Wood as an Engineering Material

Wood as an Engineering Material

- Engineering characteristics of wood
- Preservatives for wood
- Structural wood products

Environmental Issues and Wood Products

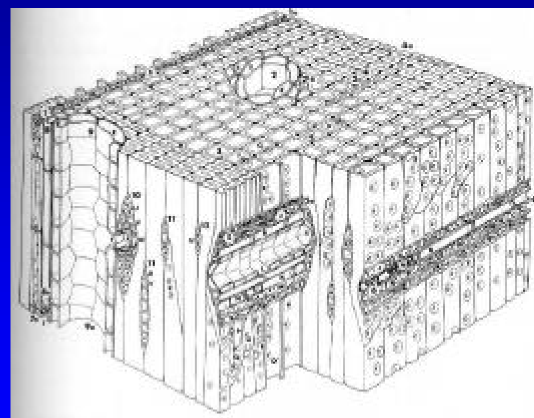
- Wood is a renewable resource
- Wood is reusable, recyclable, biodegradable
- Wood products require far less energy to manufacture than other non-wood building materials
- Growing trees reduce greenhouse gases; wood structures store carbon

Environmental Issues and Wood Products

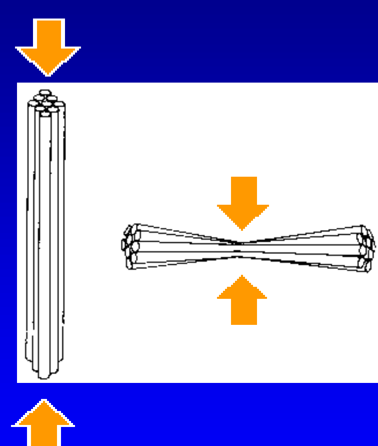
- More wood is grown in the US each year than is harvested, lost to disease, insects, and fire
- Wood growth exceeds harvest by 37% in the US
- The US has more trees today than it did 70 years ago

Basic Structure of Wood

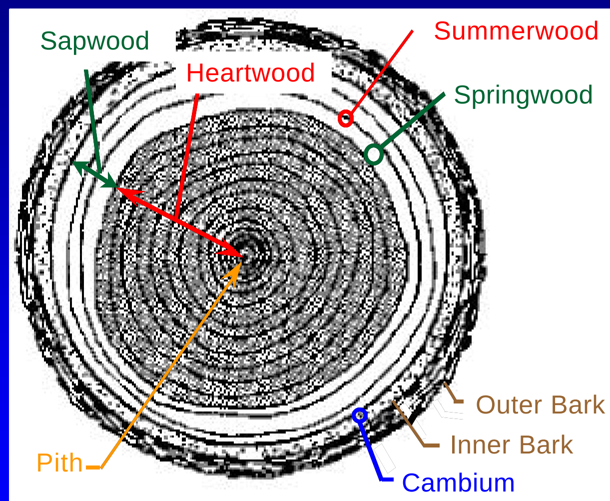
- Wood can be considered a cellular composite material



- Cellular structure gives high strength:weight ratio
- Cellular structure is very strong parallel-to-grain
- Less strength perpendicular-to-grain

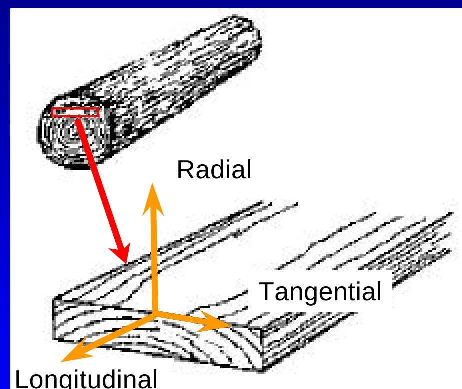


- **Features on the log cross section**



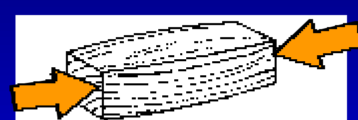
Microscopic View of Wood Cross Section

- 3 Primary axes for wood
- Parallel-to-grain
- Perpendicular-to-grain

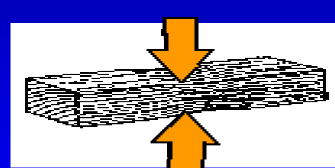


Compression Strength

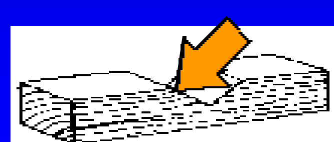
- Compression parallel-to-grain (very strong)



- Compression perpendicular-to-grain (not strong)

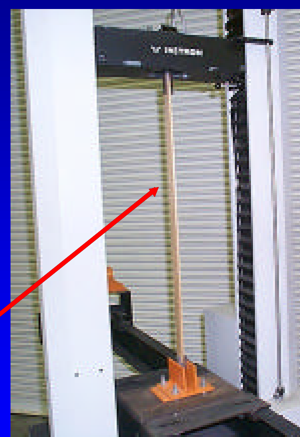


- Compression at an angle to grain



Compression Strength

- Column buckling is frequently a concern in compression member design
- Small test column shown unloaded

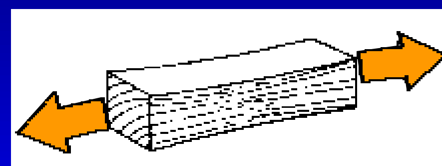


Compression Strength

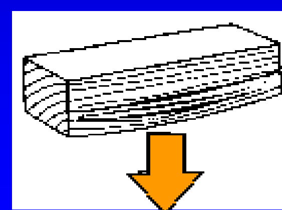
- When load is applied to column (without lateral support), the column buckles

Tension Strength

- Tension parallel-to-grain (very strong)

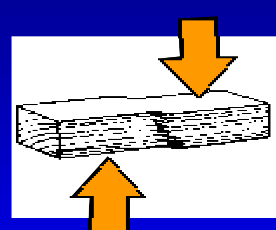


- Tension perpendicular-to-grain (not strong); Design to avoid tension perp.



Shear Strength

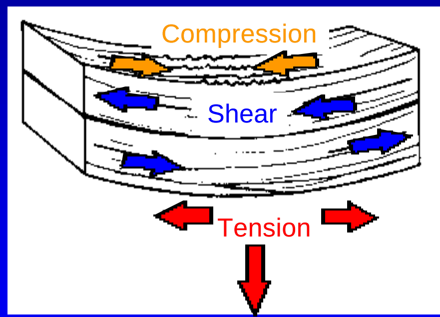
- Vertical shear (perpendicular-to-grain) is very strong



- Horizontal shear (parallel-to-grain) is controlling value; still strong.

Bending Strength

- Bending strength is a function of compression, shear, and tension strengths
- Tension strength typically limits bending strength



Example Test Beam

Sample beam from bending test. The tension face of the beam is shown here at midspan.

Bending failure on tension face of beam

Example Test Beam

Sample beam from bending test. The left side support point is shown here.

Shear failure near support
(shear failures like this are very rare in service and shear rarely governs the design of a beam)

Example Test Beam

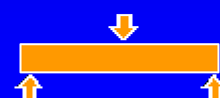
Sample beam from bending test. The load application point is shown here.

Compression (Bearing) Perp-to-Grain failure

Localized Compression Parallel-to-Grain failure (compression wrinkle)

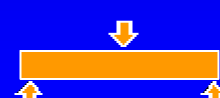
Bending Strength

- Lateral torsional buckling is another concern in bending member design
- Small test beam is shown here - unloaded



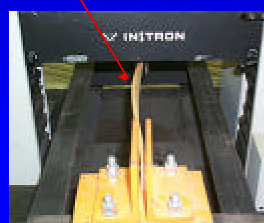
Bending Strength

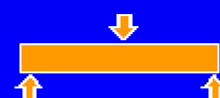
- Test beam after load was applied



Bending Strength

- Lateral torsional buckling occurs on compression edge of beam





Elastic Properties

- Wood is an orthotropic material
- It has different elastic moduli in each of the different axes
- For design, we only consider longitudinal (parallel-to-grain) modulus of elasticity

Factors Affecting the Strength of Wood

- Anatomical factors
- Environmental factors
- Service factors

Anatomical Factors

- Density or Specific Gravity
- Knots
- Slope of Grain
- Size

Density - Specific Gravity

- Strength is correlated with specific gravity
- In general, higher specific gravity means greater strength
- Higher density of growth rings usually means stronger wood
- Higher proportion of summerwood usually means stronger wood

Knots

- Knots produce stress concentrations

Knots

- Grain deviations lead to tension stresses perpendicular-to-grain

Slope of Grain

- As slope of grain increases, the ultimate strength of wood decreases (due to tension perp. stresses)

Size or Volume

- As size, or volume, of a structural component increases, its strength tends to decrease
- This is a statistical phenomenon where the likelihood of some strength reducing characteristic is greater as the volume increases

Environmental Factors

- Moisture
- Biological attack agents
- Temperature
- Fire

Environmental Factors

- Moisture
- Biological attack agents
- Temperature
- Fire
- Ultraviolet light

Moisture

- Moisture is probably the most important environmental factor affecting wood
- Wood is hygroscopic
- Strength and stiffness vary with moisture content

Moisture Terms

- Free Water - water in cell cavities, removed first when wood dries
- Bound Water - water in cell walls
- Fiber Saturation Point
  - about 28-30% moisture content
  - below this point bound water is removed
  - strength increases as MC drops
- Moisture content determined on a dry-basis by handheld meters or by oven tests

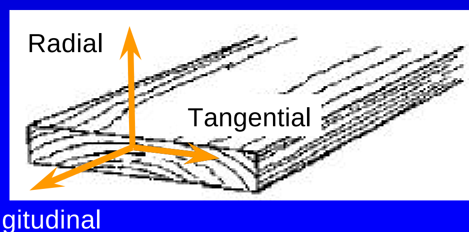
Equilibrium Moisture Content

- Examples of EMC (%) under different conditions

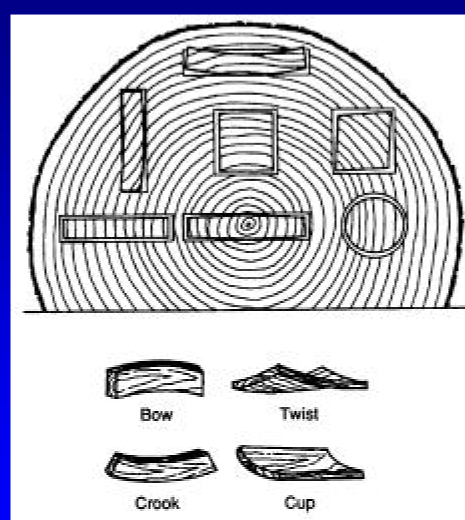
Temperature (dry-bulb)	20% RH	60% RH	98% RH
60F	4.6	11.1	26.8
80F	4.4	10.8	26.3
100F	4.2	10.3	25.6

Moisture Terms

- Shrinkage and swelling occur with changes in moisture content below FSP
- Magnitude of shrinkage
  1. Tangential
  2. Radial
  3. Longitudinal



- Wood shrinkage trends from different locations in the log



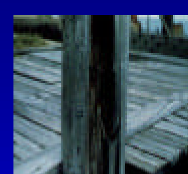
Checking

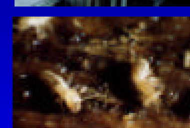
Checking is a result of shrinkage.

It is not usually structurally significant.

Biological Agents

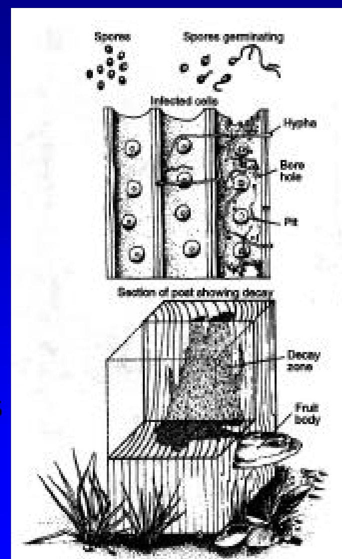
- Decay microorganisms
- Bacteria
- Insects (termites, ants, etc.)
- Marine borers



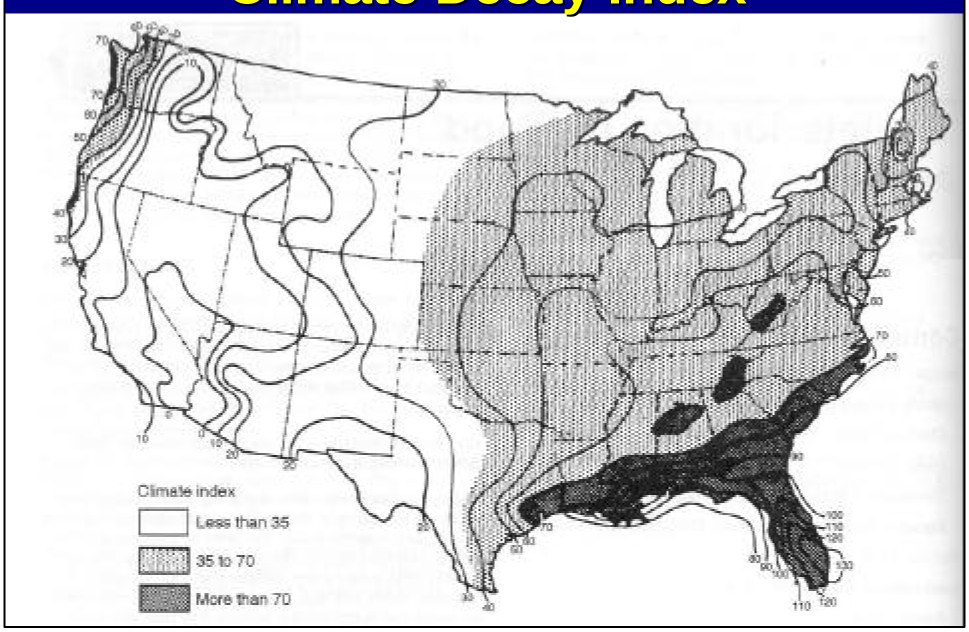


Decay

- **Decay is the breakdown of wood by microorganisms**
- **Decay fungi must have:**
  - **moisture**
  - **oxygen**
  - **temperatures above 50ºF**
  - **food (wood)**
- **Most decay usually occurs when moisture content is above FSP**



Climate Decay Index

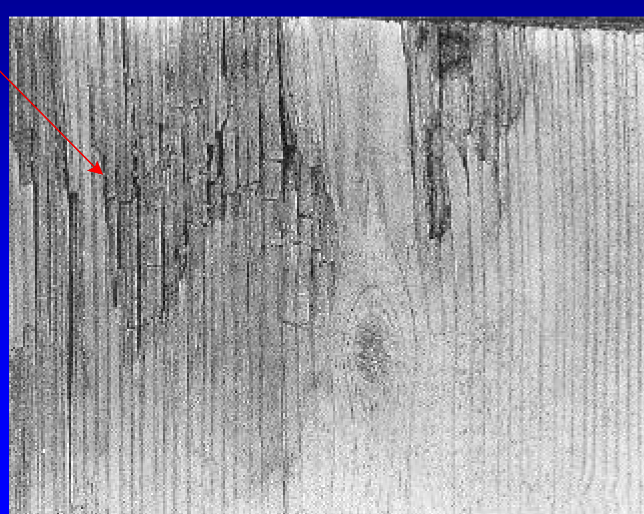


Decay Fungi

- Fungi inhabiting wood:
  - molds
  - stainers
  - soft-rot fungi (visible with microscope)
  - wood rotting basidiomycetes (toadstools, etc.)
    - white rot
    - brown rot
- Once decay starts, the fungi can produce water

Decay Fungi

Brown
Rot
Fungi



Insects - Termites

- Live in castes (workers, royalty)
- Dampwood termites:
  - live in wet, decaying wood
  - not usually significant
- Subterranean termites
  - cause majority of damage
  - usually require connection to moist soil (sometimes through shelter tubes)

Termites

- Subterranean termites
  - Formosan termites are growing concern
- Drywood termites
  - attack dry wood
  - can move by flying

Insects

- Carpenter Ants
  - excavate wood for nests
  - do not eat the wood
- Wood boring beetles:
  - grubs do most of the damage

Marine Borers

- Live in salt and brackish water and damage piers, pilings, etc.
- Molluscs bore into wood
  - shipworms (Teredo, Bankia)
  - pholads (clam-like) (Martesia, Xylophaga)
  - both live in the wood and are not readily visible

Marine Borers

- Crustaceans attack the surface of the wood
  - related to shrimp and lobsters
  - Limnoria, Chelura, Sphaeroma

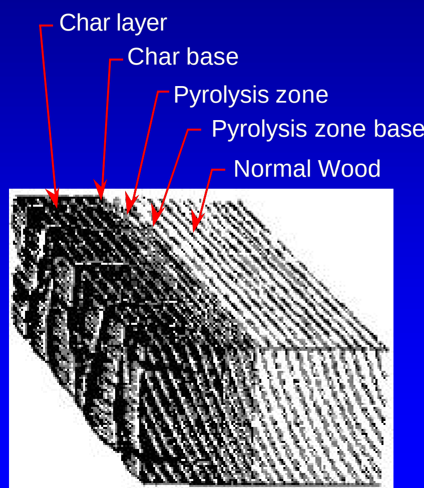
- Protection from marine borers is best provided by chemical treatment
  - creosote is usually recommended
  - high hazard areas call for dual treatment (copper-arsenate solutions and creosote)

Temperature

- Wood strength can be affected by high temperatures
- We are usually only concerned with long-term exposure to high temperatures (some industrial applications)
- Typical residential roof systems are not a concern

Fire Performance

- Wood resists fire well.
- Heavy timbers develop char layer that insulates remainder of cross section



Fire Performance

From "Restrained vs. Unrestrained: Myths and Realities"

by

Scott Melnick

***in* Structure, June 2001**

As a result of confusing changes to the Underwriters Laboratories (UL) Fire Resistance Directory and various U.S. model building codes, many engineers are over-specifying fire protection for steel framed buildings, according to a new report by Richard Gewain of Hughes Associates, Inc., and Emile W.J. Troup, a consultant and structural engineer based in New England. In many cases the over-specification results in a 25-50% addition in fire protection, which adds as much as $0.25/sq. ft. to the cost of construction. These numbers become especially troubling in light of actual fire performance. According to Gewain and Troup's review of fire data, there is no evidence of any life safety problems due to structural failure during a fire in a modern steel-framed building in the U.S.

Fire test aftermath

Glulam beam removed from structure after fire

Service Factors

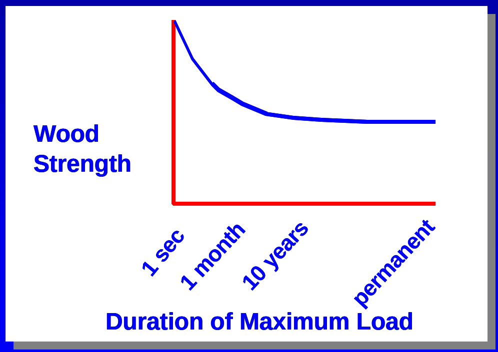
- Duration of Load
- Creep

Duration of Load

- Wood strength is time dependant
- Wood can sustain very high loads for short time periods
- Wood resists impact loads very well
- Wood can support lower loads if applied permanently

Duration of Load

- For design purposes, we adjust the design strengths of wood depending on the duration of the maximum load.



Creep

- Wood is a viscoelastic material and it experiences creep
- Creep is a continued increase in deformation under sustained load
- Under long-term loading, creep deflection is permanent

Creep

- High moisture conditions amplify creep
- To counteract creep, we can:
  - specify camber in some products
  - design to more restrictive deflection limitations