DRY-PROCESS HARDBOARDS FROM RECYCLED NEWSPRINT PAPER FIBERS

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ABSTRACT

Dry-process hardboard represents a favorable option for recycling old newspaper fibers. However, dry-process boards tend to be less dimensionally stable than boards processed by other methods. Our objective was to determine the effects of various wood fiber (WF) to old newspaper (ONP) ratios (100:0, 50:50, and 0:100 WF/ONP) on the mechanical strength and water resistance of dry-process hardboards made from these fibers. Untreated and acetylated hardboards were made with 3 or 7 percent resin and 0.5 percent wax. Boards were tested for static bending and tensile strength properties and water resistance. As expected, increasing the resin level from 3 to 7 percent generally improved all measured properties. Acetylation substantially improved the water resistance of all boards; increasing the amount of ONP caused a corresponding deterioration in both mechanical properties and water resistance.

INTRODUCTION

Hardboard, a panel material with a specific gravity ranging from 0.5 to 1.45, is made from wood that is first reduced to fibers or fiber bundles and then manufactured into rrelatively large panels of moderate thickness. In their final form, these panels retain some properties of the original wood. However, the panels also gain new properties because of the manufacturing methods and the option of using modified fibrous materials. Hardboard panels can be and often are tailored for specific end-uses.

Contaminants in wastepaper fibers, such as inks and dyes, are not necessarily a problem in the manufacture of hardboards. In many cases, hardboards are opaque (colored, painted, or overlaid) and do not require extensive cleaning and refinement. Thus, wood fiber/old newspaper (WF/ONP) composites provide an favorable option for recycling paper fiber, a highly visible and troublesome class of municipal solid waste.

The production of hardboards by dry-process technology requires much less process water than production by other methods — a feature that is particularly important because of the cost of complying with the increasingly stringent regulations that govern the quality of plant effluents [7]. However, the use of dry-process technology is somewhat limited because the process reduces hydrogen and lignin bonding; consequently, the dimensional stability of dry-process boards is less than that of wet-process boards [6]. In 1975, Laundrie and McNatt [3] evaluated the potential of using a 75:25 percent mixture of aspen and newsprint fiber to produce dry-formed, medium-density hardboards. They found that the addition of 25 percent, ONP adversely affected all mechanical properties.

Our research focused on dry-process hardboards made from virgin wood fiber, from a 50:50 WF/ONP mixture, and from 100 percent ONP. Wastepaper that has been reduced to fiber form, like ONP, has a surface area that is much greater than that of pressure-refined hardboard fiber. Consequently, we anticipated that the water absorption properties of

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hardboards made with ONP might. be unacceptably high. Rowell [4] reported that wood flakes, strands, and fibers can be chemically modified using an acetylation process. When these materials are converted into panel products. the panels possess greatly improved dimensional stability properties and reduced susceptibility to biodegradation by decay fungi. To test the dimensional stability of boards made with ONP fillers, we incorporated acetylation into the design of our experiment.

EXPERIMENTAL DESIGN AND ANALYSIS

The experiment consisted of WF/ONP formulations in the ratios of 100:0, 50:50, and 0:100. For each formulation, we tested untreated and acetylated fibers at both 3- and 7-percent resin levels (based on resin solids content and ovendry fiber weight). All boards had a wax content of 0.5 percent. Each formulation was considered a replicated set that consisted of five individual boards. A total of 60 boards were made.

MATERIALS

The wood fibers, obtained from Georgia–Pacific Company[2] (Catawba, SC), were produced from a mixture of hardwood species. The fibers were processed from hardwood pulp-grade chips through an American Defiberator digestor at 690 kPa steam pressure for 4 min and refined through a Bauer 400 refiner. After refining, the fibers were dried to a moisture content of 4 percent in a gas tribe dryer.

The newsprint fibers obtained from ONP were first hammermilled using a 25.4-mm screen opening. This material was then placed into a hydropulper for further fiberization. The resultant fillers were then mechanically dewatered and dried in an oven to a moisture content ranging between 30 and 40 percent. While at this moisture content, the fibers were hammermilled using a 6.3-mm screen opening. They were then dried to a final moisture content of 4 to 5 percent and used for the 0:100 WF/ONP formulation. Our preliminary studies showed that the 6.3-mm fraction of newsprint, fibers did not mix well with the wood fibers. Therefore, the newsprint fibers used for the 50:50 WF/ONP formulation were hammermilled again using a 1.6-mm screen opening.

The phenolic resin· obtained from the Georgia Pacific Company, had a solids content of 52 percent, viscosity of 50 to 100 cps at 25°C, and pH of 9.5 to 10.0. The wax, obtained from Hercules, Inc. (Wilmington, DE), had a. solids content of 50 percent, viscosity of 300 to 500 cps at, 25°C, and pH of 6 to 6.5.

PROCESSING

Acetylation

The acetylation reaction was carried out in a large stainless-steel reactor using acetic anhydride. The acetic anhydride was preheated in a holding tank to 110°C, and the reaction vessel was preheated to 120°C. The fibers (5.45 kg) were placed in a stainless-steel wire-mesh basket in the reactor and reacted while totally submerged in acetic anhydride for 6 h at 120°C. The fibers were then ovendried at 105°C to remove excess acetic acid and acetic anhydride. This procedure resulted in an acetyl weight gain of 20 percent.

Adhesive Application

Two methods were used for applying wax and resin. For the boards containing 100:0 and 0:100 WF/ONP, the wax and resin were sprayed on the WF or ONP fibers as they

[2] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

tumbled in a rotating drum. Our preliminary research indicated that blending WF and ONP fibers is complicated because they have very different characteristics. Consequently, a two-step procedure was developed for the 50:50 WF/ONP formulation. First, equal amounts (according to moisture content level) of wood and ONP fiber were separately blended with wax and resin in a rotating blender. Then, the two fiber-adhesive blends were mixed together in the blender. All the blended furnish was then transferred to an atmospheric single-disk refiner to break up fiber and resin clumps and to enhance the dispersion of the adhesive on the fibers. We found that the refiner greatly improved the uniformity of adhesive distribution on both types of fibers.

Board Manufacture

Five boards with a specific gravity of 1.0 and a target thickness of 3.2 mm were produced for each experimental condition. Mats were formed on a 305- by 305-mm vacuum-forming box, in which the fiber was passed through a 5.7-mm screen and onto a 1.3-mm screen. The mat was then flipped over onto a caul for pressing. All boards were pressed on a manually controlled, steam-heated press. Previous research [8] had established that boards containing acetylated material are less compressible, thus requiring a higher pressure for compaction. The boards were pressed at 190°C for 6 min at a maximum pressure of 4.95 MPa for control boards and 9.23 MPa for boards containing acetylated fiber. Because boards containing acetylated fiber required a higher maximum pressure, 6 min of additional cooling time were needed while the board was still under compaction to reduce steam vapor pressure in the pressed board and to maintain the target thickness. After pressing, all the panels were trimmed to a final size of 279 by 279 mm.

TESTING

Water absorption and thickness swell properties after a 24-h water soak and static bending and tensile propertics were determined according to ASTM D1037 standards [2]. Prior to mechanical and physical property testing at room temperature (about 23°C), the specimens were conditioned at 50 percent relative humidity and 20°C. The specimens had minimal exposure to ambient humidity during the tests.

RESULTS AND DISCUSSION

The results are presented in Tables 1 to 3. Each value is an average of 10 tests. Target specific gravity values were closely achieved, and therefore the physical and mechanical properties obtained on the various tests conducted in this experiment were not statistically adjusted to nominal values.

Static Bending Properties

The minimum required modulus of rupture (MOR) value in the ANSI–AHA standard [1] is 31.0 MPa for standard hardboard. In our study, all boards met this minimum property requirement. Untreated boards had the highest MOR values with 100:0 WF/ONP and 3 or 7 percent resin, and with 50:50 WF/ONP and 7 percent resin. Acetylated boards with 100:0 and 50:50 WF/ONP had lower MOR values. For untreated and acetylated boards with 0:100 WF/ONP, MOR values were about equal at both resin levels.

A pattern similar to that found for MOR values was noted for modulus of elasticity (MOE) values. Untreated boards had the highest MOE values with 100:0 WF/ONP and 3 or 7 percent resin and with 50:50 WF/ONP and 7 percent resin. For acetylated boards with 50:50 WF/ONP and 3 percent resin, the MOE values were somewhat higher than those for the untreated boards. For the 0:100 WF/ONP formulation at both resin levels, the MOE values of boards containing acetylated fiber were somewhat higher than those of boards containing untreated fiber.

Table I. Static bending properties of dry-process hardboards

Treatment and adhesive	Mechanical property for various WF/ONP ratios[a]					
	Modulus of rupture[b] (MPa)			Modulus of elasticity (GPa)		
	100:0	50:50	0:100	100:0	50:50	0:100
Untreated						
3% resin	80.3 (11)	50.6 (5)	35.8 (10)	4.31 (16)	3.09 (17)	1.58 (16)
7% resin	96.7 (10)	88.3 (16)	44.1 (15)	4.83 (10)	5.44 (17)	2.14 (30)
Acetylated						
3% resin	44.4 (20)	46.7 (9)	38.9 (13)	3.51 (20)	3.57 (18)	2.32 (11)
7% resin	62.7 (8)	51.5 (12)	42.3 (14)	3.82 (10)	3.24 (10)	2.71 (12)

[a]Values in parentheses are coefficients of variation (%).
[b]ANSI–AHA minimum property value for standard hardboard is 31.0 MPa.

Table II. Tensile strength properties of dry-process hardboards

Treatment and adhesive	Tensile strength (MPa) for various WF/ONP ratios[a,b]					
	Parallel to surface			Perpendicular to surface		
	100:0	50:50	0:100	100:0	50:50	0:100
Untreated						
3% resin	38.4 (6)	21.8 (14)	17.8 (18)	1.5 (32)	0.4 (39)	0.3 (30)
7% resin	38.7 (8)	39.4 (16)	21.3 (16)	2.3 (20)	0.8 (32)	0.5 (13)
Acetylated						
3% resin	18.9 (18)	17.1 (6)	18.2 (26)	1.0 (39)	0.6 (39)	0.3 (27)
7% resin	24.0 (8)	21.0 (6)	17.9 (19)	1.2 (19)	0.8 (45)	0.5 (30)

[a]Values in parentheses are coefficients of variation (%).
[b]ANSI–AHA minimum property values for standard hardboard are as follows: tensile strength parallel to surface, 15.2 MPa; tensile strength perpendicular to surface, 0.62 MPa.

Table III. Water resistance of dry-process hardboards

Treatment and adhesive	Water resistance (%) for various WF/ONP ratios[a,b]					
	Water absorption			Thickness swell		
	100:0	50:50	0:100	100:0	50:50	0:100
Untreated						
3% resin	22.5 (8)	58.3 (14)	60.7 (24)	20.4 (27)	45.5 (16)	46.7 (17)
7% resin	24.0 (9)	30.8 (4)	52.2 (23)	13.4 (13)	20.3 (5)	35.0 (20)
Acetylated						
3% resin	13.0 (26)	14.9 (8)	27.7 (23)	4.9 (26)	4.5 (29)	6.9 (27)
7% resin	9.0 (9)	14.0 (13)	31.7 (16)	3.4 (18)	3.6 (51)	5.3 (8)

[a]Values in parenthesis are coefficients of variation.
[b]ANSI–AHA maximum values for standard hardboard, are $< 35\%$ for water absorption and $< 25\%$ for thickness swell.

Tensile Strength Properties

The minimum tensile strength parallel to board surface as specified in the ANSI-AHA standard is 15.2 MPa for standard hardboard. All treatments at all formulation ratios and resin levels exceeded this minimum value. For perpendicular-to-surface tensile strength, the ANSI–AHA minimum requirement is 0.6 MPa for standard hardboard. Average values for untreated and acetylated boards with 100:0 WF/ONP and 3 or 7 percent resin and with 50:50 WF/ONP and 7 percent resin exceeded the minimum required level; however, the coefficients of variation were large.

Water Resistance

The ANSI–AHA maximum property standards for 3.2-mm-thick standard hardboard are 35 percent for water absorption and 25 percent for thickness swell.

A 24-h water-soak test was used to measure water absorption and thickness swell of untreated and acetylated boards made from the three formulations.

Untreated boards with 100:0 WF/ONP and 3 or 7 percent resin and untreated boards with 50:50 WF/ONP and 7 percent resin had lower water absorption values than the required maximum value of 35 percent. Water absorption values of untreated boards with 50:50 WF/ONP and 3 percent resin and 0:100 WF/ONP at both resin levels had higher values than those allowed by the standard.

Boards containing acetylated fibers at the 100:0 WF/ONP ratio made with 3 or 7 percent resin had 13 and 9 percent water absorption, respectively. Boards with 50:50 WF/ONP had about 14 percent water absorption at both resin levels, whereas boards with 0:100 WF/ONP at 3 or 7 percent resin had 28 and 32 percent water absorption, respectively. One noteworthy observation is that all these values are well below the allowed maximum of 35 percent as specified in the standard.

Untreated boards with 100:0 WF/ONP at both resin levels and with 50:50 WF/ONP at the 7-percent resin level had thickness swell values that were lower than or equal to this requirement. Thickness swell values for the 50:50 and 0:100 WF/ONP formulations at the 3-percent resin level averaged 46 percent. For 0:100 WF/ONP at 7 percent resin, thickness swell was 35 percent.

For boards with acetylated fiber, thickness swell values averaged from 3 to 7 percent for all formulations at both resin levels.

CONCLUDING REMARKS

Bending strength properties (MOR) for all untreated boards were higher than or about equal to those of acetylated boards at both resin levels. Bending stiffness properties (MOE) were improved by the acetylation treatment for the 50:50 ratio of WF/ONP at 3 percent resin and for the 0:100 ratio at both resin levels compared to the same formulation ratios for untreated boards. The bending strength properties of all the experimental boards exceeded the ANSI–AHA standard.

Compared to the values for acetylated boards, tensile strength values parallel to the hoard surface for untreated boards were substantially higher for the 100:0 and the 50:50 WF/ONP formulations at both resin levels. For the 0:100 WF/ONP formulation, values for tensile strength in this direction were close to each other for untreated and acetylated hoards at both resin levels. All formulations at both resin levels for untreated and acetylated boards produced tensile strength properties above the minimum property levels for standard hardboards.

Values for tensile strength perpendicular to the surface for untreated boards with 100:0 WF/ONP at both resin levels were higher than those for similar boards containing acetylated fiber. For untreated and acetylated hoards, tensile strength values for the 50:50 and 0:100 WF/ONP formulations at both resin levels were relatively close to each other. For the 0:100 WF/ONP formulation, all values for tensile strength perpendicular to

the surface were lower than the ANSI–AHA minimum property requirement for standard hardboards.

Except for bending stiffness, the acetylation process caused a substantial decrease in all other mechanical properties. Similar findings were reported for acetylated aspen flakeboards by Youngquist et al. [8] and were attributed to the low wettability and lack of adhesive penetration into acetylated flakes as well as the presence of more voids in boards made with these flakes. A scanning electron microscope study indicated that decreased wetting, flow, and penetration of acetylated flakes by the phenolic resin were causes of poor adhesion [5].

The acetylation chemical modification process substantially improved water absorption and thickness swell properties for all formulations at both resin levels. All values obtained for boards containing acetylated fiber were below the maximum values specified in the ANSI–AHA standard. This was also true for untreated boards made from the 100:0 WF/ONP formulation at both resin levels. The water absorption and thickness swell properties of all untreated hardboards with 50:50 or 0:100 WF/ONP were equal to or greater than the maximum values allowed by the ANSI–AHA standard.

In general, the mechanical properties and water resistance of all hardboards with the 100:0 and 50:50 WF/ONP formulations at the 7-percent resin level equaled or exceeded the requirements specified in the ANSI-AHA standard. The 0:100 WF/ONP formulation resulted in similar properties but the data were more scattered; property values often did not meet specified miniinurn property values.

In most cases, increasing the ONP content caused a corresponding deterioration in both mechanical properties and water resistance for hoards containing either untreated or acetylated filler at either resin level. This was most likely a result of the larger fiber surface areas associated with this material, which resulted in increased resin absorption and lower bonding effectiveness.

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