Sub: _____ SAT SUN MON TUE WED THU FRI ☐ ☐ ☐ ☐ ☐ ☐ ☐

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Dr. Tanvir Manzur

Lec-1

- Analysis method তিন।
  1) Flexibility
  2) Stiffness
  3) Moment Distribution

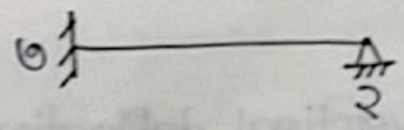
এখানে আমরা use করব general stiffness method.

DOSI- Degree of Static Indeterminacy

DOKI- " " Kinematic "

- DOSI → যের করা হয় reaction (support) থেকে।

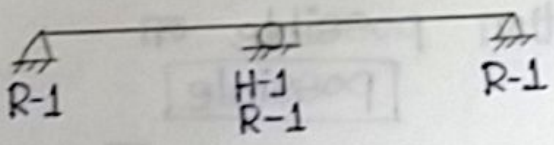
$$DOSI = 5-3 = 2$$



- DOKI → যের করা হয় deformation থেকে

$$DOKI = 4$$

H = Horizontal
V = Vertical
R = Rotation



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Steps:

১ – Load apply এর যখন structure এর DOKI বের করব।

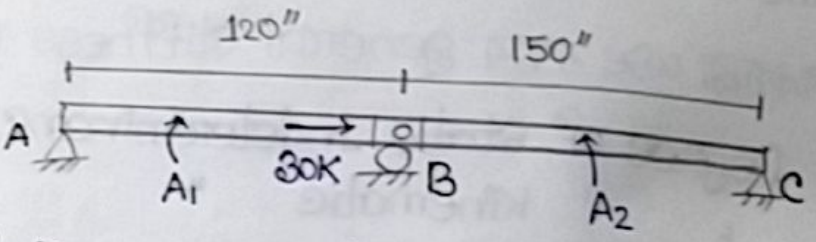
২ – যেখানে Deformation হবে সেটা lock করব fixed support দিয়ে।

৩ – এই support reaction বের করব।

৪ – locked place খুলে দিয়ে unit displacement দিব। এই Dis. এর জন্য load calculate করব।

৫ – Reaction এর সাথে equate করে Δ বের করব।

Math (1)



(১) $A_1 = 1.2 in^2$ | $E_1 = 10000$ KSi
$A_2 = 0.6 in^2$ | $E_2 = 20000$ KSi

Here, DOKI = 1

• Load horizontal (axial load), তাই vertical deflection and rotation possible না। শুধু horizontal deflection possible.

point A, Horizontal deflection possible না
" B, " " possible
" C, " " না

Rotation সম্ভব যদি → vertical load বা moment থাকে। axial load এর জন্য rotation আসে না।

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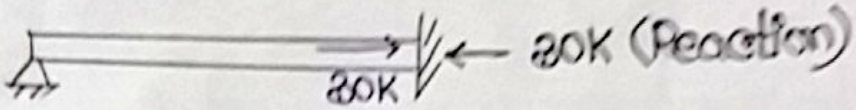
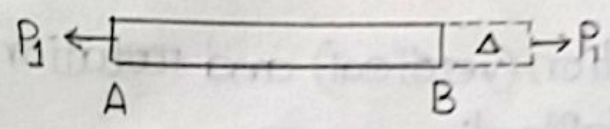
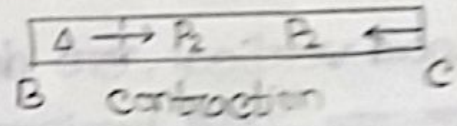
(2+6)



(8)



expansion



contraction

$\Delta = \frac{PL}{AE}$

$P_1 = \frac{AE}{L} \cdot \Delta$

$= \frac{1.2 \times 10000}{120} \cdot \Delta$

$= 100\Delta$

$P_2 = \frac{0.6 \times 20000}{150} \Delta$

$= 80\Delta$

$\leftrightarrow 30K$

$\leftarrow 100\Delta \quad \leftarrow 80\Delta$

$\therefore 180\Delta = 30$

$\therefore \Delta = \frac{1}{6}$

$\therefore P_1 = 100\Delta = 100/6 \ K$

$P_2 = 80\Delta = 80/6 \ K$

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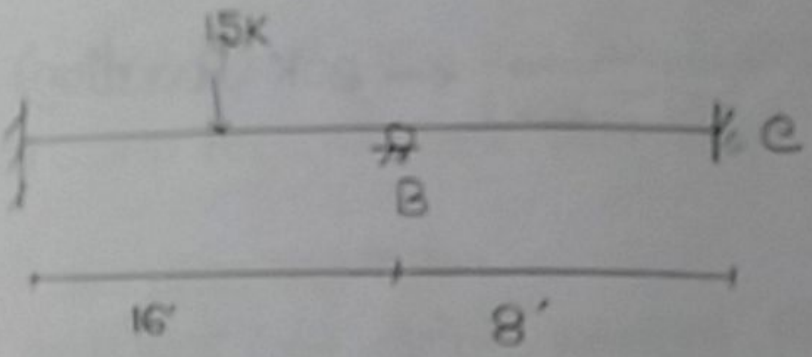
Math (2)



Load vertical, তাই deflection (vertical) and rotation হতে পারে, কোন horizontal deflection হবে না।

point A তে V, R কোনটাই অসম্ভব না

" C " " " " "

" B " V অসম্ভব না, R অসম্ভব

DOKJ = 1

- 1 unit axial deformation এর জন্য যে force লাগে তা হল → stiffness.
- 1 unit rotation এর জন্য যে moment লাগে → rotational stiffness.

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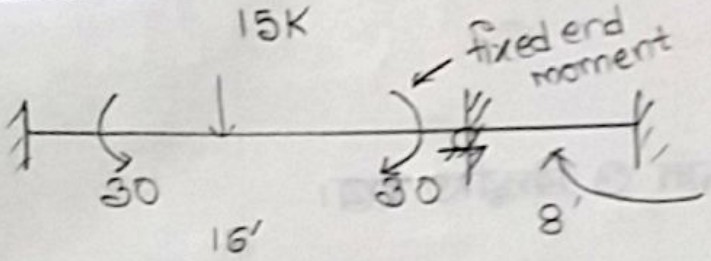
u_1 যেদিকে দিয়েছি
Moment M_1 & M_2
সেদিকে দিয়েছি

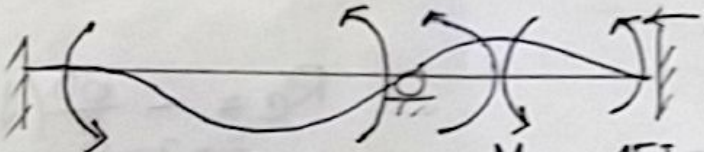
Math (2)



এখানে সমস্যা না, কেন
এই side এ load নাই

↺ + ↻
↻ − ↺

$\frac{4EI}{L_1} = \frac{4EI}{16} = \frac{EI}{4} u_1 = 10$



$M_2 = \frac{EI}{8} u_1 = 5$

$M_1 = \frac{4EI}{L_2} = \frac{4EI}{8} = \frac{EI}{2} u_1 = 20$

near end $M_1 = \frac{4EI}{L}\theta$
far end $M_2 = \frac{2EI}{L}\theta$

- DOKI -2 হলে হতো eqn, হতো OK আসত।
2 point এ moment equilibrium চিন্তা করতাম।

Now, ↻ 30 (2 +ve)

@B $\Sigma M_B = 0$

$+30 - \frac{EI}{4} u_1 - \frac{EI}{2} u_1 = 0$

$\therefore u_1 = \frac{40}{EI}$

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↷ +ve clockwise
↶ -ve anticlockwise

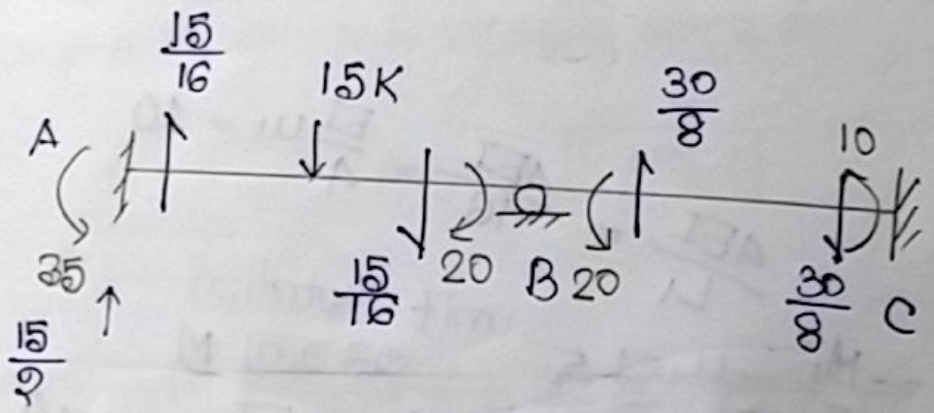
$M_{AB} = -30 - 5 = -35$

$M_{BA} = 30 - 10 = 20$

$M_{BC} = -20$

$M_{CB} = -10$

M_{BA} ও M_{BC} সমান ও বিপরীত হবে।



$R_A = +\frac{15}{2}(\uparrow) + \frac{15}{16}(\uparrow)$

$= \frac{135}{16}(\uparrow)$

$R_C = -\frac{30}{8}(\downarrow)$

$= -3.75$

$R_B = \frac{-15}{16}(\downarrow) + \frac{15}{2}(\uparrow) + \frac{30}{8}(\uparrow)$

$= 10.31$

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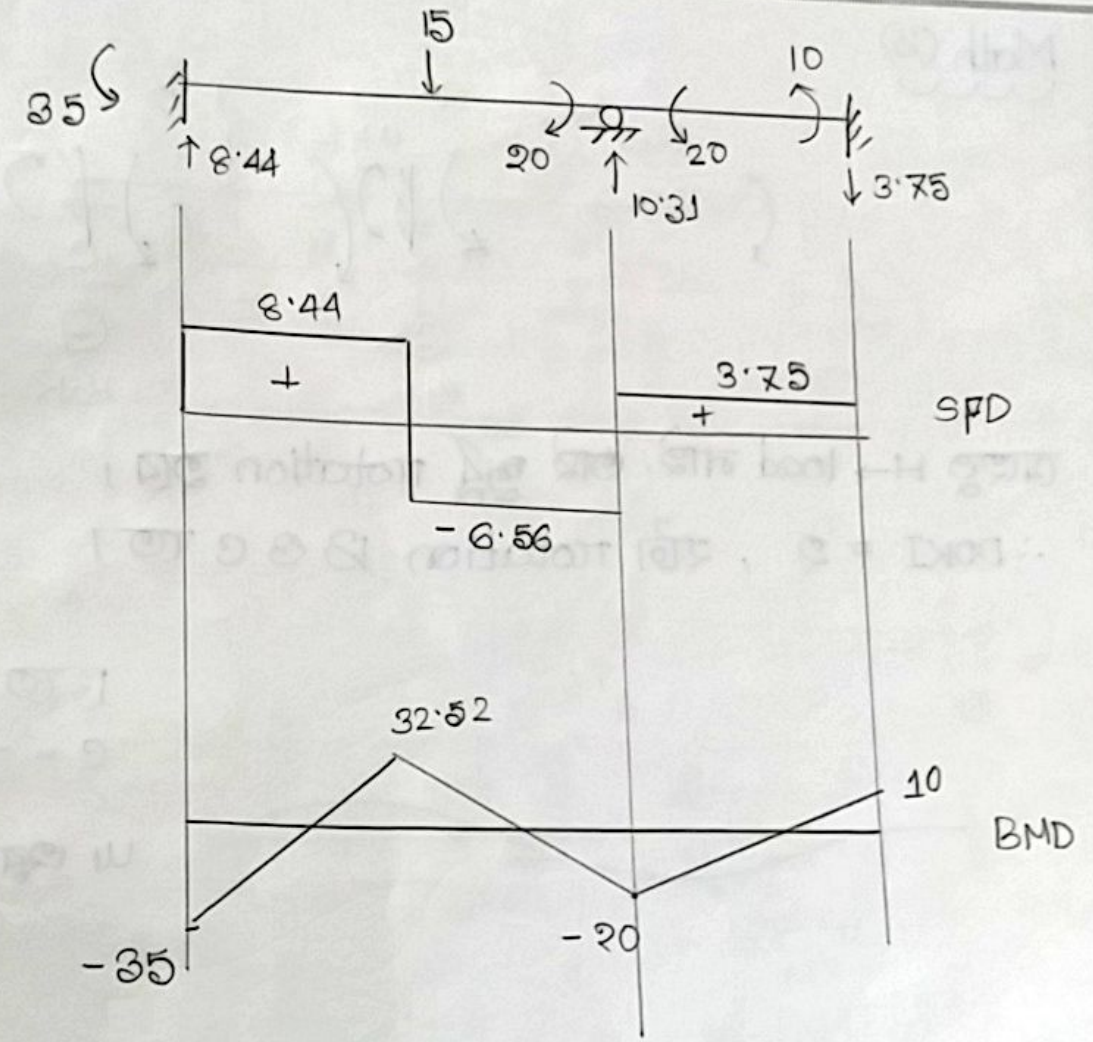

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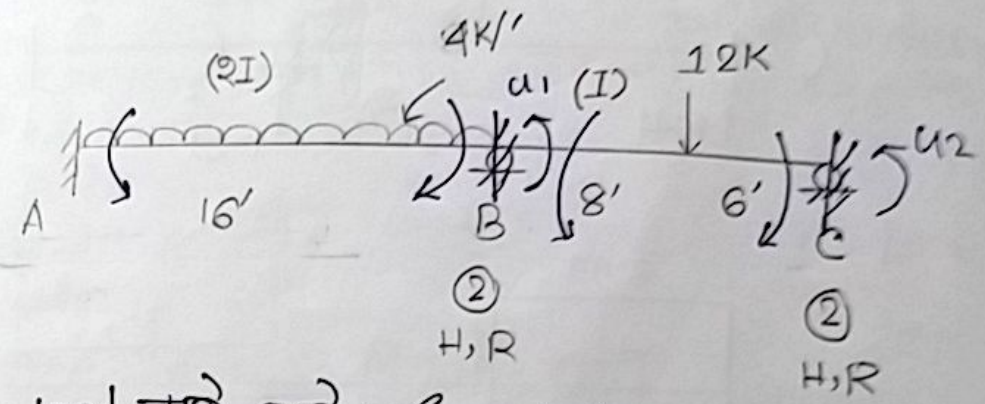
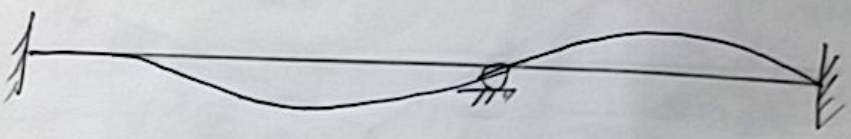
Math (3)



যেহেতু H → load নাই, তাই শুধু rotation হবে,

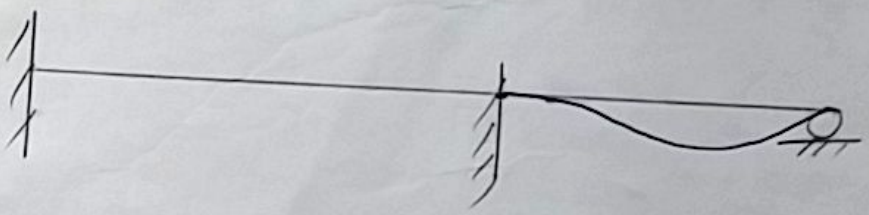
∴ DOKI = 2 , 2টা rotation B ও C তে;



B তে → 5টা

C u → 6টা

u_1 এর



u_2 এর

Q* Superposition এর নিয়ম কী?

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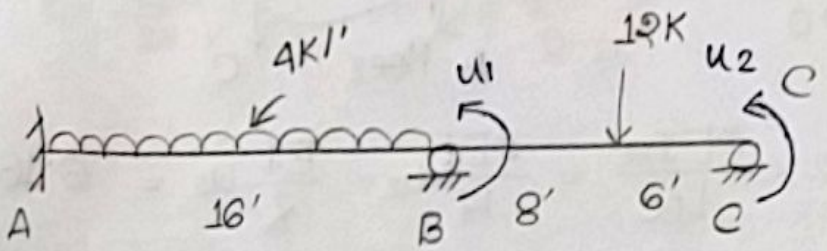
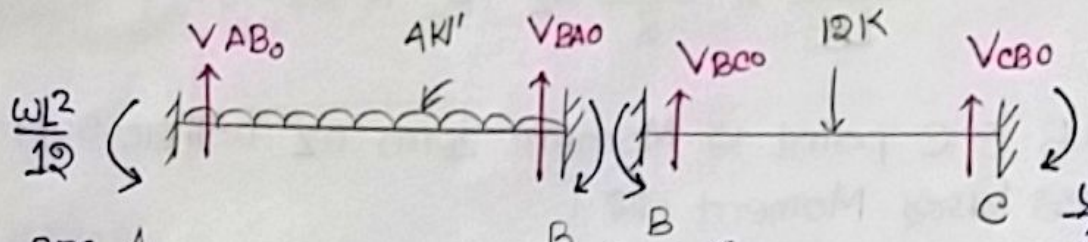
SFD
BMD
Deflected shape

(4) (3)



$I_{AB} = 2I$
$I_{BC} = I$

→ সব কয়টি support fixed করে দিব, যেখানে rotation হবে।



$U_1 = 0, U_2 = 0$

$\frac{WL^2}{12}$

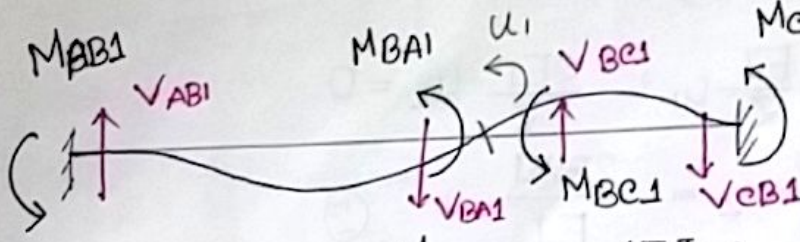
$= \frac{256}{3}$ K/ft $= 85.33$
$= M_{AB0}$

$\frac{WL^2}{12}$ $\frac{256}{3}$ K.ft
$= M_{BA0}$

$\frac{WL^2}{12}$ $\frac{2ab^2}{L^2}$
$= \frac{12 \times 8 \times 6^2}{14^2}$
$= \frac{864}{49}$ K' $= 17.63$
$= M_{BC0}$

$\frac{Pa^2b}{L^2}$
$\frac{12 \times 8^2 \times 6}{14^2}$
$\frac{1152}{49}$ K' $= 23.51$
$= M_{CB0}$

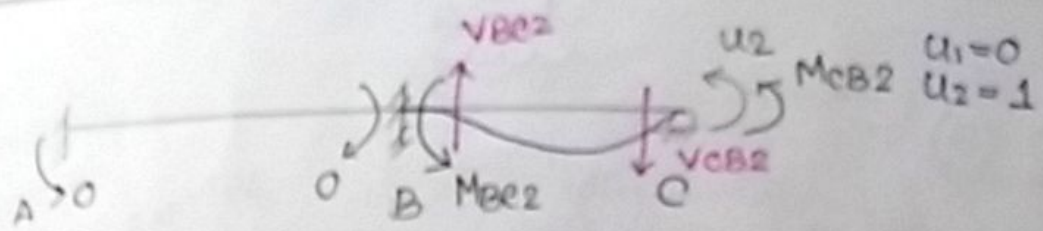
→ যেকোন একটি support খুলে দিব, অন্যগুলো fixed ই থাকবে।



$U_1 = 1$
$U_2 = 0$

$\frac{U_1 EI}{4} = M_{AB1} = \frac{2EI_{AB}}{L_{AB}}$, $M_{BA1} = \frac{4EI_{AB}}{L_{AB}} = \frac{EI}{2} U_1 = 39.16$ K'
$= 19.58$ K'

- $M_{BC1} = \frac{4EI_{BC}}{L_{BC}}$, $M_{CB1} = \frac{2EI_{BC}}{L_{BC}} = \frac{EI}{7} U_1$
$= 11.189$ K'
$= \frac{2EI}{7} U_1 = 22.378$ K'



$$M_{BC2} = \frac{2EI_{BC}}{L_{BC}} = \frac{2EI}{14}u_2 - \frac{EI}{7}u_2 = 6.16\ K\text{-}ft$$

$$M_{CB2} = \frac{4EI_{BC}}{L_{BC}} = \frac{2EI}{7}u_2 = 12.32\ K\text{-}ft$$

*B & C point ला Moment zero. ez roller support ला निश्चय Moment नाही।

$\Sigma M_B = 0$ (2+ve)

$$\Rightarrow 8533 - 1763 - \frac{EI}{2}u_1 - \frac{2EI}{7}u_1 - \frac{EI}{7}u_2 = 0$$

$$\Rightarrow \frac{11}{14}EIu_1 + \frac{1}{7}EIu_2 = 67.7$$

$$\therefore u_1\frac{11}{14} + u_2 \cdot \frac{1}{7} = \frac{67.7}{EI} \quad \ldots (1)$$

$\Sigma M_C = 0$ (2+ve)

$$\Rightarrow 2351 - \frac{EI}{7}u_1 - \frac{2EI}{7}u_2 = 0$$

$$\Rightarrow \frac{1}{7}u_1 + \frac{2}{7}u_2 = \frac{2351}{EI} \quad \ldots (2)$$

Solving (1) and (2),

$u_1 = 78.398/EI$

$u_2 = 48.12/EI$

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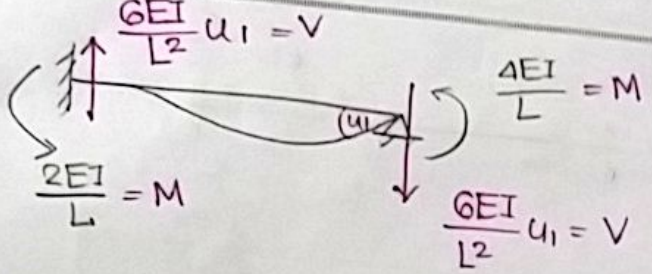
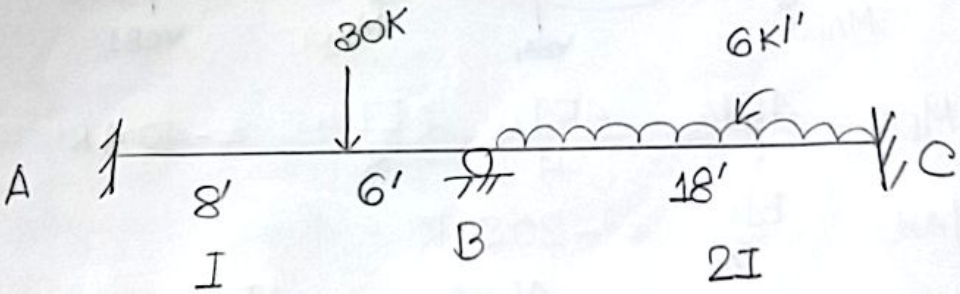


*'V' বের করার জন্য ও $\Sigma V_A = 0$, $\Sigma V_B = 0$, $\Sigma V_C = 0$ করতে হবে।

$\Sigma V_A = 0$ (↑ +ve)

[4] H.W



DOKI = 1

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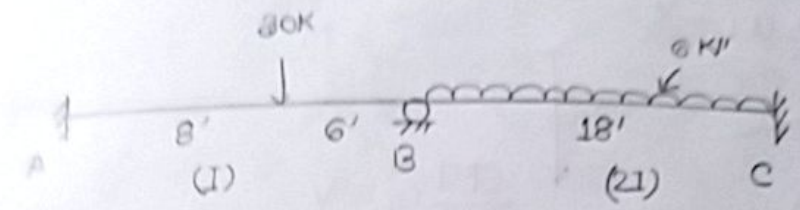
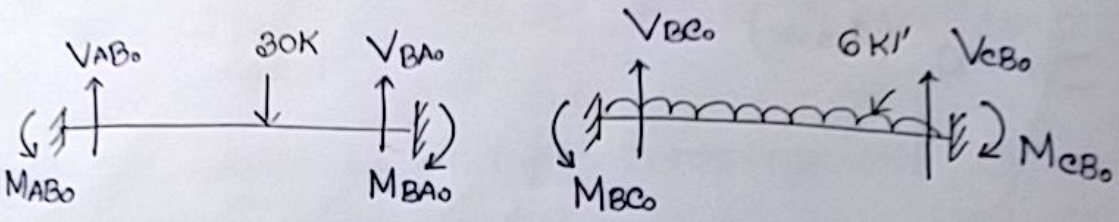
Ex1



Here, DOKI = 1

$I_{AB} = I$

$I_{BC} = 2I$



$M_{AB_0} = \frac{Pab^2}{L^2} = \frac{30 \times 8 \times 6^2}{14^2} = 44.08\ K'$

$M_{BA_0} = \frac{Pa^2b}{L^2} = \frac{30 \times 8^2 \times 6}{14^2} = 58.78\ K'$

$M_{BC_0} = \frac{wL^2}{12} = \frac{6 \times (18)^2}{12} = 162\ K'$

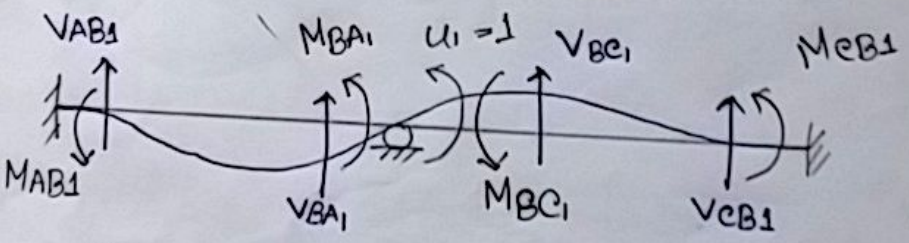
$M_{CB_0} = 162\ K'$

$V_{AB_0} = 11.81\ K(\uparrow)$

$V_{BA_0} = 18.19\ K(\uparrow)$

$V_{CB_0} = 54\ K(\uparrow)$

$V_{BC_0} = 54\ K(\uparrow)$



$M_{BA_1} = \frac{4EI}{L} u_1 = \frac{4EI}{14} u_1 - \frac{2EI u_1}{7} = -40.4\ K'$

$M_{AB_1} = \frac{EI u_1}{7} = -20.2\ K'$

$M_{BC_1} = \frac{4EI}{L} u_1 = \frac{4E \times 2I}{18} u_1 = \frac{4EI}{9} u_1 = -62.84\ K'$

$M_{CB_1} = \frac{2EI}{9} u_1 = -31.42\ K'$

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$\Sigma M_B = 0$ (2+ve)

$\Rightarrow 58.78 - 162 - \frac{9}{7} EI u_1 - \frac{4}{9} EI u_1 = 0$

$\Rightarrow 0.73 EI u_1 = -103.22$

$\therefore u_1 = \frac{-141.4}{EI}$

For AB

$\Sigma M_A = 0$ (2+ve)

$\Rightarrow 202 + 40.4 - V_{BA1} \times 14 = 0$

$\therefore V_{BA1} = 4.33\,K\,(\uparrow)$

$V_{AB1} = 4.33\,K\,(\downarrow)$

For BC

$\Sigma M_B = 0$ (2+ve)

$\Rightarrow 62.84 + 31.42 - V_{CB1} \times 18 = 0$

$\therefore V_{CB1} = 5.24\,K\,(\uparrow)$

$V_{BC1} = 5.24\,K\,(\downarrow)$

Applying superposition,

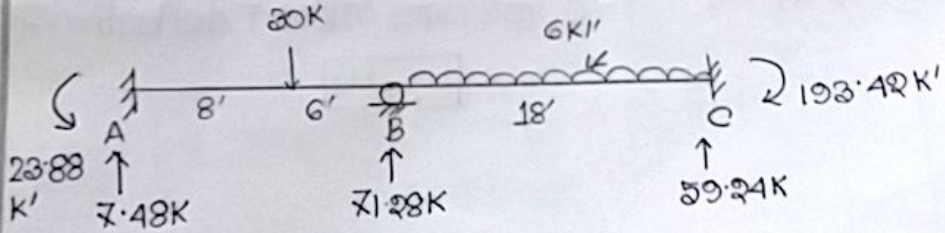
$R_A = 11.81 - 4.33\,K = 7.48\,K\,(\uparrow)$

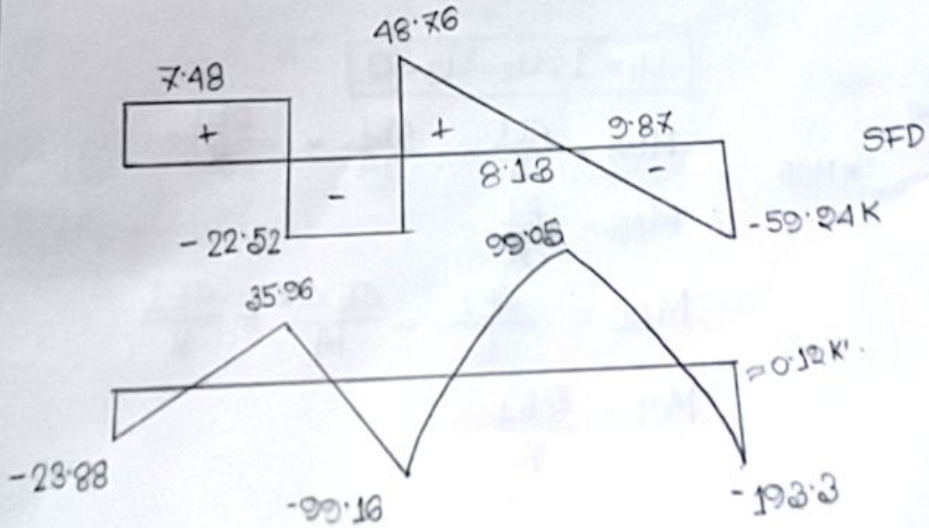
$R_B = 18.19 + 54 + 4.33 - 5.24 = 71.28\,K\,(\uparrow)$

$R_C = 54 + 5.24 = 59.24\,K\,(\uparrow)$

$M_A = -44.08 + 20.2 = -23.88\,K'$ (5)

$M_C = 162 + 31.42 = 193.42\,K'$ (2)





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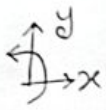
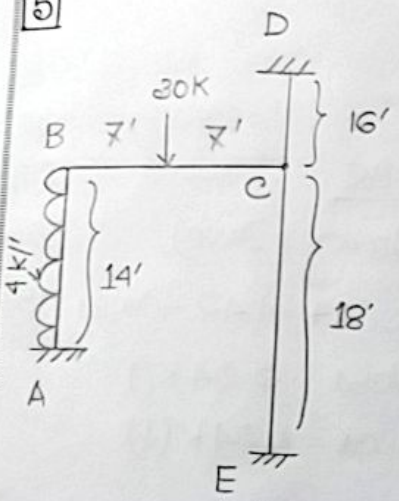
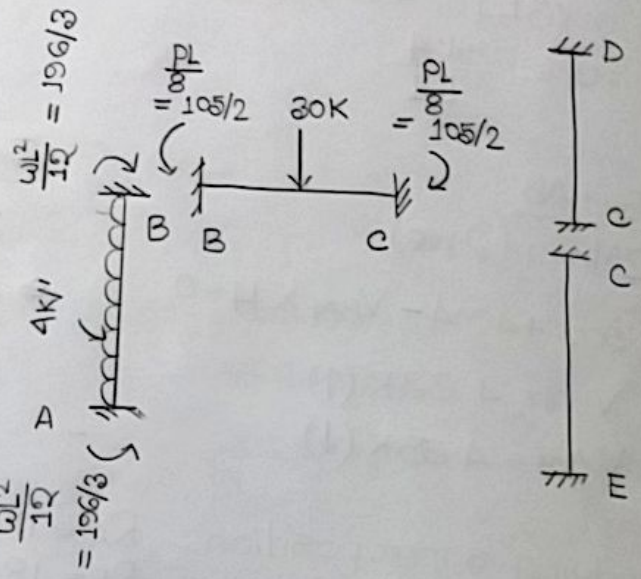
Sway Frame

CD = I
CE = 2I
AB = I
BC = 2I

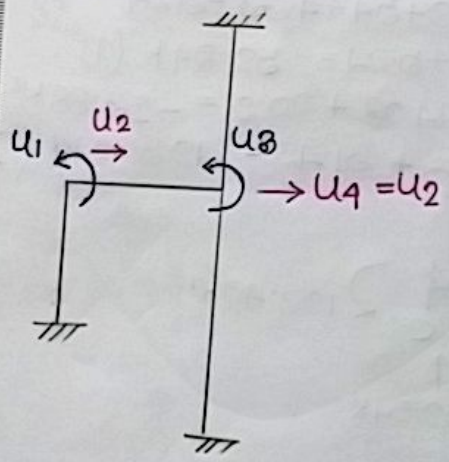
5





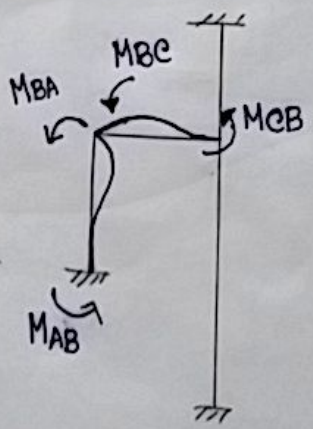


*neglect axial deformation:



Load এর কারনে B তে যতটুকু deflect করবে, at x direction, C তেও একই পরিমান deflection হবে।

$u_2 = u_4$



$u_1 = 1, u_2 = u_3 = 0$

$M_{BA} = \frac{4EI}{L} = \frac{4EI}{14} = \frac{2EI}{7}$

$M_{AB} = \frac{EI}{7}$

$M_{BC} = \frac{4EI}{L} = \frac{4E \times 2I}{14} = \frac{4EI}{7}$

$M_{CB} = \frac{2EI}{7}$

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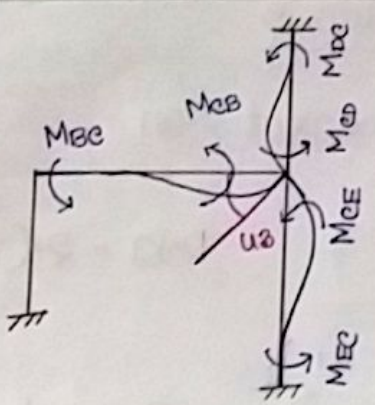
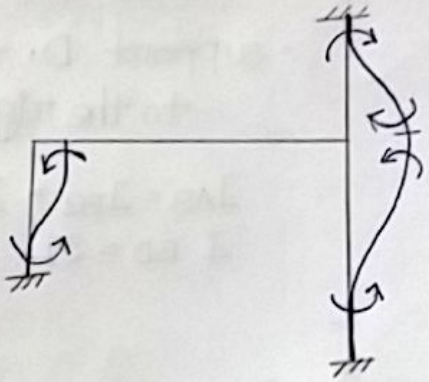
$u_3 = 1$

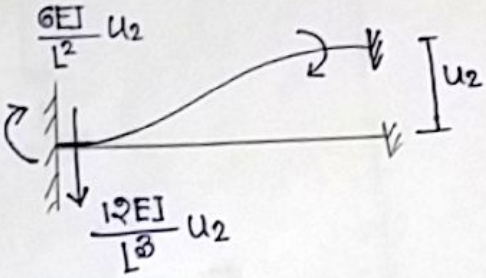


$u_2 = 1$



Formula

support settle এর Formula



B point এ, $\Sigma M_B = 0$

C " " , $\Sigma M_C = 0$

C " " $\Sigma F_x = 0$

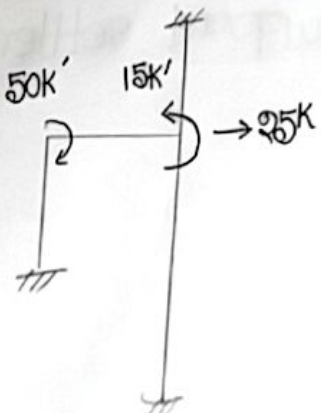
} তিন eqn

DOKI = 3

why ?

rotation ✓

$u_2 = 0$ (no translation)



rotation ✗

কিন্তু translation

($u_2 \neq 0$)

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Lec-5

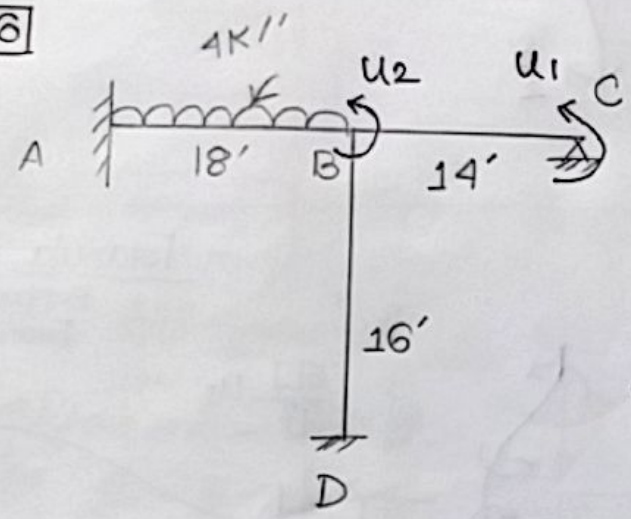
axial deformation neglect করব।

* Support settlement :

DoKI = ২ (Rotation at B, C)

Team ও থাকবে

[6]

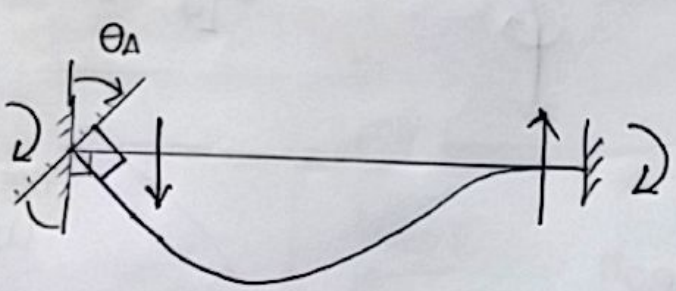


support A,

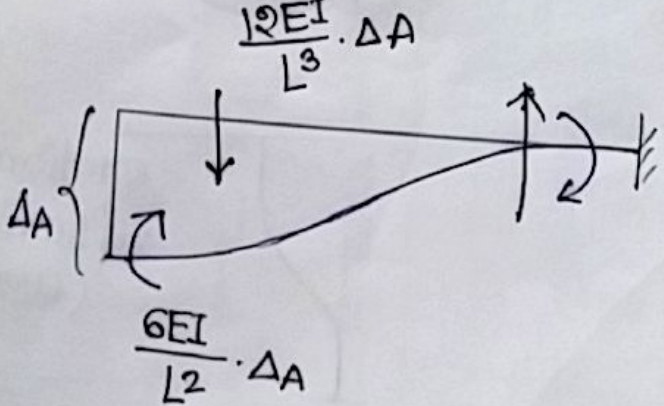
θ_A • rotates 0·03 rad (↻)
• settles down 0·15'
• support D, moves 0·2' to the right.

$I_{AB} = I_{BC} = I$

$I_{BD} = 2I$



rotation



support settlement

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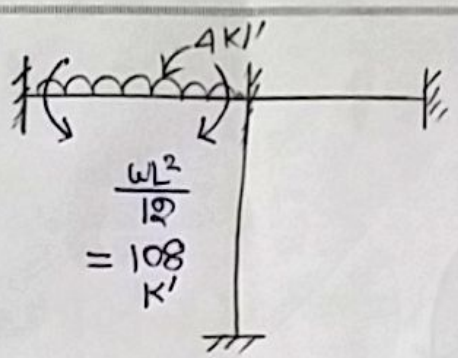
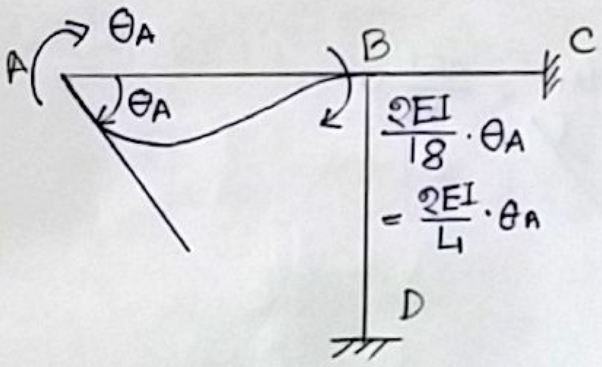
S-1

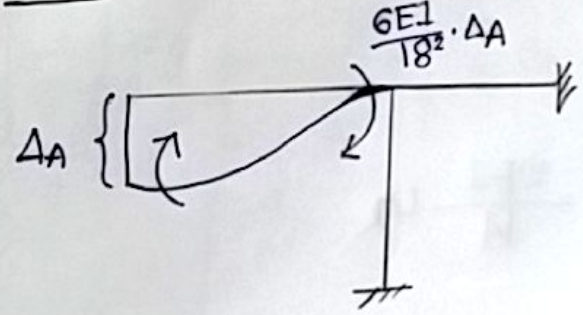


all support restrained

S-2 for θ_A, others restrained



S-3 $\Delta_A = 0.15'$



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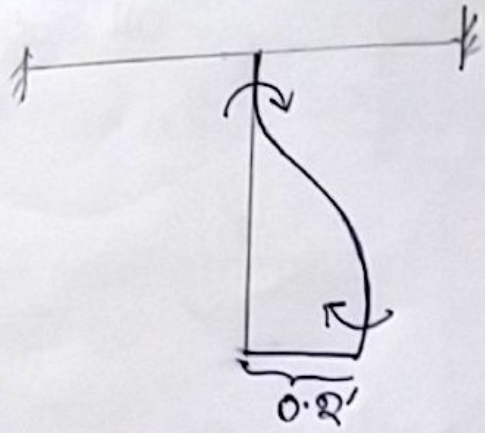
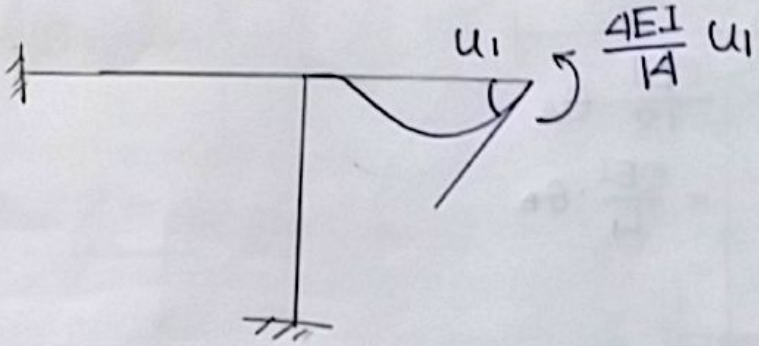
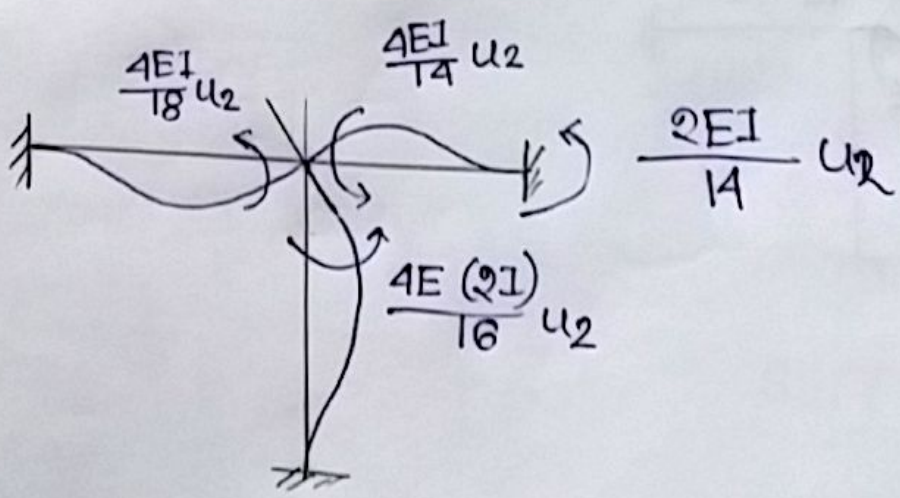
S-4



S-5 $u_1 = 1, u_2 = 0$



S-6 $u_1 = 0, u_2 = 1$



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$[F_j] = [F_m] + [F_s] + [K][u]$

where,
F_j = Applied joint load vector
F_m = Equivalent joint load vector due to span loading
F_s = " " " due to support settlement
K = stiffness vector
u = Deformation vector

at C, ΣM,

$0 = \underbrace{(0)}_{F_m} + \underbrace{(0+0+0)}_{F_s} + \left(\frac{4EI}{14}u_1 + \frac{2EI}{14}u_2\right)$

↗ applied external Moment zero.

at B. ΣM, (↻ -ve)

$0 = (-108) + \left(-\frac{2EI}{18} \times \theta_A - \frac{6EI}{18^2} \times \Delta_A - \frac{6E(2I)}{16^2} \cdot \Delta_D\right) + \left(\frac{2EI}{14}u_1 + \frac{4EI}{18}u_2 + \frac{4EI}{14}u_2 + \frac{4E(2I)}{16}u_2\right)$

$$\begin{bmatrix} 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ -108 \end{bmatrix} + \begin{bmatrix} 0+0+0 \\ -\frac{2}{18}\theta_A - \frac{6}{18^2}\Delta_A - \frac{12}{16^2}\Delta_D \end{bmatrix} EI + \begin{bmatrix} \frac{4}{14} & \frac{2}{14} \\ \frac{2}{14} & \frac{4}{18} + \frac{4}{14} + \frac{8}{16} \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} EI$$

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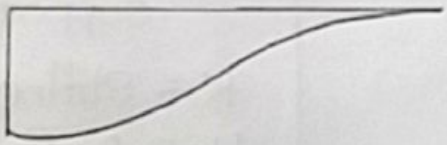
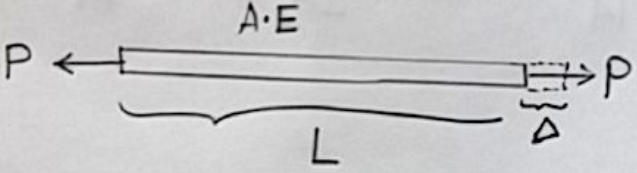
Bending stiffness :

shear stiffness :



Axial stiffness :



$$\text{stress} = \frac{P}{A}$$

$$\Delta = \frac{PL}{AE}$$

$$\therefore P = \frac{AE}{L} \cdot \Delta$$

F = stiffness x deformation = K x u

P = K x u

and $P = \boxed{\frac{AE}{L}} \cdot \Delta$

axial stiffness · K

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☒ Math আক্সেপ্টাই. বলা হল consider. axial deformation.
এই math এ DOKI ২টাই rotation, তাই কোন change
আসবে না math এ.

যদি DOKI তে কোন deformation (axial) আসে, তাহলে
change হবে।

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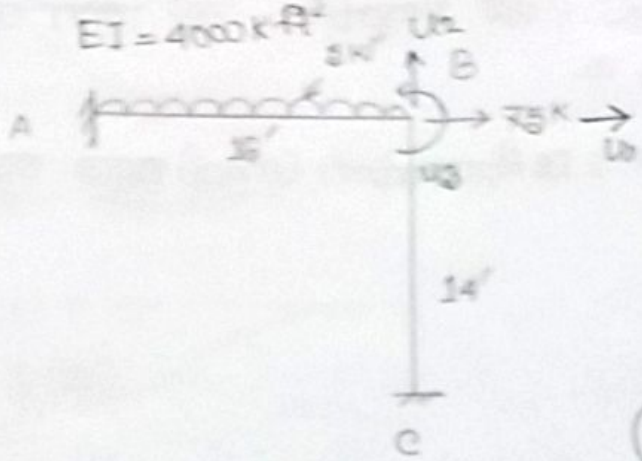
lec-6

Next Sunday
2:30 pm. extra class

$AE = 400K$

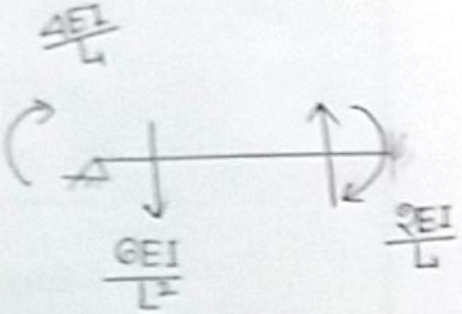
$EI = 4000 K ft^2$

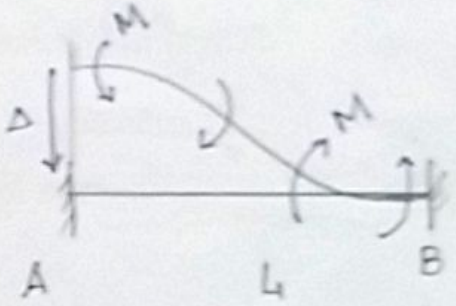
[8]



$\Delta = \frac{PL}{AE}$

$\therefore P = \frac{AE}{L} \cdot \Delta$

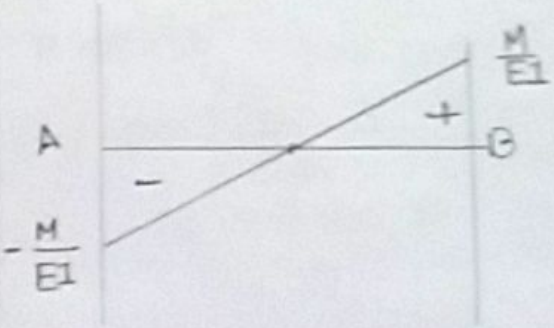




$+ A/B = \frac{1}{2} \times \frac{L}{2} \times \left(\frac{-M}{EI}\right) \times \frac{1}{3} \times \frac{L}{2}$

↑ Distance

$+ \frac{1}{2} \times \frac{L}{2} \times \left(\frac{M}{EI}\right) \times \left(\frac{1}{2} + \frac{2}{3} \cdot \frac{L}{2}\right)$



$= -\frac{ML^2}{24EI} + \frac{L}{4} \cdot \frac{M}{EI} \left(\frac{L}{2} + \frac{L}{3}\right)$

$= -\frac{ML^2}{24EI} + \frac{ML^2}{4EI} \cdot \frac{5}{6}$

$= -\frac{ML^2}{24EI} + \frac{5ML^2}{24EI}$

$= \frac{ML^2}{6EI} = \Delta$

$\therefore M = \frac{6EI}{L^2} \cdot \Delta$

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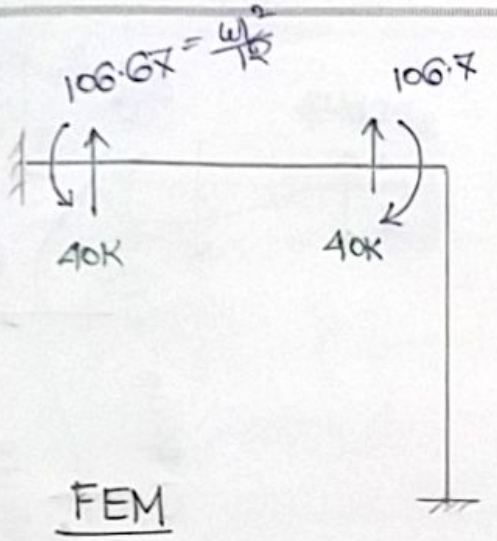
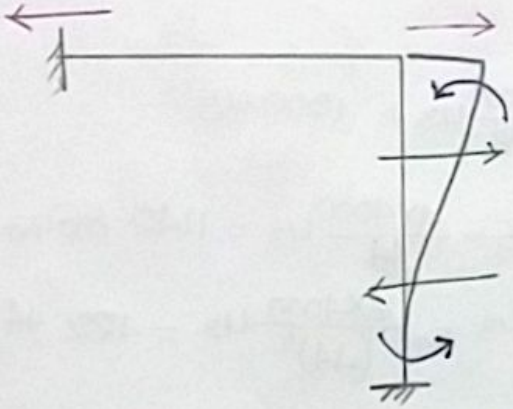


$$\begin{bmatrix} 0 \\ 40 \\ 106.7 \end{bmatrix} + \begin{bmatrix} & & \\ & & \\ & & \end{bmatrix} \begin{Bmatrix} u_1 \\ u_2 \\ u_3 \end{Bmatrix} = \begin{bmatrix} 75 \\ 0 \\ 0 \end{bmatrix}$$

FEM

(u1)

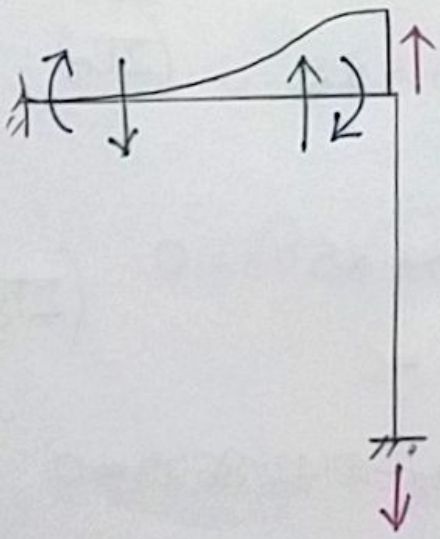


$$\frac{6EI}{L^2} \cdot u_1 = \frac{6 \times 4000}{(14)^2} u_1 = 122.45 u_1$$

$$\frac{12EI}{L^3} u_1 = \frac{12 \times 4000}{(14)^3} u_1 = 17.5 u_1$$

$$\frac{AE}{L} u_1 = \frac{400}{16} u_1 = 25 u_1$$

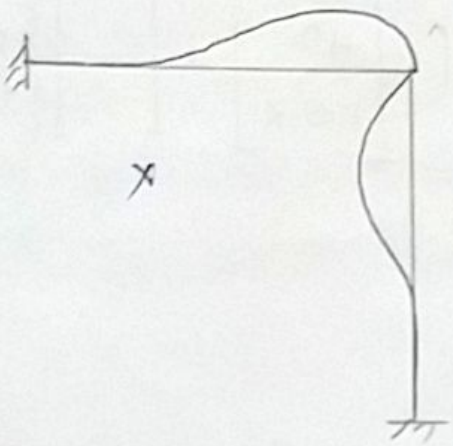
(u2)

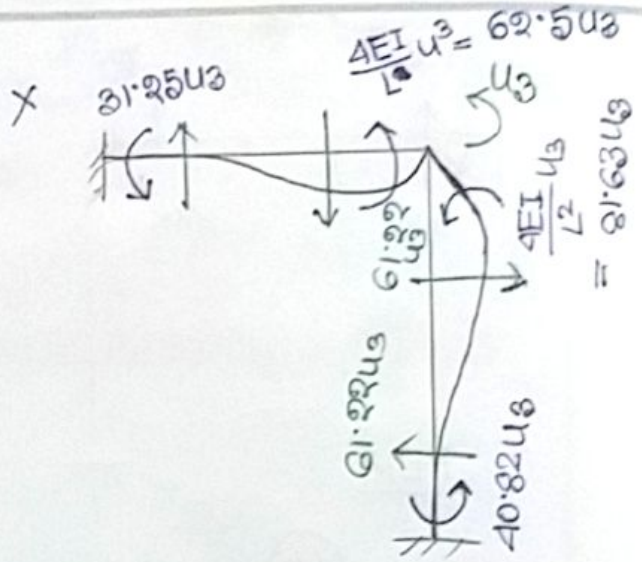


$$\frac{AE}{L} u_2 = \frac{400}{14} u_2 = 28.57 u_2$$

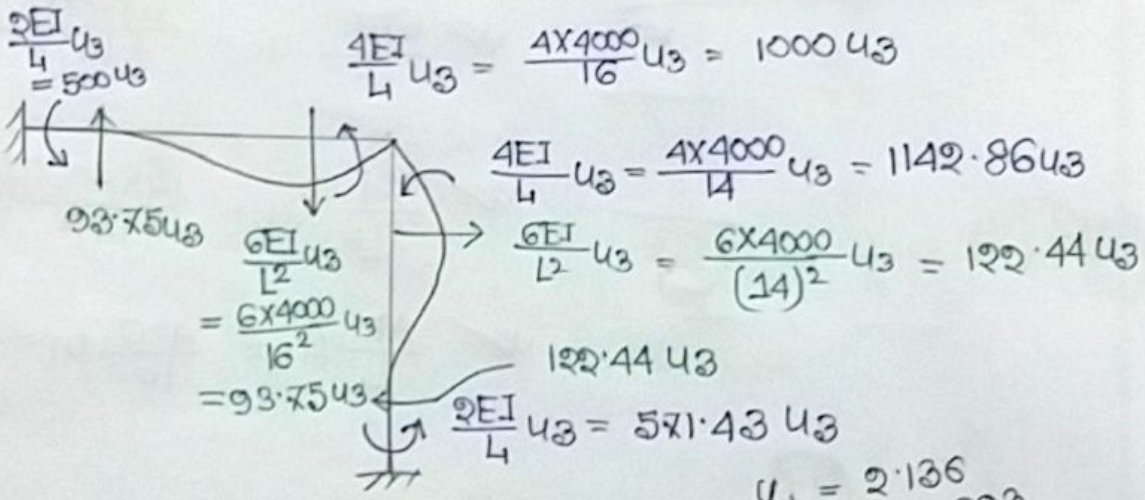
$$\frac{12EI}{L^3} u_2 = \frac{12 \times 4000}{(16)^3} u_2 = 11.72 u_2$$

$$\frac{6EI}{L^2} \cdot u_2 = \frac{6 \times 4000}{(16)^2} u_2 = 93.75 u_2$$





4EI



$u_1 = 2.136$
$u_2 = -1.293$
$u_3 = -0.129$

$25u_1 + 17.49u_1 + 122.45u_3 = 75 \quad \ldots (\Sigma F_x)_B$

$\Rightarrow 42.49u_1 + 122.45u_3 = 75$

$40 + 11.\cancel{72}u_2 + 26.57u_2 - 93.75u_3 = 0 \quad (\Sigma F_y)_B$

$\therefore 40 + 40.29u_2 - 93.75u_3 = 0$

$106.7 - 122.45u_1 + 93.75u_2 - 2142.86u_3 = 0 \quad (\Sigma M_B)$

Sub: 1 hour exam { ৯/২/২৮ মঙ্গলবার 1:05 pm C.T Lec 1-6 পর্যন্ত

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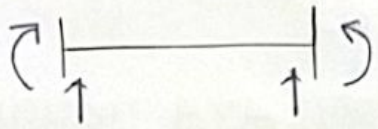
Lec-7

Truss Analysis Using Stiffness Method

For Beam,  K matrix (4×4)

truss,  K matrix (2×2)

K = (6×6)

Frame

$\Delta = \frac{PL}{AE}$, $P = \frac{AE}{L} \cdot \Delta$

$\underbrace{Q}_{\text{Force}} = K' \underbrace{d}_{\text{displacement}}$

$K' = \frac{AE}{L} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$

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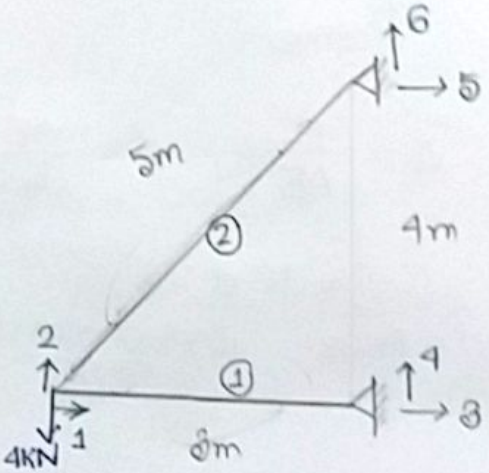
জিনু তুই math টা করে জমা দিবি।

৩ Local - 2×2
Global - 4×4
প্রত্যেক node ও displacement ২টা, x ও y বরাবর।
তাই Global matrix 6×6.
individual member এর জন্য 4×4 matrix.

member 1

$\theta_x = 0°$ $\lambda_x = \cos 0° = 1$
$\theta_y = 90°$ $\lambda_y = \cos 90° = 0$



$$K_1 = \frac{AE}{L} \begin{bmatrix} 1 & 0 & -1 & -0 \\ 0 & 0 & -0 & -0 \\ -1 & -0 & 1 & 0 \\ -0 & -0 & 0 & 0 \end{bmatrix} \begin{matrix} Nx \\ Ny \\ Fx \\ Fy \end{matrix}$$

$$= \frac{AE}{3} \begin{bmatrix} 1 & 0 & -1 & -0 \\ 0 & 0 & -0 & -0 \\ -1 & -0 & 1 & 0 \\ -0 & -0 & 0 & 0 \end{bmatrix} \begin{matrix} ① \\ ② \\ ③ \\ ④ \end{matrix}$$

$$K_1 = AE \begin{bmatrix} 0.333 & 0 & -0.333 & -0 \\ 0 & 0 & -0 & -0 \\ -0.333 & -0 & 0.333 & 0 \\ -0 & -0 & 0 & 0 \end{bmatrix}$$

N (near end)
F (Far end)

Scanned by CamScanner

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member 2

$L = 5m$

$\theta_x = 53.1^\circ \quad \lambda_x = \cos\theta_x = 0.6$

$\theta_y = 36.9^\circ \quad \lambda_y = \cos\theta_y = 0.8$

$$K_2 = \frac{AE}{5}$$

	①	②	⑤	⑥
	0.36	0.48	-0.36	-0.48
	0.48	0.64	-0.48	-0.64
	-0.36	-0.48	0.36	0.48
	-0.48	-0.64	0.48	0.64

$$= AE \begin{bmatrix} 0.072 & 0.096 & -0.072 & -0.096 \\ 0.096 & 0.128 & -0.096 & -0.128 \\ -0.072 & -0.096 & 0.072 & 0.096 \\ -0.096 & -0.128 & 0.096 & 0.128 \end{bmatrix}$$

① ও ② node common. add (+) করে দিব।

$Q_3, Q_4, Q_5, Q_6 \rightarrow$ Support reaction

chapter – 13

exam ও max 4 টা member থাকতে পারে।

$$\begin{bmatrix} \lambda_x & \lambda_y & -\lambda_x & -\lambda_y \\ -\lambda_x & -\lambda_y & \lambda_x & \lambda_y \end{bmatrix}$$

$q_F \leftarrow (-ve)\ C$

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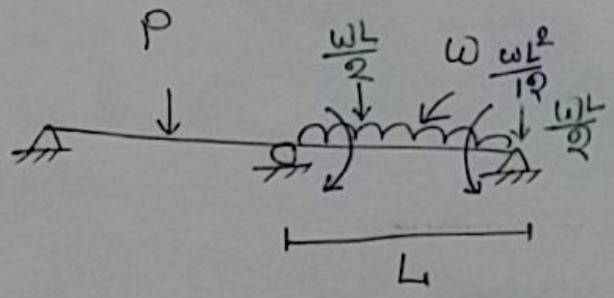
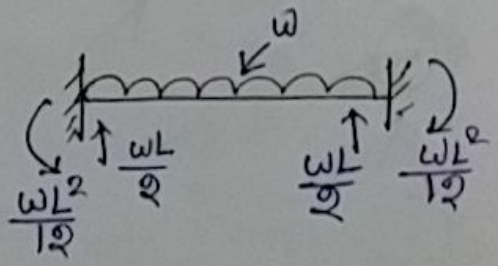
Lec-8

{WRE-425 এর Q. দেখে fore TM Sir}

Beam member stiffness matrix:

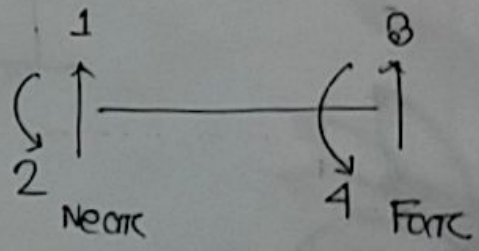
- ২টা Beam member এ node ৩টা।

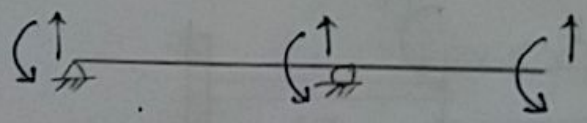




- Unknown displacement আগে নিখব, known গুলো পরে নিখব।

Example-1 (Fig 14-8)





** Unknown বের করার পর fixed end reaction যোগ করব।

- Near end, vertical 1
  Rotation 2
- Fare end, vertical 3
  Rotation 4

এটা standard হিসেবে ধরা হয়।

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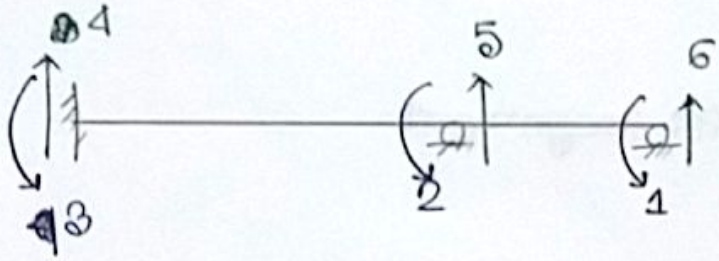
** K_{ij} ← Force
↑
displacement

• external force এ যার known displacement বসাব → matrix এ

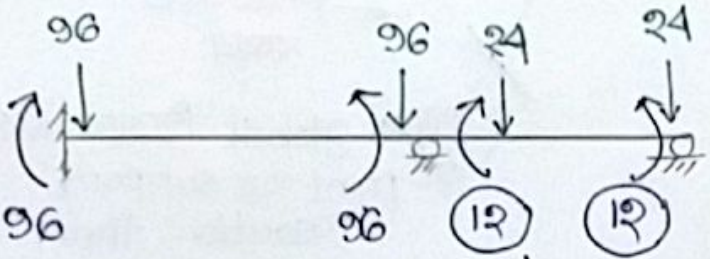
• Unknown reaction এ FEReaction add করে দিব।

Assignment

Ex-2 (Fig 14-11)

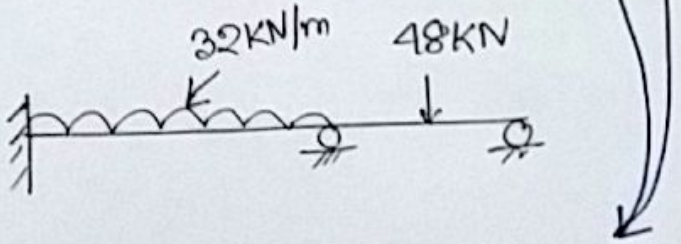


আগে node no. ঠিক করব।



then, span load কে node এর load এ transfer করব।

External force এর জন্য FEM ও FER বের করব (for load that is over the span). FEM ও FER এর opposite direction এ (আগে provide করব।



Q. যদি 48KN এর point এ displacement বের করতে বলে তখন ঐ point এ আশেপাশের node ধরে নিব।

• যেই point এ unknown ~~rotati~~ deformation, তাদের জন্য FEM or FER থেকে যেই value পাই, তাই নিব। যেমন এখানে ① ও ② এর জন্য value 12, 12 Matrix এ বসাব। আর ③, ④, ⑤, ⑥ এর গুলো সহ unknown Q ও D বের করার পর এদের সাথে FEM or FER add করে দেব করব।

Sub: _____

SAT ☐ SUN ☐ MON ☐ TUE ☐ WED ☐ THU ☐ FRI ☐

DATE: / /

* Frame member stiffness matrix:

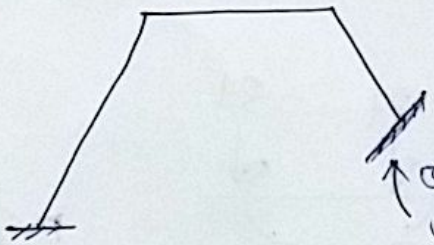
matrix → 6x6 (Frame)

- Frame এ local, global লাগে
- Axial force আসবে।

Assignment

Ex- (Fig 15-4)

শুক্রবারের জন্য দিতে হবে Assignment.



← practice করবে

↑ আগে global হিসেবে ধরব এই point এর support reaction, then local এ convert করব।