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SECTION A

SUBJECT PRCD II

SUBMITTED TO ENGR FAWAD KHAN

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Assignment No#

Question:

Explain in details type of stirrup with figure and also explain ACI codes for shear design.

STIRRUP:

Stirrup are placed at proper intervals to beam to prevent them from deformation /shear failure of beam.

Stirrups are sometimes placed diagonally and often vertically as well. This is done to prevent shear failure which is usually diagonal in case of crack in beam.

Types of Stirrups

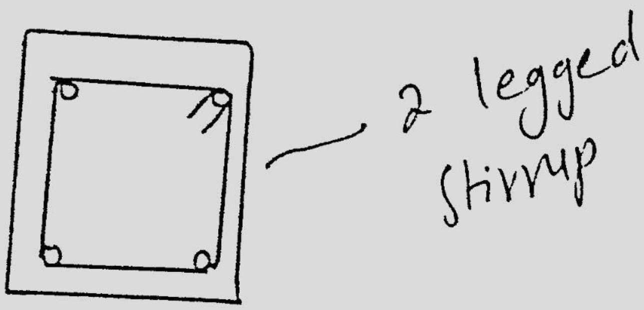
(1) Single legged stirrup:-

The practile use of this type of stirrup is very less. It is used to bind two rods.

(2) Two legged Stirrup:-

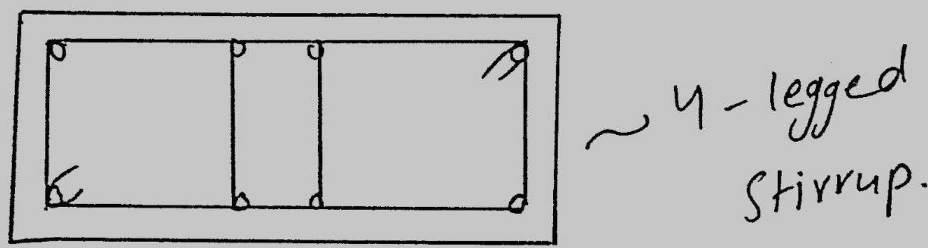
It is mostly used.

It is use to connect 4 bars.

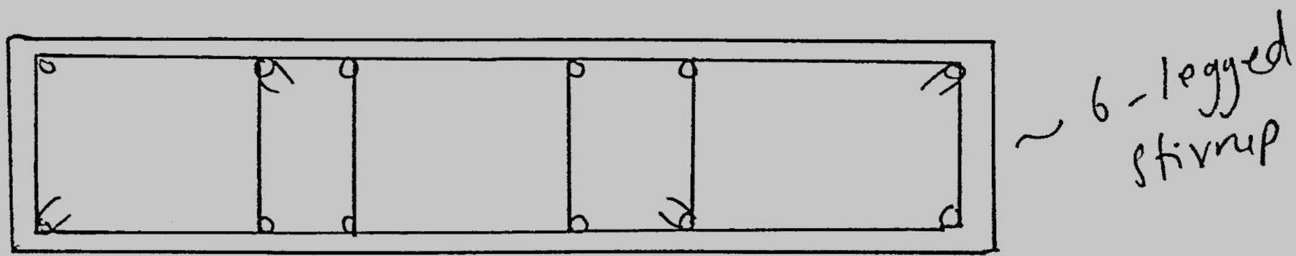


Four legged Stirrup:

These stirrups are used in case of web reinforcement.



Six Legged Stirrup



ACI CODES FOR SHER DESIGN OF BEAM

According to ACI-138 following are the formulas used for the shear design of a beam.

(1) Criticle Section:

Criticle section occure at 45° and is at distance (d) from the face of support which is equal to effective depth.

(2) Shear strenght Capacity of Concrete is:

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

(3) Minimum web reinforcemt:

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 reinforcemt equal to

$\phi = 0.75 \longrightarrow$ shear design

V_u = total factored shear applied at a given section.

⇒ For Minimum Reinforcement Area.

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

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

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

$$S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{F'c} \times b_w}$$ or $\frac{A_v \times f_y}{50 \times b_w}$ [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 two reinforcement can be find by

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

(5) **If $V_s \leq 4 \times \sqrt{f'_c} \times b_w \times d$ then max spacing for stirrup will be the smallest of the following:**

1- 24"

2- $d/2$

3- $S_{max} = \frac{A_u \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$

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

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

max. spacing will be halved

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

then either increase cross sectional dimension or increase f'_c.

Question No# 2

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 ~~required~~ reinforced with 7 in² of tensile steel area. If f'c = 4 ksi and Fy = 60 ksi then design the beam for shear.

Given Data:

$b_w = 14"$

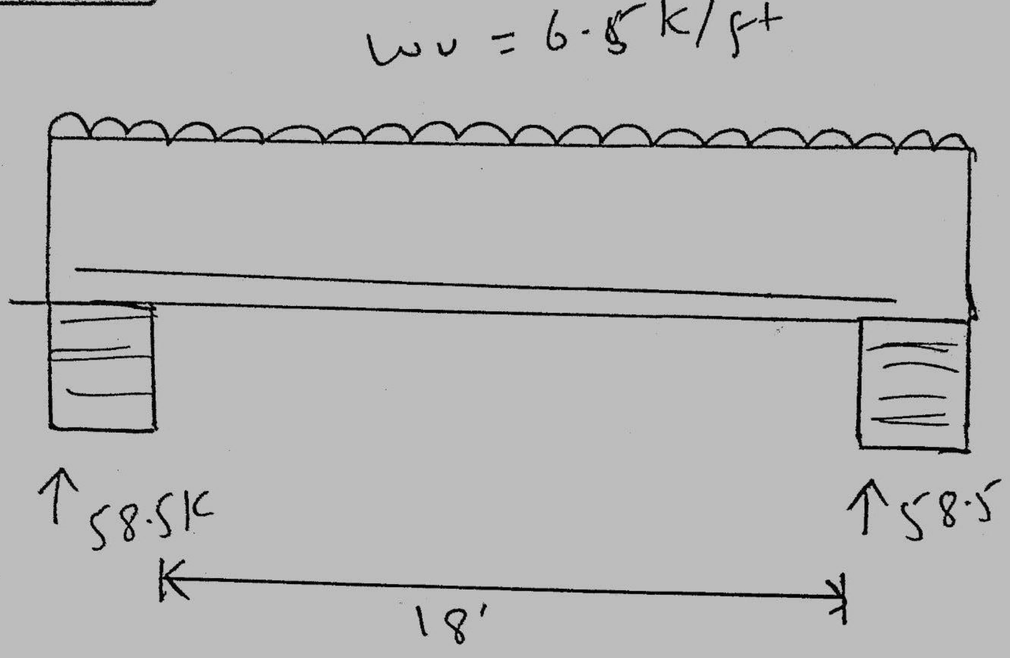
$d = 22"$

Load = 6.5 k/ft

$f'c = 4$ ksi

$f'y = 60$ ksi

Solution:



Step No# 1

Reactions on support

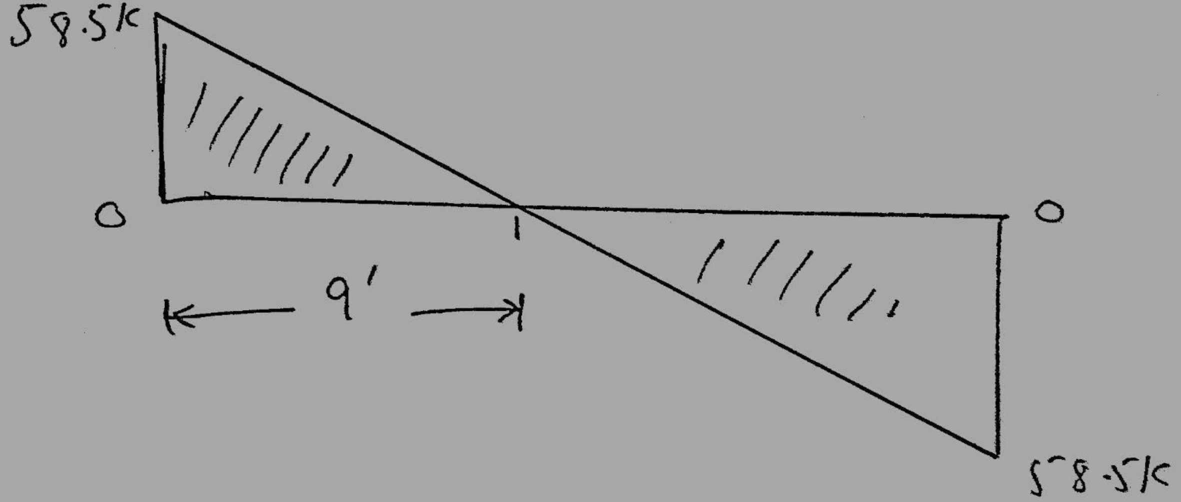
finding the reactions due to applied load

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

Step No # 2

Shear force diagram

To required shear diagram will be.



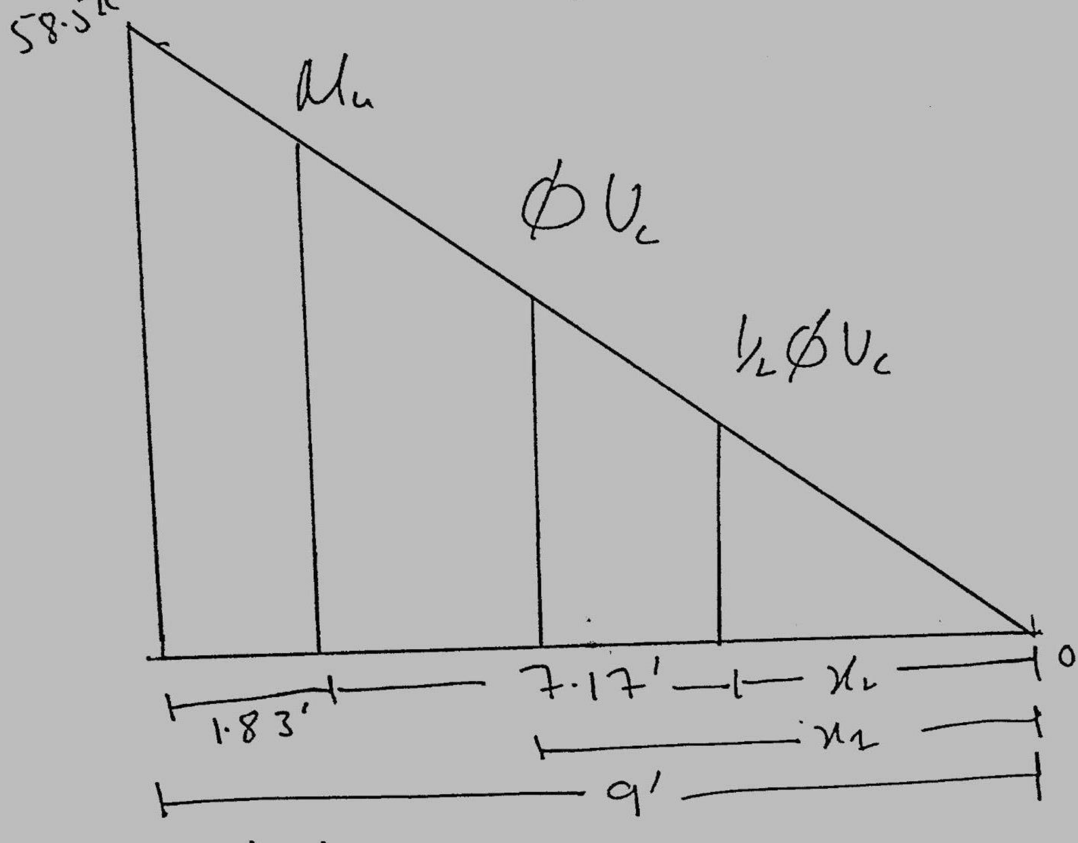
Step No # 3

Finding the value of criticle shear "Vu" and it location

As

we know that criticle shear is located at distance 'd' from face of support (d) = 22" = 1.83'

=) we will find the value of criticle shear at distance "d" by use of similiar traingles.



Step No # 4 ⇒

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

P.T.O

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 simlar traingles.

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

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

Similarly

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

$\Rightarrow$ 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 No#6

Finding the value of ϕV_s

By formula,

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

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

Step No#7

Check on section adequacy

By formula

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

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

$$= 116.87 \text{ Kips}$$

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

So section is Adequate.

Step No# 8

Check on maximum spacing for stirrups By Formula.

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

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

$= 58438$ lbs

= [illegible]

$= 58.43$ kips

As $\phi \times 4 \times \sqrt{F'_c} \times b_w \times d > \phi V_s$

So maximum will be selected from the following 4 conditions

1- $S_{max} = 24''$

2- $d/2 = 22/2$

3- $S_{max} \; \frac{A_u \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$

$$S_{max} = \frac{0.22 \times 6000}{0.75 \times \sqrt{4000} \times 14} = 19.87''$$

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

$$S_{max} = \frac{0.22 \times 60000}{50 \times 14}$$

$$S_{max} = 18.85''$$

Step No# 9
⟹

Stirrup spacing ~~for~~ from/at Criticle section will be

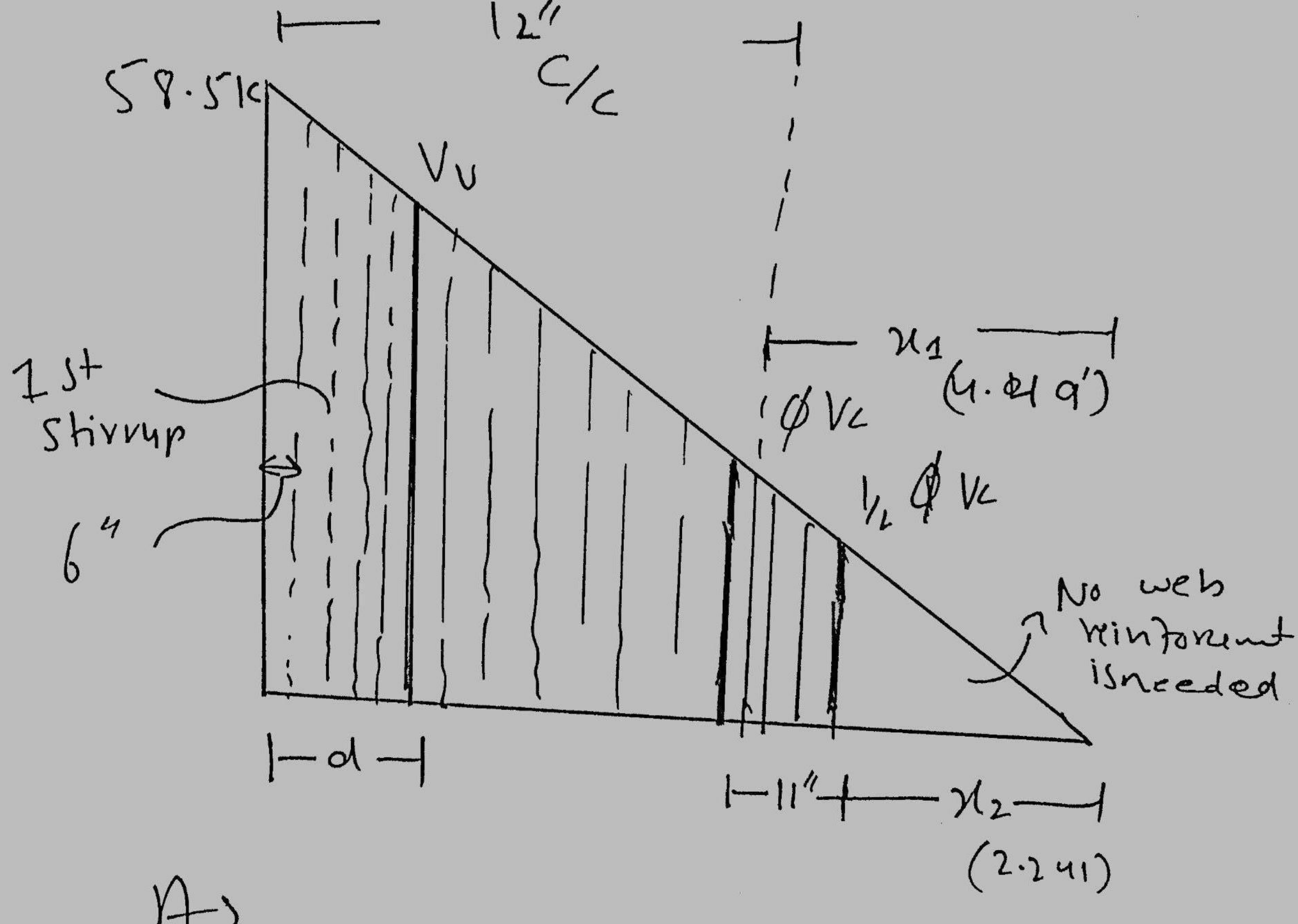
$$S = \frac{\phi \times A_v \times f_y \times d}{V_u - \phi V_c} = \frac{0.75 \times 0.22 \times 60 \times 22}{46.61 - 29.21}$$

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

$$S_o = 12'' \ c/c.$$

Step No# 10

Final Sketch will be



As

First stirrup from force of support

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

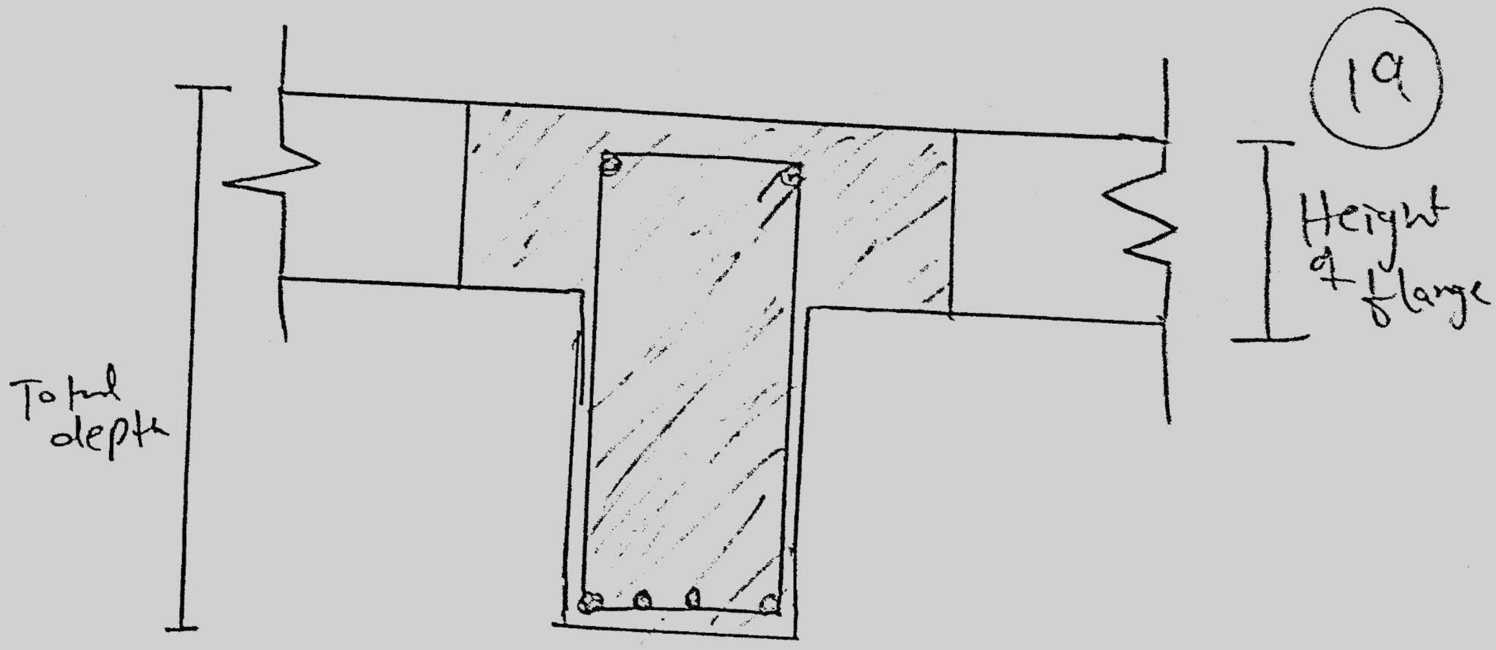
Question No# 3

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

T- Beam:-

~~It is the most~~

In most of the reinforced Concrete structure, Concrete slabs are cost monolitically with 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-beam

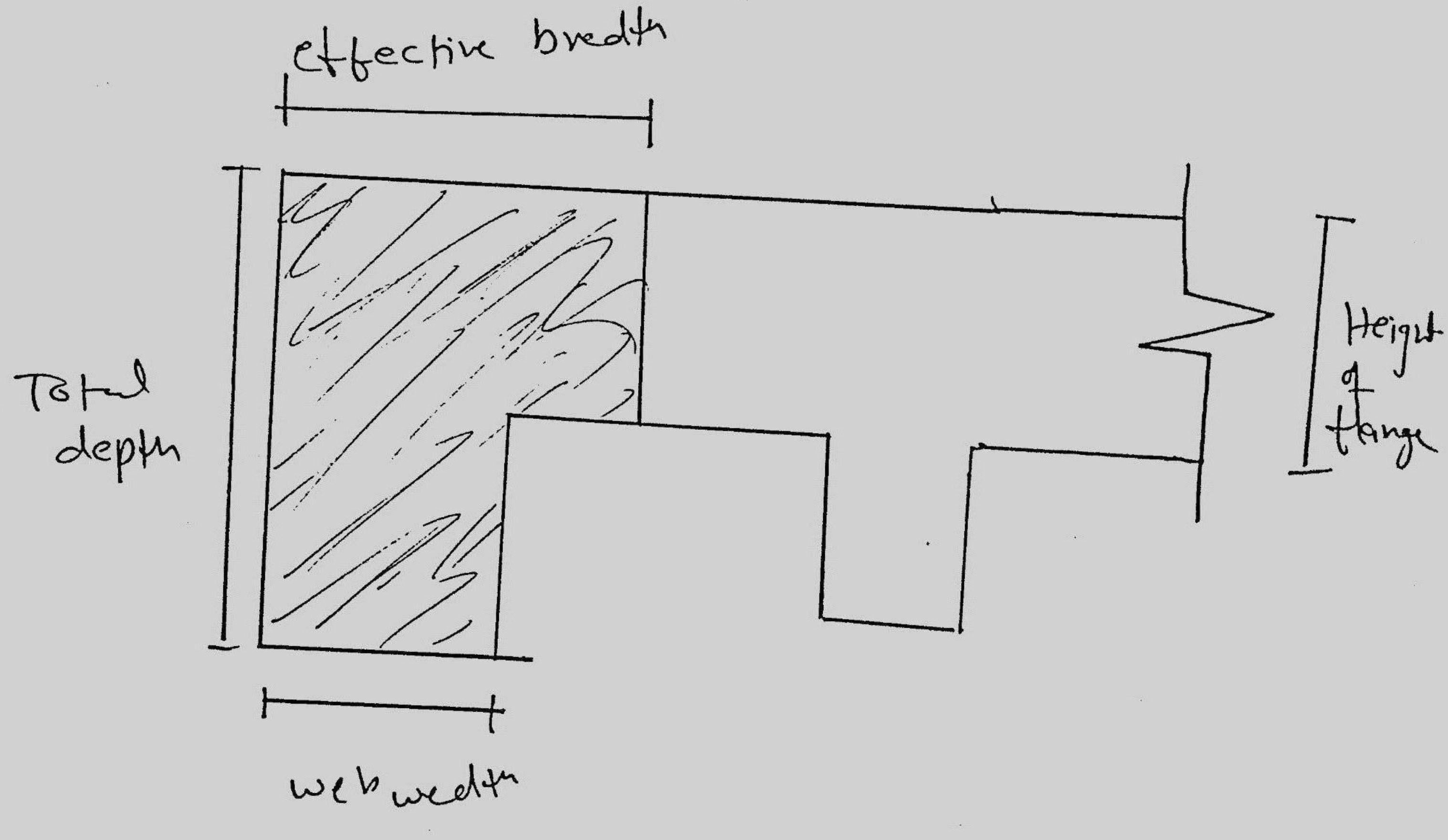
=> It is provided at the centre of the slab to resists the load.

=> 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 - Shaped structure that is in the contact with the slab and present at the corner of the floor is called L-Beam.



⇒ L - Beam are also called edge Beam

⇒ It is always provided at the Corners of the Slab

⇒ L - Beam are typical floor beam because of their reduced overall structural depth, the beam are in prestressed or reinforced concrete.

Flexural Analysis of T-Beam:-

flexural analysis of T- beam consists of the following steps

(1) For finding the ultimate factored moment, use the following formulas.

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

1 - 16 (hf) + bw

2 - c/c distance

3 - $\frac{CTS}{2}$ + bw

(3) Checking weather 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 Compressive block

h_f = Height of flange

(4) For finding Area of Steel, use.

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

where

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

(5) Formula for finding No of bars required is

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

(6) For checking the range of Reinforcement Ration

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

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

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

(7) For checking minimum width for bars accomodation:

$b_{min} = 2\,(\text{clear cover}) + 2\,(\text{dia of stirrup})$

$+ \text{No of bars}\,(\text{dia of bar})$

$+ \text{Spacing b/w bars}\,(\text{dia of bar}$

(8) Design moment is given by

if $a < h_f$

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

$M_d = \phi \times [A_s \times f_y \times (d - \frac{h_f}{2}) +$

$(A_s - A_{st}) + f_y \times (d - \frac{a}{2})$

If $a > h_f$

Question No# 4

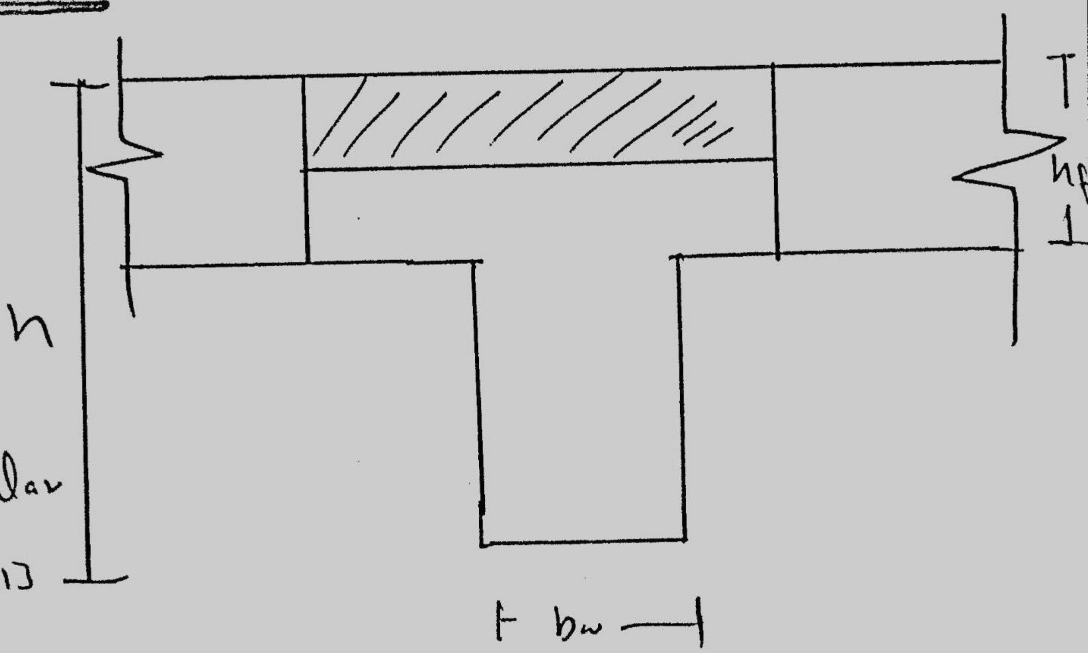
what is difference between (CASE I) and (CASE II) in the design of beam.

CASE I :

From the figure ach f

So in this Case Rectangular Beam Analysis is required,

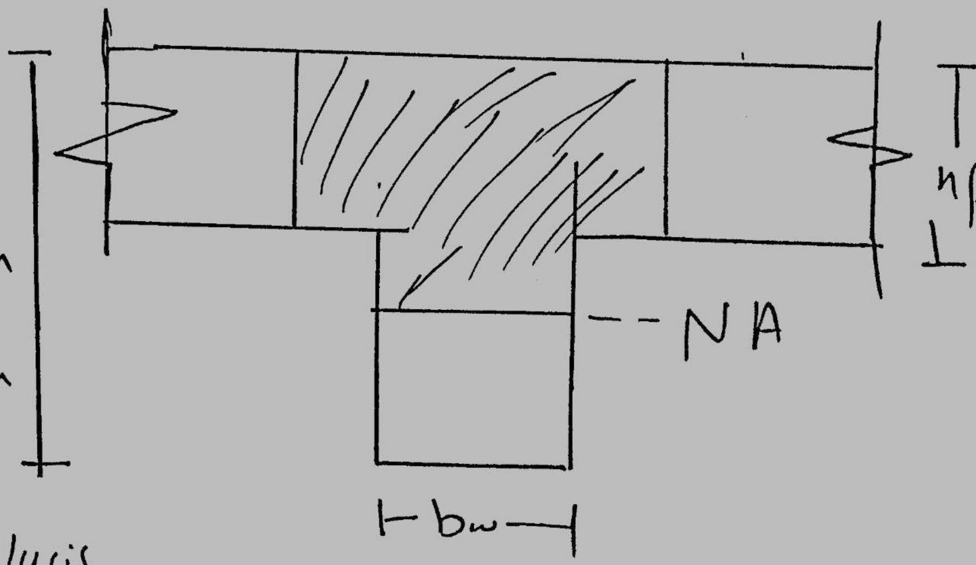
So, The design moment formula will be



Max $M_d = \phi \times f_y \times A_s \times (d - a/2)$

CASI II :-

For the figure a > hf



So in this, special beam analysis i.e. T-Beam analysis is required

So the required design moment will be

$$Md = \phi \times \left[As \times fy \times \left(d - \frac{hf}{2}\right) + (As - Asf) + Fy \times \left(d - \frac{a}{2}\right) \right]$$

Question No # 5

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 the total height is 23" Calculate the necessary flexural reinforcement if the factored applied moment is 5800 kip-inch, us $f'c = 3$ ksi and $F_y = 60$ ksi

Given :-

$h_f = 3.5"$

c/c distance = 9'

lenght / span of the beam = 16'

web width b_w = 10"

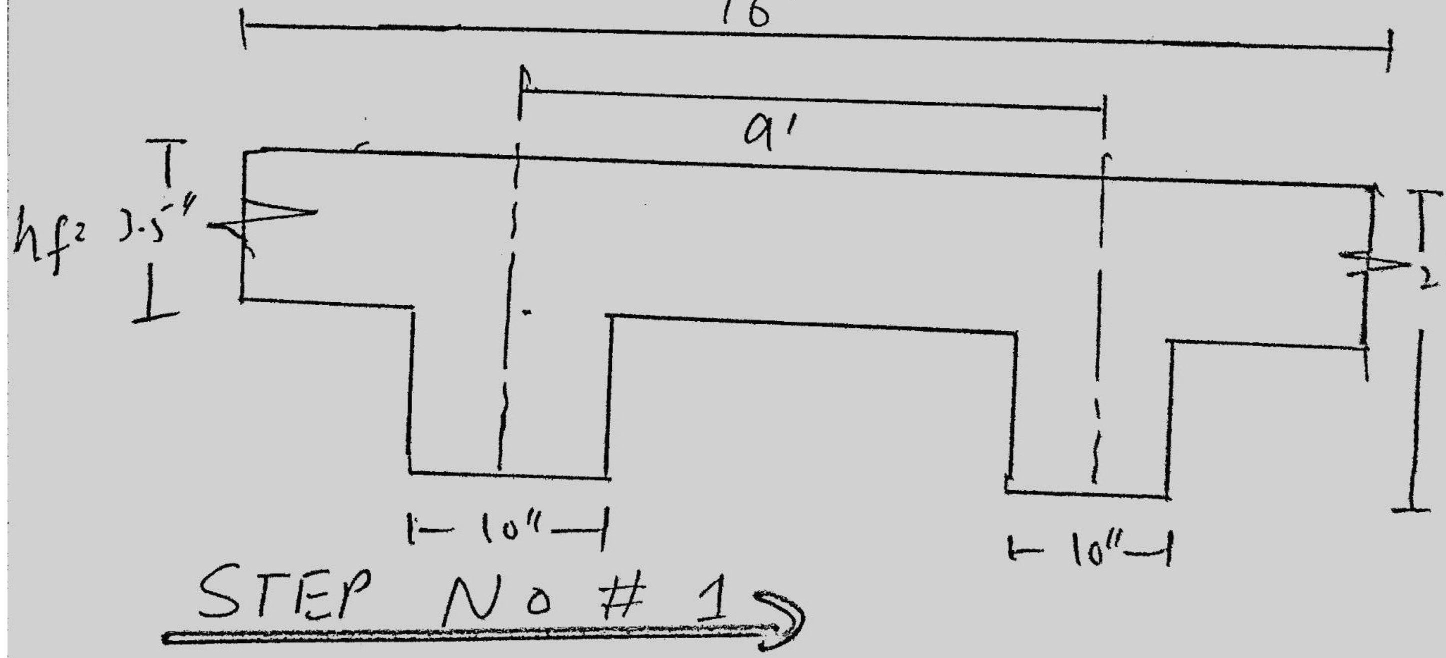
Effective depth (d) = 18"

Height (h) = 23"

total factored moment (Mu) = 5800 kip-inch

f'_c = 3 Ksi

f_y = 60 Ksi



STEP No # 1 ⇒

Calculate the effective width (b_e) fo T-beam

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

2- c/c distance = 9×12 = 108"

3- Span/4 = $\frac{16}{4} \times 12$ = 48" → select

Step No#2

Check ~~weath~~ wether rectangular or T-beam analysis is required.

Trail No# 1

Let $a = h_f = 3.5''$

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

$$= \frac{5800}{0.9 \times 60 \times (18 - 3.5/2}$$

$$= 6.61 \, in^2$$

Traid No #2

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

$$a = \frac{6.61 \times 60}{0.85 \times 3 \times 40}$$

$a = 3.2''$

$\boxed{Ast = 6.55 in^2}$ ⇒ $3.2'' < 3.5''$

So rectangular Beam design is required.

Traid No #3

$a = 3.21''$

and $Ast = \frac{5800}{0.90 \times 60 (18 - \frac{3.21}{2})}$

So area of steel is $6.55 in^2$ $\boxed{Ast = 6.55 in^2}$

Step No # 3

Check ρ_{max} and ρ_{min}

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

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

$$\rho_{max} = 0.013$$

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

$$\rho = \frac{Ast}{b \times d} = \frac{6.55}{10.18} = 0.031$$

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

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

⇒ First we have to find the Area of steel against ρ_{max}

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

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

$$A_{st} = 0.613 (10 \times 18)$$

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

Step No # 4

Finding the value of M_{u_2}:-

By Formula.

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

First finding the value of "a"

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

2.431

$$a = \frac{2.43 \times 60}{0.85 \times 16}$$

$$\boxed{a = 5.72''}$$

$\Rightarrow Mu_2 = 0.9 \times 2.43 \times 60 \times (18 - \frac{5.72}{2})$

As $Mu_2 < Mu$

$1986.67 < 5800$

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

Step No # 5 ⟹

Finding differences in moment and area of steel.

$Mu_1 = Mu - Mu_2$

$Mu_1 = 5800 - 1986.67$

$Mu_1 = 3813.33$ kip-inch

By Formula.

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

$$A_{st}' = \frac{3813.33}{0.90 \times 60 \times (18-2.5)}$$

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

Step No #6 →

Finding the total steel Area.

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

$$A_s = 2.43 + 4.56$$

$$A_s = 6.99\ in^2$$

Step No#7 ⟹

Selection of ~~total~~ Bar

IN TENSION ZONE:

let we use #8 bar.

$$\text{dia}\left(\frac{8}{8}\right) = 1''$$

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

By formula.

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

$$= \frac{6.99}{0.785}$$

$$= 8.9 \approx 9$$

So 9 Bar #8

IN COMPRESSION ZONE

let we use #7 bar

$$\text{dia} = \left(\frac{7}{8}\right)'' \quad \& \quad \text{Area} = \frac{\pi}{4}(7/8)^2$$

$$\text{Area} = 0.601 \text{ in}^2$$

By Formula.

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

$$= \frac{4.56}{0.601}$$

$$= 7.5 \approx 8$$

So 8 #7 bars.

Step No: 8

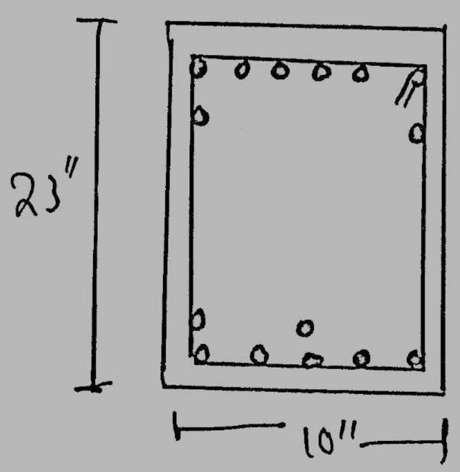
Minimum width for Accomodation of bar

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

$= 20.75''$

As $20.75'' > 10''$

So the bar will be placed in multiple layer



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

effective cover $(d') = 1.5 + \frac{3}{8} + \frac{7}{8} + \frac{1}{2}(\frac{7}{8}) = 31.8''$

Step No# 9 →

Finding the design moment

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

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

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

$= 5.31''$

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

$M_d = 6328.38$

As $6328.38 > 5800$ → So design is ok!

Question No # 6

A beam ~~re~~ is revised to developed and ultimate moment of 6000 kip-inch 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.

Given:

$b = 14''$

$h = 26''$

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Concrete Compresion Strengut ($f'c$) = 4 Ksi

Steel tensile strengut (fy) = 60Ksi

Ultimate Factored moment (Mu) = 600 kip-inches

Effective depth of beam (d) = 22"

Assume effective Cover (d') = 2.5"

Step No # 1

Reinforcement ration

By Formula

$$\rho_{max} : 0.85 \times \beta \times \frac{f'c}{fy} \times \left(\frac{\varepsilon_u}{\varepsilon_y + \varepsilon_u} \right)$$

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

$$\rho_{max} = 0.0180$$

Step No # 2

Area of Steel

$\rho_{max} = \frac{Ast}{b \times d}$

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

$Ast = 0.018 \times (14 \times 22)$

$Ast = 5.54 \, in^2$

Step No # 3

Design moment

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

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

$$a = \frac{5.54 \times 60}{0.85 \times 4 \times 14}$$

$a = 6.98''$

So

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

$Mu_2 = 5537.4$ kip-inch

As

5537.4 < 600

So we will design section doubly reinforced.

Step No# 4 ⇒

Area of steel.

$$Mu_1 = \phi \times Ast \times fy \times (d - d')$$

So area of steel in compressive zone will be

$$A'st = \frac{Mu_1}{\phi \times fy \times (d-d')}$$

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

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

Step No#6 ⟹

Total steel area

$$Ast = Ast + Ast'$$

$$As = 5.54 + 0.44$$

$$\boxed{As = 5.98 in^2}$$

Step No#7

Seletion of Bar and bar number.

1- Steel in tension zone.

we ~~tran~~ use # 7 bare

dia $(7/8)'' = 0.875''$

Area $= \frac{\pi}{4}(0.875)^2$

Area $= 0.601\ in^2$

So

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

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

10 # 7 bars.

2- Steel in compression zone.

we use #5 bar.

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

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

$Area = 0.306 in^2$

So

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

$No\ of\ bar = \frac{0.44}{0.306}$

$No\ of\ bar = 1.43 \approx 2\ bar$

So 2 # 5 ~~bars~~. bars.

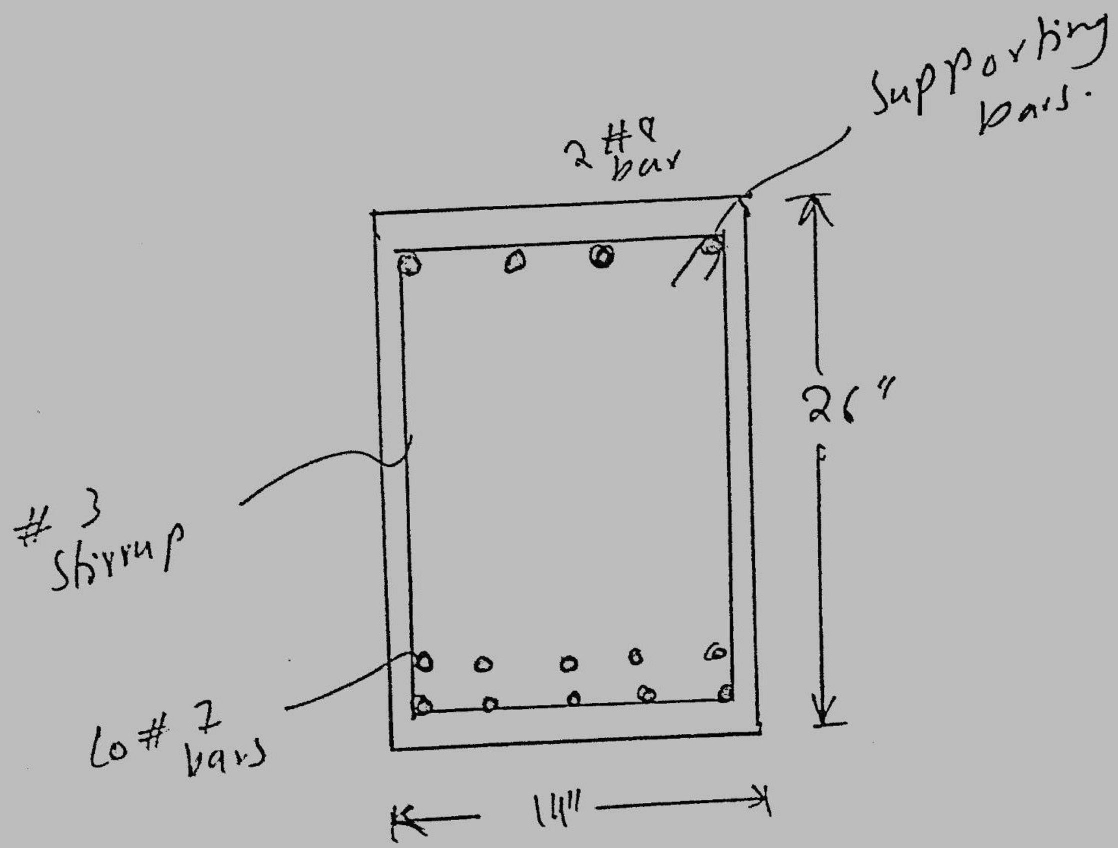
Step # No # 8

Minimum width of Beam.

$$b_{min} = 2(1.5) + 2\left(\frac{3}{8}\right) + 10\left(\frac{7}{8}\right) + 9\left(\frac{7}{8}\right)$$

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

so ~~Best~~ will provide in two layer.



Now

$\Rightarrow$ effective depth (d) $= 26 - 1.5 - \frac{3}{8} - \frac{7}{8} - \frac{1}{2}\left(\frac{7}{8}\right)$

$\Rightarrow$ effective depth (d) $= 22.82''$

$\Rightarrow$ effective cover (d') $= 1.5 + 3/8 + 1/2\,(5/8)$

effective cover (d') $= 2.18''$

Step No# 9 $\Rightarrow$

Design Moment.

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

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

50

$$a = \frac{(10 \times 0.601 - 2 \times 0.306) \times 60}{0.85 \times 4 \times 14}$$

$$a = 6.80''$$

$$M_d = 0.90\left[(2 \times 0.301) \times 60 \times (22.82 - 2.18) + (10 \times 0.601 - 2 \times 0.306) \times 60 \times (22.82 - 6.80/2)\right]$$

$M_d = 7047.6$ kip inches

As $7047.6 > 6000$

Design is safe and ok.