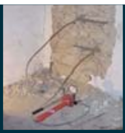  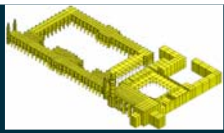  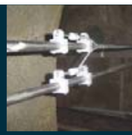 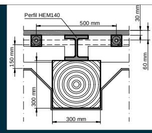

STRENGTH OF MATERIALS - I

CE-205

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CE - 205: INTRODUCTION TO STRENGTH OF MATERIALS

COURSE INTRODUCTION

NUST

Strength of Materials (SOM-I)
(CE- 205)

Periods
Theory =32
Practical =48
Total =80

Credit Hrs
Theory =2
Practical =1
Total =3

Simple Stress and Strain
Kinds of stresses and strains. Load extension diagrams for different materials. Hook's law. Moduli of elasticity. Lateral strain. Volumetric strain. Poisson's ratio. Temperature stresses and compound bars.

Stresses in beams
Theory of simple bending. Moment of resistance and section modulus. Application of flexure formula. Shear stresses in beams. Shear center. Shear flow.

Columns and Struts
Axially loaded columns. Euler's treatment. Rankine Gordon formula for short and intermediate columns. Slenderness ratio.

Circular shafts
Theory of torsion for solid and hollow circular shafts.

Springs
Open coil springs, closed coil springs, leaf springs.

Strain Energy
Strain energy due to direct loads, force, bending moment and torque. Stresses due to impact loads.

Recommended Books
Strength of Material by Pytel. A & F.L.Singer Harper & Row Publishers, Timoshinko, Popov, Boresi,

NUST

Course Objectives

Upon successful completion of this course, students should be able to:

(i) Understand and solve simple problems involving stresses and strain in two and three dimensions.

- (ii) Understand the difference between statically determinate and indeterminate problems.
- (iii) Understand and carry out simple experiments illustrating properties of materials in tension, compression as well as hardness and impact tests.

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COURSE OBJECTIVES CONTD.

(iv) Analyze stresses in two dimensions and understand the concepts of principal stresses and the use of Mohr circles to solve two-dimensional stress problems.

(v) Draw shear force and bending moment diagrams of simple beams and understand the relationships between loading intensity, shearing force and bending moment.

(vi) Compute the bending stresses in beams with one or two materials.

OBJECTIVES CONCLUDED

(vii) Calculate the deflection of beams using the direct integration and moment-area method.

(viii) Apply sound analytical techniques and logical procedures in the solution of engineering problems.

Teaching Strategies

- The course will be taught via Lectures. Lectures will also involve the solution of tutorial questions. Tutorial questions are designed to complement and enhance both the lectures and the students appreciation of the subject.
- Course work assignments will be reviewed with the students.

CHAPTER ONE

STRESS AND STRAIN RELATIONS

Chapter 1 Simple Stress and Strain

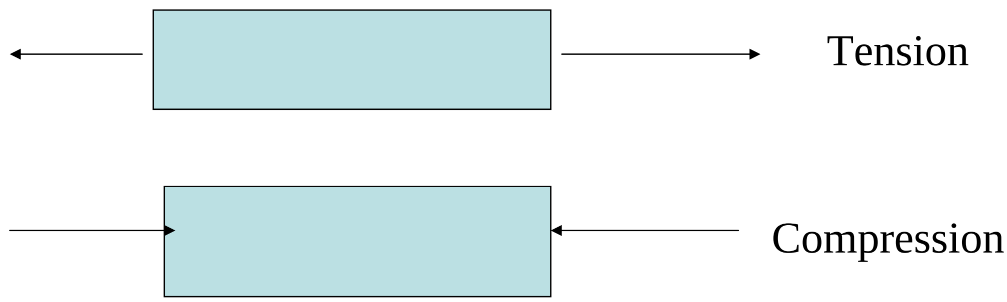
Kinds of stresses and strains.
Load extension diagrams for different materials.
Hook's law.
Moduli of elasticity.
Lateral strain.
Volumetric strain.
Poisson's ratio.
Temperature stresses and compound bars.

1.1 DIRECT OR NORMAL STRESS

- When a force is transmitted through a body, the body tends to change its shape or deform. The body is said to be strained.
- Direct Stress = $\dfrac{\text{Applied Force (F)}}{\text{Cross Sectional Area (A)}}$
- **Units:** Usually N/m^2 (Pa), N/mm^2, MN/m^2, GN/m^2 or N/cm^2
- **Note:** $1\ N/mm^2 = 1\ MN/m^2 = 1\ MPa$

Direct Stress Contd.

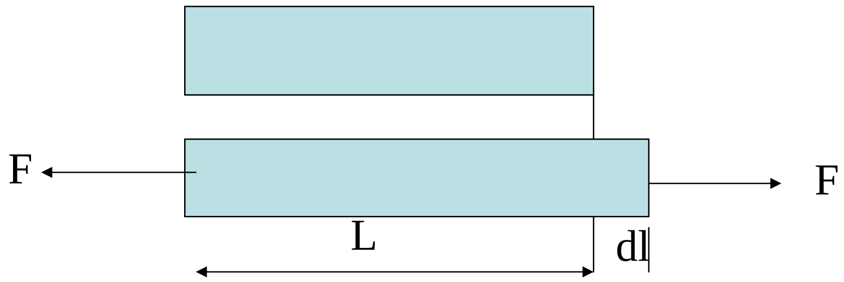
- Direct stress may be tensile, σ_t or compressive, σ_c and result from forces acting perpendicular to the plane of the cross-section



1.2 Direct or Normal Strain

- When loads are applied to a body, some deformation will occur resulting to a change in dimension.
- Consider a bar, subjected to axial tensile loading force, F. If the bar extension is dl and its original length (before loading) is L, then tensile strain is:

Direct or Normal Strain Contd.



- Direct Strain (ε) = Change in Length / Original Length

i.e. ε = dl/L

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Direct or Normal Strain Contd.

- As strain is a ratio of lengths, it is dimensionless.
- Similarly, for compression by amount, dl: Compressive strain = - dl/L
- **Note:** Strain is positive for an increase in dimension and negative for a reduction in dimension.

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Simple Stresses

Simple stresses are expressed as the ratio of the applied force divided by the resisting area or

$$\sigma = \text{Force} / \text{Area}.$$

It is the expression of force per unit area to structural members that are subjected to external forces and/or induced forces. Stress is the lead to accurately describe and predict the elastic deformation of a body.

Simple stress can be classified as normal stress, shear stress, and bearing stress. **Normal stress** develops when a force is applied perpendicular to the cross-sectional area of the material. If the force is going to pull the material, the stress is said to be **tensile stress** and **compressive stress** develops when the material is being compressed by two opposing forces. **Shear stress** is developed if the applied force is parallel to the resisting area. Example is the bolt that holds the tension rod in its anchor. Another condition of shearing is when we twist a bar along its longitudinal axis.

This type of shearing is called torsion and covered in Chapter 3. Another type of simple stress is the **bearing stress**, it is the contact pressure between two bodies.

Suspension bridges are good example of structures that carry these stresses. The weight of the vehicle is carried by the bridge deck and passes the force to the stringers (vertical cables), which in turn, supported by the main suspension cables. The suspension cables then transferred the force into bridge towers.

Normal Stress

Stress

Stress is the expression of force applied to a unit area of surface. It is measured in psi (English unit) or in MPa (SI unit). Another unit of stress which is not commonly used is the dynes (cgs unit). Stress is the ratio of force over area.

stress = force / area

Simple Stresses

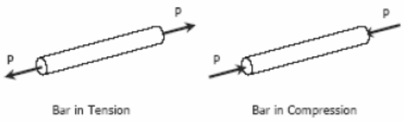
There are three types of simple stress namely; normal stress, shearing stress, and bearing stress.

Normal Stress

The resisting area is perpendicular to the applied force, thus normal. There are two types of normal stresses; tensile stress and compressive stress. Tensile stress applied to bar tends the bar to elongate while compressive stress tend to shorten the bar.

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

where P is the applied normal load in Newton and A is the area in mm^2. The maximum stress in tension or compression occurs over a section normal to the load.



Problem 104

A hollow steel tube with an inside diameter of 100 mm must carry a tensile load of 400 kN. Determine the outside diameter of the tube if the stress is limited to 120 MN/m^2.

Solution 104

$P = \sigma A$

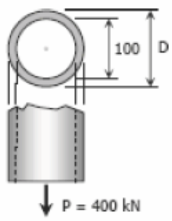
where:

$P = 400\text{ kN} = 400\,000\text{ N}$

$\sigma = 120\text{ MPa}$

$A = \frac{1}{4}\pi D^2 - \frac{1}{4}\pi(100^2)$

$= \frac{1}{4}\pi(D^2 - 10\,000)$



thus,

$400\,000 = 120[\frac{1}{4}\pi(D^2 - 10\,000)]$

$400\,000 = 30\pi D^2 - 300\,000\pi$

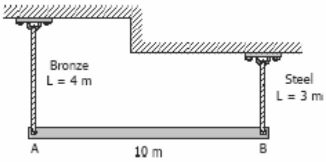
$D^2 = \dfrac{400\,000 + 300\,000\pi}{30\pi}$

$D = 119.35\text{ mm}$

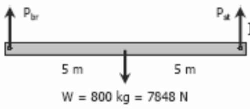
Problem 105

A homogeneous 800 kg bar AB is supported at either end by a cable as shown in Fig. P-105. Calculate the smallest area of each cable if the stress is not to exceed 90 MPa in bronze and 120 MPa in steel.

Figure P-105



Solution 105



By symmetry:

$P_{br} = P_{st} = \frac{1}{2}(7848)$

$= 3924 \text{ N}$

For bronze cable:

$P_{br} = \sigma_{br} A_{br}$

$3924 = 90 A_{br}$

$A_{br} = \mathbf{43.6 \text{ mm}^2}$

For steel cable:

$P_{st} = \sigma_{st} A_{st}$

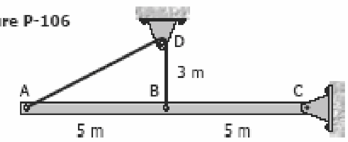
$3924 = 120 A_{st}$

$A_{st} = \mathbf{32.7 \text{ mm}^2}$

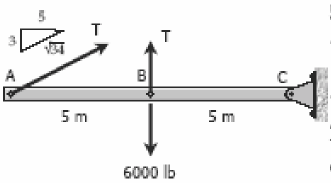
Problem 106

The homogeneous bar shown in Fig. P-106 is supported by a smooth pin at C and a cable that runs from A to B around the smooth peg at D. Find the stress in the cable if its diameter is 0.6 inch and the bar weighs 6000 lb.

Figure P-106



Solution 106



$\Sigma M_C = 0$

$5T + 10(\frac{3}{\sqrt{34}} T) = 5(6000)$

$T = 2957.13 \text{ lb}$

$T = \sigma A$

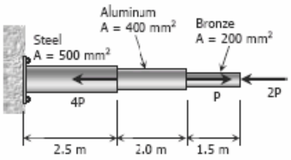
$2957.13 = \sigma[\frac{1}{4}\pi(0.6^2)]$

$\sigma = \mathbf{10\,458.72 \text{ psi}}$

Problem 108

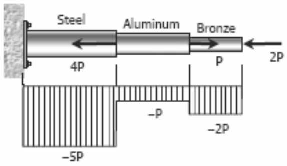
An aluminum rod is rigidly attached between a steel rod and a bronze rod as shown in Fig. P-108. Axial loads are applied at the positions indicated. Find the maximum value of P that will not exceed a stress in steel of 140 MPa, in aluminum of 90 MPa, or in bronze of 100 MPa.

Figure P-108



Solution 108

For bronze:
$\sigma_{br} A_{br} = 2P$
$100(200) = 2P$
$P = 10\,000$ N



For aluminum:
$\sigma_{al} A_{al} = P$
$90(400) = P$
$P = 36\,000$ N

For Steel:
$\sigma_{st} A_{st} = 5P$
$P = 14\,000$ N

For safe P, use $P = 10\,000$ N $= 10$ kN

Problem 110

A 12-inches square steel bearing plate lies between an 8-inches diameter wooden post and a concrete footing as shown in Fig. P-110. Determine the maximum value of the load P if the stress in wood is limited to 1800 psi and that in concrete to 650 psi.

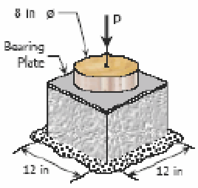
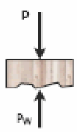


Figure P-110

Solution 110

For wood:
$P_w = \sigma_w A_w$
$= 1800[\frac{1}{4}\pi(8^2)]$
$= 90\,477.9$ lb

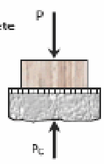
FBD of Wood



From *FBD* of Wood:
$P = P_w = 90\,477.9$ lb

For concrete:
$P_c = \sigma_c A_c$
$= 650(12^2)$
$= 93\,600$ lb

FBD of Concrete



From FBD of Concrete:
$P = P_c = 93\,600$ lb

Safe load $P = 90\,478$ lb