U. S. DEPARTMENT OF COMMERCE

BUILDING MATERIALS AND STRUCTURES

REPORT BMS9

Structural Properties of the Insulated Steel Construction Company's "Frameless-Steel" Constructions for Walls, Partitions, Floors, and Roofs

by

HERBERT L. WHITTEMORE
AMBROSE H. STANG, *and*
VINCENT B. PHELAN

NATIONAL
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Foreword

This report is one of a series issued by the National Bureau of Standards on the structural properties of constructions intended for low-cost houses and apartments. Practically all of these constructions were sponsored by groups within the building industry which advocate and promote the use of such constructions and which have built and submitted representative specimens as outlined in report BMS2, Methods of Determining the Structural Properties of Low-Cost House Constructions. The sponsor is responsible for the representative character of the specimens and for their detailed description as given in this report. The Bureau is responsible for the accuracy of the test data.

This report covers only the load-deformation relations and strength of the structural elements submitted when subjected to compressive, transverse, concentrated, impact, and racking loads by standardized methods simulating the loads to which the elements would be subjected in actual service. It may be feasible to determine later the heat transmission and fire resistance of these same constructions and perhaps, other properties.

The National Bureau of Standards does not "approve" a construction, nor does it express any opinion as to the merits of a construction for reasons given in reports BMS1 and BMS2. The technical facts on this and other constructions provide the basic data from which architects and engineers can determine whether the construction meets desired performance requirements.

Lyman J. Briggs, *Director*.

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ABSTRACT

For the program on the determination of the structural properties of low-cost house constructions the Insulated Steel Construction Co. submitted 30 specimens representing their "Frameless-Steel" constructions for walls, partitions, floors, and roofs.

The wall specimens were subjected to compressive, transverse, concentrated, impact, and racking loads; the partition specimens to impact and concentrated loads; the floor specimens to transverse, concentrated, and impact loads; and the roof specimens to transverse and concentrated loads. The transverse, concentrated, and impact loads were applied to both faces of wall specimens. For each of these loads three similar specimens were tested. The deformation under load and the set after the load was removed were measured for uniform increments of load up to the maximum load, except for concentrated loads, for which the set only was determined. The results are presented graphically and in tables.

I. INTRODUCTION

In order to provide technical facts on the performance of constructions which might be used in low-cost houses, to discover promising constructions, and ultimately to determine the properties necessary for acceptable performance, the National Bureau of Standards has invited the building industry to cooperate in a program of research on building materials and structures for use in low-cost houses and apartments. The objectives of this program are described in report BMS1, Research on Building Materials and Structures for Use in Low-Cost Housing,[1] and that part of the program relating to structural properties in report BMS2,

[1] Price 10 cents. See cover page II.

Methods of Determining the Structural Properties of Low-Cost House Constructions.[2]

As a part of the research on structural properties, six masonry wall constructions have been subjected to a series of standardized laboratory tests to provide data on the properties of some constructions for which the behavior in service is generally known. These data are given in report BMS5, Structural Properties of Six Masonry Wall Constructions. Similar tests have been made on wood-frame constructions by the Forest Products Laboratory of the United States Department of Agriculture, the results of which will be given in a subsequent report in this series.

This report describes the structural properties of constructions sponsored by one of the manufacturers in the building industry. The specimens were subjected to compressive, transverse, concentrated, impact, and racking loads, simulating loads to which the elements of a house are subjected. In actual service, compressive loads on a wall are produced by the weight of the roof, second floor and second-story walls, if any, furniture, and snow and wind load on the roof. Transverse loads on a wall are produced by the wind, concentrated and impact loads by furniture or accidental contact with heavy objects, and racking loads by the action of the wind on adjoining walls. For nonload-bearing partitions, impact loads may be applied accidentally by furniture or by persons falling against the partition, and concentrated loads by furniture or by ladders or other objects leaning against the partition. Transverse loads are applied to floors by furniture and by the occupants; concentrated loads by furniture, for example, the legs of a piano; and impact loads by objects falling on the floor or by persons jumping on the floor. Transverse loads are applied to roofs by wind and snow; concentrated loads, by persons walking on the roof, and by tools and equipment when the roof is constructed or repaired.

The deflection and set under each increment of load were determined except for concentrated loads. For some of the newer constructions the deflection and set are important when judging whether the construction will be satisfactory in a house under service conditions.

[2] Price 10 cents.

II. SPONSOR AND PRODUCT

The Specimens were submitted by the Insulated Steel Construction Co., Middletown, Ohio and represented constructions sold under the trade name "Frameless-Steel." These constructions consisted of cellular sheet-steel panels for walls, partitions, floors, and roofs, designed to be erected on masonry foundations without the use of heavy equipment, and with comparatively few and simple operations.

III. SPECIMENS AND TESTS

The Specimens represented four elements of a house which were assigned the following symbols: wall, *AH;* partition, *AI;* floor, *AJ;* and roof, *AK*. The specimens were assigned designations in accordance with table 1.

Table 1.—*Specimen designations*

Element	Construction symbol	Specimen designation	Load	Load applied
Wall	*AH*	*C1, C2, C3*	Compressive	Upper end.
Do	*AH*	*T1, T2, T3*	Transverse	Inside face.
Do	*AH*	*T4, T5, T6*	do	Outside face.
Do	*AH*	*P1, P2, P3* [a]	Concentrated	Inside face.
Do	*AH*	*P4, P5, P6* [a]	do	Outside face.
Do	*AH*	*I1, I2, I3*	Impact	Inside face.
Do	*AH*	*I4, I5, I6*	do	Outside face.
Do	*AH*	*R1, R2, R3*	Racking	Upper end.
Partition	*AI*	*I1, I2, I3*	Impact	Either face.
Do	*AI*	*P1, P2, P3* [a]	Concentrated	Do.
Floor	*AJ*	*T1, T2, T3*	Transverse	Upper face.
Do	*AJ*	*P1, P2, P3* [a]	Concentrated	Do.
Do	*AJ*	*I1, I2, I3*	Impact	Do.
Roof	*AK*	*T1, T2, T3*	Transverse	Do.
Do	*AK*	*P1, P2, P3* [a]	Concentrated	Do.

[a] These specimens were undamaged portions of the specimens used in the transverse or impact tests.

The specimens were tested in accordance with BMS2, Methods of Determining the Structural Properties of Low-Cost House Constructions,[3] which gives the requirements for the specimens and for determining the price.

The tests were begun December 6, 1937, and completed December 16, 1937. The sponsor's representative witnessed the tests.

IV. WALL *AH*

1. Sponsor's Statement

(a) *Materials*

Steel.—Mild, open-hearth, black sheets, hot-rolled, annealed, and pickled. The specified

[3] Price 10 cents.

chemical composition is given in table 2 and the average mechanical properties in table 3. American Rolling Mill Co.'s "Armco."

TABLE 2.—*Specified chemical composition of the steel*

Element	Content		Element	Content	
	Minimum	Maximum		Minimum	Maximum
	Percent	*Percent*		*Percent*	*Percent*
Carbon	0.05	0.10	Phosphorus		0.05
Manganese	.25	.35	Sulfur		.05

TABLE 3.—*Average mechanical properties of the steel*

Gage number, United States Standard	Approximate thickness	Direction	Yield point	Tensile strength	Elongation in 2 inches
	in.		*lb/in.*^{2}	*lb/in.*^{2}	*Percent*
18	0.049	In direction of rolling	27,000	41,000	32
		Across direction of rolling	30,000	45,000	29
16	.0613	In direction of rolling	28,000	42,000	32
		Across direction of rolling	31,000	45,500	29

Welds.—Electric spot welds, ¼-in. diam, spaced 4 in. on centers, made with a 50-kva welding machine equipped with automatic timing. Federal Machine & Welder Co.'s "Alligator Type Spot Welder."

Screws.—Self-tapping, ½-in., No. 8 (0.164-in. diam), 15 threads per inch, binding head, hardened and plated with cadmium about 0.00035 in. thick. Continental Screw Co.'s "Holtite."

Paint.—Priming, rust-resisting, gray; weight, 12.10 lb/gal. The formula for the paint is given in table 4. Pittsburgh Plate Glass Co.'s "Gray Metal Dipping Primer 32914–A."

TABLE 4.—*Formula for "Gray Metal Dipping Primer 32914–A"*

Paint		Pigment		Vehicle [a]	
Ingredient	Content by weight	Ingredient	Content by weight	Ingredient	Content by weight
	Percent		*Percent*		*Percent*
Pigment	53.30	Zinc chromate	7.75	Oleum spirits	62.80
Volatile	29.30	Titanox "*B*"	61.50	China wood oil	17.20
Nonvolatile	17.40	Calcium carbonate	30.75	Linseed oil	7.95
	100.00		100.00	Treated rosin	8.32
				100% Bakelite	2.03
				Lead-cobalt-manganese drier	1.70
					100.00

[a] Oil length of varnish, 33 gal (33 gal of china wood and linseed oils per 100 lb of rosin and Bakelite).

Insulation.—Granular, expanded mica (vermiculite), passed ¼-in. sieve and retained on ⅛-in. sieve. F. E. Schundler & Co.'s "Zonolite."

Asphalt roofing.—Burlap base, saturated with asphalt, mineral-surfaced; weight, 90 lb/108 ft^2. Philip Carey Co.'s "Flexible Cement Roofing, Style *B*."

Calking.—Calking compound, gun-grade, gray. Tremco Manufacturing Co.

Asphalt.—Blended, high-grade asphalt. Philip Carey Co.

(b) *Description*

(1) *Four-foot wall specimens.*—The 4-ft wall specimens were 8 ft 0 in. high, 4 ft 0 in. wide, and 3 in. thick. Each specimen consisted of two panels with sheet-steel faces, *A*, as shown in figures 1 and 2, fastened to sheet-steel studs, *B*, and sheet-steel bases, *C*, by welds. The bases fitted over a sheet-steel sill, *D*, to which the panels were fastened by screws. The panels were joined at *E* and fastened by screws and the upper ends were enclosed by a sheet-steel wall plate, *F*, fastened by screws. The panels,

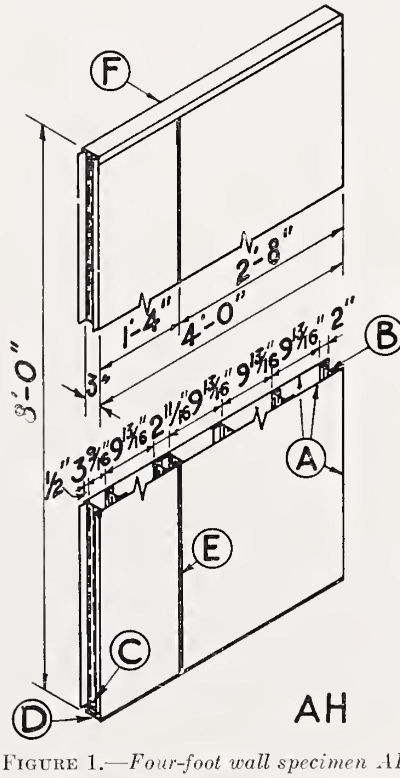

FIGURE 1.—*Four-foot wall specimen AH.*
A, face; *B*, stud; *C*, base; *D*, sill; *E*, joint; *F*, wall plate.

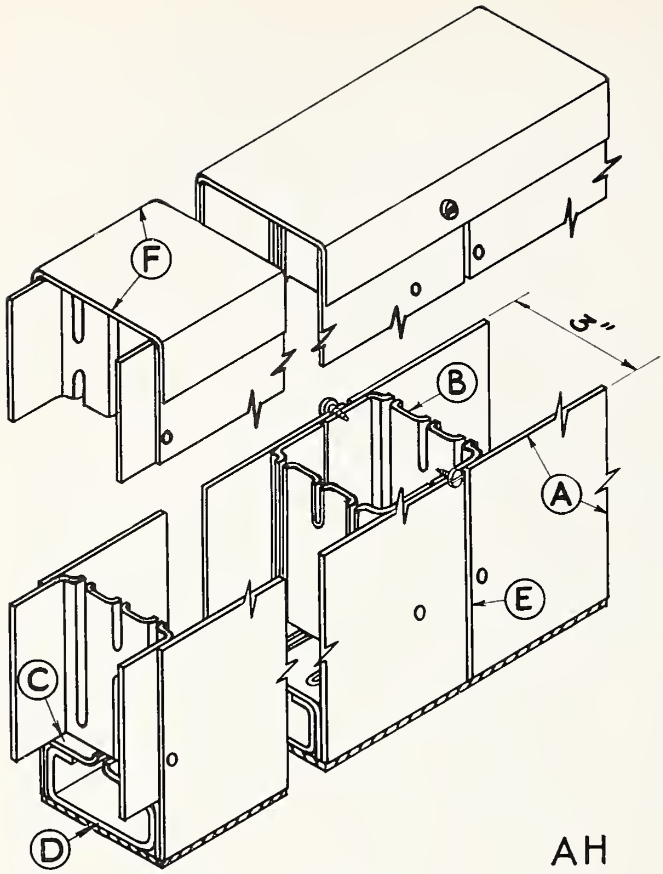

FIGURE 2.—*Details of wall specimen AH.*

A, face; *B*, stud; *C*, base; *D*, sill; *E*, joint; *F*, wall plate.

and also the plate, were completely covered with one coat of paint applied by dipping. The cells enclosed by the studs and the faces were filled with granular insulation.

The price of this construction was \$0.60/ft^2.

Faces.—The inside and outside faces, *A*, were stretcher-leveled and resquared sheet steel, No. 18 United States Standard Gage (0.049 in. thick).

Studs.—The studs, *B*, were channels, $2^{59}/_{64}$ by $1^{5}/_{16}$ in., 7 ft $10^{9}/_{16}$ in. long, cold-formed from sheet steel, No. 18 United States Standard Gage (0.049 in. thick). The webs had slots in three vertical lines, spaced $^{15}/_{16}$ in. on centers, to decrease the heat conductivity through the studs. The slots were 4 in. by $\frac{1}{8}$ in., spaced $4\frac{1}{2}$ in. on centers, and staggered to overlap halfway. The edges of the slots projected $\frac{1}{8}$ in. to stiffen the webs. The lower ends of the studs rested on the base, *C*, and the upper ends were in contact with the wall plate, *F*. To determine the relation between the location of the joint and the structural properties of the 4-ft. walls, the specimens had different panel widths and stud spacings. Specimens *AH–C1*, *C2*, *T2*, *T3*, *T4*, *I3*, and *I6* had three studs, with webs spaced $9^{13}/_{16}$ in. in each of the two 2-ft panels, a total of six studs. Specimens *AH–T1*, *T5*, *T6*, *I1*, *I2*, *I4*, and *I5* had seven studs spaced as shown in figure 1. Specimen *AH–C3* consisted of a 3-ft panel having five studs and a 1-ft panel having two studs. The stud spacing, starting at the outer edge of the 3-ft panel, was 2, $9^{13}/_{16}$, $9^{13}/_{16}$, $9^{13}/_{16}$, 4, $2\frac{1}{2}$, and 10 in.

Bases.—The bases, *C*, were identical in section with the studs, *B*. There were two bases in each specimen, one in each panel, having a length equal to the width of the panel. The flanges of the bases fitted over the sill, *D*.

Sill.—The sill, *D*, was a channel, $2\frac{3}{4}$ by $1\frac{1}{8}$ in., 4 ft 0 in. long, with flanges turned in $^{5}/_{16}$ in., and formed from sheet steel, No. 16 United States Standard Gage (0.0613 in. thick). There were holes spaced 1 ft 0 in. on centers, along the center line of the web of the sill, for anchor bolts. The holes were shaped like four-leaved clovers, 1 in. across, to permit adjustment. The sill was coated with asphalt and the bottom was covered with a strip of asphalt roofing, 3 in. wide. The panels were fastened to the sill by screws, spaced 1 ft 4 in. on centers.

Joint.—At the joint, *E*, between panels, the faces of one panel extended over the flanges of the stud in the adjacent panel and were fastened by screws, spaced 1 ft 4 in. on centers. There was ⅛-in. space between the edges of the faces of adjacent panels, which was filled with calking compound.

Wall plate.—The wall plate, *F*, was a channel, 3⅛ by 1¼ in., 4 ft 0 in. long, formed from sheet steel, No. 18 United States Standard Gage (0.049 in. thick). The plate capped the upper end of the panels with a snug fit and was fastened by screws, spaced 1 ft 4 in. on centers.

(2) *Eight-foot wall specimens.*—The 8-ft wall specimens were 8 ft 0 in. high, 8 ft 0 in. wide, and 3 in. thick. The panels were duplicates of those in the 4-ft wall specimens. Specimen *R1* had 4 panels, each 2 ft 0 in. wide, and a total of 12 studs. Specimen *R2* had 1 panel, 1 ft 4 in. wide, 2 panels, 2 ft 0 in. wide, and 1 panel, 2 ft 8 in. wide, and a total of 13 studs. Specimen *R3* had 3 panels, each 2 ft 8 in. wide, and a total of 12 studs.

(c) *Comments*

The wall panels are fabricated at the factory in standard widths of 1 ft 4 in., 2 ft 0 in., 2 ft 8 in., and 3 ft 2 in. When the faces, studs, and bases have been assembled, they are primed with one coat of paint applied by dipping. The panels are then filled with insulation and vibrated to settle the insulation so that no further settling occurs. Temporary wall plates are fastened to the upper ends of the panels to retain the insulation during shipment. When erecting the building, the sill is placed on a strip of asphalt roofing and bolted to the foundation by ⅜-in. anchor bolts, spaced 5 ft 0 in. on centers. The inside of the sill is coated with hot asphalt applied with a brush. The panels are placed over the sill and fastened to the sill and to each other by screws. The temporary wall plates are removed and the cells between studs at the joints are filled with insulation. Permanent wall plates, 12 ft long, are placed over the upper ends of the panels and fastened by screws. The permanent plates align the panels. The spaces between the edges of the faces at the joints are filled with calking compound. The lower end of the outside face is sealed with calking compound and the lower end of the inside face is sealed with hot asphalt applied with a brush.

At each corner of the building a corner panel is fastened to the wall panels by screws. Openings for standard door and window frames are cased in the field with sheet-steel channels. The joints are sealed with calking compound.

Panels for second-story walls rest on a flat bearing plate which covers the top of the first-

Figure 3.—*Wall specimen AH–C1 under compressive load.*

story panels. The faces of the second-story panels extend down 1¼ in. over the lower panels and are fastened by screws, spaced 8 in. on centers.

The outside of walls is usually finished with oil paint or portland-cement paint; however, other finishes, such as stucco, asbestos-cement shingles, or brick veneer may be used. The inside is usually finished with oil paint, casein paint, or wallpaper; however, other finishes, such as plywood or wood veneer, may be used.

Wall panels without inside faces or insulation are used for unheated buildings, such as garages and farm buildings. Instead of the continuous inside faces, these panels have sheet-steel strips, 5⅛ in. wide, at the upper and lower ends for fastening the bases and wall plates.

2. Compressive Load

Wall specimen *AH–C1*, under compressive load, is shown in figure 3.

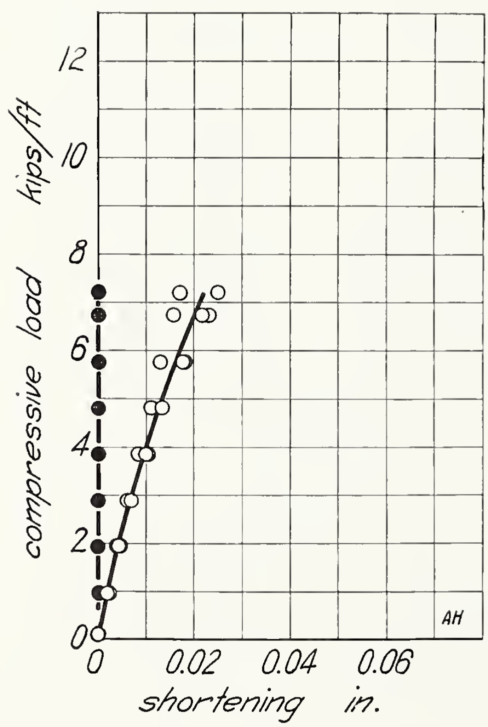

Figure 4.—*Compressive load on wall AH.*

Load-shortening and load-set results for specimens *AH–C1*, *C2*, and *C3*. Load applied at one-third the thickness of the specimen from the inside face. The loads are in kips per foot of actual width of specimen. The shortenings and sets are for a height of 8 feet. They were computed from the values obtained from the compressometer readings. The gage length of the compressometers was 7 feet.

The results for wall specimens *AH–C1*, *C2*, and *C3* are shown in table 5 and in figures 4 and 5.

Table 5.—*Structural properties of wall AH*

[Weight, 7.47 lb/ft²]

Load	Load applied	Specimen designation	Failure of loaded face, height of drop	Failure of opposite face, height of drop	Maximum height of drop	Maximum load
			ft	*ft*	*ft*	*kips/ft*
Compressive	One-third thickness of specimen from inside face.	*C1*				8.89
		C2				7.78
		C3				7.67
	Average					8.11
						lb/ft²
Transverse	Inside face; span, 7 ft 6 in.	*T1*				234
		T2				221
		T3				227
	Average					227
						lb/ft²
Transverse	Outside face; span, 7 ft 6 in.	*T4*				222
		T5				254
		T6				254
	Average					243
						lb
Concentrated	Inside face	*P1*				[a] 1,000
		P2				[a] 1,000
		P3				[a] 1,000
	Average					[a] 1,000
						lb
Concentrated	Outside face	*P4*				[a] 1,000
		P5				[a] 1,000
		P6				[a] 1,000
	Average					[a] 1,000
Impact	Inside face; span, 7 ft 6 in.	*I1*	2.0	8.0	8.0	
		I2	2.0	7.0	7.0	
		I3	2.5	5.5	5.5	
	Average		2.2	6.8	6.8	
Impact	Outside face; span, 7 ft 6 in.	*I4*	7.0	7.0	7.0	
		I5	2.0	4.5	7.0	
		I6	3.5	7.0	7.0	
	Average		4.2	6.2	7.0	
						kips/ft
Racking	Upper end	*R1*				1.39
		R2				1.36
		R3				1.26
	Average					1.34

[a] Specimen did not fail.

Each of the specimens failed by buckling of the inside face at the lower end of the specimen.

3. Transverse Load

The results are shown in table 5 and in figure 6 for wall specimens *AH–T1*, *T2*, and *T3*, loaded on the inside face, and in figure 7 for

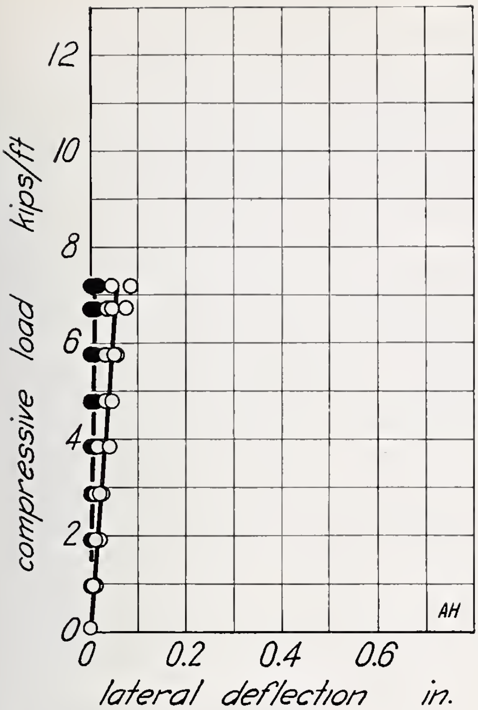

Figure 5.—*Compressive load on wall AH.*

Load-lateral deflection and load-lateral set results for specimens *AH–C1, C2*, and *C3*. Load applied at one-third the thickness of the specimen from the inside face. The loads are in kips per foot of actual width of specimen. The deflections and sets are for a gage length of 7 feet 6 inches, the gage length of the deflectometers.

wall specimens *AH–T4, T5*, and *T6*, loaded on the outside face.

Each of the specimens *T1, T2*, and *T3* failed by rupture of welds in the inside (loaded) face followed by buckling of the inside face and buckling of the studs under one of the loading rollers.

Specimens *T4* and *T6* failed by rupture of welds in the outside (loaded) face followed by buckling of the outside face and buckling of the studs under one of the loading rollers. Specimen *T5* failed by buckling of the studs under one of the loading rollers.

4. Concentrated Load

The results are shown in table 5 and in figure 8 for wall specimens *AH–P1, P2*, and *P3*, loaded on the inside face, and in figure 9 for wall specimens *AH–P4, P5*, and *P6*, loaded on the outside face.

The indentations after a load of 1,000 lb had been applied were about 0.2 in. and no other effect was observed.

5. Impact Load

The results are shown in table 5 and in figure 10 for wall specimens *AH–I1, I2*, and *I3*, loaded on the inside face, and in figure 11 for wall specimens *AH–I4, I5*, and *I6*, loaded on the outside face.

For each of the specimens the screws at the panel joint sheared near the middle of the face struck, followed by opening of the panel joint. As the height of drop was increased, the deflection and set increased, and failure resulted by increasing local deformation of first the loaded face, and then the opposite face.

6. Racking Load

Wall specimen *AH–R2*, under racking load, is shown in figure 12.

The results for wall specimens *AH–R1, R2*, and *R3* are shown in table 5 and in figure 13.

Each of the specimens failed by deformation of the faces at the screws in the panel joints. In addition, for specimen *R2*, welds in the inside

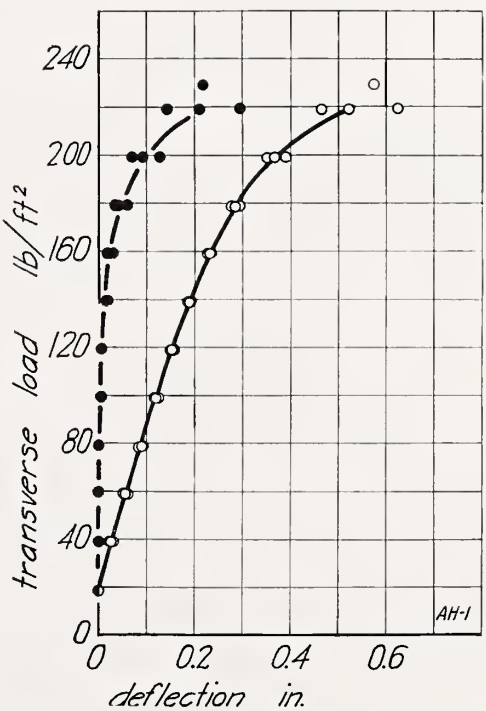

Figure 6.—*Transverse load on wall AH, load applied to inside face.*

Load deflection and load-set results for specimens *AH–T1, T2*, and *T3* on the span 7 feet 6 inches.

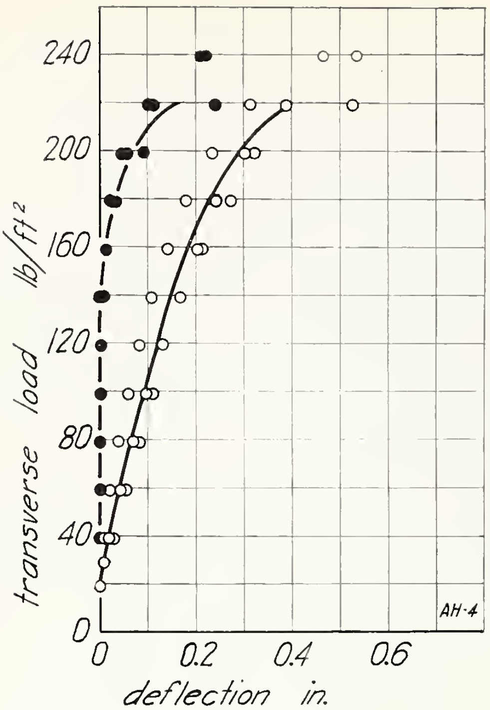

FIGURE 7.—*Transverse load on wall AH, load applied to outside face.*

Load-deflection and load-set results for specimens *AH-T4*, *T5*, and *T6* on the span 7 feet 6 inches.

face sheared near the lower end of the specimen at the edge opposite the edge to which the load was applied, and the wall plate at the upper end of the specimen buckled. For specimen *R3*, both faces buckled at the stop, and the wall plate at the upper end of the specimen also buckled.

V. PARTITION *AI*

1. Sponsor's Statement

(a) *Materials*

Gypsum board.—Fireproof wallboard, 8 ft 0 in., by 4 ft 0 in., by ⅜ in. National Gypsum Co.'s "Gold Bond."

Steel.—Mild, open-hearth, black sheets, hot-rolled, annealed, and pickled. The specified chemical composition is given in table 2 and the average mechanical properties in table 3. American Rolling Mill Co.'s "Armco."

Screws.—Self-tapping, ½-in., No. 8 (0.164-in. diam), 15 threads per inch, flat countersunk head, hardened and plated with cadmium about 0.00035 in. thick. Continental Screw Co.'s "Holtite."

Paint.—Priming, rust-resisting, gray; weight, 12.10 lb/gal. The formula for the paint is given in table 4. Pittsburgh Plate Glass Co.'s "Gray Metal Dipping Primer 32914-A."

(b) *Description*

The partition specimens were 8 ft ⅛ in. high, 4 ft 0 in. wide, and 3 in. thick. Each specimen consisted of two gypsum-board faces, *A*, as shown in figure 14, fastened by screws to sheet-steel studs, *B*. The lower end of each specimen had a sheet-steel soleplate, *C*, and the upper end a sheet-steel top plate, *D*. The sheet-steel members were covered with one coat of paint applied by dipping. The price of this construction was $0.33/ft.[2]

Faces.—The faces, *A*, were gypsum boards fastened to the studs, *B*, by screws, spaced 1 ft 4 in. on centers.

Studs.—The studs, *B*, were channels, 2¼ by 1⅛ in., 8 ft 0 in. long, cold-formed from sheet

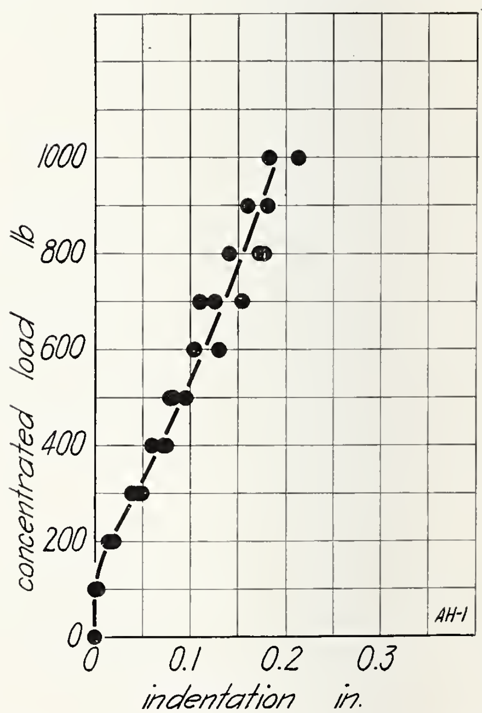

FIGURE 8.—*Concentrated load on wall AH, load applied to inside face.*

Load-indentation results for specimens *AH-P1*, *P2*, and *P3*.

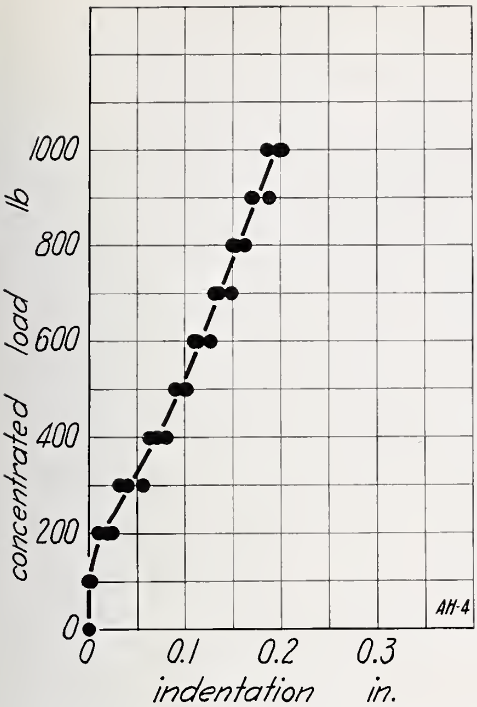

FIGURE 9.—*Concentrated load on wall AH, load applied to outside face.*

Load-indentation results for specimens *AH–P4*, *P5*, and *P6*.

steel, No. 18 United States Standard Gage (0.049 in. thick).

Soleplate and top plate.—Both plates, *C* and *D*, were channels, 2⅜ by 1½ in., 4 ft 0 in. long, cold-formed from sheet steel, No. 18 United States Standard Gage (0.049 in. thick). The flanges of the plates enclosed the ends of the studs, *B*, with a snug fit, and the webs were in contact with the ends of the studs. The plates were fastened to the studs by the screws which fastened the faces.

(c) *Comments*

When erecting the building, the plates for the partitions are fastened to the floor and ceiling by screws. The studs are placed in position and the gypsum-board faces are then fastened to the studs.

2. IMPACT LOAD

The results for partition specimens *AI–I1*, *I2*, and *I3* are shown in table 6 and in figure 15.

TABLE 6.—*Structural properties of partition AI*

[Weight, 4.04 lb/ft^2]

Load	Load applied	Specimen designation	Failure of loaded face, height of drop	Failure of opposite face, height of drop	Maximum height of drop	Maximum load
			ft	*ft*	*ft*	*lb*
Impact	One face; span, 7 ft 6 in.	*I1*	1.5	1.5	1.5	----
		I2	1.5	2.0	2.0	----
		I3	1.0	1.5	1.5	----
	Average	----	1.3	1.7	1.7	----
Concentrated	One face	*P1*	----	----	----	122
		P2	----	----	----	124
		P3	----	----	----	109
	Average	----	----	----	----	118

Each of the specimens failed by cracking of both the loaded face and the opposite face.

3. CONCENTRATED LOAD

The results for partition specimens *AI–P1*, *P2*, and *P3* are shown in table 6 and in figure 16.

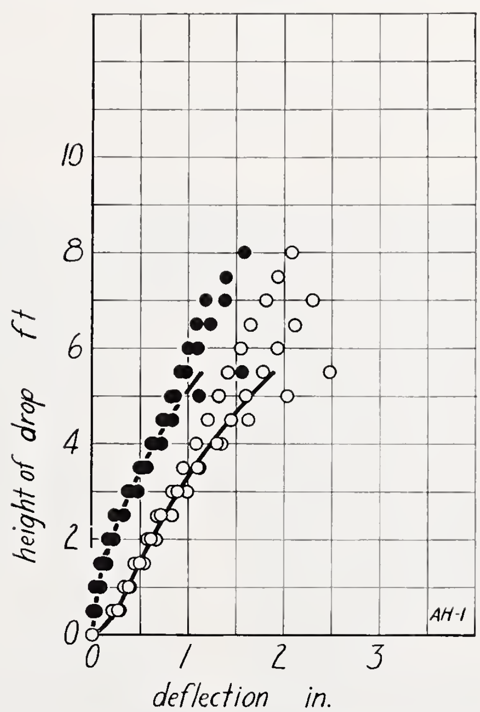

FIGURE 10.—*Impact load on wall AH, load applied to inside face.*

Height of drop-deflection and height of drop-set results for specimens *AH–I1*, *I2*, and *I3* on the span 7 feet 6 inches.

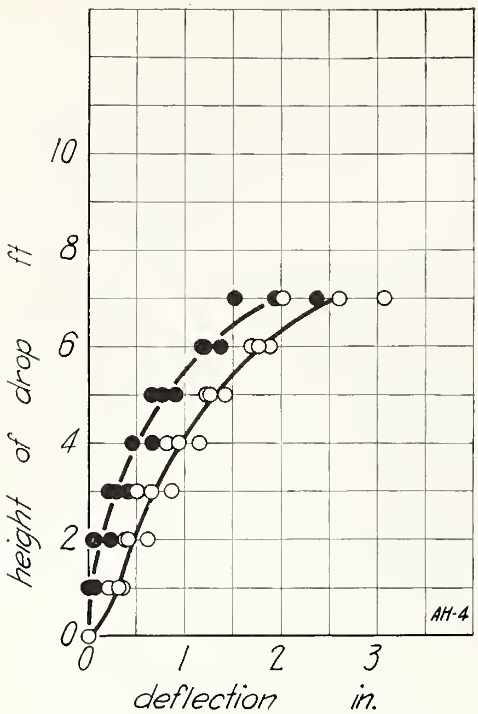

Figure 11.—*Impact load on wall AH, load applied to outside face.*

Height of drop-deflection and height of drop-set results for specimens *AH-I4, I5,* and *I6* on the span 7 feet 6 inches.

Each of the specimens failed by punching of the disk through the loaded face of the specimen.

VI. FLOOR *AJ*

1. Sponsor's Statement

(a) *Materials*

Steel.—Mild, open-hearth, black sheets, hot-rolled, annealed, and pickled. The specified chemical composition is given in table 2 and the average mechanical properties in table 3. American Rolling Mill Co.'s "Armco."

Welds.—Electric spot welds, ¼-in. diam, spaced 4 in. on centers, made with a 50-kva welding machine equipped with automatic timing. Federal Machine & Welder Co.'s "Alligator Type Spot Welder."

Screws.—Self-tapping, ½ in., No. 8 (0.164-in. diam), 15 threads per inch, binding head, hardened and plated with cadmium about 0.00035 in. thick. Self-tapping, 1½ in., No. 8 (0.164-in. diam), 15 threads per inch, flat countersunk head, hardened and plated with cadmium about 0.00035 in. thick. Continental Screw Co.'s "Holtite."

Paint.—Priming, rust-resisting, gray; weight, 12.10 lb/gal. The formula for the paint is given in table 4. Pittsburgh Plate Glass Co.'s "Gray Metal Dipping Primer 32914–A."

Wood.—Pine, shortleaf, yellow, No. 2 common. Oak, red, clear, plain, tongue-and-grooved, side-matched, and end-matched.

Figure 12.—*Wall specimen AH–R2 under racking load.*

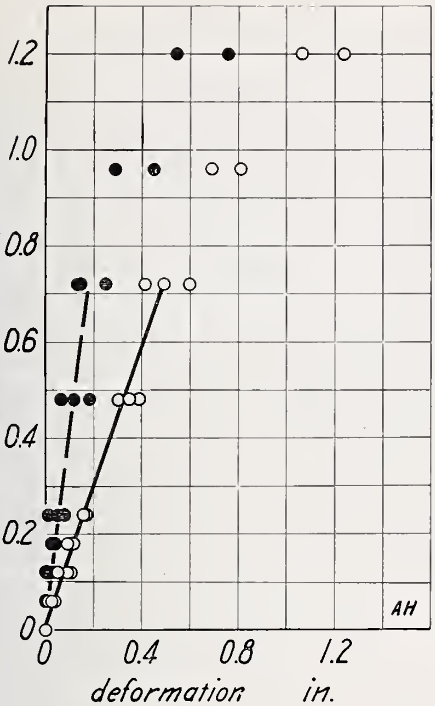

FIGURE 13.—*Racking load on wall AH.*

Load-deformation and load-set results for specimens *AH-R1*, *R2*, and *R3*. The loads are in kips per foot of actual width of specimen. The deformations and sets are for a height of 8 feet. They were computed from the values obtained from the measuring-device readings. The gage length of the measuring device was 6 feet.

Screw nails.—1½ in. long, 0.099-in. diam (No. 13 wire gage, No. 3 screw gage), 7 threads per inch, countersunk head, diamond point, made from high-grade manganese steel containing about 0.19 percent of carbon and 1.40 percent of manganese, water-quenched from 1,700° F. Hillwood Manufacturing Co.'s "Helyx Floor Screws."

(*b*) *Description*

The floor specimens were 12 ft 6 in. long, 4 ft ⅛ in. wide, and 7$\frac{3}{16}$ in. thick. Each specimen consisted of two panels fabricated from sheet-steel zees, *A*, as shown in figures 17 and 18, and sheet-steel angles, *B*, fastened by welds. The two panels were joined at *C* and fastened by screws and the ends were enclosed by sheet-steel end members, *D*, fastened by screws. The panels, and also the end members, were completely covered with one coat of paint applied by dipping. Wood sleepers, *E*, were fastened by screws to the upper faces of the panels, and a wood finish floor, *F*, was fastened by screw nails to the sleepers.

The price of this construction was $0.66/ft².

Zees.—The zees, *A*, were 8½ by 5½ by 8½ in., 12 ft 6 in. long, formed from sheet steel, No. 18 United States Standard Gage (0.049 in. thick). The flanges overlapped the adjacent sections ½ in. and were fastened by welds.

Angles.—The angles, *B*, were 8½ by 5½ in., 12 ft 6 in. long, formed from sheet steel, No. 18 United States Standard Gage (0.049 in. thick), with a ½-in. lip.

Joints.—The flanges of adjacent panels overlapped ½ in. at *C*, and were fastened by ½-in. screws, spaced 1 ft 4 in. on centers. There was ⅛-in. clearance between the webs of adjacent panels at the joint.

End members.—The end members, *D*, were channels, 5 23/32 by 1½ in., 4 ft ⅛ in. long, formed from sheet steel, No. 18 United States Standard Gage (0.049 in. thick). The webs of the end members were in contact with the ends of the panels and the flanges were fastened to the

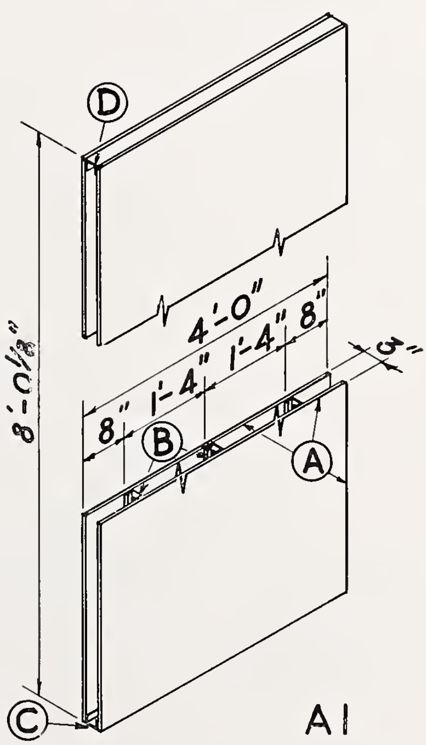

FIGURE 14.—*Partition specimen AI.*

A, face; *B*, stud; *C*, soleplate; *D*, top plate.

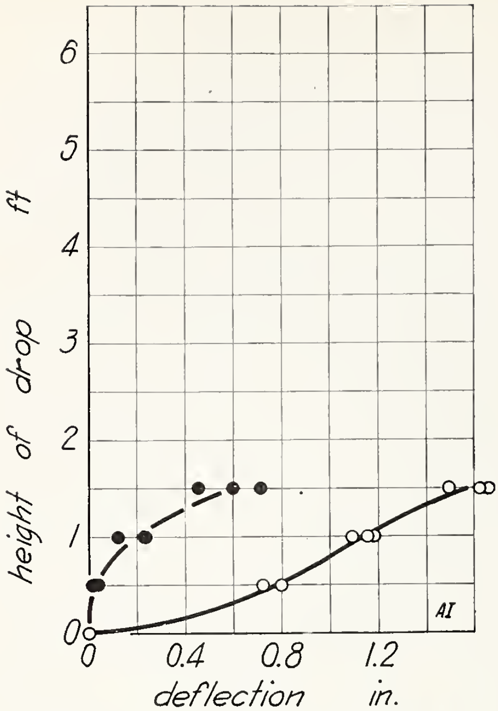

FIGURE 15.—*Impact load on partition AI.*

Height of drop-deflection and height of drop-set results for specimens *AI-I1, I2,* and *I3* on the span 7 feet 6 inches.

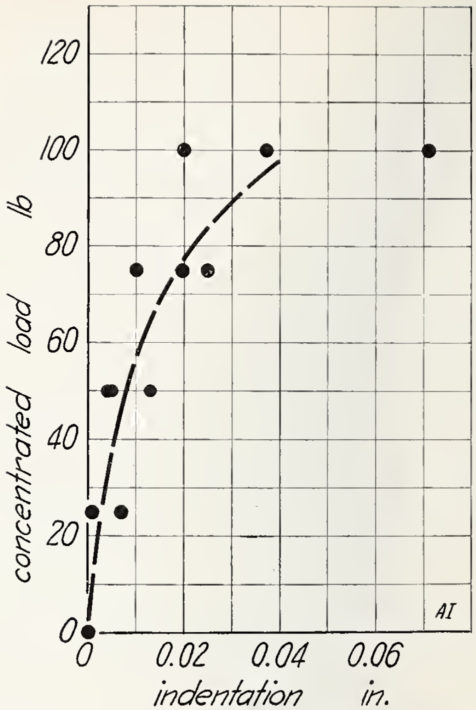

FIGURE 16.—*Concentrated load on partition AI.*

Load-indentation results for specimens *AI-P1, P2,* and *P3.*

faces of the panels by ½-in. screws, spaced 8 in. on centers.

Sleepers.—The sleepers, *E,* were pine, 25/32 by 2⅝ in. (nominal 1 by 3 in.), 4 ft 0 in. long, spaced 1 ft 4 in. on centers, and fastened to the panels by 1½-in. screws, spaced 1 ft 4 in. on centers.

Finish floor.—The finish floor was oak, 25/32 by 2¼ in. (nominal 13/16 by 2¼ in.), fastened to the sleepers by blind nailing with screw nails.

(*c*) *Comments*

The floor panels used for the first floor of a building are supported on the foundation wall.

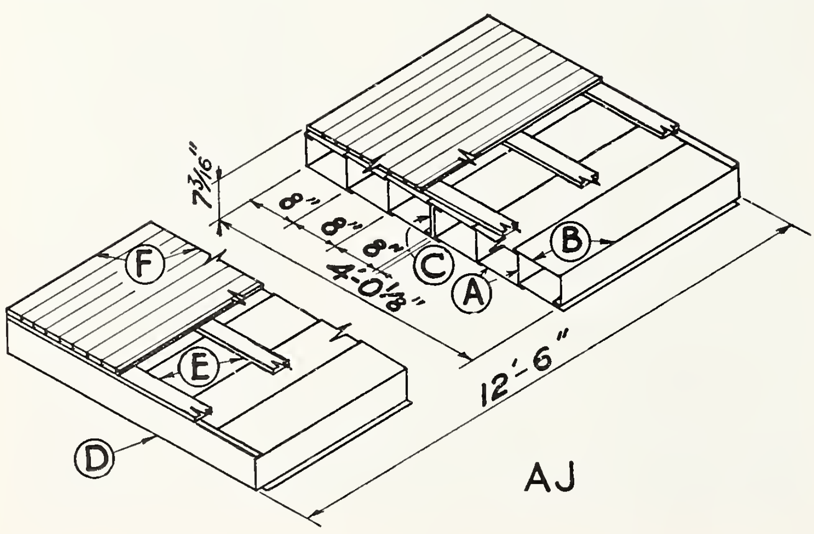

FIGURE 17.—*Floor specimen AJ.*

A, zee; *B,* angle; *C,* joint; *D,* end member; *E,* sleeper; *F,* finish floor.

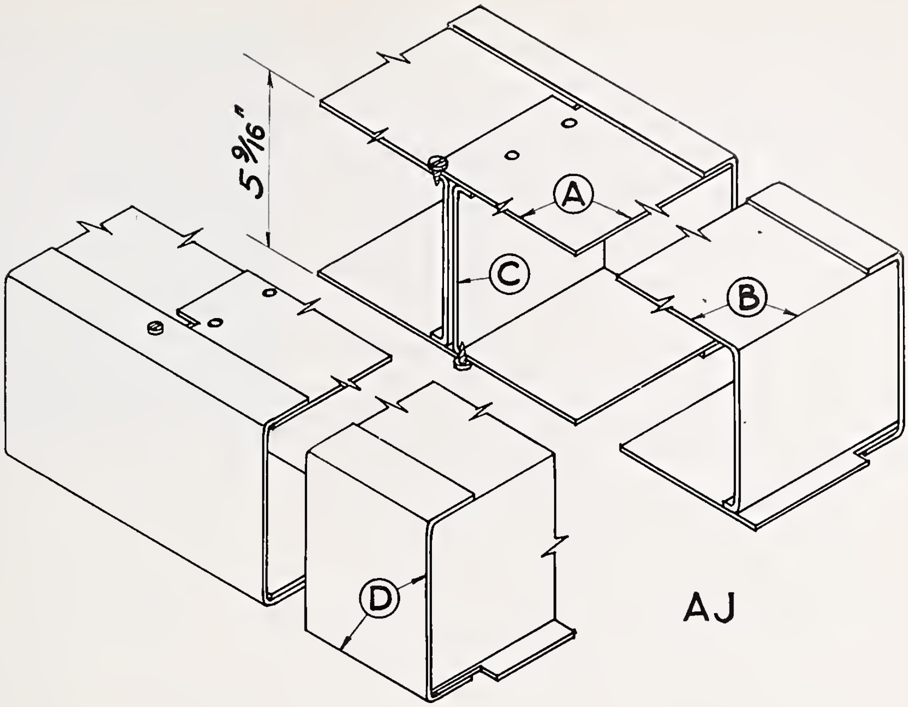

Figure 18.—*Details of the ends and the joint for floor specimen AJ.*

A, zee; *B*, angle; *C*, joint; *D*, end member.

For the second floor, the floor panels are connected to the wall panels by 1¾-by 1¾-by ⅛-in. shelf angles, one at the bottom and one at the top of the floor, and fastened to the floor panels and to the inside faces of the wall panels by screws, spaced 8 in. on centers.

The lower faces of the floor panels form the ceiling of the room below and are usually finished with oil paint or casein paint; however, other finishes such as wallboard, acoustical tile, etc., may be used. If the appearance of the overlapping joints in the lower face is objectionable, the joints may be pointed with filler before painting. Inside faces may be stippled or textured with heavy-bodied paints to conceal surface irregularities.

For heavy loads and long spans, floor panels are furnished with 6-in. web spacing, or with sections made of No. 16 United States Standard Gage steel, while for light loads and short spans, No. 20 United States Standard Gage steel is used.

2. Transverse Load

The results for floor specimens *AJ–T1*, *T2*, and *T3* are shown in table 7 and in figure 19.

Table 7.—*Structural properties of floor AJ*

[Weight, 9.52 lb/ft²]

Load	Load applied	Specimen designation	Maximum height of drop	Maximum load
			ft	*lb/ft²*
Transverse	Upper face; span, 12 ft 0 in.	*T1*		279
		T2		269
		T3		260
	Average			269
				lb
Concentrated	Upper face	*P1*		329
		P2		[a] 1,000
		P3		800
	Average			
Impact	Upper face; span, 12 ft 0 in.	*I1*	[a] 10.0	
		I2	[a] 10.0	
		I3	[a] 10.0	
	Average		[a] 10.0	

[a] Specimen did not fail.

Each of the specimens failed by buckling of the webs of the zees and angles, near one of the loading rollers, and rupture of welds in the upper faces of the panels. No failure of the wood finish floor was observed.

3. Concentrated Load

Floor specimen *AJ–P3*, under concentrated load, is shown in figure 20.

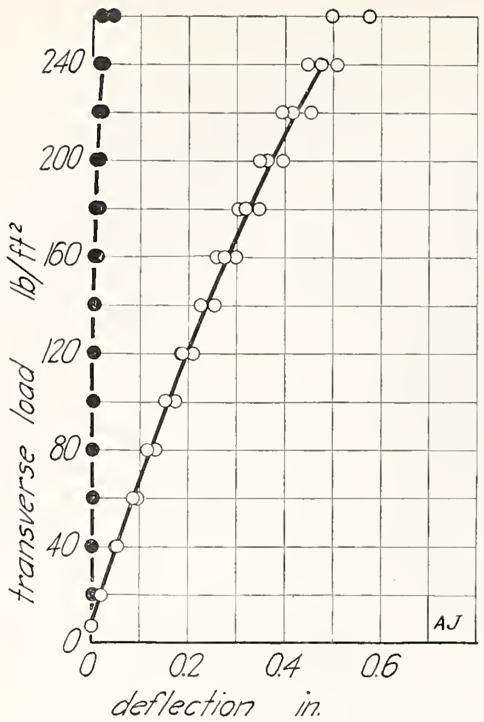

FIGURE 19.—*Transverse load on floor AJ.*

Load-deflection and load-set results for specimens *AJ–T1, T2,* and *T3* on the span 12 feet 0 inch.

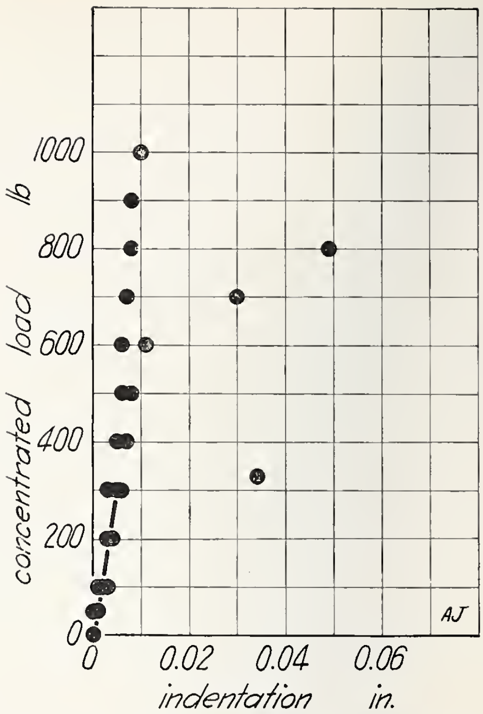

FIGURE 21.—*Concentrated load on floor AJ.*

Load-indentation results for specimens *AJ–P1, P2,* and *P3.*

The results for floor specimens *AJ–P1, P2,* and *P3* are shown in table 7 and in figure 21.

Specimens *P1* and *P3,* loaded at end-matched joints between sleepers, failed by splitting of the wood at the joints. For specimen *P2,* which was loaded on a wood strip continuous between sleepers, the indentation after a load of 1,000 lb had been applied was 0.01 in. and no other effect was observed.

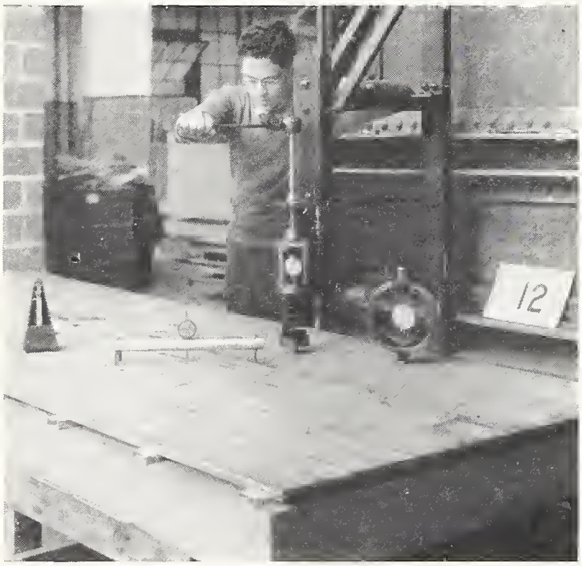

FIGURE 20.—*Floor specimen AJ–P3 under concentrated load.*

4. IMPACT LOAD

Floor specimen *AJ–I2,* under impact test, is shown in figure 22.

The results for floor specimens *AJ–I1, I2,* and *I3* are shown in table 7 and in figure 23.

For specimen *I1,* the set after a drop of 10 ft was about 0.06 in. and no other effect was observed. For specimen *I2,* the set after a drop of 10 ft was 0.015 in. and there was a longitudinal crack near an end-matched joint in the wood finish floor at the middle of the specimen. For specimen *I3,* the wood finish floor was split at an end-matched joint near the middle of the specimen, after a drop of 7 ft, and the set after a drop of 10 ft was about 0.05 in.

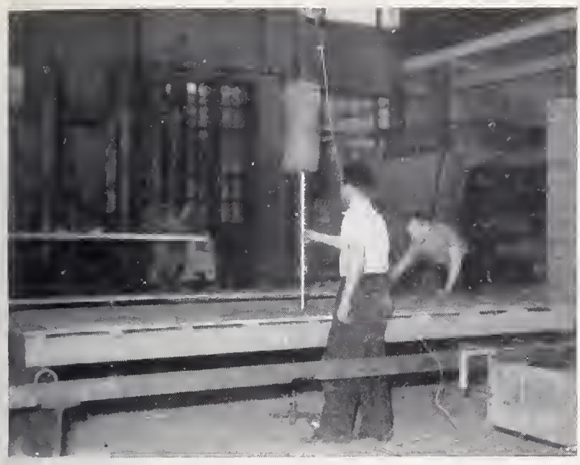

FIGURE 22.—*Floor specimen AJ–I2 during the impact test.*

VII. ROOF *AK*

1. SPONSOR'S STATEMENT

(*a*) *Materials*

Steel.—Mild, open-hearth, black sheets, hot-rolled, annealed, and pickled. The specified chemical composition is given in table 2 and the average mechanical properties in table 3. American Rolling Mill Co.'s "Armco."

Welds.—Electric spot welds, ¼-in. diam, spaced 4 in. on centers, made with a 50-kva welding machine equipped with automatic timing. Federal Machine & Welder Co.'s "Alligator Type Spot Welder."

Screws.—Self-tapping, ½-in., No. 8 (0.164-in. diam), 15 threads per inch, binding head, hardened and plated with cadmium about 0.00035 in. thick. Continental Screw Co.'s "Holtite."

Paint.—Priming, rust-resisting, gray; weight, 12.10 lb/gal. The formula for the paint is given in table 4. Pittsburgh Plate Glass Co.'s "Gray Metal Dipping Primer 32914–A."

Insulating board.—Vegetable-fiber insulating board, ½ in. thick. Celotex Corporation's "Celotex."

Roofing felt.—Rag base, saturated with asphalt; weight, 15 lb/100 ft². Philip Carey Co.'s "Feltex."

Asphalt.—Blended, high-grade asphalt. Philip Carey Co.

(*b*) *Description*

The roof specimens were 14 ft 6 in. long, 4 ft ⅛ in. wide, and 7½ in. thick. Each specimen consisted of two panels fabricated from sheet-steel zees, *A*, as shown in figure 24, and sheet-steel angles, *B*, fastened by welds. The two panels were joined at *C* and fastened by screws and the ends were enclosed by sheet-steel end members, *D*, fastened by screws. The panels, and also the end members, were completely covered with one coat of paint applied by dipping. The upper faces of the panels were covered with insulation, *E*, and built-up roofing, *F*.

The price of this construction was \$0.67/ft².

Zees.—The zees, *A*, were 8½ by 5½ by 8½ in., 14 ft 6 in. long, formed from sheet steel, No. 18 United States Standard Gage (0.049 in. thick). The flanges overlapped the adjacent sections ½ in. and were fastened by welds.

Angles.—The angles, *B*, were 8½ by 5½ in., 14 ft 6 in. long, formed from sheet steel, No. 18 United States Standard Gage (0.049 in. thick), with a ½-in. lip.

Joint.—The flanges of adjacent panels overlapped ½ in. at *C*, and were fastened by screws, spaced 1 ft 4 in. on centers. There was ⅛-in.

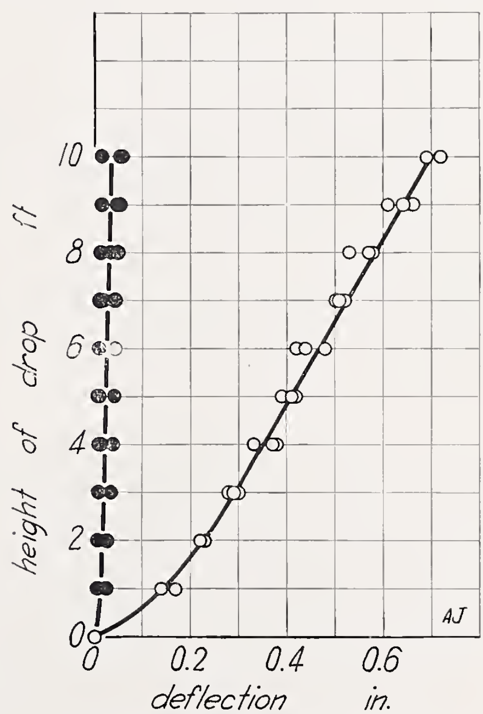

FIGURE 23.—*Impact load on floor AJ.*

Height of drop-deflection and height of drop-set results for specimens *AJ–I1*, *I2*, and *I3* on the span 12 feet 0 inch.

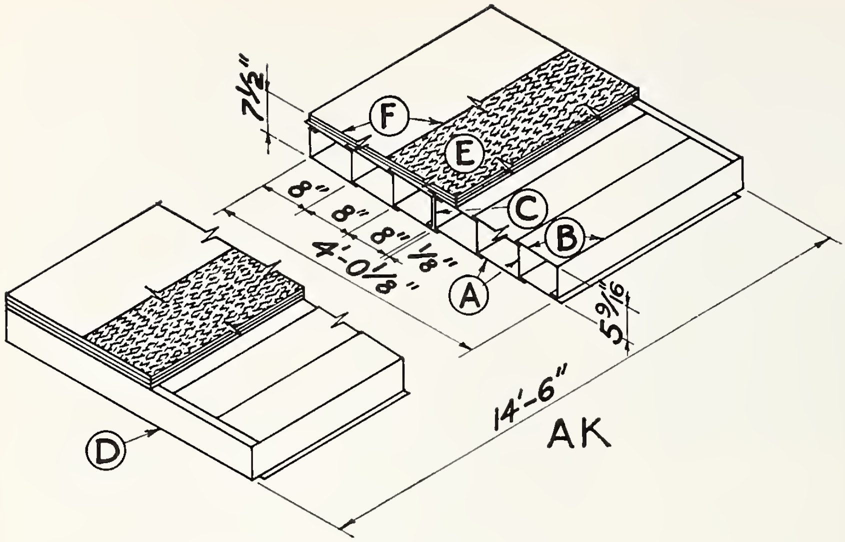

FIGURE 24.—*Roof specimen AK.*

A, zee; *B*, angle; *C*, joint; *D*, end member; *E*, insulation; *F*, built-up roofing.

clearance between the webs of adjacent panels at the joint.

End members.—The end members, *D*, were channels, $5^{23}/_{32}$ by $1\frac{1}{2}$ in., 4 ft ⅛ in. long, formed from sheet steel, No. 18 United States Standard Gage (0.049 in. thick). The webs of the end members were in contact with the ends of the panels and the flanges were fastened to the faces of the panels by screws, spaced 8 in. on centers.

Insulation.—The upper faces of the assembled panels were covered by a layer of roofing felt laid in asphalt. Three layers of insulating board, *E*, were laid in asphalt over the felt. The joints of the insulating board were staggered.

Built-up roofing.—The insulation was covered by three layers of roofing felt, *F*, laid in asphalt.

(*c*) *Comments*

For flat roofs, the roof panels are supported by 1¾-by 1¾-by ⅛-in. shelf angles fastened to the inside faces of the wall panels and to the lower faces of the roof panels by screws, spaced 8 in. on centers. The wall panels extend above the roof to form a parapet. The insulation and built-up roofing cover the inside of the parapet and the roofing extends over the top, forming a through flashing. A sheet-steel coping covers the top of the parapet and extends 4 in. down the sides. The lower faces of the roof panels form the ceiling of the room below, and are usually finished with oil paint or casein paint; however, other finishes such as wallboard, accoustical tile, etc., may be used.

For sloping roofs, the roof panels are connected to the wall panels by a sheet-steel cornice which takes the place of the wall plate and are connected at the ridge by a sheet-steel ridge roll. For roof panels not exceeding 14 ft 0 in. in length, the roof panels are identical with wall panels. Sloping roofs are covered with com-

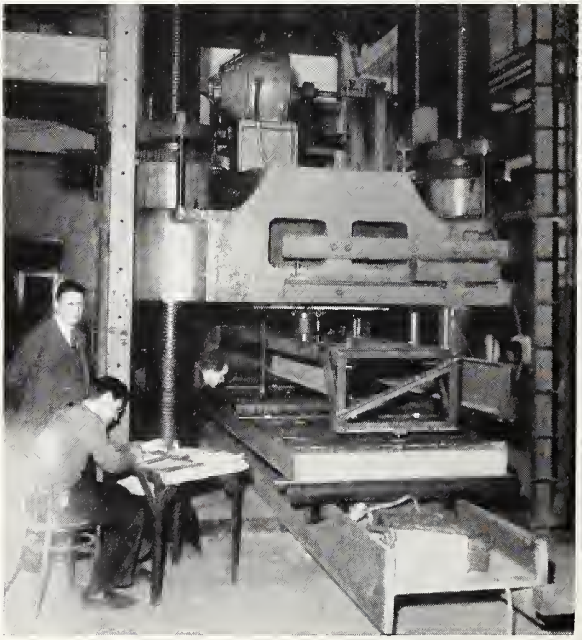

FIGURE 25.—*Roof specimen AK–T2 under transverse load.*

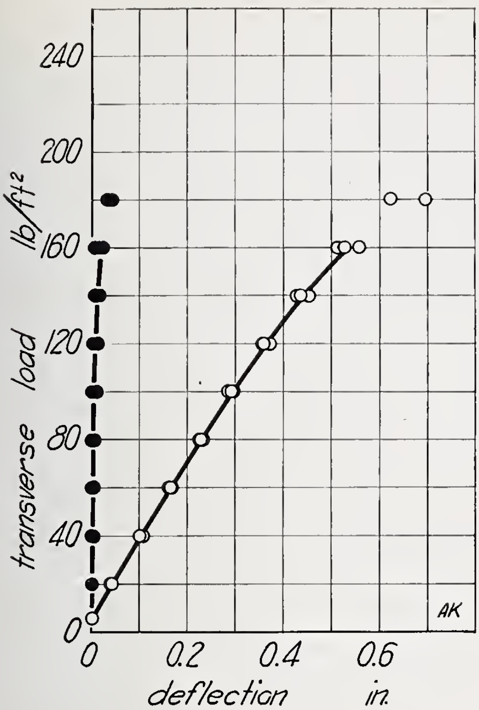

FIGURE 26.—*Transverse load on roof AK.*

Load-deflection and load-set results for specimens *AK–T1*, *T2*, and *T3* on the span 14 feet 0 inch.

position shingles laid in asphalt directly on the panels.

For sloping roofs, the ceiling joists are identical in section with the partition studs, *B*, figure 14, and are spaced 1 ft 4 in. on centers. The joists are supported at the ends by sheet-steel channels fastened to the inside faces of the wall panels by screws. Hangers are fastened to the roof panels and to the joists at frequent intervals. The face of the ceiling is gypsum board fastened to the joists by screws.

2. Transverse Load

Roof specimen *AK–T2*, under transverse load, is shown in figure 25.

The results for roof specimens *AK–T1*, *T2*, and *T3* are shown in table 8 and in figure 26.

Each of the specimens failed by buckling of the webs of the zees and angles between the loading rollers. A few welds in the upper faces of the panels failed.

TABLE 8.—*Structural properties of roof AK*

[Weight, 10.73 lb/ft².]

Load	Load applied	Specimen designation	Maximum load
			lb/ft²
Transverse	Upper face; span, 14 ft 0 in.	*T1*	188
		T2	199
		T3	179
	Average		189
			lb
Concentrated	Upper face	*P1*	700
		P2	700
		P3	460
	Average		620

3. Concentrated Load

The results for roof specimens *AK–P1*, *P2*, and *P3* are shown in table 8 and in figure 27.

For each of the specimens, the disk punched through the built-up roofing into the insulation.

VIII. ADDITIONAL COMMENTS BY SPONSOR

APPROXIMATELY 170 houses were completed or under construction on May 1, 1938 using these constructions.

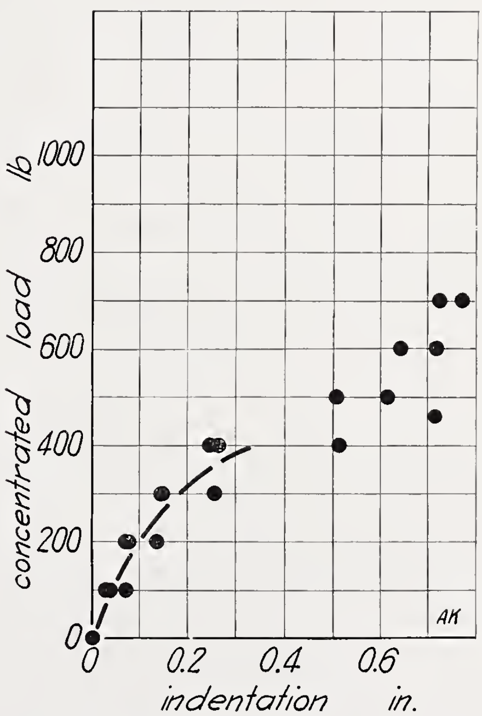

FIGURE 27.—*Concentrated load on roof AK.*

Load-indentation results for specimens *AK–P1*, *P2*, and *P3*.

The foundations for these houses were either concrete walls or concrete slabs. The chimneys were 4-in. brick walls with clay-tile flue linings, supported on the masonry foundations.

IX. SELECTED REFERENCES

American Architect, **149,** No. 2649, 39 (1936).
Architectural Record, **81,** No. 3, 34BT (1937).
Home Information, Better Homes in America, Purdue University, **1,** Nos. 10 and 11 (1936).

The sponsor supplied the information contained in the sponsor's statement. The description and drawings of the specimens were prepared by E. J. Schell and G. W. Shaw of the Building Practice and Specifications Section, under the supervision of V. B. Phelan, from this information and from the specimens themselves. That Section also cooperated in the preparation of the report.

The experimental data were obtained from tests made by the Engineering Mechanics Section under the supervision of H. L. Whittemore and A. H. Stang, with the assistance of the following members of the professional staff: F. Cardile, R. C. Carter, H. Dollar, M. Dubin, A. H. Easton, A. S. Endler, C. D. Johnson, A. J. Sussman, and L. R. Sweetman.

Washington, June 30, 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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- 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