Duration of Wood Preweathering: Effect on the Service Life of Subsequently Applied Paint

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Previous studies of the effect of preweathering of wood (weathering of wood prior to painting) on subsequent paint performance have not linked short periods of preweathering (weeks) to paint service life. To examine the link between preweathering and paint service life, we analyzed paint performance (cracking and flaking) after 14 years outside on boards that were preweathered for various amounts of time. We then compared our results with previous results from paint adhesion tests of similar boards that were also preweathered for the same amount of time. There was a direct correlation between the amount of time the siding was preweathered and the long-term performance of paint. Paint on wood preweathered for 16 weeks began to fail after just three years. Paint on wood preweathered for shorter periods lasted longer, but even those boards that were preweathered for as little as one week showed paint failure earlier than boards that were not preweathered. There was also good correlation between paint adhesive strength results from the previous study and outdoor paint performance results from this study, showing that loss of paint adhesion may be linked to paint performance in outdoor field tests.

INTRODUCTION

In the absence of adhesion failure, paint on wood exposed outdoors gradually erodes. Degradation of paint by erosion may take a decade or more, depending on the degree of exposure to sunlight and moisture and the thickness and type of paint. While a paint system is eroding it still protects the wood surface from degradation. Until this erosion process proceeds to the point where the primer begins to show, the paint surface can be renewed readily with an additional topcoat. With timely refinishing, painted wood can last for centuries.[1] Many homes built in the 1700s (for example, Mt. Vernon and John Adams' home) that have been kept painted still retain their original siding.

If, however, the paint–wood interphase fails, the paint film will debond within a short time and the paint will blister, crack, and peel. This failure can result in damage to the wood surface and more difficult and costly refinishing. One cause of interphase failure is a degraded wood surface caused by weathering prior to initial priming with paint.[2–12] These previous studies have qualitatively shown that weathering of wood prior to painting (preweathering) decreases subsequent paint performance. However, the amount of preweathering has not been quantitatively linked to long-term paint performance. For example, no study has looked at how short periods of preweathering (one week, several weeks, a few months, several months) affect long-term paint performance (10 to 14 years).

In a previous study at the USDA Forest Service, Forest Products Laboratory (FPL), decrease in paint adhesion was linked to short periods of preweathering.[13] It was found that paint adhesion decreased following as little as two to four weeks of preweathering. Paint adhesive strength continued to decrease with increased time of preweathering. Specimens preweathered for 16 weeks had approximately 50% less paint adhesive strength than controls (not preweathered). Thay and Evans[14] exposed radiata pine (*Pinus radiata*) to six weeks of summer weathering. Their results support our previous study.[13] In our previous study, the loss of paint adhesion was not linked to actual paint performance in outdoor field tests.

Figure 1 shows adhesive strength of latex primer (tensile test) for the various amounts of preweathering. These are results from our previous study on paint adhesion of the preweathered specimens.[13] A considerable drop be-

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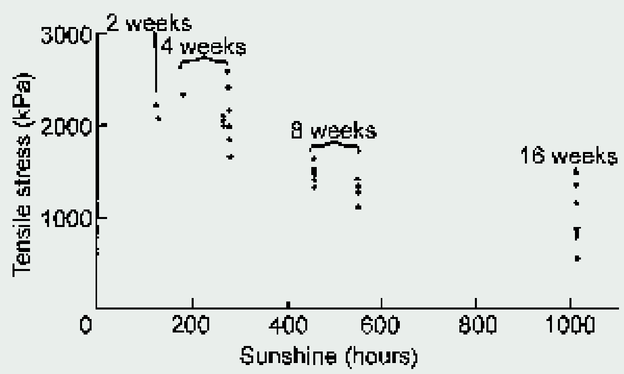

Figure 1—Adhesive strength of acrylic latex primer compared with weeks of preweathering. Only primer–wood interphase failures are shown (ML86 5260).

tween four and 16 weeks of preweathering can be seen in *Figure* 1. Most of the specimens from zero, one, and two weeks of preweathering failed in the wood substrate, not at the paint–wood interphase. Therefore, these data were not included in *Figure* 1. Data for all failures were included in our previous publication.[13] Similar results were obtained for the alkyd-oil primer (*Figure* 2). The paint adhesion was also determined using a shear test. The adhesion test methods are described in detail in our previous study.[13] The results of significance tests for both the tensile tests and shear tests are shown in *Table* 1.

This study reports paint performance after 14 years of outdoor exposure on boards that were similar to those used for the paint adhesion tests[13] and that were also preweathered for the same amounts of time. The results clearly show the effect of short periods of preweathering (one to 16 weeks) on the performance of three different paint systems (two different primers) exposed outdoors for 14 years. Paint performance is then compared with the adhesive tests previously performed on end-matched boards that were preweathered the same amount, then painted using the same two primers, but were not exposed outdoors after painting.[13]

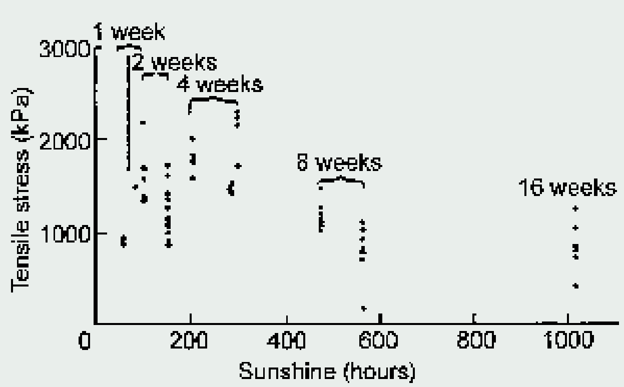

Figure 2—Adhesive strength of alkyd-oil primer versus weeks of preweathering. Only primer–wood interphase failures are shown (ML86 5262).

EXPERIMENTAL

Materials

The finishes were applied to smooth-planed western redcedar (*Thuja plicata* Donn) vertical-grained heartwood. The boards were finished with one of the following paint systems.

- Solventborne water-repellent preservative (WRP), one coat of alkyd-oil primer, and one coat of acrylic latex topcoat (WRP/alkyd/latex).
- One coat of alkyd-oil primer and one coat of acrylic latex topcoat (alkyd/latex).
- One coat of latex primer and one coat of acrylic latex topcoat (latex/latex).

All finishes were commercial formulations. For each of the preweathering periods (zero, one, two, four, eight, and 16 weeks), 12 boards were exposed outdoors for 14 years.

Methods

Freshly planed vertical-grained western redcedar boards 410 × 100 × 10 mm (16 × 4 × 3/8 in.) (longitudinal × radial × tangential) were exposed outdoors, oriented vertically facing south 15 km west of Madison, WI, in the summer of 1984 for one, two, four, eight, or 16 weeks. To determine whether there would be a significant difference in paint performance for specimens exposed at different times, there were four different exposure periods for the boards preweathered for one, two, and four weeks and two different exposure periods for the eight-week preweathering periods. There was only one exposure for the 16-week preweathering. Three boards were exposed in each of the one-, two-, and four-week preweathering periods (12 boards total per preweathering period because of the four exposure periods), six boards in each of the two eight-week preweathering periods (12 boards), and 12 boards in the 16-week preweathering period. At the same time, 12 boards (controls or zero-week specimens) were kept from exposure to sunlight in a darkened room at 27°C and 65% relative humidity for 16 weeks. Preweathering began on May 1, 1984. Following preweathering, the boards were randomly divided into two groups. One group was finished with two coats of primer and was used to conduct paint adhesion studies as previously reported.[13] The second group was finished with the paint systems described in the previous section and placed back on the test fence in September 1984. Boards from all preweathering periods (one, two, four, eight, and 16 weeks) were used for the WRP/alkyd/latex paint system. Only boards preweathered for zero, one, and 16 weeks were finished with the other two paint systems (alkyd/latex and latex/latex).

For convenience, three boards were mounted together to form a panel configured as lap siding. The boards were evaluated annually according to American Society for Testing and Materials (ASTM) standards for erosion,[15] cracking,[16] and flaking.[17] Each board in the panel was rated individually, resulting in three observations for each

Table 1—Results of a Duncan Multiple Range Test on Mean Adhesive Strength of Wood-Primer at Alpha = 0.05[a]

	Tensile Test Amount of Preweathering						Shear Test Amount of Preweathering					
	0	1 Week	2 Weeks	4 Weeks	8 Weeks	16 Weeks	0	1 Week	2 Weeks	4 Weeks	8 Weeks	16 Weeks
Latex primer[b]												
Number flaking[c]	0	0	2	10	15	10	24	11	24	24	12	6
Strength (lb/in.^{2})	—	—	310	305	200	150	800	765	750	710	560	450
Strength (kPa)	—	—	2,125	2,090	1,370	1,040	5,500	5,260	5,150	4,875	3,875	3,095
Alkyd-oil primer[d]												
Number flaking[c]	0	0	19	14	18	6	7	0	15	22	12	6
Strength (lb/in.^{2})	—	—	190	255	155	125	690	—	700	675	530	490
Strength (kPa)	—	—	1,305	1,765	1,055	870	4,745	—	4,815	4,645	3,655	3,380

(a) Strength values underlined by the same line are not significantly different, with 95% confidence.
(b) For latex primer, $R^2 = 0.782$ in tensile test and $R^2 = 0.591$ in shear test.
(c) Number of specimens flaking at the paint-wood interphase.
(d) For alkyd-oil primer, $R^2 = 0.579$ in tensile test and $R^2 = 0.455$ in shear test.

panel for each category (erosion, flaking, and cracking), annually for 12 years. After 12 years, we began taking ratings biannually. The photographs were taken after 15 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

There was one panel (three boards) for each of the one-, two-, and four-week preweathering periods, each had four exposure periods, two panels for each of the two exposures of eight weeks of preweathering, and four panels for the one exposure of 16 weeks of preweathering, which equals a total of 12 boards for each preweathering period, including 12 boards as controls. The initial evaluation of the data showed no apparent differences among panels within a particular preweathering period (one, two, four, or eight weeks). Therefore, the paint evaluations for all panels (12 boards) were combined for each preweathering period.

Erosion

Although some surface degradation undoubtedly occurred, it was not possible to distinguish any differences among the finishes for this rating category, even after 14 years. Paint erosion was determined visually, and there was no evidence of paint erosion to the point where the primer was visible. Therefore, all paint systems on all specimens were given a rating of 10 after 14 years on the fence. On some of the boards, particularly the boards preweathered for 16 weeks, most of the paint had peeled. However, erosion could not be detected on the small amount of paint that was still on the boards.

Cracking and Flaking

The most notable differences among the finishes were found for cracking and flaking. The effect of preweathering on these paint degradation mechanisms was evaluated for 14 years for the three different paint systems. In addition to the effect of preweathering on paint degradation, the experimental design also included the effects of a WRP pretreatment and an oil-alkyd versus a latex primer.

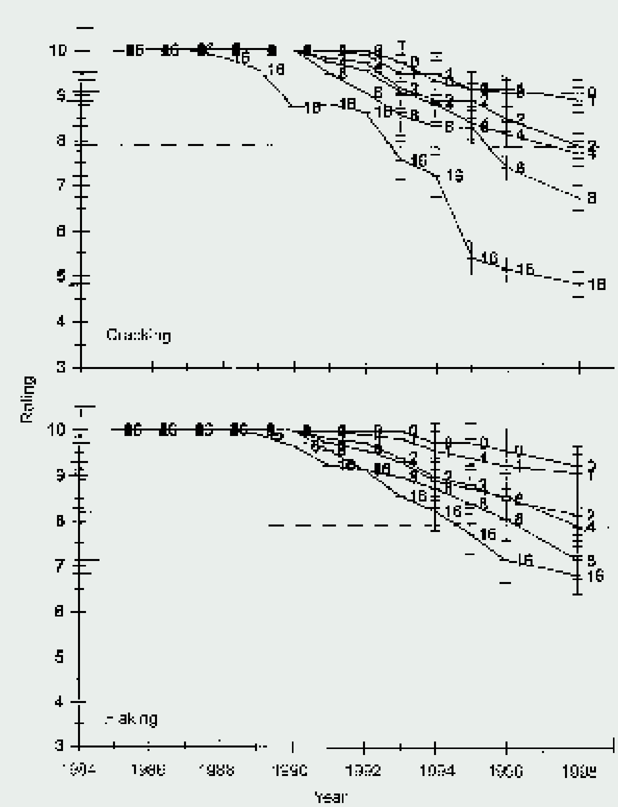

Figure 3—Paint evaluations for cracking and flaking during 14 years for the paint system consisting of a solventborne water-repellent preservative, one coat of alkyd-oil primer, and one coat of acrylic latex topcoat (WRP/alkyd/latex). The data points are the average of 12 observations, and the bars give the standard deviation.

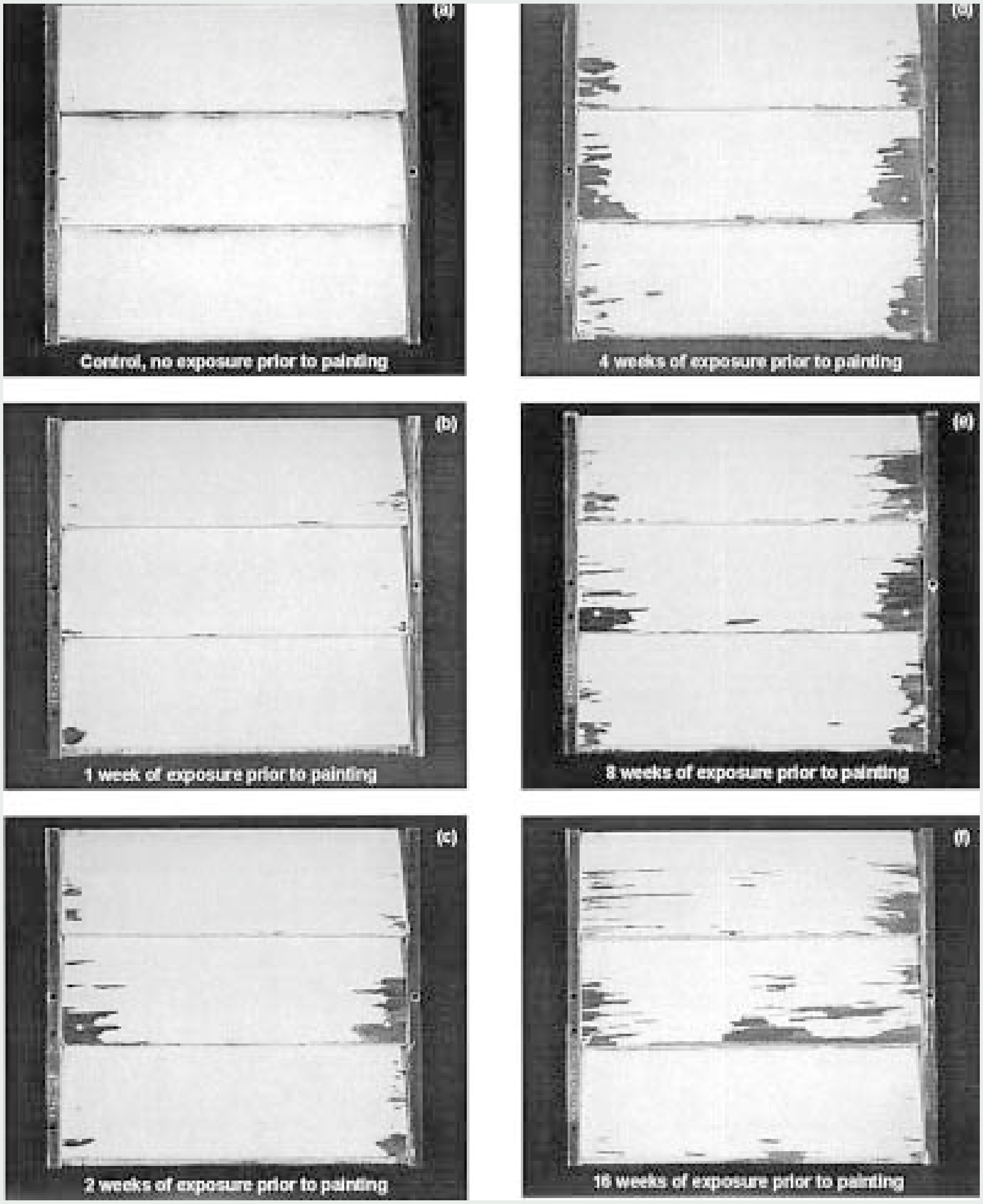

Figure 4—Examples of panels painted with a solventborne water-repellent preservative, one coat of alkyd-oil primer, and one coat of acrylic latex topcoat (WRP/alkyd/latex) after 14 years of outdoor exposure. (a) control, no exposure prior to painting, (b) preweathered 1 week, (c) preweathered two weeks, (d) preweathered four weeks, (e) preweathered eight weeks, and (f) preweathered 16 weeks.

Depending on the amount of preweathering, the boards painted with any of the three paint systems began to show cracking during the exposure period. Flaking generally followed cracking after a year or two (*Figure* 3).

WRP/Alkyd/Latex Paint System: The effect of preweathering can clearly be seen in the cracking and flaking evaluations during 14 years. The boards with 16 weeks of preweathering began to show signs of cracking after only three years of exposure, whereas those with zero- and one-week preweathering periods began to crack after nine years. Clearly, each preweathering period had different performance results. This difference in performance can be seen in the photographs of the boards after

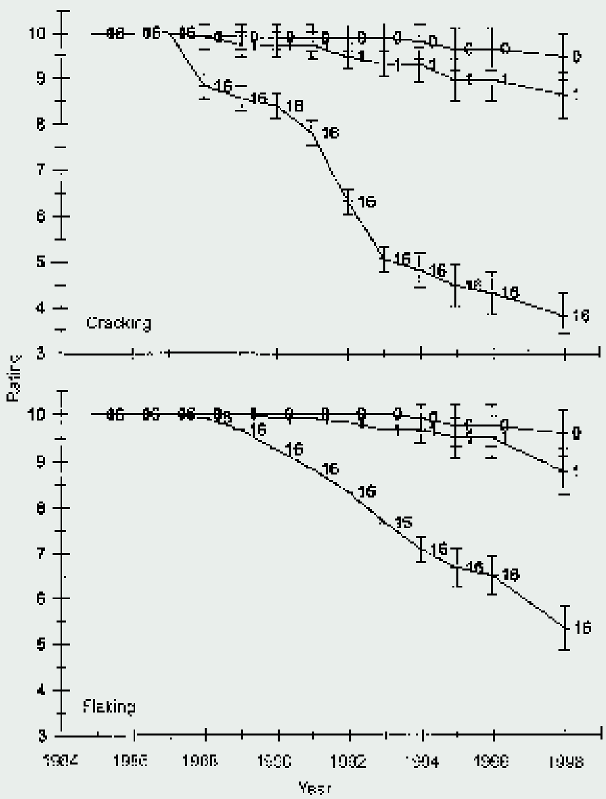

Figure 5—Paint evaluations for cracking and flaking during 14 years of outdoor exposure for specimens painted with one coat of alkyd-oil primer and one coat of acrylic latex topcoat (alkyd/latex). The data points are the average of 12 observations, and the bars give the standard deviation.

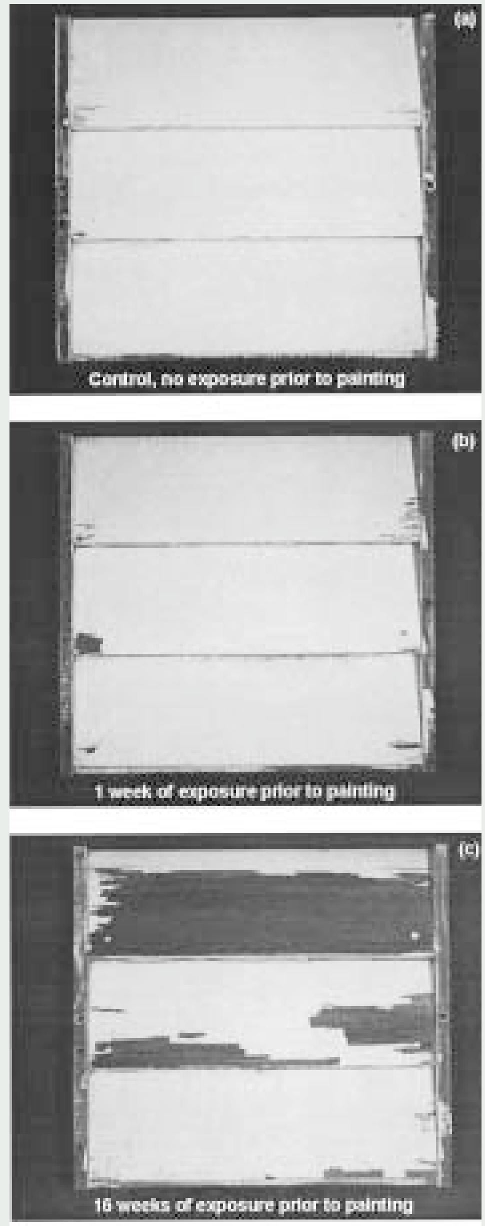

Figure 6—Examples of panels painted with one coat of alkyd-oil primer and one coat of acrylic latex topcoat (alkyd/latex) after 14 years of outdoor exposure. (a) control, no exposure prior to painting, (b) preweathered one week, and (c) preweathered 16 weeks.

15 years of exposure (*Figure* 4a–f). One panel (three of the 12 boards) for each of the preweathering times is shown. The other three panels showed the same trend. Although it is not apparent in cracking results in *Figure* 3, there is clearly a slight difference in performance between the zero- and one-week preweatherings (*Figure* 4a and b). The control (zero-week preweathering) was in almost perfect condition after 14 years of exposure. That is a service life of more than 14 years for a paint system comprised of a WRP pretreatment, one coat of primer, and one topcoat. The slight discoloration just under the bottom edge of each board is dirt.

Alkyd/Latex Paint System: The cracking and flaking ratings for the one- and 16-week preweathering periods are lower for the alkyd/latex paint system without the WRP (*Figure* 5) than for the specimens with the same amount of preweathering finished with the WRP/alkyd/latex paint system (*Figure* 4). This can be seen by comparing photographs of panels from the different paint systems preweathered for the same amount (*Figure* 6a,b, and c compared with *Figure* 4a, b, and f). After 14 years, boards pretreated with a WRP had slightly better paint performance compared with those without the pretreatment, particularly for boards that had been preweathered. There was no apparent difference for the control boards. Paint cracking developed more quickly on boards without WRP. Also, there appears to be a considerable difference between the zero- and one-week preweathering periods for boards without the WRP pretreatment (*Figure* 5). This difference was not apparent with the WRP-treated boards (*Figure* 3). For WRP-treated boards, flaking occurred about one to three years after cracking. However, for boards without WRP, flaking was immediately evident upon cracking.

Latex/Latex Paint System: In general, ratings for the performance of the alkyd/latex paint system (*Figure* 5)

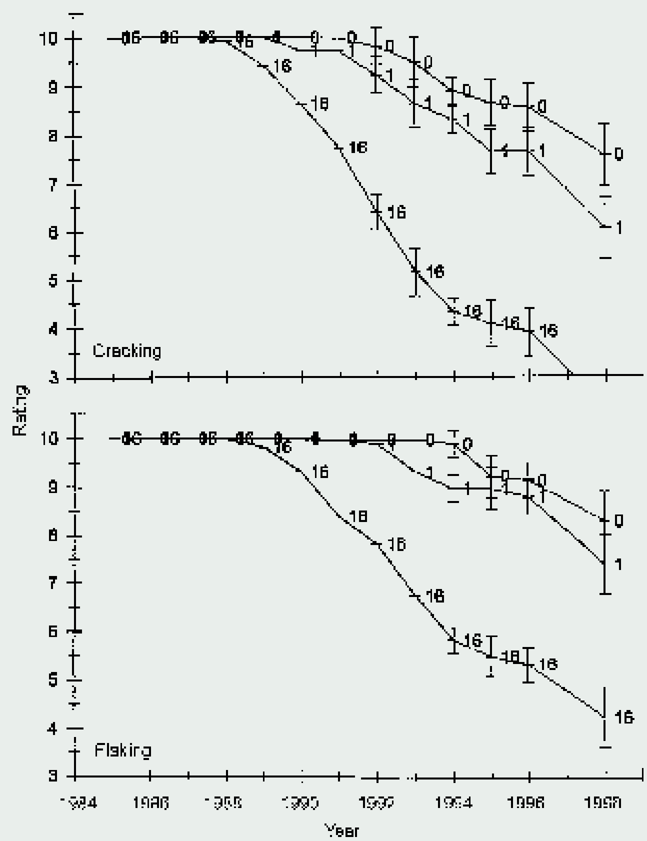

Figure 7—Paint evaluations for cracking and flaking during 14 years of outdoor exposure for specimens finished with one coat of latex primer and one coat of acrylic latex topcoat (latex/latex). The data points are the average of 12 observations, and the bars give the standard deviation.

specimens preweathered for two to 16 weeks. There appears to be a good correlation even though there was considerable cohesive wood failure (i.e., failure was contained totally in the wood) in the specimens preweathered for only zero, one, and two weeks. Our previous study clearly showed that the tensile strength of well-bonded paint to western redcedar was stronger than the cohesive strength of the wood.[13] [The tensile strength of western redcedar perpendicular to grain is about 1,500 kPa and the shear strength parallel to grain is about 6,800 kPa[18]]. Therefore, the regression analysis included only data pertaining to paint–wood bond strength. Even those specimens preweathered for two weeks had sufficient paint adhesive strength to cause primarily wood failure in the adhesion tests. This was less of a problem with the shear tests because the shear strength of western redcedar parallel to grain was somewhat higher than the paint–wood shear strength for the two-week preweathered specimens.

If any part of the paint bond was visible after the adhesion test, the specimen was included in the data set. In *Figures* 9c and d (tensile strength versus cracking and flaking), the abrupt drop for the two-week preweathered specimens is probably caused by a failure in the wood. The R^2 values for the comparisons of shear strength with cracking or flaking were 0.81 and 0.98, respectively. The R^2 values for the comparisons of tensile strength with cracking or flaking were 0.61 and 0.56, respectively. If the two-week preweathering data are removed from the data set, the R^2 values are 0.73 and 0.97 for cracking and flaking, respectively. Thus, it appears that paint adhesion tests give a reasonable indication of long-term performance of paint. Paint performance without cracking and flaking seems to require a shear strength of at least 5,000 kPa and a tensile strength of 1,800 kPa on smooth-planed western redcedar.

Figure 8—Example of panels painted with one coat of latex primer and one coat of acrylic latex topcoat (latex/latex) after 14 years of outdoor exposure. Panel was preweathered for 16 weeks.

were slightly higher than those of the latex/latex paint system (*Figure* 7). There was clearly a difference between the two paint systems within the zero-, one-, and 16-week preweathering periods. Both the alkyd/latex (*Figure* 5) and the latex/latex (*Figure* 7 and 8) paint systems started cracking and flaking about the same time (after three to four years of exposure), but the latex/latex system degraded faster in subsequent years. For the latex/latex paint system, the paint on the zero-week preweathered boards cracked and flaked sooner than expected given the inherently greater flexibility of the latex/latex paint system compared with the alkyd/latex system. The latex primer was a high quality paint but was one of the first formulations in the new generation of stain-blocking latex primers developed in the early 1980s. Its performance in cracking and flaking may not be representative of stain-blocking latex primers available today.

Paint Adhesive Strength Compared with Cracking and Flaking Evaluations

Figure 9 shows the average adhesive strength of the alkyd-oil primer compared with the cracking or flaking evaluations for the WRP/alkyd/latex paint system for

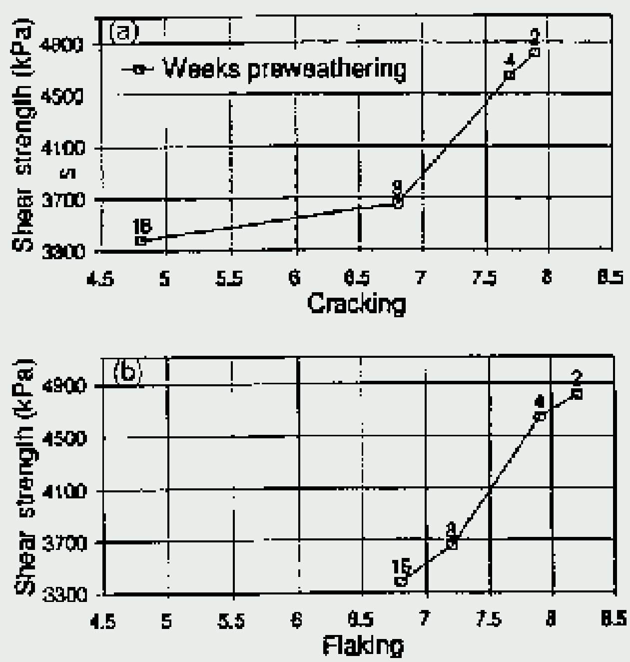

Figure 9—Paint adhesive strength (shear and tension) of the alkyd-oil primer compared with the cracking or flaking evaluations of the WRP/alkyd/latex paint system after 14 years of outdoor exposure. (a) shear strength versus cracking, (b) shear strength versus flaking, (c) tensile strength versus cracking, and (d) tensile strength versus flaking. The number of weeks of preweathering is shown with each data point. The R^2 values are 0.81, 0.98, 0.61, and 0.56 for (a) through (d), respectively. If the two-week data are not included in the regression analysis for (c) and (d), the R^2 values are 0.73 and 0.97, respectively.

CONCLUSIONS

The exposure of unpainted smooth-planed, vertical-grained western redcedar siding to weather for as little as one to two weeks can shorten the service life of subsequently applied paints. For wood exposed unfinished for 16 weeks prior to painting, cracking in the paint film was detected after only three years of outdoor exposure. In contrast, boards that were not exposed to the weather prior to painting were in almost perfect condition after 14 years of exposure. Paint adhesion tests gave a good indication of service life for those specimens exposed four or more weeks prior to painting but did not indicate potential problems with cracking and flaking for specimens preweathered for short periods because the paint–wood bond strength was about the same as the wood strength. The outdoor performance of painted wood that had been preweathered for short periods showed that there was undoubtedly some surface degradation caused by weather on these specimens during the preweathering. It is imperative that smooth-planed lumber be painted promptly during construction or that the wood be scuff-sanded prior to applying the primer.

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