RAMA UNIVERSITY

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FACULTY OF ENGINEERING AND TECHNOLOGY

Department of Mechanical Engineering

MEPS102:Strength of Material

Lecture 1

Topic: Introduction to stress and strain

Instructor:

Aditya Veer Gautam

Syllabus and Text Book

Unit 1

Axial Loading: Tension-Compression & Torsion

Normal Stress, σ , Normal Strain, ϵ ,Stress-Strain Diagrams – Specimen under tension , Hooke's Law , Elasticity, plasticity, creep ,Relaxation, Resilience, Proof resilience, Shear Strain, Sign Conventions for Shear Stresses and Strains ,Independent elastic constants

Torsion:

Hooke's Law in Shear, The Torsion Formula, Non-uniform torsion, Stresses and strains in pure shear

Unit 2

Mohr's Circle for Plane Stress and Plane Strain, Strain Measurement:

State of Plane stress, Stresses on Inclined Sections, Transformation Equations for Plane Stress, Principal Stresses and Maximum Shear Stresses, Mohr's Circle for Plane Stress, State of Plane Strain

Transformation Equations for Plane Strain, Principle strain and Maximum Shear strain, Mohr's Circle for Plane Strain, Strain Measurement, Strain Rosette, Hooke's law for plane stress, Thin Pressure, vessel, Cylindrical, Spherical

Syllabus and Text Book

Unit 3

Shear Force and Bending Moment Diagram and Associated Stresses:

Shear Force and Bending Moment, Relationships between loads, shear forces, and bending moments, Rule for drawing shear force and bending moment diagram, Pure bending, Strain curvature relation, Normal Stresses in Beams (Linearly Elastic Materials), Location of neutral axis, Moment-Curvature Relationship, Flexure Formula, Shear stresses in beams of rectangular cross section, Beams with axial loads, Combined torsion and bending.

Unit 4

Deflection of Beam:

Introduction, Differential equation of the deflection curve, Deflections by integration of the bending-moment equation, Moment area method, First Moment-Area Theorem, Second Moment-Area Theorem, Macaulay Method

Columns:

Introduction, Buckling and stability, Differential Equation for Column Buckling, Columns with other support conditions - Fixed-Free column, Fixed-fixed Column, Fixed-pinned column; Rankine Gordon formula, Column with eccentric load,

Syllabus and Text Book

Unit 5

Energy Methods:

Strain Energy in various loading conditions, Castigliano's Theorem, Use of Fictitious load (Dummy Load Method), Modified Castigliano's Theorem (Unit Load Method)

Helical Springs: deflection of springs by energy method, helical springs under axial load and under axial twist axial load and twisting moment acting simultaneously both for open and closed coiled springs

Material Testing

Testing of materials with universal testing machine; testing of hardness and impact strength

Total No of Lecture: 45
Mode: Online via Zoom

Text Book

Mechanics of Material by **James M Gere**, **Barry J Goodno** Cengage Learning Publication 7th edition

Reference Book

Strength of Material by **R K Rajput** Laxmi Publication

INTRODUCTION TO STRENGTH OF MATERIALS

- ✓ **Strength Of Materials** is a branch of applied mechanics that deals with the behaviour of solid bodies subjected to various types of forces and moments.
  - ✓ Mechanics of materials
  - ✓ Mechanics of deformable bodies

- ✓ **Principle Objectives**
  - ✓ Determine stress , strain , displacement
  - ✓ Load at which material fails

- ✓ An understanding of mechanical behaviour is essential for the safe design of all types of structures, whether airplanes and antennas, buildings and bridges, machines and motors, or ships and spacecraft.

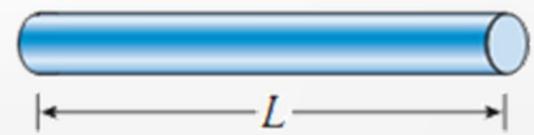
NORMAL STRESS AND STRAIN

- ✓ Fundamental concepts in strength of materials
  - ✓ Stress
  - ✓ Strain

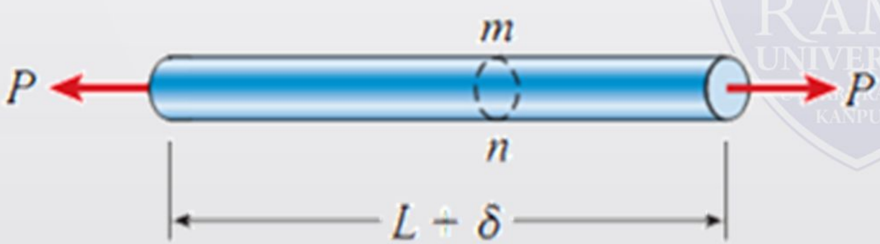
- ✓ Few Basic Definitions
  - ✓ **Prismatic bar** is a straight structural member having the same cross section throughout its length
  - ✓ **Axial force** is a load directed along the axis of the member, resulting in either tension or compression in the bar.
  - ✓ **Cross section** is a section taken perpendicular to the longitudinal axis of the bar

NORMAL STRESS AND STRAIN: Prismatic bar in tension

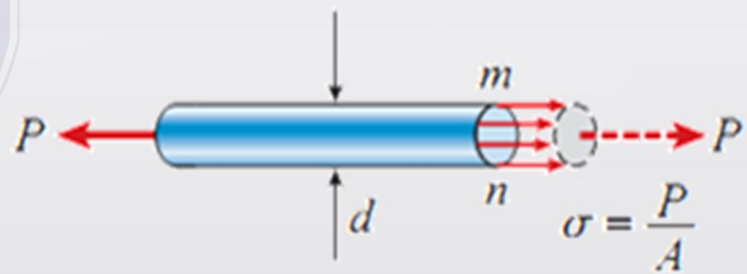
(a) free-body diagram of a segment of the bar,



(b) segment of the bar before loading



(c) segment of the bar after loading



(d) normal stresses in the bar

NORMAL STRESS

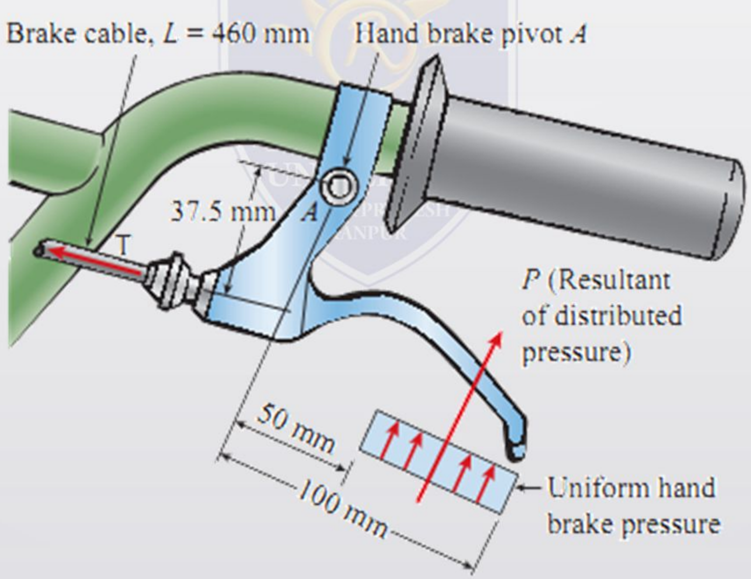
- ✓ Axial force ***P*** acting at the cross section is the resultant of ***continuously distributed stresses*** acting over the entire cross section.
- ✓ This equation $\sigma = {}^{P}/_{A}$ gives the intensity of ***stress uniformly distributed over the cross section*** in an axially loaded, prismatic bar of arbitrary cross-sectional shape.
  - ✓ Axial force ***P*** acts through the centroid of the cross-sectional area
  - ✓ Uniform stress condition exists throughout the length of the bar except near the ends
- ✓ Stresses act in a direction perpendicular to the cut surface, they are called normal stresses.
- ✓ Tensile stresses as positive and compressive stresses as negative.
- ✓ Its SI unit is pascal, Pa or N/m^2

NORMAL STRAIN

- The elongation of a segment is equal to its length divided by the total length ***L*** and multiplied by the total elongation $\boldsymbol{\delta}$. Elongation per unit length is called strain $\epsilon = {}^{\delta}/_{L}$
  - Bar in tension = tensile strain (elongation or stretching) Positive sign
  - Bar in compression = compressive strain (shortening) Negative sign
  - The strain ϵ is called a ***normal strain*** because it is associated with ***normal stresses***.
  - Dimensionless quantity, but sometime mm/m, μm/m and sometimes expressed as a percent (%), especially when the strains are large.

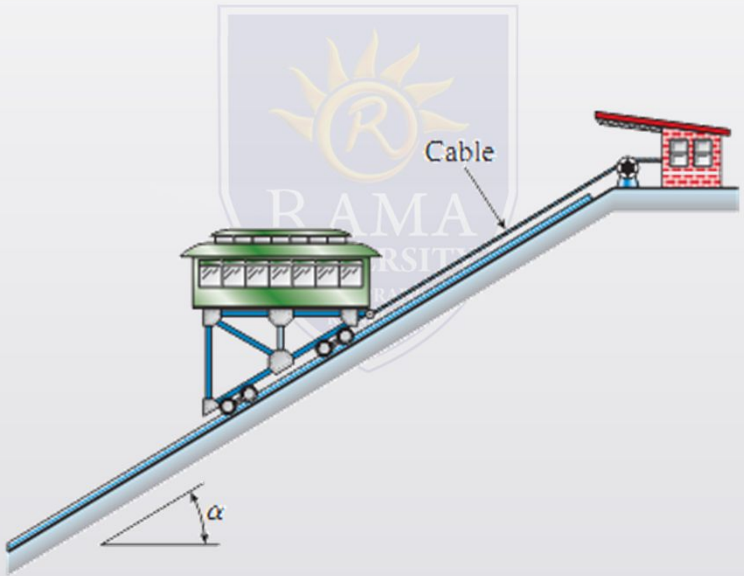
Review Questions

1. A force P of 70 N is applied by a rider to the front hand brake of a bicycle (P is the resultant of an evenly distributed pressure). As the hand brake pivots at A, a tension T develops in the 460-mm long brake cable ($A = 1.075\ mm^2$) which elongates by 0.214 mm. Find normal stress and strain in the brake cable.



Review Questions

2. A car weighing 130 kN when fully loaded is pulled slowly up a steep inclined track by a steel cable (see figure). The cable has an effective cross-sectional area of 490 mm^2, and the angle of the incline is $\alpha=30°$. Calculate the tensile stress in the cable

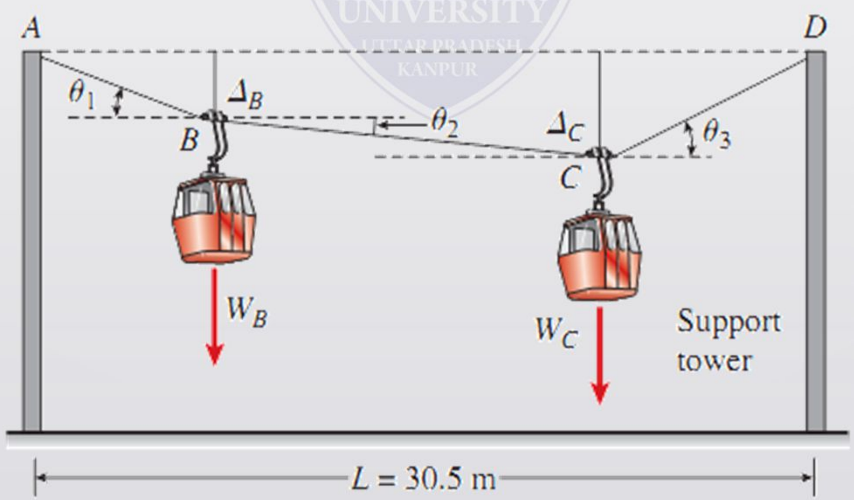


Review Questions

1.3-13 Two gondolas on a ski lift are locked in the position shown in the figure while repairs are being made elsewhere. The distance between support towers is $L = 30.5$ m. The length of each cable segment under gondola weights $W_B = 2000$ N and $W_C = 2900$ N are $D_{AB} = 3.7$ m, $D_{BC} = 21.4$ m, and $D_{CD} = 6.1$ m. The cable sag at B is $\Delta_B = 1.3$ m and that at $C(\Delta_C)$ is 2.3 m. The effective cross-sectional area of the cable is $A_e = 77$ mm^2.

(a) Find the tension force in each cable segment; neglect the mass of the cable.

(b) Find the average stress (σ) in each cable segment.

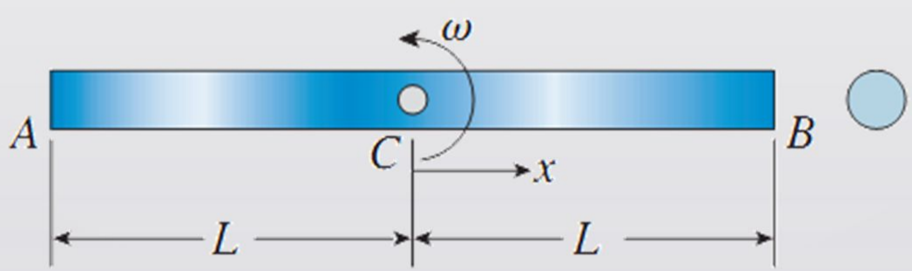


Review Questions

1.3-12 A round bar ACB of length $2L$ (see figure) rotates about an axis through the midpoint C with constant angular speed ω (radians per second). The material of the bar has weight density γ.

(a) Derive a formula for the tensile stress σ_x in the bar as a function of the distance x from the midpoint C.

(b) What is the maximum tensile stress σ_{max}?



Review Questions

1.3-11 An L-shaped reinforced concrete slab 3.6 m × 3.6 m (but with a 1.8 m × 1.8 m cut-out) and thickness t = 230 mm, is lifted by three cables attached at O, B and D, as shown in the figure. The cables are combined at point Q, which is 2.1 m above the top of the slab and directly above the center of mass at C. Each cable has an effective cross-sectional area of $A_e = 77\ \text{mm}^2$.

(a) Find the tensile force T_i (i = 1, 2, 3) in each cable due to the weight W of the concrete slab (ignore weight of cables).

(b) Find the average stress σ_i in each cable. (See Table H-1 in Appendix H for the weight density of reinforced concrete.)

(c) Add cable AQ so that OQA is one continuous cable, with each segment having force T_1, which is connected to cables BQ and DQ at point Q. Repeat parts (a) and (b). (*Hint*: There are now three force equilibrium equations and one *constraint equation*, $T_1 = T_4$.)