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SECTION	"A"
SUBJECT :	PRCD-I
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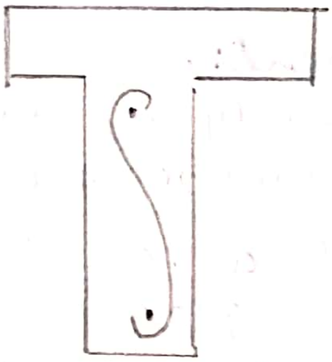
	ASSIGNMENT

QUESTION: 01

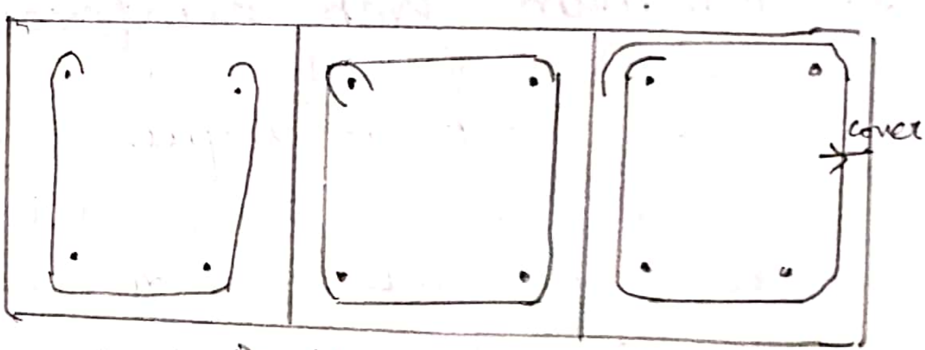
TYPES OF STIRRUPS :

On the basis of nature of construction, they are classified as

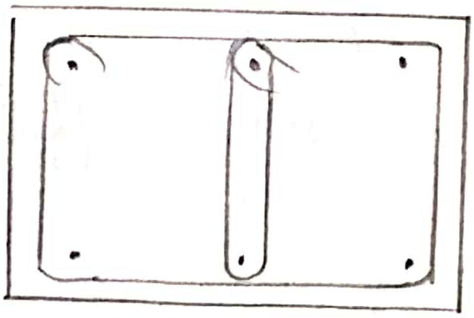
(1) Single legged stirrup (open stirrup)
(2) Two legged stirrup (closed stirrup)
(3) Four legged stirrup (closed stirrup)
(4) six legged stirrup (closed stirrup)



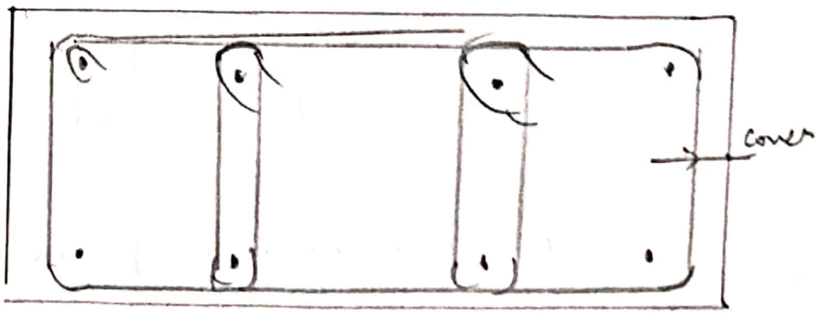
Single-legged stirrup



Double legged stirrup



FOUR Legged stirrup



six legged stirrup.

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ACI CODE FOR SHEAR DESIGN OF BEAM:

According to ACI-318 following formulae are used for shear design of Beam.

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

2. **Sheer strength capacity of concrete:-**

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

3. **Minimum Web Reinforcement:-**

If $V_c \leq \phi V_c$ then theoratically no web reinforcement is required. However ACI code require provision of atleast a minimum area of web reinforcement equal to

$\phi = 0.75 \rightarrow$ for sheer design.

∴ V_u = total factored sheer applied at given section

⇒ For Minimum Reinforcement Area

$$A_{v\,min} = \frac{0.75 \times \sqrt{f_c'} \times b_w \times s}{f_y} \quad \text{or} \quad \frac{50 \times b_w \times s}{f_y} \quad \text{[Higher value selected]}$$

By interchanging above formula we can obtain formula for max spacing

$$S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{f_c'} \times b_w} \quad \text{or} \quad \frac{A_v \times f_y}{50 \times b_w} \quad \text{[lesser value selected]}$$

4. **NO web reinforcement required:** $V_u < \frac{1}{2}\phi V_c$

Between Critical section "V_u" and "ϕV_c" spacing b/w web requirement can be found:

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

QUESTION: 02

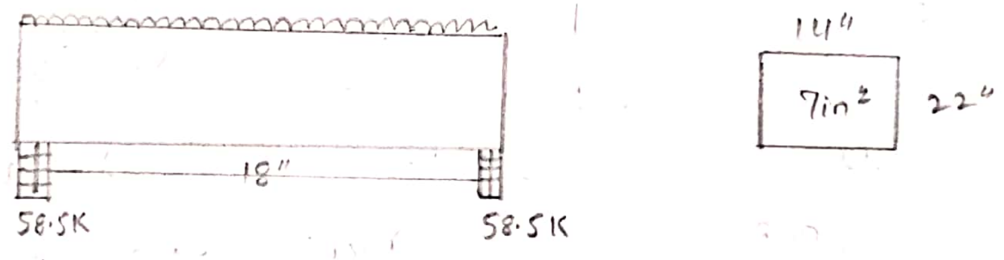
Given Data:

Effective depth (d) = 22"
Given load = 6.5 K/ft
Steel area = 7 in²
$f_c' = 4$ Ksi
$f_y = 6$ Ksi

Required:

Design beam for shear.

Solution:



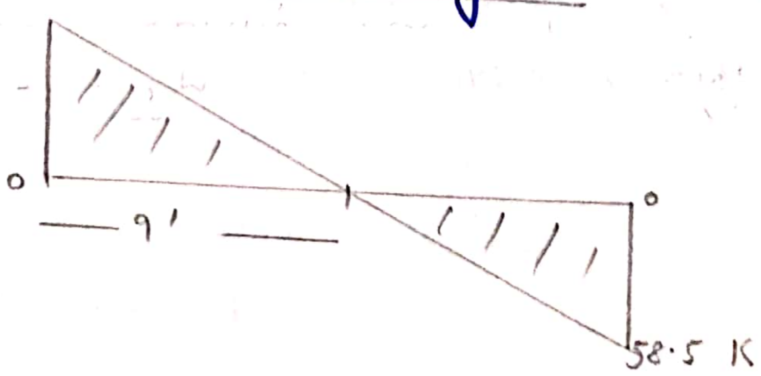
Step: 01 Reaction on Support:

Finding reaction due to applied force

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

= 58.5 Kips

Step: 02 Shear force Diagram



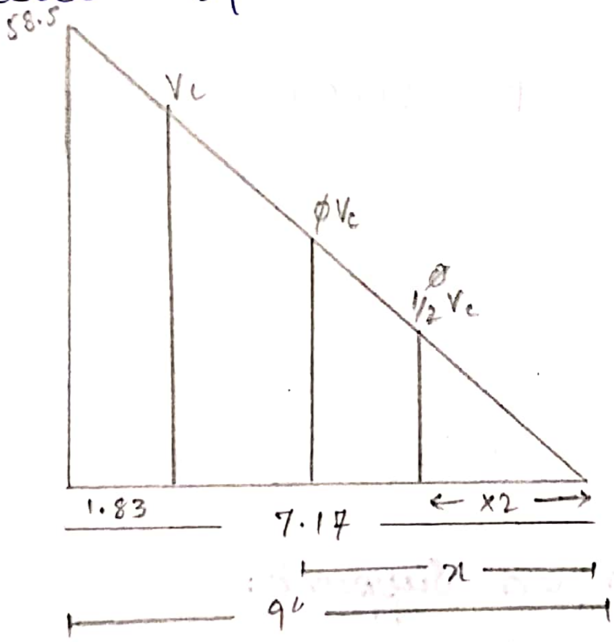
Step # 03

Finding value of critical shear 'V_c' and its location as

As we know critical shear is located at distance "d" from face of support

$$d = \frac{22''}{12} = 1.83$$

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



From similar Δ.

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

$$V_r = \frac{58.5 \times 78.17}{9}$$

$$= 46.61 \text{ Kips.}$$

Step: 04

Finding value of ϕV_c and $1/2 \phi V_c$ and also distance from zero shear to it angle.

using formula:-

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

$$= 0.75 \times 2 \times \sqrt{4000} \times 1.4 \times 22$$

$$= 29219.4 \text{ lbs}$$

$$= \frac{29219.4}{1000} = 29.21 \text{ Kips.}$$

Finding location of ϕV_c by similar Δ

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

$$x_1 = 4.49$$

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

$\frac{29.21}{2} = 14.60$ Kips.

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

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

$x_2 = 2.24'$.

Step: 05

Finding value of ϕV_c
Using formula

$\phi V_c = V_u - \phi V_c$

$= 14.61 - 29.21$

$\phi V_c = 17.4$ Kips

Step # 06

Check on section adequacy
By formula

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

put values

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

$= 116.877$ lbs

$= 116.87$ Kips

Now $\phi \times 8 \times \sqrt{fc'} \times bw \times d > \phi V_c$

So action is adequate

Step # 07

Check on Maximum spacing for stirrups. by using formula

$\phi \times 4 \times \sqrt{fc'} \times bw \times d$.

put values

$0.75 \times 4 \times \sqrt{4000} \times 14 \times 22 = 58.43$ Kips

Now

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

So maximum spacing for stirrups will be selected from following 04 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

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

$$= 0.11 in^2$$

For 2nd leg stirrup

Area $\times 02$

$0.11 \times 2 = 0.22 in^2$

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

$S_{max} = 11''$.

Step: 08

Stirrup spacing at critical section will be

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

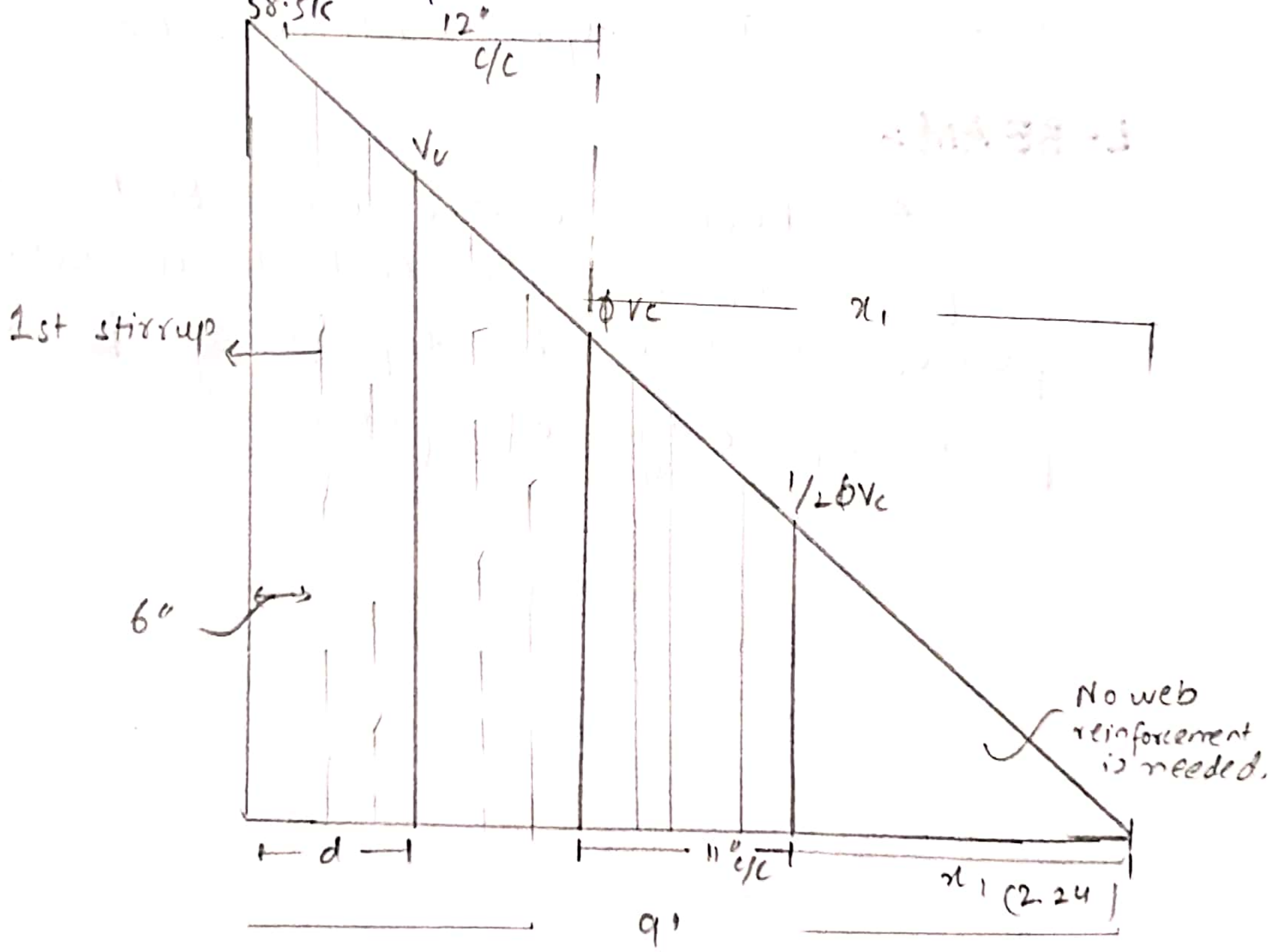
putting values:

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

$= 12.5'' \simeq 12''$ so $12''$ c/c.

Step: 09

Now final step will be



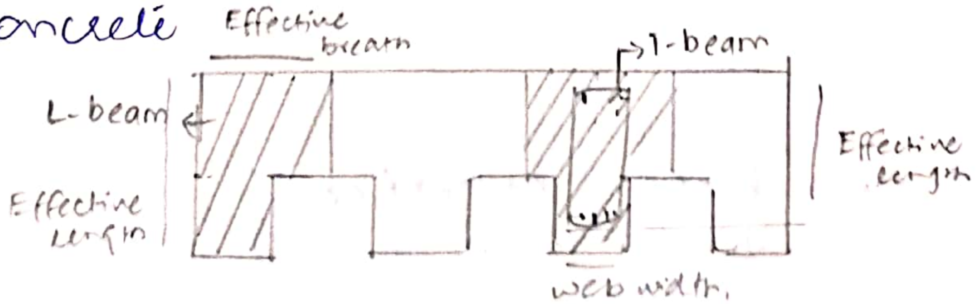
QUESTION:- 03

T-BEAM:- In most of reinforced concrete structures, concrete structures are cast monolithically with slab so, in this case beam acting as intermediate is called T-beam. It's load bearing structure with T-shaped cross-section.

- → It has T-shaped structure.
- → Upper most area is called flange.
- → Bottom rectangular portion is called web of beam.

L-BEAM:- L-shaped structure that is incontact with slab and present at corner of floor is called L-Beam.

- → They are called edge beams.
- → always provided at corner of slab
- → typical floor beams because of their reduced overall structural depth Beams are in prestressed or reinforced concrete



Flexural analysis of T-beam:

It consists of following steps.

1. **Finding ultimate factored moment.**

We use

$$M_u = \frac{w_u \times l^2}{8}$$

(w_u = total forced load
L = Total span of beam)

2. Effective Width for T-beam:-

1. $16(h_f) + b_w$ (h_f = height of flange)
2. c/c distance (CTS = clear Transverse span)
3. span/4
4. $CTS/2 + b_w$

- have to select least value
- if c/c distance is given, no need of $\frac{CTS}{2} + b_w$

3. checking whether rectangular or T-beam analysis is required.

(1) if $a > h_f$ → special analysis required
(2) if $a < h_f$ → Rectangular beam analysis ".

where a = depth of compression block
h_f = height of flange

4. Finding area of steel:

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

where $a = \frac{A_{st} \times f_y}{0.85 \times f_c' \times b_w}$

∴ ϕ = strength reduction factor
d = effective depth
a = compression block depth
b_w = web width of beam

5. 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. No. of bars required:

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

7. Minimum Width for Bar accomodation:

b_{min} = 2(Clear cover) + 2(dia of stirrup) + No. of bars (dia of bar) + spacing b/w bar (dia of bar)

8. Design Moment Given by:

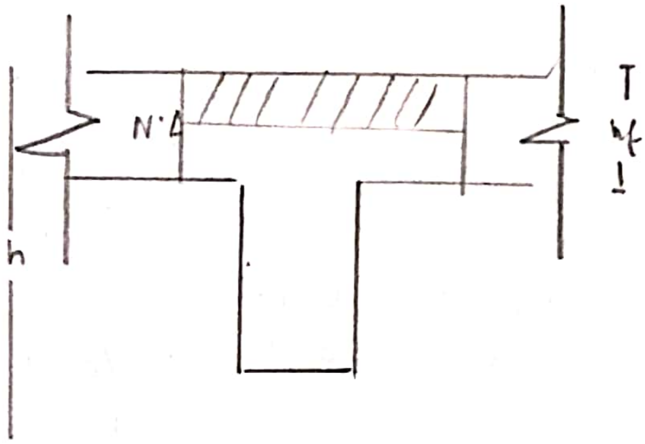
$M_d = \phi \times f_y \times A_{st} \times (d - a/2)$ → if $a < h_f$

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

QUESTION: 04

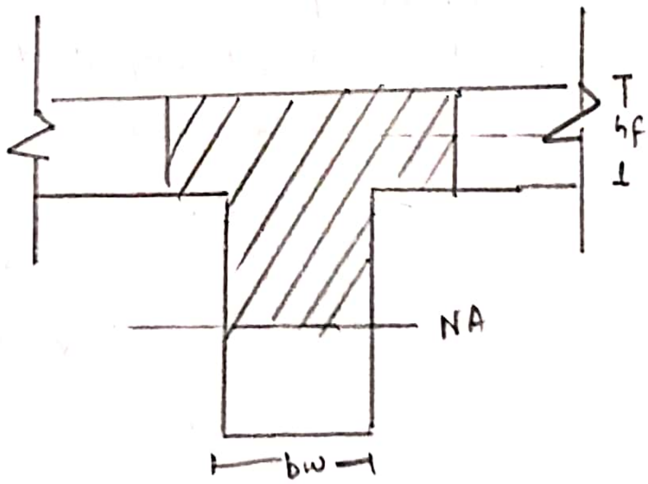
CASE- I

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 formula
required for Design
Moment will be



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

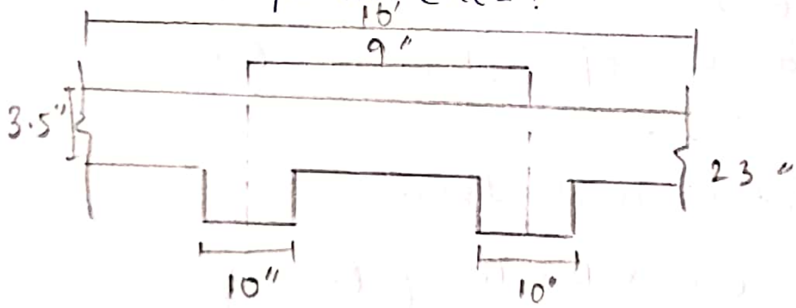
QUESTION: 05

Given Data:-

Height of flang = $h_f = 3.5''$
c/c distance = 9'
Span of beam = 16'
Web width = 10"
effective Depth = 18"
Height (h) = 23"
Total factored moment = (M_u) = 5800 kip-inch
$f_c' = 3$ ksi
$f_y = 60$ ksi

Required:

Flexural Reinforcement = ?



Step: 01

Calculate 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 least value of be as
$b_e = 48''$

Step # 02

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

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

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

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

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: 03

check ρ_{max} and ρ_{min}

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

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

$$= 0.013.$$

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

$$\rho = \frac{A_{st}}{bd} = \frac{6.56}{10 \times 18} = 0.036$$

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

$0.003 < 0.036 < 0.013$

So value of ρ_{max} is less than ρ so we have to design it as •Doubly reinforced beam.

Finding area of steel against ρ_{max}

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

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

$$= 0.013(10 \times 18)$$

$$= 2.34\ in^2$$

Step: 04

Finding value of M_{U2}

Using formula

$$M_{U2} = \phi \times A_{st} \times f_y \times (d - a/2)$$

Finding value of a

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

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

$$a = 5.72''$$

$$M_{U2} = 0.90 \times 2.43 \times 60 \times (18 - 5.72/2)$$

$M_{U2} = 1986.67$ Kip. inch

As $M_{U2} < M_U$

$1986.67 < 5800$

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

Step: 05

Difference in Movement and area of steel

$$M_{U1} = M_U - M_{U2}$$

$$= 5800 - 1986.67$$

3813.33 Kips. inch

By formula

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

put values: $\dfrac{3813.33}{0.90 \times 60 (18.25)} = 4.56\ in^2$

Step: 06

Finding total steel area

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

$= 2.43 + 4.56$

$A_s = 6.99 \, in^2$

Step: 07

Selection of bars.

→ In tension zone

We select #8 bars

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

By formula

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

$= 6.99 / 0.758$

$= 8.9 \simeq 9$

So 9 #8 bars used

In compression zone

Suppose we use #7 bars

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

Using formula =

$\text{No. of bars} = \frac{4.56}{0.601} = 7.5 \simeq 8$

So 8 #7 bars.

Step: 08

Minimum Width

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

$= 20.75"$

As $20.75 \times 10"$

So bars will be placed in multiple layers.

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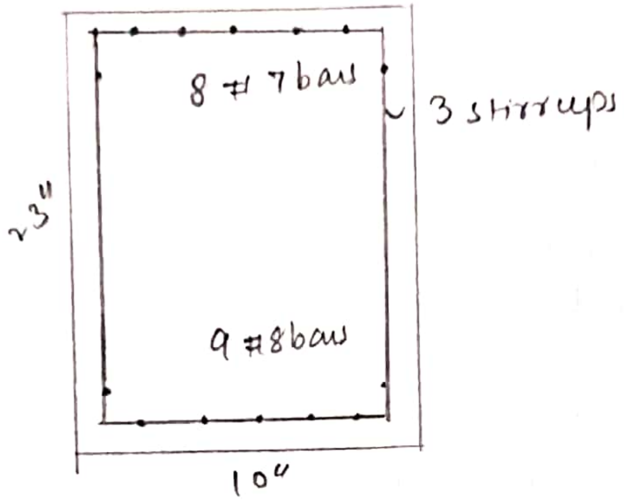

Effective Depth

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

$= 19.6'$

Effective cover (d')

$1.5 + 3/8 + 7/8 + 1/2(7/8)$

$= 3.18''$

Step: 09

Finding design moment

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

$a = \left(\dfrac{A_s - A_{st}'}{0.85 \times f_c \times b}\right) F_y$

$= \dfrac{9 \times 0.785 - 8 \times 0.601) \times 60}{0.85 \times 3 \times 10}$

$= 5.31''$

$M_d = 0.90\,[(8 \times 0.601) \times 60 \times (19.6 - 3.18) + (9 \times 0.785 - 8 \times 0.601) \times 60 \times (19.6 - \frac{5.31}{2})$

$= 6{,}328.38 > 5800$

So design is OK.

QUESTION: 06

Given Data:

Breadth = b = 14"
Height = h = 26"
Concrete compression strength = $f_c' = 4$ ksi
Steel tensile strength = f_y = 60 ksi
Effective Depth of beam = d = 22"
Ultimate factored moment = M_u = 6000 kip - inch
Assume effective cover = (d') = 2.5"

Required:

Flexural Reinforcement = ?

Solution:

Step: 01 (Reinforcement Ratio).

Using formula

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

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

$$\rho_{max} = 0.0180$$

Step: 02 Area of Steel:

$$\rho_{max} = \frac{A_{st}}{B \times d}$$

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

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

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

Step: 03 Design Moment:

using formula

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

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

putting values

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

So

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

$$= 5537.4 \text{ Kip.inch}$$

As

$$5537.4 < 600$$

So we have to design section as doubly reinforced

Step: 04 Difference in Moment:

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

$$= 6000 - 5537.4$$

$$M_{u1} = 462.6 \text{ Kips.inch}$$

Step: 05 Area of steel

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

in compression zone

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

put values

$$= \frac{462.6}{0.90 \times 60 (22 - 2.5)}$$

$$A_{st}' = 0.44 \text{ in}^2$$

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Step:06

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

$= 5.54 + 0.44 = 5.98 \, m^2$

Step: 07 selection and No. of Bars.

Steel in tension zone

We use # 7 bars

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

Now

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

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

So 10 # 7 bars

2. Steel in compression zone

We use # 5 bar

dia $= (\frac{5}{8})'' = 0.625$

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

So

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

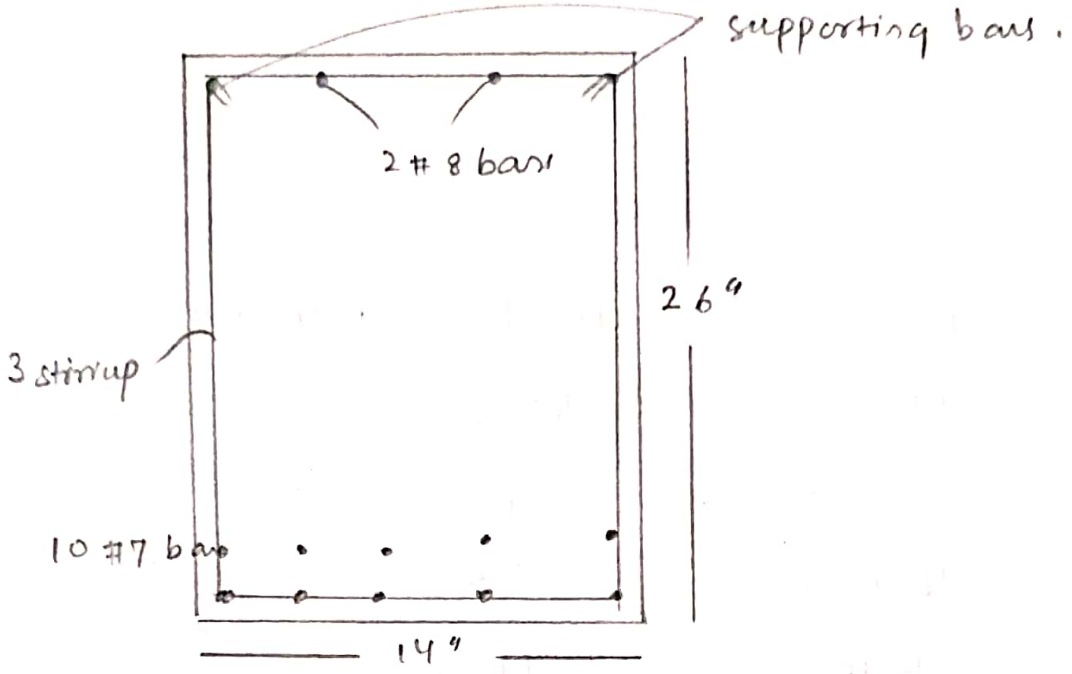
$= \frac{0.44}{0.306} = 1.43 \approx 2$ bars

So 2 #5 bars will be used.

Step: 08 :.

$b_{min} = 2(1.5) + 2(31.8) + 10(7/8) + 9(7/8)$

$= 20.37 > 14''$



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: 09 Design Moment:

$$Md = \phi \times [Ast' \times fy \times (d - d') + (Ast - Ast') \times (d - a/2)$$

$$= \frac{Ast - Ast'}{0.85 \times fc' \times b} \times fy$$

putting values

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

$$Md = 6.80"$$

$$Md = 0.90(12 \times 3.06) \times 60 \ (22.82 - 2.18) + (10 \times 0.60) - (2 \times 0.306) + 60(22.82 - 6.80/2)$$

$Md = 7047.6$ Kips inch

As $7047.6 > 6000$

Design is OK.