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MEDIUM DENSITY FIBERBOARD PANELS FROM WASTE WOOD AND PAPER*

■ **Keywords: medium density fiberboard, paper fiber, wood fiber, waste, panels, phenolic resin.**

Introduction

The word “waste” projects a vision of a material with no value or useful purpose. However, technology is rapidly evolving that holds promise for using waste wood and waste paper to make an array of high-performance composite products that are in themselves potentially recyclable.

In the United States, about 73 million tons of 6,000 different paper and paperboard products are produced and over 47 million tons are either discarded or diverted from recycling by burning or someother low value use [Franklin, Associates... 1996]. Other wood waste from new construction and demolition projects amounted to 6.1 and 22.7 tons, respectively [McKeever et al. 1995]. Taken collectively, these materials represent a significant resource base from which many different composite products can potentially be made.

These are several advantages to using recovered materials for various composites. First, the use of these materials in products made by the forest products industry will contribute greatly to long-term sustainable development and forest ecosystem management, and it will allow markets for wood-based composites to grow while minimizing the use of virgin timber. Secondly, wood-based composites of varying types are opaque, colored, painted or overlaid. Consequently recovered fibers used for composites do not require extensive cleaning and refinement to remove adhesives, inks, dyes, etc. Thus, composites provide an unusually flavorable option for the recycling of waste wood and paper.

This study was undertaken to develop the technology to produce medium density fiberboard (MDF) type composite panels from waste wood and paper which is now being landfilled. The project was conducted in 2 phases. Phase 1 was exploratory in nature and was designed to develop optimized material formulations and processing parameters needed to fabricate MDF panels that met the published MDF standard ANSI

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A208.2 – 1994 [National Particleboard Association 1994]. Phase *2* used these optimized processing parameters developed in phase 1 for the production and testing of experimental panels.

The paper reports on experiments completed to determine the material formulation and processing parameters needed for the fabrication of optimized medium density fiberboard composite panels made from a mixture of demolition wood and waste paper. Emphasis has been placed on the results of the phase 2 portion of the research program due to space limitations for this presentation.

Experimental design and analysis

The experiment used a wood fiber (WF) to paper fiber (PF) formulation in the ratio of 70% to 30%, respectively. For this formulation we tested boards at 6-, 13- and 19-mm target thickness levels with 1.0 specific gravity. The resin was applied at a level of 10 weight percent based on resin solids content and ovendry fiber. All the panels had a wax content of 1.5%. Each thickness level was considered a replicated set that consisted of 15 individual panels with the exception of the 6 mm thick panels. For this thickness level, we compared the performance of 10 panels made from WF and office waste (OW) obtained from the Forest Products Laboratory (FPL) waste paper recycling program, to five panels made from WF and commercially available OW. A total of 45 panels were made.

Materials

The raw materials used in this research program are noted in the following text.

Demolition Wood Fiber. This material was obtained from Wood Recycling, Inc. (WRI), of Peabody, MA. The preliminary trials confirmed that the fibers had a good processing capability and were feasible to use as a postconsumer wastewood fiber source.

Waste Paper Fiber. Mixed office waste was obtained from FPL's recycling program. Because of subsequent concerns that the type of OW would not be readily available for the large scale panel fabrication trials, arrangements were made to obtain a commercial waste paper, referred to as CW in Table 3, for experimentation. This material was obtained from WRI of Peabody, MA.

Phenolic Resin. Phenolic resin coded BB-610 was obtained from Neste Resins Canada, and was a high reactivity, low viscosity, slow curing liquid resin with a solids content of 55%, a viscosity of 0.055 Pa.s at 25°C, and a pH of 10.

Wax. The wax (Paracol 2370 paraffin wax emulsion) used, was obtained from Hercules, Inc. of Wilmington, DE. This material has a solids content of 58% and a pH of 8.3.

Material preparation and procedures

The section describes the processing procedures that were necessary to convert the various fibrous materials into a form that could be used to fabricate MDF type panels.

Demolition Wood Fibers. The demolition wood, which was originally received by WRI in chip form, had to be converted into fiber. The wood fiber that was manufactured for this project was made on a Sprout Bauer 914 mm thermal mechanical single disk refiner. The wood materials were chipped from urban wood waste collected in New England, and were primarily softwood species of spruce, pine, and fir. The chipped materials entered the refiner-digester through a horizontal plug screw feeder, where they were maintained under 655 kPa, for a period of 1–1/2 minutes at a steam temperature of 177°C, with a plate gap of 0.13 mm. After refining, the fibers were then dried in a flash tube dryer. This processing produced fibrous strands made of individual fibers, pieces of fiber, and fiber bundles. In this report, these fibrous strands, or bundles, are referred to as fibers. The physical characteristics of the fiber can be controlled or modified by varying the chip retention time within the digester tube, varying the gap between the refiner plates and through the selection of the refiner plate patterns.

Paper Waste. The paper fiber used was mixed office waste (OW) from FPL's recycling program, and had an average size of 216 by 279 mm. To be used in this study, the office paper waste had to be reduced to a form ranging from a small piece to a fiber. The process involved hammermilling using a 6 mm screen opening. The resultant fibers had a final moisture content of 4%. Therefore, there was no need to ovendry them for further processing. A commercial waste (CW) paper was obtained from WRI. The paper fibers were created from post consumer newsprint collected from the local municipalities curbside collection programs. This paper was processed via mechanical means through a Jacobsen Hammermill, using a 6 mm screen, in a manner similar to the FPL mixed office waste. Preliminary comparisons confirmed that fibers produced from this paper waste source were not similar in appearance to that of FPL mixed office waste.

Blending of Fibrous Materials. Our preliminary research indicated that blending wood fiber and office waste paper fibers is complicated because they have very different characteristics. Consequently, a two-step procedure was developed for the blended wood fiber/paper fiber formulations. For initial blending, proper amounts (percentages were in weight) of wood and paper fibers were mechanically blended together in a 0.37 m^3 commercial paddle blender. The two materials were further blended in Rando-Weber equipment by running them through a pin drum fiber opener and a fan which blows them into a receiving container. The blended furnish was then processed through a 305 mm single disk refiner made by Sprout Waldron. The plate gap was 0.13 mm, and the refiner plates were an open style without dams. The purpose of the refining process was to provide a uniform blend of the wood and paper fiber and not to shorten fiber length. This procedure resulted in a high quality fiber blend with few noticeable fines.

Wax and Adhesive Application

Wax. The wax was applied to the mixture of wood and paper fibers in a rotating drum blender with a pneumatic single spray gun applicator. No dilution of wax was used in this process.

Phenolic Resin. The liquid phenolic resin was sprayed onto the blended wood and paper fiber mixture at 25°C as it rotated in the drum type blender. This was done after the wax was applied. The resin was applied with the same pneumatic spray gun used to apply the wax. All the blended furnish was then refined. The purpose of the refining process in this case was to break up balls of fiber formed by blending with wax and resin. The refiner was a Sprout Bauer 203 mm atmospheric single disk refiner with a 1.3 mm plate gap. The plates were open without dams to prevent shortening of fiber. It was found that the refiner greatly improved the uniformity of wax and adhesive distribution on both types of fibers.

Board manufacture

Mats were hand-formed into a 508 by 508 mm dekel box and were manually precompressed. Depending on the target thickness of the board, the average height of the mat was 203 to 305 mm. In order to reduce the mat height and to densify it, the mat was then cold pressed at a board pressure of 3.42 MPa. This procedure reduced the mat height to about 127 to 152 mm, which allowed for easy insertion into the press. All boards were pressed on a Nordberg 914 by 914 Ę mm manually controlled, oil-heated press, with an automatic data acquisition system. The press temperature was maintained at to 213°C to 218°C. Board pressure during closing was in the range of 4.14 to 6.21 MPa and reduced to 1.38 MPa after reaching the target thickness. Depending upon target board thickness, different panel pressing procedures were used. Panel pressing parameters are summarized in Table 1.

Table 1. Panel pressing parameters

Board thickness (mm)	Press temp. (°C)	Closing time (s)	Press time (min)	Max pressure (MPa)	Degas cycle (min)
6	213	60	6	4.14	1
13	213	90	12	4.14	1
19	218	90	22	6.21	3

Stops were used to produce panels at a given thickness. After pressing, the panels were trimmed to a final size of 533 by 533 mm.

Testing

Mechanical and physical property tests were conducted on specimens cut from the experimental panels. Prior to mechanical and physical property testing at room temperature of 23°C, the specimens were conditioned at 50% relative humidity and 20°C. The specimens had minimal exposure to ambient humidity during the time required to complete the testing. Three-point static bending modulus of rupture (MOR) and modulus of elasticity (MOE), internal bond strength (IB), and screw hold tests were performed in conformance with ASTM D1037 Standards (ASTM 1994) using a Tinius Olsen testing machine [ASTM 1994]. Thickness swell and water absorption measurements were made by immersing specimens in water in a horizontal position for 24 hours at ambient temperature. This test was performed in conformance with ASTM D 1037. Linear expansion tests were conducted on length measurements made at equilibrium at 50 and 90% RH at 27°C. The linear expansion test was made in conformance with ASTM D1037.

Results and discussion

Mechanical and physical property data for three thicknesses are presented in Tables 2 and 3. For the 6 mm thickness, each value is an average of 20 tests with the exception of internal bond, which is an average of 40 tests. For the 13 and 19 mm thick panels, each value is an average of 30 tests with the exception of internal bond, which is an average of 60 tests.

The tables show the major independent variables (thickness and waste paper fiber type) and the change in performance relative to the independent variables. The results in Tables 2 and 3 have been statistically analyzed and are reported as the mean and coefficient of variation. Each stage of the research is presented individually.

Table 2 is a summary table of the full series of 40 panels (not including the panels made using commercial office waste) using 70% WF/30$% OW at 6, 13 and 19 mm thicknesses. Bending strength values decreased as panel thickness increased, and values exceeded the MDF standard only for the 6 mm thick panels. For bending stiffness, values for all panel thicknesses approximately equaled or exceeded the MDF minimum property standard requirements. Internal bond strengths decreased as panel thickness increased, and did not meet the MDF standard at any panel thickness. Face screw-holding values were obtained only for the 19 mm panels. For these panels, the minimum property requirements were exceeded. The MDF standard A208.2-1994 does not specify maximum performance levels for thickness swell, water absorption and linear expansion [National Particleboard Association 1994]. Thickness swell and water absorption are specified in the ANSIAHA Standard A135.4-1995 for basic hardboard [American Hardboard Association 1995]. For 6 mm standard hardboard, maximum allowable thickness swell and water absorption values are 20% and 25%, respectively. The thickness swell of the 6 mm panels were well below the standard requirement. The water absorption was approximately equal to the 25% limit specified in the standard. Although there is no standard for 13 and 19 mm panels, boards of these thicknesses were well within the 6 mm standard requirements. The maximum property requirement of 0.40%

Table 2. Mechanical and physical properties of panels made from demolition wood fiber and office waste paper at three thicknesses

Property	ANSI A208.2-1994 Exterior MDF	Formulation: 70%-wood fiber/ 30%-office waste Panel thickness (mm)		
		6	13	19
Static bending MOR (MPa)	34.5	37.7 (26)[a]	27.8 (39)	11.7 (36)
Static bending MOR (GPa)	3.45	3.54 (31)	3.38 (35)	4.18 (21)
Internal bond IB (KPa)	896	594.7 (25)	412.2 (15)	specimens delaminated
Screwholding Face (N)	1445	not tested	not tested	2109 (16)
Thickness swell 24-h (%)	N/A	12.5 (14)	7.3 (23)	7.1 (15)
Water absorption 24-h (%)	N/A	25.5 (26)	15.5 (39)	13.2 (15)
Linear expansion at 50–90 (%)	N/A	0.52 (6)	0.4 (21)	0.39 (12)

a – Values in parentheses are coefficients of variation (%).

Table 3. A comparison of physical and mechanical properties of panels made from office waste paper

Property	ANSI A208.2-1994 Exterior MDF	a – Formulation:	
		70% WF b 30% OW	70% WF c 30% CW
		Panel thickness (mm)	
		6	6
Static bending MOR (MPa)	34.5	37.7 (26)[d]	35.3 (36)
Static bending MOR (GPa)	3.45	3.54 (31)	3.77 (34)
Internal bond IB (KPa)	896	594.7 (25)	788.3 (9)
Screwholding Face (N)	1445	not tested	not tested
Thickness swell 24-h (%)	N/A	12.5 (14)	9.6 (13)
Water absorption 24-h (%)	N/A	25.5 (26)	16.6 (10)
Linear expansion at 50–90 (%)	N/A	0.52 (6)	0.51 (6)

a – WF = wood fiber
b – OW = office waste
c – CW = commercial waste
d – Values in parentheses are coefficients of variation (%).

for linear expansion is specified in the ANSI-AHA standard Al 35.6-1990 for hardboard siding [American Hardboard Association 1990]. Linear expansion values for the 6 mm specimens exceeded the maximum specified value of 0.40%. Values for the 13 and 19 mm panels were almost equal to the specified maximum value.

Table 3 is a summary table of the final five panels from the full series showing the comparison in values when substituting FPL supplied office waste paper for commercial waste paper. This series was made only at the 6 mm panel thickness. The data obtained in this experiment indicated that the supplied office waste could be replaced by commercial waste paper. None of the mechanical or physical properties were compromised by this change.

Concluding remarks

The Phase 1 research results indicated that the panels to be made in Phase 2 for larger scale testing should be at a material composition ratio of 70% demolition wood/30% mixed waste paper, a specific gravity 1.0, a resin content of 10%, and a wax content of 1.5%.

Taken collectively, the results of testing panels in phases 1 and 2 indicate that it is entirely possible to make MDF type panels using waste wood fiber from demolition wood and waste paper. Further experimentation at a pilot scale level will very likely result in the production of panels that have acceptable performance levels for all specified properties.

■ Abstract

This paper reports on the processing and performance aspects of medium density type fiberboards, 6 mm, 13 mm and 19 mm thick, that were made from 70 percent waste wood fiber and 30 percent waste paper fiber. Panels were made and tested using 10 percent phenolic resin, and 1 percent wax. The waste wood and waste paper fiber had very different properties and chamcteristics. Substantial process research was required to develop a method for producing a homogenous mixture of materials. Commercial standards for exterior MDF were used as a baseline to comparatively judge the experimental panels. The 6 mm thick panels had static bending MOR and MOE values which exceeded the minimum property requirements of the standard, however internal bonds were below the standard requirement. In general, panels at 13 and 19 mm thickness performed at lower mechanical performance levels than those at 6 mm thickness. This study indicates that it is entirely possible to make a thin MDF type panels using a waste wood and paper fiber mixture.

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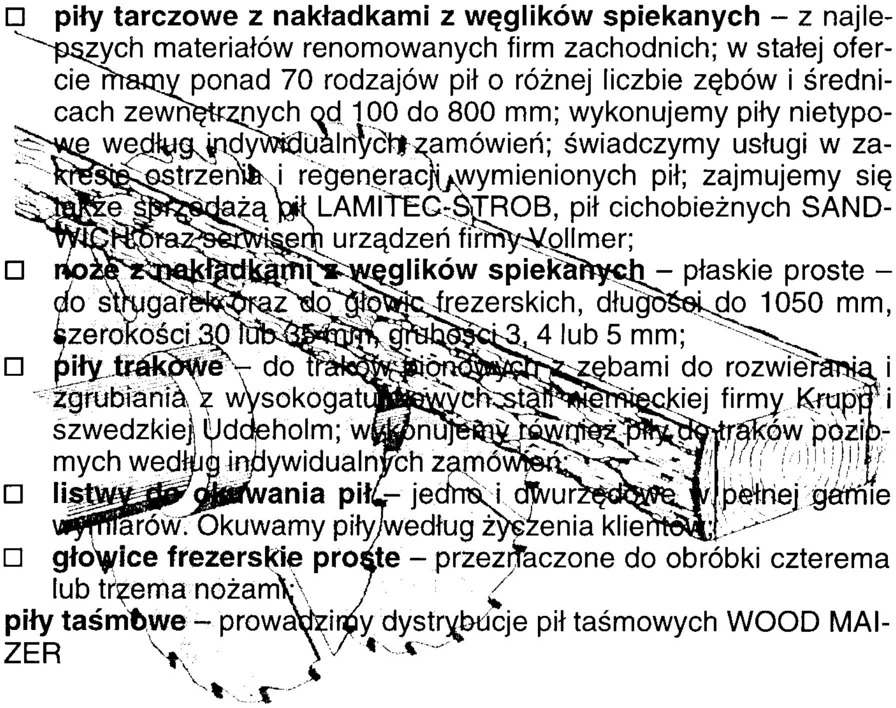

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„Stolarka" Wołomin SA – Firma z przyszłością

Zakład Stolarki Budowlanej w Wołominie uruchomiono w maju 1953 roku, stawiając mu za zadanie zaopatrywanie w stolarkę budowlaną rynków centralnej i wschodniej Polski. W krótkim czasie zakład zajął czołową w kraju pozycję wśród producentow okien i drzwi, a po prywatyzacji w 1992 roku, jest zdecydowanym liderem na tym rynku. Od 1996 roku dawny zakład „stolbudowski" przyjął nową nazwę „Stolarka" Wołomin SA.

Sprywatyzowane przedsiębiorstwo wykazuje znaczną dynamikę wzrostu wartości produkcji i wydajności pracy, przy zachowaniu stabilnego zatrudnienia. W ciągu pięciu lat wymieniono 90 procent parku maszynowego, inwestując w najnowocześniejsze w Europie linie technologiczne. Ogółem „Stolarka" zainwestowała w tym czasie ponad 60 mln zł w nowe maszyny, budowle i urządzenia służące poprawie jakości produkcji, zwiększeniu wydajności pracy i zmniejszeniu uciążliwości zakładu dla środowiska naturalnego.

„Stolarka" produkuje obecnie prawie tysiąc wzorów i odmian okien i drzwi. Do produkowanych na początku lat dziewięćdziesiątych okien zespolonych, konstruktorzy z zakładu dokładają co roku nowe produkty. W 1992 roku zmodernizowano konstrukcję okien zespolonych, by mogły one sprostać wymaganiom rynku. W 1993 roku wprowadzono okna jednoramowe malowane ostatecznie, a w 1994 roku zaczęto stosować ramiaki z drewna klejonego warstwowo. Rok 1995 to pierwsze prace nad oknami jednoramowymi z osłoną aluminiową, które w pełnej gamie zaistniały na polskim rynku już w roku następnym.

Z roku na rok następował także rozwój w technologii produkcji drzwi. W latach 1993–1996 udoskonalono produkcję drzwi płytowych malowanych i foliowanych oraz wprowadzono nowe produkty: drzwi zewnętrzne i bramy garażowe. W 1996 roku „Stolarka" opracowała i wprowadziła na polski rynek całkiem nowy produkt: drzwi fornirowane „Milano" i „Venezia", światowej klasy produkty, nie wytwarzane dotąd w kraju.

Obecnie „Stolarka" Wołomin SA jest niekwestionowanym liderem w swojej branży, sprzedającym rocznie ponad milion sztuk okien i drzwi. Potwierdzeniem stale rosnącej jakości wyrobów z Wołomina jest uhonorowanie ich w 1997 roku złotym medalem Międzynarodowych Targów Poznańskich i Polskim Godłem Promocyjnym „Teraz Polska". Zakład zatrudnia wielu absolwentów SGGW, a przedsiębiorstwem od chwili prywatyzacji kieruje absolwent Wydziału Technologii Drewna mgr inż. Leszek Mazurkiewicz.