

Performance of finishes on western juniper lumber and particleboard during outdoor exposure

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Abstract

The increasing number of western juniper trees per acre and the expansion of its range is resulting in watershed degradation, loss of site productivity, decrease in forage production, loss of wildlife habitat, and overall reduction in biodiversity. Previous studies and anecdotal evidence indicate western juniper has fairly good resistance to decay and insect attack, and it might be suitable for decking and siding applications as well as for particleboard furnish. We evaluated the performance of smooth-planed and saw-textured western juniper lumber and particleboard finished with a variety of paints and stains. Our objectives were to evaluate substrate stability (resistance to checking and warping), aboveground durability, and susceptibility to discoloration and mildew growth. We found that the performance of western juniper is similar to that of other highly colored and dimensionally stable wood species such as western redcedar. Western juniper is somewhat prone to mildew and extractives bleed through some paints. The two-coat latex paint was effective in blocking extractive bleed from lumber, but discoloration was a serious problem with particleboard. Clear penetrating finishes lasted only 1 to 2 years, and semitransparent finishes performed well only on saw-textured lumber. Two-coat, film-forming finishes gave excellent performance on both smooth-planed and saw-textured lumber.

During the last century, western juniper (*Juniperus occidentalis*) has greatly increased in the number of trees per acre. According to Gedney et al. (1999), more than 3.8 million acres (1.5 million ha) of western juniper woodland with 10 percent or more canopy cover are within the primary range in eastern Oregon, northeastern California, and southwestern Idaho. In eastern Oregon, total acreage of western juniper with 10 percent or more crown cover has increased about 500 percent since the first USDA Forest Service inventory was completed in the mid-1930s. It is projected that hundreds of thousands more acres will convert to woodland over the next 20 to 40 years (Gedney et al. 1999).

Historically, several major factors have contributed to the expansion and increasing density of western juniper:

- Reduction in periodic burning, which was initiated by Native Americans prior to settlement (western juniper is highly vulnerable to fire at seedling and sapling stage);

- Uncontrolled grazing in late 1800s through early 1900s, which reduced fine fuels and extent of natural fires;

- Above-average precipitation in late 1800s and early 1900s, which helped seed survival;

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- Aggressive fire suppression policies and measures dating to early 1800s:
- Large increase in seed production because of maturation of trees established in late 1800s and early 1900s (Miller and Wigand 1994, Miller and Rose 1995, Miller et al. 2000).

No significant insect or disease outbreaks have been observed or reported in juniper woodlands, contrary to what normally occurs when unnaturally high vegetative densities and conditions are created in forest ecosystems.

Western juniper is the least-utilized wood fiber resource in its range (Swan 2001). Total volume in woodlands with crown cover over 10 percent and in mixed conifer forests is estimated to be 467 million ft³ (13.2 million m³) (Gedney et al. 1999). Literally thousands of acres of juniper woodlands are cleared annually by landowners and land managers to improve rangeland health and reduce competition in mixed conifer stands. Because of the high costs of juniper removal, landowners and land managers are interested in identifying economically and technically feasible products and markets that will help offset the costs of management. Economic development organizations and wood products companies are also interested in this issue because western juniper utilization and conversion processing activities would likely occur in depressed rural economics, where large numbers of forest products industry jobs have been lost over the last 10 years (Swan 2001).

Because of the appearance and natural durability of western juniper (Morrell et al. 1999), two potential market segments were identified for further investigation in the early 1990s: exterior siding and decking (Swan and Connolly 1998). In the work reported here, we examine the results of an outdoor study on the performance of western juniper lumber and particleboard finished with a variety of paints and stains.

Materials and methods

Outdoor exposure studies using western juniper lumber and particleboard made from western juniper furnish were designed to evaluate the performance of finishes applied to these substrates and the durability of this species in siding and decking applications. Specimens were exposed vertically to simulate siding applications and horizontally to simulate decking applications. The back side of the vertically installed boards was protected with a tarp. For the lumber, two surface profiles were prepared: a saw-textured surface (using a bandsaw) and a planed surface. The objectives of our study were to evaluate the performance of finishes on smooth-planed and saw-textured lumber and particleboard, substrate stability (resistance to checking and warping), aboveground durability, and susceptibility to discoloration and mildew growth.

Lumber

The lumber was dried in two ways. Half the boards were air-dried to a moisture content (MC) below 20 percent; the other half were kiln-dried to the same MC level. The boards were then conditioned to 12 percent MC before finishing.

Using boards from each of these two drying methods, three replicates were used for the vertical exposure (siding application) and three replicates for the horizontal exposure (decking application). The predominately flat-grained boards were 1 inch by 6 inches by 4 feet long (25 mm by 150 mm by 1.3 m long) and had numerous knots, holes, and residual bark. Be-

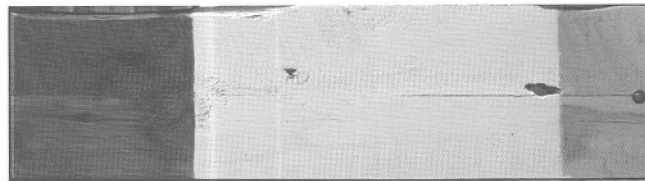


Figure 1. — Saw-textured and smooth-planed surfaces of vertically exposed lumber at test site near Madison, Wisconsin.

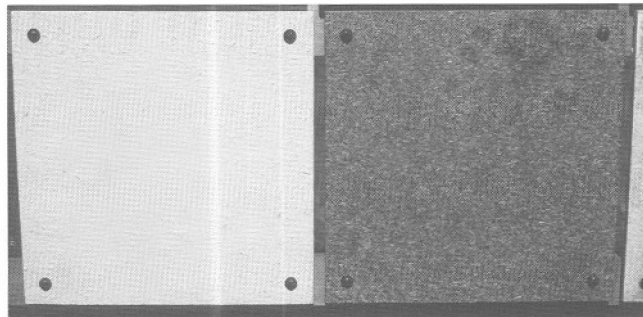


Figure 2. — Particleboard panels at test site near Madison, Wisconsin. Left, finished with two-coat paint system; right, unfinished.

fore the finish was applied, loose knots were removed and a carving tool was used to remove bark and debris from the holes. One surface of the boards was saw textured using a band saw. The boards were then run through a jointer to smooth half of this surface. Each of the resulting boards had both a saw-textured and smooth-planed surface (Fig. 1).

Particleboard

The furnish for the particleboard was obtained from two sources: slabs cut from logs and trim cut from cants (referred to as slab and trim, respectively, in some tables and figures). The only difference between slab and trim was bark content. The furnish from slabs contained about 13 percent bark residue and that from trim about 9 percent. The furnish was prepared by hammermilling wood to less than 3/8 inch (9 mm), then screening with 20 mesh to remove fines. The boards were prepared using 8 percent phenol-formaldehyde resin (GP 2341) and pressed at 381°F (194°C) for 10 minutes. Panels were prepared using a 12- by 12-inch (300- by 300-mm) press, then trimmed to 9.5 by 9.5 inches (240 by 240 mm). Panels were about 1 inch (25 mm) thick (Fig. 2).

Finishes

The finishes are described in Table 1. For the vertical exposure (siding application), all six methods (five finishes and the control) were used; for the horizontal exposure (decking application), only the penetrating finishes were used (finishes 2, 3, and 4, plus the control). The solid-color stain and the acrylic latex paints were not formulated for deck use. For the deck application, finishes 2, 3, and 4 were reapplied after 3 years.

The finishes used on the particleboard are listed in Table 2. The particleboard was finished with two-coat systems.

Methods

Finishes were brush-applied to the substrates under ambient laboratory conditions. The amount of each finish applied to substrates was measured so the coverage could be calculated.

Table 1. — Finish description, colors, and solids content for lumber.^a

Finish	Description	Color	Solids content (%)	Coverage	
				Saw-textured ----- (ft ² /gal [m ² /L]) -----	Planed
1	Control, no finish		--	--	--
2	Penetrating clear wood finish (solventborne)	Clear	61.3	210 [5.2]	420 [10.3]
3	Penetrating toned finish (solventborne)	Light brown	44.6	235 [5.8]	515 [12.6]
4	Oil-based semitransparent stain (solventborne)	Cedar brown	77.7	260 [6.4]	500 [12.3]
5	Acrylic latex solid-color stain (waterborne)	White	46.6	300 [7.4]	555 [13.6]
6	Acrylic latex wood primer (waterborne) (first coat)	White	51.6	255 [6.3]	465 [11.4]
	Acrylic latex flat top-coat (waterborne) (second coat)	White	51.6	635 [15.6]	820 [20.1]

^aSolids contents were determined using ASTM D 2832-83.

Table 2. — Finish description, colors, and solids content for particleboard.^a

Finish	Description	Color	Solids content (%)	Coverage			
				Slab		Trim	
				1st coat	2nd coat	1st coat	2nd coat
				----- (ft ² /gal [m ² /L]) -----			
1	Control, no finish		--	--	--	--	--
2	Oil-based solid-color stain (two coats)	White	76.8	210 [5.2]	445 [10.9]	190 [4.6]	415 [10.2]
3	Latex-based solid-color stain (two coats)	White	46.6	350 [8.6]	470 [11.5]	315 [7.7]	450 [11.0]
4	Oil-based alkyd primer (solventborne)	Gray	78.7	235 [5.8]	--	235 [5.8]	--
	Acrylic-latex top-coat (waterborne)	White	53.0	315 [7.7]	--	315 [7.7]	--
5	Latex-based primer (waterborne)	Gray	51.6	365 [8.9]	--	275 [6.7]	--
	Acrylic latex top-coat (waterborne)	White	51.9	470 [11.5]	--	465 [11.4]	--

^aSolids contents were determined using ASTM 2832-83.

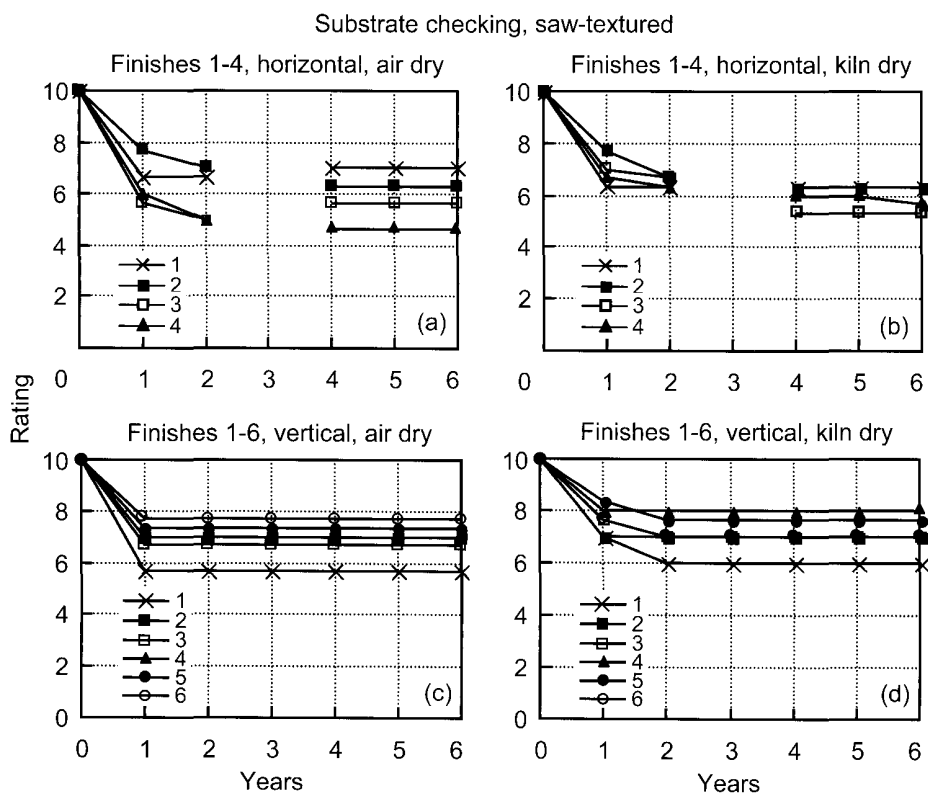


Figure 3. — Substrate checking of saw-textured air-dried and kiln-dried lumber in vertical (90 degrees) and horizontal (0 degrees) exposures. Finish 1 = no finish; 2 = penetrating clearwood finish; 3 = penetrating toned finish; 4 = oil-based semitransparent stain; 5 = acrylic latex solid-color stain; 6 = acrylic latex wood primer/acrylic latex flat top-coat.

An area on each board was left unfinished as a control. Finishes were applied to the front (exposed) face and to the edges adjacent to the front face. The back side was left unfinished, but the ends of the board were sealed with one coat of latex paint. The edges of the particleboard were painted with the same finish as used on the front face and the back face was left unfinished. Some panels were left unfinished (controls).

All lumber and particleboard specimens were exposed at the Forest Products Laboratory exposure site 3 miles (5 km) west of Madison, Wisconsin. The lumber for the simulated siding exposure and the particleboard were fastened to a vertical test fence facing south; the lumber for the simulated deck exposure was placed on a horizontal test deck. All lumber and particleboard panels were attached using stainless steel fasteners.

Specimens were evaluated using American Society for Testing and Materials (ASTM) visual grading evaluations for finish checking, flaking, and mildew growth using a

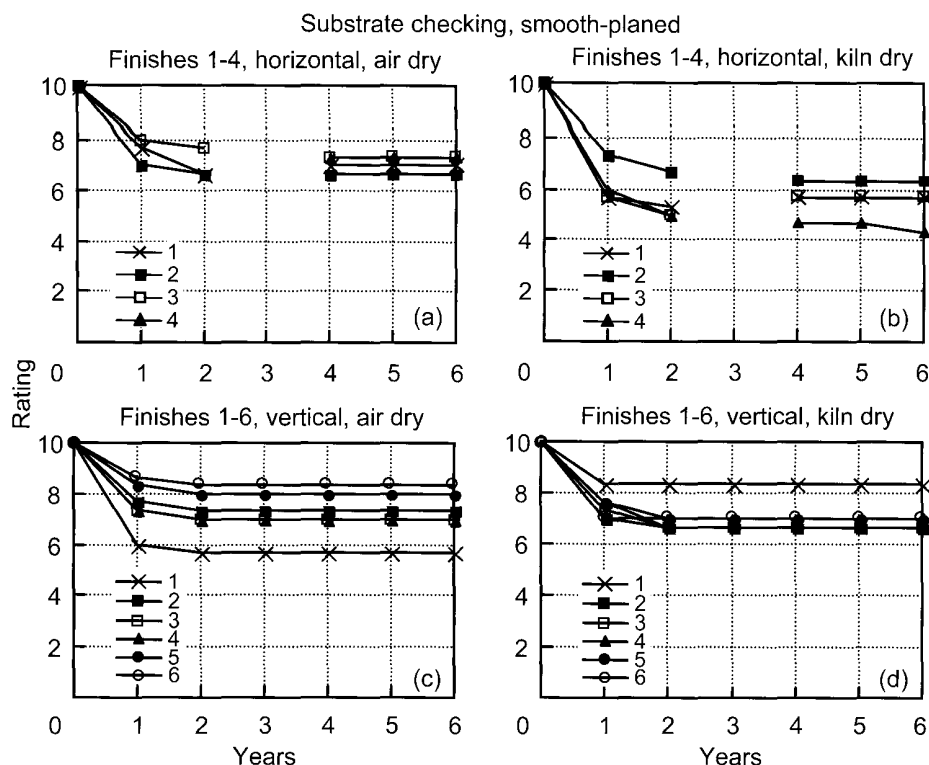


Figure 4. — Substrate checking of smooth-planed air-dried and kiln-dried lumber. Finish 1 = no finish; 2 = penetrating clearwood finish; 3 = penetrating toned finish; 4 = oil-based semitransparent stain; 5 = acrylic latex solid-color stain; 6 = acrylic latex wood primer/ acrylic latex flat top-coat.

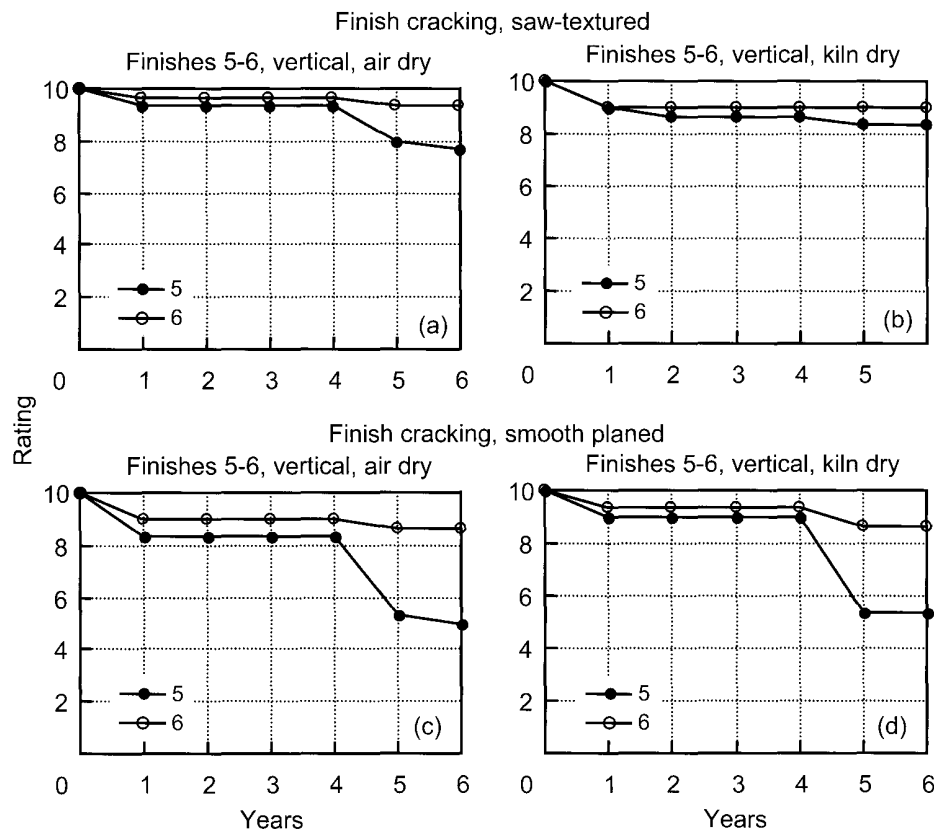


Figure 5. — Finish cracking on smooth-planed and saw-textured air- and kiln-dried lumber. Finish 5 = acrylic latex solid-color stain; 6 = acrylic latex wood primer/ acrylic latex flat top-coat.

scale of 1 to 10 (10 indicating no degradation) (ASTM 1991). A rating of 5 indicates the point at which the board or panel should be refinished. The time to a rating of 5 indicates the service life of the finish. The surface of the particleboard was also evaluated for loosening of particles, using a scale of 1 to 10 (10 indicating no degradation).

Statistical analysis

An analysis of variance (ANOVA) was done using SAS Institute statistical software (SAS 1999). The analysis was done on the basis of a split-plot experimental design with orientation (horizontal or vertical), surface (saw-textured or planed), and drying (air or kiln) as whole-plot treatments and finishes as split-plot treatments. The analysis was done only for the results from the evaluation after 6 years. In all cases, the level of significance was 0.05 or higher.

Results and discussion

Lumber

Substrate checking. — Evaluation of the saw-textured portion of western juniper (both air-dried and kiln-dried) for both the vertical (90 degrees) and horizontal (0 degrees) exposures showed rather severe substrate checking within 1 year of exposure (Fig. 3). However, not much change occurred after the first year. In Figures 3a and 3b, the break in the line at 3 years indicates the point at which the boards on the deck (horizontal exposure) were refinished. For the horizontal exposure, the finishes had little effect on substrate checking, neither with the original application nor after refinishing (Figs. 3a, 3b). For both horizontally and vertically exposed boards, all finishes performed about the same in protecting the substrate against checking, but the vertically exposed specimens apparently had slightly less checking (Figs. 3c, 3d). We would expect slightly less checking for vertically exposed boards because of decreased sun and water exposure. There appears to be no difference between the air-dried and kiln-dried boards.

Evaluation of the smooth-planed portion of western juniper (both air-dried and kiln-dried) for both vertical and horizontal exposures also

Mildew, saw-textured

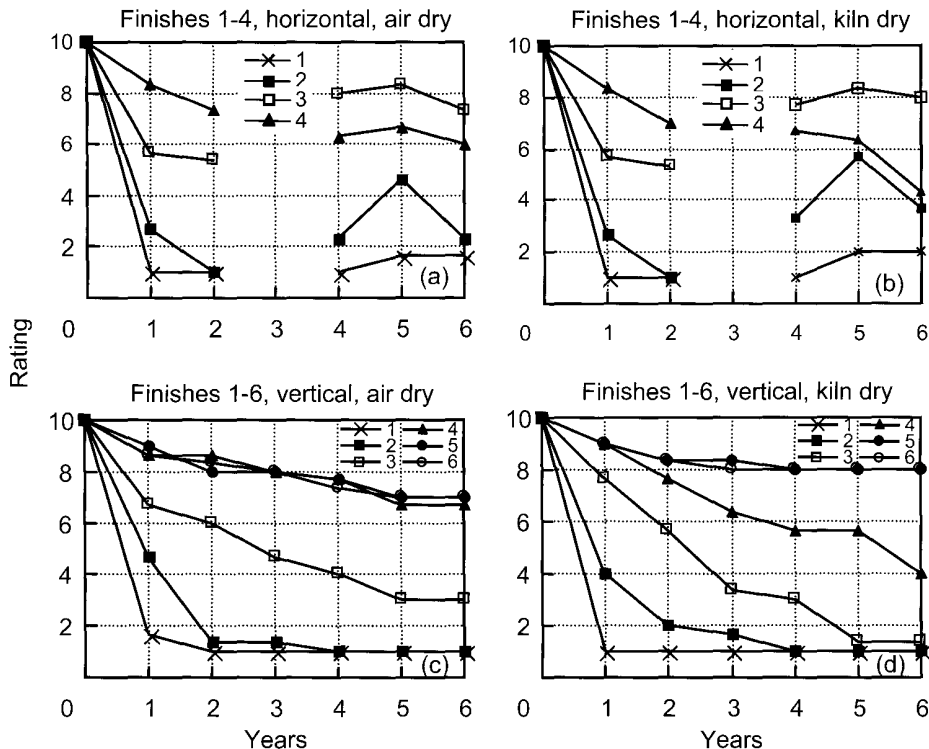


Figure 6. — Mildew evaluation of saw-textured air-dried and kiln-dried lumber. Finish 1 = no finish; 2 = penetrating clearwood finish; 3 = penetrating toned finish; 4 = oil-based semitransparent stain; 5 = acrylic latex solid-color stain; 6 = acrylic latex wood primer/acrylic latex flat top-coat.

shows rather severe substrate checking within 1 year of exposure (Fig. 4). There appears to be a slight difference between the air-dried and kiln-dried boards in the horizontal exposure (Figs. 4a, 4b).

The results were rather puzzling for the saw-textured and planed boards for various finishes. The performance of the unfinished boards (Figs. 3a, 3b; Fig 4d) appears to be better than that of the finished boards. This was contrary to our expectation. However, the ANOVA showed no significant difference between the experimental variables. There was no effect for unfinished lumber compared with different finishes. There was no effect of exposure angle; both horizontal and vertical exposures were the same for saw-textured and planed surfaces. Note that in all cases, checking was initiated within the first 2 years of exposure only and was constant after that.

Paint cracking. — Only the film-forming finishes were evaluated for cracking (Fig. 5): acrylic latex solid-color stain (finish 5, one coat) and acrylic latex wood primer/acrylic latex flat top-coat (finish 6, two-coat system). The results with these finishes were similar to results obtained with similar wood species over many years of outdoor exposure. The two-coat latex paint system was still in excellent condition after 6 years (rating of about 9) on both the smooth-planed and saw-textured surfaces. On the saw-textured surfaces, even the single coat of solid-color stain was performing well after 6 years (rating of about 8, Figs. 5a, 5b). However, on the smooth portion of the boards, the finish began to show substantial cracking after about 5 years (Figs. 5c, 5d). Single-coat applications of solid-color stains often show finish cracking after rather short outdoor exposure. The performance on western juniper is slightly better than that on some other species, but typical of what would be expected for other fine-grained low-density wood species such as western redcedar. There was no apparent difference between the air-dried and kiln-dried lumber. The significance level was 0.0003 for the two surface preparations (saw-textured and planed) and 0.0002 for the different finish systems.

Mildew, smooth-planed

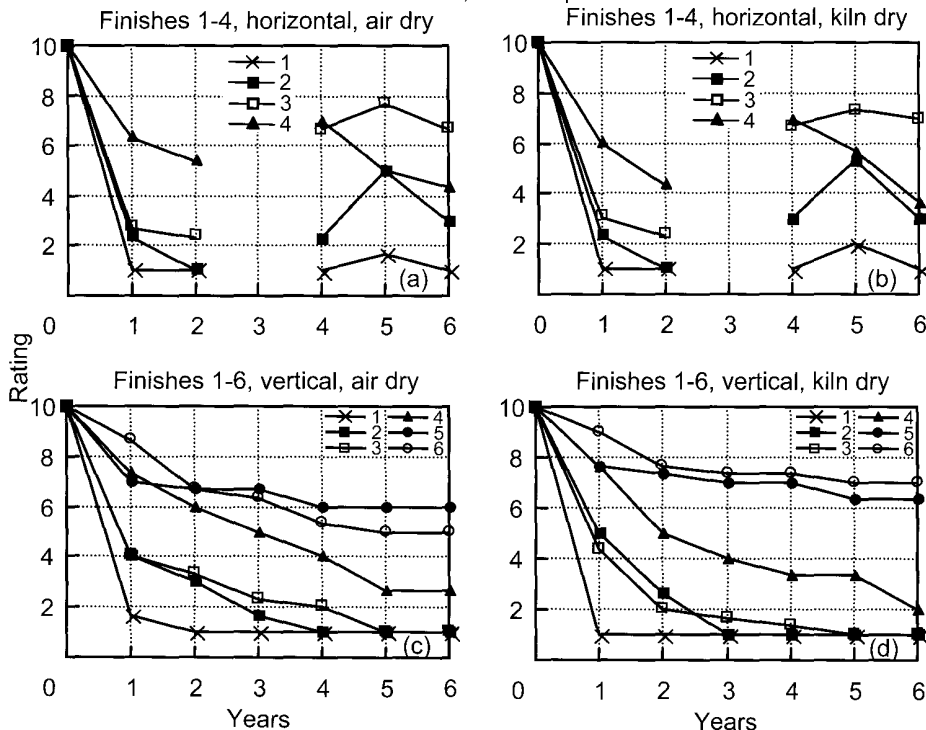


Figure 7. — Mildew evaluation of smooth-planed air-dried and kiln-dried lumber. See the Figure 6 caption for a description of the finishes.

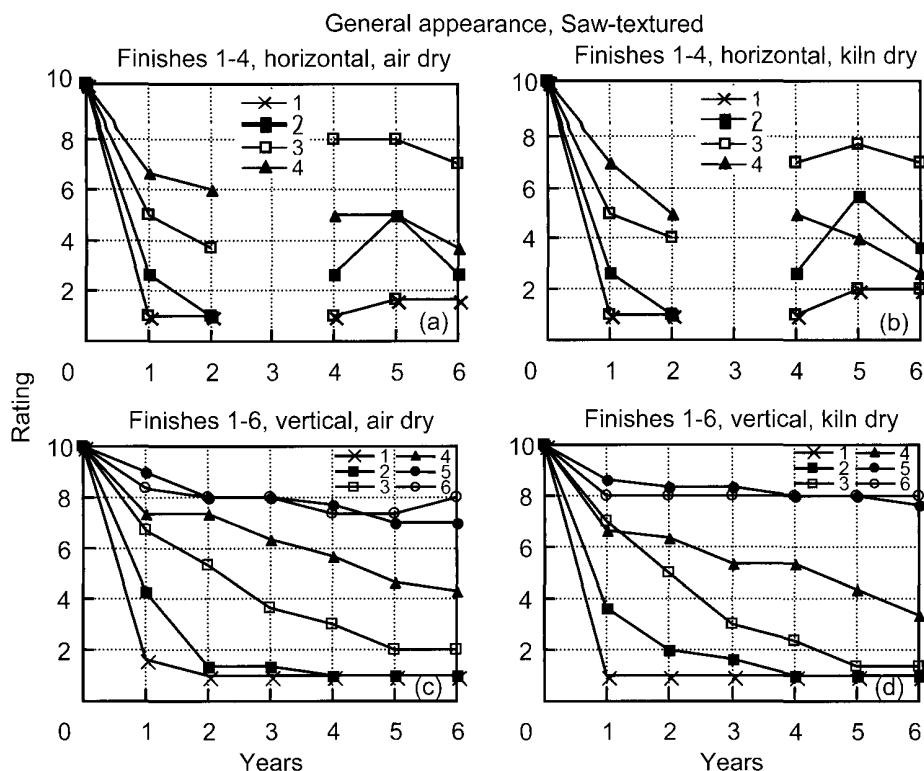


Figure 8. — General appearance of saw-textured air-dried and kiln-dried lumber, Finish 1 = no finish; 2 = penetrating clearwood finish; 3 = penetrating toned finish; 4 = oil-based semitransparent stain; 5 = acrylic latex solid-color stain; 6 = acrylic latex wood primer/ acrylic latex flat top-coat.

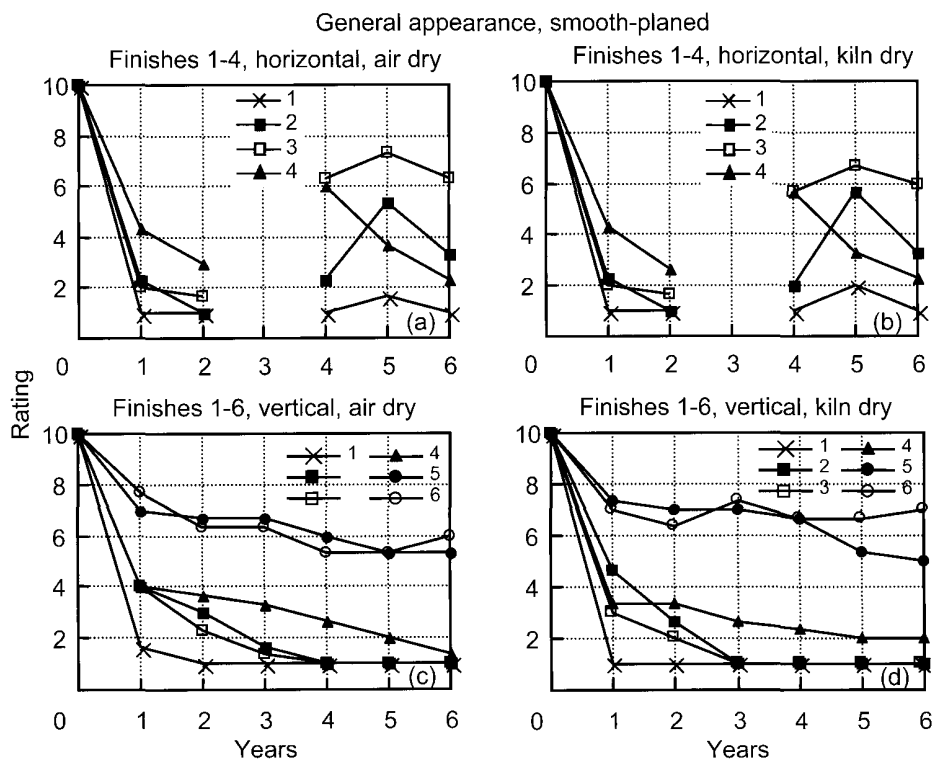


Figure 9. — General appearance of smooth-planed air-dried and kiln-dried lumber. See the Figure 8 caption for a description of the finishes.

Mildew. — Mildew growth was about the same on both the saw-textured and smooth-planed lumber (Figs. 6 and 7). Within 1 year, mildew growth was quite severe on the unfinished boards, with no apparent differences between saw-textured and smooth-planed lumber or between air-dried and kiln-dried lumber. All finishes improved resistance to mildew to some degree, but the performance of the clear finishes – the penetrating clearwood finish (finish 2) and the penetrating toned finish (finish 3) – dropped to below 5 after 1 to 2 years. Finishes performed slightly better on saw-textured surfaces because these surfaces absorbed more finish. The statistical analysis was complicated by interaction among the experimental variables, but supported the difference in finish performance where the difference was greater than 1.5 units.

General appearance. — The evaluation of general appearance is often controlled by the amount of mildew growth, which can be seen by comparing the mildew results (Figs. 6 and 7) with the general appearance results (Figs. 8 and 9). The penetrating clear finishes lasted only 1 to 2 years, even on saw-textured lumber, whereas the film-forming finishes – acrylic latex solid-color stain (one-coat system) and acrylic latex wood primer/acrylic latex flat top-coat (two-coat system) – were still in good condition on saw-textured lumber and in fair condition on smooth-planed lumber after 6 years. The oil-based semitransparent stain lasted only 1 year on smooth-planed lumber but about 5 years on saw-textured lumber (Figs. 8c, 8d, 9c, 9d). There were no apparent differences between air-dried and kiln-dried lumber. The statistical analysis showed significant effects for some finishes for exposure angle and surface preparation, for example, finish 3 (Figs. 8a, 8c). As for the results from the mildew evaluations, the results for general appearance were significant if the data differed by more than 1.5 units in the figures.

In summary, the performance of finishes on western juniper lumber was fairly consistent with the performance of finishes on other dimen-

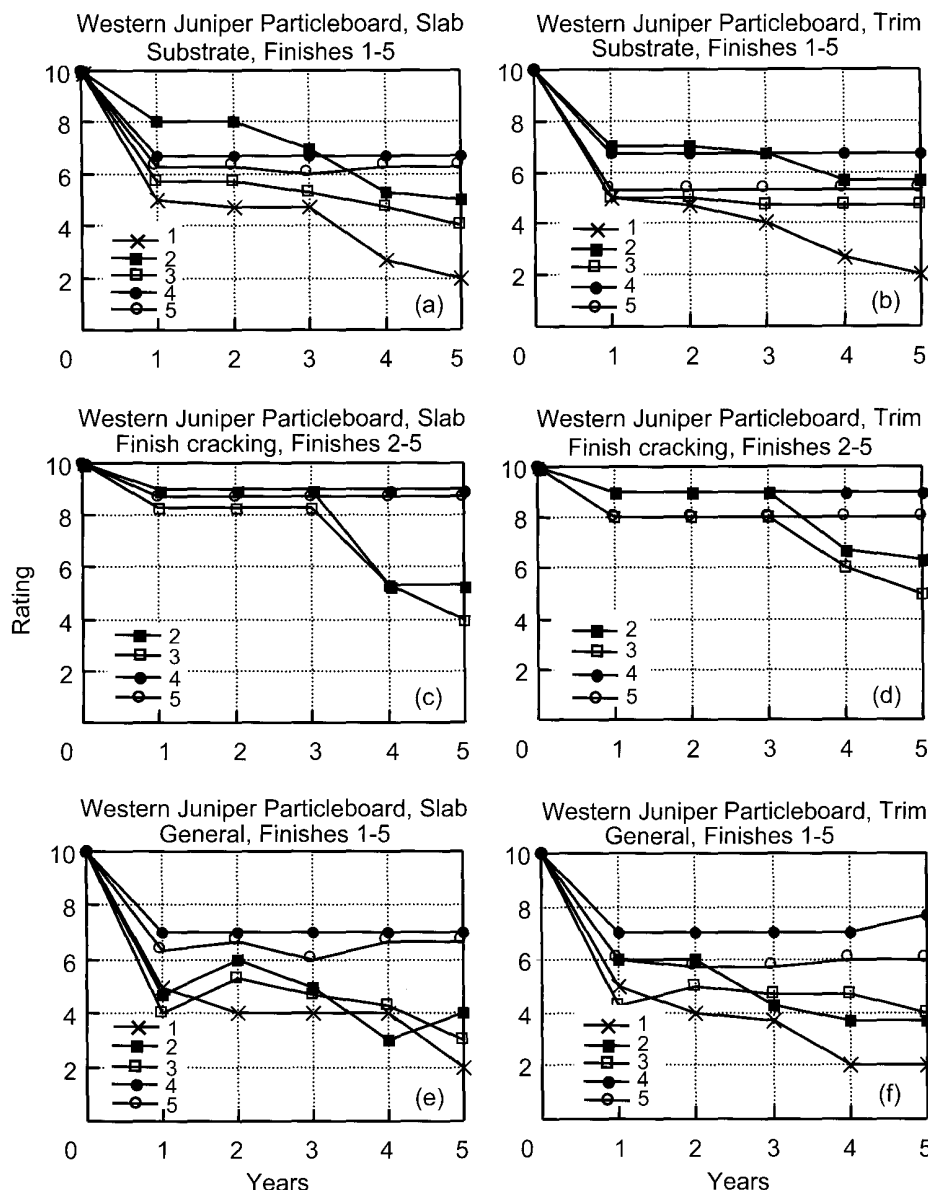


Figure 10. — Evaluation of particleboard substrate and finishes. Slabs (left side of figure) contained 13 percent bark residue; trim (right side of figure) contained 9 percent bark residue. (a) and (b) show substrate deterioration (loosening and telegraphing of surface particles); (c) and (d) show finish cracking; (e) and (f) show general appearance. Finish 1 = no finish; 2 = oil-based solid-color stain; 3 = latex-based solid-color stain; 4 = oil-based alkyd primer and acrylic-latex top-coat; 5 = latex-based primer and acrylic latex top-coat.

Table 3. — ANOVA results for performance of finishes on western juniper particleboard after 6 years of exposure.

Evaluation	Finish (mean rating) ^a				
	4	5	2	3	1
Substrate checking	6.7	5.8	5.3	4.3	2.0
Finish cracking	9.0	8.3	5.8	4.5	--
General	7.3	6.3	3.8	3.5	2.0

^aMeans connected by underscore are not significantly different.

sionally stable wood species that contain a large amount of heartwood extractives: the lumber was fairly prone to mildew growth; clear penetrating finishes lasted about 1 to 2 years; semitransparent finishes performed well on only saw-textured lumber; and two-coat film-forming finishes gave excellent performance on both smooth-planed and saw-textured lumber. In general, there were no apparent differences between air-dried and kiln-dried lumber. With the finishes used in this study, no problems were observed with drying or adhesion of the finishes.

Particleboard

The surface of the particleboard showed severe loosening and telegraphing of particles within 1 year of exposure (Figs. 10a, 10b). All the finishes decreased these problems to some degree, but in all cases the average performance rating fell within the first year. The two paint systems (finishes 4 and 5) provided slightly more protection than did the other finishes. The performance of particleboard made from slabs and trim was about the same.

The paint systems performed much better on the particleboard than did the solid-color stains (Figs. 10c, 10d). The paint showed only slight cracking after 5 years of exposure, whereas the solid-color stains began to show severe cracking after only 3 years. No differences were apparent for the two types of particleboard.

The general appearance evaluations were poor because the finishes had discolored (Figs. 10e, 10f). Bleed-through of extractives occurred within 1 year of exposure. The finishes also showed mildew growth. The ratings for the two-coat paint systems (finishes 4 and 5) dropped to about 7 within 1 year but remained approximately constant after that. Both paint systems were in fair condition after 5 years, whereas the solid-color stains were in need of refinishing (evaluation of 5 or less) after only 1 year. In each case, the oil-based primer performed well, probably because of its water resistance.

The statistical analysis showed that particleboard performance depended on the type of finish. The results of the ANOVA are shown in Table 3. We recognize that the ANOVA lacks power for the small sample sizes used in this study, but the analysis is included to augment the practical differences, or lack of differences, observed in the figures.

Durability

Finished and unfinished western juniper lumber was inspected for signs of decay or insect attack after 10 years of exposure. Although the boards experienced weathering, no obvious signs of decay or insect attack were apparent on finished or unfinished lumber.

Finished and unfinished particleboard was severely degraded after 9 years of exposure. Considerable thickness swell and loss of particle adhesion were apparent.

Conclusions

The performance of finishes on western juniper lumber was similar to that on other wood species with high amounts of extractives that have been tested in a similar fashion near Madison, Wisconsin:

- Two-coat, film-forming finishes gave excellent performance on both smooth-planed and saw-textured lumber.
- Semitransparent finishes performed well only on saw-textured lumber.
- Clear penetrating finishes lasted only 1 to 2 years.
- The wood was prone to mildew growth, especially the unfinished lumber.

In general, there were no apparent differences between air-dried and kiln-dried lumber. No problems were observed with drying, curing, or adhesion of the finish. If the desired grades are available in sufficient quantities, western juniper lumber should perform well as siding, as decking, and possibly for other outdoor products. As with other wood products, decking or siding must be properly finished and maintained. For particleboard, the difference in amount of bark did not affect the performance of the finish. Film-forming finishes, particularly

multi-coat paint systems, performed well on particleboard during the early years of exposure, but severe degradation occurred after 9 years of exposure.

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