

STRENGTH OF MATERIALS

III SEMESTER DIPLOMA MECHANICAL

SUBJECT CODE : 15ME31T

SYLLABUS :

UNIT 1 : SIMPLE STRESSES AND STRAINS

UNIT 2 : MOMENT OF INERTIA

UNIT 3 : SHEAR FORCE AND BENDING MOMENT DIAGRAMS

UNIT 4 : THEORY OF SIMPLE BENDING

UNIT 5 : STRAIN ENERGY AND IMPACT LOADING

UNIT 6 : TORSION OF CIRCULAR SHAFT

UNIT I :

SIMPLE STRESSES AND STRAINS

Simple stresses & strains viz. tensile, compressive, Shear, Crushing, Thermal stresses, & corresponding strains, Hook's Law –Problems on Direct Stress & Linear Strain- Stress- Strain curve for Ductile material and Brittle material with all parameters.- factor of Safety. Elastic Constants - Lateral Strain ,Poisson's ratio, Bulk Modulus, Shear Modulus ,Volumetric Strain Relation between elastic constants- Problems on elastic constants. Hoop stress- Longitudinal Stress in thin cylindrical & spherical shells subjected to internal pressure.- Problems on thin cylindrical shells.

UNIT II :

MOMENT OF INERTIA

Centre of Gravity, Moment of Inertia & its Importance -Parallel & Perpendicular Axis Theorem-C.G of Rectangle, Triangle, Circle, Semi-circle, Trapezium, Cone-Problems on 3 IT finding CG of T-Section, I-Section, L-Section, Channel-Section. Moment of Inertia of solid & hollow sections like Rectangle, Triangle, Circle- Moment of Inertia about C.G for I section, T section. L-section and Channel Section.

UNIT III :

SHEAR FORCE AND BENDING MOMENT DIAGRAMS

Definition - Shear Force and Bending Moment –Types of beams, types of load acting on beams ,Sagging & Hogging Bending Moment and its importance –sign convention to draw SFD and BMD- Concept of Maximum bending moment, Point of Contra flexure & its importance-Drawing S.F & B.M Diagram for Cantilever, Simply Supported Beams subjected to Point Load and U.D.L

UNIT IV :

THEORY OF SIMPLE BENDING

Introduction, assumptions in theory of simple bending.-Bending stress, relation between bending stress & radius of curvature (without proof).-Position of neutral axis, moment of resistance-Bending equation (without proof)-Modulus of section for rectangular, hollow rectangular and hollow circular sections-Beams of uniform Strength-problems UNIT V:

STRAIN ENERGY AND IMPACT LOADING 03Hrs Introduction -Strain Energy-Types of loading-Sudden, Gradual & Impact Load-resilience, proof resilience and modulus of resilience-Equation for strain energy stored in a body when the load is gradually applied and suddenly applied – problems.

UNIT VI:

TORSION OF CIRCULAR SHAFT

Introduction to Torsion , Angle of Twist , Polar Moment of Inertia , Torsion equation-(without proof)-Assumptions in theory of Torsion -Power Transmitted by a shaft, axle of solid and hollow sections subjected to Torsion - Comparison between Solid and Hollow Shafts subjected to pure torsion- Problems. (No problem on composite and non-homogeneous shaft)

TEXT BOOKS

1. Ramamurtham. S., “Strength of Materials”, 14th Edition, Dhanpat Rai Publications, 2011

2. Khurmi R S, “Applied Mechanics and Strength of Materials”, 5 Edition, S.Chand and company
REFERENCES 1. Popov E.P, “Engineering Mechanics of Solids”, 2nd Edition, Prentice-Hall of India.

UNIT 1

Simple Stresses and Strains

INTRODUCTION

The study of strength of materials is to provide the means of analysing and designing various machines and load bearing structures. In addition, to ensure that the structure used will be safe maximum against internal effects that may be produced by any combination of loading. It is an inter disciplinary subject. Mechanical and Chemical engineers need this subject to know the strength of various materials for the design of machineries and pressure vessels. Civil engineers need this subject for the design of trusses, slabs, beams, columns, etc., of buildings and bridges. Aeronautical engineers need this subject for the computer design of aircraft. Similarly mining, electrical, electronics and engineers should also know this subject for one or the other reason.

PROPERTIES OF MATERIALS

Important properties which determine the usage of the materials are physical, chemical and mechanical properties. Important physical and dimensional properties of the materials are electrical conductivity, thermal conductivity, density, specific gravity, melting point, colour, size, shape and lustre. Important chemical properties of the materials are composition, structure and corrosion resistance.

Important mechanical properties of the materials are strength, elasticity, plasticity, ductility, brittleness, stiffness, resilience, toughness, malleability and hardness.

Elasticity : Elasticity is defined as the ability of material to regain its original shape and after the deformation, when size the external forces are removed. Steel is perfectly elastic within a certain elastic limit.

Plasticity: Plasticity is defined as the ability of the material to retain the deformation under produced the load on a permanent basis. This property of the material is necessary for forging, images on coins and in ornamental work. stamping,

Ductility : Ductility is defined as the ability of a material to deform to a greater extent to be drawn out (i.e. to a reduced section or thin wire) before the sign of crack, when it is subjected to tensile force. Mild steel, aluminium, copper, tin and lead are ductile materials.

Brittleness: Brittleness is the property of a material opposite to that of ductility i.e., lack of ductility. It is the property of a material which shows negligible plastic deformation before fracture takes place. Examples of brittle materials are cast iron, high carbon steel, concrete, glass, ceramic materials, stone, etc

Strength: Strength is defined as the ability of the material to resist the external forces causing various types of stresses without breaking or rupture. Based on the type of stresses induced by external loads, strength is expressed as tensile strength, compressive strength or shear strength.

ELASTICITY:

Whenever a force acts on a body, it undergoes some deformation and the molecules offer some resistance to the deformation. It will be interesting that, when the external force is removed, the force of resistance also vanishes i.e. the body comes back to its original position. But it is only possible if the deformation caused by the external force is within a certain limit. Such a limit is called Elastic limit.

“ The property of certain materials of returning back to their original position , after removing the external force is known as elasticity”.

A body is said to be perfectly elastic, if it returns back completely to its original shape and size, after removal of external forces. If the body does not return back completely to its original shape and size after removal of external force, it is said to be partially elastic.

STRESS

Whenever a force acts on a body, it undergoes some deformation and the molecules offer some resistance to the deformation. The force of resistance per unit area, offered by a body against deformation is known as stress.

Load is the external force acting on the body and it is applied on the body while the stress is induced in the material of the body. If the resistance offered by the member and against deformation the applied force or load are equal, then the loaded member is in equilibrium.

i.e., In equilibrium, Resisting force = Applied force or Load. Stress is denoted by σ (sigma).

Mathematically,

Applied force Stress $\sigma = \text{Applied force} / \text{Cross-sectional area}$

i.e. $\sigma = P/A$

where σ = Stress, P = Applied load or External force, A = cross-sectional area

Units of Stress

If force is expressed in Newtons (N) and area of cross-section in millimetre square (mm^2), then the unit of stress is N/mm^2 . If force is metre square (m^2), then the expressed in Newton(N) and area of cross-section in unit of stress is N/m^2 .

Large quantities are represented by kilo, mega, giga and terra.

kilo = 10^3 and it is represented by 'k'.

Mega = 10^6 and it is represented by 'M'

Giga = 10^9 and it is represented by 'G'

One kilo Newton means 10^3 Newton i.e., $1 \text{ kN} = 10^3 \text{ N}$

One Mega Newton means 10^6 Newton i.e., $1 \text{ MN} = 10^6 \text{ N}$

One Giga Newton means 10^9 Newton i.e., $1 \text{ GN} = 10^9 \text{ N}$

$1 \text{ N/m}^2 = 1 \text{ Pascal} = 1 \text{ Pa}$

$10^6 \text{ N/m}^2 = 1 \text{ MN/m}^2 = 1 \text{ MPa}$ [MPa = Mega Pascal]

$10^9 \text{ N/m}^2 = 1 \text{ GN/m}^2 = 1 \text{ GPa}$ [GPa = Giga Pascal] .

Stress in SI units is expressed in N/m^2 or N/mm^2 .

Stress, $1 \text{ N/mm}^2 = 10^6 \text{ N/m}^2 = 1 \text{ MN/m}^2 = 1 \text{ MPa}$. Thus one N/mm^2 is equal to one MN/m^2 or one MPa.

Strain

When a body is subjected to external force, there will be change in dimensions of the body.

This change in dimension is called deformation. The ratio of change in dimension of body or deformation to the original dimension of the body is known as Strain. Strain is dimensionless and is denoted by ϵ (epsilon) or e .

Mathematically,

$$\text{Strain } \epsilon = \frac{\text{Change in dimension of body or Deformation}}{\text{Original dimension of the body}} \quad \text{OR} \quad \epsilon = \frac{dL}{L}$$

Types of Stresses

The following are the important types of stresses

(i) Normal stress : (a) Tensile stress & (b) Compressive stress

- (ii) Shear stress or Tangential stress.
- iii) Bearing stress.
- (iv) Bending stress.
- (v) Twisting or Torsional stress.

Types of Strain Strain may be: (i) Tensile strain (ii) Compressive strain (iii) Shear strain (iv) Volumetric strain (v) Superficial strain

1.5.6 Axial Load

The force or load acting along the axis of the bar or body is known as axial load. In Fig. 1.1, applied load P is axial load.



Fig. 1.1

1.5.7 Normal Stress

If the internal forces and the corresponding stresses acts in a direction perpendicular to the surface (i.e., cut surface), it is known as normal stress or direct stress. Normal stresses are of two types : (i) Tensile stress and (ii) Compressive stress.

1.5.8 Tensile Stress and Tensile Strain

(i) Tensile Stress

When a body or section is subjected to two equal and opposite pulls, and if it tends to pull apart the particles of the material causing extension in the direction of application of load, then the load is called tensile load and the corresponding stress induced is known as tensile stress.

Fig. 1.2(a) shows a bar subjected to tensile force or load P at its ends. Consider a section $X-X$ as shown in the figure. The portion left of the section is in equilibrium, if resisting force $P' =$ Applied tensile force P as shown in Fig. 1.2(b). Similarly, the portion right of the section is in equilibrium, if applied tensile force $P =$ Resisting force (P') and is shown in Fig. 1.2(c). This resisting force per unit cross-sectional area is known as tensile stress or unit stress.

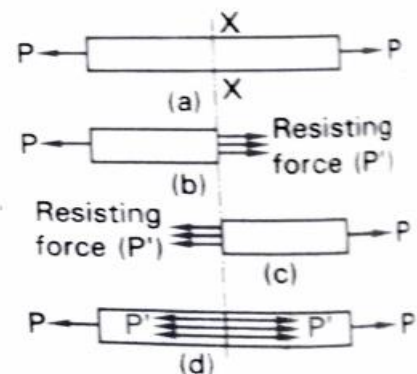


Fig. 1.2

Let $P =$ Applied tensile load, $P' =$ Resisting force, $A =$ Cross-sectional area of the bar

$$\text{Tensile stress} = \frac{\text{Resisting force}}{\text{Cross-sectional area}} = \frac{\text{Applied tensile load}}{\text{Cross-sectional area}} \quad (\because P' = P)$$

$$\therefore \text{Tensile stress, } \sigma = \frac{P}{A}$$

(ii) Tensile Strain

When a body or bar is subjected to two equal and opposite pulls i.e., tensile load or force, it causes extension or increase in length of bar in the direction of application of load. The ratio of increase in length to the original length is known as tensile strain. i.e., Tensile strain is defined as extension per unit length.



Fig. 1.3

Consider a bar subjected to tensile load or force P as shown in Fig. 1.3.

Let, $AB =$ Original length of bar $= l$

$AC =$ Final length of bar after the application of tensile load P

\therefore Extension of bar $= AC - AB = BC = \delta l$

$$\text{Tensile strain} = \frac{\text{Extension or Increase in length of bar}}{\text{Original length of bar}}$$

(i) Compressive Stress

When a body or section is subjected to two equal and opposite pushes, and it tends to push the particles of the material nearer causing shortening in the direction of application of load, then the load is called compressive load and the corresponding stress induced is known as compressive stress. Fig. 1.4(a) shows a bar subjected to compressive force or load P at its ends. Consider a section $X-X$ as shown in the figure. The portion left of the section is in equilibrium, if resisting force $P' = \text{Applied compressive force } P$ and is shown in Fig. 1.4(b). Similarly, the portion right of the section is in equilibrium, if resisting force $P' = \text{Applied compressive force } P$ and is known in Fig. 1.4(c). This resisting force per unit cross-sectional area is known as compressive stress or unit stress.

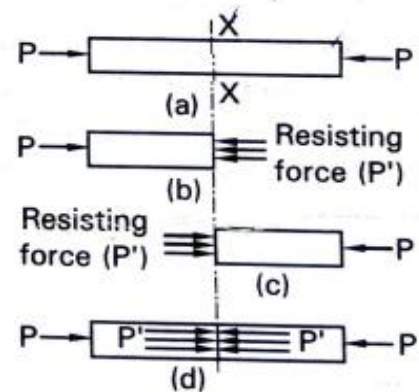


Fig. 1.4

(ii) Compressive Strain

When a body or bar is subjected to two equal and opposite pushes i.e., compressive load or force, it causes shortening or decrease in length of bar in the direction of application of load. The ratio of decrease in length to the original length is known as compressive strain. i.e., Compressive strain is defined as shortening per unit length. Consider a bar subjected to compressive load or force (P) as shown in Fig. 1.5.

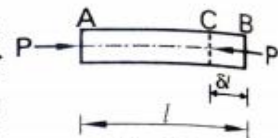


Fig. 1.5

$$\therefore \text{Compressive strain} = \frac{\text{Shortening or Decrease in length of bar}}{\text{Original length of bar}}$$

$$\therefore \text{Compressive strain, } \epsilon = \frac{\delta l}{l}$$

1.5.10 Shear Stress and Shear Strain

When a body or section is subjected to two equal and opposite forces, acting parallel or tangential across the resisting section [Fig. 1.6(a)] and tends to shear off the body across the section [Fig. 1.6(b)] then the force is called shear force and the stress induced is known as shear stress. The corresponding strain is known as shear strain.

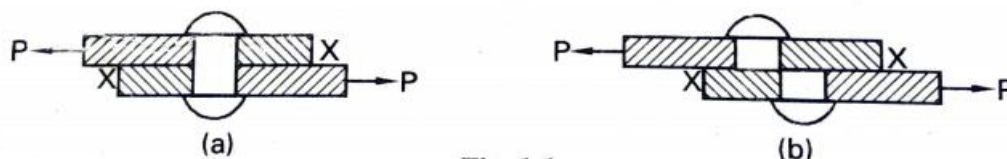
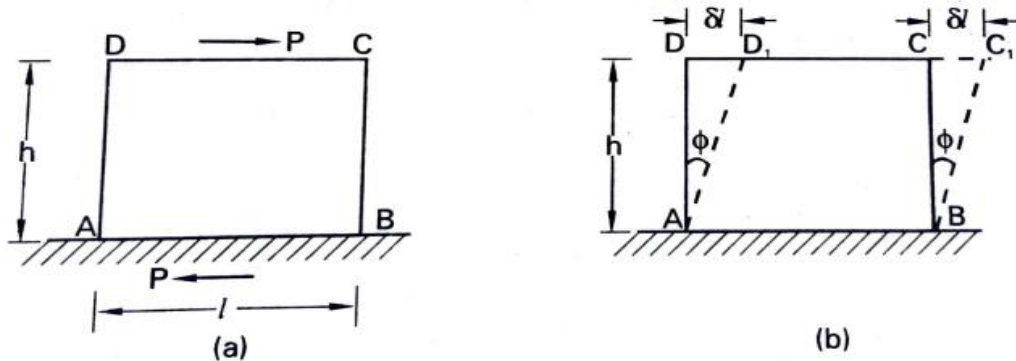


Fig. 1.6

Fig. 1.7(a) shows a rectangular block of height h , length l and unit width. Bottom face of the block is fixed and a tangential force P is applied along the top face CD . Such a force acting tangentially along a surface is known as shear force. For the equilibrium of the block, the surface AB will offer a tangential reaction P , equal and opposite to the applied tangential force P .

(ii) Shear Strain

Fig. 1.8(a) shows a rectangular block of height h , length l and unit width is subjected to shear force P on the top and bottom faces. As the bottom face is fixed, the block deformed to the position ABC_1D_1 due to the applied shear force P as shown in Fig. 1.8(b).



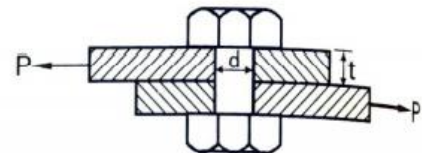
Crushing stress OR Bearing Stress

It is a localised compressive stress induced at the surface of contact between two members of machine parts that are relatively at rest. Bolts, pins and rivets induce bearing stress in the member they connect along the bearing surface or at contact surface.

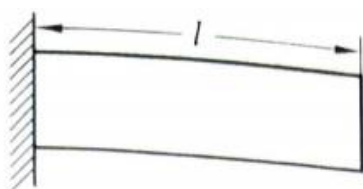
$$\begin{aligned} \text{Bearing stress} &= \frac{\text{Resisting force exerted by the bolt on plate}}{\text{Projection area of bolt on the plate section}} \\ &= \frac{\text{Force exerted by the plate on the bolt}}{\text{Projection area of bolt on the plate section}} \quad (\because P' = P) \end{aligned}$$

$$\therefore \text{Bearing stress, } \sigma_b = \frac{P}{dt}$$

where d = Diameter of bolt and t = Thickness of plate



Thermal stresses



(a) Before heating



(b) After heating

When the temperature of a material changes there will be corresponding change in its dimensions. When a member is free to expand or contract due to rise or fall of temperature, no stresses will be induced in the member. But if the natural change in length due to rise or fall of temperature be prevented then stress will be induced in the member.

HOOKE'S LAW

It states that, “ when a material is loaded within its elastic limit, the **stress is directly proportional to strain**”. It means the ratio of stress to the corresponding strain is a constant within the elastic limit. This constant is known as **Modulus of Elasticity or Young's Modulus**.

$$\text{Stress} \propto \text{Strain}$$

$$\text{i.e., } \frac{\text{Stress}}{\text{Strain}} = \text{Constant}$$

$$\text{i.e., } \frac{\sigma}{\epsilon} = E$$

where E = A constant of proportionality known as Modulus of Elasticity

σ = Stress and ϵ = strain

Hooke's law holds good for tension as well as compression.

Deformation of a Body due to Force acting on it

Consider a body subjected to a tensile force as shown in Figure (6.3).

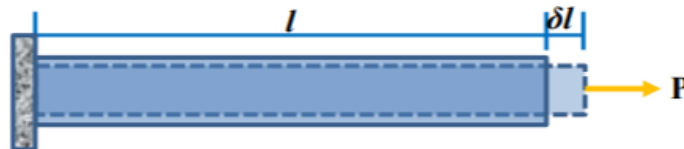


Figure (6.3)

Let P = Load or force acting on the body,

l = Length of the body,

A = Cross – sectional area of the body,

σ = Stress induced in the body,

E = Modulus of elasticity for the material of the body,

ϵ = Strain, and

δl = Deformation of the body.

Knowing that the stress is:

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

And the strain is:

$$\epsilon = \frac{\sigma}{E} = \frac{\frac{P}{A}}{E} = \frac{P}{EA}$$

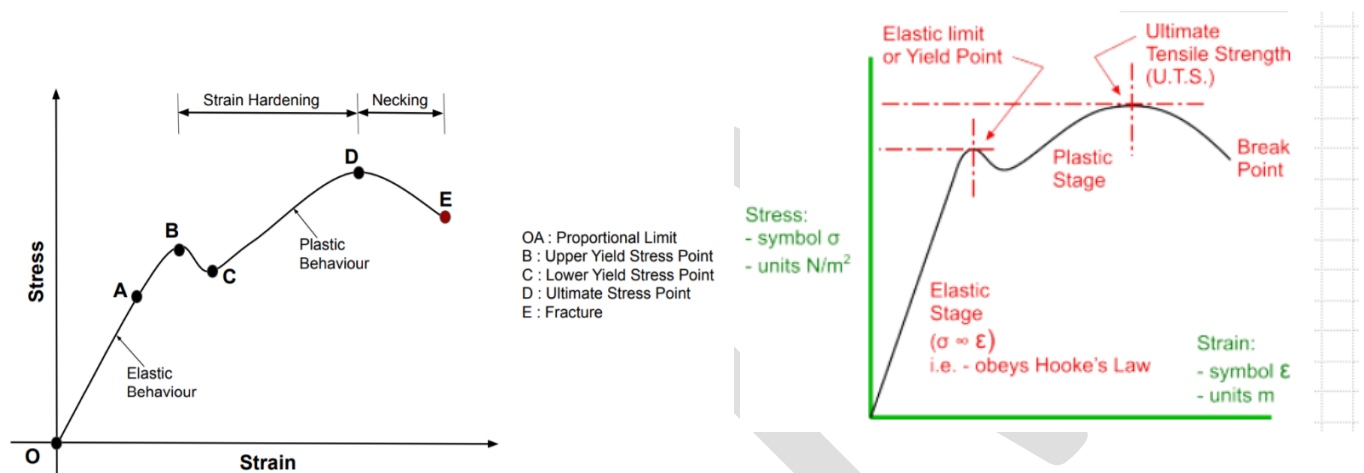
Then the deformation is:

$$\delta l = \epsilon(l) = \frac{Pl}{EA}$$

Note:

1. The above formula holds good for tensile and compressive stresses also.
2. Sometimes in calculation tensile stress and tensile strain are taken positive, where as compressive stresses and strains are taken negative.
3. $1 \text{ N/m}^2 = 10^{-6} \text{ N/mm}^2 = 1 \text{ Pa}$.
 $1 \text{ N/mm}^2 = 10^6 \text{ N/m}^2 = 1 \text{ MPa}$.
 $1 \text{ GPa} = 10^3 \text{ N/mm}^2$.

stress – strain curve for Ductile materials



Ductile Materials:

Ductile materials are those which are capable of having large strains before they are fractured. Ductile materials can withstand high stress and are also capable of absorbing large amount of energy before their failure. A ductile material has a large Percentage of elongation before failure. Some examples of ductile materials are aluminum, mild steel and some of its alloys i.e. copper, magnesium, brass, nickel, bronze and many others.

• Proportional Limit (σ_{PL})

Proportional limit is the point on stress strain curve which shows the highest stress at which Stress and Strain are linearly proportional to each other where the proportionality constant is E known as modulus of elasticity. Above this point, stress is no longer linearly proportional to strain. On stress strain curve, proportional limit is shown by P. It is denoted by σ_{PL} .

• Elastic Limit (σ_{EL})

Elastic limit is the point which shows the maximum stress that can be applied to the body without resulting in permanent deformation when stress is removed. At elastic limit when the load is removed from the body, it returns to original size and shape. At elastic limit stress is no longer linearly proportional to strain. It is denoted by σ_{EL} . For stress strain graph of mild steel, elastic limit is just close to proportional limit.

Yield point (σ_Y)

Yield point is the point which shows the stress at which a little or no increase in stress results to large increase in strain that is material continues to deform without increase in load. At this point the material will have permanent deformation. It is denoted by σ_Y . For steel, yield point

is also just above proportional limit. Yield point is of two types: o Upper yield point. o Lower yield point.

Ultimate Tensile Strength (σ_U)

As the stress on material is increased further, the stress and the strain increases from yield point to a point called ultimate tensile strength (UTS) where stress applied is maximum. Thus ultimate tensile strength can be defined as the highest stress on the specimen which it can withstand.

Fracture Stress (σ_F)

After ultimate tensile strength, the applied stress decreases until the stress is obtained where material fractures called fracture stress. Fracture stress is also called breaking strength. It is denoted by σ_F .

Necking:

Necking covers the area from ultimate tensile stress to fracture point. It is the region where cross sectional area of material will decrease in a localized spot and capacity of material to carry load will decrease. In necking region, stress strain curve has neck like curve.

Factor of safety

The ratio of ultimate stress to working stress is called factor of safety.

$$\text{Factor of safety (FOS)} = \frac{\text{Ultimate stress}}{\text{Working stress}}$$

ELASTIC CONSTANTS

(i) Linear Strain or Longitudinal Strain

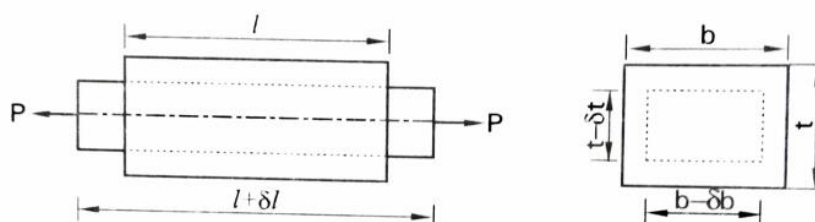
When a body is subjected to an axial tensile or compressive load, there will be an axial deformation along the length of the body. **Longitudinal or linear strain is defined as the ratio of axial deformation to the original length of the body. It is also defined as the change in length per unit length in the direction of the applied load.**

Let,
 L = Original length of the body
 δl = Change in length or Deformation in the length
 P = Applied axial load (Tensile or Compressive)

$$\text{Linear or Longitudinal strain, } \epsilon = \frac{\text{Change in length}}{\text{Original length}} = \frac{\delta l}{l}$$

(ii) Lateral Strain

When a body is subjected to an axial load, it undergoes deformation in the direction of load and perpendicular to the direction of load. Consider a rectangular bar of length l , width b and thickness t subjected to an axial tensile load P as shown in Fig. 1.16. Due to the application of this load, the length of bar will increase while the breadth and thickness will decrease. If the load is compressive, then the length of bar will decrease while the breadth and thickness will increase.



(vi) Volumetric Strain

The ratio of change in volume to the original volume of a body is known as volumetric strain and is denoted by ϵ_v . Mathematically,

$$\text{Volumetric strain, } \epsilon_v = \frac{\text{Change in volume}}{\text{Original volume}} = \frac{\delta v}{v}$$

Young's modulus is denoted by letter "E". The unit of modulus of elasticity is the same as the unit of stress which is megapascal (Mpa). 1 Mpa is equal to 1 N/mm².

$$\text{Young's Modulus}(E) = \frac{\text{Stress}}{\text{Strain}}$$

Bulk Modulus

When a body is subjected to mutually perpendicular direct stresses which are alike and equal, within its elastic limits, the ratio of direct stress to the corresponding volumetric strain is found to be constant. This ratio is called bulk modulus and is represented by letter "K". Unit of Bulk modulus is Mpa.

$$\text{Bulk Modulus}(K) = \frac{\text{Direct Stress}}{\text{Volumetric Strain}}$$

Rigidity Modulus

When a body is subjected to shear stress the shape of the body gets changed, the ratio of shear stress to the corresponding shear strain is called rigidity modulus or modulus of rigidity. It is denoted by the letters "G" or "C" or "N". Unit of rigidity modulus is Mpa.

$$\text{Rigidity modulus}(G) = \frac{\text{Shear Stress}}{\text{Shear Strain}}$$

Poisson's Ratio

When a body is subjected to simple tensile stress within its elastic limits then there is a change in the dimensions of the body in the direction of the load as well as in the opposite direction. When these changed dimensions are divided with their original dimensions, longitudinal strain and lateral strain are obtained.

$$\text{Poisson's ratio } (\mu) = \frac{\text{Lateral Strain}}{\text{Longitudinal Strain}}$$

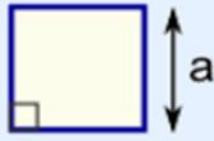
The ratio of the lateral strain to the longitudinal strain is called Poisson's ratio. It is represented by the symbol " μ ". Poisson's ratio is maximum for an ideal elastic incompressible material and its value is 0.5. For most of the engineering materials, Poisson's ratio lies between 0.25 and 0.33. It has no units.

LIST OF IMPORTANT FORMULAE

Sl. No	FORMULA	NOTATIONS
1.	<p>Stress, $\sigma = \frac{P}{A}$</p> <p>Note: Cross sectional areas of sections used in this book: Circular section of diameter 'd', $A = \frac{\pi d^2}{4}$ Hollow section of internal diameter 'd_i' and external diameter 'd_o', $A = \frac{\pi(d_o^2 - d_i^2)}{4}$ Rectangular section of breath 'b' & thickness 't', $A = b \times t$ Square section of size breadth and depth 'b', $A = b \times b = b^2$</p>	<p>P = Load or External force A = Cross sectional area.</p>
2.	<p>Strain, $\epsilon = \frac{\text{Change in dimension}}{\text{Original dimesion}}$</p>	
3.	<p>Young's modulus $E = \frac{\text{Tensile stress}}{\text{Tensile strain}}$ or $\frac{\text{Compressive stress}}{\text{Compressive strain}} = \frac{\sigma}{\epsilon}$</p> <p>Rigidity modulus $C = \frac{\text{Shear stress}}{\text{Shear strain}}$</p> <p>Bulk modulus $K = \frac{\text{Stress}}{\text{Volumetric strain}}$</p>	
4.	<p>Longitudinal strain, $\epsilon = \frac{\delta l}{l}$</p> <p>Lateral strain, $\epsilon_L = \frac{\delta b}{b}$ or $\frac{\delta t}{t}$</p>	<p>δl = Change in length, δb = Change in breadth, δt = Change in thickness, l, b & t are original length, breadth & thickness respectively.</p>

5.	Elongation, $\delta l = \frac{Pl}{AE}$	P = Load or external force, A = Cross sectional area, E = Young's modulus, l = Length of the section.
6.	Poisson's ratio $\frac{1}{m} = \frac{\text{Lateral strain}}{\text{Longitudinal strain}}$	
7.	Volumetric strain $\epsilon_v = \frac{\text{Change in volume}}{\text{Original volume}} = \frac{\delta v}{v}$ or $\epsilon_v = \epsilon \left(1 - \frac{2}{m} \right)$	
8.	Relation between E, C, K and $\frac{l}{m}$ $E = \frac{9CK}{3K + C}$ $E = 2C \left(1 + \frac{1}{m} \right)$ $E = 3K \left(1 - \frac{2}{m} \right)$	E = Young's modulus, C = Rigidity modulus, K = Bulk modulus, $1/m$ = Poisson's ration
9.	Temperature stress and strain If the expansion or contraction is allowed free, $\delta = \alpha t l$ Temperature strain = αt Temperature stress, $\sigma_t = \alpha t E$ If the supports yield by an amount δ_1 , then Temperature stress, $\sigma_t = E \left(\alpha t - \frac{\delta_1}{l} \right)$ Thrust or tensile force on end clamps, $P = \alpha t E \times A$	t = Change in temperature α = Coefficient of thermal expansion l = Length of bar A = Cross sectional area of bar E = Young's modulus σ_t = Thermal or Temperature stress

FORMULA OF AREAS



Square

$$\text{Area} = a^2$$

a = length of side

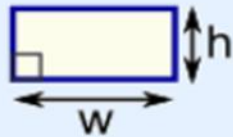


Circle

$$\text{Area} = \pi \times r^2$$

$$\text{Circumference} = 2 \times \pi \times r$$

r = radius

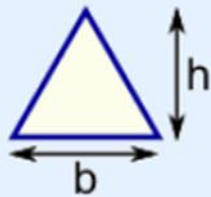


Rectangle

$$\text{Area} = w \times h$$

w = width

h = height



Triangle

$$\text{Area} = \frac{1}{2} \times b \times h$$

b = base

h = vertical height

PLR