U. S. DEPARTMENT OF COMMERCE

BUILDING MATERIALS AND STRUCTURES

REPORT BMS53

Structural Properties of a Masonry Wall Construction of "Munlock Dry Wall Brick"

Sponsored by the Munlock Engineering Co.

by

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

NATIONAL BUREAU OF STANDARDS

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ISSUED JUNE 13, 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 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 the description of materials and methods used in their fabrication. The Bureau is responsible for the method of testing and for the test results.

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

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 Masonry Wall Construction of "Munlock Dry Wall Brick" Sponsored by the Munlock Engineering Co.

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 Munlock Engineering Co. submitted 12 specimens representing their "Munlock Dry Wall Brick" wall construction.

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 a table.

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 the 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, by 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, considered as a structure, the suitability of a construction depends not only on its resistance to deformation when loads are applied but also on whether it returns to its original size and shape when the loads are removed.

II. SPONSOR AND PRODUCT

The specimens were submitted by the Munlock Engineering Co., Washington, D. C., and represented a wall construction of "Munlock Dry Wall Brick" units.

The water permeability of this wall construction has been measured by the Masonry Construction Section of the National Bureau of Standards, and the results will be included in a future publication of this series. In addition, the thermal conductivity of the construction may be determined later.

III. SPECIMENS AND TESTS

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

Table 1.—*Specimen designations, wall CP*

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

[a] The transverse and concentrated loads were applied to the same specimens. The transverse load was applied first.

Except as mentioned below, the specimens were tested in accordance with the procedure outlined in BMS2, which report also gives the requirements for the specimens and describes the presentation of the results of the tests, particularly the load-deformation graphs.

Only three specimens each were tested under the transverse, concentrated, and impact loads, not six, as required by BMS2. The wall construction was symmetrical about a plane midway between the faces; therefore the results for these loads applied to one face of a specimen should be identical with those obtained by applying the loads to the other face.

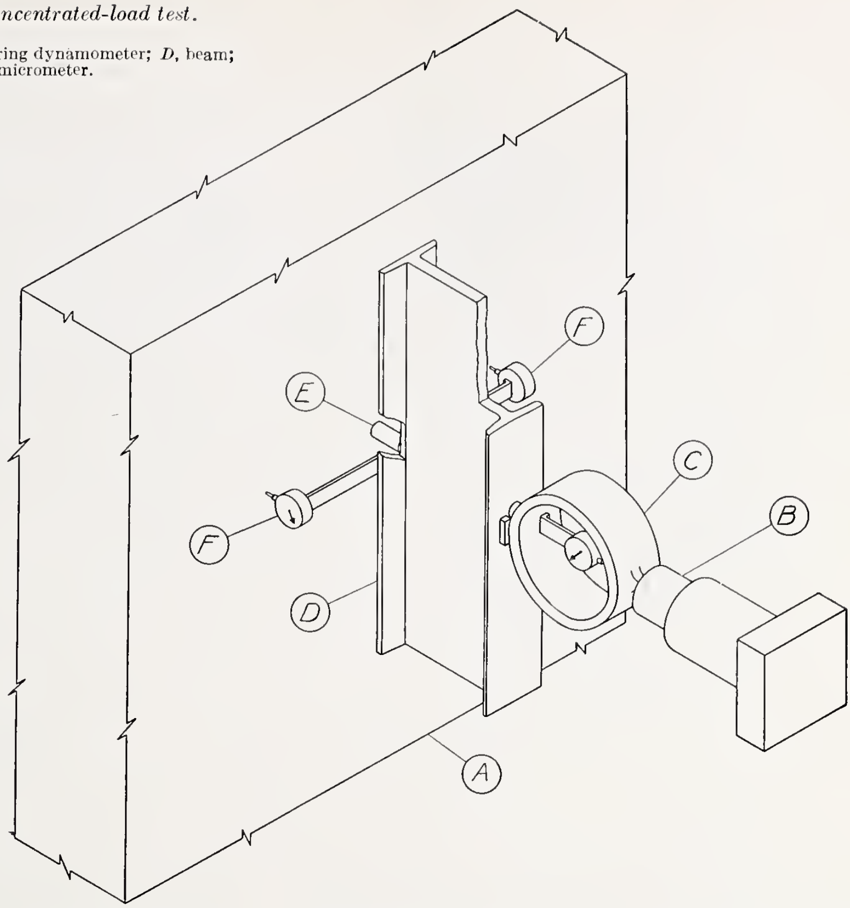
Under compressive load the shortenings and sets were measured with the compressometers attached to the steel plates through which the load was applied, not attached to the specimen as described in BMS2.

Lateral deflections under compressive and transverse loads were 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 to the specimen by clamping the hinged plate to the upper end of a face. The gage length was 7 ft. 6 in. A dial micrometer was fastened 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. Two deflectometers were attached to the specimen, one near each edge. This method of measurement was used instead of the taut-wire mirror-scale device 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 specimen, *A*, shown in figure 1, was in a vertical position, as for the transverse test. The load was applied by a jack, *B*, through a ring dynamometer (load-measuring device), *C*, to a freely movable steel beam, *D*, to which were attached a thick steel disk, *E*, and two dial micrometers, *F*. One end of the disk and the spindles of the micrometers were in contact with the face of the wall specimen. The distance between the micrometer spindles was 16 in. The dials were graduated to 0.001 in., and readings were recorded to the nearest tenth of a division. An initial load was applied to the disk to prevent shifting of the apparatus, and the average of the micrometer readings was taken as the initial reading. Greater loads were then applied to the disk, and the

FIGURE 1.—*Apparatus for concentrated-load test.*

A, wall specimen; *B*, hydraulic jack; *C*, ring dynamometer; *D*, beam; *E*, loading disk; *F*, dial micrometer.



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 similarly.

The deformations under racking load were measured with a right-angle deformeter, consisting of a steel channel and a steel angle braced to form a rigid connection. In use, the channel of the deformeter was supported by two steel plates, ½ in. thick and 4 in. square, on the top of the specimen, with the steel angle extending downward in the plane of the specimen. A dial micrometer was attached to the edge of the specimen at the stop. The spindle of the micrometer was in contact with the steel angle of the deformeter. The gage length (distance from the top of the specimen to the point of attachment of the micrometer) was 6 ft 11 in. The micrometer was graduated to 0.001 in., and readings were recorded to the nearest tenth of a division. This deformeter was used instead of the taut-wire mirror-scale device described in BMS2.

The tests were begun July 18, 1939, and completed July 26, 1939. The specimens were tested on the 28th day after they were built. The sponsor's representative witnessed the tests.

IV. WALL *CP*

1. SPONSOR'S STATEMENT

Unless otherwise mentioned, the information for this statement was obtained from the sponsor and from inspection of the specimens. The Masonry Construction Section of the National Bureau of Standards assisted the sponsor by determining some of the physical properties of the brick and mortar and by obtaining the fabrication data for the walls.

(*a*) *Materials*

"Munlock" brick.—End-cut shale units; average dimensions: length, 7.95 in.; width, 8.11 in.; face height, 2.30 in. (about 7$^{15}/_{16}$ by 8⅛ by 2$^{5}/_{16}$ in). There were five $^{15}/_{16}$-in. holes in each

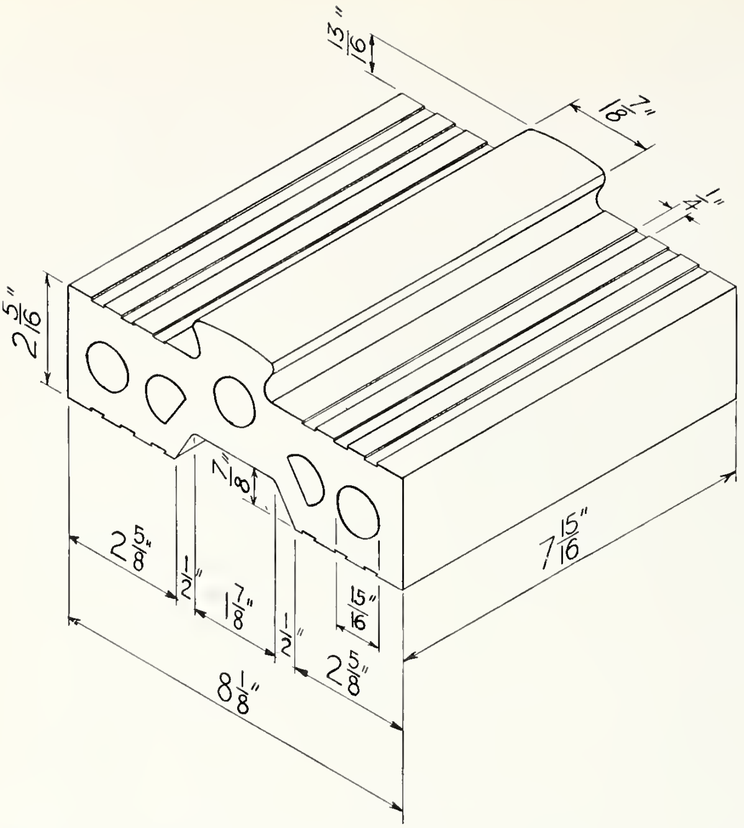


Figure 2.—*"Munlock Dry Wall Brick."* Standard unit.

brick, parallel to the length, as shown in figure 2. Along the top of each brick was a longitudinal ridge at midwidth, and a corresponding depression along the bottom.

The physical properties of the brick are given in table 2.

Table 2.—*Physical properties of "Munlock" brick, wall CP*

Compressive strength	Modulus of rupture	Water absorption, by weight					Weight, dry
		24-hr cold immersion, *C*	5-hr boiling immersion, *B*	Saturation coefficient, *C/B*	1-min partial immersion as laid [a]		
lb/in.^{2}	*lb/in.*^{2}	*Percent*	*Percent*		*g/cm*^{2}	*g/brick*	*lb/brick*
2,010	1,577	1.68	3.63	0.463	0.0243	6.55	9.62

[a] Immersed in ⅛ in. of water.

The brick were manufactured by the Colonial Brick Co., Winchester, Va.

Mortar.—The materials for the mortar were Potomac River building sand and Hy-Test Cement Co.'s "Hy-Test" masonry cement.

The mortar consisted of 1 part of cement to 3.43 parts of dry sand, by weight (1:3 by volume). The amount of water in the mix was adjusted to the satisfaction of the mason, and was 14.9 percent of the dry materials, by weight. The materials for each batch were measured by weight and mixed in a batch mixer having a capacity of ⅔ ft^3.

Samples of the mortar were taken from at least one batch for each wall, the flow before and after suction was determined in accordance with Federal Specification SS–C–181b, Cement; Masonry, and six 2-in. cubes were made. The average flow of the mortar was 87 percent and the ratio of the flow after suction to the initial flow was 53 percent. Three cubes were stored in water at 70° F and three stored in air near the wall specimens. The strength of the mortar is given in table 3.

The cement in the mortar complied with the requirements of Federal Specification SS–C–181b, Cement; Masonry, Type II, for fineness, soundness, compressive strength, water retention, and water repellency. The sieve analysis of the sand is given in table 4.

TABLE 3.—*Average compressive strength of mortar, wall CP*

[Determined on the day the corresponding wall specimen was tested]

Specimen	Compressive strength	
	Water storage	Air storage
	lb/in.^{2}	*lb/in.*^{2}
C1	1,120	510
C2	980	420
C3	1,140	630
T1	1,180	460
T2	1,180	600
T3	1,160	540
I1	1,050	480
I2	1,230	620
I3	1,110	570
R1	1,200	640
R2	1,225	560
R3	1,225	510
Weighted average	1,150	545

TABLE 4.—*Sieve analysis of the sand, wall CP*

U. S. Standard Sieve No.	Passing, by weight
	Percent
4	100.0
8	99.5
16	88.2
30	60.7
50	21.0
100	3.1

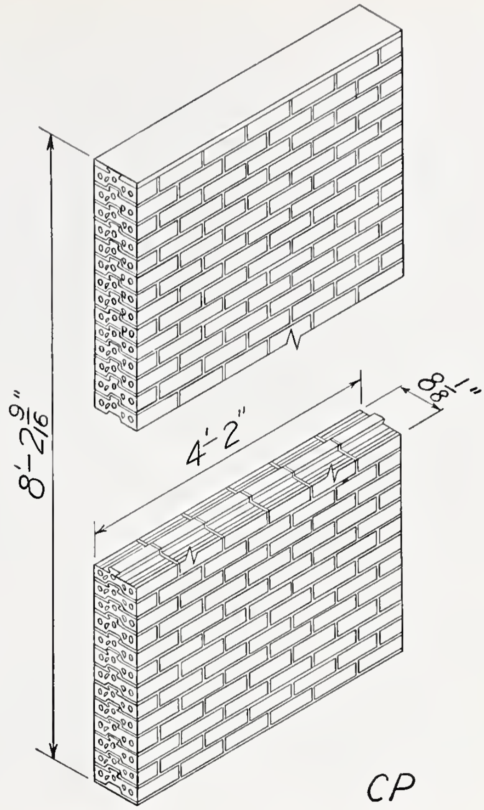


FIGURE 3.—*Four-foot wall specimen CP.*

(b) *Description of Specimens*

(1) *Four-foot wall specimens.*—The average dimensions of the specimens which are shown in figure 3 were: height, 8 ft 2 9/16 in.; width, 4 ft 2 in.; thickness, 8 1/8 in. There were 36 courses of brick in each 4-ft wall specimen, with 6 full-sized units or the equivalent in each course.

A typical wall specimen during construction is shown in figure 4. The specimens were built by an experienced mason. The brick were dry when received and were laid without preliminary wetting. The mortar for the bed joints was spread on both sides of the ridge of the brick, none being placed on the ridge. Head joints were formed by buttering one end of each unit, leaving 2 in. at midwidth without mortar. One face of the wall was plumbed and the mortar joints were cut flush with the faces of the brick. For testing purposes, each specimen was capped with mortar to make the upper surface smooth.

The price of this construction in Washington, D. C., as of July 1937, was \$0.38/ft^2.

(2) *Eight-foot wall specimens.*—The specimens were similar to the 4-ft specimens. The average dimensions were: height, 8 ft 2 9/16 in.; width, 8 ft. 3 11/16 in.; thickness, 8 1/8 in. There were 36 courses of brick in each 8-ft wall specimen, with 12 full-sized units or the equivalent in each course.

(c) *Fabrication Data*

Fabrication data are given in table 5.

TABLE 5.—*Fabrication data, wall CP*

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

Thickness of joints		Masonry units	Mortar materials		Mason's time
Bed	Head		Masonry cement	Sand, dry	
in.	*in.*	*No./ft*^{2}	*lb/ft*^{2}	*lb/ft*^{2}	*hr ft*^{2}
0.41	0.41	6.32	4.2	14.3	0.092

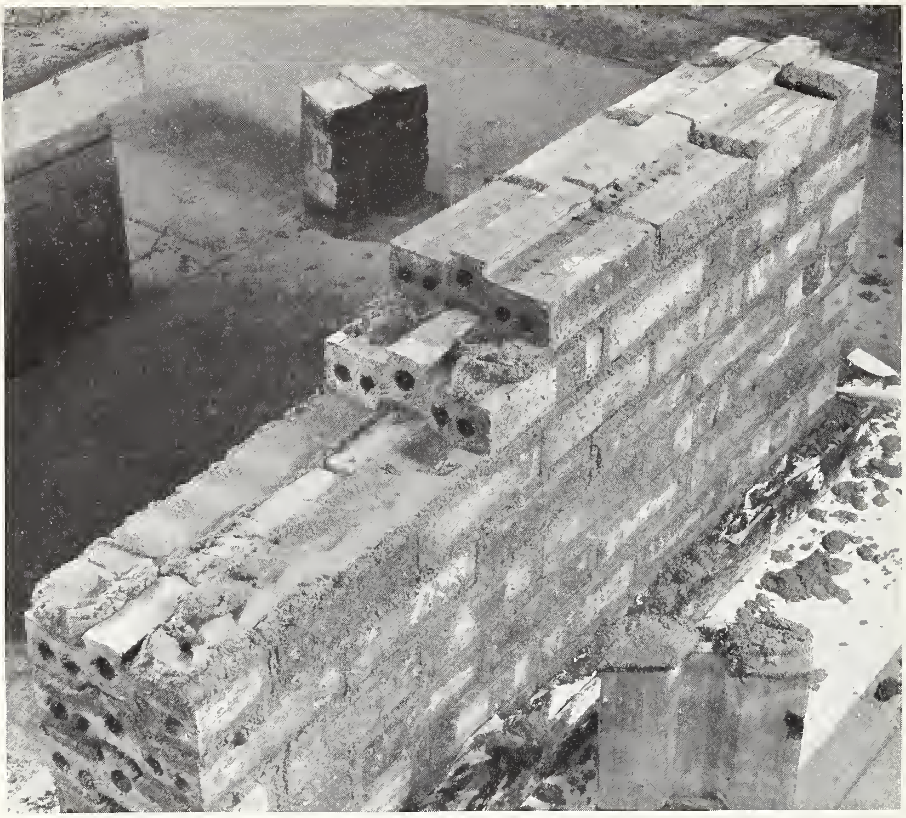


FIGURE 4.—*Typical four-foot wall specimen CP during construction.*

(*d*) *Comments*

Walls of this construction have been in use since 1935. At the present time there are five houses in Washington, D. C., with this type of wall, and other buildings have been erected in various parts of the country. Other materials, such as terra cotta and stone, may be combined in the construction.

This construction is designed to reduce labor cost, prevent passage of water through the wall, provide greater thermal insulation than conventional masonry, and by the use of self-alining units reduce the amount of mortar. The brick in the specimens described in this report are intended for 8-in. walls, and similar units are manufactured for 12-in. walls. The units may be split longitudinally through the ridge, and the split units used for veneer, facing of joists, topping of lintels, etc. Half-length units are supplied at half the price of the standard units and are used to give the appearance of headers and to provide an economical filler. At corners and around openings for doors and windows, some conventional bricks are necessary; and some of them must have one corner cut away to clear the ridge on the "Munlock" unit below. These bricks are supplied by the sponsor and are termed "closer" units.

Details of a typical house wall of this construction are shown in figure 5.

The foundation, *A*, may be conventional construction, such as brick, stone, or concrete-block masonry or poured concrete. The wall is "Munlock Dry Wall Brick" from foundation to roof plate. Full-sized brick, *B*, are used in the continuous portions of the wall. Split brick, *C*, are used at the ends of joists and around recesses for radiators, vertical pipes, and conduits, as at *D*. The spaces between joists are filled with tile, *E*. The angle lintel, *F*, supports a course of split units. The roof plate, *G*, is anchored by bolts, *H*, which pass through five courses of split brick.

Split "Munlock" brick may be used as veneer on wood frame. Details of a typical house of this construction are shown in figure 6. The foundation, *A*, may be conventional. The floor plate, *B*, the studs, *C*, and the wood sheathing, *D*, are assembled in the usual way. The split bricks, *E*, are then laid, and metal ties, *F*, are fastened to the sheathing and embedded in every fifth or sixth mortar bed joint. The space between the sheathing and the brick veneer should be about 1 in.

Any conventional inside finish may be applied. The wall shown in figure 5 may be faced on the inside and paint applied to the brick for inside finish. Plaster may be applied directly to the brick. If desired, nailing strips may be inserted in the bed joints of the wall during erection, furring then fastened to the nailing strips, and conventional lath and plaster applied. The veneer construction may have any conventional inside finish that can be applied to the wood frame.

2. Compressive Load

Wall specimen *CP–C1* under compressive load is shown in figures 7 and 8. The results for wall specimens *CP–C1*, *C2*, and *C3* are shown in table 6 and in figures 9 and 10.

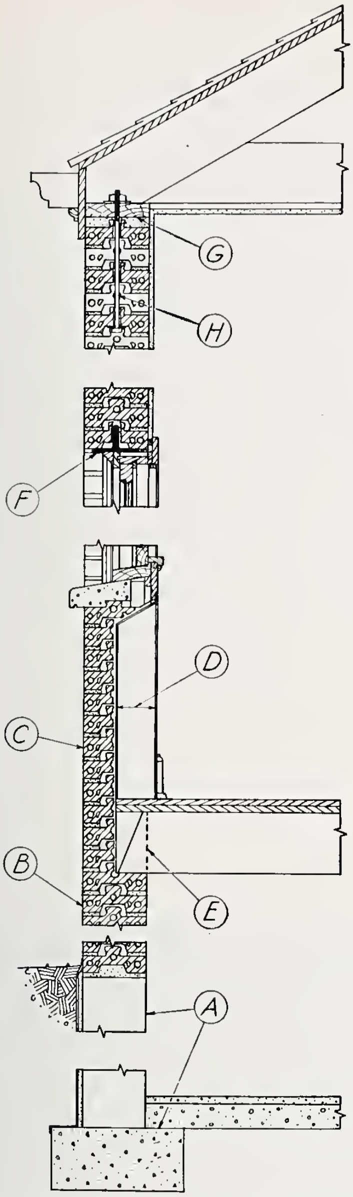


FIGURE 5.—*Details of a typical house wall of "Munlock Dry Wall Brick."*

A, foundation; *B*, full-sized brick; *C*, split brick; *D*, radiator recess; *E*, tile; *F*, lintel; *G*, roof plate; *H*, anchor bolt.

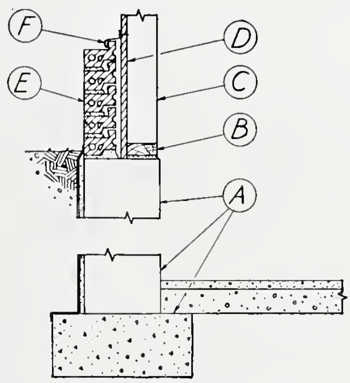


FIGURE 6.—*Details of a typical wood-frame wall with "Munlock" brick veneer.*

A, foundation; *B*, floor plate; *C*, stud; *D*, sheathing; *E*, split brick *F*, metal ties.

TABLE 6.—*Structural properties, wall CP*

[Weight, 76.7 lb/ft ²]

Compressive load		Transverse load [a]		Concentrated load		Impact load [a]		Racking load	
Specimen	Maximum load	Specimen	Maximum load	Specimen	Maximum load	Specimen	Maximum height of drop	Specimen	Maximum load
	[b] *Kips/ft*		*lb/ft* ²		*lb*		*ft*		[b] *Kips/ft*
C1	59.3	*T1*	75.0	*P1*	[c] 1,000	*I1*	5.0	*R1*	[c] 6.03
C2	59.8	*T2*	70.0	*P2*	[c] 1,000	*I2*	4.0	*R2*	[c] 6.00
C3	58.7	*T3*	89.6	*P3*	[c] 1,000	*I3*	5.0	*R3*	[c] 6.03
Average	59.3	Average	78.2	Average	[c] 1,000	Average	4.7	Average	[c] 6.02

[a] Span 7 ft 6 in. [b] A kip is 1,000 lb. [c] Test discontinued. Specimen did not fail.

Figure 7.—*Wall specimen CP–C1 under compressive load.*

A, compressometers; *B*, deflectometer.

The speed of the movable head of the testing machine was 0.072 in./min.

Under a load of 50 kips/ft, specimen *CP–C1* cracked vertically at one edge about 3 in. from the inside face, the crack extending from the mortar cap through the holes in the brick of three courses. Under the maximum load on each specimen, the upper three courses cracked vertically along the entire width of the specimen through the holes in the brick. On the inside face the units crushed, cracking horizontally, and the mortar spalled from the bed joints. On the outside face the mortar joint between the upper two courses ruptured in the bond between the mortar and the brick.

Figure 8.—*Applying compressive load to wall specimen CP–C1.*

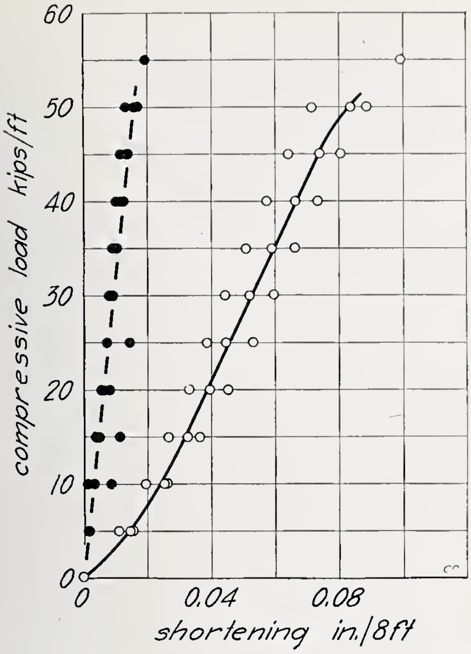


FIGURE 9.—*Compressive load on wall CP.*

Load-shortening (open circles) and load-set (solid circles) results for specimens *CP–C1, C2,* and *C3*. The load was applied 2.71 in. (one-third the thickness of the wall) from one face. The loads are in kips per foot of actual width of specimen.

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

Load-lateral deflection (open circles) and load-lateral set (solid circles) results for specimens *CP–C1,C2,* and *C3*. The load was applied 2.71 in. (one-third the thickness of the wall) 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.

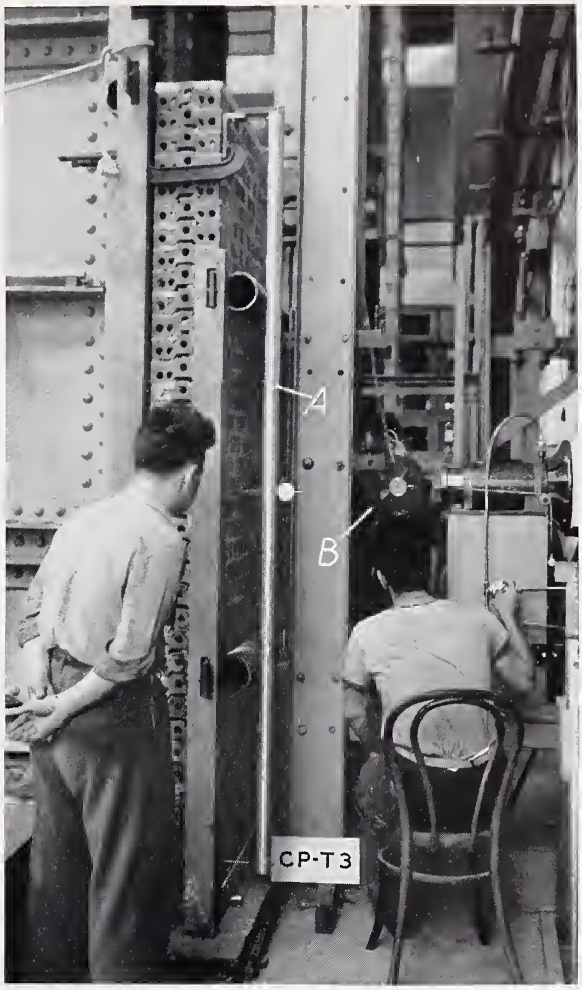


FIGURE 11.—*Wall specimen CP–T3 under transverse load.*

A, deflectometer; *B*, ring dynamometer.

3. TRANSVERSE LOAD

Wall specimen *CP–T3* under transverse load is shown in figure 11. The results for wall specimens *CP–T1, T2,* and *T3* are shown in table 6 and in figure 12.

Under the maximum load on each specimen, one mortar bed joint between the loading rollers ruptured in the bond between the brick and the mortar, the crack extending the entire width and thickness of the wall.

4. CONCENTRATED LOAD

The results of the concentrated load on wall specimens *CP–P1, P2,* and *P3* are shown in table 6 and in figure 13.

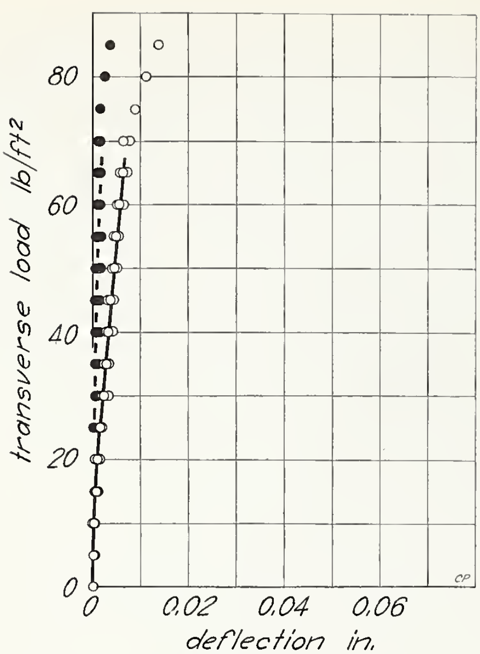


FIGURE 12.—*Transverse load on wall CP.*

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

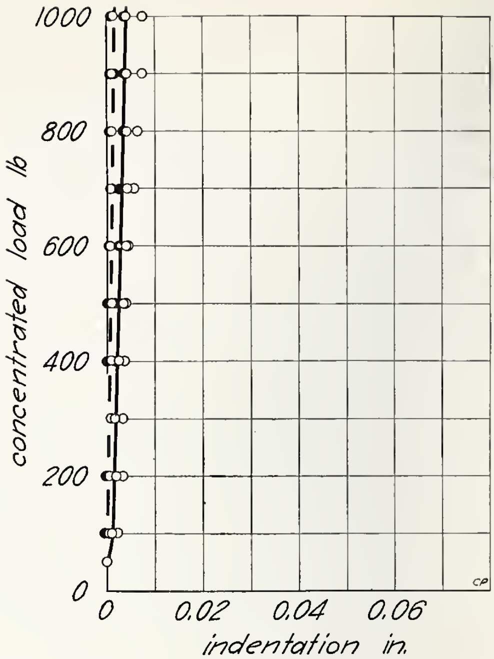


FIGURE 13.—*Concentrated load on wall CP.*

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

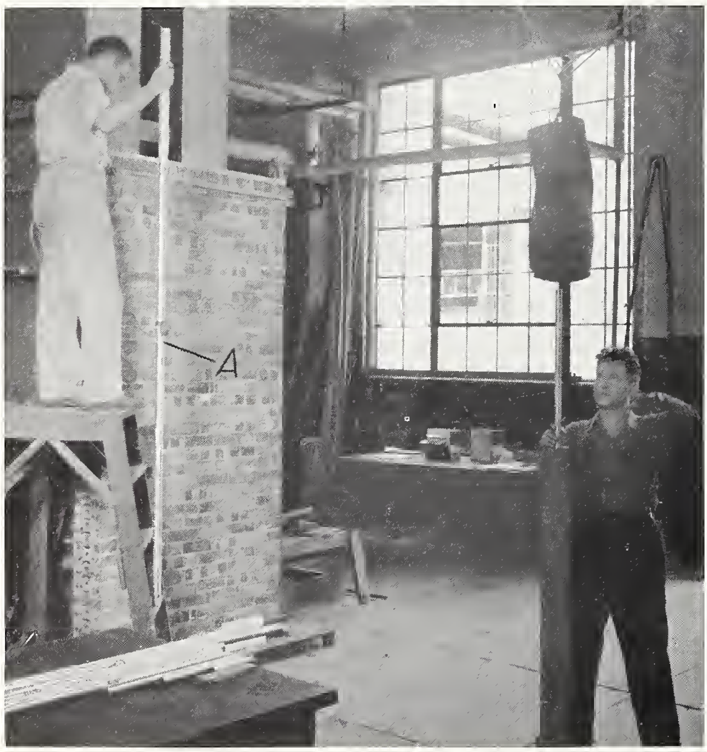


FIGURE 14.—*Wall specimen CP–I1 during the impact test.*

A, gage for measurement of set.

The load was applied to a brick near the center of the specimen. The sets after a load of 1,000 lb had been applied to specimens *CP–P1*, *P2*, and *P3* were 0.004, 0.001, and 0.001 in., respectively, and no other effects were observed.

5. Impact Load

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

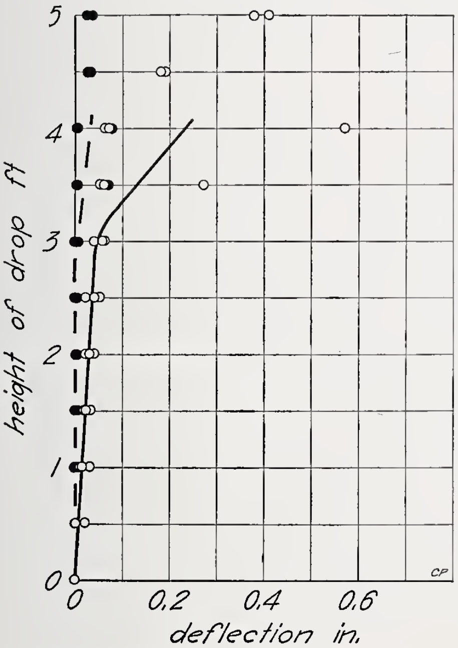


FIGURE 15.—*Impact load on wall CP.*

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

At a drop of 4.5 ft on specimen *CP–I1*, a mortar bed joint near midheight cracked in the bond between the brick and the mortar, beginning at the face not loaded and extending the entire width of the wall, but not through the entire thickness. Specimen *I2* cracked in the same way at a drop of 3.5 ft, and specimen *I3* at a drop of 4.5 ft. Under the maximum height of drop, the crack extended through the entire thickness of each wall specimen.

6. Racking Load

Wall specimen *CP–R3* under racking load is shown in figure 16. The results for wall specimens *CP–R1*, *R2*, and *R3* are given in table 6 and in figure 17.

FIGURE 16.—*Wall specimen CP–R3 under racking load.*

A, deformeter.

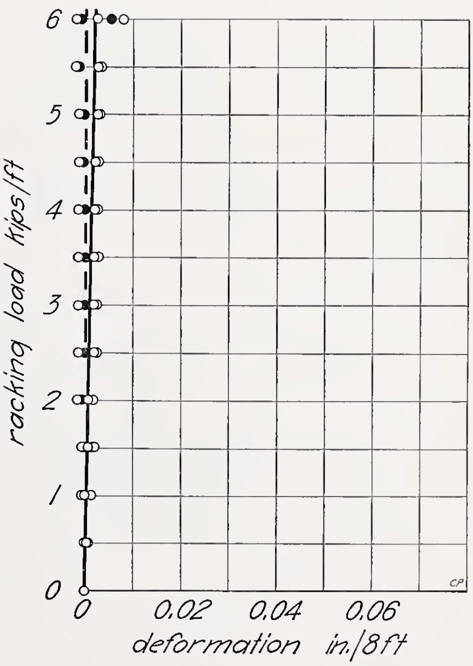


FIGURE 17.—*Racking load on wall CP.*

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

The racking load was applied to one edge of each specimen at midthickness 6 in. below the top. The sets after a racking load of 6.0 kips/ft (maximum load) had been applied were 0.000, 0.000 and 0.005 in. for specimens *R1*, *R2*, and *R3*, respectively. No other effect was observed.

The drawings of the specimens were prepared by E. J. Schell, G. W. Shaw, and T. J. Hanley, of the Bureau's Building Practice and Specifications Section, under the supervision of V. B. Phelan.

The structural properties were determined 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, A. B. Lanham, P. H. Petersen, A. J. Sussman, and L. R. Sweetman.

WASHINGTON, December 11, 1939.

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