U. S. DEPARTMENT OF COMMERCE

# BUILDING MATERIALS AND STRUCTURES

REPORT BMS48

## Structural Properties of "Precision-Built" Frame Wall and Partition Constructions Sponsored by the Homasote Co.


*by*

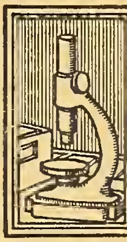
HERBERT L. WHITTEMORE

*and* AMBROSE H. STANG

*with the collaboration of*

GEORGE E. HECK

Forest Products Laboratory

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

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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 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, impact, concentrated, and racking loads by standardized methods simulating the loads to which the elements 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 constructions.

The Forest Products Laboratory, Forest Service, United States Department of Agriculture, collaborated in the tests of those constructions which had wood structural members.

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 "Precision-Built" Frame Wall and Partition Constructions Sponsored by the Homasote Co.

*by* HERBERT L. WHITTEMORE *and* AMBROSE H. STANG

*with the collaboration of*

GEORGE E. HECK, Forest Products Laboratory, Forest Service, United States Department of Agriculture

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### ABSTRACT

For the program on the determination of the structural properties of low-cost house constructions, the Homasote Co., Trenton, N. J., submitted 63 specimens, representing 2 wall and 1 partition constructions, consisting of wood frames with "Homasote" insulating fiberboard as inside face, as outside face, and as sheathing.

The specimens were subjected to compressive, transverse, concentrated, impact, and racking loads, for each of which three like specimens were tested. The transverse, concentrated, and impact loads were applied to both faces of the wall specimens. 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, Madison, Wis.

The present report describes the structural properties of constructions sponsored by one of the manufacturers in the building industry. Compressive, transverse, concentrated, impact, and racking loads were applied to the specimens, simulating loads, to which the elements of a house are subjected in actual service. Compressive loads on a wall or on a load-bearing partition are produced by the weight of the roof, second floor, and second-story walls, if any, and occupants and furniture, and by snow and wind loads on the roof. Transverse loads are produced by the wind, concentrated and impact loads by furniture or accidental contact with heavy objects, and racking loads by the action of the wind on adjoining walls.

The deformation and set under each increment of load were measured because, considered as a structure, the suitability of a wall or partition 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 Homasote Co., Trenton, N. J., and represented prefabricated wood-frame wall and load-bearing partition constructions with an insulating fiberboard, marketed under the trade name "Homasote," as inside face, as outside face, and as sheathing.

## III. SPECIMENS AND TESTS

The specimens represented two elements of a house and were assigned the following symbols: Wall, *CM*, "Homasote" fiberboard as both inside and outside face; wall, *CN*, "Homasote" fiberboard as inside face and "Homasote" fiberboard sheathing and wood bevel siding as outside face; load-bearing partition, *CO*, "Homasote" fiberboard as both faces. The individual specimens were assigned the designations given in table 1.

TABLE 1.—*Specimen designations*

| Element | Construction symbol | Specimen designation | Load | Load applied |
|---|---|---|---|---|
| Wall | *CM* | *C1, C2, C3* | Compressive | Upper end. |
| Do | *CM* | *T1, T2, T3* | Transverse | Inside face. |
| Do | *CM* | *T4, T5, T6* | do | Outside face. |
| Do | *CM* | *P1, P2, P3* [a] | Concentrated | Inside face. |
| Do | *CM* | *P4, P5, P6* [a] | do | Outside face. |
| Do | *CM* | *I1, I2, I3* | Impact | Inside face. |
| Do | *CM* | *I4, I5, I6* | do | Outside face. |
| Do | *CM* | *I4a, I5a, I6a* | do | Do. |
| Do | *CM* | *R1, R2, R3* | Racking | Top plate. |
| Do | *CM* | *R1a, R2a, R3a* | do | Do. |
| Do | *CN* | *C1, C2, C3* | Compressive | Upper end. |
| Do | *CN* | *T1, T2, T3* | Transverse | Inside face. |
| Do | *CN* | *T4, T5, T6* | do | Outside face. |
| Do | *CN* | *P1, P2, P3* [a] | Concentrated | Inside face. |
| Do | *CN* | *P4, P5, P6* [a] | do | Outside face. |
| Do | *CN* | *I1, I2, I3* | Impact | Inside face. |
| Do | *CN* | *I4, I5, I6* | do | Outside face. |
| Do | *CN* | *R1, R2, R3* | Racking | Top plate. |
| Do | *CN* | *R1a, R2a, R3a* | do | Do. |
| Partition | *CO* | *C1, C2, C3* | Compressive | Upper end. |
| Do | *CO* | *T1, T2, T3* | Transverse | Either face. |
| Do | *CO* | *P1, P2, P3* [a] | Concentrated | Do. |
| Do | *CO* | *I1, I2, I3* | Impact | Do. |
| Do | *CO* | *I1a, I2a, I3a* | do | Do. |
| Do | *CO* | *R1, R2, R3* | Racking | Top plate. |
| Do | *CO* | *R1a, R2a, R3a* | do | Do. |

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

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

Only three load-bearing partition specimens were tested under the transverse, concentrated, and impact loads, not six specimens, as stated in BMS2. Inasmuch as the load-bearing partition construction was symmetrical about a plane midway between the faces, the results for these loads applied to one face of the specimens should be identical with those obtained by applying the loads to the other face.

For the compressive load the thickness of the wall specimens was taken as the thickness of the structural portion, that is, the distance from the inside surface of the studs to the outside surface of the studs. The compressive load was applied

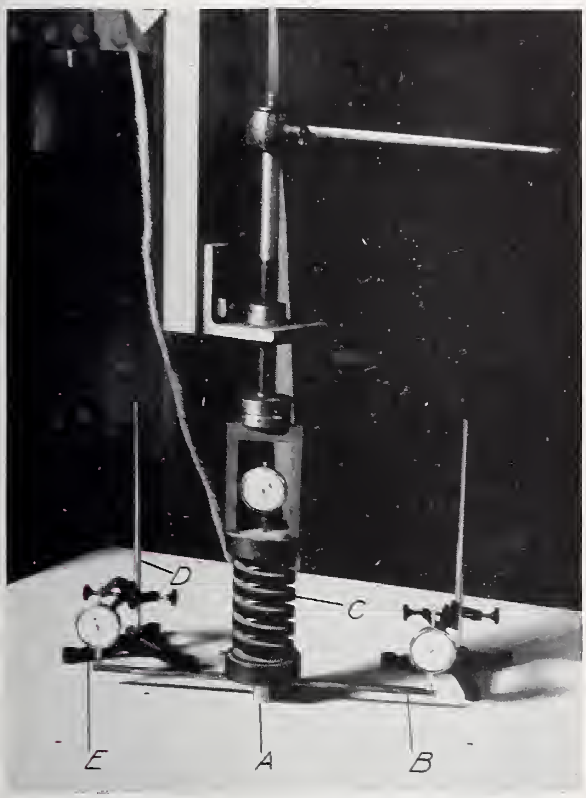


FIGURE 1.—*Apparatus for concentrated load test.*

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

along a line parallel to the inside face, and at a distance from the inside surface of the studs of one-third the thickness of the wall. Also, the thickness of the load-bearing partition specimens was taken as the distance from one surface of the studs to the other surface, and the load was applied one-third this thickness from one surface of the studs.

Wood-frame constructions under compressive load show considerable local shortening caused by crushing of the floor plate and top plate at the ends of the studs. As a result, the shortening of the entire specimen is not proportional to the value obtained from compressometers attached to the specimen over only a portion of the height. Therefore, the shortenings and sets were measured with compressometers attached to the steel plates through which the load was applied, not attached to the specimen as 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, and was measured by means of the dynamometer, *C*. Two stands, *D*, rested on the face of the specimen, each supporting 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 readings were recorded to the nearest division. The initail 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 average of the micrometer readings minus the initial reading was taken as the depth of the indentation under load.

The deformations under racking loads 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, supported by two steel plates ½ in. thick, 4 in. square, 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 and into the top of the specimen. A dial micrometer was attached to a steel block which was in contact with the floor plate 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 center of the steel block) was 7 ft 11¼ in. The micrometer was graduated to 0.001 in., and readings were recorded to the nearest division. This deformeter replaced the taut-wire mirror-scale device described in BMS2.

George E. Heck, of the Forest Products Laboratory, Madison, Wis., cooperated with the Bureau staff in this work by giving advice and making suggestions on the technique of testing wood structures.

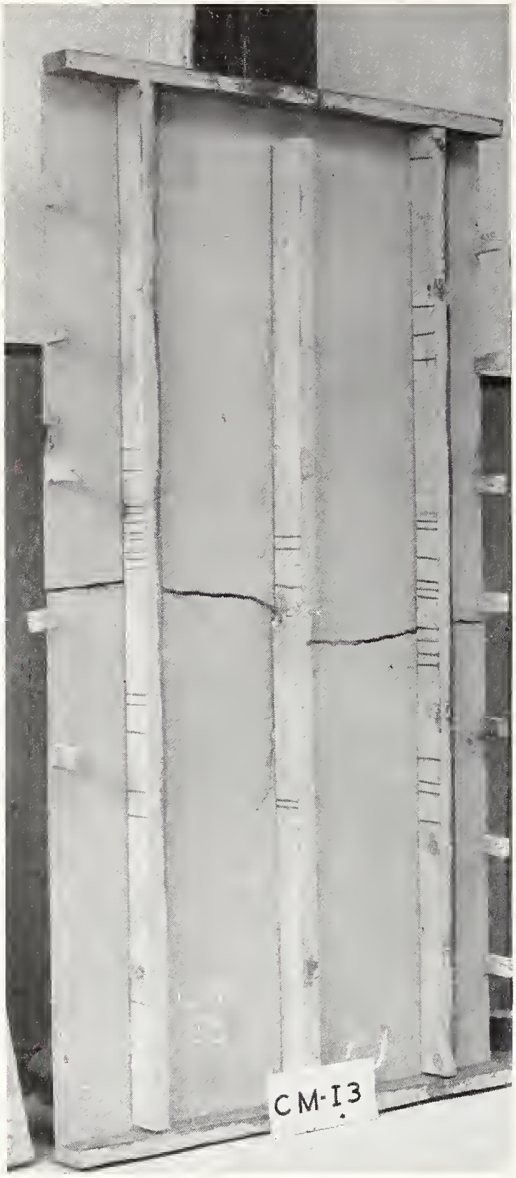


Figure 2.—*Wall CM.*
Typical specimen.

The tests were begun May 1, 1939, and completed May 9, 1939. The sponsor's representative witnessed the tests.

## IV. MATERIALS

Unless otherwise stated, the information on materials was obtained from the sponsor and from inspection of the specimens. The Forest Products Laboratory assisted by identifying the species of the wood in the framing. The Paper Section of the National Bureau of Standards assisted by determining physical properties of the fiberboard in the specimens, and the Engineering Mechanics Section assisted by determining the moisture content of the wood and fiberboard and the tensile strength of the fiberboard.

### 1. Wood

*Framing.*—The wood for the framing was identified as Douglas fir, *Pseudotsuga taxifolia.*

No. 1 common, S4S (surfaced four sides). Sizes, $^{25}/_{32}$ by $3\frac{5}{8}$ in. (nominal 1 by 4 in.) and $1\frac{5}{8}$ by $3\frac{5}{8}$ in. (nominal 2 by 4 in.).

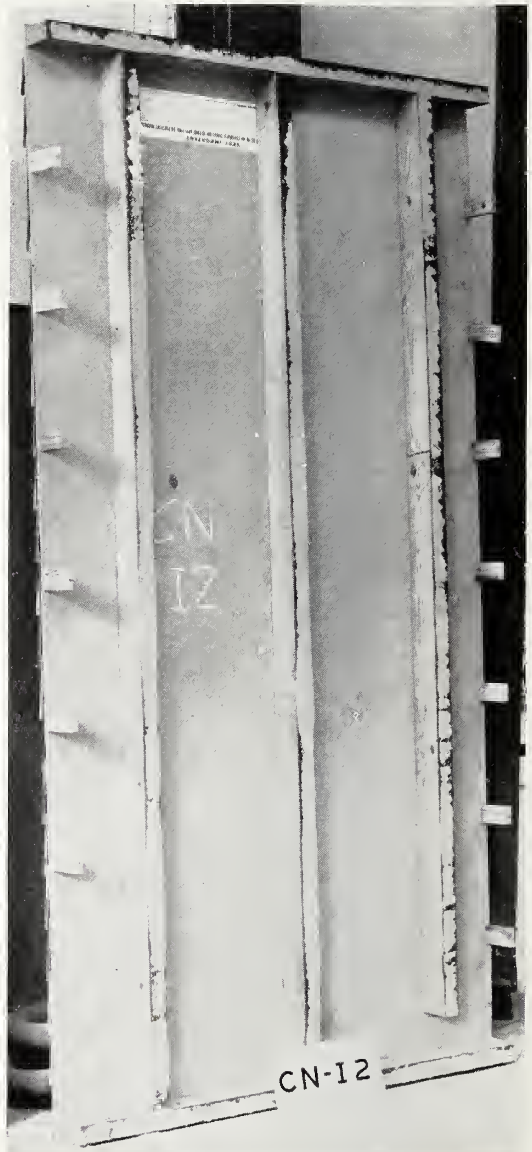


Figure 3.—*Wall CN.*
Typical specimen.

*Bevel siding.*—Red cedar, 7/16 by 3/16 by 5½ in., select, grade B or better.

*Spacers.*—Southern pine, No. 2 common, 25/32 by 1⅝ in. (nominal 1 by 2 in), S2S.

After each specimen was tested, one face was removed to expose the framing and a sample of the studs was taken for identification of the species. Photographs were made of each specimen showing the failures and the character of the wood in the framing. Figures 2 to 6 are typical specimens.


FIGURE 4.—*Wall CN.*

Typical specimen.

Two extremes in quality of framing are shown. The center stud is about the lowest and the two outer studs are the highest grade.


FIGURE 5.—*Wall CN.*

Typical specimen.

The moisture content of the framing and of the bevel siding is given in table 2.

An electric moisture meter was used for determining the moisture content. To calibrate the meter for Douglas fir, 63 samples from the frames were dried in an oven at 212° F until the weight was constant. The moisture content was the difference between the initial weight and the weight when ovendry, expressed as a percentage of the weight when ovendry. The average value was 0.4 less than the average value of the meter readings on the same samples.

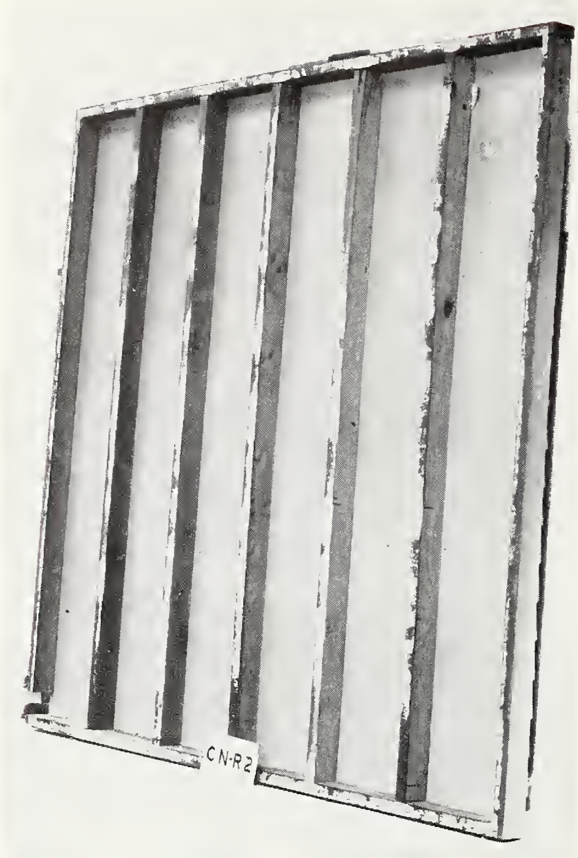

FIGURE 6.—*Wall CN.*

Typical specimen.

Therefore the average moisture content of the Douglas fir was obtained by subtracting 0.4 from the average of the meter readings and rounding the result to the nearest whole number.

TABLE 2.—*Moisture content of the wood*

[Determined on the day the wall or partition specimen was tested]

| Wood | Moisture content [a] | | |
|---|---|---|---|
| | Minimum | Maximum | Average |
| Framing, Douglas-fir | *Percent* | *Percent* | *Percent* |
| *CM* | 8 | 14 | 11 |
| *CN* | 10 | 19 | 12 |
| *CO* | 8 | 14 | 11 |
| Bevel siding, red cedar | | | |
| *CN* | 7 | 10 | 8 |

[a] Based on the weight when ovendry.

The moisture content of the frame of each specimen was determined on each stud and plate.

For the bevel siding the meter reading was taken as the moisture content and was determined on six pieces of siding from each specimen.

## 2. "Homasote" Insulating Fiberboard

Fiberboard, $^{15}\!/_{32}$ in. thick, made from vegetable fibers derived largely from waste paper. The fibers are sized with rosin and waxes for water resistance and then felted into a board.

The physical properties are given in table 3.

TABLE 3.—*Physical properties of the fiberboard*

| Property | Value |
|---|---|
| Density, lb/ft³ | 25.3 |
| Linear expansion accompanying a 45-percent change in relative humidity, percent | 0.2 |
| Nail-holding strength (lateral): | |
| Lengthwise of board, lb | 138 |
| Crosswise of board, lb | 136 |
| Tensile strength: | |
| Lengthwise of board, lb/in.² | 566 |
| Crosswise of board, lb/in.² | 606 |
| Thermal conductivity, (Btu/hr ft²)/(°F/in.) | [a] 0.45 |
| Transverse strength: | |
| Across long direction, lb | 38.6 |
| Across short direction, lb | 35.4 |
| Transverse deflection at ultimate load: | |
| Across long direction, in. | 0.85 |
| Across short direction, in. | .84 |
| Water absorption, by volume, percent | 4.2 |

[a] Value given by the sponsor.

The physical properties were determined on undamaged samples of the board taken from two wall specimens after testing. The linear expansion, tensile strength, transverse strength and deflection, and the water absorption were determined in accordance with Federal Specification LLL–F–321a, Fiberboard; Insulating, and the board complied with the requirements for these properties. The thermal conductivity failed to comply with the requirement for this class of board, for which the maximum value is 0.36 (Btu/hr ft²)/(°F/in).

The lateral nail-holding strength was measured according to the method described in BMS4, Accelerated Aging of Building Boards, except that the nail (common, 6d, 2 in. long, No. 11½ steel wire, 0.113-in. diam) was ½ in., not ¾ in., from the edge of the board. A distance of ½ in. was used because this was approximately the distance in the wall and partition specimens.

The moisture content of the fiberboard, given in table 4, was determined on one sample from each wall or partition specimen by drying at 212° F until the weight was constant.

Table 4.—*Moisture content of "Homasote" fiberboard*

[Determined on the day the wall or partition specimen was tested]

| Construction symbol | Moisture content [a] | | |
|---|---|---|---|
| | Minimum | Maximum | Average |
| | *Percent* | *Percent* | *Percent* |
| *CM* | 6 | 9 | 7 |
| *CN* | 6 | 9 | 7 |
| *CO* | 7 | 8 | 7 |

[a] Based on the weight when oven-dry.

### 3. Nails

The nails were made from steel wire and are described in table 5.

Table 5.—*Description of nails*

| Type | Size | Length | Steel wire gage | Diameter of wire, uncoated | Finish |
|---|---|---|---|---|---|
| | *Penny* | *in.* | *No.* | *in.* | |
| Box | 5 | 1⅝ | 15 | 0.072 | Cement-coated. |
| Casing | 6 | 2 | 12½ | .0985 | Bright. |
| Common | 10 | 3 | 9 | .1483 | Do. |
| Do | 16 | 3½ | 8 | .162 | Do. |
| Siding | 7 | 2¼ | 12½ | .0985 | Zinc-coated. |

### 4. Glue

Casein glue, grade A, ground. One part of glue was mixed with two parts of water, by volume. Casein Co. of America, "Casco."

## V. WALL *CM*

### 1. Sponsor's Statement

Wall *CM* was a conventional wood frame with "Homasote" fiberboard as both faces, the outside face being fastened by nails and the inside face by glue. The specimens were not painted.

The price of this construction in Washington, D. C., as of July 1937, was \$0.207/ft.[2]

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

The 4-ft wall specimens, shown in figure 7, were 8 ft 0 in. high, 4 ft 0 in. wide, and 4⁹⁄₁₆ in. thick. Each was a wood frame to which the faces were fastened. The frame consisted of three studs, *A*, fastened to a floor plate, *B*, and a top plate, *C*. Both the outside face, *D*, and the inside face, *E*, consisted of a single sheet of fiberboard. The overhanging edges of the faces were supported by spacers, *F*.

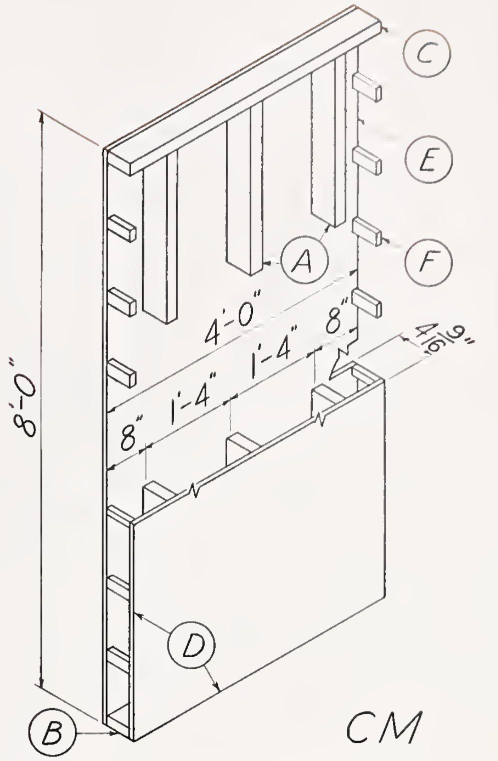


Figure 7.—*Four-foot wall specimen CM*

*A*, studs; *B*, floor plate; *C*, top plate; *D*, outside face (nailed); *E*, inside face (glued); *F*, spacer.

*Studs.*—The studs, *A*, were Douglas fir, 1⅝ by 3⅝ in., 7 ft 8¾ in. long, spaced 1 ft 4 in. on centers. Each stud was fastened to the floor plate and to the top plate by two 16d common nails passing through the plates into the stud (not toenailed).

*Floor plate and top plate.*—Both floor plate, *B*, and top plate, *C*, were Douglas fir, 1⅝ by 3⅝ in., 4 ft 0 in. long.

*Outside face.*—The outside face, *D*, consisted of one sheet of fiberboard, 4 ft 0 in. by 8 ft 0 in., fastened to the floor plate and the top plate, by 5d box nails ½ in. from the edge of the board spaced 6 in., and to the studs by 5d box nails, spaced 10 in. The nails in adjacent studs were staggered.

*Inside face.*—The inside face, *E*, was a single sheet of fiberboard, 4 ft 0 in. by 8 ft 0 in., fastened to the floor plate, the top plate, and the studs by glue, and to the floor plate and the top plate by 6d casing nails ½ in. from the edge of the board, spaced 6 in. The glue was liberally applied to the frame and to the fiberboard with a 3-in. paint brush. Wood strips, 1 by 2 in.,



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were then fastened over the fiberboard to each stud by five 6d casing nails. The strips were removed shortly before the specimen was tested.

*Spacers.*—The spacers, *F*, along the overhanging edges of the faces were southern pine, $\frac{25}{32}$ by $1\frac{5}{8}$ in., $3\frac{5}{8}$ in. long, spaced 1 ft 0 in. on centers. Each spacer was fastened to the outside face by two 5d box nails and to the inside face by one 6d casing nail, passing through the fiberboard into the spacer. Spacers are not used in a house.

In these specimens there was a stud at midwidth. Therefore during the impact test on specimens *CM–I1* to *I6*, inclusive, the sandbag struck the fiberboard over the center stud. To determine the impact properties of this construction if loaded on the fiberboard between studs, three additional 4-ft wall specimens, *CM–I4a*, *I5a*, and *I6a*, were submitted.

These specimens, shown in figure 8, were similar to the other 4-ft specimens, except that there were two full-sized studs, *A*, and two half-sized studs, *G*, and no spacers. The inside face and the outside face were fastened to the plates and full-sized studs in the same way as in the specimens shown in figure 7. The outside face was fastened to the half-sized studs by 5d box nails spaced 6 in., and the inside face was fastened by glue and by 6d casing nails spaced 6 in.

*Half-sized studs.*—The half-sized studs, *G*, were Douglas fir, $\frac{25}{32}$ by $3\frac{5}{8}$ in., 7 ft $8\frac{3}{4}$ in. long. Each half-sized stud was fastened to the floor plate and the top plate by two 10d common nails passing through each plate into the half-sized stud (not toenailed).

### (*b*) *Eight-Foot Wall Specimens*

The 8-ft wall specimens, shown in figure 9, were 8 ft 0 in. high, 8 ft 0 in. face width, and $4\frac{9}{16}$ in. thick. The specimens were similar to the

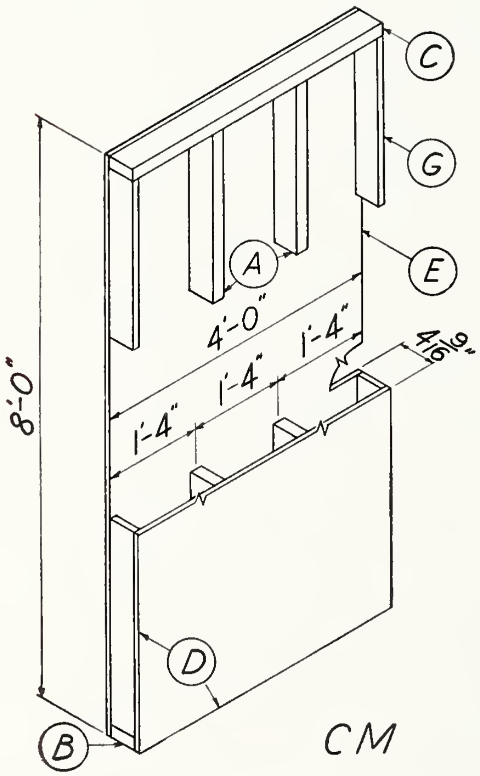


FIGURE 8.—*Four-foot wall specimen CM, with half-sized studs.*

*A*, full-sized studs; *B*, floor plate; *C*, top plate; *D*, outside face; *E*, inside face; *G*, half-sized stud.

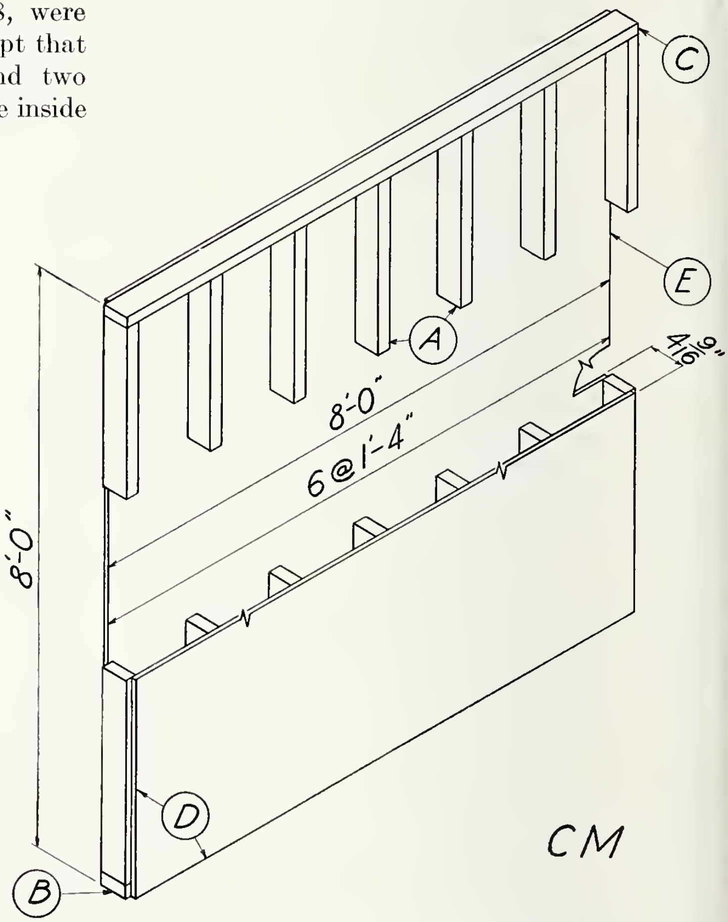


FIGURE 9.—*Eight-foot wall specimen CM*

*A*, full-sized studs; *B*, floor plate; *C*, top plate; D, outside face; *E*, inside face.

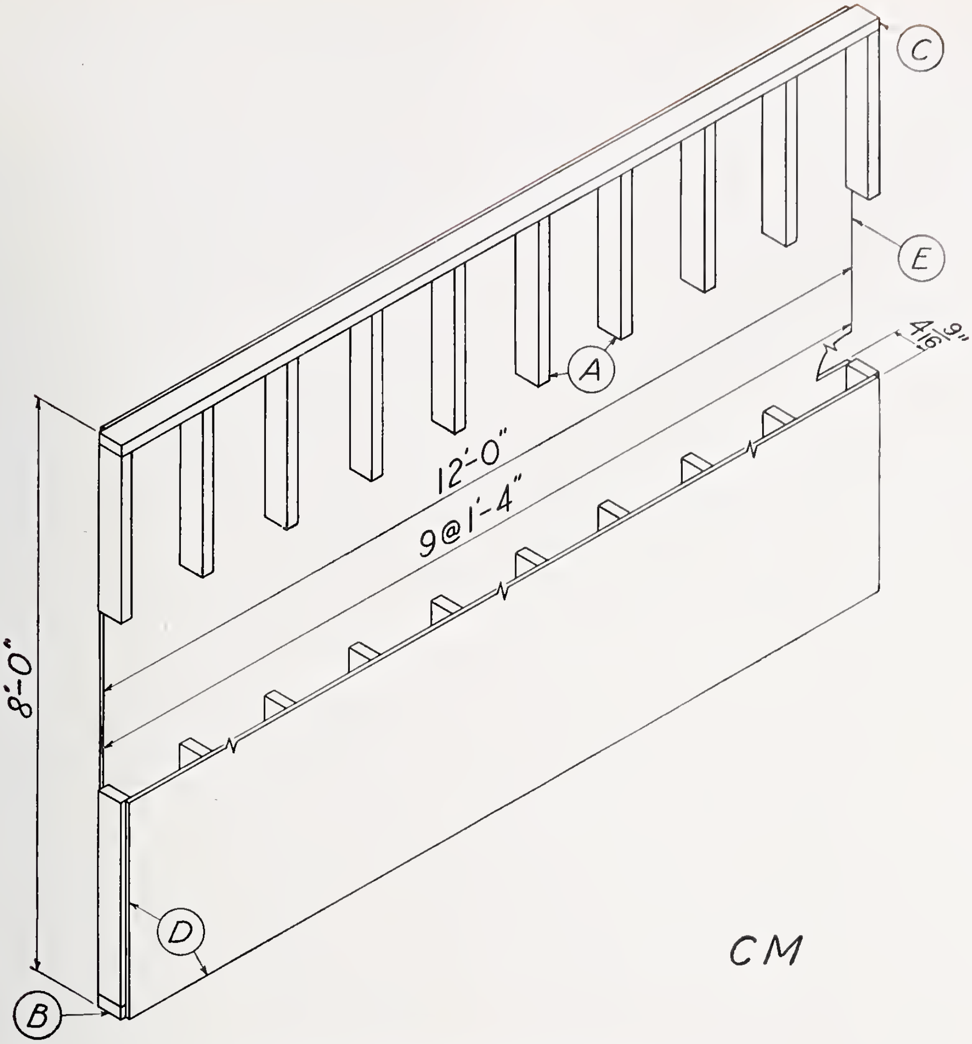


FIGURE 10.—*Twelve-foot wall specimen CM.*

*A*, full-sized studs; *B*, floor plate; *C*, top plate; *D*, outside face; *E*, inside face.

4-ft specimens except that there were seven studs, spaced 1 ft 4 in. on centers, and no spacers. There was a stud at each edge extending one-half its thickness beyond the faces. The width overall was 8 ft 1⅝ in.

*Outside face.*—The outside face consisted of one sheet of fiberboard, 8 ft 0 in. square, fastened to the floor plate, the top plate, and the edge studs by 5d box nails ½ in. from the edge of the board, spaced 6 in. It was fastened to the other studs by 5d box nails spaced 10 in.

*Inside face.*—The inside face consisted of one sheet of fiberboard, 8 ft 0 in. square, fastened to the top plate, the floor plate, and the studs by glue; and to both plates and the edge studs by 6d casing nails ½ in. from the edge of the board, spaced 6 in.

### (c) *Twelve-Foot Wall Specimens*

To determine the relation between racking properties and width of specimen three additional racking specimens, *CM–R1a*, *R2a*, and *R3a*, were submitted. These specimens, shown in figure 10, were 8 ft 0 in. high, 12 ft 0 in. face width, and 4$\frac{9}{16}$ in. thick and were similar to the 4-ft specimens, except that there were ten studs, spaced 1 ft 4 in. on centers, and no spacers. A stud at each edge extended one-half its thickness beyond the faces. The width overall was 12 ft 1⅝ in.

*Outside face.*—The outside face consisted of one sheet of fiberboard, 12 ft 0 in. by 8 ft 0 in., fastened to the plates and to the edge studs by 5d box nails ½ in. from the edge of the board, spaced 6 in. and to the other studs by 5d box nails spaced 10 in.

*Inside face.*—The inside face consisted of one sheet of fiberboard, 12 ft 0 in. by 8 ft 0 in., fastened to the top plate, the floor plate, and the studs by glue and, in addition, to both plates and the edge studs by 6d casing nails ½ in. from the edge of the board, spaced 6 in.

### (*d*) *Comments*

The outside surface of a house of this construction usually is finished with outside house paint. To give a resemblance to stucco, sand is mixed with the paint for the final coat, and this mixture is applied by stippling with a round brush.

## 2. Compressive Load

The compressive-load test results for wall specimens *CM–C1*, *C2*, and *C3* are given in table 6 and in figures 11 and 12.

The speed of the movable head of the testing machine under no load was adjusted to 0.072 in./min.

The lateral deflections shown in figure 12 were plotted to the right of the vertical axis for deflections of the specimen toward the outside face (positive deflection) and to the left of the axis for deflection, toward the inside face (negative deflection).

Table 6.—*Structural properties of walls CM and CN and load-bearing partition CO*

[Weight: Wall *CM*, 3.60 lb/ft²· wall *CN*, 4.38 lb/ft²; load-bearing partition *CO*, 3.62 lb/ft²]

| Construction symbol | Load | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Compressive [a] | | Transverse [b] | | Concentrated | | Impact [b] | | Racking | |
| | 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] *Kip/ft* |
| *CM* | *C1* | 6.45 | *T1* | 171 | *P1* | 225 | *I1* | 6.5 | *R1* | 0.56 |
| | *C2* | 8.25 | *T2* | 242 | *P2* | 234 | *I2* | 8.0 | *R2* | .57 |
| | *C3* | 3.81 | *T3* | 257 | *P3* | 250 | *I3* | 5.0 | *R3* | .58 |
| Average | | 6.17 | | 223 | | 236 | | 6.5 | | 0.57 |
| *CM* | | | *T4* | 387 | *P4* | 274 | *I4* | 6.5 | *R1a* | 0.55 |
| | | | *T5* | 433 | *P5* | 270 | *I5* | 9.5 | *R2a* | .60 |
| | | | *T6* | 260 | *P6* | 250 | *I6* | [d] 10.0 | *R3a* | .53 |
| Average | | | | 360 | | 265 | | | | 0.56 |
| *CM* | | | | | | | *I4a* | 3.0 | | |
| | | | | | | | *I5a* | 3.5 | | |
| | | | | | | | *I6a* | 3.5 | | |
| Average | | | | | | | | 3.3 | | |
| *CN* | *C1* | 4.92 | *T1* | 427 | *P1* | 225 | *I1* | [d] 10.0 | *R1* | 0.80 |
| | *C2* | 5.45 | *T2* | 440 | *P2* | 243 | *I2* | [d] 10.0 | *R2* | .79 |
| | *C3* | 5.00 | *T3* | 368 | *P3* | 242 | *I3* | [e] 10.0 | *R3* | .79 |
| Average | | 5.12 | | 412 | | 237 | | | | 0.79 |
| *CN* | | | *T4* | 393 | *P4* | 427 | *I4* | [d] 10.0 | *R1a* | 0.78 |
| | | | *T5* | 240 | *P5* | 415 | *I5* | [d] 10.0 | *R2a* | .74 |
| | | | *T6* | 370 | *P6* | 423 | *I6* | [d] 10.0 | *R3a* | .74 |
| Average | | | | 334 | | 422 | | [d] 10.0 | | 0.75 |
| *CO* | *C1* | 6.00 | *T1* | 275 | *P1* | 275 | *I1* | 8.0 | *R1* | 0.79 |
| | *C2* | 7.24 | *T2* | 280 | *P2* | 300 | *I2* | 9.5 | *R2* | .87 |
| | *C3* | 5.50 | *T3* | 318 | *P3* | 243 | *I3* | 6.5 | *R3* | .92 |
| Average | | 6.25 | | 291 | | 273 | | 8.0 | | 0.86 |
| *CO* | | | | | | | *I1a* | 3.0 | *R1a* | 0.64 |
| | | | | | | | *I2a* | 3.0 | *R2a* | .65 |
| | | | | | | | *I3a* | 3.5 | *R3a* | .54 |
| Average | | | | | | | | 3.2 | | 0.61 |

[a] The compressive loads were applied 1.21 in. (one-third the thickness of the frame) from the inside surface of the studs.
[b] Span 7 ft 6 in.
[c] A kip is 1,000 lb.
[d] Test discontinued. No studs ruptured.
[e] Test discontinued. One or more studs ruptured.

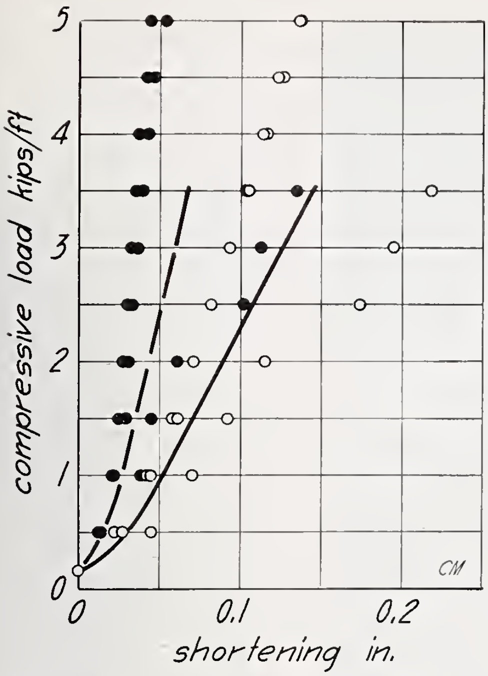


Figure 11.—*Compressive load on wall CM.*

Load-shortening (open circles) and load-set (solid circles) results for specimens *CM–C1, C2,* and *C3.* The load was applied 1.21 in. (one-third the thickness of the frame) from the inside surface of the studs. The loads are in kips per foot of actual width of specimen.

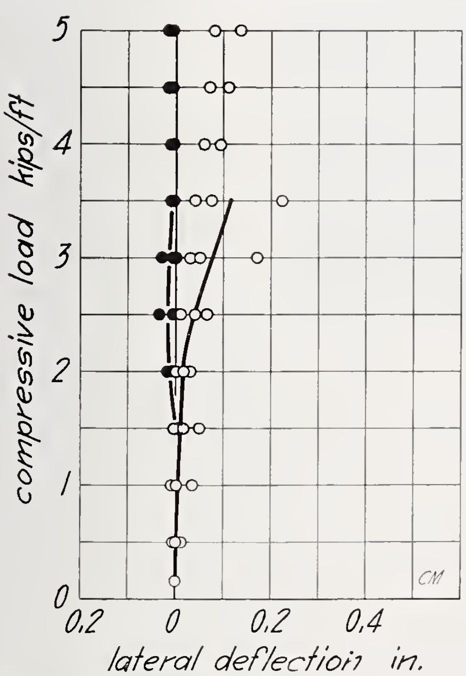


Figure 12.—*Compressive load on wall CM.*

Load-lateral deflection (open circles) and load-lateral set (solid circles) results for specimens *CM–C1, C2,* and *C3.* The load was applied 1.21 in. (one-third the thickness of the frame) from the inside surface of the studs. The loads are in kips per foot of actual width of specimen. The deflections and sets are for a gage length of 7 ft 10 in., the gage length of the deflectometers.

Under the maximum load the top plate on each of the specimens crushed locally at the inside edges of the studs, but none of the studs ruptured. The fiberboard on the inside face above midheight separated from the studs and from the top plate under a load of 2 kips/ft on specimen *C3* and under the maximum load on specimens *C1* and *C2*.

### 3. Transverse Load

Wall specimen *CM–T1* under transverse load is shown in figure 13. The results are presented in table 6 and in figure 14 for wall specimens *CM–T1, T2,* and *T3,* loaded on the inside (glued) face, and in figure 15 for wall specimens *CM–T4, T5,* and *T6,* loaded on the outside (nailed) face.

The speed of the movable head of the testing machine under no load was adjusted to 0.14 in./min.

Under a load of 100 lb/ft$^2$ one outer stud of specimen *T1* partially ruptured at a knot near midspan. In specimen *T2* under a load of 200 lb/ft$^2$ one outer stud partially ruptured at a knot under a loading roller.

Under the maximum loads on specimens *T1* and *T2* the fiberboard on the outside (unloaded) face was ruptured transversely by the force exerted by the partially ruptured stud; and this stud and the center stud ruptured completely.

One outer stud in specimen *T3* ruptured near midspan at 150 lb/ft$^2$, and at 240 lb/ft$^2$ the fiberboard on the outside face was torn by the force exerted by the ruptured stud. Under the maximum load the center stud ruptured.

In specimen *T4* the fiberboard on the inside (unloaded) face separated from the studs under a load of 220 lb/ft$^2$; the same effect occurred in specimen *T5* under a load of 300 lb/ft$^2$, and in specimen *T6* under a load of 180 lb/ft$^2$. Under loads of 220, 430, and 200 lb/ft$^2$ on these specimens, respectively, one outer stud split along the grain near midspan. Under the maximum loads the split outer stud of each specimen ruptured, followed by rupture of the center stud. The fiberboard on the inside (unloaded) face of specimen *T4* was ruptured transversely by the force exerted by the ruptured studs, but the inside faces of specimens *T5* and *T6* were undamaged.

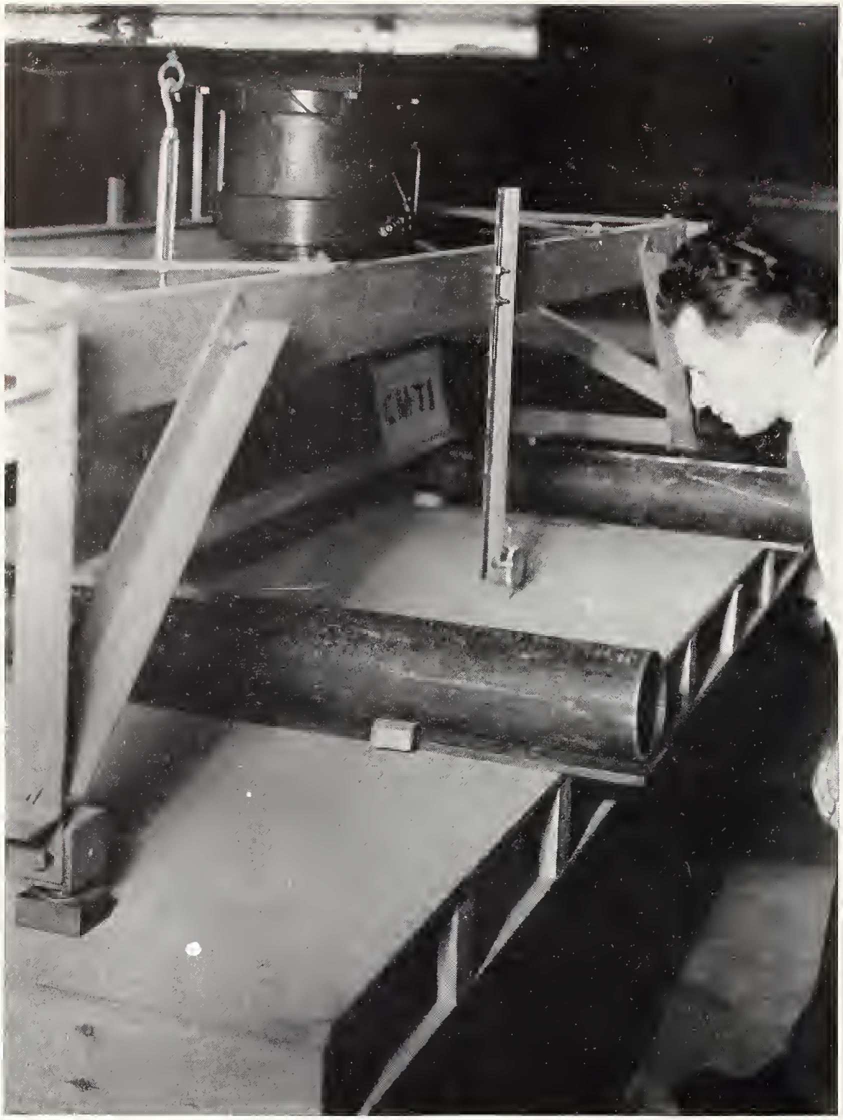


Figure 13.—*Wall specimen CM–T1 under transverse load.*

### 4. Concentrated Load

The results of the concentrated-load tests are shown in table 6 and in figure 16 for wall specimens *CM–P1*, *P2*, and *P3*, loaded on the inside face, and in figure 17 for wall specimens *CM–P4*, *P5*, and *P6*, loaded on the outside face.

The concentrated load was applied to the fiberboard midway between two studs and 8 in. from one end of the specimen. Under the maximum load on each specimen the disk punched through the fiberboard.

### 5. Impact Load

Wall specimen *CM–I4a*, during the impact test, is shown in figure 18. The results are given in table 6 and in figure 19 for wall specimens *CM–I1*, *I2*, and *I3*, loaded on the inside face, in figure 20 for wall specimens *CM–I4*, *I5*, and *I6*, loaded on the outside face, and in figure 21 for wall specimens *CM–I4a*, *I5a*, and *I6a*, loaded on the outside face.

The impact loads were applied to the center of the inside (glued) face of specimens *I1*, *I2*, and *I3*, the sandbag striking the fiberboard directly over the center stud. The effects appear in table 7.

The impact loads were applied to the center of the outside (nailed) face of specimens *I4*, *I5*, and *I6*, the sandbag striking the fiberboard directly over the center stud. The effects are given in table 8.

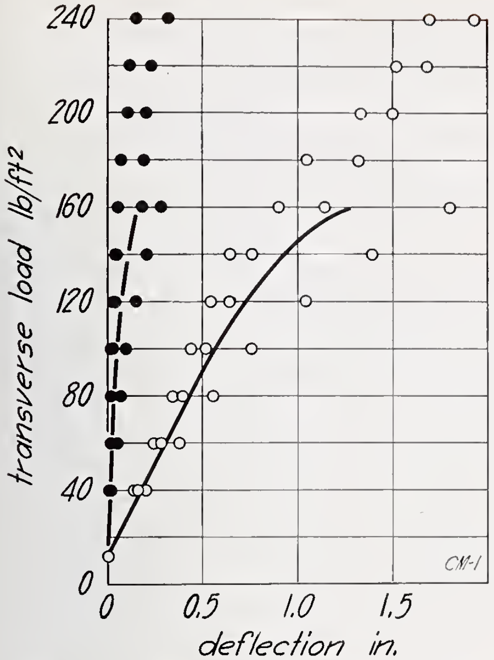


FIGURE 14.—*Transverse load on wall CM, load applied to inside face.*

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

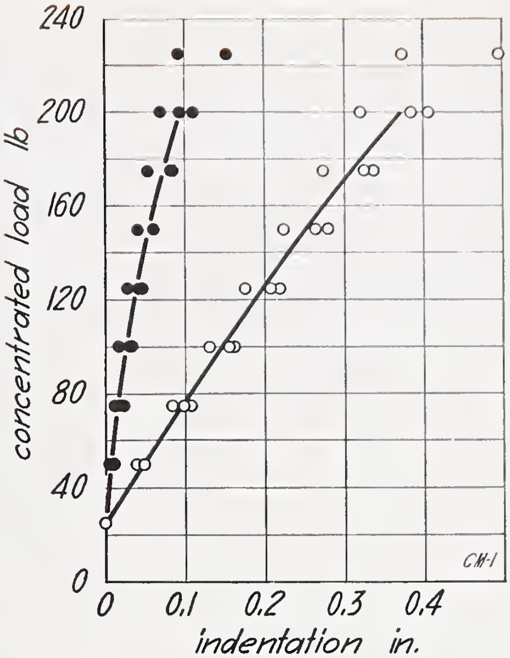


FIGURE 16.—*Concentrated load on wall CM, load applied to inside face.*

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

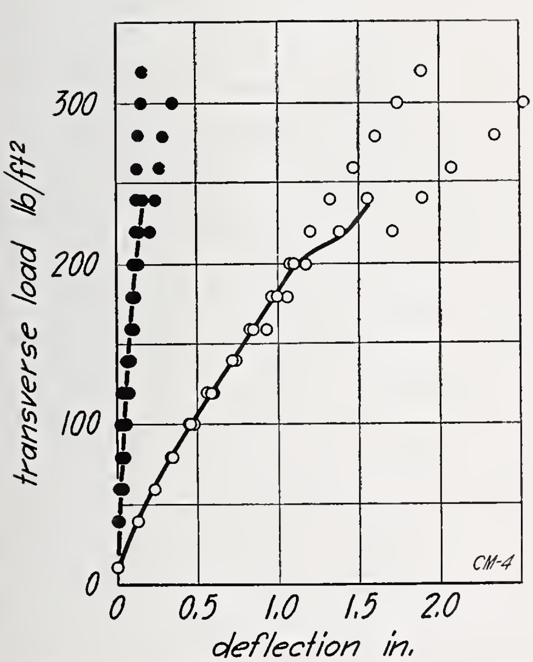


FIGURE 15.—*Transverse load on wall CM, load applied to outside face.*

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

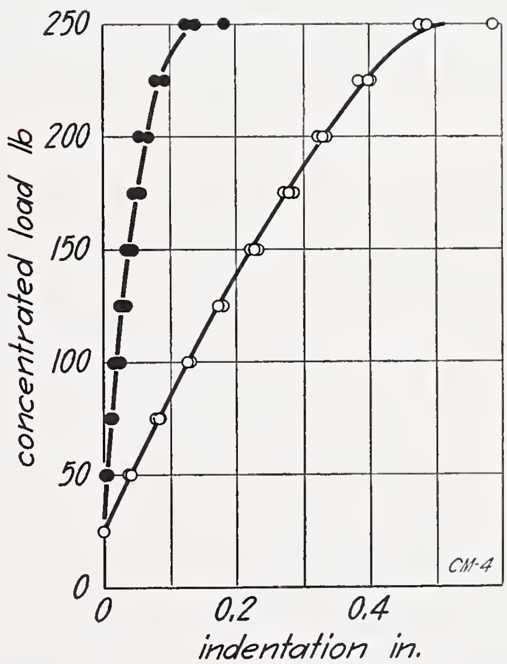


FIGURE 17.—*Concentrated load on wall CM, load applied to outside face.*

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

FIGURE 18.—*Wall specimen CM–I4a during the impact test.*

TABLE 7.—*Effects of impact load on wall CM, loaded on the inside face*

[The sandbag struck the specimens directly over the center stud]

| Description of effects | Specimen I1 | | Specimen I2 | | Specimen I3 | |
|---|---|---|---|---|---|---|
| | Height of drop | Deflection | Height of drop | Deflection | Height of drop | Deflection |
| Face loaded (glued): | | | | | | |
| Fiberboard separated from studs | *ft* 5.0 | *in.* 2.21 | *ft* 1.5 | *in.* 1.20 | *ft* 3.0 | *in.* 2.40 |
| Fiberboard ruptured where struck by the sandbag | 5.5 | 3.92 | 6.0 | 2.41 | 4.0 | 3.36 |
| Face not loaded (nailed): | | | | | | |
| Fiberboard separated from studs. Most of the nails pulled from the studs, but some heads pulled through the fiberboard | 3.5 | 1.78 | 3.0 | 1.65 | 3.0 | 2.40 |
| Fiberboard ruptured near midspan | 5.5 | 3.92 | 7.0 | 3.70 | 4.0 | 3.36 |
| Center stud ruptured | 6.0 | ------ | 7.5 | ------ | 4.5 | ------ |
| Sandbag passed through specimen; outer studs not ruptured. Maximum height of drop | 6.5 | ------ | 8.0 | ------ | 5.0 | ------ |

TABLE 8.—*Effects of impact load on wall CM, loaded on the outside face*

[The sandbag struck the specimens directly over the center stud]

| Description of effects | Specimen I4 | | Specimen I5 | | Specimen I6 | |
|---|---|---|---|---|---|---|
| | Height of drop | Deflection | Height of drop | Deflection | Height of drop | Deflection |
| Face loaded (nailed): | | | | | | |
| Fiberboard began to separate from studs. Nails pulled from the studs | *ft* 2.5 | *in.* 1.63 | *ft* 3.0 | *in.* 1.53 | *ft* 3.5 | *in.* 1.66 |
| Fiberboard ruptured where sandbag struck | 6.0 | 3.93 | 8.5 | 3.71 | 7.0 | 2.39 |
| Face not loaded (glued): | | | | | | |
| Fiberboard began to separate from studs | 1.5 | 1.17 | 2.5 | 1.39 | 2.0 | 1.21 |
| Fiberboard ruptured transversely | 6.5 | ------ | ------ | ------ | ------ | ------ |
| Fiberboard separated 3 in. from studs | ------ | ------ | 9.0 | ------ | ------ | ------ |
| Center stud: | | | | | | |
| Partially ruptured | 6.0 | 3.93 | 8.0 | 3.13 | 9.0 | 2.97 |
| Completely ruptured; outer studs not ruptured. Maximum height of drop | 6.5 | ------ | 9.5 | ------ | ([a]) | ------ |

[a] Test discontinued after 10-ft drop. Set 0.125 in. Center stud not ruptured. Fiberboard on inside face separated 2¼ in. from studs.

The impact loads were applied to the center of the outside (nailed) face of specimens *CM–I4a*, *I5a*, and *I6a*, the sandbag striking the fiberboard between the full-sized studs.

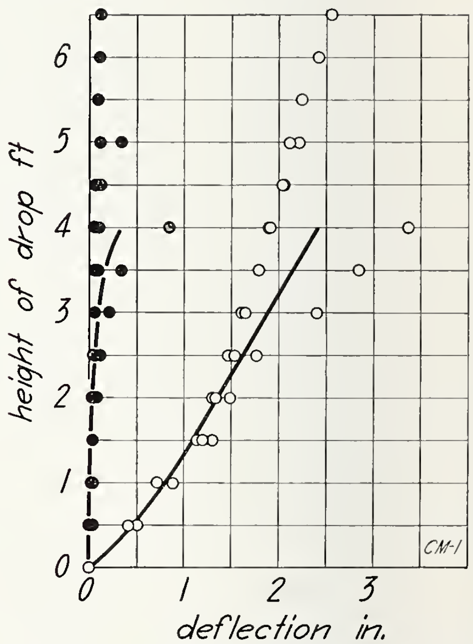


FIGURE 19.—*Impact load on wall CM, load applied to inside face.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *CM–I1*, *I2*, and *I3*. The sandbag struck the center of the specimen directly over a stud.

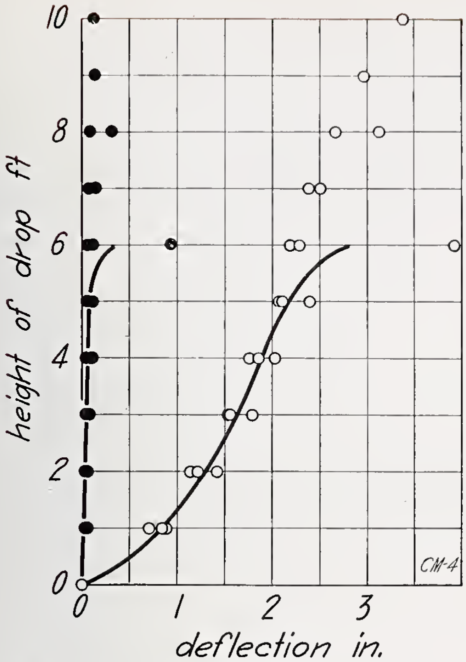


FIGURE 20.—*Impact load on wall CM, load applied to outside face.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *CM-I4, I5*, and *I6*. The sandbag struck the center of the specimen directly over a stud.

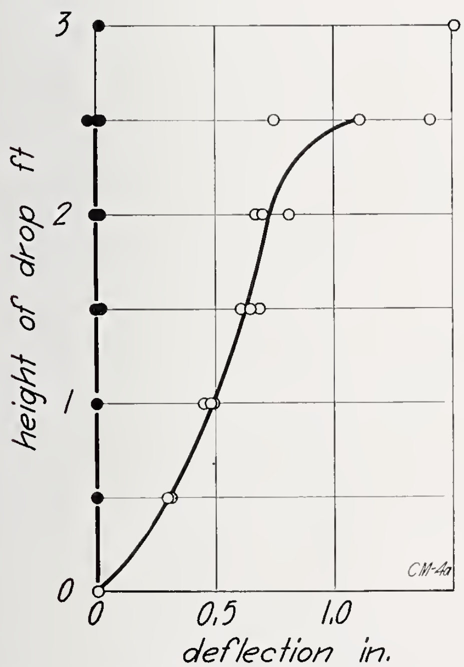


FIGURE 21.—*Impact load on wall specimens CM–I4a, I5a, and I6a.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results, load applied to outside face. The sandbag struck the center of the specimen midway between studs.

To prevent misleading results due to local effects on the loaded face of this type of specimen, the deflections and sets were measured with two deflectometers and two set gages, not one, as described in BMS2. The deflectometers were placed in contact with the unloaded face of the specimen at midheight, one at each inner stud, and the set gages rested on the loaded face, one over each of these studs.

The effects of the impact load are given in table 9.

TABLE 9.—*Effects of impact load on wall CM, loaded on the outside face*

[The sandbag struck the specimens midway between studs]

| Description of effects | Specimen *I4a* | | Specimen *I5a* | | Specimen *I6a* | |
|---|---|---|---|---|---|---|
| | Height of drop | Deflection | Height of drop | Deflection | Height of drop | Deflection |
| | *ft* | *in.* | *ft* | *in.* | *ft* | *in.* |
| Face loaded: Fiberboard ruptured where sandbag struck | 2.0 | 0.81 | 2.5 | 0.75 | 2.0 | 0.67 |
| Face not loaded: | | | | | | |
| Fiberboard began to separate from studs | | | 3.0 | 1.51 | 2.5 | 1.11 |
| Fiberboard ruptured transversely at midspan | 3.0 | 7.11 | | | 3.5 | |
| Fiberboard separated more than 6 in. from studs. No studs ruptured. Maximum height of drop | 3.0 | 7.11 | 3.5 | | 3.5 | |

## 6. RACKING LOAD

The results of the racking tests are shown in table 6 and in figure 22 for the 8-ft wall specimens *CM–R1, R2*, and *R3*, and in figure 23 for the 12-ft wall specimens *CM–R1a, R2a*, and *R3a*.

The racking loads were applied only to the top plate, and the stop was in contact only with the floor plate at the diagonally opposite corner of the specimen. The loads were applied by means of a hand-driven pump, and therefore the speed of loading could not be closely controlled.

Under the maximum loads the fiberboard on the inside face of each specimen separated from the glued surface of the frame, and the frame was displaced relative to the inside face. The nails passing through the inside face into the top plate and into the stud at the unloaded edge tore through the edges of the fiberboard. The nails passing through the outside face into the

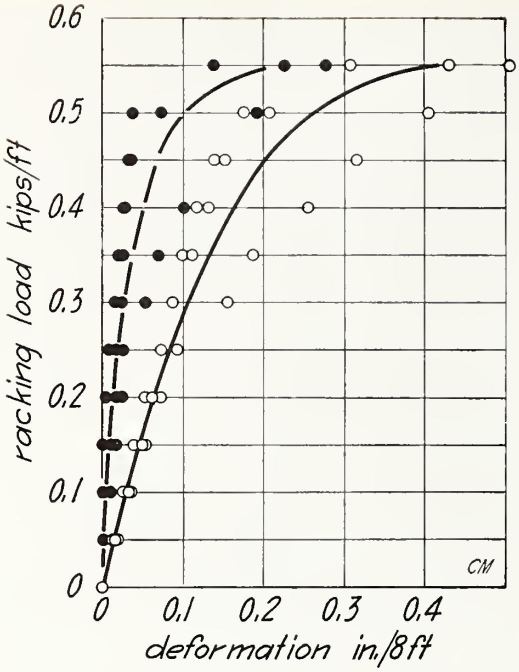


FIGURE 22.—*Racking load on wall CM.*

Load-deformation (open circles) and load-set (solid circles) results for specimens *CM-R1*, *R2*, and *R3*. The loads are in kips per foot of face width of specimen (8 ft 0 in).

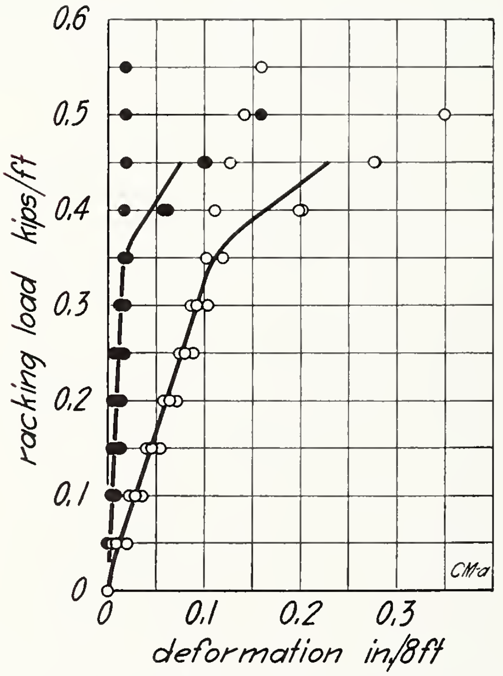


FIGURE 23.—*Racking load on wall specimens CM–R1a, R2a, and R3a.*

Load-deformation (open circles) and load-set (solid circles) results. The loads are in kips per foot of face width of specimen (12 ft 0 in).

top plate and into the unloaded edge stud bent or tore through the edges of the fiberboard.

The racking strength (kips/ft) is independent of the width of the specimen. The difference in average racking strength of the 8-ft specimens and the 12-ft specimens was not greater than the differences between individual specimens of the same width.

## VI. WALL *CN*

### 1. SPONSOR'S STATEMENT

Wall *CN* was a conventional wood frame with "Homasote" fiberboard as the inside face and as sheathing. It was similar to wall *CM*, except that there was bevel siding on the outside face. The specimens were not painted.

The price of this construction in Washington, D. C., as of July 1937, was $0.295/ft$^2$.

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

The 4-foot wall specimens, shown in figure 24, were 8 ft. 0 in. high, 4 ft. 0 in. wide, and 5⁵⁄₁₆ in. thick. Each specimen consisted of

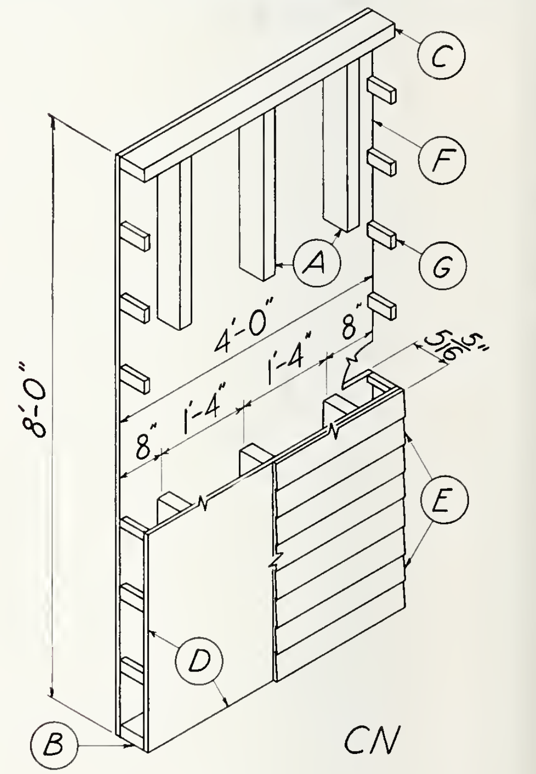


FIGURE 24.—*Four-foot wall specimen CN.*

*A*, studs; *B*, floor plate; *C*, top plate; *D*, sheathing; *E*, bevel siding; *F*, inside face; *G*, spacer.

a wood frame to which the faces were fastened. The frame consisted of three studs, *A*, fastened to a floor plate, *B*, and a top plate, *C*. The outside face was a single sheet of fiberboard, *D*, as sheathing, covered by bevel siding, *E*. The inside face, *F*, consisted of one sheet of fiberboard. The overhanging edges of the faces were supported by spacers, *G*.

*Studs.*—The studs, *A*, were Douglas fir, 1⅝ by 3⅝ in., 7ft. 8¾ in. long, spaced 1 ft. 4 in. on centers. Each stud was fastened to floor plate and to the top plate by two 16d common nails passing through each plate into the stud (not toenailed).

*Floor plate and top plate.*—Both floor plate, *B*, and top plate, *C*, were Douglas fir, 1⅝ by 3⅝ in., 4 ft. 0 in. long.

*Sheathing.*—The sheathing, *D*, was one sheet of fiberboard, 4 ft. 0 in. by 8 ft. 0 in., fastened to the floor plate and the top plate by 5d box nails ½ in. from the edge of the board, spaced 6 in. It was fastened to the studs by 5d box nails spaced 10 in.

*Bevel siding.*—The bevel siding, *E*, was red cedar, 7/16 by 3/16 by 5½ in., and in two lengths, 4 ft. 0 in. and 2 ft. 0 in. There were 21 courses, and every second course had a vertical joint over the center stud. The siding was laid 4½ in. to the weather, and each piece was fastened through the overlapping edges by 7d siding nails, one at each stud.

*Inside face.*—The inside, *F*, consisted of one sheet of fiberboard, 4 ft 0 in. by 8 ft 0 in., fastened to the floor plate, the top plate, and the studs by glue, and to the floor plate and the top plate by 6d casing nails ½ in. from the edge of the board, spaced 6 in. The glue was liberally applied to the framing and to the fiberboard with a 3-in. paint brush. Wood strips 1 by 2 in., were then fastened over the fiberboard to each stud by five 6d casing nails. The strips were removed shortly before the specimen was tested.

*Spacers.*—The spacers, *G*, along the overhanging edges of the faces, were southern pine, 25/32 by 1⅝ in., 3⅝ in. long, spaced 1 ft 0 in. on centers. Each spacer was fastened to the sheathing by two 5d box nails and to the inside face by one 6d casing nail, passing through the fiberboard into the spacer. Spacers are not used in a house.

### (*b*) *Eight-Foot Wall Specimens*

The 8-ft wall specimens, shown in figure 25, were 8 ft 0 in. high, 8 ft 0 in. face width, and 5 5/16 in. thick, and were similar to the 4-ft specimens, except that there were seven studs, spaced 1 ft 4 in. on centers, and no spacers. There was a stud at each edge extending one-half its thickness beyond the faces. The width overall was 8 ft 1⅝ in.

*Sheathing.*—The sheathing consisted of one sheet of fiberboard, 8 ft 0 in. square, fastened to the floor plate, the top plate, and the edge studs by 5d box nails ½ in. from the edge of the

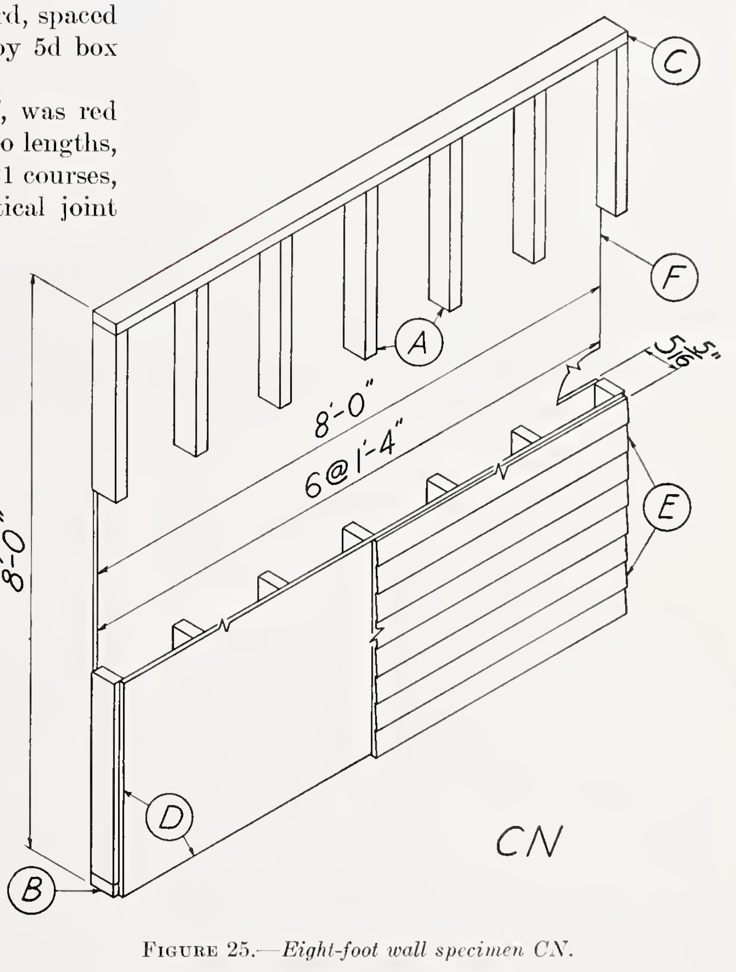


FIGURE 25.—*Eight-foot wall specimen CN.*

*A*, studs; *B*, floor plate; *C*, top plate; *D*, sheathing; *E*, bevel siding; *F*, inside face.

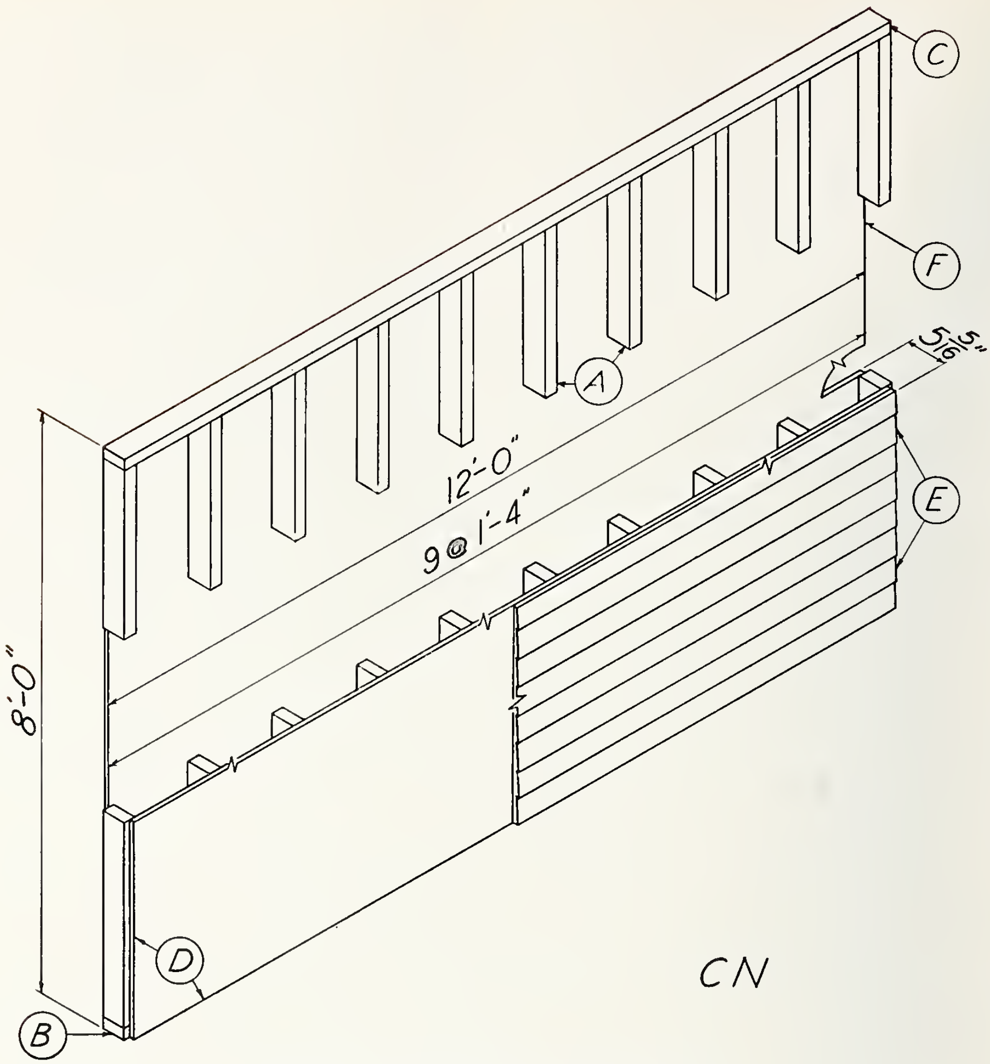


FIGURE 26.—*Twelve-foot wall specimen CN.*

*A*, studs; *B*, floor plate; *C*, top plate; *D*, sheathing; *E*, bevel siding; *F*, inside face.

board, spaced 6 in. It was fastened to the other studs by 5d box nails spaced 10 in.

*Bevel siding.*—The bevel siding was red cedar, 7/16 by 3/16 by 5½ in. There were 21 courses, 5 consisting of one continuous piece of siding and 16 having a vertical joint over a stud. Joints were located at random horizontally and vertically. The siding was laid 4½ in. to the weather and fastened through the overlapping edges by 7d siding nails, one at each stud.

*Inside face.*—The inside face consisted of one piece of fiberboard, 8 ft 0 in. square, fastened to the floor plate, the top plate, and the studs by glue and to the plates and the edge studs by 6d casing nails ½ in. from the edge of the board, spaced 6 in.

### (c) *Twelve-Foot Wall Specimens*

To determine the relation between racking properties and width of specimen three additional racking specimens, *CN–R1a, R2a,* and *R3a*, were submitted. These specimens, shown in figure 26, were 8 ft 0 in. high, 12 ft 0 in. face width, and 5 5/16 in. thick, and were similar to the 4-ft specimens, except that there were ten studs, spaced 1 ft 4 in. on centers, and no spacers. A stud at each edge extended one-half its thickness beyond the faces. The width overall was 12 ft 1⅝ in.

FIGURE 27.—*Wall specimen CN–C1 under compressive load.*


*Sheathing.*—The sheathing consisted of one sheet of fiberboard, 12 ft 0 in. by 8 ft 0 in., fastened to the floor plate, the top plate, and the edge studs by 5d box nails ½ in. from the edge of the board, spaced 6 in. It was fastened to the studs by 5d box nails spaced 10 in.

*Bevel siding.*—The bevel siding was red cedar, 7/16 by 3/16 by 5½ in. The siding was laid 4½ in. to the weather and fastened through the overlapping edges by 7d siding nails, one at each stud. There were 21 courses, 5 consisting of 2 pieces of siding and 16 of 3 pieces. The vertical joints were over studs, distributed at random vertically and horizontally.

*Inside face.*—The inside face consisted of one piece of fiberboard 12 ft 0 in. by 8 ft 0 in., fastened to the floor plate, the top plate, and the studs by glue, and to the plates and the edge studs by 6d casing nails ½ in. from the edge of the board, spaced 6 in.

### (*d*) *Comments*

Conventional exterior finishes, such as shingles, siding, stucco, and brick or stone veneer, may be applied to the prefabricated wall panels after they are assembled in a house.

Shingles are laid over horizontal wood furring strips in either single or double courses. Any size and type of wood siding may be applied directly over the "Homasote" but must be nailed to the studs.

Stucco is applied in three coats over metal lath. The lath should be furred out at least ¾ in. A calking space is left around openings to prevent cracking of the stucco if the wood frame shrinks. Weep holes should be provided to prevent accumulation of water at the foundation line.

Brick veneer is applied in the usual manner with a 1½-in. air space. Metal ties are spaced 2 ft 8 in. on centers in every fifth or sixth course. Under window sills the brickwork should be at least ½ in. below the wood to permit movement of the frame. Weep holes should be provided as for stucco.

### 2. Compressive Load

Wall specimen *CN–C1* under compressive load is shown in figure 27. The results for wall specimens *CN–C1*, *C2*, and *C3* are given in table 6 and in figures 28 and 29.

The speed of the movable head of the testing machine under no load was adjusted to 0.072 in./min.

The fiberboard on the inside face of specimen *C1* began to separate from the top plate under a load of 3.0 kips/ft; on specimen *C2*, under a load of 5.0 kips/ft; and on specimen *C3*, under the maximum load. At the maximum load the top plate of each specimen crushed locally at the inside edges of the studs. This was accompanied by separation of the fiberboard on the inside face from the upper half of the studs. The outer studs of specimen *C3* split at the top, but none of the studs ruptured.

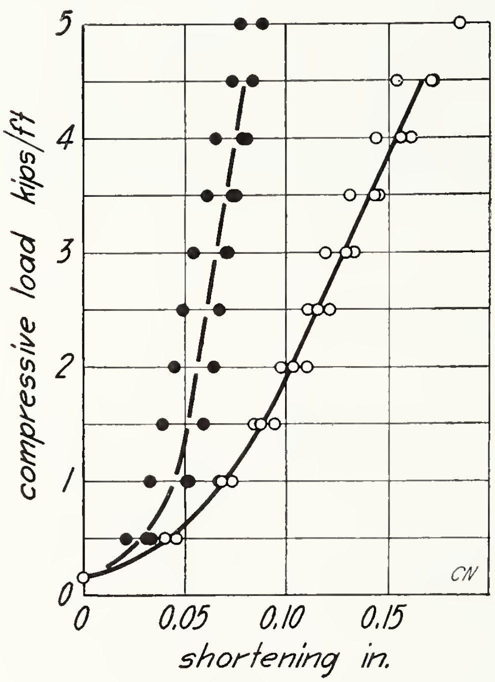


Figure 28.—*Compressive load on wall CN.*

Load-shortening (open circles) and load-set (solid circles) results for specimens *CN–C1*, *C2*, and *C3*. The load was applied 1.21 in. (one-third the thickness of the frame) from the inside surface of the studs. The loads are in kips per foot of actual width of specimen.

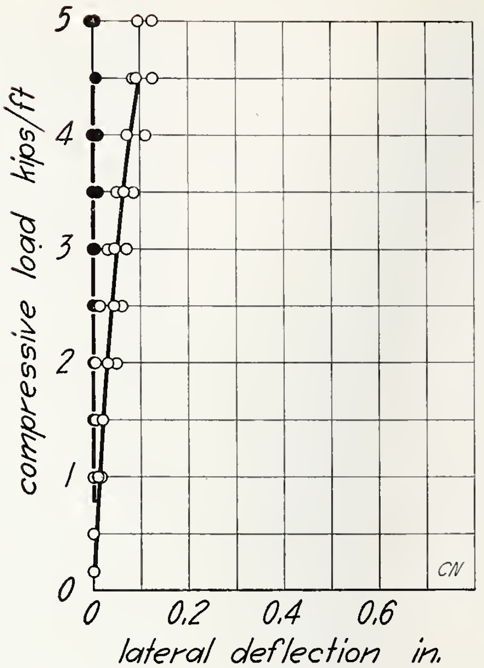


Figure 29.—*Compressive load on wall CN.*

Load-lateral deflection (open circles) and load-lateral set (solid circles) results for specimens *CN–C1*, *C2*, and *C3*. The load was applied 1.21 in. (one-third the thickness of the frame) from the inside surface of the studs. The loads are in kips per foot of actual width of specimen. The deflections and sets are for a gage length of 7 ft 10 in., the gage length of the deflectometers.

### 3. Transverse Load

The results of the transverse tests are shown in table 6 and in figure 30 for wall specimens *CN–T1*, *T2*, and *T3*, loaded on the inside face, and in figure 31 for wall specimens *CN–T4*, *T5* and *T6*, loaded on the outside face.

The speed of the movable head of the testing machine under no load was adjusted to 0.14 in./min.

Under a load of 350 lb/ft$^2$ on specimen *T1*, one outer stud partially ruptured. The center stud and one outer stud of specimen *T2* began to rupture at a load of 400 lb/ft$^2$, and one outer stud of *T3* began to rupture under a load of 275 lb/ft$^2$. Under the maximum loads, the center stud and one outer stud of each specimen ruptured near midspan. The sheathings of specimens *T1* and *T2* was undamaged,

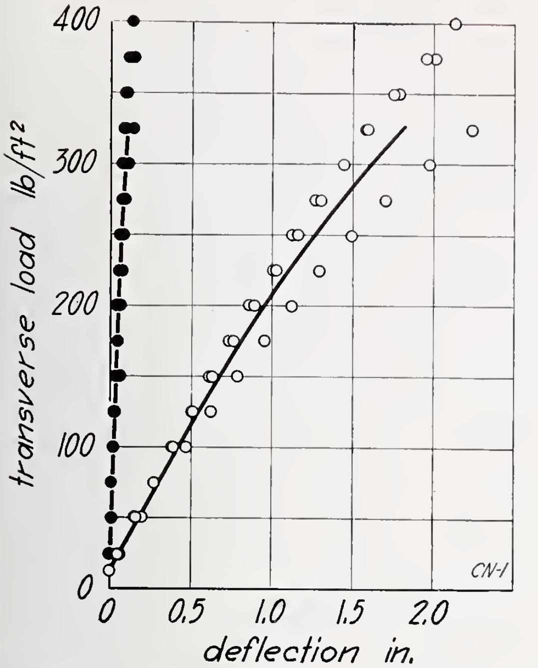


FIGURE 30.—*Transverse load on wall CN, load applied to inside face.*

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

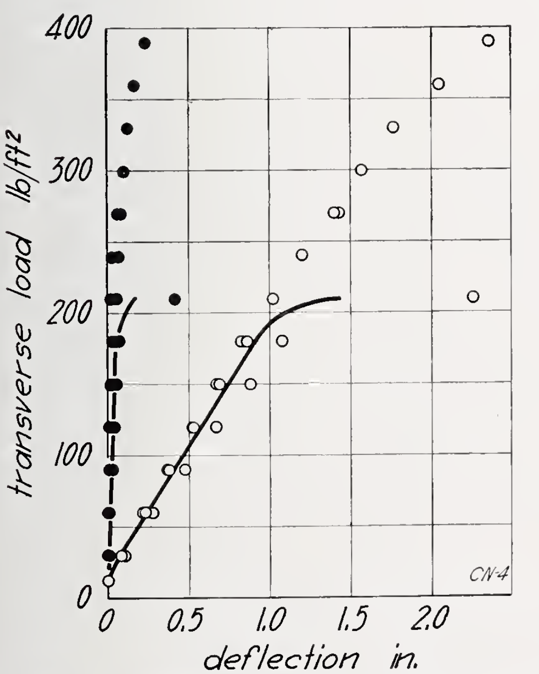


FIGURE 31.—*Transverse load on wall CN, load applied to outside face.*

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

but that of specimen *T3* was ruptured transversely.

Under a load of 390 lb/ft$^2$ on specimen *T4*, the fiberboard on the inside face began to separate from the studs near midspan; in specimen *T5* separation began under a load of 180 lb/ft$^2$, and in *T6* under a load of 263 lb/ft$^2$. One outer stud of each specimen ruptured partially under loads of 390, 208, and 263 lb/ft$^2$, respectively. Under the maximum load on each specimen, the partially ruptured outer stud and the center stud ruptured completely. The fiberboard on the inside face of specimens *T4* and *T6* was undamaged, but that on specimen *T5* was ruptured transversely.

## 4. Concentrated Load

The results of the concentrated-load tests are shown in table 6 and in figure 32 for wall specimens *CN–P1*, *P2*, and *P3*, loaded on the inside face, and in figure 33 for wall specimens *CN–P4*, *P5*, and *P6*, loaded on the outside (bevel siding) face.

The concentrated load was applied to the inside face of specimens *CN–P1*, *P2*, and *P3*

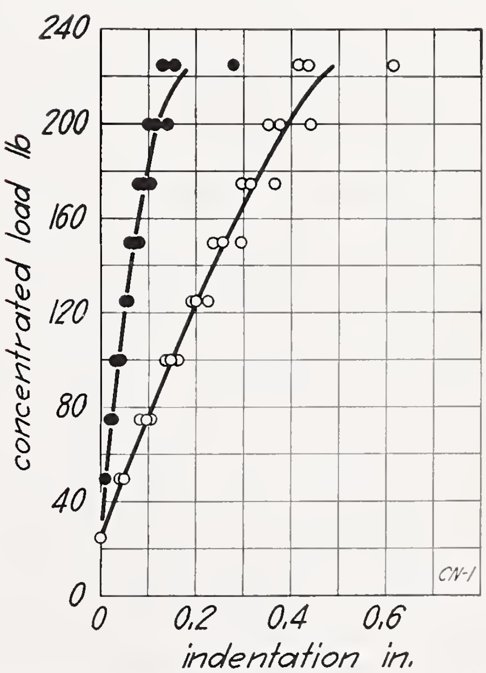


FIGURE 32.—*Concentrated load on wall CN, load applied to inside face.*

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

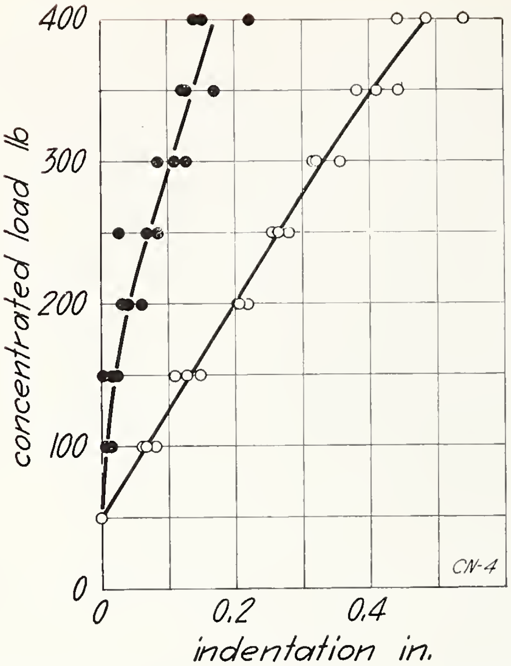


FIGURE 33.—*Concentrated load on wall CN, load applied to outside face.*

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

on the fiberboard midway between studs and 8 in. from one end of the specimen. Under the maximum load on each specimen, the disk punched through the fiberboard.

The concentrated load was applied to the outside face of specimens *P4*, *P5*, and *P6* on the bevel siding midway between studs and 8 in. from one end. At a load of 250 lb the siding of specimen *P4* split along the grain under the loading disk for about 6 in. In specimen *P5* the siding split under a load of 300 lb, and in specimen *P6* under a load of 200 lb. At the maximum load on each specimen, the disk punched through the siding and sheathing.

## 5. Impact Load

Results of the impact tests are shown in table 6 and in figure 34 for wall specimens *CN–I1*, *I2*, and *I3*, loaded on the inside face, and in figure 35 for wall specimens *CN–I4*, *I5*, and *I6*, loaded on the outside face.

The impact load was applied to the center of the inside faces of specimens *CN–I1*, *I2*, and *I3*, the sandbag striking the fiberboard directly

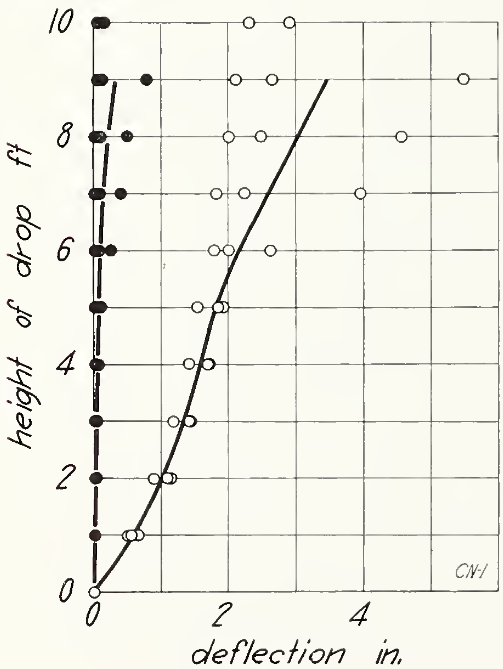


FIGURE 34.—*Impact load on wall CN, load applied to inside face.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *CN–I1, I2*, and *I3*. The sandbag struck the center of the specimen directly over a stud.

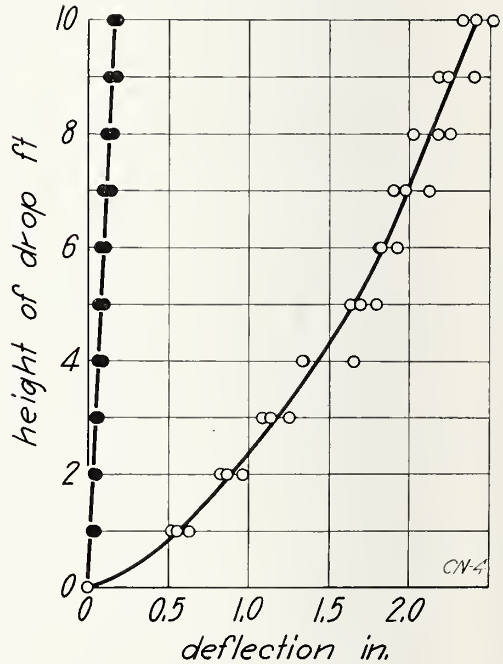


FIGURE 35.—*Impact load on wall CN, load applied to outside face.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *CN–I4, I5*, and *I6*. The sandbag struck the center of the specimen directly over a stud.

over the center stud. The effects are given in table 10.

Table 10.—*Effects of impact load on wall CN, loaded on the inside face*

| Description of effects | Specimen *I1* | | Specimen *I2* | | Specimen *I3* | |
|---|---|---|---|---|---|---|
| | Height of drop | Deflection | Height of drop | Deflection | Height of drop | Deflection |
| | *ft* | *in.* | *ft* | *in.* | *ft* | *in.* |
| Face loaded: | | | | | | |
| Fiberboard separated from one or more studs | 3.5 | 1.51 | 4.0 | 1.40 | 3.0 | 1.43 |
| Fiberboard ruptured where the sandbag struck | 10.0 | 2.90 | 8.5 | 2.04 | 7.5 | 4.08 |
| Face not loaded: Three pieces of siding at midheight ruptured at the center stud | | | | | 8.5 | 4.93 |
| Center stud ruptured, outer studs not ruptured | | | | | [a]10.0 | |

[a] Set 3.63 in.

After the 10-ft drop on specimens *I1* and *I2* the sets were 0.162 and 0.065 in., respectively.

The impact load was applied to the center of the outside face of specimens *CN–I4*, *I5*, and *I6*, the sandbag striking the bevel siding directly over the center stud. The effects are given in table 11.

Table 11.—*Effects of impact load on wall CN, loaded on the outside face*

| Description of effects | Specimen *I4* | | Specimen *I5* | | Specimen *I6* | |
|---|---|---|---|---|---|---|
| | Height of drop | Deflection | Height of drop | Deflection | Height of drop | Deflection |
| | *ft* | *in.* | *ft* | *in.* | *ft* | *in.* |
| Face loaded: Siding split along grain where the sandbag struck | 8.0 | 2.02 | 10.0 | 2.41 | 6.0 | 1.92 |
| Face not loaded: | | | | | | |
| Fiberboard began to separate from studs | 2.0 | 0.82 | 3.5 | 1.25 | 2.0 | 0.96 |
| Fiberboard separated 1¼ in. from studs at midheight | 10.0 | 2.33 | 10.0 | 2.41 | 10.0 | 2.52 |

After the 10-ft drop on specimens *I4*, *I5*, and *I6* the sets were 0.155, 0.149, and 0.188 in., respectively.

## 6. Racking Load

The results of the racking-load tests are shown in table 6 and in figure 36 for the 8-ft wall specimens *CN–R1*, *R2*, and *R3*, and in figure 37 for the 12-ft wall specimens *CN–R1a*, *R2a*, and *R3a*.

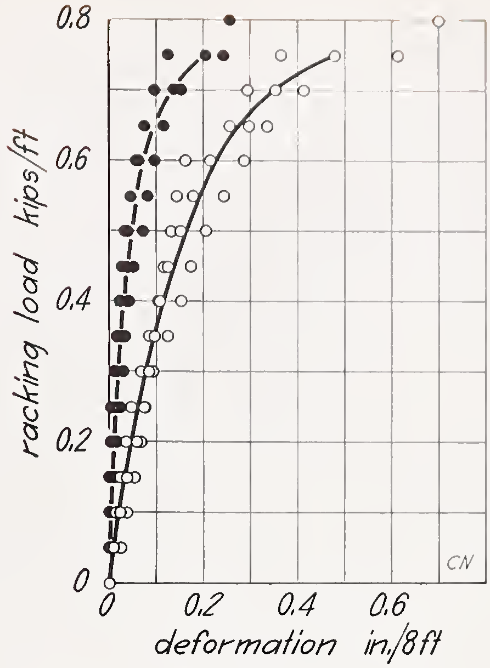


Figure 36.—*Racking load on wall CN.*

Load-deformation (open circles) and load-set (solid circles) results for specimens *CN–R1*, *R2*, and *R3*. The loads are in kips per foot of face width of specimen (8 ft 0 in).

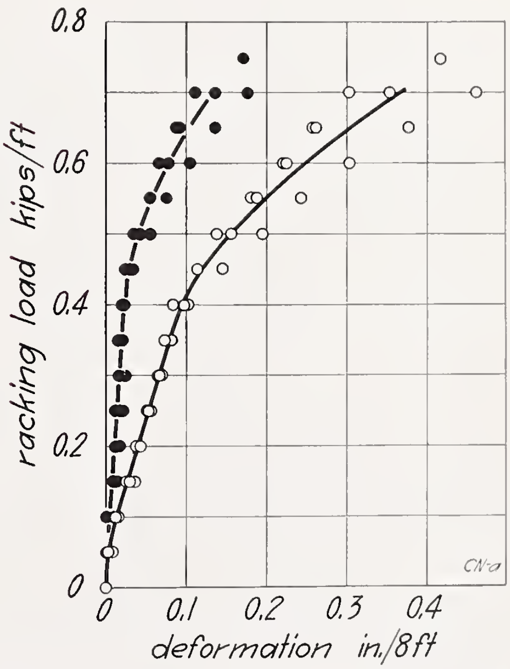


Figure 37.—*Racking load on wall specimens CN–R1a, R2a, and R3a.*

Load-deformation (open circles) and load-set (solid circles) results. The loads are in kips per foot of face width of specimen (12 ft 0 in).

The racking loads were applied only to the top plate. The stop was in contact only with the floor plate, at the diagonally opposite corner of the specimen. The racking loads were applied by means of a hand-driven pump, and therefore the speed of loading could not be closely controlled.

Under the maximum load the fiberboard on the inside face of each of the specimens separated from the glued surface of the frame, and the frame was displaced relative to the inside face. The nails passing through the inside face and those through the sheathing into the top plate and into the stud at the unloaded edge of the specimen tore through the edges of the fiberboards.

The racking strength (kips/ft) is independent of the width of the specimen. The difference in average racking strength of the 8-ft specimens and the 12-ft specimens was not greater than the differences between individual specimens of the same width.

## VII. LOAD-BEARING PARTITION *CO*

### 1. Sponsor's Statement

Load-bearing partition *CO* was a conventional wood frame with "Homasote" fiberboard as both faces. It was similar to wall *CM*, except that both faces were fastened to the frame by glue, not one face as in the walls. The specimens were not painted.

The price of this construction in Washington, D. C., as of July 1937, was $0.221/ft$^2$.

#### (*a*) *Four-Foot Partition Specimens*

The 4-ft partition specimens were similar to the 4-ft wall specimens shown in figure 7, and were 8 ft 0 in. high, 4 ft 0 in. wide, and 4$\frac{9}{16}$ in. thick. Each consisted of a wood frame to which the faces were fastened. The frame consisted of three studs, *A*, fastened to a floor plate, *B*, and a top plate, *C*. The faces, *D* and *E*, each consisted of one sheet of fiberboard. The overhanging edges of the faces were supported by spacers, *F*.

*Studs*.—The studs, *A*, were Douglas fir, 1$\frac{5}{8}$ by 3$\frac{5}{8}$ in., 7 ft 8$\frac{3}{4}$ in. long, spaced 1 ft 4 in. on centers. Each stud was fastened to the floor plate and to the top plate by two 16d common nails passing through the plates into the stud (not toenailed).

*Floor plate and top plate*.—Both floor plate, *B*, and top plate, *C*, were Douglas fir, 1$\frac{5}{8}$ by 3$\frac{5}{8}$ in., 4 ft 0 in. long.

*Faces*.—Each face, *D* and *E*, consisted of one sheet of fiberboard, 4 ft 0 in. by 8 ft 0 in., fastened to the floor plate, the top plate, and the studs by glue, and to the floor plate and the top plate by 6d casing nails $\frac{1}{2}$ in. from the edge of the fiberboard, spaced 6 in. The glue was liberally applied to the frame and to the fiberboard with a 3-in. paint brush. Wood strips, 1 by 2 in., were then fastened over the fiberboard to each stud by five 6d casing nails. The strips were removed shortly before the specimens were tested.

*Spacers*.—The spacers, *F*, along the overhanging edges of the faces, were southern pine, $\frac{25}{32}$ by 1$\frac{5}{8}$ in., 3$\frac{5}{8}$ in. long, spaced 1 ft 0 in. on centers. Each spacer was fastened to the faces by 6d casing nails, two in one face and one in the other, passing through the fiberboard into the spacer. Spacers are not used in a house.

In these specimens there was a stud at mid-width. Therefore during the impact test on specimens *CO-I1*, *I2*, and *I3* the sandbag struck the fiberboard over the center stud. To determine the impact properties of this construction if loaded on the fiberboard between studs three additional 4-ft partition specimens, *CO-I1a*, *I2a*, and *I3a*, were submitted.

These specimens were similar to the wall specimens shown in figure 8. There were two full-sized studs, *A*, and two half-sized studs, *G*, and no spacers. The faces were fastened to the plates and full-sized studs in the same way as in the other 4-ft partition specimens. Both faces were fastened to the half-sized studs by glue and by 6d casing nails spaced 6 in.

*Half-sized studs*.—The half-sized studs, *G*, were Douglas fir, $\frac{25}{32}$ by 3$\frac{5}{8}$ in., 7 ft 8$\frac{3}{4}$ in. long. Each half-sized stud was fastened to the floor plate and to the top plate by two 10d common nails passing through each plate into the half-sized stud (not toenailed).

#### (*b*) *Eight-Foot Partition Specimens*

The 8-ft partition specimens were similar to the 8-ft wall specimens shown in figure 9. They were 8 ft 0 in. high, 8 ft 0 in. face width, and

4⁹⁄₁₆ in. thick, and were similar to the 4-ft partition specimens, except that there were seven studs spaced 1 ft 4 in. on centers, and no spacers. A stud at each edge extended one-half its thickness beyond the faces. The width overall was 8 ft 1⅝ in.

*Faces.*—Each face consisted of one sheet of fiberboard, 8 ft 0 in. square, fastened to the top plate, floor plate, and the studs by glue and to both plates and to the edge studs by 6d casing nails ½ in. from the edge of the board, spaced 6 in.

### (c) *Twelve-Foot Partition Specimens*

To determine the relation between racking properties and width of specimen, three additional racking specimens, *CO–R1a*, *R2a*, and *R3a*, were submitted. These specimens, similar to the wall specimens shown in figure 10, were 8 ft 0 in. high, 12 ft 0 in. face width, and 4⁹⁄₁₆ in. thick. They were similar to the 4-ft partition specimens, except that there were 10 studs, spaced 1 ft 4 in. on centers, and no spacers. A stud at each edge extended one-half its thickness beyond the faces. The width overall was 12 ft 1⅝ in.

*Faces.*—Each face consisted of one sheet of fiberboard, 12 ft 0 in. by 8 ft 0 in., fastened to the floor plate, top plate, and the studs by glue, and to both plates and the edge studs by 6d casing nails ½ in. from the edge of the board, spaced 6 in.

## 2. Compressive Load

The results of compressive-load tests for partition specimens *CO–C1*, *C2*, and *C3* are shown in table 6 and in figures 38 and 39.

The speed of the movable head of the testing machine under no load was adjusted to 0.072 in./min.

Deflections toward the "outside" face (positive deflection) were plotted to the right of the vertical axis in figure 39. The face farthest from the load line was taken as the "outside" face. Deflections toward the "inside" face (negative deflection) were plotted to the left of the vertical axis.

Under the maximum load the fiberboard on the "inside" face of each specimen separated from the upper half of the studs, and the top

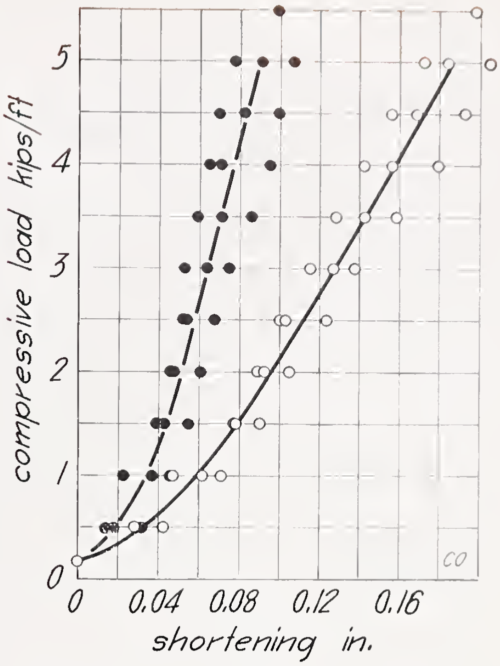


FIGURE 38.—*Compressive load on partition CO.*

Load-shortening (open circles) and load-set (solid circles) results for specimens *CO–C1*, *C2*, and *C3*. The load was applied 1.21 in. (one-third the thickness of the frame) from one surface of the studs. The loads are in kips per foot of actual width of specimen.

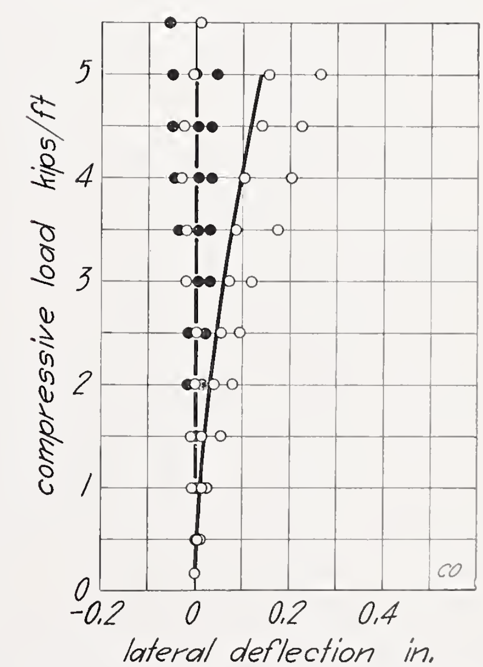


FIGURE 39.—*Compressive load on partition CO.*

Load-lateral deflection (open circles) and load-lateral set (solid circles) results for specimens *CO–C1*, *C2*, and *C3*. The load was applied 1.21 in. (one-third the thickness of the frame) from one surface of the studs. The loads are in kips per foot of actual width of specimen. The deflections and sets are for a gage length of 7 ft 10 in., the gage length of the deflectometers.

plate crushed locally at the "inside" edges of the studs.

### 3. Transverse Load

Transverse-load test results for partition specimens *CO–T1*, *T2*, and *T3* are given in table 6 and in figure 40.

The speed of the movable head of the testing machine under no load was adjusted to 0.14 in./min.

The fiberboard on the face not loaded of specimens *T2* and *T3* was forced away from the

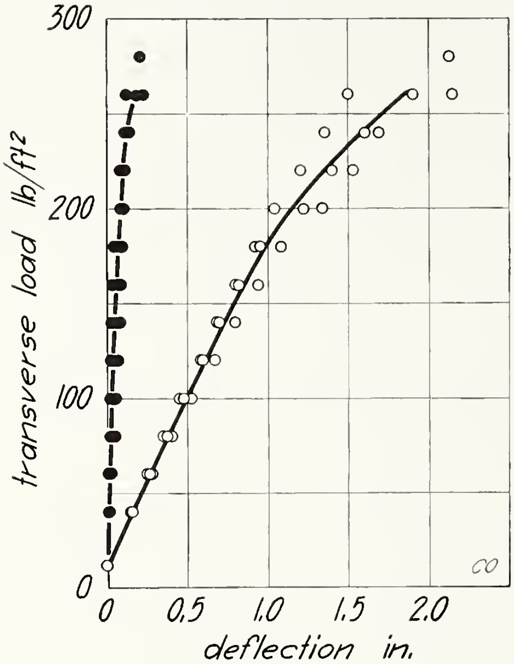


Figure 40.—*Transverse load on partition CO.*

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

studs when one of the studs ruptured partially. For specimen *T2* this effect was observed when the center stud ruptured partially under a load of 248 lb/ft², and for specimen *T3* when one outer stud ruptured partially under a load of 200 lb/ft² and completely under a load of 303 lb/ft².

Under the maximum load one outer stud in specimen *T1* ruptured along the grain near midspan; the center stud in specimen *T2* ruptured completely; and the center stud and one outer stud in specimen *T3* ruptured completely near midspan. For each of the specimens the fiberboard on both faces separated from the studs near midspan but did not rupture.

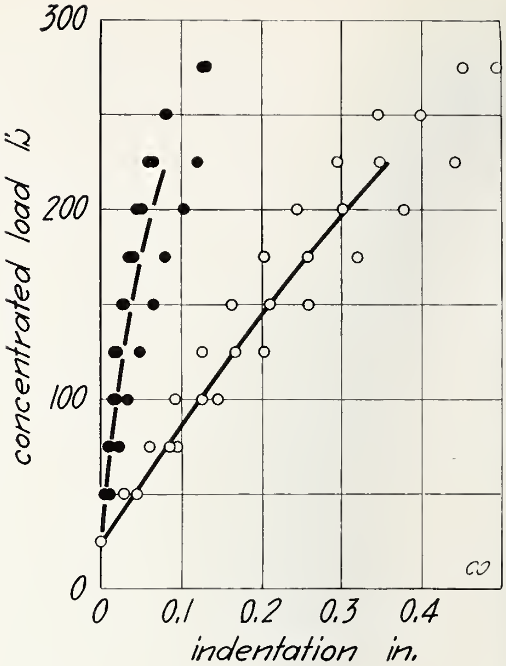


Figure 41.—*Concentrated load on partition CO.*

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

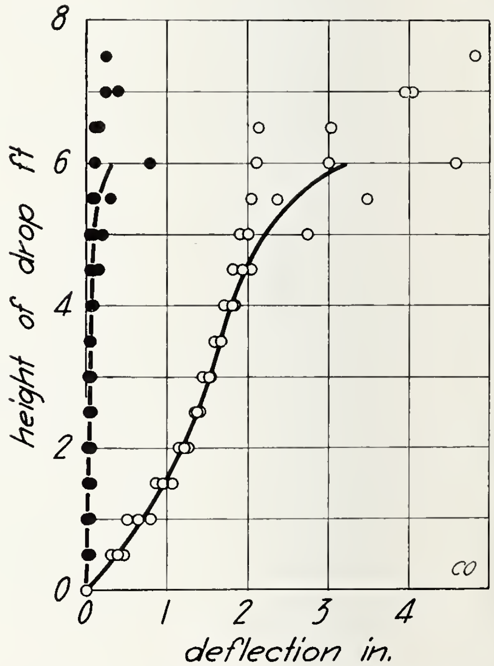


Figure 42.—*Impact load on partition CO.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *CO–I1*, *I2*, and *I3*. The sandbag struck the center of the specimen directly over a stud.

## 4. Concentrated Load

The results of concentrated-load tests for partition specimens *CO–P1*, *P2*, and *P3* are given in table 6 and in figure 41.

The concentrated load was applied to one face of each specimen on the fiberboard midway between studs and 8 in. from one end of the specimen. On each specimen the disk punched through the fiberboard under the maximum load.

## 5. Impact Load

Impact-test results are shown in table 6 and in figure 42 for partition specimens *CO–I1*, *I2*, and *I3*, and in figure 43 for partition specimens *CO–I1a*, *I2a*, and *I3a*.

The impact load was applied to the center of one face of specimens *I1*, *I2*, and *I3*, the sandbag striking the fiberboard directly over the center stud. The effects are given in table 12.

Table 12.—*Effects of impact load on partition CO*

[The sandbag struck the specimen directly over the center stud]

| Description of effects | Specimen *I1* Height of drop | Specimen *I1* Deflection | Specimen *I2* Height of drop | Specimen *I2* Deflection | Specimen *I3* Height of drop | Specimen *I3* Deflection |
|---|---|---|---|---|---|---|
| Face loaded: | | | | | | |
| Fiberboard separated from the studs | *ft* 1.0 | *in.* 0.80 | *ft.* 2.0 | *in.* 1.13 | *ft* 4.5 | *in.* 2.04 |
| Fiberboard ruptured where the sandbag struck | 7.0 | 4.03 | 7.0 | 3.94 | 5.5 | 3.48 |
| Face not loaded: | | | | | | |
| Fiberboard separated from the studs | 1.0 | 0.80 | 2.0 | 1.13 | 1.5 | 0.94 |
| Fiberboard ruptured transversely at midheight | 8.0 | | | | | |
| Fiberboard separated 3 in. or more from studs | 8.0 | | 8.0 | | 6.0 | 4.58 |
| Center stud: | | | | | | |
| Partially ruptured | 7.0 | 4.03 | 9.0 | | 5.5 | 3.48 |
| Completely ruptured, outer studs undamaged | 7.5 | | 9.5 | | 6.5 | |

The impact loads were applied to the center of one face of specimens *CO–I1a*, *I2a*, and *I3a*, the sandbag striking the fiberboard between the full-sized studs.

To prevent misleading results from local effects on the loaded face of this type of specimen, the deflections and sets were measured with two deflectometers and two set gages, not one, as described in BMS2. The deflectometers were placed in contact with the unloaded face of the specimen at midheight, one at each inner stud, and the set gages rested on the loaded face, one over each of these studs.

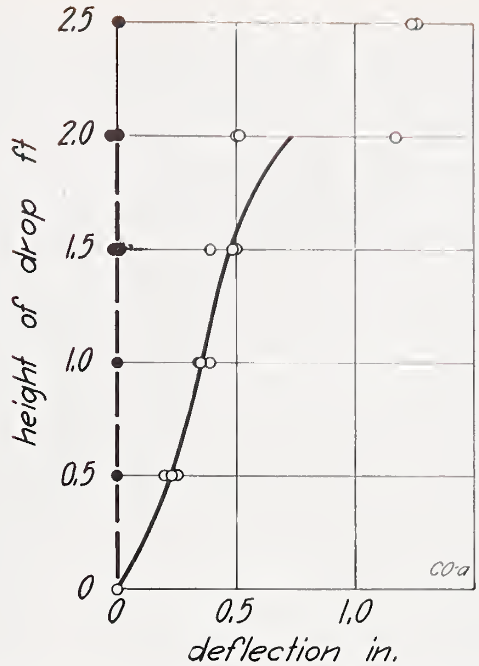


Figure 43.—*Impact load on partition specimens CO–I1a, I2a, and I3a.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results. The sandbag struck the center of the specimen midway between studs.

The effects of the impact load are given in table 13.

Table 13.—*Effects of impact load on partition CO*

[The sandbag struck the specimen midway between studs]

| Description of effects | Specimen *I1a* Height of drop | Specimen *I1a* Deflection | Specimen *I2a* Height of drop | Specimen *I2a* Deflection | Specimen *I3a* Height of drop | Specimen *I3a* Deflection |
|---|---|---|---|---|---|---|
| Face loaded: Fiberboard ruptured where the sandbag struck | *ft* 2.0 | *in.* 0.50 | *ft* 1.5 | *in.* 0.39 | *ft* 2.0 | *in.* 0.51 |
| Face not loaded: | | | | | | |
| Fiberboard ruptured transversely at midheight | 3.0 | | 2.5 | | | |
| Fiberboard separated completely from all the studs. Studs not ruptured | 3.0 | | 3.0 | | 3.0 | |

## 6. Racking Load

Partition specimen *CO–R1a* under racking load is shown in figure 44. The results are shown in table 6 and in figure 45 for the 8-ft partition specimens *CO–R1*, *R2*, and *R3*, and in figure 46 for the 12-ft partition specimens *CO–R1a*, *R2a*, and *R3a*.


FIGURE 44.—*Partition specimen CO–R1a under racking load.*

The racking loads were applied only to the top plate. The stop was in contact only with the floor plate, at the diagonally opposite corner of the specimen. The racking loads were applied by means of a hand-driven pump, and therefore the speed of loading could not be closely controlled.

Under the maximum load on each specimen the fiberboard on both faces separated from the glued surfaces of the frame, and the frame was displaced relative to the faces. The nails passing through the faces into the top plate and into the stud at the unloaded edge of the specimen tore through the edges of the fiberboard.

The racking strength (kips/ft) decreased with an increase in the width of the specimen. The average maximum racking load (kips) for the 12-ft specimens was only 6 percent greater than the average for the 8-ft specimens.

The glued joints between the fiberboard and the frame appeared to fail consecutively, beginning at the edge to which the racking load was applied.

## VIII. ADDITIONAL COMMENTS BY SPONSOR

Approximately 1,200 "Precision-Built" houses have been erected. They are widely distributed in the United States and therefore are subjected to a wide range of climatic conditions. The "Bemis" 4-in. cubical module was used in the design of these houses, which means that

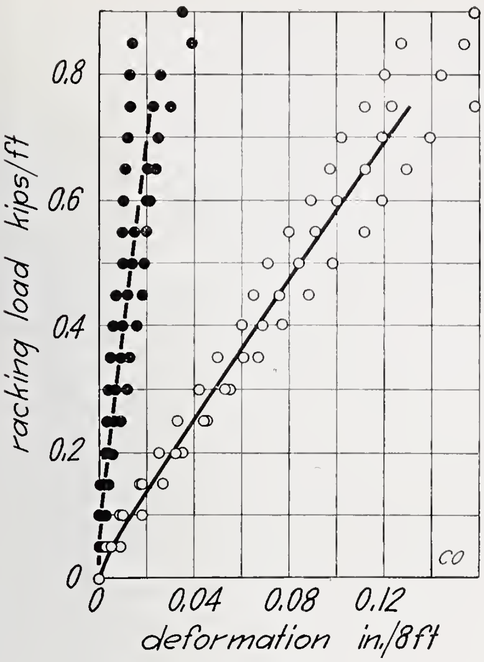


FIGURE 45.—*Racking load on partition CO.*

Load-deformation (open circles) and load-set (solid circles) results for specimens *CO–R1*, *R2*, and *R3*. The loads are in kips per foot of face width of specimen (8 ft 0 in).

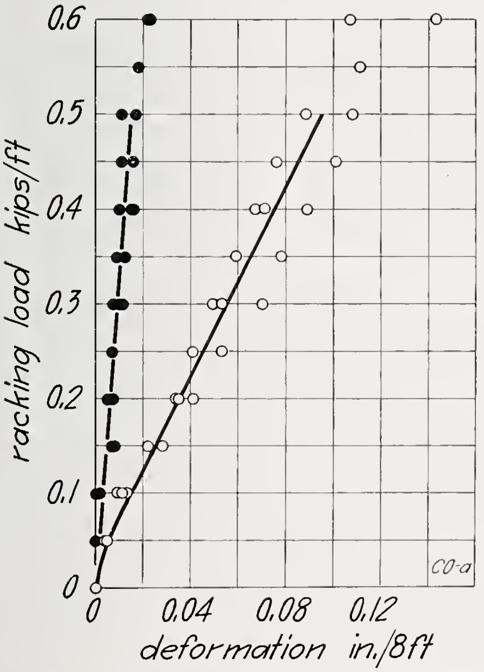


FIGURE 46.—*Racking load on partition specimens CO–R1a, R2a, and R3a.*

Load-deformation (open circles) and load-set (solid circles) results. The loads are in kips per foot of face width of specimen (12 ft 0 in).

all nominal dimensions of length, width, and height are in increments of 4 in. Modular design permits the manufacture of standard interchangeable parts for a variety of sizes and designs of buildings.

The materials are fabricated in the shops of local lumber dealers and erected by local contractors in accordance with plans and specifications furnished by the Homasote Co. The lumber for sills, plates, first-story floor joists, and roof rafters is cut to size in the shop and delivered to the site ready for assembling. The materials for wall, partition, ceiling, and second-story floor sections are cut and assembled in the shops upon jig tables approximately 22 ft long by 10 ft wide, having fixed guides along the sides and two adjustable cross guides. "Homasote" fiberboard is available in sizes up to 8 by 14 ft.

The framing of a typical house is shown in figure 47.

The superstructure is erected in accordance with the conventional platform, or western, system of house framing on a masonry foundation, with or without a basement. Wood sills, 2 by 6 in., fastened to the foundation by ⅝-in. anchor bolts, support the first-story floor joists. Sills are joined with half laps, leveled by means of slate shims, and grouted. The joists are 2 by 8 in., spaced 1 ft 4 in. on centers, and are toenailed to the sill. Starting joists, joists under parallel partitions, and headers and trimmers for openings are doubled. Continuous headers are nailed to the outside ends of the joists. For splices over girders the joists are either lapped and nailed or butt jointed and spliced with 1-in. material. The subflooring consists of 1-in. boards tongue-and-grooved, laid at an angle of 45°.

Wall and partition sections are made in standard heights of 7 ft 2 in., 7 ft 6 in., 7 ft 10 in., and 8 ft 2 in.; and in widths up to 21 ft. The widths usually correspond to the sides of a room. The sections weigh approximately 4 lb/ft² and usually can be handled by four men. When in position, the sections rest on the subfloor of either the first or the second story and are fastened to the floor and to each other by 16d nails. A continuous wood plate, 2 by 4 in., is nailed over the tops of the sections, serving to aline the sections and to form an additional tie. Corners

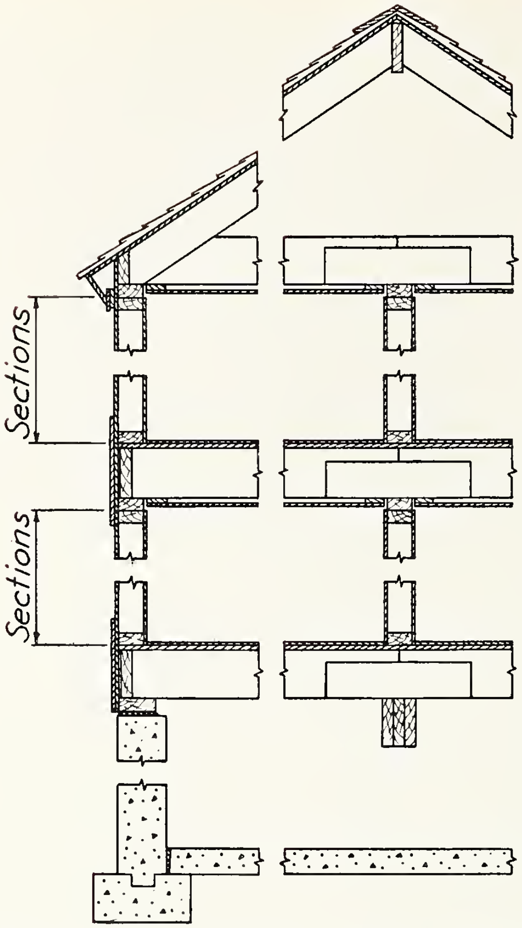


FIGURE 47.—*Section of typical "Precision-Built" house.*

are joined by means of a special assembly of three studs fastened to the end of one of the adjacent sections. The fiberboard is extended on the outside and is cut back on the inside to fit the corner. The ends of partitions are joined to the wall sections at intermediate points by a special assembly of three studs in the wall section, one of which faces the end stud of the partition section. Openings are framed for doors and windows of conventional design at the time the sections are made in the shop, the jamb studs being doubled in accordance with usual practice. Metal flashing is installed over all openings. Gable ends consist of one center section and three triangular sections.

The second-story floor sections are usually room size, and consist of 2- by 8-in. joists spaced 1 ft 4 in. on centers. There are 1- by 3-in. furring strips spaced 1 ft 4 in. on centers nailed across the bottom edges, and "Homasote" fiberboard is glued to the furring strips to form the ceiling of the first floor. If the size of the room is not larger than 8 by 14 ft, the fiberboard is one sheet. For larger rooms the fiberboard is arranged in panels and the joints are beveled or covered with strips of fiberboard or false beams. Ceiling sections are similar to second-story floor sections, except that the joists are usually 2 by 6 in.

If the attic is floored, a wood plate, 2 by 4 in., is nailed to the subfloor at the ends of the joists and the rafters fastened to this raised plate. If there is no attic floor, the rafters are fastened to the top plate of the wall. Where buildings are subjected to high wind loads, bent plates anchor the ends of the rafters to the wall sections and anchor the wall sections to the sills.

The completed buildings closely resemble conventional construction.

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The physical properties of the fiberboard were determined by the Paper Section of this Bureau, under the supervision of B. W. Scribner, with the assistance of S. G. Weissberg.

The descriptions and drawings of the specimens were prepared by E. J. Schell, G. W. Shaw, and T. J. Hanley of the Building Practice and Specifications Sections, 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 with the assistance of the following members of the professional staff: F. Cardile, H. Dollar, M. Dubin, A. H. Easton, A. S. Endler, C. D. Johnson, A. B. Lanham, A. J. Sussman, and L. R. Sweetman.

WASHINGTON, December 18, 1939.

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