

ELASTICITY, PLASTICITY and HOOKE'S LAW

If a load is removed from a material and it returns to its former shape, it is said to be elastic but if it remains deformed, it is said to be plastic.

Many engineering materials are elastic up to a certain stress, termed the elastic limit, after which they are partly elastic and partly plastic.

Elastic materials obey Hooke's law, which states that the deformation of a material is directly proportional to the load, i.e. the **ratio stress/strain is a constant**.

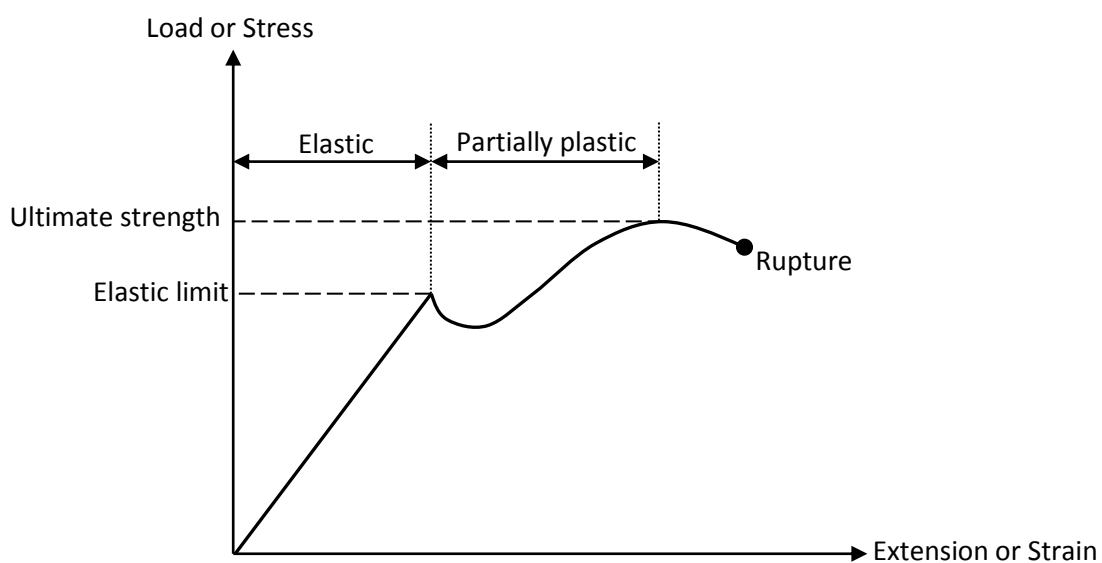


Fig. Typical stress-strain curve for a material such as mild-steel.

I. Young's Modulus

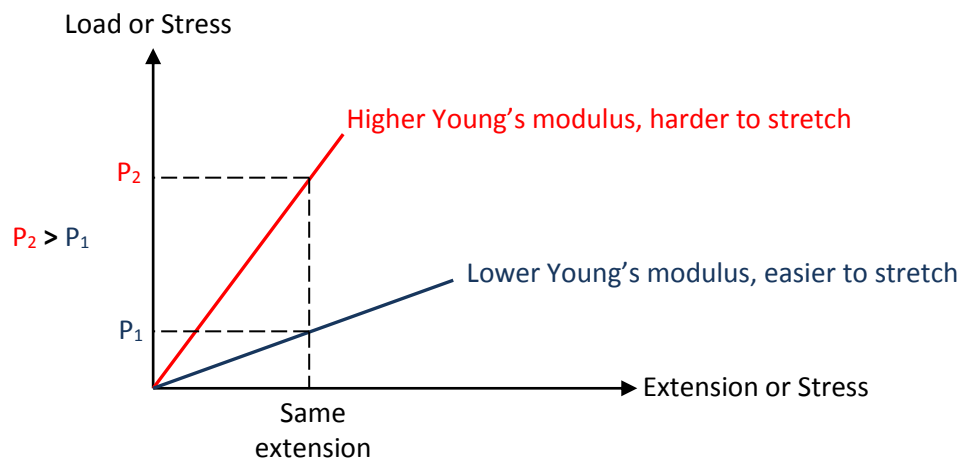
For direct stress, the constant of proportionality is called the **Young's Modulus** or **Modulus of Elasticity E**.

$$E = \frac{\text{direct stress}}{\text{direct strain}} = \frac{\sigma}{\epsilon}$$

$\text{N/m}^2 \equiv \text{Pa}$

The greater the value of E the greater the stress required for a particular strain, i.e. the greater the force for a particular extension. Thus a material with a high Young's modulus is

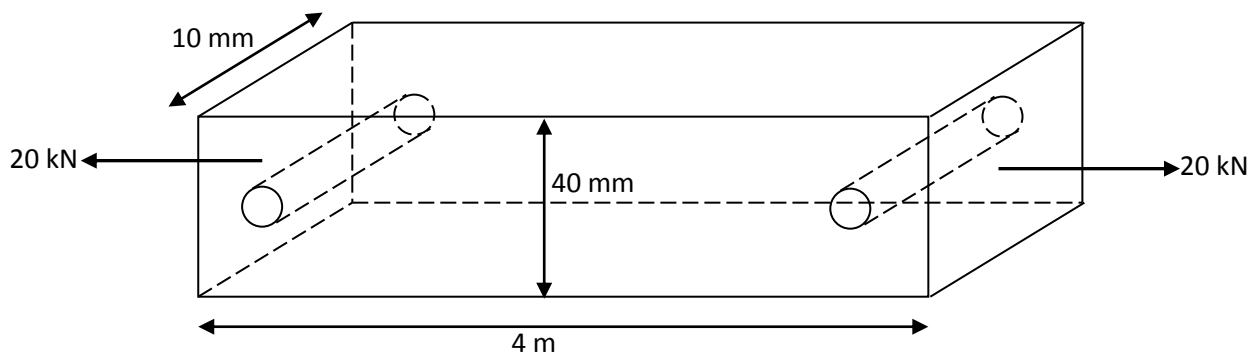
more difficult to extend than a material with a lower modulus of elasticity as shown in the following figure:



Young's modulus or modulus of Elasticity can be considered as a measure of the stiffness of a material, the higher the modulus the stiffer the material.

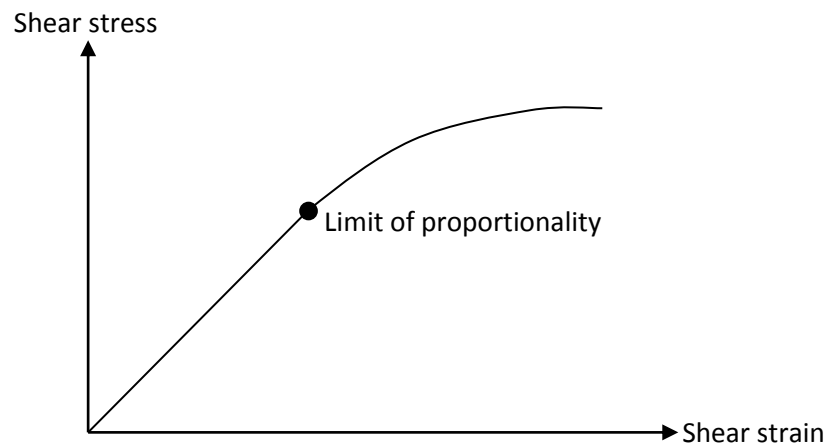
Example 1: Calculate the strain that will be produced by a tensile stress of 10 N/mm^2 extending a bar of aluminium alloy with a Young's modulus of 70 kN/mm^2 .

Example 2: A tie bar has 2 holes, a distance of 4 m apart. By how much does this distance increase when a tensile load of 20 kN is applied to the tie bar? The tie bar has a rectangular section of $40 \text{ mm} \times 10 \text{ mm}$ and the material of which the tie bar is made has a modulus of Elasticity of 210 kN/mm^2 .



II. Modulus of Rigidity

There are many materials for which the direct strain is proportional to the direct stress within some limiting stress. As seen previously such material are said to obey Hooke's law. Such elastic materials also have a shear strain proportional to the shear stress within some limiting shear stress as shown as follows:



For shear stress, the constant of proportionality is known as the **Modulus of Rigidity** or **Shear Modulus G**.

$$G = \frac{\text{shear stress}}{\text{shear strain}} = \frac{\tau}{\gamma}$$

$\text{N/m}^2 \equiv \text{Pa}$

The modulus of rigidity is a measure of rigidity or ease of twisting of a material, the greater the modulus of rigidity the more difficult it is to twist the material.