Application of honeymoon cold-set adhesive systems for structural end joints in North America

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Abstract

High quality, structural end joints can be cold-set at mill speed using a two-component honeymoon adhesive system composed of southern pine bark or pecan shell membrane tannin and a modified, commercially available, phenol-resorcinol-formaldehyde resin. Adhesive costs of a fully waterproof glueline are approximately $0.60/lb. of applied adhesive mix compared to $0.80/lb. for current melamine-formaldehyde adhesives. Capital and processing costs are reduced by eliminating the radio-frequency generator used in most laminating plants.

Laboratory studies supported by a Phase I USDA Small Business Innovation Research (SBIR) grant have established that high quality, structural end joints can be formed using a two-component honeymoon adhesive system. The components, southern pine bark (SPB) tannin or pecan shell membrane (PSM) tannin and a modified, commercial phenol-resorcinol-formaldehyde (PRF) resin, are applied in equal amounts (wt./wt.), one component to each side of the joint. When the two sides mate, an adhesive system is formed that cures rapidly at room temperature allowing the joint to be handled out of the press in a matter of minutes without application of the radio-frequency (RF) heating used by most commercial laminating plants.

The economics of the PRF/tannin honeymoon systems are attractive. Adhesive costs of a fully waterproof glueline are approximately $0.60/lb of applied adhesive mix compared to $0.80/lb for current melamine-formaldehyde (MF) end joint adhesives. Capital and processing costs are reduced by eliminating the RF generator, a device that converts only a portion of the power input into useful RF energy and is notoriously expensive to maintain and keep on line.

Introduction of PRF/tannin honeymoon adhesive systems into operating mills affords the wood products industry the opportunity to: 1) reduce the cost of producing fully waterproof structural end joints; and 2) increase the present and future value of plantation timber by "defecting" mill run boards and joining clear pieces to construct sizes and grades not otherwise available from these small, young trees.

Based on the technical and economic merits of the Phase I results, we obtained a Phase II USDA-SBIR grant to conduct mill trials and initiate transfer of honeymoon technology by meeting the following three objectives:

1. Demonstrate that PRF/tannin honeymoon adhesive formulations can be used in an operating mill, at production line speeds, to manufacture end joints that meet American Institute of Timber Construction (AITC) specifications for use in laminated beams.

2. Manufacture and test at least one commercial-sized laminated beam using laminae with PRF/tannin bonded end joints.

3. Introduce PRF/tannin honeymoon adhesive technology at the mill level by running the trials in different mills in various geographical locations.

The ojective of this communication is to summarize the use of one basic adhesive system in six different

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TABLE 1. — *Tensile strength of three PRF/tannin honeymoon end joint adhesive formulations.*

Adhesive formulation	Average tensile strength	COV[a]	5th percentile at 75 percent CL[b]
	(psi)	(%)	(psi)
4	5,550	11.281	4,375
1	4,497	16.446	3,105
5	4,785	12.149	3,704

[a] Coefficient of variation.
[b] Confidence limit.

TABLE 2. — *Strength properties of a laminated test beam formed with PRF/tannin honeymoon end joints.*

Beam specifications	Maximum load	MOR	MOE
	(lb.)	(psi)	(10^6 psi)
PRF/tannin end joints 2 by 6, 8-ply, 216-in. test span breadth = 5.25 in. diameter = 12 in.	30,600	10,449	2.27
Mill beams (avg. of 6 tests) 2 by 6, 8-ply, 216-in. test span breadth = 6.75 in. diameter = 12 in.	27,767	7,222	2.25

mills that were selected so that a broad spectrum of production facilities in the United States would be covered. Superimposed on the conditions found in these facilities were variations in line speeds and end pressures. In order to achieve optimum performance, minor adjustments in adhesive formulations have to be made to compensate for mill differences in spreading techniques, assembly times, end pressures, and product handling. These adhesive formulations are based on a honeymoon system developed in the early 1970s (1,2) and modified for the use of wattle tannin as one component (6,7). Further development of these adhesive formulations by the authors using tannins from southern pine bark and pecan nut pith have been reviewed (3-5). The principle has been commercialized by Pizzi in Chile (8). The authors will be happy to assist with formulation adjustments that might be needed to meet specific North American mill conditions if producers of end jointed wood products would wish to pursue this adhesive system.

Mill trials

Nine mill trials were completed in laminating plants of differing size and complexity, eight domestic and one offshore. The trials were carried out in a stepwise fashion using a two-component honeymoon adhesive system. Component A was a commercially available, reformulated PRF adhesive. Component B was a modified tannin extract from southern pine bark or pecan shell membrane. Adjustments in technique and formulations were made based on the results in preceding trials and between-trial laboratory work.

In seven of the trials, adhesive components were hand-applied (dabbing), thus they did not come close to achieving the targeted, desired 50/50 component ratio in the final glueline. These trials, however, showed that durable structural joints are produced over a wide range of component ratios. In trials 5 (Dimter) and 9 (last of the series), both components were applied using mechanical spreaders.

Mill trial results

Trial results are summarized in chronological order. Complete data and details can be found in Final Report USDA-SBIR Phase II Grant No. 88-33610-4171.

Trial 1, Mill A

In this trial, the species was Douglas-fir. The dimension was 2 by 6 inches. The application was by hand. This trial was a total failure. Results were highly variable due to erratic end pressure and difficulties with gentle off-bearing.

Trial 2, Mill B

The species was Douglas-fir. The dimension was 2 by 4 inches. The application was by hand. Mill B was equipped with a stop-and-go end joint line having good, adjustable end pressure. The outrun roller case was modified to simulate a gentle off-bearing system. The trial was designed to "shake out" the small differences among five formulations identified in the laboratory as having the greatest likelihood of producing joints that show rapid strength development and high durability. Three end pressure settings were included to detect any significant end pressure × formulation interactions; 141 joints were prepared. Three PRF/tannin formulations showed acceptable tensile strength at 60 gauge end pressure.

Trial 3, Mill B

The species was Douglas-fir. The dimension was 2 by 4 inches. The application was by hand. The three best formulations identified in Trial 2 were used to form end joints at a single end pressure (60 gauge). Tensile strength values are shown in Table 1.

Trial 4, Mill B

The species was Douglas-fir. The dimension was 2 by 6 inches. The application was by hand. This trial was undertaken to continue to demonstrate that high quality end joints can be made in a mill setting using the PRF/tannin honeymoon system and to manufacture laminae for test beams. Tension ply 2 by 6 (laminating grade) Douglas-fir (coast range) was end-jointed using 60 gauge end pressure. Twenty-seven end joints were tested in tension. Average tensile strength was 5,599 psi (3,999 psi 5th percentile at a 75% confidence limit (CL)). The PRF/Tannin average value is essentially equal to the average RF plant control MF-bonded end joints (5,228 psi).

Beam test data are summarized in Table 2 along with comparative test values for commercial beams of similar size and composition. The load-carrying capacity of the PRF/tannin honeymoon beam adjusted for differences in breadth equals that of the mill beams

TABLE 3. —*Average tensile strength and wood failure of Dimter-type end joints — mill trial 5.*

Type of test	No. of tests	Tensile strength	Wood failure
		(psi)	
Dry	76	5,850	
VPS[a]	83	4,111	

[a] Vacumm-pressure-soak cycle.

TABLE 4. —*Effect of line speed, end pressure, and bond age on tensile strength of 2 by 6 Douglas-fir PRF/tannin honeymoon end joints — mill trial 9.*

Line speed	End setting "gauge"	Average tensile strength	Average wood failure	Adhesive system
(ft./min.)		(psi)	(%)	
Day out of press				
30	1,400	1,728	8	PRF/tannin
50	1,500	4,309	76	PRF/tannin
100	2,000	5,485	91	PRF/tannin
150	1,800	5,321	92	RF melamine control
Aged 1 day				
30	1,400	2,797	45	PRF/tannin
50	1,500	5,282	93	PRF/tannin
100	2,000	5,017	92	PRF/tannin
Aged 10 days				
30	1,400	2,869	30	PRF/tannin
50	1,500	4,714	89	PRF/tannin
100	2,000	5,395	91	PRF/tannin

(PRF/tannin breadth = 5-1/4 in.; mill beams breadth = 6-3/4 in.).

End joints involved in the failure mechanism of the test beam were cut out for wood failure reading. The values were 85, 87, 80, 99, and 95 percent indicating that, in beam end joints that failed, it was the wood that failed, not the adhesive bond.

Trial 5, Mill C

The species was "Fichte" European fir (*Picea excelsa*). The dimension was 5 by 15 cm (approximately 2 by 6 in.). The application was by machine (Dimter).

In central Europe, especially in Germany, it has been mandatory to apply adhesive to both mating surfaces. For that reason, the equipment in Germany (and Europe in general) can apply different adhesive components to each of the two surfaces to be glued. This equipment is ideally suited for the honeymoon system in which different adhesive compositions are applied, one to each of the two surfaces to be glued. The end joint trial in the plant of Jakob Maier, Tuerkheim, Bavaria, yielded excellent results. A VCR tape of the trial is available for viewing. A composite sample of these 5-by-15-cm end joints was shipped to the Southern Forest Experiment Station for testing as strip specimens, dry and following the vacuum-pressure-soak (VPS) cycle. Average strength and wood failure values are summarized in Table 3.

Overall tensile strength values were excellent. The variability in the tensile values and the low VPS wood failure were attributed to difficulties in controlling the spreads of the two components. The VCR tape shows very clearly that the spreads were not controlled, and therefore, the desired mix ratio of 1/2 PRF plus 1/2 tannin on the mated joint was not consistent.

Trial 5 demonstrated in principle that a mechanical system capable of applying PRF and tannin, one to each side of the joint, and mating the pair, has the potential to produce AITC acceptable finger-joints without the application of RF energy or other heat sources.

Trials 6 and 7, Mill D

These trials were made in a small laminating mill using a "Folded Scarf Joint." Improvements in joint strength between trials 6 and 7 did not reach an acceptable level, and no further efforts were made to improve the results with this joint configuration.

Trial 8, Mill E

The species was Douglas-fir. The dimension was 2 by 4 inches. The application was by hand. Mill E can best be described as an enlarged and extended pilot plant operation of a size and production capacity that has been approved as a mill by the Western Wood Products Association. The end pressure machinery was designed to achieve an end pressure of 400 psi within very narrow limits throughout the run. Assembly and off-bearing of the joints were done by hand, rapidly and with care.

Twenty-four, full-size 2-by-4 joints were tested in tension. The average tensile stress was 5,470 psi with an average of 92 percent wood failure. Where there was 100 percent wood failure away from the joint, the intact finger-joints were cut into strip tension specimens, 1/4 by 1-1/2 inches in cross section. Half were tested in tension as is (dry). The remainder were subjected to a VPS cycle and tested in tension (AITC-110). These tension specimens, tested dry, averaged 5,991 psi with 86 percent wood failure, and when tested wet, averaged 5,382 psi and 81 percent wood failure.

Trial 9, Mill F

The species was Douglas-fir. The dimension was 2 by 6 inches. The application was by machine. Mill F was well organized; the management and crew were cooperative. For end jointing, the mill normally uses an MF adhesive with a 45 kW RF generator. In day-to-day operation, using the full capacity of their RF unit, the mill runs 2 by 6 Douglas-fir at 150 ft./min. line speed, 1,800 gauge end pressure. Cleanliness and overall orderliness was better than in most of the previous mill trials.

Two adhesive end joint spreaders were available to apply the components in-line. Line speeds could be varied over a wide range of conditions since the mating operation did not have to wait for manual adhesive application, as in previous trials (except Trial 5). For this trial, using PRF/tannin, the RF unit was completely turned off. Three line speed and end-pressure conditions were run: 1) 30 ft./min. at 1,400 end pressure setting; 2) 50 ft./min. at 1,500 end pressure setting; and 3) 100 ft./min. at 2,000 end pressure setting

At the time of the trial, plant temperature was 78°F (25.5°C), and lumber temperature was 71°F (21.6°C). Test material was 2 by 6 dense select structural, inland Douglas-fir.

Table 4 shows the full-size tension values obtained on the day of manufacture, 1 day following manufacture, and 10 days after manufacture (full cure) along with a typical average value for the mill's standard RF-cured, MF-bonded, end-jointed lumber. At 50 to 100 ft./min. and a retard pressure of 1,500 to 2,000, PRF/tannin honeymoon adhesive bonds produced end joints equivalent to the mill's standard RF-cured, MF-bonded joints. The general trend is for an increase in joint strength with an increase in end pressure and line speed. The three data sets in Table 4 are evidence that if line speed were increased to 150 ft./min. (current mill speed with RF-cured/MF-bond) and 1,500 to 2,000 gauge end pressure, joint strength would average around 5,000 to 5,300 psi.

Conclusions

Trial 9 is convincing evidence that, with dual spreading equipment and a consistent proper end pressure, the PRF/tannin honeymoon system is capable of producing cold-set, fully exterior quality, structural 2 by 6 Douglas-fir end joints at mill production rates. PRF/tannin honeymoon is a mill-ready, cold-set, adhesive system that will produce structural, fully waterproof joints at lower cost than current RF-cured end joint adhesives.

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