



Ability of Transparent Coatings to Retard Leaching of Borates in a Weather-Ometer® Test

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The general purpose of this project is to develop decay-resistant glulam and LVL using combined borate treatment and effective transparent coating systems. To choose the coating with potentially the best performance on borate-treated composites and potentially the highest capability of preventing borate leaching during outdoor weathering, 15 types of commercial transparent coatings were selected and tested on borate-treated solid wood samples using artificial weathering. Ponderosa pine sapwood coupons, double-length and with a central 10 mm section for prior analysis, were pressure-treated with boron, coated as per manufacturers recommendations, then cut into two daughter pieces plus the analysis sample—then the cut ends were re-coated. After the weathering the samples were evaluated for coating deterioration and a piece cut from the center of the exposed samples and the unexposed analysis sample were analyzed for boron. Losses for two or three coats of water-based transparent coatings ranged from 5% to 92%. What was most surprising was that the reference opaque paint product, an acrylic primer plus two acrylic topcoats, lost 60% even though the surface looked perfect in terms of physical deterioration.

INTRODUCTION

Engineered wood composites such as glulam and LVL are increasingly used in conditions with moderate decay hazard such as indoor swimming pools and ice arenas, supporting building overhangs and sometimes projecting beyond the roof-line. Under these conditions, pressure treatment with heavy-duty wood preservatives either prior to or post lamination may be overkill, but untreated wood may fail prematurely. Glulam and LVL made from Canadian wood species do not respond well to treatment with water-borne preservatives, gaining limited penetration and dimensional instability. Both of these materials are typically used for aesthetic as well as structural reasons and a natural wood color may be desired. Borates are the only class of preservatives that are colorless and capable of deep penetration in most

Presented at the FSC Advancement in Coatings Series, "Coatings Wood and Wood Composites: Designing for Durability," July 23-25, Seattle, WA.

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Canadian species. However, they are susceptible to leaching when continuously exposed to rainfall unless protected by a well-maintained three-coat paint finish.¹ Since glulam and, to a lesser extent, LVL, are used in part for their visual appeal, a transparent coating would be preferred.

Orsler and Holland² showed substantial redistribution of boron away from unsealed butt joints in painted hyphen units over two years and recommended the long-term significance be investigated. They did not find any difference in boron redistribution between an oil-alkyd and a waterborne acrylic but the similar moisture contents in the test units suggest these coatings did not differ much in permeability. Morris³ found similar redistribution in L-joints treated to 0.2% BAE after five years but this did not result in premature decay after 10 years. Hedley and Page⁴ demonstrated good performance from painted boron-treated L-joints after 35 years exposure with no maintenance. Peylo and Willeitner⁵ found 16% loss from test units with a thin coat of transparent varnish exposed outdoors for three years. All these test units were fully exposed to rain and, in the case of the L-joints, caulked to ensure moisture accumulation at the joint. Wood components on the exterior of buildings normally have some protection by design and are free-draining. Under real service conditions, Dickinson and Murphy⁶ found sufficient borate loading in windows after 23 years exposure to prevent decay, despite considerable paint deterioration.

The general purpose of this project is to develop decay-resistant glulam and LVL using combined borate treatment and effective transparent coating systems. In order to choose the coating with potentially the best performance on borate-treated composites and potentially the highest capability of preventing borate leaching during outdoor weathering, 15 types of commercial transparent coatings were selected and tested on borate-treated solid wood samples. An accelerated artificial weathering test with a Weather-Ometer[®] was used to determine the type of coating to be used for the bigger-scale composites test, based on the coating performance and the borate remaining after this weathering test. Although the treatment and coating combination is ultimately intended for use on composites made from primarily heartwood of a variety of

Table 1—Coatings Used on Borate-Treated Wood Coupons

Product	Description	Coats
A	Water-based paint	1 acrylic primer; 2 acrylic topcoat ^a
B	Water-based two-part two-step film	2 coats step one; 1 coat step two
C	Water-based polyurethane/acrylic film	3 coats
D	Oil-based log home stain	2 coats
E	Water-based polyurethane varnish	3 coats
F	Water-based polyurethane varnish + pretreatment	3 coats
G	Liquid plastic	1 coat
H	Oil-based well known two-step transparent film	1 coat step 1; 2 coats step 2
I	Oil based deck stain	1 coat
J	Water-based film designed to seal in borates	2 coats
K	Water-based two-step siding stain	2 coats step 1; 1 coat step 2
L	Water-based acrylic siding stain	2 coats
M	Water-based clear acrylic film	3 coats
N	Oil-based siding stain	1 coat
O	Water-based polyurethane film	2 coats
P	Water based clear two-step polyurethane film	2 coats step 1; 1 coat step 2
	None (Reference)	

^aAs used in previous coating test over borate-treated wood

species, ponderosa pine sapwood was selected for this experiment for its uniform and predictable behavior in terms of coating performance and borate leaching.

MATERIALS AND METHODS

Kiln-dried ponderosa pine sapwood samples were processed to the dimensions of 335 mm × 65 mm × 10 mm. These were double-length coupons plus a 10 mm central section for analysis prior to exposure. They were pressure-treated with disodium octaborate tetrahydrate (DOT) solution to a borate uptake around 2% boric acid equivalent (BAE) in wood. Based on the water exclusion and vapor permeability tested by UBC,⁷ 15 types of commercial transparent coatings (Table 1) were selected as the candidates for the test, as well as a water-based paint as a reference. The coatings were applied on the air-dry borate-treated samples according to manufacturers' recommendations, with replicates of six for each coating. Before the Weather-Ometer test, a 10 mm sample was cut from the center of each sample, generating two groups of coupons: Group A and Group B (each coupon with the length

Figure 1—Weather-Ometer cycle.

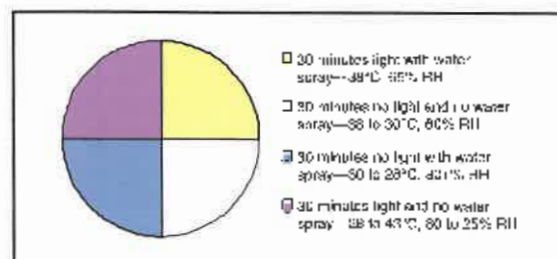


Table 2—Coating Evaluation Methods

Evaluation	Method and Standard
Substrate condition	Subjective visual assessment
Water repellency	Subjective visual assessment
Discoloration	Subjective visual assessment similar to ASTM D 3274-82
UV surface breakdown	Subjective visual assessment
Flaking	ASTM D 772-86
Erosion	ASTM D 662-93
Cracking	ASTM D 661-93
General rating	Overall appearance

of 16 cm). The cut ends of these coupons were then sealed with three coats of a two-part epoxy resin.

The accelerated weathering was done using an Atlas Weather-Ometer (model C165A) equipped with a 6500-watt, Xenon arc UV lamp and borosilicate inner and outer filters. This light source irradiated samples with near equal sunlight exposure with lower UV wavelength cut-off at about 290 nanometers. Two exposure conditions were used for evaluating the coating performance and borate remaining, one with UV and intensive water spray, the other with intensive water spray only, both for 1000 hr. Since the weathering test with the latter condition is not finished yet and the results are to be reported next quarter, this report only covers results tested under UV and intensive water spray. This weathering program consists of four phases (Figure 1): in each two-hour cycle, there is light with water spray in the first 30 min, no light and no water spray in the second 30 min, no light with water spray in the third 30

min, and light and no water spray in the last 30 min. The coating to be used on LVL and glulam samples is to be based on the results from this more severe weathering test. Five coupons from each coating group were used, with one coupon kept as the reference sample for visual assessment of weathering.

After the weathering test, the coating performance was visually assessed based on a rating system adopted from the Forest Products Laboratory (FPL) that inspects for discoloration, mold/stain, finish water repellency, flaking, erosion and cracking, and substrate condition (Table 2). Each evaluation was rated on a scale from 1 (complete failure) to 10 (perfect), and the overall general rating was assigned as the average rating of the evaluation group. After the coating evaluation, another 10 mm sample was cut from the center of each coupon. Both of the 10 mm samples, before and after the weathering test, were ground and analyzed for borate retention using the mannitol titration method,⁸ and the percentage of borate remaining for each coating was calculated.

RESULTS AND DISCUSSION

There was a considerable range of coating performance (Table 3). After 1000 hr of artificial weathering with the combined UV and water spray, the rating of the uncoated samples dropped to 1. Unsurprisingly, the paint had the highest rating, with almost no visible deterioration after the test. Closely following the paint were coating B and coating F (coating E over pretreatment with a Forintek formula) with general ratings of 9. The relative lower rating of coating F alone suggests

Table 3—General Coating Performance after the Weather-Ometer Test

Coatings	Water Substrate	Observation						General Coating Performance
		Surface		Finish				
		Repellency	UV Surface Discoloration	Breakdown	Flaking	Erosion	Cracking	
A	10	9	10	9		9		10
B	10	10	9	9		10		9
F	10	10	9	8	10		10	9
G	10	9	8	8	10		10	8
H	10	10	8	8	10		10	8
J	10	10	8	8	10		10	8
L	9	10	8	8		10		8
M	10	10	8	8	10		10	8
E	10	9	7	8	10		10	7
D	9	7	7	7		7		7
K	10	10	7	8		8		7
C	9	8	7	7		7		7
O	10	9	5	5	10		8	5
I	8	10	5	5		5		5
P	10	10	5	8	10		10	5
N	9	2	3	3		2		3
Control	8	1	1	1				1

Table 4—Borate Remaining after the Weather-Ometer Test

Coating	Description	Borate Remaining (BAE, %)	
		Mean	Standard Deviation
G	Water-based polyurethane varnish + pretreatment	95	2.9
E	Water-based polyurethane varnish	89	7.3
B	Water based two-part two-step film	86	5.8
P	Water-based clear two step polyurethane film	85	6.7
O	Water-based polyurethane film	85	7.5
J	Water-based film designed to seal in borates	81	6.6
H	Oil-based well grown two-step transparent film	78	4.0
G	Liquid plastic	78	11.2
M	Water-based clear acrylic film	75	14.1
L	Water-based acrylic siding stain	50	7.2
A	Water-based paint	42	8.8
D	Oil-based log home stain	33	11.5
K	Water-based two-step siding stain	33	16.6
I	Oil based deck stain	26	11.7
N	Oil-based siding stain	10	6.1
C	Water-based polyurethane/acrylic film	8	11.2
Control		≤ 5%	

there was a positive effect of the pretreatment. Coatings G, H, J, L, and M had general ratings of 8. Some coatings had very low ratings after the test, which suggests they may not perform well in service.

The borate analysis shows a considerable range in ability to retain borate among these coatings with intensive water spray and combined UV (Table 4). The two water-based varnishes seemed most capable of preventing borate from leaching, and the one over pretreatment with a Forintek formula was superior. Closely followed were coatings B, O, and P. Coatings G, H, J, L, and M, which performed reasonably well in terms of UV resistance, were also in the middle of the pack in terms of retarding borate leaching. In terms of product characteristics, these coatings had virtually nothing in common with each other. Surprisingly, the painted samples (coating A) lost more than half the borate during the weathering test, which seemed contradictory with its perfect coating performance. Some coatings, such as D, K, I, N, and C, seem much less capable of retarding the chemical leaching, as little borate remained in wood after the weathering test. With the exception of C, these were typically stain-type products designed not to form a film. The borate remaining in samples is presumably associated with the moisture excluding efficiency of the coating, but it also depends on other factors, particularly UV resistance. The deterioration of coating certainly accelerates the chemical leaching from wood. In parallel field tests (unpublished), the water-based varnish with and without pre-treatment has not shown as good performance as coating B, particularly in terms of resistance to black stain fungi and ability to

dry out after wetting. Consequently, it was decided to use Coating B on LVL and glulam samples for a long-term outdoor exposure test.

CONCLUSIONS

Coating B was the best in terms of the weathering resistance and borate retention. This product is being tested on borate-treated LVL and glulam samples for long-term outdoor weathering exposure. [CI](#)

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