ARCHITECTURAL STRUCTURES I: STATICS AND STRENGTH OF MATERIALS

ENDS 231

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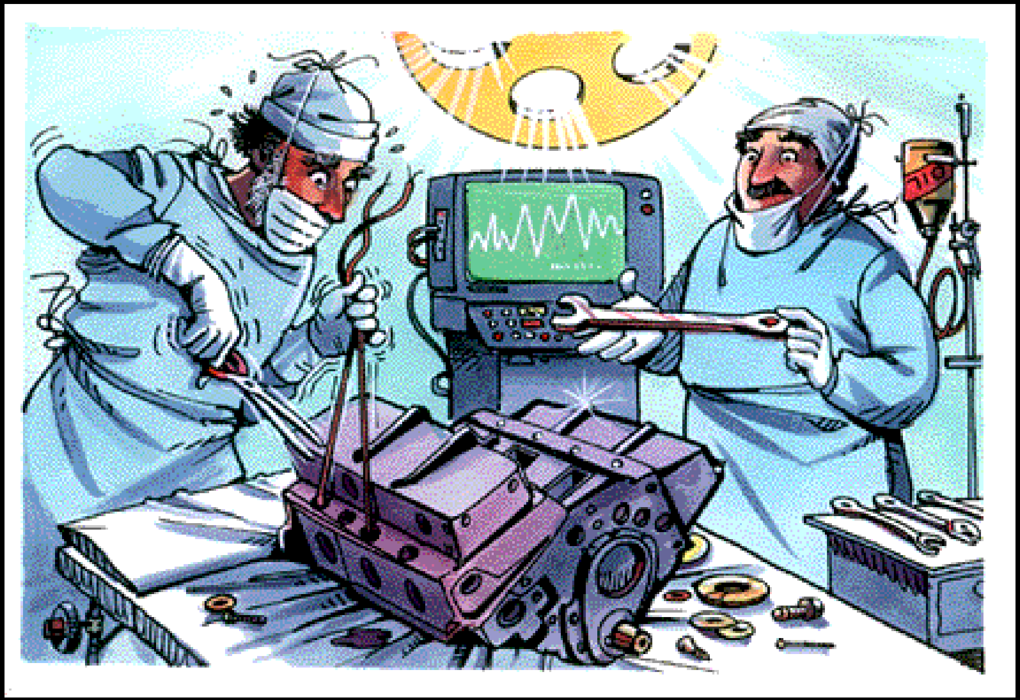
SPRING 2008

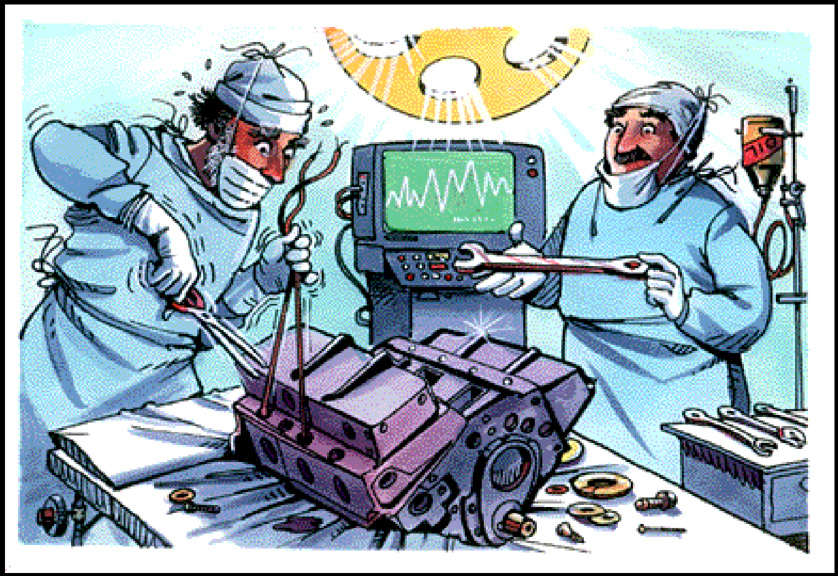
lecture
fifteen

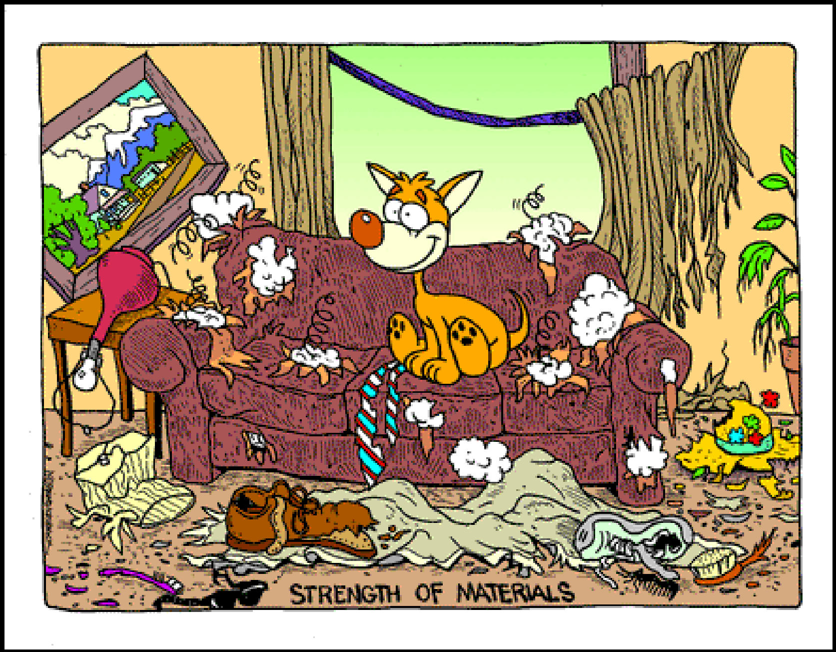


mechanics of materials

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

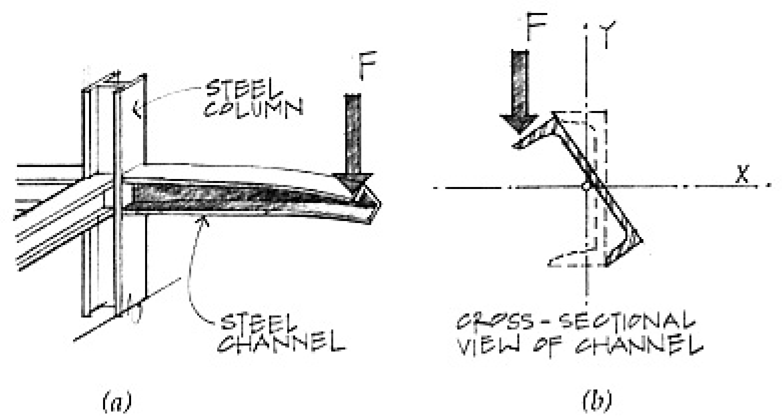


Figure 2.34 An example of torsion on a cantilever beam.

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 <u>intensity</u> of a force, like a pressure*
- *internal <u>or</u> 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: average*
- *uniform distribution exists IF the member is loaded axially (concentric)*

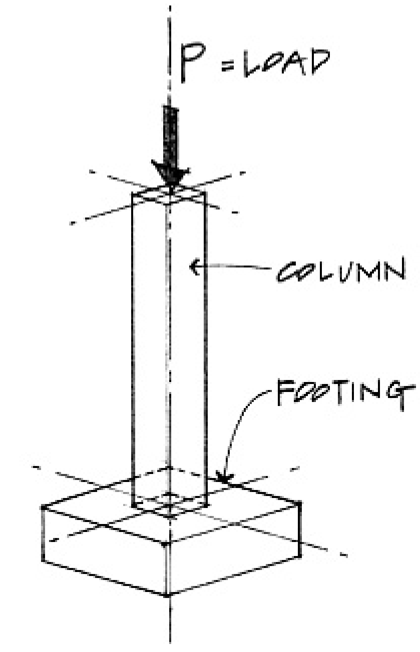
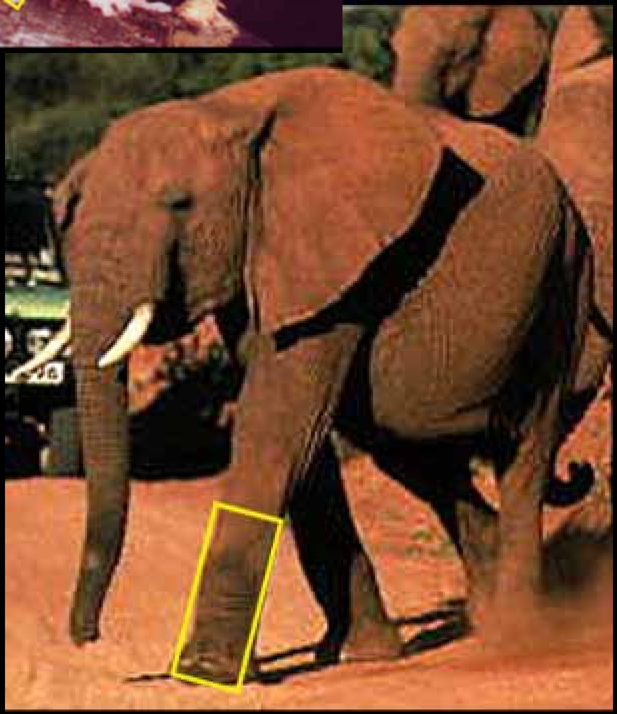


Figure 5.3 Centric loads.

Scale Effect

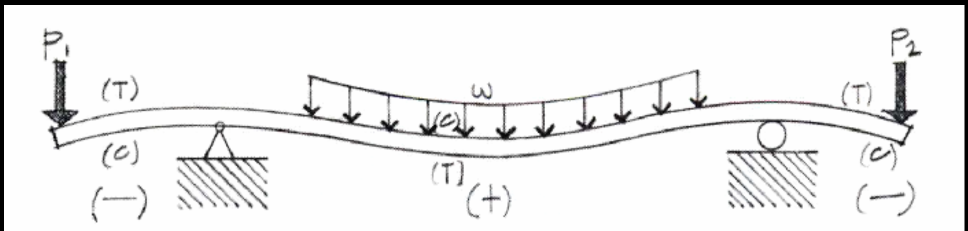
- model scale
  - material weights, small areas
- structural scale
  - much more material weight, bigger areas
- ratio is not constant:

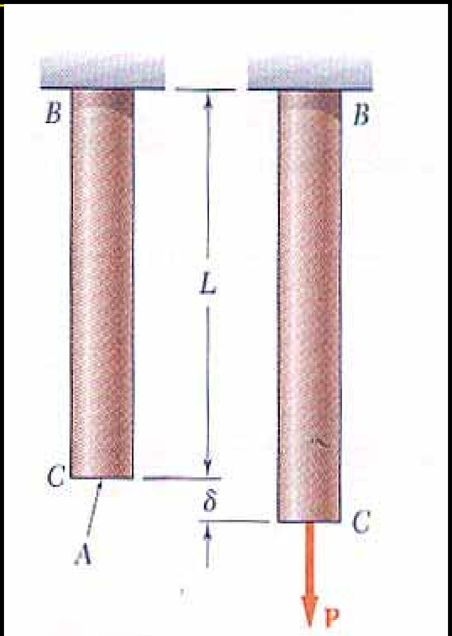
$$\frac{\gamma L^3}{L^2} = \gamma L$$



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

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

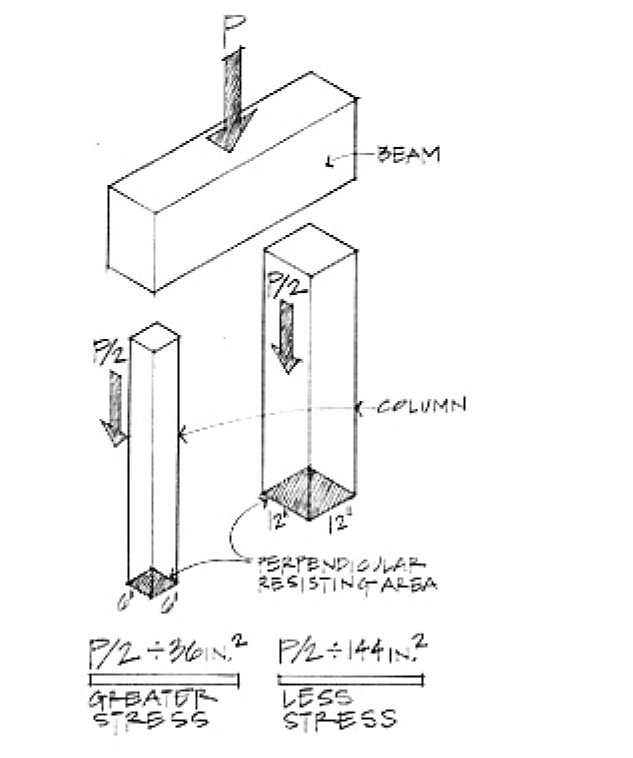


Figure 5.7 Two columns with the same load, different stress.

Shear Stress

- *stress parallel to a surface*

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

$$(\tau_{ave})$$

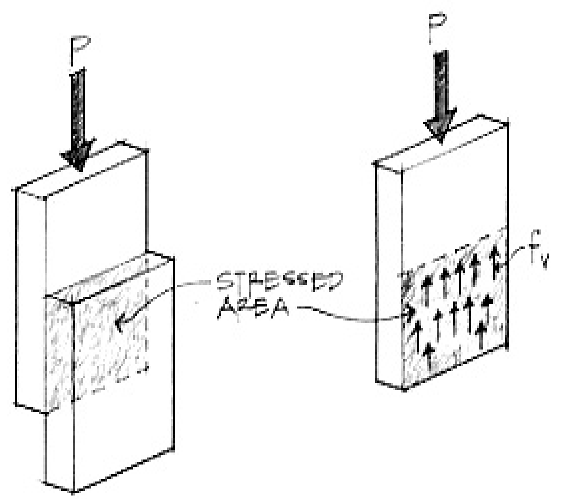


Figure 5.10 Shear stress between two glued blocks.

Bearing Stress

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

$$f_p = \frac{P}{A} = \frac{P}{td}$$
$$(\sigma)$$

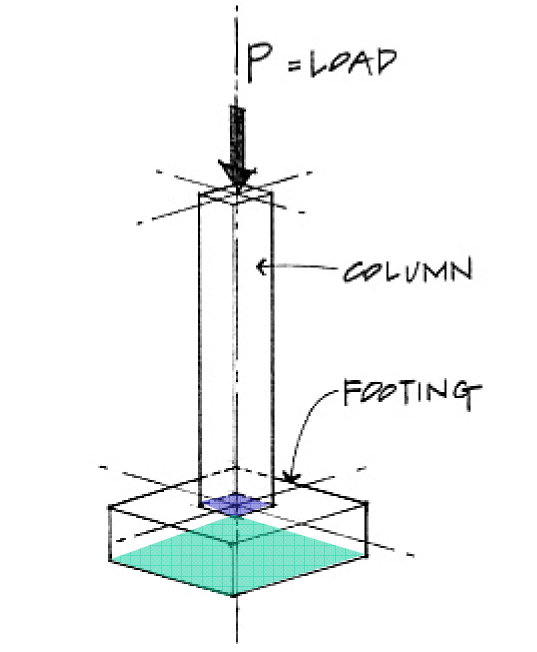


Figure 5.3 Centric loads.

Bending Stress

- *normal stress caused by bending*

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

$$(\sigma)$$

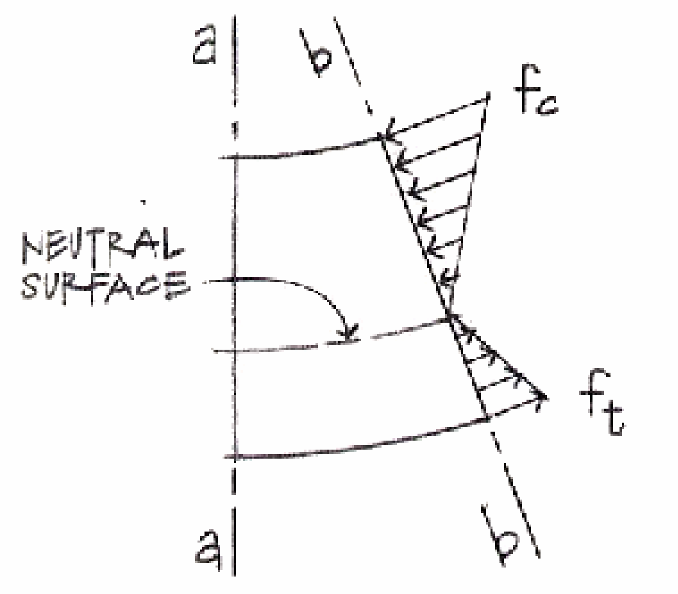


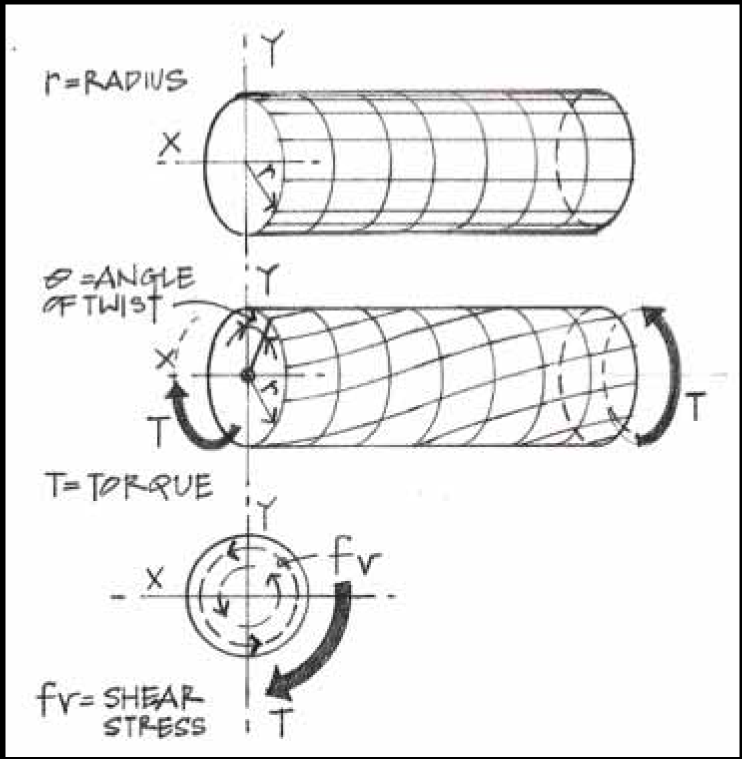
Figure 8.8 *Bending stresses on section* b-b.

Torsional Stress

- *shear stress caused by twisting*

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

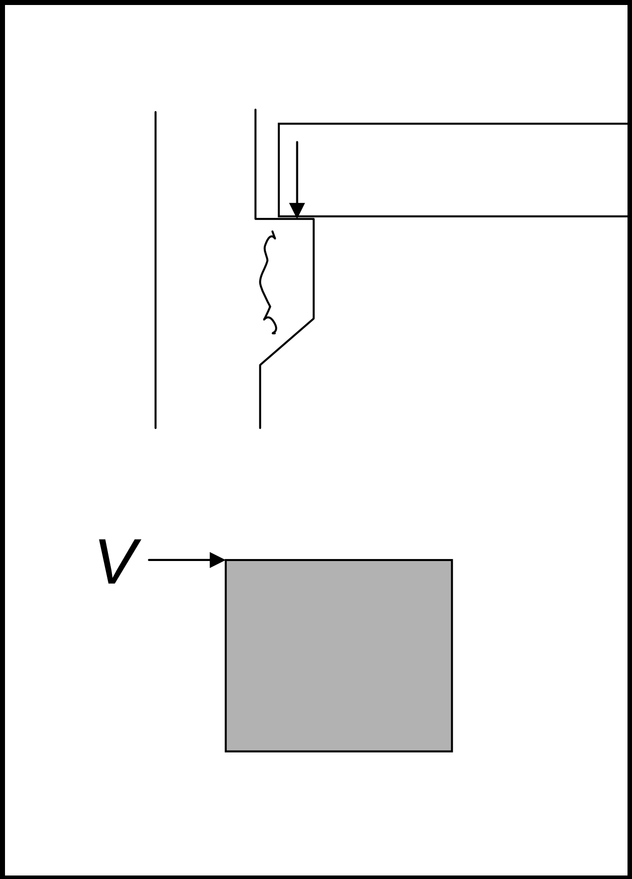
$$(\tau)$$



Structures and Shear

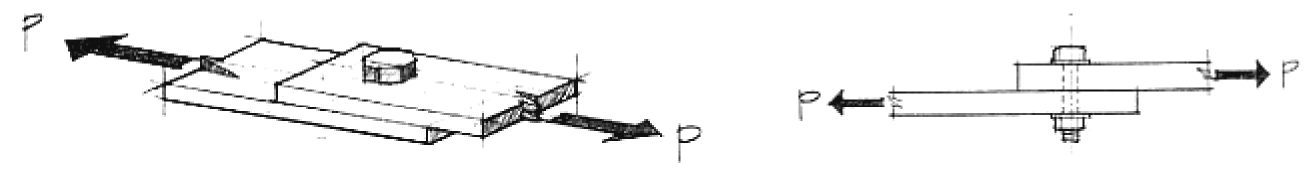
- *what structural elements see shear?*
  - *beams*
  - *bolts*
  - *splices*
  - *slabs*
  - *footings*
  - *walls*
    - *wind*
    - *seismic loads*

connections (bolts, splices)



Bolts

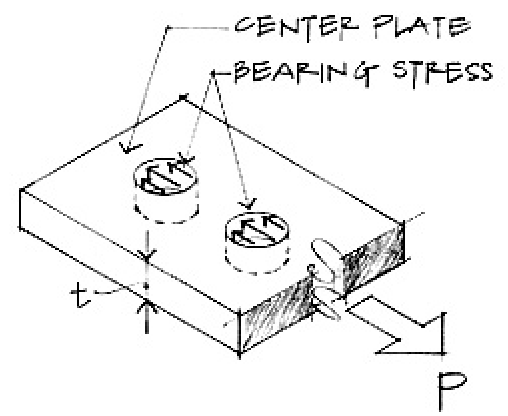
- *connected members in tension cause shear stress*



(a) Two steel plates bolted using one bolt.

(b) Elevation showing the bolt in

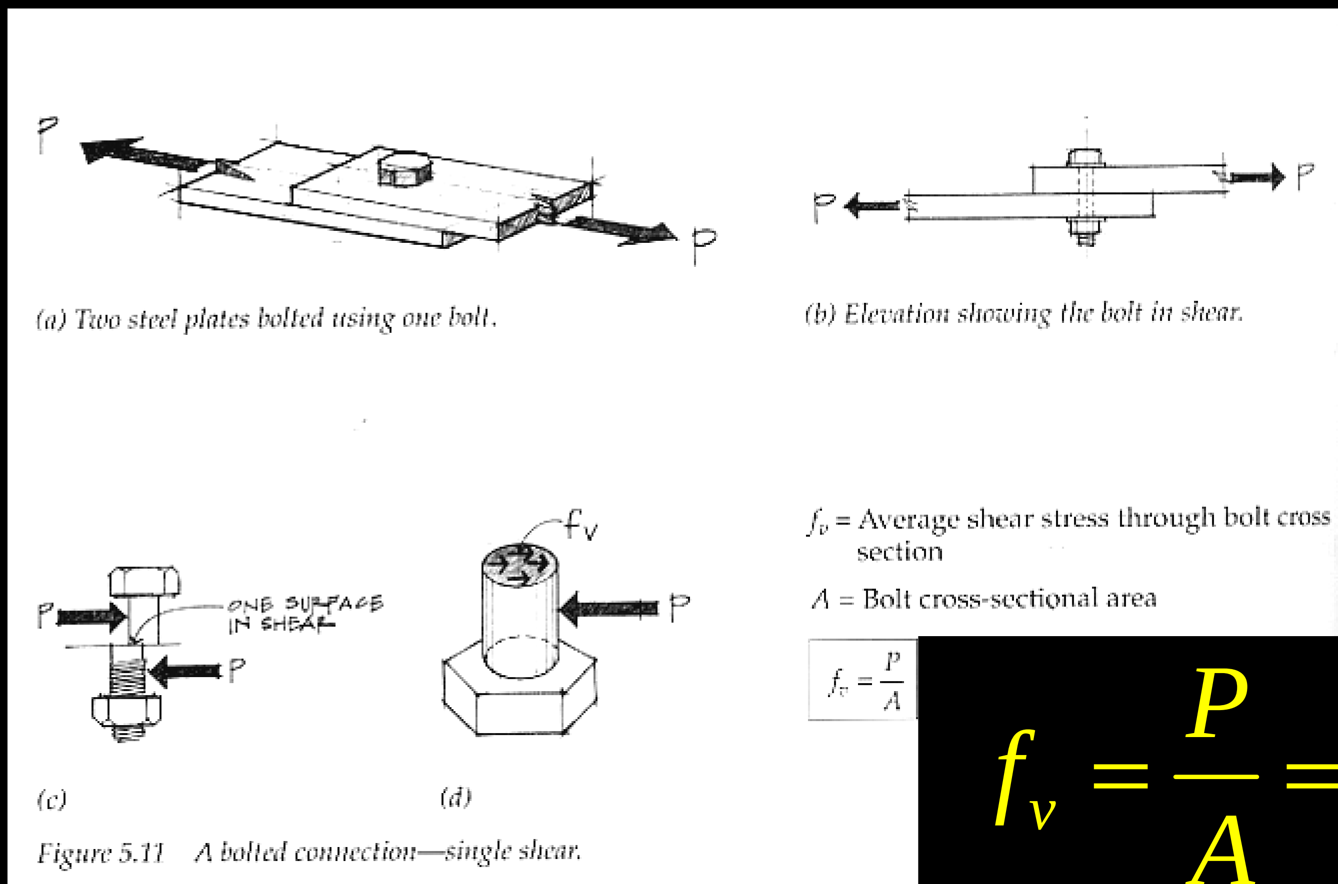
- *connected members in compression cause bearing stress*



Bearing stress on plate.

Single Shear

- seen when 2 members are connected



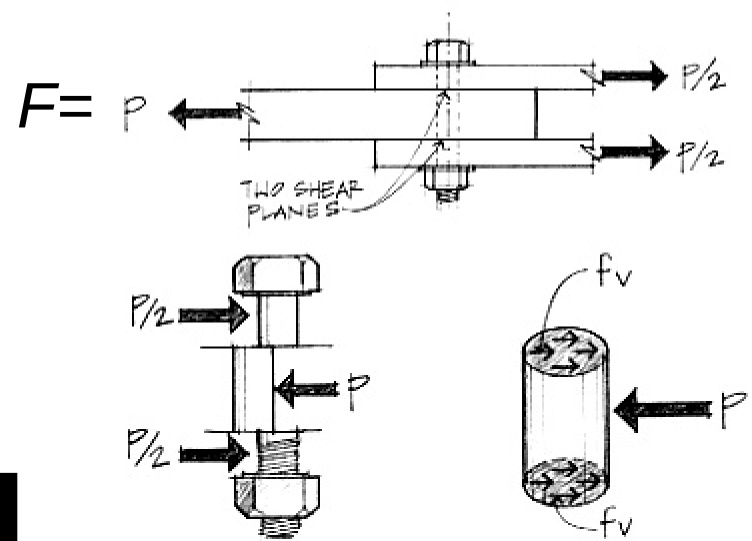
$$f_v = \frac{P}{A} = \frac{P}{\pi d^2 / 4}$$

Double Shear

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

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

(two shear planes)



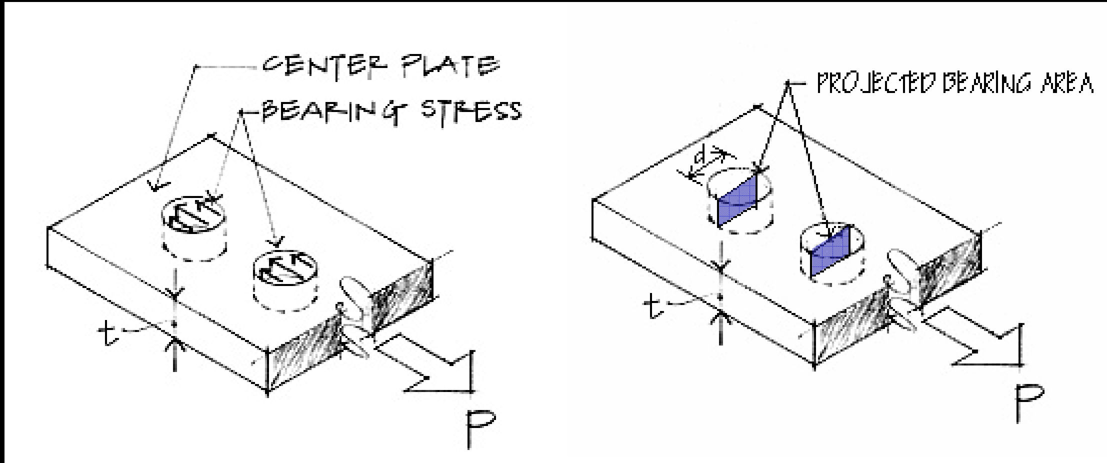
Free-body diagram of middle section of the bolt in shear.

Figure 5.12 A bolted connection in double shear.

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

Bolt Bearing Stress

- compression & contact
- projected area



Bearing stress on plate.

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