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Effect of Surface Preparation on Service Life of Top-coats Applied to Weathered Primer Paint

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Effect of Surface Preparation on the Performance of Topcoats Applied to Weathered Primer Paint

Abstract

Paint companies usually recommend that topcoats be applied to primer paint within two weeks. Unfortunately, this is not always possible. For example, onset of winter weather shortly after applying primer may delay topcoat application until spring. Scuff sanding or re-priming are often recommended remedial methods for preparing a weathered primer for topcoats, but there is little research using modern paint formulations to support these practices. Western redcedar boards having a single coat of oil-alkyd or acrylic latex primer were placed outdoors for six months (November 1995 to May 1996) at our exposure sites near Madison, Wisconsin, and Gulfport, Mississippi. After exposure for six months, the weathered primers were prepared for topcoat application by light hand-sanding and washing without repriming (treatment 1), repriming (treatment 2), or topcoating "as is" (treatment 3). They were finished with a single topcoat of acrylic latex or oil-alkyd paint and evaluated for cracking, flaking, and mildew growth annually over 12 years. We found that light sanding and washing without repriming (treatment 1) had a deleterious effect. Topcoat performance was about the same for repriming (treatment 2) and topcoating “as is” (treatment 3). Water-repellent preservative pretreatment of western redcedar prior to priming did not improve service life of the finishes.

Introduction

Background

After the introduction of water-borne latex-based coatings for exterior use in the early 1970s, several researchers reported on the performance of these finishes. Chalk adhesion of latex topcoats to oil-based primers was the one of the concerns. Hoffman and Couper (1970) reported on the effect of primers and pigments. Dolenko and Shields (1974) evaluated additives to retard weathering of water- and solvent-borne primers, and the adhesion of latexes was the subject of a Montreal Society for Coatings Technology study (Hiscock, *et al.* 1976). An appendix to the work by the Montreal Society included the Canadian government's specifications for the cross-cut (cross-hatch) method for determining paint adhesion. Brown and Hoy (1977) also reported on methods for measuring chalk adhesion of latex paints. Their report included a method for preparing a weathered surface using a carbon arc weather-O-meter and they measured topcoat adhesion by pulling off stainless steel cylinders glued to the topcoat surface. Puglisi and Schirmann (1982) evaluated intercoat adhesion to determine the effectiveness of ultraviolet (UV) radiation absorbers. White (1984) correlated the changes in the surface energy of the primer as it aged prior to topcoating with the adhesive strength of the topcoat. Garcia Valcarel and Diez Barra (1989) evaluated the weathering of a series of primers containing various water repellents, solvents, and resins that were topcoated with varnish. Previously, no research has been reported about the ability of pretreatments of weathered primers to restore the degraded surface prior to topcoat application using contemporary finishes. Nor has there been a long-term evaluation of topcoat performance over weathered primers.

Objectives

The overall goal of the study was to establish guidelines for preparing weathered primers for application of topcoats. All architectural finishes in the United States were reformulated in the early 1990s to meet regulations limiting the amount of volatile organic compounds (VOCs) contained in finishes. Therefore, we used contemporary commercial finishes because today’s

finishes are much different than those used in previously reported research. The emphasis of this study was 1) after six months of outdoor exposure (November to May), to evaluate the effect of ultraviolet (UV) degradation of primers on the long-term performance of topcoats applied to weathered primers and 2) to assess differences in primer and topcoat performance in two completely different climates.

The field site near Gulfport is approximately 15 km from the Gulf of Mexico coast in an open area surrounded by southern yellow pine (predominately loblolly pine (*Pinus taeda*)) forest. The climate is sub-tropical with hot humid summers and mild winters. The test site near Madison is approximately 5 km west of Madison in a predominately agricultural area with some encroachment of housing. The climate is temperate with a few weeks of hot, humid weather during the summer; it is usually dry in the autumn and cold in the winter; and winter temperatures usually reach –30° C in January.

Experimental

Materials

All heartwood, vertical-grained western redcedar bevel siding was purchased from a local lumberyard. The boards were typical of lumber in this grade. The water-repellent preservatives (WRPs), primers, and topcoats used in this study are listed in Table 1.

Table 1. Experimental parameters, finishes, and primer surface preparation following six months exposure

Factorial parameters		**Number**
Location:	**Madison (M), Gulfport (G)**	(2)
Pretreatment		
	A. Water-borne primer, left section B. Solvent-borne primer, right section C. No water-repellent preservative, center section (Each pretreatment was applied to all boards.)	
Primer/Topcoat		(3)
	LL[a] = Overcoat exterior latex primer and topcoat OL[b] = Alkyd primer and latex topcoat OO[c] = Oil primer and oil topcoat	
Preparation after 6 months primer weathering		(3)
	Hand-sand (80 grit) and wash (S) Repaint with primer (R) No pretreatment (N)	
Replicates		(6)
	Total number of 4-foot boards =	108 (54/site)

[a] LL is latex primer and topcoat.

[b] OL is oil-alkyd primer/latex topcoat.

[c] OO is oil-alkyd primer and topcoat.

Methods

Vertical-grained western redcedar boards 16 feet (4.9 m) long were cut to 4-foot lengths (1.2 m). Boards for Madison and Gulfport were end-matched. Variables were the type of pretreatment, primer, post-exposure surface preparation, and topcoat (Table 1). The orientation of the 4-foot boards on the test fence for six replicates is shown in Table 2.

Table 2. Orientation of boards on the fences near Madison and Gulfport [a]

Bays 1 & 4 Replicates. 1 & 4	Bays 2 & 5 Repicates 2 & 5	Bays 3 & 6 Replicates 3 & 6
LL-S	LL-R	LL-N
OL-S	OL-R	OL-N
OO-S	OO-R	OO-N
LL-R	LL-N	LL-S
OL-R	OL-N	OL-S
OO-R	OO-N	OO-S
LL-N	LL-S	LL-R
OL-N	OL-S	OL-R
OO-N	OO-S	OO-R

[a] Each replicate was placed in a single bay on the test fence randomized by primer surface preparation as shown. LL, latex primer and topcoat; OL, oil-alkyd primer and acrylic latex topcoat; OO, oil-alkyd primer and topcoat; S, sanded; R, reprimed; N, no primer preparation (painted "as is").

Note that in each bay, we placed the boards with three different primer treatments in a random order. The 4-foot lengths were cut with a saw kerf 1/8 inch deep in four places to give three 14-inch specimens on each board (Figure 1). The saw kerfs and ends of the boards were sealed using an alkyd/aluminum paint and the boards were finished with a solvent-borne (SB), water-borne (WB), water-repellent preservative (WRP), or nothing (control). After treatment with the WRP, the boards were stored at ambient laboratory conditions for 2 days then painted with one coat of primer (Table 1).

We placed the primed boards on test fences facing south near Madison, Wisconsin, and Gulfport, Mississippi, in fall 1995. Figure 2 shows the primed boards mounted on the fence at the Madison site. Figure 3 is a close up of bay 1 at the Gulfport site. Following six months exposure, the surfaces of the boards were prepared for topcoat application by (1) sanding and washing, (2) repriming, or (3) painting "as is." The boards were finished with a single topcoat while on the fence (Table 1). Following topcoat application, the painted boards were evaluated annually for cracking, flaking, and mildew/discoloration (ASTM D 661-93, D 672-86, and D 3274-95, respectively) (ASTM International 2005). A rating of 10 indicates no degradation, and 1 indicates total failure of the coatings system. A rating of 5 indicates a condition at which the coating should be refinished without having to do excessive surface preparation (in other words, the approximate service life).

Results and Discussion

The average of six visual evaluations for finish discoloration, mildew, flaking, and cracking for boards exposed for 11 years near Madison (Figures 4–7) and 12 years near Gulfport (Figures 8–11) indicates several important differences. The error bars are the first standard deviation of the six evaluations. If there is no error bar, all six evaluations were the same. The boards in Gulfport should have been evaluated after 11 years; however, it was not possible to complete the evaluation during the visit to the Gulfport site that year. Each group is organized by finish type: latex primer and topcoat (LL), oil-alkyd primer/latex topcoat (OL), and oil-alkyd primer and topcoat (OO). Each group is also organized by primer surface treatment: sanding (S), repriming (R), and finishing "as is" (N). That is LL-S, OL-S, OO-S, LL-R, OL-R, OO-R, LL-N, OL-N, and OO-N. For example, LL-S indicates a latex primer and topcoat sanded and washed prior to application of the topcoat.

Discoloration and Mildew

Discoloration and mildew evaluations were similar because, in the absence of extractives bleed, mildew growth is usually the cause of discoloration. Extractives bleed was not apparent for any of the finish systems. There is often a site difference for discoloration and mildew. Compare Figures 4 and 5 with Figures 8 and 9 (Madison and Gulfport, respectively).

As we expected, mildew growth was worse in Gulfport than in Madison. The trends over the 11/12 years for discoloration for the oil-alkyd primer and topcoat are shown in Figures 12 and 13 for Madison and Gulfport. The increase in the rating at year four in Figure 12 is not uncommon; discoloration is linked closely with mildew growth, and this can vary from year-to-year. The standard deviations are not shown; the variability in the evaluations was about the same as shown for the 11/12-year evaluations (Figures 4 and 8). The mildew evaluations for Gulfport are almost the same as the discoloration (Figure 14). Figures 12–14 show trends for the oil-alkyd primer and topcoat. Decreases for the other paint systems were similar. Figures 15 and 16 show the typical condition of the boards following 11 years near Madison and 12 years near Gulfport. The discoloration is difficult to see in the photographs.

Water-repellent Preservative Pretreatment

The evaluations after 11/12 years in Figures 4–11 for WRP pretreatment of western redcedar prior to priming (waterborne WRP, no WRP, and solvent-borne WRP) were about the same. There is considerable variability among the six replicates; this variability is expected in exterior exposure of painted wood. Evaluations appear to be slightly higher for flaking for the three pretreatments at both sites (Figures 6 and 10). There are obvious differences for the three finishes (LL, OL, and OO) and for the three primer preparations (S, R, N), but the evaluations for the WRP pretreatment are about the same for both sites.

Paint flaking

Comparison of flaking for the two sites shows little change after 11/12 years with about 8 to 10 evaluations for both sites. The bar graphs show a slightly higher value for no pretreatment. This slight difference is probably caused by degradation of the paint near the ends of the boards (Figures 15 and 16). The flaking trends for the three finishes and primer pretreatments are shown for Madison and Gulfport (Figures 17 and 18). Evaluations for all WRP pretreatments and three finishes are averaged and no discernable differences are apparent. Paint flaking often follows cracking and it may be too early to see differences.

Paint cracking

The best measure of the effect of primer surface preparation is the cracking evaluations. Inspection of Figures 7 and 11 (Madison and Gulfport, respectively) shows several interesting trends. First, there is an obvious effect for the type of finish; the all-latex system (LL) was best, oil/latex (OL) next, and all oil (OO) was worst. Sanding (S) seemed to have a deleterious effect compared with repriming (R) and topcoating without primer surface preparation (“as is” (N)). It is difficult to distinguish a difference between R and N; however, in cases where differences exist, the R is usually higher. The trends for cracking of LL OL and OO for boards exposed near Madison are shown in Figures 19–21**.** Note that the condition of the boards was rated as 10 until year 7, and then decreased. Sanding and washing was worse than repriming or topcoating “as is” prior to application of all three topcoats. The trends for boards exposed in Gulfport were slightly different (Figure 22). The sanded primer treatment was still worse than the other treatments, but the difference was not as great. The boards having oil-alkyd primer and topcoat (OO) exposed in Gulfport developed slight cracking after 3 years (ratings of about 9) and stayed consistent until about year 10. Figures 15 and 16 show the condition of boards following 11 and 12 years exposure near Madison and Gulfport, respectively. Their condition is typical of the other five replicates in the study.

Conclusions

Sanding and washing a primer paint after six months of exterior exposure in Gulfport and Madison decreased the service life of subsequently applied topcoats. Decrease in performance was found for all three paint systems (latex primer and topcoat, alkyd oil-based primer, latex topcoat, and alkyd oil-based primer and topcoat). In general, the all-latex paint system performed better than the other two. As expected, mildew growth was worse in

Gulfport, particularly for the all oil-based paint system. There was no improvement in performance by treating western redcedar with either a solvent-borne or water-borne water-repellent preservative prior to priming, compared with no WRP application prior to priming. It appears that modern primer formulations are resistant to UV degradation.

References

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Figures

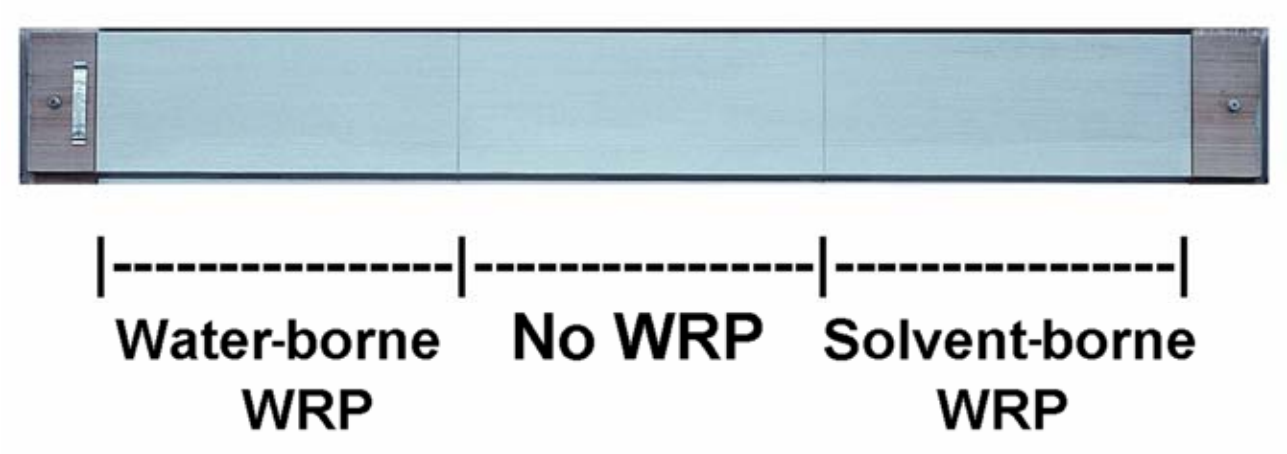

Figure 1. Sample of single painted board showing the water-repellent preservative (WRP) treatment.

Figure 2. Boards mounted on test fence near Madison, Wisconsin, after several years of outdoor exposure.

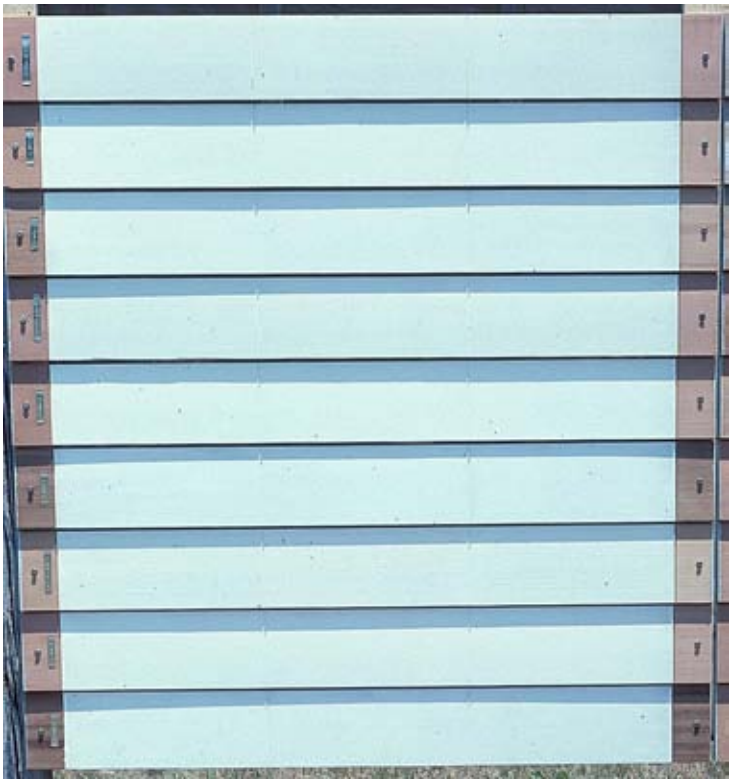

Figure 3. Close-up of one of the bays at the Gulfport, Mississippi, test site.

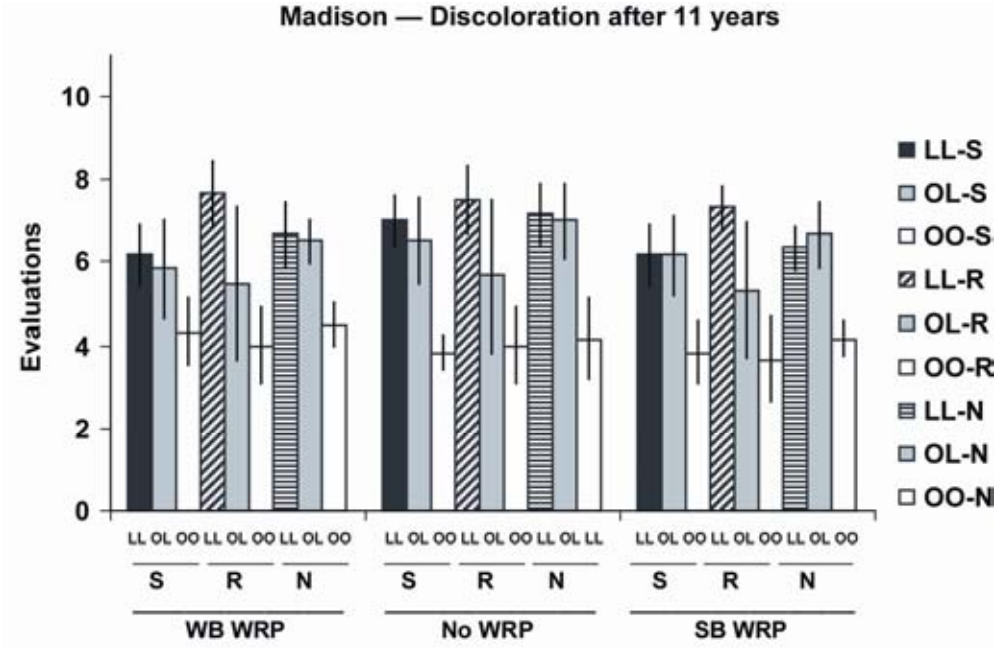

Figure 4. Discoloration evaluations of painted western redcedar following 11 years outdoor exposure near Madison, Wisconsin. Shown is the average of six replicates. The error bar is the first standard deviation. Paint systems: LL, latex primer and topcoat; OL, oil-alkyd primer/latex topcoat; OO, oil-alkyd primer and topcoat. Primer surface treatment: S, sanding and washing; R, repriming; N, nothing (finishing “as is”).

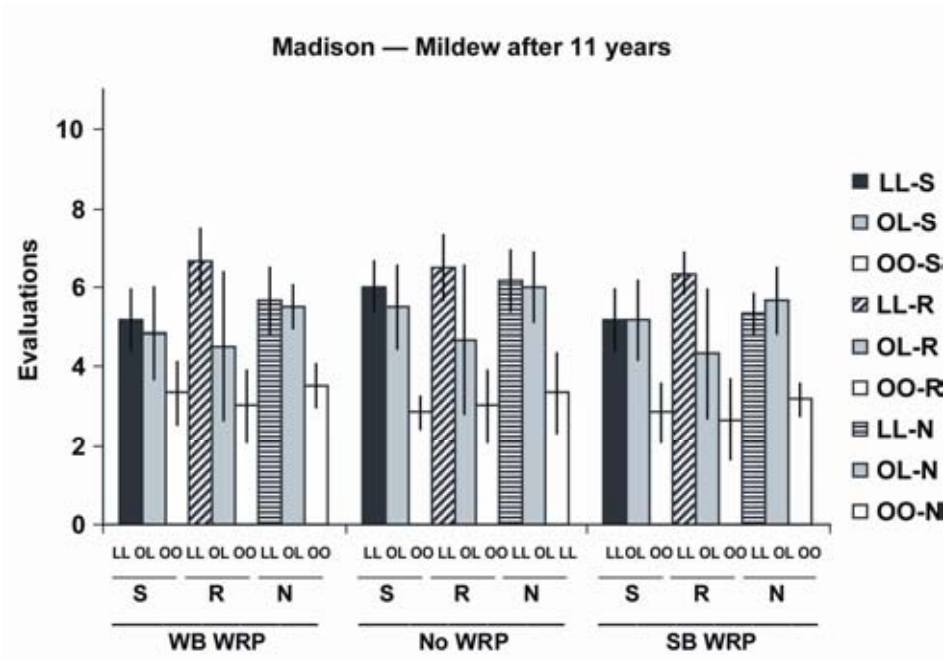

Figure 5. Mildew evaluations of painted western redcedar following 11 years outdoor exposure near Madison, Wisconsin (average of six replicates and error-bar is the first standard deviation). Paint systems: LL, latex primer and topcoat; OL, oil-alkyd primer/latex topcoat; OO, oil-alkyd primer and topcoat. Primer surface treatment: S, sanding and washing; R, repriming; N, nothing (finishing “as is”).

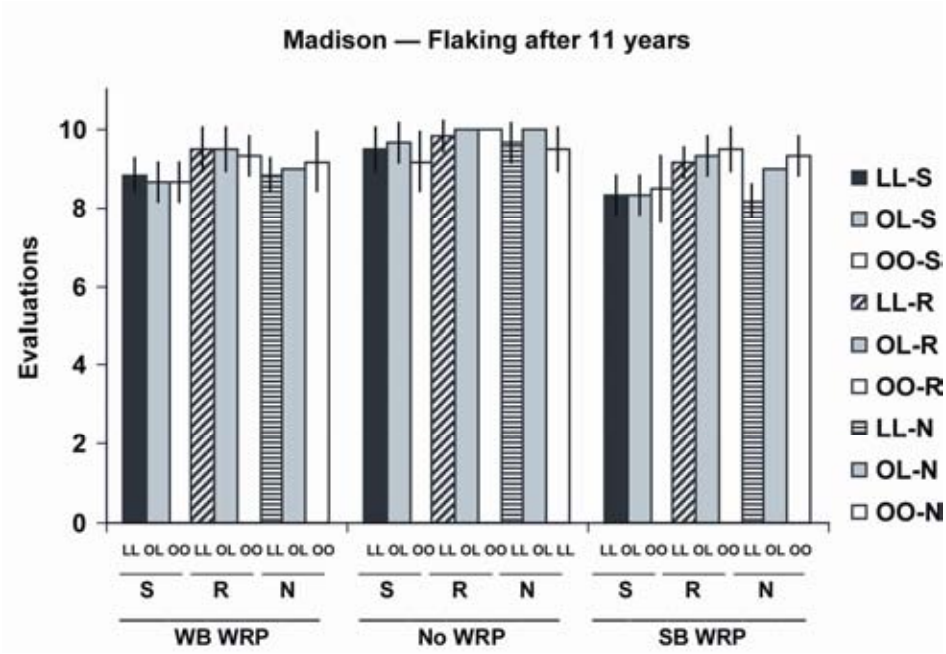

Figure 6. Flaking evaluations of painted western redcedar following 11 years outdoor exposure near Madison, Wisconsin (average of six replicates and error-bar is the first standard deviation). Paint systems: LL, latex primer and topcoat; OL, oil-alkyd primer/latex topcoat; OO, oil-alkyd primer and topcoat. Primer surface treatment: S, sanding and washing; R, repriming; N, nothing (finishing “as is”).

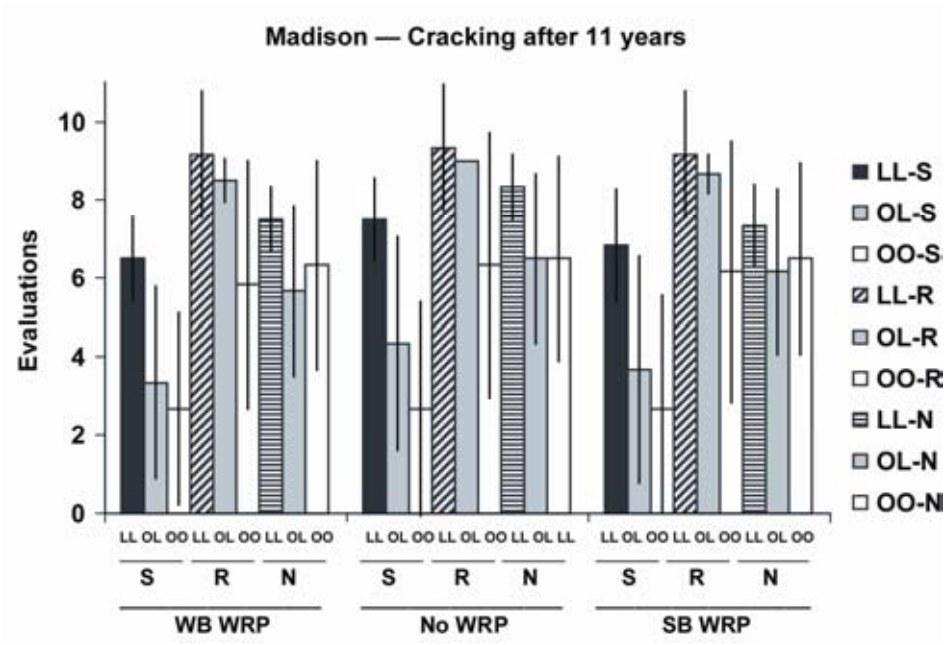

Figure 7. Cracking evaluations of painted western redcedar following 11 years outdoor exposure near Madison Wisconsin (average of six replicates and error-bar is the first standard deviation). Paint systems: LL, latex primer and topcoat; OL, oil-alkyd primer/latex topcoat; OO, oil-alkyd primer and topcoat. Primer surface treatment: S, sanding and washing; R, repriming; N, nothing (finishing “as is”).

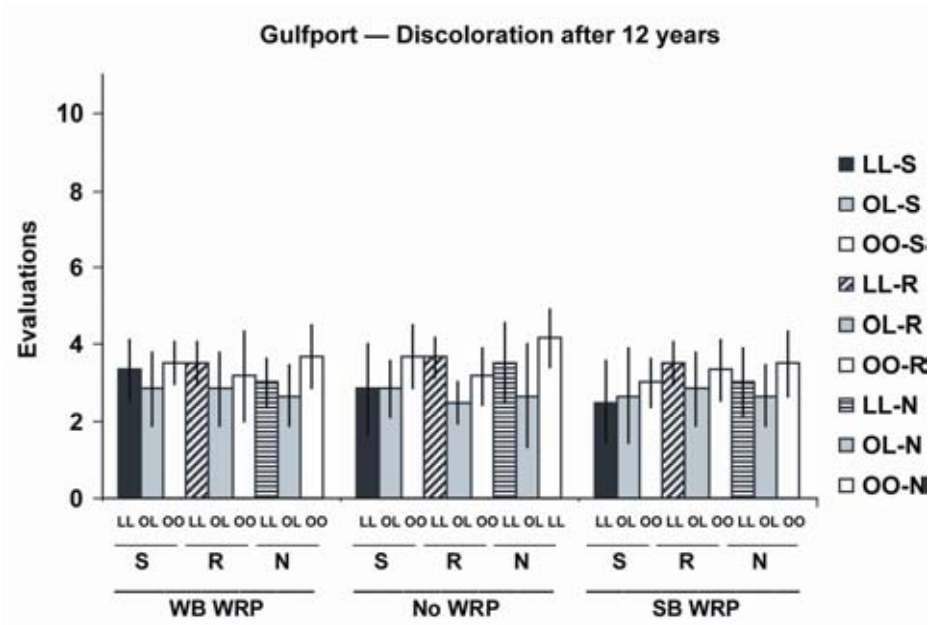

Figure 8. Discoloration evaluations of painted western redcedar following 12 years outdoor exposure near Gulfport, Mississippi (average of six replicates and error-bar is the first standard deviation). Paint systems: LL, latex primer and topcoat; OL, oil-alkyd primer/latex topcoat; OO, oil-alkyd primer and topcoat. Primer surface treatment: S, sanding and washing; R, repriming; N, nothing (finishing “as is”).

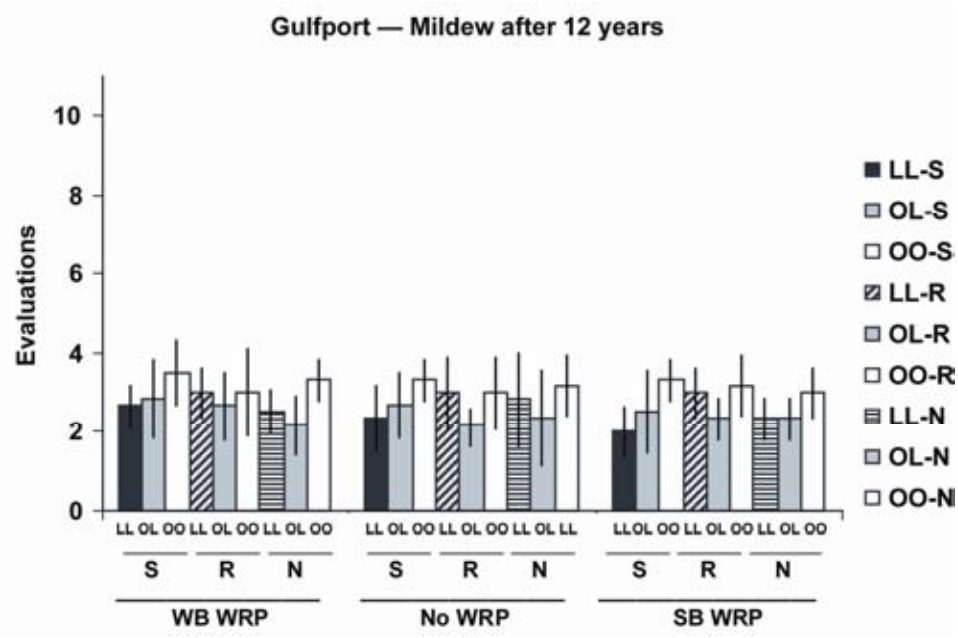

Figure 9. Mildew evaluations of painted western redcedar following 12 years outdoor exposure near Gulfport, Mississippi (average of six replicates and error-bar is the first standard deviation). Paint systems: LL, latex primer and topcoat; OL, oil-alkyd primer/latex topcoat; OO, oil-alkyd primer and topcoat. Primer surface treatment: S, sanding and washing; R, repriming; N, nothing (finishing “as is”).

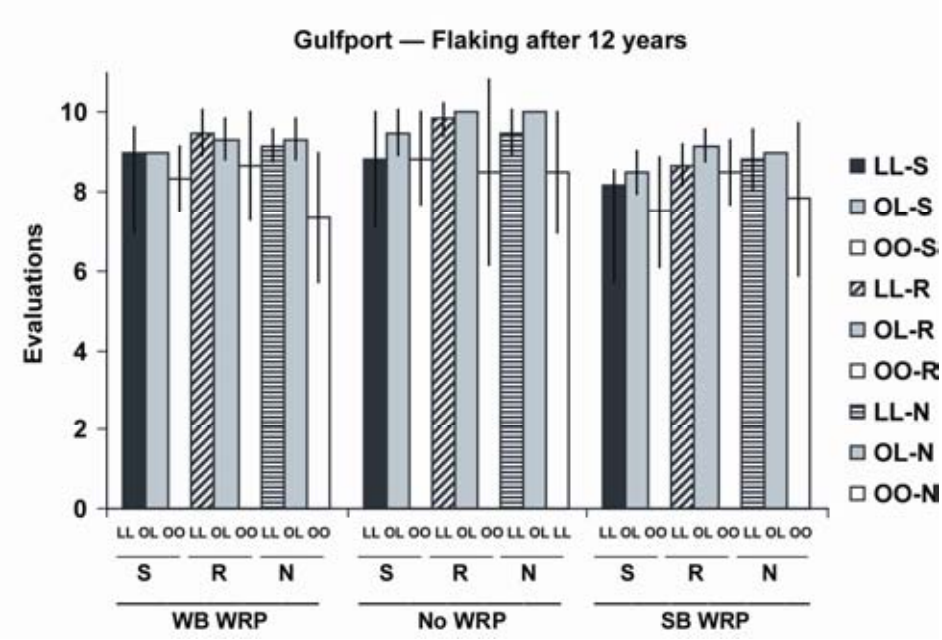

Figure 10. Flaking evaluations of painted western redcedar following12 years outdoor exposure near Gulfport Mississippi (average of six replicates and error-bar is the first standard deviation). Paint systems: LL, latex primer and topcoat; OL, oil-alkyd primer/latex topcoat; OO, oil-alkyd primer and topcoat. Primer surface treatment: S, sanding and washing; R, repriming; N, nothing (finishing “as is”).

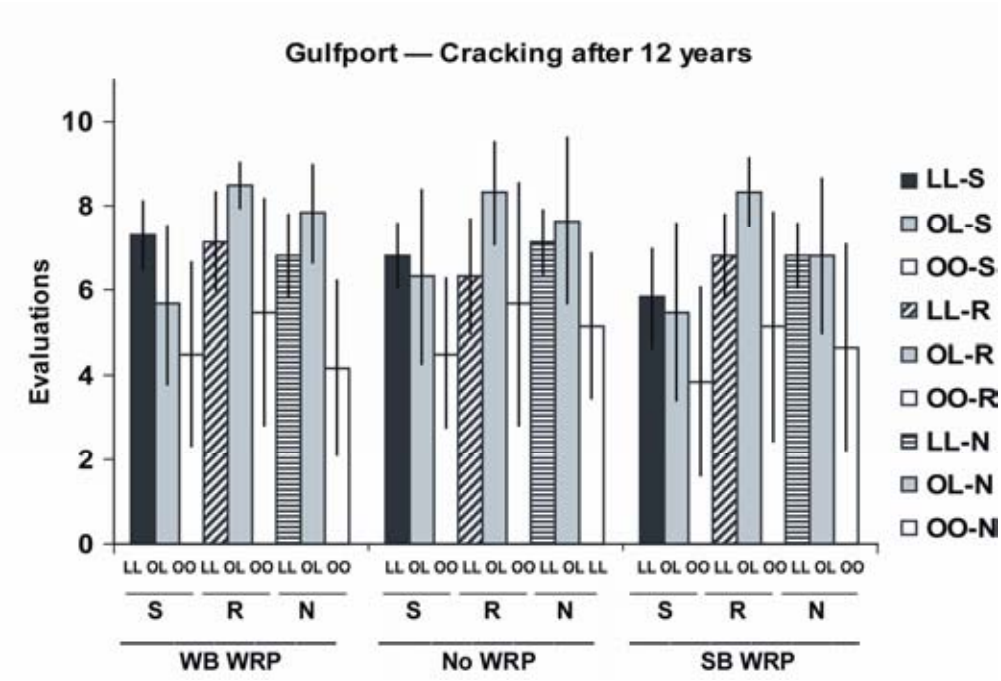

Figure 11. Cracking evaluations of painted western redcedar following 12 years outdoor exposure near Gulfport, Mississippi (average of six replicates and error-bar is the first standard deviation). Paint systems: LL, latex primer and topcoat; OL, oil-alkyd primer/latex topcoat; OO, oil-alkyd primer and topcoat. Primer surface treatment: S, sanding and washing; R, repriming; N, nothing (finishing “as is”).

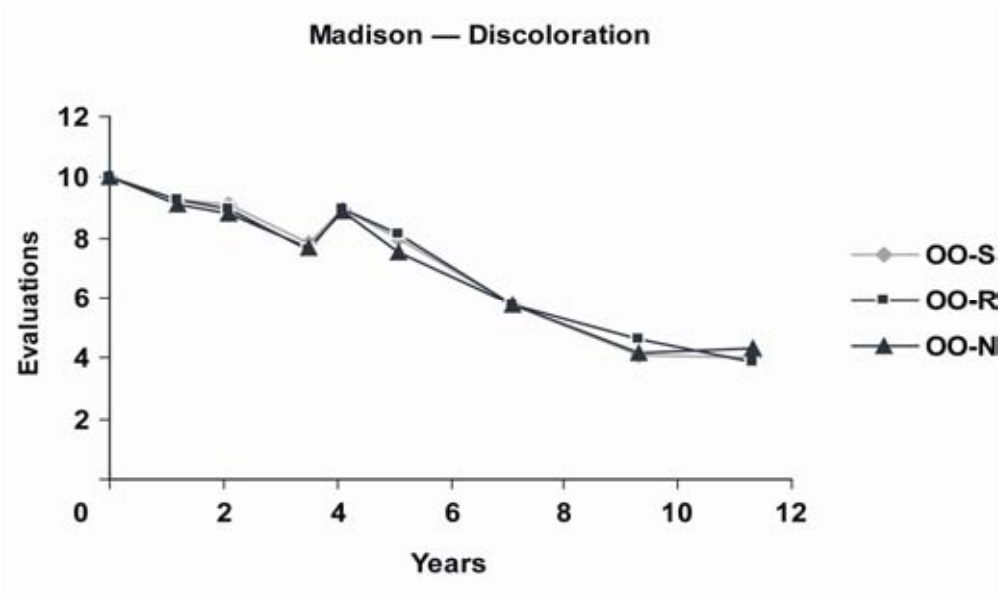

Figure 12. Paint discoloration evaluations of oil-alkyd primer and topcoat (OO) over 11 years outdoor exposure near Madison, Wisconsin. Primer surface treatment: S, sanding and washing; R, repriming; N, nothing (finishing “as is”). Average of data for water-based preservative (WPR) and no WPR treatment .

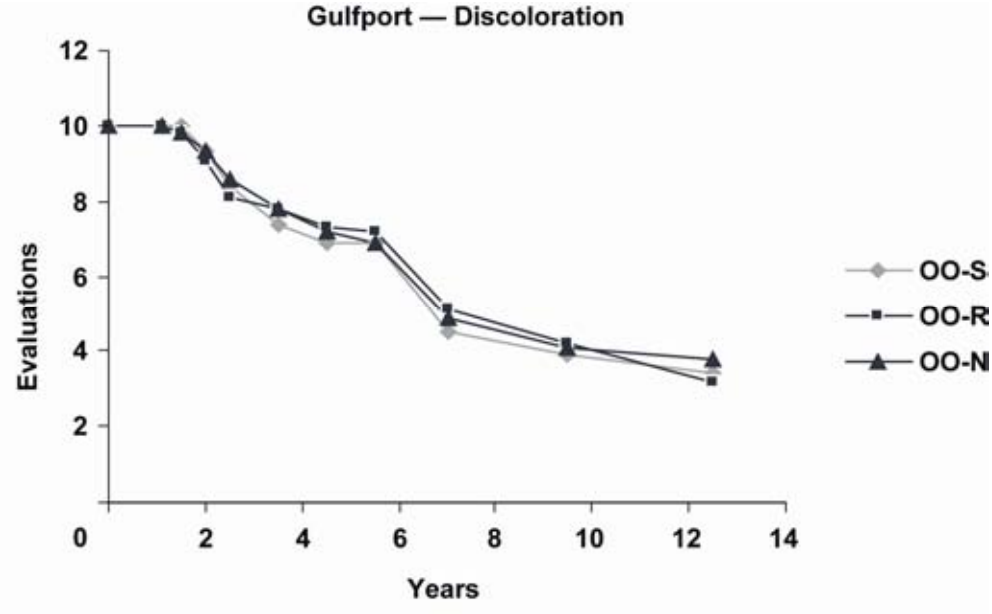

Figure 13. Paint discoloration evaluations of oil-alkyd primer and topcoat (OO) over 12 years outdoor exposure near Gulfport, Mississippi. Primer surface treatment: S, sanding and washing; R, repriming; N, nothing (finishing "as is"). Average of data for water-repellent preservative (WRP) and no WRP treatment.

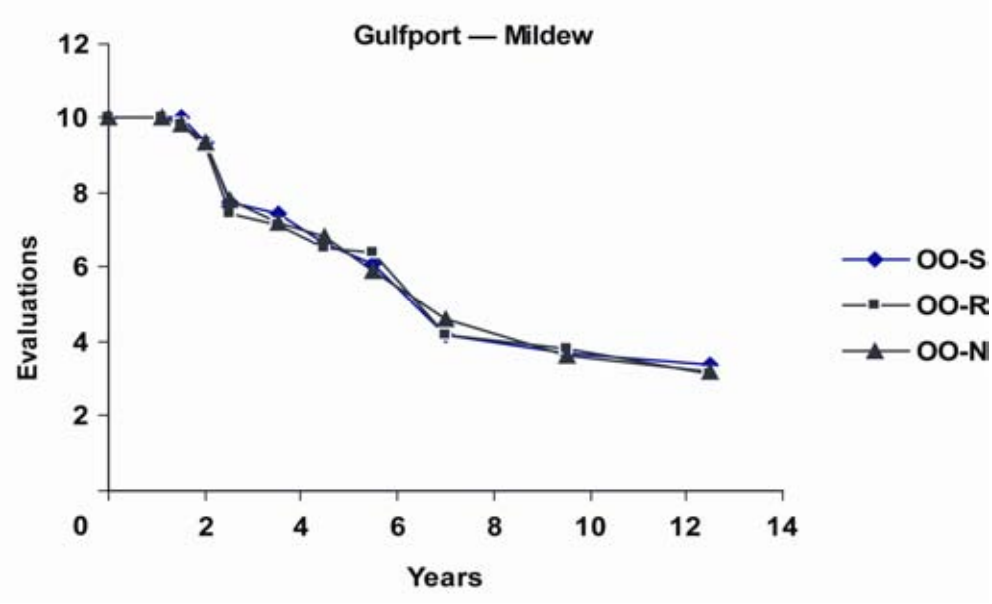

Figure 14. Mildew evaluations of oil-alkyd primer and topcoat (OO) over 12 years outdoor exposure near Gulfport, Mississippi. Primer surface treatment: S, sanding and washing; R, repriming; N, nothing (finishing "as is"). Average of data for water-repellent preservative (WRP) and no WRP treatment.

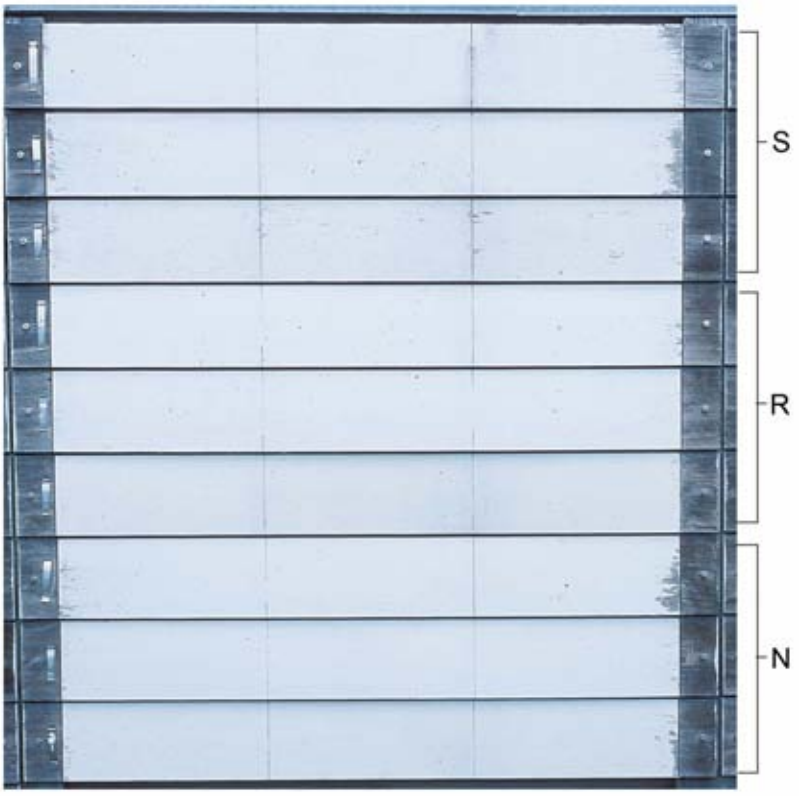

Figure 15. Boards after 11 years exposure near Madison, Wisconsin (bay 4).

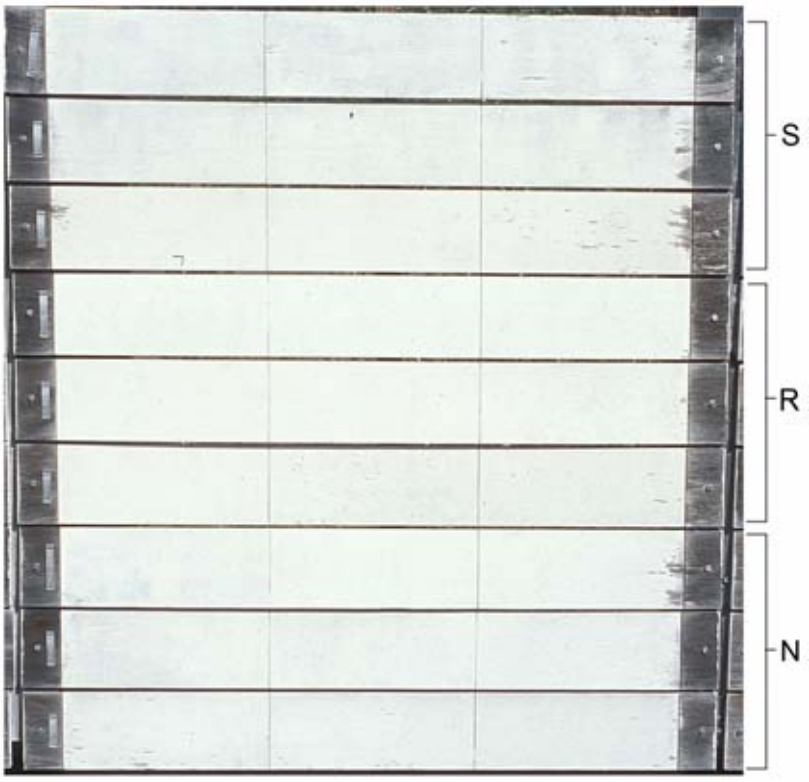

Figure 16. Boards after 12 years exposure near Gulfport, Mississippi (bay 4).

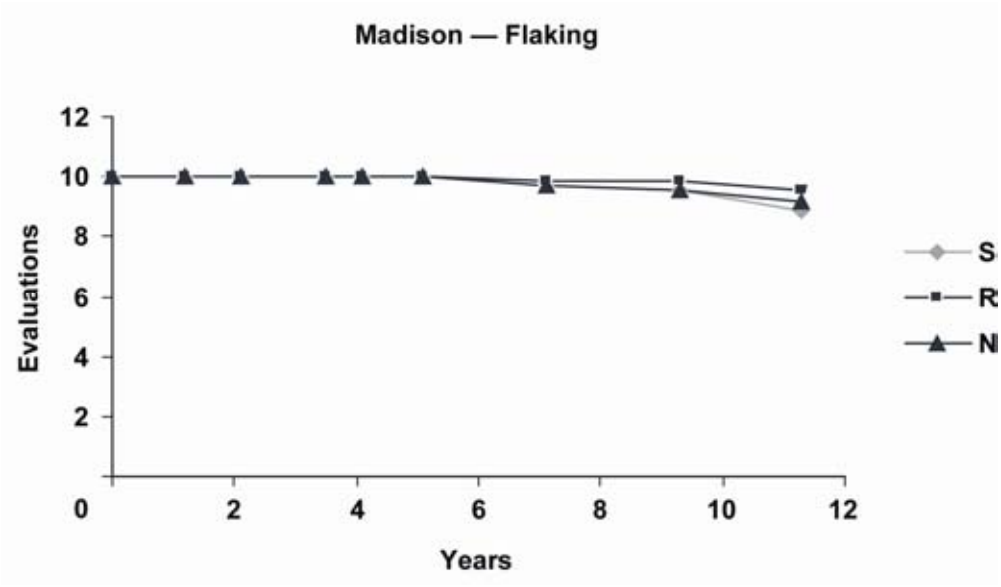

Figure 17. Paint flaking evaluations: average of all paint systems over 11 years outdoor exposure near Madison, Wisconsin. Primer surface treatment: S, sanding and washing; R, repriming; N, nothing (finishing “as is”).

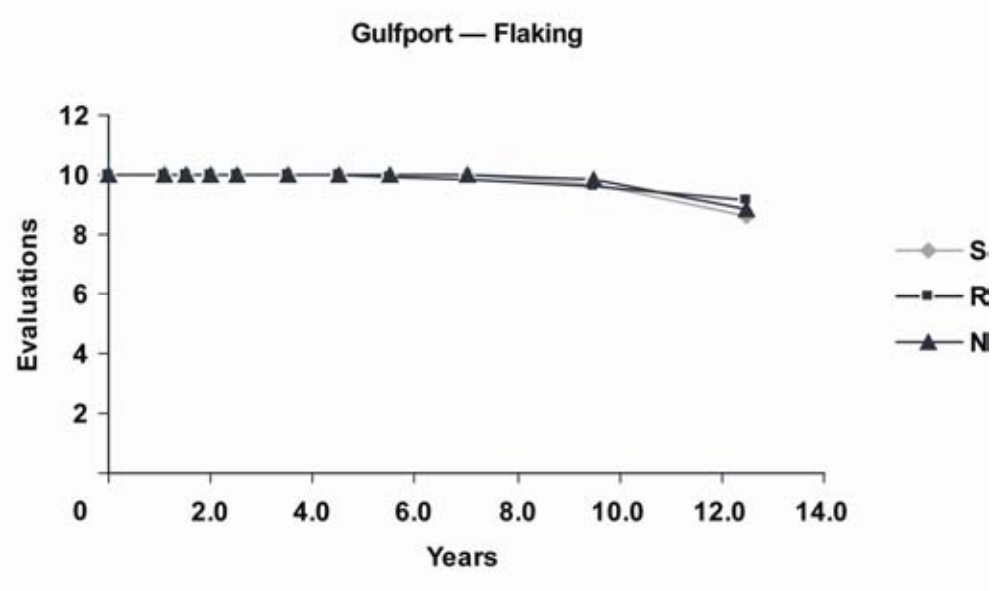

Figure 18. Paint flaking evaluations: average of all paint systems over 12 years outdoor exposure near Gulfport, Mississippi. Primer surface treatment: S, sanding and washing; R, repriming; N, nothing (finishing “as is”).

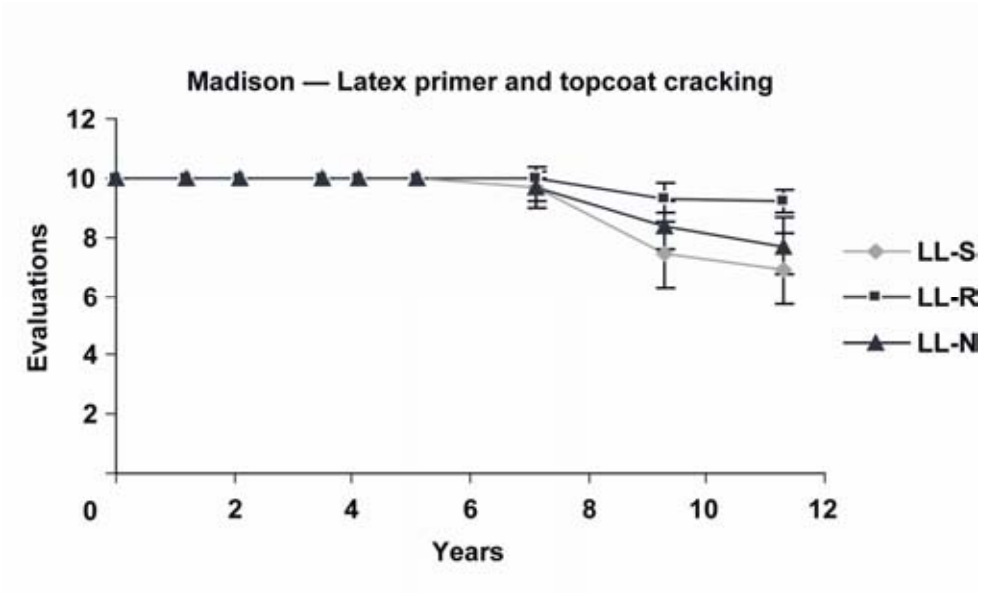

Figure 19. Paint cracking evaluations of latex primer and topcoat (LL) over 11 years exposure near Madison, Wisconsin. Primer surface treatment: S, sanding and washing; R, repriming; N, nothing (finishing “as is”).

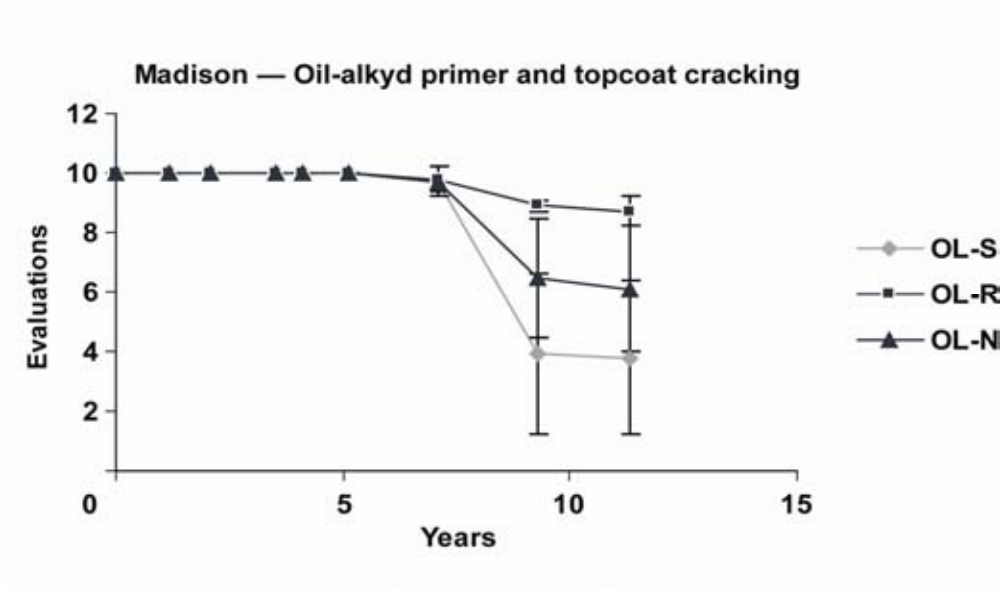

Figure 20. Paint cracking evaluations of oil-alkyd primer/latex topcoat (OL) over 11 years exposure near Madison, Wisconsin. Primer surface treatment: S, sanding and washing; R, repriming; N, nothing (finishing “as is”).

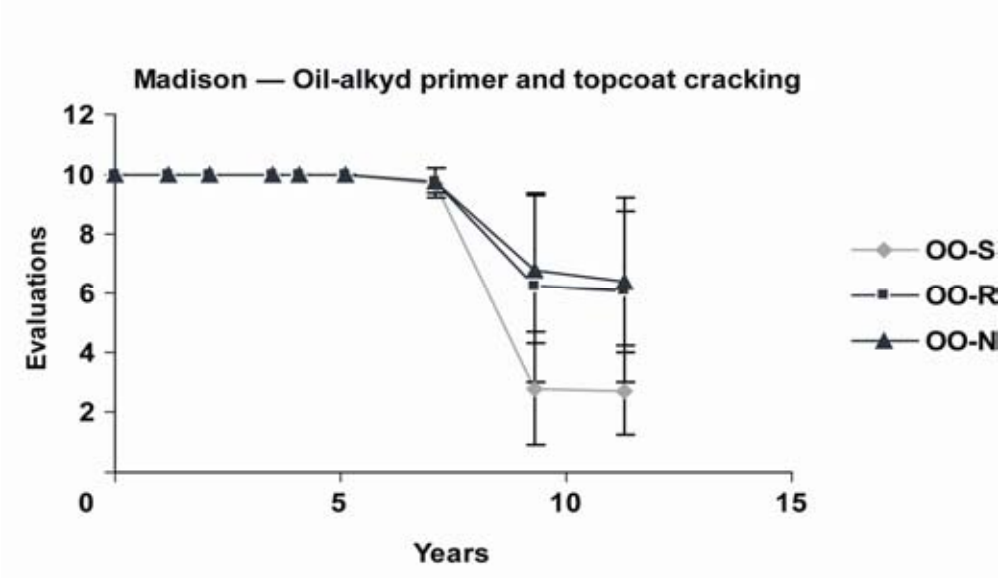

Figure 21. Paint cracking evaluations of oil-alkyd primer and topcoat (OO) over 11 years exposure near Madison, Wisconsin. Primer surface treatment: S, sanding and washing; R, repriming; N, nothing (finishing “as is”).

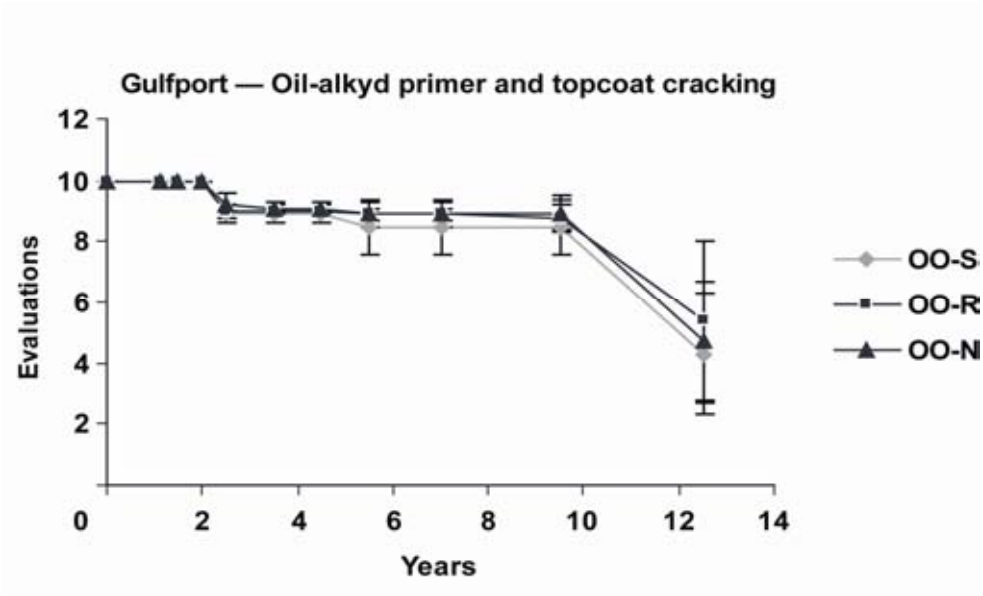

Figure 22. Paint cracking evaluations of oil-alkyd primer and topcoat (OO) over 12 years exposure near Gulfport, Mississippi. Primer surface treatment: S, sanding and washing; R, repriming; N, nothing (finishing “as is”).

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