ARCHITECTURAL STRUCTURES I:
STATICS AND STRENGTH OF MATERIALS

ENDS 231

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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*

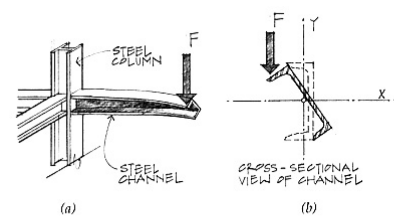


Figure 2.34 An example of torsion on a cantilever beam.

Problem Solving

1. *STATICS:*

   equilibrium of external forces, internal forces, <u>stresses</u>

2. *GEOMETRY:*

   cross section properties, deformations and conditions of geometric fit, <u>strains</u>

3. *MATERIAL PROPERTIES:*

   <u>stress-strain relationship</u> 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 (applies to ultimate stress, yield stress, compressive stress, fatigue strength)

Design (cont)

- *we'd like*

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

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

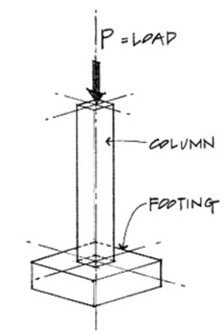
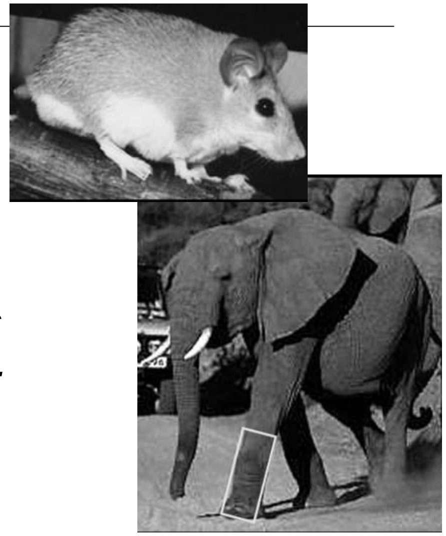


Figure 5.3 Centric loads.

Scale Effect

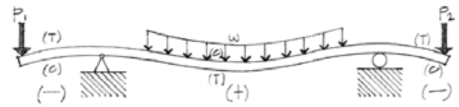
- model scale
  - material weights, small areas
- structural scale
  - much more material weight, bigger areas
- ratio is not constant:

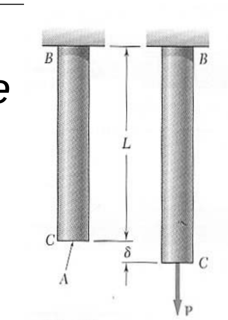
$$\frac{\gamma L^3}{L^2} = \gamma L$$



Strain

- 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

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

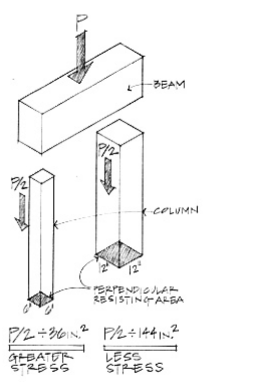


Figure 5.7 Two columns with the same load, different stress.

Shear Stress

- stress parallel to a surface

$$\underset{(\tau_{ave})}{f_v} = \frac{P}{A} = \frac{P}{td}$$

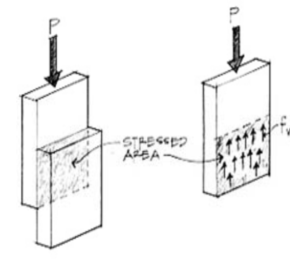


Figure 5.10 Shear stress between two glued blocks.

Bearing Stress

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

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

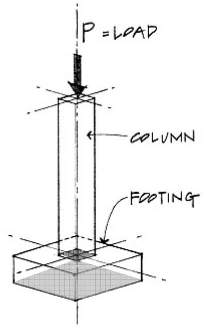


Figure 5.3 Centric loads.

Bending Stress

- *normal stress caused by bending*

$$f_b = \frac{Mc}{I} = \frac{M}{S}$$
$$(\sigma)$$

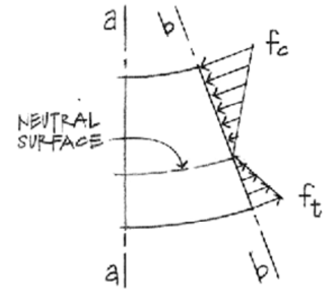
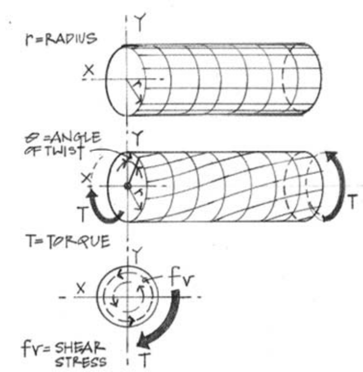


Figure 8.8 Bending stresses on section b-b.

Torsional Stress

- *shear stress caused by twisting*

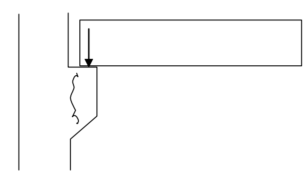
$$f_v = \frac{T\rho}{J}$$
$$(\tau)$$

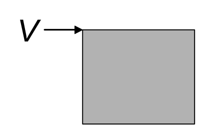


Structures and Shear

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

connections (bolts, splices)



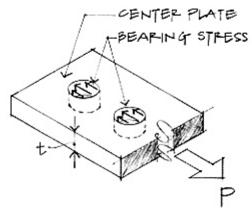


Bolts

- *connected members in tension cause shear stress*

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

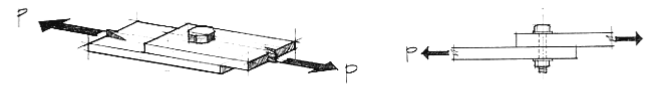
- *connected members in compression cause bearing stress*



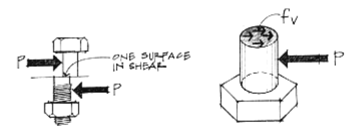
Bearing stress on plate.

Single Shear

- *seen when 2 members are connected*



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



(c) (d)

Figure 5.11 A bolted connection—single shear.

f_v = Average shear stress through bolt cross section

A = Bolt cross-sectional area

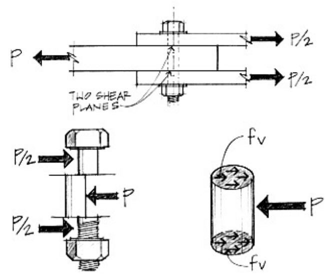
$f_v = \frac{P}{A}$

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

Double Shear

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

F=



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

Figure 5.12 A bolted connection in double shear.

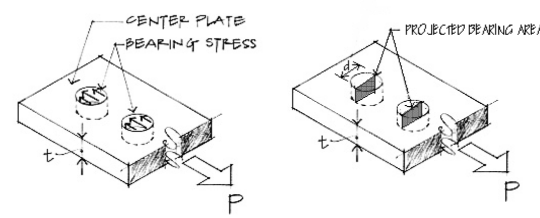
$f_v = \frac{P}{2A}$

(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.

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