CHAPTER-8: MECHANICAL PROPERTIES OF SOLIDS (ELASTICITY)

Part–1: Stress • Strain • Hooke's Law

1. Elasticity

Definition

The property of a material by virtue of which it regains its original shape and size after the deforming force is removed.

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2. Plasticity

The property of a material to retain its deformed shape after removing the external force.

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3. Deforming Force

External force which changes the shape or size of a body.

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4. Stress (σ)

Stress is the restoring force acting per unit area.

$$\sigma = \frac{F}{A}$$

Where

- F = Restoring Force
- A = Cross-sectional Area

SI Unit

$$N/m^2 = Pascal(Pa)$$

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5. Types of Stress

(i) Longitudinal Stress

$$\sigma = \frac{F}{A}$$

(ii) Shearing Stress

Force acts parallel to the surface.

$$\tau = \frac{F}{A}$$

(iii) Hydraulic (Bulk) Stress

Pressure applied equally in all directions.

$$P = \frac{F}{A}$$

6. Strain

Strain is the ratio of change in dimension to original dimension.
It is **dimensionless**.

(i) Longitudinal Strain

$$\text{Longitudinal Strain} = \frac{\Delta L}{L}$$

(ii) Volumetric Strain

$$\frac{\Delta V}{V}$$

(iii) Shear Strain

$$\theta$$

(in radians)

7. Hooke's Law

Within elastic limit,

$$\text{Stress} \propto \text{Strain}$$

or

$$\sigma \propto \varepsilon$$

8. Elastic Limit

Maximum value of stress up to which Hooke's Law is obeyed.

9. Stress–Strain Curve

Important Points

- Proportional Limit
- Elastic Limit
- Yield Point
- Ultimate Strength
- Breaking Point

10. Factor of Safety

$$\text{Factor of Safety} = \frac{\text{Ultimate Stress}}{\text{Working Stress}}$$

Part–2: Elastic Moduli • Poisson's Ratio • Elastic Energy

11. Young's Modulus (Y)

Young's Modulus is the ratio of longitudinal stress to longitudinal strain.

$$Y = \frac{\text{Longitudinal Stress}}{\text{Longitudinal Strain}}$$

or

$$Y = \frac{FL}{A\Delta L}$$

SI Unit

$$Pa(N/m^2)$$

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12. Bulk Modulus (K)

Bulk Modulus is the ratio of bulk stress to volumetric strain.

$$K = \frac{\text{Bulk Stress}}{\text{Volume Strain}}$$

Or

$$K = -\frac{P}{\Delta V/V}$$

(The negative sign indicates decrease in volume.)

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13. Compressibility

Compressibility is the reciprocal of Bulk Modulus.

$$\beta = \frac{1}{K}$$

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14. Shear Modulus (Modulus of Rigidity)

$$G = \frac{\text{Shearing Stress}}{\text{Shearing Strain}}$$

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15. Poisson's Ratio

$$\mu = \frac{\text{Lateral Strain}}{\text{Longitudinal Strain}}$$

For most solids

$$0 < \mu < 0.5$$

16. Relation Between Young's Modulus and Shear Modulus

$$Y = 2G(1+\mu)$$

17. Relation Between Young's Modulus and Bulk Modulus

$$Y = 3K(1-2\mu)$$

18. Relation Among Three Elastic Constants

$$Y = \frac{9KG}{3K+G}$$

19. Elastic Potential Energy

Stored Elastic Energy

$$U = \frac{1}{2}F\Delta L$$

Also

$$U = \frac{1}{2}kx^2$$

20. Energy Density

Elastic Energy per Unit Volume

$$u = \frac{1}{2}(\text{Stress})(\text{Strain})$$

Exam Tips

- Young's Modulus → Stretching Problems
- Bulk Modulus → Liquids & Compression
- Shear Modulus → Shape Change
- **Elastic Constants all three relations Relations** are important every year
- **Stress: SI Unit = Pascal**
- **Strain: No SI Unit (Dimensionless)**
- Hooke's Law applicable only up to **Elastic Limit**