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MECHANICS OF MATERIALS

Analysis of Stress

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Chapter Description

- Expected Outcomes
  - Identify and explain the concepts of stresses.
  - Apply the concepts of stresses in calculating the normal and shear stress of body.
  - Analyse the average stress acting over the bar's cross-sectional area.
  - Describe the single and double shear stresses thus, calculate the average shear stress.
  - Calculate the stress on oblique plane of body under loading conditions.
  - Calculate the allowable stress by applying the safety factors.

Introduction

- Mechanics of materials is a study of the relationship between the **external loads** and **internal loads** within the body.
- This subject also involves the **deformations** and **stability** of a body when subjected to external forces.
- When a body subjected to an external load is sectioned, there is a distribution of force acting over the sectioned area which holds each segment of the body in equilibrium
- The intensity of this internal force at a point in the body is referred to as stress
- Stress is defined as force per unit area that the force acts upon

Equilibrium of a deformable body

- Equilibrium of a body requires a **balance of forces** and a **balance of moments**

$$\sum \mathrm{F} = 0 \qquad \sum \mathrm{M}_O = 0$$

- For a body with *x*, *y*, *z* coordinate system with origin *O*,

$$\sum F_x = 0, \quad \sum F_y = 0, \quad \sum F_z = 0$$
$$\sum M_x = 0, \sum M_y = 0, \sum M_z = 0$$

- **Best way to calculate these forces is to draw the free-body diagram (FBD).**

Internal Resultant Loadings

- Internal resultants force – To **hold** the body together when the body **subjected to external loads**

- Objective of FBD is to determine the resultant force and moment acting within a body.

- In general, there are 4 different types of resultant loadings:

  a) Normal force, **N**

  b) Shear force, **V**

  c) Torsional moment or torque, **T**

  d) Bending moment, **M**

Types of resultant loadings

Internal resultant loadings

Normal Forces, N

Acts **perpendicular** to the area when the **external loads** tend to **push** or **pull** the body

Shear Force , V

Lies in the plane of the area and is developed when the external loads tend to cause the two segments of the body to **slide over one another**

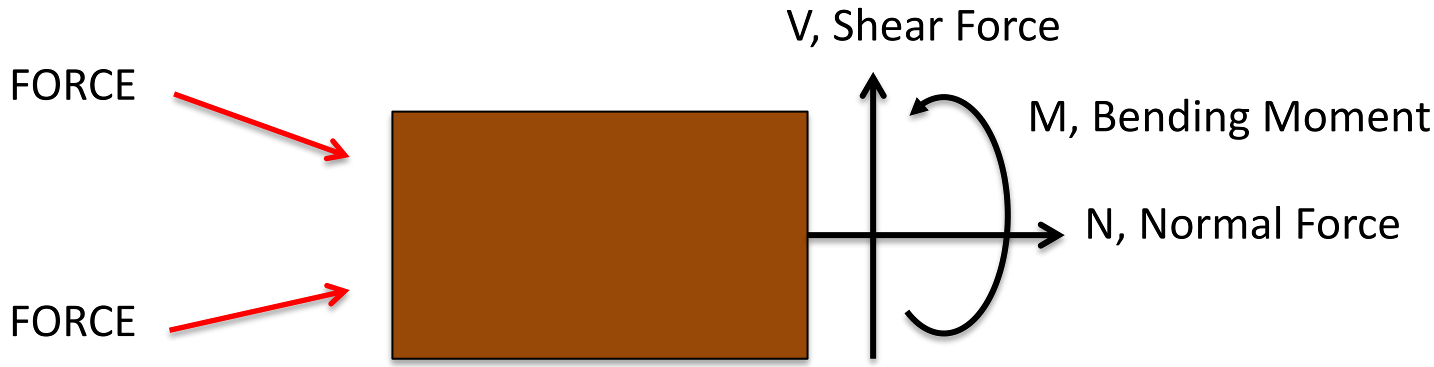
Torque , T

Known as **Torsional Moment** that developed when *the* **external loads** tend to **twist** one segment of the body with respect to the other

Bending Moment , M

The bending moment is caused by the **external loads that tend to bend** the body about an axis lying within the plane of the area

Free Body Diagram of the Internal Resultant Loadings



Procedure for analysis

STEP 1 – Support Reactions

- Decide which segment is to be considered
- Draw FBD
- Apply static equation

STEP 2 – Draw FBD

- Draw FBD of the ‘cut’ segments and indicate the unknown resultants N, V, M and T

STEP 3 – Equations of equilibrium

1.1 Normal Stress

- The most fundamental types of stress exists is the **normal stress – the intensity of force or force per unit area**
- Indicated by the lowercase Greek letter ***σ*** (sigma)
- **Normal force acts perpendicular or normal to the cross section** of the load-carrying member

$$\sigma_z = \lim_{\Delta A \to 0} \frac{\Delta F_z}{\Delta A}$$

Average normal stress

- Mathematically expressed:

$$\text{Stress}, \sigma = \frac{\text{Force}\,(F)}{\text{Area}\,(A)}$$

Unit:
N/mm^2 or MPa

Equilibrium of Stresses

Tensile Stress (+σ)

Stretch (elongate) the member and pull the material apart

Compressive Stress (-σ)

Crush and shorten the material of the load-carrying member

1.3 Shear Stress

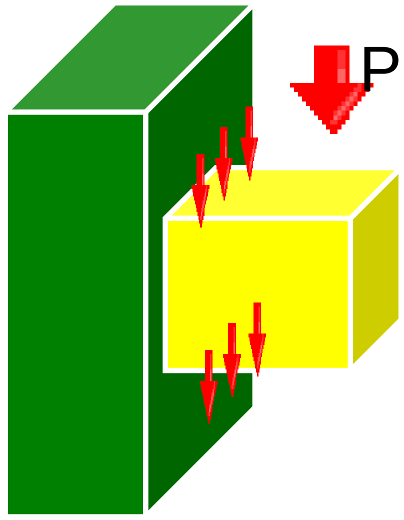
- The intensity of force or force per unit area
- **Stress acts tangent to the cross section** of the load-carrying member
- Called shear stress, τ (tau)

$$\tau_{zx} = \lim_{\Delta A \to 0} \frac{\Delta F_x}{\Delta A}$$

$$\tau_{zy} = \lim_{\Delta A \to 0} \frac{\Delta F_y}{\Delta A}$$

Average Shear Stress

- Average shear stress (τ_{avg}) distributed over each sectioned area that develops a **shear force**



$$\tau_{avg} = \frac{V}{A}$$

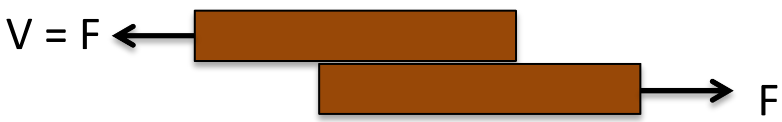
Where,

τ = average shear stress
V = internal resultant shear force
A = area at that section

TYPES OF SHEAR STRESS

Single Shear

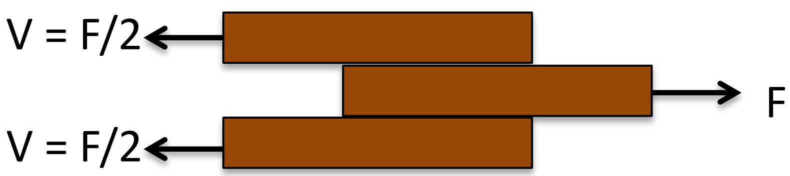
Refer as lap joints



$$\tau_{\text{ave}} = \frac{P}{A} = \frac{F}{A}$$

Double Shear

Refer as double lap joints



$$\tau_{\text{ave}} = \frac{P}{A} = \frac{F}{2A}$$

1.4 Allowable Stress

- A **factor of safety** is needed to obtained allowable load.
- The **factor of safety (F.S.)** is a ratio of the **failure load** divided by the **allowable load**

LOAD
$$F.S = \frac{F_{fail}}{F_{allow}}$$

NORMAL STRESS
$$F.S = \frac{\sigma_{fail}}{\sigma_{allow}}$$

SHEAR STRESS
$$F.S = \frac{\tau_{fail}}{\tau_{allow}}$$

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.

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