Restoration of Severely Weathered Wood

R. Sam Williams and Mark Knaebe—Forest Products Laboratory*

Severely weathered window units were used to test various restoration methods *and pretreatments. Sanded and unsanded units were pretreated with a consolidant or water repellent preservative, finished with an oil- or latex-based* paint system, *and exposed outdoors near Madison, WI, for five years. Pretreatments were applied to both window sashes (stiles and rails) and sills. In most cases, pretreatment with consolidants was detrimental to the finish. These pretreatments generally caused more flaking and cracking of the paint compared with that of untreated controls or penetrating water-repellent preservatives. The best results were* obtained by a *combination of sanding and pretreatment with a water-repellent preservative containing copper naphthenate or with tung oil.*

INTRODUCTION

Severely weathered window units (sills, sashes, and frames) can be difficult to refinish. Film-forming finishes such as paint adhere poorly to weathered surfaces. The cracked and uneven surface of severely weathered window units appears rough even after the application of several coats of paint. Moreover, it is difficult to obtain a good seal with the paint system because the stile/rail joints of weathered window sashes are often separated. In addition, the exposure of window sills, particularly those of south-facing windows, to direct and reflected solar radiation shortens the service life of paint.

Objectives

The objectives of this study were to determine the effect of sanding and water-repellent preservative or consolidant pretreatment of weathered window units on paint service life. Light and moderate hand-sanding of window sills and vigorous mechanical sanding of window sashes were used in combination with various pretreatments.

Background

In our previous work[1-4] and a recent publication by Evans,[5] short periods of weathering of unpainted wood were shown to decrease paint adhesion and service life of the finish. Others have reported on the effects of longer periods of weathering.[6-12] In recent work, we found that the most effective method for remediating a weathered wood surface was sanding.[13] Sanding improved the performance of a finish on unweathered wood as well.[14] In these studies, the period of weathering was relatively short. We expanded our research to include severely weathered wood by studying the performance of the finish on window units and support structures (sills and sashes) that had been exposed for 28 years near Madison, WI.

The window units were from a previous study by Miniutti et al.[15] who studied the effect of various solventborne water-repellent preservative (WRP) dip treatments on water repellency and service life of paint. The treatments in this study included a variety of commercial and experimental WRPs. The researchers tested 11 treatments: three WRP formulations that met the current industry standard of 60% water repellency, three WRP formulations above the 60% industry standard, three WRP formulations below the 60% standard, a preservative without water repellent, and a water repellent without preservative. Ponderosa pine sapwood window units were dip treated in the solutions for three minutes. The windows were glazed, varnished on the interior, painted on the exterior with a primer and topcoat, and installed in frames typical of that found in normal construction. A roof cap and plywood backing were used to protect the inside of the windows, but the overhang of the roof cap was minimal. Thus, the units were at fairly high risk for trapping moisture and being infected by decay. The window units were exposed outdoors facing south at a

*USDA Forest Service, One Gifford Pinchot Dr., Madison, WI, 53705-2398.

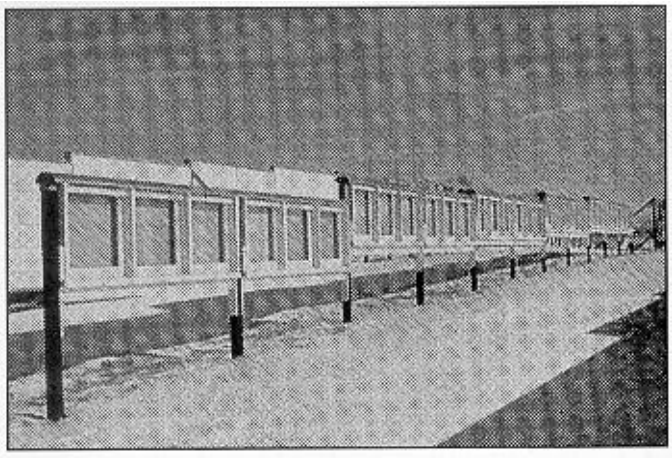

Figure 1—Window units as originally installed by Miniutti et al. [16] in 1956.

test site near Madison, WI, in a manner typical for exposure in an actual building (Figure 1).

During the first four years of the study by Miniutti et al., the windows were removed periodically to measure swelling. The initial results showed good correlation between swelling and laboratory-determined water repellent effectiveness of the various WRPs.[15] Solutions with 60% or greater water repellency provided good protection over the four-year exposure period, but showed a slight decrease in effectiveness with time. The results clearly showed that painted window units without water repellent tended to trap moisture. Moisture content of joints at the bottom of the units was above the fiber saturation point. Water was able to enter the end grain through cracks in the paint and move to the interior of the wood, where it was trapped by the paint film. Premature paint failure was observed at these locations on specimens that were not treated with a water repellent or WRP (*Figure* 2).

These window units (frames, sashes, and sills) were left to weather without maintenance until 1984. At that time, 55 units were still intact and situated on the test fence; all of the untreated controls had decayed and fallen off the fence. The intact window units were used for the study reported here. This study complements other work reported for refinishing of severely weathered siding. In that study, low solids latex paint containing raw linseed oil showed excellent performance on severely weathered western redcedar and redwood siding.[16]

MATERIALS AND METHODS

Materials

The sashes from the 55 intact window units were numerically rated in even integers from 2 to 10, with 10 designating the best condition. Thirty-six sashes were selected for study. All of these sashes had a rating of at least 6, and most had a rating of 8 or 10. All of the sashes were free of obvious decay, but were severely weathered with deep cracks and extensive surface checks (*Figure* 3). The window sills were also severely weathered but free of decay.

Pretreatments included consolidants that filled the surface cracks and WRPs that absorbed into the weathered surface but did not fill the cracks. Pretreatments for sills included three commercial consolidants and four WRPs (*Table* 1), and pretreatments for sashes included one consolidant and four WRPs (*Table* 2). Only one pretreatment was common to both sills and sashes, the modified waterborne acrylic resin consolidant. Two paint systems were used for both sills and sashes. Sills were painted with a commercial alkyd-oil primer and topcoat or a commercial alkyd-oil primer and latex topcoat. Sashes were painted with a commercial alkyd-oil primer and topcoat or a commercial latex primer and topcoat. The same oil-based primer and oil-based topcoat was used for both sills and sashes.

Table 1—Pretreatments, Surface Preparation, and Finishes for Window Sills

Variable		Abbreviation[a]
Pretreatment	Control	Control
	Zinc naphthenate WRP	Zn
	Solventborne epoxide consolidant	EC
	Modified waterborne acrylic resin consolidant	Resin
	Copper napthenate WRP	Cu
	Solventborne consolidant	SC
	Tung oil	Tung
	50% polyurethane varnish in mineral spirits	Poly
Surface prep	Light sanding by hand	Light sand
	Moderate sanding by hand	Moderate sand
Paint system	Oil-alkyd primer and topcoat	Oil
	Oil-alkyd primer and acrylic latex topcoat	Latex

(a) Abbreviations used in figures

Table 2—Pretreatments, Surface Preparation, and Finishes for Window Sashes

Variable		Abbreviation[a]
Pretreatment	Control	Control
	Solventborne WRP	SWRP
	Solventborne water repellent	WR
	50% linseed oil in mineral spirits	Linseed
	Waterborne WRP	WWRP
	Modified waterborne acrylic resin consolidant	Resin
Surface prep	Washed with bristle brush	
	Power sanded	
Paint system	Oil-alkyd primer and topcoat	
	Acrylic latex primer and topcoat	

(a) Abbreviations used in figures.

Methods

Window sills were divided into two groups. One group was lightly sanded by hand, and the other group was

moderately sanded. The sills were divided into 200-mm (S-in.) long sections and scribed to retard the flow of pretreatment chemicals and/or sealers to adjacent sections; the scribed grooves were sealed with aluminum flake paint. Pretreatments were applied to sills in the field in a random pattern prior to installing the window sashes (three replicates for each pretreatment).

The window sashes were removed from the test fence, and all surface preparation, pretreatments, and finishing were done under ambient laboratory conditions. All glazing was removed from the window sashes, and half of each sash was heavily sanded with a belt sander using 50-grit sandpaper. Sanding removed all surface checks and most cracks. The unsanded weathered surface was washed with distilled water to remove dirt. Both the sanded and unsanded parts of each sash were pretreated, glazed, and painted. There was no attempt to caulk the checks and cracks.

Although the window frames were not part of the study, they were pretreated with a commercial WRP and painted with a commercial latex primer and topcoat before the window sashes were installed.

Window units were evaluated annually for five years (1989-1993) according to ASTM standards for erosion,[17] cracking,[18] flaking,[19] and mildew growth.[20] Window units were also evaluated for general appearance using a rating scale similar to that in the ASTM standards. Three window units were used for each pretreatment to give three observations for each experimental condition. For the sills, each pretreatment was applied at random to three locations on the sills. Each half of the window sashes and each section of the window sills was rated annually for paint flaking, paint cracking, general appearance, mildew growth, and wood cracking over a five-year period. A rating of 10 was used to indicate no observable degradation and a rating of 1 to indicate complete failure of the unit. A rating of 5 indicates sufficient degradation to warrant normal refinishing if the coating system was in use on a structure.

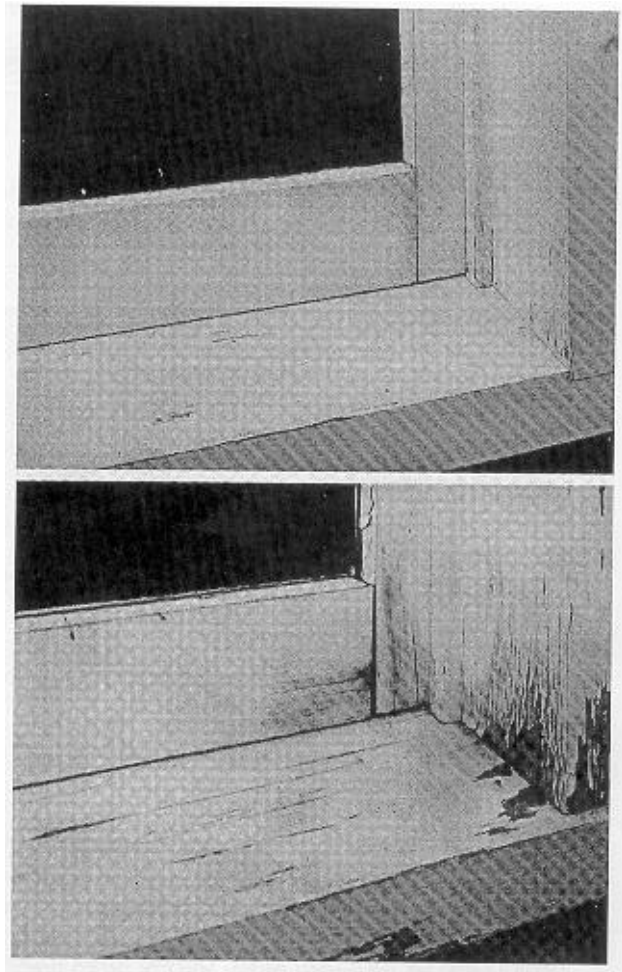

Figure2—Effect of water repellent preservative (WRP) on service life of window unit: (top) window unit pretreated with WRP prior to painting; (bottom) untreated window unit-paint degradation caused by water absorption into end grain.

RESULTS AND DISCUSSION

Although all of the window sills and sashes were treated and tested at the same time, the focus of study was slightly different for sills and sashes (Tables 1 and 2). Window sill pretreatments included three commercial consolidants and four WRPs, whereas sash pretreatments included only one consolidant and four WRPs. Except for the untreated controls, only one pretreatment (modified acrylic resin consolidant) was common to both sets of specimens. Sills were sanded either lightly or moderately by hand, whereas sashes were power sanded or not sanded. Thus, the surfaces of sills and sashes were distinct.

Window Sills

Window sills were evaluated for paint flaking and cracking, wood cracking, and general appearance (Figures 4-7). Flaking provided the best measure of the effect of sanding and pretreatment on paint performance.

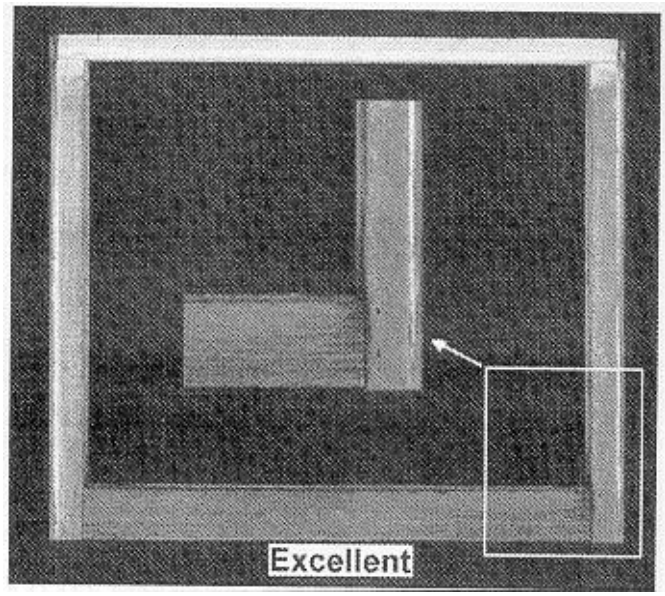

Figure 3—Pretreatment of window sash prior to painting; right half of sash has been sanded.

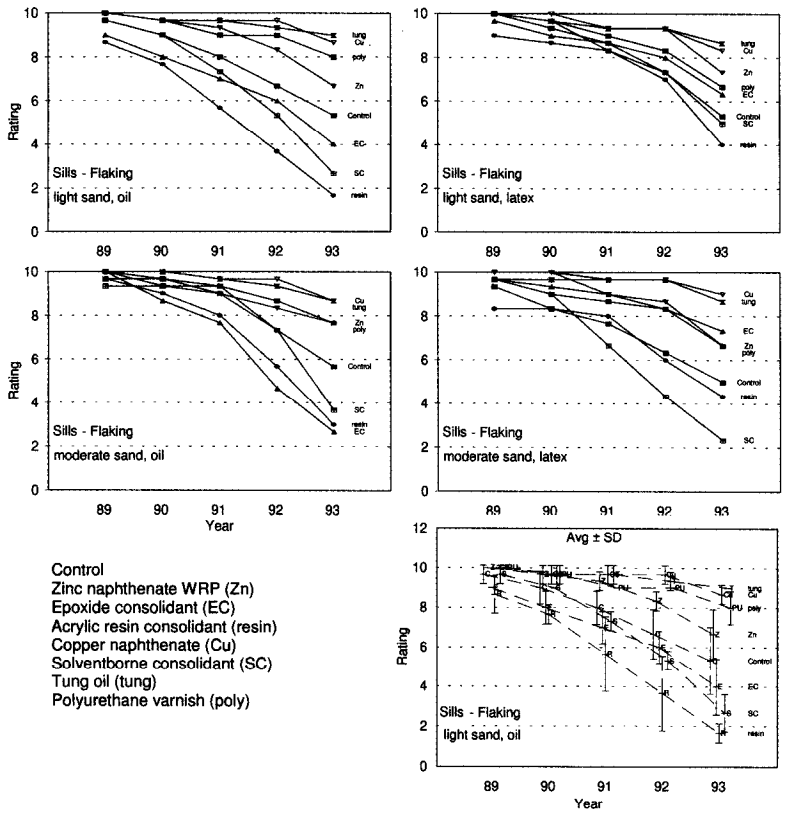

Figure 4—Mean ratings for flaking of window sill paint after five years of outdoor exposure. All sills were prepared with oil-alkyd primer, Oil designates oil topcoat; latex, acrylic latex topcoat. Bottom graph shows distribution of ratings for each pretreatment.

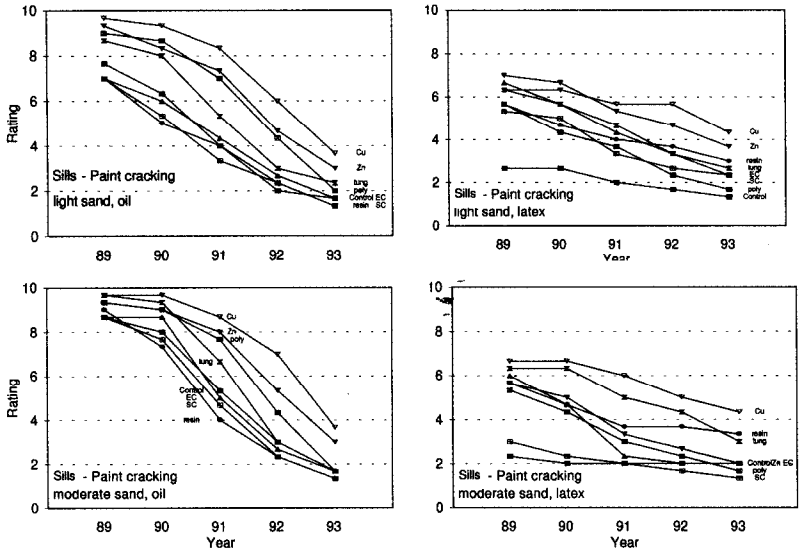

Figure 5—Mean ratings for cracking of window sill paint after five years of outdoor exposure. All sills prepared with oil-alkyd primer. Oil designates oil topcoat; latex, acrylic latex topcoat.

(Enlargements of Figures 4-7, 9-12, and 14 and others of decay ratings are available on the Forest Products Laboratory Website: www.fpl.fed.us/pubs.htm.)

Evaluation of paint cracking was complicated by deep cracks in the wood substrate, which resulted from failure of hand sanding to remove enough wood from the surface. In many cases, it was difficult to determine the extent to which the initial surface cracking of the wood influenced the ratings for paint cracking and general appearance. The general appearance rating was also greatly influenced by mildew growth on some specimens, particularly those treated with tung oil. For example, sills pretreated with tung oil had good flaking ratings (*Figure* 4), but poor general appearance ratings *(Figure* 7).

Figure 4 shows average flaking ratings and the distribution of ratings for each pretreatment. The graph for the lightly sanded sills finished with the oil-alkyd primer and topcoat (upper left) is duplicated in the lower right graph to show the distribution of ratings for each pretreatment. Each mean value is shown along with its standard deviation; the standard deviations are staggered at each time point to reveal the spread in the data. In most cases the mean is bracketed by ± 1 evaluation unit. Means that do not differ by at least 1 evaluation unit are probably not different. The plots for flaking are typical of the data for the plots for paint cracking, wood cracking, and general appearance (*Figures* 5-7).

The flaking ratings for window sills were different for various pretreatments after five years of outdoor exposure. Pretreatment with copper naphthenate WRP or tung oil improved the performance of both paint systems regardless of the amount of sanding. Zinc naphthenate WRP also improved paint performance, but not to the extent shown by the copper naphthenate WRP. The other pretreatments gave mixed results, depending on the paint system and the amount of sanding. For example, the epoxide consolidant performed better with the oil primer/latex topcoat system than with the oil primer/oil topcoat (*Figure* 4).

For several pretreatments, the paint was in worse condition after five years compared with the untreated control regardless of finish system or amount of sanding (*Fig-*

ure 4). For example, solventborne consolidant (EC) and modified acrylic consolidant (resin) performance was worse than performance of controls for both lightly and moderately sanded units finished with oil primer/oil topcoat and oil/primer/latex topcoat systems. These types of consolidants probably lack the flexibility to move with the wood as it changes dimension through daily and seasonal changes in moisture content, particularly when the consolidant is used with an oil-based primer (*Figure* 4).

The paint cracking ratings indicate that all pretreatments improved paint performance, particularly during the early years of exposure. After five years of exposure, slightly less paint cracking had occurred on sills pretreated with copper naphthenate or zinc naphthenate and finished with the oil primer/oil topcoat system (Figure 5). The cracking ratings are somewhat surprising in that they are similar for both paint systems after five years of outdoor exposure. All sills had a cracking rating of less than 5. These results probably reflect the influence of the substrate on these finishes (Figure 6). Even after sanding, the surfaces of the sills were rather badly cracked. This was more evident on the sills finished with the latex topcoat (Figure 6).

We do not have a good explanation for the low paint cracking values for the oil primer/latex topcoat after only one year of outdoor exposure other than the possible effect of the surfactants in the latex formulations. In past research using latex paint systems on wood, we found that the surfactants in these coatings permitted the wood to absorb water. In tests using latex paints on end-grain specimens, the painted wood absorbed water faster than did the unpainted controls (unpublished data). The all-oil paint system may have provided greater protection against moisture.

In evaluating the sills, it was difficult to separate substrate cracking from paint cracking. The type of sanding apparently had little influence on cracking of the wood with either paint system, probably because of the oil primer. Neither of the systems performed very well, although copper naphthenate seemed to help improve paint performance in all cases. We found it interesting that for sills finished with the latex-based topcoat, wood cracking did not change much after the first year of exposure, whereas sills finished with the oil-based primer/topcoat showed a more typical degradation over time. Those specimens treated with consolidants seemed to be more prone to cracking.

General appearance ratings *(Figure* 7) parallel those for paint and wood cracking. Pretreatment with copper naphthenate improved overall appearance.

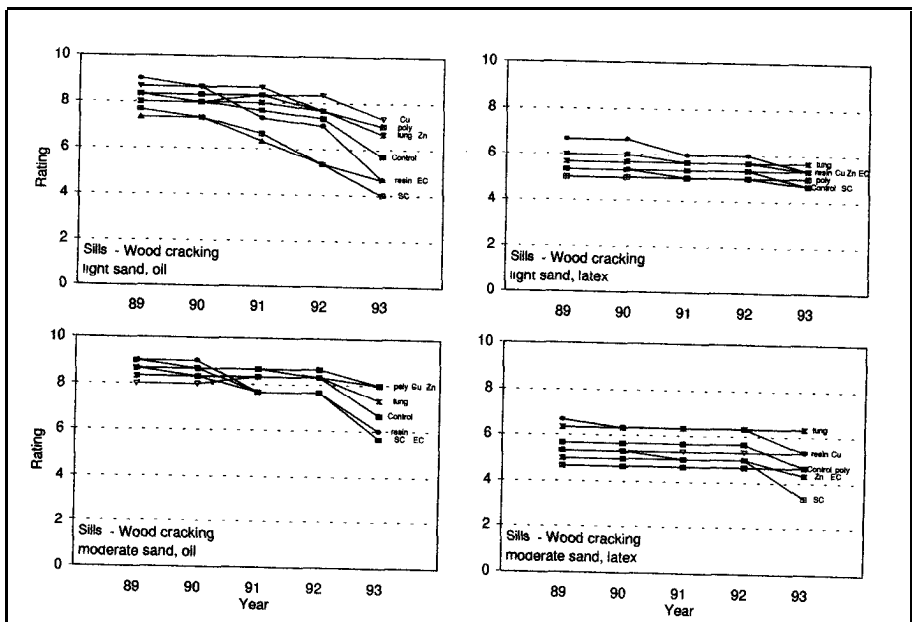

Figure 6—Mean ratings for cracking of window sill wood after five years of outdoor exposure. All sills prepared with oil-alkyd primer. Oil designates oil topcoat; latex, acrylic latex topcoat.

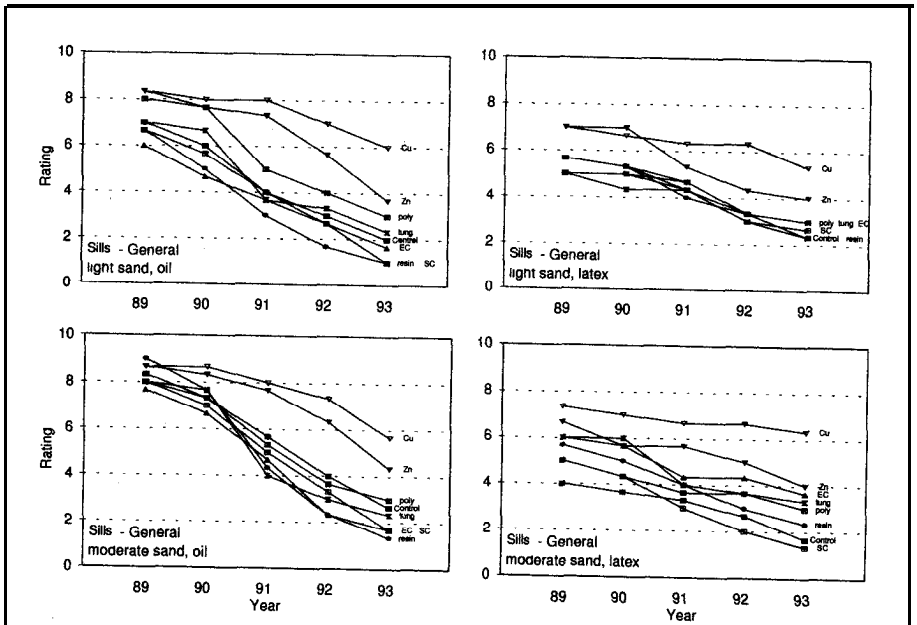

Figure 7—Mean ratings for general appearance of window sills after five years of outdoor exposure. All sills prepared with oil-alkydprimer. Oil designates oil topcoat; latex, acrylic latex topcoat.

As mentioned in the Methods section, the pretreatments were applied in the field in a random pattern. To obtain a better visual image of the three replicates and compare the pretreatments, photographs of each section of the sill were scanned into a computer file, and a matrix of the various pretreatments and finishes was constructed. Several images in this matrix were abstracted to compare various pretreatments after five years (*Figure* 8). Pretreatment with copper naphthenate resulted in the best overall appearance of the sills after five years of exposure. Tung oil also decreased paint flaking and cracking compared with the controls, but it caused mildew. Zinc naphthenate and 50% polyurethane varnish in mineral spirits were somewhat effective. Pretreatments other than these had little positive effect, and in some cases the pretreated sills had poorer overall appearance ratings than the controls, primarily because of mildew.

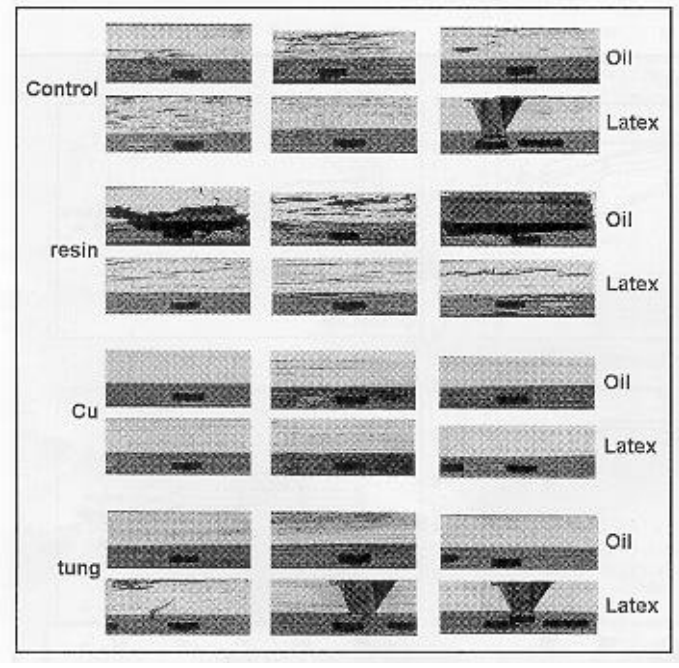

Figure 8—Composite of representative window sills showing effect of pretreatment on paint system (oilprimer/oil topcoat or oil primer/latex topcoat).

Window Sashes

Like the sills, sashes were evaluated for paint flaking and cracking, wood cracking, and general appearance *(Figures 9-12).*

Flaking performance was most affected by sanding *(Figure 9).* Little overall difference could be attributed to type of paint. As was shown in previous research, adhesion of both oil- and latex-based paints is badly compromised by weathered wood.[16] Sanding improved flaking performance of all sashes, even the untreated controls. The effect of sanding was inversely related to the effectiveness of the pretreatment; the less effective the pretreatment, the more beneficial the effect of sanding. All pretreatments improved flaking performance of sashes finished with the latex-based paint system. This was not the case for sashes finished with the oil-based paint system. For example, pretreatment with the modified acrylic resin consolidant improved flaking performance of sashes finished with the all-latex paint system, but not that of sashes finished with the oil-based system *(Figure* 9). This acrylic is apparently compatible with the latex primer, but not with the oil-based primer. Linseed oil gave rather interesting results with the oil-based paint system. It resulted in the highest rating for the unsanded half of the sash, but the lowest rating for the sanded half (*Figure* 9). Thus, linseed oil seemed to have a very beneficial effect on a badly degraded surface, but had a negative effect on a surface that had been restored by sanding. In previous work on the restoration of severely weathered wood siding, we found that formulations containing about 10% raw linseed oil gave excellent performance on badly weathered wood.[16] Pretreatment with tung oil improved the flaking rating of sills regardless of the amount of sanding (*Figure* 4). We could not determine whether this difference in the effect of oil was the result of the type of oil (linseed or tung), its concentration (50% linseed oil versus 100% tung oil), or differences in the wood surface.

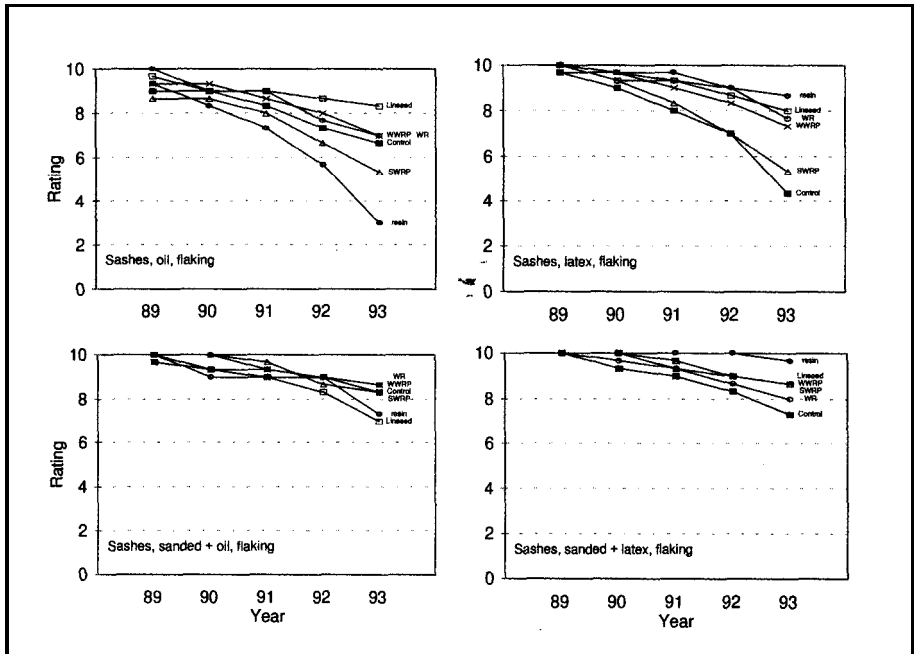

Figure 9—Mean ratings for flaking of window sash paint after five years of outdoor exposure. Oil designates oil-alkyd primer *and topcoat; latex, acrylic latex primer and topcoat.*

Except for the slight improvement resulting from the use of the waterborne water repellent on the sanded surface, none of the pretreatments were effective in preventing cracking of paint on

sashes finished with the oil-based paint system (Figure 10). All of these sashes were substantially degraded (rating of 5 or lower) within two years of exposure. However, almost all pretreatments improved the performance of the window sashes finished with the latex paint system. Sanding was very beneficial for the sash treated with the solventborne WRP (Figure 10). Compared with the results for sills, the performance of the modified acrylic resin consolidant was quite surprising. This consolidant gave excellent results, particularly for the sanded half of the sash finished with the all-latex system (Figure 10).

Figure 11 shows the effects of pretreatment on substrate cracking. When used with the latex paint system, almost all treatments decreased cracking. When used with the oil-based paint system, only the solventborne WRP decreased cracking. The excessive wood cracking probably influenced the paint cracking ratings as well, particularly for sashes finished with the oil-based paint system.

For the most part, the general appearance ratings for sashes finished with the oil-based paint system (Fig*ure* 12) showed no positive effect for the pretreatments. For sashes finished with the latex-based paint system, general appearance ratings were improved by pretreatments, in particular the modified acrylic resin consolidant *(Figure* 12). However, general appearance ratings of many specimens showed no definable trend because of the effects of mildew growth, which varied from one year to the next. In particular, the poor performance of the 50% linseed oil was attributed to mildew growth;, for this pretreatment, cracking and flaking evaluations were generally better indicators of performance.

In summary, pretreatments varied in their long-term effect on sashes, and sanding was beneficial in all cases (*Figure* 13). Pretreatment with WRP plus sanding gave the best performance.

To determine whether our results were influenced by the original condition of the sashes, we compared the original evaluation of the windows with the performance of the various treatments over the test (five-

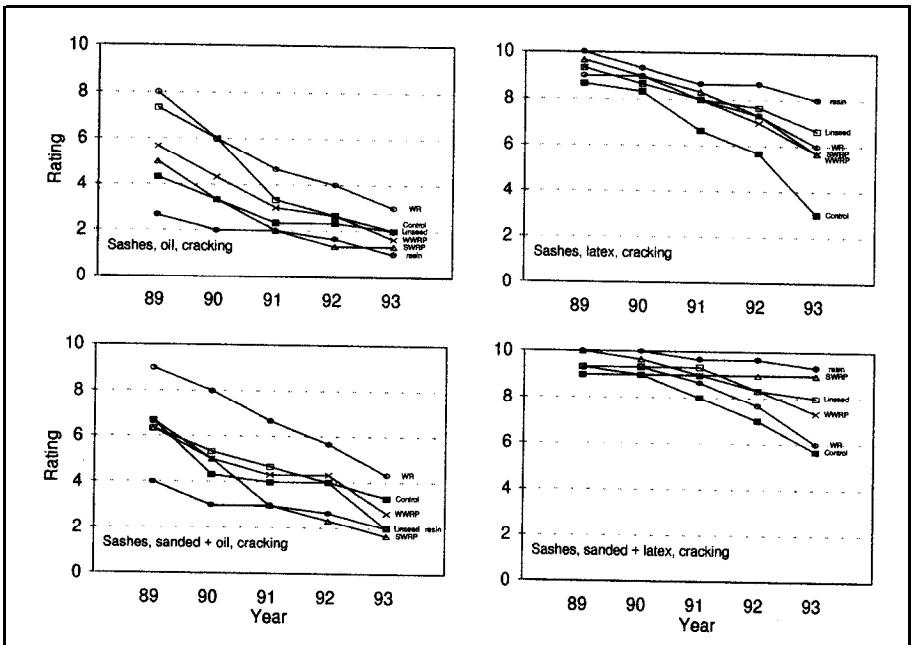

Figure 10—Mean ratings for cracking of window sash paint after five years of outdoor exposure. Oil designates oil-alkyd primer and topcoat; latex, acrylic latex primer and topcoat.

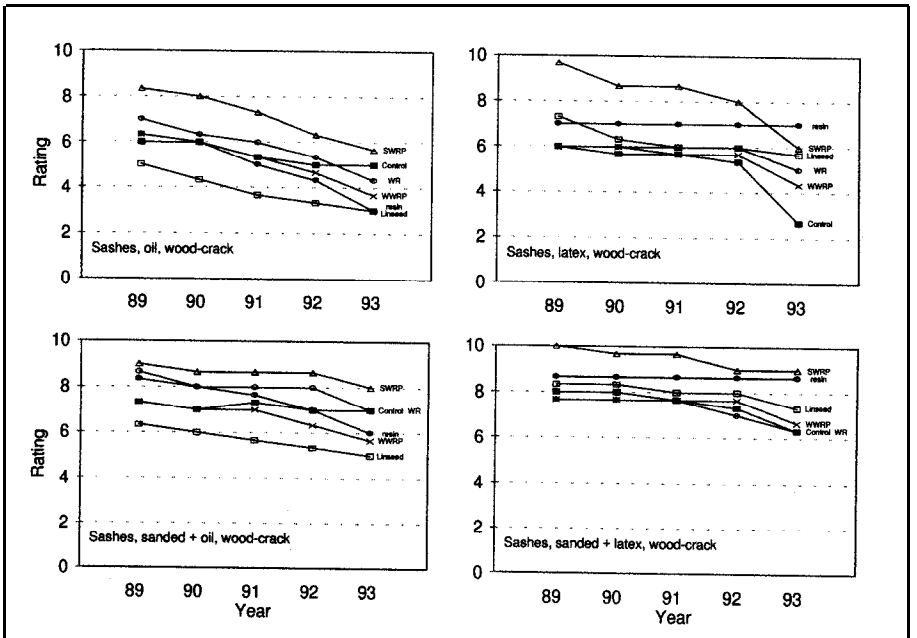

Figure 11—Mean ratings for cracking of window sash wood after five years of outdoor exposure. Oil designates oil-alkyd primer and topcoat: latex, acrylic latex primer and topcoat.

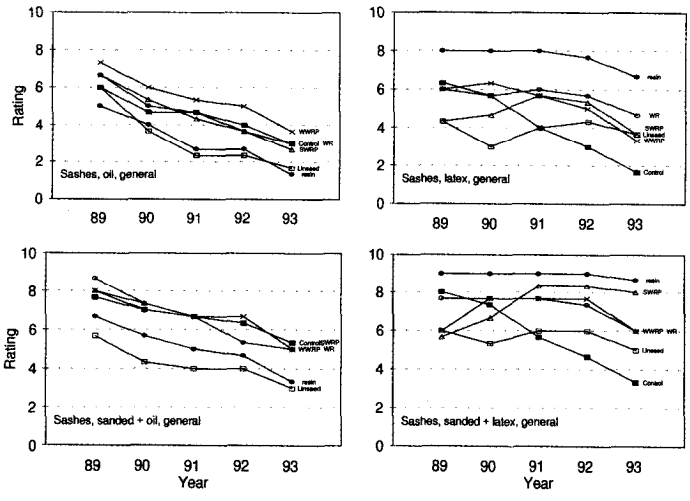

Figure 12—Mean ratings for general appearance of window sashes after five years of outdoor exposure. Oil designates oil-alkyd primer and topcoat; latex, acrylic latex primer and topcoat.

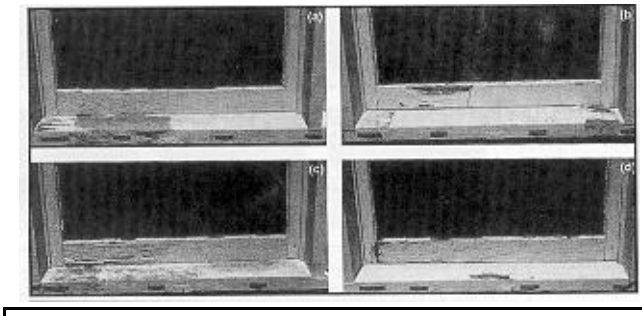

Figure 13—Effect of pretreatment and sanding on service life of window units: (a) waterborne WRP, oil topcoat, (b) solventborne WRP, latex topcoat, (c) resin, oil topcoat, (d) control. Right half of each window sash was sanded.

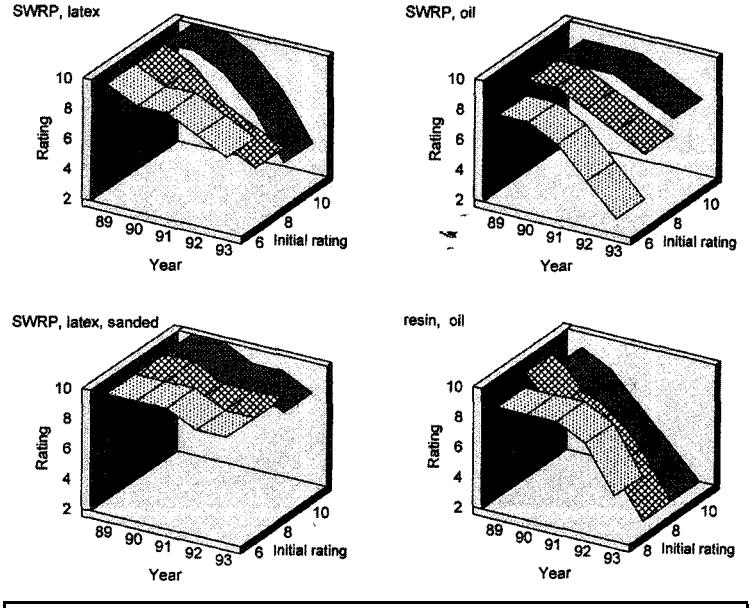

Figure 14—Flaking of paint on treated window sashes over five-year exposure period compared with original evaluation. Example is for solventborne WRP pretreatment.

year) exposure period. Recall that the window units selected for this study had originally been exposed to 28 years of weathering. Although all these units were sound and free of obvious decay, they were clearly not equal with respect to roughness and weathering from the original exposure. At the beginning of our study, all the units had a rating of at least 6, and most had a rating of 8 or 10. The plot of flaking ratings for window sashes over time compared with original ratings shows no effect beyond normal experimental variation (*Figure* 14).

CONCLUSIONS

In restoring severely weathered window units, sanding is beneficial in most cases. To obtain the best performance from the paint system used to restore window sills and sashes, it is advisable to completely remove the weathered surface by sanding. Hand sanding was not very effective for the badly weathered window sills used in this study. For window sashes, heavy mechanical sanding improved the performance of all pretreatments. Pretreatment with a water repellent preservative, linseed oil, or tung oil helped stabilize the wood surface and prevented flaking, particularly on sanded sills and unsanded sashes. However, pretreatment with linseed or tung oil caused an overall decrease in general appearance ratings because of the growth of mildew. The pretreatment that contained copper naphthenate greatly improved paint performance by stabilizing the wood surface and decreasing mildew growth. In most cases, the consolidants did not improve the performance of window units finished with the oil-alkyd based system. For those consolidants used in this study, the best performance was obtained from modified acrylic resin consolidant in combination with the acrylic-latex finish. Thus, care should be taken to match the consolidant to the type of paint system used. Incompatibility of the consolidant with the wood and paint can cause premature paint failure.

References

(1) Williams, R.S., Winandy, J.E., and Feist, W.C., "Paint Adhesion to Weathered Wood," JOURNAL OF COATINGS TECHNOLOGY, *59*, No. 749, 43 (1987).
(2) Williams, R.S., Plantinga, P.L., and Feist, W.C., "Photodegradation of Wood Affects Paint Adhesion," *Forest Prod. J.*, 40, No. 1, 45-49 (1990).
(3) Arnold, A., Feist, W.C., and Williams, R.S., "Effect of Weathering of New Wood on the Subsequent Performance of Semitransparent Stains," *Forest Prod. J.*, 42, No. 3, 10-14 (1992).
(4) Williams, R.S. and Feist, W.C., "Effect of Preweathering, Surface Roughness, and Wood

Species on the Performance of Paint and Stains," JOURNAL OF COATINGS TECHNOLOGY, *66*, No. 828, 109 (1994).
(5) Evans, P.D., Thay, P.D., and Schmalzl, K.J., "Degradation of Wood Surfaces During Natural Weathering. Effects on Lignin and Cellulose and on the Adhesion of Acrylic Primers," *Wood Science Technol.*, 30, No. 6, 411–422 (1996).
(6) Underhaug, Å., Lund, T.J., and Kleive, K., "Wood Protection—The Interaction Between Substrate and the Influence on Durability," *J. Oil & Colour Chemists' Assoc.*, 66, No. 11, 345 (1983).
(7) Miller, E.R., "Chemical Aspects of External Coatings for Softwoods," *Proc. Symposium on Chemical Aspects of Wood Technology*, Swedish Forest Products Research Laboratory, Södergam, Stockholm, Sweden (1981).
(8) Bravery, A.F. and Miller, E.R., "The Role of Pre-treatments in the Finishing of Exterior Softwood," *Proc. Annual Convention of British Wood Preservative Association*, 14–23 (1980).
(9) Boxall, J., "Painting Weathered Timber," Information Sheet 20/77, Building Research Establishment, Princess Risborough Laboratory, Alyesbury, Bucks, England, 1977.
(10) Shurr, G.G., "Coating Adhesion to Weathered Wood," *Am. Paint. Contractor*, 12, 18 (1969).
(11) Desai, R.L., "Coating Adhesion to Weathered Wood," Eastern Forest Products Laboratory, Ottawa, Canada, *Bi-monthly Research Notes*, 23, No. 5, 36–37 (1967).
(12) Kleive, K., "Weathered Wooden Surfaces—Their Influence on the Durability of Coating Systems," JOURNAL OF COATINGS TECHNOLOGY, 58, No. 740, 39 (1986).
(13) Williams, R.S. and Sotos, P., "Restoration of Severely Weathered Window Units," *Forest Prod. J.*, in press.
(14) Richter, K., Feist, W.C., and Knaebe, M.T., "The Effect of Surface Roughness on the Performance of Finishes. Part 1. Roughness Characterization and Stain Performance," *Forest Prod. J.*, 45, No. 7/8, 91–97 (1995).
(15) Miniutti, V.P., Mraz, E.A., and Black, J.M., "Measuring the Effectiveness of Water-Repellent Preservatives," *Forest Prod. J.*, 8, No. 10, 61A–65A (1961).
(16) Williams, R.S., Sotos, P., and Feist, W.C., "Evaluation of Several Paint Systems on Severely Weathered Wood," JOURNAL OF COATINGS TECHNOLOGY, in press.
(17) "Test Method D 662 for Evaluating Degree of Erosion of Exterior Paints," *Annual Book of ASTM Standards*, Vol. 06.01, American Society for Testing and Materials, Philadelphia, PA, 1991.
(18) "Test Method D 661 for Evaluating Degree of Cracking of Exterior Paints," *Annual Book of ASTM Standards*, Vol. 06.01, American Society for Testing and Materials, Philadelphia, PA, 1991.
(19) "Test Method D 772 for Evaluating Degree of Flaking (Scaling) of Exterior Paints," *Annual Book of ASTM Standards*, Vol. 06.01, American Society for Testing and Materials, Philadelphia, PA, 1991.
(20) "Test Method D 3274 for Evaluating Degree of Surface Disfigurement of Paint Films by Microbial (Fungal or Algal) Growth or Soil and Dirt Accumulation," *Annual Book of ASTM Standards*, Vol. 06.01, American Society for Testing and Materials, Philadelphia, PA, 1991.