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Section : B

Semester : 6th

Assig No : 01

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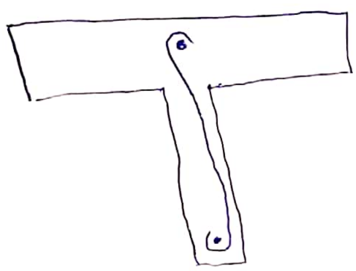
Questio No : 1

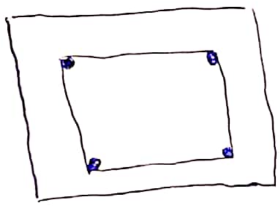
Types of stirrups:-

The following are basic types of stirups used in beams and columns.

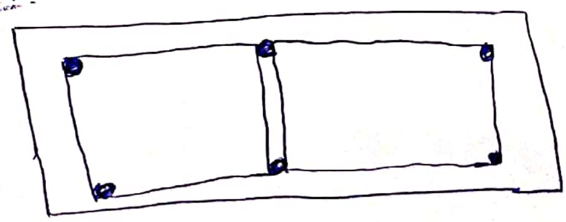
① Single legged strump:-



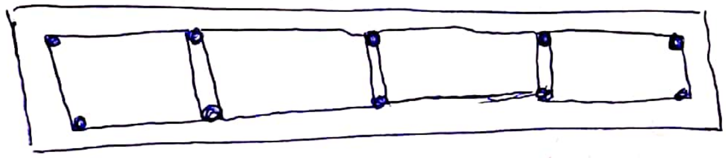
② Two-legged stirrups:-



③ Four-legged stirrups:-

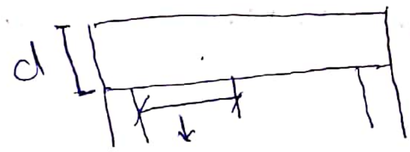


(4) Six - Legged stirrups:-



ACI codes for shear Design:-

=> Critical section is at a distance "d" from the face of support.



d = where critical section occurs at 45°.

(a) Shear strength capacity of concrete = $V_c = \gamma \times \sqrt{f_c'} * b_w * d$

V_u = Total factored shear force applied at a given section.

(b) Mini web Reinforcement: if $V_u \leq \phi * V_c$, then theoratically no web reinforcement is reauried However ACI code reauire provision of atleast a minimum area of web reinforcemt eaual to:-

=> For shear $\phi = 0.75$

=> For $A_{vmin} = 0.75 \times \sqrt{f_c'} \times \frac{b_w * S}{f_y}$

=> Count max value.

S= center to center distance b/w sterrips

bw = web breadth

fy = tensile strength

=> Max. spacing formula $S_{max} = \frac{Au \times fy}{0.75 \times \sqrt{fc'} \times bw}$

or $\frac{Au \times fy}{50 \times bw}$

* if $Vu < \frac{1}{2} * \emptyset * Vc$:-

Then no web reinforcement is needed.

=> first sterrip is provided at distance $S/2$

=> shear at critical section is represented by "Vu"

=> Between critical section "Vu" and "$\emptyset$ vc" spacing b/w web reinforcement can be find by the formula:-

$$S = \frac{\emptyset * Au \times fy \times d}{Vu - \emptyset Uc}$$

=> Preferrably $S < 4''$, because of proper compaction vibration and pouring of concrete etc.

* **Vs = Shear force carried by web reinforcement**

According to ACI Code :-

if $V_s \leq 4 \times \sqrt{f'_c} \times b_w \times d$, then max-spacing of stirrups will be smallest of following four conditions :

(i) 24" (ii) $d/2$ (iii) $S_{max} = \dfrac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$

(iv) $S_{max} = \dfrac{A_v \times f_y}{50 \times b_w}$.

and if $V_s > 4 \times \sqrt{f'_c} \times b_w \times d$ => Then max. spacing will be halved

and if $V_s > 8 \times \sqrt{f'_c} \times b_w \times d$ => Then either increase cross-sectional dimensions or increase f'_c.

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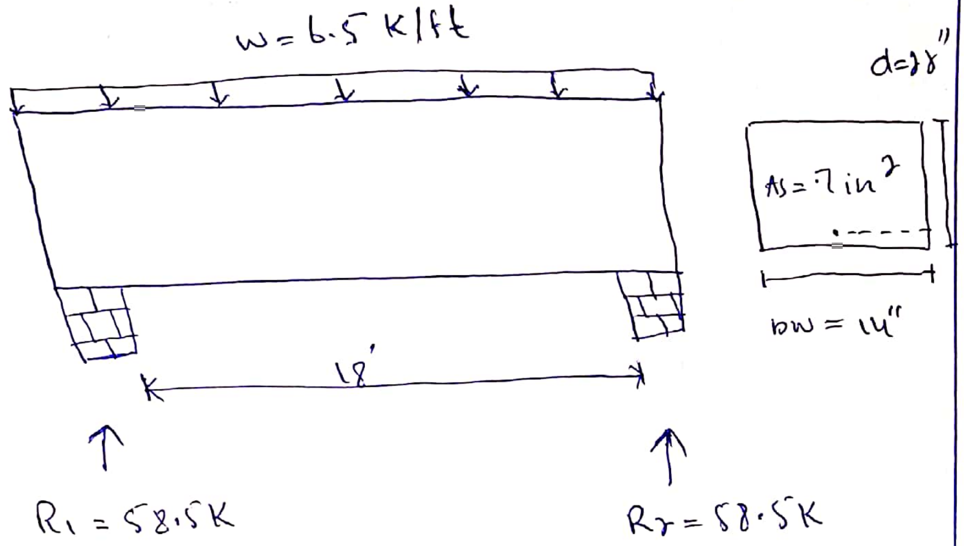
"Question No 02"

Solution:-



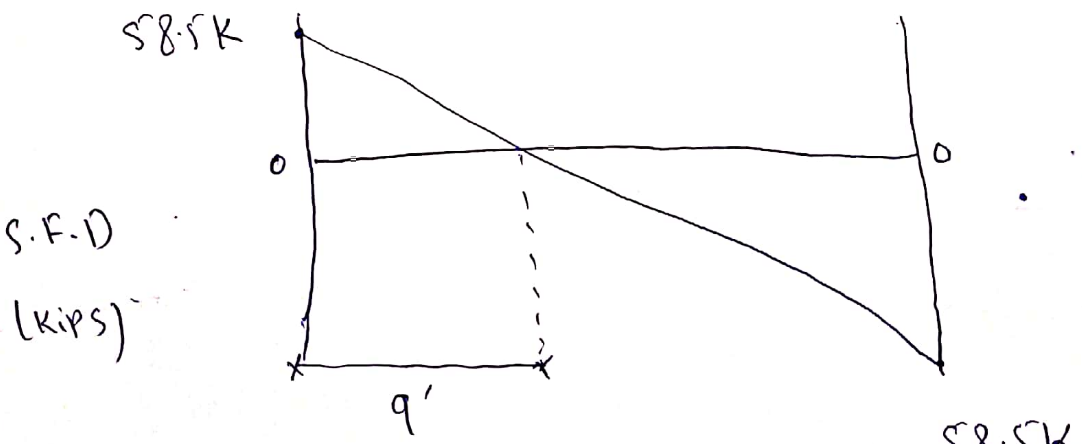
Step : 01

Find values of R_1 and R_2

$$R_1 = R_2 = \frac{\text{total load}}{2} = \frac{6.5 \times 18}{2} = \boxed{58.5 \text{ kips}}$$

Step : 02

Draw its shear force diagram



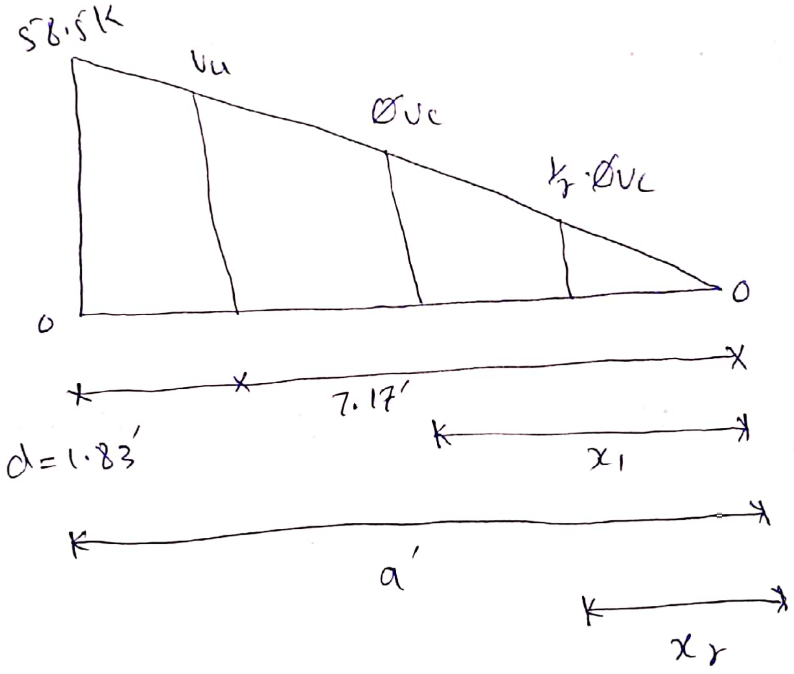
Step no3:

value of critical shear and its location:-

⇒ we already know that critical section is located at distance "d" from support's face

$d = 22'' = 1.183'$

=> value of critical shear at distance 'd' by similarity of triangles:-



From Similar Δ's:

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

$V_u = 46.61$ kips

Step: 04

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

$\phi V_c = 29.22$ kips

Location of ϕV_c by similarity of Δ's:-

$$\frac{58.5}{9} = \frac{29.22}{x_1}$$

$$x_1 = 4.5'$$

=> Now " $\frac{1}{2} \phi V_c$ "

$$= \frac{29.22}{2}$$

$$= 14.61 \text{ Kips}$$

=> Location of $\frac{1}{2} \phi V_c$ by similarity of Δ's:-

$$\frac{58.5}{9} = \frac{14.61}{x_2}$$

$$x_2 = 2.25'$$

Step: 05 value of ϕV_s:-

$$V_u = \phi V_s + \phi V_c$$

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

$$\phi V_s = 46.61 - 29.22$$

$$\phi V_s = 17.39 \text{ Kips}$$

Step : 06

Check on section adequacy

$\phi \times 8 \times \sqrt{f_c} \times b_w \times d \Rightarrow$ ~~$0.75 \times 8 \times \sqrt{4000}$~~

$$= \frac{0.75 \times 8 \times \sqrt{4000} \times 14 \times 22}{1000} = \boxed{116.88K}$$

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

hence it means section is adequate.

Step : 07

Check on max. spacing for stirrups.

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

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

$= 58.44$ kips.

$\Rightarrow$ As $(\phi \times 4 \times \sqrt{f_c'} \times b_w \times d) > (\phi V_s)$

So max spacing will be selected from following condition:

① $S = 24''$ ② $\frac{d}{2} = \frac{22}{2} = \boxed{11''}$

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

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

$S_{max} = \frac{0.22 \times 60000}{0.75 \times \sqrt{4000} \times 14}$

$S_{max} = \frac{0.22 \times 60000}{50 \times 14}$

$S_{max} = 19.88''$

$S_{max} = 18.86''$

⇒ least value of spacing for #3, 2legged sterrip will be selected.

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

Step :08

Spacing of Stirrop from critical section:

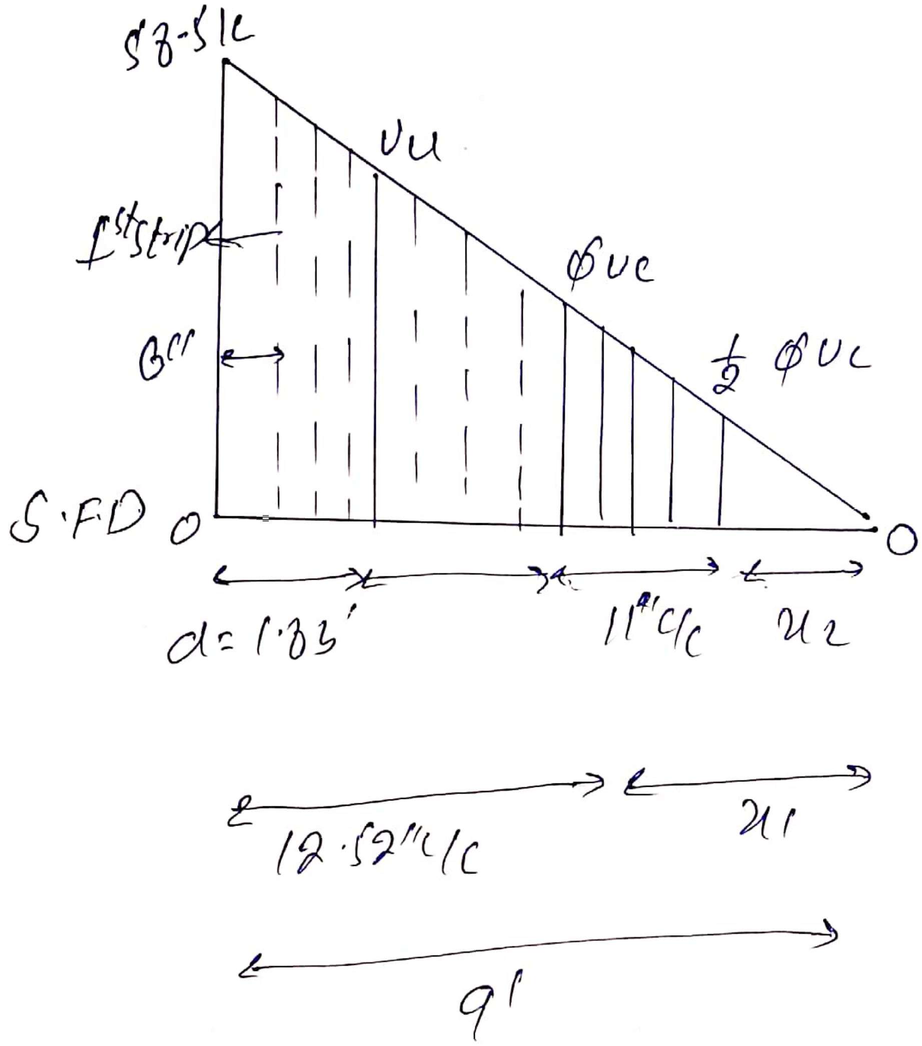
$$S = \frac{\phi \times A_v \times f_y \times d}{V_u - \phi V_c}$$

$$S = \frac{0.75 \times 0.22 \times 60 \times 22}{46.61 - 29.22}$$

$S = 12.52''$ ✓

Step : 09

Final Sketch



First Stirrup From Support Face = $\frac{s}{2}$

$$= \frac{12.52}{2}$$

$$= 6.26'' \approx 6.00''$$

Question No: 03

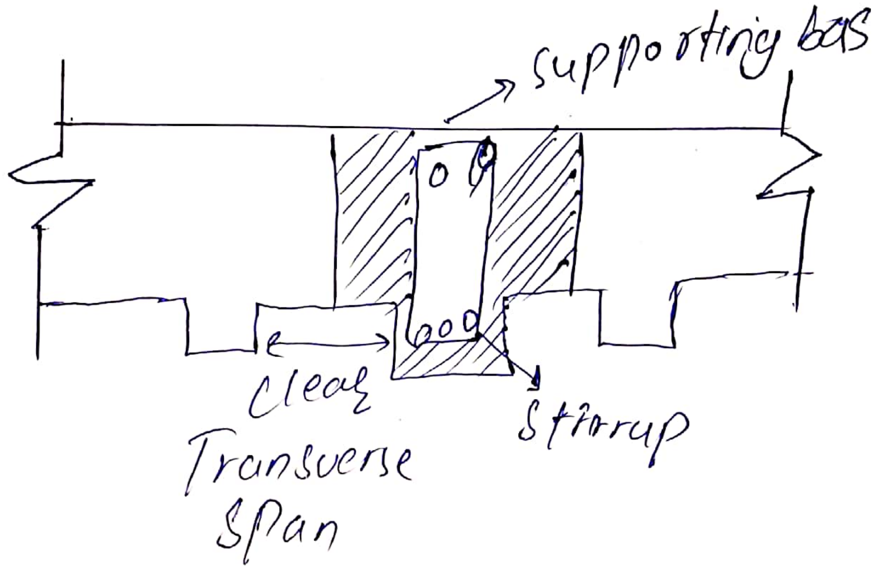
T-Beams:-

T-Beams are that type of beams whose Cross-Sections is in T-Form. These Type of beams are casted monolithically with slabs in a positive moment zone part of the slab act as part of the beam and resist the longitudinal compression.

⇒ It is provided at the centre of the slab to resist the loads.

⇒ The top of the t-shaped Cross-section serves as flange or Compression member in resisting compression stress.

=> The web of the beam below flange serves to resist shear stress.



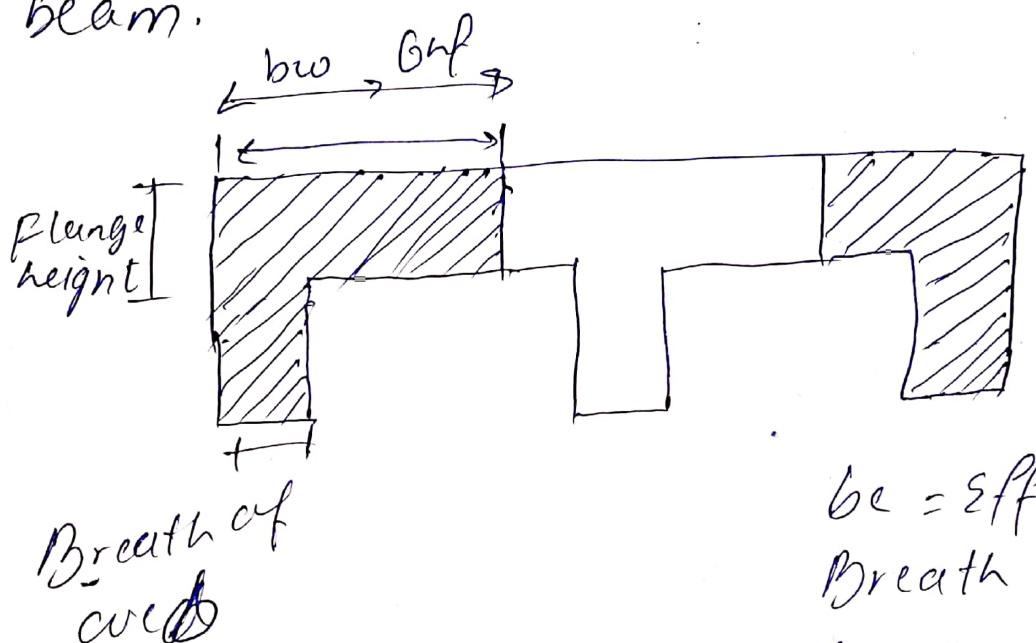
T-Beam

L-Beam:-

The beam having cross-section as that of Inv L-shape is called L-Beam. These concrete beams are poured monolithically with slabs to form the floor of building. It is always provided at the corners of the slabs.

⇒ The top of L-Shape beam cross-section is known as Flange or Slab Thickness

⇒ The bottom of L-Shape beam cross section is known as web of beam.



be = Effective Breath bw = Breath of web
hf = Height of Flinge.

L - Beams

Flexural strength Analysis (T-beam)

There are two cases in T-beam analysis, which are the following:

Case 01): when $a \leq hf$, then we will do reaction gular beam analysis

Case 02) when $a > hf$ then we will do T- Beam analysis.

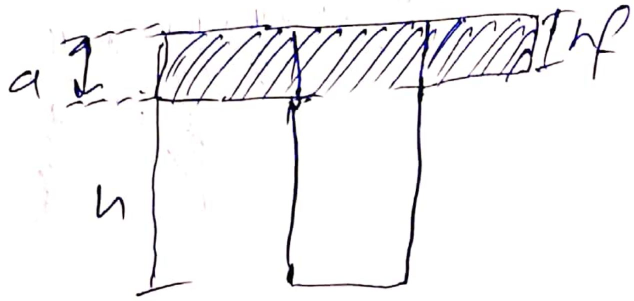
a = height of compression block.

hf = height of flange.

bw = breath of web

h = Total height / depth of beam

Case 01): $a \leq hf$



$b = be$

$Mn = Asw \times fy \times (d - \frac{a}{2})$

$Mn = 0.85 \times fc' \times bw \times a \times (d - a/2)$

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Case 02) : $a > h_f$

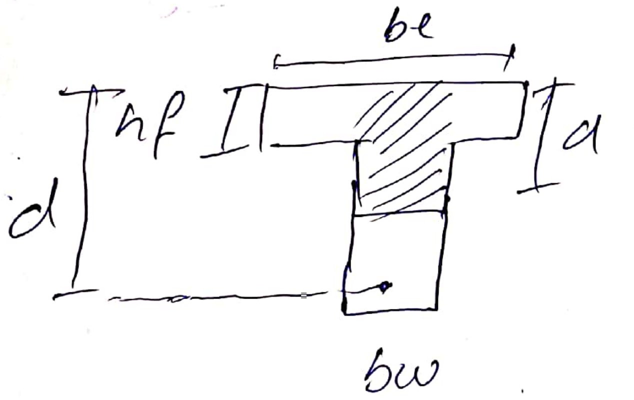


Figure : Equavalent Stress Diagram

Total Tensil Steel Area = $A_s = A_{sf} + A_{sw}$

$M_n = M_{n1} + M_{n2}$

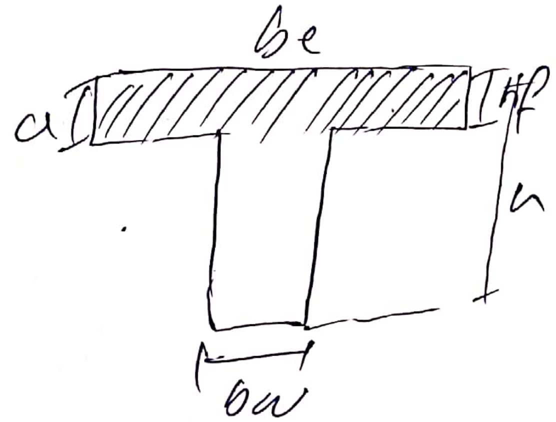
$M_{n1} = A_{sf} \times f_y \times (d_y - h_f/2) = 0.85 \times f_c' \times (b_e - b_w) \times h_f \times (d - h_f/2)$

$M_{n2} = A_{sw} \times f_y \times (d - a/2) = 0.85 \times f_c' \times b_w \times a \times (d - a/2)$.

Question #04.

Case –I

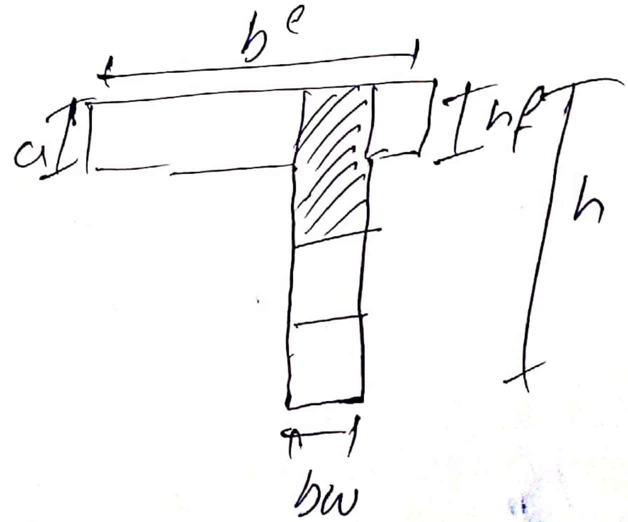
① In Case-I ($a \leq h_f$) which shows that the height of compression block is less than or upto flange level. its indication is that the beam is rectangular and it will be analysed by Rectangle Beam analysis method.

② 

③ moment $M_n = A_s \times f_y \times (d - \frac{a}{2})$

Case –II

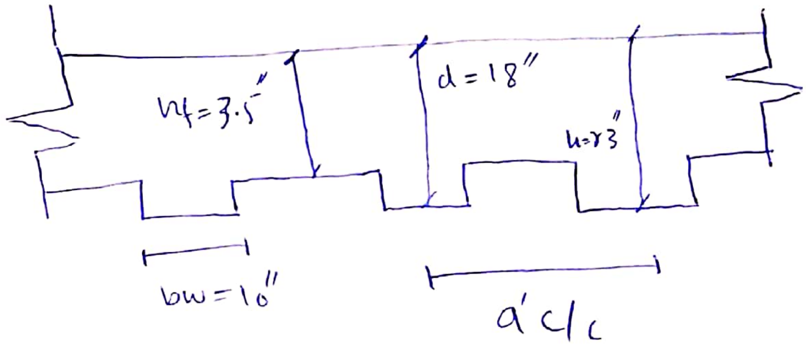
① In Case-II ($a > h_f$), which shows that the height of compression block is more than the flange level and it indicates that the beam will be analysed by T-Beam analysis method.

② 

moment $M_n = M_{n1} + M_{n2}$

Question No: 05

Solution:-



Step 01 :-

To find effective breadth "be"

ⓐ $16 \times h_f + b_w = 16 \times 3.5 + 10 = 66''$

ⓑ c/c distance $= 9 \times 12 = 108''$

ⓒ $\frac{\text{Span of Beam}}{4} = \frac{16 \times 12}{4} = 48''$

hence $b_e = 48''$

Step : 02 :-

Check for Rectangular or T. Beam

Trial : 01 ⇒ Let $a = h_f = 3.5''$

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

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

Trial : 02

$$a = \frac{As * fy}{0.85 * f'c * be} = \frac{6.61 \times 60}{0.85 \times 3 \times 48}$$

$a = 3.24''$ < $h_f = 3.5''$

=> Hence Rectangular beam analysis

$$\Rightarrow As = \frac{Mu}{\phi * fy \times (d - a/2)} = \frac{5800}{0.90 \times 60 \times (18 - \frac{3.24}{2})}$$

$As = 6.56 \, in^2$

Trial : 03

$$a = \frac{6.56 \times 60}{0.85 \times 3 \times 48}$$

$a = 3.22''$

$$\Rightarrow As = \frac{Mu}{\phi \times fy \times (d - a/2)} = \frac{5800}{0.90 \times 60 \times (18 - \frac{3.22}{2})}$$

$As = 6.55 \, in^2$

Trial : 04

$$a = \frac{6.55 \times 60}{0.85 \times 3 \times 48}$$

$$\boxed{a = 3.21''}$$

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

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

Step : 03 ρ_{max} and ρ_{mini}

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

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

$\rho_{max} = 0.0135$

$\Rightarrow \rho_{mini} = \frac{200}{f_y} = \frac{200}{60,000}$

$$\boxed{\rho_{mini} = 0.0033}$$

$\Rightarrow \rho_{provided} = \frac{Ast}{bw \times d} = \frac{6.55}{10 \times 18}$

$\rho_{provided} = 0.036$

$\rho_{mini} < \rho_{provided} > \rho_{max}$

=> Hence designing it as Doubly Reinforced Beam.

Step : 04

Ast against ρ_{max}

$$\rho_{max} = \frac{Ast}{b \times d} \Rightarrow Ast = 0.0135 \times 16 \times 8$$

$$Ast = 2.43 \text{ in}^2$$

Step : 5

$Mu_1 = Mu - Mu_2 \Rightarrow Mu_1 = 5800 - 1986.6\overline{7}$

$Mu_1 = 3813.33$ Kip"

$Mu_1 = \phi \times A's \times fy \times (d - d')$

$$A's = \frac{3813.33}{0.90 \times 60 \times (18 - 2.5)}$$

$$A's = 4.556 \text{ in}^2$$

Step : 6

Total Steel Area

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

$A_s = 2.43 + 4.556$

$A_s = 6.986 \text{ in}^2$

Step : 07

Selection of Bars

=> **For tension zone :-**

* using bar # 8.
* Area of 1 # 8 bar = 0.785 in^2
* # of bars = $\dfrac{6.986}{0.785}$

# of bars = 8.89 ≈ 9 bars

For compression zone :-

* using bar # 6.
* Area of 1 # 6 bar = 0.44 in^2
* # of bars = $\dfrac{4.556}{0.44}$

# of bars = 10.35 ≈ 11 bars

Step : 09

Check on mini width of Beam:

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

$b_{mini} = 20.75'' > 10''$ = Hence reinforcement is not good in one layer. Double layer

$$a = \frac{(A_s - A_s') \times f_y}{0.85 \times f_c' \times b} = \frac{(9 \times 0.785 + 11 \times 0.44)60}{0.85 \times 3 \times 10}$$

$a = 5.24''$

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

$M_d = 0.90 \{ (11 \times 0.44) \times 60 \times (19.625 - 3) + (2.225) \times \{ 60 \times 17.005 \}$

$M_d = 6388.26 \text{ kip}''$ > $M_u = 5800 \text{ kip}''$

Design is O.K!

QUESTION # 06

SOLUTION:

breath = b = 14" $f_c' = 4ksi$

height = h = 26" $f_y = 60ksi$

$M_u = 6000$ k-inch d = 22"

d' = 2.5"

Step : 01

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

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

$$\boxed{\rho_{max} = 0.0181}$$

Step # 02

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

$Ast = (0.0181 \times 14 \times 22) \Rightarrow Ast = 5.57 in^2$

Step#03

$Mu2 = \phi \times Ast \times fy \times (d - \frac{a}{2})$

$\Rightarrow$ Firstly finding value of "a":-

$a = \frac{Ast \times fy}{0.85 \times fc' \times b} = \frac{5.57 \times 60}{0.85 \times 4 \times 14}$

$a = 7.02"$

So, $Mu2 = 0.90 \times 5.57 \times 60 \times (22 - \frac{7.02}{2})$

$Mu2 = 5561.42 \text{ kip}" < 6000$

Step#04

$Mu1 = Mu - Mu2$

$Mu1 = 6000 - 5561.42$

$Mu1 = 438.58 \text{ kip}"$

Step : 06

$As = Ast + As'$

$As = 5.57 + 0.42$

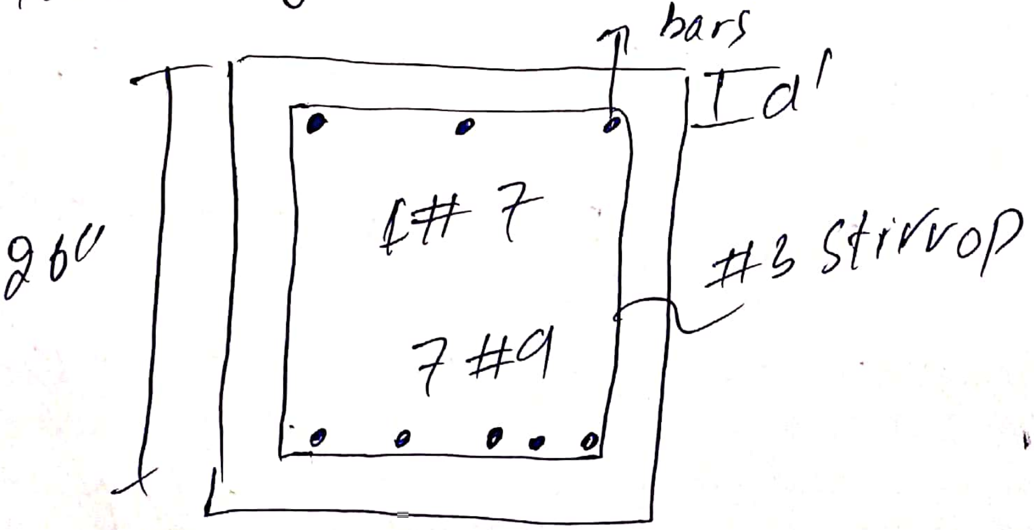
$As \; 5.99 \, in^2$

Setp : 07

$b_{min} = (2 \times 1.5) + (2 \times 3/8) + (7 \times 9/8) + (6 \times 9/8)$

$b_{min} = 18.375'' > 14''$

=> Hence not good in one layer so bars (main) should be provided in two layers



$d = 26 - (1.5 + 3/8 + 9/8 + (9/8 \times 0.5))$

$d = 22.44''$

$d' = 1.5 + 3/8 + \frac{1}{2}(7/8)$

$d' = 2.31''$

Step # 08

⇒ Firstly Finding valeu of "a"

$a = \frac{(As - A's) \times fy}{0.85 \times fc' \times b} = \frac{7 \times 0.994 - 1 \times 0.60 / \times 60}{0.85 \times 4 \times 14}$

$a = \frac{6.357 \times 60}{47.6} \Rightarrow a = 8.013''$

Now

$MD = 0.90[As' \times fy \times (d - d') + (d - a/2)$

$MD = 0.90[725.3378 + 7029.5706]$

$MD = 6979.91K'' > 6000K''$

Design is OK!