



Basic Wood Properties

FOR 111

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Wood and Water

Wood & Water

Importance of Water in Wood

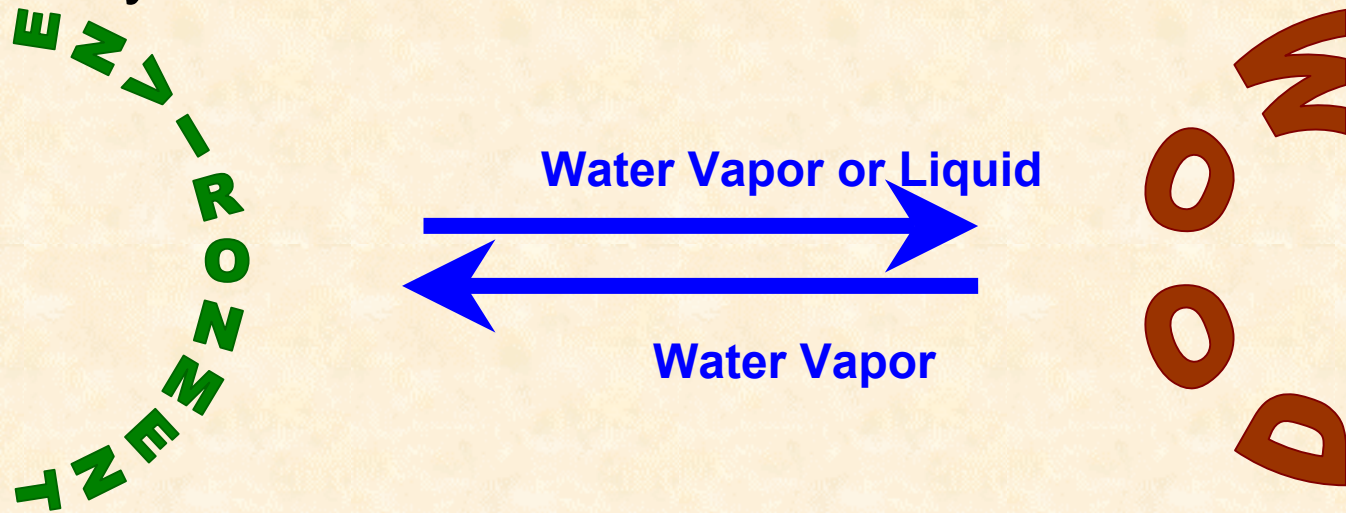
Wood Properties differ with Moisture Content (MC)

- **Dimensions**
- **Strength**
- **Thermal Conductivity**
- **Decay Resistance**
- **Electrical Resistance**
- **Dielectric Properties**

Wood & Water

Hygroscopicity

Wood is **hygroscopic** below the **FSP**. This means wood adsorbs and desorbs water from its environment until an equilibrium dependent on ambient temperature and humidity is reached.




A vertical strip on the left side of the slide shows a close-up of wood grain with concentric growth rings.

Wood & Water

Wood Moisture Measurement

The Oven Dry (OD) basis for calculating moisture content is used with lumber, plywood, particleboard and other composite products



Wood & Water

Wood Moisture Measurement

Oven dry (OD) basis calculations

$$MC = \frac{Wet\ wt. - OD\ wt.}{OD\ wt.} \times 100\%$$

Wood & Water

Location of Water in Wood

Occurs in two locations

- **Within cell lumen**

- Liquid or vapor
- Called Free Water

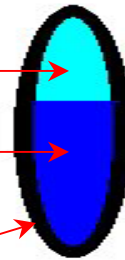
- **Within the cell wall**

- Captured in cell wall matrix
- Called Bound Water

Water Vapor

Free Water

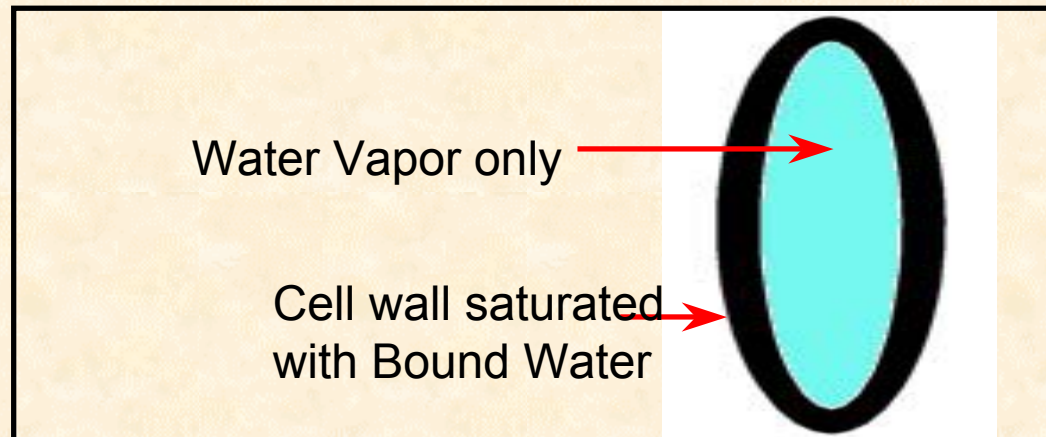
Cell Wall with
Bound Water



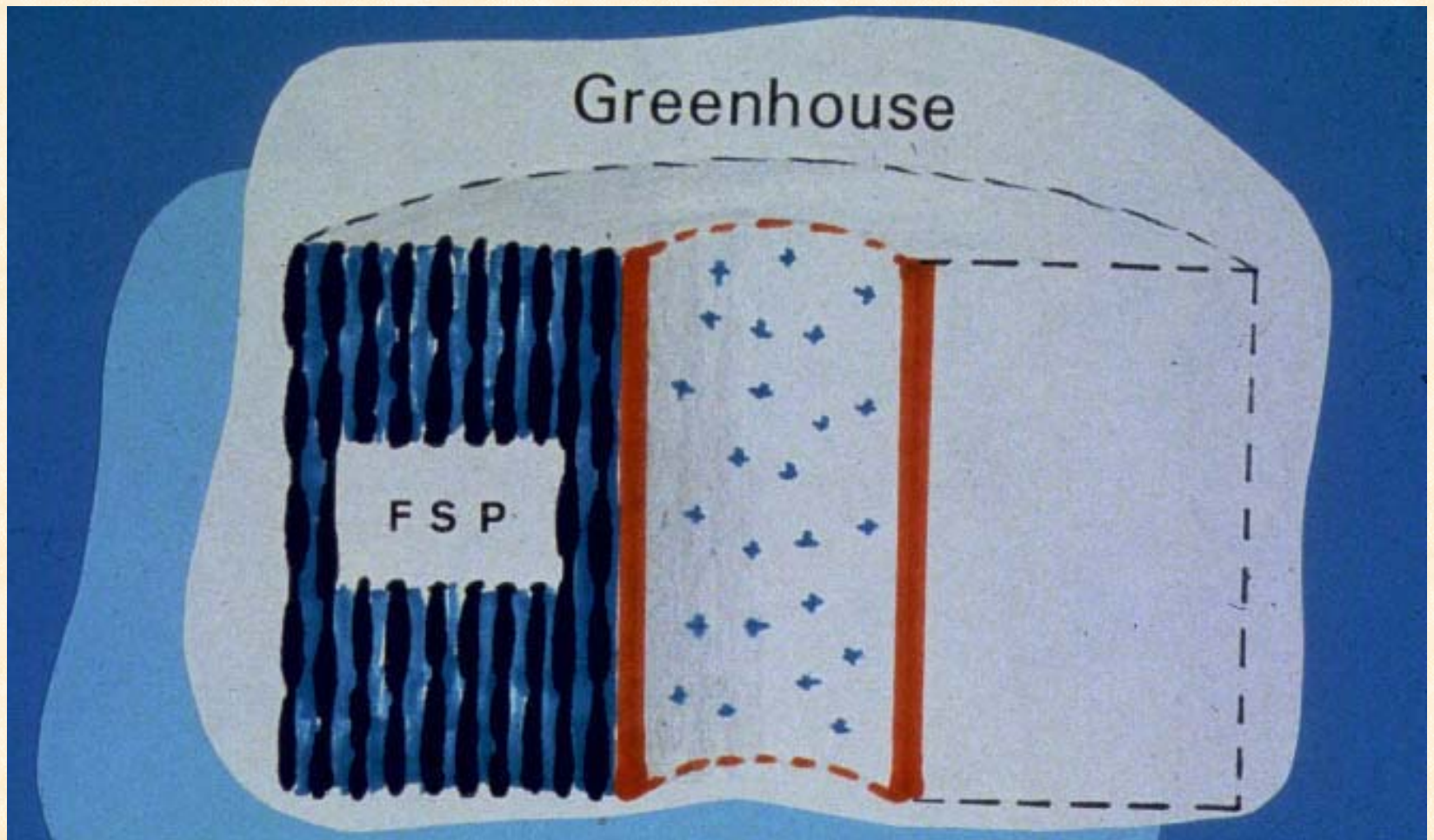
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Fiber Saturation Point

The Fiber Saturation Point (FSP) is the point at which there is no free water present in the cell lumens and there is the maximum amount of bound water present in the cell walls



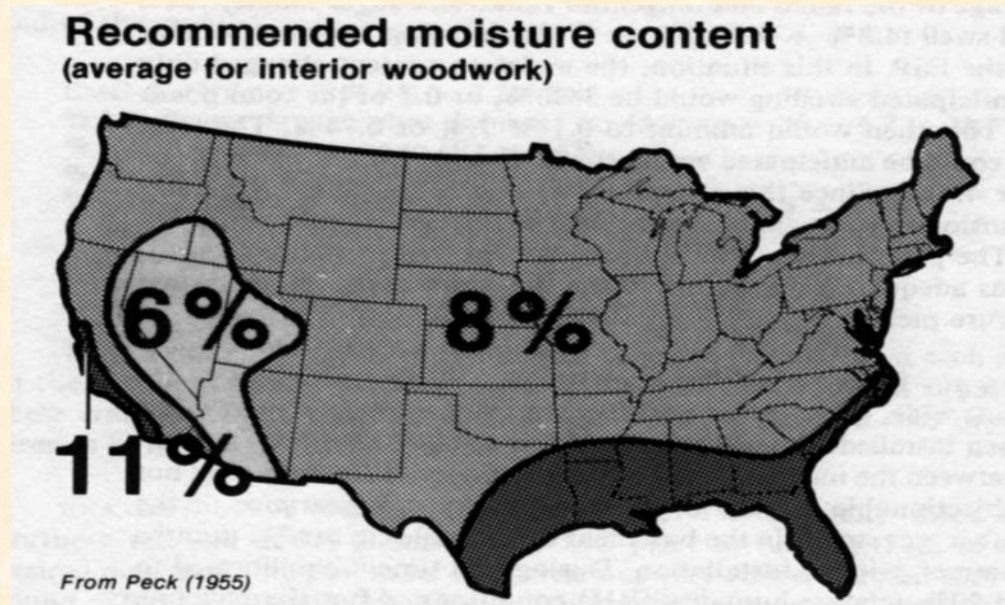
30% Equilibrium Moisture Content



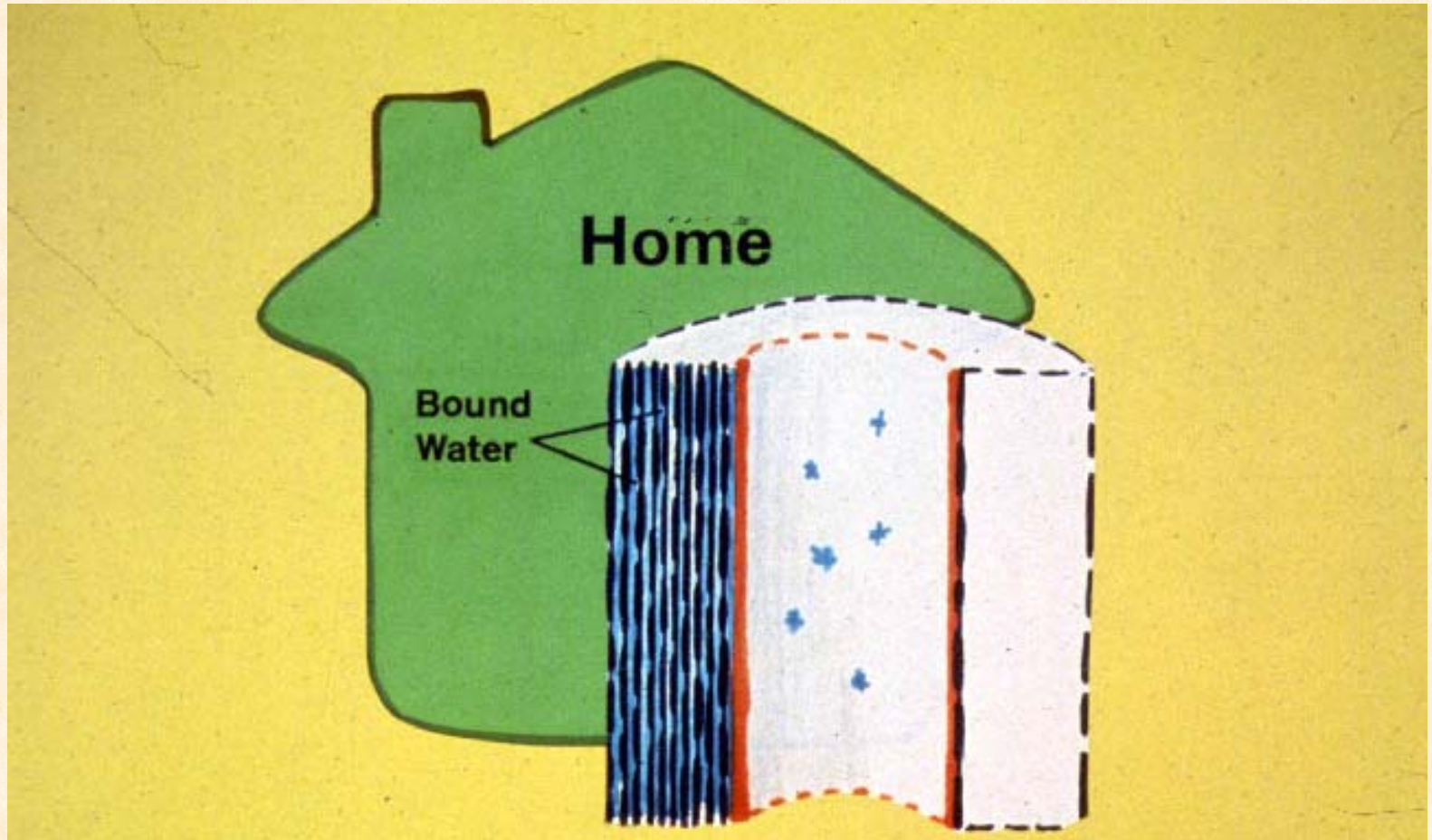
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Equilibrium Moisture Content

The **E**quilibrium **M**oisture **C**ontent (EMC) is the MC of wood when it is in equilibrium with its environment's temperature and humidity.



6 % Equilibrium Moisture Content



12 % Equilibrium Moisture Content



Wood & Water

Equilibrium Moisture Content

Factors that affect **EMC**

● Temperature & Humidity

EMC of wood at various
temperature and humidity values

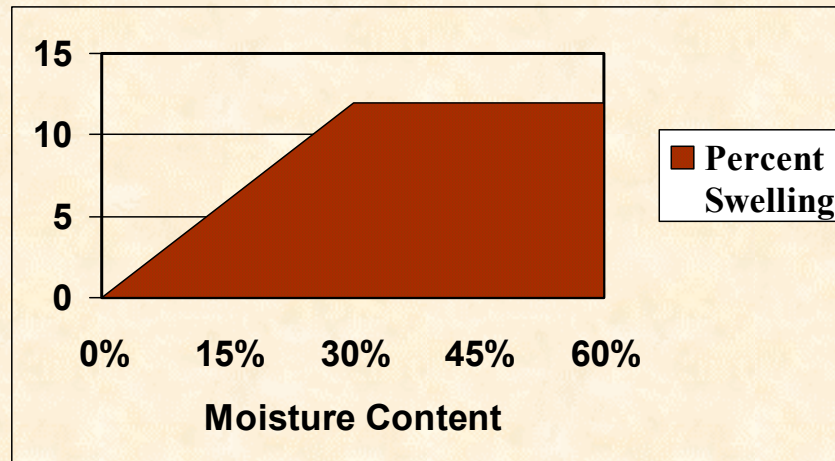
Temp. °F	Relative Humidity %		
	30%	60%	90%
30°	6.3	11.3	21.0
70°	6.2	11.0	20.5
90°	5.9	10.5	19.8
130°	5.2	9.4	18.2

Wood & Water

Wood Shrinkage

When does wood shrink and swell?

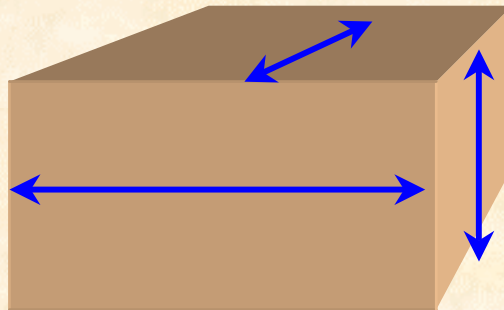
- **Wood shrinks and swells only with changes in the bound water content, i.e. below the FSP. Free water content has no affect on wood dimensions.**



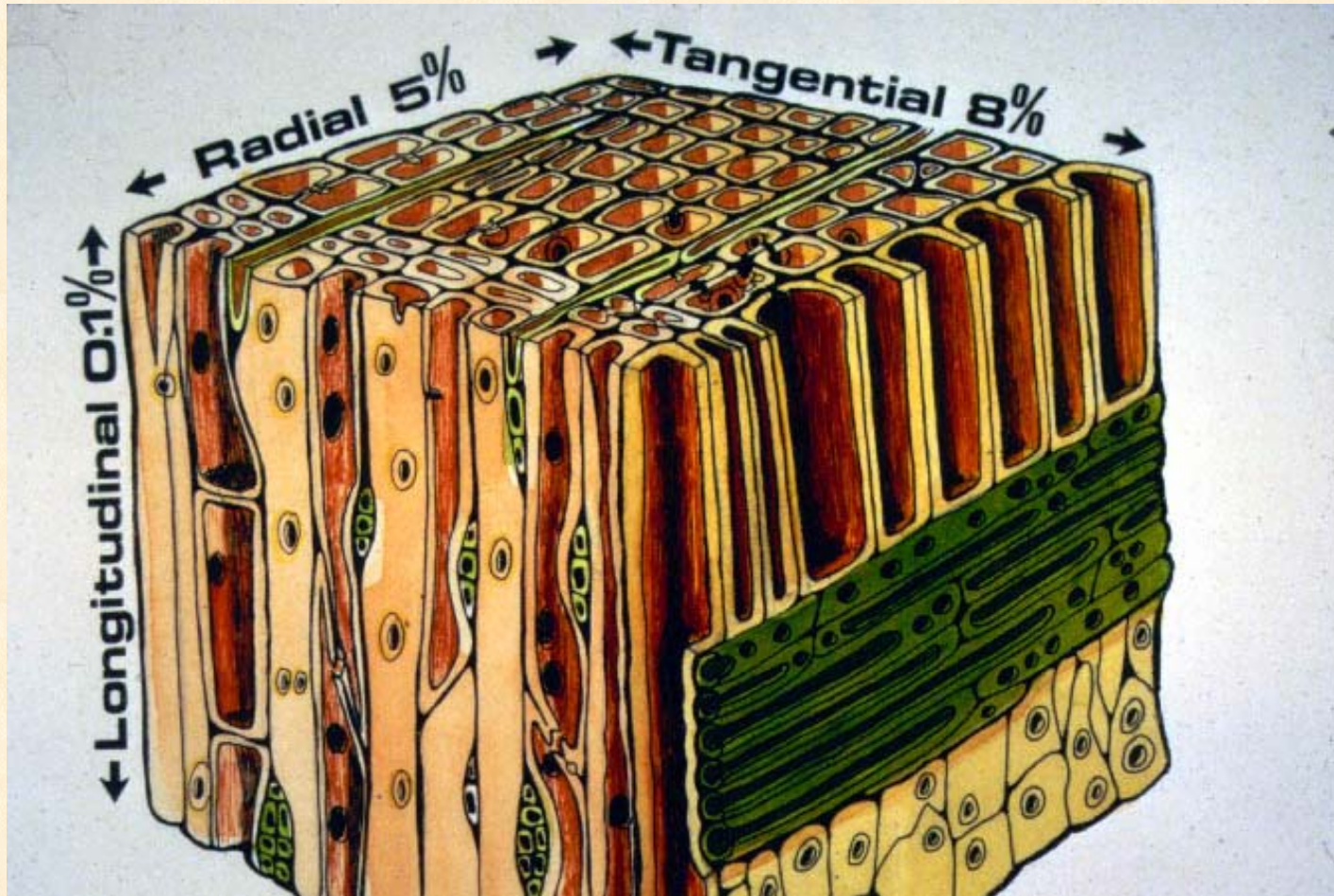
Wood & Water

Anisotropic Wood Shrinkage

Anisotropic shrinkage and swelling occur when the percentage change in dimension is different for the different directional axes found in wood



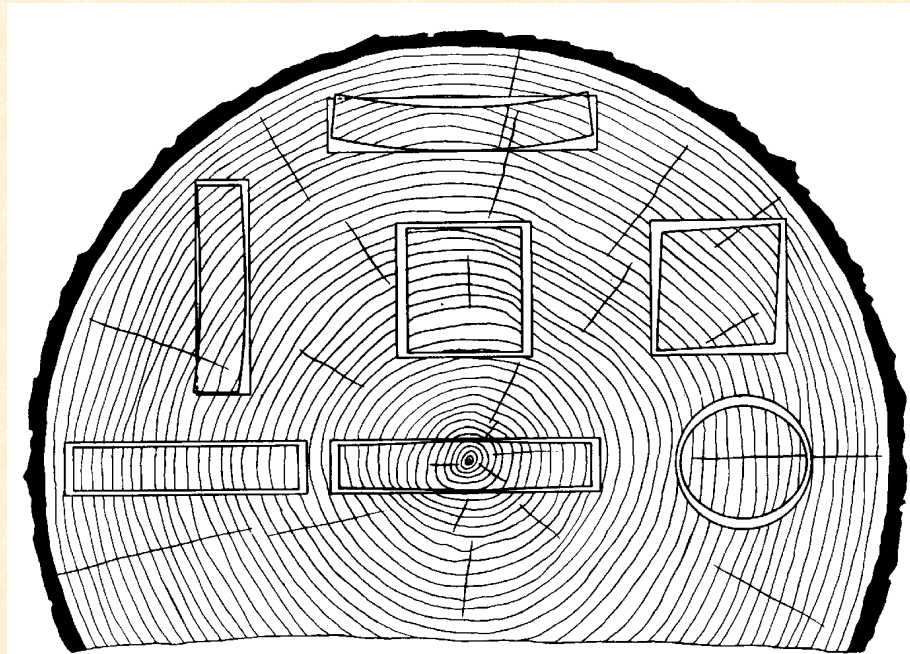
Wood Shrinks Unevenly



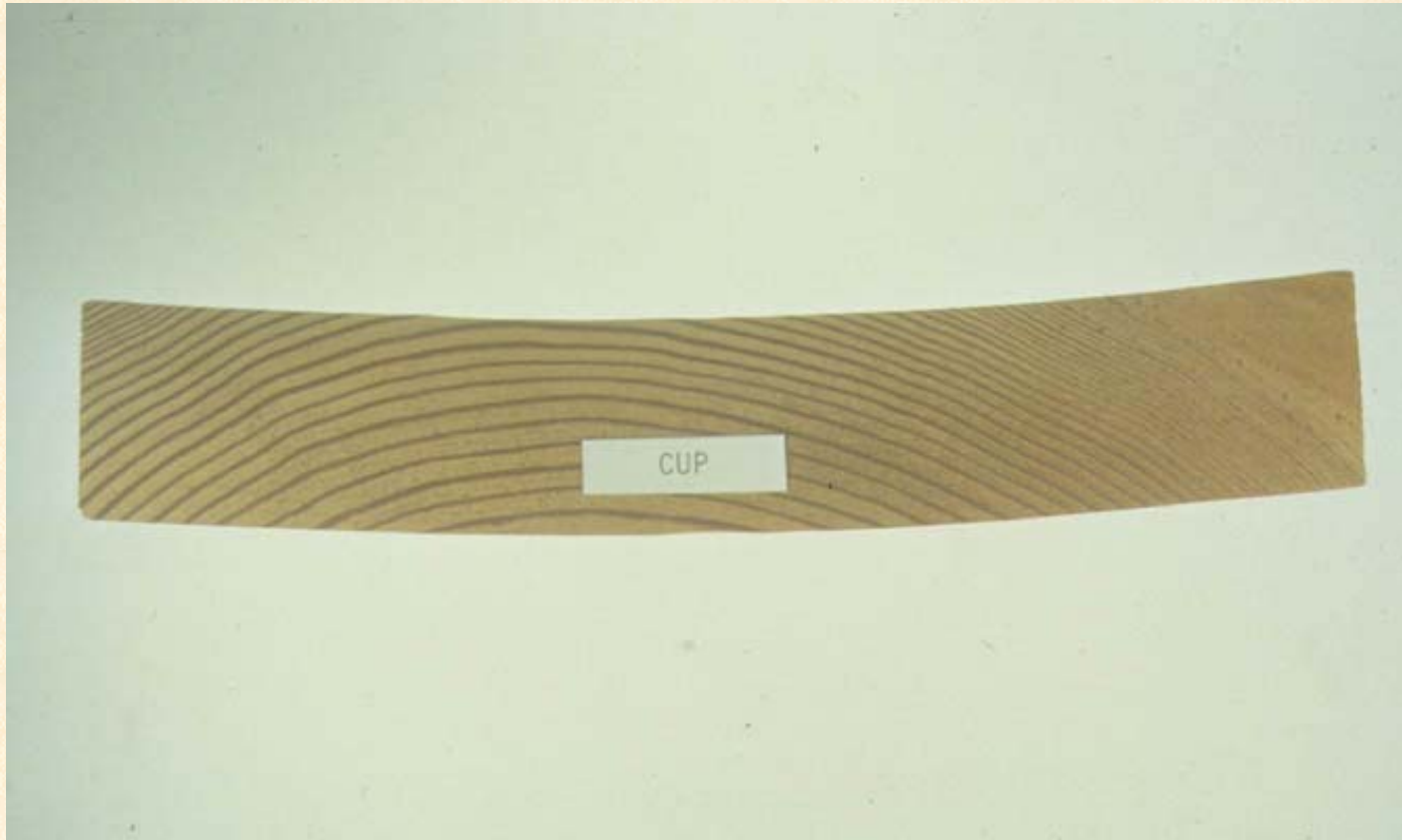
Wood & Water

Anisotropic Wood Shrinkage

Differences in transverse shrinkage and swelling rates can change cross-sectional shapes



Cup



End Checks



Surface Checks



Honeycomb



Collapse



A vertical strip on the left side of the slide shows a close-up of wood grain with concentric growth rings.

Wood & Water

Green Moisture Content

The MC in living trees varies by species. Differences between sapwood and heartwood also exist for hardwoods and softwoods.

- **Hardwoods exhibit no green MC pattern between heartwood and sapwood, species variation is extremely wide**
- **Softwoods commonly have a heartwood MC near the FSP which, of course, is much lower than the MC of its sapwood**

Wood & Water

Green Moisture Content

Species	Moisture Content	
Hardwoods	Heartwood	Sapwood
white ash	46	44
white oak	64	78
sweetgum	79	137
black walnut	90	73
Aspen	95	113
Softwoods	Heartwood	Sapwood
loblolly pine	33	110
Douglas-fir	37	115
ponderosa pine	40	148
w. red cedar	58	249
white fir	98	160

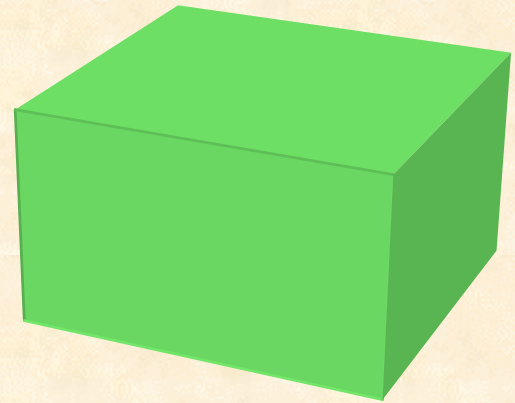
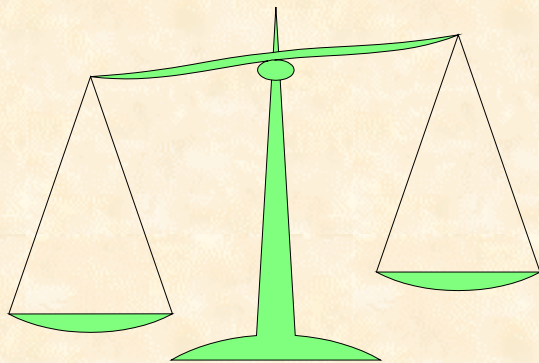


Wood Density

Wood Density

Density Defined

Density is a substance's mass per unit volume

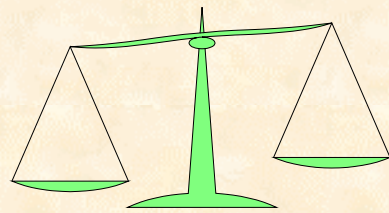


Wood Density

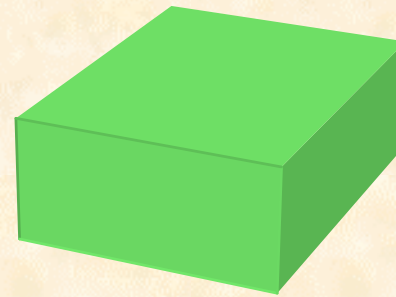
Density and MC

Wood density varies with moisture content because MC can affect both mass and volume

- **To be meaningful, the MC during both mass and volume measurements must be specified.**



MC varies



MC varies

Wood Density

Density and MC

**Possible densities for an eighteen foot 2x4
(lbs./ft³)**

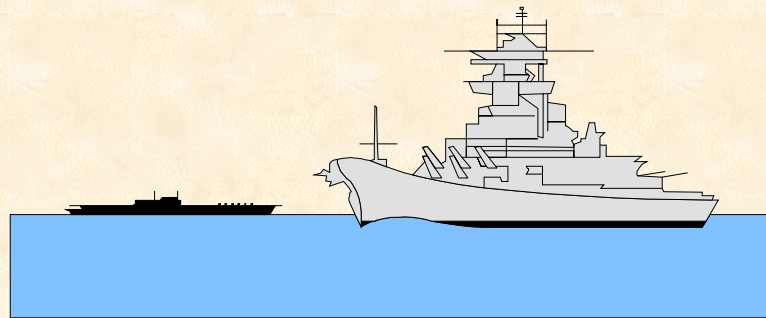
Weight Basis	Volume Basis	
	Green (0.78ft ³)	Oven-dry (0.68ft ³)
Green (38 lbs.)	48.7	55.9
Kiln-dry 15% (22 lbs.)	28.2	32.4
Oven-dry (19 lbs.)	24.4	27.9

Wood Density

Specific Gravity

Specific Gravity (SG) is the density of a substance relative to the density of water and is sometimes called *relative density* or *basic density*

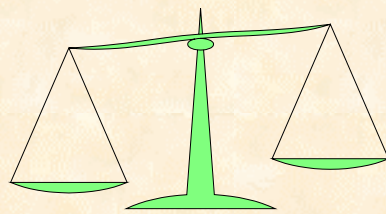
Substances with a SG of less than one will float



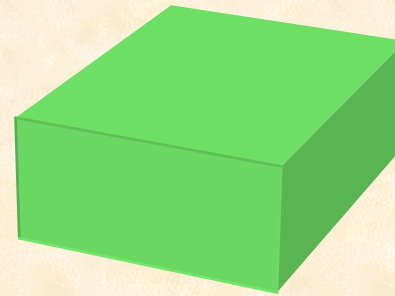
Wood Density

Specific Gravity

The specific gravity of wood is always calculated using its oven-dry mass. Therefore, only the MC during volume measurement will affect specific gravity results.



MC oven-dry



MC varies

Wood Density

Wood Porosity

Wood is a mixture of void volume and cell walls. Void volume directly relates to density because cell-wall specific gravity is constant.

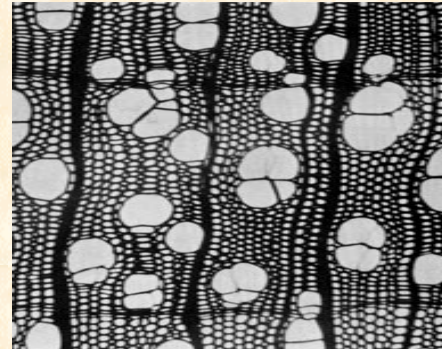
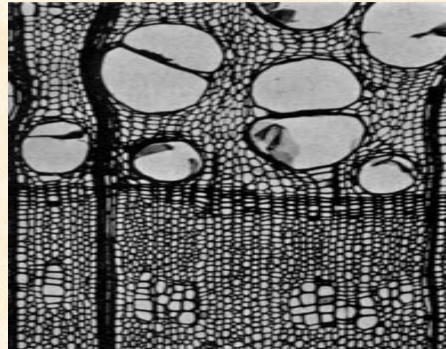
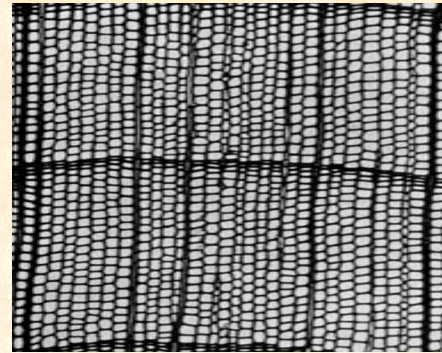
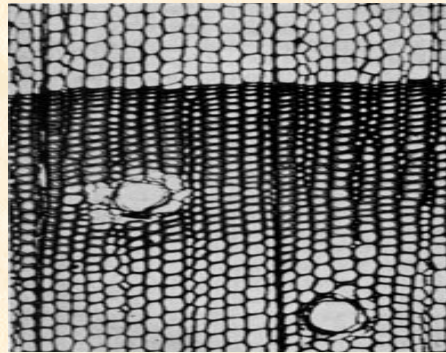
Material	Density (lbs./ft³)	Specific Gravity
Cell Wall	93.6*	1.5*
Water	62.4	1.0
Moist Air	0.075	0.0012

* Constant for all species

Wood Density

Wood Porosity

Wood density varies among species because different cell types and sizes occur in differing proportions.



A vertical strip on the left side of the slide shows a close-up of wood grain with concentric growth rings.

Wood Density

Extractives

Wood often contains organic compounds such as resins, oils, and polyphenols; and inorganic compounds such as silicates, carbonates, and phosphates.

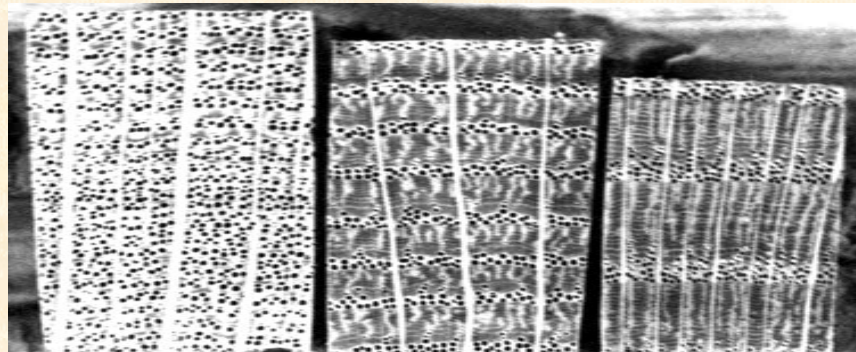
- **Often found in cell walls**
- **Increases overall density**
- **More found in heartwood, so its density tends to be slightly higher**

Wood Density

Growth Rate

Hardwoods

- Only affects ring porous species where wide growth rings produce significant increases in latewood and, therefore, density.

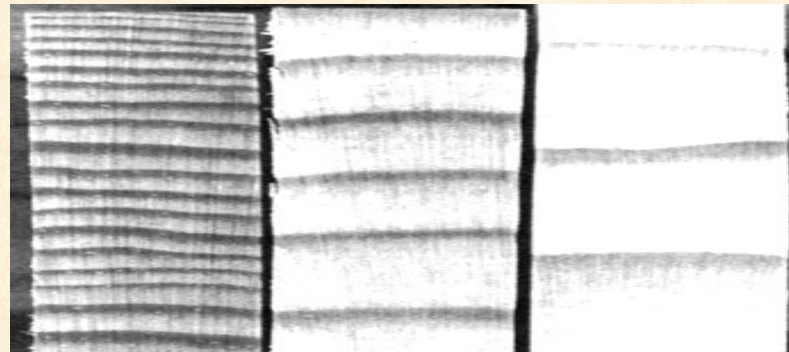


Wood Density

Growth Rate

Softwoods

- Species with wide latewood bands are more dense than those without, but such species do not produce proportionally more latewood with faster growth.



A vertical strip on the left side of the slide shows a close-up of wood grain with concentric growth rings.

Wood Density

Density Variability

The factors that are known to affect wood density within a species.

- **Location within the tree**
- **Location in its range**
- **Site conditions**
- **Genetic factors**

Wood Density

Density Variability

Species	Avg. green SG	Normal SG range
Softwoods		
Douglas-fir	0.45	0.36-0.54
loblolly pine	0.47	0.38-0.56
ponderosa pine	0.38	0.31-0.45
w. white pine	0.35	0.28-0.42
Hardwoods		
black walnut	0.51	0.41-0.61
red oak	0.56	0.45-0.67
sugar maple	0.56	0.45-0.67
white ash	0.60	0.48-0.72



Mechanical Properties

Mechanical Properties

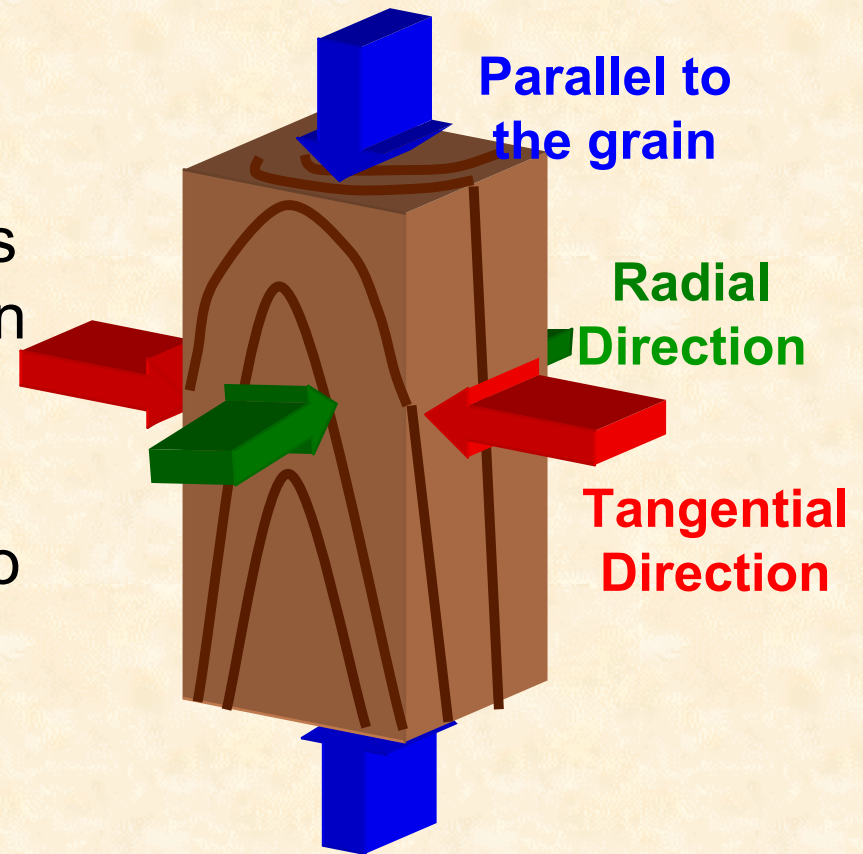
- **Mechanical or strength properties have far-ranging impacts on the use of wood in many applications**
- **Wood, like steel or concrete, is engineered and products designed based on these mechanical properties**

Mechanical Properties

Factors Affecting Strength

Anisotropic nature of wood

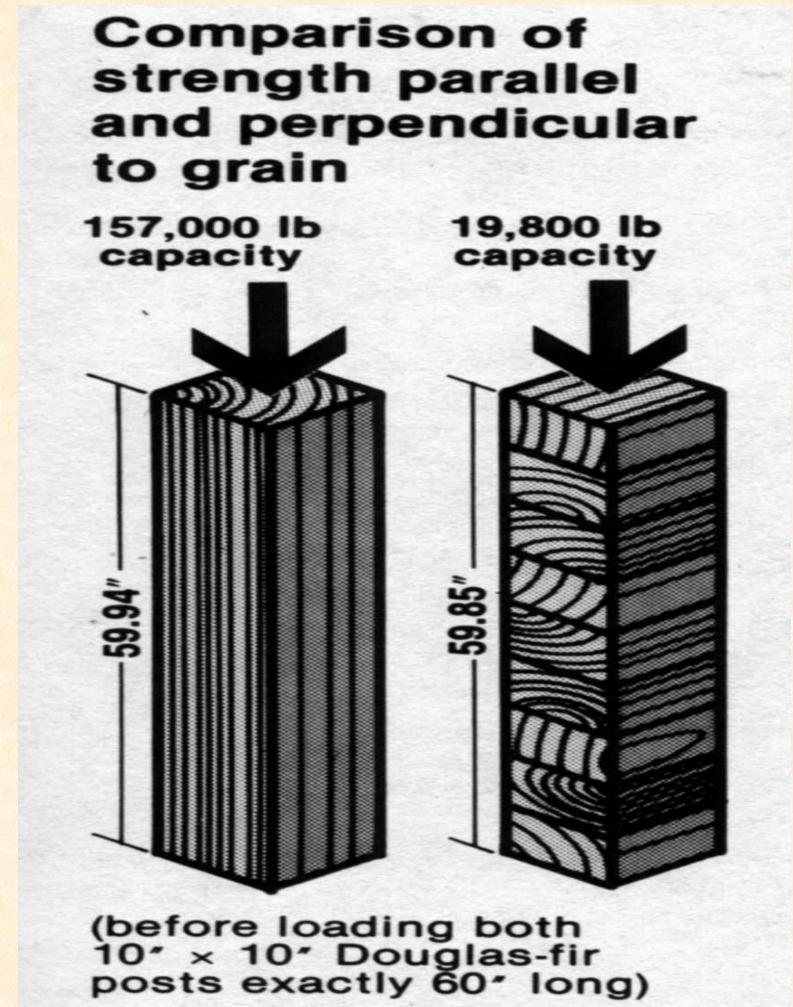
- Longitudinal properties are much different than transverse properties
- Radial and tangential properties generally do not differ greatly



Mechanical Properties

Factors Affecting Strength

Anisotropic behavior
results in dramatically
different load carrying
capacities



Strength Measurements

- **MOR – modulus of rupture**

- **Measures the ultimate strength of wood**

- **May be in bending, tension, or compression**

- **MOE – modulus of elasticity**

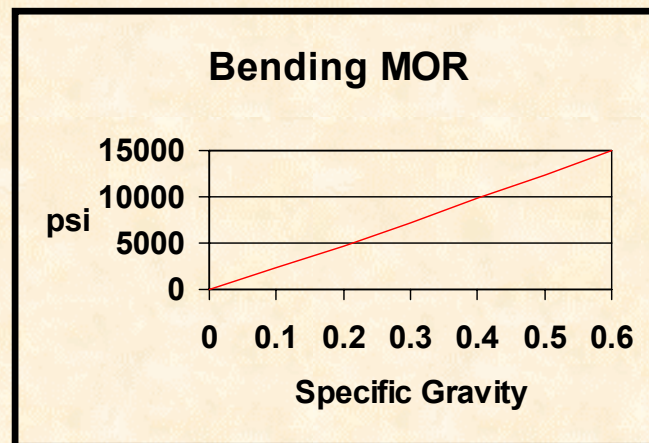
- **Measures the bending strength of wood**

Mechanical Properties

Factors Affecting Strength

Specific Gravity

- The most important predictor of wood strength is specific gravity
- Some property relationships are nearly linear and others are exponential

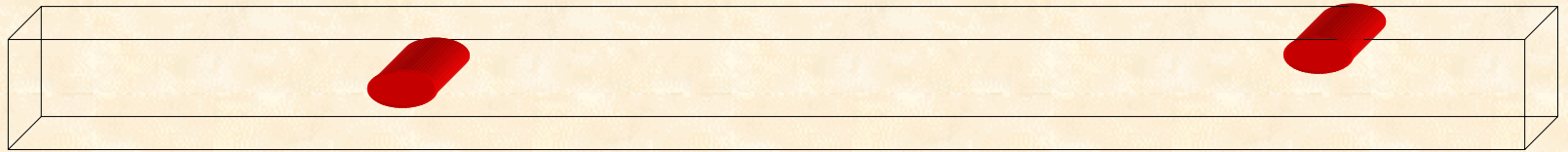


Mechanical Properties

Factors Affecting Strength

Defects that disturb fiber continuity and direction, most notably knots, adversely affect the strength of individual pieces.

A 2" knot on the edge of a 2 X 8 reduces its strength by 43% .



A 2" knot in the center of a 2 X 8 reduces its strength by only 24% .

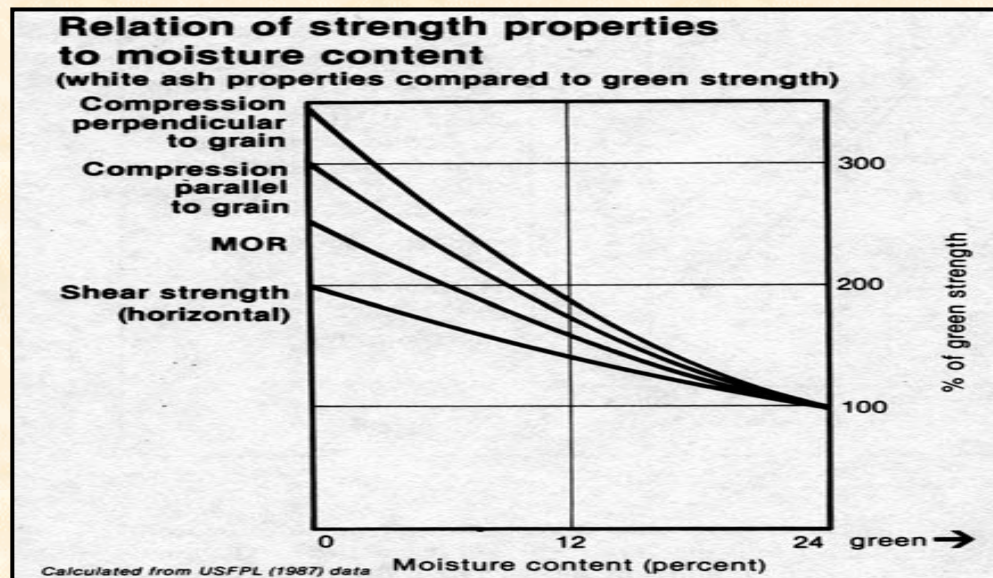
Mechanical Properties

Factors Affecting Strength

Environmental Factors

● Moisture Content

- Mechanical properties increase in value below the FSP
- The relationships are exponential



Mechanical Properties

Factors Affecting Strength

Environmental Factors – *continued*

- **Time**

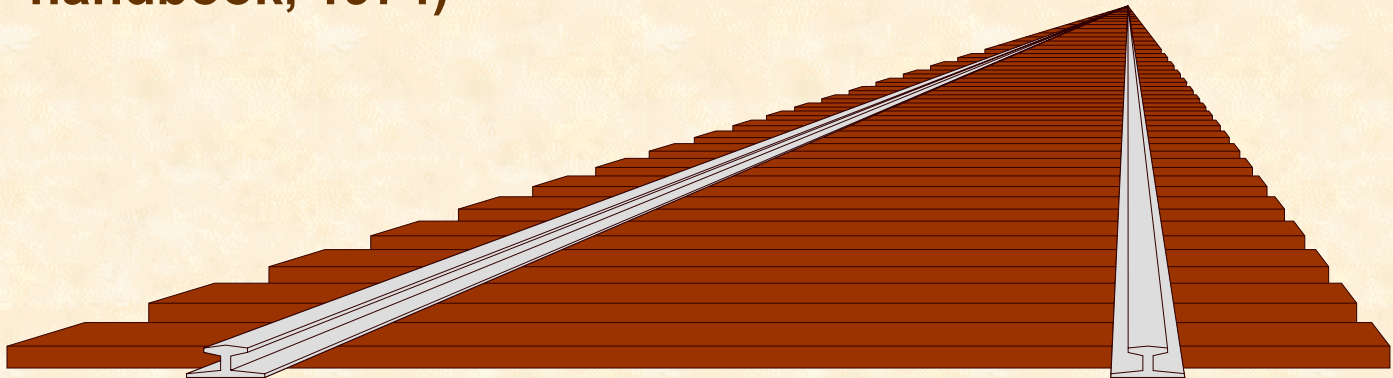
- **Creep – added deflection occurring over time under constant load. It is accelerated by high MC and cycling.**

Mechanical Properties

Factors Affecting Strength

Environmental Factors – *continued*

- **Cyclic loading or Fatigue – failure after repeated cycles of loading and unloading. For example, clear straight grained wood will retain only 60% of its original strength after 2 million cycles. (Ag. Handbook #72 – Wood handbook, 1974)**



Mechanical Properties

Factors Affecting Strength

Environmental Factors – *continued*

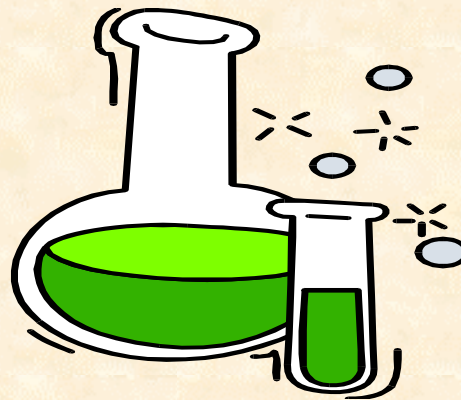
- **Temperature – Wood weakens with increased temperature, especially above 100°C. The damage is accumulative. Wood is generally stronger at lower temperatures.**

Mechanical Properties

Factors Affecting Strength

Environmental Factors – *continued*

- **Chemical exposure – Wood strength decreases with exposure to severe acidic or alkaline environments, but it is more resistant than steel to acidic conditions. Less permeable woods are more resistant.**

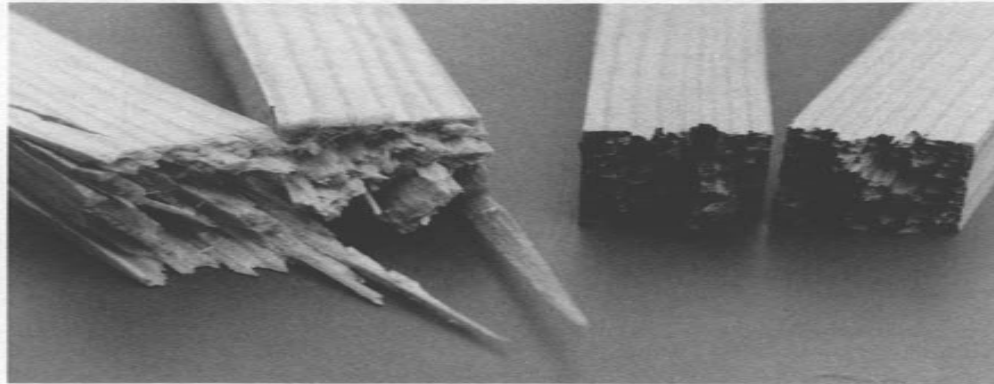


Mechanical Properties

Factors Affecting Strength

Environmental Factors – *continued*

- **Biological activity – Wood strength decreases with only small weight losses due to fungal decay. Impact strength is affected more rapidly than static strength. Failure mode is brash.**



Normal and brash failure of Douglas-fir toughness specimens. The brash character of failure resulted from decay.



Mechanical Properties

Lumber Strength Evaluation

Grading Methods

- There are two methods currently in use for grading lumber and veneer
 - Visual grading
 - MSR – machine stress rating
- Grading of lumber and veneer (plywood) determines the load carrying capacity of the products
- This information is used to design wood structures

What's Next?

- **We have looked at the basic wood science aspect of wood**
- **We have looked at basic physical properties of wood**
- **Next we will look at the products and processes that are made from wood**

The End

