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Internal Assesment Test – 1

Sub:Mechanics of Materials				Code: 21ME4
Date: 07/07/2023	Duration: 90 mins	Max Marks: 50	Sem: 4	Branch (sections): ME (A)

Answer any five full questions

		Marks	OBE CO	OBE RBT
1	(a) Sketch and explain stress-strain diagram for steel indicating all salient points and zones on it.	[05]	CO1	L2
	(b) Derive an expression for volumetric strain of a rectangular block subjected to axial load.	[05]	CO1	L2
2	Two vertical rods one of steel and the other of copper are each rigidly fixed at the top and 500mm apart. Diameters and lengths of each rod are 20mm and 4m respectively. A cross bar fixed to the rods at the lower ends carries a load of 5kN, such that the cross bar remains horizontal even after loading. Find the stress in each rod and the position of the load on the bar. Take Es = 2×10^5 N/mm^2 and Ec = 1×10^5 N/mm^2.	[10]	CO1	L3
3	A bar of 800mm length is attached rigidly at A and B as shown in Fig. 1. Forces of 30 kN and 60 kN act as shown on the bar. If E=200 MPa, determine the reactions at the two ends. If the bar diameter is 25 mm, find the stresses and change in length of each portion.	[10]	CO1	L3

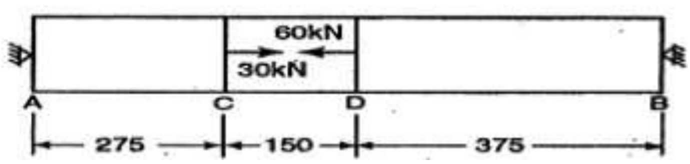

Figure 1

		Marks	CO	RBT
4	Rails are laid such that there is no stress in them at 24°C. If the rails are 12.6 m long and maximum temperature expected is i) Estimate the minimum gap between two rails to be left so that temperature stresses do not develop. ii) Calculate the thermal stresses developed in the rails if a) No expansion joint is provided. b) If a 2 mm gap is provided for expansion. iii) If the stress developed is 20 MN/m^2, what is the gap left between the rails?	[10]	CO1	L3

	Coefficient of linear expansion, $\alpha = 12 \times 10^{-6}/°C$ and Young's modulus E = 200GPa.			
5	With usual notations derive torsion equation. Also state the assumptions in pure torsion theory.	[10]	CO5	L2
6	A hollow shaft of diameter ratio 3/8 is to transmit 375 kW at 100 rpm. The maximum torque being 20 % greater than the mean; the shear stress is not to exceed 60 N/mm^2 and the twist in a length of 4 m is not to exceed 2 degrees. Calculate its external and internal diameters. Take $G = 8 \times 10^4\ N/mm^2$.	[10]	CO5	L3
7	A solid steel shaft has to transmit 75 kW at 200 rpm. Taking allowable shear stress as 70 N/mm^2, find the suitable diameter of the shaft, if the maximum torque transmitted in each revolution exceeds the mean by 30%. Also find the outer diameter of a hollow shaft to replace the solid shaft if the diameter ratio is 0.7.	[10]	CO5	L3

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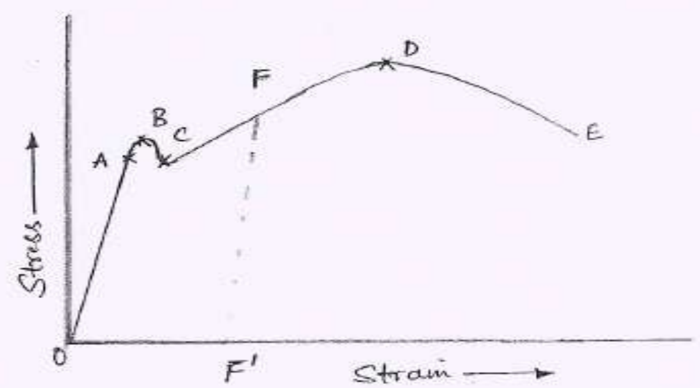
Internal Assesment Test – 1
Solutions

Sub:	Mechanics of Materials							**Code:**	21ME44
Date**:**	07/07/2023	Duration:	90mins	Max Marks:	50	**Sem:**	IV	**Branch:**	ME

1 [a]

Stress Strain relation:

Behaviour in Tension[Mild Steel]:



(a) Limit of Proportionality (A): It is the limiting value of the Stress up to which stress is proportional to strain.

(b) Elastic limit: This is the limiting value of stress up to which if the material is stressed and then released (unloaded) Strain disappears completely and the original length is regained. This point is slightly beyond the limit of proportionality.

(c) Upper yield point (B): This is the stress at which, load starts reducing and the extension increases. This phenomenon is called Yielding of material.

(d) Lower yield point (C): At this stage the stress remains same but strain increases for some time.

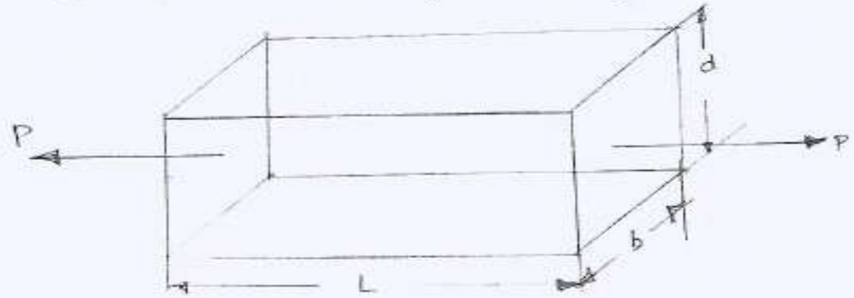
(e) Ultimate Stress (D): This is the maximum stress the material can resist. At this stage cross sectional area at a particular section starts reducing very fast. This is called neck formation. After this stage load resisted and hence the stress developed starts reducing.

(f) Breaking point (E): The stress at which finally the specimen fails is called breaking point.

1[b]

Volumetric strain of a Rectangular Bar which is subjected to an Axial load 'P' in the direction of its length.

Consider a rectangular bar of length 'L', width 'b' and depth 'd' which is subjected to an axial load 'P' in the direction of its length as shown in fig: below



Let, δL = Change in length

δb = Change in width and

δd = Change in depth

$\therefore$ Final length of the bar $= L + \delta L$

Final width of the bar $= b - \delta b$ (-ve sign due to decrease)

Final depth of the bar $= d + \delta d$ (-ve sign due to decrease)

Now Original volume of bar, $V = L \cdot b \cdot d$

Final volume $= (L + \delta L)(b - \delta b)(d + \delta d)$

$= Lbd + bd\,\delta L - Lb\,\delta d - Ld\,\delta b$

(Ignoring products of small quantities)

$\therefore$ Change in volume,

δv = Final volume − Original volume

$= (Lbd + bd\,\delta L - Lb\,\delta d - Ld\,\delta b) - Lbd$

$= bd\,\delta L - Lb\,\delta d - Ld\,\delta b$

$\therefore$ Volumetric strain,

$$e_v = \frac{\delta v}{V}$$

$$= \frac{bd\delta L - Lb\delta d - \delta bLd}{Lbd}$$

$$= \frac{\delta L}{L} - \frac{\delta d}{d} - \frac{\delta b}{b} \quad -(i)$$

But $\frac{\delta L}{L}$ = Longitudinal strain and $\frac{\delta d}{d}$ (or) $\frac{\delta b}{b}$ are lateral strains

Substituting these values in the above equation, we get

e_v = longitudinal strain − 2 × Lateral strain — (ii)

we know that, $\frac{\text{Lateral strain}}{\text{longitudinal strain}} = \mu$ [$\because$ poisson's ratio]

$\therefore$ Lateral strain = μ × longitudinal strain.

Substituting the value of lateral strain in equation (ii),

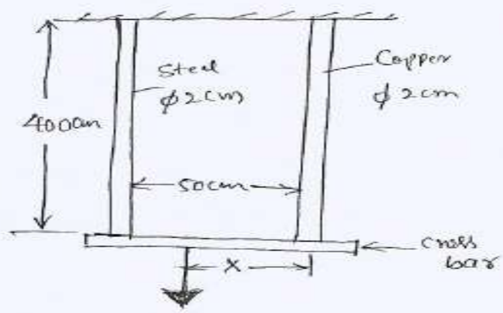
e_v = Longitudinal strain − 2 × μ longitudinal strain

e_v = longitudinal strain $(1 - 2\mu)$

$$= \frac{\delta L}{L}\left(1 - \frac{2}{m}\right) \qquad \left(\because \frac{1}{m} = \mu\right)$$

2.

Soln:



Given:

Distance between the rods

= 50 cm = 500mm

Dia. of steel rod = Dia. of copper rod

= 2cm = 20mm

$\therefore$ Area of steel rod = Area of copper rod

$= \frac{\pi}{4} \times 20^2$

$\therefore A_S = A_C = 100\pi\, mm^2$

Length of each rod = 4m = 4000mm

Total load carried by rods, P = 5000N

$E_S = 2 \times 10^5\ N/mm^2$, $E_C = 1 \times 10^5\ N/mm^2$

$\sigma_S = ?$ & $\sigma_C = ?$

Since the cross bar remains horizontal, the extensions of the steel and copper rods are equal. Also these rods have the same original length, hence the strains of these rods are equal.

$\therefore$ Strain in steel = Strain in copper.

$$\frac{\sigma_S}{E_S} = \frac{\sigma_C}{E_C}$$

$$\therefore \sigma_S = \frac{E_S}{E_C} \times \sigma_C = \frac{2 \times 10^5}{1 \times 10^5} = 2 \times \sigma_C \quad -(i)$$

Total load = Load on Steel rod + Load on Copper rod.

$= 5000\,N.$

$$5000 = \sigma_s \times A_s + \sigma_c \times A_c$$

$$= 2\sigma_c \times 100\pi + \sigma_c \times 100\pi$$

$$\sigma_c = \frac{5000}{300\pi} = \underline{5.305\ N/mm^2}$$

Substituting this value of σ_c in eqn (i)

$$\sigma_s = 2 \times \sigma_c = \underline{10.61\ N/mm^2}$$

(ii) Position of the load of 5000 N on cross bar.

Let, x = The distance of the 5000N load from the copper rod.

Load carried by each rod:

Load = Stress × Area.

Load carried by Steel

$$P_s = \sigma_s \times A_s$$

$$= 10.61 \times 100\pi$$

$$= \underline{3333\ N}$$

Load carried by copper rod.

$$P_c = \sigma_c \times A_c$$

(or)

$$P = P_s + P_c$$

$$P_c = P - P_s$$

$$= 5000 - 3333$$

$$\therefore P_c = \underline{1667\ N}$$

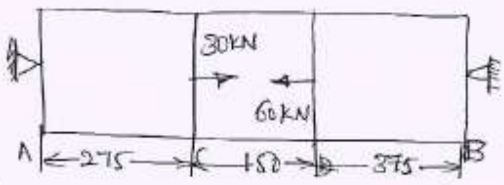
Now taking the moments about the copper rod and equating the same we get.

$$5000 \times x = P_s \times 50$$

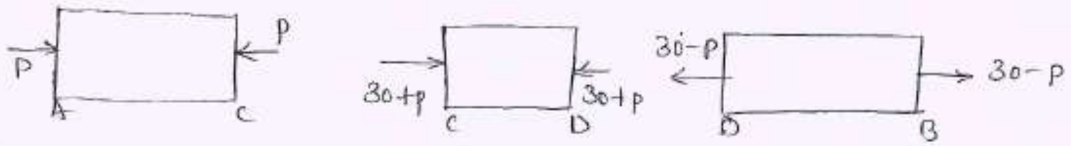
$$x = \frac{3333 \times 50}{5000}$$

$$\therefore x = \underline{33.33\ cm}$$

3.



Let 'P' be the reaction on the bar from Support at A. Then forces acting on the each portion of the bar are shown in fig. below.



Shortening of portion AC $= \frac{P \times 275}{AE}$ $\left(\because \Delta = \frac{PL}{AE}\right)$

Shortening of portion CD $= \frac{(30+P)150}{AE}$

Extension of portion DB $= \frac{(30-P)375}{AE}$

$\therefore$ Total extension $= \frac{1}{AE}\left[-P \times 275 - (30+P)150 + (30-P)375\right]$

As supports are unyielding, Total extension = 0.

$\therefore$

$$0 = -275P - 150(30+P) + (30-P)375$$

$$800P = 30 \times 375 - 150 \times 30$$

$$\therefore P = 8.4375 \text{ KN}$$

$\therefore$ Reaction of Support 'A' is $= 8.4375$ KN (Ans)

and at Support 'B' reaction is $30 - 8.4375$ KN

$= 21.5625$ KN (Ans)

Now cross-sectional area, $A = \frac{\pi}{4} \times 25^2$

$= 490.8739 \text{ mm}^2$

Stress in portion AC $= \frac{8.4375 \times 10^3}{490.8739}$ $(\because \sigma = P/A)$

$= 17.1887 \text{ N/mm}^2$ (Ans) (Comp)

Stress in portion CD = $\dfrac{(30 + 8.4375) \times 10^3}{490.8739}$

$= 78.3042 \, N/mm^2$ (Ans) (Comp)

Stress in portion DB = $\dfrac{(30 - 8.4375) \times 10^3}{490.8739}$

$= 43.9268 \, N/mm^2$ (Ans) (Tensile)

Now, $E = 200 \, GPa = 200 \times 10^9 \times \dfrac{1}{(1000)^2} \, N/mm^2 = 200 \times 10^3 \, N/mm^2$
$= 2 \times 10^5 \, N/mm^2$

Shortening of portion, AC = $\dfrac{8.4375 \times 10^3 \times 275}{490.8739 \times 2 \times 10^5} = 0.02363 \, mm$ (Ans) $\left(\Delta = \dfrac{PL}{AE}\right)$

Shortening of portion, CD = $\dfrac{(30 + 8.4375) \times 10^3 \times 150}{490.8739 \times 2 \times 10^5} = 0.05873 \, mm$ (Ans)

~~Shortening of portion~~
Extension of portion, DB = $\dfrac{(30 - 8.4375) 10^3 \times 375}{490.8739 \times 2 \times 10^5} = 0.08236 \, mm$ (Ans)