Adhesion of paint to weathered wood

Technical Note

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Abstract

Following outdoor weathering for up to 16 weeks, western redcedar *(Thuja plicata* Donn) boards were painted with alkyd oil or acrylic latex primer paints and tested in shear or tension to determine paint adhesion. The tensile strength of the paint/wood bond dropped 50 percent from approximately 300 pounds per square inch (psi) (2,068 kPa) on wood weathered for 4 weeks to 150 psi (1,034 kPa) on wood weathered for 16 weeks. Shear strength dropped 33 percent from approximately 750 psi (5,171 kPa) to 500 psi (3,447 kPa) after similar weathering periods.

Painted wood is a three-component system consisting of paint, wood, and the paint/wood interface. The critical component for maintaining long-term paint performance is the interface. One cause of interface failure is a wood surface that was degraded by weathering prior to initial priming with paint (2-6,8). Previous studies have shown in a qualitative way that long-term weathering of wood prior to painting reduced subsequent paint performance. The objective of our study was to quantify the loss of primer paint adhesion to boards weathered outdoors for a short time prior to being painted.

Short-term outdoor exposure of western redcedar (WRC) prior to painting drastically decreased the adhesion of primer paint. Freshly planed and unpainted WRC boards were exposed outdoors (oriented vertically, facing south) near Madison, Wis., for 1, 2, 4, 8, or 16 weeks during the late spring and summer of 1984. Throughout the text, the exposure times are given in weeks. However, the sunshine varied from week to week. The tensile and shear strengths in Figures 1 and 2 were plotted against hours of sunshine during the exposure times.

Following this weathering, the boards were painted with alkyd oil (Sherwin-Williams AD-Primer[1]) or acrylic latex (DuPont Lucite-Wood Primer[1]) primer paint and cured for 3 months at 27°C, 65 percent relative humidity (RH). A hard maple *(Acer saccharum)* board was glued to the top of the paint using Ashland Isoset WD2-A312 with 10 percent Isoset CX-11 catalyst.[1] Following curing at 75 psi and room temperature, shear and tensile specimens were cut. The shear specimen was a further modified version of the specimen as described in ASTM D 905 (1) and modified by Strickler (7). To facilitate attaching the specimens for tensile testing, aluminum blocks were glued to the wood. All specimens were conditioned to 12 percent equilibrium moisture content and tested using an Instron[1] test machine and a constant-displacement load rate (0.38 mm/min. for shear and 1 mm/min. for tensile tests). Ultimate shear and elastic stress-strain moduli were calculated from these data.

Many specimens weathered less than 4 weeks before painting failed primarily within the WRC substrate and yielded little useful adhesion data other than the observation that the paint/wood interface was stronger than the wood substrate. These substrate failures occurred totally within the wood and are attributed to cohesive failure of the wood and not to weathering. On specimens weathered 4 weeks, approximately 50 percent of the specimens failed at the paint/wood interface and 50 percent failed cohesively in the wood substrate. However, for specimens weathered for 8 or 16 weeks, failure occurred almost exclusively at the paint/wood interface. The paint/wood interface includes both the weathered wood surface and the portion of the paint film in contact with this surface. Specimens that failed at locations other than at this interface were deleted from the data set.

[1]The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

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TABLE 1. — *Results of Duncan's multiple-range test on the mean strength of wood/primer paint bonds at alpha = 0.05.*[a]

LATEX PAINT

	Tensile test (R^2 = 0.782)						Shear test (R^2 = 0.591)					
Number[b]	0	0	2	10	15	10	24	11	24	24	12	6
Exposure[c] (weeks)	0	1	2	4	8	16	0	1	2	4	8	16
Strength (psi)	--	--	308	303	199	151	798	763	747	707	562	449
(kPa)	--	--	2,123	2,089	1,372	1,041	5,502	5,261	5,150	4,875	3,875	3,096

OIL PAINT

	Tensile test (R^2 = 0.579)						Shear test (R^2 = 0.455)					
Number[b]	0	0	14	19	18	6	0	15	7	22	12	6
Exposure[c] (weeks)	0	1	4	2	8	16	1	2	0	4	8	16
Strength (psi)	--	--	256	189	153	126	--	698	688	674	530	490
(kPa)	--	--	1,765	1,303	1,055	869	--	4,813	4,744	4,647	3,654	3,378

[a]Values that are underscored are equivalent at a 95 percent level of significance.
[b]Number of specimens failing at the wood/paint interface.
[c]Weeks' exposure ordered in decreasing strength of specimens.

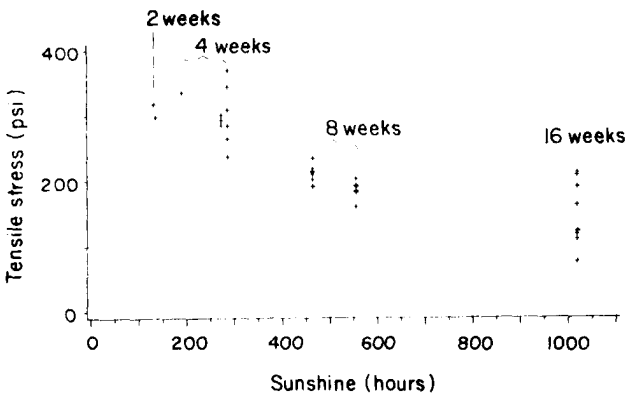

Figure 1. — Ultimate tensile stress (psi) versus wood weathering time (hr. of sunshine) of acrylic latex primer paint coated on western redcedar. Only primer/wood interface failures are shown.

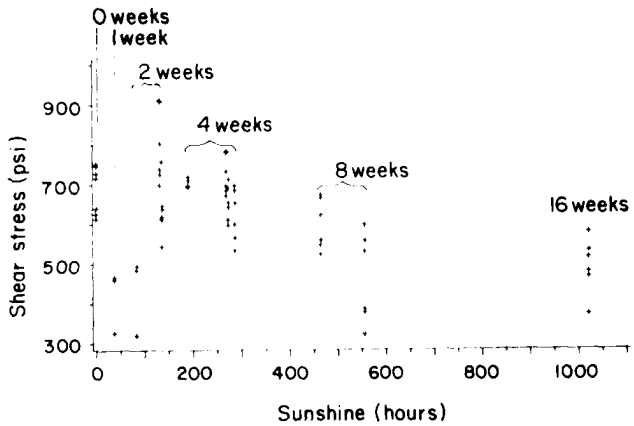

Figure 2. — Ultimate shear stress (psi) versus wood weathering time (hr. of sunshine) of alkyd oil primer paint on western redcedar. Only primer/wood interface failures are shown.

Latex primer

The mean tensile strength of the latex primer/wood bond decreased from 308 psi (2,123 kPa) after weathering 4 weeks, to 151 psi (1,041 kPa) after weathering for 16 weeks (Table 1, Fig. 1). Latex primer exhibited either cohesive wood failure or total interface failure; there was little partial wood/partial interface failure.

The shear test forced the failure to occur at the interface, and there was less wood substrate failure in this test. The shear test specimens failed primarily at the primer/wood interface, and the strength decreased from 798 psi (5,502 kPa) to 449 psi (3,096 kPa).

Oil primer

Mean tensile strength of the oil primer on wood weathered 4 weeks before painting was 256 psi (1,765 kPa) compared to 126 psi (869 kPa) after 16 weeks of weathering (Table 1). As with the latex primer, ultimate strength for many specimens weathered 2 weeks or less appeared to reflect only wood failure and were deleted from the data set. Thus, all data from the controls and for specimens weathered for 1 week drop out.

Shear strength versus weathering time of oil primer (Fig. 2) shows the same trend as the tensile data. The mean adhesion strength dropped from 698 psi (4,813 kPa) to 490 psi (3,378 kPa) (Table 1).

An overview of the mean tensile or shear strength at failure for both paints is listed in Table 1. Using a linear model:

$$\text{Load} = b_0 + b_1(\text{weathering exposure time})$$

A Duncan's multiple-range test of means shows significant (alpha = 0.05) loss of adhesion for all groups within 4 weeks of weathering. The variation in the data for the latex primer was less than for the oil primer. Latex primer exhibited a greater overall deflection prior to failure, a lower elastic modulus, and more distinct failures (cleaner breaks) than those found for the oil primer. Maximum loads for the latex primer were higher than for the oil primer. This probably relates more to differences between the two paints than to weathering effects.

Conclusions

Adhesion of both acrylic latex and alkyd oil primer paints to wood is significantly reduced after the wood substrate has weathered for 4 or more weeks before

painting. These results were observed when evaluating exterior wood finishes in southern Wisconsin. We anticipate a greater effect in warmer and, especially, sunnier climates.

Reduced paint adhesion and increased paint/wood interface failure will undoubtedly result in poor long-term paint and finish performance on wood specimens weathered 4 or more weeks before finishing. Because of this, we strongly recommend that any unprotected wood not be allowed to weather outdoors for more than 2 weeks before it is protected with some finish that will prevent photodegradation and water damage. This recommendation is based on the observation that there was almost no paint/wood interface failure observed in wood specimens that were weathered 2 weeks or less.

We are currently conducting long-term outdoor exposure studies on paint and other finishes on weathered WRC boards and Douglas-fir roughsawn plywood. The results of these long-term exposure studies and a more detailed discussion of adhesion results will be described in future publications.

Literature cited

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