Arab Academy for Science, Technology and Maritime Transport

CB 251 Testing of Materials

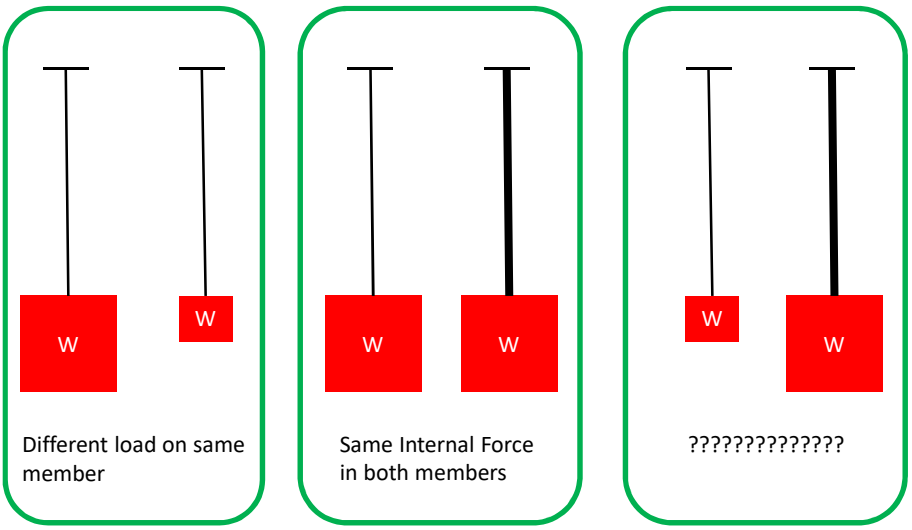
Mechanical Properties of Materials

Dr. Karim Helmy

Material Properties

1. Chemical – relate to structure of material, its formation from the elements out of which it is made, and its reactivity with chemicals, other materials, and environments.
2. Physical – response of a material due to interaction with various forms of energy (i.e. magnetic, thermal, etc) and with the human senses
3. **Mechanical** – response of a material due to an applied force.

Loads and Stresses



Stress

- The same amount of force applied to a different size of area → different "intensity" of the force.
- The "intensity" of the force is expressed in engineering terms as **STRESS**
- **Stress=Force/Area**

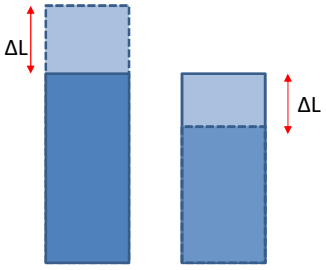
Stresses

- Two types of stresses
- Normal Stress **"σ" or "*f*"**
  - Tension or compression
  - resulting from Normal Forces and Bending Moments
- Shear Stress **"τ"** or ***"q"*** Resulting from Shear forces and Torsion
- Stresses are expressed in pressure units
- Commonly used stress units in SI system
  - **Pa** Pascal
  - **MPa** Mega Pascal or (**N/mm^2**)

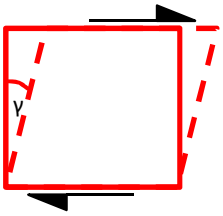
Deformation

- Deformation is the change in the form of a body due to the application of force

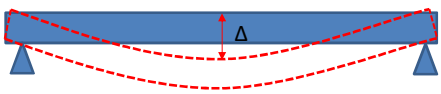
Change in dimensions
Normal Forces
Elongation contraction



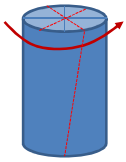
Change in Shape
Shear Forces
Distortion



Deformation



Change in shape
Deflection



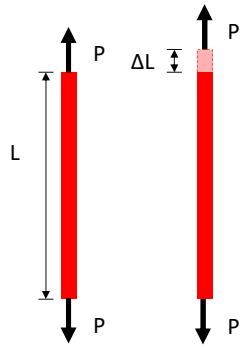
Change in shape
Twist

Strains

- Strain is the deformation related to the original dimensions

Strains

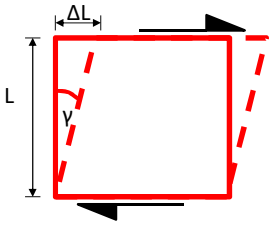
Normal Strain "ε"



Change in dimension
(Extension or Compression)

ε=ΔL/L

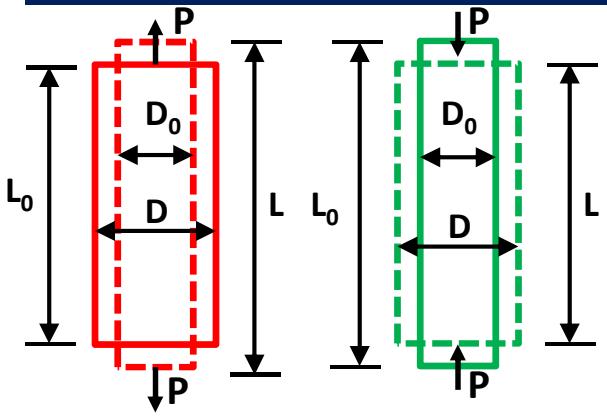
Shear Strain "γ"



The change in angle
(Distortion)

ΔL/L = tanγ ≈ γ

Poisson's Ratio



$$\upsilon = -\frac{\varepsilon_{lat}}{\varepsilon_{long}}$$

$$\varepsilon_{long} = \frac{L - L_0}{L_0} = \frac{\Delta L}{L_0}$$

$$\varepsilon_{lat} = \frac{D - D_0}{D_0} = \frac{\Delta D}{D_0}$$

Hooke's Law

- Stress is directly proportional to strain
- For materials that obey Hooke's Law
- **$\sigma=E\varepsilon$**
- $E=\sigma/\varepsilon$ is known as the modulus of Elasticity or Young's Modulus
- Expressed in pressure units usually expressed in Giga Pascals (GPa)
- Steel 200 Gpa, Aluminum 70 GPa

Modulus of Rigidity

- Is the ratio between the shear stress and strain
- **$G=\tau/\gamma$**

Strength

- Ultimate stress σ_u
- The Maximum stress the material reaches prior to failure

Elasticity and Plasticity

- Elasticity is the ability of the material to regain its original shape and dimensions after removal of loads
  - Associated with stretching but not breaking the chemical bonds between atoms in a solid
- Plasticity is the ability of the material to maintain its deformed shape and dimensions even after removal of loads
- Most materials are neither perfectly elastic nor perfectly plastic

Ductility and Brittleness

- Ductile materials has the ability to undergo extensive deformation before failure.
- Brittle materials will fail after little deformation
- Ductile materials will absorb high energy before failure while brittle materials will absorb little energy before failure

Design

- When designing a structure of a structural member the following must be considered
  - No failure
  - No excessive deformation
- To avoid failure a factor of safety **F.O.S** is used to reduce the ultimate stress to a design stress or allowable stress σ_{all}

Design

- The factor of safety is chosen based on
  - The variability in material strength
  - Importance of structural member
  - If the material is ductile or brittle
- To avoid excessive deflection an allowable deformation is prescribed