ID 14982

Subject ADVANCED DESIGN OF RCC STRUCTURE

Exam FINAL

MS CEM

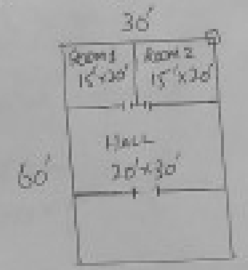
Date 23-06-2020

QUESTION # 1

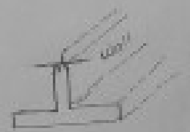
Design structural members of single story structure.

SOLUTION :-

Architectural design of structured (6.6 marla)



Design of wall footing



wall = 12" wide

D.L = 20 K/ft, L.L = 15 K/ft

γ_s = 100 lb/ft³, q_a = 4 ksf = 4000 psf

$f'c$ = 3 ksi = 3000 psi, f_y = 60,000 psi

H_s = 4' − h_c, γ_c = 150 lb/ft³, h_c = 12"

d = 12 − 3.5 = 8.5"   [code 7.7.1]

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Step 1: Effecting soil pressure "q_e"

$q_e = q_a - h_c \gamma_c - H_s \gamma_s \Rightarrow 4000 - (12/12 \times 150) - 13 \times 100)$

$q_e = 3550 \text{ psf} = 3.55 \text{ ksf}$

Step 2: Width of footing

$W = \frac{D+L}{q_e} = \frac{20+15}{3.55} = 9.86 \approx 10'$

Step 3: Depth required for shear at distance d for the face of wall.

$d = \frac{V_u}{\phi 2\sqrt{f'_c}\, b_w}$

$V_u = (10/2 - 6/12 - \frac{8.5}{12}) \times q_u$

q_u = ultimate bearing capacity

$= \frac{1.2 D.L + 1.6 L.L}{\text{width of footing}}$

$= \frac{1.2 D.L + 1.6 L.L}{10}$

$q_u = 4.8 \text{ ksf}$

$V_u = (10/2 - 6/12 - 8.5/12) \times 4.8$

$V_u = 18.2k = 18200 \text{ lb}$

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$d = \frac{V_u}{\phi 2\sqrt{f'c}\, b_w} = \frac{18200}{0.75 \times 2\sqrt{3000} \times 12}$

$d = 18.46''$

$h = d + cover = 18.46'' + 3.5\ in = 21.96$

21.96 > 12 not ok so try with greater Assume 20" footing

$h = 20''$

$d = 20 - 3.5 = 16.5''$

repeating step 1, 2 & 3

Step 1 = Effecting soil pressure "q_e"

$q_e = q_a - h_c \gamma_c - H_s \gamma_s = 4000 - (20/12 \times 150) - (\frac{28}{12} \times 100)$

$q_e = 3517\ psf = 3.517\ ksf$

Step 2 = width of footing

$w = \frac{D + L}{q_e} = \frac{20 + 15}{3.517} = 9.95' \cong 10'$

Step 3 = Depth required for shear

$V_u = (10/2 - 6/12 - 16.5/12)\, q_u$

$V_u = (10/2 - 6/12 - 16.5/12) \times 4.8$

$V_u = 15\ k$

$q_u = 4.8$

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$d = \frac{V_u}{\phi 2\sqrt{f'c}\ b_w} = \frac{15000}{0.75 \times 2 \times \sqrt{3000} \times 12} = 15.21$

$h = 15.21 + 3.5 = 18.71''$ use 20" total Depth

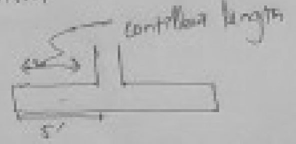
$h = 20''$, $d = 16.5''$

Step 4 = Determination of steel area (main)

Cantilever length $10/12 - 6/12 = 4.5$ ft

M_u = (cantilever length) × q_u × ½ L.Arm

$= 4.50 \times 4.80r\ \frac{4.50}{2}$



$M_u = 48.6$ ft-k

$\frac{M_u}{\phi bd^2} = \frac{48.6 \times 1000 \times 12}{0.9 \times 12 \times (16.5)^2} = 198.3$ psi

Reffering to Appendix A

when $\frac{M_u}{\phi bd^2} = 198.3$

Then by Interpolation $\rho = 0.00345$

$A_s = \rho bd = 0.00345 \times 12 \times 16.5$

$A_s = 0.68\ in^2$ refer to table A.6

using # bar @ 10" c/c spacing

$x_1 = 195.8$

$x_2 = 198.3$

$x_3 = 201.3$

$y_2 = \frac{(x_2 - x_1)(y_3 - y_1)}{(x_3 - x_1)} + y_1$

$= \frac{(198.3 - 195.8)(0.0035 - 0.002(?)) + 0.00(?)}{201.3 - 195.8}$

$y_2 = 0.00345$

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Step 5 = Longitudinal temperature & shrinkage steel

$A_s = \rho b d = 0.0018 \times 12 \times 20$

$A_s = 0.432 \text{ in}^2$ using table A-6

5 @ 8" c/c A_s selected $= 0.46 \text{ in}^2$

Step 6 = Development length

$\psi_t = \psi_e = \psi_s = 1 = 1$

$l_d/d_b = 3/40 \times f_y/\lambda\sqrt{f'_c} \; \frac{\psi_t \psi_e \psi_s}{c_b/d_b}$ — (1)

if $c_b/d_b > 2.5$ then use 2.5

c_b = side cover = 3.5"

d_b = dia of main bar $= 7/8 = 0.875$"

$c_b/d_b = 3.5/0.875 = 4 > 2.5$ so $c_b/d_b = 2.5$

using eq (1)

$l_b/d_b = 3/40 \times \frac{60{,}000}{1\sqrt{3000}} \times \frac{1 \times 1 \times 1}{2.5}$

$l_b/d_b = 32.86$

$= \frac{A_s \text{ req}}{A_s \text{ selected}} = 32.86 \times \frac{0.68}{0.72} = 31.03$

$l_d = 31.03 \times 0.875 = 27.15$"

Say $= l_d = 28$".

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Design of square coloumn footing

Step 1 : Effecting soil pressure qe

$q_e = q_a - h_c \gamma_c - H_s' \times \gamma_s$

$= 5000 - (24/12 \times 150) - (36/12) \times 100$

$q_e = 4400$ psf $= 4.4$ ksf

$q_e = 4.4$ ksf

Step 2 : Area of footing

Area of footing $= \frac{P_D + P_L}{q_e} = \frac{200 + 160}{4.4} = 81.82 \text{ ft}^2$

use 9' x 9" footing area = 81 ft²

Step 3 : Ultimate Bearing capacity

$q_u = \frac{1.2 P_D + 1.6 P_L}{\text{Area of footing}} = \frac{(1.2 \times 200) + (1.6 \times 160)}{81}$

$q_u = 6.12$ ksf

Step 4 : Depth required for two way or punching steel

i) $d = \frac{V_{u2}}{\phi 4 \sqrt{f_c'}\, b_o}$ (ii) $d = \frac{V_{u2}}{\phi\left(\frac{\alpha_s d}{b_o} + 2\right)\sqrt{f_c'}\, b_o}$

b_o = Perimeter around the punching area = 4(a+d)

$b_o = 4(a+d) = 4(16 + 19.5)$

$b_o = 142$ in

$V_{u_2} = \{A - (a+d)\} \times q_u$

$V_{u_2} = \{81 - (\frac{16+19.5}{12})\} \times 6.12$

$V_{u_2} = 442.09K = 442090 \text{ lb}$

$\boxed{V_{u_2} = 442090 \text{ lb}}$

① $d = \frac{V_{u_2}}{\phi 4 \sqrt{f'c}\, b_o} = \frac{442090}{0.75 \sqrt{3000} \times 142} = 12.95'' < 19.5$ (ok)

② $d = \frac{V_{u_2}}{\phi (\frac{\alpha_s d}{b_o} + 2) \sqrt{f'c}\, b_o} = \frac{442090}{0.75 (\frac{40 \times 19.5}{142} + 2) \sqrt{3000} \times 142} = 10.15 < 19.5$

both values of d are less then 19.5''
So punching shear is ok

Step 5: Depth required for one way shear

$V_{u_1} = (9 \times 2.208) \times q_u$
$= (9 \times 2.208) \times 6.12$

$V_{u_1} = 121.62K = 121620 \text{ lb}$

$d = \frac{V_u}{\phi 2 \sqrt{f'c}\, b_w} = \frac{121620}{0.75 \times 2 \times \sqrt{3000} \times 9 \times 12}$

$d = 13.7'' < 19.5$ ok

use $h = 24''$ for total depth

Moment: $M_u = 3.83 \times 9 \times 6.12 \times \frac{3.83}{2}$
$= 404$ ft-k

$\frac{M_u}{\phi b d^2} = \frac{404 \times 1000 \times 12}{0.9 \times (9 \times 12) \times (19.5)^2} = 131.2$ psi

Design of Slab S_1: (8)

Step # 1 Sizes : $l_b/l_a = 20/12 = 1.66$

So, it is two way slab is given.

Formula, $h_{min} = \frac{Perimeter}{180}$

$= \frac{2 \times (20+12) \times 12}{180}$

$h_{min} = 4.26 in$

Assume $h = 5''$

Step # 2 Loads

Factored Load $(W_u) = W_{u\,dl} + W_{u\,ll}$

$W_u = 1.2\,D.L + 1.6\,L.L$

$W_u = 1.2 \times 0.1225 + 1.6 \times 0.04$

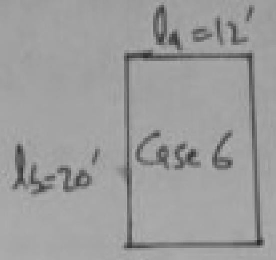
$= 0.219$ ksf

Step #3 Analysis

W_u = Ultimate uniform load psf

l_a, l_b = lenght of clear spans in [short] and long directions respectively

Therefore, for the design problem under discussion $m = l_a / l_b = 12/20 = 0.6$



Two way slab (S_2)

Table 1.2 Moment Coefficient for slab
Case #6 (m = 0.60)

Coefficient for negative moments in slabs		Coefficient for Dead load Positive moments in slab		Coefficient for live load Positive moments in slab	
$C_{a,neg}$	$C_{b,neg}$	$C_{a,dl}$	$C_{b,dl}$	$C_{a,ll}$	$C_{b,ll}$
0.095	0.00	0.056	0.006	0.068	0.006

1) $M_{a,neg} = C_{a,neg} \times W_u \times l_a^2 = 0.095 \times 0.219 \times (12)^2 = 2.99 \text{ ft-k}$

$= 2.99 \times 12 = 35.8 \text{ in-k}$

2) $M_{b,neg} = C_{b,neg} \times W_u \times l_b^2 = 0 \times 0.247 \times 20^2 = 0 \text{ ft-k}$

3) $M_{a,pos,dl} = C_{b,pos,dl} \times W_{u,dl} \times l_a^2 = 0.006 \times 0.247 \times 12^2$

$= ~~0.525 \text{ ft-k}~~ = ~~6.30 \text{ in-k}~~$

$= ~~0.184~~ \; 0.127 \times 12 = 1.52 \text{ in-k}$

(10)

(4) M_b pos dl = $C_{b\,pos\,dl} \times W_{u\,dl} \times l_b^2 = 0.006 \times 0.147 \times 20^2 = 0.525$

(5) M_a pos ll = $C_{a\,pos\,ll} \times W_{u\,ll} \times l_a^2$ = 0.3528 = 4.233 in-k

$= 0.068 \times 0.064 \times 12^2 = 0.62$ ft-k

$= 7.52$ in-k

(6) M_b pos ll = $C_{b\,pos\,ll} \times W_{u\,ll} \times l_b^2$

$= 0.006 \times 0.064 \times 20^2 = 0.153 \times 12$

$= 1.84$ in-k

Therefore finely we have

1) $M_{a,neg} = 2.99$ k-ft $= 35.8$ in-k
2) $M_{b,neg} = 0$ ft-k
3) M_a pos (dl+ll) = $1.52 + 0.35 = 1.87$ ft-k = 22.44 in-k
4) $M_{b,pos}$ (dl+ll) = $0.62 + 0.153 = 0.773$ ft-k = 9.276 in-k

Step # 04 Design.

$A_{s\,min} = 0.002\,b h_f = 0.002 \times 12 \times 5 = 0.12\ in^2$

$a = \dfrac{A_{s\,min} f_y}{0.85 f'_c b} = \dfrac{0.12 \times 40}{0.85 \times 3 \times 12} = 0.156$ in

$\phi M_n (min) = \phi A_{s\,min} f_y (d - a/2)$

$= 0.9 \times 0.12 \times 40 \times (4 - 0.156/2) = 16.94$ in-k

(Capacity provided by $A_{s\,min}$).

Also $h = \frac{l}{18.5}\left(0.4 + \frac{f_y}{100000}\right) = \frac{19.875}{18.5}\left(0.4 + \frac{40000}{100000}\right) \times 12$

$h_{actual} = 6.68''$

Also Table 4.1

$h_{actual} = l/28 = \frac{12.875}{28} = 0.46 \times 12 = 5.52''$

So,

Minimum thickness $h_{min} \approx 7.5'' = 18''$ will govern.

effective depth = $d = h - 3$
$= 18 - 3$
$= 15''$

$d = 1.25'$

Step#02:- Loads.

Material	thickness (inch)	γ (kcf)	load = γ x thickness
Slab	5	0.15	$0.15 \times 5/12 = 0.0625$
Mud	4	0.12	$0.12 \times 4/12 = 0.04$
brick	2	0.12	$0.12 \times 2/12 = 0.02$

service D.L = 0.0625 + 0.04 + 0.02 = 0.1225 ksf.

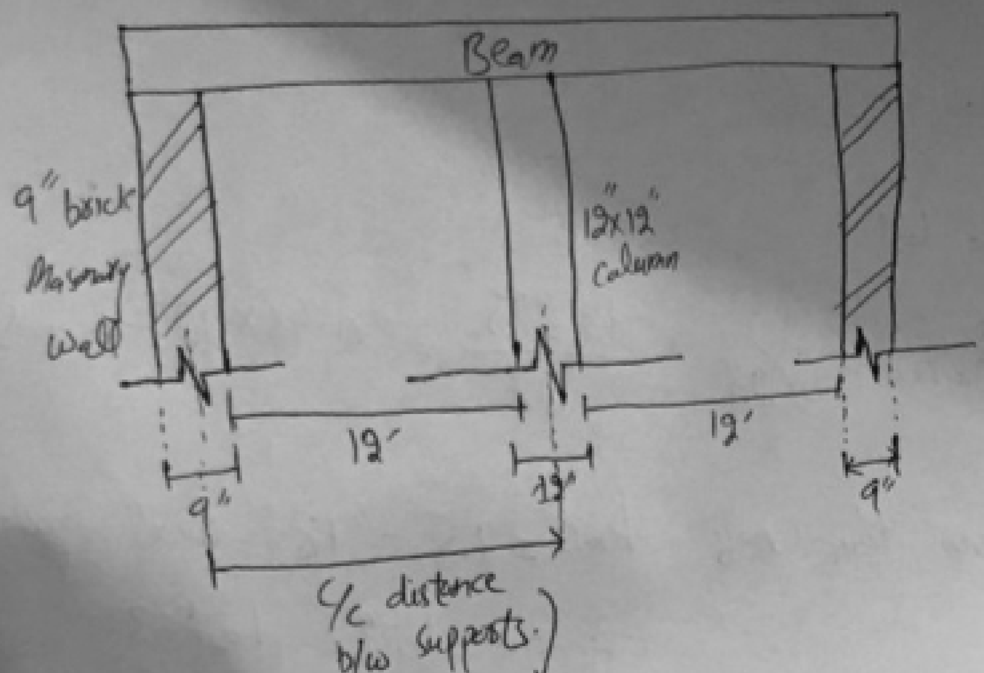
service L.L = 40 psf = 0.04 ksf.

Beam is supporting 5' slab per running foot

therefore,

service D.L from slab = 0.1225 x 5 = 0.6125 k/ft.

BEAM DESIGN:-



$$l = 12' + \frac{12''/2}{12} + \frac{9''/2}{12} = 12' + 0.5' + 0.375'$$

$$l = 12.875'$$

Exterior support - 9" brick masonry wall.

$f_c' = 3ksi = 3000psi$

$f_y = 40ksi = 40,000psi$

interior support ⇒ column support = 12" × 12"

Step 1:- $l = 12.875'$ (c/c distance b/w supports).

Sizes:- Minimum thickness of beam (ACI 9.5.2.1).

$h_{min} = 1.5' = 18''$