# Mechanical properties of wood

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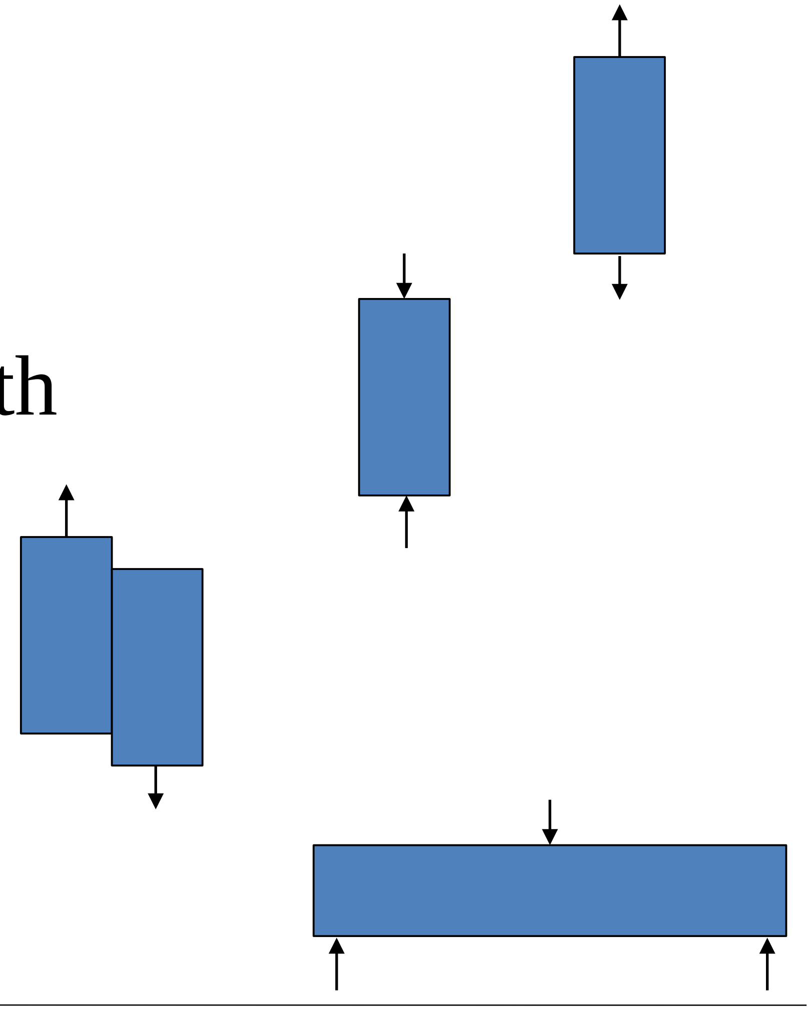
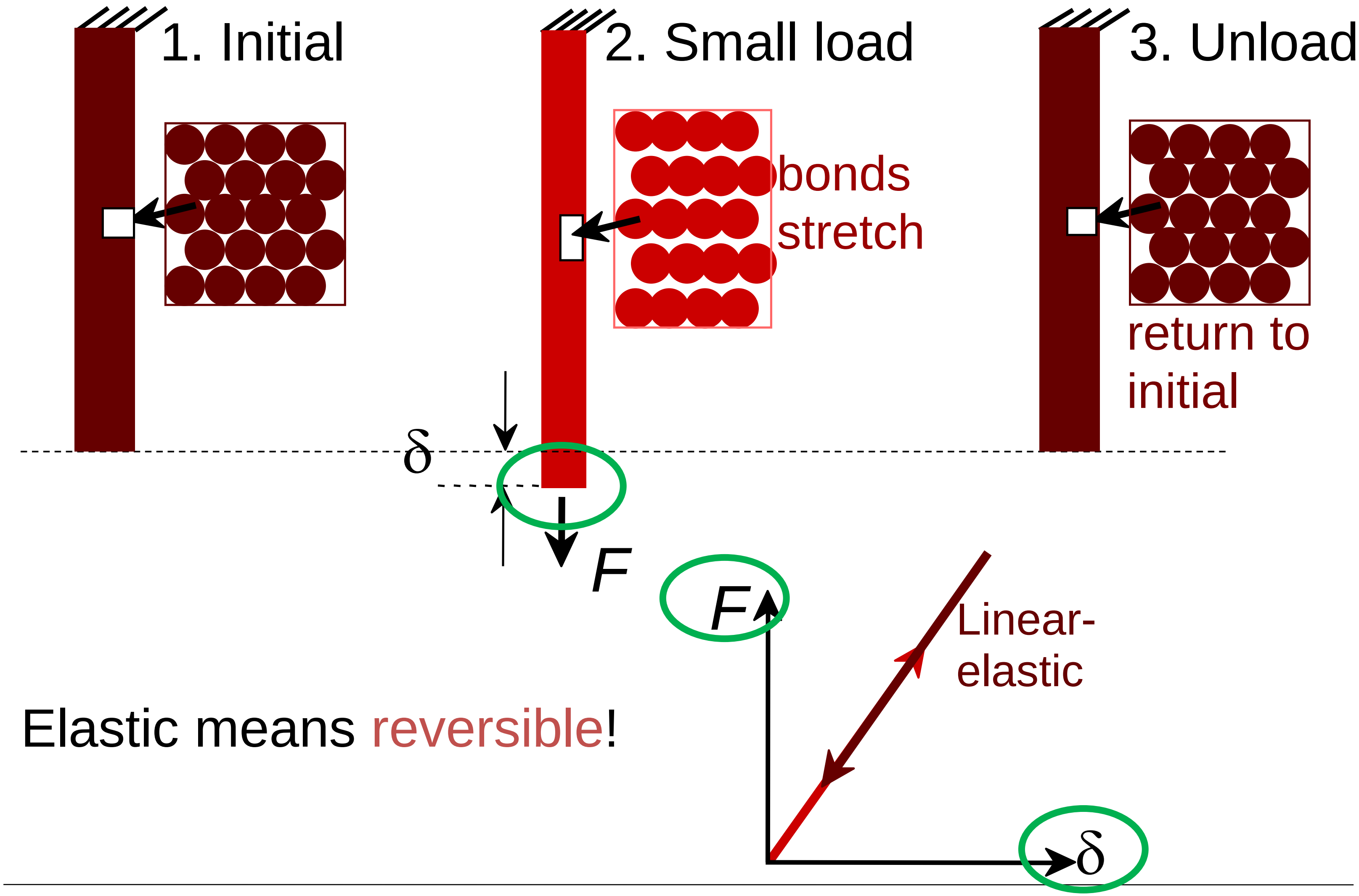
# Strength of wood

- Tensile strength
- Compressive strength
- Shear strength
- “Bending”



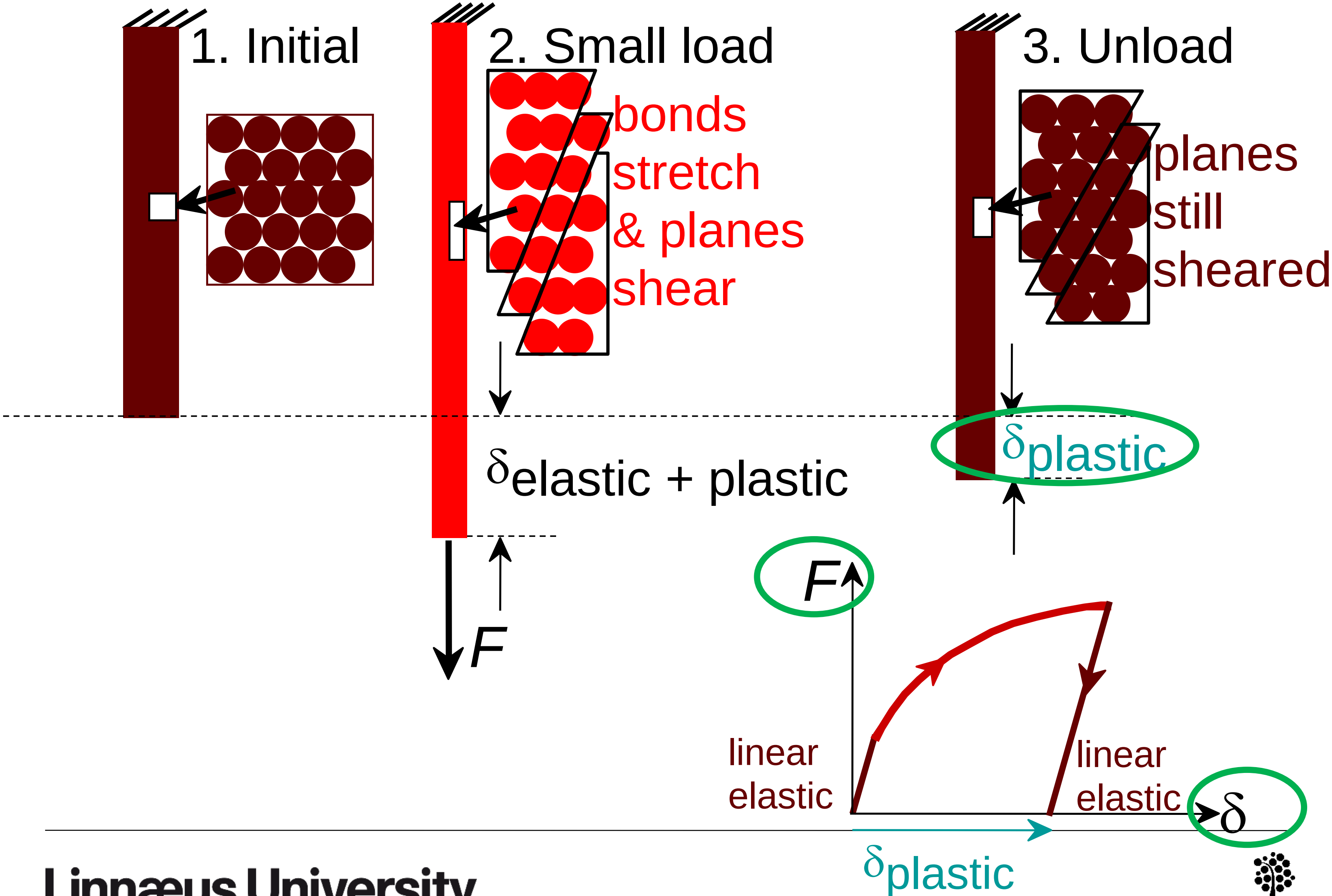
- Stress and strain: What are they and why are they used instead of load and deformation?
- Elastic behavior: When loads are small, how much deformation occurs? What materials deform least?
- Plastic behavior: At what point does permanent deformation occur? What materials are most resistant to permanent deformation?

# Elastic deformation



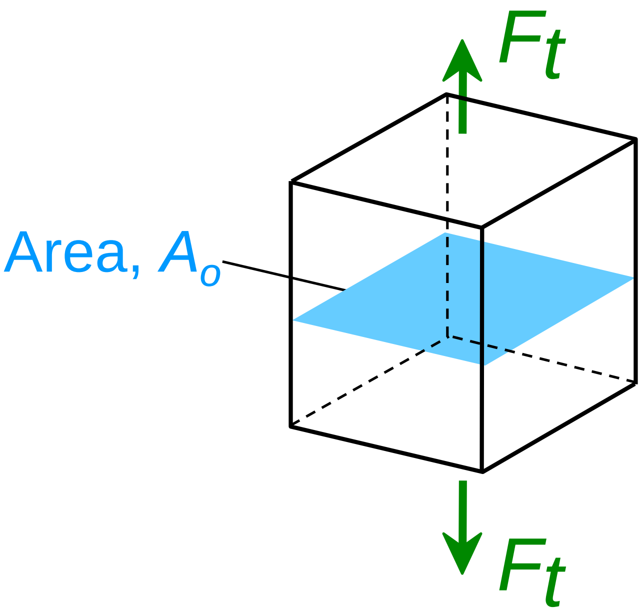

Elastic means reversible!

# Plastic deformation



# Stress

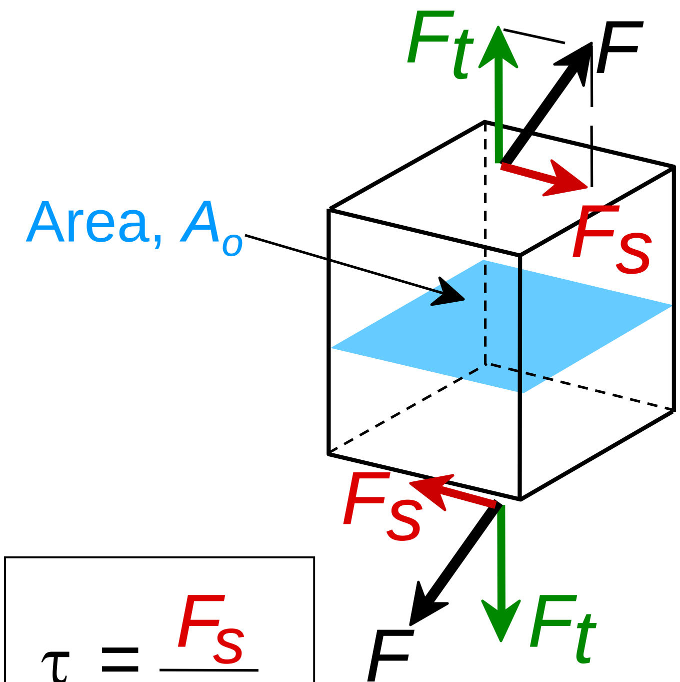
- Tensile stress, $\sigma$:




$$\sigma = \frac{F_t}{A_o} = \frac{lb_f}{in^2} \text{ or } \frac{N}{m^2}$$

original area before loading

- Shear stress, $\tau$:



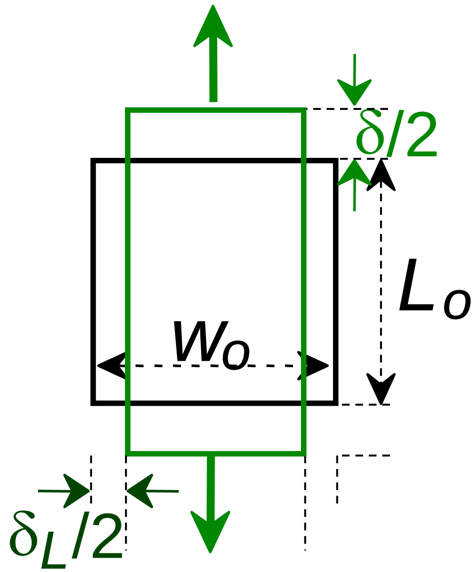

$$\tau = \frac{F_s}{A_o}$$

∴ Stress has units: $N/m^2$ or $lb_f/in^2$

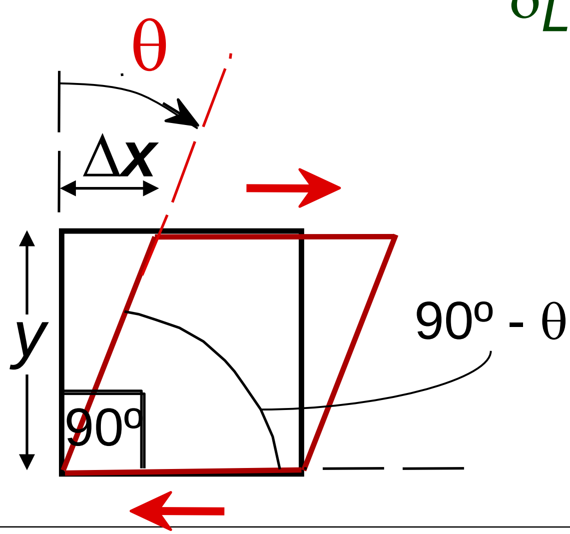
# Strain

- **Tensile strain:**

$$\varepsilon = \frac{\delta}{L_o}$$

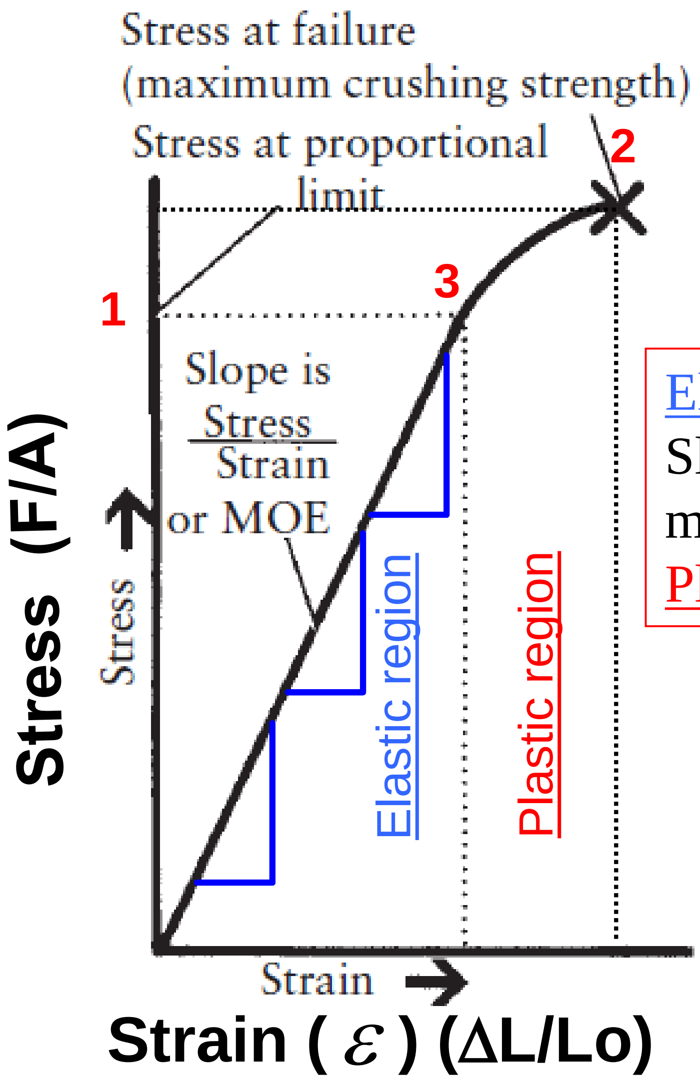



- **Shear strain:**




$$\gamma = \Delta x / y = \tan\theta$$

**Strain is always dimensionless.**




Elastic region

Slope =Young's (elastic) modulus yield strength

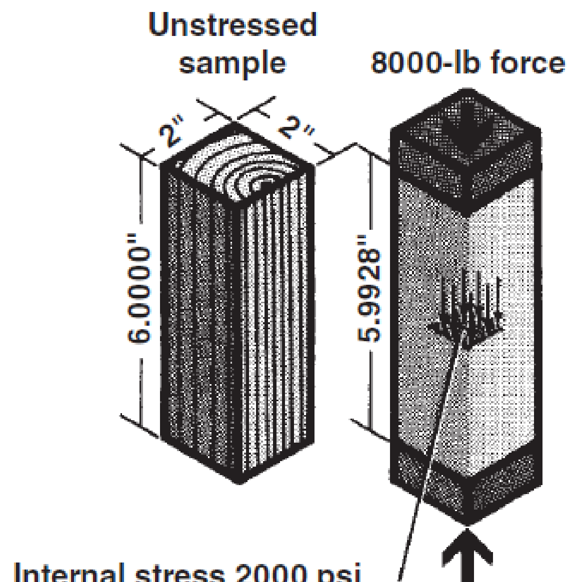
Plastic region

$$\sigma = E\,\varepsilon$$

$$E = \frac{\sigma}{\varepsilon}$$

# Modulus of elasticity

Below the proportional limit, the ratio of stress to strain, that is, the slope of the linear relationship, is called the MOE.

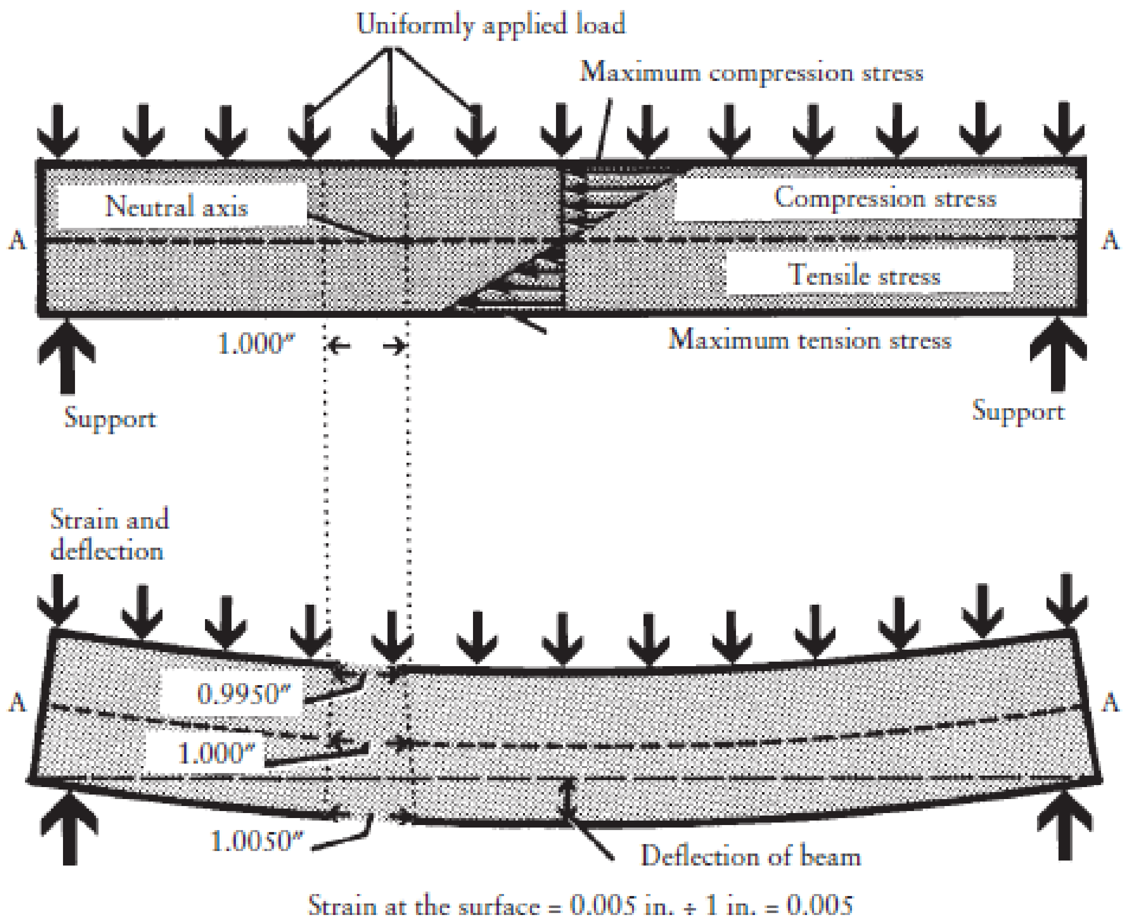



$$\text{Stress} = \frac{8000\ \text{lb}}{4\ \text{in.}^2} = 2000\ \text{psi}$$

$$\text{Strain} = \frac{6.000 - 5.9928}{6} = 0.0012\ \text{in. in.}^{-1}$$

$$\text{Young's modulus (MOE)} = \text{stress} \div \text{strain} = 2000 \div 0.0012 = 1.67 \times 10^6\ \text{psi}$$

# Bending strength



For a test specimen loaded in bending by a concentrated load at the center of its span and supported at its ends, the MOE can be calculated from the following formula:

MOE (MPa) = $PL^3/48ID$

where

P = the concentrated center load (newtons, **below the proportional limit**)

D = the deflection at mid - span (m) resulting from P

L = the span (m)

I = moment of inertia, a function of the beam ' s section . . . (width × $depth^3$)/12 for beams with a rectangular cross section; units are " *n* " to the fourth power (e.g., $m^4$)

A 50 × 50 × 762 mm clear dry specimen of red oak is supported near each end of its 711 mm long span and loaded at the center in a universal testing machine. A gradually increasing load is applied, and when the load reaches 6680 N (below the proportional limit), the deflection at mid-span under the load measures 6.6 mm.

The MOE of this specimen is determined as follows:

MOE $= PL^3/48ID$

$= [6680N\ (0.711m)^3] / [48(0.050m\ (0.050m)^3 / 12)\ 0.0066\ m]$

$= 14\ 600\ MPa$

# Modulus of rupture

***Ultimate bending strength***

This modulus is actually the equivalent stress at the point of failure. In three-point bending the modulus of rupture (MOR) is given by-

MOR ($N/mm^2$) = $3PL/2bd^2$

Where

P = load in newtons

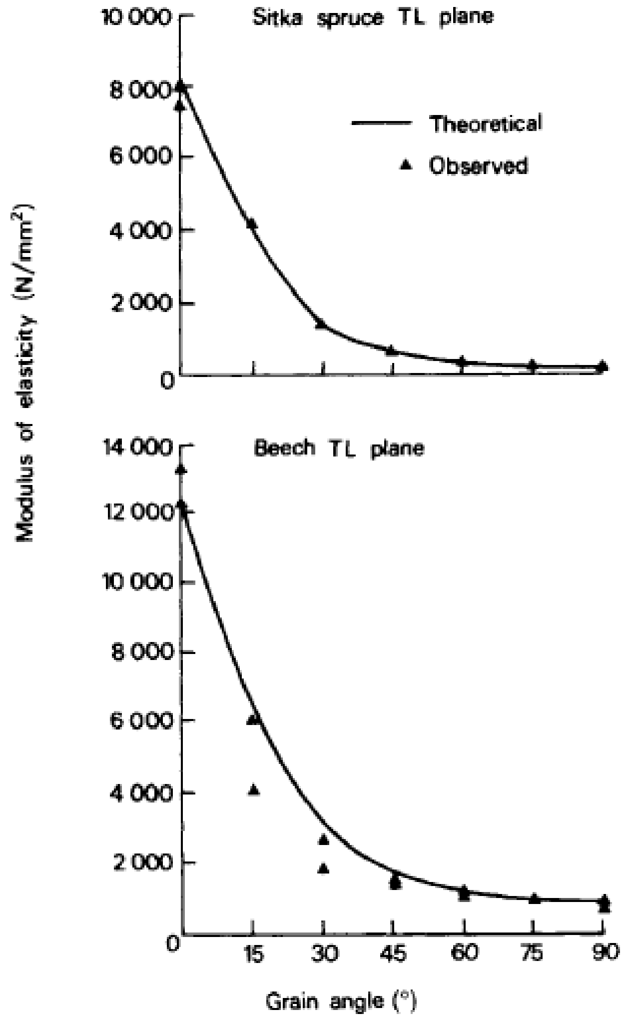
L = span length in millimetres

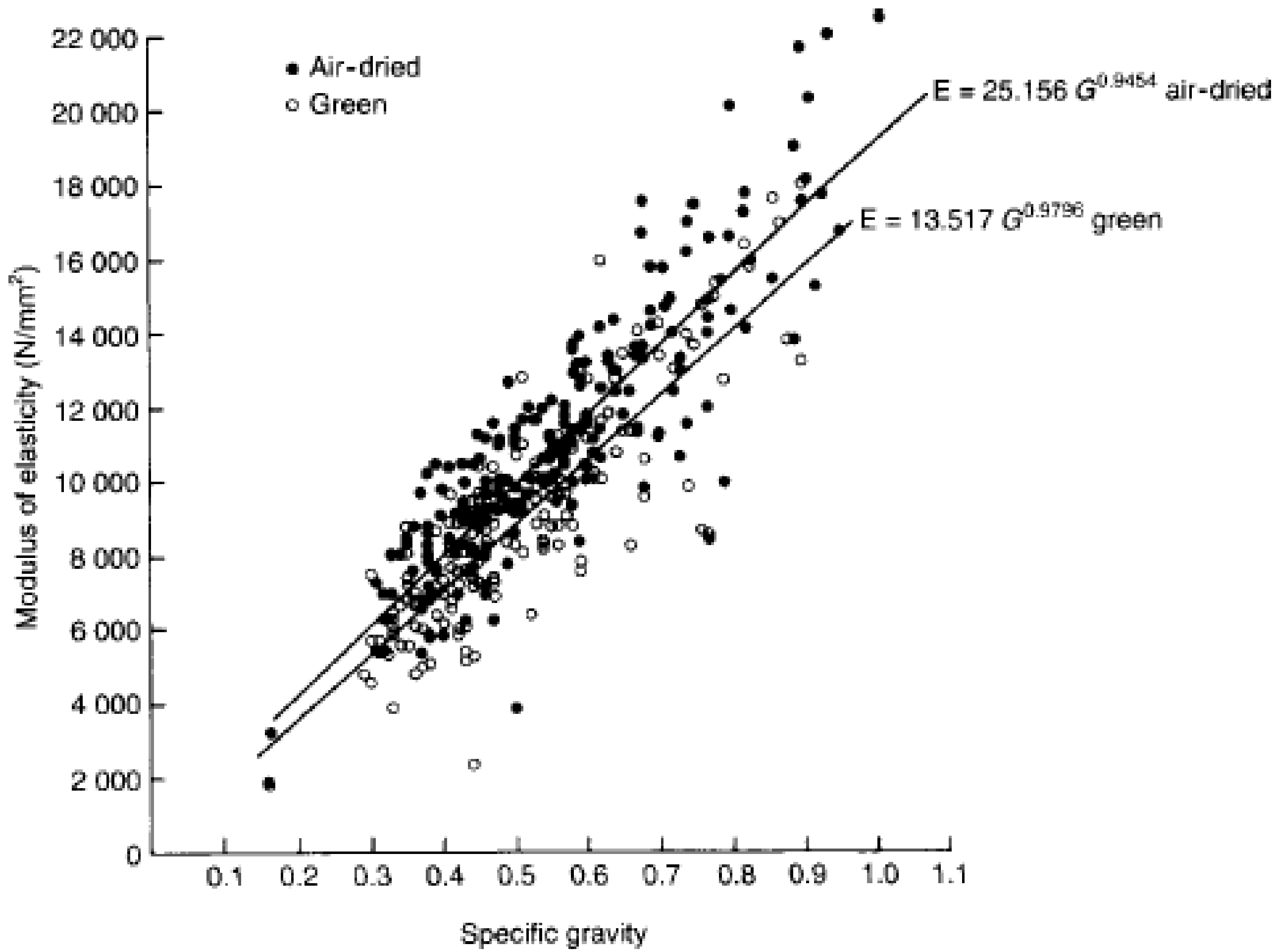
b = width of the beam in millimetres

d = thickness of the beam in millimetres.

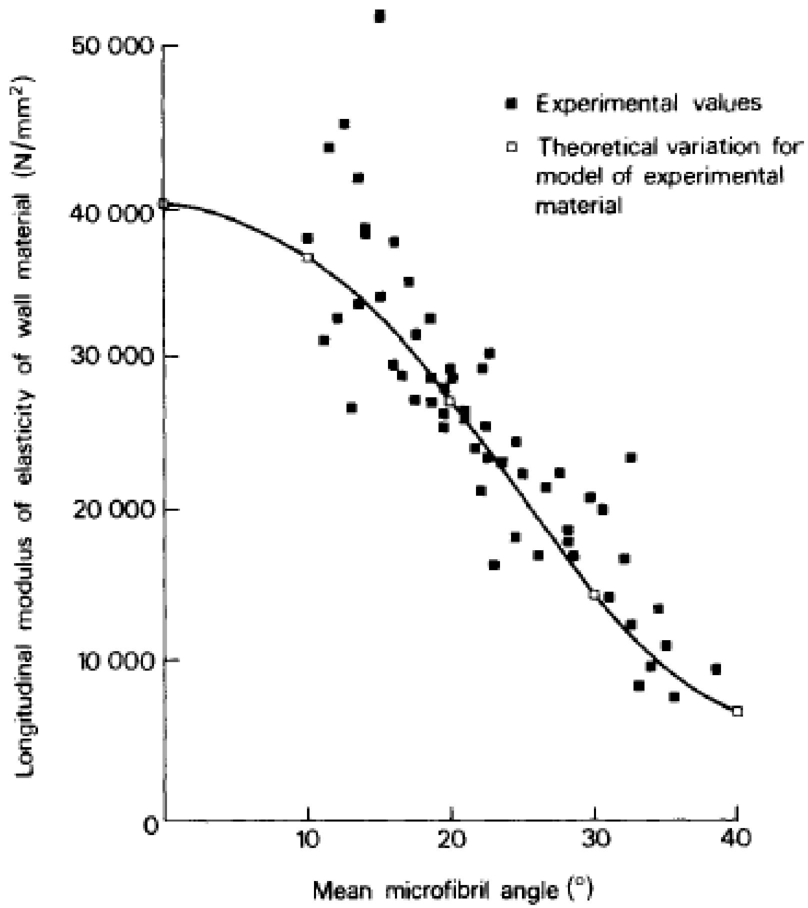
# Factors affecting Strength of Wood

- Anisotropy (Grain angle)
- Knots
- Density (latewood earlywood ratio)
- Chemical composition
- Micofibrillar angle
- Reaction wood
- Moisture content
- Temperature
- Rate and duration of loading


Sitka spruce TL plane
Theoretical
Observed
Beech TL plane
Modulus of elasticity (N/mm$^2$)
Grain angle (°)
10 000
8 000
6 000
4 000
2 000
0
14 000
12 000
10 000
8 000
6 000
4 000
2 000
0
15
30
45
60
75
90



22 000
20 000
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2 000
0
Modulus of elasticity (N/mm²)
Air-dried
Green
E = 25.156 G^0.9454 air-dried
E = 13.517 G^0.9796 green
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Specific gravity



Experimental values
Theoretical variation for model of experimental material
Longitudinal modulus of elasticity of wall material (N/mm²)
50 000
40 000
30 000
20 000
10 000
0
10
20
30
40
Mean microfibril angle (°)

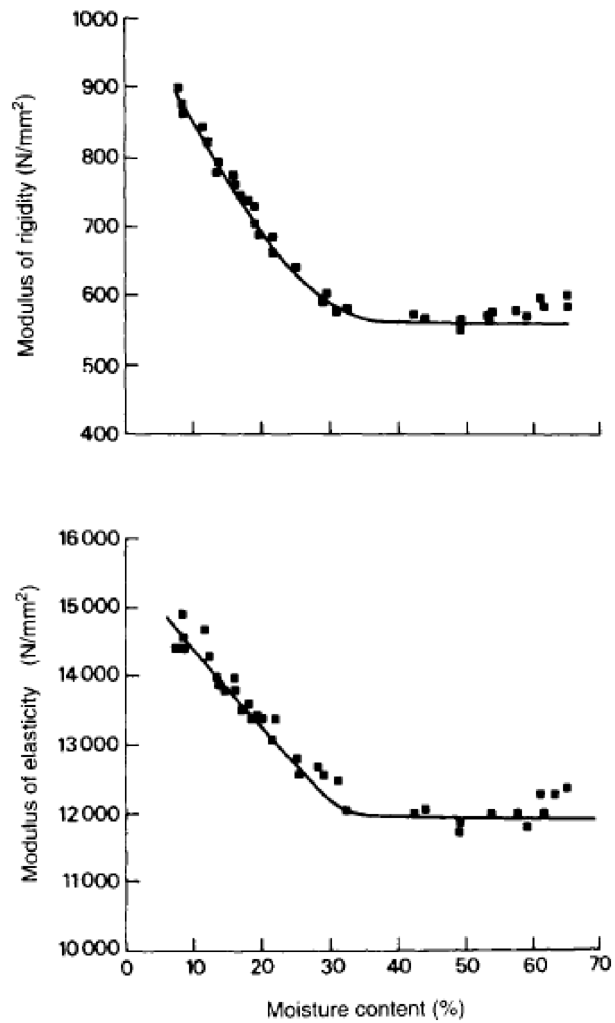
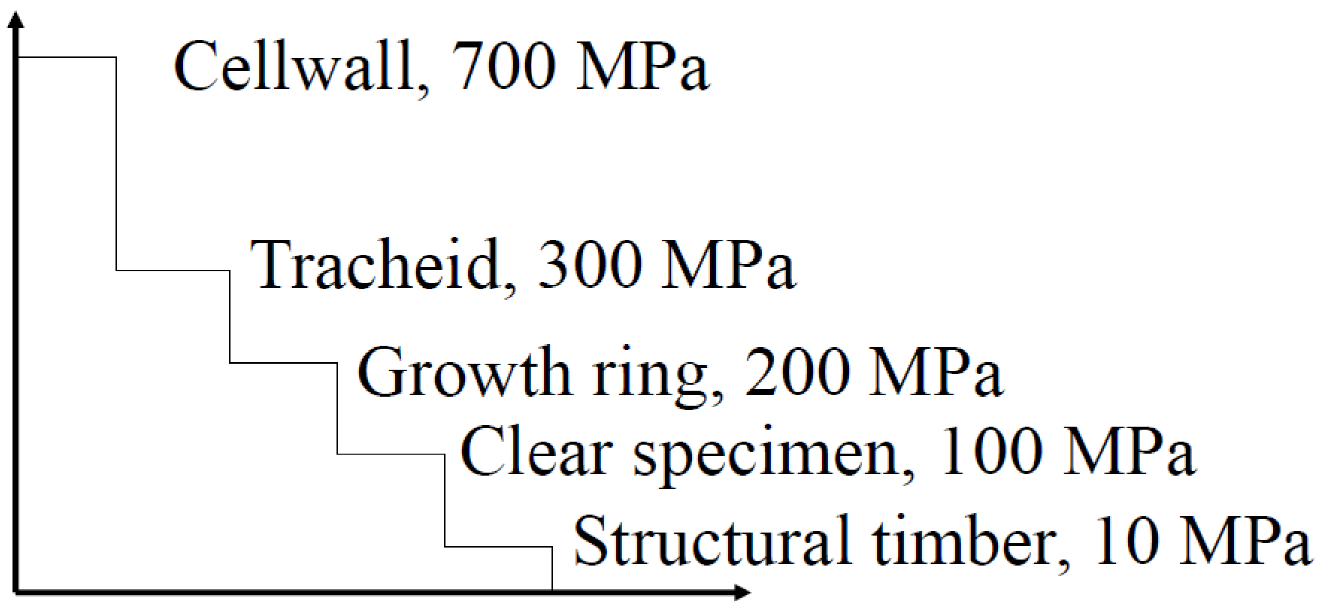

1000
900
800
700
600
500
400
Modulus of rigidity (N/mm²)
16 000
15 000
14 000
13 000
12 000
11 000
10 000
Modulus of elasticity (N/mm²)
0
10
20
30
40
50
60
70
Moisture content (%)

**Table 4–4a. Mechanical properties of some commercially important woods grown in Canada and imported into the United States (metric)[a]**

| Common species names | Moisture content | Specific gravity | Static bending: Modulus of rupture (kPa) | Static bending: Modulus of elasticity (MPa) | Compression parallel to grain (kPa) | Compression perpendicular to grain (kPa) | Shear parallel to grain (kPa) |
|---|---|---|---|---|---|---|---|
| **Hardwoods** | | | | | | | |
| Aspen | | | | | | | |
| Quaking | Green | 0.37 | 38,000 | 9,000 | 16,200 | 1,400 | 5,000 |
| | 12% | | 68,000 | 11,200 | 36,300 | 3,500 | 6,800 |
| Big-toothed | Green | 0.39 | 36,000 | 7,400 | 16,500 | 1,400 | 5,400 |
| | 12% | | 66,000 | 8,700 | 32,800 | 3,200 | 7,600 |
| Cottonwood | | | | | | | |
| Black | Green | 0.30 | 28,000 | 6,700 | 12,800 | 700 | 3,900 |
| | 12% | | 49,000 | 8,800 | 27,700 | 1,800 | 5,900 |
| Eastern | Green | 0.35 | 32,000 | 6,000 | 13,600 | 1,400 | 5,300 |
| | 12% | | 52,000 | 7,800 | 26,500 | 3,200 | 8,000 |
| Balsam, poplar | Green | 0.37 | 34,000 | 7,900 | 14,600 | 1,200 | 4,600 |
| | 12% | | 70,000 | 11,500 | 34,600 | 2,900 | 6,100 |
| **Softwoods** | | | | | | | |
| Cedar | | | | | | | |
| Northern white | Green | 0.30 | 27,000 | 3,600 | 13,000 | 1,400 | 4,600 |
| | 12% | | 42,000 | 4,300 | 24,800 | 2,700 | 6,900 |
| Western redcedar | Green | 0.31 | 36,000 | 7,200 | 19,200 | 1,900 | 4,800 |
| | 12% | | 54,000 | 8,200 | 29,600 | 3,400 | 5,600 |
| Yellow | Green | 0.42 | 46,000 | 9,200 | 22,300 | 2,400 | 6,100 |
| | 12% | | 80,000 | 11,000 | 45,800 | 4,800 | 9,200 |
| Douglas-fir | Green | 0.45 | 52,000 | 11,100 | 24,900 | 3,200 | 6,300 |
| | 12% | | 88,000 | 13,600 | 50,000 | 6,000 | 9,500 |
| Fir | | | | | | | |
| Subalpine | Green | 0.33 | 36,000 | 8,700 | 17,200 | 1,800 | 4,700 |
| | 12% | | 56,000 | 10,200 | 36,400 | 3,700 | 6,800 |
| Pacific silver | Green | 0.36 | 38,000 | 9,300 | 19,100 | 1,600 | 4,900 |
| | 12% | | 69,000 | 11,300 | 40,900 | 3,600 | 7,500 |
| Balsam | Green | 0.34 | 36,000 | 7,800 | 16,800 | 1,600 | 4,700 |
| | 12% | | 59,000 | 9,600 | 34,300 | 3,200 | 6,300 |

Strength



Cellwall, 700 MPa
Tracheid, 300 MPa
Growth ring, 200 MPa
Clear specimen, 100 MPa
Structural timber, 10 MPa

# Reading materials

Dinwoodie JM (2000) Timber: Its Nature and Behaviour. 2nd Edition. Taylor & Francis, New York, USA. ISBN: 0-419-25550-8.