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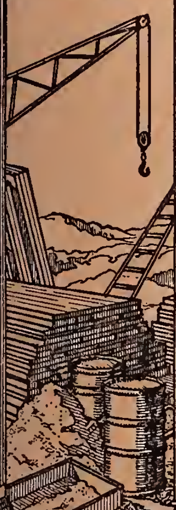

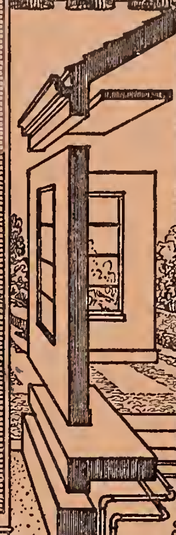

BUILDING MATERIALS AND STRUCTURES

REPORT BMS13

Properties of Some Fiber Building Boards of Current Manufacture

by

CHARLES G. WEBER

and

SAMUEL G. WEISSBERG

NATIONAL BUREAU OF STANDARDS

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ISSUED FEBRUARY 23, 1939

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Foreword

Fiber Building Boards are becoming increasingly popular as a building material, especially in the field of low-cost house construction.

The National Bureau of Standards receives numerous requests for information concerning the suitability of this class of material for various purposes and, in order to meet this need, the Bureau has been conducting investigations on the physical properties of some typical fiber building boards of current manufacture. This report covers the results of these investigations.

An earlier report in this series, BMS4, describes tests made to determine the relative deterioration of such boards under accelerated aging.

Lyman J. Briggs, *Director.*

Properties of Some Fiber Building Boards of Current Manufacture

by Charles G. Weber *and* Samuel G. Weissberg

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ABSTRACT

This article describes the fiber building boards that are under study in connection with a research on materials for low-cost house construction. Test data are given showing the properties of the different boards, and the test methods are described. Tests were made for thickness, density, thermal conductivity, flexural properties, water absorption, water permeability, air permeability, linear expansion, and nail-holding strength.

I. INTRODUCTION

The research on building materials and structures for use in low-cost housing, now in progress [1] at the National Bureau of Standards, includes a study of fiber building boards. This study deals primarily with the accelerated aging [2] of these materials to find how they may be expected to retain their properties under the conditions to which they will be exposed in use. In order to obtain data on the effects of accelerated aging, it was necessary, of course, to test the original properties of the boards. The test data on these properties are known to be of immediate interest to users of the current commercial boards, and for that reason are given here in advance of the data being obtained on the aging qualities of the boards.

The manufacture of the fiber boards, and the raw materials used in them have been described in a previous publication.[3] The properties of a number of wall boards and insulating boards were also described in articles [4] [5] containing the results of previous studies. No important developments have occurred relative to the fibrous raw materials used or the general methods of manufacture since those articles appeared. The boards are made of partially refined vegetable fibers obtained principally from crop plant wastes or waste wood. These materials are reduced to fibers by mechanical means or by exploding them with steam, usually after softening them with chemicals or by steaming them. The boards are fabricated from the pulps on modified paper-making machines. Improvements in the finished products have been rapid, however, and new types of boards have recently come on the market, notable among which is insulation sheathing. The data contained in this article were obtained on samples of current commercial products furnished by the manufacturers as representative of the boards now on the market.

II. DESCRIPTION OF BOARDS TESTED

While fiber boards are designed for a great number of special uses, only those designed for applications that appear to have a place in low-cost houses are included in this investigation. Those tested to date may be divided into three classes according to the uses for which

[1] Building Materials and Structures (1938) NBS Rep. BMS1. (Price 10 cents, see cover page II.)

[2] Building Materials and Structures (1938) NBS Rep. BMS4. (Price 10 cents.)

[3] Ind. Eng. Chem. **27**, 896–898 (1935).

[4] Misc. Pub. BS (1931) M132.

[5] Paper Trade J. **89**, 61–68 (1929).

they were primarily intended. All were of the homogeneous type, that is, not laminated, made to have comparatively low density to obtain the maximum heat insulating value. These boards owe their heat insulating properties primarily to innumerable, small air cells, and the thermal conductivity usually increases with the density at a fairly uniform rate.[6]

The first two classes, the more or less standard ½-inch insulating boards used within walls, and the ½-inch insulation wall boards used for interior finish, respectively, differ only in that those of the latter class either have one side painted or have one surface smoothed and sized for decorative treatment. The insulation sheathing is a new class of material. It includes relatively rigid insulating boards of approximately the same thickness as the lumber usually employed for sheathing, 25/32 inch.

The boards in class *I* are designed for use as heat insulation in walls, roofs, attic floors, and basement ceilings, and are sometimes used as lath or under stone or brick veneer. Boards in class *II* would serve in those applications practically as well as those of class *I* and have the added feature of being designed for use as wall boards, for finish cover on interior walls and ceilings. The insulation sheathing boards in class *III* are for use as sheathing, and as insulating roof boards. They are of approximately the same density as the boards in the other two classes, are nearly twice as thick, and have asphalt treatments for protection against infiltration of water and air.

[6] BS J. Research 5, 973 (1930) RP243.

The samples included boards made of fibers from at least five quite different raw materials; wood, bagasse (extracted sugar cane), cornstalks, licorice roots, and waste papers. However, the general properties of the finished products were essentially the same. All of them can be classed as insulating structural boards.

III. PROPERTIES AND TESTING

The properties of the boards as determined by the present laboratory methods are shown in table 1. The methods of testing were, insofar as possible, the methods that have been more or less standardized.[7]

[7] The assistance of M. S. Van Dusen and H. W. Woolley of the Bureau's heat transfer section in obtaining data on thermal conductivity is gratefully acknowledged.

TABLE 1.—*Properties of fiber building boards*

Board	Thickness	Density	Thermal conductivity	Flexural properties [a]				Water absorption, by volume (2-hr immersion)	Water permeability (time of penetration through the board)	Air permeability (rate of flow through the board)	Linear expansion (for increase from 50- to 95-percent relative humidity)	Nail-holding strength (lateral)
				Breaking load		Deflection at rupture						
				Across long direction	Across short direction	Across long direction	Across short direction					
CLASS I.—½-INCH INSULATING BOARDS WITHOUT SPECIAL FINISH												
	in.	*lb/ft³*	*Btu/hr ft² / °F/in.*	*lb*	*lb*	*in.*	*in.*	*Percent*	*hr*	*cm³/m² sec / g/cm²*	*Percent*	*lb*
A	0.49	16.9	0.35	14.3	11.3	0.72	0.76	5.7	25	454	0.15	74
B	.50	16.2	.34	16.5	13.0	.60	.72	12.5	6	1,084	.29	72
I	.52	16.9	.36	25.4	18.0	.54	.64	5.5	30	505	.15	95
J	.53	16.6	.34	20.6	15.6	.52	.68	7.9	21	498	.20	87
L	.49	19.5	.37	12.7	12.4	.30	.31	6.0	26	3,780	.10	64
M	.51	15.7	.37	17.2	11.3	.52	.57	6.3	5	383	.10	67
N	.47	16.5	.33	9.7	10.5	.50	.48	5.4	22	1,215	.10	57
O	.55	17.0	.33	12.2	11.4	.55	.50	6.8	25	2,665	.20	87
R	.48	18.2	.36	15.3	14.5	.98	1.05	5.3	5	479	.40	83
K	.51	16.5	.37	10.5	12.1	.54	.57	4.2	5	700	.30	64
A[2]	.53	21.8	.40	20.5	20.7	1.27	1.32	3.4	6	760	.40	112
CLASS II.—½-INCH INTERIOR-FINISH INSULATING BOARDS												
C	0.47	21.0	0.39	14.4	14.0	0.61	0.89	5.1	26	676	0.35	7[illegible]
D	.48	16.9	.36	15.1	11.4	.83	.89	9.0	18	207	.30	79
H	.49	25.6	.43	33.3	32.7	.85	.72	4.1	47	30	.20	143
P	.46	20.7	.35	12.0	12.1	.77	.97	9.3	21	704	.40	94
R[2]	.49	18.3	.36	16.4	14.1	.98	1.10	5.6	5	339	.40	87
CLASS III. INSULATION SHEATHING												
E	0.83	20.0	0.39	48.0	45.0	0.48	0.45	(b)	72	125	0.10	171
C[2]	.81	17.0	.38	37.8	28.2	.72	.69	(b)	163	0.021	.30	103

[a] Tests made under standard atmospheric conditions of 65-percent relative humidity and 70° F. [b] Test not applicable to this class of boards.

1. Thickness and Density

The density of board is the weight per unit of volume; hence, it is computed from dimensional measurements and weight determinations on test specimens. Thickness and density values were obtained on specimens 12 by 12 inches. The specimens were weighed on a balance reading to 0.1 g, and the thickness was measured with a vernier caliper graduated to 0.1 mm.

2. Insulating Properties

The insulating value of a board depends upon its thermal conductivity or the rate at which heat is transferred through the board. The boards having lowest thermal conductivity have the best insulating value. The conductivity is expressed as the number of heat units (Btu) that would be transferred through a square foot of the board in 1 hour with a temperature drop of 1° F per inch of thickness. It was determined on specimens 8 by 8 inches, which were prepared by drying them to constant weight at 160° F before the testing, and the tests were made on the dry specimens at a mean temperature of 90° F.

The guarded hot-plate method was used. Details of this test together with the construction of the necessary apparatus are described in the Federal specification[8] for insulating board. An electrically heated copper plate is sandwiched between two 8- by 8-inch test specimens the other surfaces of which are in contact with water-cooled copper plates which are kept at constant temperature. The power required to keep the heated plate at constant temperature is measured, and the thermal conductivity is calculated from the expression $K=Pd/JT$, where P is the power applied per unit area of slab (watts per square foot); d is the average thickness of specimen (inches); T is the temperature difference (° F); and J is the electrical equivalent of heat (1,054 j/Btu).

A guard-ring arrangement is included to make certain that the flow of heat is perpendicular to the faces of the slabs and uniformly distributed over the area of the slabs. In placing the specimens in the apparatus, one on each side of the central heating plate, enough pressure is applied to insure good contact between the specimens and the copper plates, but not enough to cause an appreciable diminution in the thickness of the specimens.

3. Flexural Properties

With the exception of the sheathing boards, the boards are not usually installed where they are required to add structural strength to a building. A reasonable flexural strength is important, however, to allow handling and installation without undue breakage. The deflection at rupture is a rough measure of the stiffness. Little or no deflection would indicate that the board was too brittle for economical application, and excessively high deflection might indicate lack of sufficient stiffness to hold its shape in panels.

The flexural strength tests were made in accordance with the standard method described in the Federal specification[8] for insulating board, and also in a previous Bureau publication.[9] The test is made by applying a load at midspan of a specimen 3 inches wide, laid across two parallel supports 12 inches apart. The load required to break the specimen, or rupturing load, and the amount that the board bends up to the breaking point, or deflection at rupture, are recorded. The load may be applied conveniently by means of a tensile testing machine with suitable fixtures.

As the sheathing boards are designed for use as siding they must provide bracing strength to the structure. Hence, high strength and stiffness are to be desired in this class of boards.

4. Water Absorption

Water absorption is an important consideration factor because it indicates the extent to which the fibers will become wet when water reaches them. Wetting is accompanied by swelling of the fibers and warping or buckling due to the resulting expansion. Also, the wetting results in loss of stiffness and insulating value. The water absorption was determined by the standard method described in the Federal specification[8] for insulating boards. Speci-

[8] Fed. Spec. LLL-F-321a.

[9] Misc. Pub. BS (1931) M132.

mens 12 by 12 inches are weighed and immersed in water for 2 hours, removed and allowed to drain 10 minutes, and reweighed. The increase in weight is the water absorbed. The result is converted to volume of water absorbed and is expressed as a percentage of the original volume of the specimen.

5. Permeability to Water and Air

As a structural component of the walls of a house, a board should offer relatively high resistance to the passage of both water and air. The fiber boards are not, with the exception of the sheathing boards, commonly used where they must function as a primary moisture barrier. However, the rate of water penetration is often important in these boards as it may affect the resistance of the finished walls to the infiltration of water. Air permeability is important, of course, because the infiltration of air causes transfer of heat in addition to that transmitted by thermal conduction.

The time of water penetration was determined by the dry indicator method.[10] [11] An eosin dye in mixture with powdered sugar and starch is sprinkled on one side of the test specimen and the specimen is floated on water with that side up until color is developed in the dye by water permeating the board. The dye is covered with glass during the test to prevent contact with atmospheric moisture, and the edges of the specimen are sealed with wax to prevent the water from entering there. The principle of the dry indicator test, which was developed by F. T. Carson of the Bureau, has been applied satisfactorily in the testing of papers and fibrous sheet products in general.

The results are expressed in time of penetration in hours. This time should be as long as practicable.

Permeability to air was determined with the Carson precision permeability tester for sheet materials. The test is described in detail in a publication by Carson.[12] The volume of air that will flow through the board per unit of area for a given pressure gradient is measured by means of a capillary flow meter. The pressure gradient is kept constant during the test by means of a sensitive pressure regulator, and errors due to edge leakage are avoided by by-passing the leakage air around the measuring apparatus.

The permeability to air should be as low as practicable.

6. Linear Expansion with Change of Humidity

Low linear expansion with changes of humidity is an important attribute of a fiber board, particularly if it is to be used for interior finish. Low expansion means a minimum of waving, buckling, and opening of seams when wall panels are subjected to extremes of relative humidity as they often are.

The linear expansion tests were made in accordance with the method described in the Federal specification.[13] Test specimens measuring 3 by 12 inches are conditioned first at 50-percent relative humidity, then at 95-percent, and the change in length determined by measuring the displacement of reference marks placed approximately 10 inches apart.

7. Nail-Holding Strength

Nail-holding strength is of interest in considering the properties of the wall-finish boards and ordinary insulating boards, as it indicates the probable danger of their becoming loosened after installation. For the sheathing boards high nail-holding strength is essential if they are to impart the required rigidity and strength to the building. For measuring nail-holding strength, a modification of a method suggested by a manufacturer[14] was used. It is not a test for the resistance to pulling of the nails, but is a method of finding the force required to move a 6-penny common nail laterally to the edge of the board. The nail is driven in a 3-inch strip of the board, centered ¾ inch from one end and driven through far enough to project about equally from both sides of the board. The opposite end of the strip is clamped in one jaw of a tensile tester, and a metal stirrup is hooked over both ends of the nail and clamped in the other jaw of the tester. Operation of the tester

[10] Paper Trade J. 98, No. 21 (May 1934).

[11] TAPPI Std. T433m, Tech. Assn. Pulp & Paper Ind., 122 East 42d Street, New York, N. Y.

[12] BS J. Research **12**, 567 (1934) RP681.

[13] Fed. Spec. LLL-F-321a.

[14] This method was proposed by M. S. Wunderlich, of the Insulite Co.

moves the nail to the edge and records the force required to do so.

IV. SUMMARY

A good insulating board should have high insulating value, as indicated by a low rate of thermal conductivity, sufficient strength for economic handling, and low permeability to air and water. The average heat-transmission value was 0.35 for the ½-inch insulating boards and 0.38 for the ½-inch interior-finish insulating boards, the average densities being 17.1 and 20.5 pounds, respectively. These data indicate that the surface treatment of the wall-finish boards raises the density slightly and that the insulating value is decreased accordingly. The boards show a wide range of values for permeability to air and water.

A thermal conductivity of 0.33 to 0.36 is the minimum that was obtained in ½-inch boards that met the strength requirements contained in the Federal specification for fiber insulating board. Apparently, a lower value can be obtained only with densities below 16 pounds per cubic foot, and such boards are not likely to meet the present requirements for strength and absorption of water.

The strength properties show a considerable range of values for flexural strength and nail-holding strength.

The insulation sheathing boards had high strength because of their greater thickness, and the low permeability to water and air was significant, particularly for board C^2.

That the source of the vegetable fiber used had a relatively unimportant effect on the essential properties of the boards may be observed from the rather uniformly good correlation between the density and other properties, especially thermal conductivity, for all boards.

WASHINGTON, November 11, 1938.

The *National Bureau of Standards* was established by act of Congress, approved March 3, 1901, continuing the duties of the old Office of Standard Weights and Measures of the United States Coast and Geodetic Survey. In addition, new scientific functions were assigned to the new Bureau. Originally under the Treasury Department, the Bureau was transferred in 1903 to the Department of Commerce and Labor (now the United States Department of Commerce). It is charged with the development, construction, custody, and maintenance of reference and working standards, and their intercomparison, improvement, and application in science, engineering, industry, and commerce.

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