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Section "A"

Subject PRCD-I

Paper Final term

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Question #01:-

A reinforced concrete slab is built integrally with its supports and consists of three equal spans, each with clear span of 15 ft. The factored live load is 160 psf and service ~~live load~~ Floor finish load is 20 psf. Design the slab using $f'_c = 4000$ psi and $f_y = 40$ ksi. Draw sketch of your final design.

Given data:

c/c Span = 15'

Total Span = 45'

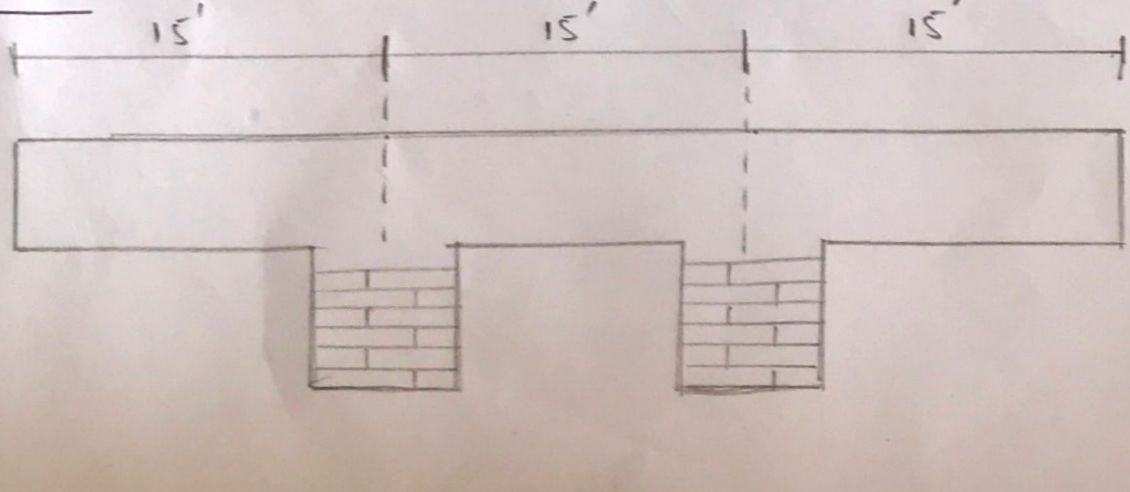
Factored live load = 160 psf

Service floor finish load = 20 psf

$f'_c = 4000$ psi or 4 ksi

$f_y = 40{,}000$ psi or 40 ksi

Solution:



Step #01 : Minimum thickness, T_{min}

As we know for both side over hanged slab,

$$T_{min} = \frac{L}{28} = \frac{15}{28} \times 12$$

for grade-60 only

$$= 6.43'' \approx 6.5''$$

As $f_y \neq 60$ ksi → 60 grade steel

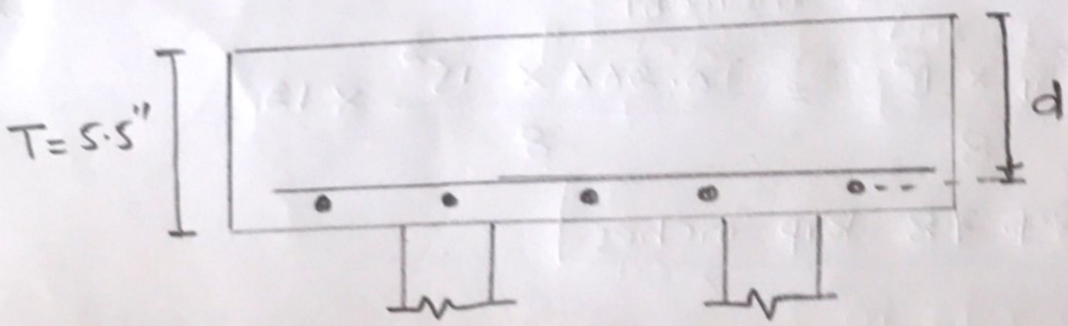
So

$$T_{min} = \left(0.4 + \frac{f_y}{100}\right) \times \frac{L}{28}$$

$$= \left(0.4 \times \frac{40}{100}\right) \times \frac{15}{28} \times 12$$

$$\boxed{T_{min} = 5.2'' \approx 5.5''}$$

Step #02: Effective depth (d)



d = T − clear cover − ½ (dia of main bar)

$$= 5.5 - \frac{3}{4} - \frac{1}{2}\left(\frac{4}{8}\right)$$

∵ #4 bar used as M.B

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

Step#03: Self weight of Slab

$$= \frac{T}{12} \times \gamma_{concrete}$$

$$= \frac{5.5}{12} \times 150$$

$$= 68.75 \text{ psf}$$

Step #04: Total Factored load

Factored live load = 160 psf

& Factored dead load = $1.2 \times (20 + 68.75)$

$= 106.5$

So Total factored load = $160 + 106.5$

$= 266.5 \text{ lb/ft}^2$

$= 0.266 \text{ K/ft}^2$

Step#05: ultimate moment

$$M_u = \frac{W_u \times L^2}{8} = \frac{0.266 \times 15^2}{8} \times 12$$

$$\boxed{M_u = 89.78 \text{ kip-inches}}$$

Step#06: Area of Steel for main Bars

Trial #01:

let $a = 0.2 \times T = 0.2 \times 5.5$

$\Rightarrow a = 1.1''$

$$A_{st} = \frac{M_u}{\phi \times f_y \times (d - \frac{a}{2})} = \frac{89.78}{0.90 \times 40 \times (4.5 - \frac{1.1}{2})}$$

$$A_{st} = 0.631 \text{ in}^2$$

Trial #2:

$$a = \frac{A_{st} \times f_y}{0.85 \times f'_c \times b} = \frac{0.631 \times 40}{0.85 \times 4 \times 12}$$

$$a = 0.619 \text{ in}$$

$$A_{st} = \frac{M_u}{\phi \times f_y \times (d - \frac{a}{2})} = \frac{89.78}{0.90 \times 40 \times (4.5 - \frac{0.619}{2})}$$

$$A_{st} = 0.595 \text{ in}^2 \neq 0.631$$

Trial #03:

$$a = 0.583 \text{ in}$$

$$\Rightarrow A_{st} = 0.592 \text{ in}^2 \neq 0.595$$

Trial #04:

$$a = 0.580 \text{ in}$$

$$\Rightarrow A_{st} = 0.592 \text{ in}^2 = 0.592$$

So $\boxed{A_{st} = 0.592 \text{ in}^2}$

Step#07:

Ast for distribution Reinforcement

$$A_{s\,min} = 0.0018 \times b \times t$$

$$= 0.0018 \times 12 \times 5.5$$

$$A_{s\,min} = 0.1188 \text{ in}^2$$

Step#08:

Spacing for main Bars

$$S = \frac{A_b}{A_s} \times 12 = \frac{0.196}{0.592} = 3.98 \approx 4'' \text{ c/c}$$

Step#09:

Spacing for dist. Bar
let use #3 bar

$A_b = 0.11 \text{ in}^2$

$$S = \frac{A_b}{A_s} \times 12 = \frac{0.11}{0.119} \times 12$$

$$S = 11.09 \approx 11'' \text{ c/c}$$

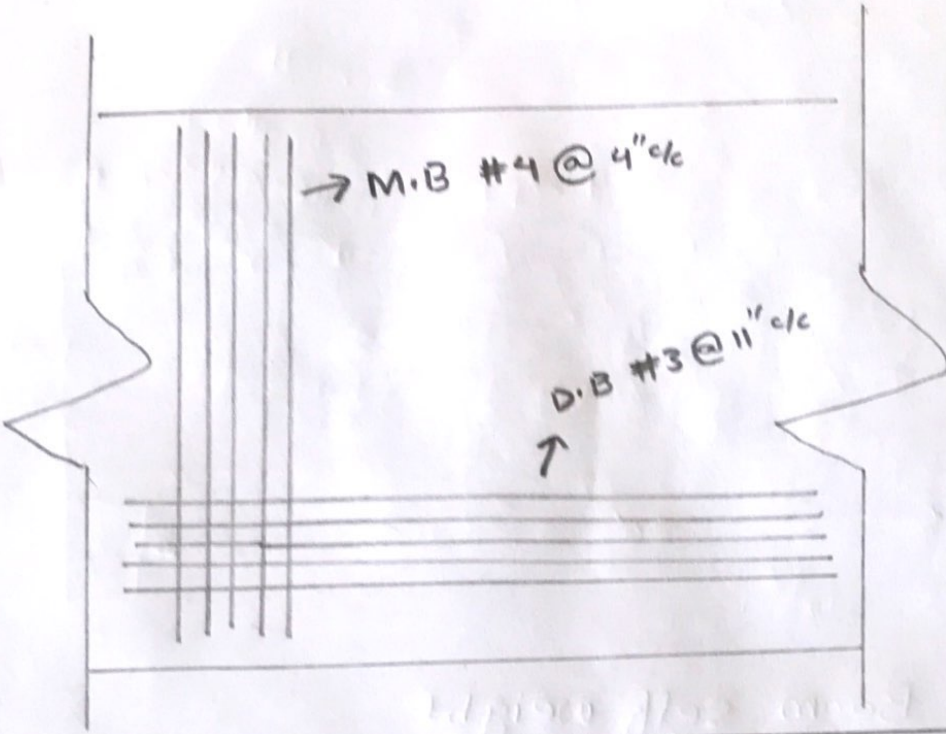
Step#10:

Final Summary

$f'_c = 4\text{ksi}$ $\quad f_y = 40\text{ksi}$, $T = 5.5''$

Main Bars ⇒ #4 at 4" c/c

Dist. Bars ⇒ #3 at 11" c/c



Question #02

Given data:

width = b = 16"

effective depth = d = 22"

Factored load = 9.4 kips/ft

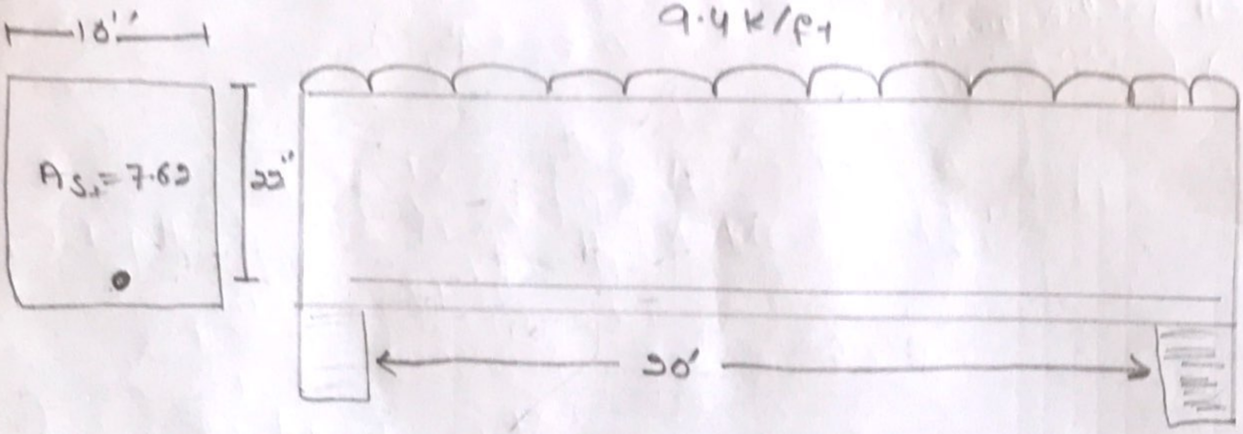
length = L = 20 ft

A_{st} = 7.62 in^2

f'_c = 4000 psi

f_y = 60000 psi

Sol:



Step#01

Beam self weight

$$W = b \times t \times \gamma_c$$

$$= \frac{16}{12} \times \frac{22}{12} \times 150 \text{ lb/ft}^3$$

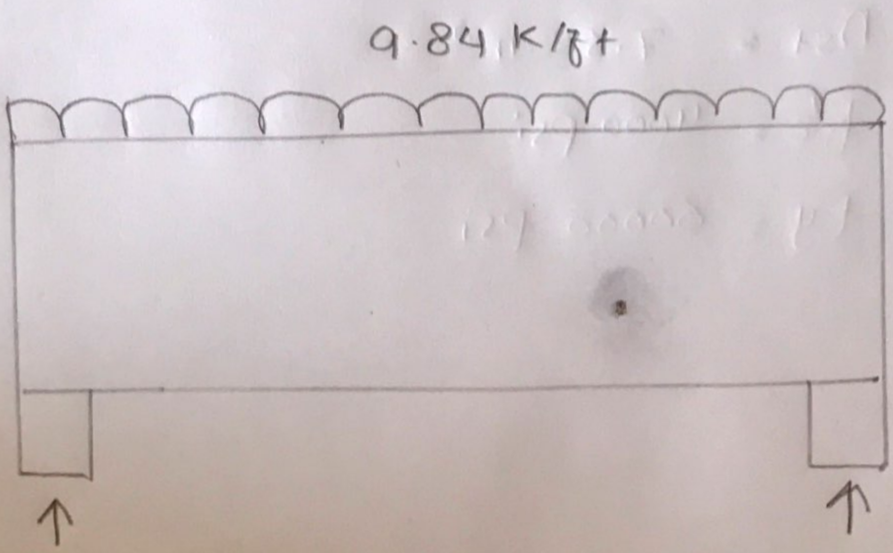
$$= 366.67 \text{ lb/ft}$$

$$W = 0.367 \text{ k/ft} \times 1.2$$

$$W = 0.44 \text{ k/ft}$$

Total factored load $= 9.4 + 0.44$

$$= 9.84 \text{ k/ft}$$

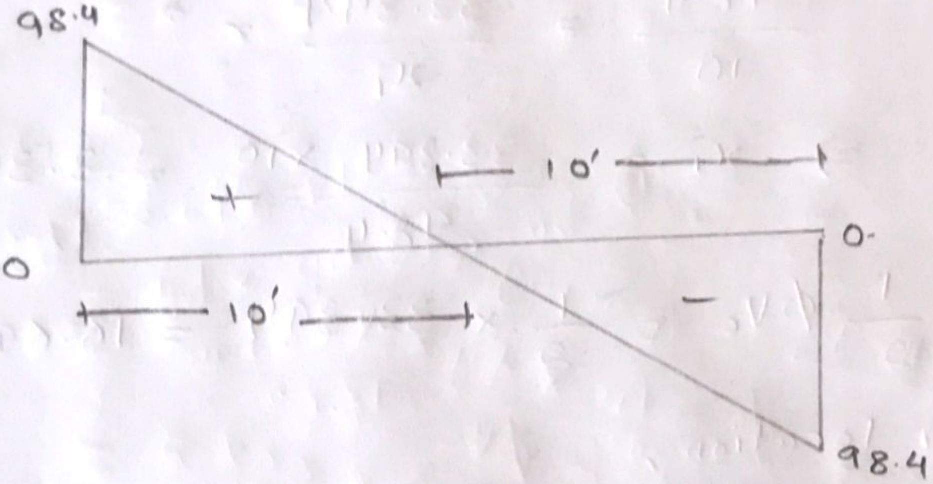


Step #2: Reactions

Total load = 9.84 × 20 = 196.8 Kips

$R_A = R_B = \frac{196.8}{2} = 98.4$ kips

Step #03: SFD

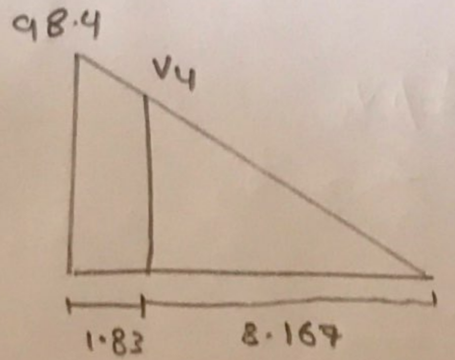


Step #04: Vu and its location

As d = 22" = 1.833'

Vu is located at distance "d" from the face of the Support

So by Similar triangle method,



$$\frac{98.4}{10} = \frac{V_u}{8.167}$$

$$\Rightarrow V_u = \frac{98.4 \times 8.167}{10}$$

$$V_u = 80.363 \text{ Kips}$$

Step#05, ϕV_c & $\frac{1}{2}\phi V_c$

As

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

$$= \frac{0.75 \times 2\sqrt{4000} \times 16 \times 22}{1000}$$

$$\phi V_c = 33.394 \text{ kips}$$

for location,

$$\frac{98.4}{10} = \frac{33.394}{x_1}$$

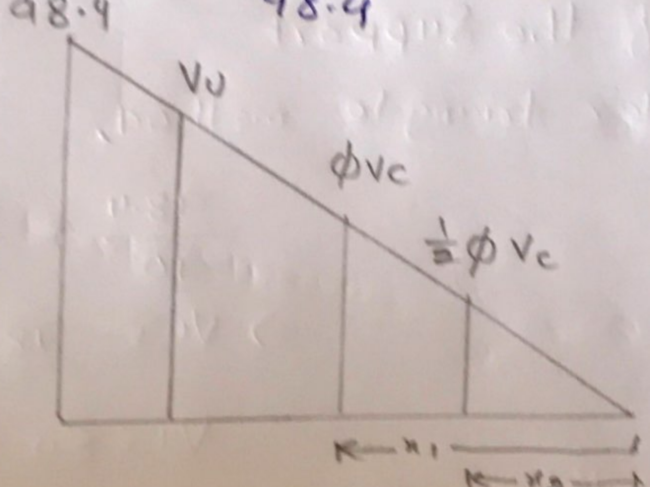
$$\Rightarrow x_1 = \frac{33.394 \times 10}{98.4} = 3.394'$$

$$\frac{1}{2}\phi V_c = \frac{1}{2} \times 33.394 = 16.697 \text{ kips}$$

for location,

$$\frac{98.4}{10} = \frac{16.697}{x_2}$$

$$\Rightarrow x_2 = \frac{16.697 \times 10}{98.4} = 1.697'$$



Step# 06 ϕV_s

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

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

$= 80.363 - 33.394$

$\phi V_s = 46.969$ kips

Step# 07: Check on section adequency

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

$= \dfrac{0.75 \times 8 \times \sqrt{4000} \times 16 \times 22}{1000}$

$= 133.575$ K

$\phi V_s < 133.575$

It means section is adequate.

Step# 08: Check on ~~minimum~~ maximum spacing for stirrups

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

$= \dfrac{0.75 \times 4 \times \sqrt{4000} \times 16 \times 22}{1000} = 66.787$ kip

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

So max spacing will be selected from from condition

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

2) $S_{max} = \frac{d}{2} = \frac{22}{2} = 11''$

3) $S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w} = \frac{0.22 \times 60{,}000}{0.75 \times \sqrt{4000} \times 16}$

$= 17.392 \approx 17.5''$

4) $S_{max} = \frac{A_v \times f_y}{50 \times b_w} = \frac{0.22 \times 60{,}000}{50 \times 16}$

$= 16.5''$

#3 bar

Area of #3 bar $= \frac{\pi}{4} (3/8)^2$

$= 0.11$

for 2 leg stirrup $= 0.11 \times 2$

$A_v = 0.22$

So $\boxed{S_{max} = 11'' \text{ c/c}}$

becaus it is the least value in the above four conditions.

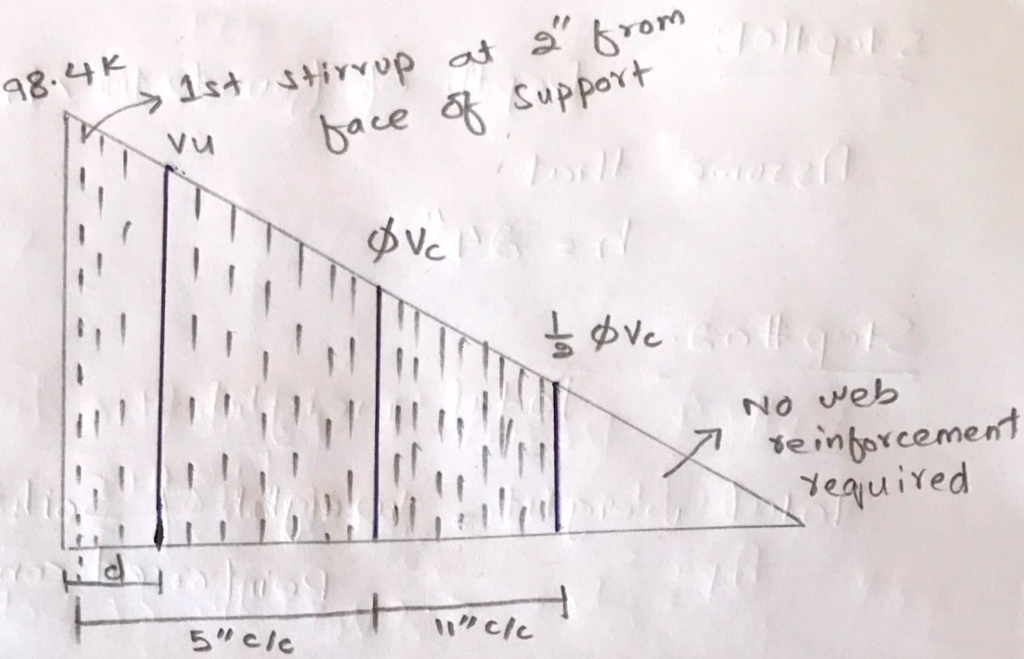
Step#09: Spacing at critical Section

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

$$= \frac{0.75 \times 0.22 \times 60 \times 22}{80.363 - 33.394}$$

$\Rightarrow \boxed{S = 4.637'' \approx 5''}$

First Stirrup $= \frac{S}{2} = \frac{5}{2} = 2.5'' \approx 2''$



Question #04:

Given data:

Column dimension = 16" × 16"

Dead Load = 100 kips

Live Load = 120 kips

Base of footing below the ground = 5'

Allowable Soil pressure = 2.5 ksf

$f'_c = 3$ ksi

$f_y = 60$ ksi

Unit weight of Soil = $\gamma_s = 120\ lb/ft^3$

Sol:

Step#01: Depth of foundation, h

Assume that

$h = 24''$

Step#02: Total weight

Total weight = weight of Soil + wt of Reinforced concrete

weight of Soil = Depth of Soil x γ_{soil}

$= 3 \times 120$

$= 360 \; lb/ft^2$

$\because D_s = 5 - \frac{24}{12}$
$= 5 - 2 = 3'$

wt of reinforced concrete = Depth of Bars x γ_c

$= 2 \times 150 = 300 \; lb/ft^2$

⇒ Total weight $= 360 + 300$

$= 660 \; lb/ft^2$

Step#03: ~~Required area for foundation~~

Effective bearing capacity

$q_e = q_{allowable} - \text{Total wt}$

$= 2.5 - 0.66 = 1.84 \; k/ft^2$

Step#04 Required Area for foundation

$$Area = \frac{Service\ load}{q_e} = \frac{100+120}{1.84}$$

$$Area = 119.565\ ft^2$$

Step#05: Foundation dimension

$$Area = \sqrt{119.56} = 10.934\ ft^2 = B \times B$$

$$B = 10.9 \quad or \quad B = 11'$$

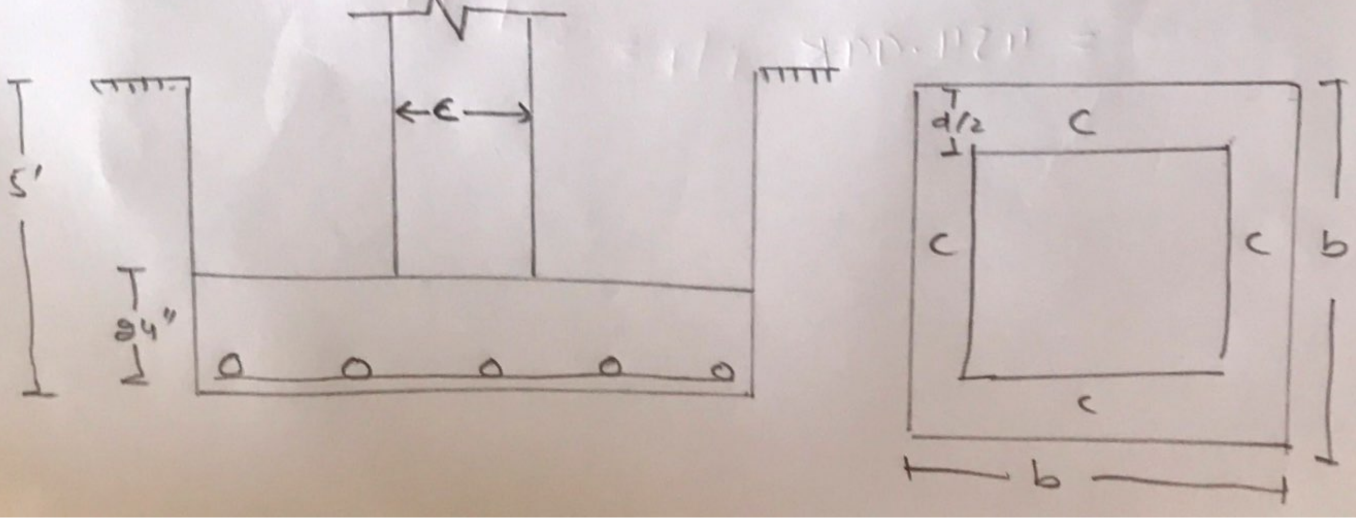
Step#06: upward bearing capacity

$$q_{upward} = \frac{Factored\ load}{B^2} = \frac{1.2 \times 100 + 1.6 \times 120}{11^2}$$

$$= 2.578\ K/ft^2$$

Step#07: Ponching Shear

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



effective depth (d)

$d = h - c.c - \text{dia of bottom bar} - \frac{1}{2} \times \text{dia of top bar}$

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

$d = 19.5''$

So

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

$b_o = 142''$

Step#8: value of V_{u2}

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

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

$= 289.60$ Kips

Step#9: value of $\phi V_{c/p}$

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

$= \frac{0.75 \times 4 \times \sqrt{3000} \times 42 \times 19.5}{1000}$

$= 454.99K$

Step# 10

Beam Shear Check

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

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

$$\Rightarrow \boxed{V_{u1} = 91.05 \text{ kips}}$$

Step# 11: Self Shear Capacity

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

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

$$\Rightarrow \phi V_c = 211.47 > V_{u1}$$

So okay!

Step #12: Mu

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

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

M_u = ~~[illegible]~~

$= 3977.88$ lb/ft

Step#13:

Area of Steel for main Bar

Trial 1:

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

$$A_{st} = \frac{M_u}{\phi \times f_y \times (d - \frac{a}{2})} = \frac{3977.88}{0.9 \times 60 \times (19.5 - \frac{4.8}{2})}$$

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

Trial 2:

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

$a = 0.76''$

$$A_{st} = \frac{3977.88}{0.9 \times 60 \times (19.5 - \frac{0.76}{2})} = 3.85 \text{ in}^2$$

Trial#3

$a = 0.68''$

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

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

Step# 14:

Check minimum Reinforcement

a) $A_{st\,min} = 0.0018 \times B \times h$

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

$= 3.168\ in^2$

b) $A_{s\,min} = \dfrac{200}{f_y} \times B \times d$

$= \dfrac{200}{60{,}000} \times (11 \times 12) \times 19.5$

$= 8.08\ in^2$

c) $A_{s\,min} = \dfrac{3 \times \sqrt{f'_c}}{f_y} \times B \times d$

$= \dfrac{3 \times \sqrt{3000}}{60{,}000} \times (11 \times 12) \times 19.5$

$= 7.04\ in^2$

So $\boxed{A_{s\,min} = 8.58\ in^2}$

Step #15: No of bars

Using #8 bar

Area of bar = $0.785\ in^2$

No of bars = $\dfrac{A_{st}}{A_b} = \dfrac{8.58}{0.785} = 10.9 \approx 11$ bars

So 11 bars in each direction

Question# 03:

Solution:

Step#01: Gross area of concrete

$A_g = b \times b$ → Squar tied column

$= 12 \times 12$

$A_g = 144\ in^2$

Step#2: Area of Steel

$A_s = 5\%$ of A_g

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

$A_s = 7.2\ in^2$

Step#03: ultimate load carrying capacity

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

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

$P_u = 466.50K$

Step#04: Final design

a) 16 x dia of long bar = $16 \times \frac{9}{8}$

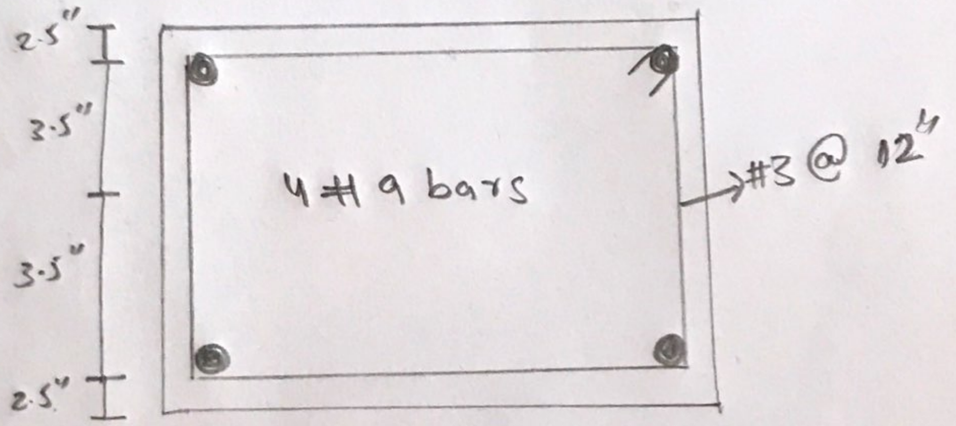
$= 18''$

b) 48x dia of the tie bar = $48 \times 3/8$

$= 18''$

c) least Column dimension $= 12''$

So c/c distance b/w ties = $12''$



There will be no Spiral Stirrup used as it is a tied Square column, we will use tie Stirrups only.