Department of Civil Engineering

Study Material

Unit-I

Simple Stresses and Strains

1. Introduction

Strength of Materials deals with the behavior of materials when subjected to different types of loads. It helps in designing safe and economical structures and machine components.

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2. Stress

Definition

Stress is the internal resisting force developed per unit area when an external force acts on a body.

Formula

σ =PA\boxed{\sigma=\frac{P}{A}} σ =AP

Where

- σ = Stress (N/mm² or MPa)
- P = Applied load (N)
- A = Cross-sectional area (mm²)

SI Unit

- Pascal (Pa)
- MPa (N/mm²)

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3. Strain

Definition

Strain is the deformation produced per unit original dimension.

Formula

ϵ=ΔLL\boxed{\epsilon=\frac{\Delta L}{L}}ϵ=LΔL

Where

- ΔL = Change in length
- L = Original length

No unit (Dimensionless)

4. Types of Stress

(a) Tensile Stress

Produced when the member is stretched.

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

Examples

- Steel cables
- Suspension bridges

(b) Compressive Stress

Produced when the member is compressed.

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

Examples

- Columns
- Concrete blocks

(c) Shear Stress

Acts parallel to the surface.

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

Examples

- Rivets
- Bolts
- Pins

(d) Bending Stress

Produced due to bending moment.

(e) Torsional Stress

Produced due to twisting moment.

5. Types of Strain

Longitudinal Strain

ϵ=ΔLL\epsilon=\frac{\Delta L}{L}ϵ=LΔL

Lateral Strain

Change in lateral dimension divided by original lateral dimension.

ϵl=Δdd\epsilon_l=\frac{\Delta d}{d}ϵl =dΔd

Shear Strain

Angular deformation.

γ=θ\gamma=\thetaγ=θ

Volumetric Strain

Change in volume divided by original volume.

ev=ΔVVe_v=\frac{\Delta V}{V}ev =VΔV

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6. St. Venant's Principle

Definition

The effect of load distribution is confined only near the point of application.

At sections sufficiently far from the load, the stress distribution becomes uniform.

Importance

Used in

- Beam analysis
- Machine design
- Structural design

7. Stress–Strain Diagram for Mild Steel

Important points

O–A

Proportional limit

Stress is directly proportional to strain.

Hooke's Law is valid.

A–B

Elastic limit

Material regains original shape after unloading.

C

Upper Yield Point

Large deformation begins.

D

Lower Yield Point

Plastic deformation starts.

D–E

Strain Hardening

Stress increases again.

E

Ultimate Stress

Maximum stress.

F

Breaking Point

Material fractures.

8. Elasticity

Ability of a material to regain its original shape after removing the load.

Examples

- Steel
- Rubber (within elastic limit)

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9. Plasticity

Ability of a material to undergo permanent deformation without breaking.

Examples

- Lead
- Clay

10. Hooke's Law

Within elastic limit,

σ =Eϵ\boxed{\sigma=E\epsilon} σ =Eϵ

Where

E = Young's Modulus

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11. Working Stress

Safe stress used in design.

σ w= σ yFOS\boxed{\sigma_w=\frac{\sigma_y}{FOS}} σ w =FOS σ y

Where

σy = Yield stress

FOS = Factor of Safety

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12. Factor of Safety (FOS)

FOS=Yield StressWorking Stress\boxed{FOS=\frac{\text{Yield Stress}}{\text{Working Stress}}}FOS=Working StressYield Stress

Typical values

- Steel = 1.5–2
- Concrete = 3
- Bridges = 4–6

13. Poisson's Ratio

Ratio of lateral strain to longitudinal strain.

$$\boxed{\mu=-\frac{\epsilon_l}{\epsilon}}$$

Usually,

$$0.25<\mu<0.35$$

For steel

$$\mu=0.3$$

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14. Volumetric Strain

$$e_v=\epsilon_x+\epsilon_y+\epsilon_z$$

For simple tension,

$$e_v=\epsilon(1-2\mu)$$

15. Pure Shear

Only shear stress acts.

Normal stresses are zero.

Examples

- Riveted joints
- Bolted joints

16. Complementary Shear Stress

Whenever shear stress acts on one plane, equal shear stress acts on the perpendicular plane.

Magnitude is equal.

Direction maintains equilibrium.

17. Elastic Moduli

(a) Young's Modulus

$$E=\frac{\sigma}{\epsilon}$$

(b) Shear Modulus

$$G=\frac{\tau}{\gamma}$$

(c) Bulk Modulus

$$K=\frac{\text{Hydrostatic Stress}}{\text{Volumetric Strain}}$$

18. Relationship Between Elastic Constants

Relation 1

$$\boxed{E=2G(1+\mu)}$$

Relation 2

$$\boxed{E=3K(1-2\mu)}$$

Relation 3

$$\boxed{E=\frac{9KG}{3K+G}}$$

19. Bars of Varying Section

When cross-sectional area changes,

Extension

$$\Delta L=\sum \frac{PL}{AE}$$

Calculate extension of each portion separately.

Add all extensions.

20. Composite Bars

Composite bars are made of two or more materials joined together.

Examples

- Steel + Copper
- Steel + Aluminum
- Reinforced concrete

Conditions

- Same extension
- Different stresses

Equation

ΔL1=ΔL2\Delta L_1=\Delta L_2ΔL1 =ΔL2

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21. Temperature Stresses

If expansion is prevented,

Stress develops.

Thermal strain

ϵ=α ΔT\boxed{\epsilon=\alpha\Delta T}ϵ=α ΔT

Thermal stress

σ=Eα ΔT\boxed{\sigma=E\alpha\Delta T} σ=Eα ΔT

Where

α = Coefficient of thermal expansion

22. Strain Energy

Energy stored due to deformation.

For axial loading,

U=PΔL2\boxed{U=\frac{P\Delta L}{2}}U=2PΔL

Also,

U=σ2V2EU=\frac{\sigma^2V}{2E}U=2Eσ2V

Where

V = Volume

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23. Resilience

Ability of material to absorb energy within elastic limit.

Proof Resilience

Maximum strain energy stored within elastic limit.

Modulus of Resilience

Energy stored per unit volume.

Ur= σ y22E\boxed{U_r=\frac{\sigma_y^2}{2E}}Ur =2E σ y2

24. Types of Loading

(a) Gradual Loading

Load is applied slowly.

Maximum stress

σ =PA\sigma=\frac{P}{A} σ =AP

(b) Sudden Loading

Load is applied instantly.

Maximum stress

σ =2PA\boxed{\sigma=2\frac{P}{A}} σ =2AP

(c) Impact Loading

Load falls from a height.

Stress is maximum.

Strain energy principle is used.

Impact stress formula

σ =PA(1+1+2AEhPL)\sigma=\frac{P}{A}\left(1+\sqrt{1+\frac{2AEh}{PL}}\right) σ =AP (1+1+PL2AEh)

Where

- h = Height of fall

Important Formula Sheet

Quantity	Formula
Stress	σ =PA\sigma=\frac{P}{A} σ =AP
Strain	ϵ= Δ LL\epsilon=\frac{\Delta L}{L}ϵ=L Δ L
Hooke's Law	σ =Eϵ\sigma=E\epsilon σ =Eϵ
Poisson's Ratio	μ =−ϵlϵ\mu=-\frac{\epsilon_l}{\epsilon} μ =−ϵϵl
Young's Modulus	E= σ ϵE=\frac{\sigma}{\epsilon}E=ϵ σ
Shear Modulus	G= τ γ G=\frac{\tau}{\gamma}G=γ τ

Quantity	Formula
Bulk Modulus	K=σevK=\frac{\sigma}{e_v}K=ev σ
Elastic Constant Relation	E=2G(1+μ)E=2G(1+\mu)E=2G(1+μ)
Elastic Constant Relation	E=3K(1−2μ)E=3K(1-2\mu)E=3K(1−2μ)
Extension	ΔL=PLAE\Delta L=\frac{PL}{AE}ΔL=AEPL
Thermal Stress	σ=EαΔT\sigma=E\alpha\Delta Tσ=EαΔT
Strain Energy	U=PΔL2U=\frac{P\Delta L}{2}U=2PΔL
Modulus of Resilience	σy22E\frac{\sigma_y^2}{2E}2Eσy2

Frequently Asked University Exam Questions (2 Marks)

1. Define stress and strain.
2. State Hooke's Law.
3. Define Poisson's ratio.
4. What is resilience?
5. Define strain energy.
6. State St. Venant's Principle.
7. Define factor of safety.
8. What is pure shear?
9. Define working stress.
10. Write the relations among elastic constants.

Frequently Asked University Exam Questions (5–10 Marks)

1. Explain the stress–strain diagram for mild steel with a neat sketch.
2. Derive the relationships among Young's modulus, shear modulus, and bulk modulus.
3. Derive the expression for strain energy due to axial loading.
4. Explain gradual, sudden, and impact loading with derivations.
5. Solve problems on composite bars.
6. Solve problems on bars of varying cross-section.
7. Derive the expression for temperature stress.
8. Explain resilience and modulus of resilience with derivation.