U. S. DEPARTMENT OF COMMERCE

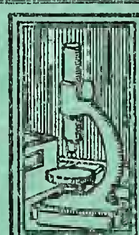
BUILDING MATERIALS AND STRUCTURES

REPORT BMS3

Suitability of Fiber Insulating Lath as a Plaster Base

by LANSING S. WELLS
and D. C. SMITH

NATIONAL BUREAU OF STANDARDS



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Suitability of Fiber Insulating Lath as a Plaster Base

by LANSING S. WELLS *and* D. C. SMITH

ISSUED AUGUST 23, 1938

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

The present report describes an investigation conducted under an allotment from the Works Progress Administration during the fiscal year 1937. As this study is closely related to the general objective of the Bureau's research program on building materials and structures, the results obtained are made available by publication in this series of reports.

Many of the techniques used in the building industry have been developed empirically as a result of experience, including successful and unsuccessful results. Most experienced bulding contractors have probably learned how to secure successful results in the application of plaster to fiber insulating lath, but there seems to be little published information to guide those who have not had previous experience. This investigation was undertaken to supply that information and resulted in the definite recommendation that only quick-setting strong plaster be used for plastering over fiber insulating lath and that the thickness of the plaster be not less than one-half inch.

Lyman J. Briggs, *Director.*

Suitability of Fiber Insulating Lath as a Plaster Base

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ABSTRACT

The investigation pertains to the properties of wall and plaster boards and the suitability of fiber insulating boards as a plaster base. Such properties as density, strength (flexural and tensile), and linear changes accompanying changes in relative humidity and wetting and drying were studied. The boards were mounted on steel frames and the extent of buckling resulting from changes in relative humidity were determined. Methods of successful application of plaster on insulating lath were determined by experiments in which the thickness, sand content, strength, and time of set of the plasters were varied independently.

I. INTRODUCTION

Among the newer building materials which are of interest in connection with low-cost houses, prefabricated houses, and the remodeling of old houses are the numerous types of wall, insulating, and plaster boards. Wall boards are used as interior and exterior finishing materials; insulating boards, largely as interior finishing surfaces or between walls as sheathing; and plaster boards, as a base for plaster finish.

Fiber boards, especially the homogeneous type of low density, may combine two functions, serving as a base for plaster and also affording thermal insulation. However, in common with many other materials, including wood, these boards change in dimensions with changes in moisture in the surrounding atmosphere, and this characteristic property must be considered in the application of the material if satisfactory results are to be obtained. Doubtless most building contractors have learned through experience methods of insuring the desired results, but there is a decided lack of published information on the suitability of these boards as plaster bases. Therefore, an investigation was undertaken to secure information on conditions necessary for the successful use of fiber insulating lath as a plaster base.

The properties of some fiber insulating boards have been determined previously,[1] but there have been many changes in the methods of

[1] Misc. Pub. NBS M132, Properties of Fiber Building Boards (Dec. 1, 1931).

manufacture. In any case, it was considered desirable to determine the density and the flexural and tensile strengths of the boards to be used in the experiments. The expansion and contraction of the boards as influenced by changes in moisture was also studied. The boards were then attached to rigid steel frames by two methods of attachment and the buckling resulting from changes in relative humidity was determined. These tests gave considerable information as to the behavior of the boards themselves and laid the foundation for the study of their suitability as plaster bases. This study was carried out by actually constructing plastered panels. Methods of securing satisfactory results were determined by experiments in which the thickness, sand content, strength, and time of set of the plasters were varied independently.

There is included also in this paper the limited investigation made of gypsum plaster boards or lath, as well as that of certain wallboards other than those of the fiber insulating type.

II. MATERIALS

1. Fiber Insulating Boards and Lath

From among the numerous wall and plaster boards available, a limited number of homogeneous fiber boards were purchased for these experiments. The boards purchased were chosen as illustrative of various materials and methods of manufacture. The individual specimens were not specially selected, and no attempt was made to systematically sample the product, since the tests were not intended as a comparison of materials commercially available, or as a study of the effect of material and methods of manufacture on the physical properties. It should be clearly understood that the data on samples obtained in the manner described are not adequate for such purposes. The data given later in the paper refer to the samples actually used, and the information as to composition and method of manufacture is given as descriptive of those samples. It cannot be concluded that the data apply to all boards of the corresponding composition and method of manufacture which are sold commercially.

The insulating fiber boards were of the usual sizes, 4 feet wide by 8 to 12 feet long and ½ inch thick, and the insulating lath, 18 inches wide by 48 inches long by ½ inch thick.

The materials from which the fiber insulating boards were manufactured and the key numbers which will be employed hereafter to designate the boards are:

1. Wood fiber.
2. Exploded wood fiber.
3. Balsam-wood fiber.
4. Western wood fiber.
5. Extracted sugar-cane fiber (bagasse).
6. Largely of pulp from waste paper.
7. Straw fiber.
8. Ground wood-pulp fiber.

2. Plywood

Realizing that investigations of plywood are within the field of the Forest Products Laboratory, only limited tests for comparative purposes were conducted on this material. Plywood boards are, of course, not used as plaster bases, but their movements attending changes in the relative humidity of the air and wetting and drying were studied. The boards investigated were manufactured with three plies of Douglas fir, using casein glue, and were ⅛-inch thick. The sample used in this study will be designated hereafter as: 9. Plywood.

3. Gypsum Wall Boards and Gypsum Lath

Inasmuch as boards with a core of set gypsum and a covering of paper are used in much the same manner as the fiber boards, two types were included. The designation of the boards (⅜ inch in thickness) will be: 10. The usual type of gypsum wall board and gypsum lath; 11. A light-weight gypsum board having some waste-paper pulp in a porous gypsum core.

4. Cement-Asbestos Board

This is a heavy dense, hard, strong board made by pressing together in a hydraulic press a mixture of portland cement and asbestos. The cement-asbestos board which was ¼ inch in thickness will be recorded henceforth as: 12. Cement-asbestos board.

5. Compressed-Fiber Board

The dense compressed fiber board investigated will be designated: 13. Pressed board.

Besides the above boards, the following materials were used:

6. Sand

Clean Potomac River sand was used in preparing the plaster panels. The sieve analysis of this sand was as follows:

U. S. Standard Sieve No.	Sand passing	U. S. Standard Sieve No.	Sand passing
	%		%
8	100. 0	50	14. 0
16	95. 0	100	1. 5
30	75. 5		

7. Gypsum Plaster

The gypsum plaster for preparing the plaster panels complied with Federal Specifications SS–P–401. The physical properties of the plaster were: Time of set (neat) 25 hours; and tensile strength, neat (average five briquets) 330 lb/in^2.

8. Calcined Gypsum

The calcined gypsum (plaster of paris) for the finishing coat of plaster for the plastered panels complied with the Federal Specifications SS–G–901. The physical properties of the material were: Time of set, 29 minutes; tensile strength (average six briquets) 585 lb/in^2, and compressive strength (average six 2-inch cubes) 3,840 lb/in^2.

9. Hydrated Lime

The hydrated lime used in preparing the finishing coat of plaster complied with Federal Specification SS–L–351 (Finishing Lime). It had the following properties:

Chemical composition

Constituent	Amount	Constituent	Amount
	%		%
CaO	48. 1	Loss on ignition	16. 4
MgO	33. 6	CO_2	1. 2
SiO_2	0. 2		
R_2O_3	. 4		
		Total	99. 9

Soundness		O. K.
Fineness:	Through No. 30 sieve	100. 0%
	Through No. 200 sieve	96. 9%
Plasticity		530

III. PROPERTIES OF THE BOARDS

1. Density and Strength

In addition to the density and strength (flexural and tensile), table 1 gives data relative to the weight, thickness, and deflection at point of rupture of the eight types of fiber insulating boards. The data are based on tests of at least three samples of three boards. In general, over the range of relative humidity studied, the flexural strength of the fiber insulating boards decreased as the relative humidity of the air

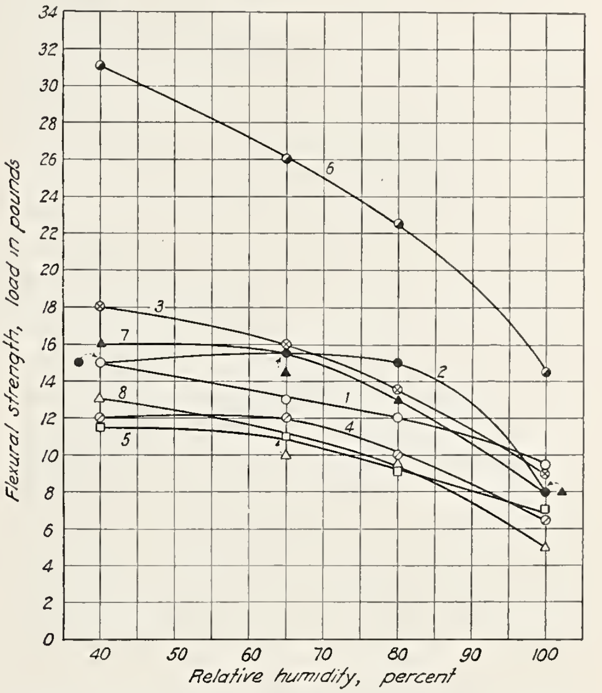

Figure 1.—*Flexural strength of fiber insulating boards as a function of the relative humidity of the air at which the boards were conditioned.*

(in which they were conditioned) increased. (See fig. 1.) A comparison of the average flexural strengths at 40-percent relative humidity with those at 80 and 100 percent shows that there was a decrease in strength of about 20 and 50 percent, respectively, at the higher humidities.

The gypsum wallboards were tested according to the procedures given in Federal Specifications SS–W–51a (similar to methods of American Society for Testing Materials: C36–34). The flexural strength was determined on specimens 12 inches wide by approximately 16 inches long, supported on fixed parallel bearings spaced 14 inches on center and loaded on a similar bearing midway between the supports. Board 10 broke at an average load of 115 pounds with the knife-edges across the fiber of surfacing and at 47 pounds with the knife-edges parallel to the fiber of surfacing when tested at 40-percent relative humidity. The corresponding loads for board 11 were 136 and 44 pounds. Measurements were not made of the strength of the gypsum wallboard at the high humidities. It is known, however, that the flexural strength of these boards, when wet, is low. Wallboards 10 and 11 weighed 1,475 and 1,335 lb/1,000 ft², respectively.

TABLE 1.—*Properties of the fiber insulating boards used in this investigation* [a]

No.	Composition of board	Density at 65% relative humidity	Weight at 65% relative humidity	Thickness at 65% relative humidity	Flexural strength, crosswise, at relative humidities of:				Deflection at rupture at 65% relative humidity	Tensile strength at 65% relative humidity	
					40%	65%	80%	100%		Crosswise	Lengthwise
		g/cm³	lb/1,000 ft²	in.	lb	lb	lb	lb	in.	lb/in.²	lb/in.²
1	Wood fiber	0.26	709	0.51	15.0	13.0	12.0	9.5	0.64	164	223
2	Exploded wood fiber	.36	910	.51	15.0	15.5	15.0	8.0	.38	152	153
3	Balsam-wood fiber	.31	768	.47	18.0	16.0	13.5	9.0	.65	254	162
4	Western wood fiber	.31	868	.54	12.0	12.0	10.0	6.5	.60	173	173
5	Extracted sugar-cane fiber	.27	699	.49	11.5	11.0	9.0	7.0	.80	152	199
6	Largely of pulp from waste paper	.45	1,143	.49	31.0	26.0	22.5	14.5	.72	323	340
7	Straw fiber	.32	798	.48	16.0	15.5	13.0	8.0	.65	288	413
8	Ground wood-pulp fiber	.30	766	.49	13.0	11.0	9.5	5.0	.58	117	157

[a] Thickness, flexural strength, deflection, and tensile strength determined according to procedure given in Federal Specification for Fiber-Board; Insulating LLL-F-321a. Flexural strength made on specimens 3 inches wide and 18 inches long placed on horizontal parallel supports 12 inches apart applying load at midspan. Measurements of flexural strengths at relative humidities of 40-, 80-, and 100-percent are not required in the specification.

2. Expansions and Contractions

(a) *With Changes in Relative Humidity*

Since wallboards in use are continuously subjected to changing atmospheric conditions, expansions and contractions are constantly taking place. A standard meter rule obtained from the length section at the National Bureau of Standards was used to measure the linear changes on specimens 4 feet square. The reference lines were approximately 97 cm apart and were made with a razor blade on a waxed surface produced with a soft wax pencil. A magnifying lense was used to facilitate the readings, recorded to the nearest 0.2 mm. Three sets of reference lines were made for measurements in each of the two directions—lengthwise and crosswise. Four or more boards of each type were measured.

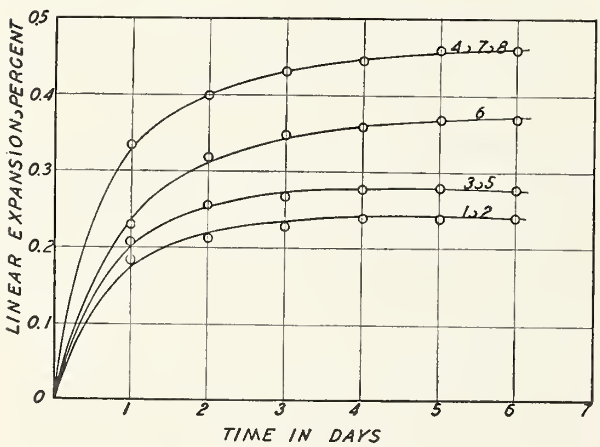

FIGURE 2.—*Expansion of fiber insulating boards on changing the relative humidity from 25 to 90 percent*

Because the linear changes attending cycles of changes in relative humidity were to be ascertained, it was necessary first to know how long the boards had to be conditioned at a specified humidity to reach dimensional "equilibrium." Figure 2 shows the rate of expansion of the boards on changing the relative humidity from 25 to 90 percent at a temperature of approximately 70° F. It can be seen that most of the expansion had occurred at the end of 3 days. In a few cases the expansions lengthwise were slightly less than those crosswise; however, the differences were small and accordingly the data obtained from the measurements in one direction (crosswise) only are given. It should be noted that three of the four curves plotted in figure 2 pertain to more than one type of board. In these cases the variations between the different types of boards were no greater than were those of separate boards of the same type.

When the boards were conditioned in air maintained at 100-percent relative humidity, condensation of moisture occurred and no constant measurements could be obtained until the boards were actually wet.

Figure 3 shows graphically the linear expansions which occurred when boards conditioned in air at 25-percent relative humidity were reconditioned at relative humidities of 60 and 90 percent, respectively. Here, as in figure 2, certain curves pertain to more than one type of board. The spread is represented by the closed vertical bar and the curve passes through the average values.

Fiberboards in practical use are subjected to numerous cycles of changes in relative humidity. To determine whether the boards returned to their original dimensions, in going from cycle to cycle, the specimens were subjected to three cycles of changing humidity. The boards were

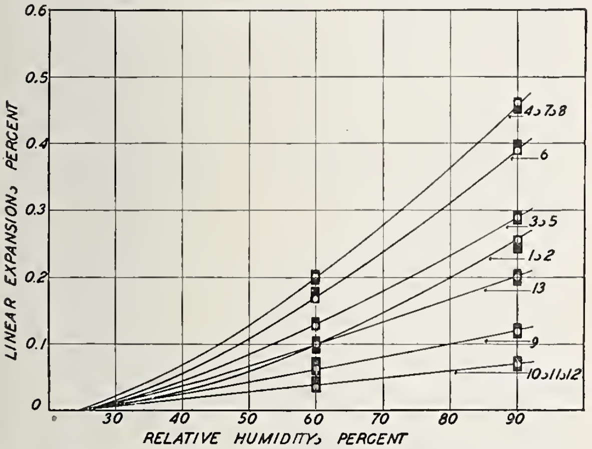

FIGURE 3.—*Percentage expansions of wallboards accompanying increases in relative humidity.*

Numbers 1 to 8, inclusive, fiber insulating boards; 9, plywood; 10 and 11, gypsum wallboard; 12, cement-asbestos board; and 13, pressed fiberboard.

first conditioned in air at 25-percent relative humidity, then at 90 percent, and the expansions noted. Figure 4 shows the expansions and contractions which accompanied three of these cycles. Apparently the absorbed moisture at 90-percent relative humidity causes the fibers to swell, with a resultant rearrangement on drying, thus giving an actual shrinkage to the boards. The kind and method of sizing used in the fabrication of the boards no doubt are factors involved in this shrinkage. The over-all movements (expansion plus contraction) which occur after the first cycle are greater than the expansions shown in figures 2 and 3.

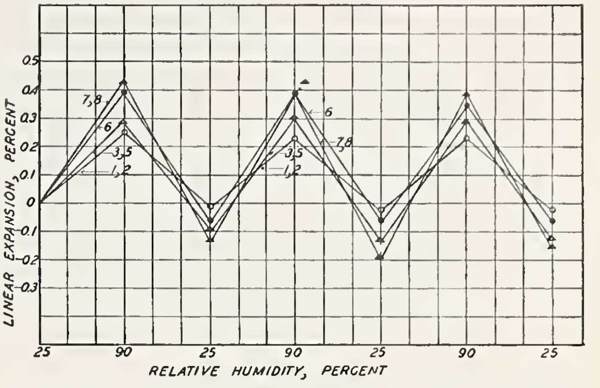

FIGURE 4.—*Dimensional changes of fiber insulating boards accompanying cycles of changes in relative humidity.*

Shrinkage did not occur when the boards were carried through 3 cycles of changes from 25-percent relative humidity to 60 percent and back to 25 percent. The results of these cyclical changes are not shown.

(*b*) *With Wetting and Drying*

As there is no assurance that fiberboards will always remain dry even though they may be used in the interior of a building, some experiments were carried out to determine the extent of the expansion and contraction which accompanies wetting and drying. Figure 7 shows the rate of expansion of several boards when they were soaked in a tank of water. It should be noted that the total expansion and rate of expansion of the boards varied rather widely. The length changes resulting from 3 cycles of wetting and drying are indicated in figure 5. The boards were dried in air at a relative humidity of 25 percent at the start and at the end of each cycle until the board attained dimensional equilibrium. From figures 4 and 5 it may be seen that wetting and drying caused about twice the dimensional changes (expansion, contraction, and resulting shrinkage) as raising the relative humidity to 90 percent, then drying.

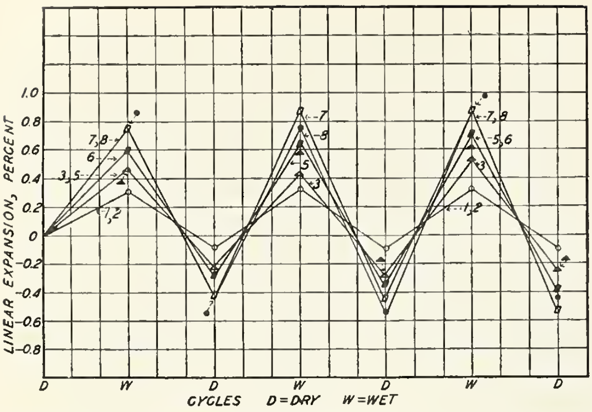

FIGURE 5.—*Dimensional changes of fiber insulating boards resulting from alternate wetting and drying.*

3. Comparison of Linear Changes of Painted With Unpainted Boards

(a) *With Changes in Relative Humidity*

It has been shown that fiber boards undergo marked expansion with an increase in the relative humidity of the air. Obviously, if the expansion can be decreased there will be less buckling when the boards are fastened, as in a wall. Accordingly, a few experiments were conducted on the total expansion and rates of expansion on boards that were painted.

Four different types of fiber insulating boards were so chosen that they included the range of expansion of the boards being studied. Specimens (4 by 4 ft) were first given a coat of sizing composed of one part of turpentine to four of spar varnish, by weight. After drying, this was followed by three coats of aluminum paint composed of 2 pounds of aluminum bronze per gallon of spar varnish. The sizing and paint were applied to both sides and to the edges of the specimens.

Since fiber insulating boards are very porous the covering capacity of paint is low. Table 2 contains data on the covering capacity for each coat, expressed in the square feet per gallon.

Figure 6 shows that the rate of expansion of the boards on changing the relative humidity from 40 to 90 percent was materially less for the painted than for the unpainted boards. In two of the four types studied the ultimate expansion was approximately the same, the slight difference being no greater than would be expected in individual boards. In two types the ultimate expansion of the painted boards was somewhat less than that of the unpainted. Painting might in part be advantageous in that it decreases the rate of expansion and therefore minimizes the effects of rapid changes in relative humidity.

TABLE 2.—*Covering capacities of coats of paint on some fiber insulating boards*

Fiber insulating board numbers	Composition of board	Sizing coat (1:4 turpentine-varnish mixture)	First coat of aluminum paint	Second coat of aluminum paint	Third coat of aluminum paint	Total for the three coats of aluminum paint
		ft²/gal	*ft²/gal*	*ft²/gal*	*ft²/gal*	*ft²/gal*
2	Exploded wood fiber	105	111	370	560	74
5	Extracted sugar-cane fiber	108	136	280	410	75
6	Largely of pulp from waste paper	150	235	358	545	113
7	Ground wood-pulp fiber	130	158	320	545	88

(b) *With Wetting*

Figure 7 shows the linear expansion resulting from soaking both the painted and unpainted boards in water. As in figure 6, painting decreased the rate of expansion. It did not, however, eliminate expansion and in several instances the ultimate expansion of the painted and unpainted boards was the same. Much that has already been said relative to the effect of painting on modifying movements accompanying changes in relative humidity is equally applicable here.

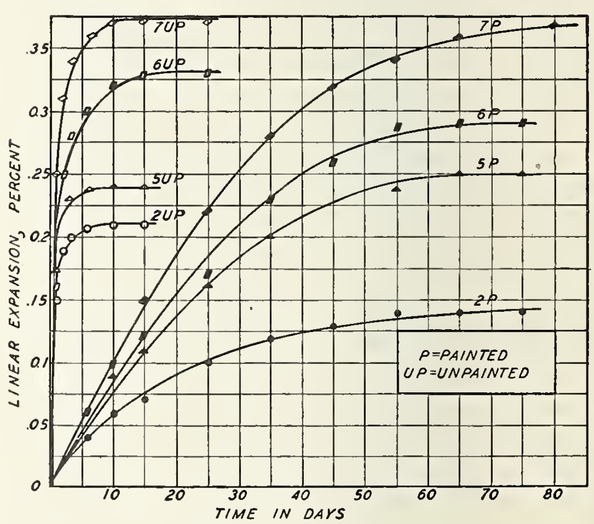

FIGURE 6.—*Expansions of painted and unpainted fiber insulating boards resulting from an increase in relative humidity from 40 to 90 percent.*

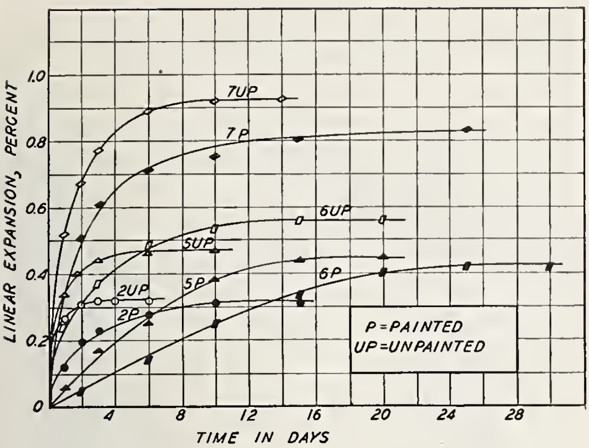

FIGURE 7.—*Expansions of painted and unpainted fiber insulating boards soaked in water at 70° F.*

IV. EXPERIMENTS ON UNPLASTERED BOARDS WHEN ATTACHED TO STUDDING

It has been shown that the various boards undergo marked expansions and contractions with an increase or decrease in the relative humidity of the air or with wetting and drying. To determine how much these movements would be reflected in buckling of the boards when they were attached, special frames were constructed for panel tests. The frames were made of 1½-inch angle-iron (welded together as shown in fig. 8) because wooden frames would have introduced the variable of expansion and contraction accompanying changes in moisture content of the wood. They were so designed that a board 4 feet square could be attached to the uprights spaced 16 inches on centers—thus simulating the spacings of studding commonly used in house construction. The flats which served as bracing for the frames and prevented outward movement of the "studding" were spaced about 5/16 inch from the face of the frame so that the boards were free to buckle inward as well as outward.

The board specimens were bolted to the frames with ¼-inch diameter steel stove bolts having heads ½ inch in diameter. They were attached only along the uprights at the bolt holes spaced 6 inches on center, except as indicated otherwise in figure 8, thus allowing freedom for buckling between the studding. It is realized that this method of attaching the boards is not comparable to nailing the boards to wooden studding. It was evident, as the investigation progressed, that the manner of attaching the boards had a marked effect on the extent of buckling. The manufacturers of the boards are cognizant of this and usually recommend that the boards be not butted together. However, the boards may be so firmly nailed that there can be but little side and end movement although space has been allowed for such.

Two methods of mounting the boards were used. In one, the boards were firmly attached along the outside studding by means of strap-iron side strips (fig. 8) 1 inch wide, 3/16 inch thick, and 48 inches long placed directly on the face of the boards. When these strips were bolted in place little or no movement in the boards could occur along the outside. Consequently, buckling across the studs was greater than when the boards were less firmly attached. In the second method, the strips were raised from the surface of the board with steel washers, ½ inch wide. Thus the boards were held in place only by the bolts and not by the iron strips. This prevented binding of the outside edges except where bolted and permitted a relief of some of the strains set up at the points of attachment either by tearing away or compressing the fibers of the boards.

The boards thus mounted were subjected to changes in relative humidity and the extent of buckling between studding determined by measuring the height from the surface of the board to a reference straightedge placed across the frame. A strip of 1-inch angle brass served as the reference straightedge and was provided with brass blocks soldered at the ends. Thus the straightedge was raised above the surface of the board when the blocks rested on the iron strips bolted along the outside edges of the frame. The height from the reference to the attached board was measured at 15 points, 9 midway between the studding and 6 directly over the studding.

A study was first made of the extent of buckling of the boards when mounted on the frames by the first method. The boards were conditioned in air at a relative humidity of 35 percent until dimensional "equilibrium" had been attained before being attached to the frames.

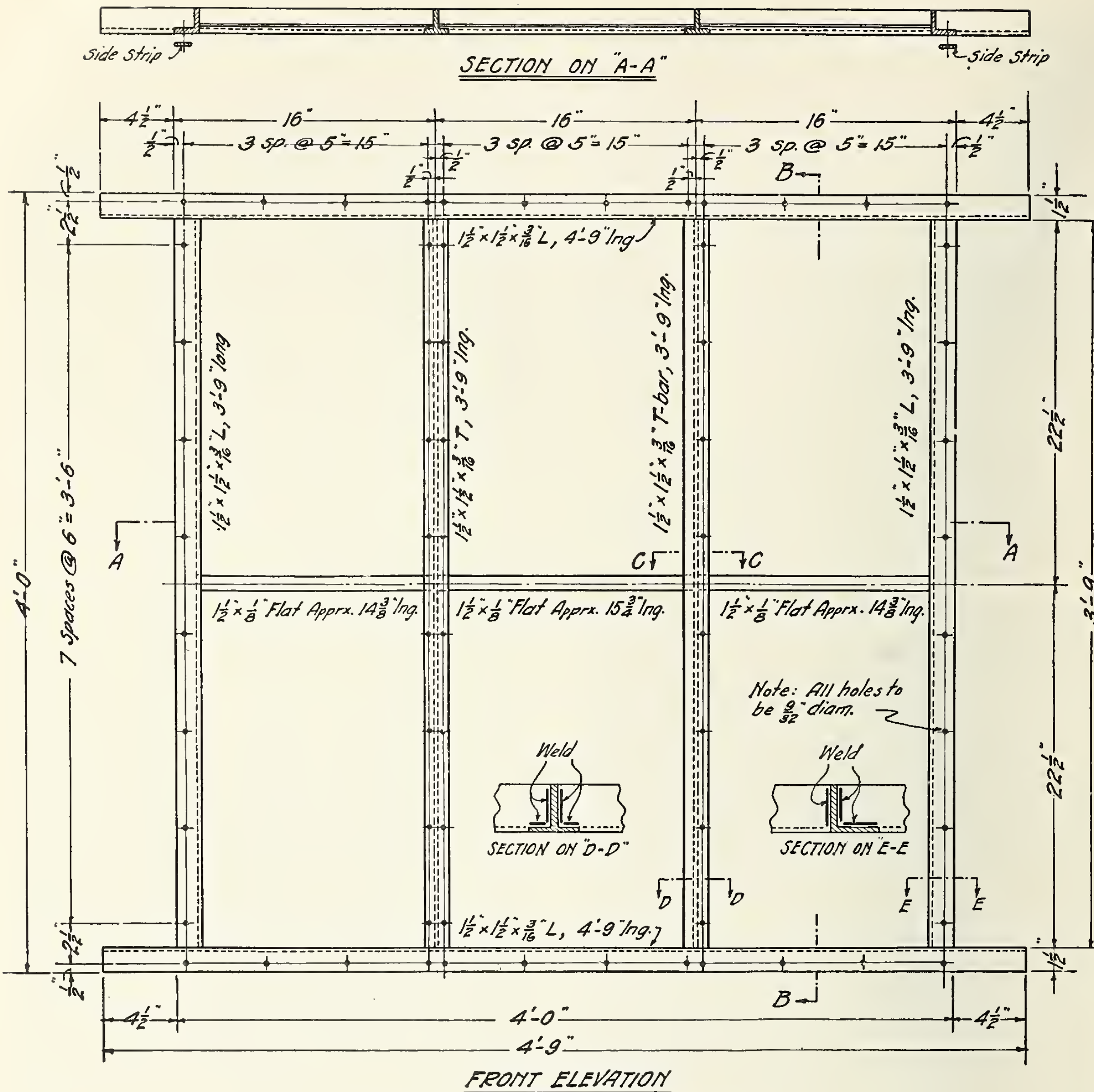

FIGURE 8.—*Details of steel frame for test panels.*

The height from the reference straight edge to the board was then measured at 15 points. The test panels were then transferred to a room where the relative humidity was 60 percent and after the boards had been similarly conditioned at this humidity measurements were again made to determine the buckling. The test panels were next removed to a third room where the relative humidity was 90 percent and similar measurements were made. The buckling was arbitrarily taken as the average of the three highest measured points. The results are shown in table 3. Figure 9 shows the buckling which occurred during the increases in relative humidity from 35 to 60 and 90 percent, respectively. Certain of the boards were grouped together since the variations between these different types were no greater than those of separate boards of the same type. The grouping is not the same as that indicated in figure 3, which shows the expansions of the unattached boards.

Table 3.—*Buckling measurements on various wall boards when attached to 4- by 4-inch angle-iron frames with iron strips binding the two outside edges*

The figures represent the average of three points showing the greatest rise. Numbers 1 to 8, inclusive, fiber insulating board; 9, plywood; 10 and 11, gypsum wall boards.

[Starting relative humidity 35 %]

No.	Composition of board	Cycle number	Buckling at relative humidities of— 60%	90%	100%	Buckling left after drying back to 35% relative humidity
			in.	*in.*	*in.*	*in.*
1	Wood fiber	1	0.03	0.11		0.03
		2	.05	.12		.05
		3			0.18	
2	Exploded wood fiber	1	.03	.11		.03
		2	.05	.12		.03
		3			.19	
3	Balsam-wood fiber	1	.07	.43		.12
		2	.16	.58		.17
		3			.70	
4	Western wood fiber	1	.05	.37		.06
		2	.10	.44		.12
		3			.61	
5	Extracted sugar-cane fiber	1	.06	.37		.07
		2	.12	.43		.10
		3			.66	
6	Largely of pulp from waste paper	1	.09	.45		.11
		2	.17	.51		.15
		3			.73	
7	Straw fiber	1	.13	.54		.15
		2	.22	.57		.17
		3			.83	
8	Ground wood-pulp fiber	1	.06	.41		.15
		2	.19	.45		.19
		3			.71	
9	Plywood	1	.07	.31		.08
		2	.13	.31		.09
		3			.36	
10	Usual type of gypsum wall board	1	.04	.05		.05
		2	.06	.10		.08
		3			.27	
11	A light weight gypsum wall board	1	.03	.05		.03
		2	.04	.07		.04
		3			.16	

The panels were next conditioned at a relative humidity of 35 percent and the buckling which remained was determined. This is recorded under column 6 of table 3. On repeating the cycle still further buckling occurred (table 3). Figure 10 shows the buckling across the studding after the panels had been conditioned a second time at 90-percent relative humidity. The more usual type of buckling was the formation of two convex surfaces and one concave surface, the latter occurring between the two inside studs. In some cases, three convex surfaces resulted but, whether two or three, there seemed to be no correlation between the manner in which the boards buckled and any other property. The alignment of the forces at the start

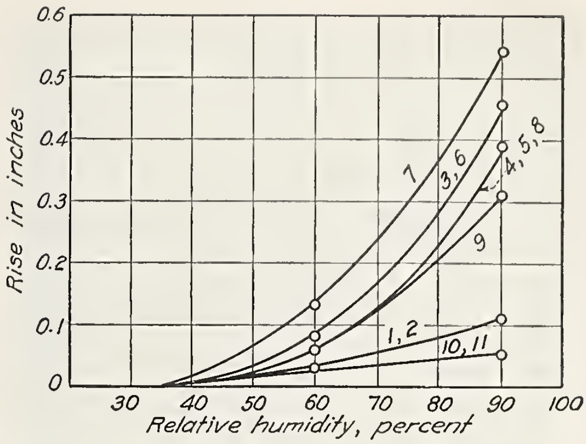

Figure 9.—*Buckling (rise in inches across 16-inch studs) of wall boards resulting from an increase in relative humidity.*

Boards were attached to steel frames, 4 feet square, with outside edges of the boards firmly bound. Numbers 1 to 8, inclusive, fiber insulating boards, and 10 and 11 gypsum wall boards.

may have been the determining factor. Panel 7 shows a board which buckled with the formation of two convex surfaces (the concave not evident in the photograph) and panel 8 the same type of board exhibiting three convex surfaces. The greater rise usually occurred when two convex surfaces were produced.

After the boards had been exposed to 2 cycles of changes in relative humidity (1 cycle, 35 to 60 to 90 and back to 35-percent relative humidity) the panels were transferred to a room in which the relative humidity was maintained at 100 percent. The data relative to the buckling which occurred are contained in table 3. Figure 11 is a photograph of the panels taken in a manner similar to that of figure 10. A comparison of these two photographs shows the rather general increase in buckling accompanying an increase in the relative humidity from 90 to 100 percent.

A study was then made of the extent of buckling of the boards mounted on the frames by the second method, previously described. Table 4 contains the data relative to the rise in inches which occurred when the boards were restrained only at the bolts. It should be noted that the boards were first conditioned at a relative humidity of 45 percent rather than 35 percent as in the studies made by the first method. This was unavoidable since the rela-

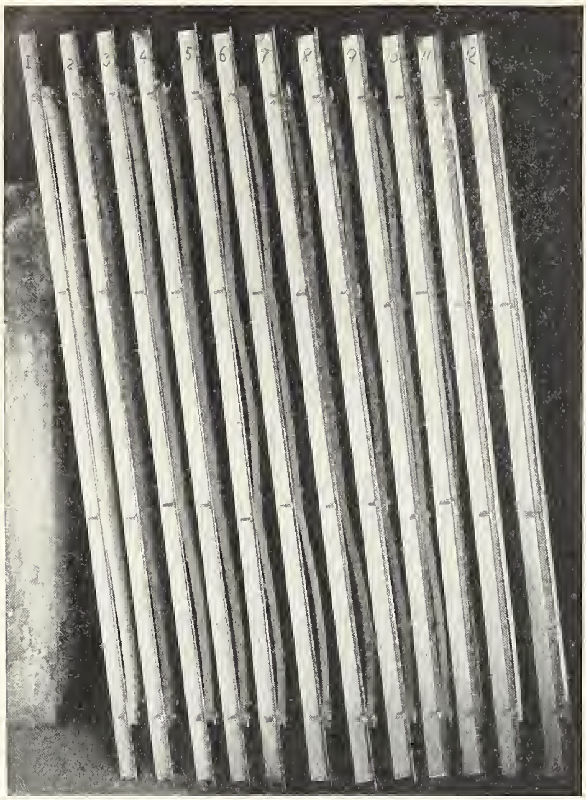

Figure 10.—*Panels showing the buckling of wall boards across the studding after the panels had been kept a second time at 90-percent relative humidity.*

Boards originally attached after being conditioned at 35-percent relative humidity.

Panels 1 to 9, fiber insulating boards as follows: 1 wood fiber, 2 exploded wood fiber, 3 balsam-wood fiber, 4 Western wood fiber, 5 extracted sugar-cane fiber, 6 largely of pulp from wastepaper, 7 and 8 straw fiber, 9 ground wood-pulp fiber. Panel 10, plywood, panel 11 usual type of gypsum wall board and panel 12, a lightweight gypsum board.

tive humidity of the room increased during the time between conducting these two sets of experiments and there was available no ready means of reducing it to 35 percent. It is doubtful if this made very much difference since the extent of buckling was small when the relative humidity was under 90 percent and did not rise rapidly until the boards had been conditioned above this relative humidity. Figure 12 shows the results graphically. A comparison of this figure with figure 9 shows that when the boards are given the freedom to take up some of the stresses by tearing or enlarging the holes through which the bolts pass (method 2, fig. 12) the buckling is considerably less than that which results when they are more firmly attached (method 1, fig. 9). This reduction in buckling is particularly noticeable at relative humidities below 90 percent.

Table 4.—*Buckling measurements of various wall boards when attached to 4- by 4-inch angle-iron frames in such a way that none of the edges is bound*

The figures represent the average of three points showing the greatest rise.

[Starting relative humidity 45%]

No.	Composition of board	Cycle number	Buckling at relative humidities of: 60%	90%	100%	Buckling left after drying back to 35% relative humidity
			in.	*in.*	*in.*	*in.*
1	Wood fiber	1	0.01	0.06		0.03
		2	.04	.06		.04
		3			0.14	
2	Exploded wood fiber	1	.02	.04		.02
		2	.04	.06		.03
		3			.14	
3	Balsam-wood fiber	1	.02	.11	.21	.05
4	Western wood fiber	1	.01	.12		.05
		2	.06	.12		.05
		3			.35	
5	Extracted sugar-cane fiber	1	.01	.07		.04
		2	.05	.08		.06
		3			.35	
6	Largely of pulp from waste paper.	1	.01	.16		.05
		2	.06	.16		.07
		3			.30	
7	Straw fiber	1	.01	.12		.06
		2	.07	.23		.08
		3			.64	
8	Ground-wood-pulp fiber	1	.01	.11		.05
		2	.06	.11		.06
		3			.49	
12	Cement-asbestos board	1	.02	.04	.04	0
13	Pressed board	1	.03	.12	.24	.02

All of the experiments on buckling described up to this point pertained to boards which had been conditioned at a fairly low relative humidity before being attached to the frames. The following experiments pertain to boards conditioned at a high relative humidity (90 percent) before being attached to the frames. Since it is evident that boards so attached would tend to shrink, as the relative humidity subsequently decreased, the boards were attached (second method) in two sections and a study made of the change in the width of the space between these two sections as the relative humidity of the air decreased. One section was 16 by 48 inches and the other 32 by 48 inches. A space

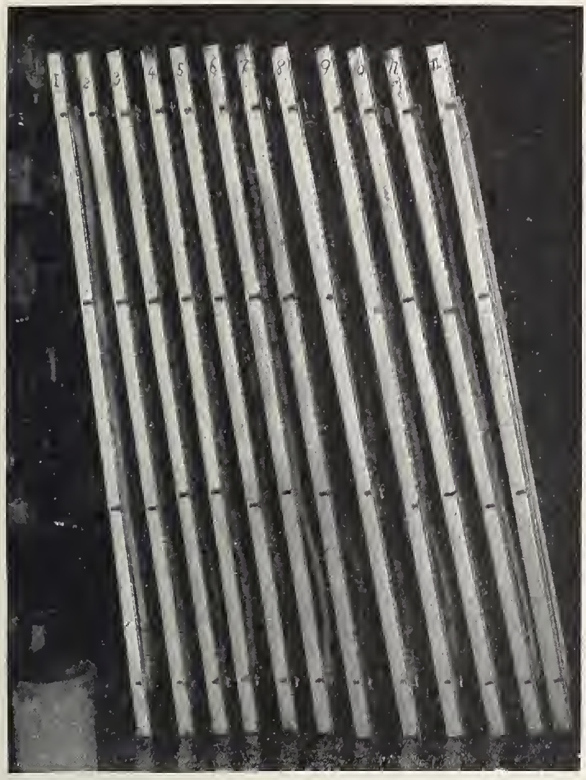

FIGURE 11.—*Panels showing the buckling of wall boards across the studding after the panels of figure 10 had been conditioned at 100-percent relative humidity.*

about ⅛ inch in width was left between these two sections along one of the uprights of the frames which served as one of the studs. Narrow strips of paper were pasted over this joint after the boards had been attached at a relative humidity of 90 percent. The strips were then severed along the joints with a razor blade and the resulting separation of the adjacent halves of the paper measured after the panels had been conditioned at a relative humidity of 50 percent. The measurements showed that the increase in the space between the two sections of the various boards ranged from 0.05 to 0.12 inch. With one exception the magnitude of the separation of the various boards was in the same order as their linear contractions, as indicated by the data contained in table 3. This exception was board 6, the fiber insulating board having the greatest density and tensile strength, crosswise (table 1). With this board there was not as much give around the holes where the boards were bolted to the frames as with the other boards.

After reference points for buckling measurements had been taken, the panels were again conditioned at 90-percent relative humidity. No convex or concave buckling occurred, indicating that the boards on expanding with a change in relative humidity from 50 to 90 percent closed up the enlarged holes formed when the boards contracted from a relative humidity of 90 to 50 percent.

These experiments suggest the method of first conditioning wallboards at a high relative humidity before attaching them to prevent buckling. This would require conditioning rooms at the job. An alternative would be to dampen the boards before they were used and to then allow them to take up the added moisture. This, however, introduces an objection since carpenters would find it difficult to saw dampened boards.

Fiber boards should never be wet and then allowed to dry out before being attached to the studding. The reason is obvious when one considers the shrinkage (figs. 4 and 5) which

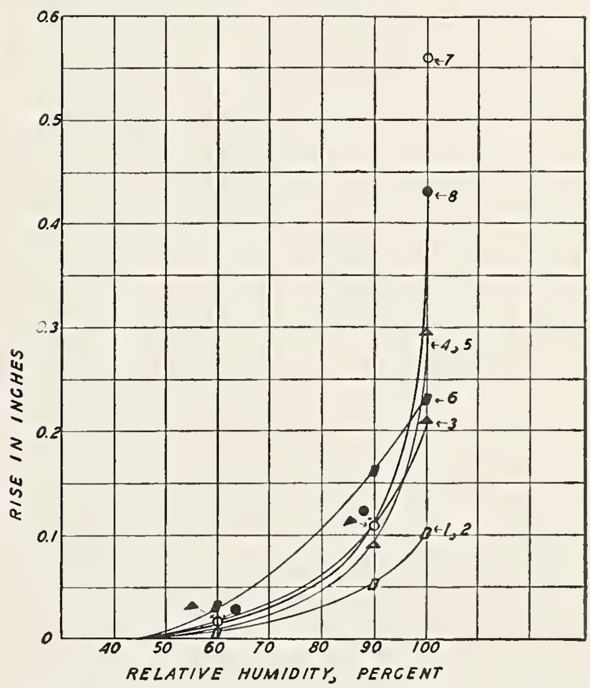

FIGURE 12.—*Buckling (rise in inches across 16-inch studs) of wall boards resulting from an increase in relative humidity.*

Boards were attached to steel frames, 4 feet square, with boards attached by bolts only, and outside edges not bound.

follows the first cycle of wetting and drying. A shrinkage as large as 0.3 inch over a 4-foot span results when some fiber insulating boards are wet and dried. If now, these boards are attached while in the contracted state, the expansion with resulting buckling should be greater than with the original boards which have not been subjected to the first cycle of wetting and drying. Experiments verified this.

V. EXPERIMENTS ON PLASTERED FIBER INSULATING LATH

1. Three-Coat Plastering

Fiber insulating lath are usually ½ inch thick, 18 inches wide, and 48 inches long. They are attached to studding so that the vertical joints are staggered. Most of these boards are ship-

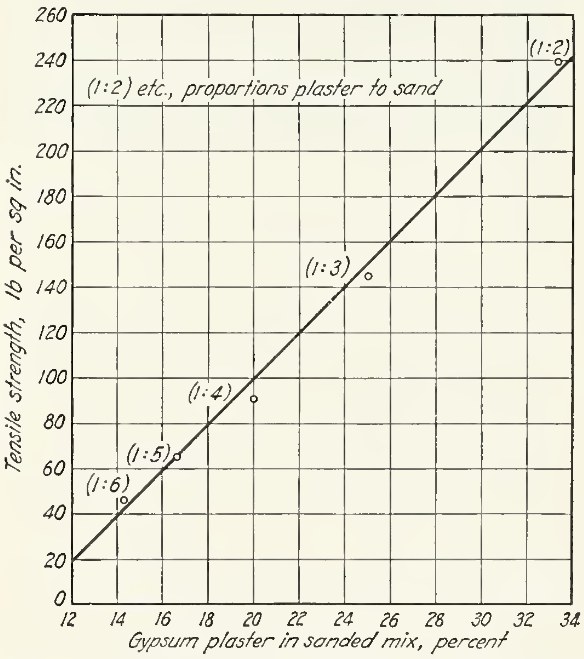

Figure 13.—*Increase of tensile strength of plasters with an increase in the percentages by weight of gypsum plaster in the sanded mixes.*

lapped, and each manufacturer appears to have some slight modification of design. The properties of the four different makes of lath which were available for test were practically identical with those of the corresponding wallboards. Consequently, the wallboards of the remaining makes were cut into strips 18 by 48 inches for the plastering experiments. The lath were bolted to the frames by method 2 of attaching, so that the middle course gave a vertical joint over a stud.

Insulating lath thus attached buckled to about the same extent as did the fiber wallboards when the relative humidity was increased an equal amount.

The investigation pertains entirely to the use of gypsum plaster over these bases. It is generally recommended in specifications for plastering that the scratch coat on lath be composed of 1 part of gypsum plaster to 2 of sand, by weight, and that the brown coat be 1:3. Leaner mixes are sometimes used, however, and occasionally the plasters are rather badly oversanded. Consequently, plastering experiments were made with the following four proportions of plaster to sand: (1) Scratch 1:2, brown 1:3, (2) scratch 1:3, brown 1:5, and (3) scratch 1:4, brown 1:6.

Figure 13 shows how the tensile strength of the set plaster decreased with an increase in sand content. In making the briquets, the mixes were brought to standard consistency as described in ASTM Standard Methods of Testing Gypsum and Gypsum Products, ASTM. Designation C 26–33.

Although it is usually recommended that the thickness of the plaster over lath be ½ inch, yet in actual practice the thickness is often less than this. The experiments on buckling previously described indicate that thicker rather than thinner plaster should be applied. Experiments were conducted on plaster ⅜ and ⅝ inch in thickness.

In the plastering experiments the insulating lath were conditioned for a week in a room where the relative humidity was about 50 percent before they were bolted to the frames. The scratch and brown coats were then applied separately. To prevent the coats from drying out before the plaster had set and hardened satisfactorily, accelerator was added to the plaster, which was slow setting. About 1 percent of finely ground, set plaster of paris accelerated the reactions so that each coat set in about 3 hours. After the brown coat had dried, the finish coat of lime putty gaged with calcined gypsum (plaster of paris) was applied. This coat, which was about 1/16 inch in thickness, was composed of 3 parts of plastic lime putty to 1 part of gaging plaster by volume.

The panels were conditioned for 2 weeks in a room where the relative humidity was 50 percent. They were then stored for periods of a month in each of two other rooms where the relative humidities were 90 and 100 percent, respectively. Buckling measurements were taken at intervals during these storage periods, after which the panels were returned to the first room.

These plastering experiments brought out some rather definite results. In the first place, the panels plastered with the third mixture (scratch, 1:4 and brown, 1:6 by weight) all developed cracks along the horizontal joints of the lath. Some also had cracks along the vertical joints. Cracks appeared in many panels while the brown coat was setting. In general, the bond between the scratch coat and the plaster base was poor. This plaster was very unsatisfactory. It is realized that this was a badly oversanded plaster. Nevertheless, the results show what may be expected when such weak plasters are used. An interesting point is, that despite the fact that they gave such an unsatisfactory performance, their strengths were of the order of magnitude of the minimum requirements of ASTM Standard Specifications for Gypsum Plasters, ASTM Designation: C 28–30. The 1:4 scratch coat had a tensile strength of 91 lb/in.^{2} (fig. 13); the minimum of a 1:2 ready-sanded scratch required by the ASTM specification is only 75 lb/in^2. The 1:6 brown coat with a tensile strength of 45 lb/in.^{2} was only slightly below the stipulated minimum of 50 lb/in.^{2} for a 1:3 mix. It can be seen from figure 13 that the tensile strength of the 1:2 plaster was 240 and the 1:3 plaster 145 lb/in.^{2}, values roughly three times those of the respective minimum requirements. Incidentally, through the strength of the neat plaster used in these experiments was over twice that of minimum requirements for neat plaster, it was, nevertheless only about 10 percent greater than the average strength of the numerous brands tested at this laboratory during the past 5 years.

The second factor worthy of note was the general satisfactory condition of the panels plastered with ⅝ inch of plaster where the scratch coat was 1:2 and the brown coat 1:3. Since the plaster set within 3 hours there was but little noticeable buckling after the scratch coat had been applied and what little had taken place was straightened by the application of the brown coat. After the finish coat had been applied and the plaster dried, there was no further buckling greater than 0.02 inch in the plastered surface even after the panels had been kept in the room where the relative humidity was 100 percent. After the panels had been dried again no cracks developed in the plaster along the horizontal or vertical joints of the lath, or in any other portion of the panel.

Several of the panels plastered with ⅜ inch of plaster (scratch 1:2 and brown 1:3) developed cracks along the horizontal joints after the panels had been dried. The cracks appeared in the plaster which was applied to those boards having high tensile strengths and high expansions with change in moisture content. However, there was but little buckling of the plaster.

These experiments suggested the idea that after the insulating lath had been "put in a plaster of paris cast" of sufficient strength they could not buckle. Since rather quick-setting plaster had been used the cast had hardened rapidly enough to prevent much buckling. In order to obtain a comparison of the flexural strengths of the set plasters with those of the lath on which they were applied several attempts were made to separate test specimens of set plaster from the plaster base. This idea was soon abandoned as it was almost impossible to remove test specimens without cracking the plaster.

Consequently, the lath with the adhering plaster were detached from the frames and specimens, 3 by 18 inches, were cut crosswise of the panel. The specimens were then divided into three groups, one of which was conditioned at 60-percent relative humidity, one at 80 percent, and the third at 100 percent. The specimens of the board with the adhering plaster were then tested for flexural strength on a 12-inch span by applying loads at midspan following the same procedure used previously in determining the strength of the boards without the attached plaster. Three or more specimens were broken in each case. Table 5 contains the data relative to the flexural strength, expressed as the average load in pounds, thus obtained for the boards with and without plaster. As indicated in the table, some of the specimens were tested with the face down (with the plaster in tension), others with the face up. The flexural strengths of the different unplastered boards are within a pound of those previously obtained and reported in table 1. Because the fiber insulating lath deflected from ½ to 1 inch before breaking and the plastered lath broke with less deflection, the values recorded in column 6 of table 5 (where the load was applied against the backing) may be considered as a fairly good measure of the strength of the plaster. It should be noted that, except for board 6, the flexural strength of the plastered boards was greater than that of the unplastered boards. The strengths were always greater with the backing in tension (face up) than with the plaster in tension.

Table 5.—*Comparison of flexural strengths of plastered and unplastered insulating lath*

(Determined according to Federal Specification LL–F–321a for the insulating fiber boards. Flexural strength made on specimens 3 inches wide and 18 inches long placed on horizontal parallel supports 12 inches apart applying load at midspan).

Plaster (gypsum: sand by weight)		Fiber insulating lath number	Composition of board	Relative humidity	Average flexural strength		
					Fiber board alone	Plaster and board	
Scratch coat	Brown coat					Face down	Face up
PLASTER ⅜ INCH THICK							
				%	*lb*	*lb*	*lb*
1:2	1:3	1	Wood fiber	60	13.8	25.0	94
1:2	1:3	1	do	80	11.8	24.0	90
1:2	1:3	1	do	100	9.0	------	65
1:3	1:5	6	Largely of pulp from waste paper.	60	27.5	------	80
1:3	1:5	6	do	80	22.0	20.0	------
1:3	1:5	6	do	100	14.0	14.5	------
1:4	1:6	5	Western wood fiber.	60	11.0	16.0	------
1:4	1:6	5	do	80	9.0	16.5	------
1:4	1:6	5	do	100	6.0	14.0	------
PLASTER ⅝ INCH THICK							
1:2	1:3	2	Exploded wood fiber.	60	15.5	------	93.0
1:2	1:3	2	do	80	14.0	31.0	------
1:2	1:3	4	Balsam wood fiber	60	12.0	28.2	91.0
1:2	1:3	4	do	100	6.5	24.4	------
1:3	1:5	5	Extracted sugar-cane fiber.	60	11.0	15.0	81.0
1:3	1:5	5	do	80	9.0	14.0	------
1:3	1:5	5	do	100	6.0	13.0	------
1:4	1:6	1	Wood fiber	60	13.8	13.3	------
1:4	1:6	1	do	80	11.8	18.0	------
1:4	1:6	1	do	100	9.0	11.2	------

Even with a plaster that sets within 3 hours there is bound to be some expansion of the board. As the board subsequently dries the set plaster tends to be placed under tension at the joint. Comparing the tensile strength of the boards (table 1) with those of the plasters (fig. 13) it can be seen that the plasters containing 4 parts or more of sand to 1 of gypsum are weaker in tension than the boards. These oversanded plasters (mix 3) are the ones which failed even when ⅝ of an inch of plaster was applied to the boards ½ inch in thickness. It will be recalled that none of the panels plastered with ⅝ inch of strong plaster developed cracks along the horizontal joints but that several did when but ⅜ inch of plaster was applied, and that these cracks occurred on boards having the higher tensile strengths.

It is obvious from these experiments that the slower the time of set of the plaster the greater the expansion of the boards before the plaster hardens and consequently, the greater the tensile deformation on the plaster at the joints when the board subsequently dries. As the time available for the investigation was limited it was not feasible to conduct extensive experiments on three-coat plastering using plasters having various times of set. Some experiments were conducted, however, on two-coat plastering where such plasters were used and the results of these experiments will be described later in this paper.

The panels plastered with the second mixture (scratch, 1:3 and brown 1:5 by weight) were intermediate in their performance between those plastered with the strong plaster (scratch 1:2 and brown 1:3) and those with the badly oversanded plaster (scratch 1:4 and brown 1:6). The bond of the scratch coat to the plaster boards was not as good as with the richer plaster nor as poor as with the more oversanded plaster. Although none of the panels plastered with ⅝ inch of the strong plaster (mix 1) cracked, yet several of those with the second mix did develop cracks. On the other hand, the cracking of the panels with the latter mixture was not as extensive as with those panels plastered with the badly oversanded plaster (mix 3).

Since this investigation is primarily concerned with fiber insulating lath as plaster bases the experiments on gypsum lath were limited.

No buckling or cracking was evident in the ⅝ inch of plaster applied separately as a scratch coat (1:2) by weight and a brown coat (1:3) when the plaster set within 3 hours, even with the use of ⅜-inch gypsum plaster boards, which were 32 inches wide and 36 inches long.

2. Two-Coat Plastering

It has been shown that with three-coat plastering unevenness of the scratch coat resulting from buckling can be straightened with the brown coat. With two-coat plastering, wherein the brown coat is applied over the scratch coat by "doubling back" before the scratch coat has set, this straightening cannot be accomplished. Furthermore, by the application of two coats of wet plaster, more water is initially available to bring about buckling than when the scratch coat is allowed to set and harden before the brown coat is applied. Consequently, it would appear even more desirable to use a quick-setting plaster with two-coat work than with three. The investigations with two-coat plastering, therefore, were confined primarily to determining the relation between the extent of buckling and the time of set of the plaster.

Figure 14.—*Four panels showing that buckling across the studding was insignificant when plaster which set within 2 hours was used but with slower setting plaster the buckling was considerable.*

Plaster on panels 1 and 2 set at 2 hours, on panel 3 at 12 hours, and on panel 4 at 24 hours.

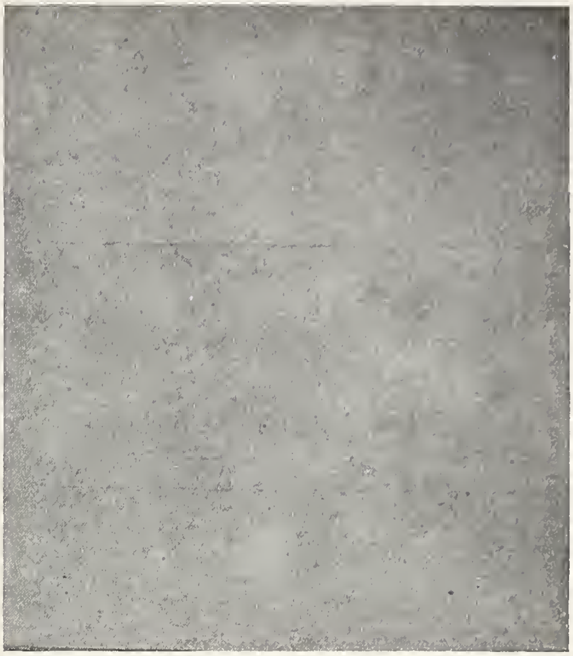

Figure 15.—*Panel showing cracks which developed in slow-setting sanded plaster along the horizontal joints of the insulating lath.*

In these experiments the boards were attached to the frames by method 2. The time of set of the plaster was then regulated so that separate batches set at approximately 2, 12, and 24 hours. Figure 14 illustrates four panels, the buckling of which occurred across the studding. The first two panels from left to right show that the buckling of two of the lath covered with plaster (1 plaster:2 sand by weight) which set in approximately 2 hours was so slight that there was no visible unevenness of the surface of the plaster. The third and fourth panels, wherein the plaster was applied over the same make of lath as that used in the second panel, show that the buckling increased as the time of set of the plaster increased, resulting in uneven plaster surfaces.

Figure 15 shows the cracks which developed in slow-setting sanded plaster along the horizontal joints of the fiber insulating lath. The cracks appeared even before the plaster had set and resulted from shear produced by a differential buckling in the separate lath. As the panel dried the cracks widened. In some instances irregular cracks appeared in the plaster along the studding. These cracks were formed before the slow-setting plaster had hard-

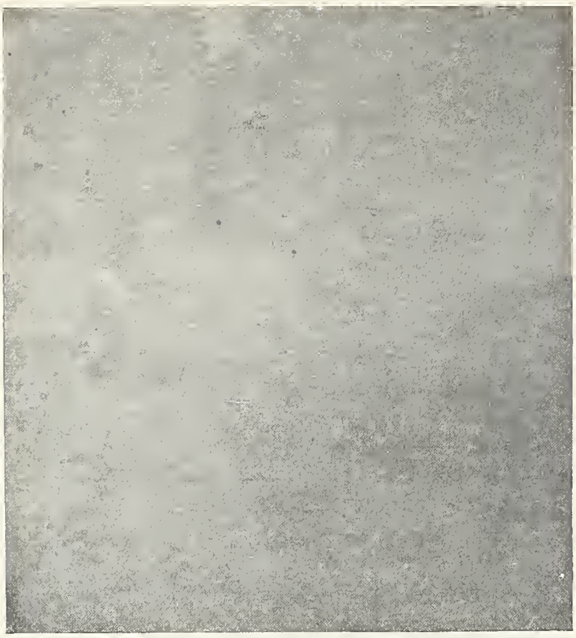

FIGURE 16.—*Panel showing horizontal cracks along the joints of the insulating lath and irregular compression cracks along the studding which developed in the slow-setting sanded plaster.*

ened and, since the edges of such cracks were raised, they probably were caused by the compressive forces at the studding. These compression cracks also widened as the panels dried with an attending shrinkage of the boards. This type of cracking is illustrated by the vertical cracks in the panel pictured in figure 16, which also shows the more regular cracks along the horizontal joints of the boards.

VI. SUMMARY AND CONCLUSIONS

A study was made of the properties of wall and plaster boards, particularly in regard to the conditions necessary for successful use of fiber insulating lath as plaster bases.

Eight types of fiber insulating boards were investigated, one of plywood, two of gypsum board, one of cement-asbestos board and one of compressed fiber board.

The thickness of the eight fiber insulating boards ranged from 0.47 to 0.54 inches and the weight from 699 to 1,143 lb/1,000 ft^2 when measured at 65-percent relative humidity.

The flexural strengths of the fiber insulating boards were measured at relative humidities of 40, 65, 80, and 100 percent and the tensile strengths at 65 percent. The average flexural strengths at 80- and 100-percent relative humidity were about 20 and 50 percent lower, respectively, than those at 40-percent relative humidity.

Studies were made of the rate of expansion occurring at 70° F when boards were transferred from a conditioning relative humidity of 25 percent to one of 90 percent. From 3 to 4 days were required for the boards to reach a state of dimensional equilibrium after the transfer. The resultant expansions ranged from about 0.07 percent for the gypsum boards and cement-asbestos board to about 0.47 percent for some fiber insulating boards, the range for these latter type being from 0.26 to 0.47 percent.

When the boards were kept at 100-percent relative humidity or placed in water the expansions were about 25 to 95 percent greater than those obtained at 90-percent relative humidity.

Boards conditioned in air at 25 percent, then at 90- or 100-percent relative humidity, showed a definite shrinkage when again dried at 25-percent relative humidity.

Painting fiber insulating boards as described, materially decreased the rate of expansion but did not eliminate expansion attending an increase in relative humidity or by wetting with water. In many cases the ultimate expansions and contractions of the painted boards were as great as those of the unpainted boards.

Boards attached rigidly along their edges to rigid steel frames, 4 feet square, gave greater buckling across studs spaced 16 inches than when the boards were less firmly attached. When firmly attached along the outside, the buckling (rise in inches across a 16-inch span) of the boards ranged from 0.05 inch for the gypsum wall board to 0.54 inch for one of the fiber insulating boards when the relative humidity was increased from 35 to 90 percent. After drying the boards again at 35-percent relative humidity, some of the buckle remained. Consequently, the buckling resulting from the second cycle of change in relative humidity was greater than that of the first cycle.

Insulating lath were attached to rigid steel frames, 4 feet square, so that the middle course gave a vertical joint over a stud. Methods of successful application of plaster on fiber insulating lath were determined by experiments in which the thickness, sand content, strength, and time of set of plasters were varied independently. It was found that:

(1) Three-coat plastering is to be preferred to two-coat plastering, especially with slow-setting plaster.

(2) Quick-setting plaster is much better than slow-setting plaster. With three-coat plastering unevenness of the scratch coat resulting from any buckling of the lath as the plaster sets could be straightened with the brown coat. Quick-setting plaster was particularly essential with two-coat plastering. With slow-setting plasters the buckling of the lath resulted in uneven surfaces and cracks along the joints even with strong plasters.

(3) Weak, oversanded plasters were very unsatisfactory even when ⅝ inch thick.

(4) Strong, quick-setting plasters ⅝ inch thick were satisfactory, but when the thickness was only ⅜ inch, cracks developed in some instances along the horizontal joints of the lath after the panels had been dried.

It is recommended, therefore, that only quick-setting, strong plaster be used for plastering over fiber insulating lath and that the thickness of the plaster be not less than ½ inch. With three-coat plastering the scratch coat (which should be the heavy coat) should be composed of 1 part of strong gypsum plaster to 2 parts of sand, by weight, and the brown coat should be in the proportions 1:3. With two-coat plastering the plaster should be 1:2, by weight.

We acknowledge, with thanks, the assistance of various members of the staff in this work, particularly the aid given by Joseph Watstein in taking many of the measurements.

WASHINGTON, February 15, 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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- Experimental Foundry

Clay and Silicate Products
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- Heavy Clay Products
- Cement and Concreting Materials
- Masonry Construction
- Lime and Gypsum
- Stone

Simplified Practice
- Wood, Textiles, and Paper
- Metal Products and Construction Materials
- Containers and Miscellaneous Products
- Materials-Handling Equipment and Ceramics

Trade Standards
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- Textiles
- Apparel
- Petroleum, Chemical and Miscellaneous Products

Codes and Specifications
- Safety Codes
- Building Codes
- Building Practice and Specifications
- Producer Contacts and Certification
- Consumer Contacts and Labeling

Office
- Finance
- Personnel
- Purchase and Stores
- Property and Transportation
- Mail and Files
- Library
- Information

Shops
- Instrument
- Woodworking
- Glassblowing
- Construction Stores and Tool Room

Operation of Plant
- Power Plant
- Electrical
- Piping
- Grounds
- Construction
- Guard
- Janitorial