MEDIUM DENSITY FIBERBOARDS FROM PLANTATION-GROWN *EUCALYPTUS SALIGNA*

Andrzej M. Krzysik, Research Specialist
John A. Youngquist, Project Leader
James H. Muehl, Forest Products Technologist
USDA Forest Service, Forest Products Lab., Madison, Wisconsin, U.S.A.[1]

Fabio Spina Franca, General Manager
Votorantim–Siderugica Barra Mansa SA, Capao Bonito, SP–Brazil

ABSTRACT. The production of industrial wood from natural forests is predicted to decline in the future. Factors that will contribute to this decline include changes in land use patterns, depletion of resources in some parts of the world, and the withdrawal of forest areas from industrial production in order to provide for environmental, recreational, and other social needs. There is a shortage of information on the suitability of fiber from many plantation-grown species for alternative composite products. This research was conducted to determine the suitability of plantation-grown *Eucalyptus saligna* from Brazil as a raw material for medium density fiberboards (MDF). Test panels of varying thickness (6, 13, and 19 mm) were made with 10% urea resin and 1½% wax. Mechanical, water resistance, and dimensional stability properties were tested according to American Society for Testing and Materials (ASTM) standards. The results showed that nearly all mechanical properties of the panels at all thickness levels were above minimum requirements for MDF as specified in the ANSI-AHA and Euro MDF standards. These results indicate that MDF-type panels can be made from wood fiber derived from *Eucalyptus saligna.* Additional work is needed to ascertain the performance of MDF panels from this species through pilot and production scale trials.

INTRODUCTION

The Food and Agricultural Organization (FAO) of the United Nations estimates that the production of industrial wood from plantations will be an increasingly important source of industrial fiber worldwide [1]. At present, countries like South Africa and New Zealand derive 100% of their industrial wood from forest plantations. Other countries that derive a high proportion of industrial wood from plantations include Chile (95%), Spain (81%), Brazil and Argentina (60%), and Japan (55%). Sedjo [2] predicted that by the year 2000 half the industrial wood produced in Latin American countries would come from forest plantations. As we approach the year 2000, his predictions are being realized.

Brazil is the largest plantation grower of various species of *Eucalyptus,* with 2.7 million hectares. Other countries that grow this species include South Afica, Congo, India, and Burundi. Most of the eucalypt fiber from Brazil is used for pulp and paper production; some is currently diverted to the production of hardboards. Other fiber-based composite products, like medium-density fiberboard, appear to be an attractive alternative for the utilization of this fiber.

Medium-density fiberboard (MDF) is a nonstructural wood-based panel that is composed of wood fibers bonded together with resin under heat and pressure. In

[1]The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin. This article was written and prepared by U.S. Government employees on official time, and it is therefore in the public domain and not subject to copyright. 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.

recent years, great changes have taken place in the MDF industry. Production of this product has increased dramatically and new plants are planned worldwide. In 1996, MDF shipments from U.S. plants set another in an unbroken series of annual records, totaling 2.1 million cubic meters, an 8.5% increase from 1995. Production for 1997 production was forecast to be 3 million cubic meters. Canadian plant capacity was predicted to increase 19%, to 1.2 million cubic meters. In 1996, European production of MDF jumped 18% to 4.5 million cubic meters, continuing an unbroken upward trend there.

The popularity of this relatively new panel product is due to its capability to be produced in molded form as well as in straight-edged, flat panels for a host of industrial markets. MDF is used extensively in factory-assembled and ready-to-assemble furniture, as well as cabinets, underlayment, drawer fronts, molding, and counter tops. Finishes and overlays can be used to provide a grain pattern typical of lumber, and many wood finishing components such as door edgings, decorative trim, frames, and cornices are being replaced by MDF. Moreover, MDF is replacing thin plywood and wet-process hardboard in the production of molded and flush door-skins.

New MDF products include generic and proprietary panels. One example is a super-refined board in which fine fibers are distributed throughout the board to facilitate deep routing and machining. In some countries, panels are being made from many different hardwood and softwood species as well as from nonwood-based lignocellulosics from raw materials such as bagasse and cotton stalks. In South America and Australia, hardboard panels have been successfully produced from a variety of wood species including *Eucalyptus grandis* and *E. saligna* [3,4]. In the United states, some panels are being produced using recycled fibers made from post-consumer wood waste.

Regional shortages in softwood fiber, the need to find suitable, lower cost hardwood fibers for the manufacture of various fiber-based products, and the need to determine if various fast-growing plantation species are suitable for MDF and hardboard panels continue to be concerns to panel manufacture. The general purpose of the research reported here was to develop the material and processing parameters for the fabrication of optimized MDF composite panels made from *Eucalyptus saligna* wood fibers.

SELECTED LITERATURE REVIEW

Literature pertaining to the manufacture of fiberboard from various species of *Eucalyptus was* reviewed and is briefly discussed in the following text.

Products of hydrolysis can affect the properties of hardboard, but they can be removed from the stock by washing. In laboratory experiments, washing the stock produced in the defibrator process from eucalypt fibers increased modulus of rupture and internal bond strength and decreased linear hygro-expansivity of the resulting hardboard. There was also a slight adverse effect on the properties of water absorption, thickness swell, and machinability, but the magnitude of change was too small for practical purposes [5].

The drainage time test method could be used as an efficient tool for the evaluation of eucalypt hardboard pulps. The dimensional stability of hardboard made from high-density *Eucalyptus maculata* improved as the drainage time increased while the opposite effect was found for boards made from low-density *Eucalyptus obliqua* [6].

In Australia, utilization of eucalypt fiber in reconstituted wood products is concentrated primarily in the hardboard industry, with smaller amounts used in plywood and particleboard. Hardboards made from eucalypt fiber have major advantages over those made from other species. No supplemental bonding resins are needed to provide a high level of strength, in contrast to the resins required for softwoods. Because eucalypt fibers are short, they do not flocculate as readily as long fibers. Consequently, boards made with eucalypt fiber have better surface properties and are preferred worldwide as the substrate for prefinished hardboard products [4].

Chauhan and Bist [7] concluded that unbarked *Eucalyptus* hybrid, including tops, twigs, and branches, is a suitable raw material for hardboard manufacture. Oil tempered boards do not require the addition of sizing agents to the pulp suspension in the semichemical wet process.

Pranda [8] reported that MDF made from *Eucalptus globuls* requires higher amounts of adhesive to reach the same mechanical properties as those of MDF made from *Pinus pinaster.* However, water absorption and thickness swell values of MDF from *Eucalyptus* were higher than those of similar panels made from *Pinus pinaster.* A possible explanation for higher resin consumption may be the higher content of fine particles and relatively high specific surface area in eucalypt fibers afier defibration of the chips.

EXPERIMENTAL DESIGN

Eucalyptus saligna fibers were used to make medium-density fiberboards with a specific gravity of 0.77 in three selected thicknesses 6, 13, and 19 mm. The fiberboards had 10% resin content and 1½% wax content (percentage based on solids content and ovendry fiber weight). Each panel thickness was considered a replicated set that consisted of 5 individual panels. In total, 15 panels were made for this experiment.

MATERIALS AND METHODS

Eucalyptus saligna wood chips were obtained from Votorantim-Siderugica Barra Mansa SA (Forest Business Unit) of Brazil. Indtial moisture content was 25% (percentage based on ovendry weight). The chips were converted into fibers for fabricating the MDF panels. The physial characteristics of the fiber were controlled or modified by varying the chip retention time within the digester, varying the gap between the refiner plates, and selecting refiner plate patterns.

The chips were defibrated in a Sprout-Bauer 305-mm thermal mechanical single-disk refiner. Defibration was done in a batch process, with each batch limited to a maximum of 4 kg by the capacity of the receiver tank. Before refining, the chips were placed into a digester, ahead of the refiner, to soften them for obtaining a higher quality fiber. The chips going into the digester were held for 20 min under 586 kPa of saturated steam pressure. Defibration occurred as the chips passed between the rotating and stationary plates of the refiner. Sprout-Bauer refiner plates (D2B503 type) with surface darns enclosed periphery were used for the refining process; the plate gap was 0.36 mm. Refining each batch took approximately 4 min (from 3 min, 45 s to 4 min, 10 s).

The adhesive, a water-soluble, liquid urea-formaldehyde resin, was obtained from Neste Resins Corporation, North Bay, Ontario, Canada. The resin, Ba-255, had a solids content of 65%, viscosity of 0.19 Pa.s at 25°C, pH of 7.62, and specific gravity of 1.281. The wax, Cascowax EW-3100P (a paraffin wax emulsion), was obtained from Borden, Inc., Columbus, Ohio. This material had a solids content of 58% and pH of 8.3.

PROCESSING

Fibers

After defibration, fibers had an approximate moisture content of 125%. Before further processing, the fibers were dried to a final moisture content of 3% to 4% in a steam-heated tray dryer at 94°C for 24 h. The drying process caused the fibers to clump together as a result of hydrogen bonding. Therefore, further processing was needed to make the fibers suitable for blending with resin and wax.

The ovendried fibers were processed through a hammermill using a 19-mm screen opening. The purpose of the hammermilling process was to separate the clumps, not to shorten fiber length. This procedure resulted in a high quality fiber furnish with few noticeable frees.

Wax and adhesive

The wax emulsion and urea-formaldehyde resin were mixed together using a high-speed laboratory mixer. The resin/wax mixture was sprayed onto the wood fiber at 25°C as it rotated in a drum-type blender. The mixture was applied with a single pneumatic spray gun applicator. All the blended furnish was then hammermilled again. In this case, the purpose of the hammermilling process was to break up any balls of fiber formed by blending with wax and resin. The same 19-mm screen opening used to separate the ovendried fiber clumps was used here.

Board manufacture

Mats were hand-formed in a 508-by 508-mm decide box attached to a vacuum. The fiber was manually forced using a brushing motion, through a 6-mm screen on the top of the box. This allowed individual fibers and fiber bundles to pass through the top screen and collect at the bottom of the box. When all the fiber had been put into the deckle box, the mats were manually pre-compressed. Depending on the target thickness of the board the average height of the mat was 203 to 356 mm. To reduce the mat height and to densify the mat, the mat was cold pressed. This procedure reduced the mat height to about 127 to 152 mm, which allowed for easy insertion of the mat into the hot press.

All panels *were* consolidated using a manually controlled, steam-heated press. The press temperature was either 170°C or 190°C. Maximum panel pressure during closing ranged from 3.05 to 6.10 MPa and was lowered to 0.11 MPa after the target thickness was reached. Different panel pressing procedures were used for different panel thicknesses (Table 1).

Table 1. Panel pressing parameters

Panel thick-ness (mm)	Press temp (°C)	Time to close (s)	Press time (min)	Max panel press. (MPa)	Degas cycle (no.)
6	190	60	5	3.05	1
13	170	60	4	6.10	0
19	190	90	6	6.10	0

In the manufacture of all panels, a thermocouple was inserted in the center of the formed mat to determine the core temperature and the time to reach the maximum temperature. For the 6-mm panels, a press temperature of 190°C was used to raise the core temperature to 110°C as quickly as possible. When 110°C was reached a brief degas cycle was used to reduce the steam pressure in the panel.

For the 13-mm panels, we found that the press temperature could be reduced to 170°C and the press time to 4 min with no adverse effect on resin curing; the resin in the panel core was completely cured under these conditions. The degas cycle was also. eliminated by carefully and slowly opening the press at the end of the pressing cycle. Using this procedure, no panel delamination occurred.

For the 19-mm panels, the press temperature needed to be 190°C to raise the core temperature to 110°C without prolonging the press cycle to an unacceptable length of time. No degas cycle was necessary for this series of panels.

TESTING

Mechanical and physical property tests were conducted on specimens cut from the selected experimental panels. For all thickness levels, each panel was weighed and measured and the specific gravity was calculated. The panels were selected on the basis of the target specific gravity (0.77 ! 0.05) and target thickness. This method of panel selection allowed us to narrow the variability in specific gravity between individual experimental panels.

Prior to mechanical and physical property testing, the specimens were conditioned at 65% relative humidity and 20°C. Three-point static bending modulus of rupture (MOR) and modulus of elasticity (MOE) and internal bond strength tests were performed in conformance with ASTM D1037 Standards [9] and ANSI A208.2 Standards [10] using an Instron testing machine. Thickness swell and water absorption measurements were made by immersing specimens in water in a horizontal position for 24 h at ambient temperature. This test was performed in conformance with ASTM D1037. Linear expansion tests were conducted on length measurements made at equilibrium conditions at 50% and 90% relative humidity and 27°C. The linear expansion test was done in conformance with ASTM D1037. Mechanical and physical property data for the three panel thicknesses are presented in Table 2. Each value is an average of 10 tests for static bending MOR and MOE, 25 tests for internal bond strength, 10 tests for thickness swell and water absorption, and 10 tests for linear expansion.

For reference purposes, the minimum property standard requirements for MDF panels as specified in ANSI A208.2 and in the Euro MDF standard are included in Table 2. The results in Table 2 were statistically analyzed and are reported as the mean and coefficient of variation. Each stage of the research is presented separately.

RESULTS AND DISCUSSION

Bending strength (MOR) values increased as panel thickness increased, and values exceeded the Interior ANSI A208.2 MDF standard [10] for all three thicknesses. For the Euro standard [11], strength of the 6-mm panels was below the specified minimum bending strength value of 40 N/Amm^2. The 12- and 19-mm panels exceeded the minimum Euro standard requirements. Bending stiffness (MOE) values for all panel thicknesses exceeded both the ANSI and Euro MDF minimum properly requirements. Internal bond strength decreased as panel thickness increased; nevertheless, internal bond strength exceeded the ANSI and Euro MDF standard requirements for each panel thickness.

The ANSI A208.2 MDF standard does not specify performance requirements for thickness swell, water absorption, and linear expansion. These water sensitivity tests were conducted on the experimental MDF panels to provide a basis of reference for others doing work in this area. Maximum thickness swell and water absorption properties are specified by ANSI for other fiber-based products like basic hardboard [12] as 25% and 35%, respectively. The Euro standard specifies maximum 24-h thickness swell values for 6-, 12- and 19-mm MDF panels as 22%, 15%, and 10%, respectively. The thickness swell and water absorption values of all the MDF panels in our experiment were well below these maximum specified levels.

Table 2. Mechanical and physical properties of panels made from *Eucalyptus saligna* fiber

Property	ANSI MDF std [10]	Euro MDF std [11] by panel thickness			Formulation (88.5% fiber/10% resin/1.5% wax) by panel thickness[a]		
		6 mm	12 mm	19 mm	6 mm	12 mm	19 mm
Static bending MOR (N/mm^2)	24.0	40	35	30	37.4 (14)	39.8 (13)	42.2 (12)
Static bending MOE (N/mm^2)	2,400	2,600	2500	2,500	3,140 (18)	4,010 (10)	4,420 (11)
Internal bond (N/mm^2)	0.60	0.70	0.65	0.60	1.12 (14)	0.87 (14)	0.66 (13)
Thickness swell 24-h (%)	NA[b]	22	15	10	11 (4)	6 (8)	3 (22)
Water absorption 24-h (%)	NA[b]	NA[b]	NA	NA	24 (4)	15 (12)	8 (26)
Linear expansion	NA[b]	0.50[c]	0.40	0.40	0.30 (9)[d]	0.25 (17)	0.24 (15)

[a]Values in parentheses are coefficients of variation (%).
[b]Not specified in test requirements.
[c]Panels cycled at 35%–85% relative humidity.
[d]Panels cycled at 50%–90% relative humidity.

CONCLUDING REMARKS

The results from this experiment indicate that laboratory MDF panels made from plantation-grown *Eucalyptus saligna* can be fabricated with properties that exceed levels specified in the appropriate existing standards. Further experimentation with other *Eucalyptus* species must be conducted to confirm our findings with *E. saligna*. Additionally, pilot scale and full production trials must be conducted to confirm our laboratory results. These research results are promising and provide encouragement that plantation-grown *Eucalyptus saligna* can be successfully used for the production of a value-added panel product like MDF.

REFERENCES

1. Pandey, D. and J. Ball. 1997. The Sustainability of Wood Production in Plantation Forestry. Unasylva 49 (193).
2. Sedjo, R.A. 1987. Forest Resources of the World: Forests in Transition. In M. Kallio, D. P. Dykstra and C. S. Binkley, eds. The Global Forest Sector: An Analytical Perspective. Chichester, West Sussex, UK, John Wiley.
3. Anon. 1977. Brazilian Mill Uses Eucalyptus. World Wood 18(4) : 30–31.
4. Hillis, W. E. and A. G. Brown, A.G. 1978. Eucalypts for wood production. Chapter 14. Reconstituted Wood Products. Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia. 317–321.
5. Holokiz, H. 1971. The Effect of Stock Washing on the Properties of Hardboard. Appita. 25 (3): 194–199.
6. Holokiz, H. 1973. Effect of Drainage Time on the Properties of Eucalypt Hardboard. Appita. 26 (6): 437–443.
7. Chauhan, B.,R.,S. and J. P. S. Bist. 1987. Hardboard From Unbarked Eucalyptus Hybrid. Composite Wood Branch, Forest Research Institute and Colleges, Dehra Dun, Uttar Pradesh, India. Indian Forester. 113 (3): 185–190.
8. Pranda, J. 1995. Medium Density Fiberboards Made From *Pinus pinaster* and *Eucalyptus globulus* Wood. Part I. Chemical Composition and Specific Surface Area of Defibrated Wood. Drevarsky Vyskum. 2 : 19–28.
9. American Society for Testing and Materials. 1994. Annual Book of ASTM Standards. ASTM D 1037-94. Standard test methods for evaluating the properties of wood-based fiber and particle panel materials. Philadelphia, PA.
10. National Particleboard Association. 1994. Medium Density Fiberboard. ANSI A208.2-1994. Gaithersburg, MD.
11. European Association of Medium Density Fiberboard Manufacturers. 1990. Medium Density Fiberboard (MDF) Industry Standard, 2nd Edition. D-6300 Glessen, Germany.
12. American Hardboard Association. 1995. Basic Hardboard, ANSI/AHA A135.4-1995. Palatine, IL.

In: ICEUPT; 99: international conference on effective utilization of plantation of plantation timber; 1999 May 21-23; Forest Prod. Assoc: pp.156-160.