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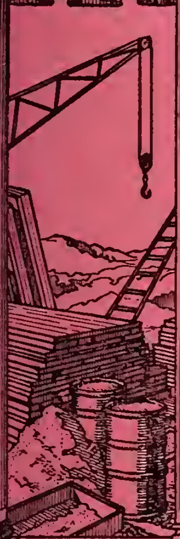


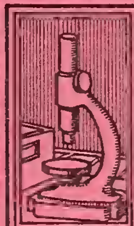
BUILDING MATERIALS AND STRUCTURES

REPORT BMS34

Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 1

by

PERCY A. SIGLER *and*
ELMER A. KOERNER



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BUILDING MATERIALS *and* STRUCTURES

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Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 1

by PERCY A. SIGLER *and* ELMER A. KOERNER

ISSUED JANUARY 15, 1940

The National Bureau of Standards is a fact-finding organization; it does not "approve" any particular material or method of construction. The technical findings in this series of reports are to be construed accordingly.

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Foreword

In connection with the research program on building materials suitable for low-cost house construction being conducted by the National Bureau of Standards, performance tests are being made on various floor coverings and methods of installation in order to determine their relative ability to withstand severe service. It is abusive treatment which causes most installations of floor coverings to become prematurely unserviceable.

This report presents the results of tests on 40 different installations in the Bureau's floor-testing chamber The condition of these installations at the end of the test is discussed, and representative photographs are shown.

A performance test on additional floor coverings and adhesives is in progress.

LYMAN J. BRIGGS, *Director.*

Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 1

by Percy A. Sigler *and* Elmer A. Koerner

CONTENTS

ABSTRACT

A performance test was conducted in the floor-testing chamber of the National Bureau of Standards on 40 different test installations involving 12 floor coverings and 11 adhesives. The floor coverings tested included several kinds of linoleum, felt-base floor coverings having various wearing surfaces, pressed fiberboard, and three strip-wood floors. The bonding agents used included lignin pastes, various resinous cements, casein-latex cement, asphaltic cements, and nails. Installations on both a concrete subfloor and a wood subfloor were tested. Descriptions of the testing equipment and test installations are given. Results showing the relative magnitude of the depressions in the floor coverings caused by the testing equipment are summarized and presented in tables. The appearance of the various installations after 48,000 cycles of the testing equipment is discussed and representative photographs are shown.

I. INTRODUCTION

The available information and literature on the relative performance in service of different floor coverings and various methods of installation are somewhat limited, especially on the more recently developed materials and methods. Variations in such important factors as the quality of materials used, type and condition of the subfloor, the use of underlays, the method of installation and adhesive used, the extent and nature of maintenance, and the nature of exposure and abuses to which the floor covering is subjected make direct comparisons in service difficult.

In an effort to determine within a comparatively short time the relative ability of various types of floor coverings and various methods of installation to withstand severe and prolonged service, a performance test, necessarily somewhat severe, was conducted in the floor-testing chamber of the National Bureau of Standards. In this performance test it was not found possible to include all factors affecting performance in service. The effects of finishing coats, maintenance, age, and temperature were not adequately covered. The testing equipment was a modification of that previously used in connection with an investigation of industrial-type floors for the Procurement Division of the Treasury Department [1].[1] The floor coverings and adhesives selected for test were those which might be suitable for low-cost house construction [2]. The materials tested represented good-quality merchandise in their respective fields. The generous cooperation of various manufacturers in furnishing materials for test is acknowledged.

Laboratory investigations are also being conducted on the various floor coverings and adhesives to determine their relative merits with respect to pertinent properties [3,4].

II. FLOOR-TESTING CHAMBER AND EQUIPMENT

The floor-testing chamber contains a concrete circular track 4 ft wide, $8\frac{1}{2}$ in. thick, and

[1] Figures in brackets indicate the literature references at the end of this paper.

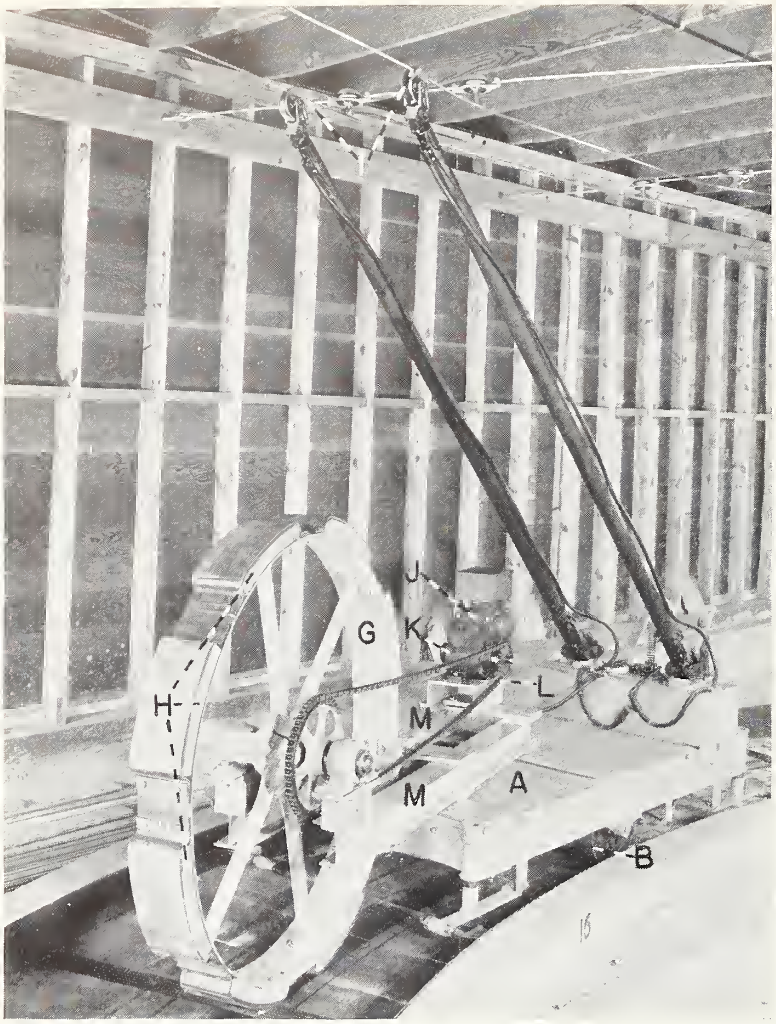

FIGURE 1.—*Performance-testing equipment.*

approximately 40 ft in diam, with a metal-shod concrete curb on each side. The circular track is divided into 20 test spaces by metal thresholds, the surfaces of which are 4 in. above the structural slab. In these test spaces wood or concrete subfloors and the various floor coverings and adhesives were installed for test. Each test space, 4 ft wide, 6 ft long, and 4 in. deep, was divided in half and a different installation made in each half.

Figures 1 and 2 show the testing equipment employed in this performance test. The equipment consisted of a platform truck, *A*, equipped with two steel wheels 12 in. in diam and 3 in. wide. The outer wheel carried a load of approximately 600 lb, and the inner wheel, *B*, a load of approximately 500 lb. On the front of the truck, as shown in figure 2, were mounted two lever mechanisms, *C*. A swivel steel-wheel caster, *E*, 2 in. in diam and ⅞ in. wide, was attached to one of the levers and exerted a force of 20 lb normal to the track. A steel-ball caster, *F*, 1 in. in diam, was attached to the other lever and exerted a force of 10 lb normal to the track. Helical springs, *D*, were used for applying a load on the casters.

The equipment was propelled around the track at a speed of approximately 2 miles per hr by a wheel, *G* (fig. 1), 4 ft in diam, which carried a load of approximately 275 lb. The wheel was shod with eight wooden blocks, *H*, 6 by 13 by 1½ in., which were covered with a cushioning layer of rubber ¼ in. thick and a wearing surface of leather ¼ in. thick. This arrangement produced a bumping and slipping action between the wheel and the test floors and imitated, to some extent, a walking action. The average slippage of the "walking wheel" during the test was approximately 1 percent. The source of power was from an overhead trolley, *I*, to a 1-hp electric motor, *J*, which rotated the walking wheel, G, through a reduction gear, *K*, and a chain drive, *L*. The equipment was guided around the circular track by placing the beams, *M*, connecting the walking wheel to the truck at the proper angle and also by rollers, *N* (fig. 2), attached to the four corners of the truck and bearing against the metal-shod curbs, *O*. The number of revolutions of the walking wheel was recorded by a counter attached to the frame of the equipment. The number of cycles around the track made by the testing equipment was recorded by a counter mounted on a post at the side of the track and operated by an arm attached to the truck.

A dial depth gage, *R* (fig. 2), was used to measure the depth of the depressions caused by the testing equipment. The depth gage had a span of 8 in. and was equipped with a flat-ended foot ⅛ in. in diam and a dial graduated in thousandths of an inch. The foot exerted a pressure of 20 lb/in².

III. TEST CONDITIONS AND PROCEDURE

The concrete subfloors were poured August 10, 1937, and given a steel-trowel finish. The concrete was mixed fairly dry and consisted of 1 part of cement, 3 parts of sand, and 4 parts of gravel. The wood subfloors were blind-nailed to four wooden sleepers which were spaced 12 in. on centers and embedded in concrete in the direction of travel of the testing equipment. The wood subfloors consisted of tongued-and-grooved strip flooring, ²⁵⁄₃₂ in. thick, of either flat-grained yellow pine or edge-grained Douglas fir.

The floor coverings and adhesives were installed during December 1937, and thus sufficient time was allowed for the concrete subfloors to dry. The atmospheric conditions in the testing chamber during the installations ranged from 60- to 70-percent relative humidity and from 50° to 60° F in temperature. A higher temperature during installation is desirable for most types of floor coverings and is essential for a few types, such as asphalt tile. The test installations were rolled with a 150-lb steel roller, and a setting-up period of at least 1 week was allowed before starting the

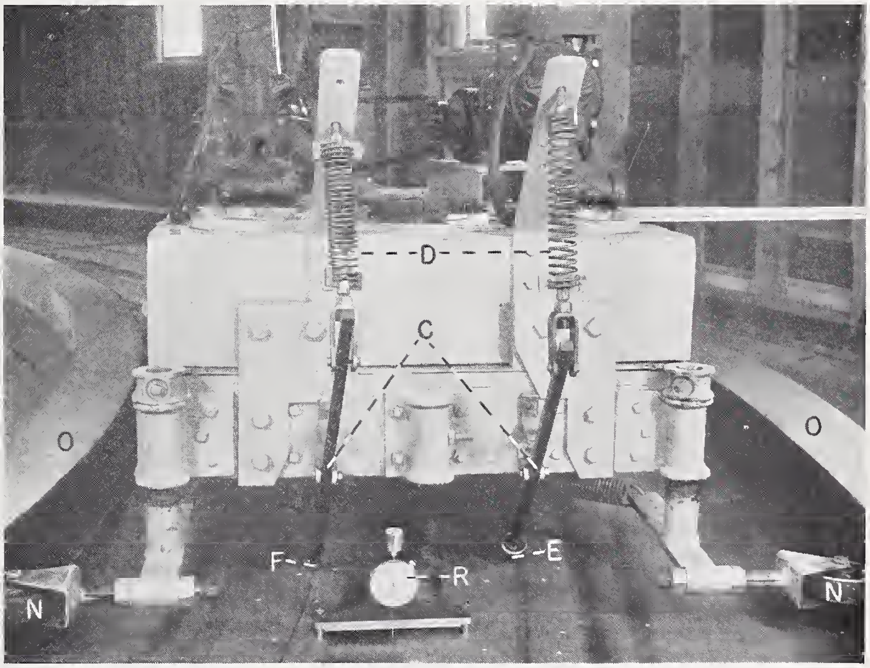

FIGURE 2.—*Front view of test truck and dial depth gage.*

testing equipment. The test floors were swept at least once a day during the performance test to remove loose particles.

Reference marks of white enamel were made on the 40 installations for use in determining the depth of the depressions caused by the equipment. Measurements of the initial depth were made on the 40 installations after 50 cycles of the test truck. Three measurements on each of the five paths caused by the testing equipment were taken on each installation, making a total of 600 readings. These measurements were repeated at 4,000, 10,000, and 20,000 cycles. After 24,000 cycles of the test truck, strips, 6 in. wide, of garnet cloth, No. 3 grit, were placed over the eight shoes of the walking wheel in order to increase the abrasive action. The strips of abrasive cloth were replaced with new ones every 2,000 cycles. Measurements for the depth of wear caused by the abrasive cloth on the walking wheel were made on the various test floors at 30,000, 40,000, and 48,000 cycles of the test truck. After 48,000 cycles, the test floors were washed with soap and water and photographed.

IV. DESCRIPTION OF TEST INSTALLATIONS

The 40 test installations involved 12 different floor coverings and 11 different adhesives. Each floor covering, with the exception of strip wood flooring, was installed on both a concrete subfloor and a wood subfloor, using two different methods of bonding on each type of subfloor. An outline of the test installations is given in table 1.

V. RESULTS

The depths of the depressions in the floor coverings caused by the metal truck wheels at 10,000 cycles are recorded in table 1. The extent of the depressions varied with the different floor coverings on the same type of subfloor and also with the same floor covering on different types of subfloors. The depressions appeared to result more from compression than from wear and occurred mainly within the first 10,000 cycles of the test truck. Measurements of the depressions made by the truck wheels were discontinued at 30,000 cycles because of failure in the bond in many of the test panels. In general, for the same floor covering the depressions were much greater with wood subfloors than with concrete subfloors. This was apparently due to the compression and permanent deformation of the wood subfloors and also to the compression of the felt underlays where used.

The leather-shod walking wheel produced very little compression or wear on the floor coverings for the first 24,000 cycles. (See table 1.) The principal action was to put a polish or glaze on the floor coverings. Use of the abrasive cloth between 24,000 and 48,000 cycles increased the rate of wear under the walking wheel considerably (see table 1) and dulled the surface of the floor coverings.

The average amount each floor covering was worn by 24,000 cycles of the walking wheel covered with abrasive cloth in shown in table 2. Although this represents severe abrasive action, such procedure was found necessary in order to cause a measurable amount of wear within the limited time of the test. The averages were computed from the difference in the results given in table 1 for depth of compression and wear at 24,000 and 48,000 cycles.

The ball and roller casters caused very little depression in any of the floor coverings and for this reason the measurements are not reported.

An attempt was made to measure the dimensional changes of the bonded floor coverings. However, some of the floor coverings showed evidence of much more expansion than the results of the measurements would indicate, the expansion taking place in the form of buckling rather than displacement along the plane of the floor.

The accompanying photographs, figures 3 to 20, show the general condition of representative installations of the different floor coverings at the end of 48,000 cycles of the equipment. The three paths shown in the photographs are those caused by the outer metal truck wheel, the steel-wheel caster, and the walking wheel. The small white dots in the photographs are reference marks of white enamel used in taking the depth measurements.

TABLE 1.—*Test installations and results of measurements for depth of compression and wear*

Test panel [a]	Subfloor	Bonding agent	Floor covering: Type and description [b]	Floor covering: Thickness [c]	Average depth of depression caused by— Metal truck wheels [d] at 10,000 cycles	Walking wheel at— 24,000 cycles	Walking wheel at— 48,000 cycles
				Inches	*Inches*	*Inches*	*Inches*
1–L	Concrete	Lignin paste	Battleship linoleum; plain pattern, brown	0.127	0.002	0.000	0.007
1–R	do	Oil-base cement, resinous	do	.127	.002	.000	.004
2–L	Wood [e]	Lignin paste	do	.127	.011	.001	.008
2–R	do	Oil-base cement, resinous	do	.127	.010	.002	.005
3–L	Concrete	Lignin paste	Inlaid linoleum; molded pattern, gray	.077	.003	.000	.010
3–R	do	Resin cement, cumar resin	do	.077	.003	.000	.008
4–L	Wood [e]	Lignin paste	do	.077	.016	.001	.012
4–R	Wood [f]	do	do	.077	.021	.005	.013
5–L	Concrete	do	Jaspe linoleum; streaked pattern, brown	.096	([g])	.000	.007
5–R	do	Resin cement, copal resin	do	.096	([g])	.001	.008
6–L	Wood [f]	Lignin paste	do	.096	([g])	.006	.023
6–R	do	Resin cement, copal resin	do	.096	([g])	.007	.015
7–L	Concrete	Lignin paste	Printed linoleum; block pattern, brown; wearing surface, enamel.	.076	.005	.000	.007
7–R	Concrete [h]	Casein-latex cement	do	.076	.004	.001	.008
8–L	Wood [e]	Lignin paste	do	.076	.014	.000	.011
8–R	Wood [e] [h]	Casein-latex cement	do	.076	.012	.000	.004
9–L	Concrete	Lignin paste	Inlaid felt-base; straight-line pattern, cream; wearing surface, linoleum composition.	.081	.006	.002	.012
9–R	do	Varnish-base cement, phenolic resin	do	.081	.005	.003	.010
10–L	Wood [i]	Lignin paste	do	.081	.008	.001	.016
10–R	do	Varnish-base cement, phenolic resin	do	.081	.010	.002	.010
11–L	Concrete	Factory-applied adhesive and lignin paste.	Inlaid felt-base; [j] straight-line pattern, gray; wearing surface, linoleum composition.	[k].092	.009	.002	.006
11–R	do	Factory-applied adhesive	do	[k].092	.006	.002	.010
12–L	Wood [i]	Factory-applied adhesive and lignin paste.	do	[k].092	.016	.002	.010
12–R	do	Factory-applied adhesive	do	[k].092	.014	.003	.009
13–L	Concrete	Lignin paste	Printed felt-base; flowered pattern, brown; wearing surface, enamel.	.074	.009	.002	.014
13–R	do	Resin cement, copal resin	do	.074	.011	.003	.014
14–L	Wood [i]	Lignin paste	do	.074	.018	.002	.016
14–R	do	Resin cement, cumar resin	do	.074	.020	.000	.003
15–L	Concrete	Lignin paste	Mastic felt-base; plain pattern, maroon; wearing surface, asphalt and pitch composition.	.090	([g])	.002	.010
15–R	do	Petrolatum-base cement, rosin resin	do	.090	([l])	([l])	([l])
16–L	Wood [i]	Lignin paste	do	.090	([g])	.000	.001
16–R	do	Petrolatum-base cement, rosin resin	do	.090	([l])	([l])	([l])
17–L	Concrete [h]	Casein-latex cement	Pressed fiberboard; [m] plain pattern, brown; density 67 lb/ft.^{3} [n]	.145	.001	.001	.020
17–R	Concrete	Oil-base cement, resinous	do	.145	.001	.000	.021
18–L	Wood [i]	Resin cement, copal resin	do	.145	.008	.001	.019
18–R	Wood [o]	Nailed, 2d casing nail	do	.145	.008	.004	.017
19–L	Concrete [p]	Hot asphalt, strips dipped	Short-strip maple; [m] equal-length shorts, no undercut, flat-grained, flat-back; density 47 lb/ft.^{3} [n]	.796	([q])	([q])	([q])
19–R	Concrete	Cut-back asphalt cement	do	.796	.009	.001	.008
20–L	Wood sleepers	Blind nailed, 8d cut nail	Strip white-oak; [m] clear-grade, flat-grained, flat-back; density 40 lb/ft.^{3} [n]	.783	.011	.001	.011
20–R	do	do	Strip yellow-pine; [m] A-grade, flat-grained, hollow-back; density 44 lb/ft.^{3} [n]	.789	.022	.001	.011

[a] *L*=left half of panel; *R*=right half of panel (facing the panels from the inside of the circular track).
[b] Color listed is the predominating color.
[c] Average thickness; ⅛-in. diam. ft; 20 lb/in^2 pressure.
[d] Average of both wheels.
[e] 1½ lb/yd^2 asphalt-saturated lining felt bonded to subfloor with adhesive listed.
[f] 1 lb/yd^2 dry lining felt bonded to subfloor with adhesive listed.
[g] Floor covering buckled considerably at early stage of test.
[h] Subfloor given a priming coat of adhesive listed.
[i] No felt lining.
[j] Factory-applied adhesive of dry lignin paste on back of floor covering.
[k] Including adhesive.
[l] Adhesive remained plastic and accumulated at sides of paths of equipment.
[m] One heavy coat of a sealer.
[n] At 65-percent relative humidity and 72° F temperature.
[o] 3½ lb/yd ^{2} asphalt-saturated lining felt laid over subfloor.
[p] Subfloor given a priming coat of cut-back asphalt primer.
[q] Floor covering arched across subfloor.

Brief summaries of the general condition and appearance of the various test installations are herewith presented:

The ⅛-in. battleship linoleum, test panels 1 and 2 (see fig. 3), was in very good condition at the end of the performance test. There was only slight failure in adhesion to the subfloors, the principal failure occurring as small ridges along the paths of the truck wheels in panel *1–L*. On a wood subfloor with an asphalt-saturated lining felt the linoleum was moderately depressed by the metal truck wheels. There was no evidence of fracture of the linoleum.

The standard gage inlaid linoleum, test panels 3 and 4 (see figs. 4 and 5), was in good condition at the end of the performance test. There was some failure in adhesion to the subfloors along the paths of the truck wheels, the worst failure occurring in panel *4–R* as distinct ridges extending for the full length of this panel. On a wood subfloor with an asphalt-saturated lining felt, test panel *4–L*, the linoleum was moderately depressed by the metal truck wheels. With a dry lining felt, test panel *4–R*, the linoleum was depressed by the metal truck wheels to a greater degree and was also depressed to a slight extent by the walking wheel. There was evidence of some separation in the dry lining felt. The linoleum was fractured to a slight extent by the metal truck wheels.

Table 2.—*Average wear of floor coverings after 24,000 cycles of the walking wheel covered with abrasive cloth* [a]

Floor covering	Average depth of wear
	Inches
Battleship linoleum	0.005
Inlaid linoleum	.009
Jaspe linoleum	.010
Printed linoleum	.007
Inlaid felt-base	.010
Do	.007
Printed felt-base	.010
Mastic felt-base	.010
Pressed fiberboard	.018
Short-strip maple	.007
Strip white-oak	.010
Strip yellow-pine	.010

[a] The relative value of a floor covering should not be based entirely on resistance to wear. Other factors should also be considered, such as cost, indentation characteristics, ease of maintenance, adherence to subfloors, resistance to tear and fracture, etc.

The medium-gage jaspe linoleum, test panels 5 and 6 (see figs. 6 and 7), was in unserviceable condition at the end of the performance test. Extensive failure in adhesion to the subfloors and buckled ridges in the linoleum perpendicular to the travel of the test truck occurred at an early stage of the test. The failures appeared first under the truck wheels and in panel *6–R* at 4,000 cycles. On a wood subfloor with a dry lining felt the linoleum was appreciably depressed by the metal truck wheels and to a slight extent by the walking wheel. There was evidence of some separation in the dry lining felt. The linoleum was fractured to a considerable extent by the truck wheels and in panel *6–R* was also fractured at one blister by the roller caster and walking wheel.

The printed linoleum, test panels 7 and 8 (see figs. 8 and 9), was in serviceable condition at the end of the performance test, although the enamel printed on the surface was worn through in spots by the abrasive action of the walking wheel in 6,000 cycles after the wheel had been covered with abrasive cloth. There was only slight failure in adhesion to the subfloors, the principal failures occurring as a few small blisters along the paths of the truck wheels in panels *7–L* and *8–L*. On a wood subfloor with an asphalt-saturated lining felt the linoleum was moderately depressed by the metal truck wheels. There was evidence of slight fracture of the linoleum by the metal truck wheels in panels *7–L* and *8–L*.

The inlaid felt-base floor coverings, test panels 9, 10, 11, and 12 (see figs. 10, 11, 12, and 13), were in unserviceable condition at the end of the performance test, with the possible exception of panel *9–L*. Failures in adhesion to the subfloors and blisters in the floor coverings occurred along the paths of the truck wheels. The metal truck wheels depressed the floor coverings to a moderate degree on both a concrete subfloor and a wood subfloor. The floor coverings were fractured to a considerable extent by the metal truck wheels. There was evidence of some separation of the linoleum composition from the felt backing in panel *9–R*.

The printed felt-base floor covering, test panels 13 and 14 (see figs. 14 and 15), withstood the severe treatment of the test fairly well, although at the end of the performance test it was in unsatisfactory condition for additional service. The enamel printed surface was worn through in spots by the abrasive action of the walking wheel in 2,500 cycles after the wheel had been covered with abrasive cloth. Along the paths of the truck wheels there was evidence of some failure in adhesion to the subfloors and some fracture of the floor covering, the worst failure occurring in panel *13–R*, where it was found necessary to cut and recement the floor covering in order to remove a blister formed by accumulation of vapor from the adhesive. The metal truck wheels depressed the floor covering to a moderate degree on a concrete subfloor and to a greater degree on a wood subfloor.

The mastic felt-base floor covering, test panels 15 and 16 (see fig. 16), was in unserviceable condition at the end of the performance test, with the possible exception of panel *15–R*, although the adhesive used in this installation remained very plastic and accumulated in ridges along the sides of the path of the testing equipment. In panel *16–R*, where the same adhesive was used, the floor covering shifted toward the inside of the track to such an extent as to necessitate its being stripped off the wood subfloor

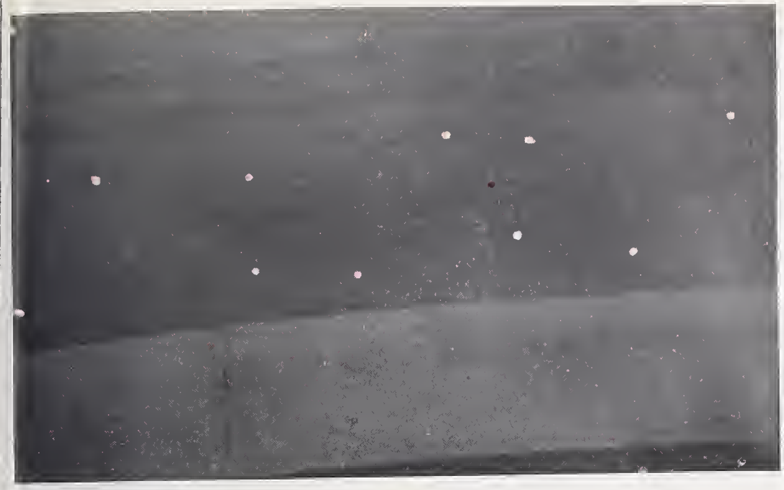

FIGURE 3.—⅛-in. battleship linoleum on wood subfloor (test panel 2–L).

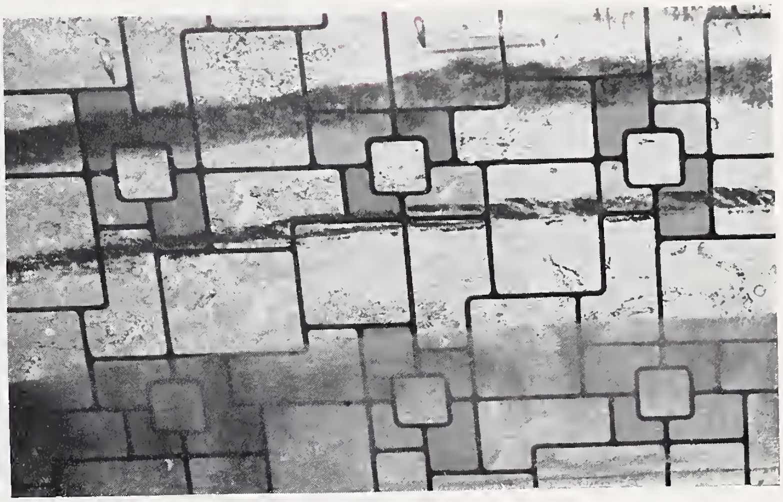

FIGURE 4.—Standard-gage inlaid linoleum on concrete subfloor (test panel 3–L).

FIGURE 5.—Standard-gage inlaid linoleum on wood subfloor (test panel 4–L).

FIGURE 6.—*Medium-gage jaspe linoleum on concrete subfloor (test panel 5–L).*

FIGURE 7.—*Medium-gage jaspe linoleum on wood subfloor (test panel 6–R).*

FIGURE 8.—*Printed linoleum on concrete subfloor (test panel 7–L).*

Figure 9.—*Printed linoleum on wood subfloor (test panel 8–L).*

Figure 10.—*Inlaid felt base on concrete subfloor (test panel 9–L).*

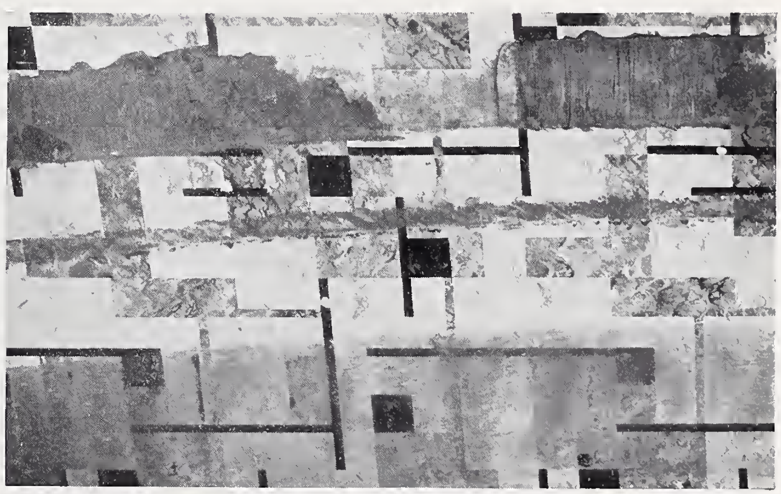

Figure 11.—*Inlaid felt base on wood subfloor (test panel 10–L).*

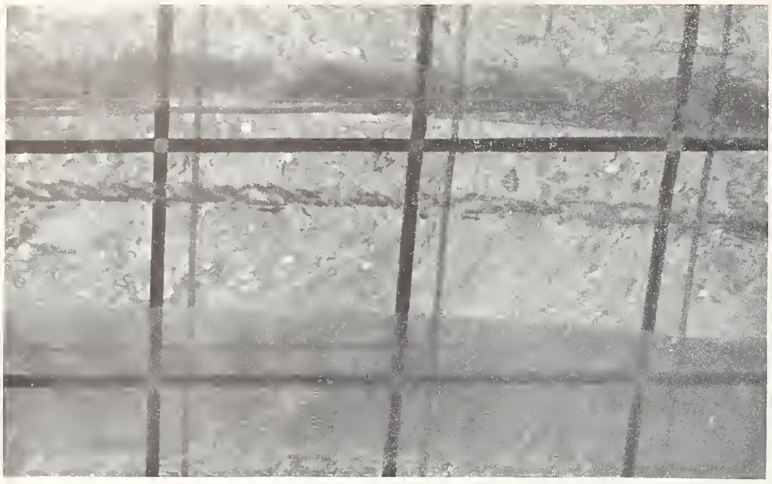

Figure 12.—*Inlaid felt base on concrete subfloor (test panel 11–R).*

Figure 13.—*Inlaid felt base on wood subfloor (test panel 12–R).*

Figure 14.—*Printed felt base on concrete subfloor (test panel 13–L).*

Figure 15.—*Printed felt base on wood subfloor (test panel 14–L).*

Figure 16.—*Mastic felt base on wood subfloor (test panel 16–L).*

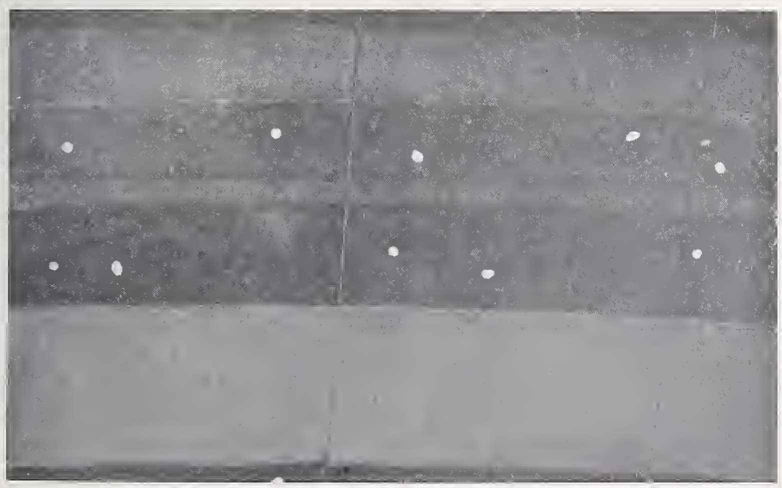

Figure 17.—*⅛-in. pressed fiberboard on wood subfloor (test panel 18–R).*

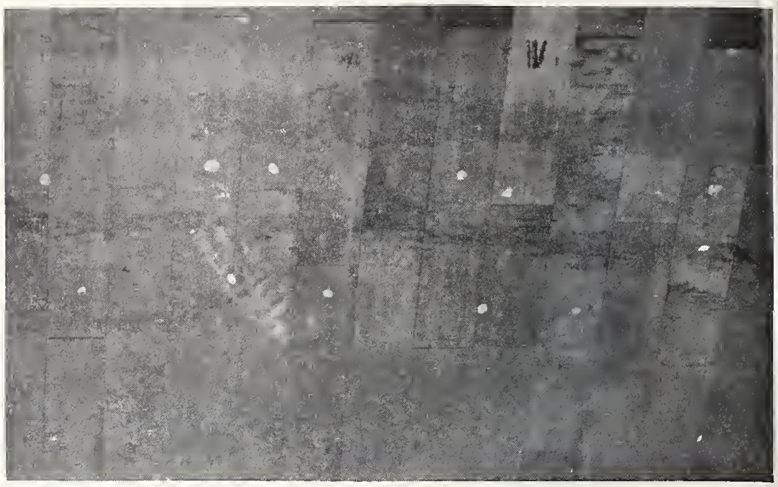

FIGURE 18.—$^{25}/_{32}$-in. short-strip maple on concrete subfloor (test panel 19–R).

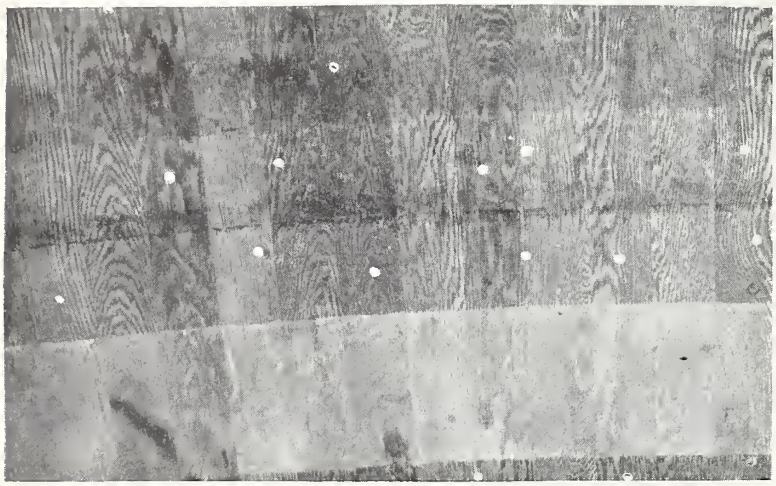

FIGURE 19.—$^{25}/_{32}$-in. strip white oak on wood sleepers (test panel 20–L).

FIGURE 20.—$^{25}/_{32}$-in. strip yellow pine on wood sleepers (test panel 20–R).

and reset. In panels *15–L* and *16–L* failure in adhesion to the subfloors occurred along the paths of the truck wheels and the floor covering was buckled and fractured to a considerable extent.

The ⅛-in. pressed fiberboard, test panels 17 and 18 (see fig. 17), was in serviceable condition at the end of the performance test, although the fiberboard was appreciably worn by the abrasive action of the walking wheel. Over a concrete subfloor the fiberboards, when first installed, showed a tendency to warp, resulting in some loose boards. There was evidence of extensive failure in adhesion to the wood subfloor in panel *18–L*, permitting the tiles to chatter when tapped on the surface, and under the action of the metal truck wheels the adhesive was pulverized and dusted out at the joints of the boards. The fiberboard did not appear to be compressed or fractured by the metal truck wheels, although it showed some deflection over a wood subfloor.

The short-strip maple flooring, test panel 19 (see fig. 18), was in very good condition except for some failure in adhesion to the concrete subfloor. In panel *19–L* the maple expanded across the grain and formed an arch approximately one-eighth of an in. above the concrete subfloor in the central portion of the track. In panel *19–R* some of the maple strips shifted toward the inside of the track, leaving a slight separation in some of the end joints. The maple was moderately depressed by the metal truck wheels. There was no evidence of fracture or splintering of the maple.

The strip white-oak flooring, test panel *20–L* (see fig. 19), was in good condition at the end of the performance test. The strips remained rigidly bonded to the sleepers. The white oak was moderately depressed, and fractured to a slight degree, by the metal truck wheels.

The strip yellow-pine flooring, test panel *20–R* (see fig. 20), was in fair condition at the end of the performance test. The strips remained rigidly bonded to the sleepers. The metal truck wheels depressed the yellow pine to an appreciable degree and caused some fracturing and splintering of the flooring.

Several of the adhesives showed good adhesive strength and durability under the severe treatment of the test; however the much-lower-cost lignin paste also showed good performance as an adhesive for bonding linoleum and felt-base floor coverings to concrete or wood subfloors. Lignin paste is partially soluble in water and should not be used where exposure to moisture is probable. The oil- or varnish-base cements rendered durable service and had an initial tackiness, which is a desirable property from the standpoint of the installer. The casein-latex cement showed good performance, although a definite interval of time is required between the spreading of the adhesive and the laying of the floor covering for proper tackiness to develop. The cumar-resin cement showed good performance. This adhesive sets very quickly, necessitating that it be spread in units of a small area at one time. Laboratory tests indicate that it is not appreciably affected by moderate exposure to moisture. The copal-resin cement, consisting principally of "Manila gum" or copal, clay, and alcohol, did not show good performance. A definite period of time is required between the spreading of the adhesive and the laying of the floor covering in order to prevent the formation of gas pockets under the floor covering and at the same time have the adhesive retain sufficient tackiness. The adhesive becomes brittle when dry and pulverizes under severe traffic. The petrolatum-base cement did not have sufficient resistance to shearing stresses to be satisfactory for bonding thin flexible floor coverings. It did not have good spreading consistency. Neither hot asphalt nor cold cut-back asphalt appeared adequate to prevent the movement of short-strip wood flooring on a concrete subfloor.

VI. COMMENTS

In view of the type of occupancy for which most of the floor coverings under investigation are intended, it must be emphasized that the action of the metal truck wheels represents very severe service to both the floor covering and the bonding agent. Failure in either one has an effect on the ability of the other to withstand service. In interpreting the results of this performance test as an aid in the selection of a floor covering and a bonding agent, the nature of the service to which they will be subjected should be given consideration. The desires of the user with respect to specific properties and the cost should also be considered. In this respect, some of the lower-cost floor coverings and methods of bonding, even though less durable, should render economical and satisfactory service provided they are not subjected to severe abuse and only moderate length of service is required or where frequent replacements may be desirable, as in rental dwellings.

In general, the results indicate that, of the floor coverings tested, battleship linoleum, inlaid linoleum, strip white oak, and short-strip maple are durable floor coverings even under severe service. A better method of bonding short-strip wood flooring to a concrete subfloor is needed. The above-mentioned floor coverings are the higher priced of the floor coverings tested. Of the lower-cost floor coverings printed linoleum, strip yellow-pine, and printed felt base showed fair performance with respect to adherence to subfloors and resistance to severe service. They should render economical service for a limited time under moderate abuse. All the linoleum and felt-base floor coverings showed better performance on a concrete subfloor than on a wood subfloor. Obviously, these conclusions are based on tests of good-quality merchandise.

The complete removal of the floor coverings, underlays, and adhesives from the subfloors was found to be rather difficult and time-consuming in many of the installations. Where occasional reinstallations may be required, ease of removal from the subfloor should be considered in the selection of floor covering, underlay, and adhesive. Considerable difficulty was encountered in the removal of asphalt-saturated felt-base floor coverings and asphalt-saturated lining felt when used in conjunction with water-insoluble adhesives. In conjunction with lignin paste considerable time was required for water to penetrate through cuts in the asphalt-saturated felt and adequately loosen the bond. Dry lining felt in conjunction with lignin paste was readily removed with water. The inlaid felt-base floor covering in test panels 11 and 12 contained a plastic rubber coating between the felt base and factory-applied adhesive and was readily removed.

In general, when durable floor coverings are used over wood subfloors under severe traffic conditions, an underlay of asphalt-saturated lining felt is desirable from the standpoint of indentation and durability. Where less durable floor coverings are used and thus occasional reinstallations probable, the use of dry lining felt in conjunction with lignin paste over wood subfloors is preferable unless other adequate means are provided for removal. On concrete subfloors more drastic methods can be employed in removing the floor coverings and adhesives without damaging the subfloor.

A performance test on additional floor coverings and adhesives is in progress.

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WASHINGTON, August 11, 1939.

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