TECHNICAL FEASIBILITY OF STRUCTURAL FLAKEBOARD MADE FROM MIXED HARDWOODS AND CYPRESS FROM NORTHERN FLORIDA

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ABSTRACT

Homogeneous and 3-layer flakeboard panels were fabricated from mixed hardwood species and baldcypress grown in northern Florida. All panels yielded adequate bending strength and stiffness and dimensional stability. For the homogeneous panels, the study indicates that only one panel condition, i.e., 5.5 percent resin content (RC) and 45 pcf, yielded internal bond (IB) values greater than 75 psi and thickness swelling (TS) equal or less than 25 percent. When comparing homogenous panels to 3-layer panels at similar RC and panel target density, all mechanical and physical properties were slightly more favorable in the homogenous panels. However, linear expansion and TS were slightly more favorable for the homogenous panels at 5.5 percent RC and 45 pcf than 3-layer panels produced at identical RC and panel target density. For the 3-layer panels, the large increase in IB and decrease in TS in response to the slight change in RC should provide the margin to produce acceptable flakeboards in plant conditions.

Northern Florida has a substantial hardwood timber resource, but no structural flakeboard mills are located in Florida. A recent study found that the total timber inventory in Florida was 435 × 10^6 m^3 (9). Because the future consumer demand for structural flakeboard and sheathing is likely to increase, and because there is a plentiful hardwood timber resource in northern Florida, structural flakeboard production in northern Florida merits consideration. Several previous studies have investigated various technical aspects of hardwood flakeboard production. Previous research by Hse et al. (5) and Price (11) has indicated that mixtures of upland hardwood species could be utilized to make structural flakeboard. Later research by Price and Hse (12) reported that structural flakeboard panels from seven bottomland hardwood species are technically feasible using several fabrication arrangements. Hse (4) examined flakeboard properties of nine hardwood species and found that all species except white oak and post oak yielded boards of acceptable dimensional stability at board densities of 44.5 pcf or less. Price (10) produced acceptable, full-size structural flakeboards using a furnish of 20 percent by weight of hickory, white oak, red oak, sweetgum, and southern pine. "Chow et al. (3) found that juvenile hardwood plantations have good potential for use as a raw material for the structural flakeboard industry.

Previous research has indicated that the most favorable panel properties can be obtained with face flakes 3 inches long by 0.015 inch thick and random width (approximately 3/8 width is most favorable). Core flakes should be slightly thicker, i.e., 0.025 inch. Other variables that enhance the production of acceptable panels are: 1) heated bolts flaked with sharp knives; 2) half the board weight comprised of the core layer; 3) all flakes randomly oriented; 4) phenol-formaldehyde (PF) liquid resin applied at a volume greater than 5 percent solids rate basis; 5) mat moisture content less than 12 percent; and 6) press pressure sufficient to reach the desired thickness within 45 seconds. Additionally, the compaction ratio (panel density to average species density) should be approximately 1.2 (12).

The most important species variable governing board properties is the density of the wood raw material itself (8).

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In short, low-density species compact readily when pressed and result in good flake contact, which improves bonding and yields boards of high strength. If the specific gravity of the species is above 0.6, it tends to be difficult to form stiff boards without increasing density unduly. Biblis (2) reported preliminary results that indicate appropriate mixtures of high- and low-density southern hardwoods (35% red oak, 15% white oak, 35% sweetgum, and 15% yellow-poplar) can be used to fabricate commercially acceptable oriented flakeboards.

There is a substantial amount of small-diameter cypress stumpage and varying amounts of other hardwood species throughout northern Florida. Therefore, if a structural panel product is to be industrially manufactured in northern Florida, it is important that most of the species that would occur in the possible procurement area be utilized in the relative percentages that those species are present in the procurement area. Currently, several oriented strandboard (OSB) plants in the South produce panels with a mixture of pine and low-density hardwoods. However, there is no plant currently using the mixture as discussed in this paper. The findings of this study should be of particular interest to the many OSB plants in the southeastern United States that have cypress stumpage available in their procurement areas. The objectives of this study were to determine the 1) technical feasibility of producing an acceptable flakeboard product from a mixture of hardwood species and cypress grown in northern Florida; 2) effect of including a large amount of cypress (35%) in the furnish for each panel type; and 3) effect of flake thickness on selected mechanical and physical properties of structural flakeboard.

MATERIALS AND METHODS

Hardwood tree species that are representative of the hardwood forest resource in northern Florida were selected from privately owned bottomland forest in northern Florida for the study (**Table 1**). Two defect-free trees were selected for each species. Trees were bucked into 6-inch bolts and converted into flakes with a Koch shaping-lathe headrig (6). The flakes measured approximately 3 inches long, random width, and thickness of either 0.015, 0.02, or 0.025 inch.

Two panel types were selected for analyses: homogenous and 3-layer. The homogenous panels only included flakes 0.02 inch thick. The 3-layer panels included flakes 0.015 inch thick on the faces and 0.025 inch thick in the core. The flakes were cut from a Koch shaping-lathe headrig (6,7). All flakes were dried to an average moisture content (MC) of 3 percent before a common, commercial phenol-formaldehyde (PF) resin (46% solids content) was applied. No wax was applied so that the true effect of other variables could be evaluated.

A production plant would orient the flakes to maximize the property-density effect, produce flakes 0.025 to 0.30 inch thick, and use less than 5 percent resin content (RC); however, our laboratory panels were made with randomly oriented flakes, and some were made with thinner flakes and higher RC than current industry practice. The panels in this study were made for comparative purposes to evaluate the technical feasibility of the species mixture. Half of the board weight was in the core and one-fourth in each face, but all layers contained the specified species mixture. **Table 1** lists the percent mixture of each individual species and its density classification. The homogenous panels were manufactured at target densities of either 40 or 44 pcf with an RC of either 4.5 or 5.5 percent PF. The 3-layer panels were all produced at an RC of 5.5 percent PF with either 42 or 45 pcf as the target density.

Panels measuring 22 inches by 40 inches by 0.5 inch were pressed at 350°F with a hot press time of 5.5 minutes and a press closing time of 30 seconds to stops. All panel types were replicated six times. From each board, three specimens were tested in bending parallel to the panel length for modulus of rupture (MOR) and modulus of elasticity (MOE).

TABLE 1. — Experimental hardwood tree species selected to produce structural flakeboard.

Species	Density classification	Amount in furnish
		(%)
Baldcypress (*Taxodium distichum* L.)	--	35
Black tupelo (*Nyssa sylvatica* Marsh.)	Low	17
Sweetgum (*Liquidambar styraciflua* L.)	Low	9
Southern magnolia (*Magnolia grandiflora* L.)	Low	3
Red maple (*Acer rubrum* L.)	Low	6
Sweetbay (*Magnolia virginiana* L.)	Low	5
Southern red oak (*Quercus falcata* Michx.)	High	15
Mockernut hickory (*Carya tomentosa* Poir. Nutt.)	High	3
White ash (*Fraxinus americana* L.)	High	6
Live oak (*Quercus virginiana* Mill.)	High	1

TABLE 2. — Mechanical and physical properties of structural flakeboard made from mixed hardwoods from northern Florida.

Panel type	Resin content	Target density	Actual density	MC	IB	MOR	MOE	LE[a]	TS[a]
	(%)	(pcf)		(%)	(psi)		(1,000 psi)	(%)	
Homogenous	4.5	42	41.1 (1.5)[b]	4.5 (0.20)	54.4 (0.81)	5,033 (0.54)	689.7 (3.94)	0.093 (1.45)	37 (3.10)
	4.5	45	42.2 (0.8)	4.4 (0.24)	67.3 (0.76)	5,160 (0.48)	691.8 (0.38)	0.159 (2.23)	32 (2.87)
	5.5	42	41.2 (2.1)	4.9 (0.26)	66.3 (0.90)	5,679 (0.48)	724.6 (0.30)	0.112 (1.48)	27 (2.33)
	5.5	45	42.6 (1.8)	4.8 (0.16)	79.9 (0.70)	5,814 (0.48)	749.9 (0.30)	0.143 (1.98)	25 (2.39)
3-layer	5.5	42	40.7 (2.4)	5.7 (0.22)	64.3 (0.97)	5,299 (0.57)	669.5 (0.44)	0.116 (2.56)	28 (3.13)
	5.5	45	42.7 (2.0)	5.0 (0.17)	73.2 (0.67)	5,627 (0.48)	720.0 (0.34)	0.133 (3.19)	27 (2.45)

[a] Values measured after an ovendry vacuum pressure soak treatment.
[b] Values in parentheses are coefficients of variation (%).

Other tests included internal bond (IB), linear expansion (LE), and thickness swell (TS) and were performed in accordance with ASTM D 1037-93 (1). The LE values were measured after an ovendry vacuum pressure soak (ODVPS) treatment. A special optical linear micrometer as described by Suchsland (13) was used for measuring LE.

RESULTS AND DISCUSSION

The mean mechanical and physical properties are presented in **Table 2**. As expected, RC was important for most mechanical and physical properties for both panel types. At the lower RC level, the density effect becomes increasingly important for mechanical properties, particularly IB. Panel density had less of an impact on mechanical properties than RC. Although higher density panels yielded slightly higher mechanical properties, the overall advantage was minor because of the poor dimensional stability associated with most of the higher density panels.

For the homogenous panels, the effect of RC was substantial for all mechanical properties except MOE. For the homogenous panels, density was significant for MOE and IB. As expected, most mechanical properties were greater at the higher RC of 5.5 percent compared to 4.5 percent for the homogenous panels. A slight improvement in most mechanical properties was achieved at the higher panel target density level of 45 pcf. It is acknowledged that a greater improvement in mechanical and physical properties could have been achieved by orienting the flakes in the panel. The lack of flake orientation does not hinder our ability to make comparisons between and within different panel types nor our ability to achieve the study objectives.

For the homogenous panels, LE values ranged from a minimum of 0.093 percent to a maximum of 0.159 percent, and TS values ranged from a minimum of 25 percent to a maximum of 37 percent. These values are consistent with those reported in a study by Hse (4) that manufactured different flakeboards consisting of a single hardwood species; his reported TS values measured by vacuum pressure soak ranged from a minimum of 20.3 percent for red maple (at a board weight of 39.5 pcf) to a maximum of 56.8 percent for white oak (at a board weight of 49.5 pcf). TS values are largely governed by compression set, IB strength, and the dimensional stability of the wood itself. This study found lower TS values and higher IB values in higher density panels, which suggests that IB was a greater contributing factor than compression set for the TS observed in this study. As expected, LE gave higher results at higher panel densities.

At the conclusion of the property testing for the homogenous panels, it was evident that IB values were low and 3-layer panels should be evaluated as a means to improve the IB. It was expected that the 3-layer panel, with thinner flakes on the face layers, would be conformed more and experience greater mat consolidation and flake-to-flake contact. Thicker flakes in the panel core were expected to have a negligible effect on bending properties but a considerable effect on IB. The thicker core flakes reduce the total surface area and give the 3-layer panels greater resin efficiency than the homogenous panels at similar panel RC. Density was important for MOR and MOE in the 3-layer panels.

A higher panel RC per surface area should improve IB. However, the 3-layer panels in this study did not yield higher IB mean values than the homogenous panels at similar panel RC and density. Different resins and RC in the face and core of the panels would have likely been beneficial.

When comparing homogenous panels to 3-layer panels at a similar RC and panel target density, all mechanical and physical properties were slightly more favorable in the homogenous panels. However, LE and TS were slightly more favorable for the homogenous panels at 5.5 percent RC and 45 pcf compared to 3-layer panels produced at identical RC and panel target density.

CONCLUSIONS

The objective of this study was to provide data to establish the technical feasibility of producing an acceptable flakeboard panel product from a mixture of hardwood species and cypress from northern Florida. Panels were produced with thicker flakes on each face (3-layer) and flakes of equal thickness (homogenous). The 3-layer panels did not yield better mechanical or physical properties than homogenous panels.

For the homogeneous panels, the study indicates that only one panel condition, i.e., 5.5 percent RC and 45 pcf, yielded IB values greater than 75 psi and TS equal to or less than 25 percent. Nevertheless, a large increase in IB and a decrease in TS in response to the slight change in RC should provide the margin to produce acceptable flakeboards. Further research is necessary to determine the economic feasibility of industrial production of structural flakeboard in northern Florida.

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