

Q-01-HI

Identifying Adhesive Bondline Quality to Improve Cross-Laminated
Timber Performance

PI(s): Daniel Hindman and Audrey Zink-Sharp | Site: VT

Anticipated Start Date: *August 2024* | Expected Duration: *24 Months*

Need & Industrial Relevance

An important need in the manufacturing of cross-laminated timber (CLT) panels is the **evaluation of the adhesive bond performance**. While the current standards provide information on locations to extract quality-control specimens from panels, questions remain about the **variability of bonding** within and **throughout the entire panel**. The use of **matched pair specimens** will allow refinement of previous studies and provide a better understanding of the role of adhesive bonding in quality-control test performance.

Research Roadmap Topics

C. Adhesive Technology, 1. Wood-Adhesive Interaction, b. Adhesive distribution and penetration
C. Adhesive Technology, 3. Performance, a. Methods for evaluating the adhesive bond

Long Term Goals

The goal of this project is to determine the correlation of adhesive bondline measurements with quality-control tests of CLT materials.

Objectives

Specific goals for year 1 of project:

- Manufacture matched microscopy and quality control test specimens
- Complete digital image microscopy of bondlines (measure adhesive bondline thickness, penetration, percent of gaps and microbubbles)
- Begin testing of shear and delamination for quality control assessment

Materials and Methods

- Single bondline, matched samples prepared for microscopic and quality-control testing
 - yellow-poplar and southern yellow pine
 - orthogonal arrangement
 - commercial polyurethane adhesive or other type as suggested by Advisory Board
- Variables
 - press pressure
 - use of primer
 - moisture content
- Test specimens prepared with varying conditions and control of pressure and press time
- Comparative Optical Microscopy
 - Measure
 - adhesive penetration in each layer
 - adhesive bondline thickness
 - percentage of gaps or microbubbles present
 - Nikon Image Systems BR and RHINO 3-D for digital imaging measurements and gap analysis
 - Explore additional methods for parsing images
 - Create panoramic images with PTGui (software) to illustrate influence of anatomy and gap formation
- Mechanical testing using shear (ASTM D905) and delamination (AITC T110) procedures
- Correlate test values with adhesive bondline properties described above
- Complete data analysis and statistical correlations

Outcomes and Deliverables

Expected Outcome	Deliverable (s)	2024					2025										2026									
		A 1	S 2	O 3	N 4	D 5	J 6	F 7	M 8	A 9	M 10	J 11	J 12	A 13	S 14	O 15	N 16	D 17	J 18	F 19	M 20	A 21	M 22	J 23	J 24	
Matched test specimens manufactured	Bondline specimens for shear, delamination, and microscopy testing	Yellow	Yellow	Yellow	Yellow	Yellow																				
Adhesive bondline properties measured with digital microscopy	Detailed methodology for microscopic evaluation of bondlines			Red	Red	Red	Red	Red	Red																	
Quality control testing completed (shear and delamination)	Test results correlated to various bondline properties								Gold	Gold	Gold	Gold	Gold	Gold												
Re-evaluation of bondline microscopy	Evaluation of bondline properties where shear failures or delamination occurred													Light Blue	Light Blue	Light Blue										
Regression and correlation models completed	Correlation of specific locations with sources of failure; correlation of bondline properties with quality control measured																	Grey	Grey	Grey						
Report prepared for WBC	Final Report to WBC																					Blue	Blue	Blue	Blue	
Manuscript for publication prepared	Peer-review journal publication																					Green	Green	Green	Green	

1. A method will be provided for evaluation of adhesive bonds and quantification of impact of gaps and microbubble formation in CLT materials.
2. Will provide information on the impact of imperfect control of manufacturing parameters on performance.
3. Could be expanded to other wood composites as well as different adhesive systems, or used to compare performance of different substrate species, substrate treatments, use of fillers or other changes to adhesive systems.
4. Microscopic images could be used to train machine and artificial intelligence learning tools for development of evaluation systems for panel production.

- Funding is requested for
 1. graduate research assistantship for 24 months
 2. tuition for the graduate student
 3. materials and supplies for mechanical testing and digital microscopy
 4. travel to WBC meetings
- The graduate student will prepare the test specimens, complete the microscopic measurements, and the shear and delamination testing.
- Data analysis and statistical correlations will be conducted by the graduate student and the project principle investigators.
- The final WBC report and journal publication will be prepared by the project team.

BUDGET	AMOUNT
First Year Expenses	
GRA & Benefits	\$35,355
Tuition & Fees	\$15,680
Materials/Supplies	\$1,500
Travel	\$1,500
Other (specify):	
YEAR 1 TOTAL:	\$54,035
<i>Expected future request amounts:</i> \$59,070	

Thank You

Questions?

Masoumi, A., Satir, E., Adhikari, S., Hindman, D., Bond, B., Zink-Sharp, A. (accepted). A comparison of microscopy and quality control testing to examine the durability of adhesive bondlines in cross-laminated timber. *Journal of Building Engineering*. Impact Factor 6.4. Publication status: Accepted. Publication type: Refereed journal article.

