Feasibility of using recycled newspapers as a fiber source for dry-process hardboards

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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 mechanical and physical properties of 3-mm and 11-mm dry-process hardboards made from various ratios of wood fiber to old newspaper (ONP) (100:0, 50:50, and 0:100). Two series of 3-mm hardboards were made, one with untreated fiber and the other with acetylated fiber. Resin levels were 3 or 7 percent, and all 3-mm hardboards had 0.5 percent wax. The 11-mm hardboards were made with untreated fiber, 5.5 percent resin, and 2 percent wax. Boards were tested for static bending and tensile strength properties, water absorption, thickness swell. and linear expansion. As expected. increasing the resin level from 3 to 7 percent generally improved all properties. Acetylation substantially improved the water absorption, thickness swell, and hear expansion but decreased the mechanical properties of all boards: increasing the amount of ONP caused a corresponding deterioration in mechanical properties, water absorption, and thickness swell.

Hardboard, a panel material with a specific gravity (SG) ranging from 0.5 to 1.45, is made from wood that is first reduced to fibers or fiber bundles and then manufactured into relatively large panels of moderate thickness. In their final form, these panels retain some properties of the original wood.

However, the panels also acquire 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 (1,2).

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, such wood fiber (WF) old newspaper (ONP) composites provide a favorable option for recycling paper fiber, which is a highly visible and troublesome class of municipal solid waste.

The production of hardboards by dry-process technology requires much less process water than does 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 (4). However, dry-processing technology reduces hydrogen bonding between the fibers: consequently, these boards generally have lower dimensional stability property values than those

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established that boards containing acetylated material are less compressible, thus requiring a higher pressure for compaction. The 3-mm-thick boards were pressed at 190°C for 6 minutes at a maximum pressure of 4.95 MPa for untreated boards and 9.23 MPa for boards containing acetylated fiber. Because boards containing acetylated fiber required a higher maximum pressure, 6 minutes of additional time for cooling were needed while the board was still under compaction to reduce steam vapor pressure in the pressed board and maintain the target thickness. The 11-mm-thick boards were pressed at 177°C for 13 minutes at a maximum pressure of 6.37 MPa, and no cooling procedure in the press was applied. After pressing, all panels were trimmed to a final size of 279 by 279 mm.

Testing

Static bending and tensile properties, along with water absorption, thickness swell. and linear expansion from 50 to 90 percent relative humidity, were determined according to ASTM D 1037 Standards (3). 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 4 in the same order as they are presented in the text. Each value is an average of 10 tests. Target SGs were closely achieved and, therefore, the physical and mechanical property values obtained in the various tests conducted in this experiment were not statistically adjusted to nominal values. The results of analysis of variance for this experiment indicate that three main factors (WF-ONP ratio, resin content, and acetylation treatment) influenced all properties of the boards at a significance level of less than 5 percent. The only

TABLE 1. — *Static bending properties of 3- and 11-mm-thick dry-process hardboards.*

	Mechanical property value for various WF-ONP ratios[a]					
	Modulus of rupture (MPa)[b]			Modulus of elasticity (GPa)[c]		
Board characteristics	100:0	50:50	0:100	100:0	50:50	0:100
Untreated, 3-mm-thick						
0.5% wax						
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-mm-thick						
0.5% wax						
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)
Untreated, 11-mm-thick						
2% wax						
5.5% resin	34.7 (16)	19.7 (30)	11.9 (9)	3.78 (28)	3.53 (30)	0.90 (35)

[a] WF-ONP = wood fiber-old newspaper. Values in parentheses are coefficients of variation (%).
[b] ANSI-AHA minimum property values are 31.0 MPa for 3-mm-thick standard hardboard and 20.7 MPa for 11-mm-thick service hardboard.
[c] No ANSI-AHA minimum property values exist for modulus of elasticity.

TABLE 2. — *Tensile strength properties of 3- and 11-mm-thick dry-process hardboards.*

	Tensile strength (MPa) for various WF-ONP ratios[a]					
	Parallel to surface			Perpendicular to surface		
Board characteristics	100:0	50:50	0:100	100:0	50:50	0:100
Untreated, 3-mm-thick						
0.5% wax						
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-mm-thick						
0.5% wax						
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)
Untreated, 11-mm-thick						
2% wax						
5.5% resin	17.1 (13)	12.0 (17)	8.5 (6)	0.43 (29)	Failed	Failed

[a] WF-ONP = wood fiber-old newspaper. Values in parentheses are coefficients of variation (%). ANSI-AHA minimum property values for 3-mm-thick hardboard are 15.2 MPa for tensile strength parallel to surface and 0.62 MPa for tensile strength perpendicular to surface. ANSI-AHA minimum property values for 11-mm-thick service hardboard are 10.3 MPa for tensile strength parallel to surface and 0.34 MPa for tensile strength perpendicular to surface.

TABLE 3. — *Water absorption and thickness swell of 3- and 11-mm-thick dry-process hardboards.*

Board characteristics	Property value (%) for various WF-ONP ratios[a]					
	Water absorption			Thickness swell		
	100:0	50:50	0:100	100:0	50:50	0:100
Untreated, 3-mm-thick						
0.5% wax						
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-mm-thick						
0.5% wax						
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)
Untreated, 11-mm-thick						
2% wax						
5.5% resin	24.3 (4)	35.0 (11)	48.3 (7)	10.1 (8)	11.3 (4)	15.9 (4)

[a] WF-ONP = wood fiber-old newspaper. Values in parentheses are coefficients of variation (%). ANSI-AHA maximum property values for both types of hardboard are <35 percent for water absorption and <25 percent for thickness swell.

TABLE 4. — *Linear expansion of 3- and 11-mm-thick dry-process hardboards.*

Board characteristics	Linear expansion (%) for various WF-ONP ratios[a]		
	100:0	50:50	0:100
Untreated, 3-mm-thick			
0.5% wax			
3% resin	0.35 (16)	0.46 (6)	0.49 (21)
7% resin	0.26 (20)	0.39 (27)	0.32 (19)
Acetylated, 3-mm-thick			
0.5% wax			
3% resin	0.22 (23)	0.19 (32)	0.30 (16)
7% resin	0.17 (20)	0.22 (15)	0.23 (23)
Untreated, 11-mm-thick			
2% wax			
5.5% resin	0.27 (18)	0.33 (6)	0.33 (23)

[a] WF-ONP = wood fiber-old newspaper. Linear expansion at 50 to 90 percent relative humidity. Values in parentheses are coefficient of variation (%). ANSI-AHA maximum property values are < 0.36 percent and < 0.40 percent for 3- and 11-mm-thick hardboard siding, respectively.

exception to this previous statement was that the effect of acetylation on board modulus of elasticity (MOE) (bending stiffness) was not significant.

Static bending properties

3-mm-thick boards. – The minimum required modulus of rupture (MOR) (bending strength) value in the American National Standards Institute-American Hardboard Association (ANSI-AHA) standard is 31.0 MPa for standard hardboard (1). In our study, all boards met this minimum property requirement. Untreated boards had the highest MOR values with the 100:0 WF-ONP formulation and 3 and 7 percent resin and with the 50:50 WF-ONP formulation and 7 percent resin. Acetylated boards with 100:0 and 50:50 WF-ONP formulations had lower MOR values. For untreated and acetylated boards with 0:100 WF-ONP formulations, MOR values were about equal at both resin levels.

A pattern similar to that found for MOR values was noted for MOE values. Untreated boards had the highest MOE values with the 100:0 WF-ONP formulation and 3 and 7 percent resin and with the 50:50 WF-ONP formulation and 7 percent resin. For acetylated boards with the 50:50 WF-ONP formulation 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 for boards containing acetylated fiber were somewhat higher than those for boards containing untreated fiber. A previous study by Youngquist et al. found that flakeboards made with acetylated aspen exhibited similar results (8).

11-mm-thick boards. – The minimum required MOR value in the ANSI-AHA standard is 20.7 MPa for service hardboard. In this study, the only hardboards that passed this requirement were those with the 100:0 WF-ONP formulation. Hardboards with the 50:50 WF-ONP formulation had MOR values about one-half of those from boards made from 100:0 WF-ONP formulation: MOR values from boards made with the 0:100 WF-ONP formulation were about one-third of those from boards made with the 100:0 WF-ONP formulation.

The MOE values of boards with the 100:0 WF-ONP formulation were about equal to those of boards with the 50:50 WF-ONP formulation, whereas MOE values of boards with the 0:100 WF-ONP formulation were approximately one-fourth of those of the 100:0 WF-ONP formulated boards.

Tensile strength properties

3-mm-thick boards. – 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 the 100:0 WF-ONP formulation and 3 and 7 percent resin and with the 50:50 WF-ONP formulation and 7 percent resin exceeded the minimum

required level: however, the coefficients of variation were large.

11-mm-thick boards. – The minimum tensile strength parallel to board surface as specified in the ANSI-AHA standard is 10.3 MPa for service hardboard. Hardboards made from the 100:0 and 50:50 WF-ONP formulations passed this standard. Tensile strength of boards made with the 0:100 WF-ONP formulation averaged 8.5 MPa, which was approximately one-half the strength of boards made with the 100:0 WF-ONP formulation. For perpendicular-to-surface tensile strength, the ANSI-AHA minimum requirement is 0.34 MPa for service hardboard. The 100:0 WF-ONP formulated boards passed this requirement: however, the coefficients of variation were large. All boards at the other two ratios could not be tested because they failed in the test grips.

Water absorption and thickness swell

The ANSI-AHA maximum property standards for both 3-m-thick Standard hardboard and 11-mm-thick service hardboard are 35 percent for water absorption and 25 percent for thickness swell.

3-mm-thick boards. – A 24-hour 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 the 100:0 WF-ONP formulation and 3 and 7 percent resin and untreated boards with the 50:50 WF-ONP formulation and 7 percent resin had lower water absorption values than the required maximum value of 35 percent. Water absorption values of untreated boards with the 50:50 WF-ONP formulation and 3 percent resin and the 0:100 WF-ONP formulation at both resin levels had higher values than those allowed by the standard.

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

Untreated boards made with the 100:0 WF-ONP formulation at both resin levels and with the 50:50 WF-ONP formulation at the 7 percent resin level had thickness swell values that were lower than or equal to the 25 percent requirement. Thickness swell values for the 50:50 and 0:100 WF-ONP formulations at the 3 percent resin level averaged 46 percent. For the 0:100 WF-ONP formulation 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.

11 mm-thick boards. — Water absorption values for the 100:0 WF-ONP formulated boards were below the 35 percent specified maximum value. Water absorption values of hardboards made with 50:50 and 0:100 WF-ONP formulations averaged 35 and 48 percent, respectively.

All hardboards at all three formulations had thickness swell values below the 25 percent specified maximum value. Hardboards made from the 100:0, 50:50. and 0:100 WF-ONP formulations averaged 10, 11, and 16 percent thickness swell, respectively.

Linear expansion

3-mm-thick boards. – The ANSI-AHA maximum permissible linear expansion value for hardboard siding is 0.36 percent for 3-mm-thick boards (2). All hardboards made from the 100:0. 50:50, and 0:100 WF-ONP formulations that contained acetylated fiber at both resin levels had linear expansion values below the maximum specification. As expected, linear expansion values were lower for hardboards containing 7 percent resin than for hardboards containing 3 percent resin.

Untreated boards at both 3 and 7 percent resin at the 100:0 WF-ONP formulation had lower linear expansion values than the specified maximum, whereas hardboards at the 50:50 and 0:100 WF-ONP formulations were above this maximum value, with one exception. It is possible that the retention of the primary wall and the S1 layer in hardboard fiber restrains swelling as water is absorbed into the cell wall. This would be the reason for the lower linear expansion values observed lor the all-hardboard fiber samples.

11-mm thick boards. – The ANSI-AHA maximum permissible linear expansion value is 0.40 percent for 11-mm-thick hardboard siding. Hardboards containing the 100:0, 50:50, and 0:l00 WF-ONP formulations had linear expansion values well below this maximum value. Linear expansion values of the 100:0 WF-ONP formulated hardboards averaged about 20 percent lower than those of the other two formulations.

Concluding remarks

The mechanical property values and the water absorption and thickness swell property values of all 3-mm-thick 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-MIA standard. The 0:100 WF-ONP formulations produced scattered data, and property values often did not meet specified minimum or maximum levels.

The acetylation process substantially improved water absorption. thickness swell, and linear expansion for all formulations at both resin levels for the 3-mm-thick hardboards.

For 11-mm-thick hardboards, mechanical property values decreased dramatically as the ONP content increased. Conversely, water absorption and thickness swell property values escalated as the ONP con tent increased.

In most cases. increasing the ONP content caused a deterioration in mechanical properties, water absorption, thickness swell, and linear expansion for

boards containing either untreated or acetylated fiber at either resin level. This was most likely a result of the larger fiber surface areas associated with this material, which resulted in lower bonding effectiveness. This is in contrast to what occurs to the hardboard fibers where the retention of the middle lamella constituents enables some thermoplastic fusion of the fibers, which may contribute significantly to their strength and water resistance.

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