Wood-Based Composites (WBC)

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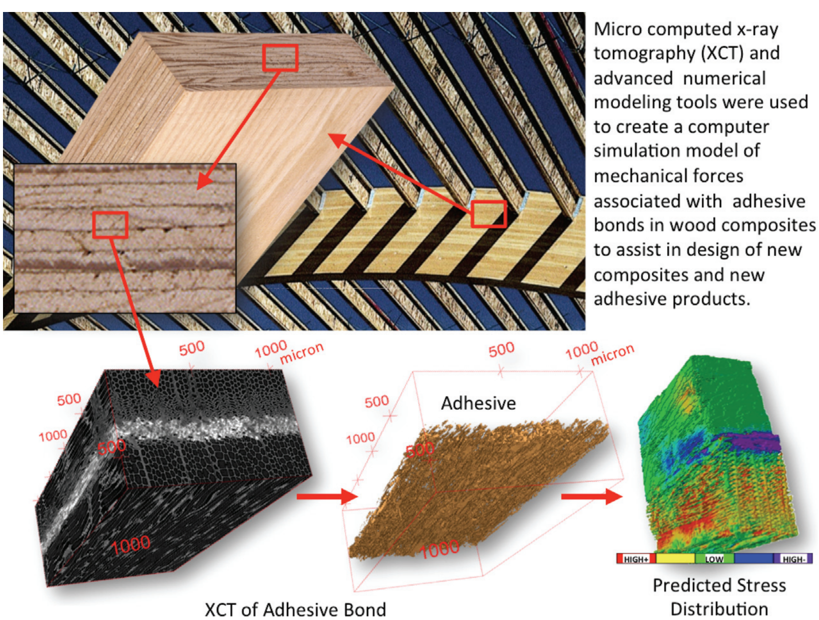
Extending America's Timber Resources Through Advanced Composite Science

Wood composites, such as laminated veneer lumber (LVL) and oriented strand board (OSB), are common products used in the construction of homes, non-residential buildings, and many consumer products. There is a great diversity of wood composites, all of which depend on adhesives in order to bond veneer, strands, particles, and/or fibers for durable, strong, and economically viable applications.

Nearly all adhesives for wood products are derived from petroleum. Many incorporate formaldehyde. Surprisingly, we know very little about why some adhesives perform better than others when bonding very complex natural materials like wood. Consequently, the development of new adhesive systems, such as those based on bio-based materials, is a slow and tedious process. This WBC research has advanced the science of adhesive bonding by developing a breakthrough method for visualizing and analyzing adhesive bonds in wood products.



Micro computed x-ray tomography (XCT) and advanced numerical modeling tools were used to create a computer simulation model of mechanical forces associated with adhesive bonds in wood composites to assist in design of new composites and new adhesive products.

More than 90% of these homes are light-frame wood construction, of which essentially all include some structural wood composite products. For most homeowners their home is their single largest investment. The durability of the wood composites in these homes is critically important to millions of homeowners.

Adhesive bonds have two functions: to hold the components together and to facilitate transfer of mechanical forces from one component to the next. The first function is the strength of the bond. In contrast, the second function, which is roughly-speaking the bond's stiffness, may affect all mechanical properties of the product. This breakthrough combines state-of-the-art imaging tools with emerging computer modeling methods that yields an integrated characterization of the fundamental behaviors of adhesive bonds. This work considers effects of adhesive penetration into the porous network of wood cells, complex loading applications, and the micron-level mechanics imposed on the bonded interface.

The long-term goal of this project has been to improve performance of wood composites and initiate innovation for the development of new adhesives. This work pushed the envelope of fundamental knowledge on the micro-mechanics of adhesive bonds in wood composites and developed a numerical model to simulate the mechanical behavior of bonded wood assemblies. Another valuable output was the creation of quantitative and visual three-dimensional (3D) data sets for the micro-structure of adhesive bonds.

3D visualization of adhesive bonds on a micron scale, in tandem with the ability to interactively rotate and dissect the virtual bonds using 3D imaging software, has created a paradigm shift in how scientists and engineers interpret the creation of adhesive bonds in wood and their resulting performance.

The project had three parts: 1) micro X-ray computed tomography (XCT) characterization of adhesive bonds; 2) micro-mechanics modeling of bonds; and, 3) macro wood-adhesive bond evaluations. The work leveraged collaborations involving scientists at Oregon State University, the US Forest Products Laboratory, the Argonne National Laboratory, and several major adhesive and composite manufacturing companies. The research was guided by close industry oversight from conception to completion; whereas, the interpretation and implementation of the results was made possible by the unique organizational structure provided by the NSF Industry/University Cooperative Research Center Program.

> **Economic Impact**: This work will positively impact the US wood products industry and the American consumer. Specific examples of markets that will benefit are: glue-laminated timber, LVL, plywood, OSB, engineered wood flooring, and component wood products, such as furniture, cabinets, windows, and doors that rely on adhesive bonding. These markets represent over $77 billion in annual sales to the US economy and manufacturing employment of nearly 500,000 (US Census Bureau). A typical wood composite manufacturing facility may spend $5 million annually on adhesives. Even a modest 2% reduction in adhesive consumption, would save approximately $100,000 for each facility. US housing construction has averaged 1.5 million new units annually since 1960. The insights gained from this research, and the model developed, provide several important benefits with implications for the bottom line. These include: 1) improved durability of glued wood products, resulting in fewer failures and longer service life; 2) optimization of wood utilization, resulting in lower demand on timber resources; 3) development of new adhesives and improved formulations for existing adhesives, resulting in improved product performance, lower cost, and less reliance on petrochemicals; and 4) reduced time and cost for future development of adhesives and new wood composites.

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