Water sorption characteristics of two wood-plastic composites

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Abstract

Wood-plastic composites are generally presumed to be inherently more resistant to moisture uptake than solid wood, but there is little data on the relative rates of moisture uptake in these materials over time. Trex® and Strandex® deck sections were immersed in water for up to 215 days, then sections were cut at various distances away from the ends and surfaces. The moisture contents in these zones were then assessed by oven-drying and weighing. Overall moisture increases were relatively slow, particularly for Strandex, but moisture levels in the outer 5 mm of the products were sufficient for fungal attack. This moisture distribution coincides with decay patterns observed in previous laboratory studies and highlights the importance of slow moisture uptake in the performance of these materials.

While wood-plastic composites (WPC) were originally marketed as being naturally decay resistant because of the belief that the plastic encapsulated and thereby protected the wood particles from fungal attack, a number of field and laboratory reports have clearly shown that WPCs gradually absorb water and eventually decay (Mankowski and Morrell 2000, Morris and Cooper 1998, Schmidt 1993, Simonsen et al. 2001). The decay rates of WPCs tend to be much slower than the woods from which they are composed, suggesting that plastic has some water-repellant effect. There are, however, few data demonstrating the moisture relationships in these materials as they relate to decay. A number of studies have used water immersion to assess changes in properties, but the immersion periods were limited (Chow et al. 2000, Sellers et al. 2000, Shi et al. 1999, Simonson et al. 1997). Other studies have used longer immersion periods, but have not attempted to profile moisture distribution from the surface inward (Jacoby et al. 2001, Johnson et al. 1999, Rowell et al. 2000, Shi et al. 2000). These latter tests often show low overall moisture content (MC) but may under estimate surface moisture distribution where fungi must initiate their attack. Developing a better understanding about how moisture moves into WPCs is an essential part of the development of test methods that more aggressively challenge these materials to fungal attack.

In this study, tests of moisture sorption characteristics of two commercially produced WPCs are described. The results should prove useful for those assessing the risk of decay for these materials under varying moisture regimes.

Materials and methods

Two WPC decking products, Trex® and Strandex®, were obtained from commercial suppliers. Strandex was supplied directly as 25-mm- by 137.5-mm- by 1.2-m-long lengths (Louisiana Pacific, Inc., Portland, OR), while Trex was obtained from a local building supply center as 37.5-mm- by 137.5-mm- by 2.4-m-long sections. The material was cut into a series of 100-mm-long sections and one end of each section received two coats of a marine-grade epoxy to retard water penetration and simulate a longer sample. The samples were then immersed in water at 5°C or 25°C. At a given interval time, four samples of each material were removed, blotted dry, and weighed to determine weight gain. A series of 5-mm-thick slices were then cut from the unsealed end of the sample as well as 25 mm and 50 mm further inward. The Trex slices were further analyzed by cutting a series of zones corresponding to 0 to 5, 5 to 10, 10 to 15, and 15 to 18 mm from the surface (**Fig. 1**). The Strandex slices were similarly cut into zones corresponding to 0 to 5, 5 to 10, and 10 to 12 mm. The material from a given zone was weigh-

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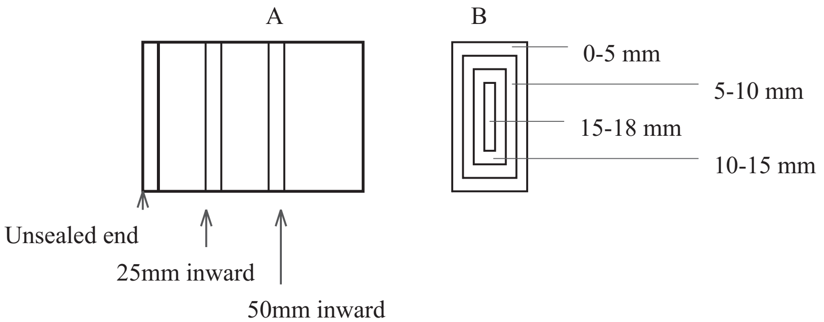

Figure 1. — Cutting patterns used to sample MC of Trex samples. A) Pattern used to cut 5-mm-thick slices from 100-mm-long samples; B) Pattern used to sample moisture gradients in Trex slices.

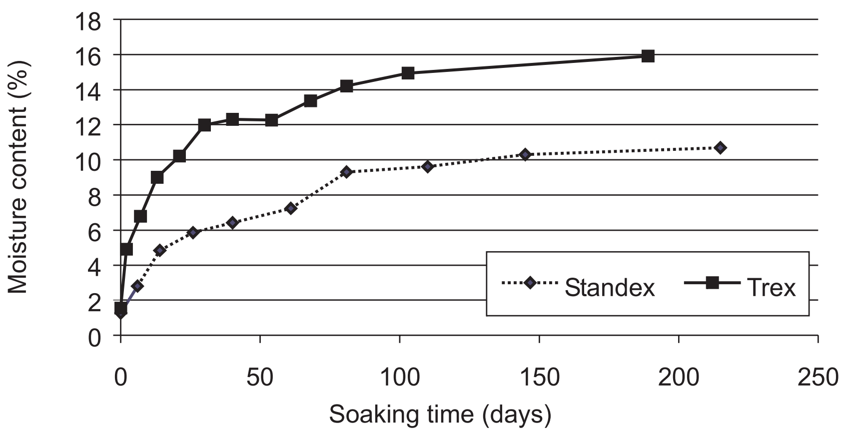

Figure 2.— Overall wood MC of 100-mm-long Trex and Strandex samples soaked in water at 5°C for up to 215 days.

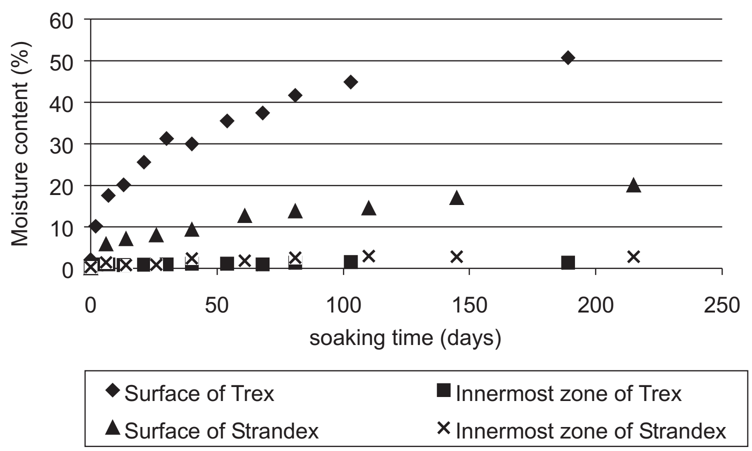

Figure 3. — Wood MC in surface (0 to 5 mm) and inner zones (15 to 18 mm and 10 to 12 mm) of Trex and Strandex samples immersed in water for up to 215 days.

ed, ovendried to stable weight at 105°C, and weighed again to determine MC. Because of the minimal sorption of water by the plastic, MC was calculated on the basis of the wood component, which was 50 percent and 60 percent by weight for Trex and Strandex samples, respectively.

The 5°C trial was run for 190 days, while the 25°C trial was run for 30 days using Trex samples. At this point, a thick microbial film had developed on the surfaces of the specimens stored in warmer water, and there was concern that this film would alter the moisture sorption characteristics of material and confound the results. MCs for the two temperatures were compared using t-tests at $\alpha = 0.05$ using Excel (Microsoft Inc. Bellevue, WA). Strandex samples were only exposed at 5°C for 215 days.

Results and discussion

Water sorption by both of the WPCs tended to be much slower than would be expected from the original wood material (USDA 1999). Overall MCs of the wood component increased from 1.56 to 15.9 percent over nearly 190 days for Trex while those for Strandex increased from 1.27 to 10.69 percent over 215 days (**Fig. 2**). These values indicate that overall moisture levels would be unsuitable for microbial attack. The lower overall moisture sorption by the Strandex samples likely reflects the characteristics of the wood particles in this material. Strandex tended to contain smaller, more uniform particles while the wood particles in Trex were larger and less uniform. Smaller particles are more likely to be evenly coated with plastic and also present a less continuous pathway for moisture ingress. Both of these characteristics may help to explain the slower moisture uptake of Strandex.

MC of the samples from the outer 5 mm of both materials increased to the greatest extent. The MC of the wood near the surface of the Trex samples increased from 2 to 45 percent over the first 100 days, then moisture uptake slowed markedly. Strandex samples absorbed moisture more slowly, increasing from 0.6 to 15 percent over 110 days. MC of the innermost zone increased only slightly from 0.3 to 3 percent in Strandex and 0.5 to 1.5 percent for the Trex over the same time periods (**Fig. 3**). These results illustrate the relatively slow movement of moisture into these products, even when fully immersed in water. Even moisture levels 5 to 10 mm in from the surface showed little change over the immersion period (**Fig. 4**), indicating that moisture sorption was both slow and localized.

The distribution of moisture found in Trex and Strandex helps to explain much about the decay patterns observed in these materials. Moisture levels tended to be elevated in the outer 5 mm, and then sharply declined further from the surface (**Fig. 5**). Fungal decay tends to occur when the MC of the wood exceeds the fiber saturation point (approximately 25% to 30% MC) (Zabel and

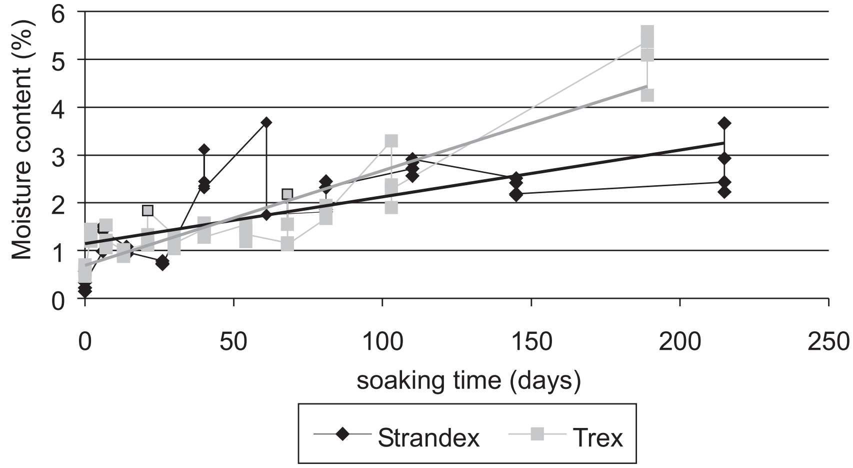

Figure 4. — Wood MCs of Trex and Strandex samples cut 5 to 10 mm inward from the surfaces of cross sections cut 25 mm in from the exposed cross section.

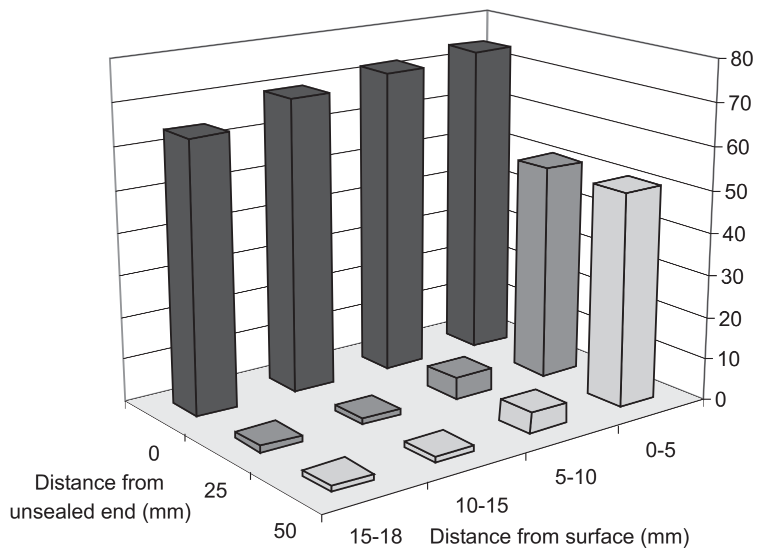

Figure 5. — Wood MC variation of Trex immersed in water for 190 days at 5°C.

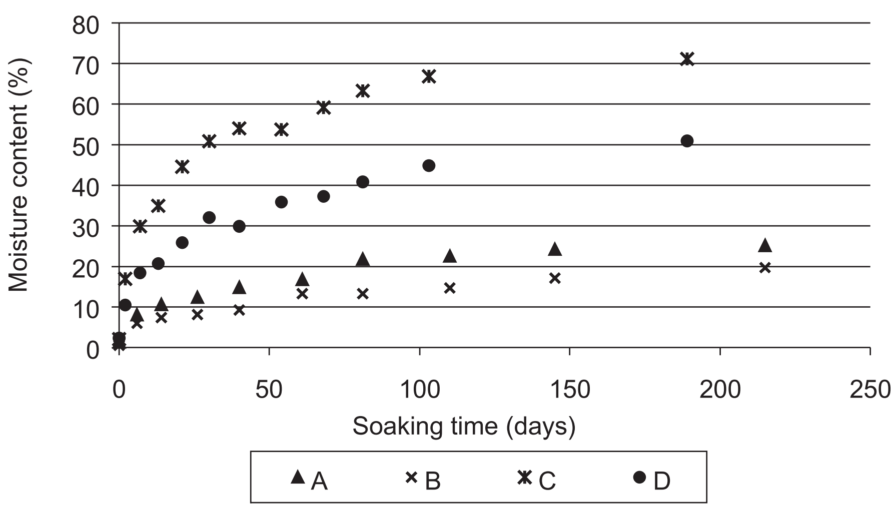

Figure 6. — Wood MC in the outer 5 mm of Strandex (A and B) or Trex (C and D) adjacent to the cut end (A and C) and 25 mm inward from that zone (B and D).

Morrell 1992). As a result, any biodeterioration is likely to be similarly confined to the surfaces of WPCs, and the interior will remain unaffected until moisture intrusion occurs. Prior laboratory attempts to decay these materials tended to produce dissolution of wood near the surface, but little visible damage further inward (Silva et al. 2001)

As expected, exposing the cross section resulted in higher moisture uptakes in comparison with slices cut from further inwards (**Fig. 6**). While cutting increases the potential that individual wood particles will be exposed to direct water contact, the overall increase in MC appeared to be closely related to the total surface area exposed to water. For example, the surface areas exposed to water from an uncoated end slice and an interior slice of Trex were 6,906 and 1,750 mm^2, respectively. Thus, cutting produced a 3.9-fold increase in exposed surface area. The moisture levels in the exposed cross sections were 4.4-fold higher than in the interior slice after 103 days. The relatively small differences between increased surface area and increased moisture levels suggest that extrusion does not produce a more moisture-resistant surface than might be present in the interior of the cross section. The results also showed that cutting through the cross sections as decks are fabricated might provide more pathways for moisture ingress. This process is similar in many ways to the cut ends on solid wood that act as water trapping zones that encourage microbial attack. This suggests that microbial attack of WPCs in applications such as decking will likely occur at joints and other water trapping features in a manner that is similar to that found with traditional wood decks.

The exposure of WPCs to water at different temperatures produced statistically higher degrees of water absorption in samples exposed at the higher temperatures (**Fig. 7**). While temperature had an impact, the slight increase over a 20°C increase in temperature suggests that the practical impact of elevated temperature on moisture uptake will be slight, even at the very end of the samples.

Conclusions

Despite significant surface moisture sorption, the interiors of the two materials tested remained dry over an extended soaking period. The overall low levels of moisture detected in the materials, even

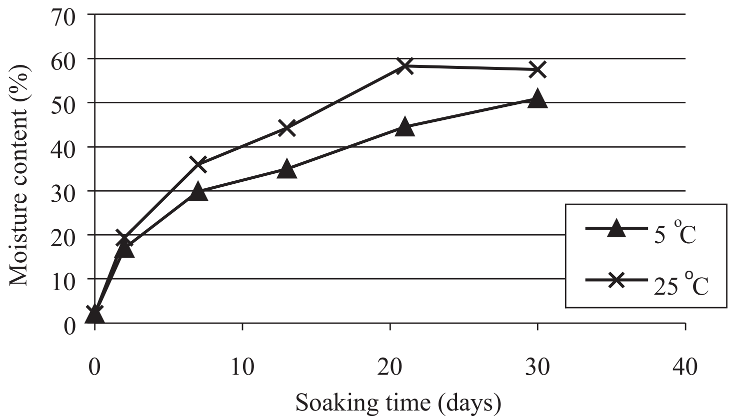

Figure 7. — Effect of water temperature on wood MC in the outer 5 mm of Trex samples immersed for 30 days at 5°C or 25°C.

near the surface, suggests that decay of these materials will be similarly retarded and will likely occur through a cycle of surface wetting and microbial attack that exposes new wood particles to moisture followed by attack of this newly moistened layer.

The rate of moisture sorption and ultimately the rate of decay will depend on wood particle size and geometry, wood/polymer ratio, and the presence of other compounds that may repel water.

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