ID# 15067

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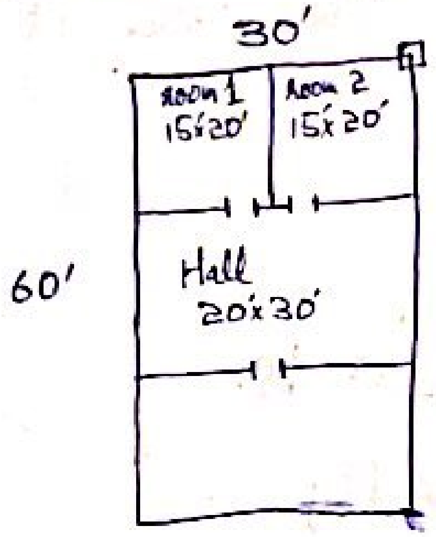
MS (CEM)

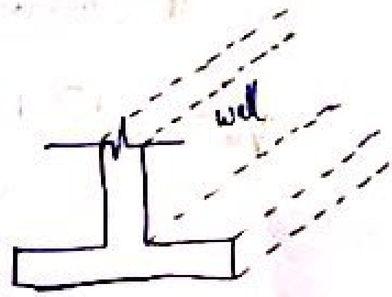
Subject: Advanced design of reinforced concrete structures.

Instructor: Engr. Fawad Ahmad.

Architectural design of structure (6.6 marla)



Design of wall footing:



wall = 12" wide

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

$\gamma_s = 100\ lb/ft^3$, $q_a = 4\ ksf = 4000\ psf$

$f_c' = 3\ ksi = 3000\ psi$, $f_y = 60,000\ psi$

$H_s = 4' - h_c$, $\gamma_c = 150\ lb/ft^3$, $h_c = 12''$

$d = 12 - 3.5 = 8.5''$ (code 7.7.1)

Step 1: Effective soil pressure q_e.

$q_e = q_a - h_c \gamma_c - H_s' \gamma_s \Rightarrow 4000 - (\frac{12''}{12} \times 150) - (3 \times 100)$

$q_e = 3550$ psf $= 3.55$ ksf.

Step 2: Width of footing

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

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

$d = \frac{V_u}{\phi 2\sqrt{f_c'}\, bw}$

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

q_u = ultimate bearing capacity

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

$= \frac{1.2 \times 20 + 1.6 \times 15}{10}$

$q_u = 4.8$ ksf

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

$V_u = 18.2$ k $= 18200$ lb

5

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

$$\boxed{d = 18.46''}$$

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

$21.96 > 12$ not OK so try with greater.

Assume 20" footing

$h = 20''$

$d = 20 - 3.5 = 16.5''$

repeating step 1, 2 & 3

Step 1: Effective Soil pressure 'q_e'

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

$q_e = 3517\ psf = 3.517\ ksf.$

.5

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.

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

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

$V_u = 15k$

$q_u = 4.8$

.103

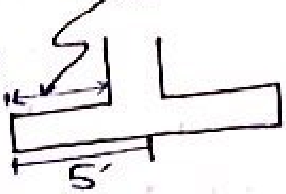
$$d = \frac{V_u}{\phi\, 2\sqrt{f'_c}\, b_w} = \frac{15000}{0.75 \times 2 \times \sqrt{3000} \times 12} = 15.21''$$

$h = 15.21 + 3.5 = 18.71''$ use $20''$ total depth

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

Step 4: Determination of steel area (main)

Cantilever length $= 10/2 - 6/12 = 4.5$ ft.



M_u = (Cantilever length) x q_u x ½ L. Arm

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

$M_u = 48.6$ ft-K

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

Reffering to Appendix A

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

then by interpulation $\rho = 0.00345$

$A_s = \rho b d = 0.00345 \times 12 \times 16.5$

$A_s = 0.68 \text{ in}^2$ refer to table A-6

using #7 bar @ 10" c/c spacing

x_1 195.8

x_2 198.3

x_3 201.3

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

$$= \frac{(198.3 - 195.8)(0.0035 - 0.0034)}{201.3 - 195.8} + 0.0034$$

$y_2 = 0.00345$

Step 5: Longitudinal Temperature & Shrinkage steel.

$A_s = \rho bd = 0.0018 \times 12 \times 20$

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

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

Step 6 Development length

(i) $\psi_t = \psi_c = \psi_s = \lambda = 1$

$$\frac{ld}{db} = \frac{3}{40} \frac{fy}{\lambda\sqrt{f'c}} \frac{\psi_t \psi_c \psi_s}{cb/db} \quad -(1)$$

if $cd/db > 2.5$ then use 2.5

cb = side cover = 3.5"

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

$cb/db = 3.5/0.875 = 4 > 2.5$ so $cb/db = 2.5$

using eq (1)

$$lb/db = \frac{3}{40} \times \frac{60000}{1\sqrt{3000}} \times \frac{1\times1\times1}{2.5}$$

$lb/db = 32.86$

$$= \frac{A_s \text{ req}}{A_s \text{ selected}} = 32.86 \times 0.4$$

$ld = 31.03 \times 0.875 = 27.$

say: $ld = 28"$

Scanned with CamScanner

Design of square column footing

Step 1: Effective soil pressure q_e

$$q_e = q_a - h_c \gamma_c - H_s' \times \gamma_s$$
$$= 5000 - \left(\tfrac{24}{12} \times 150\right) - \left(\tfrac{36}{12}\right) \times 100$$

$q_e = 4400$ psf $= 4.4$ ksf

$$\boxed{q_e = 4.4 \text{ ksf}}$$

Step 2: Area of footing.

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

use $9'' \times 9'$ footing area $= 81$ ft^2

Step 3: Ultimate Bearing Capacity

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

$$\boxed{q_u = 6.12 \text{ Ksf}}$$

Step 4: Depth required for two way or punching shear

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

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

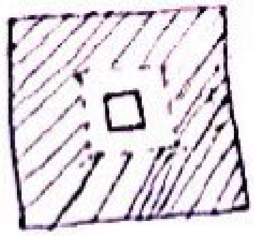
$b_o = 4(a+d) = 4(16+19.5)$

$$\boxed{b_o = 142 \text{ in}}$$

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

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

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



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

(1) $d = \frac{V_{u_2}}{\phi 4\sqrt{f_c'}\, b_o} = \frac{442090}{0.75 \times 4\sqrt{3000} \times 142} = 18.95'' < 19.5$ (OK)

(2) $d = \frac{V_{u_2}}{\phi\left(\frac{\alpha_s d}{b_o} + 2\right)\sqrt{f_c'}\, b_o} = \frac{442090}{0.75\left(\frac{40 \times 19.5}{142} + 2\right)\sqrt{3000} \times 142}$
$= 10.12'' < 19.5''$ (OK)

both values of d are less than 19.5''
So punching shear is OK

Step 5: Depth required for one way shear.

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

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

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

$d = 13.71'' < 19.5$ OK

use $h = 24$ in total depth

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

$\frac{M_u}{\cdots} = \frac{404 \times 1000 \times 12}{0.9 \times (9 \times 12) \times (19.5)^2} = 131.2$ psi table A-12

$\frac{M_u}{\phi b d^2} = 134.3$

then use greater of

① $\frac{200}{60,000} = 0.0033$

② $\frac{3\sqrt{3000}}{60,000} = 0.00274$

so $\rho = 0.0033$.

Area of steel

$A_s = \rho b d$

$= 0.0033 \times (9 \times 12) \times 19.5$

$A_s = 6.95 \text{ in}^2$

use table A-4 9#8 bar in both direction

Development lengths

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

if $c_b/d_b > 2.5$ then use 2.5

$c_b/d_b = \frac{3.5}{1} = 3.5 > 2.5$ so use 2.5

using eq ①

$l_b/d_b = 3/40 \times \frac{60000}{1\sqrt{3000}} \times \frac{1 \times 1 \times 1}{2.5} = 32.86$

$l_b/d_b \; \frac{A_s \text{ req}}{A_s \text{ sel}} = 32.86 \times \frac{6.95}{7.07} = 32.30$

$l_d = 32.30 \times d_b = 32.30 \times 1$

$\boxed{l_d = 32''}$ ok

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Design of Columns

Assume the column will have an average compression stress = about $0.6 f'_c = 2400$ psi $= 2.4$ ksi

$$A_g \text{ required} = \frac{600K}{2.4 \text{ ksi}} = 250 \text{ in}^2$$

Try 16x16 column ($A_g = 256 \text{ in}^2$) with the bar arrangement shown in fig

$$e = \frac{M_u}{P_u} = \frac{(12 \text{ in/ft})(80 \text{ ft-K})}{600K} = 1.60 \text{ in}.$$

$$P_n = \frac{P_u}{\phi} = \frac{600K}{0.65} = 923.1 \text{ K}$$

$$K_n = \frac{P_n}{f'_c A_g} = \frac{923.1K}{(4 \text{ ksi})(16 \times 16)} = 0.901$$

$$R_n = \frac{P_n e}{f'_c A_g h} = \frac{(923.1K)(1.6 \text{ in})}{(4 \text{ ksi})(16 \times 16)(16)} = 0.901$$

$$r = 11''/16'' = 0.68$$

Interpolating ~~values~~ b/w values given in graphs

r	0.600	0.6875	0.700
ρ_g	0.025	0.023	0.022

$$A_s = (0.023)(16)(16) = 5.89 \text{ in}^2$$

use 8 #8 bars = 6.28 in².

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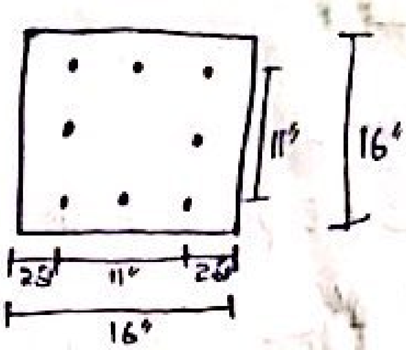

Notes

a) Note that $\phi = 0.65$ as initially assumed since the graphs used show $f_s/f_y < 1.0$ & thus $\varepsilon_t < 0.002$

b) code requirements must be checked.

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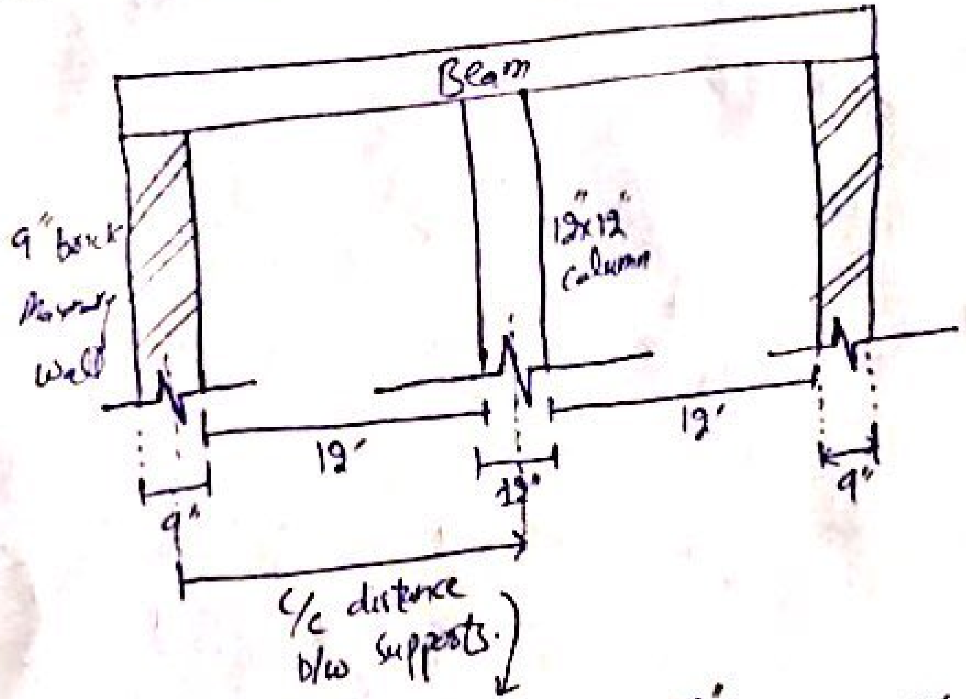
BEAM DESIGN:



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

$$L = 12.875'$$

Exterior support - 9" brick masonry wall.

$f_c' = 3\text{ksi} = 3000\text{psi}$

$f_y = 40\text{ksi} = 40{,}000\text{psi}$

interior support => column support = 12" x 12"

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

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

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

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Also $h = \frac{l}{18.5}\left(0.4 + \frac{f_y}{100000}\right) = \frac{12.875}{18.5}\left(0.4 + \frac{40000}{100000}\right) \times 12$

$h_{actual} = 6.68''$

Also Table 4.1

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

So,

Minimum thickness $h_{min} = 1.5' = 18''$ will govern.

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

$\boxed{d = 1.25'}$

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

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Slab Design :

ACI Formulae for thickness of continuous one way slab ACI 9.5.2.

one end continuous = $l/24$

both end continuous = $l/28$

Assume 6" slab. Span length for end span of slab will be equal to clear span plus depth of member.

Slab thickness calculation according to ACI 9.5.2

one end continuous

$$l/24 \times \left(\frac{0.4 + f_y}{100000}\right)$$

$$\Rightarrow 20/24 \times \left(\frac{0.4 + 40000}{100000}\right) \times 12 = 5'$$

both end continuous

$$l/28 \times \left(\frac{0.4 + f_y}{100000}\right)$$

$$\Rightarrow 30/28 \times \left(\frac{0.4 + 40000}{100000}\right) \times 12 = 6''$$

Take slab thickness = 6" (ACI 9.5.2.1)

Effective depth (d) = $h - 0.75 - (3/8)/2 = 5''$ (#3 main bar)

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3) At exterior mid span.

Positive moment $(+M_{Mext})$ = Coefficient × $(w_u l_n^2)$

$= (1/11) \times (0.214 \times 9.5^2)$

$= 1.755$ ft-k/ft $= 21.06$ in-k/ft.

4) At interior mid span.

Positive moment $(+M_{int})$ = Coefficient × $(w_u l_n^2)$

$= (1/16) \times (0.214 \times 9^2)$

$= 1.08$ ft-k/ft $= 13.$ in-k/ft

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Step 2: Loading:

Service DL $= 0.075 + 0.03 + 0.02$
$= 0.125$ ksf.

Service L.L $=$ 40 psf or 0.04 ksf (for hall)

Service load $=$ D.L + L.L $= 0.125 + 0.04 = 0.165$ ksf

Factored load $= 1.2\,DL + 1.6\,DL$
$= 1.2 \times 0.125 + 1.6 \times 0.04 = 0.214$ ksf

Step 3: Analysis:

One way slab

(1) At interior support

Negative moment $(-M_{L\,int}) =$ co-efficient $\times (w_u l_n^2)$
$= (1/12) \times (0.214 \times 9.5^2)$
$= 1.609$ ft-k/ft $= 19.31$ in-k/ft.

(2) At interior support right.

Negative moment $(-M_{R\,int}) =$ coefficient $\times (w_u l_n^2)$
$= (1/12) \times (0.214 \times 9^2)$
$= 1.44$ ft-k/ft $= 17.33$ in-k/ft

Moments:-

Negative moment = coefficient × $w_u l_n^2$

$M_{neg} = \frac{1}{9} \times (1.325 \times 12^2)$.

$M_{neg} = 21.2$ ft-K × 12

$M_{neg} = 254.4$ in-K

Positive moment = coefficient × $w_u l_n^2$

$M_{pos} = \frac{1}{11} \times (1.325 \times 12^2)$.

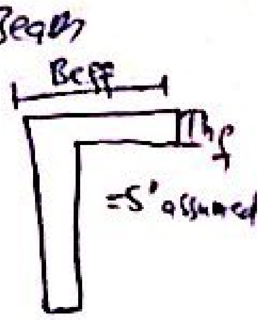
$M_{pos} = 17.34$ ft-K × 12

$\boxed{M_{pos} = 208.14 \text{ in-K}}$

Step #4 :- Design (moment/flexure).

① **For positive moment:-**

According to ACI 8.10, beff for L-Beam is minimum of .



(i) $6h_f + b_w = 6(5) + 12 = 42"$

(ii) $b_w + \frac{\text{Span length of beam}}{12} = 12 + \frac{(12.875 \times 12)}{12}$

$= 24.875"$

So, $\boxed{b_{eff} = 24.875}$

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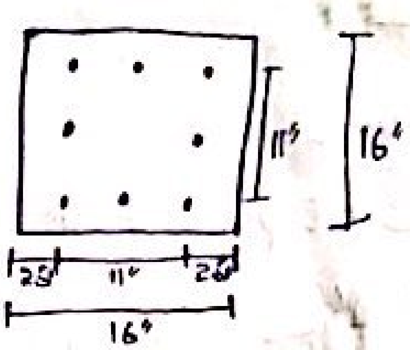

Notes

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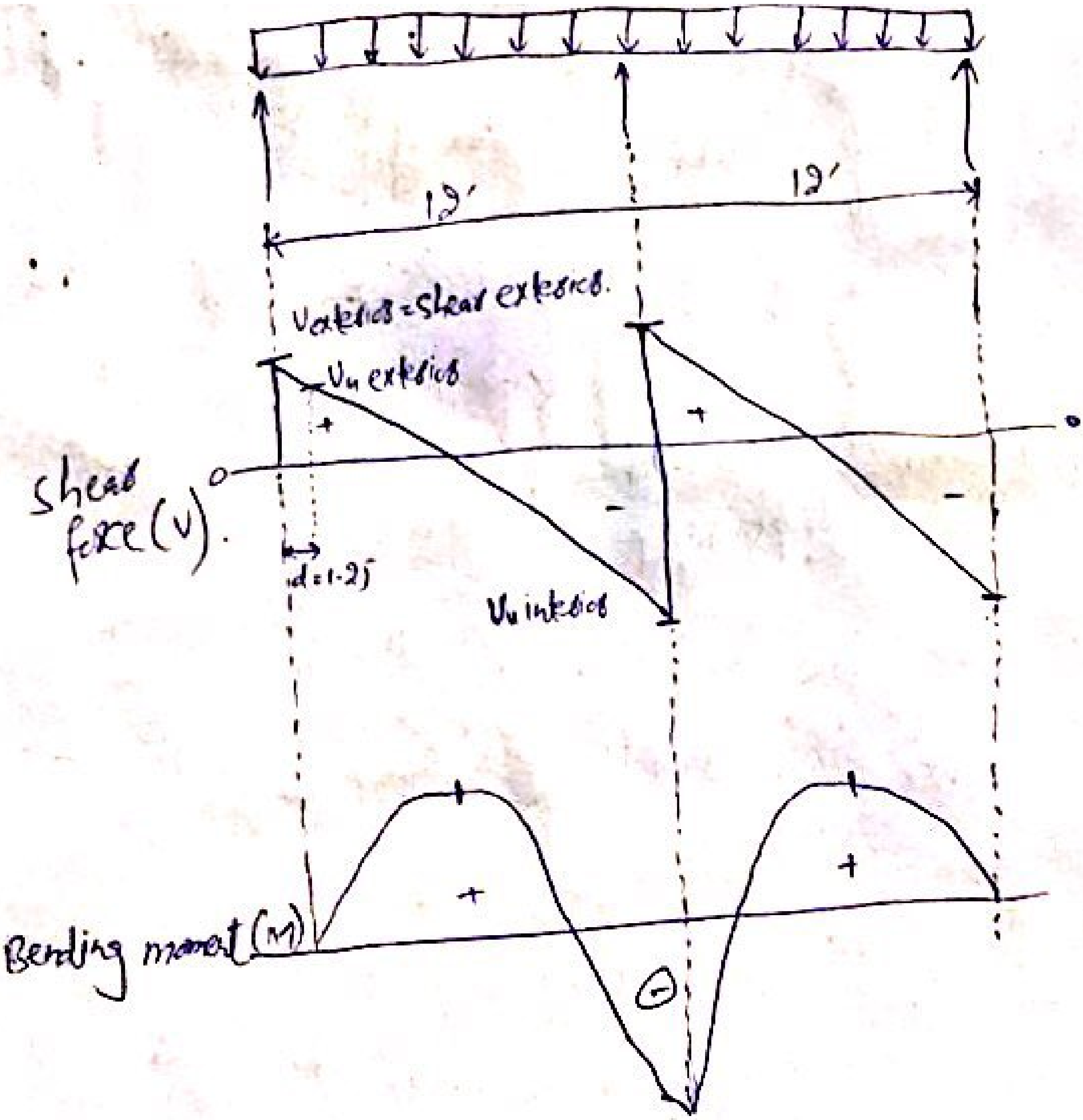
b) code requirements must be checked.



Shears:- $V_{exterior} = \frac{w_u l_n}{2} = \frac{1.325 \times 12}{2} = 7.95K.$

Vinterior

V_u exterior $= V_{ext} - d^2 = 7.95 - (1.25)^2 = 6.39K$

$V_{interior} = 1.15 \frac{w_u l_n}{2} = \frac{1.15 \times 1.325 \times 12}{2} = 9.14K.$

V_u interior $= V_{interior} - d^2 = 9.14 - (1.25)^2 = 7.58K.$

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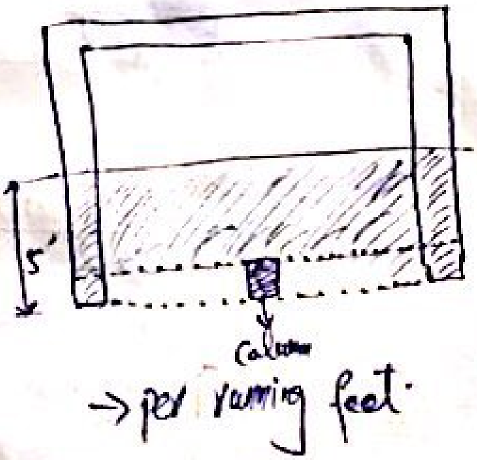

self wt of beam $= h \times b_w \gamma_c$

$$= \left(\frac{18 \times 12}{144}\right) \times 0.15$$

$$= 0.225 \text{ K/ft}$$

Total D.L $= 0.6125 + 0.225$

$$= 0.8375 \text{ K/ft}$$

Also service live load for 5' slab per running feet.

service, live load $= 0.04 \times 5 = 0.2$ K/ft

Factored load:-

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

$$w_u = (1.2 \times 0.8375) + (1.6 \times 0.2).$$

$$\boxed{w_u = 1.325 \text{ K/ft}}$$

Step #03:- Shear & Moments :-

using Table 12.1 moments and shear values

using ACI coefficients Design of concrete structures

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

$d = 13.71'' < 19.5$ ok.

use $h = 24''$ in total depth.

Moments, $M_u = 3.83 \times 9 \times 6.12 \times \frac{3.83}{2}$

$$\boxed{M_u = 404 \text{ ft-k}}$$

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

Use Appendix A table A-12

$\frac{M_u}{\phi b d^2} = 134.3$ then use greater of

① $\frac{200}{60{,}000} = 0.0033$

② $\frac{3\sqrt{3000}}{60{,}000} = 0.00274.$

so $\rho = 0.0033$

Area of steel:- $A_s = \rho b d$
$= 0.0033 \times (19 \times 12) \times 19.5$

$$\boxed{A_s = 6.95 \text{ in}^2}$$