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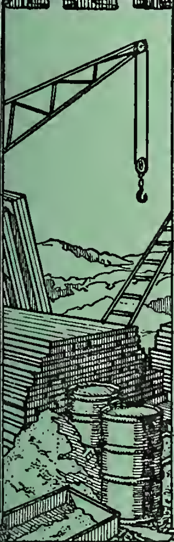


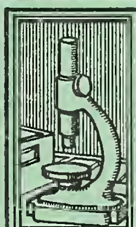
BUILDING MATERIALS AND STRUCTURES

REPORT BMS39

Structural Properties of a Wall Construction of "Pfeifer Units" Sponsored by the Wisconsin Units Company

by

HERBERT L. WHITTEMORE, AMBROSE H. STANG, *and* DOUGLAS E. PARSONS



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

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ISSUED JANUARY 31, 1940

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

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Foreword

This report is one of a series issued by the National Bureau of Standards on the structural properties of constructions intended for low-cost houses and apartments. 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 design of the constructions and for the description of the specimens 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 elements of a house 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 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 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.*

Structural Properties of a Wall Construction of "Pfeifer Units" Sponsored by the Wisconsin Units Company

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ABSTRACT

For the program on the determination of the structural properties of low-cost house constructions, the Wisconsin Units Co. submitted 18 specimens representing a wall construction of "Pfeifer 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. The results are presented in graphs and in tables.

I. INTRODUCTION

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 by 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 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 Wisconsin Units Co., West Allis, Wis., and represented a wall construction made of reinforced-concrete units marketed under the trade name "Pfeifer Units." The units are bolted together with a steel reinforcing plate in each longitudinal joint, forming a masonry wall.

III. SPECIMENS AND TESTS

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

TABLE 1.—*Specimen designations, wall CH*

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 transverse specimens.

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

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, and not attached to the specimen as described in BMS2.

Measurements of the lateral deflections under compressive loads and the deflections under transverse loads were made with a deflectometer of fixed gage length, which consisted of a light (duralumin) tubular frame having a leg at one end and a hinged plate at the other. The distance between the points of support was 7 ft. 6 in. A dial micrometer was attached to the frame at midlength. The micrometer was graduated to 0.001 in., and the readings were recorded to the nearest tenth of a division. The deflectometer was attached to the specimen in a vertical position by clamping the

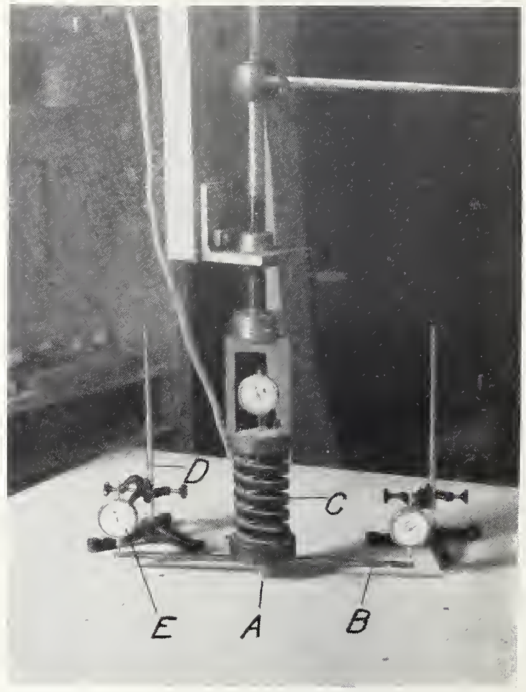

FIGURE 1.—*Apparatus for concentrated load test.*
A, steel disk; *B*, crossbar; *C*, dynamometer; *D*, stand; *E*, dial micrometer.

hinged plate to the upper end of either face. There were two deflectometers on each specimen, one near each edge. This method of measurement was used instead of the taut-wire and mirror-scale method described in BMS2.

The indentation under concentrated load and the set after the load was removed were measured, not the set only, as described in BMS2. The apparatus is shown in figure 1. The load was applied to a steel disk, *A*, to which the crossbar, *B*, was rigidly attached. The load was measured by means of the dynamometer, *C*. There were two stands, *D*, resting on the face of the specimen, and each supported a dial micrometer, E, the spindle of which was in contact with the crossbar 8 in. from the disk. The micrometers were graduated to 0.001 in., and the readings were recorded to the nearest division. The initial reading (average of the micrometer readings) was observed under the initial load, which included the weight of the disk and dynamometer. A load was applied to the disk, and the depth of the indentation under load was taken as the average of the micrometer readings minus the initial reading. The load was then removed, and the set was taken as the average of the micrometer readings minus the initial reading.

The deformations caused by 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. 8 in. The micrometer was graduated to 0.001 in., and the readings were recorded to the nearest tenth of a division. This deformeter was used instead of the system of taut wires and mirror scales described in BMS2.

The tests were begun March 15, 1939, and completed March 23, 1939. The units were made on or about December 14, 1938. The sponsor's representatives witnessed the tests.

IV. WALL *CH*

1. Sponsor's Statement

The information for this statement was obtained from the sponsor and from inspection of the specimens. The Masonry Construction Section of this Bureau assisted the sponsor by determining the physical properties of the concrete units.

(a) Materials

Concrete units.—The units were thin reinforced-concrete slabs about 2 ft square having flanges along two opposite edges.

The materials for the concrete were Petoskey Cement Co.'s "High-Early" portland cement, Western Lime and Cement Co.'s "Pure-Cal" lime, and The Waylite Co.'s "Waylite" aggregate.

"Waylite" aggregate is a lightweight material of cellular structure produced by centrifuging and beating molten blast-furnace slag in an atmosphere of steam. The sieve analysis of the aggregate is given in table 2 and the chemical composition in table 3.

Table 2.—*Sieve analysis of the "Waylite" aggregate*

U. S. Standard sieve number	Passing, by weight
	Percent
4	100
8	93
16	68
30	20
50	7
100	2

Table 3.—*Chemical composition of the "Waylite" aggregate*

[Average of samples taken on different days by the laboratory of the Youngstown Sheet and Tube Co., South Chicago, Ill., December 1937]

Ingredient	Content, by weight
	Percent
Silica, SiO_2	38.5
Alumina, Al_2O_3	12.0
Calcium oxide, CaO	45.0
Magnesia, MgO	1.7
Iron oxide, Fe_2O_3	0.4
Manganous oxide, MnO	.8
Sulfur, S, as sulfide	1.6
Total	100.0

The reinforcement in the units was welded steel-wire mesh, openings 3-in. square, weight 0.25 lb/ft^2, manufactured by the American Steel & Wire Co. The wire was No. 12 Stl. W. G. (0.1055-in. diam), having a tensile strength ranging from 70,000 to 80,000 lb/in^2. The mesh for each unit was 1 ft 11 in. high and 2 ft 3 in. wide, having nine longitudinal and eight transverse wires. The ends of the longitudinal wires projected 1 in. beyond the top and bottom transverse wires, and the ends of the transverse wires projected 1½ in. beyond the edge of the longitudinal wires. There were chairs in the three central longitudinal wires, formed by bending the wire into a V which projected about ¼ in. from the mesh. The chairs were spaced 6 in. and those in adjacent wires were staggered.

A binder was embedded in the flange at each edge of the unit. It was hot-rolled, open-hearth, SAE 1010 sheet steel, No. 20 U. S. Std. Gage (0.037 in. thick), formed as shown in figures 2 and 3. The chemical composition of the sheet steel is given in table 4. Each binder was plated with cadmium, the thickness of the coat ranging from 0.0008 to 0.0010 in. The manufacturer was the Milwaukee Stamping Co.

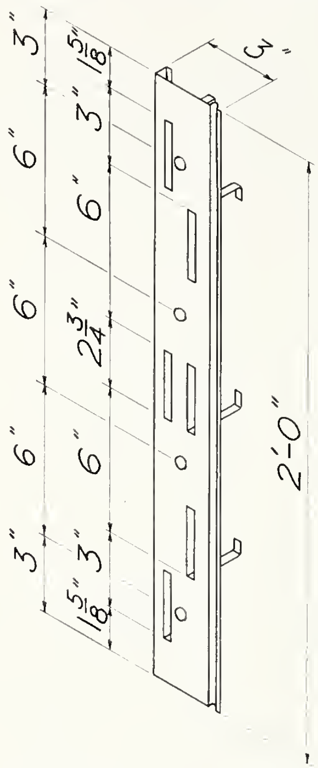

FIGURE 2.—*Sheet-steel binder.*

TABLE 4.—*Chemical composition of SAE 1010 sheet steel*

Element	Content
	Percent
Carbon	0.05 to 0.15
Manganese	.30 to .60
Phosphorus	.045 maximum
Sulfur	.055 maximum

The units were made in horizontal cast-iron molds, the mold forming the flanged face of the units. After spraying the molds with a mixture of heavy lubricating grease and naphtha, the binders were placed at the sides of the mold over plugs which formed the bolt holes in the flanges. The mesh reinforcement was placed in the mold. The concrete mix was 1 part of cement, 0.21 part of hydrated lime, and 5.84 parts of "Waylite" aggregate, by volume; the lime being added to increase the workability. The concrete was mixed in a mixer having a capacity of 9 ft³. The aggregate was first mixed with water for at least 2 minutes to insure adequate surface moisture, the cement and lime were added, and the mixing continued for

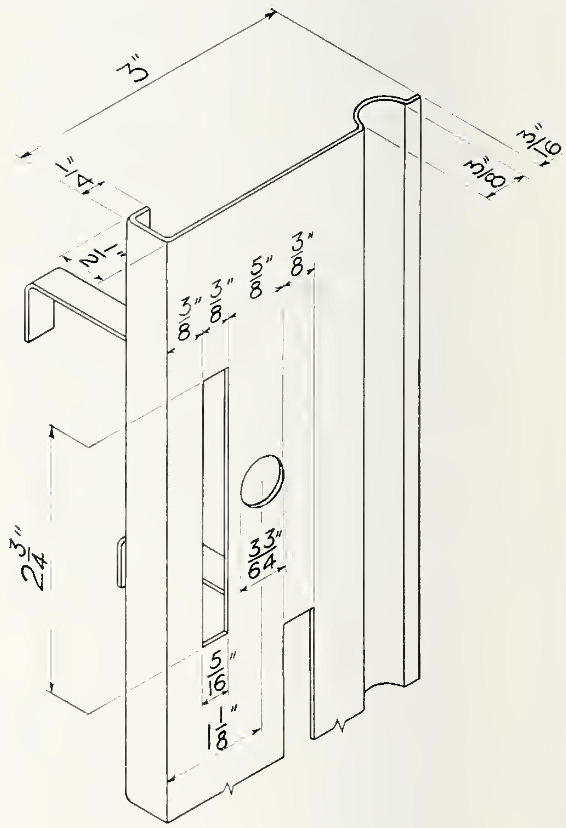

FIGURE 3.—*Details of binder.*

another 10 minutes. The amount of water was adjusted until no excess water appeared on the concrete when the mold was vibrated. The mix was delivered to the mold and vibrated by a jolt-vibrator, operated pneumatically at the rate of 85 strokes per minute. A sliding steel plate then struck off the excess concrete and the mold was removed to a curing chamber. The chamber was filled with steam at 5 lb/in.² pressure for 3 hours and then at 50 lb/in.^{2} for 6 hours, after which time the pressure was reduced slowly and the units were ready for shipment.

The units, shown in figure 4, were 2 ft 0 in. high, 1 ft 11⅞ in. wide, and 1¼ in. thick at midwidth. There was a flange, in which a sheet-steel binder was embedded, along each longitudinal edge. There were four holes, 9/16-

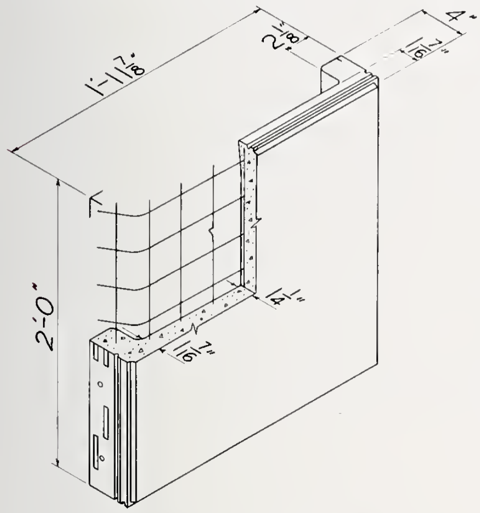

Figure 4.—*Concrete unit.*

in. diam, in each flange 2⅞ in. from the outside face of the unit and spaced 6 in. on centers. Along each edge of the unit were semicircular grooves, ⅜-in. diam. The distance from the outside face of the unit to the outer edges of the grooves was 7/16 in. The outside face of the unit was rabbeted ¼ in. along each of the four edges.

The physical properties of the units were determined on two samples. The water absorption for 24-hr cold total immersion was 13.4 percent of the dry weight of the unit, or 13.0 lb of water per ft^3 of concrete. Computed from the weight of 162 units, the average weight of one unit, when dry, was 57.6 lb.

Bonding plate.—Sheet-steel, SAE 1010, open-hearth, hot-rolled, No. 14 U. S. Std. Gage (0.077 in. thick), 8 ft 0 in. high, 2¼ in. wide. The chemical composition of the sheet steel is given in table 4. There were holes, 9/16-in. diam, at midwidth, spaced 6 in. on centers. Each plate was pickled in a 50-percent solution of muriatic acid and then completely covered by one coat of black asphaltum 0.001 in. thick. Milwaukee Stamping Co.

Bolts.

Machine, mild-steel, ½-in. diam, 5½ in. long, 13 threads per inch, threaded for a length of 1⅜ in., heads and nuts square, unfinished.

Machine, mild-steel, ½-in. diam, 2¾ in. long, 13 threads per inch, threaded for a length of 1 in., heads and nuts square, unfinished.

Washers.—Sheet-steel, 1⅜-in. diam, No. 12 U. S. Std. Gage (0.1072 in. thick).

(*b*) *Description*

Wall *CH* consisted of "Pfeifer Units" and steel bonding plates bolted together at the

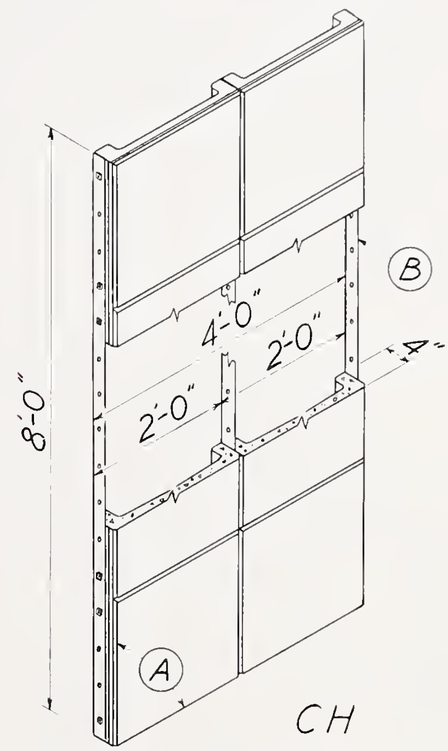

Figure 5.—*Four-foot wall specimen CH.*
A, concrete unit; *B*, bonding plate.

flanges of the units, forming a masonry wall with a flat outside face and a ribbed inside face.

The price of this construction in Washington, D. C., as of July 1937, was \$0.44/ft^2.

(*1*) *Four-foot wall specimens.*—The 4-ft specimens, shown in figure 5, were 8 ft 0 in. high, 4 ft 0 in. wide, and 4 in. thick at the ribs. Each specimen consisted of eight concrete units, *A*, and three bonding plates, *B*. There were two units in each course and a bonding plate on each longitudinal (vertical) edge and one in the joint at midwidth. The units and bonding plates were fastened by bolts through the holes in the flanges and the plates. There were eight 2¾-in. bolts along each longitudinal edge and eight 5½-in. bolts along the joint at midwidth. The bolts were in the top and bottom holes in each unit. There were two washers on each bolt, one under the head and the other under the nut. Each nut was tightened until the torque was about 11 lb-ft.

These specimens did not comply fully with BMS2, V-1 (*c*) *Width*. They were of the type shown in figure 2, BMS2; and, if the bonding plates are considered to be load-carrying members, the plates on the edges of the specimen should have been half-sized plates, thickness 0.0385 in. Each specimen therefore had the equivalent of one excess bonding plate. It did not appear practicable to machine half-sized plates from full-sized plates; and, if they had been made from sheet steel of the required thickness, there was no assurance that the properties would have any relation to the properties of the full-sized plates.

Full-sized plates were therefore used on the edges of the specimens. Furthermore, it appeared probable that, being restrained laterally on only one side, their strength would be much less than that of plates in a vertical joint between units. Observations during the tests indicated that the edge plates might be considered half-sized plates as regards the properties of this construction. Through a misunderstanding on the part of the sponsor the vertical and horizontal joints in the specimens were not sealed with asphalt-saturated cotton fabric tubing, as in a house, and the rabbets in the units were not calked. It appears probable that the seals and calking would have had little effect on the structural properties.

(*2*) *Eight-foot wall specimens.*—The 8-ft specimens, shown in figure 6, were 8 ft 0 in. high, 8 ft 0 in. wide, and 4 in. thick. The construc-

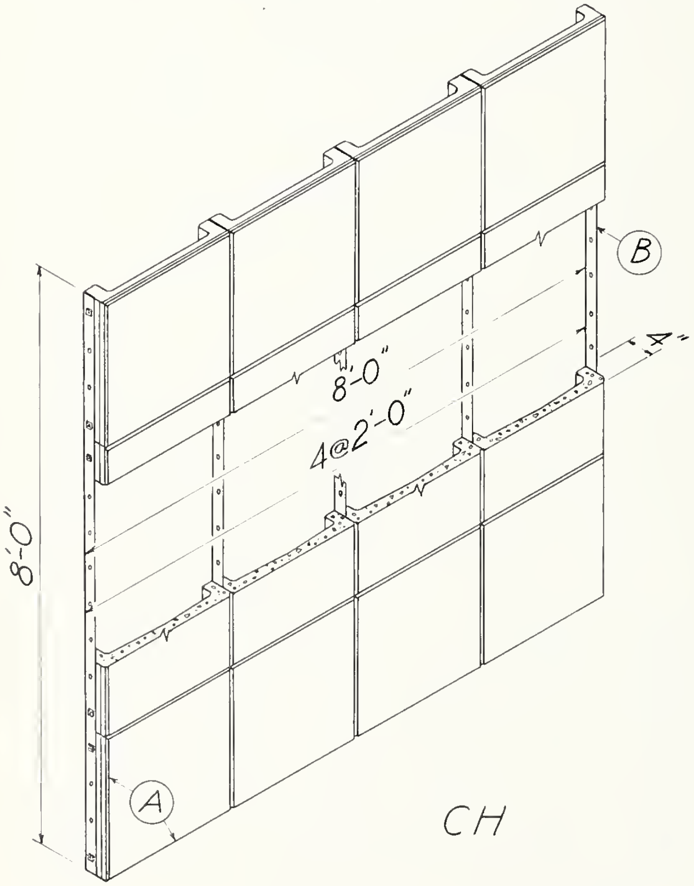

FIGURE 6.—*Eight-foot wall specimen CH.*
A, concrete unit; *B*, bonding plate.

tion was similar to the 4-ft specimens except that there were four units in each course and five bonding plates.

(c) *Comments*

"Pfeifer Units" are designed for walls, partitions, floors, and roofs. Walls and partitions are erected on a masonry foundation wall or a concrete slab. The walls are anchored by clip angles fastened by bolts to the flanges of the units, and to the foundation by anchor bolts. At each corner of the house there is a special 4- by 4-in. corner unit having wing nuts embedded in two adjacent edges, to receive bolts passing through the flanges of the adjoining units. The units are made in half and quarter sizes to provide greater flexibility in the dimensions of walls and openings. Door and window frames are of conventional wood or metal construction. Lintels are supported on steel angles which are fastened to the flanges of the wall units by clip angles. Jambs are fitted with oak strips bolted to the flanges of the units at the opening.

If the flat surface of the units forms the outside face of the wall, the inside face may be finished either by nailing wallboard directly to the ribs or by nailing lath to the ribs and covering it with plaster. The spaces between the ribs may be filled with thermal insulation or serve as chases for pipes, ducts, and conduits. In actual house construction the vertical and horizontal joints between the units are sealed by placing asphalt-saturated cotton fabric tubing, manufactured by the Anaconda Wire & Cable Co. under the trade name "Duraduct," in the grooves in the sides and edges of each unit. The joints are then calked by filling the ¼-in. rabbets along the edges of the units with a plastic asbestos calking compound.

The flanged surface of the units may be turned outward and brick veneer applied as the outside face of the wall. Metal ties for the brickwork are fastened to the bolts in the flanges of the units. The flat inside face may be painted or plastered.

For floor and roof constructions the units are bolted, with the flanges down, to lightweight steel joists. The ends of the joists are secured by bolting the webs of the joists to the flanges of the wall units. If the floor is of wood-frame construction, a wood header is bolted to the flanges of the wall units by clip angles. The floor joists are nailed to the header. If the roof is of wood-frame construction, a 2- by 4-in. wood wall plate is fastened to the top of the wall units by narrow clip angles. The clip angles extend through holes in the plate and are bolted to the flanges. In addition, 12d nails are driven through the plate into the ends of the flanges. The roof joists are nailed to the wall plate.

2. Compressive Load

Wall specimen *CH–C1* under compressive load is shown in figure 7. The results for wall specimens *CH–C1*, *C2*, and *C3* are shown in table 5 and in figures 8 and 9.

TABLE 5.—*Structural properties, wall CH*

[Weight, 15.0 lb/ft²]

Compressive load[a]		Transverse load[b]		Concentrated load		Impact load[b]		Racking load	
Specimen	Maximum load	Specimen	Maximum load	Specimen	Maximum load	Specimen	Maximum height of drop	Specimen	Maximum load
	[c]*Kips/ft.*		*lb/ft²*		*lb*		*ft*		[c]*Kips/ft*
C1	8.75	*T1*	43.7	*P1*	[d]1,000	*I1*	5.5	*R1*	1.05
C2	6.50	*T2*	48.8	*P2*	[d]1,000	*I2*	5.5	*R2*	0.88
C3	9.63	*T3*	45.0	*P3*	[d]1,000	*I3*	5.5	*R3*	1.21
Average	8.29	Average	45.8	Average	[d]1,000	Average	5.5	Average	1.05
		T4	93	*P4*	765	*I4*	9.0		
		T5	111	*P5*	785	*I5*	9.0		
		T6	112	*P6*	800	*I6*	[e]10.0		
		Average	105	Average	783	Average			

[a] Load applied 1.33 in. (one-third the thickness of the specimen) from the inside surface of the ribs.
[b] Span 7 ft 6 in.
[c] A kip is 1,000 lb.
[d] Test discontinued. Specimen did not fail.
[e] Test discontinued. Specimen damaged.

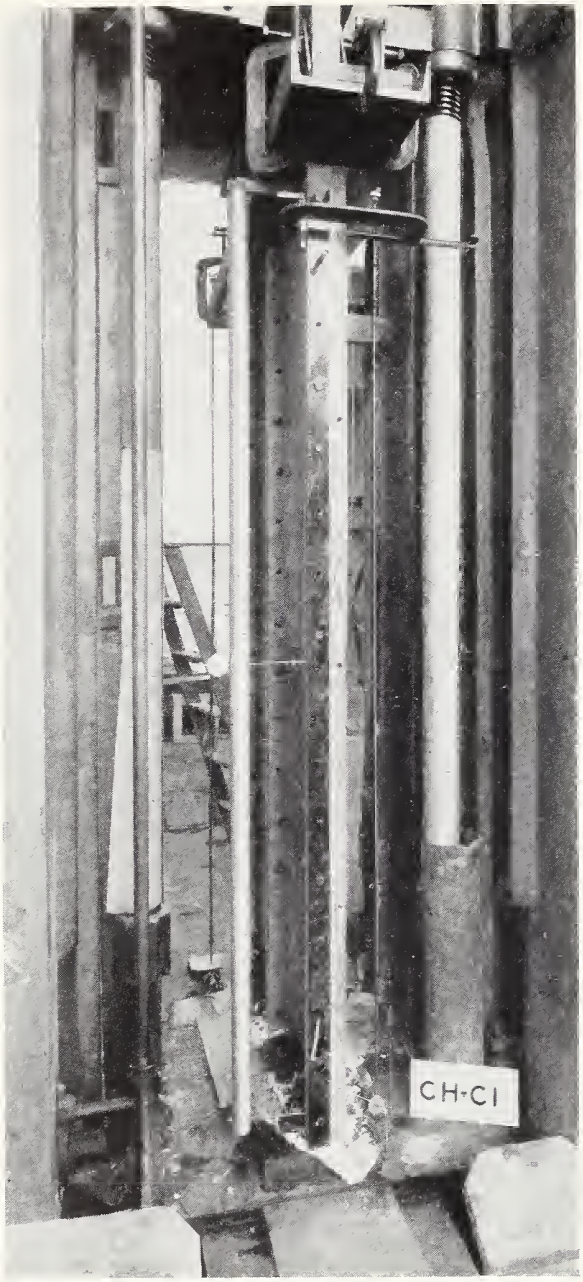

FIGURE 7.—*Wall specimen CH–C1 under compressive load.*

The shortenings and sets shown in figure 8 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 ½ in.

The lateral deflections shown in figure 9 were plotted to the right of the vertical axis for deflections of the specimen toward the outside

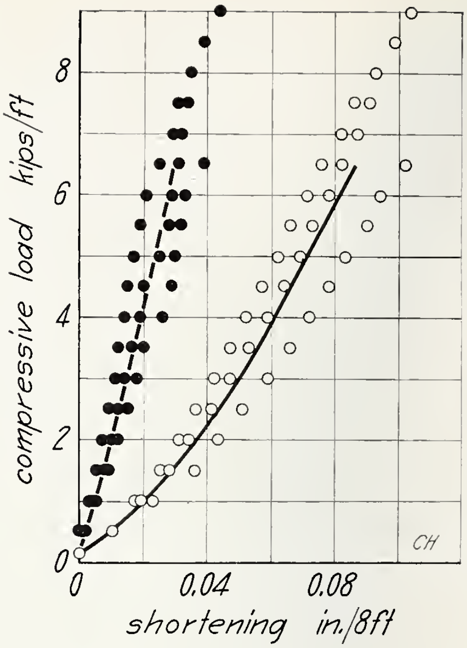

FIGURE 8.—*Compressive load on wall CH.*

Load-shortening (open circles) and load-set (solid circles) results for specimens *CH–C1, C2,* and *C3.* Load applied 1.33 in. (one-third the thickness) from the inside surface of the ribs. The loads are in kips per foot of actual width of specimen.

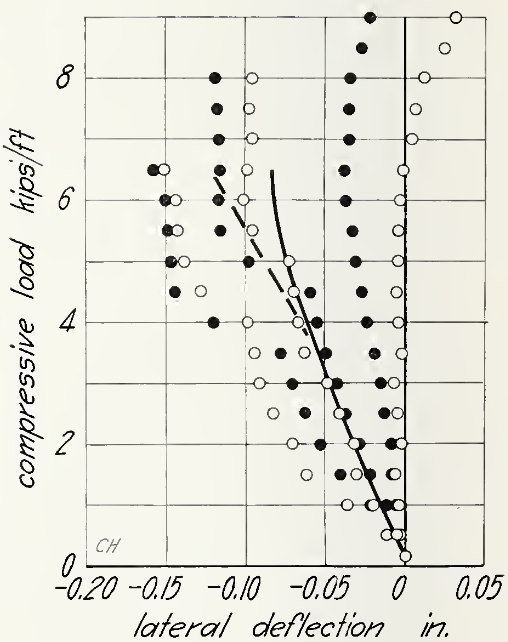

FIGURE 9.—*Compressive load on wall CH.*

Load-lateral deflection (open circles) and load-lateral set (solid circles) results for specimens *CH–C1, C2,* and *C3.* Load applied 1.33 in. (one-third the thickness) from the inside surface 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 6 in., the gage length of the deflectometers.

face (positive deflection) and to the left for deflections toward the inside face (negative deflection).

Although the load was eccentric toward the inside face, the specimens deflected initially toward the inside face. Under loads less than about 4 kips/ft on specimens *C1* and *C2* the sets were numerically little less than the deflections, but under greater loads the sets were numerically greater than the deflections and the values were nearly constant.

Under loads less than 7 kips/ft on specimen *C3* the deflections were small and the sets were numerically greater. Under greater loads this specimen deflected increasingly toward the outside face, but the sets (toward the inside face) were nearly constant. Because the thickness of the bonding plates was small (0.077 in), they probably did not have a pronounced effect on the compressive properties of the specimens, but functioned principally to join and aline the concrete units. Inspection of the specimens before they were tested showed that at the horizontal joints the units were in contact only at the flanges (which faced toward the inside of the wall). As regards the lateral deflections and sets under compressive loads, these specimens did not behave like elastic engineering structures, and no reasonable explanation for their behavior was found.

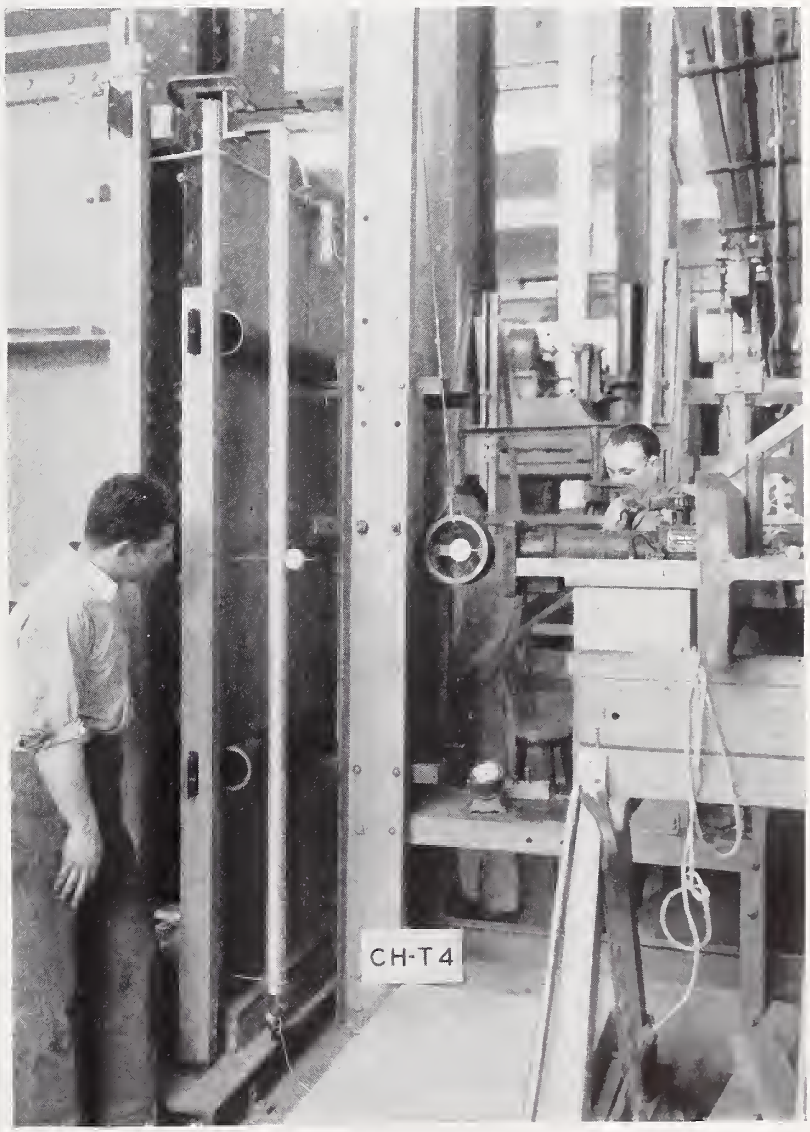

FIGURE 10.—*Wall specimen CH–T4 under transverse load.*

3. Transverse Load

Wall specimen *CH–T4* under transverse load is shown in figure 10. The results are shown in table 5 and in figure 11 for wall specimens *CH–T1*, *T2*, and *T3*, loaded on the inside face, and in figure 12 for wall specimens *CH–T4*, *T5*, and *T6*, loaded on the outside face.

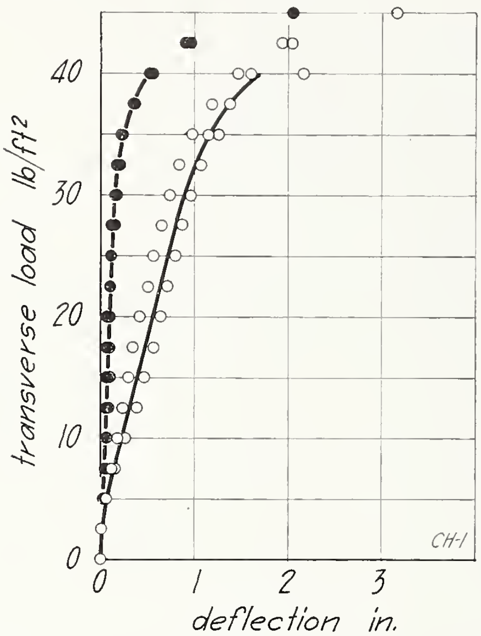

Figure 11.—*Transverse load on wall CH, load applied to inside face.*

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

The transverse load was applied to specimen *T1* in a horizontal position. The load due to the weight of the loading apparatus and the specimen was 23.3 lb/ft², and the deflection caused by this load was 0.77 in. The results for specimen *T1* are shown in figure 11 for loads of 25, 30, 35, and 40 lb/ft². The transverse loads were applied to specimens *T2*, *T3*, *T4*, *T5*, and *T6* in a vertical position, as shown in figure 10; hence there was neither initial load nor deflection.

Under a load of 35 lb/ft² on specimen *T1*, the bonding plates at the longitudinal edges buckled at midspan, and under a load of 40 lb/ft² the edges of the flanges of the units crushed along the joint at midspan. Under a load of 32.5 lb/ft² on specimen *T2*, one unit cracked along the base of the flange at midwidth, and under a load of 45 lb/ft² one outer bonding plate buckled noticeably. Under the maximum load on each of the specimens *T1*, *T2*, and *T3*, the flanges of the units at midspan crushed and the bonding plates on the longitudinal edges buckled. The deflection increased without an increase in the load.

Under a load of 70 lb/ft² on specimen *T4* and of 65 lb/ft² on specimen *T6* (applied to the outside face) the edges of one unit crushed. Under the maximum load on each of specimens *T4*, *T5*, and *T6*, the units crushed along the transverse joints and the deflection increased continuously without an increase in the load.

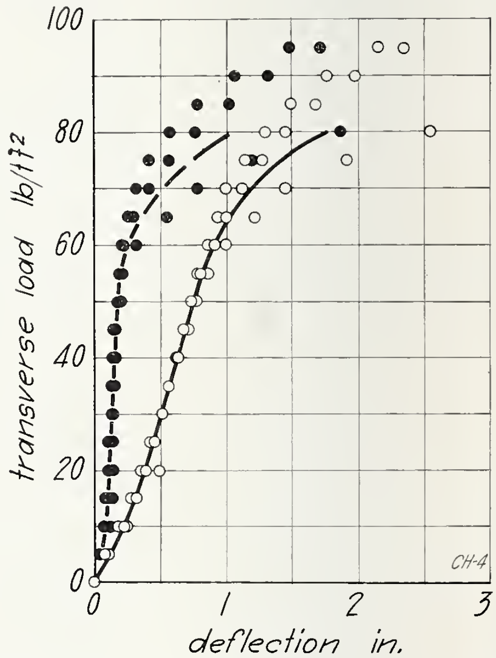

Figure 12.—*Transverse load on wall CH, load applied to outside face.*

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

4. Concentrated Load

Wall specimen *CH–P2* under concentrated load is shown in figure 13. The results are shown in table 5 and in figure 14 for wall specimens *CH–P1*, *P2*, and *P3*, loaded on the inside face, and in figure 15 for wall specimens *CH–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 flanges of a unit, the outside (flat) face resting on a steel plate. After a load of 1,000 lb had been applied, the set in speci-

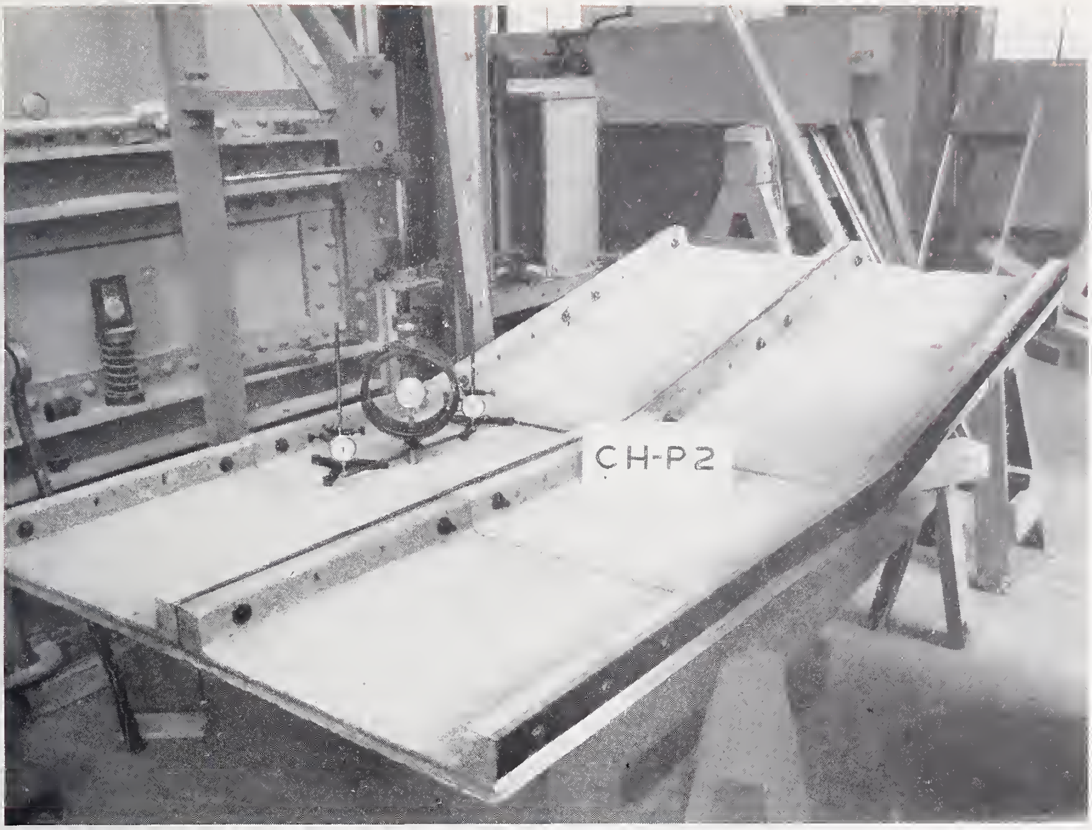

Figure 13.—*Wall specimen CH–P2 under concentrated load.*

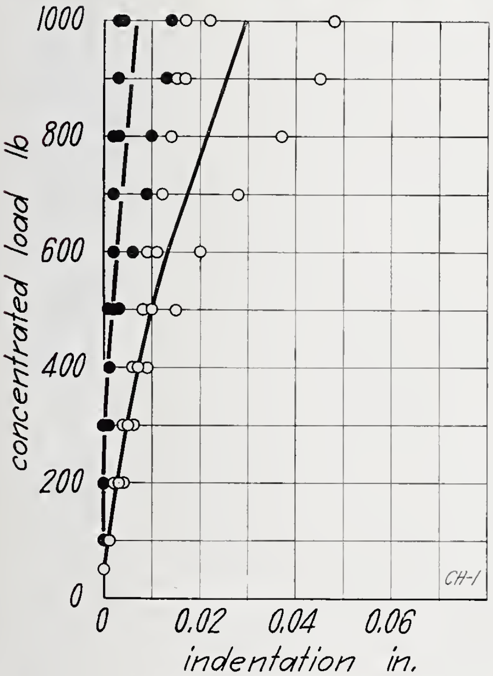

Figure 14.—*Concentrated load on wall CH, load applied to inside face.*

Load-indentation (open circles) and load-set (solid circles) results for specimens *CH–P1, P2,* and *P3.*

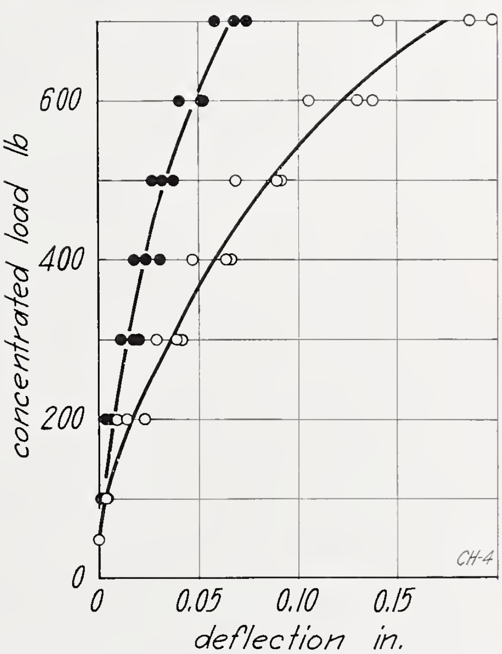

Figure 15.—*Concentrated load on wall CH, load applied to outside face.*

Load-indentation (open circles) and load-set (solid circles) results for specimens *CH–P4, P5,* and *P6.*

men *P1* was 0.003 in., in specimen *P2*, 0.014 in., and in specimen *P3*, 0.004 in., and no other effect was observed.

The concentrated loads were applied to the outside faces of specimens *P4*, *P5*, and *P6* between the flanges of a unit, the ribs of the inside face resting on a steel plate. After a load of 600 lb had been applied to each specimen, a longitudinal crack (parallel to the flanges) was visible in the inside face of the units. Under the maximum load, specimen *P4* failed by widening of this crack and specimens *P5* and *P6* by punching of the disk through the unit. The deformations were greater than those for the inside face, because they included the deflections of the web of the unit under the transverse load.

5. Impact Load

Wall specimen *CH–I3* during the impact test is shown in figure 16. The results are given in table 5 and in figure 17 for wall specimens *CH–I1*, *I2*, and *I3*, loaded on the inside face, and in figure 18 for wall specimens *CH–I4*, *I5*, and *I6*, loaded on the outside face.

The impact loads were applied to the center of the inside face of specimens *I1*, *I2*, and *I3*, the sandbag striking the ribs at a vertical and and a horizontal joint. The effects of the impact load on specimens *I1*, *I2* and *I3* are shown in table 6.

Table 6.—*Effects of impact load applied to the inside face of wall CH*

Description of effects	Height of drop for specimens		
	I1	*I2*	*I3*
	ft	*ft*	*ft*
First cracks in concrete at base of ribs of either one or two units near midspan	2.5	1.5	1.5
Failure of specimen by opening of the transverse joint at midspan	2.5	1.5	2.0
Noticeable buckling of either one or two outer bonding plates	3.0	3.0	2.5
Maximum height of drop; under load, specimen came in contact with floor; deflection about 2 ft	5.5	5.5	5.5

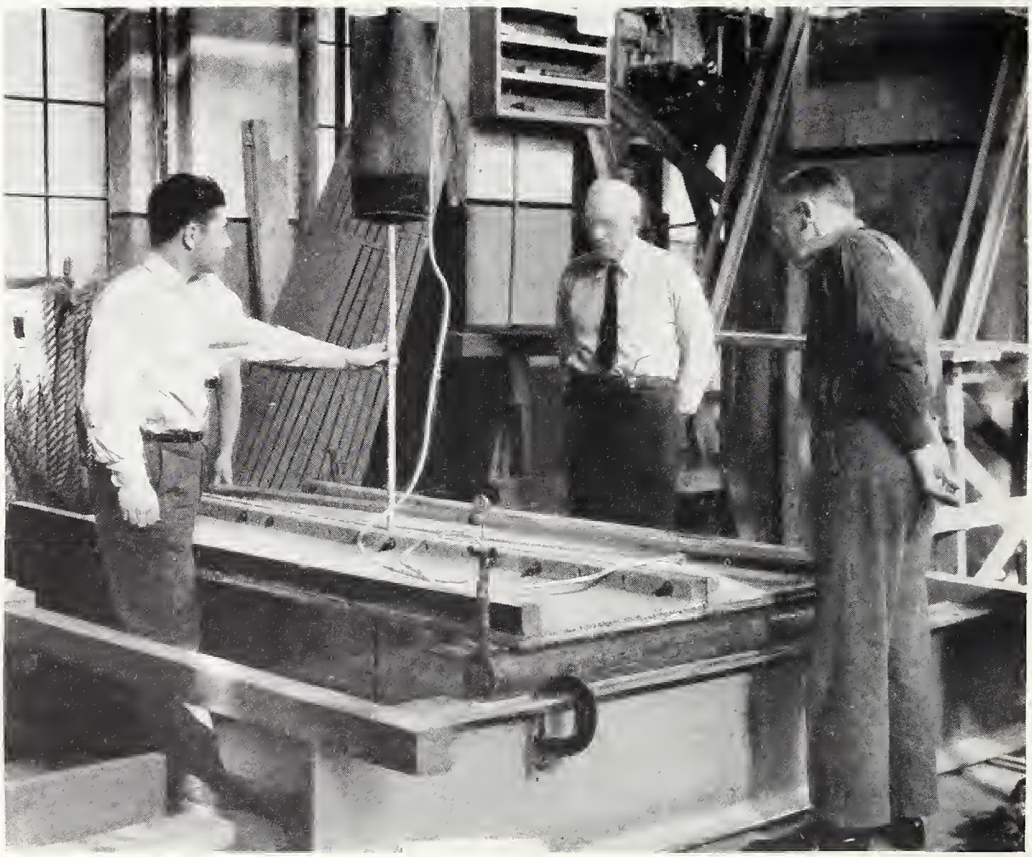

Figure 16.—*Wall specimen CH–I3 during the impact test.*

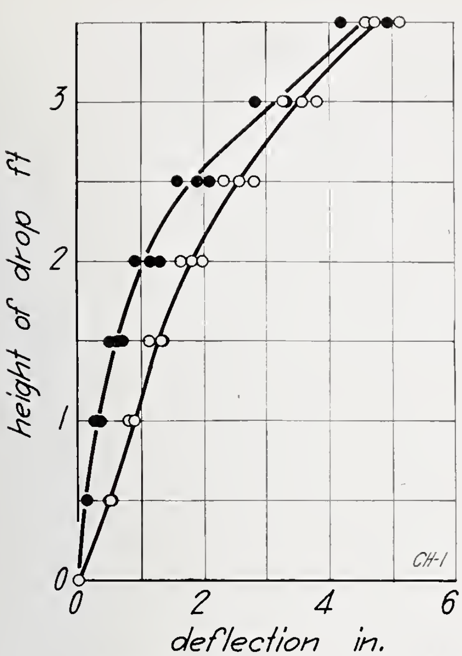

FIGURE 17.—*Impact load on wall CH, load applied to inside face.*

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

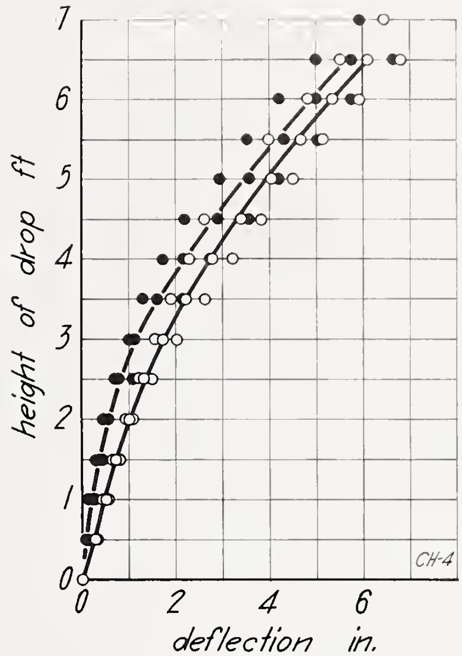

FIGURE 18.—*Impact load on wall CH, load applied to outside face.*

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

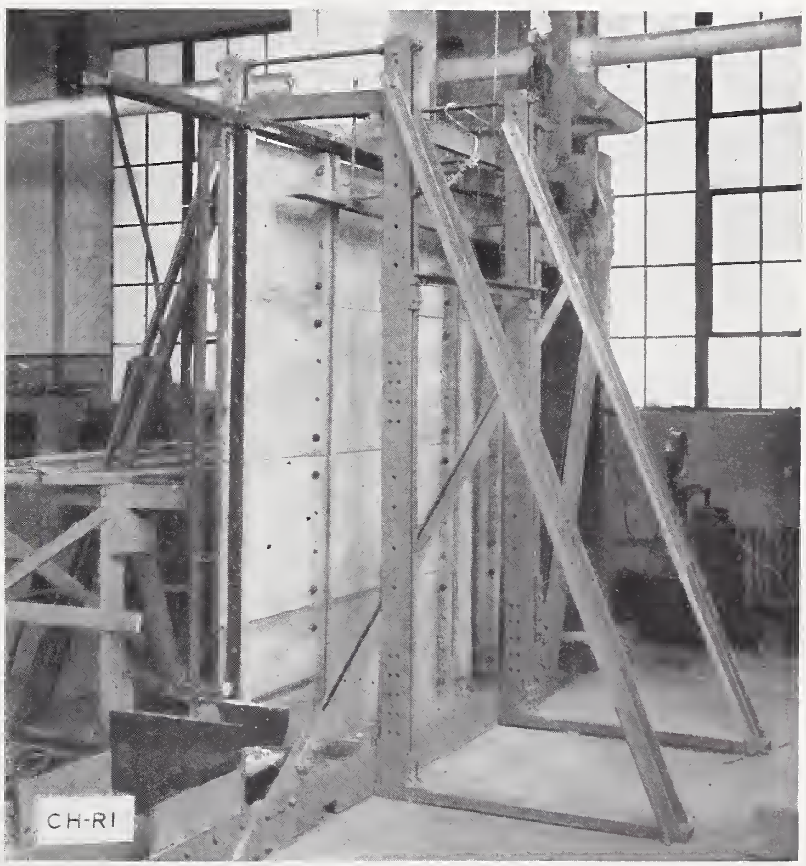

FIGURE 19.—*Wall specimen CH–R1 under racking load.*

The impact loads were applied to the center of the outside face of specimens *I4*, *I5*, and *I6*, the sandbag striking at a vertical and a horizontal joint. The effects of the impact load on specimens *I4*, *I5*, and *I6* are shown in table 7.

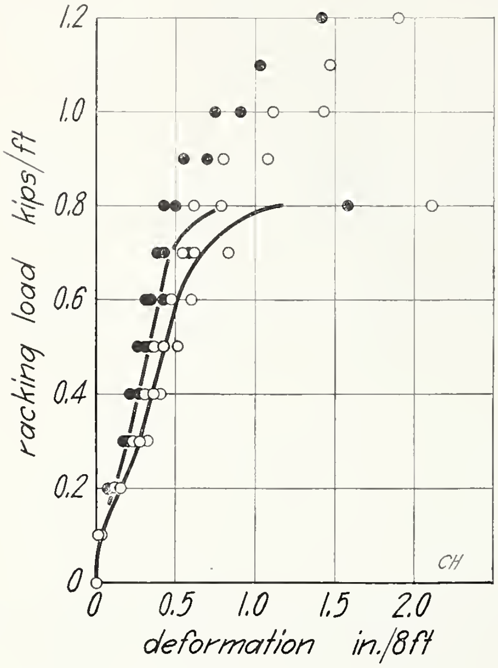

FIGURE 20.—*Racking load on wall CH.*

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

6. Racking Load

Wall specimen *CH–R1* under racking load is shown in figure 19. The results for wall specimens *CH–R1*, *R2*, and *R3* are shown in table 5 and in figure 20.

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

In specimen *R1* under a load of 0.30 kip/ft the unit in the top course adjacent to the loaded unit cracked longitudinally (vertically). A similar crack in the corresponding unit occurred in specimen *R2* when the load was 0.24 kip/ft and in specimen *R3* when the load was 0.23 kip/ft. In each of the specimens more units cracked as the load was increased. Most of the cracks were at the base of the flanges. All of the units in specimen *R1* were cracked when the load was 0.90 kip/ft and in specimen *R2* when the load was 0.80 kip/ft. Under the maximum load the units in each of the specimens crushed and cracked at the base of the flanges and the bonding plates bent.

TABLE 7.—*Effects of impact load applied to the outside face of wall CH*

Description of effects	Height of drop for specimens		
	I4	*I5*	*I6*
	ft	*ft*	*ft*
First crack along base of ribs of from one to four units	3.0	2.5	2.5
Failure of specimen by crushing at the transverse joint at midspan and further cracking of units	3.5	4.0	4.5
All units cracked	5.5	5.5	-----
Buckling of either one or two outer bonding plates	6.5	6.5	7.0
Rupture of central bonding plate near midspan	8.5	9.0	10.0
Maximum height of drop; under load, specimen came in contact with floor; deflection about 2 ft	9.0	9.0	[a]10.0

[a] Test discontinued. Specimen badly damaged, but did not come in contact with the floor.

The description and 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.

The tests for determining the structural properties were 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: C. C. Fishburn, F. Cardile, H. Dollar, M. Dubin, A. H. Easton, A. S. Endler, C. D. Johnson, A. B. Lanham, P. H. Petersen, A. J. Sussman, and L. R. Sweetman.

V. SELECTED REFERENCE

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WASHINGTON, August 9, 1939.

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