Number

Name

ID 7986

Section A

1) **TYPES OF STIRRUPS:-**

The following types of stirrups are widely used in construction:.

=> Single legged Stirrups

=> Two legged or Double legged stirrups.

=> Four legged stirrups

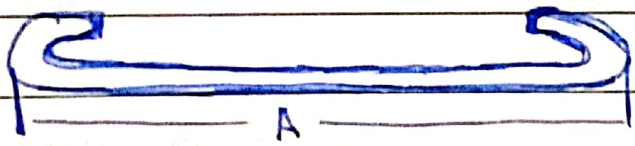
=> Six legged stirrups

=> Circular stirrups

=> Helical Stirrups

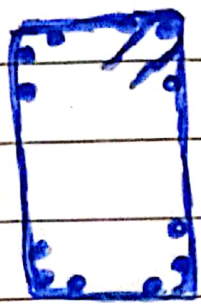
1) ~~Two~~ Single Legged Stirrups:-

Used when bending only two rods



Two Legged Stirrups:-

Mostly used stirrup. Provide in rods having minimum number of "4".



Number

Name **ID 7786**

Section

Circular Stirrups :-

⇒ The circular stirrups is provide when column is in round shape.

Helical Stirrups :-

⇒ Mostly it is used in pile column and also for the pile foundation the stirrup can use either Helical or circular.

⇒ ACI Code for Shear Design:-

⇒ **Critical section is at a distance "d"** from the face of support.

⇒ **Shear strength capacity of concrete :-** $V_c = 2 \times \sqrt{f'_c} \times b_w \times d \times$ V_u = total factored Shear force at section

⇒ **Minimum Web Reinforcement:-**

If $V_u \leq \phi \times V_c$ → Theoretically no web reinforcement is required However ACI code required atleast a minimum area of web reinforcement equal to

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

From this formula we can also find max Spacing.

Name

ID 7786

Section A

* If $V_u < \frac{1}{2} \times \phi \times V_c$ → No web Renforcement is needed.

where S = Longitudnal spacing of web

f_y = Yield Strength of steel

A_v = Total Cross-Section area of web steel

* First Stirrup is provided at distance $S/2$
* Spacing between ~~critical~~ web reinforcement Can be find by formula $S = \phi \times A_v \times f_y \times d / V_u - \phi V_c$
* Preferably $S \nless 4''$

According ACI code:-

If $V_s \leq 4 \times \sqrt{f_c} \times b_w \times d$ then max spacing of stirrup will be smallest of the four condition

i) $24''$ 2) $d/2$ 3) $S_{max} = \dfrac{A_v \times f_y}{0.75 \times \sqrt{f_c} \times b_w}$

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

And if $V_s > 4 \times \sqrt{f_c} \times b_w \times d$ then S_{max} will be half

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ID 7786

Section A

Question No 2

Given Data: = 14"

Effective depth (d) = 22"

Given load = 6.5 k/ft

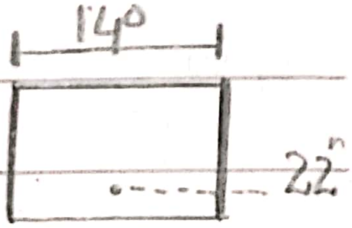
steel area = 7 in^2

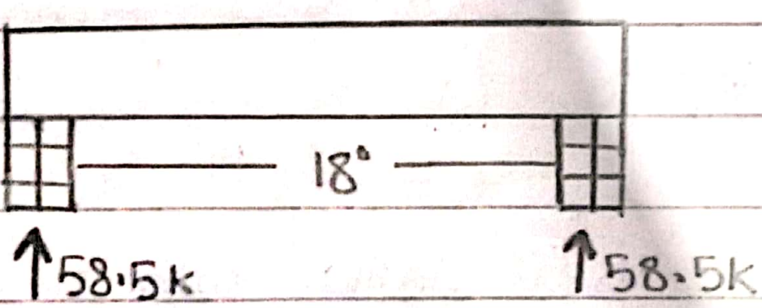
f_c' = 4 ksi

f_y = 60 ksi

Design beam for shear.

Sol





Step 1 (Reactions on supports).

First finding the reactions due to applied load.

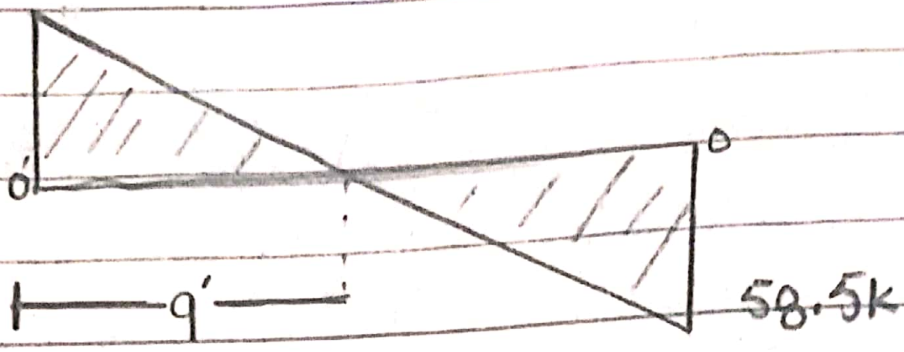
$$\text{Total load} = \frac{6.5 \times 18}{2}$$

$$= 58.5 \text{ kips.}$$

ID 7786

Section A

Step 2 (r shear Force Diagram)

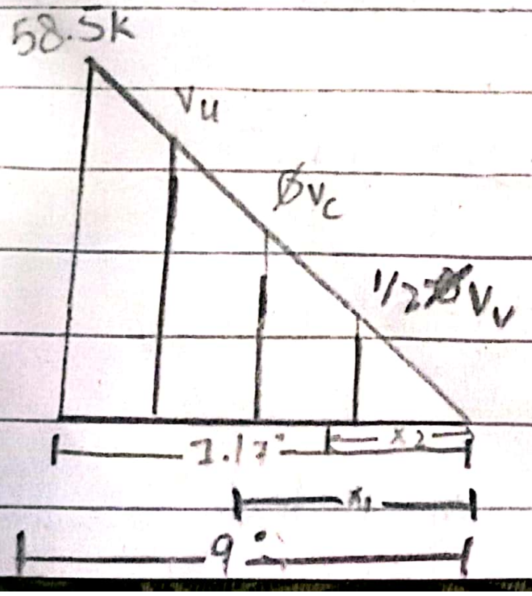


Step 3

Finding value of critical shear "V_v" and its location as.

As we know critical shear is located at distance "d" from force of support $(d) = \frac{22"}{12} = 1.83$

we will use similar triangles to find value of critical shear.



From similar triangles

$$\frac{58.5}{9} = \frac{V_v}{78.17}$$

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

$= 46.61$ kips.

ID 7786

Sec A

Step 4

Finding value of "ϕV_c" and $1/2\ \phi V_c$ and also its distance from zero shears to right side using formula.

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

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

$= 29219.4\ lbs$

$= \frac{29219.4}{1000} = 29.21\ kips$

Finding location of ϕV_c by similar triangles

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

Put value of 'ϕV_c'

$$\frac{58.5}{9} = \frac{29.21}{x_1}$$

$x_1 = 4.49'$

Similarly.

$1/2\ \phi V_c = \phi V_c/2$

$\frac{29.21}{2} = 14.60\ kips$

Now location of $1/2\ \phi V_c$

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

ID 7786

Section A

$x_2 = 2.24'$

Step 5

Finding value of ϕV_c

Using formula

$\phi V_c = V_a - \phi V_c$

$= 46.61 - 29.21$

$= 17.4$ kips.

Step 6:

Check on reaction adequacy By formula.

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

Put values

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

$= 116877$ lbs

$= 116.87$ kips

Now

$\phi \times 8 \times \sqrt{f'_c} \times bw \times d > \phi V_c$

So reaction is adequate.

Step 7:

Check on maximum spacing for stirrups

By formula:-

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ID 7786

Section A

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

put values

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

$= 58.438 \text{ lbs}$

$= 58.43 \text{ kips}$.

Now

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

So maximum spacing for stirrups will be selected from following 4 conditions.

1) $S_{max} = 24"$

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

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

Here we are using #3 stirrup dia $= (3/8)"$ $= 0.375"$

So Area $= \dfrac{\pi}{4}(0.375)^2$

$= 0.11 \text{ in}^2$

Area $\times 2$

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

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

$= 19.87"$

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ID 7786

Section A

4. $S_{max} = \frac{A_v \times f_y}{50 \times b_w} = \frac{0.22 \times 6000}{50 \times 14} = 18.8$

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

Step 8:

Stirrups spacing at critical section will be

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

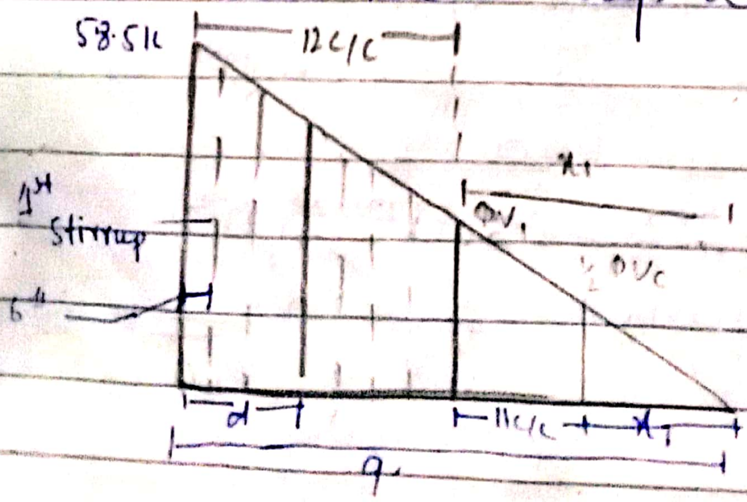
put values

$$= \frac{0.75 \times 0.22 \times 60 \times 22}{46.61 - 29.21}$$

$= 12.5'' \approx 12''$ So $12''$ c/c.

Step 9:

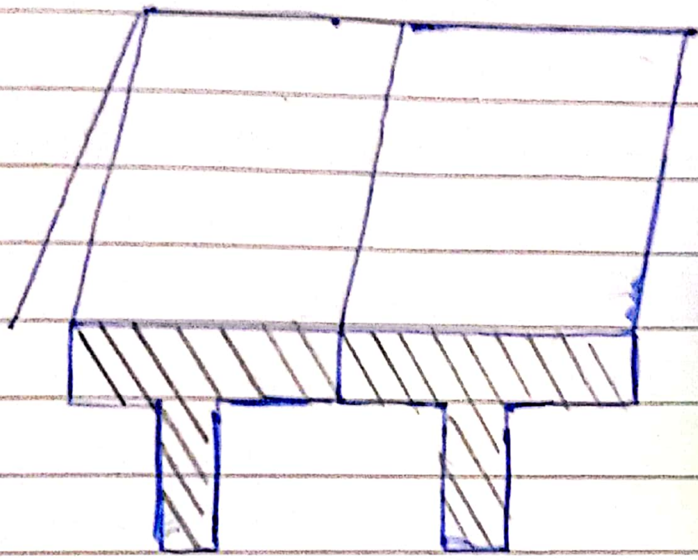
Now final step will be.



Name ID 9986
Section A

T-Beam :-

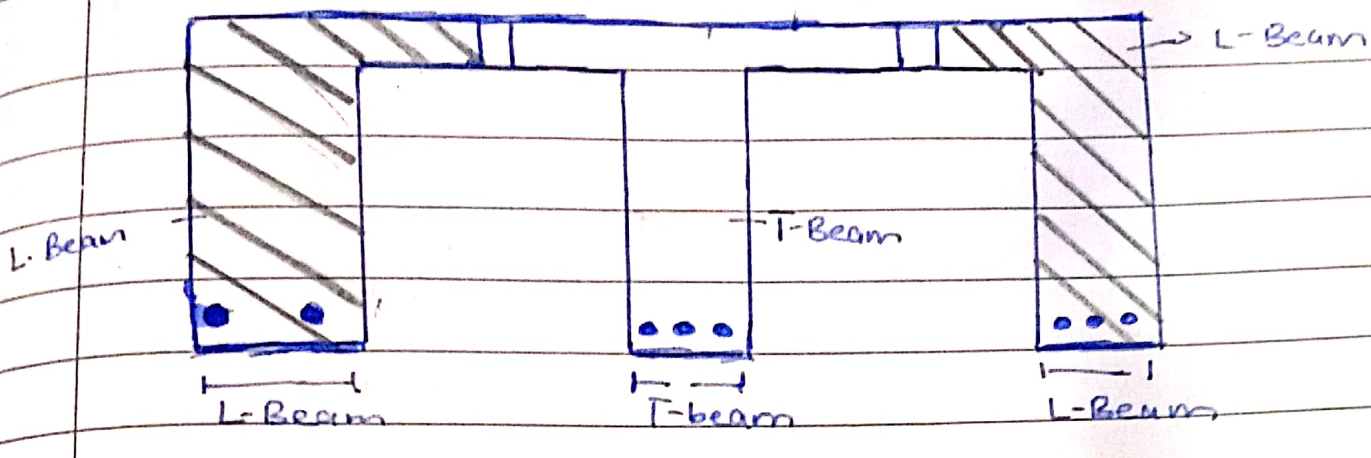
Used in construction, is a load bearing structure of reinforced concrette, wood or metal with a T-shaped cross section. The top of the T-shape cross section serve as a flange



L-Beams :-

The beams which have slabs on one side only, act as L-beams.
In bending the beams take tension forces and slabs take compression forces. Since the L-beam recieve their loads from one side only. So L-beams are subjected to :
i) bending moment
ii) Shear force
iii) torsional moment.

Name
ID 7786
Section A



b) **Flexural Strength analysis of T-Beam:-**

The neutral axis of T beam may be either in the flange or in the web, depend on the cross section, the amount of tensile steel and the strength of the matirial. If the depth to the neutral axis is less or equal to the flange thickness h_f, the beam can be analysed as if it were a rectangular beam of width equal to beam.

* When the neutral axis is in the web, the preceeding argument is no longer valid. In this case method must be developed to account for the actual T-shaped compressive zone.

* In treating T-beam It is convenient to adopt the same equalent stress distribution that is used for beams of rectangular cross section

Name ID 7786
Sec A

* Accordingly a T beam may be treated as a rectangular beam, if the depth of the equalent stress block is less than or equal to the flange thickness. **(Area of Steel)**
* T beam with effective flange width b, web width bw, effective depth to steel centeroid d and flange thickness hf.

$$a = \frac{As\,fy}{0.85 f'c\, b} = \frac{Pfy\,d}{0.85 f'c}$$

$P = As/bd$

If a is ~~greater~~ less or equal to flange thickness hf, the member may be treated as rectangular beam. If a is greater than hf then it will be assumed that the strength of the T beam is controlled by yielding of tensile steel.

$$Asf = \frac{0.85 f'c (b - bw) hf}{fy}$$

where Asf is Steel area. The force Asf fy and opposite force $0.85 f_c (b-bw) h_f$ act with a lever arm $d - h_f/2$ to provide nominal resisting moment.

Refrence:-
(Fluxeral analysis and design of beam)

Book name (Design of concrette structure)

Number of bars:-

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

Design Moment:-

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

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

Name ID 7786
Sec A

Q4 **Difference between Case I and Case II in the design of beam?**

Case I:- T beam may be treated as rectangular beam if the depth of equalent stress block is less than or equal to the flange thickness and is given as

$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{\rho f_y d}{0.85 f'_c}$$

A T-beam with effective flange width b, web width bw, effective depth to the steel centoroid d, and flange thickness hf, if for trial purposes the stress block is assumed to be completly with the flange.

Case II:-

If a is greater than hf, the member may be treated or T beam analysis is required as follows:-

It will be assumed that the strength of the T-beam is controlled by yielding of the tensile steel.

$$A_{sf} = \frac{0.85 f'_c (b - b_w) h_f}{f_y}$$

The force $A_{sf} f_y$ and the equal and opposite force $0.85 f'_c (b - b_w) h_f$ act with lever to provide resisting moment

Page No.

ID 7786

Question No 5

Given data:-

Height of flange :- h_f = 3.5"

c/c distance = 9'

Span of beam = 16'

web width (b_w) = 10"

Effective depth (d) = 18"

Height (h) = 23"

Total factored moment (M_u) = 5800 kip-inch

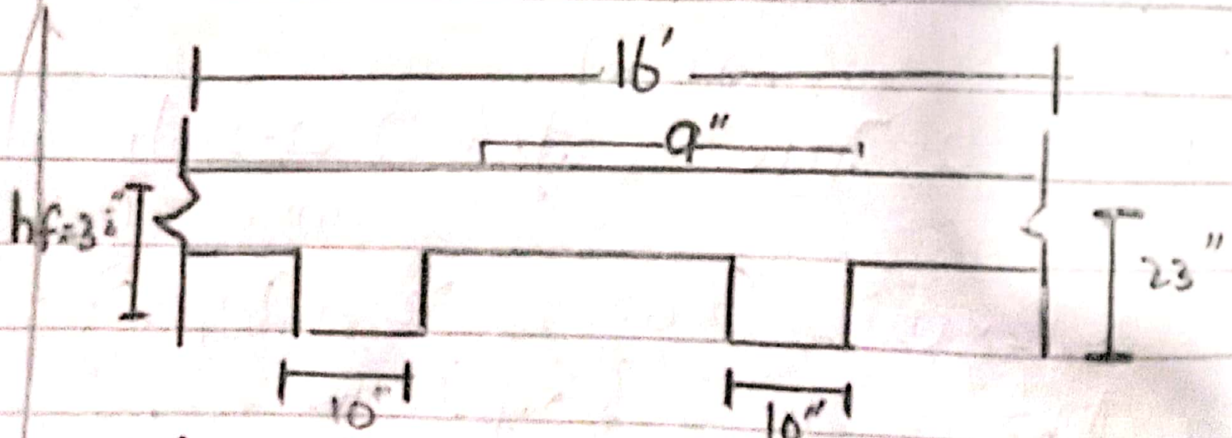
f_c' = 3 ksi

f_y = 60 ksi

Required

Flexural Reinforcement = ?

Sol



Step 1:-

Calculate effective width (b_e) for T beam

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

2: c/c distance = 9 × 12 = 108"

3 span/4 = 16/4 × 12 = 48"

ID 7786

selecting least value of "be" as
be = 48"

Step 2

check wether Rectangular or T beam analysis is required.

Trial # 01

let $a = h_f = 3.5''$

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

$$= 6.61 in^2$$

$$a = \frac{A_{st} \times f_y}{0.85 \times f_c \times b_e}$$

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

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

So Rectangular beam design is Required

Trial # 03

$a = 3.21''$

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

$$= 6.55 in^2$$

Step 3:

Check ρ_{max} and ρ_{min}

107786

Sec A

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

$$0.85 \times 0.85 \times 3/60 \left(\frac{0.003)}{0.03 + 0005}\right)$$

$$= 0.013$$

So we have to design beam in such a way that can resist to more bending moment then applied load.

Step 5:

Difference in moment and Area of a steel.

$$M_u = -M_u - M_{u_2}$$

$$= 5800 - 1986.67$$

$$= 381333 \text{ kips inch.}$$

By formula

$$A_{st} = \frac{M_u}{\phi \times f_y (d - d')}.$$

Put values.

$$= \frac{3813.33}{0.90 \times 60 (18.25)}$$

$$= 4.56 \text{ in}^2$$

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ID 7786

Sec A

Step 6

Finding total steel and Area

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

$= 2.43 + 4.56 = 6.99 in^2$

Step 7:-

selection of bars.

In tension zone

we select # bars

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

By formula

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

$= 6.99/0.785$

$= 8.9 \approx 9$

So 9 # 8 bars

In compression zone

let we use #7 bars

dia $= (7/8)''$, Area $= \frac{\pi}{4}(7/8)^2 = 0.60 in^2$

using formula

No of bars $= \frac{4.56}{0.601} = 7.5 \approx 8$

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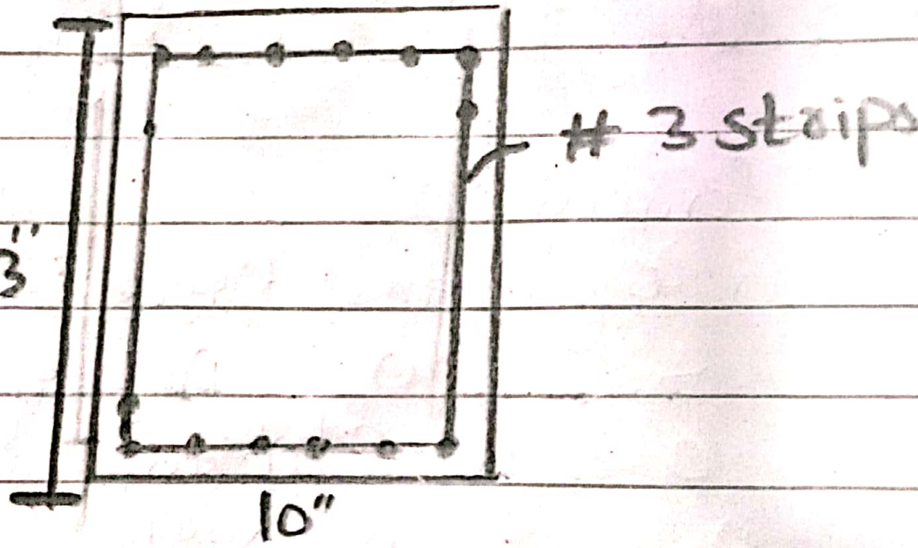
ID 7786
Sec A

Step 8

Minimum width

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

As $20.75 > 10''$
So the bars will be place in multiple layers



Effective depth.
$(d) = 23 - 1.5 + 3/8 + 8/8 + 1/8(8/8)$
$= 19.6''$

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

$= 3.18''$

ID 7786

Section A

Step 9:

Finding design moment

$$Md = \phi\left[A_s \times f_y (d-d') + [A_{st} - A_{s1}) \cdot f_y (d - a/2)\right]$$

$$a = \frac{(A_s - A_{st}) f_y}{0.85 \times f_c \times b}$$

$$\frac{(9 \times 0.785 - 8 \times 0.601) \times 60}{0.85 \times 3 \times 10}$$

$$= 5.31''$$

$$Md = 0.90 \left[(8 \times 0.601) \times 60 (19.6 - 3.16) + 9 \times 0.785 - 8 \times 0.601) \times 60 \times (19.6 - \frac{5.31}{2}) \right\}$$

$$= 6328.38 > 5800$$

So design is OK.

ID 7786
Section A

Question 6

Given data:

Breath = (b) = 14"
Height (h) = 26"
Concrete compression strength = fc' = 4ksi
steel Tensile strength = fy = 60ksi
Effective depth of beam = d = 22"
Ultimate Factored Moment (Mu) = 6000 kip-inch

Assume effective cover (d') = 2.5"

Required:

Flexural reinforcement = ?

Sol

Step 1 (Reinforcement Ratio):-

Using formula.

$$\rho_{max} = 0.85 \times B_1 \times \frac{fc'}{fy} \left(\frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y}\right)$$

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

$$\rho_{max} = 0.0180$$

Step 2 (Area of Steel)

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

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

ID 7786
Section A

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

Step 3 (Design Moment):

Using formula

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

$a = \dfrac{A_{st} \times f_y}{0.85 \times f_c' \times b}$

put values

$= \dfrac{5.54 \times 60}{0.84 \times 4 \times 14} = 6.98''$

So

$M_u = 0.90 \times 5.54 \times 60 \left(22 - \dfrac{6.98}{2}\right)$
$= 5537.4$ kipinch.

As

$5537.4 < 600$

So we have designed section as doubly reinforced.

Step 4 (Difference in Moment)

$M_{u^2} = M_u - M_{u^2}$
$6000 - 5537.4$
$M_{u_1} = 462.6$ kips-inch

Step 5 (Area of Steel)

$M_{u_1} = \phi \times A'_{st} \times f_y \times (d - d')$

ID 9786

Sec A

Area of steel in compression zone will be

$$A'st = \frac{M_{v1}}{\phi \times fy \times (d - d')}$$

Put values

$$= \frac{462.6}{0.90 \times 60 \times (22.2.5)}$$

$A_{si} = 0.44 in^2$

Step 6 (Total steel Area)

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

$= 5.54 \times 0.44 = 5.98 in^2$

Step 7 (selection Ep No of bar used)

1) steel in Tension zone.

we use # 7 bar.

dia $= (7/8)^2 = 0.875$

Area $= \frac{\pi}{4} (0.875)^2 = 0.601 in^2$

Now

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

$= \frac{5.98}{0.60} = 9.9 \approx 10$ bars.

So 10 # bar.

ID 7786

2) Steel in compression zone
we use # 5 bars
$$dia = (5/8)'' = 0.625''$$

$$Area = \frac{\pi}{4} d^2 = \frac{\pi}{4}(0.625)^2 = 0.306 in^2$$

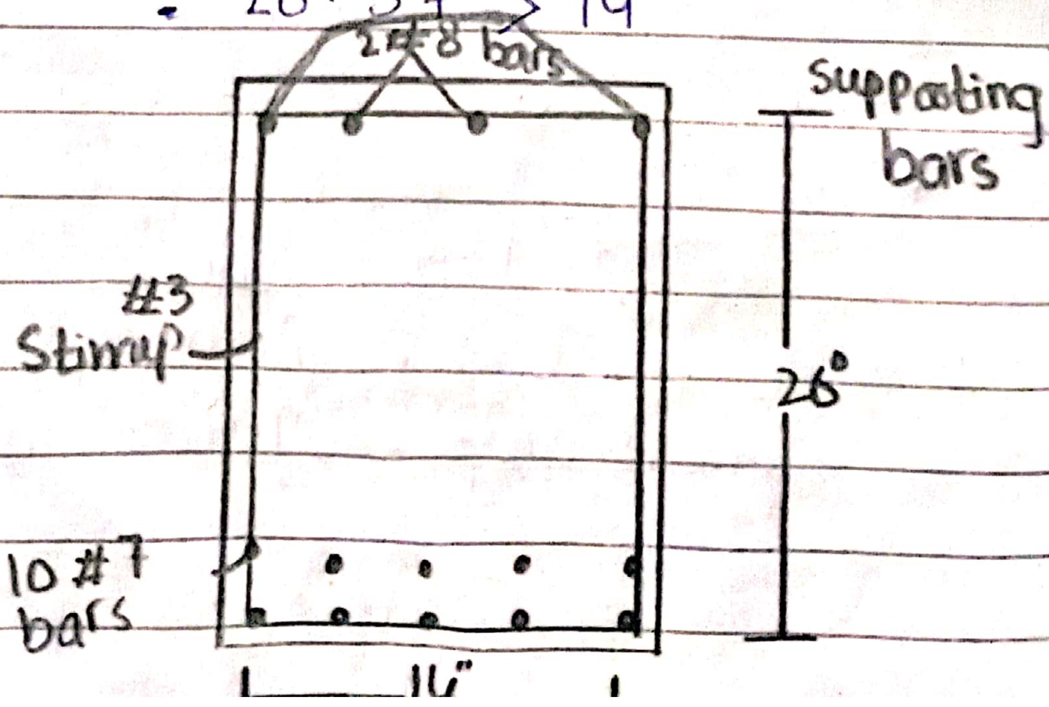
$$\text{So No of bars} = \frac{A_{st}''}{\text{Area of single bar}}$$

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

So 2 # 5 bars.

Step #8 (Minimum width beam)

$$b_{min} = 2(1.5) + 2(3/8) + 10(7/8) + 9(7/8)$$
$$= 20.37 > 14''$$



ID 7786

Now :

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

$= 22.82$

Effective cover $(d') = 1.5 - 3/8 + 1/2 (5/8)$

$= 2.18''$

Step 9 (Design Moment)

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

$a = \dfrac{(Ast - Ast') \times fy}{0.85 \times fc' \times b}$

Put values

$= \dfrac{(10 \times 0.60) - (2 \times 0.306) \times 60}{0.85 \times 4 \times 14}$

$= 6.80''$

$Md = 0.90 [(2 \times 306) \times 60 (22.82 - 2.18) + (10 \times 0.60) - 2 \times 0.306) \times 60 (22.82 - 6.80/2)]$

$Md = 7047.6$ kips - inch

As $7047.6 > 6000$

Design is OK.