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What is “wood stabilization”

There are a few different doctrines to which one might follow. There are some "tribal" definitions or interpreted uses of the terminology to pertain specifically to the application and intended use. For instance, burlsource.us defines it as such: "wood that has been impregnated with a chemical stabilizing solution. This stabilized wood can then be worked with normal wood working tools." Note the broad use of "chemical stabilizing solution" in the definition. They do not limit this to acrylates.

Why would we want to stabilize wood? Simple, if you’ve ever seen a beautiful piece of wood rendered unusable due to cracking and checking, you know why. We want to prevent the movement within the wood from damaging our often expensive pieces. Wood will swell and shrink along 3 axis at different rates. The longitudinal direction has almost no appreciable change in most species. The radial and tangential directions however can move 30-100 times more than the longitudinal direction and they do not do so equally. The difference in shrinkage between tangential and radial directions can split a piece of wood apart or warp it drastically as the water escapes the cells within the wood and the wood begins to dry. To prevent this, we must look at several methods by which we can make our wood more “stable” or “stabilize” our wood.

First, lets define stabilization. Of the many definitions out there, the one that seems to be most accurate is to define stabilization as a process or method by which movement or deterioration of wood, by loss or gain of water, is reduced or prevented by artificial means. This is fairly well documented in a series of scientific papers released between the 1950's - 1970's. In 1959 a seminar was held at the Forest Products Laboratory, Madison, Wis., on dimensional stabilization of cellulosic materials. Details are available in the 1959 Report of dimensional stabilization seminar. U.S. For. Serv., Forest Products Laboratory, report no. 2145 by Alfred J. Stamm. Conferees analyzed existing data and proposed new research programs to make wood products more dimensionally stable. Stamm had previously published and co-authored several other papers on the subject, including “Thermodynamics of the Swelling of Wood” in 1935, “Heat Stabilized Wood (Staybwood)” in 1955and “Heat-stabilized Compressed Wood (Staypak)” in 1956. In 1959, Stamm published “Effect of Polyethylene Glycol on the Dimensional Stability of Wood.”

So, what does this mean, aside from the fact Stamm was a prolific writer?
Wood stabilization has been a topic of research, practice and discussion for more than 80 years.

in 1981, the US Dep. Of Agriculture, Forest Service, Forest Products Laboratory released Research Note FPL-0243. Twenty-one years after the conference, this document listed the accepted methods of making wood dimensionally stable as follows: Cross-Lamination, Water-Resistant Coatings, Hygroscopicity Reduction, Crosslinking, and Bulking Treatments.

An example of cross-lamination would be any of the engineered woods we use today. Plywood for example takes advantage of the very minimal shrinkage in the longitudinal direction of the wood by layering sections and adhering them together with the longitudinal plane of the wood at opposing angles to the adjoining layers. Plywood is a very good example of a stabilized wood, but is not practical for most wood turning applications.

Water-Resistant Coatings however are quite useful and are used quite often in wood turning. Many suitable finishes provide stabilization to the wood by providing a moisture barrier between the wood and the relative humidity of its environment. This however has a major flaw. Given enough time, moisture will penetrate all known coatings and all finishes. Even paraffin wax can not provide a perfect barrier, though it is the best known surface coating with approximately 99% efficiency. Penetrating finishes, natural resins, waxes or drying oils dissolved in a volatile solvent form an internal coating on the lumen walls, but only penetrates the surface of the wood. In some cases, such as finials and pens, this penetration may be sufficient to penetrate the wood fully and "stabilize" the wood entirely to prevent a high degree of water repellency, but will not provide any long-term dimensional stability.

Moving on to Hygroscopicity Reduction… What in the world does that even mean? Well, this hard to pronounce, impossible to remember and big fancy term can get almost as technical as it is long and difficult to say. Basically, this is the amount or method in which water molecules become trapped within wood. They "stick" to certain elements of the wood which attract them and hold them like Velcro.

Here's an attempt to explain a bit of the technical aspect… When water enters the wood, the hydrogen (the H in H2O) forms a bond with the cell wall. This bond is a hydroxyl group and can happen with three major polymers in wood (that's right, wood itself is a natural polymer). Cellulose, hemicellulose, and lignin all react with water and are considered to be polymers. The cell walls expand to accommodate the addition of the water molecule. Any treatment that reduces the tendencies of wood to take on water in this manner also reduces the tendencies of the wood to swell. Ideally, the hydroxyl groups in the cell walls would be removed so that the water would have no capture point, but this would destroy the wood entirely in the process. Another option is to use the hydroxyl groups as a reactive site where hydroscopic chemicals can bond. Hydroscopic chemicals (water repelling) would reduce the tendency of the hydroxyl groups to bond with water, and bulk the cells with the newly bonded chemicals. This actually crosses over into bulking treatments. Another method is heat treatment. By heating the wood to temperatures up to 350 deg C (662 F) for a short time results in approximately 40% reduction in swelling. This heat treatment breaks down some of the hemicellulose components of the cell walls and reduces the number of points in which a water molecule will bond. This however, is not ideal for the condition of the wood.

Now we get to some of the good stuff! In early forms of crosslinking, studies were performed to investigate methods for chemically bonding cells together within the wood. The bonds would restrain the wood cells and prevent swelling. One of the most widely studied methods for crosslinking was the reaction between wood cell wall hydroxyls and formaldehyde. Strong acids were used to bond the same or different cellulose, hemicellulose and lignin polymers. The downfall to this form of stabilization was a reduction in mechanical properties of the wood. Compared to untreated wood, toughness, abrasion resistance, crushing and bending strength were all reduced, sometimes as much as 50%. While the wood was more durable and stable in the presence of water, the loss of these mechanical properties was not sufficient for most practical use.

While formaldehyde was not a suitable means for wood stabilization, it did spawn some interesting follow on research. The thought that the newly formed bonds and links were too rigid was considered to be the fatal flaw. To counter this, longer carbon chains were thought to be a viable solution to give more flexibility and retain the mechanical properties of the wood. Substances such as dysfunctional epoxides and isocyanates were expolored. A considerable amount of this research has gone on to improve products such as fiber-, chip, or particle-boards whereby the reconstituted materials of the wood are bound in a similar crosslinking manner along with the reaction taking place in the heat/compression stage of the manufacturing.

With all the shortfalls and limitations in the other areas, it is no shock that more focus has been placed into the area of bulking treatments than any other. This is where we find the most promise for practical application. Through bulking treatments, the cells are filled with chemical treatments and will increase in volume equal to the amount of chemicals introduced. It is therefore possible to bulk dry wood to the point and volume of when it was green wood. This artificial swelling of the cells leaves very little room for the wood to expand further and therefore will not be affected by contact with water. The results are the most dimensionally stable wood yet without degrading the mechanical properties of the wood. There are three classes of bulking treatments: nonbonded and water leachable; nonbonded and water nonleachable and bonded and water nonleachable.

Nonbonded-Leachable: The wood cell wall can be bulked with concentrated solutions of salts or sugars. Manganese, sodium barium, magnesium and lithium chloride were used. The wood becomes more hydroscopic, so a surface treatment had to be applied over the wood. The wood was dimensionally stable; however it was not impervious to water damage. Water which was able to penetrate the surface finish would remove the bulking methods, which are quite soluble in water. This method at first appears to have little practical application, but does include the use of polyethylene glycol (PEG). When treated with PEG, green wood is exchanged for the water in the cell wall. This method has been very effective in preserving wood from historic items such as sunken ships which have been brought back to the surface.

Nonbonded-Nonleachable: Wood is treated with bulking agents which do not bond with the cell structure of the wood, but form a non soluble and non leachable mass inside the cell walls. This forming of insoluble polymers inside the wood, but are not attached to the cell structure, is quite common in thin veneers. The resinoids are pushed into the cell wall structure and then cured at about 150 C for 30 minutes. This process/product is commonly referred to as “impreg,” and is the first example I give you of impregnation as a means of wood stabilization. This form of stabilization also includes the impregnation of wood with waxes. These waxes can replace the cell wall water in a two-phase process in which the water is first replaced with Ethylene glycol monoethyl ether or similar suitable glycol with a boiling point higher than water and then the glycol in the wood is replaced by a molten wax with a boiling point higher than that of the glycol used. In each phase, the element to be replaced is boiled off as it is replaced with another. While being quite effective, the wax ends interferes with gluing and finishing and therefore has not been taken up commercially for use in veneers.

Bonded-Nonleachable – Finally!!! We're going to impregnate the wood with something that will fill it up, prevent swelling and bond with the cell wall structure!!! This sounds like a permanent fix and a complete chemical modification of the wood. Well, not only are we going to chemically modify and bulk the wood, but we need something that is going to react with the hydroxyls in the cell wall. One problem here is when the cell wall is exposed to these types of treatments, the reaction continues until the cell walls rupture and split, to accommodate even more reacting chemical. So we're actually not going to get a huge amount of benefit here as we break down the cell wall structure in the process. There are also other limiting factors that have to do with Hydrogen and Oxygen molecules which are not removed in the process and it all starts to fall apart. Bonded-Nonleachable is not the way to go.
Nonbonded-nonleachable is over all the best method so far. We do not have to rupture the cellular structure in order to bond with it and the bulking agents are non-soluble in water. We can therefore fill a cell with polymers and prevent them from swelling in contact with water, but lets take it a step further. We started out with water-resistant coatings as the first method for treating a solid piece of wood. What if we took that idea inside the wood and gave the cell walls a surface coating? Well, that would certainly work to prevent moisture becoming trapped inside the cell walls, and even if the water were to become trapped inside the cell wall, the shell around the cell would prevent it from swelling. Additionally, if water were lost and the cell would shrink, the hardened shell that was formed around the cell wall would not move and would prevent the wood from shrinking. Now we have more options for stabilization methods.

Open cell vs Closed cell stabilization!

Open cell stabilization leaves the cell open. That is, we coat the outside of the individual cells in the wood with a hardening resin or polymer of some variety which will keep the wood dimensionally stable and prevent expansion and contraction of the cell. This method does not require a vacuum or pressure to penetrate within the cell walls. Wood can be soaked in the stabilization formula, taking on the additive through capillary action. This also does not require the wood be completely dry, if the stabilization fluid will not be adversely affected by the presence of water. This type of stabilization is very well covered by the modern products of Pentacryl and Wood Juice and through modern modifications to the PEG formula for specific application. Many other materials have also utilized this method for historical purposes or to improve durability. Some examples of this type of stabilization would include railroad ties which are stabilized by means of impregnation with creosote (primarily). Fence posts are stabilized through impregnation of other chemicals which prevent insect and water damage from deteriorating the wood as quickly.

Closed cell stabilization is a form of impregnation, typically nonbonded-nonleachable in nature in which the cell walls are penetrated and filled. These closed cells can not move within the wood. Many forms of closed cell stabilization can also coat the outside walls of the cell and fill some spaces between them. The use of acrylates, epoxies and polystyrene are all commonly used in this form of impregnation for purposes of stabilization.

There are many forms of stabilization, but most do not have any practical application within the turning community. Of the forms that do, there are a wide variety available to suite specific needs. Most closed cell stabilization methods, particularly those which can be done at home by a hobbyist, require the wood to be at 0% moisture content before impregnation. The contained water that is trapped within the cells when the wood is green must be removed and therefore the wood has already contracted in three different planes. Any damage that would occur due to a difference in radial and tangential shrinkage rates has already happened and the wood is likely already cracked or warped. Several methods are available to us before the wood is dry to prevent this, such as Pentacryl (a product by Preservation Solutions, LLC) for extremely wet/green wood and Wood Juice (a product by Preservation Solutions, LLC) for semi-dry woods. These products however utilize a form of open cell stabilization and do not drastically fortify wood or have much of a bulking effect. Some physical and mechanical properties of the wood may be slightly improved; however, they will not be as extreme as closed cell stabilization methods. Soft and punky woods may need fortification and bulking, but products such as Polycryl (a product by Preservation Solutions, LLC) and other rotten wood treatment products like Minwax Wood Hardener or polyurethane may offer suitable results for some uses. It is no surprise however, that the majority of individuals believe that acrylate impregnation & closed cell stabilization is the only suitable form, but this is only most effective when the moisture has already been removed from the wood. Products such as Cactus Juice (a product by Turntex Woodworks) and the resins used by commercial stabilization companies do a remarkable job of making wood dimensionally stable and fortifying the wood through bulking methods.

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- Pentacryl, Polycryl and Wood Juice are products of Preservation Solutions
- Cactus Juice Stabilizing resin is a product of Turntex Woodworks
- Minwax Wood Hardener is a product of Minwax Company