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Section B BE(C)

Semester 6th

Subject PRCD-I

Assignment No.1

Question - 01

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

Answer:-

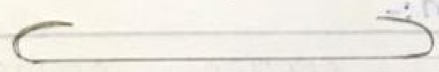
STirrup :-

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

Types of Stirrups:-

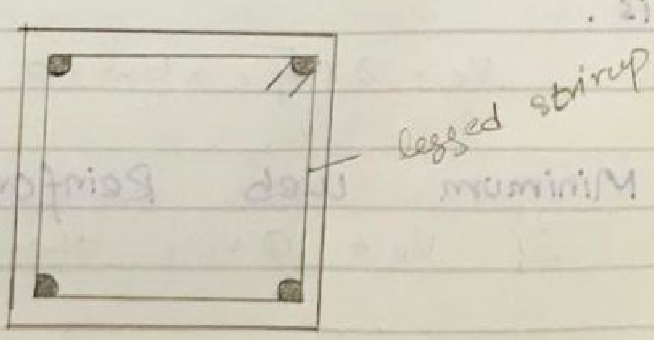
1 :- Single Legged Stirrup:-

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



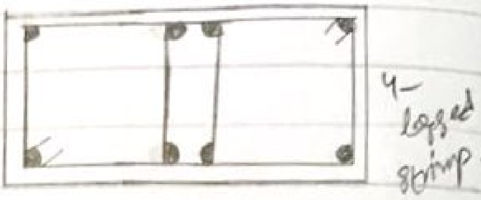
2 :- Two Legged Stirrup:-

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

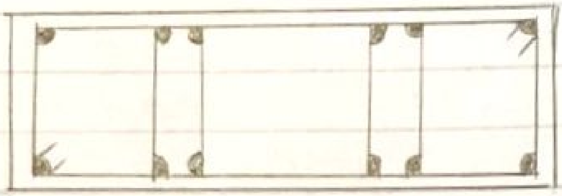


3:- **Four Legged stirrup:-**

These stirrups are used in case of web inforcement.



4:- **Six Legged Stirrup:-**



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 at least a minimum area of web reinforcement equal to,

$\phi = 0.75 \rightarrow$ For shear design

(∵ V_u = Total factored shear applied at a given design section.

⇒ For minimum Reinforcement Area:

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

Higher value is selected

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

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

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 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- $S_{max} = \dfrac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$
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 - 02

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"

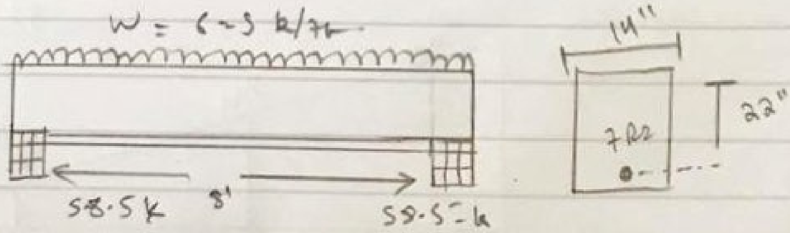
Given Load = 6.5 k/ft

steel area = 7 in²

$f'c$ = 4 ksi

fy = 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

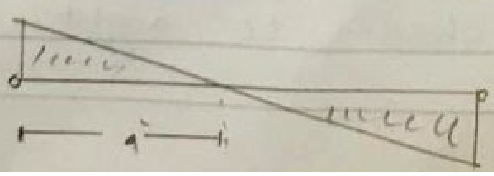


Diagram on previous page

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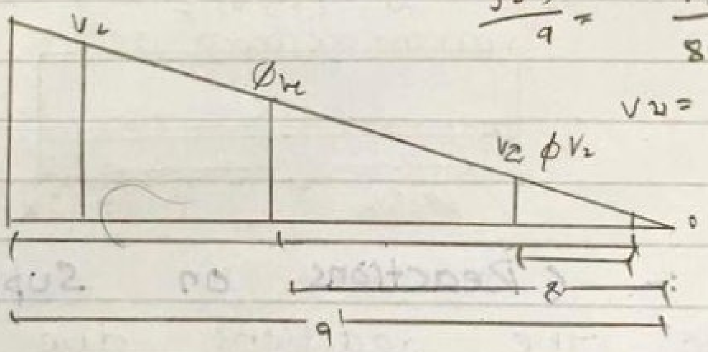
Step # 3:-

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

As we know that critical shear is located at distance "d" from face to support (d) = 22" = 1.83'

=> we will find the value of critical shear at distance "d" by use of similar triangles.

From similar triangle



$$\frac{58.5}{9} = \frac{V_2}{8.17}$$

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

$V_u = 46.61$ kips

Step # 4:-

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

By Formula (7)

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

$= 0.75 \times 2 \times \sqrt{400} \times 14 \times 22 = 29219$ lbs

29.21 kips

$\Rightarrow$ Location of ϕV_c by similar triangles,

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

$x_1 = 4.49'$

Similarly

$1/2\ \phi V_c = \phi V_c/2 = 29.21/2 = 14.60$ kips

$\Rightarrow$ Location of $1/2\ \phi V_c/2 \Rightarrow 29.21/2 = \frac{29.21}{x_1}$

$x_1 = 1460$ kips

$\Rightarrow$ Location of $1/2\ \phi V_c$ will be,

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

Step # 5:-

Finding the value of ϕV_s

By Formula, $V_u = \phi V_s + \phi V_c$

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

$= 46.61 - 29.21$

$\phi V_s = 17.4$ kips

Step # 6 :-

Check on section adequacy,

By formula,

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

$= 0.75 \times 8 \times \sqrt{400} \times 14 \times 32$

$= 116877$ lbs

$= 116.87$ kips

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

so section is Adequate!

Step # 7:-

Check on maximum spacing for stirrups,

By formula

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

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

$= 58438$ lps

$= 58.43$ kips

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

so maximum will be selected

from the following 4 conditions,

1 - $S_{max} = 24"$

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

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

Here we are using # 3 stirrup,

dia $= (3/8)" = 0.375"$

so Area $= \dfrac{\pi}{4}(0.375)^2 = 0.11$ in2

For 2 - legged stirrup

=> Area x 2

=> $0.11 \times 2 = 0.22$ in2

3- $S_{max} = \dfrac{0.22 \times 6000}{0.75 \times \sqrt{4000 \times 14}} = 19.87''$

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

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

$S_{max} = 11'$

Step # 8 :-

Stirrups spacing from/at critical section will be,

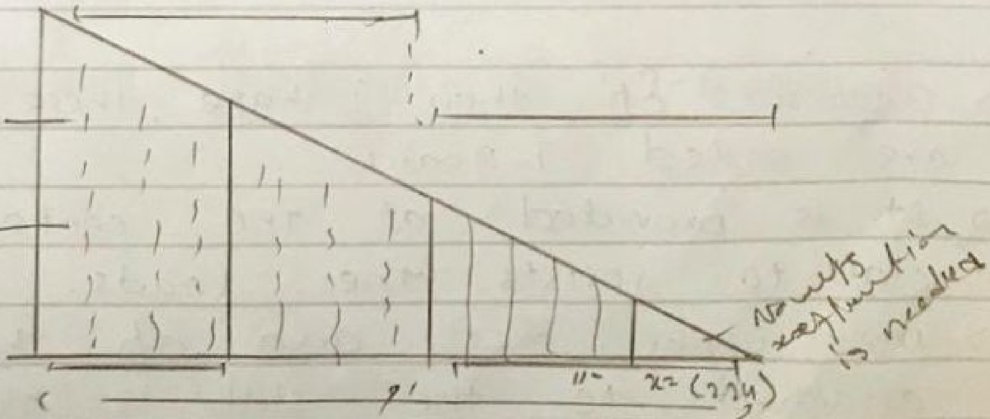
By formula,

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

$S = 12.5' = 12''$

So $= 12''$ c/c

Step # 9 :-



As first stirrup from face of support,

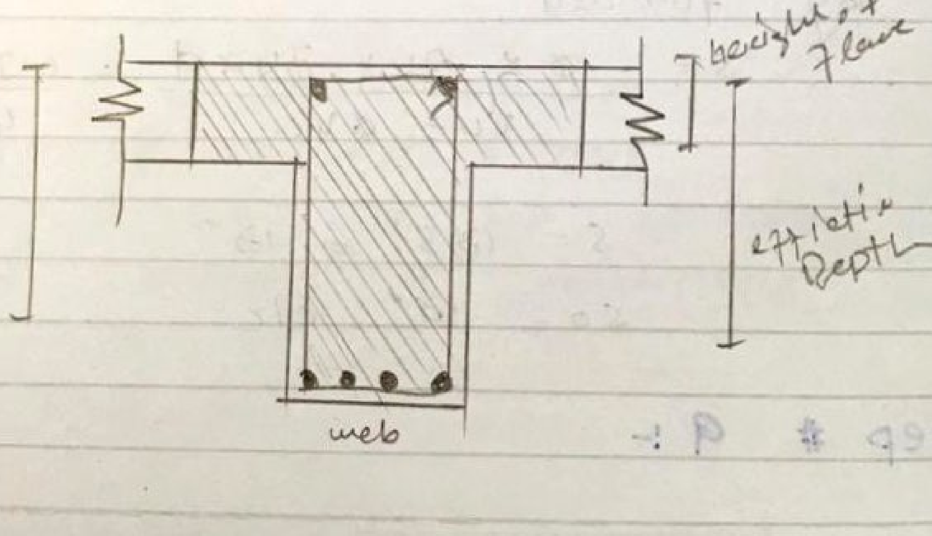
$S/2 = 12/2 = 6''$

Question -03

Define both the T-Beam and L-Beam with the help of diagram. Also explain flexual analysis of T-Beam.

T-Beam:-

On 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.

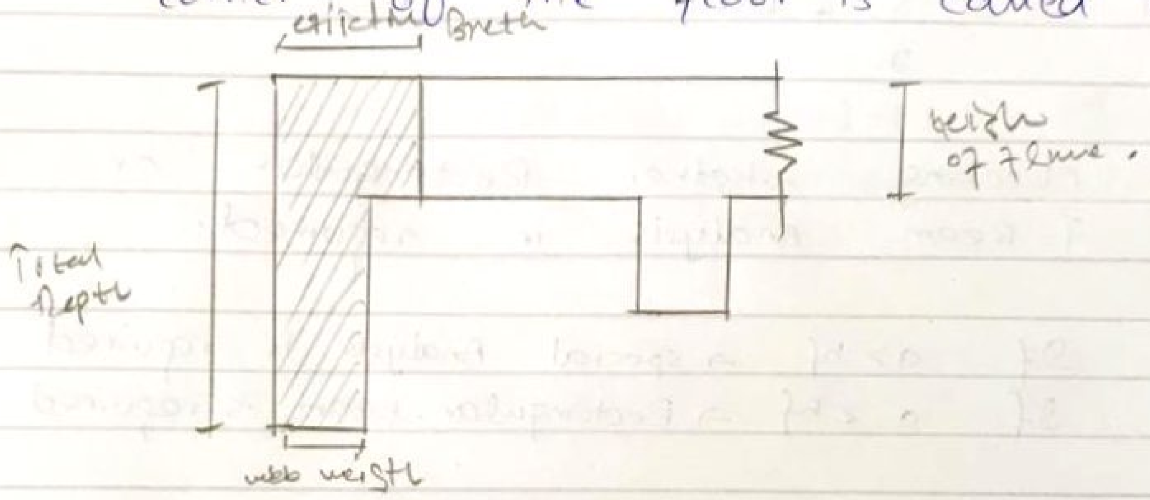


=> Because of their T-shape, these beams are called T-Beams.
=> It is provided at the center of the slab to resists the loads.
=> The upper most area of the beam attached to the slab is called flange.

=> The bottom rectangular portion of the beam is called webs of the beam.

L- Beam :-

=> L-shape 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 Presstressed 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,

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

2:- Effective width (b_e) for T-Beam is calculated as formula,

1. $16(h_f) + b_w$
2. c/c distance
3. span/4
4. $\frac{CTS}{2} + b_w$

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

(i) If $a > h_f$ → special Analysis is required
(ii) If $a < h_f$ → Rectangular beam is required

4:- For finding Area of steel, we have to use

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

where

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

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:- Formula for finding no 8:- for accomodation,

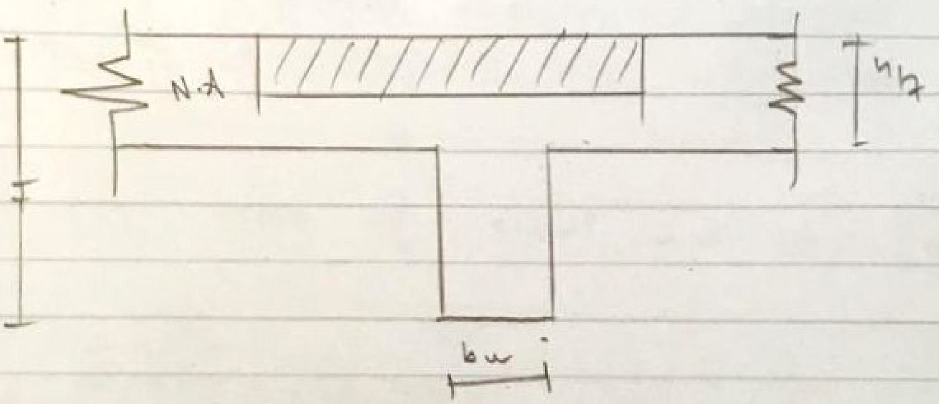
b min = 2(clear cover) + 2 (dia of stirrup) + no of bars + spacing b/w bars.

Question - 04

what is the difference b/w. Case 1 and Case -2 in the design of T-Beam?

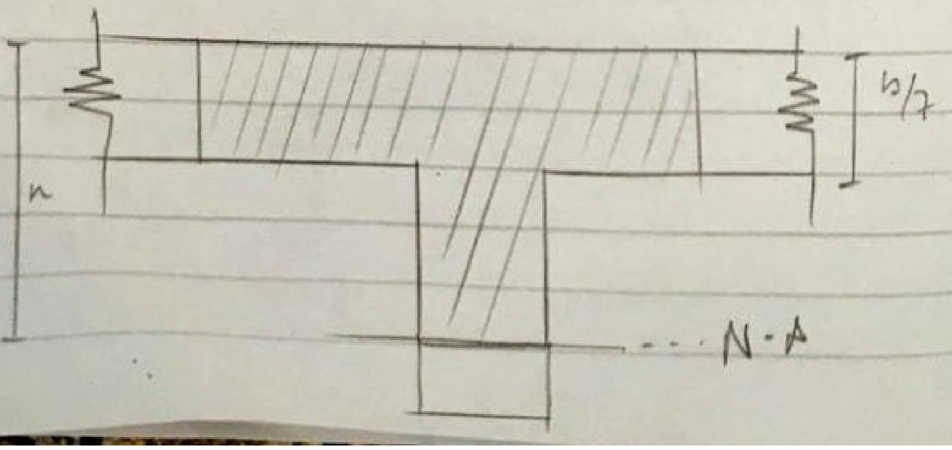
Case - 1:-

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-2:-

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



Question - 05

A floor system consist 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 reinforcment if the factored applied moment is 5800 skip-inch. Use f'c = 3 kisi and fy = 60 ksi.

Given :-

Height of flange = 3.5"

c/c distance = ?

Length/span of the beam = 16"

web width . 10"

Effective depth = 18"

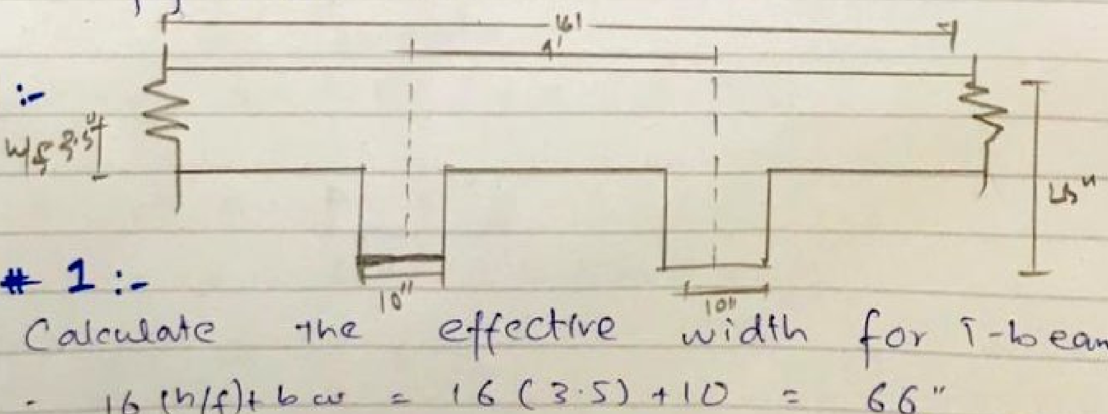
Height = 23"

Factored moment = 5800 kip-inch

$f_c' = 3$ ksi

$f_y = 60$ ksi

Sol :-



Step # 1 :-

Calculate the effective width for T-beam

1 - $16(h_f) + b_w = 16(3.5) + 10 = 66"$

2 - c/c distance = 108"

3 - Span/4 = 48"

$b_e = 48"$

Step # 2 :-

Check whether Rectangular or T-beam Analysis is required

Trial # 01 :- Let $a = h_f = 3.5''$

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

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

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

and $A_{st} = 6.55\ in^2 \Rightarrow 3.2'' < 3.5''$

Trial # 03 :- $a = 3.21''$

$$A_{st} = \frac{5800}{0.90 \times 60\ (18 - \frac{3.21}{2})}$$

$$= 6.55\ in^2$$

Step # 3 :-

Finding the value of M_{u2} :-

By Formula

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

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

$$a = 5.72''$$

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

As $M_{u2} < M_u$

$1986.67 < 5800$

Step # 5 :-

Finding Difference in moments and Area of steel.

$Mu_1 = Mu - Mu_2$

$= 5800 - 1986.67$

$Mu_1 = 3813.33$ kip - inch

By formula

$$A'_{st} = \frac{Mu}{\phi \times fy \times (d - d')}$$

$A'st = 4.56 \ in^2$

Step # 6 :-

Finding Total steel Area

$As = Ast + As't$

$= 2.43 + 4.56$

$As = 6.99 \ in^2$

Step # 7 :-

Selection of Bar :-

On tension zone:-

let we use # 8 bar

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

$= 0.785 \ in^2$

By Formula

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

$= \frac{0.699}{0.785}$

$= 8.9 = 9$

So 9 # 8 bars

In compression zone:-

Let we use # 7 bar

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

$= 0.601 \text{ in}^2$

by Formula

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

$= \frac{4.56}{0.601} = 7.8 = 8$

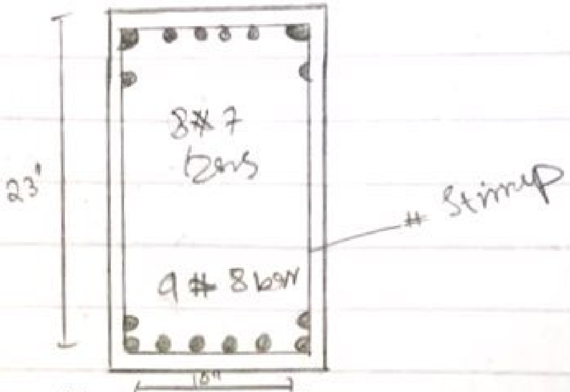
So 8 # 7 bars.

Steps # 8:-

Minimum width of Accomodation of bars

$b_{min} = 20.75''$

So the bars will be placed in multiple layers.



Effective depth = 19.6"
Effective cover = 3.18"

Step # 9 :-

Finding the Design Moment

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

First $a = \dfrac{(As - As't) \times fy}{0.85 \times f'c \times b}$

$= 5.31"$

$Md = 6328.38$

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

Question - 06

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

Sol:-

Given:-

Breadth = 14"

Height = 26"

Concrete compression strength = 4 ksi

Steel Tensile strength = 60 ksi

Ultimate factored Moment = 6000 kip-inches

Effective depth of beam = 2.5"

Assume Effective cover = 2.5"

Step # 1:- (Reinforcment Ratio)

By formula

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

$$\rho_{max} = 0.0180$$

Step # 2:- (Area of Steel)

As we know that

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

$$A_{st} = 5.54 \text{ in}^2$$

Step # 3:- (Design Moment):-

By using formula

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

$$\Rightarrow a = \frac{A_{st} \times f_y}{0.85 \times f'_c \times b} = 6.98''$$

so

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

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

As

$$5537.4 < 6000$$

Step # 4:- (Difference in Moments)

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

$$= 6000 - 5537.4$$

$$M_{u1} = 462.9 \text{ kip-inches}$$

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,

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

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

Step # 6 :- (Total steel Area)

$$A_s = A_{st} + A'_{st}$$
$$= 5.54 + 0.44$$
$$= 5.98 \text{ in}^2$$

Step # 7 :-

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 that bars = $\frac{A_s}{\text{Area of single bar}}$

$= \frac{5.98}{0.601} = 9.9 = 10$ ba

so 10 # 7 bars

② Steel in compression zone:-

we use # 5 bar,

dia = $(5/8)'' = 0.6025''$,

Area = $\frac{\pi}{4}(0.625)^2$

$= 0.306 \text{ in}^2$

So No of bars = $\frac{A'_{st}}{\text{Area of single bar}}$

$= 1.43 \approx 2$ bars

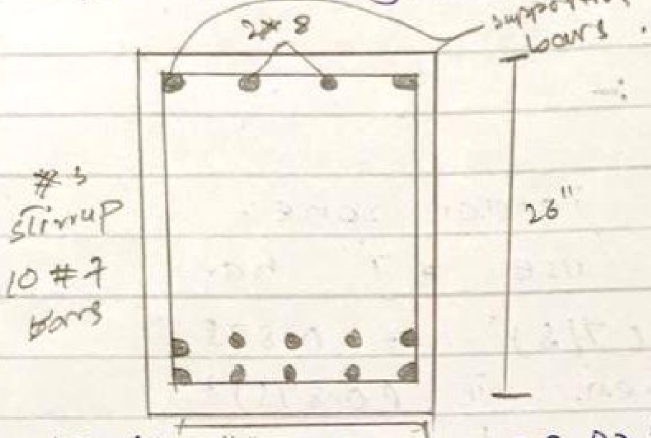
so 2 # 5 bars

Step # 8 :- (Minimum width of Beam)

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

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

so not good in one layer



Now,

=> Effective depth = 22.82''

=> Effective cover = 2.18''

Step # 9 :- (Design Moment)

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

$$a = \frac{(A_{st} - A_{st}') \times f_y}{0.85 \times f'_c \times b}$$

$= 6.80''$

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

$M_d = 7047.6$ kip-inches

As $7047.6 > 6000$

Design is OK!