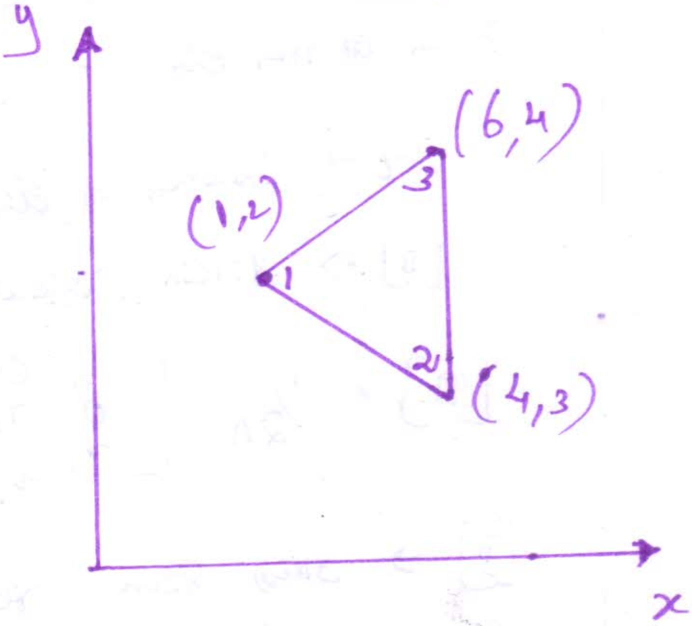
Numericals:

1) The nodal Co-ordinates of the triangular element are shown in figure. At the interior point P, the x co-ordinate is 3.5 and $N_1 = 0.4$, Calculate N_2, N_3 and the y Co-ordinate at point P.



Soln:

$x_1, x_2, x_3 = 1, 4, 6$

$y_1, y_2, y_3 = 2, 3, 6.$

$x = 3.5, \quad N_1 = 0.4.$

We know that

$N_1 + N_2 + N_3 = 1.$

$0.4 + N_2 + N_3 = 1 \Rightarrow (N_2 + N_3 = 0.6.) \rightarrow ①$

$x = N_1 x_1 + N_2 x_2 + N_3 x_3$

$3.5 = 0.4(1) + N_2(4) + N_3(6)$

$\boxed{3.1 = 4N_2 + 6N_3} \rightarrow ②$

Resolving ① & ② we get.

$N_3 = 0.35, \quad N_2 = 0.25$

$y = N_1 y_1 + N_2 y_2 + N_3 y_3$

$y = 0.4 \times 2 + 0.25 \times 3 + 0.35 \times 4$

$\boxed{y = 2.95}$

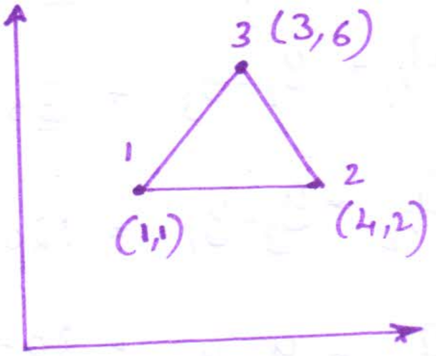
HW

(2) Determine the x, y Co-ord of point P for the Δ^{le} element shown. The shape fn N_1 & N_2 are 0.2 & 0.3 respectively?

$(N_1 + N_2 + N_3 = 1)$

$N_3 = 0.5$

$x = 2.9, \; y = 3.8$



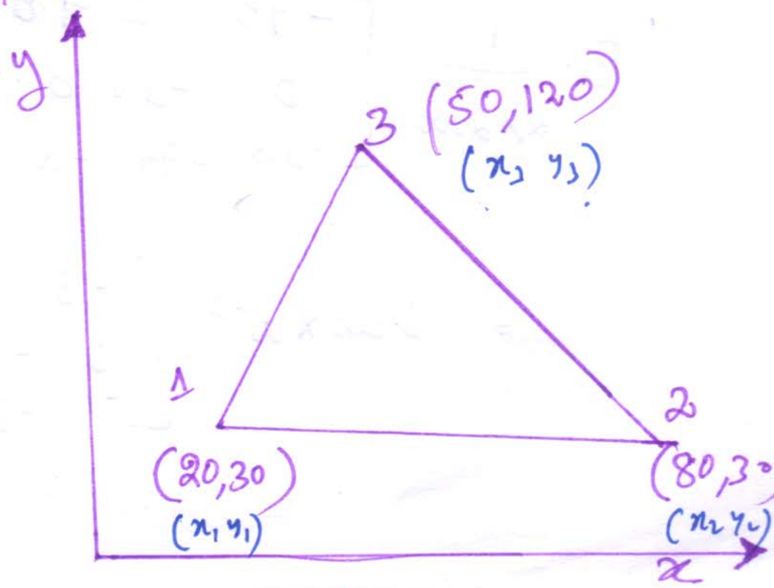
(3) Determine the stiffness matrix for the CST element shown in figure. The co-ordinates are given in units of millimeter. Assume plane stress condition.

Take

$E = 210\ GPa$

$\mu = 0.25$

$t = 10\ mm$



$$[K] = [B]^T [D] [B] \cdot A \cdot t$$

$$A = \frac{1}{2} \begin{vmatrix} 1 & x_1 & y_1 \\ 1 & x_2 & y_2 \\ 1 & x_3 & y_3 \end{vmatrix} = \frac{1}{2} \begin{vmatrix} 1 & 20 & 30 \\ 1 & 80 & 30 \\ 1 & 50 & 120 \end{vmatrix}$$

$A = 2700\ mm^2$.

$$[B] = \frac{1}{2A} \begin{bmatrix} q_1 & 0 & q_2 & 0 & q_3 & 0 \\ 0 & r_1 & 0 & r_2 & 0 & r_3 \\ r_1 & q_1 & r_2 & q_2 & r_3 & q_3 \end{bmatrix}$$

$q_1 = y_2 - y_3 = 30 - 120 = -90$

$q_2 = y_3 - y_1 = 120 - 30 = 90$

$q_3 = y_1 - y_2 = 30 - 30 = 0$

$r_1 = x_3 - x_2 = 50 - 80 = -30$

$r_2 = x_1 - x_3 = 20 - 50 \quad -30$

$r_3 = x_2 - x_1 = 80 - 20 \quad 60$

$$B = \frac{1}{2 \times 2700} \begin{bmatrix} -90 & 0 & 90 & 0 & 0 & 0 \\ 0 & -30 & 0 & -30 & 0 & 60 \\ -30 & -90 & -30 & 90 & 60 & 0 \end{bmatrix}$$

$$= 5.555 \times 10^{-3} \begin{bmatrix} -3 & 0 & 3 & 0 & 0 & 0 \\ 0 & -1 & 0 & -1 & 0 & 2 \\ -1 & -3 & -1 & 3 & 2 & 0 \end{bmatrix}$$

Stress Strain relation, [D]. Plane Stress problem. 4

$$[D] = \frac{E}{1-\mu^2}\begin{bmatrix} 1 & \mu & 0 \\ \mu & 1 & 0 \\ 0 & 0 & \frac{1-\mu}{2} \end{bmatrix}.$$

$$= \frac{2.1\times10^5}{1-(0.25)^2}\begin{bmatrix} 1 & 0.25 & 0 \\ 0.25 & 1 & 0 \\ 0 & 0 & \frac{1-0.25}{2} \end{bmatrix}$$

$$[D] = 56\times10^3\begin{bmatrix} 4 & 1 & 0 \\ 1 & 4 & 0 \\ 0 & 0 & 1.5 \end{bmatrix}$$

$$[D][B] = 56\cdot10^3\begin{bmatrix} 4 & 1 & 0 \\ 1 & 4 & 0 \\ 0 & 0 & 1.5 \end{bmatrix}\times5.555\times10^{-3}\begin{bmatrix} -3 & 0 & 3 & 0 & 0 & 0 \\ 0 & -1 & 0 & -1 & 0 & 2 \\ -1 & -3 & -1 & 3 & 2 & 0 \end{bmatrix}$$

$$= 311.08\begin{bmatrix} -12 & -1 & 12 & -1 & 0 & 2 \\ -3 & -4 & 3 & -4 & 0 & 8 \\ -1.5 & -4.5 & -1.5 & 4.5 & 3 & 0 \end{bmatrix}$$

$$[B]^T = 5.555\times10^{-3}\begin{bmatrix} -3 & 0 & -1 \\ 0 & -1 & -3 \\ 3 & 0 & -1 \\ 0 & -1 & 3 \\ 0 & 0 & 2 \\ 0 & 2 & 0 \end{bmatrix}$$

$$[B]^T[D][B] = 5.55\times10^{-3}\begin{bmatrix} -3 & 0 & -1 \\ 0 & -1 & -3 \\ 3 & 0 & -1 \\ 0 & -1 & 3 \\ 0 & 0 & 2 \\ 0 & 2 & 0 \end{bmatrix}\times 311.08\begin{bmatrix} -12 & \cdots & 2 \\ -3 & \cdots & 8 \\ -1.5 & \cdots & 3.0 \end{bmatrix}$$

$$[B]^T[D][B] = 1.728 \begin{bmatrix} 37.5 & 7.5 & -34.5 & -1.5 & -3 & -6 \\ 7.5 & 17.5 & 1.5 & -9.5 & -9 & -8 \\ -34.5 & 1.5 & 37.5 & -7.5 & -3 & 6 \\ -1.5 & -9.5 & -7.5 & 17.5 & 9 & -8 \\ -3 & -9 & -3 & 9 & 6 & 0 \\ -6 & -8 & 6 & -8 & 0 & 16 \end{bmatrix}$$

$$[K] = [B]^T[D][B]\,At.$$

$$= 1.728 \begin{bmatrix} & & \\ & & \\ & & \end{bmatrix} \times 2700 \times 10..$$

Stiffness matrix

$$[K] = 46.656 \times 10^3 \begin{bmatrix} 37.5 & 7.5 & -34.5 & -1.5 & -3 & -6 \\ 7.5 & 17.5 & 1.5 & -9.5 & -9 & -8 \\ -34.5 & 1.5 & 37.5 & -7.5 & -3 & 6 \\ -1.5 & -9.5 & -7.5 & 17.5 & 9 & -8 \\ -3 & -9 & -3 & 9 & 6 & 0 \\ -6 & -8 & 6 & -8 & 0 & 16 \end{bmatrix}$$

4) Calculate the element stresses σ_x, σ_y, τ_{xy}, σ_1 and σ_2 and the principle angle θ_p for the element shown in figure (i)

The nodal displacements are

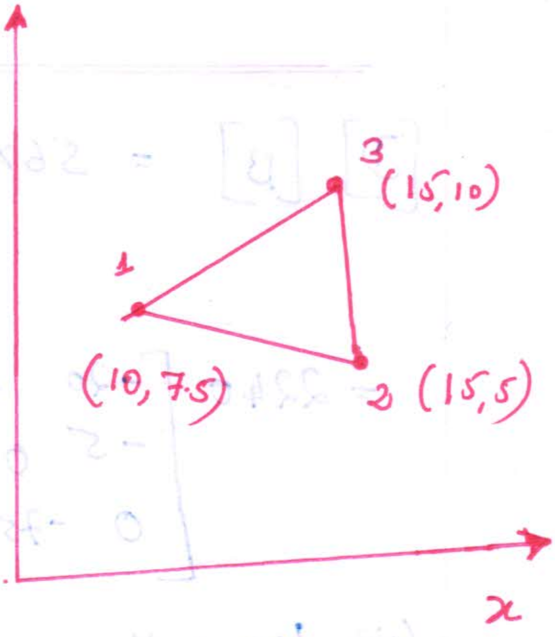
$u_1 = 2.0mm$ $\quad V_1 = 1.0 mm$

$u_2 = 0.5mm$ $\quad V_2 = 0.0 mm$

$u_3 = 3.0mm$ $\quad V_3 = 1.0 mm$

Take $E = 2.1 \times 10^5 N/mm^2$ and $\mu = 0.25$

Assume plane stress condition.



Soln:

$$\text{Area of the element } A_1 = \frac{1}{2}\begin{vmatrix} 1 & 10 & 7.5 \\ 1 & 15 & 5 \\ 1 & 15 & 10 \end{vmatrix}$$

$A = 12.5 mm^2$

$$[B] = \frac{1}{2A}\begin{bmatrix} q_1 & 0 & q_2 & 0 & q_3 & 0 \\ 0 & r_1 & 0 & r_2 & 0 & r_3 \\ r_1 & q_1 & r_2 & q_2 & r_3 & q_3 \end{bmatrix}$$

$$= \frac{1}{12.5 \times 2}\begin{bmatrix} -5 & 0 & 2.5 & 0 & 2.5 & 0 \\ 0 & 0 & 0 & -5 & 0 & 5 \\ 0 & -5 & -5 & 2.5 & 5 & 2.5 \end{bmatrix}$$

$$= 0.04\begin{bmatrix} -5 & 0 & 2.5 & 0 & 2.5 & 0 \\ 0 & 0 & 0 & -5 & 0 & 5 \\ 0 & -5 & -5 & 2.5 & 5 & 2.5 \end{bmatrix}$$

$$[D] = \frac{E}{1-\mu^2}\begin{bmatrix} 1 & \mu & 0 \\ \mu & 1 & 0 \\ 0 & 0 & \frac{1-\mu}{2} \end{bmatrix} = \frac{2.1\times10^5}{1-0.25^2}\begin{bmatrix} 1 & 0.25 & 0 \\ 0.25 & 1 & 0 \\ 0 & 0 & \frac{1-0.25}{2} \end{bmatrix}$$

$$[D] = 56\times10^3 \begin{bmatrix} 4 & 1 & 0 \\ 1 & 4 & 0 \\ 0 & 0 & 1.5 \end{bmatrix}$$

$$[D][B] = 56\times10^3 \begin{bmatrix} 4 & 1 & 0 \\ 1 & 4 & 0 \\ 0 & 0 & 1.5 \end{bmatrix} \times 0.04 \begin{bmatrix} -5 & 0 & 2.5 & 0 & 2.5 & 0 \\ 0 & 0 & 0 & -5 & 0 & 5 \\ 0 & -5 & -5 & 2.5 & 5 & 2.5 \end{bmatrix}$$

$$= 2240 \begin{bmatrix} -20 & 0 & 10 & -5 & 10 & 5 \\ -5 & 0 & 2.5 & -20 & 2.5 & 20 \\ 0 & -7.5 & -7.5 & 3.75 & 7.5 & 3.75 \end{bmatrix}$$

We know that.

$$\{\sigma\} = [D][B]\{u\} = [D][B]\begin{Bmatrix} u_1 \\ v_1 \\ u_2 \\ v_2 \\ u_3 \\ v_3 \end{Bmatrix}$$

$$= 2240 \begin{bmatrix} -20 & 0 & 10 & -5 & 10 & 5 \\ -5 & 0 & 2.5 & -20 & 25 & 20 \\ 0 & -7.5 & -7.5 & 3.75 & 7.5 & 3.75 \end{bmatrix} \begin{Bmatrix} 2.0 \\ 1.0 \\ 0.5 \\ 0 \\ 3.1 \\ 1.0 \end{Bmatrix}$$

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix} = 2240 \begin{Bmatrix} 0 \\ 18.75 \\ 75 \end{Bmatrix} = 10^3 \begin{Bmatrix} 0 \\ 42 \\ 33.6 \end{Bmatrix}$$

Max Normal Stress $\sigma_{max} = \sigma_1$

$$= \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$= \frac{0+42\times10^3}{2} + \sqrt{\left(\frac{0-42\times10^3}{2}\right)^2 + (33.6\times10^3)^2}$$

$$= 21000 + 39622.72 \Rightarrow \sigma_1 = 60.62\times10^3 N/mm^2$$

Minimum normal stress $\sigma_{min} = \sigma_2$

$$= \frac{\sigma_x+\sigma_y}{2} - \sqrt{\left(\frac{0-42\times10^3}{2}\right)^2 + (33.6\times10^3)^2}$$

$$= 21000 - 39622.72 \Rightarrow \sigma_2 = -18.62\times10^3 N/mm^2$$

Principal angle, $\tan 2\theta_p = \frac{2\tau_{xy}}{\sigma_x-\sigma_y}$

$$2\theta_p = \tan^{-1}\left(\frac{2\tau_{xy}}{\sigma_x-\sigma_y}\right)$$

$$= \tan^{-1}\left(\frac{2\times33.6\times10^3}{0-42\times10^3}\right) = \tan^{-1}(-1.6)$$

$$\theta_p = -28.997^\circ$$

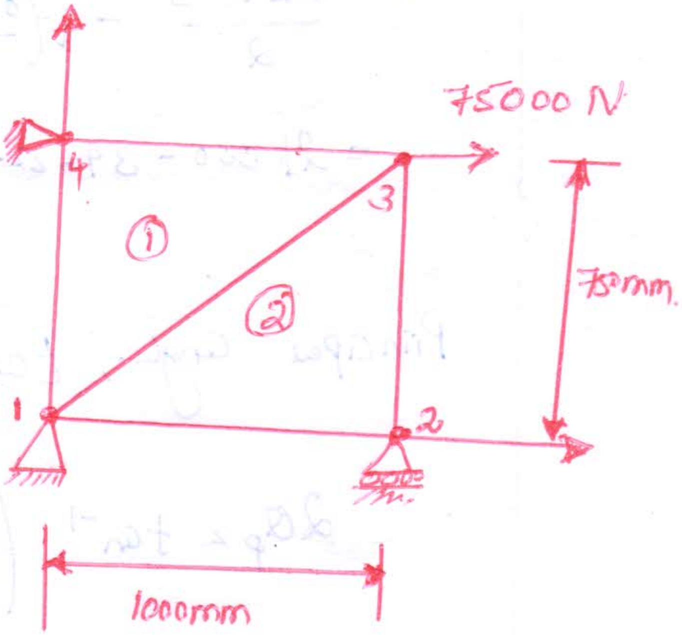
$$\theta_p \approx 30^\circ$$

(3) The 2D propped beam shown in figure is divided into two CST elements. Determine the nodal displacements and element stresses using plane stress conditions. Body force is neglected in comparison with the external forces.

Take, thickness $t = 10mm$

$E = 2 \times 10^5 N/mm^2$

$\mu = 0.25$



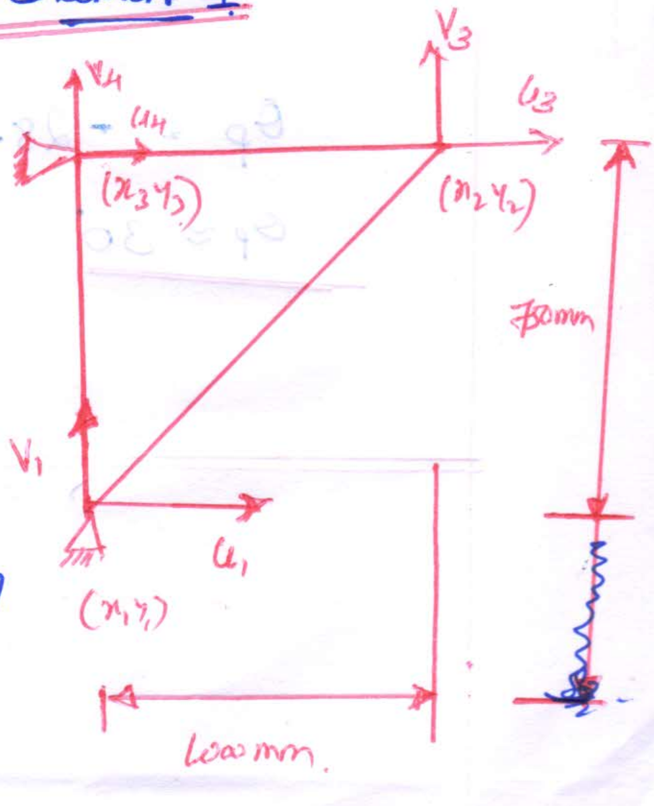
Soln:

Node 1 $\overset{x_1 \;\; y_1}{(0, 0)}$

Node 3 $\overset{x_2 \;\; y_2}{(1000, 750)}$

Node 4 $\overset{x_3 \;\; y_3}{(0, 750)}$

Element 1



$[K] = [B]^T [D] [B] \, A \cdot t$

$$A = \frac{1}{2}\begin{vmatrix} 1 & 0 & 0 \\ 1 & 1000 & 750 \\ 1 & 0 & 750 \end{vmatrix}$$

$$= 375 \times 10^3 \, mm^2$$

$$[B] = \frac{1}{2A}\begin{bmatrix} q_1 & 0 & q_2 & 0 & q_3 & 0 \\ 0 & r_1 & 0 & r_2 & 0 & r_3 \\ r_1 & q_1 & r_2 & q_2 & r_3 & q_3 \end{bmatrix}$$

$$[B] = \frac{1}{2\times 375\times 10^3}\begin{bmatrix} 0 & 0 & 750 & 0 & -750 & 0 \\ 0 & -1000 & 0 & 0 & 0 & 1000 \\ -1000 & 0 & 0 & 750 & 1000 & -750 \end{bmatrix}$$

$$= \frac{250}{750\times 10^3}\begin{bmatrix} 0 & 0 & 3 & 0 & -3 & 0 \\ 0 & -4 & 0 & 0 & 0 & 4 \\ -4 & 0 & 0 & 3 & 4 & -3 \end{bmatrix}$$

$$[D] = \frac{E}{1-\mu^2}\begin{bmatrix} 1 & \mu & 0 \\ \mu & 1 & 0 \\ 0 & 0 & \frac{1-\mu}{2} \end{bmatrix} = 2\times 10^5 \times 0.2667 \begin{bmatrix} 4 & 1 & 0 \\ 1 & 4 & 0 \\ 0 & 0 & 1.5 \end{bmatrix}$$

$$[D][B] = \frac{250}{750\times 10^3} \times 2\times 10^5 \times 0.2667 \begin{bmatrix} 4 & 1 & 0 \\ 1 & 4 & 0 \\ 0 & 0 & 1.5 \end{bmatrix}\begin{bmatrix} 0 & 0 & 3 & 0 & -3 & 0 \\ 0 & -4 & 0 & 0 & 0 & 4 \\ -4 & 0 & 0 & 3 & 4 & -3 \end{bmatrix}$$

$$= 17.78 \begin{bmatrix} 0 & -4 & 12 & 0 & -12 & 4 \\ 0 & -16 & 3 & 0 & -3 & 16 \\ -6 & 0 & 0 & 4.5 & 6 & -4.5 \end{bmatrix}$$

$$[B]^T = \frac{250}{750\times 10^3}\begin{bmatrix} 0 & 0 & -4 \\ 0 & -4 & 0 \\ 3 & 0 & 0 \\ 0 & 0 & 3 \\ -3 & 0 & 4 \\ 0 & 4 & -3 \end{bmatrix}$$

$$[B]^T[D][B] =$$

$$= 5.927\times 10^{-3}\begin{bmatrix} 24 & 0 & 0 & -18 & -24 & 18 \\ 0 & 64 & -12 & 0 & 12 & -64 \\ 0 & -12 & 36 & 0 & -36 & 12 \\ -18 & 0 & 0 & 13.5 & 18 & -13.5 \\ -24 & 12 & -36 & 18 & 60 & -30 \\ 18 & -64 & 12 & -13.5 & -30 & 77.5 \end{bmatrix}$$

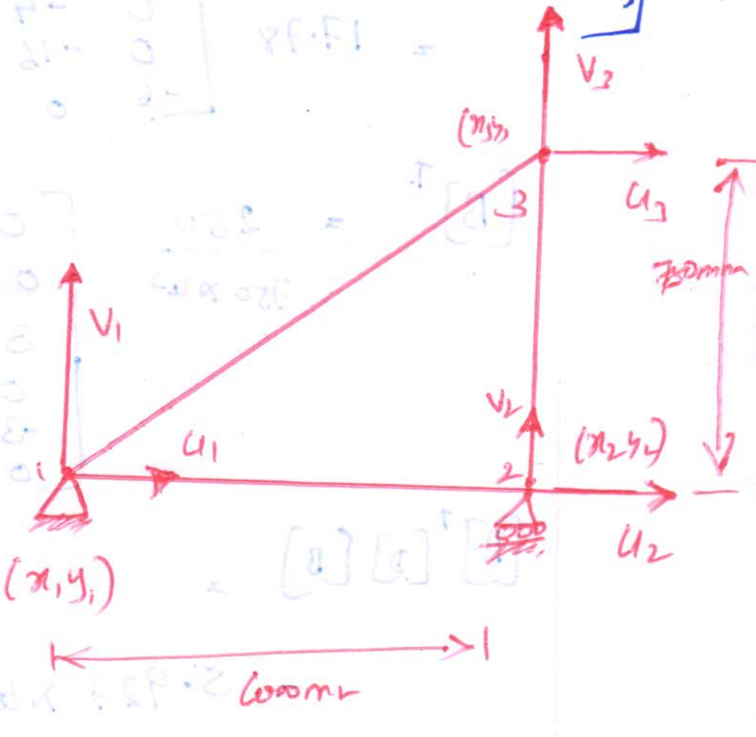
$$[K]_1 = [B]^T[D][B] \times A \times t$$

$$= 2.22 \times 10^4 \begin{bmatrix} 24 & \cdots & 18 \\ \vdots & & \\ 18 & & 77.5 \end{bmatrix}$$

$$= 1 \times 10^4 \begin{array}{c} \begin{array}{cccccc} u_1 & v_1 & u_2 & v_2 & u_4 & v_4 \end{array} \\ \begin{bmatrix} 53.28 & 0 & 0 & -39.96 & -53.28 & 39.96 \\ 0 & 142.08 & -26.64 & 0 & \cancel{-53.28}\ 26.64 & -142.08 \\ 0 & -26.64 & 79.92 & 0 & -79.92 & 26.64 \\ -39.96 & 0 & 0 & 29.97 & 39.96 & -29.97 \\ -53.28 & 26.64 & -79.92 & 39.96 & 133.2 & -66.6 \\ 39.96 & -142.08 & 26.64 & -29.97 & -166.6 & 172.05 \end{bmatrix} \end{array} \begin{array}{c} \\ u_1 \\ v_1 \\ u_2 \\ v_2 \\ u_4 \\ v_4 \end{array}$$

ELEMENT : 2

Node 1 (0, 0)
Node 2 (1000, 0)
Node 3 (1000, 750)



$$A = \frac{1}{2} \begin{vmatrix} 1 & 0 & 0 \\ 1 & 1000 & 0 \\ 1 & 1000 & 750 \end{vmatrix}$$

$$= 375 \times 10^3 \text{ mm}^2$$

$$[B] = \frac{250}{2 \times 375 \times 10^3} \begin{bmatrix} -3 & 0 & 3 & 0 & 0 & 0 \\ 0 & 0 & 0 & -4 & 0 & 4 \\ 0 & -3 & -4 & 3 & 4 & 0 \end{bmatrix}$$

$$[D] = \frac{E}{(1-\mu^2)} \begin{bmatrix} 1 & \mu & 0 \\ \mu & 1 & 0 \\ 0 & 0 & \frac{1-\mu}{2} \end{bmatrix} = \frac{2 \times 10^5 \times 0.25}{0.9375} \begin{bmatrix} 4 & 1 & 0 \\ 1 & 4 & 0 \\ 0 & 0 & 1.5 \end{bmatrix}$$

$$[D][B] = 17.78 \begin{bmatrix} -12 & 0 & 12 & -4 & 0 & 4 \\ -3 & 0 & 3 & -16 & 0 & 16 \\ 0 & -4.5 & -6 & 4.5 & 6 & 0 \end{bmatrix}$$

$$B^T = \frac{250}{750 \times 10^3} \begin{bmatrix} -3 & 0 & 0 \\ 0 & 0 & -3 \\ 3 & 0 & -4 \\ 0 & -4 & 3 \\ 0 & 0 & 4 \\ 0 & 4 & 0 \end{bmatrix}$$

$$[B]^T[D][B] = \frac{250}{750 \times 10^3} \times 17.78 \begin{bmatrix} -3 & 0 & 0 \\ 0 & 0 & -3 \\ 3 & 0 & -4 \\ 0 & -4 & 3 \\ 0 & 0 & 4 \\ 0 & 4 & 0 \end{bmatrix} \begin{bmatrix} -12 & 0 & 12 & -4 & 0 & 4 \\ -3 & 0 & 3 & -16 & 0 & 16 \\ 0 & -4.5 & -6 & 4.5 & 6 & 0 \end{bmatrix}^T$$

$$= 5.927 \times 10^{-3} \begin{bmatrix} 36 & 0 & -36 & 12 & 0 & -12 \\ 0 & 13.5 & 18 & -13.5 & -18 & 0 \\ -36 & 18 & 60 & -30 & -24 & 12 \\ 12 & -13.5 & -30 & 77.5 & 18 & -64 \\ 0 & -18 & -24 & 18 & 24 & 0 \\ 12 & 0 & 12 & -64 & 0 & 64 \end{bmatrix}$$

$$[K]_2 = [B]^T[D][B] \times A \times t.$$

$$= \times 10^4 \begin{array}{c} \begin{array}{cccccc} u_1 & v_1 & u_2 & v_2 & u_3 & v_3 \end{array} \\ \begin{bmatrix} 79.92 & 0 & -79.91 & 26.64 & 0 & -26.64 \\ 0 & 29.97 & 39.96 & -29.97 & -39.96 & 0 \\ -79.92 & 39.96 & 133.2 & -66.6 & -53.28 & 26.64 \\ 26.64 & -29.97 & -66.6 & 172.05 & 39.96 & -142.1 \\ 0 & -39.96 & -53.28 & 39.96 & 53.28 & 0 \\ -26.64 & 0 & 26.64 & -142.08 & 0 & 142.1. \end{bmatrix} \end{array} \begin{array}{c} u_1 \\ v_1 \\ u_2 \\ v_2 \\ u_3 \\ v_3 \end{array}$$

Global Stiffness matrix $[K]$

$$
\begin{array}{cccccccc|c}
u_1 & v_1 & u_2 & v_2 & u_3 & v_3 & u_4 & v_4 & \\
\hline
133.2 & 0 & -79.92 & 26.64 & 0 & -66.6 & -53.28 & 39.96 & u_1 \\
0 & 172.05 & 36.96 & -29.97 & -66.6 & 0 & 26.64 & -142.01 & v_1 \\
-79.92 & 39.96 & 133.2 & -66.6 & -53.28 & 26.64 & 0 & 0 & u_2 \\
26.64 & -29.97 & -66.6 & \overset{172.05}{\cancel{-53.28}} & 39.96 & -142.01 & 0 & 0 & v_2 \\
0 & -66.6 & -53.28 & 39.96 & 133.2 & 0 & -79.92 & 26.64 & u_3 \\
-66.6 & 0 & 26.64 & -142.08 & 0 & 172.05 & 39.96 & -29.9 & v_3 \\
-53.28 & 26.64 & 0 & 0 & -79.92 & 39.96 & 133.2 & -66.6 & u_4 \\
39.96 & -142.08 & 0 & 0 & 26.64 & -29.97 & -66.6 & 172.05 & v_4
\end{array}
$$

We know that

$$\{F\} = [K]\{u\}$$

$$
\begin{Bmatrix} F_{1x} \\ F_{1y} \\ F_{2x} \\ F_{2y} \\ F_{3x} \\ F_{3y} \\ F_{4x} \\ F_{4y} \end{Bmatrix} = [K] \begin{Bmatrix} u_1 \\ v_1 \\ u_2 \\ v_2 \\ u_3 \\ v_3 \\ u_4 \\ v_4 \end{Bmatrix}
$$

Applying the boundary Cond

① Node 1 & 4 are fixed $u_1 v_1, u_4 v_4$ is zero

② Node 2 is Roller support $u_1 \neq 0$, $v_2 = 0$.

③ at node ③ a force 7000 N is acting in x direction.

④ Body force is neglected.

$$\begin{Bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 75\times10^3 \\ 0 \\ 0 \\ 0 \end{Bmatrix} = \begin{bmatrix} 133.2 & \cdots & 39.96 \\ \vdots & & \\ 39.96 & & 172.05 \end{bmatrix} \begin{Bmatrix} 0 \\ 0 \\ u_2 \\ 0 \\ u_3 \\ v_3 \\ 0 \\ 0 \end{Bmatrix}$$

$$\begin{Bmatrix} 0 \\ 75\times10^3 \\ 0 \end{Bmatrix} = 1\times10^4 \begin{bmatrix} 133.2 & -53.28 & 26.64 \\ -53.28 & -133.2 & 0 \\ 26.64 & 0 & 172.05 \end{bmatrix} \begin{Bmatrix} u_2 \\ u_3 \\ v_4 \end{Bmatrix}$$

Solving the eqn we get

$u_2 = 0.02766\,mm$, $u_3 = 0.067\,mm$

$v_3 = -0.00431\,mm$

Stress in each element:

for element 1

$$\sigma_1 = [D][B]\{u\}$$

$$\{\sigma_1\} = 17.78 \begin{Bmatrix} 12\times0.067 \\ 3\times0.067 \\ 4.5\times-0.00431 \end{Bmatrix}$$

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix} = \begin{Bmatrix} 14.295 \\ 3.574 \\ -0.345 \end{Bmatrix} N/mm^2$$

(element 2) $\sigma_2 = [D]_2 [B]_2 \{u\}$

$$\sigma_2 \Rightarrow \cancel{17.78} \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix} = \begin{Bmatrix} 5.595 \\ 0.2492 \\ 4.196 \end{Bmatrix} N/mm^2$$