23CE302 : STRENTH OF MATERIALS

Mr. A SRINIVAS

Assistant Professor, Civil Engineering
Narsimha Reddy Engineering College (Autonomous)
Secunderabad, Telangana, India- 500100.

UNIT-III Flexural Stresses & Shear Stresses

- **Topics Covered**
- Theory of Simple Bending
- Bending Equation
- Section Modulus
- Flexural Stress
- Beam Design
- Shear Stress Distribution

Learning Outcomes

- After completing this unit, students will be able to:
- Explain the theory of simple bending.
- State assumptions of bending theory.
- Derive the bending equation.
- Calculate section modulus.
- Determine bending stresses in different sections.
- Design simple beam sections.
- Derive shear stress formula.
- Draw shear stress distributions for various beam sections

Introduction to Flexural Stresses

- **Flexural Stress**
- Developed due to bending moment.
- Compression occurs on one side.
- Tension occurs on the opposite side.
- Neutral Axis experiences zero stress.
- **Applications**
- Bridges
- Roof Beams
- Machine Frames
- Building Structures

Theory of Simple Bending

- **Definition**
- Simple bending refers to bending of beams subjected to bending moments without axial force.
- **Basic Concept**
- Upper fibers shorten.
- Lower fibers elongate.
- Neutral layer remains unchanged.
- Stress varies linearly.

Assumptions of Simple Bending Theory

- The assumptions are:
- Beam is initially straight.
- Material is homogeneous.
- Material is isotropic.
- Hooke's law is valid.
- Plane sections remain plane.
- Radius of curvature is large.
- Young's modulus is same in tension and compression.

Derivation of Bending Equation

- **Bending Equation**
- $\boxed{\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}}$
- Where
- **M** = Bending Moment
- **I** = Moment of Inertia
- **σ** = Bending Stress
- **y** = Distance from Neutral Axis
- **E** = Young's Modulus
- **R** = Radius of Curvature

Explanation of Bending Equation

- **Three Important Relations**
- **Stress Relation**
- $\sigma = \frac{My}{I}$
- **Curvature Relation**
- $\frac{1}{R} = \frac{M}{EI}$
- **Maximum Stress**
- $\sigma_{max} = \frac{Mc}{I}$
- where **c** = Maximum distance from Neutral Axis

Section Modulus

- **Definition**
- Section modulus is the measure of bending strength.
- **Formula**
- $Z = \frac{I}{c}$
- Where
- Z = Section Modulus
- I = Moment of Inertia
- c = Extreme fiber distance
- Higher section modulus → Greater bending strength.

Bending Moment Diagram (BMD)

- **Definition**
- A graphical representation showing the variation of bending moment along the beam.
- **Characteristics**
- Straight line under point load
- Parabolic under UDL
- Cubic curve under UVL
- **Uses**
- Determining Maximum BM
- Reinforcement Design
- Beam Safety

Section Modulus of Rectangular & Circular Sections

- **Rectangular Section**
- $Z = \frac{bd^2}{6}$
- **Solid Circular Section**
- $Z = \frac{\pi d^3}{32}$
- **Hollow Circular Section**
- $Z = \frac{\pi\left(D^4 - d^4\right)}{32D}$

Section Modulus of Standard Sections

- **I Section**
- Large moment of inertia
- High bending resistance
- **T Section**
- Moderate bending capacity
- **Channel Section**
- Used in steel construction
- **Angle Section**
- Used in trusses
- Unequal stress distribution

Flexural Stress in Various Sections

- **Rectangular Beam**
- $\sigma = \frac{My}{I}$
- Maximum stress at top and bottom.
- **Circular Beam**
- Stress varies linearly from center.
- **Hollow Circular Beam**
- Lower weight
  Higher strength-to-weight ratio

Design of Simple Beam Sections

- Design Steps
- Determine loading.
- Calculate maximum bending moment.
- Determine allowable stress.
- Calculate required section modulus.
- $Z = \dfrac{M}{\sigma_{allow}}$
- Select suitable beam section.

Introduction to Shear Stress

- **Shear Stress**
- Developed due to transverse loads.
- Acts parallel to beam cross-section.
- Formula
- $\tau = \frac{F}{A}$
- Where
- τ = Shear Stress
- F = Shear Force
- A = Area

Derivation of Shear Stress Formula

- General Shear Stress Formula
- $\boxed{\tau = \frac{VQ}{Ib}}$
- Where
- V = Shear Force
- Q = First Moment of Area
- I = Moment of Inertia
- b = Width at section
- This equation is used for all beam sections.

Shear Stress Distribution in Rectangular Section

- Characteristics
- Zero at top.
- Zero at bottom.
- Maximum at Neutral Axis.
- Maximum shear stress
- $\tau_{max} = 1.5\tau_{avg}$
- Distribution
- Parabolic

Shear Stress Distribution in Circular & Triangular Sections

- **Circular Section**
- Parabolic distribution
- Maximum at center
- Zero at outer surface
- **Triangular Section**
- Non-uniform
- Maximum near centroid
- Zero at top and bottom

Shear Stress Distribution in I & T Sections

- **I Section**
- Maximum in web
- Small in flanges
- Nearly uniform in web
- **T Section**
- Maximum at web
- Lower in flange
- Used extensively in steel structures.

Shear Stress Distribution in Angle & Channel Sections

- **Angle Section**
- Unsymmetrical distribution
- Neutral axis shifts
- **Channel Section**
- Maximum in web
- Less in flanges
- Applications
- Frames
- Structural members
- Machine supports

Summary

- **Key Points**
- Simple bending follows bending equation
- $\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$
- Section modulus indicates bending strength.
- Flexural stress is maximum at extreme fibers.
- Shear stress is maximum at neutral axis.
- Shear stress formula:
- $\tau = \frac{VQ}{Ib}$
- **Applications**
- Building Beams
- Bridges
- Machine Components
- Steel Structures
- RCC Design