Finger Jointing Green Southern Yellow Pine With a Soy-Based Adhesive

By **Philip H. Steele**, Steele Consulting, Starkville, Miss.; **Roland E. Kreibich**, Kreibich and Associates, Auburn, Wash.; and **Petrus J. Steynberg** and **Richard W. Hemingway**, USDA Forest Service, Pineville, La.

Soybean-based glues were first utilized in 1923 when a patent was granted for a soy meal-based glue. Shortly after World War II, the abundant availability of oil allowed development of soybean-derived glues that were more waterproof and insect proof.

In 1994, Dr. Roland Kreibich began the development of environmentally friendly soybean glues as wood adhesives.

He realized his goal of developing a waterproof exterior adhesive for wood finger joints as a substitute for petroleum-based adhesives. The adhesive he developed is applied as a honeymoon system with the soy-based hydrolyzate applied to one side of a finger joint and a phenol-resorcinol-formaldehyde (PRF) adhesive applied to the other. When these fingers are brought together, the resultant mixture in the joint forms a gel within 5–10 sec. This gelation allows finger-jointed lumber to be handled immediately.

The honeymoon adhesive system was first tested in the western United States on Douglas fir lumber with excellent results. The Western Wood Products Association has certified the honeymoon system for "vertical use only" at Willamina Lumber Co. in Willamina, Ore.

There was some reason to suspect that finger jointing of southern yellow pine (SYP) with the honeymoon system using soy-based adhesive (SBA) might prove more difficult than for western species. The Wood Handbook *(1)* classes western species in the "bond easily" or "bond well" category, whereas SYP is ranked in the "bond satisfactorily" category. On the other hand, the specific gravity and the green moisture content of SYP (Table I) are nearly identical to those of Douglas fir, a western species that has shown good results with green finger jointing in both laboratory and mill trials. Laboratory and mill trial results soon indicated that results of the honeymoon system with SYP were just as favorable as with western species.

Laboratory Tests

An important characteristic of the honeymoon system is the rapid gelation of the components, applied to opposite fingers, when the fingers are pressed together. This gelation occurs in a few seconds and results in a bond with adequate strength for the finger-jointed lumber to be handled, either manually or mechanically, immediately out of the finger jointer.

A bonding test of SYP with the honeymoon system was performed in which the SBA hydrolyzate was the component on the fingers of one side of the joint and Supplier A's PRF resin and resin hardener, combined with parapowder as an additional hardener, was the component on the other side. This

Table I

Relative Specific Gravity and Moisture Content of Douglas-fir, Loblolly, Longleaf and Shortleaf Pine

Species	Moisture content (%) Heartwood	Moisture content (%) Sapwood	Specific gravity
Douglas-fir	37	115	.47
Loblolly pine	33	110	.47
Longleaf pine	31	106	.54
Shortleaf pine	32	112	.47

Source: USDA Forest Service 1987

Figure 1

Tensile Strength Development in SYP Lumber Finger Jointed With SBA and Supplier A's PRF Resin

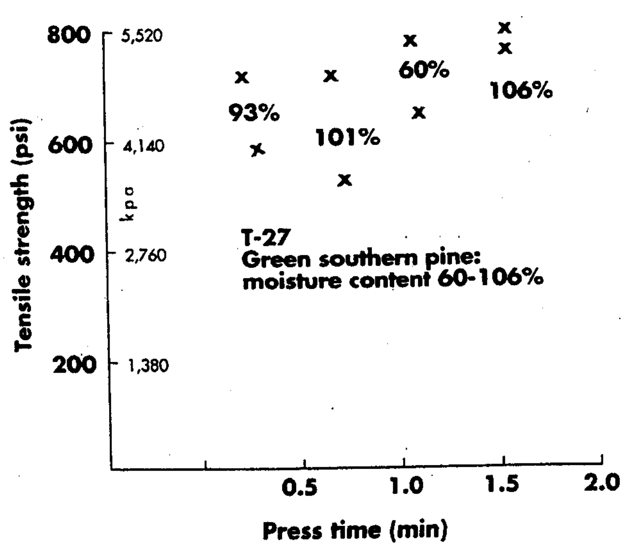


Table II

ASTM D-3110-90 Test Results for Green SYP Lumber Finger Jointed With the SBA and Supplier A's PRF Resin and Allowed To Cure at Room Temperature

	Dry		VPS		3-Cycle wet/dry		Bending	
	Ultimate tensile strength (psi)	Wood failure (%)	Ultimate tensile strength (psi)	Wood failure (%)	Ultimate tensile strength (psi)	Wood failure (%)	Modulus of rupture (psi)	Wood failure (%)
Average of 56 joints	5,117	68	3,094	89	4,549	83	7,300	88
Standard								
(dry use)	2,000	60			1,000	30	2,000	
(wet use)	2,000	60	1,600	50			2,000	

Table III

ASTM D-3110-90 Test Results for SYP Lumber Finger Jointed Wet (111% Moisture Content) to Dry (10% Moisture Content) With the SBA and Supplier A's PRF Resin and Allowed To Cure at Room Temperature

	Dry		VPS		3-Cycle wet/dry		Bending	
	Ultimate tensile strength (psi)	Wood failure (%)	Ultimate tensile strength (psi)	Wood failure (%)	Ultimate tensile strength (psi)	Wood failure (%)	Modulus of rupture (psi)	Wood failure (%)
Wet/dry	5,178	93	4,248	93	4,083	91	6,159	88
Standard								
(dry use)	2,000	60			1,000	30	2,000	
(wet use)	2,000	60	1,600	50			2,000	

Note: Average moisture content for wet to wet = 92 to 110%, wet to dry = 111 to 10%, and dry to dry = 10 to 10%
Test results are averages of eight joints at each moisture content combination

provided gel tensile strengths of 500–800 psi as shown in Figure 1. The wood moisture contents for this test ranged from 60–106% with the strength values showing no relationship to the moisture content of the wood.

All honeymoon system joints referred to in this paper were prepared with resin and hardener provided by Supplier A. except for the results shown in Table V. Supplier B's resin and hardener were applied for the mill trial referred to in Table V.

Initial studies with green SYP were based on standards for nonstructural applications. Table II shows laboratory test results based on ASTM D-3110-90, "Standard Specification for Adhesives Used in Nonstructural Glued Lumber Products." In this test, SYP lumber was finger jointed green with SBA hydrolyzate and Supplier A's PRF resin and hardener combined with additional parapowder. Curing was at ambient room temperature. Results far exceeded the standard for both dry and wet use.

A similar test was performed to determine if the finger jointing of pieces with widely varying moisture contents (MC) influenced results. In many industrial situations, moisture content of wood varies greatly depending on when it is processed. Average MC values wet/dry joints were 111% bonded to 10%. Table III gives ASTM D-3110-90 results for this test. The wet and dry use standards were surpassed by a wide margin.

Experiments were next performed to determine if varying treatment levels had the potential to improve the honeymoon joints. In this test, Supplier A's PRF resin and hardener combined with parapowder was applied on one side of the joint. SBA was used as usual on the opposite side of the joint.

There were five drying conditions tested as described at the bottom of Table IV. Best results were for joints dried for 6 hr at 105°C to an average MC of 14%, and for joints bonded with double the hardener and oven dried for 24 hr at 105°C, with tensile specimens cut and air dried for 24 hr before testing. Marginal and below wet use standard results were obtained for joints air dried at ambient temperature for one month and tested at an average MC of 16%, for joints dried for 24 hr at 105°C to an MC of 3–5%, and for joints bonded with double the amount of hardener and dried for 24 hr at 105°C, with tensile specimens cut and oven dried for 24 hr. These results indicate that wood failure percentage will exceed the wet use standard of ASTM D-3110-90 under conditions equivalent to those applied during kiln drying.

Mill Trials

Support for this interpretation was provided by results of a mill trial conducted at Georgia Pacific's Tylertown, Miss., finger joint facility. During this trial, Supplier B's PRF resin and hardener, combined with parapowder, was hand applied to one side of the joint and SBA to the other side of the joint. In this case, the nonstructural ASTM D-5572-94 standard titled "Adhesive Used for Finger Joints in Nonstructural Lumber

Table IV

ASTM D-3110-90 Test Results for Green SYP Lumber Finger Jointed With the SBA and Supplier A's PRF Resin and Tested Following Different Drying Regimes

	Dry		VPS		3-Cycle wet/dry		Bending	
	Ultimate tensile strength (psi)	Wood failure (%)	Ultimate tensile strength (psi)	Wood failure (%)	Ultimate tensile strength (psi)	Wood failure (%)	Modulus of rupture (psi)	Wood failure (%)
Wet/wet	4,850	82	2,841	33a				
	4,473	87	3,828	71b			3,423	90
					3,984b	93	6,195	97
					5,504b	65	8,206	74
					4,513c	85		
			2,982	56c				
			3,293	71d				
			2,861	19e				
			3,067	41				
Wet/dry					5,211b	80	7,145	70
Dry/dry					2,862b	97	5,886	83
Standard								
(dry use)	2,000	60			1,000	30	2,000	
(wet use)	2,000	60	1,600	50			2,000	

a: Joints air dried at ambient temperature (about 22°C) for one month and tested at an average moisture content of 14%
b: Joints dried for 6 hr at 105°C and tested at an average moisture content of 14%
c: Joints dried for 24 hr at 105°C and tested at a moisture content ranging from 3–5%
d: Joints bonded with double the amount of hardener and oven dried for 24 hr at 105°C; tensile specimens cut and air dried for 24 hr before test
e: Joints bonded with double the amount of hardener and dried for 24 hr; tensile specimens cut and oven dried at 105°C for another 24 hr

Table V

ASTM D-5572-94 Test Results for Green SYP Lumber Finger Jointed With SBA and Supplier B's PRF Resin During a Mill Trial*

	Dry		VPS		3-Cycle wet/dry		Bending	
	Ultimate tensile strength (psi)	Wood failure (%)	Ultimate tensile strength (psi)	Wood failure (%)	Ultimate tensile strength (psi)	Wood failure (%)	Modulus of rupture (psi)	Wood failure (%)
Average of 100 joints	5,206	87	4,256	67	4,161	87	7,576	85
Standard								
(dry use)	2,000	60			1,000	30	2,000	
(wet use)	2,000	60	1,600	50			2,000	

Note: Average moisture contents for wet to wet = 92 to 110%, wet to dry = 111 to 10%
Test results are averages of eight joints at each moisture content combination

*Following finger jointing the lumber was dried with a standard southern pine high-temperature kiln schedule

Products" was employed. Requirements by this standard are, for all results reported here, identical to those for ASTM D-3110-90. Green SYP lumber was finger jointed and was kiln dried by a standard SYP high temperature schedule.

The results of the Georgia Pacific study (Table V) indicate that all requirements of ASTM D-5572-94 can be substantially exceeded if high temperature kiln drying follows the finger jointing process.

The rapid gelation time of a few seconds was of concern because finger jointing machines perform at varying speeds. Few current finger jointers would be able to provide completely closed joints in 5 sec or less. An experiment was performed to determine whether joints could be partially closed for a considerable length of time and could then be totally closed without loss of joint strength. Green SYP lumber was finger jointed and assembled with hand pressure to simulate a partially closed joint. Mechanical end pressure was then applied to close the joint after 10, 20 or 30 sec. Joints were tested dry for tensile strength after a 3-cycle water soak and oven-drying treatment. The results given in Table VI show that breaking the partially closed gel bond for time periods of up to 30 sec did not significantly reduce bond strength or wood failure results.

An experiment was performed to determine the long-term durability of the previously described honeymoon system. Kiln drying was done according to a standard southern yellow pine high temperature kiln schedule. Tensile tests were performed according to ASTM D-5572. Long-term durability was determined by applying a regime of 800 cycles of boil-dry treatment with strip tension tests performed periodically. To provide a benchmark for comparison, identical joints were prepared with 100% PRF resin. Results for both the honey-

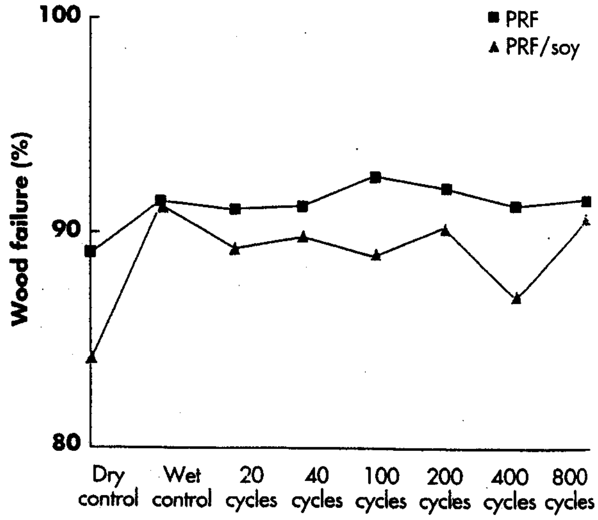
Table VI

Effect of Partially Closed Assembly Time Differences on Tensile Strength and Wood Failure of Green SYP Finger Joints Tested Dry After a Three-Cycle Water Soak and Oven-Drying Treatment

Closed assembly time (sec)	Tensile strength (psi)	Wood failure (%)
10	5,592	73
	5,531	96
	5,082	90
	4,889	75
	Mean: 5,274	*Mean:* 84
20	5,032	76
	4,062	75
	3,942	83
	5,270	100
	Mean: 4,577	*Mean:* 84
30	5,333	85
	5,090	91
	3,431	83
	4,795	81
	Mean: 4,662	*Mean:* 85

Figure 2

Wood Failure Through 800 Boil/Dry Cycles (ASTM D-3434) for SYP Lumber Finger Jointed With SBA and Supplier A's PRF Resin



moon system and 100% PRF joints are shown in Figure 2. While the honeymoon system joints have tensile strength slightly below those of 100% PRF, the pattern of decreased bond strength was nearly identical.

Wood failure values over the 800 boil-dry cycles are shown in Figure 3. Both the honeymoon system and the 100% PRF system maintained greater than 80% wood failure values over the course of the experiment. It is apparent that the variation in tensile strength was due almost entirely to loss of wood strength over the course of the boil-dry cycles rather than a loss of strength of either the PRF or honeymoon adhesive systems.

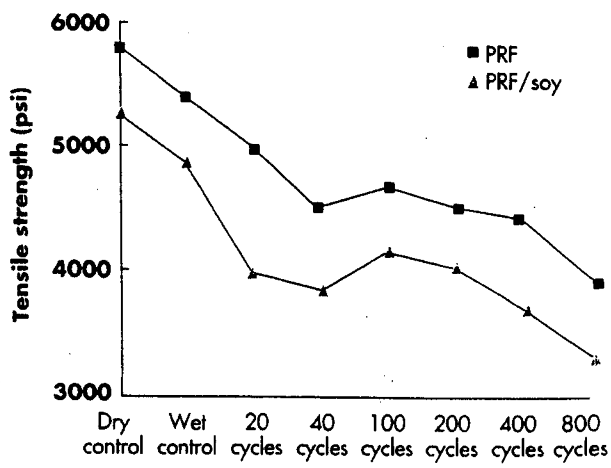
Future Applications

Without question, the next frontier for the green finger jointing of southern yellow pine is the structural market. The honeymoon system has already been certified for vertical use stud production by the Western Wood Products Association. This is the next logical step to be pursued for southern yellow pine. The United Soybean Board will work with the southern grading agencies, the Southern Pine Inspection Bureau and Timber Products Inspection to certify the honeymoon system for vertical use only.

There is also considerable interest in treating lumber finger jointed with the honeymoon system. There appears to be no reason to suspect strength loss in lumber finger jointed with the honeymoon system. Tests are currently being performed to determine whether treating will influence finger joint strength.

Figure 3

Tensile Strength Through 800 Boil/Dry Cycles (ASTM D-3434) for SYP Lumber Finger Jointed With SBA and Supplier A's PRF Resins



Summary

Progress in introducing green finger jointing to the SYP industry lags somewhat behind the introduction of green finger jointing for the western species. However, laboratory tests and mill trials indicate that the green finger jointing of SYP can be just as successful as for the western species. Initial studies with non-structural tests indicated that finger joints bonded with the honeymoon system and allowed to dry at ambient temperature provide considerably more strength than required to pass tensile and modulus of rupture (MOR) standards. Also, SYP finger joints cured by high temperature kiln schedules to 14% MC passed all non-structural standards by a wide margin.

Gelation of the bond produced in the honeymoon system occurs very rapidly. The gel bond formed in a partially closed joint must be broken to subsequently fully close the joint. There had been concern that this rapid gelation in partially closed joints might weaken finger joints if the partially closed condition lasted for more than a few seconds.

Laboratory test results indicated no significant reduction in joint strength if the gel bond in partially closed joints was broken after time periods of up to 30 sec. Therefore, variability in the length of closed assembly time should not influence strength of finger joints produced by the honeymoon system.

Long-term durability of honeymoon system finger joints was determined by applying a regime of 800 cycles of boil/dry treatment followed by strip tension tests. Honeymoon system finger joints showed just slightly lower strength than for 100% PRF joints. The pattern of strength and wood failure percentage results indicate that, although the wood strength degraded during the 800 boil/dry cycles, the adhesive bond of neither the honeymoon system finger joints or 100% PRF finger joints lost strength.

Structural certification for the honeymoon system for SYP will be sought in the future. The possibility of treating lumber finger jointed by the honeymoon system should be feasible. Tests are currently under way.

References

1. USDA Forest Service. 1987. *Wood Handbook: Wood as An Engineering Material. Agriculture Handbook 72.* Forest Products Laboratory. Washington: U.S. Government Printing Office. **AA**