Unit - 3

150

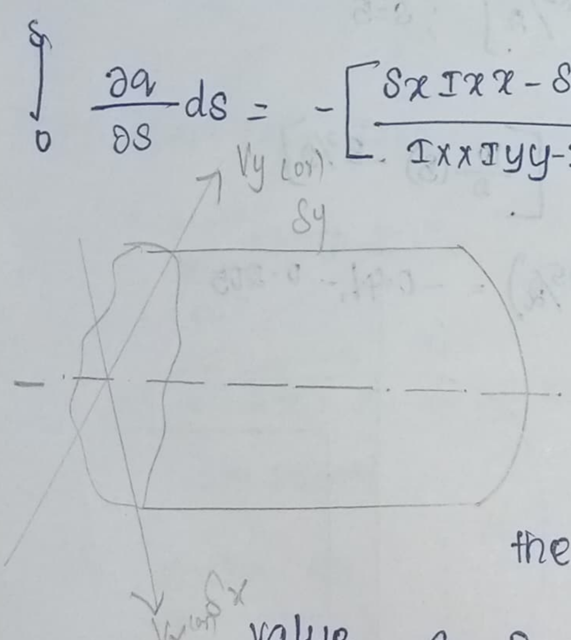
SHEARFLOW IN CLOSED SECTION.

- consider the closed section beam of orbitary section shown in fig.
- The shear load S_x & S_y (or) V_x and V_y are applied through any point in the cross section. In general direct bending stress & shear flow which are related by equilibrium equation.

$$\frac{\partial q}{\partial s} = t \frac{\partial \sigma_z}{\partial z}$$

we know that

$$\int_0^s \frac{\partial q}{\partial s} ds = -\left[\frac{S_x I_{xx} - S_y I_{xy}}{I_{xx} I_{yy} - I_{xy}^2} \int_0^s x\, t\, ds\right] - \left[\frac{S_y I_{yy} - S_x I_{xy}}{I_{xx} I_{yy} - I_{xy}^2} \int_0^s y\, t\, ds\right]$$



let we choose an object for s where the shear flow unknown value $q_{s,0}$

Integrating the above eqn

$$q_s - q_{s0} = -\left[\frac{S_x I_{xx} - S_y I_{xy}}{I_{xx} I_{yy} - I_{xy}^2}\right] \int_0^s t x\, ds - \left[\frac{S_y I_{yy} - S_x I_{xy}}{I_{xx} I_{yy} - I_{xy}^2} \int_0^s t y\, ds\right]$$

$q_s = -\left[\frac{S_x I_{xx} - \dots}{\dots} \right] + q_{s,0}$

comparing this eqn with shear flow of open section. The first two term on RHS represent the shear flow distribution in an open sec beam. load at through initial shear center. This fact indicate the method of solving for the shear loaded closed sect beam. $q_s = q_s' + q_{s,0}$

we obtain q_s by supporting that the closed beam section is cut at same centroidal point there by producing the open section

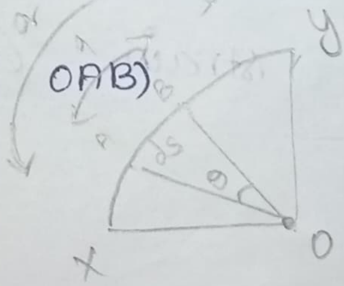
<u>BREDTH - BATHO</u> formula

$q = \tau \times t$

- let q be the shear flow per unit length

moment of q about 'O' $= q\,ds\,(OB)$

$= q\,(\text{Area of } OAB)$



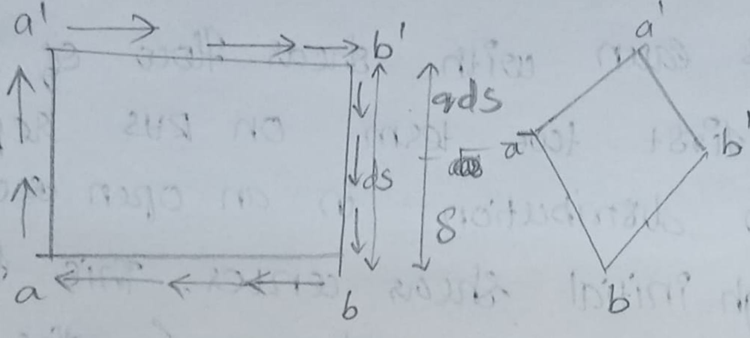
Total moment about

$T = 2q\,(Oxy)$

$T = 2Aq$

The theory of torsion of closed beam section is known as bredth - batho theory.

Angle of twist



- Consider a small plate element as shown in fig relatively a free body and length of the plate parallel to z axis and ds in the plane of tube cross section.
- under the shear force the plate undergoes the deformation as shown in fig

In phase a. a' move a distance δ w.r.t to b b'.

- The force of the phase aa' = $q\,ds$

elastic strain energy is given by $du = \frac{1}{2} q\,ds \cdot \delta$

$$\delta = \frac{\tau}{G}$$ τ → shear stress, G → modulus of rigidity → (1)

$$q = \tau \times t$$

$$\tau = q/t \qquad T = 2Aq$$

$$\delta = \frac{q}{tG} \qquad q = T/2A$$

$$\delta = \frac{T}{2AGt}$$

$$du = \frac{Tq\,ds}{4AGt}$$

$$du = \frac{T^2 ds}{8A^2 G t} \qquad q = T/2A$$

The above eqn gives the elastic strain energy for small element. From the entire cube integrating above eqn.

$$U = \frac{T^2 ds}{8A^2 G t} \int ds$$

$$\beta = \frac{\partial U}{\partial T}$$

$$\frac{\partial U}{\partial T} = \frac{2T}{8A^2 G t} \int ds$$

$$= \frac{T}{4A^2 G t} \int ds$$

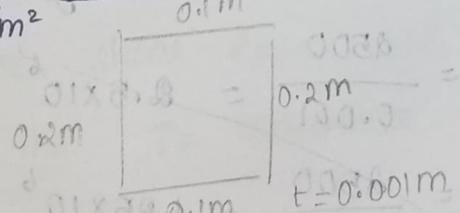
$$T = 2Aq$$

$$\beta = \frac{2Aq}{4A^2 G t} \int ds \Rightarrow \beta = \frac{q}{2AGt} \int ds$$

1. calculate shear flow, shear centre, shear stress and twist per unit length

$G = 25 \times 10^9 \ N/m^2$

$T = 1000 \ Nm$



$$A = 0.2 \times 0.1 = 0.02 \ m^2$$

$$T = 2Aq$$

$$1000 = 2 \times (0.02) \, q$$

$$1000 = 0.04 \, q \qquad q = \frac{1000}{0.04} = 25000 \ N/m$$

$$B = \frac{2500}{2(0.02 \times 25 \times 10^9 \times 0.001)} \quad \frac{q}{2AGt}\,ds \left[0.2 + 0.1 + 0.2 + 0.1\right]$$

$B = 0.015$ rad/sec.

$q = \tau / t$

1cm=10mm

$\tau = q/t$

$\tau = 25000 / 0.001$

$= 25 \times 10^6$

2) calculate the shear flow, shear stress for given section

20cm = 0.2m

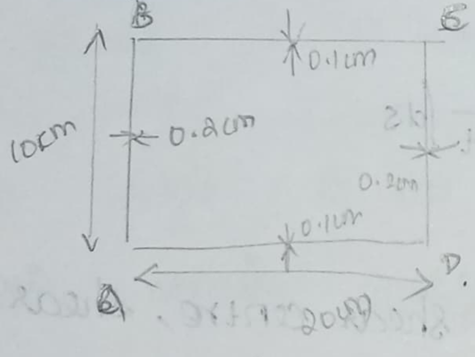
10cm = 0.1m

$G = 25 \times 10^9\ N/m^2$

$T = 100\ Nm$

$$q = \frac{T}{2A} = \frac{100}{0.2 \times 200} \quad 2500$$

$$= \frac{100}{0.04} = 2500\ N/m$$



$A = b \times d$

$= 0.20 \times 0.1 =$

$A = 0.02\ m^2$

$\tau = q/t$

$$\tau_{AB} = \tau_{BC} = \frac{2500}{0.001} = 2.5 \times 10^6 \quad (25 \times 10^5)\ N/m^2$$

$$\tau_{AB} = \tau_{DC} = \frac{2500}{0.002} = 1.25 \times 10^6 \quad (125 \times 10^5)\ N/m^2$$

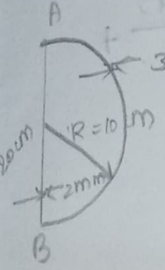
$$B = \frac{q}{2AGt}\,ds$$

$$= \frac{2500}{2 \times 0.02 \times 25 \times 10^9 \times} \left[\frac{0.1}{0.002} + \frac{0.2}{0.001} + \frac{0.1}{0.002} + 0.2/0.001\right]$$

$\beta = 1.25 \times 10^{-3}$ rad/sec.

3) Find the shear stress, shear flow, β,

$G = 30 \times 10^{5}$ N/cm² ; $T = 6000$ Ncm



$$A = \frac{\pi r^2}{2} = 157.07 \text{ cm}^2$$

$$\tau = q/t \qquad q = \frac{T}{2A}$$

$$= \frac{6000}{2 \times 157.07} = 19.09 \text{ N/cm}$$

$\tau = q/t$

$$\tau_A = \frac{19.09}{0.3} = 63.66 \text{ N/m}^2$$

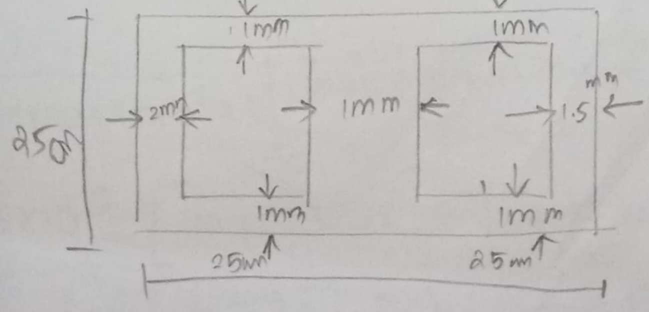
$$\tau_B = \frac{19.09}{0.2} = 95.45 \text{ N/m}^2$$

$$\beta = \frac{q}{2AGt} ds$$

$$= \frac{19.09}{2 \times (157.07)(30 \times 10^{5})} \left[\frac{20}{0.2} + \frac{\pi r}{0.3} \right] \quad (\pi r = \pi \times 10)$$

$$= 4.146 \times 10^{-6} \text{ rad/sec}$$

4) Find the shear flow and twist per unit length the $T = 75000$ Ncm.



$A_1 = b_1 \times d_1 = 25 \times 25 = 625\ cm^2$

$A_2 = b_2 \times d_2 = 25 \times 25 = 625\ cm^2$

$75000 = 2 \times 625 q_1 + 2 \times 625 q_2 \rightarrow ①$

$$B_1 = \frac{1}{2 \times 625 \times G}\left[\frac{q_1 \times 25}{0.2} + \frac{q_1 \times 25}{0.1} + \frac{q_1 \times 25}{0.1} + \frac{(q_1 - q_2)25}{0.1}\right]$$

$$= \frac{1}{1250G}\left[125q_1 + 250q_1 + 250q_1 + 250q_1 - 250q_2\right]$$

$$B_1 = \frac{1}{1250G}\left[875q_1 - 250q_2\right] \rightarrow ②$$

$$B_2 = \frac{1}{2 \times 625 \times G}\left[\frac{q_2 \times 25}{0.1} + \frac{q_2 \times 25}{0.15} + \frac{q_2 \times 25}{0.1} + \frac{(q_2 - q_1)25}{0.1}\right]$$

$$= \frac{1}{1250G}\left[250q_2 + 166.66q_2 + 250q_2 + 250q_2 - 250q_1\right]$$

$$= \frac{1}{1250G}\left[916.66q_2 - 250q_1\right] \rightarrow ③$$

2=3

$B_1 = B_2$

$$\frac{1}{1250G}\left[875q_1 - 250q_2\right] = \frac{1}{1250G}\left[916.66q_2 - 250q_1\right]$$

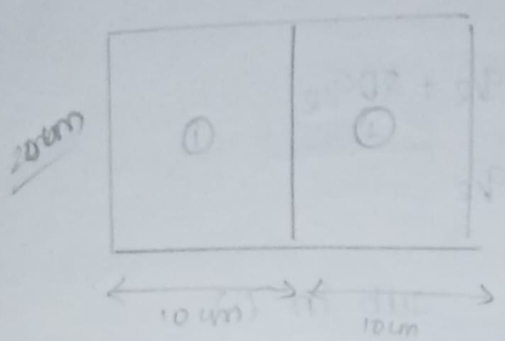
$1125q_1 - 1166.66q_2 = 0$

$q_1 = 30.54\ N/cm$

$q_2 = 29.45\ N/cm$

0.9

6\. Calculate the shear flow and it twist per unit length for the given section shown in fig. Assume $T = 1000\,N\,cm$ $G = 25\times10^9\,N/m^2$



thickness = 2cm

$T = 2Aq = 2A_1q_1 + 2A_2q_2$

$= 2\times200q_1 + 2\times200q_2$

$1000 = 400q_1 + 400q_2 \longrightarrow (1)$

$\beta_1 = \frac{1}{2A_1Gt}\oint q\,ds$

$= \frac{1}{2\times400\times25\times10^5\times2}\left[20q_1 + 10q_1 + 10q_1 + 20(q_1-q_2)\right]$

$= 5\times10^{-10}\left[20q_1 + 10q_1 + 10q_1 + 20q_1 - 20q_2\right]$

$\beta_1 = 5\times10^{-10}\left[60q_1 - 20q_2\right] \longrightarrow (2)$

$\beta_2 = \frac{1}{2A_2Gt}\oint q\,ds$

$= \frac{1}{2\times400\times25\times10^5\times2}\left[10q_2 + 20q_2 + 10q_2 + 20(q_2-q_1)\right]$

$= 5\times10^{-10}\left[10q_2 + 20q_2 + 10q_2 + 20q_2 - 20q_1\right]$

$= 5\times10^{-10}\left[60q_2 - 20q_1\right] \longrightarrow (3)$

$\beta_1 = \beta_2$

$5\times10^{-10}[60q_1 - 20q_2] = 5\times10^{-10}[60q_2 - 20q_1]$

$60q_1 - 20q_2 = 60q_2 - 20q_1$

$60q_1 + 20q_1 = 60q_2 + 20q_2$

$80q_1 = 80q_2$

$q_1 = q_2$ sub in (1)

$1000 = 400q_1 + 400q_2$

$1000 = 400q_2 + 400q_2 \Rightarrow 800q_2$

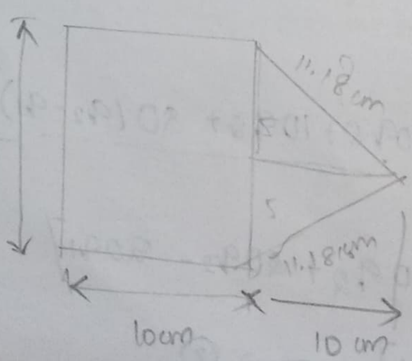
$q_2 = 1000/800 = 1.25\ N/cm$

$q_1 = 1.25\ N/cm$

$\beta_1 = 5\times10^{-10}[60(1.25) - 20(1.25)]$

$= 2.5\times10^{-8} = \beta_2 = 2.5\times10^{-8}$

6. Determine the shear flow & shear center for the section shown in fig. Assume $T = 10000\ N\ cm$ & $G = 2\ GPA$; $t = 2mm$



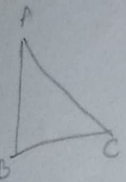
$1\ GPA = 1\ N/m^2 = 2\times10^9\ N/m^2$

$A_1 = b\times d$

$= 10\times10 = 100cm^2$

$A_2 = \frac{1}{2}\times b\times h + \frac{1}{2}\times b\times h$

$= \frac{1}{2}\times10\times5 + \frac{1}{2}\times10\times5$



$AC = \sqrt{AB^2 + BC^2}$

$AC = \sqrt{5^2 + 10^2}$

$= \sqrt{125} = 11.18\ cm$

$T = 2A_1 q_1 + 2A_2 q_2$

$10000 = 2(100 q_1) + 2(50 q_2)$

$10000 = 200 q_1 + 100 q_2 \longrightarrow (1)$

$\beta_1 = \frac{1}{2 \times A_1 G t} \oint q\, ds$

$= \frac{1}{2 \times 100 \times 2 \times 10^5 \times 0.2} \left[10 q_1 + 10 q_1 + 10 q_1 + 10 (q_1 - q_2)\right]$

$= 1.25 \times 10^{-7} \left[40 q_1 - 10 q_2\right] \longrightarrow (2)$

$\beta_2 = \frac{1}{2 \times A_2 \times G t} \oint q\, ds$

$= \frac{1}{2 \times 50 \times 2 \times 10^5 \times 0.2} \left[11.18 q_2 + 11.18 q_2 + 10 [q_2 - q_1]\right]$

$= 2.5 \times 10^{-7} \left[22.36 q_2 + 10 q_2 - 10 q_1\right]$

$= 2.5 \times 10^{-7} \left[32.36 q_2 - 10 q_1\right] \longrightarrow (3)$

$\beta_1 = \beta_2$

$1.25 \times 10^{-7} \left[40 q_1 - 10 q_2\right] = 2.5 \times 10^{-7} \left[32.36 q_2 - 10 q_1\right]$

$50 q_1 - 12.5 q_2 = 80.9 q_2 - 25 q_1$

$50 q_1 + 25 q_1 = 80.9 + 12.5 q_2$

$75 q_1 = 93.4 q_2$

$$q_1 = \frac{93.4}{75} q_2$$

$$\boxed{q_1 = 1.24\, q_2} \quad N/cm$$

$$10000 = 200(1.24) q_2 + 100 q_2$$

$$10000 = 348\, q_2 \Rightarrow \frac{10000}{348}$$

$$q_2 = 28.73 \quad N/cm$$

$$q_1 = 1.24 \times 28.73 = 35.62 \ N/cm$$

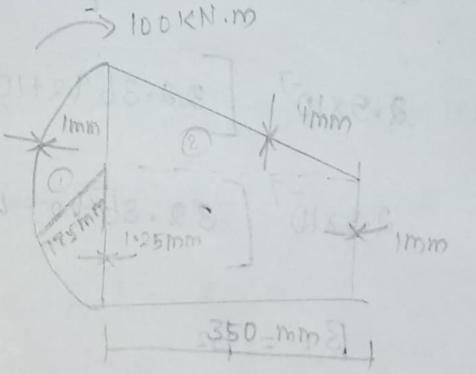
$$B_1 = 1.25 \times 10^{-7} [40(35.62) - 10(28.73)] = 1.421 \times 10^{-4}$$

$$B_2 = 2.5 \times 10^{-7} [32.36(28.73) \mp 10(35.62)]$$

$$= 1.433 \times 10^{-4}$$

7. Determine the SF & shear center for the section shown in fig. Assume $G = 25\ GPA$

thickness = ; $T = 100KNm$;



$$A_1 = \frac{\pi r^2}{2} = \frac{\pi \times (175)^2}{2}$$

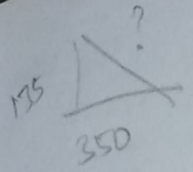
$$= 48.10 \times 10^3\ mm^2$$

$$A_2 = b \times d + \tfrac{1}{2} \times b \times h$$

$$= 350 \times 175 + \tfrac{1}{2}(350 \times 175)$$

$$= 61250 + 30625$$

$$= 91875\ mm^2$$



$\sqrt{350^2+175^2} = \sqrt{}$ $= 391.81$

$T = 100\ kNm \Rightarrow 100\times10^3\ N.m$

$100\times10^6\ Nmm$

$G = 25GPA = 25\times10^9\ N/m^2$

$= 25\times10^9\ N/10^6\ mm^2 \Rightarrow 25\ 10^{9}-10^{6} = 25\times10^3\ N/mm^2$

$T = 2A_1q_1 + 2A_2q_2$

$100\times10^6 = 2(48.10\times10^3)q_1 + 2(91875\ q_2)$

$100\times10^6 = 96260\ q_1 + 183750\ q_2 \longrightarrow (1)$

$\beta_1 = \frac{1}{2A_1Gt}\oint q\,ds$

$= \frac{1}{2\times48.10\times10^3\times25\times10^3}\left[\frac{\pi\times175}{1}q_1 + \frac{350}{1.25}(q_1-q_2)\right]$

$= 4.15\times10^{-10}(549.77q_1 + 280q_1 - 280q_2]$

$= [829.77q_1 - 280q_2] \rightarrow (2)$

$\beta_2 = \frac{1}{2A_2Gt}\oint q\,ds$

$= \frac{1}{2\times91875\times25\times10^3}\left[\frac{391.3}{1}q_1 + 175q_2 + 350q_2 + \frac{350}{1.25}(q_2-q_1)\right]$

366.39 339.65

$= 2.17\times10^{-10}[1196.3q_2 - 280q_1] \longrightarrow (3)$

$\beta_1 = \beta_2$

$4.15\times10^{-10}[829.77q_1 - 280q_2] = 2.17\times10^{-10}[1196.3q_2 - 280q_1]$

$3443.5q_1 - 1162q_2 = 2595.9q_2 - 607.6q_1$

$3443.59 q_1 + 607.69 q_1 = 2595.99 q_2 + 1162 q_2$

$4051.1 q_1 = 3757.9 q_2$

$q_1 = \frac{3757.9}{4051.1} q_2$

$q_1 = 0.927 q_2$

$100 \times 10^6 = 96200 (0.927) q_2 + 183750 q_2$

$= 272927.4 q_2$

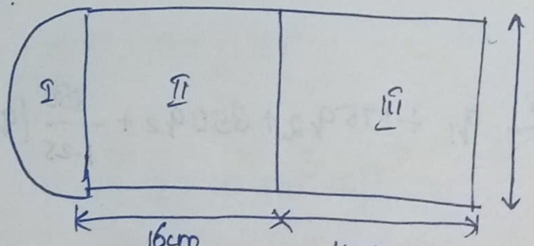
$q_2 = 366.39$ Nmm ; $q_1 = 0.927(366.39)$

$q_1 = 339.65$ Nmm

$B_1 = 7.513 \times 10^{-5}$ [7.438×10^{-5} N]

$B_2 = 7.44 \times 10^{-5}$ [7.44×10^{-5}]

8. A multi stage shown in fig is sub to a clockwise torque of 1000Nm compute the shear flow in the shell structure and the associated twist.



$t = 3mm = 0.3 cm$ every where

$T = 1000$ Nm

$\Rightarrow 100000$ Ncm

$T = 2Aq$

$A_1 = \frac{\pi r^2}{2}$ $A_2 = b \times d$ $A_3 = b \times d$

$A_1 = \frac{\pi \times 10^2}{2}$ 20×16 $= 20 \times 10$

$= 157.07 \, cm^2$ $= 320.0 \, cm^2$ $= 200 \, cm^2$

$100000 = 2 \times 157.07 q_1 + 2 \times 320 q_2 + 2 \times 200 q_3$

$100000 = 314.14 q_1 + 640 q_2 + 400 q_3 \longrightarrow (A)$

$\beta_1 = \frac{1}{2AGt} \oint q\,ds$

$\beta_1 = \frac{1}{2 \times 157.07 G \times 0.3} \left[\frac{\pi r}{2} q_1 + 200 (q_1 - q_2) \right]$

$= \left[31.4 q_1 + 20 q_1 - 20 q_2 \right]$

$\beta_1 = 0.0106/G \left[51.4 q_1 - 20 q_2 \right] \longrightarrow ①$ ✓

$\beta_2 = \frac{1}{2 A_2 G t} \oint q\,ds$

$= \frac{1}{2 \times 320 G \times 0.3} \left[16 q_2 + 16 q_2 + 20(q_2 - q_1) + 20 (q_2 - q_3) \right]$

$= 5.208 \times 10^{-3}/G \left[72 q_2 - 20 q_1 - 20 q_3 \right] \longrightarrow ②$

$\beta_3 = \frac{1}{2 A_3 G t} \oint q\,ds$

$= \frac{1}{2 \times 200 G \times 0.3} \left[10 q_3 + 20 q_3 + 10 q_3 + 20 (q_3 - q_2) \right]$

$= \frac{8.333 \times 10^{-3}}{G} \left[60 q_3 - 20 q_2 \right] \longrightarrow ③$

$\beta_2 = \beta_3 \rightarrow ④$ & $\beta_1 = \beta_3 \rightarrow ⑤$

$5.208 \times 10^{-3}/G \left[72 q_2 - 20 q_1 - 20 q_3 \right] = 8.333 \times 10^{-3}/G \left[60 q_3 - 20 q_2 \right]$

$374.4 q_2 - 104 q_1 - 104 q_3 = 499.98 q_3 - 166.66 q_2$

$+104.16 q_1 - 541.06 q_2 + 604.14 q_3 = 0$

$374.4 q_2 + 166.66 q_2 - 104 q_1 = 494.98 q_3 + 104 q_3 = 0$

$-541.06 q_2 + 104 q_1 + 603.98 q_3 = 0 \rightarrow (B)$

$\beta_1 = \beta_3$

$0.0104/G [51.4 q_1 - 20 q_2] = 8.333 \times 10^{-3}/G [60 q_3 - 20 q_2]$

$0.5448 q_1 - 0.212 q_2 = 0.4999 q_3 - 0.1666 q_2 + 0.212$

$0.5448 q_1 = 0.4999 q_3 + 0.0454 q_2 \rightarrow (C)$

$0.5448 q_1 - 0.0454 q_2 - 0.4999 q_3 = 0 \rightarrow (C)$

$q_1 = \frac{541.06}{104} q_2$ $q_1 = 65.61$ sub(A) (B) (C) in calc

$q_1 = 5.202 q_2$ $q_2 = 84.04$

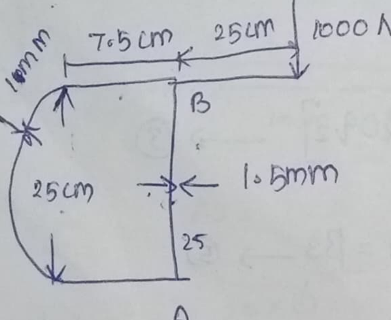
$q_3 = 63.99$ solve:-

$\beta_1 = 17.949$ $\beta_3 = 17.949$

next $\beta_2 = 17.949$

H.W? ⇒

10. Determine the shear flow and shear centre for the section shown in fig.



By force of equilibrium

$q_1 \times 25 - q_2 \, 25 = 1000$

$25 q_1 - 25 q_2 = 1000$

$2 q_2 \left(\frac{7.5 \times 25}{2}\right) + 2 q_2 \left[\frac{\pi r^2}{2} + \frac{7.5 \times 25}{2}\right] = 1000 \times 25$

$$2q_2\left[\frac{7.5\times 25}{2}\right] + 2q_2\left[\frac{\pi\times(12.5)^2}{2} + \frac{7.5\times 25}{2}\right] = 25000$$

$$187.5q_2 + 2(245.43 + 16.25)q_2 = 25000$$

$$q_2 = 28.87\ N/cm$$

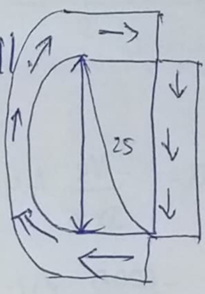
$$25q_1 - 25(28.87) = 1000$$

$$25q_1 = 1000 + 721.75 \qquad q_1 = \frac{1721.75}{25}$$

$$q_1 = 68.875$$

$$q_1 = 68.875\ N/cm$$

to locate shear centre (–) the value of q_t from q_1 & q_2 so that the all to produce zero twist for the shell



$$\beta = \frac{1}{2AG}\int\frac{q\,ds}{t} = 0$$

$$\frac{1}{2AG}\int_0^{(7.5\times2)+(\pi\times12.5)}\left(\frac{28.87 - q_t}{0.1}\right)ds + \int_0^{25}\left(\frac{68.875 - q_t}{0.15}\right) = 0$$

$$\int_0^{(7.5\times2)+(\pi\times12.5)}\left(\frac{28.875 - q_t}{0.1}\right)ds + \int_0^{25}\left(\frac{68.875 - q_t}{0.15}\right)ds = 0$$

$\int ds = s$ sub limit

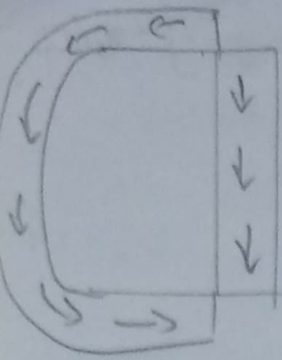
$$\left(\frac{28.875 - q_t}{0.1}\right)54.2699 + \left(\frac{68.875 - q_t}{0.15}\right)25 = 0$$

$$15669.076 - 542.699q_t + 11479.16 - 166.66q_t = 0$$

$$709.365q_t = 27148.076 \qquad q_t = \left[38.27\ N/cm\right]$$

$$\Rightarrow \frac{27148}{709.365}$$

28.8725 − 9t = −9.39206



Taking moment about A

$1000 \times e = 9.39806 \times 2\left[\frac{\pi(12.5)^2}{2} + \frac{7.5(25)}{2}\right] +$

$6884 - 9t$

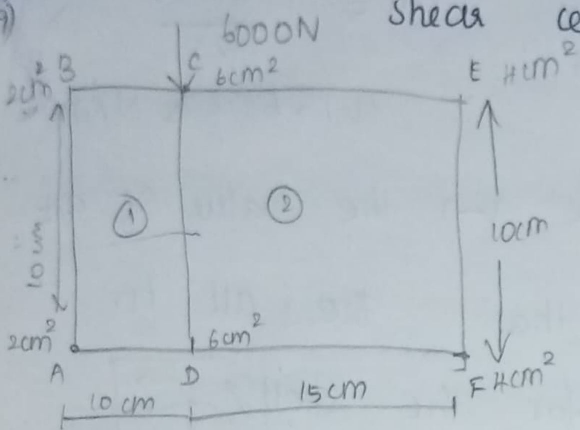
$= 30.6725\ N/cm$

$9.398\,[7.5 \times 25]$

$e = 8.1375\ cm$

ii) Find the shear flow and twist per shear length, shear center.

9)



$q = \frac{-V_y}{I_{xx}} \sum A_i y_i$

$I_{xx} = \sum A y^2$

$= A_1 + A_2 + A_3 + \dots A_6$

$= 2(-5)^2 + 2(5)^2 + 6(5)^2 + 6(-5)^2 +$

$4(-5)^2 = 50 + 50 + 150 + 150 + 100 + 100 = 600$

$q_{AB} = \frac{-V_y}{I_{xx}} A_1 y_1$

$= \frac{-6000}{600} \times 2(-5)$

$= -100\ N/cm$

$q_{BC} = q_{AB} - \frac{V_y}{I_{xx}} A_2 y_2$

$= -100 + \frac{6000}{600} \times 2 \times 5$

$= 0$

$q_{CD} = q_{BC} + \frac{V_y}{I_{xx}} A_3 y_3$

$= 0 + \frac{6000}{600} \times 6 \times 5$

$= 300$

$q_{DA} = q_{CD} + \frac{V_y}{I_{xx}} A_4 y_4$

$= 300 + \frac{6000}{600} \times 6(-5)$

$= 0$

section - II

$q_{CD} = \frac{-V_y}{I_{xx}} A_3 y_3$

$= \frac{6000}{600} \times 6 \times 5 = 300$

$q_{DF} = q_{CD} - \frac{V_y}{I_{xx}} A_4 y_4$

$= 300 + \frac{6000}{600} \times 6(-5) = 0$

$q_{EF} = q_{DE} + \frac{6000}{600} A_6 y_6 \Rightarrow 0 + \frac{6000}{600} 4(-5) = -200$

$q_{EC} = q_{FE} + \frac{6000}{600} + A_5 y_5$

$= -200 + 10 \times 4 \times 5$

$= -200 + 200$

$= 0$

I

$q_{AB}' = q_0 - 100$

$q_{BC}' = q_0 + 0$

II

$q_{CD} = q_0 + 300$

$q_{DF} = q_0' + 0$

let q_0, be the indeterminant shear flow,

$q_{AB} = q_0 + q_{AB}$

$q_{FE} = q_0' - 200$

$q_{EC} = q_0' + 0$

$q_{CD}' = q_0 + 300$

$q_{DA}' = q_0 + 0$

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$\beta_1 = 0$

$$\beta_1 = \frac{1}{2A_1 G t} \int q\, ds$$

$$0 = \frac{1}{2A_1 G t}\left[(-100 + q_0)10 + (q_0(10)) + q_0 \times 10 + (q_0 - q_0' + 300) \times 10\right]$$

$$0 = -1000 + 10q_0 + 10q_0 + 10q_0 + 10q_0 - 10q_0' + 3000$$

$$0 = 2000 + 40q_0 - 10q_0' \longrightarrow ①$$

$$\beta_2 = \frac{1}{2A_2 G t} \int q\, ds$$

$\beta_2 = 0$

$$0 = \frac{1}{2A_1 G t}\left[(300 + q_0' - q_0)10 + (q_0' \times 15) + (q_0' - 200)10 + (q_0'(15))\right]$$

$$0 = [(q_0' - q_0 + 300)10 + 15q_0' + (-200 + q_0')10 + 15q_0']$$

$$0 = 10q_0' - 10q_0 + 3000 + 15q_0' - 2000 + 10q_0' + 15q_0'$$

$$0 = 50q_0' - 10q_0 + 1000 \longrightarrow ②$$

(x)

$q_0 = -57.89$

$(q_0')_y = -31.57$

112.5

56.25

$18948 = 200q_1 + 300q_2$

$q_{AB}' = 57.89 - 100 = 42.11$

$q_{BC}' = -57.89$

$q_{CD}' = -57.89 + 300$

$= 357.89$

$q_{DA}' = -57.89$

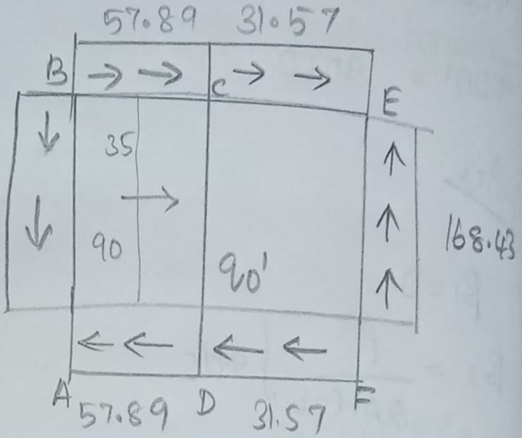
$q_{CD}' = -31.57 + 300 = 268.43$

q_{FE}'

$q_{DF}' = -31.57$

$q_{FE}' = 31.57 - 200 = 168.43$

$q_{EC}' = -31.57$



Mx ve

$(42.11 \times 10 \times 10) - (57.89 \times 10 \times 10) - (31.57 \times 15 \times 10) + (168.43 \times 10 \times 15) = -6000e$

$421 - 5789 - 4735.5 + 25264.5 = -6000e$

$18951 = -600e$

$e = -\frac{18951}{6000} = -3.158$

$T = 2Aq_t$

$q_t = T/2A \; ; \; T = V \times e$

$= -6000 \times -3.158 = 18948$

$T = 2A_1q_1 + 2A_2q_2$

$= 2 \times 100q_1 + 2 \times 150q_2$

$18948 = 200q_1 + 300q_2 \rightarrow (5)$

$B_1 = \frac{1}{2AGt}\int q\,ds$

$= \frac{1}{2AGt}\left[(q_1 \times 10) + (q_1 \times 10) + (q_1 \times 10) + (q_1 - q_2)10\right]$

$= \frac{1}{2AGt}\left[10q_1 + 10q_1 + 10q_1 - 10q_2\right]$

$= \frac{1}{2AGt}\left[40q_1 - 10q_2\right]$

$B_2 = \frac{1}{2AGt}\int q\,ds$

$= \frac{1}{2AGt}\left[(q_2 - q_1)10 + (q_2 \times 15) + (q_2 \times 15) + (q_2 \times 10)\right]$

$= \frac{1}{2AGt}\left[50q_2 - 10q_1\right]$

$B_1 = B_2$

$\frac{1}{2AGt}\left[40q_1 - 10q_2\right] = \frac{1}{2AGt}\left[50q_2 - 10q_1\right]$

$\frac{1}{2(200)}(40q_1 - 10q_2) = \frac{1}{2(150)}(50q_2 - 10q_1)$

$1.5(40q_1 - q_2) = 50(q_2 - 10q_1)$

$60q_1 - 15q_2 = 50q_2 - 10q_1$

$70q_1 - 65q_2 = 0$

$q_1 = 36.31$

$q_2 = 39.11$

$q_{AB}'' = 36.31 - 100 = -63.69 \; ; \; q_{BC}'' = 36.31$

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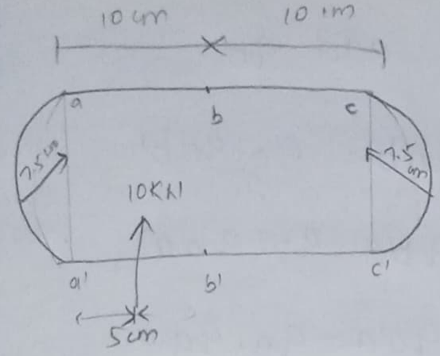
1Q)
2



$b = b' = 2cm$

$a = a' = c = c' = 1cm$

$$q = -\frac{V}{I_{xx}} yA$$

$$I_{XX} = \Sigma A_i y_i^2$$

$$= A_a y_a^2 + A_b y_b^2 + A_c y_c^2 + A_{a'} y_{a'}^2 + A_{b'} y_{b'}^2 + A_{c'} y_{c'}^2$$

$$= 1(7.5)^2 + 2(7.5)^2 + 1(7.5)^2 + 1(-7.5)^2 + 2(-7.5)^2 + 1(-7.5)^2$$

$I_{xx} = 450$

$$q_{ab} = \frac{-10 \times 10^3}{450} 1 \times (7.5)$$

$q_{ab} = -166.66$

$$q_{bc} = q_{ab} - \frac{Vy}{I_{xx}} A_b y_b$$

$$= -166.66 - \frac{10 \times 10^3}{450} \times 2(7.5)$$

$q_{bc} = -499.99$

$$q_{cc'} = q_{bc} - \frac{Vy}{I_{xx}} A_c y_c$$

$$= -499.99 - \frac{10 \times 10^3}{450} \times 1(7.5)$$

$q_{cc'} = -666.65$

$$q_{c'b'} = q_{cc'} - \frac{Vy}{I_{xx}} A_{c'} y_{c'}$$

$$= -666.65 - \frac{10 \times 10^3}{450} \times (1 \times (-7.5))$$

$= -499.99.$

$$q_{b'a'} = q_{c'b'} - \frac{Vy}{I_{xx}} A_{b'} y_{b'}$$

$$= -499.99 - \frac{10 \times 10^3}{450} \times 2(-7.5)$$

$q_{b'a'} = -166.65$

$$q_{a'a} = q_{b'a'} - \frac{Vy}{I_{xx}} A_{a'} y_{a'}$$

$$q_{a'a} = -166.65 - \frac{10 \times 10^3}{450} (1 \times -7.5)$$

$= -166.65 + 166.65$

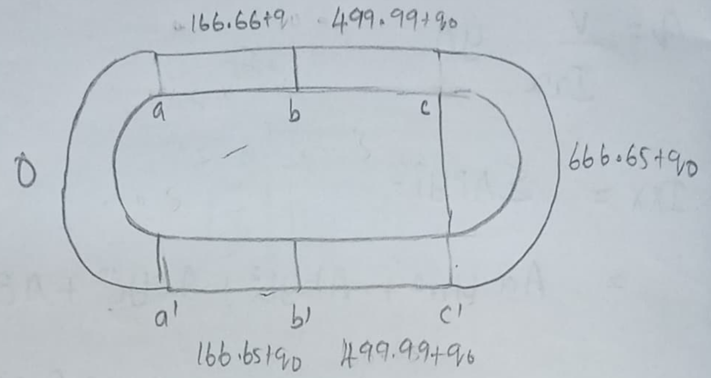
$= 0$

Intermediate shear flow add q_0

$q_{ab} = q_0 + q_{ab}$ $q_{c'b'} = q_0 + q_{c'b'}$

$q_{bc} = q_0 + q_{bc}$ $q_{b'a'} = q_0 + q_{b'a'}$

$q_{cc'} = q_0 + q_{cc'}$ $q_{a'a} = q_0 + q_{a'a}$



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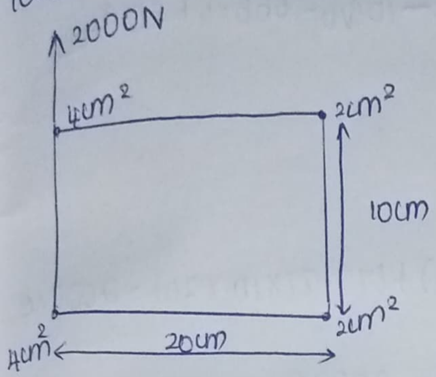
13) The figure shows a single cell beam with 4 flange. Find the internal shear flow force system when the beam came the external load of 2000N at shown



$q = \frac{-V_y}{I_{xx}} \Sigma A_i y_i$

$I_{xx} = \Sigma A_i y^2$

$= A_1 y_1^2 + A_2 y_2^2 + A_3 y_3^2 + A_4 y_4^2$

$= 4(-5)^2 + 4(5)^2 + 2(5)^2 + 2(-5)^2$

$= 100 + 100 + 50 + 50 = 300$

$q_{AB} = -V_y/I_{xx} \cdot A_1 y_1$

$q_{AB} = \frac{-2000}{300} \times 4(-5)$

$q_{AB} = 133.33$

$q_{BC} = q_{AB} - V_y/I_{xx} A_2 y_2$

$= 133.33 - \frac{2000}{300} \times 4 \times 5$

$= 0$

$q_{CD} = q_{BC} - V_y/I_{xx} A_3 y_3$

$= 0 - \frac{2000}{300} \times 2 \times 5$

$= -66.66$

$q_{DA} = q_{CD} - V_y/I_{xx} A_4 y_4$

$= -66.66 - \frac{2000}{300} \times 2 \times (-5)$

$= 0$

let q_0 be the intermediate shear flow existing at the ? for the section

$q_{AB'} = q_0 + 133.33$

$q_{BC'} = q_0$

$q_{CD'} = q_0 - 66.66$

$q_{DA'} = q_0$

$B = 0$

$$\beta = \frac{1}{2AGt} \oint q\,ds$$

$$0 = \frac{1}{2AGt}\left[(q_0 + 133.33)10 + q_0 \times 20 + (q_0 - 66.66)\times 10 + 20q_0\right]$$

$$0 = \frac{1}{2AGt}\left[10q_0 + 1333.33 + 20q_0 - 10q_0 - 666.6 + 20q_0\right]$$

$$0 = 60q_0 + 666.7$$

$$0 - 666.7 = 60q_0$$

$$-666.7 = 60q_0$$

$$q_0 = \frac{-666.7}{60}$$

$$q_0 = 11.11$$

$$q_{AB'} = q_0 + 133.33$$

$$= -11.11 + 133.33$$

$$= 122.22$$

$$q_{BC'} = -11.11$$

$$q_{CD'} = -11.11 - 133.33$$

$$= -77.77$$

$$q_{DA'} = -11.11$$

$$M = V \times e$$

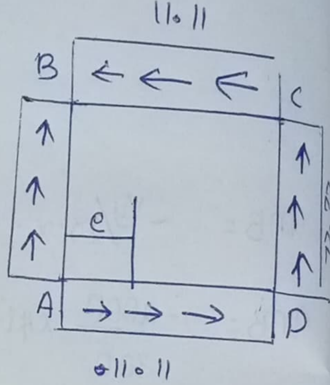
$$(11.11 \times 20 \times 10) + (77.77 \times 10 \times 20) = 2000 \times e$$

$$2222 + 1554 = 2000e$$

$$17776 = 2000e$$

$$e = \frac{17776}{2000} \quad 122.3$$

$$e = 8.88$$



$$T = V \times e$$

$$= 2000 \times 8.88 = 17760\ \text{Ncm}$$

$$T = 2Aq_t$$

$$q_t = T/2A = \frac{17760}{2 \times 200}$$

$$q_t = 44.4\ \text{N/cm}$$

$$q_{AB''} = q_0 + 133.33 + q_t$$

$$= -11.11 + 133.33 + 44.4$$

$$= 166.62$$

$q_{BC}'' = q_0 + q_t$

$= -11.11 + 44.4$

$= 33.29$

$q_{CD}'' = q_0 - 66.66 + q_t$

$= -11.11 - 66.66 + 44.4$

$= -33.37$

$q_{DA}'' = q_0 + q_t$

$= 71.11 + 44.4$

$= 33.29$