Increase in wettability of wood with weathering

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Abstract

Western redcedar panels were exposed to outdoor weathering. Wettability with water was measured as contact angle, using a videotape technique. Contact angles decreased from 77 to 51 degrees after 4 weeks of weathering. Greater wettability of weathered wood is suggested as a contributing factor to the deterioration of wood structures.

It is generally recognized that severely weathered wood does not repel water very well. Water readily wets such a surface and is quickly absorbed into the wood. How soon the wood surface loses its natural water repellency when exposed to weathering is not well known and has received little study. Wettability of a solid surface by a liquid is usually expressed as the contact angle between the solid and the liquid, a smaller contact angle signifying greater wettability (1). Decreasing contact angles with time of outdoor weathering were reported for Scots pine and European beech woods (3). The changes in wettability of wood with weathering are not well characterized, despite the considerable practical importance and economic significance of these changes.

Unpainted western redcedar panels that had been weathered outdoors for various periods were available from a study conducted in 1987 (18). It was felt that if these panels showed wettability effects even after 5 years of storage, then recently exposed panels would almost certainly show equal or greater effects. A procedure that was developed recently for determining wettability of wood surfaces (11) was well suited for use with the panels. The objective of this study was to determine if outdoor weathering changed the wettability of western redcedar.

Experimental procedures

In 1987, western redcedar *(Thuja plicata)* panels were cut to 12.7 by 25.4 by 1.9 cm from smooth beveled 2.44-m siding boards, statistically randomized, and stored at 26.6°C and 65 percent relative humtdity (RH) until the outdoor weathering exposure. Weathering began in May and was done near Madison, Wis. The panels faced south on a vertical exposure fence. After being weathered for 0, 1, 2, 4, 8, or 12 weeks, the panels were stored at 26.6°C and 65 percent RH until the wettability determinations were made 5 years later.

Wettability of the cedar panels was determined with distilled water, using an automatic micropipette to dispense 25-µl drops. We previously found variations in drop size near 25 µl to have little effect on the contact angle. A videotape recording of the profile of each drop was made, using a 3× magnification with fiber-optic lighting. Measurements of contact angles were made on "frozen" videotape images using a protractor transparency, at 2 seconds of elapsed time after the deposition of the drop. This procedure has been illustrated and described in detail by Kalnins and others (11). At least five, but usually more, drops were deposited on each panel and videotaped. The top surface along each of the two longer edges of each panel was used for placing and videotaping the drops. Three panels were used for each weathering period, except that only two were available for the 16-week weathering period. Both right and left contact angles were measured on each drop. Values were averaged to obtain one contact angle for each weathering period (Fig. 1).

Results and discussion

The average wettability values, given as contact angles, are listed and shown in Figure 1. The contact angle formed by water on the western redcedar panels before weathering averaged 77 degrees. The contact

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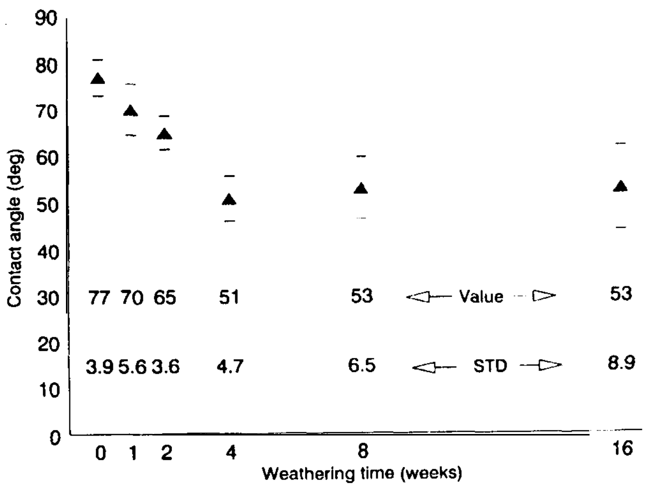

Figure 1. — Outdoor weathering results (average wettability values) in smaller contact angles of water on western redcedar. Contact angles for 0 and 1 week of weathering are significantly different from those for 4, 8, and 12 weeks by the conservative Tukey test (0.05 level of confidence). STD = standard deviation.

angle decreased with weathering (showing greater wettability) to a minimum of about 51 degrees after 4 weeks of weathering. The average contact angle did not change significantly after 8 and 16 weeks of weathering. Contact angles for 0 and 1 week of weathering are significantly different from those for 4, 8, and 16 weeks by the conservative Tukey test (0.05 level of confidence). It is noteworthy that the effect of weathering on the wettability of wood is a long-term effect and that the storage period following the weathering exposure did not result in a recovery of the natural water repellency.

The response of the contact angle on the western redcedar panels differed from that measured with the tilting plate method by Banks and Voulgaridis on beech and Scots pine (3). When untreated beech was exposed to weathering in Great Britain, the contact angle decreased from nearly 70 degrees at the start to about 55 degrees after 26 weeks, and ultimately to less than 30 degrees after 1 year. In contrast, Scots pine had a contact angle near 80 degrees at the start and after 26 weeks; by the time 52 weeks of weathering had elapsed, the contact angle was less than 30 degrees (3). In our opinion, differences in the response of wettability to weathering were due to the differences between wood species. It is suggested that extractives contributed significantly to these differences between Scots pine, beech, and western redcedar.

Beechwood has a low percentage of extractives present, and its heartwood is thought to contain a collection of relatively simple phenolics (14). Western redcedar extractives contain tropolones (α–, β–; and γ–thujaplicins, thujic acid) (19), thujaplicatin, plicatin, plicatic acid, and plicatinaphthol (8).

Scots pine extractives include d-α–, and 1–β– pinenes, d- Δ^3– carene, 1-limonene, pinosylvin, pinoresinol, -sitosterol, diterpene resin acids, oleic, linoleic, palmitic acids (5, 19), hydrocarbons, and waxes (8).

From this, one might expect that Scots pine would have the lowest initial wettability (largest contact angle), followed by western redcedar and beech.

Weathering, through the action of sunlight and water, causes gradual destruction of a wood substance, as wood is converted to volatile and water-soluble degradation products (9,10,13). A leached, eroded, cellulose-rich layer remains on the wood surface (7). At this stage, species differences are probably no longer significant in regard to wettability. Our contact angle measurements showed that the appreciable water repellency possessed by unexposed western redcedar surfaces was significantly reduced by weathering in relatively early stages, well before extensive surface degradation effects were readily observed.

Our results showed maximum wettability after about 4 weeks of weathering. It is worth noting that reduced adhesion of paint to wood has been detected after only 4 weeks of prior weathering (18). This means that at the same time that weathering has made the wood more wettable (reduced the water repellency to a minimum), the adhesion of paint to wood has become measurably weaker.

If the weathered wood surface is painted, we can only speculate to what extent the increased wettability characteristic remains in the wood surface layer after the paint has dried. If the wettability of weathered wood beneath a paint film remains high, any breaks in the film, as a result of nailing, drilling, checking, or mechanical damage, would expose the wood surface to magnified swelling and shrinking stresses. This could be a contributing factor to the inferior performance of paint over weathered wood. For example, Kleive (12) reported that weathering for 2 months or more damaged the surface of spruce wood in regard to its paint-holding ability; even a thinned, more penetrating primer did not restore the wood to its previous paint-holding quality.

Increased wettability of areas of exposed and weathered wood in previously painted but poorly maintained wood has often been observed. It is assumed that the dimensional changes in the surface layers caused by the repeated swelling and shrinking contribute to the further breakdown of the wood-paint system. The harmful effect of water on the performance of painted wood is further underscored by several reports of improved durability of paint when wood has been treated with a water repellent or a water-repellent preservative prior to painting (2,6,17).

The mechanism whereby weathering makes wood more wettable with water is not clearly understood. We suggest that the photooxidation of extractives leading to volatile products and to water-soluble materials effectively removes them from the exposed surface. Furthermore, it is known that lignin is primarily responsible for the absorption of ultraviolet radiation by wood and that lignin shows early effects of degradation caused by weathering (7,10). Rowell and Banks suggested that lignin is one component responsible for the water repellency of wood (15). The hygroscopicity of cellulose is well recognized, and its relatively greater resistance to weathering and to photodegradation has been described (7).

Loss of aromatic components in wood (lignin) as a result of photochemical degradation has been noted (7). We suggest that weathering also changes the aromatic and side-chain components of lignin so as to reduce their contribution to water repellency of wood. Carbonyl, carboxyl, quinone, peroxide, and hydroperoxide groups are formed in wood by photooxiddation (7,10); together with the action on extractives, weathering has the net effect of increasing the wettability of wood. Cellulose, being more resistant to weathering effects, becomes more abundant on the weathered wood surface (4). This presumably increases the hydroxyl concentration on the wood surface. When a drop of water contacts the weathered wood, greater interaction between the hydroxyl groups of wood and water undoubtedly occurs.

The weathered western redcedar panels retained increased wettability despite the storage period prior to the contact angle measurements. Swanson and Cordingly (16) studied the self-sizing or air-sizing effect in paper and paper products. They cited poor wetting with printing inks, water resistance in paper products intended to be absorbent, and poor adhesion during manufacture of corrugated board as problems resulting from the extended storage of paper. Vapor-phase deposition of extractives and of stearic acid on paper was shown, resulting in considerable water repellency in the previously absorbent sheets (16). Although fatty acids have been reported in the bark of cedar, a similar self-sizing effect in western redcedar wood evidently does not occur.

In summary, we suggest that weathering of wood increases the wettability by 1) reducing or removing the water repellent effect of extractives; 2) degrading the hydrophobic lignin component of wood; and 3) allowing cellulose to become more abundant on the surface. It is likely that major differences exist between species of wood.

Based on the fact that the panels stored for 5 years retained increased wettability, the study of changes in the wettability of wood is continuing. A study in progress will measure contact angles of western redcedar and southern pine panels that are weathered but not stored. A study of the role of extractives is also planned.

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