New Research Proposals 2024

Presentations

Watch the Presentations at:

https://vimeo.com/showcase/11018696
Password: wbc_2024

To access more information about the proposals please access:
https://www.wbc.center/research/planning/research-planning-site/proposals/research-proposals-2024/
Use your WBC username and password.

Access LIFE Forms at:
https://oregonstate.qualtrics.com/jfe/form/SV_dnlX6OviuzMy7Oe
Password: wbc_proposals

NEW RESEARCH PROPOSAL

RFP-24-SIN

Understanding Elevated Temperature Response of Wood and Wood Composites

PI(s): Ari Sinha, Islam Hafez, Wenjia Wang | Site: OSU

Anticipated Start Date: October 2024 | Expected Duration: 36 *Months*

Need & Industrial Relevance | Goals & Objectives

Need & Industrial Relevance

- Understanding the fire performance of building materials used in residential structures is critical particularly in light of the escalating risk of wildfires.
- Wood composites comprise of 90% of the materials within a single-family residence, yet their performance under elevated temperatures is not well-understood.
- There is a need for robust models for the behavior of wood composites under elevated temperatures.

Long Term Goals

Develop a comprehensive understanding of the thermal degradation behavior of wood composites and leverage this knowledge to predict and enhance their performance under elevated temperatures.

Research Roadmap Topics

Members will benefit from increased understanding of functionality (A2) and performance (A3) of wood-based composites eventually leading to improved product (A1).

Objectives

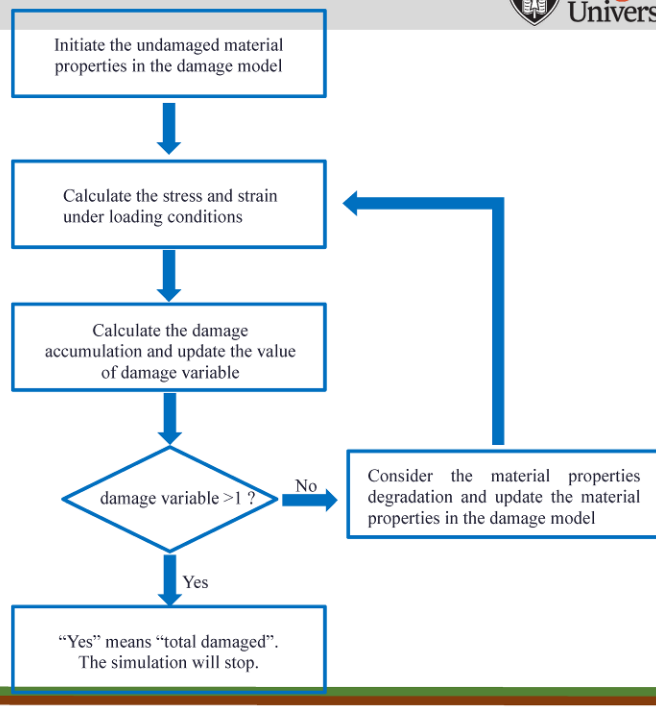
The specific objectives of this project are to:

- **Analyze** the wood composites' bending and compression properties after being exposed to elevated temperatures.
- **Determining the degradation curve of over time**, achieved through applying a constant load while exposing the material to a temperature gradient.
- **Identify Thermal Degradation Points**: Determine the temperature thresholds at which significant degradation occurs in various wood composites.
- **Discern analytical relationships between parameter and performance using statistical and machine learning based models**, more specifically – Artificial Neural Network Models.
- **Examine Microstructural Changes and build a preliminary damage mechanics based numerical Model**: Utilize microscopy to study the microstructural changes in wood composites subjected to elevated temperatures. Using the observations along with numerical automated solutions build preliminary numerical model to gain further insights into material performance.

Materials and Methods

- Systematic Literature Review (SLR): SLR uses systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyze data from the studies that are included in the review.
- Material Selection: After discussion with Technical Advisors. Potential candidates: **Solid lumber, Laminated Veneer Lumber, Plywood, MDF, and I Joists**.
- Experimental Design: Details to be developed based on discussions and testing will be conducted at OSU and at FPL.
  - Bending/compression tests under elevated temperatures will be conducted in a special chamber
  - Another set of tests will monitor deflections at a constant load in two different scenarios:
    - Constant elevated temperature
    - Changing temperature at a constant rate
- Data Analysis will be followed by statistical and Advanced Neural Network modeling
- Microstructure Evaluation: Conduct microscopic examinations, such as scanning electron microscopy (SEM), to observe microstructural alterations.
- Preliminary Numerical Model: Based on collected and in house data, a preliminary numerical model will be developed that help us gain insights into a variety of parameters for which experimental costs are prohibitive.

- Damage mechanics-based material model
- Material properties degradation will be considered
- Numerical modeling of mechanical behavior: thermo-mechanical coupled simulation
- Platform: ABAQUS (finite element simulation)



Outcomes and Deliverables

Tasks	Deliverables	Months	Responsibility
Systematic Literature Review	A paper summarizing the literature and lay of land	0-6	Sinha and Student
Material Selection, Procurement and Prep	Completed experimental design	2-3	Hafez and Student
Experimental Design		4-6	All
Testing at OSU	Baseline data on WBCs	6-9	Student, Hafez, Sinha
Testing at FPL	Temporal Degradation Curves; Exposure time and temperature interactions	9-18	Student at FPL; Hafez; Sinha
Data Analysis and Statistical Interpretation	Statistical model to understand the data and underlying phenomenon	9-18	Wang, Student and Sinha
ANN Modeling	Predictive models using machine learning methods	18-24	Student and Sinha
Microstructure Evaluation	Data on microstructural changes	20-26	Student and Hafez
Numerical Model	Predictive simulations that are user friendly	25-33	Wang and Student
Reporting and Dissemination	Dissertation; Papers; Reports	33-36	All

Expected Practical Implications/Impacts

Gaining insights into the elevated temperature performance of wood composites is essential for ensuring the safety, compliance, and efficiency of various applications across industries, while also contributing to sustainable and resilient design practices. More specifically:

1. Performance characterization at elevated temperatures for common wood composites.
2. Temporal data on elevated temperature performance of wood composites
3. Analytical and numerical models for prediction of performance of wood composites.
4. Integration of machine learning into model development.
5. Data sets that feeds into material models for any finite element or structural modeling package to build a fire endurance model.
6. WBC reports on elevated temperature performance and publications in peer-reviewed journals
7. A student dissertation.

Budget

- Graduate student support:
  - Stipends
  - Benefits
  - Tuition
- Not requested - travel and supplies
- Material donation will be asked from members
- Travel to FPL supported by the PIs

BUDGET	AMOUNT
First Year Expenses	
GRA & Benefits	$38,880
Tuition & Fees	$16,270
Materials/Supplies	
Travel	
Other (specify):	
YEAR 1 TOTAL:	$55,170
Expected future request amounts: $56,000 for the next two years.	

Q-01-HI: Identifying Adhesive Bondline Quality to Improve Cross-Laminated Timber Performance

Watch the Presentation:

WBC Wood-Based Composites Center

NEW RESEARCH PROPOSAL

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***

WBC Wood-Based Composites Center

Need & Industrial Relevance | Goals & Objectives

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																								
Adhesive bondline properties measured with digital microscopy	Detailed methodology for microscopic evaluation of bondlines																								
Quality control testing completed (shear and delamination)	Test results correlated to various bondline properties																								
Re-evaluation of bondline microscopy	Evaluation of bondline properties where shear failures or delamination occurred																								
Regression and correlation models completed	Correlation of specific locations with sources of failure; correlation of bondline properties with quality control measured																								
Report prepared for WBC	Final Report to WBC																								
Manuscript for publication prepared	Peer-review journal publication																								

Expected Practical Implications/Impacts

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.

Budget

- 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.

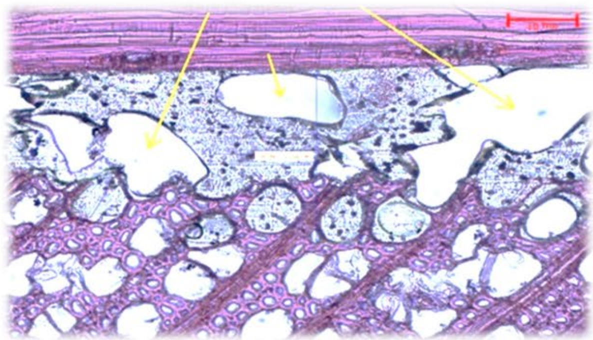
- The final WBC report and journal publication will be prepared by the project team.

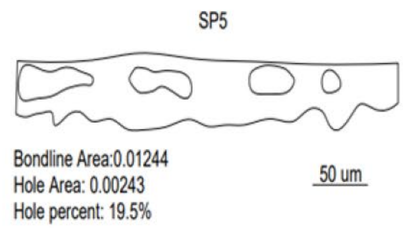
BUDGET	AMOUNT
First Year Expenses	
GRA & Benefits	$35,355
Tuition & Fees	$15,680
Materials/Supplies	$1,500
Travel	$1,500
Other (specify):	
YEAR 1 TOTAL:	$54,035
Expected future request amounts: $59,070	

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.*





Q-02-PR: Preliminary investigation of the potential for sorbitol-citrate modification to function in North American wood species and improve strandboard and plywood durability and dimensional stability

NEW RESEARCH PROPOSAL

Q-02-PR

Preliminary investigation of the potential for sorbitol-citrate modification improve aspen strandboard and Douglas-fir plywood durability and dimensional stability

PI(s): Gerald Presley
Co-PIs: Laurence Schimleck, John Simonsen, and Islam Hafez | **Site:** OSU

Anticipated Start Date: 09/2024 | **Expected Duration:** 1 year

Need & Industrial Relevance | Goals & Objectives

Need & Industrial Relevance

- Wood modification technologies can improve wood composite durability and dimensional stability.
- Sor-CA method uses bio-based molecules to modify wood
- These could replace non-biobased additives in composites
- Possible cost saving, reduced chemical leaching, possible LCA carbon improvements

Long Term Goals

Improve wood composite durability and moisture resistance

Objectives

1) Measure the impact of Sor-CA treatment on wood surface energy and the kinetics of adhesive cure
2) Measure the treatability of aspen strands and Douglas- fir veneer using the Sor-CA method
3) Measure the impact of Sor-CA treatment on aspen strandboard and Douglas-fir plywood performance

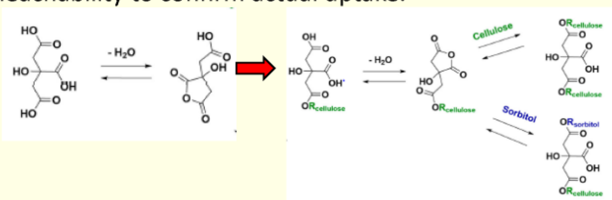
Research Roadmap Topics

TOPIC 2024-09-RD, TOPIC-2024-19

Materials and Methods

Panel-Scale Tests

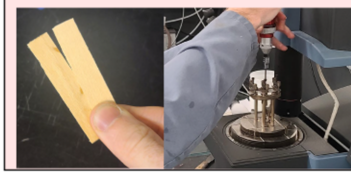
Sor-CA treatability: Vacuum treat veneers and aspen strands to 10, 25, and 40% weight gain. Cure at 140°C. Test leachability to confirm actual uptake.

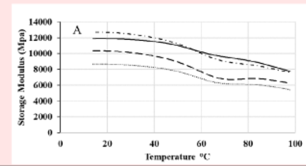


Sor-CA panel performance: 16 x 16-inch test panels (strandboard or plywood). Sor-CA retention: 10, 25, 40%.
Strandboard panels = MDI resin
Plywood panels = PF resin.
Panels tested for internal bond strength and thickness swell by ASTM 1037.

Bench-scale Tests

Resin cure kinetics: Dynamic mechanical analysis in thin maple veneer system. Treated to 10, 25, and 40% and leached prior to analysis. Veneers will be glued together using MDI or PF resins analyzed using a heat ramp to facilitate cure.





Surface Properties: Treated DF veneers or AS will be analyzed for surface energy using a contact angle analyzer. MDI or PF resins will be applied to surfaces and contact angle will be measured for each resin.

CA 94±1° CA 31±2°

Outcomes and Deliverables

Insert outcomes and deliverables using table below.
Please focus on first year of your project.

Expected Outcome	Deliverable (s)	2024				2025							
		S	O	N	D	J	F	M	A	J	J	A	S
Resin Cure Kinetics	Sor-Ca treatment impact on cure for MDI and PF												
Sor-CA treatability of veneers and strands	Weight gain, leachability of veneers, strands												
Surface characterization	Wettability/surface energy of different treatments												
Panel Performance	IB and Swell ASTM 1037												
Report													

Expected Practical Implications/Impacts

1) Does Sor-CA work in:
Douglas-fir veneer
Aspen strands

2) Does Sor-CA limit performance of:
MDI
PF

3) How low can we go with Sor-CA treatment and still get performance improvement?
Is this economically viable?

Pitfalls: Low fixation is possible, may need process optimization

Budget

Funding to Carry Shane through to graduation

BUDGET	AMOUNT
First Year Expenses	
GRA & Benefits	$30,401
Tuition & Fees	$16,260
Materials/Supplies	$2,500
Travel	
Other (specify):	
YEAR 1 TOTAL:	$49,151
Expected future request amounts:	$

NEW RESEARCH PROPOSAL

Q-03-HA

Microwave heat treatment of wood: characterization and process optimization

PI: Islam Hafez
CoPIs: Wenjia Wang and Gerald Presley | Site: OSU

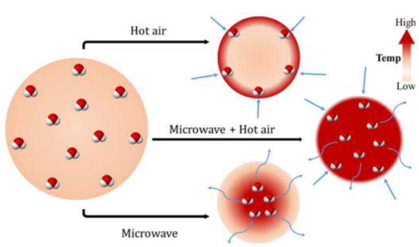
Anticipated Start Date: *October 2024* | **Expected Duration:** *9 Months*

Need & Industrial Relevance | Goals & Objectives

Need & Industrial Relevance

Industrial applications of microwave (MW) treatment of wood products in drying or adhesive activation has been receiving an increased interest in recent years. However, the impact of the treatment on the chemical and physical changes and how these changes affect the bond strength of wood composites, remains unclear. Investigating such effects will provide valuable insights and knowledge to motivate further advancements in wood treatment processes.

Why MW heating?



Karimi et al. Heat and Mass Transfer (2021) 57:133-146

Research Roadmap Topics **TOPIC 2024-09**

Long Term Goals

The overarching goal of this project is to develop an understanding and assess the potentials of microwave treatment of wood and how this impact the bonding quality of the prepared wood composites. This will be achieved through an experimental approach integrated with a predictive models.

Objectives

- Treat wood samples in a bench-scale MW.
- Characterize MW-treated samples.
- Conduct a modeling study to predict, optimize and maximize the efficiency of the MW treatment process.
- Use MW-treated samples to prepare glued specimens.
- Assess the impact of MW treatment on the bond performance of glued specimens.

Materials and Methods

Samples preparation

Solid lumber or veneer samples from Douglas fir (other wood species may be considered based on discussions with technical advisors).

Microwave treatment

The treatment will be conducted in a bench-scale microwave (Max power 1000 W). Various moisture contents and microwave powers will be studied.

Samples characterization

Microscopy: to assess the microstructure of treated samples vs control. FTIR: to examine functional groups on the surface and throughout the sample thickness. Contact angle analysis for surface properties. Dimensional stability assessment by exposure to humid air and thickness swelling (ASTM D1037) .

Bond performance evaluation

Depending on the type of treated specimens, lap shear or block shear specimens will be prepared using a commercially available adhesive (PF adhesive or as suggested by the technical advisors). ASTM D906/D4501.

Modeling

- A preliminary electromagnetic-thermal coupled modeling method of microwave heating process will be developed.
- Physical and thermal properties of materials will be obtained from lab database or literature.
- Heat transfer mechanisms of microwave and conventional heating processes will be analyzed.
- Temperature distribution in the wood samples under microwave and conventional heating will be predicted.
- Platform for microwave heating simulation: Elmer FEM multiphysical simulation software (finite element simulation)
- Platform for conventional heating simulation: Abaqus (finite element simulation)

Outcomes and Deliverables

Expected Outcome	Deliverable (s)	2024												2025											
		J	F	M	A	J	J	A	S	O	N	D		J	F	M	A	J	J	A	S	O	N	D	
Samples treatment	- Samples preparation - MW treatment																								
Characterization of MW-treated samples	- Morphology - Surface characterization - Dimensional stability																								
Modelling	- Process prediction and optimization																								
Bond performance evaluation	- Shear strength of bonded specimens																								
Dissemination	- WBC report - Publication in peer reviewed journal																								

Expected Practical Implications/Impacts

This project aims to understand how MW treatment affects various properties of wood, evaluate the changes occurring during the treatment, and determine how these changes could influence the quality of adhesive bond formed with the treated wood.

The expected practical implications and impacts are as follows:

- Enhance our understanding of chemical and physical changes of MW-treated samples compared to samples treated through conventional methods.
- Bond performance evaluation of the MW-treated samples.
- Predictive model of heat transfer mechanisms in microwave heating vs conventional heating to optimize the process and maximize efficiency.
- Provide a knowledge base that could be useful for other applications of MW treatment (e.g., heat-induced crosslinking reactions).

- Potential challenges: Monitor the temperature inside the wood during microwave treatment.
  - Make use of modeling results.
  - Find commercially available sensors.

Budget

- Graduate student support.
  - Stipends and benefits.
  - Travel will be supported by the PI.
- Materials donation will be asked from members.

BUDGET	AMOUNT
First Year Expenses	
GRA & Benefits	$17,000
Tuition & Fees	$5,500
Materials/Supplies	
Travel	
Other (specify):	
YEAR 1 TOTAL:	$22,500
Expected future request amounts: $	

NEW RESEARCH PROPOSAL

Q-05-NA

Using thermally modified wood for manufacturing mass timber elements with improved dimensional stability

PI(s): V. Nasir, L. Schimleck, I. Hafez , S. Leavengood | Site: OSU

Anticipated Start Date: ***August 2024*** **| Expected Duration:** ***12 Months***

Need & Industrial Relevance | Goals & Objectives

Need & Industrial Relevance

The growing interest in using mass timber structures necessitates addressing the durability of these products. An approach towards enhancing the durability and dimensional stability is wood thermal modification. Despite the proven effectiveness of this process on wood durability, questions raise on the mechanical performance of thermally modified wood products. Also, limited research is available on the gluing and bonding performance of these products. Thus, there is a need to assess the durability, mechanical and bonding performance of laminated thermally modified wood products.

Research Roadmap Topics

TOPIC 2024-09: Improved dimensional stability so that EWP can compete with non-wood options.

Long Term Goals

Improving the dimensional stability and durability of engineered wood products.

Objectives

The specific objectives of the project are to:

1) Testing the mechanical performance and dimensional stability of thermally modified Western hemlock
2) Preparing laminated thermally-modified wood samples.
3) Assessing the shear strength and bonding quality of the laminated samples.
4) Effect of surface treatments on the bonding performance of the laminated samples.

Materials and Methods

Materials

Thermally modified Western hemlock treated at 190°C, 212°C, and 230°C.

Dimensional Stability Assessment

treated and untreated samples are submerged in water at room temperature. The samples are weighed, and their dimensions are measured before and after immersion in water for 24 h. Finally, all samples will be oven-dried at 103 ± 2 °C for 24 h, and their dimensions and weight will be measured again. The volumetric swelling coefficient and water absorption will then be calculated, accordingly.

Mechanical Properties

Static bending test will be performed. Alternative option includes nondestructive stress-wave methods for MOE prediction.

Lamination and bonding assessment

- Two types of planing condition to produce surface with different roughness
- Lamination using one-component polyurethane (PUR) [or other options suggested by WBC members].
- Block shear samples for testing the "Shear Strength of Adhesive Bonds"
- Evaluation of percent wood failure (PWF)

Outcomes and Deliverables

Expected Outcome	Deliverable (s)	2024				2025										
		A	S	O	N	D	J	F	M	A	J	J	A	S	O	N
Dimensional stability and mechanical performance of Western hemlock treated at different temperatures	Properties of control and treated wood prior to lamination.															
Preparing laminated samples using control and thermally modified wood samples.	Sample preparation															
Applying different surface treatments	Sample preparation															
Testing dimensional stability	Post-lamination properties: dimensional stability															
Mechanical and bonding performance evaluation	Post-lamination properties: mechanical and bonding performance															
Documentation	Project progress/summary report															

WBC SPRING 2024 INDUSTRY ADVISORY BOARD MEETING Tuesday, March 5, 2024

Expected Practical Implications/Impacts

The project outcome will be used to assess the effectiveness of using thermally modified wood in manufacturing laminated products. The project could be expanded in next years by: (1) studying methods to improve the mechanical properties; (2) methods to enhance the bonding performance (e.g. different surface treatments); (3) preparing thermally modified wood veneer and manufacturing veneer-based product using the thermally modified wood; (4) conducting the methodology on other wood species of interest. Some of the beneficial impacts of the project include:

1. A baseline towards improving the durability and dimensional stability of engineered wood products,
2. Proposing thermal modification, as an environmentally friendly method and feasible at industrial scale, to enhance the durability and dimensional stability,
3. Providing a database for the bonding performance of laminated thermally-modified wood,
4. Helpful skills gained by graduate student,
5. Offering industry a feasibility study on the opportunities and challenges of applying thermal modification in manufacturing of laminated wood products.

Budget

Budget justification & request for funding

Funds are requested to support a Graduate Research Assistant ($ 17,300).

$ 1,400 was requested for materials and supplies (e.g. resin).

- No fund is requested for the thermally modified wood samples and testing equipment.
- Thermally modified Western hemlock is already provided.
- All testing and analysis will be conducted at OSU.

BUDGET	AMOUNT
First Year Expenses	
GRA & Benefits	$ 17,300
Tuition & Fees	
Materials/Supplies	$ 1,400
Travel	
Other (specify):	
YEAR 1 TOTAL:	$ 18,700
Expected future request amounts:	

NEW RESEARCH PROPOSAL

Q-06-SC

Artificial intelligence integrated near-infrared hyperspectral imaging for rapid prediction of percent wood failure (PWF) in laminated wood products

PI(s): L. Schimleck, V. Nasir, I. Hafez and L. Muszyński | **Site:** OSU

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

Need & Industrial Relevance | Goals & Objectives

Need & Industrial Relevance

Rapid and accurate prediction of percent wood failure (PWF) in adhesive bonds is a crucial QC task, however accurate and rapid assessment is problematic. Owing to the importance of PWF there is strong interest in developing an alternative.

Research Roadmap Topics

The research proposed corresponds to Research Theme A. Improved Performance and Functionality, 3b. Performance Evaluation - Improved test methods.

Long Term Goals

Our goal is to utilize visible and near infrared hyperspectral imaging (Vis-HSI and NIR-HSI respectively) combined with artificial intelligence (AI) modeling to provide an objective, smart assessment of PWF in shear samples. Specifically, we are interested in using the spectral data collected from veneers prior to adhesive application and hot pressing to predict the PWF.

Objectives (year 1)

- An AI model for rapid evaluation of PWF based on hyperspectral image data.
- Evaluation of AI model performance based on different wavelength ranges.
- Vis-HSI and NIR-HSI data collection from veneer.

Materials and Methods

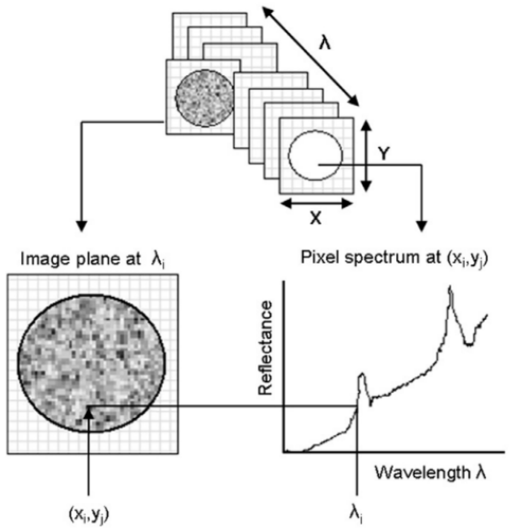


Fig. 1. Hyperspectral image cube (hypercube).

Hyperspectral imaging (HSI) combines spectroscopy and digital imaging generating a hyperspectral image (hypercube) of 3D multivariate data. Pixels in a hypercube may contain different spectral responses associated with different chemical compositions.

Two Specim Hyperspectral imaging (HSI) cameras will be used:

FX10 397-1004 nm, 448 wavelengths
FX17 931-1718 nm, 224 wavelengths
X-Y axis = 321x716 pixels, Z-axis = 448 (FX10) and 224 (FX17) wavelengths
(max. sample dimensions = 200 x 350 mm)

HSI data will be used for AI model development

- Deep learning (e.g. convolutional neural network)

Spectral data collected from veneer prior to adhesive application and hot pressing will be used to predict PWF. AI-based modeling of PWF, could be used for simulation of different layup scenarios, an important step towards an intelligent system for production planning.

J. Burger, A. Gowen / Chemometrics and Intelligent Laboratory Systems 108 (2011) 13–22

Outcomes and Deliverables

Expected Outcome	Deliverable (s)	2023			2024											2025											2026										
		O	N	D	J	F	M	A	J	J	A	S	O	N	D	J	F	M	A	J	J	A	S	O	N	D	J	F	M	A	J	J	A	S	O	N	D
Spectral data for AI model development	Vis-HSI and NIR-HSI data acquisition																																				
AI – based model for prediction of PWF	AI model development																																				
Veneer samples for use in second year project	Sourcing veneer for plywood (months 6-8)																																				
Spectral data from veneers for AI models	Vis-HSI and NIR-HSI data collection from veneer																																				

Expected Practical Implications/Impacts

- New approaches for estimating PWF based on NIR-HSI data collected from block shear samples.
- AI-based modeling and using deep learning eliminate the need for manual feature extraction/selection on spectral data.
- A potential new approach for estimation of PWF utilizing NIR-HSI data collected from veneers prior to plywood manufacture, an important step towards an intelligent production planning.

Budget

- We request funding for a graduate student (0.49 FTE). The totals provided are based on current costs associated with supporting a graduate student for one year at OSU College of Forestry.
- $1,500 are requested to support expected student travel (to visit partner facilities).

BUDGET	AMOUNT
First Year Expenses	
GRA & Benefits	$37,500
Tuition & Fees	$19,000
Materials/Supplies	
Travel	$1500
Other (specify):	
YEAR 1 TOTAL:	$58, 000
Expected future request amounts: $56,500	

Wood-Based Composites Center

NEW RESEARCH PROPOSAL

Q-07-RI

Vibrational and stress-wave methods for rapid and cost-effective assessment of veneer-based mass timber elements

PI(s): M. Riggio, V. Nasir | **Site:** OSU

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

Wood-Based Composites Center

Need & Industrial Relevance | Goals & Objectives

Need & Industrial Relevance

Pre- manufacturing design-based methods (i.e., K-method, Gamma method, SAM) for mass timber quality assurance are unable to confirm grade post-manufacture. Post-manufacture static tests are costly and time-consuming. There is a need for non-destructive testing (NDT) of mass timber elements both at the production stage and in use to: a) better QC; b) increase confidence in the product; c) validate analytical models; d) optimize products.

Research Roadmap Topics

Topic 2024-12
Evaluation of Mass Timber Products with transverse and/or longitudinal vibration techniques.
Topic 2024-11
System Effects in Mass Timber Products.

Long Term Goals

Developing an NDT method for mass timber elements as in-line quality evaluation tool for manufacturers, and, with adjustments, for on-site inspections and forensics.

Objectives

The specific objectives for the 1st year of the project are to:

1) Develop an experimental program for vibration-based and acoustic-based testing of veneer-based mass timber elements.

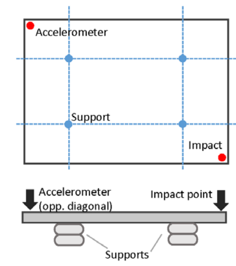
2) Collect and analyze NDT data from vibration and stress-wave (SW) testing for use in the second year to a) develop machine learning (ML) prediction models; b) validate the models against static bending data.

Materials and Methods

Vibration and Stress-wave NDT testing (first year)

Materials

- Veneer-based mass timber elements in structural dimensions (wooden species: DF)
- For VLT and MPP panels, typical length-to-thickness ratios (thin plate behavior[1])



Panel vibration test setup adapted from Faircloth et al. 2023

NDT Test setup

- Boundary conditions suitable for in-line system (e.g., all-sides freely supported conditions[2])
- Surface-mounted accelerometer and electronic impact hammer
- Point-wise, transverse through transmission for stress-wave time-of-flight
- Data collected with a sound and vibration data logger (NI) and processed with LabVIEW.

Data analysis

- Dynamic moduli determined using analytical techniques for beam-like and plate-like geometries. Rayleigh-Ritz method for thin plate analysis (determination of E_x, Ey and Gxy from 1st mode of vibration).
- Time-of-flight analysis of stress waves

[1]Zhou et al. 2020 and Opazo-Vega et al. 2021
[2]Faircloth et al. 2021

Outcomes and Deliverables

first year of the project.

Expected Outcome	Deliverable (s)	2024				2025										
		S	O	N	D	J	F	M	A	J	J	A	S	O	N	D
Material acquisition – grad student onboarding – NDT setup	Set up the experimental plan and setup															
Vibrational data for new LVL, VLT, MPL, and MPP elements	Vibration data collected															
Analyze vibrational properties of tested elements based on natural frequency from free vibration and determine dynamic moduli based on analytical solutions	Dynamic properties of the tested elements analyzed and dynamic moduli calculated.															
Stress-wave (SW) time-of-flight (ToF) data for new LVL, VLT, MPL, and MPP elements	SW data collected and ToF determined															
Analyze local vs global properties of the tested mass timber elements.	Correlate SW-ToF data and global vibrational data															
Static test setup	Static tests for NDT results initiated															
Dissemination of Phase I	NDT study presented at a relevant conference such as WCTE 2025 (vibration) and report on Phase I prepared for dissemination															
Initiate Phase II (weathering – NDT + static tests - Machine Learning analysis for prediction)	Experimental setup for NDT during weathering complete. ML analysis plan initiated.															

Expected Practical Implications/Impacts

The advancement of an effective NDT method for mass timber elements will have widespread positive impacts across the industry. These benefits extend not only to manufacturers and adhesive suppliers but also encompass developers, contractors, and insurance companies. Such innovation enables:

1. Implementing rapid, reliable, and cost-effective quality control in the plant.
2. Reducing the potential for litigation by more easily segregating below-standard products.
3. Increasing confidence in mass timber products and therefore their acceptance by the market.
4. Building a database of post-manufacturing panel properties.
5. Developing more accurate mechanical models, by using such a database.
6. Increasing material efficiency and improving production processes.
7. Identifying production and in-service factors affecting the product's quality and performance

Budget

Budget justification & request for funding

Funds are requested for a Graduate student at 0.49 FTE during academic year with equivalent summer appointment costs in year 1 using a base monthly salary of $4,874 for a total of 28,659. The graduate student will be responsible for data collection and analysis.
Fringe benefits for graduate student follow institutional approved guidelines and start at 34% in year 1 for a total of $9,774.

Graduate student tuition and fees are budgeted for 3 terms total with the per term academic year cost at $5,187 per institutional guidance.

Funds are requested for travel expenses incurred by the student to perform the research, including those needed for data collection at the partnering plants.

Funds are requested to ship test materials to OSU.

BUDGET	AMOUNT
First Year Expenses	
GRA & Benefits	$ 38,403
Tuition & Fees	$ 15,561
Materials/Supplies	
Travel	$ 1,536
Other (shipping costs):	$ 3,500
YEAR 1 TOTAL:	$ 59,000
Expected future request amounts: $ 60,000	

VGPT1

NEW RESEARCH PROPOSAL

Q-08-LE

Optimization of log conditioning and peeling process and real-time monitoring of veneer surface roughness

PI(s): S. Leavengood, V. Nasir, M. Riggio, L. Schimleck | Site: OSU

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

Need & Industrial Relevance | Goals & Objectives

Need & Industrial Relevance

Bonding performance of veneer-based wood products depends in part on veneer surface roughness, which is impacted by parameters related to log quality, log conditioning, and the peeling process. The combined effect of these parameters on the surface roughness is not well-understood and direct measurement of veneer roughness is challenging. Thus, there is a need to

(1) understand how different factors impact veneer roughness;
(2) develop a real-time monitoring framework for veneer roughness prediction; and
(3) predict the bonding performance of veneer-based products using veneer roughness.

Relevant WBC Research Themes

WBC RESEARCH THEMES : A3b, D4, D5

Long Term Goals

Development of an intelligent monitoring model for real-time estimation of veneer surface roughness using lathe vibration data and using veneer roughness information to predict bonding performance of veneer-based products.

Objectives

Specific objectives for the 1st year of the project are to:

1) Collect log quality and conditioning data.
2) Acquire lathe vibration signals during the peeling process.
3) Conduct data analytics and process lathe vibration signals.
4) Veneer roughness measurement (direct method).

Materials and Methods

Data Collection

Log parameters
• Length• Diameter (SE/LE)• Species• Sweep• Density (weight)• Stiffness (stress wave, UPT)• Heartwood/sapwood

Conditioning parameters
• Temperature• pH• time

Lathe parameters
• Time since sharpening• Knife angle• etc.

Vibration data
• signal segmented • de-noising • feature extraction/selection

Veneer roughness measurement
Method to be determined, 12”x12” specimens; likely will be done via optical profilometer

Data Analytics
• Impact of log parameters on vibration signal• Use extracted features to predict overall roughness• Establish roughness grade categories

Outcomes and Deliverables

Year 1

Expected Outcome	Deliverable (s)	2024				2025											
		S	O	N	D	J	F	M	A	J	J	A	S	O	N	D	
Log quality and conditioning data acquisition	Input dataset																
Vibration signal data acquisition	Sensory Dataset																
Veneer roughness measurement (direct method)	Roughness data (model output dataset)																
Data analytics	Pre-processed signals																
Dissemination of Phase I	Phase I progress report																
Initiate Phase II (AI and machine learning modeling, plywood fabrication, using roughness data for predicting the plywood bonding performance)	Phase II test plan																

WBC SPRING 2024 INDUSTRY ADVISORY BOARD MEETING Tuesday, March 5, 2024

Expected Practical Implications/Impacts

Development of an intelligent monitoring model for real-time estimation of veneer surface roughness using lathe vibration data and using the information to predict bonding performance of veneer-based products will lead to several beneficial impacts on the veneer-based products industry:

1. Provide a system for real time assessment of veneer lathes
    a) focused early in the manufacturing process – when opportunities still exist to make adjustments
    b) will include parameters related to log inventory
    c) improved knowledge (real-time) of knife condition
2. Data analytics will link wide variety of material and process parameters
3. Use of low-cost and robust sensors will help to speed industry adoption
4. Model developed will provide a solution to a current gap in the industry: assessment of veneer quality (specifically, roughness) on a larger scale
5. Skills gained will be very valuable for student

Budget

Budget justification & request for funding

Funds are requested for a Graduate student at 0.49 FTE during academic year with equivalent summer appointment costs in year 1 using a base monthly salary of $4,874 for a total of 28,659. The graduate student will be responsible for data collection and analysis.
Fringe benefits for graduate student follow institutional approved guidelines and start at 34% in year 1 for a total of $9,774.

Graduate student tuition and fees are budgeted for 3 terms total with the per term academic year cost at $5,187 per institutional guidance.

Funds are requested for the student to travel to the partner mill and to WBC meetings

BUDGET	AMOUNT
First Year Expenses	
GRA & Benefits	$ 38,403
Tuition & Fees	$ 15,561
Materials/Supplies	$ 2,500
Travel	$ 3,186
Other (specify):	
YEAR 1 TOTAL:	$ 59,650
Expected future request amounts: $ 60,000	

WBC Wood-Based Composites Center

NEW RESEARCH PROPOSAL

Q-09-NE

Enhancing Coating Performance on Profiled Medium-Density Fiber Boards (MDF)

PI(s): Mojgan Nejad, Chip Frazier, and Brian Love | **Site:** MSU/ VT/UM

Anticipated Start Date: ***May 2024*** | **Expected Duration:** ***12 Months***

WBC Wood-Based Composites Center

Need & Industrial Relevance | Goals & Objectives

Need & Industrial Relevance

How vertical density variation in MDF affects coating performance on profiled MDF panels?

Research Roadmap Topics

Topics 2024-1 & 2:
Address an issue raised by AkzoNobel and supported by MDF producers, especially Roseburg.

Long Term Goals

- Enhance the use of wood composites in higher-end cabinets
- Create a new center research capability that WBC members might value.

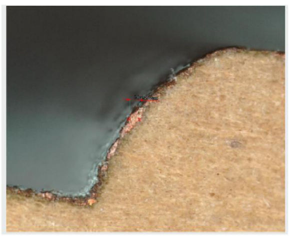
Objectives

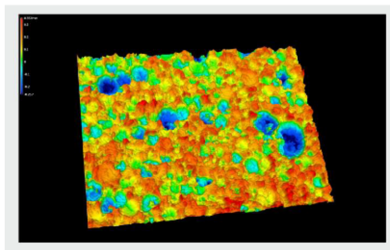
Establish 1st generation MDF-coatings analysis system and protocols.

Materials and Methods -1

1. Develop a protocol for measuring the surface properties of profiled MDF pre- and post- primer application (CLSM and 3D surface profiler).
2. Analyze the properties of solvent-borne primer, including surface tension (tensiometer), rheology (Rheometer), Tg (DCS), solid content, and contact angle on MDF and fresh profiled samples.

3D_ Optical Profilometer, Keyence

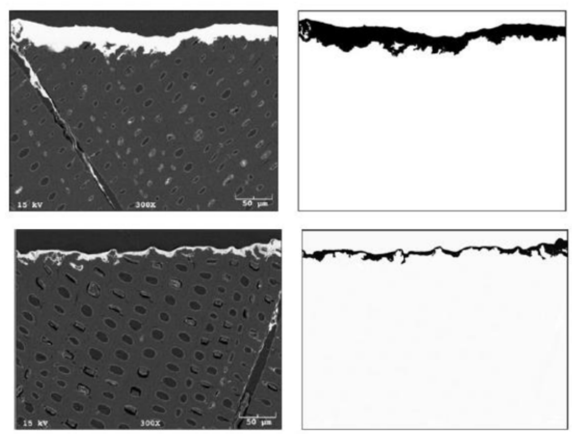




Materials and Methods-2

3. Assess the uniformity of primer coating film thickness when sprayed on various MDF profiles by analyzing cross-sections of OsO_4 stained samples in backscatter mode using SEM.

4. Find correlations between primer-film uniformity and MDF profiled roughness (using partial least square regression chemometric modeling).



Nejad and Cooper, J. Coat. Technol. Res., 8 (4) 459–467, 2011

Tasks and Timelines

Tasks	2024								2025			
	M	J	J	A	S	O	N	D	J	F	M	A
Analyze the MDF neat and profiled surfaces with 3D-Profiler.												
Measure the properties of the primer (i.e., Surface tension, Rheology, and Tg)												
Assess the uniformity of coating film sprayed on profiled MDF (3D-Profiler)												
Probe coating film thickness uniformity (cross-section SEM-BSE study)												
Modeling correlation between MDF vertical density & coating film thickness uniformity												

Expected Practical Implications/Impacts

- Develop protocols to visualize the effect of vertical density variation on profiled MDF
- Find the most efficient methods to assess coating's film uniformity spray on wood-composite (MDF) using various vertical density profiles. The same schemes can be used for Particle boards, OSB panels, etc.
- Modeling correlations between primer film uniformity and MDF profiled roughness

Budget

- Budget justification & request for funding
- Funds to support a full-time PhD student @MSU for 1 year, including research assistantship, tuition, fees, & fringe (total= $48,414).
- Travel expenses for that student to travel to WBC meetings ($3,000) to present work and network.
- $3,822 is requested to pay for lab consumables and equipment fees for 3D- Profiler, SEM, Tensiometer, and Contact Angle Measurements.

BUDGET	AMOUNT
First Year Expenses	$ 60,000
GRA & Benefits	$36,097
Tuition & Fees	$12,317
Materials/Supplies	$3,822
Travel	$3,000
Other (specify): Overhead	$4,764
YEAR 1 TOTAL:	**$60,000**
Expected future request amounts: TBD	

NEW RESEARCH PROPOSAL

Q-10-SC

Use of post-consumer wood waste for incorporation in wood-based panels: a state-of-the-art analysis

PI(s): L. Schimleck, M. Riggio, I. Hafez, G. Presley | **Site:** OSU

Anticipated Start Date: *10/2024* | **Expected Duration:** *9 months*

Need & Industrial Relevance | Goals & Objectives

Need & Industrial Relevance

Many countries have implemented policies prohibiting the disposal of wood in landfills and mandating the utilization of wood waste in various WBC products. In addition, the growing focus on cradle-to-grave EPDs necessitates exploring alternative end of life (EoL) scenarios for WBCs. However, integrating waste wood into new products faces numerous challenges, such as uncertainties regarding the consistency and provenance of the waste supply, as well as the presence of contaminants like preservatives, resins, and metals. **There is a need for standardized approaches for waste characterization and sorting, and for a better understanding on waste processing approaches and opportunities for utilization in new products.**

Long Term Goals

This project will provide a roadmap for future research and investments aimed at utilizing waste wood in WBC products, as well as optimizing current products to increase their recyclability, thus reducing their cradle-to-grave impacts.

Objectives

The objective of this project is to provide an updated, comprehensive and global perspective on wood waste management and utilization policies, technical solutions for waste wood quality control, segregation, decontamination, and recycling options. The focus is on waste generated from WBCs and their reuse in new WBC products.

Research Roadmap Topics

Contribution to topics related to waste utilization such as: **TOPIC 2023-4, TOPIC 2022-6, TOPIC 2021-2, and TOPIC 2020-9**

Materials and Methods

A survey of wood waste supply streams:

- Based on available data in a Pacific Northwest metro area and with a focus on WBC waste.

A systematic literature review on:

- C&D wood waste characterization and sorting methods, technologies and international standards.
- Methods and techniques for contaminant removal from different types of wood waste (including resins, treatments and metals among the contaminants).
- List of building products (both structural and non-structural) made using different wood waste streams and technologies and processes used (including additive and energy needed), and information on their environmental and technical performance.

To identify:

- Type and volume of construction and demolition (C&D) wood waste and, possibly, supply chain status (including waste sources, recycling outlets, demand trends and fluctuations).
- Most promising approaches for wood waste characterization based on wood waste categories.
- End-of-life scenarios for different wood waste categories.
- Wood waste pre-processing approaches for different contaminants and waste categories and other steps required to facilitate further reuse.
- Opportunities for improvement of current wood-waste based composite (WWBC) products and for development of new WWBCs.

Outcomes and Deliverables

Expected Outcome	Deliverable (s)	2024			2025											
		O	N	D	J	F	M	A	J	J	A	S	O	N	D
Survey of data from a PNW metro area	Wood waste supply survey														
Literature review of waste wood sorting techniques and methods	State-of-the-art analysis of waste wood characterization														
Literature review of waste wood processing (pre-recycling treatments)	State-of-the-art analysis of waste wood decontamination and processing methods														
Literature review of recycling techniques and available products using post-consumer wood fibers	State-of-the-art of waste wood – based composite products and future opportunities														
Final report identifying current best practices, challenges and opportunities for waste wood – based WBCs	Final report														

Expected Practical Implications/Impacts

The comprehensive review offered by this project will have broad positive impacts across both industry and academia. These benefits extend not only to WBC manufacturers, adhesive suppliers, coating companies, and other related sectors, but also to society as a whole. This knowledge will facilitate:

1. Identification of effective approaches for wood waste collection and segregation, particularly for contaminated waste and WBC waste.
2. Identification and enhancement of technologies and processes to increase the commercial viability of wood waste utilization, especially in the built environment.
3. Improved understanding of the opportunities presented by wood waste as a resource alternative to traditional wood sources.
4. Development of products with more competitive cradle-to-gate and cradle-to-grave environmental advantages.

Budget

Budget justification & request for funding

Funds are requested for a Graduate student at 0.49 FTE during academic year with equivalent summer appointment costs in year 1 using a base monthly salary of $4,874 for a total of $21,494. The graduate student will be responsible for the literature review and survey.
Fringe benefits (34%) for graduate student follow institutional approved guidelines and total $7,308.

Graduate student tuition and fees are budgeted for 3 terms with the per term academic year cost at $5,187 (per institutional guidance), for a total of $15,561.

$637 are requested for travel expenses incurred by the student.

BUDGET	AMOUNT
First Year Expenses	
GRA & Benefits	$ 28,802
Tuition & Fees	$ 15,561
Materials/Supplies	
Travel	$ 637
Other;	
YEAR 1 TOTAL:	$ 45,000
Expected future request amounts:	$ 0

NEW RESEARCH PROPOSAL

Project code: Q-11-PE

Robust fire test method for the performance evaluation of wood-based composites

PI(s): Zahra Naghizadeh, David Scarborough, Maria S. Peresin | **Site:** AU

Anticipated Start Date: September 2024 | **Expected Duration:** *12 months*

Need & Industrial Relevance | Goals & Objectives

Need & Industrial Relevance

- Knowing the fire resistance of wood-based materials is essential to minimize the impact of fires.
- The two existing standardized methods (E-84 and E-119) provide a uniform method for evaluating the fire resistance across the industry.

However, these tests:
1) Require large samples 2) Time-consuming 3) Expensive to conduct.

Research Roadmap Topics

- 2024-05
- Q-01-HI

Long Term Goals

- Create a feasible and fast pipeline for characterizing the fire performance of different wood-based materials
- Generate a database of the fire performance of wood-based products considering defects and imperfection in wood, wood composites and adhesive joints.

Objectives

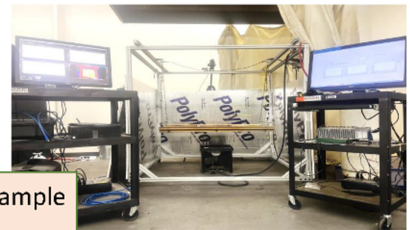
• Develop an inexpensive method for quickly and efficiently evaluating the fire resistance and flame spread properties of small samples of wood products.

• Understand how non-uniformities such as adhesive joints, knots, and cracks affect the fire resistance of the base material.

Materials and Methods

❖ Fire test set up:

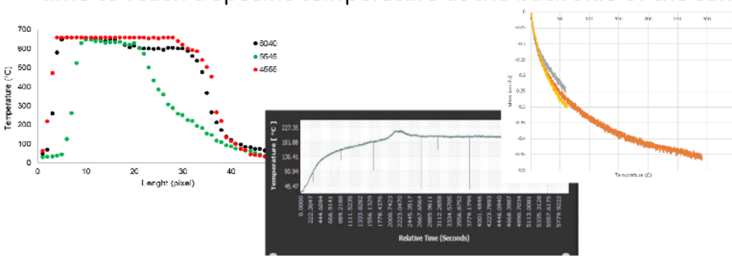
- Infrared thermal imaging
- Dynamic load cells
- Propane mass flow rate controller



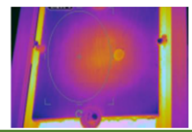
To simultaneously determine the temporal and spatial variation of sample surface temperature and temporal variation in sample mass loss.

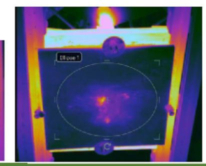
❖ The results will be reported as flame spread rate and mass loss per time to reach a specific temperature at the back side of the samples.

❖ A small-scale tunnel test, ASTM E84, to compare the results with and to validate the proposed method.



Testing this method for adhesive joints and will study the effect of defects (knots, cracks, etc.) in either wood or composite on the fire test results.





Outcomes and Deliverables

Task	Deliverable	2024				2025							
		S	O	N	D	J	F	M	A	M	J	J	A
Study different fire test geometries (vertical, horizontal, and angled) to evaluate wood products .	Fire test method development	■	■	■	■	■	■	■	■				
Develop a small version of the tunnel test to compare and validate the results	Mini tunnel test prepared	■	■	■	■								
Study the effect of the wood products' defects on the test results.	Data on the effect of wood/composite defects					■	■	■	■	■			
Evaluate the proposed method and approach for adhesive joints.	Test method for adhesive joints					■	■	■	■	■			
	Final WBC report										■		
Peer Reviewed Publication	Publish data summary in 1-2 publications											■	■

Expected Practical Implications/Impacts

1) Method development:

Develop fire test protocol and a method to quickly evaluate the fire performance of different wood-based materials under different fire geometries, scenarios, and intensities.

2) **Data produced**:

- The effect of the wood products' defects on their fire performance as well as on the test results.
- The effect of glue-line imperfection in mass timber on the fire test results.

3) **Supporting Masters student**

Budget

Funding for Future Masters Student

GRA & Benefits
12 months of Masters Student

Tuition
10%

Materials Costs
General Lab Supplies

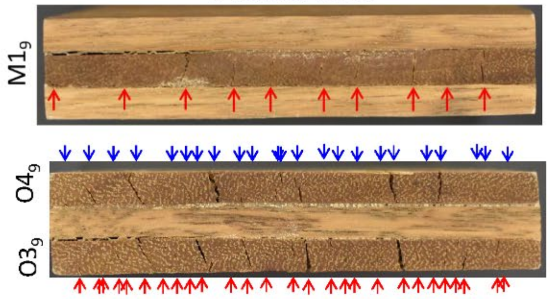
Budget	Amount
First year expenses	$52,599
GRA & Benefits	$22,920
Tuition and Fees	$2,300
Materials/Supplies	$7,000
Travel	$9,000
Others (specify)	
Year 1 total	$52,599
Expected future request: $52,599	

NEW RESEARCH PROPOSAL

Q-12-FR: Simple cross-laminate adhesive durability test

Frazier, Dillard (VT), Peresin & Gururaja (AU), Nairn (OSU)

3-ply cross-laminated spotted gum
5 x 70 x 70 mm



Anticipated Start Date: *9/2024* | **Expected Duration:** *24 Months, MS project*

Need & Industrial Relevance | Goals & Objectives

Need & Industrial Relevance

The industry needs new wood adhesion testing with a stronger foundation in mechanics, where specimen mechanics are very well understood; this gives greater insight when interpreting results.

Research Roadmap Topics

Hopper topic 2024-11:

- System Effects in Mass Timber Products

WBC research theme:

- Improved Performance and Functionality; Performance Evaluation; b, Improved test methods.

The **critical delam-crack density** varies with :

- mode-II toughness of the adhesive (different adhesives, or wood treatments),
- mode-I wood toughness (different density/porosity woods).

Provides ability to rank:

- **Adhesive durability;**
- **impact of wood density,**
- **impact of surface treatments.**

Long Term Goals

Determine how well Finite Fracture Mechanics (FFM) applies to bonded wood; use results to determine if we should work towards official ASTM certification.

Materials and Methods

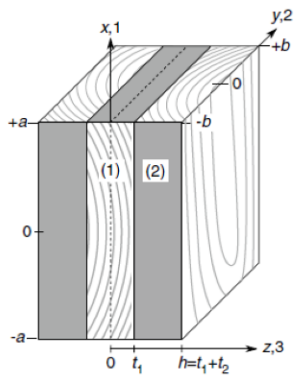


Fig. 1 Unit cell for a CLT panel with orthogonal cracking in all layers. The gray planes mark the crack surfaces (one on each end of each layer) with normals perpendicular to wood grain direction in each layer. Layer 1 is core layer with thickness $2t_1$ and cracks separated by $2a$. Layers 2 are surface layers with thickness t_2 and cracks separated by $2b$. Axes (1, 2, 3) are used to refer to panel properties while (x, y, z) refer to layer properties

European Journal of Wood and Wood Products (2019) 77:405–419
https://doi.org/10.1007/s00107-019-01399-7

ORIGINAL

Predicting layer cracks in cross-laminated timber with evaluations of strategies for suppressing them

John A. Nairn[1]

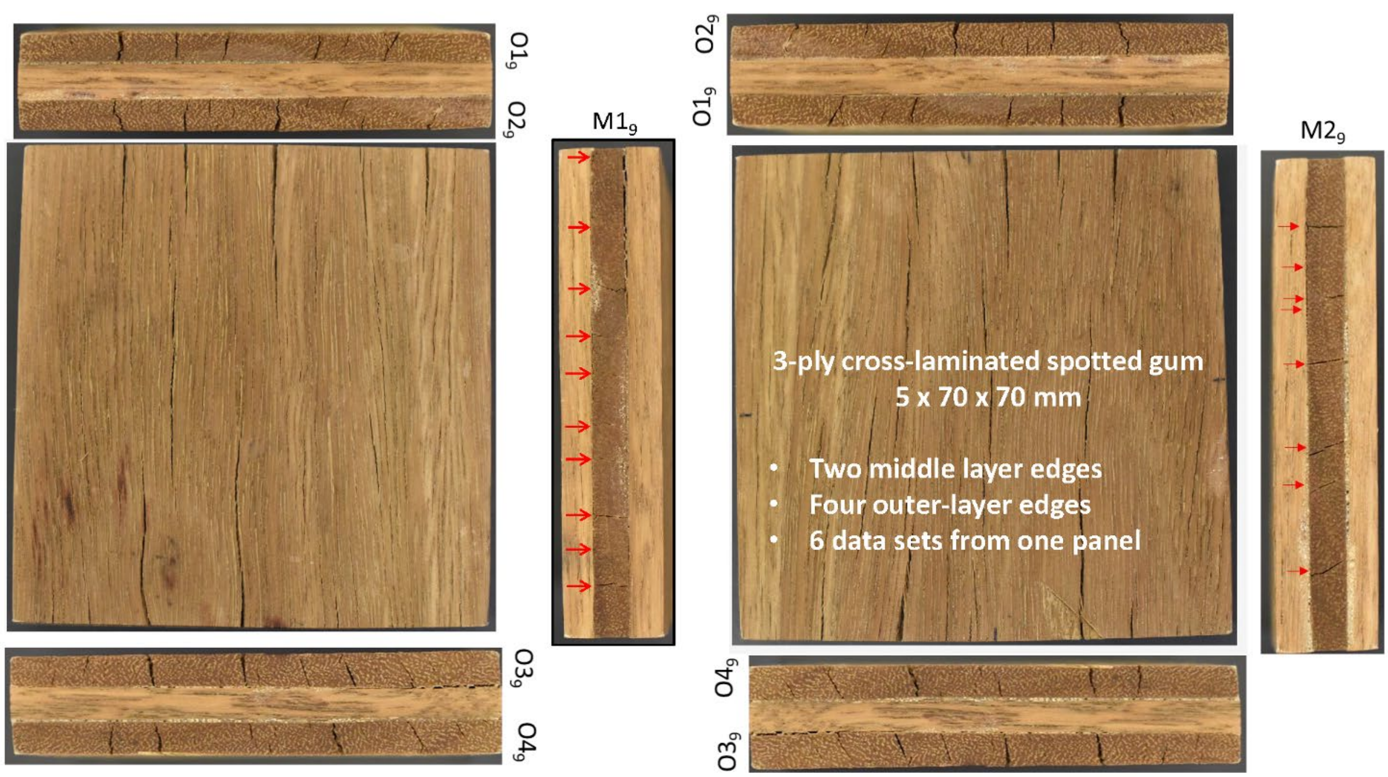
Received: 29 January 2018 / Published online: 26 March 2019

4x4 inch, 3-ply cross-laminated panel;
layer thickness, varied over 2 levels:
0.75 and 0.25 inches.

Lumber: high-grade, mature southern pine
Adhesive: Moisture-cure polyurethane

Year 1 goals:

- Machine & sort wood specimens by quality & density.
- Manufacture vacuum/pressure weathering chamber.
  - Cycle from water saturation to dry at 60C w/ vacuum
- Measure wood tensile modulus for FFM model.
- Make panels and start delamination testing.



Outcomes and Deliverables

Insert outcomes and deliverables using table below.
Please focus on first year of your project.

Expected outcome	Deliverable(s)	2024 A	2024 S	2024 O	2024 N	2024 D	2025 J	2025 F	2025 M	2025 A	2025 M	2025 J	2025 J
Wood acquisition	Sorted by grade & density												
Manufacture vacuum/pressure weathering chamber.	vacuum/pressure weathering chamber												
Measure wood tensile modulus for FFM model.	FFM model												
Start delamination testing.	Preliminary data												

Expected Practical Implications/Impacts

This project will determine how well Finite Fracture Mechanics applies to bonded wood.

Because the specimen mechanics are so well known, we should achieve more quantitative insight on delamination durability.

BUDGET	AMOUNT
First Year Expenses	
GRA & Benefits	$41,253
Tuition & Fees	$17,500
Materials/Supplies	$7,000
Travel	$1,000
Other (specify):	Not including OSU/VT indirect
YEAR 1 TOTAL:	$66,753
Expected future request amounts: ***$66,800 for year 2***	$