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SUBJECT PRC-I

SECTION B

MODULE 6th

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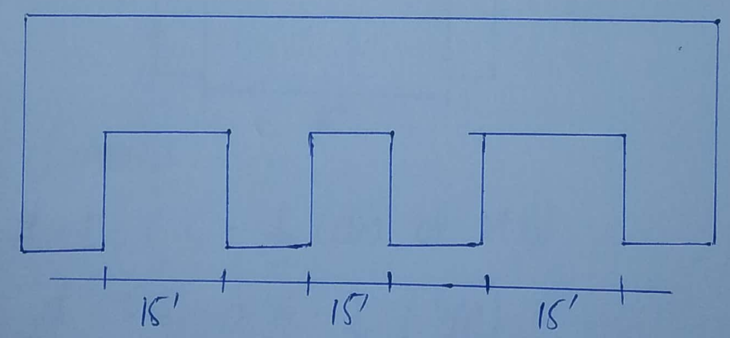
1. A reinforced concrete slab is built integrally with its supports and consists of three equal spans, each with clear span of 15ft. The factored live load is 160 psf and service floor finish is 20 psf. Design the slab using $f'_c = 4000psi$ and $f_y =$ 40ksi. Draw sketch of your final design.

Sol: Given data:

- Clear span b/w supports = 15'
- Factored live load = 160 lb/ft²
- Service floor finish load = 20lb/ft²
- $f'_c = 4000psi$
- $f_y = 40ksi$



Step01: Minimum thickness

Using formula

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

As $f_y = 40ksi$; so we will multiply a factor with this thickness.

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

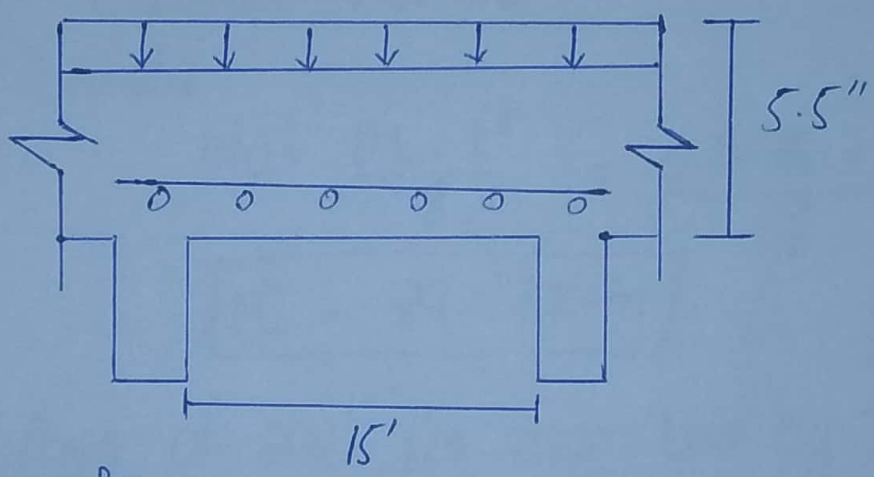
$$= \left(0.4 + \frac{40}{100}\right) = 0.8$$

Thus the min thickness will be

$$= 6.5 \times 0.8$$

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

Step02: Effective Depth



By formula

$$d = t - C.C - \frac{1}{2}(\text{dia of M.B})$$

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

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

Step03: Self weight of the slab

By formula $\Rightarrow \frac{t}{12} \times \gamma_c = \frac{5.5}{12} \times 150$

$$= 68.75 \text{ lb/ft}^2$$

Step 04: Total Factored load.

Factored live Load = 160 lb/ft²

So Factored dead load will be

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

Total factored load = D.L + L.L

$$= 106.5 + 160$$

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

Step 05: Ultimate Moment

By formula

$$M_U = \frac{W_U \times L^2}{8} = \frac{0.2665 \times (15)^2}{8}$$

$$\boxed{M_U = 89.94 \text{ k-in}}$$

Step 06: Area of steel for main bar by Trial and Repeat Method.

Trial #01:

$$\text{Let } a = 0.2 \times t$$

$$= 0.2 \times 5.5$$

$$= 1.1''$$

$$A_{ST} = \frac{M_U}{\phi \times f_y \times (d - \frac{a}{2})} = \frac{89.94}{0.90 \times 40 \times (4.5 - \frac{1.1}{2})}$$

$$A_{ST} = 0.63 \text{ in}^2$$

Trial #02:

$$a = \frac{A_{ST} \times f_y}{0.85 \times f'_c \times b} = \frac{0.63 \times 40}{0.85 \times 4 \times 12} = 0.62\ in^2$$

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

$$A_{ST} = 0.59\ in^2$$

Trial #03:

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

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

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

Step 07: Area of steel for distribution reinforcement.

By formula

$$A_{min} = 0.002 \times b \times t \rightarrow \text{(For Grade 40 steel)}$$

$$= 0.002 \times 12 \times 5.5 = 0.132\ in^2$$

Step 08: Spacing for main bars

By formula

$$\text{Spacing} = \frac{A_b}{A_{ST}} \times 12$$

We use #6 bar dia $= (6/8)''$

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

$$S = \frac{0.442}{0.59} \times 12 = 8.98 \approx 9''\ c/c$$

Step 09: Spacing For distribution Bar

$$Spacing = \frac{A_b}{A_{ST}}$$

we use #5 bar, so

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

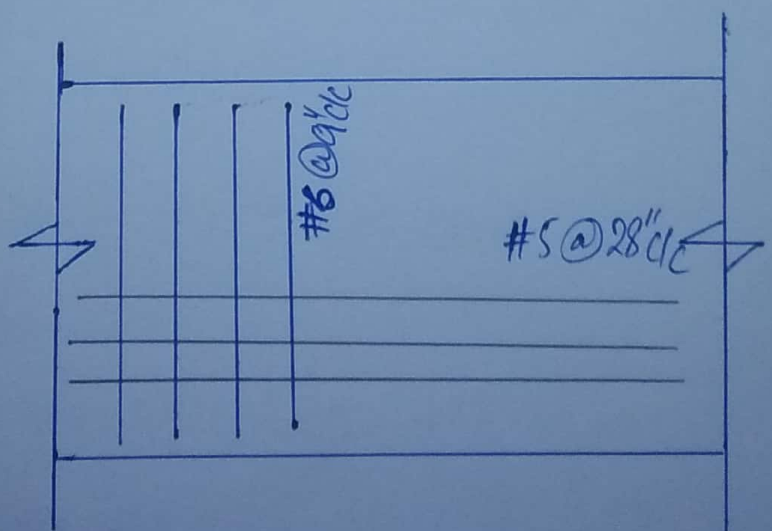
$$Spacing = \frac{0.31}{0.132} \times 12 = 28.1'' \approx 28''\ c/c$$

Step 10: Final sketch.

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

Main steel #6 at 9" c/c

Distribution steel #5 at 28" c/c



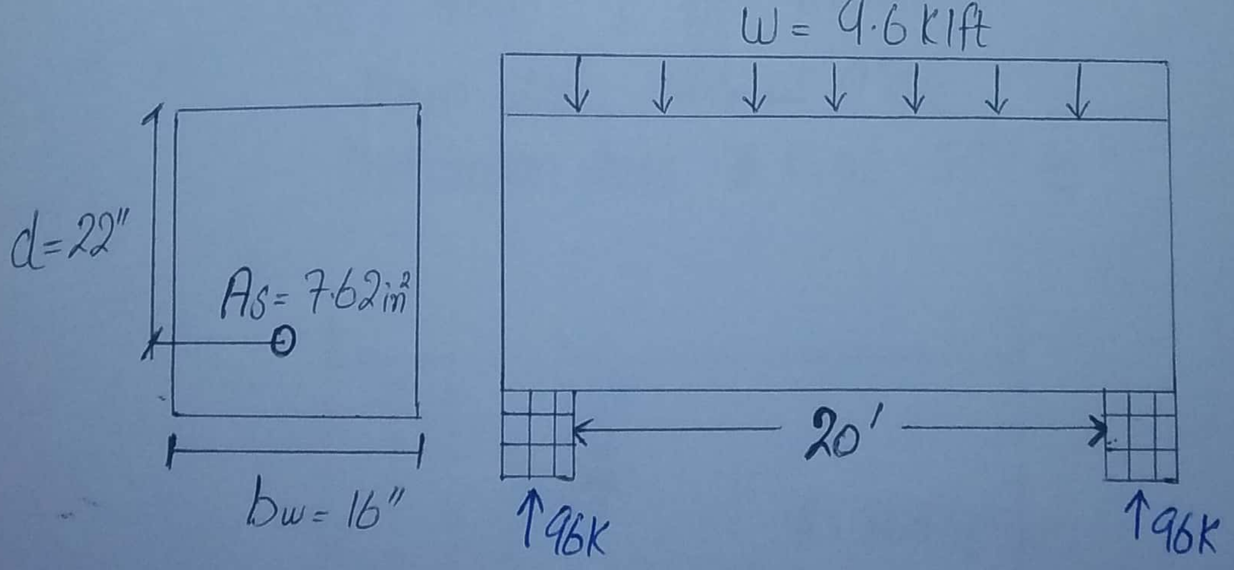
2. A simply supported rectangular beam 16" wide having an effective depth of 22" caries a total factored load of 9.4 k/ft (excluding self weight of beam) on a 20ft clear span. It is reinforced with 7.62 in^2 of tensile steel which continues uninterrupted into the supports. If f'_c = 4000psi and f_y = 60000 psi. Using #3 vertical U-stirrups. Design the web reinforcement. Draw sketch of your final drawing.

Sol: First of all find the unit load of beam

$$\text{so } t \times b \times \gamma_c$$

$$= \frac{22}{2} \times \frac{16}{12} \times 150 = 200\ lb/ft = 0.2\ k/ft$$

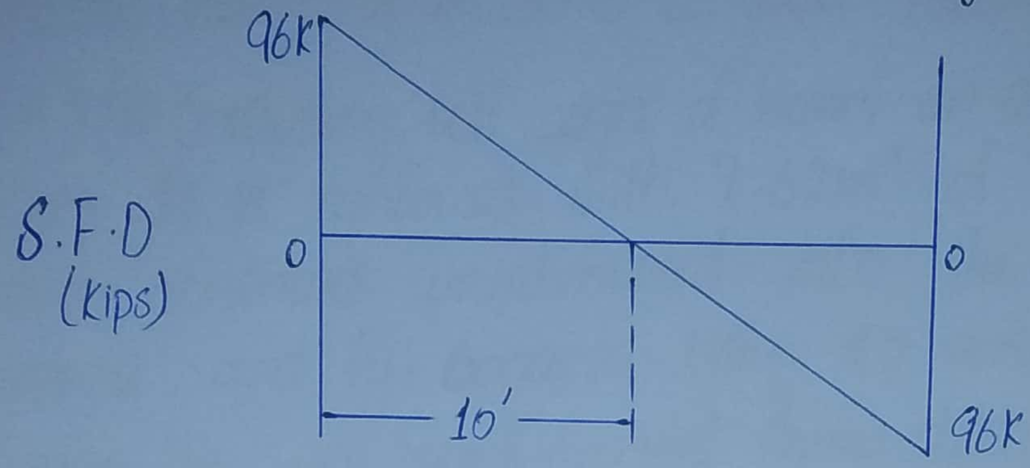
so total factored load $= 9.4 + 0.2 = 9.6\ k/ft$



Step01: Find the values of R_1 and R_2.

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

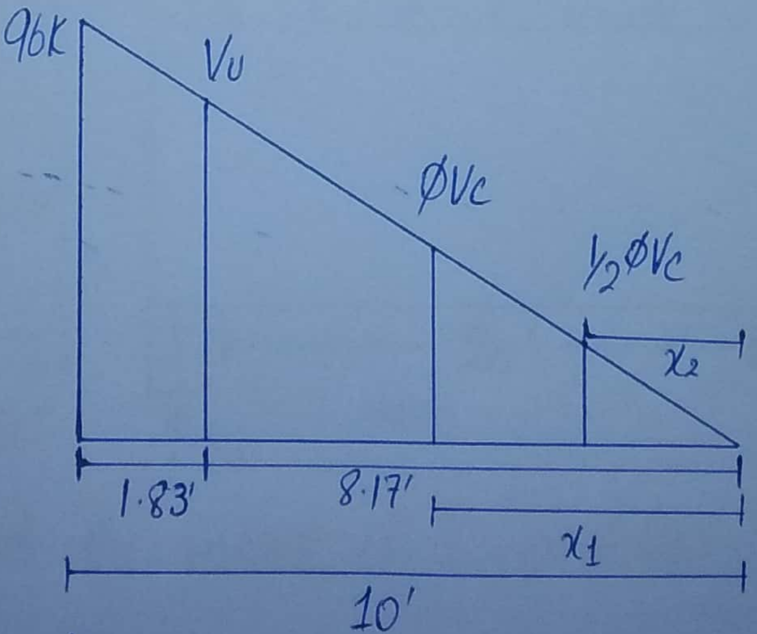
Step 02: Draw it's shear force diagram.



Step 03: Find the value of critical stress "V_u" and it's location.

As we know critical section is located at distance "d" from face of support = d = 22" = 1.83'

Value of critical shear at distance "d" by similarity of triangles.



From similar Δ's

$$\frac{96}{10} = \frac{V_u}{8.17}$$

$$V_u = 78.43k$$

Step 04: Find the values of "ϕV_c" and "$\frac{1}{2}\phi V_c$" and also it's distances from zero shear to right side.

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

$$\phi V_c = 33.40k$$

Location of ϕV_c by similarity of Δ's.

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

$$x_1 = 3.48'$$

Now:

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

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

$$x_2 = 1.74'$$

Step 05: Value of ϕV_s ($V_u = \phi V_s + \phi V_c$)

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

$$\phi V_s = 78.43 - 33.40$$

$$\phi V_s = 45.03k$$

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Step 06: Check on section adequacy.

$$\Rightarrow \quad \phi \times 8 \times \sqrt{f'_c} \times b_w \times d = \frac{0.75 \times 8 \times \sqrt{4000} \times 16 \times 22}{1000}$$

$$= 133.57K$$

As $\phi \times 8\sqrt{f'_c} \times b_w \times d > \phi V_s$ → It means section is adequate.

Step 07: Check on min spacing for stirrups.

$$\phi \times 4 \times \sqrt{f'_c} \times b_w \times d = \frac{0.75 \times 4 \times \sqrt{4000} \times 16 \times 22}{1000} = 66.79K$$

As $\phi 4\sqrt{f'_c}\, b_w d > \phi V_s = 45.03K$ Thus max spacing will be selected from the following four conditions:

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

2- $\frac{d}{2} = \frac{22}{2} = 11''$

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

$\because A_v = \frac{\pi}{4}\left(3/8\right)^2$

$A_v = 0.11 \times 2$

$A_v = 0.22$

$$= \frac{0.22 \times 60000}{0.75 \times \sqrt{4000} \times 16}$$

$$= 17.40''$$

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

$$= \frac{0.22 \times 60000}{50 \times 16}$$

$$= 16.50''$$

From the above four conditions, least value of spacing for #3, U-shaped stirrup will be selected so

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

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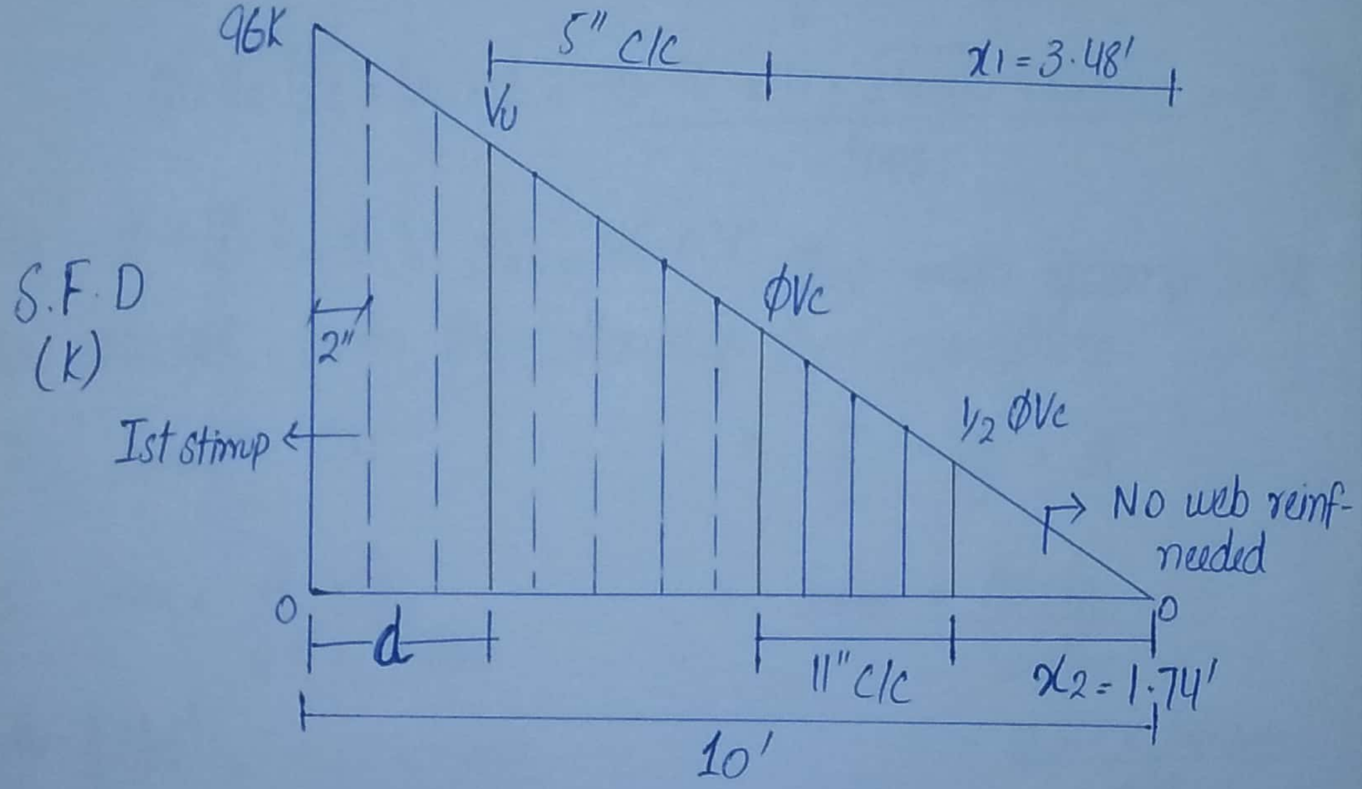
Step 08: Spacing of stirrups from 1 at critical section.

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

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

Step 09: Final sketch.



* As we know that first stirrup from face of support =

$$\Rightarrow \frac{5}{2} = 2.5 \approx 2''$$

3. Calculate the axial ultimate load carrying capacity of a 12 inch. square tied column reinforced with 4 #9. Ties are #3 spaced @ 12". Use $f'_c = 4000$ psi and $f_y = 60$ksi. Also, design necessary spirals.

Sol:

Step 01: Find gross area of concrete

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

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

Step 02: Find the area of steel

Since $A_s = 5\%$ of A_g

$= 0.05 \times 144$

$A_s = 7.2 in^2$

Step 03: Ultimate load carrying capacity

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

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

$\boxed{P_u = 466.50 k}$

Step 04: Sketch & Design of Ties (c/c to distance)

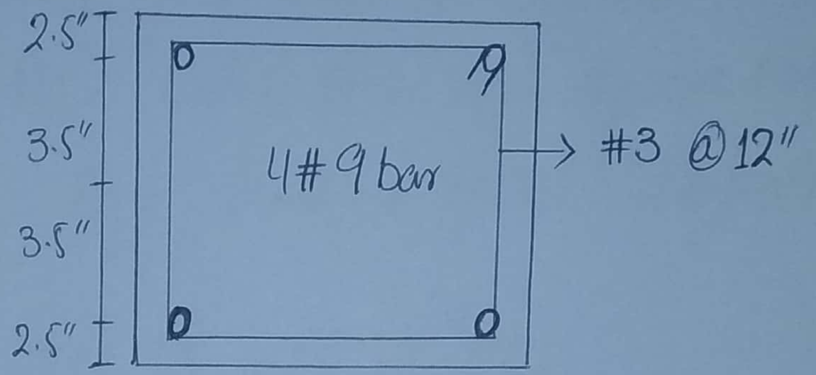
From the below values we choose the least value of all thus;

1- 16 x dia of long. bar = 16 x 9/8 = 18"

2- 48 x dia of Tie bar = 48 x 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.

4. Design a square single footing to support a 16" square tied concentrically loaded column. The column carries an un-factored axial D.L of 100k and an axial L.L of 120k. The base of footing is 5'. below final grade and the allowable soil pressure is 2.50 ksf. Use f'_c = 3ksi, f_y = 60ksi and γ_{soil} = 120pcf. Draw a sketch of your final design.

Sol: **Step 01:**

let $h = 24"$

Step 02:

Total weight = Wt of soil + Wt of R.C

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

$= 660$ psf $= 0.660$ ksf

Step 03: Effective Bearing capacity

$q_e = q_a - W$

$= 2.50 - 0.660$

$q_e = 1.84$ ksf

Step 04: Required Area for foundation

$$A_{req} = \frac{\text{Service Load}}{q_e} = \frac{100+120}{1.84} = 119.57 \text{ ft}^2$$

Step 05: Since foundation is square

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

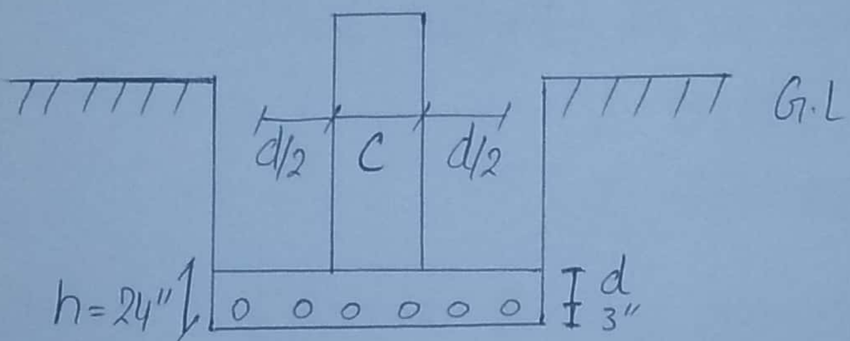
Step 06: Upward bearing capacity of soil

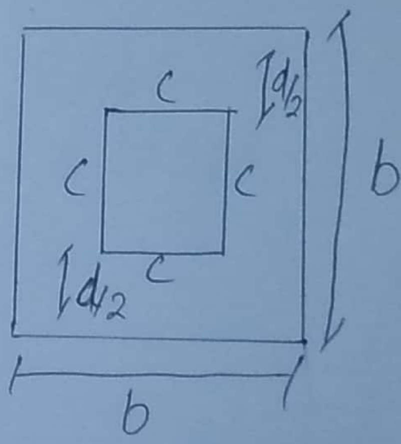
$$q_{up} = \frac{\text{Factored load}}{(B)^2} = \frac{1.2 \times 100 + 1.6 \times 120}{11^2}$$

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

Step 07: Punching shear

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





$d = h - c.c - \text{dia of bar} - \frac{1}{2} d_b$ ∴ Take #8 bar, dia $= 8/8" = 1"$

$= 24 - 3 - 1 - \frac{1}{2}(1) = 19.5"$

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

Step 08:

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

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

$$\boxed{V_{u2} = 289.60\,k}$$

Step 09:

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

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

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

Step 10: Beam shear / One way shear check.

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

$$V_{u1} = 2.58 \times 11 \times \left[\frac{11}{2} - \frac{16/12}{2} - \frac{19.5}{12}\right]$$

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

Step 11: Self shear capacity

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

$$= \frac{0.75 \times 2 \times \sqrt{4000} \times (11 \times 12 - 16)}{1000}$$

$$= 110.04\,k > V_{u1} \Rightarrow O.K$$

Step 12: Ultimate Moment

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

$$M_u = 331.49 K' = 3977.93 K''$$

Step 13: Area of steel for main bars by Trial & Repeat method.

Trial #01:

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

$$A_s = \frac{M_u}{\phi \times f_y \times \left(d - \frac{a}{2}\right)} = \frac{3977.93}{0.90 \times 60 \times \left(11 - \frac{4.8}{2}\right)} = 8.56 in^2$$

Trial #02:

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

$$A_s = \frac{3977.93}{0.90 \times 60 \times \left(11 - \frac{1.53}{2}\right)} = \boxed{7.197 in^2}$$

Trial #03:

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

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

So thus Area $= 7.1\ in^2$

Step 14: Check the min reinforcement by the following 03 methods;

a- $A_{s_{min}} = 0.0018 \times B \times h = 0.0018 \times (11 \times 12) \times 24$

$A_{s_{min}} = 5.70\ in^2$

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 values greater value will be selected.

Thus $A_{s_{min}} = 8.58\ in^2$

Step 15: Using #8 bars

$A_b = 0.785\ in^2$

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