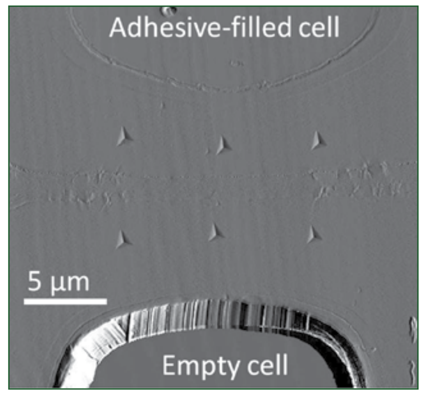
Research in Progress

Improved Understanding of Moisture Effects on Outdoor Wood-Adhesive Bondlines

Repairing historic covered bridges often requires using wood construction materials, such as plywood or laminated veneer lumber, that rely on adhesives for their structural integrity. Although the roof structure keeps the heavy timber trusses well sheltered and dry enough that they have survived 100 to 200 years, humidity changes caused by weather still affect the bridge materials. Of particular concern is how the swelling and shrinking of wood with changing humidity contributes to wood-adhesive bondline failures. When bondlines fail, costly repairs are needed to maintain historic covered bridges. In this study, we use new sophisticated techniques to probe interactions between moisture, adhesives, and wood to better understand what causes moisture-related failures in wood-adhesive bondlines.

Background

The forest resource today is much different than when covered bridges were originally constructed 100 to 200 years ago. The old-growth trees that produced the original heavy timber trusses, decking, and covering are no longer available. Instead, sustainably managed plantation and regrowth trees are now utilized. Because the current forest resource consists of smaller diameter trees, adhesives are needed to construct composite materials to replace the original members cut from large-diameter trees. However, in outdoor applications, these composite materials do not last as long as the original solid wood members, often because of moisture-induced wood-adhesive bondline failures. This results in more frequent repairs, which is an expensive and inefficient utilization of our forest resources. Improved outdoor wood adhesives would result in more cost-effective and improved methods for preserving historic covered bridges. Additionally, they would promote the expansion of the forest products industry by increasing the utilization of forest products in outdoor applications.



Nanoindents in cell wall near adhesive-filled cell and empty cell.

For a wood adhesive to produce durable bonds outdoors, it must not fail under the continuous swelling and shrinking of wood caused by ambient humidity and temperature fluctuations. To understand and improve wood-adhesive bondlines, tools must be developed to study the interactions between moisture, adhesives, and wood at the same length scale as the interphase itself. Wood is composed of long cylindrical cells that have a typical diameter of approximately half the diameter of a human hair. The cells are hollow with thin walls. When adhesive comes into contact with wood, it flows into and fills the hollow cells near the bondline. Adhesive can also infiltrate into the cell walls and modify their properties. This research develops tools to quantify adhesive infiltration, assess mechanical properties as a function of moisture content, and monitor moisture-induced swelling at the cell wall level. Furthermore, sophisticated techniques new to forest products

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research are employed to better understand how the components of wood cell walls contribute to swelling.

Objective

The objective of this research is to develop new, sophisticated techniques to better understand the interactions between moisture, wood, and adhesives at the cell wall level to facilitate the development of improved adhesives for outdoor applications.

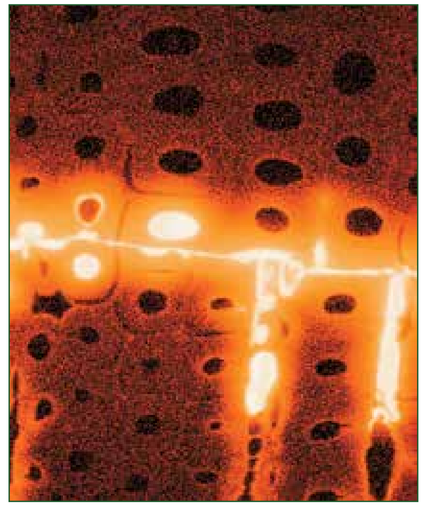
Approach

To study interactions between moisture, wood, and adhesives at the cell wall level, we will employ

- micro x-ray fluorescence to quantify adhesive infiltration into wood cell walls,
- nanoindentation to determine how adhesive infiltration modifies the moisture-dependent mechanical properties of cell walls, and
- atomic force microscopy to monitor effect of adhesive infiltration on moisture-dependent swelling of cell walls.

We also recently discovered that twist indicators, constructed from thin slivers of wood, twist in direct proportion to the sliver's moisture content. The slivers are so thin that they can be constructed containing only the couple of cells modified near an adhesive bondline. The twisting slivers will be used to study the differences in moisture uptake between cells with and without adhesive infiltration.

Small-angle scattering experiments will also be performed to gain insight into which constituents of wood cell walls contribute to swelling. This improved understanding of how wood cell walls swell will lead to improved wood adhesives that modify cell wall components to minimize swelling.



X-ray fluouresence mapping of adhesives in cells and infiltration into cell walls.

Expected Outcomes

Expected outcomes of this research include new techniques and protocols to evaluate and develop improved wood adhesives for outdoor applications and improved fundamental understanding of how wood cell walls swell with moisture.

Timeline

Micro x-ray fluorescence, nanoindentation, and sliver twisting experiments began fall 2012. Small-angle scattering and atomic force microscopy experiments will begin in 2013. All experiments will be completed and a final report written by fall 2015.

Cooperators

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