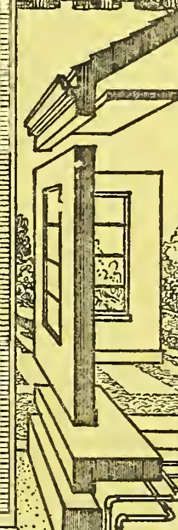
U. S. DEPARTMENT OF COMMERCE

BUILDING MATERIALS AND STRUCTURES

REPORT BMS99

Structural and Heat-Transfer Properties of "Multiple Box-Girder Plywood Panels" for Walls, Floors, and Roofs

Sponsored by Loren H. Wittner



by

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with the collaboration of

R. F. LUXFORD

Forest Products Laboratory

NATIONAL
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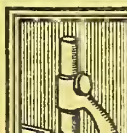

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BUILDING MATERIALS *and* STRUCTURES

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Sponsored by Loren H. Wittner

by HERBERT L. WHITTEMORE, VINCENT B. PHELAN, *and* RICHARD S. DILL

with the collaboration of

R. F. Luxford
Forest Products Laboratory
Forest Service, United States Department of Agriculture

ISSUED JUNE 11, 1943

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 and heat-transfer properties of constructions intended for low-cost houses and apartments. The constructions described herein were sponsored by Loren H. Wittner, a builder, and were included in the program for the determination of the structural properties at the request of the War Department due to its search for improved house constructions suitable for war requirements.

The sponsor built and submitted the specimens described in this report for participation in the program outlined in BMS2, Method of Determining the Structural Properties of Low-Cost House Constructions. The sponsor, therefore, is responsible for the design of the constructions and for the description of materials and method of fabrication. The Bureau is responsible for the testing of the specimens and the preparation of the report.

This report covers the load-deformation relations and strength of the elements when subjected to compressive, transverse, concentrated, impact, and racking loads by standardized methods simulating the loads to which the elements would be subjected in actual service. Heat-transfer coefficients determined by tests in a shielded hot-box heat-transfer apparatus also are included.

The National Bureau of Standards does not "approve" a construction, nor does it express an opinion as to its merits for reasons given in reports BMS1 and BMS2. The technical facts presented in this series provide the basic data from which architects and engineers can determine whether a construction meets desired performance requirements.

Lyman J. Briggs, *Director.*

Structural and Heat-Transfer Properties of "Multiple Box-Girder Plywood Panels" for Walls, Floors, and Roofs Sponsored by Loren H. Wittner

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R. F. LUXFORD

Forest Products Laboratory, Forest Service, United States Department of Agriculture

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ABSTRACT

To determine structural and heat-transfer properties, tests were conducted at the request of the War Department on wall, floor, and roof specimens of "Multiple Box-Girder Plywood Panels." The specimens were constructed by gluing and nailing one sheet of plywood between two frames and facing the outer surfaces with other sheets of plywood. The longitudinal and transverse members of the frames with the sheets of plywood formed closed cells, which provided heat insulation.

The wall specimens were subjected to compressive, transverse, concentrated, impact, and racking loads; the floor specimens to transverse, concentrated, and impact loads; and the roof specimens to transverse and concentrated loads. The loads simulated the loads to which the elements are subjected in actual service.

The deformations under load and the sets after the load was removed were measured for uniform increments of load. The results are presented in graphs and tables.

The heat-transfer properties of three wall specimens were determined in a shielded hot-box heat-transfer apparatus.

I. INTRODUCTION

To provide technical facts on the performance of constructions for low-cost houses, to discover promising new constructions, and ultimately to determine the properties necessary for acceptable performance in actual service, the National Bureau of Standards invited the cooperation of the building industry in a program of research on building materials and structures suitable for low-cost houses and apartments. The objectives of this program are described in BMS1, Research on Building Materials and Structures for Use in Low-Cost Housing.

To determine the strength of house constructions in the laboratory, standardized methods were developed for applying loads to portions of a completed house. Included in this study were masonry and wood constructions of types that have been extensively used in this country for houses and whose behavior under widely different service conditions is well known to builders and to 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 gives the structural properties of wall, floor, and roof constructions. The wall 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 wind, concentrated and impact loads by accidental contact with heavy objects, and racking loads by the action of wind on adjoining walls. Transverse loads are applied to floors by furniture and occupants; concentrated loads by furniture, for example, the legs of a piano; and impact loads by objects falling to the floor. Transverse loads are applied to roofs by wind and snow; concentrated loads by persons walking on the roof, and by tools and equipment when the roof is constructed or repaired.

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

The heat-transfer properties of three wall specimens were determined in a shielded hot-box heat-transfer apparatus. To simulate conditions which might exist in actual service, the temperature of the air near the outside face was maintained at 0° F and that near the inside face at 70° F. The observed thermal transmittance also was corrected for a wind velocity of 15 mph on the outside face of the wall and zero velocity on the inside face.

II. SPONSOR AND PRODUCT

Wall, floor, and roof specimens of Multiple Box-Girder Plywood Panels are covered by U. S. Patent 2,295,248, September 8, 1942, issued to Loren H. Wittner and licensed without royalty to the United States Government.

In these specimens three sheets of Douglas fir plywood were glued and nailed to two wood frames; one sheet of plywood was fastened between the frames and the other two to the outer surfaces.

The longitudinal and transverse members of the frames formed closed cells between the plywood.

III. SPECIMENS AND TESTS

1. Structural

The specimens represented three elements of a house and were assigned the following symbols: wall, DR; floor, DS; roof, DT; roof, demountable type, DU. The individual specimens were assigned the designations given in table 1.

Except as mentioned below, the specimens were tested in accordance with BMS2. That report also gives the requirements for the specimens and describes the presentation of the results, particularly the load-deformation graphs. The wall specimens were symmetrical with respect to a plane at midthickness. Consequently the transverse, concentrated, and impact loads were applied to one face only.

Because under compressive load the shortening of the entire specimen may not be proportional to the values obtained from compressometers attached to the specimen over only a portion of its height, the shortenings and the sets were measured with compressometers attached to the steel plates through which the load was applied, not to the specimen, as described in BMS2.

TABLE 1.—*Specimen designations*

Element	Construction symbol	Specimen designation	Load	Load applied
Wall	*DR*	*C1, C2, C3*	Compressive	Upper end.
Do	*DR*	*T1, T2, T3*	Transverse	Inside face.
Do	*DR*	*P1, P2, P3*	Concentrated [a]	Outside face.
Do	*DR*	*I1, I2, I3*	Impact	Inside face.
Do	*DR*	*R1, R2, R3*	Racking	Near upper end.
Floor	*DS*	*T1, T2, T3*	Transverse [b]	Upper face.
Do	*DS*	*P1, P2, P3*	Concentrated	Do.
Do	*DS*	*I1, I2, I3*	Impact	Do.
Roof	*DT*	*T1, T2, T3*	Transverse [b]	Do.
Do	*DT*	*P1, P2, P3*	Concentrated	Do.
Do	*DU*	*T1, T2, T3*	Transverse [b]	Do.
Do	*DU*	*P1, P2, P3*	Concentrated	Do.

[a] The concentrated and impact loads were applied to the same specimens, impact loads first.
[b] The transverse and concentrated loads were applied to the same specimens, transverse loads first.

The lateral deflections under compressive 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 in a vertical position was attached to the specimen by clamping the hinged plate to one of the faces near the upper end. The gage length (distances between the points of support) was 7 ft 6 in. A dial micrometer was mounted on the frame at midlength, with the spindle in contact with the wall specimen. The dial was graduated to 0.001 in., and the readings were recorded to the nearest division. There were two deflectometers on the specimen, one near each outer stud. This method of measurement was used instead of the taut-wire mirror-scale method described in BMS2.

The indentation under concentrated load and the set after the load was removed were measured, not the set only, as described in BMS2. The apparatus is shown in figure 1.

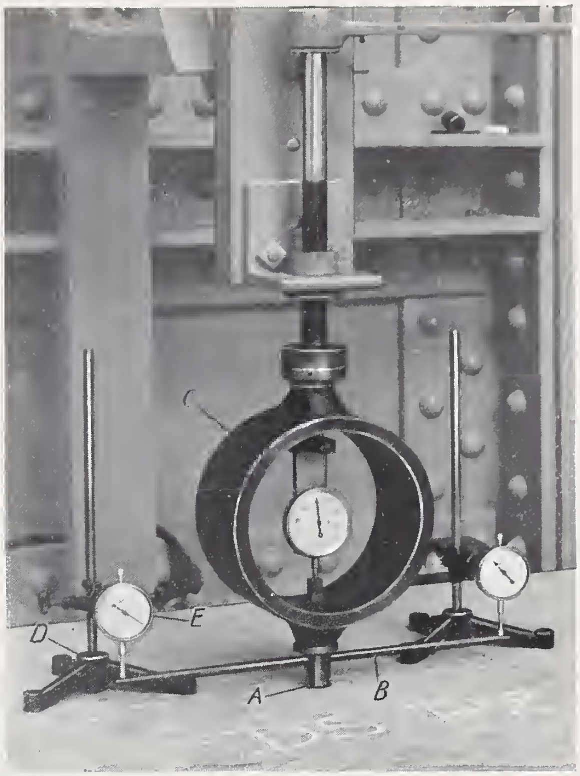

FIGURE 1.—*Apparatus for concentrated-load test.*

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

The load was applied to the steel disk, *A*, to which the crossbar, *B*, was rigidly attached. The load was measured by means of the dynamometer, *C*. Two stands, *D*, rested on the face of the specimen, one over each of two adjacent transverse frame members. Each stand supported a dial micrometer, *E*, the spindle of which was in contact with the crossbar 8 in. from the center of the disk. The micrometers were graduated to 0.001 in., and the readings were recorded to the nearest division. The initial reading (average of the micrometer readings) was observed under the initial load, which included the weight of the disk and dynamometer. A load was applied to the disk and the average of the micrometer readings minus the initial reading was taken as the depth of the indentation under load.

The deflections and sets under the impact load were measured by means of two deflectometers and two set gages, not one of each as described in BMS2. The deflectometers were placed in contact with the unloaded face of the specimen at midspan, one under each outer longitudinal member, and the set gages rested one the loaded face, one over each outer longitudinal member. The readings, therefore, were not affected by local deformations of the plywood.

To distribute the load along the racking specimens, test fixtures were attached to the top and bottom of the specimens. They were wood channels and extended the width of the specimen. The web of each channel, a 2- by 8-in. white-oak plank, was fastened to each of two 2- by 4-in. Douglas-fir flanges by twenty 3½-in. flat-head wood screws equally spaced. The test fixtures were bolted to the top and bottom of each racking specimen by seven 6½-in. carriage bolts, 5/16 in. in diameter. Each bolt extended through the flanges and through a stud in the specimen. The fixtures were also fastened to the specimens by nineteen 3½-in. flat-head wood screws, equally spaced, extending through each flange into the specimen.

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. The steel channel of the deformeter rested on the top test fixture, the steel angle extending downward in the plane of the specimen. Two nails extended through the web of the steel channel into the fixture. The bottom fixture was in contact with the stop, to which a dial mircometer was attached. The micrometer spindle was in contact with the steel angle of the deformeter. The gage length (distance from the top of the specimen to the spindle) was 8 ft. 3/16 in. The micrometer was graduated to 0.001 in., and readings were recorded to the nearest division. The deformeter was used instead of the taut-wire mirror-scale device described in BMS2.

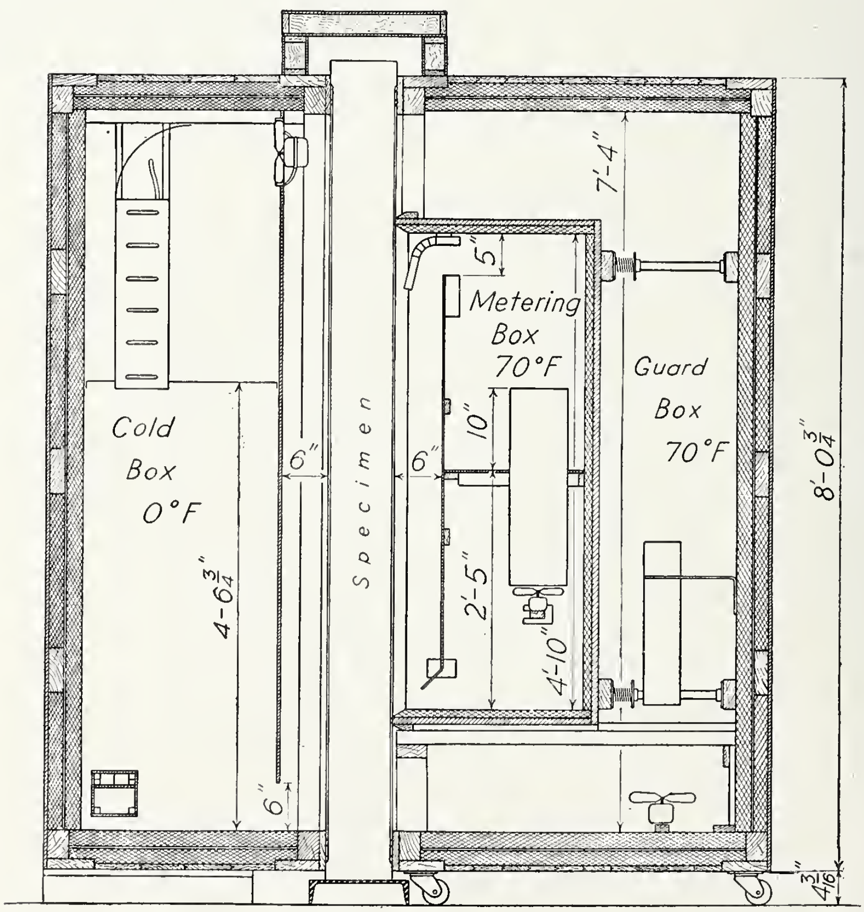

FIGURE 2.—*Longitudinal section through heat-transfer apparatus.*

The tests were begun May 4, 1942, and completed May 20, 1942. The sponsor witnessed the tests.

2. Heat Transfer

Three specimens representing the walls of a house and assigned the symbols *HT60*, *HT61*, and *HT62* were tested in a shielded hot-box heat-transfer apparatus. The arrangement for the heat-transfer test is shown in figure 2.

During a test, heat flowed from the metering and guard boxes, which were heated electrically to the same temperature, to the cold box, which was cooled by a refrigerating machine. The electric energy supplied to the metering box was closely equivalent of the heat energy transferred through the area to the specimen covered by the metering box. The energy so supplied was measured with a watthour meter; and this measurement, converted into Btu and divided by the time, the area, and the temperature difference, yielded the heat-transfer coefficient for the specimen.

By means of the guard box, the space surrounding the metering box was maintained at substantially the same temperature as its interior except on the side in contact with the specimen. This minimized heat exchange to or from the metering box except through the specimen and subjected the face of the specimen not covered by the metering box to air at the same temperature as that in the metering box.

The top and two vertical edges of the specimen projecting beyond the guard and cold boxes were enclosed by an edge-shield, through which air was circulated from the cold box at a temperature approximating the mean temperature of the specimen, in order to avoid heat gain or moisture condensation at the edges from the laboratory air.

To promote uniformity of temperature, the air within the boxes was given a gentle motion by electric fans. The energy used by the fan in the metering box was added to that introduced by the heating coils to arrive at the total energy supplied.

Air and specimen-surface temperatures were measured by copper-constantan thermocouples in conjunction with a potentiometer. Recording thermometers were used for approximate measurements of the interior temperatures of the boxes during the period preceding each test when the apparatus was being brought to a state of steady heat flow.

For testing, each specimen was placed in the apparatus in the position shown in figure 2, and the temperature in the cold box was adjusted as closely as possible to 0° F and that in the metering and guard boxes to 70° F. After a state of steady heat flow was attained, the heat transmission of the specimen, indicated by the rate at which electric energy was supplied to the metering box, was observed.

The heat-transfer measurement was made for an area 33 in. wide and 61 in. high, centrally located on the face of the specimen, substantially covering the central eight cells formed by the studs and girts. Theremocouples were placed on both the warm and the cold faces of the specimen to measure the temperatures of the surfaces over the aircells, over the studs, and over a joint between a stud and a girt.

IV. MATERIALS

Unless otherwise stated, the information on materials was obtained from the sponsor and from inspection of the specimens. The Forest Products Laboratory identified the species of the wood, and the moisture content was determined by the Engineering Mechanics Section of the National Bureau of Standards.

1. Wood

(*a*) *Framing*

The wood for the framing was identified as Douglas fir, select, grade B and better, S4S (surfaced four sides), in sizes 25/32 by 2⅛ in. (nominal 1 by 2½ in.) and 1¾ by 3½ in. (nominal 2 by 4 in.).

(*b*) *Plywood, Moisture-Resistant Type*

Douglas fir, ⅜- and ⅝-in., bonded with water-resistant protein glue having a soya-bean and casein base, sanded two sides. The ⅜-in. plywood was 3-ply, wallboard grade, and the ⅝-in. was 5-ply, SO2S (sound two sides). The plywood complied with Commercial Standard CS45–40. Douglas Fir Plywood Association (⅜-in.) "Plywall" and (⅝-in.) "Plypanel."

FIGURE 3.—*Roof DT.*
Typical specimen.

(c) Plywood, Exterior Type

Douglas fir, ⅜- and ⅝-in., bonded with hot-press synthetic-resin adhesive, sanded two sides. The ⅜-in. plywood was 3-ply and the ⅝-in. was 5-ply, both SO2S, Ext. grade. The plywood complied with Commercial Standard CS45–40. Douglas Fir Plywood Association "Ext.-D.F.P.A."

After each specimen was tested, one face was removed to expose the framing, and samples of framing and plywood were cut for identification

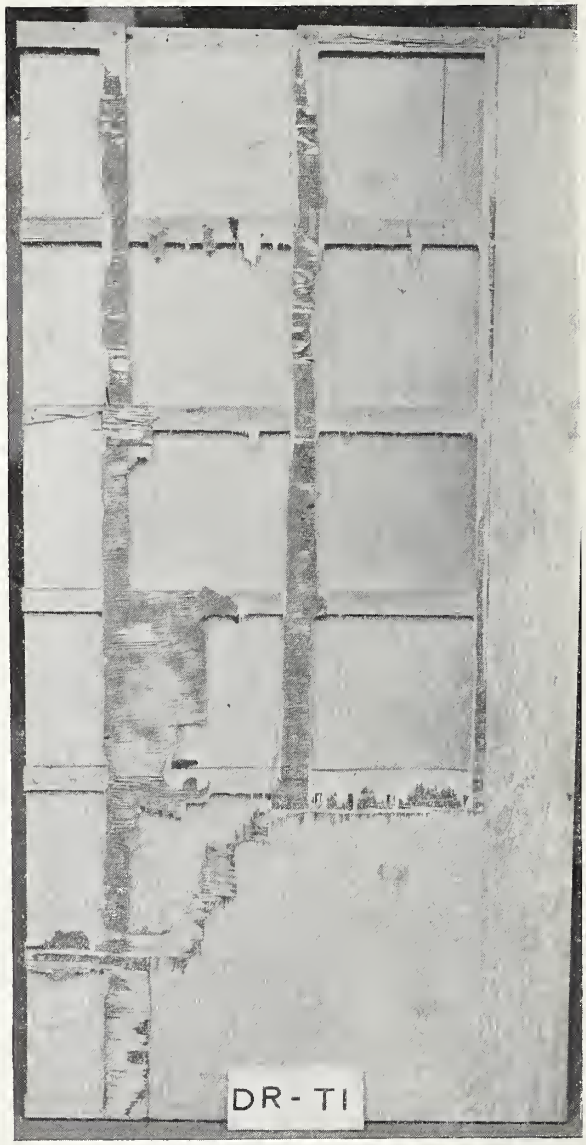

FIGURE 4.—*Wall DR.*
Typical specimen.

of the species. Figures 3 and 4 are typical specimens.

Samples of plywood and framing were taken from each specimen on the day the specimen was tested; they were weighed and then dried to constant weight in an oven at 212° F. The moisture content, given in table 2, was calculated on the oven-dry basis.

TABLE 2.—*Moisture content of the wood*

[Determined on the day the wall, floor, or roof specimen was tested]

Wood	Construction symbol	Moisture content		
		Minimum	Maximum	Average
		Percent	*Percent*	*Percent*
Framing, Douglas fir	*DR*	5.9	8.2	7.2
Do	*DS*	6.5	8.9	7.8
Do	*DT*	8.3	10.3	9.4
Do	*DU*	7.6	8.4	8.0
Plywood, Douglas fir, moisture-resistant type.	*DR*	6.0	7.9	6.9
Do	*DS*	4.3	7.5	6.1
Do	*DT*	8.1	8.4	8.3
Do	*DU*	8.3	8.4	8.3
Plywood, Douglas fir, exterior type	*DR*	4.6	7.8	5.8
Do	*DS*	4.3	6.3	5.1
Do	*DT*	4.6	5.6	5.0
Do	*DU*	4.6	6.0	5.3

2. FASTENINGS

(*a*) *Nails*

All nails were steel wire nails and are described in table 3.

TABLE 3.—*Description of the nails*

Type	Size	Length	Steel wire gage	Diameter	Finish	Nails per pound
	Penny	*in.*	*No.*	*in.*		
Common	4	1½	12½	0.0985	Bright	316
Do	6	2	11½	.113	do	181
Finishing	6	2	13	.0915	do	309
Lath	3	1⅛	15	.072	Blued	778

(*b*) *Corrugated Fasteners*

Sheet steel, 1 in. long, ½ in. deep, No. 24 U. S. Standard Gage (0.0245 in. thick), five corrugations.

3. GLUE

Urea-formaldehyde resin glue, powdered. Casein Co. of America, "Caseamite."

V. STRUCTURAL PROPERTIES

1. WALL *DR*

(*a*) *Sponsor's Statement*

Wall *DR* consisted of three sheets of Douglas fir plywood glued and nailed to two wood frames. Pieces of plywood were fastened between the frames and on the outer surfaces of the frames to form the faces of the wall. These frames, consisting of studs and girts, formed closed cells between the sheets of plywood.

The price of this construction in Washington, D. C., as of July 1937, was \$0.37 ft^2.

(1) *Four-Foot Wall Specimens*

The 4-ft. wall specimens, shown in figure 5, were 8 ft 0 in. high, 4 ft 0 in. wide, and 2$^{11}/_{16}$ in. thick. Each specimen had two like wood frames to which three sheets of plywood were fastened. Each frame consisted of three studs, *A*, connected by seven lines of girts, *B*. The middle sheet of plywood, *C*, outside face, *D*, and inside face, *E*, each consisted of two pieces of plywood. There was a longitudinal joint in each sheet.

Studs.—The studs, *A*, were Douglas fir, 25/32 by 2⅛ in. (nominal 1 by 2½ in.), 8 ft 0 in. long, spaced 1 ft 4 in. on centers.

Girts.—The girts, B, were Douglas fir, 25/32 by 2⅛ in. (nominal 1 by 2½ in.), 6$^{15}/_{16}$in. and 1 ft 1⅞ in. long, in seven transverse lines between the studs. One line was spaced 1 ft 1⅞ in. on centers from the bottom line and the other lines 1 ft 4 in. on centers. The girts were fastened to the studs by corrugated fasteners, one on each side at each intersection.

Middle sheet.—The middle sheet, *C*, was two pieces of Douglas fir plywood, moisture-resistant type, ⅜ in. thick, 8 ft 0 in. long, and 2 ft 0 in. wide. The pieces were fastened to one frame by glue and nails. There was a longitudinal joint over the middle stud. The surface of the frame in contact with the plywood was first coated with the glue mixture applied with a brush. The mixture consisted of 2 parts glue powder to 1 part water by volume or 1½ parts glue powder to 1 part water by weight. The nails were 3d blued lath nails, one line of nails along each stud and girt except at the longi-

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tudinal joint, where there was a line in each piece of plywood. In this construction all nails were spaced 4 in. The second frame was attached to the middle sheet in the same manner by glue and 4d common nails, along each stud and girt. These nails extended through the second frame, the plywood, and into the first frame.

Outside face.—The outside face, *D*, was two pieces of Douglas fir plywood, exterior type, ⅜ in. thick, 8 ft 0 in. long, 8 in. and 3 ft 4 in. wide. They were fastened by glue and nails to the frame, which had been coated with the glue mixture. The longitudinal joint in the plywood was over an outer stud. The nails were 6d finishing nails, one line of nails along each stud and girt except at the longitudinal joint, where there was a line of nails in each piece of plywood.

Inside face.—The inside face, *E*, was similar to the outside face except that the plywood was of the moisture-resistant type. It was fastened to a frame in the same manner as the outside face except that the longitudinal joint was over the other outer stud.

(2) *Eight-Foot Wall Specimens*

The 8-ft. wall specimens, shown in figure 6, were 8 ft 0 in. high, 8 ft 2⅛ in. wide, and 2¹¹⁄₁₆ in. thick. The specimens were similar to the 4-ft specimens except for the following: The middle sheet was two pieces of plywood 4 ft 0 in. wide. The faces were each three pieces of plywood

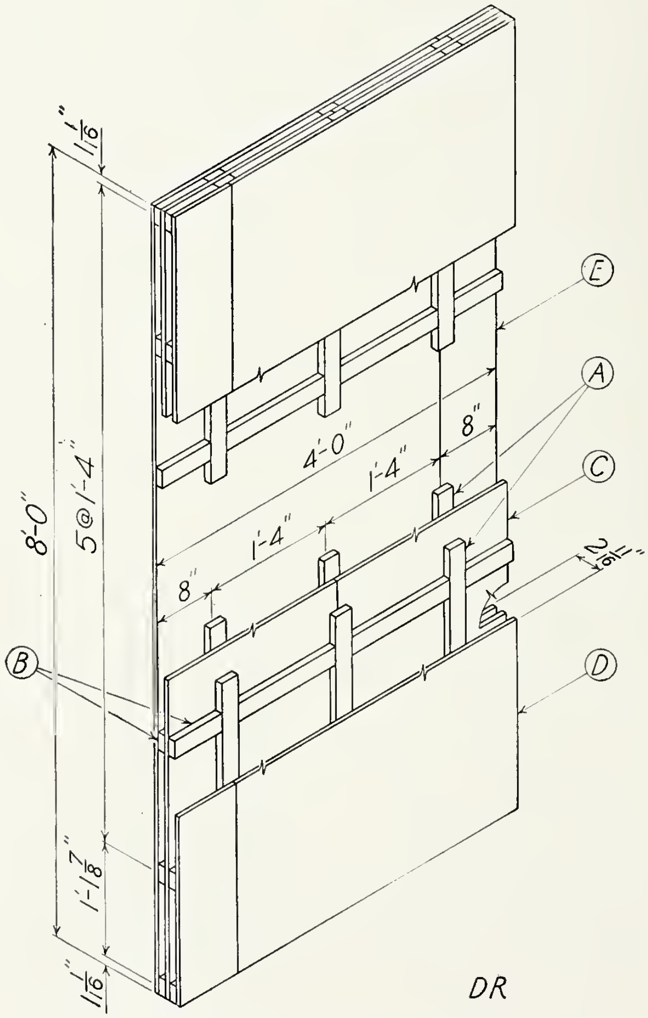

FIGURE 5.—*Four-foot wall DR.*

A, stud; *B*, girt; *C*, plywood, middle sheet; *D*, plywood, outside face; *E*, plywood, inside face.

2 ft 8 in., 4 ft 0 in., and 1 ft 4 in. wide. The longitudinal joints in the inside face were 1 ft 4 in. and 5 ft 4 in. from one edge and those in the outside face the same distances from the other edge.

(b) *Compressive Load*

Wall specimen *DR–C2* under compressive load is shown in figure 7. The results for specimens *DR–C1*, *C2*, and *C3* are given in table 4 and in figures 8 and 9.

The speed of the movable head of the testing machine under no load was adjusted to 0.07 in./min. The compressometer gage length was 8 ft 0 in.

Under a load of 11, 10.5, and 11.75 kips/ft on specimens *DR–C1*, *C2*, and *C3*, respectively, the inside faces began to buckle over each cell at

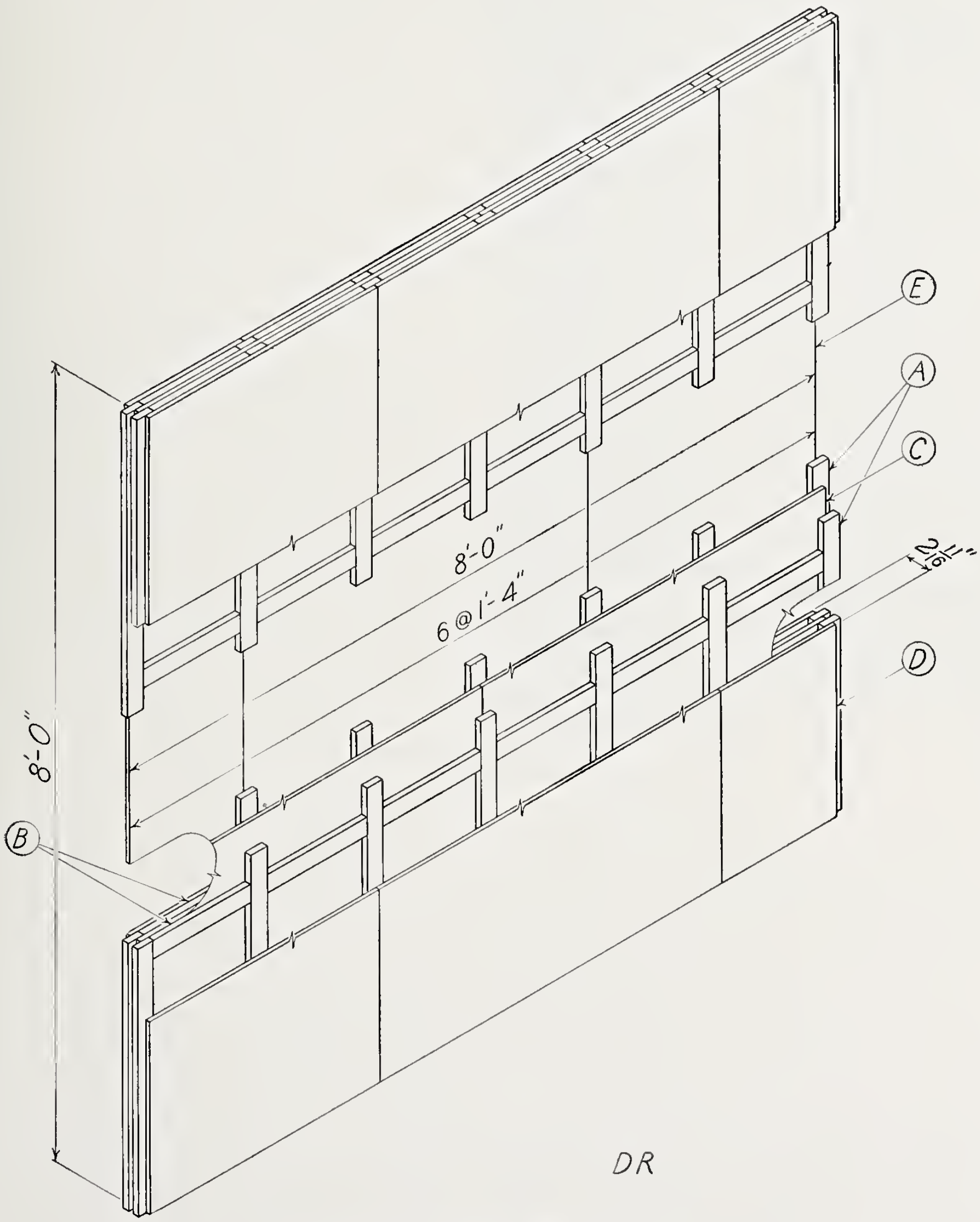

FIGURE 6.—*Eight-foot wall DR.*

A, stud; *B*, girt; *C*, plywood, middle sheet; *D*, plywood, outside face; *E*, plywood, inside face.

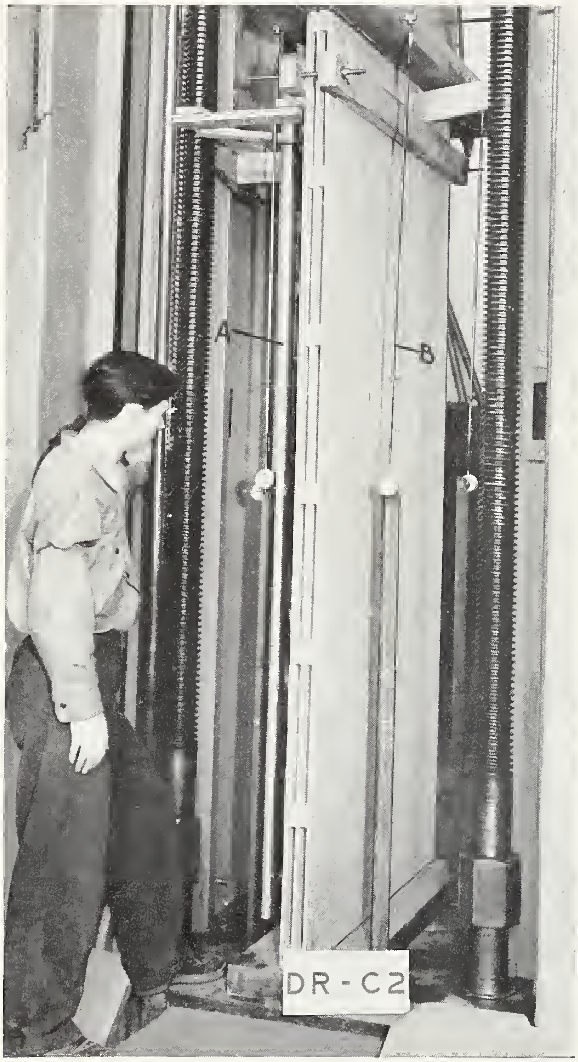

FIGURE 7.—*Wall specimen DR-C2 under compressive load.*

A, deflectometer; *B*, compressometer.

midheight. Under the maximum loads, the inside faces buckled over most of the cells and on specimens *DR–C1* and *C3* the load began to decrease with an increase of the lateral deflection. Under the maximum load, specimen *DR–C2* pushed out from under the loading channel.

(*c*) *Transverse Load*

The results of the transverse load are shown in table 4 and in figure 10 for wall specimens *DR–T1*, *T2*, and *T3*. The transverse loads were applied to the inside face. The speed of the movable head of the testing machine was

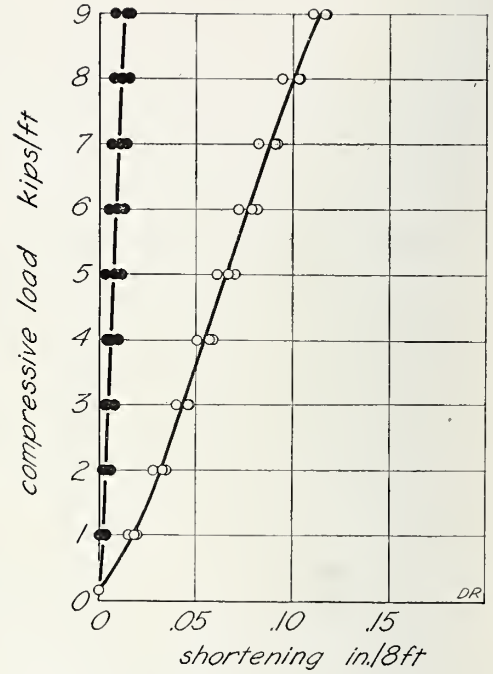

FIGURE 8.—*Compressive load on wall DR.*

Load-shortening (open circles) and load-set (solid circles) results for specimens *DR–C1*, *C2*, and *C3*. The load was applied 0.90 in. (one-third the thickness of the specimen) from the inside face. The loads are in kips per foot of actual width of specimen.

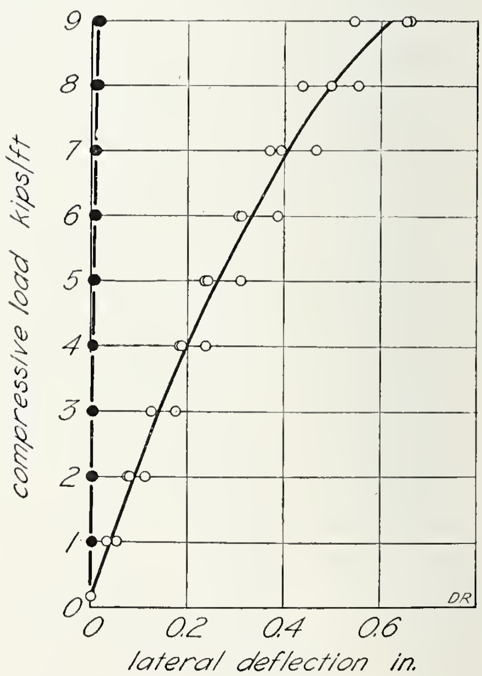

FIGURE 9.—*Compressive load on wall DR.*

Load-lateral deflection (open circles) and load-lateral set (solid circles) results for specimens *DR–C1*, *C2*, and *C3*. The load was applied 0.90 in. (one-third the thickness of the specimen) from the inside 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.

Table 4.—*Structural properties of wall DR, floor DS, and roofs DT and DU*

[Weight, based on face area: Wall *DR*, 4.38 lb/ft²; floor *DS*, 8.15 lb/ft²; roof *DT*, 7.96 lb/ft ²; roof *DU*, 8.38 lb/ft²]

Construction symbol	Compressive load [a]		Transverse load		Concentrated load; disk, 1 in. diam		Impact load; sandbag, 60 lb		Racking load	
	Specimen	Maximum load	Specimen	Maximum load	Specimen	Maximum load	Specimen	Maximum height of drop	Specimen	Maximum load
		[b] *Kips/ft*		*lb/ft²*		*lb*		*ft*		[b] *Kips/ft*
DR	*C1*	11.80	*T1* [c]	423	*P1*	[d] 1,000	*I1* [c]	[d] 10	*R1*	4.80
	C2	11.02	*T2* [c]	450	*P2*	[d] 1,000	*I2* [c]	[d] 10	*R2*	6.14
	C3	12.50	*T3* [c]	388	*P3*	[d] 1,000	*I3* [c]	[d] 10	*R3*	[d] 6.25
Average		11.77		421		[d] 1,000		[d] 10		5.73
DS			*T1* [e]	332	*P1*	[d] 1,000	*I1* [e]	[d] 10		
			T2 [e]	431	*P2*	[d] 1,000	*I2* [e]	[d] 10		
			T3 [e]	356	*P3*	[d] 1,000	*I3* [e]	[d] 10		
Average				373		[d] 1,000		[d] 10		
DT			*T1* [f]	357	*P1*	[d] 1,000				
			T2 [f]	286	*P2*	[d] 1,000				
			T3 [f]	238	*P3*	[d] 1,000				
Average				294		[d] 1,000				
DU			*T1* [f]	337	*P1*	[d] 1,000				
			T2 [f]	320	*P2*	[d] 1,000				
			T3 [f]	316	*P3*	[d] 1,000				
Average				324		[d] 1,000				

[a] The compressive loads were applied 0.90 in. (one-third the thickness of the specimen) from the inside face of the specimen.
[b] A kip is 1,000 lb. [c] Span 7 ft 6 in. [d] Test discontinued. [e] Span 12 ft 0 in. [f] Span 14 ft 0 in.

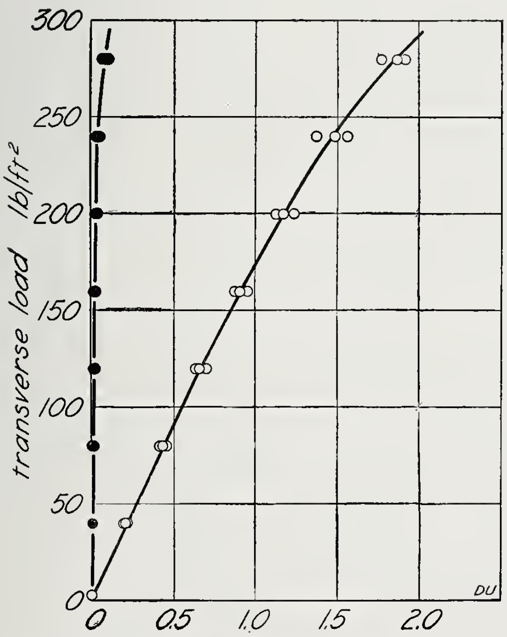

Figure 10.—*Transverse load on wall DR, load applied to the inside face.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *DR-T1*, *T2*, and *T3* on the span 7 ft 6 in. The load (pounds per square foot) is the total load divided by the product of the span and the width of the specimen.

adjusted to 0.188 in./min. The effects of the transverse load are given in table 5.

Table 5.—*Effects of transverse load on wall specimens DR-T1, T2, and T3, load applied on the inside face*

Description of effects	Specimen *T1*	Specimen *T2*	Specimen *T3*
	lb/ft²	*lb/ft²*	*lb/ft²*
Buckling of loaded face at midspan	207	297	240
Failure in compression of plywood in loaded face at midspan	[a] 423	430	358
Rupture of plywood in unloaded face under a loading roller	[a] 423	430	[a] 388
Horizontal shear failure of outside stud under a loading roller		[a] 450	[a] 388

[a] Maximum load on the specimen.

(*d*) *Concentrated Load*

The results of the concentrated load are given in table 4 and figure 11 for wall specimens *DR-P1*, *P2*, and *P3*. The concentrated load was applied to the outside face midway between two studs and 2 ft 1 in. from an end of the specimen.

After a load of 1,000 lb had been applied, the set in specimens *DR-P1*, *P2*, and *P3* was 0.101, 0.070, and 0.072 in., respectively. No other effects were observed.

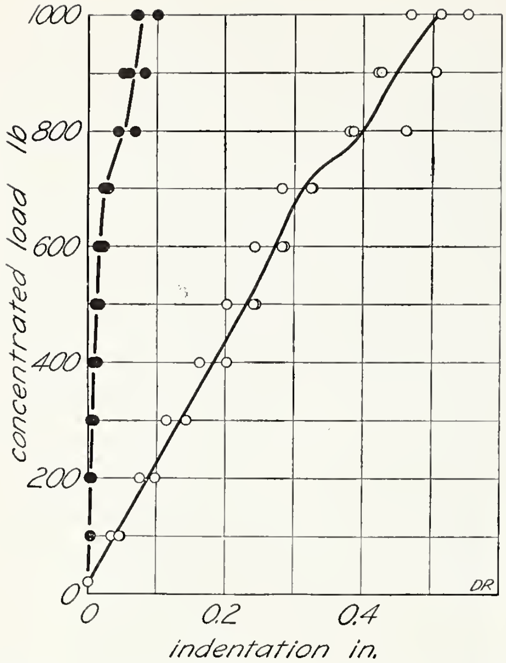

FIGURE 11.—*Concentrated load on wall DR, load applied to the outside face.*

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

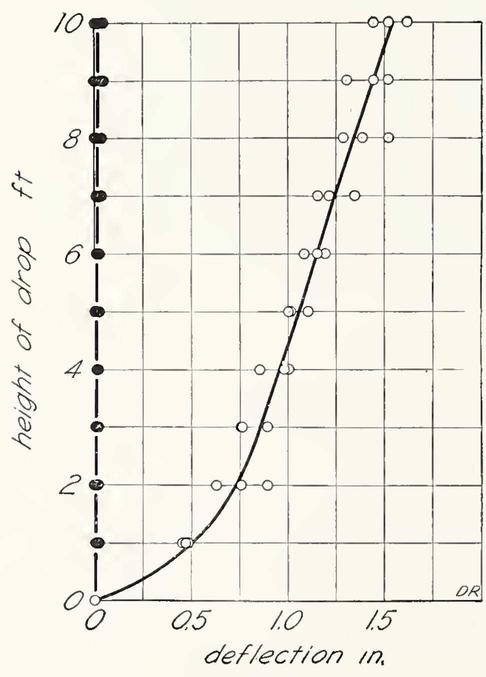

FIGURE 12.—*Impact load on wall DR, load applied to the inside face.*

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

(e) *Impact Load*

The results of the impact load on wall specimens *DR–I1*, *I2*, and *I3* are given in table 4 and in figure 12.

The impact loads were applied to the center of the inside face, the sandbag striking the plywood directly over the center stud.

After a drop of 10 ft, the set in specimens *DR–I1*, *I2*, and *I3* was 0.000, 0.004, and 0.002 in., respectively. No other effects were observed.

(f) *Racking Load*

Wall specimen *DR–R3* under racking load is shown in figure 13. The results of the rack-

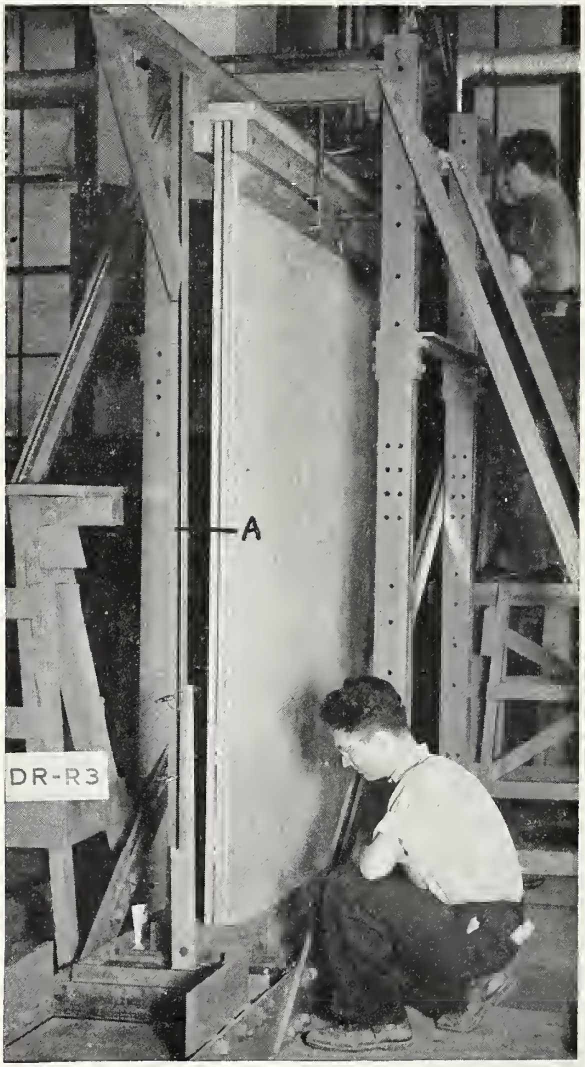

FIGURE 13.—*Wall specimen DR–R3 under racking load.* *A*, deformeter.

ing load on specimens *DR–R1*, *R2*, and *R3* are given in table 4 and figure 14.

To provide greater bearing for the loading plate on specimen *DR–R1*, the studs were sawed off flush with the plywood for 2 ft from the top of the specimen. This reduced the studs to ¾ by 1 in. and thereby decreased their strength.

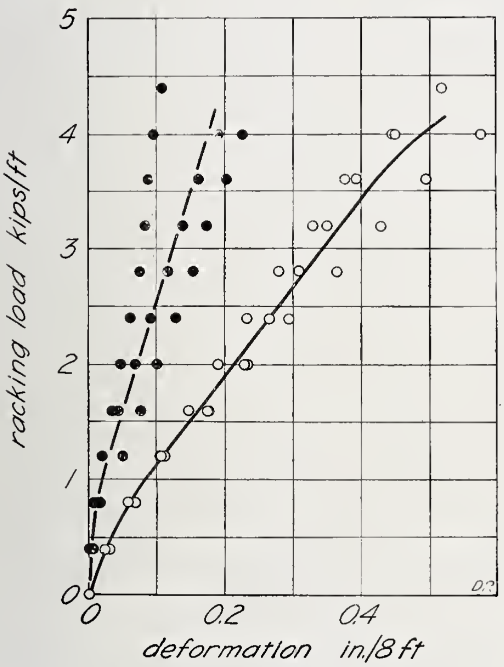

FIGURE 14.—*Racking load on wall DR.*

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

Under the maximum load on specimens *DR–R1* and *R2*, the studs adjacent to the loading plate failed 2 ft below the top of the specimen and both plywood faces ruptured near the loading plate. After a load of 6.25 kips/ft had been applied to specimen *DR–R3* the test was discontinued. There was no visible damage.

2. Floor *DS*

(*a*) *Sponsor's Statement*

Floor *DS* consisted of three sheets of Douglas fir plywood glued and nailed to two wood frames. One sheet of plywood was fastened between the frames; the other two sheets were fastened to the outer surfaces of the frames to form the flooring and the ceiling. The frames, consisting of joists and solid bridging, formed closed cells between the sheets of plywood.

The price of this construction in Washington, D. C., as of July 1937, was $0.47/ft².

(*1*) *Description of Specimens*

The floor specimens, shown in figure 15, were 13 ft 4 in. long, 4 ft 0 in. wide, and 8⅜ in. thick. Each specimen had two like wood frames to which three sheets of plywood were fastened. Each frame consisted of three joists, *A*, connected by 11 lines of solid bridging, *B*. The middle sheet of plywood, *C*, the flooring, *D*, and ceiling, *E*, each consisted of five pieces of plywood. All joints in the plywood were butted joints. All longitudinal joints were on joists and all transverse joints were on solid bridging. The joints in the three sheets were staggered so that in the vertical plane through a joint in one sheet there were no joints in the other two sheets.

Joists.—The joists, *A*, were Douglas fir, 1¾ by 3½ in. (nominal 2 by 4 in.), 13 ft 4 in. long, spaced 1 ft 4 in. on centers.

Bridging.—The solid bridging, *B*, was Douglas fir, 1¾ by 3½ in. (nominal 2 by 4 in.), 7⅛ in. and 1 ft 2¼ in. long, placed in 11 lines between the joists. One line was spaced 1 ft 2¼ in. on centers from the line at one end of the specimen and the other lines 1 ft 4 in. on centers. The bridging was fastened to the studs by corrugated fasteners, one on each side at each intersection.

Middle sheet.—The middle sheet, *C*, was five pieces of plywood, moisture-resistant type, ⅜ in. thick and 2 ft 0 in. wide. The five pieces were fastened to one frame by glue and nails. The longitudinal joint was over the middle joist. The middle sheet was offset longitudinally ⅞ in. from one end of the frame. The surface of the frame in contact with the plywood was first coated with the glue mixture applied with a brush. The nails were 3d blued lath nails, spaced 4 in., one line of nails along each joist and each line of bridging except at the joints, where there was a line in each piece of plywood. The second frame was attached to the middle sheet in the same manner by glue and 6d common nails, spaced 8 in., along each joist and line of bridging. These nails were toenailed into the joists and bridging of the

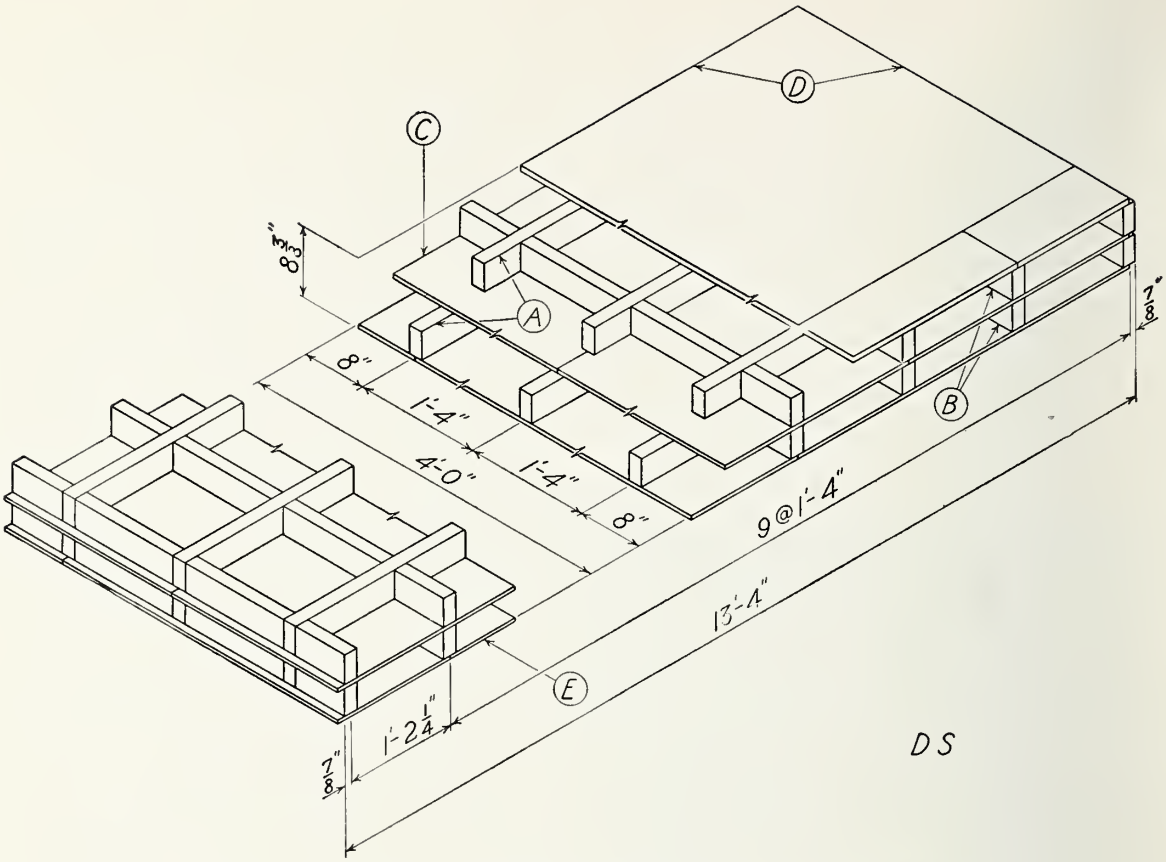

FIGURE 15.—*Floor DS.*

A, joists; *B*, solid bridging; *C*, plywood, middle sheet; *D*, plywood flooring; *E*, plywood ceiling.

second frame and extended through the middle sheet into the first frame.

Flooring.—The flooring, *D*, was five pieces of Douglas fir plywood, moisture-resistant type, ⅝ in. thick. Two pieces were 3 ft 4 in. wide and three were 8 in. wide. They were fastened by glue and nails to a frame. The longitudinal joint was over an outer joist. The flooring was offset longitudinally ⅞ in. from one end of the frame in the same direction as the middle sheet. The surface of the frame in contact with the flooring was first coated with the glue mixture applied with a brush. The nails were 6d finishing nails, spaced 4 in., one line of nails along each joist and line of bridging except at the joints, where there was a line of nails in each piece of plywood.

Ceiling.—The ceiling, *E*, was similar to the flooring except that the plywood was exterior type and ⅜ in. thick. It was fastened to the frame in the same manner as the flooring except that the longitudinal joint was centered over the other outer joist.

(*b*) *Transverse Load*

The results of the transverse load for specimens *DS-T1*, *T2*, and *T3* are given in table 4 and in figure 16. The effects of the transverse load are given in table 6. The transverse loads

TABLE 6.—*Effects of transverse load on floor specimens DS-T1, T2, and T3, load applied on the upper face*

Description of effects	Specimen *T1*	Specimen *T2*	Specimen *T3*
	lb/ft²	*lb/ft²*	*lb/ft²*
Separation of a ceiling joint and cracking of bridging directly over the joint	140	100	200
Separation of upper bridging from middle sheet	242	429	319
Rupture of an 8-in.-wide ceiling sheet under a loading roller	-----	-----	313
Horizontal shear failure of a lower joist between loading rollers	292	400	313
Horizontal shear failure of upper joist between loading rollers	-----	325	350
Maximum load	332	431	356

were applied to the upper face. The speed of the movable head of the testing machine was adjusted to 0.17 in./min.

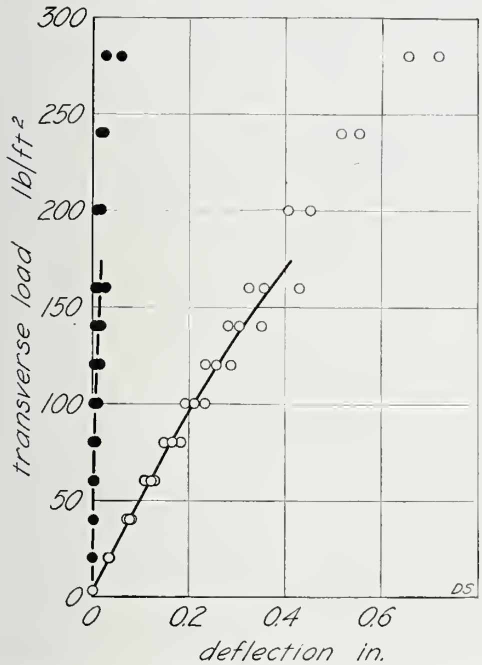

FIGURE 16.—*Transverse load on floor DS, load applied to the upper face*

Load-deflection (open circles) and load-set (solid circles) results for specimens *DS-T1*, *T2*, and *T3* on the span 12 ft 0 in. The load (pounds per square foot) is the total load divided by the product of the span and the width of the specimen.

Floor specimen *DS-T1* after the transverse test is shown in figures 17 and 18 and specimen *DS-T2* in figure 19.

(c) *Concentrated Load*

The results of the concentrated load on specimens *DS–P1*, *P2*, and *P3* are given in table 4 and figure 20. The concentrated load was applied to the upper face midway between joists and 3 ft 4 in. from one end of the specimen. It was applied at the middle of a cell.

After a load of 1,000 lb had been applied, the set in specimens *DS–P1*, *P2*, and *P3* was 0.041, 0.042, and 0.043 in., respectively. No other effect was observed.

(d) *Impact Load*

Floor specimen *DS–I2* during the impact test is shown in figure 21. The results for specimens *DS–I1*, *I2*, and *I3* are given in table 4 and figure 22.

The impact loads were applied to the center of the upper face, the sandbag striking the plywood over the center joist and bridging.

After a drop of 10 ft the set in specimens *DS–I1*, *I2*, and *I3* was 0.000, 0.007, and 0.043 in., respectively. No other effect was observed

FIGURE 17.—*Floor specimen DS-T1 after the transverse test.*

The upper joist and the upper solid bridging have separated from the middle sheet of plywood.

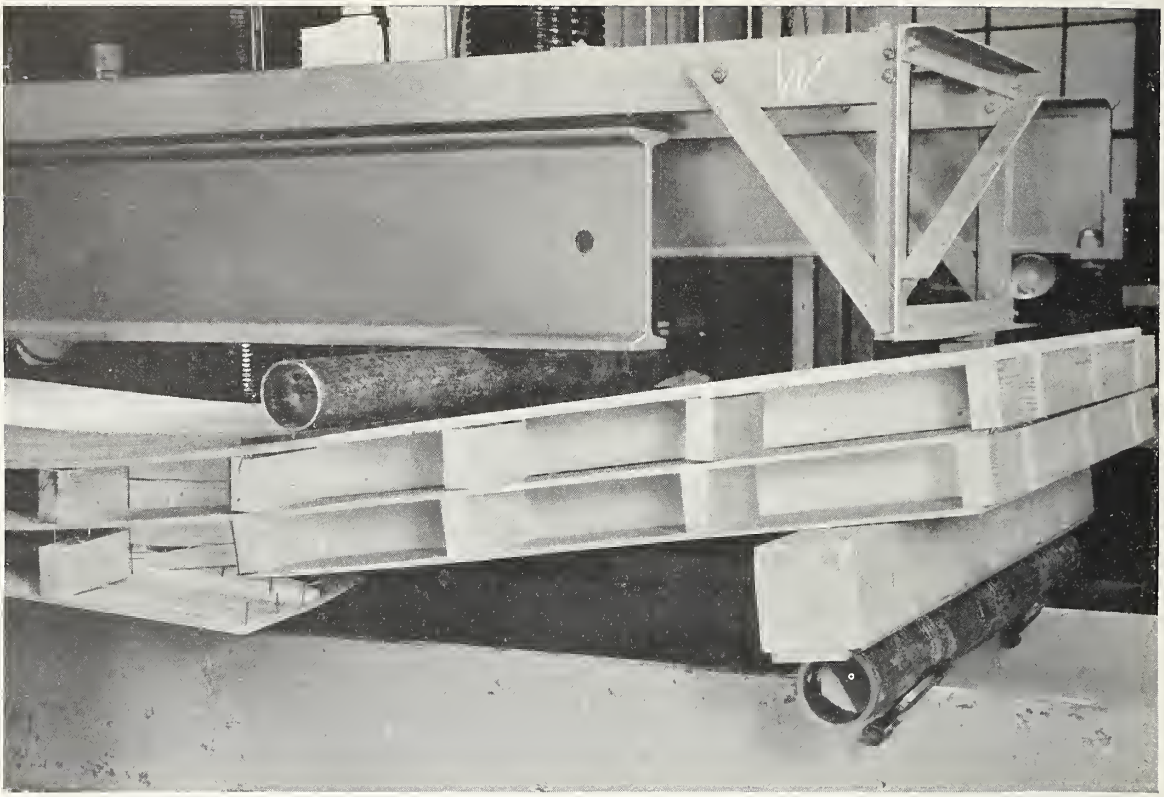

FIGURE 18.—*Floor specimen DS-T1 after the transverse test.*

The upper joist and the upper solid bridging have separated from the middle sheet of plywood. The piece of plywood in the lower face was forced down when the lower joist failed.

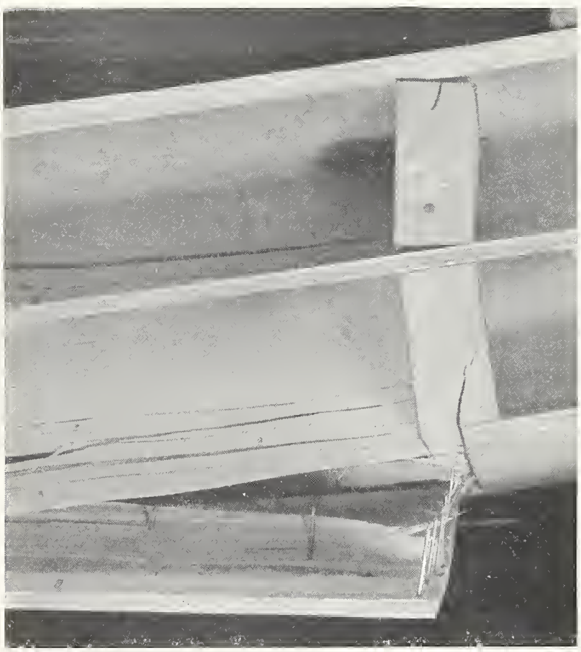

FIGURE 19.—*Floor specimen DS-T2 after the transverse test.*

The butted joint in the lower sheet of plywood failed when the solid bridging failed in tension across the grain, and, when the lower joist failed, the piece at the left was forced down, pulling the nails from the bridging and the joist.

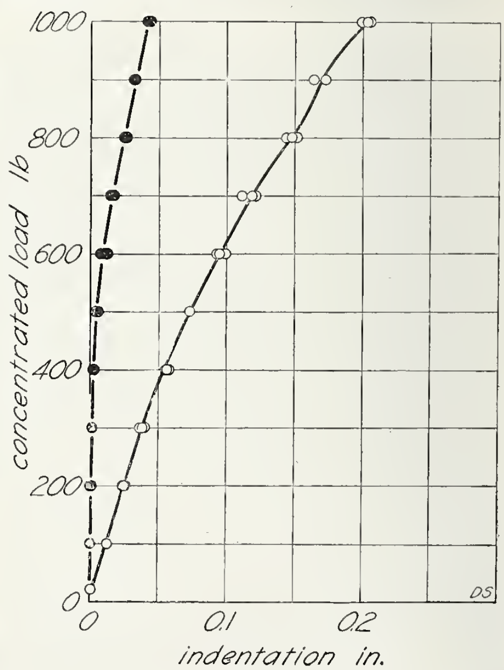

FIGURE 20.—*Concentrated load on floor DS, load applied to the upper face.*

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

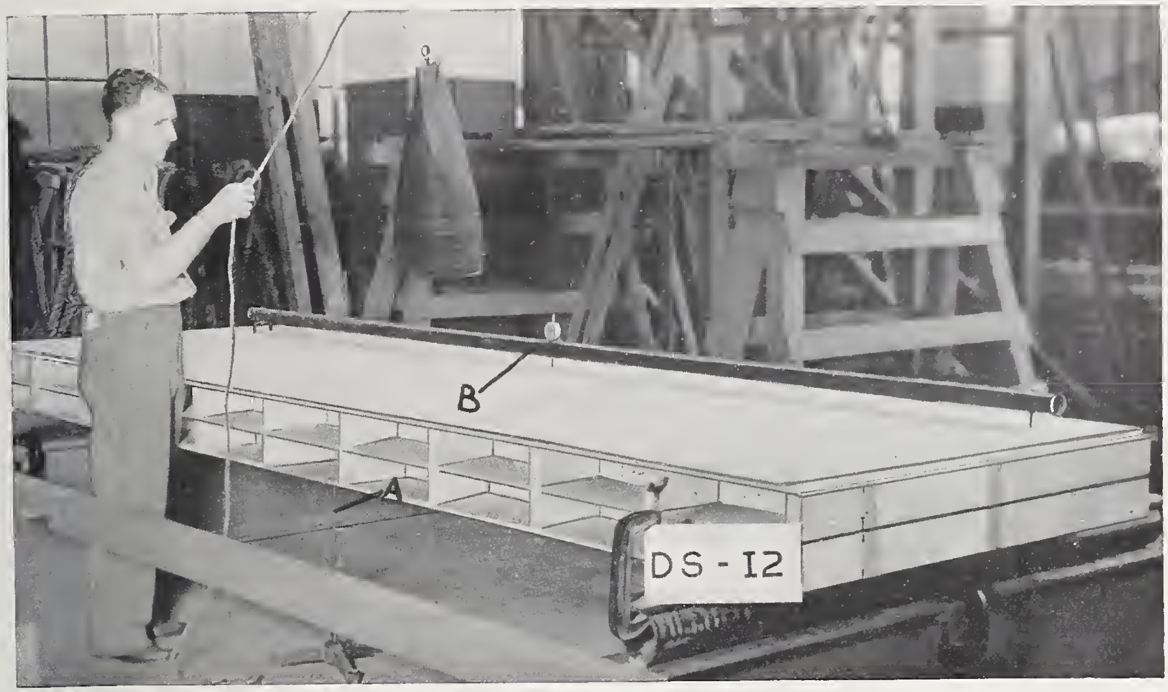

Figure 21.—*Floor specimen DS-I2 during the impact test.*

A, deflectometer; *B*, set gage

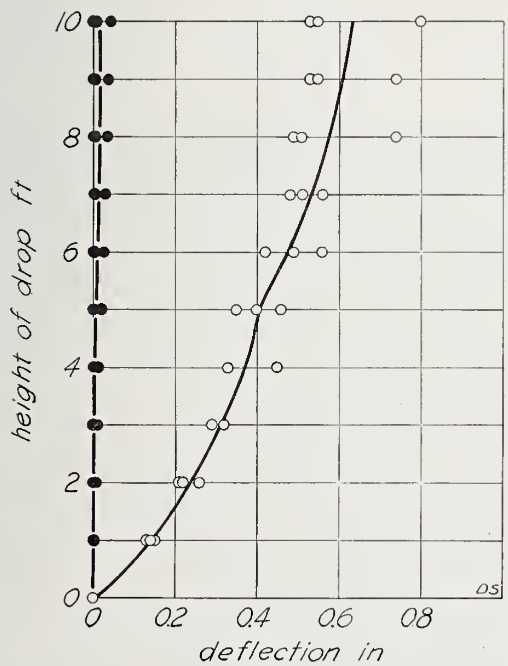

Figure 22.—*Impact load on floor DS, load applied to the upper face.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *DS-I1*, *I2*, and *I3* on the span 12 ft 0 in. The load (pounds per square foot) is the total load divided by the product of the span and the width of the specimen.

3. Roof *DT*

(*a*) *Sponsor's Statement*

Roof *DT* consisted of three sheets of Douglas fir plywood glued and nailed to two wood frames. One sheet of plywood was fastened between the frames; the other two sheets were fastened to the outer surfaces of the frames to form the roofing and the ceiling. The frames, consisting of rafters and solid bridging, formed closed cells between the sheets of plywood.

The price of this construction in Washington, D. C., as of July 1937, was \$0.53/ft^2.

(*1*) *Description of Specimens*

The roof *DT*, shown in figure 23, was similar to floor *DS* except for the following: The specimens were 14 ft 8 in. long (not 13 ft 4 in.) and there were 12 lines of solid bridging between rafters (not 11). The roofing, *D*, was of exterior-type plywood and the ceiling, *E*, of the moisture-resistant type.

(*b*) *Transverse Load*

The results of the transverse load on roof specimens *DT–T1*, *T2*, and *T3* are given in table 4 and figure 24. The transverse loads were applied to the upper face. The speed of the movable head of the testing machine was adjusted to 0.21 in./min.

Under a load of 171, 213, and 123 lb/ft^2 on specimens *DT–T1*, *T2*, and *T3*, respectively, a transverse joint in the ceiling began to separate, and cracks appeared in the bridging directly over the transverse joint. Under a load of 357 lb/ft^2 for specimen *DT–T1*, 279 lb/ft^2 for *T2*, and 200 lb/ft^2 for *T3*, the upper bridging and rafters separated from the middle sheet. Under the maximum load, an upper and a lower rafter in specimen *T1* failed in horizontal shear between the loading rollers and a lower rafter in specimens *T2* and *T3* failed under one loading roller.

Roof specimen *DT–T1* after the transverse test is shown in figures 25 and 26.

(c) *Concentrated Load*

The results of the concentrated load on roof specimens *DT–P1*, *P2*, and *P3* are given in table 4 and figure 27.

The concentrated load was applied at the middle of a cell to the upper face midway between two rafters and 3 ft 4 in. from one end of the specimen.

After a load of 1,000 lb had been applied, the set in specimens *DT–P1*, *P2*, and *P3* was 0.021, 0.030, and 0.027 in., respectively. No other effects were observed.

4. Roof *DU*

(a) *Sponsor's Statement*

Roof *DU* was a demountable construction consisting of three sheets of Douglas fir plywood glued and nailed to two wood frames. One sheet of plywood was fastened between the frames; the other two sheets were fastened to the outer surfaces of the frames to form the roofing and the ceiling. The frames, consisting of rafters and solid bridging, formed closed cells between the plywood.

The price of this construction in Washington, D. C., as of July, 1937, was \$0.53/ft^2.

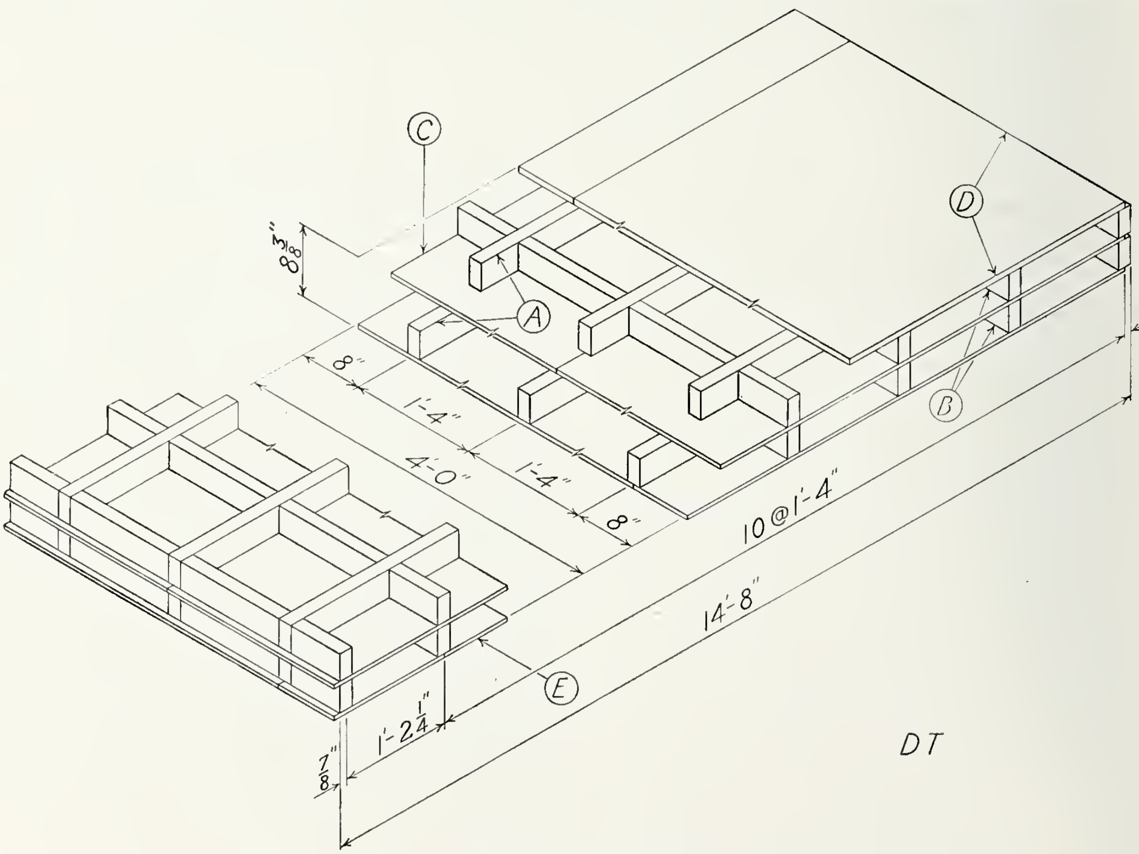

Figure 23.—*Roof DT.*
A, rafters; *B*, solid bridging; *C*, plywood, middle sheet; *D*, plywood roofing; *E*, plywood ceiling.

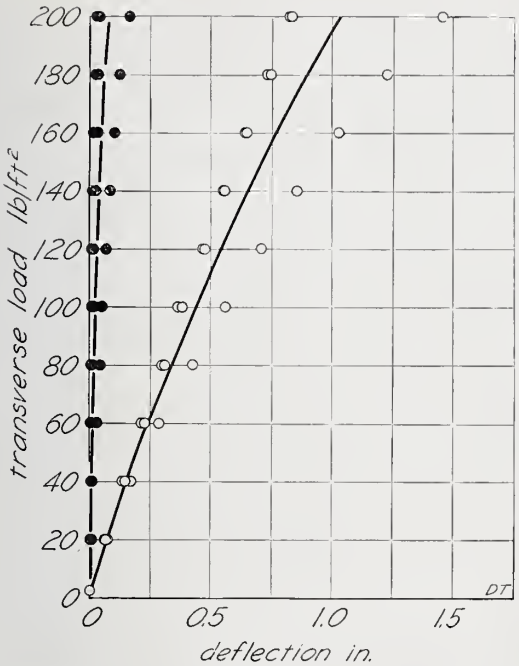

FIGURE 24.—*Transverse load on roof DT, load applied to the upper face.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *DT-T1*, *T2*, and *T3* on the span 14 ft 0 in. The load (pounds per square foot) is the total load divided by the product of the span and the width of the specimen.

FIGURE 26.—*Roof specimen DT-T1 after the transverse test.*

The butted joint in the lower sheet of plywood failed when the solid bridging failed.

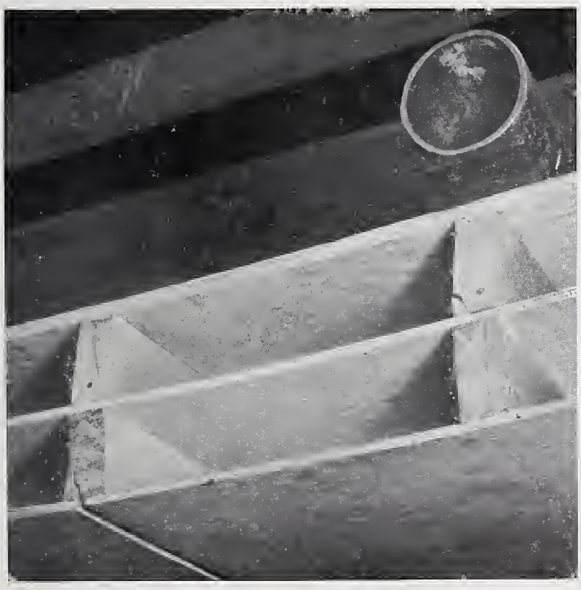

FIGURE 25.—*Roof specimen DT-T1 after the transverse test.*

The butted joint in the lower sheet of plywood failed when the solid bridging failed.

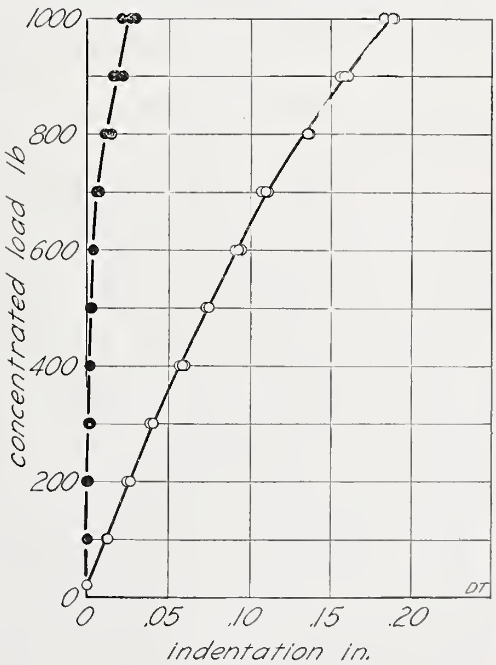

FIGURE 27.—*Concentrated load on roof DT, load applied to the upper face.*

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

(1) *Description of Specimens*

The roof *DU*, shown in figure 28, was similar to roof *DT* except for the following: The specimens were 6⅝ in. thick (not 8⅜ in). The thickness was less than that for roof *DT* because the rafters and bridging in the upper frame were flatwise (not edgewise).

The middle sheet of plywood first was fastened to the lower frame (rafters and bridging edgewise) as for floor *DS* and roof *DT*, then to the upper frame (rafters and bridging flatwise), by glue and nails extending through the plywood adjacent to the members of the lower frame and into the upper frame. There were no toenails in roof *DU*.

Each sheet consisted of three pieces of plywood with two continuous transverse joints. There were no longitudinal joints. The roofing, middle sheet, and ceiling were offset 1¾ in. both longitudinally and laterally; the roofing and ceiling in opposite directions from the middle sheet. In a demountable house the wall, floor, and roof panels are connected by inserting the tongues on one panel into grooves in the other.

(b) *Transverse Load*

Roof specimen *DU–T2* under transverse load is shown in figure 29.

The results of the transverse load on specimens *DU–T1*, *T2*, and *T3* are given in table 4 and figure 30.

The transverse load was applied to the upper face. The speed of the movable head of the testing machine was adjusted to 0.27 in./min.

Under loads of 261, 246, and 200 lb/ft^2 for specimens *DU–T1*, *T2*, and *T3*, respectively, a transverse joint in the ceiling began to separate. A piece of the ceiling on specimen *T2* separated from the lower rafters under a load of 284 lb/ft^2, and a piece of the middle sheet on specimen *T3* separated from the lower rafters under a load of 289 lb/ft^2. Under the maximum load on specimen *T1*, the lower rafters separated from the middle sheet and ceiling and a lower rafter failed in horizontal shear between the loading rollers. In specimen *T2* under the maximum load, a piece of the middle sheet separated from the lower rafters and a lower rafter ruptured at midspan. Under the maximum load on spec-

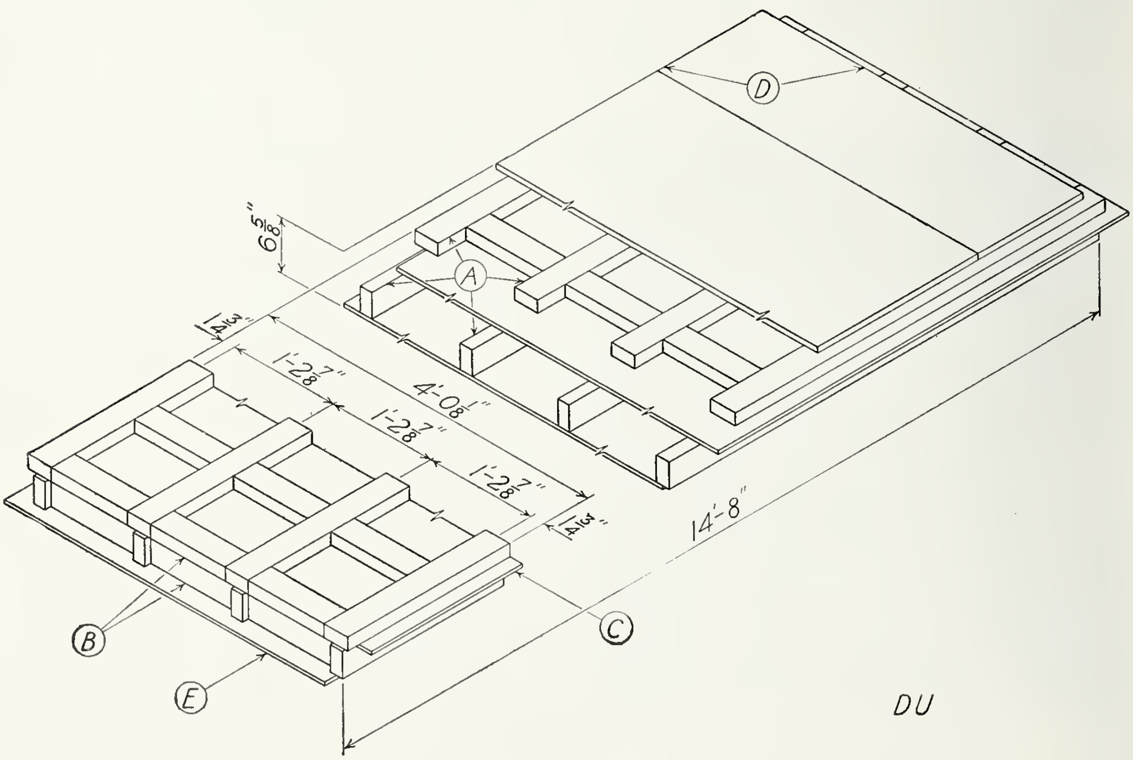

FIGURE 28.—*Roof DU.*

A, rafters; *B*, solid bridging; *C*, plywood, middle sheet; *D*, plywood roofing; *E*, plywood ceiling.

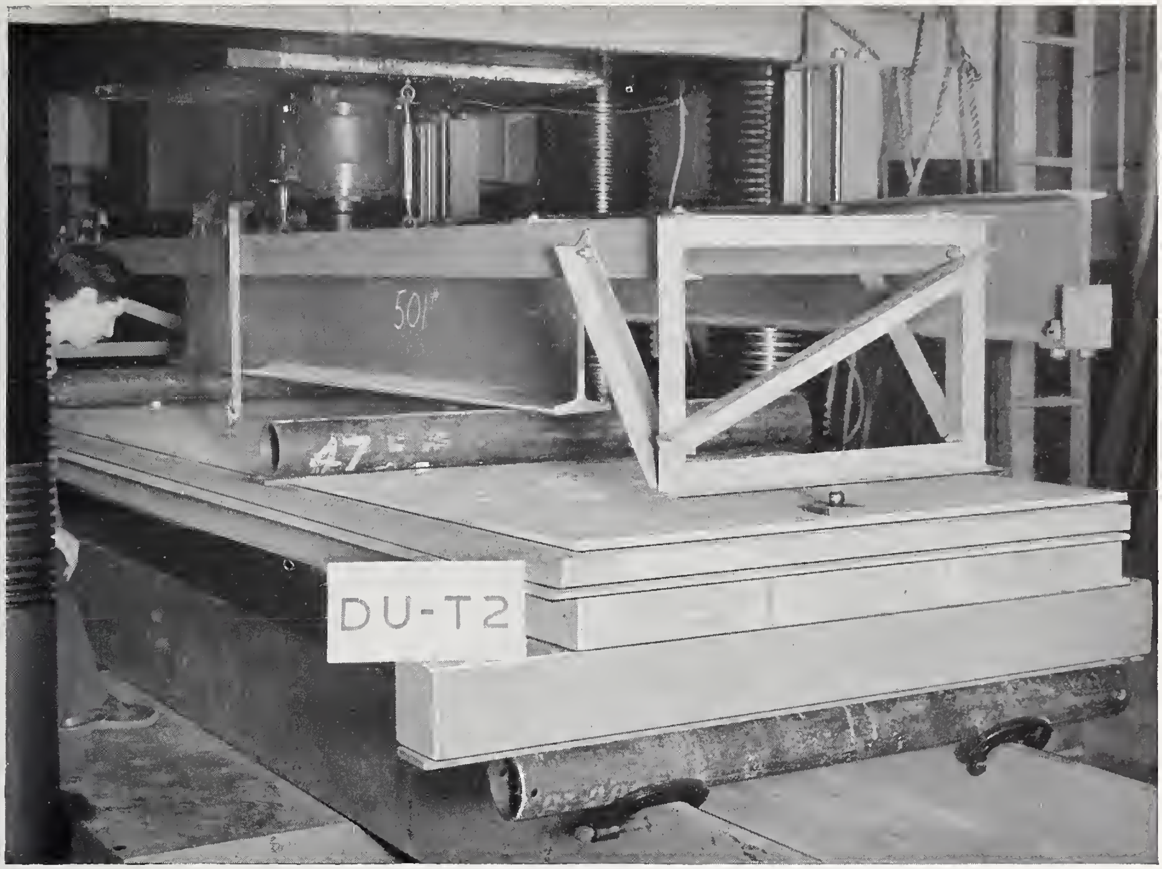

FIGURE 29.—*Roof specimen DU-T2 under transverse load.*

imen *T3*, the two outer lower rafters failed in horizontal shear under a loading roller.

(c) Concentrated Load

The results of the concentrated load on roof specimens *DU-P1*, *P2*, and *P3* are given in table 4 and figure 31. The concentrated load was applied to the upper face midway between two rafters and 3 ft 4 in. from an end of the specimen. It was applied at the middle of a cell.

After a load of 1,000 lb had been applied, the set in specimens *DU-P1*, *P2*, and *P3* was 0.022, 0.038, and 0.040 in., respectively. No other effects were observed.

VI. HEAT-TRANSFER PROPERTIES

1. Walls *HT60*, *HT61*, and *HT62*

Walls *HT60*, *HT61*, and *HT62* consisted of three sheets of Douglas fir plywood glued and nailed to two wood frames. One sheet of plywood was fastened between the frames; the other two sheets were fastened to the outer surfaces of the frames for the faces of the wall. The frames, consisting of studs and girts, formed closed cells between the plywood. These closed air cells provided thermal insulation.

The price of this construction in Washington, D. C., as of July 1937, was $0.37/ft^2.

(a) Description of Specimens

Walls *HT60*, *HT61*, and *HT62* were identical with wall *DR* except for the aluminum paint. Specimen *HT60*, shown in figure 32, was 8 ft 0 in. high, 5 ft 4 in. wide, and $2\frac{11}{16}$ in. thick. There were five studs in each frame. One coat of aluminum paint was applied to each surface of the middle sheet of plywood.

Specimen *HT61* was identical with *HT60* except that two coats of the same paint were applied on the warm-side surface of the middle

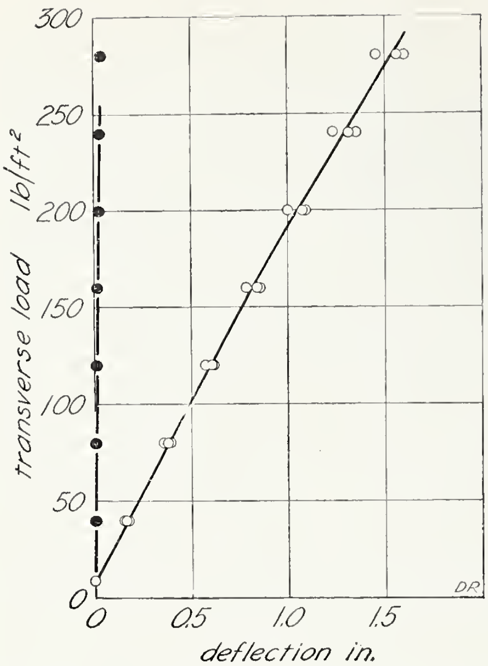

FIGURE 30.—*Transverse load on roof DU, load applied to the upper face.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *DU-T1, T2,* and *T3* on the span 14 ft 0 in. The load (pounds per square foot) is the total load divided by the product of the span and the width of the specimen.

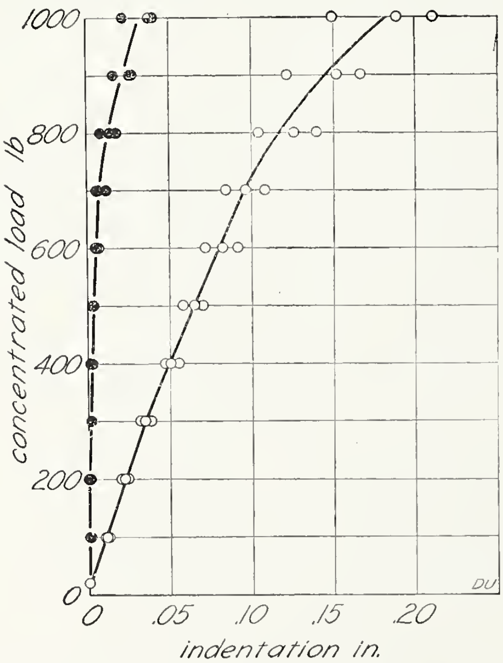

FIGURE 31.—*Concentrated load on roof DU, load applied to the upper face.*

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

sheet of plywood. There was no paint on the cold-side surface.

Specimen *HT62* was identical with *HT60* except that there was no paint on this specimen.

(*b*) *Test Results*

The results of the heat-transfer tests are given in table 7.

TABLE 7.—*Heat-transfer coefficeints and test data for wall specimens HT60, HT61,* and *HT62*

Item [a]	*HT60*	*HT61*	*HT62*
Observed thermal transmittance .... *u*	0.20	0.22	0.24
Corrected thermal transmittance .... *U*	.22	.24	.26
Thermal conductance .... *C*	.26	.30	.33
Warm surface film conductance .... *fi*	1.91	1.96	1.96
Cold surface film conductance .... *fo*	1.64	1.62	1.57
Temperature averages:			
Warm side:	°*F*	°*F*	°*F*
Air	70.5	70.5	70.5
Surface over air space	64.1	63.3	62.7
Surface over stud	60.5	60.0	59.9
Surface over frame joint	56.6	57.0	56.0
Surface, weighted average	63.1	62.4	61.9
Cold side:			
Air	0.0	−0.3	−0.6
Surface over air space	7.8	9.1	9.7
Surface over stud	10.7	10.1	11.2
Surface over frame joint	13.2	13.8	12.9
Surface, weighted average	8.6	9.5	10.1
Temperature differences:			
Air to air	70.5	70.8	71.1
Surface to surface	54.5	52.9	51.8
Surface to air, warm side	7.4	8.1	8.6
Surface to air, cold side	8.6	9.8	10.7

[a] The definitions of *u, U,* and *C,* representing the various coefficients of heat transmission, are:

u=number of Btu per hour transmitted through each square foot of specimen for each degree Fahrenheit difference in temperature between the air on the two sides, as observed under the test conditions.

U=*u* corrected for a 15-mph wind outside and zero wind inside by means of the factors *fi*=1.65 and *fo*=6.00, taken from the ASHVE "Guide."

C=number of Btu transmitted through each square foot of specimen for each degree Fahrenheit difference in temperature between the surfaces of the two sides as observed under the test conditions.

In this table the heat transmission of the specimen is expressed in three ways. Two include the effect of surface-film coefficients, and the third is independent of them. The first result, *u*, is the thermal transmittance of the specimen as observed under test conditions. Under these conditions, the warm-surface-film conductance, *fi*, and the cold-surface-film conductance *fo*, were those given in the table.

Since the air velocity and its effect on the two surfaces of the specimen may not be the same for different conditions, it seemed desirable to correct the observed thermal transmittance for a wind velocity of 15 mph on the outside face of the wall and zero velocity on the inside face, by means of the factors *fi*=1.65 and *fo*=6.00, as recommended in the ASHVE "Guide."

The thermal conductance, C, of the specimen is also presented, and this represents the number of Btu per hour transmitted through each square foot of specimen for each degree Fahrenheit difference in temperature between the surfaces of the two sides as observed under the test conditions.

The test data show that the surface temperatures of the specimens over intersections of studs and girts were considerably lower on the warm side and higher on the cold side than the surface temperatures over the studs. Since there were eight corrugated metal fasteners at each of these intersections, it is evident that the conductance at each frame joint was increased considerably by the presence of the fasteners.

The data also indicate by the differences in the temperatures of the surfaces over the air cells and over the studs that the conductance through the studs is greater than the conductance across the air cells in the wall. Although some improvement in this respect might be accomplished by staggering the studs and girts on the two sides of the middle sheet of plywood, the complications that would be entailed from a construction standpoint might far outweigh the improvement in insulating value that could be attained.

The U value of a wall construction such as *HT62*, with no reflective surfaces, as computed by means of the factors listed in the ASHVE "Guide," is 0.252. The test result is

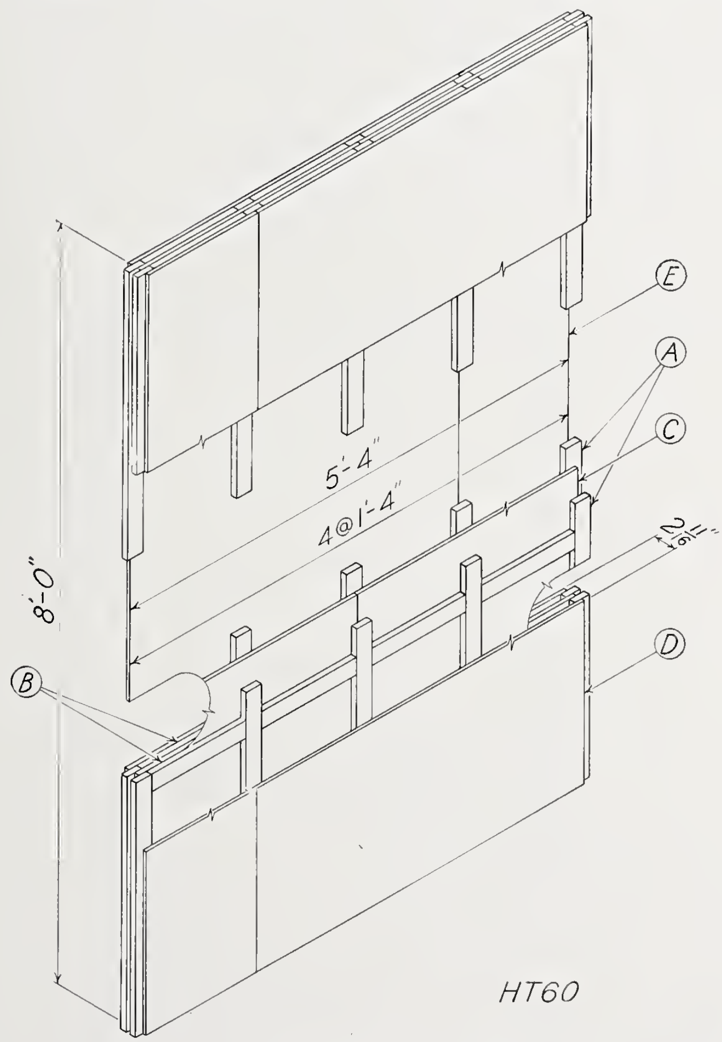

FIGURE 32.—*Wall HT60.*

A, studs; *B*, girts; *C*, plywood, middle sheet; *D*, plywood, outside face; *E*, plywood, inside face.

in agreement with this computed value of U and is slightly higher, probably because of the large conductance through the joints of the specimen which is not taken into account in the computed U value.

The values of the corrected thermal transmittance, U, before being rounded to two significant figures, as presented in the table, were 0.217, 0.244, and 0.260 for specimens *HT60*, *HT61*, and *HT62*, respectively. From these values it can be calculated that two coats of the aluminum paint applied on the warm-side surface of the middle sheet of plywood reduced the U value by 6 percent; and that one coat of paint on each face of the middle plywood sheet reduced the U value by 16 percent, or 8 percent for each painted face. Apparently, one coat of the paint was more effective than two applied one over the other. Variability in the materials composing the specimens or in details of their assembly may have contributed to this result. However, a possible explanation for the apparent greater effectiveness of single coats of paint is that a relatively larger proportion of the vehicle of the paint is absorbed into the wood in the case of a first coat than is absorbed when a second coat is applied over the first. Since the thermal reflectivity of the surface depends upon the flake surfaces being coated with as little vehicle as possible, one coat may provide the most reflective surface. The test result is not conclusive, but it is an indication that there is no economy in applying more than one coat of paint.

VII. ADDITIONAL COMMENTS BY SPONSOR

Several years ago, one house using this type of construction was built in Florida. Since then some of the details of connections have been revised with a view to simplifying and improving the methods of erection.

At the present time the construction is designed to be erected on any convential type of masonry foundation. One special design uses three concrete walls as foundation, one under the middle and two along the sides of the building, the ends open.

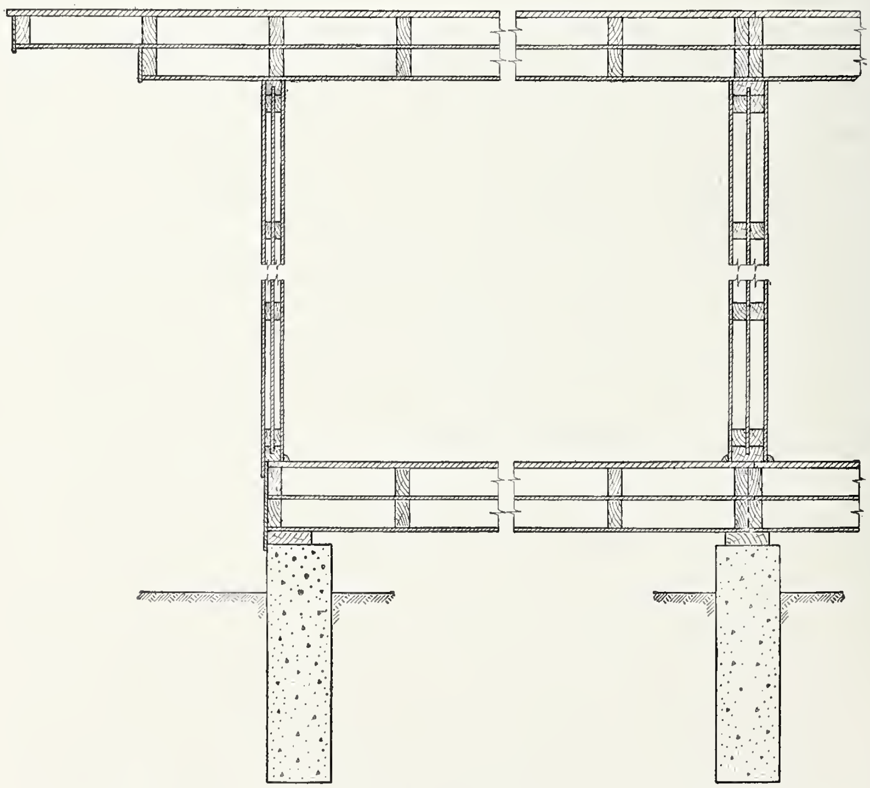

FIGURE 33.—*Section of a typical "Multiple Box-Girder Plywood Panel" house.*

To increase the strength of the transverse joints in the plywood faces the design has been changed to have a strip of plywood about 8 in. wide at the joints along the solid bridging. The pieces of plywood will be butted at midwidth of the strip. From the standpoint of fabrication, the strip of plywood is preferable to a scarfed joint in the faces.

The waterproof adhesive used in fabricating the plywood and the waterproof glue used in joining the sections withstand exposure to the weather.

Partitions are similar to walls except that the frames are made from material 1⅝ in. thick. The frames in partitions are thicker than those in walls because the loads are greater.

The thickness of the frames is sufficient to permit the installation of concealed pipes, ducts, and conduits.

A section of a typical house is shown in figure 33.

The descriptions and drawings were prepared by E. J. Schell and G. W. Shaw, of the Building Practices and Specifications Section, under the supervision of V. B. Phelan.

The heat-transfer properties were determined by H. E. Robinson, of the Heat Transfer Section, under the supervision of R. S. Dill.

The structural properties were determined by the Engineering Mechanics Section, under the supervision of H. L. Whittemore and W. G. Hoback, with the assistance of H. O. Bost, R. Goldberg, E. I. Peizer, L. R. Sweetman, and H. L. Weiss.

Washington, September 17, 1942.

BUILDING MATERIALS AND STRUCTURES REPORTS

[Continued from cover page II]

BMS32	Structural Properties of Two Brick-Concrete-Block Wall Constructions and a Concrete-Block Wall Construction Sponsored by the National Concrete Masonry Association	10¢
BMS33	Plastic Calking Materials	10¢
BMS34	Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 1	10¢
BMS35	Stability of Sheathing Papers as Determined by Accelerated Aging	10¢
BMS36	Structural Properties of Wood-Frame Wall, Partition, Floor, and Roof Constructions with "Red Stripe" Lath Sponsored by The Weston Paper and Manufacturing Co	10¢
BMS37	Structural Properties of "Palisade Homes" Constructions for Walls, Partitions, and Floors Sponsored by Palisade Homes	10¢
BMS38	Structural Properties of Two "Dunstone" Wall Constructions Sponsored by the W. E. Dunn Manufacturing Co	10¢
BMS39	Structural Properties of a Wall Construction of "Pfeifer Units" Sponsored by the Wisconsin Units Co	10¢
BMS40	Structural Properties of a Wall Construction of "Knap Concrete Wall Units" Sponsored by Knap America Inc	10¢
BMS41	Effect of Heating and Cooling on the Permeability of Masonry Walls	10¢
BMS42	Structural Properties of Wood-Frame Wall and Partition Constructions with "Celotex" Insulating Boards Sponsored by The Celotex Corporation	15¢
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BMS45	Air Infiltration Through Windows	10¢
BMS46	Structural Properties of "Scot-Bilt" Prefabricated Sheet-Steel Constructions for Walls, Floors, and Roofs Sponsored by The Globe-Wernicke Co	10¢
BMS47	Structural Properties of Prefabricated Wood-Frame Constructions for Walls, Partitions, and Floors Sponsored by American Houses, Inc	10¢
BMS48	Structural Properties of "Precision-Built" Frame Wall and Partition Constructions Sponsored by the Homasote Co	10¢
BMS49	Metallic Roofing for Low-Cost House Construction	10¢
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BMS51	Structural Properties of "Tilecrete Type A" Floor Construction Sponsored by the Tilecrete Co	10¢
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BMS65	Methods of Estimating Loads in Plumbing Systems	10¢
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