UNIT – I PROPERTIES OF MATTER

TOPIC – I INTRODUCTION – ELASTICITY

2.1 INTRODUCTION

Elasticity is the property by virtue of which a body offers resistance to any deforming force and regains its original condition when the deforming force is removed. All bodies can be deformed by the action of external forces. Bodies which can completely regain their original condition of shape and size on removal of deforming forces are said to be perfectly elastic. Bodies which retain their deformed nature even after the removal of the deforming forces are said to be perfectly plastic. If external forces fail to produce any deformation or relative displacements of the particles of the body, the body is said to be perfectly rigid. It is defined as the distance between any two points in a body is unaltered due to application of force.

2.2 STRESS AND STRAIN

Stress:

Stress is defined as the restoring force per unit area which brings back the body to its original state from the deformed state. As long as no permanent change is produced in the body, the restoring force is equal to the force applied. Unit of stress is N/m^2

Types of Stresses:

i. Normal Stress:

When the force is applied perpendicular to the surface of the body, then the stress applied is called as normal stress.

ii. Tangential stress:

When the force is applied along the surface of the body, then the stress applied is called as tangential stress. The tangential stress is called as Shearing stress.

Strain:

The change produced in the body due to change in dimension of a body under a system of forces of Equilibrium is called Strain. It has no unit.

$$\text{Strain} = \frac{Change.in.Dimension}{Original\ \ Dimension}$$

Types of Strain

i. Longitudinal (or) Tensile Strain:

It is defined as the ratio between the changes in length to the original length, without any change in its shape, after the removal of the external forces.

ii. Shearing strain:

It is defined as the angular deformation produced on the body due to the application of external tangential forces on it.

iii. Volumetric strain:

It is defined as the ratio between the changes in volume to the original volume, without any change in its shape.

2.3 HOOKE'S LAW

Robert Hooke proposed a relation between stress and strain and is named as Hooke's law by his name. According to this law, Stress is directly proportional to the strain produced, within the elastic limit.

i.e., Stress ∞ Strain

Stress = E X Strain

$$E = \frac{\text{Stress}}{\text{Strain}} \text{ Nm}^{-2}$$

Where, E is called as modulus of Elasticity and the value of E depends upon the nature of the material.

2.4 CLASSIFICATION OF ELASTIC MODULUS

Depending on the three types of strain, there are three types of modulus they are,

i. Young's modulus(Y) (or) modulus corresponding to longitudinal (or) tensile strength
ii. Bulk modulus(K) (or) modulus corresponding to the volume strain
iii. Rigidity modulus(n) (or) modulus corresponding to the shearing strain

i. Young's modulus (Y)

It is defined as the ratio between the longitudinal stress to longitudinal strain, within the elastic limits.

$$\text{Young's modulus} = \frac{\text{Longitudinal stress}}{\text{Longitudinal strain}} \text{ -------------------- (1)}$$

Explanation:

Let us consider a wire of length L with an area of cross section A. Let one end of the wire is fixed and the other end is loaded (or) stretched as shown in Fig 2.2.

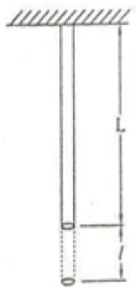

Fig 2.2

Let l be change in length due to the action of force, then

$$\text{The longitudinal stress} = \frac{\text{Longitudinal force}}{\text{Area}} = \frac{F}{A}$$

and The longitudinal strain $= \frac{\text{Change in length}}{\text{Original length}} = \frac{l}{L}$

$$\text{Young's modulus, Y} = \frac{F/A}{l/L}$$

$$\text{Young's modulus,Y} = \frac{\text{FL}}{\text{Al}}\ \text{Nm}^{-2}\ \text{(or) pascals}$$

ii. Bulk modulus (K)

It is defined as the ratio between the volume stress (or) bulk stress to the volume strain (or) bulk strain within the elastic limit.

$$\text{Bulk's modulus} = \frac{\text{Volume stress}}{\text{Volume strain}} \text{ ----------------- (1)}$$

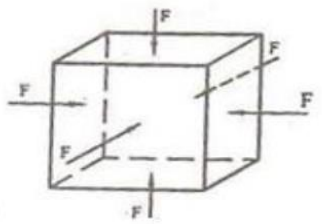

Fig 2.3

Explanation:

Let us consider a body of volume V with an area of cross section A. Let three equal forces act on the body in mutually perpendicular directions as shown in Fig 2.3. Let v be the change in volume due to the action of forces, then,

$$\text{The volume stress (or) bulk stress} = \frac{\text{Normal force}}{\text{Area}} = \frac{F}{A}$$

$$\text{The volume strain (or) bulk strain} = \frac{\text{Change in volume}}{\text{Original volume}} = \frac{v}{V}$$

$$\text{Bulk modulus (K)} = \frac{F/A}{v/V}$$

$$\text{Bulk's modulus, K} = \frac{Fv}{Va} = \frac{\text{pv}}{\text{V}}\text{NM}^{-2}\ \text{(or) pascal}$$

Where P is the pressure = F/A

The reciprocal of bulk modulus of a material is known as compressibility of that material.

iii. Rigidity modulus (G)

It is defined as the ratio between the tangential stress to the shearing strain, within the elastic limit.

$$\text{Rigidity's modulus} = \frac{\text{Tangential stress}}{\text{Tangential strain}} \text{ ---------------- (1)}$$

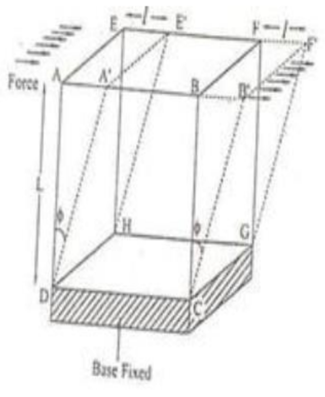

Fig 2.4

Explanation:

Let us consider a solid cube ABCDEFGH as in Fig 2.4. Whose lower face CDHG is fixed. A tangential force 'F' is applied over the upper face ABEF. The result is that the cube gets deformed into a rhombus shape A'B'CDE'F'GH. The lines joining the two faces are shifted to an angle φ. If 'L' is the original length and 'l' is the relative displacement of the upper face of the cube with respect to the lower fixed face, then Tangential stress = $\frac{F}{A}$. The shearing strain (φ) can be defined as the ratio of the relative displacement between the two layers in the direction of the stress, to the distance measured perpendicular to the layers,

Rigidity modulus, G = $\frac{F/A}{l/L}$

Rigidity modulus = $\frac{FL}{Al}$ Nm^{-2} (or) pascal