ID # 7836

SUBMITTED TO ENGR. FAWAD KHAN

SUBJECT PRCD - I

SECTION B

ASSIGNMENT # 02

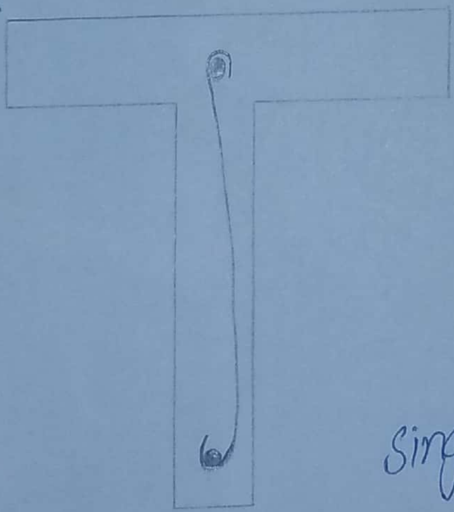
Q1 Explain in detail types of stirrups with figures and also explain ACI codes for shear design?

Ans: Following are the types of stirrups:

- Single legged stirrups.
- Two legged or Double legged stirrups.
- Four legged stirrup.
- Six legged stirrup.

1- SINGLE LEGGED STIRRUPS:

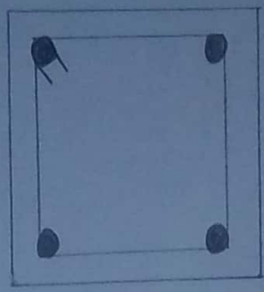
These type of stirrups are used to hold the longitudinal bars in position and prevent buckling.



Single-legged stirrup

2- DOUBLE LEGGED STIRRUP:

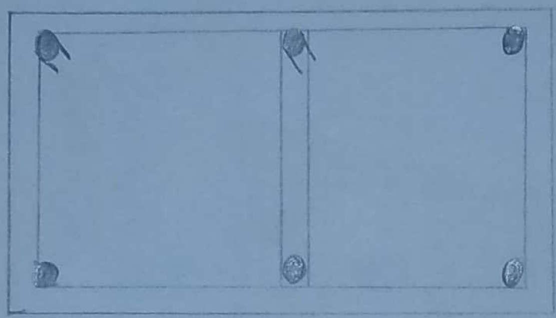
We use a single stirrup to tide a beam or a column at a time, we say it is two legged stirrup. Double legged stirrups are adequate for typical beams with relatively short widths.



Two- legged stirrup

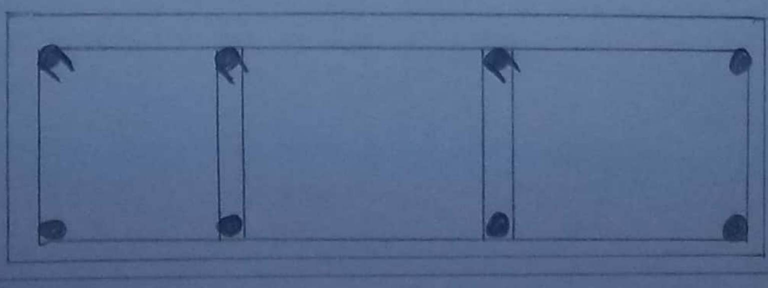
3- FOUR LEGGED STIRRUP:

We use double stirrup to tie a beam or column at a time, we say it is four legged stirrup. For beam having longer widths multiple legged or four legged stirrups are required.



4- SIX LEGGED STIRRUP:

These six legged stirrups are generally used for a continuous beam structure, It consists of regular upholding of structure at each junction while joints at the joining of beam and column.



ACI CODES FOR SHEAR DESIGN:

1- Compute the design shear force, V_u, at appropriate location

2- Compute shear strength capacity of concrete, $V_c = 2\sqrt{f'_c} \times b_w \times d$

3- Compute Minimum web reinforcement:

If $V_u < \phi \times V_c$ so no web reinforcement needed

If it is not applicable then min area of web reinforcement equal to:

i) $A_{v_{min}} = 0.75 \times \sqrt{f'_c} \times \dfrac{b_w \times S}{f_y}$ OR $A_{v_{min}} = \dfrac{50 \times b_w \times S}{f_y}$

→ Max spacings can be found by these formula's:

$S_{max} = \dfrac{A_v \times f_y}{0.75 \times \sqrt{f_c} \times b_w}$ or $S_{max} = \dfrac{A_v \times f_y}{50 \times b_w}$

4- If $V_u < \dfrac{\phi V_c}{2}$; if it's true no stirrups are required.

5- First stirrup is provided at a distance $S/2$

6- Between "V_u" and "ϕV_c" spacing between web reinforcement is found by formula:

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

7- If $V_s \leq 4 \times \sqrt{f_c} \times b_w \times d$; then max spacing of stirrups will be smallest of the following four conditions

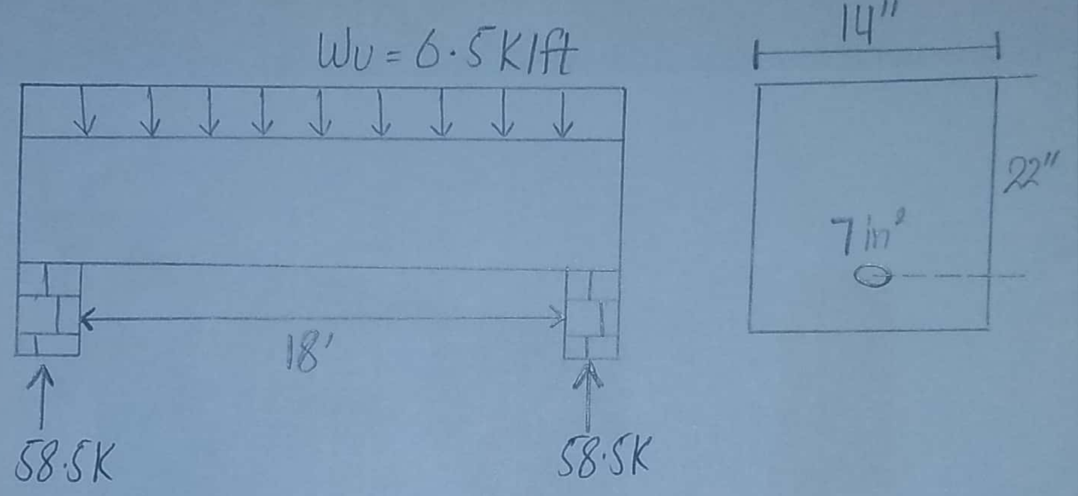
1- 24" 2- $d/2$ 3- $S_{max} = \dfrac{A_v \times f_y}{0.75 \times \sqrt{f_c} \times b_w}$ 4- $S_{max} = \dfrac{A_v \times f_y}{50 \times b_w}$

8- If $V_s > 4 \times \sqrt{f_c} \times b_w \times d$ → Then max spacing will be halved.

9- If $V_s > 8 \times \sqrt{f_c} \times b_w \times d$
Then either increase cross-sectional dimensions or increase f_c'.

Q2 A simply supported rectangular beam 14" wide having an effective depth 22" to carry a lateral load of 6.5 K/ft on a 18' simple span. It is reinforced with 7in² of tensile steel area, if f_c' is 4ksi and f_y is 60ksi then design the beam for shear.

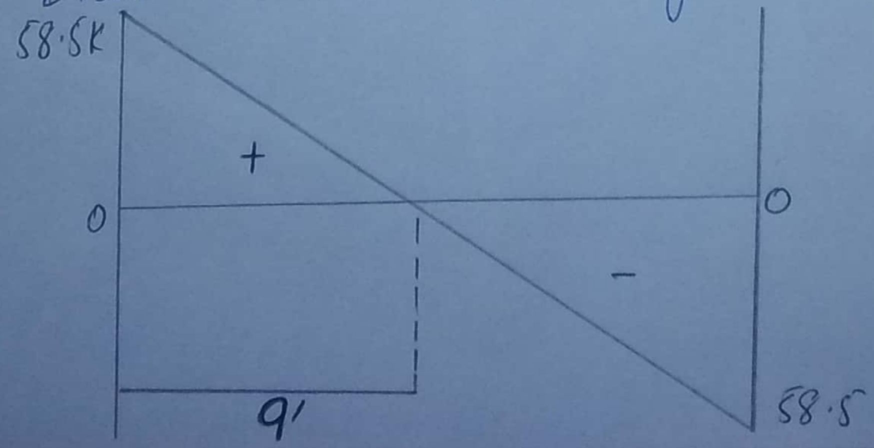
Sol:



Step 01: Find the reactions on support.

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

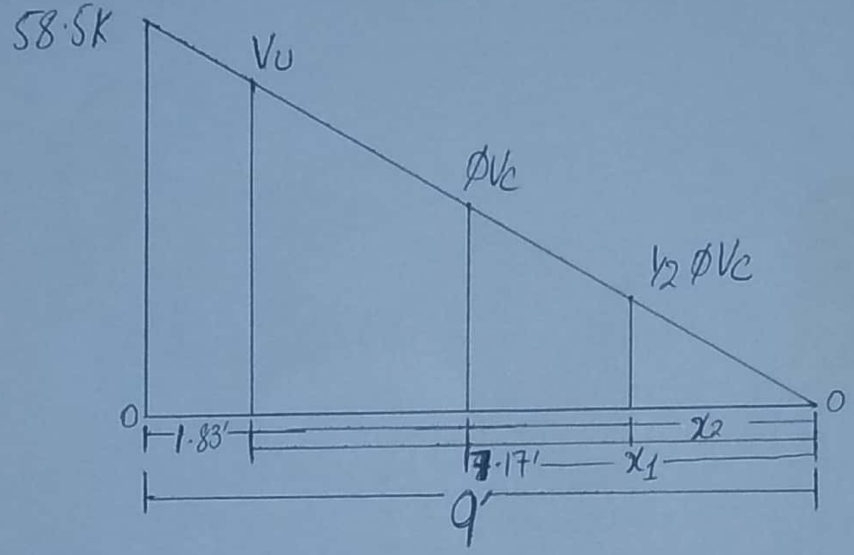
Step 02: Draw it's shear force diagram.



Step 03: Finding the value of critical stress "V_u" and it's location.

As we know that critical shear is located at distance "d" from the face of supports $d = 22'' = 1.83'$

Using Similarity of triangles



$$\frac{58.5}{9} = \frac{V_U}{7.17}$$

$$V_U = \frac{58.5 \times 7.17}{9} = 46.605K$$

Step 04: 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,

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

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

$$= 29.21K$$

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* location of "ϕV_c" by similar triangles.

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

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

Now,

→ $\frac{1}{2}\phi V_c = \frac{29.21}{2} = 14.60K$

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

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

$$\boxed{x_2 = 2.24'}$$

Step 05: Finding the value of "ϕV_s"

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

$$= 46.605 - 29.21$$

$$\boxed{\phi V_s = 17.395}$$

Step 06: Check on section adequacy

By formula

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

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

$$= 116.87K$$

As $\phi \times 8 \times \sqrt{f'c} \times b_w \times d > \phi V_s$ Thus section is adequate.

Step 07: Check on Max spacing for stirrups

By formula

$= \phi \times 4 \times \sqrt{f'c} \times bw \times d = 0.75 \times 4 \times \sqrt{4000} \times 14 \times 22$

$= 58.43K$

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

so max spacing will be selected from the following 4 conditions:

1- $24''$

2- $\frac{d}{2} = \frac{22}{2} = 11''$

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

let's suppose we use #3 stirrup ; dia = $3/8'' = 0.375''$

$Area = \frac{\pi}{4}(0.375)^2 = 0.11 in^2$

For 2-legged stirrup Area × 2

$= 0.11 \times 2 = 0.22 in^2$

3- $S_{max} = \frac{0.22 \times 60000}{50 \times 14} = 18.25''$

4- $S_{max} = \frac{Av \times fy}{50 \times bw} = \frac{0.22 \times 60000}{50 \times 14} = 19.87''$

So we choose the least value from the above values.

$S_{max} = 11''$

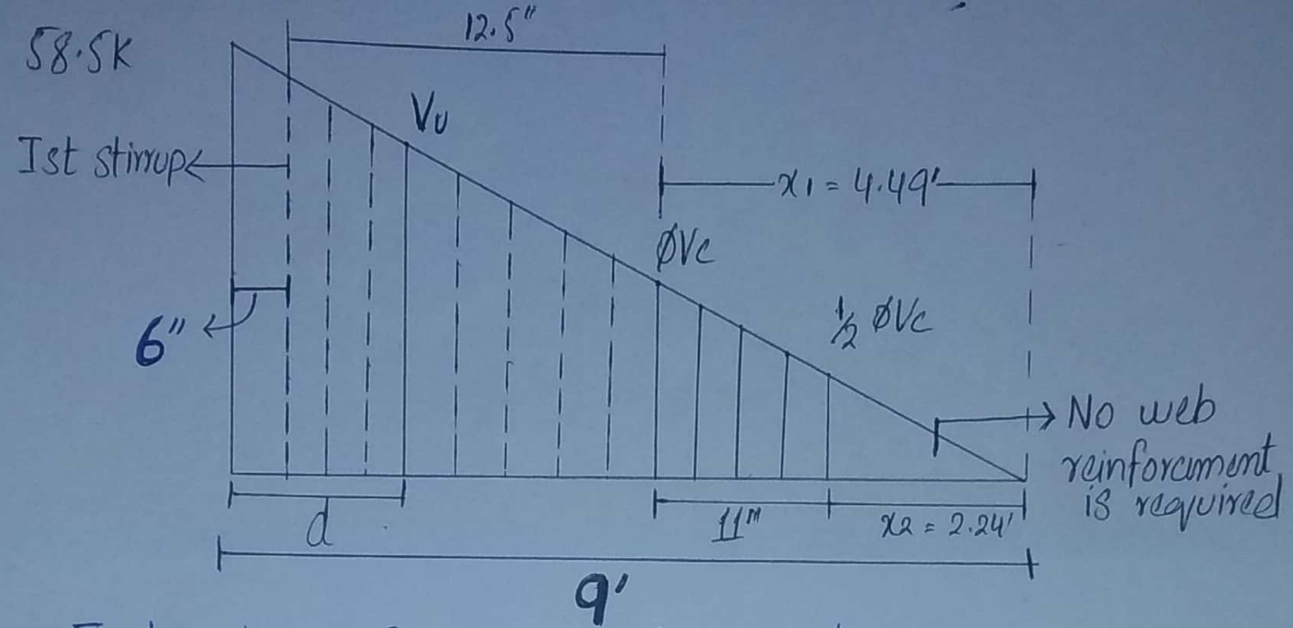
Step08: Stirrups spacing from/at critical section.

By formula; $S = \frac{\phi \times Av \times fy \times d}{Vu - \phi Vc} = \frac{0.75 \times 0.22 \times 60 \times 22}{46.605 - 29.21}$

$S = 12.52 \approx 12.5''$

so $12.5''$ ck

Step 09: Final Sketch will be.



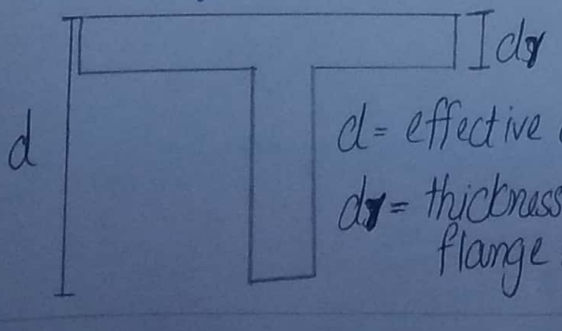
First stirrup from face of support

$$S/2 = \frac{12.5}{2} = 6.25 \approx 6''$$

Q3 Define both the T-beam and L-beam with the help of diagram. Also explain flexural strength analysis for T-beam.

T - Beam

- It is load bearing structure of reinforced concrete, wood or metal, with a T-shaped cross-section.
- The top of the T-shape serves as flange or compression member in resisting compressive stresses.

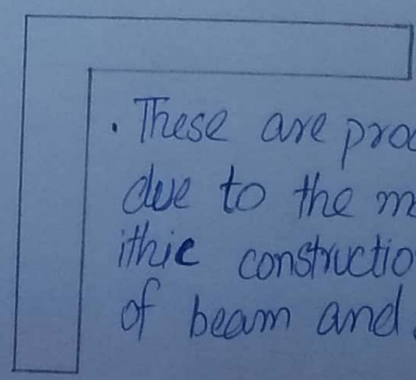


d = effective depth

df = thickness of flange slab

L - Beam

- A beam whose section has the form of an inverted L; usually placed so that it's top flange forms part of the edge of a floor.



- These are produced due to the monolithic construction of beam and slab.

FLEXURE STRENGTH ANALYSIS FOR T-BEAM:

1- Find the ultimate factored load (moment) by the formula:

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

2- Effective depth "b_e" for T-beam is computed as follows:

i- $16(h_f) + b_w$, ii- c/c distance , iii- span/4 , iv- $\frac{CTS}{2} + b_w$

∴ select the least value from the above values.

3- Check whether Rectangular or T-beam analysis is required.

i- If $a > h_f$ then T-beam analysis is required.

ii- If $a < h_f$ then rectangular analysis is required.

4- Find the Area of steel;

$$A_{ST} = \frac{M_u}{\phi \times f_y \times (d - a/2)} \quad ; \quad a = \frac{A_{ST} \times f_y}{0.85 \times f'_c \times b_w}$$

5- Check 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- Find the no of bars; No of bars = A_{ST}/A_b

7- Check min width for bars accomodation; (b_{min} = 2 C.C + 2 dia of stirrup + No. of bars (dia of bar) + spacing b/w bars (dia of bar).

8- Design Moment is given as = $M_d = \phi \times f_y \times A_{ST} \times (d - a/2) \Rightarrow$ if $a < h_f$

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

Q4 What is the difference between CASE-I & CASE-II in the design of T-beam.

Ans:

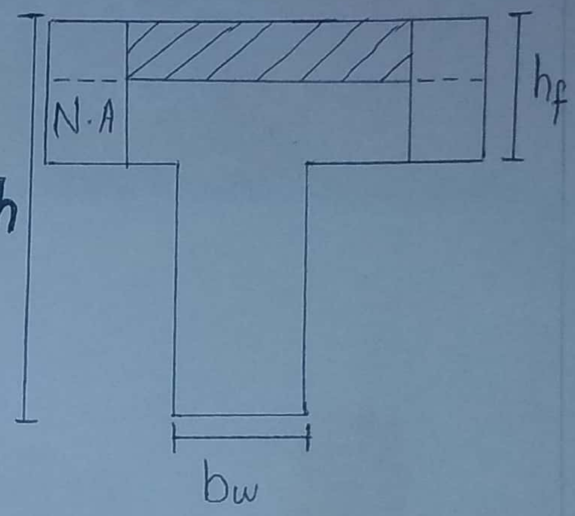
CASE-I :

From the figure

$a < h_f$

so in this case, rectangular beam analysis is required so the design moment formula will be

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



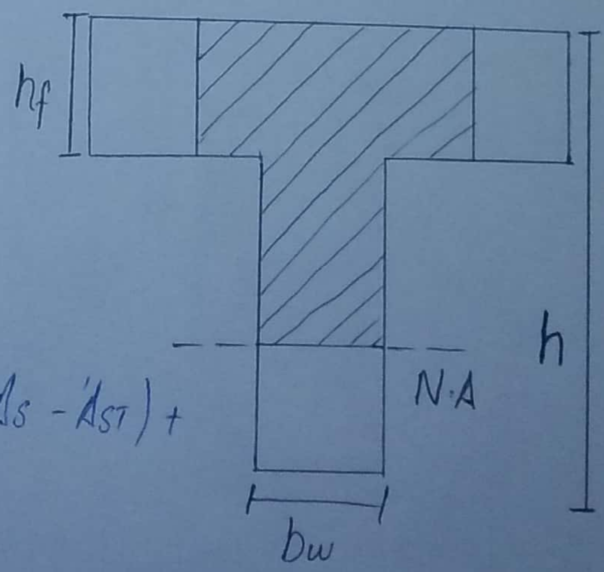
CASE-II:

From the figure,

$a > h_f$

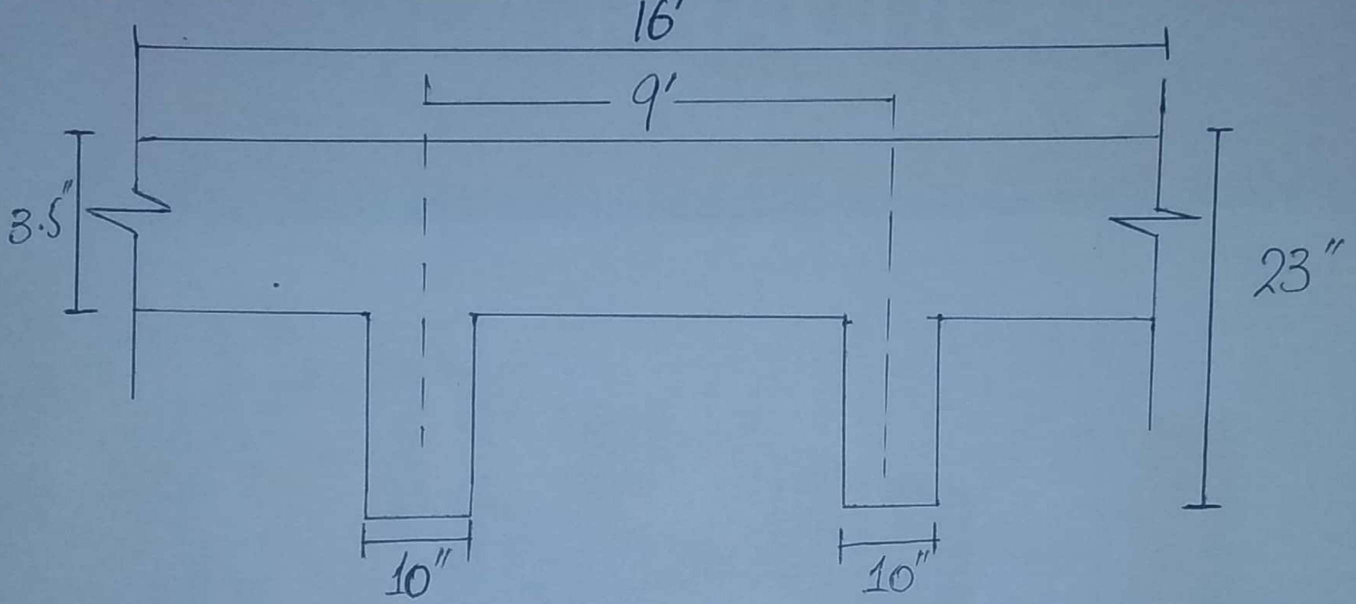
So in this, special beam analysis i.e T-beam analysis is required so design moment will be

$$M_d = \phi \times [A_s \times f_y \times (d - h_f/2) + (A_s - A'_{ST}) + f_y \times (d - a/2)]$$



Q5 A floor consists of 3.5" concrete slab support 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 reinforcement if the factored applied moment is 5800 k-in. Use $f'_c = 3ksi$ and $f_y = 60ksi$.

Sol:



Step 01: Calculate the effective width (b_e) for T-beam.

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

2- c/c distance $=$ 9×12 $= 108"$

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

Selecting the least value of $b_e = 48"$

Step 02: Check whether rectangular or T-beam analysis is required.

Trial#1

let $a = h_f = 3.5"$

$$A_{ST} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{5800}{0.90 \times 60 \times (18 - 3.5/2)} = 6.61 in^2$$

Trial #2

$$a = \frac{A_{ST} \times f_y}{0.85 \times f_c \times b_e} = \frac{6.61 \times 60}{0.85 \times 3 \times 48} = 3.24''$$

$$A_{ST} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{5800}{0.90 \times 60\left(18 - \frac{3.24}{2}\right)} = 6.56 in^2$$

Trial #3

$$a = \frac{A_{ST} \times f_y}{0.85 f_c' \times b_e} = \frac{6.56 \times 60}{0.85 \times 3 \times 48} = 3.21 \text{ in}$$

$$A_{ST} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{5800}{0.90 \times 60 \times \left(18 - \frac{3.21}{2}\right)} = 6.56 in^2$$

Thus rectangular beam analysis is required.

Step03: Check ρ_{max} and ρ_{min}

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

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

$$= 0.014$$

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

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

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

$0.003 < 0.036 < 0.014$

Thus the value of $\rho_{max} <$ and ρ_{min} so we have to calculate A_{ST} again.

$A_{ST} = \rho_{max} \times b \times d$

$A_{ST} = 0.014 \times 10 \times 18$

$A_{ST} = 2.52 \ in^2$

Step 04: Selection and No of Bars

let's use #8 so dia $(8/8) = 1''$

$Area = \pi/4 (1)^2 = 0.785 \ in^2$

By formula

No of bars $= \frac{A_{ST}}{A_b} = \frac{2.52}{0.785} = 3.21 \approx 4$ bars

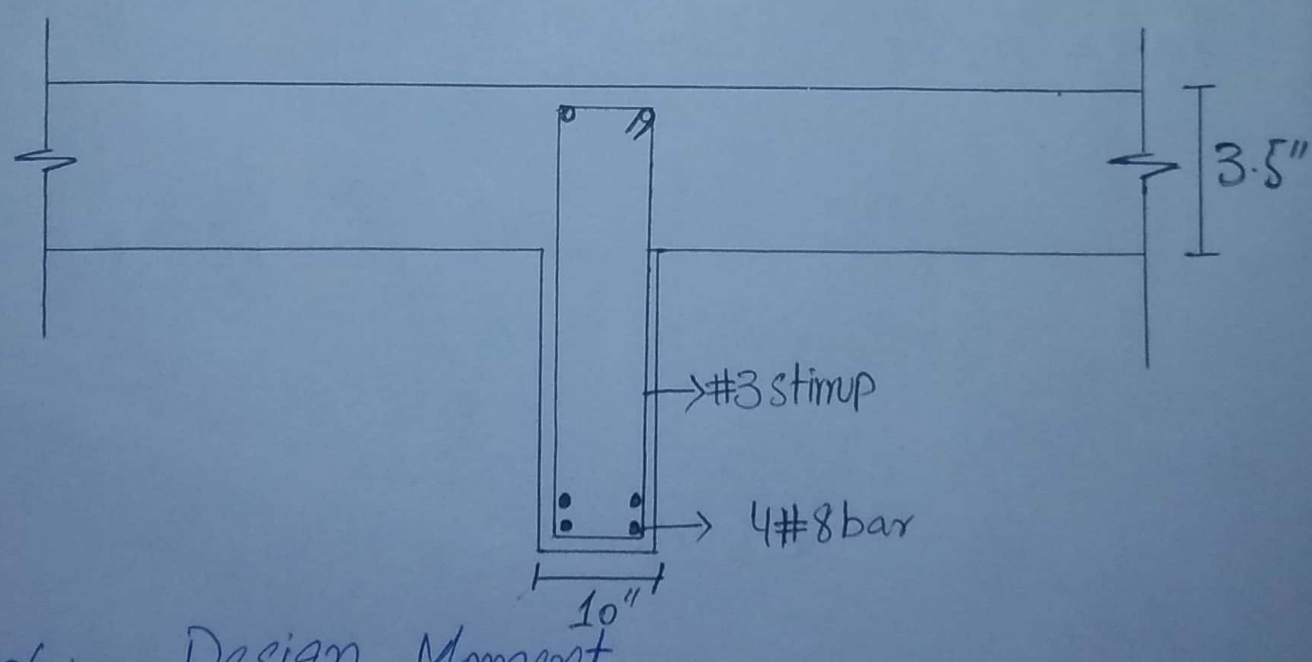
Step 05: Check on minimum width

$b_{min} = (2 \times 1.5) + (2 \times 3/8) + (4 \times 8/8) + 3(8/8)$

$= 10.75''$

As $10.75'' > 10''$

so it should be provided in two layers.



Step 06: Design Moment

By using formula

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

$\because A_{ST} \Rightarrow$ No of bars $\times$ Area of single bar

$= 4 \times 0.785$

$= 3.14 in^2$

$$a = \frac{A_{st} \times f_y}{0.85 \times f_c \times b} = \frac{3.14 \times 60}{0.85 \times 3 \times 48} = 1.54$$

$$M_d = 0.90 \times 60 \times 3.14 \times \left(18 - \frac{1.54}{2}\right)$$

$$M_d = 2921.52 \text{ k-in}$$

$$2921.52 < 5800$$

Thus design is OK!

Q6 A beam is revised to developed and ultimate moment of 6000 k-in limited to 14 x 26 inch size, use f'_c is 4ksi and f_y is 60ksi. Determine flexural reinforcement assume two rows of tensile reinforcement and effective depth of beam is 22".

Sol: Given data

Breadth = 14"

Height (h) = 26"

Concrete Compression strength (f'_c) = 4ksi

$f_y = 60$ ksi

$M_u = 6000$ k-in

$d = 22"$

Assume $d' = 2.5"$

Step 01: Reinforcement Ratio

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

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

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

Step 02: Area of steel

As we know that

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

$$= 0.0180 \times 14 \times 22$$

Area $= 5.54\ in^2$

Step 03: Design Moment

Using formula

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

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

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

$$M_{u2} = 5537.4\ k\text{-}in$$

As $5537.4 < 6000$

so we have to design a section as doubly reinforced beam.

Step 04: Difference in moments

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

$$= 6000 - 5537.4$$

$$\boxed{M_{u1} = 462.6\ k\text{-}in}$$

Step05: Area of Steel

$$M_{U1} = \phi \times A_{ST} \times f_y \times (d-d')$$

so Area of steel in compression zone will be

$$A'_{ST} = \frac{M_{U1}}{\phi \times f_y \times (d-d')} = \frac{462.6}{0.90 \times 60 \times (22-2.5)} = 0.44 in^2$$

Step 06: Total Steel Area

$$A_s = A_{ST} + A'_{ST}$$

$$= 5.54 + 0.44$$

$$= 5.98 in^2$$

Step07: Selection and No of bars used.

1- Steel in tension zone:

We use #7 bar,

dia $(7/8)'' = 0.875''$, Area $= \frac{\pi}{4}(0.875) = 0.601 in^2$

So,

$$\text{No of bars} = \frac{A_s}{A_b} = \frac{5.98}{0.601} = 9.9 \approx 10 \text{ bar}$$

So 10 #7 bars

2- Steel in compression zone:

let's use #5 bar

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

So,

$$\text{No of bars} = \frac{A_s}{A_b} = \frac{0.44}{0.306} = 1.43 \approx 2 \text{bars}$$

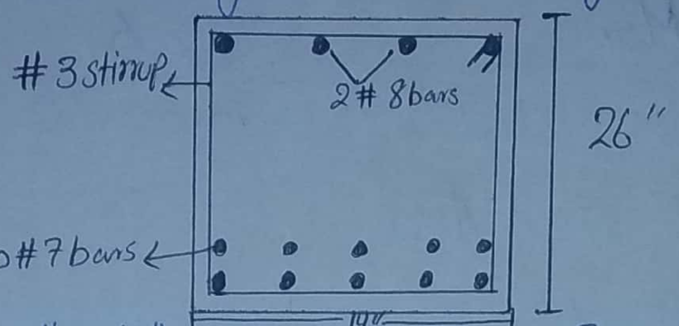
So 2 #5 bars

Step 08: Minimum width of beam

$$b_{min} = (2\times1.5) + (2\times 3/8) + 10(7/8) + 9(7/8)$$

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

so not good in one layer.



Now,

→ Effective depth $(d) = 26 - 1.5 - 3/8 - 7/8 - \frac{1}{2}(7/8)$

$= 22.82''$

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

$= 2.18''$

Step 09: Design Moment

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

$$a = \frac{(A_{ST} - A_{ST}') \times f_y}{0.85 \times f_c' \times b} = \frac{(10\times0.601 - 2\times0.306)\times60}{0.85 \times 4 \times 14}$$

$$a = 6.80''$$

$$M_d = 0.90[(2\times0.306)\times60\times(22.82-2.18) + (10\times0.601 - 2\times0.306)\times60 \times (22.82 - 6.80/2)]$$

$M_d = 7047.6$ k-in

As $7047.6 > 6000$

Design is OK!