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Section : A

Assignment :

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QNo1 ⇒ Explain in detail types of Stirrup with figures and Also explain ACI for Shear design.

Ans

STirrup

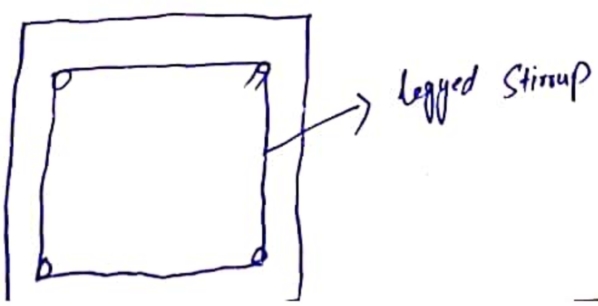
Stirrups are closed-loops bars tied at regular intervals in beam reinforcement to hold the bars in position.

Types of Stirrups:-

1→ Single legged Stirrup ⇒ The Single-leg stirrup have rarely been used because they are mostly used when bending only two rods.

2) Two legged Stirrup

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



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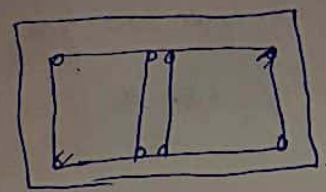
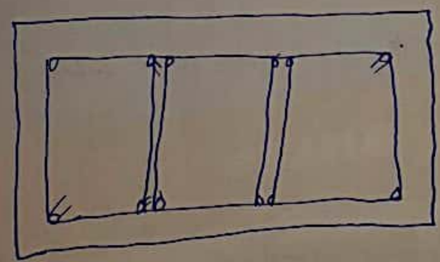
3) Four legged Stirrup:

These stirrups are used in case of web reinforcement.



4) Six legged Stirrups:



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 force of Support which is equal to effective depth.

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2) => <u>Shear Strength capacity of Concrete</u>

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

3) <u>Minimum web Reinforcement</u>

If $V_u \leq \phi V_c$ then

theoritically 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 Shear deign

(∴ V_u = Total factors Shear applied at again Section)

⇒ <u>For Minimum Reinforement Area:</u>

$$A_{v\,min} = \frac{0.75 \times \sqrt{f'_c} \times b_w \times s}{f_y} \text{ or } \frac{50 \times b_w \times s}{f_y} \rightarrow \text{Higher value is Selected.}$$

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

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$S_{max} = \dfrac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$ or $\dfrac{A_v \times f_y}{50 \times b_w}$ $\longrightarrow$ lesser value selected

4) No web - reinforcement is required if

$$V_u < \tfrac{1}{2}\, \phi V_c$$

$\Rightarrow$ 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 $V_s \le 4 \times \sqrt{f'_c} \times b_w \times d$. Then max spacing for stirrups will be the smallest of the following

1) $\Rightarrow$ 24",

2) $\Rightarrow$ $d/2$

3) $\Rightarrow$ $S_{max} = \dfrac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$ (V_s = Shear force carried by web reinforcement)

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

$\Rightarrow$ If $V_s > 4 \times \sqrt{f'_c} \times b_w \times d$

$\downarrow$

Max Spacing will be halved

$\Rightarrow$ If $V_s > 8 \times \sqrt{f'_c} \times b_w \times d$

$\downarrow$

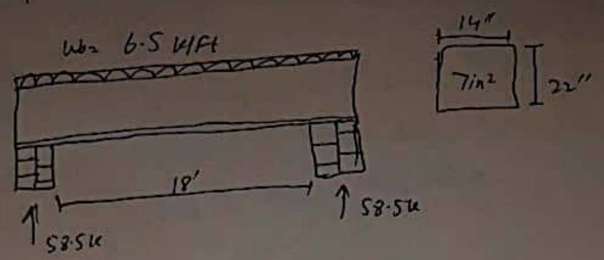
Then either increase cross-sectional dimension or increase f'_c

QNo2 $\Rightarrow$ Simply Supported rectangular beam 14" wide having an effective depth of 22" to carry a lateral load of 6.5 k/ft or a 18' simple span. It is reinforcement with $7 in^2$ of tensile Steel area, If $f'_c = 4$ ksi $f_y = 60$ ksi, then design the beam for Shear.

Given data

* Breath of web of beam $(b_w) = 14"$
* Effective depth $(d) = 22"$
* Given load = 6.5 k/ft
* f'_c = 4 ksi
* Steel area = $7 in^2$
* f_y = 60 ksi

Solution



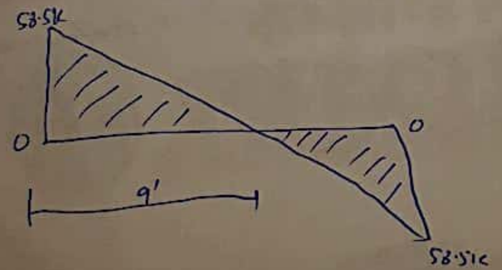
Step # 1 (Reactions on Supports)

Finding the reaction due to applied load

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

Step # 02 (Shear Force Diagram)

The required Shear diagram will be



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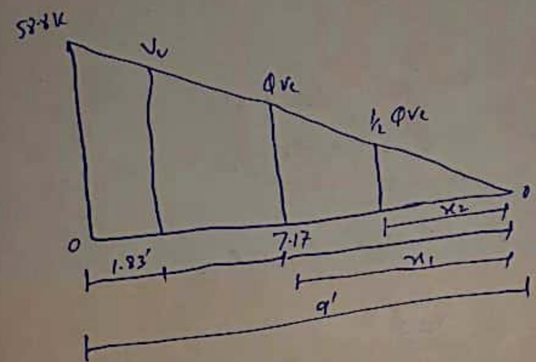
Step # 3

Find the value of critical Shear "V_u" and it's location

As,

we know that critical Shear is located at distance "d" by use of Similar triangles.



For Similar Triangles

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

$$V_u = \frac{585 \times 7.17}{9}$$

$$\boxed{V_u = 46.61\text{kips}}$$

Step # 4

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

By Formula

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

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

$= 29.21 \text{ kips}$

$\Rightarrow$ Location of ϕV_c by similar triangles,

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

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

$\Rightarrow$ Similarly

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

$\Rightarrow$ Location of $\frac{1}{2}\phi V_c$ will be,

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

Step # 5 Finding value of ϕV_c

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

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

$\boxed{\phi V_c = 17.4 \text{ kips}}$

Step # 06 ⇒ Check the maximum Spacing for Stirrups.

By Formula

$= \phi \times 4 \times \sqrt{f'_c} \times b_w \times d$

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

58.43 kips

As $\phi \times 4 \times \sqrt{f'_c} \times b_w \times d > \phi V_c$

So Maximum will be selected from the following 4 condition

1) $S_{max} = 24''$
2) $d/2 = 22/2 = 11''$
3) $S_{max} = \dfrac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$

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

4) $S_{max} = \dfrac{A_v \times f_y}{50 \times b_w} = \dfrac{0.22 \times 60000}{50 \times 14} = 18.85''$

From above 4 condition, least value of Spacing for #3

$S_{max} = 11''$

Step#8

Stirrups Spacing from/at Critical Section will be,

By formula.

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

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

So $12''$ c/c

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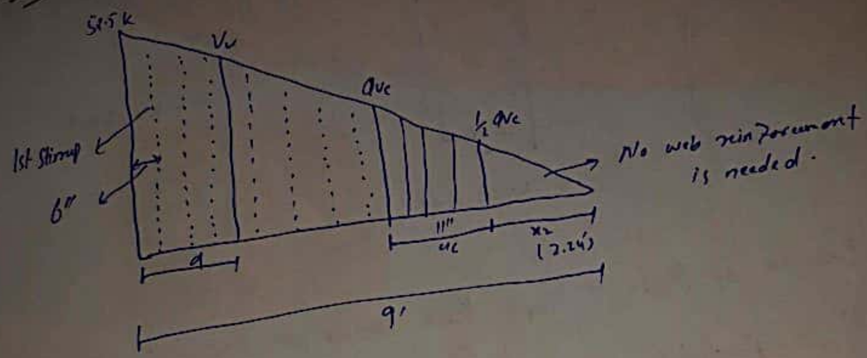
Step#9 ⇒ Final Sketch will be



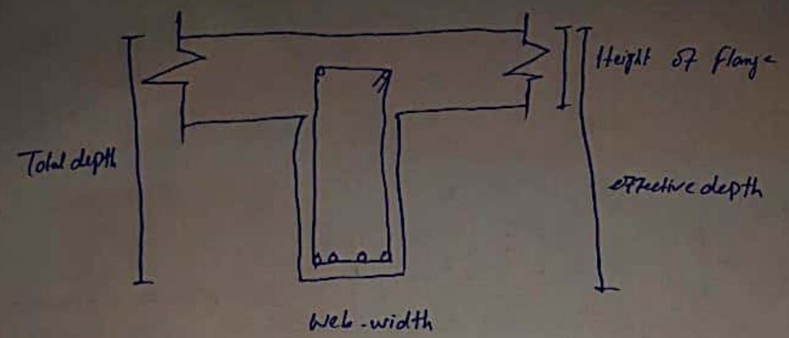
As First Stirrup from face of Support

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

QNo3 ⇒ Define both the T-Beam and L-Beam with the help of diagram. Also explain flexural analysis of T-beam.

T-Beam

In most of the reinforced 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.



⇒ Because of their T-Shape, these beams are Called T-beams.

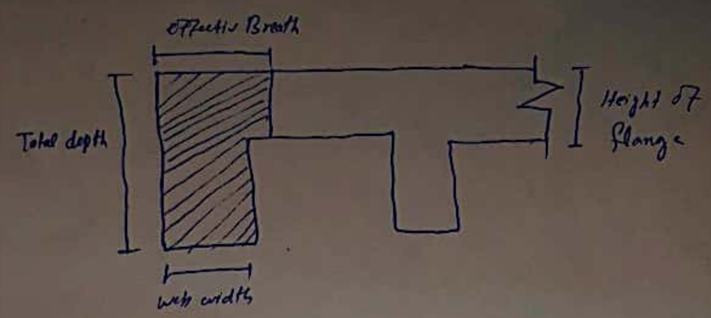
⇒ It is provided at the center of the Slab to resists the loads.

⇒ 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- beam 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 is always provided at the corners of the slab.

⇒ L- beams are typical floor beams because of their prestressed or reinforced concrete.

Flexural Analysis of T- beams

Flexural analysis of T-beams consists of the following steps

1) For finding the ultimate factored moment, we use the following formula

$$Mu = \frac{wu \times L^2}{8}$$ (wu = Total factored load
L = Total span of the beam)

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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 - $\frac{CTS}{2} \times b_w$

(h_f = height of flange

CTS = Clear transevers span)

We have Select the least value From above Formulla

If c/c distance is given then there is no need of $\frac{CTS}{2} + b_w$.

3) => Checking Whether Rectangular or T-beam Analysis is required

i) - If $a > h_f \longrightarrow$ Special Analysis is required

ii) - If $a < h_f \longrightarrow$ Rectangular beam Analysis is required

Where

(a = Depth of Compression black)

(h_f = Height of Flange).

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4) For Finding Area of Steel, we have to use

$$Ast = \frac{Mu}{\phi \times fy \times (d - a/2)}$$

ϕ = Strength de Reduction factor

d = Effective depth.

where

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

a = Compression block depth

bw = Web width of beam

5) For Checking the range of Reinforcement Ratio,

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

$$\rho_{min} = \frac{200}{fy}$$

$$\rho = \frac{Ast}{b \times d}$$

6) ⇒ Formula For Finding No of bars required is,

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

7) ⇒ For Checking Minimum width For bars accomodation,

b_{min} = 2(clear cover) + 2(dia of stirrup) + No of bars (dia of bars) + Spacing b/w bars (dia of bar)

8) ⇒ Design Moment is given by

$$Md = \phi \times fy \times Ast \times (d - a/2) \rightarrow \text{If } a < hf$$

$$Md = \phi \times As \times fy \times (d - hf/2) + (As - Ast) + fy \times (d - a/2)] \rightarrow \text{If } a > hf$$

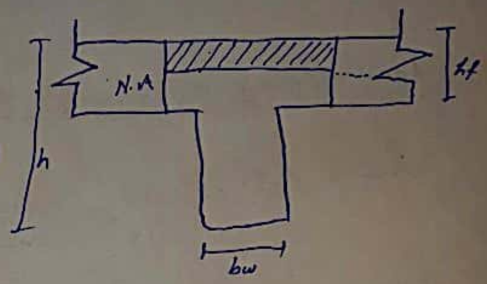
QNo4 ⇒ What is the difference b/w Case-1 and Case-2 in the design of T-beam?

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

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

Q.No5 ⇒ A Floor System consists of 3.5" concrete Slab Supported by 16' Simple Span Spaced at 9' c/c than beam having a web width of 10" necessary flexural reinforcement in the factored applied moment is 5800 kip-inch. Use $f_c' = 3$ ksi and $f_y = 60$ ksi

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"

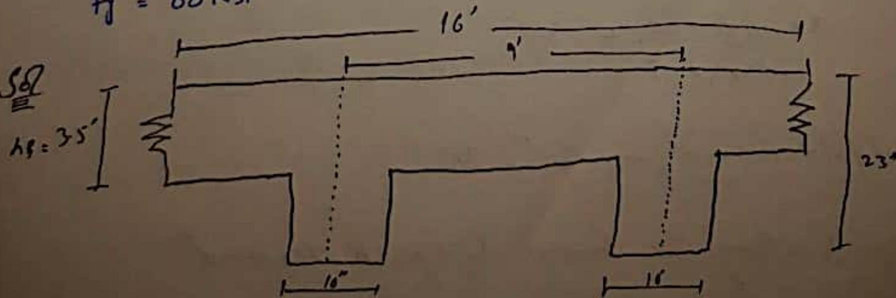
Height (h) = 23"

Total factored moment (M_u) = 5800 kip-inch

$f_c' = 3$ ksi

$f_y = 60$ ksi

Sol



Step#1 Calculate the effective width (be) for T-beam

1). $16(h_f) + b_w = 16(3.5)+10 = 66''$

2). c/c distance $9\times2 = 108''$

3) span/4 $= \frac{16}{4}\times12 = 48''$

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 $a = h_f = 3.5''$

$$A_{st} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{5800}{0.90\times60\times(18-\frac{3.5}{2})} = 6.61\ in^2$$

Trial#2

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

$$a = \frac{6.61\times60}{0.85\times3\times48} = 3.2''$$

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

So Rectangular beam Design is required

Trial # 3

Check ρ_{max} and ρ_{min}

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

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

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

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

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

$0.003 < \underline{0.036 < 0.013}$

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

$\Rightarrow$ First we have to find the area of steel against ρ_{max}

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

$A_{st} = 0.013 \times (10 \times 18)$

$\boxed{A_{st} = 2.34 \text{ in}^2}$

Step # 4 $\Rightarrow$ Finding the value of M_{u_2}:

By formula,

$M_{u_2} = \phi \times A_{st} \times f_y \times (d - a/2)$

First finding the value of "a"

$\Rightarrow a = \frac{A_{st} \times f_y}{0.85 \times f'_c \times b} = \frac{2.43 \times 60}{0.85 \times 3 \times 10} \quad a = 5.72$

$\Rightarrow M_{u_2} = 0.90 \times 2.43 \times 60 \times (18 - 5.72/2)$

$$\boxed{M_{u_2} = 1986.67 \text{ kip-inch}}$$

As

$M_{u_2} < M_u$

$1986.67 < 5800$

So we have to design the beam in such away that it can resist more bending moment than the applied external moment.

Step #6

<u>Selection of bar</u>

<u>In Tension zone</u>

let we use # 8 bar

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

By Formula

No of bar $= \dfrac{\text{Area of Steel}}{\text{Area of Single bar}} = \dfrac{6.99}{0.785} = 8.9 \approx 9$

So 9 # 8 bars

<u>In compression zone</u>

let we use # 7 bar

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

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By Formula

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

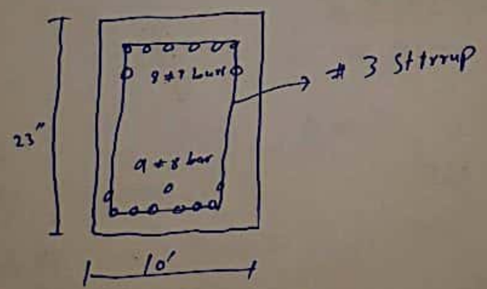
Minimum width for Accomodation of bars.

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

$= 20.75''$

As $20.75'' > 10''$

So the bars will be placed in multiple layers.



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

Effective Cover (d') $1.5 + \frac{3}{8} + \frac{7}{8} + \frac{1}{2}(\frac{7}{8}) = 3.18''$

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Step#9 Finding the design moment

$$Md = \phi\left[A_s' \times f_y \times (d-d') + (Ast-Ast') + f_y \times d - a/2)\right]$$

First $a = \frac{As - Ast'}{0.85 \times f_c' \times b} = \frac{9 \times 0.785 - 8 \times 0.60) \times 60}{0.85 \times 7 \times 10} = 5.31''$

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

$$\boxed{Md = 6328.33}$$

As $6328.33 > 5800 \rightarrow$ So design is ok

QNo 6

Given data

Bredth (b) = 14"

height (h) = 26"

Concrete compresion Strength (f_c') = 4 ksi

Steel tensile Strength (f_y) = 60 ksi

Ultimate Factored moment (Mu) = 6000 kip-inches

Effective depth of beam (d) = 22"

Assume Effective cover (d') = 2.5"

Step# 1 (Rectangular Ratio)

By Formula

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

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

$$\boxed{\rho_{max} = 0.0180}$$

Step#02 (Area of Steel)

As we know that,

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

$$\Rightarrow A_{st} = 0.0180 \times (14 \times 22) = \boxed{5.54\ in^2}$$

Step#03 (Design Moment)

By Using Formula

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

$$\Rightarrow a = \frac{A_{st} \times f_y}{0.85 \times f'_c \times b} = \frac{5.54 \times 60}{0.85 \times 4 \times 14} = \boxed{6.98''}$$

So,

$$M_{u2} = 0.90 \times 5.54 \times 60 \times \left(22 - \frac{6.92}{2}\right)$$

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

As

$$5537.4 < 6000$$

So we have to deign a section as dubbly reinforced

Step#4 (Difference In Moments)

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

$$= 6000 - 5537.4$$

$$\boxed{M_{u1} = 462.6 \text{ kip-inch}}$$

Step#05 (Area of Steel)

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

So Area of Steel in Compressions Zone will be

$$\Rightarrow A'_{st} = \frac{M_{u1}}{\phi \times f_y \times (d-d')} = \frac{462.6}{0.90 \times 60 \times (22-2.5)}$$

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

Step#6 (Total Steel Area)

$$A_t = A_{st} + A'_{st}$$

$$= 5.54 + 0.44 = 5.98 \text{ in}^2$$

Step # 07 (Selection and No of bars used)

1) Steel in tension zone:-

We use # 7 bar

dia $= (7/8)'' = 0.875$, Area $= \frac{\pi}{4}(0.875)^2$

$= 0.601\ in^2$

So,

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

$= \frac{5.98}{0.601} = 9.9 \cong 10$ bars.

So 10 # 7 bars

2) Steel in Compression zone

We use # 5 bar

dia $= (5/8)'' = 0.625''$, Area $\frac{\pi}{4}(0.625)^2 = 0.306\ in^2$

So

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

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

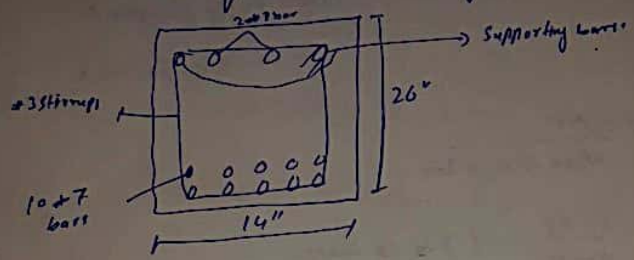
So 2 # 5 bars

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 is one layer



Now

⇒ Effective depth (d) = $26.15 - 3/8 - 7/8 - \frac{1}{2}(7/8) = 22.82"$

⇒ Effective cover (d') $1.5 + \frac{3}{8} + \frac{1}{2}(5/8) = 2.18"$

Step #9 (Design Moment)

$Md = \phi \times [A'st \times fy \times (d - d') \times (Ast - A'st) \times fy \times (d - \frac{a}{2})]$

$a = \frac{Ast - A'st) \times fy}{0.85 \times f'c \times b} = \frac{(10 \times 0.601 - 2 \times 0.306) \times 60}{0.85 \times 4 \times 14} = 6.80"$

$Md = 0.90[(2 \times 0.306) \times 60 \times (22.82 - 2.18) + (10 \times 0.601 - 2 \times 0.308)$
$\times 60 \times (22.82 - 6.80/2)]$

Md = 7047.6 kip-inches

As $7047.6 > 6000$

Design is ok!