Potential and limitations of using hardwood lumber as raw material for CLT.

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Agenda

• Markets for wood products
• CLT production process
• Research on hardwood CLT
• Challenges and drivers for hardwoods CLT
• Final thoughts
Markets for wood products

- **Logs**
  - Softwood
    - Strength-graded lumber
    - Industrial lumber
    - Engineered wood
    - Animal bedding
  - Hardwood
    - Industrial lumber
    - Appearance-graded lumber
    - Engineered wood
    - Animal bedding
  - Engineered mills
    - Structural panels: plywood and OSB
    - Non-structural panels: decorative plywood, MDF, HDF, particleboard, hardboard
    - Engineered wood: LVL, PLV, SVL, CLT, Glue-lams
    - Appearance lumber: furniture, kitchen cabinets, millwork, musical instruments, crafts.
    - Industrial lumber: pallets, cranes, railroad ties, crane mats, mining products, rails
    - Food industry: wine and whiskey barrels, food additives
    - Structural panels: plywood and OSB
    - Non-structural panels: decorative plywood, MDF, HDF, particleboard, hardboard
    - Engineered wood: LVL, PLV, SVL, CLT, Glue-lams
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- **Mills**
  - Bark, sawdust, woodchips
  - Decorative panels
    - Bark and wood chips
  - Round wood processing
    - Sawdust, bark, and woodchips
    - Utility poles, log cabins, fencing
  - Paper Mills
    - Paper products
    - Black liquor, bark
  - Engineered Panels
    - Structural panels
    - Non-structural panels
    - Bark, sawdust
  - Bioenergy
    - Firewood, pellets, briquettes, advanced liquid fuels
    - Bark, sawdust, black liquor

*By Henry Quesada ® 2018*
Markets for wood products

- Impacts on energy and global warming potential is 16% and 31% less when using timber instead of concrete.
- Energy and global warming potential is 17% and 26% less when using timber than steel.

http://www.themostnaturalresource.com/green-building/
Cross-laminated timber (CLT)

- ANSI/APA PRG 320-2012: A prefabricated solid engineered wood panel made of at least three orthogonally bonded layers of solid-sawn lumber or structural composite lumber (SCL) that are laminated by gluing of longitudinal and transverse layers with structural adhesives to form a solid rectangular-shaped, straight, and plane timber intended for roof, floor, or wall applications.
Example of CLT line (Ledinek):
- 50 m³/shift
- 1100 KW required power,
- Up to 14m x 3.2m x 0.4m panel size
### CLT Production Process

- Capital cost for a 30,000 m³ CLT plant (millions of US dollars)*

<table>
<thead>
<tr>
<th>Process system</th>
<th>Total Direct Cost</th>
<th>Indirect Cost</th>
<th>Total Capital Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>$9.8</td>
<td>$5.3</td>
<td>$15.2</td>
</tr>
<tr>
<td>Automated</td>
<td>$11.6</td>
<td>$6.2</td>
<td>$17.9</td>
</tr>
</tbody>
</table>

*Evergreen Engineering. IWF 2016.*
CLT market potential

• Demand in the US by 2020 is estimated in 300,000 m³*
  – 1 m³=424 bf

• Current manufacturing capacity is less than 34,000 m³
  – Current producers
    • DR Johnson (4,555 m³) and SmartLam (29,000 m³)
  – New plants announced:
    • International Beans: Dothan, AL. Announced in Jan. 2017
      – 227k ft² facility. $20 million investment
      – Raw material is SYP
    • Katerra: Spokane, WA
      – 250k ft²

• European CLT producers average 50,000 m³ per year

*Evergreen Engineering. IWF 2016.
CLT standards in the US

• PRG-320 revision, last modified in 2017*
  – Accept any softwood recognized by ALSC
    • Most hardwood have design values in NDS
  – Species with SG>=0.35
    • Most hardwoods have SG>= 35
    • Selected hardwoods have higher mechanical properties than softwoods
  – Grades #2&better for parallel and #3&better for perpendicular layers
    • YP 2COM and lower could make up #2&better in
  – MC, 12+-3%
    • Most hardwoods dried to low moisture content (~8%)
  – Dimensions
    • Thickness of layers: 5/8”<thickness<2”
    • Parallel layers w>=1.75 x thickness (strong axis): Exclude 2x2,2x3 dimension sizes
    • Perpendicular layers w>=3.5 x thickness (weak axis): Exclude 1x2, 1x3, 2x2, and 2x4 dimension sizes
      – Hardwoods are commonly sawn to 4/4” thickness
      – Hardwood lumber is sold in random widths
  – Adhesion
    • Higher capacity press is needed for hardwood (stronger and stiffer)
    • Higher density could cause more stresses in the bold line due to higher dimensional changes from MC variations
    • Extractives in hardwood could interfere with gluing (acidity may change)
  – Revised every 5 years
    • Quesada is a voting member of the PRG-320 technical Committee
    • Need to produce more hardwood data
      – Stiffness, bending, acoustic, fire, delamination, etc.

Research on hardwood CLT at VT

- Yellow Poplar CLT mechanical properties*
  - 6/4 #2 Common Yellow poplar
  - 3 ply panels, use PF as glue

<table>
<thead>
<tr>
<th>Mechanical Property, Yellow Poplar CLTs</th>
<th>% Difference With Southern Pine CLTs</th>
<th>% Difference with Grade V1 CLTs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending Strength, $F_b S$</td>
<td>20.4%</td>
<td>61.9%</td>
</tr>
<tr>
<td>Bending Stiffness, $E I$</td>
<td>41.3%</td>
<td>29.4%</td>
</tr>
</tbody>
</table>

- Bending stiffness and strength and resistance to delamination exceeded required values in PRG-320
- Strong and durable adhesive bonds

Research on hardwood CLT at VT

- Cost considerations
  - Lumber prices for YP and SYP (as Oct. 2017)
  - Production mix as an alternative

<table>
<thead>
<tr>
<th>Lumber grades</th>
<th>NHLA prices ($/bf)</th>
<th>SPIB prices ($/bf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>1.03</td>
<td>0.66</td>
</tr>
<tr>
<td>Lumber grades</td>
<td>#1</td>
<td>#2</td>
</tr>
<tr>
<td>Price</td>
<td>0.45</td>
<td>0.42</td>
</tr>
</tbody>
</table>
Research on hardwood CLT at VT

  - Simulation of mixed-production
    - For all logs a sawing pattern was as follows: the outer boards for each log were cut to 4/4” thickness and the inner boards were cut to 6/4” thickness.

<table>
<thead>
<tr>
<th>Log group</th>
<th>N</th>
<th>Dia (in)</th>
<th>Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>9</td>
<td>12</td>
<td>NHLA+SPIB and NHLA</td>
</tr>
<tr>
<td>Pink</td>
<td>7</td>
<td>13</td>
<td>NHLA+SPIB, and NHLA</td>
</tr>
<tr>
<td>White</td>
<td>5</td>
<td>14</td>
<td>NHLA+SPIB, and NHLA</td>
</tr>
<tr>
<td>Orange</td>
<td>10</td>
<td>12</td>
<td>NHLA</td>
</tr>
<tr>
<td>Blue</td>
<td>8</td>
<td>13</td>
<td>NHLA</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Revenue Comparison

- NHLA
- NHLA+SPIB
- Control

<table>
<thead>
<tr>
<th>Dia 12 (NHLA)</th>
<th>Dia 13 (NHLA+SPIB)</th>
<th>Dia 14 (Control)</th>
<th>Log description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$45.08</td>
<td>$57.88</td>
<td>$67.50</td>
<td>Dia 12</td>
</tr>
<tr>
<td>$44.98</td>
<td>$58.33</td>
<td>$65.52</td>
<td>Dia 13</td>
</tr>
<tr>
<td>$48.71</td>
<td>$55.68</td>
<td></td>
<td>Dia 14</td>
</tr>
</tbody>
</table>
Research on hardwood CLT at VT

- What were the barriers that impacted the initial production and commercialization of CLT systems in Western European companies?
- What are the more significant drivers and challenges for the commercialization of CLT systems?

Methods:
- Interviews and tours of top three CLT producers in Western Europe
- Interviews of CLT suppliers at the 2017 Ligna tradeshow in Germany.

<table>
<thead>
<tr>
<th>Demographic aspect</th>
<th>Company 1</th>
<th>Company 2</th>
<th>Company 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLT production capacity</td>
<td>65-75 thousand m$^3$/year</td>
<td>65-80 thousand m$^3$/year</td>
<td>95 thousand m$^3$/year</td>
</tr>
<tr>
<td>Species</td>
<td>Spruce and Fir</td>
<td>Spruce</td>
<td>Spruce</td>
</tr>
<tr>
<td>Markets</td>
<td>Europe, Australia and the USA</td>
<td>Global</td>
<td>Austria, Germany, France, UK, Italy, Sweden, Norway and the USA</td>
</tr>
<tr>
<td>Number of employees</td>
<td>50</td>
<td>40</td>
<td>175</td>
</tr>
<tr>
<td>Time producing CLT systems</td>
<td>Since 2008</td>
<td>Since 2012</td>
<td>Since 1999</td>
</tr>
<tr>
<td>Produced products before CLT</td>
<td>Lumber and engineered wood products</td>
<td>Lumber and glulams</td>
<td>None. First product</td>
</tr>
</tbody>
</table>

*Softwood Export Council (SEC) grant
Challenges to start out CLT production

Manufacturers’ perspective:

- Production setup
- Raw Materials supply
- Vertical integration
- Lack of CLT markets
- CLT code acceptance
- CLT knowledge

Profits vs. Success
Drivers to start-up CLT production

Financial
- Revenue
- Profits
- Return of investment

Collaborations
- Industry and University
- Innovation

Product uniqueness
- Customization
- New product
- Renewable material

Infrastructure
- Transportation network
- Current manufacturing

Integration
- Architects
- Engineers
- CLT production

Raw material
- Quality
- Consistency
- Closeness

Technical support
- Education
- Technical specifications
- Post-sale

Pioneering
- Innovation
- First in the market

Verticallity
- Sawmill
- Glulam
- CLT production
Commercialization Barriers of CLTs

Successful commercialization!

1. Building regulations
   - Building codes
2. Fireproof acceptance
   - Fireproof engineers in Europe still question CLT
3. Shipping and logistics
   - Outside Europe
   - Container shipping is limited
4. Current production capacity
   - No relevant mfg capacity in the USA
   - European capacity is booked for 8 months
5. CLT advantages not known
   - Engineers
   - Architects
   - General public
   - Government
6. Comm. from/to architects
7. Need policy for CLT
   - Use of CLT in public buildings
8. Design to manufacturing flow of information needs to be improved
Final thoughts

• Barriers and challenges impacting the success of CLT manufacturing and commercialization
• Acknowledgements
  – Omar Espinoza, UM
  – Dan Hindman, VT
  – Bob Smith, VT
  – USDA/Wood Innovation grants
  – Sothern Export Council
  – USDA/NIFA