U. S. DEPARTMENT OF COMMERCE

BUILDING MATERIALS AND STRUCTURES

REPORT BMS100

Relative Slipperiness of Floor and Deck Surfaces

by

PERCY A. SIGLER

NATIONAL
BUREAU OF STANDARDS

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ISSUED JULY 1, 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

A new and practical method of determining the relative slipperiness of floor surfaces under both dry and wet conditions has been developed at the National Bureau of Standards. This report describes the method and gives the results of tests of a variety of floor and deck materials. The test data show the effect of abrasives, embossments, and different wax finishes on the antislip properties of selected floor materials.

LYMAN J. BRIGGS, *Director.*

Relative Slipperiness of Floor and Deck Surfaces

by PERCY A. SIGLER

CONTENTS

ABSTRACT

A new pendulum-type machine and a method for determining the relative slipperiness of floor surfaces under various conditions are described. The surfaces were tested when dry and clean, dry and dirty, wet and clean, wet and dirty, wet and soapy, and in a few cases, oily. The results of tests of various floor materials are given, including such general types as stone, terrazzo, cement-mortar, magnesite, ceramic tile, metal, asphalt, rubber, linoleum, and wood. The surfaces of the materials were tested after grinding them with No. 180 silicon carbide. Tests were also made of the original surfaces of many of the materials. The test data show the effect of different wax finishes on the antislip properties of several selected floor materials.

In general, considerable difference in slipperiness was found between dry and wet surfaces. Most of the floor materials showed satisfactory antislip properties when dry. Many would be classed as hazardous when wet.

I. INTRODUCTION

The slipperiness of any surface is important to the physical well-being of those who walk on it. The practice of sprinkling sand or ashes on ice-covered pavements to make them less hazardous is a familiar one. This practice, of course, would be very objectionable for indoor floors and, in addition, on hard surfaces where the rough particles could not become anchored it would likely create a more hazardous condition. Considerable thought has been given to ways of improving the antislip characteristics of paving and flooring materials. Probably the most common method is to provide a roughened surface. This is accomplished in some floor coverings, such as metal stair treads and rubber matting, by forming corrugations or embossments in the surface; in others, such as ceramic tile and troweled monolithic floors, by embedding rough abrasives, like aluminum oxide or silicon carbide, in the surface. Rough surfaces are difficult to maintain and keep clean and are thus not desirable for general indoor use. Smooth-faced materials are extensively used as floor coverings, and information on their relative slipperiness in desired.

In most of the previous investigations of the slipperiness of floors, measurements were made of the coefficients of static friction between floor surfaces and leather soles. A few included measurements of kinetic or dynamic friction. The coefficients obtained for dry surfaces often appeared to be indicative of the relative slipperiness of the surfaces. However, the coefficients obtained for wet surfaces were usually higher than those obtained for the same surface when dry. This was found to be especially so for smooth-faced materials. Apparently, the results obtained by the methods previously in use are not indicative of the slipperiness of floor surfaces when wet. An appreciable area of contact between a leather sole and a floor surface was generally involved in these methods, which would be more representative of a person standing on a floor rather than in process of walking, at which time most accidental falls occur. In view of this, a machine was constructed at the National Bureau of Standards that incorporated a new and more practical method of determining the relative slipperiness of floors.

The tests were sponsored by the Federal Interdepartmental Safety Council and funds

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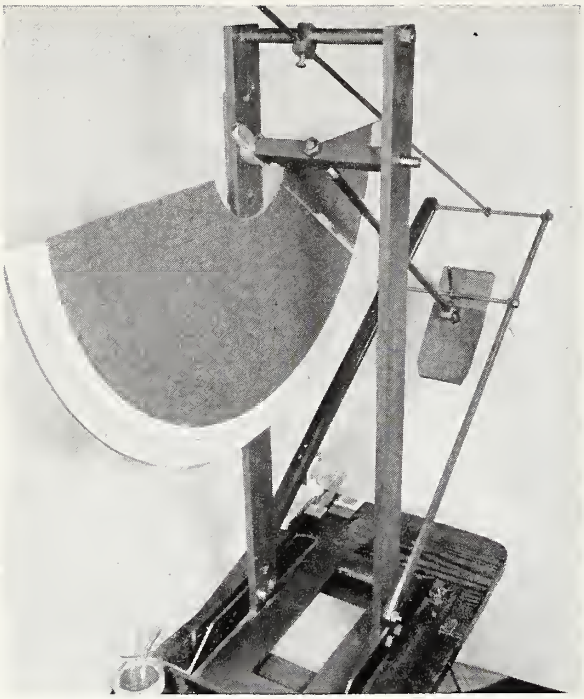


FIGURE 1.—*Pendulum-type slipperiness tester.*

were contributed by the U. S. Maritime Commission, Public Buildings Administration, Post Office Department, Navy Department, and War Department toward the expenses of the project. W. C. Clark, of the Public Buildings Administration, assisted in formulating the project, and M. N. Geib, of the National Bureau of Standards, assisted in obtaining the test data.

II. DESCRIPTION OF THE APPARATUS

The machine is primarily a compound pendulum which sweeps a leather or rubber heel over the surface to be tested (see fig. 1). A pointer attached to the framework at the center of oscillation of the pendulum indicates on a quadrant the maximum height to which the center of gravity of the pendulum rises above its lowest position. The surface of a floor specimen is held at a definite relationship to the pendulum by clamping it against the underside of a base plate. The base plate has a rectangular opening in its central portion to permit contact between a leather or rubber heel and the floor specimen.

A mechanical heel forms the lower end of the pendulum (see fig. 2) and swings over the surface of the floor specimen. This mechanism consists of a metal block, *A*, at the front of which and on the underside is hinged a metal strap, *B*. The metal strap is bent so that the unhinged end is approximately at right angles to the rod of the pendulum. A 2-inch square of leather or rubber, *C*, is clamped on the face of a wedge-shaped block, *D*, which is fastened to the underside of the metal strap, *B*. The slope of the wedge-shaped block is approximately 10° so that only the rear edge of the leather or rubber heel contacts the floor specimen. A coil spring, *E*, is placed under compression between the metal strap, *B*, and the metal block, *A*, so that the edge of the heel is pressed against the floor specimen during contact. A stop, *F*, prevents the metal strap from swinging below a fixed position.

III. TEST PROCEDURE

The procedure in testing consists of swinging the pendulum back or to the right and fastening it in a fixed position (see fig. 1). Preliminary tests, with the pendulum released at heights of 5, 10, and 15 in., indicated that a height of 10 in. was the most suitable. The maximum

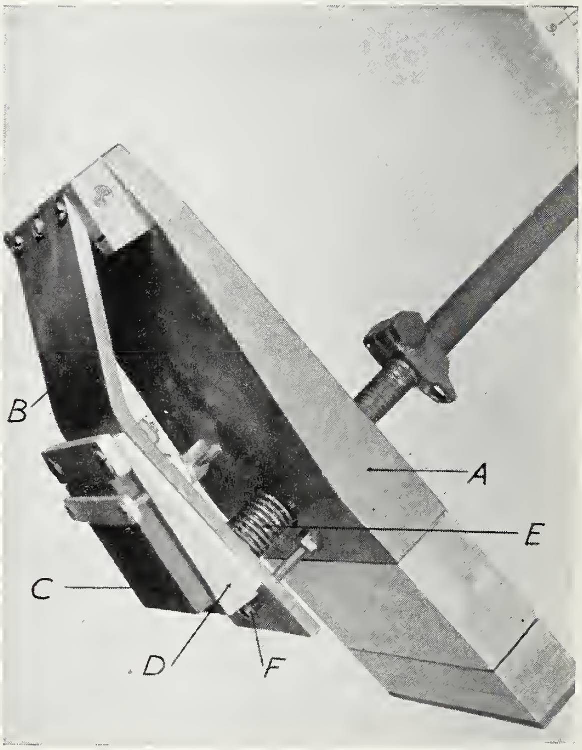


FIGURE 2.—*Detail of mechanical heel.*

velocity attained by the heel from this height is approximately 500 feet/min. The floor specimen, in a dry and clean condition, is then clamped against the base plate of the machine and the 2-in. square of leather (with the grain side down) or rubber fastened on the mechanical heel. The edge of the leather or rubber is lightly ground with No. 0 flint paper and then thoroughly brushed with a soft-bristled brush in order to bring the edge to a uniform condition. The pendulum is then released and the edge of the heel permitted to sweep over the surface of the floor specimen. The height to which the pendulum swings beyond the floor specimen or to the left is indicated by the pointer and is recorded. Tests are repeated using other edges of the heel, and the results are averaged. The agreement between the results obtained on individual edges is usually very good. The surface of the floor specimen is then changed to a desired condition and tested in a similar manner. Separate heels are used in testing under different conditions in order to facilitate the maintaining of uniform heels for each condition. Under wet conditions, the leather and rubber heels are buffed and immersed in water prior to making tests.

The work done in sliding the mechanical heel over the floor surface is $f \times D$, where f is the frictional force, and D is the distance through which it acts. This may be equated to the energy lost by the pendulum, $W(H-h)$, where W is the effective weight and $(H-h)$ is the difference in the heights of the center of gravity at the end of the swing without and with the specimen in place. The frictional force, f, is by definition, equal to the coefficient of friction, u, multiplied by the force, P, normal to the plane of contact.

From the above relations, it is found that

$$u=\frac{W\,(H-h)}{DP}.$$

For the present machine, $W=12.1$ lb, $H=9.7$ in., $D=5.1$ in., and $P=6.5$ lb. Substituting these values in the equation, we find $u=3.54-0.37\,h$.

Since the above reasoning has involved making certain assumptions and is based on dynamic friction, which is not independent of velocity or necessarily analogous to static friction, it is not strictly correct to call u the coefficient of friction. We have chosen rather to call it the "antislip coefficient."

IV. FLOOR SURFACE CONDITIONS

In selecting the various conditions under which the floor materials were tested, an endeavor was made to simulate service conditions and at the same time adopt procedures which could be controlled or duplicated in the laboratory. Specimens in equilibrium with an atmosphere of 65 percent relative humidity and 72° F were classed as dry. From a practical standpoint the clean conditions would represent an exceptionally clean floor. Dirty conditions were simulated by sprinkling china clay on the specimen and would represent a very dirty floor. Preliminary tests in which dirt consisting chiefly of sand and clay and passing through a No. 200 sieve was used gave results similar to those obtained when china clay was used. A puddle of water was maintained on the floor surface for wet conditions. As a practical comparison, the wet and dirty condition would be representative of the condition frequently encountered during a rain on a floor just inside and entrance from the street. A 0.5 percent soap solution was used for the wet and soapy condition and would represent a maintenance procedure involving the use of a very strong soap solution with no rinsing.

Preliminary tests of several stone materials having various finishes indicated that the finish is an important factor. A grinding procedure was developed in order to determine the relative antislip characteristics of the materials after exposure to the same type of abrasion. A hard marble, a soft marble, and a hard sandstone were selected for study. They were ground with silicon carbide abrasives of various grain sizes to change the original surfaces and their antislip characteristics determined after each grinding. Grain sizes used were Nos. 80, 150, and 180. The finishes obtained on the Tennessee hard marble were compared with the finish on stair treads of the same type of marble in service at this Bureau. From the nature of the results and the finishes obtained, No. 180 grit was selected for use in a uniform grinding procedure. This grinding procedure should not be interpreted as representative of wear on all types of floor surfaces regardless of their location.

A revolving cast-iron disk approximately 40 in. in diameter was used in grinding the specimens. The disk was kept wet with water and the abrasive sprinkled on the disk at frequent intervals throughout the grinding procedure. A more convenient means was adopted later. A stationary cast-iron slab was substituted for the revolving disk, and the specimens were ground by hand, using a circular motion.

V. MATERIALS TESTED AND RESULTS

The floor and deck materials are listed in table 1, along with the results of the tests. The antislip coefficients of the materials were determined for both leather and rubber heels and under five different conditions. Tests were made on the original surface of many of of the materials as well as after being ground with No. 180 silicon carbide. Materials having a corrugated surface were tested in both of the principal directions; that is, parallel to and perpendicular to the grooves.

Oily conditions were not extensively investigated. Tests of a cement mortar and a few ceramic tiles in which mineral oil, SAE No. 40, was used to obtain an oily condition gave the following results: With excessive oil on the surface, the antislip coefficients were extremely low. With all excess oil wiped from the surface, the coefficients were appreciably higher, approximately the same as obtained under wet conditions. The coefficients were increased slightly by sprinkling china clay on the oily surfaces.

TABLE 1.—*Relative slipperiness of floor and deck surfaces under various conditions*

Sample number	Floor or deck material		Antislip coefficient									
			Leather heel					Rubber heel				
	Type and description	Surface [a]	Dry and clean	Dry and dirty	Wet and clean	Wet and dirty	Wet and soapy	Dry and clean	Dry and dirty	Wet and clean	Wet and dirty	Wet and soapy
	NATURAL STONE											
1	Minnesota white granite, 4-cut	Original	0.44	0.47	0.44	0.40	0.40	0.77	0.58	0.62	0.55	0.58
1	do	Ground	.40	.44	.18	.18	.15	.62	.47	.47	.40	.44
2	Minnesota red granite, honed	do	.44	.47	.26	.22	.15	.66	.47	.44	.37	.49
3	Tennessee red marble, honed	do	.44	.49	.33	.26	.11	.88	.51	.33	.28	.22
4	Vermont white marble, honed	Original	.37	.39	.26	.22	.15	.80	.39	.15	.13	.07
4	do	Ground	.42	.51	.42	.37	.24	.86	.51	.40	.35	.29
5	Arkansas limestone, honed	do	.47	.44	.18	.15	.11	.62	.47	.55	.47	.40
6	Tennessee sandstone, split	Original	.44	.47	.49	.49	.47	.75	.55	.62	.58	.60
6	do	Ground	.46	.49	.53	.47	.46	.90	.51	.62	.55	.57
7	Virginia greenstone, edge-grained	do	.44	.47	.26	.18	.18	.77	.47	.55	.47	.47
	TERRAZZO (1:2)											
8	Marble chips, no abrasive	Original	0.37	0.40	0.22	0.18	0.15	0.80	0.44	0.26	0.18	0.15
8	do	Ground	.40	.44	.33	.29	.22	.75	.42	.42	.33	.26
9	1 Carborundum:3 marble chips	Original	.44	.47	.26	.22	.15	.86	.47	.40	.26	.29
9	do	Ground	.40	.47	.40	.26	.15	.77	.47	.62	.51	.44
10	1 Carborundum:1.7 marble chips	do	.40	.47	.29	.26	.18	.77	.47	.55	.47	.44
11	1 Carborundum: 1marble chpis	Original	.44	.44	.22	.18	.15	.69	.47	.40	.29	.37
11	do	Ground	.40	.47	.37	.29	.26	.77	.47	.55	.47	.44
12	1 Carborundum:0.6 marble chips	do	.44	.47	.29	.26	.18	.77	.55	.55	.47	.44
13	Carborundum, ½ lb/ft² [b]	Original	.40	.47	.22	.18	.15	.73	.47	.44	.33	.40
13	do	Ground	.44	.47	.40	.29	.22	.73	.47	.58	.51	.51
14	1 Alundum:3 marble chips	do	.44	.47	.29	.18	.11	.73	.47	.51	.47	.40
15	1 Alundum:1.7 marble chips	do	.47	.51	.22	.22	.18	.73	.55	.58	.47	.51
16	1 Alundum:1 marble chips	do	.44	.55	.33	.29	.29	.73	.51	.66	.51	.51
17	1 Alundum:0.6 marble chips	do	.44	.51	.29	.18	.18	.77	.51	.62	.47	.51
18	1 Vittrazzo:3 marble chips	do	.40	.51	.26	.37	.18	.73	.55	.58	.44	.40
19	1 Vittrazzo:1 marble chips	do	.44	.51	.22	.22	.15	.77	.55	.55	.47	.47
20	1 Vittrazzo:0.6 marble chips	do	.44	.47	.29	.37	.18	.73	.55	.55	.51	.47
21	Vittrazzo, ½ lb/ft² [b]	do	.44	.51	.22	.18	.18	.80	.51	.55	.37	.47
22	1 Anti-Slip:3 marble chips	do	.44	.51	.26	.33	.15	.73	.51	.51	.47	.40
23	1 Anti-Slip:1 marble chips	do	.44	.55	.29	.22	.18	.77	.55	.58	.47	.51
24	1 Macanite:4 marble chips	do	.46	.47	.37	.24	.17	.86	.51	.46	.33	.35

See footnotes at end of table.

TABLE 1.—*Relative slipperiness of floor and deck surfaces under various conditions*—Continued

Sample number	Floor or deck material: Type and description	Surface [a]	Antislip coefficient: Leather heel: Dry and clean	Dry and dirty	Wet and clean	Wet and dirty	Wet and soapy	Rubber heel: Dry and clean	Dry and dirty	Wet and clean	Wet and dirty	Wet and soapy
	CEMENT MORTAR (1:2½)											
25	Wood-float finish	Original	0.44	0.47	0.40	0.40	0.33	0.66	0.58	0.55	0.55	0.55
26	Trowel finish, acid etched	do	.44	.47	.37	.40	.37	.84	.51	.55	.55	.55
27	Trowel finish	Ground	.47	.55	.40	.40	.33	.80	.51	.62	.55	.58
28	do	do	.47	.51	.44	.44	.40	.84	.51	.69	.58	.66
29	No. 20 Carborundum, ⅓ lb/ft^2 [a b]	do	.44	.51	.37	.40	.33	.73	.55	.58	.51	.55
30	No. 30 Carborundum, ⅓ lb/ft^2 [a b]	do	.44	.51	.40	.40	.33	.80	.55	.62	.55	.58
31	No. 12–30 Alundum, ⅓ lb/ft^2 [a b]	do	.47	.51	.33	.33	.26	.84	.51	.62	.58	.62
32	No. 30 Alundum", ⅓ lb/ft^2 [a b]	do	.47	.51	.44	.40	.29	.77	.55	.66	.62	.62
33	Metalicron (Fe and AeO$_3$), ⅓ lb/ft^2 [b]	do	.47	.47	.18	.15	.11	.77	.47	.58	.51	.51
	CEMENT MORTAR (1:2)											
34	Trowel finish	Original	0.37	0.47	0.11	0.07	0.07	0.77	0.47	0.22	0.22	0.26
34	do	Ground	.47	.47	.29	.18	.15	.69	.47	.47	.40	.44
	CONCRETE											
35	Iron borings, 1 lb/ft^2 [a b]	Ground	0.44	0.55	0.18	0.22	0.15	0.73	0.55	0.58	0.47	0.47
	MAGNESITE											
36	Silica, asbestos fiber	Original	0.44	0.44	0.04	0.04	0.04	0.66	0.47	0.26	0.26	0.26
36	do	Ground	.44	.44	.11	.11	.11	.69	.47	.55	.47	.51
37	Talc, asbestos fiber, sawdust	Original	.51	.47	.07	.04	.04	.80	.47	.26	.22	.22
37	do	Ground	.40	.47	.26	.18	.18	.84	.47	.44	.37	.40
38	Marble dust, cotton fiber, copper	do	.40	.47	.18	.18	.15	.84	.51	.51	.44	.51
39	Calcite dust	do	.44	.44	.33	.26	.22	.77	.47	.58	.51	.55
40	do	Original	.40	.40	.11	.07	.07	.77	.40	.37	.26	.47
40	do	Ground	.40	.44	.26	.22	.26	.80	.44	.58	.44	.62
41	Marble (⅛ in. to dust)	Original	.37	.44	.15	.11	.15	.69	.40	.33	.37	.44
41	do	Ground	.40	.44	.26	.22	.26	.84	.44	.55	.40	.58
42	Granite chips	Original	.40	.44	.29	.29	.33	.80	.44	.55	.47	.55
42	do	Ground	.37	.44	.26	.18	.22	.73	.44	.44	.40	.62
43	Fine emery	Original	.33	.40	.07	.11	.11	.62	.40	.15	.37	.33
43	do	Ground	.40	.44	.26	.22	.26	.73	.44	.55	.47	.58
44	Granulated cork	Original	.40	.47	.18	.15	.18	.95	.47	.33	.33	.40
44	do	Ground	.47	.47	.26	.22	.26	.84	.47	.33	.29	.33
	MAGNESITE TILE											
45	Coarse abrasive, 35% Al_2O_3 abrasive	Original	0.37	0.44	0.40	0.29	0.37	0.77	0.51	0.47	0.40	0.47
45	do	Ground	.44	.47	.47	.44	.44	.77	.51	.66	.58	.58
46	Medium abrasive	do	.47	.51	.40	.37	.22	.77	.55	.62	.62	.58
47	Fine abrasive	do	.47	.47	.18	.18	.15	.88	.47	.58	.47	.55
	CERAMIC TILE											
48	Alundum, 80% Al_2O_3 abrasive	Original	0.47	0.47	0.44	0.37	0.33	0.84	0.51	.058	0.55	0.55
48	do	Ground	.49	.49	.55	.51	.47	.93	.55	.69	.58	.66
49	Alundum, 35% Al_2O_3 abrasive	Original	.40	.44	.22	.18	.15	.73	.44	.37	.37	.33
49	do	Ground	.44	.47	.33	.26	.22	.77	.47	.62	.55	.58
50	Natural clay, no abrasive	Original	.40	.40	.15	.07	.07	.73	.44	.26	.22	.22
50	do	Ground	.40	.44	.22	.22	.15	.69	.47	.40	.29	.40
51	Natural clay, 7½% Al_2O_3 abrasive	Original	.40	.40	.11	.11	.07	.69	.44	.40	.29	.33
51	do	Ground	.40	.44	.22	.22	.15	.73	.47	.47	.37	.44
52	Natural clay, 12% Al_2O_3 abrasive	Original	.40	.44	.11	.11	.11	.69	.44	.37	.33	.33
52	do	Ground	.40	.44	.18	.15	.15	.69	.47	.44	.37	.40
53	Natural clay, 35% Al_2O_3 abrasive	Original	.37	.44	.26	.22	.22	.69	.44	.51	.37	.47
53	do	Ground	.40	.47	.26	.18	.18	.77	.47	.58	.47	.55
54	Porcelain, no abrasive	Original	.44	.44	.07	.15	.04	.69	.44	.22	.22	.18
54	do	Ground	.40	.44	.26	.18	.18	.66	.47	.44	.37	.40
55	Porcelain, 6% Al_2O_3 abrasive	Original	.40	.44	.07	.11	.07	.69	.47	.29	.29	.26
55	do	Ground	.40	.47	.22	.18	.15	.69	.47	.47	.40	.44
56	Porcelain, 12% Al_2O_3 abrasive	Original	.44	.47	.11	.11	.07	.73	.47	.37	.37	.33
56	do	Ground	.40	.47	.22	.18	.15	.69	.47	.47	.47	.44
57	Porcelain, 35% Al_2O_3 abrasive	Original	.44	.47	.22	.18	.18	.77	.47	.44	.40	.40
57	do	Ground	.44	.47	.22	.22	.18	.69	.47	.51	.47	.47
58	Quarry, even surface	Original	.40	.44	.07	.07	.07	.73	.44	.29	.26	.29
58	do	Ground	.44	.44	.18	.15	.15	.69	.47	.55	.47	.47

See footnotes at end of table.

TABLE 1.—*Relative slipperiness of floor and deck surfaces under various conditions*—Continued

Sample number	Floor or deck material: Type and description	Floor or deck material: Surface [a]	Antislip coefficient: Leather heel: Dry and clean	Leather heel: Dry and dirty	Leather heel: Wet and clean	Leather heel: Wet and dirty	Leather heel: Wet and soapy	Rubber heel: Dry and clean	Rubber heel: Dry and dirty	Rubber heel: Wet and clean	Rubber heel: Wet and dirty	Rubber heel: Wet and soapy
	CERAMIC TILE—Continued											
59	Quarry, straight grooves [c]	Original	0.40	0.47	0.11	0.11	0.11	0.80	0.47	0.33	0.29	0.29
59	do [d]	do	.40	.47	.18	.26	.18	.69	.55	.37	.37	.33
59	do [c]	Ground	.40	.47	.29	.22	.26	.66	.47	.51	.37	.47
59	do [d]	do	.44	.47	.40	.44	.37	.84	.62	.55	.47	.51
60	Quarry, diagonal grooves	Original	.40	.44	.15	.15	.15	.77	.51	.33	.29	.33
60	do	Ground	.40	.47	.33	.33	.29	.69	.55	.55	.44	.51
61	Quarry, diamond pattern	Original	.37	.44	.11	.15	.11	.77	.47	.33	.29	.29
61	do	Ground	.40	.44	.29	.33	.33	.69	.51	.55	.44	.51
62	Quarry, diamond and dot	Original	.23	.44	.11	.18	.11	.73	.47	.26	.26	.26
62	do	Ground	.40	.44	.33	.29	.26	.69	.51	.55	.47	.51
	METAL											
63	Aluminum, Al_2O_3 abrasive	Original	0.44	0.47	0.51	0.47	0.47	0.77	0.58	0.58	0.51	0.58
63	do	Ground	.47	.47	.33	.26	.29	.77	.47	.66	.51	.66
64	Iron, Al_2O_3 abrasive	Original	.51	.51	.40	.40	.37	.84	.55	.37	.37	.40
64	do	Ground	.46	.47	.32	.28	.22	.69	.51	.47	.44	.44
65	Iron, embossed (ellipse)	Original	.33	.44	.15	.15	.18	.62	.47	.26	.18	.26
65	do	Ground	.37	.44	.22	.18	.22	.73	.55	.47	.40	.51
	ASPHALT											
66	Mastic, volcanic ash, cement	Original	0.47	0.47	0.26	0.26	0.22	0.77	0.51	0.55	0.44	0.51
66	do	Ground	.47	.47	.40	.40	.37	.99	.51	.69	.55	.66
67	Pavement block	Original	.47	.44	.18	.11	.11	.80	.44	.33	.33	.33
67	do	Ground	.40	.44	.18	.11	.11	.69	.44	.47	.37	.47
68	Tile, plain, black, ¼ in	Original	.55	.44	.18	.11	.07	.91	.44	.29	.26	.22
68	do	Ground	.47	.44	.11	.11	.11	.80	.44	.26	.22	.22
69	Tile, plain, black, ⅛ in	Original	.56	.43	.25	.25	.15	.87	.44	.32	.26	.21
69	do	Ground	.51	.44	.32	.32	.22	.78	.46	.37	.32	.27
70	Tile, marbleized, white, ⅛ in	Original	.47	.44	.18	.11	.07	.80	.44	.29	.26	.26
70	do	Ground	.47	.44	.15	.15	.11	.69	.47	.37	.33	.33
71	Tile, plain, red, 3/16 in	Original	.47	.44	.15	.11	.07	.80	.44	.29	.26	.26
71	do	Ground	.55	.44	.18	.15	.11	.73	.47	.40	.37	.37
	RUBBER											
72	Latex, cement, marble chips	Original	0.47	0.44	0.07	0.15	0.07	0.84	0.44	0.18	0.18	0.15
72	do	Ground	.55	.51	.33	.29	.26	.77	.55	.40	.37	.33
73	do	Original	.40	.40	.11	.11	.07	.73	.44	.18	.18	.18
73	do	Ground	.51	.55	.33	.33	.26	.73	.62	.44	.40	.37
74	Sheet, marbleized, brown, ⅛ in	Original	.32	.33	.15	.15	.11	.46	.34	.10	.16	.10
74	do	Ground	.59	.47	.21	.18	.12	.87	.47	.27	.21	.15
75	Tile, marbleized, gray, ⅛ in	do	.46	.47	.09	.09	.07	.66	.47	.15	.15	.15
76	Tile, diamond weave, sand blasted	Original	.33	.40	.18	.18	.18	.77	.44	.22	.33	.29
76	do	Ground	.40	.44	.22	.18	.18	.69	.47	.29	.37	.37
77	Soft, tile Al_2O_3 abrasive	Original	.44	.47	.18	.18	15	.80	.51	.28	.26	.26
77	do	Ground	.62	.47	.21	.15	.12	.85	.49	.29	.23	.22
78	Hard tile, Al_2O_3 abrasive	do	.42	.46	.24	.17	.11	.79	.50	.40	.34	.31
79	Matting, even surface	do	.66	.47	.15	.11	.07	.90	.51	.22	.18	.18
80	Matting, embossed (coarse)	do	.62	.53	.15	.18	.11	.88	.55	.24	.26	.18
81	Matting, embossed (medium)	do	.66	.55	.22	.22	.15	.88	.58	.29	.26	.22
82	Matting, embossed (fine)	do	.69	.53	.24	.20	.15	.91	.55	.29	.26	.22
83	Matting, straight grooves (fine) [c]	Original	.44	.40	.26	.26	.22	.66	.58	.26	.26	.18
83	do [d]	do	.58	.55	.33	.29	.26	.88	.69	.37	.33	.29
83	do [c]	Ground	.55	.47	.26	.22	.18	.88	.51	.22	.22	.18
83	do [d]	do	.73	.51	.26	.18	.18	.95	.55	.22	.22	.18
84	Matting, straight ribs (6-ply strip on edge) [c]	Original	.51	.47	.22	.22	.18	.84	.47	.26	.18	.18
84	do [d]	do	.55	.51	.29	.26	.26	.88	.58	.29	.26	.22
84	do [c]	Ground	.62	.47	.18	.18	.18	.95	.51	.22	.18	.18
84	do [d]	do	.55	.51	.29	.26	.18	.80	.66	.22	.18	.18
	CORK TILE											
85	Light shade, factory finish	Original	0.40	0.40	0.15	0.11	0.04	0.88	0.40	0.11	0.11	0.07
85	do	Ground	.51	.47	.24	.19	.17	.73	.47	.44	.33	.37
86	High density, no finish	Original	.47	.47	.22	.15	.11	.73	.47	.37	.22	.29
86	do	Ground	.47	.47	.26	.20	.20	.73	.51	.33	.26	.29

See footnotes at end of table.

Table 1.—*Relative slipperiness of floor and deck surfaces under various conditions*—Continued

Sample number	Floor and finish materials		Antislip coefficient									
			Leather heel					Rubber heel				
	Type and description	Surface [a]	Dry and clean	Dry and dirty	Wet and clean	Wet and dirty	Wet and soapy	Dry and clean	Dry and dirty	Wet and clean	Wet and dirty	Wet and soapy
	LINOLEUM											
87	Battleship, brown, ⅛ in	Original	0.43	0.40	0.19	0.22	0.16	0.80	0.44	0.18	0.18	0.16
87	do	Ground	.43	.44	.34	.29	.25	.78	.47	.40	.33	.26
88	Battleship, green, ⅛ in	do	.44	.47	.18	.15	.11	.73	.47	.40	.29	.37
89	Marbleized, white, ⅛ in	do	.44	.44	.15	.11	.07	.62	.47	.29	.22	.26
90	Composition tile, gray, ⅛ in	do	.44	.44	.18	.11	.11	.69	.47	.40	.33	.33
	FELT BACKED											
	Wearing surface:											
91	Linoleum composition	Ground	0.40	0.44	0.21	0.15	0.13	0.77	0.47	0.33	0.22	0.26
92	Cellulose nitrate composition	do	.47	.47	.24	.19	.13	.88	.47	.33	.26	.22
93	Resin treated cellulose fiber	do	.44	.44	.19	.15	.11	.80	.44	.26	.26	.26
94	Enamel	Original	.47	.40	.18	.11	.07	.88	.40	.04	.11	.04
94	do	Ground	.44	.47	.22	.17	.13	.66	.47	.37	.26	.29
	WOOD											
	No finish:											
95	Strip maple, flat-grained	Original	0.26	0.40	0.33	0.29	0.29	0.84	0.40	0.33	0.33	0.26
95	do	Ground	.29	.47	.26	.22	.18	.84	.47	.26	.18	.15
96	Strip white oak, flat-grained	Original	.26	.44	.29	.26	.26	.91	.47	.33	.26	.22
96	do	Ground	.29	.44	.26	.18	.18	.77	.47	.26	.18	.15
97	Strip red oak, flat-grained	Original	.26	.40	.33	.26	.26	.80	.40	.33	.26	.22
97	do	Ground	.29	.44	.29	.26	.22	.80	.47	.26	.18	.18
	Factory finish:											
98	Rock-elm plywood tile	Original	.33	.37	.07	.04	.04	.80	37	.18	.18	.18
98	do	Ground	.40	.44	.24	.15	.17	.77	.47	.33	.26	.26
99	Pressed fiberboard tile	Original	.40	.47	.22	.11	.11	.84	.47	.40	.29	.29
99	do	Ground	.40	.44	.24	.15	.15	.80	.47	.33	.22	.26
	SPECIAL DECKING											
	Abrasive cloth cemented to metal backing:											
100	No. 100, SiC abrasive	Original	0.69	0.62	0.69	0.66	0.66	1.10	0.73	0.80	0.77	0.77
100	do	Ground	.44	.47	.44	.40	.37	0.80	.51	.66	.55	.66
101	No. 80, SiC abrasive	Original	.69	.66	.69	.66	.66	1.10	.80	.84	.80	.80
101	do	Ground	.44	.51	.51	.47	.47	0.91	.55	.69	.66	.66
102	No. 60, SiC abrasive	Original	.62	.62	.62	.55	.58	.99	.80	.73	.69	.69
102	do	Ground	.44	.51	.47	.40	.40	.80	.58	.66	.58	.66
103	No. 50, SiC abrasive	Original	.62	.62	.62	.55	.58	.99	.80	.73	.66	.69
103	do	Ground	.40	.47	.44	.40	.44	.77	.58	.62	.55	.62
104	No. 40, SiC abrasive	Original	.62	.58	.62	.51	.55	.88	.73	.66	.62	.62
104	do	Ground	.40	.51	.47	.44	.47	.80	.58	.62	.55	.62
105	No. 24, SiC abrasive	Original	.51	.55	.51	.44	.47	.77	.69	.55	.51	.51
105	do	Ground	.40	.47	.51	.47	.47	.80	.66	.62	.55	.58
106	No. 60, Trimite cloth	Original	.55	.62	.66	.55	.55	.84	.73	.69	.62	.62
106	do	Ground	.40	.47	.40	.40	.40	.80	.51	.62	.55	.62
	Coating on metal:											
107	Rubber dispersion and abrasive	Original	.51	.55	.55	.51	.51	.77	.62	.62	.58	.69
107	do	Ground	.51	.47	.26	.26	.26	.80	.51	.51	.47	.47
108	Synthetic resin and abrasive	Original	.44	.47	.37	.33	.33	.69	.55	.37	.37	.33
108	do	Ground	.47	.47	.37	.37	.37	.73	.55	.55	.47	.55
109	do	Original	.47	.51	.44	.44	.44	.73	.55	.51	.47	.51
109	do	Ground	.47	.51	.40	.37	.37	.77	.55	.62	.51	.62
110	Asphalt mastic and sand	Original	.44	.47	.47	.47	.47	.69	.62	.55	.51	.55
110	do	Ground	.47	.47	.33	.33	.33	.84	.55	.47	.44	.47
111	Paint and ligneous abrasive	Original	.33	.44	.37	.37	.33	.62	.55	.44	.40	.44
111	do	Ground	.40	.47	.26	.22	.22	.69	.47	.58	.51	.55
112	Synthetic resin and walnut shell	Original	.40	.44	.26	.29	.22	.84	.55	.29	.29	.26
112	do	Ground	.47	.47	.26	.18	.15	.73	.47	.44	.40	.40
	Coating on pressed fiberboard:											
113	Synthetic resin and Al_2O_3 abrasive	Original	.44	.44	.26	.29	.26	.80	.51	.33	.29	.29
113	do	Ground	.47	.47	.29	.29	.26	.73	.47	.51	.44	.47
	Material cemented to metal:											
114	Rubber matting (pyramid)	Original	.55	.47	.26	.26	.22	.66	.62	.22	.26	.22
114	do	Ground	.62	.47	.22	.18	.22	.77	.62	.26	.26	.26
115	Impregnated felt (pebble grain)	Original	.37	.51	.44	.40	.33	.77	.55	.47	.40	.37
115	do	Ground	.40	.58	.40	.26	.33	.80	.58	.44	.29	.40
116	Impregnated asbestos fabric	Original	.40	.44	.26	.26	.26	.77	.51	.33	.33	.40
116	do	Ground	.44	.51	.18	.15	.18	.84	.55	.26	.22	.22

[a] Grinding was done with No. 180 silicon carbide and water.
[b] Sprinkled on surface after material was in place.
[c] Parallel to grooves.
[d] Perpendicular to grooves.

Table 2.—*Relative slipperiness of floor finishes under various conditions*

Specimen number	Floor and finish materials: Type and description	Floor and finish materials: Surface	Antislip coefficient: Leather heel: Dry and clean	Leather heel: Dry and dirty	Leather heel: Wet and clean	Leather heel: Wet and dirty	Leather heel: Wet and soapy	Rubber heel: Dry and clean	Rubber heel: Dry and dirty	Rubber heel: Wet and clean	Rubber heel: Wet and dirty	Rubber heel: Wet and soapy
	MAPLE FLOORING											
1, 2, 3	No finish material	Original	0.28	0.39	0.29	0.27	0.26	0.78	0.41	0.28	0.23	0.22
1, 2, 3	do	Ground [a]	.29	.41	.36	.30	.28	.78	.41	.36	.29	.27
1, 2, 3	Wood floor sealer (2 coats)	Sealed	.41	.44	.21	.23	.18	.87	.45	.21	.22	.17
1	Paste wax *A* (2 coats)	Waxed	.22	.33	.18	.22	.18	.62	.37	.18	.18	.15
2	Spirit wax *B* (2 coats)	do	.26	.37	.22	.18	.18	.66	.37	.18	.18	.15
3	Water-emulsion wax *C* (2 coats)	do	.29	.40	.22	.18	.15	.80	.40	.18	.18	.15
4, 5, 6	No finish material	Ground [a]	.29	.40	.32	.30	.27	.81	.40	.33	.27	.25
4, 5, 6	Floor varnish (2 coats)	Varnished	.46	.39	.15	.16	.11	.89	.40	.21	.21	.12
4	Paste wax *A* (2 coats)	Waxed	.26	.33	.18	.18	.11	.66	.33	.18	.18	.11
5	Spirit wax *B* (2 coats)	do	.26	.29	.15	.15	.11	.58	.33	.15	.15	.07
6	Water-emulsion wax *C* (2 coats)	do	.47	.40	.11	.11	.07	.91	.44	.15	.18	.07
7	No finish material	Ground [a]	.29	.40	.37	.33	.29	.80	.40	.37	.33	.29
7	Spar varnish (2 coats)	Varnished	.47	.44	.22	.18	.15	.91	.44	.29	.26	.18
7	Paste wax *D* (2 coats)	Waxed	.26	.37	.15	.18	.11	.69	.33	.18	.18	.11
	WHITE OAK FLOORING											
1, 2, 3	No finish material	Original	0.26	0.41	0.36	0.28	0.26	0.79	0.45	0.39	0.27	0.25
1, 2, 3	do	Ground [a]	.29	.43	.36	.28	.27	.79	.43	.37	.28	.26
1, 2, 3	Wood floor sealer (2 coats)	Sealed	.41	.44	.19	.19	.17	.89	.44	.22	.21	.18
1	Paste wax *A* (2 coats)	Waxed	.22	.33	.18	.18	.15	.62	.37	.15	.18	.11
2	Spirit wax *B* (2 coats)	do	.22	.29	.15	.15	.11	.58	.37	.15	.15	.11
3	Water-emulsion wax C (2 coats)	do	.33	.37	.18	.18	.15	.84	.40	.18	.18	.15
4, 5, 6	No finish material	Ground [a]	.28	.40	.32	.27	.26	.78	.40	.32	.26	.23
4, 5, 6	Floor varnish (2 coats)	Varnished	.48	.39	.15	.15	.11	.89	.40	.26	.22	.15
4	Paste wax *A* (2 coats)	Waxed	.26	.29	.15	.11	.11	.62	.33	.15	.18	.11
5	Spirit wax *B* (2 coats)	do	.26	.26	.11	.11	.11	.55	.33	.11	.15	.07
6	Water-emulsion wax *C* (2 coats)	do	.47	.37	.18	.15	.11	.80	.44	.18	.18	.11
7	No finish material	Ground [a]	.29	.40	.33	.26	.26	.80	.40	.33	.26	.26
7	Spar varnish (2 coats)	Varnished	.47	.40	.15	.11	.07	.84	.44	.22	.22	.11
7	Water-emulsion wax *E* (2 coats)	Waxed	.29	.29	.11	.11	.07	.77	.40	.15	.15	.07
	BATTLESHIP LINOLEUM											
1, 2, 3	No finish material	Original	0.43	0.40	0.19	0.22	0.15	0.80	0.44	0.18	0.18	0.16
1, 2, 3	do	Ground [b]	.43	.44	.34	.29	.25	.78	.47	.41	.33	.26
1	Paste wax A (2 coats)	Waxed	.29	.37	.22	.22	.18	.73	.40	.22	.22	.18
2	Spirit wax B (2 coats)	do	.26	.37	.18	.18	.11	.69	.40	.18	.18	.11
3	Water-emulsion wax C (2 coats)	do	.44	.40	.18	.18	.15	.99	.44	.22	.22	.18
4	Water-emulsion wax F (2 coats)	do	.37	.40	.07	.07	.07	.88	.47	.18	.18	.11
5	Water-emulsion wax G (2 coats)	do	.37	.37	.07	.07	.07	.88	.47	.15	.18	.11
6	Water-emulsion wax H (2 coats	do	.40	.40	.07	.07	.07	.91	.40	.22	.26	.11
	SHEET RUBBER											
1, 2, 3	No finish material	Original	0.32	0.33	0.15	0.15	0.11	0.46	0.34	0.13	0.16	0.10
1, 2, 3	do	Ground [b]	.59	.47	.21	.18	.12	.87	.47	.27	.21	.15
1	Paste wax A (2 coats)	Waxed	.40	.40	.11	.11	.11	.84	.47	.11	.15	.11
2	Spirit wax B (2coats)	do	.40	.37	.11	.11	.07	.80	.47	.11	.18	.07
3	Water-emulsion wax C (2 coats)	do	.55	.40	.11	.11	.07	.95	.44	.18	.18	.11
	ASPHALT TILE											
1, 2, 3	No finish material	Original	0.56	0.43	0.25	0.25	0.15	0.87	0.44	0.32	0.26	0.21
1, 2, 3	do	Ground [b]	.51	.44	.32	.32	.22	.78	.46	.37	.32	.27
2	Paste wax A (2 coats)	Waxed	.33	.40	.11	.11	.07	.77	.40	.15	.18	.07
2	Spirit wax B (2 coats)	do	.33	.40	.18	.18	.11	.80	.44	.18	.18	.11
3	Water-emulsion wax C (2 coats)	do	.47	.40	.11	.11	.07	.91	.40	.18	.18	.11
4	Water-emulsion wax F (2 coats)	do	.40	.37	.18	.18	.11	.88	.40	.22	.22	.15
5	Water-emulsionwax G (2 coats)	do	.40	.40	.18	.18	.11	.84	.40	.26	.26	.18
6	Water-emulsion wax H (2 coats)	do	.44	.40	.22	.22	.15	.88	.44	.29	.29	.26

[a] Ground with No. ½ and No. 0 flint papers.
[b] Ground with No. 180 silicon carbide and water.

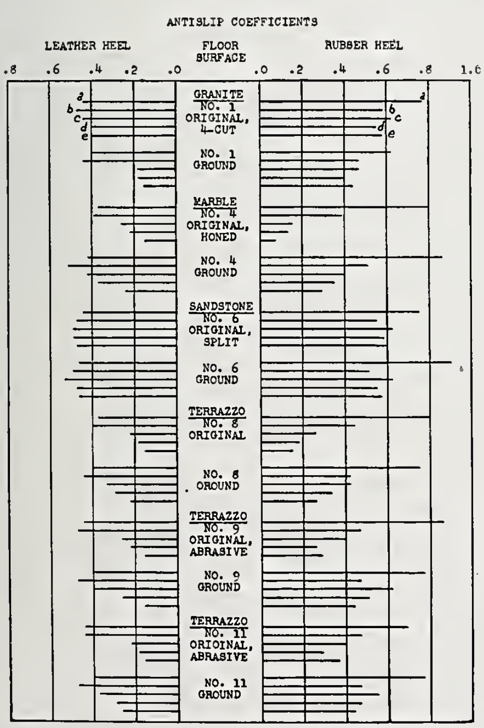
In order to determine the effect of finishing materials on the slipperiness of floors, several selected floor materials were given different finishing treatments. The floor materials and finishing treatments are listed in table 2, along with the results of the tests. For these tests the wood floors were ground with No. ½ flint paper, followed by a light grinding with No. 0

flint paper rather than by the normal procedure—with No. 180 silicon carbide and water. It was found that wetting adversely affected the wood floors, especially the oak, in that they were discolored and showed a tendency to warp upon drying. All finish materials were applied in accordance with recommended procedures and all waxed specimens thoroughly polished.

VI. SUMMARY OF RESULTS AND COMMENTS

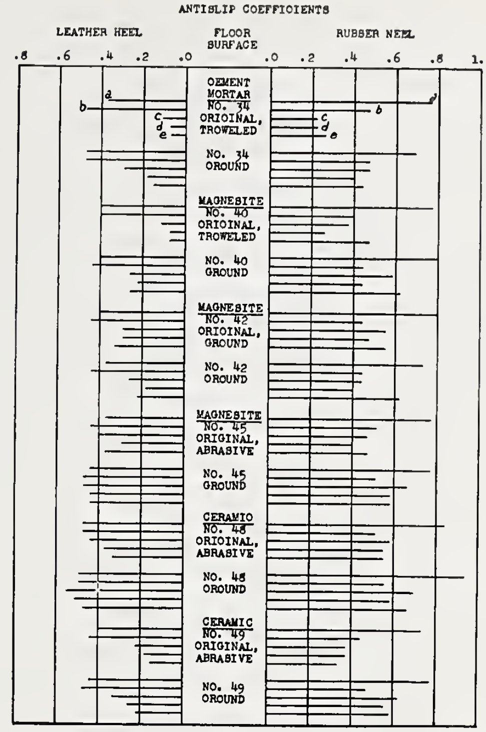
The results obtained on selected varieties of floor materials are presented graphically in figures 3 to 7, inclusive. The results of tests of different finishes on selected floor materials are shown graphically in figures 8 to 11, inclusive.

The original four-cut finish on the granite, sample 1, was rough, whereas the original honed finish on the marble, sample 4, approached a polish. With the original finishes, the hard granite showed much better antislip qualities than the soft marble, but after grinding with No. 180 silicon carbide, the antislip coefficients were greater for the marble under



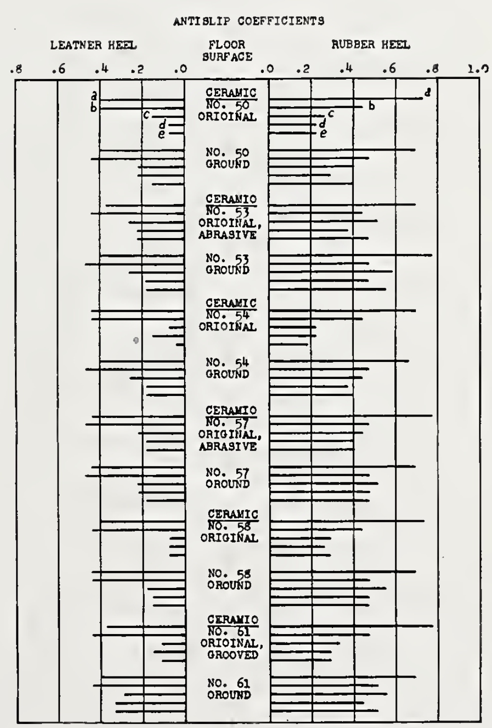
a, Dry and clean; *b*, dry and dirty; *c*, wet and clean; *d*, wet and dirty; *e*, wet and soapy.

FIGURE 3.—*Antislip characteristics of natural stone and terrazzo.*



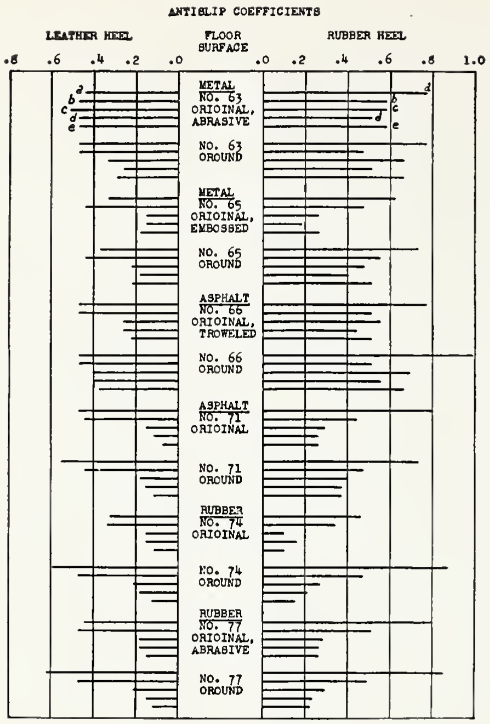
a, *b*, *c*, *d*, and *e*—see figure 3.

FIGURE 4.—*Antislip characteristics of cement-mortar, magnesite, and ceramic tile.*



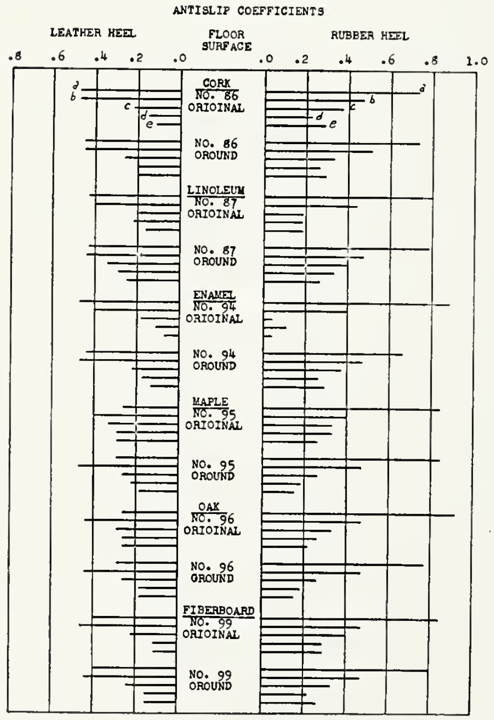
a, *b*, *c*, *d*, and *e*—see figure 3.

FIGURE 5.—*Antislip characteristics of ceramic tile.*



a, b, c, d, and *e*—see figure 3.

FIGURE 6.—*Antislip characteristics of metal, asphalt, and rubber.*



a, b, c, d, and *e*—see figure 3.

FIGURE 7.—*Antislip characteristics of cork tile, linoleum, enamel felt base, and wood.*

many of the conditions (see fig. 3). Of course, the granite has better resistance to wear than the marble, and would thus maintain a roughened surface for a longer time.

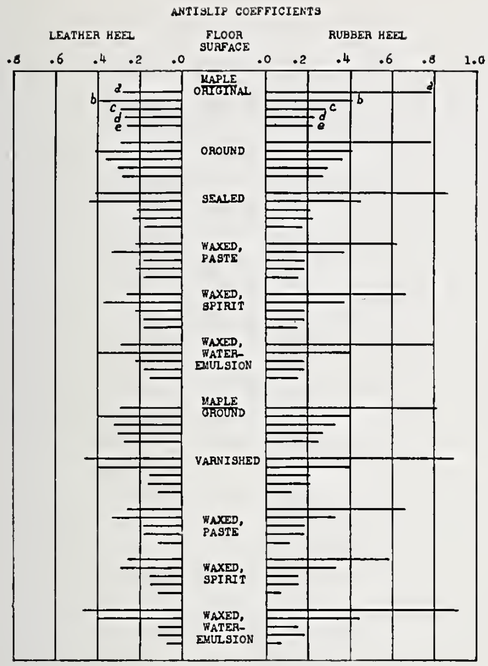
The antislip properties of terrazzo were improved by the addition of abrasive aggregates. The results obtained on ground specimens were not materially altered by the differences in amounts and types of abrasives (see table 1 and fig. 3). The abrasives consisted of Carborundum, a silicon carbide aggregate; Alundum, an aluminum oxide aggregate; Vittrazzo and Anti-Slip, crushed ceremic tiles containing abrasives; Macanite, a natural aggregate containing aluminum and iron oxides. The marble chips in terrazzo samples 8 to 23, inclusive, consisted of equal proportions of No. 1 and No. 2 granules of Tennessee marble. The marble chips in sample 24 were of Red Antique marble.

As a further investigation of the possible antislip merits of abrasives in nonuniform materials, such as terrazzo, several specimens of terrazzo containing different amounts of an acid-resisting abrasive were etched with hydrochloric acid prior to buffing. A leather-covered block was used instead of a cast-iron slab in the grinding procedure. The purpose of the above treatment was to cause the harder abrasive aggregates to protrude prominently in the surface of the terrazzo and thus represent more nearly a possible service condition. The antislip coefficients of the specimens, under wet conditions and with leather heels, were materially increased by the above treatment. The coefficients obtained with rubber heels were not appreciably altered by the treatment.

Figure 4 shows typical results of the tests on magnesite.

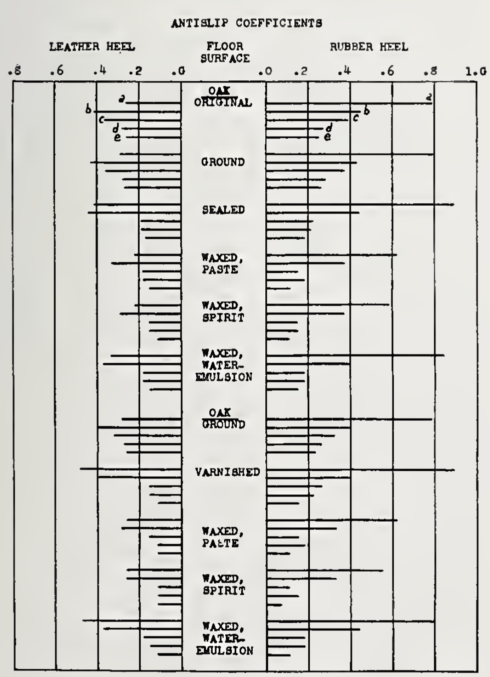
The antislip characteristics of ceramic tiles were improved by the addition of 35 percent abrasive. They were improved to a less degree by corrugations and embossments. The improvements were more pronounced on the original surfaces than on the ground surfaces (see fig. 5).

The antislip properties of maple, oak, rubber, linoleum, and asphalt tile were, under most of the conditions, increased by grinding the original surfaces and were subsequently lowered by coating the ground surfaces with finish-



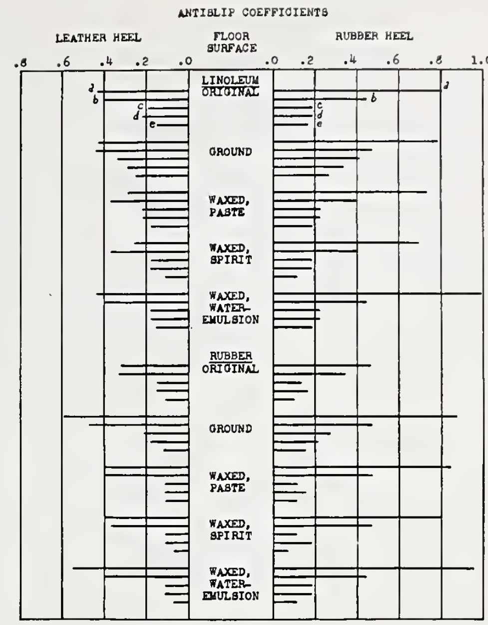
a, b, c, d, and *e*—see figure 3.

FIGURE 8.—*Effect of different wax finishes on the antislip properties of strip maple.*



a, b, c, d, and *e*—see figure 3.

FIGURE 9.—*Effect of different wax finishes on the antislip properties of strip white oak.*



a, b, c, d, and *e*—see figure 3.

FIGURE 10.—*Effect of different wax finishes on the antislip properties of linoleum and rubber.*

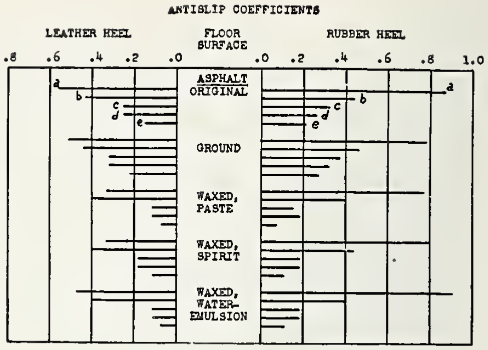
ing materials (see figs. 8, 9, 10, and 11). The results indicate that water-emulsion wax has better antislip properties than either paste or spirit waxes. The results further show that waxed floors are more hazardous, especially under dry conditions, with leather heels than with rubber heels.

It is of interest to note some differences that appear to exist between leather heels and rubber heels. The antislip coefficients obtained with rubber heels under a dry and clean condition were, in general, much higher than those obtained with leather heels under the same condition. However, under similar dirty or wet conditions this difference was not nearly so great. In this respect, the element of surprise or a sudden and marked lowering of the antislip property due to a change in conditions from that of dry and clean would be more prevalent with rubber heels than with leather heels. The coefficients obtained with leather heels were influenced by the degree of wetting of the leather, being lower with increase in wetting. This necessitated a thorough soaking of the leather heels prior to testing under wet conditions and probably represents a more severe condition than is usually encountered in service.

In view of the above, when the machine is to be used to establish a rating for a floor, the experimenter should take into account the kind of heel used for the testing, and set the limits accordingly. From a survey of the data presented in tables 1 and 2, the following limits are suggested:

Antislip value (classification)	*Leather heel* (antislip coefficient)	*Rubber heel* (antislip coefficient)
Poor	Less than 0.15	Less than 0.25.
Fair	0.15 to 0.30	0.25 to 0.40.
Good	More than 0.30	More than 0.40.

On the above basis, practically all of the floor surfaces would be rated as good under dry conditions, the principal exceptions being waxed specimens of maple, oak, and linoleum. However, under wet conditions many would be rated poor. The following floor and deck materials showed very good antislip characteristics after grinding with No. 180 silicon carbide; that is, their antislip coefficients were not less than 0.50 with a rubber heel and not less than 0.40 with a leather heel under all five test conditions (see table 1): sandstone (sample 6), cement mortar (sample 28), magnesite tile containing a course abrasive (sample 45), ceramic tile containing 80 percent abrasive (sample 48), and abrasive cloths (samples 101 to 106, inclusive). Original surfaces which were outstanding are: four-cut granite (sample 1), split sandstone (sample 6), aluminum with an abrasive embedded in the surface (sample 63), and abrasive cloths (sample 100 to 106, inclusive).



a, *b*, *c*, *d*, and *e*—see figure 3.

FIGURE 11.—*Effect of different wax finishes on the antislip properties of asphalt tile.*

WASHINGTON, March 29, 1943.

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