Bule Hora University
BHU

BSc Program in Construction Technology and Management

Construction Materials I

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1.Introduction

Materials and types

- **Material**: a substance or thing from which some thing else can be made. Examples: Cement,brick,aluminium,soil,water…

- In Engineering, materials are employed to design and build structures or elements.

- Material science examines why’s and how's of materials, making it Possible to advance the development of new materials.

- Material Engineering refers to the understanding and review of properties and uses of materials commonly used in engineering

Amorphous Materials:

- ✓Materials in which atoms are arranged randomly.
- ✓or those that do not have crystalline structure.
- ✓Are strong but brittle

Examples: soot(impure carbon),glass

- ✓Crystalline materials can be converted in to an amorphous material by quenching.
- ✓i.e. heating the material to its melting temperature followed by rapid cooling so that the material has no time to return to its crystalline arrangement

- **Brittle Materials**: Brittleness denotes relatively little or no elongation or increase in length at fracture.
  Examples: cast iron
  concrete
  Glass…

Building Materials: Materials that are used in the building industry such as cement, steel ,brick,plastics,wood,glass

Cementitious materials: Materials in which the principal binder is Portland cement or another type of hydraulic cements .

Ceramic Materials:

…The word ceramic comes from Greek, meaning "burned earth".

…ceramic materials are nonmetallic materials based on clay(silicate mineral)

…They are usually crystalline and brittle ,do not conduct electricity very well ,and can withstand high temperatures.

- Construction Materials: any material used in construction industry.
  Examples:
  cement ,soil,aggregates,asphalt,etc

- **Ductile Materials:**

- Ductility is the property that makes the material to be drawn out or stretched to a considerable extent before rupture.
- It is usually measured as the percentage of elongation (increase in length) or as the percentage of the reduction in the cross-sectional area ,when the material is subjected to tension.
- *Examples* :steel ,aluminum etc

Elastic Materials:

- Elasticity is the ability of a material to deform under load without a permanent set or deformation up on release of the load.
- It can also be defined as that property of material by virtue of which deformations from the a load or stress disappear after removal of the load.
- A perfectly elastic material recover completely its original shape and dimensions when loads are removed.
- None of the materials remain perfectly elastic throughout the range of stress leading up to failure.
- But all exhibit elastic properties up to some stress level.
- An elastic material behaves in elastically when the stresses exceeds the elastic limit, beyond which changes in volume ,shape are permanent.

- Crystalline materials: Materials in which atoms are arranged in a discernible repeated pattern in three dimensions.
- Thermoplastic Materials: Materials that turn plastic (soft)when subjected to heat. e.g. petroleum pitch

2. Classification & Properties of Materials

2.1 Classification of Materials

- Materials that are used for construction purpose can be broadly classified based on their:
  - Metallic Property
  - Physical nature
  - Mode of production

Classification Based on Metallic Property

1.Metallic : in general metals can be classified in to :**Ferrous** and **Non-ferrous.**

a. Ferrous: is the metal in which the principal element is iron.

Examples:steel,wrought iron & cast iron

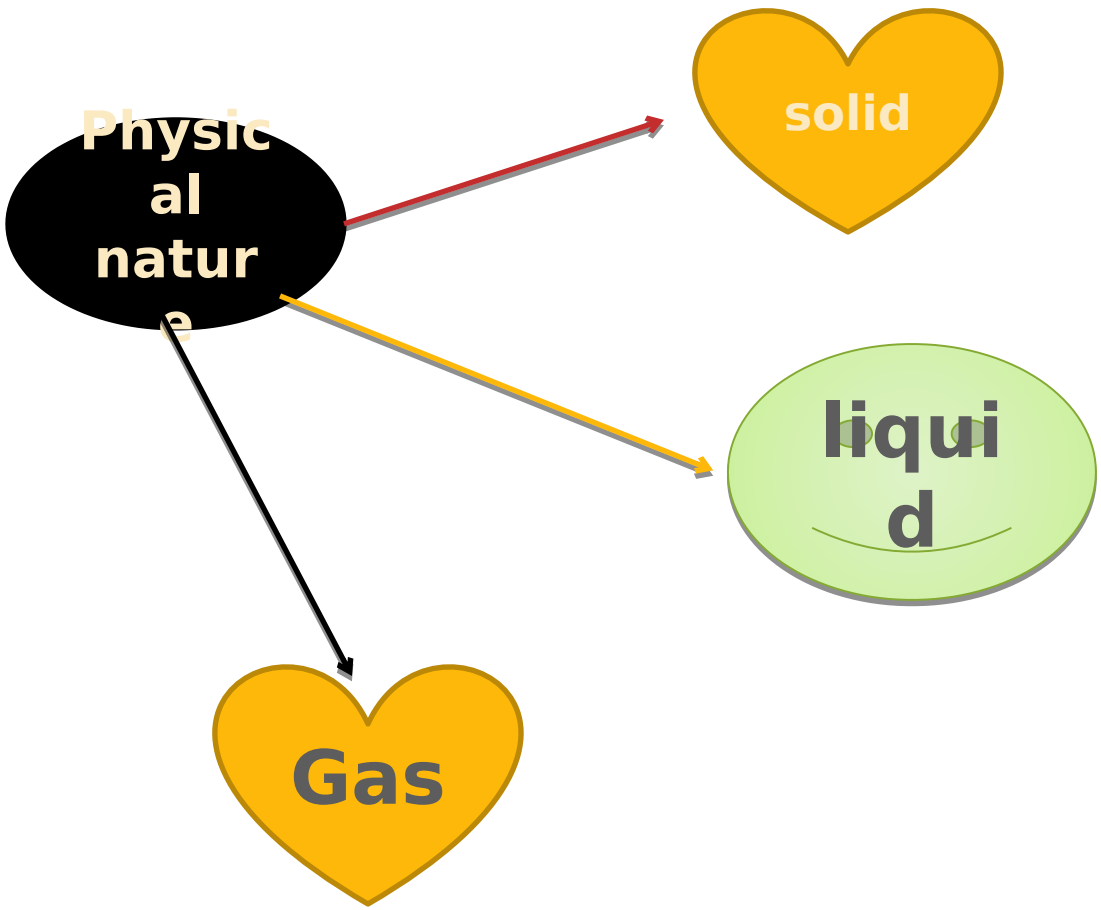
b. Non-ferrous : is the metal in which the principal element is not iron

Examples: copper,aluminium,lead,zinc,etc

2.Non metallic:

Examples;concrete,timber,stone,lime etc.

Classification Based on Physical Nature of Materials



Classification Based on Mode of Production

a) Naturally Occurring Materials
   - .stone
   - .timber

b) Industrially produced materials
   - .Cement
   - .glass

C) Materials produced at construction site
   - .Concrete
   - .mortar

2.2 Properties of Materials

Properties Which relate to materials are:

1. Physical properties

- Density & specific gravity
- Thermal property
- Acoustic /sound permeability
- Fire resistance
- Porosity

2, Chemical properties

- Corrosion Resistance
- Combustibility
- Toxicity
- Decay Resistance

3.Mechanical Properties

The resistance of material to:

- ✓ The action of external static forces (compressive, tensile, bending, shear, torsion strength)

- ✓ The action of dynamic external forces(impact and vibratory loads)

Behavior of materials under load

- Application of external force on solid body to equilibrium results in
- Internal resisting forces are developed in the body which balances the externally applied force
- The body is deformed to varying degree
- The intensity of internal force is **stress** and the deformations per unit is **strain.**

Depending on the arrangement & direction of the external forces, the stress produced in the body may be :

- Tensile
- Compressive
- Shear
- Bending
- Torsion
- Various combinations of the above.

..Mechanical properties are conducted to examine the performance of construction materials under the action of external forces.

..Mechanical tests are classified :

A. With reference to the arrangement & direction of the external forces;

- Tension Test

- ✓ Specimen under tension test is subjected to an axial tensile force
- ✓ Tensile stress is developed on cross-sectional area perpendicular to the line of action of the force.
- ✓ The specimen increase in length.

Compression Test

- Specimen is subjected to an axial compressive force
- Compressive stress is produced.
- The specimen decrease in length.

Shear test

In this test, shearing stress is determined on the x-sectional area parallel to the line of action of the external forces.

Bending Test.

- Specimen is subjected to forces that give rise to bending moments
- The resulting stresses are compressive on one side of the neutral axis & tensile on the other side.
- Shear stress exist throughout the beam.

Torsion Test

- This test is conducted to determine the shearing strength of a material
- The specimens for torsion test are generally cylindrical in shape.

B. With reference to the rate & duration of the load application.

- **Static Tests**
  - ✓ Made with gradually increasing load.

  eg. ordinary tests in tension & compression etc.
- **Dynamic Tests**
  - ✓ Made with suddenly applied loads.
- **Wear Tests**
  - ✓ Made to determine the resistance to abrasion & impact.
- **Long time Tests**
  - ✓ These are made with the loads applied to the object for long period of time.
- **Fatigue Tests**
  - ✓ These tests are made with fluctuating stresses repeated a large number of times.

C.With Reference to the effect on the specimen.

❖ Destructive Test

- ✓ The specimens are either crushed or ruptured and made useless at the end of the tests.
- ✓ Tests conducted on the following materials are best examples

..Ultimate strength of steel

..Compressive strength of concrete

❖ Non-destructive Tests

- ✓ Are used to test the strength of members of existing structures without affecting their performance.
- ✓ Example: hammer test

2.4 Stress-Strain Properties in Simple Tension Test

- In standard conventional tension test, specimen is subjected to a gradually increasing axial tensile force ‘P’ by means of testing machine.
- At various increments of load ,the change in length ΔL of the specimen is measured.

$$\Delta L = L - Lo$$

where L= new length

L_o =original length

- It is assumed that the stress is uniformly distributed for all points on each x-section. This stress is computed as follow;

$$\sigma t = p/Ao$$

where σ_t =tensile stress

- The uniform stress will produce a uniform elongation ΔL.The elongation per unit length is strain & expressed as: $\varepsilon = \Delta L / L_o$ Where ε =strain

  ΔL=elongation

  Lo=original length of the specimen

- with the values of strain & stress known for various tensile loads ,a diagram showing the relation between stress & strain ,called stress-strain diagram can be plotted

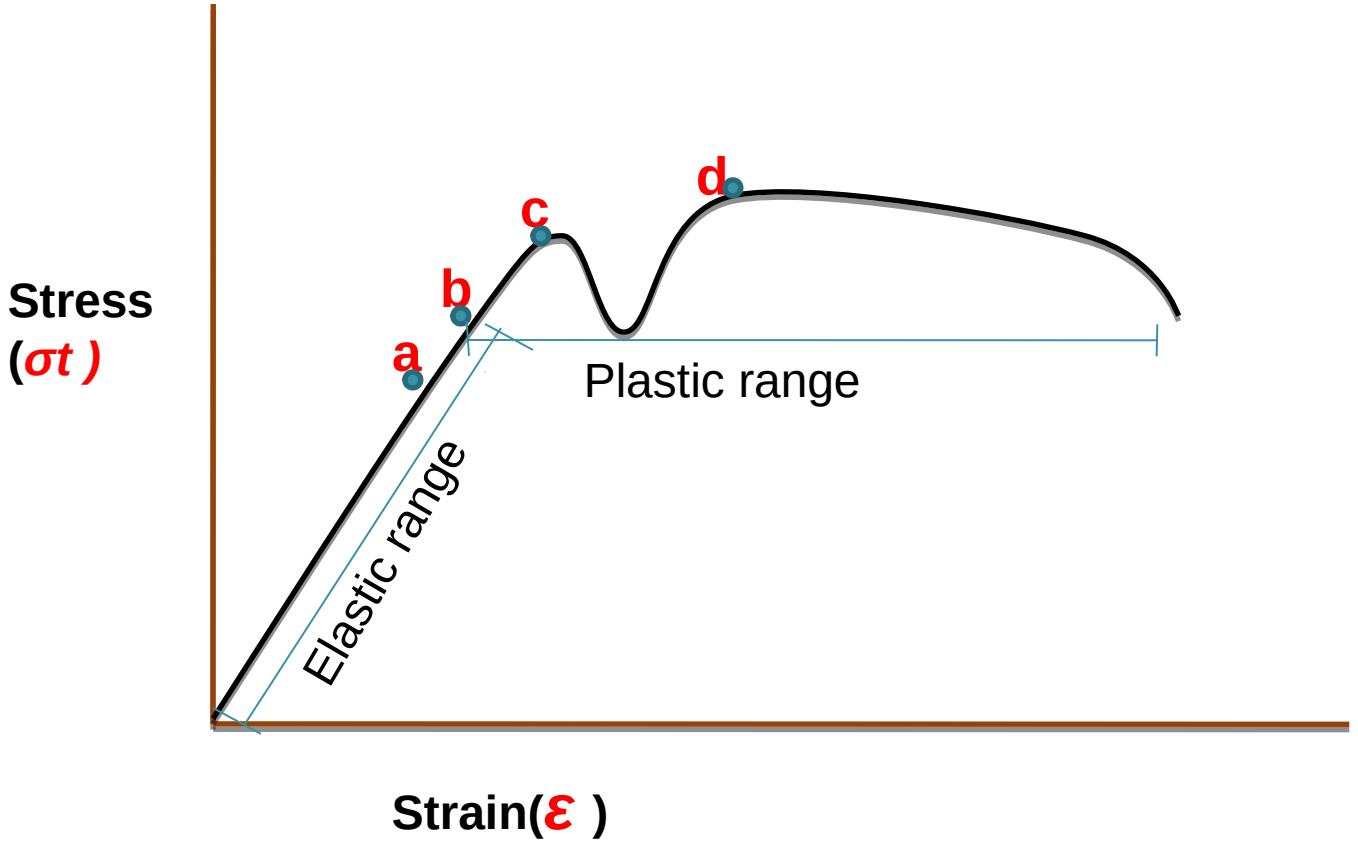


Fig 1. Stress-strain diagram for ductile materials

a= proportional limit
b=elastic limit
c=Yield strength
d= ultimate strength

Properties in the elastic range

The parameters which are used to describe the mechanical properties of a material in the elastic range are:

- proportional limit,
- elastic limit,
- modulus of elasticity, stiffness etc

4.Modulus of Elasticity(young's modulus)

- is the slope of the initial linear part of stress-strain diagram.
- The greater the modulus of elasticity, the smaller the elastic strain resulting from the application of a given values.

Methods of determining modulus of elasticity, E.

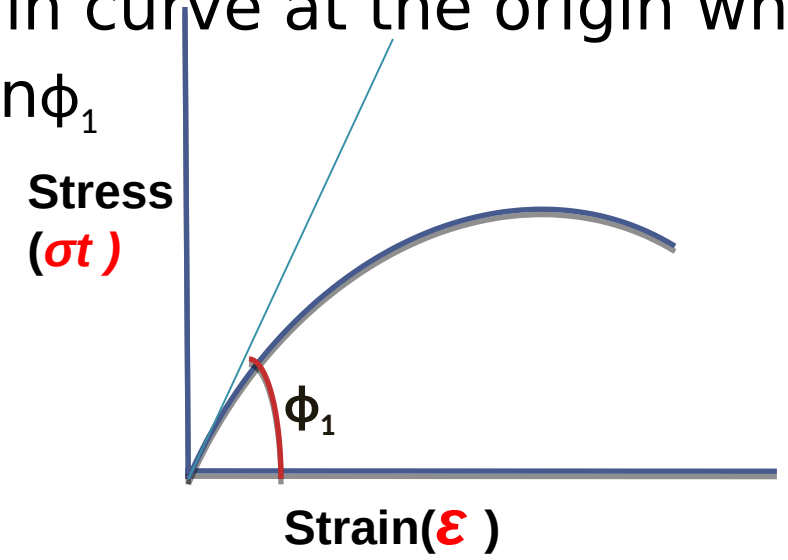
i. For ductile materials, with linear stress – strain portion,

$$E = \Delta\sigma t / \Delta\varepsilon$$

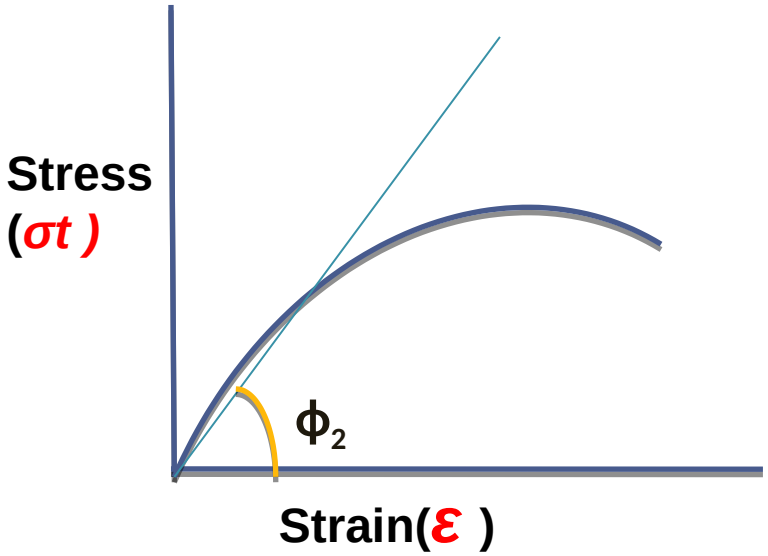
ii. For materials with non-linear stress-strain curves

- The slope of the stress- strain curve varies and the modulus of elasticity cannot be readily determined.
- The following three methods are employed to define E:

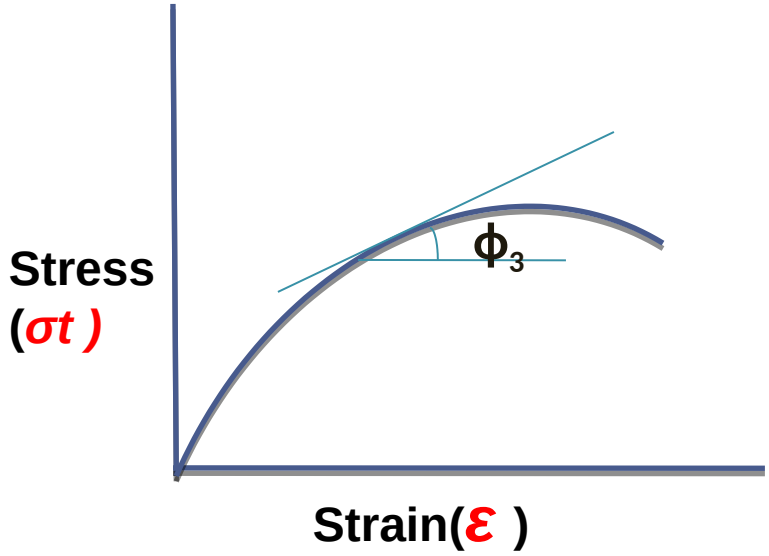
a. Initial-Tangent modulus: The slope of the stress – strain curve at the origin which has a value of $E_1 = \tan\phi_1$



b. Secant modulus : the slope of the line joining the origin and the selected point on the stress-strain curve with the value of $E_2 = \tan\phi_2$



C. Tangent modulus: The slope of the tangent to the stress –strain curve at the selected point with the value of $E_3 = \tan\phi_3$



5.Stiffness

- is the measure of the ability of material to resist deformation.
- The higher the modulus of elasticity, the stiffer the material.
- A material has a higher stiffness value when its deformation in the elastic range is relatively small.
- Comparing steel alloys with E=210Gpa and aluminium alloys with E=70Gpa,the steel alloys are about three times as stiff as the aluminium alloys i.e steel alloys will deform about one-third as much as aluminium alloys for the same stress.

6.Poisson's Ratio

- Is the ratio of the unit deformations or strains in transverse direction to the longitudinal direction within proportional limit.

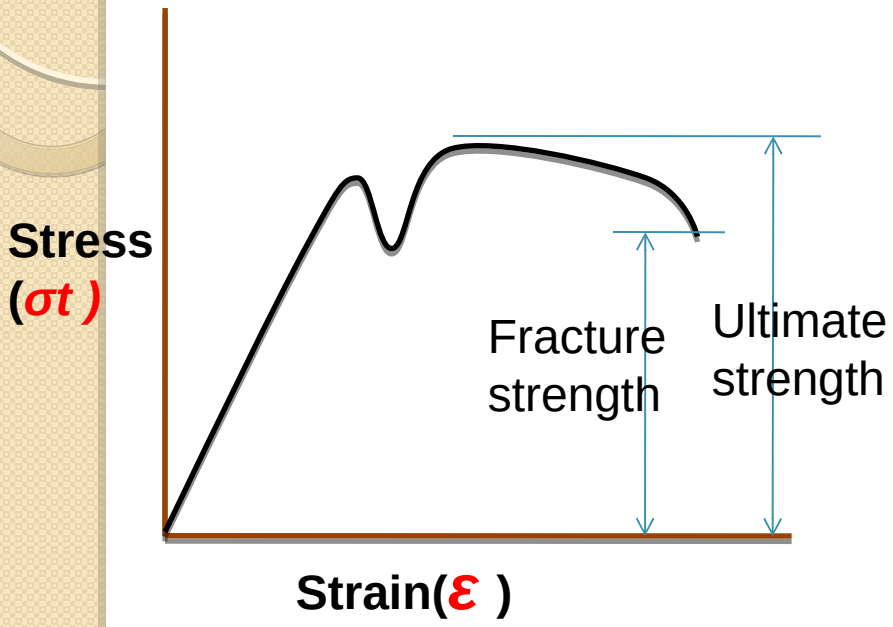
  $\mu = \varepsilon' / \varepsilon$ where ε' = transverse strain, ε =longitudinal strain

- Poisson's ratio is a measure of the stiffness of the material in the direction at right angle to applied load.

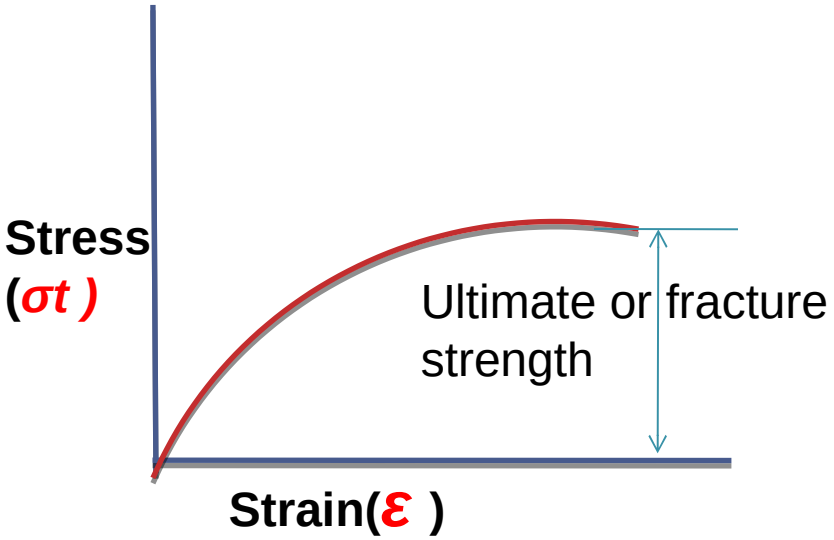
Properties for the plastic range

- The characteristic at the plastic range is that there is a permanent deformation in the stressed body after complete removal of the load.
- The parameters which are used to describe the mechanical properties for the plastic range are; ultimate strength, ductility and toughness.

- **1.Ultimate Strength**:-is the maximum strength a material can possibly resist before failure.
- Depending on the stress strain relationship of a particular material, the plastic strength will correspond to the ultimate strength or to the fracture(rupture)strength.



Ductile material



Brittle material

2.Ductility:-

- represents its ability to deform in the plastic range.
- Ductile materials show relatively higher plastic deformation, i.e they are capable of being drawn-out ,before rupture occurs.
- Ductility is measured by the percentage elongation or percentage reduction in area.

$$D_e = \frac{L_f - L_o}{L_o} * 100 \qquad Da = \frac{Ao - Af}{Ao} * 100$$

3.Toughness

- Is the ability of material to absorb energy in the plastic range
- A material with high toughness can absorb high values of strain energy in the plastic range.

Thank you!!