U. S. DEPARTMENT OF COMMERCE

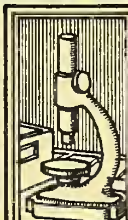
BUILDING MATERIALS AND STRUCTURES

REPORT BMS40

Structural Properties of a Wall Construction of "Knap Concrete Wall Units" Sponsored by Knap America Inc.

by

HERBERT L. WHITTEMORE, AMBROSE H. STANG, *and* CYRUS C. FISHBURN



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ISSUED FEBRUARY 21, 1940

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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. These constructions were sponsored by industrial organizations within the building industry advocating and promoting their use. The sponsor built and submitted the specimens described in this report for participation in the program outlined in BMS2, Methods of Determining the Structural Properties of Low-Cost House Constructions. The sponsor, therefore, is responsible for the design of the constructions and for the description of the materials and method of fabrication. The Bureau is responsible for the method of testing and the test results.

This report covers only the load-deformation relations and strength of the walls of a house when subjected to compressive, transverse, impact, concentrated, and racking loads by standardized methods simulating the loads to which the walls would be subjected in actual service. Later it may be feasible to determine the heat transmission at ordinary temperatures and the fire resistance of this same construction.

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 presented in this series 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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CONTENTS

ABSTRACT

For the program on the determination of the structural properties of low-cost house constructions, Knap America Inc. submitted 12 specimens representing a wall construction of "Knap Concrete Wall Units."

The specimens were subjected to compressive, transverse, concentrated, impact, and racking loads. 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 new constructions, and ultimately to determine the properties necessary for acceptable performance in actual service, the National Bureau of Standards has invited the cooperation of the building industry in a program of research on building materials and structures suitable for 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.

Masonry constructions and wood constructions of types which have been extensively used in this country for houses were included in the program because their behavior under widely different service conditions is known to builders and the public. The reports on these constructions are BMS5, Structural Properties of Six Masonry Wall Constructions, and BMS25, Structural Properties of Conventional Wood-Frame Constructions for Walls, Partitions, Floors, and Roofs. The masonry specimens were built by the Masonry Construction Section of this Bureau, and the wood-frame specimens were built and tested by the Forest Products Laboratory at Madison, Wis.

The present report describes the structural properties of a wall construction 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 walls 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, and snow and wind loads on the roof. Transverse loads on a wall are produced by the wind, concentrated and impact loads by accidental contact with heavy objects, and racking loads by the action of the wind on adjoining walls.

The deformation and set under each increment of load were measured, because, considered as a structure, the suitability of a construction depends not only on its resistance to deformation when loads are applied, but also on whether it returns to its original size and shape when the load is removed.

II. SPONSOR AND PRODUCT

The specimens were submitted by Knap America Inc., Los Angeles, Calif., and represented a patented cavity-wall construction of reinforced-concrete units marketed under the trade name "Knap Concrete Wall Units." Vertical joints in the wall contained wood splines pinned to the units.

III. SPECIMENS AND TESTS

The wall construction was assigned the symbol *BW*, and the specimens were assigned the designations given in table 1.

TABLE 1.—*Specimen designations, wall BW*

Specimen designation	Load	Load applied
C1, C2, C3	Compressive	Upper end.
T1, T2, T3	Transverse	Either face.
I1, I2, I3	Impact	Do.
P1, P2, P3 [a]	Concentrated	Do.
R1, R2, R3	Racking	Near upper end.

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

With the exceptions mentioned below, 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.

For the transverse, concentrated, and impact loads, the loads were applied to only one face, because the results for loads so applied should be the same as those obtained by applying the loads to the other face.

The compressive loads were applied over the entire thickness of each specimen along a line distant from the "inside" face by one-third this thickness. The shortenings and sets were measured by means of compressometers attached to the steel loading plates through which the load was applied to the specimen, not attached to the specimen as described in BMS2.

The deformations due to racking loads were measured with a dial micrometer, which was fastened to one end of a right-angle frame, consisting of a steel channel and a steel angle braced to form a rigid connection. In use, this deformeter was attached to the specimen by resting the channel along the top of the specimen. Two pins driven through the channel into the top of the specimen prevented relative motion between them. The steel angle was then in a suspended vertical position in the plane of the specimen, with the micrometer at its lowest point and the spindle bearing directly on the specimen. The gage length (distance from the top of the specimen to the micrometer spindle) was 6 ft. 6 in. The micrometer was graduated to 0.001 in. and readings were recorded to the nearest division. This deformeter was used instead of the system of taut wires and mirror scales described in BMS2.

The tests were begun December 19, 1938 and completed December 23, 1938. The sponsor's representatives witnessed the tests.

IV. WALL *BW*

1. SPONSOR'S STATEMENT

The information on materials and fabrication of the units was obtained from the sponsor and from inspection of the specimens.

The Masonry Construction Section of this Bureau assisted by determining the physical properties of the mortar and the units. The species of the wood splines was determined by the Forest Products Laboratory.

(a) *Materials*

Concrete units.—The materials for the concrete were Monolith Portland Cement Co.'s "Monolith" portland cement, pit sand, fine gravel, and coarse gravel from the vicinity of Los Angeles. The cement complied with the specifications of the ASTM Standard C9–30 [1]

[1] Am. Soc. Testing Materials, Book of ASTM Standards, pt. 2 (1936)

for Portland Cement. The sand contained 1 percent of silt and the gravels a trace of silt, as determined by the ASTM Standard D136–28; [2] Method of Decantation Test for Sand and Other Fine Aggregates. The specific gravity of the sand was 2.65 and of the gravels 2.64. The sieve analyses of the sand and gravels are given in table 2.

TABLE 2.—*Sieve analyses of the sand and gravels for the concrete units, wall BW*

Sieve		Passing, by weight		
Size	U. S. Standard No.	Sand	Fine gravel	Coarse gravel
Inches		*Percent*	*Percent*	*Percent*
½	----------	----------	----------	100
⅜	----------	----------	100	69
----------	3	----------	----------	11
----------	4	100	58	3
----------	6	----------	----------	1
----------	8	98	6	----------
----------	16	84	1	----------
----------	30	50	----------	----------
----------	50	17	----------	----------
----------	100	4	----------	----------
----------	200	1	----------	----------

The units were thin reinforced-concrete slabs about 1 ft 9 in. high by 3 ft 4 in. wide. There were parallel ribs on one face at midwidth and adjacent to each lateral (vertical) edge.

The reinforcement in the units was a special mesh made from cold-drawn, basic steel wire, uncoated, No. 12 Stl. W. G. (0.1055-in. diam), having a tensile strength of 92,800 lb/in^2. The wire was woven into a mesh and lap-welded. Manufactured by the E. F. Krause Wire Corporation.

The inner surface of the units was covered with a moisture-resistant paper built up of two sheets of kraft paper combined (duplexed) by asphalt. The weight of the paper was 65.5 lb/ream, or 11.3 lb/500 ft^2, and the weight of the asphalt was 54.5 lb/ream, or 9.4 lb/500 ft^2. Manufactured by the Angier Corporation.

The units were formed in horizontal molds of cast aluminum with the inner surface down. The mold was lined with the moisture-resistant paper. The mesh reinforcement was ½ in. above the bottom of the mold, and the edges of the mesh were turned down into the ribs. The concrete mix was 1 part of cement, 2.11 parts of dry sand, 1.40 parts of dry fine gravel, and 1.64 parts of dry coarse gravel, by weight, and the water-cement ratio was 3.94 gallons per sack of cement. The mold was filled with concrete and vibrated for about 1 minute. The upper surface of the unit was finished with a layer of cement and sand, and then sand floated. After removal from the mold the unit was steam-cured at 125° F for about 4 hours, after which it was kept moist for 28 days. The compressive strength of the concrete, determined on 3- by 6-in. cylinders, vibrated, steam-cured, and kept moist in the same manner as the units, was 2,900 lb/in.^{2}, age 7 days, and 4,650 lb/in.^{2}, age 28 days.

Four sizes of units are shown in figure 1; details of standard unit, A, and half-height unit, B, are shown in figure 2; with half-height unit, C, and quarter unit, D, shown in figure 3. The size of the pieces of the mesh reinforcement for the standard unit, A, was 1 ft 8¾ in. by 3 ft 6¾ in. The mesh for the other units was cut from like pieces.

All units were made in the same mold by the use of removable metal stops. There was a semicircular groove, ½-in. diam, along each edge of the standard unit. The lip of the grooves on the inner surface projected ⅛ in. beyond the lip on the outer surface. The edges of the other units were grooved except those edges in contact with a stop in the mold. There were holes having a diam of ½ in. through the ribs of the units, 1 in. from the edge of the ribs. The physical properties of two standard units were determined. The absorption for 24-hr cold total immersion was 4.6 percent of the dry weight of the unit, or 6.4 lb of water per cubic foot of concrete. The average weight was 142 lb/ft^3 of dry concrete. The dry weight of a standard unit was 95.6 lb, of a half-height unit 45.6 lb, of a half-width unit 46.9 lb, and of a quarter unit 23.7 lb.

Cement mortar.—The cement mortar was 1 part of North American Cement Co.'s "North American" portland cement to 3 parts of damp Potomac River building sand, by volume. This corresponds to 1 part of cement to 2.5 parts of dry sand, by weight, assuming that portland cement weighs 94 lb/ft^3 and that 80 lb of dry sand is equivalent to 1 ft^3 of loose damp sand. The mortar was mixed in small quantities by the mason to the consistency desired.

[2] See footnote 1.

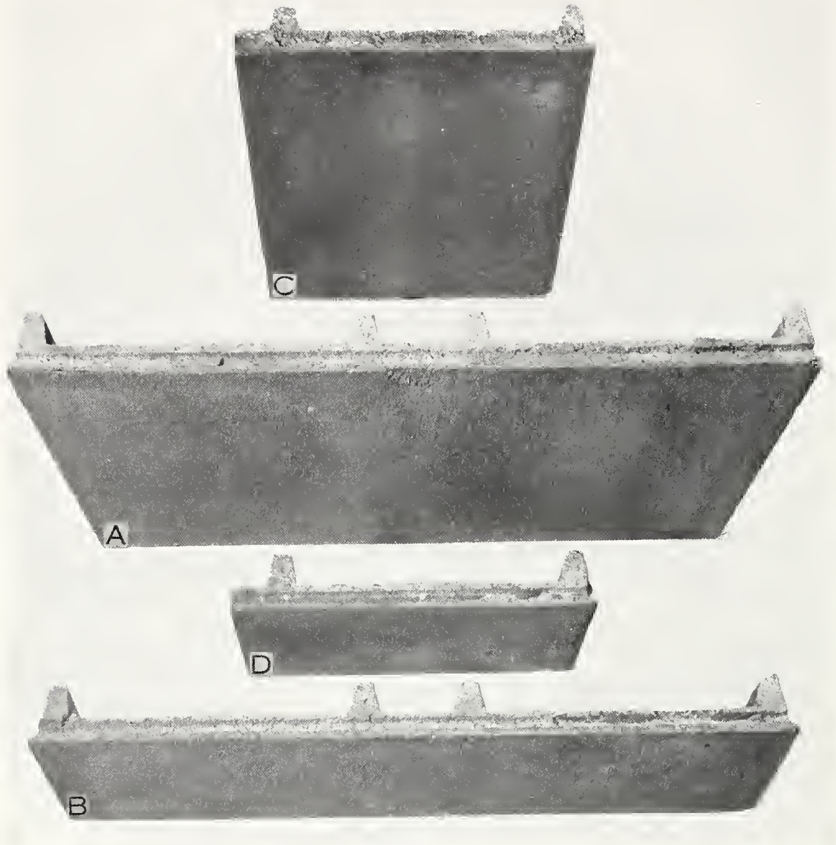

FIGURE 1.—*Concrete units.*
A, standard unit; *B*, half-height unit; *C*, half-width unit; *D*, quarter unit.

Two samples were taken from each batch of mortar, the flow determined in accordance with Federal Specification SS–C–181b, Cement; Masonry, and six 2-in. cubes made. Three cubes were stored in water at 70° F and three stored in air near each specimen. The physical properties of the mortar are given in table 3.

TABLE 3.—*Physical properties of cement mortar, wall BW*

Batch	Specimens	Flow	Age when tested	Compressive strength	
				Air storage	Water storage
		Percent	*Days*	*lb/in.²*	*lb/in.²*
1	*C2, C3, T1, T2, T3, B*	[a]> 150	7	1,070	720
2	*C1, I1, I2, R1, R2, R3*	[a]> 150	5	1,000	500

[a] Symbol (>) means "greater than."

"Brixment" mortar.—The materials for the "Brixment" mortar were Louisville Cement Co.'s "Brixment" cement and Potomac River building sand. The mix of the mortar was 1 part of "Brixment" cement to 3 parts of sand, by volume.

Wood splines.—Longleaf southern pine, merchantable grade, identified by the Forest Products Laboratory as southern yellow pine. Typical splines are shown in figure 4.

The minimum moisture content of the wood in the splines was 11 percent, the maximum 25 percent, and the average 17 percent. The moisture content was determined with an electrical moisture meter on the day the wall specimen was tested. To calibrate the meter, one sample of the wood was taken from each specimen and dried in an oven at 212° F until the weight was constant. The moisture content was the difference between the initial weight and the weight when dry, divided by the weight when dry. The average meter reading for these samples was 1.0 less than this moisture content, and therefore the moisture content of

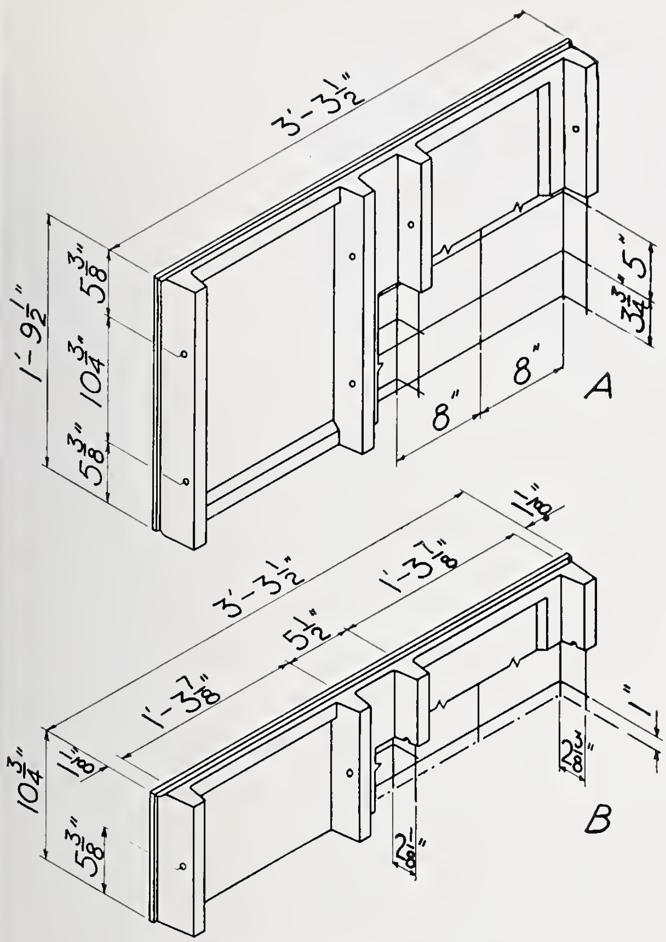

FIGURE 2.—*Details of concrete units.*
A, standard unit; *B*, half-height unit.

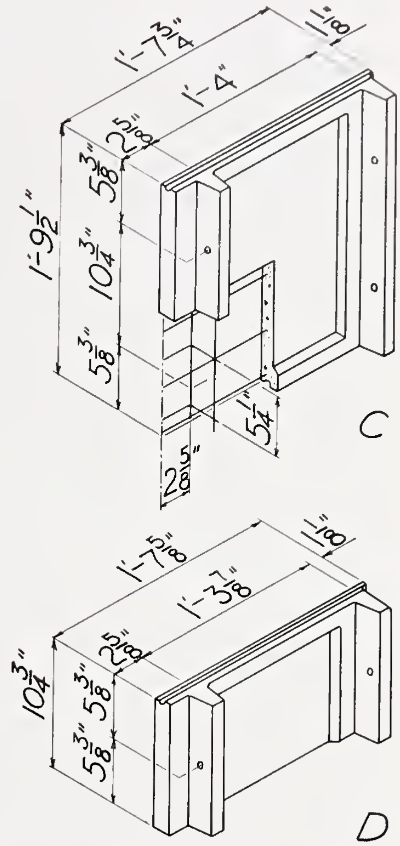

FIGURE 3.—*Details of concrete units.*
C, half-width unit; *D*, quarter unit.

the wood was obtained by adding 1.0 to the meter readings and then rounding the result to the nearest whole number.

Pins.—Steel-wire spikes, special, 7/16-in. diam, 7½ in. long, flat head, diamond point. American Steel & Wire Co.

Bolts.—Machine, mild-steel, 7/16-in. diam, 5 in. long, 14 threads per inch, threaded for a length of 1⅜ in., heads and nuts square, unfinished.

Washers.—Sheet-steel, 1¼-in. diam, No. 15 U. S. Std. Gage (0.069 in. thick).

(*b*) *Description*

Wall *BW* was a masonry cavity wall consisting of "Knap Concrete Wall Units" and wood splines. The units and the splines were connected by pins.

The price of this construction in Washington, D. C., as of July 1937, was $0.39/ft².

(1) *Four-foot wall specimens.*—The 4-ft wall specimens, shown in figure 5, were 8 ft 1¾ in. high, 5 ft 0 in. wide, and 5 in. thick. There were four courses consisting of standard units, *A*, and half-width units, *C*, and one course of half-height units, *B*, and a quarter unit, *D*, with a continuous vertical joint in each face of the specimen. Each horizontal joint was at mid-height of the opposite full-height units in the other face of the specimen. Each vertical joint was at midwidth of the opposite full-width units in the other face of the specimen. The top course of one face consisted of one half-height unit, *B*, and one quarter unit, *D*, and the bottom course of the other face consisted of two like units. There was a vertical row of half-width units in each face of the wall, and the vertical joint in one face was 1 ft 8 in. from the vertical joint in the other face. A

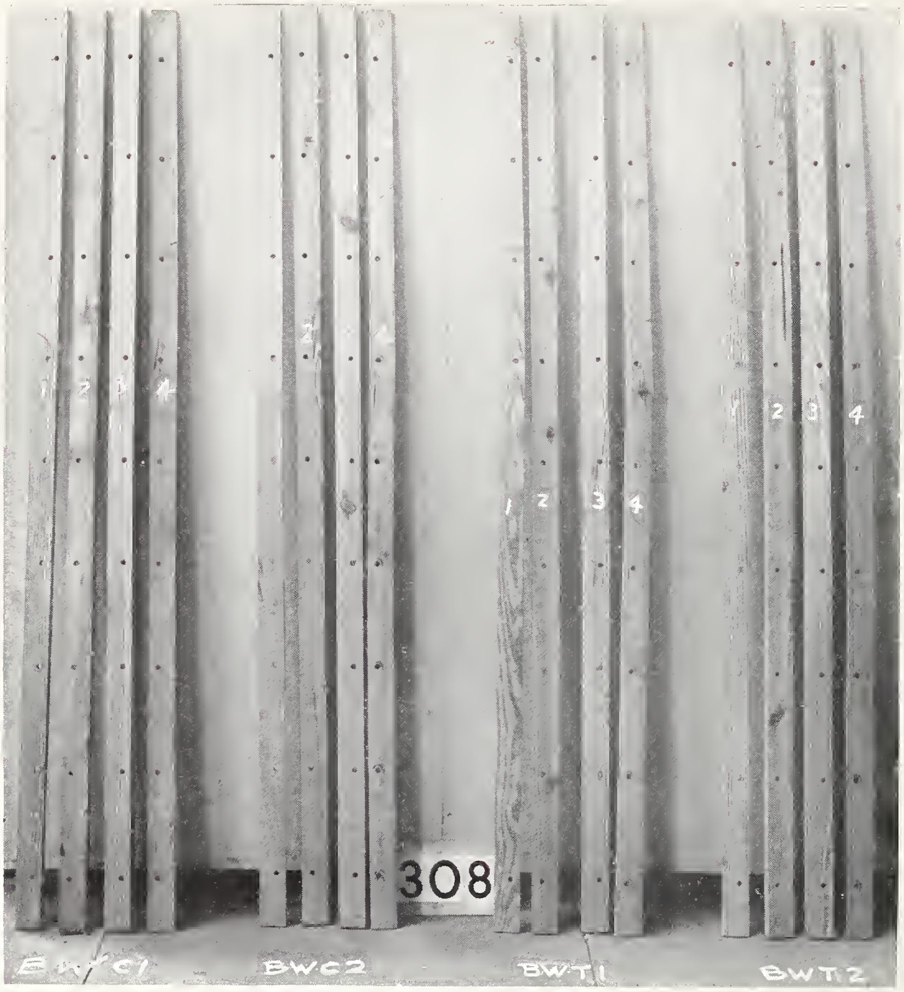

FIGURE 4.—*Typical wood splines.*

wood spline, E, $2\frac{3}{4}$ in. wide, $1\frac{5}{8}$ in. thick at one edge, and beveled on both sides to a thickness of $1\frac{1}{8}$ in. at the other edge, 8 ft $1\frac{3}{4}$ in. long, was pinned to the ribs of the units at the vertical joints; the pins passing through the holes in the ribs and through $\frac{1}{2}$-in. holes spaced $10\frac{3}{4}$ in. on centers in the splines. A half spline, F, $2\frac{3}{4}$ in. wide, $\frac{7}{8}$ in. thick at one edge, and beveled on one side to a thickness of $\frac{5}{8}$ in. at the other edge, 8 ft $1\frac{3}{4}$ in. long, was at each edge of the specimen and was fastened to the ribs of the units by bolts passing through the holes in the ribs and through $\frac{1}{2}$-in. holes spaced $10\frac{3}{4}$ in. on centers in the half splines. There was a washer under the nut on each bolt. The pinned and bolted connections are shown in figure 6.

Each joint in the specimens was calked with cement mortar, then raked to a depth of $\frac{1}{4}$ in. The specimens included in batch 2 (see table 3) were pointed with "Brixment" mortar. The joints in the specimens in batch 1 were raked but not pointed. A pointed joint is shown in figure 7.

As the only purpose of the mortars was to make the joints weatherproof, not to increase the strength, the specimens were not aged for 28 days before testing. The age ranged from 2 to 7 days after the joints were calked.

(2) *Eight-foot wall specimens.*—The 8-ft wall specimens shown in figure 8 were 8 ft $1\frac{3}{4}$ in. high, 8 ft. 4 in. wide, and 5 in. thick. The specimens were similar to the 4-ft specimens and consisted of two standard units, A, and a half-width unit, C, in each course. The top course of one face and the bottom course of the other face consisted of two half-height units, B, and a quarter unit, D. There were four splines, E, at the vertical joints between the

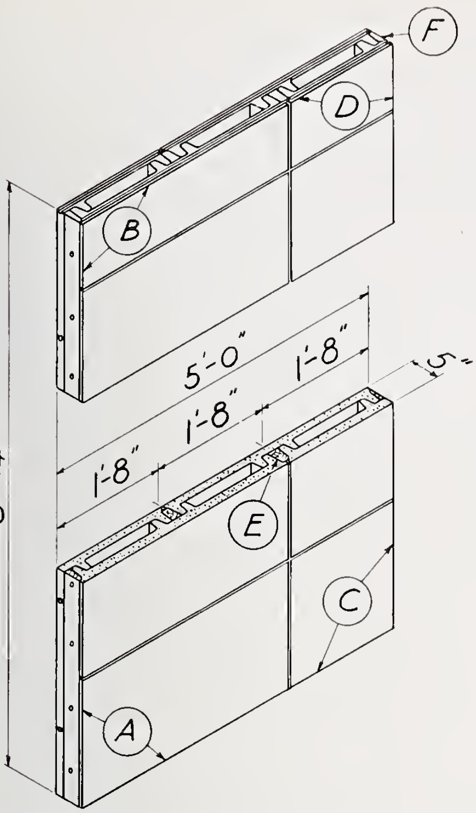

FIGURE 5.—*Four-foot wall specimen BW.*

A, standard unit; *B*, half-height unit; *C*, half-width unit; *D*, quarter unit; *E*, spline; *F*, half spline.

units, and two half splines, *F*, at the edges of the specimen.

(*c*) *Comments*

"Knap Concrete Wall Units" were originally developed in South Africa, where during the past 9 years several hundred structures have been built of this type of unit. The units described in this report were an improved design developed in the United States.

Walls and partitions are erected on either a masonry foundation wall or a concrete slab. If there is a wood floor, the joists are supported by the foundation walls. Walls are anchored by steel bars embedded in the foundation and projecting into the cavity of the wall. After two courses of units have been placed, the cavity is filled with grout to a depth of 5 in., embedding

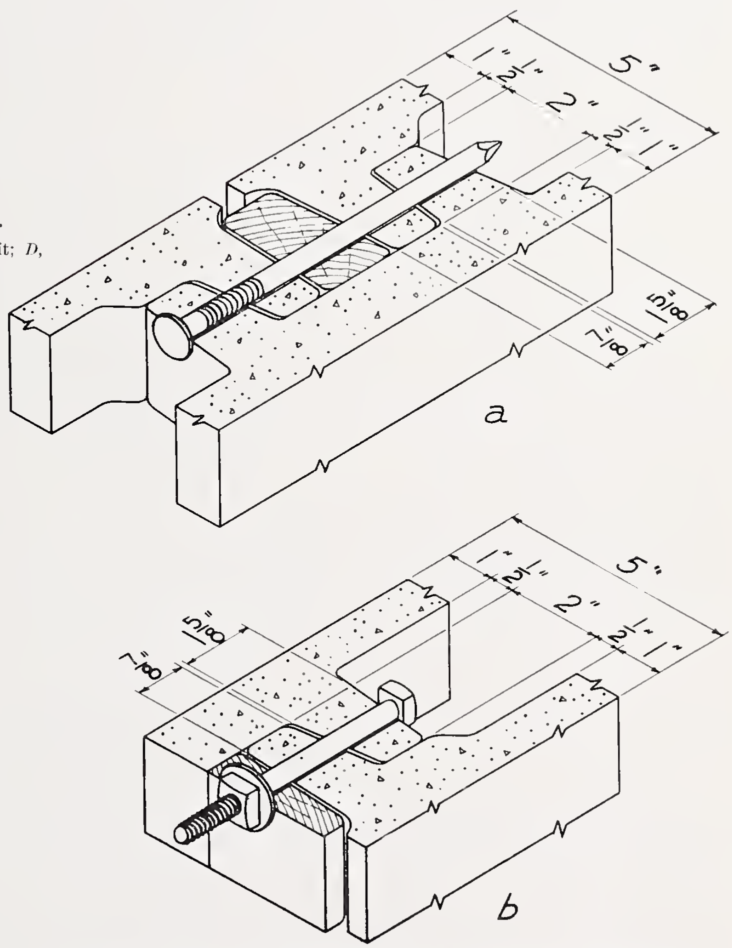

FIGURE 6.—*Fastening concrete units to wood splines.*

a, pin through ribs and spline at inner ribs; *b*, bolt through ribs and half spline at edge ribs.

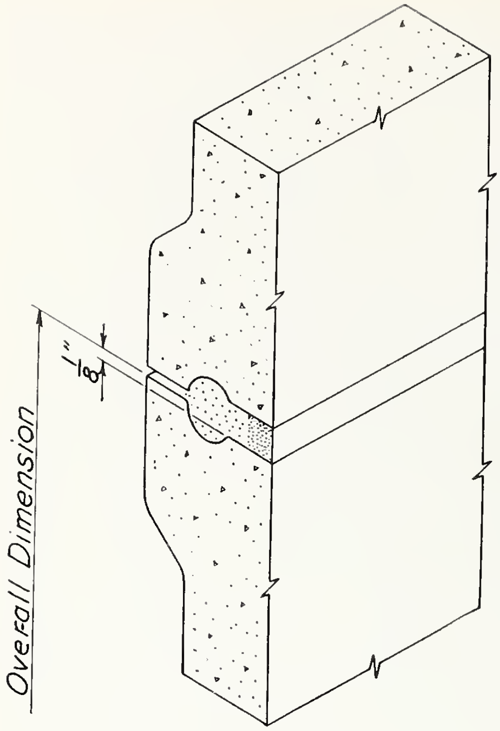

Figure 7.—*Mortar joint between units.*

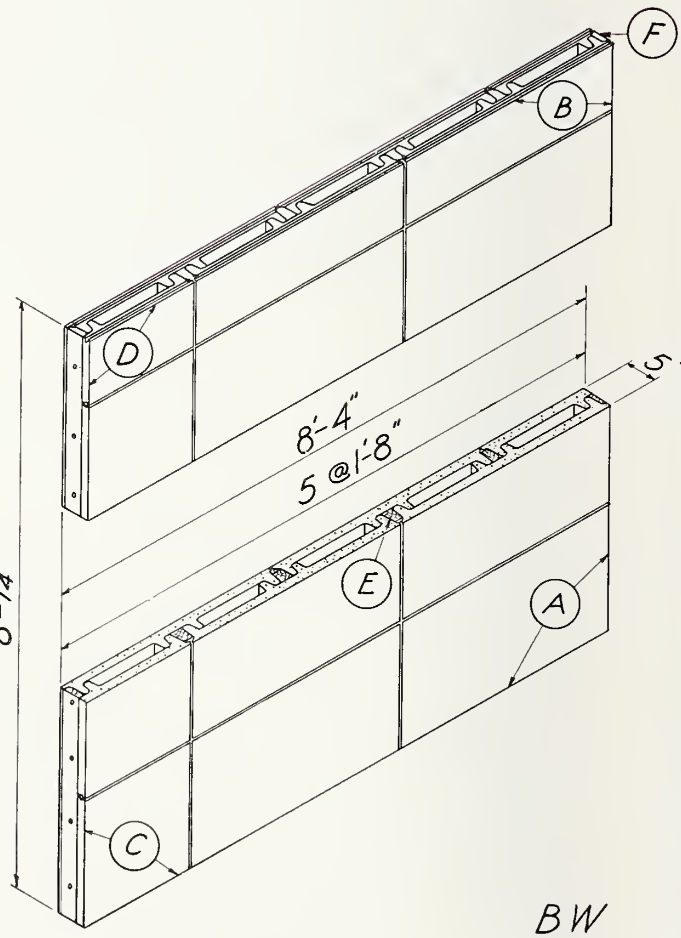

Figure 8.—*Eight-foot wall specimen BW.*
A, standard unit; *B*, half-height unit; *C*, half-width unit; *D*, quarter unit; *E*, spline; *F*, half spline.

the ends of the bars. Special interlocking units are made for the corners. Partitions of similar units or other material are secured to the walls by bolts or other devices. The units are made in various sizes to provide flexibility in design and room dimensions, the minimum width being 1 ft 3 in. Larger units in increments of 5 in. are provided for different lengths of walls between openings. The height of the wall may be varied in increments of 10¾ in. Lintels over doors and windows are not necessary. Wood door and window frames are nailed to the wood splines. For metal windows the splines are omitted and the frames fitted into the recesses between the units. Wood top plates are fastened to the wall by hook bolts which engage the upper pin holes in the splines and in the ribs of the topmost units. Special units are available for gable ends, or the gable may be constructed of other materials.

The units are not bedded in mortar when they are placed. Both the vertical and the horizontal joints are calked after the walls and roof are erected.

For two-story buildings, special units having openings are placed in the inside face at the second-story floor line, and a continuous wood bearing plate is nailed to the wood splines. The ends of the floor joists extend into the wall 4 in. and are secured by steel plates, 8 by 3 by ⅛ in., either screwed or nailed to the sides of the joists and fastened to the wall by bolts through the pin holes in the units. A reinforced-concrete floor is anchored by extending the concrete reinforcement of the floor into the wall cavities and embedding the bent ends of the bars in concrete.

Several lightweight aggregates have been used to decrease the weight of the units.

The faces of the wall require no finishes, but, if desired, plaster, paint, or wallpaper may be applied. At no place is the concrete continuous through the wall. Pipes and conduits are put in the cavities in the wall. Larger ducts, such as soil pipe, are located between double walls.

The method of fastening the units allows the house to be dismantled easily; therefore, the salvage value of the material is high.

2. Compressive Load

Wall specimen *BW-C1* under compressive load is shown in figure 9. The results for specimens *BW-C1*, *C2*, and *C3* are shown in table 4 and in figures 10 and 11.

Table 4.—*Structural properties, wall BW*

[Weight, 32.3 lb/ft²]

Compressive load [a]		Transverse load [b]		Impact load [b]		Concentrated load		Racking load	
Specimen	Maximum load	Specimen	Maximum load	Specimen	Maximum height of drop	Specimen	Maximum load	Specimen	Maximum load
	[c] *Kips/ft*		*lb/ft²*		*ft*		*lb*		[c] *Kips/ft*
C1	20.1	*T1*	204	*I1*	[d] 10.0	*P1*	[d] 1,000	*R1*	4.14
C2	24.4	*T2*	220	*I2*	[d] 10.0	*P2*	[d] 1,000	*R2*	4.20
C3	19.8	*T3*	192	*I3*	[d] 10.0	*P3*	[d] 1,000	*R3*	4.72
Average	21.4	Average	205	Average	[d] 10.0	Average	[d] 1,000	Average	4.35

[a] Load applied 1.67 in. (one-third the thickness of the specimen) from one face.
[b] Span 7 ft 6 in.
[c] A kip is 1,000 lb.
[d] Test discontinued. Specimen did not fail.

The shortenings and sets shown in figure 10 for a height of 8 ft were computed from the values obtained from the compressometer readings. The gage length of the compressometers was 8 ft 2 in.

The lateral deflections shown in figure 11 were plotted to the right of the vertical axis for deflections of the specimens toward the "outside" face (positive deflection) and to the left for deflections toward the "inside" face (negative deflection).

For specimens *C1* and *C3* the deflections and sets were positive. For specimen *C2* they were very small, sometimes positive, sometimes negative, under loads less than about 23 kips/ft. Under greater loads the deflections were positive and increased markedly with little change in the load.

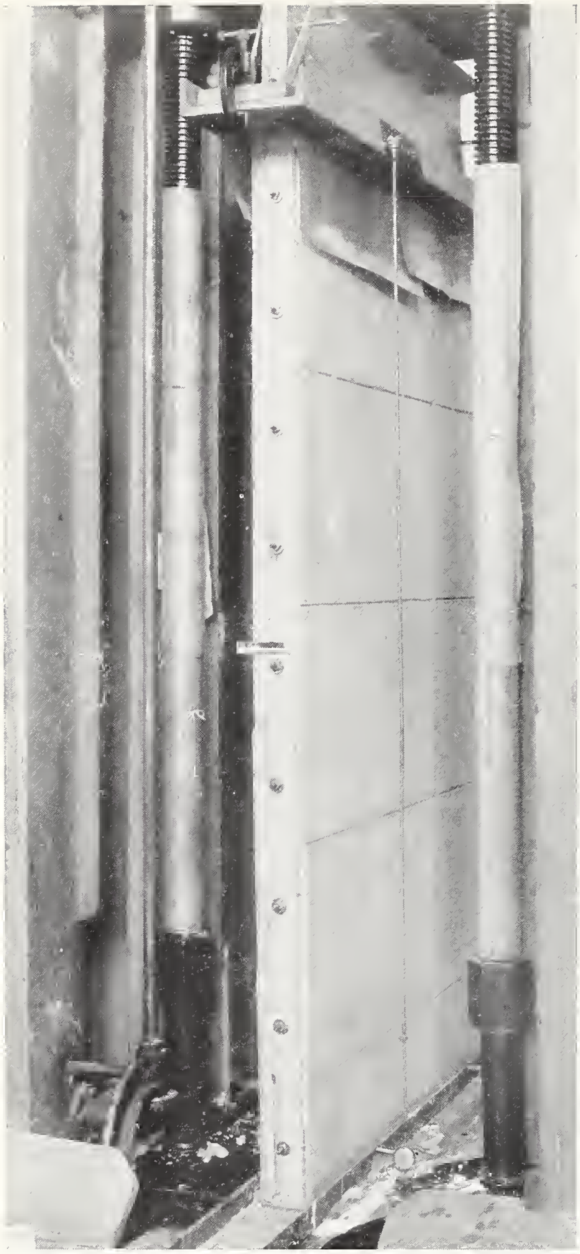

FIGURE 9.—*Wall specimen BW–C1 under compressive load.*

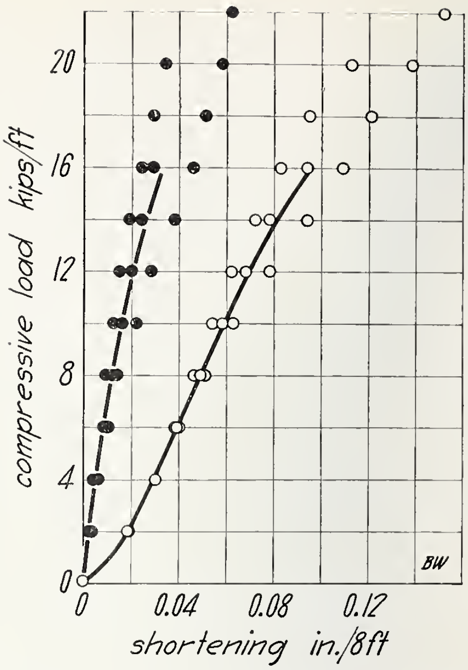

FIGURE 10.—*Compressive load on wall BW.*

Load-shortening (open circles) and load-set (solid circles) results for specimens *BW–C1*, *C2*, and *C3*. The load was applied 1.67 in. (one-third the thickness) from the inside face. The loads are in kips per foot of actual width of specimen.

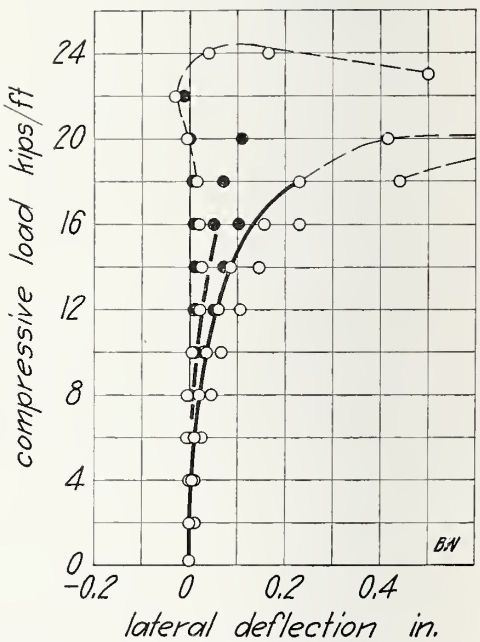

FIGURE 11.—*Compressive load on wall BW.*

Load-lateral deflection (open circles) and load-lateral set (solid circles) results for specimens *BW–C1*, *C2*, and *C3*. The load was applied 1.67 in. (one-third the thickness) from the inside face. The deflections and sets are for a gage length of 7 ft 11 in., the gage length of the deflectometers.

FIGURE 12.—*Wall specimen BW–T2 under transverse load.*

In each of the specimens the mortar crushed in most of the horizontal joints. The crushing began at a load of 14.0 kips/ft on specimen *C1*, 19.2 kips/ft on specimen *C2*, and 14.0 kips/ft on specimen *C3*. Under the maximum load each of the specimens failed by crushing of the horizontal mortar joints and of the concrete units; the lateral deflection ranging from ¾ to 1½ in.

3. TRANSVERSE LOAD

Wall specimen *BW–T2* under transverse load is shown in figure 12. The results for specimens *BW–T1*, *T2*, and *T3* are given in tables 4 and 5 and in figure 13.

TABLE 5.—*Effects of transverse load, wall BW*

Description of effects	Specimen *T1*		Specimen *T2*		Specimen *T3*	
	Load	Deflection	Load	Deflection	Load	Deflection
	lb/ft²	*in.*	*lb/ft²*	*in.*	*lb/ft²*	*in.*
Face not loaded: First transverse crack in the bond between the mortar and the concrete units along a horizontal joint near midspan	40	0.19	40	0.20	40	0.26
Face loaded:						
First transverse crack in the bond between the mortar and the concrete units along a horizontal joint	150	1.50	160	1.53	140	1.54
Crack along the vertical mortar joint	170	1.82	-----	-----	160	1.81

At the maximum load each specimen failed by rupture of all, or all but one, of the wood splines and half splines about 8 in. above midspan. Rupture in the bond between the

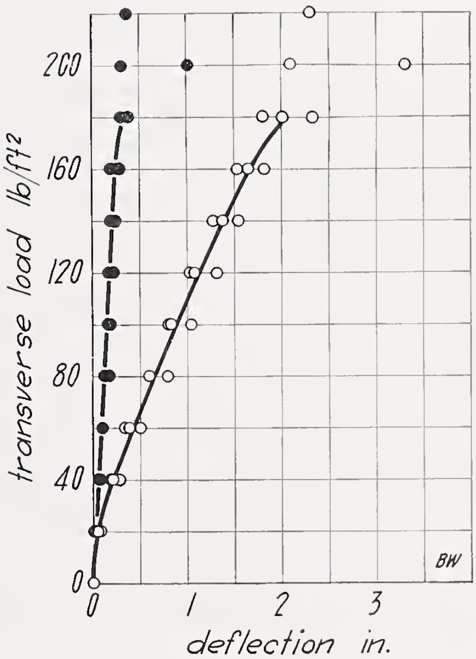

FIGURE 13.—*Transverse load on wall BW.*

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

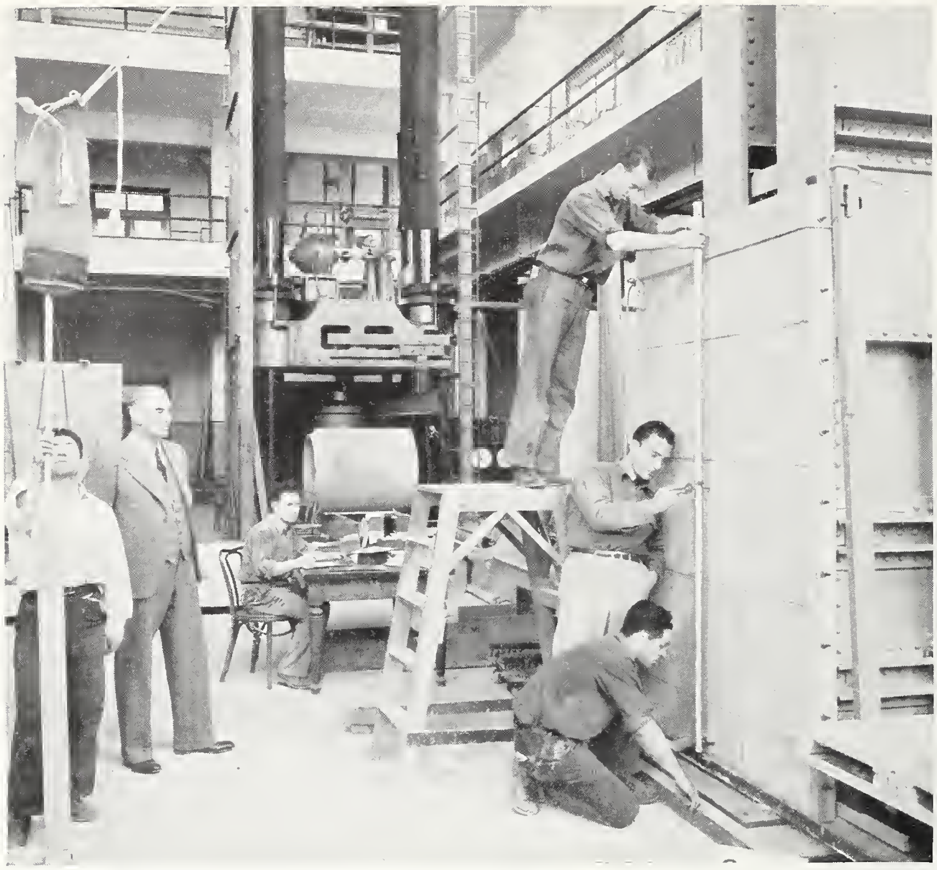

FIGURE 14.—*Wall specimen BW–I2 during the impact test.*

mortar and the units had occurred at most of the horizontal joints in each specimen.

4. IMPACT LOAD

Wall specimen *BW–I2* during the impact test is shown in figure 14. The results are shown in tables 4 and 6 and in figure 15 for wall specimens *BW–I1*, *I2*, and *I3*.

TABLE 6.—*Effects of impact load, wall BW*

Description of effects	Specimen *I1*		Specimen *I2*		Specimen *I3*	
	Height of drop	Deflection	Height of drop	Deflection	Height of drop	Deflection
	ft	*in.*	*ft*	*in.*	*ft*	*in.*
Face not loaded: First transverse crack in the bond between the mortar and the concrete units along a horizontal joint near midspan	3.0	0.27	2.5	0.30	1.0	0.11
Face loaded:						
First transverse crack in the bond between the mortar and the concrete units along a horizontal joint near midspan	3.5	.32	4.0	.43	5.0	.49
Crack along vertical mortar joint	5.0	.43	2.5	.30	5.0	.49
Crack in units at midspan	7.5	.58	9.5	.76	7.5	.69
Failure by rupture of concrete units	10.0	.66	([a])	([a])	8.0	.70

[a] Face did not fail.

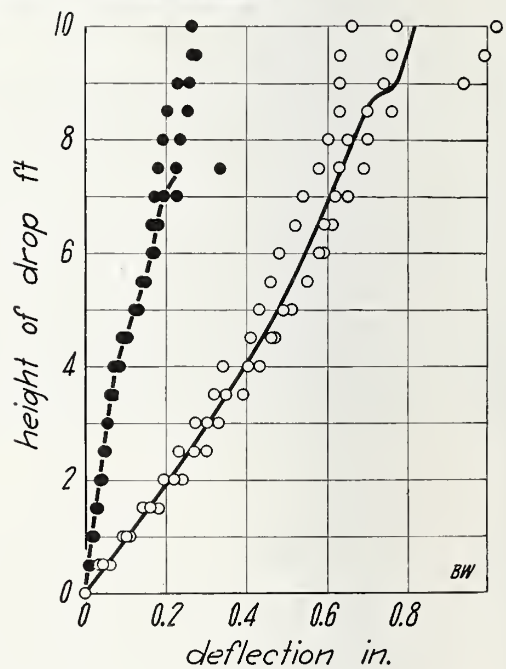

FIGURE 15.—*Impact load on wall BW.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *BW–I1*, *I2*, and *I3* on the span 7 ft 6 in.

The impact loads were applied to the center of the specimens, the sandbag striking between the ribs of a unit. After a drop of 10 ft most of the horizontal joints had cracked but no wood splines had ruptured.

5. Concentrated Load

Wall specimen *BW–P1* under concentrated load is shown in figure 16. The results for specimens *BW–P1*, *P2*, and *P3* are shown in table 4 and in figure 17.

The concentrated loads were applied midway between the ribs of a unit, from 3 to 4½ ft from the bottom end of the specimens. After a load of 1,000 lb had been applied, the indentation in specimen *P1* was 0.006 in.; in specimen *P2*, 0.005 in.; and in specimen *P3*, 0.004 in.; and no other effect was observed.

6. Racking Load

Wall specimen *BW–R1* under racking load is shown in figure 18. The results for specimens

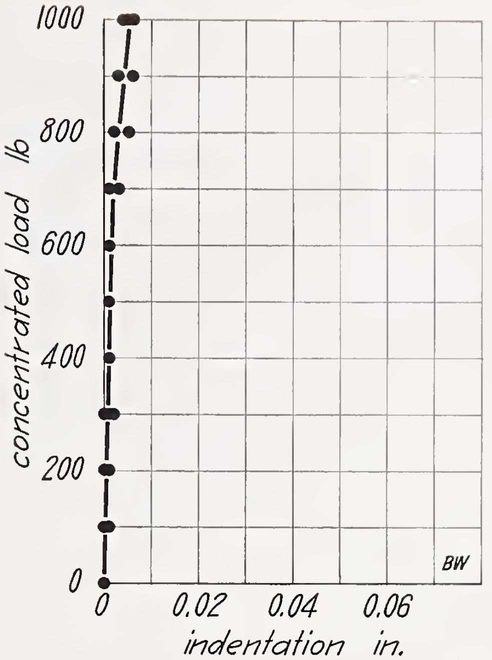

Figure 17.—*Concentrated load on wall BW.*
Load-indentation results for specimens *BW–P1*, *P2*, and *P3*.

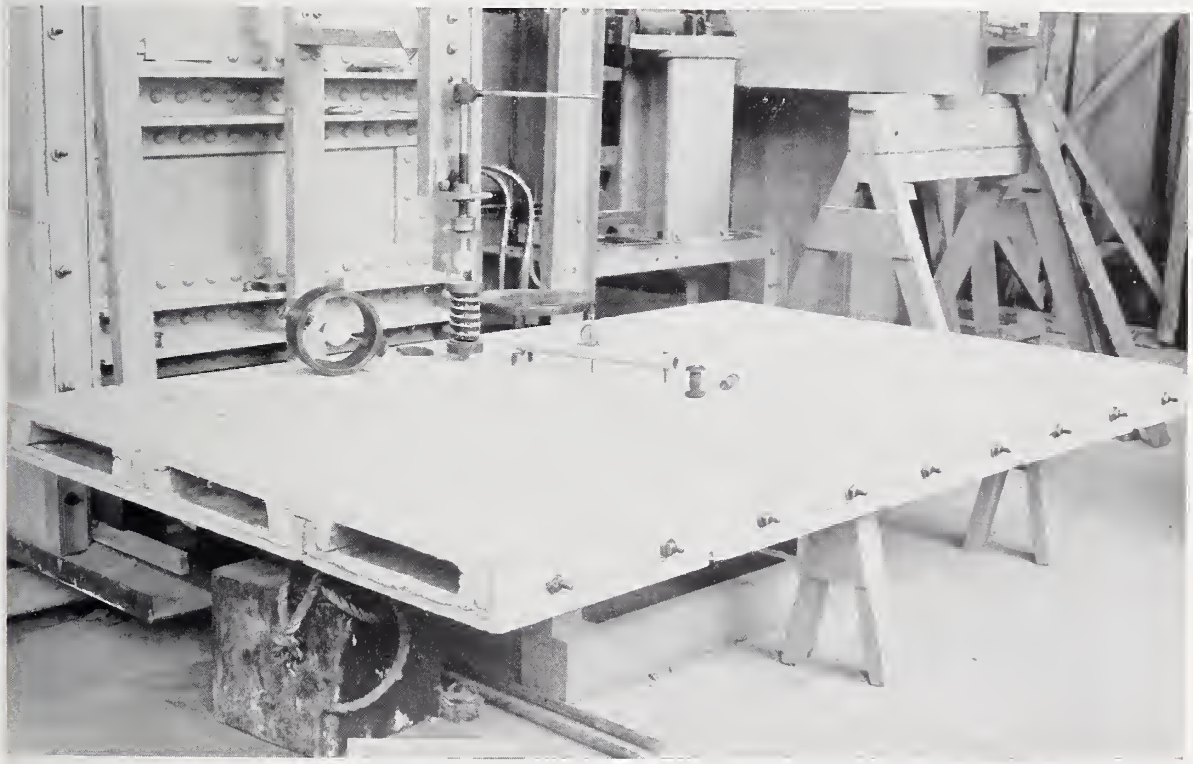

Figure 16.—*Wall specimen BW–P1 under concentrated load.*

FIGURE 18.—*Wall specimen BW–R1 under racking load.*

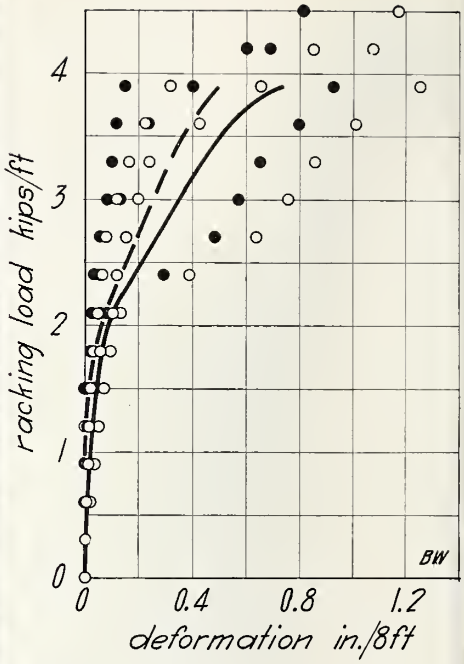

FIGURE 19.—*Racking load on wall BW.*

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

BW–R1, *R2*, and *R3* are given in table 4 and in figure 19.

The deformations and sets shown in figure 19 for a height of 8 ft were computed from the deformeter readings. The gage length of the deformeter was 6 ft 6 in.

For each of the specimens all or nearly all of the joints in both faces cracked in the bond between the mortar and the units, and most of the units broke. The first crack in the mortar occurred in a vertical joint at a load of 1.5 kips/ft. Under this load the deformation of specimen *R1* was 0.070 in.; of specimen *R2*, 0.019 in.; and of specimen *R3*, 0.022 in. The units began to break at loads of 3.3, 3.0, and 3.0 kips/ft, respectively. Under the maximum load each of the specimens failed by crushing of the units along the loaded edge and buckling of the middle units of the top course.

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 information furnished by the sponsor and by inspection of the specimens themselves.

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

WASHINGTON, August 12, 1939.

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[List continued on cover page IV]