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Effects of Bark, Density Profile, and Resin Content on Medium-Density Fiberboards From Southern Hardwoods

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Abstract

Pressure-refined barky fibers of hickory, sweetgum, and southern red oak had a greater percentage of fines than did refined bark-free fibers of these species. Inclusion of bark decreased tensile and bending strengths of fiberboards by 16 to 18 percent, MOE by 10 to 14 percent, and IB by 8 percent. Density profile of boards strongly influenced their bending properties. Specimens with greatest density variation from face to core were 37 to 59 percent higher in MOR and 32 to 50 percent higher in MOE than specimens with uniform density. Increasing resin level from 8 to 10 percent improved bending and tensile properties by only 4 to 10 percent, but IB was increased by 38 percent. Linear expansion (50 to 90 percent RH) was greatest in high-density boards and was not affected significantly by inclusion of bark. Thickness swell was significantly less in southern red oak boards than in sweetgum or hickory boards. Inclusion of bark decreased thickness swell of southern red oak and hickory boards but increased it in sweetgum boards

ECONOMIC UTILIZATION of mixed hardwood species of varying densities is a problem common to the southern and eastern sections of North America. Large-scale conversion of these mixed species into medium-density fiberboard is a promising possibility (Brooks 1970), but the difficulty of harvesting this resource remains an obstacle. Field chipping of entire trees may be more economical than harvesting them in log form. Chips from whole-tree chippers contain substantial percentages of bark, however. A major objective of this study, therefore, was to determine the effect of bark inclusion in medium-density fiberboard made from three important southern hardwoods. Boards with various density profiles and resin contents were also compared.

Study Design and Procedure

The investigation was made in two phases. In the first phase, effects of bark inclusion and density profiles on bending properties and face hardness of 3/4-inch board were determined. In the second phase, bark and resin levels in 3/8-inch boards were evaluated for their effects on strength and dimensional stability.

Table 1. — CHARACTERISTICS OF TREES SAMPLED.

Species	DBH (in.)	Tree height (ft.)	Age (years)	Specific gravity[1] With bark	Specific gravity[1] Without bark
Sweetgum	6.4	48.4	25	0.47	0.49
Southern red oak	6.2	50.3	42	.64	.63
Hickory	6.3	47.2	55	.67	.70

[1]Specific gravity of disk removed at breast height based on OD weight and green volume

Collection of Material

Material for the study was collected from central Louisiana. At least eight trees of sweetgum (*Liquidambar styraciflua* L.), southern red oak (*Quercus falcata* var. *falcata*), and mockernut hickory (*Carya tomentosa* Nutt.) were felled, bucked into 4-foot sections, marked for identification, and transported to the laboratory. All material to a 2-inch top was utilized. Alternate sections were handpeeled with a draw knife to provide 500 pounds (ovendry (OD) weight) of each sample with bark and without bark before processing into chips at a local sawmill. Average measurements are given in Table 1. The percentages of bark (based on OD weight) on stems of the size used for this study were 13.4, 20.0, and 18.6 percent for sweetgum, southern red oak, and hickory (F. G. Manwiller, Southern Forest Expt. Sta., unpublished data).

Fiber Preparation

Green chips were transported to the Bauer Bros. Co. laboratory in Springfield, Ohio, for refining in a Bauer 418 pressurized refiner. Refiner conditions were held constant at a steam pressure of 100 psi, dwell time of 5 minutes, and plate clearance of 0.05 inch. Moisture content (MC) and density before and after refining are given in Table 2.

Wet fibers were dried in a small rotating drum by introducing hot air through the center. MC was reduced to less than 5 percent in about 3-1/2 hours. Samples of each fiber type were then run through a

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Table 2. — MOISTURE CONTENT AND DENSITY OF MATERIAL BEFORE AND AFTER REFINING

Species	MC(%) Before	MC(%) After	Wet density (lb/ft³) Before	Wet density (lb/ft³) After
Sweetgum				
With bark	99	116	19 8	4 7
Without bark	106	119	20 3	4 0
Hickory				
With bark	51	57	21 0	3 2
Without bark	50	67	29 0	3 0
Southern red oak				
With bark	60	76	20 8	3 5
Without bark	59	73	19 5	3 4

Bauer-McNett classifier to determine percentages retained by 8-, 14-, 28-, and 48-mesh screens; tests were replicated at least seven times.

Dry fibers were tumbled through a spray of resin and wax in a rotating wood drum. Wax content was held constant at 1 percent wax solids (Hercules, Inc. Paracol 404N) The resin was a liquid urea-melamine-formaldehyde mixture (Allied Chemical Fiberbond binder); treatments were 8 percent resin solids for 3/4-inch boards and 8 and 10 percent for 3/8-inch boards.

Fibers for the thinner boards were milled before and after blending in a 12-inch Sprout Waldron single disk refiner equipped with spike tooth disk sections.

Mat and Board Formation

Resin-spread fibers sufficient for a single board were passed through a specially built apparatus with engaging fingers to separate them and were collected in a forming box beneath. Final mat area was 16.5 by 20 inches; mat thickness depended on final board thickness and density desired. Mat MC was about 12 percent.

Mats were prepressed at room temperature with 300 psi, then placed in an oil-heated hot press maintained at 335°F. Platen pressures and press times (including time to close) were as follows:

Board thickness (in.)	Applied pressure (psi)	Total press time (min.)
3/4	240	9
3/4	480	9
3/8	800	7 (8% resin)
3/8	800	8 (10% resin)

Thickness stops between the platens controlled board thickness. Closing time was controlled indirectly by magnitude of applied pressure. At 240 psi, closing times averaged 145 seconds for hickory with bark, 86 seconds for sweetgum, and 79 seconds for southern red oak. The 3/4-inch boards were formed to yield a density of about 0.7 g/cc, and 3/8-inch boards were made at two densities (above and below 0.7 g/cc) to permit regression of strength properties on density. Densities were computed from weight and volume at test.

A sub-experiment with special pressing regime produced 3/4-inch boards uniform in density throughout their thickness. This uniformity was accomplished by pressing mats to stops in a cool press and then allowing them to remain under pressure until a platen temperature of 285°F was attained – a procedure taking about 1-1/4 hours.

In all, there were 54 3/4-inch boards (three species, two fiber types, three pressing regimes, three replications) and 48 3/8-inch boards (three species, two fiber types, two resin levels, two densities, two replications).

Tests

All boards were conditioned at 50 percent relative humidity (RH) and 72°F, and then evaluated for bending strength (MOR), modulus of elasticity (MOE), and internal bond strength (IB). Three replications of bending specimens from each board were evaluated. Observations of IB were replicated five times. In addition, face hardness of the 3/4-inch boards was determined by modified Janka ball test on ends of bending specimens.

Tensile strength of necked-down specimens (3/8-in. only) was measured, and MOE was evaluated with a 2-inch strain-gage extensometer. Linear expansion and thickness swell (50 to 90% RH) in the boards were also determined, and differences were evaluated for statistical significance at the 0.01 level by analysis of variance and Duncan's multiple range test.

Distribution of density throughout board thickness, i.e., the density profile, is a strong determinant of board properties (Plath and Schnitzler 1974), and this density profile can be adjusted by manipulation of platen pressure and temperature (Suchsland and Woodson 1974). Data on density variation was obtained by planing off successive thin layers (0.03 in.). This technique provided absolute values for layer density but failed to give a continuous profile X-ray radiography (Nearn and Bassett 1968) was therefore utilized to obtain a continuum of data. In this method, density profiles were obtained by recording intensity of light transmission through an exposed x-ray film of fiberboard cross sections. The x-ray unit was a Faxitron Model 805, manufactured by Hewlett Packard. The film was Kodak Industrial Type AA Ready Pack. Exposure for samples 9/16-inch thick was 1.7 minutes at 30 kV and 3 milliamperes.

All tests were conducted according to ASTM D 1037-64 (1968) except that bending specimens were 2 inches wide instead of the suggested 3 inches.

Results and Discussion

Fiber Classification

Hickory was the coarsest of the fibers: the 8-mesh screen retained over 51 percent of the bark-free hickory fibers but less than 35 percent of those from the other species (Table 3).

For all three species combined, the coarse fraction retained on the 8-mesh screen was higher for fibers without bark (39.1%) than for fibers with bark (32.1%). The fine fraction passing a 48-mesh screen was lower for fibers without bark (14.2%) than for fibers with bark (20.7%). The amount retained on intermediate screens was about equal for both types of fibers.

Static Bending

Three-fourths-inch boards. – At average density of 0.68 g/cc, 3/4-inch boards of greatest MOE (556,000

Table 3 — BAUER-McNETT SCREEN CLASSIFICATION OF PRESSURE-REFINED FIBERS FROM BARKY CHIPS AND BARK-FREE CHIPS OF THREE SOUTHERN HARDWOODS.

	Mesh designation[1]				
	+8	-8/+14	-14/+28	-28/+48	-48
			(%)		
Sweetgum					
With bark	25 5	16 5	24 7	14 3	19.0
Without bark	34 6	17 8	22 7	13 1	11 8
Southern red oak					
With bark	28 0	15 1	19 3	15 4	22 2
Without bark	31 2	15 9	20 6	15 7	16.6
Hickory					
With bark	42 7	11 6	14 1	10 8	20 8
Without bark	51 6	11 7	12 8	9 7	14 2

[1]Minus indicates passing through screen, plus indicates retained by screen

psi) and MOR (5,159 psi) were bark-free sweetgum pressed with platen pressure of 480 psi (Table 4). With all pressing regimes and species pooled, average MOE was 16 percent greater for bark-free boards than for boards including bark. Similarly, MOR of bark-free boards averaged 22 percent higher than MOR of boards with bark. Boards with uniform density profiles (Fig. 1C) had lowest MOR and MOE Those pressed at 480 psi had faces about 50 percent denser than cores (Fig. 1A), and gave a 46 percent increase in MOR and a 39 percent increase in MOE over uniform boards. Boards pressed at 240 psi had sinusoidal density profiles (Fig. 1B) with faces only slightly denser than cores; strengths of these boards were intermediate (Table 4).

Three-eighths-inch boards. – At comparable densities, 3/8-inch boards pressed at 800 psi differed little in MOR and MOE from 3/4-inch boards pressed at 480 psi. Both pressing regimes yielded density profiles similar to that shown in Figure 1A. MOE was affected to a lesser extent than MOR when bark was included (Table 5); averaged over all species and resin levels, the decrease was 17 percent in MOR but only 11 percent in MOE. An increase in resin level from 8 to 10 percent increased MOR by 10 percent and MOE by 5 percent for all species and bark conditions.

Tension

The inclusion of bark decreased maximum tensile strength of 3/8-inch boards by 16 percent and tensile MOE by 10 percent (Table 5). Increasing resin level from 8 to 10 percent improved the tensile strength of bark-free boards by 4 percent and that of barky boards by 10 percent. Tensile MOE was improved by 6 percent for both types of boards. The large improvement in the tensile strength of the barky material suggests that 8 percent resin was inadequate for coverage of material with a large proportion of fines. Resin coverage is more critical to tensile strength than it is to MOE since tensile strength involves the actual failure of fibers or bonds.

IB Strength

Quality of fiber-to-fiber bonds determines IB strength. This relationship is evident from IB values of 3/8-inch boards at two resin contents. Increasing resin content from 8 to 10 percent increased IB in bark-free boards by 41 percent and in barky boards by 35 percent (Table 5). Average IB was less in hickory boards (76 psi) than in oak (100 psi) and sweetgum (91 psi), perhaps because resin distribution on the coarse and curly fibers of hickory was not as uniform as on oak and sweetgum. Inclusion of bark in the boards decreased average IB for all species and resin levels by 8 percent.

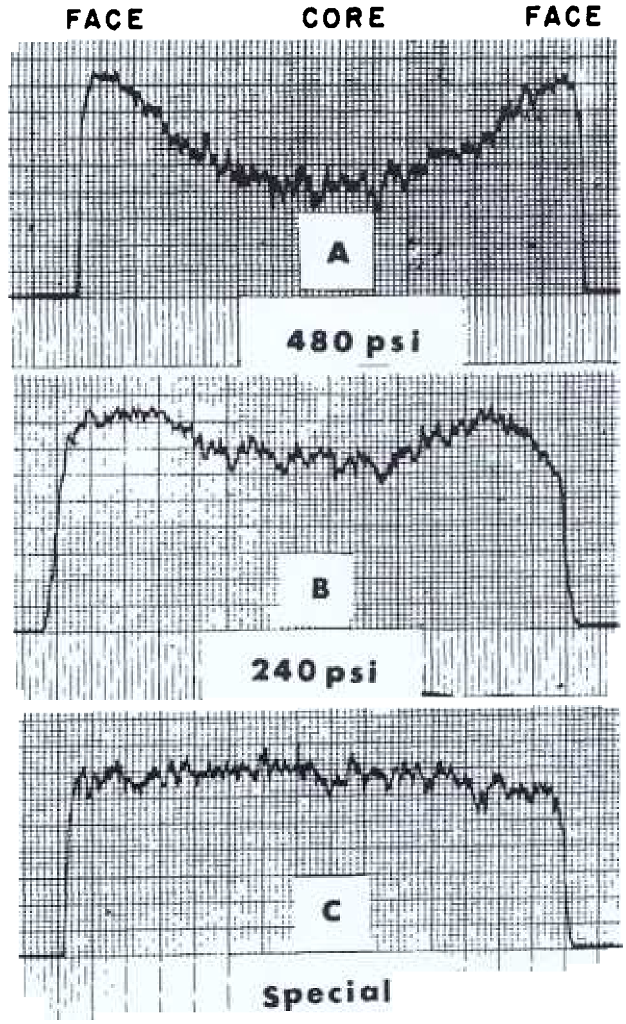

Figure 1. — Typical density profiles of fiberboards formed under three different pressing regimes, each of which yielded average board density of 0 68 g/cc Board A has face density of 0.9 g/cc and core density of 0.6 g/cc

Table 4. — STATIC BENDING PROPERTIES OF 3/4-INCH BOARDS, WITH 8 PERCENT RESIN AND DENSITY OF 0 68 g/cc AT 7 PERCENT MC, PRESSED AT 480 PSI, 240 PSI, AND UNDER A SPECIAL REGIME TO YIELD A UNIFORM DENSITY PROFILE

Fiber type	MOR (psi)			MOE (1,000 psi)		
and species	480	240	Special	480	240	Special
Without bark						
Sweetgum	5,159	4,755	3,565	556	493	408
Southern red oak	4,744	4,253	3,191	500	445	367
Hickory	4,826	3,904	3,349	482	400	355
With Bark						
Sweetgum	4,781	4,209	3,008	506	440	337
Southern red oak	3,680	3,320	2,591	418	393	288
Hickory	3,486	3,250	2,538	397	364	300

Table 5 — BENDING, TENSION, AND IB STRENGTHS OF 3/8-INCH FIBERBOARDS FROM THREE HARDWOOD SPECIES, WITH AND WITHOUT BARK, AND AT TWO RESIN LEVELS. VALUES HAVE ALL BEEN ADJUSTED TO A DENSITY OF 0.70 g/cc AT 4.6 PERCENT MC

	Sweetgum				Southern red oak				Hickory			
	8% resin		10% resin		8% resin		10% resin		8% resin		10% resin	
	w/b	wo/b	w/b	wo/b	w/b	wo/b	w/b	wo/b	w/b	wo/b	w/b	wo/b
Static bending												
MOR (psi)	4,646	5,374	4,904	6,143	4,163	5,213	4,720	5,412	4,154	4,919	4,539	5,628
MOE (1,000 psi)	504	521	498	556	433	519	470	542	423	486	442	501
Tension												
Max. stress (psi)	2,552	3,200	2,735	3,378	2,461	3,061	2,728	3,188	2,378	2,737	2,677	2,825
MOE (1,000 psi)	418	450	462	492	398	486	418	487	388	405	397	448
IB (psi)	72	75	100	116	72	92	112	126	73	64	81	84

IBs of 3/4-inch boards were not tabulated because resin distribution on their fibers was inferior to that accomplished in the 3/8-inch boards through milling of fibers in a lab refiner.

Dimensional Stability

Linear expansion in 3/8-inch boards varied by species and board density. Sweetgum expansion (0.31%) was significantly larger than either southern red oak (0.28%) or hickory (0.27%). High-density specimens (0.79 g/cc) showed greater linear expansion (0.31%) than those with density of 0.70 g/cc (0.26%). Inclusion of bark in the boards had no significant effect on linear expansion.

Thickness swell in southern red oak was significantly less than in sweetgum and hickory:

	With bark	Without bark
	----- (%) -----	
Sweetgum	9.7	9.1
Hickory	8.8	9.6
Southern red oak	7.6	8.7

Inclusion of bark decreased thickness swell in southern red oak and hickory boards but increased it for sweetgum boards. Board density and resin level had no significant effect.

Face Hardness

The Janka ball test indicated that boards with uniform density had harder faces than those with high face density and low-density cores (Table 6). This finding suggests that the Janka ball test is a better indicator of internal density than of face hardness. The imbedded ball, when pressing against a dense face over a less dense core, easily deflects the face into the core somewhat in the manner that a thin overlay might deflect under pressure into a sponge. Nevertheless, the test showed that bark-free boards were harder (1,230 lb.) than boards including bark (1,116 lb.). Hickory boards were harder (1,310 lb.) than sweetgum (1,112 lb.) and red oak (1,098 lb.) boards.

Conclusions

Fiberboards of good quality can be made from barky hardwoods, provided resin distribution is adequate. Strength properties are reduced somewhat by the inclusion of bark, but these losses can be countered by altering pressing schedules (a procedure which changes the density profile), or they could possibly be eliminated by reducing the percentage of fines by screening. Uniform density from face to core would produce tight edges, good machining characteristics, and high IB but poor bending properties. In contrast, high face density and low core density would give excellent bending properties but low IB and poor screw withdrawal. The manufacturer would have to decide which properties are most important for his product and make the necessary adjustments.

Medium-density fiberboard is sensitive to variation in raw material specific gravity and is not unlike regular particleboard in this respect. Bending strengths of fiberboards at comparable densities were greatest in boards made from raw material of low specific gravity.

Table 6 — FACE HARDNESS OF 3/4-INCH BOARDS WITH AN AVERAGE DENSITY OF 0.68 g/cc AT 7 PERCENT MC.

Fiber type and pressing regime	Face hardness (lb.) Sweetgum	Southern red oak	Hickory
Without bark			
240 psi	1,085	1,073	1,370
480 psi	1,078	1,037	1,207
Special	1,359	1,305	1,559
With bark			
240 psi	962	1,051	1,184
480 psi	1,020	968	1,118
Special	1,167	1,152	1,420

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