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Section A

Teacher Name Sir Fawad

Question: 01

Q1 Explain in detail types of Stirrups with figures and Also explain ACI Codes for Shear design.

★ Answer:

Stirrup:

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

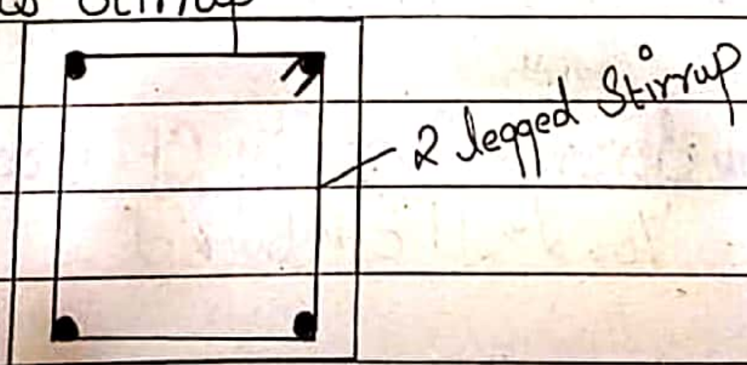
Types Of Stirrups:

1. **Single-legged Stirrup:**

The Single-leg Stirrups rarely been used because they are used when binding only two rods.

2. **Two-legged Stirrup:**

It is most Commanly Used and widely used Stirrup. Minimum 4 bars are required for providing this Stirrup



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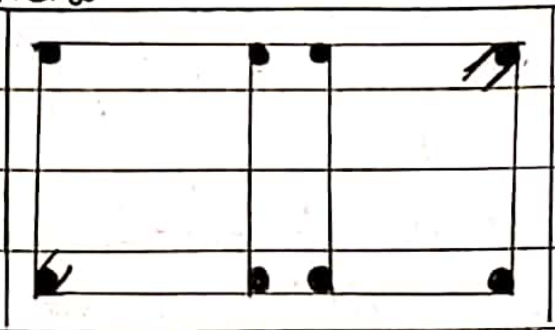
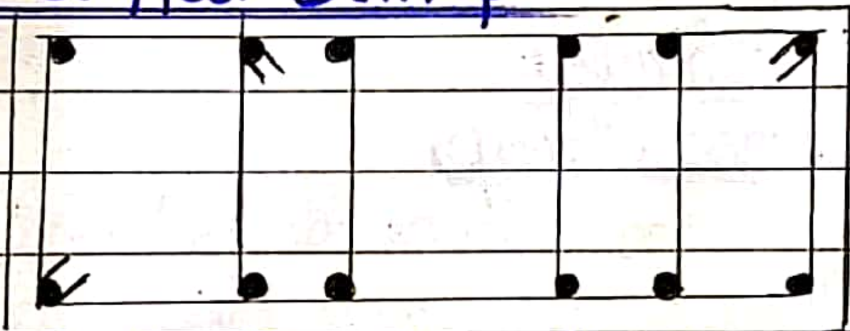
3. Four-Legged Stirrup:

These Stirrups 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 formulas used for the shear design of a beam.

1. Critical Section:

Critical Section occurs at 45° and is at disance (d) form of the force of Support which is equal to effective depth.

2. Shear Strength Capacity Of Concrete IS:

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

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3. Minimum Web Re-inforcement:-

If $V_u < \phi V_c$, then theoritically no web re-inforcement is required. However ACI Code require provision of at least a minimum area of web reinforcement equal to,

$\phi = 0.75$ ⟶ for Shear design

(∵ V_u = Total factored Shear applied at 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.

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

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5. If $V_s < 4 \times \sqrt{f'c} \times b_w \times d$, 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. $S_{max} = \dfrac{A_v \times f_y}{50 \times b_w}$

∴ (V_s = Shear force carried by wed 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

Date:

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 18' simple span. It is reinforced with $7 in^2$ of tensile steel area, if $f'c = 4$ ksi and $fy = 60$ ksi, then design the beam for shear.

Given:

Breath of web of beam (b_w) = 14"

Effective depth (d) = 22"

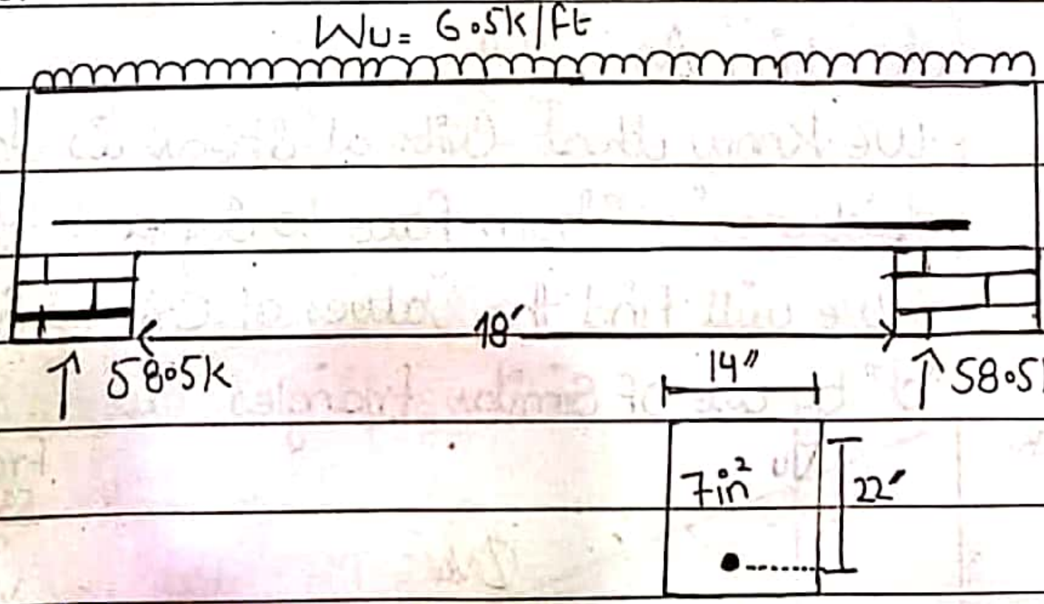
Given load = 6.5 k/ft

Steel Area = $7 in^2$

$f'c$ = 4 ksi

fy = 60 ksi

Sol:



Step: 01 (Reactions On Supports)

Finding the reactions due to applied load

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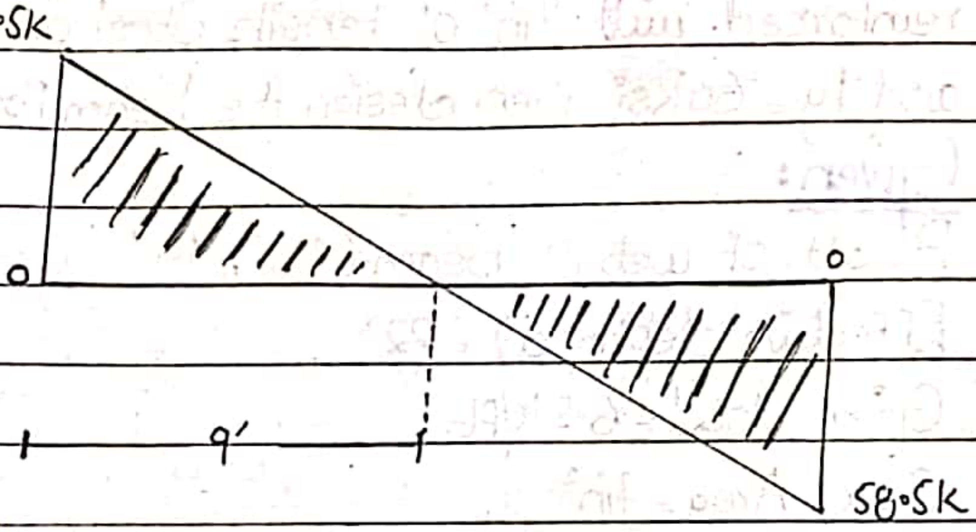
Total load $= \frac{6.5 \times 18}{2} = 58.5$ kips

Step:02 (Shear Force diagram)

The required Shear diagram will be

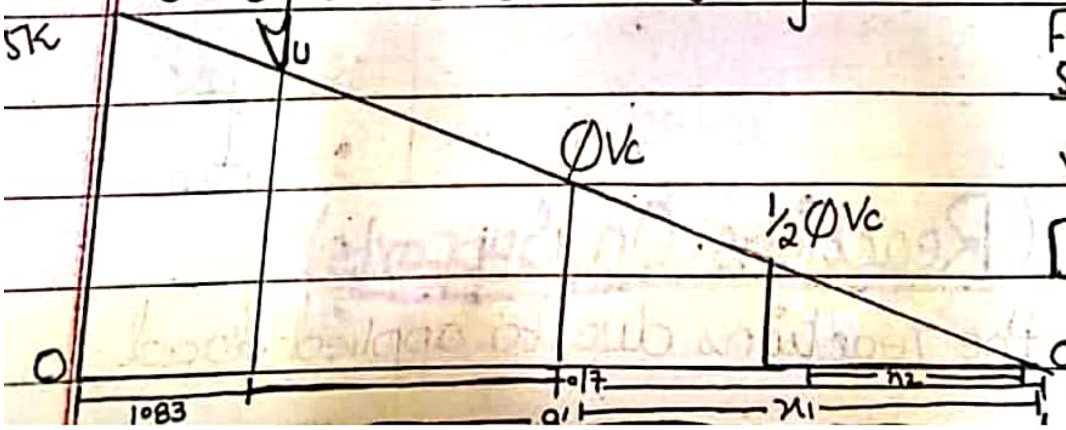


Step:03

Finding the Value of Critical Shear "Vu" and its location As,

We know that Critical Shear is located at distance "d" from face to Support (d) = 22" = 1.83'

⇒ We will find the Values of Critical Shear at distance "d" by use of Similar triangles



From Similar Triangles

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

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

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

Step 4:-

Finding the Value of "ϕV_c" and "$1/2 \phi V_c$" and also its distances from Zero Shear to right side

By formulas

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

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

$= 29.21 \text{ Kips}$

$\Rightarrow$ location of ϕV_c by similar triangles.

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

$\Rightarrow x_1 = 4.49'$

$\Rightarrow$ Similarly,

$1/2 \phi V_c = \phi V_c/2 \Rightarrow 29.21/2 = 14.60 \text{ Kips}$

$\Rightarrow$ location of $1/2 \phi V_c$ will be,

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

Step: 05

Finding the Value of ϕV_s

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

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

$= 46.61 - 29.21$

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

ate:

Step: 06

Check on Section adequacy

By Formula,

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

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

$= 116.87$ kips

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

So Maximum will be Selected from the following 4 Conditions.

Here we are using #3 Stirrup
dia $= (3/8)'' = 0.375''$
so,
Area $\frac{\pi}{4}(0.375)^2 = 0.11$ in 2
For 2-legged Stirrup
-> Area × 2
-> $0.11 \times 2 = 0.22\ in^2$

1. $S_{max} = 24''$
2. $d/2 = 22/2 = 11''$
3. $S_{max} = \frac{Av \times fy}{0.75 \times \sqrt{f'c} \times bw}$
4. $S_{max} = \frac{0.22 \times 60000}{0.75 \times \sqrt{4000} \times 14} = 19.87''$
5. $S_{max} = \frac{Av \times Fy}{50 \times bw} = \frac{0.22 \times 60000}{50 \times 14} = 18.85''$

From above 4 Conditions, least Value of Spacing for #3 2 legged Stirrup will be Selected as,

$S_{max} = 11''$

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Date:

Step: 08

Stirrups Spacing from/at Critical Section will be Formula,

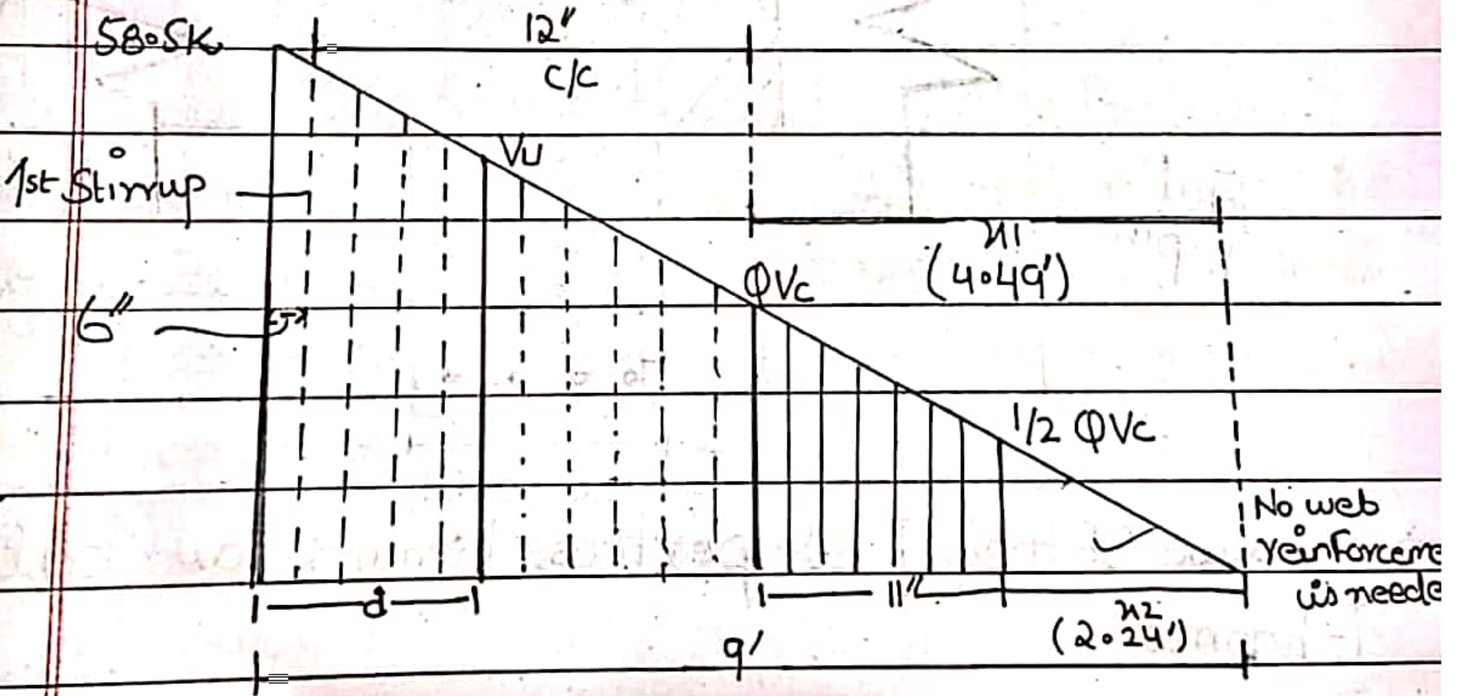
$$S = \frac{\phi \times A_v \times f_y \times d}{V_u - \phi V_c} = \frac{0.75 \times 0.22 \times 60 \times 22}{46.61 - 29.21}$$

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

So 12' c/c

Step: 09

Final Sketch will be,



As

First Stirrup from face of Support,

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

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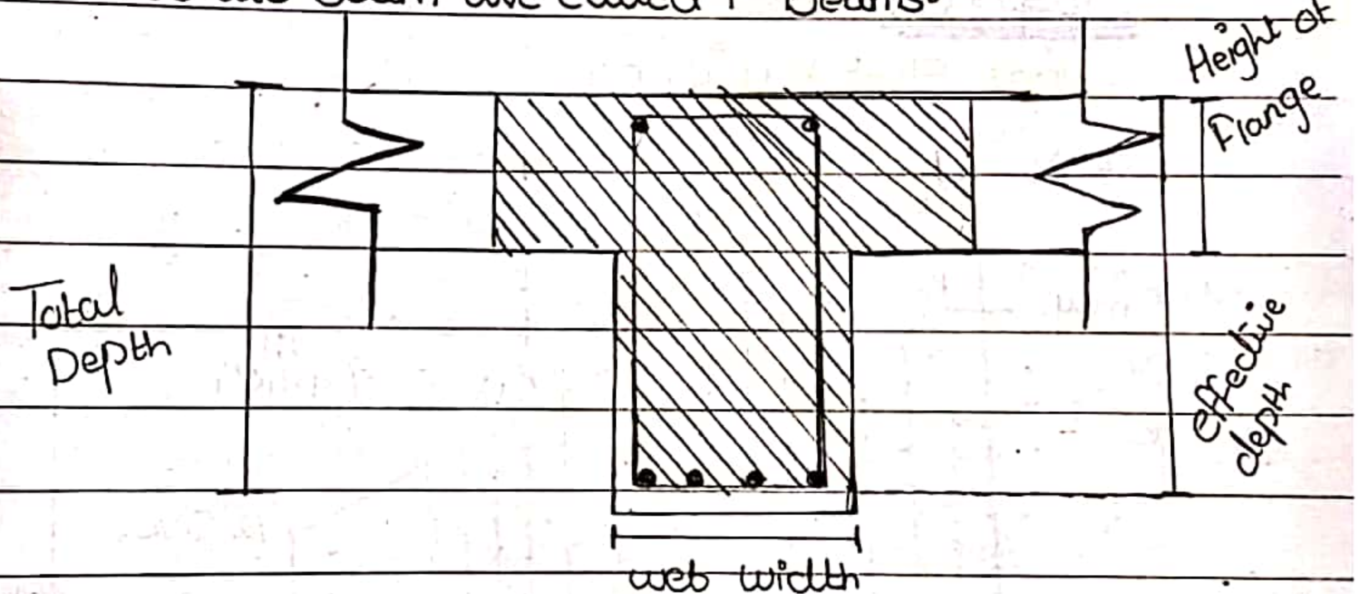
Question: 03

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 refainforced Concerete Strutures, Concrete State 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 beaams are called T-beams

⇒ It is provided at the centre of the Slab to resist the load

⇒ 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

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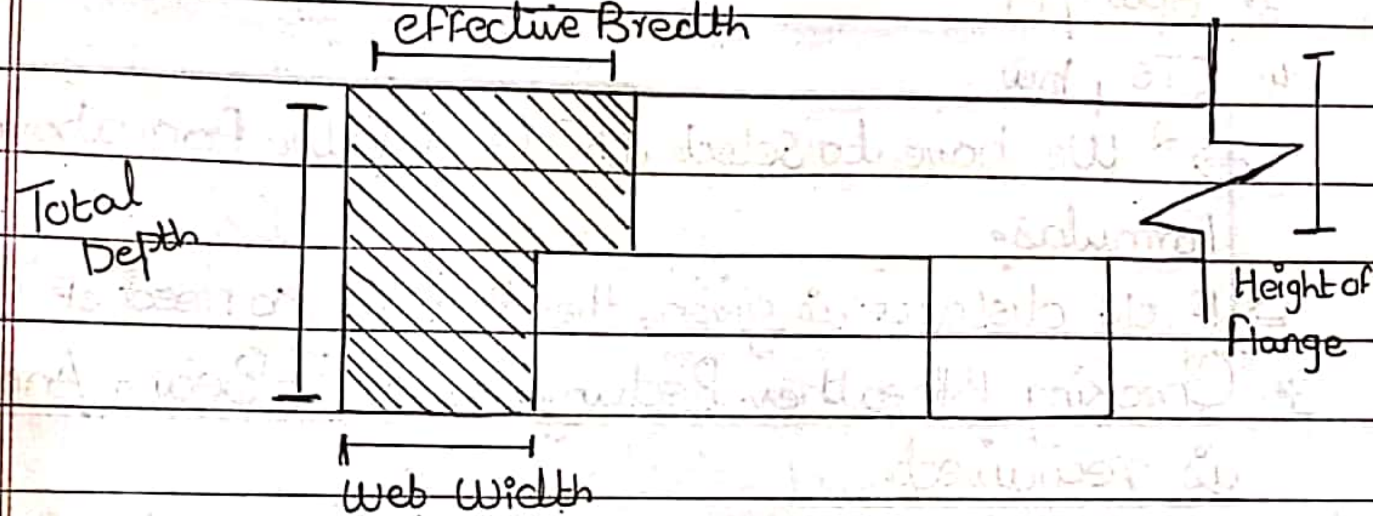
* L-Beam:

⇒ L-Shaped Structure that is is Contact with the Slab and Present at the Corner of the floor is Called L-Beam.



⇒ L-Beams are are also Called Edge Beams.

⇒ It is always provided at the Corners of the Sla

⇒ L-Beams are typical floors beams because of their reduced overall Structural depth, the beams are in Prestressed or reinforced Concrete.

* Flexural Analysis Of T-Beam:

Flexural Analysis of T-Beam Consists of Following Steps.

1. For Finding the Ultimate factored moment, we use the following formula,

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

∵ (W_u = Total factored Used, L = Total Span of the beam)

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

1. $16(h_f) + b_w$
2. C/C distance
3. Span/14
4. $\frac{CTs}{2} + b_w$

∵ (h_f = height of flange, CTS = Clear transvere 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 $a > h_f$ → Special Analysis is required

ii. If $a < h_f$ → 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

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

∵ (ϕ = Strength reduction fact, d = Effective depth, a = Compression block depth, b_w = web width of beam)

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

5. For Checking the range Of Reforcement Ratio.

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

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

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

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 bar 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

$$Md = \varphi \times Fy \times Ast \times (d - a/2) \longrightarrow \text{if } a < hf$$

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

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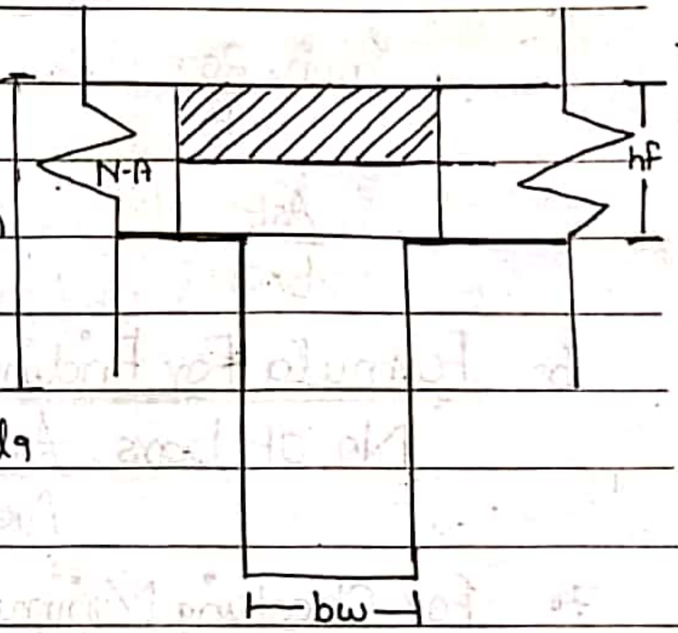
Question: 04

What is the difference b/w Case-I and Case-2 in the design of T-Beam?

Case: I



From the figure

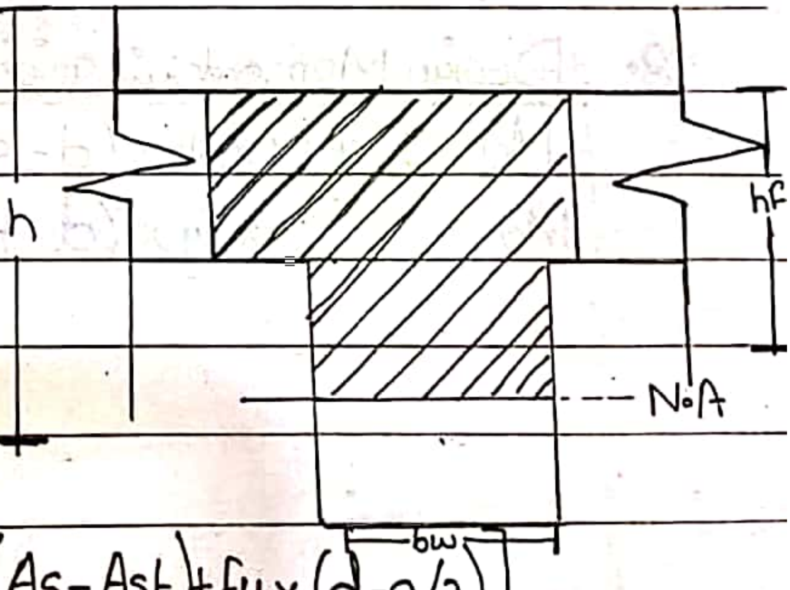
$a < h_f$

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,

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

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Question: 05

A Floor System Consists Of 3.5" Concrete Slab Supported by 16' Simple Span spaced at 9' C/C the beam having a 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:

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"

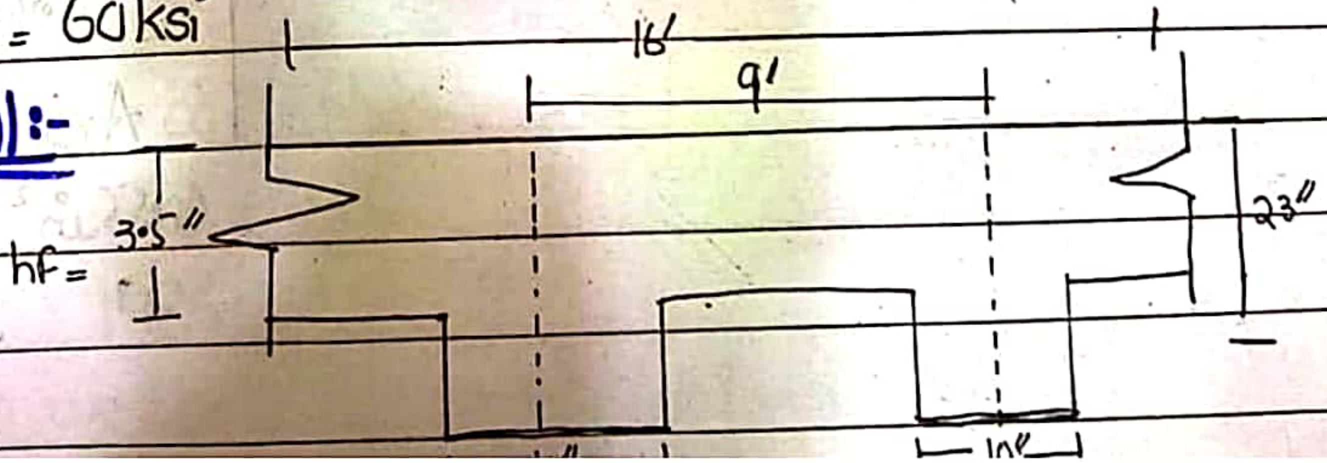
Height (h) = 23"

Total Factored moment (M_u) = 5800 Kip inch

f'_c = 3ksi

F_y = 60ksi

Sol:-



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Step#01.

Calculate the effective width (bc) 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 $= \frac{16 \times 12}{4} = 48''$

Selecting the least Value of be as,

$$b_e = 48''$$

Step#03

Check ρ_{max} and ρ_{min}

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

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

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

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

Step#02

Check wheather Rectangular or T-Beam analysis is required.

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

$Ast = \frac{Mu}{\phi \times Fy \times (d - a/2)} = \frac{5800}{0.90 \times 60 \times (18 - 3.5/2)} = 6.6\ in^2$

Trial#02:- $a = \frac{Ast \times Fy}{0.85 \times f'c \times bc}$

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

and $Ast = 6.55 in^2$ $\Rightarrow$ 3.2<3.5

So rectangular Beam design is required.

Trial#03:- $a = 3.21''$

and $Ast = \frac{5800}{0.90 \times 60 (18 - \frac{3.21}{2})} = 6.55 in^2$

So Area of Steel is $6.55 in^2$

Date:

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

$0.003 < 0.36 < 0.013$

As the Value of ρ_{max} is less than ρ, So we have to design it as "Doubly Reinforced Beam"

⇒ First we have to Find the Area to Steel against ρ_{max}

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

$Ast = 0.013 \times (10 \times 18)$

$Ast = 2.34 \text{ in}^2$

Step#04

Finding the Value of M_{u2} :-

By Formula,

$M_{u2} = \phi \times Ast \times fy \times (d - a/2)$

First Finding the Value of "a"

$⇒ a = \frac{Ast \times fy}{0.85 \times f'c \times b} = \frac{2.43 \times 6}{0.85 \times 3 \times 10}$

$a = 5.72''$

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

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

As $M_{u2} < M_u$

$1986.67 < 5800$

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

Step#05

Finding Difference in moments and Area of Steel

$M_{U1} = M_U - M_{U2}$

$= 5800 - 1986.67$

$M_{U1} = 3813.33$ Kip-inch

By formula,

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

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

Step#06

Finding Total Steel Area

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

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

Step#07

Selection Of Bar:

In Tention Zone:

let we use #8 Bar

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

Date:

By formula

No of bars = $\frac{\text{Area of Steel}}{\text{Area of Single bar}} = \frac{6.99}{0.785} = 8.9 \approx 9$

So 9 # 8 bars

In Compresion Zone:

let we use # 7 bar

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

By formula:

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

So 8 # 7 bars

Step # 08

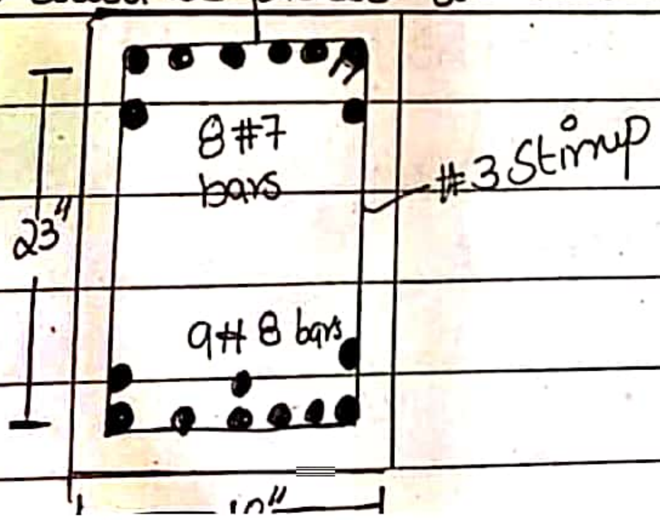
Minimum width for Accomodation of bars

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

$= 20.75''$

As $20.75'' > 10''$

So, the bar will be placed in multiple layers.



Effective depth (d) = 23 − 1.5 + 3/8 + 3/8 + 1/2 (8/8) = 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

Finding the design Moment.

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

~~Det~~ First $a = \frac{(A_s - A'_{st}) \times f_y}{0.85 \times f'_c \times b} = \frac{(9 \times 0.785 - 8 \times 0.601) \times 60}{0.85 \times 3 \times 10} = 5.31$

$\Rightarrow M_d = 0.90\,[(3 \times 0.601) \times 60 \times (19.6 - 3.18) + (9 \times 0.785 - 8 \times 0.601) \times 60 \times (19.6 - \frac{5.31}{2})]$

Md = 6328.38

As 6328.38 > 5800 → So design is OK!

Date:

Question: 06

A beam is revised to developed and ultimate moment of 6000 Kip - inch limited to 14 x 26 inch Size, use f'c = 4 Ksi rows of tensile reinforcement and effective depth of beam is 22 inch.

Sol:-

Given:-

Breath (b) = 14"

Height (h) = 26"

Concrete Compression Strength (F'c) = 4 Ksi

Steel Tensile Strength (fy) = 60 Ksi

Ultimate Factored Moment (Mu) = 6000 Kip-inches

Effective depth of beam (d) = 22"

Assume Effective Cover (d') = 2.5"

Step # 01 (Reinforcement Ratio)

By Formula,

$$\rho_{max} = 0.85 \times \beta \times \frac{f'c}{Fy} \times \left(\frac{\varepsilon u}{\varepsilon u + \varepsilon y}\right),$$

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

$$\rho_{max} = 0.0180$$

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Step#02 (Area Of Steel)

As we know that,

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

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

Step# 03 (Design Moment)

By Using Formula

$$M_{U2} = \phi \times Ast \times f_y \times (d - a/2)$$

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

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 reinforced

Step#04 (Difference In Moments)

$$M_{U1} = M_U - M_{U2}$$

$$= 6000 - 5537.4$$

$$\boxed{M_{U1} = 462.6 \text{ Kip-inches}}$$

Step#05 (Area Of Steel)

$$M_{U1} = \phi \times A's \times f_y \times (d - d')$$

So Area of Steel in Compression Zone will be,

Date:

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

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

Step # 06 (Total Steel Area)

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

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

1. Steel in Tension Zone :-

We use #7 bar,

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

$= 0.601 \; in^2$

So, No of bars = $\frac{A_s}{\text{Area of Single bar}}$

$= \frac{5.98}{0.601} = 9.9 \approx 10$ 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,

Date:

No of bars = $\frac{Ast}{\text{Area of Single bar}}$

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

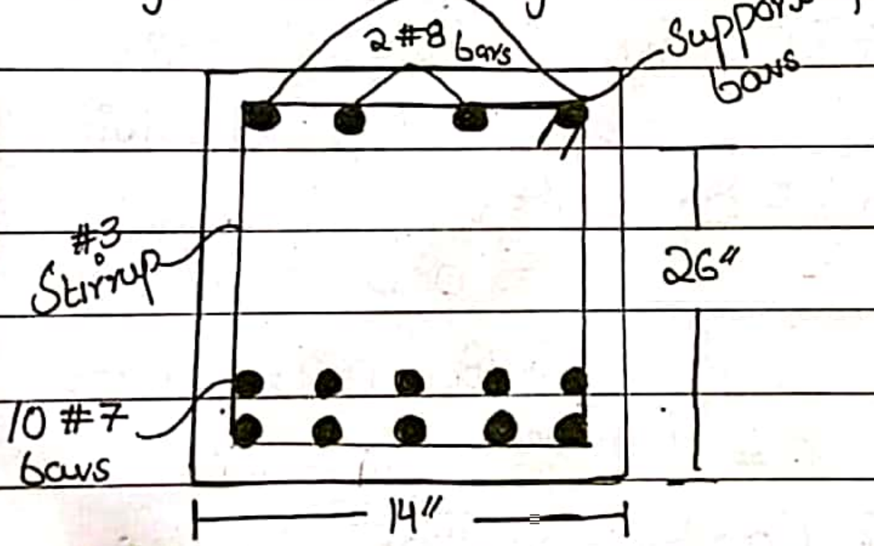
So 2 #5 bars

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,

=> Effective depth (d) = $26 - 1.5 - 3/8 - 7/8 - 1/2(7/8)$

=> Effective Cover (d') = $1.5 + 3/8 + 1/2(5/8)$

$= 2.18''$

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Step # 09 (Design Moment)

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

$$a = \frac{(A_{st} - A_{st}') \times F_y}{0.85 \times F'c \times b}$$

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

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

$M_d = 7047.6$ Kip-inches

As $7047.6 > 60000$

Design is OK!

Scanned with CamScanner