New Research Ideas

# LIFE FORMS Summary

Response Rate: 100%

Wood-Based Composites Center

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## Level of Interest

| Title | Very Interested | Interested | Interested with Change | Not Interested | Abstain |
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## Q-01-HI: Identifying Adhesive Bondline Quality to Improve Cross-Laminated Timber Performance

**Project Phase: New Research Idea**

**Project PI: Daniel Hindman & Audrey Zink-Sharp (VT)**

| Level of Interest | Count | % |
|---|---|---|
| Very Interested | 1 | 8% |
| Interested | 7 | 58% |
| Interested with Change | | |
| Not Interested | 2 | 17% |
| Abstain | 3 | 17% |
| | | **100%** |

### Questions

- What is the adhesive? What is the wood species? Will the wood layers be orthogonal to one another?

  ***Response:*** *Our previous work used polyurethane adhesive, which was typical of current CLT industrial manufacture. Species studied included southern pine and yellow-poplar hybrid CLT. The proposal did not specifically limit the study to a particular adhesive or species. For this study, we have chosen to focus on orthogonal CLT materials. However, we believe the procedures used would be applicable to a wide variety of composite materials.*

- How long does it take to perform the microscopy procedure on each specimen? I am wondering how many can be practically evaluated throughout the course of this study.

  ***Response:*** *We have completed several adhesive bondline studies in our lab at Virginia Tech in the past few years and have established procedures in place. Our experience indicates that 10 microscope slides can be prepared and analyzed with digital microscopy in one 8-hour lab day. Past studies encompassing adhesive penetration and bond thickness of 60 test specimens with 20 slides made per specimen equates to an average of 6 months of lab work. As a result, we anticipate 60 specimens can be analyzed over the course of the study.*

- There was a study made by Jesse Paris that tackles similar issues. Will this be a continuation of this applied to CLT?

  ***Response:*** *We are familiar with Jesse Paris' work and several other investigations of bondline properties and appreciate the techniques and results provided. We are proposing to rely on this background and also apply procedures established in our lab specific to CLT specimens. A new technique to assess microbubbles in the CLT bondlines has been established and outlined in a manuscript titled "Comparison of Microscopy and Quality Control Testing To Examine the Durability of Adhesive Bondlines in Cross-*

*Laminated Timber" co authored by Hindman, Zink-Sharp et al. submitted recently to the Journal of Building Engineering.*

- Will you also be looking at resin impact or purely process parameters? How will the samples be prepared both from a bond choice perspective and a microscopy prep perspective? How will you account for the impact of compounding factors such as wood densification that occurs during pressing?

  ***Response:*** *To measure the microscopic properties of each CLT bondline, a set of slides will be prepared. For each CLT, 10 microscopy blocks 10 mm × 10 mm on the surface and 20 mm long will be randomly taken from bondlines in each CLT to provide specimens with longitudinal and transverse directions. A GSL-1 sliding microtome will be used to cut thin sections approximately 30 µm thick. Sections will be stained for 2 minutes in an aqueous solution of Safranin O stain (0.8%). Excess stain will be washed and blotted from the samples with distilled water. Slides will be examined with a Nikon Eclipse LV 100 light microscope equipped with a Nikon DS-Fi1 camera and BR Nikon imaging software.*

## Suggestions

- The study plan references PRG-320. PRG-320 is for qualification of CLT; do not constrain the study trying to stay within the scope of PRG-320. The study results will have implications for products such as veneer-based CLT products and glulam beams.

  ***Response:*** *We proposed the study of CLT given the current research interest and body of work surrounding CLT. PRG-320 quality control measures are similar to ANSI A 190.1 for glued-laminated timber. The two quality control tests discussed in the methods section are also used for glued-laminated timber evaluation.*

- Will the formulations of the resins used be commercially available or custom? Are defoamers or deaerators commonly used to control air release during application and bonding?

  ***Response:*** *We would be open to industry suggestions for particular adhesive solutions. The main focus of this project is to develop correlations between the bond performance and quality control testing. However, future work could explore the effects of additives, different pressing conditions or use of defoamers or deaerators. The image analysis methods used should be especially applicable to investigate the performance of defoamers or deaerators.*

- Besides CLT, could the bond analysis be broadened to MPP and LVL, or plywood?

  ***Response:*** *Yes, we believe that this process could be broadened to the study of other materials. Our research approach was to focus on a single material to further develop the evaluation methods, then propose a follow-up project exploring the limits of wood composites which could be applied. However, we see no problem with applying these methods to MPP, LVL or plywood.*

- When quantifying adhesive penetration, all the current methods are inferior to one where image analysis is used to parse every pixel of the microscope image as wood, void, and adhesive, and then provide % of each as a distance from the glue line. This would provide much more information, and potentially improve the conclusions, relative to the standard penetration measures. For discussion, see Chris Hunt, FPL.

  ***Response:*** *Our analysis methods for adhesive penetration did use image analysis. Thank you for the reference, and we will include discussions with Chris Hunt in the project.*

## Comments

- CLT manufacturers do not use hot presses. There are microwave and radio frequency options to cure the glue lines. Mostly, it is a cold-press operation.

  ***Response****: Because we are performing an analysis of the cross-sections after panel consolidation has taken place, we do not foresee the individual pressing method as a limitation. In future projects, we expect to expand to different adhesives, and pressing systems.*

- This is an interesting idea. Linking QC results to detailed bond performance is meaningful for the industry.

  ***Response****: The authors feel that the further development of quality control and bond analysis is important to improve the performance of adhesives and structural products.*

- Interesting subject area. The use of digital images is not mentioned. The assumption is that a digital image process will be used for quantification. Will the grain angle of the adherents be controlled or randomly selected?

  ***Response****: Image analysis and processing is a key portion of this project. Given the size of the proposal document, we were not able to explain the methods in greater detail. However, we have used image analysis and RHINO 3-D rendering software to measure the area of adhesive penetration in the images.*

- Interesting idea that is useful to industry. I think it will introduce some questions as to why the poor bonding occurs when it does and hopefully, this methodology is capable of answering those questions.

  ***Response****: Thank you for this comment. Current results from our study of the microscopic features of the adhesive bondline and the quality control testing of CLTs demonstrates the effect that different manufacturing factors contribute to bonding strength. The effect of wood anatomy in penetration was observed in the mixed species CLT made of southern yellow pine and yellow-poplar. The adhesive amount and pressure applied during manufacturing contributed to the adhesive line thickness, evidenced by comparing two southern pine CLTs. When considering the shear strength in different CLTs, the penetration depends more on the adhesive type, pressure, and wood anatomy. The CLTs with high effective penetration and thin adhesive lines gained better shear strength and delamination resistance.*

*The quality of adhesive curing appeared in the bondlines as adhesive line thickness, penetration and microbubbles in the adhesive line, possibly indicating an imperfect control of manufacturing parameters that created bubbles or gaps. The adhesive penetration had the highest coefficient among other microscopic properties affecting the shear strength, wood failure, and delamination of the CLTs.*

- We don't make CLT so not relevant to us.

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

**Project Phase: New Research Idea**

**Project PI: Gerald Presley, Laurence Schimleck, John Simonsen, and Islam Hafez (OSU)**

| Level of Interest | Count | % |
|---|---|---|
| Very Interested | 2 | 17% |
| Interested | 5 | 42% |
| Interested with Change | | |
| Not Interested | 4 | 33% |
| Abstain | 1 | 8% |
| | | **100%** |

### Questions

- Will the impact of the treatment on the surface free energy of the treated substrate be measured? It would be interesting to know if the surface free energy is impacted as it may impact further treatment in the field?

  ***Response**: We can measure the impact of treatment on contact angle of resins applied to the wood surface*

- It will be interesting to evaluate both strands and DF and SYP veneers to see the efficacy of treatments in veneer products. Adding an AWPA E1 test will be good, as Sor-CA treatments have been qualified for termite protection. This may become a better indicator of the treatment efficacy.

  ***Response**: An E1 test would have to be outsourced to another lab that maintains termite testing facilities. Mississippi State University would be the one. If we did this we would have to budget for the additional expense but it is possible. Veneer treatment would also be easy to try and we could include this in the study.*

### Suggestions

- Measurement of surface-free energy before and after treatment may provide additional insight.

  ***Response**: We can certainly do this using a contact angle analyzer*

- Douglas fir can be extremely hard to impregnate, as can southern pine heartwood. I am concerned about getting the treating chemicals into the 2x4s – I don't see why aspirated pits won't block Sor-CA just as it will other treatments. The samples from the 2x4's needs to be distributed between

heartwood and sapwood/ aspirated vs open pits/ treatable vs nontreatable. Seems like much is already known about Sor-CA and that this is a minor extension.

- ***Response**: You bring up some good points. Typically when we do these types of small scale projects we isolate sapwood for treating which is not necessarily representative of what actually gets treated. I think a better way forward may be to limit this project to strands and veneers. That way permeability issues are reduced because of the high surface:volume ratio of the material. While heartwood is not easily treatable, it sill can take on waterbased chemical solutions given enough time for diffusion or if we are treating high surface area composite feedstocks. The total amount of solution that can be taken up is lower, but perhaps we can reach the necessary uptakes by increasing treating solution strength.*

## Comments

- Has the effect on above-ground exposure been considered? May want to consider overall water repellency testing, in addition to standard thickness sell. Potential use of ASTM D4446 or perhaps D5401. Granted these tests are targeted toward surface treatments of solids wood…it would be interesting to evaluate how they perform with wood composites. This may provide additional insight.

  ***Response**: I think the general consensus would be for us to do some more characterization of surface energy and the impact of the treatment on surface characteristics.*

- I am glad to see an updated experimental plan based on learnings from previous studies and think that this is an interesting study. Our low-interest rating reflects where this topic is on our priorities list, not how the project was presented.

- Please provide industrial relevance in terms of cost efficacy. 40% weight gain means a significant cost increase. How would that make this product relevant? Can we achieve a more practical loading level (~ 5% or below) and get tangible benefits?

  ***Response**: The 40% value is based off of the processes used to treat whole lumber in Europe with this method. From a durability perspective, high weight gain is required for this technology to generate a highly durable product. However, that does not mean we would not see any improvement at lower loadings, especially for properties like dimensional stability. I don't think these technologies will do much to improve durability below 5% weight gain. We could try a range of 5-20% as we did with the DMDHEU project, but going much lower is not likely to show any measurable increase in durability.*

- Rather than simply measuring the macroscopic physical properties, can you look at the cure kinetics of resin in the presence of these additives? How about effects on surface energy and resin rheology, penetration?

  ***Response**: We can certainly look at some of these but are limited with what we can access at OSU. We do have access to a DMA machine, but the cooling function for the unit is not operational so we will have some limitations with temperature control. We do have a DSC in the College of Engineering and should*

*be able to access that equipment. DSC could be used to measure the change in Tg and cure rate resins in the presence of modified wood powder of 0-20% weight gain from citrate-sorbitol treatment. Jason Weiss in the College of Engineering has also just purchased a TA HR20 Rheometer and we could try using this method to measure differences in several resin properties (Tg, G', storage/loss modulus curves) in the presence of wood treated with different loadings of citrate-sorbitol.*

- Curious to see results.

## Q-03-HA: Microwave heat treatment of wood: characterization and process optimization

**Project Phase: New Research Idea**

**Project PI: Islam Hafez, Wenjia Wang, and Gerald Presley (OSU)**

| Level of Interest | Count | % |
|---|---|---|
| Very Interested | 3 | 27% |
| Interested | 5 | 45% |
| Interested with Change | 1 | 9% |
| Not Interested | 2 | 18% |
| Abstain | | |
| | | **100%** |

### Questions

- What is the moisture content of the lumber and veneer?

  ***Response**: The plan is to test various moisture contents at different microwave powers and study their combined effect on the properties of lumber and veneer. In addition, the modeling study will be useful in predicting the heating profile for various moisture contents.*

- How will dimensional stability be quantified? dimensionally or gravimetrically?

  ***Response**: Dimensional stability will be quantified by measuring the dimension changes after exposure to a relative humidity (95%) after reaching equilibrium. Additionally, we will measure the change in dimensions after soaking in water and drying.*

- Does it make sense to understand the bond integrity as well? Could the microwave heat plasticize lignin? Will FTIR detect that? Is there a correlation of the treatment time planned for the study?

  ***Response**: Yes, understanding the bond integrity is part of this project. It is possible that the microwave heat would result in plasticization of lignin, this remains to be answered in this project. FTIR could provide preliminary information of the chemical changes resulting from heat treatment.*

- Microwave pre-treatment is common in structural composite lumber (SCL) manufacturing. Is there existing literature that discusses bonding implications for SCLs after microwave treatment?

  ***Response**: Published work discussed the drying of wood using microwave but not the effect of microwave heating on bond integrity, which remains to be answered in this project.*

- How are you going to deal with steam pressure? Thermal modification requires temperatures 160c and higher, where steam pressures are very large, potentially blowing samples up. Seems you will need uniform and low MC at start.

  ***Response**: It is not clear how the moisture content and microwave power will affect the properties of the treated samples, this will be answered in this work.*

## Suggestions

- Is there potential to include a non-destructive evaluation before and after treatment? The Metriguard 239A Stress Wave timer could prove valuable and be a method to evaluate MOE.

  ***Response**: Thank you for your suggestion. The goal of this project is to provide preliminary information of the changes in wood samples as a result of heat treatment through microwaving. Including an NDE was not within the scope of this project. However, this could be a valuable addition to the following parts of this study.*

- It would be interesting to evaluate the impact the treatment has on the surface free energy of the substrate. Is the hydrophilicity of the treated substrate less than or the same as the control? This is inferred; not explicitly stated. It would also be interesting to include a cost/benefit analysis compared to existing methodologies.

  ***Response**: Yes, this is within the scope of work and we will be examining the surface free energy. We will include some estimation of the cost compared to existing technologies.*

- Besides DF, it will be good to include SYP veneers. Does it make sense to understand the bond integrity as well? It will be good to add light microscopy to visualize potential changes in the wood structure after the microwave treatment.

  ***Response**: Thank you for your suggestion, we definitely can include SYP veneers. Yes, understanding the bond integrity is part of this project. Thank you for the suggestion of the light microscope.*

- The adhesive manufacturers that work with SCL manufacturers who use microwave pre-treatment may have some insight to share when developing the experimental plan.

  ***Response**: Thank you. Yes, I have discussed this topic with companies that use the microwave system for pretreatment.*

- Interesting concept. This could lead to other chemical crosslinking inside the wood without causing significant thermal damage on the surface.

  ***Response**: Thank you. This is correct, the key difference between microwave and conventional ovens heating is the mechanism of heat transfer; which presents an opportunity for efficient thermal modification and chemical crosslinking.*

- Consider timber cross-sections vs. lumber for deep-penetration studies.

  ***Response**: Thank you for your suggestion. We will consider this in the project.*

- You will also have to address knots specifically: with their high concentration of resins, I'm guessing they are likely to overheat once the MC gets low, as they will absorb much more than low extractive zones.

  ***Response**: Very good point. Thank you for sharing it.*

## Comments

- Would need to consider various moisture content. Need more information, how practical would this be?

  ***Response**: The plan is to test various moisture contents at different microwave powers and study their combined effect on the properties of lumber and veneer. In addition, the modeling study will be useful in predicting the heating profile for various moisture contents.*

- I think applying the microwave approach for the purpose of investigating dimensional stability is worth investigating and could lead to some interesting characterizations of chemical changes caused by the process.

  ***Response**: Thank you.*

- Heat treatment tends to relate to biological resistance (e.g., crates and pallets) in addition to being used to describe a method used to provide dimensional stability. Thermal modification imparts property enhancement as an alternative to preservative treatment. This project focuses on thermal modification, not necessarily heat treatment, using microwave energy as the source of thermal modification, but title uses heat treatment in the description.

  ***Response**: Thank you for the clarification and we will make sure to make this clear in the final proposal.*

- Its unfortunate that it does not seem possible to monitor the temperature inside the wood during microwave treatment, as none of the temperature sensors that I know of are compatible with microwaving. Finding a temperature sensor that works in the microwave would be a great benefit. Dielectric analysis of the wood components (especially checking rosins) might be able to find a frequency that is equally absorbing for all wood components. A frequency that absorbs uniformly would result in more uniform heating. Standard microwaves are tuned to a strong absorption band in water, not necessarily wood.

  ***Response**: We agree that finding a temperature sensor that works in the microwave would be beneficial. As part of this project, we will attempt to find commercial temperature sensors that could be used in the study.*

- Would be interested in in the plywood veneer aspect, but curious/skeptical if with plywood veneer if you can still modify the veneer core without affecting the surface

## Q-04-WA: Modeling of moisture-induced deformation and inverse optimization of wood panel design

**Project Phase: New Research Idea**

**Project PI: Wenjia Wang, Islam Hafez, and Mariapaola Riggio (OSU)**

| Level of Interest | Count | % |
|---|---|---|
| Very Interested | 1 | 9% |
| Interested | 1 | 9% |
| Interested with Change | | |
| Not Interested | 7 | 64% |
| Abstain | 2 | 18% |
| | | **100%** |

### Questions

- Is the goal to develop a model that would be applicable across panel types or targeted at a specific type? Internal or external exposure? Above or below grade (within building envelope)?

  ***Response:*** *Thank you so much for this question. Yes, the goal is to develop a model that would be applicable across different panel types. External exposure will be the focus at the beginning stage. Both above and below grade can be considered. Thanks!*

- Will you be able to extract the relevant diffusion and dimensional stability coefficients/mechanical parameters from literature or do these need to be gathered experimentally? I think it is an interesting project that can build on previous WBC-funded research. I think the timeline is ambitious if more than a couple of wood panel types are to be used, particularly on the experimental validation side of things. Would it be beneficial to focus on completing the work for veneer-based panels in this work and then switch focus to other types of wood panels in a follow-up study?

  ***Response****: Thanks very much for the comments! Yes, we will first try to collect relevant data from literature. Yes, we can focus on the veneer-based panels first and then study other types of wood panels. Thank you very much!*

### Suggestions

- Define inverse optimization.

  ***Response****: Thanks very much for this comment. The inverse optimization means that we consider the moisture-induced behavior of the panel when we design the layer sequence, material components for each layer, and thickness of each layer for this panel. In other words, we can use the understanding of moisture transport in wood structures to help us optimize the design of wood panels so that to minimize the potential of moisture-induced deformation of this panel. Thanks.*

- If you are going to measure the deformation of assembled panels to validate the model, then to do this properly, you should first obtain the deformation response of each layer in the panel. This can be done by digital image correlation (2 cameras to obtain 3D shape and dimensions of boards) when exposed to RH changes without restraint, and use that information to build accurate models of the stress in the panel upon assembly. Without this there will be a lot of error in the model parameters for each panel, resulting in noisy data.

  ***Response**: Thanks very much for your suggestions and comments! Very helpful suggestions! Many thanks!*

## Comments

- It would be good to be more specific about panel type being evaluated. Plywood, OSB, particleboard, MDF, etc. Is the goal to develop a model that would be applicable across panel types or targeted at a specific type? Internal or external exposure? Above or below grade (within building envelope)?

  ***Response**: Thank you so much for this comment. Yes, the final goal is to develop a model that would be applicable across different panel types. We will focus on a specific type of panel first, such as veneer-based panels, and then study other types of panels. External exposure will be the focus at the beginning stage. Both above and below grade can be considered. Thanks!*

- A couple of previous WBC projects by VT dealt with modeling and modeling validation of moisture-induced deformation. Reviewing those and reformulating the project as a follow-up rather than a new idea will be good.

  ***Response:** Thanks very much for this comment and helpful suggestion! Thanks!*

- What specific benefits will be learned from this work vs. work already in literature?

  ***Response**: Thanks very much for this comment. This work will help us understand the moisture transport in wood panels and an improved model of moisture-induced deformation will be developed. Also, this work will propose the strategy to optimize the design of wood panels to avoid severe moisture-induced deformation when used in humid environments. Thank you!*

- I'm very surprised that such models aren't already in use. Moisture transport in wood is non-Fickian. The model is based upon Fickian diffusion. Therefore, you are already starting out with a flawed model.

  ***Response**: Thank you very much for this comment. We will first use the moisture transport models reported in literature for numerical simulation. Then we will improve the models by considering more detailed moisture absorption-desorption characteristics. Thanks very much!*

- Not relevant to our business, but potentially of interest to panel producers.

  ***Response**: Thank you very much!*

## Q-05-NA: Using thermally modified wood for manufacturing mass timber elements with improved dimensional stability

**Project Phase: New Research Idea**

**Project PI: Vahid Nasir, Lawrence Schimleck, Islam Hafez, and Scott Leavengood (OSU)**

| Level of Interest | Count | % |
|---|---|---|
| Very Interested | | |
| Interested | 3 | 25% |
| Interested with Change | 3 | 25% |
| Not Interested | 6 | 50% |
| Abstain | | |
| | | **100%** |

### Questions

- How are you going to identify what wood with minimal reduction in wood?

  ***Response**: We appreciate having clarification on the question enabling us to better address it. Do you mean a reduction in wood properties such as mechanical properties?*

- What gravimetric and volumetric test methods for water absorption are going to be used? Will the surface free energy of the treated substrate(s) be measured and compared?

  ***Response**: According to the ASTM D1037-12 standard, treated and untreated samples will be submerged in 20°C water at room temperature. The samples were weighed and their dimensions were measured before and after immersion in water for 24 hours. Finally, all samples will be oven-dried at 103±2°C for 24 hours, and their dimensions and weight were measured again. Water absorption (WA) of specimens was calculated as:*

  *WA (%) = (W_s-W_o)/W_o ×100*

  *where ws is the wet weight of samples after soaking in water and wo is the oven-dry weight. The volumetric swelling coefficient (VSC) of treated and untreated specimens was calculated as:*

  *VSC (%) = (V_s-V_o)/V_o ×100*

  *where Vs is the volume after wetting with water, and Vo is the oven-dried volume of the samples.*

- What is the relevance of adding OSB panels to the experimental plan? How do you plan to account for the extractive factor on bonding after treatment?

  ***Response**: Based on the given comments, and to have a deeper focus on the laminated timber products, we will remove OSB from the scope of this project.*

- Why was Western hemlock chosen? If it's just because there is existing work with that species I would suggest using southern pine or Douglas-fir since they are more utilized for laminated structural products (southern pine would make the most sense since it is also utilized for OSB).

  ***Response**: There are several factors on choosing to focus on Western hemlock for this project. Apart from the relevant experience with this species, this is a critical species for the manufacturer of the ThermoWood; our industry partner. This will provide opportunities in which novel applications give added-value to this softwood species. As the total duration of the project is 1 year and considering the budget requested ($17,565), it should be best to focus on one wood species. This project serves as a feasibility study; however, promising outputs facilitates expanding the scope of project in the future and covering other wood species as suggested.*

- How does this project build upon previously published work? What is different from what has already been done?

  ***Response**: Previous research showed improvement of dimensional stability of Western hemlock following thermal modification. The reduction on the stiffness and hardness was also insignificant, which is promising as such reduction was commonly reported in the literature for some other wood species. Yet, literature lacks studies on using thermally modified Western Hemlock wood to make laminated timber products. We aim to answer the below main questions:*
  - *How thermal modification will impact the dimensional stability of the manufactured mass timber element?*
  - *How thermal modification will impact the mechanical performance of the manufactured mass timber element?*
  - *What could be done to improve the bonding? What would be the role of surface treatment and variation in surface roughness in glue penetration and bond quality?*
  - *If the manufactured product does not show satisfactory mechanical performance, could we consider making hybrid system using both the treated and non-treated wood?*
  - *Could the project be expanded to other species of interest? How about opportunities of thermal modification in veneer-based products?*

## Suggestions

- Use non-destructive techniques to evaluate the wood along destructive testing.

  ***Response**: Noted. NDT methods such as infrared spectroscopy and stress wave methods will be used.*

- Although there is prior data with Pacific Coast western hemlock, it will be good to add into the experimental design more commercial woods like DF, white fir, poplar, red pine, etc.

- ***Response**: Thanks for your suggestion. As the total duration of the project is 1 year and considering the budget requested ($17,565), we need to keep our focus on western hemlock as an available option. This project serves as a feasibility study; however, promising outputs paves the way for expanding the scope of project in the future and covering other wood species as suggested.*

- Please describe how this project work builds on previous work and define what new elements are expected to be learned. Would focus on CLT work because durability improvement is needed for CLT.

  ***Response**: Previous research showed improvement of dimensional stability of Western hemlock following thermal modification. The reduction on the stiffness and hardness was also insignificant, which is promising as such reduction was commonly reported in the literature for some other wood species. Yet, literature lacks studies on using thermally modified Western Hemlock wood to make laminated timber products. As suggested we will focus on CLT and aim to answer the below main questions:*
  - *How thermal modification will impact the dimensional stability of the manufactured mass timber element?*
  - *How thermal modification will impact the mechanical performance of the manufactured mass timber element?*
  - *What could be done to improve the bonding? What would be the role of surface treatment and variation in surface roughness in glue penetration and bond quality?*
  - *If the manufactured product does not show satisfactory mechanical performance, could we consider making hybrid system using both the treated and non-treated wood?*
  - *Could the project be expanded to other species of interest? How about opportunities of thermal modification in veneer-based products?*

- Dimensional stability of OSB is very important. Mass timber has less dimensional stability concerns. Focus on OSB and drop mass timber focus.

  ***Response**: Thanks for your suggestion. Some other comments suggested focusing on the mass timber elements. Due to the project duration (1 year) and the requested budget ($17,565), we decided to focus on the laminated sawn timber elements and focus on OSB in a separate project in the future.*

## Comments

- More work needs to be done on the effects of the treatment.

  ***Response**: The effect of treatment on the physical/mechanical properties of wood will be evaluated.*

- It would be interesting to evaluate and document the performance of the treated substrates in service…specifically the impact the treatment may have on subsequent surface treatments, be it aesthetic or functional.

  ***Response**: Thanks for your feedback. Yes, we agree, and aim to better characterize this impact.*

- I would not consider hardness and dynamic MOE to be the problems with thermal modification: toughness is the primary issue. Gluing is also a concern.

  ***Response**: Yes, we agree and plan to put our emphasis on the gluing and proper bond quality. Other parameters of interest (e.g. MOR) will be tested and studied.*

- We don’t make CLT

## Q-06-SC: Artificial intelligence integrated near-infrared hyperspectral imaging for rapid prediction of percent wood failure (PWF) in laminated wood products

**Project Phase: New Research Idea**

**Project PI: Lawrence Schimleck, Vahid Nasir, Islam Hafez, and Lech Muszynski (OSU)**

| Level of Interest | Count | % |
|---|---|---|
| Very Interested | 5 | 42% |
| Interested | 4 | 33% |
| Interested with Change | | |
| Not Interested | 3 | 25% |
| Abstain | | |
| | | **100%** |

### Questions

- If this method can extract information about the variation in grain angle, moisture content, percentage of earlywood and latewood, and surface roughness then it will be a very valuable QC tool. Previous research investigating NIR as a veneer grading tool showed that it is capable of measuring all of these parameters, but that there is so much information involved that it was difficult to process the data into more discrete characteristics required for rapid non-destructive grading. Will the use of AI avoid this issue? I like that this project builds on and expands on the previous WBC research in this field. Do you feel like that if this project is successful then it will get us to the point where the next step would be for someone to commercialize it?

  ***Response**: Owing to the complexity of the issue we believe it is not possible to identify discrete characteristics to explain % wood failure. Rather, if the question is to be successfully addressed, an AI approach – which can discern patterns and relationships in large data sets that we cannot – is required. AI will utilize all the data that we provide to identify what is important. While we may not be able to specifically identify what underlies the success of the methodology, there are techniques to practice aiming at veracity and explainability of the developed model. In terms of commercialization we will seek to demonstrate what can be achieved, and as a result will be a step to commercialization.*

- Would training on many individual regions of each specimen be more useful and a better match to ASTM (i.e. training it to evaluating each point of the specimen to determine if it's wood failure vs. resin in the same way a human does it)

### Suggestions

- Consideration in evaluation with anticipated failures (i.e., low glue weights) or exceptional performance (e.g., higher glue weights or cure time). Known failures should be included to validate the technology. Additional students (undergrads) should be engaged to perform fail/pass

evaluations and compare to the AI results. Consider a gage R&R (check the repeat and reliability of the method) as an output of the project.

***Response**: We agree that validation is critical. Similarly, we agree that attempting to include exceptional or poor performance as noted (low glue weights etc.) is an important step in accounting for variation that the AI system must encounter if it is, ultimately, to be successful. We will also attempt to address the questions related to repeatability and reliability.*

- Can you work with a QC lab at some mill(s) to collect their samples (and the ratings they were given) to be used in the training set and evaluation set? Not enough data to do AI. Previous WBC projects on PWF have shown low repeatability/predictability.

  ***Response** with a QC lab (or even multiple labs) to obtain samples and wood failure data would be ideal. Part of our project also seeks to collect images of veneers (approx. 1 ft x 1 ft) prior to plywood manufacture. We had planned to make the plywood at OSU but if the plywood could be manufactured in a partner's mill and tested "in-house" that would be preferred. One issue we observed in our current project is that %wood failure provided by a trained expert gave weaker models than Talbot's data and we may want to use his approach to estimate out own % wood values.*

- Ensure the model can differentiate fine wood fibers on the surface. Also, still have concerns if the derived (and not rigorously proven) visual grid method is used to train the model instead of the ASTM method (which is the actual metric specimen are evaluated against)

## Comments

- If successful, we would want the outputs available in a way that member companies can implement. Especially interested on measurements and impact of input veneer quality

## Q-07-RI: Vibrational and stress-wave methods for rapid and cost-effective assessment of veneer-based mass timber elements

**Project Phase: New Research Idea**

**Project PI: Mariapaola Riggio and Vahid Nasir (OSU)**

| Level of Interest | Count | % |
|---|---|---|
| Very Interested | 3 | 25% |
| Interested | 4 | 33% |
| Interested with Change | | |
| Not Interested | 3 | 25% |
| Abstain | 2 | 17% |
| | | **100%** |

### Questions

### Suggestions

- It would be valuable to see how these non-destructive methods can be implemented in production lines.

  ***Response**: Yes, we agree. We will explore the feasibility of integrating these non-destructive methods into production lines as we execute the project. For this purpose, we will collaborate closely with industry advisors for insights and guidance.*

- Add testing by normal acceleration procedures to get some data before the 1 year specified.

  ***Response**: Normal acceleration procedures, specifically the measurement of frequency response from free vibration, have already been incorporated into the experimental plan. We welcome further discussion on alternative procedures if the suggestion from the reviewer differs from what has been proposed.*

### Comments

- Having an NDT to evaluate these large panels during QC and in the field will be very valuable to the mass timber field.

  ***Response**: Thank you for your positive feedback.*

- Seems like it would have a high probability of success. Data is sparse on these topics.

  ***Response**: Thank you for your encouraging comment.*

- Outside our specific business interest, but generally useful for the industry

## Q-08-LE: Optimization of log conditioning and peeling process and online monitoring of veneer surface roughness by cost-effective sensory framework for producing high-quality veneer and wood products with enhanced properties

**Project Phase: New Research Idea**

**Project PI: Scott Leavengood, Vahid Nasir, Mariapoala Riggio, and Lawrence Schimleck (OSU)**

| Level of Interest | Count | % |
|---|---|---|
| Very Interested | 4 | 36% |
| Interested | 4 | 36% |
| Interested with Change | 1 | 9% |
| Not Interested | 2 | 18% |
| Abstain | | |
| | | **100%** |

### Questions

- Which method and equipment will be used in the lab for measuring veneer surface roughness?

  ***Response**: Our plan is to use a Keyence laser confocal microscope (which we have at OSU) or a laser profilometer (which we do not yet have in our labs). The latter would enable more rapid assessment of larger surfaces as discussed in "Study on the in process measurements of the surface roughness of Douglas fir green veneers with the use of laser profilometer" (Stefanowski et al., 2020. European Journal of Wood and Wood Products 78: 555-564.)*

- Is this research targeted at veneers used for construction panels (e.g. softwood) or for interior uses (e.g. hardwood)?

  ***Response**: The research will be targeted for softwood used for structural panels and/or LVL. This is at least in part due to the fact there are no hardwood veneer producers in the Pacific Northwest and we plan to do the majority of the data collection on-site with an industrial partner. The methodology should be transferable to hardwood veneer production, however.*

- Would the process be scalable for a plywood mill? How will the lathe be determined for this study?

  ***Response**: We plan to work with an industrial partner on this this project. Therefore, we will rely on the partner to select the most appropriate lathe for the research. Given that we will collect most of the data from a lathe while operating at a facility, we expect that will help to ensure scalability. And while the roughness data will be collected from smaller specimens in the lab, the overall goal is to develop a predictive model that can use lower-cost (than laser profilometers) and easier to replace sensors such as vibration sensors, i.e., to correlate vibration data at the lathe with roughness data measured in the lab. Further, the vibration data will relate not just to veneer quality, but tool wear as well which is crucial for preventive maintenance.*

- How will the relevance of this study be impacted by the wide variety of species and process parameters at the mills?

  ***Response**: For softwood veneer in the Northwest, the species are likely to be quite limited. Given the goal of developing a predictive model, a wider variety of process parameters will be beneficial in that the higher the variability in the inputs (recognizing the concurrent need for larger samples), the more robust the developed model should be. Thus, data acquisition with adequate size and choosing proper AI-based model, should enable the team to design a reliable monitoring system while accounting for the wide range of variabilities.*

- This is important research with wood basket resources that are generally showing declining quality. Would this research be performed in the laboratory or at a participating industrial facility?

  *Response: Agreed. Most of the data collection will be conducted at a participating industrial facility. Roughness data will be collected in the lab from samples taken at the mill.*

- Is the industry asking for help with optimization at this time?

  ***Response**: No, though this is not entirely unexpected in that it has become far more common for industry to seek assistance with monitoring and optimization from software providers/equipment vendors. As the previous question stated though, declining resource quality is leading to industry demand for methods for process monitoring and optimizing yield of higher-grade veneer.*

- How are you going to investigate log conditioning on a lab-scale? Will you partner with a mill that allows changing the conditions?

## Suggestions

- There is a need to determine how roughness is going to be measured (critical to the success of this project and its transition to the industry)
  - What depths?
  - What % of ribbons or sheets? Which size affects gluing?

  ***Response**: Yes, this has long been a significant challenge for research related to veneer roughness. And the PIs are not aware of any breakthroughs for measuring roughness on a large scale. It is more typical to measure roughness in the lab on relatively small (max. 12"x12") pieces. This aside, our primary focus is on development of a predictive model that will correlate a variety of inputs and vibration data. Of course, roughness is a key measure of veneer quality, of course, but we may discover that vibration data correlate well enough with bond quality such that they serve as a useful proxy for roughness. We discuss depths in the 3rd comment below.*

- What log conditioning variables are being taken into account? – variables to think about:
    - Log sort/Diameter
    - Species
    - Time in vats
    - Water temp in vats
    - Log exit temps
    - pH of water

  ***Response**: Yes, these are all excellent suggestions thank you. To these, we would likely add stress wave data from the peeler blocks, growth rate, and key lathe parameters such related to knife angles, pressure bars, etc.)*

- Is the project determining what type of peeling process it will use?
    - What lathe?
    - Old Style (COE)
    - Newer style (Japanese lathes – Hashimoto or Meinan)

  ***Response**: For this, we will likely be constrained by the process used by our industrial partner.*

## Comments

- What is the targeted veneer thickness being produced? Is the goal to have applicability across all veneer thicknesses and uses? There is a perceived decrease in quality with hardwood plywood, particularly in the face veneer. The assumption has been that it is veneer thickness related. Any work to improve face veneer quality via in situ process monitoring would be interesting.

  ***Response**: Absolutely. And we would like to be able to conduct the research on hardwood veneer production as well. However, given the PIs are located in the Northwest, we will focus on softwood veneer in the standard thicknesses of 1/8 and 1/10.*

- Much work has been done in the industry on optimizations.

  ***Response**: Yes, for yield in particular. We are not aware of similar research however to correlate a wide variety of inputs, vibration data in particular, with veneer and then bond quality. Further, we anticipate the vibration data will provide critical data for preventive maintenance as well.*

- I am not convinced that surface roughness is a good measure of veneer quality if roughness gets below a certain threshold (100s of microns). If the roughness you are discussing is in 100s or 1000s of microns, I am very interested.

  ***Response**: Yes, though we believe that roughness significantly above 100s of microns is more a measure of waviness than roughness. For example, the research referenced in the first question focused on roughness in the 10s of microns (approximately 20 to 80 microns). We would be glad to discuss with you your experience with roughness measured in the 100s or 1000s of microns.*

- Veneer quality is a big issue for industry. This is an important project.

## Q-09-NE: Enhancing Coating Performance on Profiled Medium-Density Fiber Boards (MDF)

**Project Phase: New Research Idea**

**Project PI: Mojgan Nejad, Chip Frazier, and Brian Love (MSU & VT))**

| Level of Interest | Count | % |
|---|---|---|
| Very Interested | 2 | 18% |
| Interested | 3 | 27% |
| Interested with Change | 1 | 9% |
| Not Interested | 2 | 18% |
| Abstain | 3 | 27% |
| | | **100%** |

### Questions

### Suggestions

- **(1)** It would be interesting to evaluate the impact of resin type and level on the quality of the shaped/profiled surface. Evaluating wax type/level makes sense as well. Resin type/level may provide additional benefits.

  ***Response**: Yes, we have discussed testing different resins currently used in primer formulation, as well as wax types/levels; however, with the limited budget that can only cover one grad student, expanding the scope to consider various resin types might not be possible to accomplish in the first year.*

- **(2)** Evaluation of solvent-borne primers makes sense given the volume of solvent-borne primers used. I would also evaluate the performance of waterborne primers given their industrial use.

  ***Response**: We've opted to focus on solvent-borne systems due to industry interests in the first year, but we will definitely evaluate waterborne systems in the following years.*

- The experimental plan needs work. Coating performance depends not only on the substrate surface but also on how the coating is delivered. The types of fillers proposed are interesting, but there is a need to assess how they will perform with different coating applications (brush, roll, curtain coating, sprayers, etc.). Also, is the goal of the coatings to be heat-cured or air-cured? If focusing on an industrial application, heat degradation of the fillers and effect must also be included in the experimental plan. Introducing waxes into the substrate fiber for moisture resistance could impact this, so it would be good to have a coatings company tied to the project.

  ***Response**: Excellent points: Since the cabinet producers are using spray applicators, at this point, we use spray application. I plan to visit a cabinet producer in February 2024 to better understand their application and curing processes.*

## Comments

- Interesting project that would lead to advancement in wood composite design and perhaps development of a value-added market for the panel manufacturers. The project also benefits coating producers and industrial finishers given the potential to improve current processes and reduce cost. Both would benefit domestic producers that compete with foreign producers based on cost.

  ***Response**: Thanks, we appreciate your support.*

- Interesting research idea and nice proposal. Our low interest rating reflects where this topic is on our priorities list and is not a reflection of how the project was presented.

  ***Response**: Thanks; we hope some of the evaluation techniques and surface roughness evaluation on profiled MDF will be applicable to other composite panels.*

- I feel that replacing inorganic fillers in coatings with biomass fillers will result in new problems: swelling and moisture transfer in the finished coating. Also, inorganic fillers are cheap and don't absorb any solvent and so don't need drying. They typically have a pretty low carbon footprint. I don't see how biobased fillers provide any advantage. If you have an industry partner interested in pursuing bio-fillers, then it seems like a decent project.

  ***Response**: This is an excellent point. We proposed using organic fillers to fill out some larger pores (gaps) in the inner layers of MDF exposed after profiling. Since organic fillers are better compatible with wood, adding them to the primer might help create smoother surfaces for the application of topcoats. We totally agree that there are some challenges in using organic fillers, but AkzoNobel requested testing them. Our overarching objective is to establish a coatings analysis system. The organic fillers were to involve a simple screening to determine if more study warranted.*

- Outside our area

## Q-10-SC: Characterization of post-consumer wood waste for incorporation in wood-based panels

**Project Phase: New Research Idea**

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

| Level of Interest | Count | % |
|---|---|---|
| Very Interested | 1 | 9% |
| Interested | 4 | 36% |
| Interested with Change | 1 | 9% |
| Not Interested | 4 | 36% |
| Abstain | 1 | 9% |
| | | **100%** |

### Questions

- Please include an evaluation of metal fasteners or other metal debris in the waste stream.

  ***Response*** *: Metal evaluation will be included.*

- There have been several attempts to incorporate waste wood into new products, but the main challenge has always been the cost of procurement and supply. Although the experimental plan has addressed the sorting and collection, the main challenges will be:

  - Fully determine the volume of usable wood waste at the collection points
  - Determine the volume of treated wood vs untreated wood, as this could affect the final use.
  - Calculate the cost of transportation of waste wood to mills and determine if there would be potential profits in the final product.
  - Would need to consider the resins used in the paper/pulp process (paper overlaid panels).
  - Determine the refining capabilities if considering MDF or Particleboard.
  - The experimental plan should include the potential processing steps to facilitate further reuse.
  - Determination of constant supply is key.
  - Evaluate the proximity of the reclamation center to the potential mills.

  ***Response:*** *Addressing these challenges is crucial. Although certain aspects of logistics and supply chain fall outside the scope of this proposal, our project will significantly contribute to tackling the first two issues: determining the volume of usable wood waste and distinguishing between treated and untreated wood. Moreover, the experimental plan will encompass processing steps aimed at facilitating further reuse, as recommended by the reviewer (deliverable #4)*

- There is growing concern in the industry on the disappearing markets from some primary processing residuals. This may be a topic for another cycle but would encourage the PIs to consider another project looking at primary processing residuals.

  ***Response:*** *We greatly appreciate this insight and hope that we can have further discussions regarding this question.*

## Suggestions

- Most of Europe has banned wood from landfills for years. Waste wood in Europe goes to particleboard or to incinerators for bioenergy. Need to establish contacts with Europeans that have been dealing with this for decades. Suggest looking up the literature of Bob Falk at FPL, who did extensive work on reclaiming timber during deconstruction. What are we really going to do with the wood produced? Who is going to take the risk of putting lead paint in their panel?

  ***Response****: We are familiar with the work of Bob Falk and have colleagues in Europe involved in repurposing recycled wood (we did not seek their input on this proposal but certainly will contact them during the project implementation). The Europeans have invested in technology for the detection of contamination, and with respect to lead paint or toxic preservatives, we need to do the same.*

- What are we really going to do with the wood produced?

  ***Response:*** *A very good question. We must seek solutions and viable options for reclaimed wood. With available resources becoming more limited we cannot continue to landfill wood. Incinerating wood for bioenergy is definitely a better use of this resource, but not always the optimal use. To support a cascading approach to wood waste utilization and maximize the value derived from each new use or product, a first, required step is characterizing this waste. Therefore, by undertaking this project, we aim to contribute to advancing the U.S. forest industry towards more effective practices for wood waste management and reuse, aligning with, and even surpassing, the practices already established in Europe.*

## Comments

- Interesting project idea that has the potential to further increase the sustainability of composite panels via use of waste materials. Further reduction in landfill use is also a positive.

  ***Response:*** *There are many positive outcomes, and they motivate us to seek options for wood waste.*

- Interesting idea for addressing a complex topic. This project feels to us like it would be better off as part of a larger collaborative study from a larger funding body, but we would support funding if there is strong support from other members.

  ***Response:*** *Agreed re complexity., yet we need to start somewhere, and we believe that characterization of this resource (yes, we should start seeing wood waste as a potential resource) is a first, fundamental step. We appreciate your support.*

- Concerned about logistics/economics of moving waste stream to factories. Concern about contamination and consistency of waste stream for use in panels. Product quality could be impacted if RM is not consistent. It sounds like a good idea conceptually, but difficult to implement.

  ***Response:*** *All are valid concerns, and we agree that implementation will be difficult. While different strategies for optimizing logistics, such as on-site processing could be implemented in the future, these fall outside the scope of this work. However, the project is specifically designed to address the other valid concerns raised. Through a comprehensive assessment of the type and level of contamination, as well as of the consistency of the waste stream, the project aims to establish a foundation for producing high-quality, controllable products. Ultimately, this approach not only addresses product quality concerns but also sets the stage for a more economically profitable utilization of the waste resource.*

- Project Looks to quantify how much wood waste there is. However, since there are a lack of efficient ways to use this resource, it doesn't really matter how much of it there is. Would like to see this project focus on better ways to use wood waste rather than count how many 2x4s are being thrown away.

  ***Response:*** *Thanks for the comment. While quantifying the quantity of waste is indeed a crucial aspect, our project goes beyond mere volume assessment. We recognize the significance of not just how much wood waste is available but also the 'quality' of the waste. Our focus extends to understanding the composition and characteristics of the waste, identify effective methods for characterization, and ultimately ways to utilize it effectively in wood-based composites.*

- Just getting a survey of waste materials available and processing options doesn't seem useful to us.