INTRODUCTION TO STRENGTH OF MATERIALS FOR ENGINEERING STUDENTS

PROPERTIES OF ENGINEERING MATERIALS

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Introduction

A structural designer requires knowledge of behaviour of materials under different types of load before he can be reasonably sure of designing a safe and, at the same time cost effective structure.

One of the most important properties of materials is its strength by which we mean the value of stress at which it fractures. Equally in many instances, particularly in elastic design,

PROPERTIES OF ENGINEERING MATERIALS (Cont.)

It is the stress at which yielding begins.

In addition, the designer must have knowledge of the stiffness of a material so that he can prevent excessive deflections from occurring, which could cause damage to adjacent structural members. Other factors, which must be taken into consideration in design, include the character of the different loads.

It is a common experience for example that a material such as cast iron fractures readily

PROPERTIES OF ENGINEERING MATERIALS (Cont.)

Under a sharp blow where a mild steel merely bends.

Therefore, we shall examine some of the properties of engineering materials and the method used to determine them. We shall also discuss the important materials used in engineering works with some references to their different functions.

PROPERTIES OF ENGINEERING MATERIALS (Cont.)

The basic and most widely used materials in Engineering construction are steel in its various forms and concrete. Steel is fabricated into a variety of structural shapes for use as beams, columns, plate connectors and to act as reinforcement in the comparatively weak tensile zones of concrete beams.

Concrete itself is used in the construction of beams, columns, floor slabs and foundation.

PROPERTIES OF ENGINEERING MATERIALS (Cont.)

Generally as we have noted, structural concrete is reinforced by steel bars in its weak tensile zones and it is sometimes used to encase columns as a precaution against fire damage. Instances of un-reinforced structural concrete are few and are usually restricted to gravity structures such as dams and comparatively lightly loaded foundations.

PROPERTIES OF ENGINEERING MATERIALS (Cont.)

In addition to steel and concrete, timber is employed extensively in Civil Engineering as framework during the construction of concrete structures as a structural material in light roof tissues and decorative beams. Frequently, timber beams and arches are laminated to eliminate the less desirable characteristics of timber such as cracking, shrinkage and warping. Non-structurally, timber is found in floors, ceiling, wall panels etc.

CLASSIFICATION OF ENGINEERING MATERIALS

Engineering materials may be grouped into two distinct categories, ductile materials and brittle materials, which exhibit very different properties under load. We shall define the properties of ductility and brittleness and also some additional properties, which may depend on, the applied load of which is basic characteristics of the material.

CLASSIFICATION OF ENGINEERING MATERIALS (Cont.)

1. Ductility: a material is said to be ductile if it is capable of withstanding large strains under load before fracture occurs. These large strains are accompanied by a visible change in cross-sectional dimensions and therefore give warning of impeding failure. Materials in these categories include mild steel, aluminium and some of its alloys, copper and polymers.

CLASSIFICATION OF ENGINEERING MATERIALS (Cont.)

2. Brittleness: A brittle material exhibits little deformation before fracture, the strain normally being below 5%. Brittle materials therefore may fail suddenly without visible warning. Included in this group are concrete, cast iron, high strength steel, timber and ceramics.

CLASSIFICATION OF ENGINEERING MATERIALS (Cont.)

3. Elastic Materials: A material is said to elastic if deformations disappear completely on removal of the load. All known engineering materials are linearly elastic within certain limits of stress so that strain within these limits is directly proportional to stress. E.g. Natural and Synthetic rubber materials.

CLASSIFICATION OF ENGINEERING MATERIALS (Cont.)

4. <u>Plasticity:</u> A material is perfectly plastic if no strain (deformation) disappears after the removal of load. Ductile materials are elastoplastic and behave in an elastic manner until the elastic limit is reached after which they behave plastically. When the stress is relieved, the elastic component of the strain is recovered but the plastic strain is relieved. E.g. Acetal, Acrylic, Polyethylene, Polystyrene

CLASSIFICATION OF ENGINEERING MATERIALS (Cont.)

5. Isotropic materials: In many materials, the elastic properties are the same in all directions at each point in the material although they may vary from point to point. Such a material is said to be isotropic. An isotropic material having the same properties at all point is known as homogenous. E.g. Mild Steel and Glass.

CLASSIFICATION OF ENGINEERING MATERIALS (Cont.)

6. Anisotropic materials: Materials having varying elastic properties in different directions are said to be anisotropic. E.g. Wood and Composites.

7. Orthotropic materials: Although a structural material may possess different elastic properties in different directions, this variation may be limited as in the case of timber,

CLASSIFICATION OF ENGINEERING MATERIALS (Cont.)

Which has just two values of Young's modulus, one in the direction of the grain and one perpendicular to the grain.

A material whose elastic properties are limited to three different values in three mutually perpendicular directions is known as Orthotropic. E.g. Wood, rolled metals and Crystalline materials.

TESTINGOF ENGINEERING MATERIALS

The properties of engineering materials are determined mainly by the mechanical testing of specimens machined to prescribed sizes and shapes. The testing may be static or dynamic in nature depending on the particular property being investigated. Possibly the most common mechanical static tests are tensile and compressive tests which are carried out on a wide range of materials.

Ferrous and Non-ferrous metals are subjected to both forms of tests while compression tests are carried out on many non-metallic materials such as concrete,

TESTINGOF ENGINEERING MATERIALS (Cont.)

timber and brick, which are normally used in compression. Other static tests include bending shear and hardness tests while the toughness of a material, in other words which is its ability to withstand shock loads, is determined by impact tests.

1. Tensile tests: these are normally carried out on metallic materials and timber. Test pieces are machined from a batch of material, their

TESTINGOF ENGINEERING MATERIALS (Cont.)

Dimensions being specified by Codes of Practice. They are commonly circular in cross-section, although flat test pieces having rectangular cross-sections are used when the batch of material is in the form of plate. Before the test begins the mean diameter of the test piece is obtained by taking measurements at several sections using a micrometer screw gauge.

TESTINGOF ENGINEERING MATERIALS (Cont.)

Gauge points are punched at the required gauge length, the test piece is placed in the testing machine and a suitable strain measuring device usually an extensometer is attached to the test piece at the gauge points so that the extension is measured over the given length.

2. Compression Test: This is similar in operation to a tensile test with the obvious difference that the load transmitted to the test

TESTINGOF ENGINEERING MATERIALS (Cont.)

Piece is compressive rather than tensile. This is achieved by planning the direction of loading. Test pieces are normally cylindrical and limited in length to eliminate the possibility of failure being caused by instability. Contractions are also measured over a given gauge length by a suitable strain measuring device.

3. Bending tests: Many structural members are subjected primarily to bending moments.

TESTINGOF ENGINEERING MATERIALS (Cont.)

Bending tests are therefore carried out on simple beams constructed from the different materials to determine their behaviour under this type of load.

4. Shear tests: two main types of shear test are used to determine the shear prperties of materials. One type investigates the direct or transverse shear strength of a material and is used in connection with the shear strength on

TESTINGOF ENGINEERING MATERIALS (Cont.)

Bolts, rivets and beams. The other type of shear test is used to evaluate the basic shear properties of a material such as the shear modulus, G, the shear stress at yield and the ultimate shear stress.

5. Hardness tests: the machinability of a material and its resistance to scratching or penetration are determined by its 'hardness'. Hardness tests are also used to investigate the effects of heat treatment, hardening and

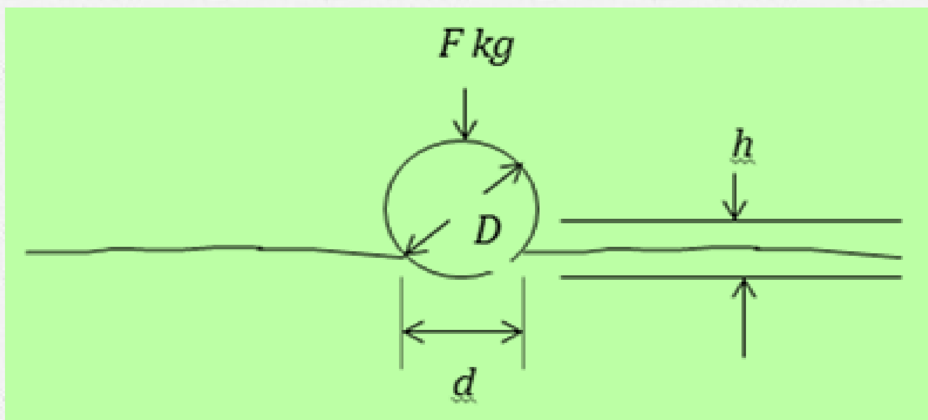
TESTINGOF ENGINEERING MATERIALS (Cont.)

Tempering . Two types of hardness tests are in common use; indentation tests, scratch and abrasion tests. Indentation tests may be subdivided into two classes, static and dynamic. Of the static tests, the Brinell is the most common. In this test, a hardened steel ball is pressed into the material under test by static load acting for a fixed period of time. The load in kg divided by the spherical area of the indentation in mm^2 is called the Brinell

TESTINGOF ENGINEERING MATERIALS (Cont.)

Hardness Number (BHN).

$$\text{BHN}= \frac{F}{\pi D h} = \frac{2F}{\sqrt{}\pi D[D-D2-d2]}$$



TESTING OF ENGINEERING MATERIALS (Cont.)

6. Impact tests: it has been found that certain materials, particularly heat treated steels, are susceptible to failure under shock loading whereas an ordinary tensile test on the same material would show no abnormality. Impact tests measure the ability of materials to withstand shock loads and provide an indication of their toughness. Two main tests are used here, the izod and the Charpy.

Assignment 1

A. Explain briefly the following types of loads:

1. Axial Loads
2. Shear Loads
3. Bending moments
4. Torsion

B. What is Cantilever?