Binderless fiberboard from two different types of fiber furnishes

Otto Suchsland
George E. Woodson
Charles W. McMillin

Abstract

Fiber furnishes from two commercial processes were used to make experimental hardboards by all four possible methods: wet formed (pressed dry and wet), and dry formed (pressed dry and wet). Since no adhesives were added, all bonding was due to natural agents. Results of mechanical and physical testing of the hardboards indicated that high quality hardboard can be made from binderless, ovendry furnish and that the pulping conditions are more critical with regard to board quality than are pressing conditions (wet or dry).

This article is an extension of a study on the effect of hardboard process variables on fiberbonding reported in this journal in May 1983 (1). That study had as its objective to find how fiberbonding in hardboard is affected by the route taken from the furnish to the finished board. Identical, severely cooked Masonite gun stock (mixed hardwoods) without additives was used for all four routes (Fig. 1). The results showed that dry formed (bone-dry) S2S board developed the highest mechanical properties, lowest water absorption, but highest linear expansion.

It is very likely that lignin, being more available in Masonite stock than in other, less severely cooked furnish (2), contributed substantially to the bonding in these boards. Since the furnish was not washed, it contained hemicelluloses which may also have played a role. In any case, an analysis of the type of bonding that actually occurred in the various boards was outside of the scope of the study. The study did establish, however, that superior hardboard can be produced from Masonite fiber without water and without added binder.

Following the original intention, the experiment was repeated with furnish prepared by the Bauer pulping process which is a less severe treatment and may result in less lignin becoming available for fiberbonding. The results of that experiment and a comparison with the results of the previous study are reported here.

The terms 'Bauer' and 'Masonite' are used here to identify two different pulping methods. The experimental boards made using furnish obtained by these two pulping methods and described in this study do in no way represent commercial products made by the 'Masonite process' or the 'Bauer process.' Neither do the results of this study allow any comparative value judgment of these two commercial processes.

Procedure

Pulping

The raw material of the Masonite furnish was whole-tree mixed hardwood chips taken from the production furnish at the Masonite plant in Laurel, Miss. The Bauer furnish was obtained in two qualities from Abitibi's hardboard mill in Alpena, Mich. The chips, in this case, were produced from debarked roundwood. The species compositions of the furnishes are indicated in Table 1.

Cooking conditions for all furnishes are schematically illustrated in Figure 2.

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.; and Principal Wood Scientist, USDA Forest Serv., Southern Forest Expt. Sta., Pineville, La. The cooperation of the Masonite Corp. and of the Abitibi-Price Corp. is gratefully acknowledged. Boards were manufactured at the Forest Prod. Utilization Lab. of the Southern Forest Expt. Sta. in Pineville, La. This paper was presented at Session 17 (Hardboard and Insulation Board) of the 37th Annual Meeting of the Forest Prod. Res. Soc., in Norfolk, Va., June 22, 1983, and is Michigan State Agri. Expt. Sta. Journal Article No. 11206. This paper was received for publication in March 1984.

Forest Prod. J. 35(2):63-68.

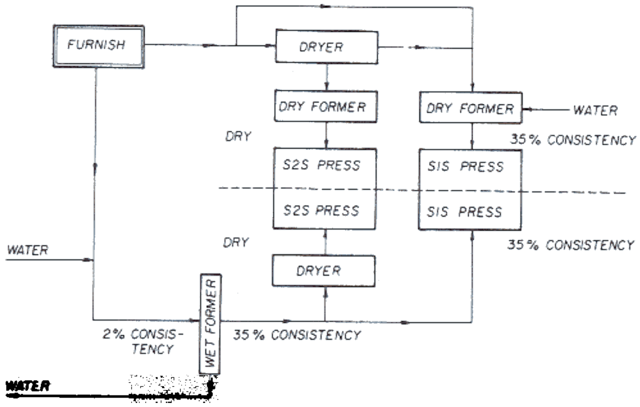

Figure 1. — Flowchart outline of the experiment (1).

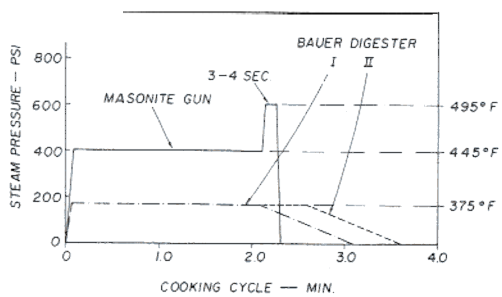

Figure 2. Schematic presentation of chip cooking cycles.

Following the unusually severe cook, the Masonite pulp was so fine with the exception of a certain fraction of slivers that it could not be refined without increasing the drainage time to impractical levels. The Tappi drainage time of the raw pulp was 23 seconds (Tappi: T1002 sm-51). Moisture content averaged 83 percent. The fraction of slivers was removed by brushing the pulp through 1/4-inch hardware cloth.

The two Bauer type pulp furnishes differed in the cooking time in the Bauer rapid digester:

Bauer I : 185 psi, 2-minute cook, 60 seconds purge time;
Bauer II: 185 psi, 2-1/2-minute cook, 60 seconds purge time.

Following cooking, the Bauer chips were refined to a freeness of 17 seconds in a Bauer 411 double disk refiner with vacuum assist. Moisture content was about 60 percent.

No water was added in the preparation of either Masonite or Bauer type furnishes except for those quantities indicated in Figure 2.

Board manufacture

All boards were made to the following nominal specifications:

Board thickness	1/8 inch
Board density	62.5 pcf
Board size	12 by 12 inches

TABLE 1. — *Composition of chip raw material.*

Furnish	Material	Percent
MASONITE	Oak	38.8
	Non-oak hardwoods	54.1
	Pine	.3
	Bark	6.6
	Fines	.2
	Total	
Furnish		
BAUER		

Note: B-Mix: 50% + birch; poplar, oak, pine, basswood, etc.
M-Wood: 50% maple; poplar, birch, oak, elm, basswood, etc.

Board size was limited by the dimensions of the sheet forming equipment. Ten replications were made for each of the three pulp types and each of the process types.

The four board types were processed as follows:

S1S-wet

- Pulp diluted with tap water to a consistency of 2.5 percent;
- Pulp dewatered on sheet former applying 25 inch vacuum, first without and then with top caul in place;
- Wet mat pressed in cold-press;
- Mat hot-pressed with screen on coarse side of mat.

S2S-wet

- Pulp diluted with tap water to a consistency of 2.5 percent (Masonite 1.5%);
- Pulp dewatered and prepressed as under S1S-wet;
- Mat placed in oven and dried at 220°F until weight remained constant;
- Mat hot-pressed without screen.

S1S-dry

- Mat formed on vacuum dry-former from pulp at moisture content as supplied (Masonite: 83%, Bauer: 60%);
- Mat soaked in tap water until saturated;
- Wet mat dewatered and prepressed as under S1S-wet;
- Mat hot-pressed with screen on coarse side of mat.

S2S-dry

- Pulp dried to constant weight at 220°F;
- Mat formed on vacuum dry-former;
- Mat hot-pressed without screen.

Achieving the proper press cycle that would result in the desired board density and thickness without developing surface water spots, blisters, or sticking to screen or cauls required considerable experimentation. Figures 3, 4, and 5 are examples of press cycles that

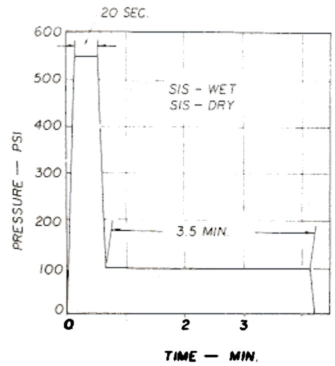

Figure 3. — Example of press cycle used to manufacture experimental S1S hardboard.
Press temperature: 390°F.

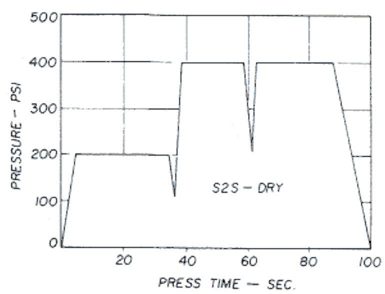

Figure 5. — Example of press cycle used to manufacture experimental S2S-dry formed hardboard. Careful breathing (no daylight) as indicated to release gases was particularly useful in the Masonite series.
Press temperature: 430°F.

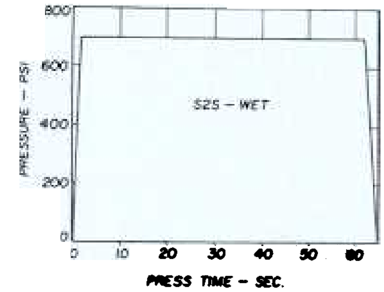

Figure 4. — Example of press cycle used to manufacture experimental S2S-wet formed hardboard.
Press temperature: 430°F.

TABLE 2. — *Pulp consistencies and white water characteristics.*

MASONITE				
	Board type			
Properties	S1S-wet	S2S-wet	S1S-dry	S2S-dry
	45	45	45	100
	2.5	1.5	45	100
	29	29	28	100
	47	45	45	
White water				
Diss. solids (%)	3.8	4.0		
Diss. solids loss (%)	16.2	15.5		
	II	II	II	I II
Consistency (%)				
Pulp	38	38	38	100
Before forming	2.5	2.5	38	100
After forming	29	29	33	100
After cold-press	59	59	42	
White water				
Diss. solids (%)	.21	.26 .21	.26	
Diss. solids loss (%)	8.2	10.1 8.2	10.1	

consistently produced satisfactory results. Pulp consistencies and white water characteristics are listed in Table 2.

Results

The interpretation of the experiment is based on results obtained from a number of standard tests. This limited evaluation does not approach a satisfactory characterization of these hardboard types with regard to their potential performance in specific applications such as paneling and siding. Neither can these results be meaningfully compared with any commercial products. They do, however, allow some comparisons within the framework of this experiment and some conclusions with regard to fiberbonding and the role of water in bond formation. The following figures show average values, adjusted where appropriate, to a common density of 1.05 g/cm^3.

Modulus of elasticity (MOE) and bending strength (MOR)

Boards made from Masonite pulp show little sensitivity to the forming method, wet or dry (Figs. 6, 7). The S2S boards have higher MOE but only slightly higher MOR. If these results reflect the quality and the extent of the bonding between fibers, hydrogen bonding must be discounted. It appears that the absence of water either in the forming process or in both forming and pressing does not diminish the bond quality. Or, in other words, satisfactory bonds can be developed in the press between bone dry fibers.

The picture is less clear in the case of boards made from Bauer pulp. MOE and MOR levels are lower than those of the Masonite boards. The longer cook, with the exception of the S2S-dry board, has a beneficial effect on these properties. The S2S-wet board appears inferior, an observation borne out by subsequent test results. However, even with the Bauer pulp, comparable bonding can be achieved without the presence of water.

Internal bond (IB)

IB is considered to be the best direct indicator of bond strength between particles and fibers. Figure 8, thus, indicates the remarkable fact that in the Masonite series the S2S-dry process, the least likely to develop good fiber bonding, produced actually the highest IB levels. One is tempted to conclude that the presence of water either in forming or pressing is actually detrimental to formation of strong fiber bonds.

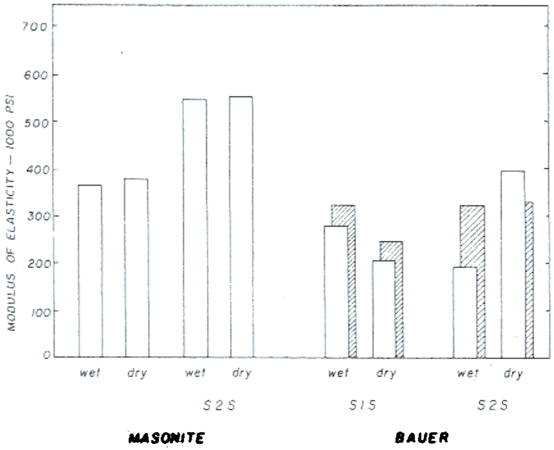

Figure 6. — Average values of modulus of elasticity, adjusted to density of 1.05 g/cm³ of experimental hardboard made from Masonite and Bauer furnishes. Shaded columns represent Bauer cook II (2-1/2 min.).

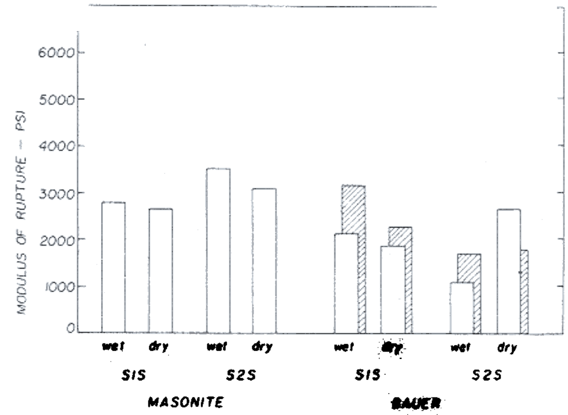

Figure 7. — Average values of modulus of rupture, adjusted to density of 1.05 g/cm³ of experimental hardboard made from Masonite and Bauer furnishes. Shaded columns represent Bauer cook II (2-1/2 min.).

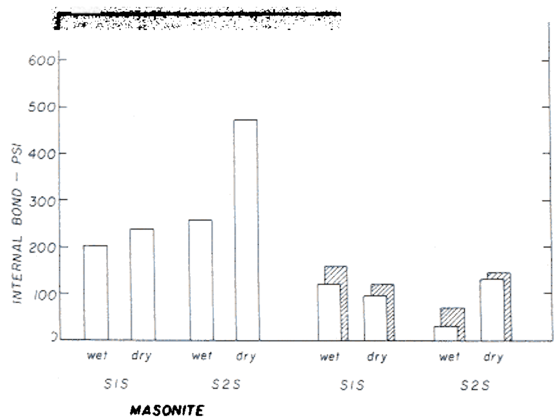

Figure 8. — Average values of internal bond, adjusted to density of 1.05 g/cm³ of experimental hardboard made from Masonite and Bauer furnishes. Shaded columns represent Bauer cook II (2-1/2 min.).

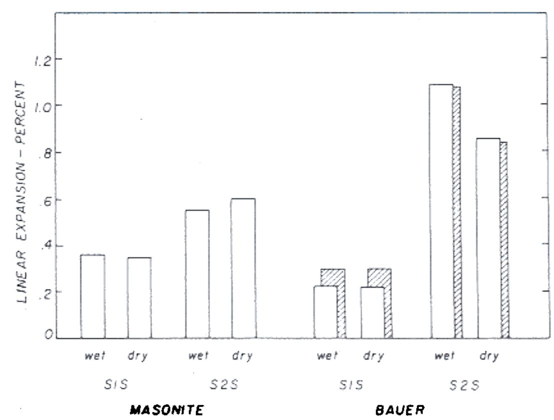

Figure 9. — Average linear expansion of experimental hardboard made from Masonite and Bauer furnishes. Shaded columns represent Bauer cook II (2-1/2 min.).

Again, the Bauer pulp series produced considerably lower values. Longer cook showed small increases. S2S-wet, again, is the weakest type.

Linear expansion

Dry pressed boards, S2S-wet and S2S-dry, show significantly larger linear expansion than wet pressed boards. S1S Bauer boards show the lowest linear expansion, while S2S Bauer boards show the largest (Fig. 9). Table 3 suggests that part of the difference between S2S and S1S may be due to larger equilibrium moisture contents of the S2S boards with the possibility of some stabilizing reaction occurring in the press in the presence of water.

Water absorption

Figures 10 and 11 show 24-hour water absorption by weight and thickness change according to the standard test which was modified by reducing the specimen size from 12 by 12 inches to 4 by 4 inches.

The Masonite pulp produces a clearly superior board in terms of resisting the uptake of liquid water. The Bauer S2S-wet type is again the weakest. In all but the S2S-dry boards, the longer cook of the Bauer chips improves these properties.

A better understanding of the water absorption behavior can be obtained by comparing the actual absorption values with the 'ideal case' or what we will call the 'limit value,' which is illustrated in Figure 12 and described in the following:

> A hardboard at room condition consists of cell wall (swollen to the equilibrium moisture content) and pore volume. The relative sizes of these two components depend on densification and on moisture content. Figure 11 illustrates the situation for a moisture content of 5 percent and a board density of 1.05 g/cm³.
>
> Without the formation of new void volume this sample can pick up a volume of water equal to the additional volumetric swelling of the cell walls from

TABLE 3. — *Summary of linear expansion tests.*

MASONITE				
	Board type			
Property	S1S-wet	S2S-wet	S1S-dry	S2S-dry
LE (50% to 93% RH)	.377	.549	.347	.599
MC (50% RH)	4.26	4.64	4.05	4.08
MC (93% RH)	8.05	8.76	7.89	9.05
MC change (%)	3.79	4.12	3.84	4.97

	S1S-wet				S1S-dry		S2S-dry	
	I	II			I	II	I	II
LE (50% to 93% RH)	.226	.289	1.09	1.08	.221	.289	.853	.838
MC (50% RH)	6.23	5.67	6.52	6.27	6.03	5.50	5.24	4.76
MC (90% RH)	14.0	14.6	17.7	16.7	13.9	13.0	15.5	13.3
MC change (%)	7.76	8.94	11.1	10.4	7.89	7.51	10.3	8.50

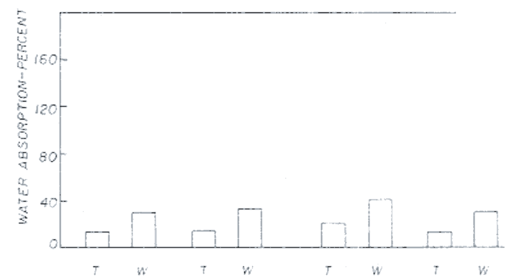

Figure 10. — Water absorption by thickness swelling (T) and weight gain (W) of experimental hardboard made from Masonite furnish.

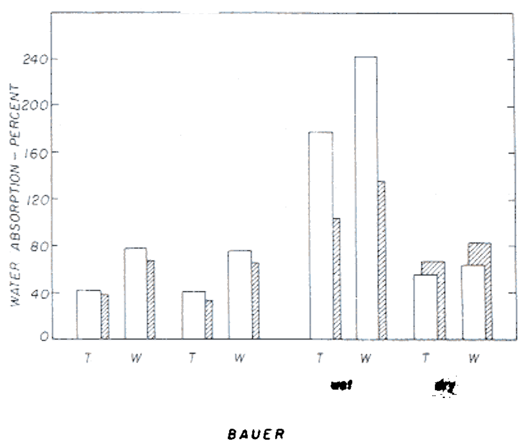

Figure 11. — Water absorption by thickness swelling (T) and weight gain (W) of experimental hardboard made from Bauer furnishes. Shaded columns represent Bauer Cook II (2-1/2 min.).

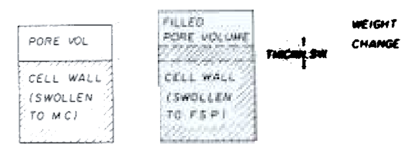

Figure 12. — Schematic illustration of theoretical limit of water absorption of hardboard under the assumption that no additional void space is generated during water absorption. Board density: 1.05 g/cm³; initial MC: 5%; fiber saturation point: 18%.

equilibrium moisture content to fiber saturation plus a volume equal to the pore volume. The cell wall swelling would be equivalent to the thickness swelling of the board. Any water absorption and thickness swelling in excess of this limit value would indicate the formation of additional void space and, therefore, a breakdown of fiber bonds.

Figures 13 and 14 show the ratio of actual water absorption over the limit value in terms of weight gain and thickness swelling.

The superiority of the Masonite pulp is apparent. It must be remembered that no waxes or other additives that could affect water absorption rate were added. Neither were any of the boards heat treated.

The Bauer boards exhibit thickness swelling and water absorption substantially in excess of the limit value. The S2S-wet board type is particularly conspicuous in that regard. This must be interpreted as a manifestation of severe structural changes (breakdown of bonds). Again, longer cooking time has a beneficial effect, again, with the exception of the S2S-dry board type.

Conclusions

1. The bonding of fibers in experimental boards made from chips prepared in Bauer Rapid Digesters and Bauer Mills and made by various methods, wet and dry, and with no additives, is weaker and less water resistant than the bonds in boards made by identical methods from severely cooked Masonite furnish.

   The reasons for this difference could not be isolated on the basis of the test results obtained. They may be complex and may include the following:

   Difference in bond quality by degree. This would reflect the extent to which the lignin may have been made available for fiber bonding by the severity of the cooking conditions. There are undoubtedly different types of bonds involved, particularly since the pulps were not washed, and therefore, retained water soluble components. Some of these bonds may be water resistant, others not.

   Fiber length may have important consequences for strength properties, linear expansion, and thickness swelling, since it may affect the three-dimensional fiber orientation in the board.

2. This more general conclusion has the greater significance:

   It does not seem to matter from which side (wet or dry formed) the press is approached.

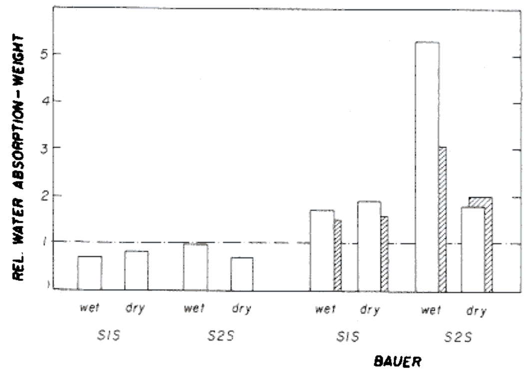

Figure 13. — Relative water absorption by weight (actual values divided by theoretical limit value) of experimental hardboard made from Masonite and Bauer furnishes. Shaded columns represent Bauer cook II (2-1/2 min.).

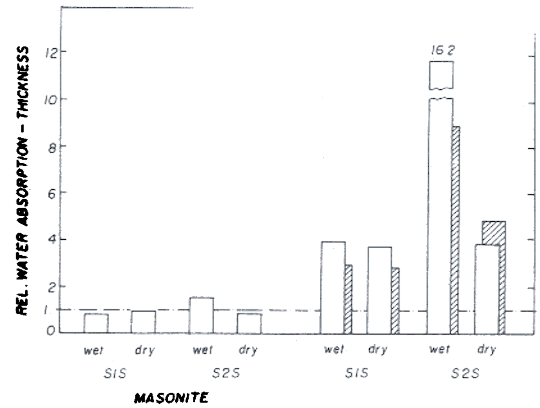

Figure 14. — Relative water absorption by thickness swelling (actual values divided by theoretical limit value) of experimental hardboard made from Masonite and Bauer furnishes. Shaded columns represent Bauer cook II (2-1/2 min.).

While there are differences between S1S and S2S boards, and between boards made from different types of pulp, there is relatively little difference between dry formed and wet formed boards.

The two processes above the wet-dry line deserve more attention because they require no, or much less water, than the two processes below that line, and also because their yields are very high, even if severe pulping conditions are used.

Literature cited

1. Suchsland, O., G.E. Woodson, and C.W. McMillin. 1983. Effect of hardboard process variables on fiberbonding. Forest Prod. J. 33(4): 58-64.
2. Koran, Z. 1970. Surface structure of thermomechanical pulp fibers studied by electron microscopy. Wood and Fiber 2(3):247-258.