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Dr. Muhammad Al Amin Siddique

Lec-1

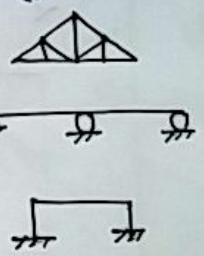
Design – Multiple solution
Analysis – Single "

- Statically determinate হলে → $\Sigma F_x = 0$
  $\Sigma F_y = 0$
  $\Sigma M = 0$

- আমরা এখানে পড়ব statically indeterminate structure.
- Analysis এ use হবে → Moment Distribution Displacement Method
  – এতে displacement unknown থাকে
  – এটা applicable for → continuous beam and frame
  → only bending deformation

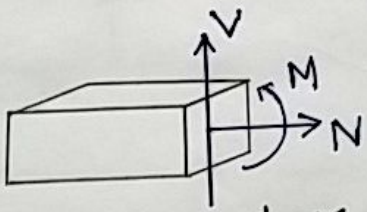
Hardy Cross (1924) আলে এই method আবিষ্কার করেন।

□ Main structural component হল: 1) Truss
2) Beam
3) Frame



- support reaction
- member force

} Unknown Force



2D Frame member এর cross section

- Member length এর perpendicular বরাবর X-section নিব।

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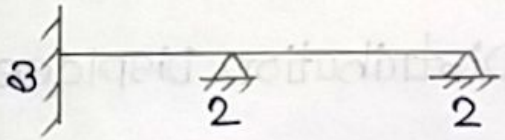
- 2 types of Moment :

1) Bending moment

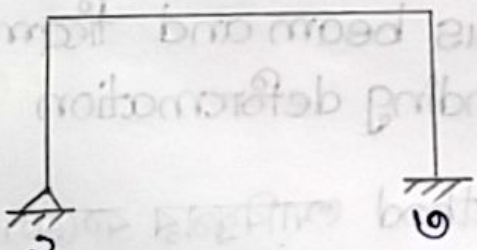
2) Twisting " : Member এর long axis এর সাপেক্ষে rotation হলে।

* এখানে, সেহেতু member এর main axis বরাবর loading হচ্ছে, তাই twisting moment develop করতে পারে না।

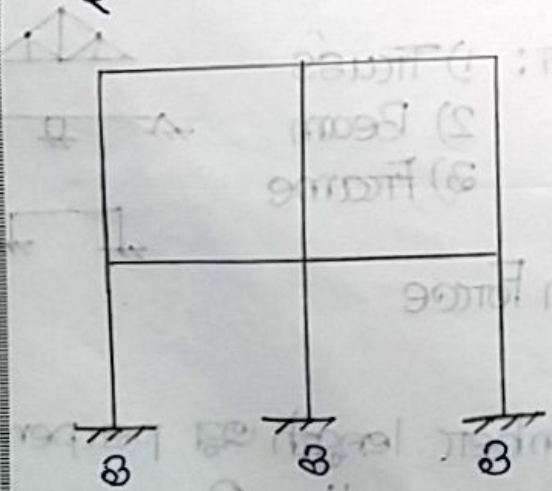
□ Determinancy :



D.O.I = Degree of Indeterminancy
= 7-3 = 4



D.O.I = 5-3 = 2



D.O.I = ?

Not 6

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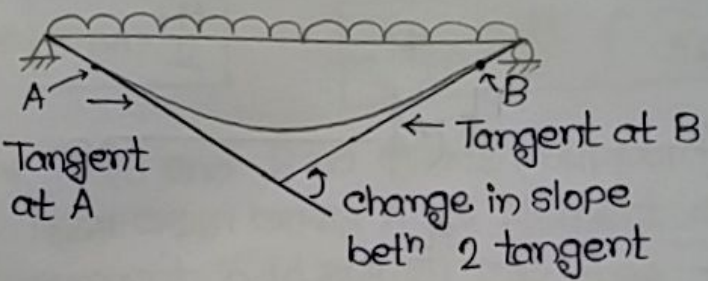
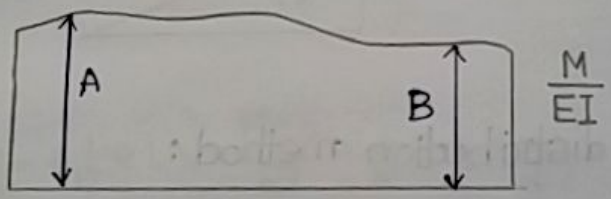
☐ Moment Area Method:



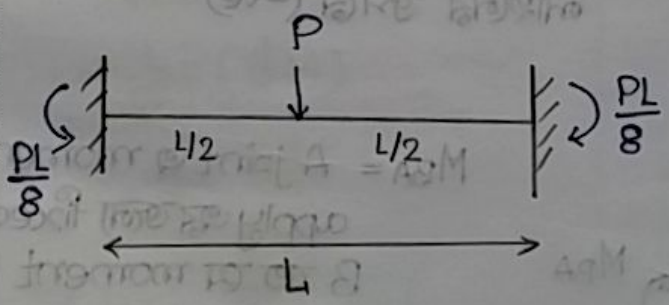


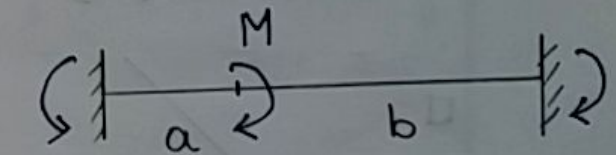
- change in slope bet^n 2 tangent, $\theta_{BA} = \sum \frac{M}{EI}$ diagram between A and B
- Tangential deviation,

→ Δ_{BA} = Moment of $\frac{M}{EI}$ diagram between A and B ω.r.t. B

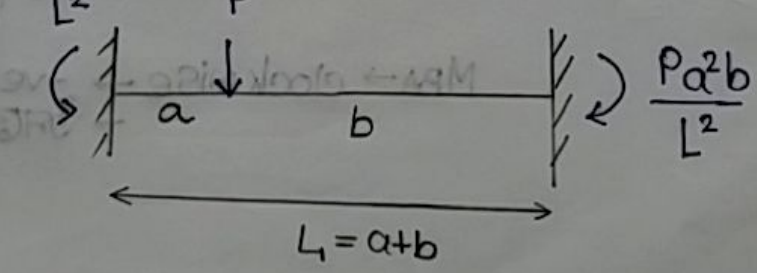
→ Δ_{AB} = " " " " " B and A ω.r.t. A

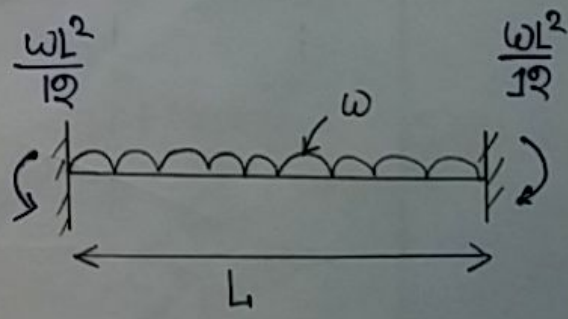
☐ Fixed End Moment (FEM):





$\frac{Mb}{L^2}(b-2a)$: $\frac{Ma}{L^2}(2b-a)$





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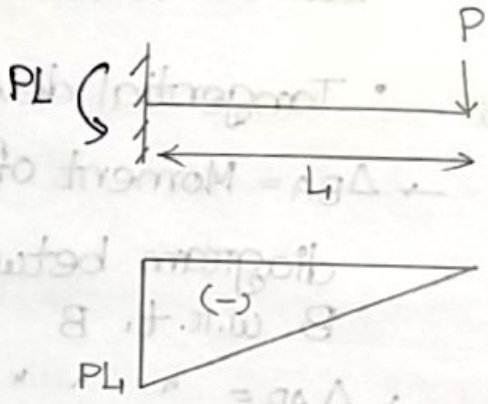
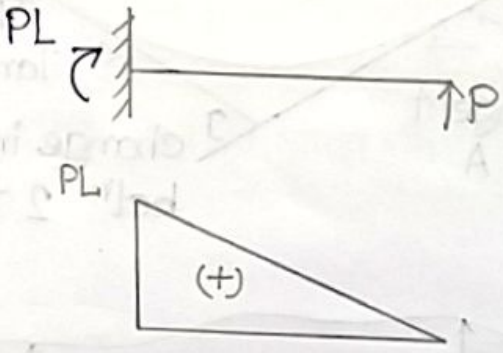
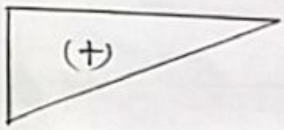
* Anti-clock wise moment (+ve)

#আগের method অনুযায়ী→

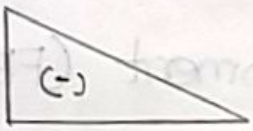




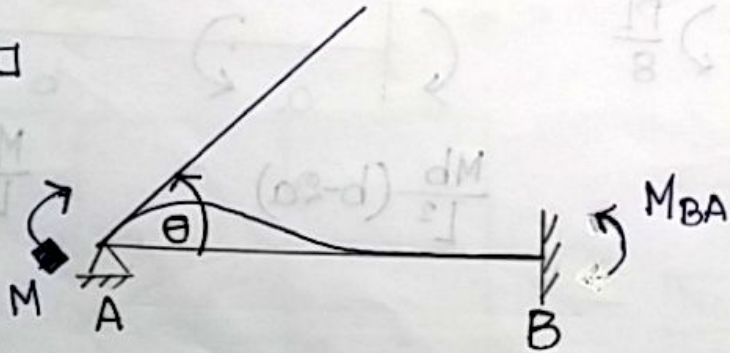
#But Now, for moment distribution method :



লাইনের নিচে (+ve)



লাইনের উপরে (-ve)



M_{BA} = A joint এ moment apply এর জন্য fixed end B তে যে moment develop করবে।

M → anti clockwise → +ve
→ নিচে

M_{BA} → clockwise → -ve
→ উপরে

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$\Delta_{AB} = 0$

$\Rightarrow \frac{1}{2} \times L \times \frac{M}{EI} \times \frac{L}{3} + \frac{1}{2} \times \frac{M_{BA}}{EI} \times L \times \frac{2L}{3} = 0$

$\Rightarrow \boxed{M_{BA} = \frac{-M}{2}}$ $\boxed{\therefore M_{BA} = \frac{M}{2} \quad (2)}$

* Fixed end B তে আগেই (support condition এর জন্য) moment ছিল। এখন আবার A তে Moment apply হওয়াতে B-তে extra moment add হয়েছে। তাই M_{BA}

$\theta_A = +\frac{1}{2} \times L \times \frac{M_{BA}}{EI} + \frac{1}{2} \times L \times \frac{M}{EI}$

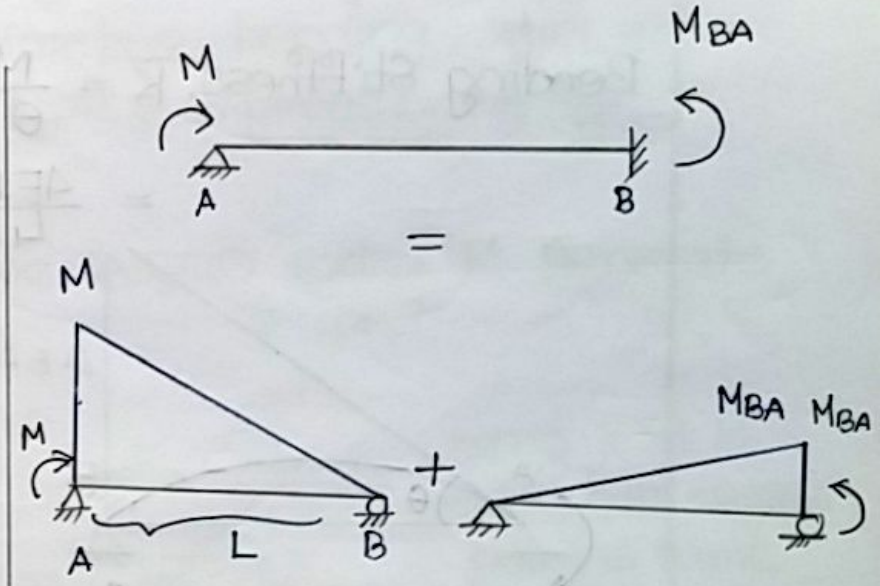
$= \frac{L}{2EI} (+M_{BA} + M)$

$= \frac{L}{2EI} (-\frac{1}{2}M + M)$

$= \frac{L}{2EI} (\frac{1}{2}M)$

$= \frac{1}{4} \frac{ML}{EI}$

$\therefore \boxed{M = \frac{4EI}{L} \cdot \theta_A}$



Same as Solid Mecha. book
Chap. 15, example 9.

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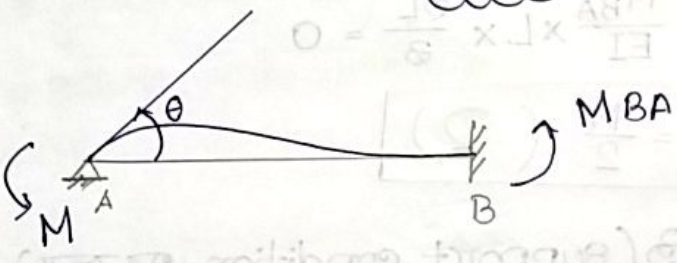


Carryover moment $= M_{BA} = \frac{M}{2}$

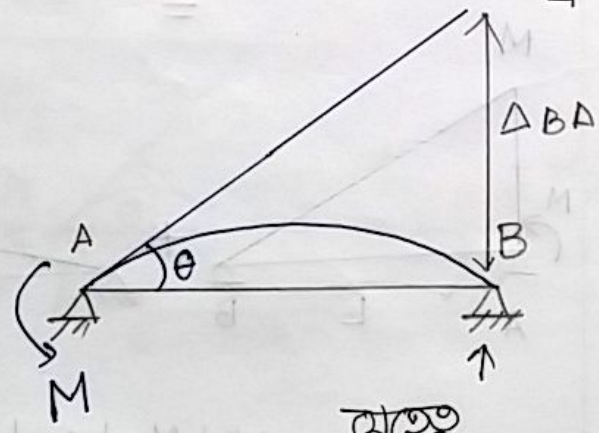
C.OF (Factor) $= \frac{\text{Carryover moment}}{\text{applied moment}} = \frac{1}{2}$

$M = \frac{4EI}{L}\theta$

Relative bending stiffness, $K = \frac{\bar{K}}{4E} = \frac{I}{L}$

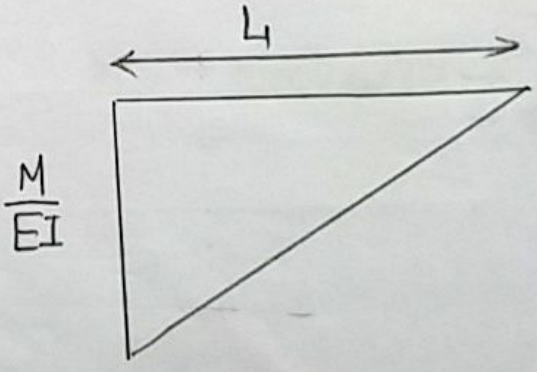
Bending Stiffness, $\bar{K} = \frac{M}{\theta}$

$= \frac{4EI}{L}$ (per rotation এর জন্য যত moment দরকার)



C.OF $= \frac{0}{M} = 0$

যেহেতু hinge support, তাই C.O.M = 0



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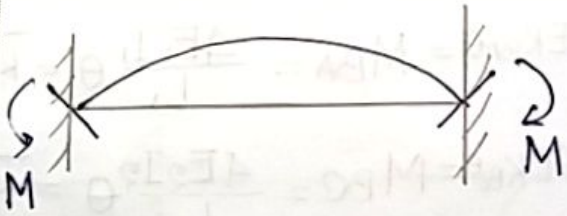
$$\Delta_{BA} = \frac{1}{2} \times \frac{M}{EI} \times L \times \frac{2L}{3} = \frac{ML^2}{3EI}$$

$$\theta = \frac{\Delta_{BA}}{L} = \frac{ML}{3EI}$$

$$\therefore M = \frac{3EI}{L}\theta$$

$$K = \frac{3EI}{L}$$

$$K = \frac{\bar{K}}{4E} = \frac{3}{4}\frac{I}{L}$$



support partially restrained

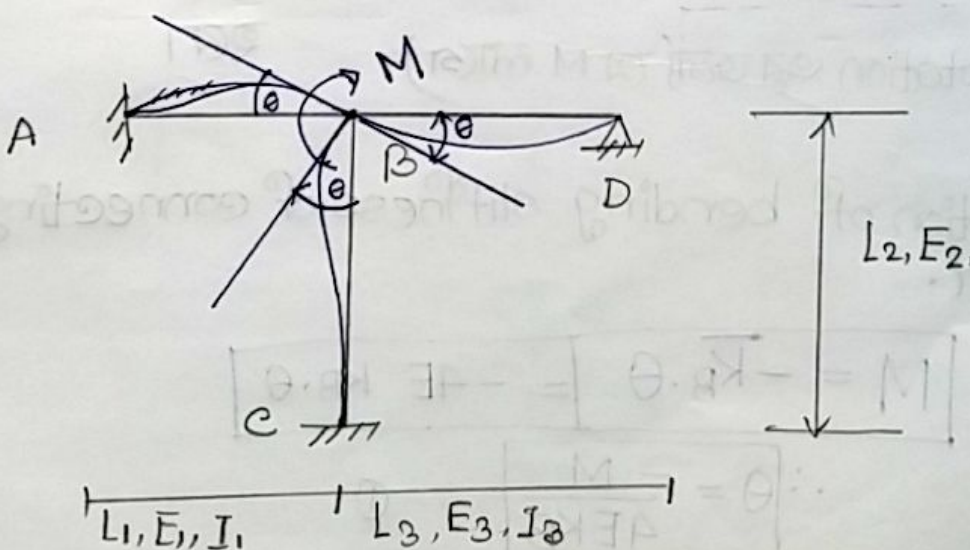
$K = 0.5\frac{I}{L}$ for symmetric bending, যখন only either tension or compression থাকে

~~C·O·M = 0~~

C·O·F = 0

C·D·M = 0 ← symmetric হওয়াতে extra M. generate করেনি।

□ Distribution Factor:



যেহেতু joint B rigid, তাই সবগুলো point এ same rotation θ আসবে। যাতে, এদের initially internal angle যে 90° ছিল, সেটাই বজায় থাকে।

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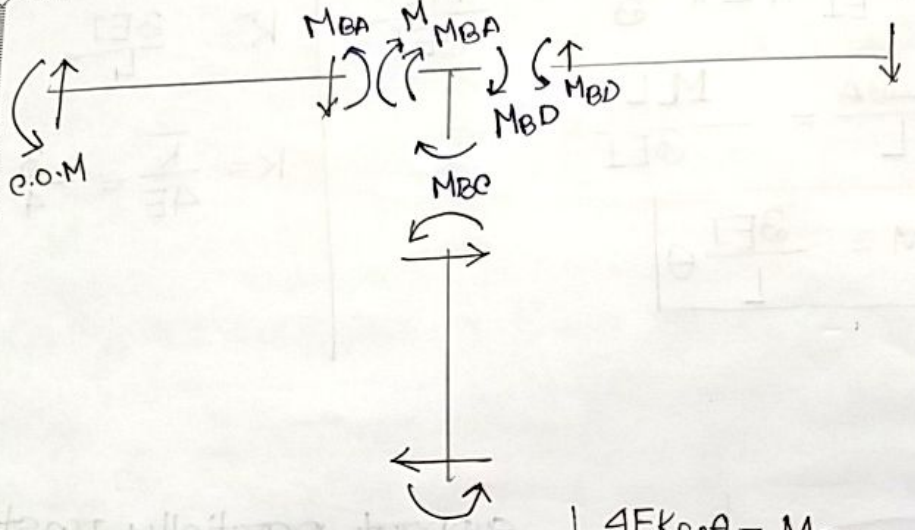

← এই end এ M develop হয়নি। CZ hinge support.

$\Sigma M_B = 0$

$\Rightarrow M + M_{BA} + M_{BD} + M_{BC} = 0$

$\Rightarrow M = -\left(\overline{K_{BA}} + \overline{K_{BC}} + \overline{K_{BD}}\right)\theta$

$= -\overline{K_B} \cdot \theta$

$= -4E K_B \cdot \theta$

$4EK_{BA}\theta = M_{BA} = \frac{4E_1 I_1}{L_1}\theta = \overline{K}_{BA}\theta$

$4EK_{BC}\theta = M_{BC} = \frac{4E_2 I_2}{L_2}\theta = \overline{K}_{BC}\theta$

$4EK_{BD}\theta \quad M_{BD} = \frac{3E_3 I_3}{L_3}\theta = \overline{K}_{BD}\theta$

$$\boxed{K = \frac{\overline{K}}{4E}}$$

K দিয়ে express করতে হলে, member এর E same হতে হবে।

Rotational stiffness of a joint =

(per unit rotation এর জন্য যে M লাগে)

= Summation of bending stiffness of connecting member.

$$\boxed{M = -\overline{K_B} \cdot \theta} \quad \boxed{= -4E\ K_B \cdot \theta}$$

$$\therefore \boxed{\theta = \frac{-M}{4EK_B}} \quad \ldots\ (1)$$

শিউলী বুক বাইন্ডিং

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$$M_{BA} = \boxed{-\frac{K_{BA}}{K_B}} \cdot M$$

$$M_{BC} = \boxed{-\frac{K_{BC}}{K_B}} \cdot M$$

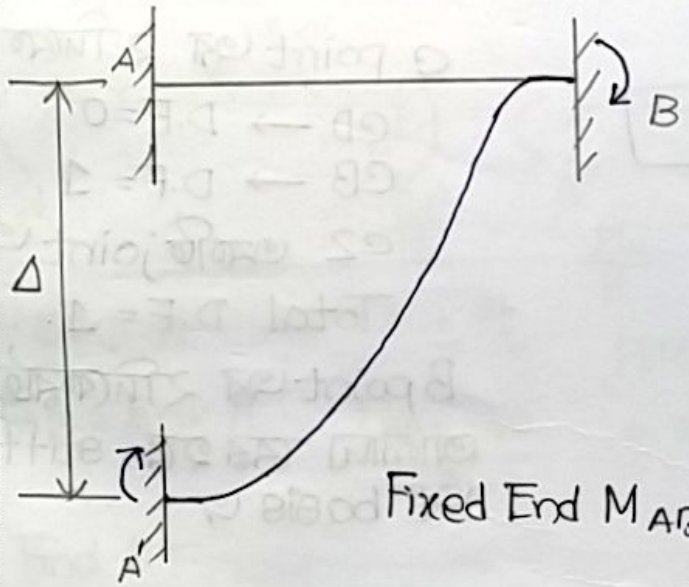
$$M_{BD} = \boxed{-\frac{K_{BD}}{K_B}} \cdot M$$

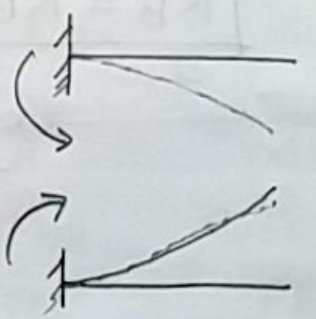
D.F.

$$D.F = \frac{\text{যেকোন member এর stiffness}}{\text{Total stiffness of a joint}}$$

* Joint এর সব D.F. যোগ করলে 1 পাওয়া যায়।

□ Support Settle করলে:

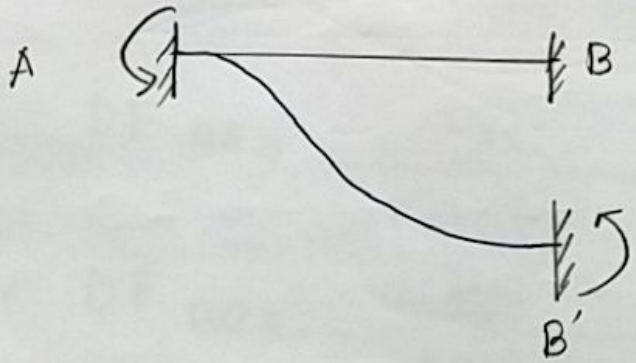




Fixed End M_{AB} = FE M_{BA}

$$= -\frac{6EI}{L^2}\Delta$$

↑ clockwise (-)ve



$$\boxed{FEM_{AB} = +\frac{6EI}{L^2}\Delta}$$

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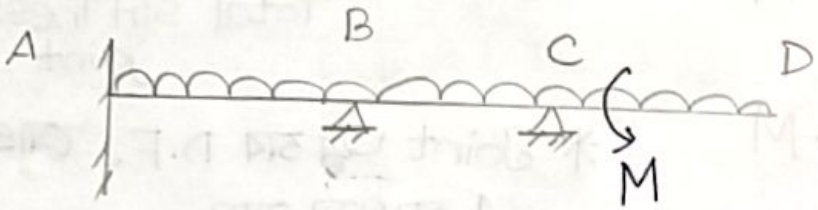

B, C তে rotate করতে পারে

overchanged portion এর D.F = 0.

কেন, এটার stiffness ও M কোন member or joint এর উপর depend করে না।

$D.F_{CD} = 0$

$D.F_{BC} = \frac{K_{BC}}{K_B}$

$D.F_{CB} = 1$

$D.F_{BA} = \frac{K_{BA}}{K_B}$

$$K_B = K_{BC} + K_{BA}$$

C point এর 2 দিকে
CD → D.F = 0
CB → D.F = 1,
C2 একটি joint এর Total D.F = 1.
B point এর 2 দিকেরটা আলাদা বের হবে, stiffness এর basis এ

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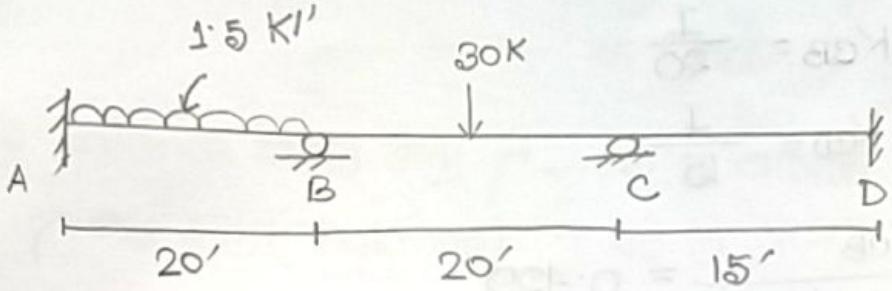
①



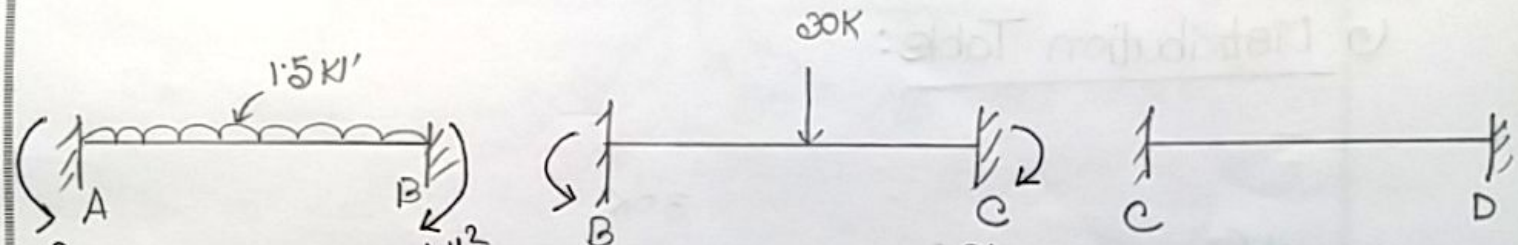
E = 29000ksi

I = 500 in^4

EI constant for all.

* যারা rotate করতে পারে, তাদের fixed করে দিব।

② Fixed করে দিব B ও C কে



$\frac{wL^2}{12}$ = 50 K.ft

$\frac{wL^2}{12}$ = 50K ft

$\frac{PL}{8}$ FEM_{BC} = 75 K'

$\frac{PL}{8}$ FEM_{CB} = −75K'

no load

So $FEM_{CD} = 0$

$FEM_{DC} = 0$

F_{AB} = 50K.ft

F_{BA} = −50 K'

② Find D.F.

Joint B: BA → $(K_{BA})_R = \frac{I}{L} = \frac{I}{20}$

BC → $(K_{BC})_R = \frac{I}{L} = \frac{I}{20}$

$D.F_{BA} = \frac{K_{BA}}{K_{BA} + K_{BC}} = 0.5$

$D.F_{BC} = \frac{K_{BC}}{K_{BA} + K_{BC}} = 0.5$

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Joint C :

CB → $K_{CB} = \frac{I}{20}$

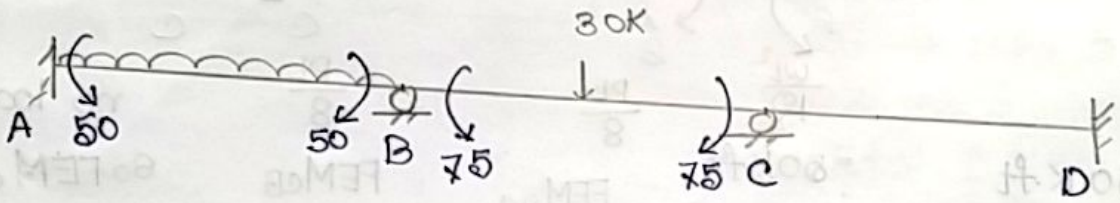
CD → $K_{CD} = \frac{I}{15}$

$D.F_{CB} = \frac{K_{CB}}{K_{CB} + K_{CD}} = 0.429$

$D.F_{CD} = \frac{K_{CD}}{K_{CB} + K_{CD}} = 0.571$

• এর পর ২ digit এ rounding করেছি

৩ Distribution Table:



	DF	0·5	0·5	0·429	0·571	
F.E.M		50	-50	+75	-75	১
			16·1 (COM)	+32·2 (C-free)	+42·8	২
			← ½ far end fixed		→ ½ fixed far end	
				(+75)	21·4 (COM)	
		-10·3 (C.O.M)	-20·6	-20·6 (B free)	-10·3 (C.O.M)	৩
			2·2	← ½ +4·4	+5·9 → ½	2·9 ৪
		-0·6	← -1·1	-1·1	→ -06	৫
			0·2	← +0·3	+0·3 →	0·2 ৬
			← -0·1	-0·1		৭
Σ		+39·1	-8·8	+7·7	-49	+49 +24·5

শিক্ষার্থী কর্তৃক বাইন্ডিং

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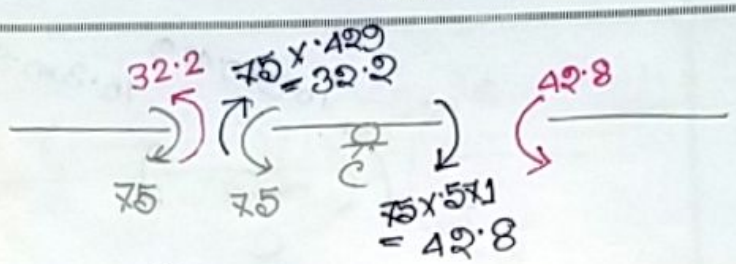
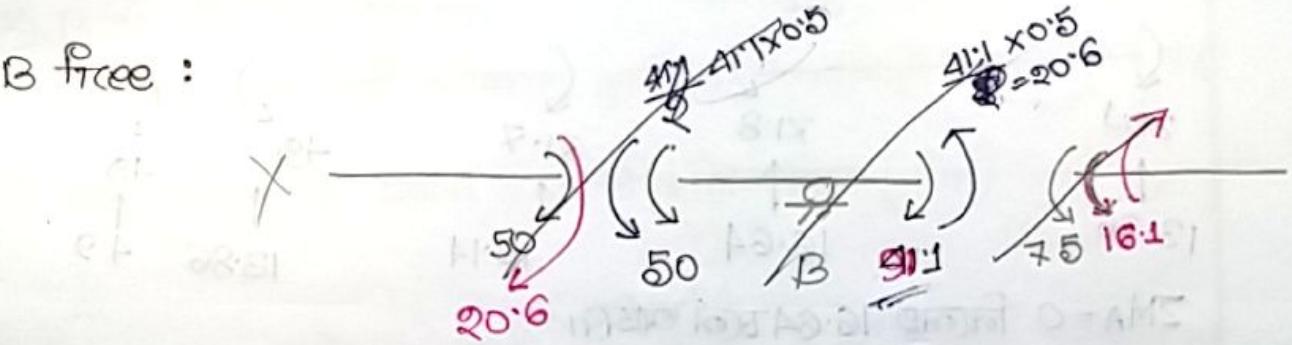
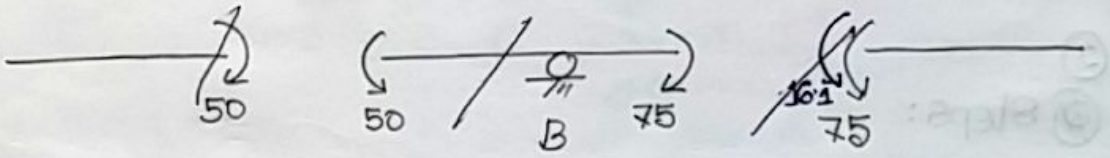
② (#) C fixed করে দিয়েছি :



75 balance করার জন্য ↑ ← এই M এসেছে
↑ এর জন্য (← balance) ↘ এই M এসেছে

B fixed :





① pencil (farend)
② pencil (nearend)
③ COM at B → 16·1 (farend)
④ B joint (nearend) এ unbalanced moment balance করব।

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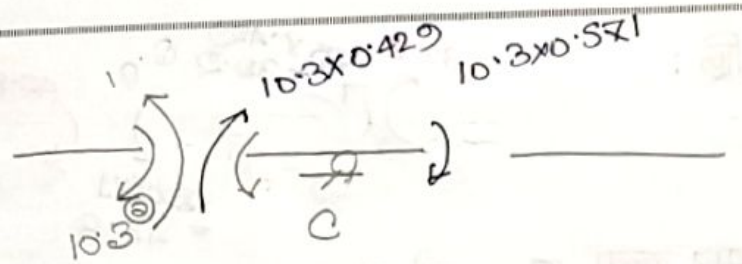

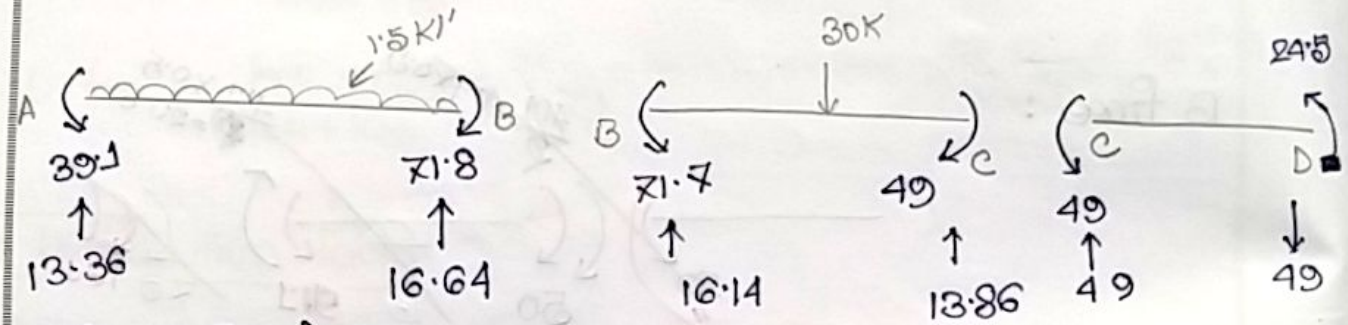

$\Sigma M_A = 0$ নিলেই 16·64 চলে আসবে।

②

Steps:

1) FS (fare)
2) FS balance (neare)
3) C তে FS unbalanee (neare) (anti)
4) balanee করব clock FS কে (neare) D.F অনুযায়ী দুই side এ দিব
5) last M এর value কে opposite direction এ দিব (fare).
6) Table এ fare end এর value আর direction বসাব।

শিউলী বুক বাইন্ডিং

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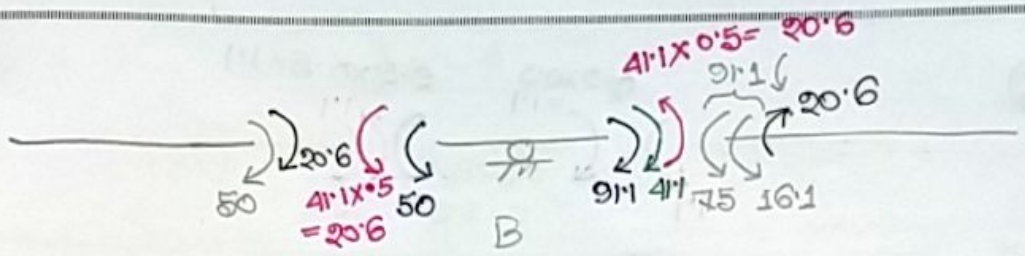
(২)(৩)



1) B এর Left → − 50 , Right → +75, +16·1 (fare)

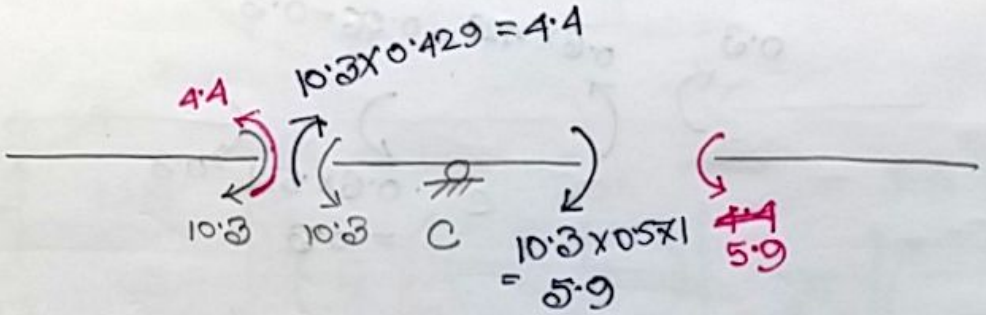
2) B এর (near) এ এদেরকে balance করব (50 & 91·1) (সমান ও বিপরীত)

3) B তে 41·1 (2) তৈরি হবে

4) একে opposite এ দিয়ে balance করব D·F অনুযায়ী (near) L & R (41·1)

5) আবার এই M কে সমান ও বিপরীতদিকে দিবে (fair)

(৪)



1) C তে Total unbalanced M = −10·3 · (Left → fare)

2) সমান ও বিপরীত 10·3 (near-L)

3) C তে unbalanced M 10·3 · দুদিকে দিবে D·F অনুযায়ী opposite এ (4·4 ← L ; 5·9 ← R) (near)

4) এদের সমান ও বিপরীত (fair)

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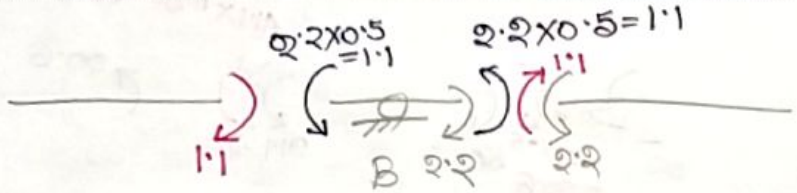
(৫)



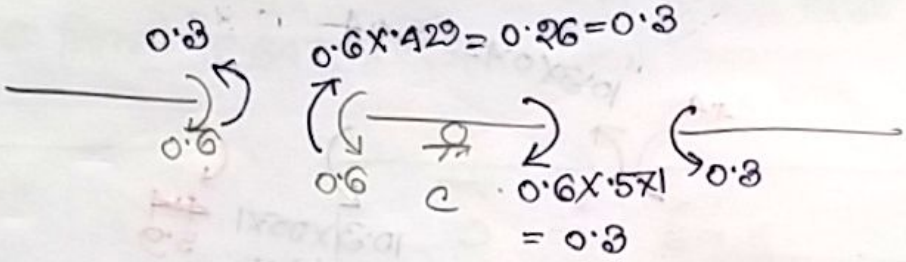
1) B তে 2·2 unbalanced M. fair (R)

2) equal & opposite (R- near)

৩) B তে 2·2 unbalanced M. opposite এ দিব D·F অনুযায়ী (near) ২ side এ

4) (fair) সমান ও বিপরীত M

(৬)



1) C এর Left (fair) -০·৬ M

2) opposite balance (near)

৩) C তে ০·৬ unbalanced M. opposite এ ২ side এই দিব D·F. অনুযায়ী।

4) (fair) opposite এ ২end এ M (০·৩)

* দশমিকের পর এক digit নিয়েছি, তাই M ০·১ এ এনেছি।

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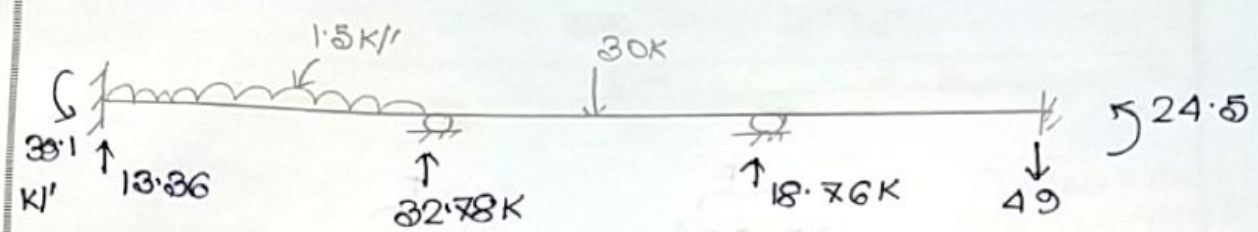
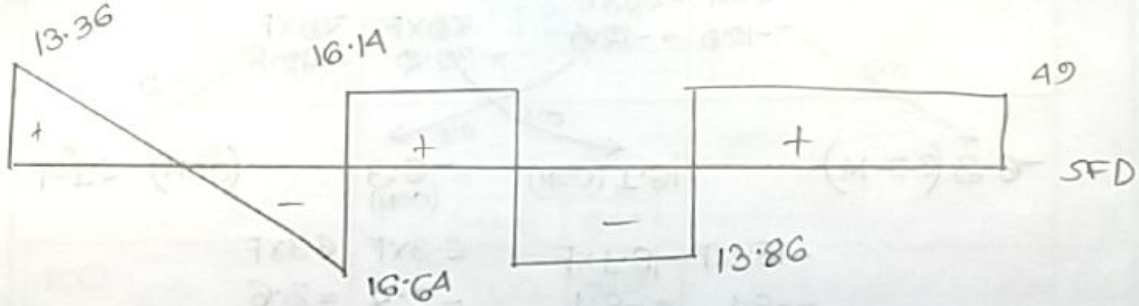
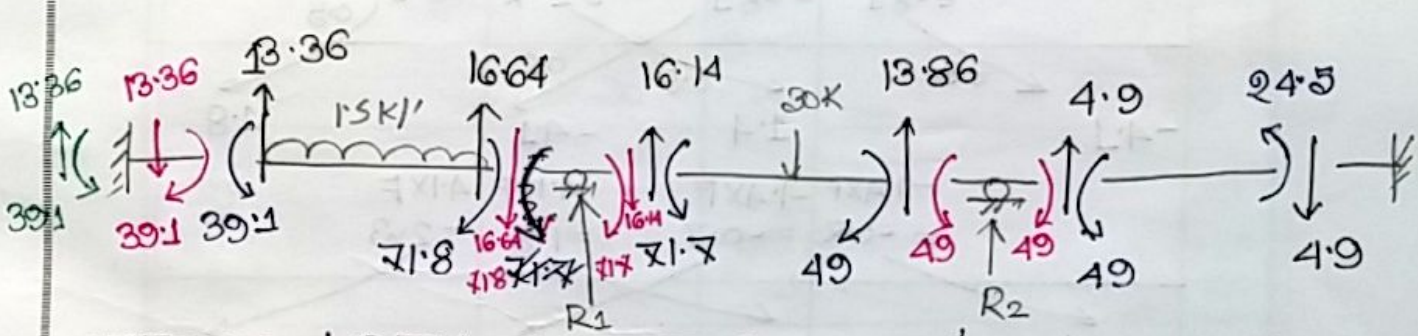
Lec-4







যে কোন end এ $\Sigma M = 0$ বসালে (কোন একটা segment এর) V পাওয়া যাবে।

$R_1 = 16.64 + 16.14$

$R_2 = 13.86 + 4.9$

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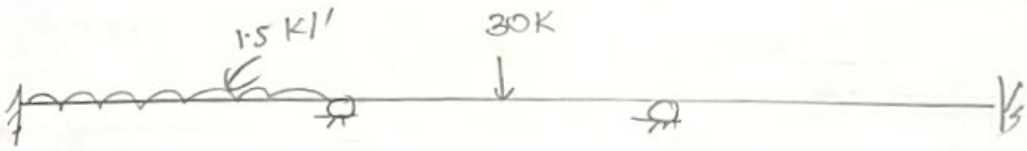
Method 2



	F		F	
	0.5	0.5	.429	.571
50	−50	75	−75	
	−25×F = −12.5	−25×F = −12.5	75×F = 32.2	75×F = 42.8
	0.5	0.5	0.5	0.5
−6.3 (C.O.M)		16.1 (COM)	−6.3 (COM)	(COM) 21.4
	−16.1×F = −8.1	−16.1×F = −8.1	6.3×F = 2.7	6.3×F = 3.6
	0.5	0.5	0.5	0.5
−4.1		1.4	−4.1	1.8
	−1.4×F = −0.7	−1.4×F = −0.7	4.1×F = 1.8	4.1×F = 2.3
−0.4		0.9	−0.4	1.2
	−0.9×F = −0.5	−0.9×F = −0.5	0.4×F = 0.2	0.4×F = 0.2
−0.3		0.1	−0.3	0.1
	−0.1×F = −0.05	−0.1×F = −0.05	0.3×F = 0.1	0.3×F = 0.2
ΣForce → 38.9	−21.8	+21.7	−49.1	+49.1 24.4

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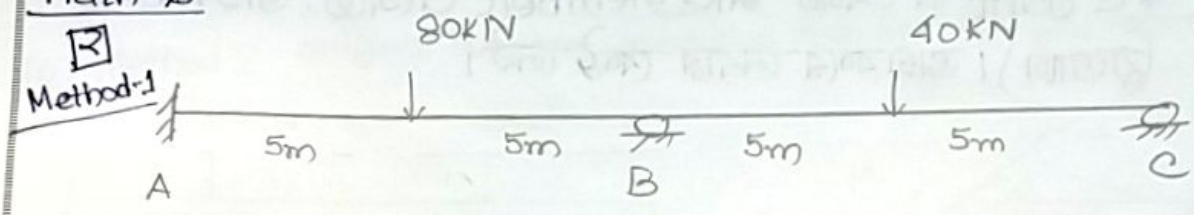
Math-8

[3]

Method-1

$I_{AB} = 1.5I$

$I_{BC} = I$



$$(K_{BA})_R = \frac{I}{L} = \frac{1.5I}{10}$$

$$(K_{BC})_R = \frac{I}{L} = \frac{I}{10}$$

$FEM_{AB} = 100\ KN.m$

$FEM_{BA} = -100\ KN.m$

$FEM_{BC} = 50\ KN.m$

$FEM_{CB} = -50\ KN.m$

$$DF_{BA} = \frac{K_{BA}}{K_{BA} + K_{BC}} = \frac{1.5I/10}{1.5I/10 + I/10} = 0.6$$

$DF_{BC} = 0.4$

	F		F
	0.6	0.4	1
	100	−100	50	−50
		50×F = 30	50×F = 20	+50×F = 50
	15		25	10
		−25×F = −15	−25×F = −10	−10×F = −10
	−7.5		−5	−5
		5×F = 3	5×F = 2	5×F = 5
	1.5		2.5	1
		−2.5×F = −1.5	−2.5×F = −1	−1
	−0.8		−0.5	−0.5
		+0.3	+0.2	0.5
	+0.2		+0.3	0.1
		−0.2	−0.1	−0.1
	~~10.6~~ 108.4	−83.4	+83.4	0

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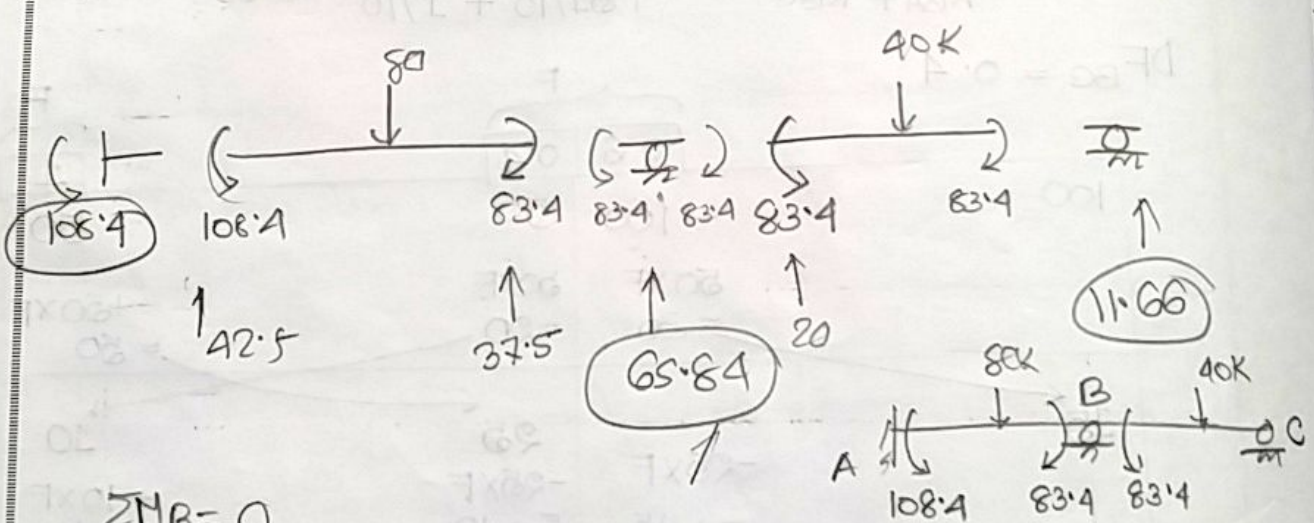
* C joint এ একটি মাত্র member এসেছে, তাই D.F = 1 (যুক্তি)। ভাগ করে নেবার কেউ নেই।



$\Sigma M_B = 0$

$\Rightarrow -108{\cdot}4 + 80 \times 5 + 83{\cdot}4 - 10 \times R_B = 0$

$\Rightarrow R_B =$

*internal support সবসময় fixed ধরব।
*external " fixed/hinged ধরব।

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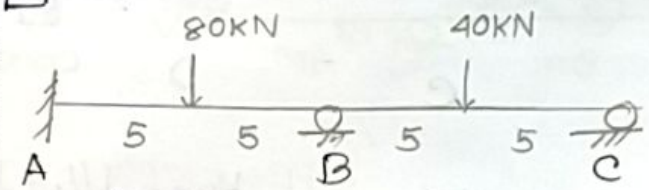
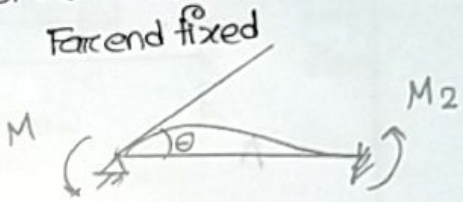
Lec-5

[2] Method 2 original support condition চিন্তা করে, far end এ.



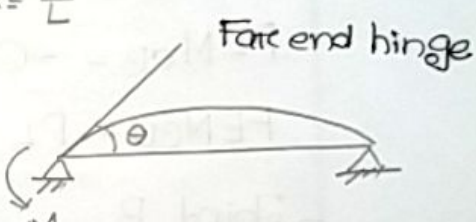
(1.5I) (I)



$K = \frac{4EI}{L}$

$K = \frac{I}{L}$

COF = $\frac{1}{2}$



$K = \frac{3EI}{L}$

$K = \frac{3}{4} \cdot \frac{I}{L}$

COF = 0

$DF_{BA} = \frac{K_{BA}}{K_{BA}+K_{BC}} = \frac{1.5I/10}{1.5I/10 + \frac{3}{4} \times \frac{I}{10}} = \frac{2}{3}$

$DF_{BC} = \frac{K_{BC}}{K_{BA}+K_{BC}} = \frac{1}{3}$

	2/3	1/3	1
	100	-100	50	-50
		33.3	16.7	+50
	16.7	0.5		25	0.5
		-16.7	-8.3	
	-8.3			
	108.4	-83.4	83.4	0

B fixed তাই C.O.M আসে

C hinge তাই COM নাই = 0.

Sub: CD এর existance নাই ধরে, CZ, C point এ constant moment দেয় এবং CD part statically determinant.

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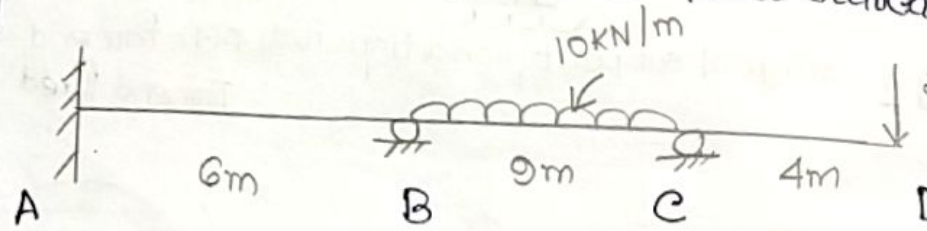
[3]



EI constant

$FEM_{BC} = \frac{WL^2}{12} = \frac{10 \times 9^2}{12} = 67.5$ KN.m

$FEM_{CB} = -67.5$ KN.m

$FEN_{CD} = PL = 30 \times 4 = 120$ KN.m

$K_{BA} = I/L = I/6$

$K_{BC} = \frac{3}{4} I/L = \frac{3}{4} \frac{1}{9} = I/12$

Joint B

$DF_{BA} = \frac{K_{BA}}{K_{BA} + K_{BC}}$

$= \frac{2}{3}$

$DF_{BC} = \frac{1}{3}$

Joint C

$DF_{BCB} = 1$

$DF_{CD} = 0$ (CD নাই ধরে)

DF এর কাজ হল M distribute করে দেয়া, কিন্তু CD এর জন্য C তে M constant. তাই DF = 0

	B		C	
	2/3	1/3	1	
	~~67.5~~	+67.5	-67.5	120
	-45	-22.5		
			-67.5	~~120 - 52.5xF~~
			52.5xF	
			= -52.5	= ~~52.5~~
	-22.5	-26.3		
		B fixed. COM = 1/2		
	26.3xF	26.3xF		
	= 17.53	= 8.77		
	8.8			
	-13.7	27.5 27.5	-120	120

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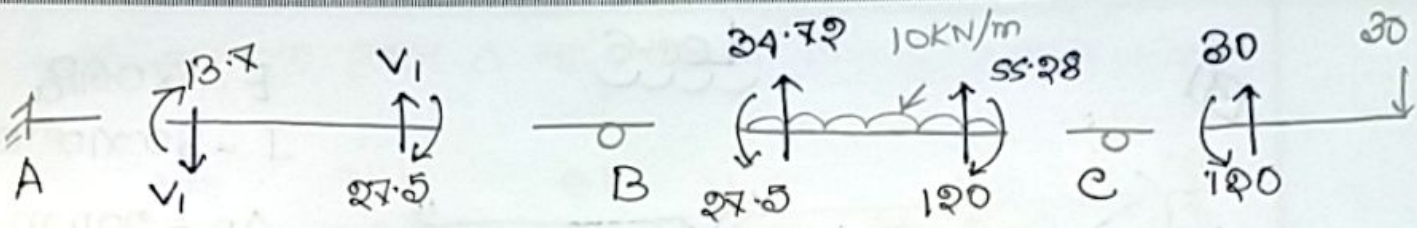

$V_1 = \frac{13.7 + 27.5}{6} = 6.87$

$R_A = 6.87\ (\downarrow) = V_1$

$R_B = 6.87 + 34.72 = 62.22\ (\uparrow)$

$R_C = 55.28 + 30 = 85.28\ (\uparrow)$

$M_A = 13.7\ K.m$ (2)

*যখন Member এর E constant, তখন K_R এও বসবে।

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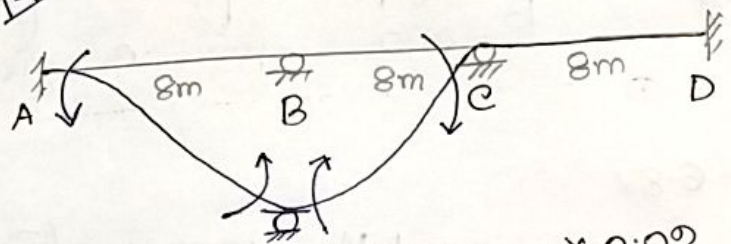
Lec-6

$E = 70 GPa$

$I = 800 \times 10^6 mm^4$

$\Delta_B = 20mm$

Ex-1



$$FEM_{AB} = \frac{6EI\Delta}{L^2} = \frac{6 \times 70 \times 800 \times 0.02}{8^2} = 105 \text{ KN.m} = FEM_{BA}$$

$$FEM_{BC} = -\frac{6EI\Delta}{L^2} = -105 \text{ KN.m} = FEM_{CB}$$

$$(K_{BA})_R = (K_{BC})_R = \frac{I}{L} = \frac{I}{8}$$

$$DF_{BA} = \frac{K_{BA}}{K_{BA} + K_{BC}} = 0.5$$

$DF_{BC} = 0.5$

$DF_{CD} = 0.5$

$DF_{DC} = 0.5$

	0.5	0.5	.5	.5	
	105	105	-105	-105	
			52.5	52.5	
		26.3			26.3
	-13.1	-13.1			
	-6.6			-6.6	
			3.3	3.3	
		1.6			1.6
	-0.8	-0.8			
	-0.4			-0.4	
			0.2	0.2	
		0.1			0.1
	-0.05	-0.05			
	98	91.1	-91	-56	56	28

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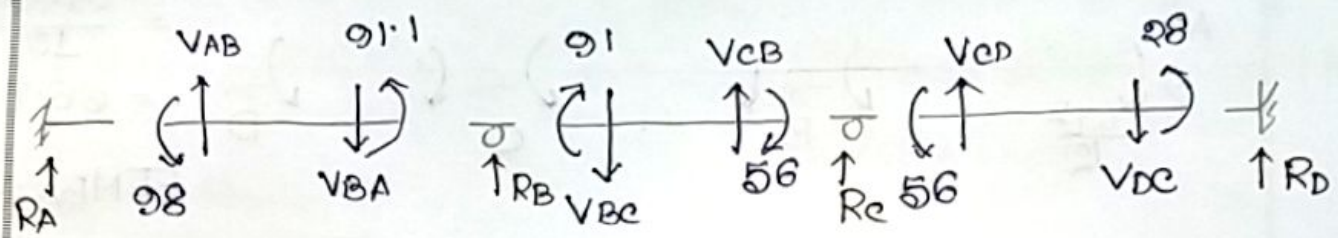
• C ও D তে কোন Δ নাই, so no 'M'.



$V_{BA} = V_{AB} = \frac{91.1+98}{8} = 23.64$

$V_{BC} = V_{CB} = \frac{91+56}{8} = 18.4$

$V_{CD} = V_{DC} = \frac{56+28}{8} = 10.5$

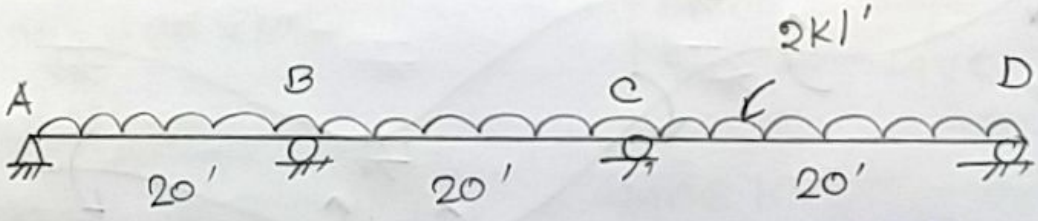
$R_A = 23.64 (\uparrow)$

$R_B = 23.64 + 18.4 = 42.04 (\downarrow)$

$R_C = 18.4 + 10.5 = 28.9 (\uparrow)$

$R_D = 10.5 (\downarrow)$

5



Given, $E = 29000 ksi$

$I = 7800 in^4$

$\Delta_B = 5/8'' = 0.625$

$\Delta_C = 3/2'' = 1.5$

$\Delta_D = 3/4'' = 0.75$

যেহেতু elastic limit এর মধ্যেই আছে, তাই principle of superposition apply করা যাবে।

- external loading
- support settlement

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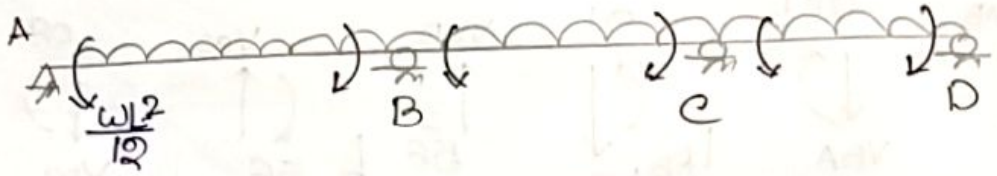
• FEM for external loading:

$$FEM_{AB} = \frac{WL^2}{12}$$

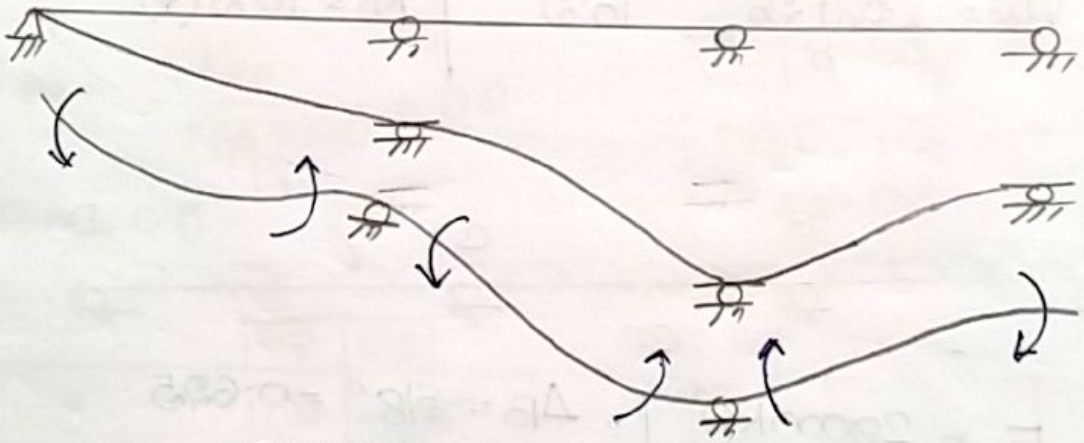
$$= \frac{2 \times 20^2}{12}$$

$$= 66.7\ K'$$



$$FEM_{BA} = -66.7\ K'$$

• For settlement:



$$FEM_{AB} = \frac{6EI\Delta}{L^2} = \frac{6 \times 29000 \times 7800 \times \frac{5}{8}}{(20 \times 12)^2}$$

$$= 1227.2\ K'$$

$$= FEM_{BA}$$

~~FEM~~

Final end Moment:

$FEM_{AB} = 66.7 + 1227.2 = 1293.9\ K'$

$FEM_{BA} = -66.7 + 1227.2 = 1160.5\ K'$

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BC

external load:

$FEM_{BC} = 66.7\ K'$

$FEM_{CB} = -66.7\ K'$

settlement

(BC এর মাঝের) → Δ (Relative) $= \frac{3}{2} - \frac{25}{8} = \frac{7}{8}''$

$FEM_{BC} = \frac{6EI\Delta}{L^2} = 1718.1\ K'$

$FEM_{CB} = 1718.1\ K'$

∴ Final Moment

$FEM_{BC} = 66.7 + 1718.1 = 1784.8\ K'$

$FEM_{CB} = -66.7 + 1718.1 = 1651.4\ K'$

CD

External load

$FEM_{CD} = 66.7\ K'$

$FEM_{DC} = -66.7\ K'$

settlement

$\Delta_{CD} = \frac{3}{2} - \frac{3}{4} = 0.75''$

$FEM_{CD} = \frac{6EI\Delta}{L^2} = -1472.7$

$FEM_{DC} = -1472.7\ K'$

Final Moment

$FEM_{CD} = 66.7 - 1472.7 = -1406\ K'$

$FEM_{DC} = -66.7 - 1472.7 = -1539.4\ K'$

এরপর M.D. Table করে বাকি কাজ করব।

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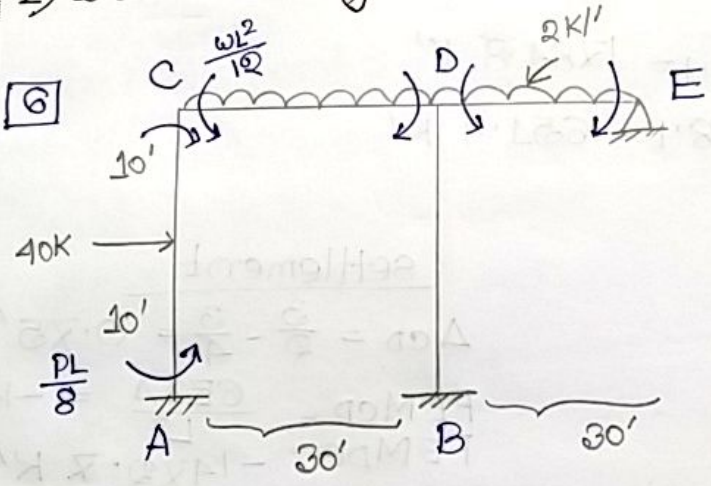
lec-7

Frames

1) without sidesway (same as → continuous beam)
2) with sidesway



$E = 29000$ ksi
$I_{AC} = 800$ in^4
$I_{BD} = 800$ in^4
$I_{CD} = 1600$ in^4
$I_{DE} = 1600$ in^4
[C, D; E Rotation]

$$FEM_{AC} = \frac{PL}{8} = \frac{40 \times 20}{8} = 100 \text{ K'}$$

$FEM_{CA} = -100$ K'

$$FEM_{CD} = \frac{wL^2}{12} = \frac{2 \times 30^2}{12} = 150 \text{ K'}$$

$FEM_{DC} = -150$ K'

$FEM_{DE} = 150$ K'

$FEM_{ED} = -150$ K'

DF

Joint C

$$DF_{CA} = \frac{K_{CA}}{K_{CA} + K_{CD}} = \frac{800/20}{800/20 + 1600/30} = 0.429$$

$DF_{CD} = 1 - 0.429 = 0.571$

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Joint D considering original support condition

$$DF_{DC} = \frac{K_{DC}}{K_{DC}+K_{DB}+K_{DE}} = \frac{1600/30}{1600/30 + 800/20 + \underbrace{\frac{3}{4}\times\frac{1600}{30}}} \quad \left(\frac{3}{4}\frac{EI}{L}\right)$$

$$= 0.4$$

$$DF_{DB} = \frac{800/20}{1600/30 + 800/20 + \frac{3}{4}\times(1600/30)} = 0.3$$

$DF_{DE} = 0.3$

Joint E

$DF_{ED} = 1$

A	C		D			E	B
AC	CA	CD	DC	DB	DE	ED	BD
0	0.429	0.5X1	0.4	0.3	0.3	1	
	-100	150	-150		150	-150	
	-21.4	-28.6				150	
-10.X			-14.3		X5		
			-60.XXF	-60.XXF	-60.XXF		
			=-24.3	=-18.2	=-18.2		
		-12.2					-9.1
	+5.2	+X					
2.6			3.5				
			-1.4	-1.1	-1.1		
		-0.X					-0.6
	+0.3	+0.4					
0.2			0.2				
			-0.1	-0.1	-0.1		
92.1	-15.9	115.9	-186.4	-19.4	205.6	0	-9.X

Next sunday → C.T. (beam) M.D.

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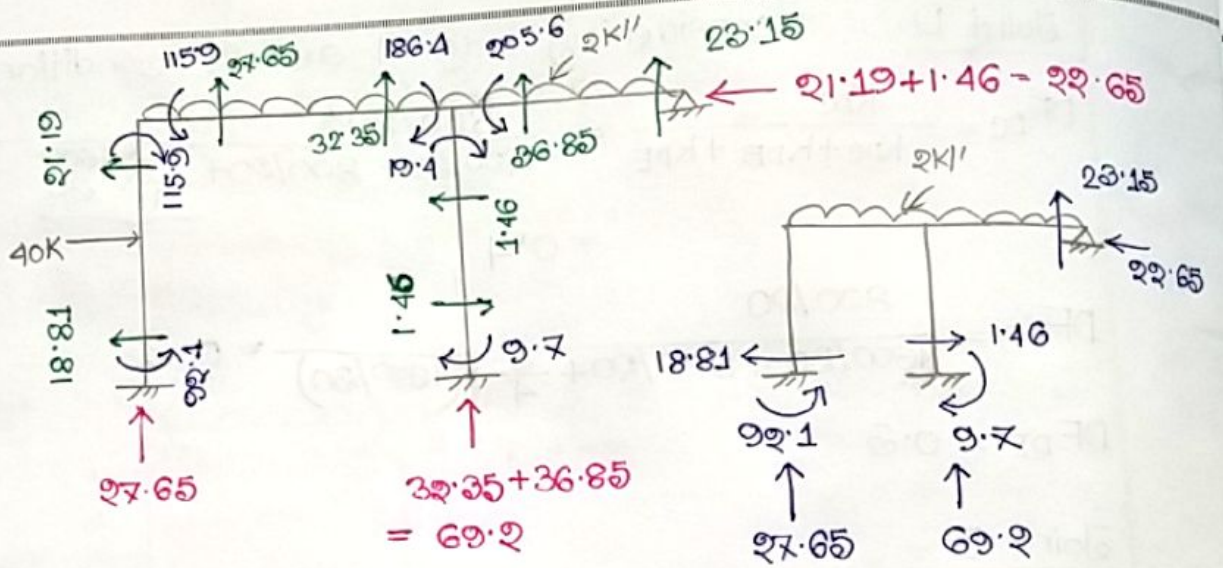

Full structure এর জন্য $\Sigma F_x, \Sigma F_y = 0$ হবে সি external loading & support reaction

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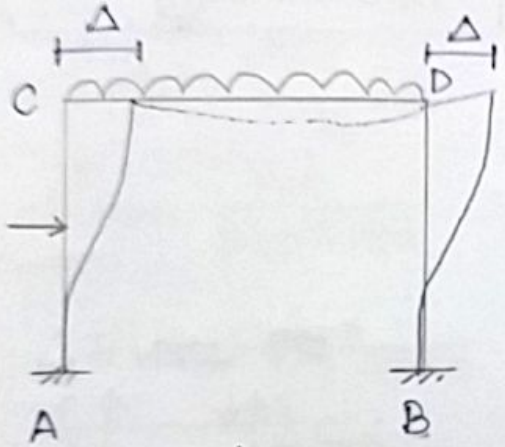
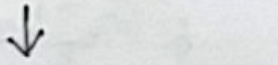
Frame with sidesway :

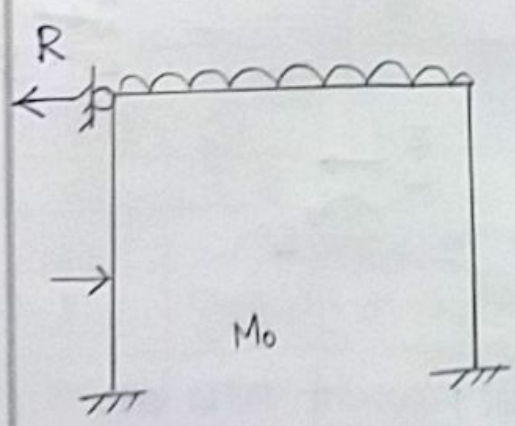
Joint translation and rotation allowed.



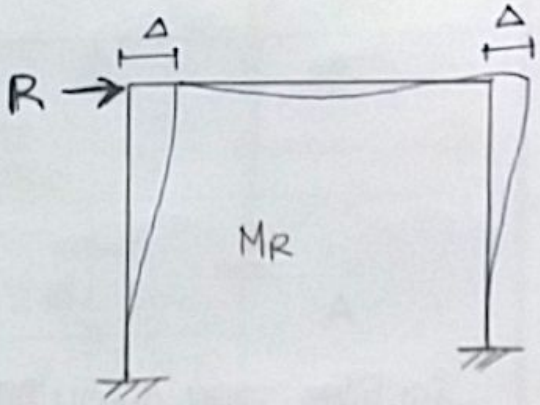
A, B → Restrained fully

C, D → Free to rotate & translate.





+



$M = M_0 + M_R$

• For significant amount of deformation $\Delta_C = \Delta_D = \Delta$

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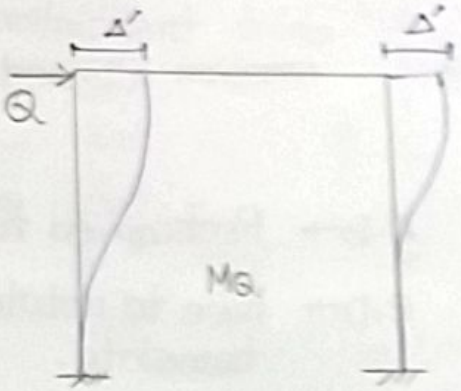
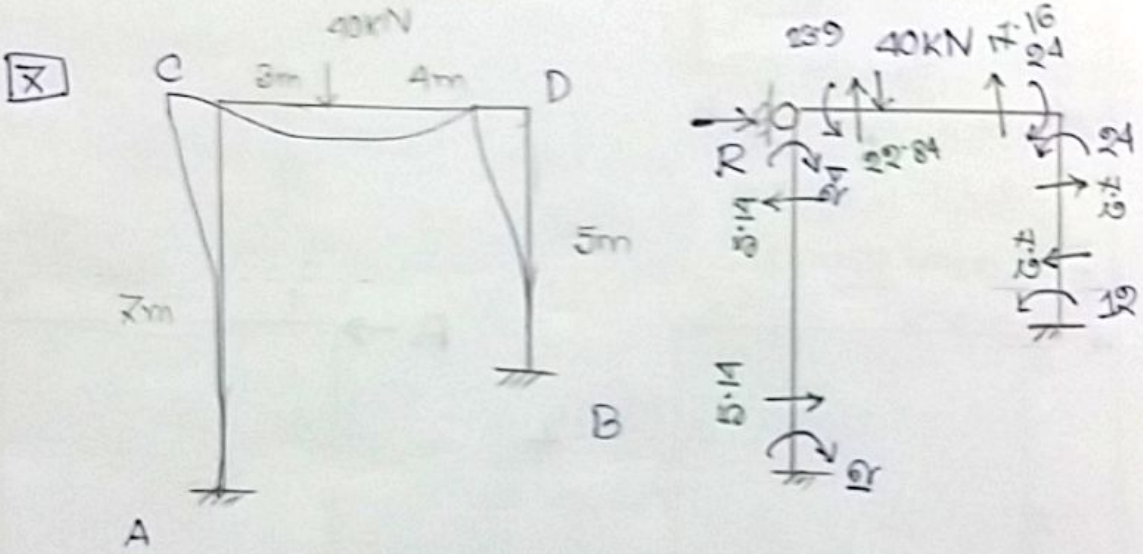
For M_R



$$M_R = \frac{M_Q}{Q} \times R$$

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



বাঁয়ে নিচ্ছি, বামে sway হচ্ছে, তাই এটা prevent করবার জন্য roller support দিচ্ছি, reaction R ধরেছি ডানে।

যদি calculation করে R এর value -ve হয়, তবে sway actually ডানে হয়েছে, এবং R actually বামে কাজ করছে।

যদি R=0 হয়, তবে কোন sideway হবে না।

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$$FEM_{CD} = \frac{40 \times 3 \times 4^2}{7^2} = 39.2\ KN.m$$

$$FEM_{DC} = \frac{40 \times 4 \times 3^2}{7^2} = -29.4\ KN.m$$

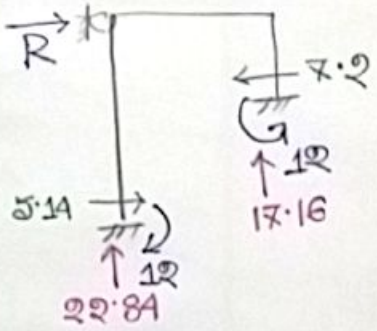
At C

$$DF_{CA} = \frac{K_{CA}}{K_{CA}+K_{CD}} = \frac{I/7}{I/7+I/7} = 0.5$$

$$DF_{CD} = \frac{K_{CD}}{K_{CD}+K_{CA}} = 0.5$$

$$DF_{DC} = \frac{I/7}{I/7+I/5} = 0.417$$

$$DF_{DB} = \frac{I/5}{I/5+I/7} = 0.583$$



$\Sigma F_x = 0$

$\Rightarrow R - 7.2 + 5.14 = 0$

$\therefore R = 2.06\ K (\rightarrow)$

A	C		D		B
AC	CA	CD	DC	DB	BD
0	0.5	0.5	0.417	0.583	0
		39.2	-29.4		
	-19.6	-19.6	+12.3	+17.1	
-9.8		+6.2	-9.8		8.6
	-3.1	-3.1	+4.1	+5.7	
-1.6		+2.1	-1.6		2.9
	-1.1	-1.1	+0.7	+0.9	
-0.6		+0.4	-0.6		0.5
	-0.2	-0.2	0.3	0.3	
-12	-24	23.9	-24	24	12

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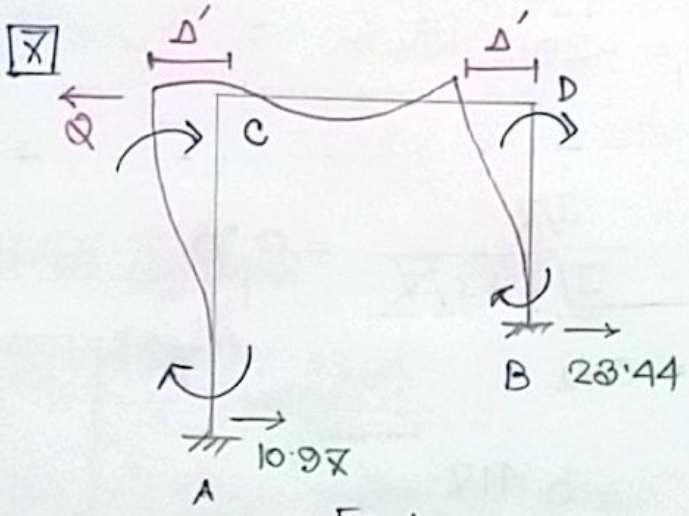

Fig-1

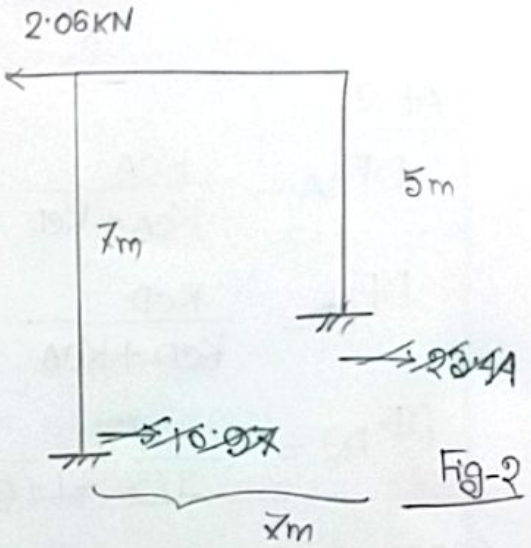

Fig-2

$$FEM_{AC} = FEM_{CA} = -\frac{6EI}{L^2}\Delta' = -\frac{6EI\,\Delta'}{49} = \boxed{-50}$$

(assumed value)

$$FEM_{BD} = FEM_{DB} = -\frac{6EI\,\Delta'}{25}$$

$$= \boxed{-98}\ KN.m$$

putting assumed value

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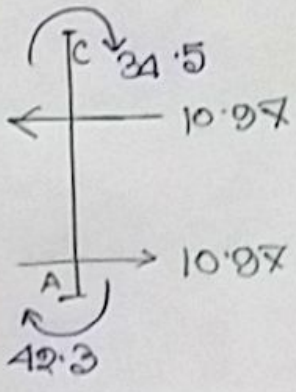
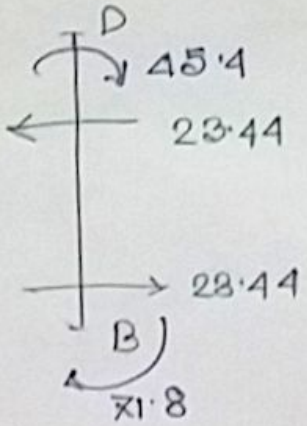
	0.5	0.5	0.417	0.583	
AC	CA	CD	DC	DB	BD
-50	-50			-98	-98
	25	25	40.9	57.1	
12.5		20.5	12.5		28.6
	-10.3	-10.3	-5.2	-7.3	
-5.2		-2.6	-5.2		-3.7
	1.3	1.3	2.2	3	
0.7		1.1	0.7		1.5
	-0.6	-0.6	-0.3	-0.4	
-0.3		-0.2	-0.3		-0.2
	0.1	0.1	0.1	0.2	
-42.3	-34.5	34.5	45.4	-45.4	-71.8





$\Sigma F_x = 0$ (Eq 1)

$\Rightarrow Q - 10.97 - 23.44 = 0$

$\therefore \boxed{Q = 34.41 \text{ KN}}$

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$M = M_0 + M_R$

$M_{AC} = -12 + \frac{2.06}{34.41}(-42.3) = -14.5 \text{ KN.m}$

$M_{CA} = -24 + \frac{2.06}{34.41}(-34.5) = -26.1$

$M_{CD} = 23.9 + \frac{2.06}{34.41}(34.3) = 26$

$M_{DC} = -24 + \frac{2.06}{34.41}(45.4) = -21.3$

$M_{DB} = 24 + \frac{2.06}{34.41}(-45.4) = 21.3$

$M_{BD} = 12 + \frac{2.06}{34.41}(-71.8) = 7.7 \text{ KN}$

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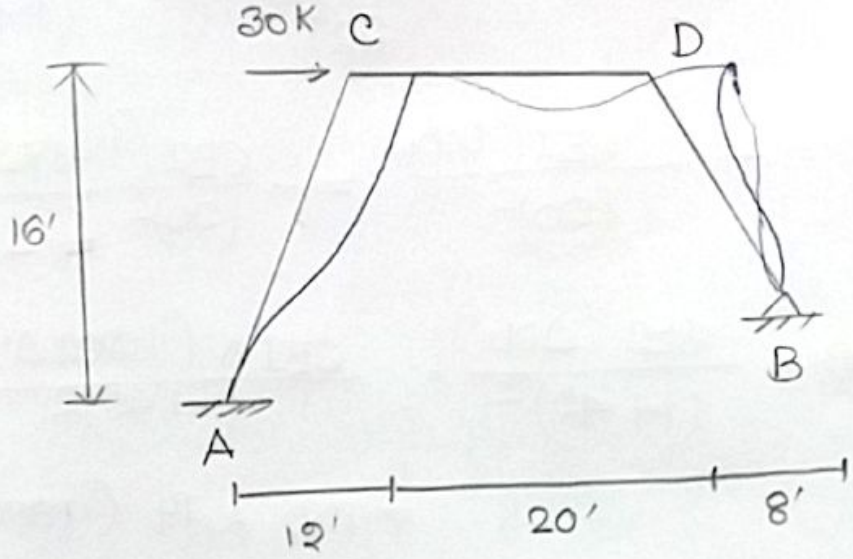
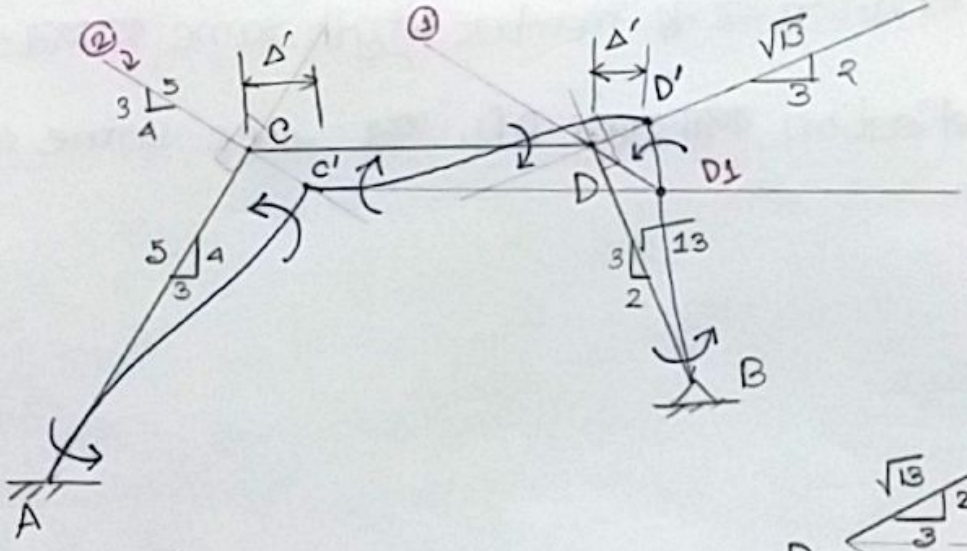


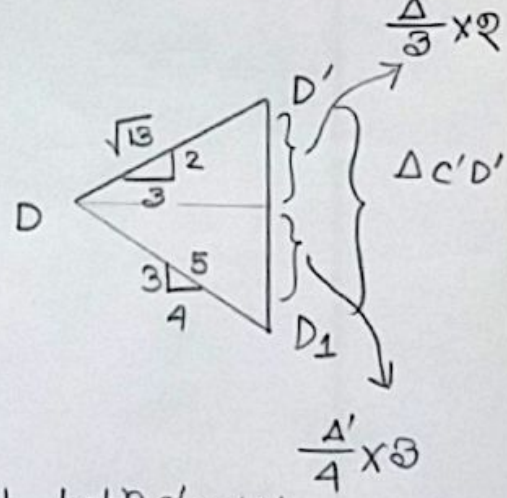
EI constant

$C'D_1$ হল CD এর parallel.

D_1 deflected shape কে ছেদ করে

line ① & ② parallel





$$\Delta CC' = \frac{\Delta'}{4} \times 5 = 1.25\,\Delta'$$

$$\Delta DD' = \frac{\Delta'}{3} \times \sqrt{13} = 1.202\,\Delta'$$

$\Delta C'D'$ = relative vertical displacement bet^n C' and D'

$= \Delta D'$

$$= \frac{\Delta'}{3} \times 2 + \frac{\Delta'}{4} \times 3 = 1.417\,\Delta'$$

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$$FEM_{AC} = FEM_{CA} = \frac{6EI\,\Delta cc'}{L^2} = \frac{6EI(1.25\Delta')}{20^2} = 54.1$$ (putting assumed value)

$$FEM_{CD} = FEM_{DC} = -\frac{6EI(D'D_1)}{(20)^2} = -\frac{6EI(1.417\Delta')}{(20)^2} = -61.3$$

$$FEM_{BD} = FEM_{DB} = \frac{6EI(\Delta DD')}{(14.42)^2} = \frac{6EI \times (1.202\Delta')}{(14.42)^2}$$

$$= 100 \text{ k-ft (assume)}$$

- deflection এর জন্য member length same থাকবে।
- deflection বলম হলে DD_1 এর slope same as AC.

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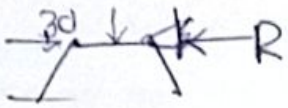
[8]

AC	0·5 CA	0·5 CD	0·49 DC	0·51 DB	1 BD
54·1	54·1	-61·3	-61·3	100	100
	3·6	3·6	-19	-19·7	-100
1·8		-9·5	1·8	-50	
	4·8	4·8	23·6	24·6	
2·4		11·8	2·4		
	-5·9	-5·9	-1·2	-1·2	
-3		-0·6	-3		
	0·3	0·3	+1·5	1·5	
0·2		0·8	0·2		
	-0·4	-0·4	-0·1	-0·1	
-0·2			-0·2		
			0·1	0·1	
55·3	56·5	-56·4	-55·2	55·2	0



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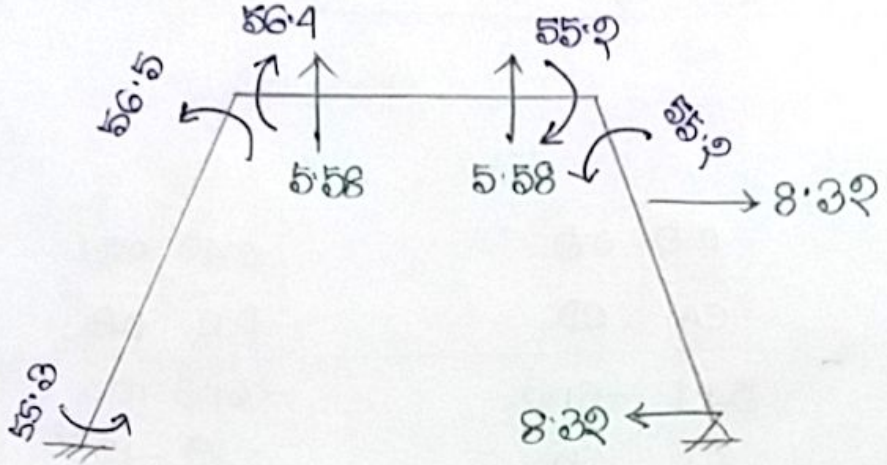

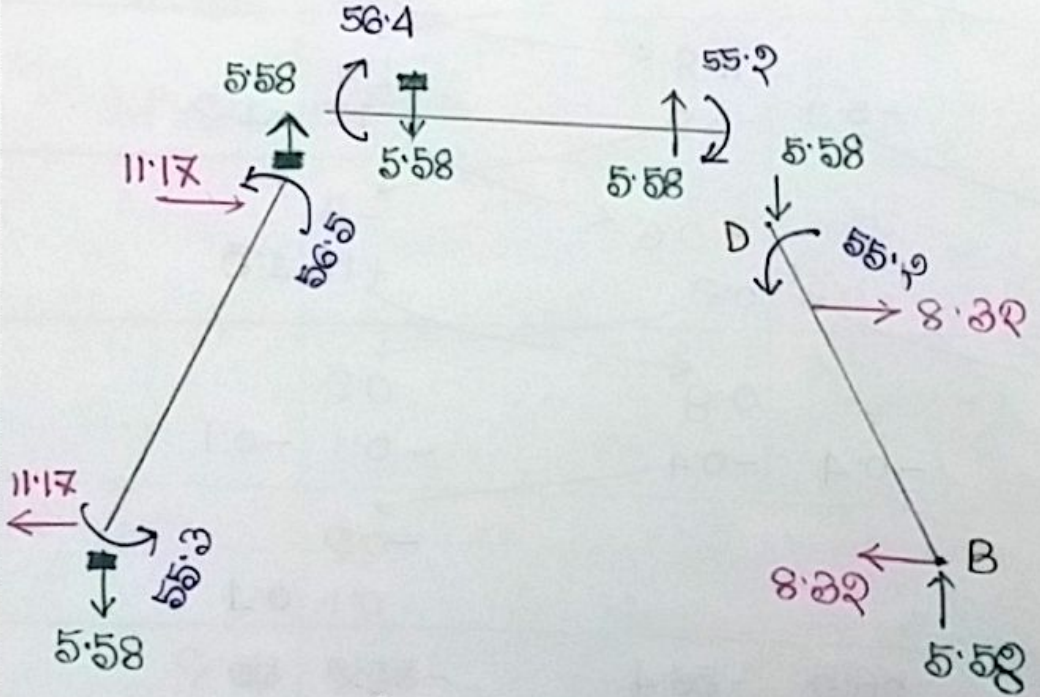

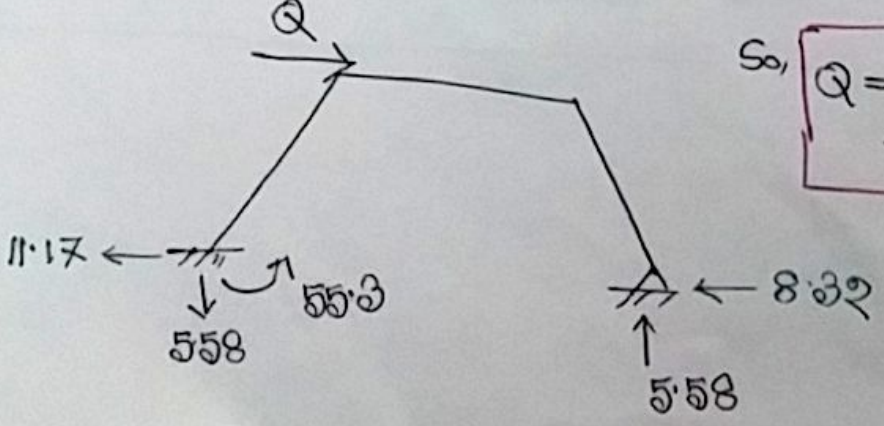

So, $Q = 11·17 + 8·32$
$= 19·49K\ (\rightarrow)$

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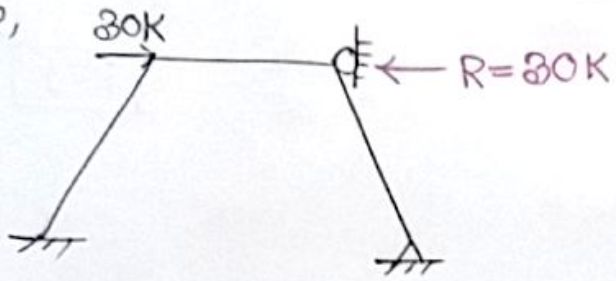
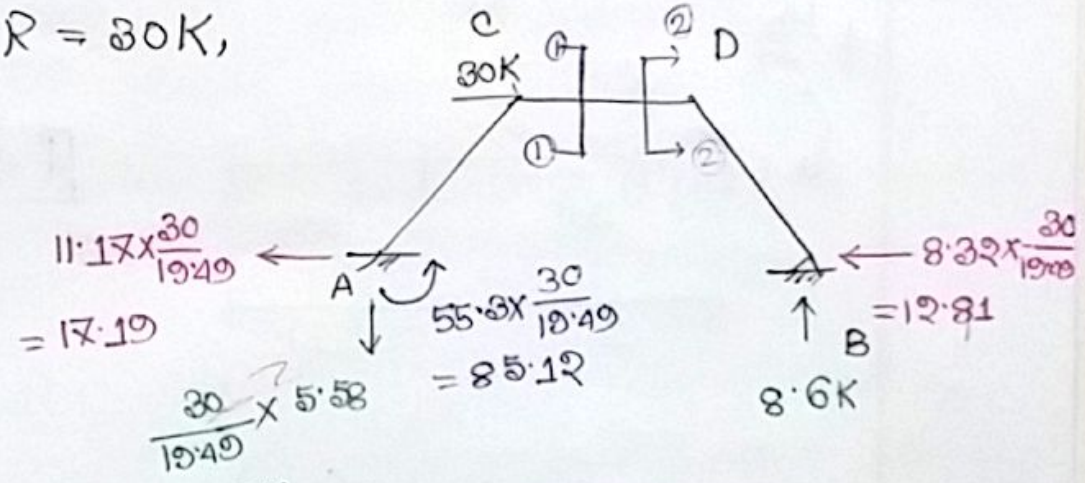
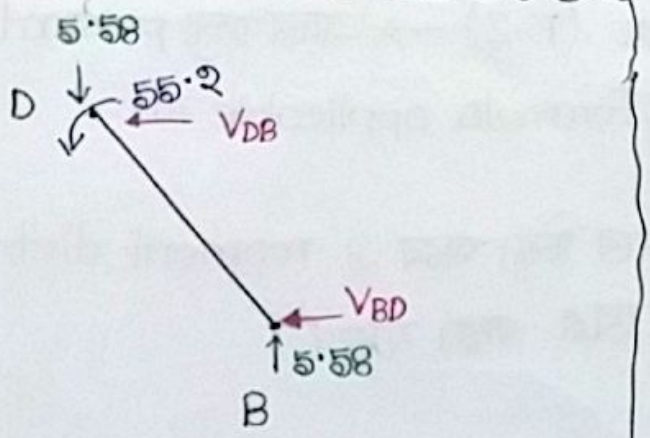
Here,



So, for R = 30K,



section ①-①

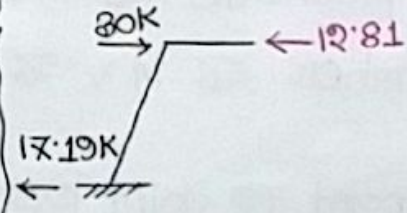


$\Sigma M_D = 0$ (+ve)

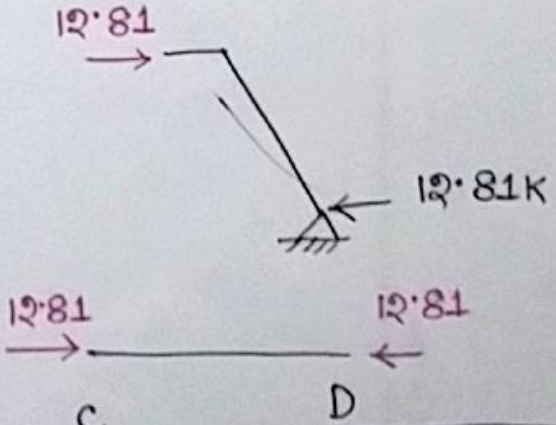
$\Rightarrow -55.2 + V_{BD} \times 12 - 5.58 \times 8 = 0$

$\therefore V_{BD} = 8.32K (\leftarrow)$

$\therefore V_{DB} = 8.32K (\rightarrow)$



section ②-②



$\therefore$ Axial force of CD = $\boxed{-12.81K (C)}$

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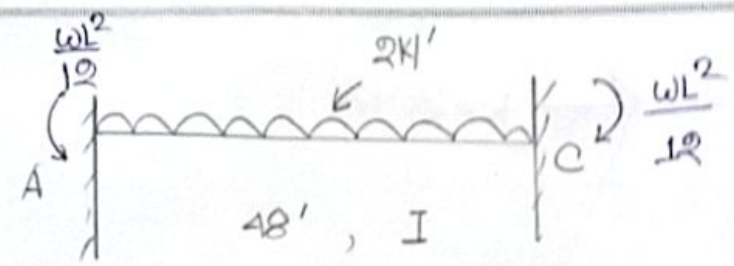
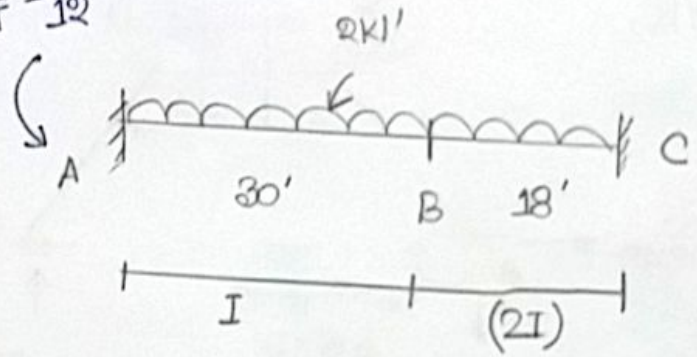


F-1

$\neq \frac{wL^2}{12}$



F-2

* Prismatic member (F-1)

* Non prismatic member (F-2) → এদের জন্য prismatic member এর M, V এর Formula applicable না।

* B point কে Joint হিসেবে চিন্তা করব ও moment distribution table এর মাধ্যমে M বের করা যায়।

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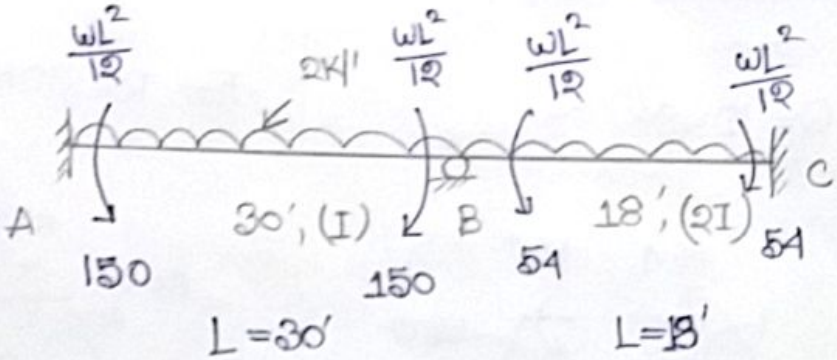
চিত্র F-2 B point এ একটা Arbitrarcy support দিয়ে আছি।



এবার moment distribution table থেকে B point এর joint এ moment equilibrium করব।

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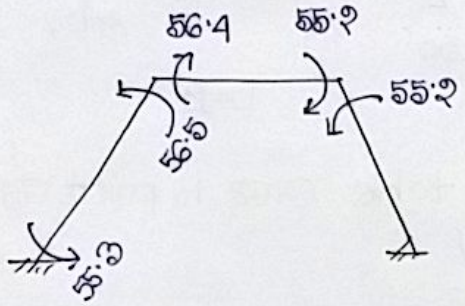
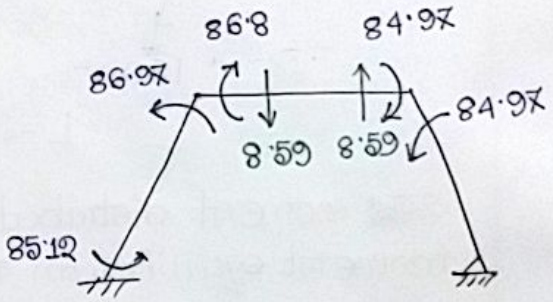
Math No.-8 cont...

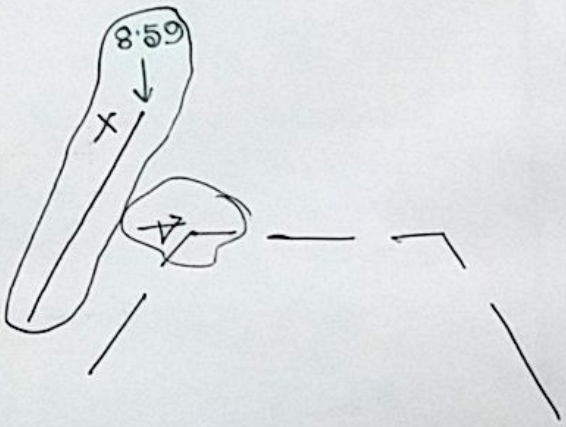
For, Q= 19.49K,



For, R= 30K, $M_R = \frac{R}{Q} \times M_Q$



অর্থাৎ, Q Force এর জন্য Joint equilibrium করলে যেই V, M, P পাচ্ছি তাটা use করলে R এর জন্য V, M, P পাব।



$$\begin{cases} M_R = \frac{R}{Q} M_Q \\ V_R = \frac{R}{Q} V_Q \\ P_R = \frac{R}{Q} P_Q \end{cases}$$

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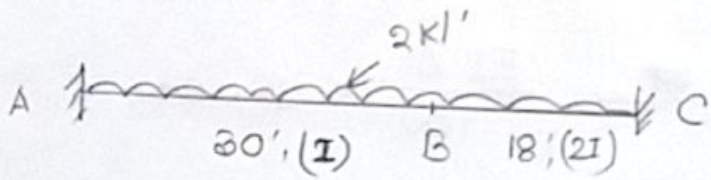
[9] cont....

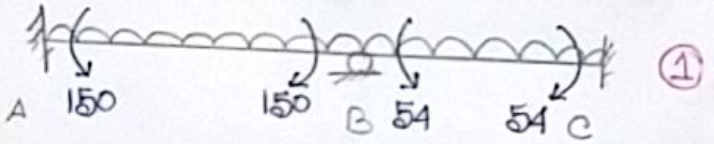


③

$$DF_{BA} = \frac{K_{BA}}{K_{BA} + K_{BC}}$$

$$= \frac{I/30}{I/30 + 2I/18}$$

$$= 0.231$$

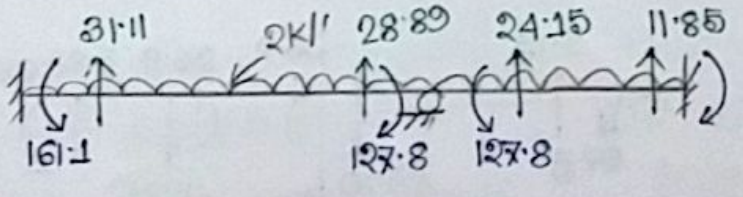


①

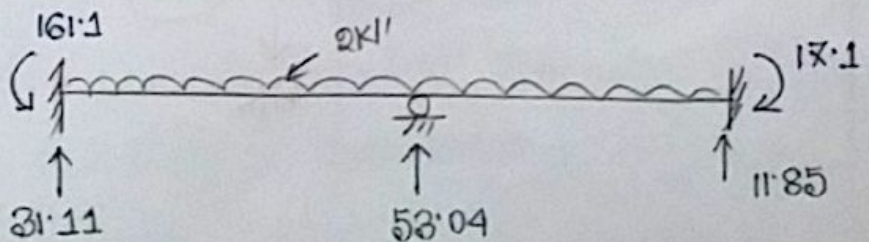
$$DF_{BC} = 0.769$$

	0.231	0.769	
AB	BA	BC	CB
150	−150	54	−54
	22.2	73.8	
11.1			36.9
161.1	−127.8	127.8	−17.1

B Joint ও unbalanced moment নেই, তাই Table closed.



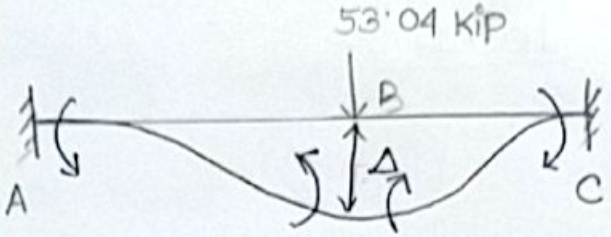
④



Sub: _____

SAT SUN MON TUE WED THU FRI

DATE: / /



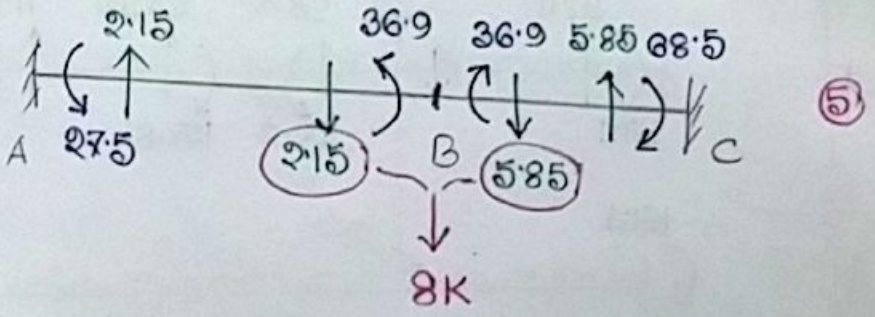
② ①+② इन original beam ③.

$$FEM_{AB=BA} = \frac{6EI\Delta}{(20)^2} = \frac{EI\cdot\Delta}{150} = 18\ K\cdot ft$$

$$FEM_{BC=CB} = -\frac{6E\cdot 2I\cdot\Delta}{(18)^2} = -\frac{EI\Delta}{27} = -100\ K\cdot ft\ (assumed)$$

$\therefore EI\Delta = 2700$

	0·231	0·769	
AB	BA	BC	CB
18	18	−100	−100
	18·9	68·1	
9·5			31·5
27·5	36·9	−36·9	−68·5



⑤

** Sunday 10:00 তায় B section review class

Sub: _____

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DATE: / /

$M_{AB} = 161.1 + 27.5 \times \frac{53.04}{8} = 343.4$ K'

$M_{CB} = -17.1 - 68.5 \times \frac{53.04}{8} = -471.2$ K-ft

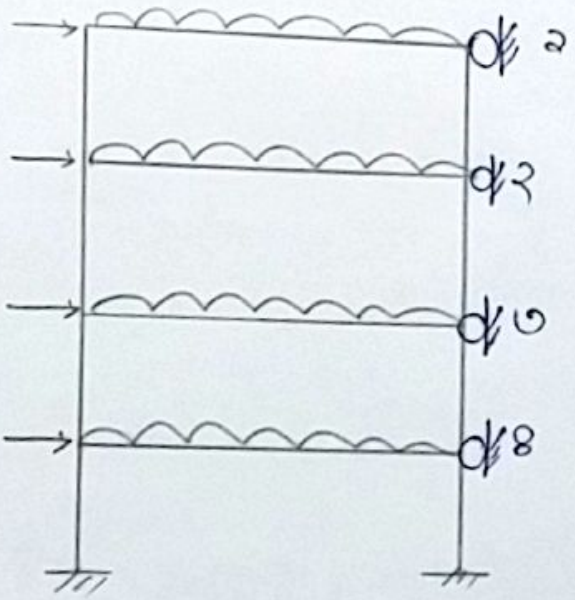
$R_A = 31.11 + 2.15 \times \frac{53.04}{8} = 45.36$ Kip (↑)

$R_C = 11.85 + 5.85 \times \frac{53.04}{8} = 50.64$ Kip (↑)

④+⑤ এর জন্য

* যার M.O.I বেশি, সে বেশি Load, V, M carry করবে।

**



← sway prevent করার জন্য সেই Roller support দিচ্ছি তো step by step redundent করব।

আগে ২, then 2, 3, 4.. এভাবে open করব। যখন ২ খুলব, তখন ২, ৩, ৪ থাকবে। এভাবে...

* $\frac{WL^2}{12}$ লিখার চেয়ে value input দিয়ে লিখলে 100% marks পাওয়া যাবে। যেমন, L = 20', W = 2K/' হলে $\frac{2 \times (20)^2}{12}$ এভাবে লিখব।