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RCD

Question

Design structural members of single story structure:

Live load = 45 Psf

Dimensions of 5 marla plot

1) Considering 1 marla = 272.25 sq. ft plot
Dimension of 5 marla will be 27x50

2) Considering 1 marla = 250 sq ft, plot
Dimension of 5 marla will be 25x50

3) Considering 1 marla = 225 sq ft, plot
Dimension of 5 marla will be 25 x 45.

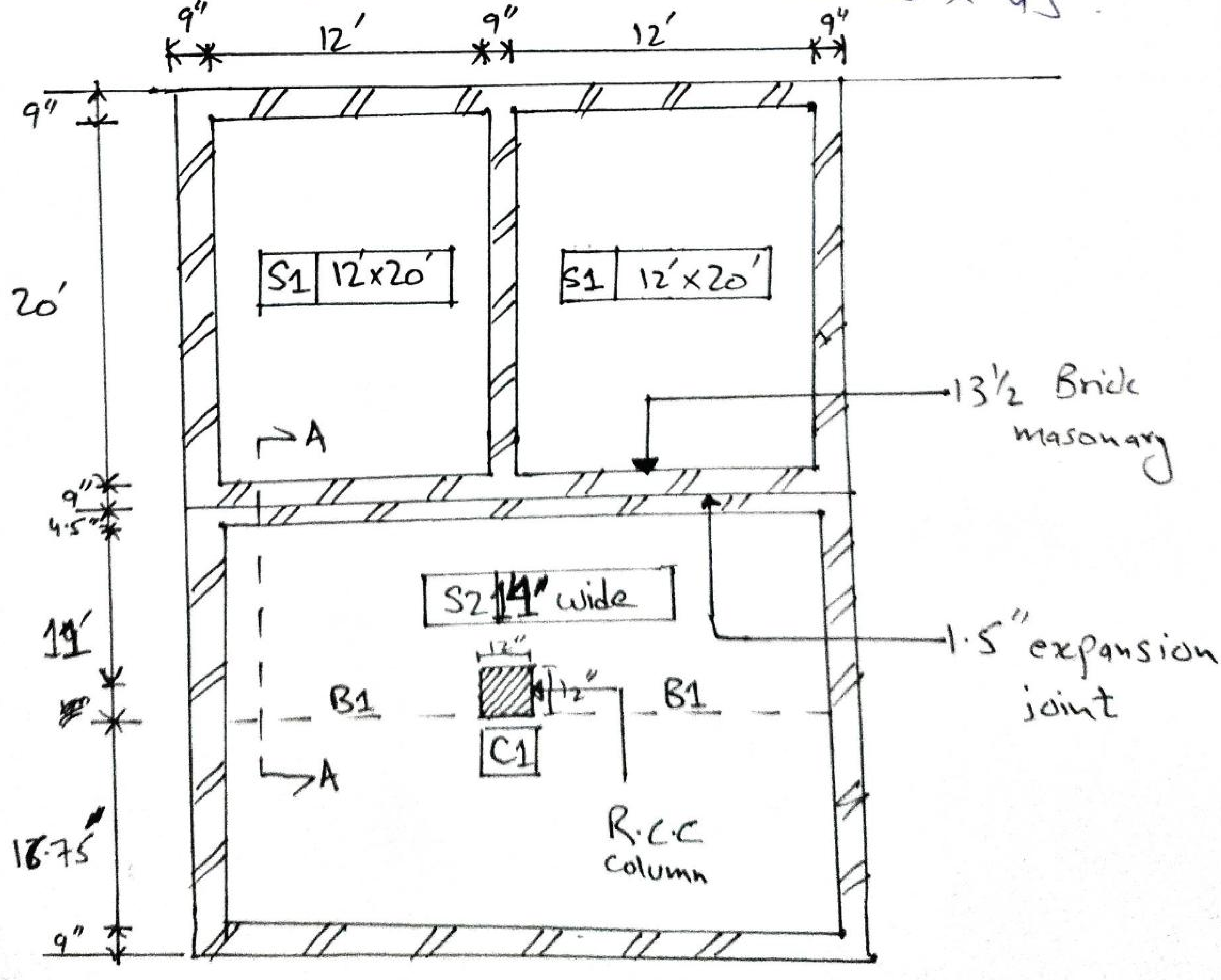

Figure 1: Slabs S_1 & S_2 to be designed

⇒ Design the roof slab, beam & Column of house given in figure.

Concrete Compressive strength $f_c' = 3ksi$

Steel yield strength $f_y = 40ksi$

Load on slab:

1) 4" thick mud
2) 2" thick brick tile

Discussion Expansion Joints

Solution:-

1) Design of Slab "S_2":

Step No. 1: Sizes $l_b/l_a = \frac{24.75}{10}$

$l_b/l_a = 2.475$

$\boxed{l_b/l_a = 2.475}$

$2.25 > 2$ "One Way Slab"

"Assume (5") slab"

Span lenght for end span according to ACI 8.7 is minimum of

$L = l_n + h_f = 10 + (5/12) = 10.41'$

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③

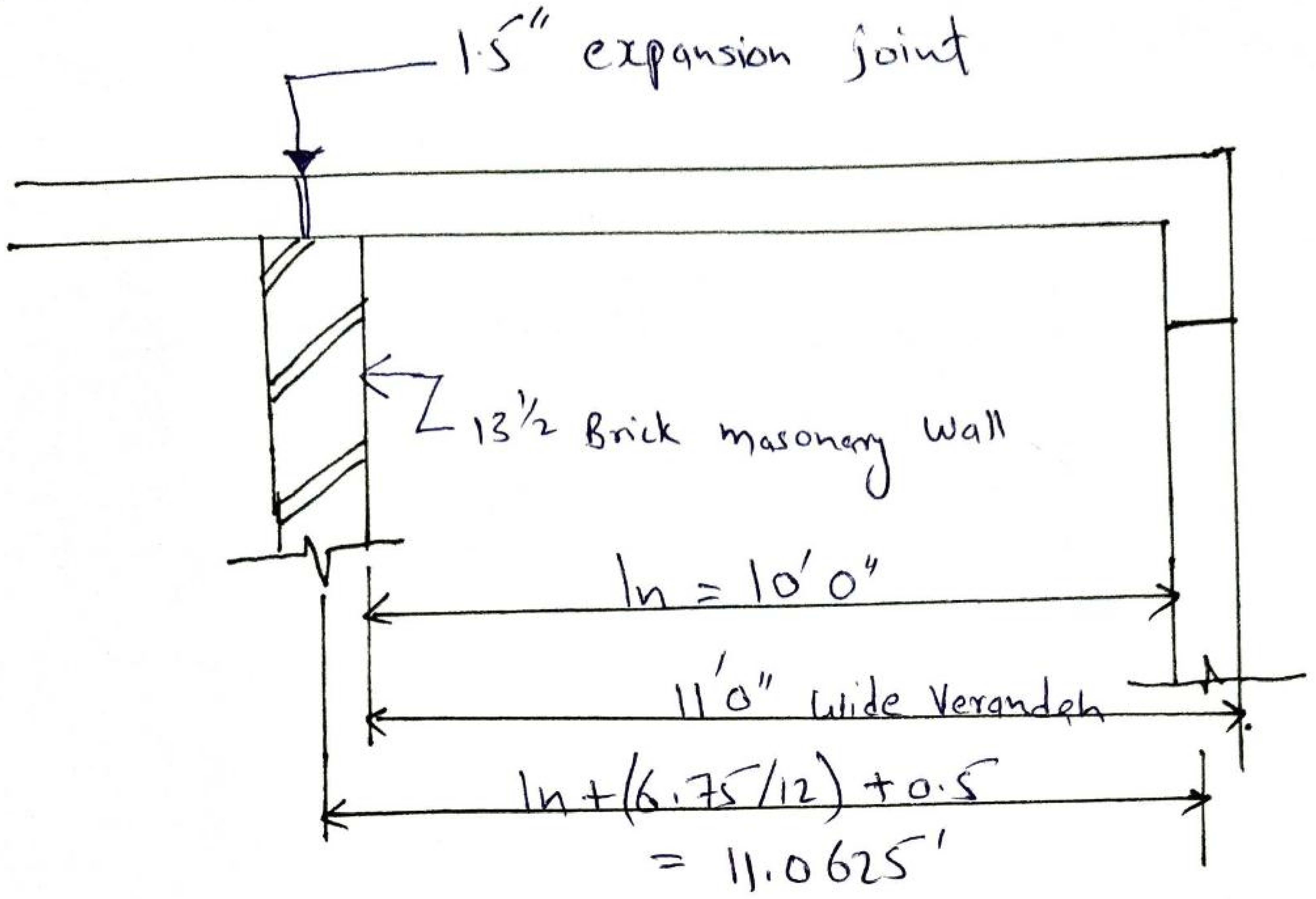

Figure 2: Section A-A

ii) C/C distance b/w supports = 11.0625'

There fore $l = 10.41'$

Slab thickness $(h_f) = (l/20) \times (0.4 + f_y/100000)$

[for $f_y < 60000$ psi]

$= (10.41/20) \times (0.4 + 40000/100000) \times 12$

$= 5.05''$ (Minimum requirement of ACI 19.5.2.1)

Therefore take $h_f = 5''$

$d = h_f - 0.75 - (3/10)/2 \quad \boxed{= 4.1''}$

Table 1.1 Dead loads

Material	Thickness(in)	γ (kcf)	Load = $\gamma \times$ thickness (ksf)
Slab	5	0.15	$0.15 \times 5/12 = 0.0625$
Mud	4	0.12	$0.12 \times 4/12 = 0.04$
Brick Tile	2	0.12	$0.12 \times 2/12 = 0.02$

Service Dead load (D.L) $= 0.0625 + 0.04 + 0.02$
$= 0.1225$ ksf

Service Live Load (L.L) = 45 psf or 0.045 ksf

Factored Load (w_u) $= 1.2\,D.L + 1.6\,L.L$
$= 1.2 \times 0.1225 + 1.6 \times 0.045$
$= 0.219$ ksf

Step # 3 Analysis:

$$M_u = \frac{w_u l^2}{8}$$ (l = Span lenght of slab)

$$M_u = \frac{0.219 \times (10.41)^2}{8} = 2.96 \text{ ft-k/ft}$$

$$M_u = 2.96 \times 12$$

$$\boxed{M_u = 35.59 \text{ in-k/ft}}$$

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Step # 04 Design

$As_{min} = 0.002\, b h_f$ (for fy 40 ksi, ACI 10.5.4)

$= 0.002 \times 12 \times 5 = 0.12\ in^2$ $a = \frac{As_{min} f_y}{0.85 f_c' b}$

$= \frac{0.12 \times 40}{0.85 \times 3 \times 12} = 0.156\ in$

$\phi M_{n(min)} = \phi As_{min}\, f_y\, (d - a/2)$

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

$= 16.94$ in-k $< M_u$

Therefore

$As = \frac{M_u}{\{\phi f_y (d - a/2)\}}$

Take $a = 0.2d$

$As = \frac{35.59}{0.9 \times 40 \times \left(4 - \left(\frac{0.2 \times 4}{2}\right)\right)}$

$As = 0.27\ in^2$

$a = \frac{0.27 \times 40}{0.85 \times 3 \times 12}$

$a = 0.352\ in$

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$$As = \frac{35.59}{0.9 \times 40 \times \left(4 - \frac{0.352}{2}\right)} = 0.258 \text{ in}^2$$

$$a = \frac{0.258 \times 40}{0.85 \times 3 \times 12} = 0.337 \text{ in}$$

$$As = \frac{35.59}{0.9 \times 40 \times \left(4 - \frac{337}{2}\right)} = 0.258 \text{ in}^2$$

So, $\boxed{As = 0.258 \text{in}^2}$ OK

Using $1/2''$ ϕ (#4) {#13} with bar area

$Ab = 0.20 \text{in}^2$

Spacing = Area of one bar $\frac{Ab}{As}$

$$= \frac{0.20 \text{ in}^2}{0.258 \text{ in}^2/\text{ft}} \times 12 \boxed{= 9.30 \text{ in}}$$

$\boxed{\approx 10 \text{in}}$

Using $3/8''$ ϕ (#3)(#10) with bar area

$Ab = 0.11 \text{ in}^2$

Spacing = Area of one bar $\frac{Ab}{As}$

$$= \frac{0.11 \text{ in}^2}{0.258 \text{ in}^2} \times 12 = 5.11 \text{ in} \boxed{\approx 6''}$$

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Finelly use #3 @ 6" c/c (#10)

Shrinkage steel or temperature steel (A_{st}):

$A_{st} = 0.002\, b h_f$

$= 0.002 \times 12 \times 5 = 0.12 in^2$

Using 3/8" ϕ (#3) {#10} with bar area $A_b = 0.11 in^2$

Spacing = Area of one bar (A_b / A_{min})

$= (0.11 / 0.12) \times 12 = 11"$ c/c

Finelly use #3 @ 9" c/c (#10)

Maximum Spacing for main steel in one way slab according to ACI 7.6.5 is minimum of

i) $3h_f = 3 \times 5 = 15"$

ii) 18"

Therefore 6" Spacing is OK.

Maximum Spacing for shrinkage steel in one way slab according to ACI 7.12.2 is minimum of

i) $5h_f = 5 \times 5 = 25"$

ii) 18"

Therefore 9" Spacing is OK.

(2) Design of Slab "S_1"

Step # 1 Sizes: $l_b/l_a = 20/12 = 1.66 < 2$

So, it is two way slab is given.

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

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

$\boxed{h_{min} = 4.26 \text{ in}}$

Assume $h = 5''$

Step # 2 Loads

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

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

$W_u = 1.2 \times 0.1225 + 1.6 \times 0.045$

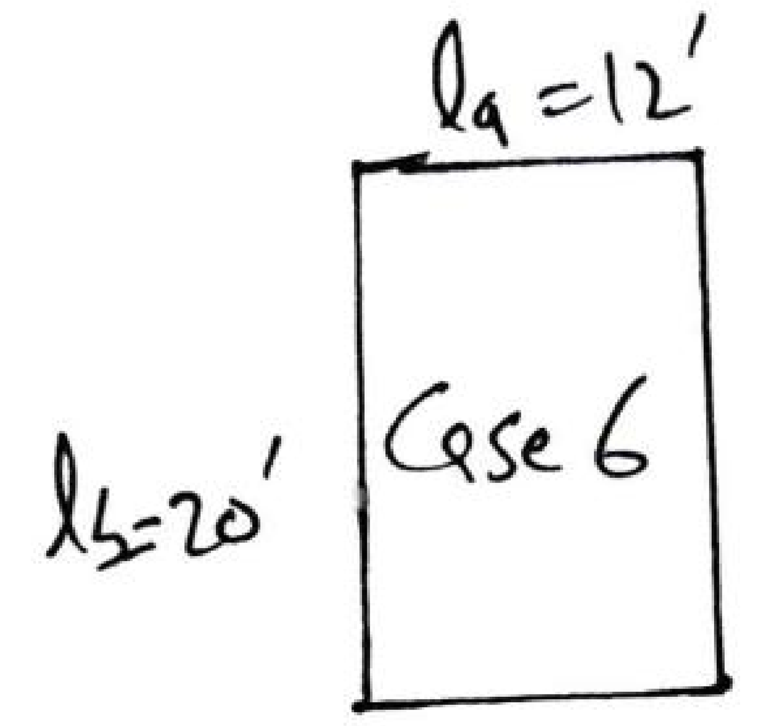
$= 0.219$ ksf

Step #3 Analysis

W_u = Ultimate uniform load Psf

l_a, l_b = lenght of cleer 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 Co-efficient 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) $M_{a\,neg} = C_{a\,neg} \times W_u \times l_a^2 = 0.095 \times 0.219 \times (12)^2 = 2.99\ ft\text{-}k$

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

2) $M_{b,neg} = C_{b\,neg} \times W_u \times l_b^2 = 0 \times 0.147 \times 20^2 \boxed{= 0\ ft\text{-}k}$

3) $M_{a\,pos\,dl} = C_{b\,pos\,dl} \times W_{u,dl} \times l_a^2 = 0.006 \times 0.147 \times 12^2$

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

$= \overset{0.127}{\cancel{0.184}} \times 12 \boxed{= 1.82\ in\text{-}k}$

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4. $M_{b\,pos\,dl} = C_{b\,pos\,dl} \times W_{u\,dl} \times l_b^2 = 0.006 \times 0.1\cancel{219}^{147} \times 20^2 = 0.525$

$0.3528 = \cancel{0.525} \times 12 = \boxed{\cancel{6.30\text{ in-k}}}$

$\boxed{4.233\text{ in-k}}$

5. $M_{a\,pos\,ll} = C_{a\,pos\,ll} \times W_{u\,ll} \times l_a^2 = 0.068 \times 0.064 \times 12^2 = 0.62\text{ ft-k}$

$\boxed{= 7.52\text{ in-k}}$

6. $M_{b\,pos\,ll} = C_{b\,pos\,ll} \times W_{u\,ll} \times l_b^2$

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

$\boxed{= 1.84\text{ in-k}}$

Therefore finely we have

1) $M_{a,neg} = 2.99\text{ k-ft} = 35.8\text{ in-k}$

2) $M_{b,neg} = 0\text{ ft-k}$

3) $M_{a\,pos}(dl+ll) = 1.52 + 0.35 = 1.87\text{ ft-k} = 22.44\text{ in-k}$

4) $M_{b,pos}(dl+ll) = 0.62 + 0.153 = 0.773\text{ ft-k} = 9.276\text{ in-k}$

Step # 04 Design.

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

$$a = \frac{A_{s\,min} f_y}{0.85 f_c' b} = \frac{0.12 \times 40}{0.85 \times 3 \times 12} \boxed{= 0.156\text{ in}}$$

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

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

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

$M_{b,pos(dl+ll)} = 0.773$ ft-k $= 9.276$ in-k $< \phi M_{n(min)}$

Therefore, $A_{s\,min} = 0.12\ in^2$ governs

Using $3/8"\ \phi$ (#3) (#10) with bar area $A_b = 0.11\ in^2$

Spacing $= (0.11/0.12) \times 12 = 11"$

Max. Spacing according to ACI 13.3.2 for two way slab is $2h_f = 2 \times 5 = 10"$

Therefore maximum spacing of 10" governs.

Finally use #3 @ 9" c/c (#10@c/c)

"Provide #3 @ 9" c/c as negative reinforcement along the long direction".

$M_{a\,pos(dl+ll)} = 1.53$ ft-k $= 18.36$ in-k $> \phi M_n$ let $a = 0.2d = 0.2 \times 4 = 0.8$ in

$$A_s = \frac{1.53 \times 12}{0.9 \times 40 \times (4 - (0.8/2))}$$

$A_s = 0.131\ in^2$, $a = \frac{0.131 \times 40}{0.85 \times 3 \times 12} = \boxed{0.171\ in}$

$$A_s = \frac{1.53 \times 12}{0.9 \times 40 \times (4 - 0.30/2)} \boxed{= 0.131\ in^2}$$ Ok

Using $3/8"\ \phi$ (#3) (#10) with bar area $A_b = 0.11\ in^2$ Spacing $= 0.11 \times 12/0.131 = 10.07" \boxed{\approx 9"c/c}$

Finally use #3 @ 9" c/c (#10 c/c)

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③ Beam Design (2 span continous).

Data given

exterior Supports = 9" brick masamory wall

$f_c' = 3ksi$

$f_y = 40ksi$

Column dimension = 12" x 12"

Step # 01 Sizes

According to ACI 9.5.2.1 table 9.5 (a):

Minimum thickness of beam with one end continous = $h_{min} = l/18.5$

l = Clear span (l_n) + depth of member (beam)

≤ c/c distance b/w supports (ACI 8.7)

Table 1.3: Clear Span of Beam

Case	Clear span (l_n)
end Span (one end continous)	$12.375 - (12/12)/2 = 11.875'$

Let depth of beam = 18"

l_n + depth of beam = $11.875' + (18/12) = 13.375'$.

c/c distance b/w beam supports = $12.375 + (4.5/12)$

$= 12.75'$

Depth (h) $= (12.75)'/18.5 \times \left(0.4 + \frac{40000}{100000}\right) \times 12$

Depth(h) = 6.62"

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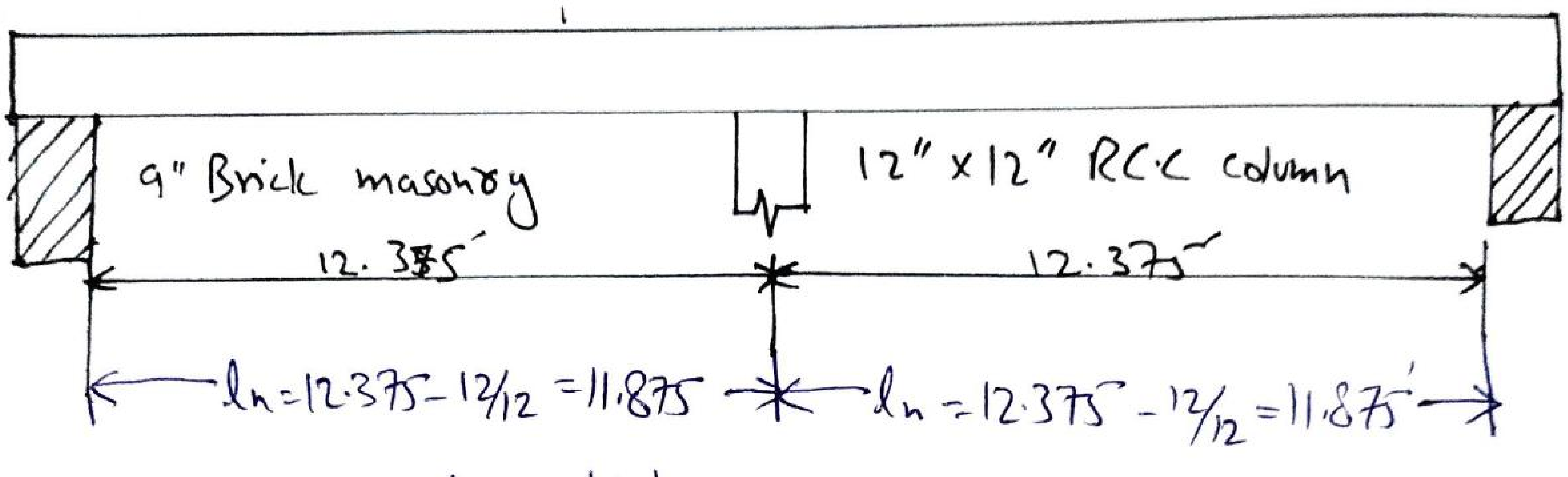
Minimum requirement of ACI 9.5.2.1 Take $h = 1.5'$

$= 18''$

$d = h - 3 = 15''$



c/c distance & cleer span Beem

Service D.L $= 0.0625 + 0.04 + 0.02 = 0.1225$ ksf

Service L.L $= 45$ or 0.045 Ksf

Beem is supporting 5' slab, There fore load per running foot will be as

service D.load from slab $= 0.1225 \times 5 = 0.6125$ k/ft

Service D.L from beem's self weigh $= h_w b_w \gamma_c$

$= (13 \times 12/144) \times 0.15$

$\boxed{= 0.1625 \text{ k/ft}}$

Total D.L $= 0.6125 + 0.1625 = 0.775$ k/ft

Service live load $= 0.04 \times 5 = 0.2$ k/ft $W_u = 1.2 D.L + 1.6 L.L = 1.2 \times 0.775 + 1.6 \times 0.20 = 1.25$ k/ft

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Step # 3 Analysis

Refer to ACI 8.3.3 for ACI moment & shear coefficients

1) At ~~ente~~ interior Support:

Negative moment (M_{neg}) = Coefficient × ($w_u l_n^2$)

$= (1/9) \times (1.25 \times (11.875)^2)$

$= 19.59 \text{ ft-k} \; \boxed{= 235.08 \text{ in-k}}$

2) At Mid Span:

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

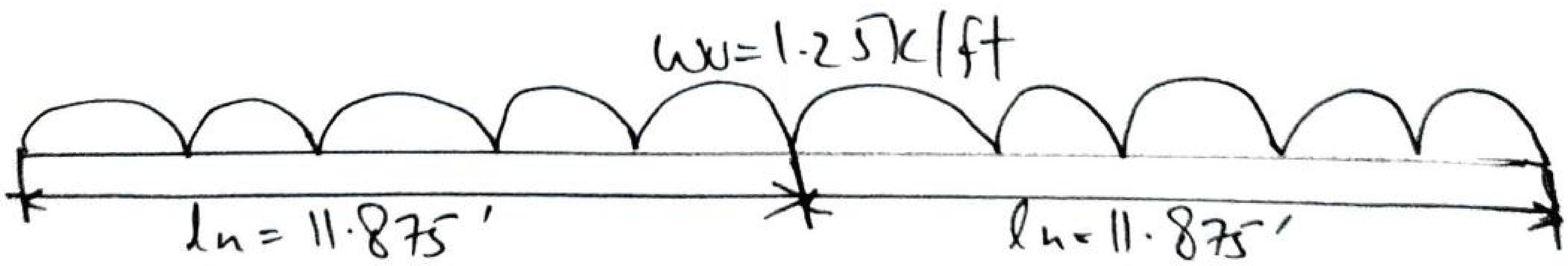
$= (1/11) \times (1.25 \times (11.875)^2)$

$= 16.02 \text{ ft-k} = 192.24 \text{ in-k}$

$V_{int} = 1.15\, w_u l_n/2 = 1.15 \times 1.25 \times 11.875/2 = 8.54 \text{ k}$

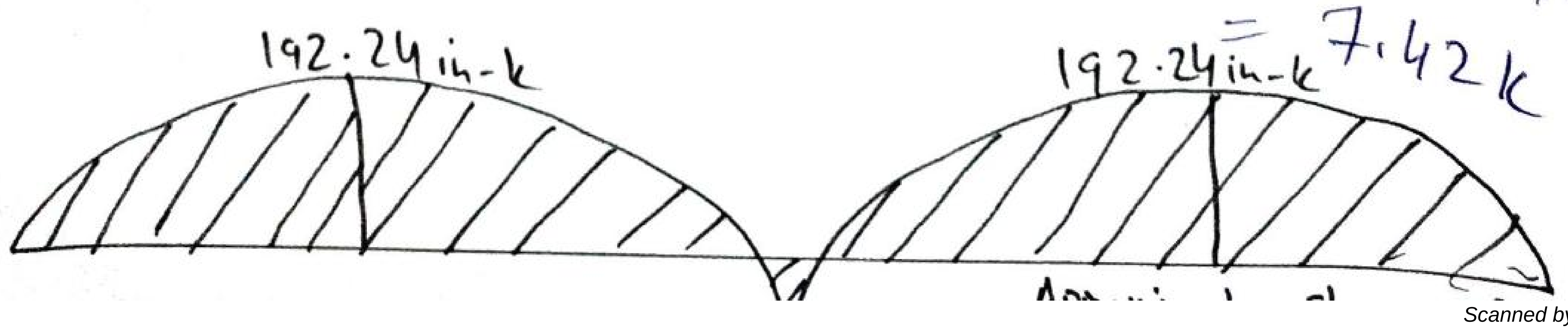
$V_{u(int)} = 8.54 - 1.25 \times 1.25 = \boxed{6.97 \text{k}}$

$V_{u(ext)} = 7.42 - 1.25 \times 1.25 = 5.86 \text{k}$



$w_u l_n/2$

$V_{ext} = w_u l_n/2 = 1.25 \times 11.875/2 = 7.42 \text{ k}$



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(4) Design of Column

i) Load of Column:

$P_u = 2V_{int} = 2 \times 8.54 = 17.08k$ (Reaction at interior support of beam)

Gross area of column cross section (A_g) = $12 \times 12 = 144 \text{ in}^2$ $f_c' = 3ksi$

$\boxed{f_y = 40ksi}$

ii) Design :

Nominal strength (ϕP_n) of axially loaded column

$\phi P_n = 0.80 \phi \{0.85 f_c' (A_g - A_{st}) + A_{st} f_y\}$ {for tied column ACI 10.3.6}

Let A_{st} = 1% of A_g (A_{st} is the main steel reinforcement area) $\phi P_n = 0.80 \times 0.65 \times \{0.85 \times 3 \times (144 - 0.01 \times 144) + 0.01 \times 144 \times 40\}$

$= 218.98 > (P_u = 17.08k)$ OK.

$A_{st} = 0.01 \times 144 = 1.44 \text{ in}^2$

Using 3/4" ϕ (#6) {#19) with bar Area

$A_b = 0.44 \text{ in}^2$

No. of bars $= A_s / A_b = 1.44/0.44 = 3.27 \approx 4$ bars use

Tie bars

using 3/8" ϕ (#3)(#10) tie bars for 3/4" ϕ (#6)
(#19) main bars

ACI (7.10.5)

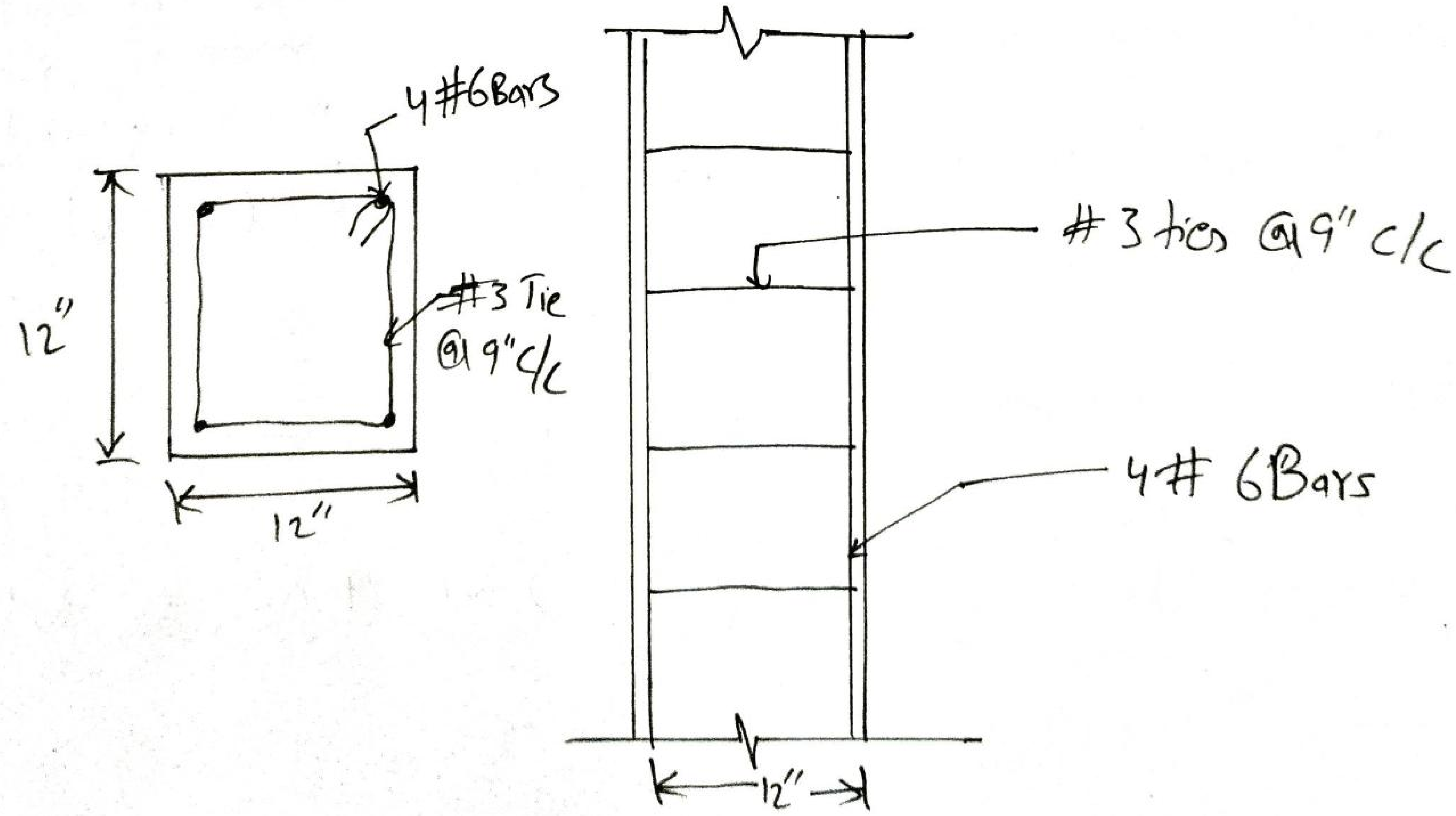
Spacing for tie bars according to ACI 7.10.5.1
is minimum of

a) 16 x dia of main bar = 16 x 3/4 = 12" C/C

b) 48 x dia of bar = 48 x (3/8) = 18" C/C

c) Least column dimension = 12" C/C

Finally use #3, tie bars @ 9" C/C
(#10, tie bars @ 225 mm C/C)



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Footing Design

Given data

$D = 20 \, k/ft$

$L = 15 \, k/ft$

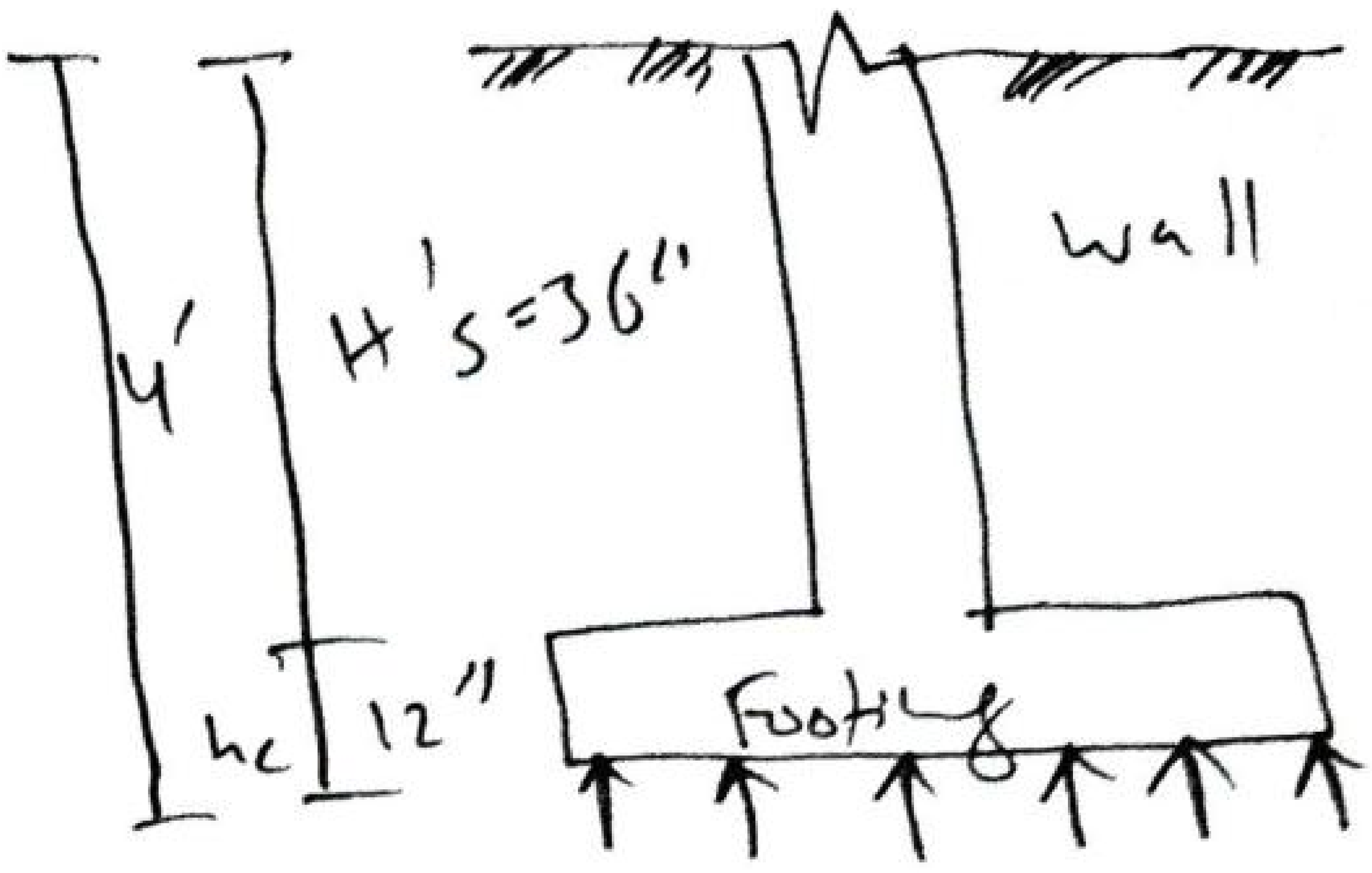
$\gamma_s = 100 \, lb/ft^3$

$q_a = 4 \, ksf = 4000 \, psf$

$f_c' = 3 \, ksi = 3000 \, psi$

$f_y = 60 \, ksi = 60{,}000 \, psi$

$H_s' = 4' - h_c$



Assumed Data;

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

$h_c = 12 in$

$d = 12 - 3.5 = 8.5 in$ (The cover reffered to Code 7, which says that for concrete permeability exposed to the earth soil a minimum of 3"-4" cover is required)

Solution

Step #1 Effective soil pressure 'q_e'

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

$$q_e = 3550 \, psf = \boxed{3.55 \, ksf}$$

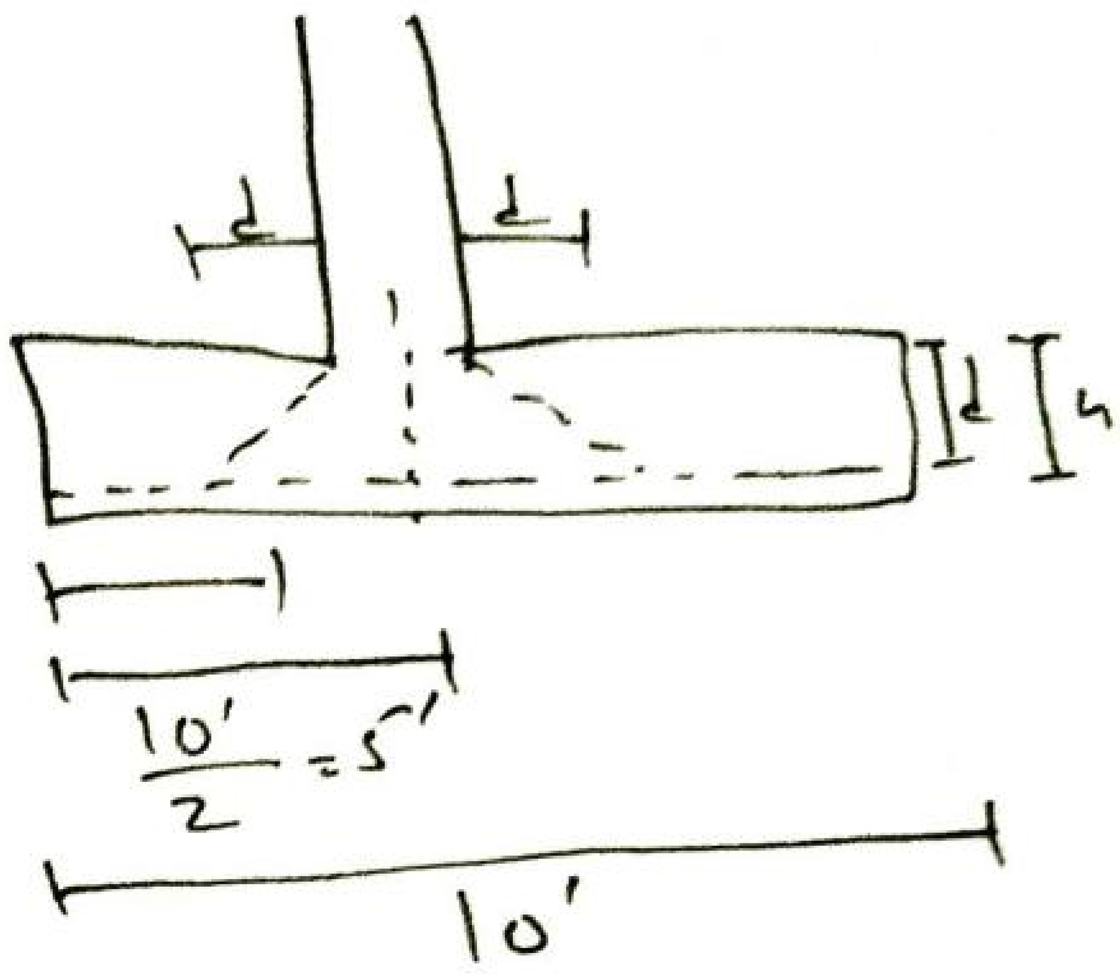
Step #2 width of footing required

$$w = \frac{D+L}{q_e} = w = \frac{20+15}{3.55} \Rightarrow w = 9.86' \text{ say } 10'$$

step # 3 d = Depth required for shear at distance d for the face of wall

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

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



qu = Ultimate Bearing Capacity

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

$$qu = \frac{1.2 \times 20 + 1.6 \times 15}{10} = qu = 4.80\ ksf$$

Now,

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

$$Vu = 18.20\,k = 18200\ lb$$

~~d = 18.20 k~~

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

$$d = d + \text{Cover} = 18.46'' + 3.5\,in = 21.96 > 12\,in$$

Actual > Assumed