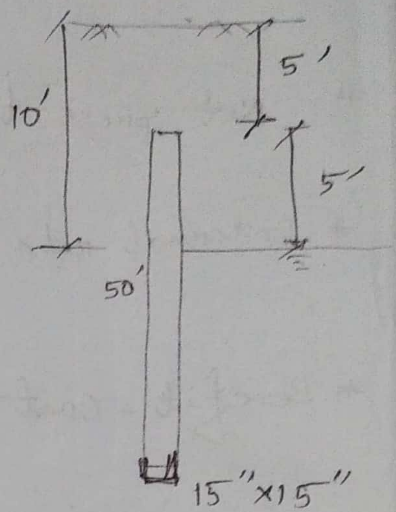
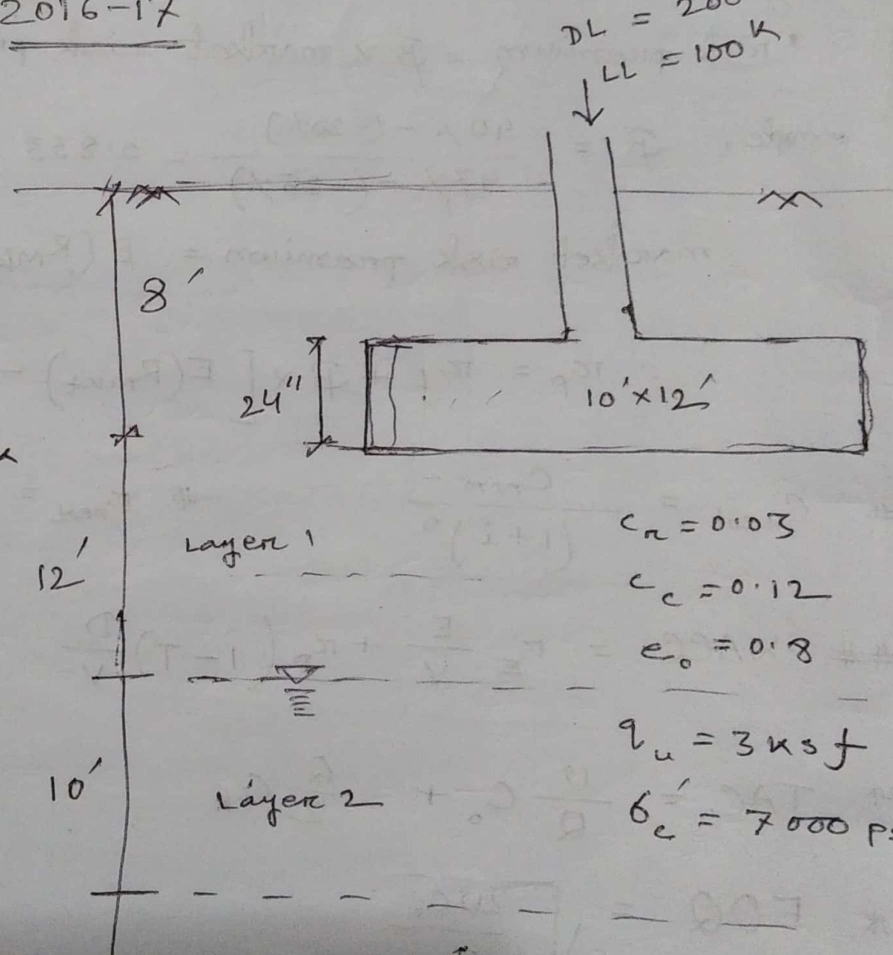
2017-18



---- o ----

2016-17



$C_r = 0.03$

$C_c = 0.12$

$e_0 = 0.8$

$q_u = 3\,ksf$

$\sigma_c' = 7000\ psf$

settlement

Layer 1

$\sigma_0' = 8\times120 + 6\times120$

$= 1680\ psf$

$Load = 200 + \frac{100}{2} = 250\ k$

$\Delta\sigma = \frac{250\times10^3}{16\times18}$

$= 868\ psf$

$\sigma_0 + \Delta\sigma = 2548 < \sigma_c$

$\therefore$ OC clay

$S_1 = C_r \times \frac{H}{1+e_0} \log \frac{\sigma_0' + \Delta\sigma}{\sigma_0'} = 0.03 \times \frac{12\times12}{1+0.8} \times \log\frac{2548}{1680}$

$= 0.434''$

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Layer 2

$\sigma_0' = 20\times120 + 5\times(120-62.5) = 2687.5$ psf

$\Delta\sigma = \frac{250\times10^3}{27\times29} = 319.28$ psf

$\therefore \sigma_0' + \Delta\sigma = 3006.78$ psf $< \sigma_c$ $\therefore$ OC clay

$S_2 = \frac{0.03\times10\times12}{1.8}\times\log\frac{3006.78}{2687.5} = 0.1''$

$\therefore$ Total settlement $= 0.434 + 0.1 = 0.53''$

FS calculation

$\frac{D_f}{B} = 0.8$, from chart $N_c = 6.2$

Actual $N_c = 6.2\times\left(1+0.2\frac{B}{L}\right) = 7.23$

$c = \frac{q_u}{2} = 1.5$ ksf $\qquad q_u = \frac{300}{10\times12} + \left(\frac{150-120}{1000}\right)\times$
$= 2.56$

$F.S. = \frac{c N_c}{q_u}$

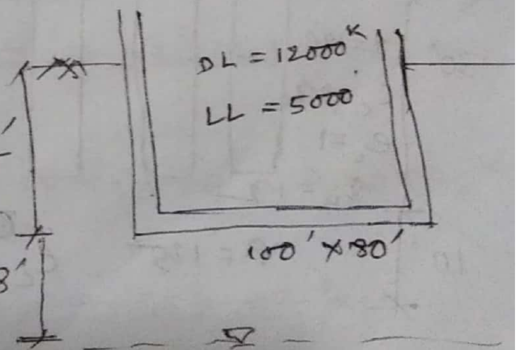
$= \frac{1.5\times7.23}{2.56} = \boxed{4.24}$ ~~6.78 ≈ 6.5~~

(2)

$P_0 = 12\times120 + 4\times120 = 1920$ psf

gross pressure $= \frac{1700\times10^3}{100\times80}$

$= 2125$ psf



$\therefore$ net pressure, $q = 2125 - 120\times12$
$= 685$ psf

$\sigma_c = 6000$ psf
$C_r = 0.04$
$e_0 = 0.9$

at middle

$\frac{B}{z} = \frac{40}{4} = 10$

$\frac{L}{z} = \frac{50}{4} = 12.5$

from chart, $I_\sigma = 0.249$

$\Delta P = 4\times0.249\times685$
$= 682.26$ psf

$P_0 + \Delta P = 2602.26 < P_c$

$S = \frac{0.04\times8\times12}{1.9}\log\frac{2602.26}{1920} = \boxed{0.27''}$

At corner

$\frac{B}{Z} = \frac{80}{4} = 20$

$\frac{L}{Z} = \frac{100}{4} = 25$

$I_\sigma = 0.25$

$\Delta P = 0.25 \times 685 = 171.25$ psf

$P_o + \Delta P = 2091.25 < P_c$

$S = \frac{0.04 \times 8 \times 12}{1.9} \log \frac{2091.25}{1920}$

$= \boxed{0.075''}$

Factor of safety

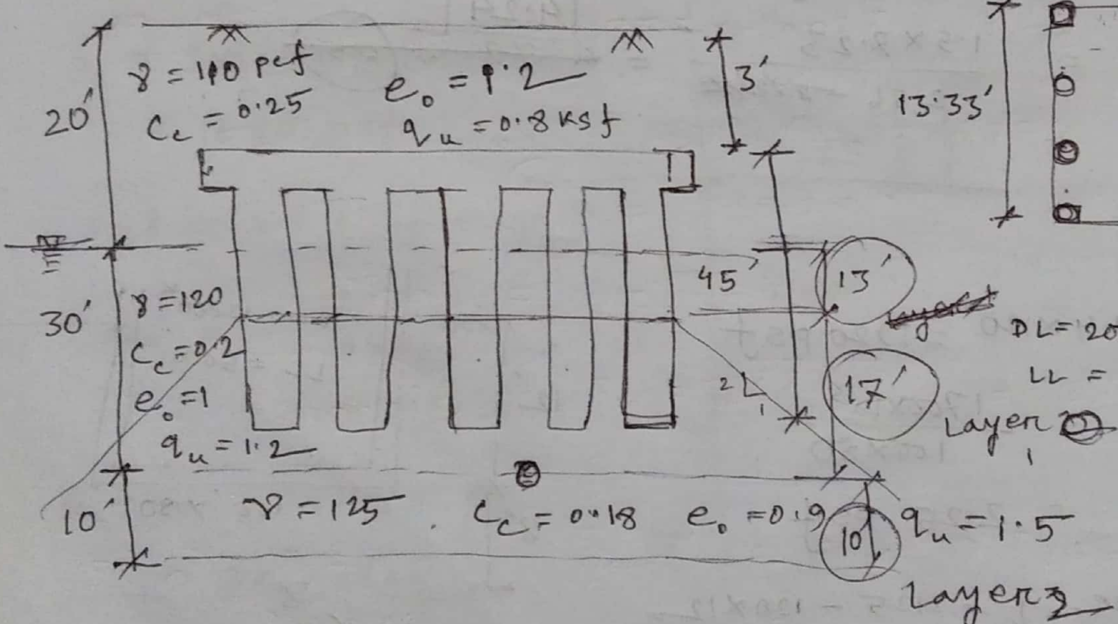
$q_b = \frac{Q}{A} = 2125 = 2.125$ ksf

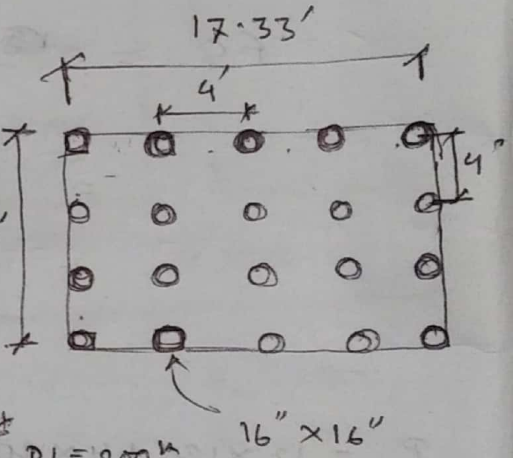
$\frac{D_f}{B} = \frac{12}{80} = 0.15$ $\quad \therefore N_c = 5.3 \times \left(1 + 0.2 \times \frac{80}{100}\right)$

$= 6.148$

$\therefore F.S. = \frac{cN_c}{q_b - \gamma' D_f} = \frac{9 \times 6.148}{2.125 - 0.12 \times 12} = 8.98 \approx 9$

3





DL = 200 k

LL = 100 k

$\frac{2}{3} L = 30'$

Layer 1

$P_o = 20 \times 110 + 13 \times (120 - 62.5) + 8.5 \times (120 - 62.5)$

$= 3436.25$ psf

$\Delta P = \frac{250 \times 10^3}{(17.3 + 8.5) \times (13.3 + 8.5)} = 444.49$ psf

$S_1 = 0.2 \times \frac{17 \times 12}{2} \log \frac{3436.25 + 444.49}{3436.25} = 1.07''$

Layer 2

$$P_o = 3436.25 + 8.5 \times (120 - 62.5) + 5 \times (125 - 62.5)$$
$$= 4237.5 \text{ psf}$$

$$\Delta P = \frac{250 \times 10^3}{39.3 \times 35.3} = 180.2 \text{ psf}$$

$$S_2 = \frac{0.18 \times 10 \times 12}{1.9} \log \frac{4237.5 + 180.2}{4237.5} = 0.205''$$

$\therefore$ Total settlement $= S_1 + S_2 = 1.275''$

Capacity as a single pile

0–20′, friction $= \alpha C A_f = 0.9 \times 0.4 \times 4 \times \frac{16}{12} \times 17 = 32.64^K$

20′–50′, friction $= 0.8 \times 0.6 \times 4 \times \frac{16}{12} \times 28 = 71.68^K$

end bearing $= cN_c A_b = 0.6 \times 9 \times \frac{16 \times 16}{144} = 9.6^K$

$\therefore$ Total capacity of 20 pile, Q_u; $= 20 \times (9.6 + 71.68 + 32.64)$
$= 2278.4^K$

Capacity as group action

0–20′, friction $= \alpha C A_f = \cancel{0.4 \times}\ 1 \times 0.4 \times (17.33 + 13.33) \times 2 \times 17$
$= 416.976^K$

20–50′ friction $= 1 \times 0.6 \times 2 \times (17.33 + 13.33) \times 28 = 1030.176^K$

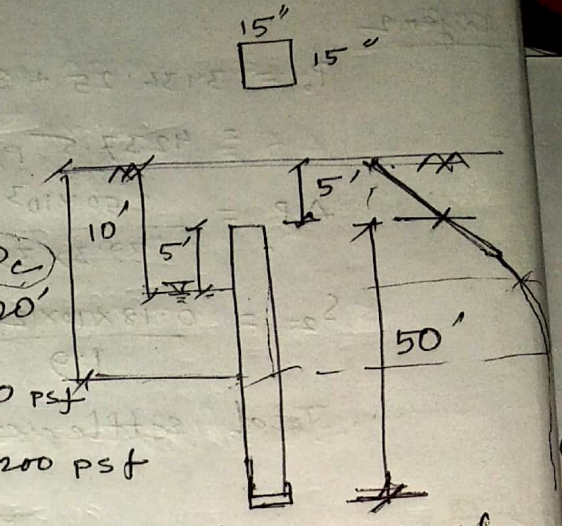
end bearing $= 0.6 \times 9 \times 13.33 \times 17.33 = 1247.45^K$

Total capacity $Q_g = 2694.6^K$

$\therefore$ capacity of the pile group $= 2278.4^K$

$$F.S = \frac{2278.4}{300} = 7.60$$

4. (a)



Skin Friction = $K \sigma_v \tan\delta \, A_{surface}$

End bearing = $q N_q A_{tip}$

$K = 1.5$

~~0-10'~~

~~Sf = 1.5 ×~~

0 - 5'

$\sigma_v = 120 \times 5 = 600$ psf

5 - 10'

$\sigma_v = 120 \times 10 = 1200$ psf

10 - 20'

$\sigma_v = 1200 + 10 \times (120 - 62.5) = 1775$ psf

0 - 10' $\quad sf = 1.5 \times \left(\frac{600 + 1200}{2}\right) \tan 25 \times 4 \times \frac{15}{12} \times 5 = 15.738^k$

10 - 20' $\quad sf = 1.5 \times \frac{1200 + 1775}{2} \times \tan 25 \times 4 \times \frac{15}{12} \times 10 = 52.029^k$

20' - 50' $\quad sf = 1.5 \times 1775 \times \tan 25 \times 4 \times \frac{15}{12} \times 30 = 186.23^k$

50' - 55' $\quad sf = 1.5 \times 1775 \times \tan 28 \times 4 \times \frac{15}{12} \times 5 = 35.4^k$

End bearing $= \sigma_v N_q A_{tip} = 1775 \times 140 \times \frac{15 \times 15}{144}$

$= 388.28^k$

$\therefore$ Total $= 677.67^k$

$\therefore$ capacity, $P_u = \frac{677.67}{2.5} = 271.068^k$

5. (c) $N_q = 41$

$N_\gamma = 42$

$\gamma = 110$ pcf

$D_f = 6.5'$

$Q_{ult} = 1688^k$

Let, $L = B = 8'$

$t = 2'$

$q_u = cN_c + \gamma' D_f N_q + \frac{1}{2}\gamma B N_\gamma$

$= 0 + 110 \times 6.5 \times 41 + \frac{1}{2} \times 110 \times B \times 42$

$= \cancel{29315 + 2310 B}$ 47.795 ksf

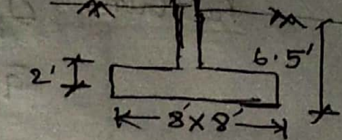
$q_{nu} = 47.795 - 0.110 \times 6.5 = 47.08$ ksf

$q_a = \frac{1688}{8 \times 8} = 26.375$ ksf

Surcharge $= 2 \times \frac{150 - 110}{1000} = 0.08$ ksf

$\therefore q_a = 26.375 + 0.08 = 26.455 \text{ ksf}$

$$F.S. = \frac{47.08}{26.455} = 1.78 > 1.5 \quad \underline{OK}$$



use 8'x8' Footing, ~~depth~~ $t_f = 2'$

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6. ⓒ $H = 8$ m   DH = large depth $\therefore D = \infty$

$\beta = 36°$

$$H_{cr} = \frac{c_u}{\gamma m}$$

$\therefore m = 0.181$ (from graph)

Assume

$\Rightarrow c_u = \gamma m H_{cr} = 17.3 \times 0.181 \times 8$

$= \boxed{25 \text{ KN/m}^3}$ (Ans.)

From the figure, we can see that critical circle is a mid point circle

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7. ⓒ $K = 1.5$ (medium dense) $\bar{q} = \frac{13 \times 17.5}{2} = 113.75 \text{ KN/m}^2$

$\delta = \frac{3}{4} \times 36 = 27°$

Friction load, $Q_f = \bar{q} K \tan\delta A_{surface} = 113.75 \times 1.5 \times \tan 27° \times \pi \times 0.5 \times 13$

$= 1775.3$ KN

For pullout, $Q_b = 0$

Pullout capacity, $Q_u = Q_f + W_{pile} = \boxed{1837 \text{ KN}}$ (Ans.)

Allowable Pullout ~~capacity~~, $Q_a = \frac{Q_f}{F.S} + W_{pile}$

$\gamma_{conc.}$

$$= \frac{1775.3}{3} + \frac{\pi}{4} \times 0.5^2 \times 13 \times 24$$

$N_q = 80$

$= \boxed{653 \text{ KN}}$ (Ans.)

Now,

$q_o' = \cancel{13}\,13.5 \times 17.5 = \cancel{227.5}\,236.25 \text{ KN/m}^2$

End bearing, $Q_b = q_o' N_q A_{tip} = \cancel{227.5}\,236.25 \times 80 \times \frac{\pi}{4} \times (0.8)^2$

$= \cancel{9148.32 \text{ KN}}$ 9500.18 KN

Friction:

~~$Q_f = 17.75 ...$~~

$\bar{q} = \frac{13.5 \times 17.5}{2} = 118.125 \ KN/m^2$

$Q_f = 1.5 \times 118.125 \times \tan 27 \times \pi \times 0.5 \times 13 + 1.5 \times 118.125 \times \tan 27 \times \pi \times 0.8 \times 0.5$

$= \cancel{622.94 \ KN} \ 1957 \ KN$

$\therefore$ Total capacity, $Q_u = 11457.18$ KN

Allowable load $= \frac{11457.18}{3} = \boxed{3819 \ KN}$

(Ans.)

8. (b) $c = \frac{q_u}{2} = 25 \ KPa = 25 \ KN/m^2$

$\gamma = 16.8 \ KN/m^3$

$F_s = \frac{c \sum_{n=1}^{n=p} \Delta L_n + \sum_{n=1}^{n=p} W_n \cos\alpha_n \tan\phi}{\sum_{n=1}^{n=p} W_n \sin\alpha_n}$

$\Delta L_n = \frac{b_n}{\cos\alpha_n}$

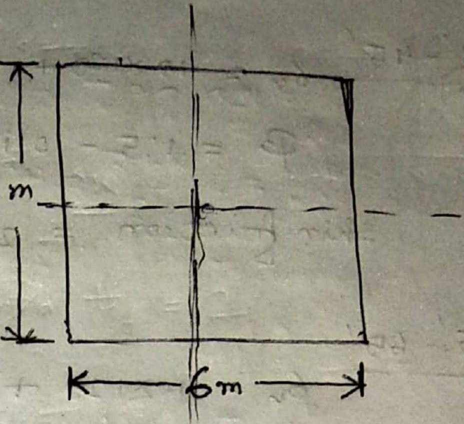
slice no.	b_n (m)	h_n (m)	W_n (KN/m)	α_n (deg)	ΔL_n (m)	$W_n \cos\alpha_n$	$W_n \sin\alpha_n$
1	2.6	4	174.72	58°	4.91	92.59	148.17
2	3	5.8	292.32	39°	3.86	227.18	183.96
3	3	5.6	282.24	20°	3.19	265.22	96.53
4	3	4.2	211.68	9°	3.04	209.07	33.11
5	3.5	1.9	111.72	−5°	3.51	111.29	−9.74
Σ					18.51	905.35	452.03

$\therefore F_s = \frac{25 \times 18.51 + 905.35 \times \tan 0^\circ}{452.03}$

$= \boxed{1.024}$

(Ans.)

8. (c) $c = 0$ (sand) $D_f = 3m$



$L' = L = 6\ m$

$B' = 6 - 2 \times \frac{6}{10} = 4.8\ m$

$\gamma = 18.5\ kN/m^3$

$\phi = \sqrt{20 N_{cor}} + 15° = 35°$

$\therefore N_q = 33.55,\ N_\gamma = 37.75$

$N_\phi = \tan^2\left(45° + \frac{\phi}{2}\right) = 3.69$

$s_q = 1 + 0.1 N_\phi \left(\frac{B'}{L'}\right) = 1.295$

$d_q = 1 + 0.1\sqrt{N_\phi}\left(\frac{D_f}{B'}\right)$
$= 1.12$

$s_\gamma = s_q = 1.295$

$d_\gamma = d_q = 1.12$

$q = cN_c s_c d_c + \gamma' D_f N_q s_q d_q + \frac{1}{2}\gamma' B' N_\gamma s_\gamma d_\gamma$

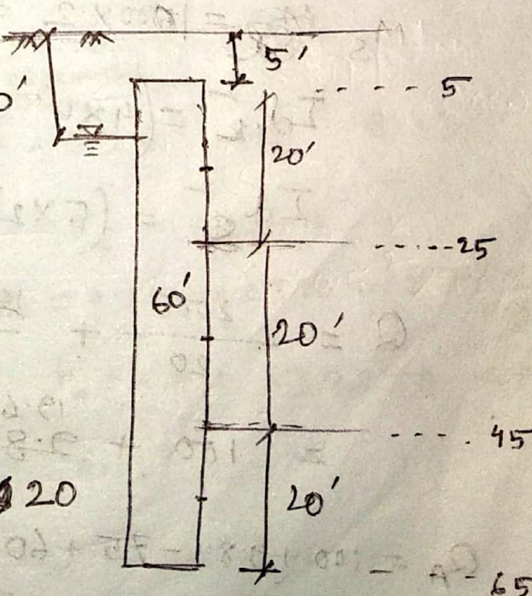
$= 0 + 18.5 \times 3 \times 33.55 \times 1.295 \times 1.12 + \frac{1}{2} \times 18.5 \times 4.8 \times 37.75$
$\times 1.295 \times 1.12$

$= 5131.70\ kN/m^2$

$Q_{ult} = q \times L' \times B' = 147792.96\ KN = \boxed{148\ MN}$
(Ans.)

2015 - 16

1. (a) Skin Friction



5 - 25

$\sigma_v = 120 \times 10 + 5 \times (120 - 62.5)$
$= 1487.5\ psf$

$\beta = 1.5 - 0.135\sqrt{15} = 0.98$

Skin Friction $= 1487.5 \times 0.98 \times \pi \times \frac{30}{12} \times 20$
$= 228.98\ Kip$

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$\underline{25'-45'}$

$\sigma_v = 10 \times 120 + 25 \times (120 - 62.5) = 2637.5$ psf

$\beta = 1.5 - 0.135\sqrt{35} = 0.701$

Skin friction $= 2637.5 \times 0.701 \times \pi \times 2.5 \times 20 = 290.42^K$

$\underline{45'-65'}$

$\sigma_v = 10 \times 120 + 45 \times (120 - 62.5) = 3787.5$ psf

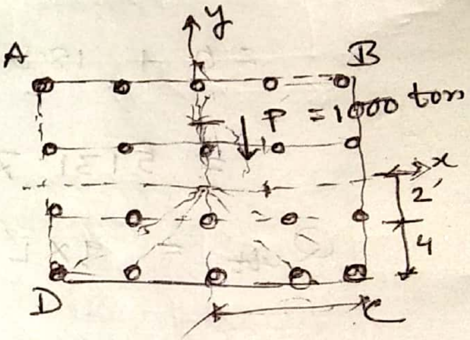
$\beta = 1.5 - 0.135\sqrt{55} = 0.4988$

skin friction $= 296.76^K$

End bearing $= 1.2 N_f A_{tip} = 1.2 \times 35 \times \frac{\pi \times 2.5^2}{4} = 206.17^K$

$\therefore$ Capacity of the pier $= \boxed{1022^K}$

2. (a)



Additional load

4' soil

$= 20 \times 16 \times 5 \times 150 + 4 \times \cancel{20} \times 16 \times 120$
(pile cap)

$= 393.6^K = 196.8$ ton

$M_L = 1000 \times 3 = 3000$ ton-ft $= 6000$ k-ft

$M_S = 1000 \times 2 = 4000$ k-ft

$\Sigma d_x^2 = (4 \times 4^2 + 4 \times 8^2) \times 2 = 640$ ft^2

$\Sigma d_y^2 = (5 \times 2^2 + 5 \times 6^2) \times 2 = 400$ ft^2

$Q = \frac{2000}{20} + \frac{\overset{393.6}{\cancel{196.8}}}{20} \pm \frac{6000 \times 8}{640} \pm \frac{4000 \times 6}{400}$

$= 100 + \overset{19.68}{\cancel{9.84}} \pm 75 \pm 60$

$Q_A = 100 + 9.84 - 75 + 60 = \cancel{94.84^K}$ 104.68^K

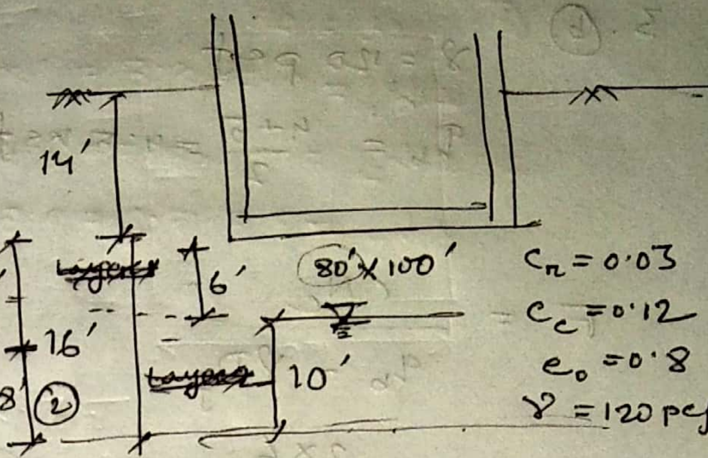
$Q_B = 244.84^K$ $\qquad$ $Q_D = -25.16^K$ (tension)

$Q_C = 124.84^K$

3. ⓐ ⓑ gross pressure = 4000 psf

net pressure = (4000 − 14×120)

= 2320 psf



Settlement at layer 1

$P_o = 18\times120$ ~~$+ 3\times(120-62.5)$~~

$=$ ~~2320 psf~~ ~~2040 psf~~

2160 psf

at center

$\frac{B}{z} = \frac{40}{4} = 10$ ~~13.33~~

$\frac{L}{z} = \frac{50}{4} =$ ~~16.67~~ 12.5

From chart, $I_6 = 0.24989$

$\Delta P = 4\times0.24989\times2320$

$= 2319$ psf

$P_o + \Delta P = 4479$ psf $< P_c$

$S_1 = \frac{0.03\times8\times12}{1.8}\log\frac{4479}{2160}$

$= 0.51''$

at corner

$\frac{B}{z} = 20$ & $\frac{L}{z} = 25$

$I_6 = 0.25$

$\Delta P = 0.25\times2320 = 580$ psf

$P_o + \Delta P = 2740 < P_c$

$S_1 = \frac{0.03\times8\times12}{1.8}\log\frac{2740}{2160}$

$= 0.17''$

Layer 2 $P_o = 20\times120 + 6\times(120-62.5) = 2745$ psf

at center

$\frac{B}{z} = \frac{40}{12} = 3.33$

$\frac{L}{z} = \frac{50}{12} = 4.17$

$I_6 = 0.246$

$\Delta P = 4\times0.246\times2320 = 2282.88$

$P_o + \Delta P = 5027.88 < P_c$

$S_2 = \frac{0.03\times8\times12}{1.8}\log\frac{5027.88}{2745} = 0.42''$

at corner

$\frac{B}{z} = 6.67$, $\frac{L}{z} = 8.33$

$I_6 = 0.249$

$\Delta P = 0.249\times2320 = 577.68$ psf

$P_o + \Delta P = 3322.68 < P_c$

$S_2 = 0.13''$

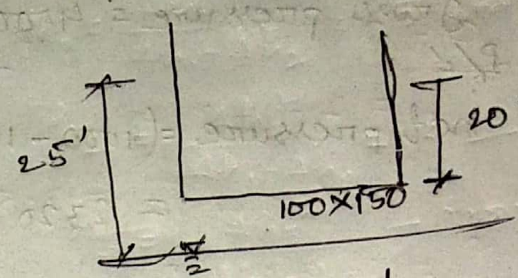
∴ Total S at center = 0.93''

" corner = 0.30'' (Ans.)

3. (b)

$\gamma = 120$ pcf

$q_b = \frac{4+5}{2} = 4.5$ ksf



$c = 2$ ksf

$\frac{D_f}{B} = 0.2$

$N_c = 5.3 \times \left(1 + 0.2 \times \frac{100}{150}\right)$

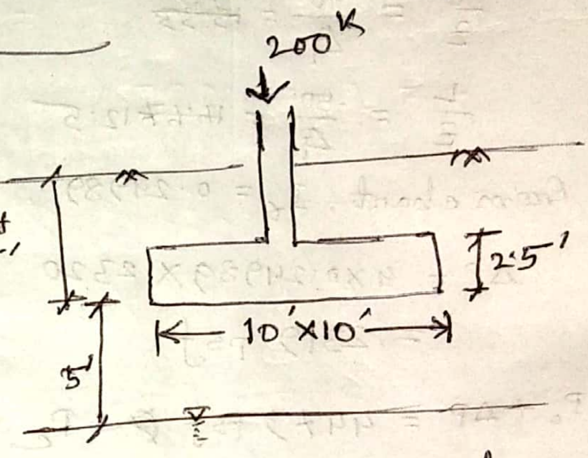
≈ 6

$$F = \frac{cN_c}{q_b - \gamma D_f}$$

$$= \frac{2 \times 6}{4.5 - 0.12 \times 20} = 5.7$$

(Ans.)

4. (a)



We have to take N value at a depth $D_f + B$

$= 15'$

$N_{avg.} = 20$

$\gamma = 120$ pcf

net pressure at the bottom of footing $q_{net} = \frac{200}{10 \times 10} + 2.5 \times \frac{150 - 120}{1000}$

≈ 2.075 ksf $= 1.0375$ tsf

water table correction factor, $C_w = 0.5 + 0.5 \times \frac{D_N}{D_f + B}$

$= 0.5 + 0.5 \times \frac{10}{10+5}$

$= 0.833$

$\frac{D_f}{B} = 0.5$ and $N = 20$

$\therefore$ Allowable, $q_a = 0.11N = 2.20$ tsf

Corrected $q_a = 2.20 \times 0.833 = 1.83$ tsf

for 1" settlement

settlement of the footing $= \frac{1}{1.83} \times 1.0375$

$= 0.567'' \approx 0.57''$

For $q_a = \cancel{1.83} \; 2.20$ tsf , $B = 3.3'$

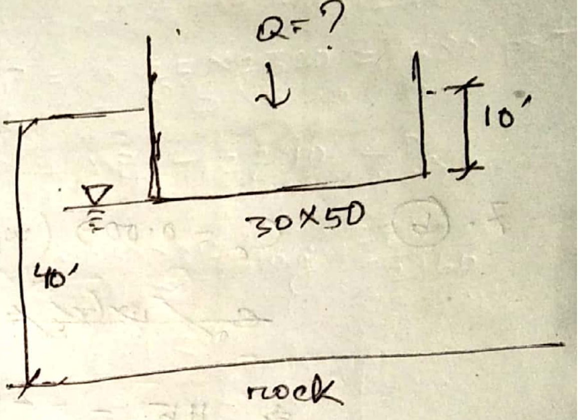
for, $B = 10'$, $q_a = \frac{2.20}{3.30} \times 10 = 6.67$ tsf

Corrected $q_a = 0.833 \times 6.67 = 5.56$ tsf

Factor of safety $= \frac{5.56 \times 2}{1.0375} = 10.7$

(Ans.)

5. (c) $N_{avg.} = 19$



$\gamma = 100$ pcf

$D_f + B = 10 + 30 = 40$

$q_a = 0.22\,N = 4.18$ tsf

$C_w = 0.5 + 0.5 \times \frac{10}{40} = 0.625$

Corrected $q_a = 4.18 \times 0.625 = 2.6125$ tsf

Surcharge $= \gamma D_f = 100 \times 10 = 1000$ psf $= 1$ ksf

$= 0.5$ tsf

Contact pressure $= (2.6125 + 0.5) = 3.1125$ tsf

$\therefore Q = 3.1125 \times 30 \times 50 = \boxed{4668.75 \text{ tons}}$

(Ans.)

≈ 4670 tons

6. (b) ~~$E_1 N_1 = E_2 N_2$~~ standard wt. of hammer $= 140$ lb

~~Hammer~~ wt. of used " $= 120$ lb

(a)

$W_1 N_1 = W_2 N_2$

$\Rightarrow 120 \times 10 = 140 \times N_2$

$\Rightarrow N_2 = 8.57 \approx 9$

(Ans.)

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(d)

$\Delta t = 24$

$\Delta h_1 = 9.5 - 8.5 = 1\ m$

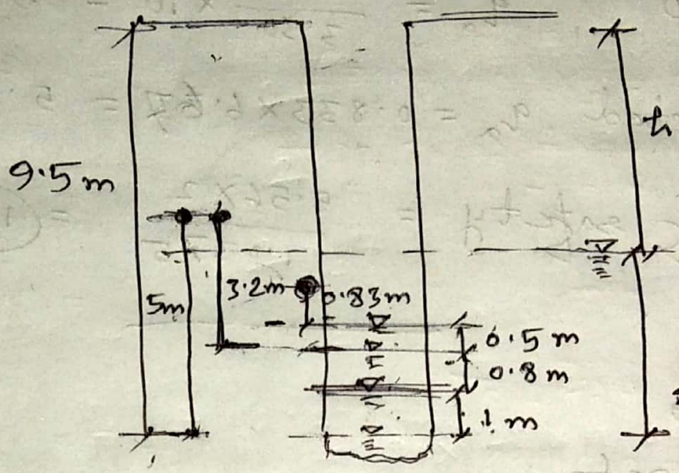
$\Delta h_2 = 8.5 - 7.7 = 0.8\ m$

$\Delta h_3 = 7.7 - 7.2 = 0.5\ m$

$h_0 = \dfrac{\Delta h_1^2}{\Delta h_1 - \Delta h_2} = 5\ m$

$h_2 = \dfrac{\Delta h_2^2}{\Delta h_1 - \Delta h_2} = 3.2\ m$

$h_3 = \dfrac{\Delta h_3^2}{\Delta h_2 - \Delta h_3} = 0.83\ m$



$h_w = 5.12\ m$

(Ans.)

$\dfrac{5 + (3.2 + 0.8 + 1) + (0.83 + 0.5 + 0.8 + 1)}{3}$

≈ 4.38

7. (b) $C_c = 0.009\,(w_L - 10) = 0.27$

$\gamma_{sat} = \dfrac{G_s + e}{1+e}\,\gamma_w$

$\Rightarrow 115 = \dfrac{2.65 + e_0}{1 + e_0} \times 62.5$

$\Rightarrow e_0 = 0.96$

$P_0 = 10 \times 125 + 20 \times (125 - 62.5) + 10 \times (115 - 62.5)$

$= 3025$ psf

$\Delta P = \dfrac{500 \times \frac{\pi}{4} \times 80^2}{\frac{\pi}{4} \times (80 + 40)^2} = 222.22$ psf

$S = \dfrac{0.27 \times 20 \times 12}{1.96} \log \dfrac{3025 + 222.22}{3025}$

~~$= 0.10508'' \approx$~~ $0.1'' = 1.02''$

(Ans.)

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$\beta = 45°$
$\phi = 20°$
$m = 0.06$

8. (a) (i) $H_{cr} = \dfrac{c}{\gamma m} = \dfrac{25}{18 \times 0.06}$

$= \boxed{23.15\ m}$ (Ans.)

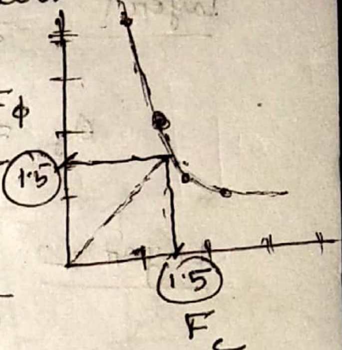
(ii) Let us assume that the full friction is mobilized

$\phi_d = \phi = 20°$

$\therefore m = 0.06 = \dfrac{c_d}{\gamma H} \Rightarrow c_d = 0.06 \times 18 \times 10$
$= 10.8\ kN/m^2$

$F_\phi = \dfrac{\tan\phi}{\tan\phi_d} = 1$ and $F_c = \dfrac{c}{c_d} = \dfrac{25}{10.8} = 2.31$

$\therefore F_\phi \neq F_c$, So this not the F.S. with respect to strength



ϕ_d	F_ϕ	m	c_d (kN/m^2)	F_c
20	1	0.06	10.8	2.31
15	1.36	0.085	15.3	1.63
10	2.06	0.11	19.8	1.26
5	4.16	0.136	24.48	1.02

From graph, $F_\phi = F_c = F_s = \boxed{1.50}$ (Ans.)

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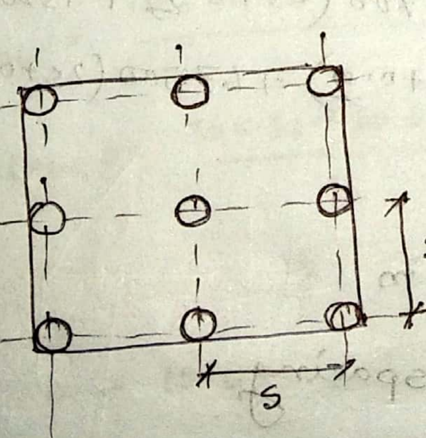
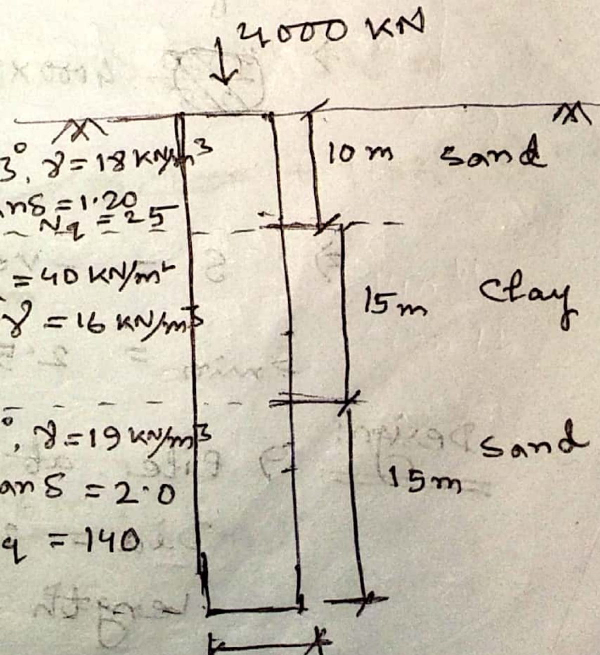
3.





Assume,

Dia of pile, d = ~~50 cm~~ 20 cm
= ~~0.5 m~~ 0.2 m

Length = 40 m

End bearing, $Q_b = \cancel{c N_c A_b} = q_o' N_q A_b$

$q_o' = 10\times18 + 15\times16 + 15\times19 = 705$ kN/m²

$\therefore Q_b = 705 \times 140 \times (2s + 0.2)^2$

$= 98700 (2s + 0.2)^2$

Skin Friction:

$A_{f_1} = 4\times(2s+0.2)\times 10$

$A_{f_2} = 4\times(2s+0.2)\times 15$

$A_{f_3} = 4\times(2s+0.2)\times 15$

Layer 1 $\quad \bar{q}_1 = \frac{10\times18}{2} = 90$ kN/m²

$Q_{f_1} = \bar{q}_1 K_1 \tan\delta_1 A_{f_1} = 90\times1.20\times4(2s+0.5)\times10$

$= 4320(2s+0.5)$

Layer 2

$Q_{f_2} = \alpha C_u A_{f_2} = 1\times40\times4(2s+0.2)\times15 = 2400(2s+0.5)$

Layer 3 $\quad \bar{q}_3 = 10\times18 + 15\times16 + \frac{15}{2}\times19 = 562.5$ kN/m²

$Q_{f_3} = 562.5\times2\times4(2s+0.2)\times15 = 67500(2s+0.5)$

Now, $\cancel{Q_{ug} = Q_b + Q_f}$ $\quad Q_{allow} = \frac{Q_b + Q_f}{F.S.}$

$\Rightarrow$ $\cancel{4000/2.5}$ $4000\times2.5 = 98700(2s+0.2)^2 + 4320\times(2s+0.2)$

$+ 2400(2s+0.2) + 67500(2s+0.2)$

$\Rightarrow \quad s = -ve$

$s_{min} = 2.5d = 0.5$ m

Design: 9 Pile at 0.5 m spacing

Dia = 20 cm

Length = 40 m

Check:

capacity as a single pile

$$Q_b = q' N_q A_b = 705 \times 140 \times \frac{\pi}{4} \times 0.2^2 = 3100.75 \text{ KN}$$

$$Q_f = Q_{f_1} + Q_{f_2} + Q_{f_3}$$

$$= 90 \times 1.20 \times \pi \times 0.2 \times 10 + 1 \times 40 \times \pi \times 0.2 \times 15 + 562.5 \times 2 \times \pi \times 0.2 \times 15$$

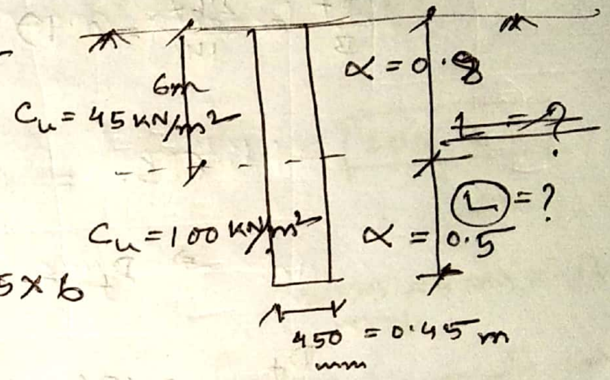
$$= 11658.45 \text{ KN}$$

$$Q_{allow} = \frac{(3100.75 + 11658.45) \times 9}{2.5} = \cancel{5904 \text{ KN}}\ 53133 \text{ KN} > 4000 \text{ KN}$$

$\boxed{\text{OK}}$

4. End bearing, $Q_b = 100 \times 9 \times \frac{\pi}{4} \times 0.45^2$

$$= 143.14 \text{ KN}$$



skin friction:

Layer 1 : $Q_{f_1} = 0.8 \times 45 \times \pi \times 0.45 \times 6$

$$= 305.36 \text{ KN}$$

Layer 2: $Q_{f_2} = 0.5 \times 100 \times \pi \times 0.45 \times L = 70.686L$ KN

$W_{pile} = \frac{\pi}{4} \times 0.45^2 \times (6 + L) \times 24 = 3.82(L+6)$ KN

~~1st condn.~~

① $Q_{allow} = \frac{143.14 + 305.36 + 70.686L}{3} = 400 \Rightarrow L = 10.6$ m

② $Q_{allow} = \frac{305.36 + 70.686L}{3} + 3.82(L+6) = 200$

$$\Rightarrow L = 2.75 \text{ m}$$

$\therefore L = 10.6$ m

$\therefore$ Length of pile = $\boxed{16.6 \text{ m}}$ (Ans.)

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6. Raft size $= 14\,m \times 21\,m$

$q_u = 80\ kN/m^2 \quad \therefore c = 40\ kN/m^2$

$q_b = 120\ kN/m^2$

Let, $\frac{D_f}{B} = 0.1$ From chart, $N_c = 5.3$

modified $N_c = 5.3 \times \left(1 + 0.2 \times \frac{14}{21}\right)$

$= 6$

$F.S. = \frac{cN_c}{q_b - \gamma D_f}$

$\Rightarrow 120 - 15 \times D_f = \frac{40 \times 6}{3}$

$\Rightarrow D_f = 2.67\ m$

Now,

$\frac{D_f}{B} = \frac{2.67}{14} = 0.19$ From chart, $N_c = 5.4$

modified, $N_c = 6.12$

$F.S. = 3 = \frac{40 \times 6.12}{120 - 15 \times D_f}$

$\Rightarrow D_f = 2.56\,m \approx 2.6\ m$

$\frac{D_f}{B} = 0.186$ which is close to 0.19

so, further trial is not required

$\therefore$ Required depth for raft, $D_f = \boxed{2.6\ m}$

(Ans.)

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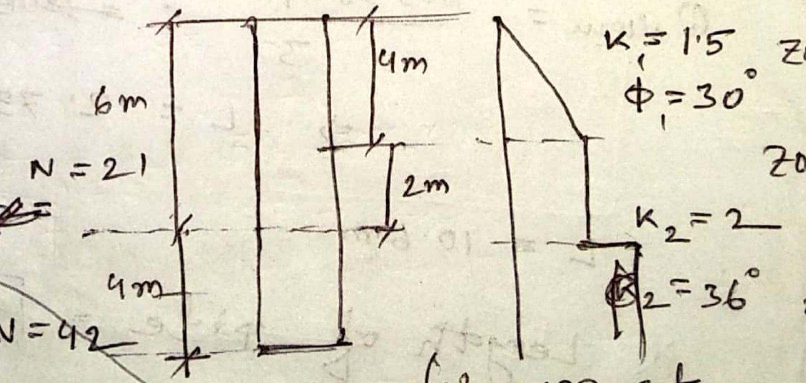
7. $D_c = 16B = 16 \times 0.25$

$= 4\ m$



0.4m

$\delta = \frac{3}{4}\phi = 22.5°$

$S_f = \sigma_v K \tan\delta A$

$= 18.87 \times 1 \times 1.5 \times \tan 22.5 \times \pi \times 0.25 \times 4$

$\gamma = 120\ pcf$

$= 18.87\ kN/m^3$

$q_0' = 4 \times 18.87 = 75.48\ KN/m^2$

at Layer 2, $q_2' = 75.48 + \frac{1}{2} \times 4 \times 18.87 = 113.22\ KN/m^2$

$\underline{0-4m}$ $\quad \delta = \frac{3}{4}\phi = 22.5°$

skin Friction $= \frac{75.48}{2} \times 1.5 \times \tan 22.5° \times \pi \times 0.25 \times 4$

$= 73.67\ KN$

$\underline{4-6m}$ Skin friction $= 75.48 \times 1.5 \times \tan 22.5° \times \pi \times 0.25 \times 2$

$= 73.67\ KN$

$\underline{6-10m}$ skin Friction $= 113.22 \times 2 \times \tan 27° \times \pi \times 0.25 \times 4$

$\delta = \frac{3}{4}\phi = 27°$ $\quad = 362.47\ KN$

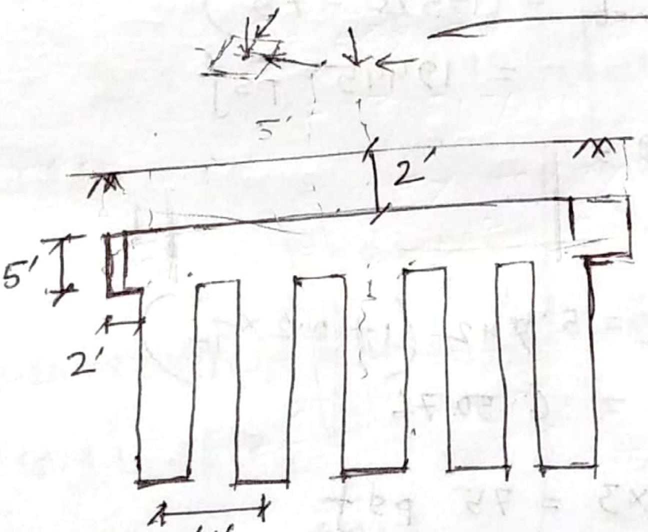
End bearing, $Q_b = (75.48 + 4 \times 18.87) \times 42 \times \frac{\pi}{4} \times 0.25^2$

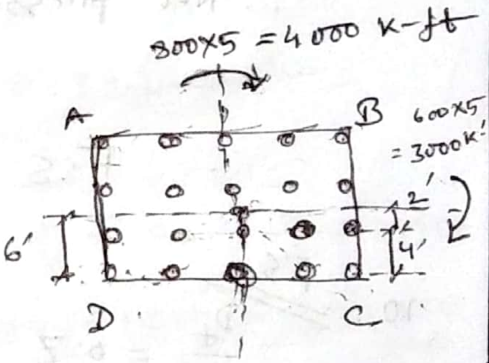
$= 311.23\ KN$

$\therefore P_{total} = 821.04\ KN$ $\quad \therefore P_{allow} = \frac{821.04}{4} = \boxed{205\ KN}$

(Ans.)

9. (b)





$\Sigma d_L^2 = (4 \times 4^2 + 4 \times 8^2) \times 2$

$= 640\ ft^2$

$\Sigma d_s^2 = (5 \times 2^2 + 5 \times 6^2) \times 2$

$= 400\ ft^2$

~~Q/=~~ Additional load

$= 20 \times 16 \times 5 \times 150 + 2 \times 20 \times 16 \times 120$

$= 316.8\ K$

$$Q = \frac{2000}{20} + \frac{316.8}{20} \pm \frac{4000 \times 8}{640} \pm \frac{3000 \times 6}{400}$$

$$\left.\begin{aligned} Q_{max} &= 210.84^{k} \\ Q_{min} &= 20.84^{k} \end{aligned}\right\} \text{(Ans.)}$$

10. Factor of safety

$\therefore \frac{D_f}{B} = \frac{7}{10} = 0.7 \rightarrow N_c = 5.742$

corrected $N_c = 5.742 \times \left(1 + 0.2 \times \frac{10}{15}\right)$

$= 6.5076$

net bearing capacity, $q_d = CN_c = 3 \times 6.5076$

$= 19.52$ ksf.

Additional weight $= (150 - 125) \times 3 = 75$ psf

$\therefore$ Net pressure, $q_{net} = (19520 - 75)$

$= 19445$ psf

F.S. $= 19.5$

10. FS

$\frac{D_f}{B} = 0.7$, $N_c = 5.742\left(1 + 0.2 \times \frac{10}{15}\right)$

$= 6.5076$

$q_u = (150 - 125) \times 3 = 75$ psf

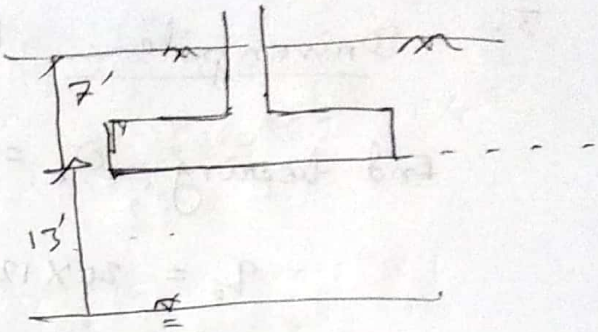
$$F.S. = \frac{CN_c}{q_u - \cancel{\gamma D_f}} = \frac{3 \times 6.5076 \times 10^3}{75 - \cancel{125 \times 7}}$$

gross pressure =

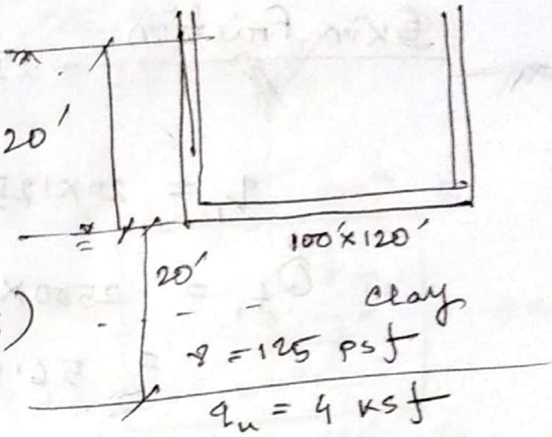
$p_o = 13.5 \times 125 = 1687.5$ psf

$P_o + \Delta P < P_c$, OC clay

$S = \frac{0.03 \times 13 \times 12}{1.7} \log 1 = 0$



11. Factor of safety



$q_u = 4$ ksf

$e_o = 0.8$

$C_c = 0.15$

$C_r = 0.04$

$P_c = 7000$ psf

$q_{net} = 4000 - 125 \times 20$
$= 1500$ psf

$\frac{D_f}{B} = \frac{20}{100} = 0.2$, $N_c = 5.312 \times \left(1 + 0.2 \times \frac{100}{120}\right)$
$= 6.2$

$F.S. = \frac{cN_c}{q_{net}} = \frac{2000 \times 6.2}{1500}$
$= 8.27 \approx 8$ (Ans.)

$P_o = 20 \times 125 + 10 \times (125 - 62.5) = 3125$ psf

At middle

$\frac{B}{Z} = 5$, $\frac{L}{Z} = 6$ $\therefore I_6 = 0.24885$

$\Delta P = 4 \times 0.24885 \times 1500 = 1493.1$ psf

$P_o + \Delta P = 4618.1 < P_c$

$\therefore S = \frac{0.04 \times 20 \times 12}{1.8} \log \frac{4618.1}{3125}$

$2 \times \cancel{0.45''} = 0.91''$ (Ans.)

At corner

$\frac{B}{Z} = 10$, $\frac{L}{Z} = 12$ $\therefore I_6 = 0.24989$

$\Delta P = 0.24989 \times 1500 = 374.835$ psf

$P_o + \Delta P = 3499.835$ psf $< P_c$

$S = \frac{0.04 \times 20 \times 12}{1.8} \log \frac{3499.835}{3125}$

$2 \times \cancel{0.13''} = 0.26''$ (Ans.)

3.

<u>Driven pile</u> $L = 40'$

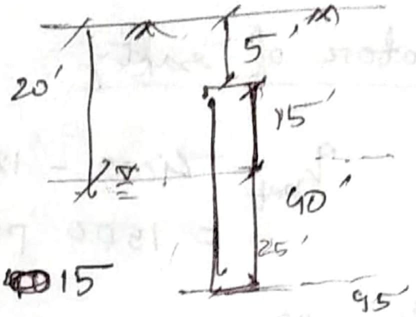
End bearing, $Q_b = q_o N_q A_b$

$q_o = 20 \times 125 + \overset{25}{\cancel{20}} \times (125 - 62.5) = \overset{4062.5}{\cancel{3750}}$ psf

$\therefore Q_b = \overset{4062.5}{\cancel{3750}} \times 80 \times \cancel{4} \frac{15 \times 15}{144} = \cancel{586 \; 655^k}$

$= 507.8^k$

<u>Skin Friction</u> $D_c = 20'$



$q_1 = 20 \times 125 = 2500$ psf

$Q_{f_1} = 2500 \times 1 \times 0.3 \times 4 \times \frac{15}{12} \times 15$

$= 56.25^k$

$q_2 = 2500 + \frac{1}{2} \times 25 \times (125 - 62.5) = 3281.25$ psf

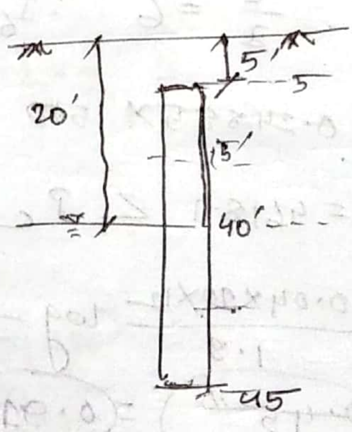
$Q_{f_2} = 3281.25 \times 2 \times 0.5 \times 4 \times \frac{15}{12} \times 25 = 410.156^k$

$\simeq 410.2^k$

Allowable capacity $= \frac{507.8 + 56.25 + 410.2}{2.5}$

$= \boxed{390^k}$ (Ans.)

<u>Drilled Pier</u> Dia $= 30'' = 2.5'$



$\beta = 1.5 - 0.135\sqrt{z}$

$= 1.5 - 0.135\sqrt{z}$

<u>5 – 20'</u>

$\sigma_v = 20 \times 125 = 2500$ psf

$\beta = 1.5 - 0.135\sqrt{12.5} = 1.023$

$Q_{f_1} = 2500 \times 1.023 \times \pi \times 2.5 \times 15 = 301.3^k$

<u>20' – 45'</u> $\sigma_v = 20 \times 125 + 25 \times (125 - 62.5) = 4062.5$ psf

$\beta = 1.5 - 0.135\sqrt{32.5} = 0.73$

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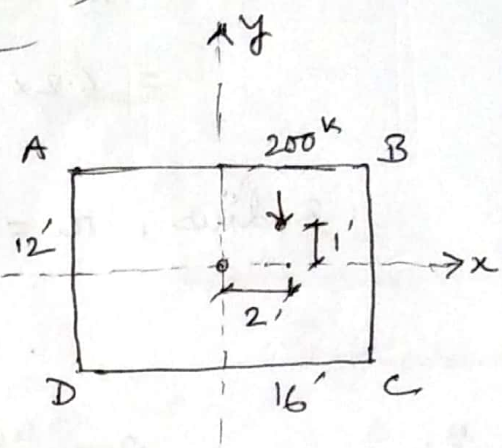
$Q_{f_2} = 4062.5 \times 0.73 \times \pi \times 2.5 \times 25 = 582.3^K$

End bearing: $Q_b = 1.2\, N_f\, A_{tip} = 1.2 \times 30 \times \frac{\pi}{4} \times 2.5^2$

$= 176.7^K$

$\therefore$ Allowable capacity $= \frac{301.3 + 582.3 + 176.7}{2.5}$

$= \boxed{424^K}$ (Ans.)



9. (a) ~~Corner~~ $M_x = 200 \times 1 = 200$ K-'

$M_y = 200 \times 2 = 400$ K-'

Conventional method

$$q = \frac{200}{12 \times 16} \pm \frac{200 \times 6}{\frac{16 \times 12^3}{12}} \pm \frac{400 \times 8}{\frac{12 \times 16^3}{12}}$$

$= 1.042 \pm 0.521 \pm 0.781$

$q_A = 0.782$ ksf $\quad q_C = 1.302$ ksf

$q_B = 2.344$ ksf $\quad q_D = -0.26$ ksf (tension)

Meyerhof method $\quad L' = 16 - 2 \times 2 = 12' \quad B' = 12 - 2 \times 1 = 10'$

$\therefore q = \frac{200}{10 \times 12} = 1.67$ (Ans.)

6. (a) (i) $H_{cr} = \frac{c_u}{\gamma m} = \frac{20}{17 \times 0.19}$ $\quad$ From graph, $m = 0.19$

$= \boxed{6.2\,m}$ (Ans.)

(ii) As $\beta = 60^\circ > 53^\circ$, the critical circle is a toe circle.

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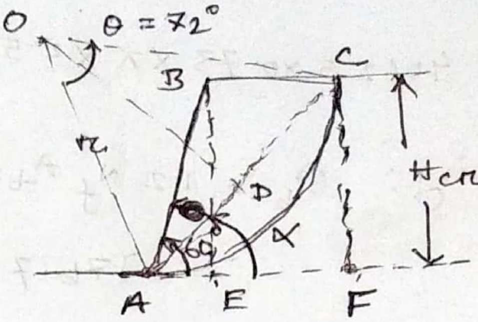
(c)

From graph,

$\alpha = 36^\circ$

$\theta = 72^\circ$



$\overline{AF} = H_{cr} \cot\alpha$

$= 6.2 \times \cot 36^\circ = \boxed{8.53\ m}$

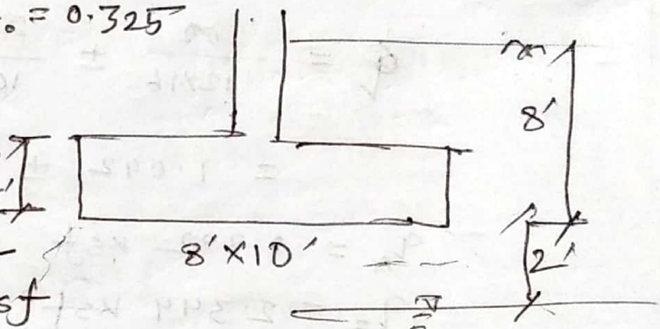
$\overline{BC} = \overline{AF} - \overline{AE} = H_{cr}\cot\alpha - H_{cr}\cot\beta$

$= 6.2 \times (\cot 36^\circ - \cot 60^\circ) = \boxed{4.95\ m}$

Radius, $r = \dfrac{H_{cr}}{2\sin\alpha \sin\frac{\theta}{2}} = \boxed{8.97\ m}$

8.

$\gamma_d = \dfrac{G_s \gamma_w}{1+e_0} \Rightarrow e_0 = 0.325$



Settlement

$\sigma_0' = 9 \times 125 = 1125$ psf $\quad \frac{30''}{=2.5'}$

$\Delta\sigma = \dfrac{250 \times 10^3}{9 \times 11} = 2525.25$ ~~2.525~~ psf

$\therefore \sigma_0' + \Delta\sigma = 3650.25$ ~~427.525~~ $< \sigma_{v\,max}$

$\therefore$ OC clay

$\gamma = 125$ pcf

$C_c = 0.15$

$C_r = 0.04$

$\sigma_{v\,max} = 8000$ psf

$S = \dfrac{0.04 \times 2 \times 12}{1.325} \log \dfrac{3650.25}{1125}$ (~~427.525~~)

$= 0.37''$

(Ans.)

Capacity:

$\dfrac{D_f}{B} = \dfrac{8}{8} = 1$

From graph, $N_c = 6.2$

corrected $N_c = 6.2 \times \left(1 + 0.2 \times \frac{8}{10}\right)$

$= 7.192$

$q_d = CN_c = 1 \times 7.192 = 7.192$ ksf

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Additional weight $= (150-125)\times 2.5 = 62.5$ psf

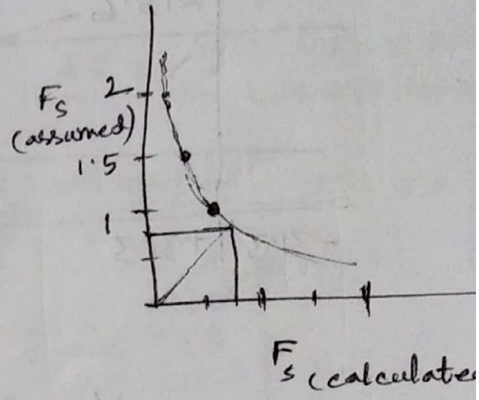
Net pressure under footing $= (7192 - 62.5) = 7129.5$ psf

Capacity of the footing $= 7129.5 \times 8 \times 10 = 570.36^k$

Allowable capacity $= \dfrac{570.36}{2.5} = \boxed{228^k}$ (Ans.)

7. (a)

$F_{assumed}$	$\dfrac{c}{F_s \gamma H}$	ϕ_d	$F = \dfrac{\tan\phi}{\tan\phi_d}$
1	0.0508	16.1°	1.26
1.5	0.0339	21.9°	0.905
2	0.0254	24°	0.82



$\gamma = 105$ pcf $c = 400$ psf

$\phi = 20°$ $r_u = 0.4$

$\beta = 20°$

$H = 75'$

$F_s = 0.75$

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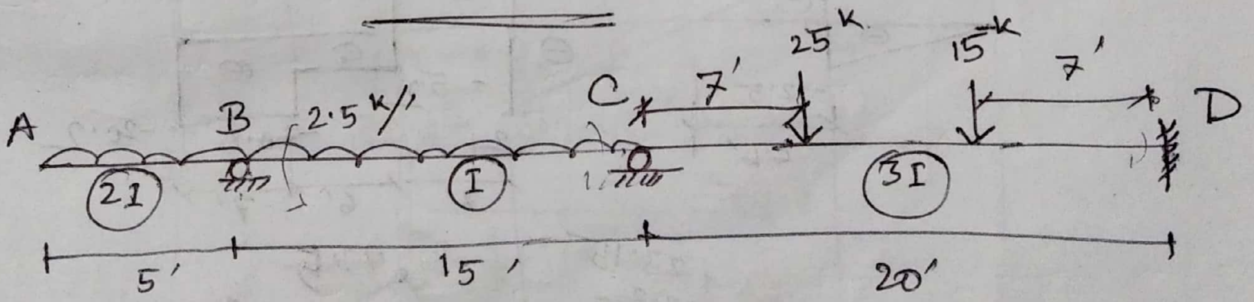
(a)



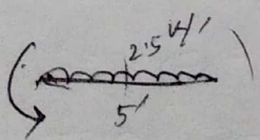
~~DF_{BA}~~

$DF_{BC} = 1$

$DF_{DC} = 0$

$DF_{CD} = \dfrac{\frac{3I}{20}}{\frac{3I}{20} + \frac{3}{4}\times\frac{I}{15}} = 0.75$

$DF_{CB} = 0.25$



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$FEM_{BA} = \cancel{31.30\ k\text{-}'}\ -31.3\ k\text{-}'$

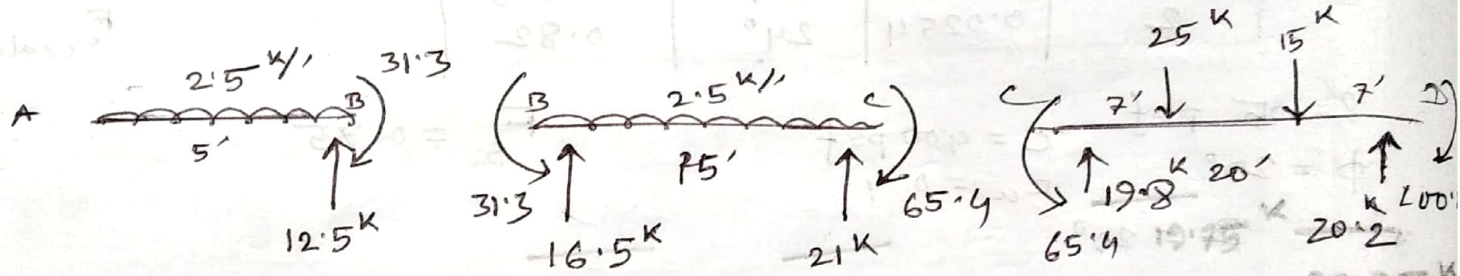
$FEM_{CD} = +97.8\ k\text{-}'$

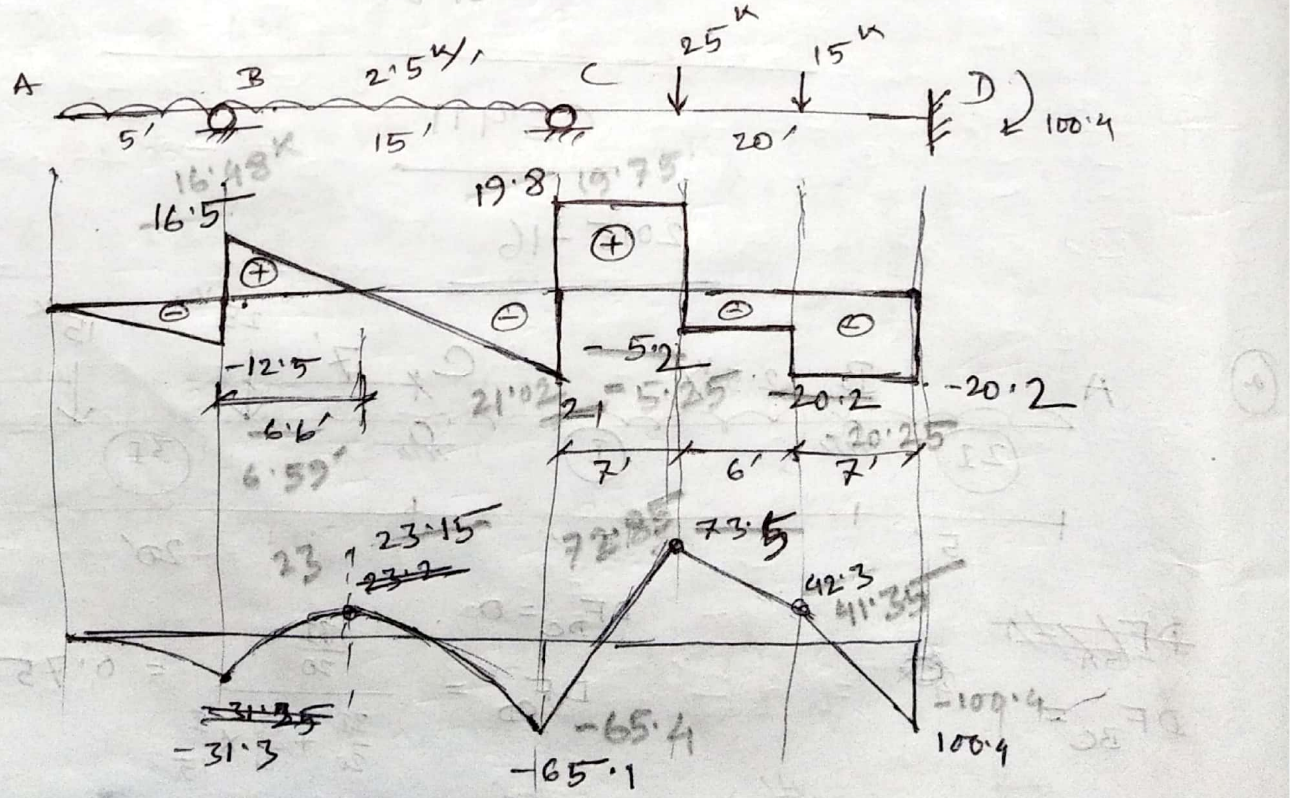
$FEM_{BC} = +\frac{2.5 \times 15^2}{12} = +46.9\ k\text{-}'$

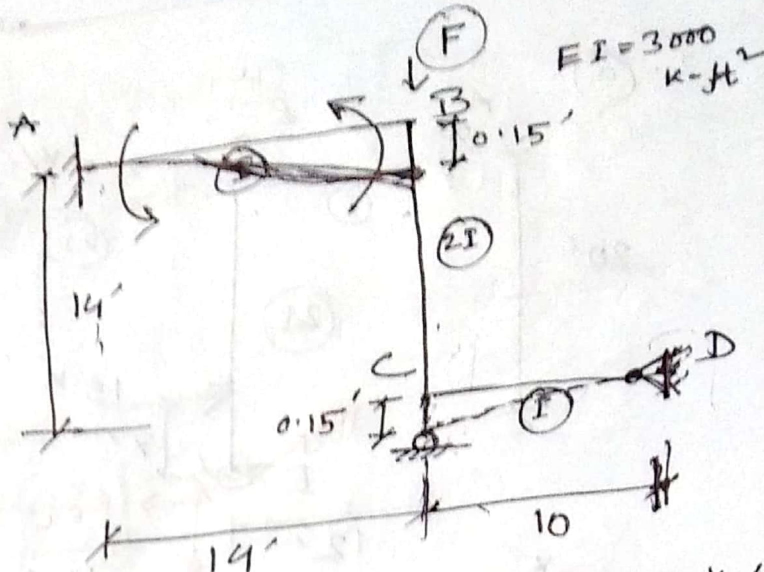
$FEM_{DC} = -84.2\ k\text{-}'$

$FEM_{CB} = -46.9\ k\text{-}'$

	1	0.25	0.75	
BA	BC	CB	CD	DC
-31.3	+46.9	-46.9	+97.8	-84.2
	-15.6	-12.7	-38.2	
		-7.8		-19.1
		+2.0	+5.8	
				+2.9
-31.3	+31.3	-65.4	+65.4	-100.4







$DF_{AB} = 0$

$$DF_{BA} = \frac{\frac{I}{14}}{\frac{I}{14} + \frac{2I}{14}} = 0.33$$

$DF_{BC} = 0.67$

$$DF_{CB} = \frac{\frac{2I}{14}}{\frac{2I}{14} + \frac{3}{4}\times\frac{I}{10}} = 0.66$$

$DF_{CD} = 0.34$

$DF_{DC} = 1$

$$FEM_{AB} = \frac{6EI\Delta}{L^2} = \cancel{+13.78\ k} \quad +13.8\ k\text{-}'$$

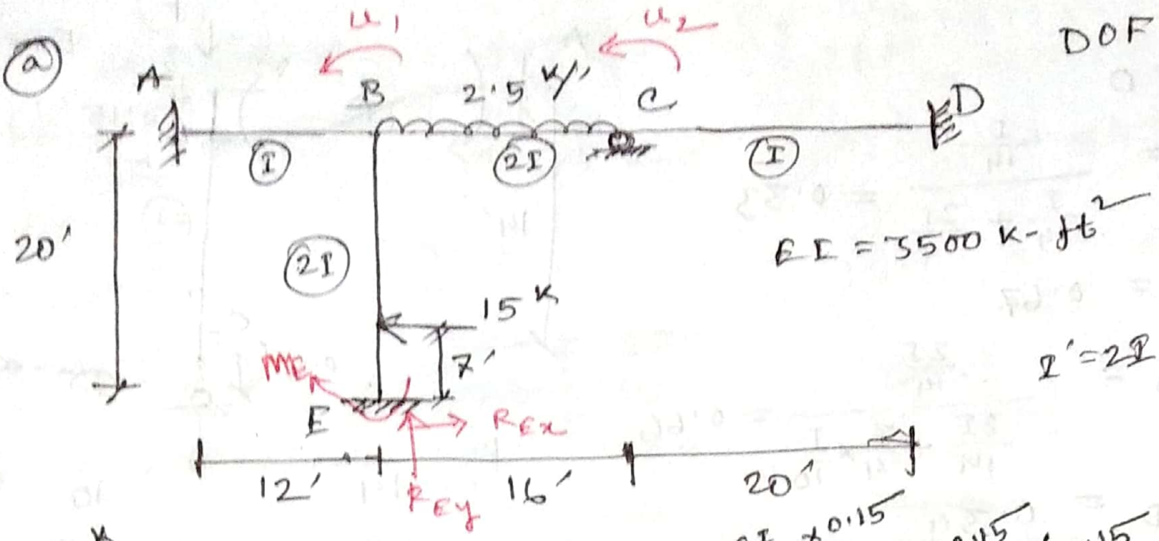
$$FEM_{BA} = \cancel{+13.78\ k} \quad +13.8\ k\text{-}'$$

AB	BA	BC	CB	CD	DC
	0.33	0.67	0.66	0.34	1
+13.8	+13.8				
	-4.6	-9.2			
-2.3			-4.6		
			+3.0	+1.6	
		+1.5			
	-0.5	-1.0			
-0.3			-0.5		
			+0.3	+0.2	
		+0.2			
	-0.1	-0.1			
+11.2	+8.6	-8.6	-1.8	+1.8	0

$$\therefore \text{Force}, F = \frac{11.2 + 8.6}{14} = \boxed{1.41^{k}}$$ (Ans.)

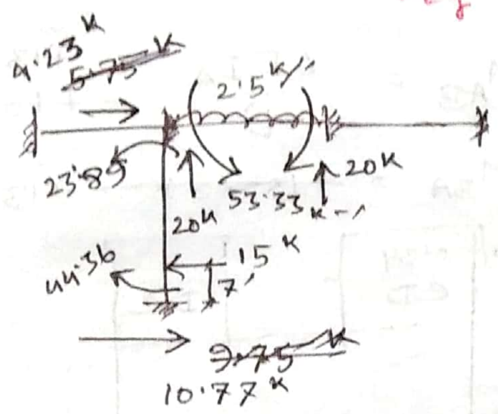
2. (a)

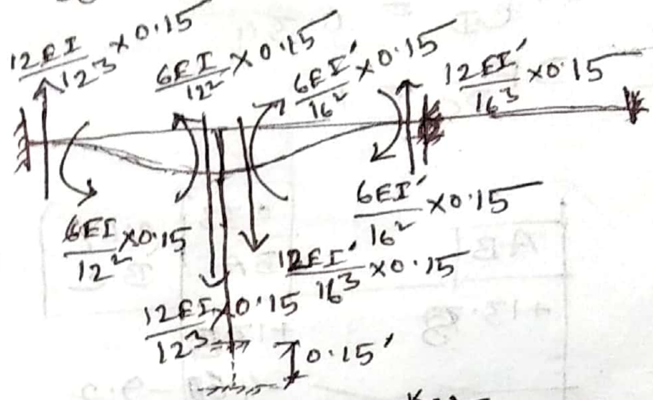
DOF = 2

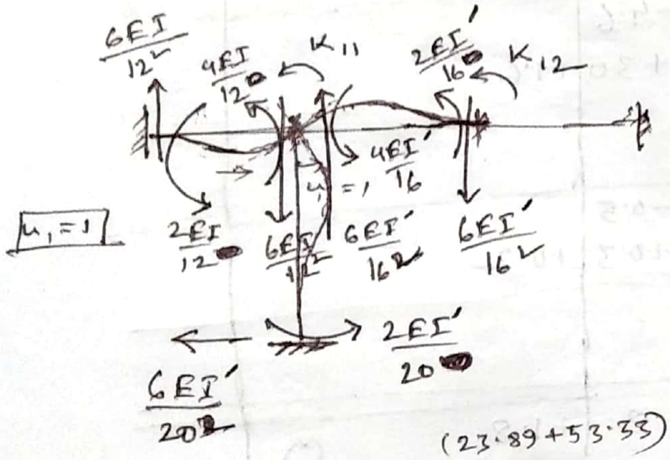


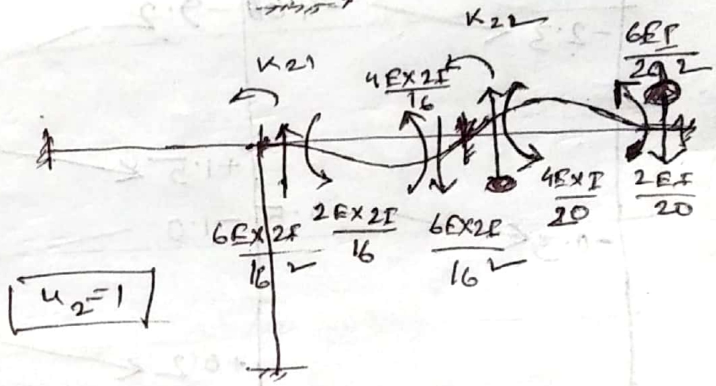
$EI = 3500\ k\text{-}ft^2$

$I' = 2I$









$(23.89 + 53.33)$

$$\begin{bmatrix} 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 77.22 \ \cancel{53.33} \\ -53.33 \end{bmatrix} + \begin{bmatrix} \frac{6}{12^2}\times 0.15 - \frac{12}{16^2}\times 0.15 \\ -\frac{12}{16^2}\times 0.15 \end{bmatrix} EI$$

$$+ \begin{bmatrix} \left(\frac{4}{12} + \frac{8}{16} + \frac{8}{20}\right) & \frac{4}{16} \\ \frac{4}{16} & \frac{8}{16} + \frac{4}{20} \end{bmatrix} EI \begin{bmatrix} u_1 \\ u_2 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} = \begin{bmatrix} \\ \cdot \end{bmatrix} \frac{1}{EI}$$

-89.438

143.28

$$\Rightarrow \begin{bmatrix} 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 77.22 \\ -53.33 \end{bmatrix} + \begin{bmatrix} -2.734 \\ -24.609 \end{bmatrix} + \begin{bmatrix} 4316.67 & 875 \\ 875 & 2450 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} = \begin{bmatrix} -0.026 \\ +0.041 \end{bmatrix}$$

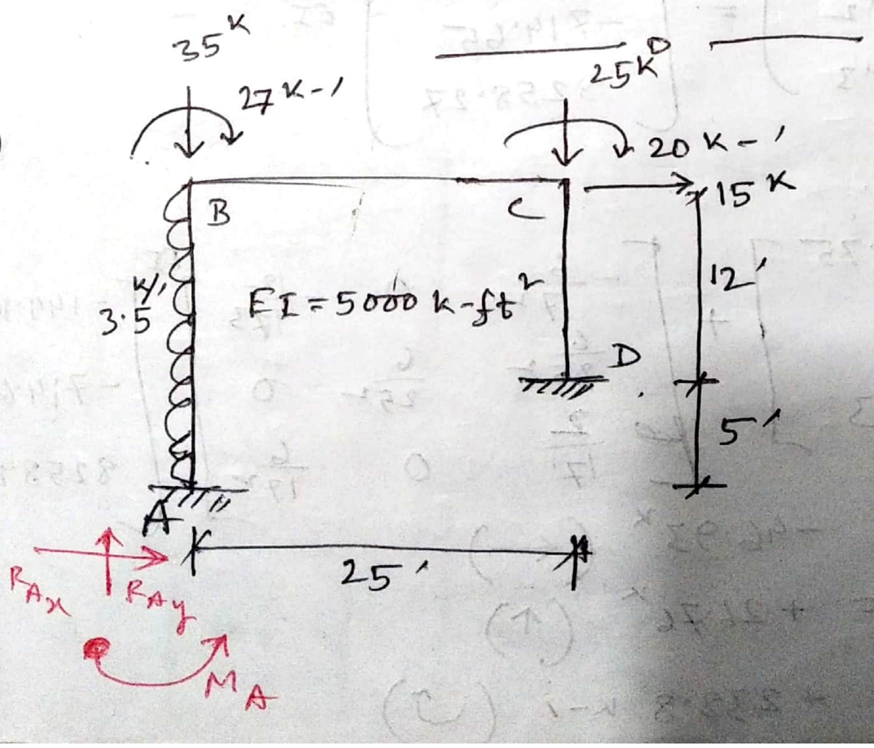
Now,

$$\begin{bmatrix} R_{Ex} \\ R_{Ey} \\ M_E \end{bmatrix} = \begin{bmatrix} 10.77 \\ 20 \\ 44.36 \end{bmatrix} + \begin{bmatrix} 0 \\ -\frac{12EI}{12^3}\times 0.15 - \frac{12\times 2EI}{16^3}\times 0.15 \\ 0 \end{bmatrix} + \begin{bmatrix} -\frac{12}{20^2} & 0 \\ \frac{12}{16^2}+\frac{6}{12^2} & \frac{12}{16^2} \\ -\frac{4}{20} & 0 \end{bmatrix} EI \begin{bmatrix} -0.026 \\ +0.041 \end{bmatrix}$$

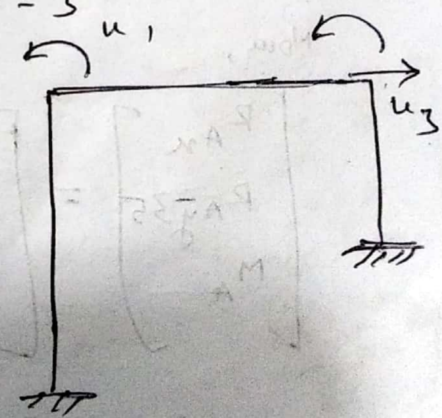
$$\therefore \begin{bmatrix} R_{Ex} \\ R_{Ey} \\ M_E \end{bmatrix} = \begin{bmatrix} 13.5^K (\rightarrow) \\ 19.5^K (\uparrow) \\ 62.56 (\circlearrowleft) \end{bmatrix}$$

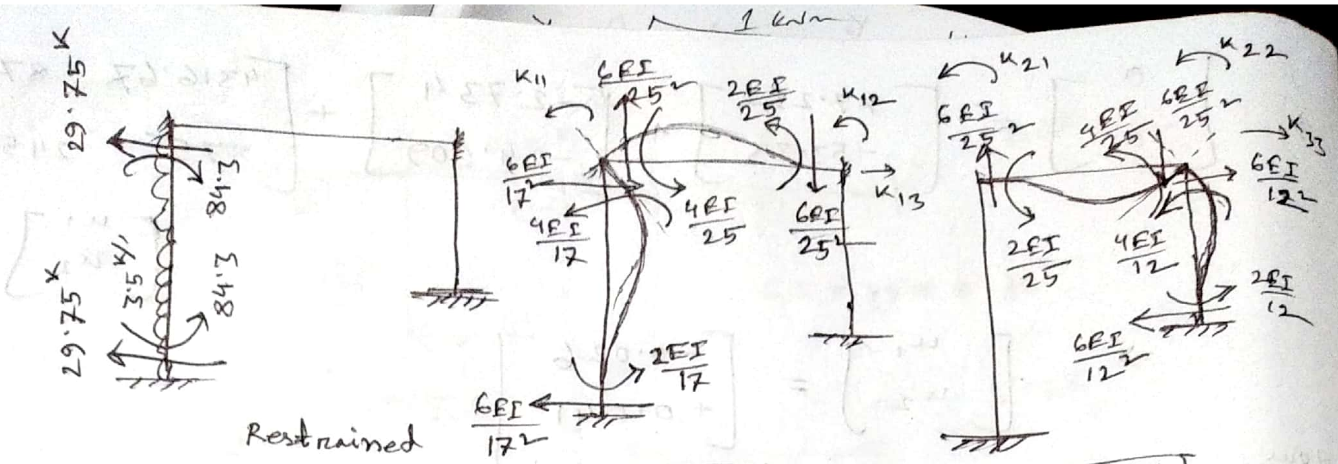
(Ans.)

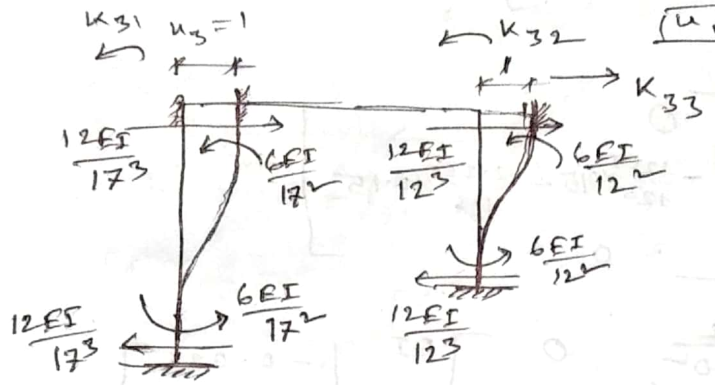
2. (b)



DOF = 3







$$\begin{bmatrix} -27 \\ -20 \\ 15 \end{bmatrix} = \begin{bmatrix} -84.3 \\ 0 \\ -29.75 \end{bmatrix} + \begin{bmatrix} \left(\frac{4}{25}+\frac{4}{17}\right) & \frac{2}{25} & \frac{6}{17^2} \\ \frac{2}{25} & \left(\frac{4}{25}+\frac{4}{12}\right) & \frac{6}{12^2} \\ \frac{6}{17^2} & \frac{6}{12^2} & \left(\frac{12}{17^3}+\frac{12}{12^3}\right) \end{bmatrix} EI \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix} = \begin{bmatrix} -144.14 \\ -714.65 \\ 8258.27 \end{bmatrix} \frac{1}{EI}$$

Now,

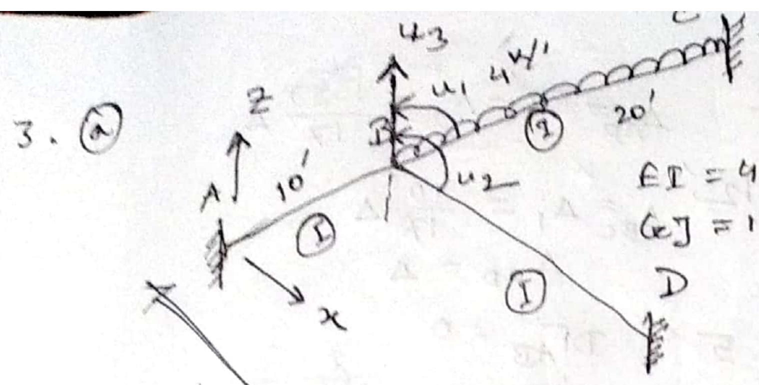
$$\begin{bmatrix} R_{Ax} \\ R_{Ay} \\ M_A \end{bmatrix} = \begin{bmatrix} -29.75 \\ 0 \\ 84.3 \end{bmatrix} + \begin{bmatrix} -\frac{6}{17^2} & 0 & -\frac{12}{17^3} \\ \frac{6}{25^2} & \frac{6}{25^2} & 0 \\ \frac{2}{17} & 0 & \frac{6}{17^2} \end{bmatrix} EI \begin{bmatrix} -144.14 \\ -714.65 \\ 8258.27 \end{bmatrix} \frac{1}{EI}$$

$\therefore$ $R_{Ax} = -46.93^k$ ($\leftarrow$)

$R_{Ay} = +26.76^k$ ($\uparrow$)

$M_A = +238.8$ k-' ($\circlearrowleft$)

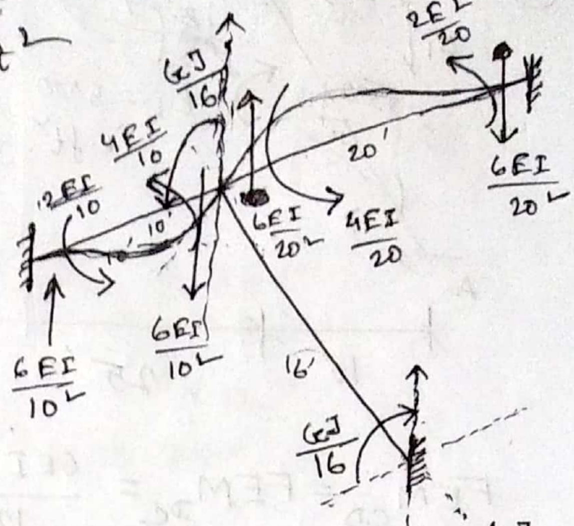
3. (a)

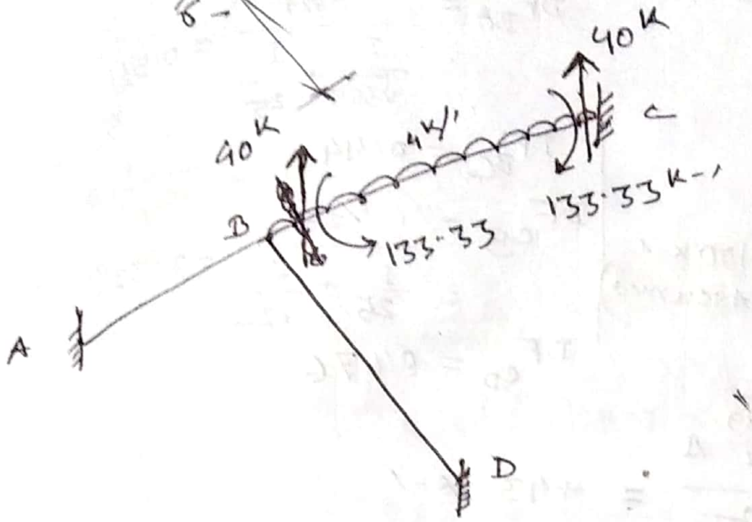


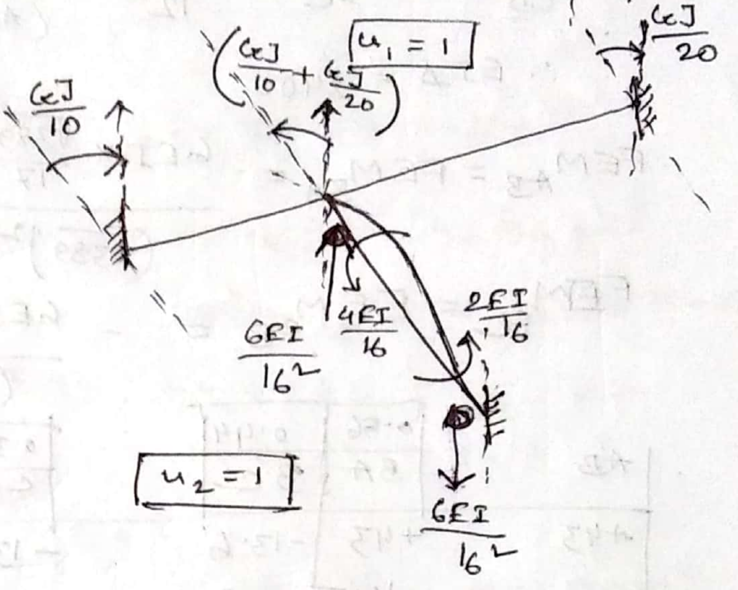
DOF = 3

$EI = 4000 \text{ k-ft}^2$

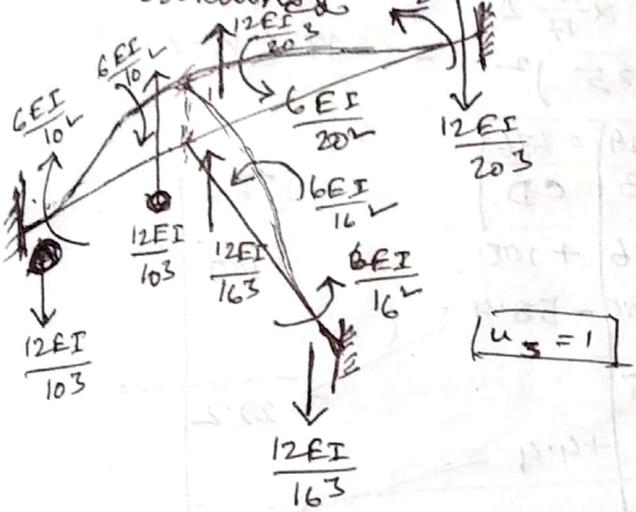
$GJ = 1500 \text{ k-ft}^2$







Restrained



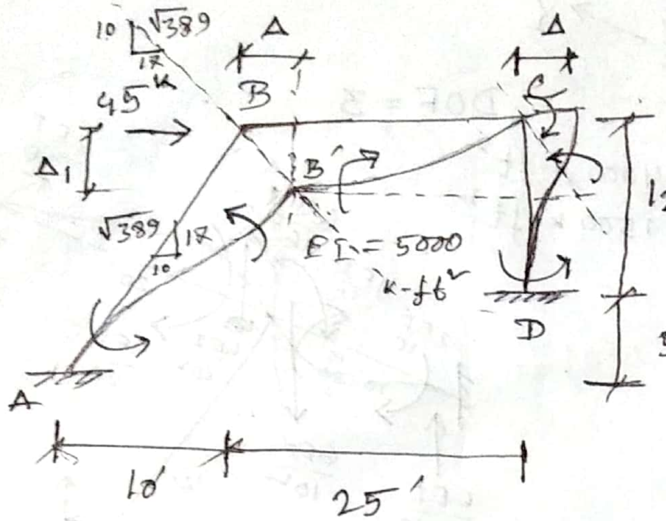
Vertical deflection at B = $1.089' \approx \boxed{1.1'} \downarrow$

(Ans.)

$$\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 133.33 \\ 0 \\ 40 \end{bmatrix} + \begin{bmatrix} \left(\frac{4EI}{10} + \frac{4EI}{20} + \frac{GJ}{16}\right) & 0 & \left(\frac{6EI}{20^2} - \frac{6EI}{10^2}\right) \\ 0 & \left(\frac{4EI}{16} + \frac{GJ}{10} + \frac{GJ}{20}\right) & \frac{6EI}{16^2} \\ \left(-\frac{6EI}{10^2} + \frac{6EI}{20^2}\right) & \frac{6EI}{16^2} & \left(\frac{12EI}{10^3} + \frac{12EI}{20^3} + \frac{12EI}{16^3}\right) \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix} = \begin{bmatrix} -0.132 \\ 0.083 \\ -1.089 \end{bmatrix}$$

(b)



$\Delta_{AB} = BB' = \Delta_2 = \frac{\sqrt{389}}{17}\Delta$

$\Delta_{BC} = \Delta_1 = \frac{10}{17}\Delta$

$\Delta_{CD} = \Delta$

$DF_{AB} = 0$

$DF_{BA} = \dfrac{\frac{I}{\sqrt{389}}}{\frac{I}{\sqrt{389}} + \frac{I}{25}} = 0.56$

$DF_{BC} = 0.44$

$DF_{CB} = \dfrac{I/25}{\frac{I}{25} + \frac{I}{12}} = 0.324$

$DF_{CD} = 0.676$

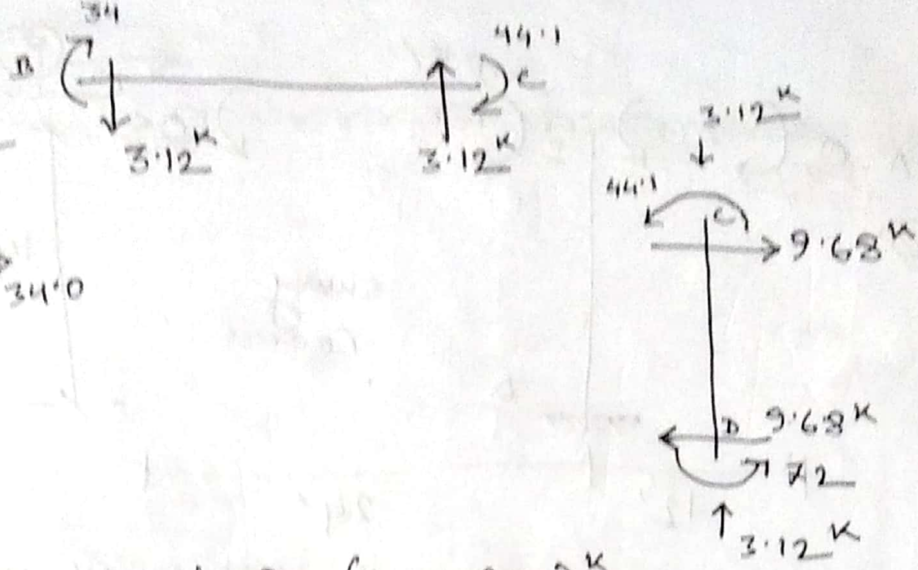
$FEM_{CD} = FEM_{DC} = \dfrac{6EI\Delta}{12^2} = +100\ k\text{-}'$ (Assumed)

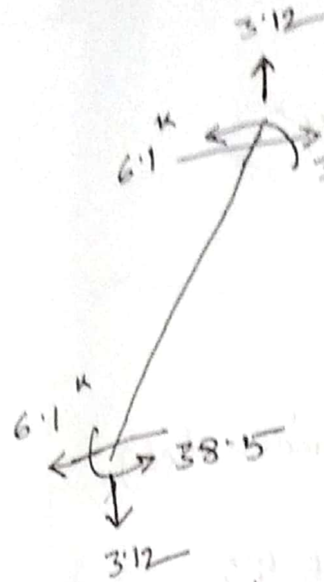
$\therefore EI\Delta = 2400$

$FEM_{AB} = FEM_{BA} = \dfrac{6EI \times \frac{\sqrt{389}}{17}\Delta}{(\sqrt{389})^2} = +43\ k\text{-}'$

$FEM_{BC} = FEM_{CB} = -\dfrac{6EI \times \frac{10}{17}\Delta}{(25)^2} = -13.6\ k\text{-}'$

AB	BA (0.56)	BC (0.44)	CB (0.324)	CD (0.676)	DC
+43	+43	−13.6	−13.6	+100	+100
	−16.5	−12.9	−28.0	−58.4	
−8.3		−14.0	−6.5		−29.2
	+7.8	+6.2	+2.1	+4.4	
+3.9		+1.1	+3.1		+2.2
	−0.6	−0.5	−1.0	−2.1	
−0.3		−0.5	−0.3		−1.1
	+0.3	+0.2	+0.1	+0.2	
+0.2					+0.1
+38.5	+34.0	−34.0	−44.1	+44.1	+72.0





$\therefore Q = (6{\cdot}1 + 9{\cdot}68)^K = 15{\cdot}78^K$

$R = 45^K$

$\therefore$ Final moments,

$FEM_{AB} = +38{\cdot}5 \times \frac{45}{15{\cdot}78} = +109{\cdot}79$ k-ft

$FEM_{BA} = +96{\cdot}96$ k-′ $\quad FEM_{BC} = -96{\cdot}96$ k-′

$FEM_{CB} = -125{\cdot}76$ k-′ $\quad FEM_{CD} = +125{\cdot}76$ k-′

$FEM_{DC} = 205{\cdot}32$ k-′

$\therefore$ Horizontal sway at point C,

$\frac{6EI\Delta}{12^2} = 100 \Rightarrow \Delta = \frac{12}{25}$ for $Q = 15{\cdot}78^K$

$\therefore$ For $R = 45^K$, $\Delta_C = \frac{12}{25} \times \frac{45}{15{\cdot}78} = 1{\cdot}37'$

$\approx \boxed{16{\cdot}44''}$ (Ans.)

By superposition,

$M_A = +109{\cdot}79$ k-′ (↺)

$R_A = 3{\cdot}12 \times \frac{45}{15{\cdot}78} = 8{\cdot}9^K$ (↓)

$M_D = +205{\cdot}32$ k-′ (↻)

$R_D = 8{\cdot}9^K$ (↑)

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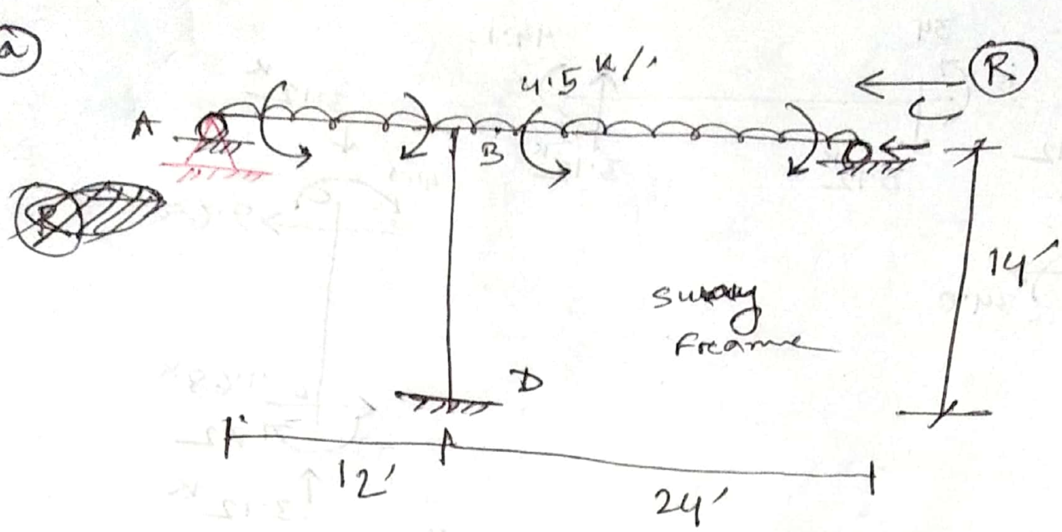
4. (a)



Restrained (sidesway prevented)

$DF_{AB} = 1$

$DF_{BA} = \dfrac{\frac{3}{4} \times \frac{I}{12}}{\frac{3}{4}\times\frac{I}{12} + \frac{3}{4}\times\frac{I}{24} + \frac{I}{14}} = 0.38$

$DF_{BD} = 0.43$

$DF_{CB} = 1$

$DF_{BC} = \dfrac{\frac{3}{4} \times \frac{I}{24}}{\frac{3}{4}\times\frac{I}{12} + \frac{3}{4}\times\frac{I}{24} + \frac{I}{14}} = 0.19$

$DF_{DB} = 0$

$FEM_{AB} = +54$ k-'

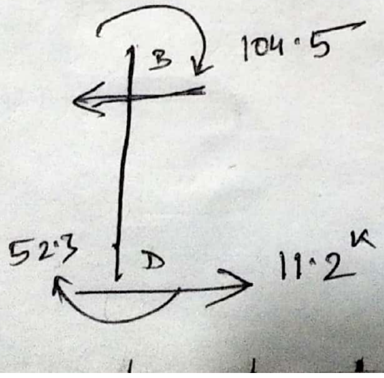
$FEM_{BA} = -54$ k-'

$FEM_{BC} = +216$ k-'

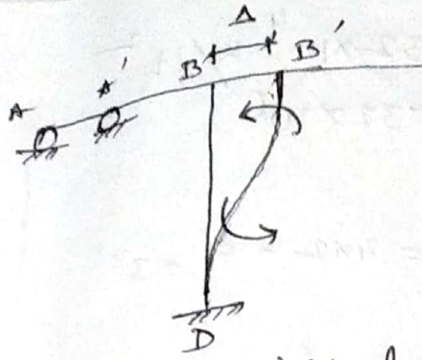
$FEM_{CB} = -216$ k-'

carryover

1	0.38	0.43	0.19	1	
AB	BA	BD	BC	CB	DB
+54	-54		+216	-216	
-54	-61.6	-69.7	-30.7	+216	
	-27		+108		-34.9
	-30.8	-34.8	-15.4		
					-17.4
0	-173.4	-104.5	+277.9	0	-52.3

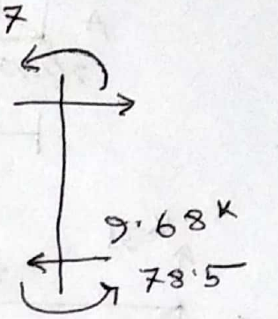


$\therefore R = 11.2^k$ to be applied to make it non-sway Frame.



~~FM~~ $FEM_{BD} = FEM_{DB} = \frac{6EI\Delta}{14^2}$

$= +100$ k-' (assumed)



sway permitted

carry over

AB	BA	BD	BC	CB	DB
1	0.38	0.43	0.19	1	
		+100			+100
	−38	−43	−0.79		
					−21.5
0	−38	+57	−19	0	+78.5

$\therefore Q = -9.68^k$

$$\boxed{M = M_0 + \left(\frac{R}{Q}\right) M_Q}$$ *

Final moments: $FEM_{AB} = 0$

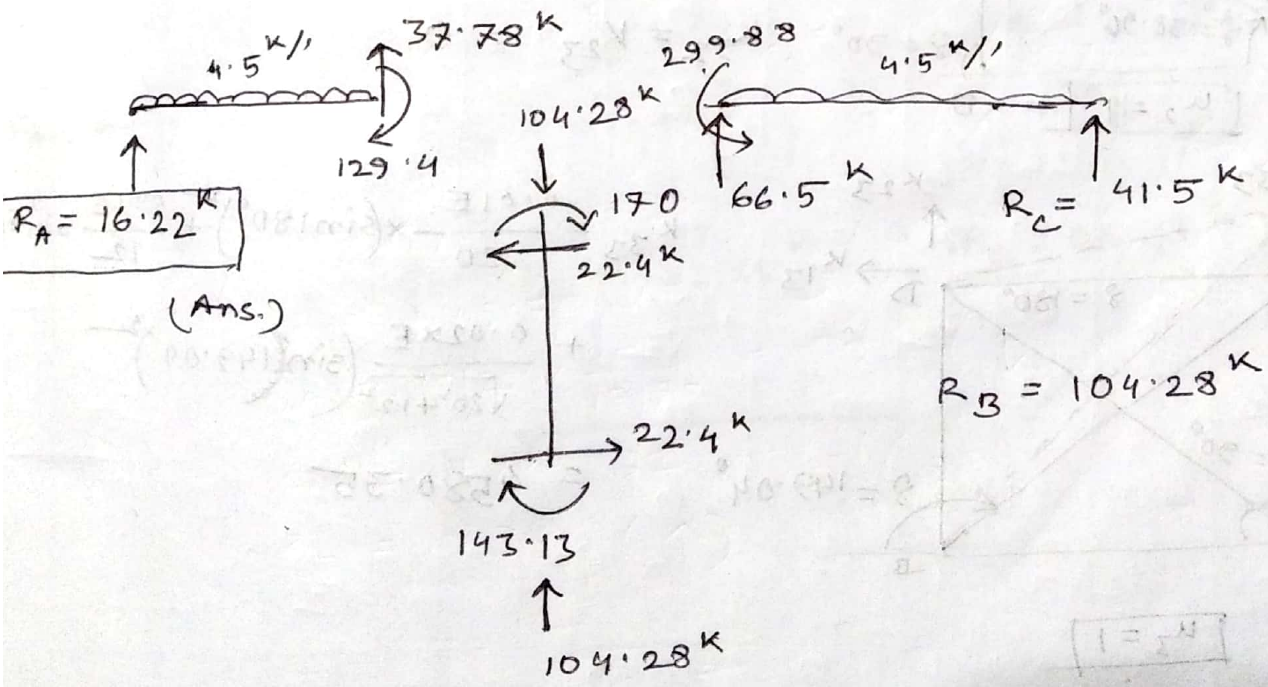
$FEM_{BA} = -173.4 + \left(\frac{11.2}{-9.68}\right) \times -38 = -129.4$ k-'

$FEM_{BD} = -170.45$ k-'

$FEM_{BC} = 299.88$ k-'

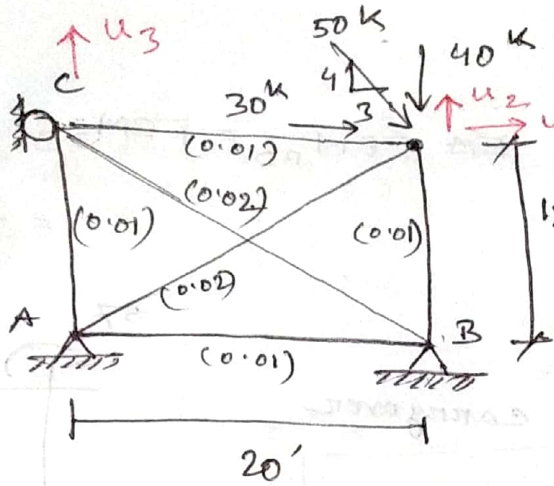
$FEM_{CB} = 0$

$FEM_{DB} = -143.13$ k-'



$R_B = 104.28^K$

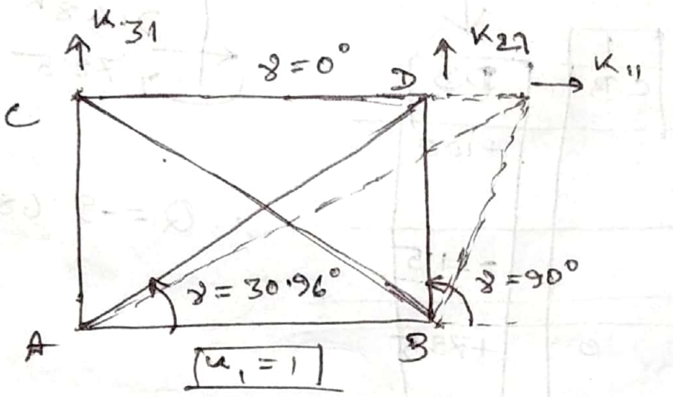
(b)



$E = 432 \times 10^4 \ k/ft^2$

$= 4.32 \times 10^6$

DOF $= 4 \times 2 - 5 = 3$



$$K_{11} = \frac{0.01 \times E}{20} \cos^2 0^\circ + \frac{0.01 \times E}{12} \cos^2 9$$

$$+ \frac{0.02 \times E}{\sqrt{20^2+12^2}} \cos^2 30.96^\circ$$

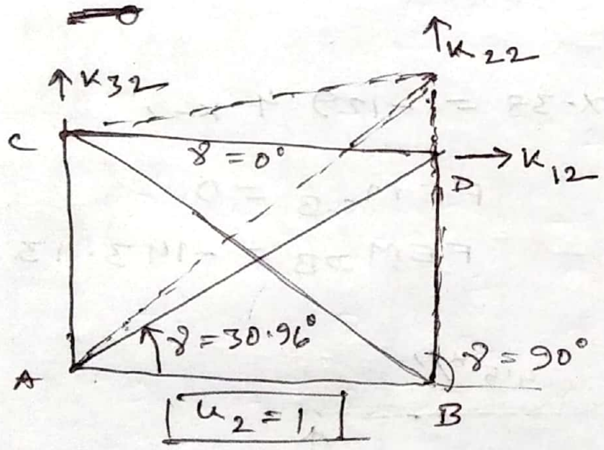
$$\simeq 4884.02$$

$$K_{12} = K_{21} = \frac{0.01 E}{20} \cos 0^\circ \sin 0^\circ +$$

$$\frac{0.01 E}{12} \cos 90^\circ \sin 90^\circ + \frac{0.02 \times E}{\sqrt{20^2+12^2}} \cos 30 \ \sin 30.9$$

$$= 1634.17$$

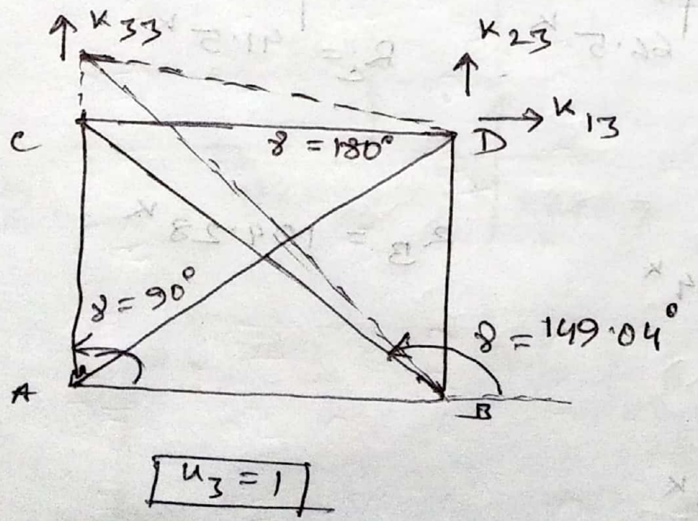
$K_{13} = K_{31} = 0$



$$K_{22} = \frac{0.01 \times E}{12} \times (\sin 90^\circ)^2 + \frac{0.02 \times E}{\sqrt{20^2+12^2}} \sin(30.96^\circ)^2$$

$$= 4580.35$$

$K_{32} = K_{23} = 0$



$$K_{33} = \frac{0.01 E}{20} \times (\sin 180^\circ)^2 + \frac{0.01 E}{12} \sin$$

$$+ \frac{0.02 \times E}{\sqrt{20^2+12^2}} (\sin 149.04)^2$$

$$\simeq 4580.35$$

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$$\begin{bmatrix} 30 \\ -40 \\ 0 \end{bmatrix} = \begin{bmatrix} 4884.02 & 1634.17 & 0 \\ 1634.17 & 4580.35 & 0 \\ 0 & 0 & 4580.35 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix} = \begin{bmatrix} 0.0103 \\ -0.0124 \\ 0 \end{bmatrix}$$

Bar Forces:

$$F_{CD} = \frac{0.01 \times 4.32 \times 10^6}{20} \times \left[0.0103 \times \cos 0^\circ + (-0.0124)\sin 0^\circ\right]$$

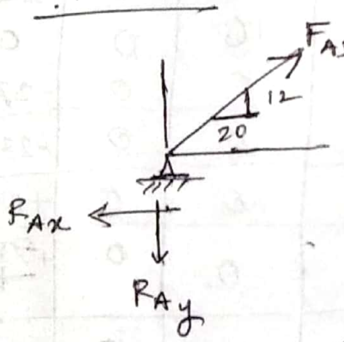
$$= +22.25^K \quad \text{(Tension)}$$

$$F_{BD} = \frac{0.01 \times 4.32 \times 10^6}{12} \times \left[0.0103 \cos 90^\circ + (-0.0124)\sin 90^\circ\right] = -44.64^K \text{ (compression)}$$

$$F_{AD} = \frac{0.02 \times 4.32 \times 10^6}{\sqrt{20^2+12^2}} \times \left[0.0103 \cos 30.96^\circ + (-0.0124)\sin 30.96^\circ\right] = 9.1^K \text{ (Tension)}$$

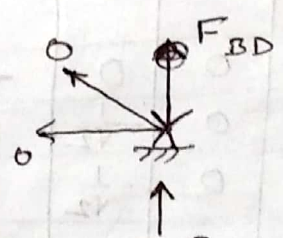
$F_{AB} = 0$, $F_{AC} = 0$, $F_{BC} = 0$

Reactions:



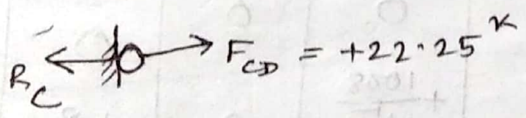
$R_{Ax} = 7.8^K (\leftarrow)$

$R_{Ay} = 4.68^K (\downarrow)$



$R_{Bx} = 0^K$

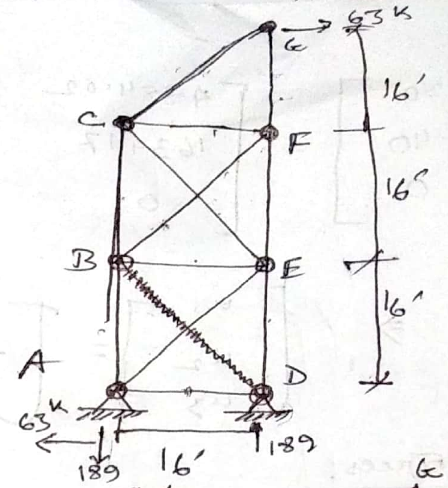
$R_{By} = 44.64^K (\uparrow)$

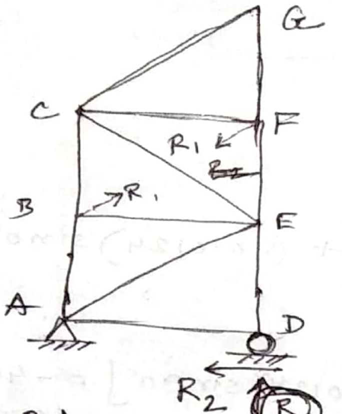


$\therefore R_C = 22.25^K (\leftarrow)$

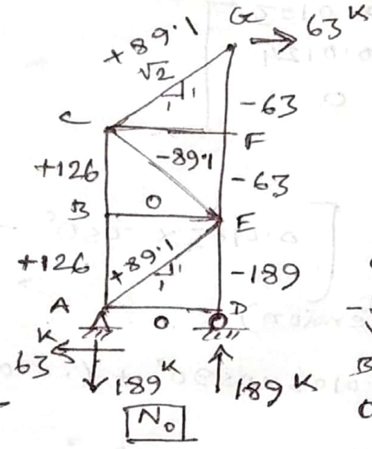
5. (a)

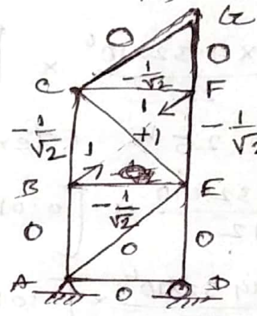
$$\text{DosI} = b + r - 2j$$
$$= 12 + 4 - 2 \times 7$$
$$= 2^{\circ}$$

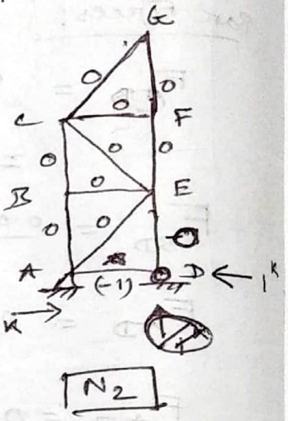




Release structure







$$\boxed{N = N_0 + N_1 R_1 + N_2 R_2}$$

Bar	L	N_0	N_1	N_2	$N_0 N_1 L$	$N_0 N_2 L$	$N_1 N_1 L$	$N_2 N_2 L$	$N_1 N_2 L$	N
AD	16	0	0	-1	0	0	0	16	0	0
BE	16	0	$-\frac{1}{\sqrt{2}}$	0	0	0	+8	0	0	-27
CF	16	0	$-\frac{1}{\sqrt{2}}$	0	0	0	+8	0	0	-27
AB	16	126	0	0	0	0	0	0	0	+12
BC	16	126	$-\frac{1}{\sqrt{2}}$	0	$-\frac{2016}{\sqrt{2}}$	0	+8	0	0	+98
DE	16	-189	0	0	0	0	0	0	0	-1
EF	16	-63	$-\frac{1}{\sqrt{2}}$	0	$+\frac{1008}{\sqrt{2}}$	0	+8	0	0	-90
FG	16	-63	0	0	0	0	0	0	0	-63
AE	$16\sqrt{2}$	89.1	0	0	0	0	0	0	0	+89
BF	$16\sqrt{2}$	0	1	0	0	0	$+16\sqrt{2}$	0	0	39.
CE	$16\sqrt{2}$	-89.1	1	0	$-1429\sqrt{2}$	0	$+16\sqrt{2}$	0	0	-49
CG	$16\sqrt{2}$	89.1	0	0	0	0	0	0	0	+8
Σ					- [illegible]	0	+69.255	16	0	

$$\Delta_{01} = \sum \frac{N_0 N_1 L}{AE} = -\frac{2726.60}{AE} \qquad \delta_{11} = \sum \frac{N_1 N_1 L}{AE} = \frac{69.255}{AE}$$

$$\Delta_{02} = \sum \frac{N_0 N_2 L}{AE} = 0 \qquad \delta_{12} = \delta_{21} = \sum \frac{N_1 N_2 L}{AE} = 0$$

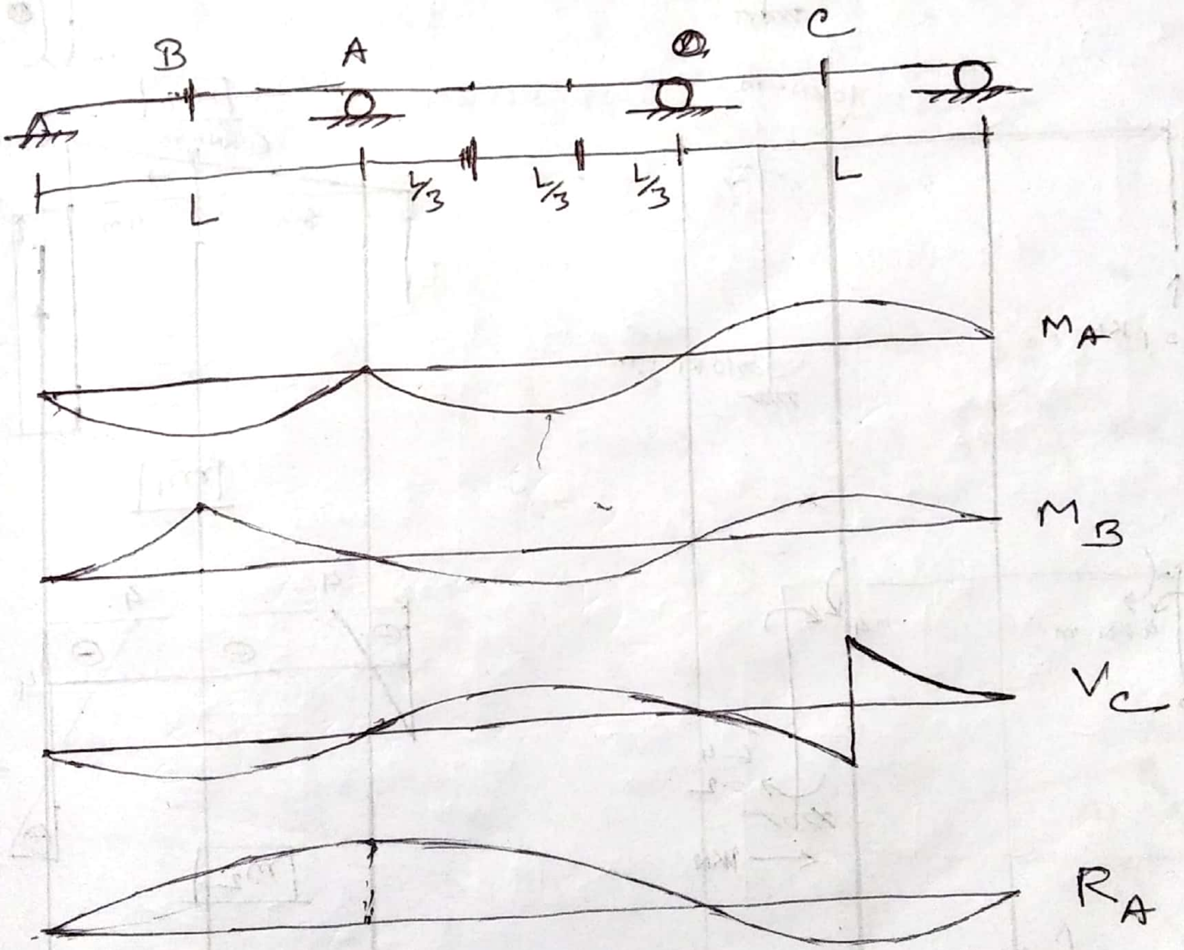
$$\delta_{22} = \sum \frac{N_2 N_2 L}{AE} = \frac{16}{AE}$$

$$\begin{Bmatrix} -2726.60 \\ 0 \end{Bmatrix} \frac{1}{AE} + \begin{bmatrix} 69.255 & 0 \\ 0 & 16 \end{bmatrix} \frac{1}{AE} \begin{Bmatrix} R_1 \\ R_2 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix}$$

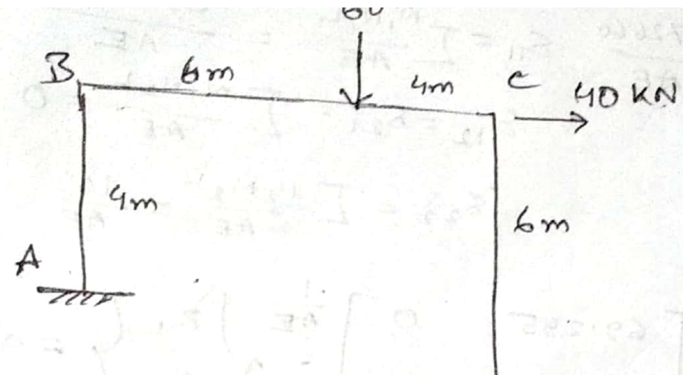
$$\Rightarrow \begin{Bmatrix} R_1 \\ R_2 \end{Bmatrix} = \begin{Bmatrix} 39.37 \\ 0 \end{Bmatrix}$$

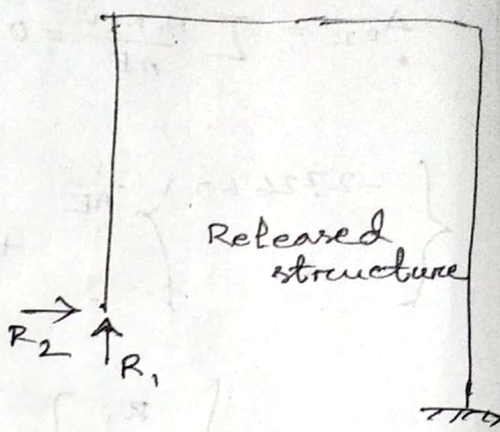
---

6. (a)

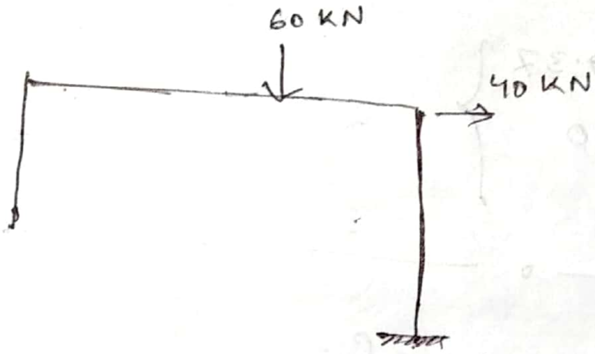


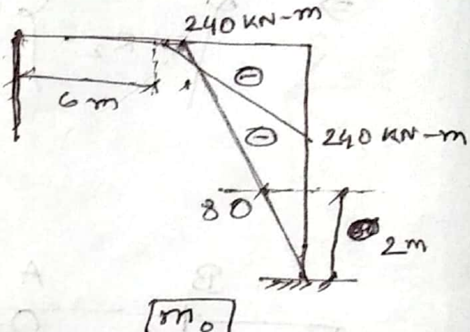
(b)

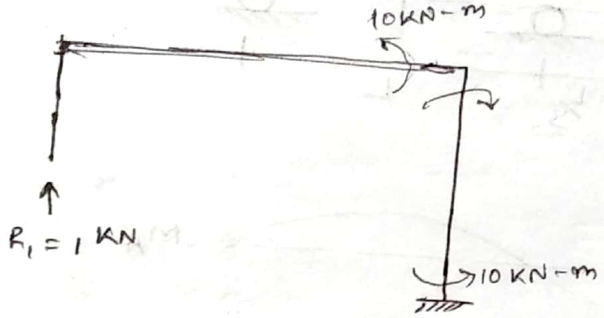


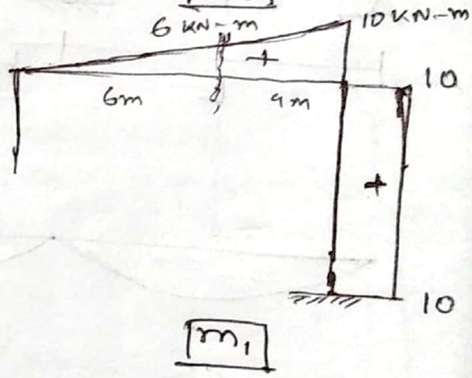


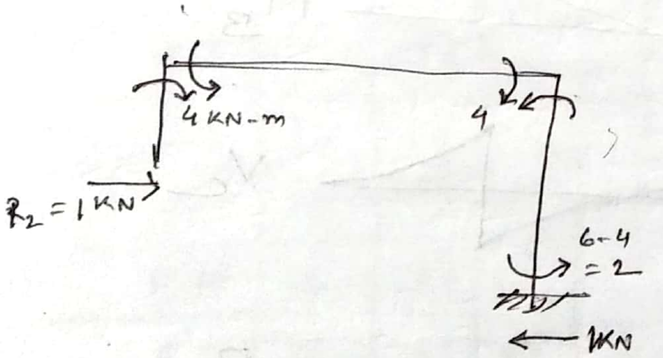
$DOSI = 5 - 3 = 2^{\circ}$

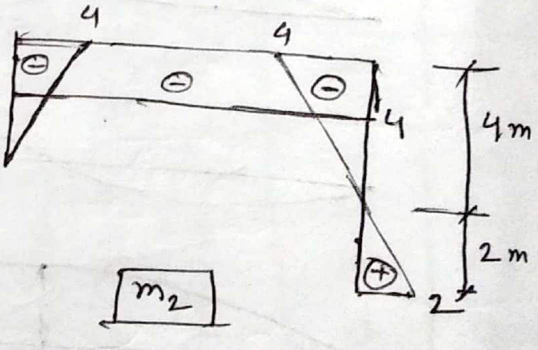












$$\Delta_{01} = \int \frac{m_0 m_1}{EI} dx = \frac{1}{EI} \times \frac{1}{6} \times (-240) \times [\cancel{2\times} 6 + 2\times 10] \times 4 + \frac{1}{EI} \times \frac{1}{2} \times (-240) \times 10 \times 6$$

$$= -\frac{11360}{EI}$$

$$\Delta_{02} = \int \frac{m_0 m_2}{EI} = \frac{1}{EI} \times \frac{1}{2} \times (-240) \times (-4) \times 4 + \frac{1}{EI} \times \frac{1}{6} \times (-4) \times \left[-2\times 240 - 80 \right] \times 4 + \frac{1}{6EI} \times (-80) \times 2 \times 2$$

$$= \frac{3360}{EI}$$

$$\delta_{11} = \int \frac{m_1 m_1}{EI} = \frac{1}{3EI} \times 10 \times 10 \times 10 + \frac{1}{EI} \times 10 \times 10 \times 6 = \frac{2800}{3EI}$$

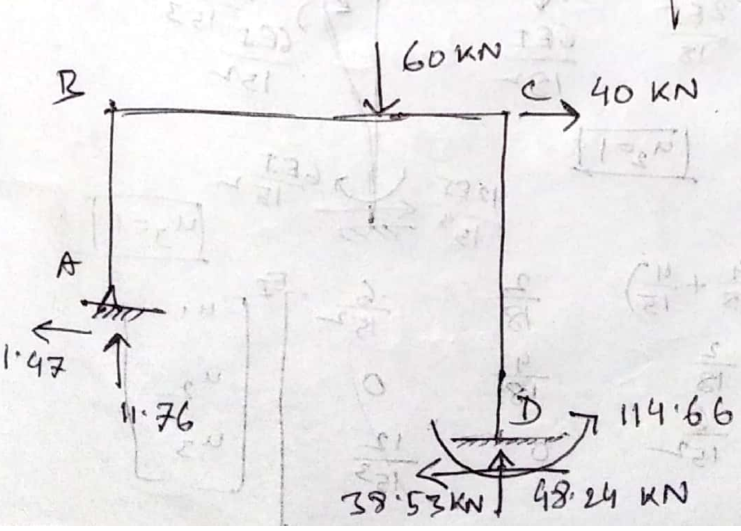
$$\delta_{12} = \delta_{21} = \int \frac{m_1 m_2}{EI} = \frac{1}{2EI} \times (-4) \times 10 \times 10 + \frac{1}{2EI} \times 10 \times (-4) \times 4 + \frac{1}{2EI} \times 2 \times 10 \times 2 = -\frac{260}{EI}$$

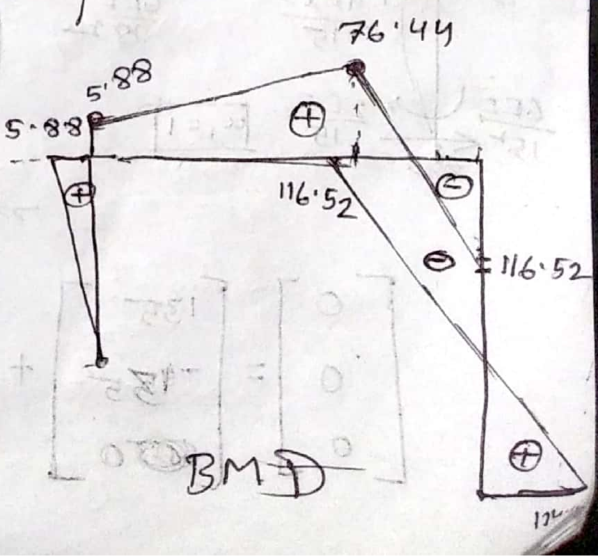
$$\delta_{22} = \int \frac{m_2 m_2}{EI} = \frac{1}{3EI} \times (-4) \times (-4) \times 4 + \frac{1}{EI} \times (-4) \times (-4) \times 10 + \frac{1}{3EI} \times (-4) \times (-4) \times 4 + \frac{1}{3EI} \times 2 \times 2 \times 2$$

$$= \frac{616}{3EI}$$

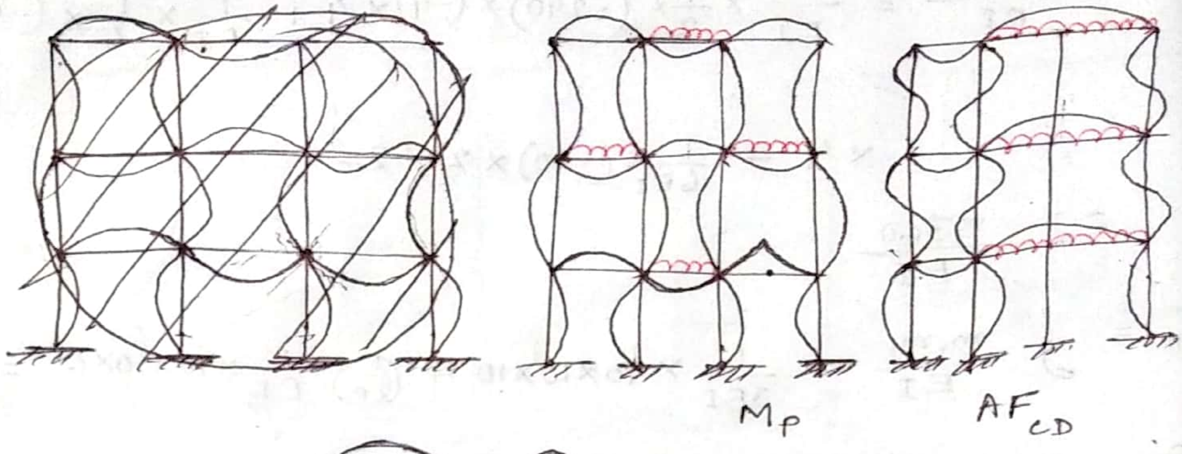
$$\begin{Bmatrix} -11360 \\ 3360 \end{Bmatrix} \frac{1}{EI} + \begin{bmatrix} \frac{2800}{3} & -260 \\ -260 & \frac{616}{3} \end{bmatrix} \frac{1}{EI} \begin{Bmatrix} R_1 \\ R_2 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix}$$

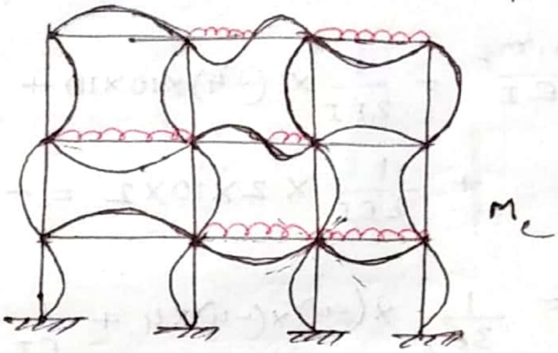
$$\Rightarrow \begin{Bmatrix} R_1 \\ R_2 \end{Bmatrix} = \begin{Bmatrix} 11.76 \\ -1.47 \end{Bmatrix}$$



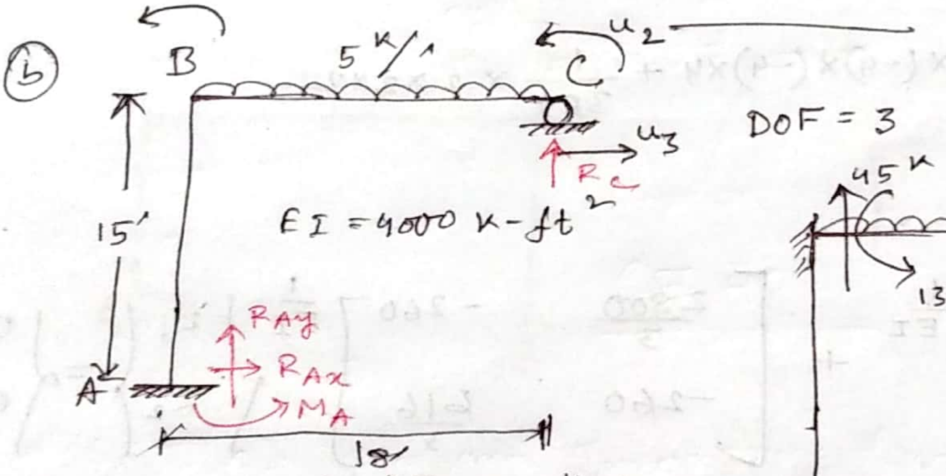


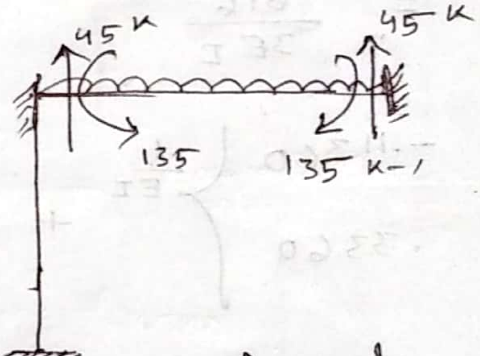
7. (a)

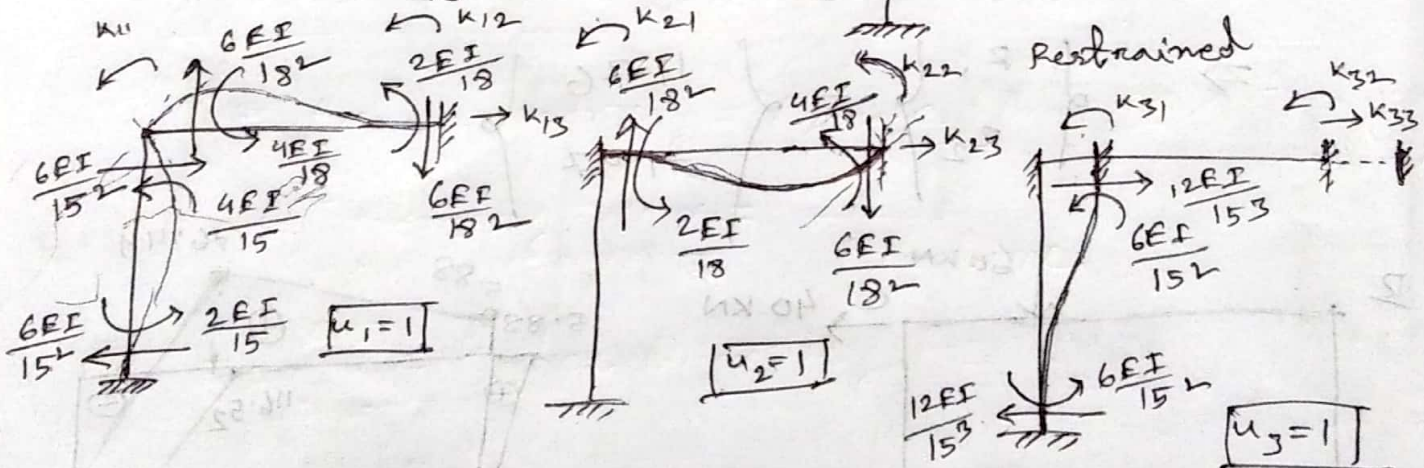




(b)







$$\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 135 \\ -135 \\ 0 \end{bmatrix} + \begin{bmatrix} \left(\frac{4}{18} + \frac{4}{15}\right) & \frac{2}{18} & \frac{6}{15^2} \\ \frac{2}{18} & \frac{4}{18} & 0 \\ \frac{6}{15^2} & 0 & \frac{12}{15^3} \end{bmatrix} EI \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix} = \begin{bmatrix} -867.86 \\ 1041.43 \\ 6508.93 \end{bmatrix} \frac{1}{EI}$$

$\therefore$ The amount of sway, $u_3 = \dfrac{6508.93}{4000} = \boxed{1.63'}$ (Ans.)

Now,

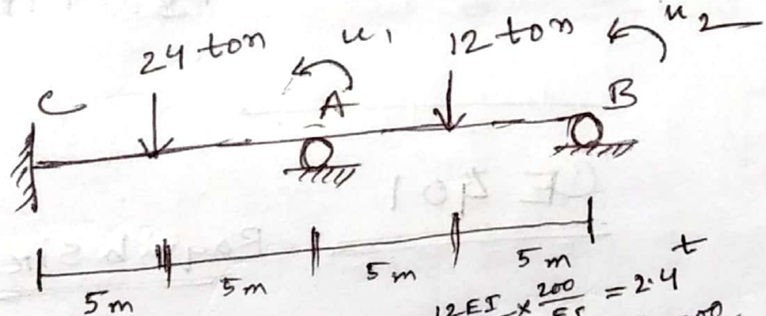
$$\begin{bmatrix} R_{Ax} \\ R_{Ay} \\ M_A \\ R_C \end{bmatrix} = \begin{bmatrix} 0 \\ 45 \\ 0 \\ 45 \end{bmatrix} + \begin{bmatrix} -\frac{6}{15^2} & 0 & -\frac{12}{15^3} \\ \frac{6}{18^2} & \frac{6}{18^2} & 0 \\ \frac{2}{15} & 0 & \frac{6}{15^2} \\ -\frac{6}{18^2} & -\frac{6}{18^2} & 0 \end{bmatrix} EI \begin{bmatrix} -867.86 \\ 1041.43 \\ 6508.93 \end{bmatrix} \frac{1}{EI}$$

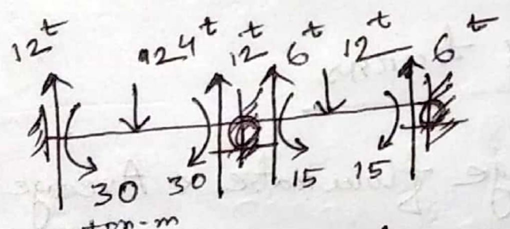
$R_{Ax} = 0$ $\qquad M_A = 57.86$ k-ft

$R_{Ay} = 48.21^k (\uparrow)$ $\qquad R_C = 41.79^k (\uparrow)$

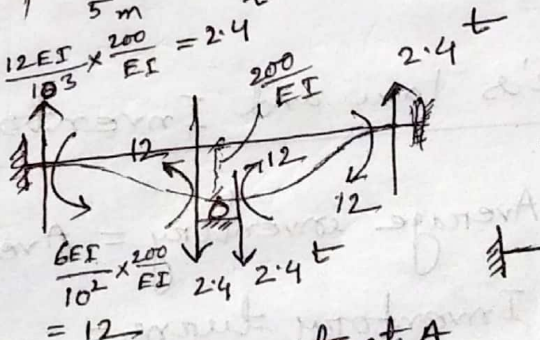
~~$M_A =$~~

8. (a)

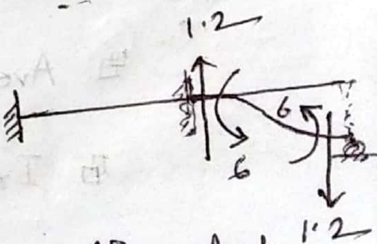




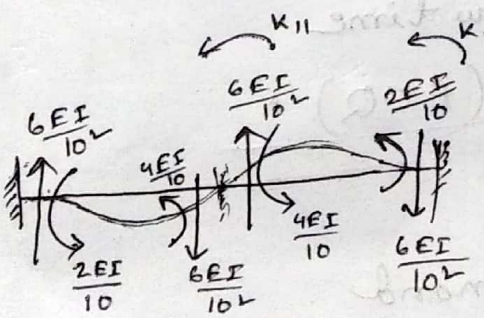
Restrained



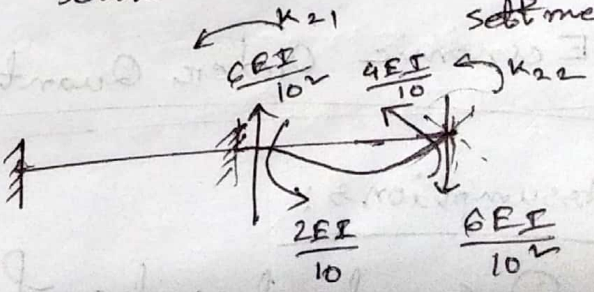
settlement at A



settlement at B



$\boxed{u_1 = 1}$



$\boxed{u_2 = 1}$

$$\begin{bmatrix} 0 \\ 0 \end{bmatrix} = \begin{bmatrix} -15 \\ -15 \end{bmatrix} + \begin{bmatrix} 0 \\ -12 \end{bmatrix} + \begin{bmatrix} 6 \\ 6 \end{bmatrix} + \begin{bmatrix} \frac{.4}{5} & \frac{2}{10} \\ \frac{2}{10} & \frac{4}{10} \end{bmatrix} EI \begin{bmatrix} u_1 \\ u_2 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} = \begin{bmatrix} -\frac{15}{7} \\ \frac{375}{7} \end{bmatrix} \frac{1}{EI}$$

Now,

$$\begin{bmatrix} R_{cy} \\ M_c \\ R_A \\ R_B \end{bmatrix} = \begin{bmatrix} 12 \\ 30 \\ 18 \\ 6 \end{bmatrix} + \begin{bmatrix} 2.4 \\ 12 \\ -4.8 \\ 2.4 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1.2 \\ -1.2 \end{bmatrix} + \begin{bmatrix} \frac{6}{10^2} & 0 \\ \frac{2}{10} & 0 \\ 0 & \frac{6}{10^2} \\ -\frac{6}{10^2} & -\frac{6}{10^2} \end{bmatrix} EI \begin{bmatrix} -\frac{15}{7} \\ \frac{375}{7} \end{bmatrix} \frac{1}{EI}$$

$\therefore R_{cy} =$ ~~14.27 ton (↑)~~ 14.3 ton (↑)

$M_c = 41.57$ ton-m

$R_A = 17.6$ ton (↑)

$R_B = 4.1$ ton (↑)

CE 401

Raquib sir

* Little's law and Inventory turns:

  - Average inventory = Average flow rate × Average flow time
  - Inventory turns = $\frac{1}{\text{Flow time}}$

* Economic Order Quantity (EOQ) *

Assumptions:

(i) Constant rate of demand

(ii) Shortage not allowed