TOPIC: MECHANICS AND PROPERTIES OF MATTER

General Objective: The Learner should be able to use properties of materials in explaining and designing structures

SUB-TOPICS:

- **Properties of materials under stress.**
- **Bending beams and effect of shapes.**
- **Structures**

MECHANICAL PROPERTIES OF MATERIALS

This deals with the behaviour materials used in construction of structures like bridges, dams, pillars, roof structures, vehicles, bicycles, etc. when acted upon by forces.

Examples of common materials used in construction include:

- Timber
- Metals
- Glass
- Plastics
- Rubber
- Concrete
- Bricks

Before materials are put to use, it is necessary to test whether the finished structure will withstand the weather conditions and forces which they will be subjected to.
These conditions are known as **mechanical properties** of materials.

Some mechanical properties include:

- Strength
- Stiffness
- Ductility
- Brittleness
- Elasticity
- Plasticity
- Hardness

Strength;

It is the ability of material to withstand large forces before breaking.
The material which has this property is said to be strong e.g concrete, metals etc.

Factors affecting strength of a material:

	Factor	**Effect**
1	Cross-sectional area/thickness/diameter of the material	The strength of the material increases with increase in cross-sectional area.
2	Nature of the material	Strength varies from material to material.
3.	Magnitude of applied force.	Small forces are easier to withstand than larger forces.

Stiffness;

It is the property of material that makes it resist being bent.
Materials with this property are said to be stiff e.g. steel, iron and concrete.

Ductility;
It is a property of materials that makes it possible to be molded it into different shapes and sizes or rolled into sheets, wires or useful shapes without breaking.
Materials which have this property are called **ductile materials** e.g.
Copper wire, Soft iron wire, e.t.c.

Brittleness;
This is the property of a material that makes it break suddenly when a force is applied on it.
Materials which have this property are called brittle materials e.g. bricks, chalks, glass, charcoal etc.

Properties of brittle materials:
(i) Can bend very little and suddenly break without undergoing plastic deformation.
(ii) Cannot be moulded into other shapes.
(iii) They are strong under compression but very weak under tension.
(iv) When a brittle material breaks, its pieces can be fitted back together almost exactly and can be glued back.

Elasticity;
This is property that makes material stretch when force is applied on it and regains original size and shape when the force is removed. Materials with this property are called elastic materials e.g. rubber, copper spring etc.

Plasticity;
This is the property which makes materials to stay permanently deformed even when the applied force causing the deformation is removed. Materials which have this property are called plastic materials e.g. plasticine, clay, putty or tar etc.

Hardness;
This is a measure of how difficult it is to scratch a surface of a material. Hard materials include; metals, stones etc.

CONSTRUCTION MATERIALS;
These include concrete, bricks, glass, timber, iron bars, iron sheets etc.

TIMBER AS A BUILDING MATERIAL;
It is used for making furniture, walls, bodies of vehicles, bridges, making ceilings etc.

Advantages	**Disadvantages**
It is cheap	Can get rotten
It is durable when seasoned and treated	It is not fire resistant
It is easy to work with.	Needs treating and seasoning.

Mechanical properties;
It is strong, stiff and somehow hard.

BRICKS AND BLOCKS AS BUILDING MATERIALS.

These are stony materials.

Bricks and blocks are used for construction of bridges, walls, floors etc.

Mechanical properties;

Bricks and blocks are

- hard
- strong under compression
- stiff.

Advantages; - They are cheap, durable, and easy to work with.

Disadvantages; - They are brittle.

GLASS AS A BUILDING MATERIAL

Glass is used as a building material because it has a number of desirable properties which include;

- It is transparent.
- Few chemicals react with it.
- It can be melted and formed into various shapes.
- Its surface is hard and difficult to scratch.
- It can be reinforced (strengthened).

Disadvantage: Glass is brittle.

CONCRETE

A concrete is a mixture of cement, sand and gravel (small stones) with water.

Concrete is strong under compression but weak under tension. It can withstand tensional forces when it is reinforced.

Reinforced concrete;

- Wet concrete is poured on steel rods when it dries; it gets stuck on the rods which are strong under tension. This forms a rein forced concrete.
- It can also be re-in forced by putting fibre in concrete when it is wet and leave it to harden.

Other reinforcing materials include;

- Bamboo stripes
- Wood stands
- Metal rods and wire mesh.

Advantages of reinforced concrete;

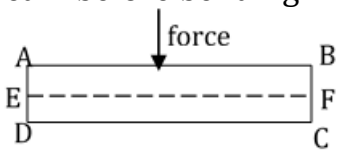
- It is weather resistant.
- It does not need firing and it is fire resistant.
- It is ductile when still wet.
- It is durable.
- It has a high tensile strength.
- It is stiff or tough.

Advantages of concrete over bricks;

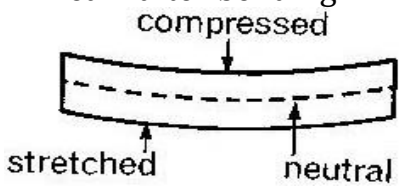
- Concrete can be molded in various shapes.
- Concrete does not need firing.
- Concrete is weather resistant.
- Concrete can have a range of properties depending on the proportion of the mixture.
- Concrete can be used to fill holes of different shapes.

BEAMS:
A beam is a long piece of materials e.g. wood, metal, concrete etc.
It is usually horizontal and supported at both ends. It carries the weight of the part of the building or other structures.
When a force is applied on a beam it **bends** in a way that one side of the beam is compressed (under compression), while its opposite side is stretched (under tension). However, its centre is un stretched (neutral).

(a) Beam before bending:



(b) Beam after bending.

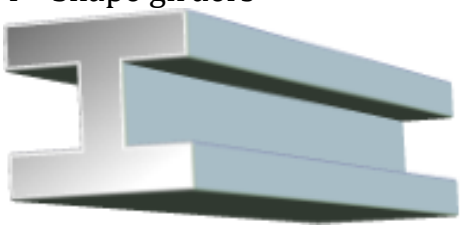


EF – is the neutral axis
AB – Under compression
DC – Under tension
EF – Unstretched i.e. it neither under tension nor compression.

Neutral axis/plane of a beam:- this is the central region of a beam that is neither under tension nor compression when forces are applied to the beam.

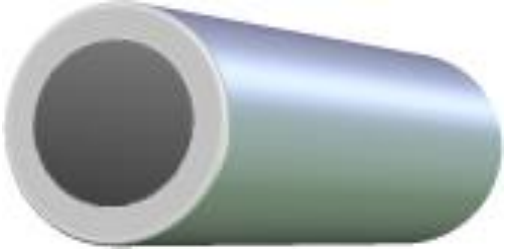
The neutral axis of beam does not resist any forces and can therefore be removed without weakening the beam.

GIRDERS: A girder is a beam in which the material's neutral axis can be removed.
Examples of Girders;
(i) I – Shape girders

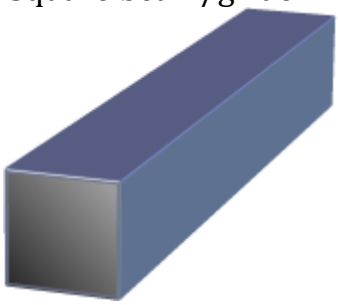


This I – shaped girder is used in construction of large structures like bridges.

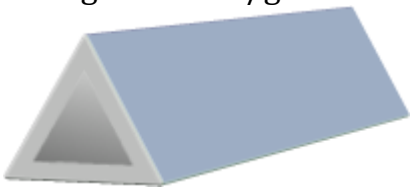
(ii) Hollow tube/girder (hollow cylinder)



(iii) Square beam/girder



(iv) Triangular beam/girder

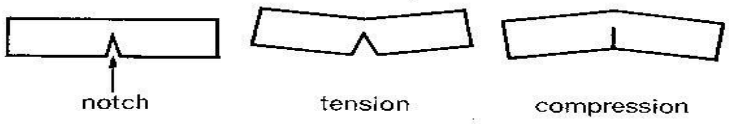


(v) L – Shaped girder.

Advantages of hollow beams:
The pipes used for construction of structures like bicycles, bridges e.t.c. are made hollow because hollow beams:
- are light.
- are economically cheap since less material is used for construction.
- are stronger under both compression and tension.
- Notches do not spread easily so there is less risk of breaking.
- Can expand and contract easily.

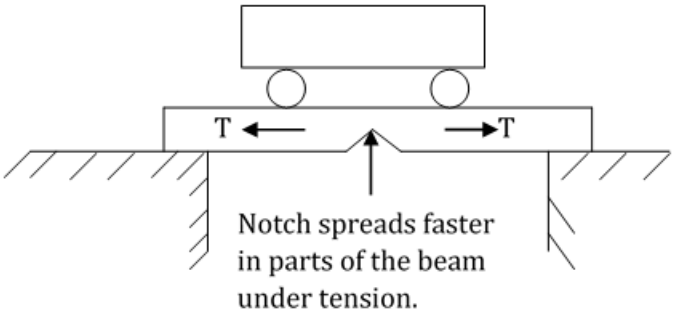
Disadvantages of solid beams
- They are heavy.
- They are economically expensive
- They are weak.

NOTCH AND NOTCH EFFECT:
A **notch** is a cut on a weak point on a material.
or
A **notch** is a small V-shaped or circular cut in the surface or edge of a material.



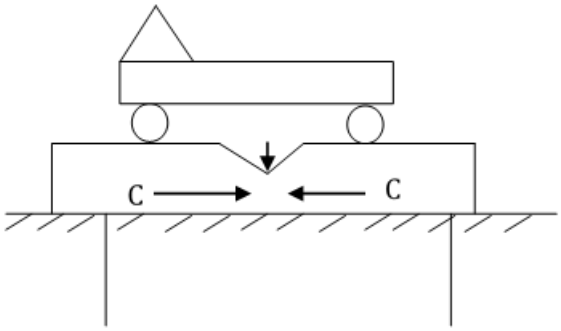
A notch weakens the strength of a material when it is the region of tension than when it is under compression.
A notch, crack or scratch on the surface of a material spreads more easily under tensile forces than compression forces.

(a)



The beam breaks easily when the car crosses the bridge because the notch is in the region of tension and therefore it weakens the beam.

(b)



The beam does not break easily when the car crosses.

Notch effect: This is the effect that the notch has on the strength of the material i.e. the notch weakens the strength of the material.

WAYS OF REDUCING NOTCH EFFECT:

- Designing the structures in such way that all its parts are under compression.
- Making the surface of the construction material smooth.
- Use of laminated rather solid materials in construction.
- Making the notch blunt.

STRUCTURES:

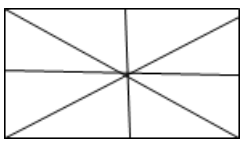
A structure consists of pieces of materials joined together in a particular way.
The pieces of materials used to strengthen structures are collectively called girders.

Shape and strength of structures

There are many types of shapes of structures in common use. The type and shape of a structure determine it's strength. Some common shapes used in structures are triangular, dome, T and L-shapes.
Triangular structures are more rigid than others. **Therefore, rectangular structures can be made rigid by adding a diagonal piece(s) to change it into two or more triangular structures**.

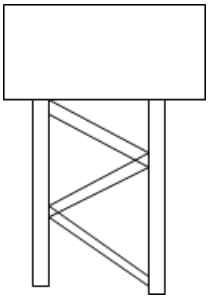
(a)

(b)

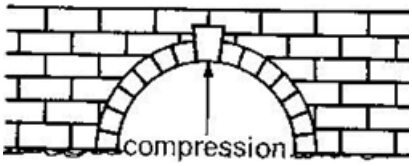


Examples of structures;

(i) Stands of water tank.

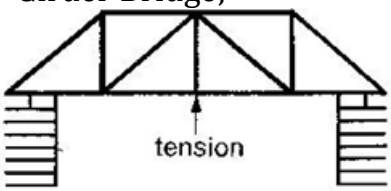


(ii) Arched bridge



Both the upper and lower parts of the bridge are under compression. The bridge is weak under tension.

(iii) Girder Bridge;

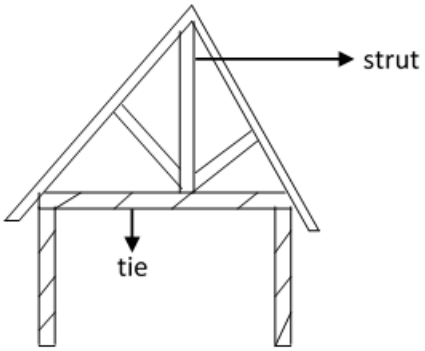


STRUTS AND TIES:

Tie: A tie is a girder under **t**ension.
It can be replaced by a string.

Strut: A strut is a girder under compression.

Roof structure

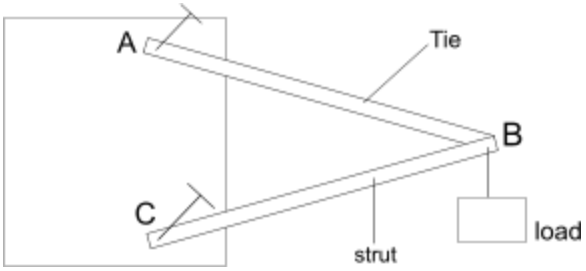


HOW TO IDENTIFY STRUTS AND TIES IN A STRUCTURE.

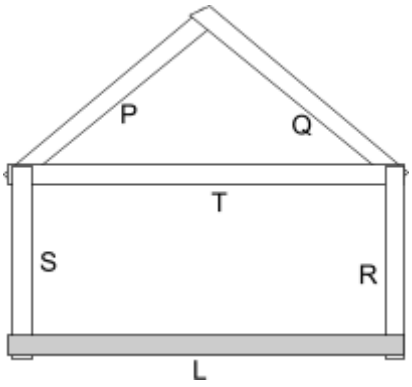
- Remove each of the girder one at a time from the structure of the frame work and observe the effect it causes on the frame work is noted.
- If the frame work moves further apart, the girder is a tie otherwise the girder is a strut.

Experiment to distinguish between a tie and a strut.

Two straws are fixed on the side of a piece of soft board.
A small load is added at the end B. The structure supports the load.
The straw AB is now replaced by the string of the same length.
If the structure still supports the load, then AB is under tension hence it is a tie.
Similarly, straw AB is then replaced with the string of the same length. If the structure does not support the load and it collapses then AB was under compression and it is a strut.

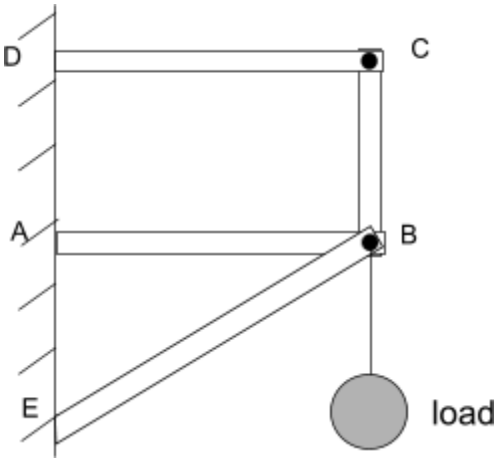


Example;
In the frame work below, identify the struts and ties.
(a)

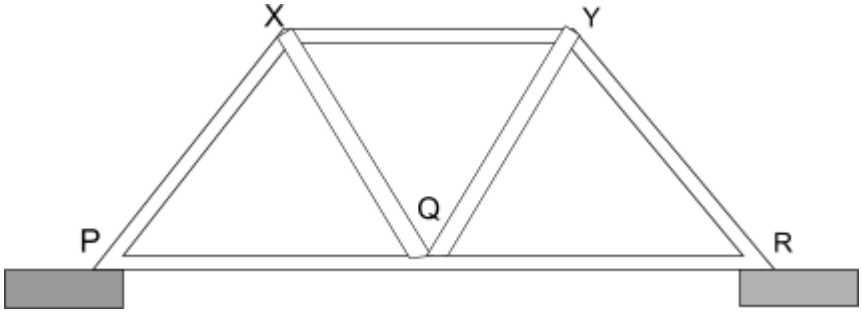


T – Tie P – Strut S- Strut
Q – Strut L – Tie R- Strut

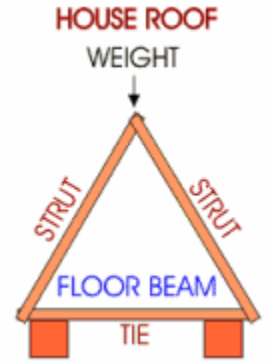
(b)

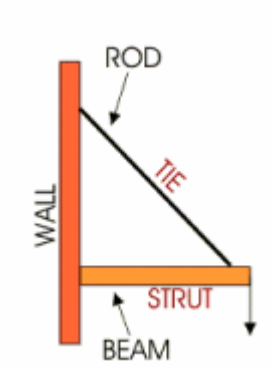


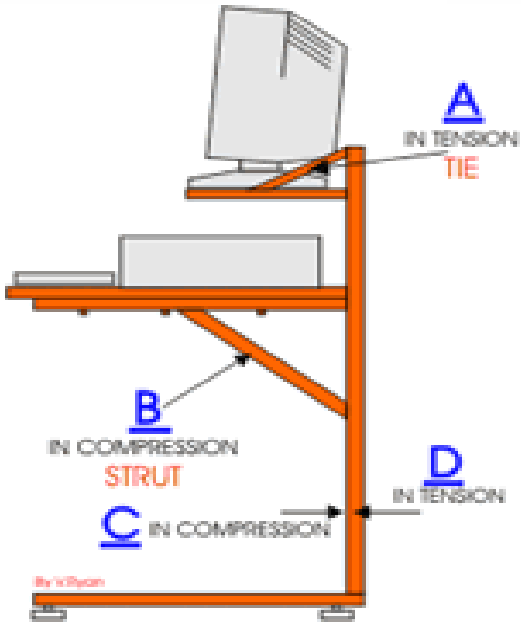
EB, CB, AB – struts
Ties DC



Struts:	Ties:
XY	XQ
XP	QY
PR	
YR	
PQ	
QR	







TENSILE STRESS

This is the force per unit area.

$$\text{Tensile stress} = \frac{\text{Force}}{\text{Area}}$$

SI unit of tensile stress is newton per square metre.

Example

1. A nylon string has a diameter of 2 mm, pulled by a force of 100 N. Determine the stress. (Ans: $3.15 \times 10^{6}\text{Nm}^{-2}$)
2. A force of 20N acting on a wire of cross sectional area 10cm^2 = makes its length to increase from 3m to 5m. Find stress? (Ans: 2Nm^{-2})

TENSILE STRAIN

This is the extension per unit original length of the solid.

$$\text{Tensile strain} = \frac{\text{Extension}}{\text{original length}}$$

$$\text{Tensile strain} = \frac{E}{l_o}$$

$$\text{Extension} = \text{New length} - \text{original length}$$

$$E = l - l_o$$

Examples

1. A 2.0-m-long wire stretches by 1.0 mm when subjected to a load. What is the tensile strain in the wire?
2. A cord has original length of 100 cm is pulled by a force. The change in length of the cord is 2 mm. Determine the strain. (Ans: 0.002)

Young's Modulus

Young's modulus is a mechanical property that measures the stiffness of a solid material. It defines the relationship between stress and strain in a material.

Young's modulus is named after the 19th-century British scientist Thomas Young.

It is the ratio of stress to strain of a material.

$$\text{Young's modulus} = \frac{\text{stress}}{\text{strain}}$$

SI unit of Young's modulus is newton per square metre.

Examples

1. A copper wire of length 10cm is subjected to a force of 2N if the cross-section area is 5cm^2 and a force causes an extension of 0.2cm.
   Calculate;

   (i) Tensile stress

   $$\text{Stress} = \frac{\text{Force}}{\text{Area}}$$

   $$\text{Stress} = \frac{2}{0.0005}$$

   $$\text{Stress} = 4000\text{Nm}^{-2}$$

   (ii) $$\text{Strain} = \frac{\text{extension}}{\text{original length}}$$

   $$\text{Stress} = \frac{0.0002}{0.1}$$

   $$\text{Stress} = 0.002\text{m}$$

   (iii) **Young's modulus**

   $$Y = \frac{\text{stress}}{\text{strain}}$$

   $$Y = \frac{4000}{0.002}$$

   $$\text{Stress} = 2.0 \times 10^7\text{Nm}^{-2}$$

2. A string 4 mm in diameter has original length 2 m. The string is pulled by a force of 200 N. If the final length of the spring is 2.02 m, determine:
   (a) Stress (Ans: $1.592 \times 10^{7}\text{Nm}^{-2}$)
   (b) Strain (Ans: 0.01)
   (c) Young's modulus (Ans: $1.6 \times 10^{9}\text{Nm}^{-2}$)

3. A concrete has a height of 5 meters and has unit area of 3 m3 supports a mass of 30,000 kg. Determine
   (a) The stress (Ans: $1.0 \times 10^{5}\text{Nm}^{-2}$)
   (b) The strain (Ans: 5.0×10^{-6})
   (c) The change in height! Acceleration due to gravity (g) $= 10\text{ms}^{-2}$.
   (d) Young's modulus of concrete $= 2.0 \text{ x } 10^{10}\ \text{Nm}^{-2}$ (Ans: 0.025mm)

4. A mass of 200kg is placed at the end of the wire 15cm long and cross sectional 0.2cm^2 if the mass causes an extension of 1.5cm
   Calculate.
   (i) Tensile stress
   (ii) Tensile stress.

5. A mass of 200g is placed at the end of a wire 15cm long are cross sectional area 0.2m. If the mass causes an extension of 1.5. Calculate
   (i) Tensile stress
   (ii) Tensile strain
   (iii) Young modulus

END.