U. S. DEPARTMENT OF COMMERCE

BUILDING MATERIALS AND STRUCTURES

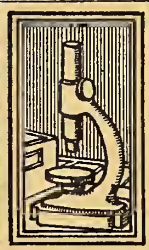
REPORT BMS12

Structural Properties of "Steelox" Constructions for Walls, Partitions, Floors, and Roofs Sponsored by Steel Buildings, Inc.

by

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

NATIONAL
BUREAU OF STANDARDS



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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 the detailed description given in each 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 at ordinary temperatures and the fire resistance of these same constructions and perhaps other properties.

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

Lyman J. Briggs, *Director.*

Structural Properties of "Steelox" Constructions for Walls, Partitions, Floors, and Roofs Sponsored by Steel Buildings, Inc.

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ABSTRACT

For the program on the determination of the structural properties of low-cost house constructions, Steel Buildings, Inc. submitted 30 specimens representing their "Steelox" 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 like 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, Methods of

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

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.[3] 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 loads 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 a person falling against the partition, and concentrated loads by furniture or by a ladder or other object 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.

[3] Price 15 cents.

II. SPONSOR AND PRODUCT

The specimens were submitted by Steel Buildings, Inc., Middletown, Ohio, and represented constructions sold under the trade name "Steelox." The load-bearing wall, floor, and roof constructions consisted essentially of interlocking, channel-shaped, sheet-steel panels. The nonload-bearing partition was of conventional wood-frame construction.

III. SPECIMENS AND TESTS

The specimens represented four elements of a house which were assigned the following symbols: Wall, *AL*; partition, *AM*; floor, *AN*; and roof, *AO*. The specimens were assigned designations in accordance with table 1.

Table 1.—*Specimen designations*

Element	Construction symbol	Specimen designation	Load	Load applied
Wall	*AL*	*C1, C2, C3*	Compressive	Upper end.
Do	*AL*	*T1, T2, T3*	Transverse	Inside face.
Do	*AL*	*T4, T5, T6*	do	Outside face.
Do	*AL*	*P1, P2, P3*[a]	Concentrated	Inside face.
Do	*AL*	*P4, P5, P6*[a]	do	Outside face.
Do	*AL*	*I1, I2, I3*	Impact	Inside face.
Do	*AL*	*I4, I5, I6*	do	Outside face.
Do	*AL*	*R1, R2, R3*	Racking	Upper end.
Partition	*AM*	*I1, I2, I3*	Impact	Either face.
Do	*AM*	*P1, P2, P3*[a]	Concentrated	Do.
Floor	*AN*	*T1, T2, T3*	Transverse	Upper face.
Do	*AN*	*P1, P2, P3*[a]	Concentrated	Do.
Do	*AN*	*I1, I2, I3*	Impact	Do.
Roof	*AO*	*T1, T2, T3*	Transverse	Do.
Do	*AO*	*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,[4] which also gives the requirements for the specimens and for determining the price. For the transverse specimens the deflection was measured with two taut-wire mirror-scale deflectometers, one on each edge, instead of with the deflection-measuring frame and dial micrometers.

The tests were begun January 3, 1938, and completed January 12, 1938. The sponsor's representative witnessed the tests.

[4] Price 10 cents.

IV. WALL *AL*

1. Sponsor's Statement

(a) *Materials*

Steel.—Hot-rolled sheets, hot-dip galvanized and prepared for paint by the "Paint Grip" process. The chemical composition of the steel is given in table 2 and the average mechanical properties in table 3. American Rolling Mill Co.'s "Armco."

Table 2.—*Chemical composition of the steel*

Element	Content	
	Minimum	Maximum
	Percent	*Percent*
Carbon	0.05	0.10
Manganese	.25	.35
Phosphorus		.05
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 in.
	in.		*lb/in.*^{2}	*lb/in.*^{2}	*Percent*
20	0.0368	In direction of rolling	26,000	40,000	32
		Across direction of rolling	29,500	44,000	29
18	.049	In direction of rolling	27,000	41,000	32
		Across direction of rolling	30,000	45,000	29
12	.1072	In direction of rolling	33,000	46,000	39
		Across direction of rolling	34,000	47,000	39

The sheets were galvanized with Prime Western zinc complying with ASTM Standard B6–37 and having a maximum of 1.60 percent of lead and 0.08 percent of iron. The weight of the zinc coating was 1.25 to 1.50 oz/ft^2 for the 18- and 20-gage sheets and 1.75 to 2.00 oz/ft^2 for the 12-gage sheets.

The galvanized sheets were prepared for paint by the "Paint Grip" process according to the following specification:

"All galvanized sheets and members shall be phosphated by immersion in a solution containing free phosphoric acid, an oxidizing agent (nitrate), and iron and zinc phosphate. After this treatment the articles shall be thoroughly rinsed in clear water."

Hook bolts.—Special, ⅜-in. diam, 16 threads per in., 1½ in. long, with ¹¹⁄₁₆-in. hook, made from SAE 1035 cold-drawn steel, not heat-treated; with standard wrought-steel washers, and hexagonal steel nuts, cold-punched and trimmed, single chamfer and countersink. Bolts, nuts, and washers were plated with cadmium not less than 0.0002 in. thick. Lamson & Sessions Co.

Screws.—Self-tapping, ¾ in., No. 10 (0.190-in. diam), 13 threads per in., round head, hardened and plated with cadmium about 0.00035 in. thick. Parker-Kalon Corporation's "Type A."

Asphalt emulsion.—Brushing consistency. The formula is given in table 4. Armstrong Paint and Varnish Works' "XA–1696."

Table 4.—*Formula for asphalt emulsion "XA–1696"*

Ingredient	Content, water-free basis	
	Minimum	Maximum
	Percent	*Percent*
Bentonite clay	4	4.5
Asphalt	93	
Asbestos fiber	1.5	2
Rust inhibitor		1

Asphalt.—Softening point 180° F. Logan-Long Co.

Felt.—Rag base, saturated with asphalt; weight, 65 lb/108 ft^2 (Asphalt roofing). Philip Carey Co.

Adhesive.—The formula is given in table 5. Armstrong Paint and Varnish Works' "No. 106–V."

Table 5.—*Formula for adhesive "No. 106–V"*

Ingredient	Content
	Percent
Parolite	38
Gilsonite	12.9
Flux asphalt	10.2
Kerosene	38.9
	100.0

Wood.—Pine, shortleaf, yellow, No. 1 common, finished four sides.

Screw nails.—Heavy-duty, 1½ in. long, No. 6, 8 threads per in., quadruple thread, flat head, needle point, made from SAE 1315 (high side) steel, water-quenched from 1,750° F, and plated with cadmium about 0.0001 in. thick. Hillwood Manufacturing Co.'s "Helyx Drive Screw Nails."

'*Insulating board.*—Wood-fiber. Insulite Co.'s 'Graylite Building Board."

Finishing nails.—6d, 2 in. long.

Paint.

Casein, priming. United States Gypsum Co.'s "K-Cemo."

Casein, finish. United States Gypsum Co.'s "Texolite."

Oil, priming, blue lead. Armstrong Paint and Varnish Works' "No. 1506."

Oil, undercoating, white. Armstrong Paint and Varnish Works' "XA 2140."

Oil, finish, white. Armstrong Paint and Varnish Works' "No. 1555."

The formulas for the oil paints are given in tables 6, 7, and 8.

Table 6.—*Formula for blue-lead paint "No. 1506"*

Paint		Pigment		Vehicle	
Ingredient	Content, by weight	Ingredient	Content, by weight	Ingredient	Content, by weight
	Percent		*Percent*		*Percent*
Pigment	57.24	Sublimed blue lead	69.88	Boiled linseed oil	96.47
Vehicle	42.76	Zinc oxide	30.12	Mineral spirits	3.53
	100.00		100.00		100.00

Table 7.—*Formula for white undercoating paint "XA 2140"*

Paint		Pigment		Vehicle	
Ingredient	Content, by weight	Ingredient	Content, by weight	Ingredient	Content, by weight
	Percent		*Percent*		*Percent*
Pigment	64.94	Lead carbonate	25.02	Raw linseed oil	35.79
Vehicle	35.06	Titanium dioxide	29.54	Spar varnish	34.23
	100.00	Silica and silicates	45.44	Cobalt drier	2.60
			100.00	Mineral spirits	27.38
					100.00

Table 8.—*Formula for white finish paint "No. 1555"*

Paint		Pigment		Vehicle	
Ingredient	Content, by weight	Ingredient	Content, by weight	Ingredient	Content, by weight
	Percent		*Percent*		*Percent*
Pigment	64.70	Lead carbonate	59.35	Refined linseed oil	96.32
Vehicle	35.30	Zinc oxide	15.92	Heat-treated linseed oil	3.40
		Titanium dioxide	4.64	Zinc drier	0.12
		Barium sulfate	4.64	Lead drier	.08
		Silica and silicates	15.45	Manganese drier	.08
	100.00		100.00		100.00

(*b*) *Description*

(1) *Four-Foot Wall Specimens.*—The 4-ft wall specimens were 8 ft 0 in. high, 4 ft 0 in. wide, and 4½ in. thick. Each specimen consisted of three interlocked sheet-steel "Steelox" panels, *A*, as shown in figures 1 and 2, fastened to a sheet-steel sill, *B*, at the lower end, and to a sheet-steel wall plate, *C*, and a sheet-steel angle, *D*, at the upper end, by hook bolts. One flange of the wall plate was also fastened to the panels by screws. The panels formed the outside face and studs. The sides of the flanges of the panels which were in contact after assembly were covered with oil priming paint applied with a brush before assembly. The inside of the assembled panels, sill, and plate was covered with one coat of asphalt emulsion applied with a

brush, and the lower end was sealed with asphalt, ½ in. thick. The bottom of the sill was covered with a strip of felt fastened by adhesive. Horizontal wood furring strips, *E*, were fastened to the studs by screw nails and an insulating-board inside face, *F*, was fastened to the furring strips by finishing nails. The inside face was covered with one coat of casein priming paint and one coat of casein finish paint. The outside face was covered with two coats of oil undercoating paint and one coat of oil finish paint.

The price of this construction was \$0.52/ft^2.

Panels.—The panels, *A*, were channels, 1 ft 4 in. by 3 in., 7 ft 11¾ in. long, formed from stretcher-leveled and resquared sheet steel, No. 20 United States Standard Gage (0.0368 in. thick before galvanizing). The edges of the flanges of each panel were formed to interlock with the flanges of adjacent panels. The flanges when interlocked formed studs of two thicknesses of steel, integral with the outside face.

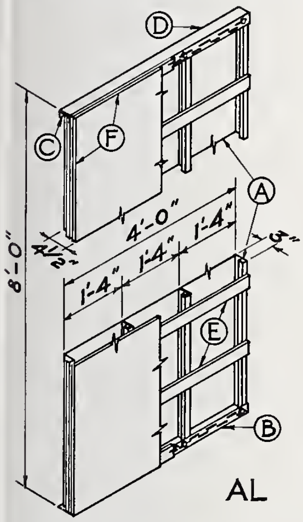

FIGURE 1.—*Four-foot wall specimen AL.*

A, panel; *B*, sill; *C*, wall plate; *D*, angle; *E*, furring strip; *F*, inside face.

Sill.—The sill, *B*, was an angle, 3¼ by 2⅛ in., 4 ft 1 in. long, formed from sheet steel, No. 12 United States Standard Gage (0.1072 in. thick before galvanizing). The horizontal 3¼-in. leg had holes for ½-in. anchor bolts, spaced 1 ft 4 in. on centers. The vertical leg had slots, 2⅞ by ⅜ in., spaced 5 in. on centers, in two rows, spaced ¾ in. The slots were staggered and overlapped ⅜ in. The panels were fastened to the sill by hook bolts which passed through the slots and engaged the studs.

Wall plate.—The wall plate, *C*, was a channel, ⅝ by 3¼ by 1⅛ in., 4 ft 1 in. long, formed from sheet steel, No. 18 United States Standard Gage (0.049 in. thick before galvanizing). The plate enclosed the upper ends of the panels with a snug fit and the 1⅛-in. flange was fastened to the panels by screws, one in each panel at midwidth. The primary purpose of the plate is to align the panels during the erection of the building.

Angle.—The angle, *D*, was the same in section as the sill, *B*. In a house the member corresponding to this angle is the support either for a floor or roof and is never identical with angle *D*.

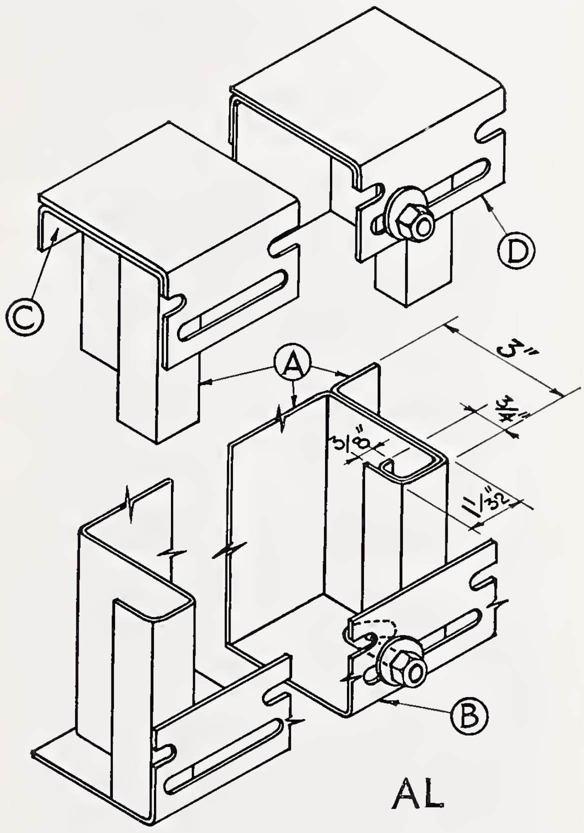

FIGURE 2.—*Details of wall specimen AL.*

A, panel; *B*, sill; *C*, wall plate; *D*, angle.

Furring strips.—The furring strips, *E*, were pine, 25/32 by 2⅝ in. (nominal 1 by 3 in.), 4 ft 1 in. long, spaced 1 ft 4 in. on centers. The strips were fastened to the studs by screw nails, one at each stud.

Inside face.—The inside face, *F*, was a one-piece insulating board, 8 ft 0 in. by 4 ft 0 in. by ¾ in., fastened to each furring strip by finishing nails. Two nails were used at each of the fastening points, which were spaced approximately 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 4½ in. thick. The specimens were similar to the 4-ft specimens and each specimen had six "Steelox" panels and two insulating boards, each 8 ft 0 in. by 4 ft 0 in. by ¾ in. The joint between the boards was vertical.

(c) *Comments*

The standard width of "Steelox" wall panels is 1 ft 4 in., but panels having other widths can be supplied.

When erecting the building, the sill with its felt strip is fastened to the foundation by ex-

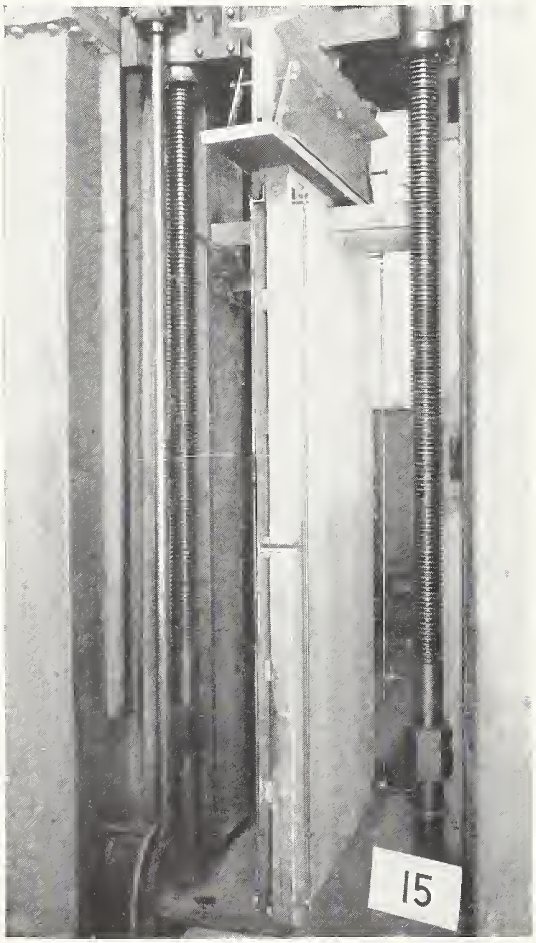

FIGURE 3.—*Wall specimen AL–C3 under compressive load.*

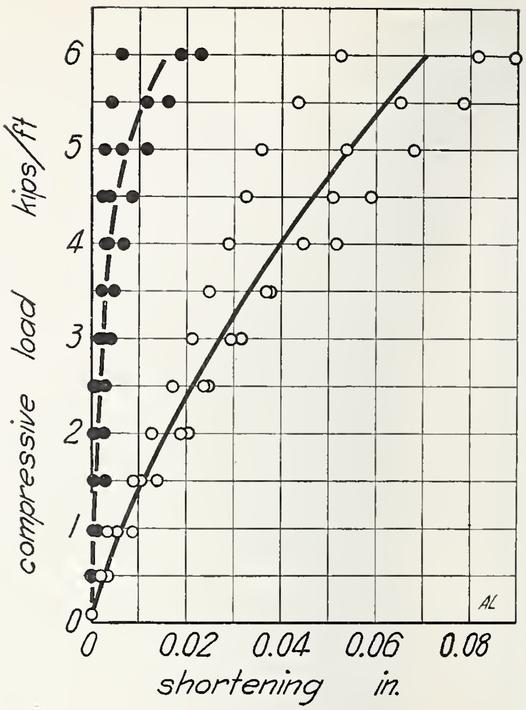

FIGURE 4.—*Compressive load on wall AL.*

Load-shortening and load-set results for specimens *AL–C1*, *C2*, and *C3*. For the compressive load the thickness of the specimens was taken as 3 in., that of the structural portion. The load was applied 2 in. from the outside face. The loads are in kips per foot of actual width of specimen. The shortenings and sets are for a height of 8 ft. They were computed from the values obtained from the compressometer readings. The gage length of the compressometers was 7 ft 6 in.

pansion or anchor bolts, and at one corner of the building a corner panel is fastened to the sill by hook bolts. Starting at the corner, the wall panels are interlocked with the corner panel and with each other and fastened to the sill by hook bolts. The flanged sides of the panels are covered with blue-lead paint before assembly. Shorter panels are used at window openings. The inside of the sill is covered with asphalt, ½ in. deep, and the inside of the assembled steel is covered with asphalt emulsion.

Openings for standard door and window frames are framed with sill and lintel angles, fastened by hook bolts. Through-the-wall flashing is used over the top of the frames and sealed with asphalt between the lintel angles and the wall panels.

The wall panels may be further insulated by rock-wool batts placed between the studs after erection. When so insulated the sill is not covered with asphalt.

2. Compressive Load

Wall specimen *AL–C3* under compressive load is shown in figure 3. The results for wall specimens *AL–C1*, *C2*, and *C3* are shown in table 9 and in figures 4 and 5.

Table 9.—*Structural properties of wall AL*

[Weight, 4.96 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	2 in. from outside face.[a]	*C1*				6.50
		C2				6.32
		C3				6.34
	Average					6.39
						lb/ft²
Transverse	Inside face; span, 7 ft 6 in.	*T1*				144
		T2				164
		T3				151
	Average					153
Transverse	Outside face; span, 7 ft 6 in.	*T4*				135
		T5				138
		T6				134
	Average					136
						lb
Concentrated	Inside face	*P1*				250
		P2				250
		P3				265
	Average					255
Concentrated	Outside face	*P4*				300
		P5				400
		P6				375
	Average					358
Impact	Inside face; span, 7 ft 6 in.	*I1*	6.5	7.0	7.5	
		I2	4.0	6.0	7.0	
		I3	5.5	6.5	9.5	
	Average		5.3	6.5	8.0	
Impact	Outside face; span, 7 ft 6 in.	*I4*	4.0	7.5	9.0	
		I5	3.0	7.0	9.0	
		I6	3.5	8.0	9.0	
	Average		3.5	7.5	9.0	
						kips/ft
Racking	Upper end	*R1*				0.552
		R2				.610
		R3				.635
	Average					.599

[a] For the compressive load, the thickness of the specimens was taken as 3 in., that of the structural portion only.

Specimens *C1* and *C3* failed by buckling of the outside faces at the lower ends of the specimens. Specimen *C2* failed by buckling of the outside face and studs at two-thirds of the height above the lower end.

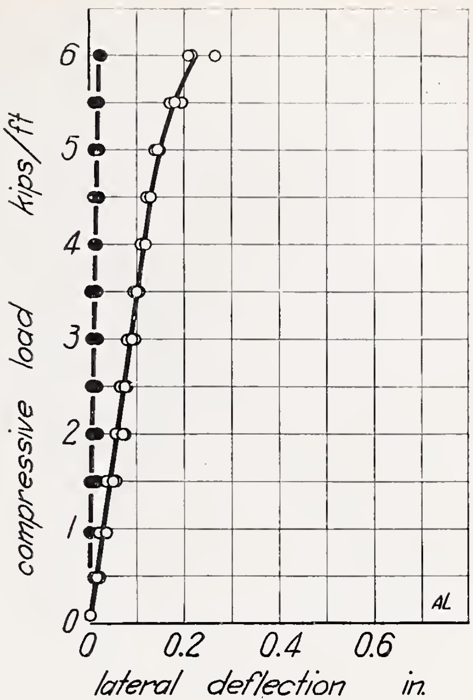

Figure 5.—*Compressive load on wall AL.*

Load-lateral deflection and load-lateral set results for specimens *AL–C1*, *C2*, and *C3*. For the compressive load the thickness of the specimens was taken as 3 in., that of the structural portion. The load was applied 2 in. from the outside face. The loads are in kips per foot of actual width of specimen. The deflections and sets are for a gage length of 7 ft 6 in., the gage length of the deflectometers.

3. Transverse Load

The results are shown in table 9 and in figure 6 for wall specimens *AL–T1*, *T2*, and *T3*, loaded on the inside face, and in figure 7 for wall specimens *AL–T4*, *T5*, and *T6*, loaded on the outside face.

Each of the specimens *T1*, *T2*, and *T3* failed by buckling of the studs under one of the loading rollers.

Specimens *T4* and *T6* failed by buckling of both the studs and the outside (loaded) faces between the loading rollers. Specimen *T5* failed by buckling of the studs at one of the loading rollers and buckling of the outside face between the loading rollers.

4. Concentrated Load

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

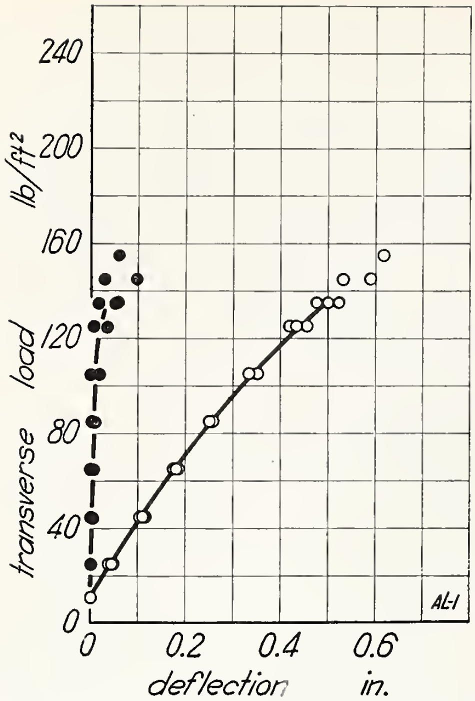

FIGURE 6.—*Transverse load on wall AL, load applied to inside face.*

Load-deflection and load-set results for specimens *AL-T1, T2,* and *T3* on the span 7 ft 6 in.

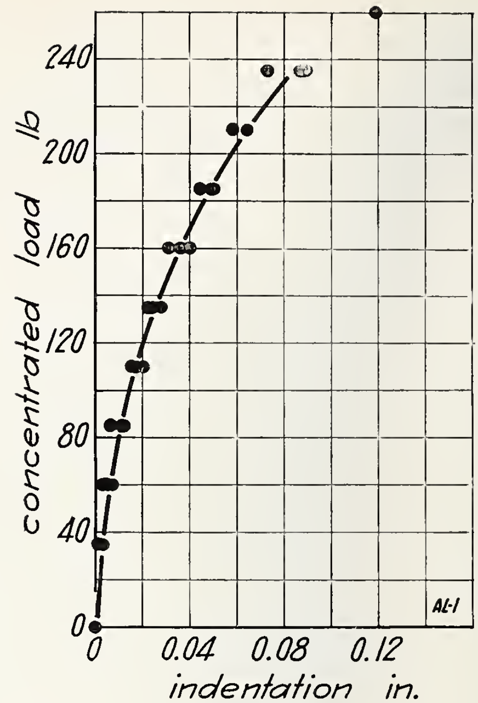

FIGURE 8.—*Concentrated load on wall AL, load applied to inside face.*

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

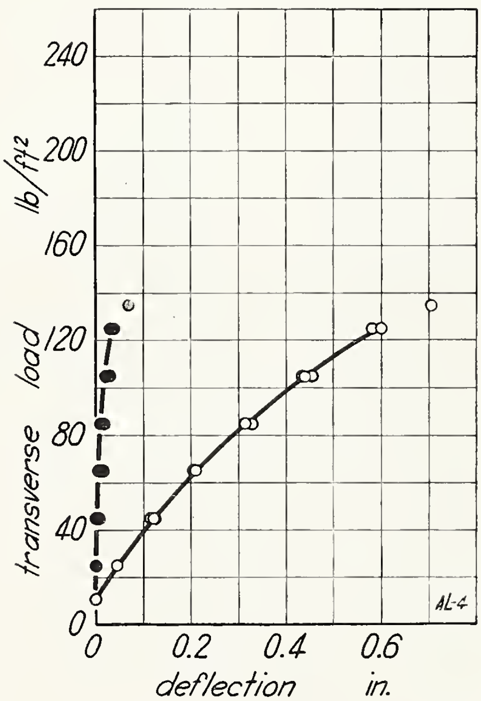

FIGURE 7.—*Transverse load on wall AL, load applied to outside face.*

Load-deflection and load-set results for specimens *AL-T4, T5,* and *T6* on the span 7 ft 6 in.

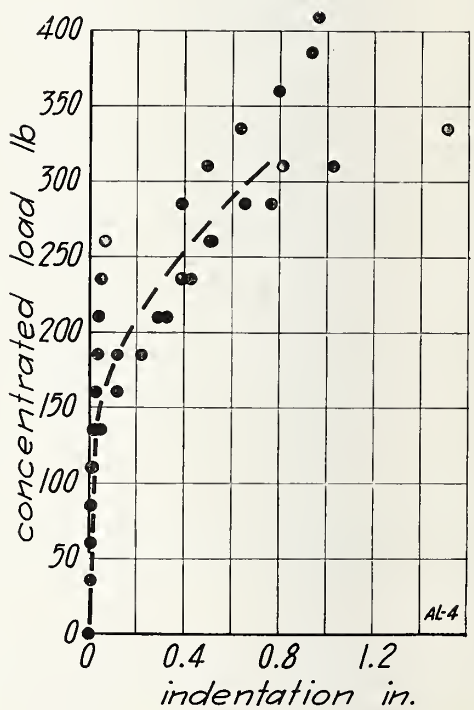

FIGURE 9.—*Concentrated load on wall AL, load applied to outside face.*

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

Each of the specimens $P1$, $P2$, and $P3$ failed by punching of the disk through the loaded face of the specimen.

For specimens $P4$, $P5$, and $P6$, the indentations were 0.81, 0.96, and 1.90 in. after loads of 300, 400, and 375 lb, respectively. Loads greater than these were not applied because the loaded faces of the specimens deformed so that they interfered with the dynamometer.

5. Impact Load

The results are shown in table 9 and in figure 10 for wall specimens *AL–I1*, *I2*, and *I3*, loaded on the inside face, and in figure 11 for wall specimens *AL–I4*, *I5*, and *I6*, loaded on the outside face.

Specimen *I1* failed by cracking of the inside (loaded) face across the entire width of the specimen at midspan and buckling of the studs near the middle of the specimen. Specimens *I2* and *I3* failed by rupture of the inside (loaded) face and the furring strips at the middle of the specimens, buckling of the outside faces and studs, and opening of the panel joints.

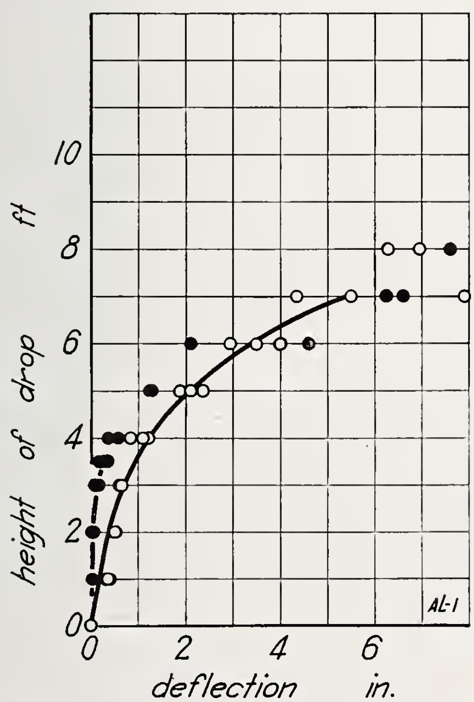

Figure 10.—*Impact load on wall AL, load applied to inside face.*

Height of drop-deflection and height of drop-set results for specimens *AL–I1*, *I2*, and *I3* on the span 7 ft 6 in.

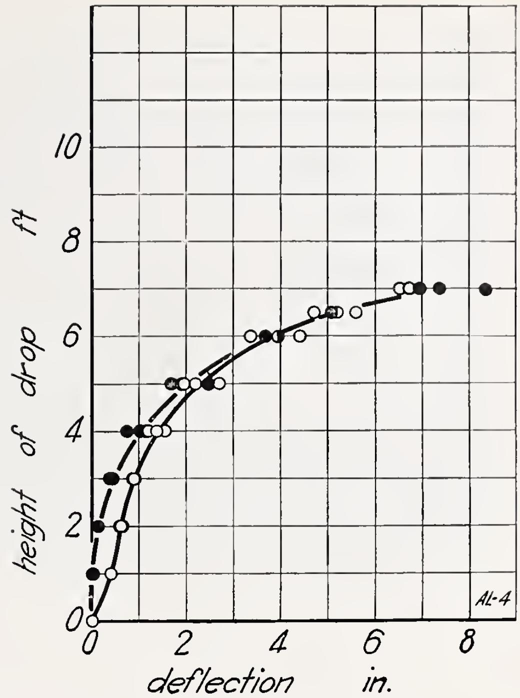

Figure 11.—*Impact load on wall AL, load applied to outside face.*

Height of drop-deflection and height of drop-set results for specimens *AL–I4*, *I5*, and *I6* on the span 7 ft 6 in.

Specimens *I4*, *I5*, and *I6* failed by opening of the panel joints, followed by buckling of the studs and the outside (loaded) faces at the middle of the specimens, and rupture of the inside faces.

Figure 12.—*Wall specimen AL–R3 under racking load.*

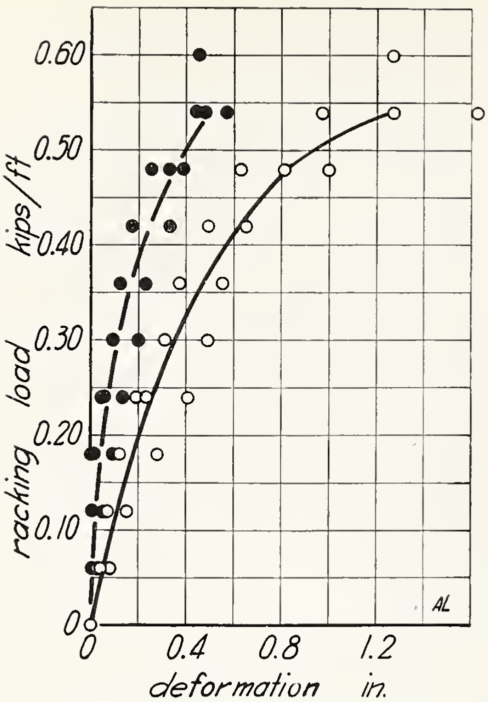

FIGURE 13.—*Racking load on wall AL.*

Load-deformation and load-set results for specimens *AL–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 ft. They were computed from the values obtained from the measuring-device readings. The gage length of the measuring device was 6 ft.

6. RACKING LOAD

Wall specimen AL–R3 under racking load is shown in figure 12. The results for wall specimens *AL–R1*, *R2*, and *R3* are shown in table 9 and in figure 13.

Each of the specimens failed by buckling of the outside faces of the panels at both the upper and lower ends of the specimens and opening of the panel joints. A few screws fastening the wall plates to the upper ends of the specimens sheared.

V. PARTITION *AM*

1. SPONSOR'S STATEMENT

(*a*) *Materials*

Insulating board.—Wood-fiber. Insulite Co.'s "Graylite Building Board."

Wood.—Pine, shortleaf, yellow, No. 1 common, finished four sides.

Nails.

Finishing, 6d, 2 in. long.

Common, 16d, 3½ in. long.

Paint.

Casein, priming. United States Gypsum Co.'s "K–Cemo."

Casein, finish. United States Gypsum Co.'s "Texolite."

(*b*) *Description*

The partition specimens were 8 ft 0 in. high, 4 ft 0 in. wide, and 4⅝ in. thick. Each specimen consisted of two insulating-board faces, *A*, as shown in figure 14, fastened to wood framing by nails. The wood framing consisted of two studs, *B*, and two half studs, *C*, fastened to a soleplate, *D*, and a top plate, *E*, by nails. Both faces were covered with one coat of priming paint and one coat of finish paint.

The price of this construction was \$0.17/ft².

Faces.—The faces, *A*, were one-piece insulating boards, 8 ft 0 in. by 4 ft 0 in. by ½ in., fastened to the wood framing by finishing nails, spaced 1 ft 4 in. along each stud and half stud.

Studs.—The studs, *B*, were pine, 1⅝ by 3⅝ in. (nominal 2 by 4 in.), 7 ft 8¾ in. long.

Half studs.—The half studs, *C*, were pine, 25/32 by 3⅝ in. (nominal 1 by 4 in.), 7 ft 8¾ in. long.

Soleplate and top plate.—Both plates, *D* and *E*, were pine, 1⅝ by 3⅝ in. (nominal 2 by 4 in.), 4 ft 0 in. long. The plates were fastened to the studs and half studs by common nails, two at each end of the studs.

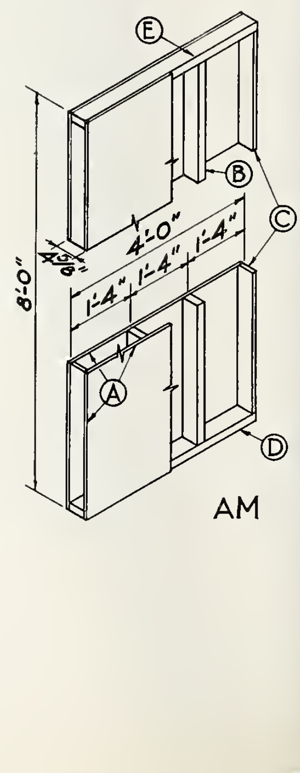

FIGURE 14.—*Partition specimen AM.*

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

2. Impact Load

The results for partition specimens *AM–I1*, *I2*, and *I3* are shown in table 10 and in figure 15.

Table 10.—*Structural properties of partition AM*

[Weight, 3.04 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*	*lb*
Impact	One face; span 7 ft 6 in.	*I1*	1.0	1.5	1.5	
		I2	1.0	1.5	1.5	
		I3	1.0	1.5	1.5	
	Average		1.0	1.5	1.5	
Concentrated	One face	*P1*				145
		P2				147
		P3				150
	Average					147

Each of the specimens failed by rupture of the loaded face at a drop of 1 ft and rupture of the opposite face at a drop of 1.5 ft.

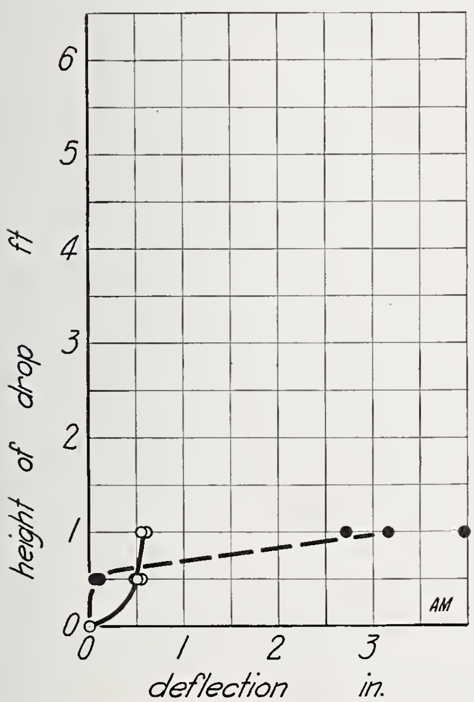

Figure 15.—*Impact load on partition AM.*

Height of drop-deflection and height of drop-set results for specimens *AM–I1*, *I2*, and *I3* on the span 7 ft 6 in.

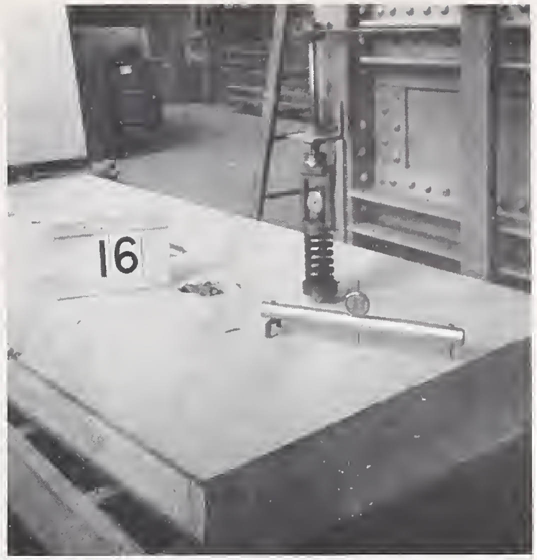

Figure 16.—*Partition specimen AM–P1 under concentrated load.*

3. Concentrated Load

Partition specimen *AM–P1* under concentrated load is shown in figure 16. The results for partition specimens *AM–P1*, *P2*, and *P3* are shown in table 10 and in figure 17.

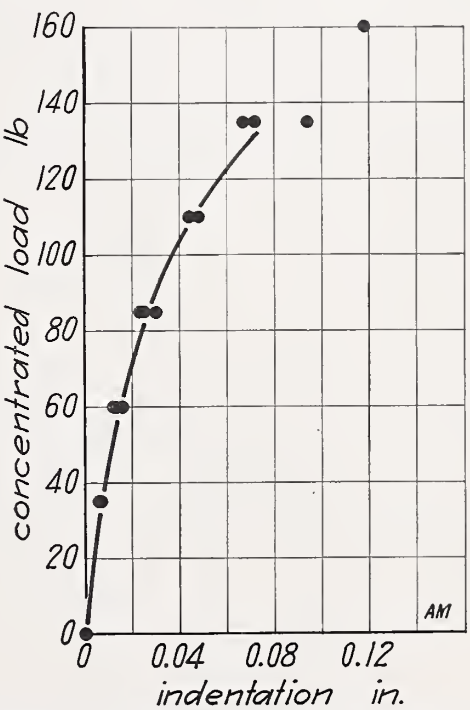

Figure 17.—*Concentrated load on partition AM.*

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

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

VI. FLOOR *AN*

1. Sponsor's Statement

(*a*) *Materials*

Steel.

Black sheets, hot-rolled, stretcher-leveled, and resquared. The chemical composition of the steel is given in table 2 and the average mechanical properties in table 3. American Rolling Mill Co.'s "Armco."

Galvanized sheets, hot-rolled. The chemical composition of the steel is given in table 2 and the average mechanical properties in table 3. The sheets were galvanized with Prime Western zinc complying with ASTM Standard B6–37 and having a maximum of 1.60 percent of lead and 0.08 percent of iron. The weight of the zinc coating was 1.75 to 2.00 oz/ft². American Rolling Mill Co.'s "Armco."

Bolts.—Stove, ¼-in. diam, 20 threads per in., ½ in. long, round head, made from SAE 1010 steel, not heat-treated, and plated with cadmium not less than 0.0002 in. thick. Lamson & Sessions Co.

Paint.—Oil, priming, blue lead. The formula is given in table 6. Armstrong Paint and Varnish Works' "No. 1506."

Asphalt emulsion.—Brushing consistency. The formula is given in table 4. Armstrong Paint and Varnish Works' "XA–1696."

Wood.

Oak, red, plain, clear, tongue-and-grooved, end-matched.

Pine, shortleaf, yellow, No. 1 common, finished four sides.

Screw nails.—Heavy-duty, 1½ in. long, No. 6, 8 threads per in., quadruple thread, flat head, needle point, made from SAE 1315 (high side) steel, water-quenched from 1,750° F, and plated with cadmium about 0.0001 in. thick. Hillwood Manufacturing Co.'s "Helyx Drive Screw Nails."

Flooring nails.—5d, cement coated.

(*b*) *Description*

The floor specimens were 14 ft 6 in. long, 4 ft 0 in. wide, and 5⁵⁄₁₆ in. thick. Each specimen consisted of four interlocked sheet-steel "Steelox" panels, *A*, as shown in figure 18, fastened to sheet-steel end members, *B*, by bolts. The panels formed the lower face and joists. The panels were covered with one coat of paint applied by spraying. The sides of the flanges of the panels which were in contact after assembly were covered with paint applied with a brush before assembly. The inside of the assembled panels was covered with one coat of asphalt emulsion applied with a brush after assembly. Wood sleepers, *C*, were fastened to the joists by screw nails and a wood-finish floor, *D*, was fastened to the sleepers by flooring nails.

The price of this construction was $0.48/ft².

Panels.—The panels, *A*, were channels, 1 ft 0 in. by 4 in., 14 ft 5 ²⁵⁄₃₂ in. long, formed from black sheet steel, No. 18 United States Standard Gage (0.049 in. thick). The edges of the flanges of each panel were formed to interlock with the flanges of adjacent panels. The flanges when interlocked formed joists of two thicknesses of steel, integral with the lower face.

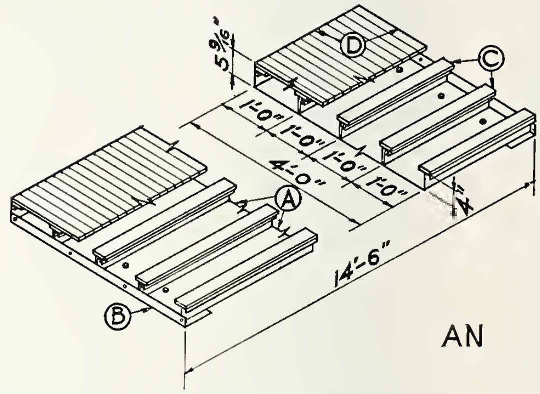

Figure 18.—*Floor specimen AN.*

A, panel; *B*, end member; *C*, sleeper; *D*, finish floor.

End members.—The end members, *B*, were angles, 6⅝ by 2⅜ in., 4 ft 1 in. long, formed from galvanized sheet steel, No. 12 United States Standard Gage (0.1072 in. thick before galvanizing). The horizontal 6⅝-in. legs were fastened to the panels by bolts, spaced 4 in. on centers. The vertical legs had ⅜-in. diam holes, spaced 1 ft 4 in. on centers, for hook-bolt connections to the sill.

Sleepers.—The sleepers, *C*, were pine, ²⁵⁄₃₂ by 2⅝ in. (nominal 1 by 3 in.), 14 ft 6 in. long, fastened to the joists by screw nails, spaced about 1 ft 6 in. on centers.

Finish floor.—The finish floor, *D*, was oak, $^{25}/_{32}$ by $2\frac{1}{4}$ in. (nominal $^{13}/_{16}$ by $2\frac{1}{4}$ in.), fastened to the sleepers by blind nailing with flooring nails, one at each sleeper.

(*c*) *Comments*

The standard width of "Steelox" floor panels is 1 ft 0 in., but panels having other widths can be supplied.

In the building, the end members to which the floor panels are fastened rest on part of the felt strip under the sill. The vertical legs of the end members are fastened to the studs of the wall panels and to the sill by hook bolts, one at each stud.

The finish floor may be yellow pine, oak, or maple. The lower faces of the floor panels form the ceiling when there is a room below and may be finished with paint or wallpaper.

2. Transverse Load

The results for floor specimens *AN–T1*, *T2*, and *T3* are shown in table 11 and in figure 19.

Table 11.—*Structural properties of floor AN*

[Weight, 8.03 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*		189
		T2		193
		T3		188
	Average			190
				lb
Concentrated	Upper face	*P1*		[a] 1,000
		P2		[a] 1,000
		P3		[a] 1,000
	Average			[a] 1,000
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 joists at or between the loading rollers and transverse movement of the finish floor with respect to the lower face. The angle between the joists and the lower face, originally 90°, decreased to about 70°.

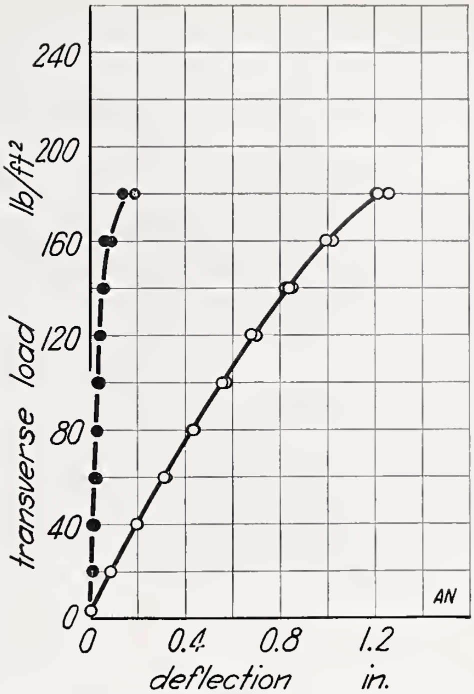

Figure 19.—*Transverse load on floor AN.*

Load-deflection and load-set results for specimens *AN–T1*, *T2*, and *T3* on the span 12 ft 0 in.

3. Concentrated Load

The results for floor specimens *AN–P1*, *P2*, and *P3* are shown in table 11 and in figure 20.

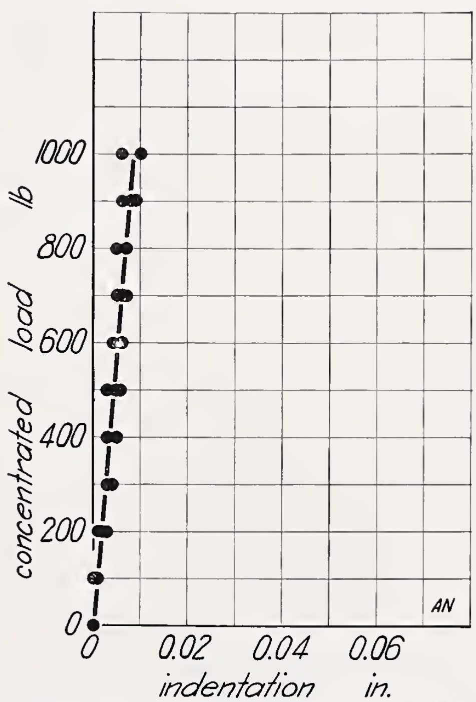

Figure 20.—*Concentrated load on floor AN.*

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

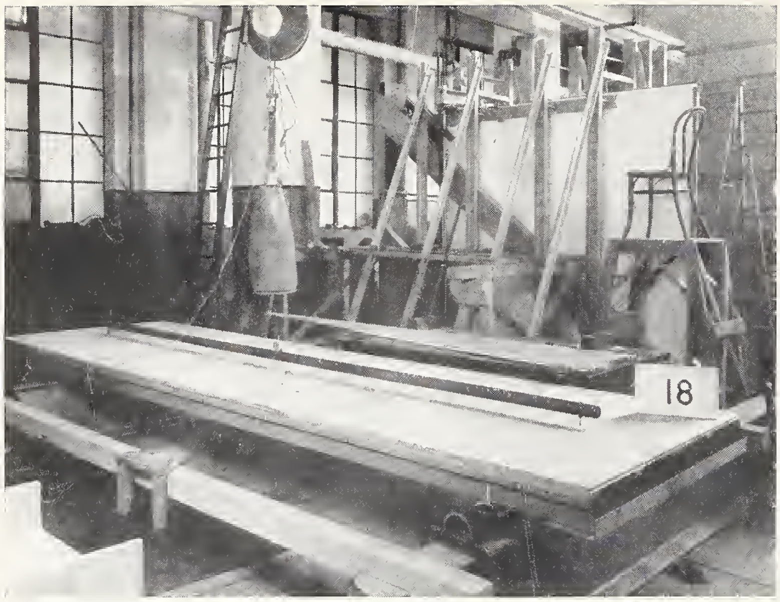

FIGURE 21.—*Floor specimen AN–I1 during the impact test.*

The indentations after a load of 1,000 lb had been applied were 0.010, 0.010, and 0.006 in. for specimens *P1*, *P2*, and *P3*, respectively, and no other effect was observed.

4. IMPACT LOAD

Floor specimen *AN–I1* during the impact test is shown in figure 21. The results for floor specimens *AN–I1*, *I2*, and *I3* are shown in table 11 and in figure 22.

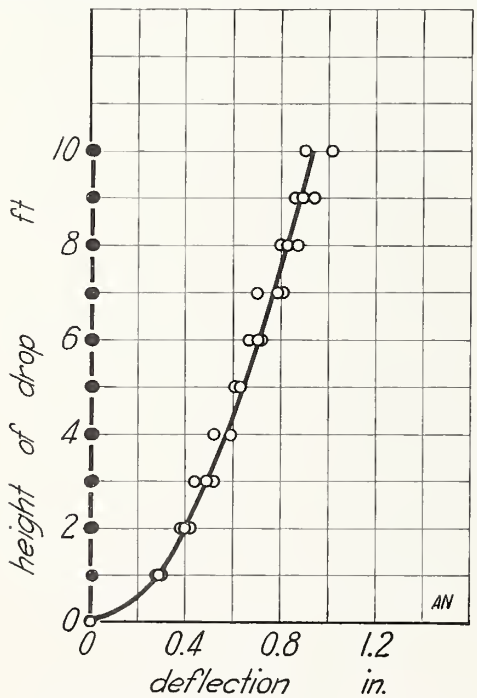

FIGURE 22.—*Impact load on floor AN.*

Height of drop-deflection and height of drop-set results for specimens *AN-I1*, *I2*, and *I3* on the span 12 ft 0 in.

The sets after a drop of 10 ft were 0.016, 0.007, and 0.006 in. for specimens *I1*, *I2*, and *I3*, respectively, and no other effect was observed.

VII. ROOF *AO*

1. SPONSOR'S STATEMENT

(*a*) *Materials*

Steel.—Hot-rolled sheets, hot-dip galvanized and prepared for paint by the "Paint Grip" process. The chemical composition of the steel is given in table 2 and the average mechanical properties in table 3. American Rolling Mill Co.'s "Armco."

The sheets were galvanized with Prime Western zinc complying with ASTM Standard B6–37 and having a maximum of 1.60 percent of lead and 0.08 percent of iron. The weight of the zinc coating was 1.25 to 1.50 oz/ft^2 for the 20-gage sheets and 1.75 to 2.00 oz/ft^2 for the 12-gage sheets.

The galvanized sheets were prepared for paint by the "Paint Grip" process according to the following specification:

"All galvanized sheets and members shall be phosphated by immersion in a solution containing free phosphoric acid, an oxidizing agent (nitrate), and iron and zinc phosphate. After this treatment the articles shall be thoroughly rinsed in clear water."

Bolts.—Stove, ¼-in. diam, 20 threads per in., ½ in. long, round head, made from SAE 1010 steel, not heat-treated, and plated with cadmium not less than 0.0002 in. thick. Lamson & Sessions Co.

Asphalt emulsion.—Brushing consistency. The formula is given in table 4. Armstrong Paint and Varnish Works' "XA-1696."

Wood.—Pine, shortleaf, yellow, No. 1 common, finished four sides.

Screw nails.—Heavy-duty, 1½ in. long, No. 6, 8 threads per in., quadruple thread, flat head, needle point, made from SAE 1315 (high side) steel, water-quenched from 1,750° F, and plated with cadmium about 0.0001 in. thick. Hillwood Manufacturing Co.'s "Helyx Drive Screw Nails."

Insulating board.—Wood-fiber, ¾ in. thick. Insulite Co.'s "Bildrite Sheathing."

Box nails.—4d, 1½ in. long.

Roofing felt.—Rag base, saturated with asphalt. Logan-Long Co.

Asphalt.—Softening point 180° F. Logan-Long Co.

Paint.

Oil, priming, blue lead. The formula is given in table 6. Armstrong Paint and Varnish Works' "No. 1506."

Casein, finish. United States Gypsum Co.'s "Texolite."

(*b*) *Description*

The roof specimens were 14 ft 6 in. long, 4 ft 0 in. wide, and 4⅞ in. thick. Each specimen consisted of three interlocked sheet-steel "Steelox" panels, *A*, as shown in figure 23, fastened to sheet-steel end members, *B*, by bolts. The panels formed the lower face and joists. The sides of the flanges of the panels which were in contact after assembly were covered with oil paint applied with a brush before assembly. The inside of the assembled panels was covered with one coat of asphalt emulsion applied with a brush. Wood furring strips, *C*, were fastened to the joists by screw nails, and insulation, *D*, was fastened to the furring strips by box nails. The insulation was covered by a built-up roofing, *E*, laid in asphalt. The lower face of the specimen was covered with casein paint.

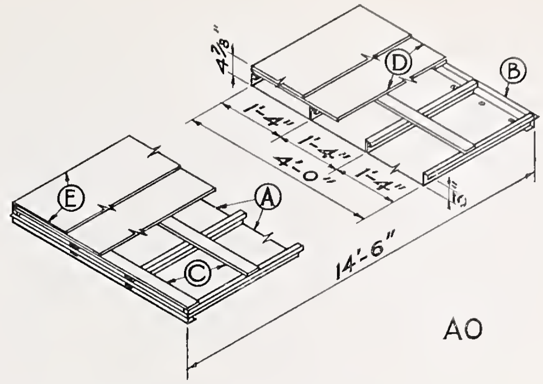

FIGURE 23.—*Roof specimen AO.*

A, panel; *B*, end member; *C*, furring strip; *D*, insulation; *E*, built-up roofing.

The price of this construction was \$0.52/ft².

Panels.—The panels, *A*, were channels, 1 ft 4 in. by 3 in., 14 ft 5²⁵⁄₃₂ in. long, formed from stretcher-leveled and resquared sheet-steel, No. 20 United States Standard Gage (0.0368 in. thick before galvanizing). The edges of the flanges of each panel were formed to interlock with the flanges of adjacent panels. The flanges when interlocked formed joists of two thicknesses of steel, integral with the lower face.

End members.—The end members, *B*, were zees, 1 by 2¼ by 2⅛ in., 4 ft 1 in. long, formed from sheet steel, No. 12 United States Standard Gage (0.1072 in. thick before galvanizing). The vertical webs had slots, 2 by 7⁄16 in., spaced 1 ft 4 in. on centers, for hook-bolt connections to wall panels. The 2⅛-in. flanges were fastened to the panels by bolts, spaced 8 in. on centers.

Furring strips.—The furring strips, *C*, were pine, 25⁄32 by 2⅝ in. (nominal 1 by 3 in.), 4 ft 1 in. long, spaced about 1 ft 6 in. on centers, and fastened to the joists by screw nails, one at each joist.

Insulation.—The insulation, *D*, was insulating board, ¾ in. thick, fastened to the furring strips by box nails, spaced about 1 ft 4 in. on centers.

Built-up roofing.—The built-up roofing, *E*, consisted of three plys of roofing felt, each laid in and covered with asphalt applied by mopping. There was one 30 lb/108 ² ft ply and two 15 lb/108 ft² plys.

(c) Comments

For flat roofs, the roof panels are supported by the end members which are fastened to the studs of the wall panels by hook bolts, one at each stud, the upper flanges of the end members fitting into slots cut in the studs. The insulation and built-up roofing cover the inside of the parapet formed by the wall extending above the roof line. A sheet-steel coping covers the top of the parapet and the edge of the roofing. If there is no parapet, a galvanized cross flashing under the roofing is formed by the apron of the sheet-metal hanging gutter. The lower faces of the roof panels form the ceiling of the room below and may be finished with paint or wallpaper.

For sloping roofs, the steel panels are similar to those for flat roofs, but no insulation or built-up roofing is applied over them. The panels are supported at the eaves by a formed sheet-steel section which rests on the wall plate and is fastened to the studs by hook bolts. The roof panels are fastened with S-shaped sheet-steel clips. The panels are connected to the ridge by a built-up sheet-steel ridge member with flanges on which the panels bear. These flanges are covered with 65-lb roofing felt. Over this is applied calking material into which the panels are embedded. The portions of the roof panels that are in contact after assembly are painted with blue-lead paint before assembly. A sheet-steel ridge cap covers the ridge and is fastened to the roof panels by screws. The upper face of the roof is covered with two coats of roofing paint. The lower face is covered with one coat of asphalt emulsion.

For sloping roofs, the ceiling joists are wood, supported by a flange of the sheet-steel member which supports the roof panels, and fastened to it by nails passing through holes in the flange. Insulating board, ¾ in. thick, is fastened by nails to the top of the joists and ½-in. insulating board to the bottom. Loose rock-wool insulation is used between the joists around the perimeter of the building. The lower board forms the ceiling and may be finished with paint.

2. Transverse Load

Roof specimen *AO–T2* under transverse load is shown in figure 24. The results for roof specimens *AO–T1*, *T2*, and *T3* are shown in table 12 and in figure 25.

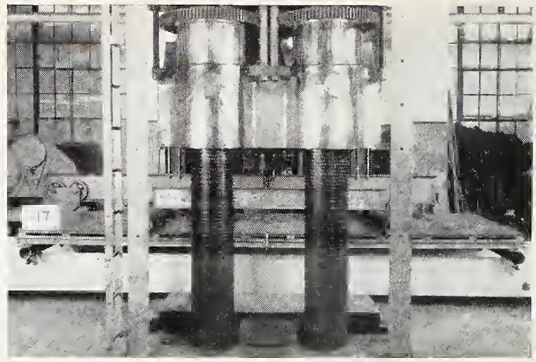

Figure 24.—*Roof specimen AO–T2 under transverse load.*

Table 12.—*Structural properties of roof AO*

[Weight, 6.99 lb/ft²]

Load	Load applied	Specimen designation	Maximum load
			lb/ft²
Transverse	Upper face; span 14 ft 0 in.	*T1*	57
		T2	56
		T3	57
	Average		57
			lb
Concentrated	Upper face	*P1*	445
		P2	425
		P3	455
	Average		442

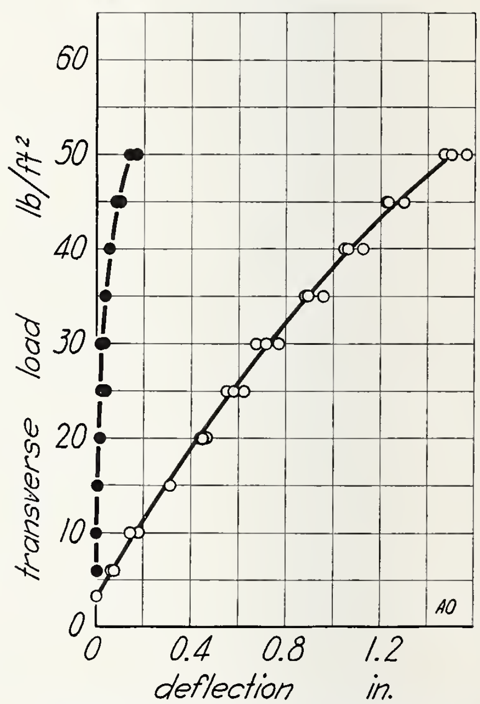

Figure 25.—*Transverse load on roof AO.*

Load-deflection and load-set results for specimens *AO–T1*, *T2*, and *T3* on the span 14 ft 0 in.

Specimens *T1* and *T2* failed by buckling of the joists near midspan. Specimen *T3* failed by buckling of the joists under one of the loading rollers.

3. Concentrated Load

The results for roof specimens *AO–P1*, *P2*, and *P3* are shown in table 12 and in figure 26.

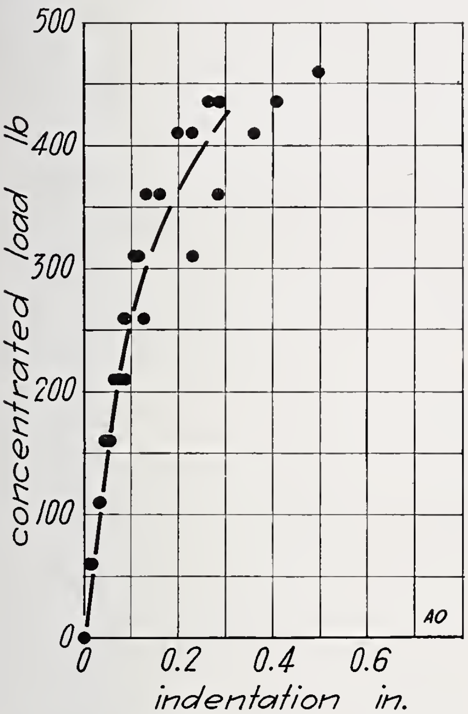

Figure 26.—*Concentrated load on roof AO.*

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

Each of the specimens failed by punching of the disk through the built-up roofing and insulation.

VIII. ADDITIONAL COMMENTS BY SPONSOR

Approximately 350 houses using these constructions were completed or under construction July 1, 1938.

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.

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 Bureau's 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.

IX. SELECTED REFERENCES

Architectural Record **78,** No. 2, 125 (1935).
Architectural Forum **63,** 567 (1935).
American Architect **149,** No. 2649, 39 (1936).

Washington, August 4, 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.

SUBJECTS OF BUREAU ACTIVITIES

Electricity
- Resistance Measurements
- Inductance and Capacitance
- Electrical Instruments
- Magnetic Measurements
- Photometry
- Radio
- Underground Corrosion
- Electrochemistry
- Telephone Standards

Weights and Measures
- Length
- Mass
- Time
- Capacity and Density
- Gas Measuring Instruments
- Thermal Expansivity, Dental Materials, and Identification
- Weights and Measures Laws and Administration.
- Large-Capacity Scale Testing
- Limit Gages

Heat and Power
- Thermometry
- Pyrometry
- Heat Measurements
- Heat Transfer
- Cryogenics
- Fire Resistance
- Automotive Power Plants
- Lubrication and Liquid Fuels

Optics
- Spectroscopy
- Polarimetry
- Colorimetry and Spectrophotometry
- Optical Instruments
- Radiometry
- Atomic Physics, Radium, and X-Rays
- Photographic Technology
- Interferometry

Chemistry
- Paints, Varnishes, and Bituminous Materials
- Detergents, Cements, Corrosion, Etc.

Chemistry—Continued
- Organic Chemistry
- Metal and Ore Analysis, and Standard Samples
- Reagents and Platinum Metals
- Electrochemistry (Plating)
- Gas Chemistry
- Physical Chemistry
- Thermochemistry and Constitution of Petroleum

Mechanics and Sound
- Engineering Instruments and Mechanical Appliances
- Sound
- Aeronautic Instruments
- Aerodynamics
- Engineering Mechanics
- Hydraulics

Organic and Fibrous Materials
- Rubber
- Textiles
- Paper
- Leather
- Testing and Specifications
- Fiber Structure
- Organic Plastics

Metallurgy
- Optical Metallurgy
- Thermal Metallurgy
- Mechanical Metallurgy
- Chemical Metallurgy
- Experimental Foundry

Clay and Silicate Products
- Whiteware
- Glass
- Refractories
- Enameled Metals
- 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
- Wood, Wood Products, Paper, Leather, and Rubber
- Metal Products
- 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