Lecture Three
Materials and examination tools

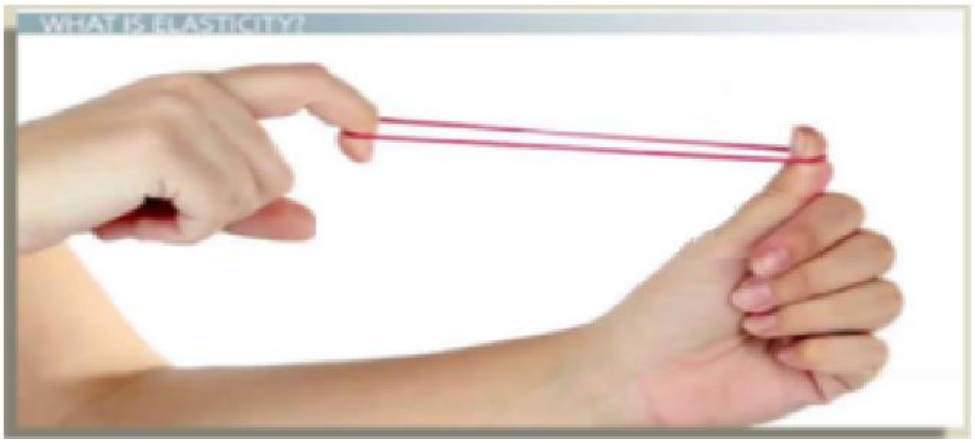
Mechanical Properties of Building Materials

Mechanical properties of the materials are find out by applying external forces on them. These are very important properties which are responsible for behavior of a material in its job. The mechanical properties are,

- Strength
- Hardness
- Elasticity
- Plasticity
- Brittleness
- Fatigue
- Impact strength
- Abrasion resistance
- Creep

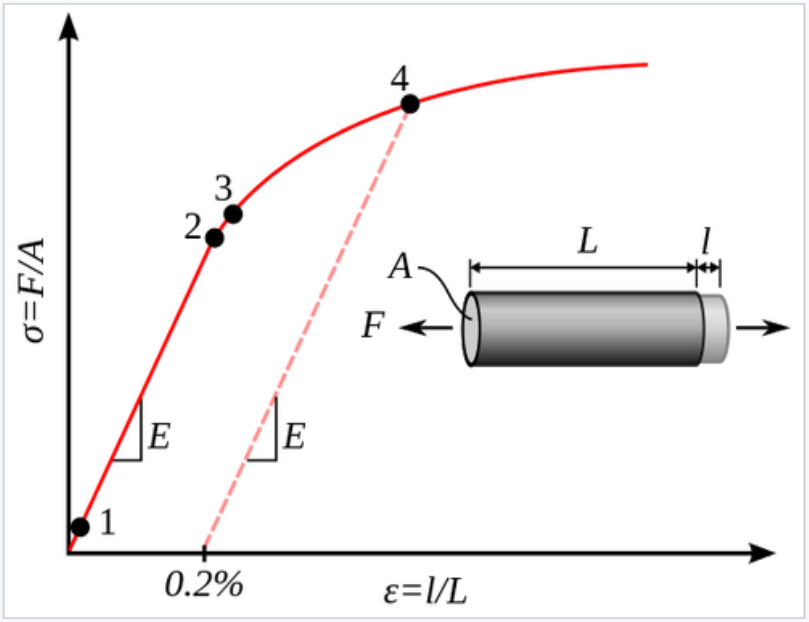
1. Elasticity of Building Materials المرونة

Elasticity it's The capacity of a material to regain its initial shape and size after removal of load is known as elasticity and the material is called as elastic material. Ideally elastic materials obey Hooke's law in which stress is directly proportional to strain. Which gives modulus of elasticity as the ratio of unit stress to unit deformation. Higher the value of modulus of elasticity lower the deformations.



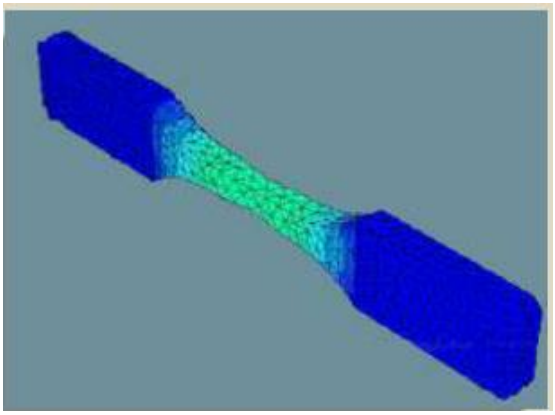
2. Plasticity:المطاوعةالبلاستيكية

When the load is applied on the material, if it will undergo permanent deformation without cracking and retain this shape after the removal of load then it is said to be plastic material and this property is called as plasticity. They give resistance against bending, impact etc. Examples: steel, hot bitumen etc.



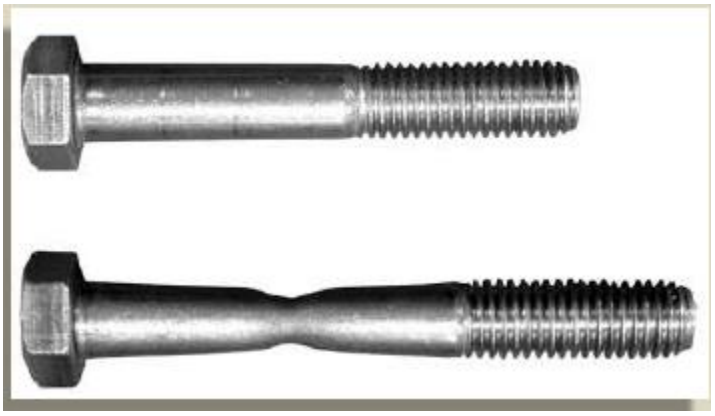
Stress–strain curve showing typical yield behavior for nonferrous alloys. (Stress, σ, shown as a function of strain, ϵ.)

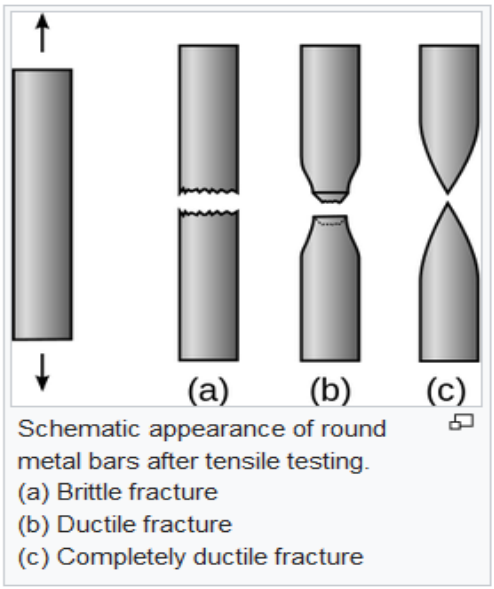
1. True elastic limit
2. Proportionality limit
3. Elastic limit
4. Offset yield strength



3. Ductility:(المطيلية (السحبية

Ductility is a measure of a material's ability to undergo significant plastic deformation before rupture or breaking, which may be expressed as percent elongation or percent area reduction from a tensile test.





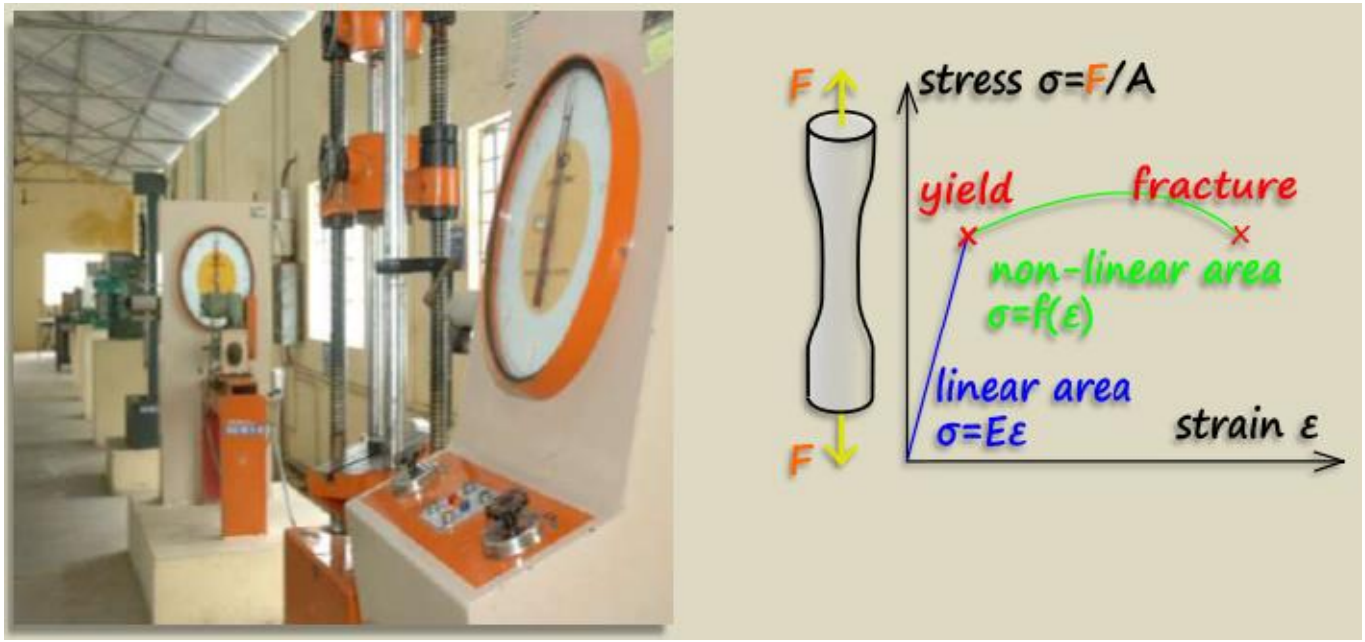
Schematic appearance of round metal bars after tensile testing.
(a) Brittle fracture
(b) Ductile fracture
(c) Completely ductile fracture

4. Malleability:(المطروقية (قابلية السحب

Malleability is a substance's ability to deform under pressure (compressive stress). If malleable, a material may be flattened into thin sheets by hammering or rolling. Malleable materials can be flattened into metal leaf. One well-known type of metal leaf is gold leaf. Many metals with high malleability also have high ductility. Some do not; for example lead has low ductility but high malleability.

5. Strength of Building Materials:المقاومة

The capacity of a material to resist failure caused by loads acting on it is called as strength. The load may be compressive, tensile or bending. It is determined by dividing the ultimate load taken by the material with its cross sectional area. Strength is an important property for any construction materials. So, to provide maximum safety in strength, factor of safety is provided for materials and it is selected depending on nature of work, quality of material, economic conditions etc.



Uniaxial stress is expressed by

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

where F is the force [N] acting on an area A [mm^2]. The area can be the undeformed area or the deformed area, depending on whether engineering stress or true stress is of interest. Where (N/mm^2=Mpa).

6. Strain of Building Materials:التشوه (ألأنفعال)

The **engineering strain (Deformation)** is expressed as the ratio of total deformation to the initial dimension of the material body in which the forces are being applied. The engineering normal strain or engineering extensional strain or nominal strain e of a material line element or fiber axially loaded is expressed as the change in length ΔL per unit of the original length L of the line element or fibers. The normal strain is positive if the material fibers are stretched and negative if they are compressed. Thus, we have:

$$\varepsilon = (L_2 - L_1)/L_1$$

$$\varepsilon = \Delta L / L_1$$

where ε is the *engineering normal strain*, L_1 is the original length of the fiber and L_2 is the final length of the fiber. Measures of strain are often expressed in parts per million or microstrains.

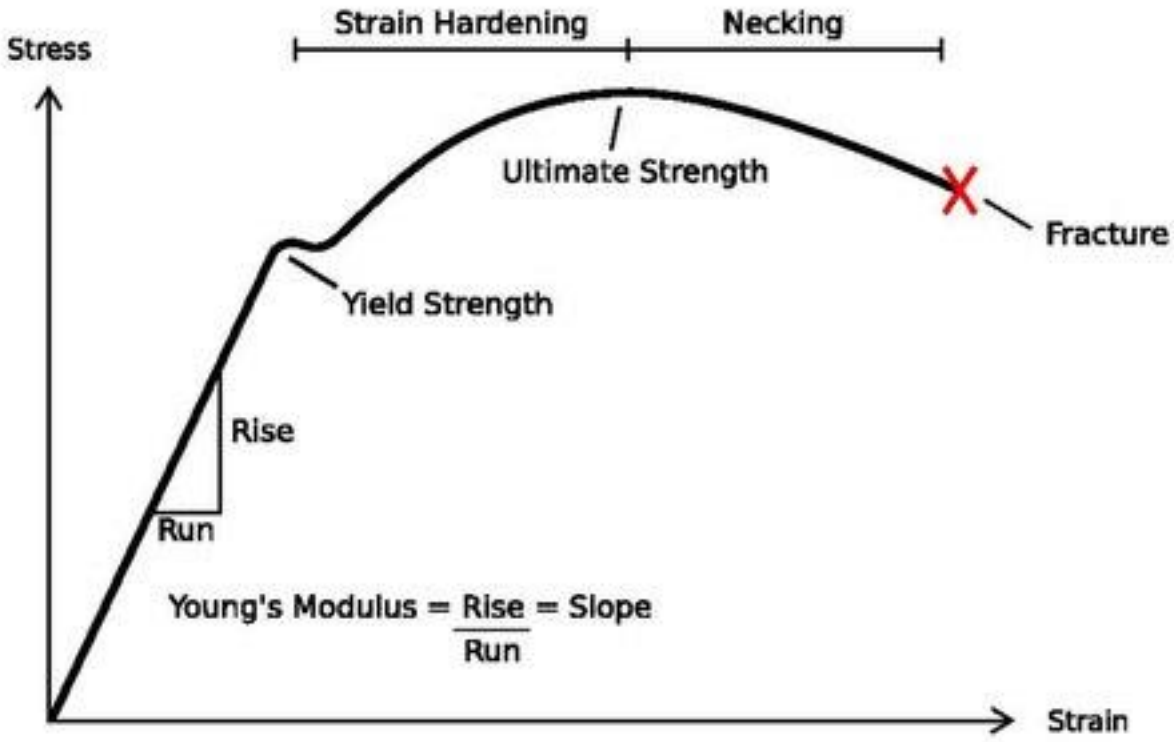
7. Modulus of Elasticity :معامل المرونة

An elastic modulus (also known as modulus of elasticity) is a quantity that measures an object or substance's resistance to being deformed elastically (i.e., non-permanently) when a stress is applied to it. The elastic modulus of an object is defined as the slope of its stress–strain curve in the elastic deformation region:[1] A stiffer material will have a higher elastic modulus. An elastic modulus has the form:

where stress is the force causing the deformation divided by the area to which the force is applied and strain is the ratio of the

change in some parameter caused by the deformation to the original value of the parameter. If stress (σ) is measured in Mega pascals(Mpa), then since strain(ε) is a dimensionless quantity, the units of modulus of elasticity (E) will be in Mega pascals to.

$$E = \frac{\sigma}{\varepsilon}$$

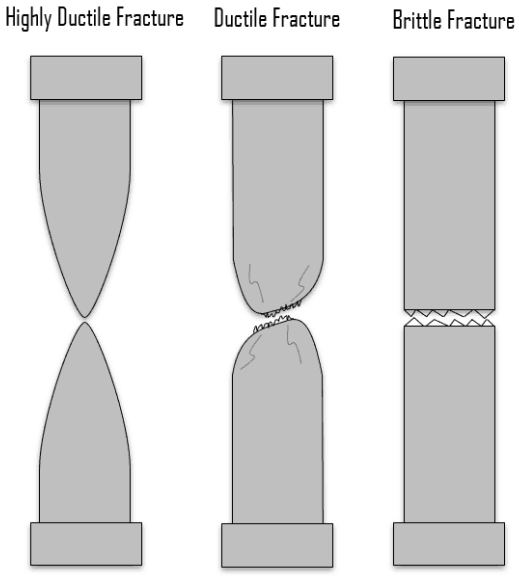


8. Brittleness :القصافة

A material is brittle if, when subjected to stress, it breaks with little elastic deformation and without significant plastic deformation.

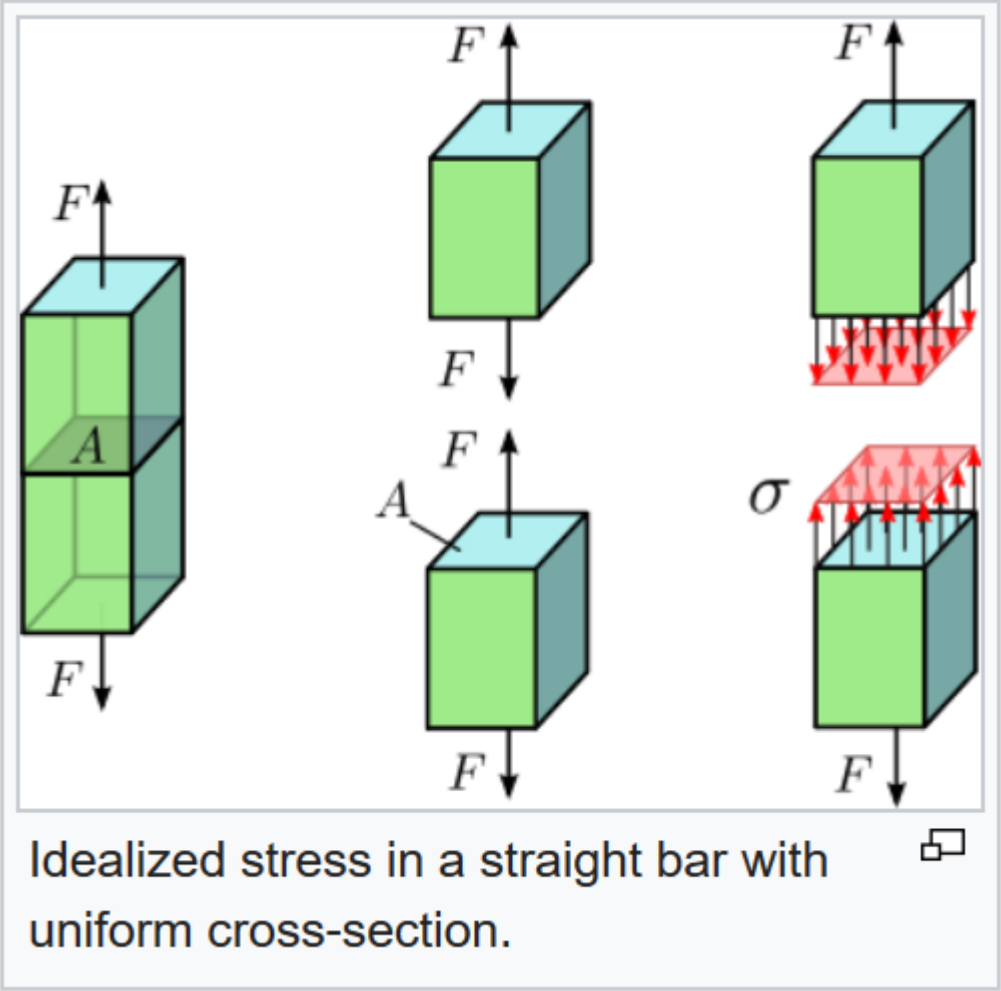
When the material is subjected to load, if it fails suddenly without causing any deformation then it is called brittle material and this property is called as brittleness.

Examples: concrete, cast-iron etc.



9. Tensile Stress :مقاومة الشد

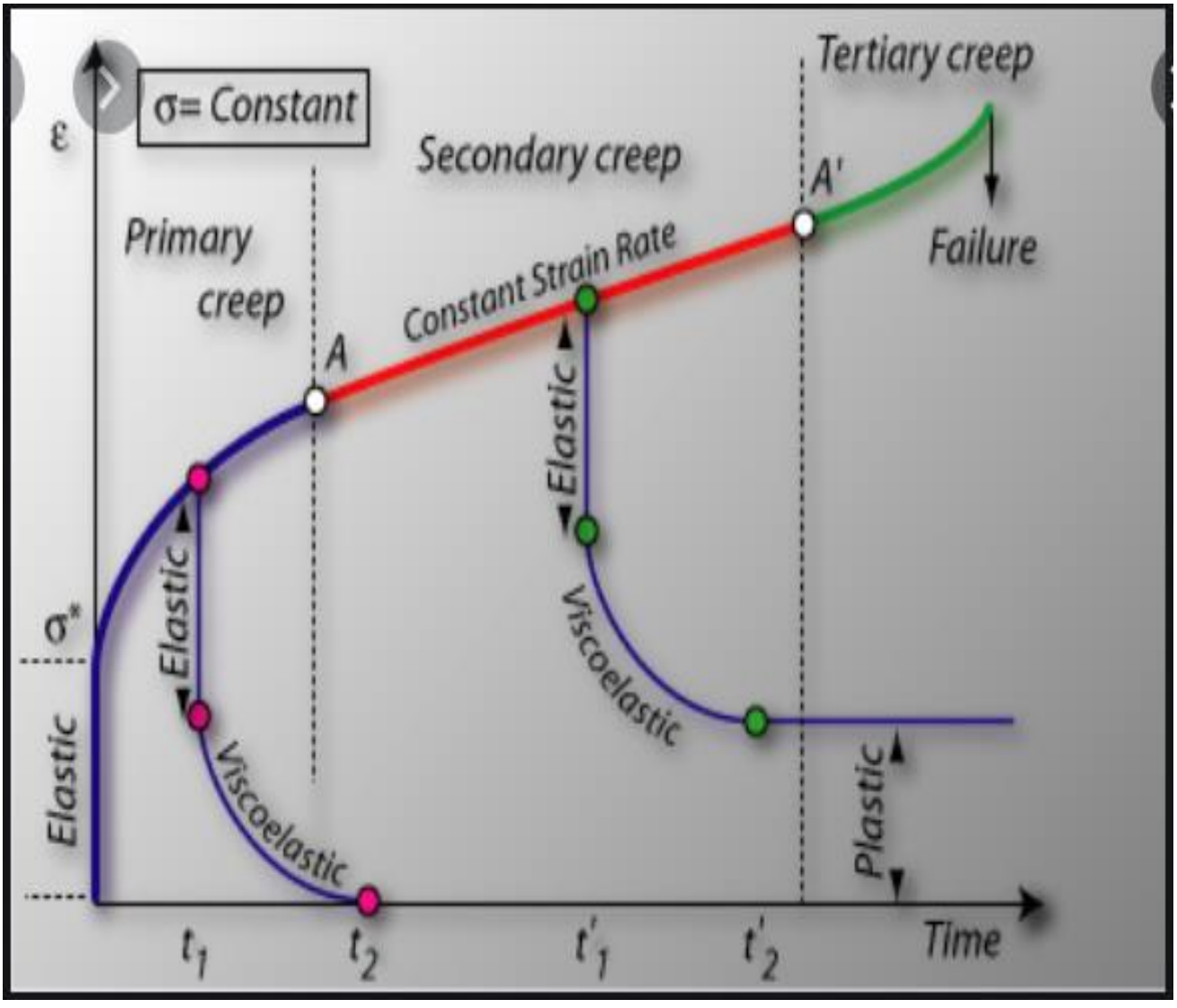
A common situation with a simple stress pattern is when a straight rod, with uniform material and cross section, is subjected to tension by opposite forces of magnitude (F) along its axis. If the system is in equilibrium and not changing with time, and the weight of the bar can be neglected, then through each transversal section of the bar the top part must pull on the bottom part with the same force(F) with continuity through the full cross-sectional area(A) . Therefore, the stress (σ) throughout the bar, across any horizontal surface, can be expressed simply by the single number (σ), calculated simply with the magnitude of those forces, F, and cross sectional area(A).



Idealized stress in a straight bar with uniform cross-section.

10. Creep:الزحف

Creep the deformation caused by constant loads for long periods. It is time dependent and occurs at very slow rate. It is almost negligible in normal conditions. But at high temperature conditions creep occur rapidly. Creep is the property of material which indicates the tendency of material to move slowly and deform permanently under the influence of external mechanical stress. It results due to long time exposure to large external mechanical stress with in limit of yielding. Creep is more severe in material that are subjected to heat for long time.



11. Stiffness:الصلابة (الكزازة)

Stiffness is the extent to which an object resists deformation in response to an applied force. The elastic modulus of a material is not the same as the stiffness of a component made from that material. Elastic modulus is a property of the constituent material; stiffness is a property of a structure or component of a structure, and hence it is dependent upon various physical dimensions that describe that component. That is, the modulus is an intensive property of the material; stiffness, on the other hand, is an extensive property of the solid body that is dependent on the material and its shape and boundary conditions. For example, for an element in tension or compression, the axial stiffness is

$$k = E \cdot \frac{A}{L}$$

where

E : is the (tensile) elastic modulus (or Young's modulus),

A : is the cross-sectional area,

L : is the length of the element.

Similarly, the torsional stiffness of a straight section is

$$k = G \cdot \frac{J}{L}$$

where

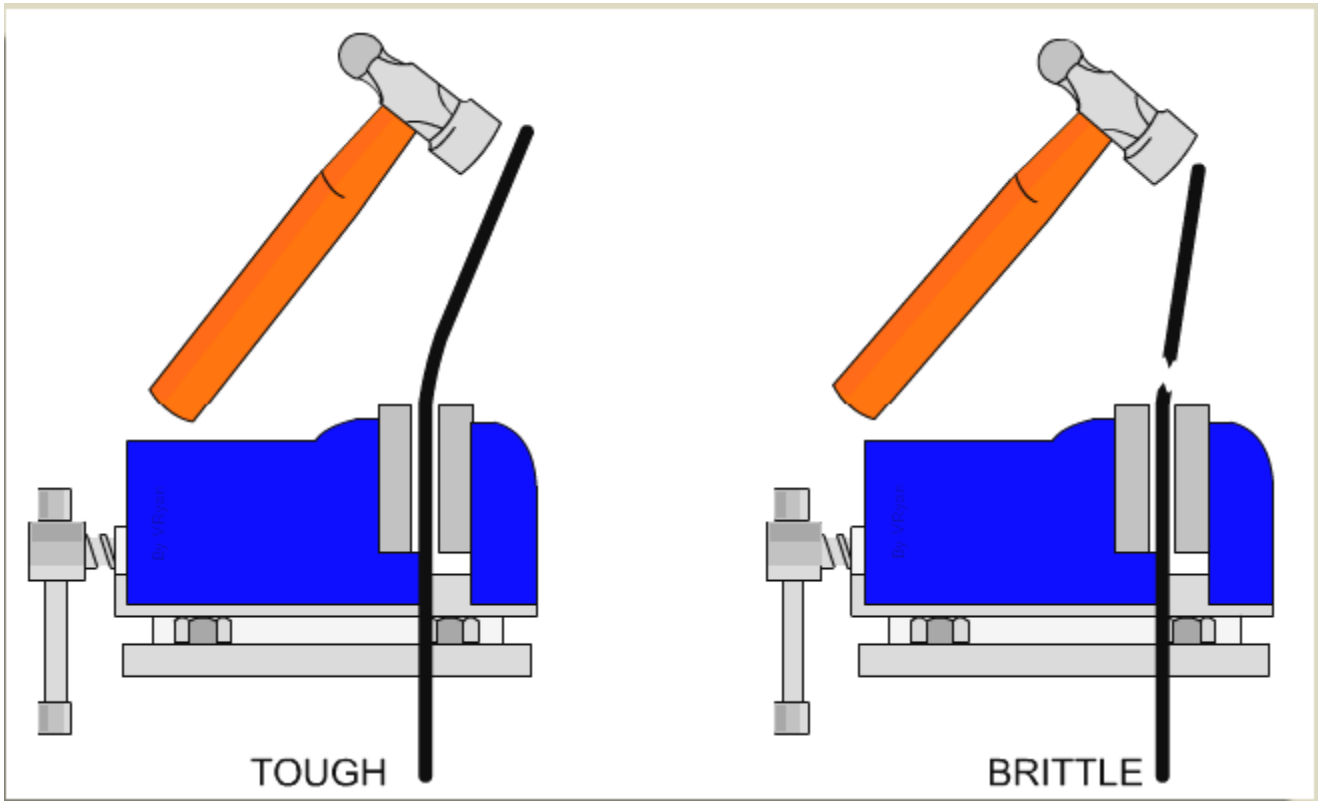
G: is the rigidity modulus of the material,

J : is the torsion constant for the section.

12. Toughness :القساوة

* It is the ability of material to absorb the energy and gets plastically deformed without fracturing. Its numerical value is determined by the amount of energy per unit volume. It unit is Joule/ m^3. Value of toughness of a material can be determines by stress strain characteristics of material.

• For good toughness material should have good strength as well as ductility. For example: brittle materials, having good strength but limited ductility are not tough enough. Conversely, materials having good ductility but low strength are also not tough enough. Therefore, to be tough, material should be capable to withstand with both high stress and strain.

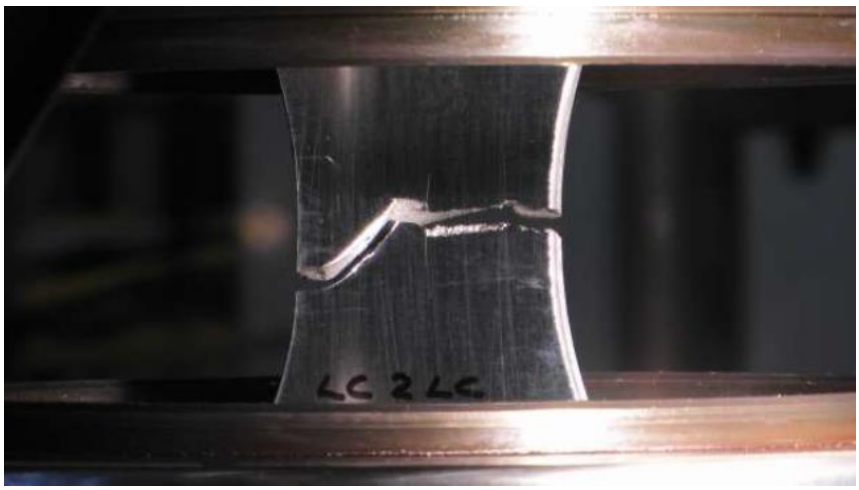


13. Fatigue :الكلل

* In materials science, fatigue is the weakening of a material caused by cyclic loading that results in progressive and localised structural damage and the growth of cracks. Once a fatigue crack has initiated, each loading cycle will grow the crack a small amount, typically producing striations on some parts of the fracture surface. The crack will continue to grow until it reaches a critical size, which occurs when the stress intensity factor of the crack exceeds the fracture toughness of the material, producing rapid propagation and typically complete fracture of the structure.

* **Fatigue is the weakening of material caused by the repeated loading of material. When a material is subjected to cyclic loading, and loading greater than certain threshold value but much below the strength of material** (ultimate tensile strength limit or yield stress limit, microscopic cracks begin to form at grain boundaries and interfaces. Eventually the crack reached to a critical size.

* **This crack propagates suddenly and the structure gets fractured. The shape of structure effects the fatigue very much. Square holes and sharp corners lead to elevated stresses where the fatigue crack initiates.**

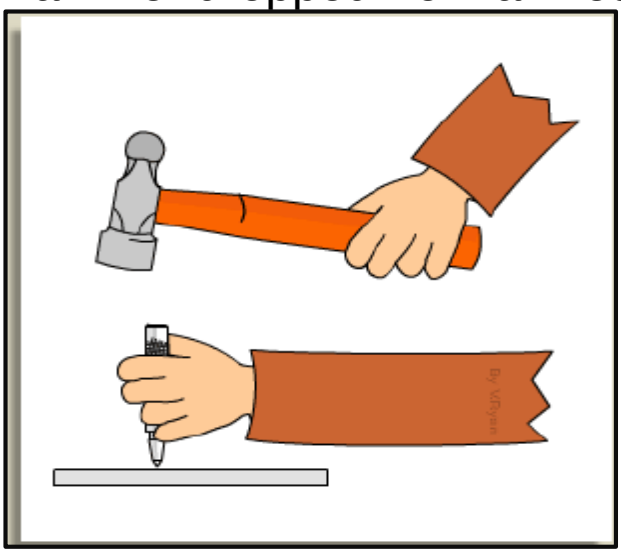


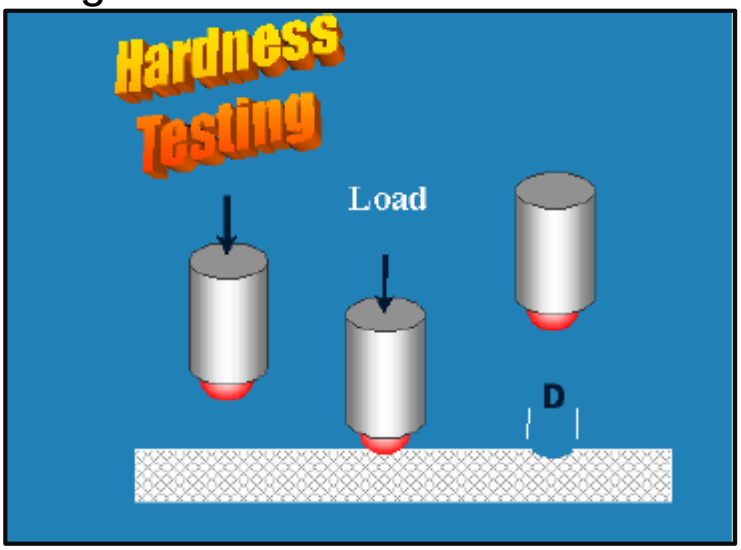
14. Hardness of Building Materials :الصلادة

* The property of a materials to resist scratching by a herder body. MOHS scale is used to determine the hardness of a materials. Hardness is most important to decide the usage of particular aggregate. It also influences the workability. It is ability of material to oppose the dent due to punch of external had and sharp object.

* **Rebound Hardness**

Rebound hardness is also called as dynamic hardness. It is determined by the height of “bounce” of a diamond tipped hammer dropped from a fixed height on the material





15. Impact Strength:مقاومة الصدم

If a material is subjected to sudden loads and it will undergo some deformation without causing rupture is known as its impact strength. It designates the toughness of material. The **impact strength** of a material is defined as its capability to resist a sudden applied load or force. It is normally conveyed as the amount of mechanical energy absorbed in the process of deformation under the applied **impact** loading and is expressed as energy lost per unit of thickness ft.lb/in or J.cm.

16. Abrasion Resistance:مقاومة التآكل

The loss of material due to rubbing of particles while working is called abrasion. The abrasion resistance for a material makes it durable and provided long life. **Abrasion resistance** refers to the ability of an adhesive to resist wearing due to contact with another surface. Wearing occurs when a hard rough surface slides across a softer surface, usually the adhesive material, causing the undesired removal of material from the surface.

QUSTIONS OF LECTURE THREE

1-Steel bar have radius (7mm) and initial length (1400mm) and modulus of elasticity for steel (220,000 N/mm2) find:

1-Elongation of steel bar if applied force was (4500 N)?

2- If the Elongation of steel bar was(1.2mm) find the applied force?

2- Define the following (Abrasion resistance, Impact Strength, Hardness, Fatigue, Toughness, Stiffness, Creep, Tensile Stress, Brittleness, Modulus of Elasticity, Strain, Strength, Malleability, Ductility, Plasticity, Elasticity).

3- Steel bar have diameter (16mm) and initial length (1300mm) and modulus of elasticity for steel (200,000 N/mm^2), Applied force caused elongation (2.64mm). What is the elongation if the same force applied to another bar have diameter (16mm) and initial length (1500mm) and modulus of elasticity (150,000 N/mm^2)?

4- If the standard of dimensions of clay Bricks are (24x11.5x7.5) cm what's the type of clay Bricks for the following:

1-The dimensions of sample of clay Bricks (23x11x7.5) cm

2- The Percent of Efflorescence Area of clay Bricks is (120) cm^2.

3-Force applied to clay Brick is (498) KN.

(Show the Specifications limits and where to use in buildings)