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Program :- B.Sc Civil Engineering

Assignment :- Plain and Reinforced Concrete Design-I

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Q No 1

Explain in detail types of Stirrups with figure and also explain ACI Codes for Shear design.

Ans:- **Stirrup:-** Stirrups are closed-loop bars tied at regular interval in beam reinforcement to hold the bars in Position.

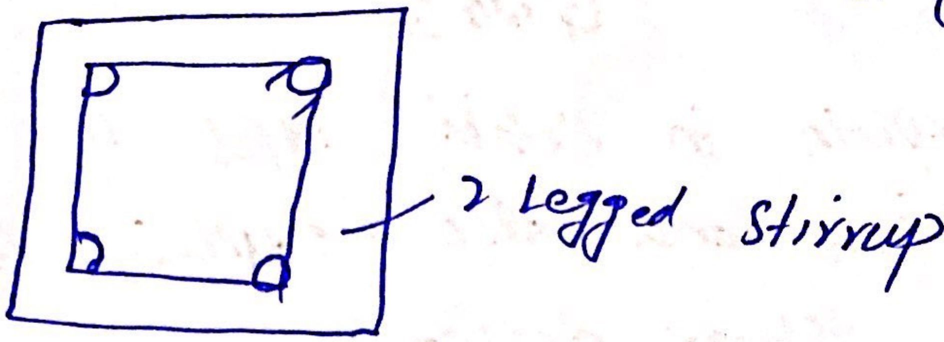
Types of Stirrups:-

i) Single Legged Stirrup:-

The single Legged Stirrup have rarely being used because they are mostly used when binding only two rods

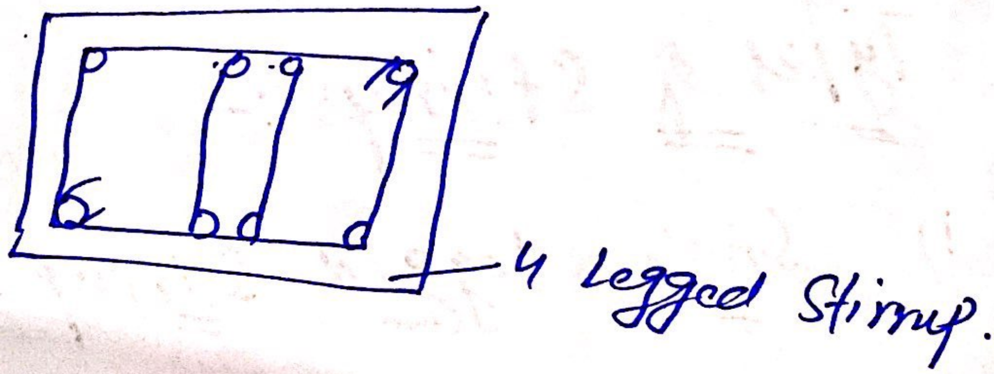
2) Two Legged Stirrup:-

It is most Commonly and widely used Stirrup. Minimum 4 bars are required for Providing this Stirrup.

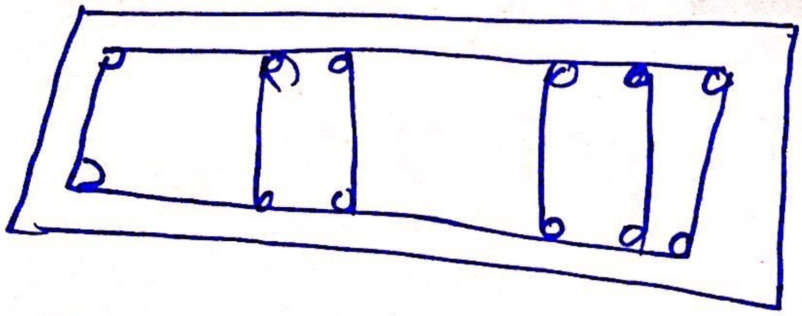


3) Four Legged Stirrup:-

These Stirrup's are used in case of web reinforcement



4) Six Legged Stirrup:-



ACI Codes for Shear Design of a Beam:-

According to ACI-318 following are the formula used for the

Shear design of a beam.

1) Critical Section:-

Critical Section occur at 45° and it is distance (d) from the face of Support which is equal to effective depth.

2) Shear strength capacity of Concrete is:-

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

3) Minimum Web Reinforcement:-

if $V_u \leq \phi V_c$, then theoritically no wed reinforcedment is required. However ACI Code require Provision of atleast a minimum area of web reinforcement equal to

$\phi = 0.75 \longrightarrow$ For shear design

($\because$ V_u = Total Factored shear applied to a given Section)

→ For Minimum Reinforcement Area:-

$$A_{vmin} = 0.75 \times \frac{\sqrt{f'_c} \times b_w \times s}{f_y}$$

or $\dfrac{S_o \times b_w \times S}{f_y}$

By interchanging the above formula we can obtain the formula for minimum spacing

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

4 - No-web reinforcement is required to

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

-> Between critical section "V_u" and "ϕV_c", spacing b/w web reinforcement can be find by

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

5) if $\underline{V_s \leq 4 \times \sqrt{f'_c} \times b_w \times d}$, then max spacing for stirrups will be the of the following.

i = 24"

2 = d/2

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

(4) $S_{max} = \dfrac{A_u \times f_y}{S_o \times b_w}$

Q No 2

A Samply supported rectangular beam 14" wide having in effective depth of 22" to carry a Lateral load of 6.5k/ft on a 18' Sample Span. It is reinforcement with $7 in^2$ of tensile Steel area of. $f'c = 4ksi$ and $fy = 60ksi$ The design the beam for Shear.

Given :-

Breath of web of beam $(bw) = 14"$

Effective depth (d) $= 22"$

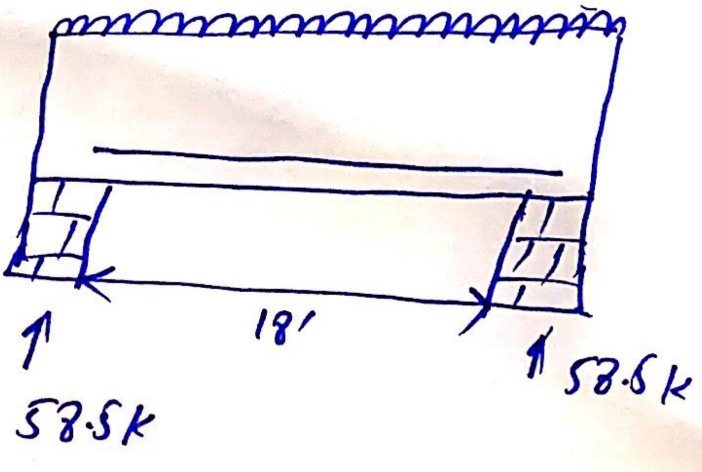
Given load $= 6.5 k/ft$

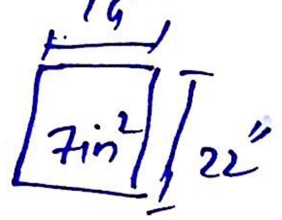
Steel area $= 7 in^2$

$f'c = 40ksi$

$fy = 60 ksi$

Sol :-





→ 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-section dimensions or increase f'_c.

Step # 01 :-

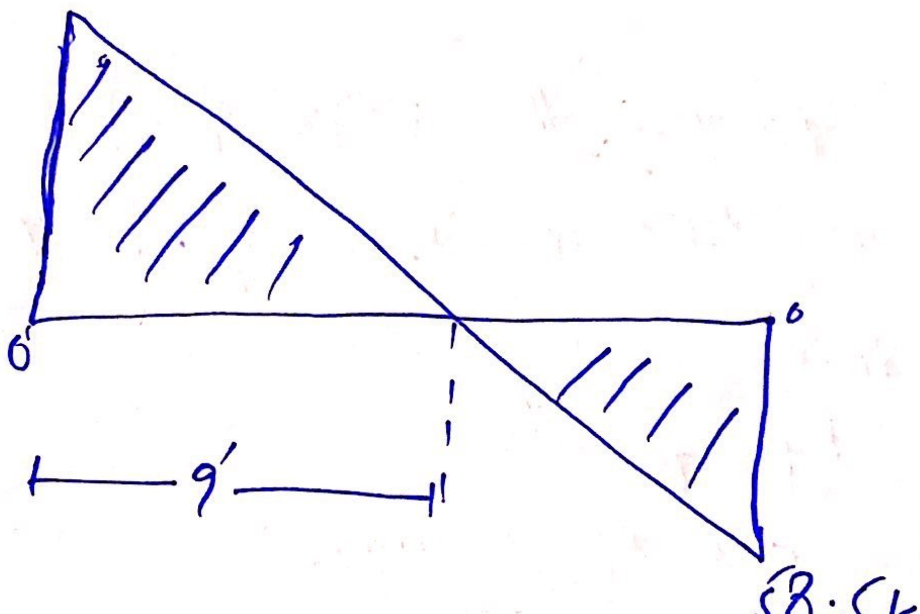
Reaction on Support :-

Finding the reaction due to applied Load.

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

Step # 2 :- (Shear Force Diagram)

The required shear diagram will be

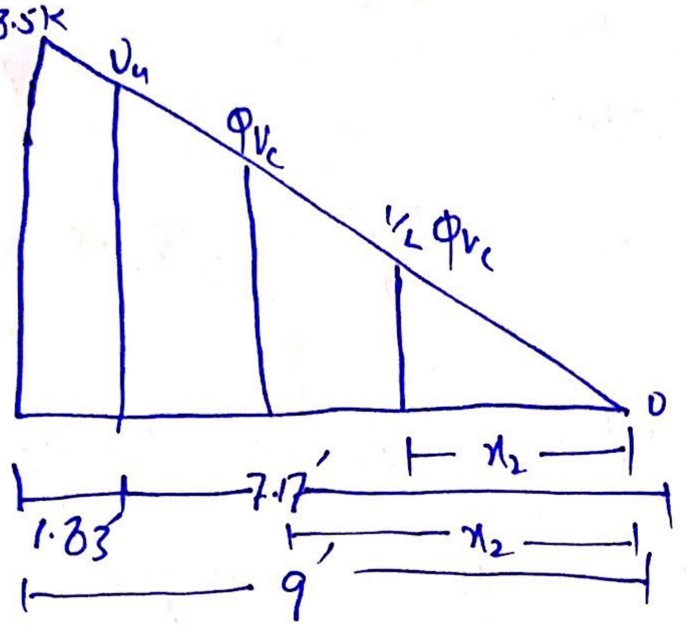


Step # 3 :-

Finding the value of critical Shear V_a and its location as,

We know that critical Shear is located at distance "d" from Face of Support (d) = 22" = 1.83'

=> So we will find the value of critical shear at distance (d) by use of similar triangle.



Step # 4:- Finding the value of ϕV_c and $\frac{1}{2}\phi V_c$ and also it distance from zero shear to right side.

By formula

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

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

$$= 29.21 \text{ kips}$$

=> location of ϕV_c by similar triangle

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

$$\Rightarrow x_1 = 4.49'$$

→ Similarity

$\frac{1}{2}\phi V_c = \phi V_c/2 \Rightarrow 29.21/2 = 14.6$ kips.

→ 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:-

Find the value of ϕV_s

By Formula. $V_u = \phi V_s + \phi V_c$

→ $\phi V_s = V_u - \phi V_c$

$= 46.61 - 29.21$

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

Step # 6

Check on section adequacy

By Formula

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

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

$= 116.87$ kips.

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

So section is Adequate..

Step # 7:- Check on Maximum Spacing for Stirrup:-

By formula

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

$= 0.75 \times 4 \times \sqrt{4000} \times 14 \times 22 = 58433 \text{ lbs}$

$= 58.43 \text{ kips}.$

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

So maximum will be selected from the following 4 conditions.

i) $S_{max} = 24''$

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

3) $S_{max} = \dfrac{A_v \times f_y}{0.75 \times \sqrt{f'c} \times bw}$

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

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

From 4 above conditions, least value of spacing for #3 2 legged stirrup will be selected as

$S_{max} = 11''$

Chick on maximum spacing for stirrups

By formula

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

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

$= 58.43\ kips$

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

so maximum will be selected from the following 4 conditions.

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

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

3) - $S_{max} = \dfrac{A_u \times f_y}{0.75 \times \sqrt{f'c} \times b_w}$

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

4) - $S_{max} = \dfrac{A_u \times f_y}{50 \times b_w} = \dfrac{0.22 \times 60000}{50 \times 14} = 18.25''$

From above 4 condition, least value of spacing for #3, $S_{max} = 11''$

<u>Step # 8:-</u> Stirrups spacing from/at critical section will be:

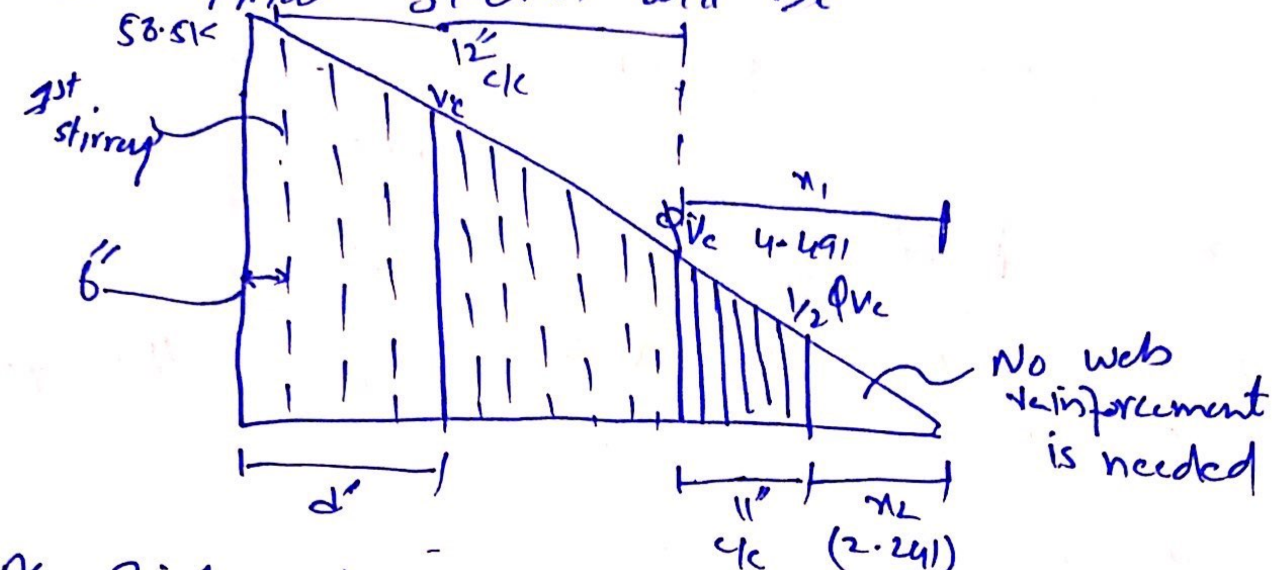
$S = \dfrac{\phi \times A_u \times f_y \times d}{V_u - \phi V_c} = \dfrac{0.75 \times 0.22 \times 60 \times 22}{46.61 - 29.21}$

$S = 12.5'' \approx 12''$

$S_o = 12'' \text{ c/c}$

Step # 9 :-

Final Sketch will be



As first stirrup of face of support;

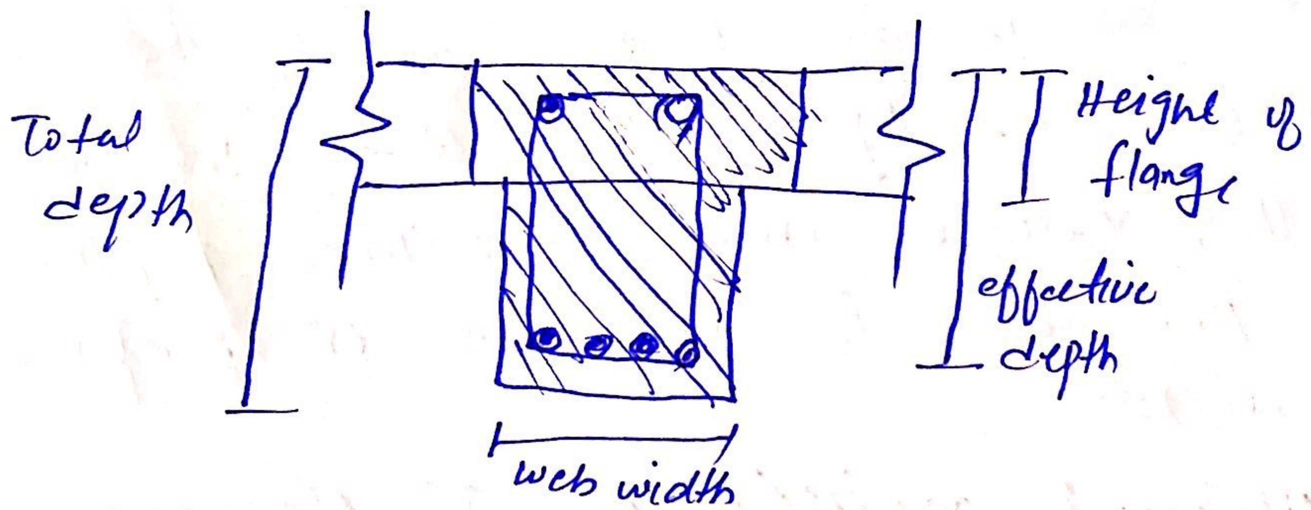
$S/2 = 12/2 = 6''$

QNo 3

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

T- Beam :-

=> In most of the reinforcement concrete structure, concrete slabs, are cost monolithically with the slabs, so in this case that the beam act as in intermedita beam are called T- Beam

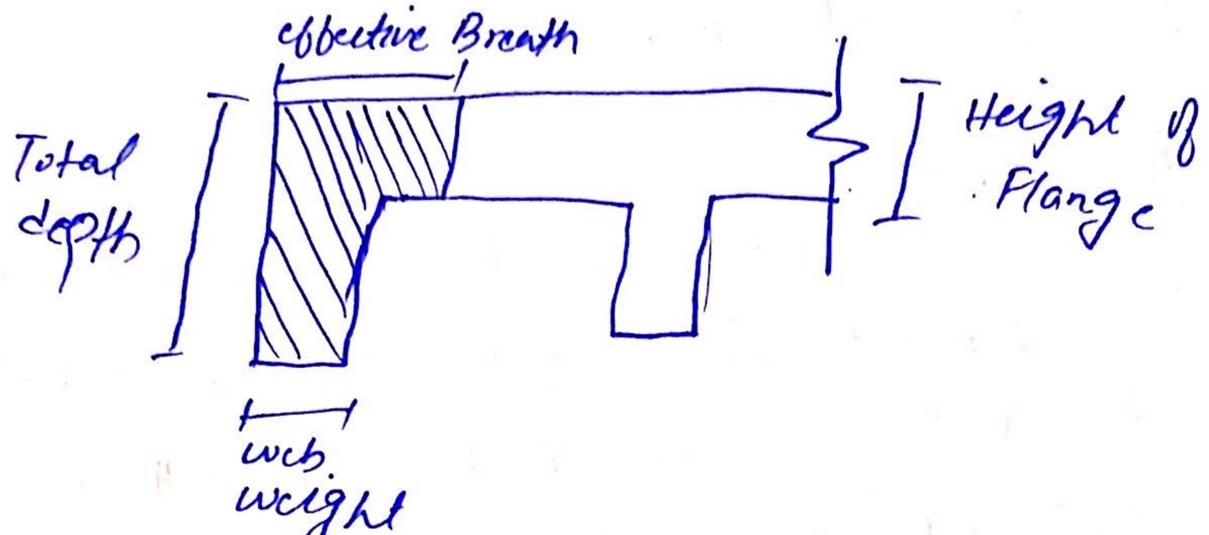


=> The upper most area of the beam attached to the slab is called Flange

-> The bottom ractangular portion of the beam is called web of the beam.

L-Beam:-

→ L-Beam is structure that is an Contact with the Slabs and Presant at the Corner of the Floor is Called L-Beam.



⇒ L-Beam are also called Edge Beam.

⇒ It also provide at the Corner of the Slabs.

⇒ L-Beam are typical Floor Beam. Because of their reduced overall structure depth, The Beam are in prestressed or reinforced Concrete.

Flexural analysis of I-Beam:-

1- For Finding the ultimate Factored moment we are the following formula:-

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

2) - Effective width for T-Beam is Calculate as:-

1) - $16(hf) + bw$
2) - c/c distance
3) - span/4
4) - $\frac{CTS}{2} + bw$

3) Checking whether Rectangular or T-Beam Analysis:-

i) - if $a > hf$ → special analysis is required
ii) - if $a < hf$ → Rectangular Beam analysis is required

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

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

where

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

(5) - For checking minimum width for Bars accomodation:-

$$\text{No. of bars} = \frac{\text{Area of steel}}{\text{Area of Single Bar}}$$

(1)- Design moment is given by:-

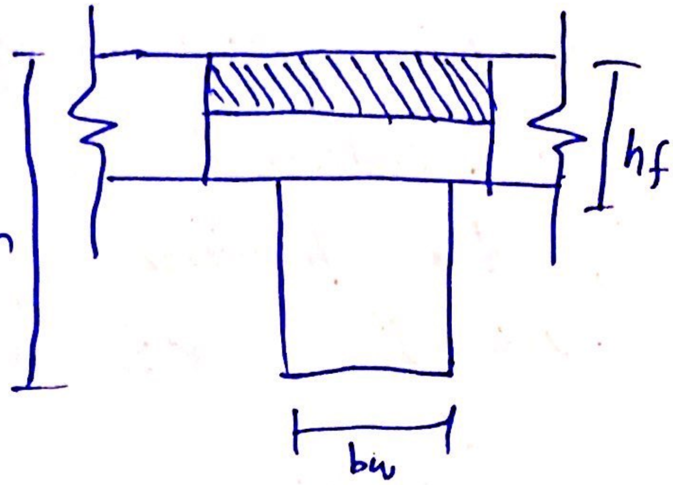
$$md = \phi \times fy' \times Ast \times (d - a/2) \rightarrow \text{if } a < hf.$$

$$md = \phi \times \{As \times fy \times (d - hf/2) + (As - AST) + fy \times (d - a/2)\} \rightarrow \text{if } a > hf$$

Q No 4

What is the difference between Case-I And Case-II in the design of T-Beam.

Cas-I :-



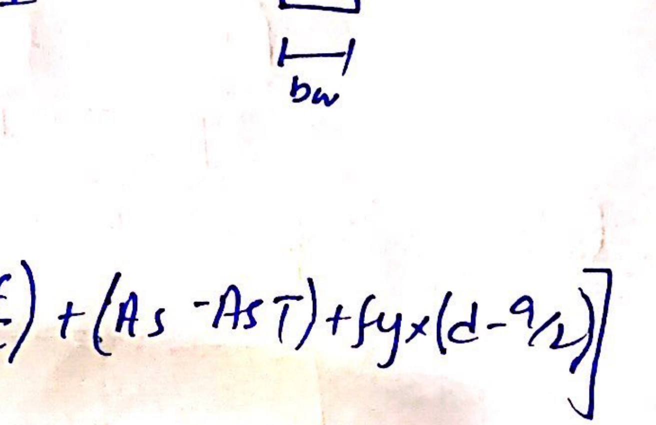
From the figure

$a < hf$

So in this case, Rectangular Beam analysis is required so, The Design moment formula will be

$$Md = \phi \times fy \times AST \times (d - a/2)$$

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

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

7834 (18)

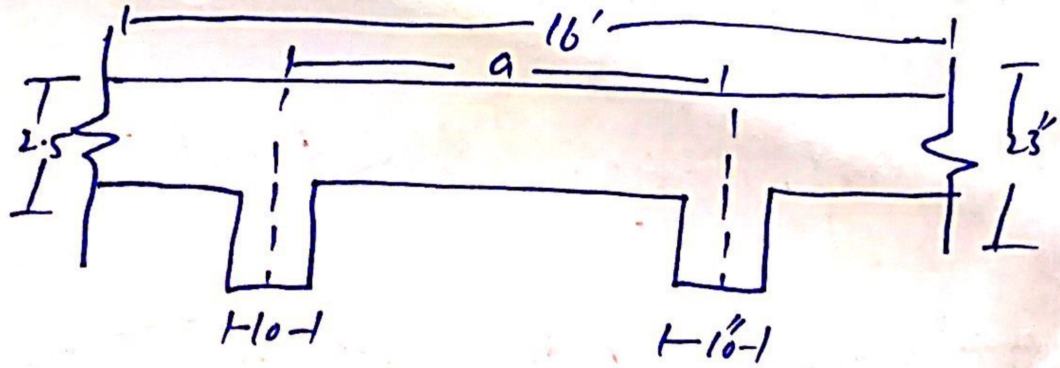
Q No 5

A Floor system consists of 3.5" Concrete Slab supported by 16' simple span spaced at 9' c/c the beam having a width of 10" and effective depth of 18" and total height is 23". Calculate the necessary flexural reinforcement if the factored applied moment is 5800 kip-inch. Use $f'c = 3$ Ksi and $fy = 60$ ksi.

Given :.

Height of Flange = 3.5"
c/c distance = 16'
Length/span of the beam = 10"
Web width (bw) = 18"
Effective depth = 23"
Total factored moment (Mu) = 5800 kip-inch
$f'c = 3$ Ksi
$fy = 60$ ksi

Sol:-



Step#1:- Calculat the effective width for T-Beam

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

2- c/c distance $= 9\times12 = 108''$

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

Selecting the least value of be as,

$$\boxed{b_e = 48''}$$

Step#2:- Check whether rectangular or T-Beam Analysis is required.

Trial #01:- Let $a = h_f = 3.5''$

$$A_{ST} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{5800}{0.90\times60\times(18-3.5/2)} = 6.61\,in^2$$

Trial #02:- $a = \dfrac{A_{ST}\times f_y}{0.85\times f'_c\times b_e}$

$$a = \frac{6.61\times60}{0.85\times3\times48} = 3.2''$$

$A_{ST} = 6.55\,in^2 \Rightarrow 2.2'' < 3.5''$

So Rectangular Beam Design is Required.

Trial #3:- $a = 3.21''$

$$A_{st} = \frac{5800}{0.90\times60\left(18-\frac{3.21}{2}\right)} = \boxed{6.55\,in^2}$$

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

Step # 03:- chick ρ_{max} and ρ_{min}

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

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

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

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

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

$$0.003 < 0.036 < 0.013$$

$\Rightarrow$ First we have the 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:- Finding the value of Mu_2

By Formula

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

First finding the value of "a"

$$\Rightarrow a = \frac{Ast \times fy}{0.85 \times f'c \times b} = \frac{2.43 \times 60}{0.85 \times 3 \times 10}$$

7839 (21)

$a = 5.72''$

$\Rightarrow M_{u2} = 0.90 \times 2.43 \times 60 \times (18 - 5.72/2)$

$$\boxed{M_{u2} = 1986.67 \text{ kip-inch}}$$

As $M_{u2} < M_u$

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

Step # 5 :- Finding difference of moment, And Area of Steel :-

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

$= 5800 - 1986.67$

$$\boxed{M_{u1} = 381.33 \text{ kip-inch}}$$

By Formula

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

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

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 Bars:-

In tension zone:-

let we use #8 bar

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

By formula

$$No. \ of \ Bars = \frac{Area \ of \ Steel}{Area \ of \ single \ bar} = \frac{6.99}{0.785} = 8.9 \approx 9$$

So 9 #8 bars.

In Compression Zone:-

Let we use #7 bars

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

By formula

$$No. \ of \ Bars = \frac{Area \ of \ Steel}{Area \ of \ Single \ Bar} = \frac{4.56}{0.601} = 7.5 \approx 8$$

So 8 #7 bars

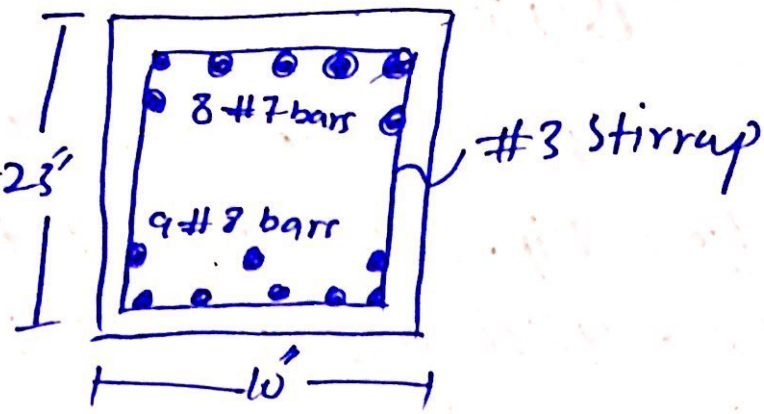
Step #8:- Minimum width for accomodation Bars:-

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

$$= 20.75''$$

As $20.75'' > 10''$

So the bars will be placed in multiple Layers.



Effective depth $= 23 - 1.5 + 3/8 + 8/8 + \frac{1}{2}(8/8) = 19.6''$

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

Step #9 :- Find the design moment.

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

First $a = \dfrac{(A_s - A'_{st} \times f_y}{0.85 \times f'_c \times b} = \dfrac{9 \times 0.75 - 3 \times 0.601 \times 60}{0.85 \times 3 \times 10} = 5.31''$

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

$\Rightarrow \boxed{M_d = 6328.38}$

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

Q No 6

A beam is revesied to developed and ultimate moment of 6000 kip-inches limited to 14x26 inch size, use $f'c = 4ksi$ and $fy = 60 ksi$. Determine Flexural reinforcement assume two rows of tensile reinforcement and effective depth of beam is 22 inches.

Sol:-

Given data:-

Breadth = 14"
Height = 26"
Concrete Compression Strength ($f'c$ = 4ksi
Steel tensile strength (fy) = 60ksi
ultimate factored moment (Mu) = 6000 kip-inches
Effective depth of beam = 22"
Assume effective Cover (d') = 2.5"

Step # 1:- (Reinforcement Ratio)

By Formula

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

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

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

Step # 2 :- (Area of Steel)

we know that

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

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

Step # 3 :- (Design Moment)

By using formula

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

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

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

$= 5537.4$ kip - inch

As, $5537.4 < 6000$

So we have to design a section as doubly

Reinforcement :-

Step # 4 Differences In Moments:-

$$M_{u1} = M_u - M_{u2}$$
$$= 6000 - 5537.4$$
$$\boxed{M_{u1} = 462.6 \text{ Kip-inches}}$$

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,

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

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

Step # 6:- Total Steel Area:-

$$A_{sF} = A_{st} + A'_{st}$$
$$= 5.54 + 0.44 = 5.98 \text{ in}^2$$

Step # 7:- Selection and No. of bars used:-

1- Steel in Tension zone:-

we use # 7 bars

$$dia = (7/8)'' = 0.875'', \quad Area = \frac{\pi}{4}(0.875)^2$$
$$= 0.601 \text{ in}^2$$

So, No. of Bars $= \dfrac{Ast}{\text{Area of single Bars}}$

$= \dfrac{5.98}{0.601} = 9.9 \simeq 10$ bars

So 10 # 7 bars

② - Steel in Compression Zone:-

we use # 5 bar,

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

$= 0.306\ in^2$

So No. of bar $= \dfrac{Ast}{\text{Area of single bars}}$

$= \dfrac{0.44}{0.306} = 1.43 \simeq 2$ bars

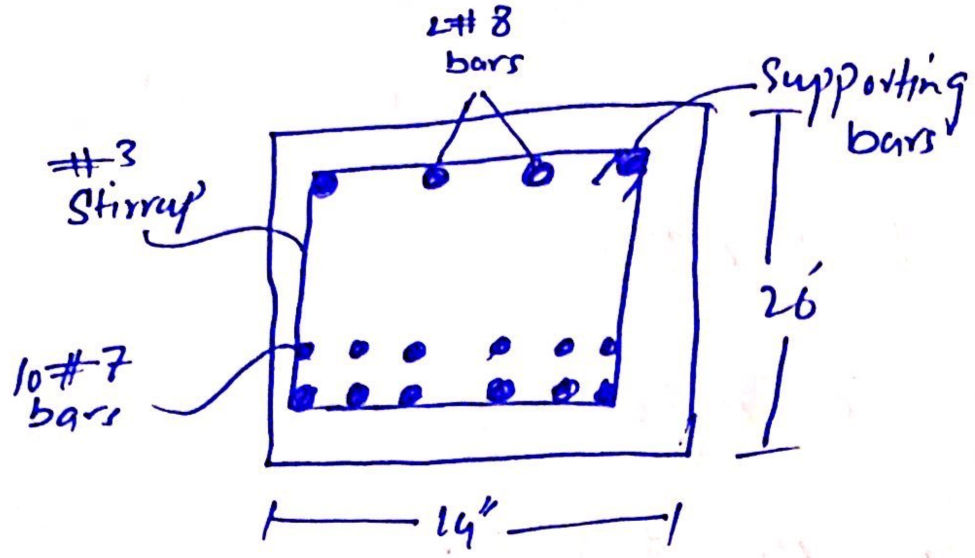
So 2 #5 bars

Step # 8:- Minimum Width of Beam:-

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

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

So not good in one layer



Now ⇒ effective depth $= 26 - 1.5 - 3/8 - 7/8 - \frac{1}{2}(7/8)$
$= 22.82''$

⇒ effective Cover $= 1.5 + 3/8 + \frac{1}{2}(5/8) = 2.18''$

Step # 9 :-

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

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

$$= \frac{(10 \times 0.601 - 2 \times 0.306) \times 60}{0.85 \times 4 \times 14} = 6.80''$$

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

Md = 7047.6 kip-inches

As 7047.6 > 6000

Design is OK!