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Section # A

Assignment # PRCD-1

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## Question: 01

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

★ Answer:

### Stirrups

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

### Types Of Stirrups:

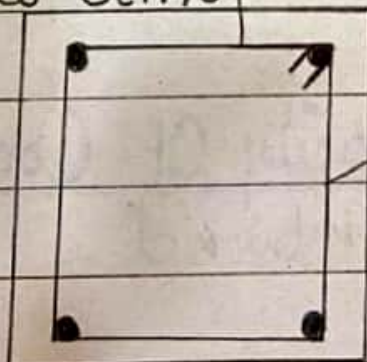
#### 1. Single-Legged Stirrup:

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



#### 2. Two-Legged Stirrup:

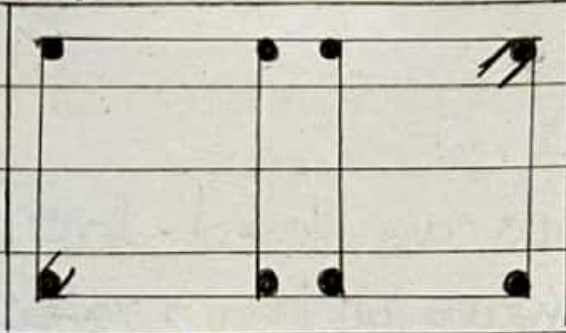
It is most commonly used and widely used stirrup. Minimum 4 bars are required for providing this stirrup.



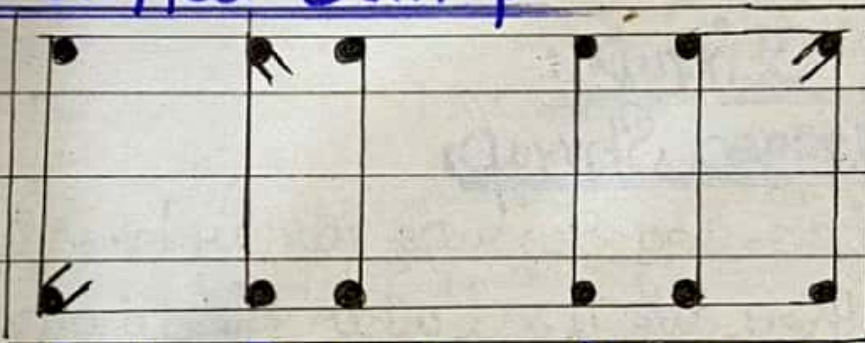
2 legged stirrup

### 3. Four-Legged Stirrup:

These Stirrups are used in case of web reinforcement



### 4. Six-legged Stirrup:



### \* ACT 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  $45^\circ$  and is at distance  $(d)$  from the force of support which is equal to effective depth.

#### 2. Shear Strength Capacity Of Concrete IS:

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

### 3. Minimum Web Reinforcement:-

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

$$\phi = 0.75 \longrightarrow \text{for Shear design}$$

( $\because V_u =$  Total Factored Shear applied at given Section)

$\Rightarrow$  For Minimum Reinforcement Area:-

$$A_{u \min} = 0.75 \times \frac{\sqrt{f'_c} \times b_w \times S}{f_y} \text{ or } \frac{S_o \times b_w \times S}{f_y} \rightarrow \left. \begin{array}{l} \text{higher} \\ \text{Value is} \\ \text{Selected} \end{array} \right\}$$

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

$$S_{\max} = \frac{A_u \times f_y}{0.75 \times \sqrt{f'_c} \times b_w} \text{ or } \frac{A_u \times f_y}{S_o \times b_w} \rightarrow \left. \begin{array}{l} \text{lesser Value} \\ \text{is} \\ \text{Selected} \end{array} \right\}$$

4. No web-reinforcement is required if:-

$$V_u < 1 \phi V_c$$

$\Rightarrow$  Between Critical section " $V_u$ " and " $\phi V_c$ ", spacing b/w web reinforcement can be find by,

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

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④

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 the following.

1° 24"

2°  $d/2$

3°  $S_{max} = \frac{A_u \times F_y}{0.75 \times \sqrt{F'_c} \times b_w}$

∴ ( $V_s$  = Shear Force Carried by web reinforcement)

4°  $S_{max} = \frac{A_u \times F_y}{50 \times b_w}$

⇒ IF  $V_s > 4 \times \sqrt{F'_c} \times b_w \times d$

Man  $\downarrow$  spacing will be halved

⇒ IF  $V_s > 8 \times \sqrt{F'_c} \times b_w \times d$

Then either  $\downarrow$  increase cross-sectional dimensions or  $\uparrow$  increase  $F'_c$

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## Question: 02

A Simply Supported rectangular beam 14" wide having an effective depth of 22" to carry a lateral load of 6.5k/ft on 18' simple span. It is reinforced with 7in<sup>2</sup> of tensile steel area, if  $f'_c = 4 \text{ ksi}$  and  $f_y = 60 \text{ ksi}$ , then design the beam for Shear

### Given:

Breadth of web of beam ( $b_w$ ) = 14"

Effective depth ( $d$ ) = 22"

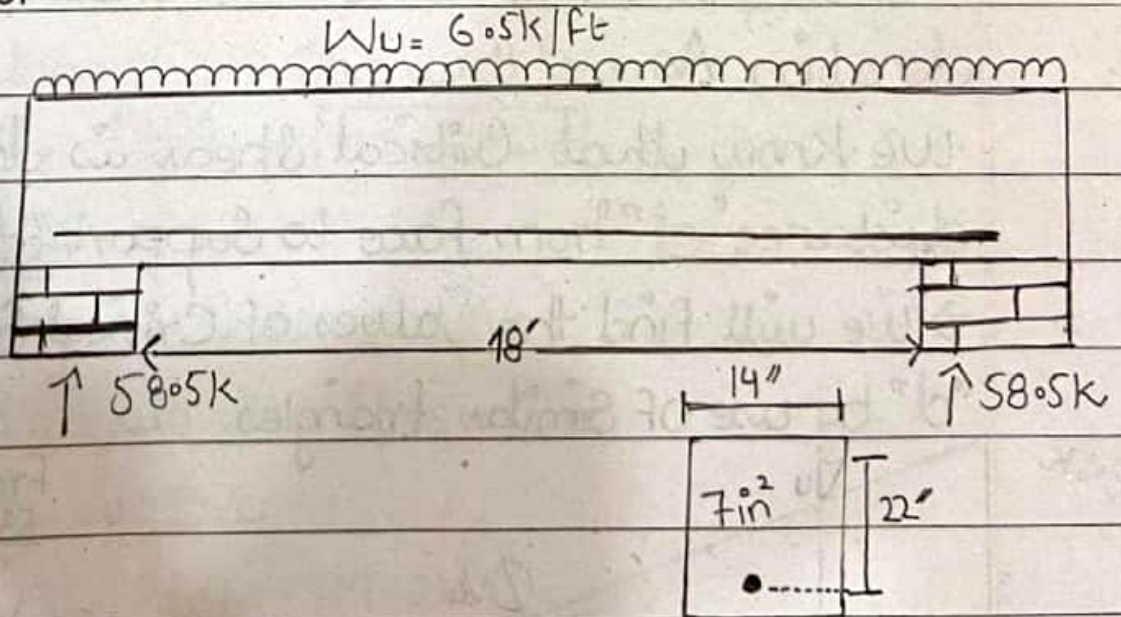
Given load = 6.5k/ft

Steel Area = 7in<sup>2</sup>

$f'_c = 4 \text{ ksi}$

$f_y = 60 \text{ ksi}$

### Sol:



### Step: 01 (Reactions On Supports)

Finding the reactions due to applied load

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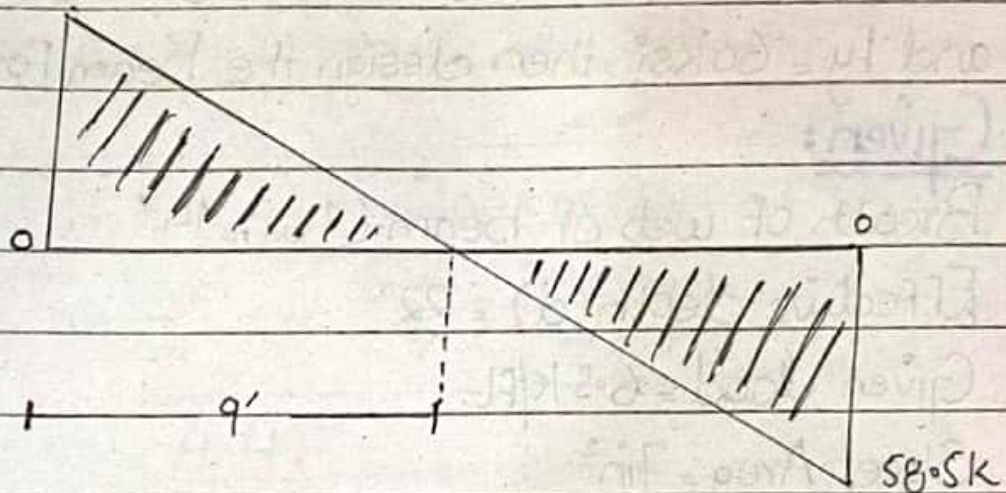
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$$\text{Total load} = \frac{6.5 \times 18}{2} = 58.5 \text{ kips}$$

### Step: 02 (Shear Force Diagram)

The required Shear diagram will be

58.5k

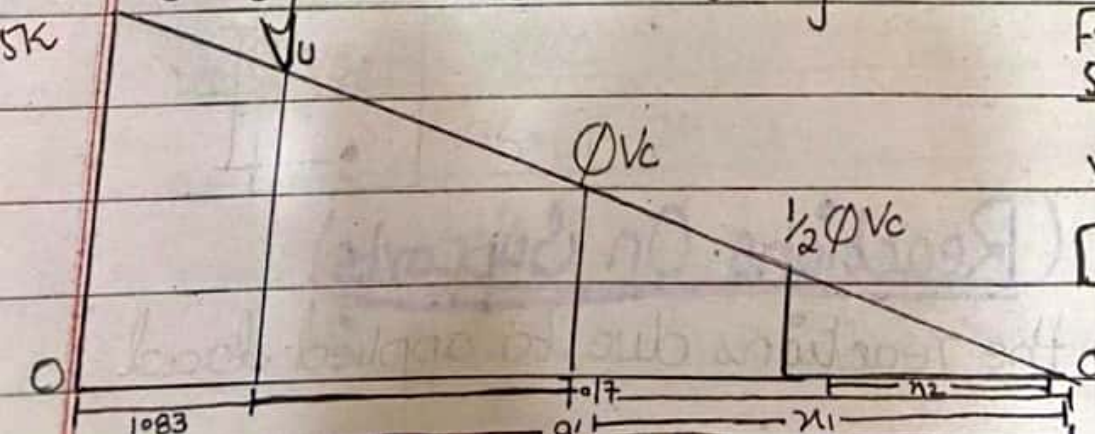


### Step: 03

Finding the Value of Critical Shear " $V_u$ " 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

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

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

Step 4:-

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

By Formulas

$$\begin{aligned} \Rightarrow \phi V_c &= \phi \times 2 \times \sqrt{f'_c} \times b_w \times d \\ &= 0.75 \times 2 \times \sqrt{4000} \times 14 \times 22 = 29219 \text{ Lbs} \\ &= 29.21 \text{ Kips} \end{aligned}$$

$\Rightarrow$  location of  $\phi V_c$  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  $\phi V_s$

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: 06

Check on Section adequacy

By Formula,

$$= \phi \times 8 \times \sqrt{F'c} \times b_w \times d$$

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

$$= 116.87 \text{ kips}$$

As  $\phi \times 8 \times \sqrt{F'c} \times b_w \times d > \phi V_s$

So Maximum will be Selected from the following 4

Conditions,

1°  $S_{max} = 24''$

2°  $d/2 = 22/2 = 11''$

3°  $S_{max} = \frac{A_u \times f_y}{0.75 \times \sqrt{F'c} \times b_w}$

4°  $S_{max} = \frac{0.22 \times 60000}{0.75 \times \sqrt{4000} \times 14} = 19.87''$

5°  $S_{max} = \frac{A_u \times f_y}{s_o \times b_w} = \frac{0.22 \times 60000}{s_o \times 14} = 18.85''$

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

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

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

Step: 08

Stirrups Spacing from/at Critical Section will be Formula,

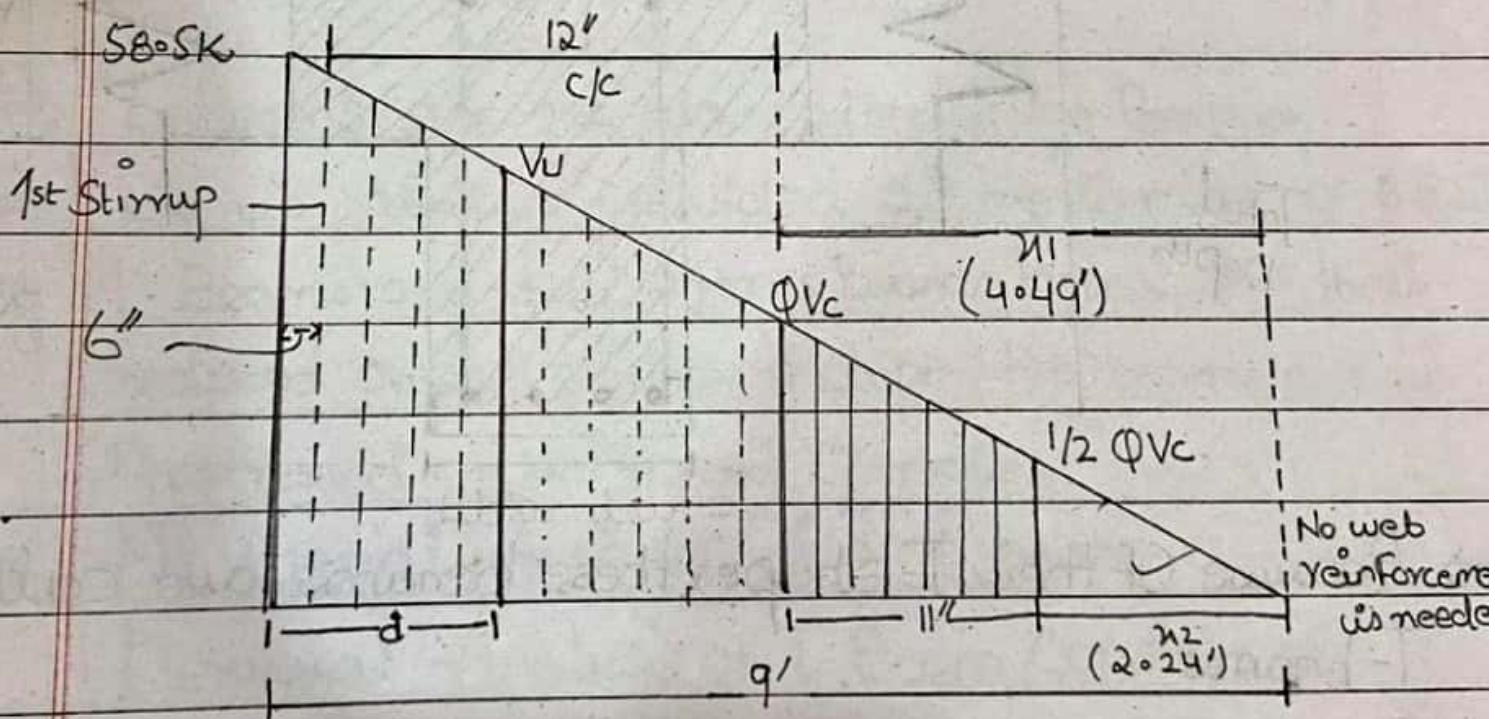
$$S = \frac{\phi \times A_u \times F_y \times d}{V_u - \phi V_c} = \frac{0.75 \times 0.22 \times 60 \times 22}{46.61 - 29.21}$$

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

So 12' c/c

Step: 09

Final sketch will be,



As

First Stirrup from face of Support,

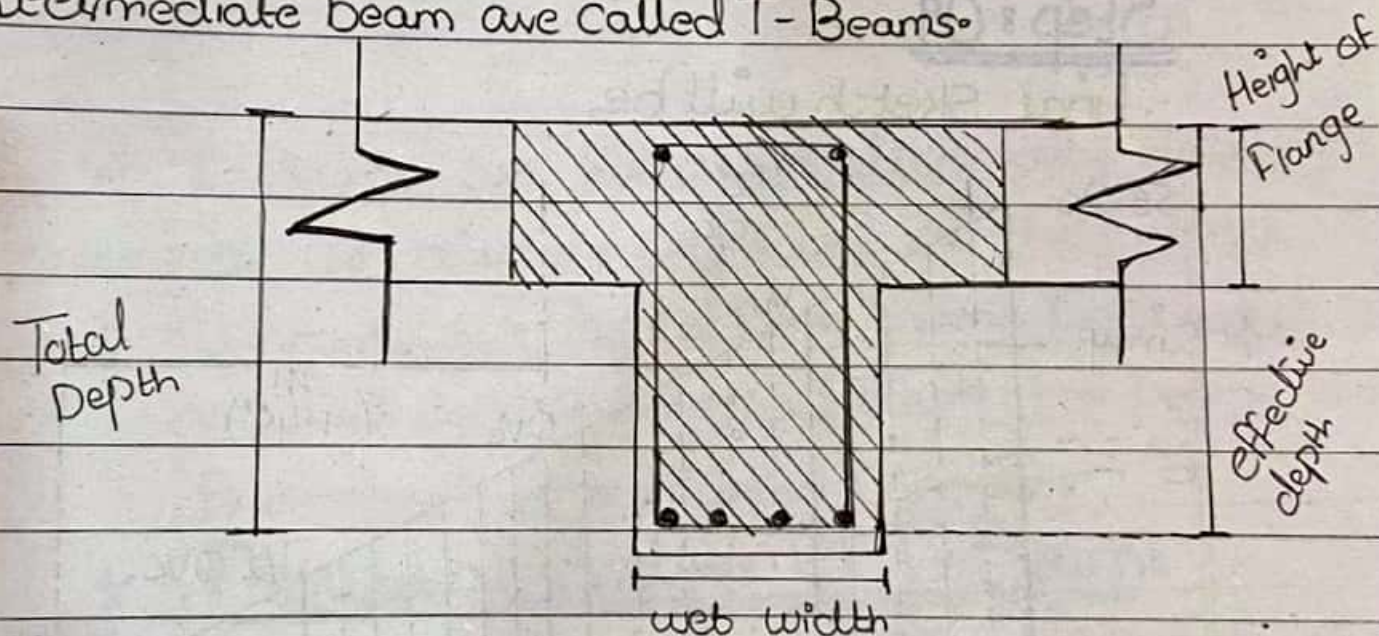
$$S/2 = 12/2 = 6''$$

## Questions 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 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

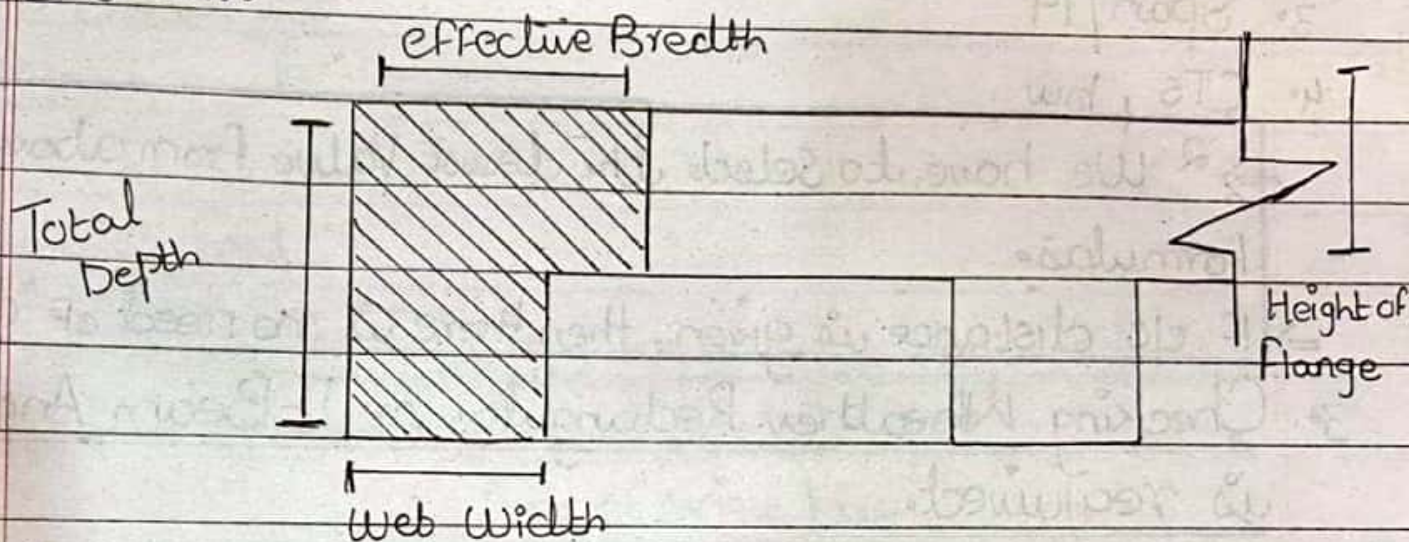
⇒ It is provided at the centre of the slab to resist the load

⇒ 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

## \* 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-Beams 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 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,

$$M_u = \frac{W_u \times L^2}{8} \quad \because \begin{cases} W_u = \text{Total Factored Load} \\ L = \text{Total Span of the beam} \end{cases}$$

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

- 1°  $16(h_f) + b_w$
- 2° C/c distance
- 3°  $\text{Span}/14$
- 4°  $\text{CTS} + b_w$

∴  $\left( \begin{array}{l} h_f = \text{height of flange} \\ \text{CTS} = \text{Clear transverse span} \end{array} \right)$

⇒<sup>2</sup> We have to select the least value from above formulas.

⇒ If c/c distance is given, then there is no need of "CTS + bw"

3° Checking Whether Rectangular or T-Beam Analysis is required.

- i If  $a > h_f \rightarrow$  Special Analysis is required
  - ii If  $a < h_f \rightarrow$  Rectangular beam analysis is required
- Where:  $\left( \begin{array}{l} a = \text{Depth of Compression block} \\ h_f = \text{height of flange} \end{array} \right)$

4° For Finding Area of Steel, we have to use

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

∴  $\left( \begin{array}{l} \phi = \text{Strength reduction factor} \\ d = \text{Effective depth} \\ a = \text{Compression block depth} \\ b_w = \text{web width of beam} \end{array} \right)$

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

$0.85 \times f'_c \times b_w$

5° For Checking the range of Reinforcement Ratio,

$$S_{max} = 0.85 \times \beta \times \frac{F'_c}{F_y} \left( \frac{\epsilon_u}{\epsilon_u + \epsilon_y} \right)$$

$$S_{min} = \frac{200}{F_y}$$

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

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,

$$b_{min} = 2(\text{clear cover}) + 2(\text{dia of Stirrup}) + \text{No of bars} \left( \text{dia of bar} \right) + \frac{\text{Spacing}}{\text{blw bars}} \left( \text{dia of bar} \right)$$

8° Design Moment is given by

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

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

### Questions 04

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

#### Case: I

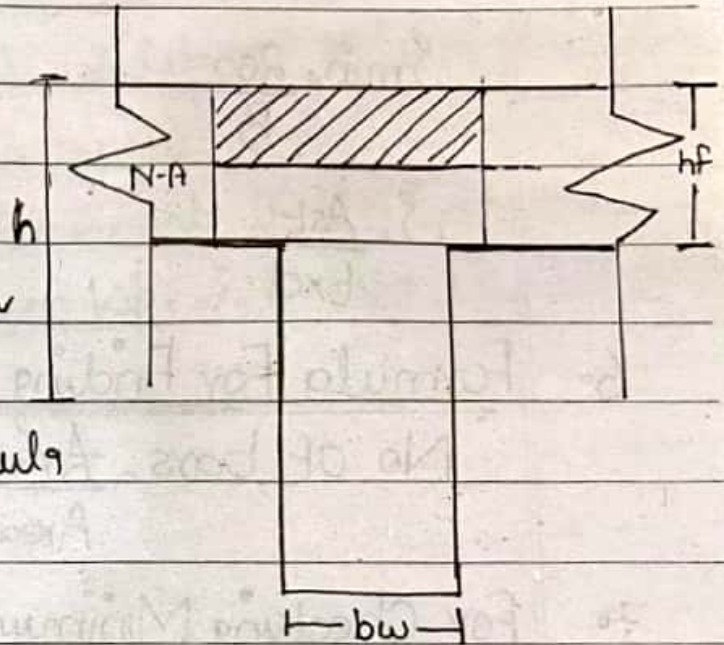
From the figure

$$a < hf$$

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,

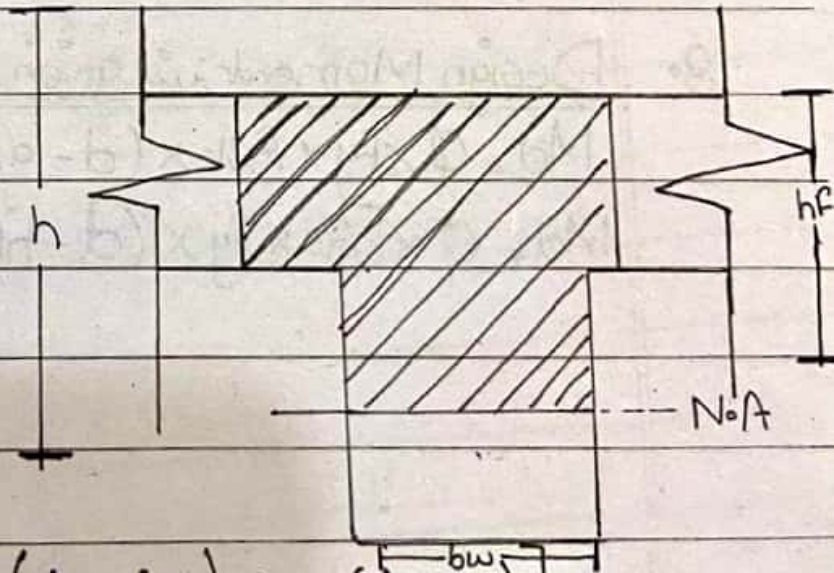
$$a > hf$$

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

So, the required design

Moment will be,

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



# 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  $f'_c = 3 \text{ ksi}$  and  $f_y = 60 \text{ ksi}$

## 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"

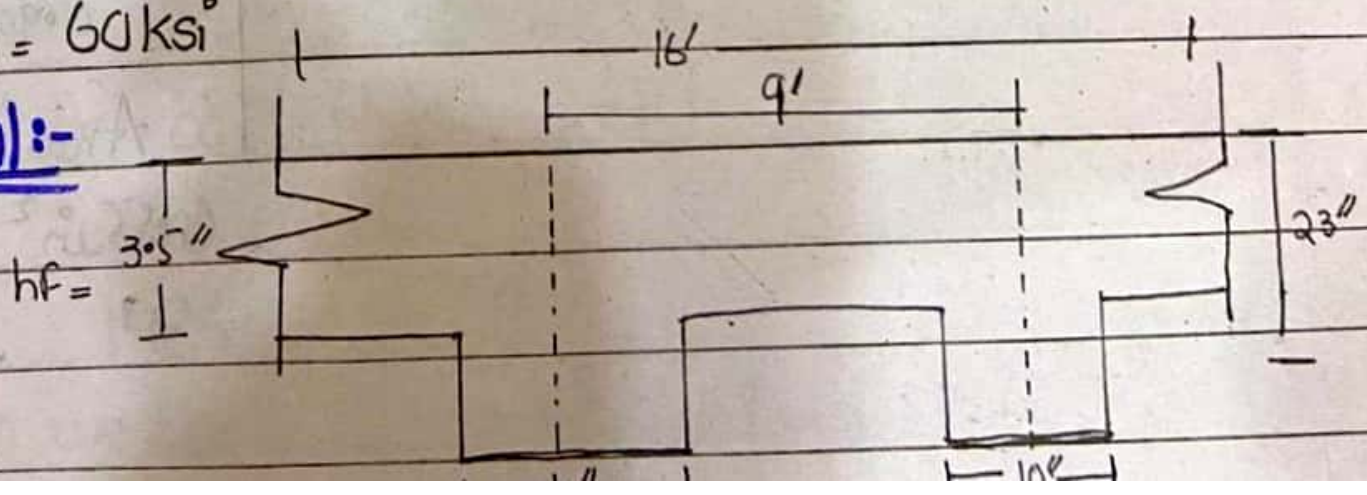
Height ( $h$ ) = 23"

Total Factored moment ( $M_u$ ) = 5800 Kip inch

$f'_c = 3 \text{ ksi}$

$f_y = 60 \text{ ksi}$

## Sol:-





Step # 01.

Calculate the effective width (bc) for T-beam

- 1<sup>o</sup>  $16(h_f) + b_w = 16(3.5) + 10 = 66"$
- 2<sup>o</sup> C/c distance =  $9 \times 12 = 108"$
- 3<sup>o</sup> Span/4 =  $16 \times 12 = 48"$

Step # 02

Check whether Rectangular or T-Beam analysis is

Selecting the least Value of bc as required.

$b_e = 48"$

Step # 03

Check  $\delta_{max}$  and  $\delta_{min}$

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

$$A_{st} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{5800}{0.9 \times 60 \times (18 - 3.5/2)} = 6.6 \text{ in}^2$$

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

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

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

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

$$\text{and } A_{st} = 6.55 \text{ in}^2 \Rightarrow 3.2 \times 3.5$$

So rectangular Beam design is required.

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

$$\delta = \frac{A_{st}}{b \times d} = \frac{6.55}{10 \times 18} = 0.036$$

Trial # 03 :-  $a = 3.21"$

$$\text{and } A_{st} = \frac{5800}{0.9 \times 60 \left( 18 - \frac{3.21}{2} \right)} = 6.55 \text{ in}^2$$

So Area of Steel is  $6.55 \text{ in}^2$

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

$$0.003 < 0.36 < 0.013$$

As the Value of  $\rho_{max}$  is less than  $\rho$ , So we have to design it as "Doubly Reinforced Beam"

⇒ First we have to find the Area to Steel against  $\rho_{max}$

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

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

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

### Step # 04

Finding the Value of  $M_{u2}$  :-

By Formula,

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

First Finding the Value of "a"

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

$$a = 5.72''$$

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

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

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

$$M_{u1} = M_u - M_{u2}$$
$$= 5800 - 1986 - 67$$

$$M_{u1} = 3813.33 \text{ Kip-inch}$$

By formula,

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

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

### Step # 06

Finding Total Steel Area

$$A_s = A_{st} + A'_{st}$$
$$= 2.43 + 4.56 = 6.99 \text{ in}^2$$

### Step # 07

Selection Of Bar:

In Tention Zone:

let we use # 8 Bar

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

By formula

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

So 9 # 8 bars

In Compression Zone:

let we use # 7 bar

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

By formula:

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

So 8 # 7 bars

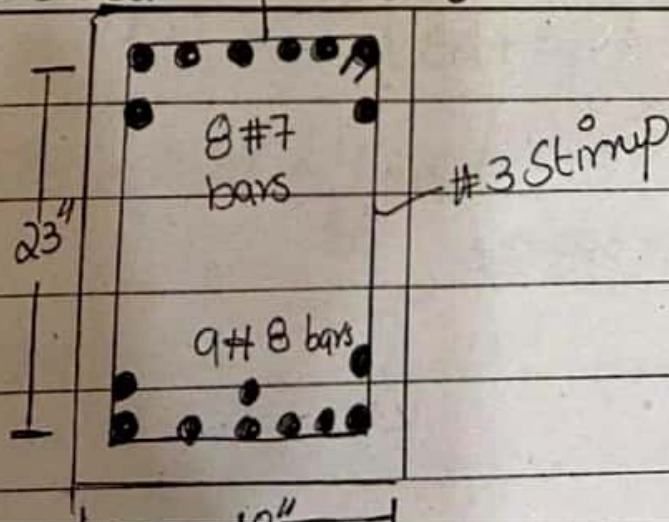
### Step # 08

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.



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

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

### Step # 09

Finding the design Moment.

$$M_d = \phi [A_s' \times f_y \times (d - d') + (A_s - A_s') \times f_y \times (d - a/2)]$$

$$\text{First } a = \frac{(A_s - A_s') \times f_y}{0.85 \times F_c' \times b} = \frac{(9 \times 0.785 - 8 \times 0.601) \times 60}{0.85 \times 3 \times 10} = 5.31$$

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

$$M_d = 6328.38$$

$A_s = 6328.38 > 5800 \rightarrow$  So design is OK!

## Questions 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:-

Breadth ( $b$ ) = 14"

Height ( $h$ ) = 26"

Concrete Compression Strength ( $f'_c$ ) = 4 ksi

Steel Tensile Strength ( $f_y$ ) = 60 ksi

Ultimate Factored Moment ( $M_u$ ) = 6000 kip-inches

Effective depth of beam ( $d$ ) = 22"

Assume Effective Cover ( $d'$ ) = 2.5"

### Step # 01 (Reinforcement Ratio)

By Formula,

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

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

$$\rho_{max} = 0.0180$$

Step # 02 (Area Of Steel)

As we know that,

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

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

Step # 03 (Design Moment)

By Using Formula

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

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

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

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

$$\text{As, } 5537.4 < 6000$$

So we have to design a section as doubly reinforced

Step # 04 (Difference In Moments)

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

$$= 6000 - 5537.4$$

$$M_{u1} = 462.6 \text{ kip-inches}$$

Step # 05 (Area Of Steel)

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

So Area of Steel in Compression Zone will be,

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

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

### Step # 06 (Total Steel Area)

$$A_s = A_{st} + A_{s't}$$

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

#### 1. Steel in Tension Zone:-

We use #7 bar,

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

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

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

So 10 #7 bars

#### 2. Steel in Compression Zone

We use #5 bar,

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

$$= 0.306 \text{ in}^2$$

So,



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

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

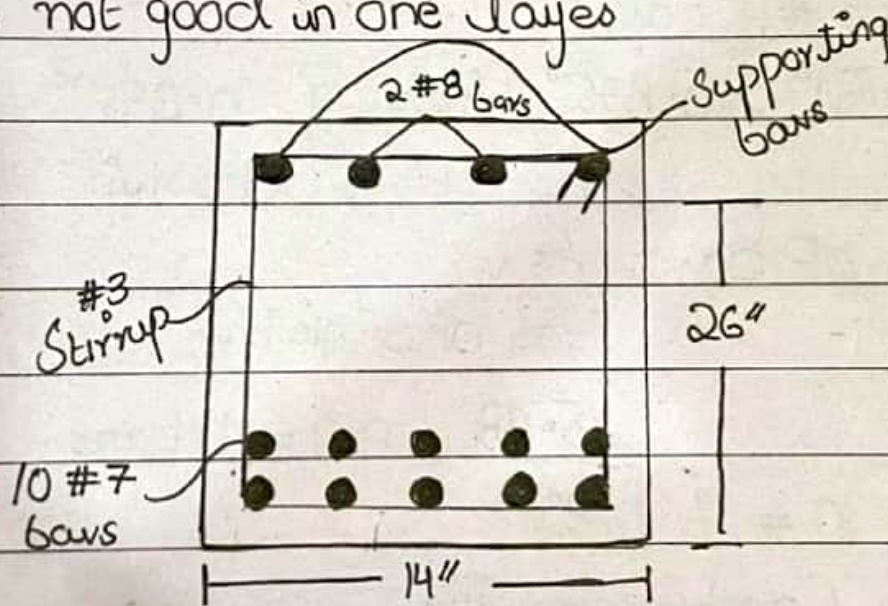
So 2 #5 bars

### Step # 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,

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

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

$$= 2.18''$$

Date: \_\_\_\_\_

(25)

## Step # 09 (Design Moment)

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

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

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

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

$$M_d = 7047.6 \text{ Kip-inches}$$

$$A_s \quad 7047.6 > 60000$$

Design is OK