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**Department of Civil Engineering**

**CVE 204 – Strength of Materials**

**1.0 Concept of Stress and Strain**

**1.1 Stress**

External forces (dead, imposed, wind, etc.) acting on a rigid body are termed loads. For elastic material, these forces **deforms** the body and sets up **internal resistance** to the deforming forces.

The resisting forces are called **stresses**, and the deformation (elongation or shortening) is called the **strain**.

Stress σ

* Defined as load (P) per unit area (A)

σ = $\frac{P}{A}$ **1**

 where P = applied load (N, KN), and

A = cross sectional area of the loaded section

The unit of stress =

**1.1.1 Types of Stresses**

1. Normal stress – act normal to the stressed surface area under consideration. Normal stress is of two forms:
	* Tension
	* Compression
2. Shear Stress ($τ)$

Shearing stress – this is a stress that acts tangentially to the stressed surface under consideration

Consider two plates A and B joined together by a rivet connection and subjected to a tensile load P

The joint can fail if the rivet shears as shown

**The shear stress** $τ= \frac{P}{A}$

It should be pointed out here that applied load is tangential to the resisting area. That is the forces act parallel to the resisting area/surfaces. Thus shear stress is also called **tangential stress**.

The tensile and compressive stresses on the other hand are caused by forces acting perpendicular to the areas resisting the forces. Tensile and compressive stresses are called **normal stresses**

**1.2 Strain**

Tensile and Compressive Strain

Strain is the measure of the deformation of produced in a member by the applied load. This strain could be **tensile or compressive** depending on the type of the applied load.

It δl is the change in length of a material of length l due to the applied load, the strain ɛ, is given by:

 ɛ = $\frac{δl}{l}$ **2**

The strain may be assumed to be constant across the cross section the following conditions are satisfied:

1. The specimen is of constant cross section
2. The material is homogeneous
3. The applied load is axial (so as to produce a uniform stress)

Shear Strain ($φ$)

This is the strain/displacement caused by forces in the direction of the force.

Consider the diagram below

Shear strain is defined as the deformation caused by shear force per unit height or length. That is,

 $φ= \frac{LL}{BL}= \frac{MM}{BM}= \frac{CC}{BC} tanφ= φ $(for small values of $φ, tanφ= φ$)

**1.3 Stress-Strain Relationship for Steel**

The behaviour of materials subjected to tension is studied by plotting the stress against the corresponding strain observed by gradual application of loads. Such curves differ for different material. The curve for ductile and brittle material are shown below.

***1.3.1 Stress-Strain curve for Ductile Material***

This is the stress-strain curve.

* The curve is linear up to a value, known as the yield point (stress at this point is the yield stress).
	+ This is the elastic range
	+ Stress is proportional to the strain
	+ The bar will return to original length when unloaded
	+ The slope of the stress-strain curve in the elastic range is called the modulus of elasticity or Young’s modulus (E).
		- Structural steel has E = 205 KN/mm2.
* Beyond this point, the steel rod deforms in-elastically on increase in ,load
	+ This is the plastic range
	+ The strain is permanent after unloading as the material does not return to its original length. .
	+ This occurs until the material yield at **C**. The Stress here is the Yield Stress.
* Beyond the yield point, the material deform without increase in load
* D is the ultimate tensile strength of the steel
* E is the breaking point when the area is reduced

The above diagram is characteristic of mild steel. For other type of grades of steel, variations in regions are to be expected.

**Hooke’s Law**

States that within elastic limit, for materials subjected the simple tension or compression, the stress is proportional to the strain. That is:

 E = $\frac{σ}{ɛ}$ **3**

E = the constant called Young’s modulus of elasticity. Unit = N/mm2, N/cm2, etc.

**Change in Length of a member due to application of Load**

In other to find the change in length when a member is subjected to load, equation 1, 2, and 3 can be combined as follows

:

 E = $\frac{\frac{P}{A}}{\frac{δl}{l}}$

 Simplifying gives

 δl = $\frac{PL}{AE}$ **4**

equation 4 is used to find the elongation in a memebr

***1.3.1. 2Stress-Strain curve for Brittle Material***

Materials that exhibit absence of ductility.

 It breaks under tension or impact

Has low proportional point

Do not show yield point

Tensile Strength

The stress-strain curve for steel is generally obtained from the test performed on standard steel specimens, from which tensile strength can be determined. The tensile strength is calculated on the net cross-sectional area of the member

 σ = $\frac{P}{A}$

Other properties that can be obtained from tensile strength test includes: hardness of steel and shear strength, modulus of elasticity.

All structural steel has practically the value of modulus of elasticity (= 205 KN/mm2 or 2.1 x 105MPa).

Compressive Strength

Careful test have shown that stress-strain curves for mild, high yield and higher steel in compression are in fact similar to the one in tension up to the point of maximum stress. This property greatly simplifies design procedures and permitted in many cases, the use of geometrically symmetrical section, especially in bending.

**Complimentary Shear Stress**

A shear stress in one place on a block in equilibrium is automatically accompanied by an equal and opposite shear stress known as complimentary shear stress in another place perpendicular to the first plane.

**Modulus of Rigidity (G)**

For elastic materials, it has been found out that the shear strain is directly proportional to the shear stress producing it. The ratio of shear stress to shear strain is called the modulus of rigidity G. That is:

 G = $\frac{τ}{φ}$

The unit is for the shear stress (N/mm2)

Thus shear stress needed to produce a unit shear strain is called the modulus of rigidity.

* 1. **Worked Examples – Stresses and Strains**

1.4.1 Constant section

* + 1. Varying Cross section
		2. Principle of Superposition

1.4.4. Tapering Cross section

* + 1. Composite Sections

1.4.6. Temperature Stresses

**Factor of Safety**

There are so many uncertainties that engineers encounter in practice. First, for engineering members, it is practically impossible to determine with accuracy, either the external loads or the internal forces that such material will be subjected to. Also the quality of materials used can vary. Workmanship can also fall below the expected standard. Thus, to allow these uncertainties, it is desirable to allow a margin of strength above and over that which calculations showed to be sufficient. This allowance is introduced by applying either factor of safety or a load factor.

The stress/strain curve of a material gives a valuable information on how to determine the factor of safety. By knowing the elastic limit, yield point and ultimate stress in material, it is easy to establish the magnitude stress that is safe. This is done by keeping the safe stress well below the elastic limit. This safe stress is called the working stress. The ratio of elastic stress to the **working stress** is called the factor of safety

 Factor of Safety = $\frac{elastic limit}{working stress}$

 {\displaystyle {\text{Factor of safety}}={\frac {\text{yield stress}}{\text{working stress}}}}