Mechanics of Materials

Notation:

A = area (net = with holes, bearing = in contact, etc...)
d = diameter of a hole
f = symbol for stress
$f_{allowable}$ = allowable stress
f_v = shear stress
f_p = bearing stress (see P)
$F_{allowed}$ = allowable stress (used by codes)
F_v = allowable shear stress
kPa = kilopascals or 1 kN/m^2
q = allowable soil bearing pressure
psi = pounds per square inch
P = name for axial force vector
P' = name for internal axial force vector
R = name for reaction force vector
t = thickness of a hole or member
x = horizontal dimension
y = vertical dimension
γ = density of a material (unit weight)
σ = engineering symbol for normal stress
τ = engineering symbol for shearing stress

Mechanics of Materials is a basic engineering science that deals with the relation between externally applied load and its effect on deformable bodies. The main purpose of Mechanics of Materials is to answer the question of which requirements have to be met to assure STRENGTH, RIGIDITY, AND STABILITY of engineering structures.

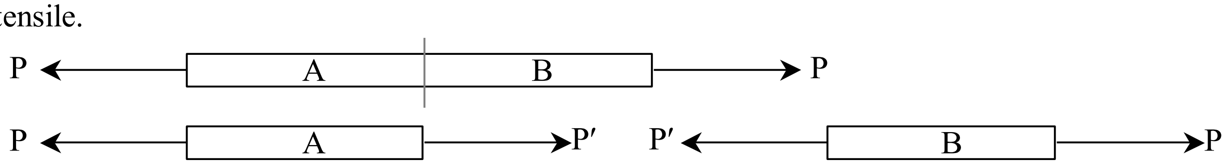
To solve a problem in Mechanics of Materials, one has to consider THREE ASPECTS OF THE PROBLEM:

1. **STATICS**: equilibrium of external forces, internal forces, stresses
2. **GEOMETRY**: deformations and conditions of geometric fit, strains
3. **MATERIAL PROPERTIES**: stress-strain relationship for each material, obtained from material testing.

- STRESS – The intensity of a force acting over an **area**.

Normal Stress

Stress that acts along an *axis* of a member; can be internal or external; can be compressive or tensile.



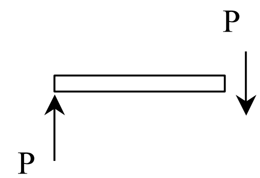
$$f = \sigma = \frac{P}{A_{net}}$$

Strength condition: $f = \dfrac{P}{A_{net}} < f_{allowable}\ or\ F_{allowed}$

Shear Stress

Stress that acts perpendicular to an *axis or length* of a member, or **parallel** to the cross section is called shear stress.

Shear stress cannot be assumed to be uniform, so we refer to *average shearing stress.*



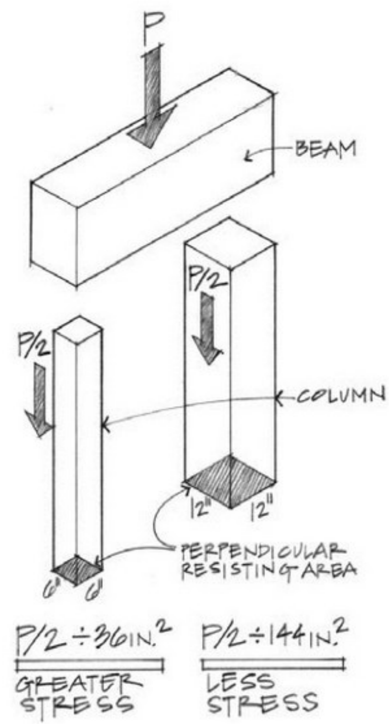
$$f_v = \tau = \frac{P}{A_{net}}$$

Strength condition: $f_v = \dfrac{P}{A_{net}} < \tau_{allowable} \; or \; F_{allowed}$

Bearing Stress

A compressive normal stress acting *between two bodies.*

$$f_p = \frac{P}{A_{bearing}}$$



Bending Stress

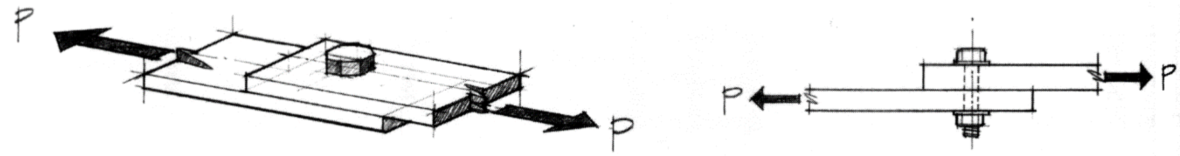
A normal stress caused by bending; can be compressive or tensile. (Discussed in Note Set on Beam Bending.)

Torsional Stress

A shear stress caused by torsion (moment around the axis). (Discussed in Note Set on Torsion.)

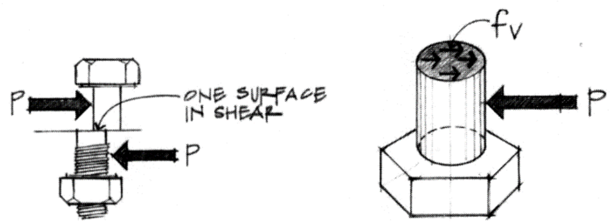
Bolts in Shear and Bearing

<u>Single shear</u> - forces cause only one shear "drop" across the bolt.



(a) Two steel plates bolted using one bolt.

(b) Elevation showing the bolt in shear.



(c) *(d)*

f_v = Average shear stress through bolt cross section

A = Bolt cross-sectional area

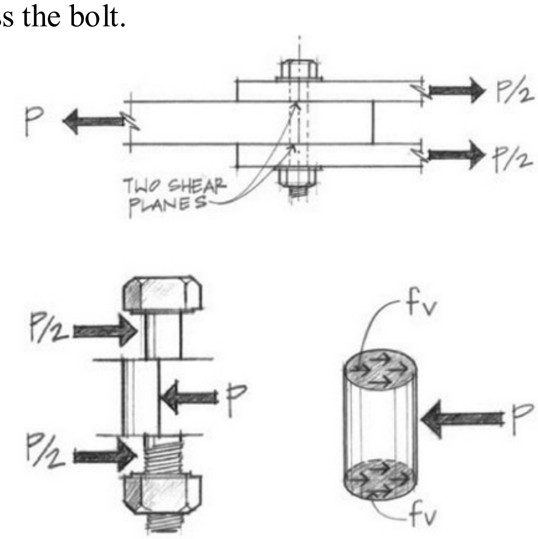
$$f_v = \frac{P}{A}$$

Figure 5.11 A bolted connection—single shear.

<u>Double shear</u> - forces cause two shear changes across the bolt.

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

(two shear planes)

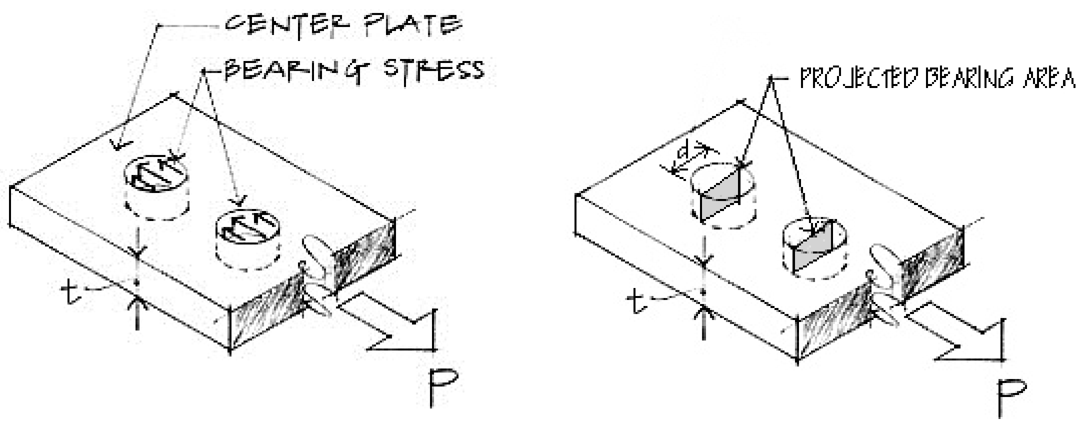


Free-body diagram of middle section of the bolt in shear.

Figure 5.12 A bolted connection in double shear.

<u>Bearing of a bolt on a bolt hole</u> – The bearing surface can be represented by *projecting* the cross section of the bolt hole on a plane (into a rectangle).

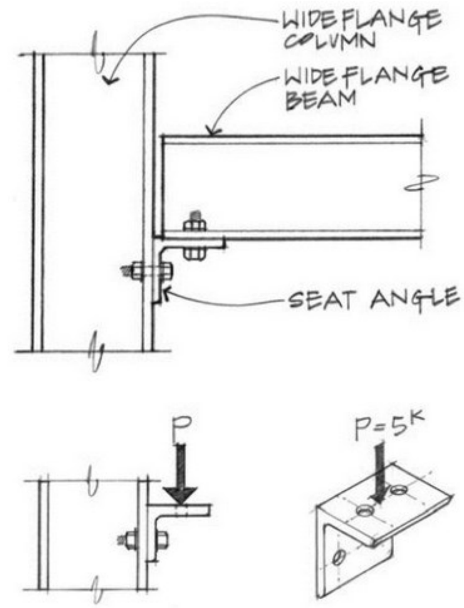
$$f_p = \frac{P}{A} = \frac{P}{td}$$



Bearing stress on plate.

Example 1 (pg 259)*

5.2 A typical method of temporarily securing a steel beam onto a column is by using a seat angle with bolts through the column flange. Two $\frac{1}{2}$″-diameter bolts are used to fasten the seat angle to the column. The bolts must carry the beam load of $P = 5$ k in single shear. Determine the average shear stress developed in the bolts. Determine the bearing stress in the angle from the bolts when the angle is 3/8” thick. Assume A36 steel: F_u= 58 ksi, E = 29 x 10^3 ksi.

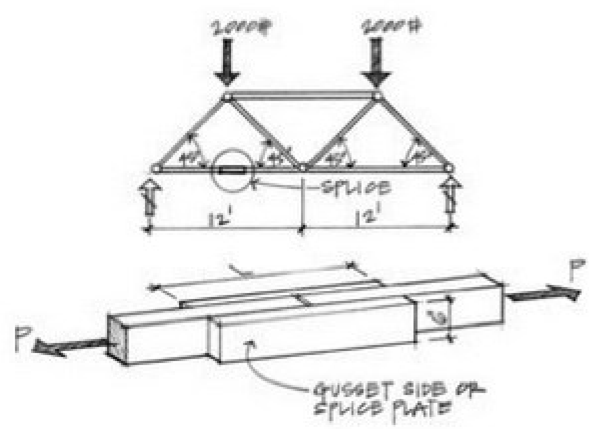


Example 2 (pg 261)*

5.5 A timber roof truss is subjected to roof loads as shown. Because timber lengths are relatively restrictive, it is necessary to provide a glued splice on the bottom chord. Determine the tensile force in the bottom chord member (splice). Assuming the members and splice plate are 6″ deep and the glue has a shear capacity of 25 #/in.^{2} (with a lot of safety factor), determine the required length L of the splice.

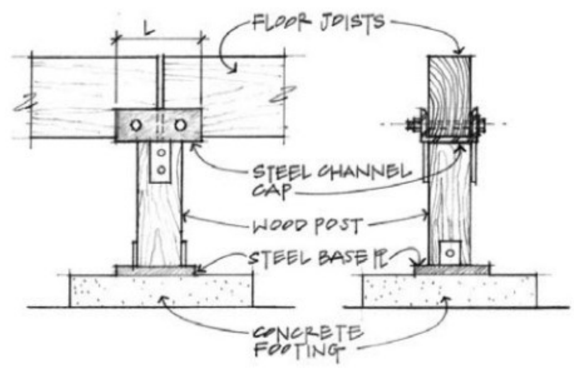
$P = 2{,}000\#$ @ splice

Also determine the elongation in a bottom chord due to the tensile force. Assume E = 1,200 ksi, and the width is 2 in.



Example 3 (pg 259)

5.3 In a typical floor support, a short timber post is capped with a steel channel to provide a larger bearing area for the joists. The joists are 4″ × 12″ rough cut. The steel base plate is provided to increase the bearing area on the concrete footing. The load transmitted from each floor joist is 5.0 k.



Find the following:

a. The minimum length of channel required to support the joists if the maximum allowable bearing stress perpendicular to the grain is 400 psi.
b. The minimum size of post required to support the load if the maximum stress allowed in compression parallel to the grain is 1,200 psi.
c. The size of base plate required if the allowable bearing on concrete is 450 psi.
d. The footing size if allowable soil f_p = 2,000 psf.