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Semester:- 6th
Program:- Civil Engineering
Assignment:- Plain & Reinforced Concrete Desi
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QUESTION - 1

Explain in detail types of stirrups with figures and Also explain ACI codes for shear design.

Answer:-

Stirrup:-

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

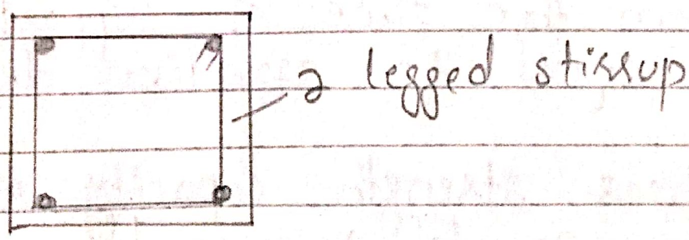
Types Of Stirrups:-

1- Single Legged Stirrup:-

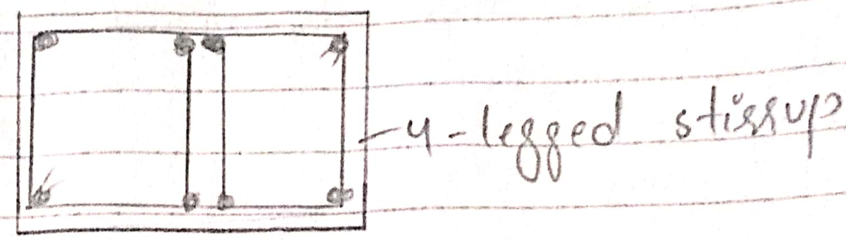
The single-leg stirrups have rarely been used because they are mostly used when binding only two rods-

2 Two legged stirrup:-

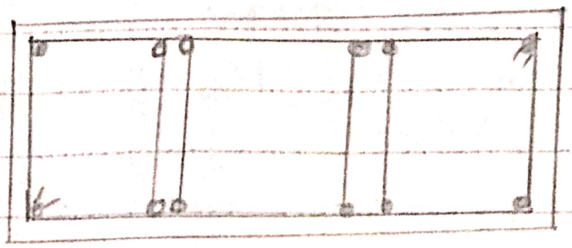
It is most commonly and widely used stirrup. Minimum 4 bars are required for providing this stirrup.



3 Four legged stirrup:-
These stirrups are used in case of web reinforcement.



4 Six legged Stirrup:-



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 equal 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 Reinforcements:-

If $V_u < \phi V_c$, 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 design

($\because V_u$ = Total factored shear applied at a given section)

=> For Minimum Reinforcement Area:-

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

$$\frac{50 \times b_w \times S}{f_y} \rightarrow \text{[Higher value is selected]}$$

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

$$S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{f'c} \times b_w} \text{ or}$$

$$\frac{A_v \times f_y}{50 \times b_w} \rightarrow \text{[Lesser value is selected]}$$

1 No web reinforcement is required if

$V_u < 1/2\,\phi V_c$

-> Between critical section 'V_u' and 'ϕV_c', spacing b/w web reinforcement

Can be find by,

$$S = \frac{\phi \times Av \times fy \times d}{Vu - \phi Vc}$$

5 If $Vs \leq 4 \times \sqrt{f'c} \times bw \times d$, then max spacing for stirrups will be the smallest of the following.

1 - 24"

2 - d/2

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

4 - $S_{max} = \frac{Av \times fy}{50 \times bw}$

∴ (Vs = shear force carried by web reinforcement)

=> If $Vs > 4 \times \sqrt{f'c} \times bw \times d$

Max spacing will be halved

=> If $Vs > 8 \times \sqrt{f'c} \times bw \times d$

↓

Then either increase cross-sectional dimensions or increase $f'c$.

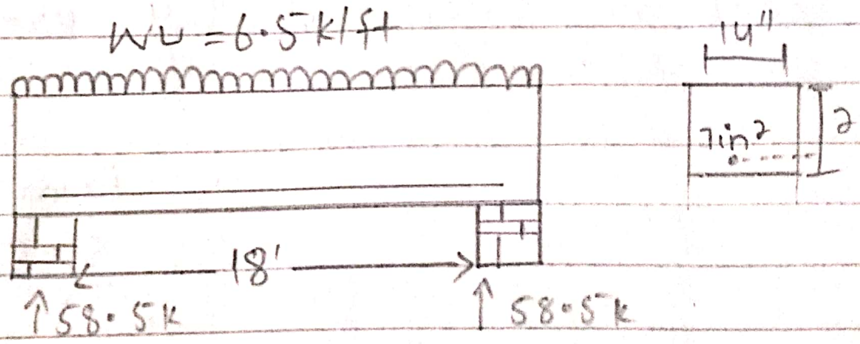
QUESTION -02

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

Given:~

Breadth of web of beam $(b_w) = 14''$
Effective depth $(d) = 22''$
Given load = 6.5 k/ft
Steel Area = 7in²
$f'c = 4$ ksi
$fy = 60$ ksi

Sol:~



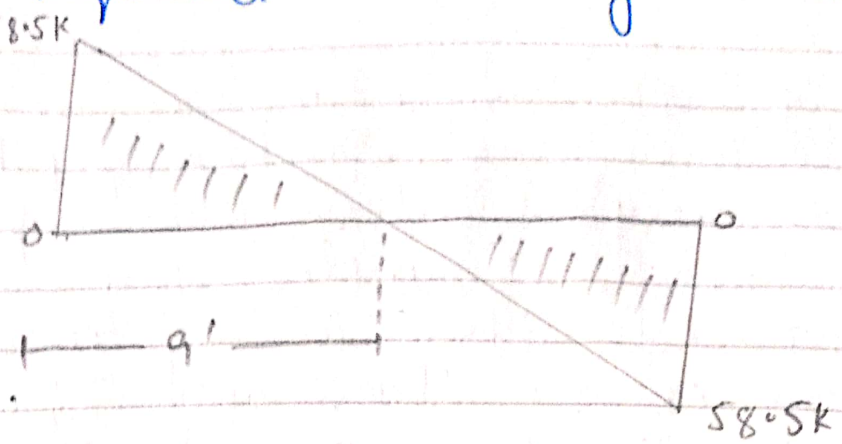
Step#1:~ (Reactions on Supports)

Finding the reactions due to applied load

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

Step # 2 :- (Shear Force Diagram)

The required shear diagram will be



Step # 3 :-

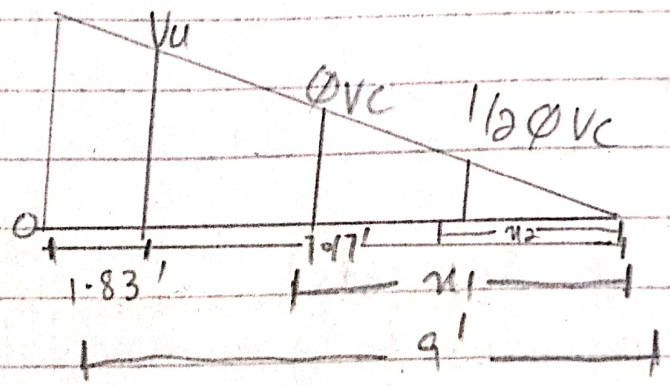
Finding the value of critical shear 'Vu" and its location.

As,

We know that critical shear is located at distance "d" from face of support

(d) = 22" = 1.83'

=) We will find the values of critical shear at distance 'd" by use of similar triangles.



From Similar Triangle

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

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

Vu = 46.61 kips

Step 4:~

Finding the value of "ϕV_c" and "1/2 V_c" and also its distances from zero shear to right side.

By formula,

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

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

$= 29.21$ kips

$\Rightarrow$ Location of ϕV_c by similar triangles,

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

$\Rightarrow x_1 = 4.49'$

$\Rightarrow$ Similarly,

$1/2\ \phi V_c = \phi V_c/2 \Rightarrow 29.21/2 = 14.60$ kips

$\Rightarrow$ location of $1/2\ \phi V_c$ will be,

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

Step 5:~

Finding the value of ϕV_s

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,

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

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

$= 116.87$ kips

As $\phi \times 8 \times \sqrt{f'c} \times bw \times d > \phi Vs$
So section is Adequate!

Step 7:-

Check on Maximum spacing for stirrups,
By formula,

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

$= 0.75 \times 4 \times \sqrt{4000} \times 14 \times 22 = 58438$ Lbs
$= 58.43$ kips

As $\phi \times 4 \times \sqrt{f'c} \times bw \times d > \phi Vs$
So Maximum will be selected from the following 4 conditions,

1. $S_{max} = 24''$
2. $d/2 = 22/2 = 11''$
3. $S_{max} = \dfrac{Av \times fy}{0.75 \times \sqrt{f'c} \times bw}$

Here we are using #3 stirrup, dia $= (3/8)'' = 0.375''$
So
Area $= \frac{\pi}{4}(0.375)^2 = 0.11$ i
For 2-legged stirrup
=> Area × 2
=> $0.11 \times 2 = 0.22$ in²

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

4. $S_{max} = \dfrac{Av \times fy}{50 \times bw} = \dfrac{0.22 \times 60000}{50 \times 14} = 18.85''$

From above 4 conditions, Least value of spacing for #3, 2 legged stirrup will be selected as,

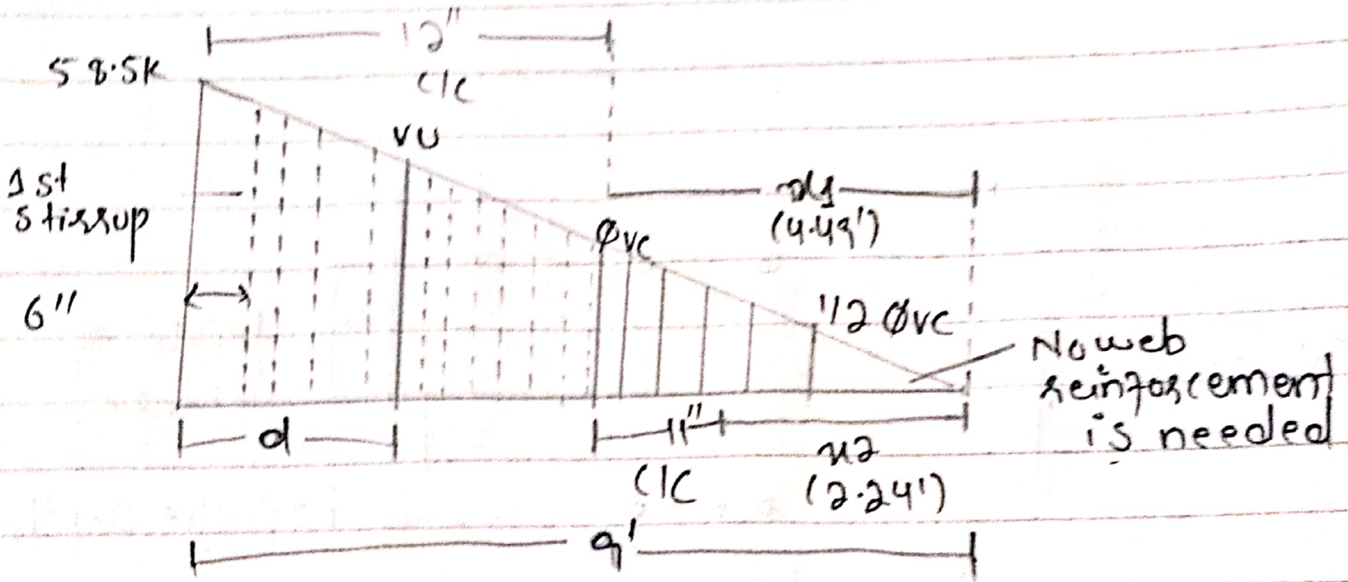
$S_{max} = 11''$

Step 8:~
Stirrups spacing from/at critical section will be,
By formula,

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

$S = 12.5'' \approx 12''$
so 12" c/c.

Step 9:~
Final sketch will be

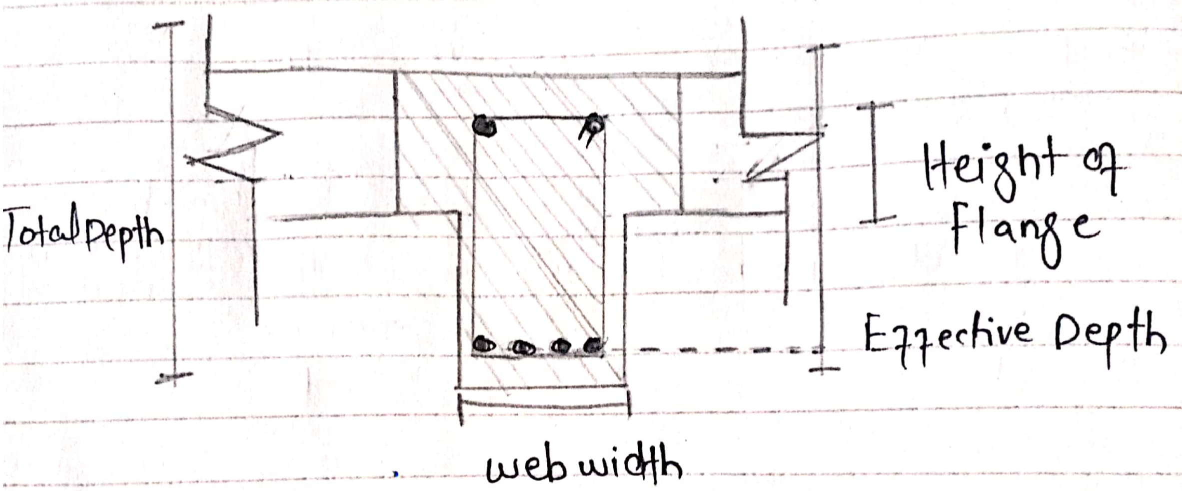


Question - 03

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

T-BEAM:~

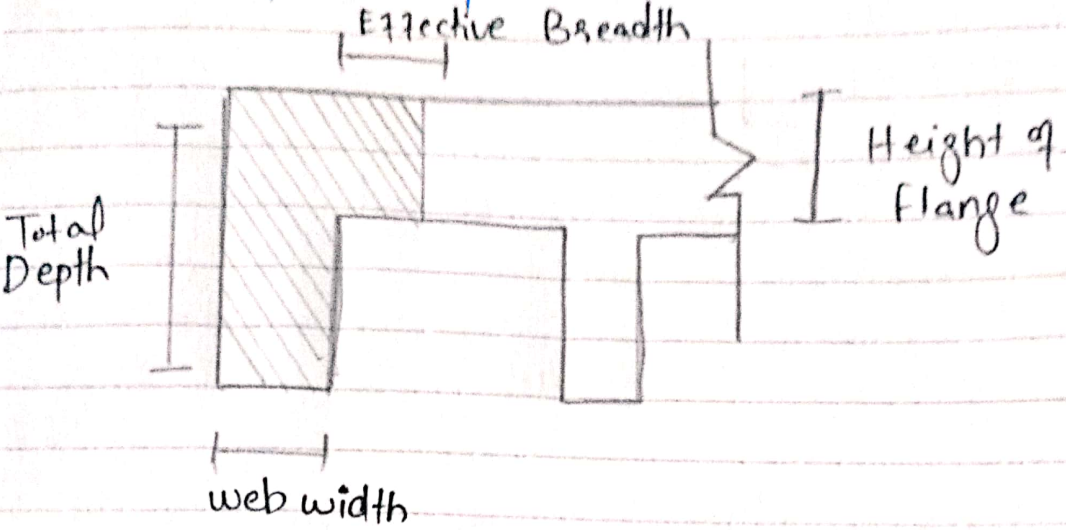
=> In most of the reinforcement concrete structures, concrete slabs are cost monolitically with the slab so, in this case the beam that act as an intermediate beam are called T-Beams.



=> 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 position of the beam is called web of the beam.

L- Beam:-

=> L - 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 reduced overall structural depth, the beams are in Prestressed or reinforced concrete.

Flexural Analysis OF T-Beams:-

Flexural Analysis of T-Beam consist of the following steps:-

- 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)

2 Effective width (be) for T-Beam is calculated as:-

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

∵ (h_f = height of flange, CTS = clear transverse span)

- We have to select the least value from above formulas
- If c/c distance is given, then there is no need of $\frac{CTS + b_w}{2}$

3 Checking whether Rectangular or T-Beam Analysis is required

i) If $a > h_f$ → special Analysis is required
ii) If $a < h_f$ → Rectangular beam Analysis is 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

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

∵ (ϕ Strength Reduction facts.
d = Effective depth
a = compression block depth
b_w = web width of beam.)

5 For checking the range of Reinforcement Ratio

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

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

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

6 Formula for finding No. of bars required is,

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

7 For checking Minimum width for bars accomodation,

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

8 Design Moment is given by,

$M_d = \phi\, fy \times Ast \times (d - a/2) \rightarrow$ if $a < hf$

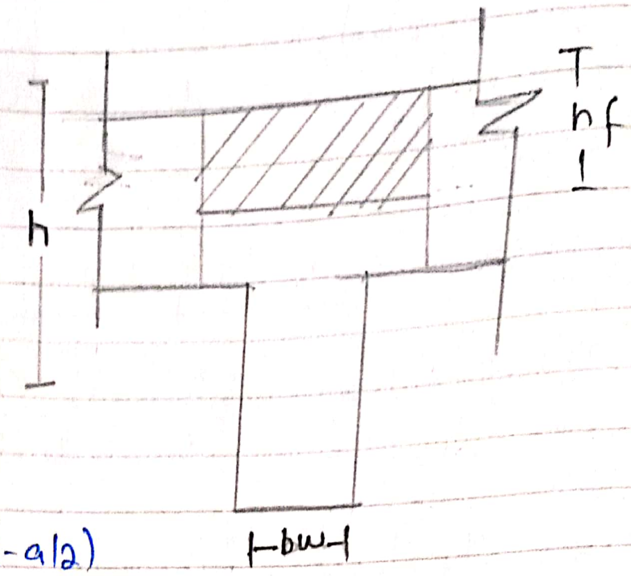
$M_d = \phi\, [As \times fy \times (d - hf/2) + (As - Ast) + fy \times (d - a/2)] \rightarrow$ if $a > hf$.

QUESTION- 04

What is the difference b/w case-1 and Case-2 in the design of T Beam?

CASE-I:~

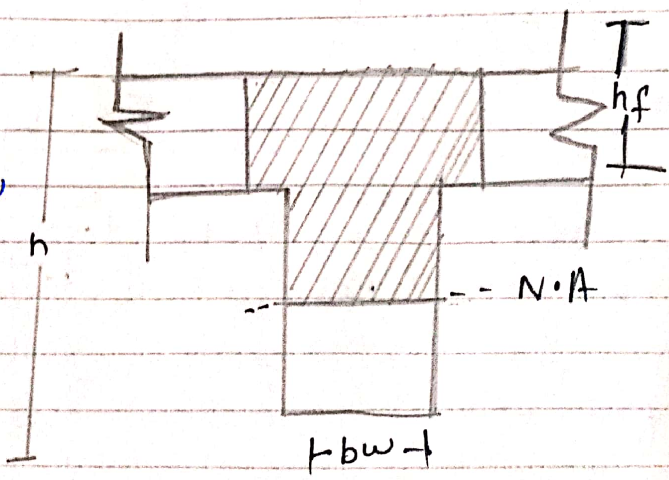
From the figure
$a < h_f$
So in this case,
Rectangular Beam Analysis is Required.
So,
The Design Moment Formula will be



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

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,



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

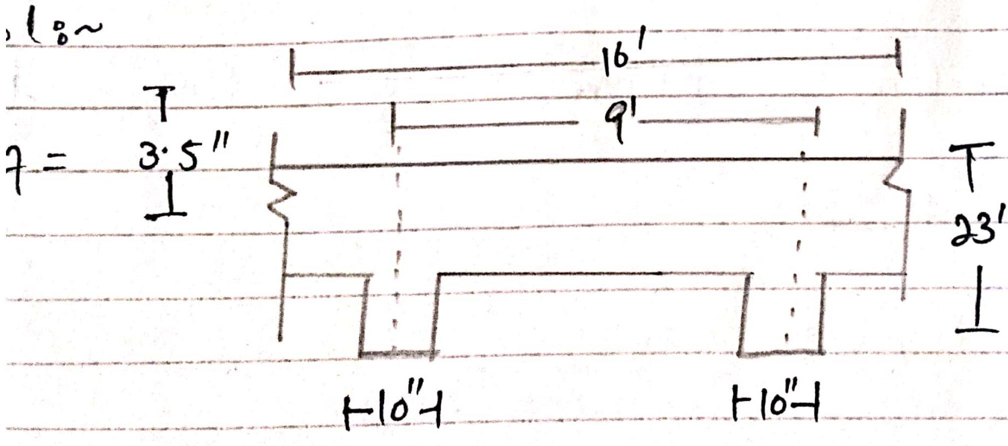
QUESTION - 05

A floor system consists of 3.5" concrete slab supported 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 kip-inch. Use $f'c$ = 3 ksi and fy = 60 ksi.

Given:~

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 (MU) = 5800 kip-inch
$f'c$ = 3 ksi
fy = 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 $= 9 \times 12 = 108''$

3 - Span/4 $= 16/4 \times 12 = 48''$

Selecting the least value of be as,

$b_e = 48''$

Step #2:~

Check whether Rectangular or T-beam Analysis is required.

Trial # 01:~ Let $a = h_f = 3.5''$

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

Trial #02:~

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

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

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

So rectangular beam Design is Required!

Trial # 03:~

$a = 3.21''$

$$\text{and } A_{st} = \frac{5800}{0.90 \times 60 (18 - 3.21/2)} = 6.55 \text{ in}^2$$

So Area of steel is 6.55 in^2.

Step # 3:~

Check ! ρ max and ρ min

$\Rightarrow \rho_{max} = 0.85 \times B \times \frac{f'c}{fy} \left(\frac{\epsilon u}{\epsilon u + \epsilon t}\right)$

$= 0.85 \times 0.85 \times 3/60 \; (0.003/0.003 + 0.005) = 0.013$

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

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

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

$0.003 < 0.036 < 0.013$

As the value of ρmax is less than ρ, so we have to design it as "Doubly Reinforced Bea

$\Rightarrow$ First we have to find the Area of steel against ρmax.

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

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

$Ast = 2.34 \; in^2.$

Step # 4:~

Finding the value of Mu_2:~

By formula,

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

First Finding the value of "a"

$\Rightarrow a = \frac{Ast \times fy}{0.85 \times f'c \times b} = \frac{2.43 \times 60}{0.85 \times 3 \times 10}$

$a = 5.72''$

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

$M_{u2} = 1986.67$ kip-inch.

As $M_{u2} < M_u$

$1986.67 < 5800$

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

Step # 5:-

Finding Difference in moments and Area of Steel:

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

$= 5800 - 1986.67$

$M_{u1} = 3813.33$ kip-inch.

By formula,

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

$A_{st}' = 4.56 \text{ in}^2$.

Step # 6:-

Finding Total Area:-

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

$= 2.43 + 4.56 = 6.99 \text{ in}^2$

Step # 7:-

Selection of Bar:-

In Tension zone:-

Let we use # 8 bar

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

By formula,
No of bars = $\frac{\text{Area of steel}}{\text{Area of single bar}} = \frac{6.99}{0.785} = 8.9$

So 9 # 8 bars

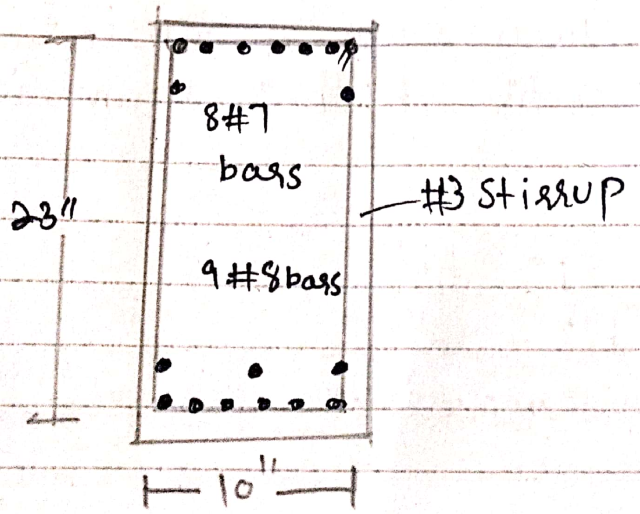
In compression zone:-
Let we use # 7 bar
dia = (7/8)", Area = $\frac{\pi}{4}(7/8)^2 = 0.601 in^2$

By formula,
No. of bars = $\frac{\text{Area of steel}}{\text{Area of single bar}} = \frac{4.56}{0.601} = 7.5$

So 8 # 7 bars.

Step # 8 :-

Minimum width for Accomodation of bars.
b min = (2 x 1.5) + (2 x 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 + 8/8 + 1/2 (8/8)
= 19.6"

Effective cover (d') = 1.5 + 3/8 + 7/8 + 1/2 (7/8) = 3.18"

Step # 9:~

Finding the Design Moment.

$Md = \phi \left[A's \times fy \times (d - d') + (As - A'st) \times fy \times (d - a/2) \right]$

First $a = \frac{(As - A'st) \times fy}{0.85 \times f'c \times b} = \frac{(9 \times 0.785 - 8 \times 0.601) \times 60}{0.85 \times 3 \times 10}$

$= 5.31"$

$= Md = 0.90 [(3 \times 0.601) \times 60 \times (19.6 - 3.18) + (9 \times 0.785 - 8 \times 0.601) \times 60 \times (19.6 - 5.31/2)]$

$Md = 6328.38$

As 6328.38 > 5800 → So design is ok!

QUESTION - 06

A beam is revised to developed and ultimate moment of 6000 kip-inches limited to 14x26 inch size, use f'c = 4 ksi and fy = 60 ksi. Determine flexural reinforcement assume two rows of tensile reinforcement and effective depth of beam is 22 inches.

Sol:~

Given:-

Breadth (b) = 14"

Height (h) = 26"

concrete compression strength (f'c) = 4 ksi

Steel Tensile strength (f_y) = 60 ksi
Ultimate factored Moment (M_U) = 6000 kip inches.
Effective depth of beam (d) = 22"
Assume Effective cover (d') = 2.5".

Step # 1:~ (Reinforcement Ratio)

By formula,

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

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

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

Step # 2 :- (Area of steel)

As we know that,

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

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

Step #3:- (Design Moment):-

By using formula

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

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

So,

$$M_{U2} = 0.90 \times 5.54 \times 60 \times (22 - 6.98/2)$$

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

As,

$$5537.4 < 6000$$

So we have to design a section as doubly reinforced.

Step # 4:- (Difference in Moments)

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

$= 6000 - 5537.4$

$M_{U1} = 462.6$ kip inches.

Step # 5:- (Area of steel)

$M_{U1} = \phi \times A'st \times fy \times (d - d')$

So Area of steel in compression zone will be,

$\Rightarrow A'st = \frac{M_{U1}}{\phi \times fy \times (d-d')} = \frac{462.6}{0.90 \times 60 \times (22-2.5)}$

$\Rightarrow A'st = 0.44 \text{ in}^2.$

Step # 6:- (Total steel Area).

$As = Ast + A'st$

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

Step # 7:- (Selection & No. of bars used)

1 Steel in Tension zone:-

We use # 7 bar,

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

$= 0.601 \text{in}$

So, No. of bars $= \frac{Ast}{\text{Area of single bar}}$

$= \frac{5.98}{0.601} = 9.9 \approx 10$ 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,

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

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

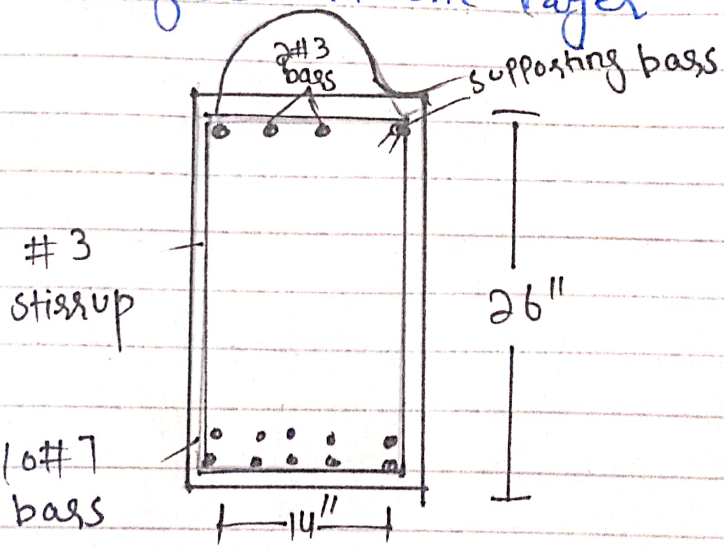
So 2 # 5 bars.

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 in one layer



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)

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

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

$= \dfrac{(10 \times 0.601 - 2 \times 0.306) \times 60}{0.85 \times f'_c \times b}$

$= \dfrac{(10 \times 0.601 - 2 \times 0.306) \times 60}{0.85 \times 4 \times 14} = 6.86''$

$M_d = 0.90\ [(2 \times 0.306) \times 60 \times (22.82 - 2.18) + (10 \times 0.601 - 2 \times 0.306) \times 60 \times (22.82 - 6.86/2)]$

$M_d = 7047.6$ kip-inches

As $7047.6 > 6000$

Design is ok!

Scanned with CamScanner