Pressing of three-layer, dry-formed MDF with binderless hardboard faces

Otto Suchsland
George E. Woodson
Charles W. McMillin

Abstract

Severely cooked Masonite pulp was used as face material in three-layer experimental medium-density fiberboard (MDF). The core layer consisted of conventional MDF furnish with resin binder added. The faces were formed absolutely dry without additives of any kind. The three-layer mat was hot-pressed to overall densities ranging from 44 to 56 pcf. The faces had hardboard-like density, appearance, and characteristics. Face characteristics controlled overall bending strength and bending stiffness. Core characteristics controlled water absorption and linear expansion. This separation of characteristics into face and core allows flexibility in board design.

This is the third in a series of articles reporting on experiments with severely cooked Masonite fiber furnish (5, 6).

Previous experiments established the following:

a) This type of furnish provides a high degree of fiber to fiber bonding making the addition of binders unnecessary.
b) The route followed from furnish to press (wet-wet, wet-dry, dry-wet, dry-dry) does not substantially affect the quality of this type of bond (Fig. 1).

Of special interest was the binderless S2S-dry hardboard made from this furnish. Its appearance seemed much more closely related to wet-formed hardboard than that of commercial dry-formed hardboards, which are essentially medium-density fiberboard (MDF) pressed to a high density and which rely entirely on resin bonding.

Given the absence of water in such a binderless S2S process, the question arose whether or not these hardboard characteristics could be obtained in faces of a three-layer moderate-density board with a core layer made of regular resin bonded MDF fiber.

Such board design would overcome one of the real limitations of the hardboard process, which is that the desirable hardboard attributes like hardness, smoothness, high bending stiffness, printability, paintability, weather resistance, etc., can only be achieved at high density and at moderate board thickness. It would also overcome some of the limitations of MDF, such as relatively high resin content and formaldehyde emission through the board surfaces.

The experiment described here explores the possibility of making such a board in one pressing operation.

Objectives

Our objective was to explore the potential of a one-step pressing operation for generating in the binderless faces of a medium-density three-layer fiberboard characteristics similar to those of separately pressed thin hardboard (S2S-dry) from the same binderless furnish.

The authors are, respectively, Professor, Dept. of Forestry, Michigan State Univ., East Lansing, MI 48824-1222; Associate Professor of Wood Utilization, Louisiana Tech Univ., Ruston, LA 71273; and Principal Wood Scientist, USDA Forest Serv., Southern Forest Expt. Sta., 2500 Shreveport Hwy., Pineville, LA 71360. This paper is the result of a cooperative research effort between the USDA Forest Serv., Southern Forest Expt. Sta. and the Forestry Depts. of Louisiana Tech and Michigan State Univs. Boards were manufactured at the Forest Prod. Utilization Lab. of the Southern Forest Expt. Sta. in Pineville, La. This paper is Michigan State Agri. Expt. Sta. Journal Article No. 11516. It was presented at Session 7 (Hardboard and Insulation Board) of the 38th Annual Meeting of the FPRS in St. Louis, Mo., June 25, 1984. It was received for publication in December 1984.

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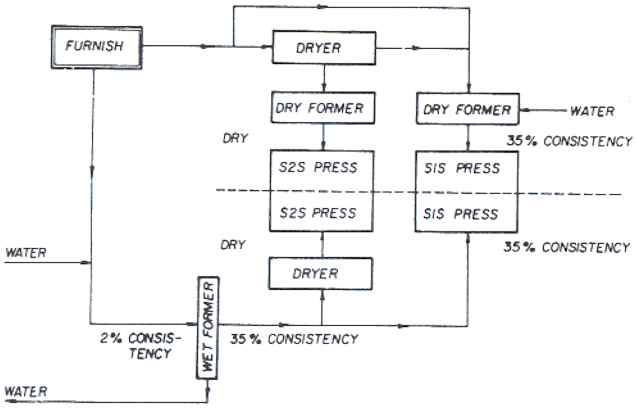

Figure 1. — Flow chart outline of experiment designed to test the effect of route taken from furnish to press on board properties (5).

FACE / CORE RATIO	40 / 60								50 / 50							
DENSITY G/CC	.85				.75				.85				.75			
CORE MATER.	Y.P.		M.H.		Y.P.		M.H.		Y.P.		M.H.		Y.P.		M.H.	
PRESS LOAD TONS	50	70	50	70	50	70	50	70	50	70	50	70	50	70	50	70
REPLICATIONS	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

Figure 2. — Schematic of experimental design. Face ratios are by weight on ovendry basis. Core materials are yellow-poplar (YP) and mixed hardwoods (MH) MDF fibers. Pressure is in tons with these specific board pressure equivalents: 50 tons — 700 psi; 70 tons — 970 psi.

Experimental procedure

To produce such three-layer boards in one pressing operation requires a differential densification of face and core, i.e. a substantial density gradient. Density gradients and their control have been thoroughly studied in particleboard and MDF. The weight ratio of face to core material and the press closing time are two of the most important control variables (2, 4).

Figure 2 shows the experimental design.

Face/core ratios are by weight of ovendry fibers.

Two different core materials were used: yellow-poplar (YP) and mixed southern hardwoods (MH). Both furnishes were prepared from chips in a pressurized Bauer refiner under laboratory conditions.

The pressures shown on Figure 2 are actually total loads applied in tons and are equivalent to specific pressures of 700 psi and 970 psi, respectively (board size: 12 by 12 in.).

The Masonite furnish (face material) was produced in a commercial Masonite gun (400 psi for 2 min., followed by 650 psi for 5 sec. (5)). The furnish was neither washed nor refined. Prior to forming, the furnish was dried to 0 percent moisture content. No resin or other additives were added.

The MDF fiber had a moisture content between 5 and 7 percent. After resin binder application (9% solids based on dry fiber furnish) and just prior to forming, its moisture content averaged 11 percent.

The three layers were vacuum-formed separately and assembled into a three-layer mat. Full pressure was applied immediately, released after 1 minute, reapplied for another minute, and then reduced to 170 psi for the rest of the 4-minute press cycle. Press temperature was 430° F. Closing times varied between 10 and 35 seconds depending on density and pressure. Nominal board thickness was 3/8 inch. The board structure is shown in Figure 3.

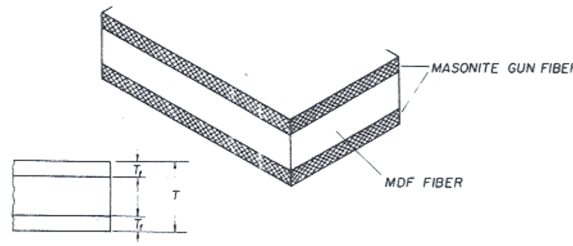

Figure 3. Schematic of three-layer board design. Shelling ratio = $2T_f/T$.

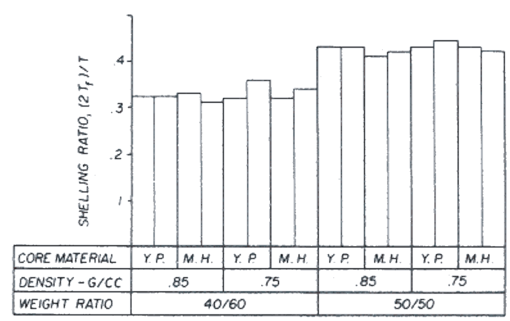

Figure 4. — Shelling ratios as measured on bending specimens.

Results

In contrast to particleboard and MDF experience, the shelling ratio, an indicator of the face/core density gradient, was unaffected by press cycle (closing time or initial pressure). The shelling ratio is defined as the ratio of both face thicknesses over total board thickness. The only significant variable in this case is the weight ratio (Fig. 4). The shelling ratios indicate considerable face densification for both weight ratios used:

Weight ratio	Shelling ratio	Density ratio
40/60	33/67	1.60 avg.
50/50	43/57	

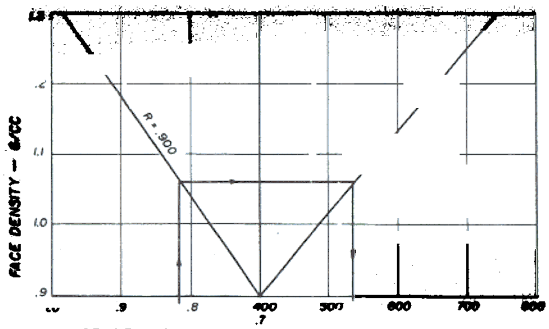

Figure 5. — Nomograph showing relationships between board density and face density, and between face density and MOE in bending of board.

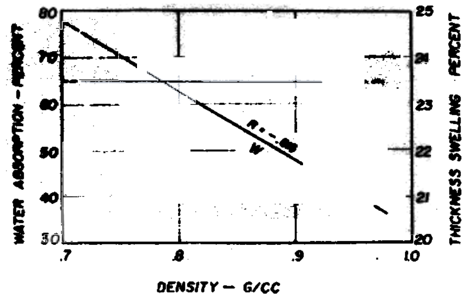

Figure 7. — Relationships between board density and thickness swelling, and between board density and water absorption by weight of three-layer board. Both water absorption and thickness swelling were measured after 24-hour water soak.

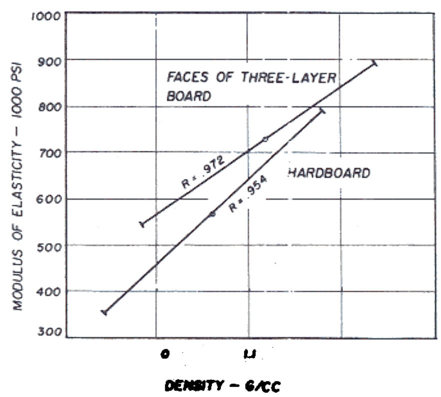

Figure 6. — Relationships between the face density and the MOE of the face of 3/8-inch three-layer boards, and between the density and MOE of 1/8-inch hardboard made from same furnish as faces of three-layer board.

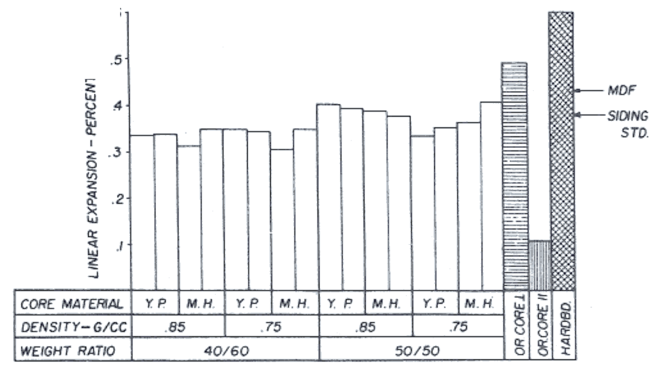

Figure 8. — Linear expansion as response to relative humidity change from 50 to 90 percent of experimental three-layer fiberboard, and in comparison with three-layer boards having oriented strand core, and with 1/8-inch hardboard made from same furnish as faces of three-layer board. Horizontal arrows on right indicate level of expansion allowed by hardboard siding standard and of average commercial MDF (3).

Face density is most significantly controlled by overall density. This is best shown in nomograph form (Fig. 5):

> By increasing overall density, the face density increases (R = .90), and as a consequence of the higher face density, the overall modulus of elasticity (MOE) of the three-layer board increases (R = .87).

Of particular interest was the quality of the faces as compared with thin hardboard made from the same furnish in previous studies (S2S-dry). The MOE of the faces was, therefore, determined separately by determining the MOE of both three-layer specimens and of specimens with faces removed by planing. The MOE of the faces was then obtained by:

$$E_f = \frac{E_t - E_c(1-\lambda)^3}{1-(1-\lambda)^3}$$

where

E_f = MOE of faces,
E_t = MOE of total board,
E_c = MOE of core,
λ = Shelling ratio.

These results were compared with the MOE of the 1/8-inch hardboard with face and board density as the independent variable. The two relationships shown in Figure 6 are very similar. Thus, face layers of moderate-density three-layer boards had been densified to the same density range as thin hardboards, and in that density range bending stiffness of face and hardboard were almost identical.

Internal bond, strictly a core property, showed weak correlation with board and core densities. Actual values ranged from 90 to 150 psi, in line with commercial board values.

Water absorption and thickness swelling of the three-layer board are illustrated over the board density range in Figure 7. The corresponding values for the previously made hardboard (S2S-dry) were 30 percent for water absorption and 12 percent for thickness swelling. Due to greater core porosity, water absorption of the

Note: All standard tests were conducted according to ASTM 1037.

three-layer board was greater than that of the hardboard. This is reflected in the strong negative density effect. It may be noted that at an overall board density of slightly above 1.0 the extrapolated water absorption line intersects the 30 percent level, the value of the hardboard. This indicates that water absorption is primarily controlled by density or porosity.

Thickness swelling is unaffected by density and is substantially above that of the hardboard. This indicates that most of the thickness swelling occurs in the core and that the mechanisms of thickness swelling of MDF and hardboard are different.

Linear expansion as a response to relative humidity change from 50 to 93 percent was much smaller than that of the previously made S2S-dry hardboard, which was .60 percent (see Fig. 8). This difference is undoubtedly due to the restraining effect of the relatively stable MDF component.

A few additional boards were made in which the MDF core was replaced by oriented sweetgum strands (.5 by 3.0 by .020 in.). The linear expansion of these boards perpendicular and parallel to the core orientation is also shown in Figure 8. Again, the core dominates the expansion. In the direction of core orientation, the linear expansion is less than one-third the maximal expansion allowed by the hardboard siding standard (1).

All board surfaces were as smooth and hard as those of wet-formed and wet-pressed hardboard.

Conclusions

1. Absolutely dry, binderless Masonite furnish develops hardboard densities and characteristics in the face layers of experimental 3/8-inch three-layer boards in an overall density range of 0.7 to 0.9 g/cm^3 (44 to 56 pcf).

2. Face density and, therefore, bending stiffness of such boards are primarily controlled by overall density.

3. Such three-layer boards allow great flexibility of property combinations because mutually exclusive properties such as hardboard surface smoothness and low linear expansion can be separated and concentrated in either face or core, while their respective dominance can be controlled by appropriate shelling ratio selection.

Literature cited

1. American National Standard ANSI/AHA A135. 6-1983. Hardboard Siding. U.S. Dept. of Commerce. 1983. 5 pp.
2. Keylwerth, R. 1958. Zur Mechanik der mehrschichtigen Spanplatte. Holz als Roh- und Werkstoff. 16(11):419-430.
3. Suchsland, O., D.E. Lyon, and P.E. Short. 1978. Selected properties of medium-density fiberboard. Forest Prod. J. 28(9):45-49.
4. ________ and G.E. Woodson. 1976. Properties of medium-density fiberboard produced in an oil-heated laboratory press. USDA Forest Serv. Res. Pap. SO-116. 10 pp.
5. ________, ________, and C.W. McMillin. 1983. Effect of hardboard process variables on fiberbonding. Forest Prod. J. 33(4):58-64.
6. ________, ________, and ________. 1985. Binderless fiberboards from two different types of fiber furnishes. Forest Prod. J. 35(2):63-68.