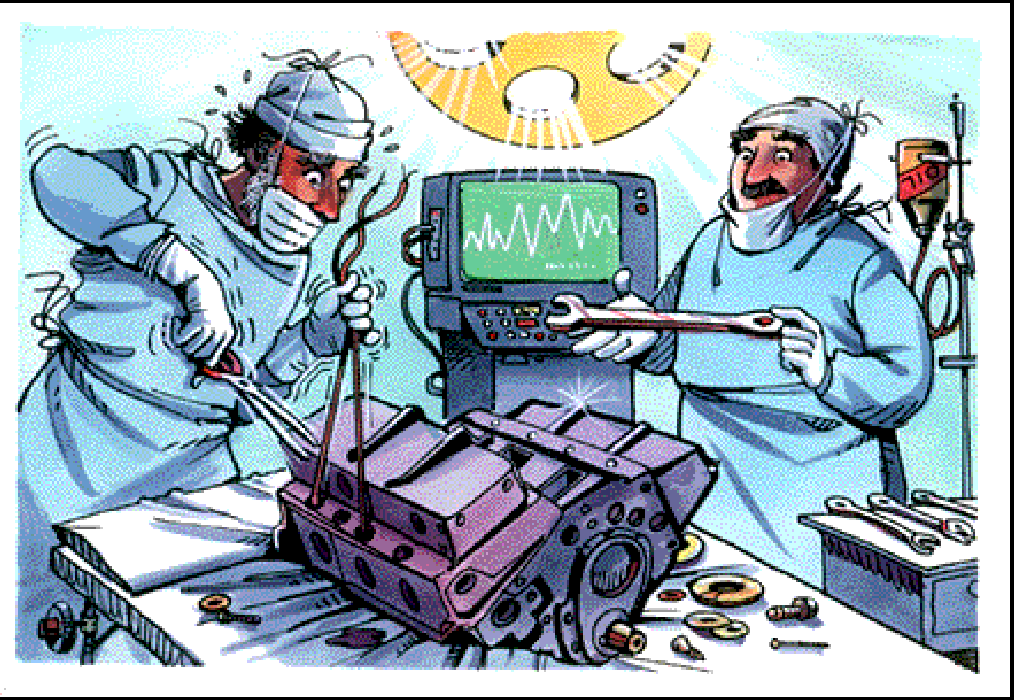
ARCHITECTURAL STRUCTURES I: STATICS AND STRENGTH OF MATERIALS

ENDS 231

DR. ANNE NICHOLS

SPRING 2007

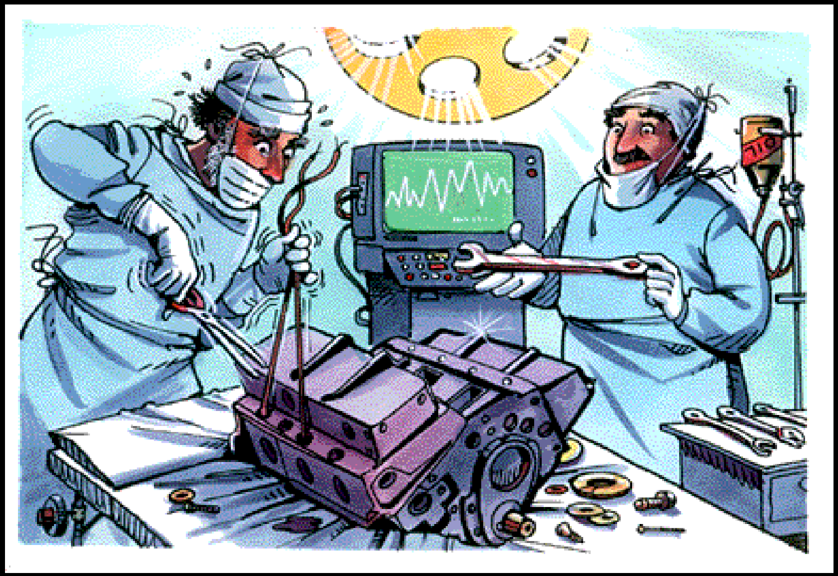
lecture fifteen

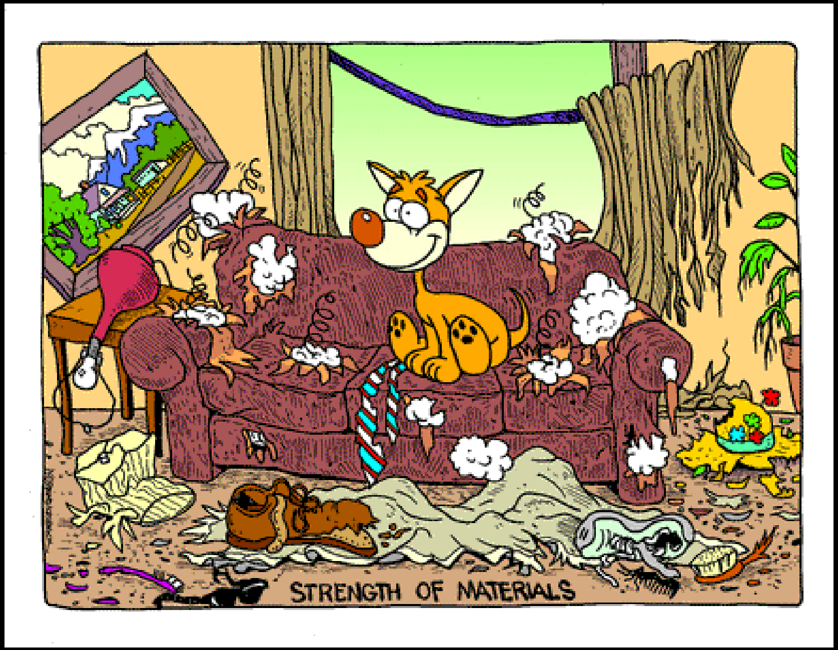


mechanics of materials

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

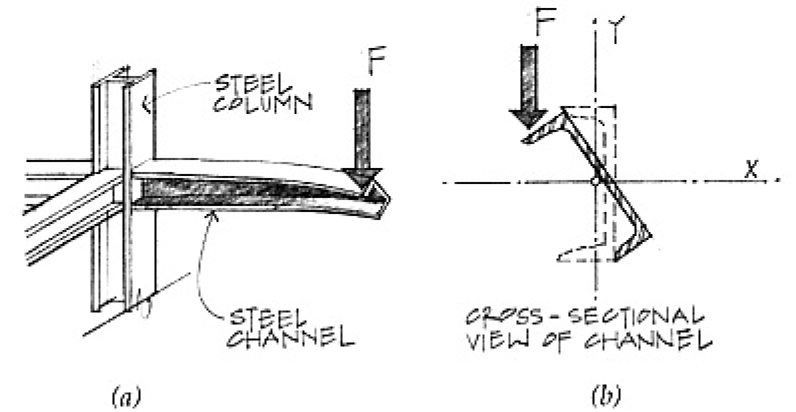


Figure 2.34 An example of torsion on a cantilever beam.

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*

$$stress = f = \frac{P}{A}$$

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*

$$f_{actual} << F_{allowable}$$

- *stress distribution may vary: <u>average</u>*
- *uniform distribution exists IF the member is loaded axially (concentric)*

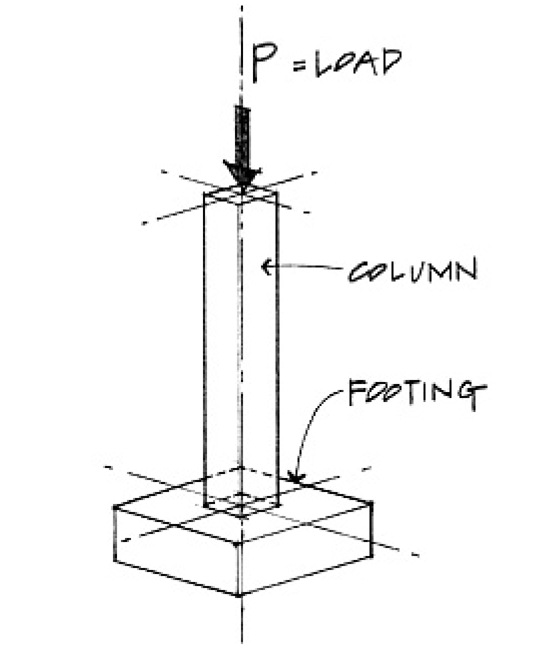
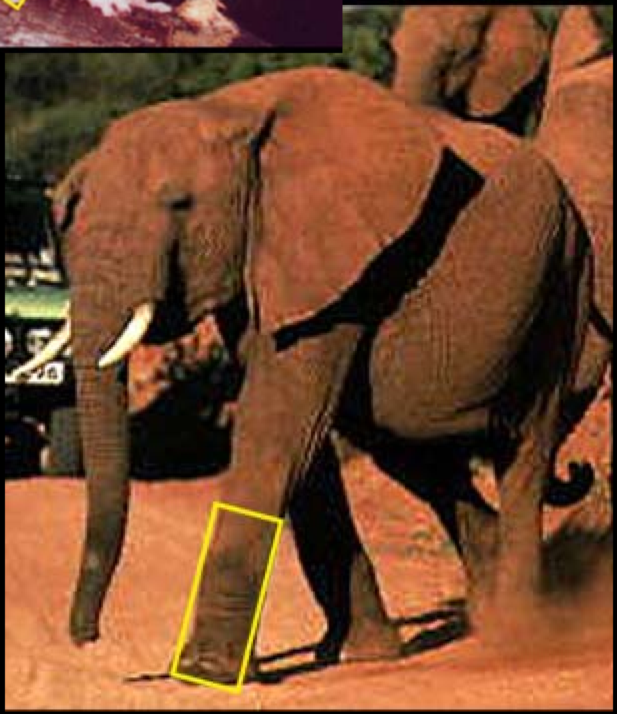


Figure 5.3 Centric loads.

Scale Effect

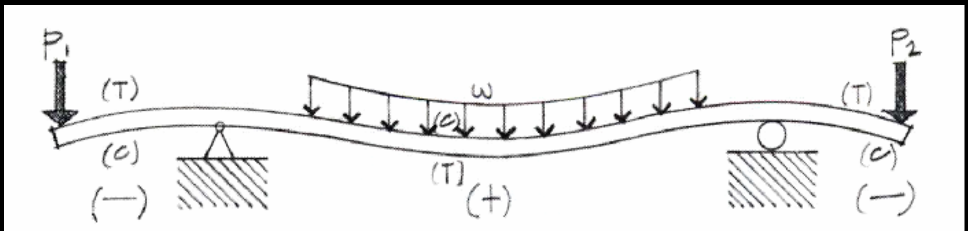
- model scale
  - material weights, small areas
- structural scale
  - much more material weight, bigger areas
- ratio is not constant:

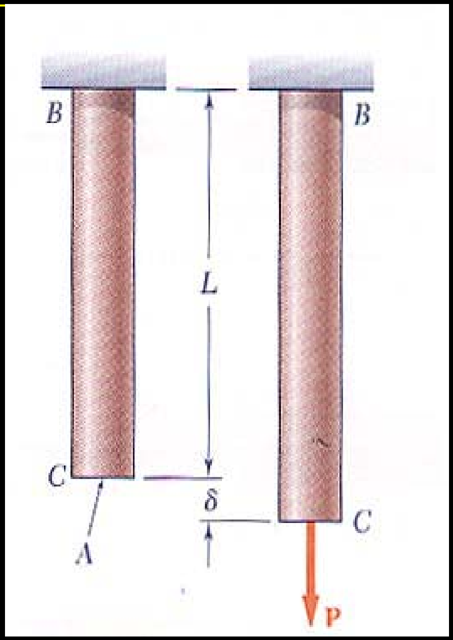
$$\frac{\gamma L^3}{L^2} = \gamma L$$



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

- <u>normal</u> stress is normal to the cross section
  - stressed area is perpendicular to the load

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

$$(\sigma)$$

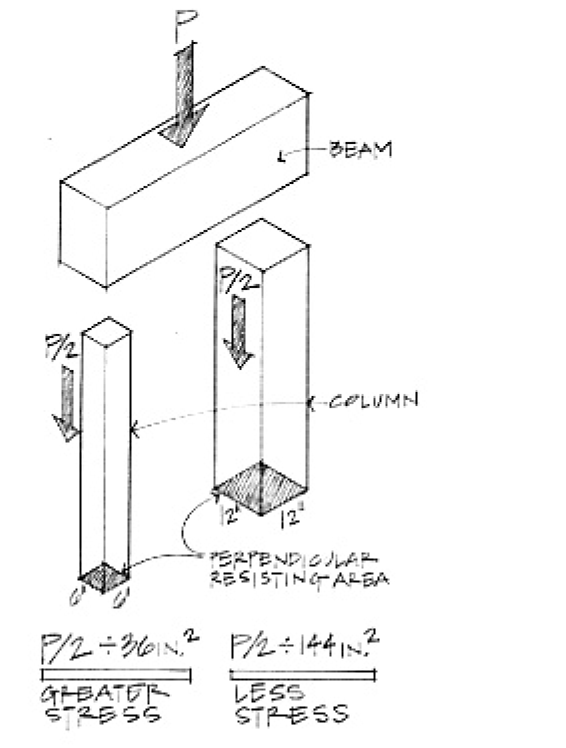


Figure 5.7 Two columns with the same load, different stress.

Shear Stress

- stress parallel to a surface

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

$$(\tau_{ave})$$

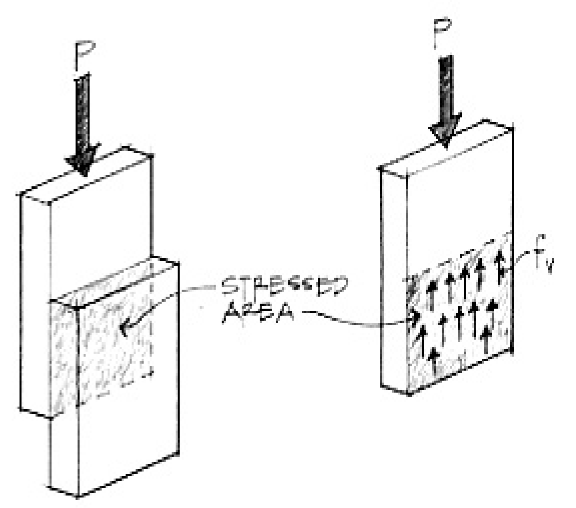


Figure 5.10 Shear stress between two glued blocks.

Bearing Stress

- *stress on a surface by <u>contact</u> in compression*

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

$$(\sigma)$$

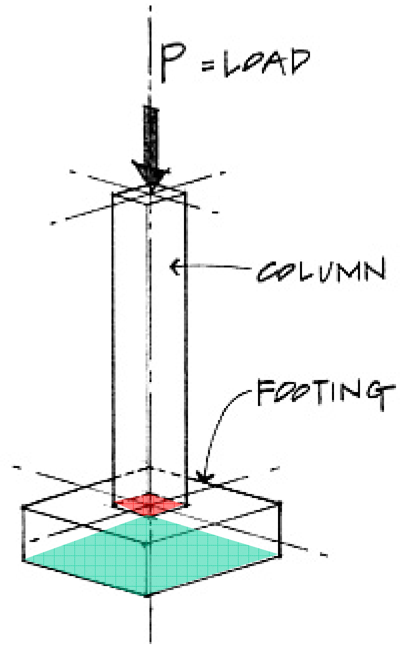


Figure 5.3 Centric loads.

Bending Stress

- *normal stress caused by bending*

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

$$(\sigma)$$

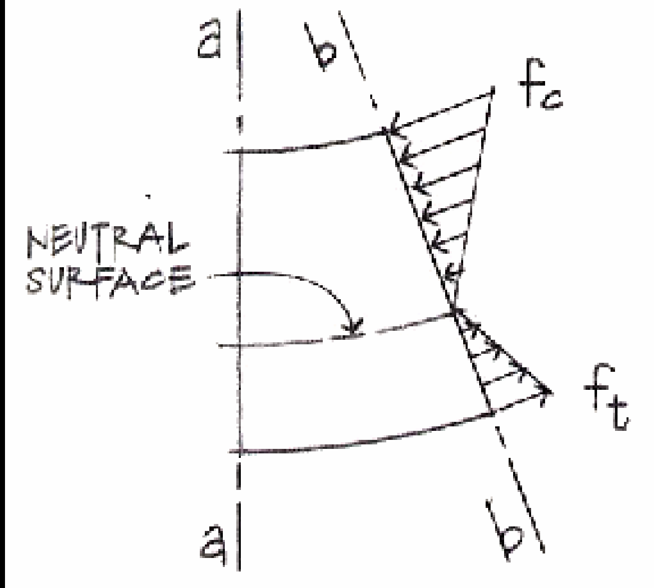
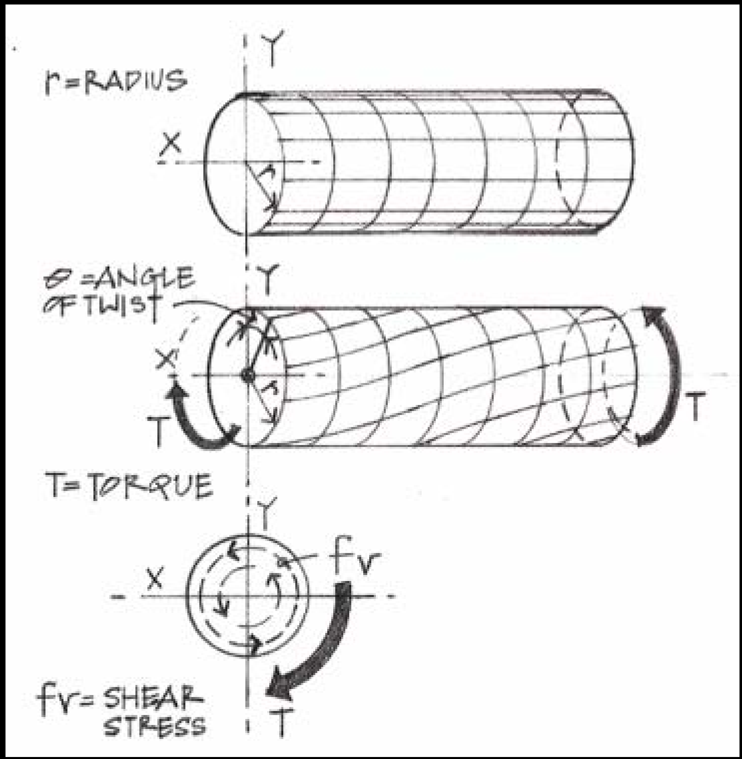


Figure 8.8 Bending stresses on section b-b.

Torsional Stress

- *shear stress caused by twisting*

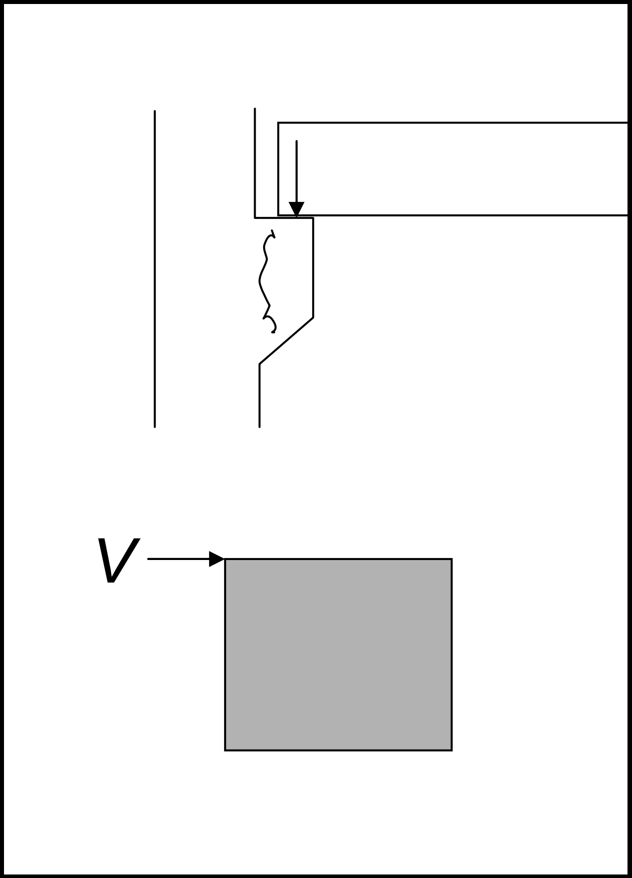
$$f_v = \frac{T\rho}{J}$$
$$(\tau)$$



Structures and Shear

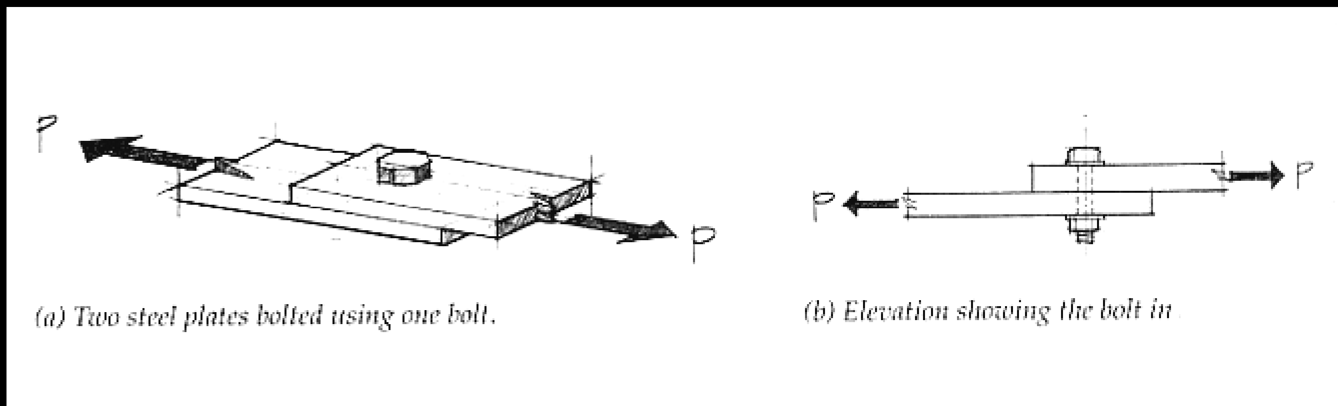
- what structural elements see shear?
  - beams
  - bolts
  - splices
  - slabs
  - footings
  - walls
    - wind
    - seismic loads

connections (bolts, splices)

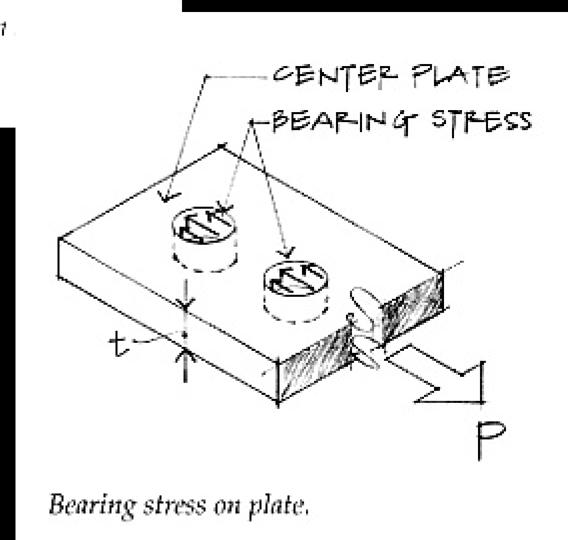


Bolts

- connected members in tension cause shear stress



- connected members in compression cause bearing stress



Bearing stress on plate.

Single Shear

- *seen when 2 members are connected*

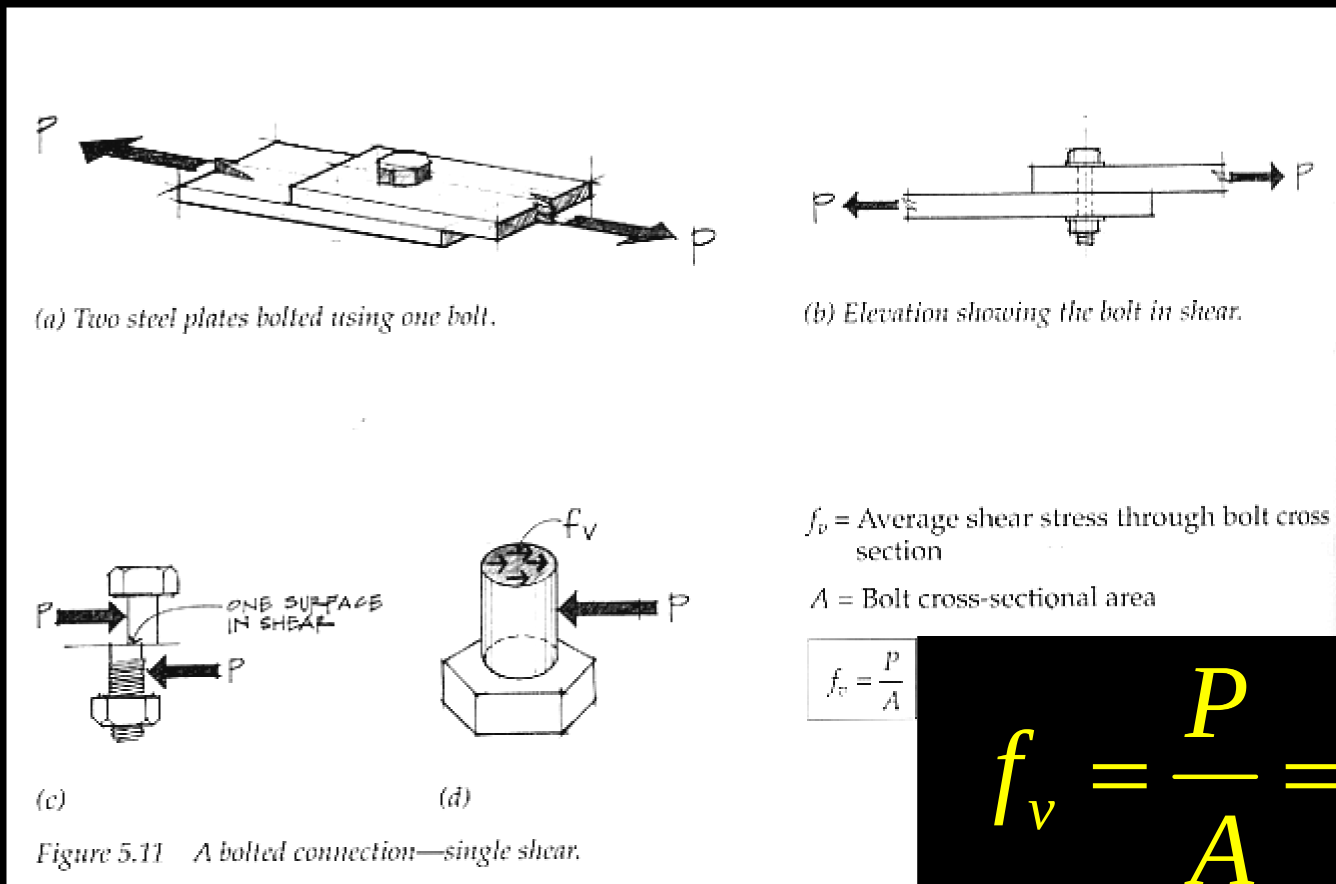
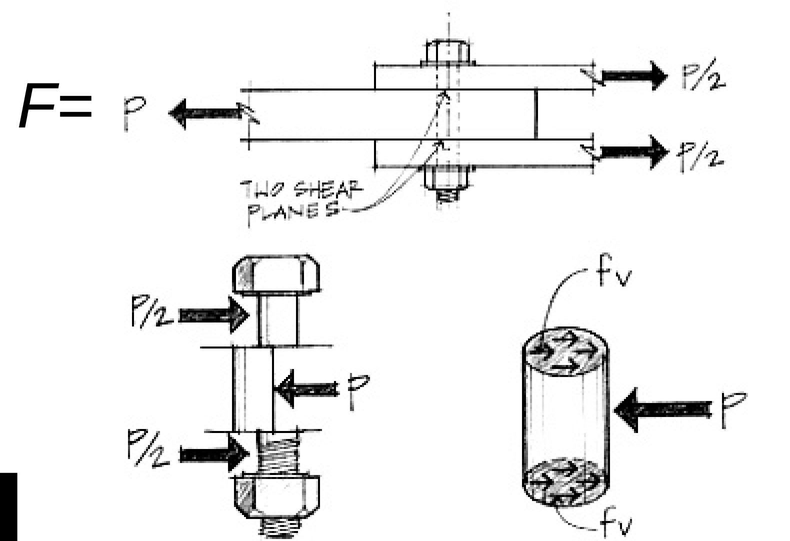


Figure 5.11 A bolted connection—single shear.

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

Double Shear

- seen when 3 members are connected
- <u>two</u> areas



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

Figure 5.12 A bolted connection in double shear.

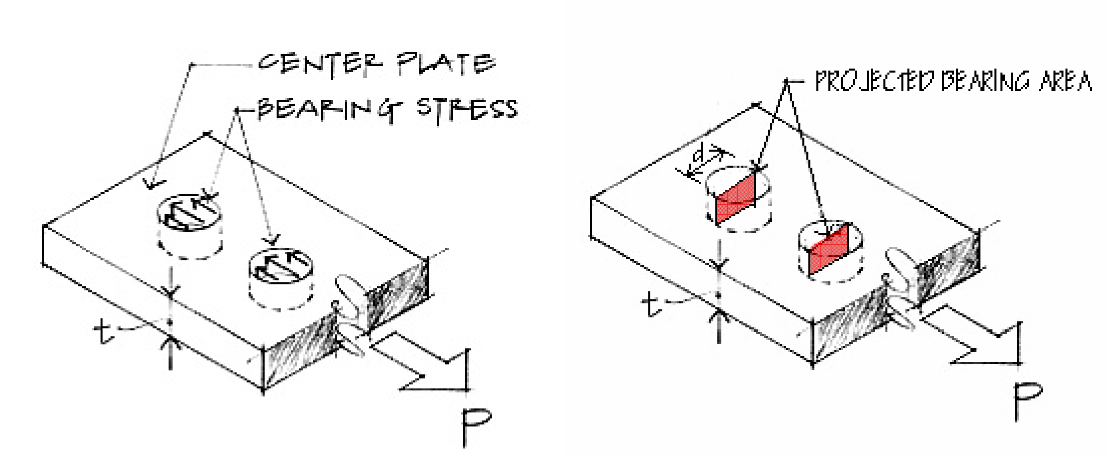
$$f_v = \frac{P}{2A}$$

(two shear planes)

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

Bolt Bearing Stress

- compression & contact
- projected area



Bearing stress on plate.

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