ID# 7835

SUBMITTED TO ENGR. FAWAD KHAN

SUBJECT PRCD-I

SECTION B

ASSIGNMENT # 02

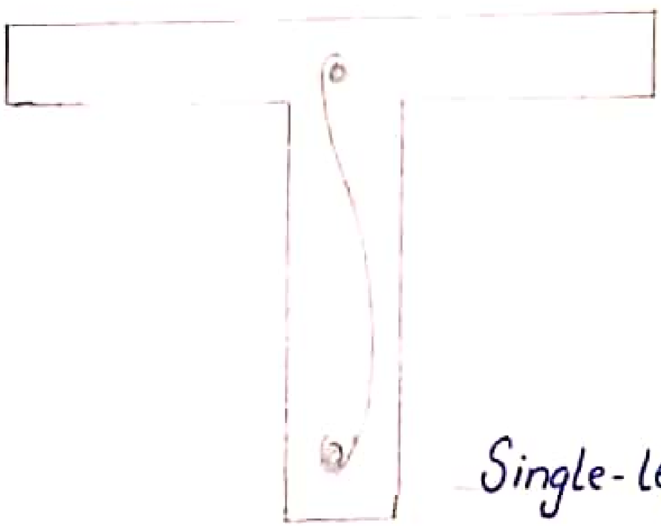
**Q1** Explain in detail types of stirrups with figures and also explain ACI codes for shear design?

**Ans** Following are the types of stirrups:

- Single legged stirrups.
- Four Legged stirrup.
- Two legged or Double legged stirrups.
- Six legged stirrup.

## 1 SINGLE LEGGED STIRRUPS:

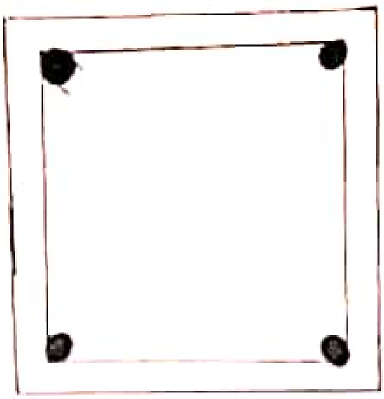
These type of stirrups are used to hold the longitudinal bars in position and prevent buckling.



Single-legged Stirrup

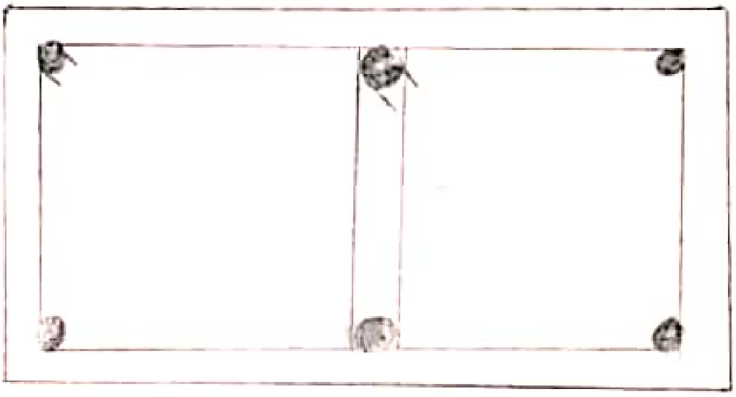
## 2. DOUBLE LEGGED STIRRUP:

We use a single stirrup to tide a beam or a column at a time, we say it is two legged stirrup. Double-legged stirrups are adequate for typical beams with relatively short widths.



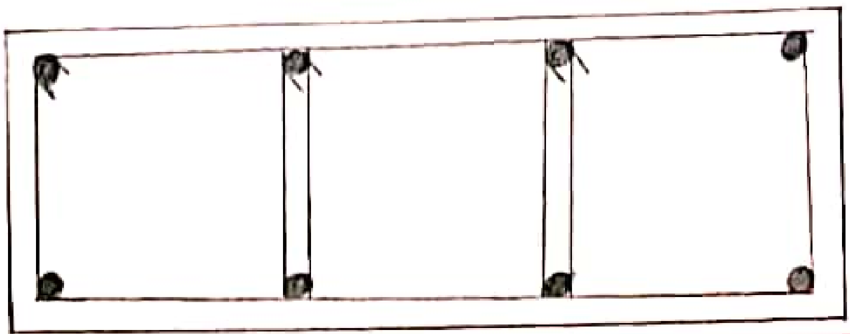

3. FOUR LEGGED STIRRUP:

We use double stirrup to tie a beam or column at a time, we say it is four legged stirrup. For beam having longer widths multiple legged or four legged stirrups are required.



4. SIX LEGGED STIRRUP:-

These six legged stirrups are generally used for a continous beam structure, It consists of regular upholding of structure at each Junction while joints at the joining of beam and column.



# ACI CODES FOR SHEAR DESIGN:

1. Compute the design shear force, $V_u$, at appropriate location.
2. Compute shear strength capacity of concrete, $V_c = 2 \times \sqrt{f'_c} \times b_w \times d$
3. Compute Minimum web reinforcement.

If $V_u \leq \phi \times V_c$ so no web reinforcement needed

If it is not applicable then min area of web reinforcement equal to:

i) $A_{v_{min}} = 0.75 \times \sqrt{f'_c} \times \dfrac{b_w \times S}{f_y}$ (OR) $A_{v_{min}} = \dfrac{50 \times b_w \times S}{f_y}$

→ Max spacings can be found by these formula's.

$$S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w} \quad \text{(OR)} \quad S_{max} = \frac{A_v \times f_y}{50 \times b_w}$$

4- If $V_u \leq \dfrac{\phi V_c}{2}$, if it's true no stirrups are required.
5- First stirrup is provided at a distance $S/2$.
6- Between "$V_u$" and "$\phi V_c$" spacing between web reinforcement is found by formula:

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

7. If $V_s \leq 4 \times \sqrt{f'_c} \times b_w \times d$; then max spacing of stirrups will be smallest of the following four conditions

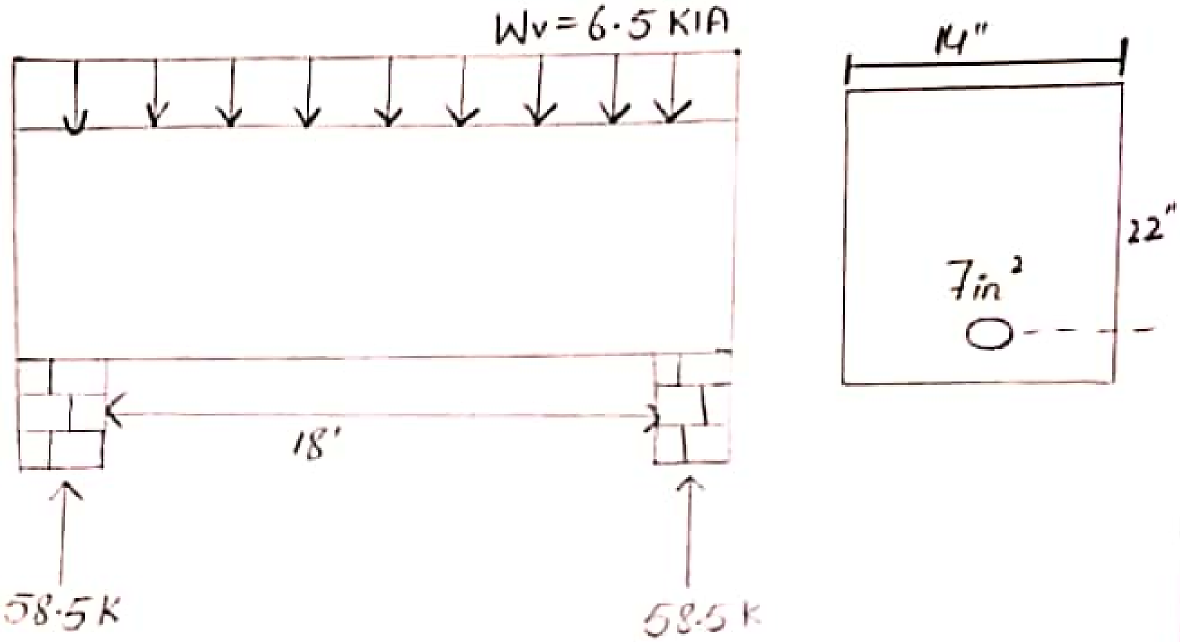
1- 24" 2- $d/2$ 3- $S_{max} = \dfrac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$ 4- $S_{max} = \dfrac{A_v \times f_y}{50 \times b_w}$

8. If $V_s > 4 \times \sqrt{f'_c} \times b_w \times d$ → Then max spacing will be halved.
9. If $V_s > 8 \times \sqrt{f'_c} \times b_w \times d$

Then either increase cross-sectional dimensions or increase $f'_c$.

Q2 A simply supported rectangular beam 14" wide having an effective depth 22" to carry a lateral load of 6.5 K/ft on a 18' simple span. It is reinforced with 7 $in^2$ of tensile steel area, if $f'_c$ is 4ksi and $f_y$ is 60ksi then design the beam for Shear.

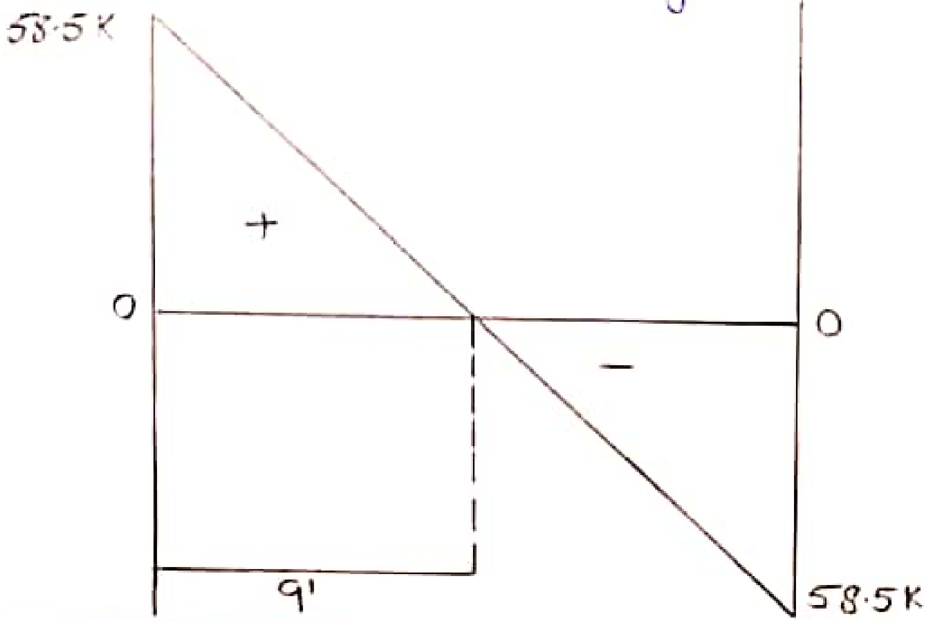
Sol




Step 01: Find the reactions on support.

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

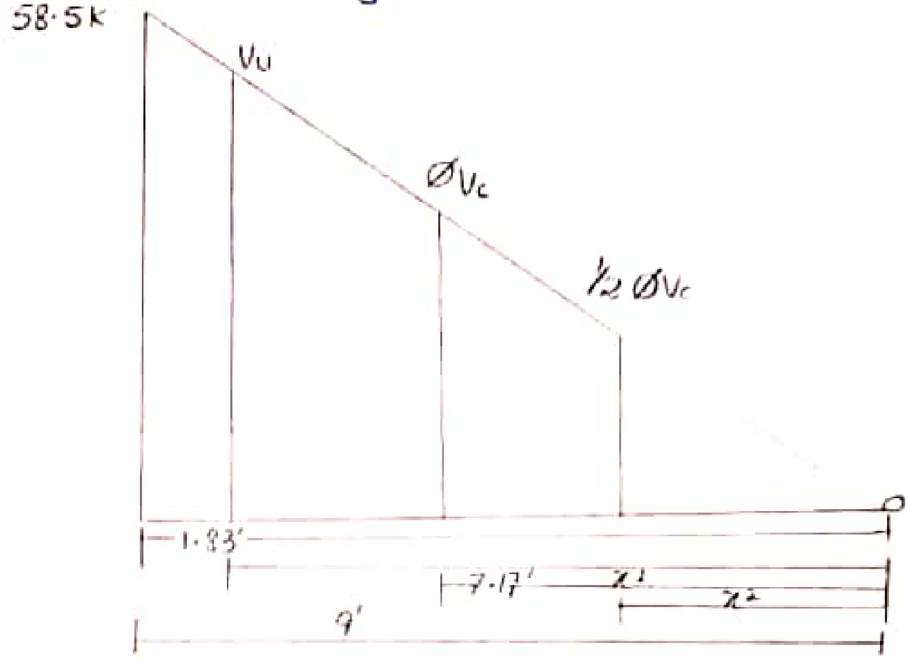
Step 02: Draw its shear force diagram.



Step 03: Finding the value of critical stress "$V_u$" and it's location.

As we know that critical shear is located at distance "d". from the face of Supports $d = 22" = 1.83'$

Using Similarity of triangles.




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

$$V_u = \frac{58.5 \times 7.17}{9} = 46.605\,k$$

Step 04: Finding the value of "$\phi V_c$" and "$\frac{1}{2}\phi V_c$" and also its distances from zero shear to right side.

By formula,

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

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

$$= 29.21\,K.$$

★ Location of "$\phi V_c$" by similar triangles

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

$$x_1 = 4.49'$$

Now,

→ $\frac{1}{2} \phi V_c = \frac{29.21}{2} = 14.60\,K$

→ Location of $\frac{1}{2} \phi V_c$ will be

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

$$x_2 = 2.24'$$

Step 05: Finding the value of "$\phi V_s$"

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

$$= 46.605 - 29.21$$

$$\phi V_s = 17.395$$

Step 06: check on section adequacy

By formula

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

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

$$= 116.87\ K$$

As $\phi \times 8 \times \sqrt{f'c} \times b_w \times d > \phi V_s$ Thus section is adequate.

Step 07: check on Max spacing for stirrups

By formula $= \phi \times 4 \times \sqrt{f'c} \times b_w \times d = 0.75 \times 4 \times \sqrt{4000} \times 14 \times 22$

$$= 58.43\ K.$$

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

So max spacing will be selected from the following 4 conditions.

1- 24"  2- $d/2 = 22/2 = 11"$  3- $S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{f'c} \times bw}$

lets suppose we use # 3 Stirrup; dia = 3/8" = 0.375".

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

For 2-legged Stirrup Area x 2

$= 0.11 \times 2 = 0.22 in^2$

3- $S_{max} = \frac{0.22 \times 60000}{50 \times 14} = 18.25"$

4- $S_{max} = \frac{A_v \times f_y}{50 \times bw} = \frac{0.22 \times 6000}{50 \times 14} = 19.87"$

So we choose the least value from the above values.

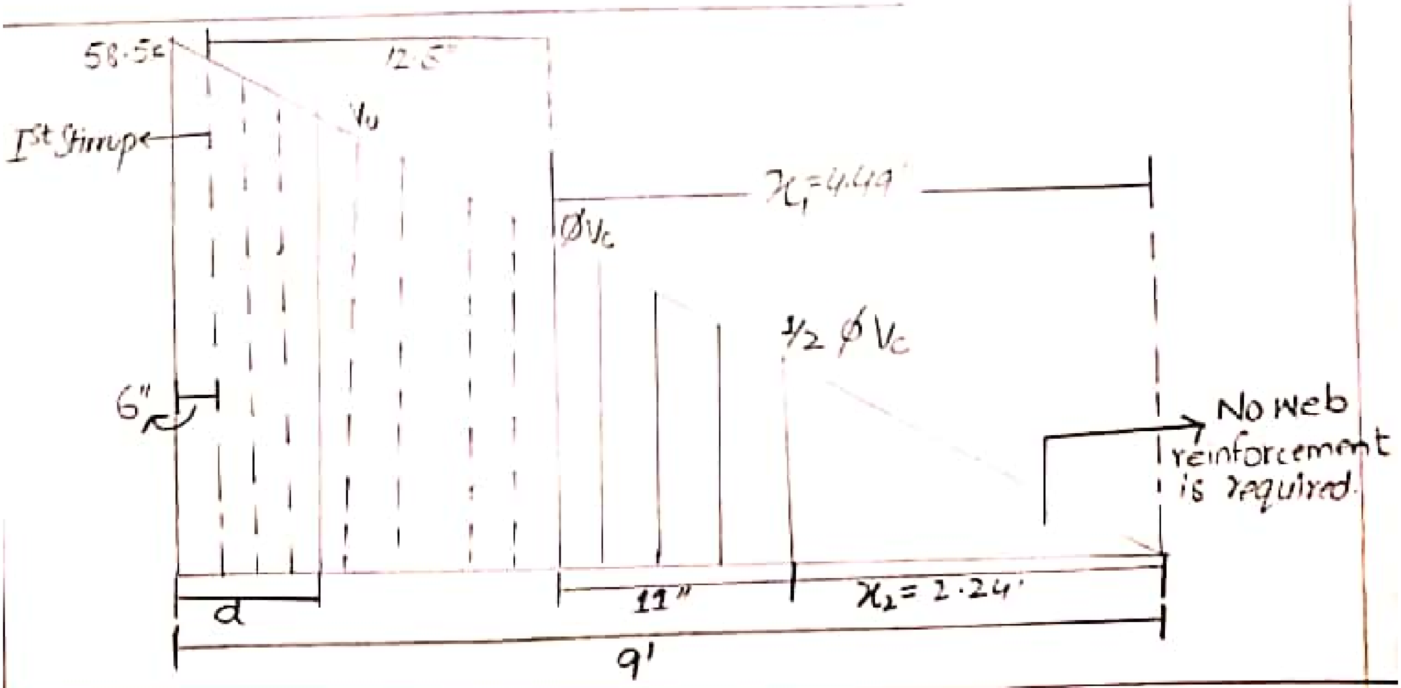
$S_{max} = 11"$.

Step 08: Stirrups spacing from/at critical section

By formula;  $S = \frac{\phi \times A_v \times f_y \times d}{V_u - \phi V_c} = \frac{0.75 \times 0.22 \times 60 \times 22}{46.605 - 29.21}$

$S = 12.52 \approx 12.5"$

So 12.5" Ok.



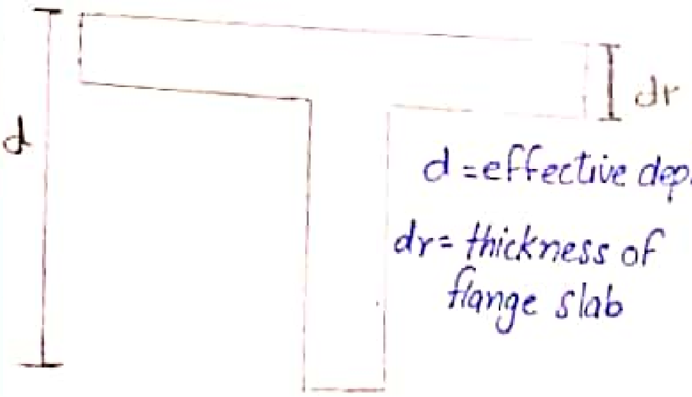
First stirrup from face of support

$S/2 = 12.5/2 = 6.25 \approx 6''$

Q3 Define both the T-beam and L-beam with the help of diagram. Also explain flexural strength analysis for T-beam.

## T-Beam

- It is load bearing structure of reinforced concrete, wood or metal, with a T-shaped cross-section.
- The top of the T-shape serves as flange or compression member in resisting compressive stresses.

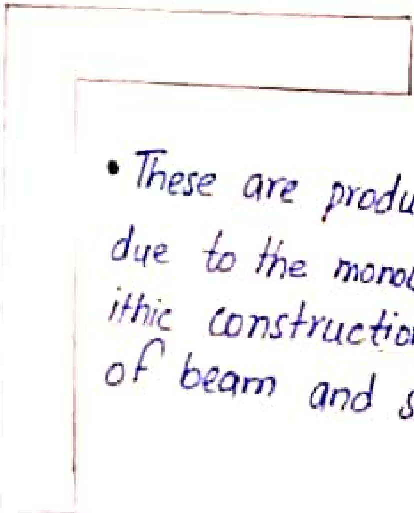



d = effective depth

dr = thickness of flange slab

## L-Beam

- A beam whose section has the form of an inverted L, usually placed so that it's top flange forms part of the edge of a floor.



- These are produced due to the monolithic construction of beam and slab

## FLEXURE STRENGTH ANALYSIS FOR T-BEAM:

1- Find the ultimate factored Load (moment) by the formula:

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

2- Effective depth "be" for T-beam is computed as follows:

i- $16(h_f) + b_w$ , ii- c/c distance, iii- Span/4, iv- $\frac{CTS}{2} + b_w$

∴ Select the least value from the above values.

3- Check whether Rectangular or T-beam analysis is required.

i If $a > h_f$ then T-beam analysis is required.

ii If $a < h_f$ then rectangular analysis is required.

4- Find the Area of steel;

$$A_{ST} = \frac{M_u}{\phi \times f_y \times (d - a/2)} \; ; \quad a = \frac{A_{ST} \times f_y}{0.85 \times f'_c \times b_w}$$

5- Check the range of reinforcement ratio

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

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

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

6- Find the no of bars; No of bars $= A_{ST}/A_b$

7- Check min width for bars accomodation; ($b_{min} = 2 C.C + 2$ dia of stirrup + No. of bars (dia of bars) + spacing b/w bars (dia of bar))

8- Design Moment is given as $= M_d = \phi \times f_y \times A_{ST} \times (d - a/2)$ — if $a < h_f$

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

if $a > h_f$

Q4 What is the difference between CASE-I & CASE-II in the design of T-beam.

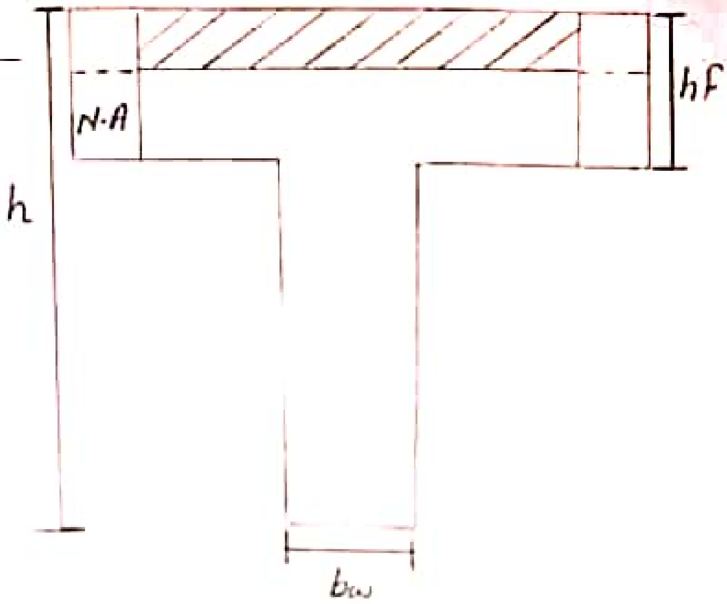
Ans **CASE-I:**

From the figure

$a < h_f$

So in this case, rectangular beam analysis is required so the design moment formula will be:

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



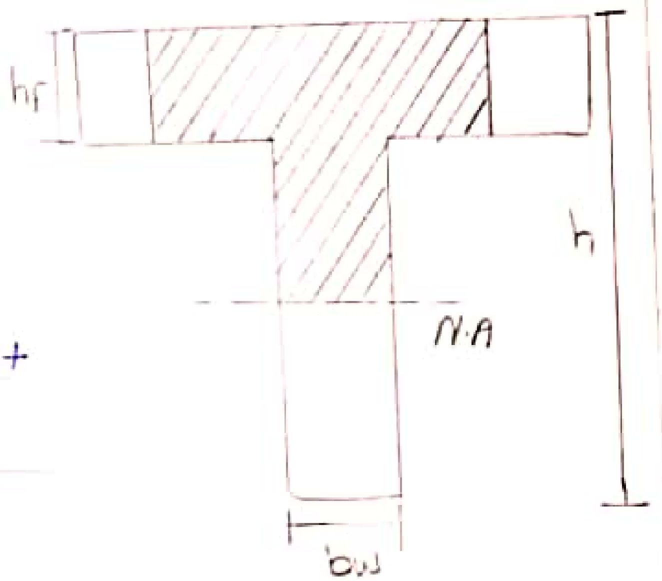

## CASE - II :

From the figure,

$a > h_f$

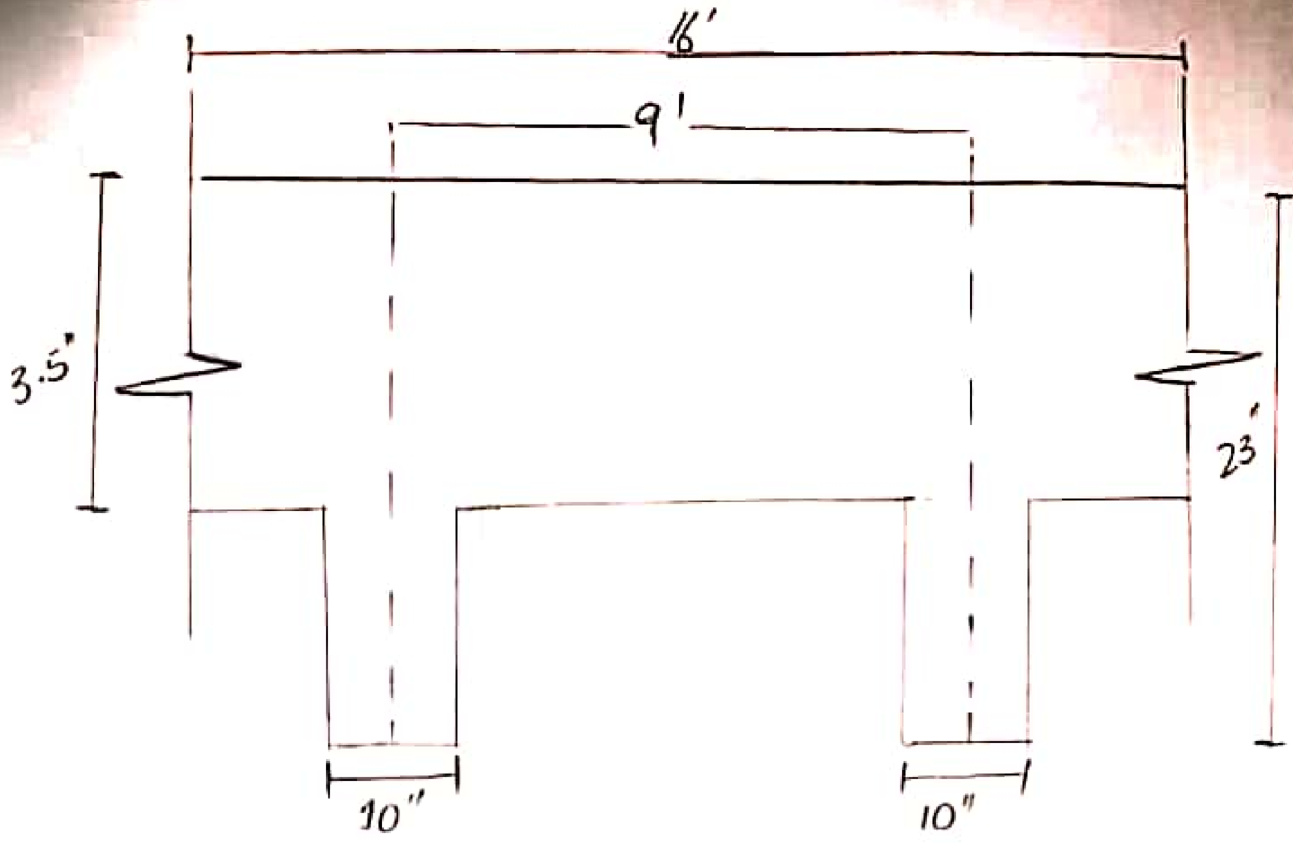
So in this, special beam analysis i.e T-beam analysis is required so design moment will be

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




Q5 A floor consists of 3·5" concrete slab support 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 neccessary flexural reinforcement if the factored applied moment is 5800 k-in. Use $f'_c = 3$ ksi and $f_y = 60$ ksi.

Sol-




Step 01: Calculate the effective width (be) 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 $= 16/4 \times 12 = 48''$

Selecting the least value of $b_e = 48''$.

Step 02: Check whether rectangular or T-beam analysis is required.

**Trial#01:**

let $a = h_f = 3.5''$

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

**Trial #02:-**

$$a = \frac{A_{ST} \times f_y}{0.85 \times f_c \times b_e} = \frac{6.61 \times 60}{0.85 \times 3 \times 48} = 3.24''$$

$$A_{ST} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{5800}{0.90 \times 60(18 - \frac{3.24}{2})} = 6.56\ in^2.$$

## Trial # 03:

$$a = \frac{A_{ST} \times f_y}{0.85 f'_c \times b_e} = \frac{6.56 \times 60}{0.85 \times 3 \times 48} = 3.21\ in$$

$$A_{ST} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{5800}{0.90 \times 60 \times (18 - \frac{3.21}{2})} = 6.56\ in^2.$$

Thus rectangular beam analysis is required.

## Step 03: check $\rho_{max}$ and $\rho_{min}$

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

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

$$= 0.014$$

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

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

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

$0.003 < 0.036 < 0.014$

Thus the value of $\rho_{max} <$ and $\rho_{min}$ so we have to calculate $A_{ST}$ again.

$$A_{ST} = \rho_{max} \times b \times d$$

$$A_{ST} = 0.014 \times 10 \times 18$$

$$A_{ST} = 2.52\ in^2$$

## Step 04: Selection and No. of Bars

let's use #08 so dia $(8/8) = 1"$

Area $\pi/4\,(1)^2 = 0.785\ in^2.$

By formula

No. of bars $= \frac{A_{ST}}{A_b} = \frac{2.52}{0.785} = 3.21 \simeq 4$ bars

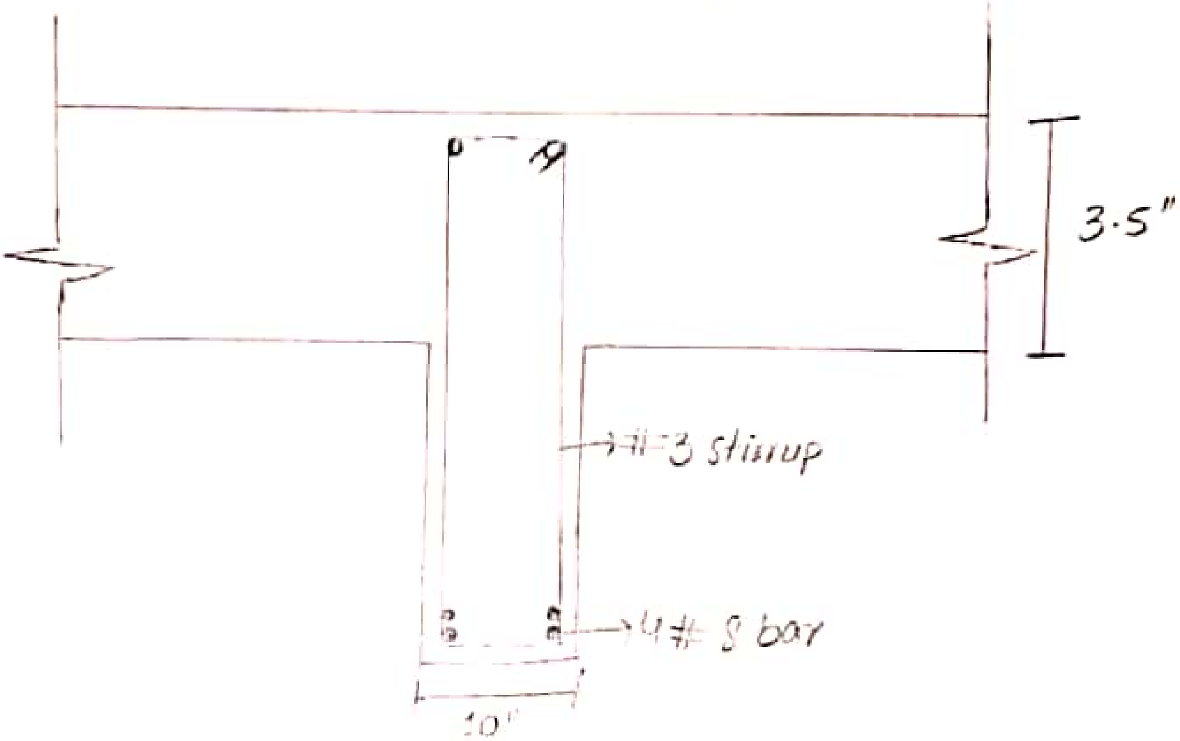
Step:05: Check on minimum width

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

$= 10.75''$

As $10.75'' > 10''$

So it should be provided in two layers




Step 06 : Design Moment

By using formula

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

$\therefore A_{ST} \Rightarrow$ No. of bars $\times$ Area of single bar

$= 4 \times 0.785$

$= 3.14\ in^2$

$a = \frac{A_{ST} \times f_y}{0.85 \times f_c \times b} = \frac{3.14 \times 60}{0.85 \times 3 \times 48} = 1.54$

$M_d = 0.90 \times 60 \times 3.14 \times \left(18 - \frac{1.54}{2}\right)$

$M_d = 2921.52$ k-in

$2921.52 < 5800$

Thus design is Ok!

Q6 A beam is revised to developed and ultimate moment of 6000 k-in limited to 14x26 inch size, use $f'_c$ is 4ksi and $f_y$ is 60ksi. Determine flexural reinforcement assume two rows of tensile reinforcement and effective depth of beam is 22

Sol. Given data:

Breadth = 14"

Height (h) = 26"

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

$f_y$ = 60 ksi

$M_u$ = 6000 K-in

d = 22"

Assume d' = 2.5"

Step 01: Reinforcement Ratio.

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

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

$\rho_{max} = 0.018$

Step 02: Area of steel

As we know that

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

$$= 0.0180 \times 14 \times 22$$

Area = 5.54 in².

Step 03: Design Moment

using formula

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

$$a = \frac{A_{ST} \times f_y}{0.85 \times f'c \times b} = \frac{5.54 \times 60}{0.85 \times 4 \times 14} = 6.98''$$

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

$$M_{u2} = 5537.4 \text{ k-in}$$

$$As \quad 5537.4 < 6000$$

So we have to design a section as doubly reinforced beam.

Step 04: Difference in moments

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

$$= 6000 - 5537.4$$

$$M_{u1} = 462.6 \text{ k-in}$$

Step 05: Area of steel

$$M_{u1} = \varnothing \times A_{ST} \times f_y \times (d - d')$$

So Area of steel in compression zone will be:

$$A'_{ST} = \frac{M_{u1}}{\varnothing \times f_y \times (d - d')} = \frac{462.6}{0.90 \times 60 \times (22 - 2.5)} = 0.44 \text{ in}^2$$

Step 06: Total steel Area

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

$$= 5.54 + 0.44$$

$$= 5.98 \text{ in}^2$$

## Step 07: Selection and No. of bars used.

1- Steel in tension zone:

We use # 7 bar,

dia $(7/8)" = 0.875"$, Area $= \pi/4 (0.875) = 0.601\ in^2$.

so

No. of bars $= \frac{A_s}{A_b} = \frac{5.98}{0.601} = 9.9 \approx 10$ bar

So: 10# 7 bars.

2- Steel in compression zone:

let's use # 05 bar

dia $= 5/8" = 0.625"$, $A = \pi/4 \ (0.625)^2 = 0.306\ in^2$

So,

No. of bars $= \frac{A_s}{A_b} = \frac{0.44}{0.306} = 1.43 \approx 2$ bars.

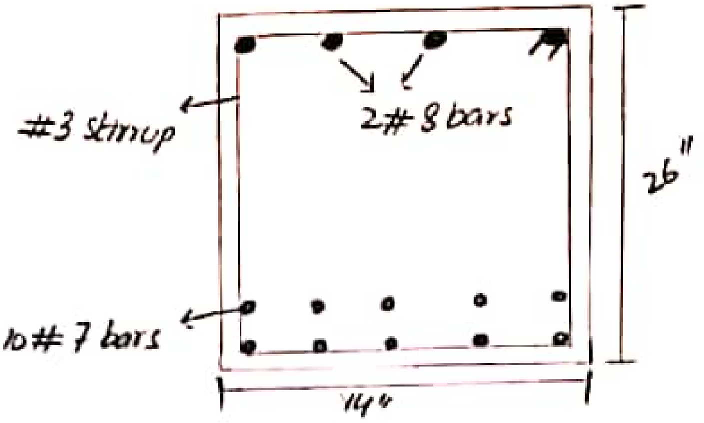
So 2#5 bars

## Step 08: Minimum width of beam

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

$b_{min} = 20.377\ 14"$

So not good in one layer.




Now,

→ Effective depth $(d) = 26 - 1.5 - 3/8 - 7/8 - 1/2\,(7/8) = 22.82''$

→ Effective cover $(d') = 1.5 + 3/8 + (5/8)1/2$

$= 2.18''$.

Step 09: Design Moment

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

$$a = \frac{(A_{st} - A'_{st}) \times f_y}{0.85 \times f'_c \times b} = \frac{(10 \times 0.601 - 2 \times 0.306) \times 60}{0.85 \times 4 \times 14}$$

$$a = 6.80''$$

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

$$M_d = 7047.6 \text{ K-in}$$

As $7047.6 > 6000$

Design is OK!