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Subject :- Plain and Reinforced Concrete Design - I

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# ( QUESTION - 01)

## GIVEN DATA:-

=> 3 equal spans concrete slab

=> clear span b/w supports = 15 ft

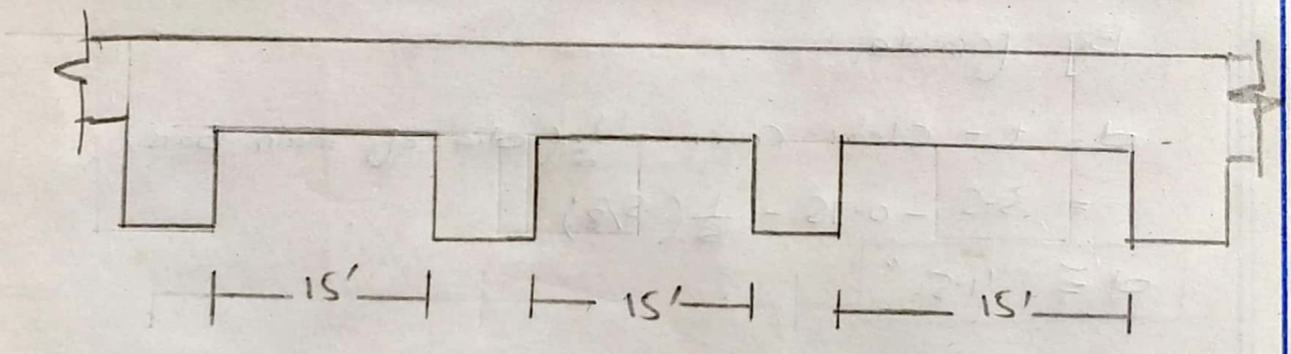
=> Factored live load = 160 lb/ $ft^2$

=> Service Floor ~~finish~~ finish load = 20 lb/ $ft^2$

=> $f'_c$ = 4000 psi

=> $f_y$ = 40 ksi

## SOLUTION:-




## STEP #1 (Minimum Thickness)

By using formula

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

As $f_y \rightarrow 40$ ksi

So we will multiply a factor with this thickness

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

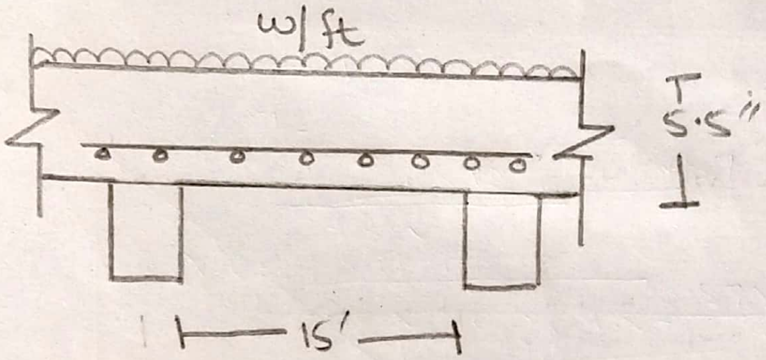
$$= \left(0.4 + \frac{40}{100}\right) = 0.8$$

Hence the minimum thickness will be

$6.5 \times 0.8$

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

## STEP # 2 :- (Effective Depth)




By formula

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

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

$\boxed{d \cong 4.5''}$

## STEP # 03 :- ( Self Wt. of Slab)

By formula

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

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

## STEP # 04:- ( Total Factored Load)

Factored live load $= 160 \text{ lb/ft}^2$

So the Factored Dead load will be

$D \cdot L = 1 \cdot 2(20 + 68 \cdot 75) = 106 \cdot 5 \ lb/ft^2$

Total Factored Load = D·L + L·L

$= 106 \cdot 5 + 160$

$= 266 \cdot 5 \ lb/ft^2 = 0 \cdot 2665 \ K/ft^2$

## STEP # 5 :- (Ultimate Moment)

By using formula

$$M_u = \frac{w_u \times L^2}{8} = \frac{0 \cdot 2665 \times (15)^2}{8} \times 12$$

$$\boxed{= 89 \cdot 94 \ \text{kip-inches}}$$

## STEP # 6 :- Area of Steel For Main Bars By Trial and Repeat Method

### Trial # 01 :-

Let depth of Compression block

$a = 0 \cdot 2 \times t$

$= 0 \cdot 2 \times 5 \cdot 5 = 1 \cdot 1''$

$$A_{st} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{89 \cdot 94}{0 \cdot 90 \times 40 \times (4 \cdot 5 - \frac{1 \cdot 1}{2})}$$

$A_{st} = 0 \cdot 63 \ in^2/ft$

### Trial # 02 :-

$$a = \frac{A_{st} \times f_y}{0 \cdot 85 \times f'_c \times b} = \frac{0 \cdot 63 \times 40}{0 \cdot 85 \times 4 \times 12} = 0 \cdot 62''$$

$$A_{st} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{89.94}{0.90 \times 40 \times (4.5 - \frac{0.62}{2})}$$

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

## Trial # 03 :-

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

$$A_{st} = \frac{89.94}{0.90 \times 40 \times (4.5 - \frac{0.57}{2})} = \boxed{0.59\ in^2/ft}$$

So we will use

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

## STEP # 07 :- (Area of Steel For Distribution Reinforcement)

By formula

$$A_{s\,min} = 0.002 \times b \times t \rightarrow \text{For Grade 40 Steel}$$

$$= 0.002 \times 12 \times 5.5 = 0.132\ in^2/ft.$$

## STEP # 08 :- (Spacing For Main Bars)

By formula of spacing

$$\text{Spacing} = \frac{\text{Area of one bar}}{\text{Area of steel}} \times 12$$

we are using #5 bar

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

~~$S = \frac{0.59}{0.31} \times 12$~~

$$S = \frac{0.31}{0.59} \times 12 = 6.31 \simeq 6.0''$$

Hence $6.0''$ c/c

## STEP #9 :- (Spacing For Distribution Bars)

Also by using formola

$$\text{Spacing} = \frac{\text{Area of one bar}}{\text{Area of steel}}$$

we are using #5 bar , so

dia = $(5/8)''$ , Area = $0.31\ in^2$

$$\text{Spacing} = \frac{0.31}{0.132} \times 12 = 28.1 \simeq 28'$$

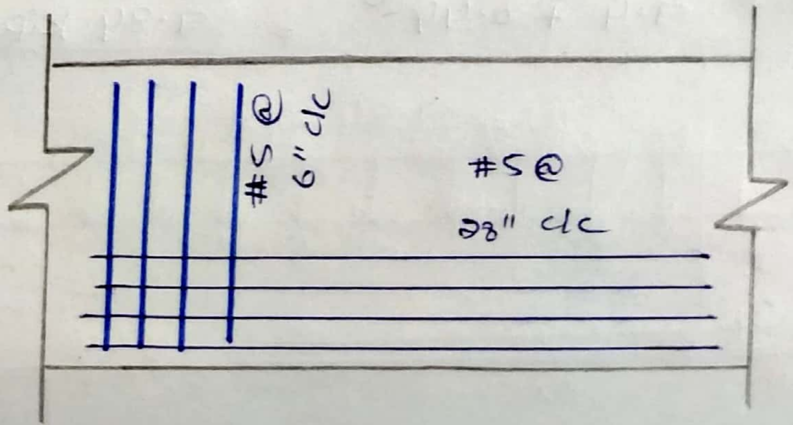
So $28''$ c/c

## STEP # 10 (Final Sketch)

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

Main steel = #5 at $6''$ c/c

Distribution steel = #5 @ $28''$ c/c



# ( Question # 02)

## GIVEN DATA :-

Breadth (b) = 16″

Effective depth = 22″

Total Factored Load = 9.4 kips/ft

Span = 20′

Area of steel = 7.62 $in^2$

$f'_c$ = 4000 psi

$f_y$ = 60000 psi

## Solution :-

First we have to find the Self-weight of beam,

By formula,

W = breadth × thickness × Unit weight of Concrete

$\because$ ( t = b×2 = 16

$= b \times t \times 150\ lb/ft^3$

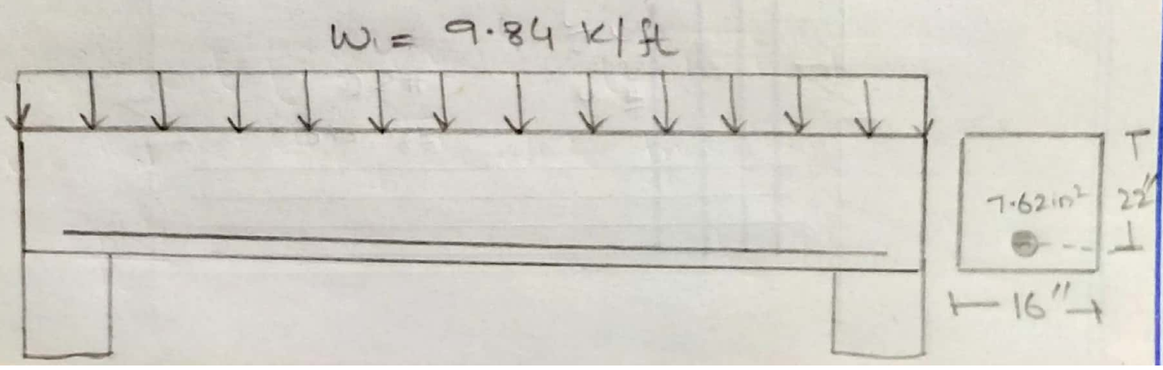
$= \frac{16}{12} \times \frac{22}{12} \times 150 = 366.67\ lb/ft = 0.3666\ k/ft$

So the Factored load will be

$= 1.2(0.3666) = 0.44$ kips/ft

So the total applied factored load will be,

$9.4 + 0.44 = \boxed{9.84\ kips/ft}$



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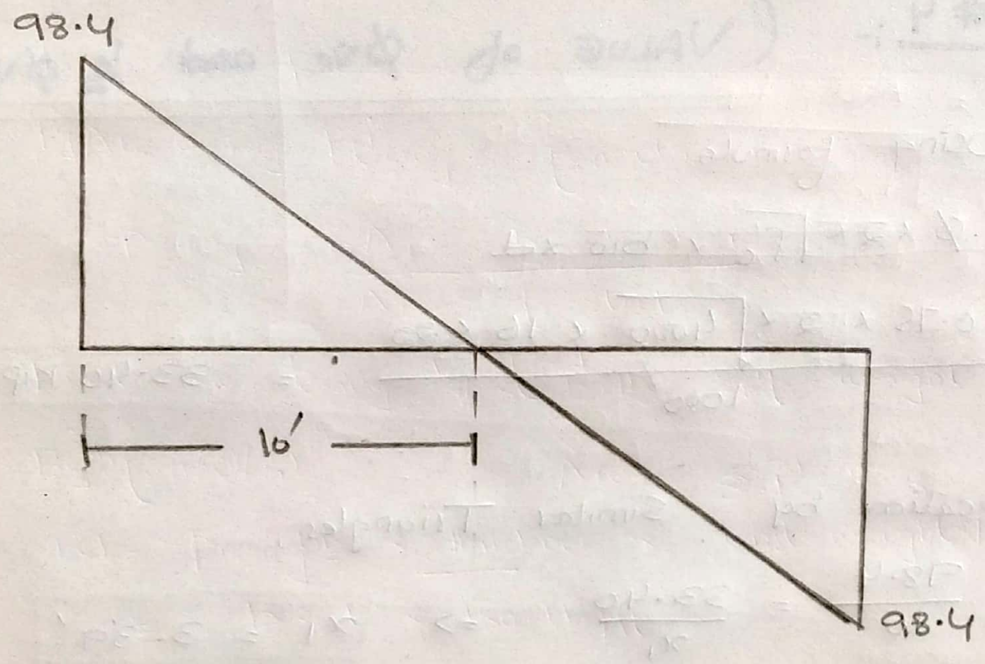
## STEP #1 :- (Reaction Values)

Total Load $= \frac{9.84 \times 20}{2} = 98.4$ Kips

Hence both the Support Contains 98.4 kips.

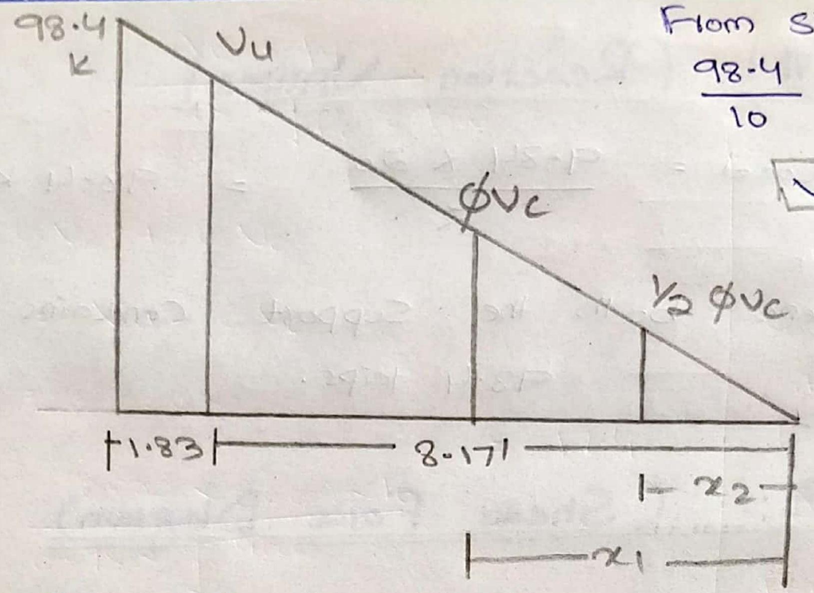
## STEP #2 :- (Shear Force Diagram)




## STEP #3 :- (Value of Critical Shear) $V_u$

As we know that Critical shear "$V_u$" is located at distance "d" $= 22'' = 1.83'$

=> So we will find the value of critical shear at distance "d" by Similar triangles,




From Similar $\Delta^s$,

$$\frac{98.4}{10} = \frac{V_u}{8.17}$$

$\boxed{V_u = 80.39 \text{ kips}}$

## STEP # 4 :- (VALUE of $\phi V_c$ and $\frac{1}{2}\phi V_c$)

By Using formula

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

$$= \frac{0.75 \times 2 \times \sqrt{4000} \times 16 \times 22}{1000} = \boxed{33.40 \text{ kips}}$$

=> Its Location by Similar Triangles,

$$\frac{98.4}{10} = \frac{33.40}{x_1} \Rightarrow \boxed{x_1 = 3.39'}$$

=> Now,
By using formula

~~Location~~ $\frac{1}{2}\phi V_c = \phi V_c / 2$

$$= 33.40/2 = \boxed{16.70 \text{ kips}}$$

=> Location of $\frac{1}{2}\phi V_c$

By Similar Triangles,

$$\frac{98.4}{10} = \frac{16.70}{x_2} \Rightarrow \boxed{x_2 = 1.69'}$$

## STEP # 5 :- (Value of $\phi V_s$)

As

$V_u = \phi V_s + \phi V_c$

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

$= 80.39 - 33.40$

$\boxed{\phi V_s = 46.99 \text{ kips}}$

## STEP # 6 :- (Check on Section Adequacy)

By formula

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

$$= \frac{0.75 \times 8 \times \sqrt{4000} \times 16 \times 22}{1000} = 133.57 \text{ kips}$$

As $133.57 > \phi V_s$

So Section is Adequate!

## STEP #7 :- (Miximum Spacing For Stirrups)

$\Rightarrow \phi \times 4 \times \sqrt{f'_c} \times b_w \times d$

$$= \frac{0.75 \times 4 \times \sqrt{4000} \times 16 \times 22}{1000} = 66.79 \text{ kips}$$

As $\phi 4 \sqrt{f'_c}\, b_w d > \phi V_s$

So maximum spacing will be selected from the following 4 Conditions.

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

2- $d/2 = 22/2 = 11''$

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

$= \dfrac{0.22 \times 60000}{0.75 \times \sqrt{4000} \times 16} = 17.40''$

∵ As we are using #3 U-stirrops, So it has dia (3/8)" and Area 0.11 in².

For 2 legged, we will multiply it by 2

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

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

$= \dfrac{0.22 \times 60000}{50 \times 16} = 16.50''$

Now from above 4 conditions, we use $\boxed{S_{max} = 11''\ c/c}$

because it is the least value we will use for #3 2 legged stirrup.

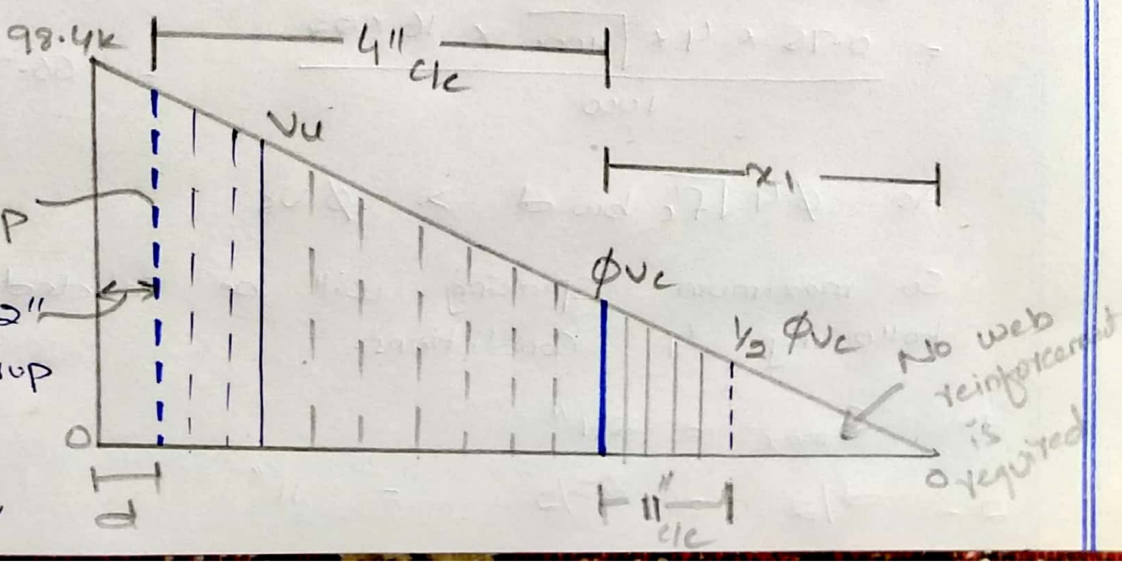
## STEP # 8 :- (Spacing of Stirrup at Critical Section)

By formula

$S = \dfrac{\phi \times A_v \times f_y \times d}{V_u - \phi V_c} = \dfrac{0.75 \times 0.22 \times 60 \times 22}{80.39 - 33.40}$

$4.6'' \cong 4''$

$\Rightarrow \boxed{S = 4''\ c/c}$




First stirrup $= \dfrac{S}{2} = \dfrac{4}{2} = 2''$

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# ( QUESTION - 04 )

## GIVEN DATA :-

Column dimensions $\longrightarrow$ Square Column of 16" x 16"

Dead Load = 100 kips
Live Load = 120 kips

Base of footing below ground = 5'

Allowable Soil pressure = 2.50 $k/ft^2$

$f'_c = 3$ ksi

$f_y = 60$ ksi

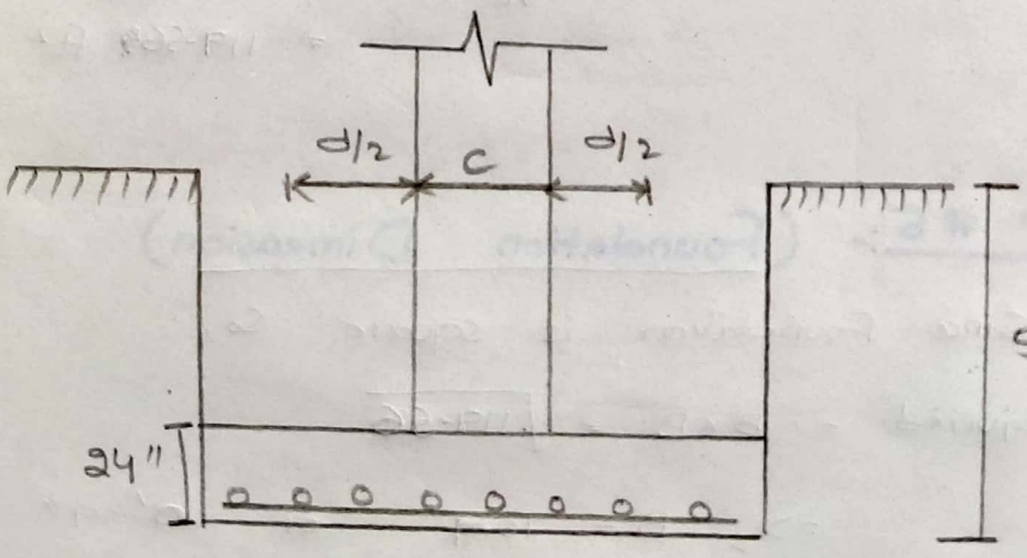
Unit weight of soil $(\gamma_s)$ = 120 $lb/ft^3$

## Solution :-

### STEP #1 :- (Depth of Foundation)

Assuming depth of foundation as,

$h = 24"$




### STEP #2 :- (Total Weight)

Total weight = wt. of Soil + wt. of Reinforced Concrete

Total weight = $\left(\begin{matrix}\text{Depth of Soil} \\ \times \\ \gamma_{soil}\end{matrix}\right) + \left(\begin{matrix}\text{Depth of R.C} \\ \times \\ \gamma_{concrete}\end{matrix}\right)$

$= (3 \times 120) + (2 \times 150)$

$= 660 \text{ lb/ft}^2$

$\boxed{= 0.660 \text{ K/ft}^2}$

## STEP #3 :- (Effective Bearing Capacity)

By formula,

$q_{effective} = q_{allowable} - \text{Total weight}$

$= 2.50 - 0.660$

$\boxed{q_e = 1.84 \text{ K/ft}^2}$

## STEP #4 :- (Required Area For Foundation)

By formula

$A_{required} = \dfrac{\text{Service Load}}{q_e} = \dfrac{100 + 120}{1.84}$

$= 119.564 \text{ ft}^2$

## STEP #5 :- (Foundation Dimension)

Since Foundation is square So,

$A_{required} = B \times B = \sqrt{119.56}$

$\Rightarrow B = 10.9'$ or $10' - 9''$

$\boxed{B = 10.9'}$ or $\boxed{B = 11'}$

## STEP #6 :- (Upward Bearing Capacity)

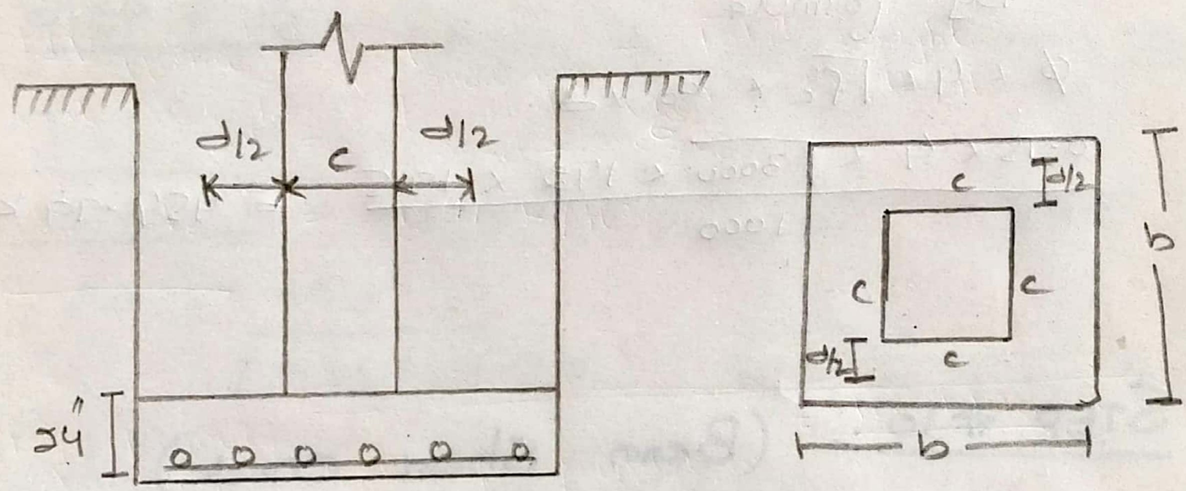
$$q_{upward} = \frac{\text{Factored Load}}{(B)^2} = \frac{1.2(100) + 1.6(120)}{(11)^2}$$

$$= 2.58 \ k/ft^2$$

## STEP # 7 :- (Punching Shear)

By formula

$b_o = 4(c + d)$




Effective depth (d)

d = h − Clear Cover − dia of bottom bar − ½ dia of top bar

$= 24 - 3 - (1) - \frac{1}{2}(1)$

$\boxed{d = 19.5''}$

We are using #8 bar
dia $= (8/8)'' = 1''$
Area $= 0.785 \ in^2$

So the Punching shear will be,

$b_o = 4(16'' + 19.5'')$

$\boxed{b_o = 142''}$

## STEP # 8 :- (Value of $V_{u_2}$)

By formula,

$$V_{u_2} = q_{up} \times \left[ B^2 - (c+d)^2 \right]$$

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

$$\boxed{V_{u_2} = 289.60 \text{ kips}}$$

## STEP # 9 :- (Value of $\phi V_{cIP}$)

By formula

$$\phi \times 4 \times \sqrt{f'_c} \times b_o \times d$$

$$\frac{0.75 \times 4 \times \sqrt{3000} \times 142 \times 19.5}{1000} = \boxed{454.99 \text{ k}}$$

## STEP # 10 :- (Beam Shear Check)

By formula,

$$V_{u_1} = q_{up} \times B \times \left[ \frac{B}{2} - \frac{c}{2} - d \right]$$

$$= 2.58 \times 11 \times \left[ \frac{11}{2} - \frac{16/12}{2} - \frac{19.5}{12} \right]$$

$$\boxed{V_{u_1} = 91.05 \text{ kips}}$$

## STEP # 11 :- (Self-Shear Capacity)

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

$$= \frac{0.75 \times 2 \times \sqrt{3000} \times (11 \times 12) + 19.5}{1000}$$

$$\phi V_c = 211.47 > V_{u_1} \rightarrow \text{ok!}$$

## STEP # 12 :- (Ultimate Moment)

By formula

$$M_u = \frac{q_{up} \times B}{8} \times (B - C)^2$$

$$= \frac{2.58 \times 11}{8} \times \left(11 - \frac{16}{12}\right)^2$$

$$= 331.49 \text{ k-ft} = 3977.88 \text{ kip-inch}$$

## STEP # 13 :- (Area of steel for main bars)

=> **Trial # 01** :- Let $a = 0.2 \times h$

$$= 0.2 \times 24 = 4.8''$$

$$A_{st} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{3977.88}{0.90 \times 60 \times \left(19.5 - \frac{4.8}{2}\right)}$$

$$\boxed{A_{st} = 4.31 \text{ in}^2}$$

=> **Trial # 02** :-

$$a = \frac{A_{st} \times f_y}{0.85 \times f'_c \times B} = \frac{4.31 \times 60}{0.85 \times 3 \times (11 \times 12)}$$

$$a = 0.76''$$

$$A_{st} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \boxed{3.85 \text{ in}^2}$$

=> **Trial # 3** :-

$a = 0.68''$ #

$$\boxed{A_{st} = 3.85 \text{ in}^2}$$

## STEP # 14 :- (Check the Minimum Reinforcement)

Using 3 methods :-

a - $Ast_{min} = 0.0018 \times B \times h$

$= 0.0018 \times (11 \times 12) \times 24$

$= \underline{3.168}\ in^2$

b- $As_{min} = \frac{200}{fy} \times B \times d$

$= \frac{200}{60000} \times (11 \times 12) \times 19.5$

$= \underline{8.58}\ in^2$

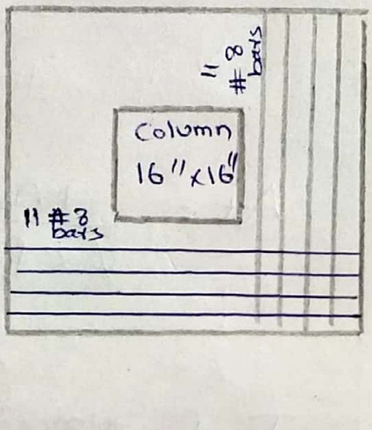
c - $As_{min} = \frac{3 \times \sqrt{f'c}}{fy} \times B \times d$

$= \frac{3 \times \sqrt{3000}}{60000} \times (11 \times 12) \times (19.5)$

$= \underline{7.04}\ in^2$

From above 3 Conditions, greater value will be Selected.

$\boxed{As_{min} = 8.58\ in^2}$




## STEP #15 :- No. of bars

Using # 8 bars,

Area = $0.785\ in^2$

No. of bars = $\frac{Ast}{Ab} = \frac{8.58}{0.785} = 10.9 \approx 11$ bars in each direction

## (Question :- 03)

**Solution :-**

### STEP #1 :- (Gross Area of Concrete)

As,

Gross Area $(A_g) = b \times b$

( $b \times b$ because it is square tied column)

$A_g = 12 \times 12 = 144\ m^2$

$144\ m^2 \longrightarrow$ Actual Area

### STEP #2 :- (Area of Steel)

As,

$A_{st} = 5\ \%$ of Gross Area

$= \frac{5}{100} \times 144$

$\boxed{A_{st} = 7.2\ in^2}$

### STEP #3 :- (Ultimate Load Carrying Capacity)

By formula,

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

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

$\boxed{P_u = 466.50\ k}$

## STEP #4: (Sketch of Ties)

We have to choose the least value from the following below 3 formulas

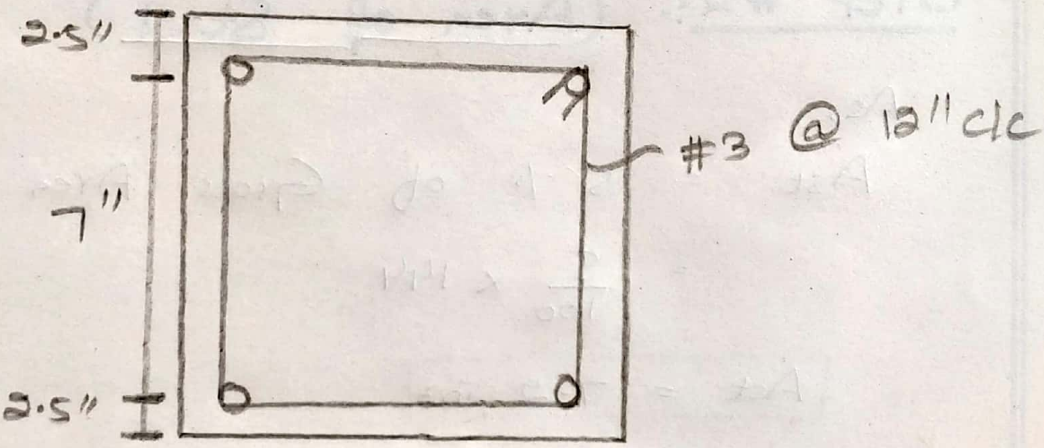
1 - 16 (dia of long bars) $= 16 \times 9/8$
$= 18''$

2 - 48 (dia of Tie bar) $= 48 \times 3/8$
$= 18''$

3 - Least Column dimension $= 12''$

So the least value is $12''$

=> $12''$ c/c




=> No spiral designing is used / required in the above case because it is a square tied column, so rectangular or square shaped stirrups / ties are used in this case.