# WOOD 474

# Wood Strength and Mechanics

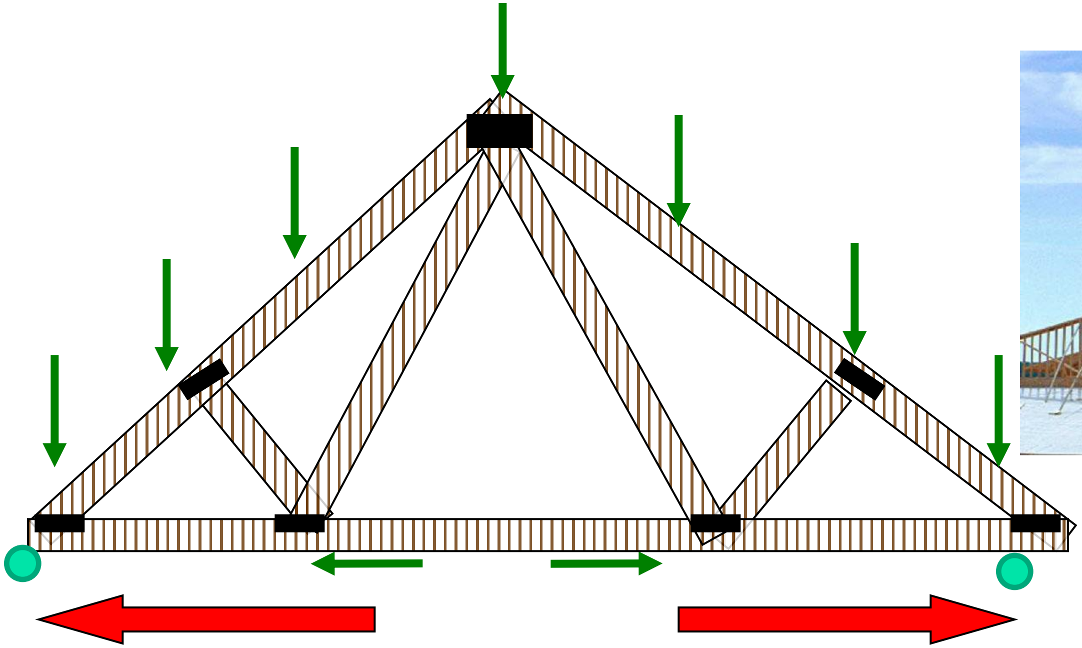
# Mechanical Properties of Wood

## Strength Properties

1. Tension strength (// to grain, ⊥ to grain)
2. Compression strength (// to grain, ⊥ to grain)
3. Bending strength - MOR (Modulus of Rupture)
4. Shear strength
5. Toughness
6. Resilience
7. Side hardness
8. Work to maximum load

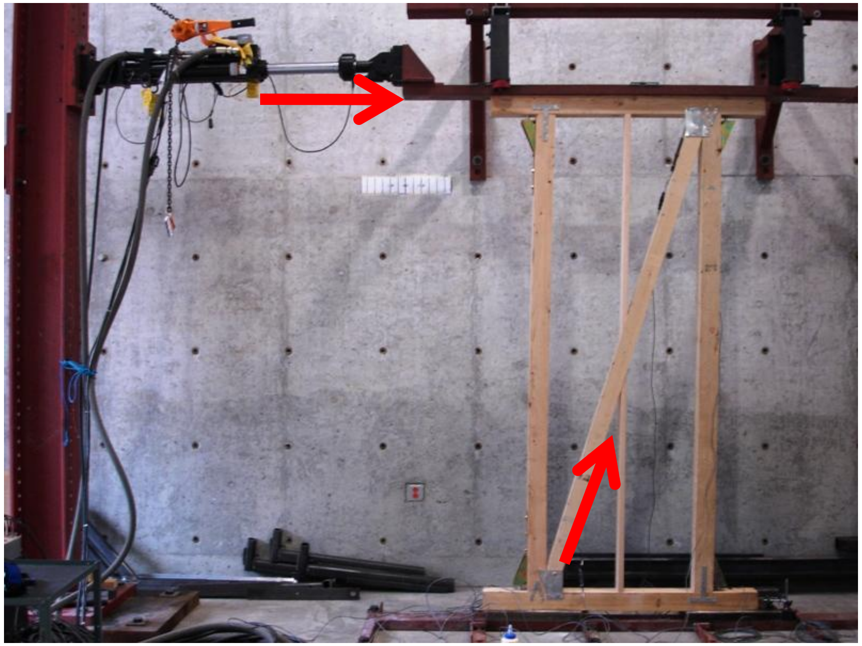
## 1. Tension strength (// to grain)

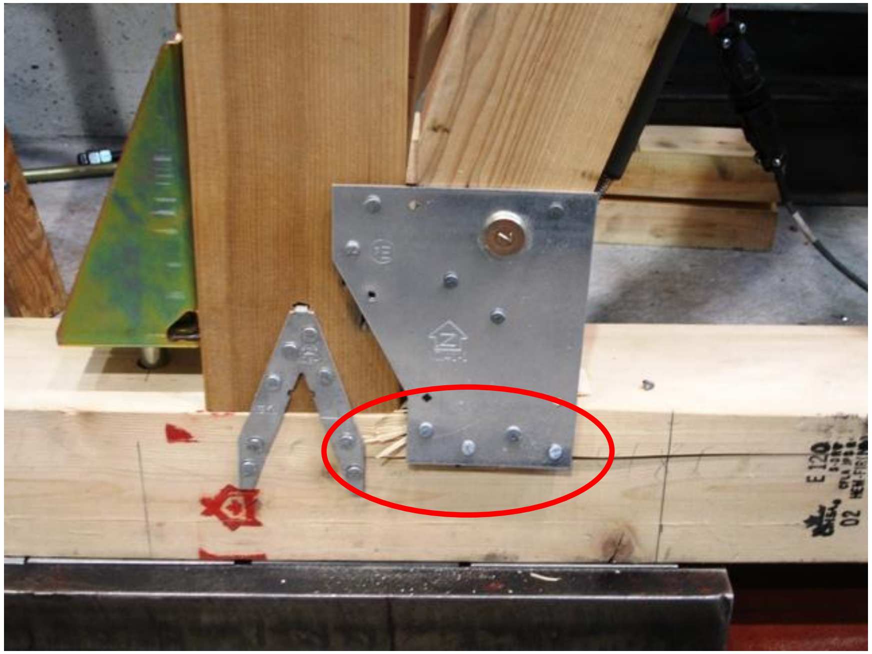
Important in design of truss-type wood structures, such as metal plate connected roof trusses in light-frame construction in North America.



# 1. Tension strength (⊥ to grain)

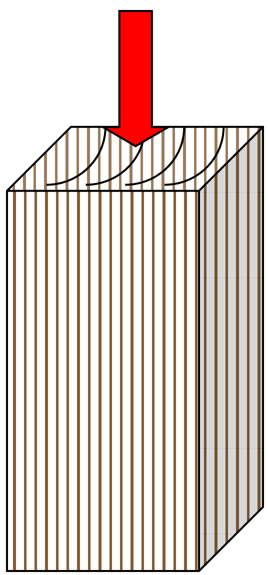
Important in design of connections in wood buildings, such as diagonal-braced walls in post-and-beam construction in Japan.





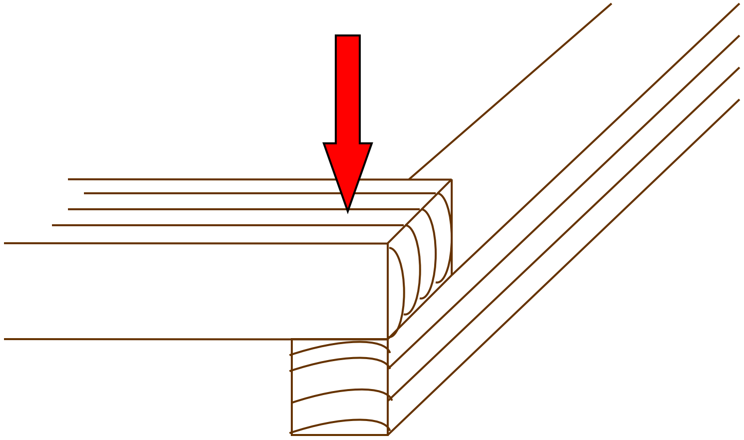
# 2. Compression strength (// to grain)

Important in design of piles, and columns in wood buildings



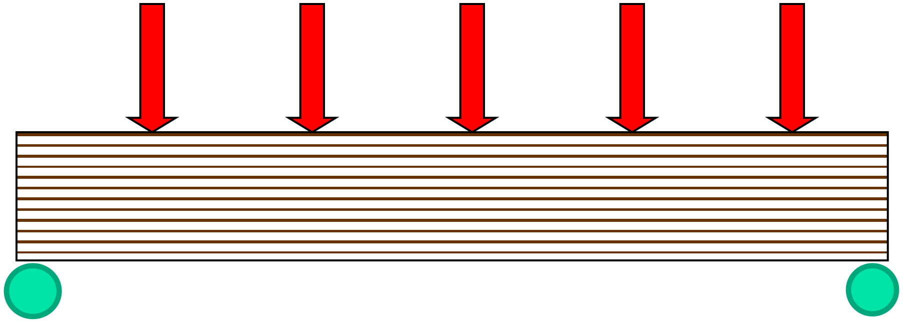
# 2. Compression strength (⊥ to grain)

Important in design of connections between wood members and beam supports



# 3. Bending strength (MOR)

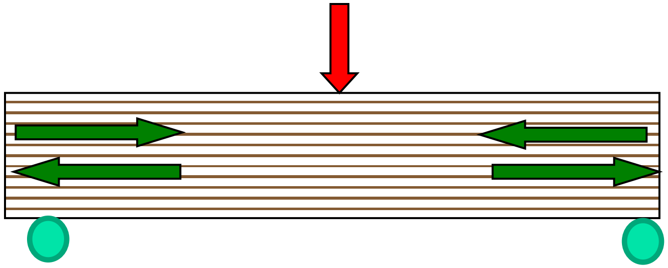
determines the peak load a relatively long beam will carry

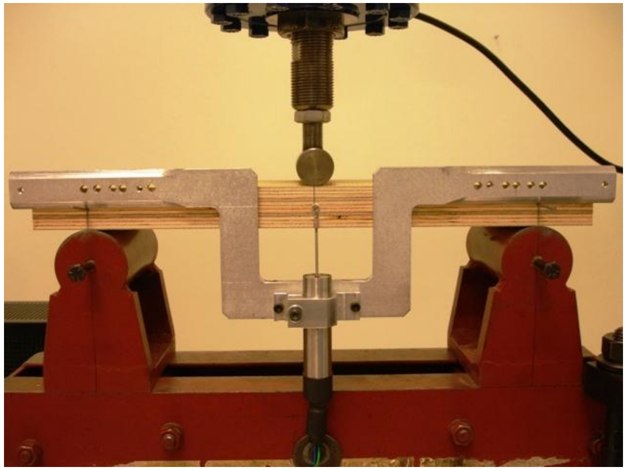


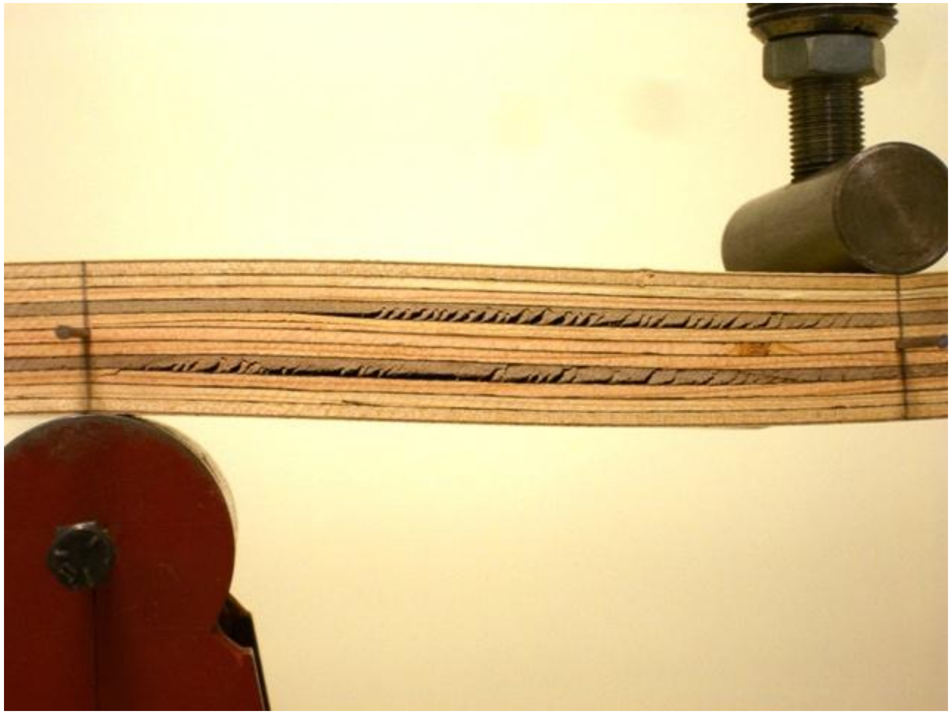
MOR is accepted criterion of strength, although not a true stress as it is only true to the proportional limit (i.e., a beam is assumed to deform in the linear elastic range).

# 4. Shear strength

determines the load-carrying capacity of a beam or plate with relatively short span

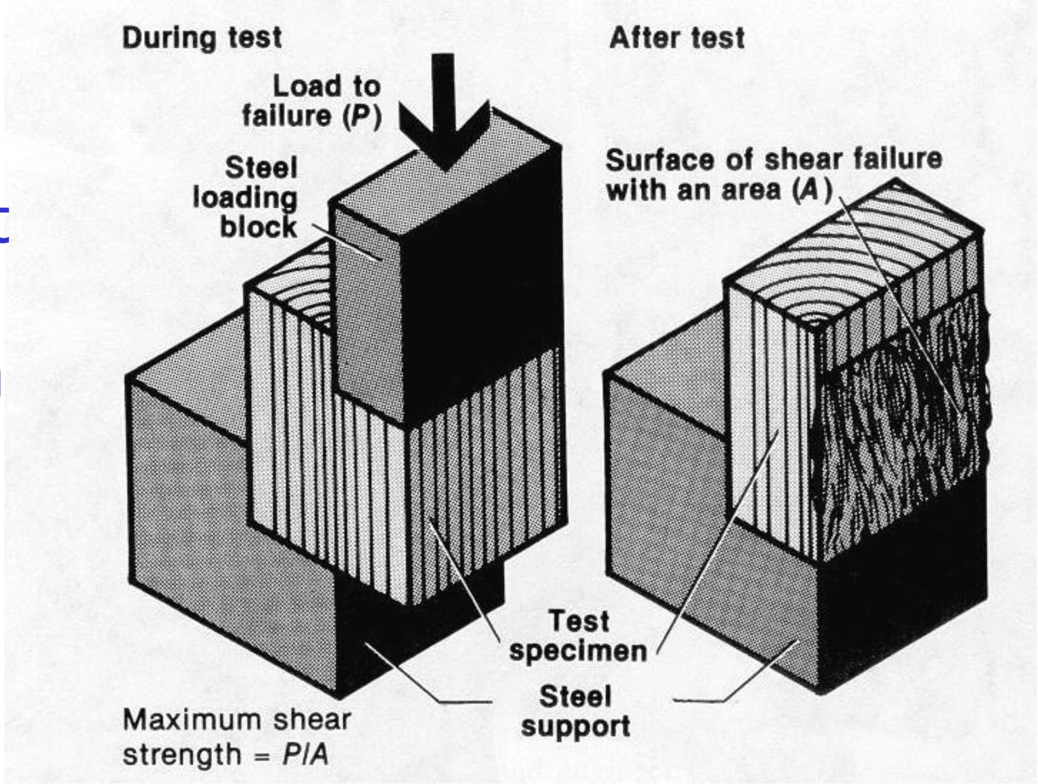






# 4. Shear strength

Shear effect tends to make one part of wood slide against the adjacent wood; wood is weak in shear strength // to grain



# Mechanical Properties of Wood

## Elastic Properties

**1. Modulus of Elasticity (MOE):**

Measure of resistance to bending (i.e. directly related to stiffness of a beam), also a factor in the strength of a long column.

**2. Modulus of elasticity // to grain (Young's Modulus)**

Measure of resistance to elongation or shortening of a specimen under uniform tension or compression.

# Mechanical Properties of wood

**Stress**

**&**

**Strain**

## Stress

When a member carries external forces, stresses occur internally within the body of the member. It is a distributed force per unit of area.

**Normal Stress: $\sigma = P/A$**

**Shear Stress: $\tau = V/A$**

where P is the applied normal force, V is the applied shear force, A is the area.

Therefore, units of stress are force per unit area,

e.g., $lbf/in^2$ (or psi); $N/m^2$ (or Pa) ; $N/mm^2$ (or MPa)

## Strain

The external forces deform the shape and size of the member. The change in length per unit of length in the direction of the stress is called the strain.

**Normal strain: $\varepsilon = \Delta L / L$**

where $\Delta L$ is the change of the length

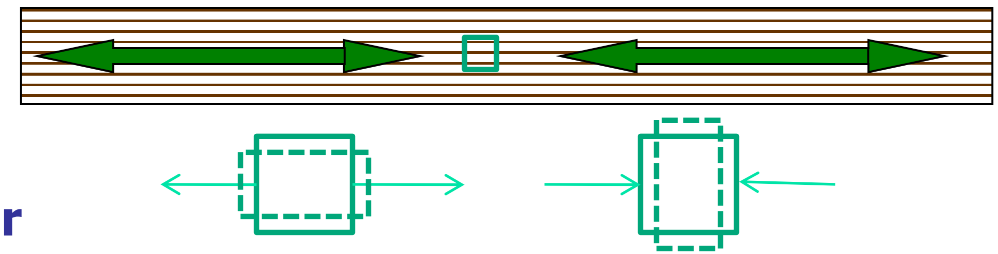
$L$ is the original length

**Shear Strain: $\gamma = \theta - \beta$**

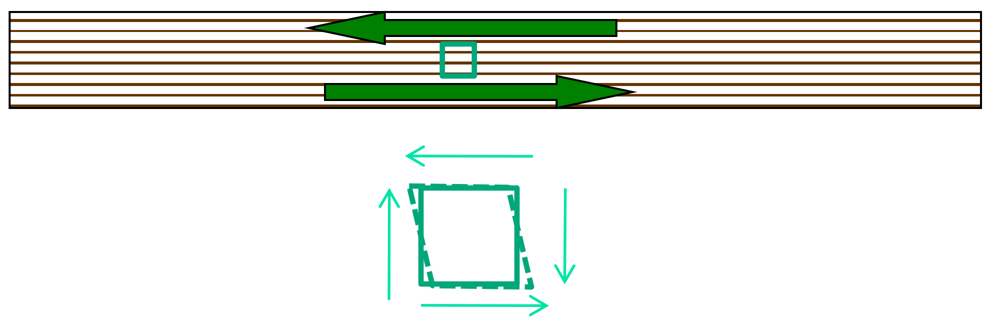
where $\theta$ is the angle before deformation

$\beta$ the angle at that same point after deformation

**Normal stress & strain (tension or compression)**



**Shear stress & strain**



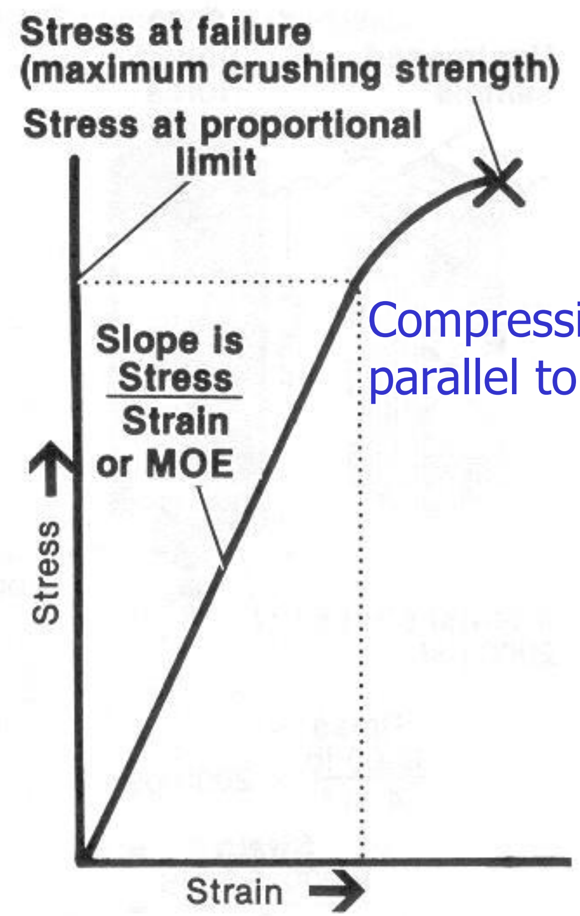
# Stress & Strain under Axial Loading

**Strain** results when stress applied to wood

There is a linear relationship up to the **proportional limit**.

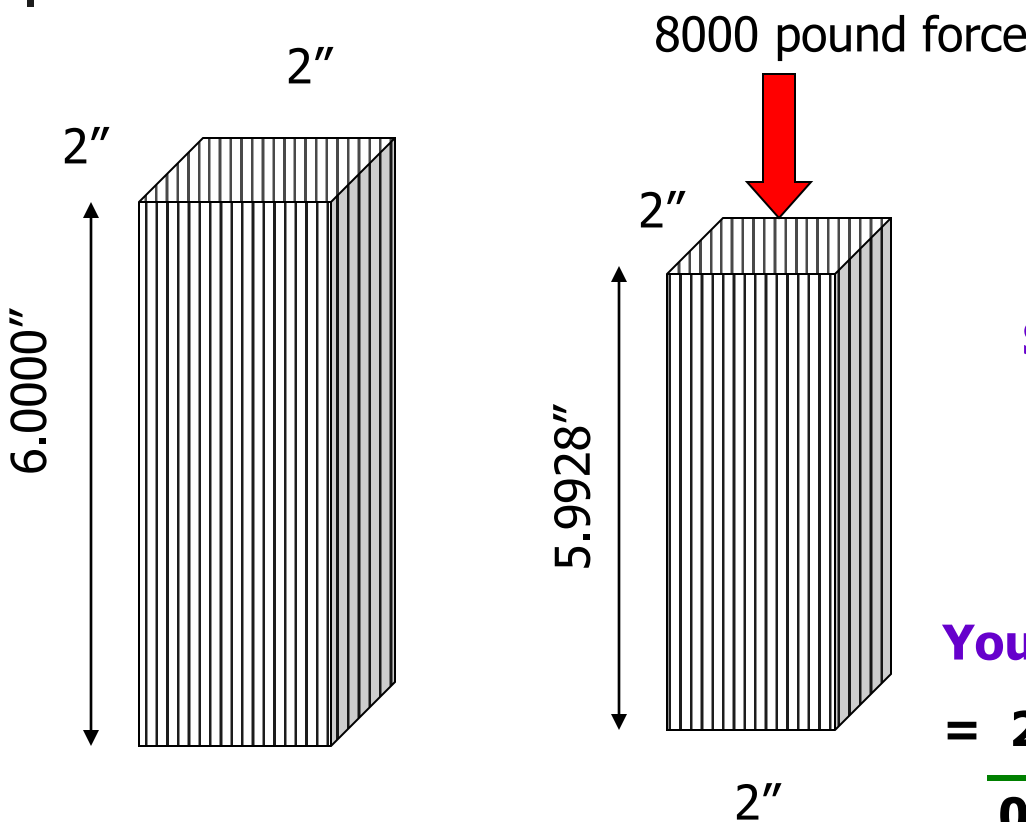
When stress is removed, strain is completely recovered

Below the proportional limit, the ratio between stress and strain is constant. It is called **Young's Modulus**




Compression parallel to grain

# An example




**Stress** $= \dfrac{8000}{4\ in^2} = 2000$ **psi**

**Strain** $= \dfrac{5.9928 - 6.000}{6.000}$

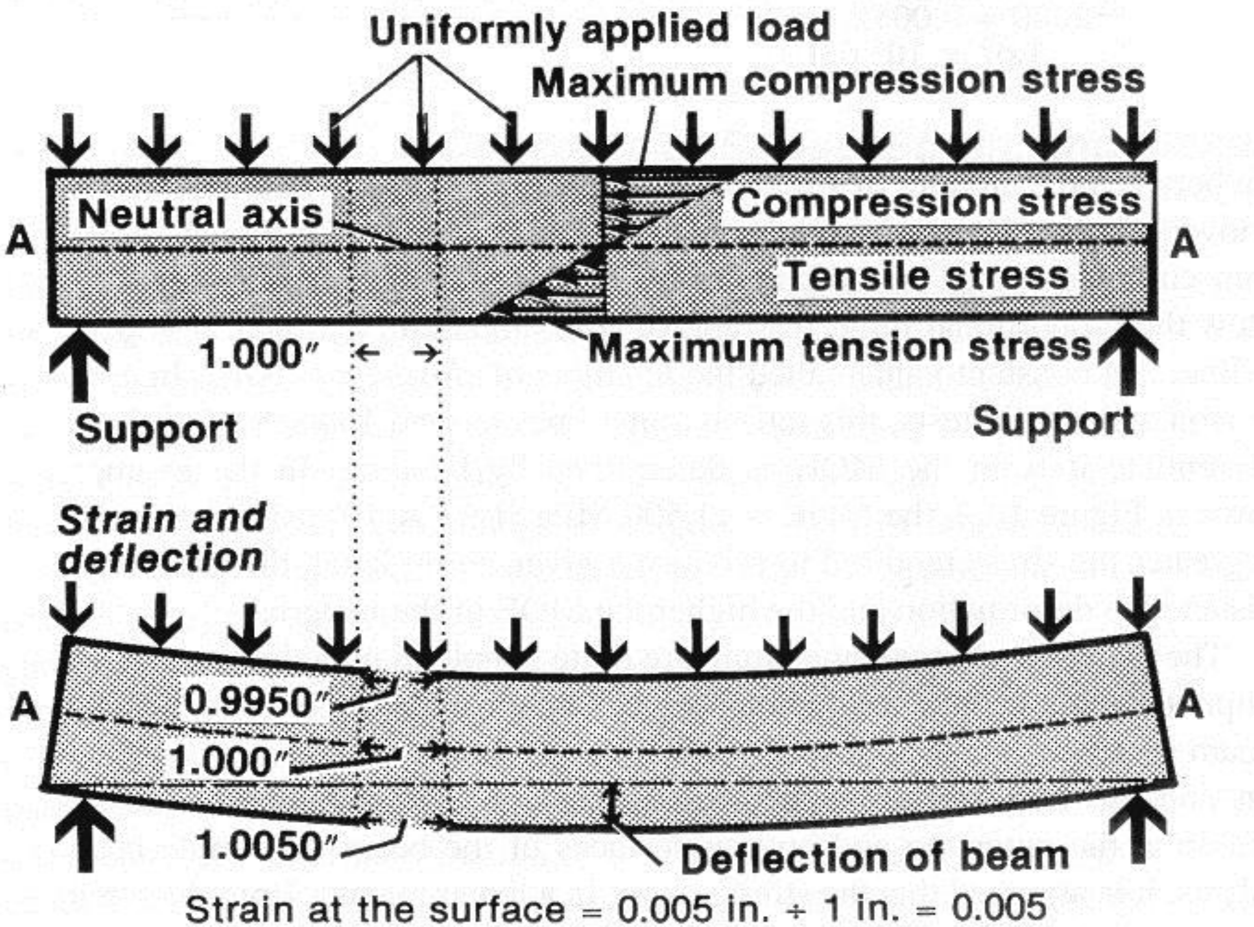
$= -0.0012$

**Young's Modulus = Stress/Strain**

$= \dfrac{2000}{0.0012} = 1.67 \times 10^6$ **psi**

1 psi = 6.894 kPa

# Stress & Strain in Bending

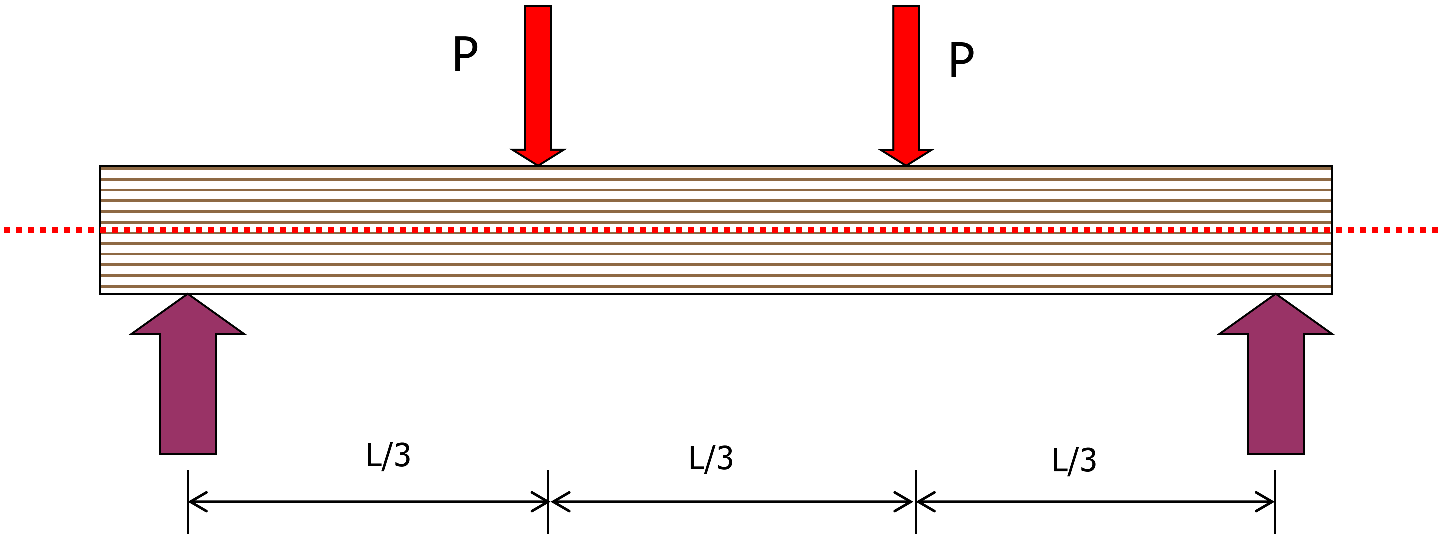


# Some observations of bending stress & strain

1. A beam has more complex stresses and strains than a uni-axial tension or compression member;
2. In the simple beam analysis, bending stresses vary linearly from top to bottom. Top half of a beam is under compression and bottom half is under tension;
3. No tension/compression on the neutral axis, and the length of the neutral axis remains unchanged;
4. Maximum stresses occur at the upper and lower surfaces;
5. Because upper surface is under compression, it shortens and the lower surface elongates; and
6. Amount of bending deformation is called the “deflection”.

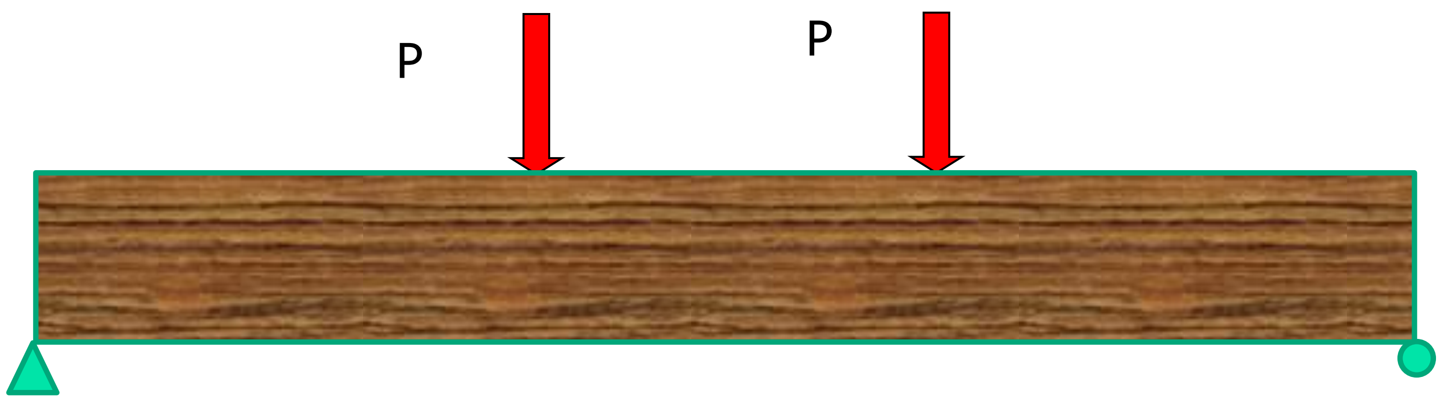
# Modulus of Elasticity (MOE)

- **Determined by static bending tests in which third point transverse loads are applied on a simply supported beam.**



# Modulus of Elasticity (MOE)

- **Measure applied load, deflection, beam cross section, and span.**



# Modulus of Elasticity (MOE)

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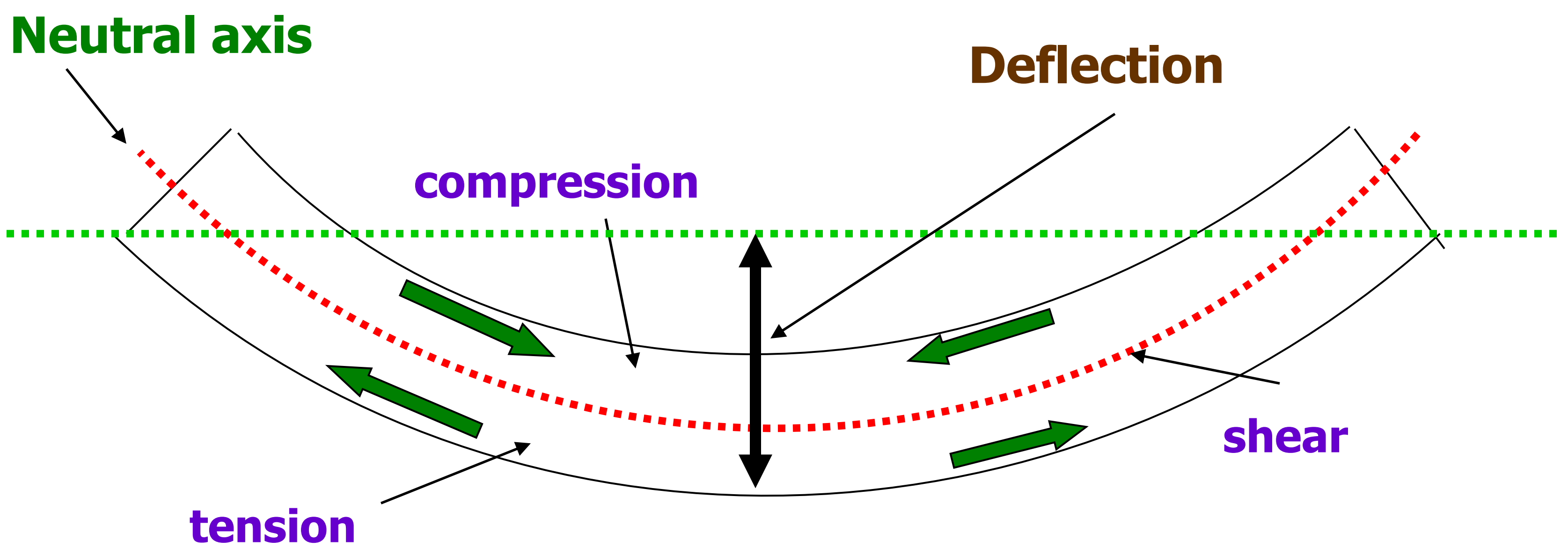


# Modulus of Elasticity (MOE)

- MOE is then calculated using beam dimensions, span, Load, and deflection:

  **MOE = $23PL^3/(648I\Delta)$**

  where P = concentrated load (in newtons)

  $\Delta$ = deflection (m or mm) at mid-span

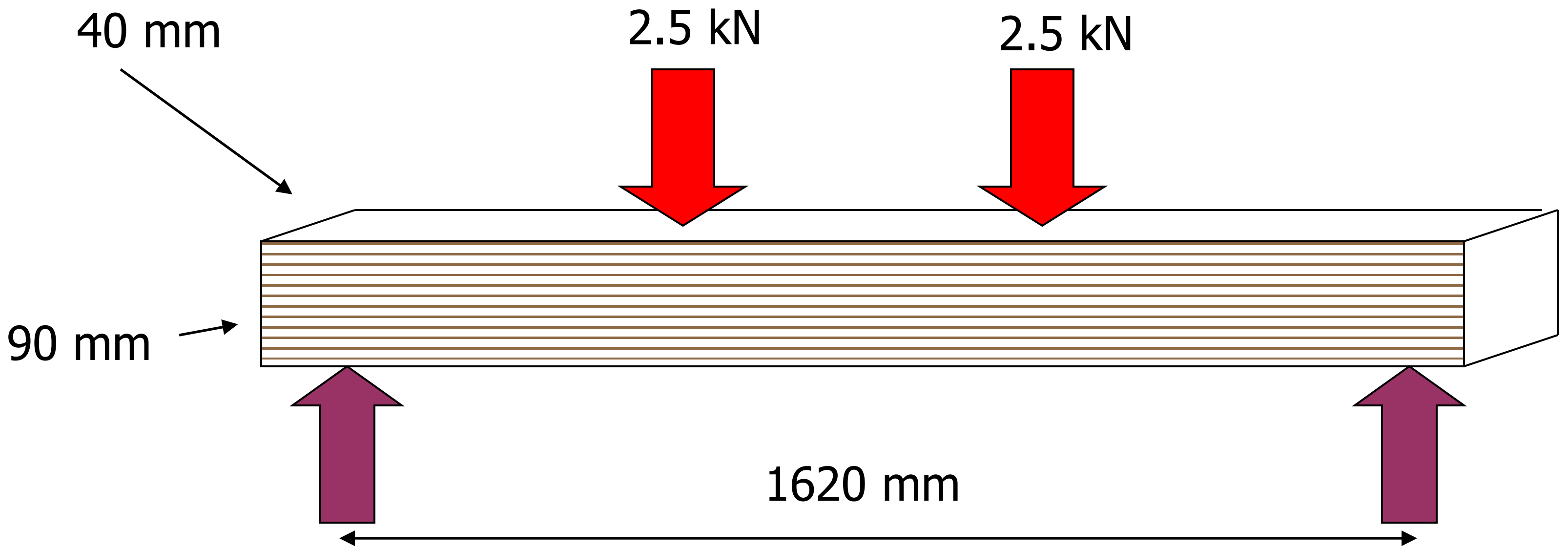
  L = span (m or mm)

  I = moment of inertia, which depends on beam size - width x $depth^3/12$ so units are $m^4$ or $mm^4$

# Example 1

- **40 x 90 x 1660 mm SPF**
- **Simply Supported at each end with a span of 1620 mm**
- **Loads are applied equally at third point**
- **Gradual increasing load**
- **At a total load of 5 kN deflection at midspan is 16 mm**
- **What is MOE?**

# Example 1



# Example 1

- **MOE = 23PL³/(648IΔ)**

- **MOE =** $\dfrac{23 * 2{,}500 * 1620^3}{648\,[40*90^3/12]\,16}$ **[N/mm²]**

- **MOE = 9703 MPa**

**1 N/mm² = 1 MPa**

# Example 2

- A 100 mm square piece SPF of same type and quality as in example 1 is placed between two roof beams 2 m apart
- Third point loads from a space heater weighing 1,360 kg (13,350 N) are hung from the beam.
- How much will the beam deflect?

# Example 2

- **MOE = 23PL³/(648IΔ)**

  $MOE = 23PL^3/(648I\Delta)$

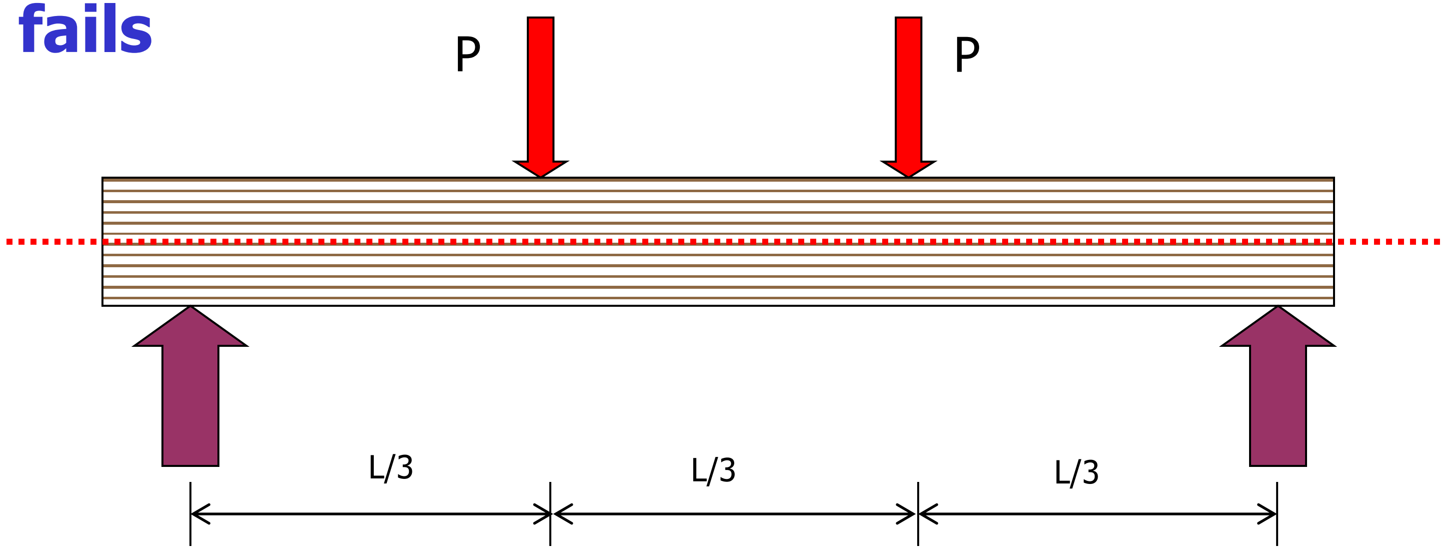
- **Rewrite** $\Delta = 23PL^3/(648\ I\ MOE)$

- $$\Delta = \frac{23 * 13350/2\ (2000)^3}{648(9703)(\ 100(100)^3/12)}$$

  $= \quad 23.44\ mm$

# Modulus of Rupture (MOR)

- **Determined by a static bending test**
- **Load a simply supported beam at the 3rd point until it fails**




- **Bending strength MOR= (PL/6)(c/I)**

where c = half depth of beam

# Modulus of Rupture (MOR)

- **MOR = P L/6 x (h/2)/(b x h³/12)**

  **= P L /(b x h²)**

$$MOR = PL/6 \times (h/2)/(b \times h^3/12) = PL/(b \times h^2)$$

where P is ½ the maximum load recorded during the test; L is beam span; b is beam width; and h is beam depth.

Note: this equation is valid only if the beam square or rectangular and is simply supported at both ends and loaded at third point.

# Example 3

- **Sample of SPF (as in example 1)**
- **Loaded to failure by a testing machine**
- **Breaking load is 10,000 N => P=5000 N**

**Calculate the MOR?**

- **MOR = PL/(b x h²)**

$$= \frac{5000 \times 1620}{40 \times 90^2}$$

- **MOR = 25 MPa**

# Example 4

- Sample of SPF (as in example 2)

  What is maximum space heater weight which can be loaded?

- $MOR = PL/(b \times h^2)$
- Reorganize $P = MOR \times b \times h^2/L$
- $$P = \frac{(25) \times 100 \times (100)^2}{(2000)}$$
- P = 12,500 N; Total load = 2P = 25 kN
- Weight = 2550 kg !

# Practice questions 1

- **As in Example 2 calculate the deflection but in place of SPF use:**

a) **coastal Douglas-fir of same dimensions and MOE of 13,400 MPa**

b) **Western hemlock 75 x 75 mm and 800 mm span, with MOE of 11,300 MPa.**

# Practice questions 2

- **As in Example 4 calculate the maximum space heater weight for:**

a) **coastal Douglas-fir of same dimensions and MOR of 40 MPa**

b) **Western hemlock 75 x 75 mm and 800 mm span, with MOR 35 MPa.**