Introduction to Thermally Modified Wood

Authors: Brian Bond, Ph.D. | Associate Dean for Extension, Outreach, and Engagement-Department of Sustainable Materials | Virginia Tech | bbond@vt.edu
Reviewed by: Clay Altizer | FRA Southwide Region Manager| caltizer@forestresources.org

TECHNICAL RELEASE • OCTOBER 2025 25-TR-28

INTRODUCTION

Wood is one of our most versatile building materials, valued for its strength, beauty, renewability, and ability to sequester carbon. In its natural state, when exposed to exterior conditions, it is susceptible to decay and significant dimensional changes. To address these challenges, researchers and manufacturers developed the process of thermal modification. Thermal modification (TM) of wood was first commercialized in Europe as a means to reduce reliance on chemical preservatives to prevent decay in exterior wood and has been adopted for many products here in North America.

THERMAL MODIFICATION: WHAT DOES IT DO?

Thermal modification involves heating wood in a controlled environment with little or no oxygen to prevent combustion. In North America, most thermal modification processes happen in a vacuum. The process consists of three stages. First, kiln-dried lumber is placed into the treatment chamber and gradually heated to high temperatures, while more moisture is removed. Next, during the thermal treatment phase, peak temperatures between 180 and 220°C alter the chemical structure of the wood. Finally, the wood is cooled, and in some processes, reconditioned with moisture and stabilized for use. Research has shown that higher temperatures, those above 200°C, provide greater decay resistance than lower temperatures.

What happens to the wood? Generally speaking, the temperatures and durations of treatment lead to chemical changes in the wood. Wood is composed mainly of three chemical components: cellulose, hemicellulose, and lignin. The thermal modification process leads to the degradation of hemicelluloses, partial modification of lignin, an increase in the crystallinity in cellulose, and a reduction in the chemical structure that normally binds water.

COLOR CHANGES

One of the most noticeable effects of thermal modification is the color change. As wood is heated, its natural tone shifts to a richer, darker brown that often resembles exotic hardwoods. This darkening occurs uniformly throughout the cross-section, not just on the surface. The intensity of the color depends on the treatment temperature and duration, with higher temperatures producing deeper, browner shades. Like most wood products, TM wood will fade or turn gray over time in outdoor settings unless it is protected with UV-resistant coatings. The TM color changes enable lighter-colored, lower-value, sustainably harvested hardwoods to resemble the color of more exotic tropical hardwoods, creating a new market opportunity for this material. Figure 1 demonstrates the darkening of yellow poplar at different temperatures from a laboratory test. Darker and richer colors can be commercially produced (Figure 2).

Fig. 1 – Color changes in yellow-poplar at different temperatures during a laboratory test.

Fig. 2 – Commercially produced thermally modified yellow-poplar.

DECAY RESISTANCE

The initial goal of TM and one of its most significant advantages is the improvement in biological durability. The degradation of hemicelluloses, which fungi rely on for food, makes the wood less hospitable to decay organisms. As a result, thermally modified wood demonstrates significantly improved durability against brown rot, white rot, and soft rot fungi when compared to untreated wood. Our tests on TM hardwoods indicate that it does not provide increased resistance to termites. Also, while decay resistance is significantly improved, it does not meet the standards for ground contact.

DIMENSIONAL CHANGES

The chemical changes in wood result in reduced moisture uptake, which in turn reduces swelling, shrinking, and warping. Overall shrinkage and swelling can be reduced by 40–80% depending on the species. For example, in our work on hardwoods, we observed reductions as small as 24% for hickory and as large as 70% for ash. The equilibrium moisture content (EMC) is typically 40–50% lower than that of untreated wood at the same relative humidity.

MECHANICAL PROPERTIES

While thermal modification enhances specific characteristics of wood, it also reduces its bending strength and impact resistance. The loss of hemicelluloses and the structural changes in lignin reduce the wood's flexibility, resulting in lower bending strength. Impact resistance is also diminished, making the material more brittle and more prone to cracking under sudden loads. Although the stiffness, or elastic modulus, may remain relatively stable or even improve slightly under moderate treatment levels, higher temperatures typically reduce it as well. In short, thermally modified wood is mechanically weaker than untreated wood of the same species. For this reason, it is not recommended for load-bearing uses; however, it performs well in non-structural and aesthetic applications, such as decking, cladding, and siding.

.

SUMMARY

Thermally modified wood represents an innovative solution for applications where wood is used in exterior applications and for replicating the color of higher valued tropical species. By altering the chemical structure of cell wall components through controlled heat treatment, the material gains enhanced resistance to decay, improved dimensional stability, and a rich, appealing color. These advantages make it especially suitable for siding, decking, flooring, and furniture, particularly where environmental sustainability is a priority. Thermally modified wood is a promising material for a wide range of non-structural uses, offering a natural, chemical-free, and sustainable alternative to traditional preservative-treated wood and imported hardwoods.

COLLEGE OF NATURAL RESOURCES AND ENVIRONMENT
VIRGINIA TECH