



mechanics of 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

Mechanics of Materials

- MECHANICS
- MATERIALS



Knowledge Required

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

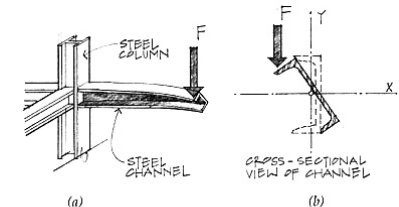


Figure 2.34 An example of torsion on a cantilever beam.

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)
- } acceptance vs. failure

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)

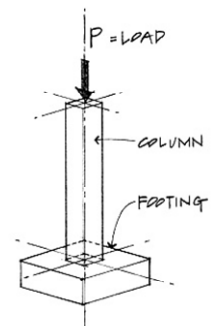


Figure 5.3 Centric loads.

Scale Effect

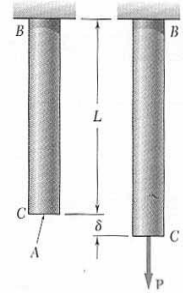
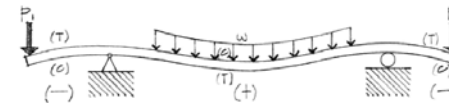
- *model scale*
 - material weights, small areas
- *structural scale*
 - much more material weight, bigger areas
- *ratio is not constant:*

$$\frac{\gamma L^3}{L^2} = \gamma L$$



Strain

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



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

$$\text{strain} = \varepsilon = \frac{\Delta L}{L}$$

Normal Stress

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

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

(σ)

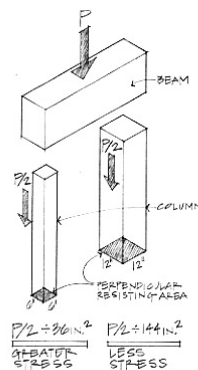


Figure 5.7 Two columns with the same load, different stress.

Shear Stress

- *stress parallel to a surface*

$$f_v = \frac{P}{A} = \frac{P}{td}$$

(τ_{ave})

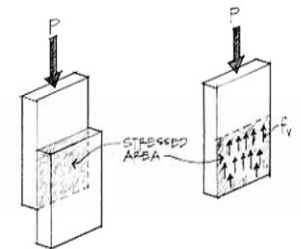


Figure 5.10 Shear stress between two glued blocks.

Bearing Stress

- stress on a surface by contact in compression

$$f_p = \frac{P}{A} = \frac{P}{td}$$

$$(\sigma)$$

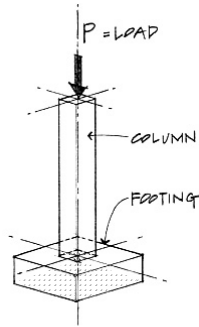


Figure 5.3 Centric loads.

Bending Stress

- normal stress caused by bending

$$f_b = \frac{Mc}{I} = \frac{M}{S}$$

$$(\sigma)$$

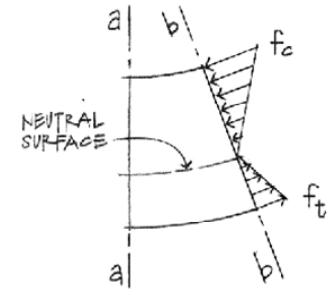


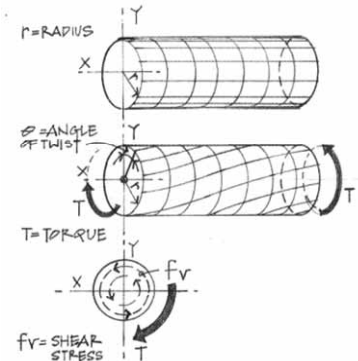
Figure 8.8 Bending stresses on section b-b.

Torsional Stress

- shear stress caused by twisting

$$f_v = \frac{T\rho}{J}$$

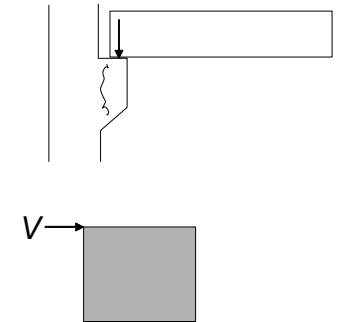
$$(\tau)$$



Structures and Shear

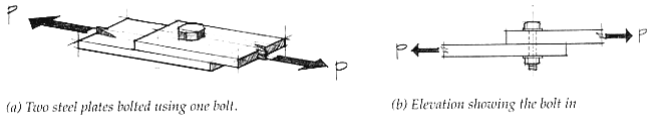
- what structural elements see shear?

- beams
 - bolts
 - splices
 - slabs
 - footings
 - walls
 - wind
 - seismic loads
- connections



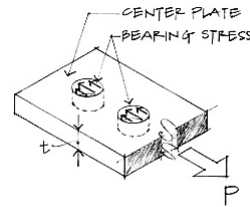
Bolts

- connected members in tension cause shear stress



(a) Two steel plates bolted using one bolt. (b) Elevation showing the bolt in shear.

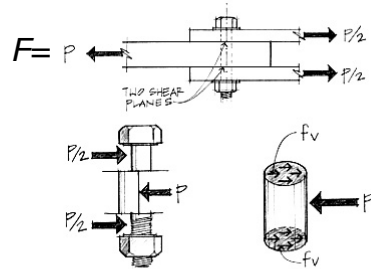
- connected members in compression cause bearing stress



Bearing stress on plate.

Double Shear

- seen when 3 members are connected
- two areas



Free-body diagram of middle section of the bolt in shear. Figure 5.12 A bolted connection in double shear.

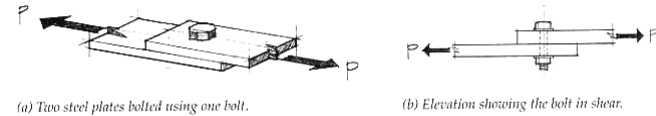
$$f_v = \frac{P}{2A}$$

(two shear planes)

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

Single Shear

- seen when 2 members are connected



(a) Two steel plates bolted using one bolt. (b) Elevation showing the bolt in shear.

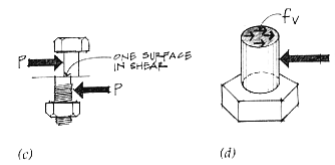


Figure 5.11 A bolted connection—single shear.

f_v = Average shear stress through bolt cross section

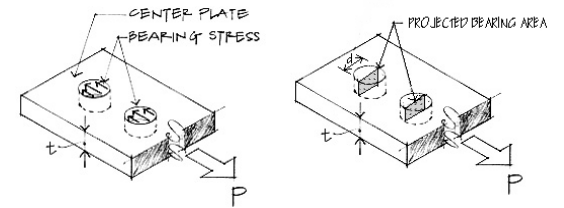
A = Bolt cross-sectional area

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

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

Bolt Bearing Stress

- compression & contact
- projected area



Bearing stress on plate.

$$f_p = \frac{P}{A_{projected}} = \frac{P}{td}$$