Question 1 :-

GIVEN DATA:-

Clear span b/w support = 15'

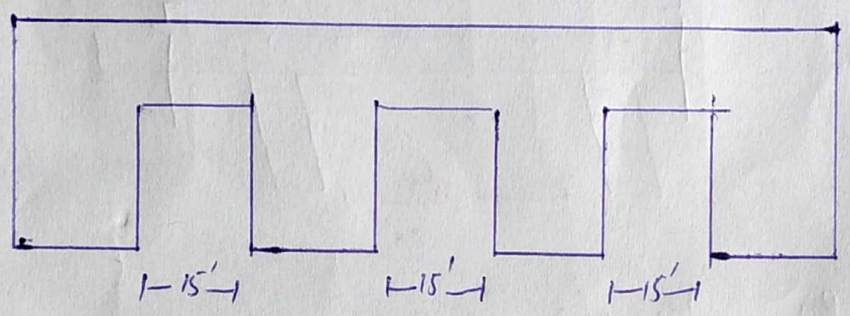
Factored live load = 160 lb/ft²

servis floor finish load = 20 lb/ft²

$f'_c = 4000\ Psi$

$f_y = 40\ ksi$

Sol:-



step# 1:- Minimum Thickness

By using formula

$$t_{min} = l/28 = \frac{15}{28} = 6.4 \approx 6.5''$$

As $F_y \rightarrow 40\ ksi$

so we will multiply a factor with this thickness

$$\text{Factor} = \left(0.4 + \frac{F_y}{100}\right)$$

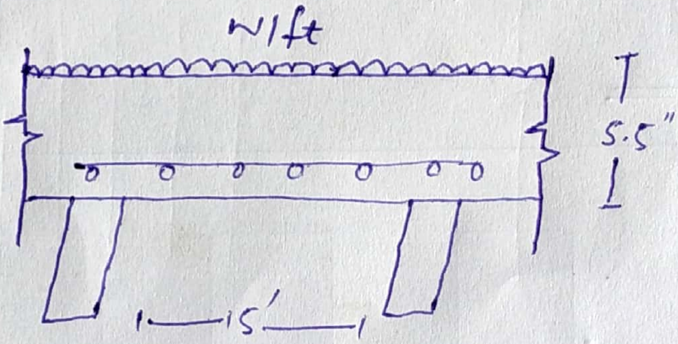
$= \left(0.4 + \frac{40}{100}\right) = 0.8$

Hence the minimum thickness will be

6.5×0.8

$t_{min} = 5.2 \approx 5.5''$

• Step # 2 :- Effective depth :-



By formula

$d = t - \text{clear cover} - \frac{1}{2}(\text{dia of main bars})$

$= 5.5 - 0.75 - \frac{1}{2}(5/8)$

$d = 4.5''$

• Step # 3 :- self wt. of slab :-

By formula

$\frac{t}{12} * \gamma_{concrete}$

$= \frac{5.5}{12} \times 150 = 68.75\ lb/ft^2$

Step # 4 Total factored load :-

Factored live load = 160 lb/ft²

So the factored dead load will be

$D.L = 1.2 (20 + 68.75) = \boxed{106.5 \text{ lb/ft}^2}$

Total factored load = D.L + L.L

= 106.5 + 160

$TFL = 266.5 \text{ lb/ft}^2 \Rightarrow \boxed{0.2665 \text{ k/ft}^2}$

Step # 5 ultimate Moment :-

By using formula

$$M_u = \frac{w_u \times l^2}{8} = \frac{0.2665 \times (15)^2 \times 12}{8}$$

$$\boxed{M_u = 89.94 \text{ kips-inches}}$$

Step # 6 :- Area of steel for main bars by trail and repeat method :-

Trial # 1 :-

let depth of compression block

$a = 0.2 \times t$

$= 0.2 \times 5.5 = 1.1''$

$$A_{st} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{89.94}{0.90 \times 40 \times (45 - \frac{1.1}{2})}$$

$$\boxed{A_{st} = 0.63\ in^2}$$

* **Trial # 2 :-**

$$a = \frac{A_s f_y}{0.55 \times f_c' \times b} = \frac{0.63 \times 40}{0.85 \times 4 \times 12} = \boxed{0.62\ in^2}$$

$$A_{st} = \frac{M_u}{\phi \times f_y (d - \frac{a}{2})} = \frac{89.94}{0.90 \times 40 (4.5 - 0.6/2)}$$

$$\boxed{A_{st} = 0.59\ in^2}$$

* **Trial # 3 :-**

$$a = \frac{0.59 \times 40}{0.85 \times 4 \times 12} = \boxed{0.57''}$$

$$A_{st} = \frac{89.94}{0.90 \times 40 (4.5 * \frac{0.57}{2})}$$

$$\boxed{A_{st} = 0.59\ in^2}$$

So we will use $\boxed{A_{st} = 0.59\ in^2}$

step # 7 :- Area of Steel for distribution reinforcement

By formula

$A_{min} = 0.002 \times b \times t$ — (for grade 40 steel)

$0.002 \times 12 \times 5.5 = \boxed{0.132\ in^2}$

step # 8 :- spacing for main bars :-

By formula

$\text{spacing} = \frac{A_b}{A_{st}} \times 12$

we use # 6 bar dia = (6/8)"

$\text{Area} = \frac{\pi}{4}(6/8)^2 = \boxed{0.442\ in^2}$

step # 9 :- spacing for distribution bar

$\text{spacing} = \frac{A_b}{A_{st}}$

we use #5 bars so

$\text{dia} = (5/8)''$, $\text{Area} = \frac{\pi}{4}(5/8)^2 = \boxed{0.31\ in^2}$

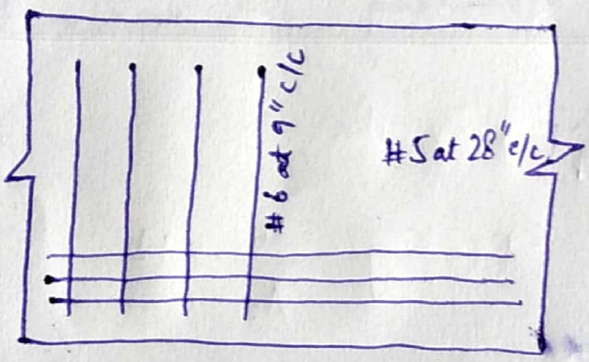
$\text{spacing} = \frac{0.31}{0.132} \times 28.1 \approx \boxed{28''\ c/c}$

* **Step # 10 sketch:-**

$f'_c = 4$ ksi , $f_y = 40$ ksi

Main Steel # 6 at 9" c/c

Distribution Steel # 5 at 28" c/c



Q # 2 :-

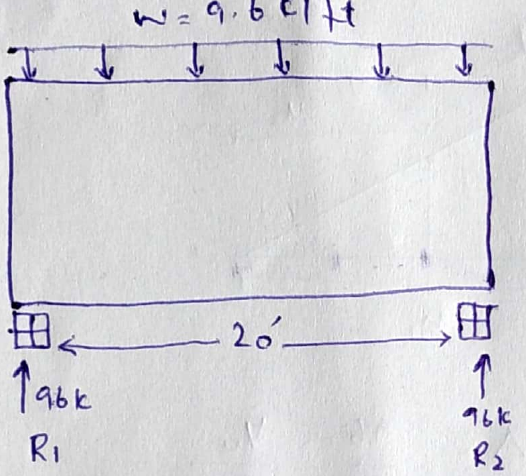
At first find the unit load of beam so

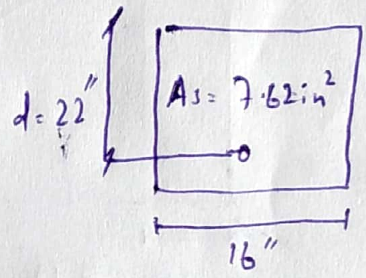
$b \times \gamma_c$

$\Rightarrow \frac{16}{12} \times 150 = 200 \text{ lb/ft} = 0.2 \text{ k/ft}$

total factored load $= 9.4 + 0.2$

$= 9.6 \text{ k/ft}$

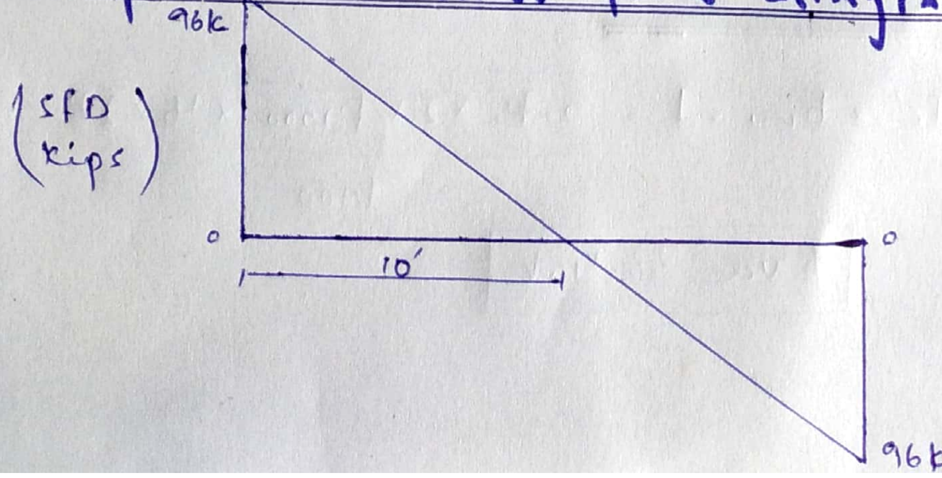




Step # 1 :- find value of "R1" and "R2"

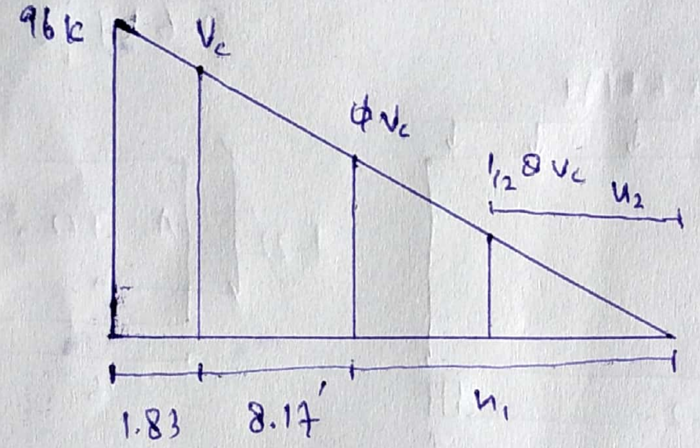
total load $= 9.6 \times \frac{20}{2} = \boxed{96 \text{ k}}$

Step # 2 :- shear force diagram :-



step # 3 :- value of critical stress "V_u" and its location :-

As we know that location is located distance "d" from face of support $d = 22'' = 1.83'$ value of critical shear at distance "d" by similarity triangles.



from similar Δ's $\frac{96}{10} = \frac{V_u}{8.17}$

$$V_u = 78.43 \text{ k}$$

step # 4 :- finding value of "ϕV_c" and "$\frac{1}{2} \phi V_c$" and its distance from zero shear to right side.

$$\phi V_c = \phi \times 2 \times \sqrt{F_c'} \times b_w \times d = \frac{0.75 \times 2 \times \sqrt{4000} \times 16 \times 22}{1000}$$

$$\phi V_c = 33.40 \text{ k}$$

location of ϕV_c by similarity of $\Delta s'$

$$\frac{96}{10m} = \frac{33.40}{x_1}$$

$$\boxed{x_1 = 3.48'}$$

Now

$$\frac{1}{2}\phi V_c = \frac{33.40}{2} = \boxed{16.70\,k}$$

location of $\frac{1}{2}\phi V_c \Rightarrow \frac{96}{10} = \frac{16.70}{x_2}$

$$\boxed{x_2 = 1.74'}$$

* **Step # 5 :- find value of ϕV_s ($V_u = \phi V_s + \phi V_c$)**

so we have

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

$$\phi V_s = 78.43 - 33.40$$

$$\boxed{\phi V_s = 45.03\,k}$$

* **Step # 06 :- check Section Adequacy :-**

$$\phi \times 8 \times \sqrt{f_c'} \times b_w \times d = \frac{0.75 \times 8 \times \sqrt{4000} \times 16 \times 22}{1000}$$

$$\boxed{= 133.57\,k}$$

$133.57\,k > \phi V_s$ (mean Section is adequate)

step # 7 :- check mini spacing for Stirrups :-

$\phi \times 4 \times \sqrt{f_c'} \times b_w \times d \Rightarrow \dfrac{0.75 \times 4 \times \sqrt{4000} \times 16 \times 22}{1000}$

$\boxed{= 66.79\,k} \rightarrow \phi V_s = 44.03\,k$

Thus max spacing will be selected from the following 4 conditions.

① $S_{max} = 24''$

② $\dfrac{d}{2} = \dfrac{22}{2} = 11''$

③ $S_{max} = \dfrac{A_v \times f_y}{0.75\sqrt{f_c'} \times b}$

$A_v = \dfrac{\pi}{4}\left(\dfrac{3}{8}\right)^2 \because A_v = 0.11 \times 2 = 0.22$

$S_{max} = \dfrac{0.22 \times 60000}{0.75 \times \sqrt{4000} \times 16}$

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

$S_{max} = \dfrac{0.22 \times 60\,000}{50 \times 16} = 16.50$

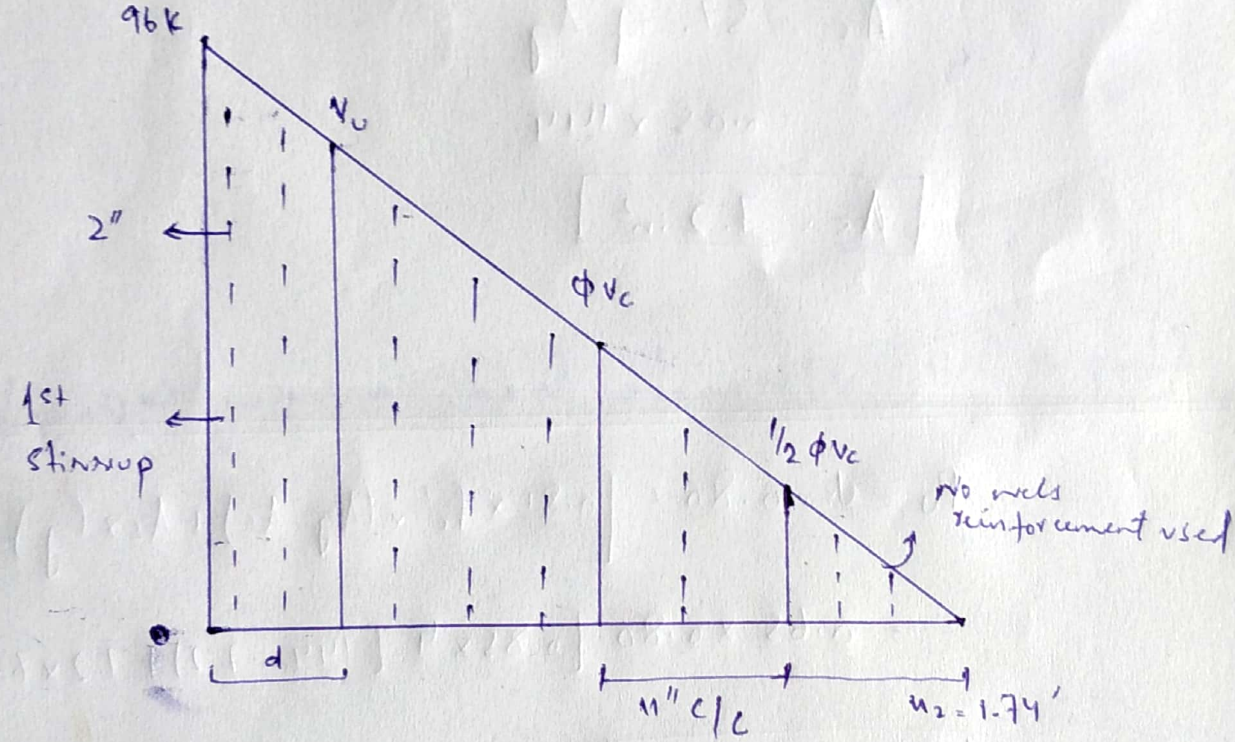
From above 4 conditions least value for spacing for # 3 ✓ spaced will be selected so $S_{max} = 11''$ c/c

Step #8 :- Spacing of Stirrup from at critical section :-

$$S = \frac{\phi \times A_v \times f_y \times d}{V_u - \phi V_c} = \frac{0.75 \times 0.22 \times 60 \times 22}{78.43 - 33.40}$$

$$S = 4.84 \approx 5'' \, c/c$$

Step # 9 :- Final Sketch :-



we know that first stirrup from face of support = $S/2$ = 2.5 ≈ 2"

* Q # 3 :-

* Step # 1 :- find gross Area of concrete :-

$A_g = b \times b$ (since it is squared tied column)

$A_g = 12 \times 12 = 144 in^2$ (Actual)

+1 Step # 2 :- Area of Steel :-

$A_s = 5\%$ of A_g

$= 0.05 \times 144$

$A_s = 7.2 in^2$

+1 Step # 3 :- ultimate load carrying capacity :-

$P_u = \phi \times 0.80 \times [0.85 \times f_c' \times (A_g - A_s) + A_s \times f_y)$

$= 0.65 \times 0.80 [0.85 \times 4 [144 - 7.2) + 7.2 \times 60]$

$P_u = 466.50k$

+1 Step # 4 :- sketch ⁿ, design of Ties (c/c to distance)

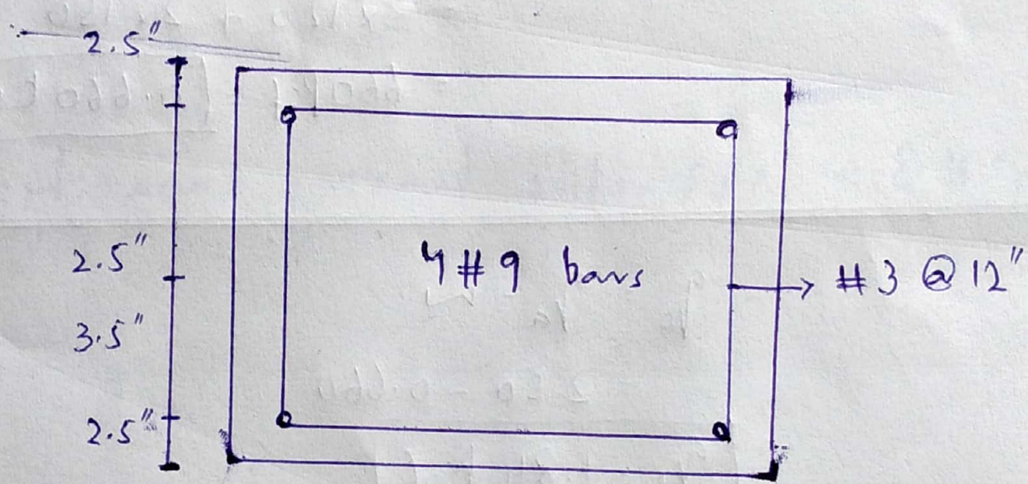
from the below value we chose the least value of all thus;

① 16x dia of long bar = $16 \times \frac{9}{8}$ = 18"

② 48x dia of tie bar = $48 \times \frac{3}{8}$ = 18"

③ least column dimension = 12"

so c/c distance b/w ties = 12"



*⇒ Since it is a tied square column so there is no spiral stirrup used, the stirrup used is of rectangular shape due to the specification of the structure thus we will use tie stirrups instead.

Q No # 4 :-

step# 1 :-

let h = 24"

step # 2 :-

Total weight = wt. of soil + wt. of Rc

= 3x120 + 2x150

= 660 psf = **0.660 ksf**

step # 3 :- effective bearing capacity :-

$q_e = q_a - w$

$= 2.50 - 0.660$

$\boxed{q_e = 1.84 \text{ ksf}}$

step # 4 :- Required Area for foundation

$A_{req} = \frac{\text{Service load}}{q_e} = \frac{100 + 120}{1.84}$

$\boxed{= 119.57 \text{ ft}^2}$

step # 5 :- since foundation is square :-

$A_{req} = b \times b = 119.57 \Rightarrow B \cong 11'$

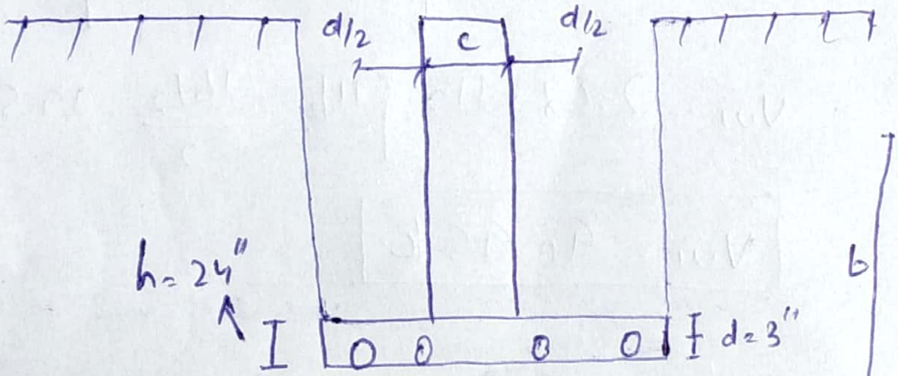
Step # 6 :- upward bearing capacity of Soil :-

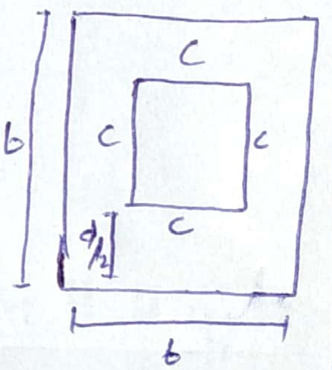
$$q_{up} = \frac{\text{Factored load}}{(B)^2} = \frac{1.2\times100+1.6\times120}{11^2}$$

$$q_{up} = 2.58\ k/ft^2$$

Step # 7 :- Punching Shear :-

$$b_o = 4\times(c+d)$$





$d = h - c.c - \text{dia of bar} - \tfrac{1}{2} d_b$

$= 24 - 3 - 1 - \tfrac{1}{2}(1) = 19.5''$

$b_o = 4\times(16+19.5) = 142''$

∴ Take #8 bar

dia $= \frac{8}{8} = 1''$

Step # 8 :-

$$V_{u2} = q_{up}\times\left[B^2 - (c+d)^2\right]$$

$$= 2.58\times\left[11^2 - \left(\frac{16+19.5}{12}\right)^2\right]$$

$$V_{u2} = 289.60k$$

Step # 9 :-

$$\phi V_{c/p} = \phi \times 4 \times \sqrt{f'_c} \times b \times d$$

$$= \frac{0.75 \times 4 \times \sqrt{4000} \times 142 \times 19.5}{1000}$$

$$\boxed{\phi V_{c/p} = 525.38}$$

Step # 10 :- Beam shear/one way shear check :-

$$V_{u1} = q_{up} \times B \times \left[B/2 - c/2 - d \right]$$

$$V_{u1} = 2.58 \times 11 \times \left[11/2 - \frac{16/2}{2} - 19.5 \right]$$

$$\boxed{V_{u1} = 90.95\,k}$$

Step # 11 :- self shear capacity :-

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

$$= \frac{0.75 \times 2 \times \sqrt{4000} \times [11 \times 12.16]}{1000}$$

$$\boxed{= 110.04\,k > V_{u1} \Rightarrow ok.}$$

Step # 12 :- ultimate moment :-

$$M_u = \frac{q_{up} \times B}{8} \times (B - c)^2 = \frac{2.58 \times 11}{8} \times \left(11 - \frac{16}{12}\right)^2$$

$$\boxed{M_u = 331.49\,k' \text{ or } 3977.93\,k''}$$

Step # 13 :- Area of steel for main bars by trial and reped method :-

* **Trial # 1 :-**

let $a = 0.2 \times h = 0.2 \times 24 = 4.8''$

$$A_s = \frac{M_u}{\phi \times f_y (d - a/2)} = \frac{3977.3}{0.90 \times 60 \left(11 - \frac{4.8}{2}\right)} = \boxed{8.56 in^2}$$

* **Trial # 2 :-**

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{8.56 \times 60}{0.85 \times 3 \times 11 \times 12} = \boxed{1.53''}$$

$$A_s = \frac{3977.3}{0.90 \times 60 \times \left(11 - \frac{1.53}{2}\right)} = \boxed{7.197''}$$

* **Trial # 3 :-**

$$a = \frac{7.197 \times 60}{0.85 \times 3 \times 11 \times 12} = \boxed{1.28''}$$

$$A_s = \frac{3977.93}{0.90 \times 60 \times \left(11 - \frac{1.28}{2}\right)} = \boxed{7.1 in^2}$$

So that area = $7.1 in^2$

Step # 14 :- Check the min reinforcement by the following 3 method :-

(a) $A_{s\,min} = 0.0018 \times B \times h = 0.00018 \times (11 \times 12) \times 24$

$= 5.70\ in^2$

(b) $A_{s\,min} = \frac{200}{f_y} \times B \times d = \frac{200}{60000} \times (11 \times 12) \times 19.5$

$= 8.58\ in^2$

(c) $A_{s\,min} = \frac{3 \times \sqrt{f_c'}}{f_y} \times B \times d = \frac{3 \times \sqrt{3000}}{60000} \times (11 \times 12) \times 19.5$

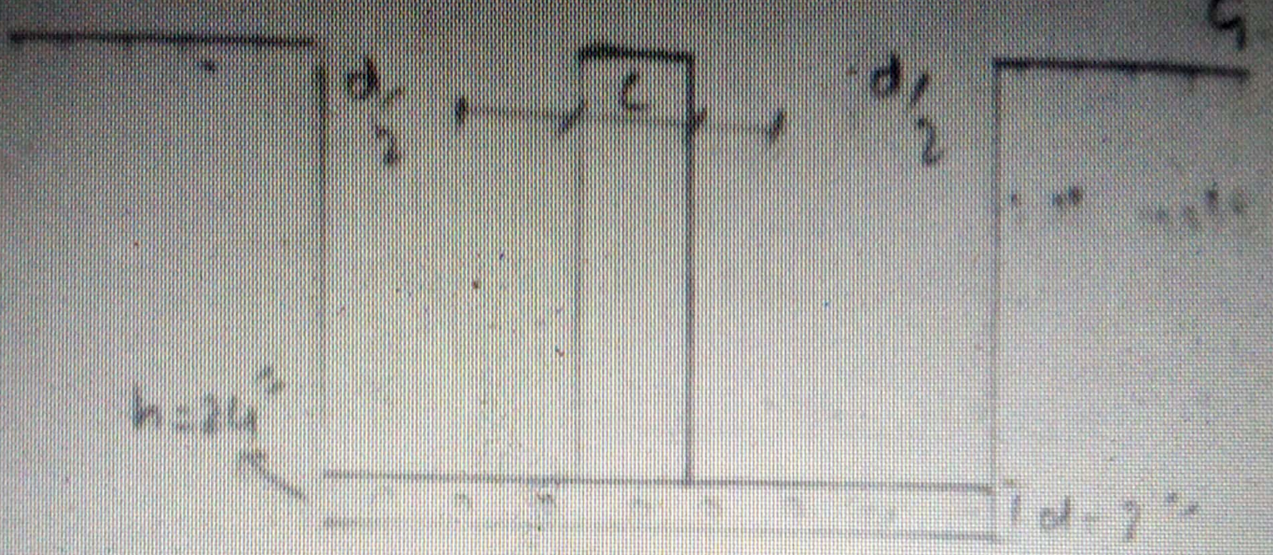
$= 7.05\ in^2$

from above value greater value will be selected Thus $A_{s\,min} = 8.58\ in^2$

Step # 15 :- Using #8 bar :-

$A_b = 0.785\ in^2$

No. of bars $= \frac{A_s}{A_b} = \frac{8.58}{0.785} = 10.92 \approx 11$ bars in each direction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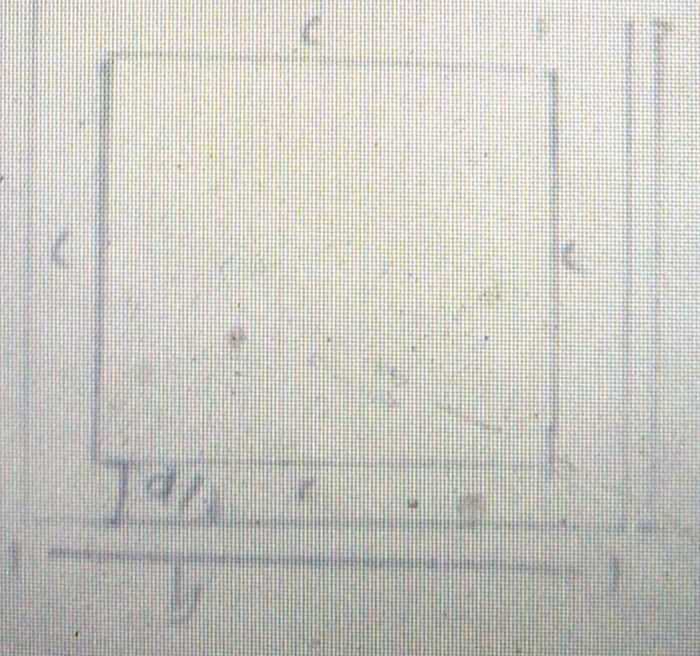
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