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Medium Density Fiberboard from Mixed Southern Hardwoods

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Abstract

Medium-density fiberboards of acceptable quality were made from a mixture of barky chips from 14 southern hardwoods. Boards made from fiber refined at three different plate clearances did not vary significantly in bending, internal bond (IB), or linear expansion. But, lack of replications and the fact that the refiner was not loaded to capacity caused these results to be inconclusive. Increasing press time from 6.5 to 9.5 minutes did not significantly affect bending, linear expansion, or thickness swell, but did result in an improvement in IB from 64 to 73 psi (0.44-0.50 MPa). Bending properties (MOR and MOE) of the boards were predicted by weighing fiberboard properties for individual species according to the proportion of ovendry chips in the mixture. The averages ranged from 1% below to 6% above the actual values. IB values were predicted less successfully. Additional predictions based on established regression of bending properties versus dry chip bulk density were also made. A weighted average dry chip bulk density of 11.84 lb/ft^3 (190 kg/m^3) yielded values of MOR and MOE from 4% below to 1% above the actual values. Values of MOR at densities of 0.62 and 0.83 were 3330 and 5550 psi (22.9-38.2 MPa), respectively; corresponding values for MOE were 325,000 and 469,000 psi (2239-3230 MPa).

Introduction

A problem of many of the forested regions of the United States is how to use mixed hardwoods economically. The problem is especially acute in the southern forest region where these species appear in stands with pines. A possible solution to the problem is to use hardwoods in medium density fiberboard. Because of the advent of whole-tree chipping, it is very likely that more material can be used with bark included and in mixture of different species. Rooney (2) concluded that predictable operations could be attained with existing digestion-refining equipment if species variations and mixes were shown.

Objective

One objective of this study was to determine the effects of plate clearance and cure time on linear expansion, bending, and IB properties of experimental fiberboards made from fiber produced by pressure-refining a mixture of barky chips composed of 14 southern hardwoods. Medium density fiberboards (3/4-in. or 19 mm thick) were made from fibers refined at three plate clearances (0.050, 0.075, and 0.100 in. or *1.3, 1.9* and *2.5* mm) and pressed at two cure times (6.5 and 9.5 min.).

A second objective was to determine if properties of boards made from chip mixtures could be predicted from properties of boards made from the individual species. Properties of thin boards (3/8-in. or 9.5 mm thick) made from the mixture refined with 0.050-in. (1.3 mm) plate clearance were compared with those predicted by weighing properties of boards made from the individual species.

Procedure

Collection and Preparation of Material

Material for the study was collected as described in Woodson (3). Green barky chips from each of 14 species were thoroughly mixed according to ratios in which the species commonly occur in the South (Table 1). The chips were separated into three equal piles and refined in a

Table 1. Moisture content and percentage of each species used in making fiberboards.

Species	Moisture Content	Proportion by O D Weight
	----------- Percent -----------	
Sweetgum (*Liquidambar styraciflua* L.)	124	18.75
Black tupelo (*Nyssa sylvatica* Marsh.)	87	7.60
Hickory, true (*Carya* spp.)	53	12.20
Post oak (*Quercus stellata* Wangenh.)	76	10.30
So. red oak (*Q. falcata* Michx.)	73	10.05
Blackjack oak (*Q. marilandica* Muenchh.)	68	7.85
Water oak (*Q. nigra* L.)	75	10.55
White oak (*Q. alba* L.)	68	9.20
Yellow-poplar (*Liriodendron tulipifera* L.)	108	2.70
Sweetbay (*Magnolia virginiana* L.)	96	2.45
White ash (*Fraxinus americana* L.)	49	4.05
Winged elm (*Ulmus alata* Michx.)	80	2.15
Red maple (*Acer rubrum* L.)	75	1.65
Hackberry (*Celtis occidentalis* L.)	61	0.80

Bauer 418 pressurized refiner[1] at a steam pressure of 95 psi (0.6 MPa) retention time of 5 minutes, and plate clearance of 0.050, 0.075, or 0.100 in. (1.3, 1.9, or 2.5 mm). Chips entered the refiner at 73% moisture content and emerged at 110%.

Wet fibers were dried to about 3% moisture content at a temperature of 220°F (104°C) before blending with 10% urea-melamine-formaldehyde resin solids (Allied Chemical Fiberbond Binder) in a rotating drum-type blender.

Mat and Board Formation

Enough resin-spread fibers for making one 3/4-in. (19 mm) board were passed through a 12-in. (305 mm) single-disc laboratory refiner equipped with spike-tooth disc section. The milled fibers were then blown into a cyclone and allowed to fall about 4 ft (1.22 m) into a forming box (16.5 by 20 in. or 419 by 508 mm). Mats were pre-pressed at room temperature with a pressure of 100 psi (0.7 MPa) and were hot-pressed at 330°F (166°C) with a pressure of 485 psi (3.3 MPa). Mat moisture content entering the hot press averaged 9.6%, and closing time to thickness stops averaged 47 seconds.

Preliminary tests indicated that temperature in the center of the core or 3/4-in. (19 mm) boards increased from room temperature to 227°F (108°C) in 4.5 minutes when platens were 330°F (166°C) (Figure 1). Although longer cure times of 6.5 and 9.5 minutes were selected to determine variations in board properties, complete cure should have been accomplished in the core after 5.5 minutes.

The 3/8-in. (9.5 mm) boards, used for comparison with boards made from one species, were formed at two densities (0.62 and 0.82 g/cm^3 or 38.7 and 51.2 lbs/ft^3) and replicated four times. Press conditions were constant at temperatures of 330°F (166°C) and pressure of 485 psi (3.3 MPa).

All laboratory boards were conditioned at 70°F (21°C) and 50% relative humidity (RH) before they were tested for bending and IB properties. Two bending samples (2 and 3 in. or 50.8 and 76.2 mm wide), five IB specimens, and one linear expansion sample were prepared from each board. The 2- and 3-in. samples were used to determine if width affected bending. All tests were conducted according to ASTM D 1037-72a. Specimen densities were based on weight and volume at the equilibrium conditions (50% RH).

[1]Mention of trade names is solely for identification of material and equipment used and does not imply endorsement by the USDA.

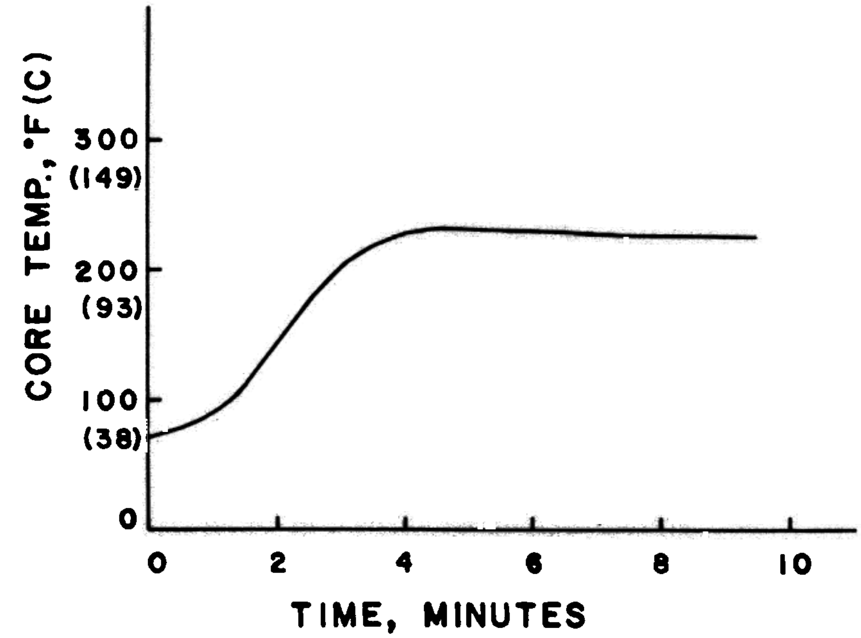

Figure Increase of core temperature with press time in 3/4-in. (19 mm) medium-density fiberboard (0.70 g/cm^3) made from mixed hardwoods. Initial mat moisture content was 10%; resin content, 10%; platen temperature, 330°F (166°C).

Results and Discussion

Mats cured for 9.5 minutes emerged from the hot press at 5.3% moisture content (MC) and those cured for 6.5 minutes emerged at 6.5% MC. A check of specimens after conditioning at 50% RH and 70°F (21°C) indicated that those cured for 9.5 minutes were slightly lower in MC (7.1%) than those cured for 6.5 minutes (7.3%). This difference was not considered significant. Analysis of all the specimens indicated that board densities also did not differ significantly and averaged 0.69 g/cm^3 (43 lbs/ft^3).

Static Bending

Modulus of rupture (MOR) was not affected significantly by refiner plate setting or cure time (Table 2). Modulus of elasticity (MOE) was not significantly different between the two cure times, but MOE was slightly greater in the boards refined at the larger plate clearances (Table 2).

Refiner runs were not replicated; however, and the fibers were refined at load rates less than capacity for the refiner. It is possible that these factors influenced the results.

Table 2. Modulus of rupture (MOR) and modulus of elasticity (MOE) for fiberboards [3/4-in. (19 mm) thick and 3 in. (76.2 mm) wide] from mixed hardwoods refined at three plate settings and pressed for two cure times. Average density of specimens was 0.69 g/cm^3 (43 lbs/ft^3) at 7% moisture content.

Plate Setting	Modulus of Rupture		Modulus of Elasticity	
	6.5 min.	9.5 min.	6.5 min.	9.5 min.
in. (mm)	psi (MPa)		1000 psi (MPa)	
0.050 (1.3)	4060 (28.0)	4120 (28.4)	424 (2.9)	425 (2.9)
0.075 (1.9)	4225 (29.1)	4060 (28.0)	441 (3.0)	429 (2.9)
0.100 (2.5)	4400 (30.3)	4190 (28.9)	449 (3.1)	440 (3.0)

The standard bending specimen used in the laboratory is 3 in. (76.2 mm) wide for fiberboards 3/4-in. (19 mm) thick, but is is sometimes convenient to reduce the width to 2 in. (50.8 mm). To determine if the reduction in width affected the bending results, samples were prepared at both widths and compared. The MOR and MOE were not significantly different for 2- or 3-in.-wide (50.8 or 76.2 mm-wide) specimens (Table 3). Since cure time was not a significant factor, the values were pooled together. Each value in Table 3 represents an average of eight observations.

Internal Bond

Internal bond (IB) tests indicated that cure times of 6.5 minutes gave lower than 9.5 minutes and that values for the three plate settings were not significantly different (Table 4). When averaged over all plate settings. IB values for cure times of 6.5 and 9.5 minutes were 64 and 73 psi (0.44 and 0.50 MPa) respectively.

Table 3. Modulus of rupture (MOR) and modulus of elasticity (MOE) for 3/4-in. (19 mm) thick fiberboards from mixed hardwoods refined at three plate settings and tested at two widths. Average density of specimens was 0.69 g/cm^3 (43 lbs/ft^3) at 7% moisture content.

Plate Setting	Modulus of Rupture		Modulus of Elasticity	
	2 in. (50.8 mm)	3 in. 76.2 mm)	2 in. (50.8 mm)	3 in. (76.2 mm)
in. (mm)	psi (MPa)		1000 psi (MPa)	
0.050 (1.3)	3960 (27.3)	4090 (28.2)	410 (2.8)	425 (2.9)
0.075 (1.9)	4030 (27.8)	4140 (28.5)	427 (2.9)	435 (3.0)
0.100 (2.5)	4290 (29.6)	4290 (29.6)	449 (3.1)	449 (3.1)

Table 4. Internal bond for 3/4-in. (19 mm) thick fiberboards from mixed hardwoods refined at three plate settings and pressed at two cure times. Average density of specimens was 0.69 g/cm^3 (43 lbs/ft^3) at 7% moisture content.

Cure Times (min)	Plate Setting, Inches (mm)		
	0.050 (1.3)	0.075 (1.9)	0.100 (2.5)
	psi (MPa)		
6.5	63 (0.43)	67 (0.46)	62 (0.43)
9.5	80 (0.55)	69 (0.47)	70 (0.48)

Moisture Response

Linear expansion (over a span of 12 in. or 305 mm) and thickness swell (50 to 90% RH) were measured on 2-in. (50.8 mm)-wide specimens. The specimens remained in each conditioning chamber 30 days. Linear expansion and thickness swell were converted to coefficients of expansion (percent change per percent moisture content change). Specimens cured for 6.5 minutes in the press appeared to have lower linear expansion coefficients (0.015) than those cured for 9.5 minutes (0.017), although considerable variation was encountered. These coefficients are based on an average increase in MC of 9.9%. Linear expansion coefficients for samples refined at a plate clearance of 0.050 in. (1.3 mm) were higher (coefficient of 0.020) than those for samples refined at clearances of 0.075 (1.9 mm) and 0.100 in. (2.5 mm) (coefficients of 0.014 and 0.015). Thickness swell coefficients were unresponsive to cure time or plate setting. In 50- and 90-% RH environments the average coefficient was 0.75 for an increase in MC from 7.6 to 17.5%.

Effect of Species Mixing

To determine if species mixtures react in a predictable manner, 3/8-in.-thick (9.5 mm) fiberboards were made from the mixture of species outlined in Table 1. The bending properties and IB of 3/8-in.-thick (9.5 mm) fiberboards made from each of the 14 species used in the mixture were previously shown by Woodson (3). The results from that study were used to attempt a prediction of the properties of the fiberboards made from mixed species. Press conditions were identical to those of the earlier study. Bending and IB of the boards from individual species were weighted according to the percentages outlined in Table 1 to determine an average value for the mixture. The results indicate close agreement between actual and predicted bending properties (Table 5). Comparisons for IB were not as favorable.

Further predictions were made by determining a weighted dry chip bulk density of the mixture of 14 species. This weighted value [11.84 lb/ft^3 (190 kg/m^3)] was then converted into linear regressions expressing bending MOR and MOE versus dry chip bulk density. Because in the previous study these regressions indicated that MOR and MOE decreased with increasing dry chip bulk density, it became possible to make predictions from the following linear regressions (bending property represents the y-variable and dry chip bulk density is the x-variable):

Bending Property	Specimen Density (g/cm^3)	y-Intercept	Slope	r
MOR (psi)	0.62	6535	-269	.815
MOR (psi)	0.82	9896	-384	
MOE (1000 psi)	0.62	634	-27	
MOE (1000 psi)	0.82	796	-28	

The results are shown in the following tabulation:

Specimen density	Modulus of Rupture		Modulus of Elasticity	
	Actual	Calculated	Actual	Calculated
g/cm^3 (lbs/ft^3)	psi (MPa)		1000 psi (MPa)	
0.62	3330	3350	325	314
(38.7)	(22.9)	(24.3)	(2.23)	(2.16)
0.82	5550	5350	469	464
(51.2)	(38.2)	(36.8)	(3.23)	(3.20)

Table 5. Predicted[1] and actual modulus of rupture, modulus of elasticity and internal bond for 3/8-in. (9.5 mm) thick fiberboards of mixed hardwoods with 10% resin.

Specimen density	Modulus of Rupture		Modulus of Elasticity		Internal Bond	
	Actual	Predicted	Actual	Predicted	Actual	Predicted
g/cm^3 (lbs/ft^3)	psi (MPa)		1000 psi (MPa)		psi (MPa)	
0.62	3330	3530	325	331	75	82
(38.7)	(22.9)	(24.3)	(2.2)	(2.3)	(0.52)	(0.56)
0.82	5550	5490	469	476	155	175
(51.2)	(38.2)	(37.8)	(3.2)	(3.3)	(1.07)	(1.20)

[1]Predicted values are weighted averages by percentage of ovendry weight per species in the mixture.

This tabulation indicates that if the exact species mix and the properties of the individual components are known, the bending properties of the mixture can be closely approximated. A similar prediction for IB could not be made because the relationship between IB and dry chip bulk density was not significant.

References

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