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

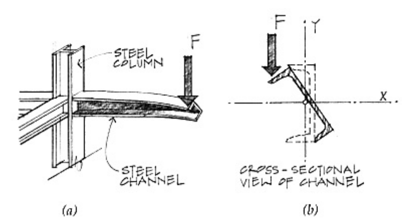


Figure 2.34 An example of torsion on a cantilever beam.

Problem Solving

1. STATICS:

   equilibrium of external forces, internal forces, 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)

(ultimate, yield, compressive stress and fatigue strength:) acceptance vs. failure

Design (cont)

- we'd like

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

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

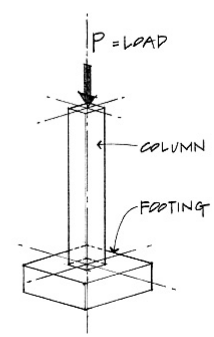
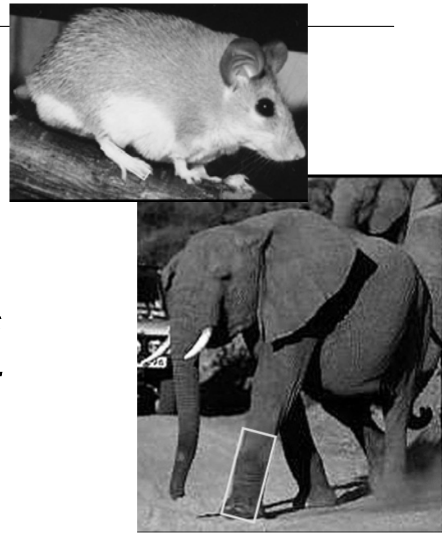


Figure 5.3 Centric loads.

Scale Effect

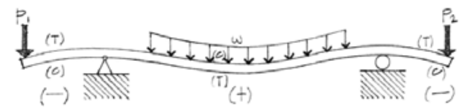
- model scale
  - material weights, small areas
- structural scale
  - much more material weight, bigger areas
- ratio is not constant:

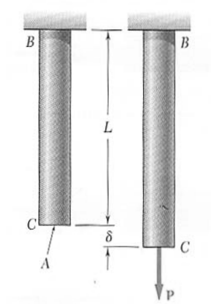
$$\frac{\gamma L^3}{L^2} = \gamma L$$



Strain

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





- STRAIN:
  - change in length over length

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

Normal Stress

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

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

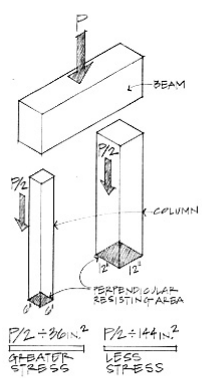


Figure 5.7 Two columns with the same load, different stress.

Shear Stress

- stress <u>parallel</u> to a surface

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

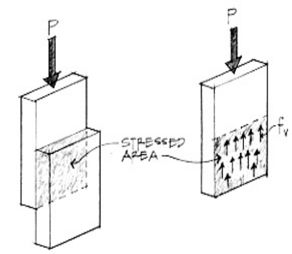


Figure 5.10 Shear stress between two glued blocks.

Bearing Stress

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

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

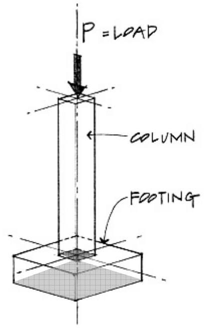


Figure 5.3 Centric loads.

Bending Stress

- *normal stress caused by bending*

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

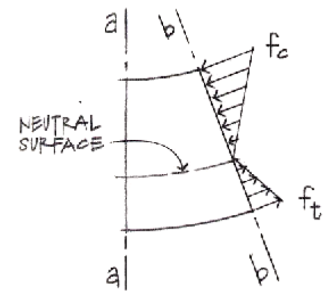
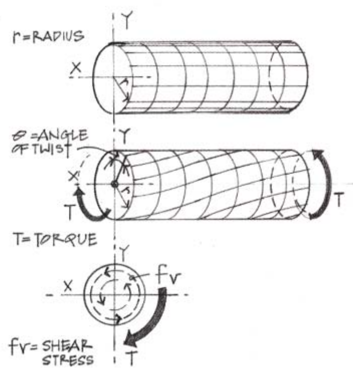


Figure 8.8 Bending stresses on section b-b.

Torsional Stress

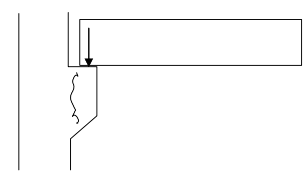
- *shear stress caused by twisting*

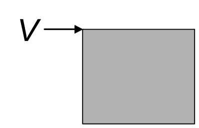
$$f_v = \frac{T\rho}{J}$$
$$(\tau)$$



Structures and Shear

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



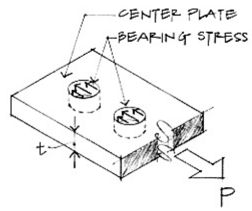


Bolts

- *connected members in tension cause shear stress*

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

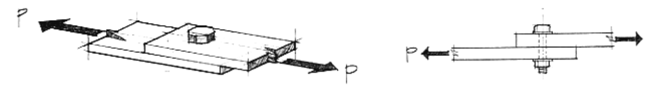
- *connected members in compression cause bearing stress*



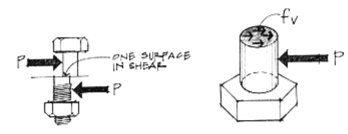
Bearing stress on plate.

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

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

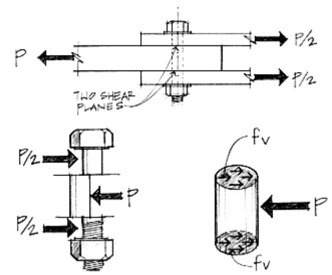
$$f_v = \frac{P}{A} = \frac{P}{\pi \, d^2/4}$$

Double Shear

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

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

(two shear planes)



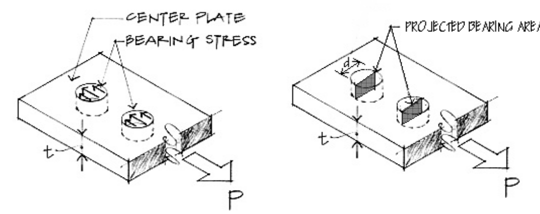
Free-body diagram of middle section of the bolt in shear.

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.

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