Effect of Preweathering, Surface Roughness, and Wood Species On the Performance of Paint and Stains

R. Sam Williams and William C. Feist
USDA Forest Service*

To quantify the effect of preweathering of new wood surfaces on subsequent finish performance, unfinished wood siding was exposed outdoors for four or eight weeks. Following this preweathering, the specimens were finished with a variety of finishes and placed outdoors again for several years (weathered). The finished specimens were evaluated annually to determine the effect of preweathering on finish performance.

The durabilities of 30 different finish systems, consisting of six finishes and five substrates, were evaluated over a five-year period. The wood species were primarily hardwoods and dense softwoods. For these dense species, which weather slowly, a few weeks of preweathering decreased paint performance. The effect of preweathering varied depending on the length of time the siding was preweathered, wood species, surface roughness, and finish. The results of the weathering were compared with the results of adhesion testing of similar panels preweathered before finishing.

INTRODUCTION

Outdoor weathering of unprotected wood can cause severe surface degradation.[1-3] Wood siding is often exposed to many weeks of weathering before being coated with paints or other finishes. This weathering before finishing (preweathering) can lead to chemical and physical changes on the wood surface that weaken the future paint-wood interface. This interface is crucial for adhesion of film-forming finishes; wood preweathered for several months before being painted showed decreased adhesion and shortened paint service life.[4-10]

Traditional siding materials consist primarily of vertical-grained western redcedar, redwood, and similar dimensionally stable and decay-resistant species. Over the past several decades, other species and composite materials such as plywood and fiberboard have been used to make siding. We anticipate increased use of these materials as well as new composites and other species, particularly hardwoods. The weathering characteristics of these substrates as they relate to finish performance has not been well studied.

The effect of preweathering of several wood species has been reported. Desai[10] studied the effect of preweathering of ponderosa pine, red pine, white pine, eastern white-cedar, western larch, eastern hemlock, western hemlock, spruce, and western white pine. He reported that the adhesive strength of a two-part urethane coating decreased on most specimens exposed up to 400 hours in a carbon-arc weatherometer. He reported no effect for eastern hemlock and western white pine. Boxall[4] studied primer paint adhesion to sapwood of Baltic redwood–also called Scotch pine *(Pinus sylvestris)*–

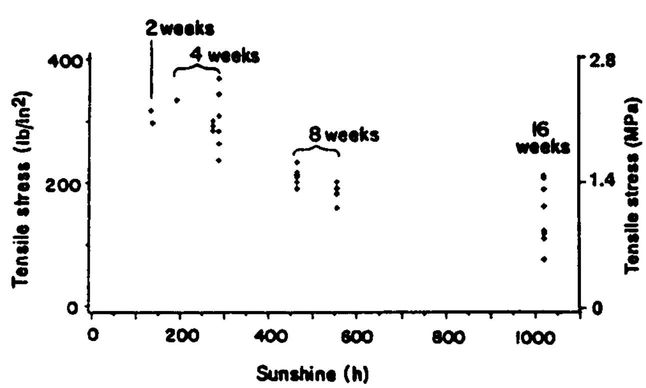


Figure 1—Ultimate tensile stress (lb/in^2) (MPa) plotted against sunlight exposure time of acrylic latex primer on western redcedar. Only primer/wood interface failures are shown (Duplicated from reference 11)

*Forest Products Laboratory, One Gifford Pinchot Dr., Madison, WI 53705-2398.

Table 1—Characteristics of Finishes

Finish	Color	Nonvolatile Content (%)	Weight (kg/L (lb/gal))
Semitransparent stain[a]	Brown	76.3	0.95 (7.91)
Acrylic latex primer	White	52.0	1.17 (9.76)
Acrylic latex topcoat-A[b]	White	53.0	1.31 (10.93)
Alkyd primer	White	78.0	1.37 (11.40)
Acrylic latex topcoat-B[b]	White	64.0	1.44 (12.02)
Alkyd topcoat	White	70.3	1.12 (9.32)
Solid-color oil-based stain	Tan	61.1	1.18 (9.81)
Solid-color latex stain	Tan	32.7	1.17 (9.72)

(a) Laboratory prepared: all others are commercial finishes.
(b) A and B designate different commercial topcoats.

weathered outdoors for seven months prior to finishing. Bravery and Miller[5] also used Baltic redwood to assess the effect of preweathering on paint adhesion. Underhaug et al.[3] and Kleive[6] used spruce *(Picea abies)* in similar studies.

Prior to our investigations,[11-14] nothing had been published describing the consequences of short-term preweathering (days to weeks) before painting, and previous investigators had not linked film bond strength to durability of the paint. Our studies showed that short-term preweathering of wood caused up to a 50% drop in the bond strength of film-forming finishes. The severity of the effects of four to eight weeks preweathering on paint adhesion depended on the type of paint and wood species. Paint adhesion tests of acrylic latex or solvent-borne oil alkyd paint demonstrated decreased paint bond strength for low-density wood species. such as western redcedar. With higher density wood species, only acrylic latex primer paint showed lower bond strength after the same amount of preweathering. Although paint failures normally occurred preferentially on the latewood of unpreweathered wood, preweathered substrates showed more frequent adhesive failure for the earlywood. This change in failure mode was attributed to the more rapid degradation of the earlywood during preweathering.

Short-term preweathering of both smooth-planed western redcedar siding and roughsawn Douglas-fir plywood degraded the wood surface such that it accepted more semitransparent oil-based stain.[13] Increased stain absorption usually gives greater service life. However, the increased stain absorption by the preweathered wood did not give longer service life; it compensated the surface degradation to give the same overall service life, but at an increased cost. Preweathering also decreased the service life of paint on these substrates.[14]

Earlier studies focused primarily on the relationship between preweathering and paint bond strength. The paint bond strength was determined on freshly painted and cured panels before outdoor exposure of the painted panels. These studies included bond strength of acrylic latex and alkyd primers on western redcedar,[11] southern pine, Douglas-fir, yellow-poplar, Engelmann spruce, and western redcedar.[12]

Table 2—Spreading Rates and Evaluation of Semitransparent Stain[a]

Pre-weathering Time (weeks)	Spreading Rate[b] (m²/L (ft²/gal))	Rating after Weathering Period[c]														
		1 Year			2 Years			3 Years			4 Years			5 Years		
		F	E	C	F	E	C	F	E	C	F	E	C	F	E	C
						Engelmann spruce (smooth-planed)										
0	10.6 (430)	—	7.3	—	—	5.0	—	—	4.3	—	—	4.0	—	—	3.0	—
4	9.0 (365)	—	7.0	—	—	4.3	—	—	4.0	—	—	3.3	—	—	2.0	—
8	12.0 (490)	—	7.3	—	—	5.3	—	—	4.7	—	—	4.0	—	—	4.0	—
						Yellow-poplar (smooth-planed)										
0	10.7 (435)	—	7.0	—	—	5.0	—	—	4.0	—	—	3.0	—	—	2.0	—
4	8.0 (325)	—	7.0	—	—	5.0	—	—	4.0	—	—	3.0	—	—	1.7	—
8	7.7 (315)	—	7.0	—	—	5.0	—	—	4.0	—	—	4.0	—	—	2.7	—
						Southern pine (scratch-sanded plywood)										
0	5.6 (230)	—	6.0	—	—	5.0	—	—	4.0	—	—	3.0	—	—	2.0	—
4	4.0 (165)	—	7.0	—	—	6.0	—	—	4.0	—	—	3.0	—	—	2.0	—
8	3.9 (160)	—	7.0	—	—	5.0	—	—	4.0	—	—	3.0	—	—	3.0	—
						Southern pine (roughsawn plywood)										
0	3.1 (125)	—	7.0	—	—	7.0	—	—	6.0	—	—	5.0	—	—	4.0	—
4	2.6 (105)	—	8.0	—	—	8.0	—	—	6.0	—	—	5.0	—	—	4.0	—
8	2.6 (105)	—	7.5	—	—	8.0	—	—	5.5	—	—	5.5	—	—	4.5	—
						Sweetgum (roughsawn plywood)										
0	2.7 (110)	—	8.5	—	—	7.5	—	—	6.5	—	—	6.0	—	—	4.0	—
4	2.4 (100)	—	7.0	—	—	7.0	—	—	6.5	—	—	5.5	—	—	4.5	—
8	2.2 (90)	—	7.0	—	—	6.0	—	—	6.0	—	—	5.5	—	—	5.5	—

(a) Finish was laboratory prepared.
(b) Mean spreading rate for panel.
(c) Entries are means of three ratings for smooth-planed boards and means of two ratings for plywood based on a scale of 10 (perfect condition) to 1 (total failure). F, flaking; E, erosion; C, cracking.

Table 3—Spreading Rates and Evaluation of Acrylic Latex Primer and Topcoat[a]

Preweathering Time (weeks)	Spreading Rate[b] (m²/L (ft²/gal)) P	TC	Rating after Weathering Period[c] 1 Year F	E	C	2 Years F	E	C	3 Years F	E	C	4 Years F	E	C	5 Years F	E	C
Engelmann spruce (smooth-planed)																	
0	8.0 (325)	14.0 (570)	10	10	10	10	10	10	10	10	9.7	10	10	9.7	10	10	9.7
4	7.4 (300)	14.0 (570)	10	10	10	10	10	10	10	10	10	10	10	10	9.7	10	9.0
8	7.6 (310)	14.2 (580)	10	10	10	10	10	9.7	10	10	9.3	9.3	10	9.3	9.3	10	9.3
Yellow-poplar (smooth-planed)																	
0	7.8 (320)	13.5 (550)	10	10	10	10	10	10	10	10	9.7	10	10	9.7	10	10	9.0
4	7.6 (310)	12.8 (520)	10	10	10	10	10	9.7	10	10	9.7	10	10	9.7	9.3	10	9.0
8	6.3 (255)	13.7 (560)	10	10	9.7	10	10	9.7	10	10	9.7	10	10	9.7	9.0	10	8.5
Southern pine (scratch-sanded plywood)																	
0	5.0 (205)	10.6 (430)	10	10	10	10	10	10	9.0	10	10	9.0	10	9.0	9.0	10	8.5
4	5.0 (205)	10.2 (415)	10	10	9.0	9.0	10	9.0	9.0	10	9.0	9.0	10	9.0	8.5	10	8.5
8	5.3 (215)	10.3 (420)	10	10	10	9.0	10	9.0	9.0	10	9.0	9.0	10	9.0	8.5	10	8.5
Southern pine (roughsawn plywood)																	
0	3.4 (140)	6.6 (270)	10	10	10	9.5	10	9.5	9.5	10	9.5	9.5	10	9.5	9.0	10	8.5
4	3.4 (140)	7.6 (310)	10	10	10	10	10	9.0	10	10	9.0	10	10	9.0	9.5	10	9.0
8	3.3 (135)	7.9 (320)	10	10	10	9.5	10	9.0	9.0	10	9.0	9.0	10	8.5	9.0	10	9.0
Sweetgum (roughsawn plywood)																	
0	3.8 (155)	8.3 (340)	10	10	10	10	10	10	9.5	10	9.5	9.5	10	9.5	9.5	10	8.0
4	3.7 (150)	7.6 (310)	10	10	10	10	10	9.0	9.0	10	9.0	9.0	10	9.0	9.0	10	8.0
8	3.7 (150)	7.4 (300)	10	10	10	9.5	10	9.5	9.5	10	9.5	9.0	10	9.0	9.0	10	9.0

(a) Finish was obtained from commercial sources.
(b) Mean spreading rate for panel. P, primer; TC, topcoat.
(c) Entries are means of three ratings for smooth-planed boards and means of two ratings for plywood based on a scale of 10 (perfect condition) to 1 (total failure). F, flaking; E, erosion; C, cracking.

The tensile paint bond strength to western redcedar decreased from 2,125 to 1,040 kPa for the acrylic latex primer and 1,765 to 870 kPa for the alkyd primer listed in *Table* 1.[11] The paint bond strengths shown in *Figure* 1 are typical of the results obtained with alkyds and acrylic latex on western redcedar.[11] These were the same primers used in the outdoor exposure studies reported here.

In this research, we expanded the number of species and finishes to reflect the current changes in the type of siding used in residential construction in the United States. We compared the paint bond strengths previously reported for several other species with the paint service life on these species. Species included in this report are primarily dense softwoods, such as southern pine; and hardwoods, such as yellow-poplar and sweetgum. The effect of preweathering of dense wood species on subsequent finish performance has not previously been reported. Also, we compared the performances of roughsawn and smooth southern pine plywood.

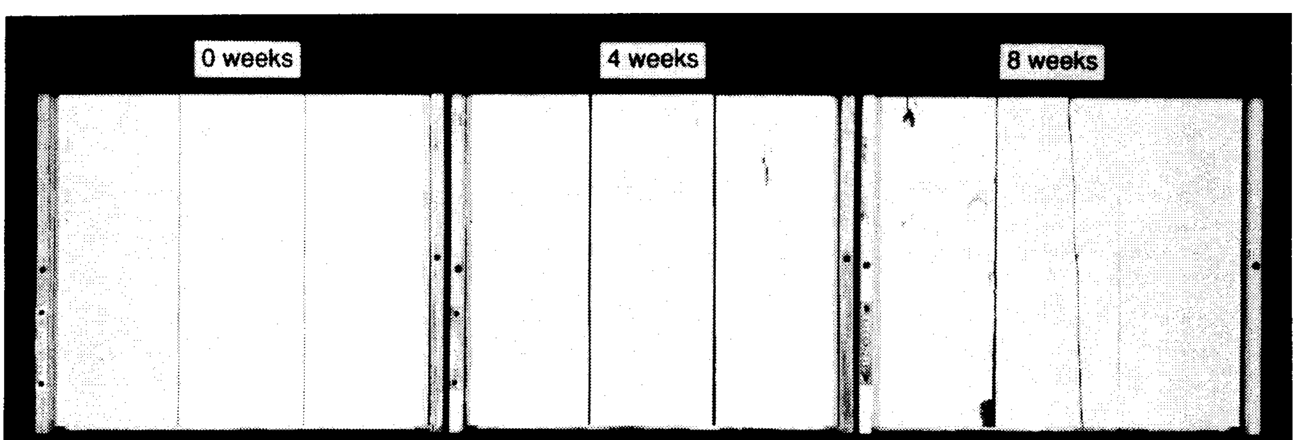


Figure 2—Engelmann spruce panels after five years of outdoor exposure. Panels were preweathered for 0, 4, or 8 weeks and then finished with acrylic latex primer and topcoat (M91-0235)

Table 4—Spreading Rates and Evaluation of Alkyd Primer and Acrylic Latex Topcoat[a]

Preweathering Time (weeks)	Spreading Rate[b] (m²/L (ft²/gal))		Rating after Weathering Period[c]														
			1 Year			2 Years			3 Years			4 Years			5 Years		
	P	TC	F	E	C	F	E	C	F	E	C	F	E	C	F	E	C
Engelmann spruce (smooth-planed)																	
0	6.4 (260)	9.7 (395)	10	10	10	10	10	10	10	10	9.3	10	10	9.3	9.7	10	9.0
4	5.5 (225)	8.7 (355)	10	10	10	10	10	8.0	10	10	8.0	10	10	8.0	8.7	10	6.7
8	6.5 (265)	9.6 (390)	10	10	10	10	10	10	10	10	9.3	10	10	9.3	9.7	10	8.7
Yellow-poplar (smooth-planed)																	
0	6.0 (245)	8.3 (340)	10	10	10	10	10	10	10	10	9.3	10	10	9.3	10	10	9.3
4	5.9 (240)	9.2 (375)	10	10	8.0	10	10	8.3	10	10	8.3	9.3	10	7.6	9.0	10	6.7
8	6.1 (250)	7.4 (300)	10	10	8.0	10	10	7.0	10	10	7.0	9.0	10	6.0	8.7	10	4.7
Southern pine (scratch-sanded plywood)																	
C	4.8 (195)	7.7 (315)	10	10	9.0	10	10	7.0	9.5	10	6.0	9.5	10	5.0	9.5	10	4.0
4	3.8 (155)	7.6 (310)	10	10	9.0	10	10	6.0	10	10	4.0	10	10	3.0	10	10	3.0
8	4.2 (170)	7.7 (315)	10	10	8.0	10	10	4.0	10	10	3.0	9.0	10	2.0	9.0	10	2.0
Southern pine (roughsawn plywood)																	
0	3.4 (140)	5.6 (230)	10	10	10	9.5	10	5.5	9.0	10	4.0	9.0	10	3.4	9.0	10	2.5
4	3.4 (140)	5.9 (240)	10	10	10	9.0	10	8.0	9.0	10	6.0	9.0	10	4.0	9.0	10	4.0
8	3.2 (130)	5.9 (240)	10	10	9.0	10	10	6.0	10	10	5.0	10	10	4.0	9.0	10	3.0
Sweetgum (roughsawn plywood)																	
0	3.7 (150)	6.3 (255)	10	10	10	10	10	8.0	10	10	6.0	10	10	6.0	10	10	3.0
4	3.4 (140)	6.1 (250)	10	10	9.0	10	10	9.0	10	10	4.0	10	10	4.0	9.5	10	2.0
8	3.3 (135)	6.5 (265)	10	10	10	10	10	7.0	10	10	5.0	10	10	4.0	10	10	2.0

(a) Finish was obtained from commercial sources.
(b) Mean spreading rate for panel. P, primer; TC, topcoat.
(c) Entries are means of three ratings for smooth-planed boards and means of two ratings for plywood based on a scale of 10 (perfect condition) to 1 (total failure). F, flaking; E, erosion; C, cracking.

Table 5—Spreading Rates and Annual Evaluations of Alkyd Primer and Topcoat[a]

Preweathering Time (weeks)	Spreading Rate[b] (m²/L (ft²/gal))		Rating after Weathering Period[c]														
			1 Year			2 Years			3 Years			4 Years			5 Years		
	P	TC	F	E	C	F	E	C	F	E	C	F	E	C	F	E	C
Engelmann spruce (smooth-planed)																	
0	5.3 (215)	10.0 (410)	10	10	10	10	10	10	10	10	10	10	10	9.7	9.3	10	9.3
4	5.6 (230)	8.9 (365)	10	10	9.7	10	10	9.7	10	10	9.3	9.3	10	9.0	8.0	10	7.3
8	5.3 (215)	8.5 (345)	10	10	10	10	10	10	9.7	10	9.3	9.3	10	9.0	8.7	10	8.3
Yellow-poplar (smooth-planed)																	
0	5.6 (230)	9.6 (390)	10	10	9.0	10	10	9.3	10	10	9.3	10	10	9.3	10	10	9.7
4	4.8 (195)	8.8 (360)	10	10	10	10	10	9.3	10	10	8.7	10	10	8.0	9.0	10	6.7
8	5.0 (205)	8.2 (335)	10	10	9.3	10	10	8.7	9.0	10	8.7	8.3	10	8.3	7.7	10	8.0
Southern pine (scratch-sanded plywood)																	
0	3.8 (155)	6.9 (280)	10	10	10	9.0	10	6.0	9.0	10	5.0	9.0	10	4.0	8.5	10	3.0
4	3.9 (160)	6.4 (260)	10	10	6.0	9.0	10	4.0	9.0	10	4.0	7.0	10	3.5	5.5	10	2.0
8	3.8 (155)	7.2 (295)	10	10	9.0	9.0	10	6.0	9.0	10	5.0	7.0	10	3.5	5.5	10	2.5
Southern pine (roughsawn plywood)																	
0	2.8 (115)	7.4 (300)	10	10	10	9.0	10	8.0	9.0	10	6.0	9.0	10	4.5	9.0	10	3.0
4	2.8 (115)	6.7 (275)	10	10	10	8.5	10	6.5	9.0	10	4.5	9.0	10	4.0	9.0	10	3.0
8	2.9 (120)	6.6 (270)	10	10	8.0	10	10	8.0	10	10	5.0	9.0	10	4.0	9.0	10	2.0
Sweetgum (roughsawn plywood)																	
0	3.3 (135)	6.3 (255)	10	10	10	9.0	10	7.0	9.0	10	5.0	9.0	10	3.0	9.0	10	2.0
4	3.4 (140)	6.7 (275)	10	10	10	8.0	10	4.0	8.0	10	3.0	8.0	10	2.0	8.0	10	1.0
8	3.4 (140)	6.4 (260)	10	10	9.0	8.0	10	6.0	8.0	10	2.0	8.0	10	2.0	8.0	10	2.0

(a) Finish was obtained from commercial sources.
(b) Mean spreading rate for panel. P, primer; TC, topcoat.
(c) Entries are means of three ratings for smooth-planed boards and means of two ratings for plywood based on a scale of 10 (perfect condition) to 1 (total failure). F, flaking; E, erosion; C, cracking.

Table 6—Spreading Rates and Evaluation of Solid-Color Latex Stain[a]

Preweathering Time (weeks)	Spreading Rate[b] (m^2/L (ft^2/gal))	Rating after Weathering Period[c]														
		1 Year			2 Years			3 Years			4 Years			5 Years		
		F	E	C	F	E	C	F	E	C	F	E	C	F	E	C
Engelmann spruce (smooth-planed)																
0	11.2 (455)	10	9.0	7.0	9.0	10	7.7	9.0	10	6.0	9.0	9.0	5.0	8.3	9.0	3.0
4	8.6 (350)	10	9.0	4.0	10	10	2.0	10	8.3	2.0	7.0	7.3	1.3	4.0	7.3	1.3
8	8.6 (350)	10	8.0	4.0	9.0	10	2.0	8.0	9.0	2.0	6.7	8.7	2.0	5.3	7.7	2.0
Yellow-poplar (smooth-planed)																
0	8.8 (360)	10	9.0	6.0	9.0	10	4.7	8.0	8.0	2.3	7.7	8.0	2.0	5.3	6.3	2.0
4	9.0 (365)	10	10	2.0	7.7	10	2.0	6.7	8.0	2.0	5.0	6.7	1.0	2.0	2.0	1.0
8	8.5 (345)	10	8.0	2.0	7.3	10	2.0	7.3	9.0	2.0	4.3	8.0	1.0	1.3	1.3	1.0
Southern pine (scratch-sanded plywood)																
0	5.0 (205)	10	10	4.0	9.0	10	2.0	9.0	10	2.0	9.0	10	2.0	7.5	10	2.0
4	4.5 (185)	10	10	4.0	9.0	10	3.0	8.5	10	3.0	6.5	10	3.0	5.5	10	3.0
8	5.0 (205)	10	10	4.0	9.0	10	2.0	9.0	10	2.0	7.0	10	2.0	6.0	10	2.0
Southern pine (roughsawn plywood)																
0	3.1 (125)	10	10	6.0	9.0	10	5.0	9.0	10	5.0	9.0	10	4.5	9.0	10	3.5
4	2.8 (115)	10	10	3.0	9.0	10	2.0	9.0	10	2.0	8.0	10	2.0	6.0	10	2.0
8	2.8 (115)	10	10	4.0	9.0	10	2.0	8.5	10	2.0	8.0	10	2.0	7.0	10	2.0
Sweetgum (roughsawn plywood)																
0	3.1 (125)	10	10	8.0	10	10	4.0	10	10	4.0	10	10	4.0	10	10	3.5
4	3.1 (125)	10	10	4.0	9.0	10	4.0	9.0	10	4.0	8.0	10	2.0	7.0	10	2.0
8	3.2 (130)	10	10	2.0	9.0	10	4.0	8.0	10	4.0	7.5	10	2.0	6.5	10	2.0

(a) Finish was obtained from commercial sources.
(b) Mean spreading rate for panel.
(c) Entries are means of three ratings for smooth-planed boards and means of two ratings for plywood based on a scale of 10 (perfect condition) to 1 (total failure). F, flaking; E, erosion; C, cracking.

MATERIALS AND METHODS

Wood was obtained from commercial sources. The species were Engelmann spruce *(Picea engelmannii),* yellow-popiar *(Liriodendron tulipifera),* southern pine *(Pinus* sp.), and sweetgum *(Liquidambar styraciflua).* The Engelmann spruce and yellow-poplar were smooth-planed lumber and the sweetgum was roughsawn plywood. The southern pine included both roughsawn and scratch-sanded plywood. The scratch-sanded surface was produced by sanding with coarse sandpaper. The resulting surface was rougher than the planed boards, but will be referred to as smooth to differentiate it from the roughsawn southern pine.

The uncoated boards or plywood strips were preweathered outdoors (July through September, 1986), oriented vertically facing south near Madison, WI, for four or eight weeks. Four control panels of each substrate were stored in a dark room at 65% relative humidity and 27°C instead of being preweathered. The preweathered and control panels were then lightly cleaned using a soft brush wetted with distilled water, air dried, and painted. Test panels 406 mm (16 in.) wide by 343 mm (13.5 in.) long were assembled using three individual lumber specimens or two individual plywood specimens per panel for each preweathering period *(Figures* 2-5).

Eight finishes *(Table* 1) were used to give six different finish systems *(Tables* 2-13). The finish applied per panel was weighed, and the resulting spreading rates calculated *(Tables* 2-7). One coat of primer and one topcoat of paint, or one coat of stain, was applied to the panel by brush. After drying for one week under ambient laboratory conditions, the finished panels were reinstalled vertically facing south near Madison, in a random arrangement.

Panels were evaluated annually using American Society for Testing and Materials (ASTM) standard methods and were rated for flaking (ASTM D 772-86),[15] erosion (ASTM D 662-86),[16] and cracking (ASTM D 661-86).[17] These degradation modes were expressed on a scale of ratings from 10 to 1 (10–perfect condition; 1–total failure).[18] Finish service life is defined as the time it takes to reach a rating of 5 and indicates when panels need to be refinished.

RESULTS AND DISCUSSION

Of 30 finish-substrate combinations *(Tables* 2-13), the greatest differences in durability were observed among the different finish types with the substrate types having a secondary effect. The effects of preweathering are superimposed on these differences. The finish-substrate combinations are arranged by finish and by substrate. Each finish is discussed separately in terms of the coverage, or spreading rate, on the substrate and the trends in degradation. The finishes were evaluated for flaking (F), erosion (E), and cracking (C) *(Tables* 2-7), and the substrates were evaluated for checking (Ch) and cracking (C) *(Tables* 8-13). In some cases, the performance of the substrate affected finish performance and was the critical factor in the mode of finish failure.

Paint and stain spreading rates—the coverage of the substrate in square meters per liter (square feet per gallon)—

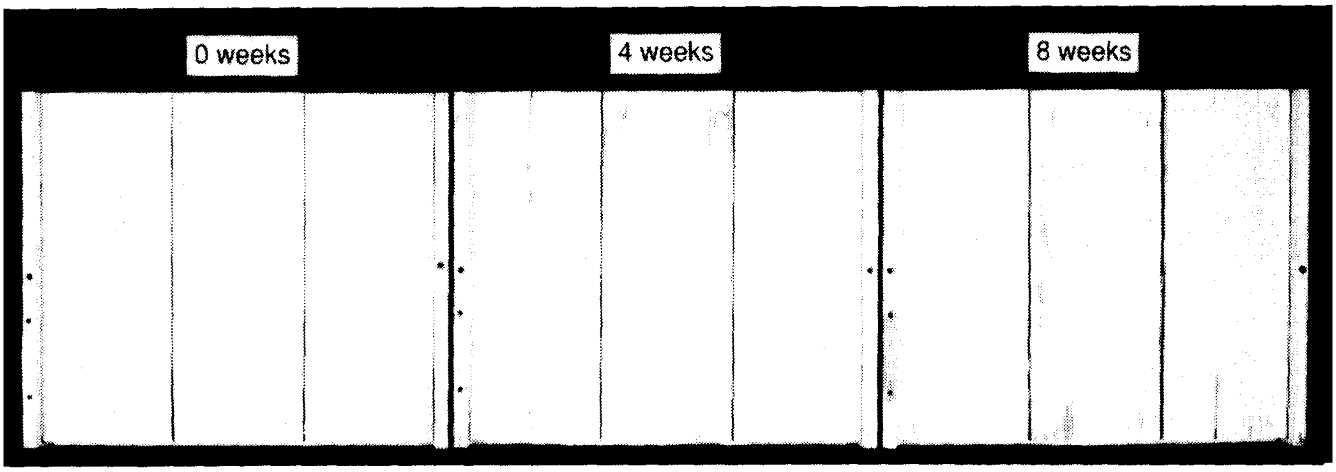
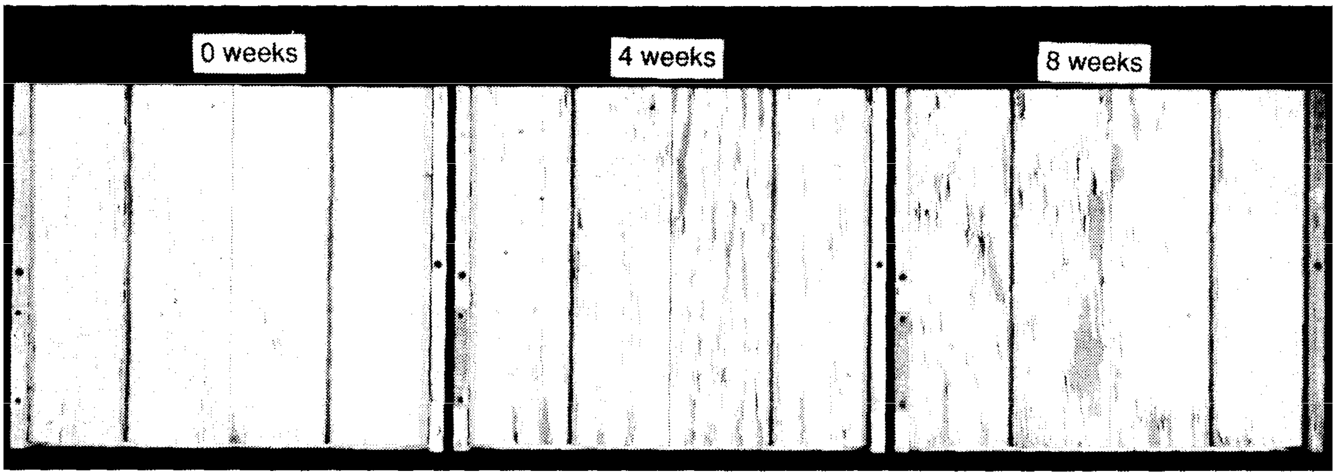


Figure 3—Yellow-poplar panels after five years of *outdoor* exposure. Panels were preweathered for 0, 4, or 8 weeks and then finished with alkyd primer and acrylic latex topcoat (M91-0233)



igure 4—Smooth *southern* pine plywood panels after five years of outdoor exposure. Panels were preweathered for 0, 4, or 8 weeks and then finished with alkyd primer and topcoat (M91-0236)

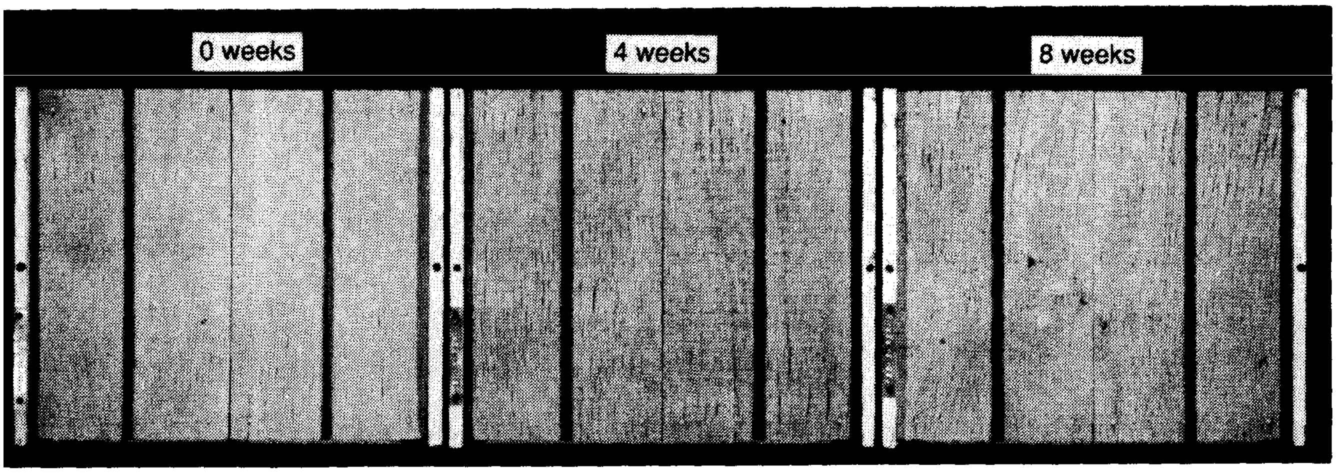


Figure 5—Roughsawn sweetgum plywood panels after five years of outdoor exposure. Panels were preweathered for 0, 4, or 8 weeks and then finished with solid-color oil-based stain (M91-0238)

decreased as the absorption or thickness of the finish, or both, increased *(Tables* 2-7). The roughsawn southern pine and sweetgum plywood accepted more finish (i.e., had a lower spreading rate) than did the smooth southern pine plywood or Engelmann spruce and yellow-poplar boards. These results are similar to those reported earlier.[6,18-20] These sources also reported higher absorption of penetrating finishes (water-repellent preservatives and semitransparent stains) on wood preweathered for several years. The change in spreading rate of penetrating stains following short periods of preweathering (weeks) was previously reported only for smooth western redcedar and roughsawn Douglas-fir.[13]

The spreading rate and finish performance changes in the five finishes, caused by preweathering, are discussed separately in the following subsections. The spreading rates and finish ratings are tabulated by substrate in *Tables* 2-7. The substrate ratings are tabulated in *Tables* 8-13.

Semitransparent Stains

The ratings of semitransparent stain *(Table* 2) on the five substrates were similar to those reported earlier for western redcedar and Douglas-fir. For all substrates, except Engelmann spruce, the spreading rate decreased with increased preweathering (i.e., more finish was absorbed with increased preweathering). For smooth yellow-poplar and smooth southern pine plywood the spreading rate decreased, after eight weeks preweathering, from 10.7 to 7.7 m^2/l (435 to 315 ft^2/gal) and 5.6 to 3.9 m^2/l (230 to 160 ft^2/gal), respectively. The percentage decrease of 3.1 to 2.6 m^2/l (125 to 105 ft^2/gal) and 2.7 to 2.2 m^2/l (110 to 90 ft^2/gal) for the roughsawn southern pine and sweetgum plywoods was about half that for the smooth wood. The change attributed to preweathering was probably obscured by the higher finish absorption rate by the rough wood. The spreading rate for Engelmann spruce did not fit the trends observed with the other species and cannot be explained at this time.

The substrates were evaluated for checking and cracking *(Table* 8). The checking ratings showed a preweathering effect at the one-year evaluation for all the plywood panels. The differences attributed to preweathering disappeared as the panels weathered. Preweathering did not appear to affect the Engelmann spruce or the yellow-poplar. The smooth-planed boards had only minor checking, but the cracking was much more severe, even at one year. The rapid cracking of the substrates may have obscured the effect of preweathenng.

The semitransparent stain was evaluated only for erosion and was fairly similar for smooth Engelmann spruce, yellow-poplar, and southern pine. All three had ratings less than five by the third year of exposure. The roughsawn plywood ratings fell to less than five after five years. These results are typical of the difference in durability of semitransparent stains on smooth and rough surfaces. They reflect the increased durability commensurate with higher stain absorption on rough surfaces.

The effects of preweathering corresponded with data reported earlier for western redcedar and Douglas-fir.[13]

Table 7—Spreading Rates and Evaluation of Solid-Color Oil-Based Stain[a]

Preweathering Time (weeks)	Spreading Rate[b] (m^2/L (ft^2/gal))	Rating after Weathering Period[c] 1 Year F	E	C	2 Years F	E	C	3 Years F	E	C	4 Years F	E	C	5 Years F	E	C
Engelmann spruce (smooth-planed)																
0	11.7 (475)	10	10	10	9.0	10	8.7	9.0	10	8.3	9.0	10	7.0	9.0	10	5.7
4	9.8 (400)	10	10	5.0	9.0	10	4.0	9.0	10	3.0	7.7	10	2.7	6.0	10	2.3
8	9.8 (400)	10	9.0	4.0	8.0	10	4.0	8.7	10	3.0	6.3	9.0	2.0	5.3	8.0	2.0
Yellow-poplar (smooth-planed)																
0	10.8 (440)	10	10	8.0	9.7	10	6.0	9.0	9.0	4.0	8.0	9.0	4.0	6.0	8.0	2.0
4	8.5 (345)	10	8.0	4.0	7.3	10	2.0	7.3	10	2.0	5.3	10	2.0	4.0	7.0	2.0
8	10.1 (410)	9.0	8.0	2.0	7.3	10	2.0	6.7	0.9	2.0	5.0	7.0	1.7	2.3	3.0	1.7
Southern pine (scratch-sanded plywood)																
0	6.1 (250)	10	10	3.0	7.0	10	2.0	6.5	10	2.0	6.5	10	2.0	5.5	10	2.0
4	5.0 (205)	10	10	4.0	9.0	10	2.0	7.5	10	2.0	6.0	10	2.0	5.0	10	2.0
8	4.9 (200)	10	10	5.0	8.0	10	4.0	6.0	10	4.0	6.0	10	4.0	5.0	10	4.0
Southern pine (roughsawn plywood)																
0	3.7 (150)	10	10	10	10	10	10	9.0	10	4.0	9.0	10	4.0	8.5	10	3.0
4	3.2 (130)	10	10	10	9.0	10	2.0	7.5	10	2.0	7.0	10	2.0	6.0	10	2.0
8	3.1 (125)	10	10	2.0	9.0	10	2.0	8.5	10	2.0	7.5	10	2.0	6.5	10	2.0
Sweetgum (roughsawn plywood)																
0	3.2 (130)	10	10	6.0	10	10	4.0	10	10	4.0	10	10	4.0	10	10	3.5
4	3.4 (140)	10	10	4.0	10	10	4.0	8.5	10	2.0	7.0	10	2.0	5.5	10	2.0
8	3.3 (135)	10	10	4.0	9.0	10	4.0	7.0	10	2.0	7.0	10	2.0	6.0	8.0	2.0

(a) Finish was obtained from commercial sources.
(b) Mean spreading rate for panel.
(c) Entries are means of three ratings for smooth-planed boards and means of two ratings for plywood based on a scale of 10 (perfect condition) to 1 (total failure). F, flaking; E, erosion; C, cracking.

Table 8—Evaluation of Substrate Finished with Semitransparent Stain[a]

Preweathering Time (weeks)	Rating after Weathering Period[b]									
	1 Year		2 Years		3 Years		4 Years		5 Years	
	Ch	C	Ch	C	Ch	C	Ch	C	Ch	C
Engelmann spruce (smooth-planed)										
0	9.0	7.7	2.0	7.0	2.0	5.7	2.0	5.7	2.0	6.3
4	8.0	7.0	2.0	6.0	2.0	4.0	2.0	4.0	2.0	4.0
8	8.0	7.3	2.0	6.7	2.0	6.3	2.0	4.7	2.0	4.7
Yellow-poplar (smooth-planed)										
0	8.0	8.7	2.0	8.0	2.0	8.0	2.0	8.0	2.0	8.0
4	7.0	8.7	2.0	8.0	2.0	8.0	2.0	8.0	2.0	8.0
8	8.0	8.7	2.0	7.7	2.0	7.7	2.0	7.3	2.0	7.0
Southern pine (scratch-sanded plywood)										
0	8.0	10	4.0	10	4.0	6.0	3.0	6.0	2.0	6.0
4	6.0	10	4.0	10	4.0	4.0	3.0	4.0	2.0	4.0
8	6.0	10	6.0	10	4.0	6.0	4.0	6.0	2.0	6.0
Southern pine (roughsawn plywood)										
0	4.0	10	4.0	10	4.0	6.0	3.0	6.0	2.0	6.0
4	4.0	10	4.0	10	3.5	6.0	3.5	6.0	2.5	5.0
8	2.0	10	6.0	10	2.0	4.0	2.0	4.0	2.0	4.0
Sweetgum (roughsawn plywood)										
0	9.0	10	6.5	10	5.5	8.0	5.5	8.0	4.0	8.0
4	8.0	10	4.0	10	4.0	9.0	4.0	9.0	4.0	9.0
8	6.0	10	6.0	10	6.0	8.0	4.0	7.0	3.5	7.0

(a) Finish was laboratory prepared. Spreading rate same as *Table* 2.
(b) Entries are means of three ratings for smooth-planed boards and means of two ratings for plywood based on a scale of 10 (perfect condition) to 1 (total failure). Ch, checking; C, cracking.

Table 9—Evaluation of Substrate Finished with Acrylic Latex Primer and Topcoat[a]

Preweathering Time (weeks)	Rating after Peathering Period[b]									
	1 Year		2 Years		3 Years		4 Years		5 Years	
	Ch	C	Ch	C	Ch	C	Ch	C	Ch	C
Engelmann spruce (smooth-planed)										
0	10	10	10	10	10	9.7	10	9.7	10	9.7
4	10	10	10	10	10	10	10	10	9.7	10
8	10	10	10	10	10	8.7	9.3	8.7	9.3	8.3
Yellow-poplar (smooth-planed)										
0	10	10	10	10	10	10	10	10	10	10
4	10	10	10	9.3	10	9.3	10	9.0	10	8.3
8	10	10	10	10	10	9.7	10	9.7	10	9.3
Southern pine (scratch-sanded plywood)										
0	10	10	10	10	10	10	10	10	9.0	10
4	10	10	10	10	10	9.5	10	9.5	9.0	9.0
8	10	10	9.0	10	9.0	10	9.0	10	9.0	10
Southern pine (roughsawn plywood)										
0	10	10	10	10	9.5	10	9.5	10	8.5	10
4	10	10	10	10	10	10	10	10	9.0	10
8	10	10	10	10	9.0	10	9.0	10	9.0	10
Sweetgum (roughsawn plywood)										
0	10	10	10	10	9.5	10	9.5	10	9.5	10
4	10	10	10	10	9.0	10	9.0	10	9.0	10
8	10	10	10	10	10	9.5	10	9.5	9.0	8.5

(a) Finish was obtained from commercial sources. Spreading rate same as *Table* 3.
(b) Entries are means of three ratings for smooth-planed boards and means of two ratings for plywood based on a scale of 10 (perfect condition) to 1 (total failure). Ch, checking; C, cracking.

Table 10—Evaluation of Substrate Finished with Alkyd Primer and Acrylic Latex Topcoat[a]

Preweathering Time (weeks)	Rating after Weathering Period[b]									
	1 Year		2 Years		3 Years		4 Years		5 Years	
	Ch	C	Ch	C	Ch	C	Ch	C	Ch	C
	Engelmann spruce (smooth-planed)									
0	10	10	10	10	10	10	10	10	10	10
4	10	10	9.0	10	9.0	9.0	9.0	8.0	7.7	6.3
8	10	10	10	10	10	10	10	9.3	9.3	9.0
	Yellow-poplar (smooth-planed)									
0	10	10	10	10	10	10	10	10	10	10
4	10	9.3	9.0	8.7	9.0	8.0	9.0	8.0	8.7	8.0
8	10	9.0	8.3	7.7	8.0	7.7	7.0	7.3	7.0	7.3
	Southern pine (scratch-sanded plywood)									
0	10	10	9.0	10	8.0	9.0	7.0	9.0	6.0	9.0
4	10	10	8.0	10	7.0	8.0	6.0	8.0	6.0	8.0
8	10	10	6.0	10	4.0	8.0	4.0	8.0	4.0	8.0
	Southern pine (roughsawn plywood)									
0	10	10	8.0	10	6.0	8.5	5.5	8.5	4.5	8.0
4	10	10	9.0	10	8.0	9.0	7.0	9.0	5.0	8.0
8	10	10	8.0	10	6.0	8.0	4.0	8.0	4.0	8.0
	Sweetgum (roughsawn plywood)									
0	10	10	10	10	7.5	9.0	7.5	9.0	6.5	8.5
4	10	10	10	10	7.0	8.0	6.7	7.0	5.5	7.0
8	10	10	10	10	8.0	9.0	7.5	9.0	6.5	7.5

(a) Finish was obtained from commercial sources. Spreading rate same as *Table* 4.
(b) Entries are means of three ratings for smooth-planed boards and means of two ratings for plywood based on a scale of 10 (perfect condition) to 1 (total failure). Ch, checking; C, cracking.

Preweathenng of these substrates caused increased absorption of stain but did not lead to increased finish durability.

Acrylic Latex Primer and Topcoat

For acrylic latex primer and topcoat, both Engelmann spruce and yellow-poplar accepted about the same amount of paint, and the spreading rate of primer decreased with increased preweathering *(Table* 3). The smooth southern pine plywood accepted more paint than the Engelmann spruce and yellow-poplar boards, but less than the roughsawn southern pine and roughsawn sweetgum plywood.

The specimens were evaluated for substrate checking and cracking *(Table* 9) and finish flaking, erosion, and cracking *(Table* 3). An example of the all-latex paint system on Engelmann spruce is shown in *Figure* 2. The performance of all specimens was excellent for four years. At the five-year evaluation, some checking and cracking of the substrate, and flaking and cracking of the finish, was detected, but differentiating effects caused by preweathering was not possible. The ratings for the plywood panels (smooth and roughsawn southern pine and roughsawn sweetgum) were slightly lower than for the Engelmann spruce and yellow-poplar. This was probably caused by the slightly better finishing characteristics of Engelmann spruce and yellow-poplar compared with southern pine and roughsawn sweetgum.

On a Roman numeral scale of I to V, with I indicating the best finishing characteristics, the finishing characteristics of Engelmann spruce and yellow-poplar are III, and southern pine and roughsawn sweetgum are IV.[9] None of the species in this study have the characteristics of redwood or western redcedar (rated as I[9]). Although the substrates used in this study are more difficult to finish and maintain, they better represent the variety of wood siding materials currently used in residential construction in the United States. Even with these difficult-to-finish substrates, the high-quality acrylic latex paint system had little degradation after five years.

Alkyd Primer and Acrylic Latex Topcoat

The spreading rates for the alkyd primer/latex topcoat paint system *(Table* 4) were slightly lower than for the all-latex paint system. The lower spreading rates of primer may be partially explained by the higher absorption rate of the lower molecular weight modified oils. The viscosities of the two primers were different and may also have affected the spreading rates. A different acrylic latex topcoat was used in the all-latex system than in the alkyd primer/latex topcoat system. As with the primers, the spreading rates of the two acrylic latex topcoats were quite different. The difference was probably caused by the viscosity because the primer should block absorption into the substrate. As with other finishes, the species and surface roughness affected the spreading rate. The roughsawn substrate accepted more primer and topcoat than the smooth boards, and the smooth southern pine plywood had spreading rates intermediate to these.

The degradation rates of these paint systems depended on the type of substrate and preweathering time. This was most apparent for yellow-poplar, smooth southern pine, and roughsawn sweetgum. An example of this finish is shown in

Table 11—Evaluation of Substrate Finished with Alkyd Primer and Topcoat[a]

Preweathering Time (weeks)	Rating after Weathering Period[b]									
	1 Year		2 Years		3 Years		4 Years		5 Years	
	Ch	C	Ch	C	Ch	C	Ch	C	Ch	C
Engelmann spruce (smooth-planed)										
0	10	10	10	10	10	10	10	10	10	10
4	10	9.7	10	9.7	10	9.7	9.0	9.7	8.3	9.0
8	10	10	10	10	9.7	10	9.7	10	9.0	10
Yellow-poplar (smooth-planed)										
0	10	9.7	9.3	9.7	9.3	9.3	9.3	9.3	9.7	9.0
4	10	10	10	10	9.0	9.3	8.7	9.3	7.7	9.0
8	10	9.3	10	8.3	10	7.3	8.7	7.0	8.7	7.0
Southern pine (scratch-sanded plywood)										
0	10	10	7.0	10	6.5	7.5	5.5	7.5	4.5	7.5
4	8.0	10	6.0	10	5.0	8.0	5.0	7.0	4.0	7.0
8	10	10	7.0	10	6.0	8.5	5.0	7.0	4.0	7.0
Southern pine (roughsawn plywood)										
0	10	10	9.0	10	8.0	9.0	6.5	8.5	6.5	8.5
4	10	10	10	10	6.5	9.0	5.0	8.0	4.0	8.0
8	10	10	9.0	10	6.5	8.0	5.5	8.0	4.0	7.0
Sweetgum (roughsawn plywood)										
0	10	10	10	10	8.0	10	6.0	8.0	6.0	8.0
4	10	10	5.0	10	4.0	9.0	4.0	8.0	3.0	6.0
8	10	10	9.0	10	6.0	9.0	4.0	8.0	4.0	8.0

(a) Finish was obtained from commercial sources. Spreading rate same as *Table* 5.
(b) Entries are means of three ratings for smooth-planed boards and means of two ratings for plywood based on a scale of 10 (perfect condition) to 1 (total failure). Ch, checking; C, cracking.

Table 12—Evaluation of Substrate Finished with Solid-Color Latex Stain[a]

Preweathering Time (weeks)	Rating after Weathering Period[b]									
	1 Year		2 Years		3 Years		4 Years		5 Years	
	Ch	C	Ch	C	Ch	C	Ch	C	Ch	C
Engelmann spruce (smooth-planed)										
0	9.0	8.7	8.0	8.0	7.0	7.7	6.0	7.0	5.7	6.0
4	4.0	8.0	2.7	4.0	2.7	4.0	1.3	4.0	1.0	4.0
8	4.0	8.0	2.7	5.7	2.7	5.3	1.0	5.3	1.0	5.0
Yellow-poplar (smooth-planed)										
0	9.0	10	4.0	9.0	4.0	9.0	2.0	8.7	2.0	8.7
4	4.0	9.3	4.0	9.3	2.0	9.0	2.0	8.3	2.0	8.3
8	2.0	9.3	2.0	9.0	2.0	8.7	2.0	7.7	2.0	7.7
Southern pine (scratch-sanded plywood)										
0	6.0	10	5.0	10	4.0	6.0	4.0	6.0	4.0	6.0
4	4.0	10	4.0	10	4.0	6.0	4.0	6.0	4.0	6.0
8	6.0	10	4.0	10	4.0	6.0	4.0	6.0	4.0	6.0
Southern pine (roughsawn plywood)										
0	6.0	10	5.0	10	5.0	7.5	4.5	7.0	4.5	7.0
4	4.0	10	4.0	10	3.5	8.0	3.5	8.0	2.5	8.0
8	5.0	10	4.0	10	3.5	6.0	3.5	6.0	3.5	6.0
Sweetgum (roughsawn plywood)										
0	9.0	10	8.0	10	7.0	8.0	6.0	8.0	5.5	6.5
4	6.0	10	8.0	10	6.0	8.0	4.0	8.0	4.0	8.0
8	6.0	10	8.0	10	6.0	7.0	3.0	7.0	3.0	6.0

(a) Finish was obtained from commercial sources. Spreading rate same as *Table* 6.
(b) Entries are means of three ratings for smooth-planed boards and means of two ratings for plywood based on a scale of 10 (perfect condition) to 1 (total failure). Ch, checking; C, cracking.

Table 13—Evaluation of Substrate Finished with Solid-Color Oil-Based Stain[a]

Preweathering Time (weeks)	Rating after Weathering Period[b]									
	1 Year		2 Years		3 Years		4 Years		5 Years	
	Ch	C	Ch	C	Ch	C	Ch	C	Ch	C
				Engelmann spruce (smooth-planed)						
0	9.0	10	9.0	9.0	8.3	9.0	8.0	8.3	7.0	7.3
4	7.0	8.7	6.0	7.0	6.0	6.7	6.0	6.3	4.7	6.0
8	6.3	10	6.0	8.0	6.0	7.3	5.3	6.3	4.0	5.0
				Yellow-poplar (smooth-planed)						
0	8.0	10	8.0	10	6.0	10	6.0	9.7	5.0	9.3
4	8.0	10	8.0	10	7.0	10	5.3	9.7	3.3	9.7
8	8.0	10	6.0	10	6.0	10	4.7	10	3.0	9.0
				Southern pine (scratch-sanded plywood)						
0	4.0	10	4.0	10	4.0	8.0	4.0	7.0	4.0	7.0
4	4.0	10	6.0	10	4.0	4.0	4.0	4.0	4.0	4.0
8	6.0	10	6.0	10	6.0	6.0	6.0	6.0	6.0	6.0
				Southern pine (roughsawn plywood)						
0	4.0	10	5.0	10	3.5	8.5	3.5	7.7	3.0	7.5
4	4.0	10	3.0	10	2.0	8.0	2.0	6.0	2.0	6.0
8	2.0	10	4.0	10	3.5	6.0	3.5	6.0	3.5	6.0
				Sweetgum (roughswan plywood)						
0	8.0	10	9.0	10	6.0	8.0	5.0	7.0	3.5	6.0
4	6.0	10	7.0	10	5.0	7.0	5.0	6.0	2.5	5.0
8	8.0	10	8.0	10	6.0	6.0	5.0	6.0	3.0	5.0

(a) Finish was obtained from commercial sources. Spreading rate same as *Table* 7.
(b) Entries are means of three ratings for smooth-planed boards and means of two ratings for plywood based on a scale of 10 (perfect condition) to 1 (total failure). Ch, checking; C, cracking.

Figure 3. The longer the preweathering time, the more substantial the change was, not only on the finish, with more flaking and cracking, but also on the substrate *(Table* 10), with more checking and cracking. Note that all erosion values are 10. The finish degradation was probably caused by the degradation of the substrate. The short preweathering time was sufficient to initiate microchecking of the substrate surface that affected the finish within one to two years. The microchecking that occurred in the substrate prior to application of the finish developed into cracks that propagated through the alkyd primer to the surface of the paint system. This crack propagation did not occur with the all-latex paint system described previously.

Alkyd Primer and Topcoat

The alkyd primer and topcoat system *(Tables* 5 and 11, *Figure* 4) followed the same trends as the alkyd primer/latex topcoat system. The spreading rates, substrate checking and cracking, and finish flaking and cracking all depended on the type of substrate and preweathering time. The effect is more obvious on the difficult-to-finish substrates (smooth southern pine, roughsawn southern pine, and roughsawn sweetgum).

Solid-Color Stains

The performances of the solid-color latex stain *(Table* 6) and the solid-color oil-based stain *(Table* 7, *Figure* 5) were almost the same. Several substrates had increased finish sorption with increased preweathering time. Those included Engelmann spruce, roughsawn southern pine, and smooth southern pine finished with the solid-color oil stain and Engelmann spruce finished with solid-color latex stain. These spreading rates had little effect on overall performance. In almost all cases, the finishes failed by the second year. Small changes in durability caused by increased sorption of finish were completely obscured by the rapid finish degradation.

The effect of preweathering was evident, particularly during the shorter exposure times. The rating for finish cracking was considerably less for those specimens that were preweathered (e.g., at the one-year evaluation, Engelmann spruce specimens preweathered for eight weeks had a rating of about half that of nonpreweathered panels). The only finish systems to give even minimal performance (at least three years) were those on Engelmann spruce, but only on those specimens that were not preweathered.

Finish Durability

The results contained in *Tables* 2-13 are summarized in *Table* 14. This table shows the service life of the finishes in years. The finish was considered failed when any one of the ratings was five or less. Those systems marked with a >5 had ratings above five after five years exposure. An obvious decrease in performance caused by preweathering is designated with a Y under preweathering effect. An N indicates consistent ratings regardless of preweathering, and a ? indicates inconsistent results. These interpretations are subjective, but in most cases a Y indicates a difference of two units

Table 14—Finish Service Life and Preweathering Effect on Finish

Finish	Service Life[a] (Years)					Preweathering Effect[a]				
	ES	YP	SP/S	SP/R	SG/R	ES	YP	SP/S	SP/R	SG/R
Semitransparent stain	2[b]	2	2	4	4	N[c]	N	N	N	Y
Acrylic latex primer and topcoat-A	>5	>5	>5	>5	>5	N	N	N	Y	N
Alkyd primer/latex topcoat-B	>5	>5	2	3	3	N	Y	Y	?	Y
Alkyd primer and topcoat	>5	>5	3	3	2	N	Y	Y	Y	Y
Solid-color latex stain	1	1	1	1	1	Y	Y	?	Y	Y
Solid-color oil-based stain	1	1	1	2	1	Y	Y	?	Y	Y

(a) ES, Engelmann spruce; YP, yellow-poplar; SP/S, southern pine, scratch-sanded plywood; SP/R, southern pine, roughsawn plywood; SG/R, sweet gum, roughsawn plywood.
(b) Finish was considered failed when one of the ratings was 5 or less.
(c) N, consistent ratings regardless of preweathering; Y, obvious decrease in performance caused by preweathering; ?, inconsistent results.

in ratings between the nonpreweathered controls and the eight-week preweathered specimens. This difference usually occurred with the finish cracking or flaking ratings.

The effect of preweathering generally showed up as the panels started to degrade. Panels that showed little degradation after five years generally showed no difference between the preweathered and control specimens and are the ones given the N designation. Distinguishing a preweathering effect was difficult if the panels degraded quickly. This was most apparent on the panels finished with the solid-color stains. The inconsistent results with solid-color stains on smooth southern pine may have been caused by the rapid degradation of this finish system.

The deterioration of paint can occur through a number of mechanisms. This research focused only on the effect of preweathering. Information on other types of degradation and wood finish interactions is contained in other sources.[1,2,9,21-24]

Adhesion Tests and Durability

Paint adhesion to Engelmann spruce, yellow-poplar, and southern pine following preweathering periods similar to those used in this study was reported earlier.[12] In this earlier study, significant differences ($p = 0.05$) in paint adhesion for different amounts of preweathering were not found for southern pine or yellow-poplar, but were found for Engelmann spruce. However, close inspection of the test specimens of all species revealed loss of adhesion at the earlywood/paint interface. This debonding at the earlywood was similar to the failure mode observed with the adhesion tests of western redcedar and Douglas-fir reported earlier.[11]

Although adhesion tests of preweathered wood correlated with field performances for western redcedar and Engelmann spruce, adhesive tests were not effective in predicting the field performances of yellow-poplar, southern pine, or sweetgum. Adhesion testing may not be an appropriate method for predicting performance with some species. This is particularly true for dense species that tend to cause paint failure by checking and cracking. It is also possible that these more dense species may require longer preweathering periods before significant decreases in paint bond strength are apparent. On-going studies will address these uncertainties.

CONCLUSIONS

The service life of a wide range of finishes on five different substrates was decreased by short-term preweathering of the wood substrate prior to finishing. Preweathering of wood for as little as four weeks led to decreased finish service life. The type of finish had the greatest effect on service life, followed by surface roughness, type of substrate, and finally the amount of preweathering. This research, as well as that reported earlier for western redcedar and Douglas-fir, indicates that short-term preweathering (four weeks) decreases the service life of a wide range of finishes and substrates.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the laboratory assistance of Peter G. Sotos and Mark Knaebe.

References

(1) Feist, W.C. and Hon, D.N.-S., *Chemistry of Weathering and Protection*, The Chemistry of Solid Wood, Advances in Chemistry Series, 207, Rowell, R.M. (Ed.), American Chemical Society, p 401-451 (1984).
(2) Sell, J. and Leukens, U., "Investigations on Weathered Wood Surfaces. Part 2: Weathering Phenomena of Unprotected Wood Species," *Holz als Roh-und Werkstoff*, 29, No. 1, 23-31 (1971).
(3) Underhaug, A., Lund, T.J., and Kleive, K., "Wood Protection—The Interaction Between Substrate and the Influence on Durability," *J. Oil Colour Chem. Assoc.*, *66*, No. 11, 345-351 (1983).
(4) Boxall, J., "Painting Weathered Timber," Information Sheet 20/77. Building Research Establishment, Princes Risborough Laboratory, Alyesbury, Bucks, England, 1977.
(5) Bravery, A.F. and Miller, E.R., "The Role of Pretreatment in the Finishing of Exterior Softwood," *Proceedings, Annual Convention of the British Wood Preserving Association*, 14-23, 1980.
(6) Kleive, K., "Weathered Wooden Surfaces—Their Influence on the Durability of Coatings Systems," JOURNAL OF COATINGS TECHNOLOGY, *58*, No. 740, 39 (1986).
(7) Kühne, H., Hochweber, M., and Sell, J., *Freiland-Bewitterungsversuche an Aussenanstrichen für Holz-Versuchszeitraum*, 1962-1967. EMPA-Bericht Nr. 182, Dübendorf, Switzerland, 1968.
(8) Sell, J. and Feist, W.C., "Role of Density in the Erosion of Wood During Weathering," *Forest Prod. J.*, 36, No. 3, 57-60 (1986).
(9) Forest Products Laboratory, "Wood Handbook: Wood as an Engineering Material," *USDA Agric. Handb.*, 72, U.S. Government Printing Office, Washington, D.C., 1987.

(10) Desai, R.L., "Coating Adhesion to Weathered Wood," Eastern Forest Products Laboratory, Ottawa, Canada, Bi-Monthly Research Notes, 23, No. 5, 36-37 (1967).
(11) Williams, R.S., Winandy, J.E., and Feist, W.C., "Paint Adhesion to Weathered Wood," JOURNAL OF COATINGS TECHNOLOGY, *56*, No. 749, 43 (1987).
(12) Williams, R.S., Plantinga, P.L., and Feist, W.C., "Photodegradation of Wood Affects Paint Adhesion," *Forest Prod. J.*, 40, No. 1, 45-49 (1989).
(13) Arnold, M., Williams, R.S., and Feist, W.C., "Effect of Weathering on New Wood on the Subsequent Performance of Semitransparent Stains," *Forest Prod. J.*, 42, No. 3, 10 (1992).
(14) Williams, R.S. and Feist, W.C., "Effect of Weathering of New Wood on the Subsequent Performance of Paint or Solid-Color Stain," *Forest Prod. J.*, 43, No. 1, 8-14 (1993).
(15) Test Method D 772-86 for Evaluation Degree of Flaking (Scaling) of Exterior Paints," *Annual Book of ASTM Standards*, Vol 06.01, American Society for Testing and Materials, Philadelphia, PA, 1991.
(16) Test Method D 662-86 for Evaluation Degree of Erosion of Exterior Paints," *Annual Book of ASTM Standards*, Vol 06.01, American Society for Testing and Materials, Philadelphia, PA, 1991.
(17) Test Method D 661-86 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.
(18) Feist, W.C., "Weathering Performance of Finished Southern Pine Plywood Siding," *Forest Prod. J.*, 38, No. 3, 22-28 (1988).
(19) Kühne, H., Leukens, U., Sell, J., and Waelchli, O., *Freiland-Bewitterungsversuche an Holz und Aussenanstrichen für Holz-Ergebnisse der 2. Versuchsperiode 1968 bis 1971*, EMPA-Bericht Nr. 198, Duebendorf, Switzerland, 1972.
(20) Miller, E.R., "Chemical Aspects of External Coatings for Softwoods," Symposium on Chemical Aspects of Wood Technology, Swedish Forest Products Research Laboratory, Södergam, Stockholm, Sweden, 1981.
(21) Banov, A., *Paints and Coatings Handbook:* Structures: Farmington, MI, 1973.
(22) Browne, F.L., "Wood Properties That Affect Paint Performance," USDA Forest Service, Forest Products Laboratory, Report No. R1053, Madison, WI, 1948.
(23) Hamburg, H.R. and Morgans, W.M., *Hess' Paint Film Defects: Their Causes and Cures*, 3rd Edition, Chapman and Hall, London, 1979.
(24) Feist, W.C., "Finishing Wood Exteriors," USDA Forest Service, Forest Products Laboratory, Research Paper, FPL 647, Madison, WI, 1986.

on recycled paper