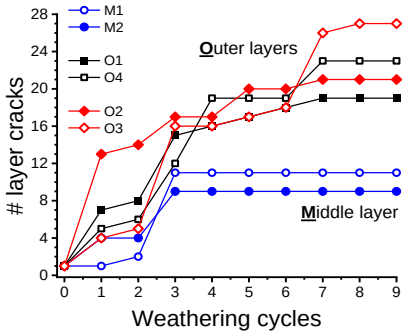
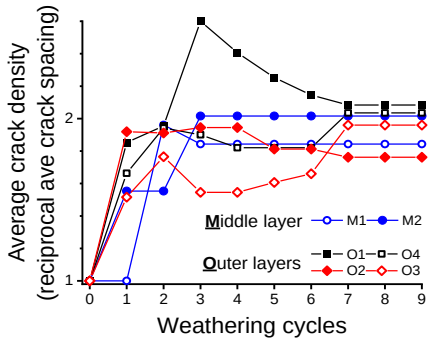
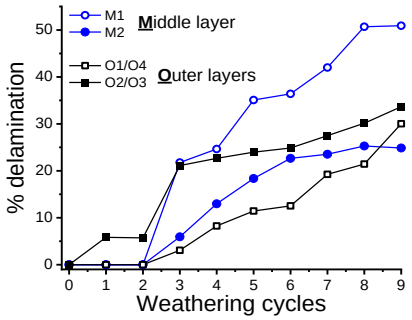
WBC NEW PROJECT PROPOSAL

PROJECT TITLE:	**Q-12-FR: Simple cross-laminate adhesive durability test**				
EXPECTED DURATION:	**2 years, MS**	**START DATE:**	**Fall 2024**	**SITE:**	**VT/AU/OSU**
INVESTIGATOR(S):	**Frazier, Dillard (VT), Peresin & Gururaja (AU), Nairn (OSU)**	**SUBMITTED BY:**	**Frazier, Dillard, Peresin, Gururaja & Nairn**		
RELATED TO TOPIC/THEME:	Hopper topic 2024-11, **System Effects in Mass Timber Products**; WBC research theme: Improved Performance and Functionality; Performance Evaluation; b, **Improved test methods**.				

GOALS & OBJECTIVES: Our objective is to develop a new delamination-durability test that is simple, but analytically rigorous so results are interpreted with more insight. The 3-ply cross-laminated assembly (image below left) works due to extensive aerospace R&D. Finite fracture mechanics (FFM, an energy approach) predicts the formation of layer cracks when residual stresses, from moisture change, exceed the transverse mode-I toughness of wood. As weathering cycles increase, layer cracks develop (endgrain splits) and FFM predicts delamination onset to occur at a critical crack density (frequency/unit spacing); collectively, the data below suggests a critical level at about 3 weathering cycles. The outer layers crack more, likely because they dry more rapidly than the middle. **Theoretically**, the critical delam-crack density will vary as the mode-II toughness of the adhesive varies, and/or as the mode-I wood toughness varies. **Practically**, the onset of delamination signals the onset of panel failure. Therefore tests to observe delamation could reveal significant differences in adhesive fracture toughness, and its role in panel durability. The FFM model is effective for wood (see related work), and agreement with theory is likely a strong function of wood quality. As wood-grain deviations and defects compromise layer orthotropicity, the agreement with the model is expected to decline. This 2-year MS project will help determine how well FFM applies to bonded wood; practical challenges will be identified as we consider seeking formal test certification. Currently, the method requires laborious image inspection, and tedious spreadsheet work. Industrial adoption requires automated crack and delamination measurement. A 3D optical profilometer should be ideal, and we are investigating the possibility.







Data from the **spotted-gum project** from **only one** 3-ply cross lamination over 9 weather cycles. Curves are for cracks & delaminations seen on four edges of the panel: layer-cracking, average crack density, and % delam with weathering. Theoretically, M1/M2, O1/O4, and O2/O3 should be identical pairs, but defects & grain deviations complicate cracking.

EXPERIMENTAL PLAN

Under simulated weathering, investigate wood-layer thickness effects on progression of crack density and onset of bondline delamination. The model predicts strong layer-thickness effects; layer-cracking is promoted in thicker layers, suppressed in thinner layers, and delamination is easier in thicker layers. The model assumes three identical layers, with unchaging properties. We should try to meet the ideals of the model using the highest quality, straight-grained lumber (southern yellow pine); and simulated weathering must use vacuum drying to avoid wood exposures above 60°C. We envision a custom-made, heated weathering vessel, capable of pressure & vacuum. Wood tensile moduli must be measured to build the FFM model. Test specimens will be 4x4 inches, with 3 cross-laminated layers; layer thickness will be varied over 2 levels: 0.75 and 0.25 inches. Adhesive: moisture-cure polyurethane.

RELATED WORK / RELEVANCE

Please see Nairn, 2019 (*Predicting layer cracks in cross-laminated timber with evaluations of strategies for suppressing them*. European J. Wood & Wood Prod., 77, 405-419). This paper demonstrates that finite fracture mechanics applies very well to wood substrates. Furthermore, it reveals why this specimen geometry has great potential for a new adhesion test. To our knowledge, none have tried to translate the theory to actual measurements of delamination durability of bonded wood.

DELIVERABLES: rigorous, narrowly focused delam-data set to judge the potential of this new test. **BENEFIT FOR MEMBERS:** See "related topic/theme" above; this work is directly applicable to mass timber, and similar laminated products. **MILESTONES:** **Year 1**-Manufacture of weathering chamber; mechanical properties testing; delamination testing. **Year 2**-delamination testing; data analysis.

BUDGET

Year 1 Budget Estimate:
Student GRA and benefits: $41,253
Tuition and Fees: $17,500
Travel and Other: $1,000
Materials/Supplies: $7,000
Total Yr. 1: $66,753 (Not including OSU/VT indirect)