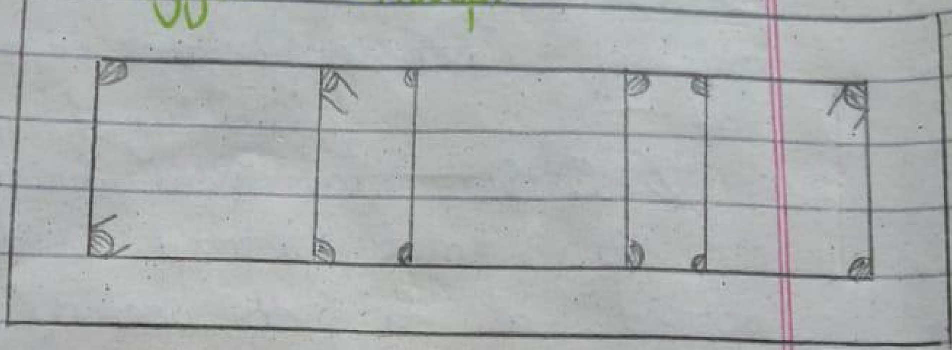
4- Six legged Stirrup:-



ACI Cods for shear Design of A Beam:-

According to ACI-318 following are the formoles used for the shear design of a beam.

1- Critical Section:-

critical Section occurs at 45° and 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 Reinforcement:-

If $V_c \leq \phi V_c$, then theoritically no web reinforcement is required However ACI code require 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 stirrup will be the smallest of the following

1- 24"

2- d/2

3- $S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$ (V_s = shear force carried by web reinforcement.)

4- $S_{max} = \frac{A_v \times f_y}{50 \times b_w}$

=> If $V_s > 4 \times \sqrt{f'_c}\, b_w \times d$
↓
Max spacing will be halved

=> If $V_s > 8 \times \sqrt{f'_c}\, b_w \times d$
↓
Then either increase cross-sectional dimension or increase f'_c.

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

Ans:- Given:-

Breadth of web of beam (b_w) = 14"

Effective depth (d) = 22"

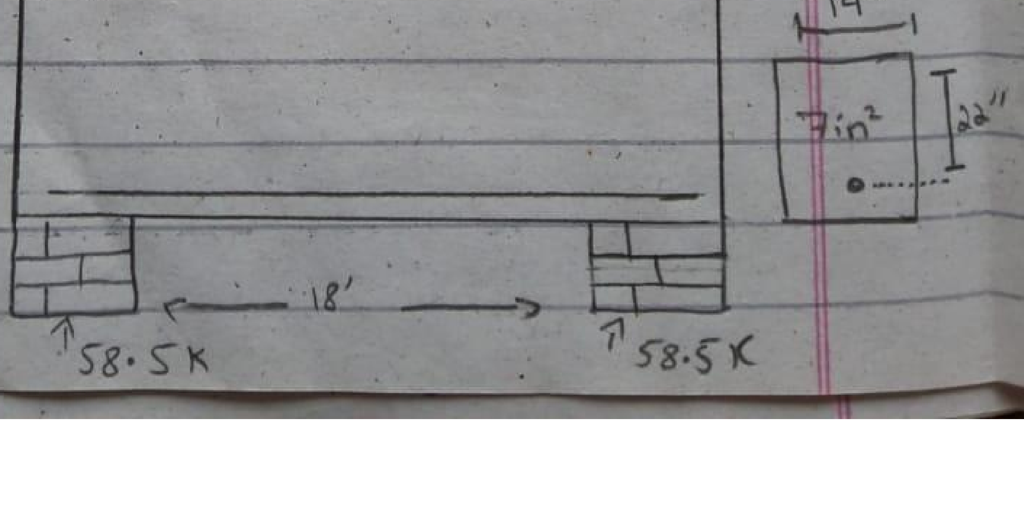
Given load = 6.5 K/ft

Steel Area = 7 in²

$f'_c = 4$ ksi

$f_y = 60$ ksi

Sol:-

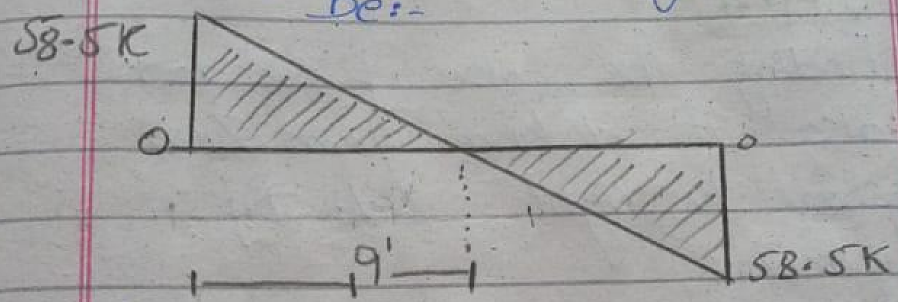


STEP # 1 :- (Reaction on Supports)

Finding the reaction due to applied load total load = $\frac{6.5 \times 18}{2} = 58.5$ Kips.

STEP # 2 :- (Shear force Diagram)

The required shear diagram will be:-



Step # 3 :-

Finding the value of Critical shear "Vu" and its located at distance "d" As we know that critical shear is locate at distance "d" from force of support (d) = 22" = 1.83'

=> we will find the value of critical shear at distance "d" by use of similar triangle.

from similar triangle

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

$$V_u = \frac{58.5 \times 7.17}{9} = \boxed{V_u = 46.61 \text{ Kips}}$$

provision of at least a minimum area of web reinforcement equal to,

$\phi = 0.75 \rightarrow$ for shear design

(∵ V_u = total factored shear applied at a given section)

=> for Minimum Reinforcement Area:-

$$A_{v\,min} = \frac{0.75 \times \sqrt{F'_c} \times b_w \times S}{f_y} \quad \text{or}$$

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

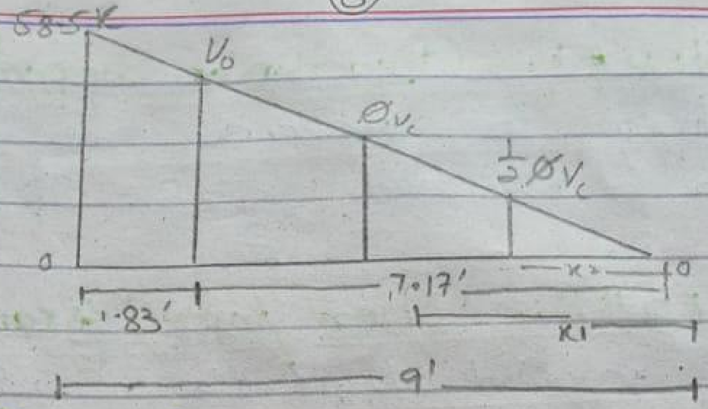
By interchanging the above formula, we can obtain the formula for maximum spacing

$$S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{F'_c} \times b_w} \quad \text{or} \quad \frac{A_v \times f_y}{50 \times b_w} \rightarrow \text{(lesser value is selected)}$$

4- No web-reinforcement is required if

$$V_u < \frac{1}{2} \phi V_c$$

=> Between critical Section "V_u" and "ϕV_c", Spacing b/w web



Step # 4:-

Finding the value of "ϕV_c" and also its distance from Zero shear to right side By formula,

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

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

$= 29.21$ kips

$\Rightarrow$ Location of ϕV_c by Similar triangle; $\frac{58.5}{9} = \frac{\phi V_c}{x_1} = \frac{58.5}{9}$

$= \frac{29.21}{x'}$ $\Rightarrow$ $x_1 = 4.49'$

$\rightarrow$ Similarly,

$\frac{1}{2}\phi V_c = \phi V_c/2 = 29.21/2$

$= 14.60$ 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 the value of ϕV_c

By formula $V_u = \phi V_s + \phi V_c$

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

$= 46.61 - 29.21$

$\boxed{\phi V_s = 17.4 \text{ Kips}}$.

Step#6:-

Cheak on Section adequacy

By formula

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

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

$= 116.87 \text{ Kips}$

As $\phi \times 8 \times \sqrt{f'_c} \times b_w \times d > \phi V_s$

So Section is Adequacy.

Step#7:-

Cheak on Maximum Spacing for Stirrup.

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

(1) - $S_{max} = 24''$ (2) $d/2 = 22/2 = 11''$

(3) $S_{max} = \frac{Av \times fy}{0.75 \times \sqrt{f'c} \times bw}$ $S_{max} = \frac{0.22 \times 60000}{0.75 \times \sqrt{4000} \times 14}$

$= 19.87$

(4) $S_{max} = \frac{Av \times fy}{50 \times bw} = \frac{0.22 \times 60000}{50 \times 14} = 18.85''$

from the above 4 conditions, least value of spacing for #3, 2 legged stirrup will be selected as, $S_{max} = 11''$

[Hear we are using #3 stirrup
dia $= (3/8)'' = 0.375''$
So Area $= \frac{\pi}{4}(0.375)^2 = 0.11 in^2$
for 2-legged stirrup
→ Area × 2 ⇒ $0.11 \times 2 = 0.22 in^2$]

Step # 8:-

stirrup spacing from/at Critical Section will be.
By formule,

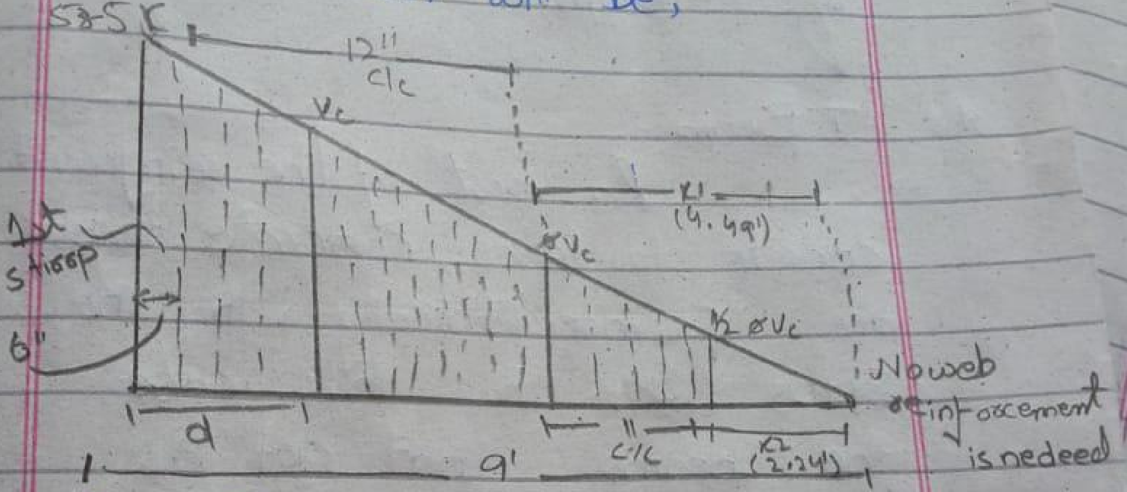
$$S = \frac{\phi \times Av \times fy \times d}{Vu - \phi Vc} = \frac{0.75 \times 0.22 \times 60 \times 22}{46.61 - 29.21}$$

$S = 12.5'' \approx 12''$

so 12 c/c

STEP # 9:-

Final sketach will be,



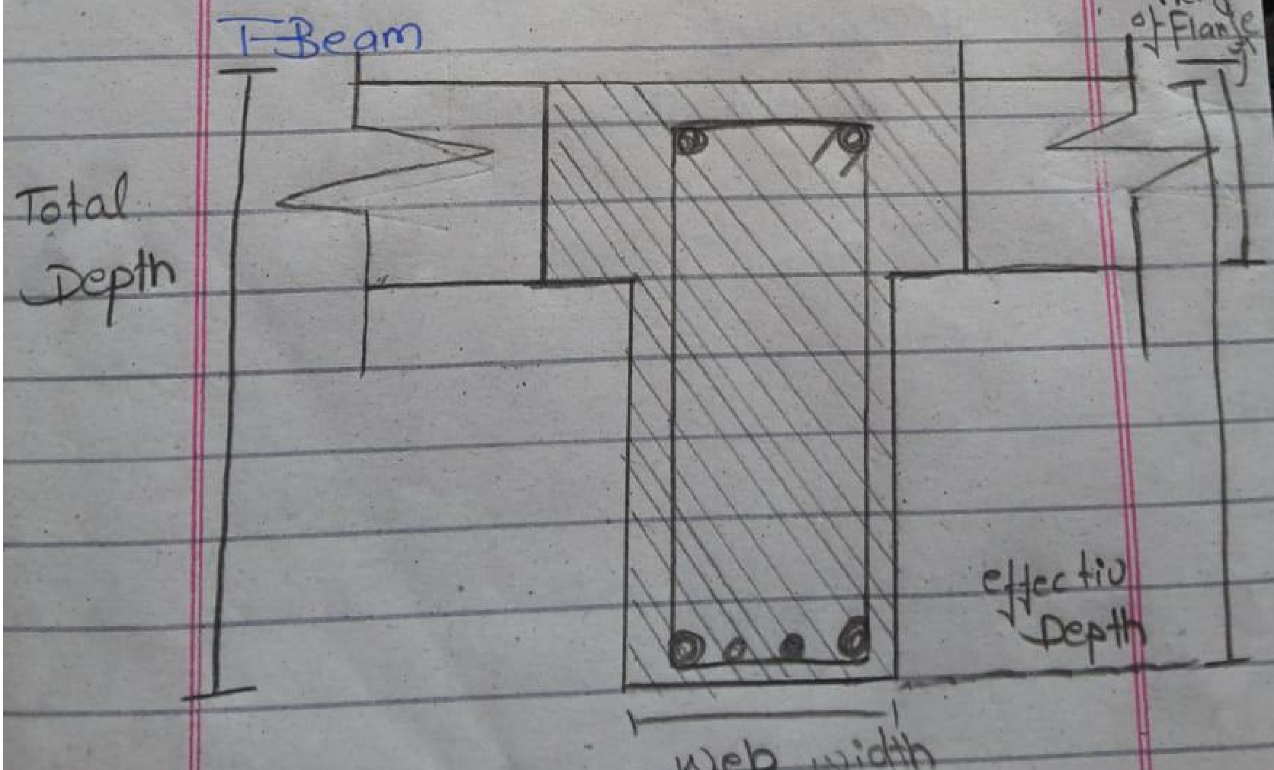
As first stirrup from force of support

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

Q.No.3:- Define both the T-Beam and with the help of diagram Also explain flexural analysis of T-Beam:-

Ans T-Beam:-

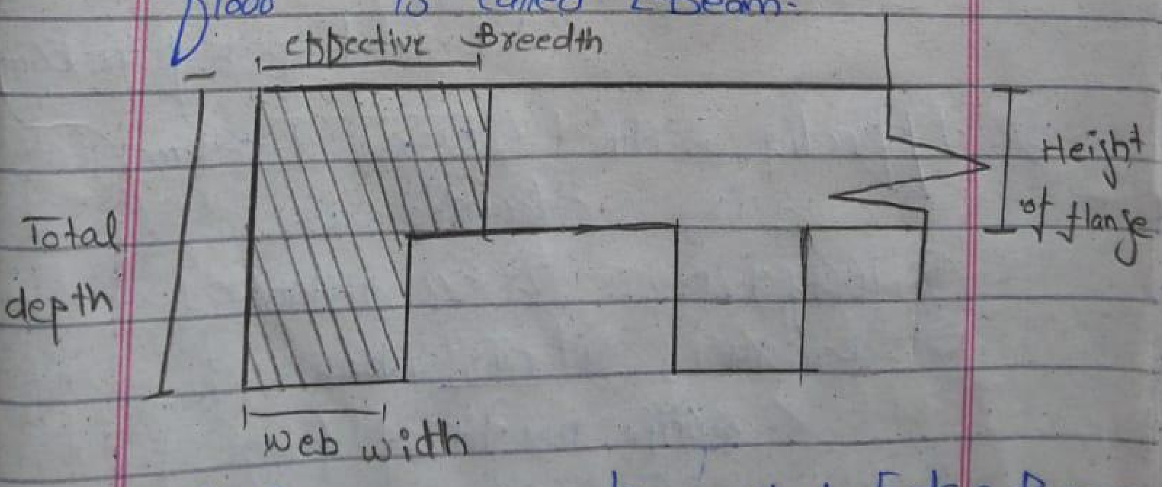
=> In most of the reinforced cocrete structures, concrete slabs are cosmonolithically with the slabs So, in this case the beams that act as an intermediate beam are called T-Beam



=> 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 are called T-Beam attached to the slab is called flange.
=> The bottom rectangular portion 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 corner of the slab.
=> L-Beams are typical floor beams because of their reduce over vall stoacftural depth, the beams are in prestressed or reinforced concrete.

FLEXURAL Analysis OF T-BEAM:-

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

1:- for fininding the ultimate factored moment we use the following formula.

$$Mu = \frac{wv \times L^2}{8}$$

(wv = Total factored load
L = total spain of the beam)

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

(1)- $16(hf) + bw$ (2) c/c distance
(3) Span 14 (4) $\frac{CTS}{} + bw$

∴ (hf = height of flage.
CTS = Clear transper span.)

- We have to selected the least value from above formuley.
- If c/c distance is given, then there is no need of "CTS + bw".

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.

whear

(a = Depth of compression block)
(hf = Height of flange)

4:- **For Finding Area of steel, we have to use**

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

whear

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

∴ (ϕ = strenght Reduction factor
d = effective depth
a = compressin block depth
bw = web width of beam)

(16)

Q.No4

5:- For cheaking the range of Reinforcement Ratio,

$$\rho_{max} = 0.85 \times B \times \frac{f'c}{fy} \times \left(\frac{\varepsilon_4}{\varepsilon_4 \times \varepsilon_y}\right)$$

Ans

$$\rho_{min} = \frac{200}{fy} \qquad \rho = \frac{Ast}{b \times d}$$

6 formula for finding No of bears required is:-

$$\text{No of bears} = \frac{\text{Area of steel}}{\text{Area of single bear.}}$$

7- For cheaking minimum width for bears accomodation:-

b.min = 2(Clear cover) + 2(dia of stirrop) + No of bars (dia of bar) + Spacing b/w bars (dia of bar)

8:- Design Moment is given by:-

$Md = \phi \times fy \times Ast \times (d - a/2) \rightarrow$ if $a > hf$

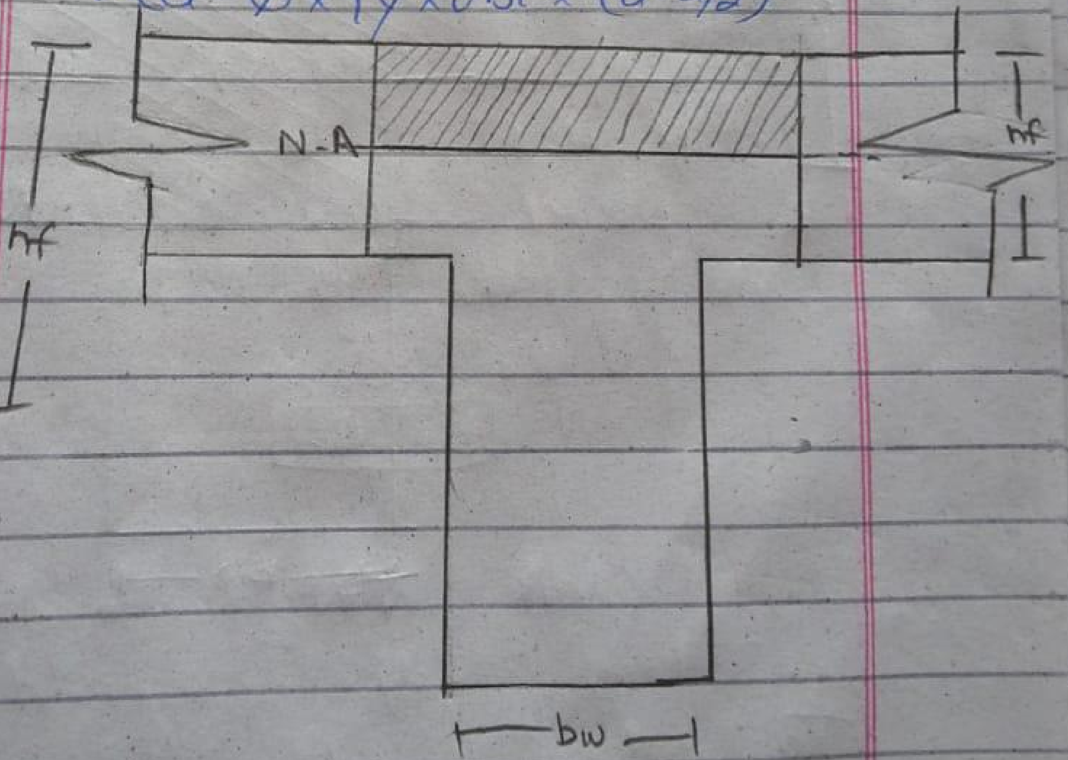
$Md = \phi \times [As \times fy \times (d - hf/2) + (As - Ast) + fy \times (d - a/2)] \rightarrow$ if $a > hf$.

Q.No4 What is that different b/w CASE-1 and CASE-2 in the design of T-Beam?

Ans **CASE-I:-**

From the figure $a < hf$
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 $a > hf$ So

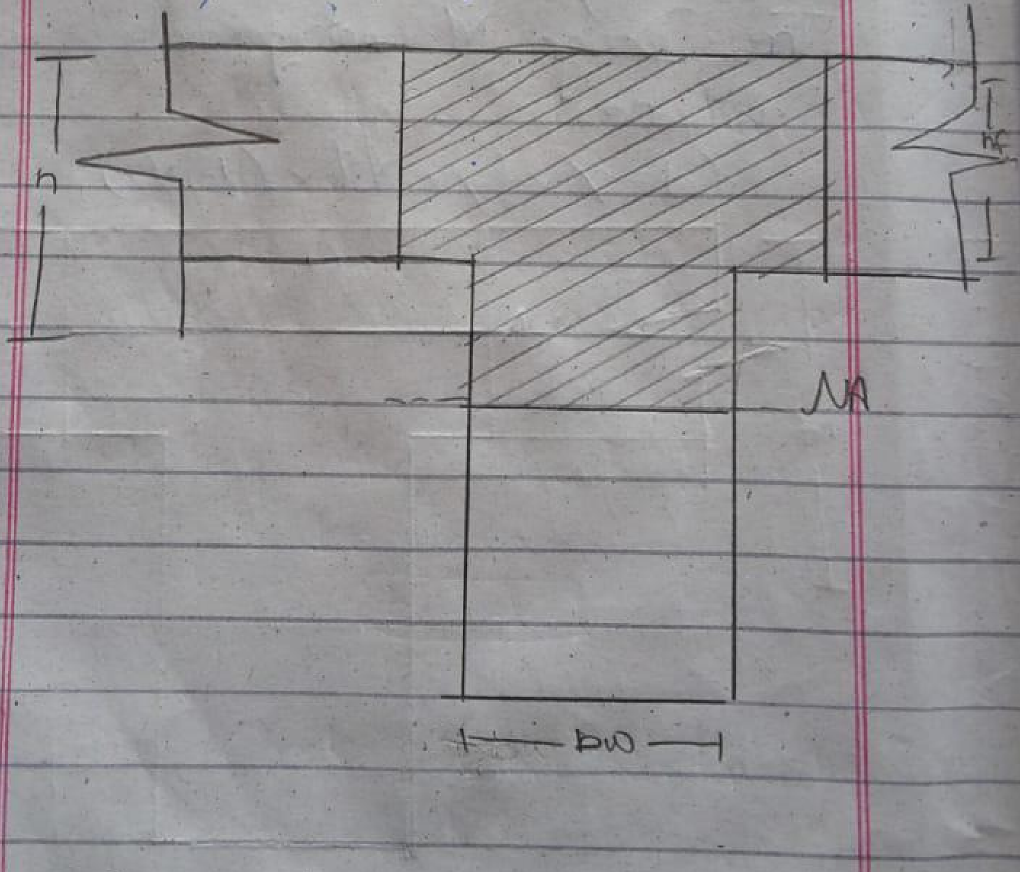
18.

in this Special beam analysis ie T-Beam Analysis is required

So

the required Design Moment will be

$$Md = \phi \times [As \times fy \times (d - \frac{hf}{2}) + (As - Ast) + fy \times (d - a/2)]$$



Q.No5 A floor system consist of 3.5" concrete also supported by 16 Simple span spaced at 9' c/c the beam having a web width of 10" and effective depth of of 18" and total height is 23" Calculator the neccesery flexural reinforcement if the factored applied moment is 5800 kips inch Use f'c = 3 ksi and fy 60ksi.

Ans **Given:-**

Height of flage (hf) = 3.5"

c/c distance = 9'

lenght/span of the beam = 16'

web width (bw) = 10"

Effective wedth (d) = 18"

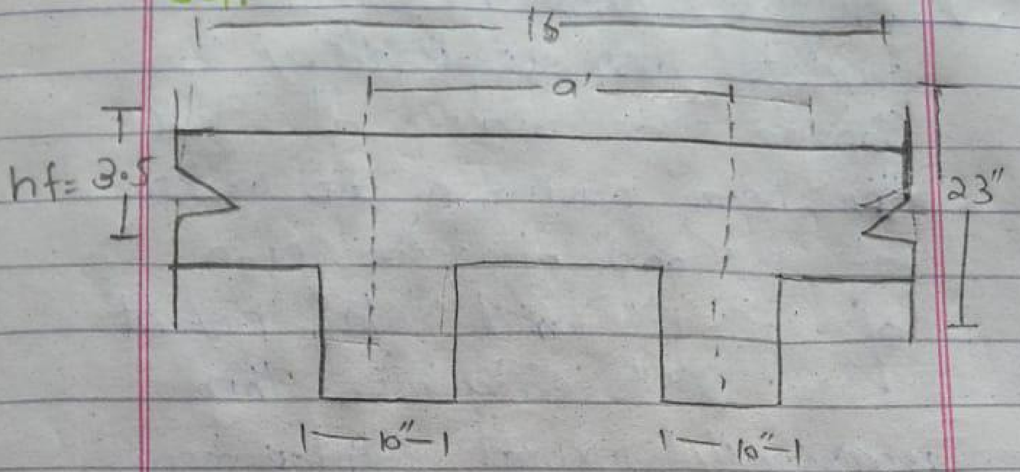
Height (h) = 23"

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 hf + bw = 16(3.5)+10 = 66"

2 - c/c distance = 9x12 = 108"

3 - Span/4 = $\frac{16}{4}$ x12 = 48"

Selecting the least value of be as;

be = 48

Step # 2:-

Cheak whether Rectangular or T-beam Analysis is required

Trial # 01 :- Let a = hf = 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:-

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

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

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

So Rectangular Beam Disgn is Required!

Trial # 03:-

$$a = 3.21'' \text{ and } A_s = \frac{5800}{0.90 \times 60 (18 - \frac{3.21}{2})}$$

$= 6.55 in^2$. So area of steel is $6.55 in^2$.

Step # 3:-

Cheak ρ_{max} and ρ_{min}.

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

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

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

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

$\rho_{min} < \rho < \rho_{max} = 0.003 < 0.036 < 0.013$

As the value of Smax is less than S, so we have to design it as "Doubly Reinforced Beam".

=> first we have to find the Area of steel against Smax.

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

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

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

Step II :-

Finding the value of M_{u2}

By formula,

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

first finding the value of "a"

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

$a = 5.72''$

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

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

As $M_{u2} < M_u$

$1986.67 < 5800$

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

Step # 5:-

Finding different in moment and Area of steel

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

$= 5800 - 1986.67$

$M_{u1} = 3813.33$ Kip-inch

By formula,

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

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

Step # 6:-

Finding total steel area:-

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

$= 2.43 + 4.56 = 6.99\ in^2$

Step # 7:-

Selection of Bar:-

In tension Zone :-

Let we use # 8 bar

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

= 0.785 in^2

By formula:-

No of bars =

$\frac{\text{Area of steel}}{\text{Area of single bar}} = \frac{6.99}{0.785}$

= 8.9 ≈ 9

So 9 # bars

<u>In comparison Zone:-</u>

Let we use # bar

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

By formula,

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

$\frac{4.56}{0.601} = 7.5 \approx 8$

So 8 # 7 bars.

Step 8:-

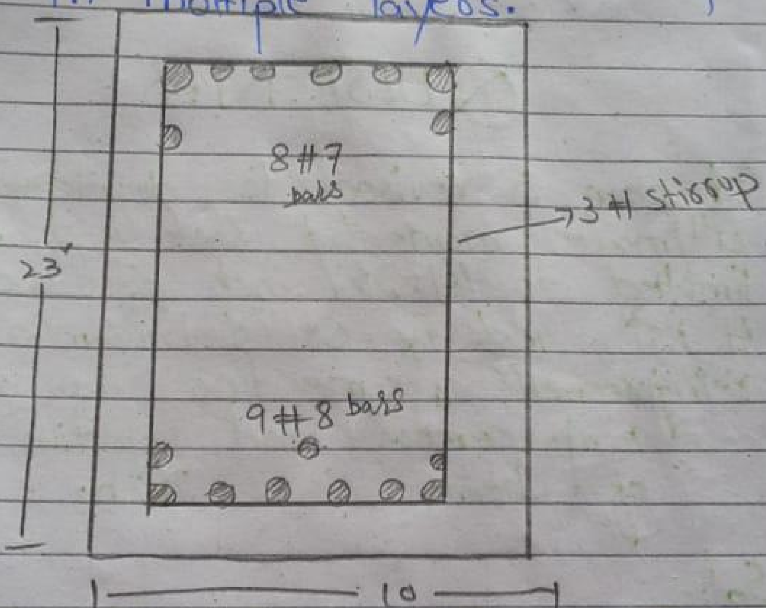
Minimum width for Accomodation of bars

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

$= 20.75''$

As $20.75 > 10''$

So the bars will be placed in multiple layers.



Effective depth (d) $= 23 - 1.5 + \frac{3}{8} + \frac{8}{3} + \frac{8}{8} + \frac{1}{2}\left(\frac{8}{8}\right) = 9.6''$

Effective cover (d') $= 1.5 + \frac{3}{8} + \frac{7}{8} + \frac{1}{2}\left(\frac{7}{8}\right)$

$3.18''$

Step #9:- Finding the Design Moment

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

$\times (d - a/2)$

First $a = \frac{(A_s - A_{st}) \times f_y}{0.85 \times f_c \times b}$ $\frac{(9 \times 0.785 - 8 \times 0.60)}{0.85 \times 3 \times 10}$ ×60

= 5.31

Md = 0.90 ((8×0.601) ×60×(196 − 3.18) +
(9×0.785 − 8×0.601) × Md = 6328.38

As 6328.38 > 5800 → So design is ok!

QUESTION: 6

6. A beam is revised to developed and ultimate moment of 6000 kip-inches limited to 14×26 inch size use f'c 4 ksi and fy = 60 ksi Determin flexoral reinforcement assume two row of tensile reinforcement and effective depth of beam is 22 inch?

Ans Sol:-

Given:-
Breadth (b) = 14"
Height (h) = 26"
Concreat compression strenght (f'c) = 4 ksi
Steel tensil strength (fy) = 60 ksi
Ultimate factored moment (Mu) = 6000 kip-inch
Effective depth of beam (d) = 22"
Assume Effective cover (d) = 2.5"

Step # 1 Reinforcement Ratio:-

By formula:-

$$S_{max} = 0.85 \times \beta \times \frac{f'c}{fy} \times \left(\frac{\varepsilon_u}{\varepsilon_c \times \varepsilon_y}\right)$$

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

$S_{max} = 0.0180.$

step # 2:- Area of Steel:-

As we know that

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

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

Step # 3 Design Moment:-

By using formula:-

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

$a = \frac{Ast \times fy}{0.85 \times f'c \times b} = \frac{5.54 \times 60}{0.85 \times 4 \times 14} = 6.98''$

So:-

$$Mu_2 = 0.90 \times 5.54 \times 60 \times \left(22 - \frac{6.98}{2}\right)$$

$= 5537.4$ Kip-inch

As

$5537.4 < 6000$

So we have to design a section as doubly reinforced.

Step # 4 Difference In moment:-

$Mu_1 = Mu - Mu_2 = 6000 - 5537.4 =$

$M_{u1} = 462.6$ Kip-inches

Step # 5:- Area of Steel:-

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

So Area of steel in compression Zone will be.

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

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

Step # 6 (total Steel Area):-

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

$= 5.54 + 0.44 = 5.98\ in^2$.

Step # 7 :- Selection & No of bars used:-

1:- Steel in tension Zone:-

we used # 7 bar

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

$= 0.601\ in^2$

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

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

S 10 # 7 bars

2:- Steel in compresion Zone:-

we used # 5 bars . dia $= (5/8)'' =$

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

$0.306\ in^2$

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

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

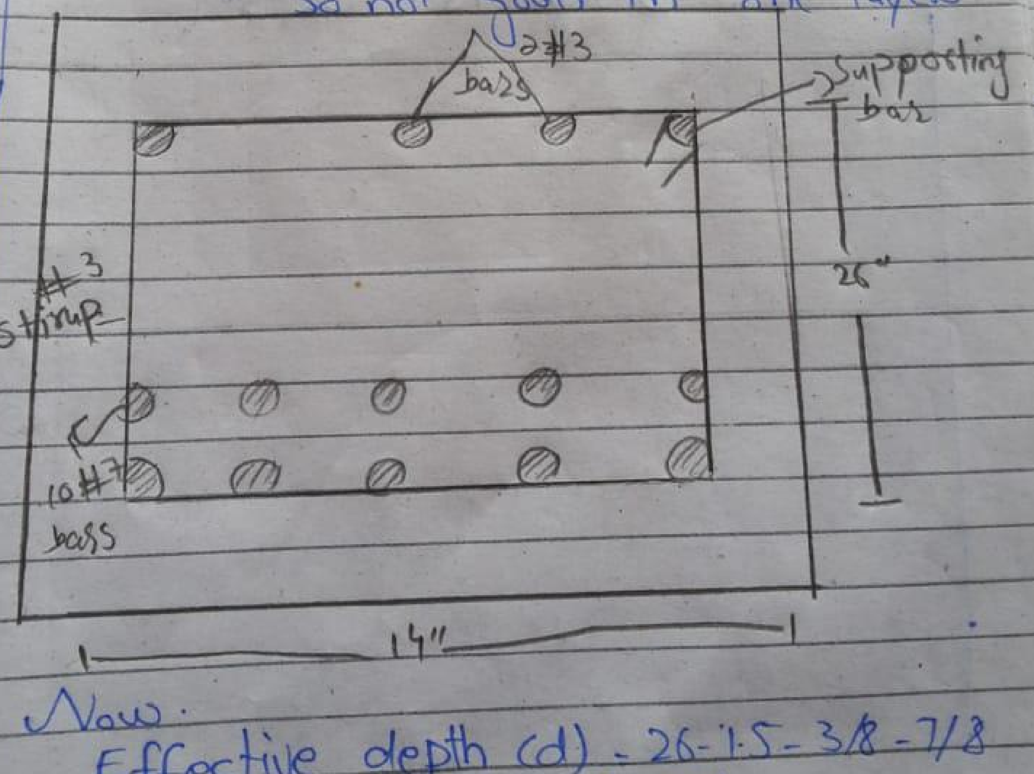
So 2#5 bars.

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 layers



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)

$Md = \emptyset \times [A'st \times fy \times (d'd) + (Ast - A'st)$
$\times fy \times (d - a/2)]$

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

$= 6.80''$

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

$Md = 7047.6$ kip-inches

As $7047.6 > 60000$

Design is OK...

1

Nam " Mazhar - hayat
ID " 7819
Seetion " "A"
subject " PRCD-1
submitted to " Sir. Fawad - Khan
Data " 26/6/2020

QN1 Explain in detail types of stirrups with figures and also explain ACI Codes for shear design?

Ans **STIRRUP:-**

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

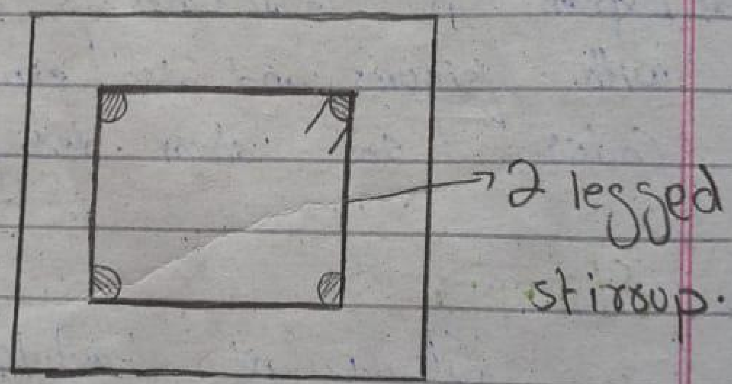
Types of STIRRUP:-

1:- **Single Legged STIRRUP:-**

The single leg Strirrup have rerely been used because they are mostly used when binding only two rods:

2- Two legged STIRRUP:-

it is most commonly and widely used stirrop. minimom 4 bears are required for providing this stirrup.



3- Four Legged Stirrup:-

These stirrup are used in case of web reinforcement.