

Guest Lecture - Terry Neimeyer
KCI Technologies Inc
and
Concepts in
Strength of Materials

CIEG 125 Introduction to Civil
Engineering
Fall 2006

Lecture 5

Today's class

- Guest Lecture
- **Group 7, 8 and 9 ethics presentations**
- Strength of Materials

Outline - Materials

- From Rigid to Deformable Bodies
- Stress
- Strain
- Modulus of Elasticity
- Deformation Examples
- Design Stress

Rigid and Deformable Bodies

- To use only static analysis:
 - structural members are assumed to be rigid bodies
 - the number of support reactions matches the number of equilibrium equations
- However:
 - Structures are not completely rigid
 - They deform to resist the loads they carry
 - They often are statically indeterminate

Deformation of Bodies

- To determine how a structure deforms:
 - we must know what the forces are in the various members of the structure
 - we must know how those forces are distributed over each member
(called stress)
 - we must know how the member responds or deflects under these forces
(called strain)

Stress

- Stress is defined as the internal force per unit area in a structural member.

σ = stress

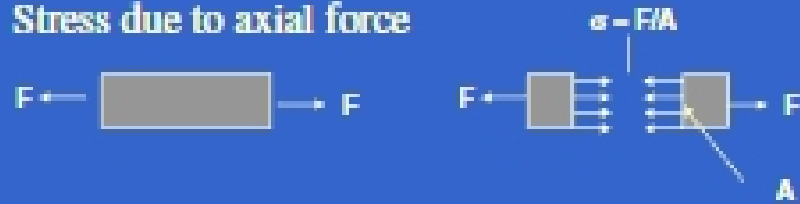
= F/A = Force / Area

Dimensions: $M L / T^2 / (L^2) = M / (L T^2)$

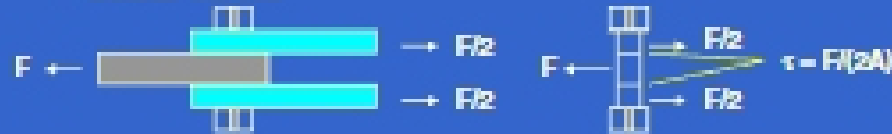
Units: N/m^2 or lb / in^2 (psi)

Stress, con't.

- Stress due to axial force

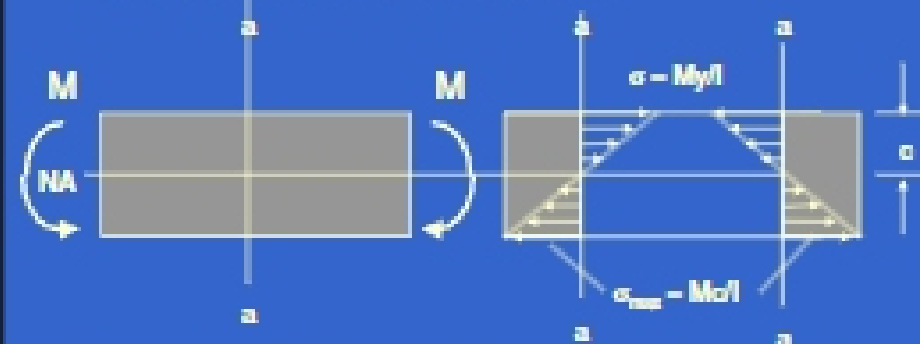


- Shear stress



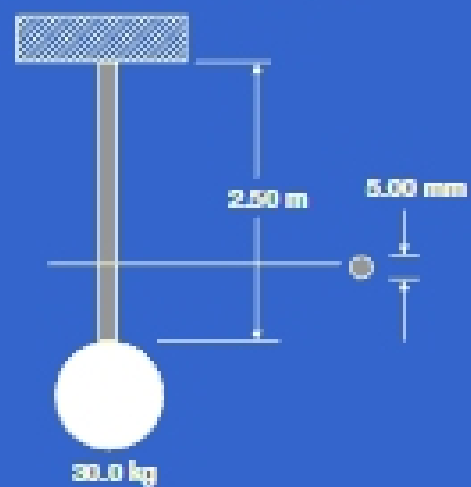
Stress, con't.

- Stress due to bending moments



I = moment of inertia = measure of how much area is away from NA

Stress Example



$$F = 30.0 \text{ kg} \cdot 9.81 \text{ m/s}^2 = 294 \text{ N}$$

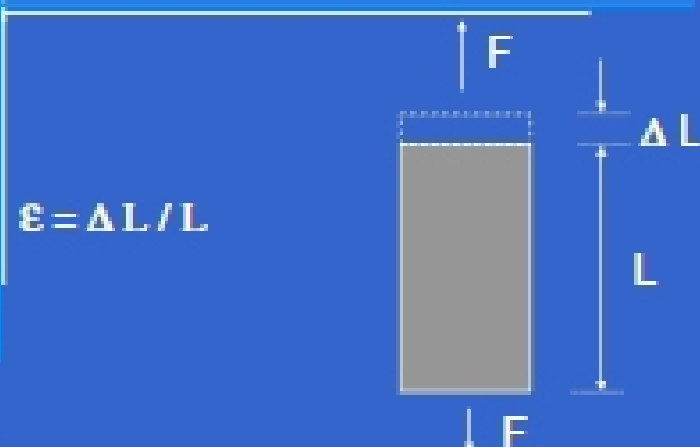
$$A = (\pi/4)(5.00 \text{ mm})^2 = 19.6 \text{ mm}^2$$

$$\sigma = F/A = 294 \text{ N} / 19.6 \text{ mm}^2 = 15.0 \text{ N/mm}^2 = 1.5 \times 10^7 \text{ Pa} = 15 \text{ MPa}$$

Strain

- Materials change shape (deform) under load.
- For an axial load, the elongation or compression per unit length is the strain.
 $\text{strain} = \Delta L/L$
- Strain has no units and is dimensionless

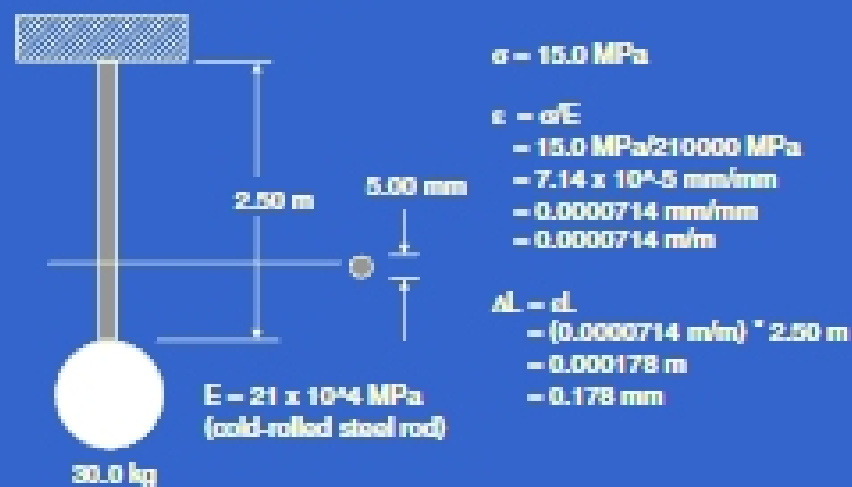
Strain, con't.



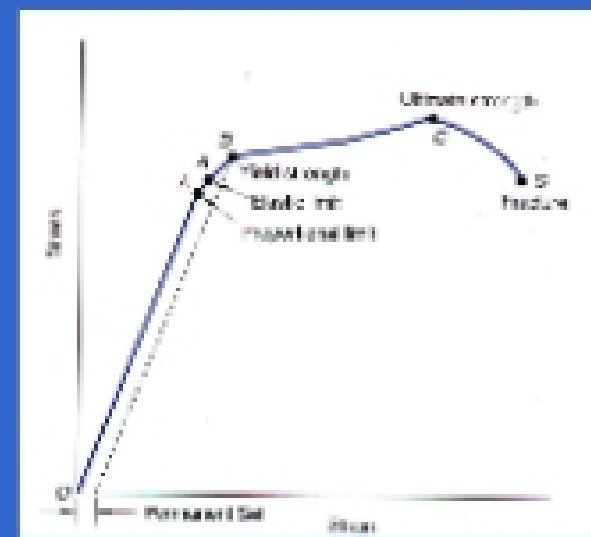
Modulus of Elasticity

- The modulus of elasticity, E , relates stress to strain for different materials
- $\sigma = E \epsilon$
- Linear relation first discovered by Hooke
- Relationship between σ and E is also known as Hooke's law
- Dimensions: Dimensions: $M L / T^2 / (L^2) = M / (L \cdot T^2)$
- Units: N/m^2 (Pa), N/mm^2 (MPa), lb/in^2 (psi), $kips/in^2$ (ksi)

Strain Example



Modulus of Elasticity, con't.



Modulus of Elasticity, con't.

- Elastic limit
 - upper limit of stress range over which material will return to its original shape.
- Proportional limit
 - upper limit of stress range over which E is constant
 - defines range over which a constant linear relationship between stress and strain exists.

Modulus of Elasticity, con't.

- Yield Strength
 - stress at which material undergoes a permanent strain of somewhere from 0.05 to 0.3
 - material is said to "yield" or start to "go plastic"
- Ultimate Strength
 - highest stress carried by the material
 - usually occurs after a lot of strain
 - notice the strain hardening behavior of material

Moduli of Elasticity

Material	E, psi	E, Gpa
Cold-rolled steel	30×10^6	210
Cast iron	16×10^6	110
Copper	16×10^6	110
Aluminum	10×10^6	70
Stainless steel	27×10^6	190
Nickel	30×10^6	210

Table B1 (page 200) in Engineering Fundamentals and Problem Solving, 11th ed.

Ultimate and Yield Strengths

Material	Ultimate Strength		Yield Strength	
	Mpa	psi	Mpa	psi
Cast iron	310	45×10^3	210	30×10^3
Wrought Iron	345	50×10^3	210	30×10^3
Structural Steel (A36)	415	60×10^3	240	35×10^3
Stainless Steel	620	90×10^3	210	30×10^3
Aluminum	125	18×10^3	85	12×10^3
Copper	455	66×10^3	415	60×10^3

Table B2 (page 200) in Engineering Fundamentals and Problem Solving, 11th ed.