NAME : YASEEN KAMAL

ID# : 7794

SECTION : A

SEMISTER : 6th

PROGRAM : B.Sc Civil Engr

ASSIGMENT : PLAIN & REINFORCED CONCRETE DESIGN - I

SUBMITTED TO : ENGR. FAWAD KHAN

QUESTION NO. 1

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

ANS:,

STIRRUP:

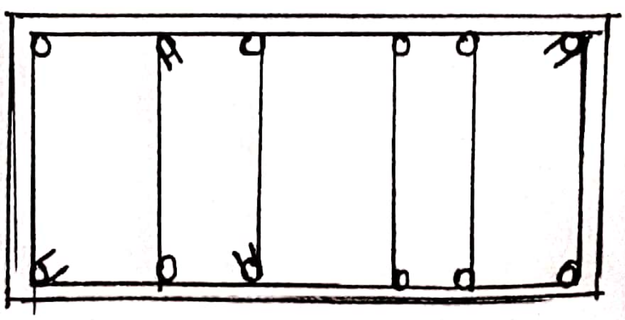
Stirrup are closed - loop bars tied at regular intervals in beam reinforcement to hold the bars in position.

TYPES OF STIRRUPS:

1- Single Legged Stirrups:

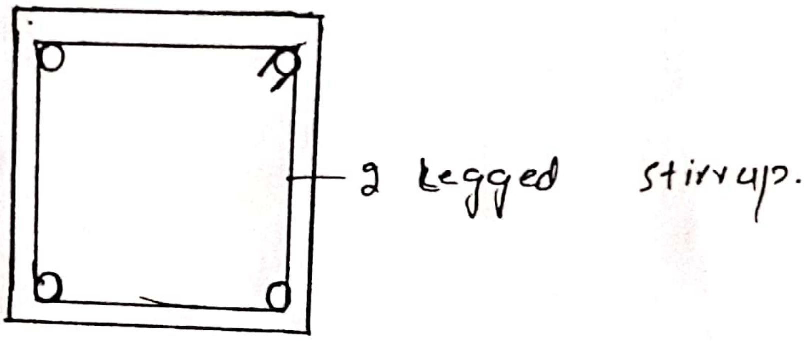
The single - leg stirrups have rarely been used because they are mostly used when binding only two rods.

2- Six Legged Stirrups:



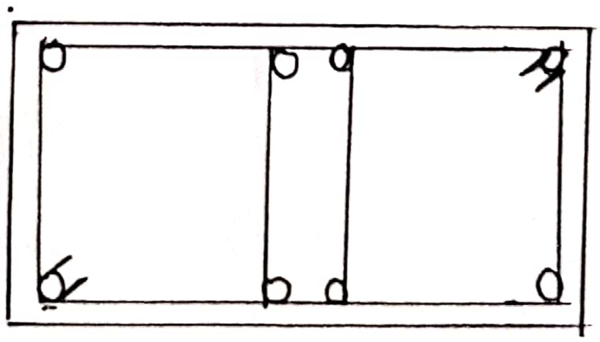
3- Two - Legged stirrup:

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



4- Four - Legged stirrup:

The stirrups are used in case of web reinforcement.



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 distance (d) from the face 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 $V_u \leq \phi V_c$, then theoritically no web reinforcement is required. However ACI code require provision of atleast a minimum area of web reinforcement equal to

ϕ = 0.75 → For shear design.

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

⇒ For Minimum Reinforcenment Area:

$$A_{v\,min} = \frac{0.75 \times \sqrt{f'_c} \times b_w \times S}{f_y} \text{ or } \frac{50 \times b_w \times S}{f_y}$$

[Higher value is selected]

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

$$S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w} \text{ or } \frac{A_v \times F_y}{50 \times b_w} \rightarrow$$ [Lesser value is selected]

4- No -web- reinforcement is required if.

$$\boxed{V_u < \frac{1}{2} \phi V_c}$$

⇒ Between critical section "V_u" and "ϕV_c", spacing b/w web reinforcement can be find by,

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

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- $S_{max} = \dfrac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$

∵ (V_s = Shear force carried by web reinforcement)

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

$\Rightarrow$ If $V_s > 4 \times \sqrt{f'_c} \times b_w \times d$

$\downarrow$

Max. spacing will be halved.

$\Rightarrow$ If $V_s > 8 \times \sqrt{f'_c} \times b_w \times d$

$\downarrow$

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

QUESTION # 02

A simply supported rectangular beam 14" wide having an effective depth of 22" to carry a lateral Lord of 6.5 k/ft on a 18' simple span. It is reinforced with 7 in² of tensile steel area, if f_c' = 4 ksi and f_y=60 ksi, then design the beam for shear

GIVEN DATA:

Breadth of web of beam (b_w) = 14"

Effective depth (d) = 22"

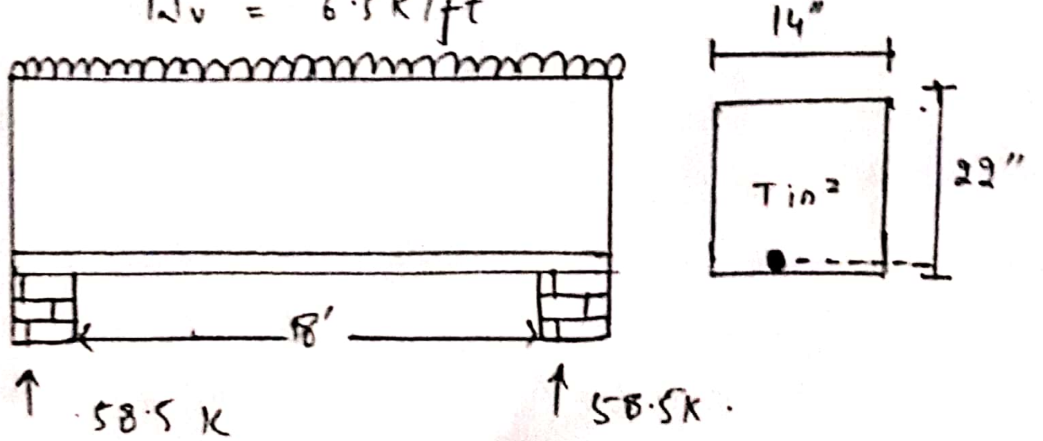
Given load = 6.5 K/ft

Steal Area = 7in²

f_c' = 4 ksi

f_y = 60 ksi

SOLUTION:



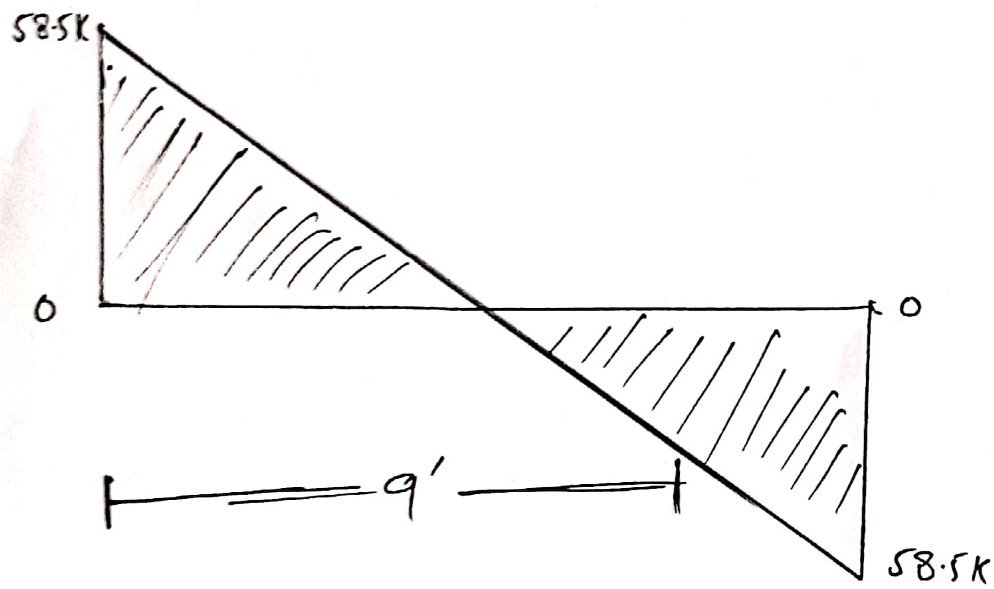
STEP#1: (Reactions on Supports) ⑦

Finding the reactions due to applied load.

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

STEP #2: (Shear force Diagram)

The required shear diagram will be



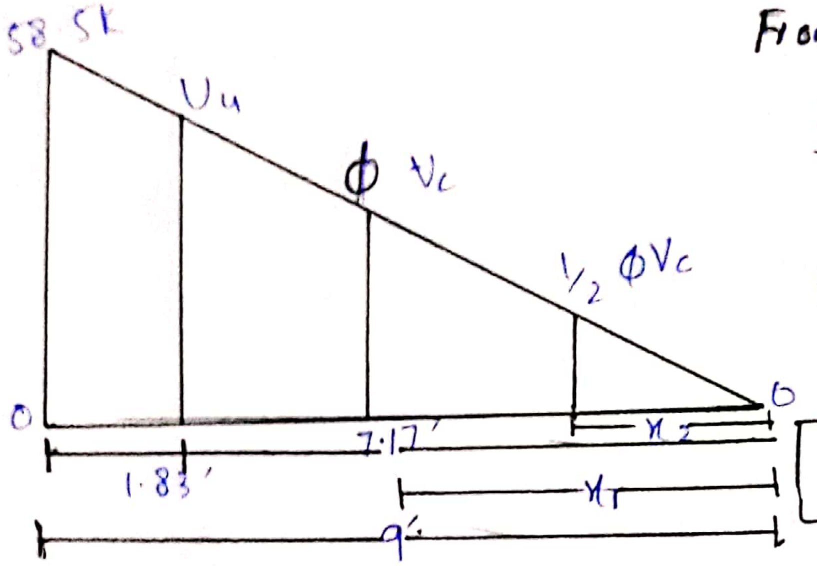
STEP # 3:

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

⇒ we will find the values of critical

Shear at distance "d" by use of similar triangles.



From Similar Triangles

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

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

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

STEP # 4:

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

By formula,

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

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

$= 29.21 \text{Kips}$

$\Rightarrow$ Location of ϕV_c by similar triangles,

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

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

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$\Rightarrow$ Similarly,

$\Rightarrow$ $\frac{1}{2}\,\phi V_c = \phi V_c/2 \Rightarrow 29.21/2 = 14.60$ 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.

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

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

$= 116.87$ kips

As $\phi \times 8 \times \sqrt{f'_c} \times b_w \times d > \phi V_s$.

So section is Adequate!

STEP # 7:

Check on Maximum spacing for Stirrups,

By formula,

$$= \phi \times 4 \times \sqrt{f'_c} \times b_w \times d$$

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

$$= 58.43 \text{ Kips}$$

As $\phi \times 4 \times \sqrt{f'_c} \times b_w \times d > \phi V_s$.

so maximum will be selected from the following 4 conditions,

1- $S_{max} = 24''$

2- $d/2 = 22/2 = 11''$

3- $S_{max} = \dfrac{A_u \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$

Here we are using #3 stirrup, dia $(3/8)'' = 0.375''$
So. Area $= \pi/4 \, (0.375)^2 = 0.11 in^2$
For 2 legged stirrup.
→ Area × 2
→ $0.11 \times 2 = 0.22 in^2$

$$\Rightarrow S_{max} = \frac{0.22 \times 6000}{0.75 \times \sqrt{4000} \times 14} = 19.87''$$

4- $S_{max} = \dfrac{A_u \times f_y}{50 \times b_w} = \dfrac{0.22 \times 6000}{50 \times 14} = 18.85''$

From above 4 conditions, Least value of spacing for #3, 2 legged stirrup will be selected as, $\boxed{S_{max} = 11''}$

STEP # 8:

Stirrups spacing from 1st critical section will be,

By formula,

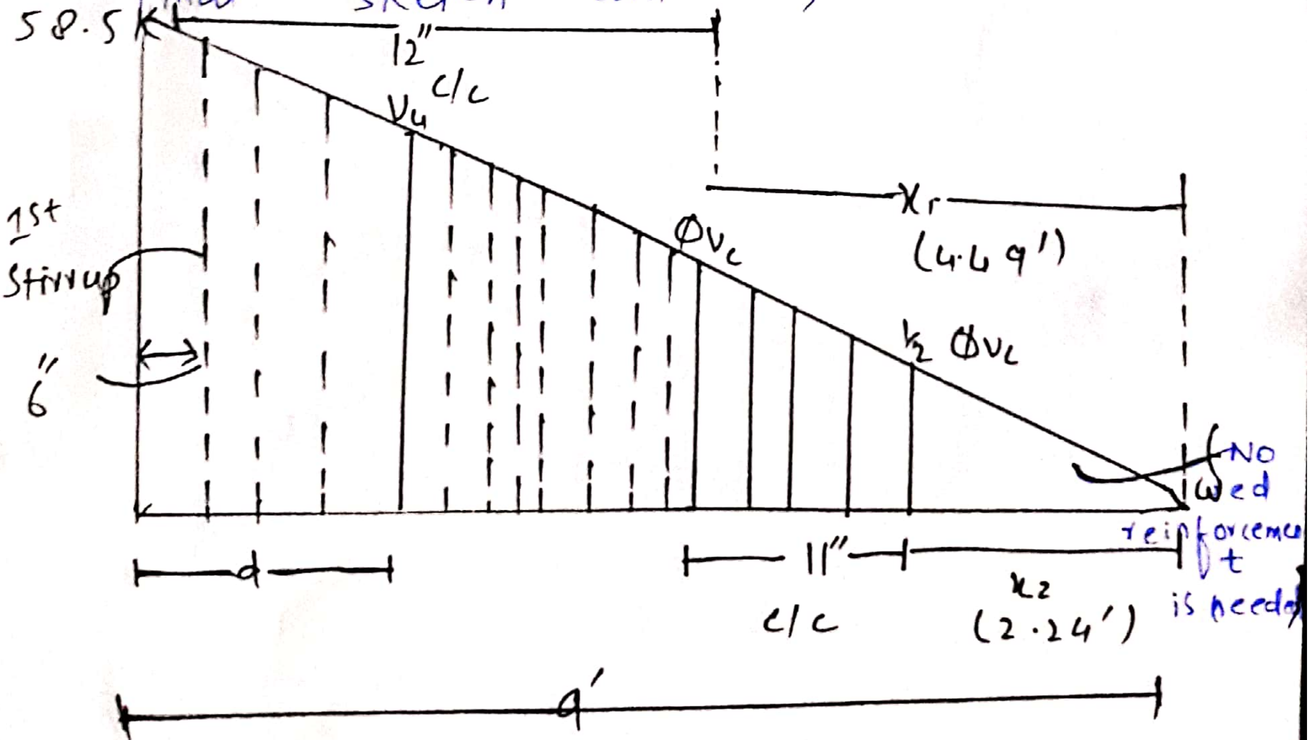
$$S = \frac{\phi \times A_v \times f_y \times d}{V_u - \phi V_c} = \frac{0.75 \times 0.22 \times 60 \times 22}{46.61 - 29.21}$$

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

So $12''$ c/c.

STEP # 9:

Final sketch will be;



As First stirrup from face of support,

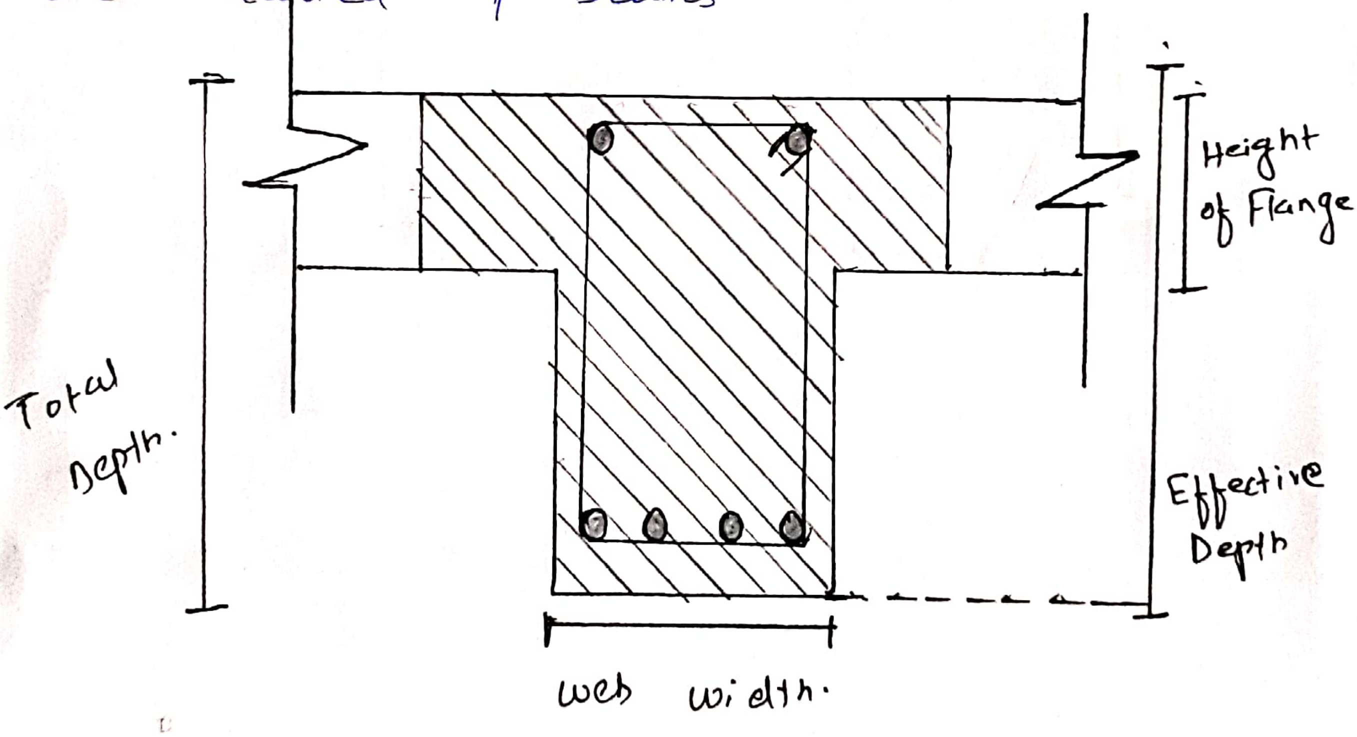
$S/2 = 12/2 = 6''$

QUESTION # 3

Design 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.

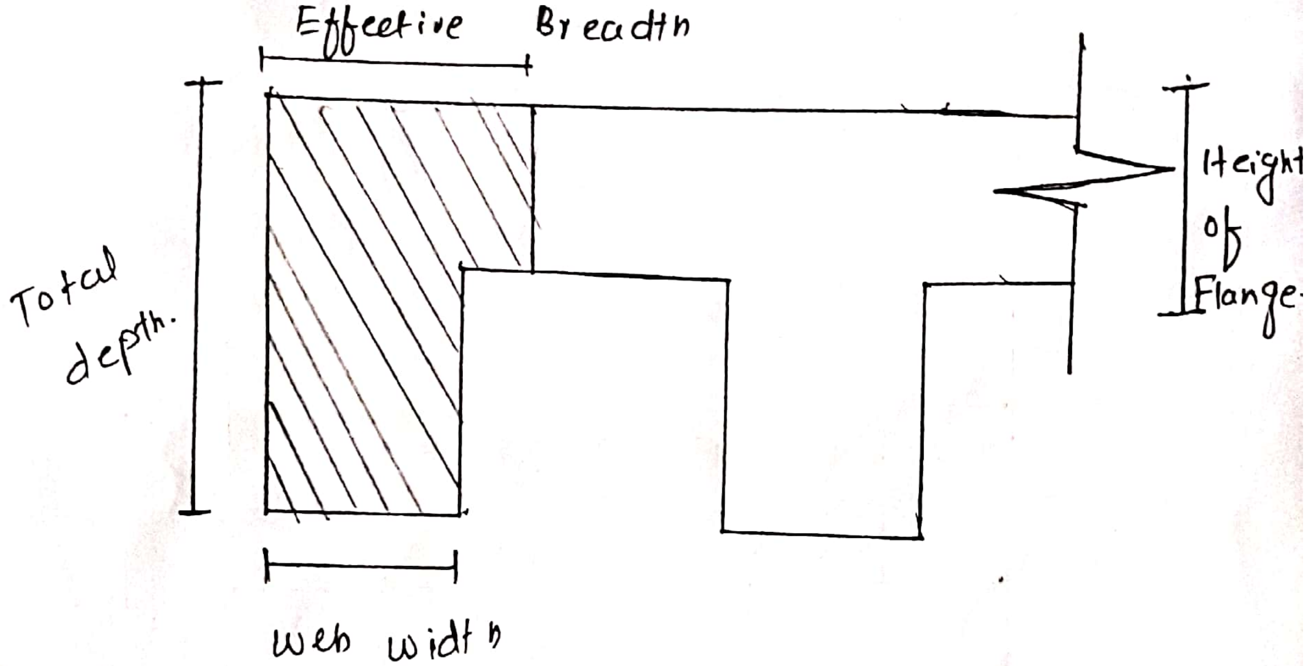
=) It is provided at the center of the slab to resists the loads.

=) 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 Anaylsis of T-Beam consists of the 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 Load.
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 / 4
4- $\frac{CTS}{2} + b_w$

∵ (h_f = height of flange
CTS = Clear transverse 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;

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

where

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

$\because$ (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,

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

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

$$\rho = A_{st}/b \times d.$$

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 bars accomodation,

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

8- Design Moment is given by,

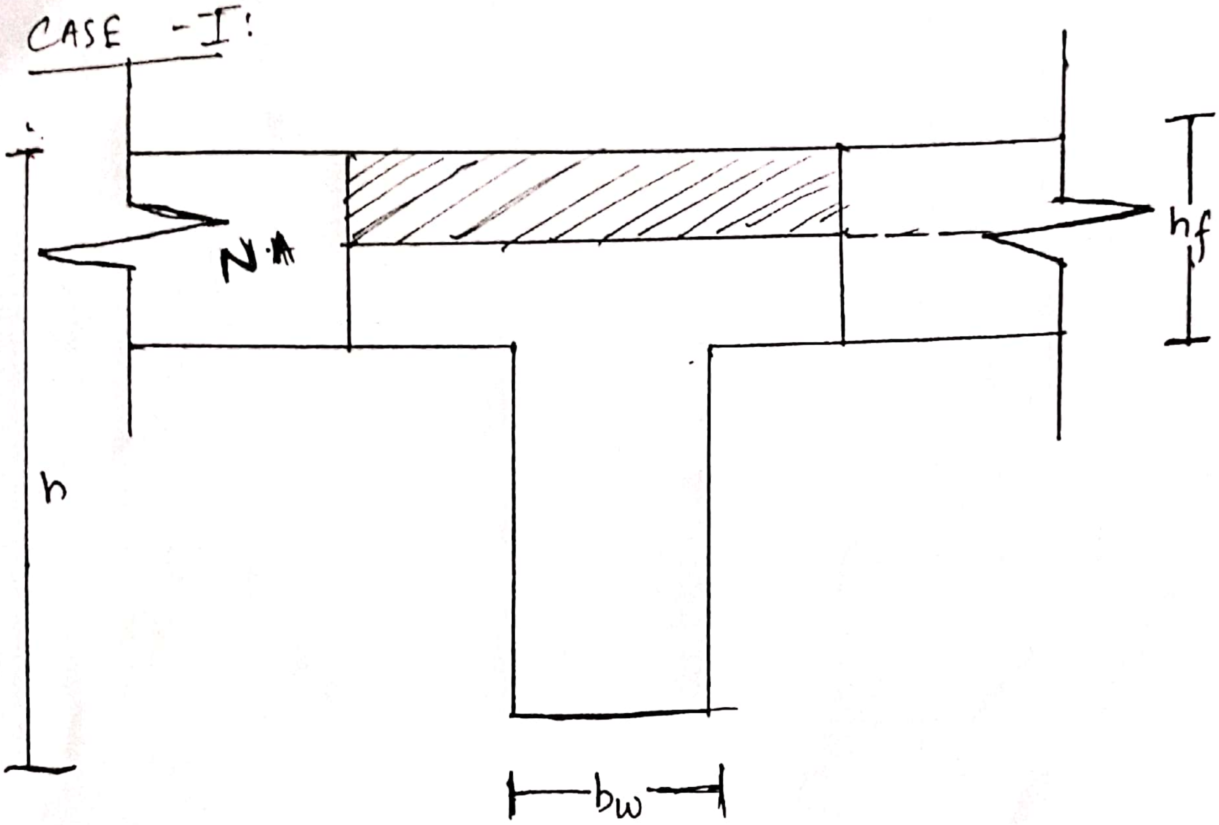
$$M_d = \phi \times F_y \times A_{st} \times (d - a/2) \rightarrow \text{if } a < h_f$$

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

QUESTION # 04

What is the difference b/w CASE - 1 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

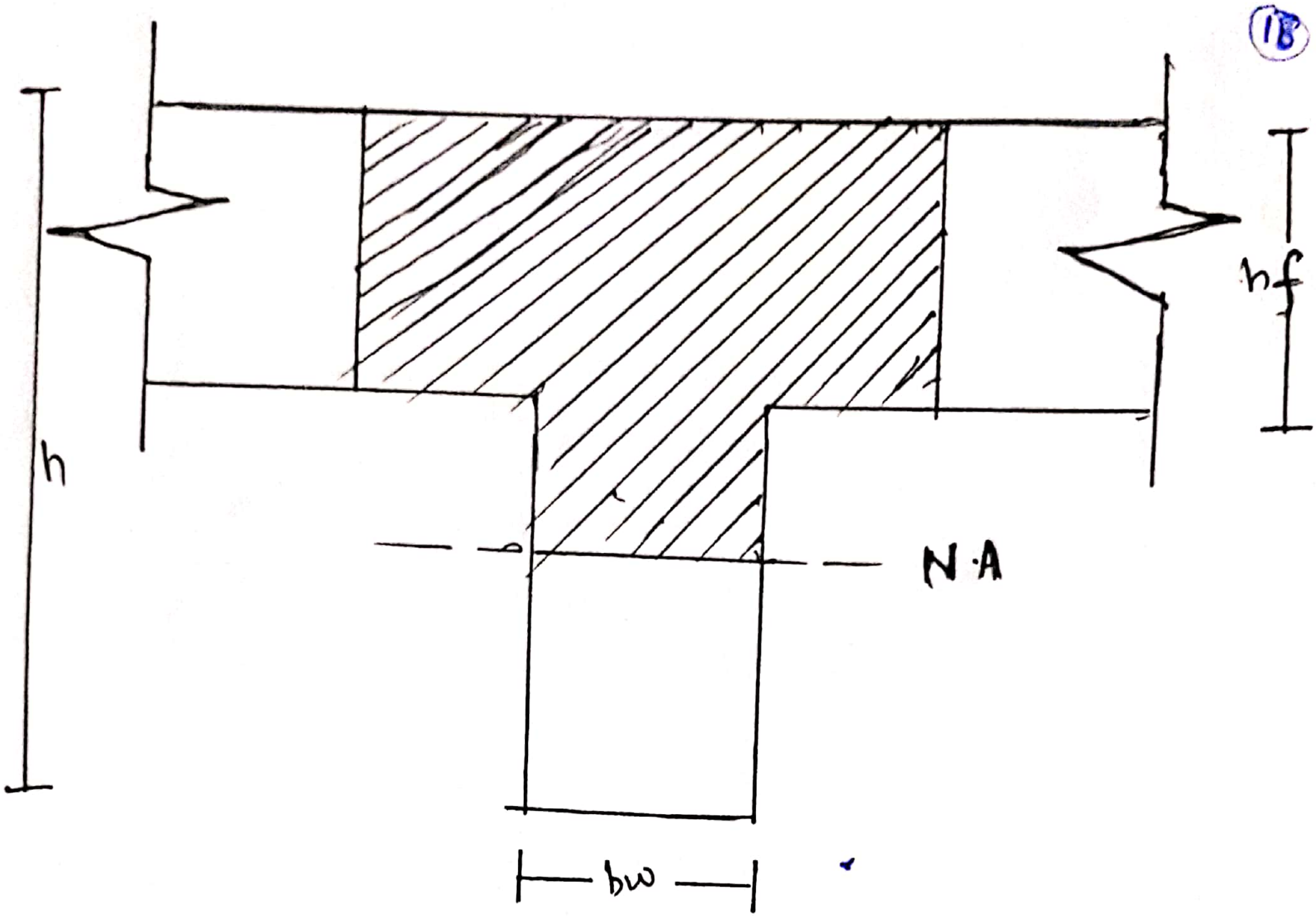
$$M_d = \phi \times f_y \times A_{st} \times (d - a/2)$$

CASE - II

From the figure,

$a > h_f$

(18)



So in this, special beam analysis ie, T- Beam Analysis is required.

So the required Design Moment will be,

$$Md = \phi \times [As \times fy \times (d - hf/2) + (As - Ast) \times fy \times (d - a/2)].$$

QUESTION N #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 = 3KSi and f_y = 60 KSi.

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"

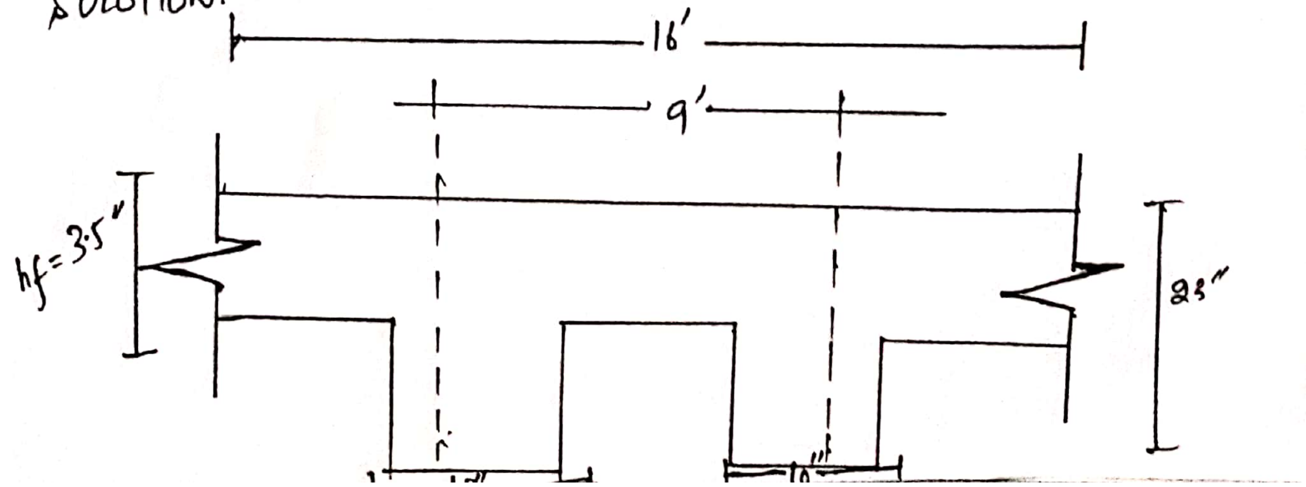
Height (h) = 23'

Total factored moment (M_u) = 5800 kip-inch

f'_c = 3KSi

f_y = 60KSi

SOLUTION:



STEP # 1

calculate the effective width (b_e) 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 be as,

$\boxed{b_e = 48''}$

STEP # 2

check wheather 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:

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

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

$= 3.2'' < 3.5''$

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

So Rectangular Beam Design is Required!

Trial # 03:

$$a = 3.21''$$

and

$$A_{st} = \frac{5800}{0.90 \times 60\left(18 - \frac{3.21}{2}\right)} = \boxed{6.55 in^2}$$

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

STEP# 3:

Check of ρ_{max} and ρ_{min}.

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

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

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

$$\Rightarrow \rho = \frac{A_{st}}{b \times d} = \frac{6.55}{10 \times 18} = 0.036.$$

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

$$0.003 < \underbrace{0.036 < 0.013}$$

$$\downarrow$$

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 of steel against of 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 # 4:

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"

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

$$a = 5.72''$$

$$\Rightarrow Mu_2 = 0.90 \times 2.43 \times 60 \times (18 - 5.72/2)$$

$$\boxed{Mu_2 = 1986.67\ Kip - inch}$$

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 # 5:

Finding Difference in moments and Area of steel.

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

$= 5800 - 1986.67$.

$$\boxed{M_{u1} = 3818.33 \text{ kip-inch}}$$

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 # 6:

Finding Total Steel Area.

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

$= 2.42 + 4.56 = 6.99 \text{ in}^2$.

STEP # 7:

Selection of Bar:

In Tension Zone:

Let we use #8 bar

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

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 compursion zones

Let we use # 7 bar.

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

By formula.

$$\text{No of bars} = \frac{\text{Area of steel}}{\text{Area of single bar}} = \frac{4.56}{0.601} =$$

$7.5 \approx 8$

So 8 # 7 bars.

STEP #8:

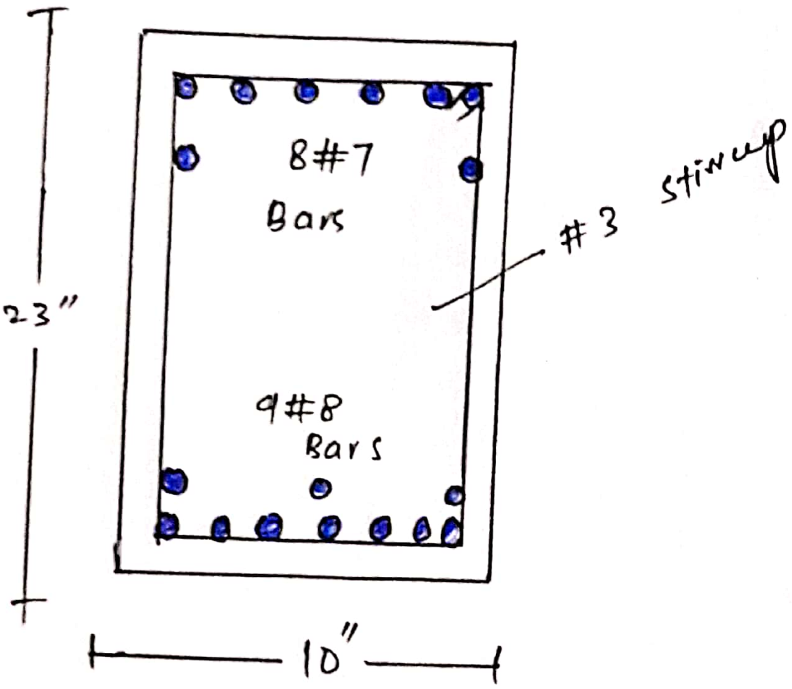
Minimum width for accomodation of bars:

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

$= 20.75''$

As $20.75'' > 10''$

So the bars will be placed in multiple layers:



Effective depth (d) $= 23 - 1.5 + 3/8 + 8/8 + 1/2\,(8/8)$

$= 19.6''$

Effective cover (d') $= 1.5 + 3/8 + 7/8 + 1/2\,(7/8) = 3.18''$

STEP # 9:

Finding the design Moment:

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

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

$= 5.31''$

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

$$\boxed{M_d = 6328.38}$$

As $6328.38 > 5800 \rightarrow$ so design is OK!

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QUESTION# 06:

(17)

A beam is revised to developed and ultimate moment of 6000 Kip-Inches limited to 14×26 inch size, use $f'_c = 4ksi$ and $f_y = 60ksi$. Determine flexural reinforcement assume two rows of tensile reinforcement and effective depth of beam is 22 inches.

SOLUTION:

GIVEN:

Breadth (b) = 14"

Height (h) = 26"

Concrete compression strength (f_c') = 4ksi

Steel Tensile strength (f'_c) = 60ksi

Ultimate Factored Momement (Mu) = 6000kip-inches

Effective depth of beam (d) = 22"

Assume Effective cover (d') = 2.5"

STEP# 1 (Reinforcement Ratio)

By formula,

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

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

$$\boxed{\rho_{max} = 0.0180}$$

STEP # 2 (Area of steel)

As we know that,

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

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

STEP # 3: (Design Moment):

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,

$$Mu_2 = 0.90 \times 5.54 \times 60 \, (22 - 6.98/2)$$

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

As,

$$5537.4 < 6000$$

so we have to design a section as doubly reinforced.

STEP # 4: (Difference In Moments).

$$Mu_1 = Mu - Mu_2.$$

$$= 6000 - 5537.4$$

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

STEP # 5 (Area of Steel)

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

so area of steel in compression zone will be.

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

$\Rightarrow \boxed{A'_{st} = 0.44 \text{ in}^2.}$

STEP # 6 (Total Steel Area):

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

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

STEP # 7 (selection & No of Bars used)

1- Steel in Tension zone:

we use # 7 bar,

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

$= 0.601 \text{ in}^2.$

So

No of bars $= \dfrac{A_s}{\text{Area of single bar}}$

$= \dfrac{5.98}{0.601} = 9.9 \approx 10$ bars.

So 10 #7 bars.

2- Steel in compression zone:

we use # 5 bars.

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

$= 0.306\ in^2$.

So,

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

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

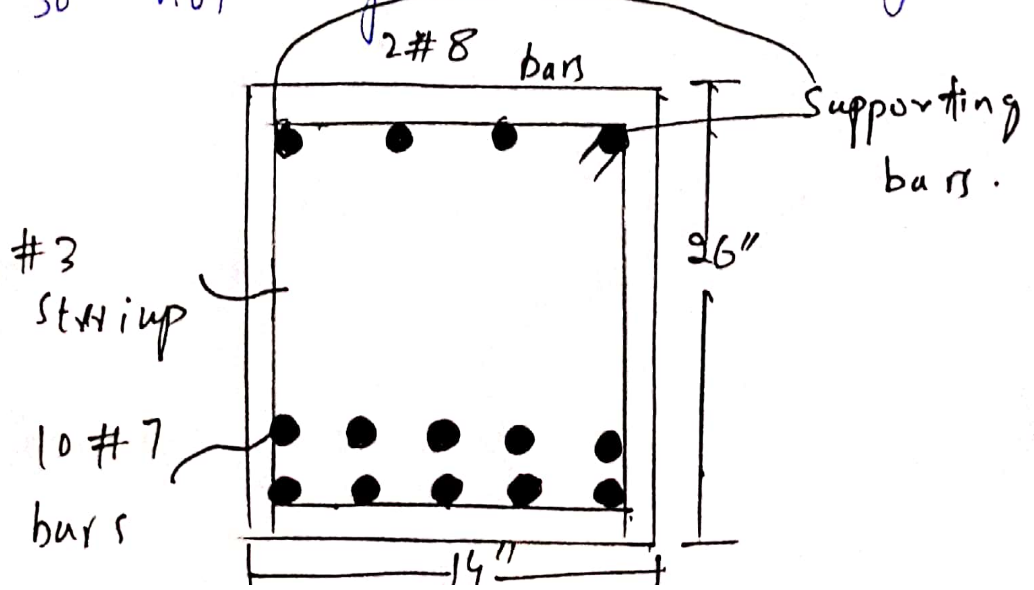
So 2# 5 bars.

STEP #8: (Minimum Width of Beam)

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

$b_{min} = 20.27 > 14''$

So not good in one Layer.



Now,

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

$\Rightarrow$ Effective cover (d') $= 1.5 + 3/8 + 1/2\,(5/8)$
$= 2.18''$

STEP # 9: (Design Moment):

$$Md = \phi \times [As't \times fy\,(d - d') + (Ast - As't) \times fy \times (d - a/2)]$$

$$a = \frac{(Ast - Ast') \times fy}{0.85 \times f'c \times b}$$

$$= \frac{((10 \times 0.601) - 2 \times 0.366) \times 60}{(0.85 \times 4 \times 14)} = 6.80''$$

$$Md = 0.90\,[(2 \times 0.306) \times 60 \times (22.82 - 2.18) + ((10 \times 0.601) - 2 \times 0.366) \times 60 \times (22.82 - 6.80/2)]$$

$Md = 7047.6$ kip-inches

As $7047.6 > 6000$

$\boxed{\text{Design is ok!}}$