U. S. DEPARTMENT OF COMMERCE

BUILDING MATERIALS AND STRUCTURES

REPORT BMS32

Structural Properties of Two Brick-Concrete-Block Wall Constructions and a Concrete-Block Wall Construction Sponsored by the National Concrete Masonry Association

by

HERBERT L. WHITTEMORE

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DOUGLAS E. PARSONS

NATIONAL BUREAU OF STANDARDS

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ISSUED NOVEMBER 2, 1939

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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 the program outlined in BMS2, Methods of Determining the Structural Properties of Low-Cost House Constructions. The sponsor, therefore, is responsible for the description of the specimens and the 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, racking, impact, and concentrated 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 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.*

Structural Properties of Two Brick-Concrete-Block Wall Constructions and a Concrete-Block Wall Construction Sponsored by the National Concrete Masonry Association

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ABSTRACT

For the program on the determination of the structural properties of low-cost house constructions, the National Concrete Masonry Association, Chicago, Ill., submitted 48 specimens representing 3 wall constructions, 2 of which consisted of brick facing and concrete-block backing, the other of concrete blocks only.

The specimens were subjected to compressive, transverse, concentrated, impact, and racking loads. The transverse, concentrated, and impact loads were applied to both faces of the brick-concrete-block wall constructions. For each of the 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 the 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. The results of similar tests made on wood-frame constructions by the Forest Products Laboratory, Forest Service, United States Department of Agriculture, are given in BMS25, Structural Properties of Conventional Wood-Frame Constructions for Walls, Partitions, Floors, and Roofs.

The present report describes the structural properties of three wall constructions sponsored by one of the groups 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 furniture or 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 the suitability of a wall 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 National Concrete Masonry Association, Chicago, Ill., and represented a brick-concrete-block wall construction with a facing of rowlock brick (laid on edge) and a backing of "Haydite" concrete blocks, a brick-concrete-block wall construction with a facing of split brick and a backing of "Waylite" concrete blocks, and a "Pottsco" concrete-block wall construction. The joints were cement-lime mortar.

III. SPECIMENS AND TESTS

The wall construction with rowlock-brick facing and "Haydite" concrete-block backing was assigned the symbol *BF*, the construction with split-brick facing and "Waylite" concrete-block backing was assigned the symbol *BO*, and the "Pottsco" concrete-block wall was assigned the symbol *BP*. The specimens were assigned designations in accordance with table 1.

TABLE 1.—*Specimen designations, walls BF, BO, and BP*

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

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

The specimens were tested in accordance with BMS2, Methods of Determining the Structural Properties of Low-Cost House Constructions. This report 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 September 12, 1938, and completed February 10, 1939. The specimens were tested 28 days after they were built. The sponsor's representative witnessed the tests.

IV. MATERIALS

1. Sources of Information

Sponsor's statement.—Unless otherwise stated, the information on materials was obtained from the sponsor and from inspection of the specimens.

Masonry Construction Section.—The properties of the brick, concrete units, and mortar were determined by the Masonry Construction Section of the Bureau.

2. Brick

Side-cut shale brick with textured edges and ends. The brick for wall *BF* were made by the John H. Black Co., Buffalo, N. Y., with the average dimensions 3.70 by 7.99 by 2.26 in. (about 3$^{11}/_{16}$ by 8 by 2¼ in). The brick for wall *BO* were made as full-sized brick and as split brick. The average dimensions of the full-sized brick were 3.77 by 8.06 by 2.23 in. (about 3¾ by 8$\frac{1}{16}$ by 2¼ in.) and of the split brick 1.87 by 8.01 by 2.21 in. (about 1⅞ by 8 by 2$\frac{3}{16}$ in). Manufactured by the Binghamton Brick Co., Binghamton, N. Y.

Masonry Construction Section.—When laid, the brick were damp. The absorption for 1-min partial immersion was determined for two brick taken about every 30 min from the mason's scaffold. The physical properties of the brick, determined in accordance with the ASTM Standard C67–37,[1] Standard Methods of Testing Brick (Modulus of rupture, compressive strength, absorption), are given in table 2.

TABLE 2.—*Physical properties of the brick, walls BF and BO*

Construction symbol	Compressive strength	Modulus of rupture	Water absorption: 5-hr cold	Water absorption: 24-hr cold, *C*	Water absorption: 5-hr boil, *B*	Water absorption: Saturation coefficient, *C/B*	1-min partial immersion [a]: Dry	1-min partial immersion [a]: As laid	Weight, dry
	lb/in.^{2}	*lb/in.*^{2}	*Percent*	*Percent*	*Percent*		*g/brick*	*g/brick*	*lb/brick*
BF	10,800	1,790	7.5	8.2	10.3	0.79	23	15	5.06
BO (full-sized)	11,700	1,290	5.3	5.9	7.5	.79	26	14	5.43
BO (split)	13,100	1,370	4.2	4.7	6.6	.67	10	7	2.69

[a] Immersed on flat side in ⅛ in. of water.

3. CONCRETE UNITS

(*a*) "*Haydite*" *Units, Wall BF*

Concrete blocks and bricks made with a burned clay or shale aggregate marketed under the trade name "Haydite." The full-sized "Haydite" blocks had two cells, as shown in figure 1. Half blocks were also manufactured. The average dimensions of the full-sized blocks were 5.95 by 15.80 by 7.84 in. (about 5$\frac{15}{16}$ by 15$\frac{13}{16}$ by 7$\frac{13}{16}$ in.) and of the half blocks 5.95 by 7.71 by 7.82 in. (about 5$\frac{15}{16}$ by 7$\frac{11}{16}$ by 7$\frac{13}{16}$ in). The average dimensions of the "Haydite" brick were 3.86 by 8.00 by 2.21 in. (about 3⅞ by 8 by 2$\frac{3}{16}$ in). The blocks and brick were manufactured by the John H. Black Co., Buffalo, N. Y.

[1] Am. Soc. Testing Materials Supplement to Book of ASTM Standards, p. 78–82 (1937).

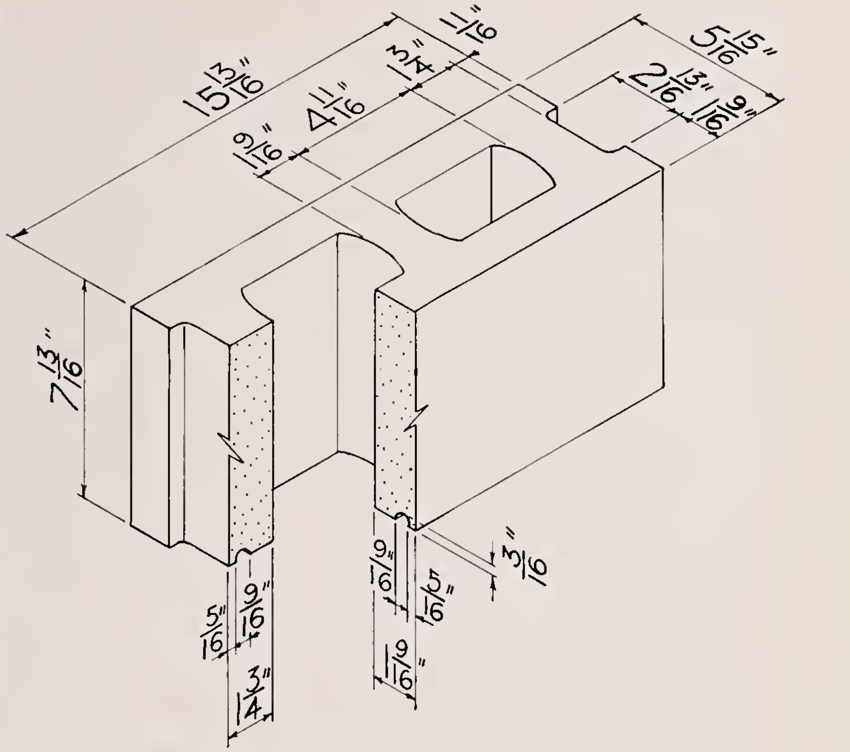

FIGURE 1.—"*Haydite*" *concrete block.*

(*b*) "*Waylite*" *Units, Wall BO*

Concrete blocks and bonding units made with an expanded slag aggregate marketed under the trade name "Waylite." The full-sized "Waylite" blocks had three cells, as shown in figure 2. Half blocks were also manufactured. The average dimensions of the full-sized blocks were

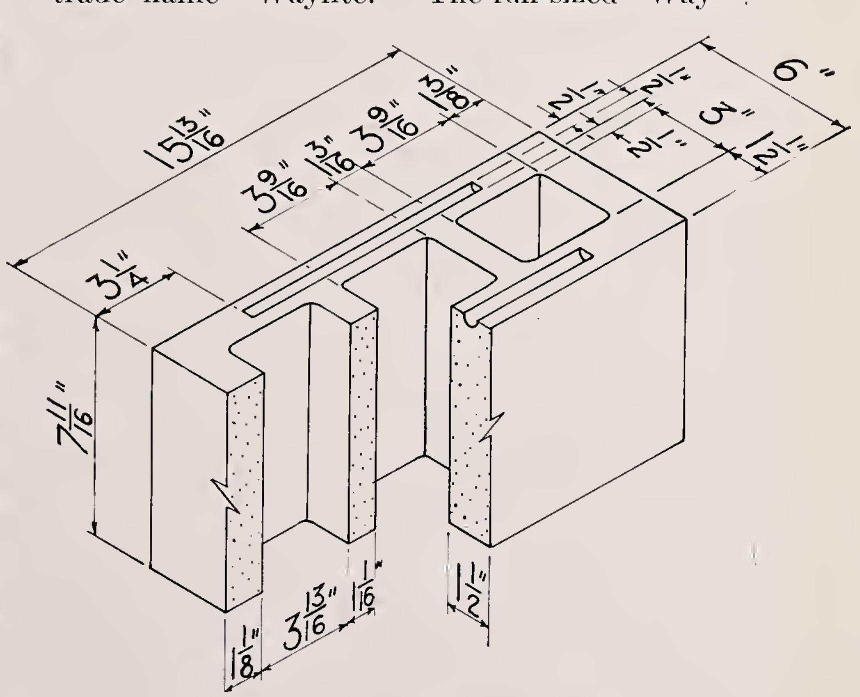

FIGURE 2.—"*Waylite*" *concrete block.*

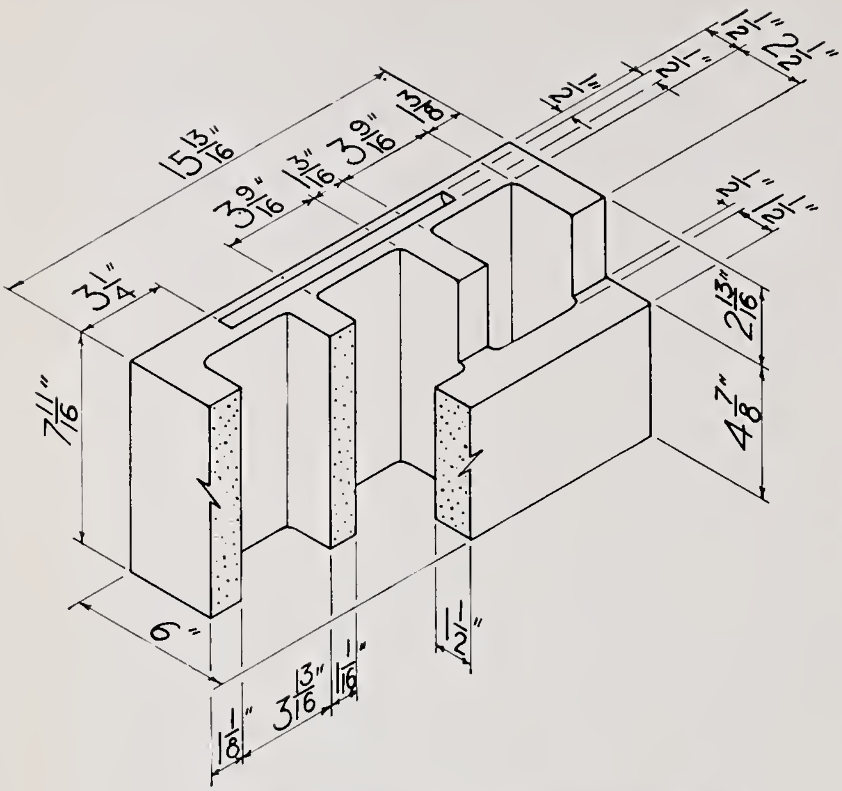

FIGURE 3.—*"Waylite" concrete bonding unit.*

6.03 by 15.83 by 7.71 in. (about 6 by 15¹³⁄₁₆ by 7¹¹⁄₁₆ in.) and of the half blocks 6.01 by 7.72 by 7.71 in. (about 6 by 7¾ by 7¹¹⁄₁₆ in.). The "Waylite" bonding units also had 3 cells, as shown in figure 3. The average dimensions of the bonding units were 6.03 by 15.84 by 7.71 in. (about 6 by 15¹³⁄₁₆ by 7¹¹⁄₁₆ in.). The blocks and bonding units were manufactured by the Chicago Insulcrete Co., Franklin Park, Ill.

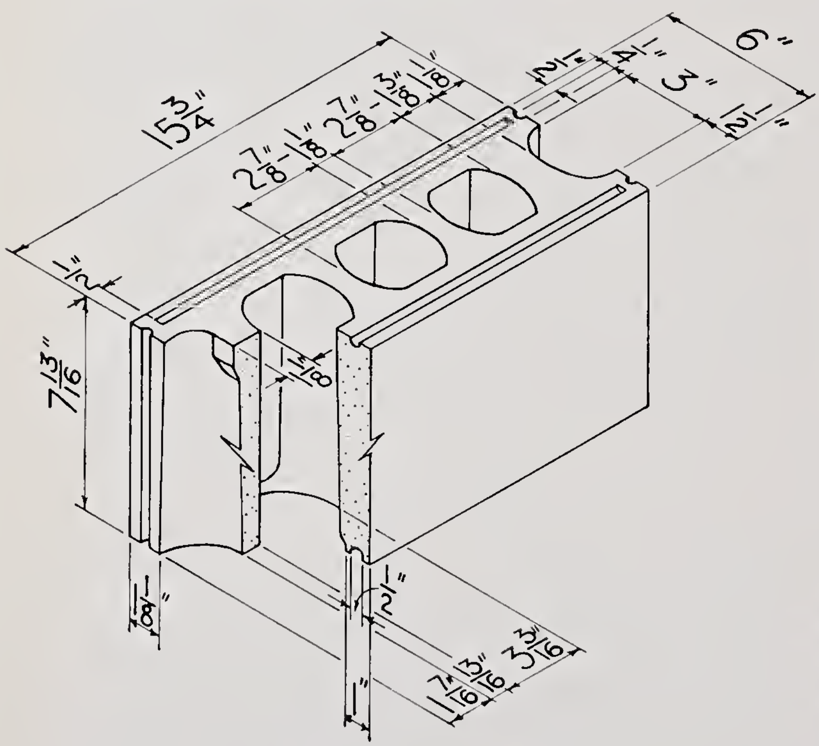

FIGURE 4.—*"Pottsco" concrete block.*

(c) *"Pottsco" Units, Wall BP*

Concrete blocks made with an expanded slag aggregate marketed under the trade name "Pottsco." The full-sized "Pottsco" blocks had three cells, as shown in figure 4. Half blocks were also manufactured. The average dimensions of the full-sized blocks were 6.00 by 15.73 by 7.80 in. (about 6 by 15¾ by 7¹³⁄₁₆ in.) and of the half blocks 6.00 by 7.71 by 7.86 in. (about 6 by 7¹¹⁄₁₆ by 7⅞ in.). The blocks were manufactured by the Midwest Concrete Pipe Co., Franklin Park, Ill.

Masonry Construction Section.—The physical properties of the concrete units given in table 3 were determined in accordance with ASTM Standard C90–36,[2] Standard Specifications and Tests for Load-Bearing Concrete Masonry Units, so far as this standard was applicable.

TABLE 3.—*Physical properties of the concrete units, walls BF, BO, and BP*

Concrete unit	Thickness of face shell, minimum	Modulus of rupture	Compressive strength, gross area	Water absorption by total immersion, 24-hr. cold		Weight, dry	
	in.	*lb/in.²*	*lb/in.²*	*Percent, by weight*	*lb/ft³ of concrete*	*lb/unit*	*lb/ft³ of concrete*
"Haydite" full-sized block	1.56	---	1,440	14.5	12.4	25.6	88.1
"Haydite" half block	1.55	---	-----	14.5	12.1	12.4	87.4
"Haydite" brick	---	385	1,670	13.6	--	3.0	
"Waylite" full-sized block	1.46		1,510	9.5	9.8	28.2	102.7
"Waylite" half block	1.46	-		10.0	9.9	13.0	97.8
"Waylite" bonding block	1.50	.	1,330	10.3	9.9	22.1	97.0
"Pottsco" full-sized block	1.08		1,020	14.2	13.2	24.1	93.7
"Pottsco" half block	1.09	---		14.0	13.3	12.0	94.3

4. MORTAR

The materials for the mortar were Medusa Cement Co.'s "Medusa" portland cement, lime putty made by slaking Standard Lime and Stone Co.'s "Washington" quicklime, and Potomac River building sand.

[2] Am. Soc. Testing Materials, Standards, pt. 2, Non-Metals, p. 168–71 (1936).

The mortar was 1 part of cement, 0.42 part of hydrated lime, and 5.1 parts of dry sand, by weight. The proportions by volume were 1 part of cement, 1 part of hydrated lime, and 6 parts of loose damp sand, assuming that portland cement weighs 94 lb/ft^3, dry hydrated lime 40 lb/ft^3, and 80 lb of dry sand is equivalent to 1 ft^3 of loose damp sand. The materials for each batch were measured by weight and mixed in a batch mixer having a capacity of ⅔ ft^3. The amount of water added to the mortar was adjusted to the satisfaction of the mason.

Masonry Construction Section.—The cement complied with the requirements of Federal Specification SS–C–191a, Cement; Portland, for fineness, soundness, time of setting, and tensile strength. The lime putty contained 40 to 45 percent of dry hydrate, by weight, and had a plasticity of over 600, measured in accordance with Federal Specification SS–L–351, Lime; Hydrated (for) Structural Purposes. The sieve analysis of the sand is given in table 4.

TABLE 4.—*Sieve analysis of the sand in mortar, walls BF, BO, and BP*

U. S. Standard Sieve number	Passing, by weight	
	Wall *BF*	Walls *BO* and *BP*
	Percent	*Percent*
8	100	100
16	94	87
30	75	57
50	18	12
100	2	2

The average water content of the mortar, by weight of dry materials. was 22.9, 22.1, and 21.1 percent for walls *BF*, *BO*, and *BP*, respectively. Samples were taken from at least one batch of mortar for each wall specimen, 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 in air on the wall specimen. The physical properties of the mortar are given in table 5.

TABLE 5.—*Physical properties of mortar, walls BF, BO, and BP*

Specimen	Flow	Compressive strength [a]	
		Air storage	Water storage
	Percent	*lb/in.*^{2}	*lb/in.*^{2}
BF–C1	100	478	691
BF–C2	122	425	663
BF–C3	117	385	631
BF–T1	98	787	606
BF–T2	94	685	511
BF–T3	107	676	621
BF–T4	106	666	618
BF–T5	106	842	727
BF–T6	98	701	595
BF–I1	95	510	706
BF–I2	97	547	636
BF–I3	101	655	755
BF–I4	97	763	725
BF–I5	98	765	752
BF–I6			
BF–R1	94	426	709
BF–R2	94	412	639
BF–R3	96	807	829
Average	101	619	671
BO–C1	109	548	830
BO–C2	107	658	853
BO–C3	109	812	885
BO–T1	110	583	773
BO–T2	108	625	868
BO–T3	109	682	814
BO–T4	96	633	880
BO–T5	104	643	802
BO–T6	110	576	778
BO–I1	108	659	868
BO–I2	112	666	796
BO–I3	109	919	841
BO–I4	109	528	753
BO–I5	110	691	815
BO–I6	109	894	867
BO–R1	108	563	808
	108	563	796
BO–R2	110	767	832
	107	671	848
BO–R3	107	1,058	992
	109	976	934
Average	108	701	840
BP–C1	115	450	787
BP–C2	111	676	817
BP–C3	108	652	773
BP–T1	109	548	814
BP–T2	110	626	814
BP–T3	107	590	809
BP–I1	112	568	881
BP–I2	108	569	978
BP–I3	108	597	823
BP–R1	109	594	798
	110	562	838
BP–R2	109	714	864
	108	548	830
BP–R3	108	633	882
	111	702	837
Average	109	602	836

[a] Determined on the day the wall specimen was tested (age 28 days).

V. FABRICATION DATA

The fabrication data, determined by the Masonry Construction Section, are given in table 6.

Table 6.—*Fabrication data, walls BF, BO, and BP*

[The values per square foot were computed using the face area of the specimens]

Construction symbol	Masonry unit		Thickness of joints		Mortar materials			Mason's time
			Bed	Head	Cement	Lime, dry hydrate	Sand, dry	
		Number/ft²	*in.*	*in.*	*lb/ft²*	*lb/ft²*	*lb/ft²*	*hr/ft²*
BF	Brick	ᵃ 4.31	0.56	0.49	1.85	0.78	9.44	0.12
	"Haydite" block	ᵃ 0.90	.64	.52				
	"Haydite" brick	.90						
BO	Full-sized brick	1.07			1.87	.78	9.53	.14
	Split brick	5.37	.44	.36				
	"Waylite" block	0.55	.27	.50				
	"Waylite" bonding block.	.55						
BP	"Pottsco" block	1.10	.38	.42	0.65	.27	3.32	.042

ᵃ For walls containing 25 facing courses.

VI. WALL *BF*

1. Sponsor's Statement

(*a*) *Description*

The specimens were built with a brick facing, *A*, shown in figure 5, and a backing of "Haydite" concrete units, *B*, with cement-lime mortar. In order to increase the height of the transverse and impact specimens, they were built with a bonding course at the upper end. Including the top stretcher course, there were 25 courses of brick in the facing and 15 courses of "Haydite" concrete units in the backing. The facing consisted of rowlock stretcher courses (brick laid on edge), bonded at every fifth course by a stretcher course of brick laid on the flat side. Two courses of "Haydite" concrete blocks were used as a backing for every four courses of facing rowlock stretchers. The brick bonding course was backed by a stretcher course of "Haydite" concrete brick. The 4-ft wall specimens were 8 ft 3 in. high, 4 ft ½ in. wide, and 8½ in. thick, except for the compressive specimens which were 8 ft ½ in. high. The 8-ft wall specimens were 8 ft ½ in. high, 8 ft 1½ in. wide, and 8½ in. thick.

The bed joints of the facing were furrowed slightly and all the head joints were filled. The mortar in the bed joints of the "Haydite" concrete blocks was laid under the back and face shells only. The head joints in the face were buttered with mortar, whereas the inner head joints were left open. The collar joint between facing and backing was not filled.

The price of this construction in Washington, D. C., as of July 1937, was \$0.41/ft².

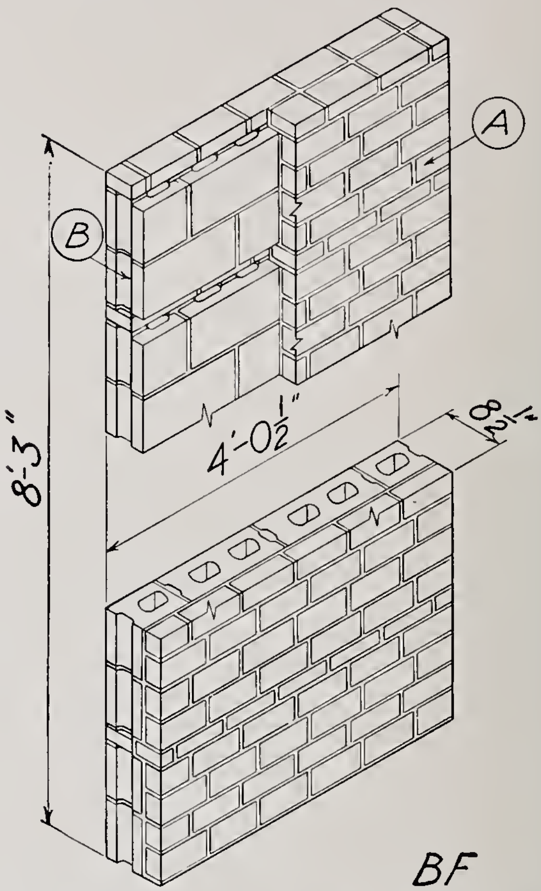

Figure 5.—*Four-foot wall specimen BF, having top bonding course.*

A, facing; *B*, backing.

(*b*) *Comments*

The cost of this construction is less than that of the conventional brick-faced wall because less brick is required. For an 8-in. wall the backing unit is 6 in. thick, and for a 12-in. wall the backing unit is 10 in. thick. Time studies indicate that the labor cost for walls of this construction is somewhat less than for conventional brick-faced walls. It is recommended not only for low-cost houses but especially for churches, schools, and industrial buildings.

2. Compressive Load

The results for wall specimens *BF–C1*, *C2*, and *C3* are shown in table 7 and in figures 6 and 7.

TABLE 7.—*Structural properties, walls BF, BO, and BP*

[Determined on the 28th day after the specimens were built]

Construction symbol	Weight, based on face area	Load: Compressive [a] Designation	Load: Compressive [a] Maximum load	Load: Transverse [b] Designation	Load: Transverse [b] Maximum load	Load: Concentrated Designation	Load: Concentrated Maximum load	Load: Impact [b] Designation	Load: Impact [b] Maximum height of drop	Load: Racking Designation	Load: Racking Maximum load
	lb/ft²		*Kips/ft* [c]		*lb/ft²*		*lb.*		*ft.*		*Kips/ft* [c]
BF	60.9	*C1*	34.0	*T1*	67.1	*P1*	[d] 1,000	*I1*	3.5	*R1*	6.03
		C2	45.2	*T2*	45.9	*P2*	[d] 1,000	*I2*	3.5	*R2*	5.19
		C3	47.3	*T3*	56.7	*P3*	[d] 1,000	*I3*	10.0	*R3*	[d] 6.15
Average			42.1		56.6		[d] 1,000		5.7		
BF				*T4*	40.0	*P4*	[d] 1,000	*I4*	4.5		
				T5	60.0	*P5*	[d] 1,000	*I5*	3.5		
				T6	48.0	*P6*	[d] 1,000	*I6*	4.0		
Average					49.3		[d] 1,000		4.0		
BO	60.8	*C1*	32.4	*T1*	80.0	*P1*	[d] 1,000	*I1*	3.5	*R1*	5.50
		C2	33.9	*T2*	55.2	*P2*	[d] 1,000	*I2*	4.5	*R2*	[d] 6.13
		C3	39.9	*T3*	101.6	*P3*	[d] 1,000	*I3*	4.0	*R3*	[d] 6.13
Average			35.4		78.9		[d] 1,000		4.0		
BO				*T4*	38.2	*P4*	[d] 1,000	*I4*	3.5		
				T5	34.0	*P5*	[d] 1,000	*I5*	4.5		
				T6	37.8	*P6*	[d] 1,000	*I6*	5.0		
Average					36.7		[d] 1,000		4.3		
BP	30.7	*C1*	28.0	*T1*	8.1	*P1*	[d] 1,000	*I1*	1.5	*R1*	1.80
		C2	24.0	*T2*	11.6	*P2*	[d] 1,000	*I2*	1.5	*R2*	1.60
		C3	19.6	*T3*	13.0	*P3*	[d] 1,000	*I3*	1.5	*R3*	2.02
Average			23.9		10.9		[d] 1,000		1.5		1.81

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

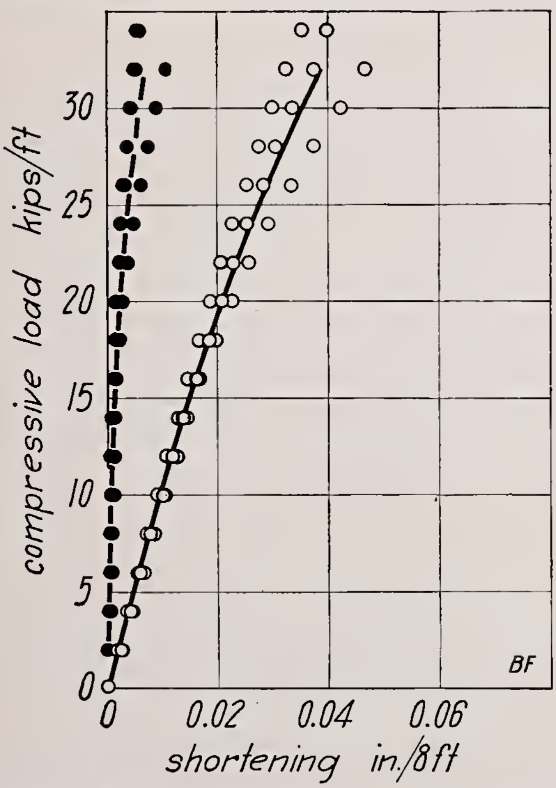

FIGURE 6.—*Compressive load on wall BF.*

Load-shortening (open circles) and load-set (solid circles) results for specimens *BF-C1*, *C2*, and *C3*. The load was applied 2.83 in. (one-third the thickness of the wall) from the inside face. The loads are in kips per foot of actual width of specimen.

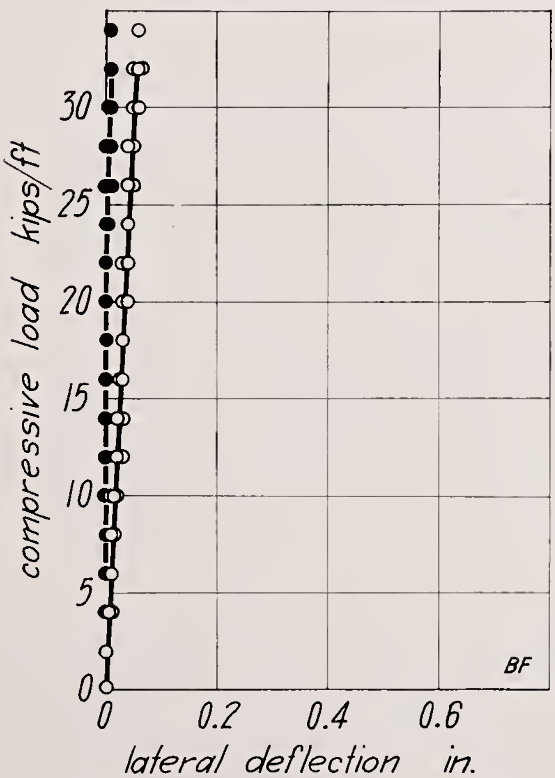

FIGURE 7.—*Compressive load on wall BF.*

Load-lateral deflection (open circles) and load-lateral set (solid circles) results for specimens *BF-C1*, *C2*, and *C3*. The load was applied 2.83 in. (one-third the thickness of the wall) from the inside face. The loads are in kips per foot of actual width of specimen. The deflections and sets are for a height of 6 ft 8 in., the gage length of the deflectometers.

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The shortenings and sets for a height of 8 ft were computed from the values obtained from the compressometer readings. The compressometers were attached to the specimens, the gage length being 6 ft 7½ in.

Each of the specimens failed by crushing of the concrete units in the backing in two or three

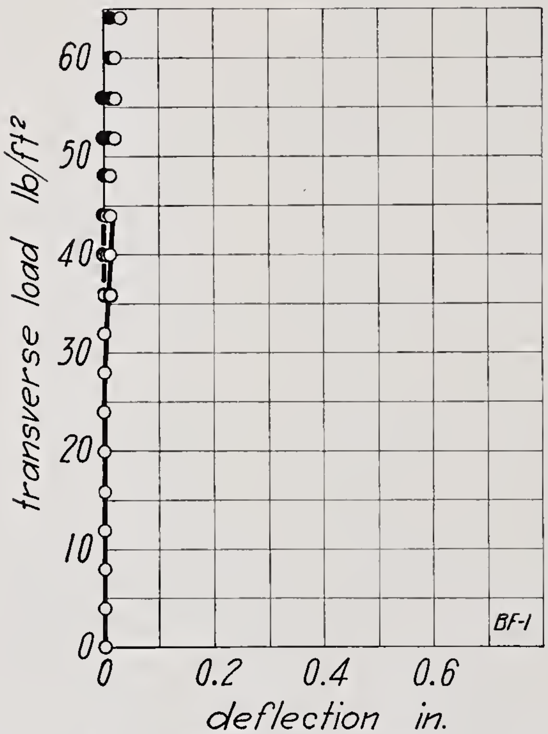

FIGURE 8.—*Transverse load on wall BF, load applied to inside face.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *BF–T1, T2, T3* on the span 7 ft 6 in. The deflections and sets are for a gage length of 7 ft 4 in., the gage length of the deflectometers.

courses at the upper end of the specimen. The mortar of the top bed joint in the backing of specimens *C1* and *C2* also crushed. In addition, in each of the specimens, the bond between the mortar and brick in the facing ruptured two or three courses from the upper end of the specimen.

3. Transverse Load

The results are shown in table 7 and in figure 8 for wall specimens *BF–T1, T2,* and *T3*, loaded on the inside face, and in figure 9 for wall specimens *BF–T4, T5,* and *T6*, loaded on the outside face.

At the maximum load each of the specimens *T1, T2,* and *T3* failed by rupture of the bond between the mortar and a brick bonding course in the facing at one or two bed joints at or between the loading rollers. In specimen *T2* the rupture extended through the backing also.

At the maximum load each of the specimens *T4, T5,* and *T6* failed by rupture of the bond between the mortar and the concrete units at a bed joint in the backing at or between the loading rollers. In specimen *T4* the rupture occurred at a bonding course; in specimens *T5* and *T6* the rupture extended through the facing also.

4. Concentrated Load

Wall specimen *BF–P5* under concentrated load is shown in figure 10. The results are shown in table 7 and in figure 11 for wall specimens *BF–P1, P2,* and *P3*, loaded on the inside face, and in figure 12 for wall specimens *BF–P4, P5,* and *P6*, loaded on the outside face.

The concentrated loads were applied over the center web of a concrete block of specimens

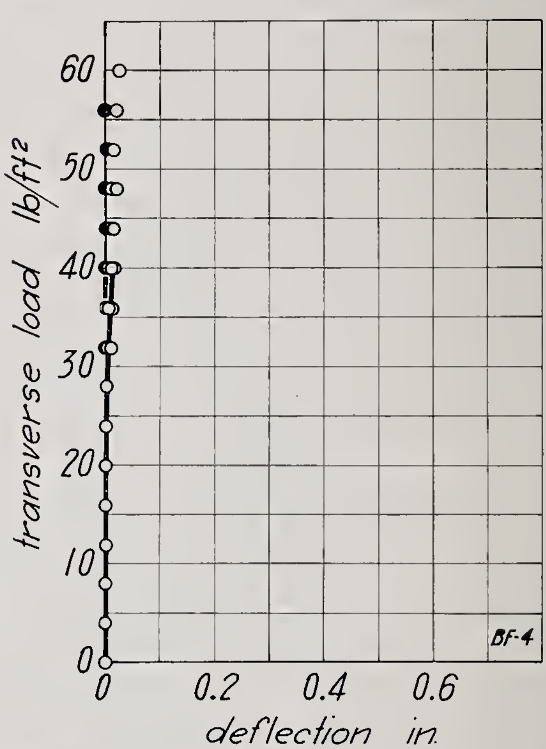

FIGURE 9.—*Transverse load on wall BF, load applied to outside face.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *BF–T4, T5,* and *T6* on the span 7 ft 6 in. The deflections and sets are for a gage length of 7 ft 4 in., the gage length of the deflectometers.

P1 and *P3* and over one cell of a concrete block of specimen *P2*. In specimens *P1, P2,* and *P3*, the indentations after a load of 1,000 lb had been applied were 0.006, 0.001, and 0.004 in., respectively, and no other effect was observed.

FIGURE 10.—*Wall specimen BF–P5 under concentrated load.*

A, loading disk.

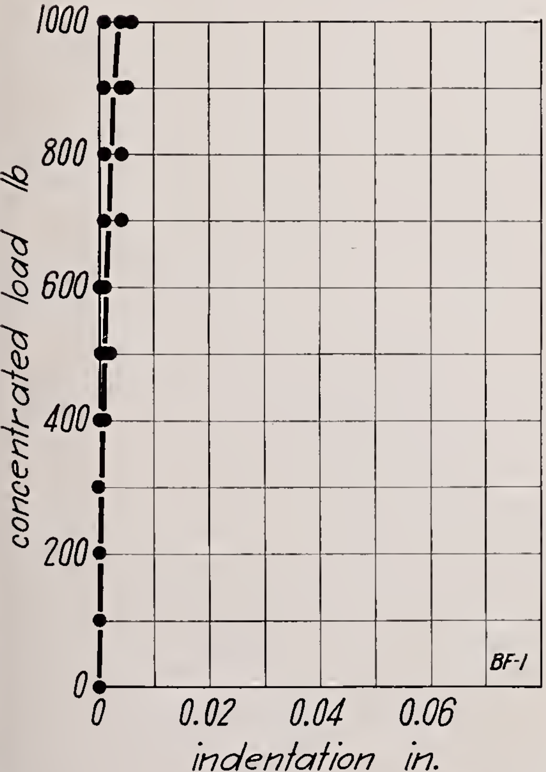

FIGURE 11.—*Concentrated load on wall BF, load applied to inside face.*

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

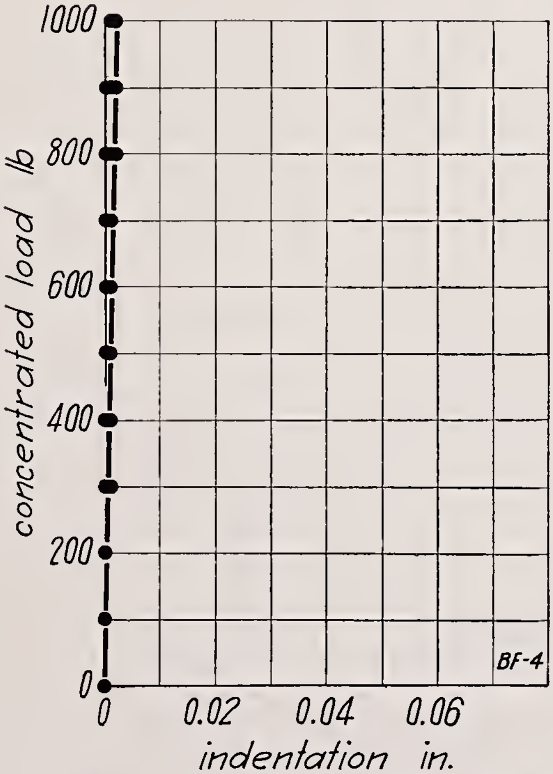

FIGURE 12.—*Concentrated load on wall BF, load applied to outside face.*

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

The concentrated loads were applied to a brick in a bonding course of specimens *P4* and *P5* and to a brick in a rowlock course of specimen *P6*. In specimens *P4*, *P5*, and *P6*, the indentations after a load of 1,000 lb had been applied were 0.002, 0.001, and 0.001 in., respectively, and no other effect was observed.

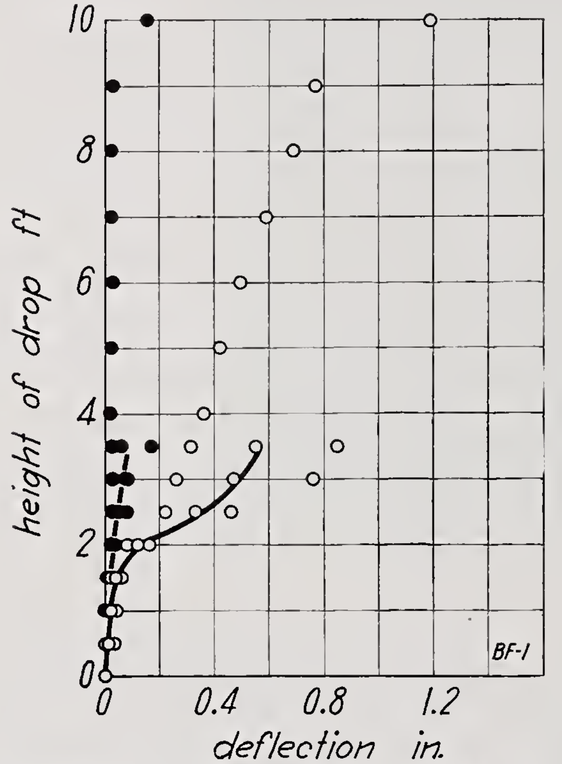

Figure 13.—*Impact load on wall BF, load applied to inside face.*

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

5. Impact Load

The results are shown in table 7 and in figure 13 for wall specimens *BF–I1*, *I2*, and *I3*, loaded on the inside face, and in figure 14 for wall specimens *BF–I4*, *I5*, and *I6*, loaded on the outside face.

In each of the specimens *I1*, *I2*, and *I3* at drops of 2.5, 2, and 2 ft, respectively, the bond between the mortar and the brick ruptured at a bed joint in the facing near midspan. At drops of 3, 3, and 4.5 ft, respectively, the bond between the mortar and the concrete units ruptured at a bed joint in the backing at about the same height as the cracks in the facing. At the maximum drop each of these specimens failed by opening of these cracks or by rupture of other bed joints. The failure of specimen *I3* occurred at a bonding course.

In each of the specimens *I4*, *I5*, and *I6* at a drop of 2 ft the bond between the mortar and the concrete units ruptured at a bed joint in the backing near midspan. At drops of 3, 3, and 2.5 ft, respectively, the bond between the mortar and the brick ruptured at a bed joint in the facing at the same height. At the maximum drop each specimen failed by opening of these cracks. The failure of specimen *I6* occurred at a bonding course.

6. Racking Load

Wall specimen *BF–R2* under racking load is shown in figure 15. The results for wall specimens *BF–R1*, *R2*, and *R3* are shown in table 7 and in figure 16.

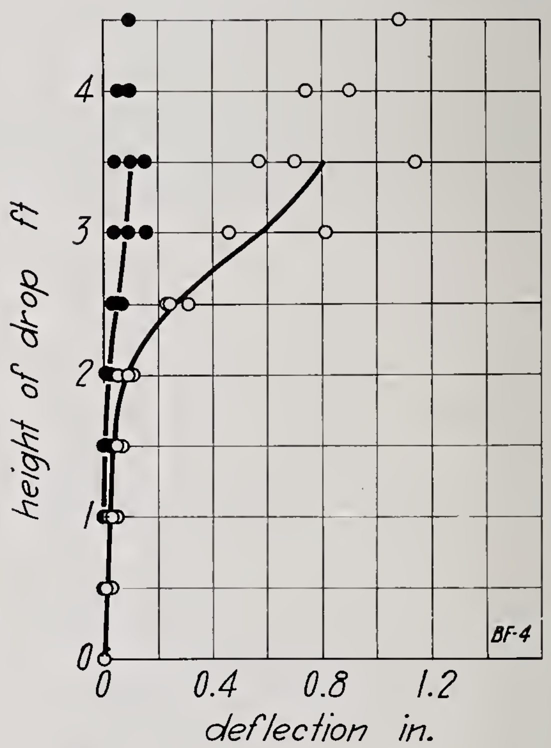

Figure 14.—*Impact load on wall BF, load applied to outside face.*

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

The deformations and sets shown in figure 16 were computed from the measuring-device readings. The gage length of the vertical measuring device was 6 ft 7½ in. The gage length of the horizontal measuring device was 5 ft 0 in.

Figure 15.—*Wall specimen BF–R2 under racking load.*

Specimens *R1* and *R2* failed by rupture of the bond between the mortar and blocks in the backing and the mortar and brick in the facing in stepwise cracks in the bed and head joints diagonally from the load to the stop. Some bricks and blocks also broke. Specimen *R3* did not fail; the set after a load of 6.15 kips/ft had been applied was 0.007 in., and no other effect was observed.

VII. WALL *BO*

1. Sponsor's Statement

(*a*) *Description*

The specimens were built with a brick facing, *A*, shown in figure 17, and with a backing of "Waylite" concrete blocks, *B*, with cement-lime mortar. Each specimen consisted of 36 courses of brick in the facing and 12 courses of "Waylite" concrete blocks in the backing. In order to increase the height of the transverse, impact, and racking specimens, a header course, *C*, of full-sized brick was laid over the top of these specimens. The facing consisted of split-brick stretcher courses, 2$\frac{3}{16}$ in. high and 1$\frac{7}{8}$ in. thick, bonded to the backing at every sixth course by a stretcher course of full-sized brick. The backing consisted of "Waylite" concrete blocks, alternate courses being bonding units into which the brick bonding courses of the facing fitted. The 4-ft wall specimens were 8 ft 3 in. high, 4 ft ½ in. wide, and 8½ in. thick, except for compressive specimens which were 8 ft 1 in. high. The 8-ft wall specimens were 8 ft 3 in. high, 8 ft 2 in. wide, and 8½ in. thick.

The bed joints of the facing were furrowed slightly, and all the head joints were filled. The mortar in the bed joints of the "Waylite" concrete blocks was laid under the back and face shells only. The head joints were buttered at the edges only, the center being left open. The collar joint between the facing and backing was not filled.

The price of this construction in Washington, D. C., as of July 1937, was \$0.48/ft^2.

(*b*) *Comments*

Split brick suitable for this construction are made by manufacturers in New York, Ohio,

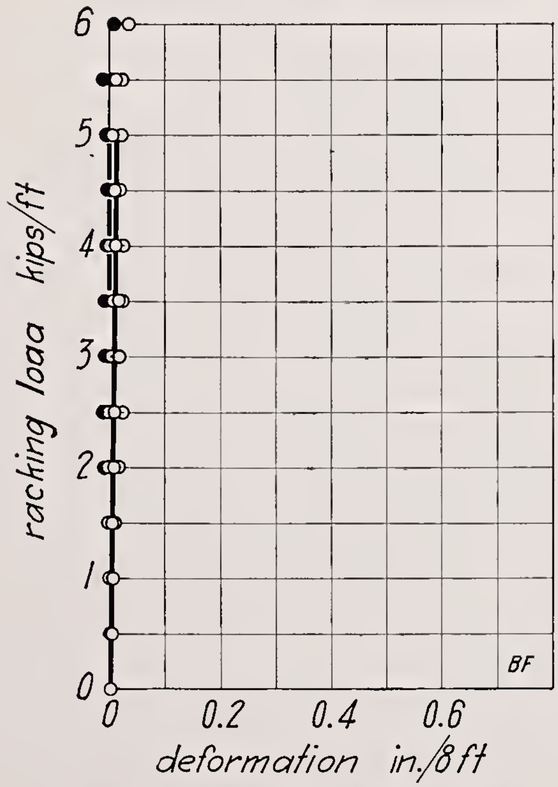

Figure 16.—*Racking load on wall BF.*

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

Minnesota, and Illinois. At present split brick are available only in face brick. If the price is about one-half the price of standard-sized brick, a substantial decrease in the cost of the wall can be realized.

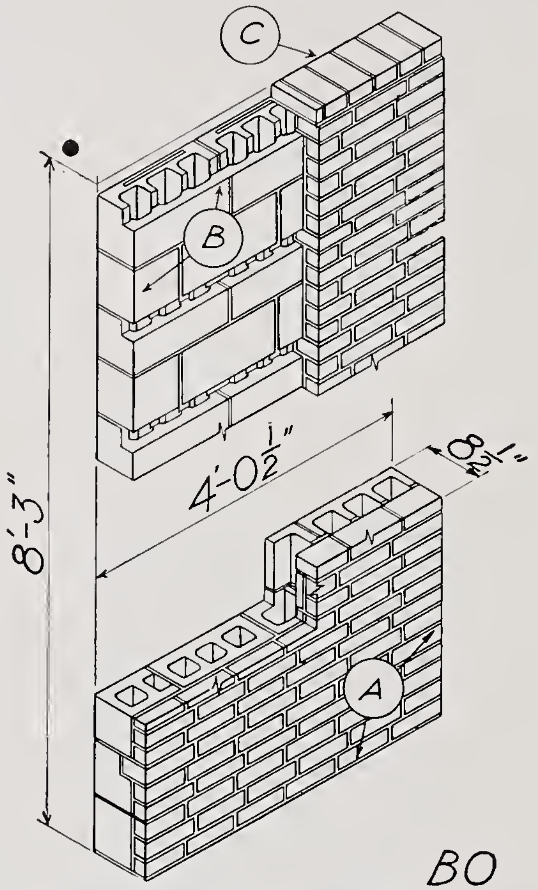

FIGURE 17.—*Four-foot wall specimen BO, having top header course.*

A, facing; *B*, backing; *C*, header course.

2. Compressive Load

The results for wall specimens *BO–C1*, *C2*, and *C3* are shown in table 7, and in figures 18 and 19. The shortenings and sets shown in figure 18 for a height of 8 ft were computed from the values obtained from the compressometer readings. The compressometers for specimen *C1* were attached to the specimen, the gage length being 7 ft 1 in. The compressometers for specimens *C2* and *C3* were attached to the upper and lower bearing plates, the gage length being 8 ft 1 in. The computed shortenings in 8 ft for specimen *C1* were less than the shortenings in 8 ft for specimens *C2* and *C3*.

Each of the specimens failed by crushing of the concrete blocks in the backing in two or three courses at the upper end of the specimen. In specimen *C3* the bond between the mortar and brick ruptured in a course near the upper end of the specimen.

3. Transverse Load

The results are shown in table 7 and in figure 20 for wall specimens *BO-T1*, *T2*, and *T3*, loaded on the inside face, and in figure 21 for wall specimens *BO–T4*, *T5*, and *T6*, loaded on the outside face.

Each of the specimens *T1*, *T2*, *T3*, *T4*, and *T6* failed by rupture of the bond between the mortar and brick at a bed joint in the facing and between the mortar and concrete blocks at a bed joint in the backing at or between the loading rollers. The break appeared first in the face opposite the load and then extended to the loaded face. In specimen *T5* at a load of 28 lb/ft² the bond between the mortar and concrete blocks ruptured at a bed joint near mid-span, and at a load of 30 lb/ft² the bond between the mortar and the brick ruptured at a bed joint at the same height. At the maximum

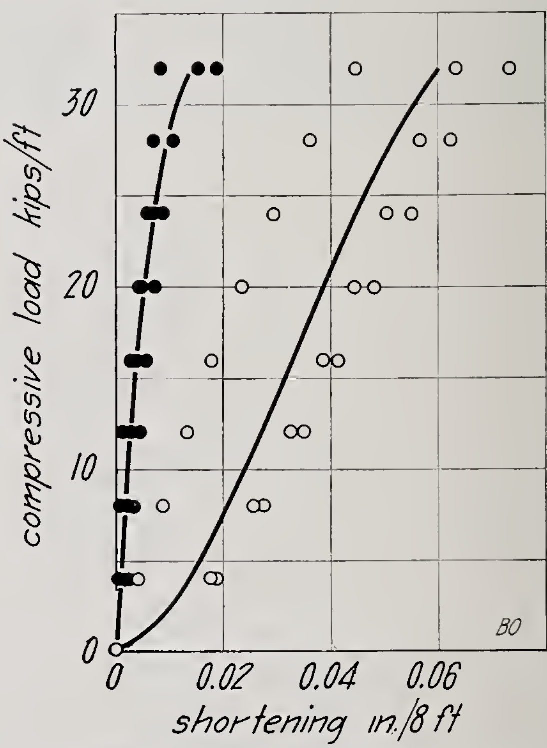

FIGURE 18.—*Compressive load on wall BO.*

Load-shortening (open circles) and load-set (solid circles) results for specimens *BO–C1*, *C2*, and *C3*. The load was applied 2.83 in. (one-third the thickness of the wall) from the inside face. The loads are in kips per foot of actual width of specimens.

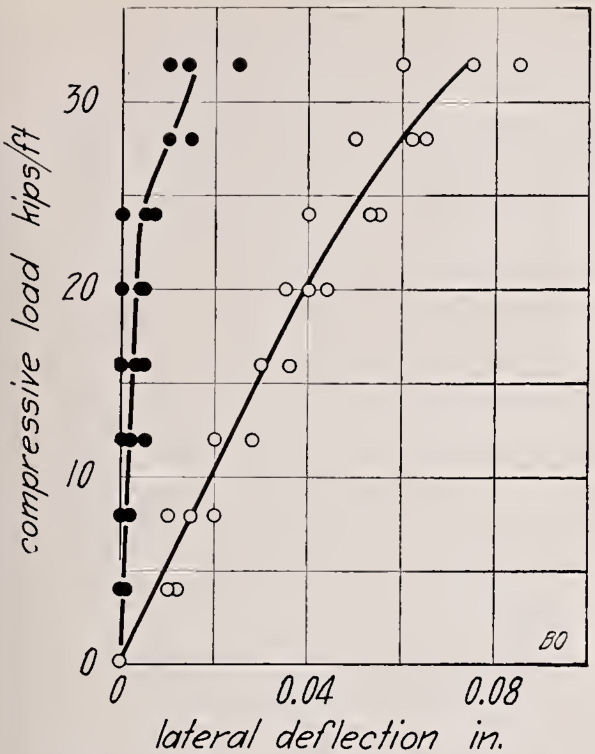

FIGURE 19.—*Compressive load on wall BO.*

Load-lateral deflection (open circles) and load-lateral set (solid circles) results for specimens *BO-C1, C2,* and *C3*. The load was applied 2.83 in. (one-third the thickness of the wall) from the inside face. The loads are in kips per foot of actual width of specimen. The deflections and sets are for a height of 7 ft 8 in., the gage length of the deflectometers.

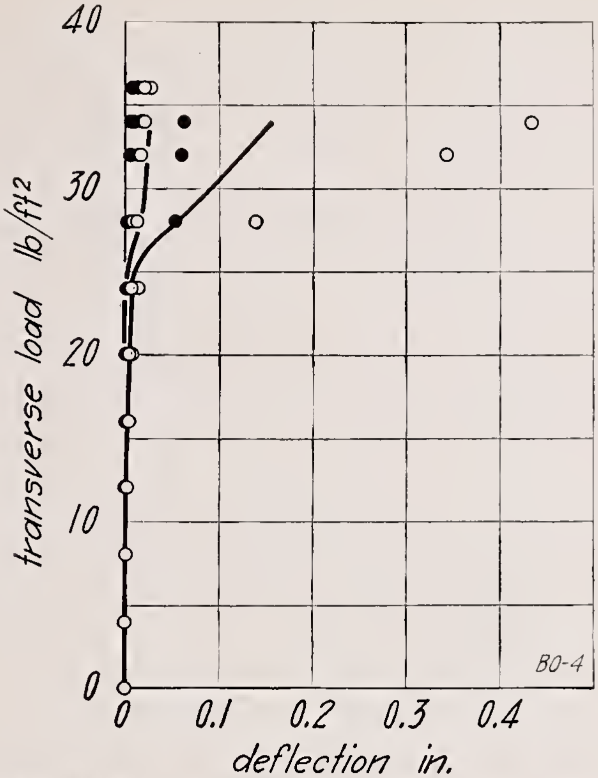

FIGURE 21.—*Transverse load on wall BO, load applied to outside face.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *BO-T4, T5,* and *T6* on the span 7 ft 6 in. The deflections and sets are for a gage length of 7 ft 6 in., the gage length of the deflectometers.

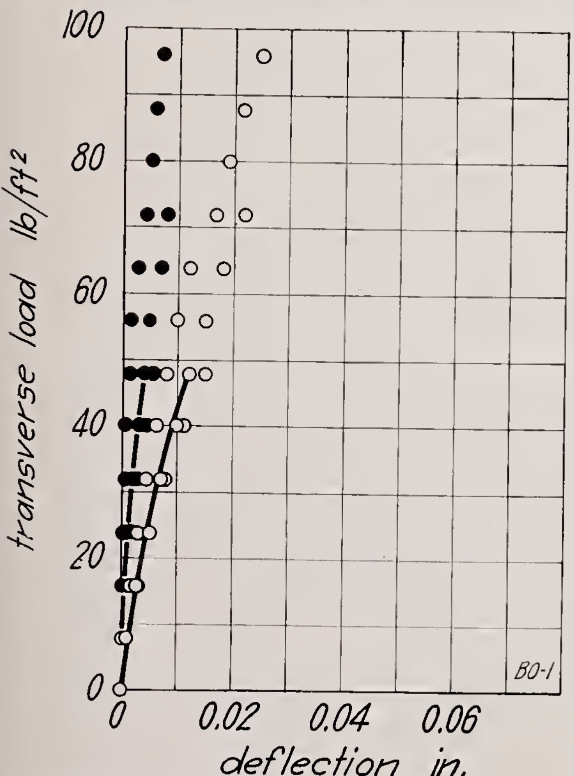

FIGURE 20.—*Transverse load on wall BO, load applied to inside face.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *BO-T1, T2,* and *T3* on the span 7 ft 6 in. The deflections and sets are for a gage length of 7 ft 6 in., the gage length of the deflectometers.

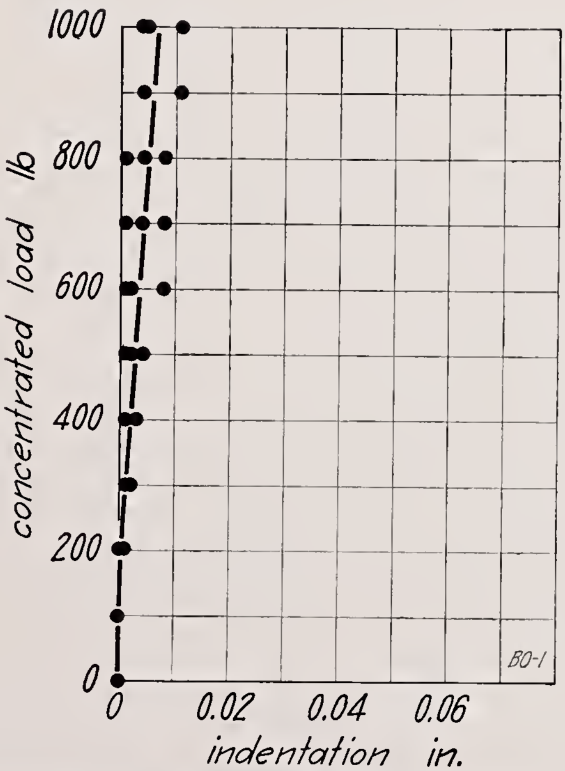

FIGURE 22.—*Concentrated load on wall BO, load applied to inside face.*

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

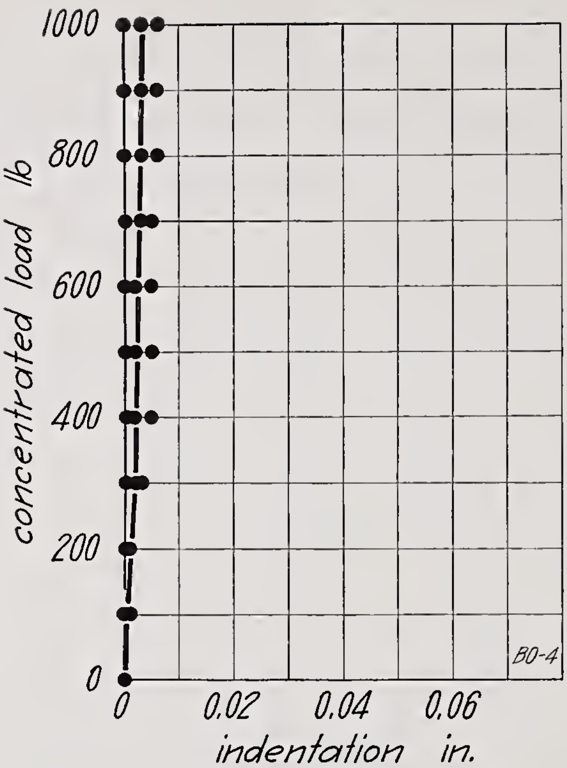

FIGURE 23.—*Concentrated load on wall BO, load applied to outside face.*

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

load this specimen failed by opening of these cracks. The cracks in specimens *T2, T5*, and *T6* occurred at bonding courses in the facing and backing.

4. Concentrated Load

The results are shown in table 7 and in figure 22 for wall specimens *BO–P1, P2*, and *P3*, loaded on the inside face and in figure 23 for wall specimens *BO–P4, P5*, and *P6*, loaded on the outside face.

The concentrated loads were applied over one cell of a concrete block of specimens *P1, P2*, and *P3*, and on a split brick of specimens *P4, P5*, and *P6*. In specimens *P1, P2, P3, P4, P5*, and *P6*, the indentations after a load of 1,000 lb had been applied were 0.011, 0.004, 0.005, 0.006, 0.000, and 0.003 in., respectively, and no other effect was observed.

5. Impact Load

Wall specimen *BO–I3* during the impact test is shown in figure 24. The results are shown in table 7 and in figure 25 for wall specimens *BO–I1, I2*, and *I3*, loaded on the inside face, and in figure 26 for wall specimens *BO–I4, I5*, and *I6*, loaded on the outside face.

In specimens *I1, I2*, and *I3* at drops of 2.5, 4, and 2 ft, respectively, the bond between the mortar and brick ruptured at a bed joint in the facing near midspan. At drops of 3, 4.5, and 3 ft, respectively, the bond between the mortar and concrete blocks ruptured at a bed joint in the backing near midspan. At the maximum drops the specimens failed by opening of these cracks.

In specimens *I4, I5*, and *I6* at drops of 1.5, 2, and 1.5 ft, respectively, the bond between the mortar and concrete blocks ruptured at a bed joint in the backing near midspan. At drops of 2.5, 3, and 3 ft, respectively, the bond between the mortar and brick ruptured at a bed joint in the facing near midspan. At the maximum drops the specimens failed by opening of these cracks.

The failure in each specimen under impact load occurred at a bonding course.

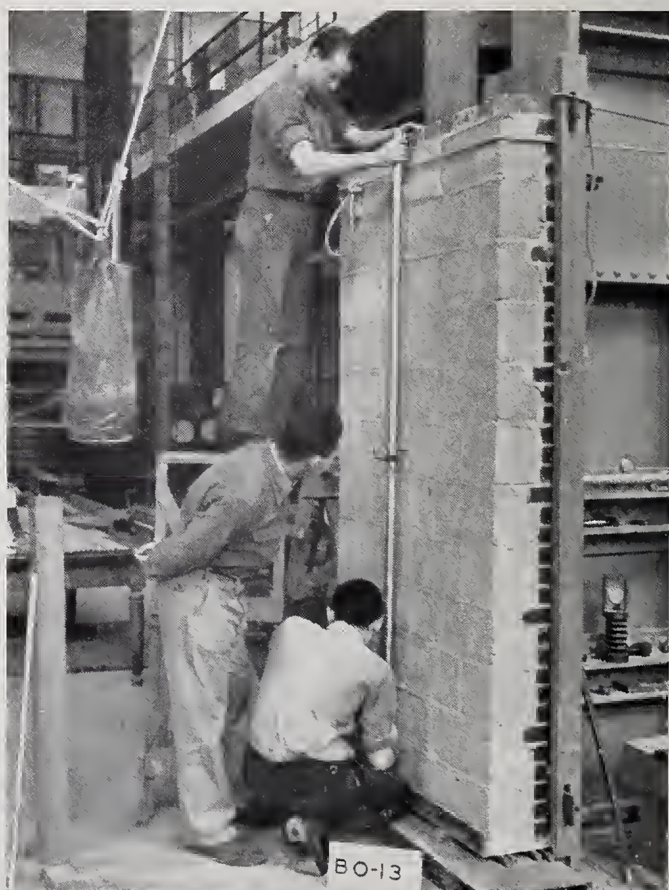

FIGURE 24.—*Wall specimen BO–I3 during the impact test.*

6. Racking Load

The results for wall specimens *BO–R1*, *R2*, and *R3* are shown in table 7 and in figure 27.

The deformations and sets shown in figure 27 were computed from the measuring-device readings. The gage length of the measuring device was 6 ft 9½ in.

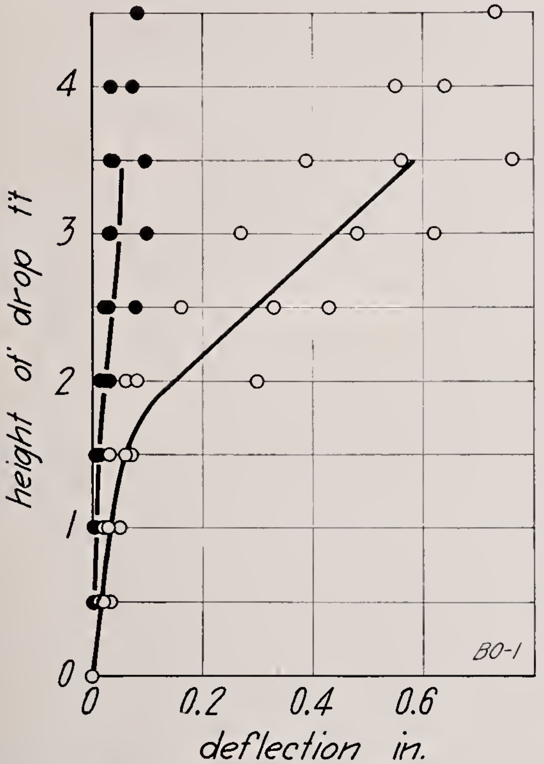

Figure 25.—*Impact load on wall BO, load applied to inside face.*

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

Specimen *R1* failed by rupture of the bed and head joints of both the facing and the backing in stepwise cracks diagonally from the loaded corner to the stop. Some brick and concrete blocks also broke. Specimens *R2* and *R3* did not fail; the sets after a load of 6.13 kips/ft had been applied were 0.002 and 0.005 in., respectively, and no other effect was observed.

VIII. WALL *BP*

1. Sponsor's Statement

(*a*) *Description*

The specimens were built with "Pottsco" concrete blocks, as shown in figure 28, and cement-lime mortar. The head joints were staggered by using half stretchers at the ends of alternate courses. The 4-ft wall specimens were 8 ft 2 in. high, 4 ft 0 in. wide, and 6 in. thick. The 8-ft wall specimens were 8 ft 2 in. high, 8 ft ½ in. wide, and 6 in. thick.

The mortar in the bed joints was placed at the front and back shells only, and the head joints were buttered with mortar at the faces only, leaving the inner portion of both the head and bed joints open.

The price of this construction in Washington, D. C., as of July 1937, was $0.31/ft².

(*b*) *Comments*

To comply with the requirements of most building codes, a masonry bearing wall must be at least 8 in. thick. However, in the Southwest, the bearing walls of many garages, one-story houses, and other small buildings are only 6 in. thick. Although there is little difference in the cost of 6- and 8-in. concrete masonry walls, the increase in the floor area is appreciable. For example, if a house is 24 ft. square on the outside, the increase in floor

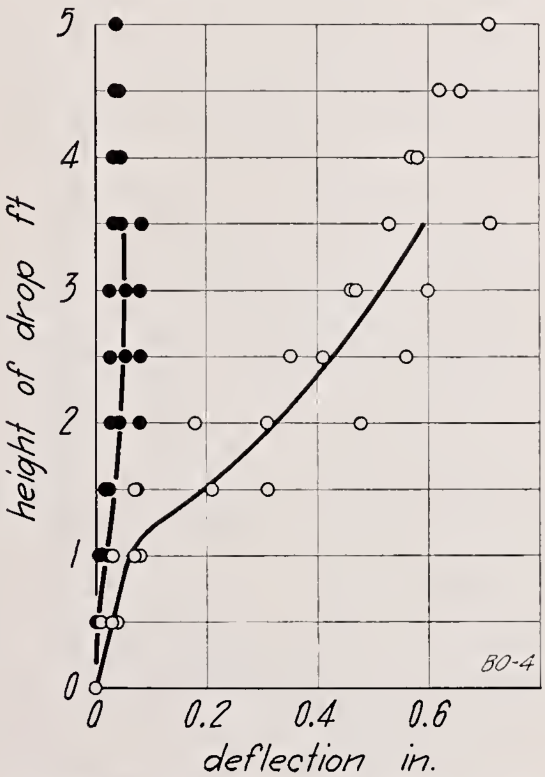

Figure 26.—*Impact load on wall BO, load applied to outside face.*

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

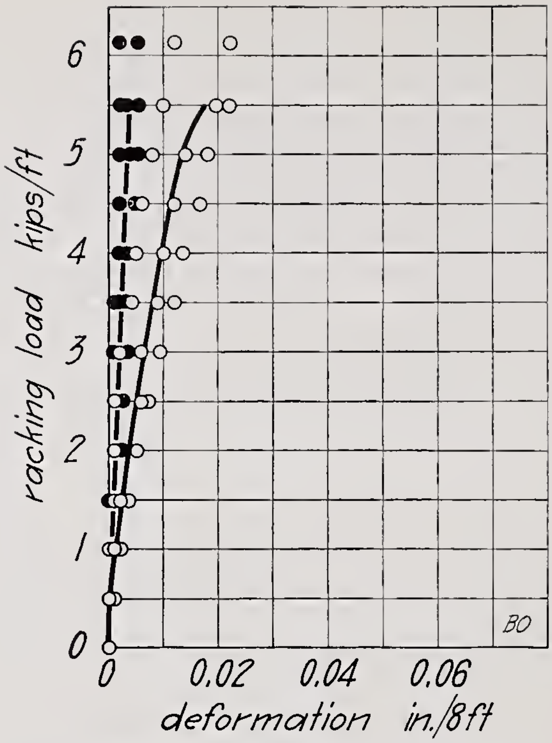

FIGURE 27.—*Racking load on wall BO.*

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

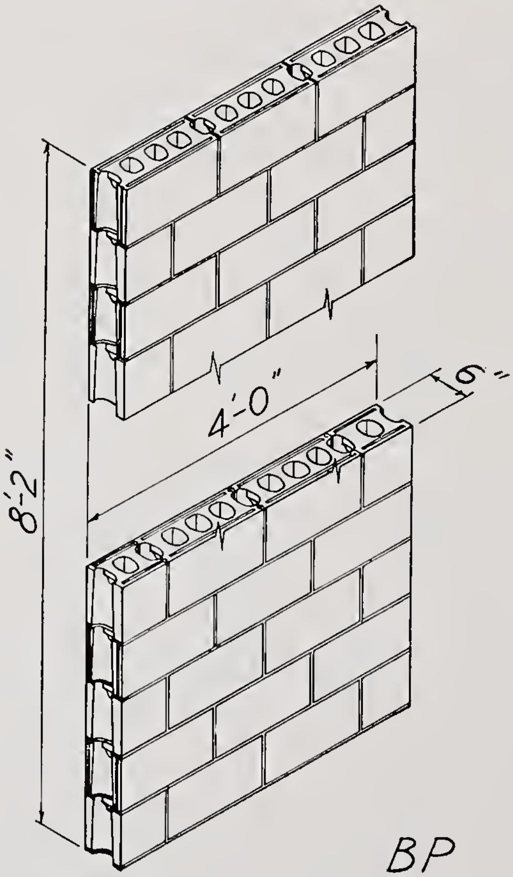

FIGURE 28.—*Four-foot wall specimen BP.*

FIGURE 29.—*Wall specimen BP–C2 under compressive load.*

area is 15 ft^2, an appreciable increase in the size of the room.

2. Compressive Load

Wall specimen *BP–C2* under compressive load is shown in figure 29. The results for wall specimens *BP–C1*, *C2*, and *C3* are shown in table 7 and in figures 30 and 31.

The shortenings and sets shown in figure 30 for a height of 8 ft were computed from the values obtained from the compressometer readings. The compressometers were attached to the upper and lower bearing plates, the gage length being 8 ft 3 in.

Each of the specimens failed by crushing of from two to four of the top courses and vertical cracking of the concrete blocks in these courses.

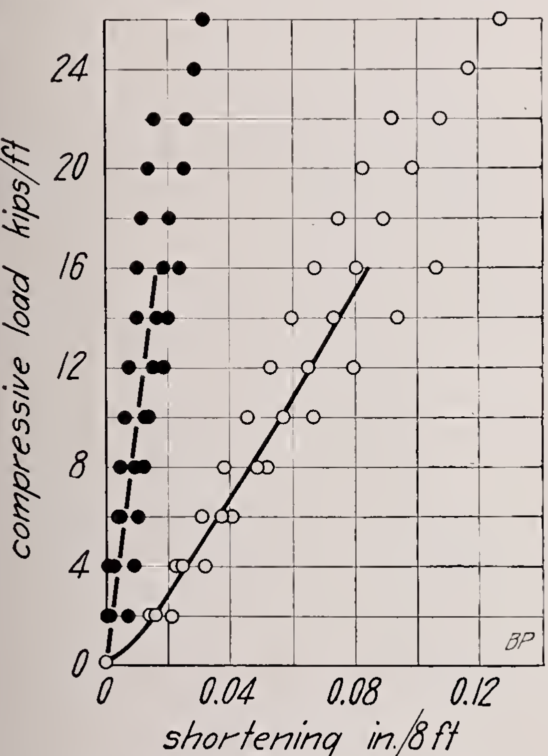

FIGURE 30.—*Compressive load on wall BP.*

Load-shortening (open circles) and load-set (solid circles) results for specimens *BP–C1*, *C2*, and *C3*. The load was applied 2.00 in. (one-third the thickness of the wall) from the inside face. The loads are in kips per foot of actual width of specimen.

3. Transverse Load

Wall specimen *BP–T2* under transverse load is shown in figure 32. The results for wall specimens *BP–T1*, *T2*, and *T3* are shown in table 7 and in figure 33.

Each specimen failed by rupture of the bond between the mortar and the concrete blocks in a bed joint near the upper loading roller.

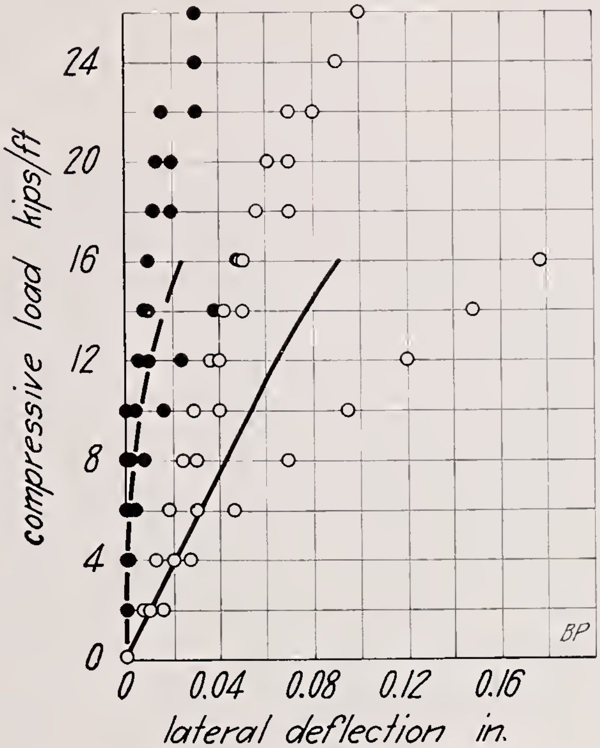

FIGURE 31.—*Compressive load on wall BP.*

Load-lateral deflection (open circles) and load-lateral set (solid circles) results for specimens *BP–C1*, *C2*, and *C3*. The load was applied 2.00 in. (one-third the thickness of the wall) from the inside face. The loads are in kips per foot of actual width of specimen. The deflections and sets are for a length of 7 ft 6 in., the gage length of the deflectometers.

4. Concentrated Load

The results for wall specimens *BP–P1*, *P2*, and *P3* are shown in table 7 and in figure 34.

The concentrated loads were applied to each specimen over one cell of a concrete block. In specimens *P1*, *P2*, and *P3* the indentations after a load of 1,000 lb had been applied were 0.023, 0.009, and 0.007 in., respectively, and no other effect was observed.

5. Impact Load

The results for wall specimens *BP–I1*, *I2*, and *I3* are shown in table 7 and in figure 35.

At a drop of 0.5 ft the bond between the mortar and the concrete blocks in each specimen ruptured at a bed joint near midspan. At the maximum drop each specimen failed by opening of the cracks.

6. Racking Load

The results for *BP–R1, R2,* and *R3* are shown in table 7 and in figure 36.

The deformations and sets shown in figure 36 for a height of 8 ft were computed from the measuring-device readings. The gage length of the measuring device was 6 ft 10½ in.

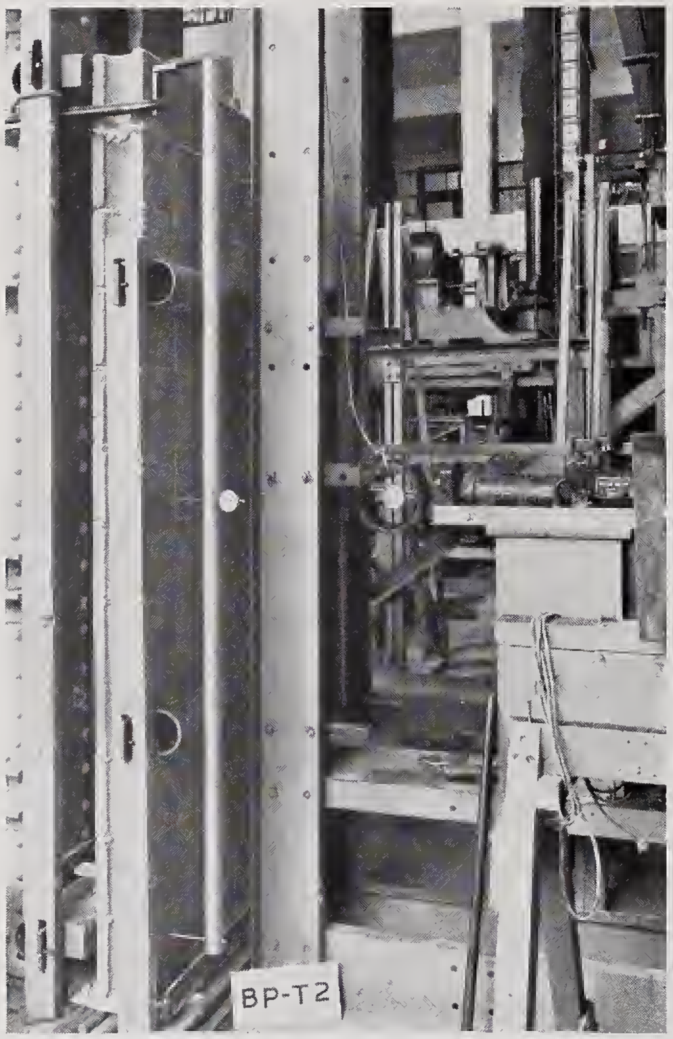

Figure 32.—*Wall specimen BP–T2 under transverse load.*

At loads of 1.47, 1.25, and 1.62 kips/ft on specimens *R1*, *R2*, and *R3*, respectively, each specimen cracked through the bed and head joints diagonally from the loaded corner to the stop. At the maximum load each specimen failed by rupture of these joints and, in specimen *R3*, by rupture of the bed and head joints along another line diagonally from the loaded corner to the stop. In addition, two concrete blocks broke in specimens *R2* and *R3*.

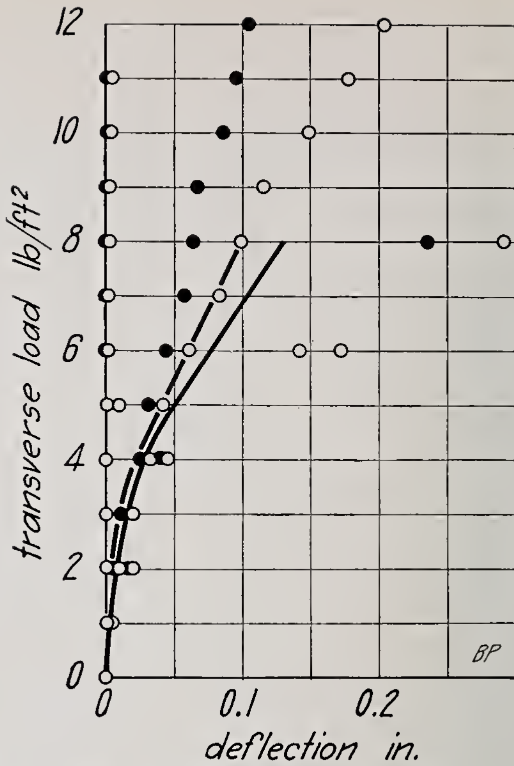

Figure 33.—*Transverse load on wall BP.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *BP–T1, T2,* and *T3* on the span 7 ft 6 in. The deflections and sets are for a length of 7 ft 6 in., the gage length of the deflectometers.

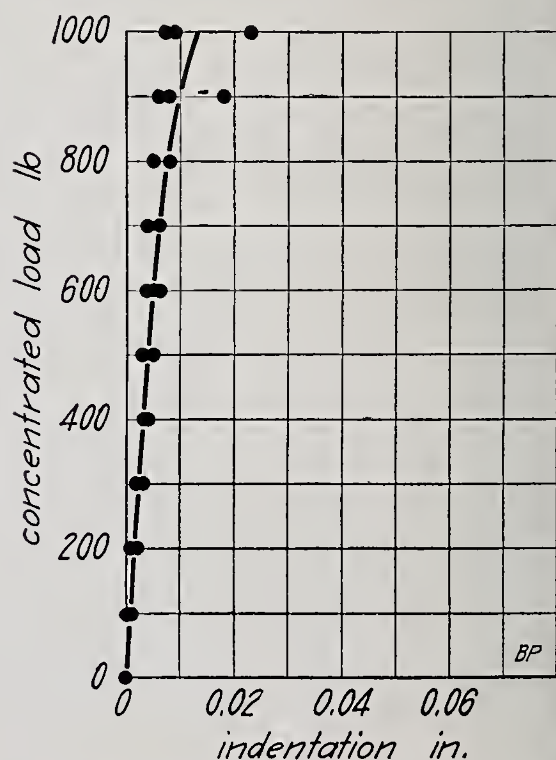

Figure 34.—*Concentrated load on wall BP.*

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

The drawings of the specimens 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 the specimens and information furnished by the sponsor.

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

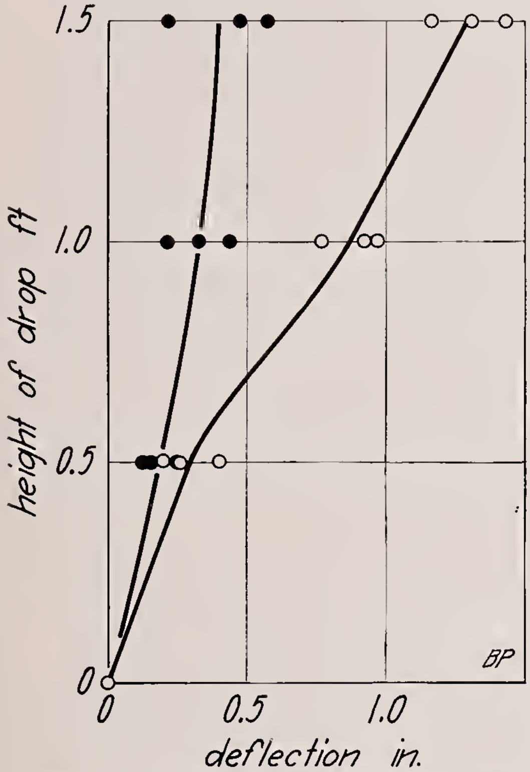

FIGURE 35.—*Impact load on wall BP.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *BP-P1, P2,* and *P3* on the span 7 ft 6 in.

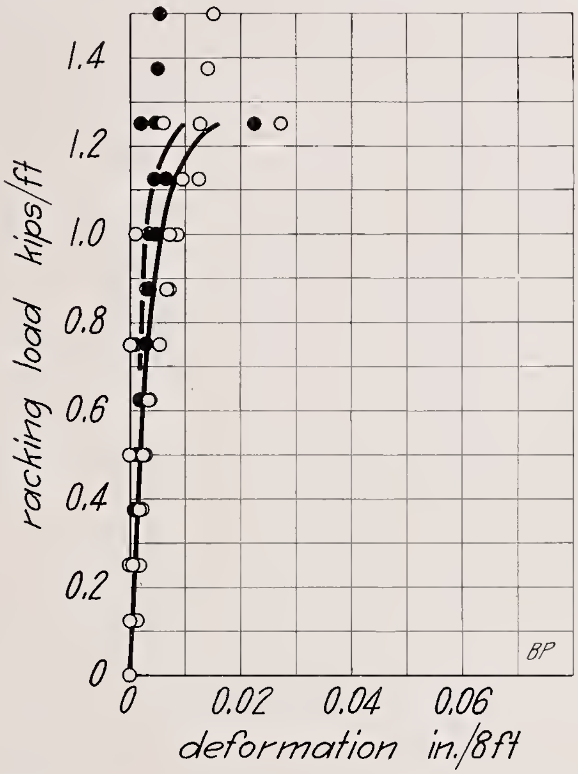

FIGURE 36.—*Racking load on wall BP.*

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

WASHINGTON, July 1, 1939.

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