Cross Laminated Timber Manufacturing, Use, and Research: Progress in Low Grade Appalachian Hardwoods

David B. DeVallance
Associate Professor

Joseph F. McNeel
Professor & Director

Rafael Azambuja
Ph.D. Candidate

Curt Hassler
Visiting Researcher

Wood Science and Technology Program
and the
Appalachian Hardwood Center
Division of Forestry and Natural Resources
West Virginia University
Outline

Research & Demonstration Update

Commercial Development – Hardwoods?

- HWD CLT Disadvantages
- HWD CLT Advantages
- Advancing HWD CLT Potential
INTRODUCTION

Cross Laminated Timber

- Utilization of **local species** will grant sustainability to the region and consequently establish CLT panels worldwide (1).

- The Appalachian Region has a positive growth/harvest ratio of **2.45**, increasing 300,000 acres in the last 25 years (2). A diverse region with over 50 trees species, which more than **20 species** can be used commercially (3).

References:


Cross Laminated Timber – Board specifications

- **Species restriction**
  - *Hardwoods are not specified in current PRG 320 standard* *

- **Boards dimensions, width, thickness, length**
  - Major direction – width not less than 1.75x thickness
  - Minor direction – width not less than 3.5x thickness
  - Thickness not less than 5/8 inch (16mm) or more than 2 inches (51mm)
Cross Laminated Timber – Board specifications

- **Visual grade**
  - Major direction - #2 (Structural grading, e.g. NeLMA)
  - Minor direction - #3 (Structural grading, e.g. NeLMA)

- **MSR grade** (PRG 320, C16, and C24)

<table>
<thead>
<tr>
<th></th>
<th>PRG 320</th>
<th>C16</th>
<th>C24</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specific Gravity</strong></td>
<td>0.35</td>
<td>0.31</td>
<td>0.35</td>
</tr>
<tr>
<td><strong>MOE mean</strong></td>
<td></td>
<td>1.276 x 10^6 psi (8,800 MPa)</td>
<td>1.566 x 10^6 psi (10,800 MPa)</td>
</tr>
<tr>
<td><strong>MOE min</strong></td>
<td><strong>1.2 x 10^6 psi</strong> (8,273 MPa)</td>
<td>0.841 x 10^6 psi (5,800 MPa)</td>
<td>1.044 x 10^6 psi (7,200 MPa)</td>
</tr>
</tbody>
</table>
INTRODUCTION

Global production of CLT, 1990-2015

- Note: f = forecast.
- Source: Institute of Timber Engineering and Wood Technology, Graz

Source: Institute of Timber Engineering and Wood Technology, Graz

Nabholz: Constructing the Largest Cross-laminated Timber project in United States

https://www.nabholz.com/cross-laminated-timber-project-america-nabholz/
Outline

Research Update

Commercial & Development – Hardwoods?

• HWD CLT Disadvantages
• HWD CLT Advantages
• Advancing HWD CLT Potential
Recent CLT Efforts at WVU

2012: Development of Low-Grade Hardwood Cross-Laminated Timbers
(USDA/NIFA: Led by Virginia Tech, WVU – Adhesion) – Dr. DeVallance & Daniel Hovanec

2014: Demand and Product Innovations for Green Products Sourced from Appalachian Hardwoods (USDA FS - WERC) - Dr. DeVallance & Rafael Azambuja

2014: Evaluating low-grade, mixed Appalachian hardwoods for mechanical and adhesive properties required to produce CLT panels (WVU Hardwood Research Trust) – Dr. DeVallance & Rafael Azambuja

2017: Producing CLT Panels from Low Value Appalachian Hardwoods, Part 1
(USDA FS - WERC) – Drs. McNeel, Hassler, and DeVallance

2018: Producing CLT Panels from Low Value Appalachian Hardwoods, Part 2
(Funded - USDA FS - WERC) – Drs. DeVallance, Hassler, and McNeel
General Objectives

• Determine which species from the Appalachian region have the most potential to be used in production of CLT panels (on-going)

• From these species determine the available dimension and grade of the boards to be used in CLTs production (on-going)

• Determine the structural lumber grade within low-grade hardwoods that can be effectively used in manufacturing CLT (on-going)

• Evaluate optimized CLT panel lay-up from low-grade lumber (on-going)

• Demonstrate hardwood CLT production technology (planned)

• Demonstrate hardwood CLT use (planned)
Yellow-poplar and maple are species of interest based on preliminary research.

**Percentage of species**
- **Others**: 6%
- **Cherry**: 9%
- **White Oak**: 11%
- **Mix Maple**: 15%
- **Red Oak**: 22%
- **Yellow Poplar**: 37%

**Yellow poplar Grades**
- **FAS**: 16%
- **Sel**: 25%
- **1 Com**: 22%
- **2 Com**: 3%
- **Pallet**: 33%

**Mix maple Grades**
- **FAS**: 21%
- **Sel**: 22%
- **1 Com**: 18%
- **2 Com**: 12%
- **Flr**: 3%
- **Pallet**: 24%
RESEARCH EFFORTS: Length and Width Category

**Soft Maple – Length (%)**
- 6' - 10': 35%
- 6' - 8': 21%
- 9' - 10': 9%
- 11' - 12': 5%
- 13' - 14': 8%
- 15' - 16': 23%

**Soft Maple – Width (%)**
- 3-6": 9%
- 7-7.25": 29%
- 8-20": 62%

**Yellow poplar - Length (%)**
- 6' - 8': 24%
- 9' - 10': 10%
- 12': 8%
- 13' 14': 29%
- 16': 29%

**Yellow Poplar - Width (%)**
- 3-7.25": 11%
- 8": 47%
- 9-20": 42%
Vibration and Machine Stress Rating (MSR)

- NHLA grades are not structural grades
- Yellow-poplar and Red maple #2 Common NHLA graded boards were evaluated for structural property distribution
- Modulus of Elasticity (MOE) was evaluated using transverse vibration and MSR Proof loading

RESEARCH EFFORTS: Phase 1: Structural Grades
RESEARCH EFFORTS: Phase 1: Structural Grades

Proof Load MOE

**YP - PL**

- $R^2 = 0.9262$

**RM - PL**

- $R^2 = 0.9675$

### MOE (10^6 psi)

<table>
<thead>
<tr>
<th></th>
<th>YP - PL</th>
<th>RM - PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1.71</td>
<td>1.89</td>
</tr>
<tr>
<td>Median</td>
<td>1.71</td>
<td>1.90</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>0.30</td>
<td>-0.29</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.25</td>
<td>-0.07</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.97</td>
<td>1.25</td>
</tr>
<tr>
<td>Max</td>
<td>2.42</td>
<td>2.50</td>
</tr>
<tr>
<td>5th</td>
<td>1.34</td>
<td>1.51</td>
</tr>
<tr>
<td>40%</td>
<td>1.67</td>
<td>1.82</td>
</tr>
</tbody>
</table>

### Frequency (%)

- **YP - PL**
  - MOE (x10^6 psi):
    - [0.97, 1.22]: 4%
    - [1.22, 1.47]: 10%
    - [1.47, 1.72]: 10%
    - [1.72, 1.97]: 8%
    - [1.97, 2.23]: 8%
    - [2.23, 2.47]: 6%

- **RM - PL**
  - MOE (x10^6 psi):
    - [1.25, 1.45]: 5%
    - [1.45, 1.65]: 15%
    - [1.65, 1.85]: 15%
    - [1.85, 2.05]: 10%
    - [2.05, 2.25]: 10%
    - [2.25, 2.45]: 15%
    - [2.45, 2.65]: 10%
RESEARCH EFFORTS: Structural Grades

MOE results compared favorably to laminations used in commercially available softwood CLTS

<p>| Table 3 - CrossLam® CLT Allowable Design Properties for Laminations (°) |</p>
<table>
<thead>
<tr>
<th>CLT Grade</th>
<th>F_{b,0} (psi)</th>
<th>E_{mp} (10^6 psi)</th>
<th>F_{w,0} (psi)</th>
<th>F_{v,0} (psi)</th>
<th>F_{v,0} (10^6psi)</th>
<th>F_{l,0} (psi)</th>
<th>F_{l,0} (10^6psi)</th>
<th>F_{V,0} (psi)</th>
<th>F_{V,0} (10^6psi)</th>
<th>F_{L,0} (psi)</th>
<th>F_{L,0} (10^6psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V2.1</td>
<td>875</td>
<td>1.4</td>
<td>450</td>
<td>1150</td>
<td>135</td>
<td>45</td>
<td>500</td>
<td>1.2</td>
<td>250</td>
<td>650</td>
<td>135</td>
</tr>
<tr>
<td>V2M1.1</td>
<td>875</td>
<td>1.4</td>
<td>450</td>
<td>1150</td>
<td>135</td>
<td>45</td>
<td>875</td>
<td>1.4</td>
<td>450</td>
<td>1150</td>
<td>135</td>
</tr>
<tr>
<td>E1M4</td>
<td>2100</td>
<td>1.8</td>
<td>1575</td>
<td>1875</td>
<td>160</td>
<td>50</td>
<td>500</td>
<td>1.2</td>
<td>250</td>
<td>650</td>
<td>135</td>
</tr>
<tr>
<td>E1M5</td>
<td>2100</td>
<td>1.8</td>
<td>1575</td>
<td>1875</td>
<td>160</td>
<td>50</td>
<td>875</td>
<td>1.4</td>
<td>450</td>
<td>1150</td>
<td>135</td>
</tr>
</tbody>
</table>

Notes:
1. Tabulated values are allowable design values and not permitted to be increased for the lumber size adjustment factor in accordance with the NDS.
2. The CLT grades are developed based on APA Product Report PR-L314. Please refer to specific grade layups for complete panel information.
3. The design values shall be used in conjunction with the section properties provided by the CLT manufacturer based on the actual layup used in manufacturing the CLT panel (see tables above).
4. Values are calculated per 1 foot wide section of panel.
5. The panel weight is based on SPF lumber values in the 2015 NDS.

CrossLam® Design Guide v4.0 - USA


<table>
<thead>
<tr>
<th></th>
<th>YP - PL</th>
<th>RM - PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1.71</td>
<td>1.89</td>
</tr>
<tr>
<td>Median</td>
<td>1.71</td>
<td>1.90</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>0.30</td>
<td>-0.29</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.25</td>
<td>-0.07</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.97</td>
<td>1.25</td>
</tr>
<tr>
<td>Max</td>
<td>2.42</td>
<td>2.50</td>
</tr>
<tr>
<td>5th</td>
<td>1.34</td>
<td>1.51</td>
</tr>
<tr>
<td>40%</td>
<td>1.67</td>
<td>1.82</td>
</tr>
</tbody>
</table>
General information/assumptions indicted that 2 Common and 3 Common (pallet grade) hardwood lumber is 4/4 thicknesses.

Knowing the standard require 3.5x thickness, every board above 4” in width would be acceptable to produce CLT panels.

From available data, 99% of yellow-poplar and 95% of soft maple met this dimension criteria.

Only 1% of yellow-poplar #2A common (NHLA graded) did not met the minimum requirement of 1.2e from PRG-320.

Since boards are end-jointed, there are no restrictions for lengths.

When performing an economic analysis, #2 NHLA graded hardwood lumber and #2 structurally graded softwoods should not be compared.
RESEARCH EFFORTS: On-going

- Mill studies throughout the Appalachian Region are being conducted to determine available species and grades (WERC Wood Innovation Funding).

- Work is underway using Yellow-poplar to grade 4m bdft of 2 common and 4m bdft of 3 Common (pallet grade) lumber using NHLA, NELM, Transverse Vibration, and MSR techniques (WERC Wood Innovation Funding).

- Yellow-poplar and mixed maple are being evaluated for optimal lamination placement and to look at the influence of mixed species layering (HRT funding).
RESEARCH EFFORTS: On-going

- #2A Common NHLA Graded Lumber
  - “Green”
  - Rough Cut – for final 1” thick (or dry 4/4)
  - 7-1/4 inches in width

- Pallet Grade NHLA Graded Lumber
  - “Green”
  - Rough Cut – for final 1” thick (or dry 4/4)
  - 7-1/4 inches in width

WERC & HRT Research
Combined Flow Chart of Work

- Dried in Kiln
- Grading
  - NHLA
  - NELMA
- Surfaced to 7/8 (0.875) - inch thick

- Ripped to Standard Width
  - Grading
    - NHLA
    - NELMA

- Sorting MOE Classes
- Grading
  - NDE Proof Load
  - NDE Vibration
- Ship to WVU

- Grading
  - NHLA
  - NELMA

- Output
  - Sorted MOE
  - Graded Lumber

- High Grade Sorted Material
- Layer Assignment
  - 10 CLT Panels (Control Panels)
  - Surfaces:
    - ¼” inch thick

- CLT Production
  - 10 CLT Panels
    - Control

- Low Grade Sorted Material
- Layer Assignment
  - Parallel Layers
  - Surfaces:
    - ¼” inch thick

- Layer Assignment
  - Perpendicular Layers
  - Surfaces:
    - ¼” inch thick

- CLT Production
  - 10 CLT Panels
    - High Grade Parallel
    - Lower Grade Perpendicular
Producing CLT panels from Low Value Appalachian Hardwoods: Part 2, Demonstrating CLT Panel Production, Properties, and Use

1. Further evaluate the structural grades and suitability of No. 2A Common and lower (e.g., No. 3A Common) and pallet grade hardwood lumber within CLT panels.
2. Demonstrate mill based production of CLT panels using mixtures of No. 2 Common and pallet grade lumber in optimized configurations.
3. Provide data to further the acceptance of hardwood CLT panels under the ANSI/APA PRG 320 standards.
4. Perform CLT demonstration workshops and utilize hardwood CLTs within a demonstration structure at West Virginia University.
Grant Number: 2016-DG-11083150-053
Status: In Progress

Contact Information: Virginia Tech
College of Natural Resources and Environment
Department of Sustainable Biomaterials
1650 Research Tech Drive
Blacksburg, VA 24061
540-231-0978
http://www.sbio.vt.edu/

Description: The goal of this project is to provide hardwood lumber producers with information to assist them in entering the cross laminated timber (CLT) market with material produced from low value hardwoods. The goal will be accomplished by first determining manufacturing capabilities of current hardwood producers for the production of raw materials used in CLTs. Current capabilities and limitations of traditional hardwood lumber producers will be determined through a survey of industries in the Appalachian region. Secondly, with the support of the local hardwood industry on specific procurement, manufacturing, costing and quality control procedures (such as visual strength grading), an analytical tool will be developed to assist manufacturers with making decisions for the successful production of raw materials for CLTs.

Objectives: Project objectives are: 1. Conduct a survey to determine the current technical limitations of hardwood lumber producers for the production of CLT raw materials. 2. Develop an analytical tool for hardwood lumber manufacturers to determine the best production mix of traditional lumber products vs CLT raw materials. 3. Develop and conduct workshops and other dissemination activities to inform hardwood lumber manufacturers, state, and federal organizations of the results of the project.

Objectives: Project objectives are: 1. Conduct a survey to determine the current technical limitations of hardwood lumber producers for the production of CLT raw materials. 2. Develop an analytical tool for hardwood lumber manufacturers to determine the best production mix of traditional lumber products vs CLT raw materials. 3. Develop and conduct workshops and other dissemination activities to inform hardwood lumber manufacturers, state, and federal organizations of the results of the project.

Objectives: Project objectives are: 1. Conduct a survey to determine the current technical limitations of hardwood lumber producers for the production of CLT raw materials. 2. Develop an analytical tool for hardwood lumber manufacturers to determine the best production mix of traditional lumber products vs CLT raw materials. 3. Develop and conduct workshops and other dissemination activities to inform hardwood lumber manufacturers, state, and federal organizations of the results of the project.

Keywords: Virginia, hardwoods, cross laminated timber, CLT, workshop, survey

Funding:
- US Forest Service Grant: $208,977
- Cooperative Funding: $112,539
- Total: $321,516

Results: No references are available at this time.
RESEARCH EFFORTS: Other Hardwood Research

Contact Information
Xinfeng Xu
School of Forest Resources and Environmental Science
Michigan Technological University
Houghton, Michigan
(906) 487-2294, xinfengx@mtu.edu

Machining for dimensional tolerance
Applying face glue
Pressing CLT's
Testing mechanical and physical properties

Slide Courtesy of Patrick Donahue, pdonahue@d.umn.edu, University of Minnesota - Duluth
Outline

Research & Demonstration Update

Commercial Development – Hardwoods?

- HWD CLT Disadvantages
- HWD CLT Advantages
- Advancing HWD CLT Potential
US Commercial CLT Facilities With PRG 320 Certification

SmartLam, LLC is proud to be the first manufacturer of Cross Laminated Timber products in the United States. Our focus is to develop practical, innovative, and sustainable solutions to satisfy all our customer’s project requirements.

D.R. Johnson's Engineered CLT
THE FIRST U.S. CERTIFIED MANUFACTURER FOR CROSS-LAMINATED TIMBER

D.R. Johnson
OREGON, USA
WOOD INNOVATIONS

***Note: Sterling (Illinois) also makes TerraLam CLT Mats for non-structural applications***
US Commercial CLT Facilities: Planned

Dothan, Alabama – **International Beams**, a producer of engineered wood products, announced today that it will invest nearly $20 million to open a manufacturing facility near Dothan to produce innovative timber panels and beams using Southern Pine lumber.

IB said its project will create 60 full-time jobs on a two-shift operation, with the possibility that figure could rise by 25 positions over a five-year period. Anticipated capital investment in the new facility is $19.6 million.

IB X-LAM USA Announces APA Certification of Structured Glue-Laminated Timber (GLULAM)

**Dothan – June 1, 2018** – IB X-LAM USA announced that their plant in Dothan, AL has met certification requirements of APA – The Engineered Wood Association to manufacture structural glue-laminated timbers, enabling the facility to produce glulam beams and columns.

In addition to Glulam, IB X-LAM USA also plans to manufacture cross-laminated timber (CLT) at the Dothan facility. Equipment for CLT production is currently being installed and is expected to be complete in Fall 2018.

Positive Customer Impact

Many customers will benefit from the first CLT operation in the Southeast. Glulam and CLT is manufactured using sustainably farmed wood and provides significant environmental benefits over other building materials, such as concrete and steel. The CLT panels are fabricated to strict tolerances in the plant, greatly reducing labor costs on construction sites. IB X-LAM USA will offer CLT and Glulam with finish grade lamella for projects that incorporate the inherent beauty created by exposed timber that can positively affect the occupant of a space.
US Commercial CLT Facilities: Planned

Maine -- from Paper to Pre-Fab

On February 13, LignaCLT Maine, LLC announced plans to construct a manufacturing plant at a pre-existing paper mill facility in Millinocket, Maine. LignaCLT is planning to manufacture CLT and glulam (where lumber is glued together in the same direction) and expects to directly employ about 100 people at the $30 million facility beginning next year. Millinocket was selected because it was home to Great Northern Paper Co. for over one hundred years, and has access to the facilities that traditionally supported paper mills – hydroelectric dams (i.e. cheap power), good roads, and low-grade softwoods, primarily spruce.

LignaCLT Maine’s parent company LignaTerra Global is a Charlotte, North Carolina company. On the decision to open a mass timber facility in Maine, CEO and co-founder Nick Holgorsen commented that “the type of trees that are important to the cross-laminated timber production process are plentiful here in Maine. Second, we know that Maine has a dedicated, productive workforce with timber industry experience. We see this as an opportunity to provide jobs and help communities thrive.” After the closure of the Millinocket mill, the median age in town increased to 48 and median income dropped to under $30,000. The hope is that CLT can help bring people and prosperity back to the region.

Just two days later, on February 15, Montana-based SmartLam announced plans to open a second manufacturing facility in Maine. The company was awarded $3 million from the Maine Technology Asset Fund 2.0 program, and the total project cost is estimated to be $23.5 million. While site selection is still underway, the facility is expected to bring 100 direct and 200 indirect jobs to the state.

The three-year old SmartLam is growing by leaps and bounds, producing more than 12 million board feet per year of CLT at its Columbia Falls, Montana factory. To keep up with growing demand from architects and designers on the East Coast, SmartLam looked towards Maine’s woodbasket for a potential second manufacturing site.

Bringing the companies to Maine required several years of work from a dozen or more non-profits, universities and community colleges. The research on wood products occurring at the University of Maine and local colleges was also a critical factor in attracting the companies.

- LignaCLT Maine announced facility in Maine on 2/13/18 (low-grade spruce)
- SmartLam announced facility in Maine on 2/15/18 (assumed spruce/fir)
- Eastern Hemlock also potential in NE
Commercial Hardwood CLTs?

So where does that leave US hardwoods in CLT manufacturing, specifically for construction?

Answer: Currently R&D and Demonstration only

- The American Hardwood Export Council (AHEC) presents ‘The Smile’ by architect Alison Brooks for the London Design Festival…
- The Smile is a cross-laminated (CLT) tulipwood (yellow-poplar) structure exhibited at the Rootstein Hopkins Parade Ground of the Chelsea College of Arts, London, England…
- Endless stair: 2013 London Design Festival
In an effort to enhance awareness around using wood as an innovative building material, The United States Forest Service awarded Boston based architectural firm, IKD, $250,000 to fund the construction of the first hardwood cross laminated timber (CLT) project in the United States.

The Indiana Hardwood CLT Project uses low-grade hardwood to create a high quality CLT product that will then be used in commercial projects. NHLA is honored to have helped IKD with this project and would like to recognize NHLA board member Dave Bramlage of Cole Hardwoods for helping to secure the necessary materials for this project. Oak, Hickory, Maple, Ash and Beech are some of the materials used.

The idea is that low-value hardwood, such as grade 3 common oak, maple, and ash, can be used to create high-value Cross Laminated Timber which can then be used in commercial applications. CLT, a relatively new engineered wood product that is an incredibly strong, fireproof, lightweight alternative to steel and concrete, can be used to construct mid- to high-rise buildings in urban settings. In the United States, however. CLT is currently made only of softwoods; the hardwood variety is not available as it is in Europe. Hardwood CLT offers numerous benefits over softwood, included superior mechanical properties, material volume savings, and higher quality appearance in visible settings.


Note: This was not the first hardwood CLT timber project in the US. First funded demonstration HWD structure, however.
Hardwood CLT Buildings

WORLD’S FIRST BUILDING MADE FROM HARDWOOD CLT

Kathryn Allen
Materials World magazine, 1 Aug 2017

First used publicly in 2013, American tulipwood cross-laminated timber has been used to build a cancer support centre in Oldham, UK.

Maggie’s Oldham, UK, is the world’s first building made from hardwood cross-laminated timber (CLT). Located at specialist NHS cancer hospitals, Maggie’s Centres provide professional support to people living with cancer. Maggie’s Oldham, situated in the grounds of the Royal Oldham Hospital, is the 21st Centre to open.

CLT is a prefabricated wood panel, consisting of several sheets of timber layered in alternating directions to increase strength. The 27.6m³ of American tulipwood and 1.1m³ of American ash that make up Maggie’s are equivalent to 55.22m³ and 2.1m³, respectively, of sawn wood prior to processing.

Growing in all 33 of the US States that host hardwoods, tulipwood is the fourth-most abundant timber in US hardwood forests. With the speed of growth greater than the level of harvesting, tulipwood is also under-exploited. It is fast-growing, naturally reseeds and is a carbon store – at the point of fabrication, having been felled, dried and transported, the tulipwood was calculated to store more CO₂ than its processing and transportation had generated.

Around 70% stronger in bending than typical CLT-grade softwood, American tulipwood CLT is also light and sustainable. Planet Ark’s report, Wood Housing, Health and Humanity 2015, is one of several recent studies reporting measurable health and wellbeing benefits of wood in the built environment.
Outline

Research & Demonstration Update

Commercial Development – Hardwoods?

• HWD CLT Disadvantages
• HWD CLT Advantages
• Advancing HWD CLT Potential
DISADVANTAGES: HARDWOOD FOR CLT PANELS

- Hardwood lumber is sawn and “face” graded for appearance, NOT dimensionally graded for structural characteristics.

- It is difficult to impossible to have an architect or engineer sign off on the use of hardwood CLT panels because of the lack of structural grading standards (ANSI/APA PRG-320).

- You can’t use high quality NHLA grade lumber in hardwood CLT’s because the cost of the raw material will be significantly more than panels made from softwoods.

- We don’t yet know if CLT panels can be made from low grade hardwood and still compete with softwood panels in terms of cost, utility, and grade…

- Potential issues with adhesion with some hardwood species.
Decay resistance varies between hardwoods and softwoods, specifically in potential CLT material.

### Table 3-10. Grouping of some domestic and imported woods according to average heartwood decay resistance

<table>
<thead>
<tr>
<th>Resistant or very resistant</th>
<th>Moderately resistant</th>
<th>Slightly or nonresistant</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Domestic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baldcypress, old growth</td>
<td>Baldcypress, young growth</td>
<td>Alder, red</td>
</tr>
<tr>
<td>Catalpa</td>
<td>Douglas-fir</td>
<td>Ashes</td>
</tr>
<tr>
<td>Cedar</td>
<td>Larch, western</td>
<td>Aspens</td>
</tr>
<tr>
<td>Atlantic white</td>
<td>Pine, longleaf, old growth</td>
<td>Beech</td>
</tr>
<tr>
<td>Eastern redcedar</td>
<td>Pine, slash, old growth</td>
<td>Birches</td>
</tr>
<tr>
<td>Incense</td>
<td>Redwood, young growth</td>
<td>Buckeye</td>
</tr>
<tr>
<td>Northern white</td>
<td>Tamarack</td>
<td>Butternut</td>
</tr>
<tr>
<td>Port-Orford</td>
<td></td>
<td>Cottonwood</td>
</tr>
<tr>
<td>Western redcedar</td>
<td></td>
<td>Elms</td>
</tr>
<tr>
<td>Yellow</td>
<td>Pine, eastern white, old growth</td>
<td>Basswood</td>
</tr>
<tr>
<td>Cherry, black</td>
<td></td>
<td>Firs, true</td>
</tr>
<tr>
<td>Chestnut</td>
<td></td>
<td>Hackberry</td>
</tr>
<tr>
<td>Cypress, Arizona</td>
<td></td>
<td>Hemlocks</td>
</tr>
<tr>
<td>Junipers</td>
<td></td>
<td>Hickories</td>
</tr>
<tr>
<td>Locust, Black*</td>
<td></td>
<td>Magnolia</td>
</tr>
<tr>
<td>Honeylocust</td>
<td></td>
<td>Maples</td>
</tr>
<tr>
<td>Mesquite</td>
<td></td>
<td>Pines (other than those listed)*</td>
</tr>
<tr>
<td>Mulberry, red*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oaks, white*</td>
<td>Osage orange*</td>
<td>Sweetgum</td>
</tr>
<tr>
<td>Redwood, old growth</td>
<td></td>
<td>Sycamore</td>
</tr>
<tr>
<td>Sassafras</td>
<td></td>
<td>Tanoak</td>
</tr>
<tr>
<td>Walnut, black</td>
<td></td>
<td>Willows</td>
</tr>
<tr>
<td>Yew, Pacific*</td>
<td></td>
<td>Yellow-poplar</td>
</tr>
</tbody>
</table>

Source: USDA Wood Handbook
ADVANTAGES: HARDWOODS FOR CLT PANELS

- Potential to reduce material volume and meet same strength properties?
- Is this actually the case?
- Is it this simple?
- Many items need addressed, such as adhesion, machinability, processing, and strength of economically available species.

www.archdaily.com
However, available species, costs, and adhesion properties may limit the opportunity to use higher strength hardwood category species.

In some cases, hardwoods may have better strength to SG ratio.

However, much of this depends on defect location, size, species, and specific property.

Source: USDA Wood Handbook
ADVANTAGE?: HARDWOODS FOR CLT PANELS

- Our prior research indicated yellow-poplar and combinations of red maple and yellow-poplar meet PRG 320 requirements given proper lay-up.

- Some hardwoods, however, may have difficulty meeting PRG 320 adhesion requirements.

---

Table 10-1. Categories of selected wood species according to ease of bonding

<table>
<thead>
<tr>
<th>U.S. Hardwoods</th>
<th>U.S. Softwoods</th>
<th>Imported Woods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alder</td>
<td>Fir</td>
<td>Balsa</td>
</tr>
<tr>
<td>Aspen</td>
<td>White</td>
<td>Catrix</td>
</tr>
<tr>
<td>Basswood</td>
<td>Grand</td>
<td>Courbaril</td>
</tr>
<tr>
<td>Cottonwood</td>
<td>Noble</td>
<td>Deterna</td>
</tr>
<tr>
<td>Chestnut, American</td>
<td>Pacific</td>
<td></td>
</tr>
<tr>
<td>Magnolia</td>
<td>Pine</td>
<td></td>
</tr>
<tr>
<td>Willow, black</td>
<td>Eastern white</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Western white</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Redcedar, western</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Redwood</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spruce, Sitka</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bond easily</td>
<td></td>
</tr>
<tr>
<td>Butternut</td>
<td>Douglas-fir</td>
<td>Meranti (Lauan)</td>
</tr>
<tr>
<td>Elm</td>
<td>Larch, western</td>
<td>Light red</td>
</tr>
<tr>
<td>American</td>
<td>Pine</td>
<td>White</td>
</tr>
<tr>
<td>Rock</td>
<td>Sugar</td>
<td>Yellow</td>
</tr>
<tr>
<td>Hackberry</td>
<td>Ponderosa</td>
<td>Okoche</td>
</tr>
<tr>
<td>Maple, soft</td>
<td>Redcedar, eastern</td>
<td>Iroko</td>
</tr>
<tr>
<td>Sweetgum</td>
<td></td>
<td>Okoche</td>
</tr>
<tr>
<td>Sycamore</td>
<td></td>
<td>Opepe</td>
</tr>
<tr>
<td>Tupelo</td>
<td></td>
<td>Peroba rosa</td>
</tr>
<tr>
<td>Walnut, black</td>
<td></td>
<td>Sapele</td>
</tr>
<tr>
<td>Yellow-poplar</td>
<td></td>
<td>Spanish-cedar</td>
</tr>
<tr>
<td></td>
<td>Bond well</td>
<td>Suapura</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Walabu</td>
</tr>
<tr>
<td>Ash, white</td>
<td>Yellow-cedar</td>
<td>Meranti (Lauan)</td>
</tr>
<tr>
<td>Beech, American</td>
<td>Angelines</td>
<td></td>
</tr>
<tr>
<td>Birch</td>
<td>Per-Orford-cedar</td>
<td>Azobe</td>
</tr>
<tr>
<td>Sweet</td>
<td>Pines, southern</td>
<td>Benge</td>
</tr>
<tr>
<td>Yellow</td>
<td></td>
<td>Dibungga</td>
</tr>
<tr>
<td>Cherry</td>
<td></td>
<td>Kari</td>
</tr>
<tr>
<td>Hickory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pecan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>True</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Madrone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maple, hard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oak</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red 9 White 10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: USDA Wood Handbook
Our preliminary research indicates that Hardwood CLT panels could use what is viewed as low grade appearance lumber (2 common and below), which is produced in abundance by Appalachian sawmills.

Current hardwood manufacturing method requires a system for MSR and Structural Grading to better categorize low grade appearance lumber for use in CLTs to be advanced.

Tremendous potential for new construction – ranging from large commercial structures to simple two bedroom homes.

Many medium to large capacity sawmills in Appalachia have the potential to modify their existing operations to produce CLT panels.

Capital costs for CLT panel manufacturing are low to moderate, while the labor costs are generally manageable.

Potential to produce stronger, thinner, more durable and aesthetically pleasing, and lighter weight CLT panels from hardwoods, if hurdles and specific species are selected.
We need a better understanding of the regional, national, and international CLT Panel markets.

Prices for the hardwood lumber in CLT panels need to be competitive with softwood structural lumber, particularly with SYP!

Lumber grading techniques need to address CLT manufacturing needs (WVU is addressing this issue through funded research).

Hardwood lumber used for CLT panels needs to be viewed as traditional construction lumber, not specialty furniture/cabinet material.

Barriers to inclusion of hardwoods into PRG 320 need to be overcome (i.e., need research and test data).

Need to stop comparing economic and panel configuration comparisons of NHLA graded hardwoods to softwood structural grades.
Cost Considerations: Better Data Needed

- Need to **stop comparing** economic and panel configuration comparisons of NHLA graded hardwoods to softwood structural grades.

**NOT STRUCTURALLY COMPARABLE** and **CHANGES FREQUENTLY**

2x6 #2&btr West SPF, KD was $4 (**April 13, 2018 – Random Length**)

Slide Courtesy of Patrick Donahue, pdonahue@d.umn.edu, University of Minnesota - Duluth
HARDWOOD PROCUREMENT QUESTIONS

- Can the Appalachian Region provide enough hardwood lumber to support multiple hardwood CLT plants?
- Can an individual hardwood mill provide enough lumber for a CLT manufacturing facility?
- Consider an average CLT plant produces 12-24MMBF/year, how many average hardwood sawmills are needed?
- How much of the hardwood mill output is suitable for CLT production?
- Do the current hardwood processing methods make sense for a CLT production industry?
- Others…………………………………..?
What needs to be done if we seriously want to produce hardwood CLT panels...

- Hardwood Associations and state Forest Manufacturing Associations (WV, OH, PA, NY, MD, etc.) need to come together and initiate a program to **encourage the acceptance of hardwood CLT panels** for commercial construction by building code standard organizations, like the International Building Code (IBC).

- Simultaneously, **mechanical testing on Yellow-poplar and Soft Maple** (and other species) CLT lay-ups should be ramped up and test results submitted to the ANSI PRG 320 Standards Review Panel for inclusion in the ANSI/APA - CLT standards.
While ANSI/APA PRG 320 does not specify the use of hardwoods, it may be possible to get certification under “Custom Grades”

Would be for that specific lay-up pattern only
Questions, Comments, Discussion?