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Borate Rods as an On-Site Remedial Treatment for Control of Decay in Wood Decks

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ABSTRACT—A conventional wood recreational deck constructed with spruce-pine-fir lumber was sampled for active growth of wood decay fungi before and 10 months after remedial preservation treatment with fused disodium octaborate rods (IMPEL®) at boric acid levels from 1.5-10 kg/m³. Extent of boron distribution was observed with a color indicator dye (curcumin) after 10 months exposure. Remedial treatment with the boron rods was nearly 100% effective. Active decay cultures from treated material were found only in samples obtained from boards treated at the inhibition dosage level (1.5kg/m³) of boric acid. Suggested lethal dosages ($\geq$ 3kg/m³) were effective in all cases as indicated by the failure to recover any decay fungi. In contrast, the numbers of active decay cultures from nontreated boards increased over the exposure period. Curcumin tests for diffusion indicated excellent distribution of boric acid in wood material where moisture contents exceeded 25% (ovendry weight basis).

Introduction

Alarming increases in the structural failure of millwork exposed outdoors (1-7), due to biodeterioration by wood decay fungi has led to the search for reliable fungistatic remedial preservative treatments to be utilized *in situ* to arrest or inhibit decay activity (3,5,8-12). Various reasons cited as contributing to this observed and often premature failure are primarily related to the failure to keep wood dry in service through poor design or building techniques used in construction, inadequate preventive maintenance (e.g., painting), improper retention (weight of preservative per unit volume of wood) or preservative type for the intended exposure situation or even more importantly, the lack of proper preservation treatment prior to installation (1,2,5,6,7,10,12-16).

While a large selection of over-the-counter preservatives and preservative-treated lumber is available, lack of consumer awareness of correct application or uses as well as the capital expense involved in procuring the proper material, often leads to a poor selection of materials and inevitable failure. Also, despite proper selection, most preservative-treated material offered for outdoor building uses, such as in decks or retaining walls, contains a large proportion of heartwood, which is generally untreatable by even the best of available preservatives or treating processes. Furthermore, cutting treated wood at installation often exposes untreated decay-susceptible wood within the treated shell. Quite often these newly exposed areas are left without supplemental on-site treatment. Preservative brush-on stains likewise are ineffective in protecting wood from internal decay once surface checks develop in service.

Removal and replacement of defective material can be costly. For example, a survey of 16 St. Paul, Minn. contractors produced average repair cost estimates of $200-325 to repair four wood deck joists (2″ x 8″ x 10′), and $2000-3000 to replace the 10 lower timbers (6″ x 6″ x 8′) of a retaining wall. Furthermore, often as an alternative to replacement of an entire piece of wood exhibiting heavy decay in a small localized area, the obviously decayed material may be excavated and replaced with vinyl or wood putty materials. The possibility of incipient decay (which is not readily visible) in the remaining material, or ongoing decay in adjoining components in intimate contact with the defective material is often ignored by the untrained observer. Since other remedial actions seldom accompany this cut and replace procedure, the end effect is more suitably labeled a cosmetic rather than a corrective solution.

Remedial preservative treatment of wood with early decay may prove useful as an alternative solution to replacement or temporary repair methods by extending the service life of wood out of ground contact and/or decreasing the labor and material costs of present day maintenance and repair. Implementation and subsequent inspection of these treatments could easily be incorporated as part of a routine periodic maintenance program (e.g., painting). Other potential applications for a reliable remedial preservative treatment may be in the maintenance of wooden railroad ties, bridges, utility poles, and window joinery. Wherever wood moisture contents (MC) (the amount of moisture in wood expressed as a percentage of the ovendry weight of the wood) may be constantly or occasionally above the fiber saturation point (30% MC) and thus in danger of infection by wood decay fungi, remedial preservative treatment may be useful.

Past experiences with boron compounds have documented their abilities as proven wood preservative chemicals (17). A recently developed remedial treatment product based on boron—a fused crystalline borate rod [IMPEL® (Wood-Slimp GmbH, Denmark)]—has been examined in field and laboratory studies in other countries. The borate rods have

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shown promise as a remedial treatment for railway ties and window joinery components of Scots pine (*Pinus sylvestris L.*) in Sweden (3,8,13). Similar results on door joinery of Western hemlock [*Tsuga heterophylla* (Raf.) Sarg.] in England (9), and on small rounds of *Eucalyptus oblique* (L'Hertier.) in an accelerated field simulator trial were obtained in Australia (18). A Canadian study demonstrated the effectiveness of a boron dip diffusion treatment to control decay in Western hemlock and amabilis fir [*Abies amabilis* (Dougl.) Forbes] lumber (19). Studies in the United States of the rods' effectiveness at protecting Douglas fir [*Pseudotsuga menziesii* (Mirb.) Franco] pile cutoffs have shown preliminary positive results (20).

Extent of chemical diffusion from borate rods was directly related to the moisture content in Western hemlock, Sitka spruce [*Picea sitchensis* (Bong.) Carr.] and Scots pine in studies in the United Kingdom (9,21). Of importance here is that the diffusion in wood most at risk to decay (i.e., joint areas with exposed end grains and with the highest moisture contents) is adequately protected by the treatments. The studies show that where moisture contents are sufficient to support fungal growth (i.e., $\geq$ fiber saturation point), the potential exists for the distribution of inhibitory or toxic levels of remedial preservative chemicals. The relationship between moisture content, wood volume, and remedial treatment must be completely understood in order to use this treatment effectively.

To date, comparative studies and verification of test results on wood used in home construction are lacking in the United States. While moisture diffusion rates in the various species of pine are considered approximately similar (22), other wood species are found in common usage in the United States. Differences in efficacy and distribution of active ingredients of remedial treatments are possible. Also, species of decay fungi important in destruction of such wood differ from country to country. Therefore, a test of the efficacy of the borate rod remedial treatment was conducted on a wood deck built from predominantly utilized and locally available wood material, and exposed in a high moisture hazard and existing decay situation.

Materials and Methods

The deck (8 x 3.5 m) selected for the field test was constructed 5-6 years earlier using spruce-pine-fir (various species) decking material. The deck had been painted with a water-repellent wood preservative stain every 24 months. A total of 61 individual surface deck boards (4 x 9 x 244 cm) were separated into two groups based on their signs of advanced (obvious) or incipient degrees of decay. There were 31 and 30 boards in each group respectively. The deck boards were probed with an ice pick for softness or brash fibers and moisture content readings were taken as additional aids to the visual assessment of the degree of decay for a particular board. Fifteen boards from each of the two groups were randomly selected for remedial treatment. Treatment consisted of placing 8mm diameter borate rods into drilled holes (depots) and sealing the hole with a fluted nylon plug. The boards were treated at boric acid (BA) retention levels of 1.5, 4.0, 6.0 or 10 kg/m^3 designed to protect them with preservative over an inhibition (1.5kg BA/m^3) to lethal (> 3.0kg BA/m^3) dosage range as suggested by previous studies (3,13,17,18,19,20). Specific retention levels were obtained by varying the length of rod deposited or the number of depot sites per board. Also, for a given board and retention level, the rods could be distributed into two or more depot holes depending on the speed of diffusion or area of coverage desired.

Prior to treatment, wood core samples 2cm in length and 6mm in diameter were removed aseptically from the undersurface of each board for decay fungi isolation purposes. One core was removed at 5cm distance from the end grain and another core at 10cm distance longitudinally from the nearest anticipated rod depot site (Figure 1). Where obviously advanced decay was noted at a particular sampling site, cores were removed from sounder- appearing material immediately adjacent to the zone of decay.

The samples were split into three equal sections, briefly surface flamed, and placed on a medium of malt extract agar. The medium was amended with 20ppm benomyl to selectively observe and identify basidiomycete wood decay fungi because of their importance as structural destroyers of wood products. Mold and stain fungi were also observed and noted. Also, we wished to test the results of other studies (3,5) that showed the borate rods to be less effective against mold and stain fungi.

Following a 10-month waiting period, the deck was resampled immediately adjacent (within 2cm) to the original sampling sites for the presence of living decay fungi. Rod depot sites were also examined for loss of chemical through solubilization and the treated deck boards were sawed longitudinally along the tangential plane to measure the extent of boron diffusion by colorimetric means (23). For this, a curcumin dye solution was sprayed on the wood. The solution reacts with boric acid to produce a red color. While the dye showed the extent of preservative diffusion, it provided only a rough indication of preservative concentration within diffusion zones based on the intensity of the red color developed. Where color tests failed to indicate the presence of boron in an area expected to contain the chemical, small wood samples were removed and exposed in agar plates to detect the presence of any residual boron. The effectiveness of the remedial treatment was judged by the absence of previously detected fungi. This was verified through cultural analysis of the replicate core samples removed from positions adjacent to previously sampled sites along the boards.

Results and Discussion

To be lethally effective as a remedial preservative treatment, it is necessary that boric acid levels of at least 3.0kg/m^3 be obtainable at least 12cm from a rod depot site within nine months of deposition (3). Areas of red coloration

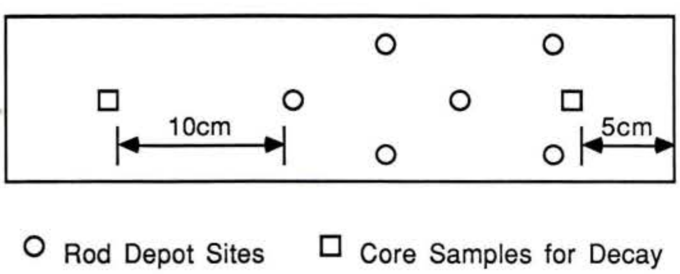

Figure 1. Core sampling and depot site arrangement on deck boards (number of depot sites for a given board depends on desired treatment level).

resulting from the curcumin dye test are indicative of this minimum recommended retention level. Using these guidelines, diffusion from the rods was very good in spruce and pine deck boards, extending longitudinally 20-30 cm beyond the nearest depot site (Figure 2). In fir pieces diffusion was limited to an area 1-4 cm around the depot site but did extend around decay pockets when depot sites were placed in close proximity to these decay areas (Figure 3). Rods were depleted (i.e., no solids remained) after the 10-month exposure period from all depot sites except in fir boards where 18 of 40 depot sites contained an average of 1.1gm (±0.5gm) of residual rod (approximately 85% of initial mass). Diffusion patterns from the curcumin test were erratic in heavily decayed boards, which correlates with earlier reports by Edlund (3). In boards with pockets of decay, boron concentration appeared highest (most intense red color) in the areas immediately surrounding the pockets, which is to be expected in view of the higher moisture content associated with these areas.

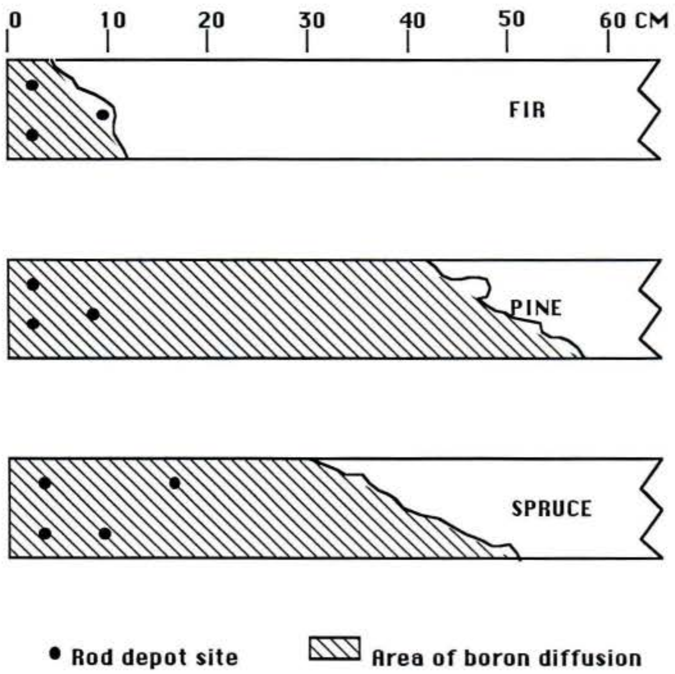

Figure 2. Longitudinal section showing boron diffusion in deck boards.

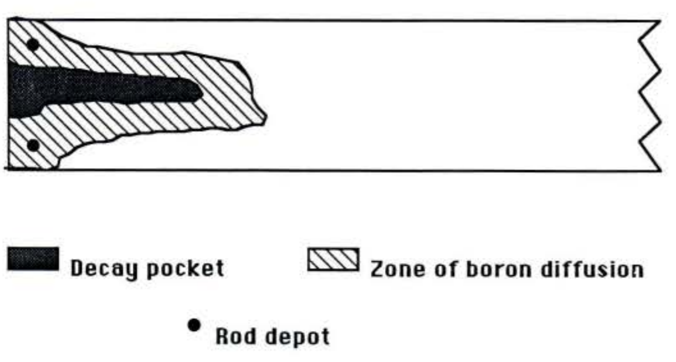

Figure 3. Boron diffusion around decay pocket in fir deck board.

Due to the lower diffusion distances measured in the fir samples, laboratory tests were made with pieces of the fir deck boards artificially wetted to 20-40 % moisture content (dry weight basis). These sample boards were exposed for seven weeks in a controlled environment and demonstrated greater boron diffusion potential in fir when moisture contents are above 30% (Table 1). This indicates that the limited diffusion in the fir deck samples resulted from a lack of available moisture in the lumber and not the diffusion properties of this particular wood species.

Decay fungi in treated boards were eliminated from all core sampling sites within 2cm of rod depot sites (Table 2). No viable decay fungi were found in cultures from areas adjacent to decayed wood in material treated above 2kg BA/m^3. Decay fungi were found in pine and fir boards at the 10cm distant sampling site. However, in these boards, the low level of initial treatment (i.e., the inhibition dosage of 1.5kg BA/m^3), or the poor chemical diffusion demonstrated in fir pieces seemed to be the most likely reasons for continued survival of the decay fungus. These treatment zones failed to develop a red color when sprayed with the curcumin dye, further evidence for poor diffusion of boron or low levels of treatment.

Mold fungi, while not completely eliminated, were reduced based on isolation frequency. In advanced decay boards a reduction in mold fungi from 67 to 33 % was observed in areas adjacent to treatment and from 53 to 27 % in areas 10cm from treatment. Treated incipient decay boards had similar mold and stain fungi decreases from 80 to 13 % within 2 cm of treatment and from 40 to 13 % in areas 10cm from treatment. These results compare with previous work (3), indicating a reduction in mold fungi levels although these fungi appear to be less sensitive to boron than the more important wood destroying basidiomycetes. The most commonly isolated mold fungus was a species of *Alternaria*.

By contrast, untreated material (Table 3) had increases in isolation frequency for both classes of fungi over the 10-month period. Decay fungi in advanced decay boards increased from 93 to 100 % and mold/stain fungi isolations increased from 27 to 47 %. In untreated incipient decay boards, decay fungi isolations increased from 31 to 93 % while mold/stain fungi isolations increased from 50 to 73 %. The decay fungus most commonly isolated was *Gloeophyllum trabeum* [(Pers. ex Fr.) Murr.], but nine other species of basidiomycetes were also present.

In several instances (64 of 121), the barbed nylon plugs used to seal the depot holes after chemical deposition were protruding 3 to 8 mm from the surface of the treated boards by test end. All plugs had been installed initially flush to the board's surface. It is believed that this plug egress may be caused by freezing and thawing of moisture adjacent to the depot sites or anisotropic dimensional changes of the wood. This should be studied further since plugs falling from the undersides of boards might allow solid rod residue to fall from the depot hole.

Also noted at test end were crystalline surface deposits (blooming) on the undersurface of 8 of 30 treated boards, at distances 5 to 26 cm away from the nearest rod depot site. The deposits were seen primarily on pine boards treated at the 4.0kg BA/m^3 level (4 of 8 cases). In four of these instances, the blooming also was associated with the plug egress problem mentioned previously. Blooming has not been mentioned in any previous reports dealing with remedial treatments by Impel rods but has been cited in

Table 1. Longitudinal and across the grain diffusion in fir deck boards (4 x 9 x 30 cm) exposed in a greenhouse for seven weeks after rod implants.

Sample	Initial MC (% ovendry weight)	Final MC (% ovendry weight)	Longitudinal Diffusion (mm)	Across Grain Diffusion (mm)
K[a]	14.8	21.2	16[c]	10[c]
K1	14.9	20.6	28	40
K2	15.7	20.7	31	40
A[b]	32.3	34.4	47	40
A3	41.1	44.2	81	40

[a]K-samples primarily heartwood.
[b]K-samples primarily sapwood.
[c]Measurement of bright red zone from edge of depot site.

Table 2. Percent of bore samples from treated deck boards with fungi present before and 10 months after treatment with borate rods.

	Board Group			
	Advanced Decay (n=15)		Incipient Decay (n=15)	
	Decay Fungi	Stain/Mold Fungi	Decay Fungi	Stain/Mold Fungi
Before Treatment:				
Within 2cm of depot	100	67	93	80
10 cm from depot	93	53	53	40
After Treatment:				
Within 2cm of depot	0	33	0	13
10cm from depot	33	27	27	13
Boron Visualized*				
Yes	1	1	1	0
No	4	3	3	2

*At isolation point where fungi were found after treatment.

a report on the use of liquid boron dip treatments for green lumber (19). Atomic absorption analysis confirmed these blooms to be boric acid crystals.

Table 3. Percent of bore samples from untreated deck boards with fungi present before and after 10 months exposure.

	Board Group			
	Advanced Decay (n=15)		Incipient Decay (n=15)	
	Decay Fungi	Stain/Mold Fungi	Decay Fungi	Stain/Mold Fungi
Initial Sampling	93	27	31	50
After 10 months	100	47	93	73

*At isolation point where fungi were found after treatment.

Conclusions

The Impel rod remedial treatment was very effective in eliminating established decay fungi and preventing further decay in most instances. This suggests it has great potential as a remedial treatment in protecting spruce-pine-fir deck lumber from fungal decay. In all cases where moisture contents exceeded 28%, treatment loading at 1.5kg boric acid/m^3 was sufficient to eliminate most existing decay fungi in the deck material at distances up to 10cm from a depot site.

Of some concern is the crystal blooming. Given the small dimensions of construction components in the United States, smaller rods spaced more frequently along an individual component may be desirable to assure adequate distribution without overloading a particular depot site and contributing to blooming. As recommended in previous studies (3), rod depot spacings of every 2cm across the grain and every 15cm along the grain appear most reliable. In this test on wood species commonly used in the United States, diffusion and fungal eradication appeared more even and effective when depot sites were spaced 15cm apart with the treatment loading divided between them rather than when a board was loaded at one or two closely spaced sites.

Assuming the potential problem of crystal blooming can be corrected, boron rods as a remedial preservative treatment appear promising for use in wood decks and should be investigated for further application in other areas where wood is not exposed to a constantly high moisture content level, which would leach boron from the wood over time.

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