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STRUCTURES

REPORT BMS61

Structural Properties of Two  
Nonreinforced Monolithic  
Concrete Wall Constructions

*by*

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NATIONAL  
BUREAU OF STANDARDS

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# BUILDING MATERIALS *and* STRUCTURES

REPORT BMS61

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



ISSUED OCTOBER 28, 1940

The National Bureau of Standards is a fact-finding organization;  
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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 organizations within the building industry advocating and promoting their use. The sponsor built and submitted the specimens described in this report for participation in the program outlined in BMS2, Methods of Determining the Structural Properties of Low-Cost House Constructions. The sponsor, therefore, is responsible for the design of the constructions and for the description of materials and methods of fabrication. The Bureau is responsible for the testing of the specimens and the preparation of the report.

This report covers only the load-deformation relations and strength of the structural element submitted when subjected to compressive, transverse, impact, concentrated, and racking loads by standardized methods simulating the loads to which the element would be subjected in actual service.

The National Bureau of Standards does not "approve" a construction, nor does it express an opinion as to its merits for 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 Two Nonreinforced Monolithic Concrete Wall Constructions

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

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## ABSTRACT

For the program on the determination of the structural properties of low-cost house constructions, the Masonry Construction Section of the National Bureau of Standards built 24 specimens representing two nonreinforced monolithic concrete wall constructions. The only difference in their construction was in the proportions of the concrete.

The specimens were subjected to compressive, transverse, impact, concentrated, 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 each increment of load; the results are presented in graphs and a table.

## I. INTRODUCTION

To provide technical facts on the performance of constructions for 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 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 BMS1, Research on Building Materials and Structures for Use in Low-Cost Housing.

To determine the strength of house construc-

tions in the laboratory, standardized methods were developed for applying loads to specimens simulating portions of a completed house. Included in this study were masonry and wood constructions of types which have been extensively used in this country for houses and whose behavior under widely different service conditions is well 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 two monolithic concrete walls thinner but otherwise similar to types widely used as foundations for buildings. Although the compressive and transverse strengths of monolithic concrete walls have been investigated previously,<sup>1</sup> it seemed desirable to obtain additional data on the properties of nonreinforced concrete walls and to determine their resistances to racking, impact, and concen-

<sup>1</sup> Frank E. Richart and Nathan M. Newmark, *The strength of monolithic concrete walls*. Bul. Univ. Ill. Engrg. Expt. Sta. 277 (1935).

trated loads. As the behavior of concrete walls in service as foundations for houses is known, this report gives information on conventional masonry constructions supplementing that in BMS 5.

Compressive, transverse, impact, concentrated, and racking loads were applied to the specimens, producing effects similar to those resulting from loads which occur in an occupied house. In actual service, compressive loads on a foundation wall are produced by the weight of the roof, walls, furniture, and occupants, and snow and wind loads on the roof. Transverse loads on a wall are produced by the earth in contact with the wall, impact and concentrated loads by furniture or accidental contact with heavy objects, and racking loads by action of the wind on the walls above the foundation.

The deflection and set under each increment of load were measured, because 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 loads are removed.

## II. SPONSOR

The specimens were built by the Masonry Construction Section of the National Bureau of Standards.

## III. SPECIMENS AND TESTS

The only difference in the wall constructions was in the proportions of the concrete. One construction was assigned the symbol *CZ* and the other the symbol *DA*. The individual specimens were assigned the designations given in table 1.

TABLE 1.—*Specimen designations, walls CZ and DA*

Specimen designation	Load	Load applied
<i>C1, C2, C3</i> .....	Compressive.....	Upper end.
<i>T1, T2, T3</i> .....	Transverse.....	Either face.
<i>I1, I2, I3</i> .....	Impact <sup>a</sup> .....	Do.
<i>P1, P2, P3</i> .....	Concentrated.....	Do.
<i>R1, R2, R3</i> .....	Racking.....	5 in. below upper end.

<sup>a</sup> The impact and concentrated loads were applied to the same specimens, the impact loads first.

Except as mentioned below, the specimens were tested in accordance with report BMS2, which also gives the requirements for the speci-

mens and describes the presentation of the results of the tests, particularly the load-deformation graphs.

The specimens were cast in a vertical position. For the transverse and impact loads, only three specimens were built for each load, because the specimens were symmetrical about a vertical plane midway between the faces; the results for transverse and impact loads applied to one face should be identic with those obtained by applying loads to the opposite face. The concentrated loads were applied to one face only of each specimen for the same reason.

Under compressive load the shortening was measured over the entire length of the specimen by compressometers attached to the steel loading plates through which the load was applied, not to the specimen as described in BMS2. The speed of the movable head of the testing machine was adjusted to 0.044 in./min.

The lateral deflection under compressive load was measured 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 deflectometer was attached near the upper end of the specimen by clamping the hinged plate to either face; the deflectometer was vertical and the gage length (distance between the points of support) was 7 ft. 6 in. A dial micrometer was attached to the frame at midlength, with the spindle in contact with the face of the wall specimen. The dial was graduated to 0.001 in. and readings were recorded to the nearest division. There were two deflectometers, one near each edge of the specimen. This method of measurement was used instead of the taut-wire mirror-scale method described in BMS2.

For the transverse and impact loads the wall specimens were vertical. The lateral deflections under transverse load were measured in the same way as for the compressive load.

The indentation under concentrated load and the set after the load was removed were measured, instead of the set only, as described in BMS2. The apparatus is shown in figure 1. The load was applied to the thick steel disk, *A*, to which the crossbar, *B*, was rigidly attached. The load was measured by means of the dynamometer, *C*. Two stands, *D*, rested on the



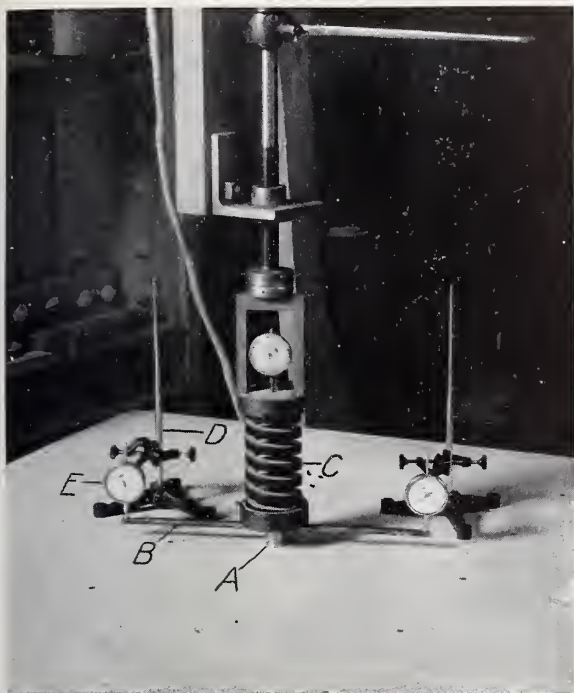


FIGURE 1.—Apparatus for concentrated-load test.

A, steel disk; B, crossbar; C, dynamometer; D, stand; E, dial micrometer.

face of the specimen, each supporting a dial micrometer, *E*, the spindle of which was in contact with the crossbar 8 in. from the center of the disk. The micrometers were graduated to 0.001 in. and 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 the dynamometer. A load was applied to the disk and the average of the micrometer readings minus the initial reading was taken as the depth of the indentation under load. The set after the load was removed was determined in the same manner.

The deformations under racking loads were measured with a right-angle deformer, consisting of a steel channel and a steel angle braced to form a rigid connection. In use, the channel of the deformer rested along the top of the specimen, with the steel angle extending downward in the plane of the specimen. Two pins passed snugly through holes in the channel into the top of the specimen. A dial micrometer was attached to the steel angle. The spindle of the micrometer was in contact with

the edge of the specimen. The gage length (distance from the top of the specimen to the spindle of the micrometer) was 6 ft. 8 in. The micrometer was graduated to 0.001 in. and readings were recorded to the nearest tenth of a division. This deformer was used instead of the taut-wire mirror-scale system described in BMS2.

The tests were begun February 12, 1940 and completed February 28, 1940.

## IV. MATERIALS

### 1. CEMENT

The portland cement complied with Federal Specification SS-C-191a, Cement; Portland. Delivered in bulk. Lehigh Portland Cement Co., "Lehigh."

### 2. AGGREGATES

The aggregates were Potomac River sand and gravel. The sieve analyses were made by the materials inspectors of the District of Columbia stationed at the aggregate plant.

#### (a) Fine

The fine aggregate complied with Federal Specification SS-A-281, Aggregate; (for) Portland Cement Concrete, class 1, grade A. The sieve analysis given in table 2 is the average of six analyses.

TABLE 2.—Sieve analysis of aggregates, walls CZ and DA

U. S. Standard Sieve	Passing, by weight	
	Fine aggregate (sand)	Coarse aggregate (gravel)
	Percent	Percent
1 in.-----		100
3/4 in.-----		95
3/8 in.-----	100	43
No. 4-----	98	3
No. 16-----	68	
No. 50-----	14	
No. 100-----	3	

#### (b) Coarse

The coarse aggregate complied with Federal Specification SS-A-281, Aggregate; (for) Portland Cement Concrete, class 2, grade A. The sieve analysis given in table 2 is the average of 4 analyses.

## V. WALL CZ

### 1. DESCRIPTION

Wall CZ was a nonreinforced monolithic concrete wall. The concrete consisted of 1 part of portland cement, 2.71 parts of sand, and 5.31 parts of gravel, by dry weight. Each face was concrete as poured.

The price of this construction in Washington, D. C., as of July 1937, was \$0.31/ft<sup>2</sup>.

#### (a) Four-Foot Wall Specimens

The wall specimens shown in figure 2 were 8 ft 3 $\frac{1}{8}$  in. high, 4 ft 0 $\frac{1}{16}$  in. wide, and 6 $\frac{1}{8}$  in. thick.

*Form.*—For convenience in handling the

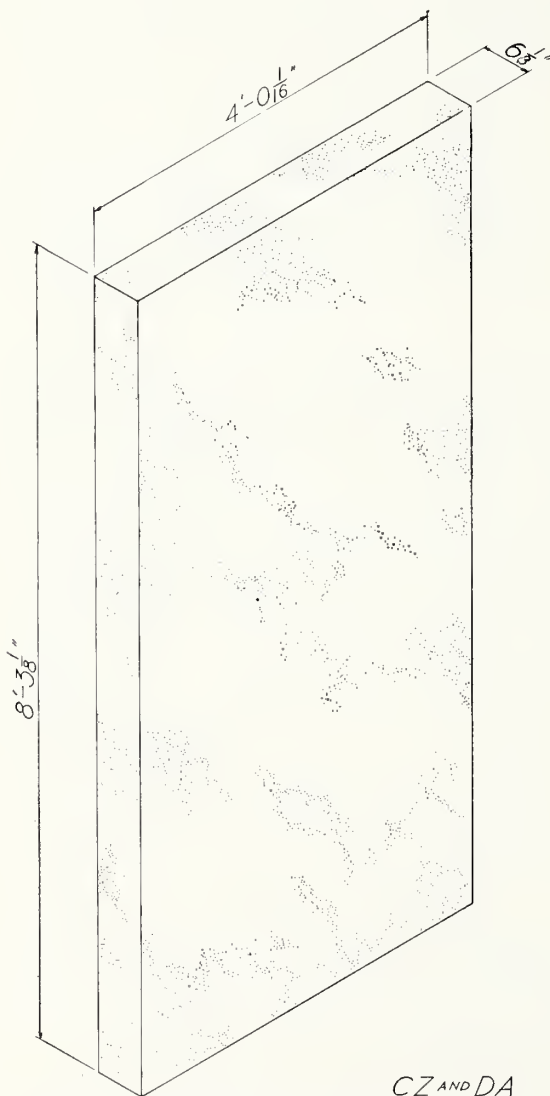


FIGURE 2.—Four-foot wall specimens CZ and DA.

specimens, the wood form was assembled on a structural steel channel, with the flanges up.

Each side of the form was plywood,  $\frac{1}{16}$  in. thick and 4 ft 0 in. wide—the width of the specimen. The sides were nailed to four vertical studs, 2 by 4 in., with the 2-in. face in contact with the plywood. The studs were spaced 1 ft 4 in. and the outside studs extended one-half their thickness beyond the edge of the plywood. Two plates, 4 ft 2 in. long, were nailed along the tops of the studs.

The ends of the form, 1 $\frac{1}{8}$  by 7 $\frac{1}{8}$  in., were placed between the outside studs and against the plywood. The distance between the plywood sides was 6 in.

To prevent spreading of the sides, wood wales, 4 by 4 in., were placed on each side at heights of 9 in., 3 ft 9 in., and 7 ft 0 in. The wales at each height were connected by steel ties,  $\frac{7}{32}$ -in. diam. In the lower wales there were 5 ties. In the middle and upper wales there were three ties.

*Concrete.*—The concrete was transit-mixed and consisted of 1 part of portland cement, 2.71 parts of sand, and 5.31 parts of gravel, by dry weight; 1 part of portland cement, 3.0 parts of damp sand, and 5.0 parts of damp gravel, by loose volume.

TABLE 3.—Physical properties of the concrete, wall CZ  
[The weight of the concrete, age either 28 or 29 days, based on the volume of the walls, was 148 lb/ft<sup>3</sup>]

Specimen	Water, per sack of cement	Slump	Compressive strength age 28 or 29 days	
			Cylinders cured with wall speci- mens	Cylinders cured at 70° F and 95 to 100% relative humidity
	gal	in.	lb/in. <sup>2</sup>	lb/in. <sup>2</sup>
C1	7.5	6 $\frac{1}{2}$	2,180	3,460
C2	7.5	5 $\frac{1}{2}$	2,490	3,900
C3	8.2	7	1,250	2,150
T1	8.2	6 $\frac{1}{4}$	1,550	2,680
T2	7.5	6 $\frac{1}{2}$	1,500	2,690
T3	7.5	6	1,500	3,000
I1	5.8	6 $\frac{3}{4}$	2,380	3,620
I2	5.8	4 $\frac{3}{4}$	2,280	3,510
I3	5.8	4	2,610	3,730
R1	7.5	4 $\frac{1}{4}$	2,150	3,600
R2	8.2	4 $\frac{1}{2}$	1,550	2,480
R3	7.5	5	2,010	3,200
Average	7.2	5 $\frac{1}{2}$	1,950	3,170

For each specimen the slump was determined in accordance with ASTM Tentative Standard D 138-32 T, Method of Test for Consistency of Portland-Cement Concrete. Two



6- by 12-in. cylinders were made from the same concrete as for each specimen. One cylinder was stored near the specimens and the other at 70° F and a relative humidity of 95 to 100 percent.

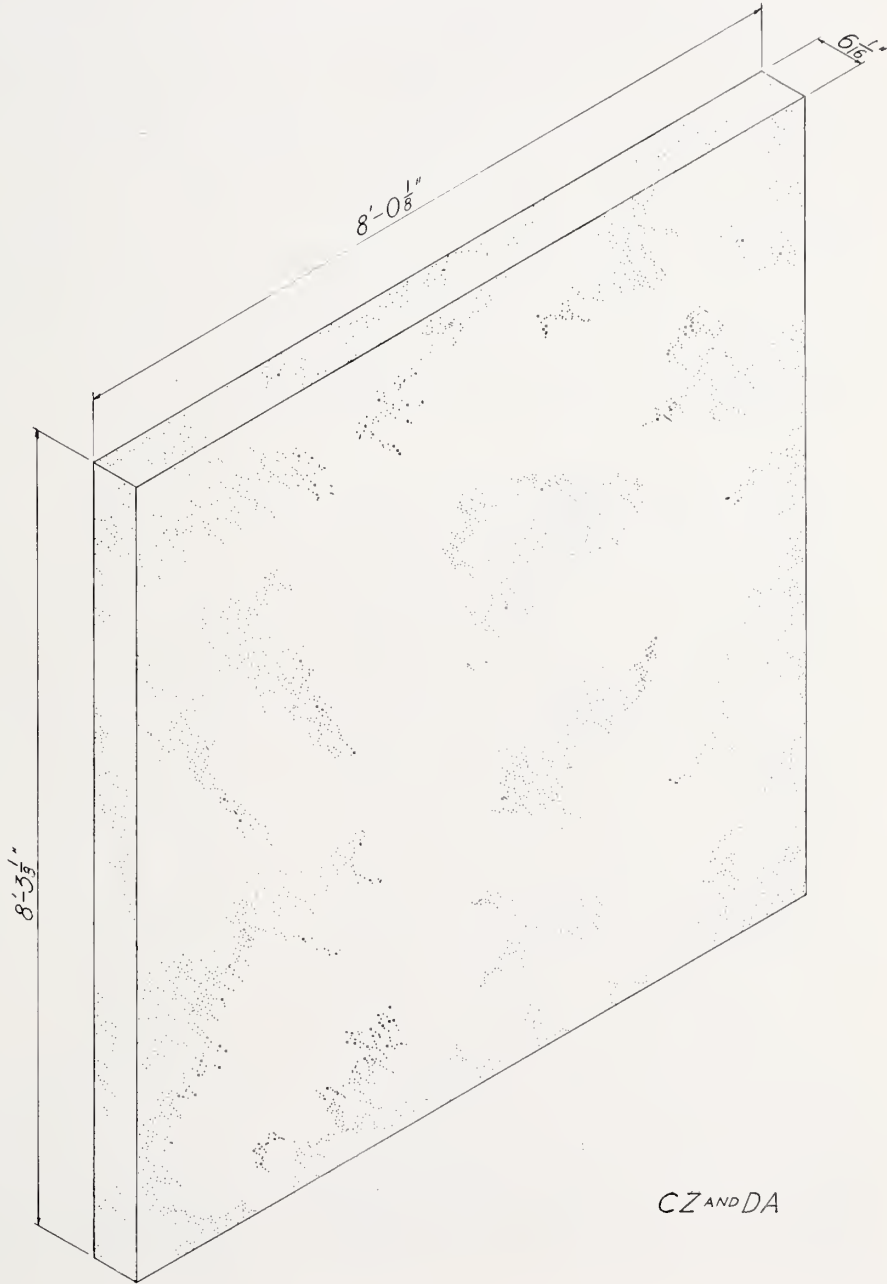
The compressive strength of each cylinder was determined on the day the corresponding floor specimen was tested, age either 28 or 29 days. The physical properties of the concrete are given in table 3.

The concrete was cast in layers 12 in. deep within 1½ hours after mixing began and was well rodded. The forms were removed the second day after the concrete was placed. The depressions caused by the removal of the ties were pointed with cement mortar.

(b) *Eight-Foot Wall Specimens*

The 8-ft wall specimens, shown in figure 3, were 8 ft 3½ in. high, 8 ft 0½ in. wide, and

FIGURE 3.—Eight-foot wall specimens CZ and DA.



6 $\frac{1}{16}$  in. thick. They were similar to the 4-ft specimens.

The forms for the 8-ft specimens were similar to those for the 4-ft specimens except that there were two studs at midwidth, five ties in

the lower and the middle wales, and three in the upper wales.

## 2. COMPRESSIVE LOAD

The results for wall specimens CZ-C1, C2, and C3 are given in table 4 and in figures 4 and 5.

TABLE 4.—*Structural properties of nonreinforced monolithic concrete wall constructions CZ and DA*

[Weight, based on the face area: Wall CZ, 74.9 lb/ft<sup>2</sup>; wall D.A, 75.1 lb/ft<sup>2</sup>]

Construction symbol	Load									
	Compressive <sup>a</sup>		Transverse, span 7 ft. 6 in.		Impact, span 7 ft. 6 in.		Concentrated		Racking	
	Speci- men	Maxi- mum load	Speci- men	Maxi- mum load	Speci- men	Maxi- mum height of drop	Speci- men	Maxi- mum load	Speci- men	Maxi- mum load
CZ	C1	<sup>b</sup> Kips/ft 186	T1	lb/ft <sup>2</sup> 253	I1	ft c 10.0	P1	lb c 1,000	R1	<sup>b</sup> Kips/ft c 6.25
	C2	144	T2	277	I2	c 10.0	P2	c 1,000	R2	c 6.25
	C3	109	T3	266	I3	c 10.0	P3	c 1,000	R3	c 6.25
	Average	146		265		c 10.0		c 1,000		c 6.25
DA	C1	189	T1	297	I1	c 10.0	P1	c 1,000	R1	c 6.25
	C2	179	T2	216	I2	c 10.0	P2	c 1,000	R2	c 6.25
	C3	149	T3	220	I3	c 10.0	P3	c 1,000	R3	c 6.25
	Average	172		244		c 10.0		c 1,000		c 6.25

<sup>a</sup> The compressive load was applied 2 in. (one-third of the thickness) from one face of the specimen.

<sup>b</sup> A kip is 1,000 lb.

<sup>c</sup> Test discontinued. Specimen did not fail.

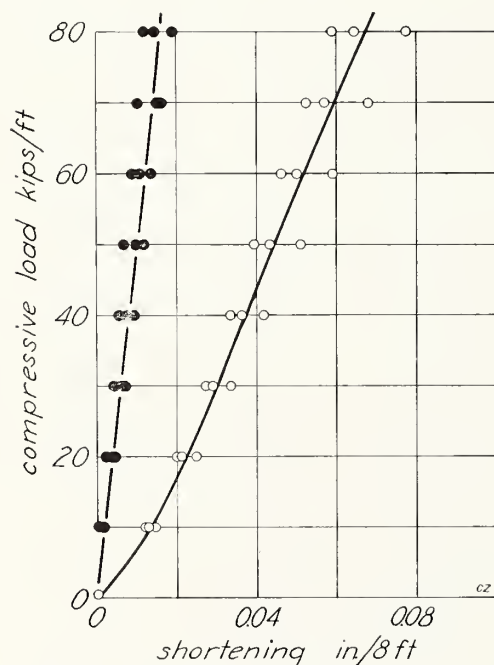


FIGURE 4.—Compressive load on wall CZ.

Load-shortening (open circles) and load-set (solid circles) results for specimens CZ-C1, C2, and C3. Load applied 2 in. (one-third the thickness) from one face. The loads are in kips per foot of actual width of specimen.

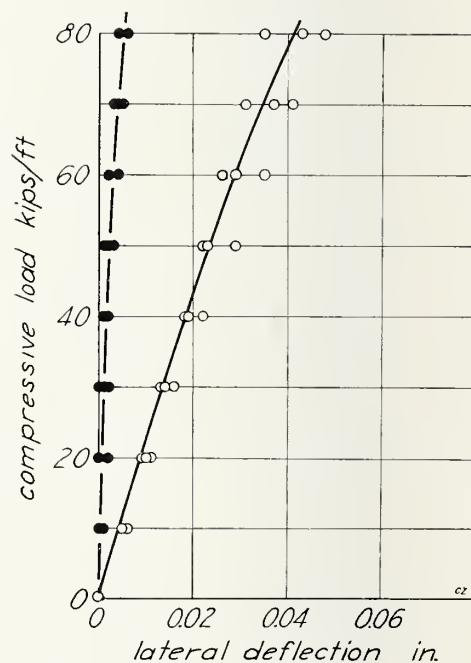


FIGURE 5.—Compressive load on wall CZ.

Load-lateral deflection (open circles) and load lateral set (solid circles) for specimens CZ-C1, C2, and C3. Load applied 2 in. (one-third the thickness) from one face. The loads are in kips per foot of actual width of specimen. The deflections and sets are for a gage length of 7 ft 6 in. the gage length of the deflectometers.

The gage length of the compressometers was 8 ft 3¼ in. The shortenings and sets shown in figure 4 for a height of 8 ft were computed from the values obtained from the compressometer readings.

Under the maximum load the concrete on each specimen crushed and spalled at the top of specimen on the face nearer the load line.

### 3. TRANSVERSE LOAD

The results are shown in table 4 and figure 6 for specimens *CZ-T1*, *T2*, and *T3*.

Under the maximum load specimen *T1* ruptured transversely under a loading roller, specimen *T2* at midspan, and *T3* between the loading rollers.

### 4. IMPACT LOAD

The results of the impact loads on wall specimens *CZ-I1*, *I2*, and *I3* are shown in table 4 and figure 7.

After the 10-ft drop the set in specimen *CZ-I1* was 0.004 in., in *I2* 0.003 in., and in *I3* 0.001 in. No other effects were observed.

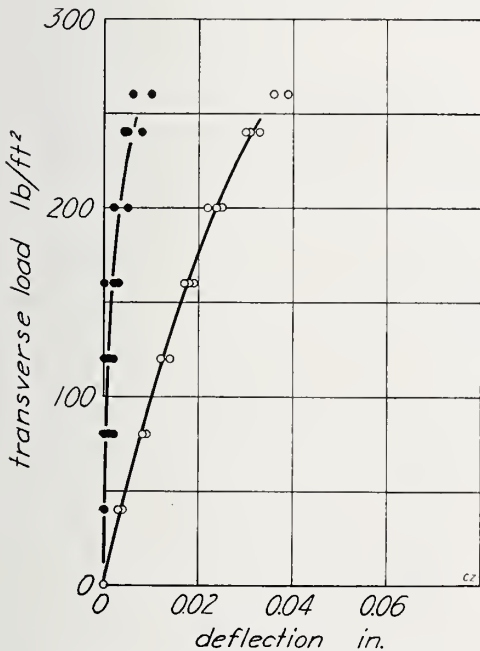


FIGURE 6.—Transverse load on wall CZ.

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

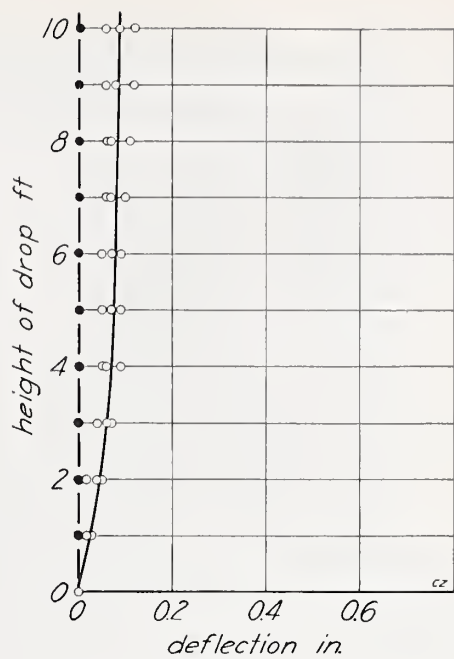


FIGURE 7.—Impact load on wall CZ.

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

### 5. CONCENTRATED LOAD

Wall specimen *CZ-P3* under concentrated load is shown on the right in figure 8. The results of the concentrated loads on wall specimens *CZ-P1*, *P2*, and *P3* are shown in table 4 and figure 9.

The concentrated loads were applied to one face only. The set after a load of 1,000 lb. had been applied to specimens *P1* and *P2* was 0.001 in. and to *P3*, 0.000 in. No other effects were observed.

### 6. RACKING LOAD

The results of the racking load on wall specimens *CZ-R1*, *R2*, and *R3* are shown in table 4 and figure 10.

After a load of 6.25 kips/ft had been applied, the set in specimen *CZ-R1* was 0.002 in./8 ft and in specimen *R2* 0.004 in./8 ft.

The racking specimens were built on the webs of steel channels having the flanges down. Under loads greater than 2.5 kips/ft the flanges of the channel on which specimen *R3* was built spread suddenly. This occurred a number of times as the load was increased. The vibration



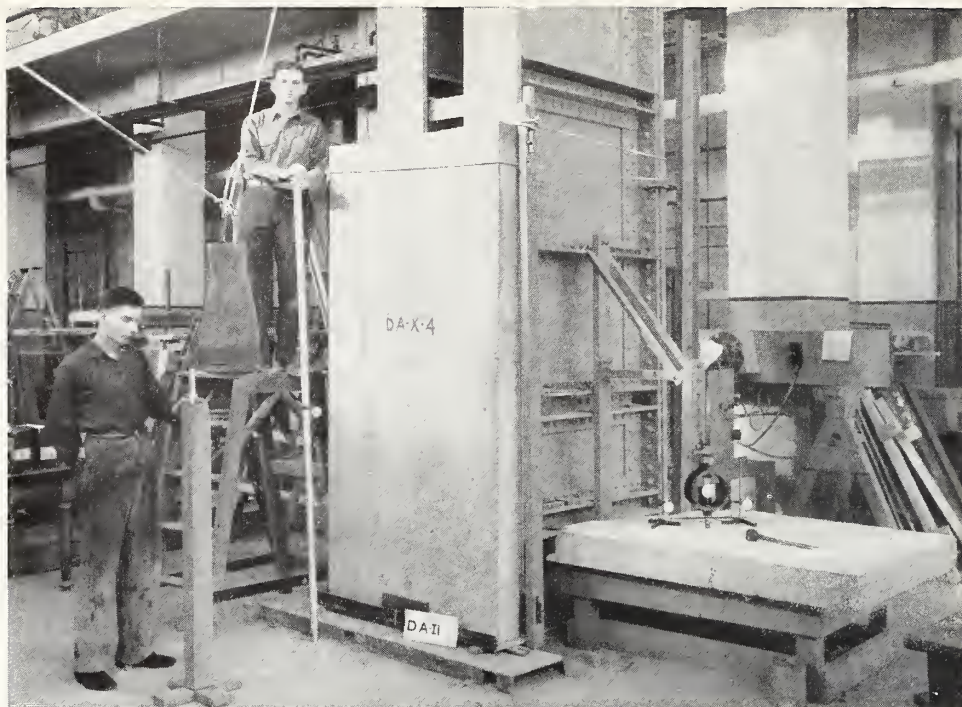


FIGURE 8.—Wall specimen CZ-P3 under concentrated load and specimen DA-11 during the impact test.

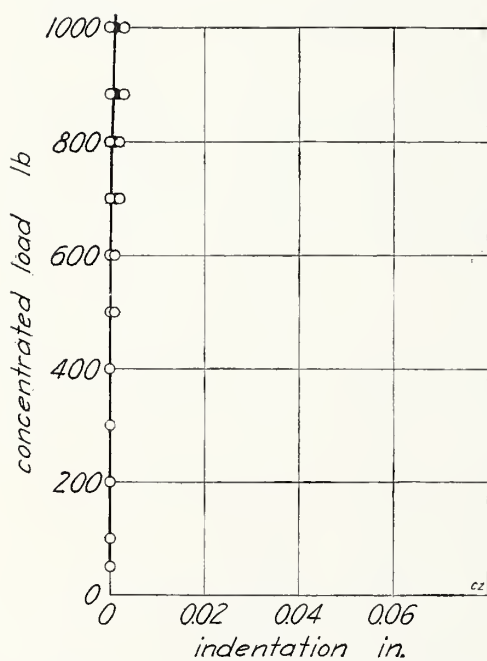


FIGURE 9.—Concentrated load on wall CZ.

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

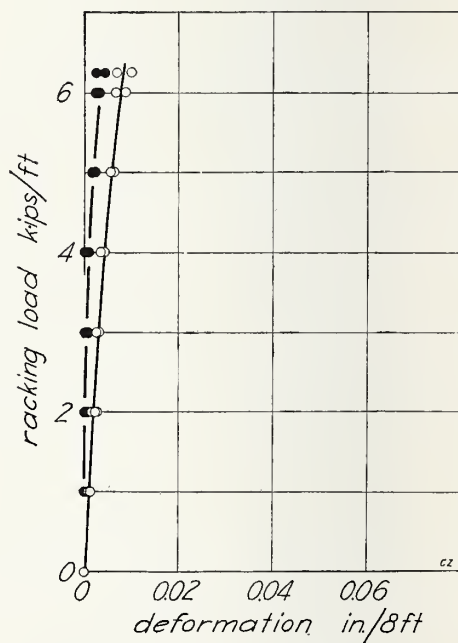


FIGURE 10.—Racking load on wall CZ.

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

of the specimen whenever the flanges spread changed the location of the deformer relative to the top of the specimen. Therefore, the deformation and set could not be determined from the readings of the dial micrometer.

VI. WALL DA

1. DESCRIPTION

Wall DA was a nonreinforced monolithic concrete wall. The concrete consisted of 1 part of portland cement, 2.53 parts of sand, and 3.41 parts of gravel, by dry weight. The only difference in these specimens and specimens CZ was in the proportions of the concrete. Each face was concrete as poured.

The price of this construction in Washington, D. C., as of July 1937, was \$0.32/ft<sup>2</sup>.

(a) Four-Foot Wall Specimens

Wall specimen DA, shown in figure 2, was 8 ft 3 7/8 in. high, 4 ft 0 1/16 in. wide, and 6 1/8 in. thick.

Concrete.—The concrete was transit-mixed and consisted of 1 part of portland cement, 2.53 parts of sand, and 3.41 parts of gravel, by dry weight; or 1 part of portland cement, 2.8 parts of damp sand, and 3.2 parts of damp gravel, by loose volume.

TABLE 5.—Physical properties of the concrete, wall DA  
[The weight of the concrete, age either 28 or 29 days, based on the volume of the walls, was 148 lb/ft<sup>3</sup>]

Specimen	Water, per sack of cement	Slump	Compressive strength age 28 or 29 days	
			Cylinders cured with wall speci- mens	Cylinders cured at 70° F. and 95 to 100% relative humidity
	gal	in.	lb/in. <sup>2</sup>	lb/in. <sup>2</sup>
C1-----	7.1	6 1/2	3,010	3,800
C2-----	7.1	6	2,760	3,710
C3-----	7.1	6 1/2	2,450	4,200
T1-----	7.1	6 1/2	2,300	3,910
T2-----	7.2	5 1/4	1,920	3,250
T3-----	7.2	4 3/4	1,800	3,180
II-----	5.2	6	2,890	4,330
I2-----	5.2	5 3/4	2,740	4,430
I3-----	5.2	5	3,150	4,160
R1-----	7.3	6	3,130	3,960
R2-----	7.1	5 3/4	1,760	3,100
R3-----	7.2	4	1,460	2,600
Average-----	6.7	5 3/4	2,450	3,720

For each specimen the slump was determined in accordance with ASTM Tentative Standard D138-32 T, Methods of Test for Consistency

of Portland Cement Concrete. Two 6- by 12-in. cylinders were made from the same concrete as for each specimen. One cylinder was stored near the wall specimens and the other at 70°F and a relative humidity of 95 to 100 percent. The compressive strength of each cylinder was determined on the day the corresponding wall specimen was tested, age either 28 or 29 days. The physical properties of the concrete are given in table 5.

(b) Eight-Foot Wall Specimens

The 8-ft wall specimens, shown in figure 3, were 8 ft 3 7/8 in. high, 8 ft 0 1/8 in. wide and 6 1/16 in. thick. The specimens were similar to the 4-ft specimens.



FIGURE 11.—Wall specimen DA-C3 under compressive load.

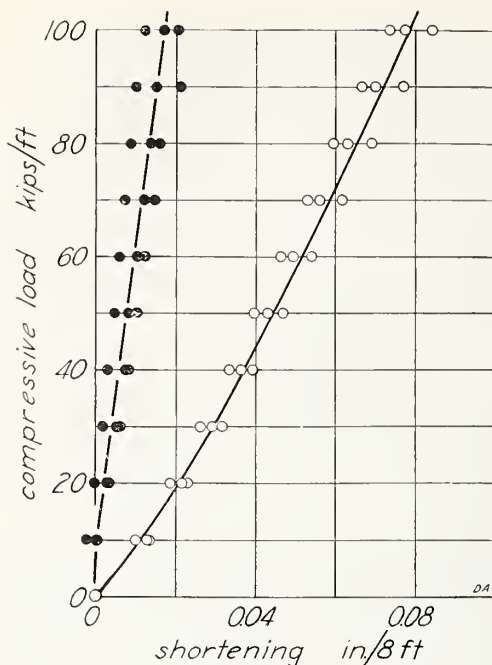


FIGURE 12.—Compressive load on wall DA.

Load-shortening (open circles) and load-set (solid circles) results for specimens DA-C1, C2, and C3. Load applied 2 in. (one-third the thickness) from one face. The loads are in kips per foot of actual width of specimen.

## 2. COMPRESSIVE LOAD

Wall specimen DA-C3 under compressive load is shown in figure 11. The results for wall specimens DA-C1, C2, and C3 are shown in table 4 and in figures 12 and 13.

The gage length of the compressometers was 8 ft  $3\frac{3}{16}$  in. The shortenings and sets shown in figure 12 for a height of 8 ft were computed from the values obtained from the compressometer readings.

Under the maximum load specimen DA-C1 collapsed suddenly and specimens C2 and C3 crushed and spalled at the top of the specimen on the face nearer the load line.

## 3. TRANSVERSE LOAD

Wall specimen DA-T1 under transverse load is shown in figure 14. The results for specimens DA-T1, T2, and T3 are given in table 4 and figure 15.

Under the maximum load each specimen ruptured transversely between the loading rollers.

## 4. IMPACT LOAD

Wall specimen DA-I1 during the impact test is shown in figure 8. The results for specimens DA-I1, I2, and I3 are shown in table 4 and in figure 16.

After the 10-ft drop the set in each specimen was 0.003 in. No other effects were observed.

## 5. CONCENTRATED LOAD

The results on specimens DA-P1, P2, and P3 are shown in table 4 and figure 17.

The concentrated loads were applied to one face. The set after a load of 1,000 lb had been applied was 0.001 in. for specimen P1, 0.004 in. for P2, and 0.003 in. for P3.

## 6. RACKING LOAD

Wall specimen DA-R2 under racking load is shown in figure 18. The results for specimens DA-R1, R2, and R3 are shown in table 4 and figure 19.

After a load of 6.25 kips/ft had been applied, the set in specimen DA-R1 was 0.001 in./8 ft, in R2 0.002 in./8 ft, and in R3 0.003 in./8 ft. No other effects were observed.

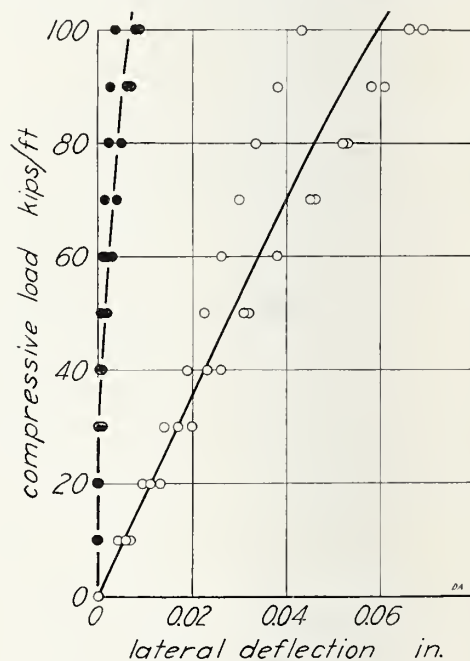
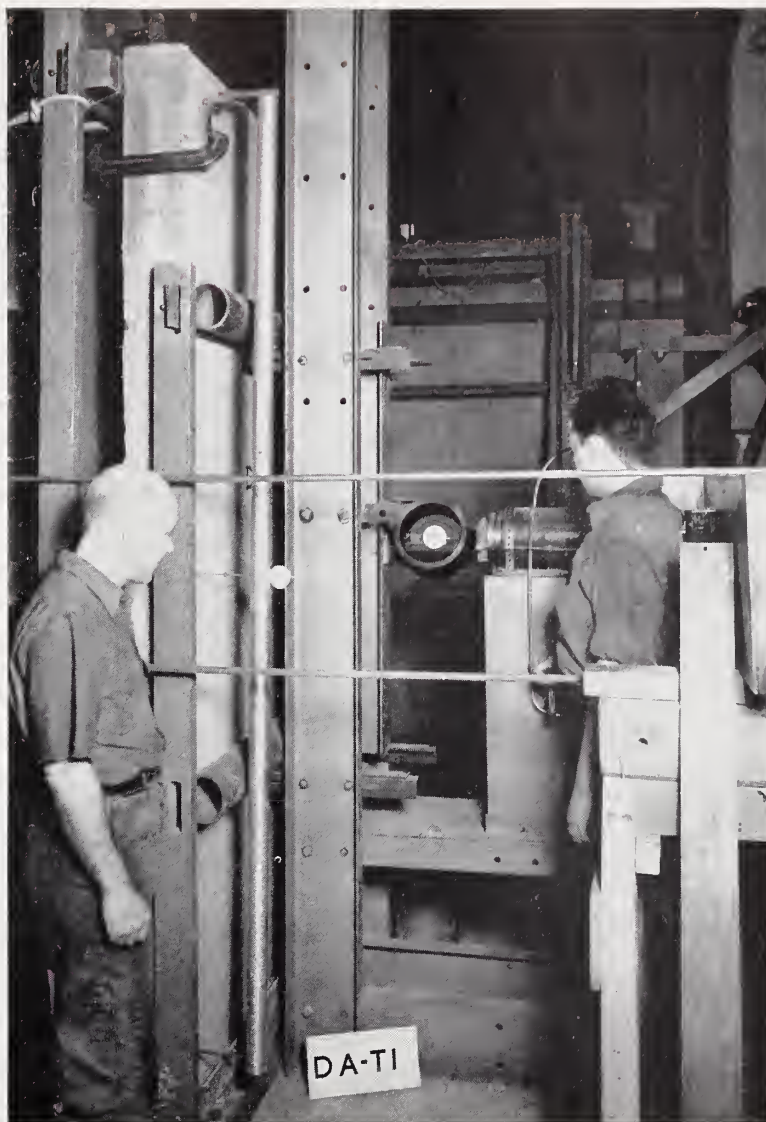


FIGURE 13.—Compressive load on wall DA.

Load-lateral deflection (open circles) and load-lateral set (solid circles) results for specimens DA-C1, C2, and C3. Load applied 2 in. (one-third the thickness) from one face. The loads are in kips per foot of actual width of specimen. The deflections and sets are for a gage length of 7 ft 6 in., the gage length of the deflectometers.



FIGURE 14.—Wall specimen *DA-T1*  
under transverse load.



## VII. COMMENTS

The two concrete mixtures in wall constructions *CZ* and *DA* differed with respect to cement content and ratio of fine to coarse aggregates. The slumps were nearly equal and the water-cement ratios (7.25 and 6.67 gallons per sack, respectively) were not very different. The concrete wall (1:3:5 mixture by volume of portland cement, loose sand, and loose gravel) was harsh and, in spite of the thorough rodding of each 12-in. layer, there was some honeycombed concrete in most of the specimens, as illustrated in figure 20. The concrete in wall *DA* (1:2.8:3.2 mixture by volume of portland

cement, loose sand, and loose gravel) did not segregate as readily as that for wall *CZ* and appeared to require less work for compacting. No honeycombed concrete was observed in the specimens.

At the same age, 28 days, the average compressive strength (pounds per square inch) of the wall specimens *CZ* was approximately the same as the average compressive strength of the corresponding 6- by 12-in. concrete cylinders cured with the wall specimens. There is the same relation between the wall specimens *DA* and the corresponding concrete cylinders. Despite the greater compressive strengths of the cylinders of the richer concrete (*DA*), the aver-

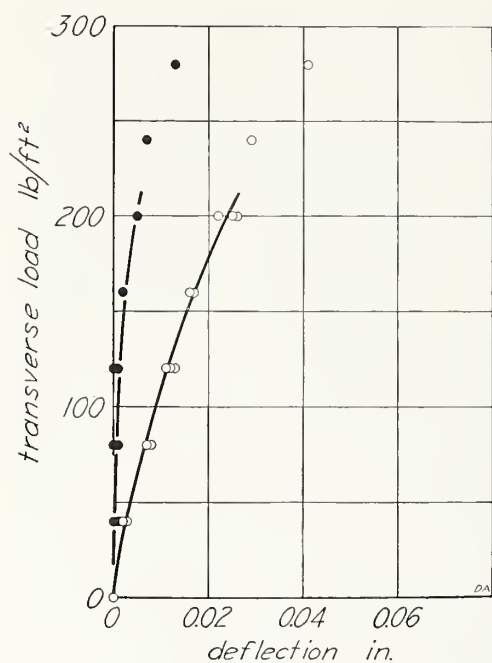


FIGURE 15.—Transverse load on wall DA.

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

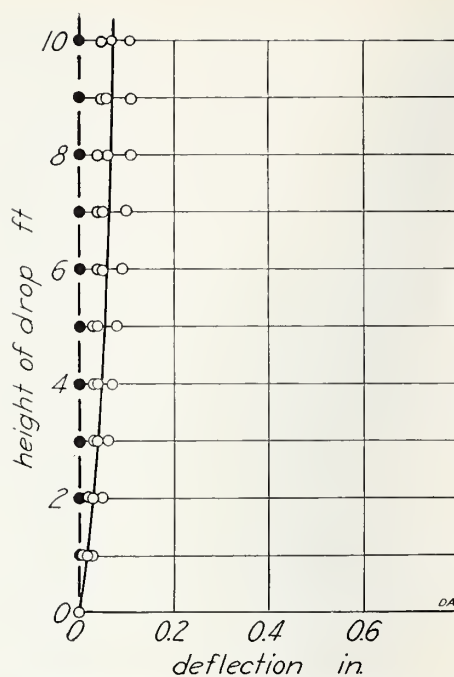


FIGURE 16.—Impact load on wall DA.

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

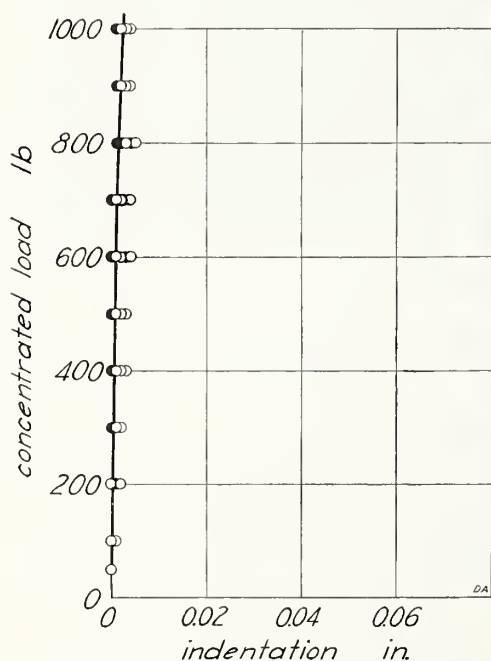


FIGURE 17.—Concentrated load on wall DA.

Load-indentation (open circles) and load-set (solid circles) results for specimen DA-P1, P2, and P3.



FIGURE 18.—Wall specimen DA-R2 under racking load.



age transverse strengths of the CZ specimens containing the leaner concrete was about 9 percent more than for specimens DA. The concrete for both constructions was compacted more carefully than would often be the case in constructing foundation walls for low-cost housing. The harshness of the leaner mixture and the presence of scattered small volumes of

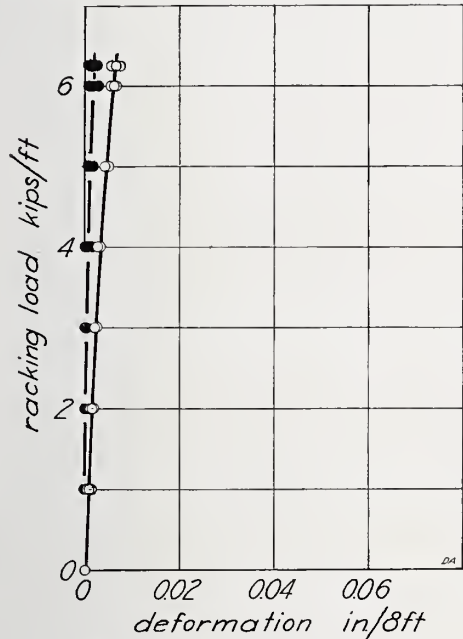


FIGURE 19.—Racking load on wall DA.

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

honeycombed concrete in walls CZ indicate that if a less effective method of compacting had been used the results would not have been so favorable for these walls.

In applying the results of these tests to construction where the workmanship may not always be as careful, it is well to bear in mind, also, the marked influence on transverse strength of the presence of horizontal construction joints.<sup>2</sup>

The drawings of the specimens were prepared by E. J. Schell and G. W. Shaw, of the

<sup>2</sup> See footnote 1.



FIGURE 20.—Illustration of honeycombed concrete in wall specimens CZ.

Building Practice and Specifications Section of this Bureau, under the supervision of V. B. Phelan.

The structural properties were determined by the Engineering Mechanics Section, under the supervision of H. L. Whittemore and A. H. Stang, and the physical properties of the concrete by the Masonry Construction Section, under the supervision of D. E. Parsons. They were assisted by the following members of the professional staff: E. S. Cohen, A. H. Easton, C. C. Fishburn, A. Heiter, D. C. List, M. F. Peck, P. H. Petersen, L. R. Sweetman, and H. L. Weiss.

WASHINGTON, MAY 20, 1940.







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