.43 \times 60 \times (18 - 5.72/2)$$

$$\boxed{M_{U_2} = 1986.67 \text{ kip-inch}}$$

$$M_{U_2} < M_U$$

$$1986.67 < 5800$$

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

Step # 5:

Find diffrence in moment and Area of Steel.

$M_{U_1} = M_U - M_{U_2}$

$= 5800 - 1986.67$

$\boxed{M_{U_1} = 3813.33 \text{ kip-inch}}$

$A'_{st} = \dfrac{M_U}{\phi \times f_y \times (d-d_1)} = \dfrac{3813.33}{0.90 \times 60 \times (18 - 2.5)}$

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

Step # 6:

Finding total steel area.

$A_s = A_{st} + A'_{st}$

$= 2.43 + 4.56 = 6.99 \text{ in}^2$

Step # 7

Selection of Bar

In tension zone

Let we use # 8 bar

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

No: of Bar $= \dfrac{\text{Area of Steel}}{\text{Area of single bar}} = \dfrac{6.99}{0.785} = 8.9 \simeq 9$

So 9 bars of # 8

In Compression Zone

we use #7 bars

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

By formula

$$\text{No. of Bars} = \frac{\text{Area of steel}}{\text{Area of single bar}} = \frac{4.56}{0.601}$$

$$= 7.5 \simeq 8.$$

So 8 bars of #7.

Step # 8

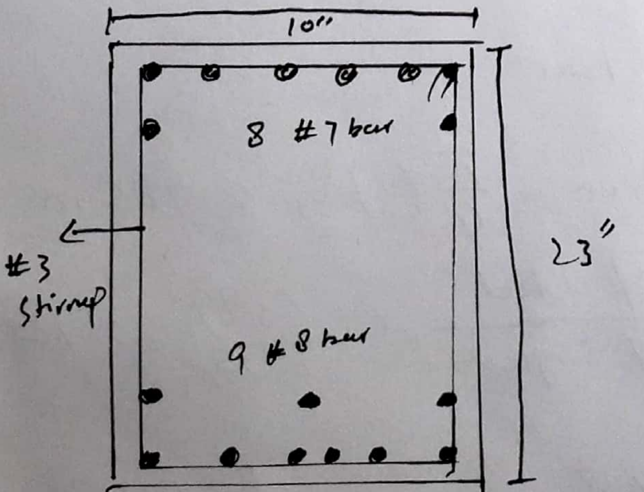
Minimum width for Accodation of bar

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

$$= 20.75''$$

As $20.75'' > 10''$

So, the bars will be placed in multiple Layers



depth $= d = 23 - 1.5 + 3/8 + 8/8 + 1/2(8/8) = 19.6''$

Effective cover $(d') =$

$1.5 + 3/8 + 7/8 + \frac{1}{2}(7/8) = 3.18''$

Step # 09:

Design moment:

$$M_d = \phi \left[A'_s \times f_y \times (d - d') + (A_s - A'_{st}) \times f_y \times (d - a/2) \right)$$

$$a = \frac{(A_s - A'_{st}) \times f_y}{0.85 \times f'_c \times b} = \frac{(9 \times 0.785 - 8 \times 0.601) \times 60}{0.85 \times 3 \times 10}$$

$$a = 5.31''$$

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

$$\boxed{M_d = 6328.38}$$

6328.38 7 5800 ⟶ design is OK

Question - 06

Given Data:

$b = 14''$

$h = 26''$

$f'_c = 4\ ksi$

$f_y = 60\ ksi$

$M_u = 6000$ kip-inches

$d = 22''$

Assume ⇒ $d' = 2.5''$

Solution:-

Step #01 Reinforcement Ratio:-

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

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

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

Step # 02:- Area of steel

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

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

Step # 3:- Design moment:

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

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

So

$$M_{u_2} = 0.90 \times 5.54 \times 60 \times \left(22 - \frac{6.98}{2}\right)$$

$$\boxed{M_{u_2} = 5537.4 \text{ kip-inch}} < 6000$$

So we will design a section as doubly reinforced.

Step # 04 Diffrence in moment:

$$M_{u_1} = M_u - M_{u_2}$$

$$= 6000 - 5537.4$$

$$\boxed{M_{u_1} = 469.6 \text{ kip-inch}}$$

Step # 5:- Area of Steel

$$M_{u_1} = \phi \times A_{st} \times f_y \times (d - d')$$

So area of steel in Compression zone

$$A_{st}' = \frac{M_{u_1}}{\phi \times f_y \times (d-d')} = \frac{462.6}{0.90 \times 60 \times (22-2.5)}$$

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

Step # 06 Total steel area:

$$A_s = A_{st} + A_{st}'$$

$$= 5.54 + 0.44$$

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

Step # 07 :- No: of Bars used & selection:-

1- Steel in Tension zone:-

we use # 7 bar

dia $(7/8)'' = 0.875''$, Area $= \frac{\pi}{4}(0.875'')^2$

$= 0.601 \text{ in}^2$

$$\text{No: of Bars} = \frac{A_s}{\text{Area of Single bar}} = \frac{5.98}{0.601} = 9.9$$

10 bars will use #7

2- Steel in Compression zone:-

use #5 bar

dia $= (5/8)'' = 0.625''$, Area $= \frac{\pi}{4}(0.625'')^2 = 0.306\,in^2$

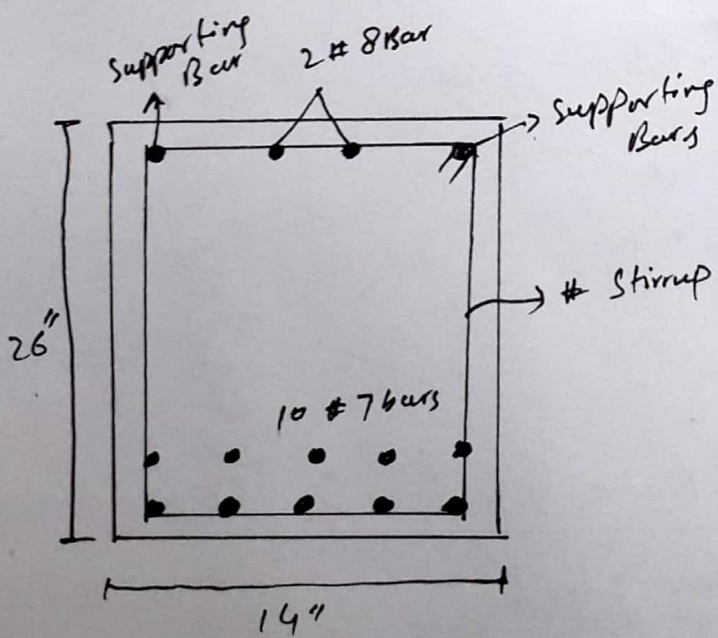
$$\text{No: of Bars} = \frac{A_{st}'}{\text{Area of Single bar}} = \frac{0.44}{0.306} = 1.43$$

2 bars of #5 will use.

Step # 8:- Minimum width of Beam

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

$b_{min} = 20.37 > 14''$ ⇒ not good in one layer



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:

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

$$a = \frac{(A_{st} - A_{st}') \times f_y}{0.85 \times f_c' \times b} = \frac{(10 \times 0.601 - 2 \times 0.306) \times 60}{0.85 \times 4 \times 14}$$

$$= 6.80''$$

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

$Md = 7047.6$ kip-inch

As

$7047.6 > 6000$

So Design is Ok