U. S. DEPARTMENT OF COMMERCE

BUILDING MATERIALS AND STRUCTURES

REPORT BMS50

Stability of Fiber Building Boards as Determined by Accelerated Aging

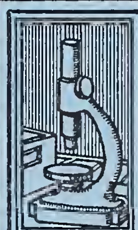
by

DANIEL A. JESSUP,

CHARLES G. WEBER, *and*

SAMUEL G. WEISSBERG

NATIONAL BUREAU OF STANDARDS



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ISSUED MAY 13, 1940

The National Bureau of Standards is a fact-finding organization; it does not "approve" any particular material or method of construction. The technical findings in this series of reports are to be construed accordingly.

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Foreword

Vegetable-fiber boards, which have wide application in house construction, were subjected to accelerated aging to find their probable stability or lasting qualities. The physical properties of the materials in this class were described in an earlier report in this series, BMS13, and the present report contains data on the changes in those properties produced by accelerated aging. These changes are used as a basis for judgment of relative stability.

Lyman J. Briggs, *Director.*

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ABSTRACT

Fiber building boards were aged by exposure to cycles of wetting, freezing, drying, and baking and to outdoor weathering. The boards were tested before and after aging to determine the changes produced, and judgment of stability was based on the changes. The properties tested were weight, thickness, expansivity, thermal conductivity, flexural properties, nail-holding strength, water absorption, ash, rosin, and permeability to air and water. Data were obtained on the relationship between the moisture contents of the boards and the relative humidity of the surrounding air and on the resistance of the boards to rot-producing fungi.

In general, the retention of the most essential properties—namely, thermal conductivity and strength—was excellent. Furthermore, the boards did not support the growth of rot-producing fungi except at relative humidities above 85 percent. At the high humidities, the fiber boards are subject to mold growth, but it was shown that the growth can be prevented, or at least appreciably retarded, by use of fungicides.

I. INTRODUCTION

Fiber building boards have been tested in connection with the research on building materials and structures for low-cost housing. Previous publications have described the properties [1] of various commercial boards and the tests [2] used for determining the stability of them. This article presents the results of tests on the stability of commercial products furnished by the manufacturers as representative of the boards now on the market. The relative resistance of the different boards to deteriorative influences was judged by the effects of accelerated aging and outdoor weathering exposures and by the resistance to rot-producing fungi under controlled conditions. Data on relative-humidity-moisture-content relationships were obtained also.

Some of the most important properties of the boards are thermal insulating value; resistance to the absorption of moisture, which causes swelling and warping of the board; nail-holding strength; resistance to air infiltration; and flexural strength. Fiber boards were known to be generally satisfactory in these respects when new, and the retention of their properties under the aging treatments was taken as the criterion of the resistance to aging.

II. DESCRIPTION OF SAMPLES

The boards tested in this investigation were obtained from cooperating manufacturers. Not all of the commercial brands were tested, but those included are considered to be representative of the types available commercially. Eleven manufacturers submitted 17 different boards for test.

[1] Building Materials and Structures (1939) NBS Rep. BMS13. (Price, 10 cents.)

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

220368°—40

All of the boards tested were of the low-density class, designed to provide thermal insulation. They were the ½-inch boards for use within walls or for interior finish. For sake of convenience in comparing test results, they are classified into three groups according to composition and finish; however, the general characteristics of all boards are essentially comparable.

III. PROPERTIES AND TESTING

Insulating boards, when used as a component part of a building, are exposed to wide variations of temperature and moisture. Accelerated aging [3] was employed to find the probable stability of the boards under such influences. They were subjected to an intensified simulation of normal aging. The treatment consisted of the following cycle: Immersion in water 1 hour; spraying with condensed steam at 90° to 95° C for 3 hours; storing 20 hours at −12° C; heating 3 hours at 100° C in dry air; again spraying with condensed steam at 90° to 95° C for 3 hours; and heating in dry air at 100° C for 18 hours. This cyclic treatment was continued for a total of 300 hours.

Insulating board is not, in general, designed for use as exterior finish. However, since receipt of a large number of inquiries regarding its suitability for this purpose has indicated widespread interest in it, a number of exposure tests were made. During the tests, water was sprayed on the samples at regular intervals to accelerate the natural weathering. The edges of the boards were sealed against moisture by a coating consisting of powdered aluminum in spar varnish. Two specimens of each board under test were subjected to the outdoor exposure. The surface of one specimen of each was painted with a linseed oil-white lead paint suggested by the Bureau's paint section. The second specimen of each board was exposed with no protection of the surface.

[3] See footnote 2.

TABLE 1.—*Properties of fiber building boards and effects of accelerated aging*

Laboratory designation of board	Thickness	Density	Ash	Chloroform soluble material (resins, etc.)	Linear expansion (for increase from 50- to 95-percent relative humidity)	Thermal conductivity	Flexure properties [a]: Breaking load, Across long direction, Before aging	Breaking load, Across long direction, After aging	Breaking load, Across short direction, Before aging	Breaking load, Across short direction, After aging	Deflection at rupture, Across long direction, Before aging	Deflection at rupture, Across long direction, After aging	Deflection at rupture, Across short direction, Before aging	Deflection at rupture, Across short direction, After aging	Nail-holding strength (lateral), Before aging	Nail-holding strength (lateral), After aging	Water absorption, by volume (2-hr immersion), Before aging	Water absorption, After aging	Water permeability (time of penetration through board), Before aging	Water permeability, After aging	Air permeability (rate of flow through board), Before aging	Air permeability, After aging
BOARDS MADE FROM CROP PLANT WASTES AND WASTE PAPER																						
	in.	*lb/ft³*	%	%	%	*Btu/hr / ft² (°F/in.)*	*lb*	*lb*	*lb*	*lb*	*in*	*in*	*in*	*in*	*lb*	*lb*	%	%	*hr*	*hr*	*cm³/sec / m²(g/cm²)*	*cm³/sec / m²(g/cm²)*
A	0.49	16.9	2.8	2.0	0.15	0.35	14.3	11.1	11.3	9.0	0.72	0.93	0.76	1:14	74	63	5.7	76.0	25	0.13	454	593
H	.49	25.6	1.6	3.6	.20	.43	33.3	26.5	32.5	28.0	.85	1.02	.72	0.86	143	115	4.1	4.0	47	45	30	48
K	.51	16.5	8.2	2.1	.30	.37	10.5	7.8	12.1	8.7	.54	.56	.57	.57	64	50	4.2	63.0	5	1	700	743
M	.51	15.7	0.9	1.6	.10	.37	17.2	11.0	11.3	4.7	.52	.75	.57	.71	67	54	6.3	78.0	5	0.16	383	371
R	.48	18.2	4.2	4.6	.40	.36	15.3	12.7	14.5	12.1	.98	1.70	1.05	1.47	83	64	5.3	78.0	5	1	479	459
AA [b]	.53	21.8	3.0	25.8	.40	.40	20.5	21.1	20.7	22.3	1.27	1.06	1.32	0.93	112	115	3.4	6.7	6	4	760	802
BOARDS MADE OF WOOD FIBER																						
B	0.50	16.2	0.6	3.3	0.20	0.34	16.5	12.5	13.0	10.6	0.60	0.77	0.72	0.85	72	61	12.5	76.0	6	0.03	1,084	1,350
I [b]	.52	16.9	.6	5.4	.15	.36	25.4	17.1	18.0	13.8	.54	.79	.64	.81	95	75	5.5	5.0	30	16	505	673
J	.53	16.6	.5	2.6	.20	.34	20.6	17.7	15.6	14.3	.52	.75	.68	.87	87	79	7.9	74.0	21	0.35	498	595
L	.51	18.8	.3	5.5	.20	.37	17.0	13.4	16.9	12.4	.34	.39	.37	.39	71	62	4.7	5.6	16	6	3,300	3,540
N [c]	.47	16.5	1.0	3.0	.10	.33	9.7	5.6	10.5	6.2	.50	.43	.48	.59	57	31	5.4	3.6	22	20	1,215	1,945
O	.55	17.0	0.7	2.3	.20	.33	12.2	10.9	11.4	10.5	.55	.77	.50	.72	87	70	6.8	23.0	25	9	2,665	3,480
INTERIOR-FINISH BOARDS WITH SPECIAL SURFACING ON ONE SIDE																						
C	0.47	21.0	2.4	5.4	0.35	0.39	14.4	10.1	14.0	9.5	0.61	0.83	0.89	0.92	72	59	5.1	4.9	26	10	676	1,260
D	.48	16.9	3.8	2.7	.30	.36	15.1	10.0	11.4	10.1	.83	1.27	.89	.90	79	70	9.0	71.0	18	0.05	207	313
P	.46	20.7	2.3	3.2	.40	.35	12.0	9.6	12.1	10.0	.77	0.88	.97	1.07	94	75	9.3	7.3	21	12	704	1,940
JJ	.50	17.2	3.2	2.1	.20	.35	16.2	15.2	13.1	11.8	.71	.79	.72	0.86	70	67	6.2	7.0	12	6	328	537
RR	.49	18.3	6.3	4.9	.40	.36	16.4	12.4	14.1	11.6	.98	1.37	1.10	1.35	87	64	5.6	71.0	5	1	339	416

[a] For specimens 3 in. wide on supports 12 in. apart.
[b] Impregnated with asphalt.
[c] Treated with wax.

Another factor affecting the stability of fiber building boards is their susceptibility to rotting. The boards were tested for resistance to the action of rot-producing fungi by inoculating specimens with three of the typical rot-producing fungi commonly found around wood constructions; storing the specimens under warm, moist conditions favorable to the growth of the fungi; and observing the spread of the fungi and their effects on the boards.

Data on the various properties of the boards before and after accelerated aging are shown in table 1. A comparison of the data for the aged and unaged samples gives an indication of the relative stability. Since the methods of testing have been given in detail in previous publications [4] and in a Federal specification [5] for insulating boards, they are described only briefly here.

1. Thermal Insulation

The insulating value of a board depends upon its thickness and the thermal conductivity of the material of which it is composed. In any given thickness, the insulting value is inversely proportional to the thermal conductivity of the material. Conductivity is expressed as the number of heat units (Btu) that would be transferred through 1 square foot of the board in 1 hour with a temperature drop of 1° F per inch of thickness.

Measurements of thermal conductivity were made by the guarded hot-plate method previously described. The tests reported were made by H. W. Woolley of the Heat Transfer Section of the Bureau.

The accelerated aging of the boards had no appreciable effects on the insulating value, as indicated by the results of thermal-conductivity measurements.

2. Flexural Properties

The ½-inch insulating boards are not usually installed where they are required to contribute materially to the strength of the structure. A reasonable flexural strength is required for economic handling and installation without undue breakage, and the boards must retain enough strength and rigidity to prevent damage to the walls through sagging or breaking of the boards after installation. The flexural strength was determined by the method described in the Federal specification for insulating boards and in the previous Bureau publication.[6] The method consists in loading at midspan a specimen 3 inches wide, supported by two parallel supports 12 inches apart, until the specimen breaks.

Decreases in flexural strength were not large except for boards *M* and *N*. The initial strength of *N* was relatively low.

3. Nail-Holding Strength

Nail-holding strength is of interest as it indicates the probable danger of the boards becoming loosened after installation. The test method consists essentially in measuring the force required to move a 6-penny common nail to the edge of a board from a position ¾-inch from the edge.

Aging caused losses of nail-holding strength for most of the boards, but in most instances the losses were not serious. Board *N* suffered the greatest loss, and it had relatively low nail-holding strength initially.

4. Water Absorption

Water absorption is an important factor in the usefulness of fiber building boards, because it indicates the extent to which the fibers will become wet when moisture reaches them. Wetting is accompanied by swelling of the fibers, and warping or buckling of the board may result. Most insulating boards are sufficiently resistant to wetting when new; however, if the absorption should increase appreciably after installation, the usefulness of the boards would be impaired. The water absorption was determined by the method defined in the Federal specification for insulating boards.

Specimens are weighed before and after immersion in water for 2 hours. The resulting increase in weight indicates the amount of water absorbed and is reported in percentage of the volume of the specimen before immersion.

There was considerable lack of uniformity with respect to the effects of aging on the

[4] See footnotes 1 and 2.
[5] Fed. Spec. LLL-F-321a, Fiber Board; Insulating.
[6] See footnote 1.

water absorption of different boards. Two of those in group 1 were practically unaffected, whereas the other 4 showed a rather sharp increase. Of the 11 boards in groups 2 and 3, 5 showed sharp increases, and the others were unchanged.

5. Water Permeability

Insulating boards are not commonly used where they must function as a moisture barrier. However, the rate of water penetration is often important because it may contribute to the resistance of the finished walls to the infiltration of water. The rate of penetration of water through the boards was determined by the dry-indicator method. An indicator consisting of a mixture of eosin dye, powdered sugar, and starch is sprinkled on one surface of the specimen; a glass cover is sealed over the indicator; and the edges of the specimen are sealed with wax to prevent water from reaching the indicator except by penetration through the board and to prevent evaporation of the transuded moisture. The specimen thus prepared is floated on water, and the time of transudation of water in an amount sufficient to develop color in the indicator is a measure of the permeability.

The results of this test placed the samples in much the same order as did the results for water absorption.

6. Air Permeability

Permeability to air may be important in its relationship to the insulating value of a fiber board. The infiltration of air causes a transfer of heat in addition to that transmitted by thermal conduction. The permeability was determined with the Carson precision permeability tester described in a previous Bureau publication.[7] The volume of air that will flow through a board per unit area for a given pressure gradient is measured by means of a capillary flow meter.

Changes in permeability to air with aging were small for specimens in groups 1 and 2. The boards designed for use as interior finish showed changes of considerable magnitude after aging because of breakdown of the surface finishes. This deterioration does not appear important, as when the boards are in use they presumably will be redecorated from time to time.

7. Outdoor Weathering

Table 2 contains data on the comparative results of tests after accelerated aging and after 15 months' exposure to outdoor weathering. The results of the outdoor aging appear to be roughly comparable to those of accelerated aging. Differences were large in a few instances with respect to water absorption and water penetration. It could not be expected that like values would be obtained by the two aging treatments. However, the similarity of the trend of results produced by the two methods indicates that the effects of outdoor weathering are comparable to those obtained by the more rapid and convenient method of accelerated aging. The boards which had been painted on the exposed surfaces were little affected after exposure for 15 months.

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

Table 2.—*Comparison of effects of accelerated aging and outdoor weathering* [a]

Board	Water absorption by volume			Water permeability			Air permeability			Flexural strength				Nail-holding strength			
	Initial	After accelerated aging	After outdoor exposure	Initial	After accelerated aging	After outdoor exposure	Initial	After accelerated aging	After outdoor exposure	Initial	After accelerated aging	After outdoor exposure	After outdoor exposure (painted)	Initial	After accelerated aging	After outdoor exposure	After outdoor exposure (painted)
	%	%	%	hr.	hr.	hr.		$cm^3/m^2/sec$ / g/cm^2		lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
D	9	71	44	18	0.05	5	207	813	434	15	10	14	15	75	63	73	83
H	4	4	5	47	45	30	30	47	31	33	28	28	32	143	115	115	123
I	6	5	15	30	16	7	505	673	654	18	14	14	24	95	75	73	96
N	5	4	7	22	20	7	1,215	1,945	1,560	10	5	8	15	57	31	40	64
P	9	7	23	21	12	5	704	1,940	2,160	12	10	9	15	94	75	69	75
RR	5	71	10	5	1	7	479	439	435	14	12	14	16	87	64	86	84

[a] Values showing properties after outdoor exposure were obtained on samples too small for standard tests and values are approximate.

8. Moisture-Content—Relative-Humidity Relationships

The fiber boards are seldom in direct contact with water for long periods; however, the air in contact with them may vary from a dry condition to one near the saturation point. The moisture content of a board is controlled by the condition of the surrounding air and is important as it affects such properties as thermal conductivity, resistance to rotting, and strength.

Relative-humidity–moisture-content relationships were determined for six typical boards, representative of the different types under study. The specimens were conditioned to constant weight at 95-percent relative humidity, then at seven other humidities in order of descending values, the lowest condition being 15 percent. The conditioning was accomplished in a cabinet in which the humidity was controlled by circulating the air over saturated salt solutions. The specimens were arranged to permit weighing without opening the cabinet.

Table 3 shows the relative-humidity–moisture-content relationships for the boards. It should be noted that the results for five of the boards are very similar, but the sixth board contained appreciably less moisture at each humidity. This board is made from exploded wood fibers and contains a large amount of natural resin, lignin, etc.

Table 3.—*Relative-humidity–moisture-content relationship*

[Desorption values]

Relative humidity	Moisture content of board—					
	D	*H*	*J*	*K*	*N*	*L*
%	%	%	%	%	%	%
15	3.4	4.0	3.5	3.9	3.8	2.7
17.5	3.9	4.5	3.9	4.4	4.3	3.0
37	6.8	7.4	6.9	7.2	7.2	5.4
48	8.2	8.7	8.4	8.5	8.4	6.5
65	10.7	11.2	11.0	10.9	11.0	8.4
75	12.4	12.9	12.8	12.6	12.7	9.7
88	15.2	15.8	15.8	15.5	15.8	11.4
95	16.5	17.2	17.2	17.4	17.2	12.2

9. Resistance to Rot-Producing Fungi

There has been much interest in the susceptibility of the fiber boards to rotting. Hence, tests were made to determine under what conditions the boards will support the growth of rot-producing fungi and the effects of such growths on the properties of the boards. The selection of fungi was based on a recommendation of the Division of Forestry Pathology, U. S. Department of Agriculture, and the cultures were prepared in the Forest Pathology Laboratory.

Specimens of fiber building boards inoculated with the cultures of rot-producing fungi and stored over water at approximately 95-percent humidity and room temperature showed changes in nail-holding strength that were proportional to the apparent extent of the growth. Those showing only local stain were little affected, those with local decay showed considerable loss in strength, and those with general decay retained little or no nail-holding strength. There was not much difference in the rate and extent of growth on aged specimens and the unaged samples.

Fungus growth is generally considered to proceed most favorably under warm, moist conditions. An effort was made to determine the relative humidity most favorable to growth. Specimens of the building boards were inoculated and stored in jars over saturated salt solutions selected to produce various relative humidities. The specimens were weighed before storage and again after 4 months and the changes were noted. Those stored at humidities below 88 percent showed no visible signs of fungus growth and no significant loss in weight, but those conditioned above 88 percent showed heavy growth and appreciable loss in weight.

When specimens were exposed in a jar at 33-percent relative humidity for 2 weeks, the agar on which the fungus was grown dried and showed no evidence of growth. However, when the specimens were subsequently placed over water, the growth spread rapidly and continued to grow for the entire duration of the test. This would indicate that if the material has been infected with fungus, growth will not progress if the relative humidity remains low, but if high humidity prevails, growth will progress rapidly. Specimens of various species of woods, including pine, cypress, fir, maple, and walnut, were inoculated with cultures of the same fungi used on the fiber boards and stored over water with the fiber board specimens. The apparent growth and spread of the fungi on the woods were about the same as on the fiber boards. Hence, it appears that the fiber building boards are probably no more subject to attack and decay by rot-producing fungi than is the wood commonly used in house construction.

Zinc chloride, lead acetate, a water-soluble chlorophenolic compound, and an oil-soluble chlorophenolic compound were used in a study of the effectiveness of some of the common wood preservatives in preventing fungus growth on fiber building boards. Specimens of the boards were treated under reduced pressure with solutions of the preservatives to obtain retentions in the boards ranging from 0.1 to 1.0 percent. Specimens were conditioned to suitable moisture content, inoculated with the rot-producing fungi, and stored in approximately 95-percent relative humidity at room temperature. There was no apparent development of fungus on these specimens.

10. Chemical Properties

Tests for the cellulosic purity of the fiber boards did not produce results of value in estimating stability. The average initial alpha-cellulose content was relatively low and the lignin content relatively high, approximately 50 percent and 20 percent, respectively. No significant changes of these properties occurred during aging. Apparently the chemical tests commonly used on fiber sheetings are of little value for measuring the deterioration of this type of board.

IV. SUMMARY AND CONCLUSIONS

The apparent stability of a number of fiber building boards of current manufacture was determined by observing their resistance to accelerated aging, outdoor weathering, and attack by rot-producing fungi.

Accelerated aging produced large increases in water absorption of some of the boards and in water permeability of most of the boards, which indicates that they should not be depended upon to function as a moisture barrier.

The aging produced significant changes in air permeability for most of the boards having special surfaces for interior finish. The changes resulted from a breakdown of the finish, and since the boards, when in use presumably will be redecorated from time to time, no decrease in serviceability should result from this kind of deterioration.

Changes of nail-holding strength and flexural properties were not, in general, large enough to be considered serious under the aging treatment.

The fiber boards are apparently no more susceptible to damage from the growth of rot-producing fungi than are the woods used in house construction. Treatment of the boards with a wood preservative will improve their resistance to fungi.

The average stability of the boards under the various deteriorative influences was relatively good, but the results indicate that this type of board is not suitable for the exterior covering of buildings.

Washington, February 14, 1940.

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BMS26	Structural Properties of "Nelson Pre-Cast Concrete Foundation" Wall Construction Sponsored by the Nelson Cement Stone Co., Inc	10¢
BMS27	Structural Properties of "Bender Steel Home" Wall Construction Sponsored by The Bender Body Co	10¢
BMS28	Backflow Prevention in Over-Rim Water Supplies	10¢
BMS29	Survey of Roofing Materials in the Northeastern States	10¢
BMS30	Structural Properties of a Wood-Frame Wall Construction Sponsored by the Douglas Fir Plywood Association	10¢
BMS31	Structural Properties of "Insulite" Wall and "Insulite" Partition Constructions Sponsored by The Insulite Co	15¢
BMS32	Structural Properties of Two Brick-Concrete-Block Wall Constructions and a Concrete-Block Wall Construction Sponsored by the National Concrete Masonry Association	10¢

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BUILDING MATERIALS AND STRUCTURES REPORTS

[Continued from cover page III]

BMS33	Plastic Calking Materials	10¢
BMS34	Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 1	10¢
BMS35	Stability of Sheathing Papers as Determined by Accelerated Aging	10¢
BMS36	Structural Properties of Wood-Frame Wall, Partition, Floor, and Roof Constructions with "Red Stripe" Lath Sponsored by The Weston Paper and Manufacturing Co	10¢
BMS37	Structural Properties of "Palisade Homes" Constructions for Walls, Partitions, and Floors, Sponsored by Palisade Homes	10¢
BMS38	Structural Properties of Two "Dunstone" Wall Constructions Sponsored by the W. E. Dunn Manufacturing Co	10¢
BMS39	Structural Properties of a Wall Construction of "Pfeifer Units" Sponsored by the Wisconsin Units Co	10¢
BMS40	Structural Properties of a Wall Construction of "Knap Concrete Wall Units" Sponsored by Knap America, Inc	10¢
BMS41	Effect of Heating and Cooling on the Permeability of Masonry Walls	10¢
BMS42	Structural Properties of Wood-Frame Wall and Partition Constructions with "Celotex" Insulating Boards Sponsored by the Celotex Corporation	10¢
BMS43	Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 2	10¢
BMS44	Surface Treatment of Steel Prior to Painting	10¢
BMS45	Air Infiltration Through Windows	10¢
BMS48	Structural Properties of "Precision-Built" Frame Wall and Partition Constructions Sponsored by the Homasote Co	10¢
BMS49	Metallic Roofing for Low-Cost House Construction	10¢
BMS50	Stability of Fiber Building Boards as Determined by Accelerated Aging	10¢