

**ARCHITECTURAL STRUCTURES I:  
STATICS AND STRENGTH OF MATERIALS**

**ENDS 231**

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**FALL 2007**

lecture  
**fifteen**



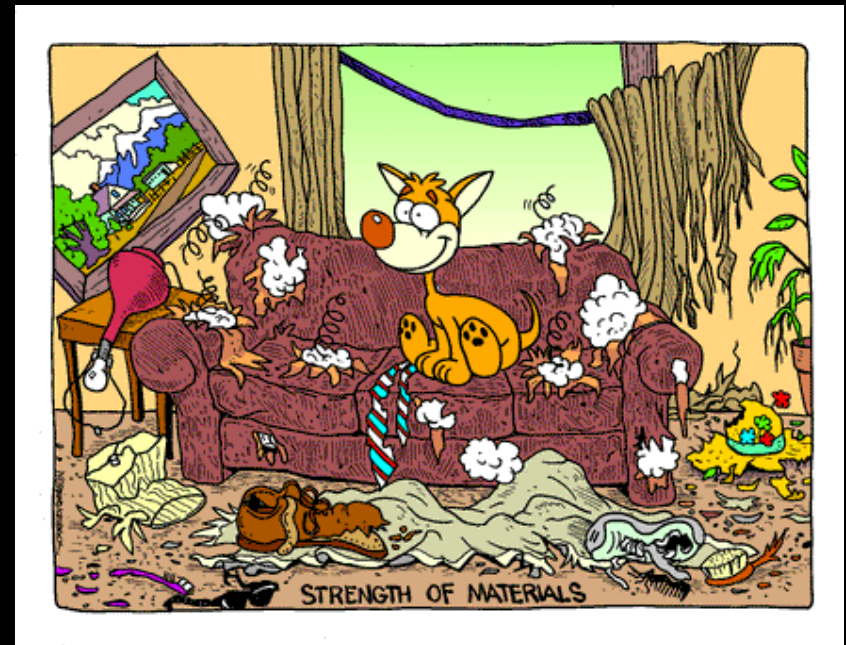
**mechanics of  
materials**

# Mechanics of Materials

- MECHANICS



- MATERIALS



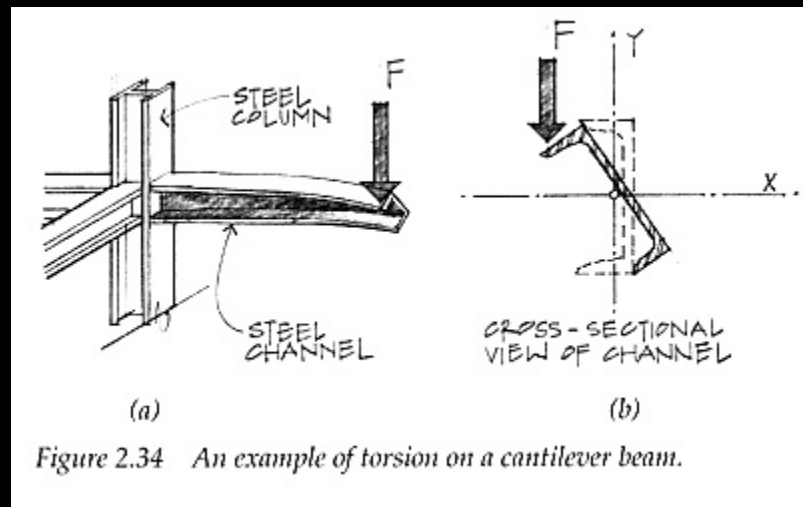
# *Mechanics of Materials*

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- *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*



# 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

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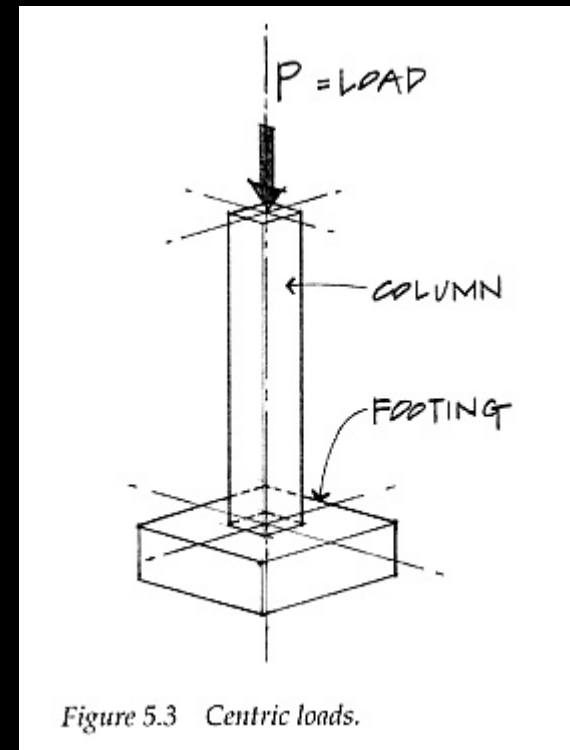
- *materials have a critical stress value where they could break or yield*
    - *ultimate stress*
    - *yield stress*
    - *compressive stress*
    - *fatigue strength*
    - *(creep & temperature)*
- acceptance vs. failure*

## Design (cont)

- we'd like

$$f_{actual} \ll F_{allowable}$$

- stress distribution may vary: average
- uniform distribution exists IF the member is loaded axially (concentric)

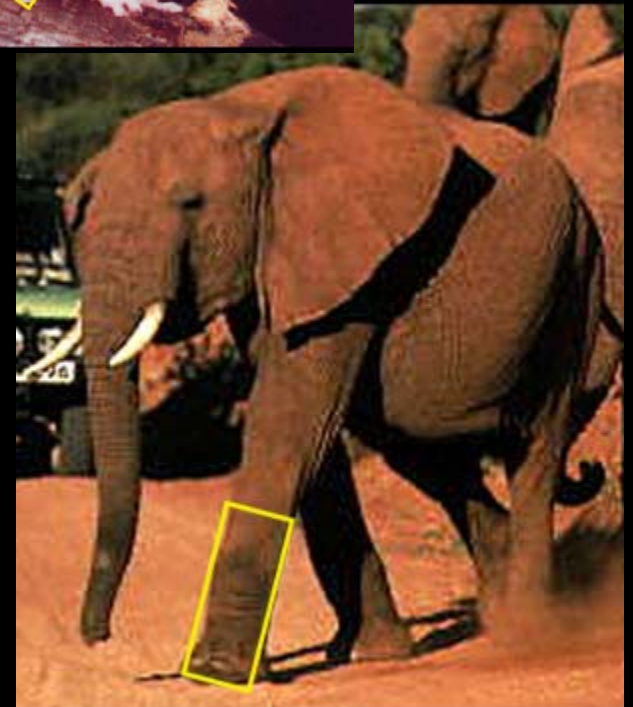




# Scale Effect

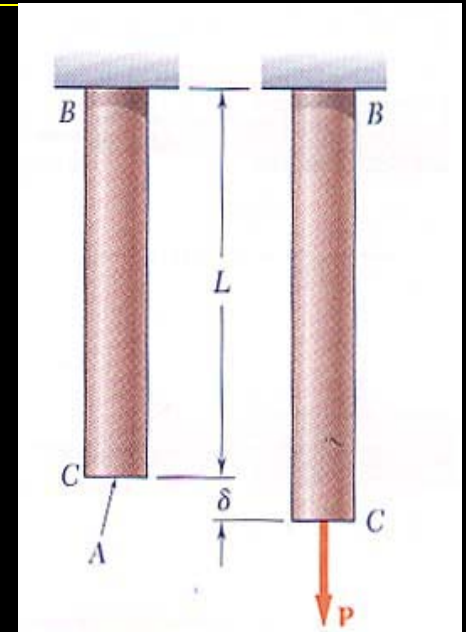
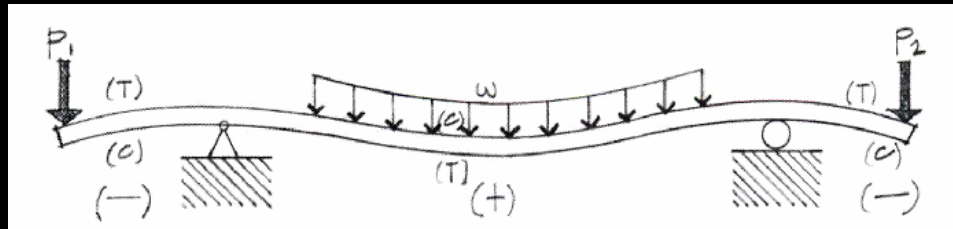
- *model scale*
  - *material weights, small areas*
- *structural scale*
  - *much more material weight, bigger areas*
- *ratio is not constant:*

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



# Strain (next lecture)

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



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

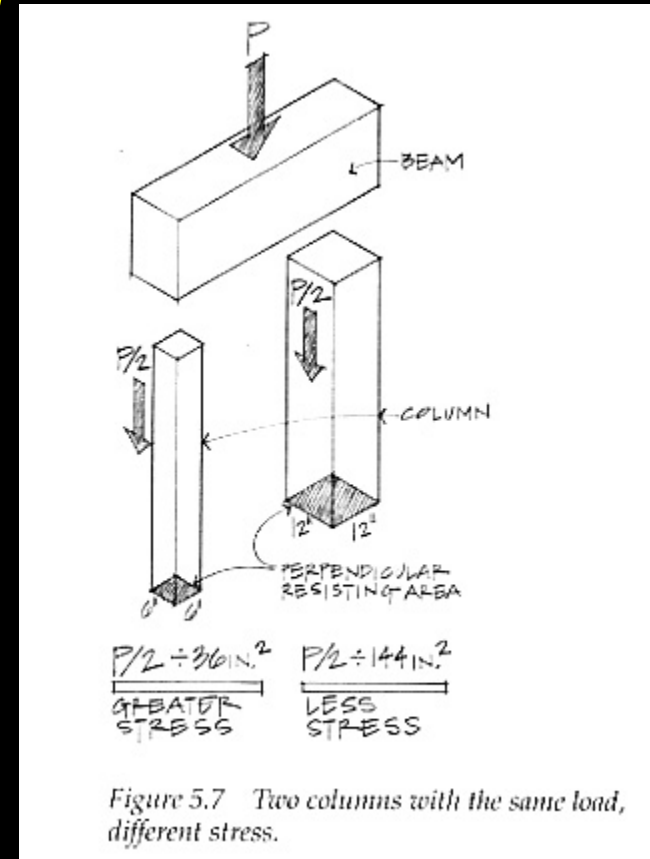
$$\text{strain} = \varepsilon = \frac{\Delta L}{L}$$

# Normal Stress

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

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

( $\sigma$ )



# Shear Stress

- *stress parallel to a surface*

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

$(\tau_{ave})$

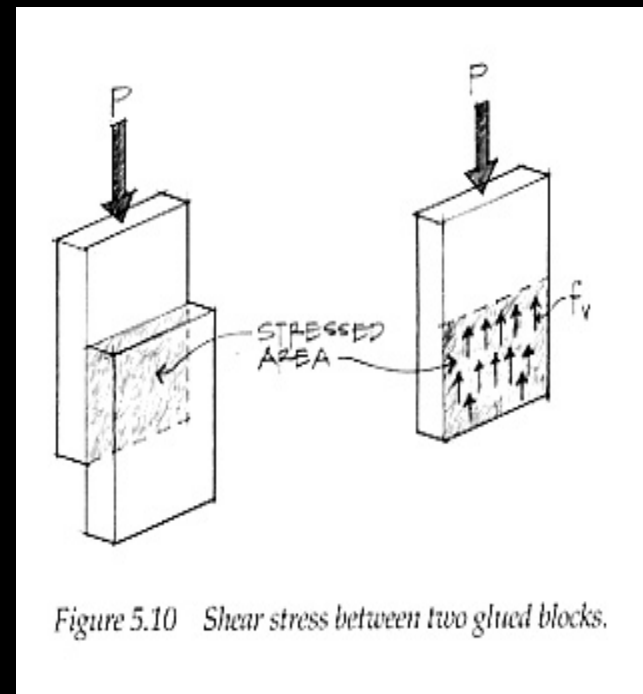


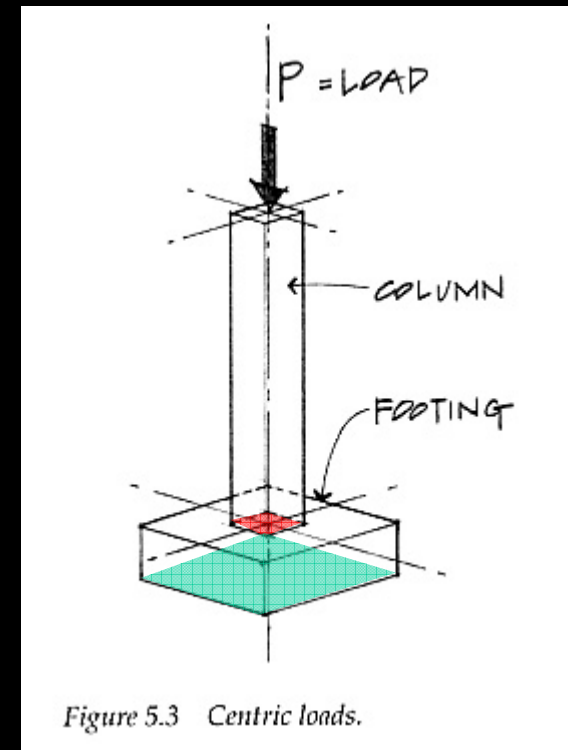
Figure 5.10 Shear stress between two glued blocks.

# Bearing Stress

- *stress on a surface by contact in compression*

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

$(\sigma)$

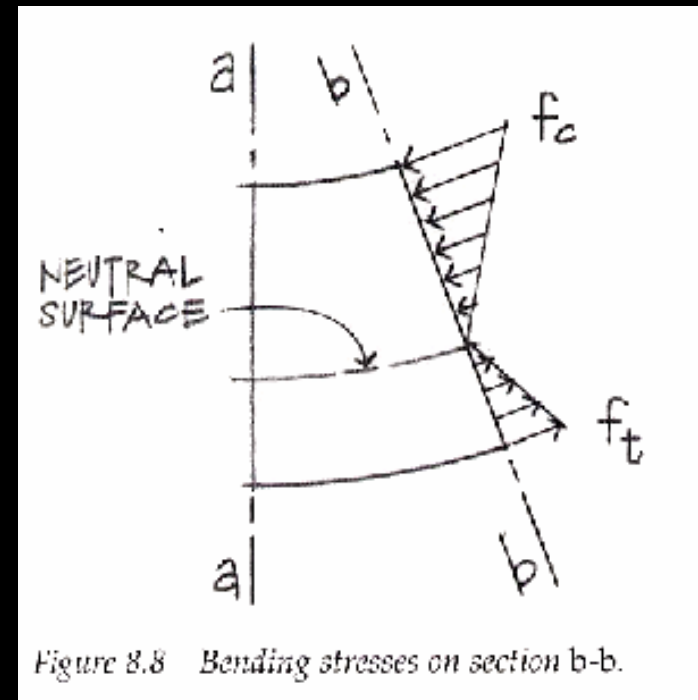


# Bending Stress

- *normal stress caused by bending*

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

$(\sigma)$

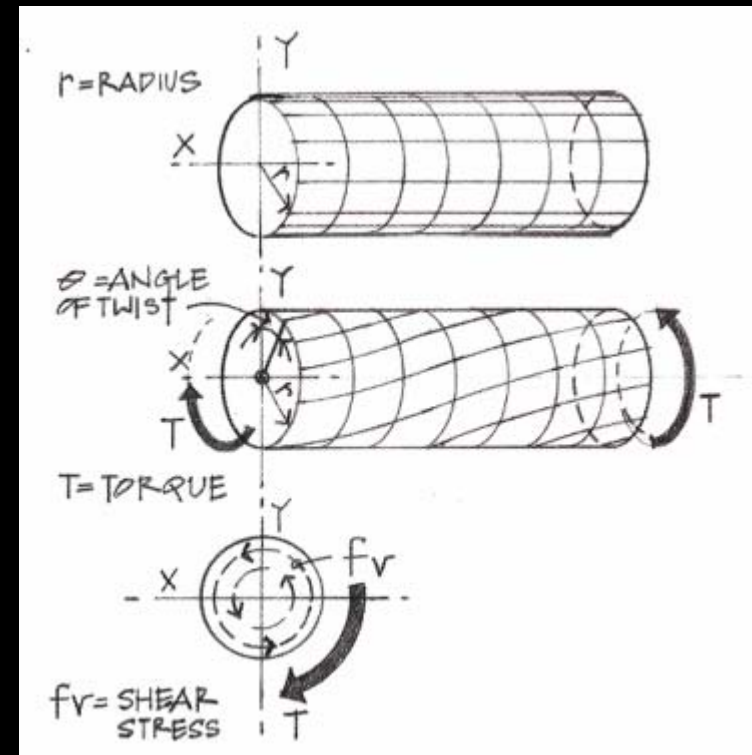


# Torsional Stress

- *shear stress caused by twisting*

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

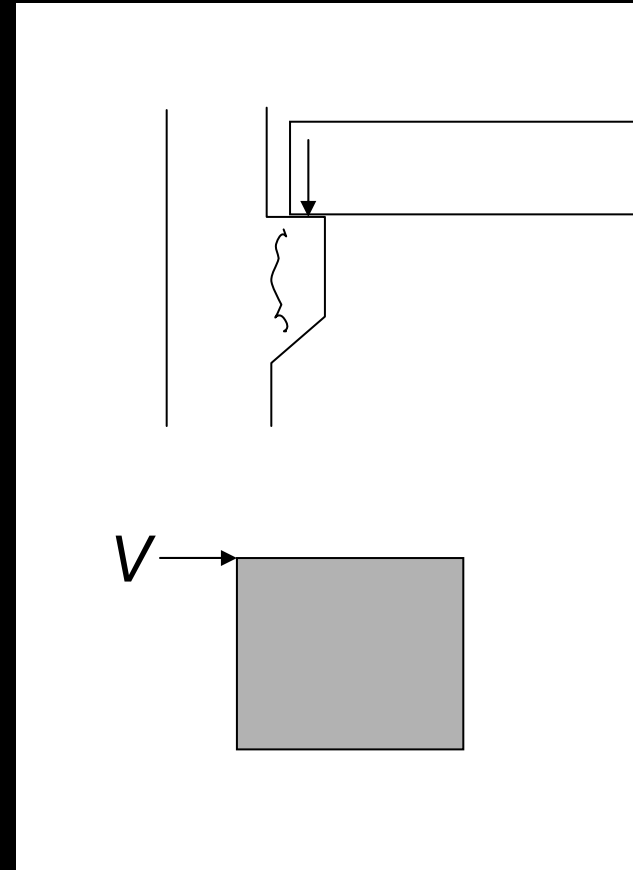
( $\tau$ )



# Structures and Shear

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

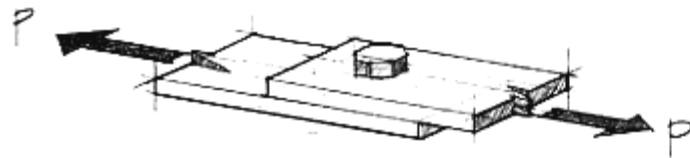
} *connections*



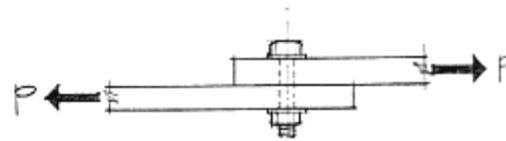


# Bolts

- *connected members in tension cause shear stress*

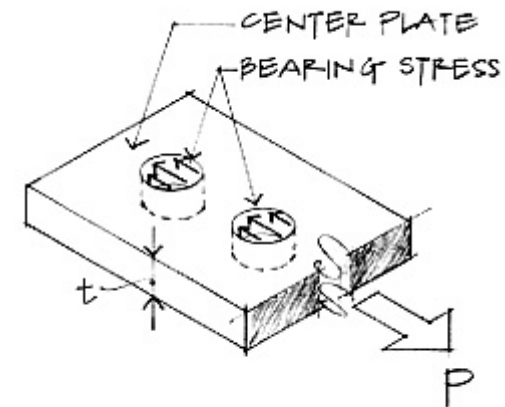


(a) Two steel plates bolted using one bolt.



(b) Elevation showing the bolt in

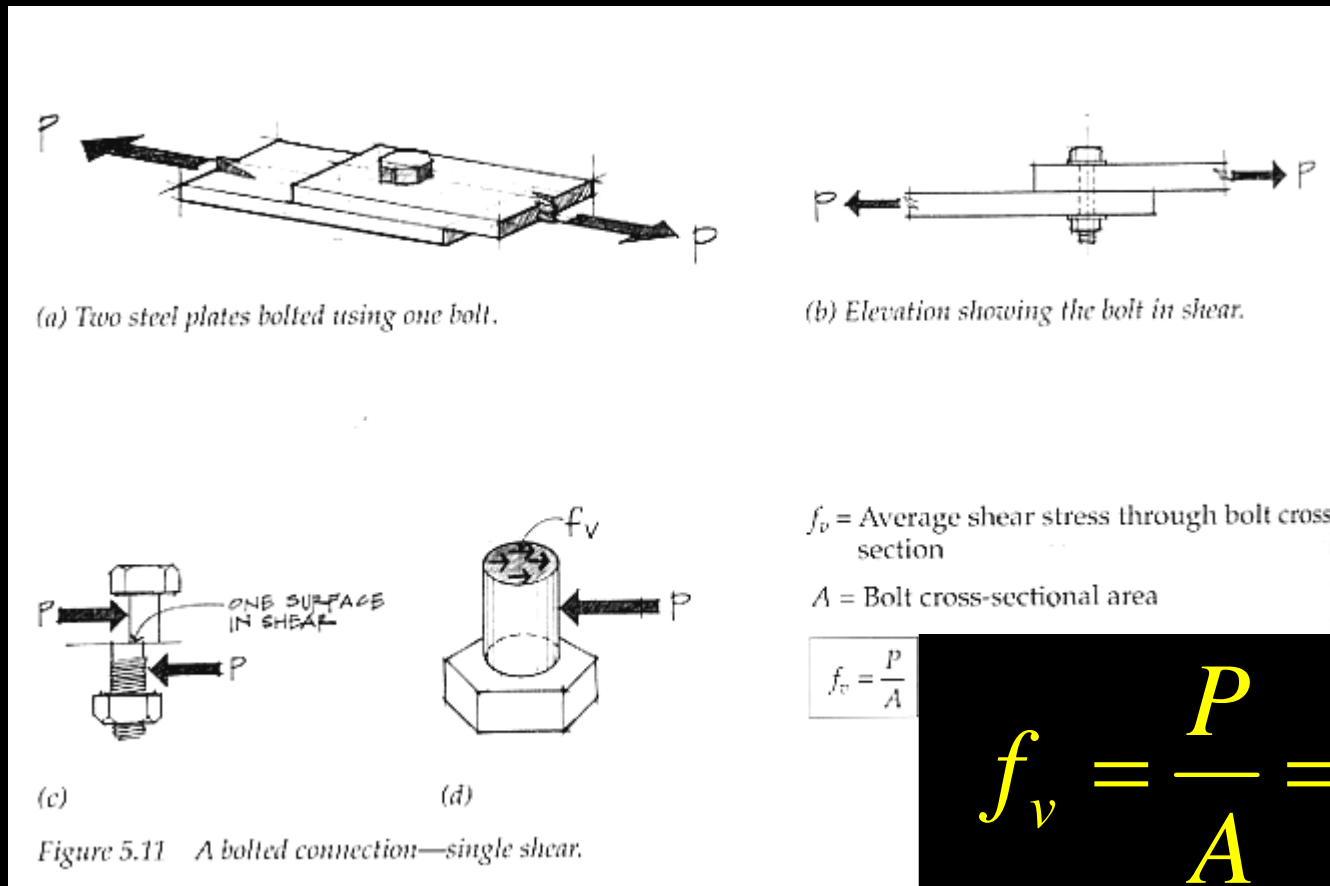
- *connected members in compression cause bearing stress*



Bearing stress on plate.

# Single Shear

- *seen when 2 members are connected*



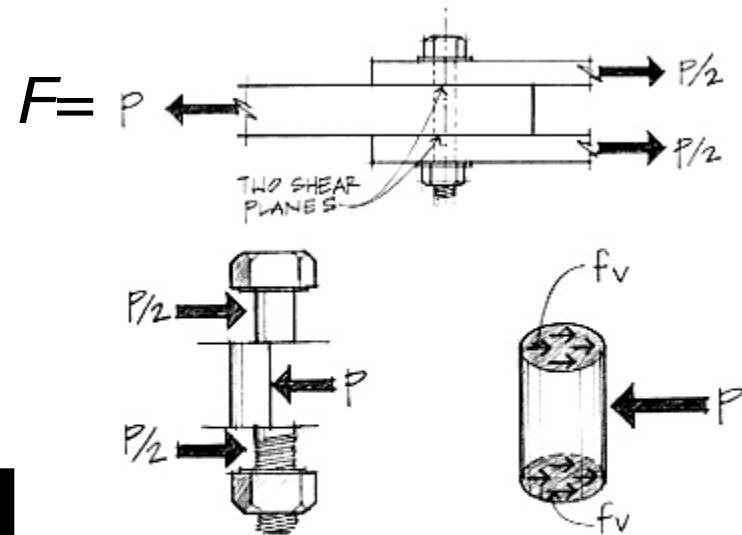
# Double Shear

- *seen when 3 members are connected*
- two areas

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

(two shear planes)

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

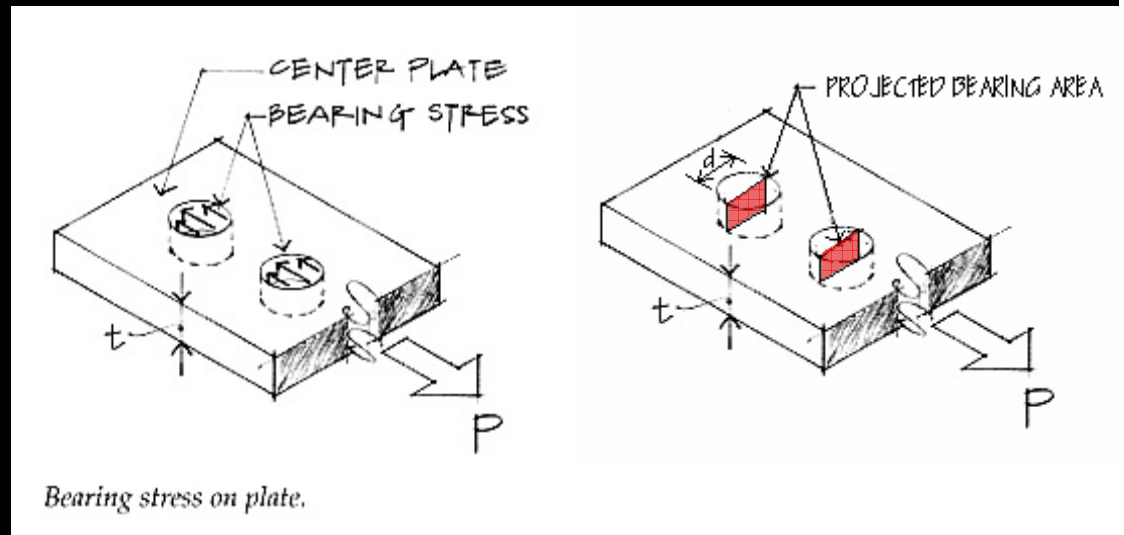


Free-body diagram of middle section of the bolt in shear.

Figure 5.12 A bolted connection in double shear.

# Bolt Bearing Stress

- *compression & contact*
- *projected area*



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