COMPARISON OF RED MAPLE (*ACER RUBRUM* L.) AND ASPEN (*POPULUS GRANDIDENTATA* MICHX) 3-LAYERED FLAKEBOARDS[1]

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ABSTRACT

Three-layered flakeboards were fabricated using long and short flakes of red maple (*Acer rubrum* L.) and aspen (*Populus grandidentata* Michx). Panels were fabricated using three layers of a single species or face layers of a single species with a core layer of the other species. Static bending, internal bond, and nail withdrawal values indicated that red maple and aspen boards for the most part were comparable. A mixed species board with aspen in the face layers and red maple in the core layer had some of the highest static bending values. Dimensional stability values were acceptable among all boards with the mixed species boards producing some of the lowest values. Red maple 3-layered flakeboards were similar to aspen 3-layered boards and it appeared that red maple and aspen may be mixed to produce quality 3-layered flakeboards.

Keywords: bending, internal bond, nail withdrawal, dimensional stability, red maple, aspen, flakeboard.

INTRODUCTION

The wood composite particleboard industry has evolved from small internal operations within larger companies that utilized within plant generated wood residues to full-scale independent flakeboard plants that utilize primarily roundwood. The flakeboard industry is competing with other forest products industries for selected species. Currently, the industry is using many wood species in the manufacture of flakeboards with aspen being a desirable species in certain regions.

One advantage of aspen has been availability. It is a low density species that can be made into an acceptable board product because of its high compressibility. The quantity of aspen raw material may be decreasing and the cost of other favorable species, especially conifers, is increasing. Thus, in the future, it may become necessary to utilize other low cost, low density hardwood species and improve manufacturing operations to produce quality boards.

Investigations using hardwoods have been reported. Hse (1975) found that modulus of rupture (MOR) values differed significantly with wood species. Hse (1975) also reported that high density species produced panels with significantly lower internal bonds compared to the other lower density species examined. Studies by Price (1976) and Price and Hse (1983) using seven species of bottom-

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land hardwoods in various combinations indicated that a panel with acceptable properties is technically feasible using several fabrication arrangements such as 55:45 percent blend (by weight) of low density to high density species. Kelly and Price (1985) recently reported that structural flakeboard panels composed of a mixture of hardwoods did not perform as well as commercial waferboard when subjected to weatherometer tests. These results indicated that a mixture of hardwoods, compared to waferboard constructed with a single species, may have some dimensional stability problems.

One species that may prove to be acceptable as a substitute for aspen or in combination with aspen is red maple. Although red maple has a slightly higher density, research has shown that boards of comparable quality to aspen may be produced using red maple (Jackowski and Smulski 1988; Kuklewski et al. 1985; Springate 1980; Hse 1975). Springate (1980) compared homogeneous and layered waferboard panels of aspen, white birch, and red maple (40:30:30 ratio) and reported nearly identical results from both types of panels. No difference in modulus of rupture (MOR), modulus of elasticity (MOE), and internal bond (IB) values were found between samples using white birch or red maple in the core layers. Jackowski and Smulski (1988) compared isocyanate versus phenol formaldehyde bonded boards and found that satisfactory red maple flakeboard could be produced with isocyanate resins. Since red maple is underutilized and readily accessible, more information is needed to evaluate the potential for red maple in wood composite products.

The major objective of this study was to evaluate the properties of aspen and red maple 3-layered flakeboards. Aspen or red maple flakes were oriented into three layers, with the top and bottom faces having the same general flake direction and the core having a flake orientation of 90 degrees to the faces. Flakes of two different dimensions were used in this study. Groups of boards were made that contained red maple flakes or aspen flakes. In addition, mixed species layered boards were made with flakes using red maple face/aspen core or aspen face/red maple core. The properties of these panels helped to determine the relationship between layering characteristics and species on board properties.

PROCEDURES

Three pole-size trees of red maple (*Acer rubrum* L.) and three pole-size trees of aspen (*Populus grandidentata* Michx) were flaked. Each tree was cut into 4-ft bolts, manually debarked, and quartered along the length of the bolt. The selected trees exhibited uniform stem taper and lacked the presence of decay. All bolts were then bundled according to species and transported to a Pallmann Pulverizer facility in Clifton, New Jersey, for conversion to flakes. The bolts were chipped at approximately 80% moisture content (oven-dry basis) using a Pallmann drum chipper. Each species of chips was then flaked with a laboratory-scale flaker. Flaking parameters were adjusted to maintain a uniform thickness of 0.02 inches, and a target length-to-width ratio (aspect ratio) of two to one (Kuklewski et al. 1985). Flakes were dried in a forced-air oven for 24 hours at a dry bulb temperature of 160 F with no noticeable curling of the flakes. Moisture content (oven-dry basis) of the particles after drying was approximately 8%.

The manufactured flakes were screened and classified using a rotary drum screen. Flakes that were retained on ¼ by ½ inch screen were classified as long flakes, whereas flakes that passed through the screen were classified as short flakes (fines below $\frac{1}{16}$ inches in length were removed).

The flakes were placed into a large rotating drum for resin application. A preweighed amount of flakes was charged into the drum prior to adding powdered phenolic resin (6% based on oven-dry weight) to the drum. The resin-treated flakes were equilibrated at 70 F and 30% relative humidity (RH) before mat preparation. Wax was not applied to the flakes.

An electrostatic field was used for flake alignment in the boards. Flakes were dropped between two electrically charged plates (21 inches long) separated by 3.25 inches and operating at 30,000 volts. After each pass by the charged plates, the caul plate was automatically lowered so that the top of the flakes on the caul plate was 0.5 to 1 inch from the bottom of the charged plates. After the bottom face layer (25% of total board weight) was deposited on the caul plate, the caul plate was turned 90 degrees and the core layer was formed (50% of total board weight). The caul plate was again turned 90 degrees and the top face layer (25% of total board weight) was formed. The formed mats were hot pressed to stops at 350 F. The target board dimensions were 20 inches by 20 inches by 0.5 inch.

Each board was pressed to stops and marked according to its face flake alignment and the board design and replication. The six board designs tested in this study were as follows: 1) faces—red maple long flakes/core—red maple long flakes (RML/RML); 2) faces—red maple long flakes/core—red maple short flakes (RML/RMS); 3) faces—red maple long flakes/core—aspen short flakes (RML/AS); 4) faces—aspen long flakes/core—red maple short flakes (AL/RMS); 5) faces—aspen long flakes/core—aspen short flakes (AL/AS); and 6) faces—aspen long flakes/core—aspen long flakes (AL/AL). All boards were equilibrated at 70 F and 30% RH and trimmed to the dimensions of 18 inches by 18 inches before testing.

Flake alignment was measured on each board face. The flake angle was measured with respect to a reference line parallel to the flake alignment of the faces. One hundred intersections were selected (50 on each face) by using computer-generated random numbers on a grid placed on each face of the panel. The angles of the flakes selected were measured and used to calculate the average flake angle per board.

Mechanical property test specimens were obtained from each board and tests were performed according to ASTM Standard D 1037-78. Two static bending samples (tension side was the first layer formed) in the parallel and two in the perpendicular direction with respect to face flake alignment were tested from each board. Coupons (2) were taken from each bending specimen after testing to measure moisture content and density. Two internal bond specimens per panel were also tested. Nail withdrawal tests were performed on two 3 inch by 6 inch samples and tested immediately after the nails were driven into the samples.

Linear expansion, thickness swell, and water adsorption tests were also performed on the six test boards. Two 3 inch by 9 inch linear expansion samples, one perpendicular and one parallel to the flake alignment, were taken from each board. These samples were conditioned at 50% relative humidity followed by conditioning over saturated salt solutions to 16% EMC conditions at 77 F (75% relative humidity) in an enclosed container. The long dimension of each sample was measured after 14, 21, and 28 days, respectively, in the high humidity chamber. The thickness swell and water adsorption tests were performed on 6-inch

TABLE 1. *Summary of flake angle, moisture content and density date.*[1]

Board type face/core	Flake angle (degrees)	Moisture content (%)	Density (lb/ft^3)
RML/RML	36.67AB	6.2A	37A
RML/RMS	44.13AB	5.9A	35A
RML/AS	38.67AB	5.8A	37A
AL/RMS	35.02B	6.3A	37A
AL/AS	45.18A	6.1A	35A
AL/AL	38.69AB	6.1A	36A

[1] Means with the same letter are not significantly different at the 0.05 level. Moisture content and density values are an average of 24 and 12 measurements per board type, respectively.

square samples taken from the center of each board. The specimens were submerged horizontally in a water bath and their length, width, and thickness dimensions were measured after 2 and 24 hours of soaking time.

Data were analyzed using analysis of variance procedures. Significant differences among board properties were further analyzed using Duncan's multiple range test.

RESULTS AND DISCUSSION

Moisture content values for the panels ranged from 5.8 to 6.3% (Table 1), and board densities ranged from 35 to 37 lb/ft^3 (Table 1) with no significant differences among boards. However, face flake angle values in degrees were significantly different and had a considerable range with the average values varying from 35.02 to 45.18 degrees. Variation in flake moisture content during board fabrication using the electrostatic field may have contributed to the flake angle variations. This range in average flake angle values indicated that the flake alignment for some panels was unacceptable. Poor flake alignment may have influenced some of the board properties. The flake angle values (Table 1) were much higher than those reported by Kuklewski et al. (1985), where mechanical alignment equipment was used.

The modulus of rupture values (Table 2) had a number of trends. Results for specimens cut with their long dimension parallel to flake alignment direction generally were higher, except RML/RMS boards, than specimens with the flake alignment perpendicular to the long dimension. Boards with aspen face flakes had MOR values that were similar or significantly higher for both testing directions than boards with red maple face flakes (Table 2). The highest parallel MOR values were associated with the AL/RMS boards and the lowest values were associated with RML/RMS boards. It appeared that a species effect may be present since both boards had RMS in the core. However, the AL/RMS boards had much better face alignment values than the RML/RMS boards. In the perpendicular direction, MOR values for the aspen boards (AL/AS and AL/AL) were higher than for the other board types. The testing direction and flake alignment appeared to influence the RML/RML, RML/AS, and AL/RMS boards more than the other board types.

Boards that did not have significant MOR differences between parallel and perpendicular direction also had similar trends in the MOE values between the two testing directions (Table 2). Modulus of elasticity values in the parallel direction were highest for the AL/RMS and RML/RML boards, which also had the lowest flake angle values. The RML/RMS and AL/AS boards had the highest

TABLE 2. *Summary of the static bending, internal bond and nail withdrawal data.*[1]

Board type Face/Core	MOR (psi)[2]		MOE (10^3 psi)[2]		Internal bond[2] (psi)	Nail withdrawal[2] (lb)
	Parallel[3]	Perpendicular[4]	Parallel	Perpendicular		
RML/RML	3,880AB	2,380BC	819AB	452C	37A	138A
RML/RMS	2,520C	2,570BC	499D	558AB	26A	137A
RML/AS	3,470BC	2,120C	746ABC	421C	32A	104A
AL/RMS	4,940A	2,640BC	866A	419C	39A	122A
AL/AS	3,870AB	3,650A	603CD	626A	34A	107A
AL/AL	4,190AB	3,740A	700BC	586AB	42A	129A

[1] Means with the same letter are not significantly different at the 0.05 level.
[2] Values are an average of 6 specimens per board type.
[3] The span is parallel to the flake alignment direction.
[4] The span is perpendicular to the flake alignment direction.

flake angle values and lowest parallel MOE values among the board types. These two boards also contained somewhat similar parallel and perpendicular MOE values. Boards with the highest parallel MOE values (RML/RML, RML/AS and AL/RMS) had the lowest perpendicular MOE values (Table 2). These three board types also had some of the lowest flake angle values.

The MOR and MOE values indicated that flake angle and species contributed to these properties. The highest parallel MOR and MOE values were associated with AL/RMS boards, which also had the lowest flake orientation values during board fabrication. The lowest parallel MOR and MOE values were associated with RML/RMS boards which also had one of the highest flake angle values. Statistically, the AL/RMS was similar to the RML/AS and RML/RML in bending MOE values. This MOE relationship between these three board types was evident between the AL/RMS and RML/RML in parallel MOR evaluations, which had the two lowest flake angle values. The red maple combined with aspen produced boards with above average parallel bending properties and below average perpendicular bending properties.

The bending strength values of 3-layered aspen/red maple combinations were comparable or better than those reported for single species by Kuklewski et al. 1985. All of the parallel MOR values in this study were above the flakeboard values reported by Carll (1986), except the RML/RMS panels. As expected, the parallel-aligned specimen values in general were higher in both MOR and MOE than the perpendicular-aligned specimens. These values were comparable to earlier studies (Geimer 1976; Kieser and Steck 1978; Krisnabamung 1974; Maloney 1977), but lower than values reported by Jackowski and Smulski (1988) and Springate (1980). Mat forming technique, board densities, and the resultant flake alignment values may in part explain the differences between values obtained in this study to those reported in the literature.

Statistical analysis showed no significant effects among all of the board types in internal bond and nail withdrawal values (Table 2). Some gains in nail withdrawal properties were measured for 3-layered aligned red maple flakeboards. The low internal bond values may be associated with resin distribution or possibly moisture content variations of the furnish. Since wax was not used in the fabrication of the panels, actual powdered phenolic resin content in the panels may have been below the target level of 6%. The internal bond values were below the values recommended by Carll (1986). Kuklewski et al. (1985) reported IB values

TABLE 3. *Summary of dimensional stability data.*[1]

Board type Face/Core	Thickness swell		Volume		Weight		Linear expansion	
	2 h	24 h	2 h	24 h	2 h	24 h	Parallel	Perpen-dicular
	% Change							
RML/RML	40.6B	45.5AB	41.0B	46.0AB	77.8A	94.0A	0.19A	0.10A
RML/RMS	47.9A	53.6A	48.3A	54.2A	96.3A	109.3A	0.13A	0.09A
RML/AS	41.0B	43.6B	41.4AB	44.1B	89.9A	102.2A	0.14A	0.15A
AL/RMS	40.4B	43.1B	40.8B	43.6B	84.9A	99.0A	0.10A	0.12A
AL/AS	43.8AB	46.3AB	44.3AB	46.9AB	88.7A	102.6A	0.14A	0.14A
AL/AL	40.1B	42.9B	40.7B	43.4B	83.6A	97.4A	0.16A	0.14A

[1] Means with the same letter are not significantly different at the 0.05 level. Values are an average of 3 measurements per board type.

from 52.5–117.7 psi for aligned red maple boards fabricated without wax. A significant reduction in IB properties were found to occur in this study (26–37 psi) compared with IB values reported by Kuklewski et al. (1985). This reduction may be due to poor contact between flakes in the parallel and perpendicular mode during board fabrication. An increase in resin levels or changes in furnish moisture content at this interface may improve the bonding between layers.

No significant differences were evident in the 2- and 24-hour weight change values among all the board types (Table 3). However, the RML/RMS boards were significantly different from most of the board types in volume and thickness swell values. The RML/RMS had the highest volume and thickness swell values among the board types. This indicated a possible species or flake length influence on the values. Brumbaugh (1960), found boards made from ½-inch-long Douglas-fir flakes to have a significantly greater moisture absorption after the 2- and 24-hour water immersions when compared with boards made of 2 inch and 4 inch flakes. He attributed the increase in water absorption to more end grain exposed for shorter flakes. The mixed species boards (RML/AS and AL/RMS) had significantly lower volume and thickness swell values than RML/RMS boards, particularly in the 24-hour values. While significant differences existed among the boards, the range in volume and thickness swell values was not large.

Parallel and perpendicular linear expansion values were statistically the same among all boards and similar to values for aligned boards reported by Kuklewski et al. (1985) and Jackowski and Smulski (1988). In fact the linear expansion values for all board types were excellent, and most values were 25 to 55% lower than the minimum value reported in Carll (1986). Similar conclusions were drawn by Geimer et al. (1975) in their study. They found that no statistical differences occurred among 3-layer Douglas-fir board types using both random and oriented flake alignment. Geimer et al. (1975) reported that an addition of 40% aligned face flakes to a nonaligned core could be made before linear expansion perpendicular to the grain became excessive.

SUMMARY

This study examined the use of red maple and aspen flakes in single and mixed species 3-layered flakeboards using long and short flakes. The static bending, internal bond, and nail withdrawal values indicated that red maple and aspen boards for the most part were comparable. Internal bond values were low for all layered test boards. Mixed species boards, particularly AL/RMS, produced some of the highest static bending values in the parallel direction. These boards had the lowest flake alignment values of all the test panels. Dimensional stability values were acceptable among all of the boards, with the mixed species boards producing some of the lowest values. Red maple 3-layered flakeboards were similar to aspen 3-layered flakeboards, and red maple and aspen may be mixed to produce acceptable 3-layered flakeboards. For most of the properties, boards with combined layers of red maple and aspen had property values similar to or better than the single species boards. The AL/RMS and RML/AS boards also had some of the lowest flake alignment values.

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