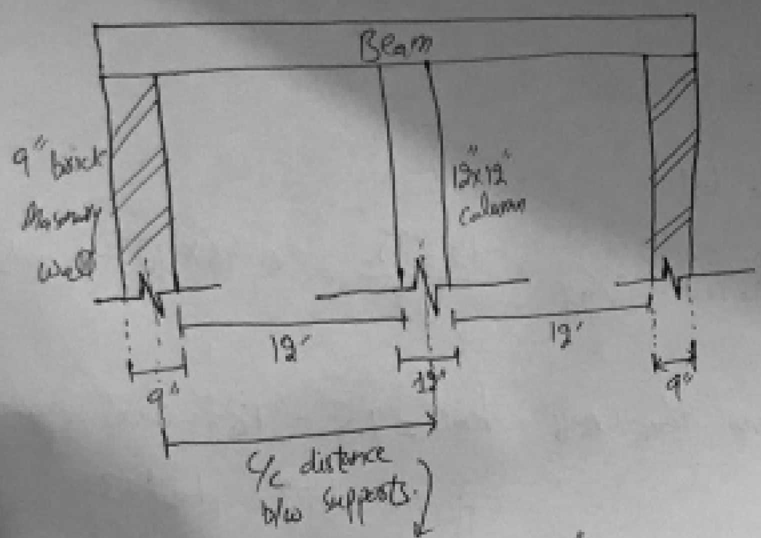
BEAM DESIGN:-



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

$$l = 12.875'$$

Exterior support - 9" brick masonry wall.

$f_c' = 3ksi = 3000psi$

$f_y = 40ksi = 40,000psi$

interior support ⇒ column support = 12" x 12"

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

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

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

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

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

So,

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

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

$d = 1.25'$

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 $= 0.1225 \times 5 = 0.6125$ k/ft.

Subject: "Advanced Design of Reinforced Concrete structures"

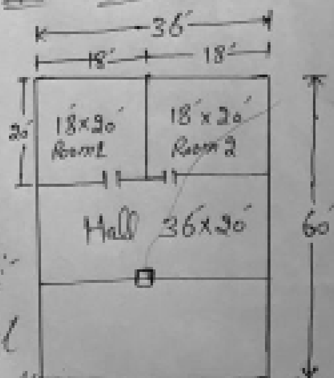
I.D: 15533

Instructor: Engr. Fawad Ahmad.

Date: 23/06/2020

Question:- Design structural members of single story structure.

⇒ Architecture Design of 60'x36' Marla plot:-

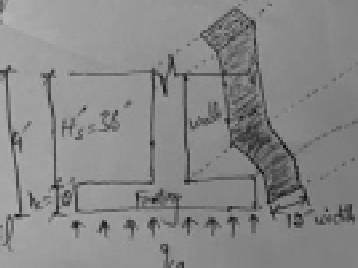


⇒ Area of plot in marla's:

$$\frac{60 \times 36}{272} = 7.9 \text{ Marla}.$$

First we will Design wall footing:-

Design a wall footing to support a 12" wide reinforced concrete wall with a dead load D = 20K/ft & a live load L = 15K/ft. The bottom of the footing is to be 4' below the final grade, the soil weight 100lb/ft³, the allowable soil



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

$d = 13.71'' < 19.5$ 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 :- $A_s = \rho b d$

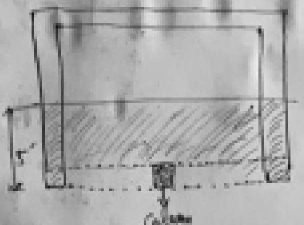
$= 0.0033 \times (19 \times 12) \times 19.5$

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

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

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

$= 0.225\ K/ft$



→ per running feet.

Total D.L = $0.6125 + 0.225$

$= 0.8375\ K/ft$

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

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

Factored load:-

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

$W_u = (1.2 \times 0.8375) + (1.6 \times 0.2)$

$W_u = 1.325\ K/ft$

Step #03:- Shear & Moments:-

Using Table 12.1 moments and shear values

Using ACI coefficients Design of concrete structures.

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

$h_{actual} = l/28 = \frac{19.875}{28} = 0.46 \times 12 = 5.52''$

So,

Minimum thickness $h_{min} = 17.5'' = 18''$ will govern.

effective depth = $d = h - 3$

$= 18 - 3$

$= 15''$

$d = 1.25'$

Step#02:- Loads.

Material	thickness (inch)	γ (kcf)	load = γ × thickness
slab	5	0.15	$0.15 \times 5/12 = 0.0625$
Mud	4	0.12	$0.12 \times 4/12 = 0.04$
brick	3	0.12	$0.12 \times 3/12 = 0.03$

service D.L = 0.0625 + 0.04 + 0.03 = 0.1325 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 × 5 = 0.6125 k/ft.

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)

3) At exterior mid span

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

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

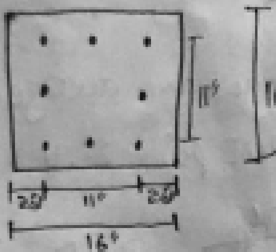
$= 1.755$ ft-k/ft $= 21.06$ in-k/ft.

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



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.

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 + LL = 0.125 + 0.04 = 0.165 ksf

Factored load = 1.2 DL + 1.6 DL
= 1.2 × 0.125 + 1.6 × 0.04 = 0.214 ksf

Step 3 : Analysis :

One way slab

(1) At interior support

Negative moment ($-M_{Lint}$) = co-efficient × ($w_u l_n^2$)

= (1/12) × (0.214 × 9.5²)

= 1.609 ft-k/ft = 19.31 in-k/ft.

(2) At interior support right.

Negative moment ($-M_{Rint}$) = coefficient × ($w_u l_n^2$)

= (1/12) × (0.214 × 9²)

= 1.44 ft-k/ft = 17.33 in-k/ft

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.

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

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

$$K_n = \frac{P_n}{f_c' A_g} = \frac{923.1 \text{ k}}{(4 \text{ ksi})(16 \times 16)} = 0.901$$

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

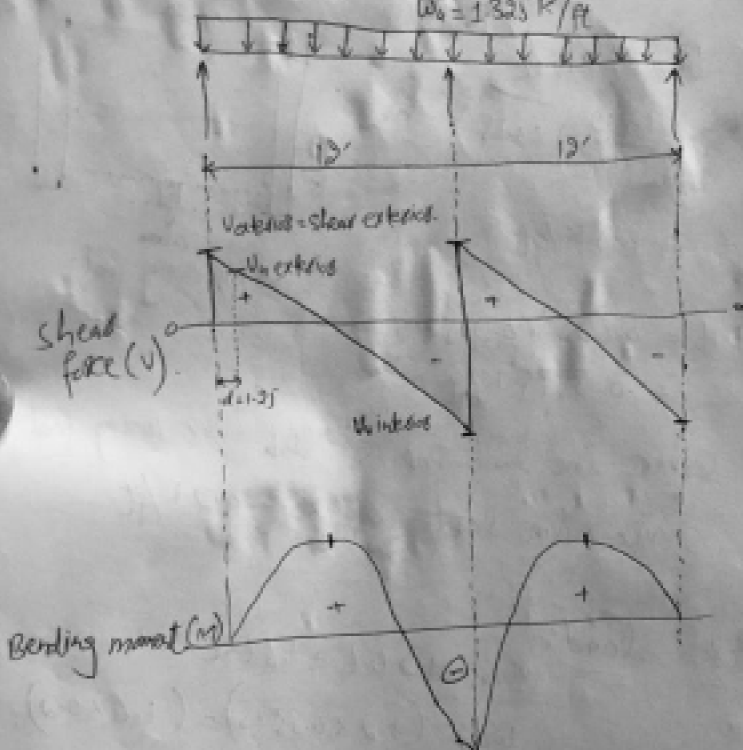
$$r = 11''/16'' = 0.68$$

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.



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

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

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

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

Moments:-

Negative moment = coefficient × $w_u l_n^2$

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

$M_{neg} = 21.2$ ft-K × 12

$M_{neg} = 254.4$ in-K

Positive moment = coefficient × $w_u l_n^2$

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

$M_{pos} = 17.34$ ft-K × 12

$M_{pos} = 208.14$ in-K

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

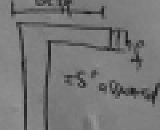
① For positive moment:-

According to ACI 8.10, b_{eff} for L-Beam is minimum of

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

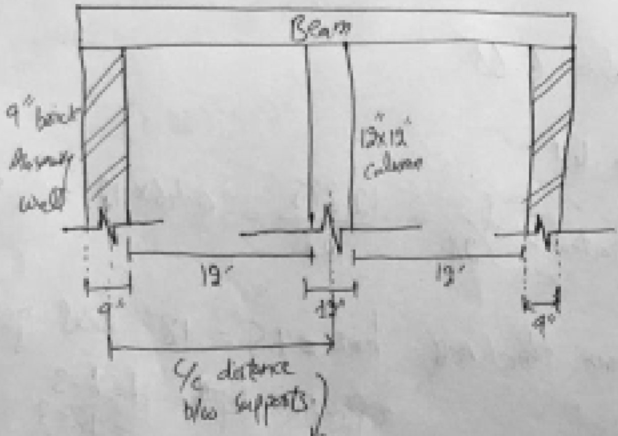
(ii) $b_w + \frac{\text{Span length of beam}}{12} = 12 + \frac{(12.875 \times 12)}{12}$

$= 24.875"$



So, $b_{eff} = 24.875$

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"

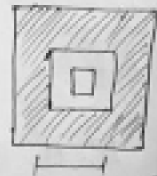
step 1:- $l = 12.875'$ (c/c distance b/w support)

size:- Minimum thickness of beam (ACI 9.5.2.1)

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

$V_{u2} = \{A - (a+d)^2\} \times q_u$

$V_{u2} = \left\{81 - \left(\frac{16+19.5}{12}\right)^2\right\} \times 6.12$



16+19.5 = 35.5"
Two way shear.

$V_{u2} = 442.09k = 442090$ lb.

$V_{u2} = 442090$ lb

(i) $d = \frac{V_{u2}}{\phi 4\sqrt{f'_c}\, b_o} = \frac{442090}{0.75\times 4\sqrt{3000}\times 142}$

$d = 18.95" < 19.5$ (ok).

(ii) $d = \frac{V_{u2}}{\phi\left(\frac{\alpha_s d}{b_o}+2\right)\sqrt{f'_c}\, b_o} = \frac{442090}{0.75\left(\frac{40\times 19.5}{142}+2\right)\sqrt{3000}\times 142}$

$d = 10.13 < 19.5"$ (ok).

both values of d are less than 19.5"
so punching shear is ok.

Step#05: Depth required for one way shear.

$V_{u1} = (9\times 2.208)\times q_u$
$= (9\times 2.208)\times 6.12$

$V_{u1} = 121.62k \Rightarrow$ **$V_{u1} = 121620$ lb**

Step # 02 :- Area of footing.

Area of footing $= \frac{P_D + P_L}{q_e} = \frac{200 + 160}{4.40} = 81.82\ ft^2$

Use 9' x 9" footing Area = 81 ft^2.

Step # 03 :- ultimate bearing capacity.

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

$\boxed{q_u = 6.12\ ksf}$

Step # 04 · Depth required for two way or punching shear:

The "d" required for two-way shear is the largest value obtained from the following expression.

(i) $d = \frac{V_{u3}}{\phi 4 \sqrt{f_c'}\, b_o}$

(ii) $d = \frac{V_{u3}}{\phi \left(\frac{\alpha_s d}{b_o} + 2\right) \sqrt{f_c'}\, b_o}$

α_s = 40 for column where perimeter is four sided

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

$b_o = 4(16 + 19.5)$

$\boxed{b_o = 142\ in}$

Step#6 Developement length

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

$$\frac{l_d}{d_b} = \frac{3}{40} \frac{f_y}{\lambda \sqrt{f_c'}} \frac{\psi_t \times \psi_e \times \psi_s}{c_b/d_b} \rightarrow eq\ (1).$$

ψ_t = Reinforcement location factor

ψ_e = Coating factor

ψ_s = Reinforcement size factor.

λ = concrete modification factor.

if $c_b/d_b > 2.5$ the use 2.5

C_b = side cover = 3.5"

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

$$c_b/d_b = \frac{3.5}{0.875} = 4 > 2.5 \text{ so } c_b/d_b = 2.5$$

using eq (1)

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

$$\frac{l_b}{d_b} = 32.86$$

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

$l_d = 31.03 \times 0.875 = 27.15"$

Say ⇒ $\boxed{l_d = 28"}$

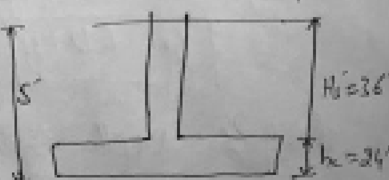
1) Design a Square column footing for a 16 inch square tied interior column that supports a dead load $P_D = 200k$ & live load $P_L = 160k$. the column is reinforced with #8 bars, the base of the footing is 5' below grade, the soil weight is 200 lb/ft³, $f_y = 60{,}000$ psi & $f'_c = 3000$ psi and $q_a = 5000$ psf.

Assumed data

$\gamma_c = 150\ lb/ft^3$

$h_c = 24''$, $d = 19.5''$

$H_s = 36''$



⇒ step #01

⇒ effective soil pressure "q_e"

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

$q_e = 4400\ psf = 4.40\ ksf$

$\boxed{q_e = 4.40\ ksf}$

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

$$\boxed{d = 15.21''}$$

$h = 15.21 + 3.5$

$h = 18.71$ in (use 20'' total depth).

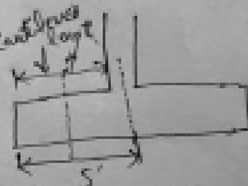
$h = 20''$

$d = 16.5''$

Step # 4: Determination of steel area (Main)

Cantilever length $= \frac{10}{2} - \frac{6}{12}$

$\boxed{C.L = 4.50\text{ ft}}$



$M_u = C.L \times q_u \times \frac{1}{2}$ ~~[illegible]~~ CL.

$M_u = \underline{4.50} \times 4.80 \times \frac{1}{2} \times 4.50$.

$\boxed{M_u = 48.6\text{ ft-K}}$

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

Assuming when,

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

then by interpolation $\rho = 0.00345$

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

$A_s = 0.68 in^2$ Refer Area of steel table A.6

using #7 bar @ 10" c/c spacing

$A_{s\,selected} = 0.72 in^2$

Interpolation

$M_u/\phi bd^2$	ρ
$x_1 = 195.8$	$0.0034 \; y_1$
$x_2 = 198.3$	$y_2 = ?$
$x_3 = 201.3$	$0.0035 \; y_3$

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

$$y_2 = \frac{(198.3 - 195.8)(0.0035 - 0.0034)}{201.3 - 195.8} + 0.0034$$

$y_2 = 0.00345$

step # 05 :- Longitudinal temperature and shrinkage steel

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

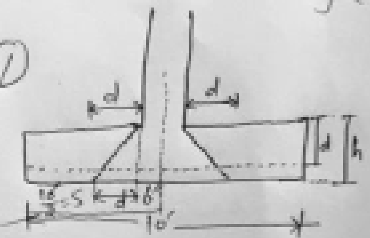
$A_s = 0.432 in^2$ using table A.6.

#5 @ 8" c/c

$A_{s\,selected} = 0.46 in^2$

ID = 15533

$$V_u = \left(\frac{10}{2} - \frac{6}{12} - \frac{8.5}{12}\right) \times q_u \rightarrow eq\ (1)$$



q_u = ultimate bearing capacity

$$q_u = \frac{1.2D.L + 1.6L.L}{\text{width of footing}} = \frac{(1.2\times 20) + (1.6\times 15)}{10}$$

$$\boxed{q_u = 4.80\ ksf}$$ put it in eq (1)

Now,

$$V_u = \left(\frac{10}{2} - \frac{6}{12} - \frac{8.5}{12}\right) \times 4.80$$

$V_u = 18.20K$

$$\boxed{V_u = 18200lb}$$

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

$d = 18.46''$

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

approximately $h = 22'' > 12$ inches

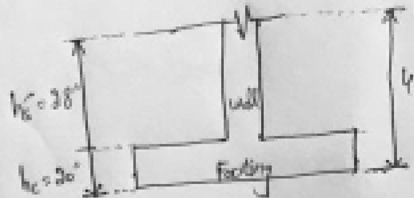
Actual > Assumed

Not OK Try again

Assume 20" footing.

$h = 20"$

$d = 20 - 3.5 = 16.5"$



Repeating step 1, 2 & 3.

step#01: effective soil pressure "q_e"

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

$q_e = 3517$ psf

$\boxed{q_e = 3.517 \text{ ksf}}$

step#02: width of footing Required

$$W = \frac{D+L}{q_e} = \frac{20+15}{3.517} = 9.95' \text{ say } 10'$$

$\boxed{W = 10 \text{ ft}}$

step#03: Depth required for shear.

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

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

$\boxed{q_u = 4.80 \text{ ksf}}$

$$V_u = \left(\frac{10}{2} - \frac{6}{12} - \frac{16.50}{12}\right) \times q_u$$

$$V_u = \left(\frac{10}{2} - \frac{6}{12} - \frac{16.50}{12}\right) \times 4.80$$

$\boxed{V_u = 15 \text{ K}}$

pressure q_a is 4 ksf and there is no appreciable sulfur content in the soil $f_y = 60$ ksi and $f_c' = 3$ ksi.

Assumed data:- $\gamma_c = 150\ lb/ft^3$

$h_c = 12''$

$d = 12 - 3.5 = 8.5in$ (From ACI code 7.7.1)

Solution:- step#01: Effective Soil Pressure "q_e"

$q_e = q_a - h_c\gamma_c - H_s'\gamma_s$ (where $H_s' = 4' - h_c$ $= 4' - 12/12$ $\boxed{H_s' = 3'}$ $4ksf = 4000psf$.)

$= 4000 - \left(\frac{12''}{12} \times 150\right) - (3 \times 100)$

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

Step 2:- Width of Footing required.

$W = \frac{\text{Dead load + live load}}{\text{effective soil pressure}}$.

$W = \frac{20 + 15}{3.5} = 9.86' \simeq$ say 10ft.

$\boxed{W = 10ft}$

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

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