MECHANICS OF MATERIALS

Mechanical Properties of Materials

By

NUR FARHAYU ARIFFIN
Faculty of Civil Engineering & Earth Resources

Chapter Description

- Expected Outcomes
  - Understand the concept of tension and compression test.
  - Explain the relationship between stress – strain diagram under tensile test.
  - Identify the mechanical properties of materials by using the concept of stress – strain diagram.
  - Explain the stress – strain behaviour of ductile and brittle materials.
  - Explain the concept of Hooke's law concept and apply to calculate MOE.
  - Apply the Poisson's ratio formula to calculate Poisson's ratio.
  - Explain the relationship between shear stress – shear strain diagram concept and apply to calculate MOR.

Introduction

- The **ability** of a material to **sustain a load** depends on its strength and can be determine by experiment.
- The most important tests to perform in this regard are the **tension** and **compression** test.
- Example of the materials are:

  - Steel

  - Aluminium

  - Wood

  - Plastic

Tension and Compression Test

- The tests objective is to determine the strength and characteristics of materials

TENSILE TEST

COMPRESSION TEST

Tensile test

- A **tensile test**, also known as tension test, is probably the most fundamental type of mechanical test that can be performed on material
- Tensile testing – to **pull** apart a material **until it breaks**

Compression Test

- A compression test determines behavior of materials under **crushing loads** (being **pushed** together)
- The specimen is compressed and deformation at various loads

The Stress–strain Diagram

<u>Conventional Stress–Strain Diagram</u>

- Nominal or **engineering stress** is obtained by dividing the applied load *P* by the specimen's original cross-sectional area.

$$\sigma = \frac{P}{A_0}$$

- Nominal or **engineering strain** is obtained by dividing the change in the specimen's gauge length by the specimen's original gauge length.

$$\varepsilon = \frac{\delta}{L_0}$$

Strain Hardening

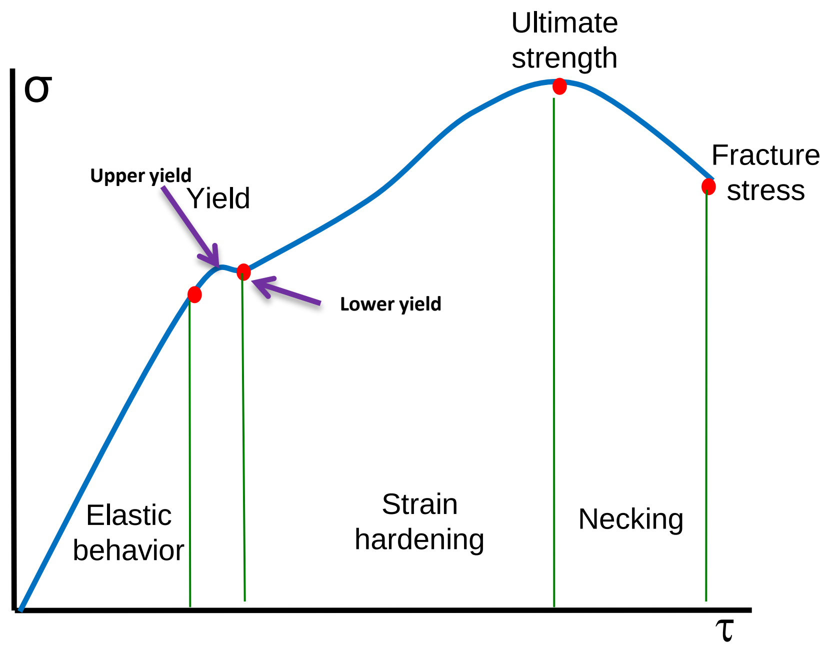
- As the materials stretches, it can withstand increasing amounts of **stress**

Ultimate Strength

- Based on the engineering definition of stress, the ultimate strength is the largest stress that the material can withstand

Yield

- A slight increase in stress causes a marked increase in strain
- Beginning at yield, the material is **permanently altered**. Only a portion of the strain will be recovered after the stress has been removed
- Strains are termed inelastic since only a portion of the strain will be covered upon removal of the stress
- The yield strength is an important design parameter for the material



Necking

- The cross-sectional area begins to decrease markedly in a localized region of the specimen
- The tension force required to produce additional stretch in the specimen decrease as the area is reduced
- Necking occurs in ductile but not in brittle materials

Elastic Behavior

- In general, the initial relationship between stress and strain is linear
- Elastic strain is temporary, meaning that all strain is fully recovered upon removal of the stress
- The slope of this line is called the **elastic modulus** or the **modulus of elasticity**

Fracture Stress

- The fracture stress is the engineering stress at which the specimen breaks into two pieces

Stress–Strain Behavior of Materials

Ductile Materials

- Material that can subjected to **large strains** before it ruptures is called a **ductile material**
- Engineer choose ductile materials for design because these materials are capable of **absorbing shock** and if overloaded it will exhibit large **deformation before failed**
- Ductility defined as the material's capacity for **plastic** deformation
- Example: Copper, aluminium, and **steel**

- The ductility of material can be report its percent **elongation** or **reduction** in area at the time of fracture

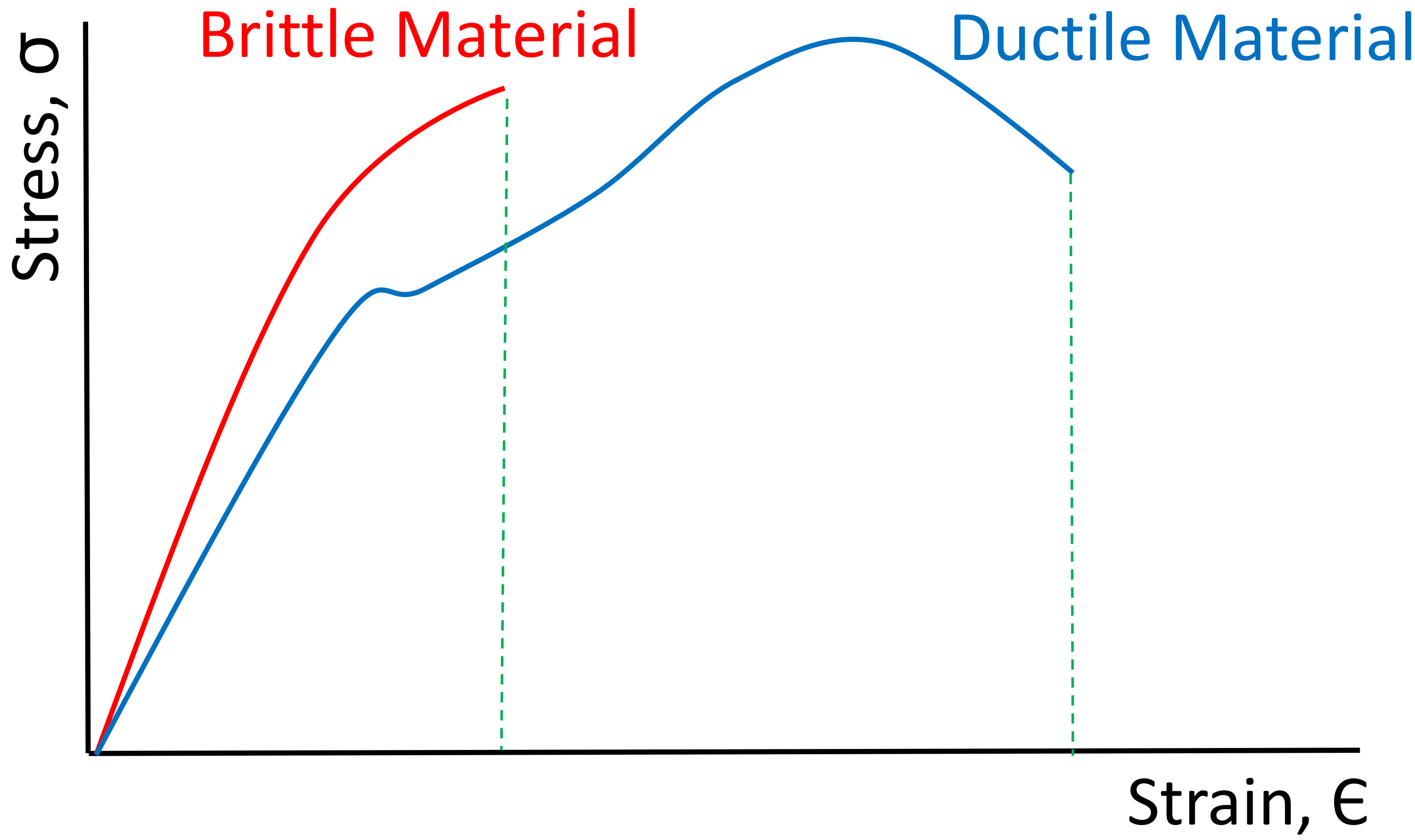
$$\text{Percentage Elongation} = \frac{L_{final} - L_{original\,(gauge\ length)}}{L_{original\,(gauge\ length)}} \times 100\%$$

$$\text{Percentage Reduction of Area} = \frac{A_{original} - A_{final}}{A_{original}} \times 100\%$$

Brittle Materials

- Materials that exhibit **little** or **no yielding** before failure are referred to as **brittle materials**
- An example : gray cast iron, **concrete**
- Therefore, **concrete** beams, slabs, columns etc. are reinforced **with steel** as they can bear those tensile forces easily and hence prevent the section from cracks.

Comparison between Stress – Strain Behavior of Materials



Hooke's Law

- Hooke's Law defines the **linear relationship** between stress and strain within the elastic region.

$$\sigma = E\varepsilon$$

σ = stress

E = modulus of elasticity or *Young's modulus*

ε = strain

- E can be used only if a material has linear–elastic behaviour.

Strain Energy

- When material is deformed by external loading, it will store energy **internally** throughout its volume
- Energy is related to the strains called **strain energy**
- Strain energy is **energy stored** in a material due to its **deformation**
- This energy per unit volume is called **strain-energy density**

Strain Energy- Modulus of Resilience

- When stress reaches the **proportional limit**, the strain-energy density is the **modulus of resilience, u_r**

$$u_r = \frac{1}{2}\sigma_{pl}\varepsilon_{pl} = \frac{1}{2}\frac{\sigma_{pl}^2}{E}$$

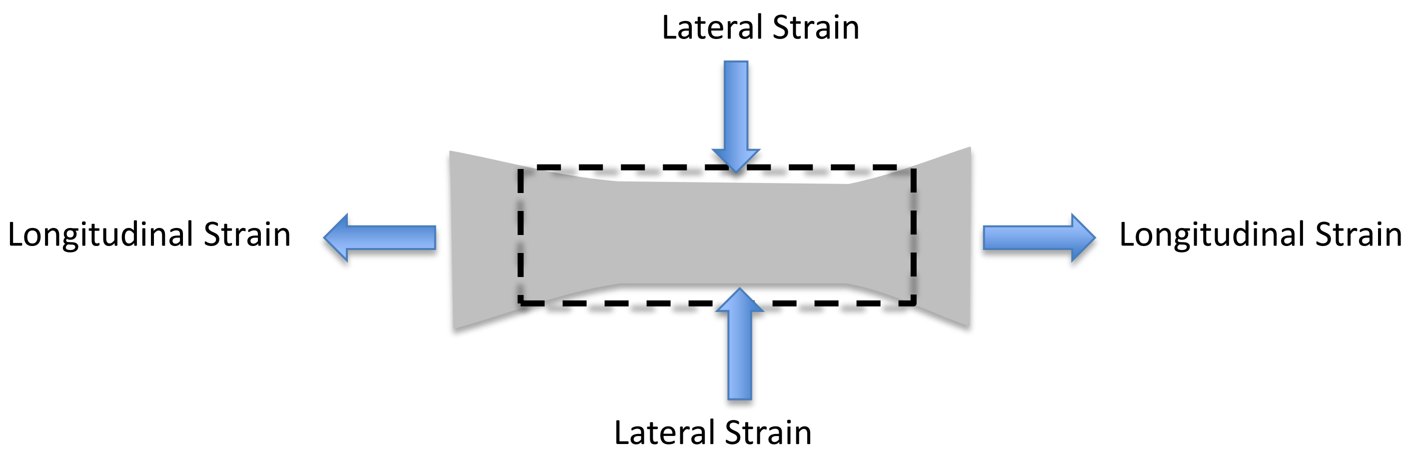
- The modulus of resilience is proportional to the **area under** the **elastic portion** of the stress-strain diagram.
- Units are J/m^3.

Strain Energy- Modulus of Toughness

- Modulus of toughness, u_t represents the **entire area** under the stress–strain diagram indicates just **before** it **fractures**
- Equal to the area under the **entire** stress-strain curve.
- Units are Pa or psi.

POISSON'S RATIO

- Poisson's ratio ***v***, is a measure of the **lateral strain** of a homogeneous and isotropic material versus its **longitudinal strain**.
- These strain are generally of opposite signs, that is , if one is an elongation, the other will be contraction



- Poisson's ratio, *v* states that in the elastic range, the ratio of these strains is a constant since the **deformations** are **proportional**

$$v = -\frac{\varepsilon_{lateral}}{\varepsilon_{longitudinal}}$$

$$v = \frac{-\varepsilon_y}{\varepsilon_x} = \frac{-\frac{\delta d}{d}}{\frac{\delta L}{L}}$$

- Poisson' ratio is **dimensionless** and most metal has a value of v between 1/3 and 1/4, the largest possible value of v is 1/2

Failure Of Materials Due To Creep

- When material support a load for long period of time, it will deform until a sudden fracture occurs
- This **time-dependent** permanent deformation is known as **creep**
- Both stress and/or temperature play a significant role in the rate of creep
- Creep strength will decrease for higher temperatures or higher applied stresses

Failure Of Materials Due To Fatigue

- When metal subjected to **repeated cycles** of stress or strain, it will ultimately leads to fracture
- This behaviour is called **fatigue**
- Endurance or **fatigue limit** is a limit which no failure can be detected after applying a load for a specified number of cycles
- This limit can be determined in S-N diagram

References

- Hibbeler, R.C., Mechanics Of Materials, 9th Edition in SI units, Prentice Hall, 2013.
- Ferdinand P. Beer, E. Russell Johnston, Jr., John T. DeWolf, David F. Mazurek, Mechanics of materials 5th Edition in SI Units, McGraw Hill, 2009.

MOHD FAIZAL MD. JAAFAR
MOHD AMIRULKHAIRI ZUBIR
NUR FARHAYU ARIFFIN