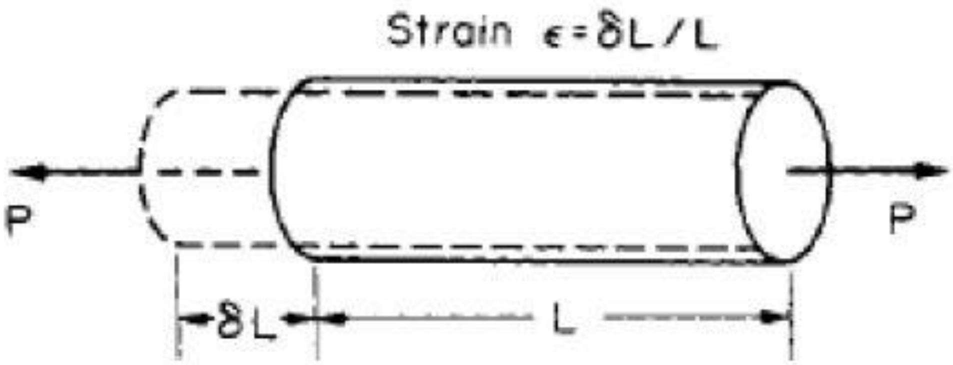
LECTURE NO. 2

STRAINS

If a bar is subjected to a direct load, the bar will change in length. If the bar has a length L and changes in length by ΔL, the strain produced is defined as:

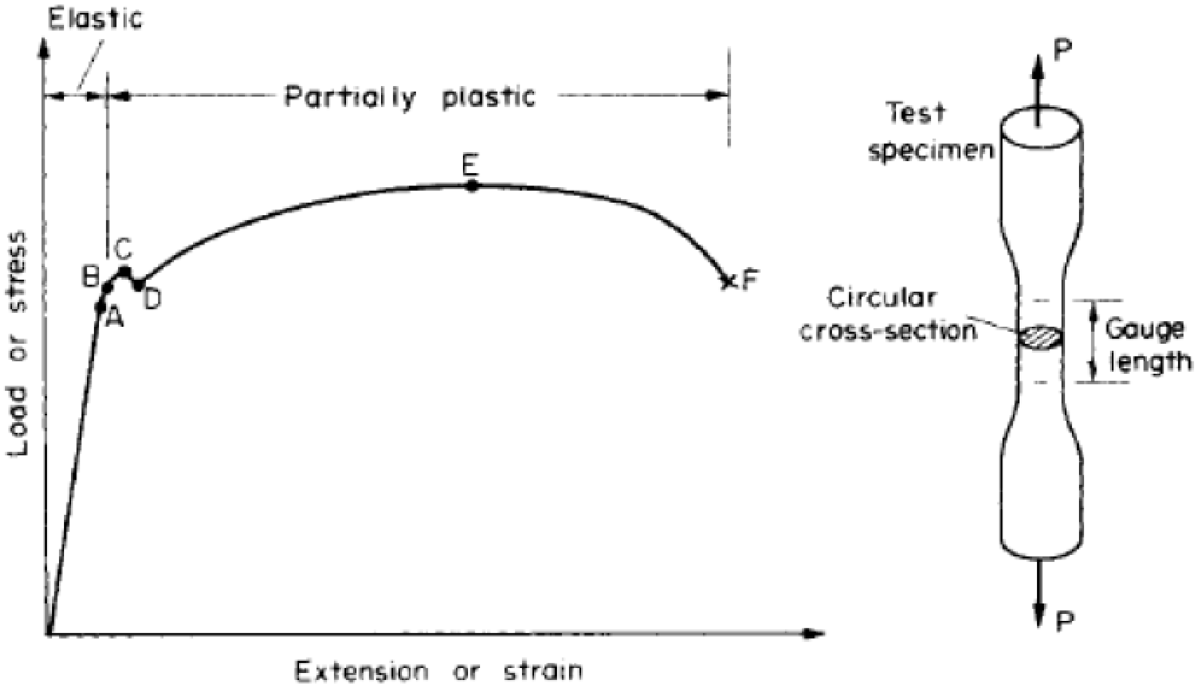
$$strain = \frac{\text{change in length}}{\text{orginal length}}$$

$$\varepsilon = \frac{\Delta L}{L}$$



Stress – Strain Diagram

The strength of material is not the only criterion that must be considered in designing structures the stiffness of material is frequently of equal importance.



If a specimen of structural steel is gripped between the jaws of testing machine and the unit load or stress was plotted against unit elongation (or strain). The resulted diagram shown is called a stress-strain diagram

Notes:

1. The material behaves elastically till *elastic limit B*.

2. Point *A* is called *proportionality limit* where stress is proportional to strain.

3. The material beyond elastic limit is *plastically deformed*.

4. *C* is called *upper yield point*, and *D* is the *lower yield point*.

5. *E* is where the *ultimate stress* occur, in this point necking occur.

6. *F* is the *fracture point*.

Hooke's Law

A material is said to be elastic if it returns to its original, unloaded dimension, when load is removed. In most engineering materials this elastic behavior is linear, i.e. the stress is directly proportional with strain, **Hooke's law** states that:

$$\text{Stress } (\sigma) \propto \text{Strain } (\varepsilon)$$

$$\frac{stress}{strain} = constant$$

$$\sigma = E * \varepsilon$$

Where E is called the modulus of elasticity or Young's modulus.

Note:

In most common engineering applications strain is rarely exceeded 0.001 or 0.1%.

$$\sigma = E\varepsilon, \quad \text{since } \sigma = \frac{F}{A} \quad \text{and} \quad \varepsilon = \frac{\delta}{L}$$

$$\frac{F}{A} = E\frac{\delta}{L}$$

$$\delta = \frac{FL}{AE}$$

Poisson's Ratio

When a specimen subjected to axial tensile loading a *reduction or lateral contraction induces* to the specimen's cross-sectional area. Similarly, a contraction owing to an axial compressive load is accompanied by a lateral extension. In the linearly elastic region, it is found experimentally that lateral strains, say in the *y* and *z* directions, are related by a constant of proportionality ν , to the axial strain caused by *uniaxial stress only* $\varepsilon_x = \sigma_y / E$, in the *x* direction:

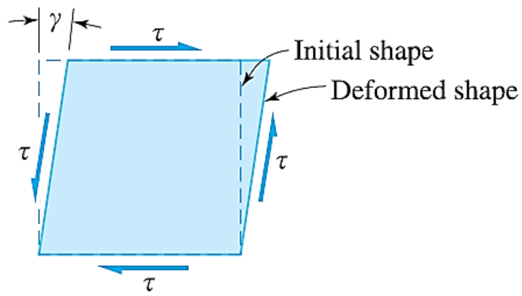
Alternatively, the definition of *v* may be stated as:

$$\nu = -\frac{lateral\ strain}{axial\ strain}$$

Here ν is known as Poisson's ratio, after S. D. Poisson (1781-1840). The values of Poisson's ratio are 0.25 to 0.35 for most metals. Extreme cases range from a low of 0.1 (for some concretes) to a high of 0.5 (for rubber).

Hooke's Law in Shear

Shear stress causes the deformation shown in the figure. The lengths of the sides of the element do not change, but the element undergoes a distortion from a rectangle to a parallelogram. The shear strain, which measures the amount of distortion, is the angle γ (lowercase Greek gamma), always expressed in radians. It can be shown that the relationship between shear stress τ and shear strain γ is linear within the elastic range; that is,



$$\tau = G\,\gamma$$

Which is Hooke's law for shear. The material constant G is called the shear modulus of elasticity (or simply shear modulus), or the modulus of rigidity. The shear modulus has the same units as the modulus of elasticity (Pa).

Example 1

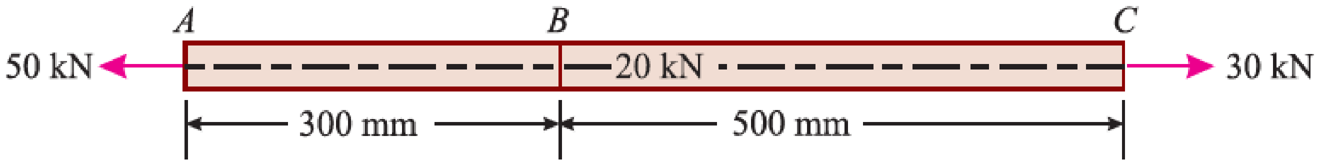
A steel rod 1m long and 20 mm *****20 mm in cross-section is subjected to a tensile force of 40 kN. Determine the elongation of the rod, if modulus of elasticity for the rod material is 200 GPa.

Example 2

A hollow cylinder 2 m long has an outside diameter of 50 mm and inside diameter of 30 mm. If the cylinder is carrying a load of 25 kN, find the stress in the cylinder Also find the deformation of the cylinder, if the value of modulus of elasticity for the cylinder material is 100 GPa,

Example 3

A steel bar of cross-sectional area 200 mm^2 is loaded as shown in Fig. Find the change in length of the bar. Take E as 200 GPa.



Example 4

A member formed by connecting a steel bar to an aluminum bar is shown in Fig. Calculate the magnitude of force P, that will cause the total length of the member to decrease by 0.25 mm. The values of elastic modulus for steel and aluminum are 210 GPa and 70 GPa respectively.