Evaluation of Several Finishes on Severely Weathered Wood

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Alkyd-, oil-modified-latex-, and latex-based finishes were applied to severely weathered western redcedar and redwood boards that did not have any surface treatment to ameliorate the weathered surface prior to painting. Six finishes were evaluated annually for 11 years for cracking, flaking, erosion, mildew growth, discoloration, and general appearance. Low-solids-content latex finishes that contained about 10% raw linseed oil and 11% acrylic resin (i.e., the oil-modified latex finishes) performed better on badly weathered wood than did the alkyd and the other latex finish, even after 11 years. Latex finishes that contained raw linseed oil probably stabilized the weathered surface and plasticized the finish. The stabilization of the wood surface and the flexibility of the finish throughout its service life are the important factors in finish performance on these weathered substrates.

INTRODUCTION

Our previous reports[1–4] and a recent publication by Evans et al.[5] show that short periods of weathering of unpainted wood caused decreased finish adhesion and decreased finish service life after the wood was painted. Many others have shown similar results for long periods of weathering.[6-12] We found that the most ‘effective method for remediating the weathered wood surface is sanding prior to painting (R.S. Williams and M. Knaebe, 1998, unpublished data). Other research showed that sanding prior to painting can improve finish performance even on unweathered wood.[13] However, in many situations, sanding is not an economically viable option for refinishing structures, such as barns and other large agricultural buildings. These structures may be left unpainted for many years once the previous finish has failed.

The objective of this study is to compare the service life of alkyd-, oil-modified-latex-, and latex-based finishes applied to severely weathered wood surfaces without doing extensive surface preparation prior to painting. Finishes included three latex-based (Finishes 2, 4, and 6, with Finishes *2* and 4 being the oil-modified latex) and three oil-based finishes (Finishes 1, 3, and 5) brush-applied to severely weathered western redcedar and redwood beveled siding.

EXPERIMENTAL

Materials

The finishes were applied to western redcedar (*Thuja plicata*) or redwood (*Sequoia sempervirens*) vertical-grained heartwood that had been used in a previous unpublished study. The boards were ¾ × 6 in. (19 × 152 mm) beveled siding installed vertically, facing south with 5 in. *(127* mm) exposed surface per board. The boards had originally been used for a study of solventborne semitransparent stains in 1965. These finishes had eroded (weathered) from the surface by 1975, and the boards were then left to weather for an additional 10 years prior to being used for this study. Four boards were used for each finish (two western redcedar and two redwood) to comprise a panel 20 × 48 in. (51 × 122 mm). As shown in *Figure* 1, the surface of the boards was badly eroded, but all boards were free of decay.

The finishes used for this study are listed in *Table* 1. The paint components listed in *Table* 1 were taken directly from the paint can labels, and it is difficult to determine the exact nature of the resin systems from this information. However, the oil-based paints were all soya alkyd resins containing linseed oil and the latex resins were all poly(viny1 acetate)/acrylic resin copolymers, some of which contained raw linseed oil. According to

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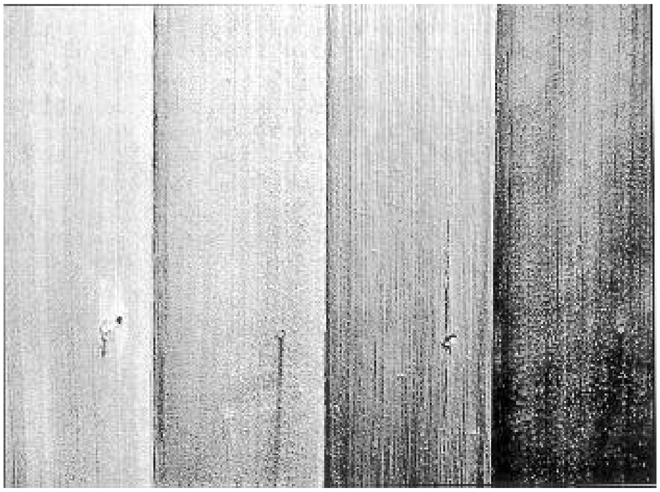

Figure 1—Typical panel consisting of four boards prior to finishing.

the manufacturer of Finish 6, the vinyl acrylic resin listed in Table 1 was actually a poly(vinyl acetate)/acrylic resin. This study included "off the shelf" formulations so that our results would be representative of what the consumer could expect to find available. Our goal is to show what is needed to get the best performance on various wood substrates, not to test paint formulations. We used products that were available to the consumer-the down side of this being not knowing the exact formulation of the paint.

The observed spread rates were lower (more paint applied) than normally recommended by manufacturers (*Table* 1). The lower spread rates show that the weathered wood surface absorbed a considerable amount of finish.

Methods

Fasteners were added or replaced as necessary, and the boards were left on the exposure fence for refinishing. Each panel was wetted with tap water using a hose, lightly washed with a bristle brush, and rinsed with tap water using a hose at very low pressure. There was no attempt to pressure wash the surface. After the boards dried for 24 hr, the first coat of finish was applied, followed by a second coat after an additional 24 hr. The finishes were brush-applied.

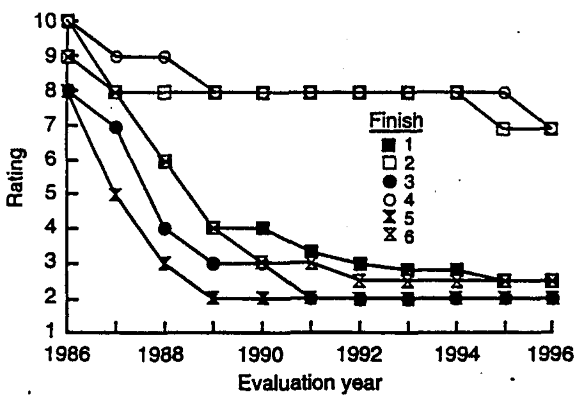

Figure 2—Average cracking rating for the finishes during 11 years (panels finished in 1985) of exterior exposure near Madison, WI. 10 = no degradation; 5 = point at which refinishing should be done; 1 = complete failure of finish (Finishes 1, 3, and 5 are alkyd based; Finishes 2, 4, and 6 are latex based).

The panels were evaluated annually according to American Society for Testing and Materials (ASTM) standards for erosion,[14] cracking,[15] flaking,[16] and mildew growth.[17] The panels were also evaluated for discoloration and general appearance using an appearance scale similar to that in the ASTM standards. Each board in the panel was rated individually to give four observations for each panel for each category (flaking, cracking, mildew growth, etc.) annually for 11 years. A rating of 10 indicates no observable degradation and 1 indicates complete failure of the specimen. A rating of 5 indicates sufficient degradation to warrant normal refinishing if the finish was in use on a structure.

RESULTS AND DISCUSSION

Erosion

All six finishes had an erosion rating of 10 after 11 years on the fence. Although some surface degradation undoubtedly occurred, there were no visible signs of finish erosion. It was not possible to distinguish any differences among the finishes for this rating category, even after 11 years.

Cracking

The most notable difference among the finishes was found for cracking (*Figure* 2). All three of the alkyd-based finishes failed within four years (rating less than 5) and had ratings of 3 or less after seven years. One of the latex finishes (Finish 6) showed performance similar to the alkyd-based finishes. Two of the latex finishes, the oil-modified latex Finishes 2 and 4, showed exceptional performance in the cracking category; these were the more flexible latex finishes. Finishes 2 and 4, which were latex, contained raw linseed oil. This oil also probably helped stabilize the weathered surface.

ALKYD FINISHES: By the sixth year of exposure (1972), the performance of all alkyd paints was about the same. The embrittlement of these types of paints are well known, and their poor performance in cracking was not surprising. The poor performance of the oil/alkyds seem to be typical of these paint systems, particularly on poor substrates. The weathered surfaces were badly cracked and checked at the time the paint was applied. The alkyd-based finishes contained boiled linseed oil (Finish 1 also contained 3.7% raw linseed oil). The boiled linseed oil probably did little to improve the performance of these finishes. The oil probably was crosslinked into the polymer matrix along with the alkyd resin but may have had a minor effect on polymer flexibility. It is interesting that during the first two to three years, alkyd-based Finish 1, with the small amount of raw linseed oil, performed better than the other two alkyd-based finishes (*Figure* 2).

LATEX FINISHES: The most interesting result from the cracking evaluation is the difference among the three latex paints. The results in Figure 2 clearly show outstanding performance of Finishes 2 and 4 compared with Finish 6. All three contained silicates and poly(vinyl acetate)/acrylic resin copolymers at about the same concentration *(Table* 1). There are two noteworthy differences between Finishes 2 and 4 and Finish 6. Finish 6 contained titanium dioxide (Type III), whereas Finishes 2 and 4 contained red iron oxide. And, Finish 6 contained no raw linseed oil, whereas Finishes 2 and 4 contained substantial amounts of raw linseed oil. Almost half the resin in Finishes 2 and 4 was linseed oil (10% linseed oil, 11% poly(vinyl acetate)/acrylic resin copolymer). The difference in pigment undoubtedly affected the stability of the finish against UV radiation, which would affect the film surface property, primarily chalking and erosion. The cracking was a bulk property failure, probably initiated at the wood-finish interphase. Apparently, the only consistent factor in the good performance in the cracking category of Finishes 2 and 4 is the inclusion of raw linseed oil.

Table 1—finish Components and Spread Rates

Finish	Component	Amount (%)	Density (lb/gal (kg/L))	Solids (%)	Spread rate (ft^2/gal (m^2/L)) First coat	Second coot
1 (Alkyd)			9.72 (1.6)	77.1	130 (3.18)	170 (4.16)
	Nonvolatile (red)	67.7				
	Red iron oxide class 1	5.4				
	Calcium carbonate	36.3				
	Soya alkyd resin	16.3				
	Bodied linseed oil	3.7				
	Raw linseed oil	5.4				
	Driers	0.6				
	Volatile	32.3				
	Aliphatic hydrocarbons	32.3				
2 (Latex)			9.79 (1.17)	44.2	115 (2.82)	210 (5.14)
	Nonvolatile (red)	41.8				
	Red Iron oxide class 1	10.2				
	Silicates	10.2				
	Vinyl acetate/acrylic resin	11.2				
	Raw linseed oil	10.2				
	Volatile	58.2				
	Water	58.2				
3 (Alkyd)			9.68 (1.16)	74.4	130 (3.18)	190 (4.66)
	Nonvolatile (farm red)	65.0				
	Red iron oxide	7.1				
	Calcium carbonate	30.5				
	Soya alkyd resin	24.2				
	Boiled linseed oil	3.2				
	Volatile	35.0				
	Mineral Spirits	35.0				
4 (Latex)			9.79 (1.17)	43.6	100 (2.45)	165 (4.04)
	Nonvolatile (farm red)	44.0				
	Red iron oxide class 1	13.6				
	Silicates	6.7				
	Additives	1.8				
	Raw linseed oil	10.3				
	Poly(vinyl acetate)/acrylic resin	11.2				
	Driers	0.4				
	Volatile	56.0				
	Water	56.0				
5 (Alkyd)			10.61 (1.27)	77.1	100 (2.45)	145 (3.55)
	Nonvolatile (white)	69.9				
	Titanium dioxide type III	12.0				
	Calcium carbonate	33.3				
	Folpet	0.3				
	Soya alkyd resin	10.9				
	Boiled linseed oil	4.6				
	Driers	0.7				
	Volatile	30.1				
	Aliphatic hydrocarbons	30.1				
6 (Latex)			10.10 (1.21)	41.6	115 (2.82)	185 (4.53)
	Nonvolatile (white)	40				
	Titanium dioxide type III	10.6				
	Silica and silicates	12.0				
	Vinyl acrylic resin[a]	13.7				
	Glycol and glycol esters	3.2				
	Zinc dimethyldithiocarbamate	0.5				
	Volatile	60.0				
	Water	60.0				

(a)According to me manufacturer, this resin was actually a poly(vinyl acetate)/acrylic resin copolymer.

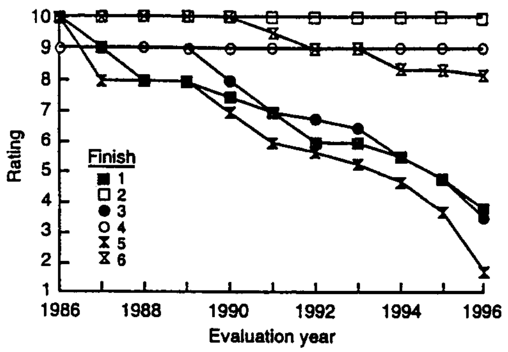

Figure 3—Average flaking rating for the finishes during 11 years (panels finished in 1985) of exterior exposure near Madison, WI. 10 = no degradation; 5 = point at which refinishing should be done; 1 = complete failure of finish (Finishes 1, 3, and 5 are alkyd based; Finishes 2, 4. and 6 are latex based).

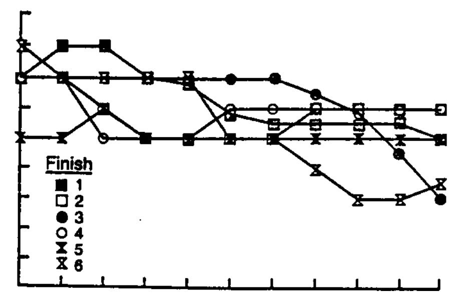

Figure 6—Average mildew rating for the finishes during 11 years (panels finished in 1985) of exterior exposure near Madison, WI. 10 = no degradation; 5 = point at which refinishing should be done; 1 = complete failure of finish (Finishes 1, 3, and 5 are alkyd based; Finishes 2, 4. and 6 are latex based).

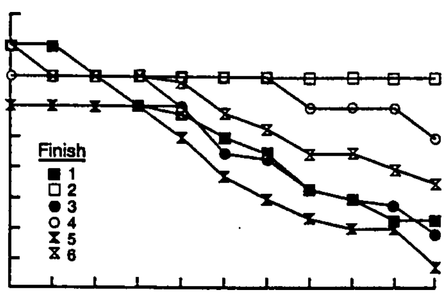

Figure 4—Average discoloration rating for the finishes during 11 years (panels finished in 1985) of exterior exposure near Madison, WI. 10 = no degradation; 5 = point at which refinishing should be done; 1 = complete failure of finish (Finishes 1, 3, and 5 are alkyd based; Finishes 2, 4, and 6 are latex based).

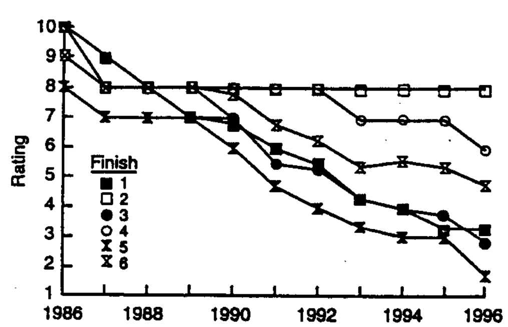

Figure 5—Average general rating for the finishes during 11 years (panels finished in 1985) of exterior exposure near Madison, WI. 10 = no degradation; 5 = point at which refinishing should be done; 1 = complete failure of finish (Finishes 1, 3, and 5 are alkyd based; Finishes 2, 4, and 6 are latex based),

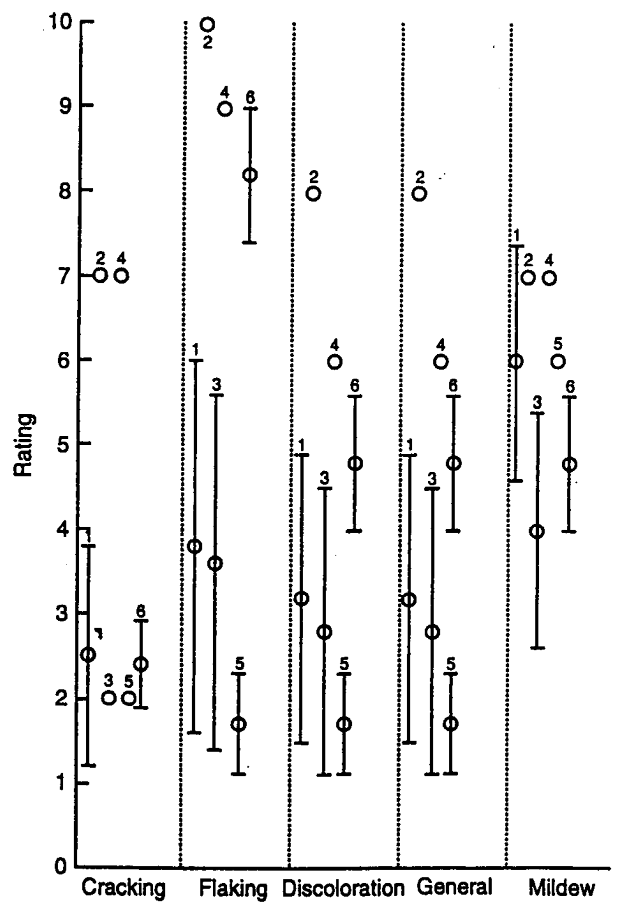

Figure 7—Comparison of mean ratings and standard deviations for Finishes 1 through 6 in each of the five evaluation categories after 11 years exterior exposure near Madison, WI (Finishes 1, 3, and 5 are alkyd based; Finishes 2, 4, and 6 are latex based).

Although this study did not involve monitoring the curing or the coalescing of the finishes, we suspect that the linseed oil partitioned to the wood surface during the coalescing of the latex paints where it slowly cured yielded a reinforced surface that was in close contact with latex film. Schneider and others have reported extensively on the interaction of linseed oil with wood and have shown that the oil absorbs easily into the lumen and to some extent into the cell wall.[18-24] Each fatty acid is capable of bonding to six hydrogen bonding sites and displacing 90 water molecules.[25] In addition to the consolidation of the surface, linseed oil makes the surface less hydroscopic.

This slow-drying oil may have also further plasticized the latex paint film, giving it greater resistance to cracking. This plasticizing effect may have had a minor effect during the early years of exposure. Inclusion of small molecules in polymeric systems is a common practice to improve flexibility. However, the oil probably evaporated or washed from the paint with tune, or if in high enough concentration, it may have cured to form occlusions. We did not evaluate the films for this. The main effect appears to have been the consolidation of the weathered wood.

Flaking

The average flaking ratings for the six finishes also showed that the latex finishes performed better than the alkyd finishes (*Figure* 3). After 11 years of exposure, all three latex finishes had an average flaking rating above 8. The latex finish formulated without raw linseed oil had slightly more flaking than the other two oil-modified-latex-based finishes but it still performed much better than the three alkyd-based finishes. In general, the latex formulations performed much better than expected for flaking. Our previous research on paint adhesion to weathered wood showed that latex paint adhesion was about the same as that for alkyd-based paint.' In that study, the latex paint contained 27% acrylic resin, with a total nonvolatile content of 52%. The nonvolatile contents of the latex-based finishes shown in *Figure 3* are at about 40% with only about 11 to 14% acrylic resin. In this study, the wood surfaces were much more severely weathered and open to penetration of the finish than the wood weathered for up to 16 weeks in the previous experiment.' The adhesion of these latex finishes to the severely weathered wood was quite good (*Figure 3).* These latex finishes seemed to perform more like penetrating stains than paints.

Discoloration and General Appearance

The discoloration and general appearance ratings for the six finishes show similar trends (*Figures* 4 and 5). The lower values of the general rating for the latex finishes are caused by the influence of mildew and discoloration. Even with this decrease in rating because of mildew, Finishes 2 and 4 had exceptional ratings after 11 years. The mildew ratings are more or less the same for all finishes and show a slight decrease during the 11 years (*Figure* 6).

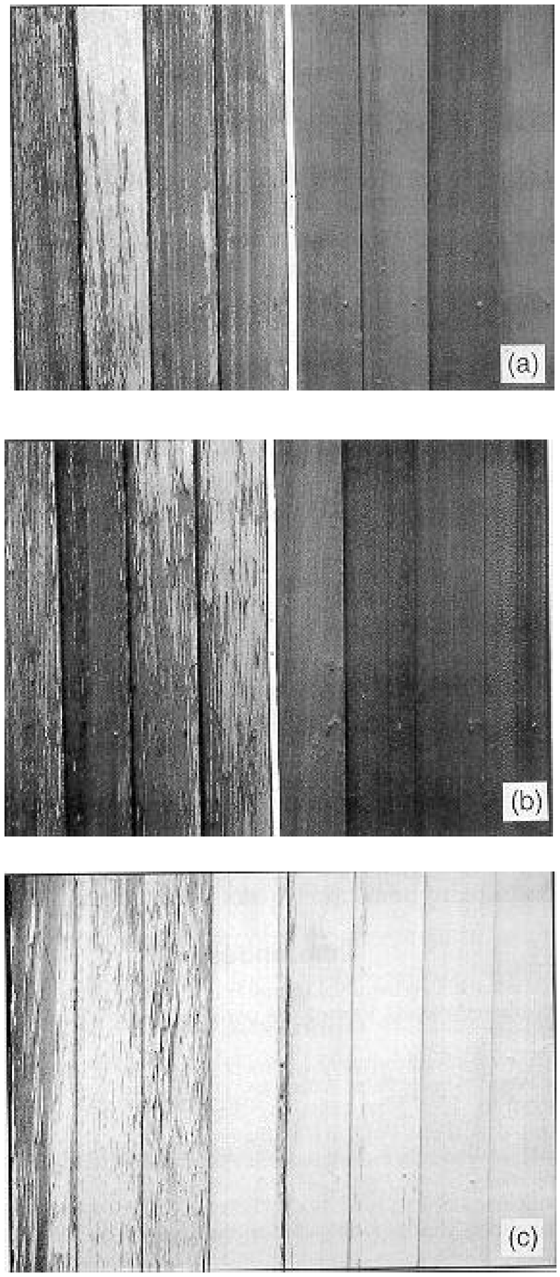

Figure 8—Typical surface of panels consisting of four boards finished with (a) *alkyd-based Finish 1 on the left and latex-based Finish 2 on the right, (b) alkyd-based finish 3, left, and latex-based Finish 4, right, and (c) alkyd-based finish 5, left, and latex-based Finish 6, Right, after 11 years exterior exposure near Madison, WI. Finish 6 was inadvertently applied to one board that should have been painted with Finish 5.*

Overall Evaluation After Eleven Years

The means and standard deviations for each finish in each category from the 11-year evaluations are shown in *Figure* 7. The general and discoloration ratings are virtually the same, and both show the effect of mildew growth, extractive bleed, and dirt accumulation. Examples for visual comparisons of the latex- and alkyd-based finishes after 11 years of outdoor exposure are shown in *Figure 8*.

CONCLUSIONS

Because previous research on finish adhesion to weathered wood showed early finish failure, the results from this study were quite surprising. Oil-modified-latex-based Finishes 2 and 4, which contained low solids (about 40%) with about 10% raw linseed oil and 11% acrylic resin, gave exceptional service life on badly weathered wood. These finishes are still giving acceptable service after 11 years of south-facing exposure near Madison, WI. The data suggests that the crucial factors in the exceptional service lives of Finishes 2 and 4 are probably (1) the inclusion of raw linseed oil that consolidated the wood surface and (2) the low latex resin content that enabled the paint to act like a penetrating stain. Finishes of this type may be useful where it is not possible to remove the weathered wood surface. Although it has previously been shown that it is essential to remove the weathered surface if nonpenetrating finishes are used, this study indicates that a highly oil-modified poly(vinyl acetate)/acrylic resin copolymer may give excellent results on these surfaces without extensive surface preparation. These finishes seem to penetrate the surface of the wood, consolidating it without causing embrittlement. It appears that a viable finish for weathered wood must penetrate the weathered surface, whether it is called a paint or a stain by the manufacturer.

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