Assignment

Name Waqas Hussain

ID# 7799

Semester 6th

Section "A"

Subject PRCD-I

Submitted to

Engr Fawad Khan
Sir

Question#02:

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 $f_y = 60$ ksi, then design the beam for shear.

Given data:-

Breadth of web of Beam = $b_w = 14''$

Effective depth = $d = 22''$

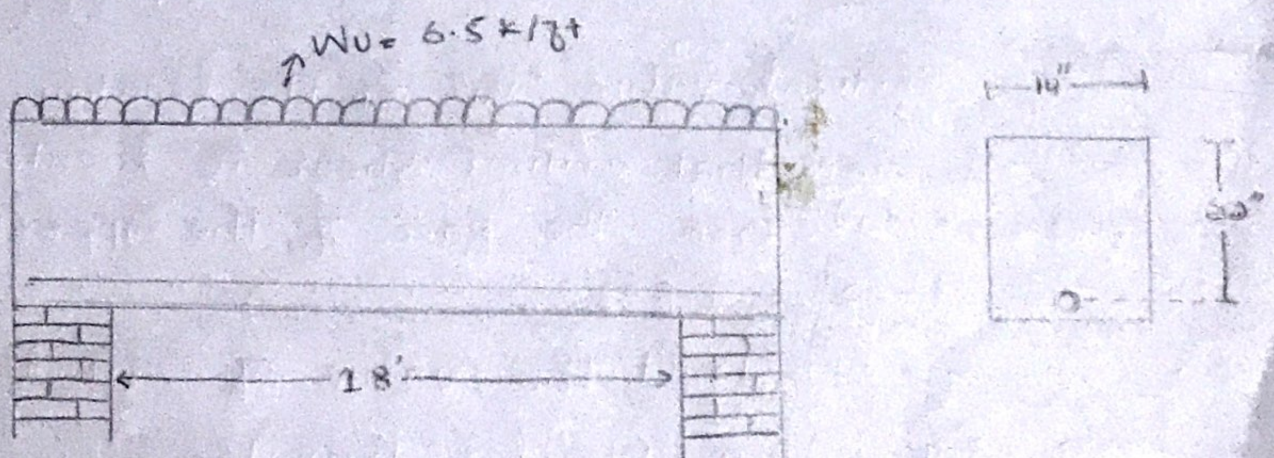
Load = $W_u = 6.5$ k/ft

Area of Steel = 7 in²

$f'_c = 4$ ksi or 4000 psi

$f'_y = 60$ ksi or 60,000 psi

Solution:



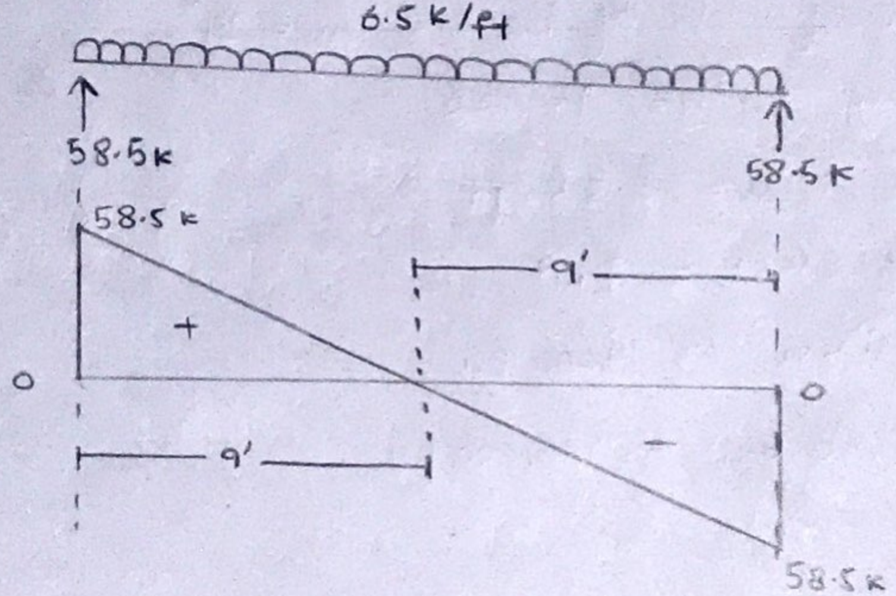
Step # 01: To find reactions on the Supports.

Total load = 6.5×18 = 117 kips

As the beam is simply supported and having a UDL So both the Support will have Same reactions. So,

$$R_A = R_B = \frac{117}{2} = 58.5 \text{ kips}$$

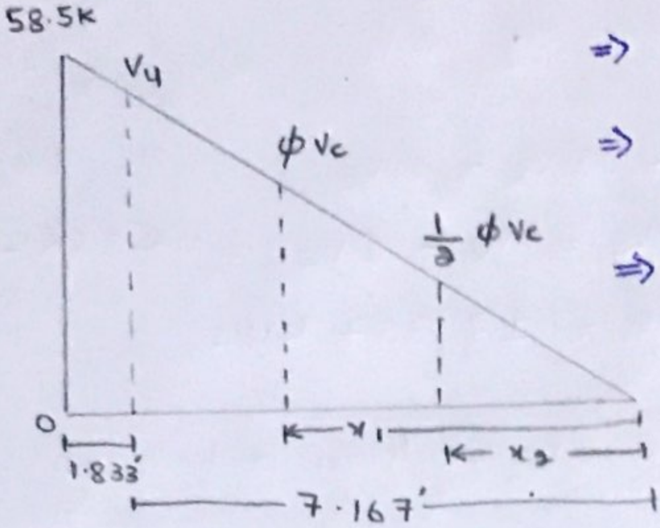
Step # 02: To draw SFD of the beam



Step # 03: Critical shear value "Vu" & its location

As we all know that critical Shear is located at distance "d" from the face of the Support. which is d = 22" = 1.833'

So we can find out the value of critical Shear by using similar triangles method.



$$\Rightarrow \frac{58.5}{9} = \frac{V_u}{7.167}$$

$$\Rightarrow V_u = \frac{58.5 \times 7.167}{9}$$

$$\Rightarrow V_u = 46.586\ K$$

<u>Step#04</u>: To find values and distances of "ϕV_c" & "$\frac{1}{2}\phi V_c$"

As we know by formula

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

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

$$= 29219.446\ lbs$$

$$\Rightarrow \phi V_c = 29.219\ kips$$

For its location,

$$\frac{58.5}{9} = \frac{29.219}{x_1} \Rightarrow x_1 = \frac{29.219 \times 9}{58.5}$$

$$\Rightarrow x_1 = 4.495' \ \cancel{kip}$$

For "$\frac{1}{2}\phi V_c$",

As $\phi V_c = 29.219 \Rightarrow \frac{1}{2}\phi V_c = \frac{1}{2} \times 29.219$

$$\Rightarrow \frac{1}{2}\phi V_c = 14.61\ kips$$

<u>Location</u> $\rightarrow$ $\frac{58.5}{9} = \frac{14.61}{x_2} \Rightarrow x_2 = \frac{14.61 \times 9}{58.5}$

$$x_2 = 2.248'$$

Step#05:- value of "ϕV_s"

As we know

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

$$\Rightarrow \phi V_s = V_u - \phi V_c = 46.586 - 29.219$$

$$\Rightarrow \phi V_s = 17.367 \text{ kips}$$

Step#06: Check on section adequency

So

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

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

$$= 116.878 \text{ kips}$$

As we see that

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

So the Section is adequate.

Step #07: Check on maximom spacing for stirrups

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

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

$$= 58.439 \text{ kips}$$

As

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

So maximum spacing will be Selected from the four conditions

1 $\Rightarrow S_{max} = 24''$

2 $\Rightarrow \dfrac{d}{2} = \dfrac{22}{2} = 11''$

3 ⇒ $S_{max} = \dfrac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$ ∵ $A_v = 0.22\ in^2$ for two leg stirrup using #3 bar.

$= \dfrac{0.22 \times 60{,}000}{0.75 \times \sqrt{4000} \times 14} = 19.877''$

4 ⇒ $S_{max} = \dfrac{A_v \times f_y}{50 \times b_w} = \dfrac{0.22 \times 60{,}000}{50 \times 14}$

$= 18.857''$

As $S_{max} = 11''$ is the smallest value in the above four conditions, So

$S_{max} = 11''$ c/c

Step#08: Stirrups spacing at critical section

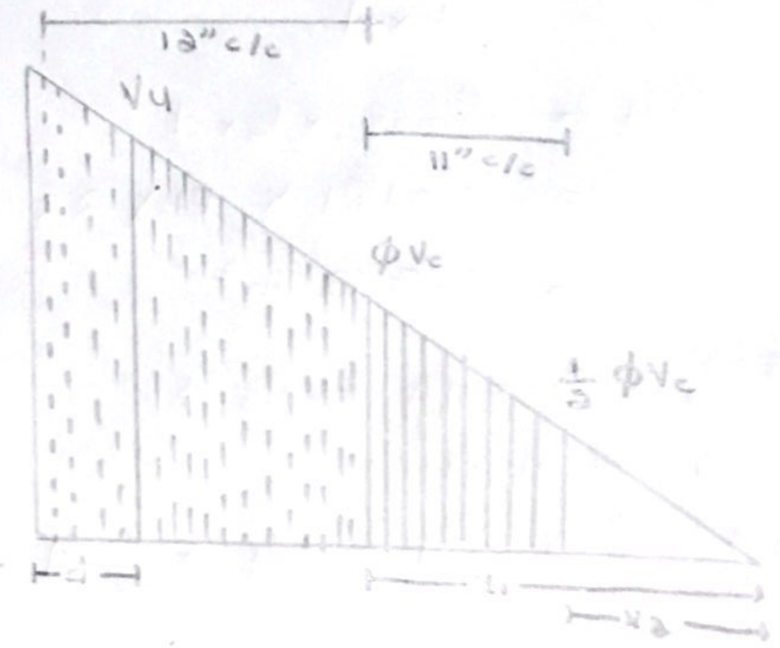
$S = \dfrac{\phi \times A_v \times f_y \times d}{V_u - \phi V_c} = \dfrac{0.75 \times 0.22 \times 60 \times 22}{46.586 - 29.219}$

$S = 12.541'' \approx 12''$ c/c

Step#09: Final sketch

1st stirrup

$\Rightarrow \dfrac{S}{2} = \dfrac{12}{2} = 6''$



Question # 06:-

A beam is revised to developed and ultimate moment of 6000 k-inchis limited to 14 x 26 inch size, use $f'_c = 4\,ksi$ & $f_y = 60\,ksi$. Determine flexural reinforcement assume two rows of tensile reinforcement and effective depth is 22 inch.

Solution:

Step #01 : Reinforcement Ratio

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

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

$$\rho_{max} = 0.0181$$

Step #02: Area of Steel

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

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

$$= 0.0181 \times 14 \times 22$$

$$A_{st} = 5.563\ in^2$$

Step # 03: Design moment

As we know that

$$Mu_2 = \phi \times A_{st} \times f_y \times \left(d - \frac{a}{2} \right)$$

As

$$a = \frac{A_{st} \times f_y}{0.85 \times f'_c \times b} = \frac{5.563 \times 60}{0.85 \times 4 \times 14}$$

$$a = 7.012''$$

So

$$M_{u_2} = 0.90 \times 5.563 \times 60 \times \left[22 - \frac{7.012}{2}\right]$$

$$M_{u_2} = 5555.635 \text{ kip-inch}$$

As

$M_{u_2} < M_u$, so we have to design the beam as doubly reinforced.

Step#04: M_{u_1}

$$M_{u_1} = M_u - M_{u_2} = 6000 - 5555.635$$

$$M_{u_1} = 444.365 \text{ kip-inch}$$

Step#05: A_{st} in compression zone

As

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

$$\Rightarrow A'_{st} = M_{u_1} / \phi \times f_y \times (d - d')$$

$$= \frac{444.365}{0.90 \times 60 \times (22 - 2.5)}$$

$\because d' = 2.5''$ Assumed

$$A'_{st} = 0.422 \text{ in}^2$$

Step#06: Total steel area

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

$= 5.563 + 0.422$

$A_s = 5.985 \text{ in}^2$

Step#07: No of bars

1) For tension zone:

lets use/try #8 bar

Area of #8 bar $= \frac{\pi}{4}\left(\frac{8}{8}\right)^2 = 0.785 \text{ in}^2$

So,

No of bars $= \frac{A_s}{\text{Area of bar}} = \frac{5.985}{0.785}$

$= 7.62 \approx 8$ bars

$\Rightarrow$ 8 #8 bars

2) For Compression zone:

lets try #4 bar

Area of #4 bar $= \frac{\pi}{4} \times \left(\frac{4}{8}\right)^2 = 0.196$

So, No of bars $= \frac{A'_{st}}{\text{Area of Single bar}} = \frac{0.422}{0.196}$

$= 2.153 \approx 2$bars

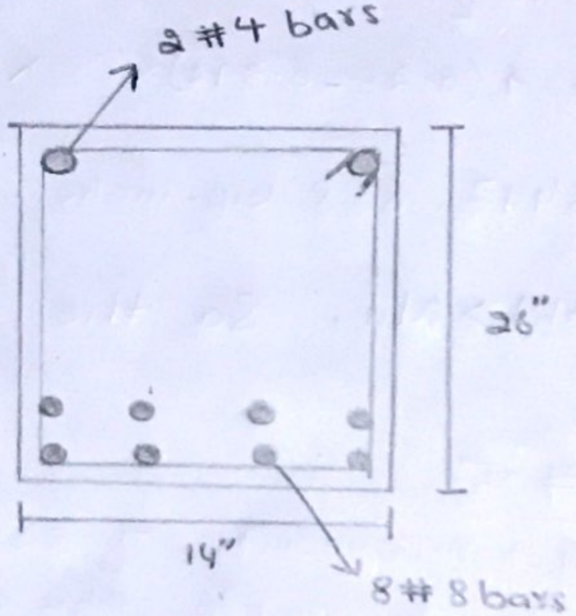
So, 2# 4 bars

Step#8 : b_{min}

$$b_{min} = (2 \times 1.5'') + \left(2 \times \frac{3}{8}''\right) + \left(8 \times \frac{8}{8}''\right) + \left(7 \times \frac{8}{8}\right)''$$

$$= 18.75'' > 14''$$

So the bars will be in two layers in tension zone



$$d = 26'' - 1.5'' - \frac{3}{8}'' - \frac{8}{8}'' - \frac{1}{2}\left(\frac{8}{8}\right)''$$

$$d = 22.625''$$

$$d' = 1.5'' + \frac{3}{8}'' + \frac{1}{2} \times \frac{4}{8}''$$

$$d' = 2.125''$$

Step#09: Design moment

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

$$a = \frac{(A_{st} - A'_{st}) \times f_y}{0.85 \times f'_c \times b}$$

$$= \frac{[(8 \times 0.785) - (2 \times 0.196)] \times 60}{0.85 \times 4 \times 14}$$

$$a = 7.422''$$

$$M_d = 0.90 \left[0.392 \times 60 \times (22.625 - 2.125) + (6.28 - 0.392) \times 60 \times \left(22.625 - \frac{7.422}{2}\right)\right]$$

$$M_d = 6447.688 \text{ kip-inches}$$

As $M_d > M_u$, So the design is Ok!

Question #05

A floor System consists of 3.5" concrete slab Supported by 16' Simple span spaced at 9' c/c, the beam having Web 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 $f_y = 60$ ksi.

Given data:-

Height of flange = H_f = 3.5"

Span of the beam = L = 16'

c/c distance = 9'

web width = b_w = 10"

Effective depth = d = 18"

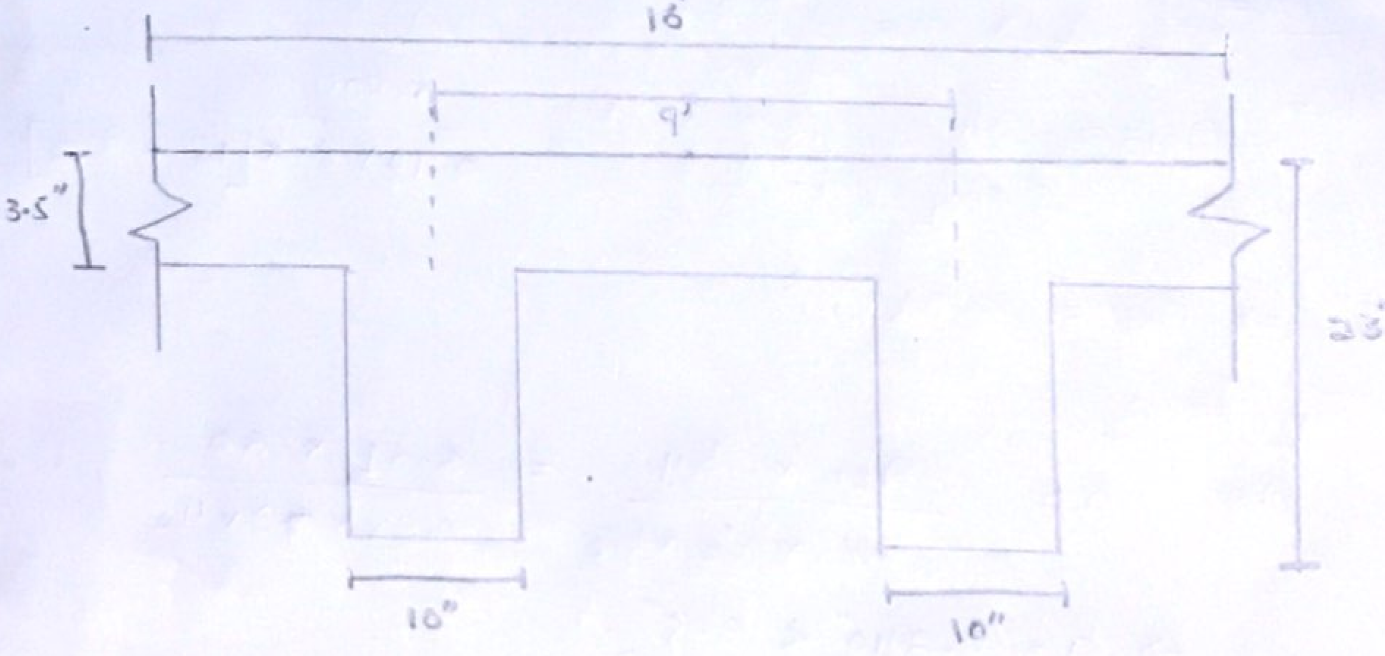
Total height = h = 23"

Total factored moment = M_u = 5800 kip-inch

f'_c = 3 ksi or 3000 psi

f_y = 60 ksi or 60,000 psi

Solution:



Step#01

To Calculate the effective width (be) for the T beam. So,

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

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

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

As 48" is the least value we have So,

$$b_e = 48''$$

Step #02:

To check either rectangular or T-beam analysis is required.

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

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

$\Rightarrow A_{st} = 6.61 \text{ in}^2$

Trial #02:

As $a = \frac{A_{st} \times f_y}{0.85 \times f'_c \times b_e} = \frac{6.61 \times 60}{0.85 \times \cancel{4}3 \times 48}$

$\Rightarrow a = 3.240'' < 3.5''$

So Rectangular beam design is required

Scanned with CamScanner

Now

$$A_{st} = \frac{5800}{0.90 \times 60 \times \left[18 - \frac{3.24}{2}\right]}$$

$$\Rightarrow A_{st} = 6.557 \text{ in}^2 \neq 6.61 \text{ in}^2$$

Trial #03:

$$a = \frac{6.557 \times 60}{0.85 \times 3 \times 48} = 3.214''$$

$$\Rightarrow A_{st} = \frac{5800}{0.90 \times 60 \times \left[18 - \frac{3.214}{2}\right]}$$

$$\Rightarrow A_{st} = 6.552 \neq 6.557$$

Trial #04:

$$a = \frac{6.552 \times 60}{0.85 \times 3 \times 48} = 3.212''$$

$$A_{st} = \frac{5800}{0.90 \times 60 \times \left(18 - \frac{3.212}{2}\right)}$$

$$A_{st} = 6.552 = 6.552$$

So Area of Steel is 6.552 in^2

Step# 03: δ_{max} and δ_{min}

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

$$\Rightarrow \delta_{max} = 0.0135$$

$$\rho_{min} = \frac{200}{f_y} = \frac{200}{60{,}000}$$

$$\rho_{min} = 0.0033$$

$$\rho = \frac{A_{st}}{b \times d} = \frac{6.552}{10 \times 18} = 0.0364$$

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

$$\Rightarrow 0.0033 < 0.0364 \nless 0.0135$$

So we have to design it as "Doubly reinforced beam"

Now we will find the Area of Steel against ρ_{max}.

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

$$\Rightarrow A_{st} = \rho_{max} \times b \times d = 0.0135 \times 10 \times 18$$

$$A_{st} = 2.43 \text{ in}^2$$

<u>Step#04:</u> M_{u2}

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

$$= \cancel{0.90} \times \cancel{2}.$$

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

$\Rightarrow a = 5.718''$

Hence

$$Mu_2 = 0.90 \times 2.43 \times 60 \times \left(18 - 5.718/2\right)$$

$$Mu_2 = 1986.802 \text{ Kip-inch} < 5800 \text{ kip-inch}$$

Step #05: Mu_1 & A'_{st}.

As

$$Mu = Mu_1 + Mu_2$$

$$\Rightarrow Mu_1 = Mu - Mu_2$$

$$= 5800 - 1986.802$$

$$\boxed{Mu_1 = 3813.188 \text{ kip-inch}}$$

As

$$A'_{st} = \frac{Mu}{\phi \times fy \times (d-d')}$$

$$= \frac{3813.188}{0.90 \times 60 \times (18 - 2.5)}$$

$$\Rightarrow \boxed{A'_{st} = 4.556 \text{ in}^2}$$

Step#06: Total steel area

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

$$= 2.43 + 4.556$$

$$\boxed{As = 6.986 \text{ in}^2}$$

Step#07:

Bar selection

i) For tension zone:

let use #10 bar,

dia of bar $= \left(\frac{10}{8}\right)''$, Area of bar $= \frac{\pi}{4} \times \left(\frac{10}{8}\right)^2$

$= 1.227 \text{ in}^2$

So,

No of bars $= \dfrac{\text{Area of Steel}}{\text{Area of a bar}}$

$= \dfrac{6.552}{1.227}$

$= 5.34 \approx 5$

5 # 10 bars

ii) For compression zone,

let use #8 bar.

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

So, No of bars $= \dfrac{4.556}{0.785}$

$= 5.8 \approx 6$

6 # 8 bars

Step# 8 :

$$b_{min} = (2 \times 1.5) + (2 \times 3/8) + (5 \times 10/8) + (4 \times 10/8)$$

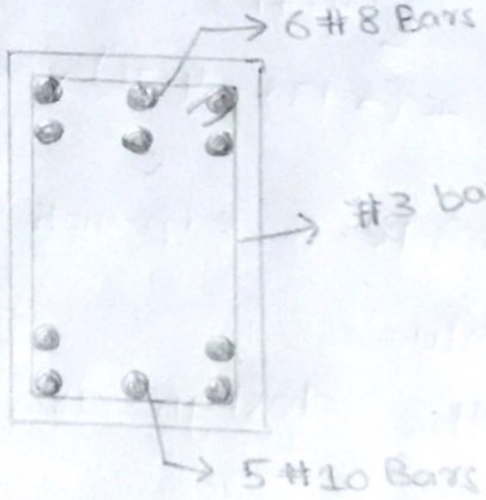
$b_{min} = 15'' > 10''$

So, the bars in tension zone will be in two layers.

$$b_{min} = (2 \times 1.5) + (2 \times 3/8) + (6 \times 8/8) + (5 \times 8/8)$$

$b_{min} = 14.75'' > 10''$

So the steel bars in compression zone will also be in two layers



Effective depth $= d = 23 - 1.5 - \frac{3}{8} - \frac{10}{8} + \frac{1}{2}\left(\frac{10}{8}\right)$

$= 19.25''$

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

$= 3.375'$

Step#09: Design moment

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

For this

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

$$= \frac{(6.136 - 4.71)\, 60}{0.85 \times 3 \times 10}$$

$$a = 3.355 \text{ in}$$

#10 bar area $= 1.227$

$As = 5 \times 1.227$

$As = 6.136 \text{ in}^2$

#8 bar area $= 0.785$

$A'st = 4.71 \text{ in}^2$

$$\Rightarrow Md = 0.90 \left[\cancel{6.136}\; 4.71 \times 60 \times (19.25 - 3.375) + (6.136 - 4.71) \times 60 \times \left(19.25 - \frac{3.355}{2}\right) \right]$$

$$Md = 6390.8 \text{ kip-inch}$$

$Md > Mu$

So the design is OKay!

Q1) Explain in detail types of stirrups with figures and also explain ACI codes for Shear design.

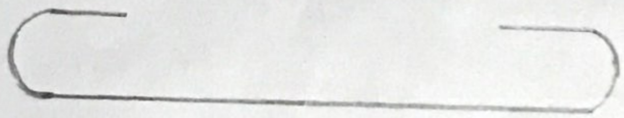
Ans: STIRRUP:

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

TYPES OF STIRRUPS:

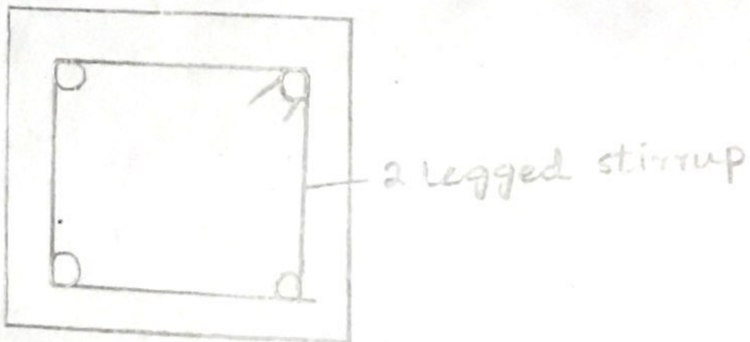
1) Single Legged Stirrup:-

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



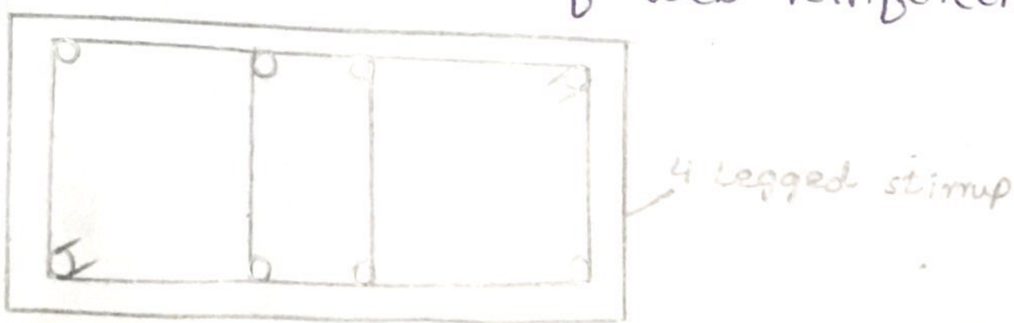
2) Two Legged stirrup:-

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

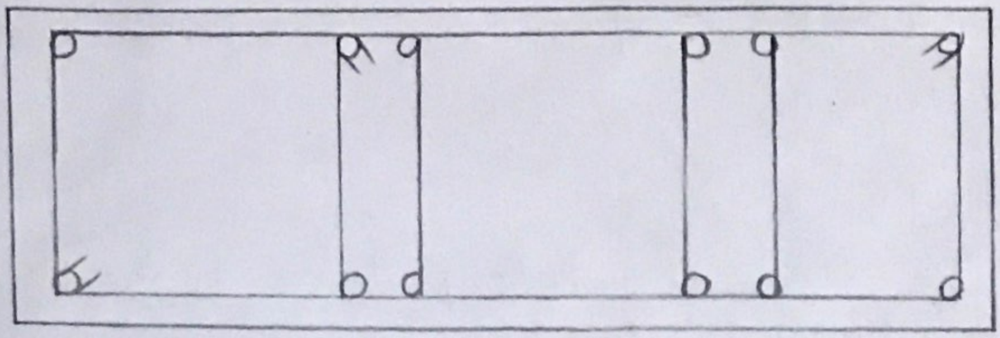


3) Four Legged stirrup:-

These stirrups are used in case of web reinforcement.



4) Six Legged Stirrup:-



ACI CODES FOR SHEAR DESIGNS OF A BEAM

According to ACI-318, following are the formulas used for 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 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 web reinforcement 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 at a given section)

=) For minimum Reinforcement Area :-

$$A_{v_{min}} = \frac{0.75 \times \sqrt{f'_c} \times b_w \times S}{f_y} \quad \text{or} \quad \frac{50 \times b_w \times S}{f_y} \rightarrow \left[\begin{array}{c}\text{Higher value}\\ \text{is selected}\end{array}\right]$$

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

$$S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w} \quad \text{or} \quad \frac{A_v \times f_y}{50 \times b_w} \rightarrow \left[\begin{array}{c}\text{Lesser value}\\ \text{is selected}\end{array}\right]$$

4) No web-reinforcement is required if :-

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

→ Between critical section "Vu" and "ϕVc", spacing between web reinforcement can be fined by,

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

5) If $V_s \le 4 \times \sqrt{f'c} \times b_w \times d$:-

Then more spacing for stirrups will be the smallest of the following.

1) 24"
2) d/2
3) $S_{max} = \frac{A_u \times f_y}{0.75 \times \sqrt{f'c} \times b_w}$
4) $S_{max} = \frac{A_u \times f_y}{50 \times b_w}$

∵ (V_s = shear force carried by web reinforcement)

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

↓

Max-spacing will be halved

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

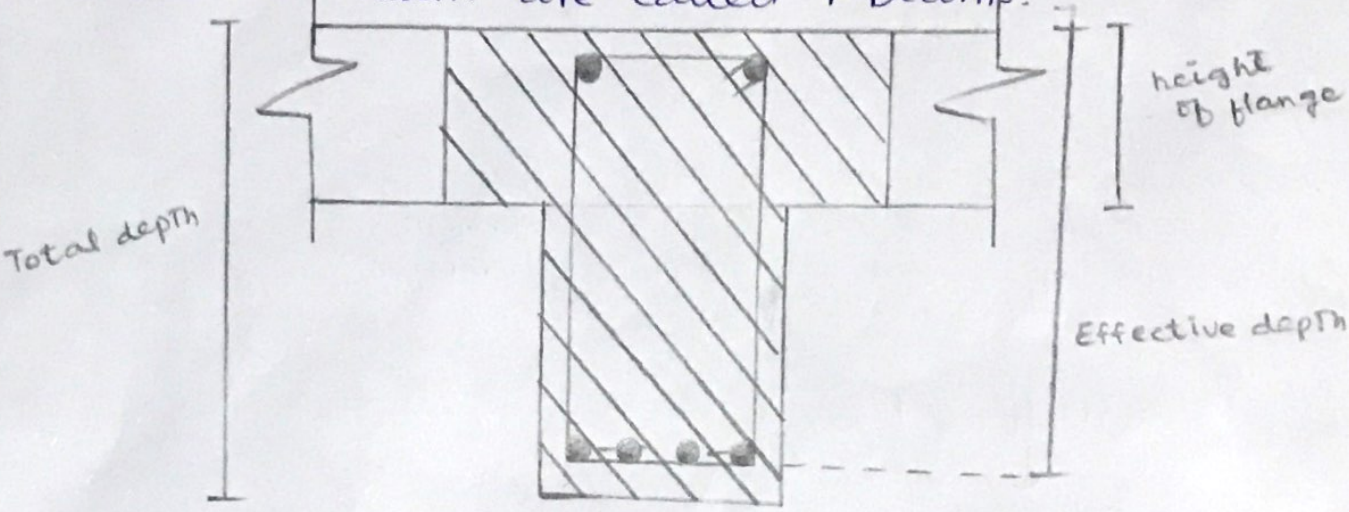
↓

Then either increase cross-sectional dimensions or increase f'c.

Q3) Define both the T-Beam and L-Beam with the help of diagram. Also explain flexural analysis of T-Beam.

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-Beams.



=> Because of their T-shape, these beams are called T-Beams.

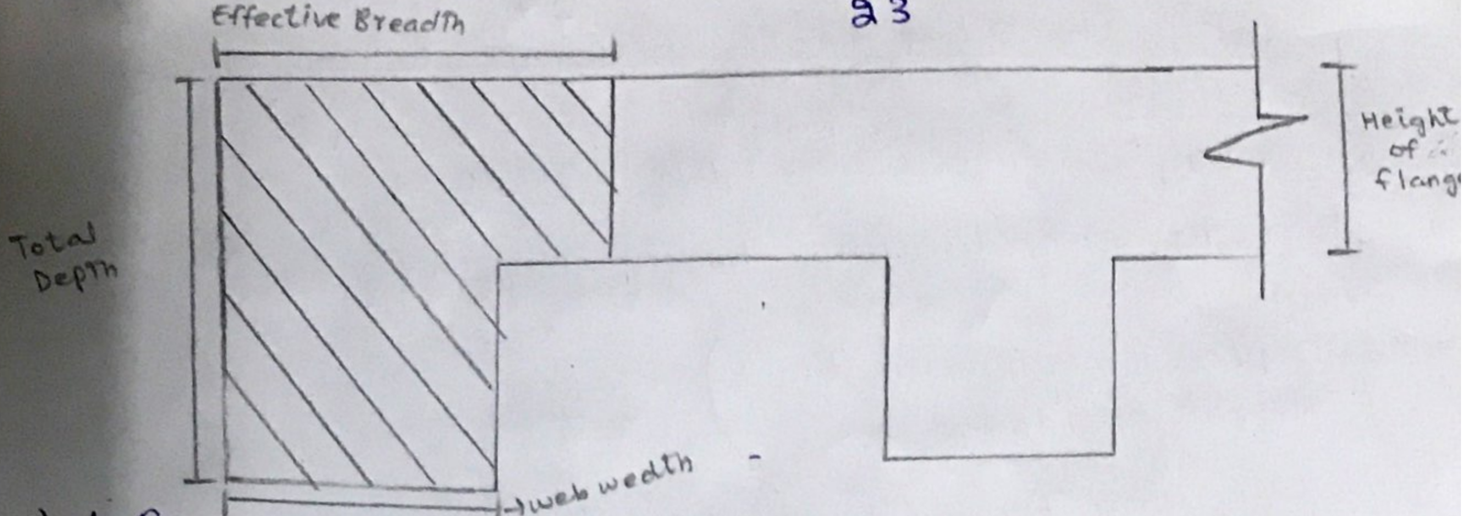
=> It is provided that at the center of the slab to resist the loads.

=> The upper most area of the beam attached to the slab is 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 the corner of the floor is called L-Beam.



⇒ L-Beam are also called Edge Beams.

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

⇒ L-Beams are typical floor beams because of their reduced overvall structural depth, the beams are in prestressed or reinforced concrete.

FLEXUAL ANALYSIS OF T-BEAM:-

Flexual analysis of T-Beam consists of the following steps:-

1- For finding the ultimate factored moment, we use the following formula.

$$M_U = \frac{W_U \times L^2}{3}$$

∵ (W_U = Total Factored Load, L = Total Span of the beam)

2- Effective width (be) for T-Beam is calculated as:-

1. $16(h_f) + b_w$
2. c/c distance
3. span/4
4. $\frac{CTS}{2} + b_w$

∵ (h_f = height of flange, CTS = Clear Transverse span)

- We have to select the least value from above formulas
- If c/c distance is given, then there is no need of $\frac{CTS}{2} + b_w$

3- Checking wheather Rectangular or T-Beam Analysis is required:-

i) If $a > hf$ → Special analysis is required.

ii) If $a < hf$ → Rectangular beam analysis is required.

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

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

∵ ϕ = strength reduction factor

d = Effective depth

a = compression block depth

bw = web width of beam

5- For checking the range of reinforcement Ratio,

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

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

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

6- Formula for Finding No. of bars required is,

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

7- For checking minimum width for bars accomodation:-

$$b_{min} = 2(\text{clear cover}) + 2(\text{dia of stirrup}) + \text{No. of bars}(\text{dia of bar}) + \text{Spacing b/w bars}(\text{dia of bar})$$

8- Design Moment is given by,

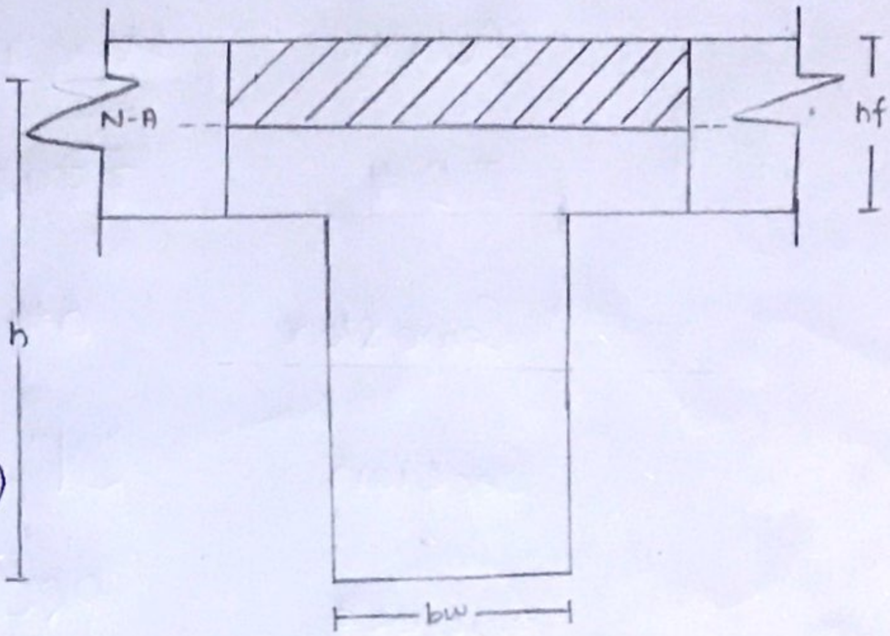
$$Md = \phi \times fy \times Ast \times (d - a/2) \rightarrow \text{if } a < hf$$

$$Md = \phi \times [As \times fy \times (d - hf/2) + (As - Ast) + fy \times (d - a/2)] \rightarrow \text{if } a > hf$$

Q4) What is the difference b/w CASE-1 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
$M_d = \phi \times f_y \times A_{st} \times (d - a/2)$



CASE-II :-

From the figure,
$a > h_f$
so in this, special beam analysis i.e, T-Beam analysis is required.
So
the required Design Moment will be,
$M_d = \phi \times [A_s \times f_y \times (d - \frac{h_f}{2}) + (A_s - A_{st}) + f_y \times (d - a/2)]$