U. S. DEPARTMENT OF COMMERCE

BUILDING MATERIALS AND STRUCTURES

REPORT BMS20

Structural Properties of "Twachtman" Constructions for Walls and Floors Sponsored by Connecticut Pre-Cast Buildings Corporation

by

HERBERT L. WHITTEMORE
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DOUGLAS E. PARSONS

NATIONAL BUREAU OF STANDARDS

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

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Foreword

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 description given in each report. The Bureau is responsible for 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 later to determine 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 the 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.*

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ABSTRACT

For the program on the determination of the structural properties of low-cost house constructions the Connecticut Pre-Cast Buildings Corporation submitted 24 specimens representing "Twachtman" precast hollow reinforced-concrete constructions for walls and floors.

The wall specimens were subjected to compressive, transverse, concentrated, impact, and racking loads; and the floor specimens to transverse, concentrated, and impact 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, except for concentrated loads, for which the set only was determined. The results are presented in graphs 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, and that part of the program relating to structural properties in report BMS2, Methods of Determining the Structural Properties of Low-Cost House Constructions.

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 occupants, wind load on adjoining second-story walls, 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. 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.

The deformation and set under each increment of load were measured because the suitability of a wall or floor construction depends in part on its resistance to deformation under load and whether it returns to its original size and shape when the load is removed.

II. SPONSOR AND PRODUCT

The specimens were submitted by the Connecticut Pre-Cast Buildings Corporation, Irvington, N. Y., and represented a wall and a floor construction marketed under the trade name "Twachtman." The specimens were manufactured by the Richmond Ready Mix Concrete Corporation, Richmond, Va., one of the companies licensed to manufacture "Twachtman" constructions. These constructions consisted of precast hollow reinforced-concrete wall and floor panels designed to be erected on masonry foundations by the use of crane trucks.

III. SPECIMENS AND TESTS

The specimens represented two elements of a house which were assigned the following symbols: wall *AR* and floor *AS*. The specimens were assigned designations in accordance with table 1.

TABLE 1.—*Specimen designations*

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

[a] These specimens were undamaged portions of the transverse specimens.

The specimens were tested in accordance with BMS2, Methods of Determining the Structural Properties of Low-Cost House Constructions, which also gives the requirements for the specimens and describes the presentation of the results of the tests, particularly the load-deformation graphs.

The tests were begun March 14, 1938, and completed March 23, 1938. The specimens were tested 28 days after they were built. The sponsor's representative witnessed the tests.

IV. WALL *AR*

1. SPONSOR'S STATEMENT

(*a*) *Materials*

Cement.—Portland, high-early-strength. Lehigh Portland Cement Co.'s "Hi-Early."

Slag.—Blast-furnace, water-cooled, and crushed, passed ½-in. sieve and retained on No. 100 sieve; weight 50 to 55 lb/ft ^{3}. The Pottsco Corporation's "Pottsco."

Mortar.—One part of cement to 5 parts of slag (passed No. 4 sieve), by weight.

Concrete.—One part of cement and 3.3 parts of slag, by weight.

Welded wire fabric.—Steel wire, No. 13 gage (0.0915-in. diam), electrically welded in a 4-by 4-in. mesh, complying with the American Society for Testing Materials Standard A 185–37. American Steel and Wire Co.

Metal lath.—Flat, expanded metal, formed from open-hearth sheet steel, coated with paint; weight 3.4 lb/yd ^{2}. Truscon Steel Corporation.

Reinforcement bars.—Steel, structural, billet, open-hearth, deformed, round. Specified mechanical properties: tensile strength, 70,000 to

80,000 lb/in.^{2}; yield point, 40,000 lb/in.^{2}; elongation in 8 in., minimum, percent, 1,125,000/tensile strength.

Wire.—Steel, black, No. 18 gage (0.0475-in. diam).

(*b*) *Description*

(1) *Four-foot wall specimens.*—The 4-ft wall specimens were 8 ft 0 in. high, 4 ft 6 in. wide, and 6 in. thick. Each specimen was a hollow reinforced-concrete slab having faces 1 in. thick and four studs integral with the faces. The specimens were cast in a horizontal position with the inside face down. Mortar was spread to a depth of ½ in., welded wire fabric, *A*, shown in figure 1, placed on the mortar, and before the mortar had set, concrete was placed over the fabric to a depth of ½ in., completing the inside face. A metal-lath form, *B*, with the reinforcement and hooks fastened in their proper relative positions by wire, was placed on the fresh concrete. The reinforcement consisted of vertical reinforcement, *C*, for each stud, lateral reinforcement, *D*, for the outside face, and end reinforcement, *E*, at each end. Eyes, *F*, were fastened to the upper ends of the reinforcement for the two inner studs. Concrete for the studs and outside face was placed in the form, compacted by vibrators, and leveled to a depth of ½ in. above the top of the metal lath. The outside face was finished with mortar, ½ in. deep, placed on the fresh concrete, screeded, and troweled smooth.

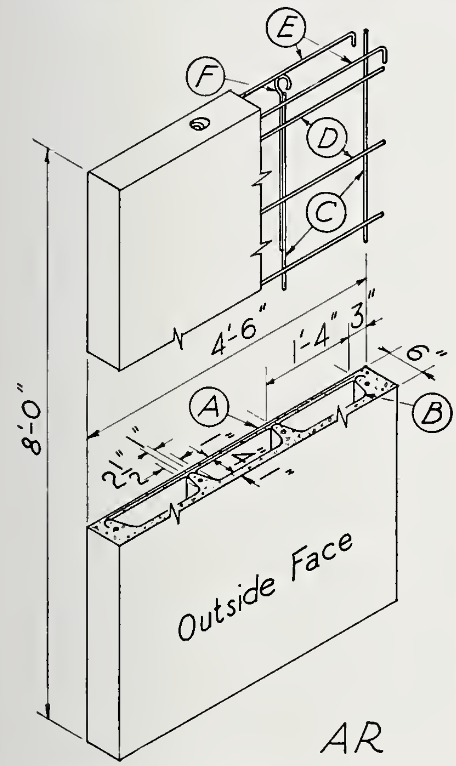

FIGURE 1.—*Four-foot wall specimen AR.*

A, welded wire fabric; *B*, metal-lath form; *C*, vertical reinforcement; *D*, lateral reinforcement; *E*, end reinforcement; *F*, eye.

The price of this construction in Washington, D. C., as of July 1937, was \$0.33/ft^2.

Welded wire fabric.—The welded wire fabric, *A*, was one sheet 7 ft 10 in. by 4 ft 0 in.

Metal-lath form.—The metal-lath form, *B*, consisted of four strips 6 ft 0 in. by 2 ft 0 in., and one strip 6 ft 0 in. by 1 ft 0 in. The length of the strips was at right angles to the length of the specimen. The strips overlapped about 2 in. and were shaped by dies to the form of the studs.

Vertical reinforcement.—The vertical reinforcement, *C*, consisted of one ⅜-in. diam reinforcement bar, 7 ft 6 in. long, in each stud, at midthickness.

Lateral reinforcement.—The lateral reinforcement, *D*, consisted of eight ¼-in. diam reinforcement bars, 4 ft 2 in. long, spaced 1 ft 0 in. on centers, and ½ in. below the outside face.

End reinforcement.—The reinforcement, *E*, at each end consisted of two ½-in. diam reinforcement bars, 4 ft 8 in. long, having 3-in. right-angle bends at each end. The bars were spaced about 5 in. on centers and about 1 in. from the ends of the specimen.

Eyes.—There were two lifting eyes, *F*, at the upper end of each specimen. The eyes were ½-in. diam reinforcement bars, 3 ft 0 in. long, with one end bent to a ring, 3 in. diam. Each eye was in a recess in the end of the specimen.

(2) *Eight-foot wall specimens.*—The 8-ft wall specimens were 8 ft 0 in. high, 8 ft 6 in. wide, and 6 in. thick. The specimens were similar to the 4-ft specimens. Each specimen had a stud at each edge and five intermediate studs, spaced 1 ft 4 in. on centers.

(*c*) *Comments*

The wall panels are cast in adjustable steel forms which provide a smooth inside face complete with trim. Window frames, door hinges, registers, and other hardware are placed in the forms and cast integrally with the panels. The panels are made full-story height and usually the width is the width of the room. When erected, the panels rest on the floor panels and are fastened to the floor panels and to adjacent wall panels. At corners, the edges of the panels are beveled 2 in. back from the inside face to form the joint. The panels are fastened by means of ½-in. diam reinforcement bars which project 4 in. from the edges of the panels near the upper and lower ends. The bars overlap when the panels are in position and are fastened by ⅝-in. cable clamps. The outside of the corner is formed by concrete, cast in a steel form. Intermediate joints usually occur at partitions, in which case, the inside faces of adjacent wall panels are each recessed ⅞ by 3 in. for the story height, the outside face is recessed 2 by 2 by 4 in. at the top and bottom, and the wall panels are then placed with a ¾-in. space between the edges. The edge of the partition panel, which is similar to the wall panels, fits into the inside recess in the wall panels and is fastened by two ½-in. bolts which project 4¾in. from the edge of the partition and extend through the space between the wall panels. One bolt is near the upper end and one near the lower end. Each bolt engages a 4- by 4- by ½-in. steel plate set in the outside recesses of the wall panels and is fastened with a nut. The joint and recesses are filled with cement mortar and finished smooth.

When joints occur where there is no partition, the edges of the panels are keyed together with concrete. A recess, 3½ by 2 in., is formed in the edge of each panel. The panels are placed with a ¾-in. space between the edges, and the recesses and joint filled with concrete.

Paint or other decorative finish may be applied directly to the panels. Lap siding, brick veneer, and other finishes may be used. Wood finishes are fastened by hardened steel nails.

2. Compressive Load

Wall specimen *AR–C1* under compressive load is shown in figure 2. The results for wall specimens *AR–C1*, *C2*, and *C3* are shown in table 2 and in figures 3 and 4.

The shortenings and sets shown in figure 3 for a height of 8 ft were computed from the values obtained from the compressometer readings. The gage length of the compressometers was 7 ft 6 in.

Specimens *C1* and *C3* failed by crushing of the upper ends of the specimens, cracking of the outside faces transversely (across the specimens) near the upper ends, and cracking ver-

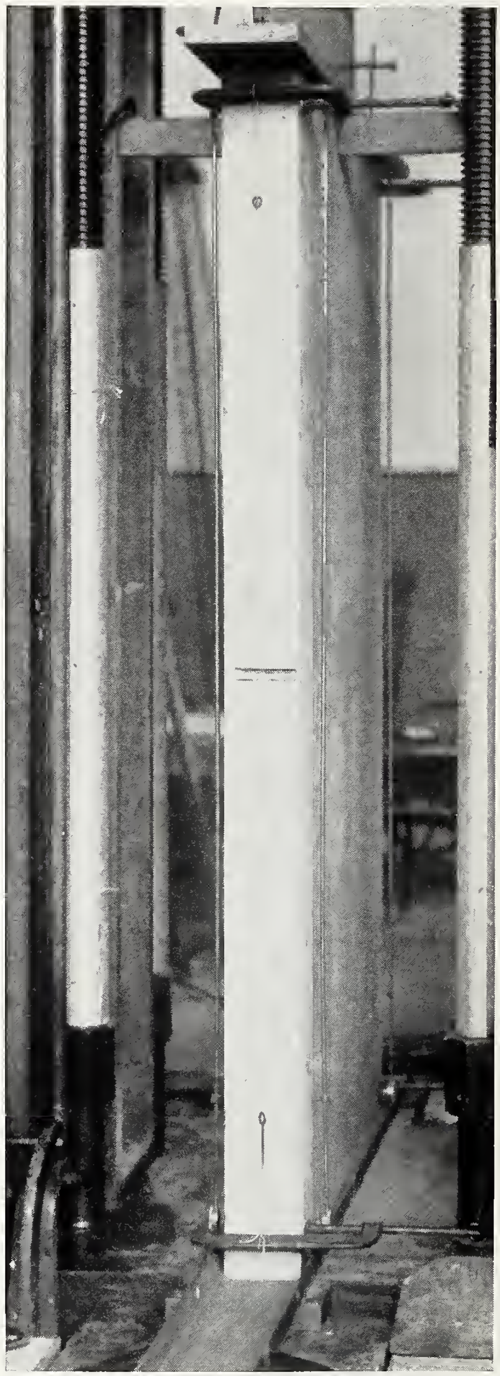

Figure 2.—*Wall specimen AR–C1 under compressive load.*

tically at the edges near the upper ends. Specimen *C2* failed by crushing of the lower end.

TABLE 2.—*Structural properties, wall AR*
[Weight, 36.8 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*	[a] *Kips/ft*
Compressive	Upper end, 2 in. from the inside face	*C1*				72.0
		C2				79.3
		C3				88.7
	Average					80.0
						lb/ft²
Transverse	Inside face; span, 7 ft 6 in	*T1*				172
		T2				130
		T3				110
	Average					137
Do	Outside face; span, 7 ft 6 in	*T4*				350
		T5				391
		T6				380
	Average					374
						lb
Concentrated	Inside face	*P1*				[b] 1,000
		P2				[b] 1,000
		P3				[b] 1,000
	Average					[b] 1,000
Do	Outside face	*P4*				[b] 1,000
		P5				[b] 1,000
		P6				[b] 1,000
	Average					[b] 1,000
Impact	Inside face; span, 7 ft 6 in	*I1*	9.5	5.0	9.5	
		I2	10.0	4.0	10.0	
		I3	8.5	3.0	10.0	
	Average		9.3	4.0	9.8	
Do	Outside face; span, 7 ft 6 in	*I4*			[b] 10.0	
		I5			[b] 10.0	
		I6			[b] 10.0	
	Average				[b] 10.0	
						[a] *Kips/ft*
Racking	Near upper end	*R1*				[b] 5.88
		R2				[b] 5.88
		R3				[b] 5.88
	Average					[b] 5.88

[a] A kip is 1,000 lb.
[b] Specimen did not fail. Test discontinued.

3. TRANSVERSE LOAD

The results are shown in table 2 and in figure 5 for wall specimens *AR–T1*, *T2*, and *T3*, loaded on the inside face, and in figure 6 for wall specimens *AR–T4*, *T5*, and *T6*, loaded on the outside face.

The transverse loads were applied with the specimens in a horizontal position. The initial deflection and set readings shown in figures 5 and 6 were taken under a load of about 48 lb/ft² caused by the weight of the specimens

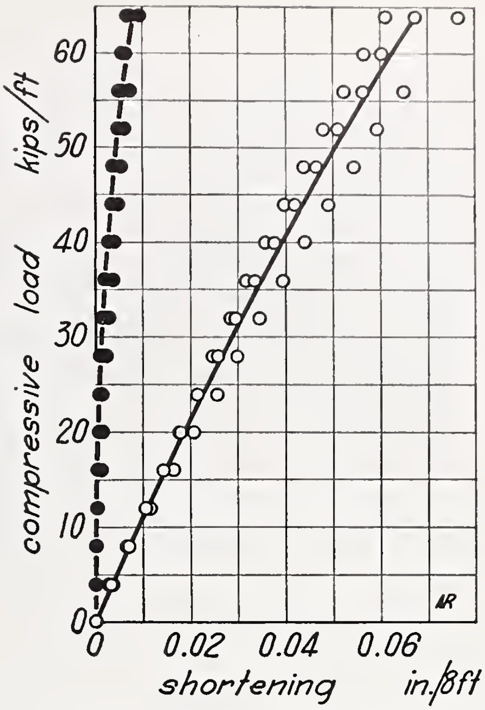

FIGURE 3.—*Compressive load on wall AR.*

Load-shortening (open circles) and load-set (solid circles) results for specimens *AR–C1*, *C2*, and *C3*. The load was applied 2 in. from the inside face. The loads are in kips per foot of actual width of specimen.

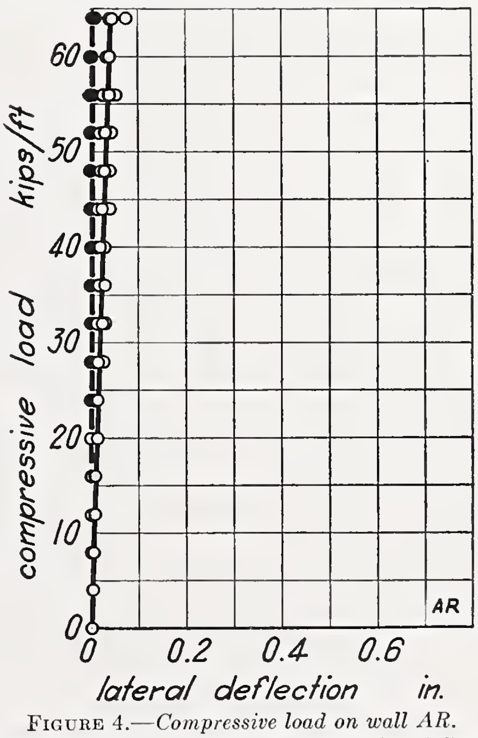

FIGURE 4.—*Compressive load on wall AR.*

Load-lateral deflection (open circles) and load-lateral set (solid circles) results for specimens *AR–C1*, *C2*, and *C3*. The load was applied 2 in. 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 ft 6 in., the gage length of the deflectometers.

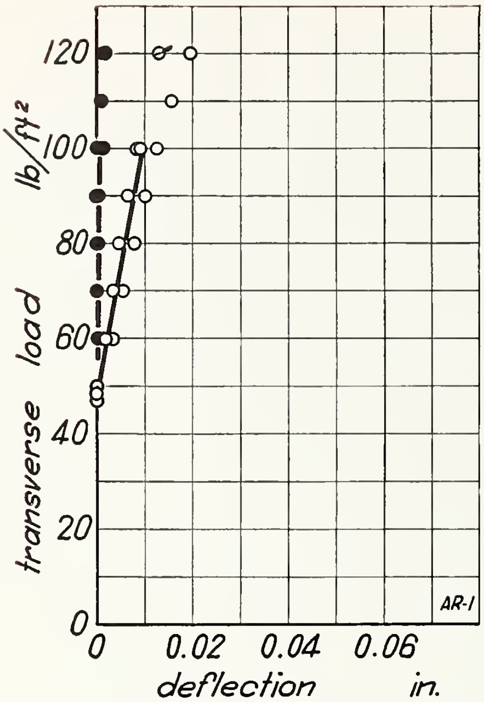

FIGURE 5.—*Transverse load on wall AR, load applied to inside face.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *AR–T1, T2,* and *T3* on the span 7 ft 6 in.

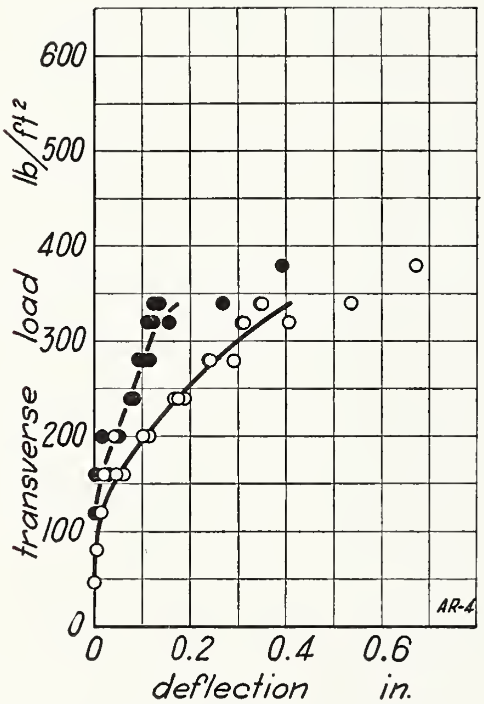

FIGURE 6.—*Transverse load on wall AR, load applied to outside face.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *AR–T4, T5,* and *T6* on the span 7 ft 6 in.

between the supporting rollers and the weight of the loading apparatus.

Specimens *T1*, *T2*, and *T3* failed by rupturing transversely (across the specimen) at or between the loading rollers.

For specimens *T4* and *T6* at loads of 260 and 240 lb/ft^2 and deflections of 0.26 and 0.17 in., respectively, the inside face of each specimen cracked transversely (across the specimen). At the maximum loads each of the specimens *T4*, *T5*, and *T6* failed by rupturing transversely (across the specimen) at or between the loading rollers.

4. Concentrated Load

The results are shown in table 2 and in figure 7 for wall specimens *AR–P1*, *P2*, and *P3*, loaded on the inside face, and in figure 8 for

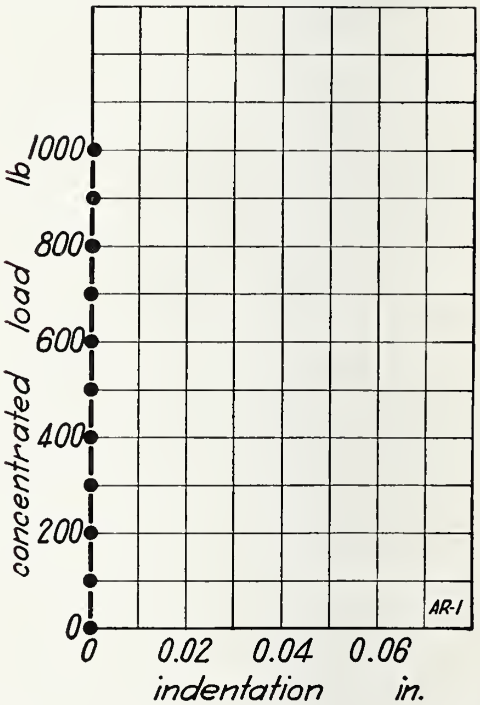

FIGURE 7.—*Concentrated load on wall AR, load applied to inside face.*

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

wall specimens *AR–P4*, *P5*, and *P6*, loaded on the outside face.

The concentrated loads were applied to the inside face of specimens *P1*, *P2*, and *P3* between two studs and about 1½ ft from one end. The indentations after a load of 1,000 lb had been applied were less than 0.001 in. for each of the specimens and no other effect was observed.

The concentrated loads were applied to the outside face of specimens *P4*, *P5*, and *P6* between two studs and at least 1½ ft from one end. The indentations after a load of 1,000 lb

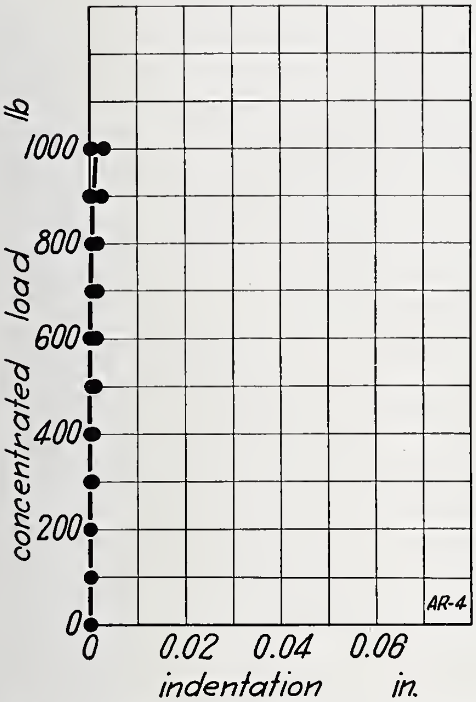

FIGURE 8.—*Concentrated load on wall AR, load applied to outside face.*

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

had been applied were 0.003, 0.000, and 0.000 in. for specimens *P4*, *P5*, and *P6*, respectively, and no other effect was observed.

5. Impact Load

The results are shown in table 2 and in figure 9 for wall specimens *AR–I1*, *I2*, and *I3*, loaded on the inside face, and in figure 10 for wall specimens *AR–I4*, *I5*, and *I6*, loaded on the outside face.

The impact loads were applied to the center of the inside face of specimens *I1*, *I2*, and *I3*, the sandbag striking midway between the two inner studs. At drops of 5, 4, and 3 ft and deflections of 0.20, 0.16, and 0.06 in. for specimens *I1*, *I2*, and *I3*, respectively, the outside face of each specimen failed by cracking transversely (across the specimen) at midspan. At drops of 8.5, 8.5, and 7.5 ft for specimens *I1*, *I2*, and *I3*, respectively, the inside face (face struck) of each

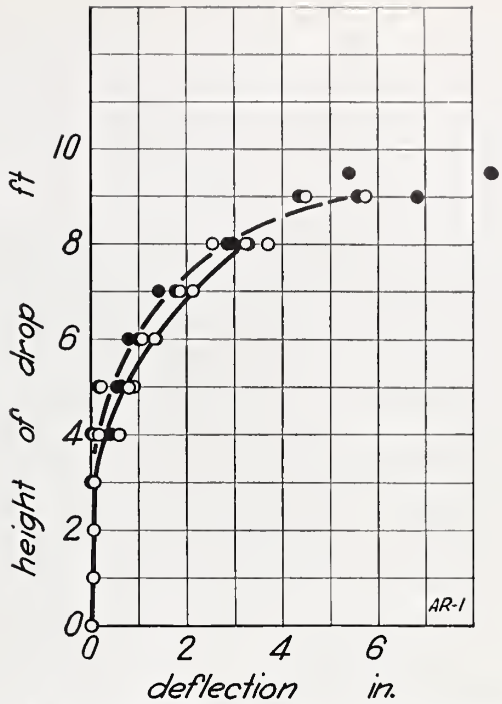

FIGURE 9.—*Impact load on wall AR, load applied to inside face.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *AR–I1, I2*, and *I3* on the span 7 ft 6 in.

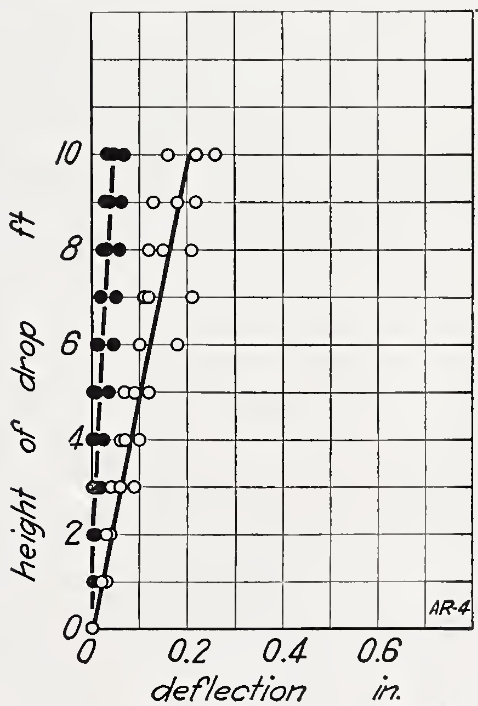

FIGURE 10.—*Impact load on wall AR, load applied to outside face.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *AR–I4, I5*, and *I6* on the span 7 ft 6 in.

specimen cracked where the sandbag struck. At the maximum drops, specimens *I1* and *I2* failed by breaking in two at midspan. For specimen *I3* at a drop of 8.5 ft the inside face (face struck) failed by rupturing of the face where the sandbag struck, and at a drop of 10 ft the specimen failed by rupturing transversely (across the specimen) at midspan.

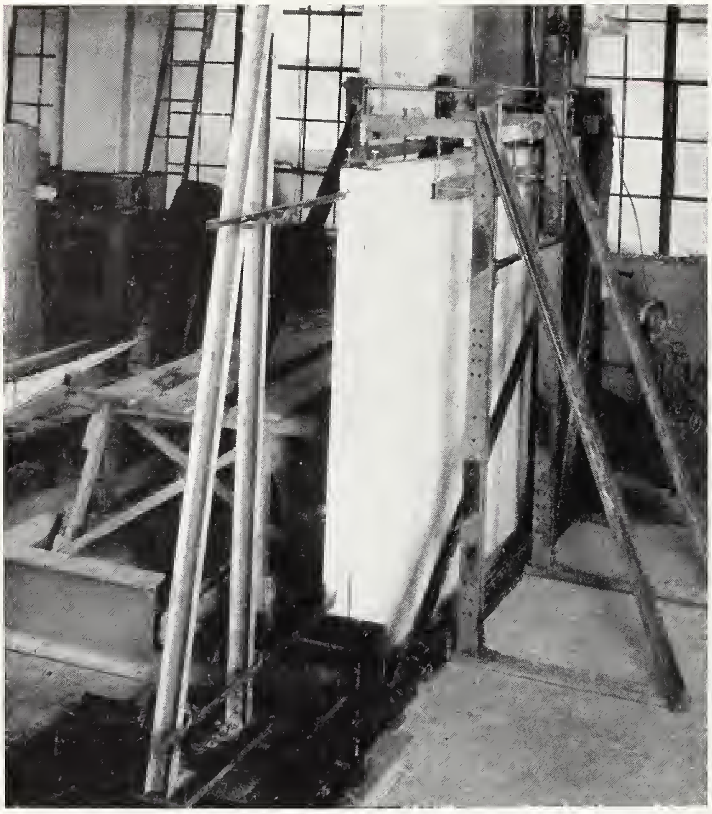

FIGURE 11.—*Wall specimen AR–R3 under racking load.*

The impact loads were applied to the center of the outside face of specimens *I4*, *I5*, and *I6*, the sandbag striking midway between the two inner studs. At drops of 5 and 5.5 ft and deflections of 0.09 and 0.08 in. for specimens *I5* and *I6*, respectively, the inside face of each specimen cracked transversely (across the specimen) near midspan. The sets after a drop of 10 ft were 0.067, 0.046, and 0.032 in. for specimens *I4*, *I5*, and *I6*, respectively, and no other effect was observed.

6. Racking Load

Wall specimen *AR–R3* under racking load is shown in figure 11.

The results for wall specimens *AR–R1*, *R2*, and *R3* are shown in table 2 and in figure 12.

The deformations and sets for a height of 8 ft, shown in figure 12, were computed from the values obtained from the measuring-device readings. The gage length of the vertical measuring device was 6 ft 3 in. The gage length of the horizontal measuring device was 5 ft 0 in. The error of observation in measuring the deformations and sets was about 0.01 in., causing some of the set readings to be negative. An error of 0.01 in. in a height of 8 ft is negligible for tests of this kind.

The sets after a load of 5.88 kips/ft had been applied were less than 0.01 in. for each of the specimens. For specimens *R1* and *R2* no other effect was observed, and for specimen *R3* only a slight crack about 1 ft long was observed near the center of the inside face.

V. FLOOR *AS*

1. Sponsor's Statement

(*a*) *Materials*

The materials for floor *AS* were the same as for wall *AR*.

(*b*) *Description*

The floor specimens were 12 ft 6 in. long, 4 ft 6 in. wide, and 6 in. thick. Each specimen was a hollow reinforced-concrete slab having faces 1 in. thick and four joists integral with the faces. The specimens were cast in a horizontal position with the lower face down. Mortar was spread to a depth of ½ in., welded wire fabric, *A*, shown in figure 13, placed on the mortar, and before the mortar had set concrete was placed over the fabric to a depth of ½ in., completing the lower face. A metal-lath form, *B*, with the reinforcement and eyes fastened in their proper relative positions by wire, was placed on the fresh concrete. The reinforcement consisted of longitudinal reinforcement, *C*, for each joist, lateral reinforcement, *D*, for the upper face, and end reinforcement, *E*, at each end. Eyes, *F*, were fastened to each end of the reinforcement for the two inner joists. Concrete for the joists and upper face was placed in the form, compacted by vibrators, and leveled to a depth of ½ in. above the top of the metal lath. The upper face was finished with mortar, ½ in. deep, placed on the fresh concrete, screeded, and troweled smooth.

The price of this construction in Washington, D. C., as of July 1937, was \$0.33 ft².

Welded wire fabric.—The welded wire fabric, *A*, was one sheet, 12 ft 4 in. by 4 ft 0 in.

Metal-lath form.—The metal-lath form, *B*, consisted of six strips of metal lath 6 ft 0 in. by 2 ft 0 in., and one strip 6 ft 0 in. by 1 ft 0 in. The length of the strips was at right angles to the length of the specimen. The strips overlapped about 2 in. and were shaped by dies to the form of the joists.

Longitudinal reinforcement.—The longitudinal reinforcement, *C*, consisted of three reinforcement bars in each joist fastened together by wire. The length of the assembled bars was 12 ft 2 in. for the two outer joists and 12 ft 0 in. for the two inner joists. The lowest bar of each assembly was a ⅜-in. diam bar with each end bent upward 2 in., and placed with its center 1¼ in. above the lower face of the specimen. A ½-in. diam bar was placed just above the lowest bar, being bent diagonally upward starting about 1 ft from each end, extending about 2 in. along the top, then bent downward for about 2 in. at the ends. The top bar was ⅜ in. diam with its ends bent downward 3¾ in. and with the center of the bar 5¼ in. above the lower face of the specimen.

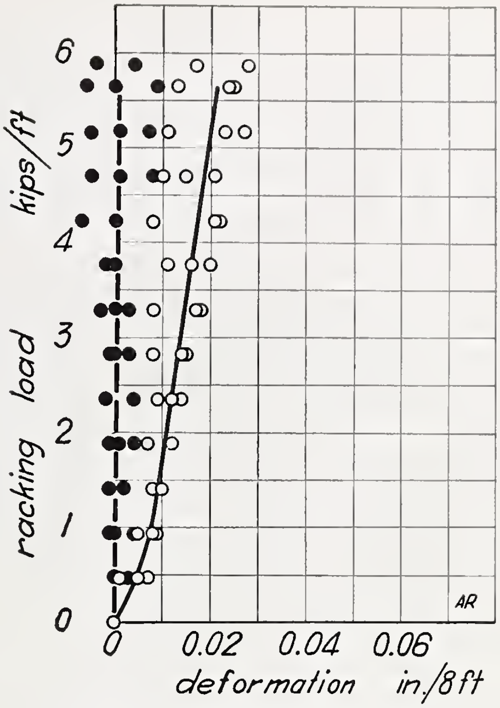

FIGURE 12.—*Racking load on wall AR.*

Load-deformation (open circles) and load-set (solid circles) results for specimens *AR-R1*, *R2*, and *R3*. The loads are in kips per foot of actual width of specimen.

Lateral reinforcement.—The lateral reinforcement, *D*, consisted of thirteen ¼-in. diam reinforcement bars, 4 ft 2 in. long, spaced 1 ft 0 in. on centers, and ½-in. below the upper face.

End reinforcement.—The reinforcement, *E*, at each end was one ⅜-in. diam bar, 4 ft 8 in. long, having a 3-in. right-angle bend at each end. The bars were at mid-thickness and about 1 in. from the ends.

Eyes.—There were two lifting eyes, *F*, at each end of the specimen. The eyes were ½-in. diam reinforcement bars, 3 ft 0 in. long, with one end bent to a ring 3 in. diam. The eyes were fastened to the reinforcement for the two inner joists by wire. Each eye was in a recess in the end of the specimen.

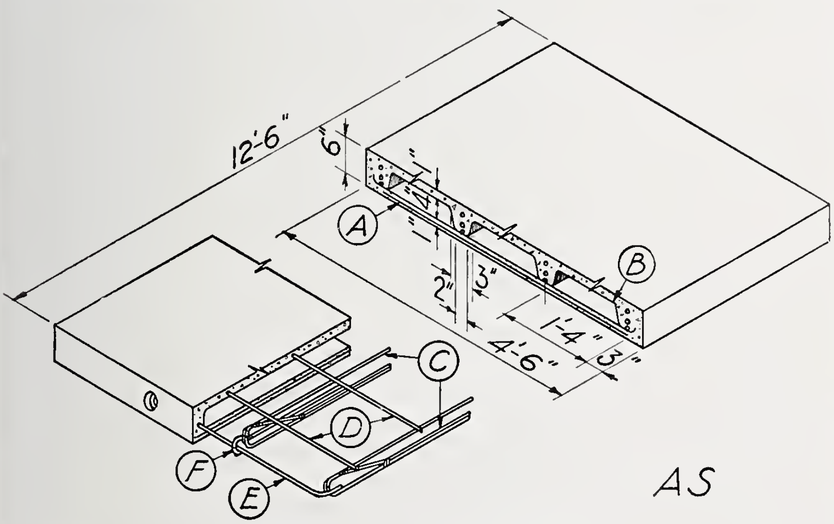

FIGURE 13.—*Floor specimen AS.*

A, welded wire fabric; *B*, metal-lath form; *C*, longitudinal reinforcement; *D*, lateral reinforcement; *E*, end reinforcement; *F*, eye.

(*c*) *Comments*

The floor panels are cast in adjustable steel forms in the same manner as the wall panels. The length of the panels usually corresponds to the length of the room and the width may be as great as 8 ft. Sleeves and boxes for piping and conduit are placed in the form and cast integrally with the panels.

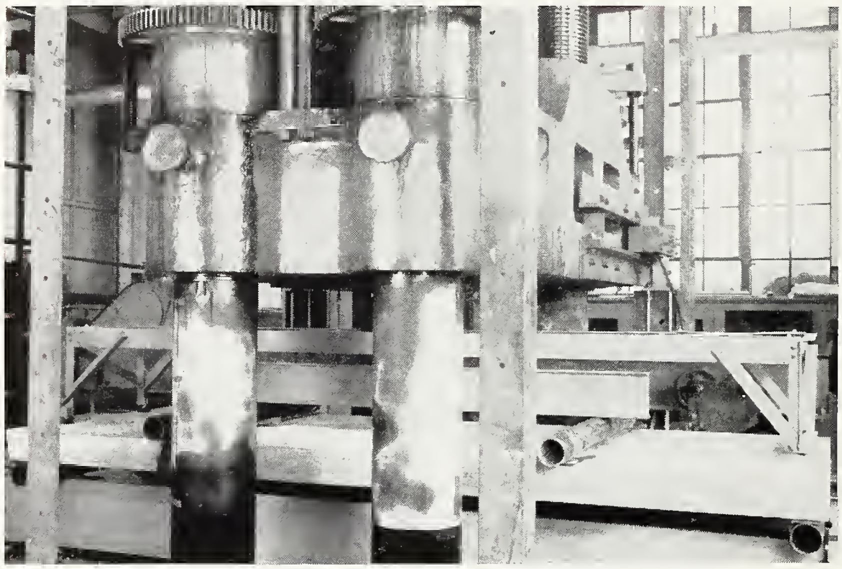

FIGURE 14.—*Floor specimen AS–T2 under transverse load.*

TABLE 3.—*Structural properties, floor AS*

[Weight, 37.7 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*		236
		T2		211
		T3		240
	Average			229
				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. Test discontinued.

The panels are placed directly on the foundation walls, which have first been leveled with cement mortar. After the panels are placed, the exposed ends and sides are finished flush with the wall panels with a ¾-in. coat of mortar.

The finish floor may be wood block, tile, or linoleum cemented to the panels; or wood flooring may be laid on wood sleepers.

2. Transverse Load

Floor specimen *AS–T2* under transverse load is shown in figure 14.

The results for floor specimens *AS–T1*, *T2*, and *T3* are shown in table 3 and in figure 15.

For each of the specimens the lower face cracked transversely across the specimen at several places between the loading rollers. The first cracks occurred at loads of 120, 100, and 60 lb/ft² and deflections of 0.45, 0.43, and 0.19 in. for specimens *T1*, *T2*, and *T3*, respectively. At the maximum loads each of the specimens failed by rupturing transversely (across the specimen) at one or more places between the loading rollers.

3. Concentrated Load

Floor specimen *AS–P1* under concentrated load is shown in figure 16.

The results for floor specimens *AS–P1*, *P2*, and *P3* are shown in table 3 and in figure 17.

The concentrated loads were applied to the upper face of each specimen between two studs and about midlength. The indentations after a load of 1,000 lb had been applied were 0.001, 0.001, and 0.000 in. for specimens *P1*, *P2*, and *P3*, respectively, and no other effect was observed.

4. Impact Load

Floor specimen *AS–I3* during the impact test is shown in figure 18. The results for floor specimens *AS–I1*, *I2*, and *I3* are shown in table 3 and in figure 19.

The impact loads were applied to the upper face of each specimen, the sandbag striking midway between the two inner studs. At drops of 5.5 and 8.5 ft and deflections of 0.24 and 0.28 in. for specimens *I1* and *I2*, respectively, the lower face of each specimen cracked transversely (across the specimen) near midspan. The sets after a drop of 10 ft were 0.108, 0.095, and 0.114 in. for specimens *I4*, *I5*, and *I6*, respectively, and no other effect was observed.

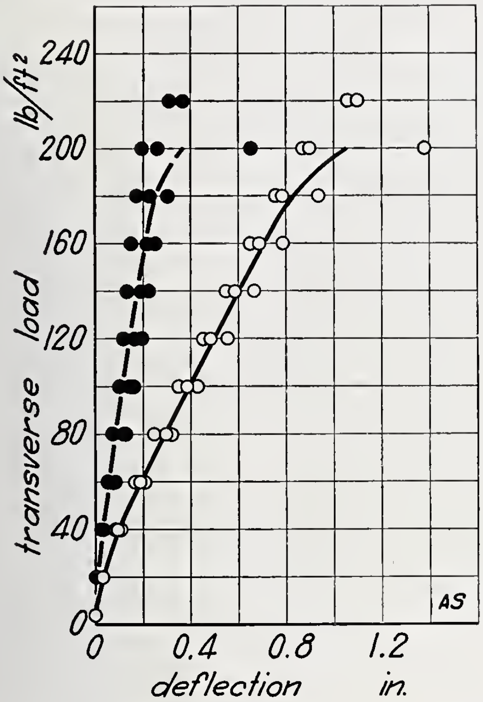

Figure 15.—*Transverse load on floor AS.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *AS–T1*, *T2*, and *T3* on the span 12 ft 0 in.

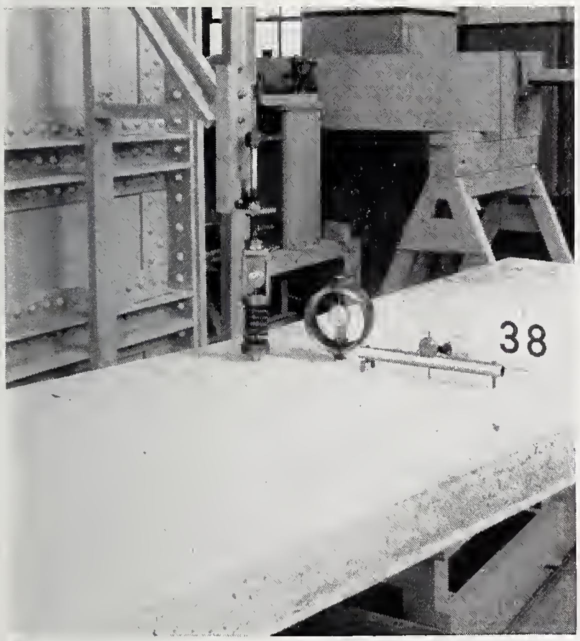

Figure 16.—*Floor specimen AS–P1 under concentrated load.*

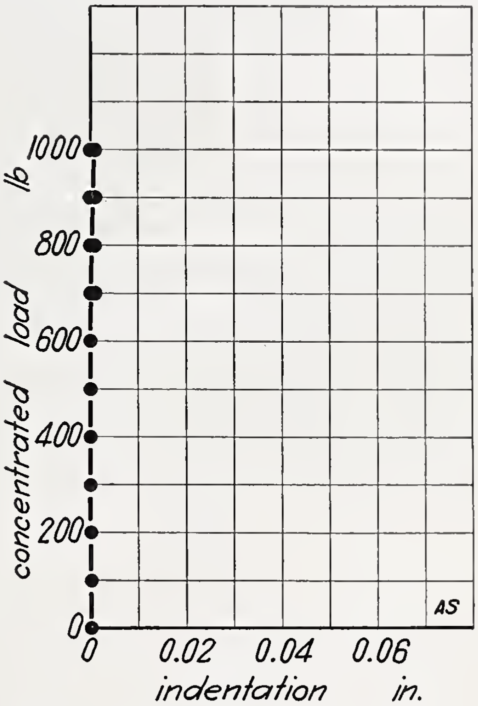

Figure 17.—*Concentrated load on floor AS.*

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

VI. ADDITIONAL COMMENTS BY SPONSOR

"Twachtman" elements for house construction were developed by the sponsor as a result of 2 years of research work and unit cost analyses of various materials and methods. Panels of reinforced concrete were finally chosen as offering the most desirable combination of cost, transportation, workability, and long life. In order to overcome unconventionality of appearance, excessive labor in erection, and waterproofing of many joints, it was decided to make the panels as large as the width of the structure permitted, provided this did not exceed the size which could be readily transported.

About 35 houses embodying these constructions were completed on March 1, 1939. The foundations were concrete footings and either conventional masonry or precast hollow concrete panels, similar to wall *AR*.

The panels were delivered to the house site by truck and placed in position by a crane truck, as shown in figure 20. When delivered, the panels were completely equipped with hardware, openings for pipe and conduit, etc., and required only to be assembled and to have the joints between panels sealed.

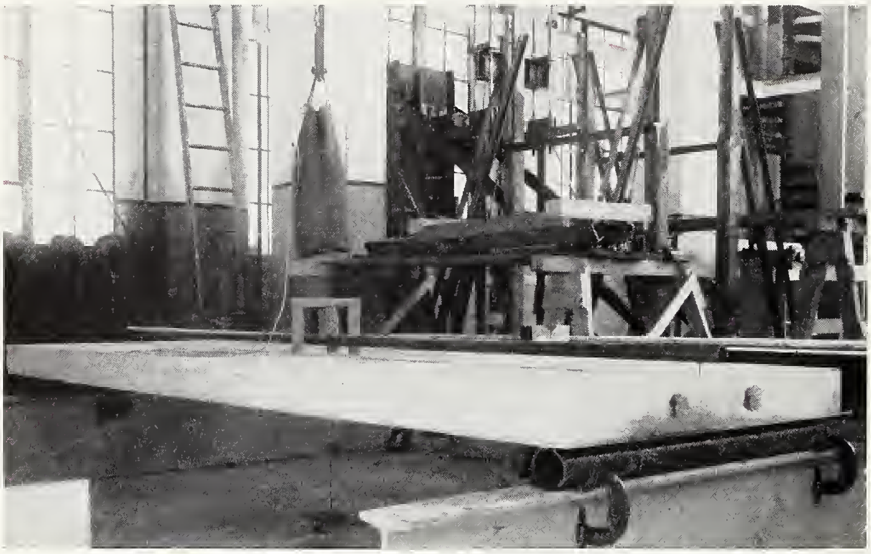

FIGURE 18.—*Floor specimen AS–I3 during the impact test.*

The walls and floors were the precast hollow reinforced-concrete constructions described in this report and the partitions were similar to the wall panels. The buildings had either flat or sloping roofs.

For flat roofs, roof panels, similar to the floor panels, rested directly on the walls. After the roof panels were placed, the exposed ends and sides were finished with a ¾-in. coat of cement mortar flush with the outside of the wall. The panels were covered with a built-up roofing. A precast-concrete coping, 7½ by 5 in., was placed with a ¾-in. overhang, around the edges of the roof, except on one side which was left open for drainage. On this side, metal flashing extended under the roofing and down into a metal gutter. The ceiling was formed by the lower faces of the roof panels.

Sloping roofs were either precast-concrete panels or conventional wood-frame construction. The concrete panels were similar to the floor panels, except that the lower face was omitted, and the concrete was a lean mix, containing 1 part of cement and 8 parts of slag, by volume. The gable ends and ceilings were concrete panels. The ceiling panels were similar to the roof panels, except inverted and made with the same concrete mix used for floor and wall panels. The roofs were covered by composition shingles nailed directly to the concrete.

For wood-frame roof construction, a wood plate was fastened by ½-in. anchor bolts to the upper ends of the wall panels and the rafters fastened to this plate. The gable ends were wood studs with wood sheathing, building paper, and lap siding. The ceilings were wood joists and either wallboard or metal lath and plaster.

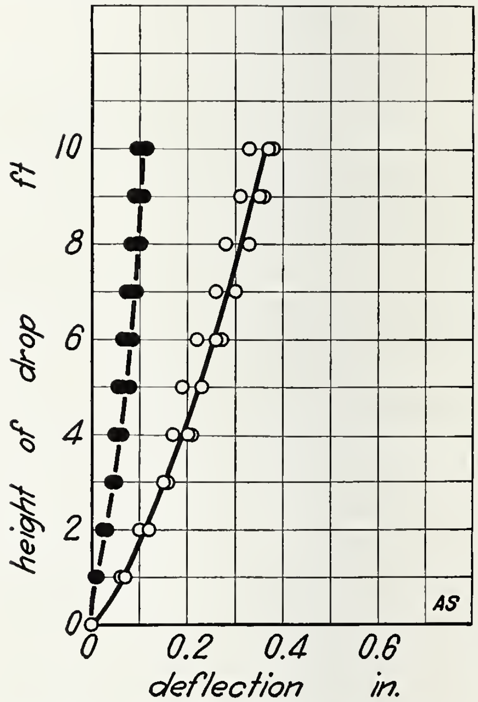

FIGURE 19.—*Impact load on floor AS.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *AS–I1, I2*, and *I3* on the span 12 ft 0 in.

FIGURE 20.—*Erecting "Twachtman" wall panel by means of a crane truck.*

Chimneys were supported by the floors and were 4-in. brick masonry with clay-tile flue linings.

The description, drawings, and sponsor's comments were prepared by E. J. Schell, G. W. Shaw, and T. J. Hanley, of the Bureau's Building Practice and Specifications Section, under the supervision of V. B. Phelan, from information furnished by the sponsor and from the specimens.

The structural properties were determined 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.

The Masonry Construction Section, under the supervision of D. E. Parsons, cooperated in making the tests.

VII. SELECTED REFERENCES

Architectural Forum **63,** No. 6, 548 (1935); **68,** No. 2, 70 (1938).

American Architect **149,** No. 2649, 36 (1936).

WASHINGTON, March 8, 1939.

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