Second Chances: Discussion of Modified Wood

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Prior Second Chances articles have reviewed different challenges with the use and repair of wood systems. This article takes a different tack and discusses less common wood materials to consider when assessing your project. Selecting the correct treatment of wood materials for exterior decks, cladding, and structural uses creates challenges for designers and builders as they try to achieve a desired appearance and function while addressing wood vulnerabilities to moisture, decay and general durability (Figures 1, 2, and 3).

Figure 1. Advance decay in a timber framed bell tower (left) - (Crowe Photo).

Figure 2. Advance decay and fruiting bodies in a newer multi-family housing development (right) - (Crowe Photo).

It was common practice up until 2003, to use Copper Chromated Arsenate (CCA) treated products, (e.g., Wolmanized) unless a durable species were practical. This waterborne preservative treatment includes various copper concentrations, chromium, and arsenic, and has a demonstrated success since the early 1900s. By December of 2003, in agreement with the EPA, manufacturers voluntarily discontinued manufacturing chromated arsenicals-treated wood products for residential applications. In the immediate time following this change, alternate waterborne preservative treatments were explored in the industry as the search for a "safe" poison was pursued. New formulations needed to replace the chromium and arsenic and began using more significant percentages of copper, ammonia and chlorides such as Alkaline Copper Quaternary (ACQ). These formulations proved to be more corrosive to the traditionally used galvanized connectors and fasteners, and they necessitated a more substantial galvanized coating (such as hot-dipped) or stainless steel components. Formulations had been further altered and employed a combination of micronized copper and borates, such as MicroPro

Figure 3. At lower moisture contents certain wood species are vulnerable to insects. (Crowe Photo)

produced by Koppers Performance Chemicals Inc. The newer formulations are less corrosive to connections, but the use of hot-dipped galvanized or 300 series stainless steel is still advisable for exterior use.

Wood treated with waterborne preservatives (such as that subjected to exterior conditions) remains in high demand in the industry. Although a popular and serviceable material, waste from treated wood is toxic and necessitates added precautions for its disposal. To reduce hazardous wastes, modified wood treatment processes provide viable alternatives for specific wood uses. Modified wood material processes, as described below, are non-toxic, and can provide an eco-friendlier alternative to more traditional preservative treatments. It is through the modification processes, which work on a microscopic level, that the durability of these materials (resistance to rot and insects) and dimensional stability is enhanced. Designs also need to account for the fact that current waterborne wood treatments may experience strength loss of about 10 to 15 percent. When considering modified wood material, it is also important to recognize their effects on wood strength as well as durability. Similar to that of the more conventional treatments, the use of corrosion-resistant fasteners, such as 300-series stainless steel, is advisable.

Wood Material

In reviewing wood treatments, it is important to understand the composition of the wood base material. Wood is a naturally occurring material composed of cellulose, lignin, hemicelluloses and minor amounts of extraneous materials contained within the cellular structure. Figure 4 provides a diagram of a wood log depicting the combination of heart wood, sap wood, and the cambium layer (bark), which is the assembly of cellulous, hemicellulos and lignin. This diagram also illustrates grain orientation and includes larger images of the cellulous structure within hardwoods and softwoods. This discussion will be looking at softwood, the more commonly treated material, due to faster growth rates and more favorable ability to accept the treatment.

Three grain orientations are seen in the enlarged wood diagram, as parallel (along length of log), tangential (tangent to the curved surface of the log), and radially (from the center of the log extending outward). Wood material behavior differs along each of the three grain orientations. Along the length of the member, strength characteristics are greatest and the rate of hygroscopic expansion (changes in volume attributed to changes in moisture content) are the least. Perpendicular and tangential to grain, the strength is dramatically reduced, and the rates of hygroscopic expansion and contraction are vastly increased. Tangential expansion is approximately half of that in the radial direction while longitudinal expansion is generally less than 1 percent from fiber saturation and oven dry. Figure 5, from the Wood Handbook, illustrates

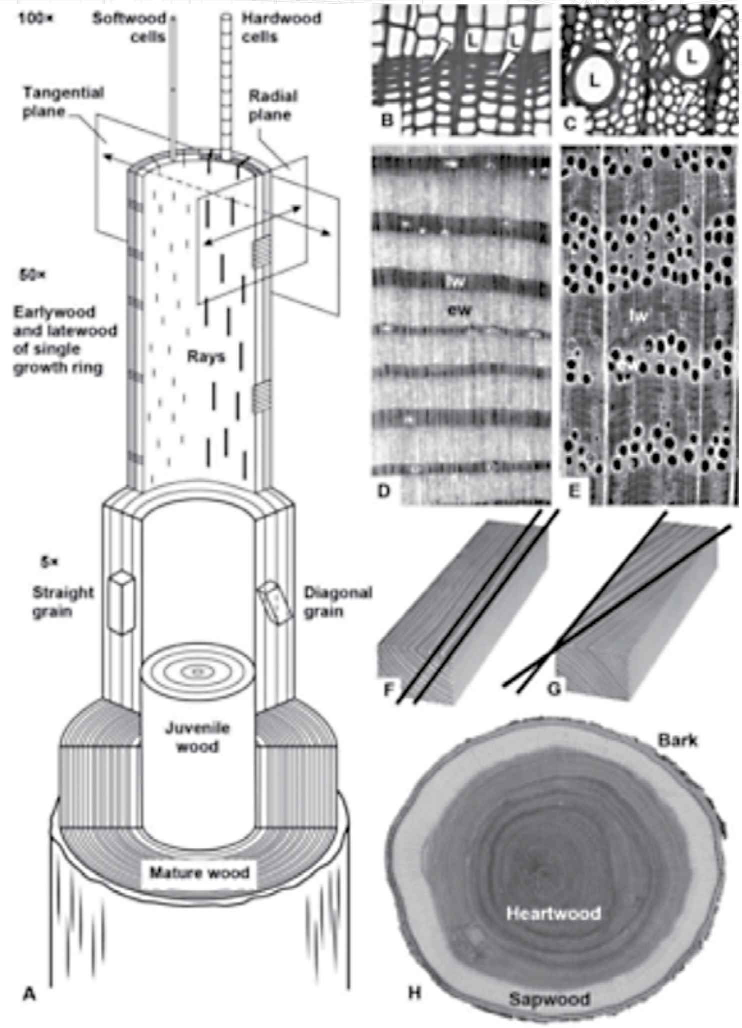

Figure 4. Illustration of labeled log cross section and enlarged views of wood-cell construction. Image from the Wood Handbook published by the Forest Products Laboratory.

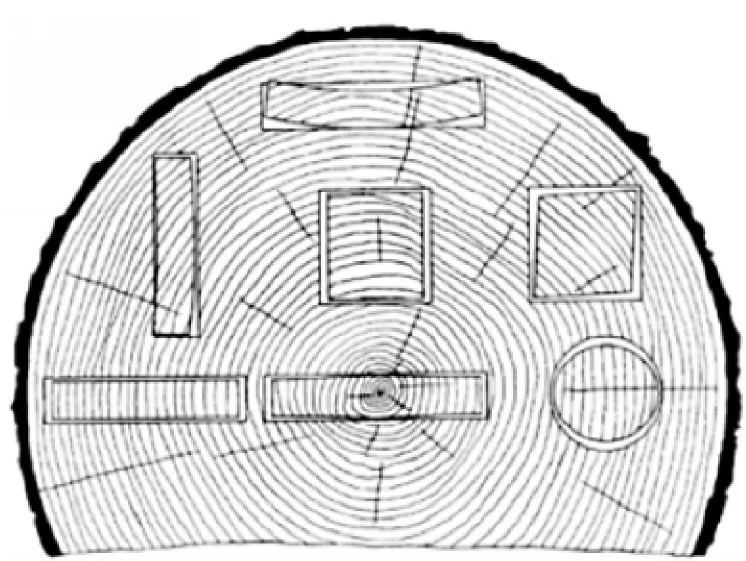

Figure 5. View of log cross section with different piece distortion shown with changes in moisture content. Image from the Wood Handbook published by the Forest Products Laboratory.

the propensity of effects on wood materials with changes in moisture content based on where the wood is extracted from the tree. These volumetric changes in the wood introduce detailing challenges with exterior wood use.

Volumetric changes in wood as noted above are attributed to changes in moisture content. Wood moisture contents will vary with changes in the relative humidity of the wood's environment. This is known as the equilibrium moisture content (EMC), when wood is not absorbing or releasing moisture. The volumetric changes occur when the wood moisture is below the fiber saturation point, which typically falls between 25-and-30 percent based on the material. Although, it may take on additional moisture when wood is at fiber saturation, it will no longer swell. At fiber saturation, wood becomes vulnerable to decay. If the moisture content of wood is kept below its fiber saturation point, decay should not be problematic. The building code defines 19 percent as the actual maximum moisture content within dry service conditions.

Wood will decay when four conditions exist: favorable temperatures (generally between 35 and 100 degrees F), moisture (around the fiber saturation point), oxygen, and food (wood). If one of these can be eliminated, decay can be prevented. Conventional waterborne preservatives work to eliminate food sources in order to prevent decay. Copper is a consistent antimicrobial and bonds tenaciously well to the wood cell walls. Borates also serve as a good antimicrobial; however, borates are diffusible preservatives that can leach out over time with changes in moisture content. While these conventional waterborne preservatives can disrupt the food source, they cannot achieve 100% treatment of the wood cross section, and thus require additional touch-up at cuts and tooling locations.

Wood Modification

Wood modification introduces a non-toxic approach to the preservative treatment of wood. Wood modification technology as discussed herein has been around for most of the 20th century. It was not until more recently, that these materials have become more available.

Wood modification encompasses various approaches to enhance the durability of wood (resistance to decay and insects) for exterior use. These treatments may serve as a viable alternative to convention wood preservative treatments as they can provide benefits such as treatment of 100 percent of the wood cross-section with non-toxic processes. These processes are thermal treatment, kebonization, and acetylation.

Thermal Treatment

Thermal modification of wood (heat treatment - not to be confused with heat sterilization of wood) is a non-toxic process that basically cooks sugars and extractives out of the wood. The sugars and extractives (e.g., waxes, fatty acids, resin acids, and terpenes of a tree) are food sources for fungi and insects. Treated species include redwood, ash, spruce, and radiata pine. The process includes heating the wood to about 400 degrees F, in an oxygen-free environment to remove the organic compounds from the wood cells. The high heat decomposes the sugar compounds creating a durable wood that is resistant to insects and decay. The thermal modification reduces the EMC of the wood approximately 30-50 % lower than that of non-treated wood. Thus, with relative humidity at around 80 percent, (at around 70 F) the resulting EMC of this wood is still only about 8 percent. The result is a more dimensionally stable wood member with less propensity for shrinking and swelling, and reduced cupping or twisting potential.

With the elimination of chemical treatments and the removal of sugars, extractives, and moisture, the wood is also lighter and less dense. Unfortunately, there is also a reduction in strength that generally corresponds with the reduction in density. The treated material is generally marketed for wood siding and similar cladding/vertical surfaces uses that do not include ground contact (Figure 6). Manufacturers recommend coating this material for

Figure 6 Image of Russwood Thermopine®, design by Fife Architects, photo by Keith Hunter.

Figure 7. Photo curtesy of Kebony shows Kebonized wood cladding and decking (SYP) at Onda Restaurant in Oslo, Norway.

protection against ultraviolet rays. Though the material has demonstrated good resistance to beetles, the material is not resistant to termites. Products offered in this category are rated for 20 or 25 years of exterior use.

Kebonization

Kebonization is another wood-modification process that has been commercially available since 2004 and marketed in the US since 2007. This process is generally used with Scots pine, southern yellow pine, radiata pine and maple. This process modifies wood with bio-based alcohol followed by a heat treatment by Kebony ASA in Norway. Initially, the wood is kiln dried to about 4% moisture content and pressure treated with a furfuryl alcohol that is produced from a bio-based liquid (a waste byproduct from sugar cane). The material is then heated up to about 230 F (significantly less than the thermal treated material) at which time the alcohol treatment is polymerized and "permanently transforms the cell structure."

The modification process results in swollen wood cell walls that are no longer vulnerable to the prior ranges of shrinking and swelling. In addition, the changes that take place in the polymerization and thickening of the wood cell also creates a much harder wood material with increased density (~35%), and increased modulus of elasticity (MOE) and modulus of rupture (MOR) values. The feel of the end product is more consistent with that of teak or Ipe (also known as Brazilian walnut) rather than the southern yellow pine and/or maple parent material. This modified wood is widely used as exterior cladding on sloped and vertical surfaces (Figure 7) and is used as an alternative decking and dock material as well. Thirty-year warranties are available for this product, and no coating or other ultra-violet light protection is required for exterior use. This material is not marketed for ground contact.

Acetylation

Acetylation is the third process that we will discuss. This process, which has been commercially available since 2007 in the United States and is primarily used with southern yellow pine and radiata pine, includes a treatment that is somewhat similar to that of waterborne preservatives. The wood is dried to approximately 4 percent moisture content and is then treated with an acetic anhydride (essentially vinegar). This treatment modifies the wood on a molecular level. More specifically, the process removes hydroxyl molecules at the wood cell walls and replaces them with acetic molecules. The result is more swollen cell walls, and a more hydrophobic material that prevents the moisture fluctuations with changes in relative humidity changing the hygroscopic behavior of the wood.

The swollen cell walls and lack of moisture fluctuations result in a lighter and more dimensionally stable material, and the EMC of the acetylated material is drastically reduced. By preventing moisture from approaching fiber saturation, the wood material is not vulnerable to decay. The treatment also provides some termite resistance. The end product necessitates the use of stainless steel fasters. Predrilling is also commonly needed as an increased surface hardness can be prone to splits. However, there is no reduction in MOR or MOE values. Common applications for this material include windows and doors, wood

Figure 8. Wood bridge constructed with acetylated Accoya in Sneek, Netherlands Built: 2008-2010. (Photo Curtesy of Accsys)

cladding, wood decking and structural application (Figure 8). The product can carry a 50 year warranty above ground and a 25 year warranty with ground contact.

Summary

Although waterborne preservatives still maintain a vital role in the construction industry, it is important to recognize both the strengths and limitations of these conventional treatment processes. Where concerns related to durability, dimensional stability, or toxicity of the product are present, wood modification processes may be worth exploring. Similar to that of conventional treatments, not all wood modification processes are best suited for every application of exterior wood. Product selections should be carefully considered. The table below helps to further illustrate properties of these materials for general information. Wood modification such as thermal treatment, kebonization, and acetylation that have become more readily available over the last two decades can, in some instances, produce viable alternative products that may otherwise require traditional (toxic) treatment processes or the use of scarce tropical decay resistant species.

Bio

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Technical Properties Summary of Selected Modified and Treated wood (Note1)

Technical Properties	Units	Non Treated SYP	Treated SYP (Waterborne) UC4A	Non Treated Radiata Pine	Heat Treated Radiata Pine	Kebony SYP	Accoya Radiata Pine
Density (12% Comparison)	pcf	36	32	32	25	43	32
EMC at 70 F and 65% RH	%	12	12	12	6 to 7	6	3 to 5
Bending Strength (MOR)	psi	12,760	11,500	11,700	9,200	13,345	11,600
Stiffness (MOE)	psi	1.81E6	1.62E6	1.48E6	1.2E6	2.25E6	1.27E6
Max Swelling. (Dry to wet) - Tangential direction.	%	5	5	8	4	2.0	1.5
Decay Resistance Exterior	Y/N	N	Y	N	Y	Y	Y
Decay Resistance Ground Contact	Y/N	N	Y	N	N	N	Y
100% Treatment of cross section	Y/N	NA	N	NA	Y	Y	Y
Fire rating ASTM E-84 Class C	Y/N	Y	Y	Y	Y	Y	Y
Coating Required	Y/N	Y	Y, UV and Aesthetics	Y	Y	N	N

Note 1. Properties approximated from available literature and Wood Handbook.

Test Questions - Second Chances: Discussion of Modified wood

1. In what year did the industry discontinue the use of CCA by agreement with the EPA?
   a. 2000 b. 2001
   c. 2002 d. 2003

2. What issues were discovered with new treatments that replaced the CCA:
   a. There were no problems with the new treatments,
   b. Treated wood required enhanced corrosion protection from the former traditional galvanized coatings.
   c. Only stainless steel should be used with new treatments.
   d. B and C.

3. What conditions must be present for decay to occur.
   a. Oxygen, light, food, and favorable temperatures.
   b. Oxygen, food, moisture, and favorable temperatures.
   c. Non-treated wood, moisture at fiber saturation, and favorable temperatures.
   d. B and C.

4. Waterborne preservative treatments typically result in partially treated wood material while modified wood results in affecting the entire cross section.
   a. True b. False

5. Wood modification is a non-toxic process that has been around since the early 1900s that adds metal and chemical treatments to the wood to enhance the longer term durability of the material.
   a. True b. False

6. Copper and borate treatments do not bond well to the wood cell structure and will leach out over time. These treatments do not provide a long serviceable life.
   a. True b. False

7. Wood will expand and contract with changes in humidity when the wood has a moisture content is between 30 percent to 100 percent.
   a. True
   b. False

8. If you were looking to use a modified wood product in close proximity to grade the most appropriate choice would be:
   a. Acetylated wood material
   b. Kebonized wood material
   c. Thermally treated wood material
   d. A combination non treated and treated material.

9. The acetylation process results in a material that will actually be stronger but have a reduced density when compared to the untreated material.
   a. True
   b. False

10. Select the most accurate statement (s) from below.
    a. Thermal treatment of wood actual results in a weakening of the original wood material with regard to MOR and MOE but will still result in an enhanced durability.
    b. Kebonized wood introduces a bio-based alcohol that results in a swollen wood material that is less dimensionally stable than the non-treated material but provides a more durable product that does not require any exterior coatings.
    c. Acetylated wood material is appropriate for structural applications.
    d. A, B, and C
    e. A and C

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