Upcoming Workshops

Wood Industry Week @ WERC '14

March 11 - 13, 2014

To be held at the Wood Education and Resource Center, Princeton WV.
For more information on this 3-day workshop, please see here or contact Urs Buehlmann.

For other information on the USDA FS’ Wood Education and Resource Center:
http://www.na.fs.fed.us/werc/events.shtml
Phone: (304) 487-1510

Why you should attend

- To get an update on techniques to improve your operation
- To learn about new trends and opportunities in the industry
- To learn from experts and colleagues
- To learn about customer expectations, global implications and the future
- To network and to benefit from five days of learning, discussing, and observing with experts

Past Workshops

Wood Industry Week @ WERC '12
Wood Technology 101

Wood anatomy & structure
Natural Variability
  Within-species
  Between-species
Wood and water relations
Wood: Basic Anatomy & Structure
Wood - It Does Grow on Trees

The sun provides energy used to combine carbon dioxide gas (from the air) with water (from the soil).

\[ \text{CO}_2 + \text{H}_2\text{O} = \text{glucose (sugar)} \]

Glucose units are linked together in very long chains to form cellulose.

Cellulose is the primary component of wood fibers.
Why do trees make wood?

1. Mechanical support
2. “Plumbing”
Microfibril arrangement within individual cell walls:

Arrangement of cells:

End-grain at low magnification

Source: Identifying Wood: Accurate Results with Simple Tools, R. Bruce Hoadley
Textbook of Wood Technology, A.J. Panshin and C. de Zeeuw
Rays

- Lateral movement of fluids & storage
- Parenchyma cells
- Zone of weakness
Rays

- End grain

- Edge/side grain

Ray cells
Natural Variability of Wood
Variability Within Species

- Genetic (e.g., variety)
  - *Populus deltoides* var. *deltoides* (eastern cottonwood)
  - *Populus deltoides* var. *occidentalis* (plains cottonwood)

- Site variables:
  - Soil
  - Climate, Aspect (N or S), Latitude, Elevation, Topography
  - Stand characteristics (development, history)

- Grain orientation, earlywood/latewood, heartwood/sapwood, juvenile wood/mature wood, reaction wood
Grain Orientation

The 3 faces of wood
Earlywood/ Latewood

EW = earlywood (springwood)
LW = latewood (summerwood)

Earlywood – Latewood Morphology
Softwood Tracheids

Jozsa and Middleton “A discussion of wood quality attributes and their practical implications”. Special publication. No. SP 34. FORINTEK Canada Corp.
Sapwood vs. Heartwood:

- **Sapwood**
  - Active sap conduction
  - Reserve food storage in parenchyma cells
  - Moisture content higher than heartwood (softwoods)
  - Low decay-resistance

- **Heartwood**
  - No sap conduction
  - All cells dead
  - Low permeability (Difficult to dry, treat, etc.)
  - Often contains juvenile wood
  - Presence of extractives (coloration and decay-resistance in some species)
Moisture Differences Between Heartwood & Sapwood

- **softwoods**: heartwood moisture content generally lower than sapwood
- **hardwoods**: a ‘mixed bag’

### Average Moisture Content of Green Wood (%)

<table>
<thead>
<tr>
<th>Species</th>
<th>Heartwood</th>
<th>Sapwood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Douglas-fir (coastal)</td>
<td>37</td>
<td>115</td>
</tr>
<tr>
<td>ponderosa pine</td>
<td>40</td>
<td>148</td>
</tr>
<tr>
<td>western redcedar</td>
<td>58</td>
<td>249</td>
</tr>
<tr>
<td>red oak</td>
<td>80</td>
<td>69</td>
</tr>
<tr>
<td>sugar maple</td>
<td>65</td>
<td>72</td>
</tr>
<tr>
<td>black walnut</td>
<td>90</td>
<td>73</td>
</tr>
</tbody>
</table>
Juvenile Wood:
Juvenile Wood:

- “atypical wood formed around the pith during the first few years of growth.”
  source: Identifying Wood by R. Bruce Hoadley

- The amount of juvenile wood present is related to the age of the cambium, not the distance from the pith. The usual duration is between 5 and 20 years.
Characteristics of Juvenile Wood:

- higher microfibril angle
- larger longitudinal dimensional change
- shorter cells
- higher lignin and lower cellulose contents
Jozsa and Middleton "A discussion of wood quality attributes and their practical implications". Special publication. No. SP 34. FORINTEK Canada Corp.
Shrink/Swell:

Drying
Western juniper paneling:
1/4" juniper face, 5/32" juniper back and luan core
Face is all heartwood, back is mostly sapwood

Warp due to unbalanced construction - face is thicker and shrinks more in length than back
Reaction Wood:

- **Compression Wood** in Softwoods
  - forms “beneath the lean”
  - forms in both earlywood and latewood

- **Tension Wood** in Hardwoods
  - forms “above the lean”
  - in many woods forms in earlywood only (both ew & lw in some evergreen hardwoods)
Compression Wood (Softwoods)
Characteristics of Tension Wood:

- Much more variability between species than for compression wood
- Often more difficult to detect than compression wood
- "Gelatinous" layer found in fiber lumens
- Higher microfibrillar angle = greater longitudinal shrinkage
Characteristics of Tension Wood

- Fuzzy appearance due to fibers tearing loose during machining
- Staining produces blotchy patches
- Lower strength in tension both parallel and perpendicular to the grain
- Increased occurrence of collapse during drying
- Higher equilibrium moisture content
- Longer fibers (shorter opposite the lean)
- 40-50% more cellulose, less lignin (as % of total)
Fuzzy Grain

Tension wood can be a problem if the piece is remanufactured.

Source: Forest Products and Wood Science by John Haygreen and Jim Boyer
Variation Between Species

Softwoods and Hardwoods
Softwoods and Hardwoods

- Softwoods (conifers, evergreens)
  - *Gymnosperms* – “naked seed”
  - Spruce, fir, cedar, pine, hemlock, larch
  - Simple structure
  - No vessels (pores)

- Hardwoods (broadleaves, deciduous)
  - *Angiosperms* – seed contained in ovary
  - Oak, maple, birch, poplars (aspen, cottonwood), alder, myrtle, walnut, cherry, hickory, ash, etc.
  - More complex structure
  - Vessels (pores)
Cell Types in Softwoods:

- **Longitudinal**
  - Tracheids
  - Parenchyma

- **Transverse**
  - Parenchyma
  - Ray tracheids (pine family)
Eastern white pine in 3-D view, magnified 150x
Cell Types in Hardwoods:

- **Longitudinal**
  - Vessel elements
  - Tracheids
    - vascular
    - vasicentric
  - Fibers
    - fiber tracheids
    - libriform fibers
  - Axial parenchyma
    - strand
    - fusiform

- **Transverse**
  - Ray parenchyma
    - homocellular
    - heterocellular

- Vessel element

- Procumbent

- Upright
Sweetgum in 3-D view, magnified 350x
Hardwoods
Hardwoods – Gross characteristics

- Pore distribution/ Arr. of latewood vessels
  - Ring-porous
    - earlywood pores large, in distinct row
  - Diffuse-porous
    - all pores about same size
  - Semi-ring-porous
    - pore size gradation, earlywood pores not in distinct row

- Inclusions in vessels (tyloses)

- Color

- Rays - size & distribution
Pore distribution

- Ring-porous
- Semi-ring-porous
- Diffuse-porous

white ash  black walnut  yellow birch
Ring-porous hardwoods

- Chestnut and oak
  - Latewood pores in radial rows or flare out
- Elm and hackberry
  - Latewood pores wavy tangential rows (uniformly through latewood)
- Hickory and pecan
  - Latewood pores solitary or compact radial lines
- Confusing ring-porous woods
  - Ash, sassafras, catalpa, mulberry, black locust, Osage-orange, sumac
northern red oak

American elm

shagbark hickory

white ash
Red vs. white oak

northern red oak  white oak
Semi-ring-porous hardwoods

- Live oak and tanoak
  - Wood very heavy, large rays
- Persimmon
  - Wood very heavy, small rays
- Walnut and butternut
  - Dark brown to cinnamon brown wood, fine rays
tanoak

black walnut
Diffuse-porous hardwoods

- Beech and sycamore
  - Large rays (visible on all surfaces), growth rings distinct

- Hornbeam and alder
  - Large aggregate rays (widely scattered “streaks”)

- Confusing diffuse-porous woods
  - Maples, dogwood, holly, cherry, yellow-poplar, basswood, birch, myrtle, willow, poplars, buckeye, sweetgum, tupelo
American beech

red alder
sugar (hard) maple  
black cherry  
eastern cottonwood
Drying Defects

Wood-moisture relations
Moisture Issues:

- What causes warping, splitting, collapse, honeycomb, and what is “casehardening?”
Wood holds water 2 ways:

- **Free water** – water and water vapor in the cell lumens and adhering to the cell wall (like water in a bucket or glass)

- **Bound water** – water ‘chemically’ held within the cell walls.
Adsorption of colored water in hybrid poplar - end grain & edge grain
Fiber Saturation Point (FSP)

“That moisture content at which the cell wall is completely saturated with water, but no moisture is present in the cell lumen.”
Loss & Gain of Water

- Beginning at the green state:
  - Free water is lost first until wood reaches FSP (30% is a rough value for many species).
  - Below FSP is when shrinkage will begin, loss of water between microfibrils in the cell walls allows for “less space” between them.
Shrink/Swell:
Equilibrium Moisture Content (EMC):

“The moisture content eventually attained in wood exposed to a given level of relative humidity and temperature”.

*Understanding Wood: A craftsman’s guide to wood technology, R. Bruce Hoadley*

<table>
<thead>
<tr>
<th>Temp. (°F)</th>
<th>30%</th>
<th>60%</th>
<th>90%</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>6.3%</td>
<td>11.2%</td>
<td>20.9%</td>
</tr>
<tr>
<td>80</td>
<td>6.1%</td>
<td>10.8%</td>
<td>20.2%</td>
</tr>
<tr>
<td>110</td>
<td>5.6%</td>
<td>10.0%</td>
<td>19.1%</td>
</tr>
</tbody>
</table>
“How much” the piece moves depends on:

- species-
- density (cell wall thickness, i.e., how much “stuff” is there to move)
- extractives
- previous moisture history
- size of the piece
- magnitude of moisture content change
- degree of restraint

incense-cedar
n. red oak

(75x) (75x)
## Dimensional Change in Wood

<table>
<thead>
<tr>
<th>Species</th>
<th>INITIAL CONDITIONS</th>
<th>FINAL CONDITIONS</th>
<th>Change in MC</th>
<th>Metric (mm)</th>
<th>Grain Orientation</th>
<th>Approximate Dimensional Change in</th>
<th>Final Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MC (%)</td>
<td>Temp</td>
<td>RH (%)</td>
<td></td>
<td>Thickness</td>
<td>Width</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Douglas-fir, interior north</td>
<td>19</td>
<td>72</td>
<td>45</td>
<td>10.565</td>
<td>0.75</td>
<td>5.5</td>
<td>0.01 in 0.137 in</td>
</tr>
<tr>
<td>2 larch, western</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 fir, grand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Flatsawn includes plainsawn, rotary peeled, or plain-sliced. Quartersawn includes edge-grained, vertical grained, or quarter-sliced. Mixed grain includes bastard sawn lumber. The calculated shrink/swell is the average of quartersawn and flatsawn.

**EMC = Equilibrium Moisture Content**

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![flatsawn, plainsawn](image1)

[quatersawn, edge-grained vertical-grained (VG)](image2)

[bastard sawn](image3)
Shrinkage - Warp

- Bow
- Crook
- Twist
- Cup
- Diamonding

crook
Drying Stresses

- Moisture movement is approximately 10-15 times faster from the end-grain than from the edge-grain.
- The outer shell dries faster than the core.
End Checking:

- Occurs in early stages of drying (\(\sim>24\%\) MC)
- Usually occur in rays
- Caused by stresses developed due to rapid moisture loss through board ends
- Wetting after formation drives checks further into board
- Can be minimized by using high initial RH, **end coating** (very soon after felling), or end-stickering
Collapse:

- A distortion, flattening, or crushing of wood cells
- Caused by:
  - compressive drying stresses
  - liquid tension (capillary pressure)
- Occurs early in drying (visible later)
- Can be minimized by using lower initial dry-bulb temperatures, partial air-drying
- Reconditioning may “cure” (212° F, 100% RH)
Casehardening:

“A condition of stress and set in wood in which the outer fibers are under compressive stress and the inner fibers under tensile stress, the stresses persisting when the wood is uniformly dry.”

Source: Dry Kiln Operator’s Manual
Casehardening

- Dry-Shell - Tension
- Wet Core - Compression
- Dry Shell - Compression
- Dry Core - Tension
Testing for Casehardening

Source: Dry Kiln Operator’s Manual
Drying stresses must be relieved if lumber will be remanufactured.

Stresses are relieved by conditioning during drying.
Honeycomb (a.k.a. internal checking)

From: Understanding Wood by Bruce Hoadley
Honeycomb does not appear on the surface of a planed red oak board (lower) but does appear after the board is machined into millwork (upper).
Acknowledgements