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Subject = PRCD I

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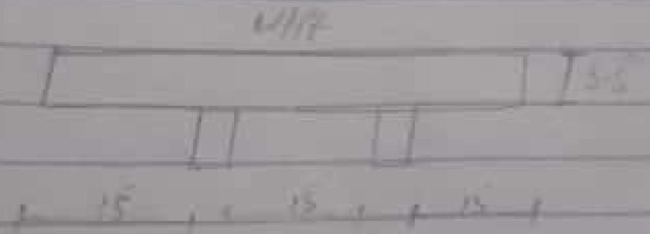
Q No (01)

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 floor finish load is 30 psf. Design the slab using $f_c' = 4000$ psi and $f_y = 40$ ksi. Draw sketch of your final design.

Given Data:

- → 3 equal spans concrete slab
- → Clear span b/w supports = 15 ft
- → Factored live load = 160 lb/ft^2
- → Service floor finish load = 30 lb/ft^2
- → $f_c' = 4000$ psi
- → f_y = 40 ksi

Solution:



Step 01 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

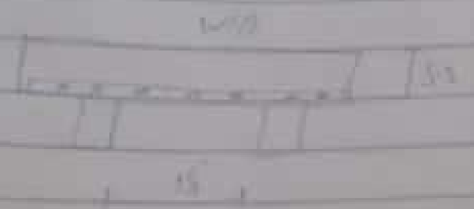
Factor $= (0.4 + \frac{fy}{100})$

Factor $= (0.4 + \frac{40}{100}) = \boxed{0.8}$

Hence the minimum thickness will be

$t_{min} = 6.5 \times 0.8 = \boxed{5.2 \simeq 5.5''}$

<u>Step #2 (Effective Depth)</u>



By formula

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

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

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

<u>Step #03 (Self wt of slab)</u>

By using formula

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

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

Step # 04 (Total factored load)

Factored Dead Load will be

$DL = 1.2\,(20 + 68.75) = \boxed{106.5\ lb/ft^2}$

Factored Live Load = 160 lb/ft²

$\boxed{LL = 160\ lb/ft^2}$

Total factored Load = DL + LL

= 106.5 + 160

= 266.5 lb/ft² = $\boxed{0.2665\ k/ft^2}$

Step # 05 (Ultimate moment)

By using formula

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

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

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

Step # 06 : Area of Steel for main Bars By Trial and Repeat Method

Trial # (a)

Let depth of compression block

$a = 0.2 \times t$

$a = 0.2 \times 5.5$

$\boxed{a = 1.1"}$

Trail #(b) :

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

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

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

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

Step-07

Step 07: Area of Steel for distribution reinforcement

By formula

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

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

Step 08:

Spacing for main bars

by formula

Spacing $= \frac{A_b \times 12}{A_{st}}$

We use #6 bar dia $= \left(\frac{6}{8}\right)''$

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

Step 9: Spacing for distribution bars

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

We use #5 bars so

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

Spacing $= \frac{0.31}{0.132} \times 12 = 2.81'' \approx 28''$ c/c

<u>Step 10</u> Draw Sketch

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

Main Steel #6 at 9" c/c

Distribution Steel #5 at 9" c/c

Q No (3)

A Simply supported rectangular beam 16 inch, wide having an effective depth of 22 inches carries a total factored load of 9.4 kips/ft (excluding self-weight of beam) on a 20-ft clear span. It is reinforced with 7.62 in² of tensile steel which continues uninterrupted into the supports. If $f_c' = 4000$ psi and $f_y = 6000$ psi, using #3 vertical U-stirrups. Design the web reinforcement. Draw a sketch of your final design.

Given Data :-

→ Rectangular beam width 16 inch
→ Effective depth = 22"
→ Total factored load = 9.4 kips/ft
→ Clear span = 20 ft
→ Reinforced with ~~[illegible]~~ = 7.62 in²
→ f_c' = 4000 psi
→ f_y = 6000 psi
→ using #3 vertical U-stirrups.
→ excluding self-weight of beam.

Solution

First we have to find the self-weight of beam by formula

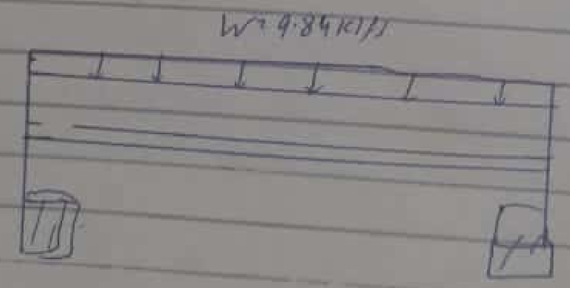
W = breath x thickness x unit weight of concrete t = b/2 = 16

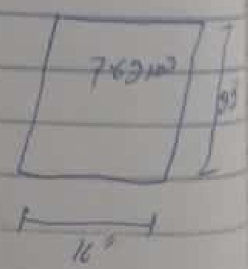
= b x t x 150 lb/ft³

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

So the factored load will be = 1.2 (0.3666) = 0.49 kip/ft

So the total applied factored load will be 9.84 kips/ft



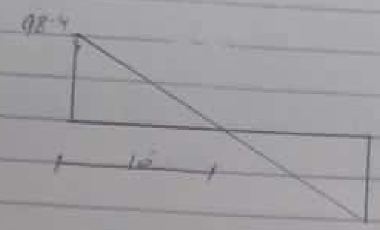


Step #1 (Reaction Values)

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

Hence both the support contains 98.4 kips

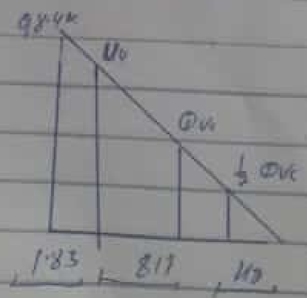
Step # 2 (Shear force Diagram)



Step # 3 Value of Critical Shear Vu

As we know that Critical Shear "Vu" 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 Δs

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

$V_u = 80.39$ kips

(11)

Step # 4: Value of ϕV_c and $1/2\ \phi V_c$

By using formula

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

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

Its location by similar triangles

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

Now

by using formula

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

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

Location of $1/2\ \phi V_c$

By similar triangle

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

Step # 5 (Value of ϕV_s)

As

$V_u = \phi V_s + \phi V_c$

$\phi V_s = V_u - \phi V_c$

$= 80.34 - 33.40$

$\boxed{\phi V_s = 46.94 kips}$

Scanned with CamScanner

Step #6 Check on Section Adequacy

By formula

$\phi \times 8\sqrt{f'c} \times bw \times d$

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

As $133.57 > \phi Vc$

So Section is Adequate.

Step #7 Maximum Spacing for Stirrups

$\Rightarrow \phi \times 4 \times \sqrt{f'c} \times bw \times d$

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

As $\phi 4\sqrt{f'c}\, bw\, d > \phi Vc$

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

① Smax 24"

② $d/2 = 22/2 = 11$

③ Smax $\frac{Av\, fy}{0.75 \times \sqrt{f'c} \times bw}$

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

(4) Spacing Smax $= \frac{Av \times fy}{50 \times bw}$

$= \frac{0.22 \times 60000}{50 \times 16} = 16.5$

Now from above 4 condition because it is the least value we will use for #5 2 legged stirrup

∴ As we are using #3 U-stirrup so it has dia 3/8" and Area 0.11 in² for will multiply it by 2

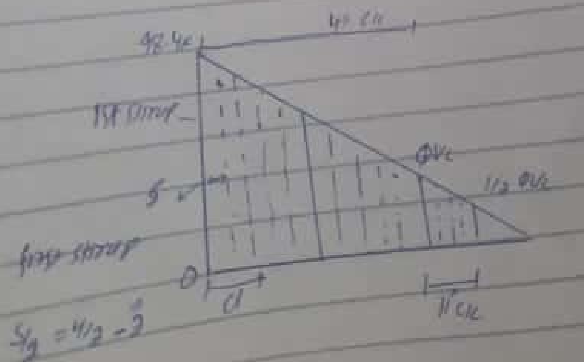
$0.11 \times 2 = 0.22 in^2$

Step #8 Spacing of stirrup at critical section:

By formula

$$S = \frac{\phi \times Av \times fyd}{Vu - \phi Vc} = \frac{0.75 \times 0.22 \times 60 \times 22}{80.39 - 33.4}$$

$S = 4"$ c/c $4.6 \approx 4$



no web reinforcement is required

$S_{g} = 4/2 = 2"$

Q.No (3)

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

Given Data

- → Column = 12 inch square
- → reinforced = 4 # 9
- → Ties are # 5 spaced @ 12 inches
- → f'_c = 4000 psi
- → f_y = 6 ksi

Solution ::

Step # 01

Find gross area of concrete

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

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

Step # 02

Find area of steel

Since $A_s = 5\%$ of A_g

$A_s = 0.05 \times 144$

$A_s = 7.2 \text{ in}^2$

Step # 03

Ultimate Load carrying capacity

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

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

$P_u = 466.50k$

Step # 04

Sketch of ties (c/c to distance)

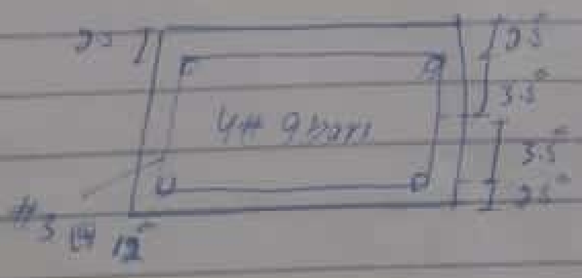
From the below value we choose the Least value of all thus

→ 16 x dia of long bar = 16 x 9/8 = 18"

→ 48 x dia of Tie bar = 48 x 3/8 = 18"

→ Least column dimension = 12"

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



So 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 that we will use tie stirrup instead

Qno 4

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

Given Data:-

→ D.L = 120 kips
→ L.L = 120 kips
→ The base of footing is below final grade = 5ft
→ Allowable soil pressure is = 2.50 ksf
→ f'_c = 3ksi
→ f_y = 60ksi
→ γ_{soil} = 120 pcf

Solution

Step # 01 =

$h = 24''$

Step # 02 =

Total weight = Wt of soil + Wt of RC

= 3×120 + 2×150 = 660 psf = 0.660 ksf

Step 03

Required Area for foundation

Area = $\frac{\text{Service load}}{q_e}$ = $\frac{100+120}{1.84}$ = 119.57 ft²

Step #4 Effective bearing capacity

$q_e = q_a - w_c$

$q_e = 3.50 - 0.660$

$q_e = 1.84$ ksf

Step #5 Since foundation is square

Area = b×b = 119.57 ⇒ B ≅ 11

Step #6

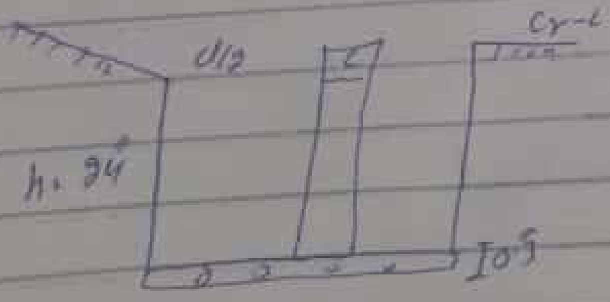
Upward bearing capacity of soil

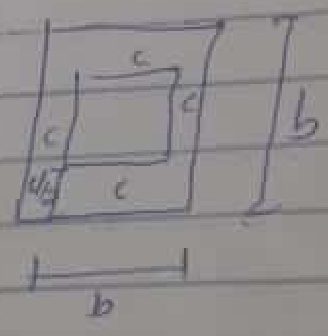
$q_{up} = \frac{\text{factored load}}{(B)^2}$

$q_{up} = \frac{1.2\times100 + 1.6\times120}{11^2}$ = **2.58 k/ft²**

Step #7 punching shear

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





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

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

$b_0 = 4 \times (16 + 19.5) = 142$

Step #08

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

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

$V_{u2} = 289.6k$

Step #09

$\phi V_{cp} = \phi \times 4 \sqrt{f'_c} \times b_0 d$

$= \frac{0.75 \times 4 \times \sqrt{4000} \times 149 \times 19.5}{1000}$

$\phi V_{cp} = 525.38$

Step #10 Beam Shear one way Shear check

$V_u = q_{u} \times B \times [B/2 - c/2 - d]$

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

$\boxed{V_u = 92.25k}$

Step # 11

Self Shear capacity

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

$= \frac{0.75 \times 2 \times \sqrt{[illegible]}}{1000} \times (12 \times 12 - 1.2)$

$= 11.24k > V_u =$ O.K

Step # 12 Ultimate moment

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

$M_u = 331.49k \approx 3977.93k''$

Step # 13 Area of steel for main bars by Trail and Repeat method

Trail # 01

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

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

Trail # 02

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

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

Trial 03.

$$a = \frac{7.11 \times 60}{0.85 \times 3 \times 11 \times 12} = \boxed{1.28}$$

$$A_s = \frac{3977.43}{0.90 \times 60\left(11 - \frac{1.28}{2}\right)} = \boxed{7.11\,in^2}$$

Step 14 Check the min reinforcement by the following 03 method

(a) $A_{s\,min} = 0.0018 \times B \times h = 0.0018 \times (11 \times 12) \times 24 = \boxed{5.70\,in^2}$

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

(c) $A_{s\,min} = 3 \times \frac{\sqrt{f_c'}}{f_y} \times B \times d = \frac{3 \times \sqrt{3000}}{60000} \times (11 \times 12) \times 19.5 = \boxed{7.05\,in^2}$

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

Step 15 using # 8 bars

$A_b = 0.785\,in^2$

no of bars $= \frac{A_s}{A_s} = \frac{8.58}{0.785} = 10.93 \approx 11$ bars in each direction