Advanced analysis tools and programs to accelerate the adoption of more natural structures

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While wood is a highly desirable building material from an ecological and sustainability perspective, we do not understand its fundamental properties nearly as well as we understand competing materials such as steel and concrete. We can avoid toxic preservatives by acetylating wood, but we don't fundamentally understand why acetylation works. Hydroxymethylated resorcinol (HMR) can dramatically improve the water resistance of wood bonds, but no one has been able to explain the mechanism. This lack of understanding slows progress by forcing wood technology industries to rely on inefficient empirical strategies to develop and validate new products and technologies.

A more efficient route to developing new wood-based materials is to develop a detailed fundamental understanding of the properties of wood and wood-derived materials. A detailed understanding allows selection of the proper design values and provides a roadmap for achieving those values. This talk will provide an overview of new tools and approaches being taken by USFS Forest Products Laboratory scientists to understand the fundamental mechanisms behind decay resistance of modified wood and moisture durability of wood adhesives. Advances in these areas will accelerate the development of improved wood modifications, a wide range of bio-based (lignin, tannin, protein) adhesives, traditional adhesives, and other biomass utilization strategies. The improved performance of these technologies will generate new market opportunities for wood and bio-based materials.

Understanding what makes wood decay resistant

The leading hypothesis explaining the decay resistance mechanism of modified wood is that nanoscale water-swollen regions of the wood allow transport of fungal "digestive juices" to move into the cell wall and allow partially digested sugars to diffuse out of the cell wall to feed the fungus. What is lacking is a test of this hypothesis: at the nanometer scale, where is the water? What are the properties of these water swollen regions? What are the diffusion rates in these regions before and after acetylation? What chemicals are fungi using to digest the wood cell wall? Some approaches include:

- Diffusion measurements – Testing hypotheses behind the effectiveness of bulking and crosslinking treatments in enhancing decay resistance (Zelinka *et. al.,* 2014)
- Decay mechanisms - Understanding the chemical systems fungi depend on to degrade wood

Durable adhesive performance

Many years of empirical experience have provided general rules about which adhesives will work and which will not under a given set of conditions, but little in the way of fundamental, quantifiable principles that can be used to design durable bonds, especially with novel substrates or adhesive systems. Until recently, there was little understanding of such questions as why phenol formaldehyde works so well in moisture cycling and epoxy does not, why melamine formaldehyde does not work well for acetylated wood, how isocyanate adhesives stick to the wood, or how HMR improves bonding. The following techniques and programs are attempting to provide the detailed understanding needed to answer these questions, and design adhesive properties to match the substrate and environmental conditions. Some approaches include:

- Theoretical models of the critical components of adhesive durability (Frihart 2009)
- Improved measurements of mechanical properties of wood cell walls - nanoindentation advances, applied to effects of adhesive infiltration, moisture response, viscoelastic properties
- Nanoscale swelling: Small Angle Neutron Scatter (SANS) to measure nanoscale swelling inside the wood cell wall; native and modified wood, with and without adhesive. (Plaza *et al.,* 2016)
- Measuring swelling forces and moisture sorption of the interphase wood cells
- Detailed understanding of chemical structures of wood - NMR techniques that allow a detailed look at the chemistry inside a wood cell wall

Summary

A solid theoretical understanding of materials properties has given us rust-resistant cars and amazingly powerful computers. Unfortunately, we do not have the deep fundamental understanding of wood to fully utilize the potential of wood and wood-derived products. This talk provides an overview of some of the efforts underway to generate the fundamental understanding required to get the best, most economical performance from wood-based materials.

References

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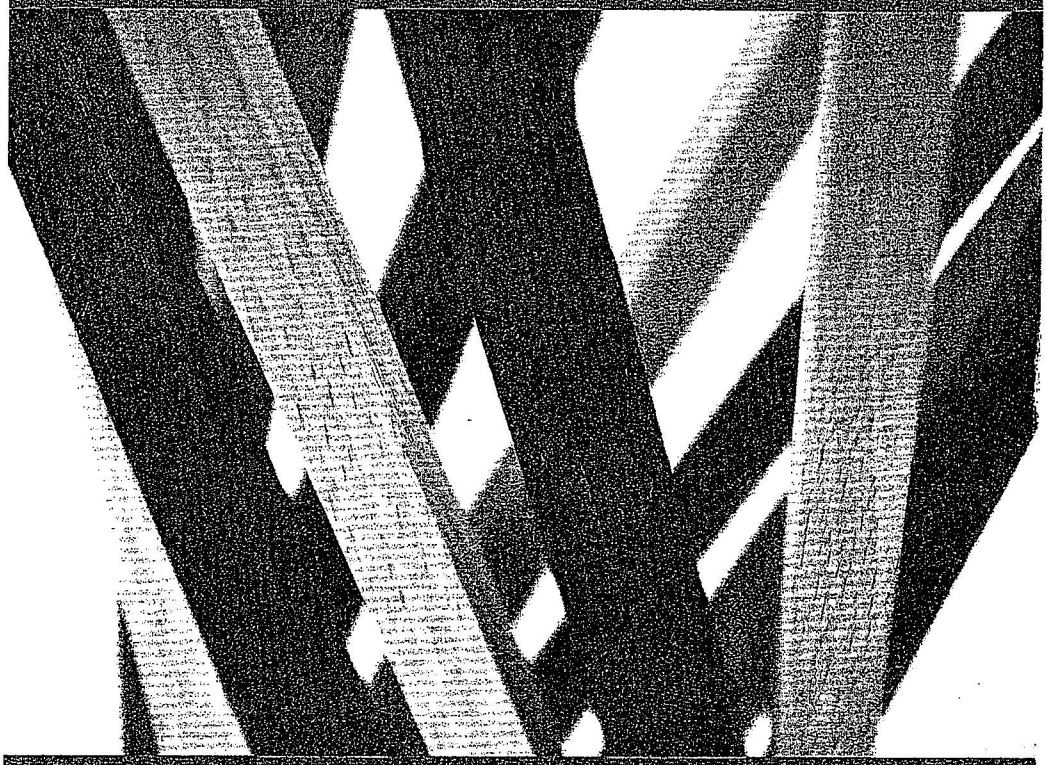

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