VELAMMAL COLLEGE OF ENGINEERING AND TECHNOLOGY, MADURAI – 625009
DEPARTMENT OF CIVIL ENGINEERING
CE8301 STRENGTH OF MATERIALS I

UNIT I STRESS, STRAIN AND DEFORMATION OF SOLIDS

Simple Stresses and strains – Elastic constants - Relationship between elastic constants – Stress Strain Diagram – Ultimate Stress – Yield Stress – Deformation of axially loaded member - Composite Bars - Thermal Stresses – State of Stress in two dimensions – Stresses on inclined planes – Principal Stresses and Principal Planes – Maximum shear stress - Mohr's circle method.

<u>Knowledge Level: Understand</u>

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1. What is Strength of Material?

When an external force acts on a body, it undergoes deformation. At the same time the body resists deformation. This resistance by which materials of the body opposes the deformation is known as strength of the material.

2. What is Rigid body?

A rigid body is a solid body in which deformation is zero or so small it can be neglected. The distance between any two given points on a rigid body remains constant in time regardless of external forces exerted on it. A rigid body is usually considered as a continuous distribution of mass.

3. What is deformable solids?

A body which undergoes deformation due to application of external forces.

4. Define stiffness.

The stiffness may be defined as an ability of a material to withstand external load without any major deformation.

5. What is stability? Explain

It is the overall property of a member made out a material to maintain the overall equilibrium preventing complete collapse. That is the ability of a material to withstand external forces without collapse.

6. Define: Stress

When an external force acts on a body, it undergoes deformation. At the same time the body resists deformation. The magnitude of the resisting force is numerically equal to the applied force. This internal resisting force per unit area is called stress.

Stress = Force/Area $\sigma = P/A$ (unit is N/mm^2)

7. Define: Strain

When a body is subjected to an external force, there is some change of dimension in the body takes place. Numerically the strain is equal to the ratio of change in length to the original length of the body. There is no unit for strain.

Strain = Change in length/Original length

$$e = \partial L/L$$

8. What are the types of stresses? (or) What are the three type of stresses? *(May/June 2013)*

Stresses are of 2 types namely axial stress and tangential stress. Axial stresses are categorized as tensile stress and Compressive stress based on the action direction of axial force. Tangential stresses are also called as Shear stress. Hence the stresses are Tensile, Compressive and shear stress.

9. Define tensile stress?

It may be defined as the tensile (or) pulling force per unit area.

10. Define compressive stress?

It may be defined as the compressive (or) pushing force per unit area.

11. Define shear stress?

It may be defined as the shear (or) tangential force per unit area.

12. Define crushing stress?

It may be defined as the crushing (or) collapsing force per unit area.

13. Distinguish between Compression and Tension. (Apr/May 2018)

Compression	**Tension**
When a member is subjected to pushing force the corresponding stress is called as compressive stress and the action is compression.	When a member is subjected to pulling force the corresponding stress is called as tensile stress and the action is tension.
Example: Columns, Struts	Example: Bracing bar, inclined members in truss, force exerted by rope, cable, chain
The suspension ropes on the suspension bridge experience tension, as opposed to the vertical columns/piles experiencing compression.	

14. What is simple stress?

When a body is subjected to an external force in one direction only, the stress developed in the body is called simple stress.

15. What is Compound stress?

When a body is subjected to an external force in more than one direction, the stress developed in the body is called Compound stress.

16. Define: Elastic limit

Some external force is acting on the body, the body tends to deform. If the force is released from the body it regains its original position. The limiting force which will not induce any permanent deformation is called elastic limit of the material.

17. State: Hooke's law. ***(Nov/Dec 2016) (Apr/May 2017)***

It states that when a material is loaded within its elastic limit, the stress is directly proportional to the strain.

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

$$\sigma \propto e$$

$$\sigma = Ee$$

Where E - Young's modulus in N/mm^2

18. Define: Young's modulus

The ratio of longitudinal/linear stress and strain is constant within the elastic limit. This constant is known as Young's modulus. E = linear Stress /linear Strain

19. Define: Longitudinal strain

When a body is subjected to axial load P, there is an axial deformation in the length of the body. The ratio of axial deformation to the original length of the body is called lateral strain.

Longitudinal strain = Change in length/Original length

$= \partial L/L$

20. Define: Lateral strain

The strain at right angles to the direction of the applied load is called lateral strain.

Lateral strain = Change in breadth (depth)/Original breadth (depth)

$= \partial \mathbf{b}/b$ or $\partial \mathbf{d}/d$

21. Define: shear stress and shear strain.

The two equal and opposite force act tangentially on any cross sectional plane of the body tending to slide one part of the body over the other part. The stress induced is called shear stress and the corresponding strain is known as shear strain also called as angular distortion.

22. Define: volumetric strain

Within elastic limit, the ratio of change in volume to the original volume of the body is called volumetric strain.

Volumetric strain = change in volume / original volume

$$e = \partial V / V$$

23. Define: Poisson's ratio ***(Nov/Dec 2014) (Nov/Dec 2016) (Apr/May 2018)***

(or) What is meant by Poisson's ratio? Which material has the higher value of Poisson's ratio? ***(Nov/Dec 2015)***

When a body is stressed within its elastic limit, the ratio of lateral strain to the longitudinal strain is constant for a given material, known as Poisson's ratio. For most of the materials it lies from 0.25 to 0.33.

Poisson' ratio (μ or 1/m) = Lateral strain /Longitudinal strain

The Poisson's ratio is highest for Aluminum = 0.33

24. Define: Bulk modulus ***(Nov/Dec 2014)***

Within elastic limit, the ratio of direct stress to volumetric strain is called as bulk modulus.

Bulk modulus, K = Direct stress / Volumetric strain

25. What is meant by limit of proportionality and shear modulus? ***(Nov/Dec 2013)***

Limit of Proportionality: The limit at which the stress is directly proportional to strain for a material is called as limit of proportionality. Within the limit of proportionality the material behaves elastically.

Shear Modulus: Within elastic limit, the ratio of shear stress to shear strain is called as Modulus of rigidity.

Shear modulus, N = shear stress / shear strain

26. Define: Shear modulus or Modulus of rigidity

Within elastic limit, the ratio of shear stress to shear strain is called as Modulus of rigidity.

Shear modulus, N = shear stress / shear strain

27. State the relationship between Young's Modulus and Modulus of Rigidity.

$E = 2N(1+\mu)$ Where, E - Young's Modulus; N– Modulus of rigidity; μ - Poisson's ratio

28. Give the relationship between Bulk Modulus and Young's Modulus.

$E = 3K(1-2\mu)$ Where E - Young's Modulus; K - Bulk Modulus; μ- Poisson's ratio

29. What are the three elastic constants?

i. Modulus of Elasticity ii. Bulk Modulus iii. Shear modulus

30. Determine the Poisson's ratio and bulk modulus of a material, for which Young's modulus is 1.2 x 10^5 N/mm^2 and modulus of rigidity is 4.8 x 10^4N/mm^2.

We know that $E = 2N(1+\mu)$ Where E - Young's Modulus; N– Modulus of rigidity; 1/m - Poisson's ratio

Modulus of rigidity $N = E/[2(1+\mu)]$

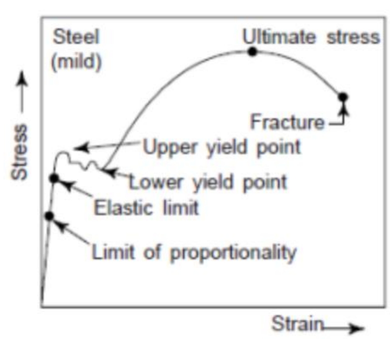
$4.8 \times 10^4 = 1.2 \times 10^5/[2(\mu+1)]$

Poisson's ratio $\mu = 0.25$

$E = 3K(1-2\mu)$ Where E - Young's Modulus; K - Bulk Modulus; μ- Poisson's ratio

Bulk modulus $K = E/3[1-2\mu] = 8 \times 10^4$ N/mm^2

31. Draw the stress-strain diagram for mild steel and indicate the salient points. (APR / MAY 2017)



32. What is meant by factor of safety? (Apr/May 2015)
The ratio between the Ultimate (or) Yield stress and the working (or) permissible (or) design stress is called as factor of safety.
33. What is principle of super position?
The resultant deformation of the body is equal to the algebraic sum of the deformation of the individual section. Such principle is called as principle of super position
34. What is compound (or) composite bar?
A composite bar composed of two or more different materials joined together such that the system is elongated or compressed in a single unit.
35. What is composite bar? How will you find the stresses and load carried by each members of a composite bar?
A composite member is composed of two or more different materials, joined together in such a way that the system is elongated or compressed as a single unit. In such a case, the following two governing conditions are to be followed.
i) Change in length of the composite bar = Change in length of material 1 of the composite bar = Change in length of material 2 of the composite bar

$$P_1L_1/A_1 E_1 \quad = \quad P_1L_1/A_1 E_1 \quad = \quad P_2L_2 /A_2 E_2$$

ii) Total load P = load carried by material 1 of composite bar + load carried by material 2 of composite bar

$$P = P_1 + P_2$$

The load in each of the material of the composite bar is calculated from the above two conditions as P_1 and P_2 respectively.
Stress induced in material 1 of composite bar $= P_1/ A_1$
Stress induced in material 2 of composite bar $= P_2/ A_2$
36. Define Thermal stress and strain.
If the temperature of a body is lowered or raised, its dimensions will decrease or increase accordingly. If the changes are not permitted, then the stress thus developed in the body is called Thermal stress or temperature stress and the corresponding strain is known as Thermal strain or temperature strain.
37. List the methods to find the stresses in oblique plane?
1. Analytical method
2. Graphical method

38. Define principle stresses and principle plane. ***(Nov/Dec 2013) (Nov/Dec 2015) (Apr/May 2017) (Apr/May 2018)***
Principle stress: The magnitude of normal stress, acting on a principal plane is known as principal stresses.
Principle plane: The planes which have no shear stress are known as principal planes.
39. What is the radius of Mohr's circle?
Radius of Mohr's circle is equal to the maximum shear stress.
40. What is the use of Mohr's circle? ***(May/June 2013) (Nov/Dec 2016)***
To find out the normal, tangential and resultant on any inclined plane of complex stress system and also to find principle stresses and their planes in a complex stress system.

PART B / PART C

Simple stresses and Strains

1. A bar of 25mm diameter is subjected to a pull 40 kN. The measured extension on gauge length of 200 mm is 0.085 mm and the change in diameter is 0.003mm. Calculate the Poisson's ratio and the values of the three moduli. ***(Nov/Dec 2013)***

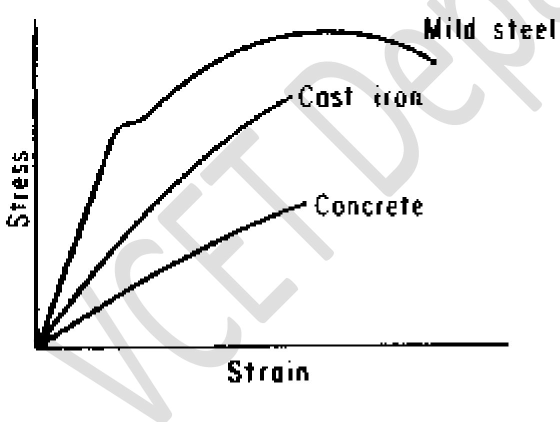
2. A hollow cast iron cylinder 4m long, 300mm outer diameter, and thickness of metal 50mm is subjected to a central load on the top when standing straight. The stress produced is 75000 kN/m^2, assume Young's modulus for cast iron as 1.5 X 10^8kN/m^2 and find (i) magnitude of the load,(ii) Longitudinal strain produced and (iii) total decrease in length. ***(Nov/Dec 2014)***

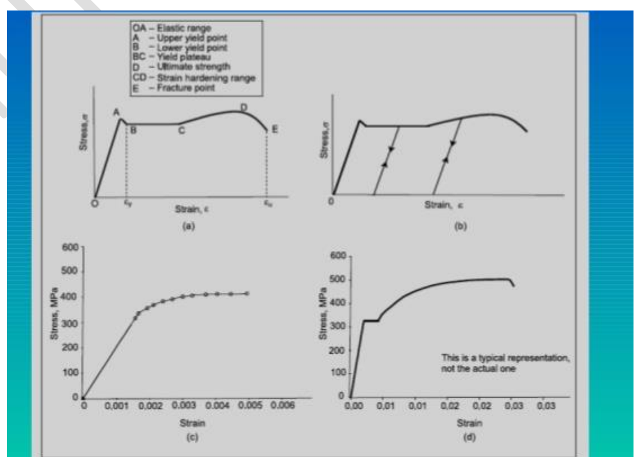
3. When a square bar of certain material (40mm X 40mm in section) is subjected to an axial pull of 160 kN, the measured extension on a gauge length of 200 mm is 0.1mm and the decrease in each side of square bar is 0.005mm. Calculate modulus of Elasticity, shear modulus and Bulk modulus for this material. ***(Apr/May 2015)***

4. A steel bar 300 mm long, 40 mm wide and 25 mm thick is subjected to a pull of 180 kN. Determine the change in volume of the bar. Take E= 2 X 10^5 N/mm^2 and 1/m=0.3. ***(Nov/Dec 2016)***

5. The following data relate to a bar subjected to a tensile test: Diameter of the bar =30 mm; tensile load =54 kN; Gauge length =300 mm; Extension of the bar = 0.112 mm: Change in diameter = 0.00366 mm. Calculate Poisson's ratio and the values of three moduli. ***(Apr/May 2017)***

6. (i) From the observation of stress-strain curves of mild-steel, TOR steel and concrete, what are all the distinguishing features can be observed? ***(Nov/Dec 2017)*** (6 marks)





Typical stress-strain curve for (a) mild steel rebar (b) MS rebar under repeated loading (c) CTD bar (d) TMT bar

7. A flat steel plate of trapezoidal form of uniform thickness of 20 mm tapers uniformly from a width of 100mm to 200mm in a length of 800 mm. If an axial tensile force of 100 kN is applied at each end, find the elongation of the plate. ***(Nov/Dec 2014)***

8. (ii)A rod 2.5 m long tapers uniformly from a diameter of 65 mm at one end to 35 mm at other end. It is subjected to an axial pull of 25 kN. Assume Young's Modulus E = 210 GPa. Neglecting extension due to self-weight, determine the extension of the bar. ***(Apr/May 2018)***

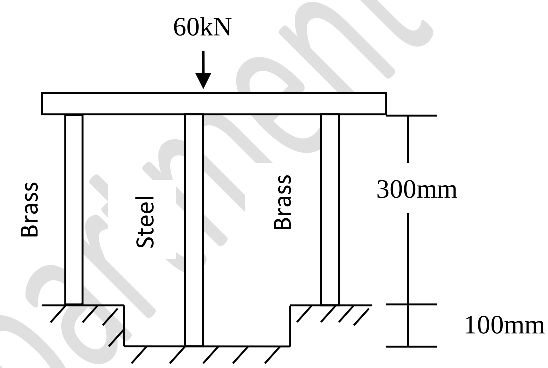
PART B / PART C

Composite/Compound/Thermal Stresses

9. A bar 0.3m long is 50mm square in section for 120mm of its length, 25mm diameter for 80mm and 40mm diameter for the remaining length, if a tensile force of 100kN is applied to the bar, calculate the maximum and minimum stress produced in it, and the total elongation. Take E = 200 GN/m^2 and assume uniform distribution of load over the cross section. ***(May/June 2013)***

10. A compound bar with loading is shown in fig 1 What is the relative position of point B with respect to point A? Take the Young's modulus of elasticity of the bar as 210 GPa. ***(Nov/Dec 2017)***

11. A steel rod of cross-sectional area 2000 mm^2 and two brass rods each of cross-sectional area 1200mm^2 together support a load of 60 kN as in figure Find the stresses in the rods. Take E= for steel = 2 X 10^5 N/mm^2 and E for brass = 1 X 10^5 N/mm^2. ***(Nov/Dec 2013)***



12. A solid cylindrical brass bar of 25 mm diameter is enclosed in a steel tube of 50 mm external and 25 mm internal diameter. The bar and the tube are both initially 1.5m long and are rigidly fastened at both ends. Find the stresses induced in the two materials when the assembly is subjected to an increase of 50˚C .Take coefficient of thermal expansion of steel as 12 X 10^{-6} /˚C and, modulus of elasticity of steel as 200GPa and that Modulus of elasticity of brass as 100 GPa.***(Apr/May 2015)***

13. A composite bar is made with a copper flat of size 50 mm X 30 mm and a steel flat of 50 mm X 40 mm of length 500 mm each placed one over the other. Find the stress induced in the material when the composite bar is subjected to an increase in temperature of 90˚C. Take coefficient of thermal expansion of steel as 12 X 10^{-6} /˚C and that of copper as 18 X 10^{-6} /˚C, Modulus of elasticity of steel = 200 GPa and Modulus of elasticity of copper = 100 GPa. ***(Nov/Dec 2015)***

14. A steel 2.4 cm external diameter and 1.8 cm internal diameter encloses a copper rod 1.5 cm diameter to which it is rigidly connected at the two ends. If at a temperature of 10˚C, there is no longitudinal stress, calculate the stresses in the rod and the steel tube, when the temperature is raised to 200 ˚C. Take E_s = 2.1 X 10^5 N/mm^2; E_c = 1 X 10^5 N/$mm^{2;}$; α_s =1.1 X 10^{-5}/˚C; α_c = 1.8 X 10^{-5}/˚C . ***(Apr/May 2017)***

PART B / PART C

Stress on inclined plane / Principal Stresses and Strains

15. A short metallic column of 500 mm^2 cross sectional area carries an axial compressive load of 100 kN. For a plane inclined at 60 degrees with the direction of load. Calculate (i) normal stress (ii) Tangential stress (iii) Resultant stress (iv) Maximum shear stress (v) obliquity of resultant stress. ***(May/June 2013)***

16. The stresses on two mutually perpendicular planes through a point on a body are 30 MPa and 20 MPa both tensile, along with a shear stress of 15 MPa. Find (i) the position of principal plane and stresses across them. (ii) the planes of maximum shear stress and (iii) the normal and tangential stress on the plane of maximum shear stress. ***(Nov/Dec 2015)***

17. An element has a tensile stress of 600 N /mm^2 acting on two mutually perpendicular planes and shear stress of 100 N/mm^2 on these planes. Find the principal stress and maximum shear stress. ***(Nov/Dec 2016)***

18. Two planes AB and AC which are right angles carry shear stress of intensity 17.5 N/ mm^2 while these planes also carry a tensile stress of 70 N/mm^2 and a compressive stress of 35 N/mm^2 respectively as show in the following figure. Determine the principal planes and the principal stresses. Also determine the maximum shear stress and planes on which it acts. ***(Apr/May 2017)***

19. For a two-dimensional state of stress on an elements, deduce the necessary mathematical equations for the principal stresses and maximum shear stresses. ***(Nov/Dec 2017)***

20. An element in a stressed material has tensile stress of 500 MN / m^2 and compressive stress of 350 MN / m^2 on mutually perpendicular planes and shear stress of 100 MN /m^2 on these planes. Determine the principal stresses and location of principal planes. Also determine the maximum shear stress. ***(Apr/May 2018)***