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Section A

Assignment Plain & Reinforcement Concrete Design - I

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Question - 01

Explain in Detail Types of Stirrups with figures also explain ACI codes for Shear design.

Ans :→

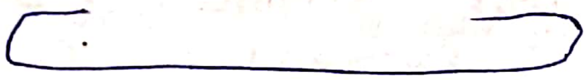
Stirrup :→

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

Types of Stirrups :→

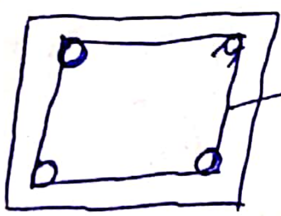
1 → Single legged Stirrup :-

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



2 → Two legged Stirrup :-

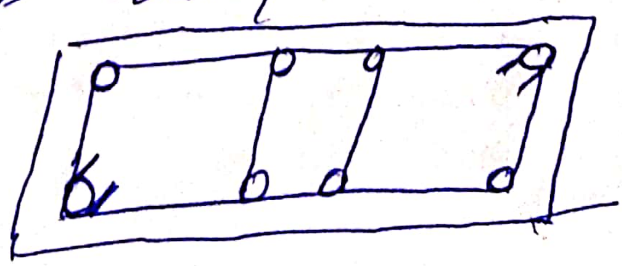
It is most commonly and widely used Stirrup - ordinary 4 bars is used.



2 legged Stirrup

3 → Four legged Stirrup :-

These Stirrup are used in case of web Reinforcement.



4 legged Stirrup

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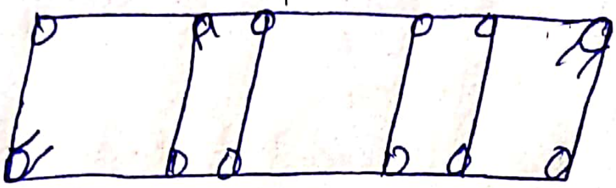
4- Six Legged Stirrup:-



Now ACI Codes for Shear Design of a beam.
According to ACI-318, following are the formula 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 theoretically no web reinforcement is required.
$$\phi = 0.75 \longrightarrow \text{for Shear design.}$$

=> For Minimum Reinforcement Area:-
$$A_{v\,min} = \frac{0.75 \times \sqrt{f'_c} \times b_w \times S}{f_y}$$

By Interchanging we can obtain
$$\frac{A_v \times f_y}{50 \times b_w}$$ (lesser value is Selected)

4 → No web-reinforcement is required

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

⇒ Between Critical Section

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

5 → If $V_s \leq 4 \times \sqrt{f'_c} \times b_w \times d$, Then max Spacing for Stirrup will be the Smallest of the following.

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

⇒ 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-Section dimension or increase f'_c.

Q No (02)

Given Data:-

Breadth of web of beam (b_w) = 14"

Effective depth (d) = 22"

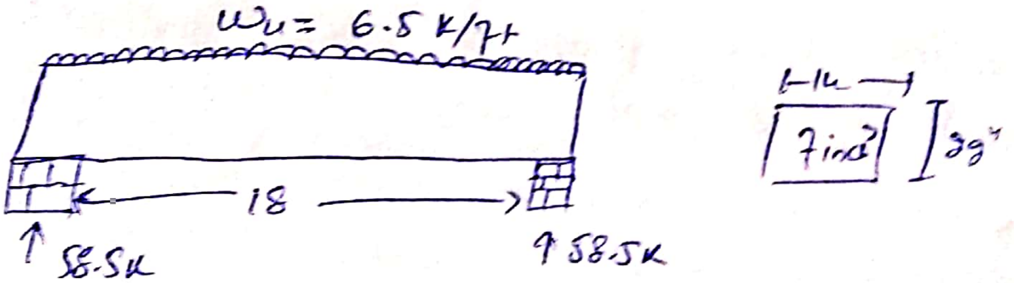
Given load = 6.5 k/ft

Steel area = 7 inch^2

f'_c = 4 ksi

f_y = 60 ksi

Sol:-

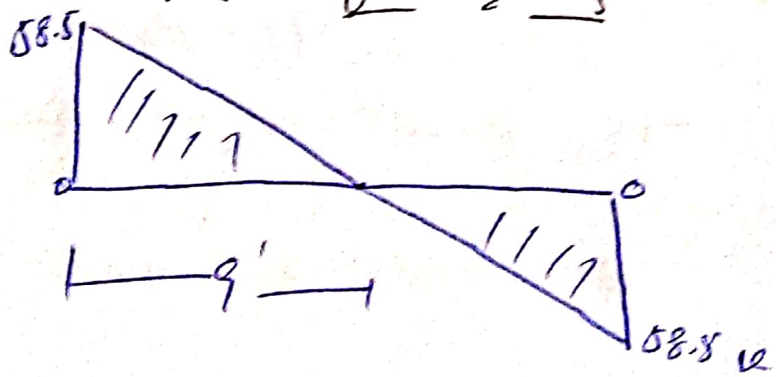


Step # 1 :-> Reaction on Support

Finding the Reactions due to applied load

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

Step 2:- Shear Force Diagram

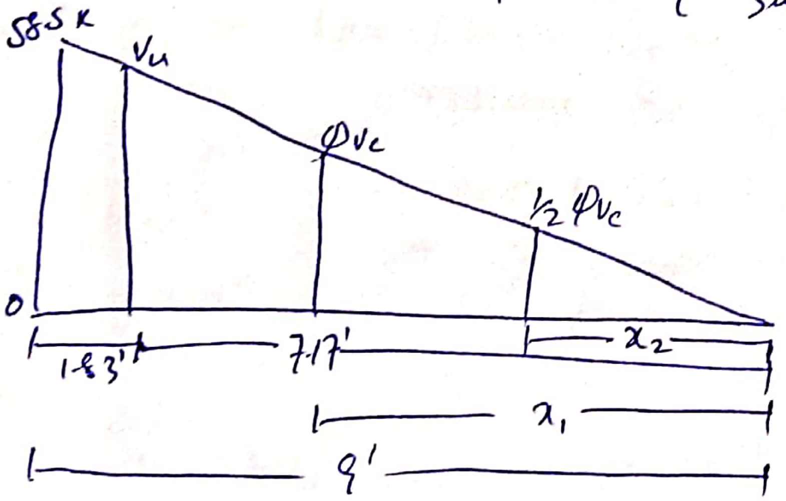


Step 3 :→

Finding the value critical Shear 'Vu' and its location.

we know that critical Shear is located at distance "d" from face of Support (d) = 22"
= 1.83'

⇒ we will find the value of critical Shear at distance "d" by use of Similar triangles



From Similar Δ

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

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

$V_u = 46.61$ kips

Step 4 :—

Finding the value of ϕV_c & "$\frac{1}{2}\phi V_c$" and also it distance from zero Shear to right side.

By formula

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

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

$$= 29.21 \text{ kips}$$

⇒ Location of ϕV_c by Similar Triangle

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

⇒ location of ½ 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, $V_u = \phi V_s + \phi V_c$

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

$= 46.61 - 29.21$

$\phi V_s = 17.4$ kips.

Step 6:-

Check on Section adequacy

By formula,

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

$= 0.75 \times 8 \times \sqrt{4000} \times 14 \times 22 = 116877$ lbs $= 116.87$ 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.

$\phi \times 4 \times \sqrt{f'c} \times bw \times d = 58.43$ kips

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

Smax Selected.

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

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

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

(using #3 Stirrup $d = (3/8)''$

3 – $S_{max} = \dfrac{0.22 \times 60000}{0.75 \times \sqrt{4000} \times 14} = 19.87''$

4 – $S_{max} = \dfrac{A_v \times f_y}{50 \times b_w} = \dfrac{0.22 \times 60000}{50 \times 14} = 18.88$

From abov 4 condition least value spacing for #3 2 legged stirrup will be selected as,

$S_{max} = 11''$

Step 8:-

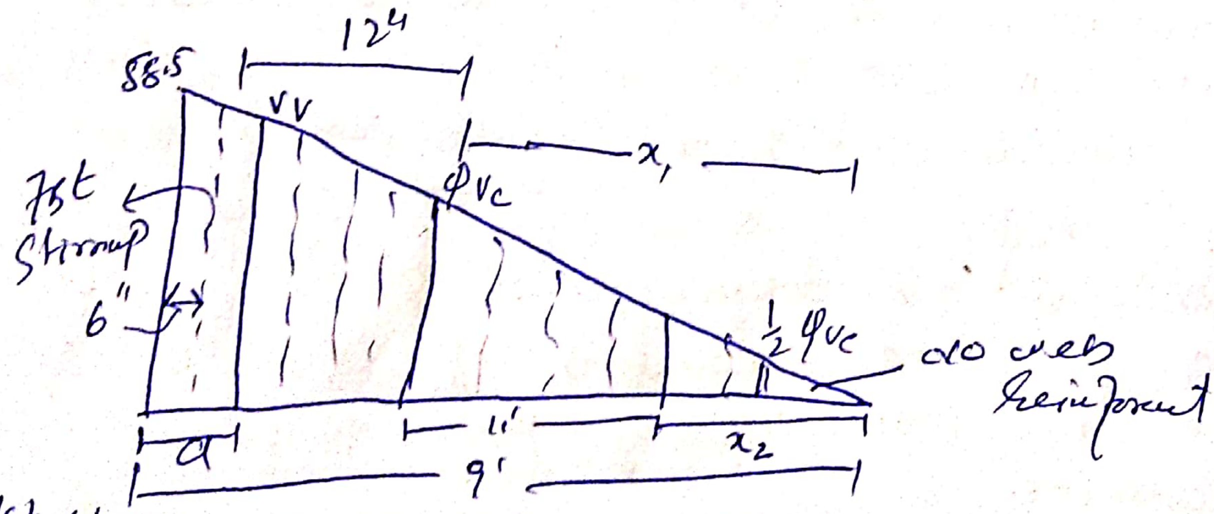
By formula.

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

$S = 12.5'' \simeq 12''$

$S_o = 12''$ c/c

Step 09:→ Final Scatch.



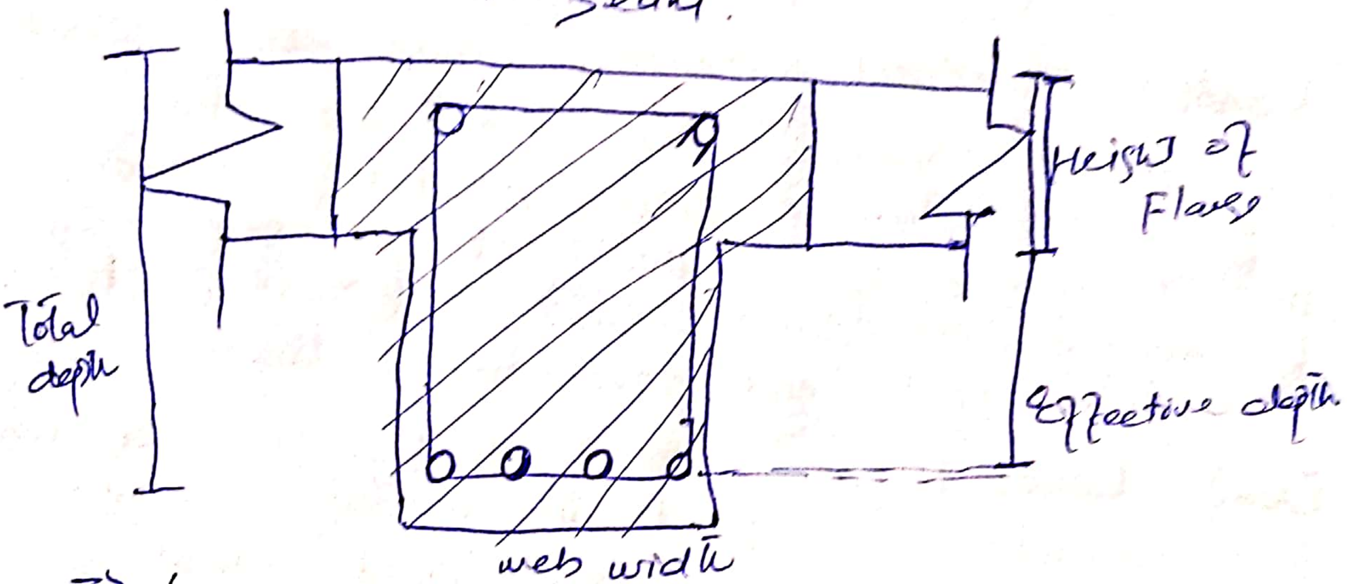
@ 1st Strip

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

Qa10 - 03

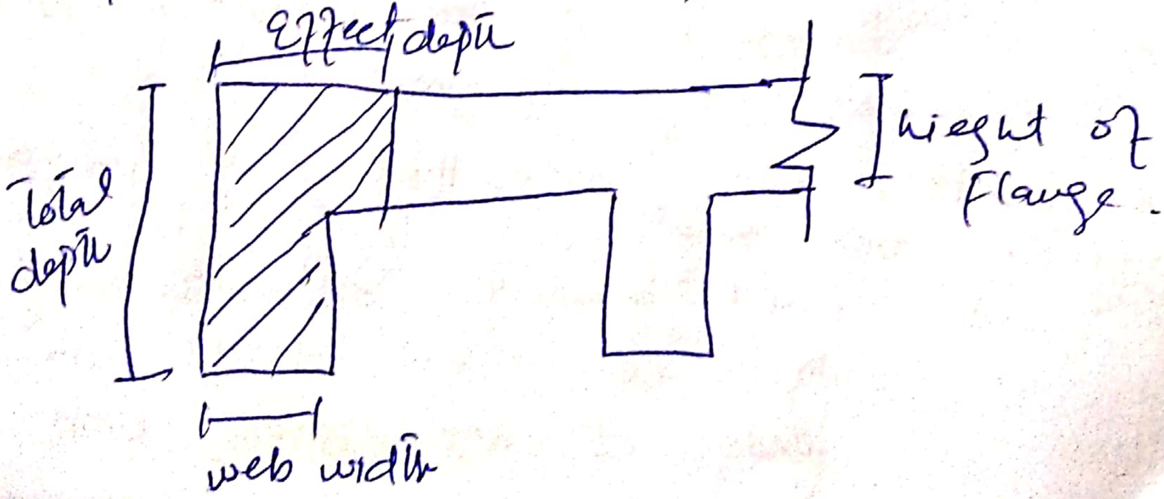
T-Beam :→

=> In most of the Reinforcement Concrete Structure, Concrete Slabs are Cast monolithically with the Slab So, in this case the beam that act as an intermediate beam are called T-Beam.



=> L-Beam :→

L-Shaped Structure that is in contact with the slab and present at the corner of floor is called L-Beam.



Flexural Analysis of T-Beam :-

Flexular Analysis of T beam consist of the following step.

1 → For finding the Ultimate Factored moment we use the following formula.

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

2 → Effective with be for T-Beam is Called as

1 → 16 (h_f) + b_w
2 → c/c distance
3 → Span/6
4 → $\frac{C/S}{2} + b_w$

3 → Checking whether Rectangle or T-beam Analysis is Required.

i → If $a > h_f$ → Special Analysis Required
ii → If $a < h_f$ → Rectangular beam Analysis 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

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

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 find No. of bars required is

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

8 - For checking minimum width.

$b_{min} = 2(\text{Clear} + 2(\text{dia of } st)) + \text{No of bar}$

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Qno 04

What is the Difference b/w case-I and case II in the Design of T-Beam?

Ans :-> **Case I :-**

From figure

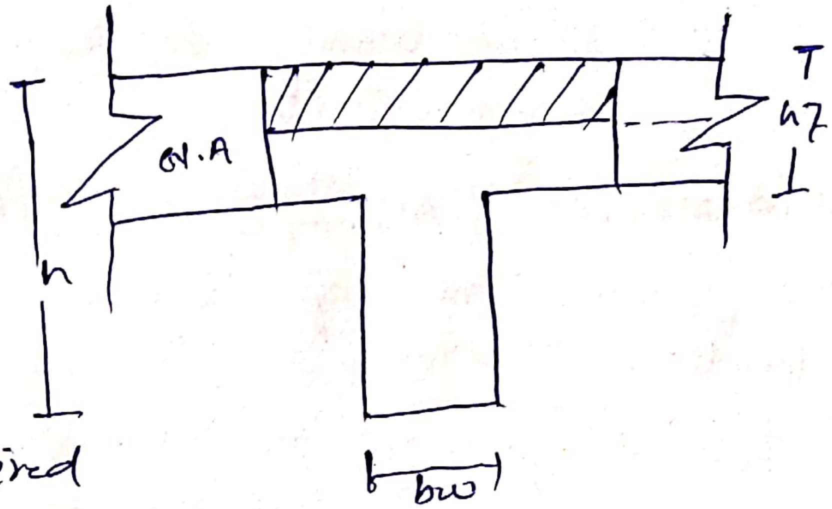
$a < h_f$

So in this case, Rectangular Beam Analysis is Required

So,

The Design moment formula will be

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

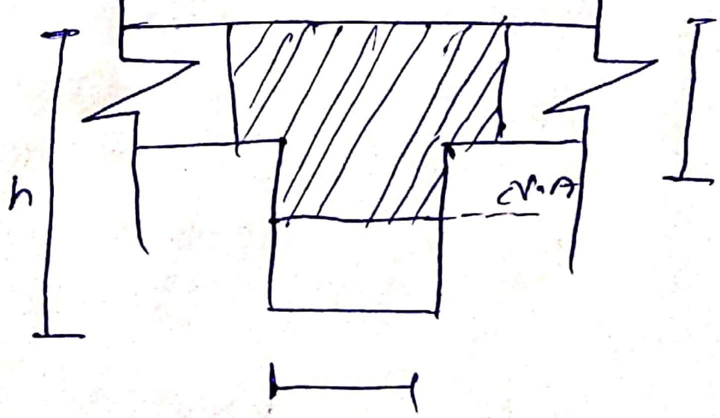


Case 2 :-

From figure,

$a > h_f$

So in this, Special beam analysis i.e, T-Beam Analysis is Required



So

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

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Q no (05)

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"

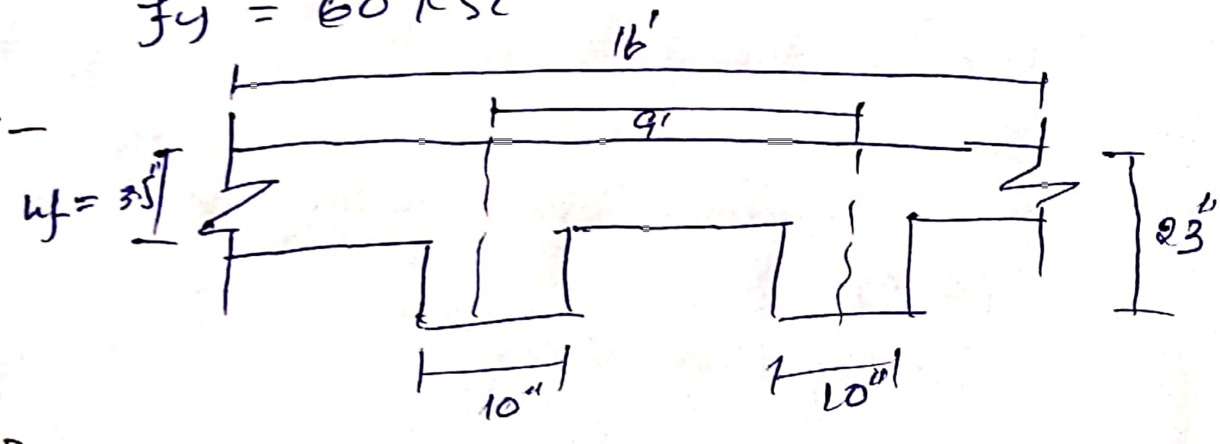
Height (h) = 23"

Total factored moment (M_u) = 5800 kip/inch

f'_c = 3 ksi

f_y = 60 ksi

Sol :-



Step 1 :-

Calculate the effect width be for T-beam

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

2- c/c distance = 9×12 = 108"

3- Span/4 = $\frac{16}{4} \times 12$ = 48"

Selecting the least value of b_c as

$b_c = 48''$

Step 2 :-

Check whether Rectangular or T-beam Analysis is Required

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

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

$A_{st} = 6.61 \text{ in}^2$

Trial 2 :- $$a = \frac{A_{st} \times f_y}{0.85 \times f'_c \times b_c}$$

$a = 3.2'' < 3.5$

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

Rectangular Design required.

Trial 3 :- $a = 3.21''$

$$A_{st} = \frac{5800}{0.9 \times 60(18 - \frac{3.21}{2})}$$

$= 6.55 \text{ in}^2$

So Area of Steel is 6.55 in^2

Step 3 :-

Check ρ_{max} and ρ_{min}

$\Rightarrow \rho_{max} = 0.85 \times \beta \times \frac{f'c}{fy} \left(\frac{\varepsilon u}{\varepsilon u + \varepsilon r} \right)$

$= 0.013$

$\Rightarrow \rho_{min} = \frac{200}{fy} = \frac{200}{6000} = 0.003$

$\Rightarrow \rho = \frac{Ast}{bxd} = \frac{6.55}{10 \times 18} = 0.036.$

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

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

$$\boxed{Ast = 2.34 \ in^2}$$

Step 4 :-

Find Mu_2 :

By formula

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

First finding the a

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

$$a = \frac{2.43 \times 60}{0.85 \times 3 \times 10}$$

$$a = 5.72''$$

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

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

As $\quad M_{u2} < M_u$

$\quad 1986.67 < 5800$

So we have to design the beam to resist bending.

Step 5 :-

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

$$= 5800 - 1986.67$$

$$\boxed{M_{u1} = 3813.33 \text{ kip-inch}}$$

By formula

$$A'_{st} = \frac{M_u}{\phi \times f_y \times (d - d')} = \frac{3813.33}{0.90 \times 60 \times (18 - 2.5)}$$

$$\boxed{A'_{st} = 4.56 \text{ in}^2}$$

Step 7 :-

Section of bar

In tension zone :-

using #8 bar

dia = 1" Area = 0.785 in^2

No. of bar = $\frac{\text{Area of Steel}}{\text{Area of Single bar}}$

$= \frac{6.99}{0.785} = 8.9 \cong 9$

So 9 #8 bars.

In Compression zone :-

Let we use #7 bar

dia = (7/8)" , Area $\frac{\pi}{4}(7/8)^2 = 0.6 \text{ in}^2$

No. of bars = $\frac{\text{Area of Steel}}{\text{Area of Single bar}}$

$= \frac{4.56}{0.601} \Rightarrow 7.5 \cong 8$

So 8 #7 bars.

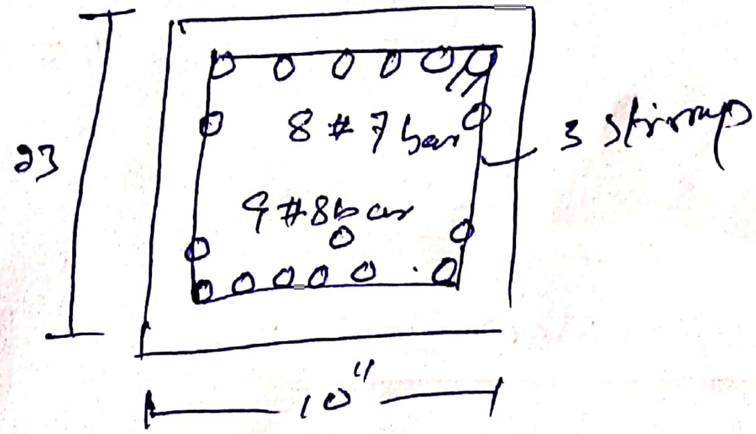
Step 8:-

Minimum width for accomodation of bars.

$$b_{min} = (2\times1.5) + (2\times 3/8) + 9(8/8) + 8(8/8)$$
$$= 20.75''$$

As 20.75 > 10

So, the bars will be placed in multiple layers.



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

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

Step 9:-

Finding the Design moment.

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

$a = 5.31''$

$M_d = 6328.38$

As $6328.38 > 5800$ → So Design is OK!

Question 6

Sol :→

Given Data

Breadth = b = 14"
Height. h = 26"
Concrete compression f'_c = 4 ksi
Steel Tensil f_y = 6ksi
Ultimate factor moment Mu = 6000 kip inch
Effective depth of beam = 22"
Assume Effective cover = 25

Step 2:– Reinforcement Ratio

$$\rho_{max} = \frac{Ast}{bd} =$$

$Ast = 0.0180 \times (14 \times 22)$

$\boxed{Ast = 5.54 \, in^2}$

Step 3:– Design moment

By using formula

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

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

$$\boxed{a = 6.98''}$$

So

$$Mu_2 = 0.90 \times 8.54 \times 60 \times (22 - \frac{6.98}{2})$$

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

As

$$5537.4 < 600$$

So we have to design a Section as doubled reinforcement.

Step 04:-

Area of Steel

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

So Area of Steel in Compress Zone

$$As't = \frac{Mu_1}{\phi \times fy \times (d-d')}$$

$$\boxed{As't = 0.44 \text{ in}^2}$$

Step 06:- Total Steel area

$A_{sT} = A_{st} + A_s{}'t$

$= 5.54 + 0.44$

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

Step 07:- Selection of No. of bars

1- In tension zone:-
we use #7 bar

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

$= \dfrac{5.98}{0.601} = 9.9 \simeq 10$ bar

So 10 #7 bar

2- Steel in compression zone:-
we use #5 bar

No. of bar $= \dfrac{A_{st}}{\text{Area of single bar}}$

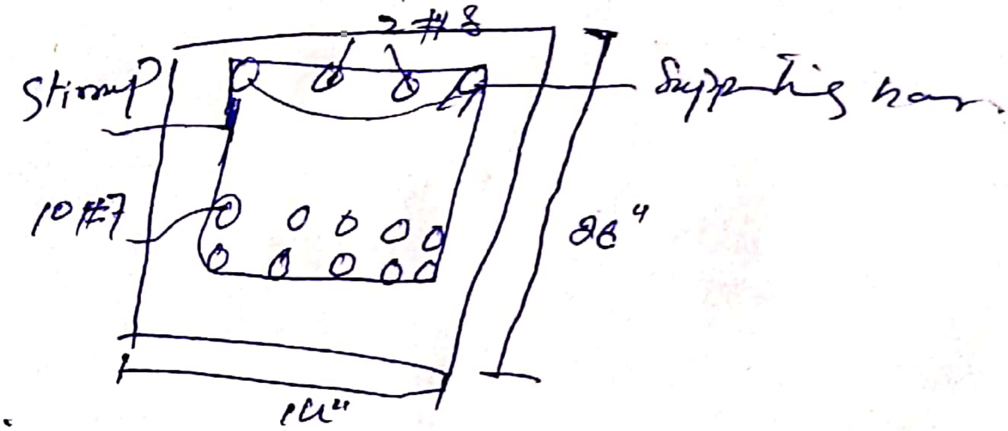
$= \dfrac{0.44}{0.306} = 1.43 \simeq 2$ bar

So 2 #5 bars.

Step 8:- Minimum width

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

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



Effective dep = 22.82"

Effect Cover = 2.18"

Step 9:- Design Moment

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

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

$\boxed{a = 6.80}$

$M_d = 0.90[2 \times 0.308) \times 60 \times (22.82 \times 60 \times (22.5-6$

$M_d = 7047.6$ kip-inch

As $7047.6 > 6000$

So Design is OK!

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