

Durability of yellow-poplar and sweetgum and service life of finishes after long-term exposure

R. Sam Williams*

William C. Feist*

Abstract

This report describes the results of long-term outdoor exposure on durability of hardwood plywood and the service life of various finishes. Smooth (abrasive-planed) and rough (saw-textured) yellow-poplar (*Liriodendron tulipifera* L.) and sweetgum (*Liquidambar styraciflua* L.) plywood panels were exposed outdoors for 16 years near Madison, Wisconsin. The performance of several finishes was evaluated over a 12-year period, and the panels were evaluated for decay after 16 years. Oil or latex semitransparent stain provided less than 5 years of service life. Nevertheless, the wood showed only minor decay after 16 years. In contrast, latex paint was in excellent condition after 12 years, but the wood showed considerable decay. Our results indicate that more weather resistant film-forming finishes increase the incidence of decay in yellow-poplar and sweetgum.

The volume of mature second- and third-growth yellow-poplar and sweetgum in eastern forests of the United States is estimated to be about 21.2 and 17.3 billion ft.³ (6.0 and 4.9 billion m³), respectively (Smith 1997). Using these species for siding could increase the value of this resource. Long service life will depend on effective methods for finishing the wood.

Browne (1942) studied the performance of a lead-based oilborne formulation on lumber from old-growth stands. In previous work, we examined the durability of several finishes on saw-textured redwood (*Sequoia sempervirens*) plywood, abrasive-planed Douglas-fir (*Pseudotsuga menziesii*) plywood, and aspen (*Populus* spp.) waferboard (Feist 1982). The waferboard showed decay after several years of exposure. A later study revealed decay in abrasive-planed yellow-poplar lumber after as few as 6 years of exposure (Feist 1987). The results of that study led to the conclusion that yellow-

poplar would benefit from the use of water-repellent preservative pretreatments.

There has previously been no information on the long-term performance of hardwood plywood siding from second- and third-growth stands of yellow-poplar and sweetgum using modern finishes. We report the durability of yellow-poplar and sweetgum and the service life of typical finishes after 16 years of outdoor exposure near Madison, Wisconsin.

Methods and materials

Smooth (abrasive-planed) and rough (saw-textured) yellow-poplar (*Liriodendron tulipifera* L.) and sweetgum (*Liqui-*

dambar styraciflua L.) 5-ply plywood from a commercial source had a nominal thickness of 5/8 inch (16 mm) and 1/2 inch (13 mm), respectively. Plywood surfaces were flat-grain and representative of plywood made with lathepeeled veneers. The surface veneer was grade A veneer. The plywood was cut into panels 406 mm (16 in.) long by 406 mm (16 in.) wide.

Panels were finished with a laboratory-prepared oil-based semitransparent stain (Black et al. 1979) and several commercial finishes (Table 1). The laboratory formula (FPL-046) was typical of a semitransparent stain available during the mid-1980s. The percentage of solids for the finishes was determined

The authors are, respectively, Supervisory Research Chemist, and Retired Research Chemist, USDA Forest Serv., Forest Products Lab., One Gifford Pinchot Dr., Madison, WI 53705-2398. We thank Peter Sotos for conducting the field evaluations and John Gangstad for producing the spread sheets and data plots. This paper was received for publication in February 2003. Article No. 9625.

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Table 1. — Spreading rates of finishes for abrasive-planed and saw-textured sweetgum and yellow-poplar.^a

Species and surface	Spreading rates of various finishes										
	Finish 1, 76% solids, FPL-046		Finish 2, 60% solids, solid-color oil-based stain		Finish 3, 45% solids, solid-color latex-based stain		Finish 4, primer 52% solids, topcoat 53% solids, latex paint		Finish 5, 25% solids, latex-based semitransparent stain		
	1st coat	2nd coat	1st coat	2nd coat	1st coat	2nd coat	Primer	1st coat	2nd coat	1st coat	2nd coat
	----- (m ² /L (ft. ² /gal.)) -----										
Sweetgum, abrasive-planed	11.4	15.7	13.2	13.3	14.1	10.7	8.1	11.4	9.1	11.2	16.7
	(465)	(641)	(538)	(542)	(576)	(437)	(330)	(466)	(371)	(458)	(679)
	10.6	19.8	10.9	13.7	12.6	11.2	8.6	10.2	7.7	13.3	15.7
	(433)	(805)	(442)	(558)	(515)	(456)	(352)	(417)	(312)	(541)	(641)
	12.1	15.1	11.3	14.6	12.1	10.2	8.3	11.3	6.0	9.6	17.3
	(494)	(616)	(462)	(593)	(494)	(415)	(338)	(462)	(246)	(391)	(706)
Yellow-poplar, abrasive-planed	10.6	17.5	10.5	13.9	12.1	11.3	8.2	11.7	7.9	8.6	12.9
	(430)	(714)	(427)	(566)	(494)	(461)	(333)	(477)	(324)	(351)	(524)
	11.2	19.8	9.6	11.6	12.8	10.8	7.9	11.1	7.6	12.2	17.0
	(458)	(805)	(391)	(473)	(522)	(441)	(321)	(454)	(310)	(498)	(692)
	10.6	33.5	9.4	14.1	11.8	9.6	8.2	12.2	8.3	11.0	15.2
	(433)	(1,365)	(383)	(575)	(482)	(391)	(334)	(499)	(336)	(447)	(618)
Yellow-poplar, saw-textured	3.1	8.4	3.8	8.1	4.0	6.0	3.9	6.7	6.6	3.1	5.4
	(127)	(341)	(156)	(331)	(165)	(245)	(159)	(275)	(268)	(128)	(219)
	3.0	7.3	3.9	8.1	4.0	6.2	3.9	6.5	7.1	3.0	6.3
	(123)	(299)	(159)	(331)	(164)	(254)	(159)	(265)	(287)	(122)	(258)
	2.9	5.8	3.9	7.0	3.9	6.4	3.7	6.4	8.2	2.9	6.1
	(118)	(238)	(158)	(285)	(159)	(261)	(150)	(260)	(334)	(119)	(247)
Sweetgum, saw-textured	2.1	6.3	3.6	7.0	3.9	6.4	3.6	5.7	7.9	2.8	5.6
	(87)	(255)	(148)	(285)	(158)	(263)	(149)	(231)	(321)	(115)	(229)
	2.4	7.3	3.4	7.0	3.7	5.8	3.5	5.9	7.6	2.9	5.6
	(99)	(299)	(141)	(283)	(150)	(238)	(145)	(241)	(310)	(118)	(226)
	2.4	6.1	3.5	7.0	3.8	6.5	3.7	5.5	7.7	2.9	5.9
	(97)	(247)	(141)	(285)	(154)	(266)	(150)	(224)	(312)	(118)	(239)

^aSpreading rates given for three replicates.

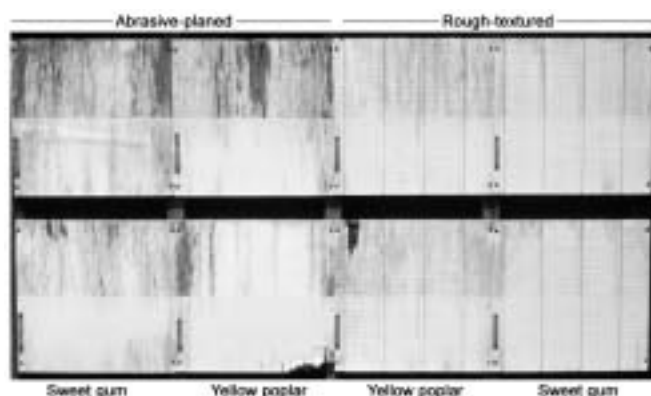


Figure 1. — Sweetgum and yellow-poplar panels after 12 years of exposure. Upper half of each panel was finished with one coat of primer and one top coat of latex paint, lower half with one coat of primer and two top coats of paint. Note decay on abrasive-planed yellow-poplar.

using ASTM D 2832 and other appropriate standards (ASTM 1991).

Panels were finished under ambient conditions and stored in the laboratory for 2 weeks before outdoor exposure. For the stains, one coat of finish was applied to half of the panel and two coats to the other half. For the latex paint, one coat of primer and one top coat was applied to half of the panel and one coat of primer and two top coats to the other half. Average finish coverage is given in Table 1.

Panels were oriented vertically (longitudinal grain of surface veneer) on a test fence facing south (Fig. 1). Performance of finishes was evaluated annually for 6 years, then biannually for an additional 6

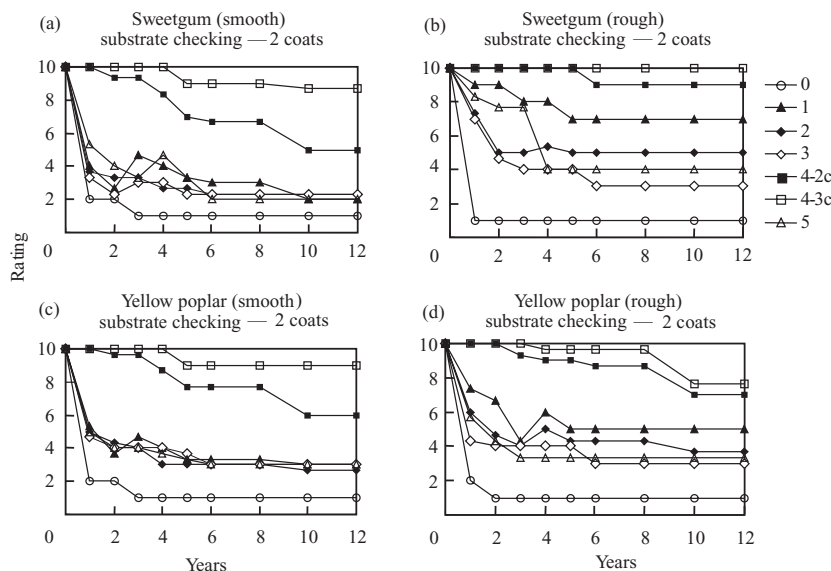


Figure 2. — Substrate checking after 12 years of exposure: a) sweetgum, smooth (abrasive-planed); b) sweetgum, rough (saw-textured); c) yellow-poplar, smooth; d) yellow-poplar, rough. (0 = no finish; 1 = oil-based semitransparent stain; 2 = oil-based solid-color stain; 3 = latex-based solid-color stain; 4-2c = latex primer and one top coat; 4-3c = latex primer and two top coats; 5 = latex-based semitransparent stain).

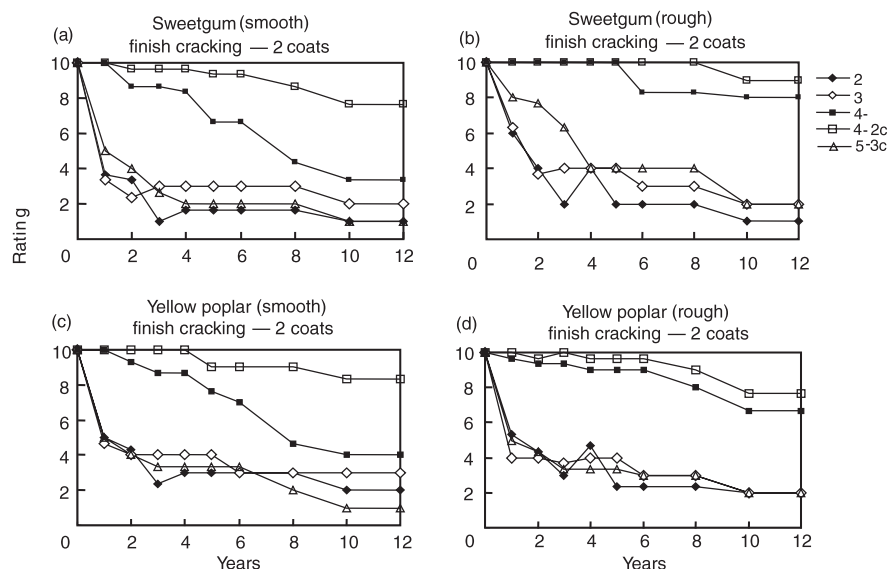


Figure 3. — Finish cracking after 12 years of exposure: a) sweetgum, smooth; b) sweetgum, rough; c) yellow-poplar, smooth; d) yellow-poplar, rough. See Figure 2 for description of finishes.

years. Panels were evaluated visually for erosion (ASTM D 662), cracking (ASTM D 661), flaking (ASTM D 772), as well as substrate checking, mildew growth, and general appearance. Panels were rated on the following scale: 10 = no deterioration; 5 = need to refinish; 1 = complete degradation of the finish. The time required for a panel to receive a rat-

ing of 5 was considered the service life of the finish.

Evaluations for three replicates were averaged and standard deviations determined. For simplicity, standard deviations are not shown in the figures. Standard deviations for the three replicates were less than one unit for about 93 percent of the paint systems. It was ex-

tremely rare for the standard deviation to be more than two units (18 of 3,100 averages). Evaluations of paint systems that differed by two or more units were considered to be statistically different. Evaluations that did not differ by more than one unit were considered to be statistically not different.

After 16 years of outdoor exposure, the panels were destructively evaluated for decay by probing with an icepick in several places. Each board was rated on the following scale: 10 = no decay (sound); 8 = minor decay; 5 = decayed and no longer serviceable; 1 = massive decay (panel not intact).

Results and discussion

Substrate

The effect of finishes on the substrate checking is shown in Figure 2. Compared with unfinished panels, finishes provided all panels with some protection from checking. On abrasive-planed panels, all finishes, except latex paint, were rated 5 or less after only 1 year of outdoor exposure. The paint systems provided the best protection against weathering. The latex primer plus one top coat had an average rating of 5 after 10 years. The three-coat paint system (primer plus two top coats) had an average rating of 9 after 12 years.

The saw-textured panels accepted more finish than did the abrasive-planed panels and therefore substrate checking evaluations were slightly higher for the saw-textured panels (Table 1, Fig. 2). The oil-based semitransparent stain provided much better protection to the saw-textured substrate than to the abrasive-planed substrate. In fact, this stain was the only finish other than the latex paint that gave acceptable performance over the 12-year exposure.

The finishes performed similarly on both species.

Finish service life

Cracking. — Because of interactions between the finish and substrate, finish cracking often parallels substrate checking. Evaluations of finish cracking for both abrasive-planed and saw-textured panels (Fig. 3) were similar to those for substrate checking (Fig. 2). For the two-coat latex paint system on abrasive-planed substrate, the evaluations dropped below 5 after 7 years. Other than the latex semitransparent stain on saw-textured sweetgum, which lasted 3

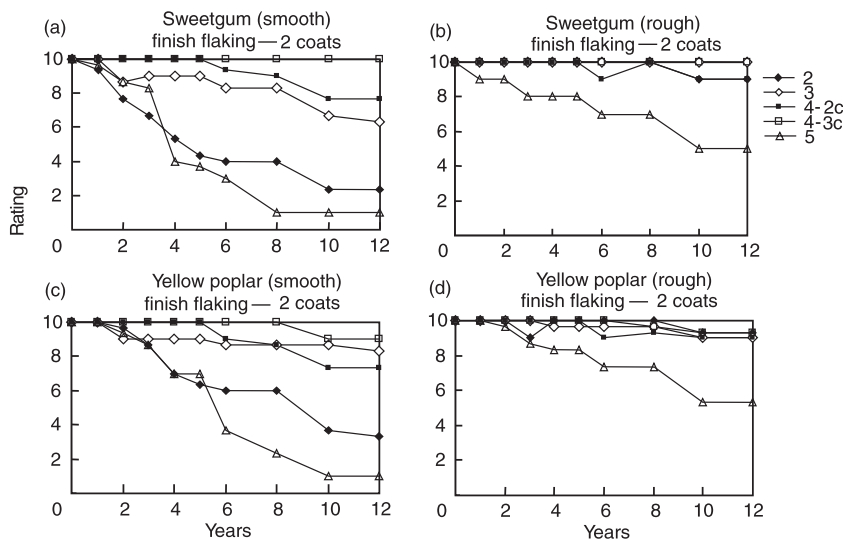


Figure 4. — Finish flaking after 12 years of exposure: a) sweetgum, smooth; b) sweetgum, rough; c) yellow-poplar, smooth; d) yellow-poplar, rough. See Figure 2 for description of finishes.

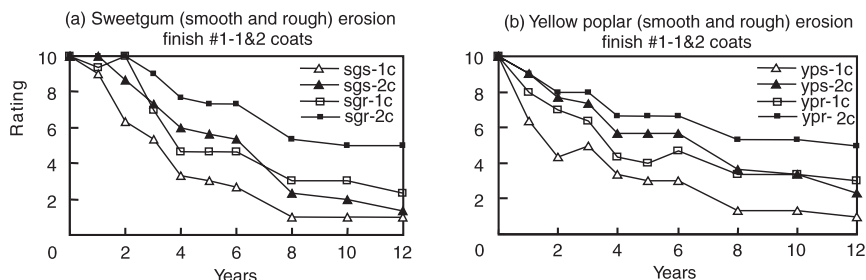


Figure 5. — Finish erosion after 12 years of exposure: sgr = rough sweetgum; sgs = smooth sweetgum; ypr = rough yellow-poplar; yps = smooth yellow-poplar. (1c = one coat of oil-based semitransparent stain; 2c = two coats of oil-based semitransparent stain).

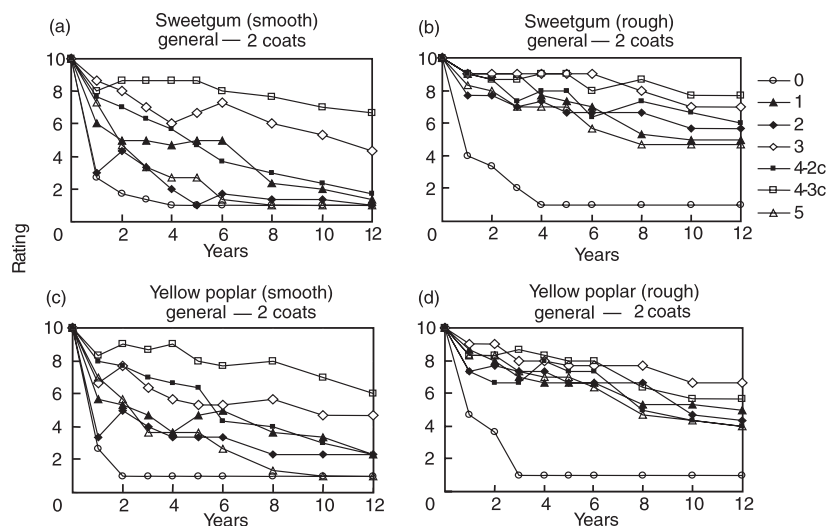


Figure 6. — Finish general appearance after 12 years of exposure: a) sweetgum, smooth; b) sweetgum, rough; c) yellow-poplar, smooth; d) yellow-poplar, rough. See Figure 2 for description of finishes.

years, all other film-forming finishes failed in cracking after 1 year (evaluation of 5 or less). The oil-based semitransparent stain (FPL-046) was not evaluated for finish cracking because it is a penetrating finish with no film buildup and therefore not susceptible to cracking.

Surface texture had a notable effect on finish cracking for panels finished with latex paint (Fig. 3). The number of top coats had a great effect on finish performance for the abrasive-planned (smooth) substrate (Figs. 3a, 3c) but nearly no effect on that for the saw-textured (rough) substrate (Figs. 3b, 3d), probably because the saw-textured surface could accept a large amount of finish in a single coat (Table 1).

Considerable differences in flaking were seen for the various finishes on the abrasive-planned substrate (Figs. 4a, 4c). The two- and three-coat latex paint and the two-coat latex solid color stain performed for 12 years, whereas the oil solid color stain and the latex semitransparent stain needed refinishing after about 5 to 6 years. The oil-based semitransparent stain was not included in the evaluation of flaking. The poor performance by the oil-based solid color stain compared to the latex finishes was probably caused by the more brittle nature of the oil finish. The latex semitransparent stain flaked because it lacked sufficient film thickness. Although the coverage of this stain was similar to that of the other finishes, its solids content was about half that of the other finishes (Table 1). Even on the saw-textured surface, the latex semitransparent stain performed poorly compared with the other finishes (Fig. 4).

Erosion. — All finishes were evaluated for erosion over the 12-year exposure, but the evaluations were meaningful only for the oil-based semitransparent stain. The service life of this type of penetrating finish is determined by its erosion rate. Because the other finishes were film-forming finishes, their service life were controlled by other failure mechanisms such as cracking and flaking. In general, the film-forming finishes had high erosion ratings after 12 years even when cracking was severe.

The erosion ratings for the oil-based semitransparent stain clearly show the effect of substrate texture (Fig. 5). In general, two coats of oil-based semitrans-

Table 2. — Decay ratings for panels after 16 years of exposure.^a

Wood species	Surface	Finish ^b	Decay ratings for replicates			Average rating
Sweetgum	Abrasive-planed	None	10	8	10	9
	Saw-textured	None	8	10	5	8
Yellow-poplar	Abrasive-planed	None	10	10	10	10
	Saw-textured	None	5	8	8	7
Sweetgum	Abrasive-planed	1	10	8	8	9
	Saw-textured	1	10	8	8	9
Yellow-poplar	Abrasive-planed	1	8	8	8	8
	Saw-textured	1	8	5	5	6
Sweetgum	Abrasive-planed	2	10	8	10	9
	Saw-textured	2	8	8	5	7
Yellow-poplar	Abrasive-planed	2	8	8	10	9
	Saw-textured	2	1	1	5	3
Sweetgum	Abrasive-planed	3	10	8	8	9
	Saw-textured	3	8	8	5	7
Yellow-poplar	Abrasive-planed	3	10	8	8	9
	Saw-textured	3	1	5	5	4
Sweetgum	Abrasive-planed	4	8	1	1	3
	Saw-textured	4	8	1	1	3
Yellow-poplar	Abrasive-planed	4	5	1	1	3
	Saw-textured	4	8	5	1	5
Sweetgum	Abrasive-planed	5	8	8	8	8
	Saw-textured	5	5	5	8	6
Yellow-poplar	Abrasive-planed	5	8	1	8	6
	Saw-textured	5	1	8	8	6

^aRating scale: 10 = sound; 1 = massive decay.

^bFinishes: 1 = FPL-046; 2 = oil-based solid-color stain; 3 = latex-based solid-color stain; 4 = latex-based primer and top coat; 5 = latex-based semitransparent stain.

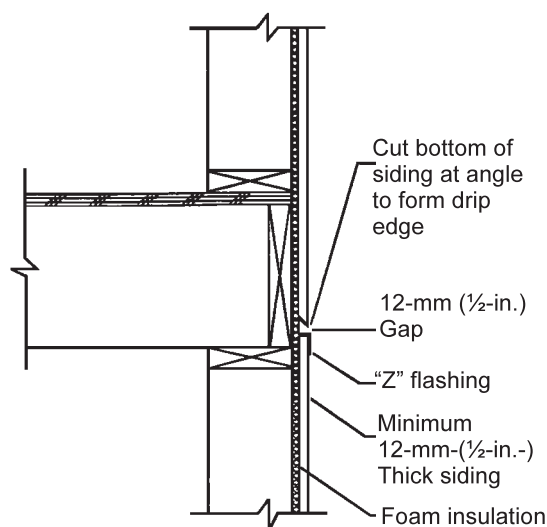


Figure 7. — Positioning of sheet siding above Z-flashing. 1 in. = 25.4 mm.

parent stain had a service life of about 12 years on a saw-textured substrate and 5 to 6 years on an abrasive-planed substrate. One coat lasted about 5 to 6 years on a

saw-textured substrate but only 3 years on an abrasive-planed substrate.

General appearance. — The general appearance rating is largely governed by

mildew growth on the surface. In most cases, all finished panels had higher appearance ratings compared with those of unfinished controls (**Fig. 6**). On abrasive-planed substrates, only the three-coat latex paint system and the latex solid color stain had ratings of 5 or higher after 12 years of exposure. On saw-textured substrates, these finishes performed better than the others. Nevertheless, all finishes had acceptable appearance ratings up to approximately 10 years of exposure.

Wood durability

As discussed in the previous section on finish service life, the performance of the latex paint system was excellent over the 12-year exposure period. However, the evaluation for decay after 16 years of exposure showed that panels finished with this system had the most severe decay (**Table 2**). The decay was easily visible (**Fig. 1**). The paint apparently trapped more moisture than did the other finish systems, thereby causing more decay.

Results of previous studies revealed the advantages of using a water-repellent preservative on wood siding and panel products prior to painting. If yellow-poplar and sweetgum are to be used successfully for siding, it may be necessary to use a water-repellent preservative prior to painting. It should be noted that the test panels were not protected from rain. The test fence did not have an overhang and the panels were exposed without flashing. Properly installed Z-flashing with the upper panel back-cut to form a drip edge would probably improve siding durability (**Fig. 7**). The panel edges should also be sealed with either a primer or a water-repellent preservative.

Conclusions

The best overall performance of yellow-poplar and sweetgum plywood was obtained on saw-textured (rough) surfaces finished with an oil-based semitransparent stain. The two-coat oil-based semitransparent stain gave about 5 years of service life. After 16 years of exposure, the decay rating for the panels finished with this stain was about the same as that for the unfinished controls. The three-coat paint system had excellent paint service life, but the paint trapped moisture that caused substrate decay.

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