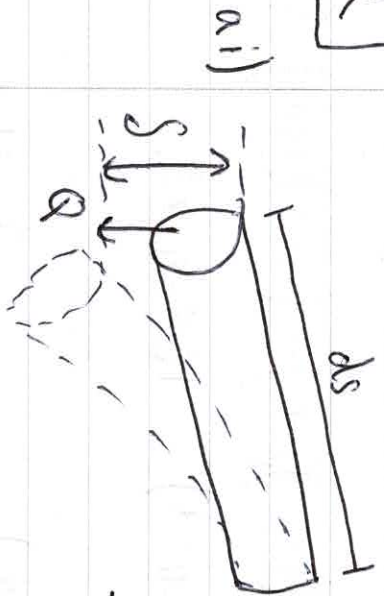


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Q2



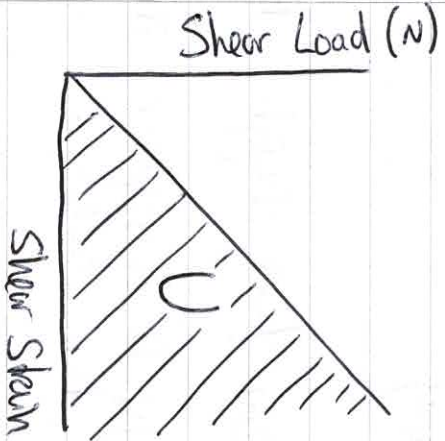
Shear Modulus $G = \frac{\text{Shear Stress}}{\text{Shear Strain}}$

$$\therefore \epsilon = \gamma / \gamma$$

$$\rightarrow \epsilon = Q/A \quad \therefore G = Q/\gamma A$$

$$\therefore \underline{\underline{Y = Q/AG}}$$

a ii)



Strain energy = area under graph.

$$\therefore = \frac{1}{2} Q Y$$

$$Y = Q/AG$$

$$\therefore \text{Strain energy} = \left(\frac{1}{2}\right)(Q)\left(\frac{Q}{AG}\right)$$

~~XXXXXXXXXX~~

Considering Total Strain energy = $\int_0^L \left(\frac{Q^2}{2AG}\right) ds$

$$\therefore U = \underline{\underline{\frac{Q^2 L}{2AG}}}$$

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b i) width = $0.03 \times 0.02 \text{ m}$ thickness = 0.0025 m
 $L = 2.4 \text{ m}$

Shear = $480 \times 10^6 \text{ N/m}^2$

$\sigma = F/A \rightarrow \text{Area} = (0.03)(0.02) - (0.025)(0.015) = 2.25 \times 10^{-4} \text{ m}^2$

$\therefore F = (480 \times 10^6)(2.25 \times 10^{-4}) = 108 \times 10^3 \text{ N}.$

$U = \frac{P^2 L}{2AE} \quad \therefore U = \frac{(108 \times 10^3)^2 \cdot (2.4)}{(2)(2.25 \times 10^{-4})(190 \times 10^9)} = \underline{\underline{327.415}}$

b ii) $PE = Mgh = \text{potential energy from height } h$

Assuming this potential energy is transferred into strain energy within the bar section:

$U = \frac{P^2 L}{2AE} = \frac{\sigma^2 A^2 L}{2AE} = \frac{\sigma^2 AL}{2E} = \frac{\sigma^2 V}{2E}$

$\therefore \frac{\sigma^2 V}{2E} = Mgh \quad \therefore h = \frac{\sigma^2 V}{2Emg}$

$\therefore h = \frac{\sigma^2 V}{2Emg}$

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b iii)

$$U = (A)(L) = (2.25 \times 10^{-4})(2.4) = 5.4 \times 10^{-4} \text{ m}^3$$

$$h = \frac{\sigma^2 V}{2E\omega} \quad \therefore \sigma^2 = \frac{2E\omega h}{V}$$

$$\therefore \sigma = \sqrt{\frac{2E\omega h}{V}} = \sqrt{\frac{(12)(140 \times 10^9)(20)(9.81)(0.45)}{(5.4 \times 10^{-4})}}$$

$$= \underline{\underline{249.26 \times 10^6 \text{ N/m}^2}}$$

biv)

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$$\boxed{\begin{matrix} \textcircled{0} \\ 4 \end{matrix}}_a$$

$$\underline{I_{xx}}$$

$$I_{xx} \text{ CHANNELS: } 2(26 \cdot 2 \times 10^6) = 52 \cdot 4 \times 10^6 \text{ mm}^4$$

$$I_{xx} \text{ PLATES: } 2\left(I + Ah^2\right) = 2\left(\frac{BD^3}{12} + Ah^2\right) \\ = 2\left(\frac{(300)(12)^3}{12} + (3600)(106)^2\right) = 80 \cdot 99 \times 10^6 \text{ mm}^4$$

$$\therefore I_{xx} \text{ TOTAL} = (52 \cdot 4 + 80 \cdot 99) \times 10^6 = 133 \cdot 39 \times 10^6 \text{ mm}^4$$

$$\underline{I_{yy}}$$

$$I_{yy} \text{ CHANNELS: } 2(I + Ah^2) = 2(1 \cdot 57 \times 10^6 + (4400)(79^2)) \\ = 58 \cdot 06 \times 10^6 \text{ mm}^4$$

$$I_{yy} \text{ PLATES: } 2\left(\frac{BD^3}{12}\right) = 2\left(\frac{(12)(300)^3}{12}\right) = 54 \times 10^6 \text{ mm}^4$$

$$\therefore I_{yy} \text{ TOTAL} = (58 \cdot 06 + 54) \times 10^6 = 112 \cdot 06 \times 10^6 \text{ mm}^4$$

$\therefore I_{xx} > I_{yy} \therefore$ STRUT WILL BUCKLE
ABOUT Y AXIS.

$$b) A = 2[4400 + (300 \times 12)] = 16000 \text{ mm}^2$$

$$\therefore K = \sqrt{\frac{I_{yy}}{A}} = \sqrt{\frac{112 \cdot 06 \times 10^6}{16000}} = \underline{\underline{83 \cdot 69 \text{ mm}}}$$

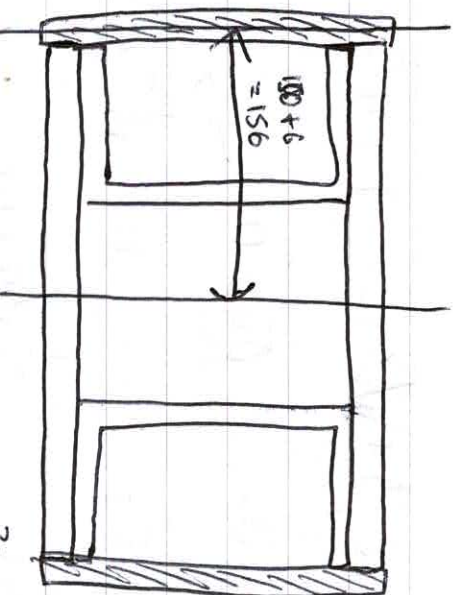
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c) Slenderness Ratio = $L/k = \frac{8500}{83.69} = \underline{\underline{95.59}}$

d) $P_E = \frac{U L^2 EI}{L^2} = \frac{U L^2 (200 \times 10^9) (1.1206 \times 10^{-4})}{(8)^2}$

= $3.46 \times 10^6 \text{ N} = \underline{\underline{3.46 \text{ MN}}}$

e) $P_R = \frac{\sigma_y A}{1 + a \left(\frac{L}{k} \right)^2} = \frac{(320 \times 10^6) (0.016)}{1 + \left(\frac{1}{7500} \right) (95.59)^2} = 2.30 \times 10^6 \text{ N}$
 = $\underline{\underline{2.30 \text{ MN}}}$



/// = Added sections

$\therefore I_{xx}$ Vertical plates = $2 \left(\frac{BD^3}{12} \right) = 2 \left(\frac{(6)(224)^3}{12} \right) = 11.24 \times 10^6 \text{ mm}^4$

$\therefore I_{yy}$ Vertical plates = $2 \left(I + Ah^2 \right) = 2 \left(\frac{(224)(6)^3}{12} + (224)(6)(156)^2 \right)$
 = $32.71 \times 10^6 \text{ mm}^4$

$\therefore \text{Total } I_{xx} = (33.39 + 11.24) \times 10^6 = 114.63 \times 10^6 \text{ mm}^4$

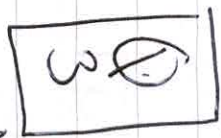
Total $I_{yy} = (112.06 + 32.71) \times 10^6 = 144.77 \times 10^6 \text{ mm}^4$

$\therefore$ Now buckles about I_{xx}

$\therefore P_E = \frac{(U L^2) (200 \times 10^9) (1.1463 \times 10^{-4})}{(8)^2} = \underline{\underline{3.53 \times 10^6 \text{ N} = 3.53 \text{ MN}}}$

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a)

$$\sigma = 0.075 \text{ m}$$

$$\text{thickness} = 0.005 \text{ m}$$

$$\sigma_y = 235 \times 10^6 \text{ N/m}^2$$

$$\nu = 0.3$$

$$n = 6$$

$$\frac{T}{J} = \frac{\tau}{R} \quad \therefore \tau = \frac{TR}{J}$$

$$J = \frac{W d^4}{32} \rightarrow \frac{(W)(0.075)^4}{32} = 3.11 \times 10^{-6} \text{ m}^4$$

$$\therefore \tau = \frac{(T)(0.0375)}{3.11 \times 10^{-6}} \rightarrow \tau = 12057.88 \text{ T}$$

$$\sigma_{1,2} = \frac{1}{2} \left[(\sigma_x + \sigma_y) \pm \sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_{xy}} \right]$$

$$\text{only horizontal} \quad \therefore \sigma_x \propto \sigma_y = 0$$

$$\text{take } a = \sigma_x + \sigma_y, \quad b = \sqrt{(\sigma_x + \sigma_y)^2 + 4\tau_{xy}}$$

$$\therefore \sigma_1 = \frac{1}{2}a + \frac{1}{2}b = \frac{1}{2}\sqrt{4\tau_{xy}}$$

$$\sigma_3 = \frac{1}{2}a - \frac{1}{2}b = -\frac{1}{2}\sqrt{4\tau_{xy}}$$

$$\therefore \text{TRESCA} \rightarrow \frac{1}{2}\sqrt{4\tau_{xy}} - \left(-\frac{1}{2}\sqrt{4\tau_{xy}}\right) = \sqrt{4\tau_{xy}} = \frac{\sigma_y}{n}$$

$$\therefore \sqrt{4\tau_{xy}} = \frac{325 \times 10^6}{12057.88}$$

$$\therefore 4\tau_{xy} = \frac{2.64 \times 10^{16}}{1.036 \times 10^{17}}$$

$$\therefore \tau_{xy} = \frac{2.64 \times 10^{16}}{2.072 \times 10^{17}} = 2.64 \times 10^{-2}$$

$$\text{shear} =$$

$$\frac{2.64 \times 10^{16}}{12057.88}$$

$$=$$

$$\frac{2.64 \times 10^{16}}{12057.88}$$

$$\therefore \tau = \frac{2.64 \times 10^{16}}{12057.88}$$

$$= 2.189 \text{ Nm}$$

$$\therefore \tau = 2.189 \text{ Nm}$$

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3b) considering $a = \frac{1}{2} \sqrt{4\epsilon_{xy}}$ & $b = \frac{1}{2} \sqrt{4\epsilon_{xy}}$

$$\sigma_1 = \frac{1}{2} \sqrt{4\epsilon_{xy}}, \quad \sigma_3 = -\frac{1}{2} \sqrt{4\epsilon_{xy}}, \quad \sigma_2 = 0$$

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 2\sigma_y^2$$

$$\therefore \left(\frac{1}{2} \sqrt{4\epsilon_{xy}}\right)^2 + \left(\frac{1}{2} \sqrt{4\epsilon_{xy}}\right)^2 + \left(-\frac{1}{2} \sqrt{4\epsilon_{xy}} - \frac{1}{2} \sqrt{4\epsilon_{xy}}\right)^2 = 2\sigma_y^2$$

$$\begin{aligned} & \left(\frac{1}{2} \sqrt{4\epsilon_{xy}}\right) \left(\frac{1}{2} \sqrt{4\epsilon_{xy}}\right) + \left(\frac{1}{2} \sqrt{4\epsilon_{xy}}\right) \left(\frac{1}{2} \sqrt{4\epsilon_{xy}}\right) + \left(-\sqrt{4\epsilon_{xy}}\right) \left(-\sqrt{4\epsilon_{xy}}\right) \\ & \therefore \frac{1}{4}(4\epsilon_{xy}) + \frac{1}{4}(4\epsilon_{xy}) - 2(4\epsilon_{xy}) = 2\sigma_y^2 \end{aligned}$$

$$\therefore \left(-\frac{3}{2}\right)(4\epsilon_{xy}) = 2\sigma_y^2$$

$$\therefore -6\epsilon_{xy} = 2\sigma_y^2$$

$$\therefore -3\epsilon_{xy} = \sigma_y^2$$

$$\therefore -\epsilon_{xy} = \frac{(325 \times 10^6)^2}{3} = 4 \cdot 130 \times 10^{16} \text{ N/m}^2$$

$$\therefore T = \frac{4 \cdot 130 \times 10^{16}}{12057 \cdot 88} = \underline{\underline{3 \cdot 425 \times 10^{12} \text{ Nm}}}$$

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M6X00420

c)

?

if New torque = $4.11 \times 10^{12} \text{ Nm}$

$$d) \% \text{ difference} = \left(\frac{3.425 \times 10^{12}}{4.11 \times 10^{12}} \right) (100) = 83.33\%$$