U. S. DEPARTMENT OF COMMERCE

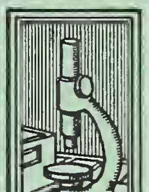
BUILDING MATERIALS AND STRUCTURES

REPORT BMS51

Structural Properties of "Tilecrete Type A" Floor Construction Sponsored by the Tilecrete Co.

by

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



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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 construction and the description of materials and methods of fabrication. The Bureau is responsible for the method of testing and for the test results.

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

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

Lyman J. Briggs, *Director.*

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ABSTRACT

For the program on the determination of the structural properties of low-cost house constructions, the Tilecrete Co. submitted six specimens representing its "Tilecrete Type A" floor construction.

The specimens were subjected to transverse, impact, and concentrated loads. For each of the loads three like specimens were tested. The deformation under load and the set after the load was removed were measured for uniform increments of load. The strength under transverse load was also determined. The results are presented in graphs and in a table.

I. INTRODUCTION

To provide technical facts on the performance of constructions which might be used in low-cost houses, to discover promising new constructions, and ultimately to determine the properties necessary for acceptable performance in actual service, the National Bureau of Standards has invited the cooperation of the building industry in a program of research on building materials and structures suitable for low-cost houses and apartments. The objectives of this program are described in report BMS1, Research on Building Materials and Structures for Use in Low-Cost Housing, and that part of the program relating to structural properties in report BMS2, Methods of Determining the Structural Properties of Low-Cost House Constructions.

Masonry constructions and wood constructions of types which have been extensively used in this country for houses were included in the program because their behavior under widely different service conditions is known to builders and the public. The reports on these constructions are BMS5, Structural Properties of Six Masonry Wall Constructions, and BMS25, Structural Properties of Conventional Wood-Frame Constructions for Walls, Partitions, Floors, and Roofs. The masonry specimens were built by the Masonry Construction Section of this Bureau, and the wood-frame specimens were built and tested by the Forest Products Laboratory at Madison, Wis.

The present report describes the structural properties of a floor construction sponsored by one of the manufacturers in the building industry. Transverse, impact, and concentrated loads were applied to the specimens, simulating the loads to which the floors of a house would be subjected in actual service. Transverse loads are applied to floors by furniture and 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 deflection and set under each increment of load were measured because the suitability of a floor 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 Tilecrete Co., Washington, D. C., and represented its "Tilecrete Type A" floor construction, consisting of expanded steel joists, asbestos-cement fillers, concrete fill, and a white-oak finish floor.

Structural Properties of a "Tilecrete" Floor Construction Sponsored by Tilecrete Floors, Inc., BMS16, reports the results of tests on "Tilecrete Type T" floor construction submitted by the same organization. Type T construction consisted of expanded steel joists, tile fillers, concrete fill, and a finish floor.

III. SPECIMENS AND TESTS

The floor construction was assigned the symbol *CT* and the individual specimens were assigned the designations given in table 1.

TABLE 1.—*Specimen designations, floor CT*

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

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

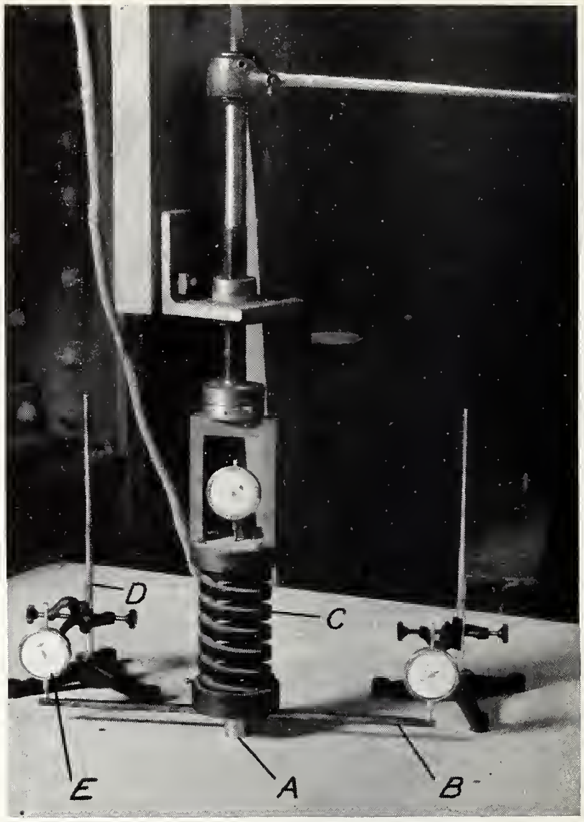

FIGURE 1.—*Apparatus for concentrated-load test.*

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

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

To prevent misleading results of the impact test 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 midspan, one at each joist, and the set gages rested on the loaded face, one over each joist.

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 the thick steel disk, *A*, to which the crossbar, *B*, was rigidly attached. The load was measured by means of the dynamometer, *C*. The dynamometer was of either the spring type or the ring type. 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 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 set after the load was removed was determined similarly.

The specimens were tested on October 3 and 4, 1939, on the 28th day after the pouring of the concrete fill. The sponsor's representative witnessed the tests.

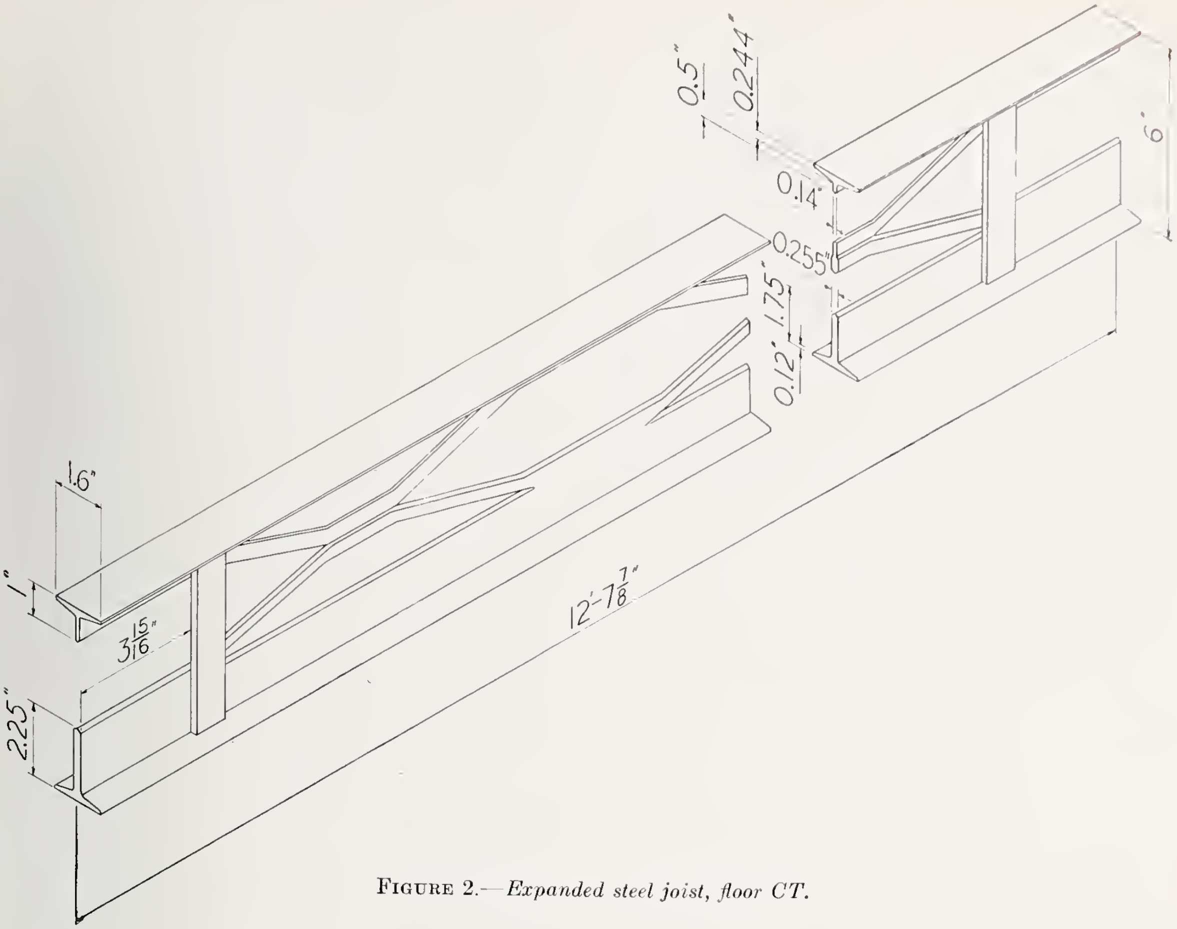

FIGURE 2.—*Expanded steel joist, floor CT.*

IV. FLOOR *CT*

1. SPONSOR'S STATEMENT

The information for this statement was obtained from the sponsor and from inspection of the specimens. The Masonry Construction Section of the National Bureau of Standards assisted by determining the physical properties of the concrete and of the asbestos-cement fillers, the Engineering Mechanics Section by determining the moisture content of the wood flooring, and the Forest Products Laboratory by identifying the species of wood in the flooring.

(*a*) *Materials*

Expanded steel joists.—Open-hearth, hot-rolled, one-piece members, 12 ft 7⅞ in. long, 6 in. deep; weighing 4.1 lb/ft; manufactured from special **I**-beams by a continuous process of hot-rolling, slitting, and expanding. They were straightened by cold-rolling. The panel-length of the web was 1 ft 4⁷⁄₁₆ in. A joist is shown in figure 2. The end struts, fastened by arc welds, reinforced the joists at the supports. The chemical composition of the steel is given in table 2 and the mechanical properties in table 3.

TABLE 2.—*Chemical composition of the steel in the joists, floor CT*

Element	Content
	Percent
Carbon	0.23
Manganese	.45
Phosphorus	.011
Sulfur	.030

TABLE 3.—*Mechanical properties of the steel in the joists, floor CT*

Yield point	Tensile strength	Elongation in 8 in.
lb/in.²	*lb/in.²*	*Percent*
42,000	64,300	23.7

"Bethlehem Open-Web Expanded Steel Joist, Type 62", Bethlehem Steel Corporation.

Concrete.—Transit-mixed, containing 1 part of portland cement, 2.5 parts of sand, and 4.3 parts of gravel (maximum size, 1 in), by dry weight, with 6 to 8 gal of water per sack of cement (94 lb). The concrete was delivered in three batches.

For each batch the slump was determined in accordance with ASTM Standard D 138–32T, and six 6- by 12-in. cylinders were made. Three cylinders were stored in air near the floor specimens, and the other three were stored at 70° F and a relative humidity of 95 to 100 percent. The compressive strength of each cylinder was determined on the day the corresponding floor specimen was tested, age 28 days. The physical properties of the concrete are given in table 4.

TABLE 4.—*Physical properties of the concrete, floor CT*

Batch	Slump	Compressive strength	
		Cylinders cured with floor specimens	Cylinders cured at 70° F and 95- to 100-percent relative humidity
	in.	*lb/in.*²	*lb/in.*²
1	7	2, 010	----------
2	7⅝	2, 460	2, 920
3	[illegible]⅛	2, 360	2, 660

The sand and gravel were obtained from pits near Bowie, Md.; portland cement, "Alpha" brand, from the Alpha Portland Cement Co.; concrete, from the Transit-Mixed Concrete Co., Washington, D. C.

Asbestos-cement fillers.—Full-sized asbestos-cement fillers, as shown in figure 3, 1 ft 11$\frac{13}{16}$ in. long, 1 ft 11¾ in. wide (range 1 ft 11⅝ in. to 1 ft 11⅞ in), and ¼ in. thick. The depth of the fillers was 3$\frac{9}{16}$ in. The half-sized fillers were the same as full-sized fillers cut along the longitudinal center line.

TABLE 5.—*Physical properties of the asbestos-cement fillers, floor CT* [a]

Water content, by weight		Modulus of rupture, ovendry			Weight of filler, ovendry
As received	After 24-hr cold immersion	Sample cut lengthwise	Sample cut crosswise	Average	
Percent	*Percent*	*lb/in.*²	*lb/in.*²	*lb/in.*²	*lb*
10. 5	25. 7	3, 310	3, 945	3, 630	7. 16

[a] Determined in accordance with Federal Specification SS–S–291, Shingles; Roofing, Cement-Asbestos.

The fillers were manufactured by the so-called wet process, in which a revolving cylindrical screen passes through a slurry of asbestos fiber, portland cement, and water, picking up a thin web of the asbestos-cement mixture. The web is transferred to a wool blanket and carried to a forming cylinder on which successive webs are collected and compressed until the sheet is the desired thickness. After removal from the forming cylinder, the built-up sheet, without further pressing, is cut into blanks of the proper size and laid on metal forms until sufficiently cured for handling. The concave face was smooth and the upper face was covered with circular depressions, 0.15 in. in diameter and 0.02 in. deep. The asbestos fiber was from Canada, Russia, and Vermont, mixed in the proportions which gave satisfactory results.

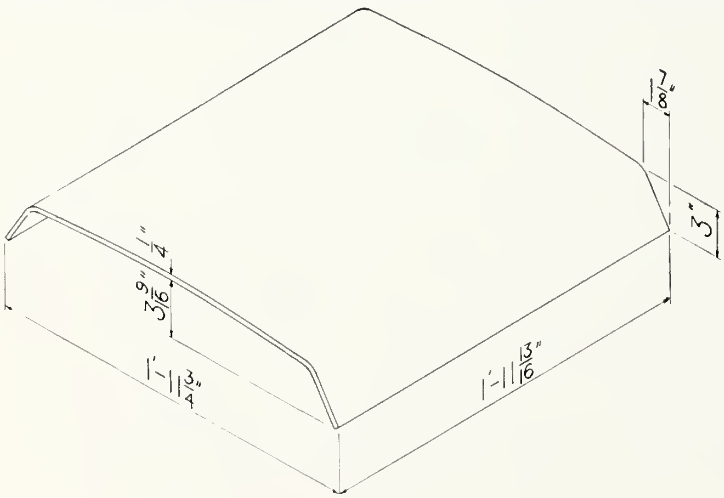

FIGURE 3.—*Full-sized asbestos-cement filler, floor CT.*

The manufacturer refused to divulge the proportions of asbestos, cement, and other substances, if any, contained in the fillers.

The physical properties of the asbestos-cement fillers are given in table 5. The manufacturer was the Ruberoid Co.

Asphalt primer.—A mixture of asphalt and petroleum solvent, containing 50 percent of asphalt, by weight. The asphalt was steam-refined from Mexican Panuco crude petroleum. The softening point of the asphalt was 110° F by the ring-and-ball method,[1] and the penetration [2] was 60 to 100 at 77° F. The unit of penetration is one one-hundredth of a centimeter. The boiling range of the petroleum solvent was 280° to 420° F. Manufactured by Cities Service Co. for McBride & Moeller, Inc.

Asphalt mastic.—A mixture of asphalt and latex rubber, containing 10 percent of rubber, by weight. The asphalt was steam-refined from Mexican Panuco crude petroleum. The physical properties of the asphalt were: softening point, 127° to 130° F, by the ring-and-ball method;[3] penetration,[4] 15 to 17 at 32° F (200-g weight on needle, 60 sec), 45 to 55 at 77° F (100 g, 5 sec), 220 to 275 at 115° F (50 g, 5 sec). Manufactured by Cities Service Co. for McBride & Moeller, Inc.

Finish flooring.—White oak, identified as *Quercus sp.* The flooring was of two types, one manufactured in Sweden and the other by the Kentucky Flooring Co., Orange, Va.

The Swedish flooring was manufactured in pairs of dovetailed strips, each strip 25/32 in. thick by 25/32 in. face width. The pairs of strips were 16 in. long and were dressed, tongue-and-grooved, and end-matched.

The American flooring was dressed, tongue-and-grooved, and end-matched strips, 25/32 in. thick by 2¼ in. face width. The strips were 12 to 20 in. long.

The moisture content of the flooring, determined for 12 strips from each specimen, was 11 percent, based on the weight when dry. An electric moisture meter was used in the determination. To calibrate the meter for the wood in the flooring, two samples of the flooring from each specimen 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 dry, expressed as a percentage of the weight when dry. The average value was 0.1 greater than the average of the corresponding meter readings. Therefore, the moisture content was obtained by adding 0.1 to the average of the meter readings and rounding the result to the nearest whole number. The moisture content was determined on the day the floor specimen was tested.

Glue.—A mixture of casein and rubber latex. The manufacturer refused to divulge further information. Casein Co. of America, "Casco Flexible Cement No. 7982."

(*b*) *Description of Specimens*

Each specimen of floor *CT*, shown in figure 4, was 12 ft 8⅛ in. long, 4 ft ¼ in. wide, 7 5/16 in. thick; and consisted of two steel joists, *A;* full-sized asbestos-cement fillers, *B;* half-sized asbestos-cement fillers, *C;* concrete, *D;* asphalt primer and mastic, *E;* and white oak finish flooring, *F.*

The price of this construction in Washington, D. C., as of July 1937, was \$0.28/ft².

Joists.—The steel joists, *A* (fig. 2), were 12 ft 7⅞ in. long, 6 in. deep; spaced 2 ft 0 in. on centers. The joists were held in position by temporary wood bracing during the construction of the specimens.

Asbestos-cement fillers. The full-sized asbestos-cement fillers, *B*, and the half-sized fillers, *C*, rested on the lower flanges. The outer edges of the half-sized fillers rested on temporary wood supports. Flat pieces of asbestos-cement board were placed at the ends of the specimen, as shown in figure 4, to make the thickness of the concrete at the ends of the specimen equal to the depth of the joists.

Concrete.—The concrete, *D*, was 2⅜ in. thick at the crown of the fillers, and was screeded level ½ to ⅝ in. above the upper flanges of the joists. The concrete for specimens *CT–I1* and *I3* was from batch 1, for specimens *I2* and *T1* from batch 2, and for specimens *T2* and *T3* from batch 3. After ½ to 1 hr, the surface of each specimen was dusted with 25 to 30 lb of a mixture of equal parts of portland cement and sand and then troweled smooth.

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[1] American Society for Testing Materials, ASTM Standard D 36–26.
[2] American Society for Testing Materials, ASTM Standard D 5–25.
[3] See footnote 1.
[4] See footnote 2.

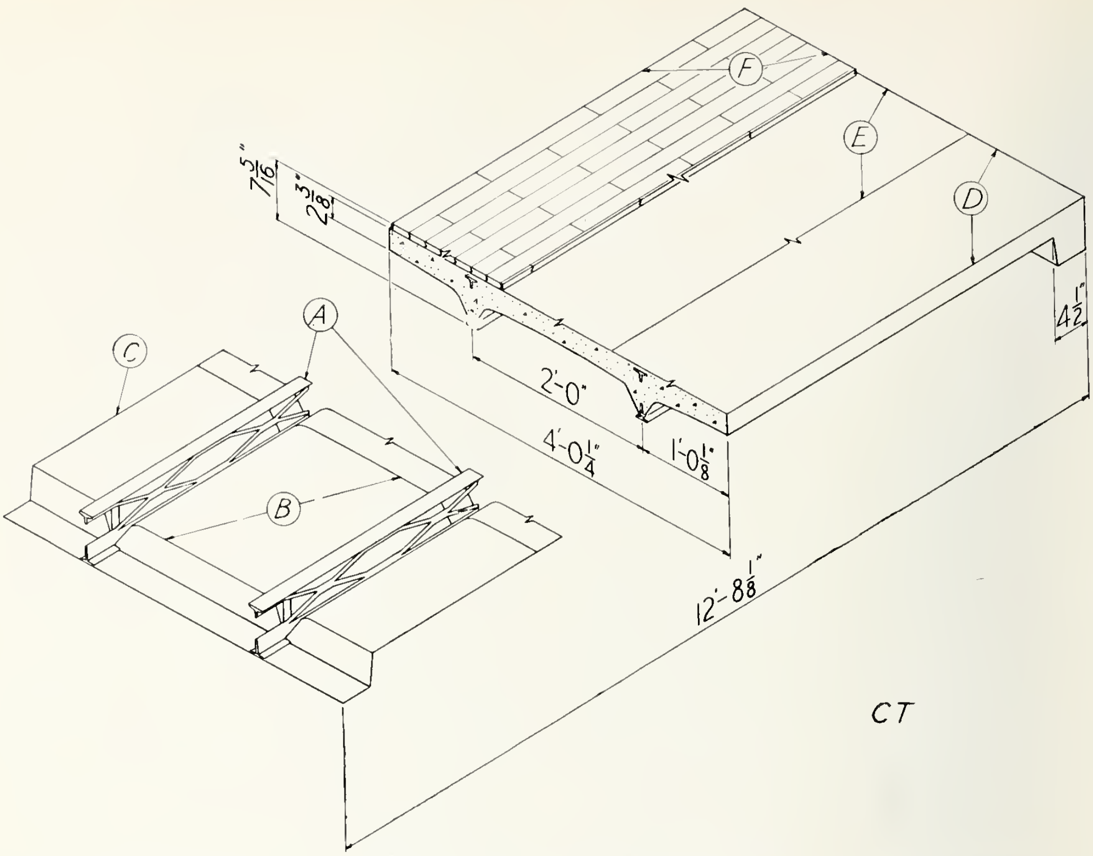


FIGURE 4.—*Floor specimen CT.*

A, expanded steel joists; *B*, full-sized asbestos-cement fillers; *C*, half-sized asbestos-cement fillers; *D*, concrete; *E*, asphalt primer and mastic; *F*, finish flooring.

Asphalt primer and mastic.—The primer and the mastic were applied by the flooring contractor about 3 weeks after the concrete was poured. The surface of the concrete was heated by a blowtorch flame to remove moisture and to raise the temperature to at least 80° F. The primer was heated to 80° to 90° F and spread, 1 gal/100 ft^2, with a brush. It was allowed to dry for 6 hr or more. Before the asphalt mastic was applied, the surface of the primer was heated by a blowtorch flame to at least 80° F. The mastic was heated to 350° to 400° F, poured on the floor, and scored by a rake, which left a corrugated surface. The quantity of mastic was 4 gal/100 ft^2, and the thickness was $\frac{1}{16}$ to $\frac{3}{32}$ in.

Finish flooring.—The flooring was laid several days after the asphalt mastic was applied. The surface of the mastic was heated by a blowtorch flame to at least 70° F immediately before applying the flooring.

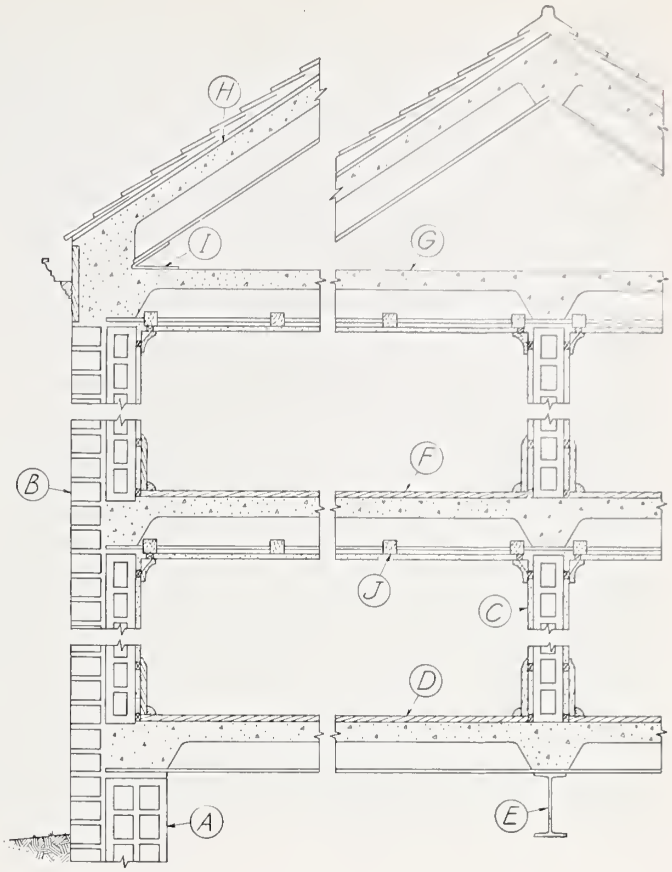
The Swedish flooring was laid as a panel 12 ft long by 4 ft wide, the strips being held together temporarily by cleats nailed across the panel. The American flooring also was laid as a panel, the strips being joined by casein, latex glue at the edges and ends and by cleats. These panels were placed on the mastic and pressed down by a man walking on the surface. The cleats were then removed. Only five Swedish panels were available, and these were applied to specimens *CT–T1*, *T2*, *I1*, *I2*, and *I3*. The American panel was applied to specimen *T3*.

(*c*) *Comments*

Tilecrete type A floor construction has been employed in about 700 family units in Virginia, in 10 homes in Washington, D. C., and in 2 business buildings in Westchester County, N. Y. Both single-family and apartment buildings have been erected.

FIGURE 5.—*Section of a typical house with "Tilecrete" floor construction.*

A, foundation; *B*, outside wall; *C*, partition; *D*, first floor; *E*, girder; *F*, second floor; *G*, third floor; *H*, roof; *I*, angle clip; *J*, furring strips.



A section of a typical house with this floor construction is shown in figure 5. The foundation, *A*, and the outside walls, *B*, are of any accepted load-bearing construction. Partitions, *C*, and party walls are of conventional fire-safe design. The first floor, *D*, is supported by the foundation and by the steel girder, *E*. The second floor, *F*, and third floor, *G*, are supported by the outside wall and load-bearing partition.

The roof, *H*, also may be of "Tilecrete" construction, and may be either flat or sloping. Each rafter is connected to a joist of the top floor by an angle clip, *I*.

Various types of conventional floor coverings may be applied. Wood flooring is nailed to sleepers embedded in the concrete or is bonded to the concrete slab by mastic. Clay tile is grouted to the slab.

Ceiling finish is fastened to wood furring strips, *J*, secured to the bottom flanges of the joists. The strips are 1⅝ by 1⅝ by 23¾ in., with ends beveled and notched to fit the flanges of the joists. Either fiberboard or lath is nailed to the furring strips. In basements the furring strips and ceiling finish may be omitted, and the lower face of the first floor may be painted or whitewashed.

On flat roofs, built-up asphalt felt is usually applied; and on sloping roofs, shingles or tile.

Pipes, wires, and conduits are placed in the spaces enclosed by the asbestos-cement fillers and the ceiling finish. These spaces may be converted into airtight ducts for air-conditioning and heating systems by enclosing them with flat asbestos-cement boards resting on the lower flanges of the joists. Cross ducts require special structural details.

2. TRANSVERSE LOAD

Floor specimen *CT–T1* under transverse load is shown in figure 6. The results of the transverse load on specimens *CT–T1*, *T2*, and *T3* are given in table 6 and in figure 7.

FIGURE 6.—*Floor specimen CT–T1 under transverse load.*

TABLE 6.—*Structural properties, floor CT*

[Weight, 44.2 lb/ft²]

Transverse load [a]		Impact load [a]		Concentrated load	
Specimen	Maximum load	Specimen	Maximum height of drop	Specimen	Maximum load
	lb/ft²		*ft*		*lb*
T1	373	*I1*	[b] 10.0	*P1*	[b] 1,000
T2	332	*I2*	[b] 10.0	*P2*	[b] 1,000
T3	325	*I3*	[b] 10.0	*P3*	[b] 1,000
Average	343	Average	[b] 10.0	Average	[b] 1,000

[a] Span 12 ft 0 in.
[b] Test discontinued. Specimen did not fail.

Under a load of 300 lb/ft² the concrete and asbestos fillers of specimen *CT–T1* cracked transversely to the joists directly under a loading roller. In specimen *T2* under 250 lb/ft² two asbestos fillers ruptured under a loading roller, and under 275 lb/ft² the rupture extended completely across the specimen and into the concrete. In specimen *T3* at 250 lb/ft² one filler ruptured under each loading roller, and at

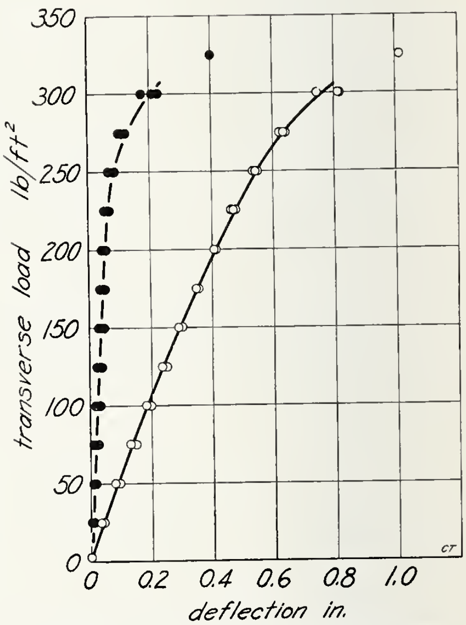


FIGURE 7.—*Transverse load on floor CT.*

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

FIGURE 8.—*Floor specimen CT–I1 during the impact test.*

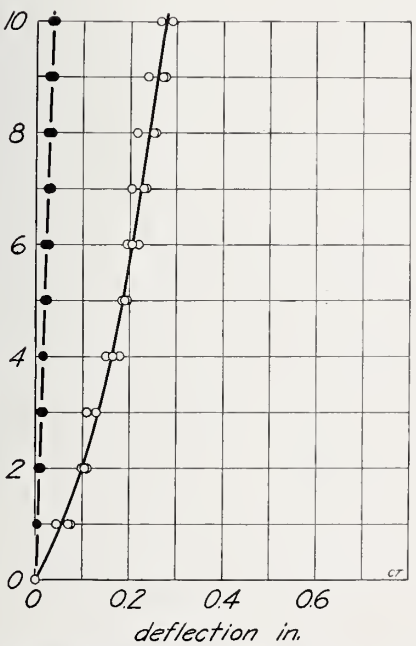


FIGURE 9.—*Impact load on floor CT.*

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

275 lb/ft^2 the rupture in the fillers extended completely across the specimen and into the concrete. In each of the specimens, as the load was increased further, the transverse cracks in the concrete widened, and others appeared. Under a load of 373 lb/ft^2 (maximum load) on specimen *T1* the concrete cracked at the joists longitudinally to the specimen, the cracks beginning at one end but not extending the entire length. Similar cracks occurred in specimen *T2* under 332 lb/ft^2 (maximum load) and in *T3* under 300 lb/ft^2. Under the maximum load the deflection of each specimen was about 3 in., and the cracks in the concrete were about 3/16 in. wide.

3. Impact Load

Floor specimen *CT–I1* during the impact test is shown in figure 8. The results of the impact load on specimens *CT–I1*, *I2*, and *I3* are given in table 6 and in figure 9.

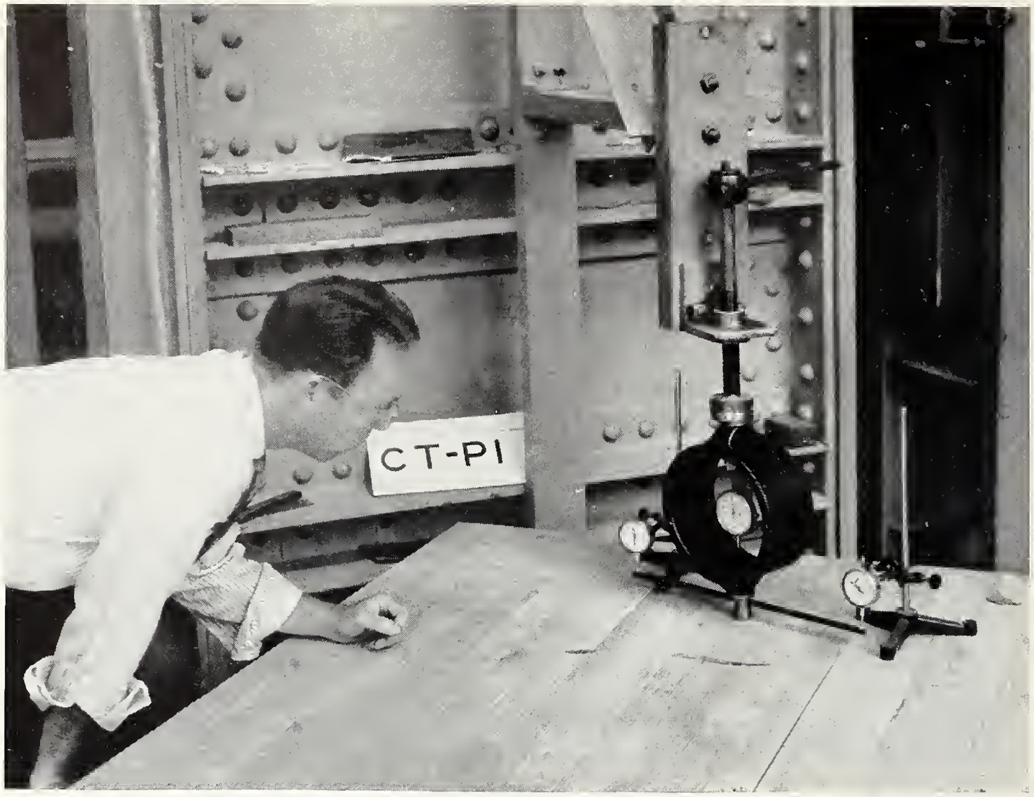


FIGURE 10.—*Floor specimen CT–P1 under concentrated load.*

Ring dynamometer shown.

The impact load was applied to the floor specimens on the upper face, the sandbag striking the finish flooring midway between the joists. After the 10-ft drop on specimens *CT–I1, I2* and *I3*, the tests were discontinued, and the sets were 0.032, 0.037, and 0.031 in., respectively. No other effects were observed.

4. Concentrated Load

Floor specimen *CT–P1* under concentrated load is shown in figure 10. The results of the concentrated load on specimens *CT–P1, P2,* and *P3* are given in table 6 and in figure 11.

The concentrated load was applied to the finish flooring midway between the joists, about 1 ft from the end of the specimen. After a load of 1,000 lb had been applied the set in specimen *CT–P1* was 0.007 in., in *P2* was 0.021 in., and in *P3* was 0.016 in., and the tests were discontinued. There was a slight visible dent in the flooring of specimens *P2* and *P3*, but no other effects were observed.

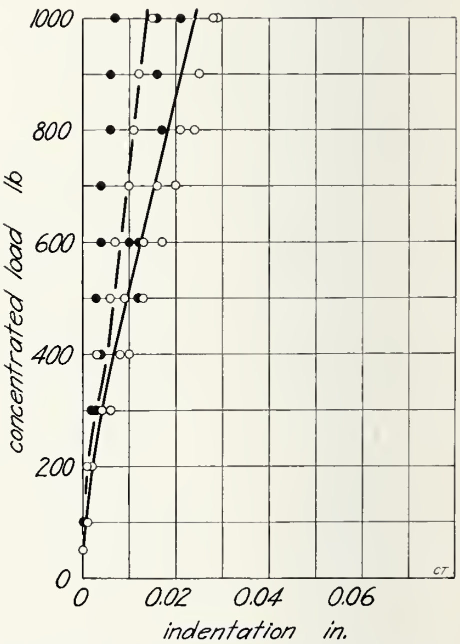


FIGURE 11.—*Concentrated load on floor CT.*

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

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

The structural properties were determined by the Engineering Mechanics Section, under the supervision of H. L. Whittemore and A. H. Stang, and the Masonry Construction Section, under the supervision of D. E. Parsons, with the assistance of the following members of the professional staff: C. C. Fishburn, A. H. Easton, A. S. Endler, M. Greenspan, A. B. Lanham, and D. C. List.

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