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Section A

Semester 6th

Program BSc Civil Engr

Assigment Plain & Reinforced Concrete Desig I

Submitted to Engr Fawad

Stirrups:-

A stirrup is a closed loop of reinforcement bar that is used to hold main reinforcement bars together in RCC structure.

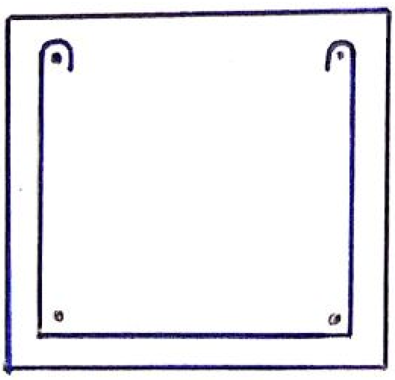
Stirrups provide the lateral support to the main bars against buckling.

Types

Single Legged Stirrups:-

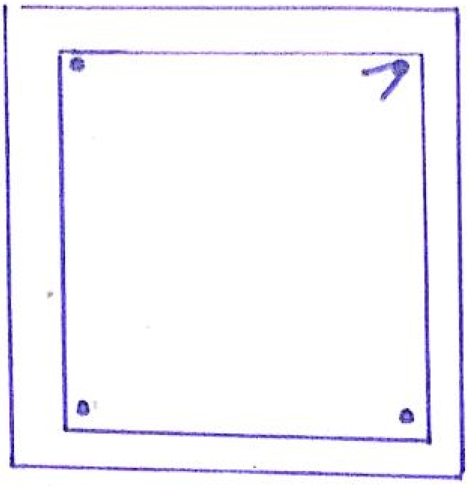
The single legged stirrups have rarely been used because they are mostly used when binding only two rods.

A single stirrup has two legs. and used when binding only two rods.



Double Legged Stirrups:-

Double legged stirrups are adequate for typical beam with relatively short widths. To provide this stirrup a minimum 4 number of rod is required.

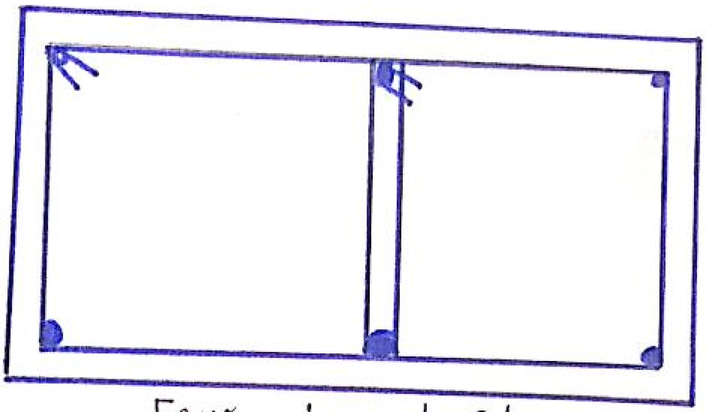


Double Legged stirrup.

Four Legged Stirrups:-

If double stirrup is applied to tie a beam or column simultaneously, it is called 4 legged stirrup.

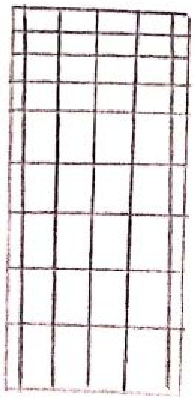
It can resist greater shear force.



Four legged stirrup.

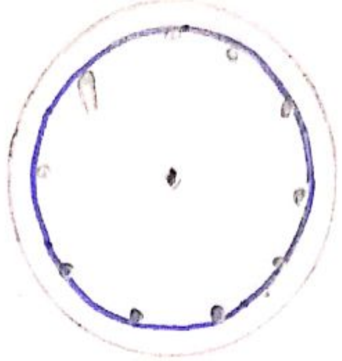
Helical Stirrup:-

Mostly it is used in pile column and pile foundation the stirrup can use either Helical or circular.

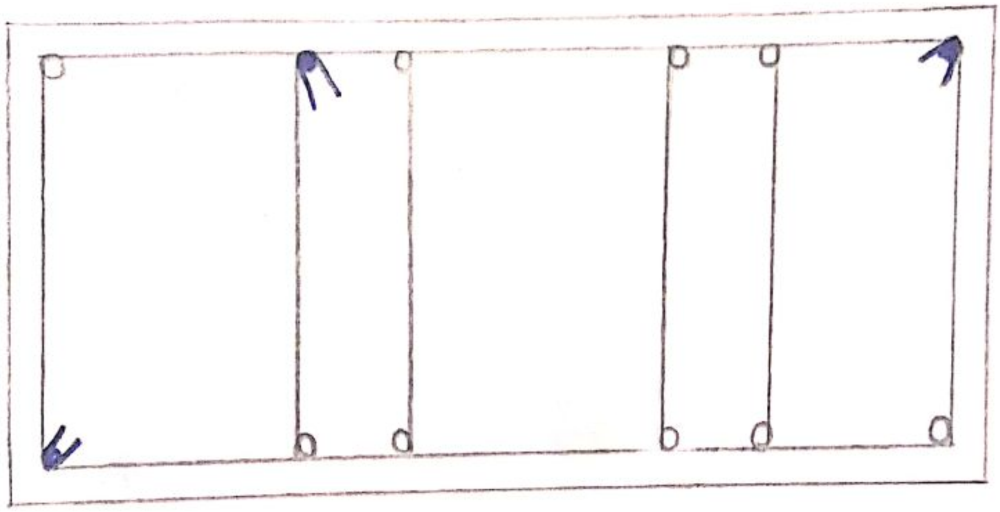


Circular Stirrup:-

It is used when column is of round shape.



Six Legged Stirrup :-



ACI CODES FOR SHEAR DESIGN OF A BEAM

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

1. Critical Section:-

Critical section occurs at 45° and is at distance (d)" from 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 $V_u \le \phi V_c$, then theortically no web reinforcement is required. However ACI code required. However ACI code require provision of atleast a minimum area of web reinforcement equal to.

Where $\phi = 0.75 \rightarrow$ for shear design.

V_u = Total factored shear applied at a given section.

For Minimum Reinforcement area:-

$$A_{v_{min}} = \frac{0.75 \times \sqrt{f_c'} \times b_w \times S}{f_y} \text{ or } \frac{50 \times b_w \times S}{f_y} \rightarrow \text{Higher value is selected.}$$

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

$$S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{f_c'} \times b_w} \text{ or } \frac{A_v \times f_y}{50 \times b_w} \rightarrow [\text{lesser value is selected}]$$

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 $V_s \le 4 \times \sqrt{f_c'} \times b_w \times d$, then maximum spacing for stirrups will be smallest as

i) 24" ii) $d/2$ iii) $S_{max} = \frac{A_v \times f_y}{0.75 \sqrt{f_c'} \times b_w}$

iv) $S_{max} = \frac{A_v \times f_y}{50 \times b_w}$ Where V_s = Shear force carried by web reinforcement

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

Maximum spacing will be halved.

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

Then either increase cross-sectional dimension or increase f_c'.

Question : 2

Given Data

Breadth of web of beam (b_w) = 14"

Effective depth (d) = 22"

Given load = 6.5 k/ft

Steel area = 7 in^2

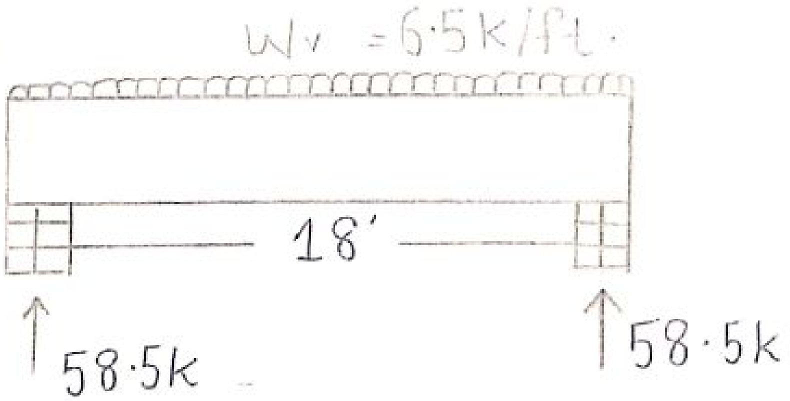
$f_c' = 4ksi$

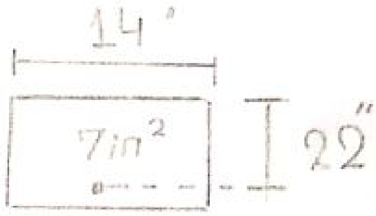
$f_y = 60ksi$

Required

Design beam for shear

Sol:-





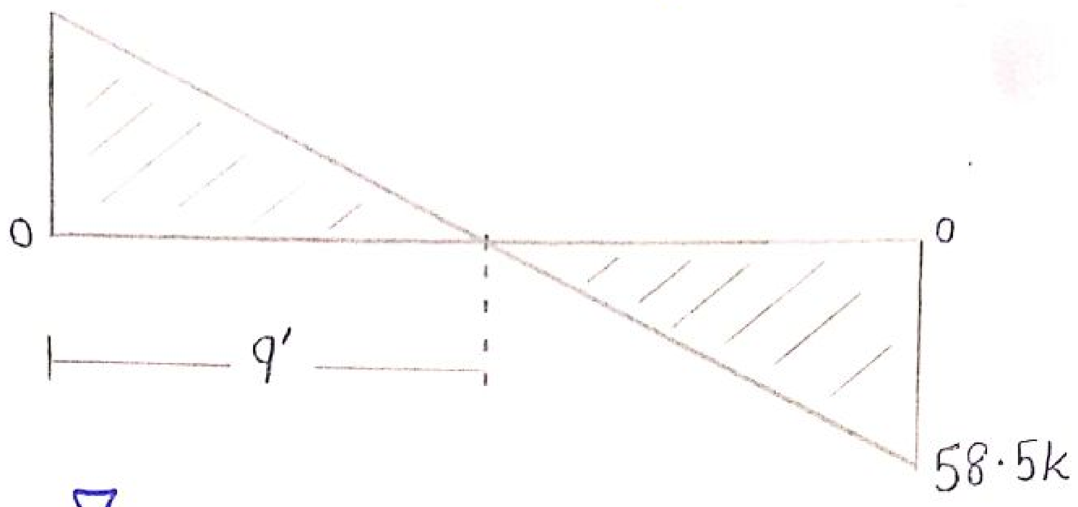
Step 1 (Reactions on Supports)

First 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)

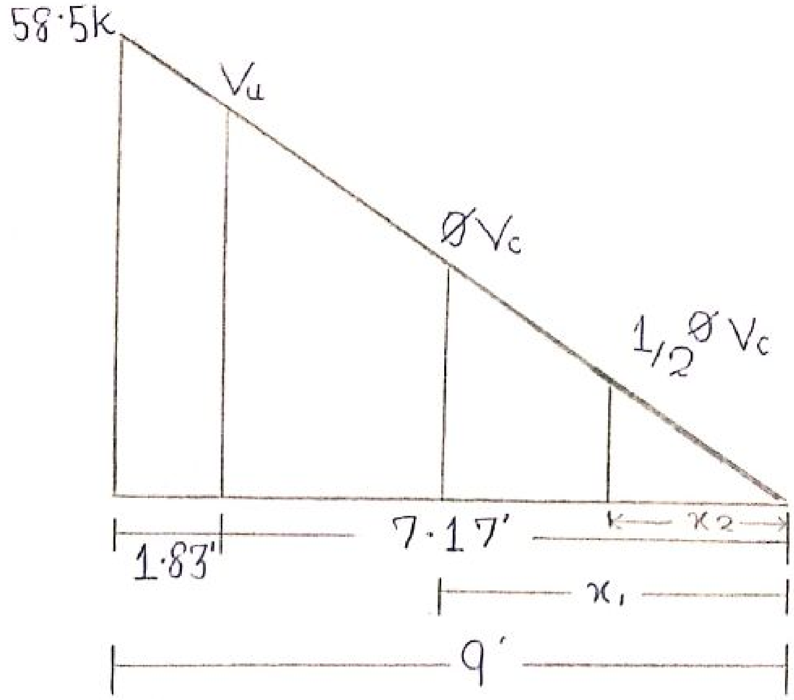


Step 3

Finding value of critical shear "V_u" and its location as

As we know critical shear is located at distance "d" from face of support $(d) = \frac{22''}{12} = 1.83'$

We will use similar triangles to find value of critical shear.



From Similar triangles

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

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

$$= 46.61 \text{ kips}$$

Step 4

Finding value of "ϕV_c" and '$1/2 \phi V_c$' and also its distance from zero shear to right side

Using formula.

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

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

$$= 29219.4 \text{ lbs}$$

$$= \frac{29219.4}{1000} = 29.21 \text{ kips}$$

Finding Location of ϕV_c by similar triangles

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

Put value of 'ϕV_c'

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

$$x_1 = 4.49'$$

Similarly

$$1/2 \phi V_c = \phi V_c / 2$$

$$\frac{29.21}{2} = 14.60 \text{ kips}$$

Now location of $1/2 \phi V_c$

$$\frac{58.5}{9} = \frac{14.60}{x_2}$$

$$x_2 = 2.24'$$

Step 5

Finding value of ϕV_c

Using formula

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

$$= 46.61 - 29.21$$

$$= 17.4 \text{ kips}.$$

Step 6

Check on section adequacy

By formula.

$$\phi \times 8 \sqrt{f_c'} \times b_w \times d$$

Put values

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

$$= 116877 \text{ lbs}$$

$$= 116.87 \text{ kips}$$

Now

$$\phi \times 8 \times \sqrt{f_c'} \times b_w \times d > \phi V_c$$

So section is adequate.

Step 7

Check on maximum spacing for stirrups

Using formula

$$\phi \times 4 \times \sqrt{f_c'} \times b_w \times d$$

Put values.

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

$$= 58438 \text{ lbs}$$

$$= 58.43 \text{ kips}$$

Now

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

So maximum spacing for stirrups will be selected from following 4 conditions

1) $S_{max} = 24"$

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

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

Here we are using #3 stirrup dia = $(3/8)" = 0.375"$

So

$$Area = \frac{\pi}{4}(0.375)^2$$

$$= 0.11 in^2.$$

For 2nd leg stirrup

Area × 2

$0.11 \times 2 = 0.22 in^2$

3. $S_{max} = \frac{0.22 \times 6000}{0.75 \times \sqrt{4000} \times 14}$

$= 19.87"$

4. $S_{max} = \frac{A_v \times f_y}{50 \times b_w} = \frac{0.22 \times 6000}{50 \times 14} = 18.85"$

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

$S_{max} = 11"$

Step 8

Stirrups spacing at critical section will be

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

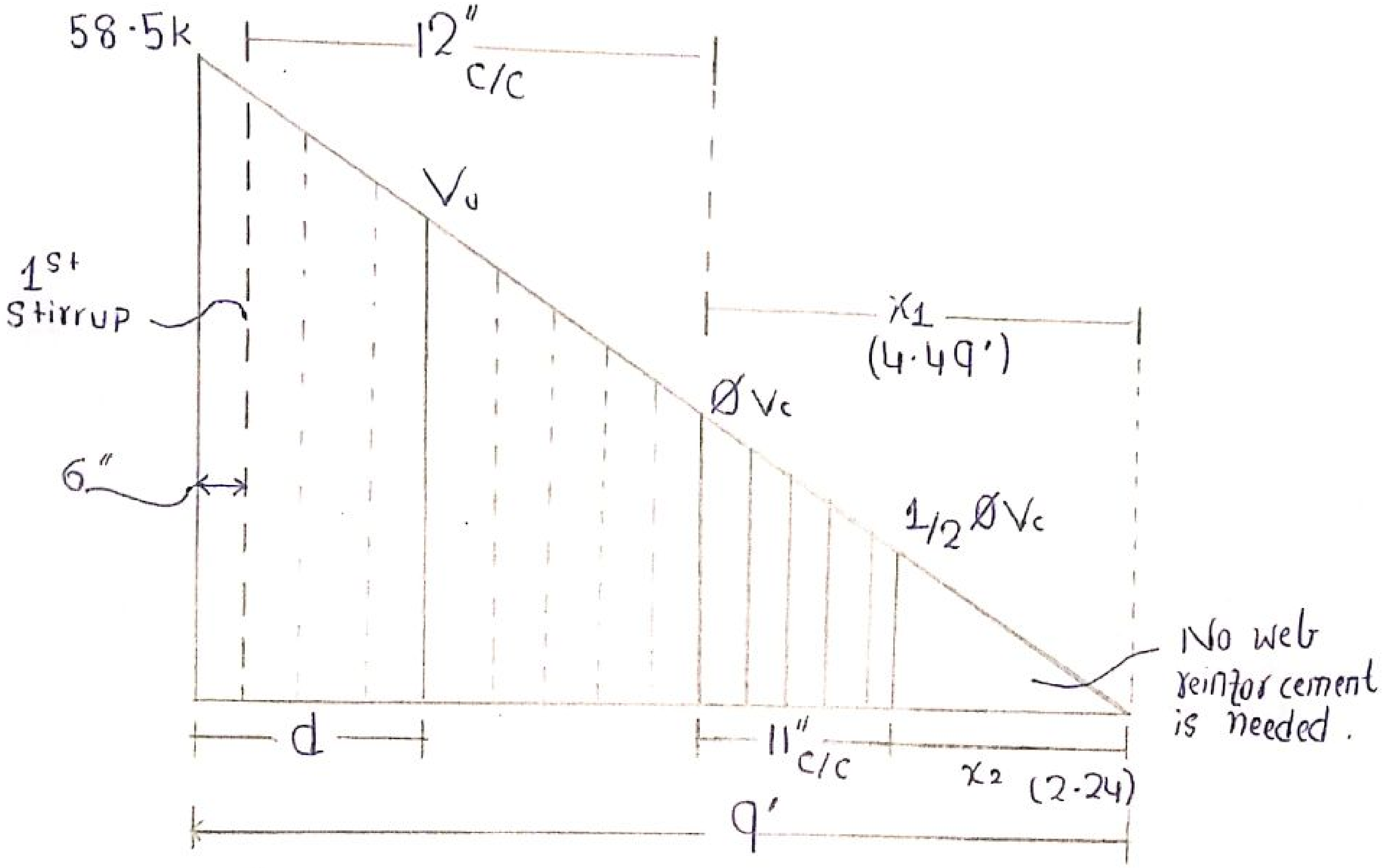
Put values

$$= \frac{0.75 \times 0.22 \times 60 \times 22}{46.61 - 29.21}$$

$= 12.5'' \approx 12''$ So $12'' C/C$.

Step 9

Now final step will be.



As first stirrup from face of support

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

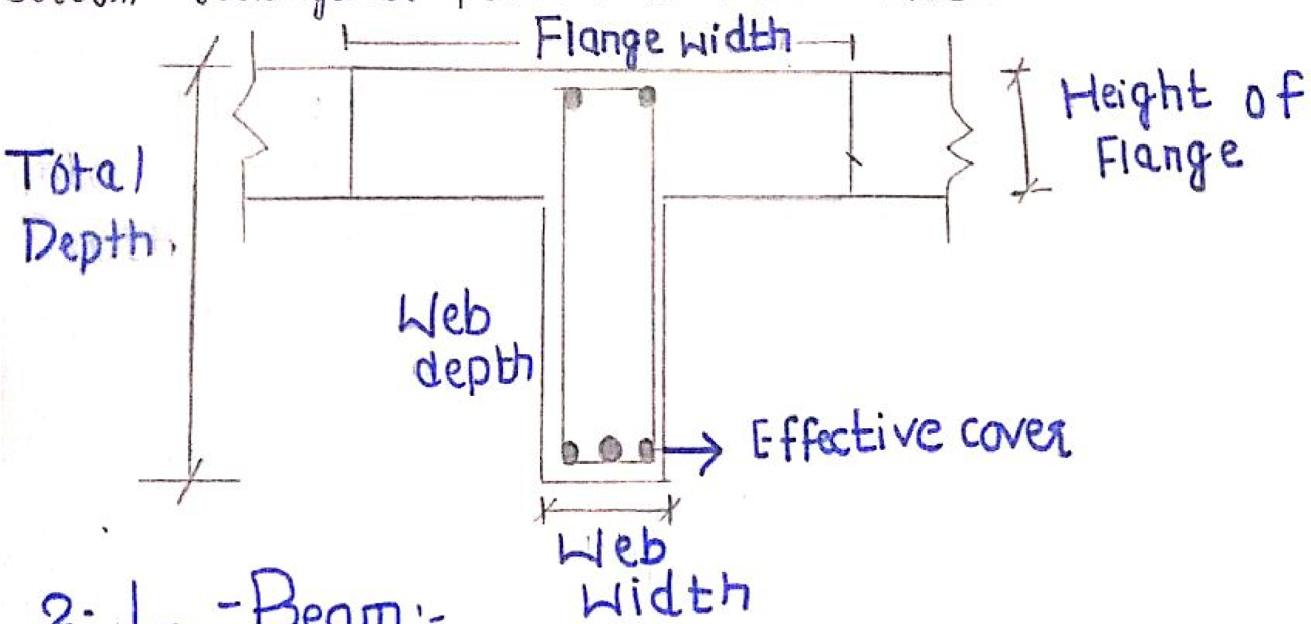
Question 3

T-Beam :-

A T-beam used in construction is a load bearing structure of reinforced concrete, wood or metal with a T-shaped cross-section. The top of T-shaped cross section severs as a flange or compression member in resisting compressive stresses.

The disadvantage of T-beam is that it has no bottom flange with which to deal with tensile force.

There are steel T-beam and Reinforced concrete T-beam. The upper area of beam is called flange and bottom rectangular portion is called web.



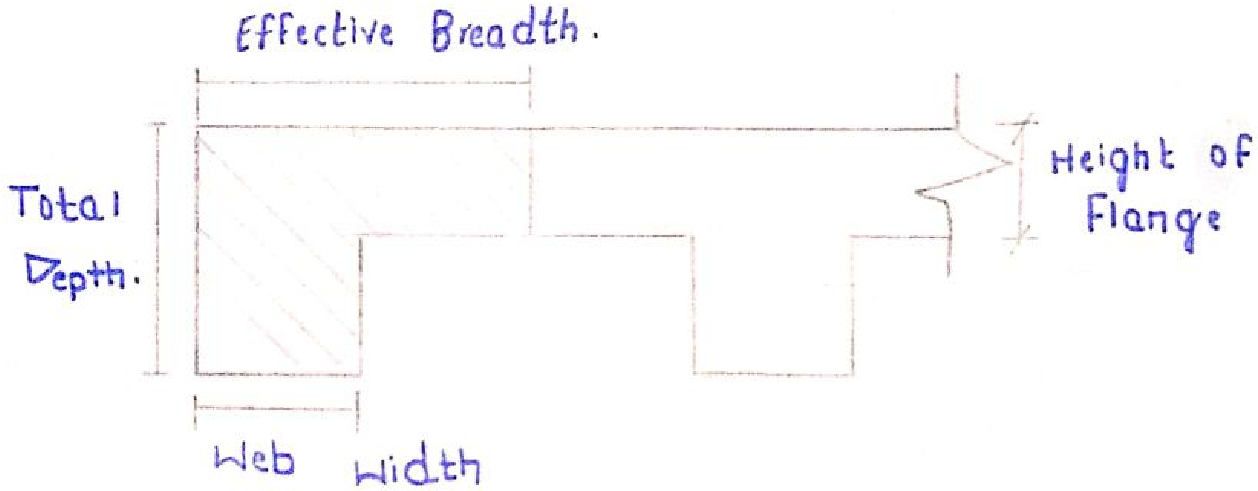
2. L-Beam :-

A beam whose section has the form of an inverted L usually placed so that its top flange form part of edge of a floor.

The end beams which have slab on one side act as L-Beam.

L-Beam are typically floor beam because of reduced overall Stuctural depth, the beam are in prestressed or reinforced concrete.

→ They are also called edge beam.
→ It is always provided at cornor of floor.



FLEXURAL ANALYSIS OF T-BEAM

Flexural analysis involves following steps.

i- For finding Ultimate Factored moment

We use formula.

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

where.

W_u = Total Factored Load.

L = load span of beam.

ii) Effective width (bc) for T-beam :-

It is calculated as.

1) 16(hf) + bw
2) C/C distance
3) Span / 4
4) $\frac{CTS}{2} + bw$

where

hf - height of flange

CTS - Clear transver span.

- We have to select least value from above formula.
- If c/c distance is given then no need of $\frac{CTS}{2} + bw$.

3- Checking whether Rectangular or T-Beam analysis is required:-

If $a > hf$ → Special analysis is required.
If $a < hf$ → Rectangular Beam analysis is required.

where
a = Depth of compression black.
hf = Height of flange.

4- For finding area of steel:-

We have to use formula.

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

Now

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

where
ϕ = Strength Reduction factor
d = Effective depth.
a = Compression black depth
b_w = web width of beam

5- For checking range of Reinforcement Ratio:-

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

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

$$\rho = A_{st}/b \times d.$$

6- Finding Number of bars required:-

We use formula.

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

7- For checking Minimum width for bars accomdation

b_{min} = 2 (clear cover) + 2(dia of stirrup) + No of bars(dia of bars) + spacing between bars (dia of bars).

8. Design Moment:

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

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

if $a > h_f$.

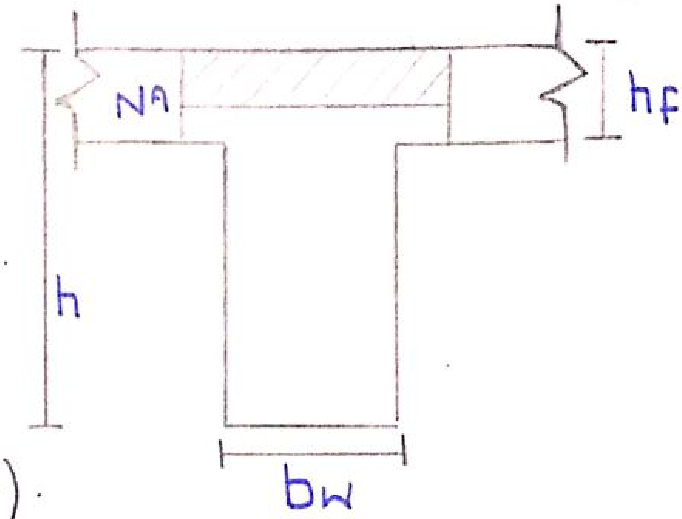
Q 4

Case I

From figure

$a < h_f$

So in this case rectangular beam analysis is required. The Design moment is



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

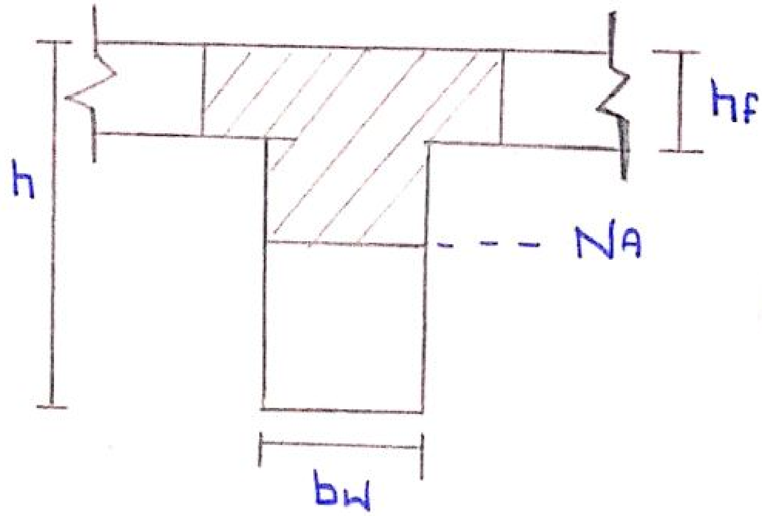
Case II

From figure

$a > h_f$

So in this, special beam analysis i.e. T Beam analysis is required.

Design moment is



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

Question 5

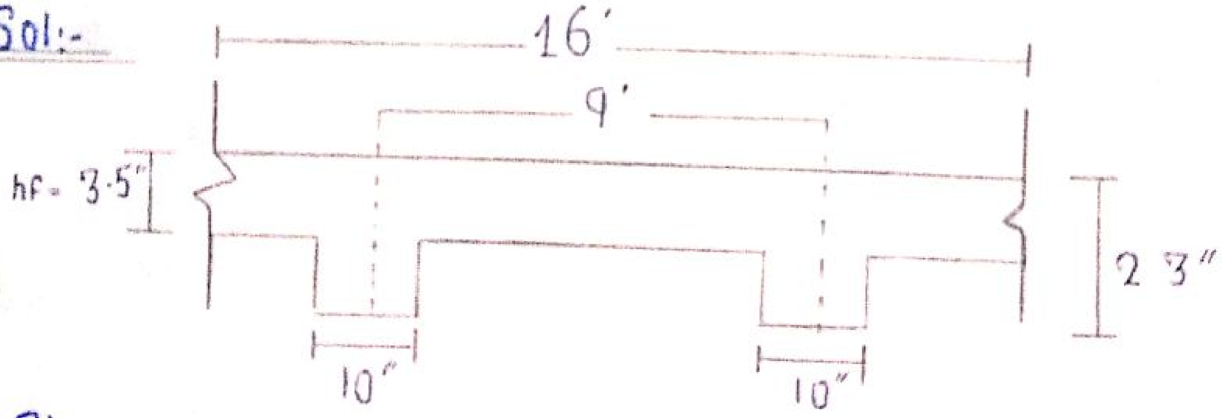
Given Data:-

Height of flange = hf = 3.5"
C/C distance = 9'
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' = 3ksi
f_y = 60ksi

Required:-

Flexural Reinforcement = ?

Sol:-



Step 1

Calculate effective width (b_e) 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 of 'b_e' as

$b_e = 48"$

Step 2

Check whether Rectangular or T beam analysis is required.

Trial # 01

Let $a = h_f = 3.5''$

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

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

Trial # 2

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

$$a = \frac{6.61 \times 60}{0.85 \times 3 \times 48} = 3.2'' \approx 3.5''$$

and. $A_{st} = 6.55 \text{ in}^2$

So Rectangular Beam Design is Required.

Trial # 03.

$a = 3.21''$

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

$$= 6.55 \text{ in}^2$$

So area of steel is 6.55 in^2

Step 3:

Check ρ_{max} and ρ_{min}

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

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

$$= 0.013$$

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

$\rho = \frac{A_{st}}{b \times d} = \frac{6.56}{10 \times 18} = 0.036$

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

$0.003 < 0.036 < 0.013$

As value of ρ_{max} is less than ρ, so we have to design it as "Doubly Reinforced Beam".

Finding area of steel against ρ_{max}

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

$A_{s1} = \rho_{max} (b \times d)$

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

$A_{st} = 2.34 \; in^2$

Step 4

Finding value of M_{u2}

Using formula.

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

Finding value of "a"

$a = \frac{A_{s1} \times f_y}{0.85 \times f_c' \times b}$

$= \frac{2.43 \times 60}{0.85 \times 3 \times 10}$

$a = 5.72''$

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

$M_{u2} = 1986.67$ kip-inch

As $M_{u2} < M_u$

$1986.67 < 5800$.

So we have to design beam in such a way that can resist more bending moment then applied load.

Step 5:-

Difference in moment and area of steel.

$M_{u1} = M_u - M_{u2}$
$= 5800 - 1986.67$
$= 3813.33$ kips inch

By formula.

$A_{st}' = \frac{M_u}{\phi \times f_y (d - d')}$

Put values.

$= \frac{3813.33}{0.90 \times 60 (18.25)}$

$= 4.56 in^2$.

Step 6

Finding Total steel area

$A_s = A_{st} + A_{st}'$
$= 2.43 + 4.56 = 6.99 in^2$.

Step 7

Selection of bars.

In Tension zone

We select #8 bars.

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

By formula

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

$= 6.99 / 0.785$

$= 8.9 \approx 9$.

So 9 #8 bars.

In Compression Zone

Let we use #7 bars

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

Using formula

No of bars $= \frac{4.56}{0.601} = 7.5 \approx 8$.

So 8 #7 bars

Step 8

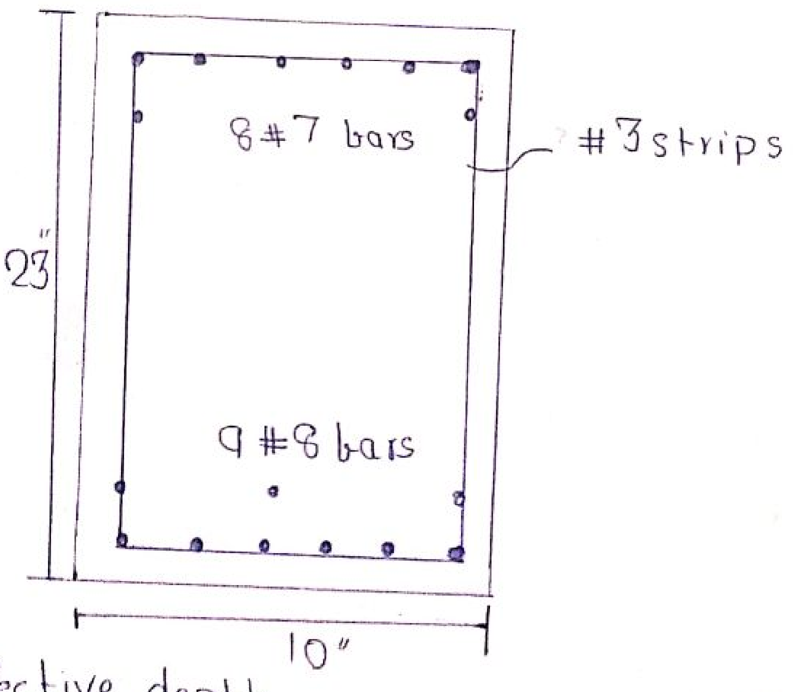
Minimum width

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

$= 20.75''$

As $20.75'' > 10''$

So the bars will be placed in multiple layers.



Effective depth.

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

$= 19.6''$

Effective cover (d')

$.1.5 + 3/8 + 7/8 + 1/2(7/8)$

$= 3.18''$

Step 9

Finding design moment.

$$Md = \varnothing\ [As \times fy\,(d-d') + (Ast - A'st) \times fy\ (d - a/2)]\ .$$

$$a = \frac{(As - Ast')\ fy}{0.85 \times fc \times b}$$

$$= \frac{(9 \times 0.785 - 8 \times 0.601) \times 60}{0.85 \times 3 \times 10}$$

$$= 5.31''$$

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

$$= 6328.38 > 5800$$

So design is Ok!

Question 6

Given Data:-

Breath = (b) = 14"

Height = (h) = 26"

Concrete compression strength = $f_c' = 4ksi$

Steel Tensile Strength = $f_y = 60ksi$

Effective depth of beam = d = 22"

Ultimate Factored Moment (Mu) = 6000 kip-inch

Assume effective cover (d') = 2.5"

Required:-

Flexural reinforcement = ?

Sol:-

Step 1 (Reinforcement Ratio):-

Using formula

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

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

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

Step 2 (Area of steel)

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

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

$$= 0.0180 (14 \times 22)$$

$$= 5.54 \text{ in}^2.$$

Step 3 (Design Moment)

Using formula

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

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

Put values

$= \frac{5.54 \times 60}{0.84 \times 4 \times 14} = 6.98''$

So

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

$= 5537.4$ kip-inch

As

$5537.4 < 600$

So we have to design section as doubly reinforced.

Step 4 (Difference in Moment)

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

$= 6000 - 5537.4$

$M_{u1} = 462.6$ kips-inch

Step 5 (Area of Steel)

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

Area of steel in compression zone will be

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

Put values

$= \frac{462.6}{0.90 \times 60 \times (22 - 2.5)}$

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

Step 6 (Total Steel Area):-

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

$= 5.54 + 0.44 = 5.98 \text{ in}^2$

Step 7 (Selection & No of bars used):-

1. Steel in Tension zone

We use #7 bar

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

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

Now

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

$= \frac{5.98}{0.601} = 9.9 \approx 10 \text{ bars}$

So 10 #7 bars.

2- Steel in Compression Zone

We use #5 bar.

dia $= (5/8)'' = 0.625''$

Area $= \frac{\pi}{4} d^2 = \frac{\pi}{4}(0.625)^2 = 0.306 \text{ in}^2$

So

No of bars $= \frac{A_{st}'}{\text{Area of single bar.}}$

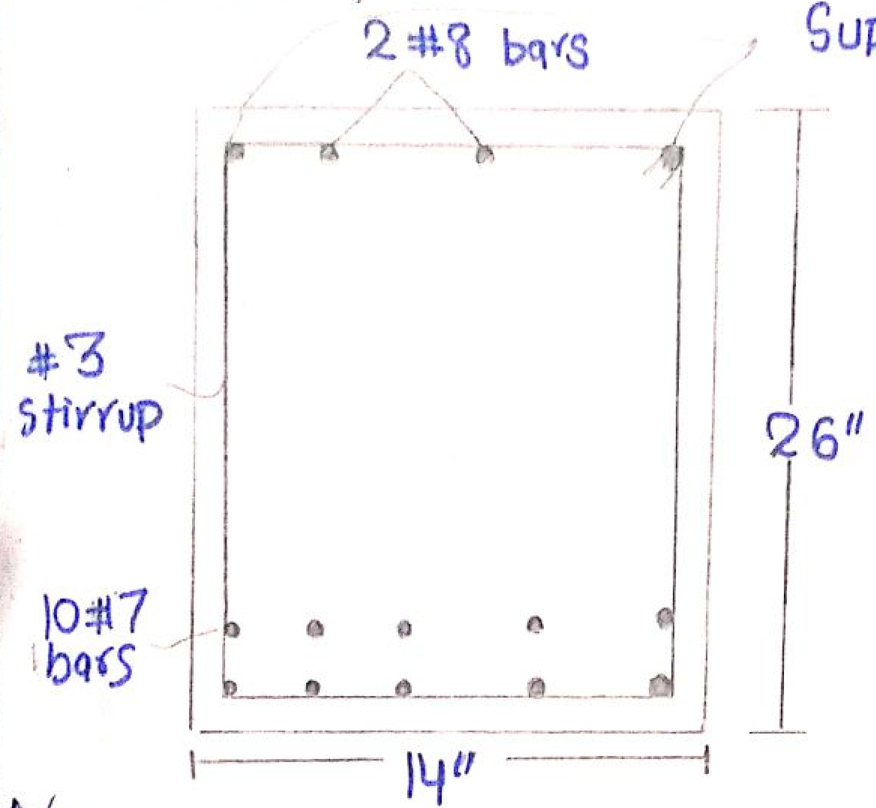
$= \frac{0.44}{0.306} = 1.43 \approx 2 \text{ bars}$

So 2 #5 bars

Step 8 (Minimum width of beam)

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

$= 20.37 > 14''$



Now

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)

$M_d = \varnothing \times [A_{st}' \times f_y \times (d - d') + (A_{st} - A'_{st}) \times (d - a/2)]$

$= \dfrac{(A_{st} - A_{st}') \times f_y}{0.85 \times f_c' \times b}$

Put values.

$= \dfrac{(10 \times 0.60) - (2 \times 0.306) \times 60}{0.85 \times 4 \times 14}$

$= 6.80''$

$$M_d = 0.90 \left[(2 \times .306) \times 60 (22.82 - 2.18) + (10 \times 0.601) - 2 \times 0.306) \times 60 (22.82 - 6.80/2) \right\}$$

M_d = 7047.6 kips-inch

As 7047.6 > 6000

Design is Ok.