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M6X00420
Advanced Stress Analysis and FEA

Q1
a) 1D Elements:
- A simple optimisation study
- Basic scenarios
- Rods, Bars, Beams, Pipes etc
- Needs length and width measurements only.

2D Elements:

- Sheet components
- Requires length, width and "thickness"
-

3D Elements
- Complex geometries.
- Requires full cartesian geometry in x, y and z

Use 1D for simple cases
Use 2D for sheet or "surface" studies
Use 3D for full geometry complex studies

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Q1

B)

1. Use the rule-of-Thumb "Three elements in the Smallest Geometry."

2. In Complex geometries the overall ~~element~~ global element size can be small at the cost of solvetime. If there are simple geometries the elements can be larger to aid solvetime.

3. Element shape can determine size.

4. Local mesh refinement.

c) Element order is based off the balance between solve time and quality of results. If you want a fast solve use a 1st order set of elements to reduce the number of calculations. If you want a high quality result then use a higher order element to increase the nodes and number of calculations.

d) H mesh = Automatically reduce the mesh size based on the error norm

P mesh = Increase the order of elements used.

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Q2

a) i) $\gamma = \frac{Q}{AG}$ $\quad G = \frac{\tau}{\gamma}$

$= \frac{Q}{\gamma A}$ $\quad$ data. $\tau = \frac{Q}{A}$

$\gamma = \frac{Q}{AG}$

ii)

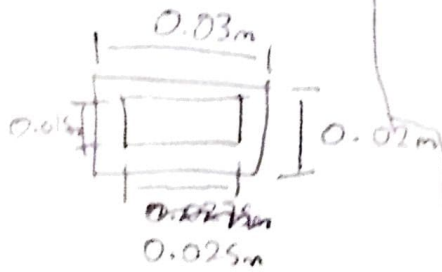
Strain Energy $= \frac{1}{2} Q \gamma$

$= \frac{1}{2} Q \frac{Q}{AG}$

$= \frac{1}{2} \frac{Q^2}{AG}$

$= \int_0^L \frac{Q^2}{2AG} \, ds$

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

b) i) 

$L = 2.4m$

$\sigma = 480 \text{ MPa}$

$E = 170 \text{ GPa}$

$A = \underbrace{(0.03 \times 0.02)}_{6\times10^{-4}} - \underbrace{(0.025 \times 0.015)}_{3.75\times10^{-4}}$

$= 2.25 \times 10^{-4} m^2$

$P = \sigma A = 480 \times 10^6 \times 2.25 \times 10^{-4} = 108000 N$

$108 kN$

$U_b = \frac{P^2 L}{2AE} = \frac{108000^2 \times 2.4}{2 \times 2.25\times10^{-4} \times 170 \times 10^9}$

$\therefore U_b = 327.41 J$

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Q2

b) ii) $h = \frac{\sigma^2 V}{2EW}$ $\quad W = mg \quad \therefore \frac{\sigma^2 V}{2Emg} = h$

So, $PE = mgh$

$= mg(h + \Delta L)$

$E = \frac{\sigma}{\varepsilon} = \sigma \div \frac{\Delta L}{L} = \frac{\sigma L}{\Delta L} \quad \therefore \Delta L = \frac{\sigma L}{E}$

$mg(h + \Delta L) = \frac{P^2 L}{2AE}$

$mg\left(h + \frac{\sigma L}{E}\right) = \frac{\sigma^2 L}{2AE}$

$mg\left(h + \frac{\sigma L}{E}\right) = \frac{\sigma^2 AL}{2E} \qquad AL = V$

$mg\left(h + \frac{\sigma L}{E}\right) = \frac{\sigma^2 V}{2E}$

$\frac{\sigma^2 V}{2Emg} = h + \cancel{\frac{\sigma L}{E}}$

So, $h = \frac{\sigma^2 V}{2EV}$ due to extension being "Not significant"

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Q4

a) $I_{xx} = 2I_{xx}\,'C' + 2I_{xx}\,'Plate'$

$= 2 \times 26.2 \times 10^6 + 2\left(\frac{300 \times 12^3}{12} + Ah^2\right)$

$= 52.4 \times 10^6 + 0.8928 \times 10$

$= 53.2928 \times 10^6\ mm^4$

$I_{yy} = 2I_{yy}\,'C' + 2I_{yy}\,'Plate'$

$= 2 \times (1.57 \times 10^6 + Ah^2) + 2\left(\frac{12 \times 300^2}{12}\right)$

$= 58.0608 \times 10^6 + 0.18 \times 10^6$

$= 58.2408 \times 10^6\ mm^4$

∴ The strut will buckle about I_{xx} as $I_{yy} > I_{xx}$

b) $K = \sqrt{\frac{I}{A}}$

$= \sqrt{\frac{53.2928 \times 10^6}{2 \times 4400 \times (300 \times 12)}}$

$= \sqrt{3330.8}$

$= 57.71\ mm$

c) Slenderness Ratio $= \frac{L}{k} = \frac{8}{57.7 \times 10^{-3}} = 138.65$

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Q4

d) Pinned Both

$$P_e = \frac{\pi^2 E I}{L^2}$$

$$= \frac{\pi^2 \times 200\times10^9 \times 53.2928\times10^{-6}}{8^2}$$

$$= 1643683.917\ N$$

$$= \underline{1643.68\ kN}$$

e) $$P_{Ro} = \frac{\sigma_y A}{1 + a\left(\frac{L}{k}\right)^2}$$

$$= \frac{320\times10^6 \times 16000\times10^{-3}}{1 + \frac{1}{7500} \times 138.65^2}$$

$$= 1436920.186\ N$$

$$= \underline{1436.92\ kN}$$

F) $I_{xx} = I_{xx}$ original $+ 2 I_{xx}$ New Plates

$$= 53.2928\times10^6 + 2\left(\frac{6\times224^3}{12}\right)$$

$$= 53.2928\times10^6 + 11.239424\times10^6$$

New $I_{xx} = 64.53224\times10^6\ mm^4$

$$P_e = \frac{\pi^2 EI}{L^2} = \frac{\pi^2 \times 200\times10^9 \times 64.53224\times10^{-6}}{8^2}$$

$$= 1990336.5\ N$$

$$= 1990.34\ kN$$

Euler load for xx would increase by $\underline{346.66\ kN}$