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Section - "A"

Semester: 6^{th} B.sc civil Engineering

Assignment: plain & Reinforced Concrete Design I

Submitted to Engr. Fawad Khan

Q No! 01

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

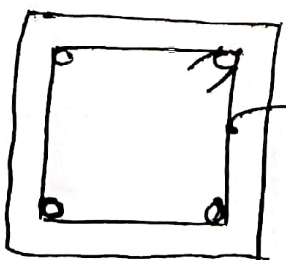
Ans:- **Types of Stirrups:**

① **Single legged stirrup:**

The Single-leg stirrup have rarly been used because they are mostly used when binding only two rods:

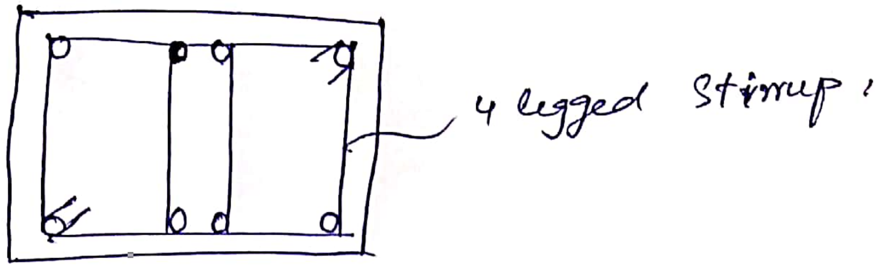
② **Two legged stirrups:**

It, is The most commonly and widely used stirrup. minimum 4 bars are required for Providing This stirrups.

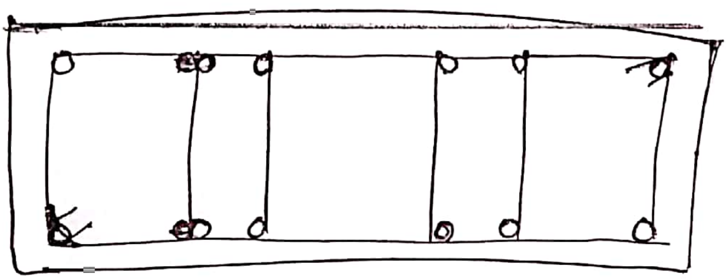

2 legged stirrup,

③ **Four legged stirrup :-**

These stirrups are used in case of web reinforcement.



④ **Six legged stirrup:**



ACI Codes for Shear Design of Beam:

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

1- Critical Section :- Critical section occurs at 45° and is at distance (d)" from the face at 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 provisions of atleast a minimum area of web reinforcement equal to, $\phi = 0.75 \rightarrow$ for shear design

($\because V_u$ = Total factored shear applied at a given section)

$\Rightarrow$ For Minimum Reinforcement Area :-

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

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

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

4 No web reinforcement is required if

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

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⇒ Between critical Section "V_{cr}" 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 following.

1- 24"

2- $d/2$

3- $S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{f'c} \times b_w}$ ∴ (V_s = Shear force carried by web reinforcement)

4- $S_{max} = \frac{A_v \times f_y}{50 \times b_w}$

⇒ 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 dimension or increase $f'c$.

Q No! 02

Given data:

Breadth of web of Beam (bw) 14"

Effective depth (d) = 22"

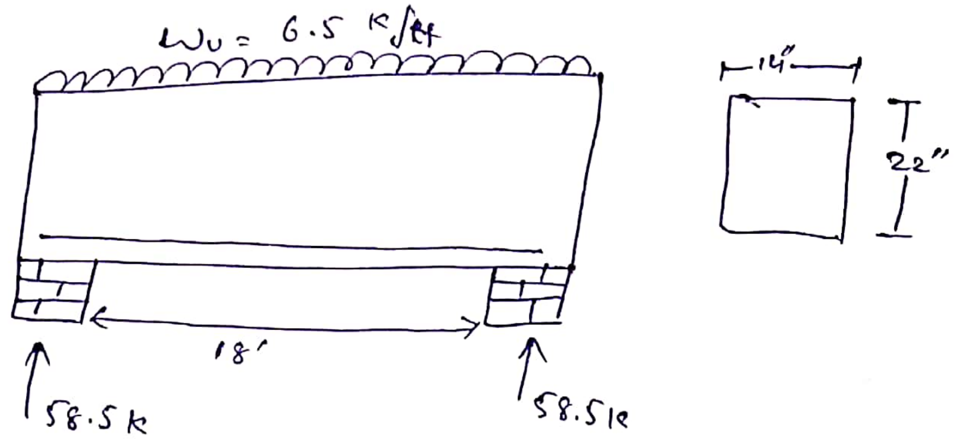
Given load = 6.5 k/ft

steel Area = 7 inches^2

$f'c = 4$ ksi

$fy = 60$ ksi

Sol:



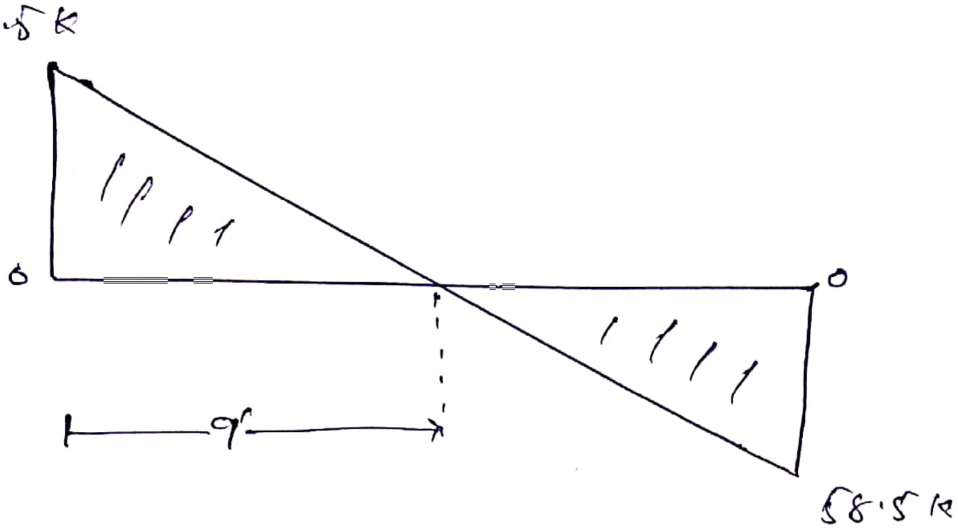
Step # 1 (Reactions on Supports).

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



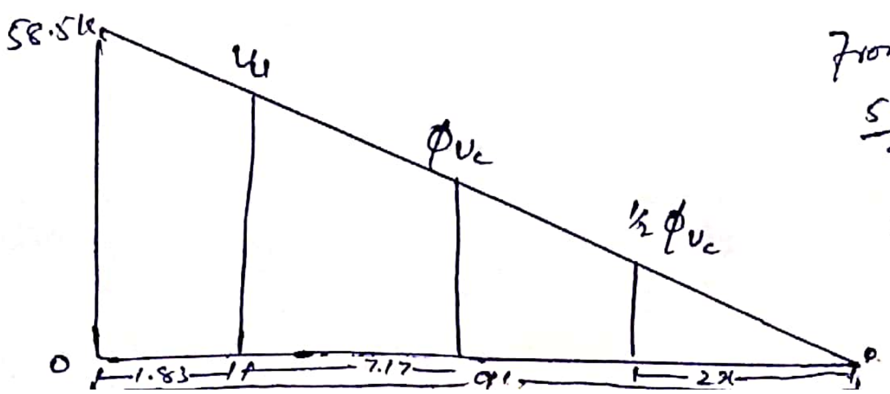
Step # 3:

Finding The value of critical Shear "V_u" and its location As:

We know that Critical Shear is located at distance "d" from face of support (d)

$= 22'' = 1.83'$

2) we will find the value of critical shear at distance "d" by use of similar triangles:



From similar triangles:

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

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

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

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Step #4

<u>Finding the value of "ϕV_c" and "$\frac{1}{2}\phi V_c$" and also its distance from the Zero sheare to right side:</u>

By formula:

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

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

$= 29.21$ kips

location of ϕV_c by similar triangles

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

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

similarly,

$\Rightarrow \frac{1}{2}\phi V_c = \phi V_c/2 = \frac{29.21}{2} = 14.80$ kips

$\Rightarrow$ 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

Finding the value of ϕV_s

By formula, $V_u = \phi V_s + \phi V_c$

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

$= 46.61 - 29.21$

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

Step # 6

Check on section adequacy

By formula:

$= \phi \times 8 \times \sqrt{f'c} \times bw \times d$

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

$= 116.87 \text{ kips}$

As $\phi \times 8 \times \sqrt{f'c} \times bw \times d > \phi V_s$

So section is Adequate;

Step # 7.

Check on maximum Spacing for Stirrups

By formula,

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

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

$= 58.43 \text{ kips}$:

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

So maximum will be selected from the following 4 Conditions

Here we are using #3 stirrups

dia = $(3/8)'' = 0.375''$

So area $= \frac{\pi}{4}(0.375)^2 = 0.11 in^2$

for 2-legged stirrup

$\Rightarrow$ Area $\times 2$

$0.11 \times 2 = 0.22 in^2$

① - $S_{max} = 24''$

② - $d/2 = 22/2 = 11''$

③ $S_{max} = \dfrac{0.22 \times 60000}{0.75 \times \sqrt{4000} \times 14} = 19.87''$

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 4 Conditions, least value of spacing for #3 2 legged stirrup will be selected as:

$S_{max} \; 11''$.

Step # 8:

Stirrups spacing from/at Critical section will be

By formula:

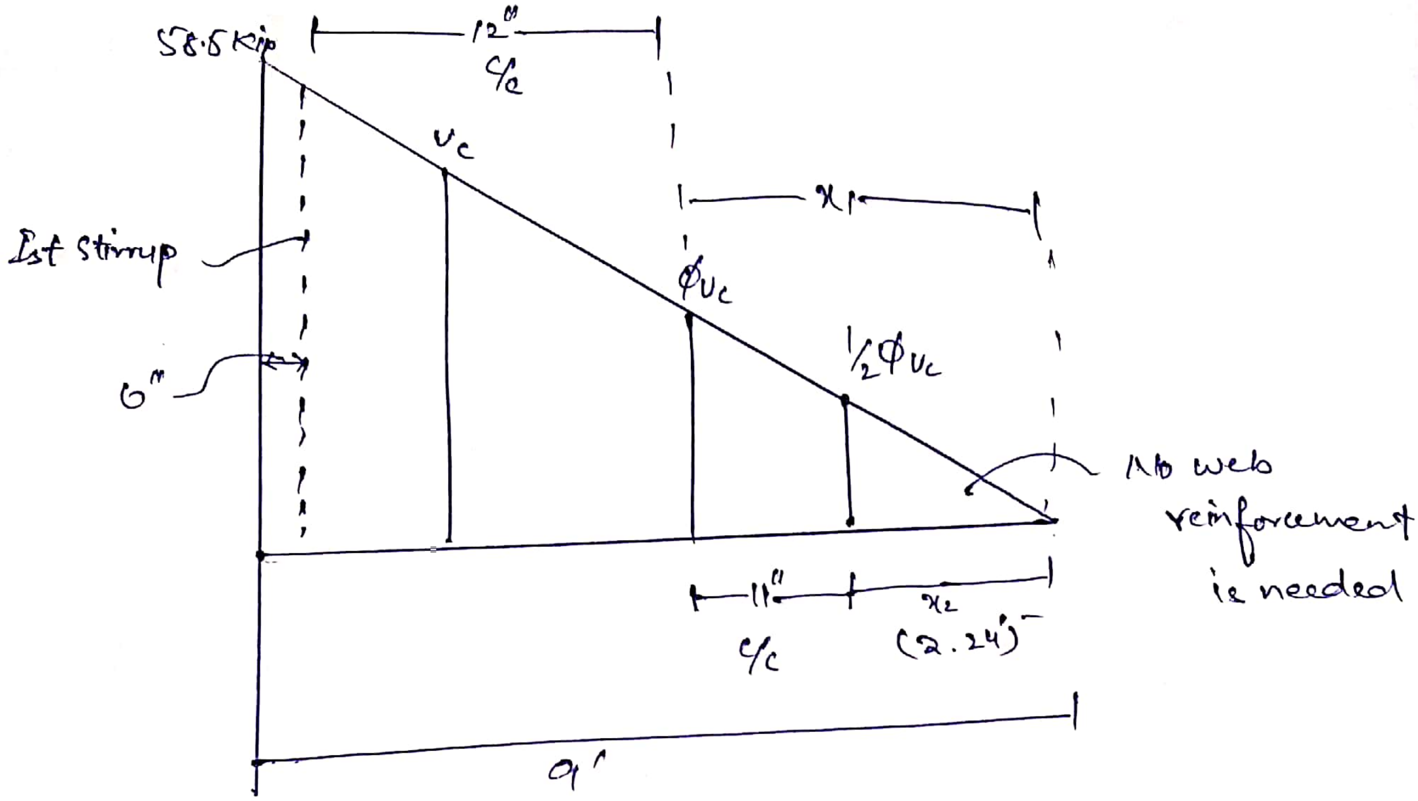
$$S = \frac{\phi \times A_v \times f_y \times d}{V_u - \phi V_c} = \frac{0.75 \times 0.22 \times 60 \times 22}{46.61 - 29.81}$$

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

So $12''$ c/c.

Step #9

Final Sketch will be



As First stirrup from face of Support:

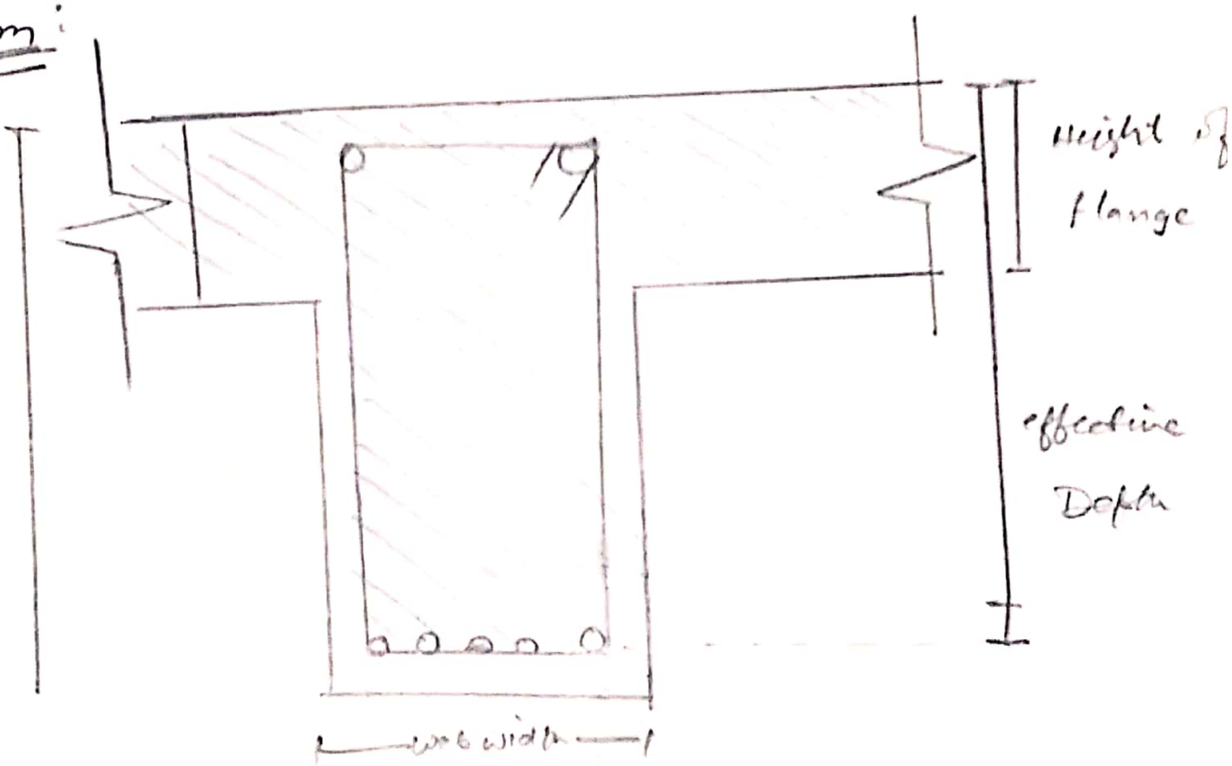
$$S/2 = 12/2 = 6''$$

Q No: 03

Define both the T beam and L Beam with the help of diagram. Also Explain flexural analysis of T Beam.

T Beam:

Ans:



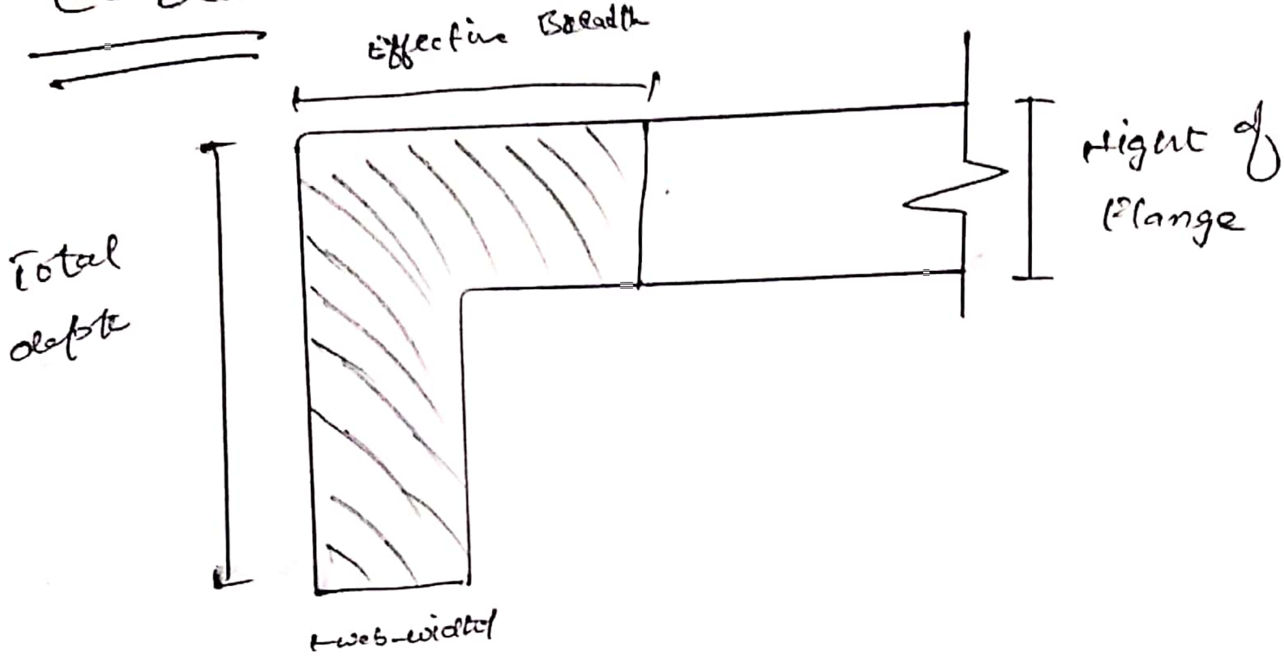
⇒ In most of the reinforcement structure. concrete slabs are cost monolithically with the Salb so - in this Case the beam that act as an intermediate beam are called T- Beam.

⇒ Because of Their T-Beam shape These beam are

T- Beam.

The bottom rectangular of beam is called web of the beam.

L-Beam:



⇒ L-Shape structure that is in contact with the slab and present at the corner of the floor is called L-Beam.

2) L-Beam are also called Edge Beam.

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

⇒ L-Beam are typical floor beam because of their reduced over all structure depths

The beam are in presetessed or reinforced concrete.

Flexural Analysis of T-Beam:

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

(1) $M_u = \frac{W_u \times l^2}{8}$;- (W_u = Total factored load, l = Total span of the beam)

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

1- $16(h_f) + b_w$ ∴ h_f = height of flange

2- c/c distance   C.T.S = clear transverse span)

3 span /4

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

(3) Checking whether Rectangle or T-Beam analysis is required:

i- If $a > h_f$ → special Analysis is required

ii- If $a \le h_f$ → Rectangular beam analysis is required

(where a = Depth of compression block)
h_f = Height of flange.

4- for finding Area of Steel, we have to use

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

where

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

∴ ϕ strength Reduction factor

d = Effective depth

a = compression block depth

b_w = web width of beam

(5) for checking the range of reinforcement Ratio.

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

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

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

(6) For checking minimum width for Bar accomodation

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

(7) formula for finding No of bars required is

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

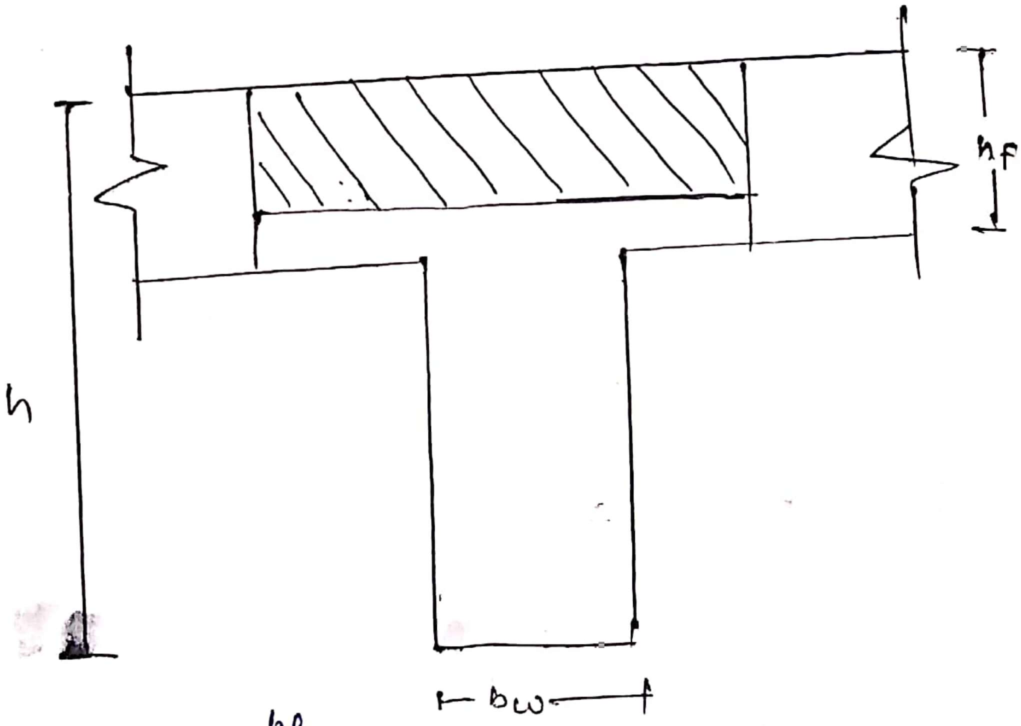
(8) - Design moment is given by

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

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

Q No! 04

What is the difference b/w Case I & Case II in the design of T-Beam?



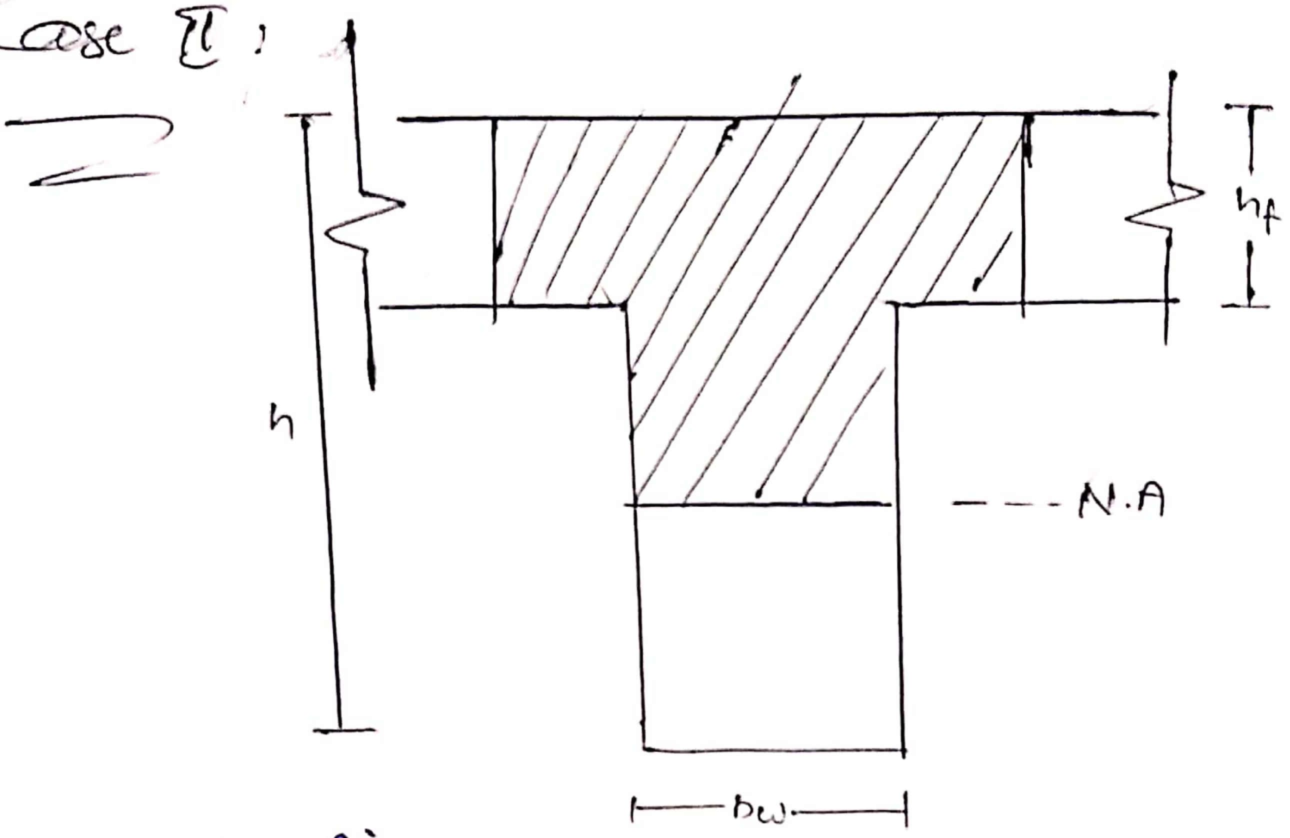
From the figure $a < h_f$

So in this case, rectangular Beam anaylsis 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

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

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Q No. 05

I

Given data:

Height of flange (h_f) = 3.5"

C/c distance = 9'

Length / span of the beam = 16'

web-width (b_w) = 10"

Effective depth (d) = 18"

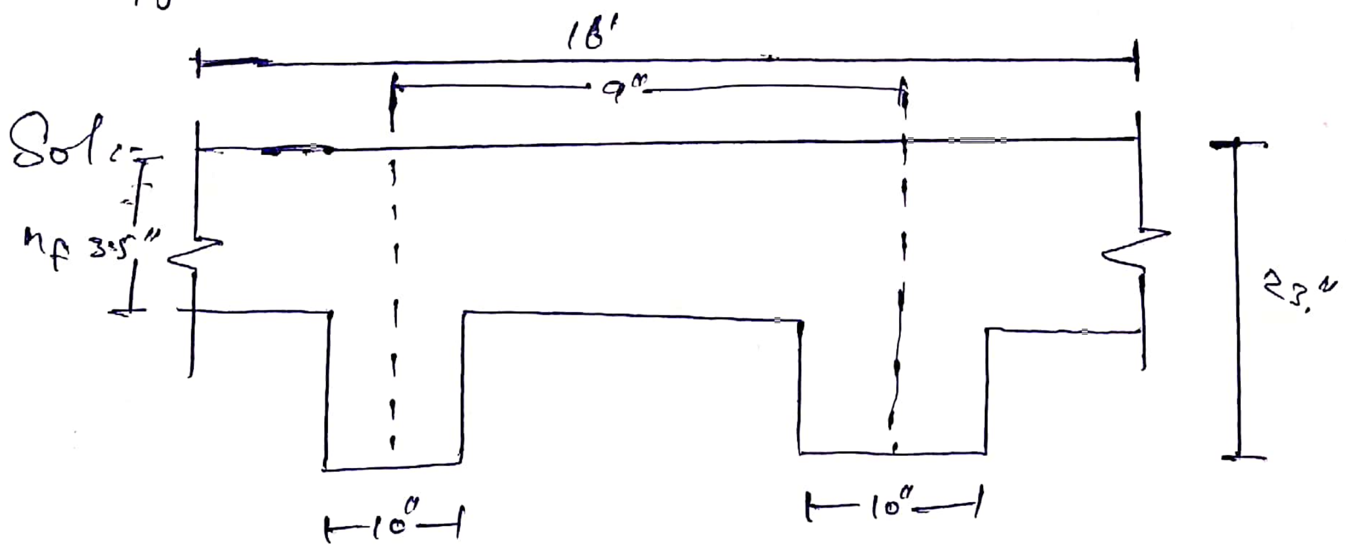
Height (h) = 23"

Total factored moment (M_u) = 5800 kip-inch

f'_c = 3 ksi

f_y = 60 ksi

Sol:-



Step #1: Calculate the effective width for T Beam

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

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2 - c/c distance = 9 x 12 = 108"

3 - Span/4 = $\frac{16}{4} \times 12$ = 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 = hf = 3.5"

$$A_{st} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{5800}{0.90 \times 60(18 - \frac{3.5}{2})} = 6.61 \text{ in}^2$$

Trial # 02

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

$$a = \frac{6.61 \times 60}{0.85 \times 3 \times 48} = 3.2"$$

$\Rightarrow 3.2" < 3.5"$

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

So Rectangular Beam design is required.

Trial # 03   a = 3.21"

$$\text{and } A_{st} = \frac{5800}{0.90 \times 60(18 - 3.21/2)} = 6.55 \text{ in}^2.$$

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

Step # 03 :

Check ρ_{max} and ρ_{min}

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

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

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

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

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

$0.003 < 0.036 < 0.013$

As the value of ρ_{max} is less than 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 # 04 :

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

$$\Rightarrow a = \frac{Ast \times fy}{0.85 \times f'c \times b} = \frac{2.43 \times 60}{0.85 \times 3 \times 10} = 5.72''$$

$$a = 5.72''$$

$$\Rightarrow Mu_2 = 0.90 \times 2.43 \times 60 \times \left(18 - \frac{5.72}{2}\right)$$

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

As $Mu_2 < Mu$

$1986.67 < 5800$

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

Step # 05

~~Diff~~ Finding Difference in moment and Area of steel

$$Mu_1 = Mu - Mu_2$$

$$= 5800 - 1986.67$$

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

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By formula:

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

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

Step #06

Find Total steel Area:

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

$= 2.43 + 4.56 = 6.99\ in^2$

Step #07

Selection of Bar:

In tension Zone:

let we use #8 bar

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

By formula

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

$= 8.9 \simeq 9$

So 9 #8 bars;

In Compression zone :-

Let we use #7 bar

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

By formula.

$$\text{No. of bar} = \frac{\text{Area of Steel}}{\text{Area of Single bar}} = \frac{4.56}{0.601} = 7.5 \simeq 8$$

So 8 #7 bars.

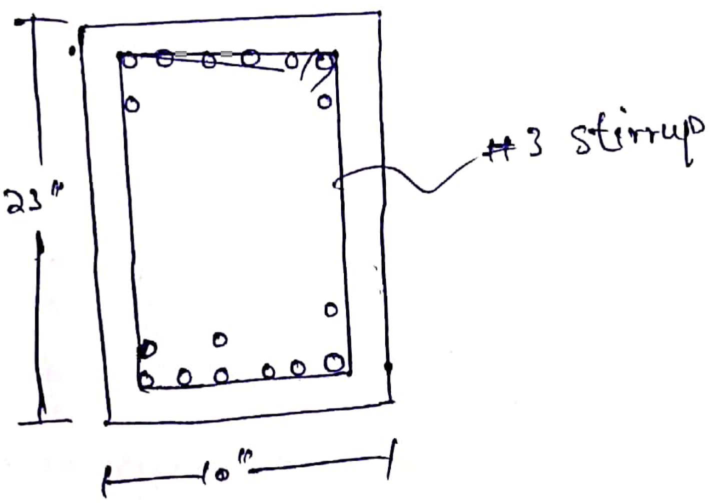
Step # 08

Minimum width for Accomodation of bars

$$b_{min} = (2\times1.5) + (2\times 3/8) + 9(8/8) + 8(8/8)$$

$$= 20.75''$$

As The Barss will be placed in multiple layer



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

Effective Cover (d') = $1.5 + \frac{3}{8} + \frac{7}{8} + \frac{1}{2}\left(\frac{7}{8}\right) = 3.18''$

Step # 09 :

Find The design moment

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

First $a = \dfrac{(As - A'st) \times fy}{0.85 \times f'c \times b} = \dfrac{(9 \times 0.785 - 8 \times 0.601) \times 60}{0.85 \times 3 \times 10} = 5.31''$

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

$$\boxed{Md = 6328.38}$$

As $6328.38 > 5800$

$\therefore$ The design is OK

Q no! 06

Given data:

Breadth (b) = 14"

Height (h) = 26"

Concrete compression strength ($f'c$) = 4 ksi

steel Tensile strength (fy) = 60 ksi

ultimate factored moment (Mu) = 6000 kip - inch

Effective depth of beam (d) = 22"

Assume Effective cover (d') = 2.5"

Step # 01 (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 # 02: (Area of Steel)

As we knowe that.

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

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

Step #03 (<u>Design moment</u>)

By using formula:

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

$$\Rightarrow a = \frac{Ast \times fy}{0.85 \times f'c \times b} = \frac{5.54 \times 60}{0.85 \times 4 \times 14} = \boxed{6.98''}$$

So,

$$Mu_2 = 0.90 \times 5.54 \times 60 \times \left(22 - \frac{6.98}{2}\right)$$

$$= 5537.4 \text{ kip-inch}$$

As

$$5537.4 < 6000$$

So we have to design a section as doubly reinforced

Step #4: (<u>Differente In moments</u>)

$$Mu = Mu - Mu_2$$

$$= 6000 - 5537.4$$

$$\boxed{Mu_1 = 462.6 \text{ kip-inches}}$$

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 will be

$\Rightarrow A_{st}' = \dfrac{M_{u_1}}{\phi \times f_y \times (d - d_1)} = \dfrac{462.6}{0.90 \times 60 \times (22 - 2.5)}$

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

Step # 06 Total Steel Area:

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

$= 5.54 + 0.44 = 5.98\ in^2$

Step # 07 (Selection & No. of bars used)

1- Steel in Tension zone :-

We use # 7 bar,

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

$= 0.601\ in^2$

So

No. of bars $= \dfrac{A_s}{\text{Area of single bar}} = \dfrac{5.98}{0.601} = 9.9 \simeq 10$ 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

$$No. \ of \ bar = \frac{A's_t}{Area \ of \ single \ bar} = \frac{0.44}{0.306} = 1.43 \approx 2$$

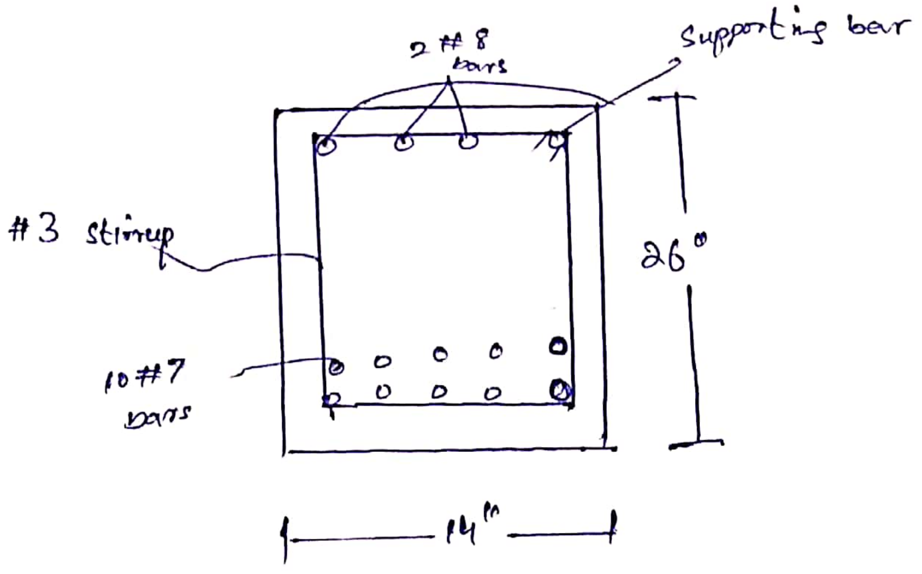
So 2 #5 bars.

Step # 08, 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,

$\Rightarrow$ effective depth $(d) = 26 - 1.5 - 3/8 - 7/8 - \frac{1}{2}(7/8)$

$= 22.83''$

$\Rightarrow$ Effective Cover (d') $1.5 + 3/8 + \frac{1}{2}(5/8)$

$= 2.18''$

Step# 9 (Design moment)

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

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

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

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

$M_d = 7047.6$ kip-inches

As $7047.6 > 6000$

$\therefore$ The design is OK.