U. S. DEPARTMENT OF COMMERCE

# BUILDING MATERIALS AND STRUCTURES

REPORT BMS26



## Structural Properties of "Nelson Pre-Cast Concrete Foundation" Wall Construction Sponsored by the Nelson Cement Stone Company, Inc.

*by*

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

NATIONAL BUREAU OF STANDARDS

The program of research on building materials and structures, carried on by the National Bureau of Standards, was undertaken with the assistance of the Central Housing Committee, an informal organization of governmental agencies concerned with housing construction and finance, which is cooperating in the investigations through a subcommittee of principal technical assistants.



The Forest Products Laboratory of the United States Department of Agriculture is cooperating with both committees on investigations of wood constructions.

[For list of BMS publications and how to purchase, see cover page III.]

UNITED STATES DEPARTMENT OF COMMERCE · Harry L. Hopkins, Secretary
NATIONAL BUREAU OF STANDARDS · Lyman J. Briggs, Director

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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 foundation walls of a house when subjected to compressive, transverse, concentrated, impact, and racking loads by standardized methods simulating the loads to which the wall would be subjected in actual service.

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 this 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 Nelson Cement Stone Co. submitted 18 specimens representing their "Nelson Pre-Cast Concrete Foundation" construction for walls.

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 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 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 of the 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 a foundation 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 foundation wall are produced by the weight of the floor, walls, roof, furniture and occupants, wind load on adjoining walls, and snow and wind loads on the roof. Transverse loads on a foundation wall are produced by earth pressure, concentrated loads by accidental contact with heavy objects, and racking loads by earth pressure on adjoining foundation walls.

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

## II. SPONSOR AND PRODUCT

The specimens were submitted by the Nelson Cement Stone Co., Inc., East Braintree, Mass., and represented a foundation wall construction marketed under the trade name "Nelson Pre-Cast Concrete Foundation." This construction consisted of precast, ribbed reinforced-concrete panels for foundation walls, designed to be erected by crane trucks.

## III. SPECIMENS AND TESTS

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

TABLE 1.—*Specimen designations, wall BV*

| Specimen designation | Load | Load applied |
|---|---|---|
| *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. |

[a] These specimens were undamaged portions of the impact 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 December 14, 1938, and completed February 3, 1939. The tests were made either on the 28th or the 29th day after the specimens were cast. The sponsor's representative did not witness the tests.

## IV. WALL *BV*

### 1. SPONSOR'S STATEMENT

#### (*a*) *Materials*

*Cement.*—Edison Cement Co.'s "Edison Portland Plus Cement."

*Sand.*—Pit sand, moisture content 4 percent. The sieve analysis of the sand is given in table 2.

TABLE 2.—*Sieve analysis of the sand, wall BV*

| Sieve number, U. S. Std. | Passing, by weight |
|---|---|
| | *Percent* |
| 4 | 95 |
| 15 | 45 |
| 50 | 16 |
| 100 | 7 |

*Gravel.*—Pit gravel, washed, maximum size ¾ in.; moisture content about 1 percent.

*Concrete.*—One part of cement, 2.8 parts of dry sand, and 4.2 parts of dry gravel, by weight. Slump 3½ in.

*Mesh.*—Mild-steel wire, cold-drawn, complying with ASTM Standard A82–34, No. 12 gage (0.1055-in. diam), galvanized, welded in a 6- by 6-in. mesh in rolls 4 ft wide; weight, 0.13 lb/ft$^2$. Consolidated Expanded Metal Co.'s "Steelcrete."

*Reinforcement bars.*—Rail-steel, deformed, complying with ASTM Standard A16–35, ½ in. round and ⅜ in. round. Northern Steel Co.

*Anchor nuts.*—Mild steel, square, unfinished, ¾ in., American standard.

#### (*b*) *Description*

(*1*) *Three-foot wall specimens.*—The 3-ft wall specimens were 8 ft 0 in. high, 3 ft 0 in. wide, and 10 in. thick. Each specimen was a reinforced-concrete slab with reinforced-concrete ribs at the sides and ends. The specimens were cast with the inside face down, and the outside dimensions varied as much as ¼ in. from the nominal dimensions. A sheet-steel core was used to form the inside face. The web of the specimen was reinforced by mesh, *A*, shown in figure 1, and the vertical and horizontal ribs by reinforcement, *B* and *C*, respectively. The reinforcement and concrete were placed in the form, and the outside face was screeded to a rough, level surface. There were two holes, 1 in. in diam and 4¾ in. deep, in the upper end of the specimen, with a ¾-in. anchor nut embedded at the bottom of each hole, to receive bolts for handling the panels and bolts for fastening the sill. There were no grooves in the vertical edges of the specimens.

The mesh, *A*, was a single sheet placed 1½ in. from the outside face. The sheets for different specimens varied in width from 2 ft 9 in. to 3 ft 0 in., and in length from 7 ft 9 in. to 8 ft 0 in. The edges of the sheet were bent into the ribs. The mesh in these specimens was not like the mesh regularly used by the sponsor for wall panels of this construction. In the mesh regularly used the vertical wires are spaced 12 in., and the spacing of the horizontal wires ranges from 2 in. at the lower end to 7 in. at the upper end of the wall panels.

The vertical reinforcement, *B*, consisted of one ⅜-in. diam deformed bar, about 7 ft 9 in. long, in each vertical rib, and spaced in different specimens from 1 to 4 in. from the inside edge of the rib.

The horizontal reinforcement, *C*, consisted of one ½-in. diam deformed bar in each horizontal rib, except for specimens *BV–C2*, *C3*, and *I6* which had ⅜-in. diam bars. The bars were about 2 ft 9 in. long, and were spaced in different specimens from 2 to 4 in. from the inside edge of the rib.

(*2*) *Nine-foot wall specimens.*—The 9-ft wall specimens were 8 ft 0 in. high, 9 ft 0 in. wide, and 10 in. thick. The specimens were similar to the 3-ft specimens and had intermediate vertical ribs, spaced 3 ft 0 in. on centers, as shown in figure 2. There were no grooves in the vertical edges of the specimens.

The mesh, *A*, was in two sheets, each 4 ft 0 in. high and 9 ft 0 in. long, placed 1½ in. from the outside face. The vertical reinforcement, *B*, in the ribs at each edge of the specimen was a ⅜-in. diam bar, except for specimen *BV–R1* which had a ½-in. diam bar in one rib. The horizontal reinforcement, *C*, was ½-in. diam bars about 8 ft 9 in. long. The vertical reinforcement, *D*, in the intermediate ribs was ½-in. diam bars, except for specimen *BV–R1*, which had a ⅜-in. diam bar in one intermediate rib.

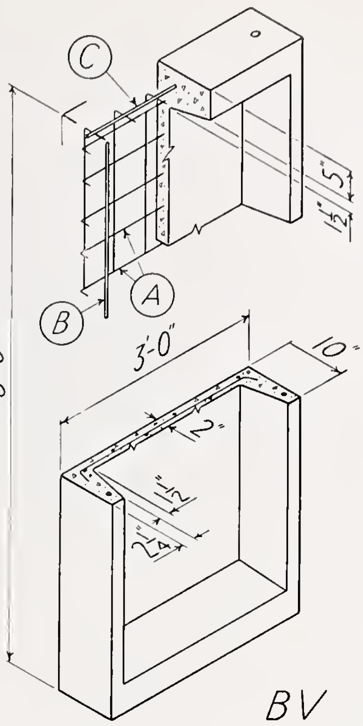


Figure 1.—*Three-foot wall specimen BV, showing inside face.*

*A*, mesh; *B*, vertical reinforcement; *C*, horizontal reinforcement.

The price of this construction in Washington, D. C., as of July 1937, was $0.35/ft².

### (*c*) *Comments*

These foundation wall panels are cast in horizontal wood forms with sheet-steel cores and are transported to the building site by truck and erected by means of a crane truck. Openings for windows, ventilators, and pipes are provided by cores set in the form. The panels are made full wall height and in widths up to 15 ft. The standard thicknesses of the panels are 10, 11, and 12 in.

When erected, the panels rest on a poured-concrete footing with a ½-in. mortar bed between footing and panel. The mortar mix is 1 part of cement to 3 parts of sand, by volume. The vertical edges of the panels are grooved, 1¾ in. wide by ¾ in. deep, and the panels are spaced ¾ in. apart. The spaces and the grooves are filled with grout, 1 part of cement to 3 parts of sand, by volume. Corner panels are

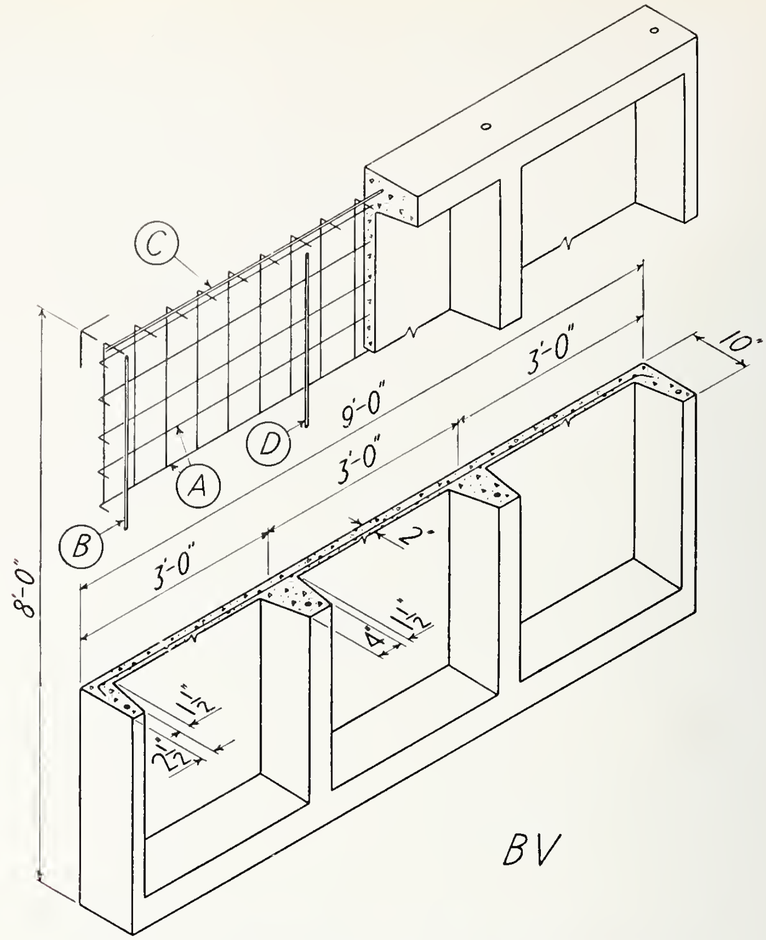


FIGURE 2.—*Nine-foot wall specimen BV, showing inside face.*
*A*, mesh; *B*, vertical reinforcement in edge ribs; *C*, horizontal reinforcement; *D*, vertical reinforcement in intermediate ribs.

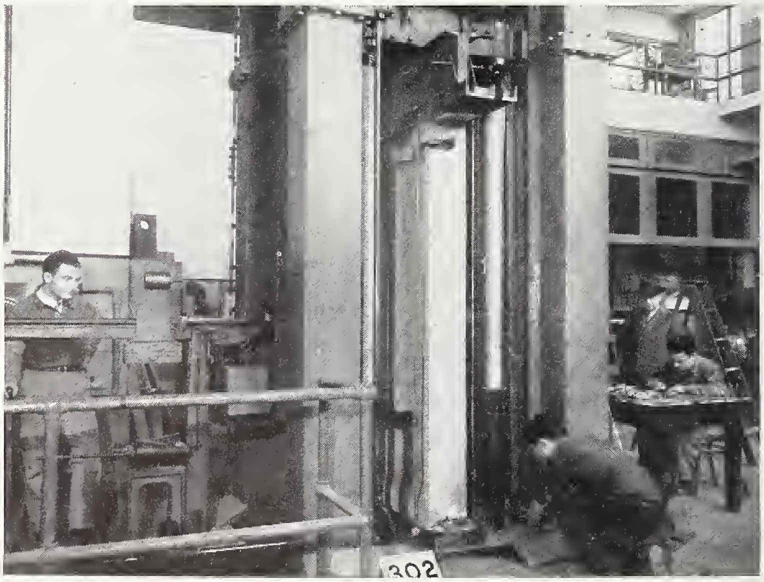


FIGURE 3.—*Wall specimen BV–C1 under compressive load.*

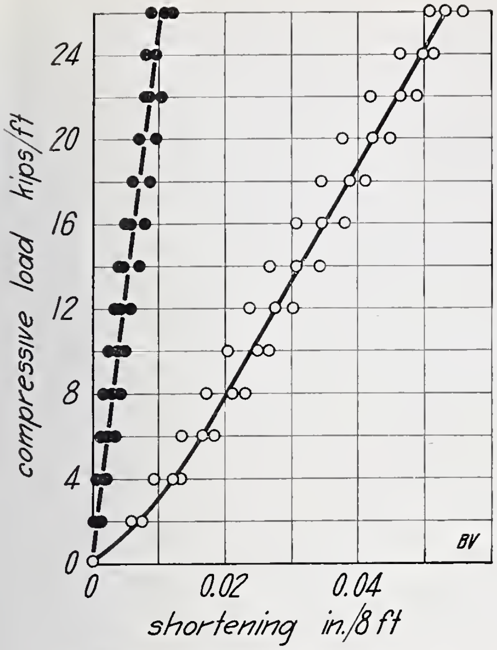


Figure 4.—*Compressive load on wall BV.*

Load-shortening (open circles) and load-set (solid circles) results for specimens *BV–C1*, *C2*, and *C3*. The load was applied 3.33 in. from the inside edge of the ribs. The loads are in kips per foot of actual width of specimen.

made with a wide-faced vertical rib and a groove to match the edge of the adjacent panel. The joints between panels are raked about ¾-in. deep on the outside face and filled with asphalt mastic below ground level and with a linseed-oil and asbestos-fiber calking compound above ground. No waterproofing or other finish is required for the panels themselves. Anchorage for the superstructure is provided by a connection to the threaded nuts embedded in the top ribs.

There have been 26 houses built with the "Nelson Pre-Cast Concrete Foundation." Plans have been developed for a precast reinforced-concrete wall construction similar to the foundation wall, but thinner, and with lighter reinforcement. The sponsor proposes to erect the panels in three horizontal courses for a height of one story. The first course will be from the top of the foundation to the bottom of the windows, the second course from the bottom of the windows to the top of the windows, and the third course from the top of the windows to the wall plate, or to the bottom of the second-story windows. The panels will be made in lengths up to 24 ft.

The walls will be insulated by loose-fill insulation placed between the ribs of each panel. Furring strips, imbedded in the edges of the ribs, will provide for attaching various inside faces. The outside finish will be cast in the panels.

## 2. Compressive Load

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

The shortenings and sets shown in figure 4 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 of the compressometers was 8 ft ½ in.

For each of the specimens the concrete cracked in several places. The first cracks occurred at loads of 26, 20, and 18 kips/ft for specimens *C1*, *C2*, and *C3*, respectively, near the upper end of each specimen, in both the face and one rib.

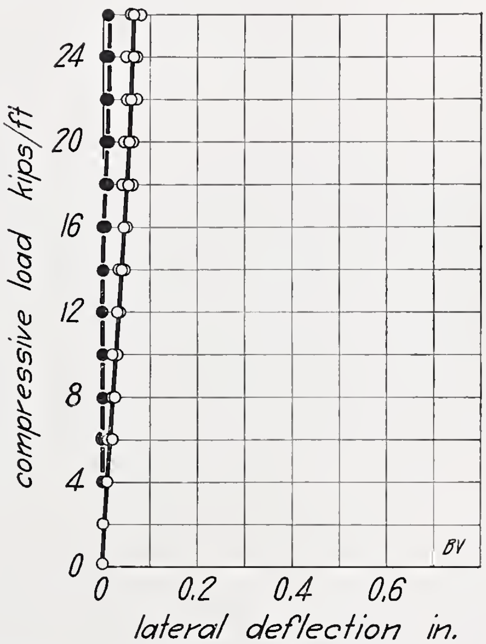


Figure 5.—*Compressive load on wall BV.*

Load-lateral deflection (open circles) and load-lateral set (solid circles) results for specimens *BV–C1*, *C2*, and *C3*. The load was applied 3.33 in. from the inside edge of the ribs. The loads are in kips per foot of actual width of specimen. The deflections and sets are for a gage length of 7 ft 9 in., the gage length of the deflectometers. Each specimen deflected toward the outside face.

TABLE 3.—*Structural properties, wall BV*

[Weight, 51.7 lb/ft²]

| Load | Load applied | Specimen designation | Maximum height of drop | Maximum load |
|---|---|---|---|---|
| | | | *ft* | [a] *Kips/ft* |
| Compressive | Upper end, 3.33 in. from the inside edge of the ribs. | *C1* | | 28.0 |
| | | *C2* | | 36.8 |
| | | *C3* | | 39.5 |
| | Average | | | 34.8 |
| | | | | *lb/ft²* |
| Transverse | Inside face; span, 7 ft 6 in | *T1* | | 491 |
| | | *T2* | | 415 |
| | | *T3* | | 385 |
| | Average | | | 430 |
| Do | Outside face; span, 7 ft 6 in | *T4* | | 422 |
| | | *T5* | | 540 |
| | | *T6* | | 406 |
| | Average | | | 456 |
| | | | | *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* | 7.0 | |
| | | *I2* | 6.0 | |
| | | *I3* | 6.5 | |
| | Average | | 6.5 | |
| Do | Outside face; span, 7 ft 6 in | *I4* | [b] 10.0 | |
| | | *I5* | [c] 10.0 | |
| | | *I6* | [c] 10.0 | |
| | Average | | | |
| | | | | [a] *Kips/ft* |
| Racking | Near upper end | *R1* | | [b] 5.56 |
| | | *R2* | | [b] 5.56 |
| | | *R3* | | [b] 5.56 |
| | Average | | | [b] 5.56 |

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

At the maximum loads each of the specimens failed by crushing of the inside edges of the vertical ribs just below the top horizontal rib and rupturing of the outside face just below this rib.

### 3. TRANSVERSE LOAD

Wall specimen *BV–T3* under transverse load is shown in figure 6. The results are shown in table 3 and in figure 7 for wall specimens *BV–T1*, *T2*, and *T3*, loaded on the inside face, and in figure 8 for wall specimens *BV–T4*, *T5*, and *T6*, loaded on the outside face.

The transverse loads were applied with the specimens in a horizontal position. The initial

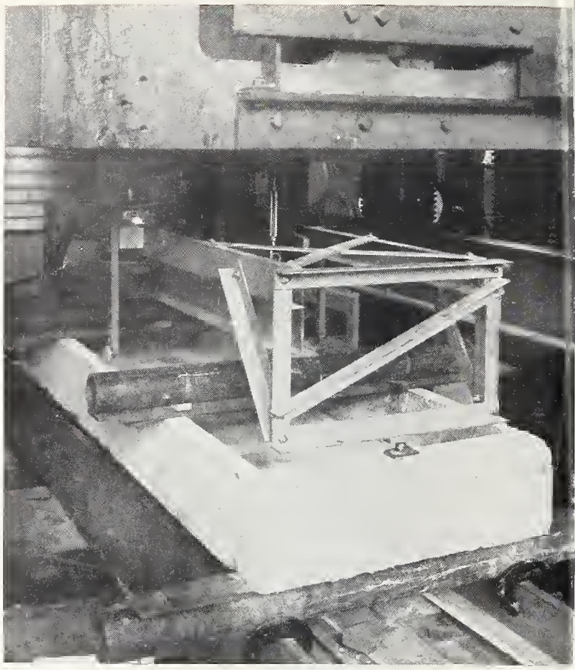

FIGURE 6.—*Wall specimen BV–T3 under transverse load.*

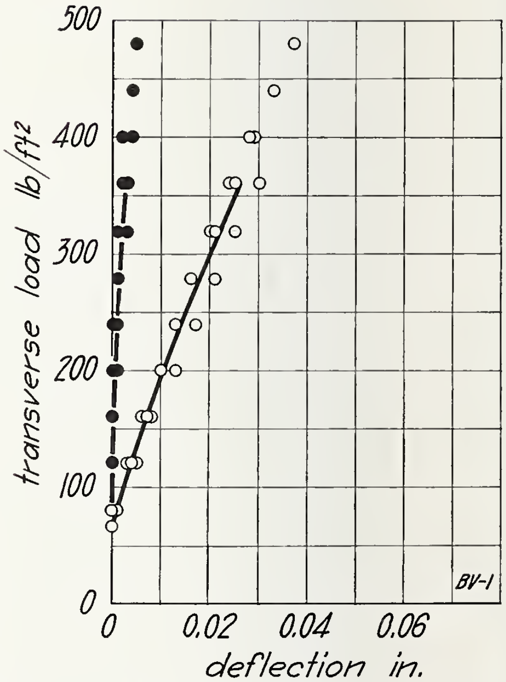


FIGURE 7.—*Transverse load on wall BV, load applied to inside face.*

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

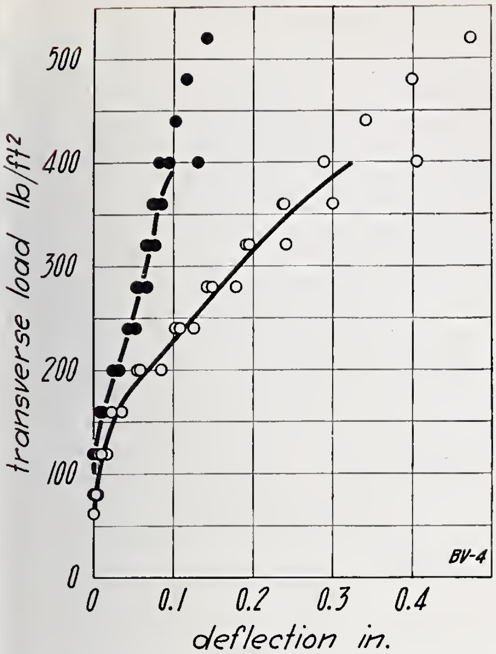


FIGURE 8.—*Transverse load on wall BV, load applied to outside face.*

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

deflection and set readings shown in figures 7 and 8 were taken under a load of about 65 lb/ft² caused by the weight of the specimen between the supporting rollers and the weight of the loading apparatus.

The loads were applied to the inside edges of the ribs of specimens *T1*, *T2*, and *T3*. Each of these specimens failed by rupture of the concrete transversely across the specimen at or between the loading rollers.

For specimens *T4*, *T5*, and *T6* the concrete in the longitudinal ribs cracked in several places between the supporting rollers, the cracks starting at the inside edge of the ribs and extending to about midthickness. The first cracks occurred at loads of 170, 219, and 235 lb/ft² and deflections of 0.05, 0.08, and 0.09 in. for specimens *T4*, *T5*, and *T6*, respectively. At the maximum loads each of the specimens failed by rupture of the concrete in both ribs diagonally between a supporting roller and the nearest loading roller, and rupture of the concrete between ribs transversely across the specimen under this loading roller.

### 4. Concentrated Load

Wall specimen *BV–P4* under concentrated load is shown in figure 9. The results are shown in table 3 and in figure 10 for wall specimens *BV–P1*, *P2*, and *P3*, loaded on the inside face, and in figure 11 for wall specimens *BV–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 the ribs. There was no measurable indentation for any of these three specimens after a load of 1,000 lb had been applied.

The concentrated loads were applied to the outside face of specimens *P4*, *P5*, and *P6*, between the side ribs and from 1½ to 2½ ft from one end. The indentations after a load of 1,000 lb had been applied were 0.000, 0.002, and 0.002 for specimens *P4*, *P5*, and *P6*, respectively, and no other effect was observed.

### 5. Impact Load

Wall specimen *BV–I5* during the impact test is shown in figure 12. The results are shown in table 3 and in figure 13 for wall specimens *BV–I1*, *I2*, and *I3*, loaded on the inside face, and in figure 14 for wall specimens *BV–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*,

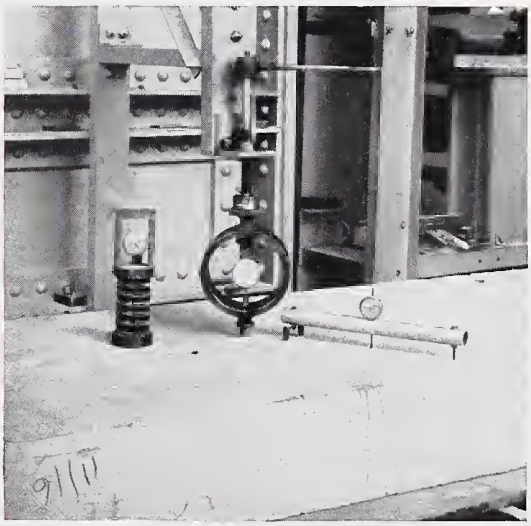

FIGURE 9.—*Wall specimen BV–P4 under concentrated load.*

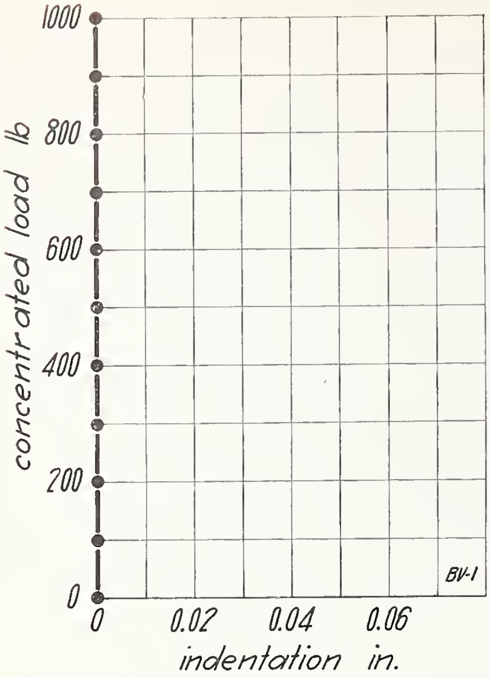


FIGURE 10.—*Concentrated load on wall BV, load applied to inside face.*

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

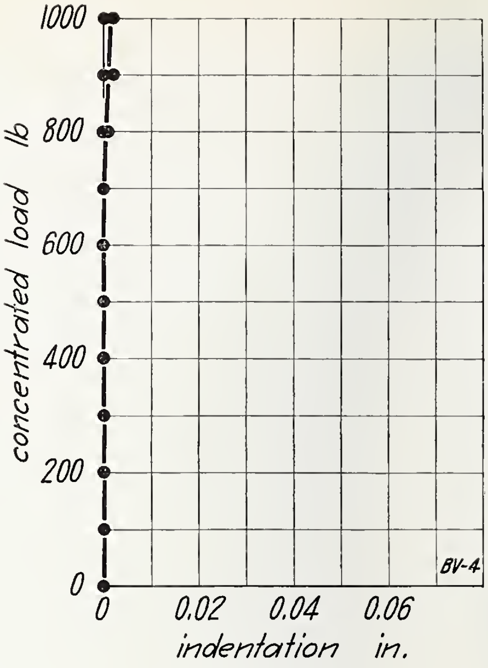


FIGURE 11.—*Concentrated load on wall BV, load applied to outside face.*

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

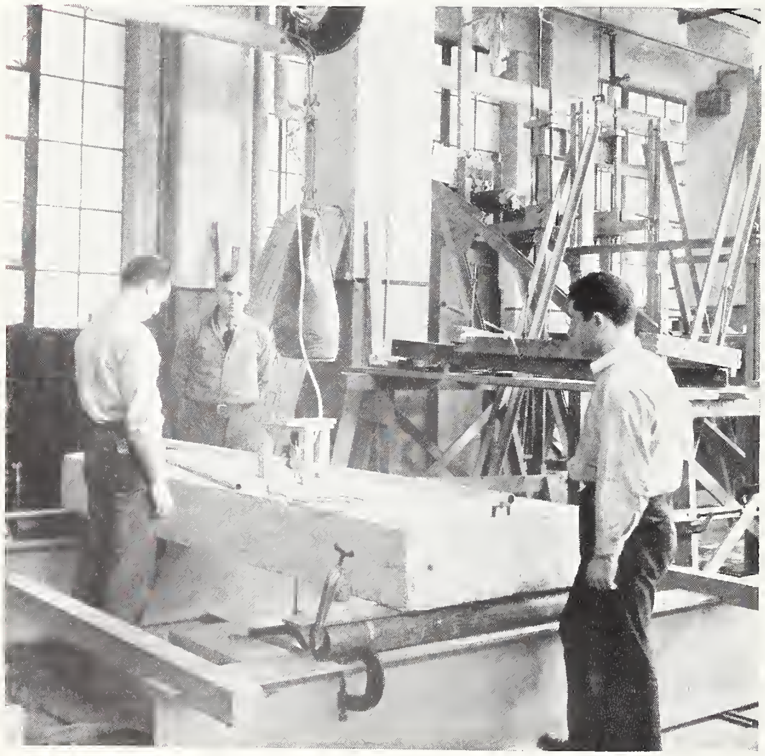

FIGURE 12.—*Wall specimen BV–15 during the impact test.*

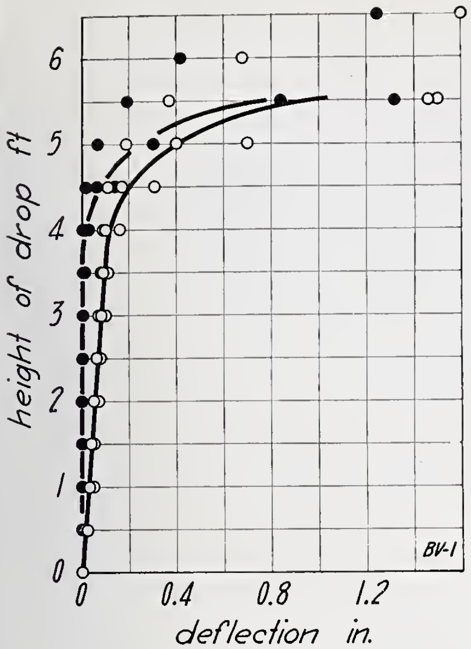


FIGURE 13.—*Impact load on wall BV, load applied to inside face.*

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

the sandbag striking midway between the ribs. At drops of 5, 4.5, and 4 ft and deflections of 0.19, 0.17, and 0.16 in. for specimens *I1*, *I2*, and *I3*, respectively, the outside face of each specimen cracked transversely across or part way across the specimen near midspan. At drops of 6, 5, and 5 ft, respectively, these cracks opened about ⅛ in. and extended to the inside edge of the ribs. At the maximum drops each of the specimens failed by breaking into two or three pieces, which were held only by the reinforcement.

The impact loads were applied to the center of the outside face of specimens *I4*, *I5*, and *I6*, the sandbag striking midway between the ribs. At drops of 4, 3, and 6.5 ft and deflections of 0.21, 0.14, and 0.35 in. for specimens *I4*, *I5*, and *I6*, respectively, both ribs cracked near midspan, the crack extending from the edge of the ribs to the base (intersection with inside face). At drops of 9.5, 8.5, and 7 ft, respectively, the inside face of each specimen cracked transversely between the ribs near midspan. For specimen *I4* the set after a drop of 10 ft was 0.055 in., and there were several cracks in the edges of the ribs. For specimen *I5* at a drop of 9 ft the inside face cracked longitudinally adjacent to both ribs for a length of about 3 ft near midspan, and at a drop of 10 ft these cracks opened and penetrated to the outside face. The set after the 10-ft drop was 0.391 in. For specimen *I6* at a drop of 8 ft the outside face cracked transversely across the specimen near midspan, the crack extending through to the inside face; and at a drop of 10 ft there were several cracks in the inside face radiating from the center of the specimen below where the sandbag struck. The set after the 10-ft drop was 0.031 in.

## 6. Racking Load

Wall specimen *BV-R1* under racking load is shown in figure 15. The results for wall specimens *BV-R1*, *R2*, and *R3* are shown in table 3 and in figure 16.

The deformations and sets for a height of 8 ft were computed from the values obtained from the measuring-device readings. The gage length of the measuring device was 6 ft 7 in.

For specimens *R2* and *R3* at loads of 3 and 3.5 kips/ft, respectively, the top rib cracked

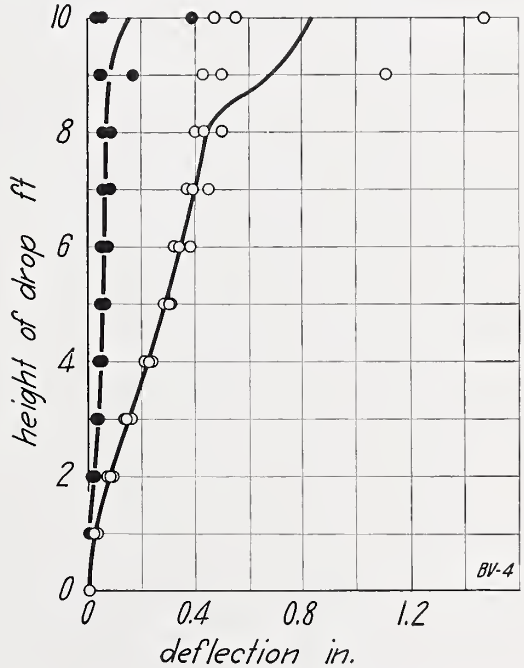


FIGURE 14.—*Impact load on wall BV, load applied to outside face.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *BV-I4*, *I5*, and *I6* on the span 7 ft 6 in.

FIGURE 15.—*Wall specimen BV–R1 under racking load.*

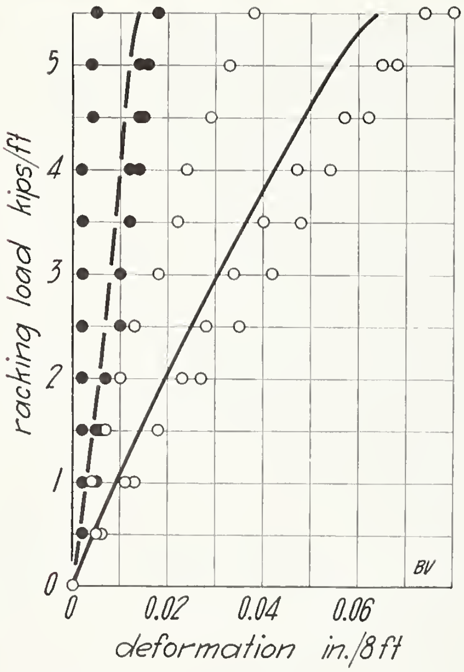


FIGURE 16.—*Racking load on wall BV.*

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

vertically near the loaded corner, 1½ ft from the corner for specimen *R2* and 3 ft for specimen *R3*. The sets after a load of 5.56 kips/ft had been applied were 0.022, 0.018, and 0.005 in. for specimens *R1*, *R2*, and *R3*, respectively, and no other effect was observed.

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The description, drawings, and sponsor's comments 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 from the specimens themselves.

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: F. Cardile, H. Dollar, M. Dubin, A. H. Easton, A. S. Endler, C. D. Johnson, A. J. Sussman, and L. R. Sweetman.

WASHINGTON, MAY 6, 1939.

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