2017-18 (odd sem) ①

Solutions for IAT 1 Question paper

Sem : V

Sub : DME I

Sections : A & B

Sub code : 15ME54

Staff : RPR.

1 (a) A machine element in the form of a cantilever, supported at one end and carrying a lateral load of 60KN is 0.8 m long. The cross section is rectangular with its depth equal to thrice its width. The deflection is limited to 2mm at the loading end. If the allowable stress in the material is 80MPa, design the section. Take E = 200GPa.

Soln. data

$F = 60KN$

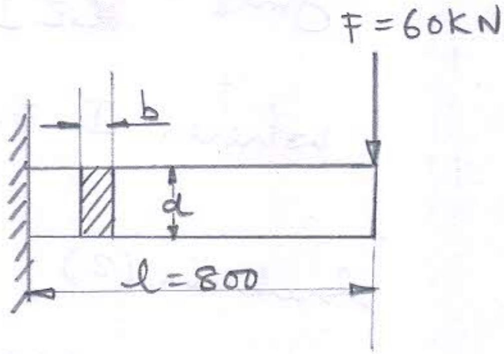
$l = 800mm$

$d = 3b$

$y_{max} = 2.0 mm$

$\sigma_d = 80MPa$

$E = 200 \times 10^3 N/mm^2$



to find

b & d

(i) c/s dimensions limiting the stress :

$$\sigma_b = \frac{M_b}{z_b} \quad — (1)$$

where $M_b = Fl$ (T2.8 / P2.34).

2

$$Z_b = \frac{bh^2}{6} \quad (T2.7/P2.33).$$

$$\therefore M_b = 60\times10^3 \times 800$$
$$= 48\times10^6 \text{ N-mm}.$$

$$Z_b = \frac{bh^2}{6} = \frac{b(3b)^2}{6} = \frac{9b^3}{6} = \frac{3b^3}{2} \text{ mm}^3.$$

Sub in (1),

$$80 = \frac{48\times10^6}{\left(\frac{3b^3}{2}\right)}$$

$$\Longrightarrow b = 73.68 \text{ mm}.$$

ii) C/s dimensions limiting the deflection

$$y_{max} = \frac{Fl^3}{3EI} \quad —(2) \quad (T2.8/P2.34)$$

$$\text{where } I = \frac{bd^3}{12} \quad (T2.7/P2.33).$$

Sub in (2),

$$2 = \frac{60\times10^3 \times 800^3 \times 12}{3\times200\times10^3 \times b(3b)^3}$$

$$\Longrightarrow b = 58.07 \text{ mm}.$$

Selecting the higher value for b, select $b = 74$ mm

$\therefore d = 222$ mm

b) A bracket shown in figure is subjected to a pull of 15 KN at 60° to the vertical. Det. the max. tensile stress in the bracket. (3)

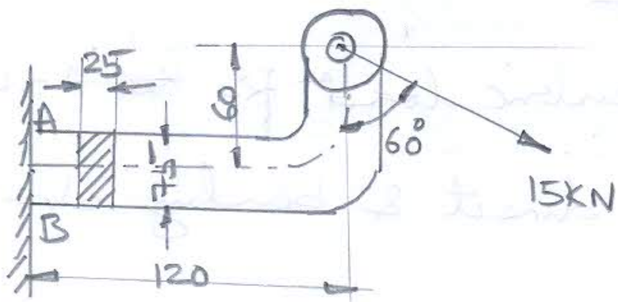
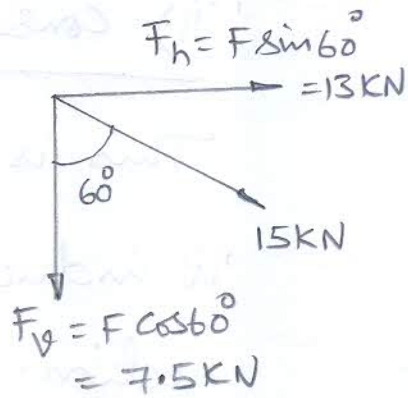


Fig 1(b)



data

$b = 25mm$

$h = 75mm$

$A = 1875\ mm^2$

to find

Max. tensile stress in the bracket.

In fig 1.B, AB is the critical section.

i) consider F_v

This force produces B.M in section A-B.

$$\sigma_{b1} = \frac{M_b}{Z_b} \quad -(1)$$

where $M_b = F_v \times 120$

$= 7.5 \times 10^3 \times 120$

$= 9 \times 10^5\ N\text{-}mm$

$$Z_b = \frac{bh^2}{6} = \frac{25 \times 75^2}{6} = 23.43 \times 10^3\ mm^3.$$

Sub in (1),

$$\therefore \sigma_{b1} = \frac{9 \times 10^5}{23.43 \times 10^3} = 38.41\ N/mm^2.$$

$(\sigma_{b1})_A = 38.41\ N/mm^2$

& $(\sigma_{b1})_B = -38.41\ N/mm^2$

ii) Consider F_h :

This is an eccentric load for sec A-B. Hence, it induces both direct & bending stresses in the section.

$$\sigma_t = \frac{F_h}{A} = \frac{13\times10^3}{25\times75} = 6.93\ N/mm^2$$

$$\sigma_{b2} = \frac{M_b}{Z_b} = \frac{F_h \cdot e}{\left(\frac{bh^2}{6}\right)} = \frac{13\times10^3\times60}{\left(\frac{25\times75^2}{6}\right)}$$

$$= 33.28\ N/mm^2.$$

$(\sigma_{b2})_A = 33.28\ N/mm^2$

$(\sigma_{b2})_B = -33.28\ N/mm^2.$

$\therefore$ Max. tensile stress in section A-B

$= \sigma_{b1} + \sigma_t + \sigma_{b2}$

$= 38.41 + 6.93 + 33.28$

$= 78.62\ N/mm^2$ (at A of sec A-B).

2(a) A rod of circular section is to sustain a torsional moment of 300 KN-m and a bending moment of 200 KN-m. Selecting C45 steel ($\sigma_y = 353$ MPa) and assuming a F.S of 3, determine the dia. of rod as per the following theories of failure. (5)

i) Max. shear stress theory
ii) Distortion energy theory
iii) Total energy theory

Ans: data

$M_t = 300 \times 10^3$ N-m
$= 300 \times 10^6$ N-mm.

$M_b = 200 \times 10^6$ N-mm.

$\sigma_y = \sigma_e = 353$ N/mm^2

$n = 3$.

to find

$d = ?$

Torsional shear stress $(\tau) = \frac{M_t}{Z_t}$.

$= \frac{M_t}{\left(\frac{\pi d^3}{16}\right)}$

$= \frac{300 \times 10^6 \times 16}{\pi d^3}$

$= \left(\frac{1.527 \times 10^9}{d^3}\right)$ N/mm^2

Bending stress $(\sigma_b) = \frac{M_b}{Z_b}$.

$= \frac{200 \times 10^6 \times 32}{\pi d^3}$

$= \left(\frac{2.037 \times 10^9}{d^3}\right)$ N/mm^2

$\therefore$ Max. principal stress $(\sigma_1) = \frac{\sigma_b}{2} + \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + \tau^2}$

$$= \left(\frac{2.854 \times 10^9}{d^3}\right) N/mm^2$$

Min. principal stress $(\sigma_2) = \frac{\sigma_b}{2} - \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + \tau^2}$ (6)

$$= \frac{-(0.817 \times 10^9)}{d^3} N/mm^2$$

(i) Max. shear stress theory

$$\sigma_1 - \sigma_2 = \frac{\sigma_e}{n}$$

$$\frac{(2.854 + 0.817) 10^9}{d^3} = \frac{353}{2}$$

$\Rightarrow d = 314.83 mm$.

ii) Distortion energy theory

$$\sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2} = \frac{\sigma_e}{n}$$

$\Rightarrow d = 305 mm$.

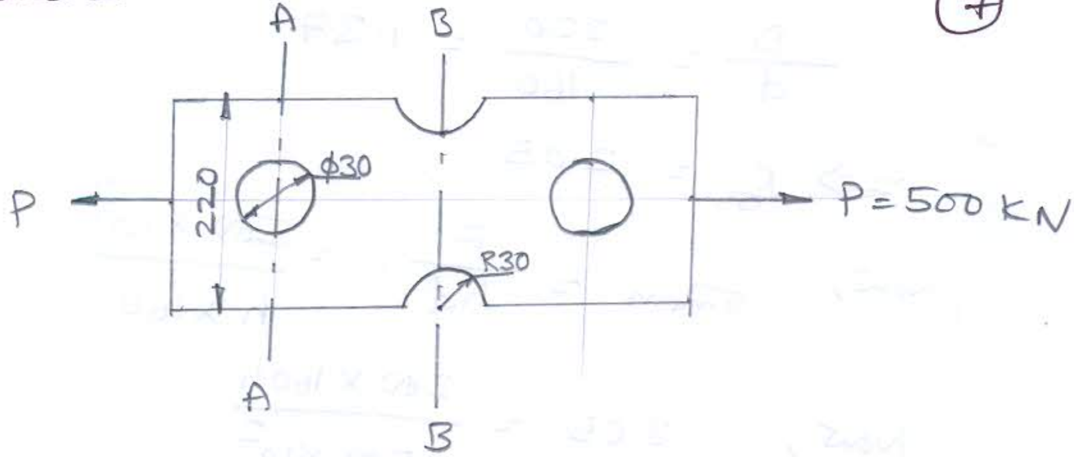
iii) Max. total energy theory

$$\sqrt{\sigma_1^2 + \sigma_2^2 - 2\nu\sigma_1\sigma_2} = \frac{\sigma_e}{n}$$

assuming $\nu = 0.3$ for steel,

$d = 300.58 mm$.

2(b) A bar of rectangular section is subjected to an axial pull of 500 kN. Calculate the thickness if the allowable stress in the bar is 200 MPa. (7)



Ans: 1) Consider sec A-A

Refer Fig 4.5

$d = 30\,mm$

$\omega = 220\,mm$

$\sigma_{max} = 200\ N/mm^2$

$\therefore \frac{d}{\omega} = 0.136$

$\Rightarrow k_\sigma = 2.65$

$$\sigma_{nom} = \frac{F}{(\omega - d)h} = \frac{500 \times 10^3}{(220-30)h} = \frac{500 \times 10^3}{190h}$$

$$\text{Now } k_\sigma = \frac{\sigma_{max}}{\sigma_{nom}}$$

$$2.65 = \frac{200}{500 \times 10^3} \times 190h$$

$\Rightarrow h = 34.86\,mm$

2) Consider section B-B

Refer Fig 4.22A / P4.21.

$r = 30\,mm$

$D = 220\,mm$

$$d = 220 - 60 = 160\ mm.$$

$$\frac{r}{d} = \frac{30}{160} = 0.18$$

$$\frac{D}{d} = \frac{220}{160} = 1.37$$

$$\Rightarrow K_t = 2.05.$$

Now, $\sigma_{nom} = \frac{F}{hd} = \frac{500 \times 10^3}{h \times 160}$

Now, $2.05 = \frac{200 \times 160h}{500 \times 10^3}$

$$\Rightarrow h = 32.03\ mm.$$

Selecting the higher value of the above two,

select $h = 35\ mm.$

3(a) A steel rod is 1.5m long. It has to resist longitudinally an impact of 2.5 KN falling under gravity at a velocity of 0.99 m/sec. Maximum computed stress is limited to 150MPa. Design the dia of rod. Take $E = 206.8\ GPa$.

Ans: data

$l = 1500\ mm.$

$W = 2.5\ KN$

$v = 0.99\ m/sec.$

$\sigma_i = 150\ N/mm^2$

$E = 206.8 \times 10^3\ N/mm^2.$

to find

$d = ?$

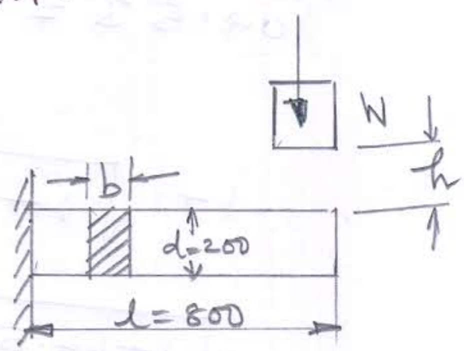
'd' is determined by equating Resilience of rod to K.E of mass. (9)

$$\left(\frac{\sigma_i^2}{2E}\right) \times V = \frac{1}{2} m u^2 \times 10^3$$

$$\left(\frac{150^2}{2 \times 206.8 \times 10^3}\right) \times \left(\frac{\pi d^2}{4} \times 1500\right) = \frac{1}{2} \times \frac{250}{9.81} \times 0.99^2 \times 10^3$$

Solving $d = 44.14\,mm$
$\simeq 45\,mm$

3(b) A cantilever beam of span 800 mm has a rectangular c/s of depth 200 mm. The free end of beam is subjected to a transverse load of 1KN that drops on to it from a height of 40 mm. Selecting C40 steel ($\sigma_y = 328.6$ MPa), & F.S = 3, determine the width of rectangular section. Take E = 206.8 GPa.



Ans: data

$l = 800$ mm.
$d = 200$ mm. $n = 3$.
$W = 1KN$.
$h = 40$ mm.

$$\sigma_{bi} = \frac{\sigma_y}{FS} = \frac{328.6}{3} = 109.53\ N/mm^2$$

to find

$b = ?$

$$\sigma_{bi} = (\sigma_b)_{st}\left[1+\sqrt{1+\frac{2h}{\delta_{st}}}\right] \quad -(1)$$ (10)

$$(\sigma_b)_{st} = \frac{M_b}{z_b} = \frac{Fl}{\left(\frac{bd^2}{6}\right)}$$

$$= \frac{6 \times Fl}{b \times 200^2}$$

$$= \left(\frac{120}{b}\right) N/mm^2 \quad -(2)$$

Now $y = \frac{Fl^3}{3EI}$

$$= \frac{1 \times 10^3 \times 800^3 \times 12}{3 \times 206.8 \times 10^3 \times b \times 200^3}$$

$$= \frac{1.24}{b} \quad -(3)$$

Sub (2) & (3) in (1).

$$109.53 = \frac{120}{b}\left[1+\sqrt{1+\frac{2 \times 40\, b}{1.24}}\right]$$

$$1+\sqrt{1+64.51b} = 0.912b.$$

$$\sqrt{1+64.51b} = (0.912b - 1)$$

Squaring on both sides,

$$\cancel{1+} 64.51b = 0.831b^2 - 1.824b \cancel{+1}$$

$$\text{i.e. } 0.831b^2 - 66.33b = 0$$

$$\Rightarrow b = 79.82\,mm \text{ say } 80\,mm.$$