lecture
fifteen

mechanics of materials
Mechanics of Materials

• MECHANICS

• MATERIALS
Mechanics of Materials

- **external loads and their effect on deformable bodies**
- **use it to answer question if structure meets requirements of**
  - stability and equilibrium
  - strength and stiffness
- **other principle building requirements**
  - economy, functionality and aesthetics
Knowledge Required

- material properties
- member cross sections
- ability of a material to resist breaking
- structural elements that resist excessive
  - deflection
  - deformation

Figure 2.34  An example of torsion on a cantilever beam.
Problem Solving

1. STATICS:
   - equilibrium of external forces,
   - internal forces, stresses

2. GEOMETRY:
   - cross section properties, deformations and conditions of geometric fit, strains

3. MATERIAL PROPERTIES:
   - stress-strain relationship for each material obtained from testing
Stress

- stress is a term for the intensity of a force, like a pressure
- internal or applied
- force per unit area

\[ \text{stress} = f = \frac{P}{A} \]
Design

- materials have a critical stress value where they could break or yield
  - ultimate stress
  - yield stress
  - compressive stress
  - fatigue strength
  - (creep & temperature)
Design (cont)

• we’d like \[ f_{\text{actual}} \ll F_{\text{allowable}} \]

• stress distribution may vary: average

• uniform distribution exists IF the member is loaded axially (concentric)

Figure 5.3  Centric loads.
Scale Effect

• model scale
  – material weights, small areas

• structural scale
  – much more material weight, bigger areas

• ratio is not constant:
  \[
  \frac{\gamma L^3}{L^2} = \gamma L
  \]
Strain (next lecture)

- materials deform
- axially loaded materials change length
- bending materials deflect

**STRAIN:**
- change in length over length

\[ strain = \varepsilon = \frac{\Delta L}{L} \]
Normal Stress

- **normal stress is normal to the cross section**
  - stressed area is perpendicular to the load

\[ f_{\text{t or c}} = \frac{P}{A} \]

*Figure 5.7  Two columns with the same load, different stress.*
Shear Stress

- stress parallel to a surface

\[
\tau_{ave} = \frac{P}{A} = \frac{P}{td}
\]

Figure 5.10  Shear stress between two glued blocks.
Bearing Stress

- stress on a surface by contact in compression

\[ f_p = \frac{P}{A} = \frac{P}{td} \]

Figure 5.3 Centric loads.
Bending Stress

- normal stress caused by bending

\[ f_b = \frac{Mc}{I} = \frac{M}{S} \]
Torsional Stress

- shear stress caused by twisting

\[ f_v = \frac{T\rho}{J} \]
Structures and Shear

• *what structural elements see shear?*
  
  – beams
  – bolts \{connections\}
  – splices
  – slabs
  – footings
  – walls
    – wind
    – seismic loads

wind
seismic loads
**Bolts**

- connected members in tension cause shear stress

![Diagram: Two steel plates bolted using one bolt.](image1)

![Diagram: Elevation showing the bolt in place.](image2)

- connected members in compression cause bearing stress

![Diagram: Bearing stress on plate.](image3)
Single Shear

• seen when 2 members are connected

\[ f_v = \frac{P}{A} = \frac{P}{\pi \frac{d^2}{4}} \]

Figure 5.11 A bolted connection—single shear.
**Double Shear**

- seen when 3 members are connected
- two areas

\[
f_v = \frac{P}{2A} = \frac{P}{2} = \frac{P}{\pi d^2/4}
\]

Free-body diagram of middle section of the bolt in shear.

*Figure 5.12  A bolted connection in double shear.*
Bolt Bearing Stress

- compression & contact
- projected area

\[ f_p = \frac{P}{A_{\text{projected}}} = \frac{P}{td} \]