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Section : B

Semester : 6th

Program : B.Sc Civil Engineering

Assignment : Plain and Reinforced Concrete Design - I

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QUESTION - 01

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

Ans:

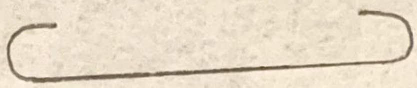
STIRUP:

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

Types of Stirrups:

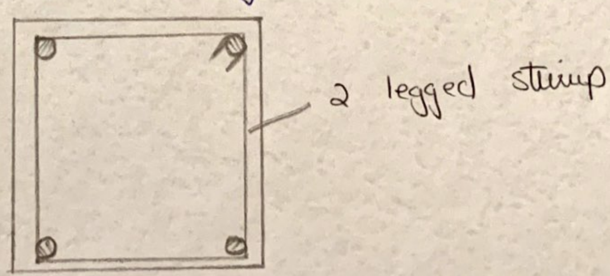
① Single legged Stirrup:

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



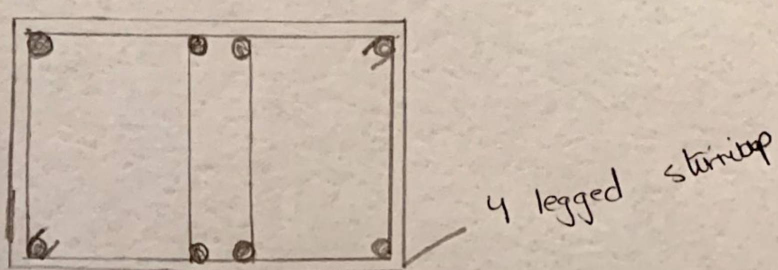
② Two legged Stirrup:

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

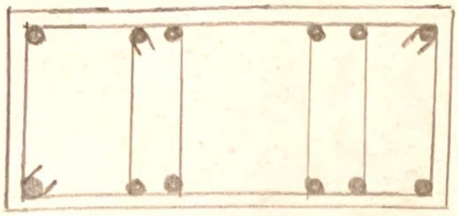


③ Four legged Stirrup:

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 sheer design of a beam.

(1) Critical Section : It occurs at 45° and is at distance (d)" from the face of support which is equal to effective depth.

(2) Sheer 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 theoratically no web reinforcement is required. However ACI code require provision of atleast a minimum area of web reinforcement equal to,

$\phi = 0.75 \longrightarrow$ For sheer design.

(∴ V_u = Total factored sheer applied at a given section)

=> For minimum reinforcement area:

$$A_{v\,min} = \frac{0.75 \times \sqrt{f'c} \times b_w \times S}{f_y} \quad \text{or} \quad \frac{50 \times b_w \times S}{f_y} \rightarrow$$ [higher value is selected]

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

$$S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{f'c} \times b_w} \quad \text{or} \quad \frac{A_v \times f_y}{50 \times b_w} \rightarrow$$ [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 requirement 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- $S_{max} = \dfrac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$

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

⇒ 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

QUESTION - 0 2

A simply supported rectangular beam 14" wide having an effective depth of 22" to carry a lateral load 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 $fy = 60$ ksi, then design the beam for shear.

Given :

Breadth of web of beam (b_w) = 14"

Effective depth (d) = 22"

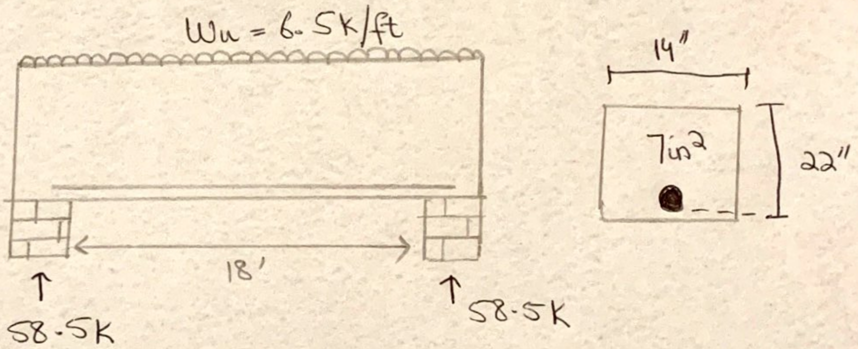
Given load = 6.5 k/ft

Steel Area = 7 in²

$f'c$ = 4 ksi

f_y = 60 ksi

Sol:



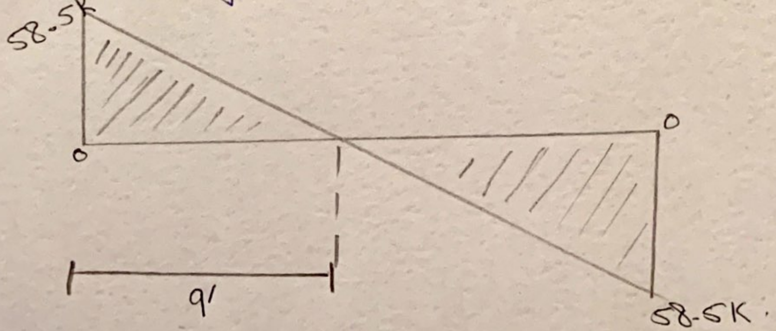
Step # 1 : (Reactions on Supports)

finding the reactions due to applied load.

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

Step # 2 : (Shear Force Diagram)

The required shear diagram will be

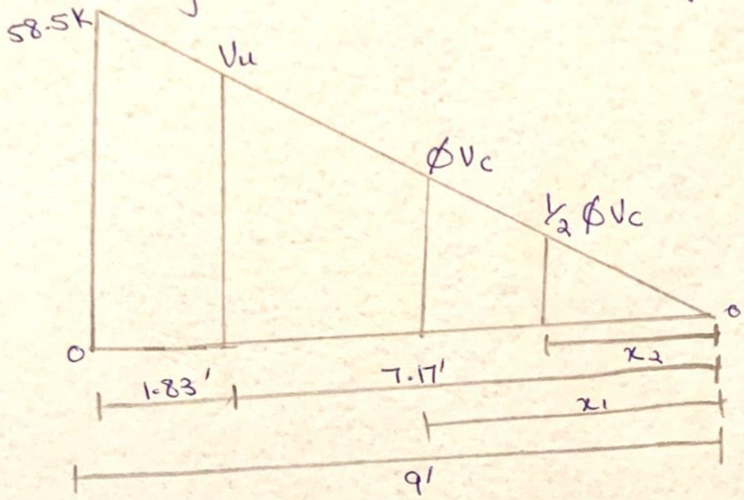


Step # 3:

Finding the value of critical shear "Vc" and its location.

As,
we know that critical shear is located at distance "d" from face of support (d) = 2" = 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 value of 'ØVc' and '½ ØVc' and also the distances from zero shear to right side.

By formulas,

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

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

$$= 29.21 \text{ Kips.}$$

=> location of ØVc by similar triangles,

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

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

=> Similarly,

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

=> location of ½ ØVc will be,

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

STEP #5:

Finding the value of ϕV_c

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,

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

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

$= 116.87 \text{ kips}$

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

So section is Adequate!

Step # 7:

check on maximum spacing for stirrups,

By formula,

$= \phi \times 4 \times \sqrt{f'c} \times bw \times d$

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

$= 58.43 \text{ Kips.}$

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

so maximum will be selected from the following 4 conditions

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

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

3- $S_{max} = \dfrac{A_v \times f_y}{0.75 \times \sqrt{f'c} \times bw}$

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

$\Rightarrow$ area $\times 2$

$\Rightarrow 0.11 \times 2 = 0.22 \text{ in}^2$

3 - $S_{max} = \dfrac{0.22 \times 60{,}000}{0.75 \times \sqrt{4000} \times 14} = 19.87''$

4- $S_{max} = \dfrac{A_v \times f_y}{50 \times b_w} = \dfrac{0.22 \times 60{,}000}{50 \times 14} = 18.85''$

from above 4 conditions, least value of spaing for #3 2 legged stirrup will be selected as,

$S_{max} = 11''$

Step 8:

Stirrups spaing from/at critical section will be, by formula,

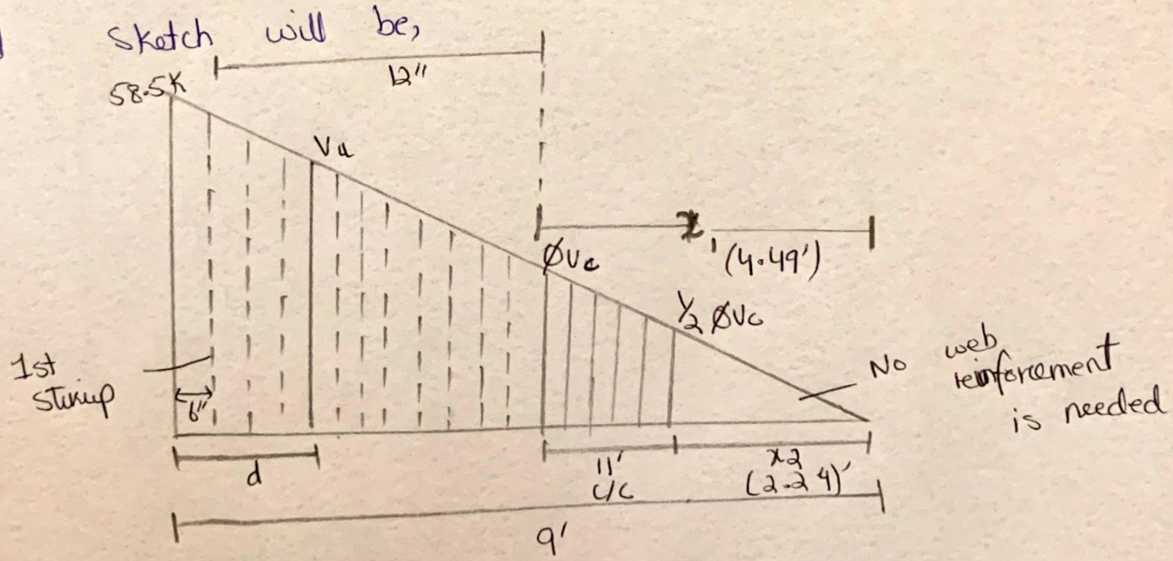
$$S = \frac{\phi \times A_v \times f_y \times d}{V_u - \phi V_c} = \frac{0.75 \times 0.22 \times 60 \times 22}{46.61 - 29.21}$$

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

so $12''$ c/c

Step 9:

final sketch will be,



As first stirrup from face of support,

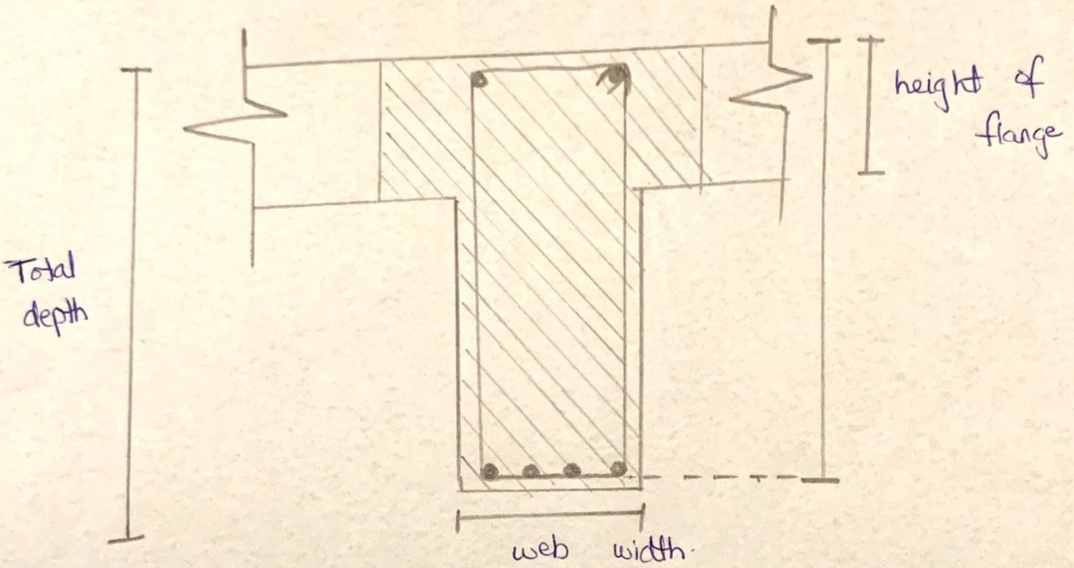
$S/2 = 12/2 = 6''$.

QUESTION - 03

Define both the T-beam & L-beam with the help of diagram. Also explain flexural analysis of T-beam.

T - Beam :

=> In most of the required concrete structures, concrete slabs are cast monolithically with 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.

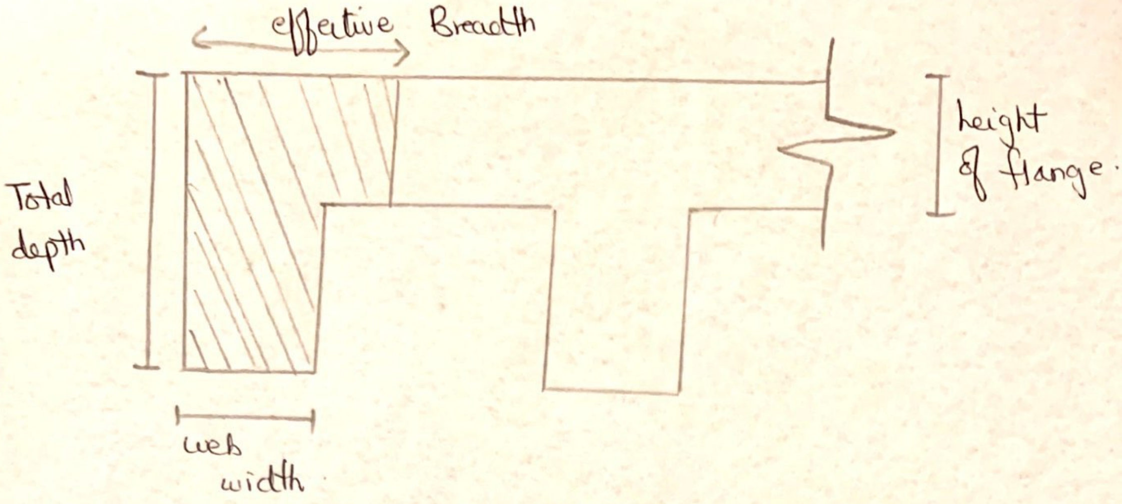
=> It is provided at the center of the slab to resists the loads.

=> 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's 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 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 forced 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- $\frac{CTS + b_w}{2}$

∴ (h_f = height of flange
CTS = clear transverse span)

- we've to select the least value from above formulas
- If c/c distance is given, then there's no need of " $\frac{CTS}{2} + b_w$ "

3- Checking whether Rectangular or T-Beam Analysis is required.

i- If $a > hf$ → Special Analysis is required.

ii- If $a < hf$ → Rectangular beam Analysis is required.

where

(a = depth of compression block
hf = height of flange)

4- For finding area of steel, we've to use.

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

∵ (ϕ = strength reduction factor
d = effective depth
a = Compression block depth.
bw = 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 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- 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,

$$b_{min} = 2(\text{clear cover}) + 2(\text{dia of stirrup}) + \text{no. of bars}(\text{dia of bar}) + \text{spacing b/w bars}(\text{dia of bar})$$

8- Design moment is given by.

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

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

↓ if $a > hf$.

QUESTION-04

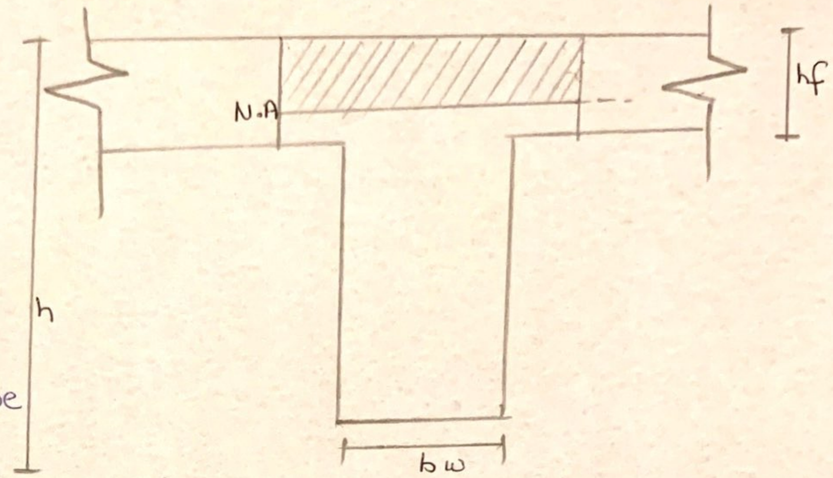
What is the difference b/w case-1 & case-2 in the design of T-beam?

CASE-I:

from the figure

$a < h_f$

So in this case, Rectangular Beam Analysis is Required. So, The Design Moment formula will be



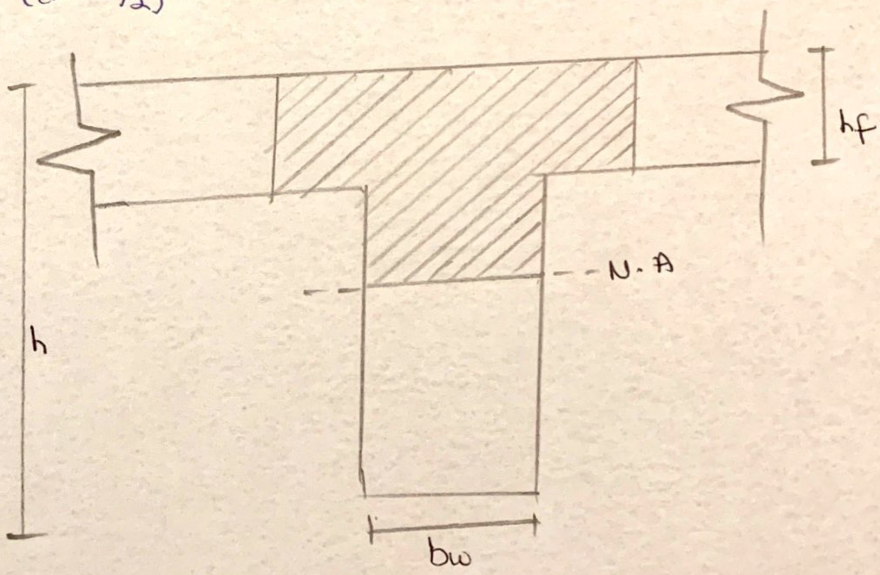
$$M_d = \phi \times f_y \times A_{st} \times (d - a/2)$$

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,

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

QUESTION - 05

A flour 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" & 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 & $f_y = 60$ ksi

Given :

height of flange $(h_f) = 3.5"$

c/c distance $= 9'$

Length / span of beam $= 16'$

web width $(b_w) = 10"$

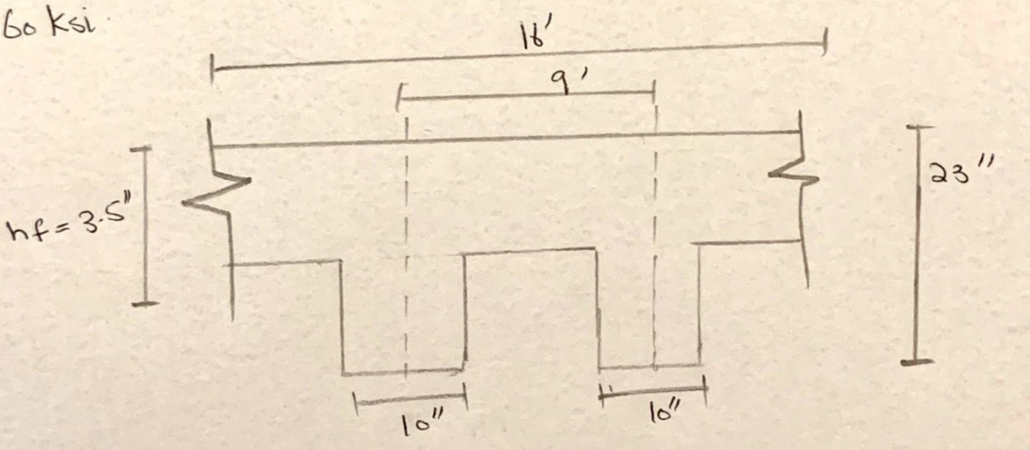
effective depth $(d) = 18"$

height $(h) = 23"$

Total factored moment $(M_u) = 5800$ kip inch.

$f'_c = 3$ ksi

$f_y = 60$ ksi



Step # 1

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 $= \frac{16}{4} \times 12 = 48"$

Selecting the least value of be as,

$\boxed{b_e = 48"}$

Step # 2:

Check whether rectangular or T-Beam Analysis is required

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

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

Trial # 02 :

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

$$a = \frac{6.61 \times 60}{0.85 \times 3 \times 48} = 3.2'' \\ = 3.2'' < 3.5''$$

& $\boxed{A_{st} = 6.55 \text{ in}^2}$

So Rectangular Beam Design is Required!

Trial # 03: $a = 3.21''$

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

So Area of steel is 6.55 in^2

Step # 3:

check ρ_{max} & ρ_{min}

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

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

$$\Rightarrow \rho_{min} = \frac{200}{f_y} = \frac{200}{60{,}000} = 0.003$$

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

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

$0.003 < 0.036 < 0.013$

As the value of ρ_{max} is less than ρ, so we've to design it as "doubly reinforced Beam"

=> first we've to find the area of steel against ρ_{max}.

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

$$A_{st} = 0.013 \times (10 \times 18) = \boxed{2.34\ in^2}$$

Step # 4:

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"

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

$$a = 5.72''$$

$$\Rightarrow M_{u2} = 0.90 \times 2.43 \times 60 \times (18 - 5.72/2)$$

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

As $M_{u2} < M_u$

$1986.67 < 5800$

So we've to design the beam in such a way that it can resist more bending moment than the applied external moment.

Scanned with CamScanner

STEP # 5:

Finding difference in moments & Area of steel.

$M_{u_1} = M_u - M_{u2}$

$= 5800 - 1986.67$

$\boxed{M_{u_1} = 3813.33 \text{ Kip-inch}}$

By formula,

$$A'_{st} = \frac{M_u}{\phi \times f_y \times (d-d')} = \frac{3813.33}{0.90 \times 60 \times (18.25)} = \boxed{4.56 in^2}$$

STEP #6:

Finding total steel Area:

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

$= 2.43 + 4.56 = 6.99 in^2.$

STEP # 7:

Selection of Bar:

In Tension Zone:

let we use # 8 bar

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

By formula:

$$\text{no. of bars} = \frac{\text{area of steel}}{\text{area of single bar}} = \frac{6.99}{0.785} = 8.9 \approx 9$$

In compression zone:

let we use # 7 bar

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

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:

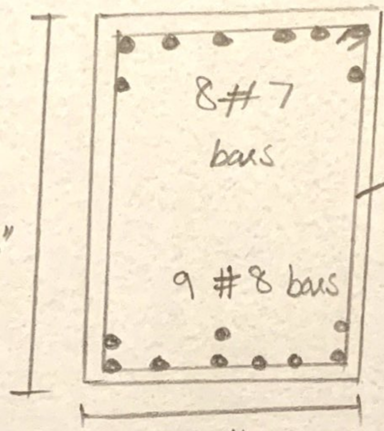
minimum width for accomodation of bars.

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

$$= 20.75''$$

As $20.75'' > 10''$

so, the bars will be placed in multiple layers:



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

$$\text{Effective cover } (d') = 1.5 + 3/8 + 7/8 + \tfrac{1}{2}(7/8) = 3.18''$$

STEP #9:

Finding the Design moment:

$$M_d = \phi \left[A's \times f_y \times (d - d') + (A_s - A's t) \times f_y + (d - a/2) \right]$$

first $a = \frac{(A_s - A's t) \times f_y}{0.85 \times f'c \times b} = \frac{(9 \times 0.785 - 8 \times 0.601) \times 60}{0.85 \times 3 \times 10} = 5.31''$

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

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

QUESTION-06:

A beam is required to developed & ultimate moment of 6000 kip-inches limited to 14x26 inch size, use $f'c = 4ksi$ & $fy = 60$ ksi. Determine flexural reinforcement assume two rows of tensile reinforcement & effective depth of beam is 22 inches.

Breadth $(b) = 14''$

height $= 26''$

$f'c = 4ksi$

$fy = 60$ Ksi

$Mu = 6000$ kip-inches

$d = 22''$

$d' = 2.5$ — assume.

Step # 1 : Reinforcement Ratio.

By formula,

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

$$= 0.85 \times 0.85 \times \frac{4}{60} \times \left(\frac{0.003}{0.003 + 0.005}\right) = 0.0180.$$

Step # 2 : Area of Steel.

As we know that.

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

$$Ast = 0.0180 \times (14 \times 22) = 5.54 \, in^2.$$

STEP # 3 : Design Moment

$Mu_2 = \phi \times Ast \times fy \times (d - a/2)$

$\Rightarrow a = \dfrac{Ast \times fy}{0.85 \times f'c \times b} = \dfrac{5.54 \times 60}{0.85 \times 4 \times 14} = 6.98''$

So

$Mu_2 = 0.90 \times 5.54 \times 60 \left(22 - \dfrac{6.98}{2}\right)$

$= 5537.4$ kip-inch

As $5537.4 < 6000$

So we 've to design a section as doubly reinforced.

Step #4 Difference in moments.

$Mu_1 = Mu - Mu_2$

$= 6000 - 5537.4$

$Mu_1 = 462.6$ kip-inches

Step # 5. Area of steel

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

So area of steel in compression zone will be

$\Rightarrow A'st = \dfrac{Mu_1}{\phi \times fy \times (d - d')} = \dfrac{462.6}{0.90 \times 60 \times (22 - 2.5)}$

$= 0.44 in^2.$

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 $= \frac{\pi}{4}(0.875)^2$

$= 0.601 \text{ in}^2$

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 bar,

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

$= 0.306 \text{ in}^2$

so, no. of bars $= \dfrac{A_{st}'}{\text{area of single bar}}$

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

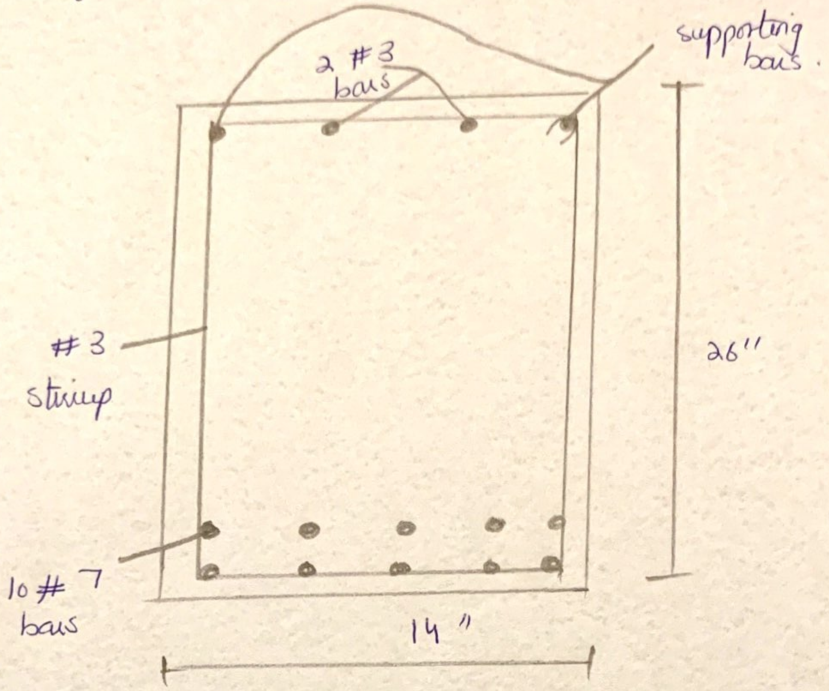
so 2 # 5 bars.

Step # 8 Minimum width of Beam. (20)

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

$b_{min} = 20.37 > 14''$

so not good in one layer.



Now,

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

$= 22.82''$

=> effective cover (d') $= 1.5 + 3/8 + \frac{1}{2}(5/8)$

$= 2.18''$

Step #9 Design moment.

$M_d = \phi \times [A'st \times f_y \times (d - d') + (Ast - A'st) \times f_y \times (d - a/2)$

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

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

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

$M_d = 7047.6$ kip-inches

As 7047.6 > 6000

Design is ok!