Gluing Southeast Asian Hardwood Veneers to Douglas Fir

Summary Report

by

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CONCLUSIONS

Ten cycles of the standard boil method (10 days) or 40 cycles of the automatic boil method (2 days) detected nondurable exterior plywood bonds between the imported hardwood and Douglas fir. Both aging methods correlated well with plywood performance after 12 months of outdoor exposure if specimens were sheared while wet and wood failure was estimated. A 16-cycle boil method (2 days) was developed that also detected nondurable exterior bonds and was accomplished manually. The following tests, as used in this study, were not sufficiently sensitive to detect some nondurable exterior plywood bonds that included Southeast Asian hardwoods: vacuum/pressure soak, 2-cycle boil, 2,400 hours in a weatherometer, or wet/dry cycling. Breaking load did not correlate with exterior bond performance of plywood specimens (cross-laminated) with any of these accelerated aging methods.

Keruing-faced plywood was as durable as red meranti plywood when made with adhesive B, a low-molecular-weight resin with 40 percent solids, which is similar to that used in the 1940's for exterior plywood. This same resin resulted in marginal bonds with red balau, but poor bonds with kapur veneer. Other adhesives resulted in an erratic performance with keruing and a poor performance with kapur and red balau.

Shorea kalunti, a yellow lauan, and *Parashorea lucida*, a red meranti, resulted in poor bonds with adhesive B, even at optimum gluing conditions. All other veneers examined—Philippine apitong plus yellow and white lauans—had excellent adhesive bonds with adhesive B.

OBJECTIVES

Determine which aging method best detects unsatisfactory gluebonds in exterior plywood made with Southeast Asian hardwood veneers: vacuum/pressure soak (PS 1-74); standard boil (PS 1-74) for 2, 5, 10, or 25 cycles; automatic boil (ASTM D3434) for 20, 40, 100, or 200 cycles; weatherometer (ASTM G23-69); or wet/dry cycling.

Determine the durability of exterior plywood made with keruing face veneers at optimum production conditions.

Determine whether sanding or alkali extraction can counteract excessive concentrations of extractives on the surface of keruing veneer.

Determine whether yellow lauans and merantis or Philippine apitongs are difficult to glue with phenolic plywood adhesives.

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*Details of this study may be obtained from Wilkie, G. 1976. Determining Appropriate Accelerated Aging Tests for Keruing Plywood. M.S. Thesis, Oregon State University, Corvallis. 89 p., or from the Cooperator at the address on the cover.

PROCEDURES

Veneers for this study were peeled and dried in Southeast Asia from logs of confirmed identification. Plywood panels (4 feet x 4 feet, 3 ply, 3/8 inch thick, with hardwood face and back and Douglas fir core) were made with three adhesives according to manufacturer's instructions for adhesive mix and spreads, with assembly times of 5, 20, and 45 minutes and a press time of 5-1/2 minutes at 300°F. See Table 1 for description of adhesives. Matched samples of the plywood were subjected to the tests described in Table 2, or 12 months of outdoor exposure before vacuum/pressure soak. Amount of delamination was measured on the samples from weatherometer and wet/dry cycling. For all other aging methods, the wet specimens were sheared, and the breaking loads and wood failures were analyzed statistically.

RESULTS

Selection of Best Aging Method

The best aging method was considered to be the one that caused the least amount of wood failure when samples were tested, and correlated well with test performance after 12 months of outdoor exposure. Additional samples

TABLE 1. Characteristics of phenolic resins used in adhesives.

	Adhesives		
Characteristic	A	B	C
Phenolic solids, %	45.0	40.0	56.0
pH	11.2	10.5	9.8
Molecular weight	Moderate	Low	Low and moderate combined
Viscosity, centipoise	1,100	800	700

TABLE 2. Accelerated aging tests.

Test	Conditions
Vacuum/pressure soak	Submerged in water at 70°F for 30 minutes at vacuum of 25 inches of mercury, then 30 minutes at 70 psi pressure.
Standard boil	2, 5, 10, or 25 cycles of samples submerged in boiling water for 4 hours, then dried at 145°F for 20 hours.
Automatic boil	20, 40, 100, or 200 cycles of samples submerged in boiling water for 10 minutes, chilled in ambient air for 3.75 minutes, and dried at 225°F for 57 minutes.
Weatherometer	1,200 cycles of continuous radiation from carbon arcs with 18-minute water spray out of every 2 hours.
Wet/dry	Same cycle as weatherometer with steam heat rather than carbon arc radiation.

are being exposed to exterior conditions for as long as 6 years to allow confirmation of these results. The average percentage of wood failure after shearing samples exposed outdoors for 12 months and then vacuum/pressure soaked is given in Table 3, along with the performance of samples aged by wet/dry cycling and weatherometer. Each species is identified in the tables by a number. The matching performances after the standard boil, automatic boil, or vacuum/pressure soak for aging are reported in Figures 1, 2 and 3.

When vacuum/pressure soaked and sheared after 12 months of outdoor exposure, many samples of red balau and kapur were low in wood failure—30 to 50 percent—and some samples of keruing were near or below 85-percent wood failure. Before outdoor exposure, these poor bonds were not detected consistently by shearing samples after vacuum/pressure soak or two cycles of standard boil. Likewise, delamination of samples aged by the weatherometer or wet/dry cycle was not sufficient to indicate that these bonds were poor.

The poor bonds appearing in panels after 12 months of outdoor exposure could be predicted by five or more cycles of standard boil, or by 20 or more cycles of automatic boil. The correlation coefficients, R, between these accelerated aging methods and outdoor exposure were about 0.9. Because variability was minimized in this study, to detect poor adhesive bonds from commercial production, we recommend extending the standard boil to at least 10 cycles and the automatic boil to 40 cycles.

TABLE 3. Area intact or wood failure in samples aged by the weatherometer, wet/dry cycling, and outdoor exposure.

Species		Area intact after 2,400 hours of weatherometer			Area intact after 2,400 hours of wet/dry cycling			Wood failure after 12 months of outdoor exposure[1]		
		Adhesive			Adhesive			Adhesive		
		A	B	C	A	B	C	A	B	C
		%	%	%	%	%	%	%	%	%
Douglas-fir	00	100	100	100	100	100	100	99	71	87
Red meranti	21	100	100	100	100	100	100	96	97	92
Red balau	4	100	100	91	100	100	100	74	88	71
Keruing from West Malaysia	28	100	–	–	100	–	–	98	–	–
	16	100	–	–	100	–	–	75	–	–
	27	100	100	100	100	100	100	85	100	80
	26	97	–	–	99	–	–	37	–	–
	18	99	–	–	100	–	–	89	–	–
	23	100	100	100	100	100	100	96	97	80
Keruing from Sumatra	12	100	–	–	100	–	–	96	–	–
	11	100	–	–	100	–	–	95	–	–
	10	99	–	–	100	–	–	68	–	–
	13	100	–	–	100	–	–	97	–	–
	14	100	–	–	100	–	–	87	–	–
	15	100	100	98	100	100	100	75	96	82
Kapur	20	98	98	97	100	100	100	57	34	55
	22	79	78	88	97	99	100	36	41	25

[1]After outdoor exposure, plywood panels were cut into samples, vacuum/pressure soaked and sheared.

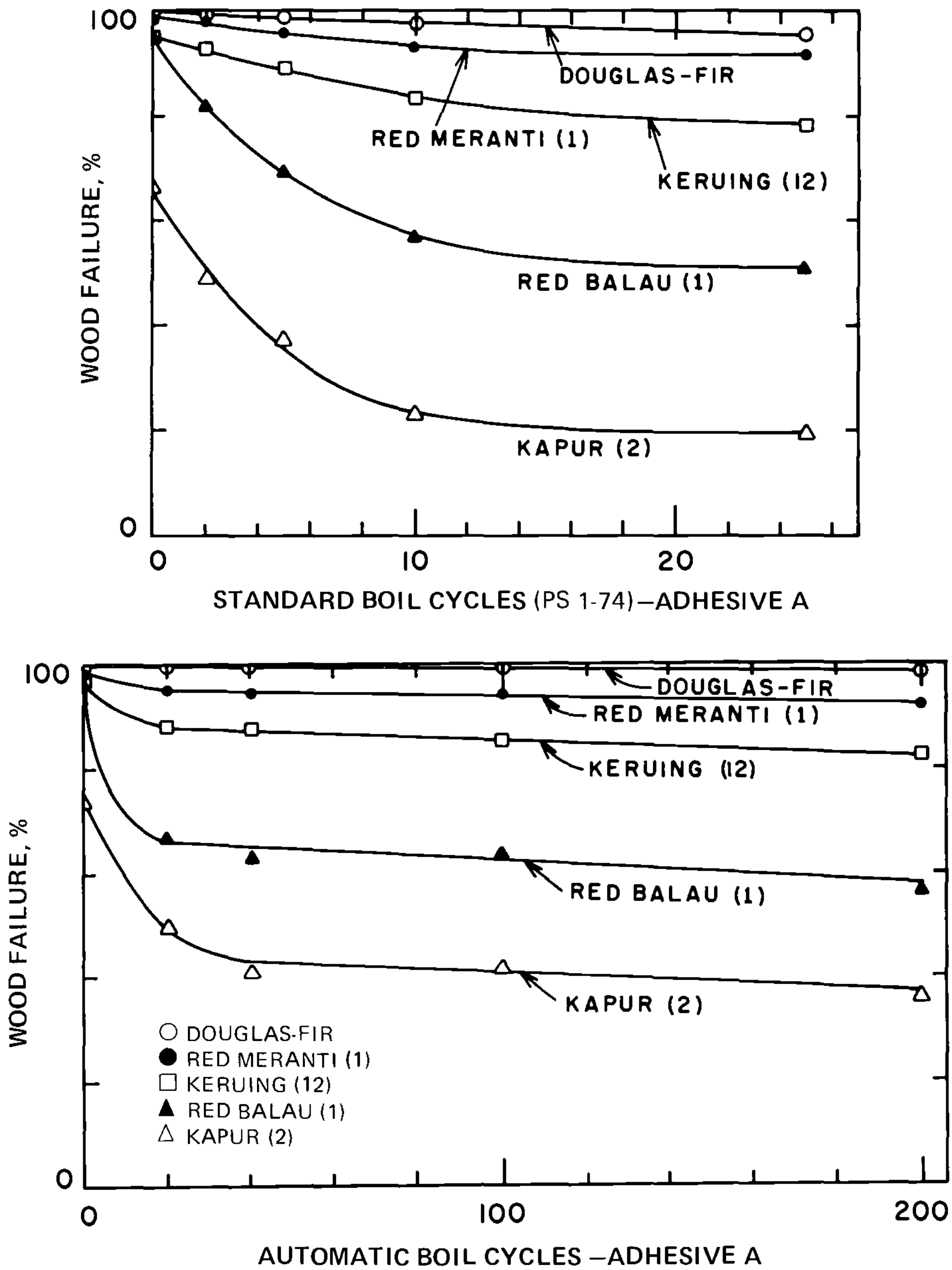


FIGURE 1. Wood failures for standard and automatic boil cycle methods—adhesive A. Values reported at zero cycles are for vacuum/pressure soak. In parentheses is the number of species averaged. Each data point is an average of 72 wood-failure specimens for each species.

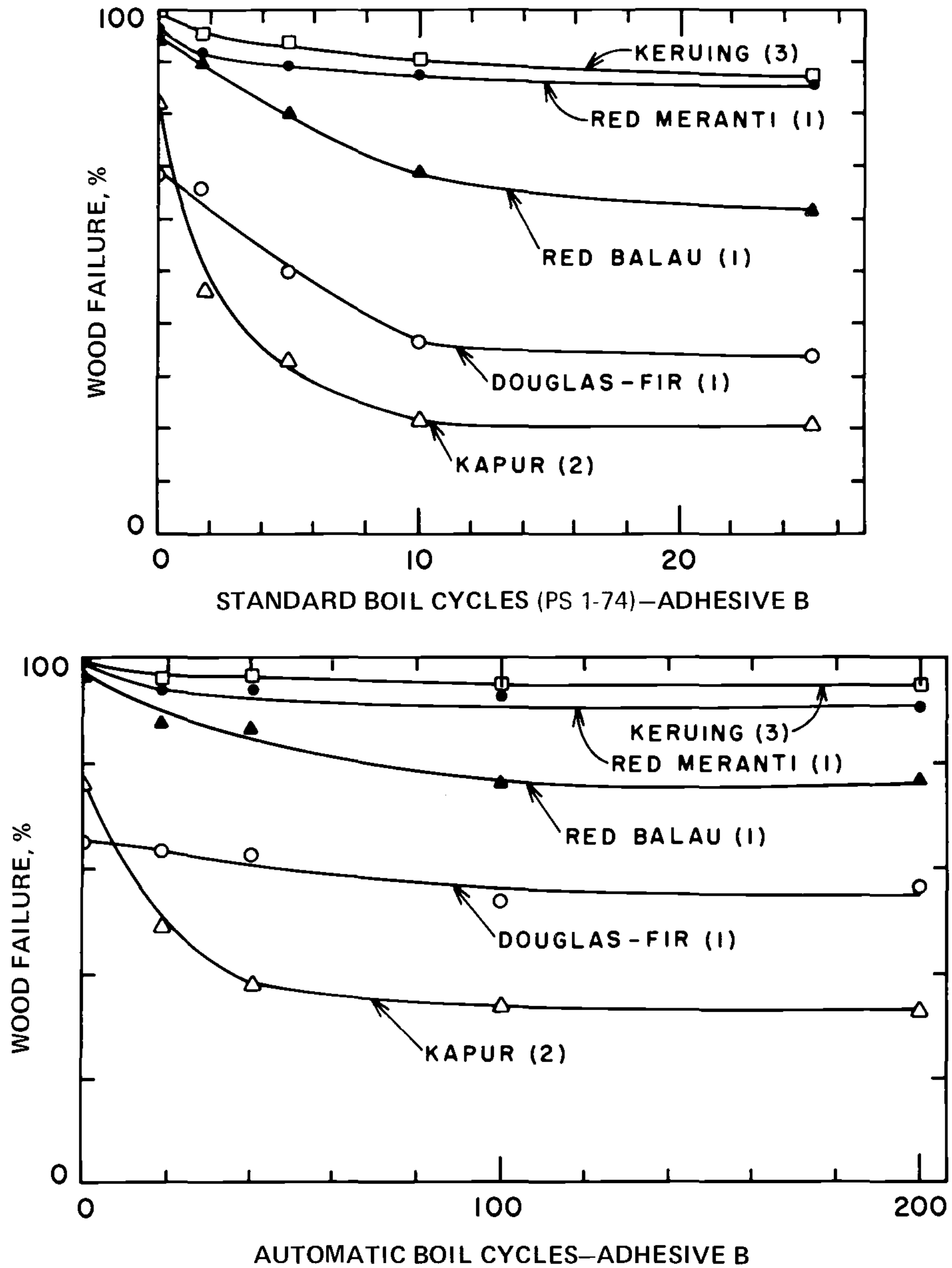
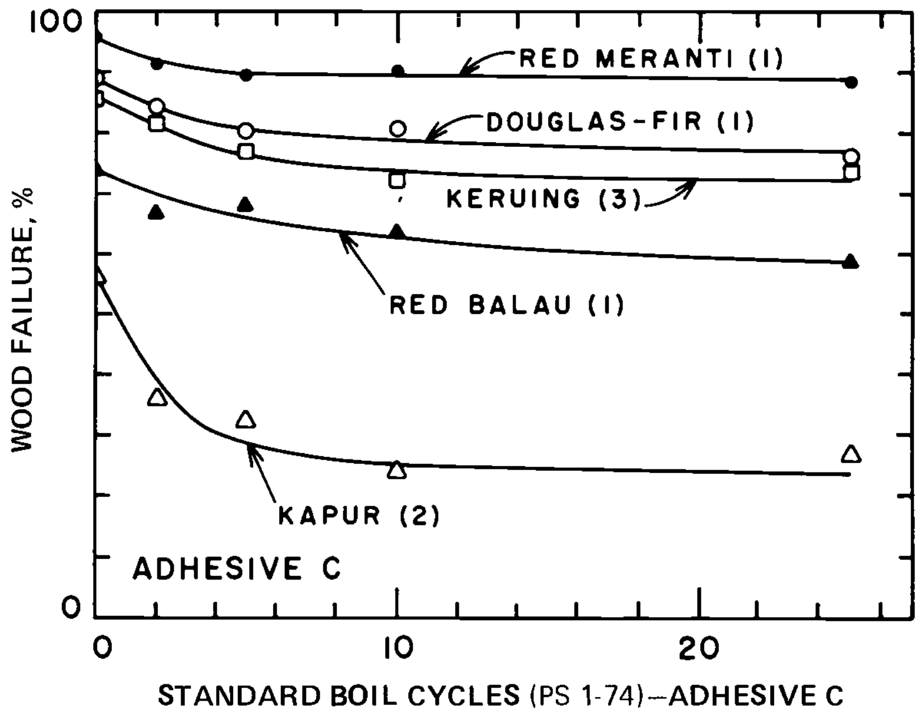


FIGURE 2. Wood failures for standard and automatic boil cycle methods—adhesive B. Values reported at zero cycles are for vacuum/pressure soak. In parentheses is the number of species averaged. Each data point is an average of 72 wood-failure specimens for each species. The low values of wood failure for Douglas-fir with adhesive B were caused by accidental wetting of those core veneers.



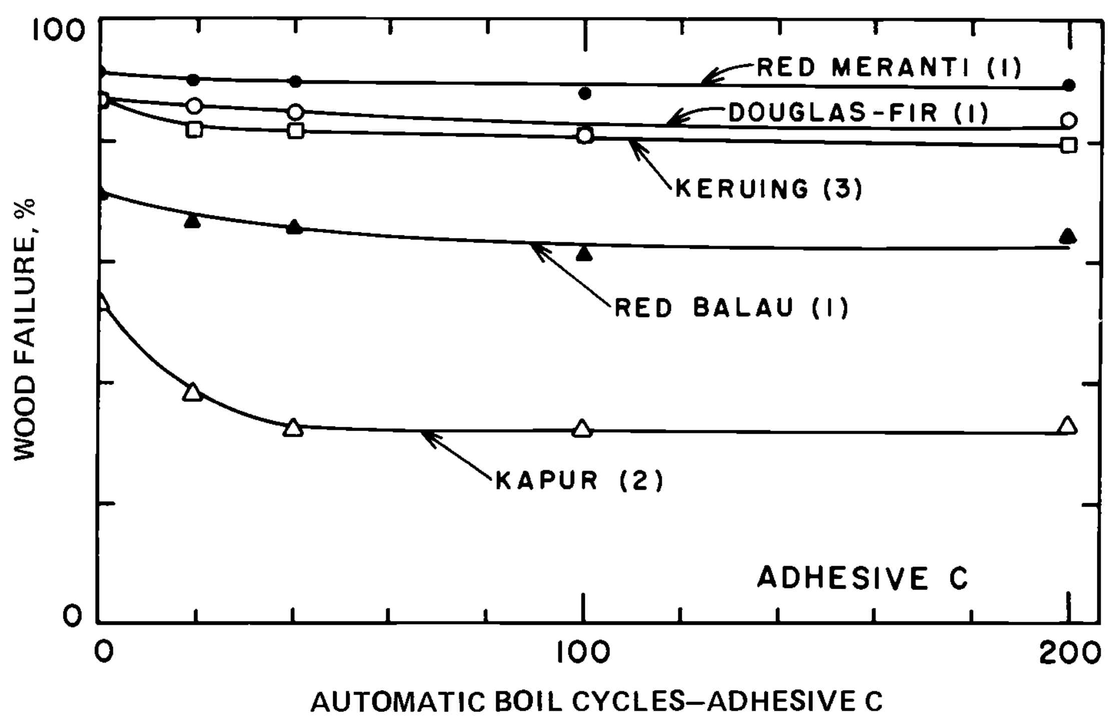


FIGURE 3. **Wood failures for standard and automatic boil cycle methods—adhesive C.** Values reported at zero cycles are for vacuum/pressure soak. In parentheses is the number of species averaged. Each data point is an average of 72 wood-failure specimens for each species.

All factors considered, the 40-cycle automatic-boil test appears to be best for industrial applications. Only 2 days are required, and as many as 2,000 specimens can be aged at a time. The drawback is that the machine to do the aging costs about $30,000. To circumvent such an expenditure when only a few samples are to be tested, we developed a 2-day manual boil cycle that caused nearly the same magnitude of bond degradation as the 40-cycle automatic boil. The procedure is as follows: 7 cycles of 10 minutes in boiling water, 5 minutes in ambient air, 60 minutes in a forced-convection oven at 225°F; one cycle of 10 minutes in boiling water, 5 minutes in ambient air, and overnight in a forced-convection oven at 225°F; repeat these 8 cycles the second day for a total of 16 cycles, vacuum/pressure soak the specimens on the third day, shear while wet, and estimate wood failure with normal procedures. The results of this test are reported in Table 4 for samples glued with adhesive A. The correlation coefficient, R, between these results and outdoor exposure was 0.91.

TABLE 4. Wood failure after 16 cycles of manual boil aging with adhesive A.

Species	Wood failure
	%
4	51
10	54
13	95
15	78
16	71
20	39
21	92
26	29
27	81

Durability of Keruing-Faced Plywood Panels

Keruing seems to respond to type of adhesive more than other species groups included in this study. Table 5 gives a comparison of adhesives A and B for all keruings that occasionally gave poor bonds during the study. Excluded from Table 5 are four species of keruing that glued readily with both adhesives. Note that adhesive B resulted in consistently good bonds, but the performance with adhesive A was sporadic. Neither of these adhesives bonded kapur satisfactorily. Adhesive C was excluded from this comparison because we had difficulty controlling spreads at the recommended rate. Many bonds with adhesive C appeared to have inadequate adhesive and were dried out.

TABLE 5. Wood failure with keruing after 40 cycles of automatic boil aging with adhesives A and B.

Keruing species	Adhesive A: assembly time, min.			Adhesive B: assembly time, min.		
	5	20	45	5	20	45
	%	%	%	%	%	%
10	83	76	62	95	97	99
14	87	91	86	85	97	99
15	87	93	83	97	100	100
16	80	91	84	98	91	98
23	95	98	98	96	98	99
26	48	58	54	92	94	100
27	94	97	98	95	99	99
28	97	100	98	97	100	100
Average	*84*	*88*	*83*	*96*	*97*	*99*

Effect of Veneer Surface Treatment

Sanding and caustic extraction of veneer were examined for their ability to eliminate the erratic bond performance of keruing veneer. Adhesive B was selected for these experiments. This adhesive bonded keruing consistently, however, even without these surface treatments. Thus, the results reported in Table 6 provide no comparison of bond quality as a result of surface treatment. This experiment will be repeated with adhesive A and reported later.

Gluability of Philippine Apitong, Yellow Lauans, and Merantis

We screened several other Southeast Asian hardwoods for gluing difficulty (Table 7), using adhesive B. Only *Shorea kalunti*, a yellow lauan, and *Parashorea lucida*, a red meranti, appeared difficult to glue with adhesive B. The cause of these poor bonds is not known. Note that other yellow and white lauans and the Philippine apitong produced durable adhesive bonds.

TABLE 6. Effect of surface treatment on gluing of keruing with adhesive B; percentage of wood failure.

		Surface treatments																	
		None						1% caustic extraction						Sanding					
		5[1]		20		45		5		20		45		5		20		45	
Species		V/P[2]	Boil[3]	V/P	Boil	V/P	Boil	V/P	Boil	V/P	Boil	V/P	Boil	V/P	Boil	V/P	Boil	V/P	Boil
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Keruing Sumatra	10	92	95	93	97	99	99	91	91	91	96	91	99	91	97	95	91	96	98
	14	97	95	98	97	100	99	100	99	100	99	100	100	98	100	99	100	96	99
	15	98	97	99	100	99	100	99	99	99	100	99	100	97	98	99	100	99	100
Keruing West Malaysia	16	99	98	96	91	94	98	98	99	99	99	95	90	95	95	96	98	96	98
	26	96	92	96	94	99	100	98	95	100	97	98	99	97	89	99	100	100	100
	28	98	97	99	100	100	100	100	100	99	100	99	100	99	100	100	99	100	100

[1]Assembly time, minutes. [2]Vacuum/pressure. [3]Forty-cycle boil.

TABLE 7. Screening of Southeast Asian hardwoods for gluing difficulty: wood failure after vacuum/pressure and 40-cycle automatic-boil aging with adhesive B.

		Assembly times			
		20 minutes		45 minutes	
		V/P[1]	40-cycle boil	V/P	40-cycle boil
		%	%	%	%
Shorea bracteolata (white)	5	98	94	98	98
Shorea assamica (white)	1	97	97	98	99
Shorea resina-nigra (yellow)	17	93	93	98	98
Shorea faguetiana (yellow)	25	98	97	98	99
Shorea kalunti (yellow)	6	94	68	92	71
Parashorea lucida (red)	2	91	74	93	68
Anisoptera spp., mersawa	3	97	98	97	98
Heritera spp., mengkulang	19	99	89	95	78
Dipterocarpus spp., small leaf apitong	29	96	97	98	99
Dipterocarpus spp., large leaf apitong	30	98	97	99	95
Shorea philippinensis, manggasinoro	31	91	96	91	93
Pentacme contorta, white lauan	32	98	86	94	83
Shorea negrosensis, red lauan	33	96	96	98	93

[1]Vacuum pressure.