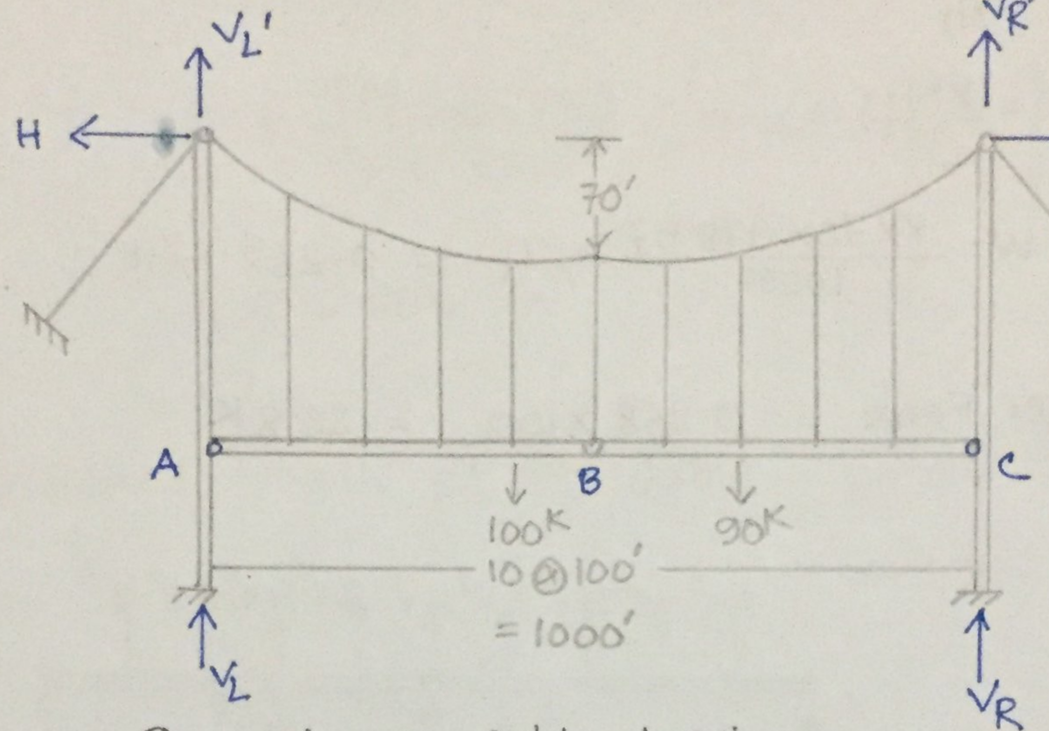
Assignment - 1



Determine: ① maximum cable tension

② Hanger force

③ Shear Force Diagram

④ Bending moment diagram

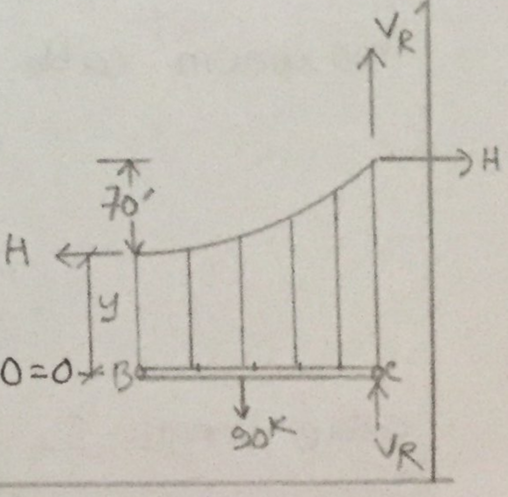
⑤ Unstressed Length of Cable.

Solution: $\circlearrowleft \sum M_A = 0$

$$100 \times 400 + 90 \times 700 - (V_R + V_R') \times 1000 = 0$$

$$V_R + V_R' = \frac{40000 + 63000}{1000}$$

$$\therefore V_R + V_R' = 103^K$$



$\overset{+}{\circlearrowleft} \sum M_B = 0$

$$-\cancel{Hy} + H(\cancel{y} + 70) - \overbrace{(V_R + V_R')}^{103} \times 500 + 90 \times 200 = 0$$

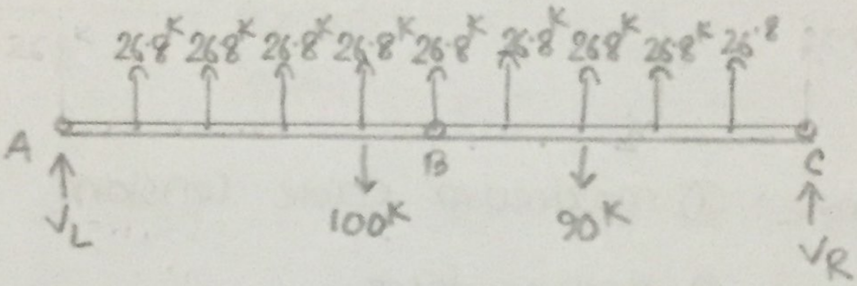
$\therefore H = 478.57^K$

$$H = \frac{wL^2}{8h}$$

$$w = \frac{8hH}{L^2}$$

$$\therefore w = \frac{8 \times 70 \times 478.57}{1000^2} \text{ K/ft} = 0.268 \text{ K/ft}$$

Hanger Force $= 0.268 \times 100 = 26.8^K$



$$\overset{+}{\circlearrowright} \Sigma M_A = 0$$

$$-26.8(100 + 200 + 300 + 400 + 500 + 600 + 700 + 800 + 900)$$
$$+ 100 \times 400 + 90 \times 700 = V_R \times 1000$$

$\therefore V_R = -17.6^K \quad \therefore V_R = 17.6^K (\downarrow)$

$\therefore V_L = 33.6^K (\downarrow)$

maximum cable tension, $T = H(1+16\theta^2)^{\frac{1}{2}}$

$$T = 478.57 \times \left(1 + 16 \cdot \frac{h^2}{L^2}\right)^{1/2} \quad [\gamma = 0]$$

$$\therefore T = 476.207^K$$

cable Length, $S = \frac{L}{2}(1+16\theta^2)^{1/2} + \frac{L}{8\theta} h\left(4\theta + (1+16\theta^2)^{\frac{1}{2}}\right) = 101292 \text{ ft.}$

cable stretch, $\Delta S = \frac{HL}{AE}\left[1+16Q^2/3\right]$

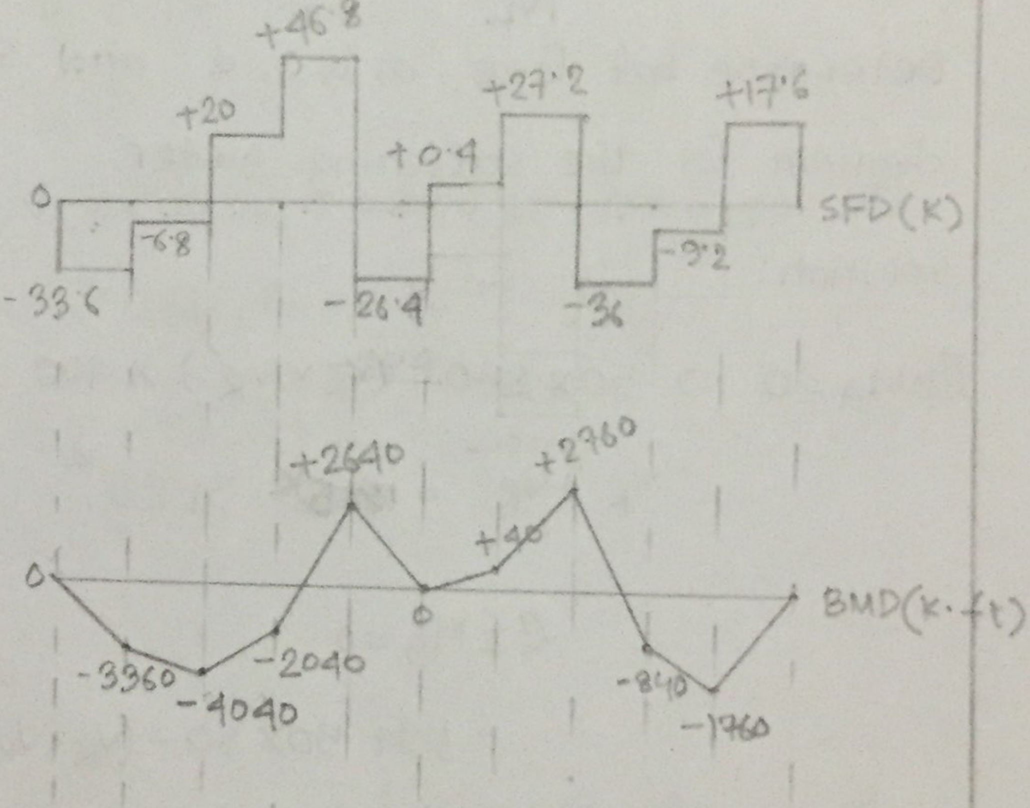
$$= \frac{478.57 \times 1000}{50 \times 27 \times 10^6}\left[1+16/3\left(\frac{70}{1000}\right)^2\right]$$

$$= 0.004 \text{ ft.}$$

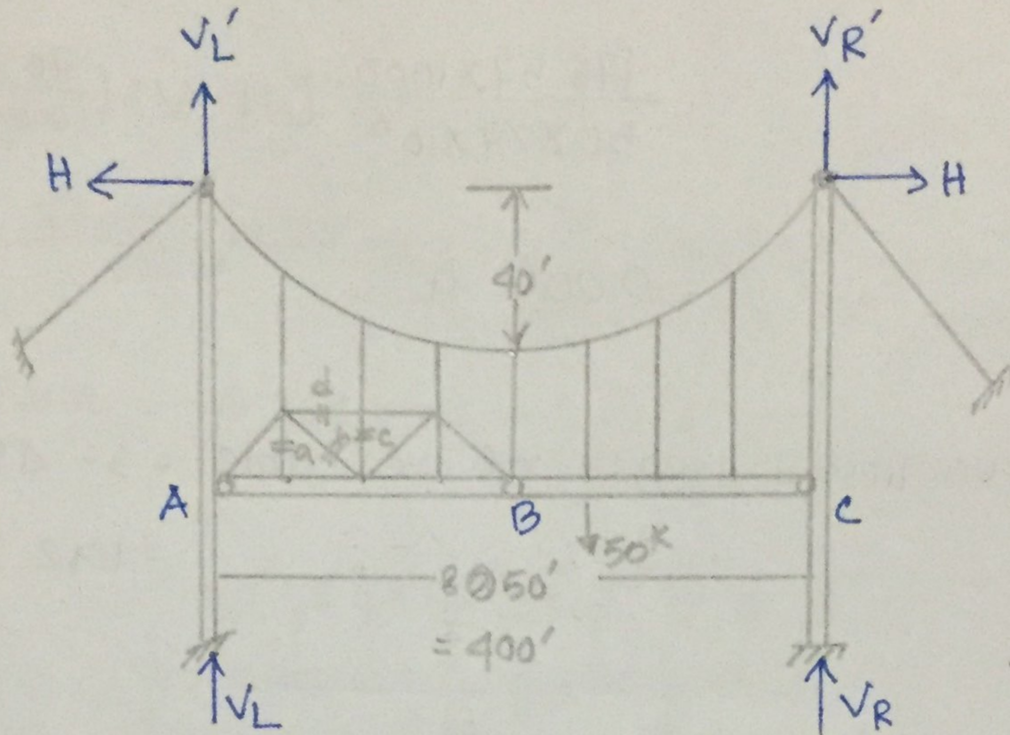
$\therefore$ unstressed length of the cable $= S - \Delta S$

$$= 1012.916 \text{ ft.}$$

Ans:



Assignment-2



Determine bar force a, b, c, d and SF and BM diagram for the stiffening girder.

Solution:

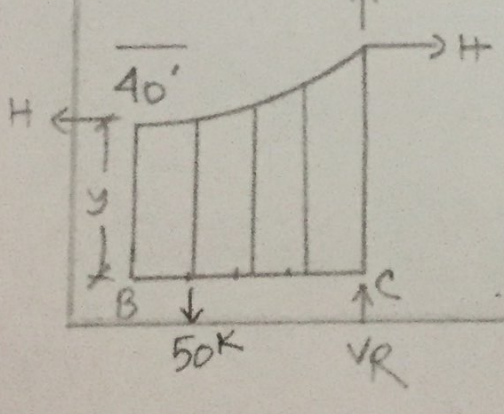
$\circlearrowright \Sigma M_A = 0 \Rightarrow 50 \times 250 - (V_R \times V_R') \times 400 = 0$

$\therefore V_R + V_R' = 31.25^K$

$\circlearrowright \Sigma M_B = 0$

$- \cancel{Hy} + 50 \times 50 \div (V_R + V_R') 200 +$

$H(\cancel{y} + 40) = 0.$



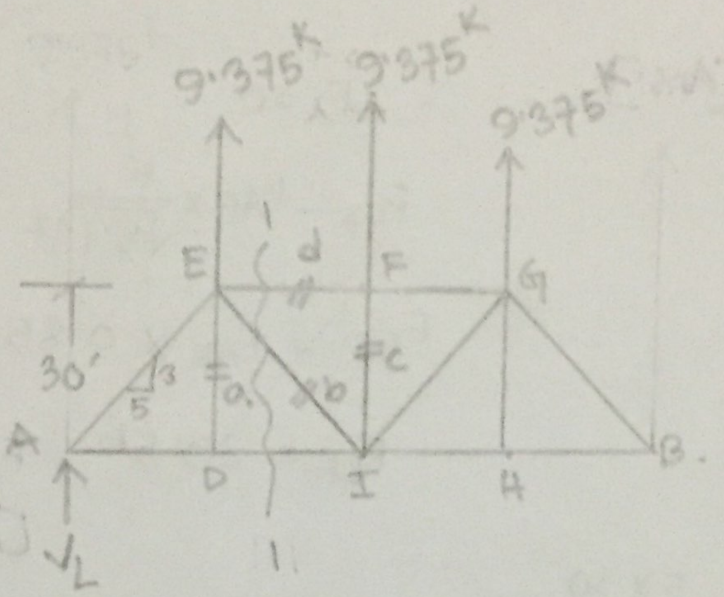
$H = 093.75^K$

$H = \dfrac{wL^2}{8h}.$

$\therefore w = 8 \times 40 \times 93.75 / 400^2 = 0.1875\ ^K/ft.$

$\therefore$ Hanger force $= 0.1875 \times 400/8 = 9.375^K$

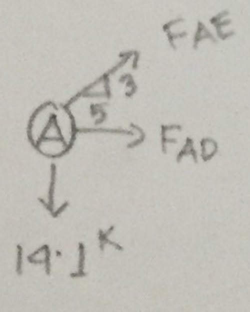
$T_{max} = H(1+16\theta^2)^{1/2} = 93.75(1+16 \times 0.1^2)^{1/2} = 101^K$



$\overset{+}{\circlearrowright}\Sigma M_B = 0 \Rightarrow V_L \times 200 + 9.375(50+100+150) = 0.$

$\therefore V_L = -14.1^K$

$\therefore V_L = 14.1^K (\downarrow)$



$\overset{\rightarrow +}{\Sigma F_x = 0}$

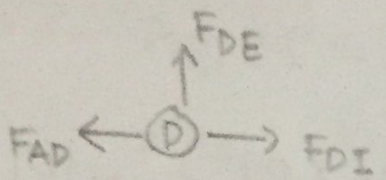
$F_{AD} \times \frac{5}{\sqrt{5^2+3^2}} \times F_{AE} = 0.$

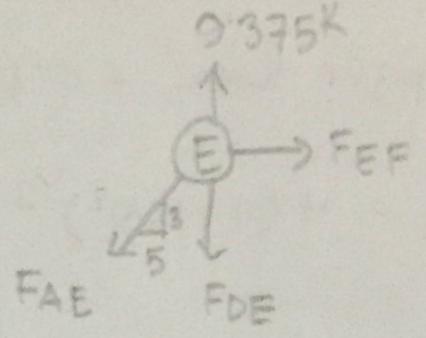
$F_{AD} = -F_{AE} \times 0.857$

$\overset{+}{\uparrow}\Sigma F_y = 0$

$-14.1 + F_{AE} \times \frac{3}{\sqrt{5^2+3^2}} = 0$

$F_{AE} = \frac{14.1}{0.51} = 27.4^K$





$\overset{+}{\uparrow} \Sigma F_y = 0$

$\therefore F_{DE} = F_a = 0$ [Ans:].

$\overset{+}{\rightarrow} \Sigma F_x = 0$

$F_{EF} - F_{AE} \times \dfrac{5}{\sqrt{5^2+3^2}} = 0$

$F_{EF} = F_{AE} \times 0.857$

$F_{EF} = 23.5^K = F_d\ (\rightarrow)$

[Ans:]

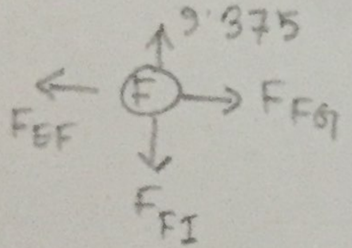
From section 1-1

$\overset{+}{\circlearrowright} \Sigma M_D = 0$

$F_{EF} \times 30 + F_{EI} \times \dfrac{5 \times 30}{\sqrt{5^2+3^2}} = 0$

$F_{EI} = -\dfrac{\sqrt{5^2+3^2}}{150} \times 30\ F_{EF}$

$F_{EI} = -27.4^K = F_b\ (\nwarrow)$ [Ans:]



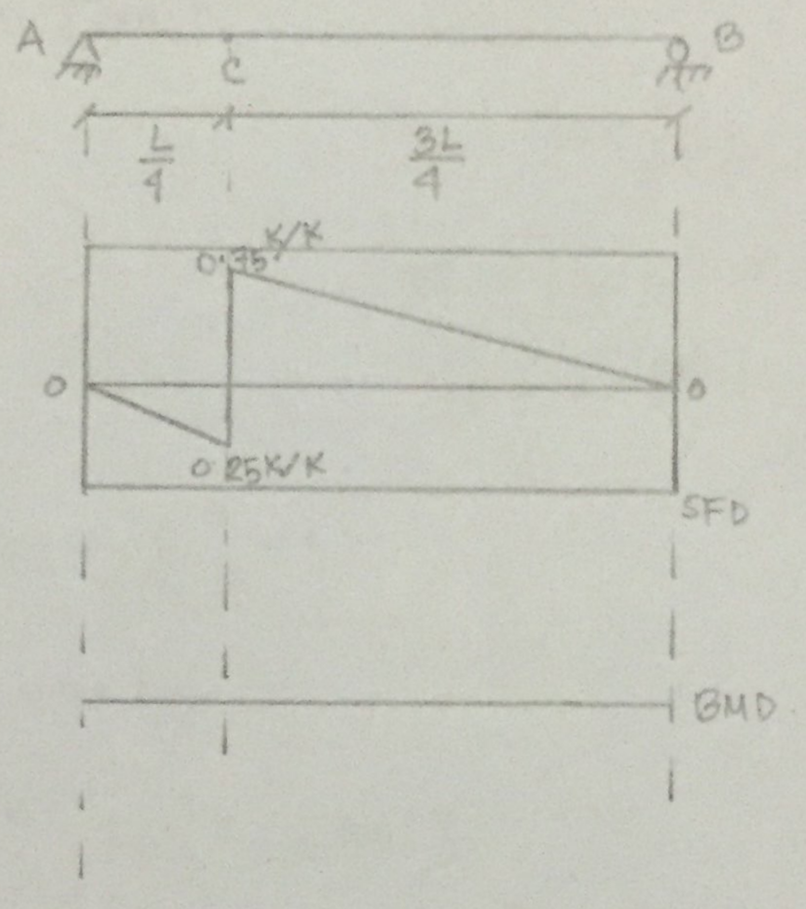
$\overset{+}{\uparrow} \Sigma F_y = 0$

$9.375 - F_{FI} = 0.$

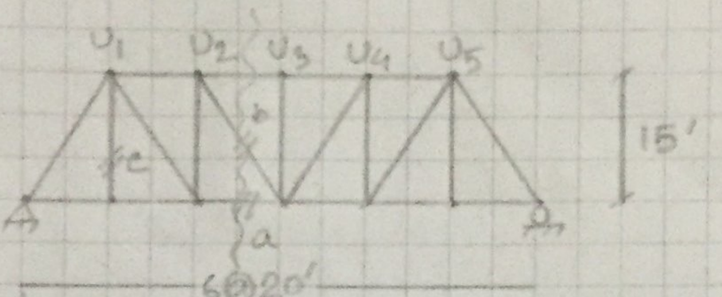
$\therefore F_{FI} = 9.375^K\ (\uparrow)$ [Ans:]

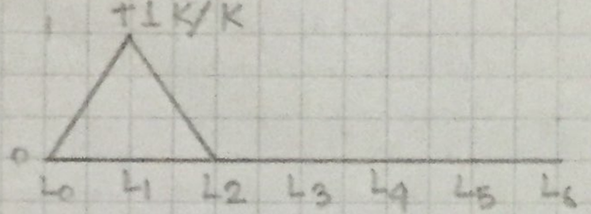
Assignment -3

Draw I.L for shear and Moment at C.



4 Assignment - 4



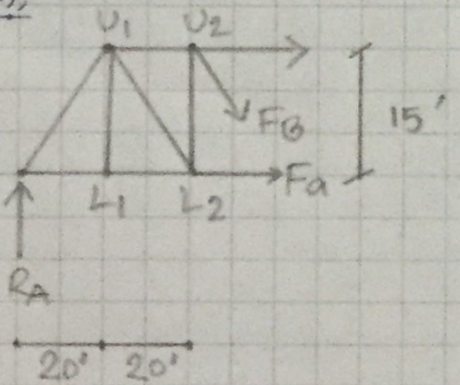


IL Diagram for bar c

For bar force (a),

case: 1

When 1^K load moves from L_0 to L_2



$\overset{+}{\circlearrowleft} \sum M_{u_2} = 0$

$R_A \times 40 - 1 \times x - F_a \times 15 = 0$

$\therefore F_a = \dfrac{40 R_a - x}{15}$

case 2: when 1^K load moves from L_2 to L_6

$\overset{+}{\circlearrowleft} \sum M_{u_2} = 0 \quad R_A \times 40 - F_a \times 15 = 0 \quad \therefore F_a = \dfrac{40 R_A}{15}$

For bar force (b).

case: 1

Load moves from L_0 to L_2

$\sum F_y = 0$

$R_A - 1 - \frac{3}{5} F_b = 0$

$\therefore F_b = \frac{5}{3}(R_A - 1)$

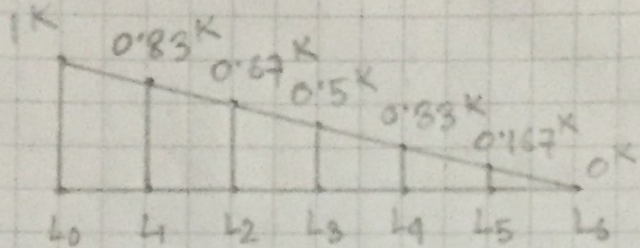
case: 2

Load moves from L_2-L_6

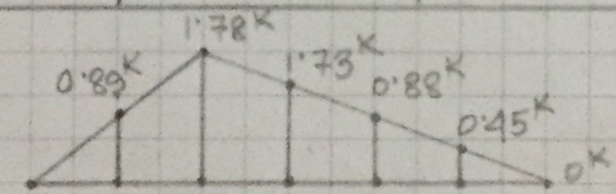
$\sum F_y = 0 \Rightarrow R_A - \frac{3}{5} R_b = 0$

$F_b = \frac{5}{3} R_A$

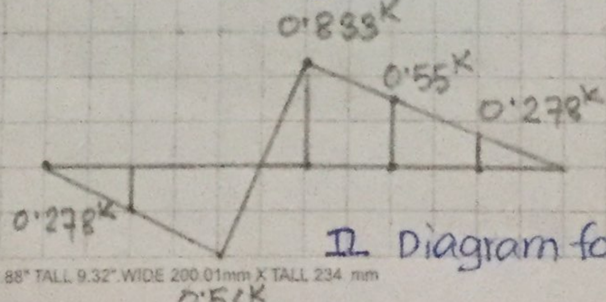
IL Diagram For R_A.



position of 1^K Load	bar force 'a'	bar force 'b'
L_0	$F_a = 0$	$F_b = 0$
L_1	$F_a = 0.89^K$	$F_b = -0.278^K$
L_2	$F_a = 1.78^K$	$F_b = -0.56^K$
L_3	$F_a = 1.73^K$	$F_b = 0.833^K$
L_4	$F_a = 0.88^K$	$F_b = 0.55^K$
L_5	$F_a = 0.45^K$	$F_b = 0.278^K$
L_6	$F_a = 0^K$	$F_b = 0$

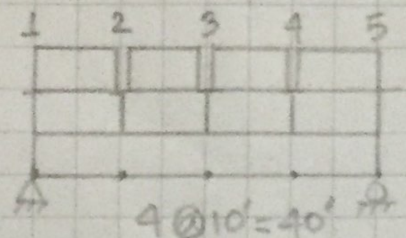


IL Diagram For bar force 'a'

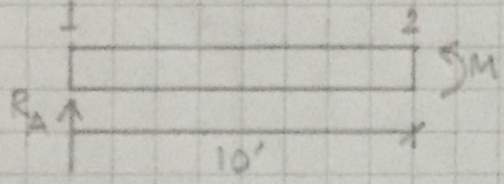


IL Diagram for bar force 'b'

Assignment -5



Draw IL Diagram for moment at panel point 2 of the girder.



<u>case 1:</u> when the Load moves from 1 to 2

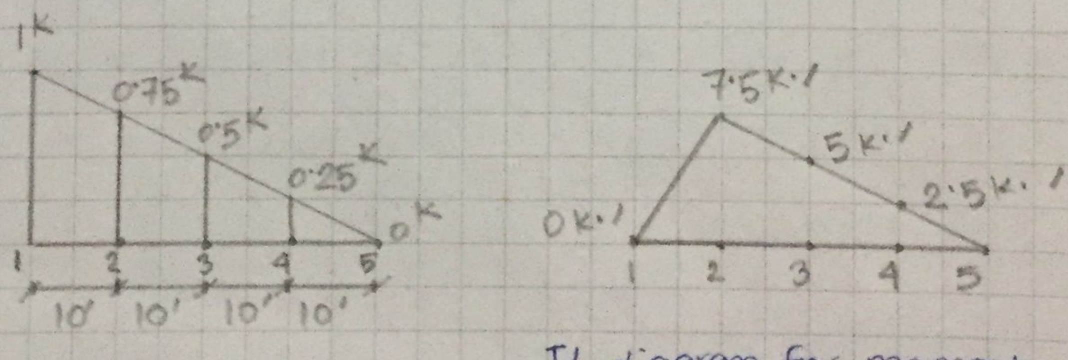
$$R_A \times 10 - 1 \times x = M$$

$$\therefore M = 10R_A - x$$

<u>case 2:</u> when the Load moves from 2 to 5.

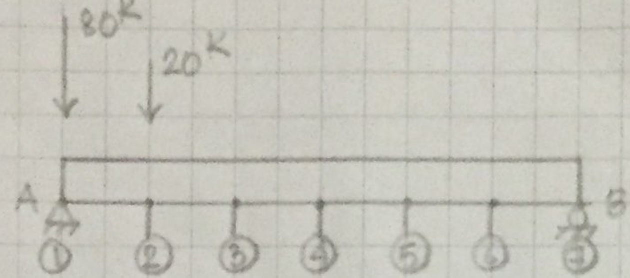
$$R_A \times 10 - M = 0$$

$$M = 10R_A$$

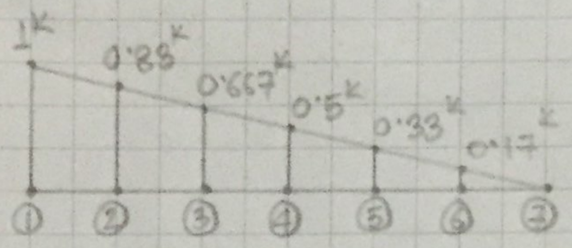


IL diagram for moment at panel point 2:

Assignment-6



What is the maximum reaction for moving truck?



Value of IL × Load = Reaction

1) When 80^K wheel at point 1 and 20^K wheel at point 2 [GOVERNS]

$R = 80 \times 1 + 20 \times 0.83 = 96.67^K$

2) when 80^K 〃 〃 〃 2 and 20^K 〃 〃 〃 3 $R = 79.98^K$

3) when 80^K 〃 〃 〃 3 and 20^K 〃 〃 〃 4 $R = 69.36^K$

4) when 80^K 〃 〃 〃 4 and 20^K 〃 〃 〃 5. $R = 46.6^K$

5) when 80^K 〃 〃 〃 5 and 20^K 〃 〃 〃 6 $R = 29.78^K$

6) when 80^K 〃 〃 〃 6 and 20^K 〃 〃 〃 7 $R = 13.34^K$

Zakaria Sir

CT-2

Moving Loads

1. Position of wheel to produce max^m reaction.

$$\Delta R = \frac{\Sigma Pd}{L} + \frac{P'e}{L} - P_1$$

ΣP = that stay on span before and after mov^m.

P' = wheel that comes on span e = dist^n of P'

P_1 = wheel that left the span

2. Position of wheel to produce max^x shear:-

$$\Delta V = \frac{\Sigma Pd}{L} + \frac{P'e}{L} + \frac{P_2 e_1}{L} - P_1$$

P' = wheel that comes on span. e = distance of P'

P_2 = wheel that left span. e_1 = distance of P_2

$P_1 = P_1$ = wheel that cross point C

3. Maximom moment at a section for a simple span:-

$$\frac{W_1}{a} = \frac{W}{L}$$

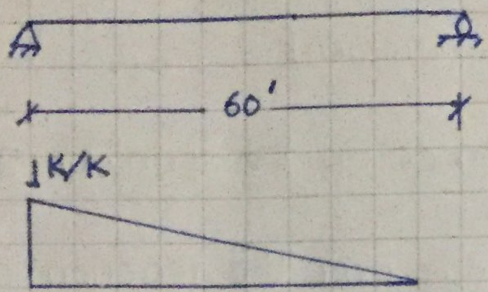
wheel placed at max^m moment (IL) point

Just right $\frac{W}{L} > \frac{W_1}{a}$

Just left $\frac{W}{L} < \frac{W_1}{a}$

is this criteria is satisfied

position of wheel to produce maximum reaction for a simply supported span



Observation:

cycle-1

1) Ra in bridges in creases till wheel 1 comes on A
2) Ra suddenly decreases as wheel 2 moves of the span

cycle-2

3) Ra in bridges again increases till wheel 2 comes on A
4) Ra suddenly decreases as wheel 2 moves from the span

5) .... (Repeated)

6) .... (Repeated)

change in reaction 'ΔR' for distance 'd' travelled :

$$\Delta R = \frac{\Sigma P d}{L} + \frac{P' e}{L} - P_1$$

where, ΣP = Sum of wheels that stay on the span before and after the movement

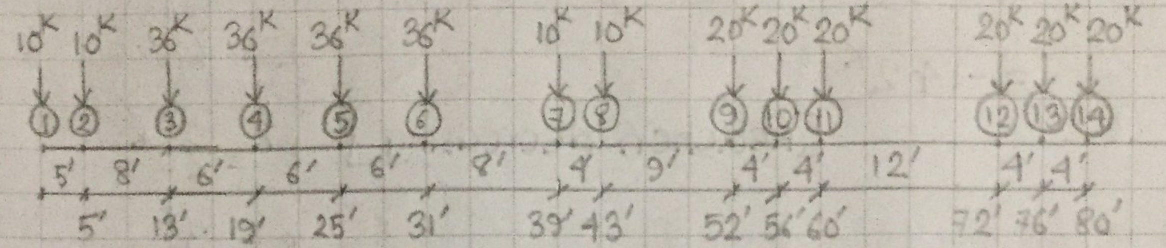
P' = wheel that comes on the span during movem.

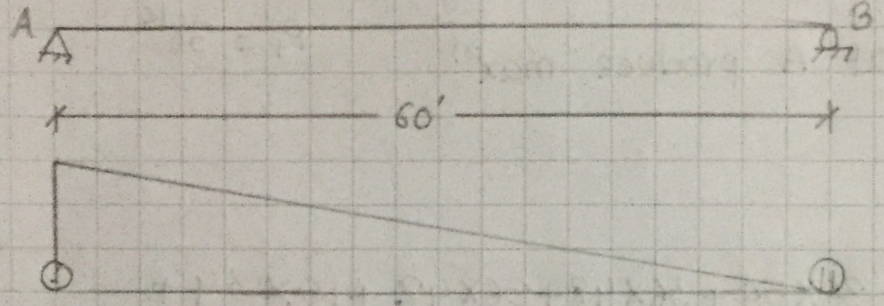
P_1 = the wheel which was over the reaction and is moved of the span.

e = distance travelled by P' on the span.

Problem:

Find maximum reaction for a simple span of 60′ for given wheel Load





Trial 1: Move wheel 2 at A

$$\Delta R = \frac{\Sigma Pd}{L} + \frac{P_1 e}{L} - P_1$$

$$= \frac{234^K \times 5'}{60'} + \frac{0 \times 0}{60'} - 10^K$$

$$= +9.5^K \text{ [Reaction Increasing]}$$

Here,

$\Sigma P =$ 2 − 11 $= 234^K$

$d = 5'$

$P' = 0$ $\quad P_1 =$ 1 $=$

Trial 2: move wheel 3 to A

$$\Delta R = \frac{\Sigma Pd}{L} + \frac{P'e}{L} - P_1$$

$$= \frac{224^K \times 8'}{60'} + \frac{20^K \times 1'}{60'} - 10^K$$

$$= +20.2^K \text{ [Reaction Increasing]}$$

Here,

$\Sigma P =$ 3 − 11 $= 224^K$

bcoz 12 before was not on span.

Trial 3: Move wheel 4 to A

$$\Delta R = \frac{\Sigma Pd}{L} + \frac{P'e}{L} - P_1$$

$$= \frac{208' \times 6'}{60'} + \frac{20^K \times 3'}{60'} - 36^K$$

$$= -14.2^K$$

[Reaction decreasing]

Here. [∵ 13 নতুন আসছে]

ΣP = 4 − 12 = 208^K

$d = 6'$

$L = 60'$

$P' = 20^K$

$e = 3'$

$P_1 = 36^K$

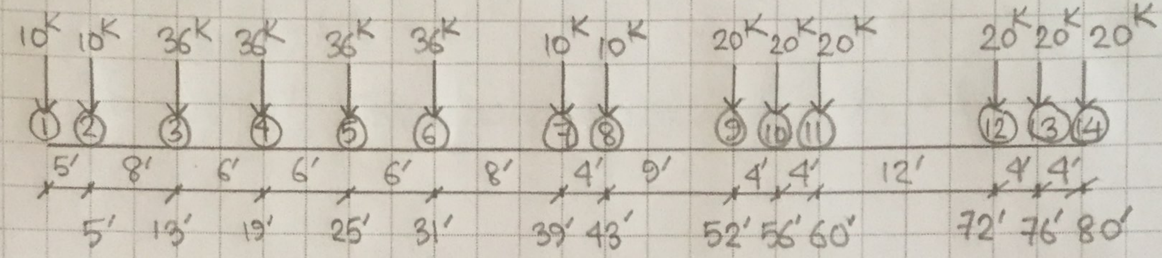
Hence, wheel 3 at A produce max^m Reaction.

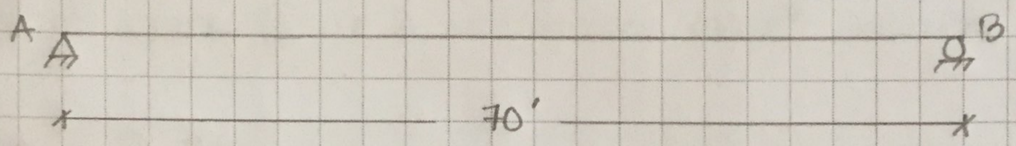
$$R_A = \frac{1}{60}[36\times60 + 36\times54 + 36\times48 + 36\times42 + 10\times34 + 10\times30 + 20\times21 + 20\times17 + 20\times13 + 20\times1)$$

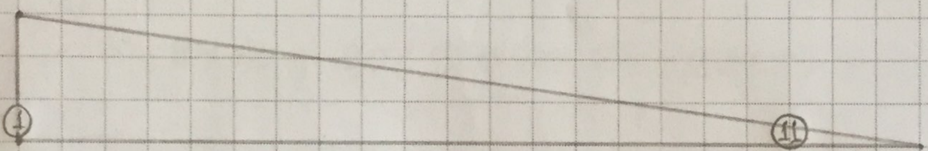
$\therefore R_A = 150.4^K$ (maximum Reaction)

Assignment 7

Find maximom reaction for a simple span of 70' for given wheel Load







Trial 1: Move wheel ② to A

$$\Delta R = \frac{\Sigma P \cdot d}{L} + \frac{P'e}{L} - P_1$$

$$= \frac{234 \times 5}{70} + \frac{20 \times 03'}{70} - 10^K$$

$= \quad ^K$ [Reaction Increasing]

7.57

Here, ΣP = ② − ⑪ = 234^K

$d = 5'$ $P' = 20^K$ $e = 03'$

$L = 70'$ $P_1 = 10^K$

Trial 2: Move wheel ③ to A

$$\Delta R = \frac{\Sigma P d}{L} + \frac{P'e}{L} - P_1$$

$$= \frac{244 \times 8}{70} + \frac{3 \times 20 + 7 \times 20}{70} - 10$$

$= 20.74^K$ [Reaction Increasing]

Here, ΣP = ③ − ⑫ = 244^K

$d = 8'$ P' = ⑬ = 20^K

$e = 3'$ $L = 70'$ $P_1 = 10^K$

$e' = 7'$ P'' = ⑭ = 20^K

Trial 3: Move wheel ④ to A

$$\Delta R = \frac{\Sigma P.d}{L} + \frac{P'e}{L} - P_1$$

$$= \frac{248^K \times 6'}{70'} + 0 - 36^K$$

$$= -14.74^K$$ [Reaction Decreasing]

$\Sigma P =$ ④ $-$ ⑭ $= 248^K$

$d = 6'$ $P' = 0$

$P_1 = 36^K$

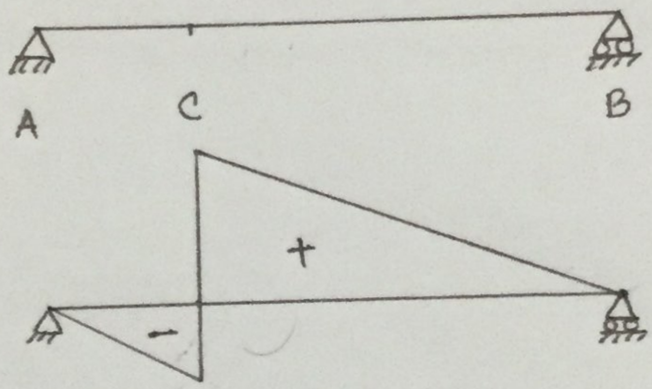
Hence wheel ③ at A will produce max^m reaction.

$$R_A = \frac{1}{70} \times [36 \times 70 + 36 \times 64 + 36 \times 58 + 36 \times 52 + 10 \times 44 + 10 \times 40 + 20 \times 31 + 20 \times 27 + 20 \times 23 + 20 \times 11 + 20 \times 7 + 20 \times 3]$$

$\therefore R_A = 166.62^K$ (max^m Reaction)

Position of wheel to produce max^m shear at a section of simple span (Article 62)

control point C



$$\Delta V = \frac{\Sigma Pd}{L} + \frac{P'e}{L} + \frac{P_2 e_1}{L} - P_1$$

where, ΣP = summation of wheel Loads that stay on the span before and after the movement

d = distance travelled

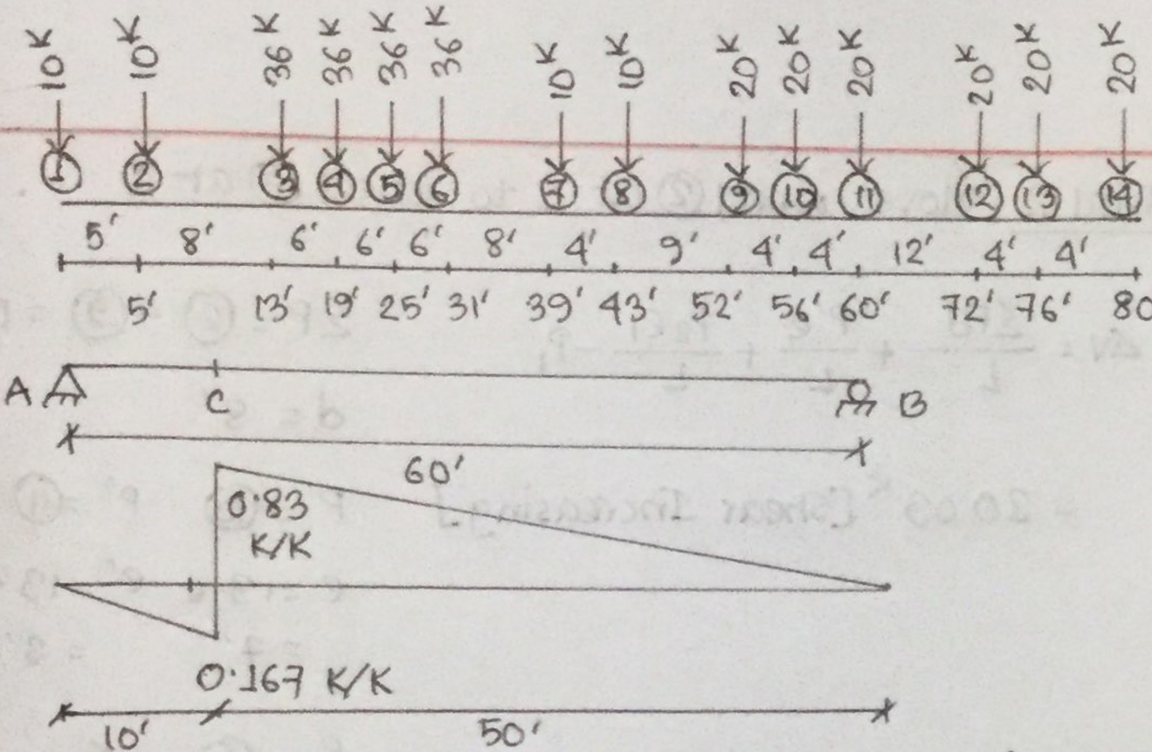
e = distance travelled by P' on the span.

P' = wheel that comes on during the movement

P_2 = wheel that move of the span

e_1 = distance travelled by P_2 before moving of the span

P_1 = wheel that cross point C



Find maximum shear at a distance 10' from the left support. Assume a span Length of 60'

Trial 1: Move wheel ① at C to wheel ② at C

$$\Delta V = \frac{\Sigma P d}{L} + \frac{P' e}{L} + \frac{P_2 e_1}{L} - P_1$$

Here, $\Sigma P =$ ① − ⑧ $= 184^K$ $\quad e =$

$d = 5'$

$P' =$ ⑨ $= 20^K$

$e = 3'$

$P_2 = 0$

$P_1 =$ ① $= 10^K$

$$\therefore \Delta V = \frac{184^K \times 5'}{60'} + \frac{20 \times 3}{60} + 0 - 10 = +6.33^K$$ [Shear Increasing]

Trial 2: Move wheel 2 at C to wheel 3 at C

$$\Delta V = \frac{\Sigma Pd}{L} + \frac{P'e}{L} + \frac{P_2 e_1}{L} - P_1$$

$= 20.03^K$ [Shear Increasing]

$\Sigma P = 2 - 9 = 194^K$

$d = 8'$

$P' = 10$ $P'' = 11$

$e = 13-6 = 7'$ $e' = 13-10 = 3'$

$P_2 = 1 = 10^K$

$e_1 =$ আছে আর 3 5'.

তারপর 8' so 5'

$P_1 =$ wheel 2 $= 10^K$

Trial 3: Move wheel 3 at C to wheel 4 at C

$$\Delta V = \frac{\Sigma Pd}{L} + \frac{P'e}{L} + \frac{P_2 e_1}{L} - P_1$$

$= -12.1^K$ [Shear Decreasing]

$\Sigma P = 3 - 11 = 224^K$

$d = 6'$ $P' = 0$

$P_2 = 2 = 10^K$

$e_1 = 9'$

$P_1 = 36^K$.

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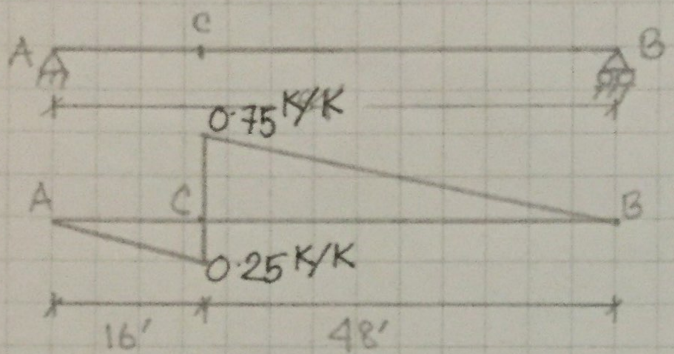
Assignment 8

Find maximum shear at quarter point of span. $L = 64'$

Loading is same as shown in preaous assignment.



Trial 1: Move wheel 1 at C to wheel 2 at C

$$\Delta V = \frac{\Sigma P d}{L} + \frac{P'e}{L} + \frac{P_2 e'}{L} - P_1$$

$$= \frac{184 \times 5}{64} + \frac{20 \times 1}{64} - 10$$

$= 4.6875^K$ [Rhear Increasing]

$\Sigma P =$ wheel 1 − wheel 8 $= 184^K$

$d = 5'$ $L = 64'$ $P' =$ wheel 9 $= 20^K$

$e = 1'$ $P_2 = 0$ $P_1 =$ wheel 1 $= 10^K$

Trial 2: Move wheel 2 at C to wheel 3 at C

$$\Delta V = \frac{\Sigma P d}{L} + \frac{P'e}{L} + \frac{P_1 e'}{L} - P_1$$

$$= \frac{204 \times 8}{64} + \frac{20 \times 5 + 20 \times 1}{64} - (10 \cancel{+10})$$

$= 17.375^K$ [Shear Increasing]

$\Sigma P =$ wheel 1 − wheel 9 $= 204^K$

$d = 8'$ $L = 64'$ $P' =$ 10 $= 20^K$ $e = 5$

$P'' =$ 11 $= 20^K$ $e'' = 1$

$P_2 = 0$

$P_1 =$ wheel ~~1 + 2~~ $= \cancel{20^K}$ 10^K

Trial 3: Move wheel 3 at C to wheel 4 at C

$$\Delta V = \frac{234 \times 6}{64} + \frac{0}{64} + \frac{10^K \times 3'}{64} - 36^K$$

$= -13.59^K$ [Shear Decreasing]

$\Sigma P =$ 2 − 11 $= 234^K$ $d = 6'$

$P' = 0$, $P_2 =$ 1 $= 10^K$ $e' = 3'$

$P_1 = 36^K$

Hence wheel 4 at C will Produce max^m shear.

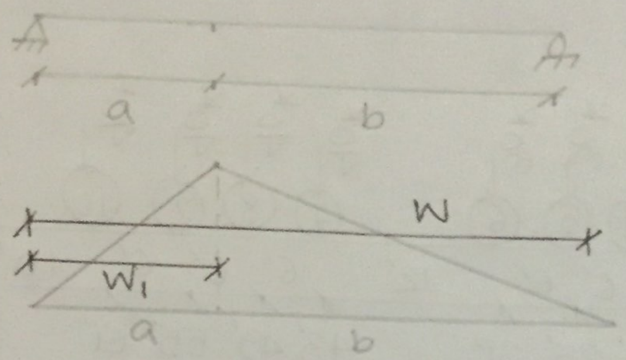
$$\therefore \text{Maximum shear} = \frac{3}{4} \times \frac{1}{48} (36 \times 48 + 36 \times 42 + 36 \times 36 + 36 \times 30 + 10 \times 22 + 10 \times 8 + 20 \times 9 + 20 \times 5 + 20 \times 1)$$

$$- \frac{0.25}{16} (10 \times 8 + 10 \times 3)$$

$$= 36.97^{K}$$

[Ans:]

Maximum moment at a section for a simple span beam



Required Criteria for maximum moment is given by.

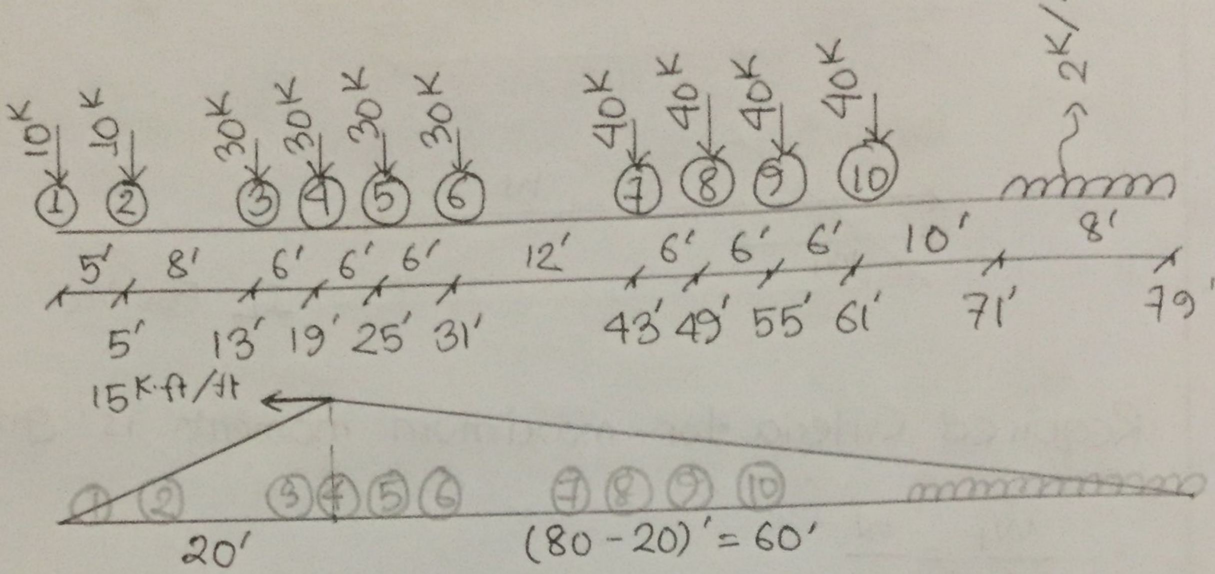
$$\frac{W_1}{a} = \frac{W}{L}$$

average load on Left of section = average load on span.

The wheel will be placed at C if,
- Just to the right $\frac{W}{L} > \frac{W_1}{a}$
- Just to the Left $\frac{W}{L} < \frac{W_1}{a}$.

this criteria is obtained.

Find maximum moment at quarter point of span Length 80'. Loading as following:



Hence wheel 4 at C produces maximum moment at quarter point of the 80' span.

Maximum moment at C =

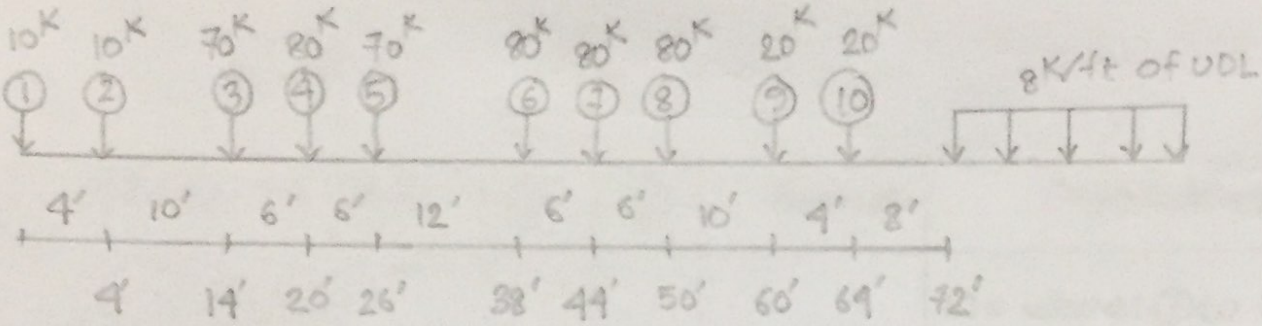
$$\frac{15}{20}[30 \times 14 + 10 \times 8 + 10 \times 1] +$$

$$\frac{15}{60}[30 \times 60 + 30 \times 54 + 30 \times 48 + 40 \times 36 + 40 \times 30 + 40 \times 24 + 40 \times 18] +$$

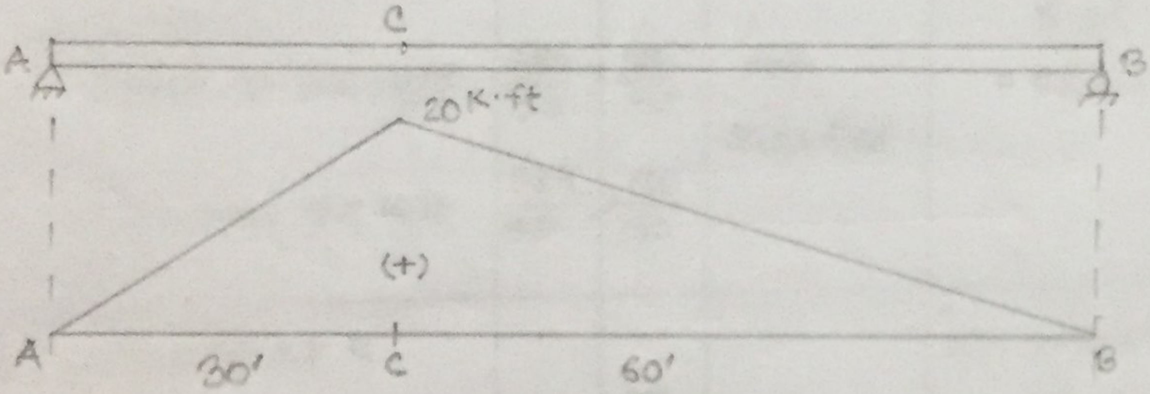
$$\frac{1}{2} \times 8 \times (\frac{15}{60} \times 8) \times 2^{K/'}$$

=

Trial No. #	Position of wheel at C	Remarks	Calculation
1	wheel 3 — just to the left $\frac{304}{80} > \frac{20}{20}$ just ot the right $\frac{304}{80} > \frac{50}{20}$	criteria not satisfied	JTL W = wheel 1 − wheel 10 +2' from the udl $= 300^K + 4^K$ $= 304^K$ $W_1 = 20^K$ JTR $W = 304^K$ $W_1 = 50^K$
2	wheel 4 — Just to the left $\frac{316}{80} > \frac{50}{20}$ Just to the right $\frac{316}{80} < \frac{80}{20}$	criteria satisfied	JTL W = wheel 1 + 11 + 8' of the udl $= 300^K + 16^K$ $= 316^K$ $W_1 = 50^K$ JTR $W = 316^K$ $W_1 = 80^K$



For the axial load shown, calculate maximum moment at $\frac{1}{3}$ point of a simply supported beam of span 90'



Trial No.	Position of wheel	$\frac{W}{L}$	$\frac{W_1}{a}$	Remark	Calculation
1	wheel 3 at C a) Just to the right b) Just to the left	 $\frac{536}{90} >$ $\frac{536}{90} >$	 $\frac{20}{30}$ $\frac{90}{30}$	not satisfied	W = wheel 1 to 10 + 2' of UDL $= 520 + 2\times8 = 536^K$ W_1 = wheel 1 and 2 $= 20^K$
2	wheel 4 at C a) Just to the right b) Just to the left	 $\frac{584}{90} >$ $\frac{584}{90} >$	 $\frac{90}{30}$ $\frac{170}{30}$	not satisfied	W = wheel 1 to 10 + 8' of UDL $= 520 + 8\times8 = 584^K$
3	wheel 5 at C a) Just to the right b) Just to the left	 $\frac{632}{90} >$ $\frac{632}{90} <$	 $\frac{170}{30}$ $\frac{240}{30}$	Criteria satisfied	W = wheel 1 to 10 + 14' of UDL $= 632^K$ W_1 = wheel 1 to 4 $= 170^K$

Hence, maximum moment occures when wheel 5 is at C

$$\therefore \text{Maximum moment} = \frac{20}{60}[70*(60)+80*(48+42+36)+20*(26+22)]$$

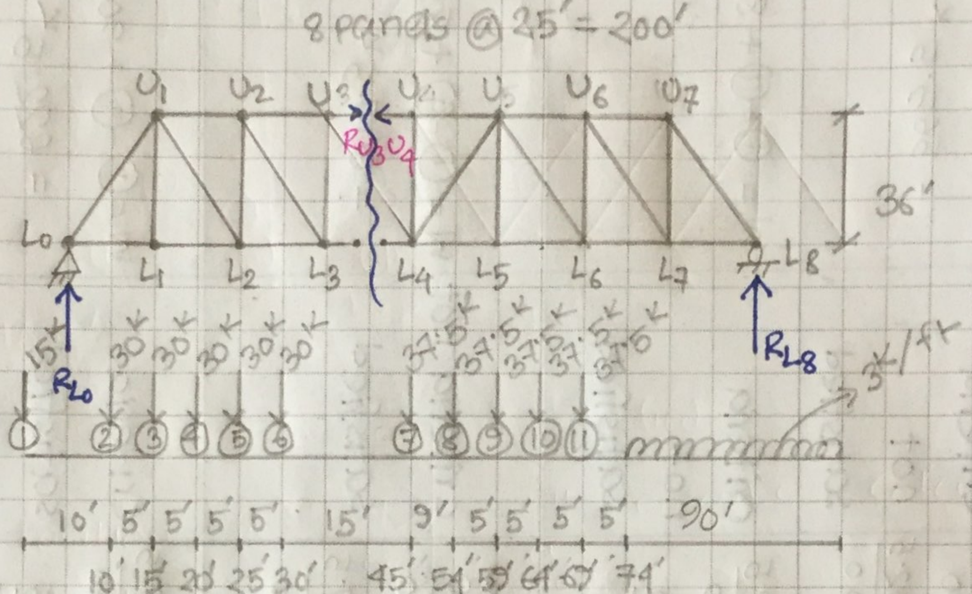
$$+\frac{20}{30}[80*24+70*14+10*(8+4)]$$

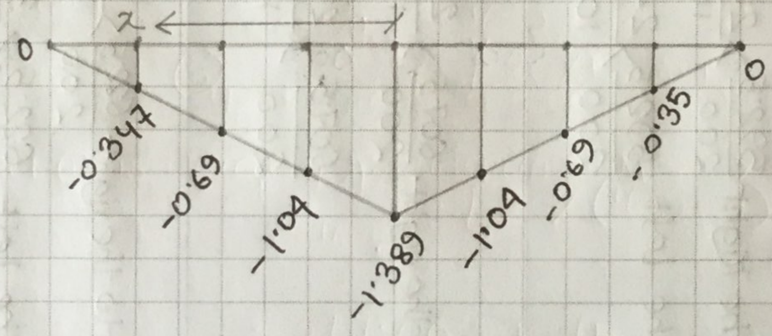
$$+\frac{1}{2}*8*14*\left(\frac{20}{60}*14\right)$$

$$\therefore M_{max} = 7541\cdot33 \text{ kip-ft.} \quad [\text{Ans!}]$$

Assignment - 9

Find Maximum stress in U_3U_4 for the Truss and Loads:-





$$\overset{+}{\circlearrowleft} \sum M_{L_4} = 0 \Rightarrow R_{L_0} \times 100 - 1 \times x + R_{U_3U_4} \times 36 = 0$$

Position of Load	R_{L_0}	$R_{U_3U_4}$
L_0	1	0
L_1	0.875	-0.347
L_2	0.75	-0.69
L_3	0.625	-1.04
L_4	0.5	-1.389
L_5	0.375	-1.04
L_6	0.25	-0.69
L_7	0.125	-0.347
L_8	0	0

Trial No.	Position of Wheel $\frac{W}{L}$ $\frac{W_1}{a}$	Remarks	Calculation
1	Wheel 7 Just to the right $\frac{565.5}{200} > \frac{165}{100}$ Just to the left $\frac{565.5}{200} > \frac{202.5}{100}$	criteria not satisfied	W = 1 - 11 + 71' of UDL $= 565.5^K$
2	wheel 8 just to the right $\frac{592.5}{200} > \frac{202.5}{100}$ just to the left $\frac{592.5}{200} > \frac{240}{100}$	criteria not satisfied	W = 1 - 11 + 80' of UDL
3	wheel 9 just to the right $\frac{607.5}{200} > \frac{240}{100}$ $\frac{607.5}{200} > \frac{277.5}{100}$	criteria not satisfied	W = 1 - 11 + 85' of UDL $= 607.5^K$
4	wheel 10 just to the right $\frac{622.5}{200} > \frac{277.5}{100}$ just to the left $\frac{622.5}{200} < \frac{315}{100}$	criteria satisfied ^_^	W = 1 - 11 + 90' of UDL $= 622.5^K$

Hence, the maxm stress is $= \frac{1.38}{100}[37.5 * 100 + 37.5 * 95] + \frac{1}{2} * 90 * (\frac{1.38}{100} * 90)$

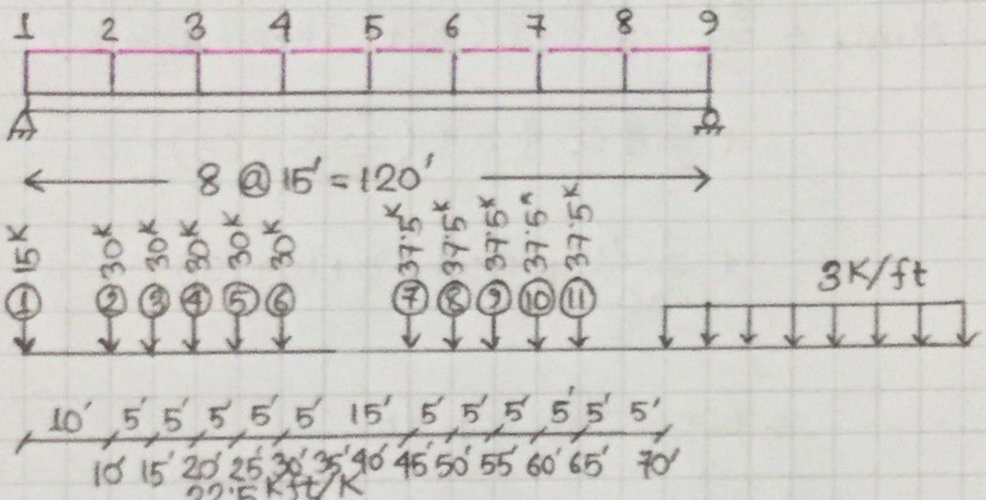
$+ \frac{1.38}{100}[37.5 * 95 + 37.5 * 90 + 37.5 * 85 + 30 * 70 + 30 * 65 + 30 * 60 + 30 * 55 + 30 * 50 + 15 * 40]$

$= 515.94^K$

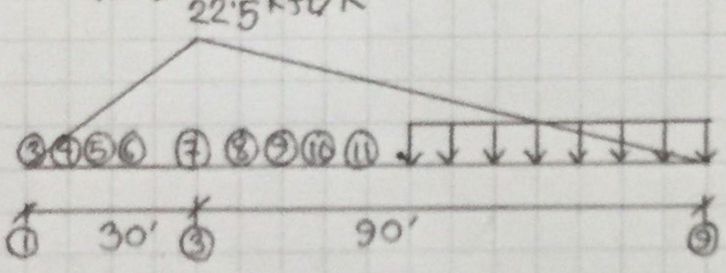
[Ans.]

Assignment - 10

Find maximum moment at panel point 3-4 (3rd panel) of 8 panel span with floor beams. Panel Length 15'. Loading is shown below (axle)



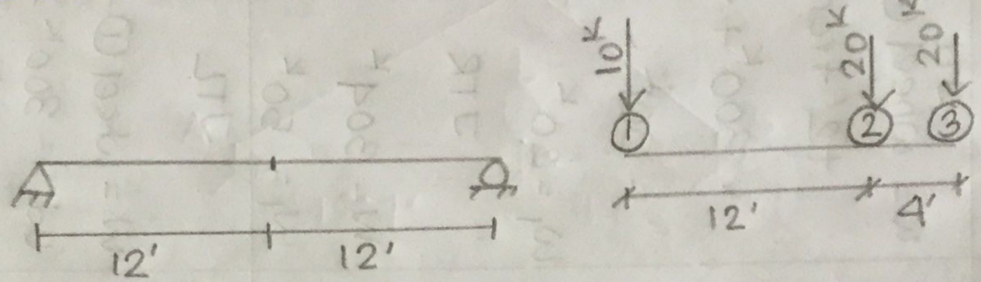
Solution:

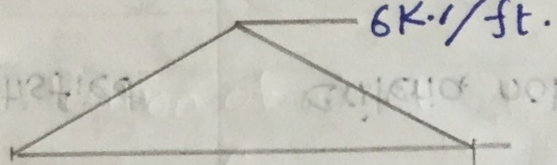


Trial No	Position of axle load	$\frac{W}{L}$	$\frac{W_1}{a}$	Remarks	Calculation
1	Wheel ⑥ at 3 a) Just to right b) just to left	$\frac{502.5}{120} < \frac{135}{30}$ $\frac{487.5}{120} < \frac{150}{30}$		Criteria not satisfied	W = ① to wheel ⑪ + 50' of UDL $= 352.5 + 50 \times 3 = 502.5^K$ W_1 = wheel ① - wheel ⑤ $= 135^K$ W = wheel ② to wheel ⑪ + 50' $= 352.5 - 15 + 50 \times 3 = 487.5^K$
2	wheel ⑦ at 3 a) just to right b) just to left	$\frac{502.5}{120} > \frac{120}{30}$ $\frac{472.5}{120} > \frac{127.5}{30}$ $3.94 < 4.25$		criteria satisfied	W = wheel ③ - ⑪ + 65' of UDL $= 502.5^K$ W_1 = ③ to ⑥ W = ④ to ⑪ + 65' of UDL $= 475.5^K$ W_1 = ④ to ⑦ $= 127.5^K$

Lec - 7

☐ Find Max^m moment for span 24'. Assume following axial Loads:-





I.L for moment at midspan

Procedure

1. Find the wheel that gives max^m moment at the center.

When wheel ① is placed at midspan:-

$M = 10 \times 6 = 60^{K \cdot '}$

When wheel ② is placed at midspan: -

$M = 20 \times 6 + 20 \times \frac{6}{12} \times 8 = 20 \times 6 + 20 \times 4 = 200^{K \cdot '}$

Hence, wheel ② at midspan gives maximum moment.

2. Place the wheels and the C.G of the wheels on the span such that they are equidistant from the center or midspan.

3. If the wheel doesnot satisfy the IL criterion for maximum moment at that point, descend the wheel and try with the next wheel.

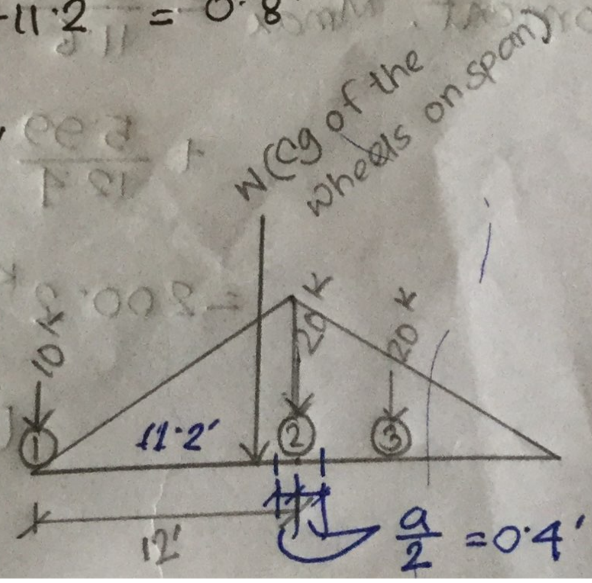
Let, C.G of the wheels on span is 'x' ft from wheel ①

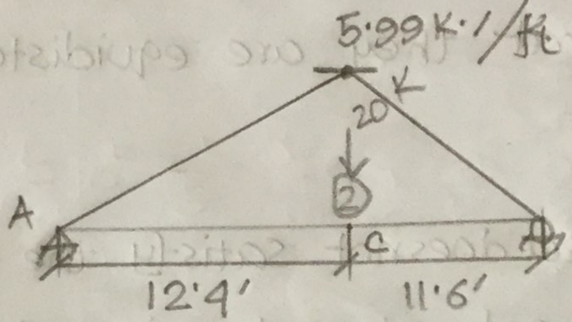
$$x = \frac{10^k \times 0 + 20^k \times 12 + 20^k \times 16}{10+20+20} = 11.2'$$

Let, a = distance between that wheel and C.G of the wheels on span [Here wheel ②]

$\therefore a = 12' - 11.2' = 0.8'$

$\frac{a}{2} = 0.4'$





Trial No:	Position of wheel at C	Remarks $\frac{W}{L}$ $\frac{W_1}{a}$		Calculation
1	wheel ② J.T.T.L	$\frac{50}{24} > \frac{10}{12.4}$	Criteria satisfied	
	J.T.T.R	$\frac{50}{24} < \frac{10+20}{12.4}$		

$$\max^m \text{ moment, } M_{max} = \frac{5.99}{11.6}\left[20 \times 11.6 + 20 \times (11.6 - 4)\right]$$

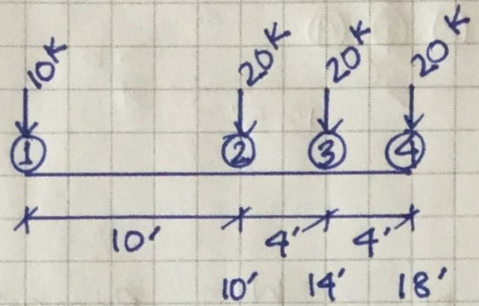
$$+ \frac{5.99}{12.4}\left[10^K \times (12.4 - 12)\right]$$

$$= 200.2^{K'}$$

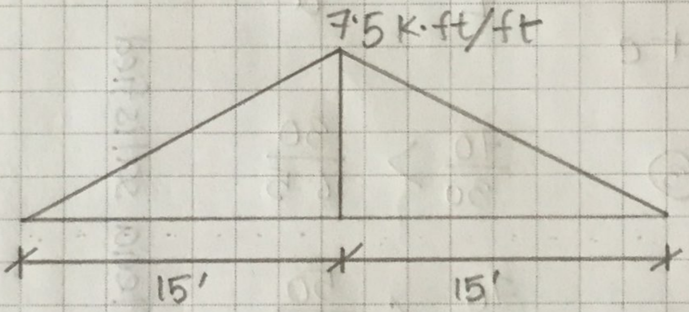
[Ans:]

Assignment -11 01720033788

Find Max^m moment for span 30'. Consider the Following axle Loads:-



<u>Sol^n:</u>



IL diagram for bendingmoment at midspan

When wheel ① is placed at midspan:- $M = 10 \times 7.5 + 20 \times \frac{7.5}{15} * 5 + 20 \times \frac{7.5}{15} * 1$

$= 135 \ k \cdot ft/ft$

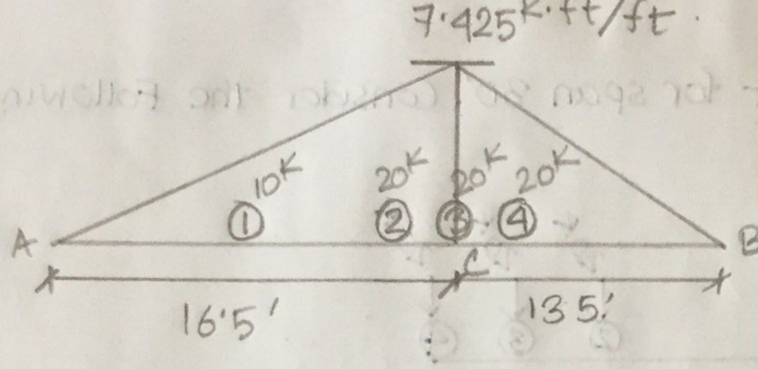
when, wheel ② is placed at midspan, $M = 355 \ k \cdot ft/ft$.

wheel ③ is placed at midspan, $M = 375 \ k \cdot ft$

when ④ is placed at midspan, $M = 330 \ k \cdot ft$.

Hence, wheel ③ at C produces max^m moment.

$x = 12'$ $a = 15' - 12' = 3'$ $a/2 = 1.5'$



Trial	Position of wheel at C	$\frac{W}{L}$		$\frac{W_1}{a}$	Remarks	Calculation
1	Wheel 3	$\frac{70}{30}$	$>$	$\frac{30}{16\cdot5}$	Criteria satisfied	
		$\frac{70}{30}$	$<$	$\frac{50}{16\cdot5}$		

Max^m moment, M_{max} $= \frac{7\cdot425}{13\cdot5}\left[20\times13\cdot5+20\times(13\cdot5-4)\right]$

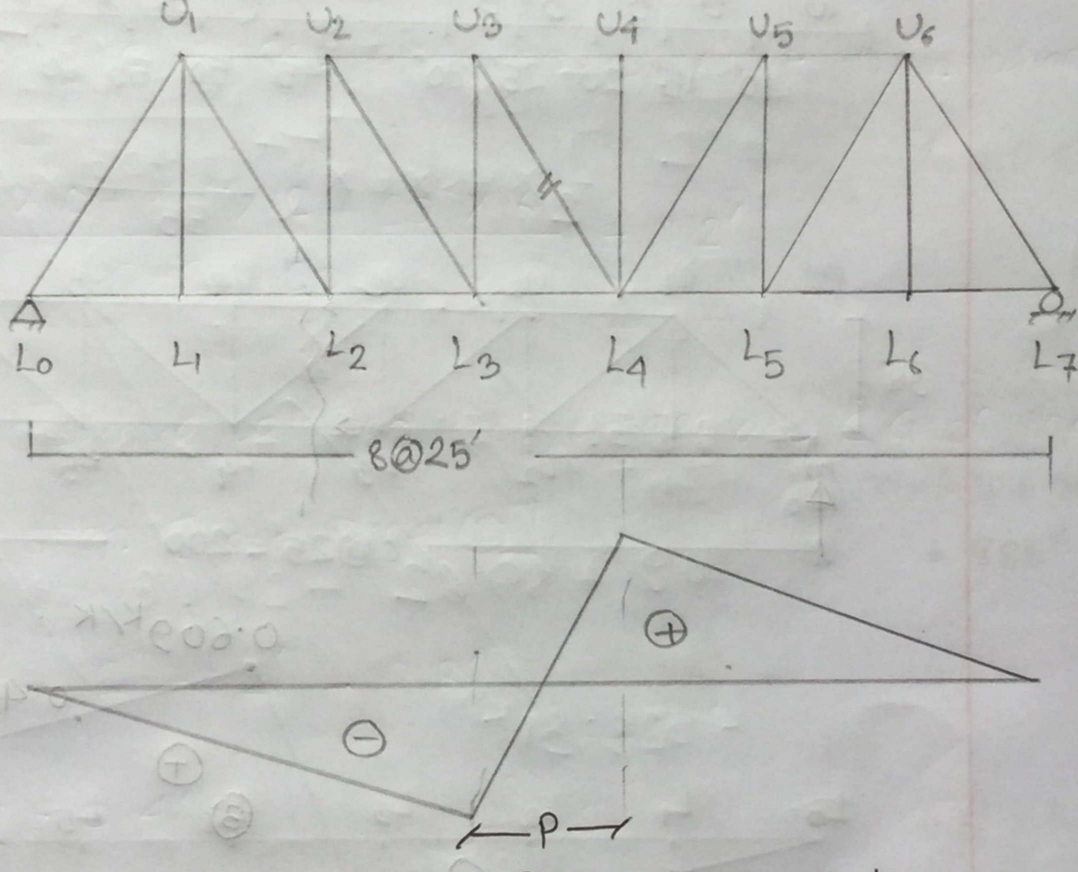
$+\frac{7\cdot425}{16\cdot5}\left[20\times(16\cdot5-4)+20\times(16\cdot5-14)\right]$

$= 377\cdot003$ K·ft

[Ans:]

Art. 69 Position of wheel to produce maximum

web stress in truss / panel shear in span with floor beams.



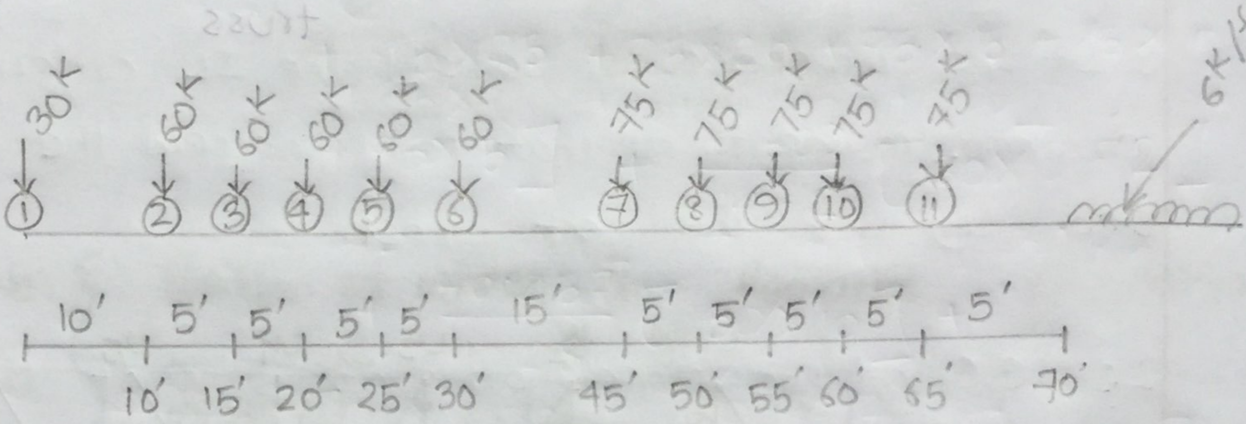
IDEALIZED IL for stress in U_3L_4

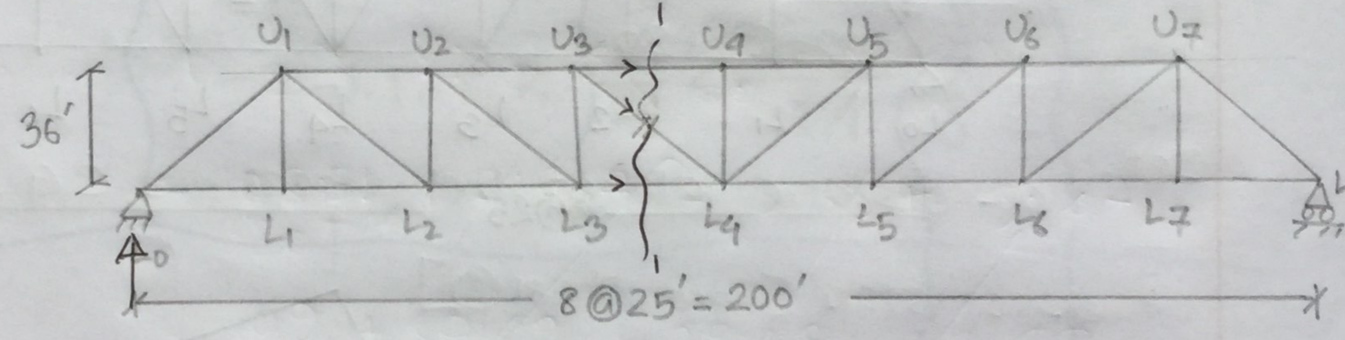
Required criteria for max^m, $\frac{W}{L} = \frac{W_1}{P}$

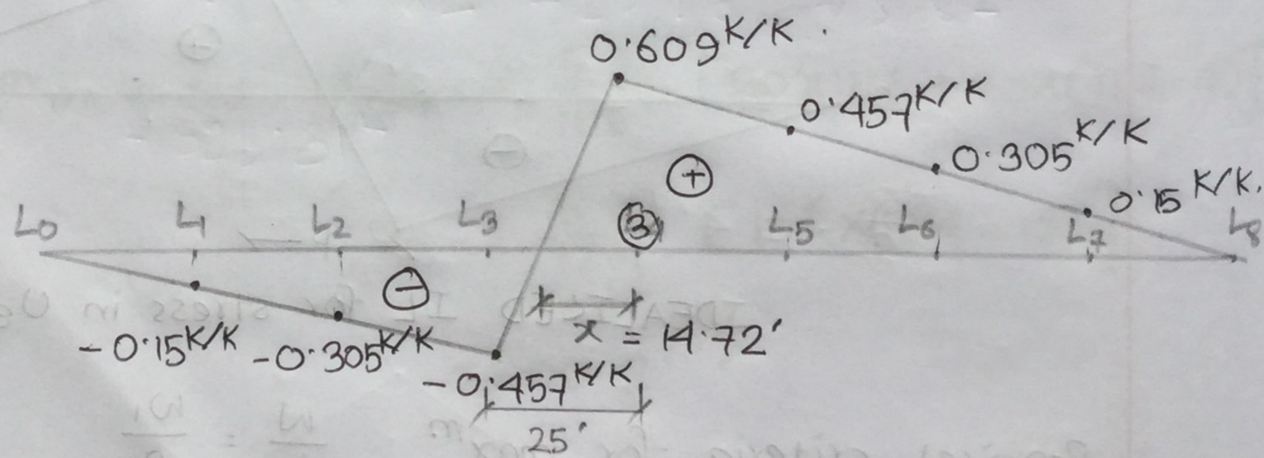
W = Load on span $\qquad$ W_1 = Loads on panel

L = Span Length $\qquad$ P = panel length

Prob 221 Find max^m Tension and Compression in U_3L_4 of the truss shown. for the following axle loads.







At section 1-1 [When 1^K load moves from L_0 to L_3]

$\overset{+}{\uparrow}\Sigma F_y = 0$ [Load at L_3]

$$R_{L0} - 1^K - U_3L_4 \times \frac{36}{\sqrt{36^2+25^2}} = 0$$

$$\frac{5}{8} - 1 = \frac{U_3L_4}{\sqrt{36^2+25^2}} \times 36$$

$$U_3L_4 = -0.457^{K/K}$$

[1^K load at L_4] $\quad U_3L_4 = (1-0.5) \times \frac{\sqrt{36^2+25^2}}{36} = 0.609^{K/K}$

For max^m tension wheel will more from L_4

Trial No. Position of wheel $\frac{W}{L}$ $\frac{W_1}{P}$ Remarks Calculati

1. wheel 1 at L_4 J.T.T.B $\frac{885}{200} > \frac{0}{25}$ $\quad W = 1\text{-}11 + 30' = 885^K$

   J.T.T.L $\frac{885}{200} > \frac{30}{25}$

2. wheel 2 at L_4 J.T.T.R $\frac{945}{200} > \frac{30}{25}$ $\quad W = 1\text{-}11 + 40'$

   J.T.T.L $\frac{945}{200} > \frac{90}{25}$

3. wheel 3 at L_4 JTTR $\frac{975}{200} > \frac{90}{25}$ criteria satisfied. $\quad W = 1\text{-}11 + 45'$

   JTTL $\frac{975}{200} < \frac{150}{25}$

Hence wheel 3 at L_4 will produce max^m tension.

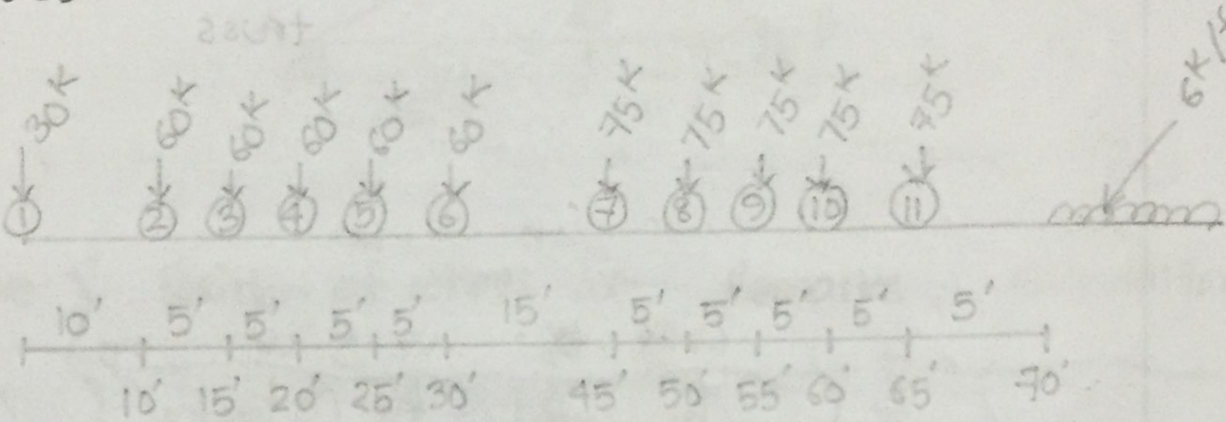
$$T_{max} = \frac{0.609}{100}\left[60*(100+95+90+85)+75*(70+65+\ldots 50)\right.$$

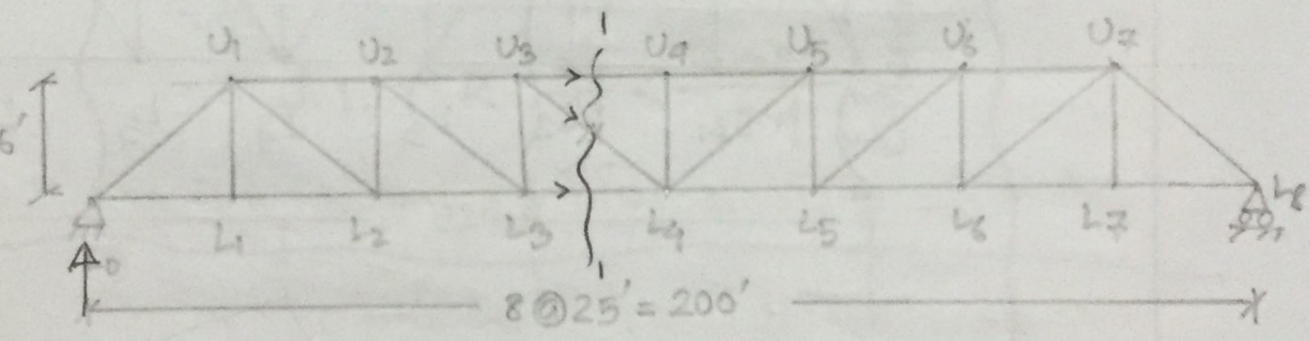
$$+\frac{0.609}{14.72}\left[60\times 9.72\right] - \frac{0.457}{10.28}\left[30*10\right]$$

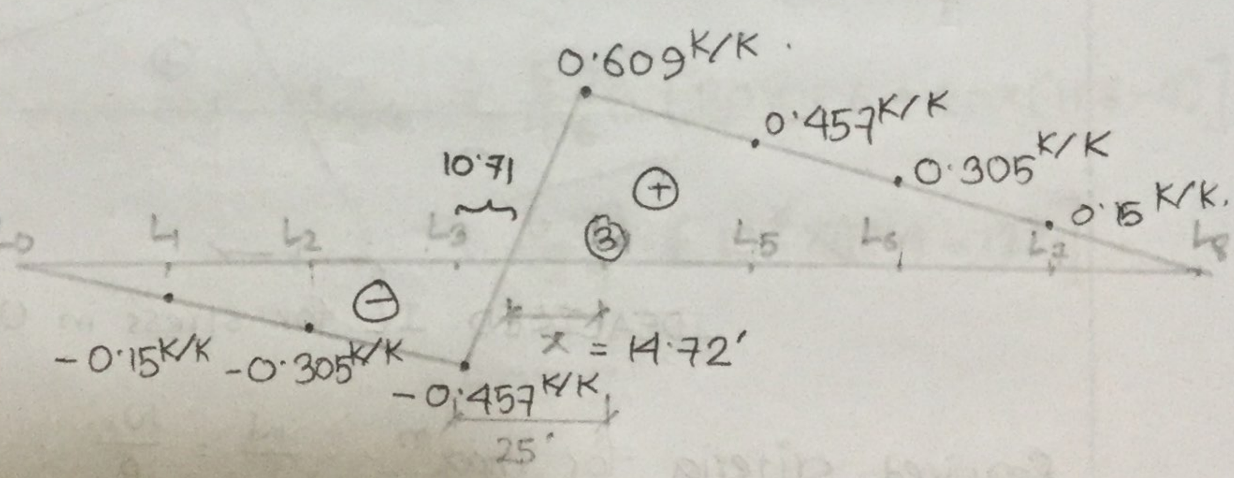
$$+\frac{1}{2}*45*6*\left(\frac{0.609}{100}*45\right)$$

$$= 319.703^K = 320^K \text{ [Ans:]}$$

Prob 221. Find max^m Tension and Compression in U_3L_4 of the truss shown. for the following axle loads.







Compute maximum Compression in U_3L_4 of the truss

Load moving from L_0 to L_8 [Point to be noted]

Trial No.	Position of wheel	$\frac{W}{L}$ $\frac{W_1}{P}$	Remarks	Calculation
1	wheel ① at L_3 a) just ot the right b) just to the left	$\frac{735}{200} > \frac{30}{25}$ $\frac{735}{200} > 0$	Criteria not satisfied	$W = ① - ⑪ + 5'$ $= 735'$ $W_1 = ① = 30^K$ $W_1 = 735'$ $W = 0^K$
2	wheel ② at L_3 a) just to the right b) just to the left	$\frac{795}{200} > \frac{90}{25}$ $\frac{795}{200} > \frac{30}{25}$	Criteria not satisfied	$W = ①$ to $⑪$ + 15' of UDL $= 705 + 90^K$ $= 795^K$ $W_1 = ① - ② = 90^K$
3	wheel ③ at L_3 a) just to the right b) just left	$\frac{825}{200} < \frac{150}{25}$ $\frac{825}{200} > \frac{90}{25}$	criteria satisfied	$W = ① - ⑪ +$ 20' of UDL $= 705 + 120$ $= 825^K$ $W_1 = ① - ③$ $= 150^K$ $W_1 = ① - ②$ $= 90^K$

so, wheel 3 at L_3 gives maximum compression.

$\therefore$ Max^m Compression =

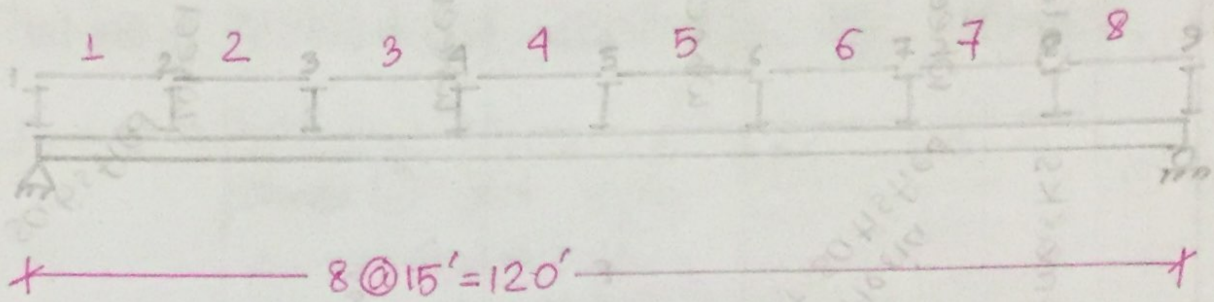
$$\frac{0.457}{75}\left[60(70+75+65+60)+75(45+40+35+25)\right]$$

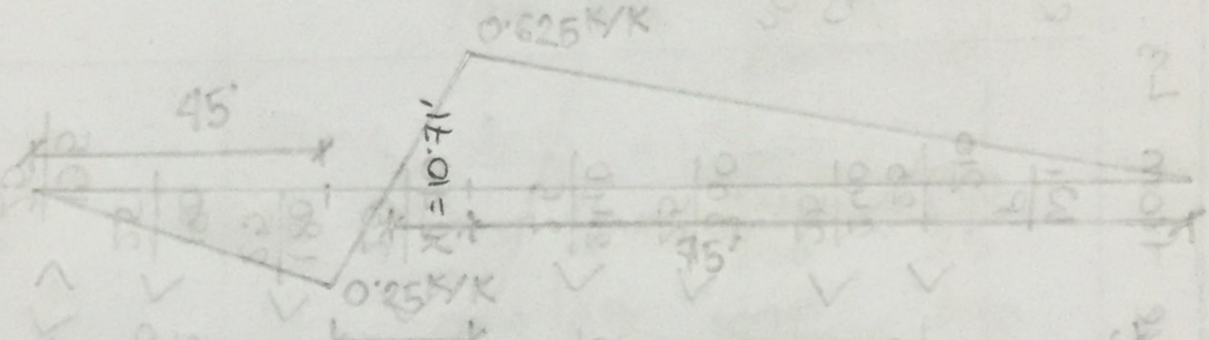
$$+\frac{1}{2}\times 20\times 6\times \frac{0.457}{75}\times 20+\frac{0.457}{10.71}\times 60\times(10.71-8)$$

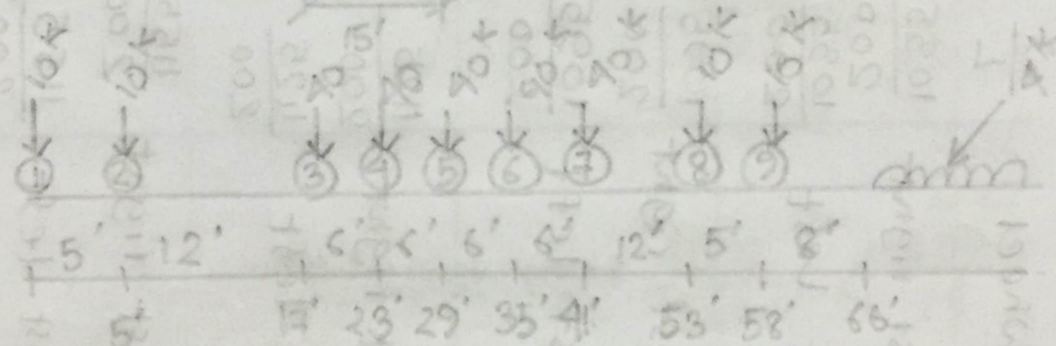
$$-\frac{0.609}{14.28}(30\times 4.28)$$

$= 195^K$ for axle load [Ans:].

Find max^m shear in 3rd panel of span of 8 panels [panel Length 15' each] Loading as following







Area of positive shear > area of negative shear.

Hence wheel will move from right to left

Trial	Position of wheel		$\frac{W}{L}$		$\frac{W_1}{P}$	Remarks	Calculation
1	wheel ① at point 4	Just right	$\frac{276}{120}$	$>$	$\frac{20}{15}$	not satisfied	$240 + 9'$ of udl $= 276^K$
		Just Left	$\frac{276}{120}$	$>$	$\frac{10}{15}$		
2	wheel ② at point 4	Just right	$\frac{296}{120}$	$>$	$\frac{10}{15}$	not satisfied	$240 + 14'$ of udl $= 296^K$
		just left	$\frac{296}{120}$	$>$	$\frac{20}{15}$		
3	wheel ③ at point 4	just right	$\frac{344}{120}$	$>$	$\frac{10}{15}$	criteria is satisfied	$240 + (12+14)'$ of UDL $= 344^K$
		Just left	$\frac{344}{120}$	$<$	$\frac{50}{15}$		

Hence, wheel 4 at panel point 4 will produce maximum shear

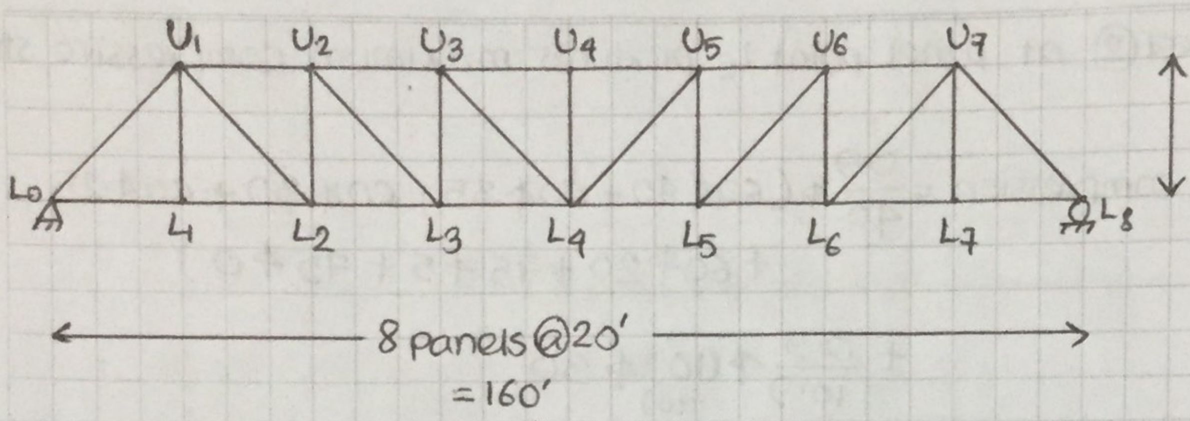
$$\max^m \text{shear} = \frac{0.625}{75}\left[40*(75+69+63+57+51) + 10*(39+34)\right]$$

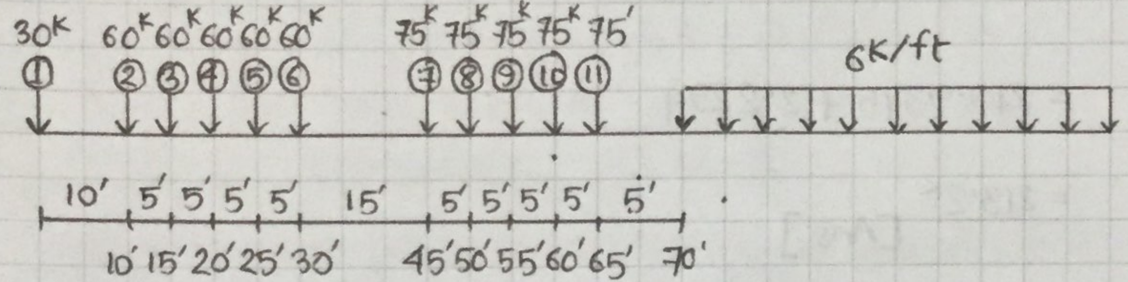
$$+ \frac{0.625}{10.71}[0] - \frac{0.25}{4.29}[1.29*10] - \frac{0.25}{45}[43*10]$$

$$+ \frac{1}{2}*26*4*\left(\frac{0.625}{75}*26\right)$$

$$= 111.08 + 0 - 0.75 - 2.389 + 11.267 = 119.2 = 120^K$$

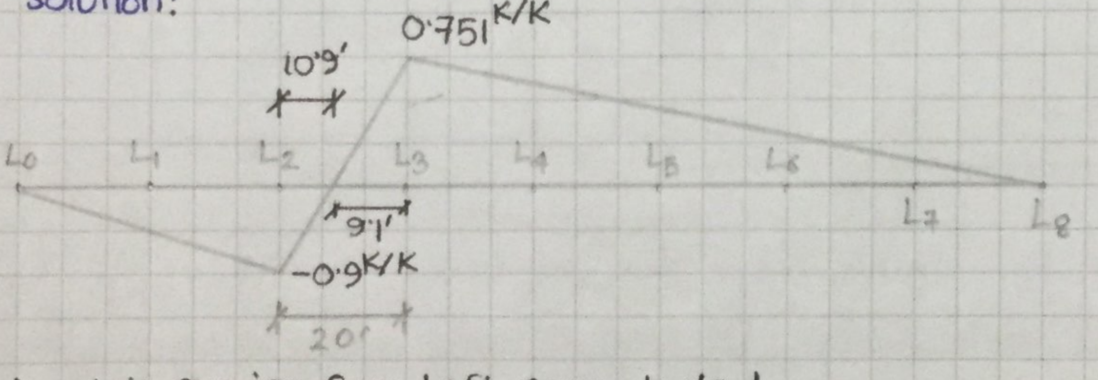
Assignment-12





Find maximum stress in U_2L_3 of the truss shown. Axle Load given.

Solution:



Max^m stress occures in Compression.

Load is moving from Left support to L_2

Trial No.	Position of wheel	$\frac{W}{L}$ $\frac{W_1}{a}$	Remarks	Calculation
1	wheel ① at L_2 a) Just to the right b) Just to the left	$\frac{330}{160} > \frac{30}{20}$ $\frac{330}{160} > \frac{0}{20}$	not satisfied	W = wheel ① - wheel ⑥ = 330^K
2.	② at L_2 a) right b) just to the left	$\frac{480}{160} < \frac{90}{20}$ $\frac{405}{160} > \frac{30}{20}$	satisfied	W = wheel ① - wheel ⑧ = 480^K W = wheel ① - wheel ⑦ = 405^K

Hence, wheel 2 at panel point L_2 produces maximum compressive stress.

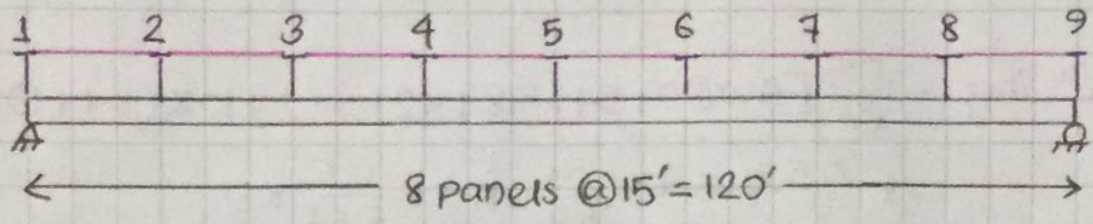
$$\text{Maximum compression} = \frac{0.9}{40} * (60*40 + 60*35 + 60*30 + 60*25 + 60*20 + 75*5 + 75*0)$$

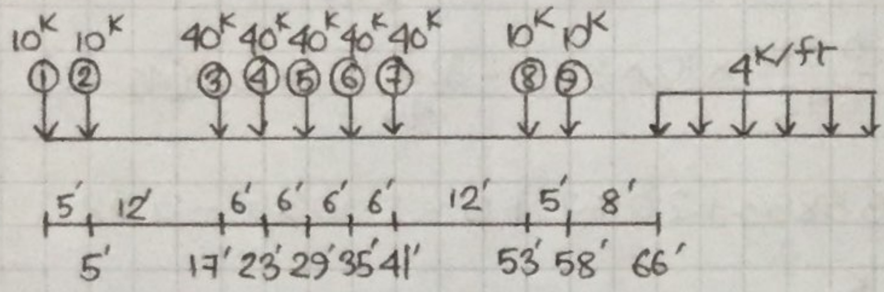
$$+ \frac{0.9}{10.9} * (10.9*30 - 10)$$

$$= 210.9375 + 2.2294$$

$$= 213.2^K$$ [Ans:]

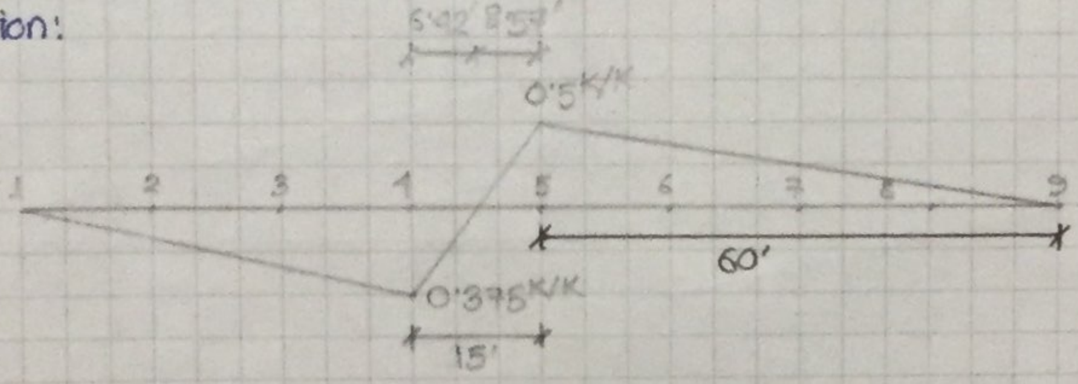
Assignment-13





Calculate maximum shear in 4^{th} Panel of a span of 120'. Assume the given axle loadings.

Solution:



Here, area of positive shear > area of negative shear. Load will bo no 5.

Trial No.	Position of wheel	$\frac{W}{L}$ $\frac{W_1}{a}$	Remarks	Calculation
1	wheel ② at panel P.5 a) just to the right b) just to the left	$\frac{240}{120} > \frac{10}{15}$ $\frac{240}{120} > \frac{20}{15}$	not satisfied	{ W = wheel① - wheel⑨ = 240^K $W_1 = 10^K$ { W = 240^K W_1 = wheel① + wheel②
2	wheel ③ at panel p. 5 a) just to the right b) just to the left	$\frac{284}{120} > \frac{10}{15}$ $\frac{284}{120} < \frac{50}{15}$	criteria satisfied	{ W = wheel① - wheel⑨ + 11' of UDL = $340 + 4\times 11^K$ = 284^K { W_1 = wheel② + wheel③ = 50^K

Hence, maximum shear occures at 4th panel when wheel ③ is on panel point 5.

$$\therefore Max^m \; Shear = \frac{0.5}{60}[40\times(60+54+48+42+36)+10\times(24+19)]$$

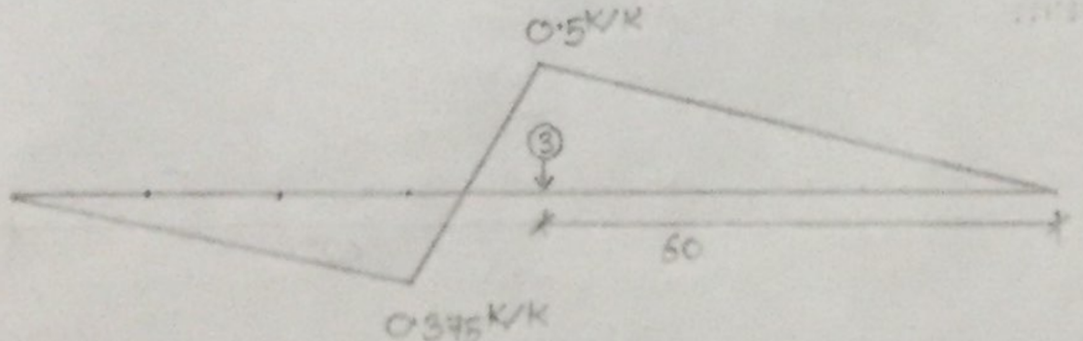
$$+ 0.5\times 11\times 4\times\left(\frac{0.5}{60}\times 11\right)+\frac{0.5}{8.57}\times 0$$

$$-\frac{0.375}{6.42}\times 10\times 3.43-\frac{0.375}{45}\times 10\times(45-2)$$

$$= 83.5833+2.0167+0-2.0035-3.58$$

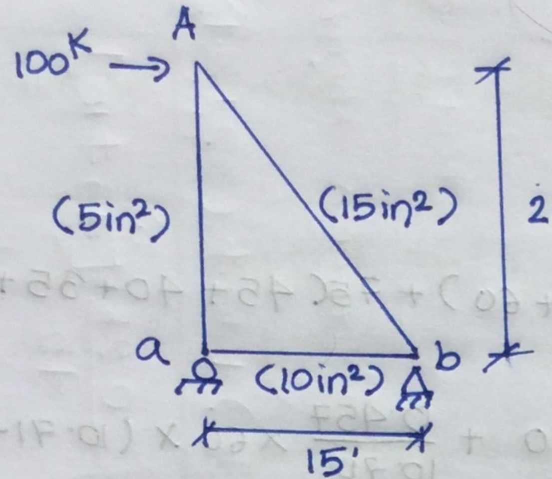
$$= 80^K$$

[Ans:]



VIRTUAL WORK

Problem: 1



Compute Horizontal Deflection at A. The following datas are given:-

$E = 30.000$ ksi

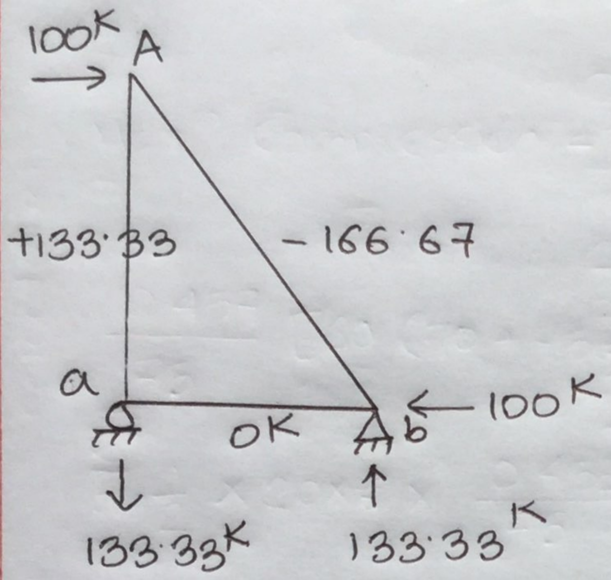
$\alpha_t = \frac{1}{15,000}$ /°F

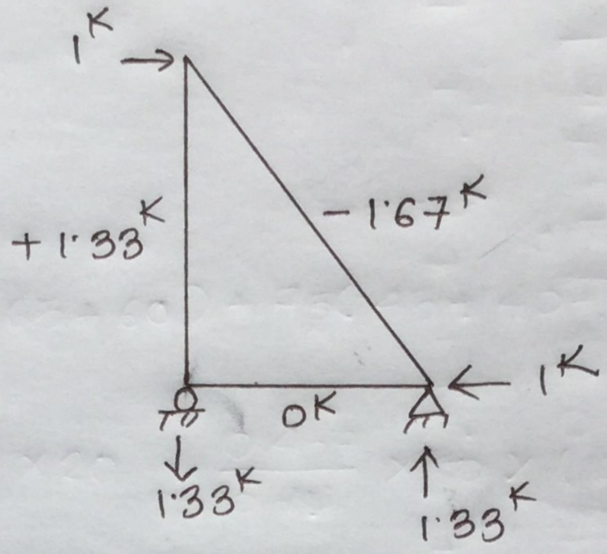
Temperature change for bottom chord member = 40°F incr.

diagonal chord member = 30° F Decreasing

vertical chord member = 20° F Decreasing

Soln: ① P force Analysis:-





② Q- force Analysis:-

position	Bar	Length (ft)	Area (in^2)	$\frac{L}{A}$	F_Q (K)	F_P (K)	$F_Q F_P \frac{L}{A}$	t	$F_Q t L$
horizontal	ab	15	10	1.5	0	0	0	+40	0
Diagonal	Ab	25	15	1.67	-1.67	-166.67	463.16	-30	1250.25
vertical	Aa	20	5	4	1.33	133.33	710.92	-20	-533.2

$\Sigma F_P F_Q \frac{L}{A} = 1174$ $\qquad \Sigma F_Q t L = 717$

③ Applying principal of Virdual work:-

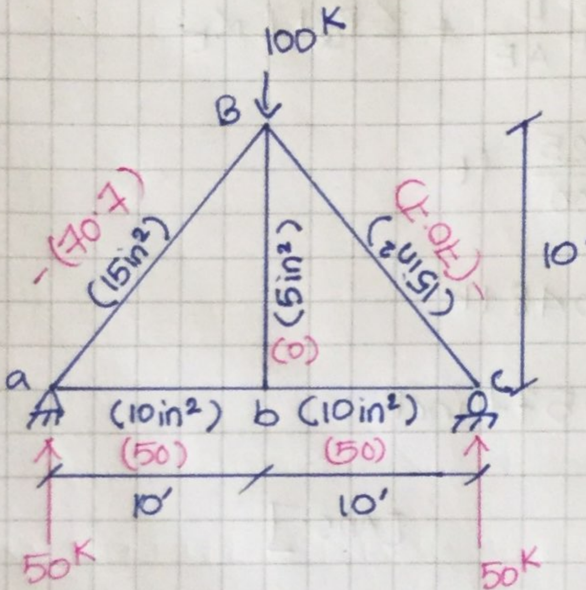
$$1 \cdot \partial = \frac{1174}{30{,}000} + 717 \times \frac{1}{15{,}0000}$$

$\therefore \partial = 0.087$ ft $= 0.0439$ ft $= 0.523$ inch

[Ans:]

Assignment-16

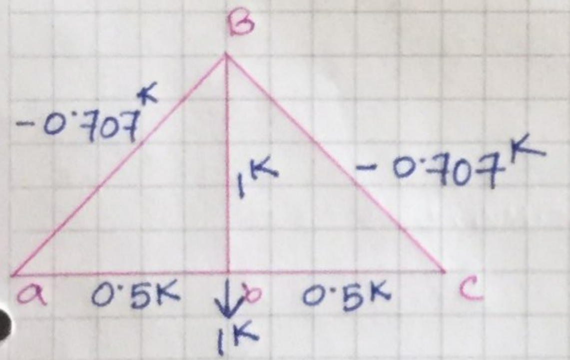
Sol^n: step 1. Real force analysis



Compute Vertical Deflection at B

Given = E = 30,000 ksi

step. 2: Virtuale force analysis



position	bar	L	A	$\frac{L}{A}$	FQ	Fp	$F_Q F_P \frac{L}{A}$	t	FQtL
horizontal bar	ab	10	10	1	+0.5	+50	+25	0	0
	bc	10	10	1	+0.5	+50	+25	0	0
diagonal bar	aB	14.14	15	0.94	-0.707	-70.7	47.12	0	0
	BC	14.14	15	0.94	-0.707	-70.7	47.12	0	0
vertical	Bb	10	5	2	1	0	0	0	0
							144		0

Step 8: Applying Principle of Virtual Work:

$$W_S = W_D$$

$$\Rightarrow Q \cdot \partial = \Sigma F_Q P_P \frac{L}{AE} + \Sigma P_Q t L \alpha_t$$

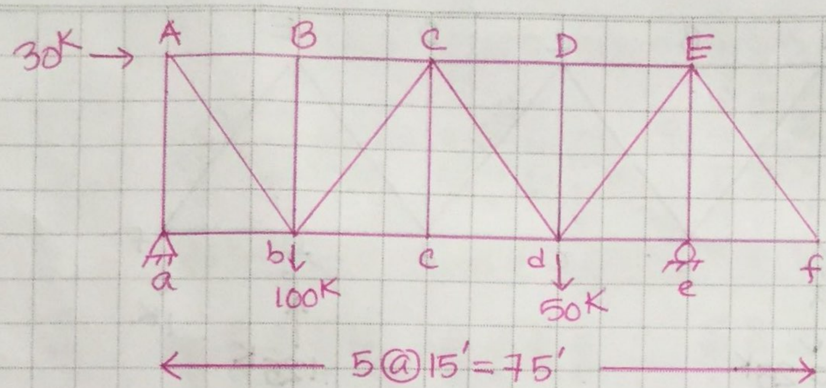
$$\Rightarrow 1 \cdot \partial = \frac{144.25}{30{,}000} \text{ ft}$$

$$\Rightarrow \partial = 0.0048 \text{ ft}$$

$$\therefore \partial = 0.0577 \text{ inch}$$

[Ans:]

Assignment 17



Given,
E = 30,000 ksi
$\alpha_t = 1/150,000$ /°F

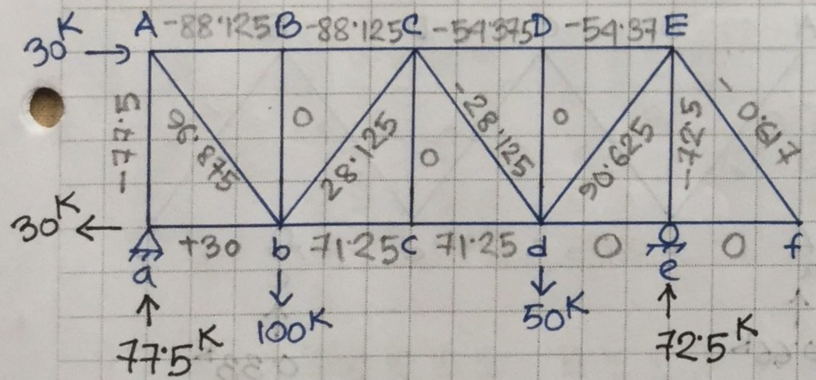
Given, Temperature change,

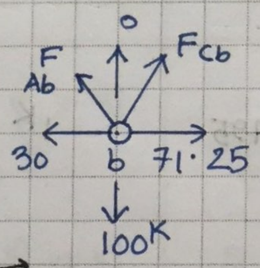
1. bottom and top chord member — 40°F increase
2. Diagonal chord member — 30°F decrease
3. Vertical chord member — 20°F decrease

Compute (a) vertical deflection at f (b) Horizontal Deflection at A

Solution:

Step 1: P force analysis





$\overrightarrow{\sum F_x} = 0$

$-30 + 71·25 + F_{Cb} \times \frac{15}{25} - F_{Ab} \times \frac{15}{25} = 0$

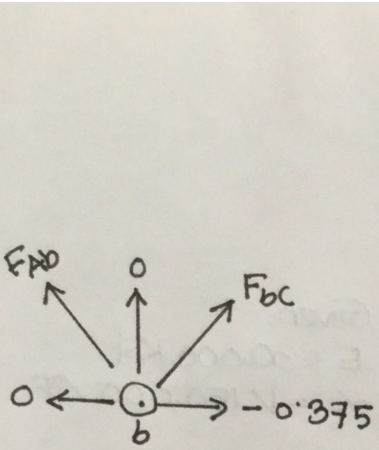
$F_{Cb} \times \frac{15}{25} - F_{Ab} \times 15/25 = -41·25$ — ①

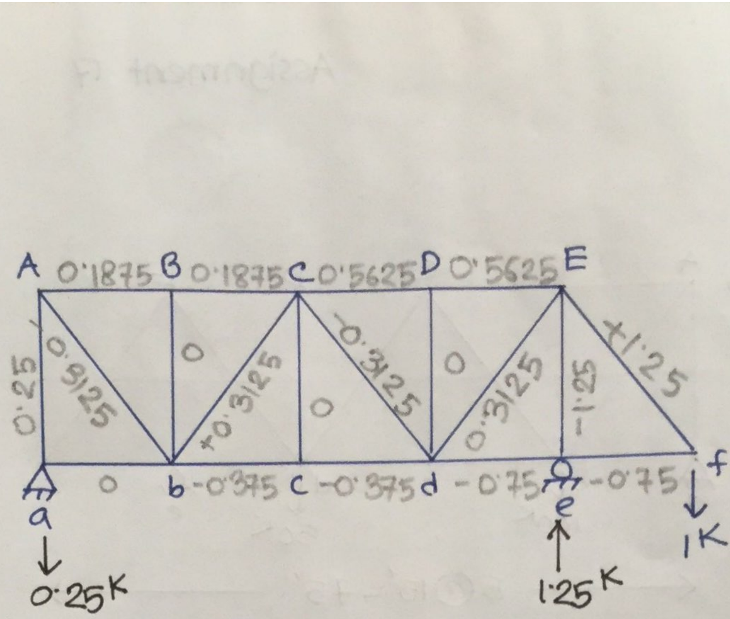
$+\uparrow \sum F_y = 0$

$-100 + F_{Cb} \times 20/25 + F_{Ab} \times 20/25 + 0 = 0$

$F_{Cb} \times 20/25 + F_{Ab} \times 20/25 = 100$ — ②

$F_{Cb} = 28·125^K$ $F_{Ab} = 96·875^K$





$\overset{+}{\rightarrow}\Sigma F_x = 0$

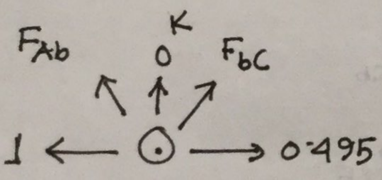
$-0.375 + F_{bc} \times \frac{15}{25} - F_{ab} \times \frac{15}{25} = 0$

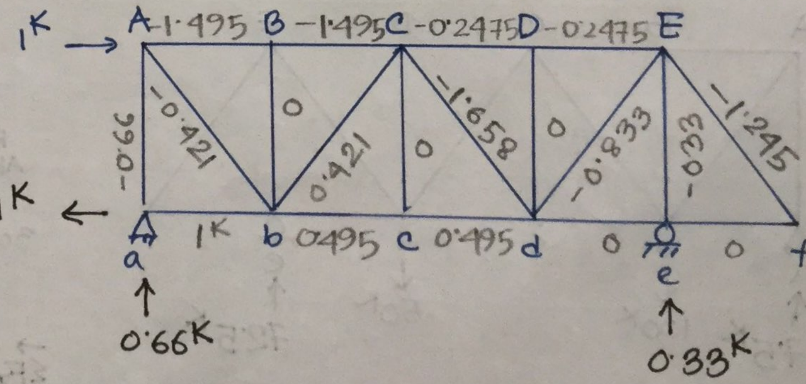
$15F_{bc} - 15F_{ab} = 9.375$ — ①

$\overset{+}{\uparrow}\Sigma F_y = 0$

$F_{bc} \times \frac{20}{25} + F_{Ab} \times \frac{20}{25} = 0$

$20F_{bc} + 20F_{Ab} = 0$ — ②





$\overset{+}{\rightarrow}\Sigma F_x = 0$

$-1 + 0.495 + F_{bc} \times \frac{15}{205} - F_{AB} \times \frac{15}{205} = 0$

$F_{bc} \times \frac{15}{205} - F_{Ab} \times \frac{15}{205} = 0.505$ — ①

$\overset{+}{\uparrow}\Sigma F_y = 0$

$F_{bc} \times \frac{20}{25} + F_{Ab} \times \frac{20}{25} = 0$ — ②

$F_{bc} = 0.421 \quad F_{Ab} = -.421$

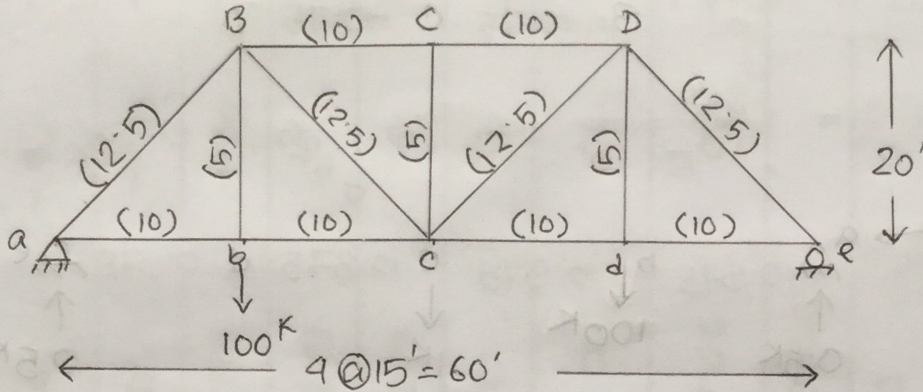
position	bar	Length L	Area A	L/A	FQ	Fp	FQ Fp L/A	t	FQtL
horizontal	ab	15	10	1·5	0	30	0	+40	0
	bc	15	10	1·5	−0·375	71·25	−40·078	+40	− 225
	cd	15	10	1·5	−0·375	71·25	−40·078	+40	− 225
	de	15	10	1·5	−0·75	0	− 0	+40	− 450
	ef	15	10	1·5	−0·75	0	0	+40	− 450
	AB	15	10	1·5	0·1875	−88·125	−24·785	+40	112·5
	BC	15	10	1·5	0·1875	−88·125	−24·785	+40	112·5
	CD	15	10	1·5	0·5625	−54·375	−45·879	+40	337
	DE	15	10	1·5	0·5625	−54·375	− 45·879	+40	337
diagonal	Ab	25	15	1·67	−0·3125	96·875	− 50·57	−30	+ 234·375
	bC	25	15	1·67	0·3125	28·125	14·67	−30	* − 234·375
	Cd	25	15	1·67	−0·3125	−28·125	+ 14·67	−30	+ 234·375
	dE	25	15	1·67	0·3125	90·625	47·29	−30	− 234·375
	Ef	25	15	1·67	1·25	−0·617	−1·288	−30	− 937·5
vertical	Aa	20	5	4	0·25	−77·5	− 77·5	−20	− 100
	Bb	20	5	4	0	0	0	−20	− 0
	Cc	20	5	4	0	0	0	−20	− 0
	Dd	20	5	4	0	0	0	−20	− 0
	Ee	20	5	4	−1·25	−72·5	362·5	−20	+ 500
							88·288		−988·5

$\partial f = 88{\cdot}288/E + (-988{\cdot}5)\alpha_t = -0{\cdot}003647\ \text{ft}$ ∴ (UP)

position	bar	L	A	L/A	Fp	FQ	$F_P F_Q \frac{L}{A}$	t	FQtL
horizontal	ab	15	10	1·5	30	1	45	40	600
	be	15	10	1·5	71·25	0·495	52·9	40	297
	cd	15	10	1·5	71·25	0·495	52·9	40	297
	de	15	10	1·5	0	0	0	40	0
	ef	15	10	1·5	0	0	0	40	0
	AB	15	10	1·5	−88·125	−1·495	197·62	40	−897
	BC	15	10	1·5	−88·125	−1·495	197·62	40	−897
	CD	15	10	1·5	−54·375	−0·2475	20·17	40	−148·5
	DE	15	10	1·5	−54·375	−0·2475	20·187	40	−148·5
Diagonal	Ab	25	15	1·67	96·875	−0·421	−67·974	−30	315·75
	bC	25	15	1·67	28·125	0·421	19·734	−30	−315·75
	Cd	25	15	1·67	−28·125	−1·658	77·72	−30	1243·5
	dE	25	15	1·67	90·625	−0·833	−125·82	−30	625·75
	ef	25	15	1·67	−0·167	−1·245	0·3465	−30	933·75
Vertical	Aa	20	5	4	−77·5	−0·66	34·6	−20	264
	Bb	20	5	4	0	0	0	−20	0
	Cc	20	5	4	0	0	0	−20	0
	Dd	20	5	4	0	0	0	−20	0
	Ee	20	5	4	−72·5	−0·33	95·7	−20	132
							790·728		2301

$\therefore \delta_A = 790/E + 2301\alpha_t = 0{\cdot}0417$ foot (right)

Example 8.1 [Page 256 Norris]



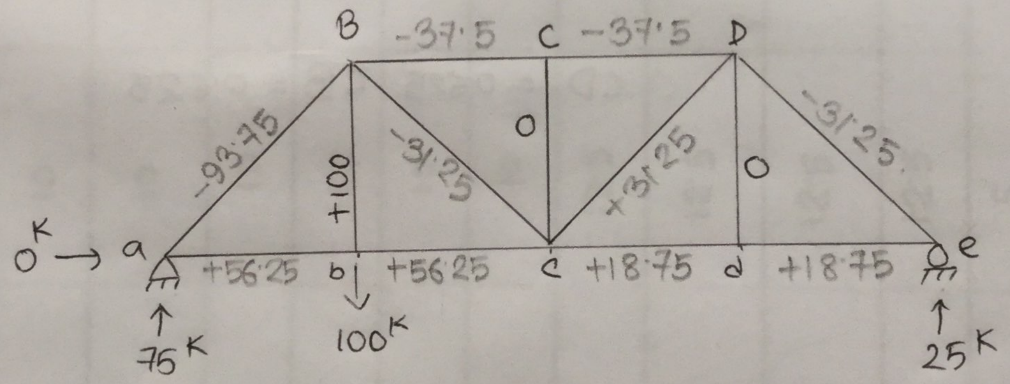
a) Compute the vertical component of deflection due to applied load 100^K shown. $E = 30 \times 10^3 \ kip/in^2$

b) Compute the vertical component of deflection of joint c, due to a decrease of temperature of 50°F in the bottom chord only.

$\alpha_t = 1/150{,}000$ per °F

Solution:

Step 1: Real Force analysis:



joint a, $\Sigma F_y = 0$

$$75 + F_{aB} \times \frac{20}{25} = 0.$$

$F_{aB} = -93.75$. $F_{ab} = 56.25$

$$\Sigma F_x = 0, \ 0 - 93.75 \times \frac{15}{25} + F_{ab} = 0$$

joint B, $\Sigma F_y = 0$

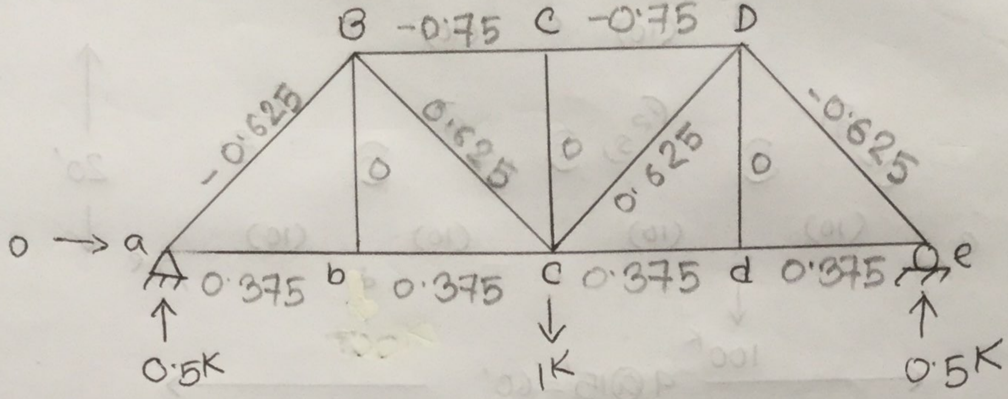
$$-F_{BC} \times 20/25 + 100 + (-93.75) \times \frac{20}{25} = 0.$$

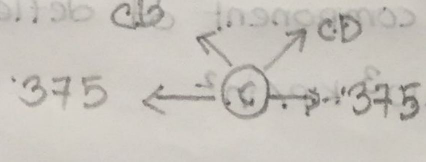
$F_{BC} = -31.25$

$\Sigma F_x = 0$ $F_{De} = -31.25$

$-F_{De} \times 15/25 - 18.75 = 0.$

Step: 2





$$\Sigma F_x = 0$$

$$-\cdot375 + \cdot375 + CD \times \frac{15}{25} - CB \times \frac{15}{25} = 0$$

$$CD \times 15 - CB \times 15 = 0$$

$$\Sigma F_y = 0$$

$$CB \times \frac{20}{25} + CD \times \frac{20}{25} - 1 = 0$$

$$CD \times 20 + CB \times 20 = 25$$

$$\therefore CD = 0{\cdot}625 \quad CB = 0{\cdot}625$$

	Bar	L	A	$\frac{L}{A}$	F_Q	F_P	$F_Q F_P \frac{L}{A}$	t	Fat
horizontal	ab	15	10	1·5	0·375	56·25	31·64	−50	−281·25
	bc	15	10	1·5	0·375	56·25	31·64	−50	−281·25
	cd	15	10	1·5	0·375	18·75	10·55	−50	−281·25
	de	15	10	1·5	0·375	18·75	10·55	−50	−281·25
	BC	15	10	1·5	−0·75	−0375	+42·19	0	0
	CD	15	10	1·5	−0·75	−37·5	+42·19	0	0
Diagonal	aB	25	12·5	2	−0·625	−93·75	+117·19	0	0
	Bc	25	12·5	2	+0·625	−31·25	−39·06	0	0
	cD	25	12·5	2	+0·625	+31·25	+39·06	0	0
	De	25	12·5	2	−0·625	−31·25	+39·06		
Vertical	Bb	20	5	4	0	+100	0	0	0
	Cc	20	5	4	0	0	0	0	0
	Dd	20	5	4	0	0	0	0	0
	Σ						325·01		−1125

a) $\sum Q d = \sum F_P F_Q \frac{L}{AE} + \sum F_Q t L \alpha_t$

$\Rightarrow 1 \cdot \delta_c = \frac{325 \cdot 01}{E} + 0$ [No temp. change]

$\therefore \delta_c = 0.0183$ ft (down)

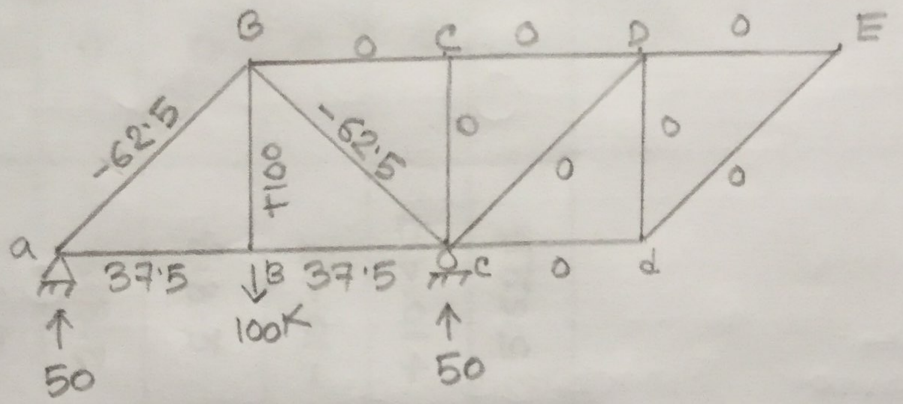
b) $\sum Q \cdot d = \sum F_Q t L \alpha_t$

$= -1125 \ast \frac{1}{150{,}000}$

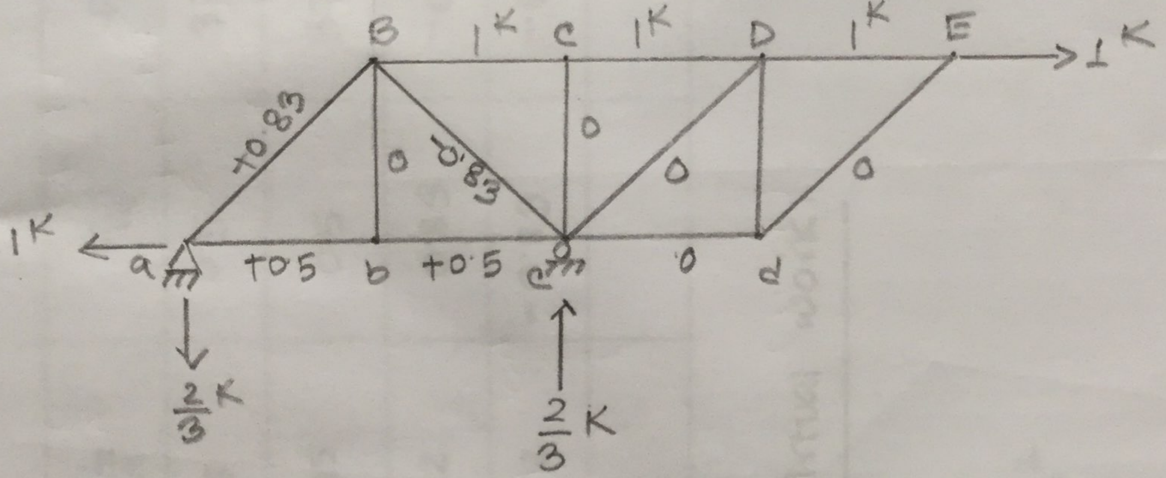
$\therefore \delta = -0.0075$ ft (upward)

...ple 8.2 [Page 258 Norris]

step: 1 Real Force Analysis



Step: 2 Virtual Force Analysis



Bar	L	A	$\frac{L}{A}$	F_Q	F_P	$F_Q F_P \frac{L}{A}$	F	$F_Q \varepsilon L$
ab	1·5	10	0·15	0·5	37·5	2·813	0	0
bc	1·5	10	0·15	0·5	37·5	2·813	0	0
aB	2·5	12·5	0·2	0·83	−62·5	−10·417	0	0
Bc	2·5	12·5	0·2	−0·83	−62·5	+10·417	0	0
Σ						5·625		0

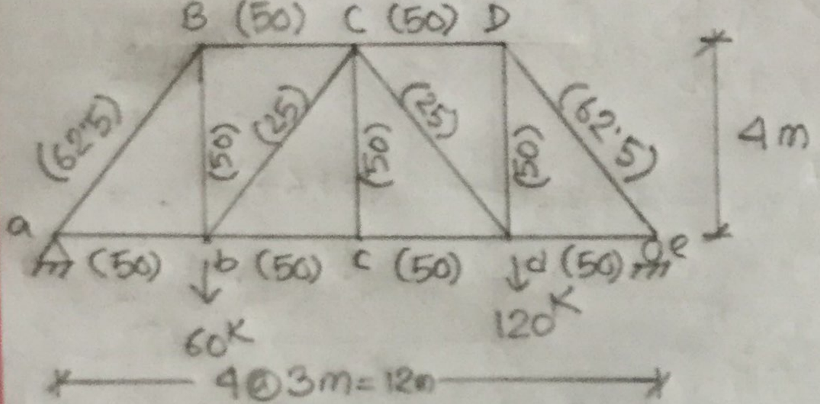
Step 3: Applying principles of virtual work:

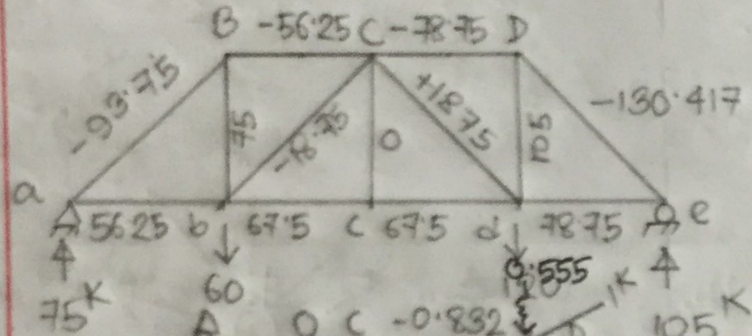
$$1.\partial_E = \frac{5.625}{E}$$

$$= \frac{5.625\ KN^2 m/cm^2}{20.7 \times 10^3\ Kn/cm^2}$$

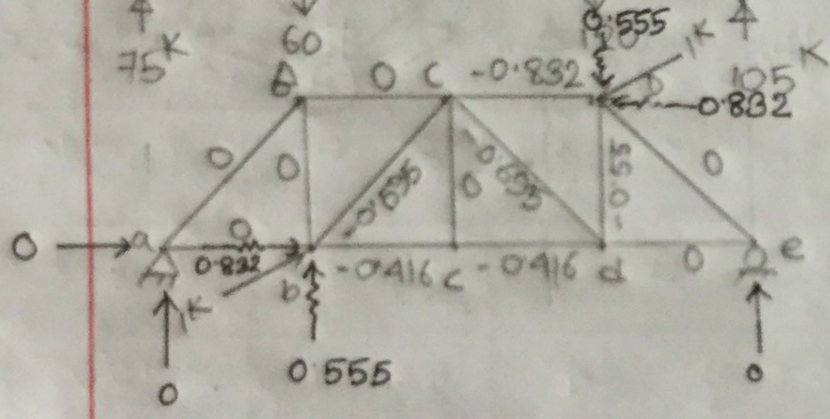
$$\therefore \partial_E = 0.00027174\ m \quad \text{(right)}$$

Example 8·4





$-0.832 \times 4 - x \times 4 = 0$



Position	Bar	L	A	L/A	Fq	Fp	Fq Fp L/A	t	Fq t L
Horizontal	ab	3	50	0.06	0	56.25	0	-10	0
Horizontal	bc	3	50	0.06	-0.416	67.5	-1.6848	-10	12.48
Horizontal	cd	3	50	0.06	-0.416	67.5	-1.6848	-10	12.48
Horizontal	de	3	50	0.06	0	78.75	0	-10	0
Horizontal	BC	3	50	0.06	0	-56.25	0	40	0
Horizontal	CD	3	50	0.06	-0.832	-78.75	3.9312	40	-99.84
Diagonal	aB	5	62.5	0.08	0	-93.75	0	0	0
Diagonal	bC	5	25	0.2	-0.693	-18.75	2.59875	0	0
Diagonal	Cd	5	25	0.2	0.693	18.75	2.59875	0	0
Diagonal	De	5	62.5	0.08	0	-130.417	0	0	0
Vertical	Bb	4	50	0.08	0	75	0	0	0
Vertical	Cc	4	50	0.08	0	0	0	0	0
Vertical	Dd	4	50	0.08	-0.55	105	-4.62	0	0
							1.1391		-74.88

a) $\sum Qd = \sum F_Q F_P \frac{L}{AE}$

$\Rightarrow 1^{KN}(\partial_b^{\nearrow}) + 1^{KN}(\partial_D^{\swarrow}) = \frac{1}{E} \times 1.1391$

$\Rightarrow 1^{KN}(\partial_{b-D}^{\rightarrow\leftarrow}) = \frac{1.1391}{20.7 \times 10^3}$

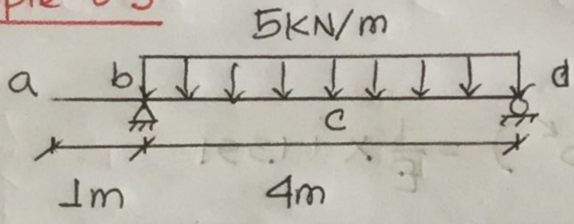
$\therefore \partial_{b-D}^{\rightarrow\leftarrow} = 5.5 \times 10^{-5}$ m (together).

b) $\sum Qd = \sum F_Q t L \alpha_t$

$1^{KN}(\partial_{b-D}^{\nearrow\swarrow}) = \frac{1}{75{,}000}(-74.88)$

$(\partial_{b-D}^{\nearrow\swarrow}) = -9.984 \times 10^{-4}$ m (apart)

Example 8·5

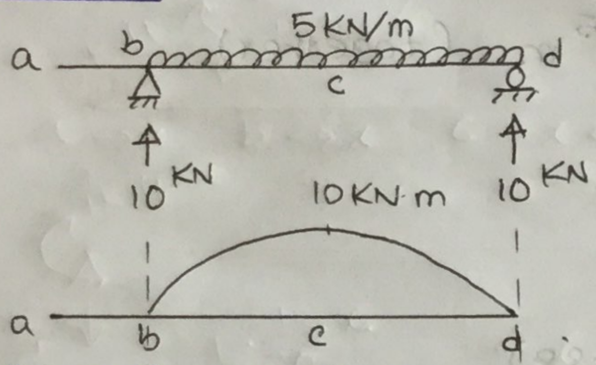


compute the vertical deflection of 'a' due to the load shown.

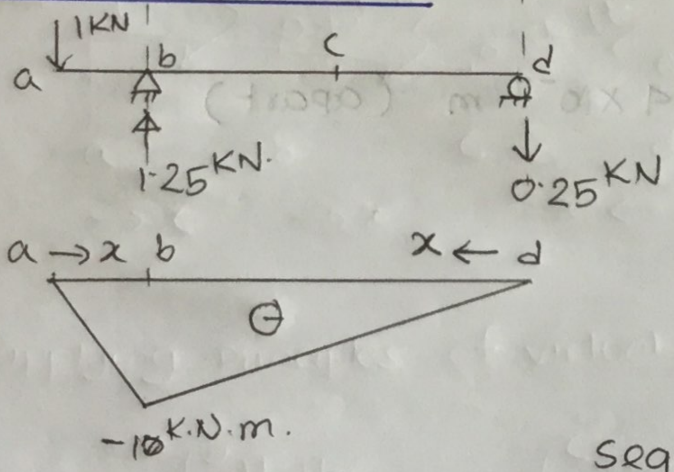
$E = 207 \times 10^3$ MPa

$I = 10^{-4}\ m^4$

Solution:



Virtual Force analysis:-



Segment	MQ	MP.
ab $0 < x \leq 5/5$	$-x$	0
db $0 < x \leq 20/5$	$-\frac{x}{4}$	$10x - 5x \cdot \frac{x}{2}$.

applying principles of virtual work:-

$$Q \cdot \delta = \int_a^b \frac{M_P M_Q}{EI} \, ds + \int_d^b \frac{M_P M_Q}{EI} \, ds$$

$$= 0 + \int_1^4 \frac{\left(10x - \frac{5x^2}{2}\right)\left(-\frac{x}{4}\right)}{EI} \, dx.$$

$$= \frac{1}{EI} \int_0^4 \left(-\frac{10x^2}{4} + \frac{5x^3}{8}\right) dx.$$

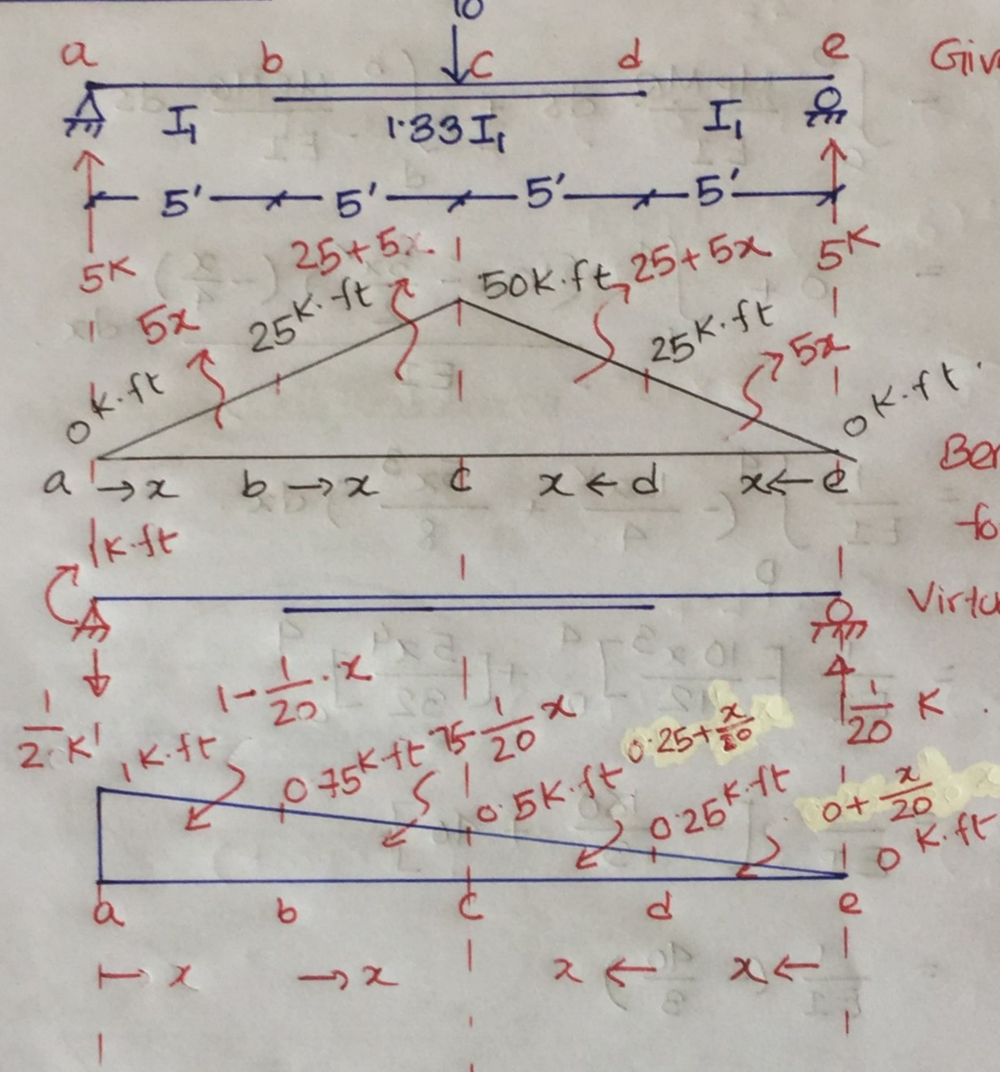
$$= \frac{1}{EI} \left[-\frac{10x^3}{12}\right]_0^4 + \left[\frac{5x^4}{32}\right]_0^4$$

$$= \frac{1}{EI} \left[-\frac{160}{3} + 40\right]$$

$$= \frac{1}{EI} \left(-\frac{40}{3}\right)$$

$$= -6.44 \times 10^{-4} \text{ m} \quad \therefore \text{upward}$$

Example 8·6 Compute Change in slope at 'a'



Given, $E = 30000\,ksi$

$I_1 = 150\ in^4$

$I_2 = 200\ in^4$

Bending moment for real Force

Virtual force analysis

Bending moment for virtual Force

applying principles of virtual work :-

$$1\,\alpha_a = \int_a^b \frac{M_P M_Q}{EI_1}dx + \int_b^c \frac{M_P M_Q}{EI_2}dx + \int_d^c \frac{M_P M_Q}{EI_2}dx + \int_e^d \frac{M_P M_Q}{EI_1}dx$$

$$= \int_a^b \frac{5x\left(1-\frac{x}{20}\right)}{EI_1}dx + \int_b^c \frac{(25+5x)\left(0{\cdot}75-\frac{x}{20}\right)}{EI_2}dx$$

$$+ \int_d^c \frac{(25+5x)\left(0{\cdot}25+\frac{x}{20}\right)}{EI_2}dx + \int_e^d \frac{5x\cdot\frac{x}{20}}{EI_1}dx.$$

$$= \frac{625}{12EI_1} + \frac{1375}{12 \times 1.33EI_1} + \frac{875}{12 \times 1.33EI_1} + \frac{125}{12EI_1}$$

$$= 0.0065 \text{ radian } (\therefore \text{ clockwise})$$

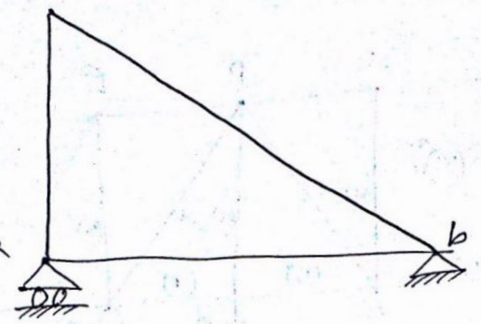
movement ↑↓

lecture-12

date - 11.04.17

Support settlement effect :-

Example - 8.3



given; following support movements

a তে reaction 1টা so
b তে R's 2টা so

@ 'a' vertical ~~horizontal~~ = 0.5" to ~~left~~ down

@ 'b' horizontal = ~~0.75"~~ ~~to down~~ 0.5" to left

@ 'b' vertical = 0.75" to down

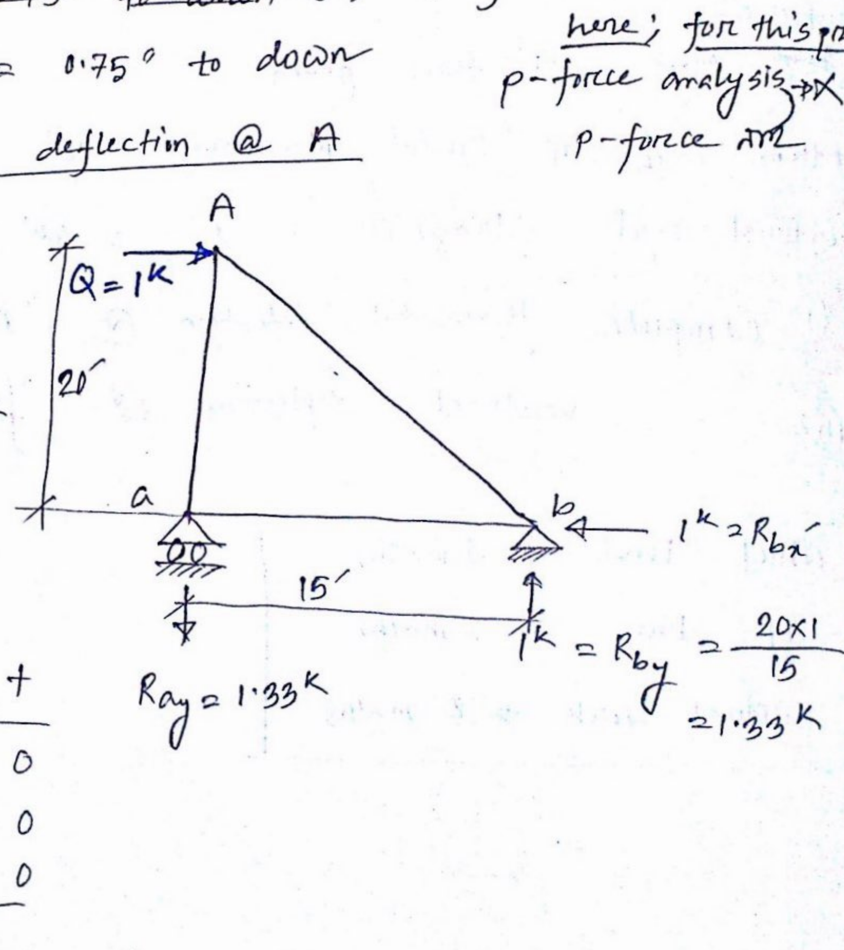
here; for this prob.
p-force analysis → X
p-force নাই

Compute horizontal deflection @ A

Q force analysis

Q force দিতে হবে A তে horizontal direction এ আমার

$Q = 1^k$



Table

bars	—	—	F_P	t
			0	0
			0	0
			0	0

Principle of virtual work (including support movements) :-

$$W_s = \Sigma Q \cdot \delta + W_R$$

W_R → external virtual work done by the reaction forces

For this problem,

$$W_s = W_{sL}$$

$$\Rightarrow Q \cdot \delta + W_R = \cancel{\Sigma \frac{F_Q F_P L}{EA}} + \cancel{\Sigma F_Q Q_t t L} = 0$$

0 (as $F_P = 0$) $\boxed{\text{but } F_Q \neq 0}$

0 (as $t = 0$)

$\boxed{Q_t \to \alpha_t}$

a তে R আসছে ↓ ← why
applied movement ↓
so (+)

fore converting into feet → why

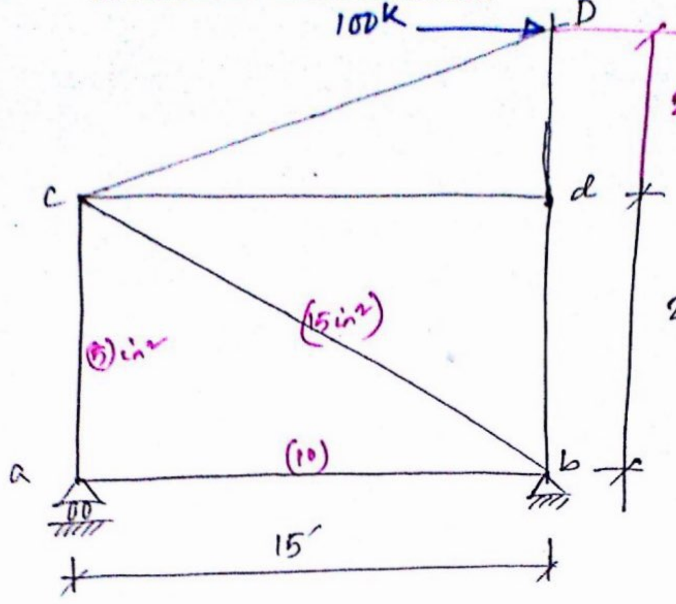
b তে R → ↑
applied → ↓ so (−)

$$\Rightarrow (1 * \delta_{Ah}) + (+1.33^k)\left(+\frac{0.25}{12}\right) + (+1^k)\left(+\frac{0.5}{12}\right) + (1.33^k)\left(-\frac{0.75}{12}\right) = 0$$

$$\therefore \boxed{\delta_{Ah} = +0.01375 \text{ ft}}$$

Assign #19

VVI math



$E = 30,000$ ksi

$\alpha_t = \frac{1}{1,50,000}$

Temp. change,

vertical member = 40°F decrease

Diagonal " = 50°F increase

support movement

@ 'a' vertical = 0.8″ upward

@ "b" horizontal = 0.3″ to right

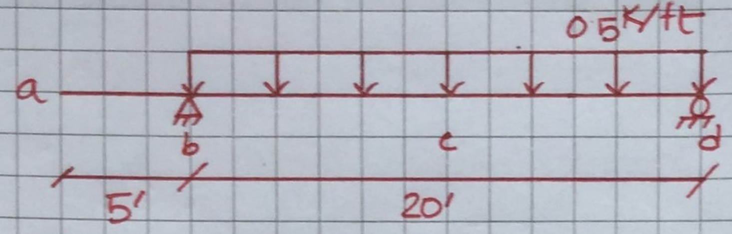
@ "b" vertical = 0.9″ down

Q. → Compute horizontal deflection @ D

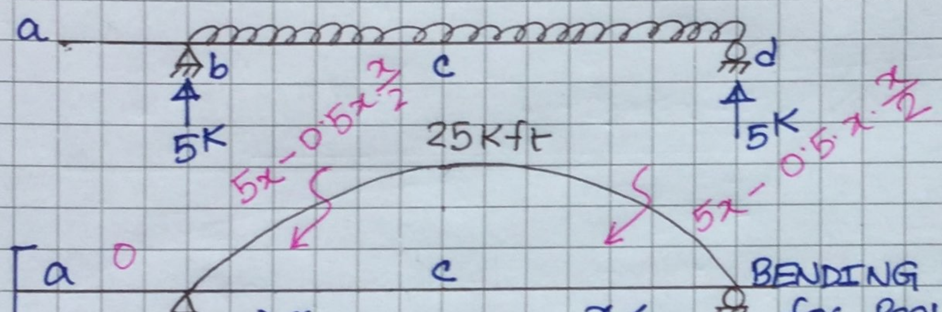
and vertical " @ D

Assignment - 19

Given, $E = 30{,}000$ Ksi. $I = 200 \text{ in}^4$. Compute change in slope at 'a' and deflection at C.

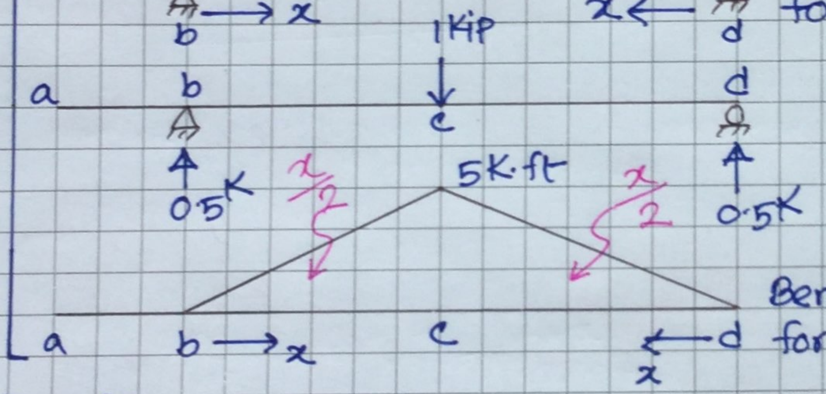


Solution: <u>Real force analysis:</u>



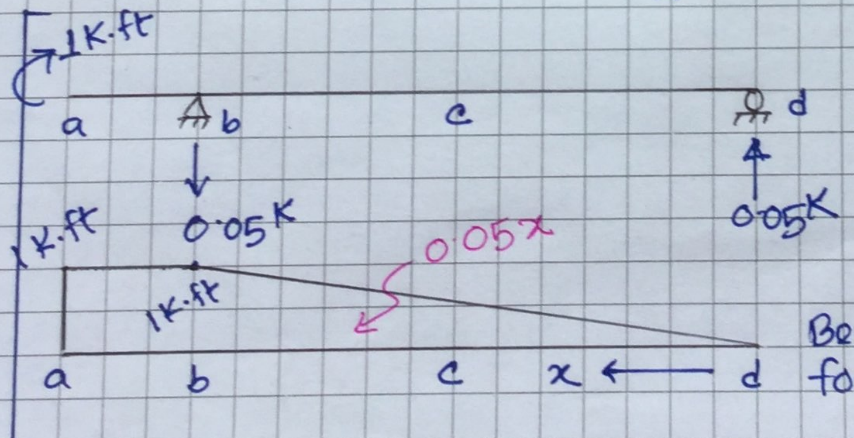
BENDING Moment Diagram for Real Force Analysis

Virtual Force Analysis.



Bending moment diagram for virtual force at C

Virtual Force Analysis



Bending moment diagram for virtual moment at 'a'

Change in slope at 'a'

$$Q\alpha_A = \cancelto{0}{\int_a^b \frac{M_P M_Q}{EI}\,dx} + \int_d^b \frac{M_P M_Q}{EI}\,dx$$

$$= \int_0^{20} \frac{\left(5x - 0.5\frac{x^2}{2}\right)(0.05x)}{EI}\,dx$$

$$= \frac{1}{EI} \times \frac{500}{3}$$

$$= \frac{1}{(30000 \times 144) \times (200/144^2)} \times \frac{500}{3}$$

$$\alpha_A = 4\times10^{-3} \text{ radian } (\therefore \text{ clockwise})$$

deflection at C:

$$Q\cdot\partial_C = \cancelto{0}{\int_a^b \frac{M_P M_Q}{EI}\,dx} + \int_b^c \frac{M_P M_Q}{dx}\,dx + \int_d^c \frac{M_P M_Q}{EI}\,dx$$

$$= \int_0^{10} \frac{\left(5x - 0.5\frac{x^2}{2}\right)\left(\frac{x}{2}\right)}{EI}\,dx + \int_0^{10} \frac{\left(5x - 0.5\frac{x^2}{2}\right)\left(x/2\right)}{EI}\,dx.$$

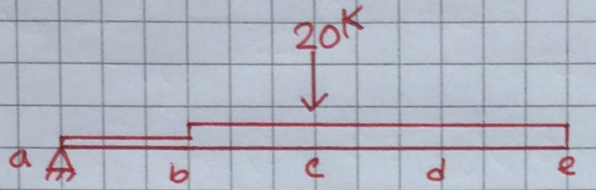
$$= 2\int_0^{10} \frac{\left(5x - 0.5\frac{x^2}{2}\right)\left(\frac{x}{2}\right)}{EI}\,dx$$

$$= \frac{2}{EI} \times \frac{3125}{6}$$

$$\partial_C = 0.025\text{ ft} \;\therefore (\text{down})$$

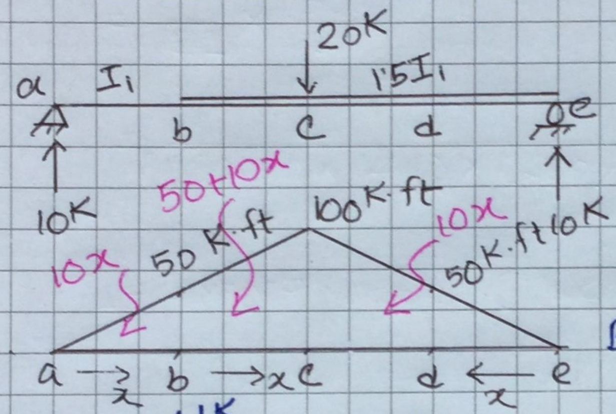
Assignment-20

Compute deflection at 'b' and change in slope at e for the following beam shown. Given that, $E = 30000$ Ksi, $I_1 = 200\ in^4$ $I_2 = 300\ in^4$

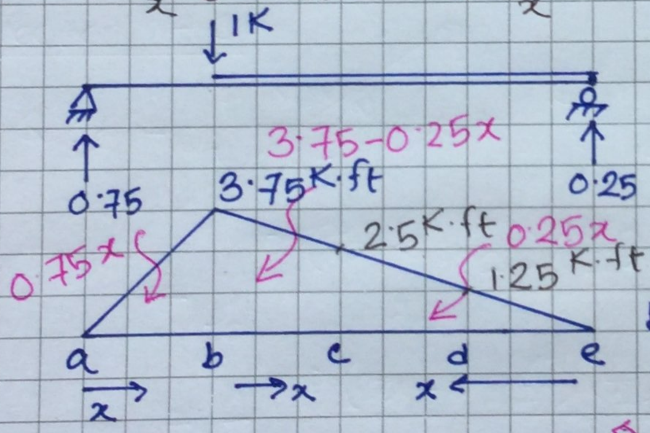


Solution:

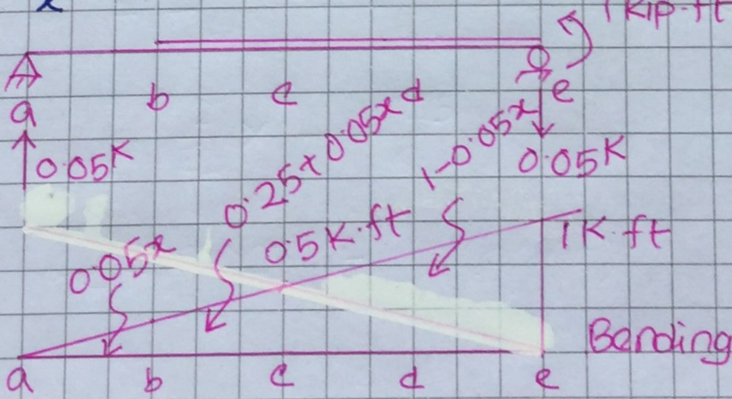
Real Force analysis:



Bending moment for Real Force



Bending moment for virtual force 'b'



Bending moment for virtual moment @ e

Deflection at 'b'

$$Q \cdot \partial_B = \int_a^b \frac{M_P M_Q}{EI_1} dx + \int_b^c \frac{M_P M_Q}{EI_2} dx + \int_e^c \frac{M_P M_Q}{EI_2} dx$$

$$= \int_0^5 \frac{(10x)(0.75x)}{EI_1} dx + \int_0^5 \frac{(50+10x)(3.75-0.25x)}{EI_2} dx$$

$$+ \int_0^{10} \frac{(10x)(0.25x)\,dx}{EI_2}$$

$$= \frac{1}{EI_1} \times \frac{625}{2} + \frac{1}{EI_2} \times \frac{6875}{6} + \frac{2500}{3} \times \frac{1}{EI_2}$$

$= 0.039167$ ft ($\therefore$ down)

change in slope at 'e'

$$Q \cdot \alpha_e = \int_a^b \frac{M_P M_Q}{EI_1} dx + \int_b^c \frac{M_P M_Q}{EI_2} dx + \int_e^c \frac{M_P M_Q}{EI_2} dx$$

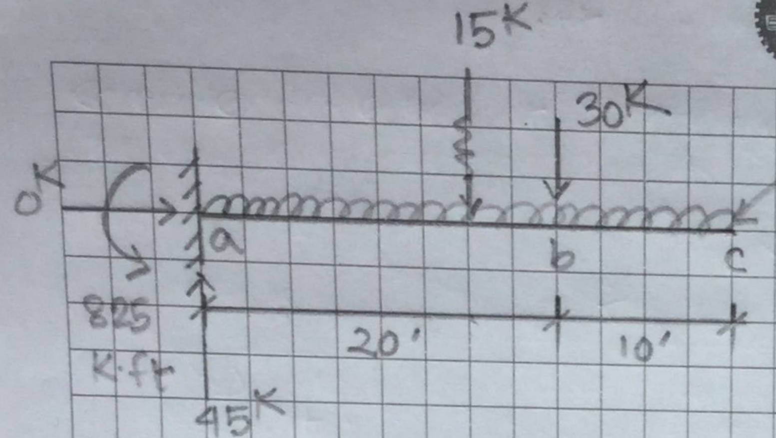
$$= \int_0^5 \frac{(10x)(0.05x)}{EI_1} dx + \int_0^5 \frac{(50+10x)(0.25+0.05x)}{EI_2} dx$$

$$+ \int_0^{10} \frac{(10x)(1-0.05x)}{EI_2} dx$$

$$= \frac{1}{EI_1} \times \frac{125}{6} + \frac{1}{EI_2} \times \frac{875}{6} + \frac{1}{EI_2} \times \frac{1000}{3}$$

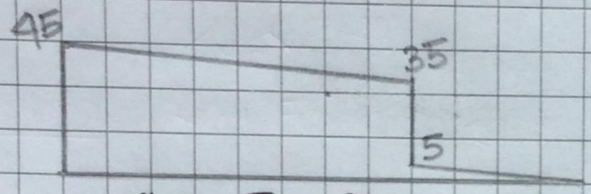
$= 0.012$ radian ($\therefore$ clockwise)

Assignment-21

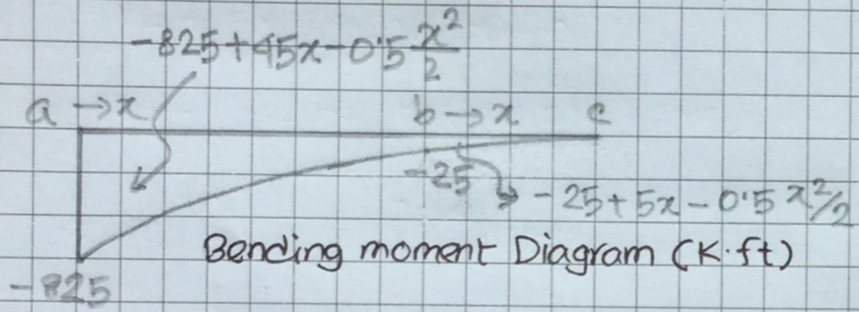


Compute
a) deflection at 'c'
b) change in slope at 'c'
c) deflection at 'b'

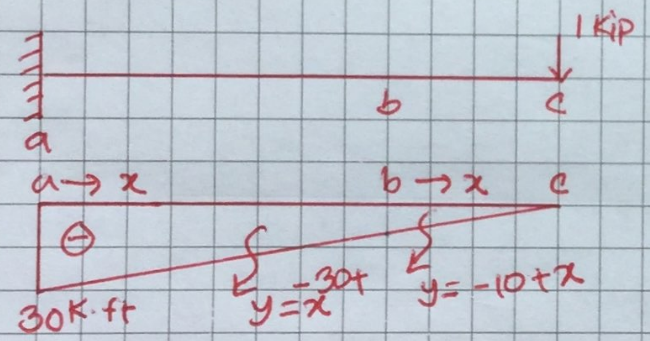
Given $E = 30000\,ksi$ $I = 200\,in^4$



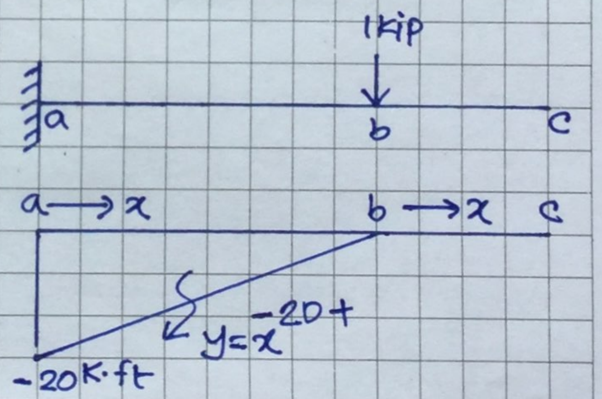
Shear Force Diagram (K)



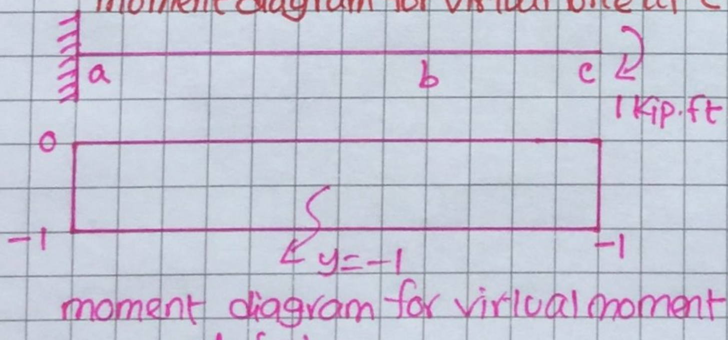
Bending moment Diagram (K·ft)



moment diagram for virtual force at 'c'



moment diagram for virtual force at 'b'



moment diagram for virtual moment at 'c'

39 SQUARE HOUSE 33 SQUARE HOUSE, WIDE 7.88" TALL 9.32". WIDE 200.01mm x TALL 234.50mm

Deflection at C:

$$Q \cdot \partial_c = \int_a^b \frac{M_P M_Q}{EI} dx + \int_b^c \frac{M_P M_Q}{EI} dx$$

$$= \int_0^{20} \frac{(-825 + 45x - 0.5 \frac{x^2}{2})(-30+x)}{EI} dx + \int_0^{10} \frac{(-25+5x-0.5\frac{x^2}{2})(-10+}{EI} dx$$

$$= \frac{190{,}000}{EI} + \frac{625}{EI}$$

$$= \frac{190625}{EI} = 4.575 \text{ ft (down)}$$

Change in slope at C:

$$Q \cdot \alpha_c = \int_a^b \frac{M_P M_Q}{EI} dx + \int_b^c \frac{M_P M_Q}{EI} dx$$

$$= \int_0^{20} \frac{(-825+45x-0.5\frac{x^2}{2})(-1)}{EI} dx + \int_0^{10} \frac{(-25+5x-0.5\frac{x^2}{2})(-1)}{EI} dx$$

$$= \frac{1}{EI}\left(\frac{24500}{3} + \frac{250}{3}\right)$$

$$= \frac{24750}{3EI}$$

$$= 0.198 \text{ radian (clockwise)}$$

Deflection at 'b':

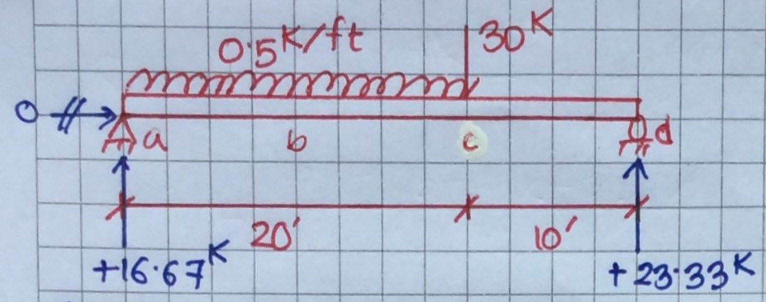
$$Q \cdot \alpha_b = \int_a^b \frac{M_P M_Q}{EI} dx + \cancelto{0}{\int_b^c \frac{M_P M_Q}{EI} dx}$$

$$= \int_0^{20} \frac{325000}{3EI}$$

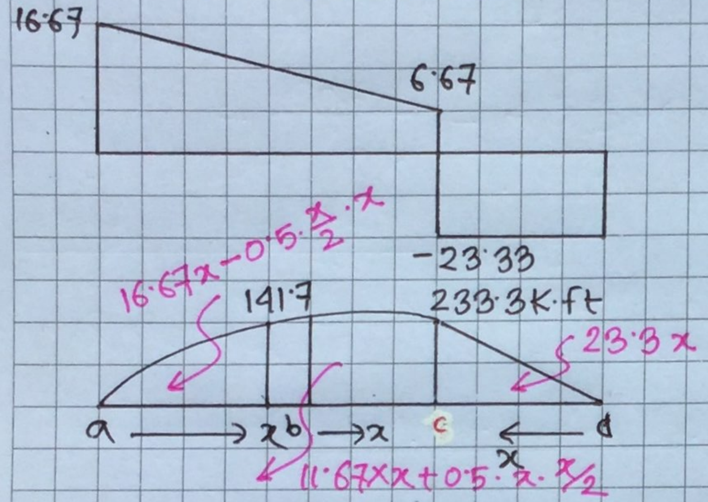
$$= 2.6 \text{ ft (}\therefore\text{ down)}$$

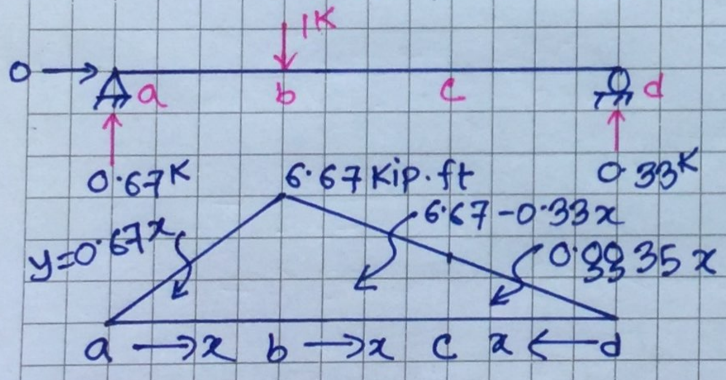
Assignment -22

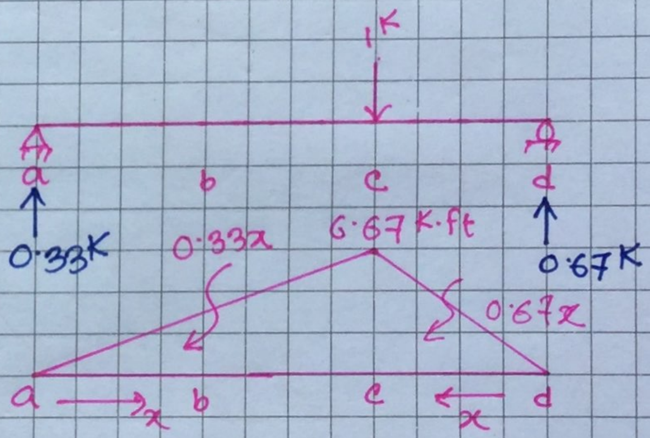
Given $E = 30000$ ksi, $I = 200\ in^4$. Compute
a) deflection at 'b'
b) deflection at 'c'
c) change in slope at 'a'
d) change in slope at d



Solution: Real Force Analysis:







deflection at 'b'

$$Q\cdot\partial_b = \int_{a=0}^{b=10}\frac{(16.67x-0.5\frac{x^2}{2})(0.67x)}{EI}dx + \int_0^{10}\frac{(141.7+11.67x-0.5\times x^2/2)(6.67-0.33x)}{EI}dx$$

$$1\cdot\partial_b = \frac{3304.2167}{EI} + \frac{9682.5}{EI} + \frac{2563}{EI} + \int_0^{10}\frac{(23.3x)(0.33x)}{EI}dx$$

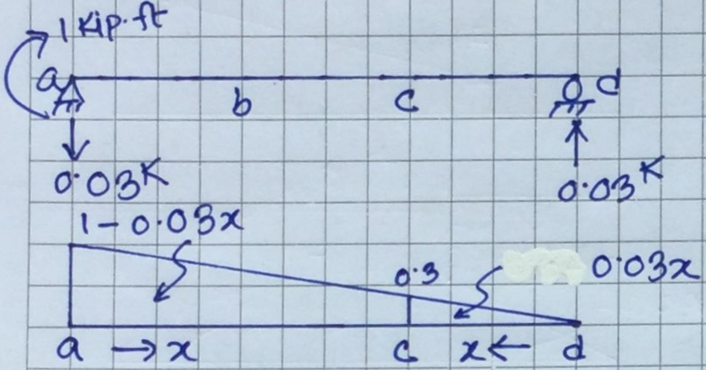
$$\partial_b = 0.373\text{ ft (Ans:)}$$

$$Q\cdot\partial_C = \int_0^{20}\frac{(16.67x - 0.5\times x\times x\times 1/2)(0.33x)}{EI}\,dx + \int_0^{10}\frac{(23.3x)(0.67x)}{EI}\,dx$$

$$= \frac{11369.6}{EI} + \frac{5203.67}{EI}$$

$$= 0.39 \text{ ft (down)}$$

<u>change in slope at 'a'</u>

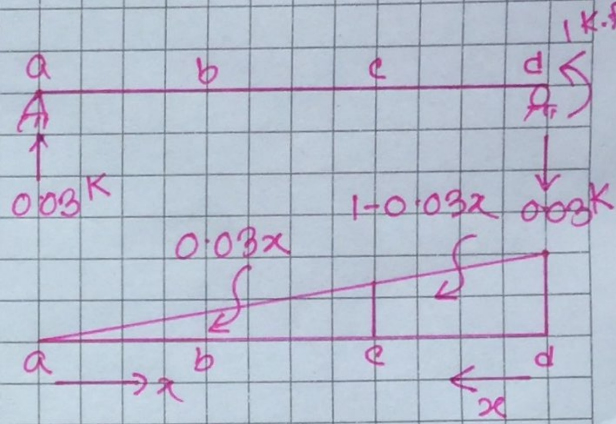


$$Q\cdot\alpha_A = \int_0^{20}\frac{(16.67x - 0.5x^2/2)(1-0.03x)}{EI}\,dx + \int_0^{10}\frac{(23.3x)(0.03x)}{EI}\,dx$$

$$= 0.0392 + 0.005592$$

$$= 0.044792 \text{ ft (clockwise)}$$

<u>change in slope 'd'</u>

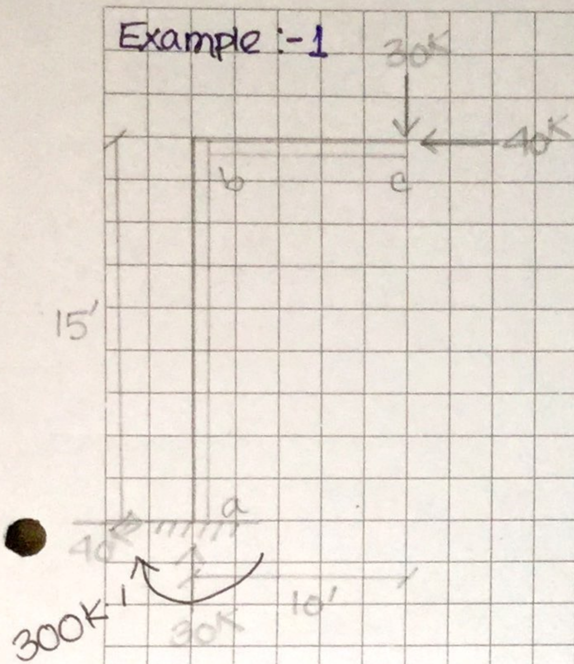


$$Q\cdot\alpha_d = 0.0248064 + 0.022368$$

$$= 0.04717 \text{ radian (anticlockwise)}$$

VIRTUAL WORK METHOD FOR FRAMES

Example :- 1

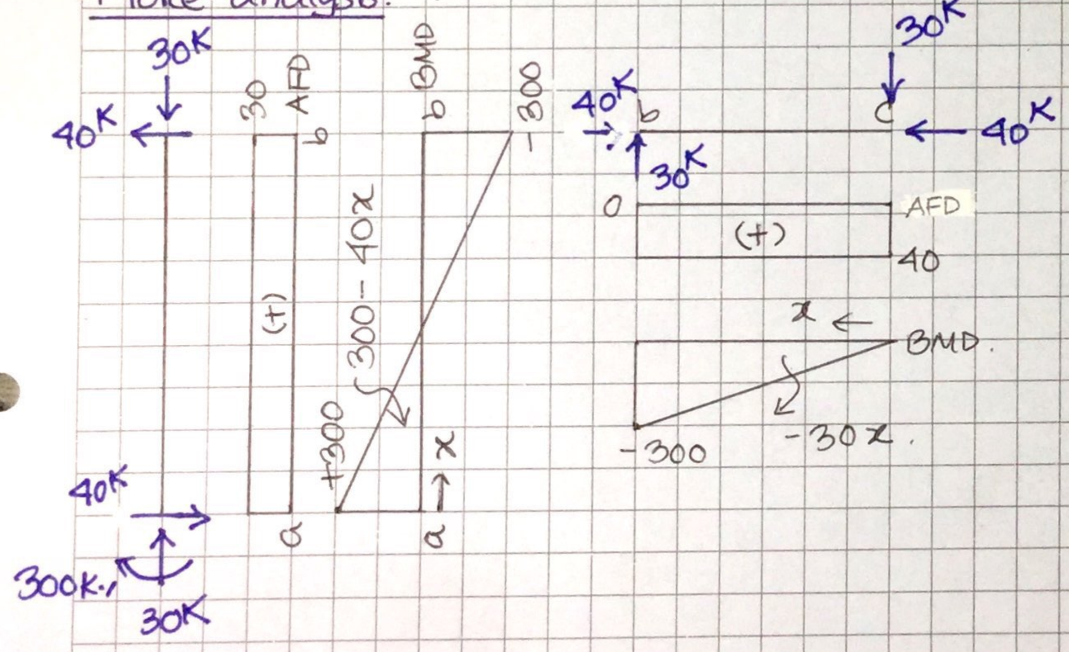


Compute Change in slope at 'C'.
vertical deflection at 'C'

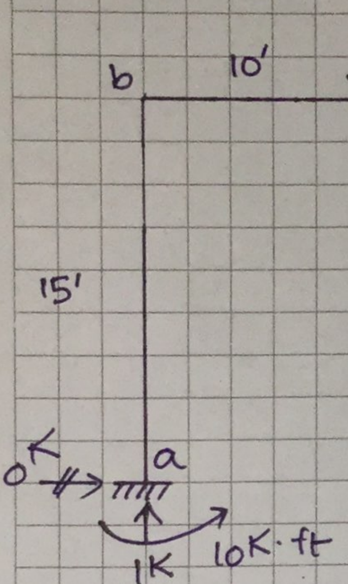
Given, $E = 30\,000$ ksi, $A_{col} = 12\,in^2$, $I_{col} = 300\,in^4$
$A_{beam} = 10\,in^2$, $I_{beam} = 200\,in^4$

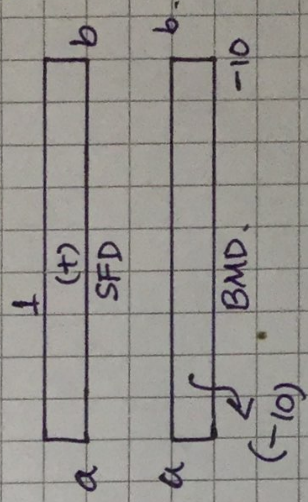
Solution:-

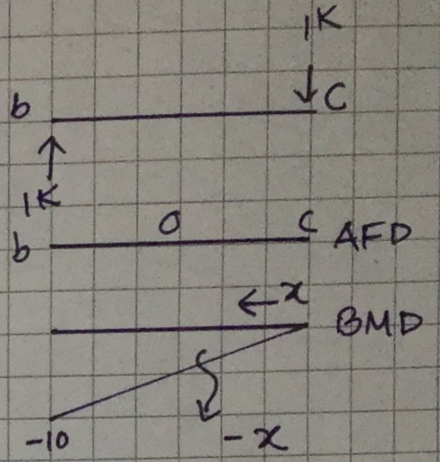
P force analysis:



Q force Analysis: For Vertical Deflection at 'c'







Applying Principles of Virtual Work:-

$$\Sigma Q \cdot \partial = \left(\frac{F_P F_Q L}{EA}\right)_{ab} + \cancel{\left(\frac{F_P F_Q L}{EA}\right)_{bc}}^{\,0} + \int_a^b \frac{M_P M_Q}{EI}\,dx + \int_b^c \frac{M_P M_Q}{EI}\,dx.$$

$$= \frac{(+30)(+1)(15')}{30000 \times 12} + 0 + \int_0^{15} \frac{(300-40x)(-10)}{EI}\,dx + \int_0^{10} \frac{(-30x)(x)}{EI}\,dx$$

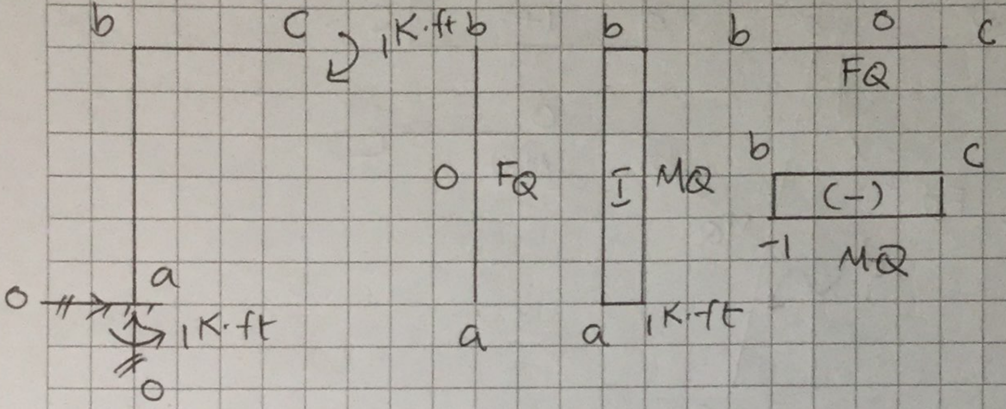
$$= \frac{1}{800} + 0 + \frac{6}{25}$$

$$= 0.2412 \text{ ft}$$

[Ans:]

Change in slope at 'C')

Q force analysis:



$$\therefore Q\cdot\alpha_c = \sum F_P F_Q L/AE + \sum F_Q t L \alpha_t + \int M_P M_Q / EI \, dx$$

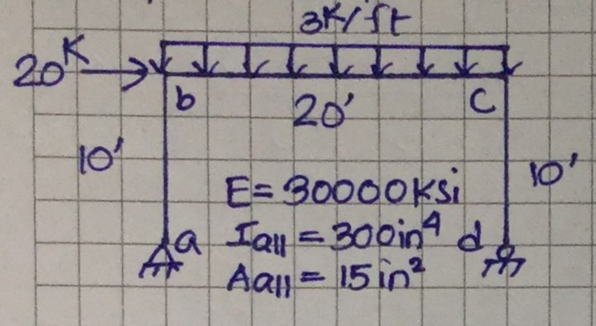
$$= \int_a^b \frac{M_P M_Q}{EI} dx + \int_b^c \frac{M_P M_Q}{EI} dx$$

$$= \int_0^{20} \frac{(-800)(-1)}{30000 \times \frac{300}{144}} dx + \int_0^{10} \frac{(-300-50x)(-1)}{30000 \times \frac{200}{144}} dx$$

$$= \frac{32}{125} + \frac{33}{250}$$

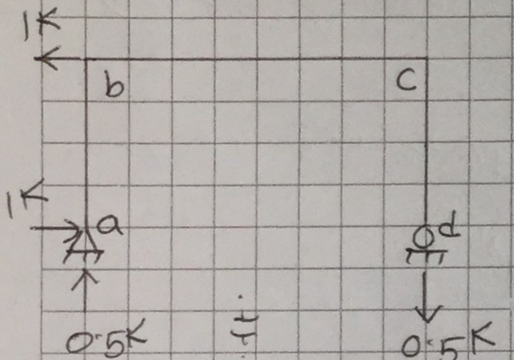
$= 0.388$ radian (clockwise)

Example 2: Compute horizontal deflection at joint 'b'

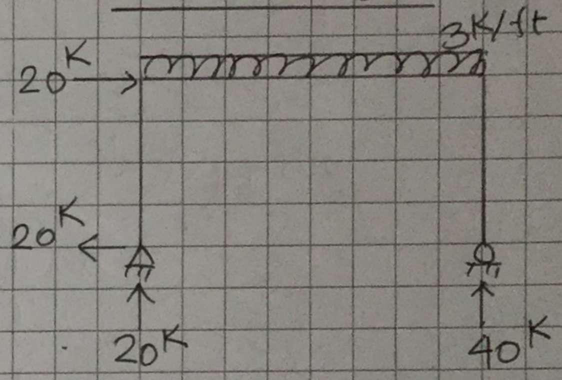


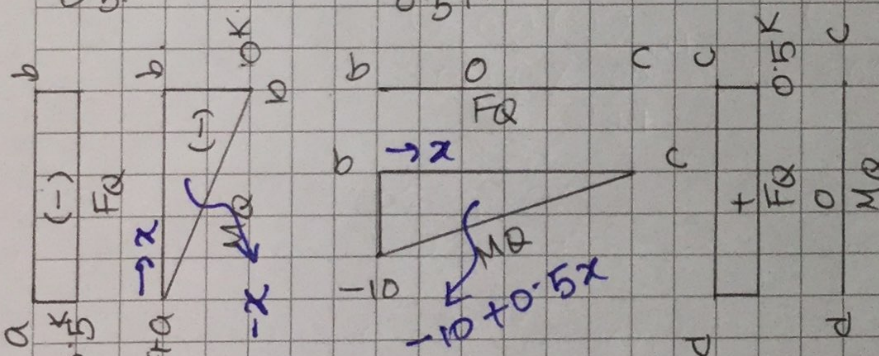
Compute horizontal deflection at joint 'b'

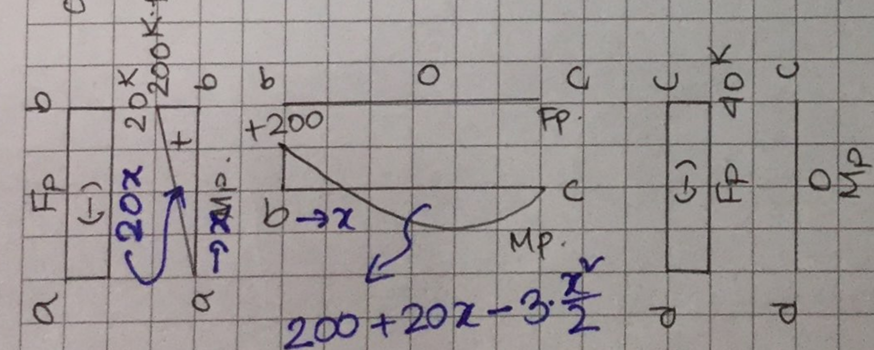
Q force Analysis:



P force analysis:





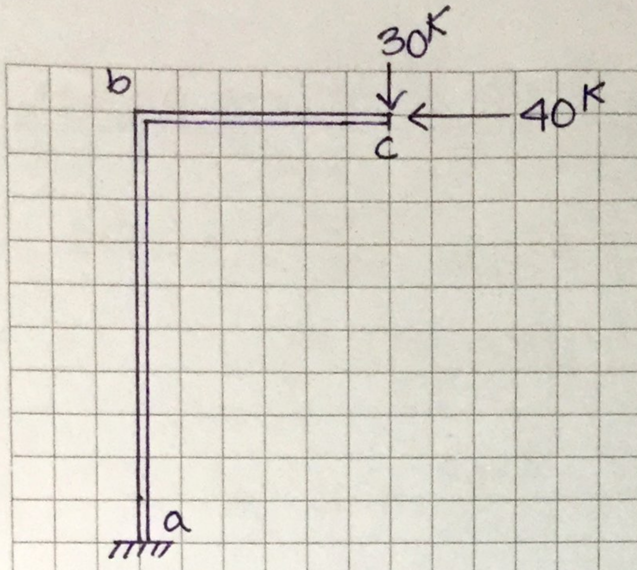


$$Q \times \partial_b = \frac{(-0.5)\times(-20)\times 10}{15\times 30\times 10^3} + \frac{(+0.5)(-40)\times 10}{15\times 30\times 10^3} + \int_0^{10} \frac{(20x)(-x)}{30\times 10^3 \times \frac{300}{144}}\,dx + \int_0^{20} \frac{(10+0.5x)\left(200+20x-\frac{3x^2}{2}\right)}{30\times 10^3\times\frac{300}{144}}$$

$$= \frac{1}{4500} + \frac{-1}{2250} - \frac{8}{75} - \frac{28}{75}$$

$= -0.48$ ft ($\therefore$ right)

Assignment - 23



Compute change in slope at c.

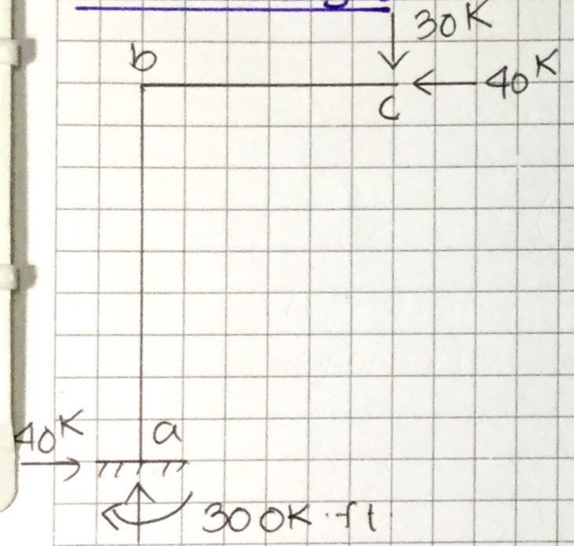
Given, $E = 30000$ Ksi

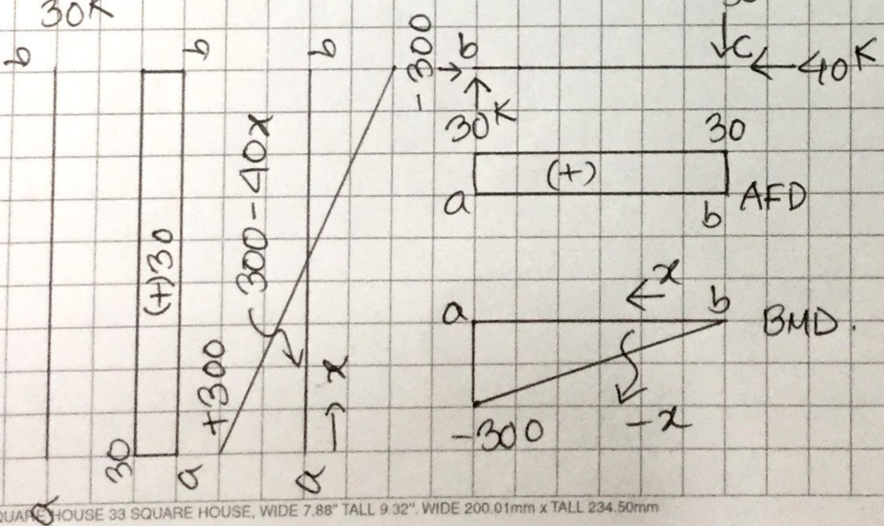
$A_{ab} = 12\ in^2 \quad A_{bc} = 10\ in^2$

$I_{ab} = 300\ in^4 \quad I_{bc} = 200\ in^4$

Solution:-

P force analysis:



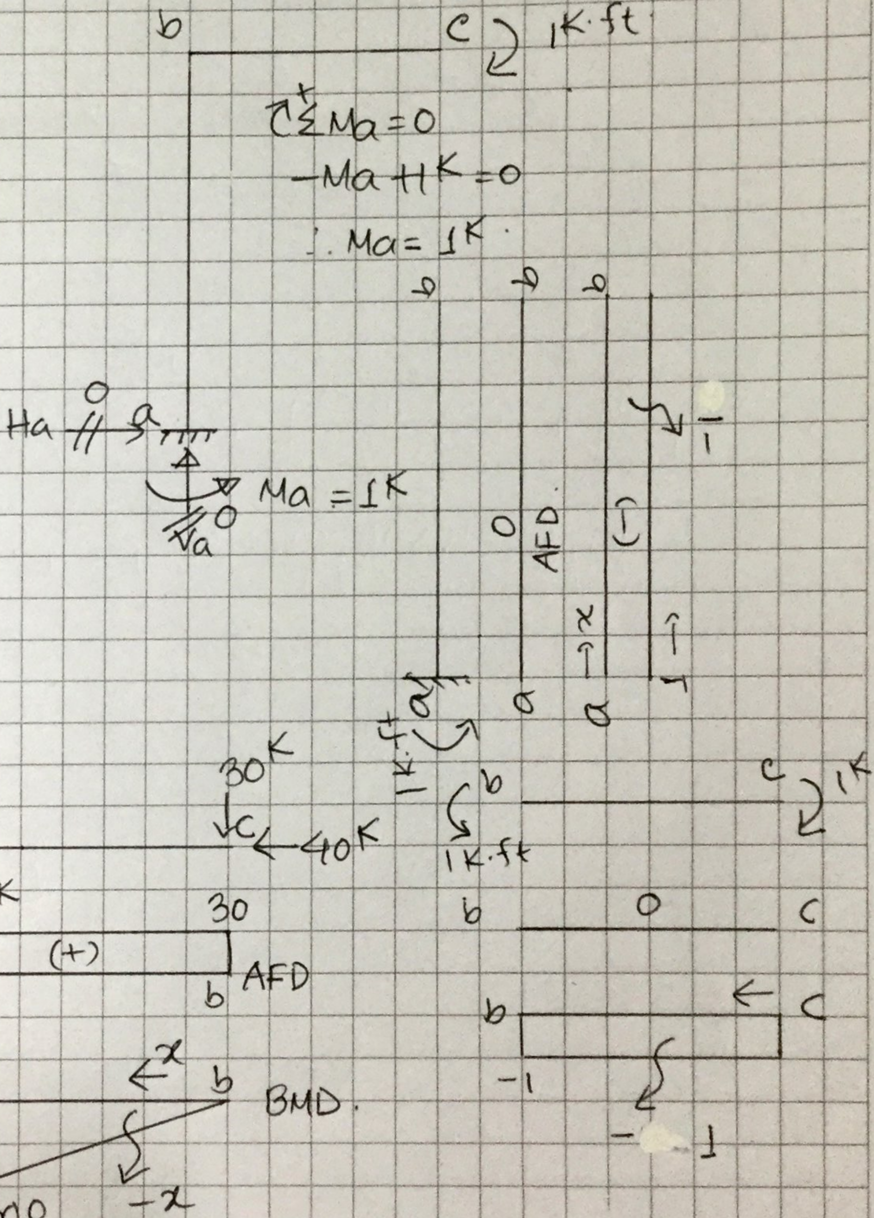


Q-force analysis:

$\overset{+}{\circlearrowleft} \sum M_a = 0$

$-M_a + 1^K = 0$

$\therefore M_a = 1^K$



Applying principles of virtual work:

$$\Sigma Q \cdot \delta = \left(\cancel{\frac{F_P F_Q L}{EA}}\right)_{ab}^{0} + \left(\cancel{\frac{F_P F_Q L}{EA}}\right)_{bc}^{0} + \int_0^{15} \frac{M_P M_Q}{EI}\,dx + \int_0^{10} \frac{M_P M_Q}{EI}\,dx$$

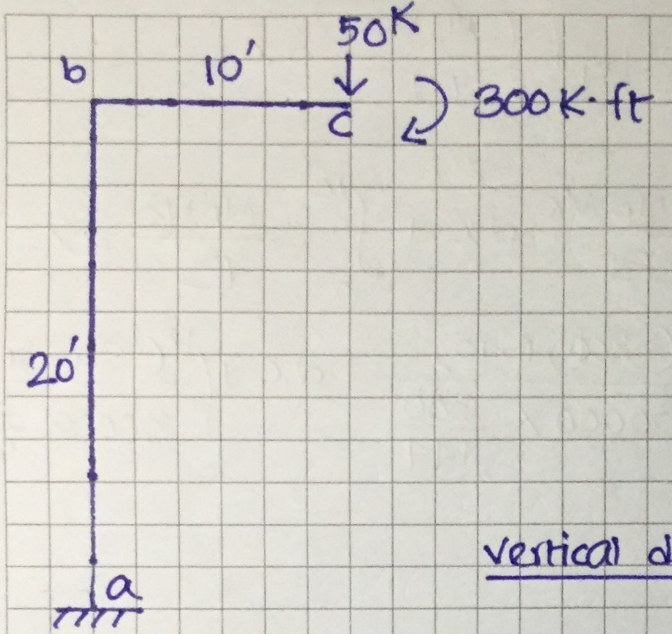
$$= \int_0^{15} \frac{(300-40x)(-1)}{EI}\,dx + \int_0^{10} \frac{(-x)(-1)}{EI}\,dx$$

$$= 0 + \frac{50\times 3}{125000} = \frac{3}{2500}$$

$$= 1.2\times 10^{-3} \text{ radian } (\therefore \text{clockwise})$$

[Ans:]

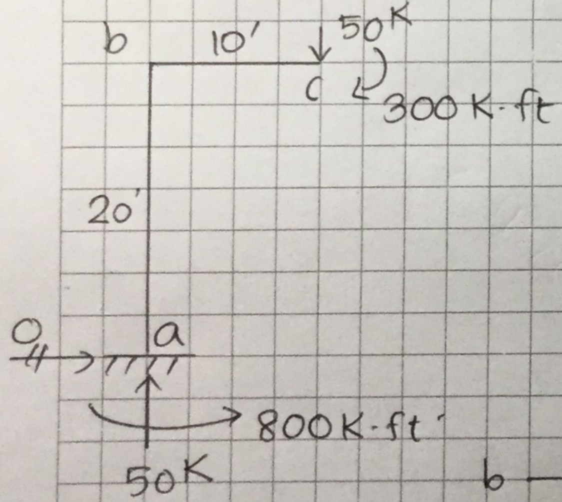
Assignment 24



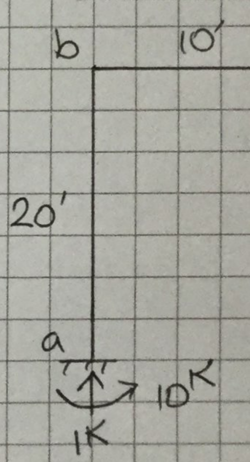
Compute vertical deflection at c
b) change in slope at c
c) horizontal deflection at 'b'

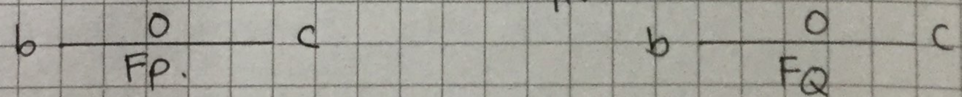
vertical deflection at 'c'

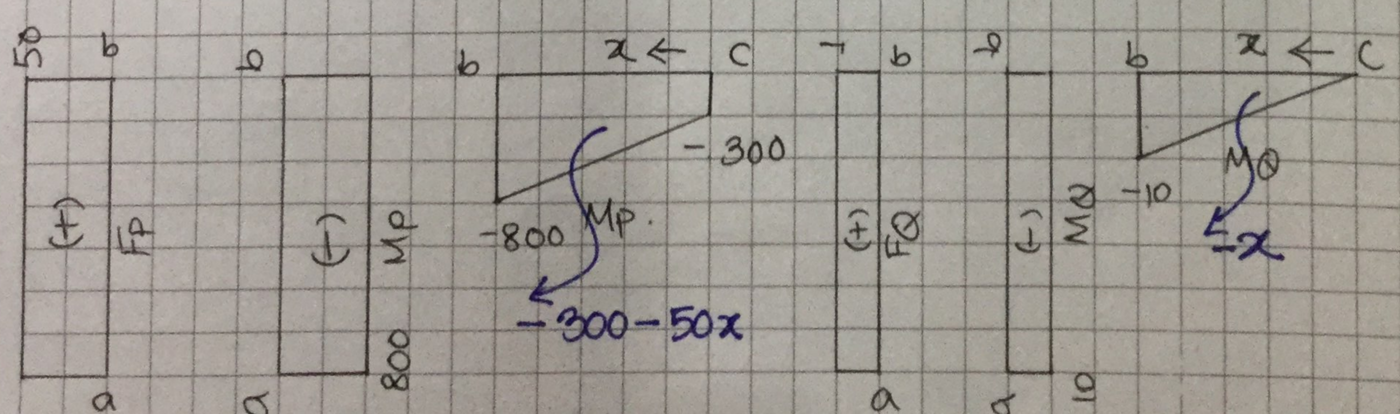
P force analysis:



Q force analysis:







$$Q\,\partial_c = \sum \frac{F_P F_Q L}{AE} + \sum F_Q t L \alpha_t + \int \frac{M_P M_Q}{EI}\,dx$$

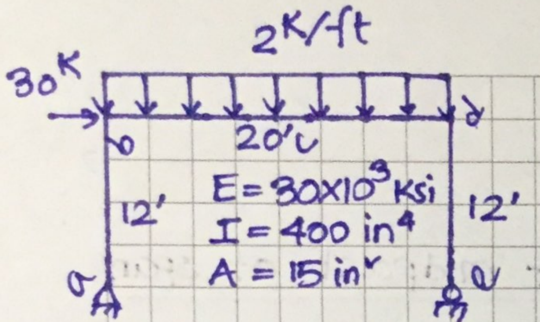
$$= \left(\frac{F_P F_Q L}{AE}\right)_{ab} + \int_0^{20} \frac{M_P M_Q}{EI}\,dx + \int_0^{10} \frac{M_P M_Q}{EI}\,dx.$$

$$= \frac{50 \times 1 \times 20}{12 \times 30000} + \int_0^{20} \frac{(-800)(-10)}{30000 \times \frac{300}{144}}\,dx + \int_0^{10} \frac{(-300-50x)(-x)}{30000 \times \frac{200}{144}}\,dx$$

$$= \frac{1}{360} \pm \frac{64}{25} + \frac{19}{25}$$

$$= 3.32 \text{ ft.}$$

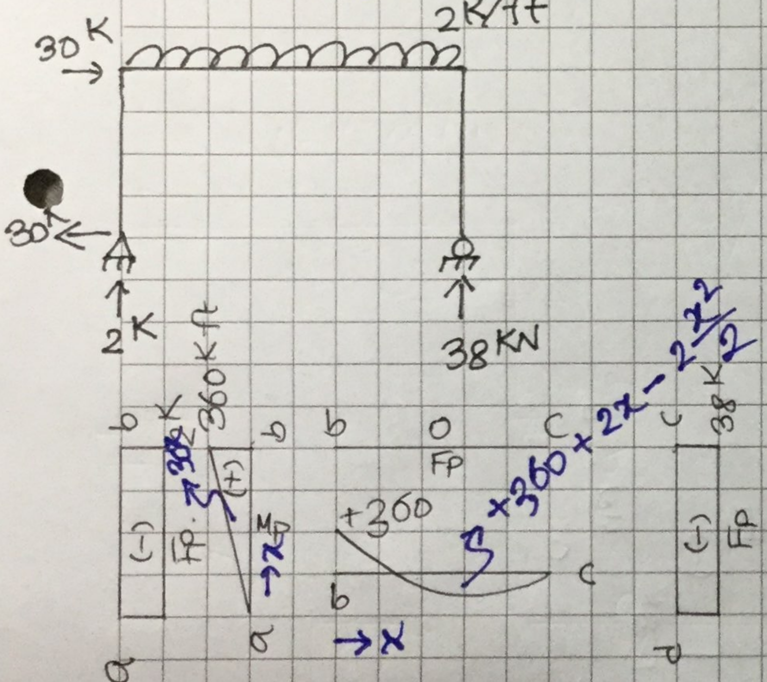
Assignment 25



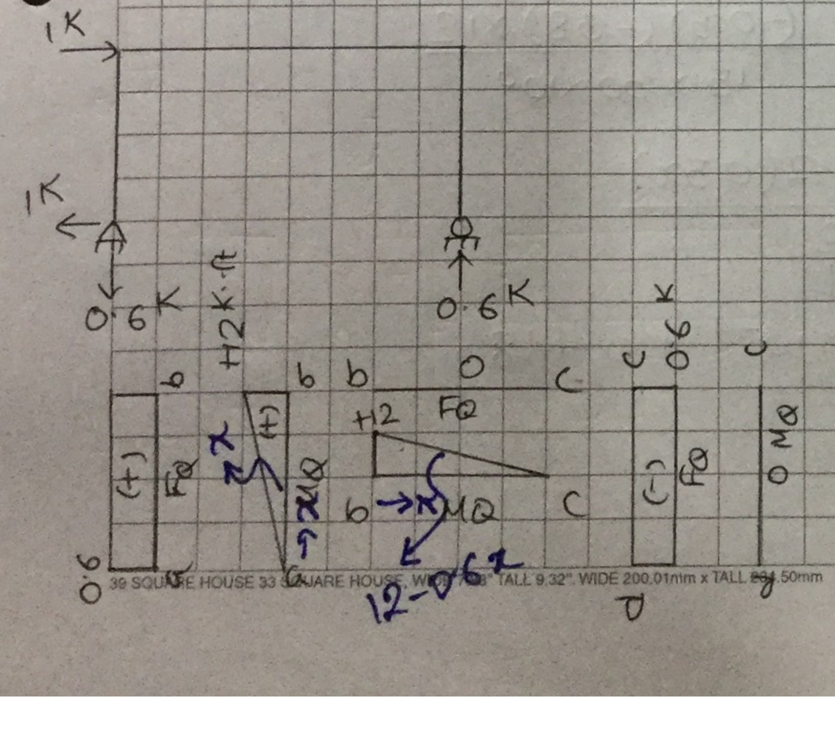
Compute Horizontal Deflection at 'b' and vertical deflection at the midpoint of beam

horizontal deflection at 'b'

P foce Analysis:



Q focrce Analysis:

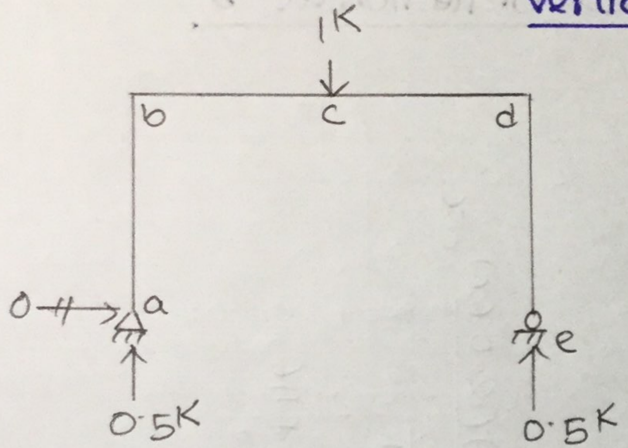


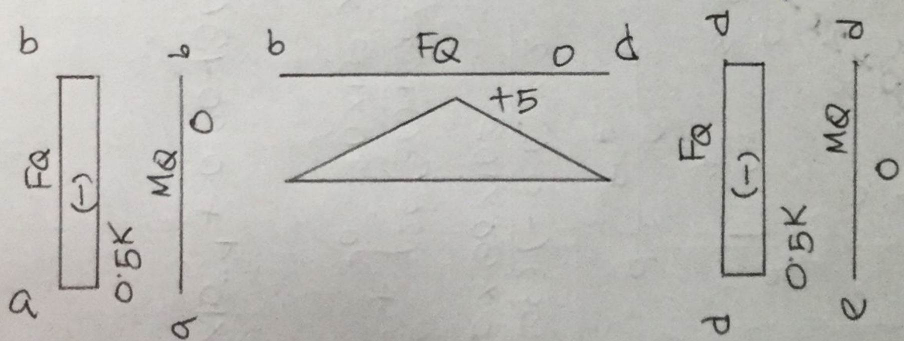
$$Q\partial_b = \frac{(-2)(+0.6)\,12}{30\times10^3\times15} + \frac{(-38)(-0.6)\times12}{15\times30\times10^3} + \frac{\int_0^{12}(30x)(x)\,dx}{30\times10^3\times\frac{400}{144}} + \int_0^{20}\frac{\left(360+2x-2\frac{x^2}{2}\right)(12-0.6x)}{30\times10^3\times\frac{400}{144}}\,dx$$

$$= -32\times10^{-6} + 6.08\times10^{-4} + 0.20736 + 0.4416$$

$$= 0.649536 \text{ ft}$$

vertical deflection at midpoint of span





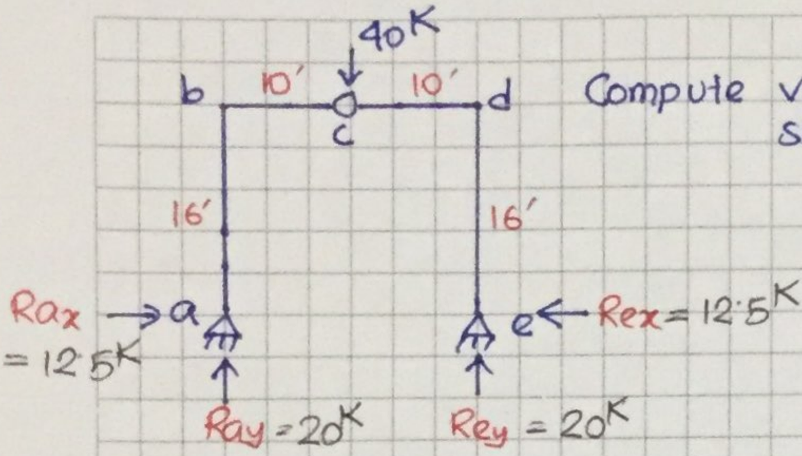
$$Q\partial_c = \frac{(-2)(-0.5)\times 12}{15\times 30\times 10^3} + \frac{(-0.5)(-38)\times 12}{15\times 30\times 10^3}$$

$$+\int_0^{20} \frac{\left(360+2x-2\frac{x^2}{2}\right)\cdot 2(0.5x)}{30\times 10^3 \times \frac{400}{144}}$$

$$= 2.67\times 10^{-5} + 5.067\times 10^{-4} + 0.448$$

$$= 0.4485334 \text{ ft.}$$

Assignment -26



Compute vertical deflection at 'c'. and slope of member 'cb'

P-force analysis:

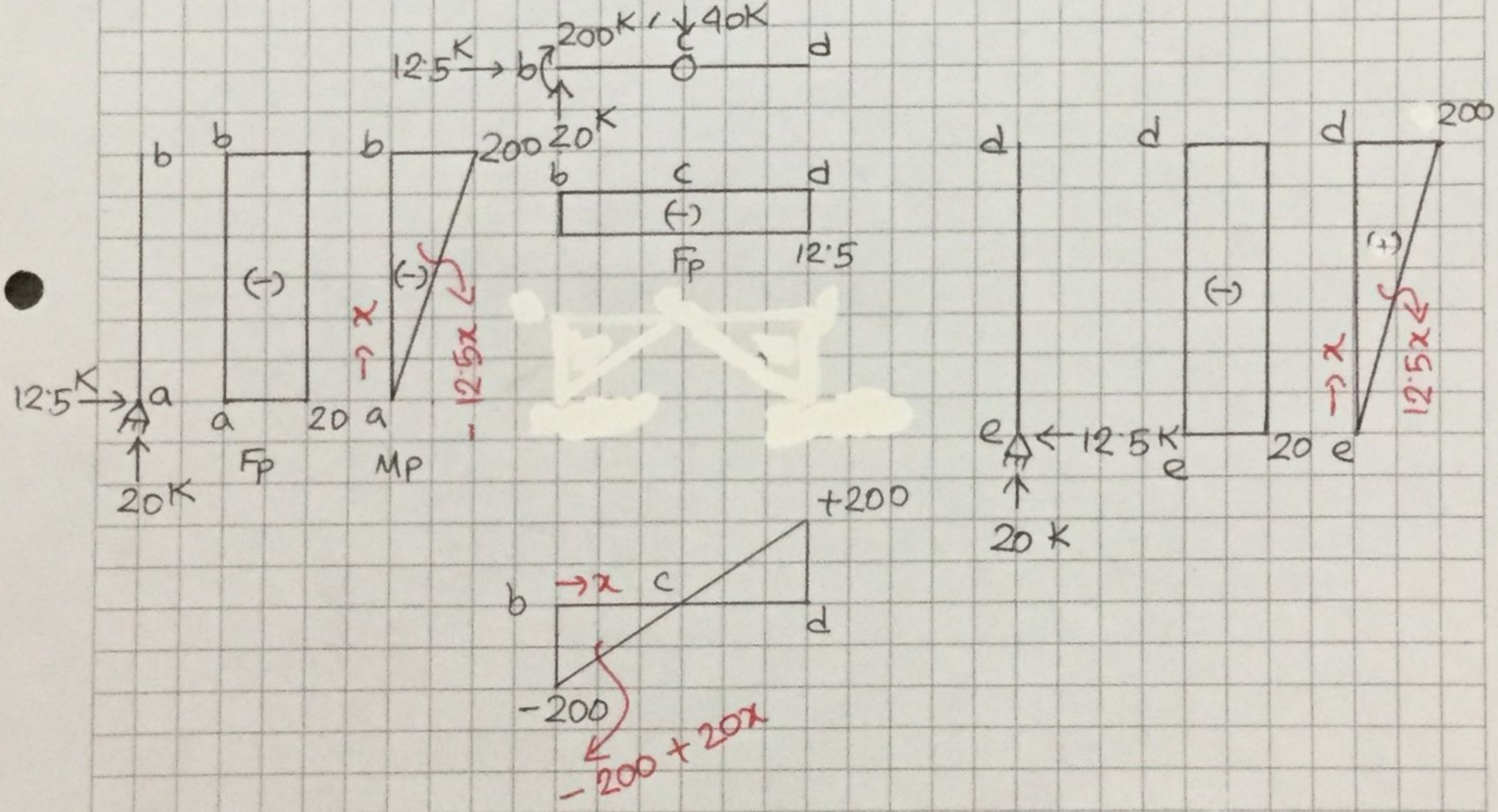
$\circlearrowright^{+} \sum M_A = 0 \quad 40 \times 10 - R_{ey} \times 20 = 0$

$\therefore R_{ey} = 20^K \quad \therefore R_{ay} = 20^K$

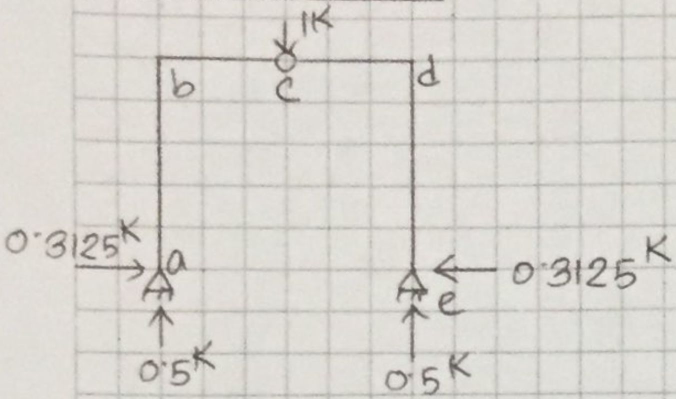
$\circlearrowright^{+} \sum M_c = 0$ (Left portion) $-R_{ey} \times 10 + R_{ex} \times 16 = 0$

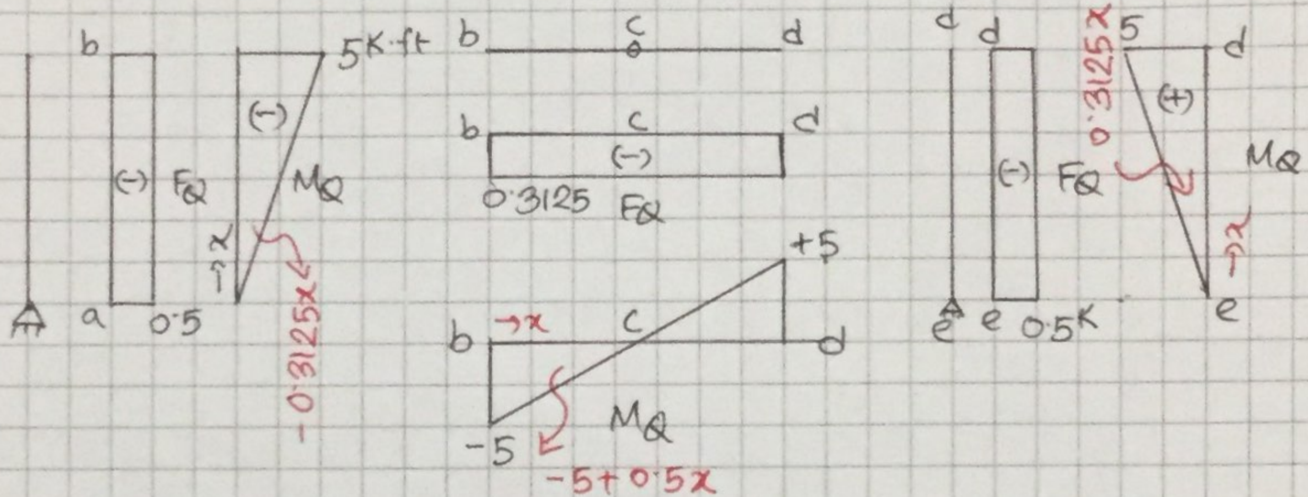
$\therefore R_{ex} = 12.5^K$

$\therefore R_{ax} = 12.5^K$



Q-force analysis:





applying principles of virtual work:-

$$Q \cdot \partial_c = \Sigma \frac{F_P F_Q L}{AE} + \Sigma \frac{F_Q t L \alpha t}{1} + \int \frac{M_P M_Q}{EI} dx$$

$$1 \cdot \partial_c = \frac{(-20)(-0.5)(16)}{15 \times 30 \times 10^3} + \frac{(-12.5)(-0.3125)(20)}{15 \times 30 \times 10^3} + \frac{(-0.5)(-20)(16)}{15 \times 30 \times 10^3}$$

$$+ \int_0^{16} \frac{(-12.5x)(0.3125x)}{30 \times 10^3 \times 400/144} dx + \int_0^{16} \frac{(12.5x)(0.3125x)}{30 \times 10^3 \times 400/144} dx$$

$$+ \int_0^{20} \frac{(-5+0.5x)(-200+20x)}{30 \times 10^3 \times 400/144} dx$$

$$= \frac{4}{5625} + \frac{1}{5760} + \frac{6}{125} + \frac{2}{25} = 0.1288847 \text{ ft}$$

EARTHQUAKE LOADING PROVISIONS IN BNBC

- Main Considerations
  - Strength Economy Probability

In moderate zone Economy can be achieved by providing reduced earthquake load which may damage the structure but will save human lives.

- Earthquake forces are selected such that
  - the building would not collapse in the event of rarely occurring major EQ, although it may be subjected to damage (safety consideration)
  - the building should be able to respond without structural damage, to shocks of moderate intensities (serviceability consideration).

- **Selection of EQ Force**
  - Forces are applied as static forces for the following structures
    - All structures in Seismic Zone 1; and in Zone 2, struc. having importance category IV (low risk)
    - Regular structure under 75 m height
    - Irregular structure not more than 20 in height.
  - Alternatively, a Dynamic EQ analysis is required if,
    - Structure is of 75 m or more height and is not located in Zone 1.
    - Structure 20 m or more high in Zone 3 and not having the same structural system throughout their height
    - Structures, located on Soil Profile Type S_4 (Table 6.2.25) , having a time period greater than 0.7 second.

Equivalent Static Force Method

- Base Shear, V= (ZIC)W / R

  Z = seismic zone coefficient given in BNBC Table 6.2.22

  I = structure importance coefficient given in BNBC Table 6.2.23

  R= response modification coefficient for struc.. system given in Table 6.2.24 (for reduction of actual EQ load ie allowing discount on the EQ force)

  W= total seismic dead load

  $C = (1.25\ S) / (T^{2/3})$ $\quad C \not> 2.75$ and $\frac{C}{R} \not< 0.075$

  S=site coefficient for soil characteristics (Table 6.2.25)

  T= fundamental period of vibration in second

  <u>Seismic Dead Load, W</u> is the total dead load of a structure, including permanent partitions and applicable portions of other loads as listed below:

  - 25% of the floor LL in storage or warehouse occupancies
  - All loads of partitions, but not less than 0.6 kN/m^2
  - Total weight of permanent equipment

- **Structure Period, T** shall be calculated from one of the following methods:

  Method A: $T=C_t(h_n)^{3/4}$

  Where C_t=0.083 for steel moment resisting frames

  =0.073 for RC moment resisting frames and eccentric braced steel frames

  =0.049 for all other structural systems

  h_n= Height in metres above the base to level n.

  Alternatively, the value of C_t for buildings with concrete or masonry shear walls may be taken as $0.031/\sqrt{A_c}$

  $A_c = \sum A_e \left[0.2 + (D_e/h_n)^2\right]$

  A_c=combined effective area, in sq. metres, of shear walls in first story of the structure.

  - A_e=effective horizontal cross-sectional area, in sq. metre, of a shear wall in the first story of a structure
  - D_e=Length, in metre, of a shear wall element in the first story in the direction of the applied forces
  - D_e/h_n shall not exceed 0.9

Method B :

$$T = 2\pi\sqrt{\sum_{i=1}^{n} w_i \delta_i^2 \Big/ g\sum_{i=1}^{n} f_i \delta_i}$$

The values of f_i represent any static lateral force distributed approximately as EQ forces.

The elastic deflection δ_i shall be calculated using the applied lateral forces, f_i The value of T determined by Method B shall not exceed that calculated by Method A by more than 40%.

Vertical Distribution of Lateral Forces

The base shear V shall be distributed along the height of the structure in accordance with the following formula:

$$V = F_t + \sum_{i=1}^{n} F_i$$

where F_i = lateral force applied at storey level i.

F_t =Concentrated lateral force considered at the top of the building in addition to the force F_n

The concentrated lateral force F_t acting at the top of the building shall be determined as follows:

$F_t = 0.07TV \leq 0.25\ V$ when $T > 0.7$ second

$F_t = 0.0$ when $T \leq 0.7$ second

The remaining portion of the base shear ($V - F_t$) shall be distributed over the height of the building , including level n, according to the following relationship :

$$F_x = \frac{(V - F_t) w_x h_x}{\sum_{i=1}^{n} w_i h_i}$$

Structural Systems for Buildings

Bearing Wall System: System without a complete vertical load carrying space frame.

Dual System: A combination of Moment Resisting Frame and Shear Walls or Braced Frames to resist lateral loads.

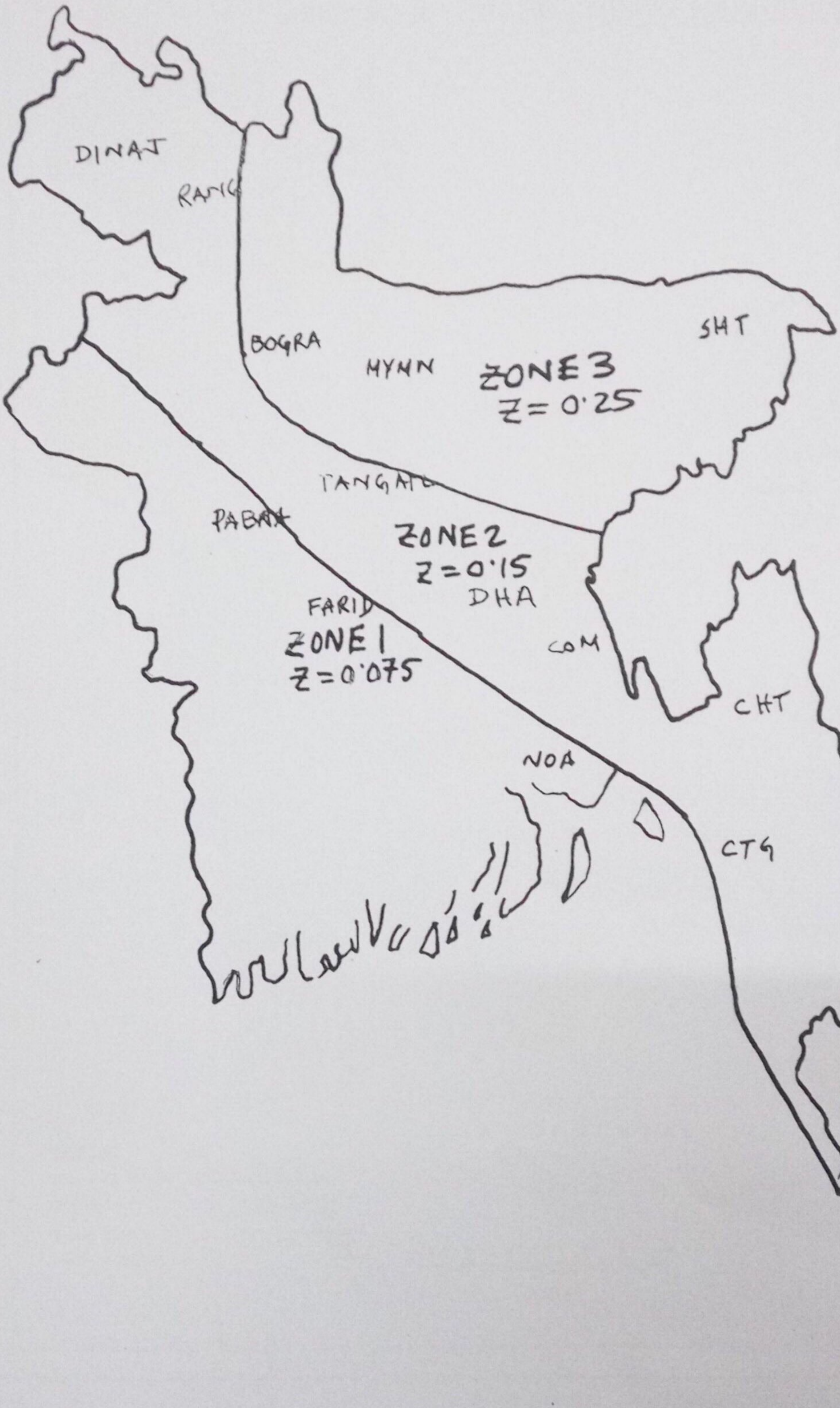
Moment Resisting Frame: A frame in which members and joints are capable of resisting forces primarily by flexure.

Ordinary Moment Resisting Frame: A moment resisting frame not meeting special detailing requirements for ductile behaviour.

Shear Wall : A wall designed to resist lateral forces parallel to the plane of the wall (also known as vertical diaphragm or a structural wall).

- **Desirable Behaviour of EQ Resistant Structures**
  - Ability to withstand high lateral force is not the only requirement.
  - Building designed with small seismic force but having high flexibility and energy absorbing mechanism will perform better than a building designed with a very high lateral force but with little flexibility.
  - Aim is to ensure maximum possible elastic behaviour by proper detailing of the joints etc.

SEISMIC ZONING MAP
Fig. 6.2.10



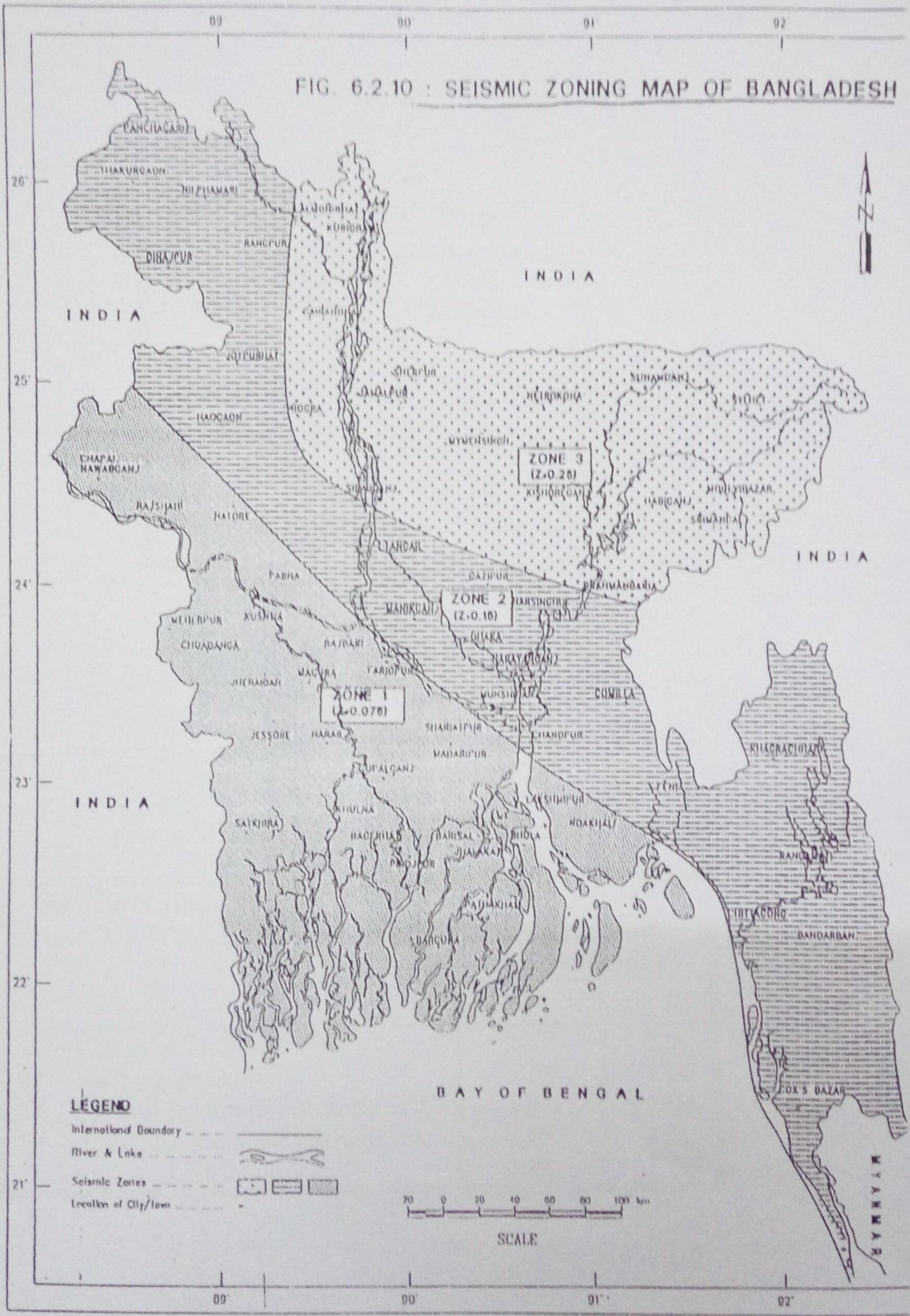


FIG. 6.2.10 : SEISMIC ZONING MAP OF BANGLADESH

Table 6.2.22

Seismic Zone Coefficients, Z

Seismic Zone (see Fig 6.2.10)	Zone Coefficient
1	0.075
2	0.15
3	0.25

Table 6.2.23

Structure Importance Coefficients *I, I′*

Structure Importance Category (see Table 6.1.1 for occupancy)	Structure Importance Coefficient	
	I	*I′*
I Essential facilities	1.25	1.50
II Hazardous facilities	1.25	1.50
III Special occupancy structures	1.00	1.00
IV Standard occupancy structures	1.00	1.00
V Low-risk Structures	1.00	1.00

24

R depends on struc. sys.

Table 6.2.24

Response Modification Coefficient for Structural Systems, $R \simeq 4 \sim 12$

Basic Structural System[1]	Description of Lateral Force Resisting System	R [2]
a. Bearing Wall System	1 Light framed walls with shear panels	
	i) Plywood walls for structures, 3 storeys or less	8
	ii) All other light framed walls	6
	2 Shear walls	
	i) Concrete	6
	ii) Masonry	6
	3 Light steel framed bearing walls with tension only bracing	4
	4 Braced frames where bracing carries gravity loads	
	i) Steel	6
	ii) Concrete [3]	4
	iii) Heavy timber	4
b. Building Frame System	1. Steel eccentric braced frame (EBF)	10
	2 Light framed walls with shear panels	
	i) Plywood walls for structures 3-storeys or less	9
	ii) All other light framed walls	7
	3. Shear walls	
	i) Concrete	8
	ii) Masonry	8
	4. Concentric braced frames (CBF)	
	i) Steel	8
	ii) Concrete [3]	8
	iii) Heavy timber	8
c. Moment Resisting Frame System	1. Special moment resisting frames (SMRF)	
	i) Steel	12
	ii) Concrete	12
	2. Intermediate moment resisting frames (IMRF), concrete[4]	8
	3 Ordinary moment resisting frames (OMRF)	
	i) Steel	6
	ii) Concrete [5]	5
d. Dual System	1 Shear walls	
	i) Concrete with steel or concrete SMRF	12
	ii) Concrete with steel OMRF	6
	iii) Concrete with concrete IMRF [4]	9
	iv) Masonry with steel or concrete SMRF	8
	v) Masonry with steel OMRF	6
	vi) Masonry with concrete IMRF [3]	7
	2. Steel EBF	
	i) With steel SMRF	12
	ii) With steel OMRF	6
	3. Concentric braced frame (CBF)	
	i) Steel with steel SMRF	10
	ii) Steel with steel OMRF	6
	iii) Concrete with concrete SMRF [3]	9
	iv) Concrete with concrete IMRF [3]	6
e. Special Structural Systems	See Sec 1.3.2, 1.3.3, 1.3.5	

Notes : (1) Basic Structural Systems are defined in Sec 1.3.2, Chapter 1.
(2) See Sec 2.5.6.6 for combination of structural systems, and Sec 1.3.5 for system limitations.
(3) Prohibited in Seismic Zone 3.
(4) Prohibited in Seismic Zone 3 except as permitted in Sec 2.5.9.3.
(5) Prohibited in Seismic Zones 2 and 3. See 1.7.2.6.

Table 6.2.25

Site Coefficient, S for Seismic Lateral Forces [1]

Site Soil Characteristics		Coefficient, S
Type	Description	
S_1	A soil profile with either : a) A rock-like material characterized by a shear-wave velocity greater than 762 m/s or by other suitable means of classification, or b) Stiff or dense soil condition where the soil depth is less than 61 metres	1.0
S_2	A soil profile with dense or stiff soil conditions, where the soil depth exceeds 61 metres	1.2
S_3	A soil profile 21 metres or more in depth and containing more than 6 metres of soft to medium stiff clay but not more than 12 metres of soft clay	1.5
S_4	A soil profile containing more than 12 metres of soft clay characterized by a shear wave velocity less than 152 m/s	2.0

Note : (1) The site coefficient shall be established from properly substantiated geotechnical data. In locations where the soil properties are not known in sufficient detail to determine the soil profile type, soil profile S_3 shall be used. Soil profile S_4 need not be assumed unless the building official determines that soil profile S_4 may be present at the site, or in the event that soil profile S_4 is established by geotechnical data.

Example : Eq. Static EQ Force

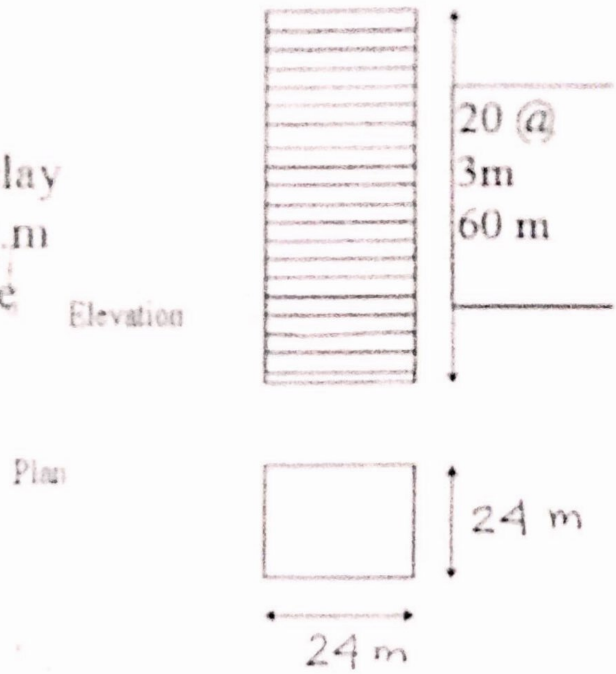
Calculate the distribution of EQ forces on the 20 storied office building shown in figure.

Location : Dhaka

Soil Type : Soft to medium stiff clay

DL including partition=12 kN/sq.m

Structure type : SMRF in concrete



Solution:

Zone 2: $Z=0.15$ $I=1.0$

$$C = \frac{1.25S}{T^{2/3}}$$

Soil Type $S_3 = 1.5$

$T=C_t(h_n)^{3/4}$

$h_n = 60$ m

$C_t=0.073$

$T=0.073X(60)^{3/4}$

$= 1.57$ Sec

$$C = \frac{1.25 \times 1.5}{(1.57)^{2/3}}$$

$C \quad = 1.386 < 2.75$

$C \not> 2.75$ and $(C/R) \not< 0.075$

Here R=12 hence: C/R=0.115 >0.075

Therefore, C=1.386 O.K

Seismic Dead Load

W= 12 kN/sq. m x (24x24 sq. m)x 20 floors
= 138240 kN

Base Shear, V= (ZIC)x W/R
= (0.15 x 1 x 1.386 /12)x W
= 0.0173 W
= 2392 kN

Vertical Distribution of Forces:

The concentrated lateral force F_t at the top of the building:

$F_t = 0.07TV \leq 0.25$ V when T > 0.7 second

$F_t = 0.0$ when T ≤ 0.7 second

$F_t = 0.07 \times 1.57 \times 2392 = 264$ kN here : $F_t \le 0.25\ V$ i.e. $F_t = 264$ kN O.K.

$$F_x = \frac{(V - F_t)\, w_x h_x}{\sum_{i=1}^{n} w_i h_i}$$

$w_x = 12 \times 576$ kN for each floor.
In this example w is same for all the floors.

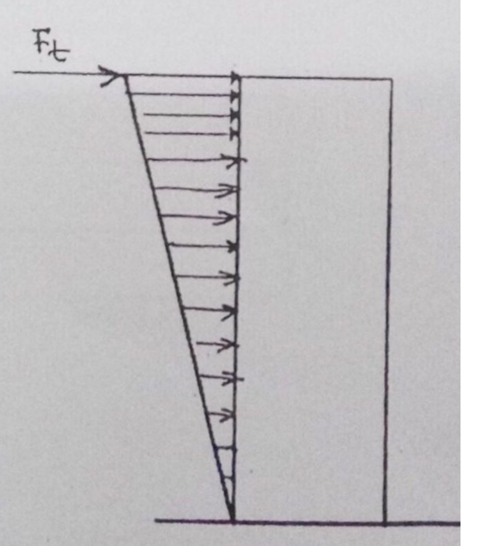
For any building for which w is same for each floor:

$$F_x = \frac{\cancel{w}_x (V - F_t)\, h_x}{\cancel{w}_i \sum_{i=1}^{n} h_i}$$

$$F_x = \frac{(2392 - 264)h_x}{(3+6+9+..........+60)}$$

$$F_x = \frac{2128\, h_x}{3 \times \frac{(20 \times 21)}{2}}$$

$$F_x = 3.38\, h_x$$



EQ Forces at various levels

Floor Level	h_x , m	F_x , kN
20	60	202.7
19	57	192.5
18	54	182.4
17		
16		
15		
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Wind Pressure and Coefficients

Basic Wind Pressure

The basic wind pressure on a surface is given by $q_b = \rho_{air} V_b^2/2$ ....(1)

where ρ_{air} = Density of air = 0.0765/32.2 = 23.76×10^{-4} slug/ft^3

V_b = Basic wind speed, ft/sec = 1.467 × Basic wind speed, mph

$\therefore$ Eq. (1) $\Rightarrow q_b = 23.76 \times 10^{-4} \times (1.467\, V_b)^2/2 = 0.00256\, V_b^2$ ....(2)

where q_b is in psf (lb/ft^2) and V_b is in mph (mile/hr).

The basic wind speeds at different important locations of Bangladesh are given below. A more detailed map for the entire country is available in BNBC 1993.

Location	V_b (mph)
Dhaka	130
Chittagong	160
Rajshahi	95
Khulna	150

Sustained Wind Pressure

The wind velocity (and pressure) increases from zero at the base of the structure and is also a function of the exposure (i.e., open terrain or congested area). Moreover one has to account for the importance of the structure; i.e., design the sensitive structures more conservatively.

The sustained wind pressure on a building surface at any height z above ground is given by

$q_z = 0.00256\, C_I\, C_z\, V_b^2$ ....(3)

where C_I = Structural importance coefficient, C_z = Height and exposure coefficient.

Category	C_I
Essential facilities	1.25
Hazardous facilities	1.25
Special occupancy	1.00
Standard occupancy	1.00
Low-risk structure	0.80

Height z (ft)	C_z		
	Exp A	Exp B	Exp C
0~15	0.368	0.801	1.196
50	0.624	1.125	1.517
100	0.849	1.371	1.743
150	1.017	1.539	1.890
200	1.155	1.671	2.002
300	1.383	1.876	2.171
400	1.572	2.037	2.299
500	1.736	2.171	2.404
650	1.973	2.357	2.547
1000	2.362	2.595	2.724

Design Wind Pressure

The design wind pressure can be calculated by multiplying the sustained wind pressure by appropriate pressure coefficients due to wind gust and turbulence as well as local topography.

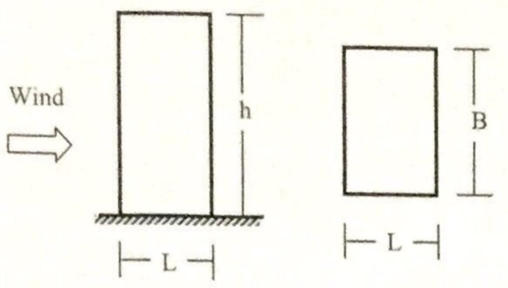
The design wind pressure on a surface at any height z above ground is given by

$p_z = C_G\, C_t\, C_p\, q_z$ ....(4)

where C_G = Wind gust coefficient, C_t = Local topography coefficient, C_p = Pressure coefficient.

Height z (ft)	C_G (for non-slender structures)		
	Exp A	Exp B	Exp C
0~15	1.654	1.321	1.154
50	1.418	1.215	1.097
100	1.309	1.162	1.067
150	1.252	1.133	1.051
200	1.215	1.114	1.039
300	1.166	1.087	1.024
400	1.134	1.070	1.013
500	1.111	1.057	1.005
650	1.082	1.040	1.000
1000	1.045	1.018	1.000

The value of C_G for slender structures (height > 5 times the minimum width) would be determined by dynamic analysis. Although code-based formulae are available, it is unlikely to exceed 2.0.
The pressure coefficient C_p for rectangular buildings with flat roofs may be obtained as follows

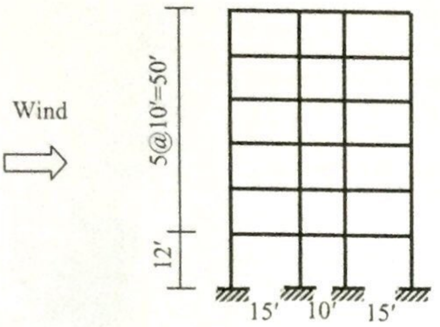


h/B	L/B					
	0.1	0.5	0.65	1.0	2.0	≥ 3.0
≤ 0.5	1.40	1.45	1.55	1.40	1.15	1.10
1.0	1.55	1.85	2.00	1.70	1.30	1.15
2.0	1.80	2.25	2.55	2.00	1.40	1.20
≥ 4.0	1.95	2.50	2.80	2.20	1.60	1.25

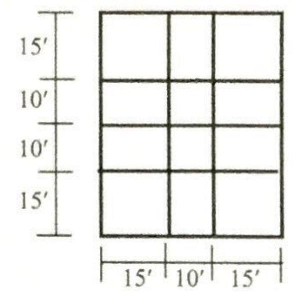
Calculation of Wind Load

Wind Load on a Building

Calculate the wind load at each story of a six-storied hospital building (shown below) located at a flat terrain in Dhaka. Assume the structure to be subjected to Exposure B.



Side Elevation



Building Plan

Solution

The design wind pressure at a height z is given by $p_z = 0.00256\ C_I\ C_z\ C_G\ C_t\ C_p\ V_b^2$
Since the building is located in Dhaka, the basic wind speed $V_b = 130$ mph
For the hospital building (essential facility), Structural importance coefficient $C_I = 1.25$
In plane terrain, Local topography coefficient $C_t = 1.0$
Building height $h = 62'$, dimensions $L = 40'$ and $B = 50'$; i.e., $h/B = 1.24$ and $L/B = 0.80 \Rightarrow C_p \cong 1.98$
$\therefore p_z = 0.00256 \times 1.25 \times C_z \times C_G \times 1.00 \times 1.98 \times (130)^2 = 107.08\ C_z\ C_G$
$\therefore$ The corresponding force $F_z = B\ h_{eff}\ p_z = 50\ h_{eff}\ p_z$; where h_{eff} = Effective height of the tributary area
$h_{eff} = 6' + 5' = 11'$ at 1st floor, $(5' + 5' =)\ 10'$ between 2nd and 5th floor and $5'$ at 6th floor
The coefficients C_z, C_G and the design wind pressure p_z and force F_z at different heights are shown below.

Story	z (ft)	C_z	C_G	p_z (psf)	F_z (kips)	F_{frames} (kips)				
1	12	0.801	1.321	113.30	62.32	9.35	15.58	12.46	15.58	9.35
2	22	0.866	1.300	120.55	60.27	9.04	15.07	12.05	15.07	9.04
3	32	0.958	1.270	130.28	65.14	9.77	16.29	13.03	16.29	9.77
4	42	1.051	1.239	139.44	69.72	10.46	17.43	13.94	17.43	10.46
5	52	1.135	1.213	147.42	73.71	11.06	18.43	14.74	18.43	11.06
6	62	1.184	1.202	152.39	38.10	5.72	9.53	7.62	9.53	5.72