

Effective adhesive systems and optimal bonding parameters for hybrid CLT

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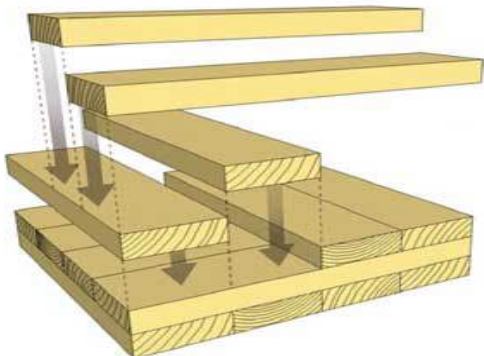
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Presentation Overview

- Brief intro to cross laminated timber (CLT)
- Our hypothesis
- Screening study
- Preliminary results
- Further Research

Cross Laminated Timber (CLT)

What is
CLT ?



http://www.prosalesmagazine.com/products/lumber/x-marks-the-opportunity_o

Layers: Typically 3, 5, or 7
Area: Up to ~ 10 X 60 ft²



http://www.internationaltradenews.com/klh_massivholz_gmbh/portrait/



<http://www.structurearchives.org/article.aspx?articleID=1474>

Our Hypothesis

CLT panels with hybrid layups, where layers arranged from high- and low-grade lamellas or composed of mixed species, can meet the current standard requirements for critical engineering parameters as specified in the ANSI PRG 320-2012 performance standard, and that adhesive systems alternative to polyurethane (PUR) can be successfully utilized in hybrid CLT products.

Hypothesis in a nutshell

- High-grade face material and low-grade core material can be used
- Mixed species can be used
- Alternative adhesives can be used

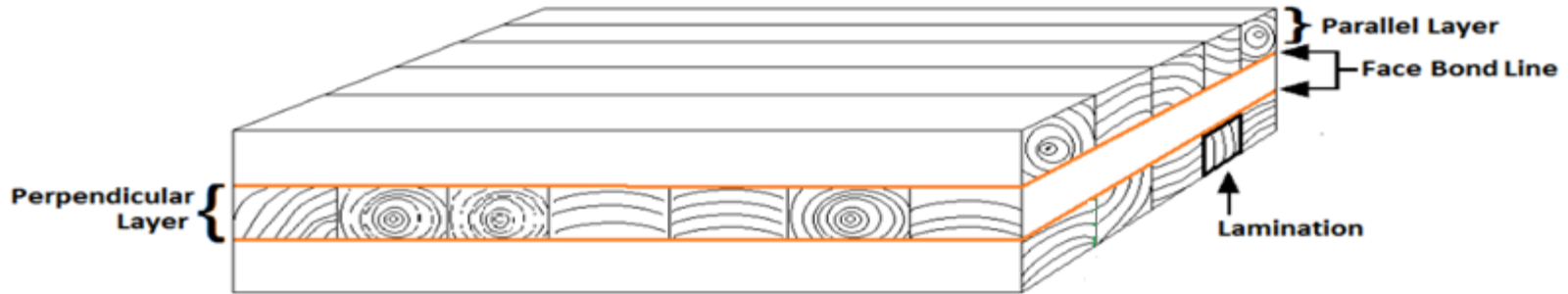
Goal of Screening Study

The screening study will be conducted on a pass-fail basis to help us select adequate species/adhesive combinations for connection tests and full-scale mechanical and physical tests.

Screening Study

Testing 2 x 2 foot panels with 3 layers

- Bond line shear
- Delamination



Screening Study Test Variables

Panel species combinations:

H = High Grade		Face Material	
		Lodgepole Pine (H) (reference)	Douglas-fir (H)
L=Low Grade			
Core Material	Lodgepole Pine (Low)	4 panels	4 panels
	Douglas-fir (Low)		4 panels
	Hemlock (Low)	4 panels	4 panels
	Lodgepole Pine (High) (reference)	4 panels	

Adhesives:

Number	Adhesive Types
1	PRF
2	PUR

Clamping Pressures:

Number	Pressure (MPa) [psi]
1	0.69 [100]
2	0.40 [58.0]
3	0.10 [14.5]

Goals of Preliminary Study

1. Test equipment and methods
2. Develop testing instructions
3. Compare variation of shear and delamination samples within a panel

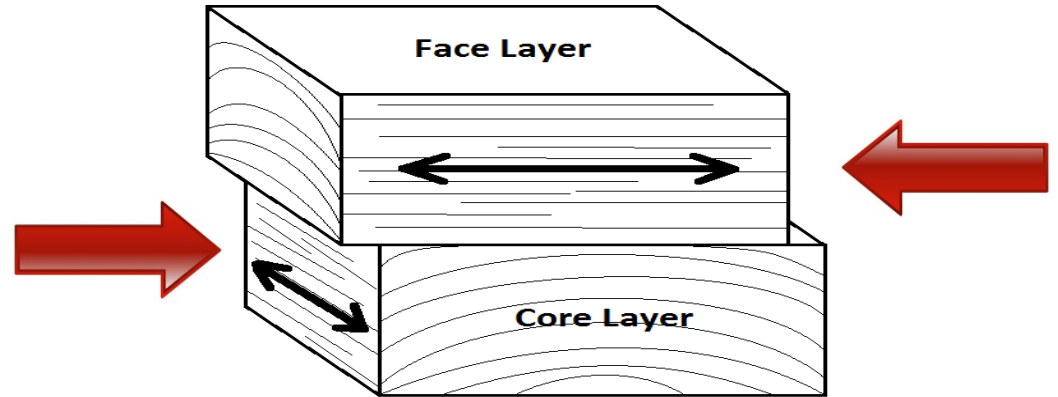
Bond Line Shear Test

Modified ASTM 1037

- Modified for 90° grain orientation between layers
- 2x1.5 inch bond area
- 1 inch thick layers

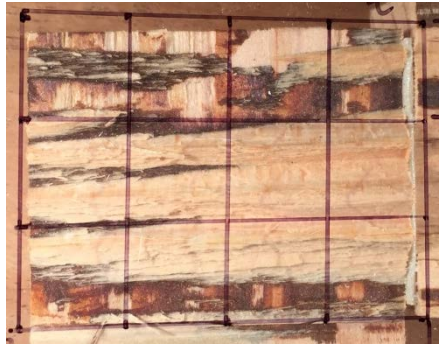
Focus:

- Shear strength
- Percent wood failure



Percent Wood Failure

Initial Approach



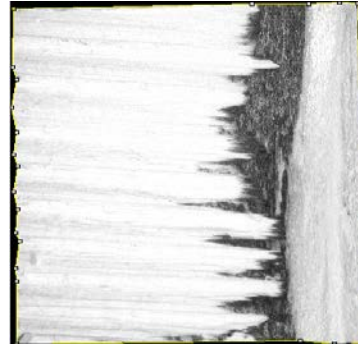
- Slow
- Challenging

Second approach:

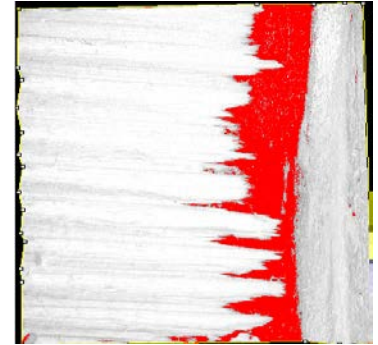
Goal: Automatic optical assessment of the % WF



1) Initial Image



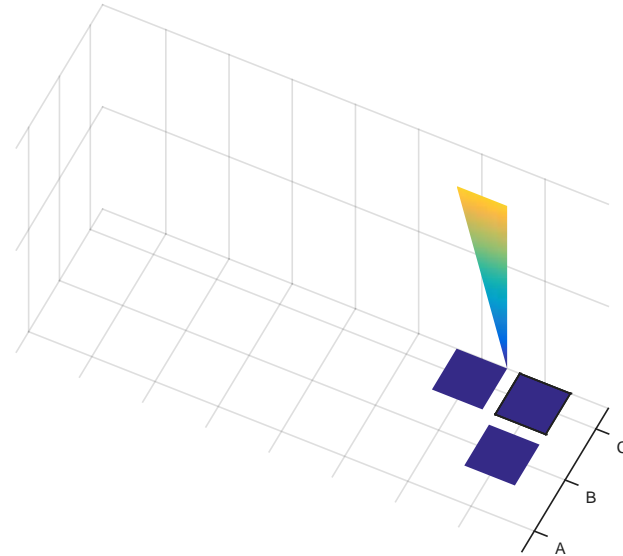
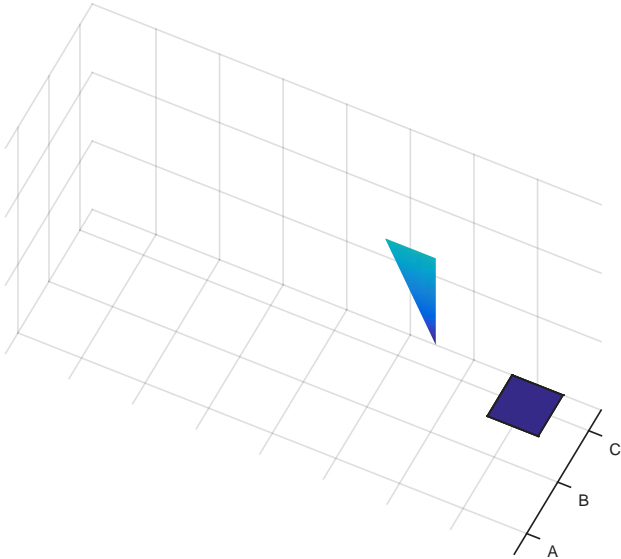
2) Red Spectrum



3) Thresholding

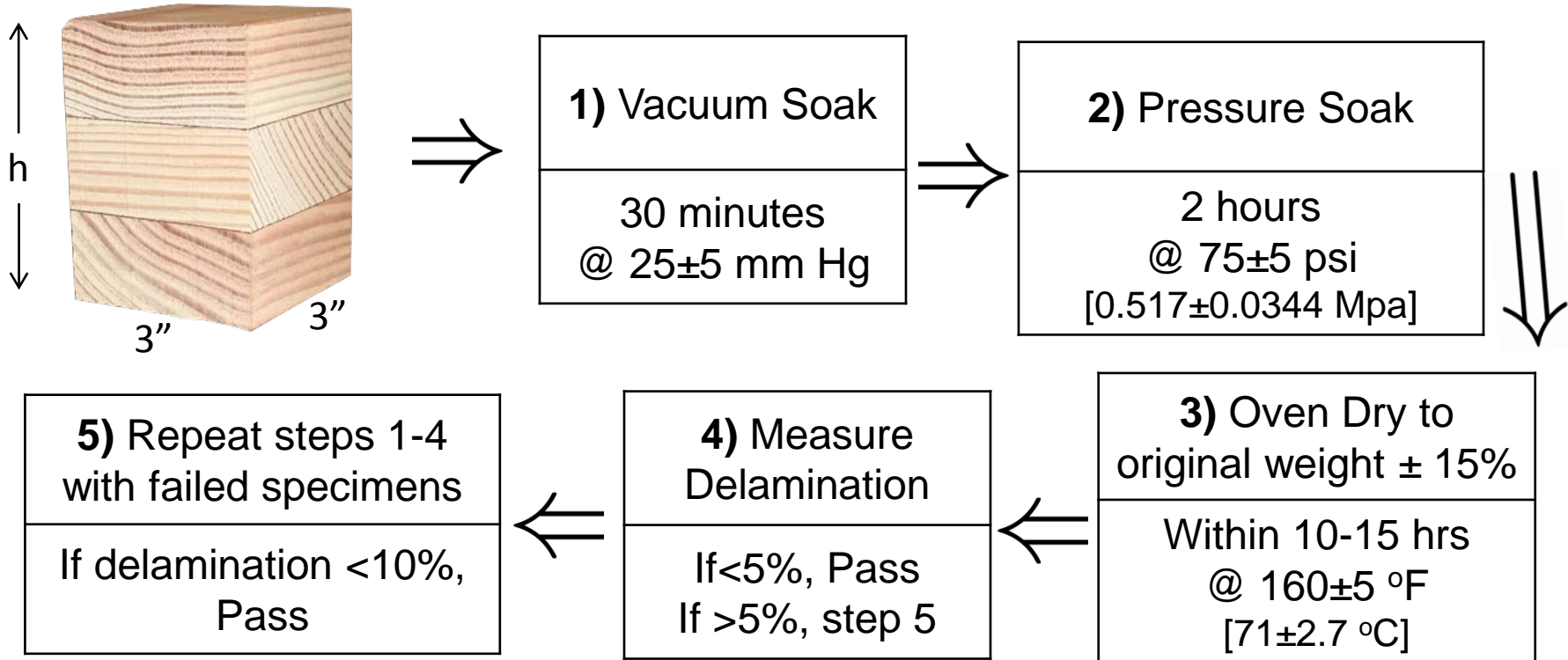
Preliminary Shear Test Results

A7	B7	C7
A6	B6	C6
A5	B5	C5
A4	B4	C4
A3	B3	C3
A2	B2	C2
A1	B1	C1



Delamination Test

AITC Test T110-2007: Cyclic
Delamination Test



Common Modes of Sample Delamination



Mixture of Delamination
and Wood Failure



Delamination only in
early wood.

Delamination Test Results

A7	B7	C7
A6	B6	C6
A5	B5	C5
A4	B4	C4
A3	B3	C3
A2	B2	C2
A1	B1	C1

	B	A	C
1	2.81%	0.00%	3.33%
2	0.00%	0.00%	3.97%
3	0.00%	0.00%	3.16%
4	0.00%	0.41%	0.00%
5	2.73%	2.15%	0.00%
6	2.15%	0.00%	2.65%
7	0.00%	7.95%	4.14%

Key	
Pass after 1 cycle	
Pass after 2 cycles	
Failed to dry within tolerance	

Preliminary Results

- Shear block testing equipment is satisfactory.
- Further research into drying oven needed.
- Large variation within shear blocks of single panel.
- Optical measurements offer semi-automatic method to measure WF% while reducing user input.

Future Research

- Improve manufacturing
- Check variation between panels
- Determine rolling shear values for all species
- Develop and Test PUR optical WF% assessment
- Develop automated WF% assessment
- Develop optical assessment for measuring delamination

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- Lab manager: Milo Clausen
- Oregon State University faculty and graduate students