U. S. DEPARTMENT OF COMMERCE

BUILDING MATERIALS AND STRUCTURES

REPORT BMS15

Structural Properties of "Wheeling Long-Span Steel Floor" Construction Sponsored by the Wheeling Corrugating Company

by

HERBERT L. WHITTEMORE
AMBROSE H. STANG *and*
VINCENT B. PHELAN

NATIONAL
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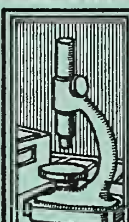

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ISSUED MARCH 21, 1939

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UNITED STATES GOVERNMENT PRINTING OFFICE · WASHINGTON · 1939

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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. Practically all of these constructions were sponsored by groups within the building industry which advocate and promote the use of such constructions and which have built and submitted representative specimens as outlined in report BMS2, Methods of Determining the Structural Properties of Low-Cost House Constructions. The sponsor is responsible for the representative character of the specimens and for the detailed description given in each report. The Bureau is responsible for the accuracy of the test data.

This report covers only the load-deformation relations and strength of the structural element submitted when subjected to transverse, impact, and concentrated loads by standardized methods simulating the loads to which the element would be subjected in actual service. It may be feasible to determine later the heat transmission at ordinary temperatures and the fire resistance of this same construction and perhaps other properties.

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

LYMAN J. BRIGGS, *Director.*

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CONTENTS

ABSTRACT

For the program on the determination of the structural properties of low-cost house constructions, the Wheeling Corrugating Co. submitted six specimens representing their "Wheeling Long-Span Steel Floor" construction.

The specimens were subjected to transverse, impact, and concentrated loads. For each of these loads three like specimens were tested, the concentrated-load tests being made on undamaged portions of the specimens used for the impact tests. The deformation under load and the set after the load was removed were measured for uniform increments of load, except for concentrated loads, for which the set only was determined. The strength under transverse load was also determined. The results are presented graphically and in a table.

I. INTRODUCTION

In order to provide technical facts on the performance of constructions which might be used in low-cost houses, to discover promising constructions, and ultimately to determine the properties necessary for acceptable performance, the National Bureau of Standards has invited the building industry to cooperate in a program of research on building materials and structures for use in 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,[1] and that part of the program relating to structural properties in report BMS2, Methods of Determining the Structural Properties of Low-Cost House Constructions.[2]

Conventional wood-frame constructions, including those for floors, have been subjected by the Forest Products Laboratory of the United States Department of Agriculture to a series of standardized laboratory tests to provide data on the properties of some constructions for which the behavior in service is generally known. These data will be given in a subsequent report in this series.

This report describes the structural properties of a floor construction sponsored by one of the manufacturers in the building industry. The specimens were subjected to transverse, impact, and concentrated loads, simulating loads to which the floor of a house is subjected. In actual service, transverse loads are applied to floors by furniture and by the occupants; impact loads by objects falling on the floor or by persons jumping on the floor; and concentrated loads by furniture, for example, the legs of a piano.

The deformation and set under each increment of load were measured because the suitability of a floor construction depends in part on its resistance to deformation under load and whether it returns to its original size and shape when the load is removed.

[1] Price 10 cents. See cover page II.

[2] Price 10 cents.

II. SPONSOR AND PRODUCT

The specimens were submitted by the Wheeling Corrugating Co., Wheeling, W. Va., and represented a construction marketed under the trade name "Wheeling Long-Span Steel Floor System." This construction consisted of sheet-steel channel-shaped joists, assembled by welding the wide overlapping upper flanges to form a continuous sheet-steel subfloor to which the finish floor and ceiling were attached.

III. SPECIMENS AND TESTS

The floor construction was assigned the symbol *AY* and the specimens were assigned designations in accordance with table 1.

TABLE 1.—*Specimen designations*

Specimen designation	Load	Load applied
T1, T2, T3	Transverse	Upper face.
I1, I2, I3	Impact	Do.
P1, P2, P3 [a]	Concentrated	Do.

[a] These specimens were undamaged portions of the specimens used for the impact tests.

The specimens were tested in accordance with BMS2, Methods of Determining the Structural Properties of Low-Cost House Constructions.[3] This report also gives the requirements for the specimens and describes the presentation of the results of the tests, particularly the load-deformation graphs.

The specimens were tested on July 18 and 19, 1938, at either 28 or 29 days after the finish coat of plaster had been applied. The sponsor's representative witnessed the tests.

IV. FLOOR *AY*

1. SPONSOR'S STATEMENT

(*a*) *Materials*

Steel.—Hot-rolled copper-bearing sheets, tensile strength 45,000 to 55,000 lb/in^2. The chemical composition of the steel is given in table 2. Wheeling Steel Corporation's "Cop-R-Loy."

Paint.—Three parts black asphaltum paint and four parts naphtha. Blue Ribbon Paint Co.

Welds.—Fillet welds made by metal arc welding, using direct current. The welding rods were Lincoln Arc Welding Co.'s "Fleetweld," No. 7 coated.

TABLE 2.—*Chemical composition of the steel*

Element	Content	
	Minimum	Maximum
	Percent	*Percent*
Carbon	0.08	0.12
Manganese	.30	.45
Phosphorus		.015
Sulfur		.0355
Copper	.20	.25

Asphalt roofing.—Rag-felt base, saturated with asphalt, mica-surfaced; weight, 55 lb/108 ft^2. Ruberoid Co.'s "Ruberoid Smooth Roll Roofing No. 100."

Asphalt.—Softening point 175° to 190° F. Philip Carey Co.'s "Manco."

Wood.

Sleepers, beech, maple, and ash, about 80 percent of material was practically clear stock (free from defects) and the other 20 percent contained a few minor defects. These three species have about equal strengths.

Flooring, oak, white, clear, tongued-and-grooved, end-matched.

The species and grades of the woods were determined by representatives of the Forest Service of the United States Department of Agriculture.

Screws.—Self-tapping, ⅝ in., No. 14 (0.242-in. diam), 10 threads per in., binding head, hardened. Parker-Kalon Co.'s "Type *A*."

Nails.

Roofing, galvanized, 1 and 1¼ in. long, No. 10 gage (0.1350-in. diam), with ½-in. diam paper-felt washers.

Finishing, 6d, 2 in. long, No. 13 gage (0.0915-in. diam).

Lath.—Flat-ribbed, expanded-metal, ⅜- by ⅝-in. diamond mesh, formed from open-hearth sheet steel, No. 28 United States Standard Gage (0.0153 in. thick), coated with black paint; weight, 3.4 lb/yd^2. Wheeling Steel Corporation's "Bar *X*."

Lath clips.—Wire, steel, annealed, galvanized, No. 14 steel wire gage (0.0800-in. diam before galvanizing).

Plaster.—The materials used for the plaster were United States Gypsum Co.'s "Red Top" gypsum plaster, Potomac River building sand,

[3] Price 10 cents.

Certain-teed Products Co.'s "Blue Rapids Gaging Plaster" and "Beaver Finishing Lime."

The physical properties of the plaster, determined by the Lime and Gypsum Section of the National Bureau of Standards, are given in table 3.

TABLE 3.—*Physical properties of the plaster*

Material	Time of set	Ratio of plaster to sand [a]	Tensile strength [b]	Compressive strength [b]
	hr		*lb/in.*^{2}	*lb/in.*^{2}
Gypsum plaster (neat)	10		290	
Sanded plaster (scratch)		1:1.8	135	830
Sanded plaster (brown)		1:2.5	80	380

[a] Average of 2 determinations.
[b] Average of 6 determinations.

The neat gypsum plaster was tested in accordance with Federal Specification SS–P–401 for Plaster; Gypsum. The tensile and compressive strengths of the scratch and brown sanded plasters were obtained on representative samples of the wet plaster taken from the job. The plaster was cast in molds, and subsequently treated according to paragraph F–2f(1) of Federal Specification SS–P–401. The ratio of plaster to sand in the set plaster was determined by the ammonium-acetate method given in the 1938 revision of Methods of Testing Gypsum and Gypsum Products, American Society for Testing Materials Designation C 26–33.

The finish coat of plaster was one part of gaging plaster to three parts of hydrated finishing lime, by volume.

(b) *Description*

The floor specimens were 12 ft 6 in. long, 4 ft 0 in. wide, and $8\frac{1}{8}$ in. thick. Each specimen consisted of four sheet-steel channel-shaped joists, *A*, as shown in figure 1. The joists were covered with one coat of paint applied by spraying before assembly. The wide upper flanges overlapped adjacent flanges and were fastened by welds to form a continuous sheet-steel deck. The upper flange of one outside joist extended to half the spacing of the webs and a portion of an upper flange was welded to the other outside joist so that the webs were symmetrical about a longitudinal center line. The lower flanges were fastened to steel end members, *B*, by welds. The deck was covered with sound insulation, *C*, consisting of a layer of asphalt roofing fastened by asphalt. Wood sleepers, *D*, were fastened to the deck by angles, *E*, and a wood finish floor, *F*, was laid on the sleepers. A ceiling, *G*, of metal lath and plaster was fastened to the joists.

The price of this construction in Washington, D. C., as of July 1937 was \$0.65/ft^2.

Joists.—The joists, *A*, were channels, $13\frac{3}{16}$ by 5 by $2\frac{7}{8}$ in., 12 ft 6 in. long, formed from sheet-steel, No. 14 United States Standard Gage (0.0766 in. thick). The upper flange of each joist had a recessed shelf, $1\frac{1}{2}$ in. wide,

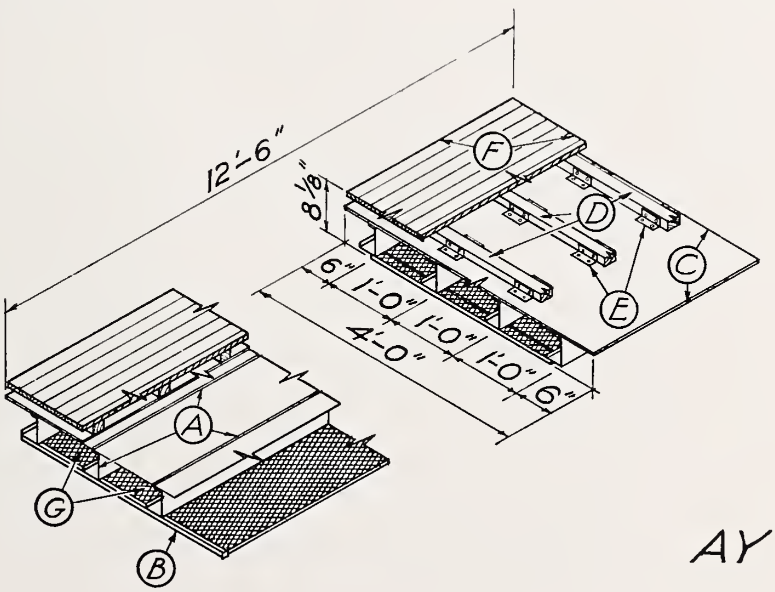

FIGURE 1.—*Floor specimen AY.*

A, joist; *B*, end member; *C*, sound insulation; *D*, sleeper; *E*, angle; *F*, finish floor; *G*, ceiling.

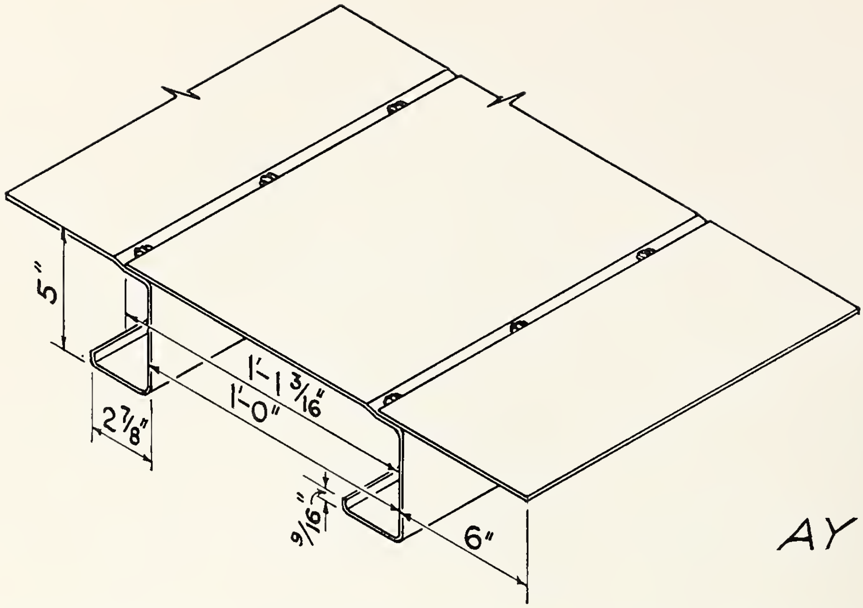

FIGURE 2.—*Details of joists and method of assembly.*

on which the flange of the adjacent joist rested. The joists were fastened by welds, ½ in. long, spaced 6 in. on centers. The details of the joists and the method of assembly are shown in figure 2.

End members.—The end members, *B*, were bars, 1 by 1 in., 4 ft 0 in. long, fastened to the lower flange of each joist by fillet welds, one at each side of each flange. These bars represented the regular end members used when the joists rest on masonry walls. The regular end members are steel plates, 4 in. wide and ¼ in. thick.

Sound insulation.—The sound insulation, *C*, was one layer of asphalt roofing fastened to the deck with asphalt.

Sleepers.—Thirteen wood sleepers, *D*, 1½ by 2 in., 4 ft 0 in. long, spaced 1 ft 0 in. on centers, were fastened to the deck by angles, *E*. Each sleeper had four angles on each side, spaced 1 ft 1½ in. on centers.

Angles.—The angles, *E*, were 1⁷⁄₁₆ by 1⁷⁄₁₆ in., 3½ in. long, formed from sheet steel, No. 14 United States Standard Gage (0.0766 in. thick). The horizontal leg of each angle had two holes, ⁹⁄₃₂-in. diam, spaced 2½ in. on centers, and the vertical leg had two holes, ⁵⁄₃₂-in. diam, spaced 2½ in. on centers. Each angle was placed over the sound insulation and fastened to the deck by two screws and to the sleeper by two roofing nails. A paper-felt washer under the head of each roofing nail prevented breaking off the head when the nail was driven.

Finish floor.—The finish floor, *F*, was oak flooring, ²⁵⁄₃₂ by 2¼ in. (nominal ¹³⁄₁₆ by 2¼ in.). Each strip of flooring was fastened by blind nailing to each sleeper with one finishing nail.

Ceiling.—The ceiling, *G*, had six sheets of lath, 2 ft 11 in. by 2 ft 3 in., placed with the ribs across the lower flanges of the joists and stretched to overlap 3½ in. The four ribs of each sheet were fastened to the lower flange of each joist by lath clips twisted to tighten the ribs against the flanges. The lath was covered with plaster, ¾ in. thick, consisting of a scratch coat, a brown coat, and a finish coat. The ceiling did not extend the full width of the specimen but was only 2 ft 11 in. wide. It is believed that this did not appreciably affect the structural properties of the specimens.

(*c*) *Comments*

Approximately 25 buildings using this construction were completed or under construction on October 1, 1938. One of these buildings was a house built on a masonry foundation with sheet-steel walls, floors, and roof.

The sheet-steel joists used for this floor construction are made in depths of 5, 6, and 8 in. from 12- and 14-gage sheet steel and are used for spans not exceeding 22 ft.

The joists when used for the first floor of a building are supported by the foundation walls, resting on a sheet-steel plate fastened to the masonry by anchor bolts. The lower flanges of the joists are first fastened to the bearing plate by welds and then the upper flanges are fastened to the flanges of adjacent joists by welds. If the distance from wall to wall is excessive, the joists are supported by intermediate beams, the lower flanges resting on and being fastened to the beams by welds. The second floor is supported by shelf angles fastened to the wall.

The finish floor may be wood flooring laid on sleepers, tile block laid in a composition filler directly on the steel deck, concrete, or terrazzo.

2. Transverse Load

Floor specimen *AY–T1* under transverse load is shown in figure 3. The results for floor specimens *AY–T1*, *T2*, and *T3* are shown in table 4 and in figure 4.

Each of the specimens failed by buckling of the joists at one or both loading rollers. In addition, the plaster ceiling of each specimen cracked in three places across the specimen. The first cracks appeared under one loading roller or at midspan and occurred at loads of 90, 140, and 140 lb/ft² and deflections of 0.21, 0.36, and 0.36 for specimens *T1*, *T2*, and *T3*, respectively. The other cracks occurred under or between the loading rollers for specimens *T1* and *T2* and near each supporting roller for specimen *T3*. For each of specimens *T1* and *T3* one weld holding the flange of a joist to the end member ruptured at a load of 320 lb/ft² for specimen

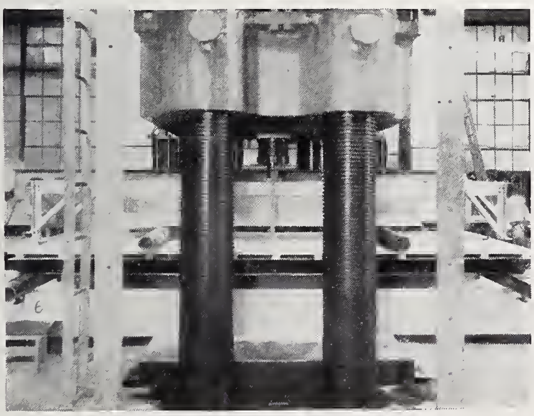

Figure 3.—*Floor specimen AY–T1 under transverse load.*

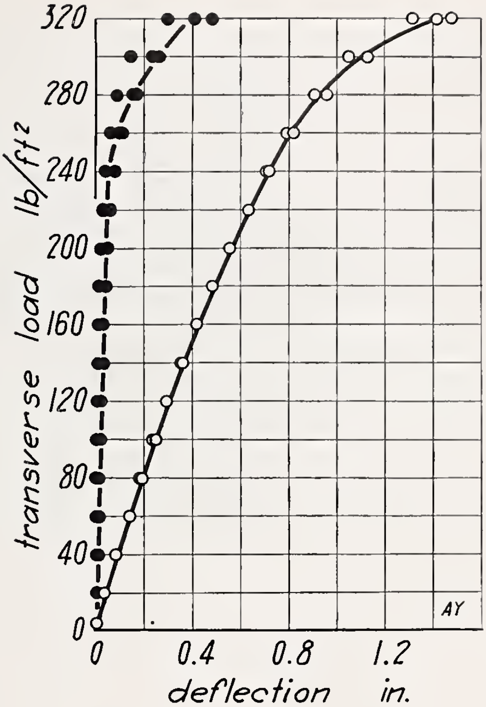

Figure 4.—*Transverse load on floor AY.*

Load-deflection (open circles) and load-set (closed circles) results for specimens *AY–T1*, *T2*, and *T3* on the span 12 ft 0 in.

Table 4.—*Structural properties of floor AY*

[Weight,[a] 16.1 lb/ft²]

Load	Load applied	Specimen designation	Maximum height of drop	Maximum load
			ft	*lb/ft²*
Transverse	Upper face; span, 12 ft 0 in.	*T1*		339
		T2		334
		T3		340
	Average			338
Impact	Upper face; span, 12 ft 0 in.	*I1*	[b] 10.0	
		I2	[b] 10.0	
		I3	[b] 10.0	
	Average		[b] 10.0	
				lb
Concentrated	Upper face	*P1*		[b] 1,000
		P2		[b] 1,000
		P3		[b] 1,000
	Average			[b] 1,000

[a] The weight would have been about 10 to 15 percent greater if the specimens had full-width ceilings.
[b] Specimen did not fail.

T1 and 340 lb/ft² (maximum load) for specimen *T3*.

3. Impact Load

Floor specimen *AY–I1* during the impact test is shown in figure 5. The results for floor

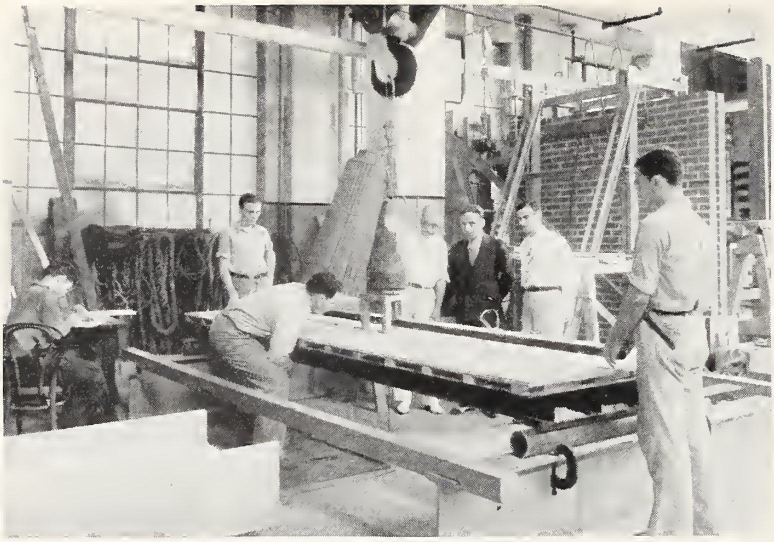

FIGURE 5.—*Floor specimen AY–I1 under impact load.*

specimens *AY–I1, I2,* and *I3* are shown in table 4 and figure 6.

The impact loads were applied to the middle of the upper face of each specimen so that the sandbag struck the finish floor directly over the center sleeper and midway between the webs of the center joists. For each specimen the plaster ceiling cracked across the specimen at one place near midspan. The cracks occurred at drops of 4, 6.5, and 10 ft and deflections of 0.41, 0.51, and 0.64 in. for specimens *I1, I2,* and *I3,* respectively. The sets after a drop of 10 ft were 0.029, 0.041, and 0.042 in. for specimens *I1, I2,* and *I3,* respectively, and no other effect was observed.

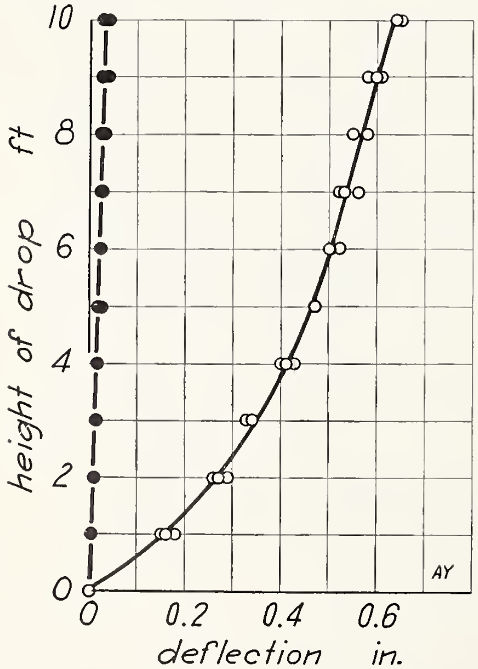

FIGURE 6.—*Impact load on floor AY.*

Height of drop-deflection (open circles) and height of drop-set (closed circles) results for specimens *AY–I1, I2,* and *I3* on the span 12 ft 0 in.

4. CONCENTRATED LOAD

Floor specimen *AY–P2* under concentrated load is shown in figure 7. The results for floor specimens *AY–P1, P2,* and *P3* are shown in table 4 and in figure 8.

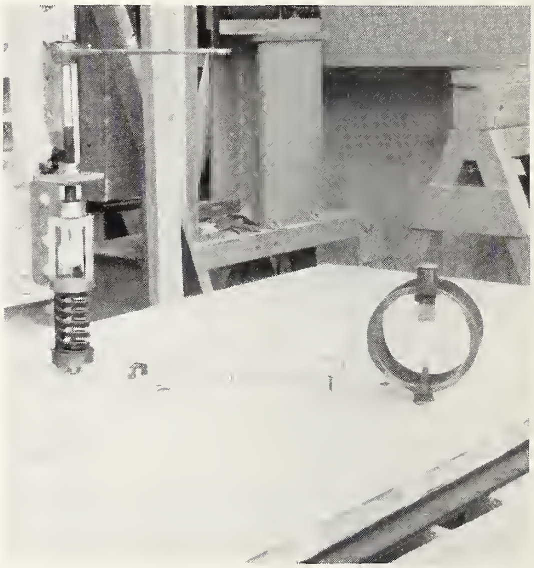

FIGURE 7.—*Floor specimen AY–P2 under concentrated load.*

The concentrated loads were applied to the finish floor of each specimen on a strip of the flooring near an end-matched joint which was not directly over a sleeper. The indentations after a load of 1,000 lb had been applied were 0.039, 0.019, and 0.018 in. for specimens *P1*, *P2*, and *P3*, respectively, and no other effect was observed.

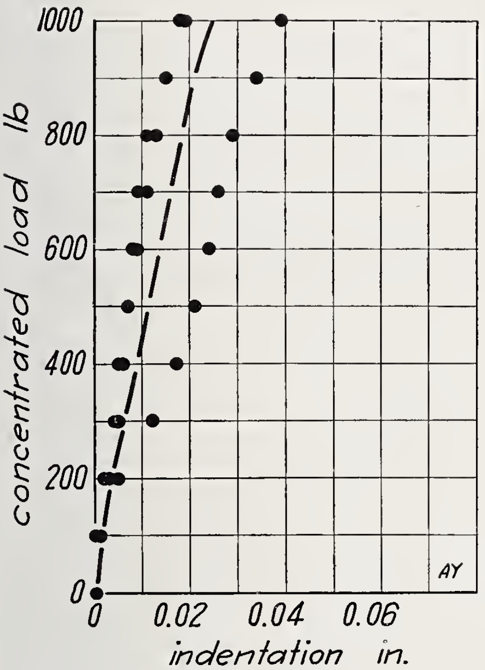

FIGURE 8.—*Concentrated load on floor AY.*

Load-indentation results for specimens *AY-P1*, *P2*, and *P3*.

The sponsor supplied the information contained in the sponsor's statement. The description and drawings of the specimens were prepared by E. J. Schell and G. W. Shaw of the Bureau's Building Practice and Specifications Section, under the supervision of V. B. Phelan, from this information and from the specimens themselves. That Section also cooperated in the preparation of the report.

The species and grades of the woods were determined by R. K. Helphenstine, Jr., and W. D. Brush of the Division of Forest Products, Forest Service, United States Department of Agriculture.

The structural properties were determined by the Bureau's Engineering Mechanics Section, under the supervision of H. L. Whittemore and A. H. Stang, and the Lime and Gypsum Section, under the supervision of L. S. Wells, with the assistance of the following members of the professional staff: W. F. Clarke, F. Cardile, R. C. Carter, H. Dollar, M. Dubin, A. H. Easton, A. S. Endler, C. D. Johnson, A. J. Sussman, and L. R. Sweetman.

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WASHINGTON, November 18, 1938.

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The *National Bureau of Standards* was established by act of Congress, approved March 3, 1901, continuing the duties of the old Office of Standard Weights and Measures of the United States Coast and Geodetic Survey. In addition, new scientific functions were assigned to the new Bureau. Originally under the Treasury Department, the Bureau was transferred in 1903 to the Department of Commerce and Labor (now the United States Department of Commerce). It is charged with the development, construction, custody, and maintenance of reference and working standards, and their intercomparison, improvement, and application in science, engineering, industry, and commerce.

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