U. S. DEPARTMENT OF COMMERCE

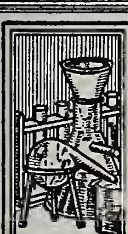
BUILDING MATERIALS AND STRUCTURES

REPORT BMS59

Properties of Adhesives for Floor Coverings

by

PERCY A. SIGLER
and ROBERT I. MARTENS



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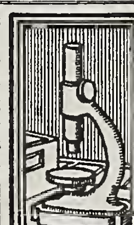

The program of research on building materials and structures, carried on by the National Bureau of Standards, was undertaken with the assistance of the Central Housing Committee, an informal organization of governmental agencies concerned with housing construction and finance, which is cooperating in the investigations through a committee of principal technicians.

The Forest Products Laboratory of the Forest Service is cooperating with both committees on investigations of wood constructions.

[For list of BMS publications and directions for purchasing, see cover page III.]

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ISSUED SEPTEMBER 19, 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 for use in low-cost house construction, being conducted by the National Bureau of Standards, a study was made of adhesives for floor coverings. Failure of a floor covering to adhere to the subfloor has a considerable effect on the ability of the floor covering to withstand service. In view of the increasing desire for floor coverings in basements, the moisture resisting qualities of commercial adhesives and of a few experimental preparations were investigated.

This report presents the results of tests on a variety of adhesives and primers along with comments on their suitabilities for use on concrete floors that are subject to dampness.

LYMAN J. BRIGGS, *Director.*

Properties of Adhesives for Floor Coverings

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ABSTRACT

An investigation was conducted on adhesives and primers used for bonding linoleum and other floor coverings to subfloors. Tests were made to determine their resistance to both a straight pull and a stripping pull when used to bond ⅛-inch battleship linoleum to concrete, wood, and metal. Specimens were tested in a dry condition and after exposure to moisture. Pieces of linoleum bonded to concrete slabs with selected adhesives and primers were inspected periodically during exposure to moisture. The methods of testing are described and the results are presented in tables. In view of the results of this investigation it would appear advisable in new constructions to waterproof concrete floors which are in contact with the ground.

I. INTRODUCTION

In locations where complete coverage of the floor space is desired, it is advantageous to bond some types of floor coverings to the subfloor. It is well known that a failure in the bond will cause almost any floor covering to become prematurely unserviceable. Failure of a bond may result from an unclean or wet condition of the subfloor, separation in an underlay, a faulty adhesive or method of installation, or from excessive dimensional changes of a floor covering with changes in relative humidity and temperature. In general, no difficulty is experienced in making satisfactory installations on subfloors which are dry, even, rigid, and clean.

The results of performance tests on installations of various floor coverings and adhesives on comparatively dry subfloors have been reported in previous Bureau publications [1, 2] [1].

It has not been established, however, that satisfactory installations of such floor coverings as wood, linoleum, rubber, and felt base can be made over concrete subfloors which are damp or which may become so. Installations of asphalt tile with asphaltic cements have met with fair success on concrete subfloors which are in contact with the ground. Such installations are not always successful where excessive dampness prevails and should not be made at a time when the surface of the concrete is wet. Adhesives claimed to be "waterproof" have been on the market for some time. In view of the lack of information on adhesives for floor coverings, a study was made of their comparative bonding strengths and moisture-resisting properties.

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

II. METHODS OF TESTING

1. Outline of Procedure

The investigation was conducted along several lines. The various adhesives were used to bond linoleum to wood, steel, and concrete. The resistances of the adhesives to a straight pull and a stripping pull were measured. Similar specimens on concrete were exposed to moisture and their resistances to a straight pull determined.

Specimens on concrete were prepared, using "waterproof" priming coats in conjunction with an adhesive selected as a control. The specimens were exposed to moisture and adhesive-strength tests were made as a means of determining the effectiveness of the primers as moisture barriers.

Squares of linoleum, 12 by 12 in., were bonded to concrete slabs with selected adhesives and primers. The slabs were exposed to moisture and strips of linoleum were removed periodically to inspect the bond.

A practical measure was made of the permeability to moisture of selected adhesives, primers, and membranes.

2. Adhesive-Strength Tests

(a) *Straight-Pull Test on Dry Specimens*

The specimens for the straight-pull test were prepared by bonding 2-in. squares of ⅛-in. battleship linoleum to blocks of wood, steel, or concrete with each of the various adhesives. The adhesives were spread with a notched trowel in order to control the thickness within practical limits, and each adhesive was allowed to dry for about 5 minutes before affixing the linoleum, unless otherwise specified by the manufacturer. A small wooden block was cemented to the top surface of the linoleum on each specimen with a cellulose nitrate

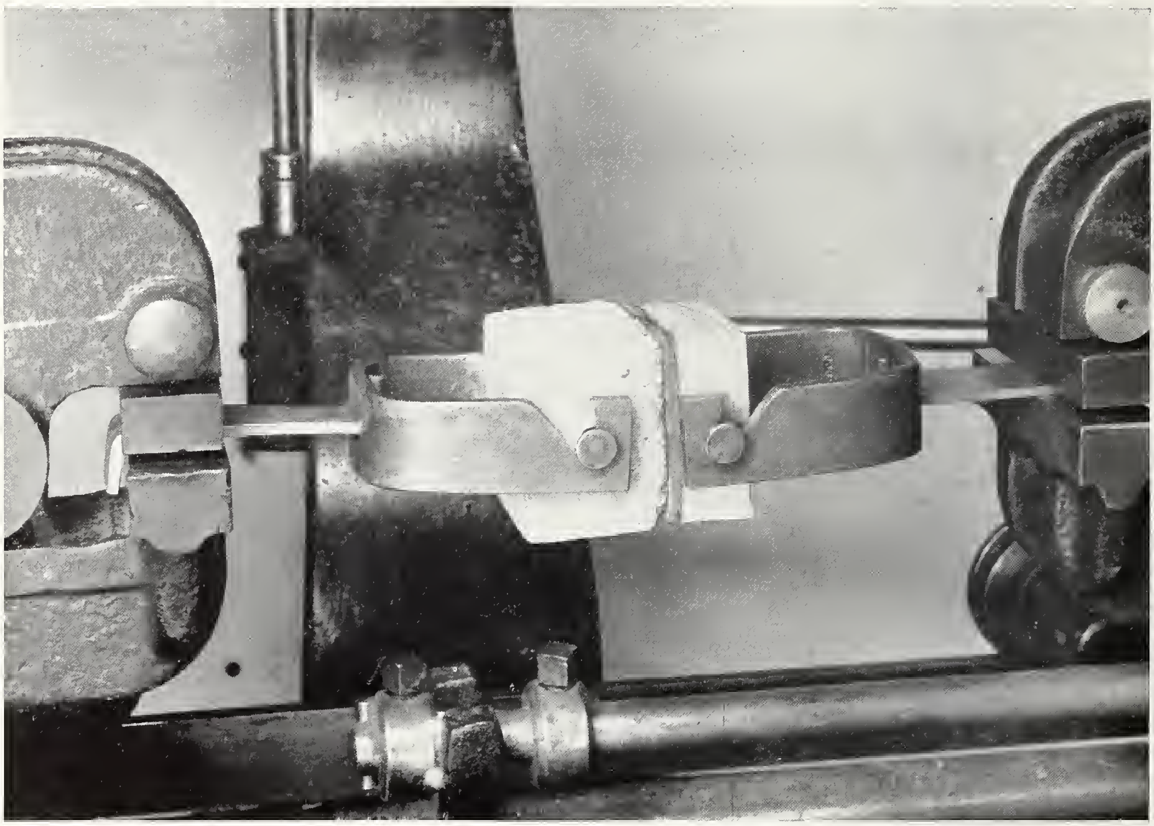

Figure 1.—*Straight-pull test.*

cement, to serve as a clamping surface in testing the specimens.

The specimens thus prepared were subjected to a pressure of approximately ¾ lb/in.^{2} and were allowed to dry for 7 days under this pressure in an atmosphere of 65-percent relative humidity and at a temperature of 70° F. The force required to rupture the bond was then determined in a tensile-testing machine (see fig. 1). The force was applied at approximately right angles to the bonded surfaces and at a power jaw speed of 2 in./min.

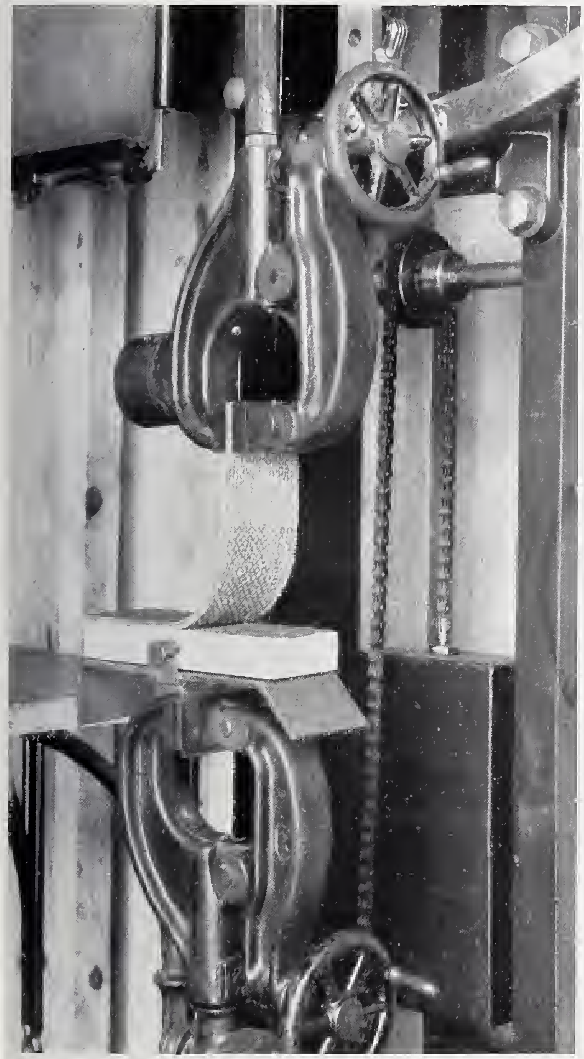

Figure 2.—*Stripping-pull test.*

Failure in the bond usually occurred at the junction of the adhesive with the burlap backing of the linoleum. Preliminary tests showed that the nature of the burlap backing had an appreciable effect on the results. The bonding strength of an adhesive was higher with a linoleum which had the burlap deeply keyed to the linoleum mix than with a linoleum which had the burlap moderately keyed. The linoleum adopted for these tests was one with the burlap moderately keyed to the linoleum mix. The steel blocks were cold-rolled steel ½ in. thick. The concrete blocks were 1½ in. thick, and were made of 2 parts of cement, 6 parts of concrete sand, and 1 part of water, by weight. The wooden blocks used were cut from a planed white-pine board ¾ in. thick.

(b) *Straight-Pull Test on Specimens Exposed to Water*

For determining the effect of moisture on the resistance of the adhesives to a straight pull, the specimens on concrete blocks were similar to those prepared for the dry test. After the drying period of 7 days, the specimens were exposed to moisture for either 7 days or 14 days. The 7-day exposure was made by setting the concrete block in water to a level about ¼ in. below the top of the concrete. For the 14-day exposure the water level was maintained even with the top of the concrete. In the latter case the edge of the linoleum was covered with a layer of the adhesive; this layer was scraped off before testing. The force required to rupture the bond was determined immediately upon removal from the water.

(c) *Stripping-Pull Test on Dry Specimens*

Specimens for the stripping-pull test consisted of 2- by 6-in. pieces of wood, steel, or concrete, to which strips of ⅛-in. battleship linoleum, 2 in. wide and 8 in. long, were bonded. The strip of linoleum was placed on the block so that one end of the linoleum extended 2 in. beyond the block for the purpose of clamping. After a 7-day drying period under a pressure of approximately ¾ lb/in.^{2}, the maximum force required to strip the linoleum over a distance of 4 in. was determined. Before making the test, the linoleum was stripped back by hand for a distance of about 1 in. The stripping force was applied at an angle of approximately 90° with respect to the surface of the base and at a power jaw speed of 2 in./min (see fig. 2).

3. Exposure Tests on Concrete Slabs

(a) *Linoleum Bonded to Concrete and Exposed to Dampness*

The concrete slabs were 14 by 28 by 1½ in. and were made of 2 parts of cement, 6 parts of concrete sand, and 1 part of water, by weight. The top surface of each slab was given a steel trowel finish. The slabs were allowed to dry for at least 2 weeks. Squares of ⅛-in. battleship linoleum, 12 by 12 in., were bonded to the slabs with moisture-resisting adhesives or with selected adhesives in conjunction with moisture-resisting priming coats. The adhesives were allowed to dry approximately 24 hours. Each slab was then set in a tray of water that was maintained at a level of about ¼ in. below the top surface of the concrete. Strips of the linoleum were removed periodically to inspect the bond. Figure 3 shows specimens exposed to moisture. Strips of linoleum, 3 in. wide, have been removed from the slab and have been placed in an inverted position on the remaining pieces of linoleum for the purpose of demonstration.

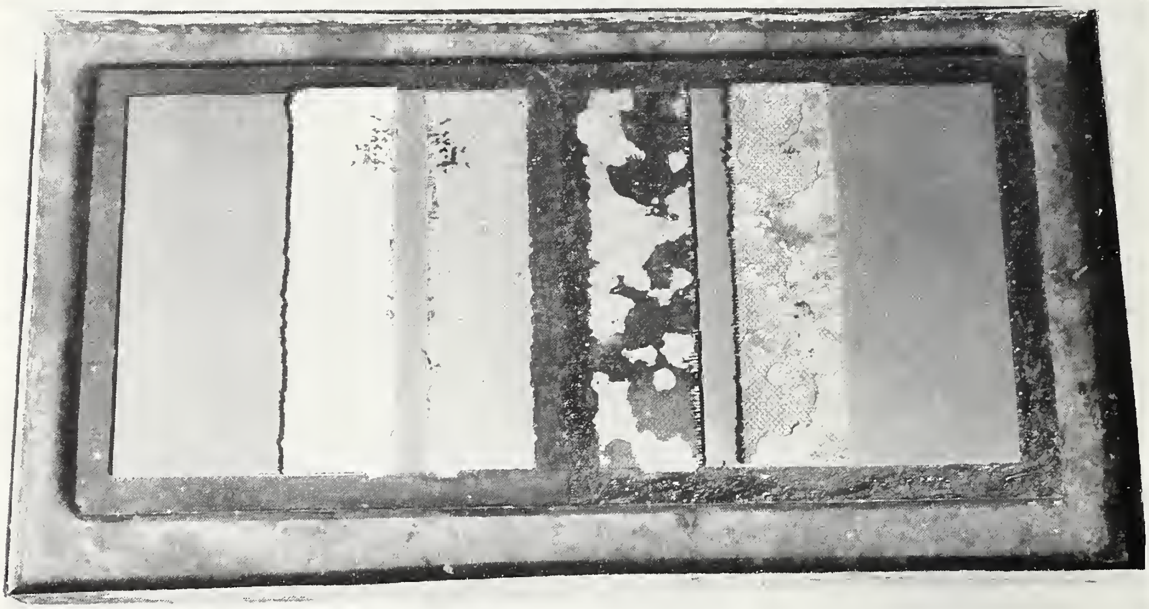

Figure 3.—*Exposure test of linoleum bonded to concrete slab.*

(b) *Permeability of Coatings to Moisture*

A few selected adhesives and a few selected primers were spread on concrete slabs and allowed to dry. Care was taken to see that complete coverage was obtained. Three coats of the primers were applied. The adhesives were troweled three times, each troweling being at right angles to the previous one. A small tray of anhydrous calcium chloride and a small tray of anhydrous copper sulfate were placed over each coating. A watch glass, 6 in. in diameter, was placed over the trays as a cover. The edge of the watch glass was sealed to the coating with paraffin to prevent moisture in the atmosphere from affecting the indicators. The slabs were then set in water to within ¼ in. of the coatings, and the length of time required for the indicators to be obviously affected was noted (see fig. 4). In the presence of moisture, calcium chloride granules form a liquid, and anhydrous copper sulfate, which is white, is hydrated and turns green.

The permeability to moisture of a few selected membranes bonded with adhesives to concrete

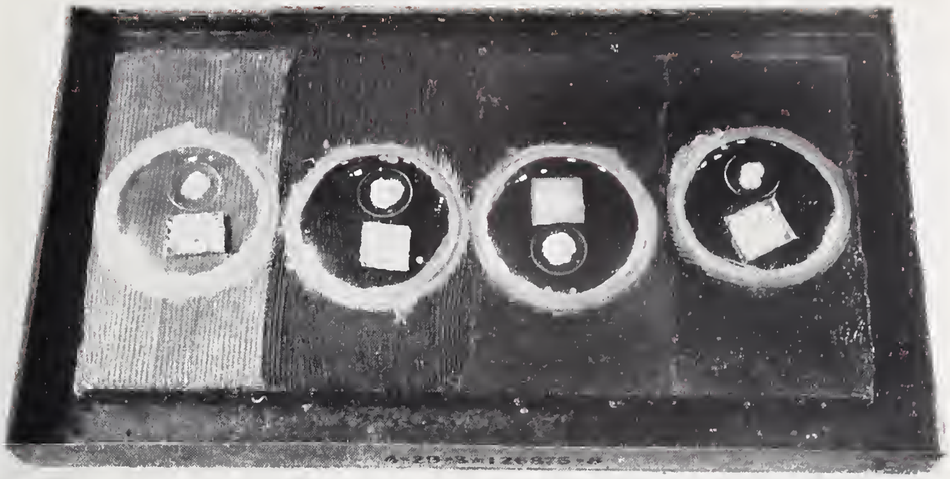

FIGURE 4.—*Test of permeability of coatings to moisture.*

slabs was also determined in a similar manner (see fig. 5).

III. RESULTS

Table 1 shows the comparative bonding strengths of various commercial adhesives as well as of a few experimental preparations when used to bond linoleum to wood, steel, or concrete. The effects of exposure to moisture on the bonding strengths of the adhesives are also shown in this table. Adhesive-strength tests were made on a few asphaltic adhesives in which asphalt tile was substituted for linoleum in the test specimens. The results of these tests are presented in table 2.

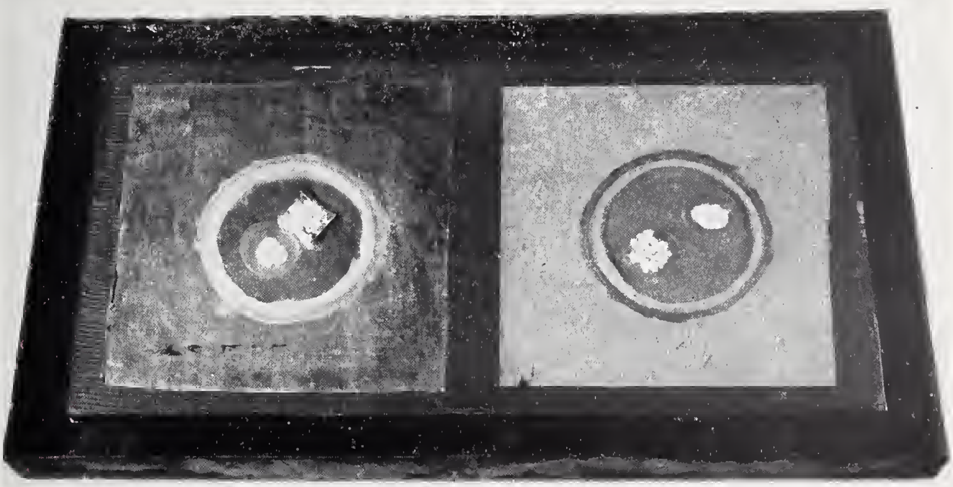

FIGURE 5.—*Test of permeability of membranes to moisture.*

Table 1.—*Results of adhesive-strength tests with linoleum*

Adhesive		Straight pull (4-in.² area)					Stripping pull (2-in. width)		
Sample designation	Type	Dry [a]			Exposed to water [a]		Dry [a]		
					7 days	14 days			
		Wood	Steel	Concrete	Concrete	Concrete	Wood	Steel	Concrete
		lb	*lb*	*lb*	*lb*	*lb*	*lb*	*lb*	*lb*
A	Lignin paste	256	324	314	0		13	7	10
B	do	249	378	268	0		5	6	4
C	do	280					5		
D	do	324					5		
E	Copal resin cement	252	248	308	125		9	4	7
F	do			291	44		6		
G	do			198	213	118	4		
H	do			246		131			
I	Cumar resin cement	294	285	345	275	206	12	12	12
J	Resin and oil cement	336	304	226	96	133	8	9	9
K	do	279	286	248	143	116	11	10	9
L	Rosin and petrolatum paste	20	16	27	20	23	0		
M	Casein-latex cement	399	325	429	93		28	10	31
N	do			480	43		12		18
O	do			165	51		32		
P [b]	Alumina cement and latex paste	336	360	362	220	232	16		
Q [c]	do			281	186	113			
R [b]	White portland cement and latex paste			262	105	126			
S	Rubber dispersion cement			104		71			
T	do			75		17			
U	"Cut-back" rubber cement			245	138	103	23		
V	"Cut-back" asphalt cement			236	106	64	10		
W	do			71					
X	Asphalt emulsion, soap type	19		43					
Y	Asphalt emulsion, clay type			75					
E1	Caol-tar cement [d]			305	260	104	9		
E1 [e]	do. [d]			273	256	203			
E2	do. [d]			84	52		1		
E3	do. [d]			252	171	89	6		
E4	Cumar resin cement applied hot (75° C) [d]			48	67	20	1		
E4 [f]	do. [d]			56		42			
E5	Portland cement and cellulose nitrate dope [g]			187	92				

[a] After 7 days' drying.
[b] No vulcanizing agent.
[c] With vulcanizing agent.
[d] Experimental adhesives prepared by a manufacturer's research laboratory.
[e] Top surface of concrete block given 2 coats of coal-tar primer.
[f] Adhesive remained in a plastic state. Allowed to dry 23 days before testing.
[g] Experimental preparation.

Table 2.—*Results of adhesive-strength tests with asphalt tile*

Adhesive		Straight pull (4-in.² area)					
Sample designation	Type	Dry [a]			Exposed to water [a]		Exposed to saturated solution $Ca(OH)_2$ [a]
					7 days	14 days	7 days
		Wood	Steel	Concrete	Concrete	Concrete	Concrete
W	"Cut-back" asphalt cement	*lb* 83	*lb* 105	*lb* 140	*lb* 191	*lb* 160	*lb* 91
X	Asphalt emulsion, soap type	132	119	203	128	85	54
Y	Asphalt emulsion, clay type	201	178	228	143	50	49
Z	do	139	202	124	94		68

[a] After 7 days' drying.

As an aid in determining the effectiveness of moisture-resisting primers, adhesive-strength specimens were prepared on concrete blocks which had been previously treated with the primers. All primers were applied in three coats and each coat was allowed to dry separately. Lignin paste and an oil-base cement were the adhesives used for determining the comparative effectiveness of the primers as moisture barriers. Lignin paste is partially soluble in water and thus has very little adhesive strength when wet. The oil-base cement is not readily soluble in water, however, tests showed that its adhesive strength is noticeably lowered by contact with moisture. The results of adhesive-strength tests on these specimens are shown in table 3.

As a supplement to the adhesive-strength tests, specimens of a larger size were exposed to moisture. A personal inspection was the principal means of determining the results of these exposures. The results of this study on selected adhesives and primers are recorded in table 4.

Table 5 shows the comparative permeability to moisture of selected adhesives, primers, and membranes.

Table 3.—*Comparative effectiveness of priming coats as moisture barriers*

Primer	Resistance to straight pull (4-in.^{2} area)				
	Control adhesive, lignin paste		Control adhesive, resin and oil cement		
	Dry [a]	Exposed to water [a] for 7 days	Dry [a]	Exposed to water [a]	
				7 days	14 days
	Concrete	Concrete	Concrete	Concrete	Concrete
	lb	*lb*	*lb*	*lb*	*lb*
None	268	0	258	96	133
Bakelite dope [3]	------	55	366	400	188
Bakelite and glyceryl-phthalate dope [3]	------	85	263	252	208
Bakelite and china wood oil dope [3]	------	161	263	203	154
Cellulose nitrate dope	------	10	------	140	------
Cumar resin dissolved in toluene	------	10	224	201	160
Rubber resin paint	361	0	239	227	184
Aluminum powder and varnish	230	104	269	228	194
Coal tar	------	108	137	148	86

[a] After 7 days' drying.

Table 4.—*Results of exposure to moisture of 12- by 12-in. pieces of linoleum bonded to concrete slabs with selected adhesives and primers*

Adhesive	Primer	Appearance (6 weeks or less)
Lignin paste (*B*)	None	Paste was moist. Bond was poor.
Do	Bakelite dope [3]	Paste was very wet. Bond was poor. Adhesion of primer to concrete was fair.
Do	Bakelite and glycerylphthalate dope [3].	Paste was wet. Bond was poor. Primer was easily separated from concrete.
Do	Bakelite and China wood oil dope [3].	Paste was very wet. Bond was poor. Adhesion of primer to concrete was fair.
Do	Cumar resin and china wood oil in toluene.	Paste was wet. Bond was poor. Primer was easily peeled from concrete.
Do	Cumar resin and tricresyl phosphate in toluene.	Do.
Do	Asphalt	Do.
Do	Coal tar	Paste was wet. Bond was poor. Adhesion of primer to concrete was good.
Copal resin cement (*G*).	Skim coat of adhesive.	After 3 weeks, the linoleum buckled and separated from the concrete slab. Adhesive and back of linoleum was very wet.
Cumar resin cement (*I*).	do	Bond was fair. Back of linoleum was dry.
Do	Bakelite dope [3]	Bond was poor. Primer stuck to adhesive and was easily separated from concrete.
Do	Coal tar	Do.
Resin and oil cement (*J*).	None	Bond was fair. Back of linoleum was dry.
Resin and oil cement (*K*).	do	Do.
Alumina cement and latex paste (*P*)	do	Bond was fair. Back of linoleum was wet.
Do	Cement-latex	Do.
"Cut-back" rubber cement (*U*).	None	Do.
Do	"Cut-back" rubber.	Do.
"Cut-back" asphalt cement (*V*).	Skim coat of adhesive.	After 3 weeks, the linoleum buckled and separated from the concrete slab.
Coal-tar cement (E1).	Coal tar	After 5 days, the linoleum buckled and separated from the concrete slab.
Coal-tar cement and coal-tar felt.	do	Bond was poor. Linoleum and felt were easily separated from primed concrete slab.

Table 5.—*Comparative permeability to moisture of selected coatings*

Primer	Adhesive	Membrane	Time required to affect indicators
Chlorinated-rubber paint.	None	None	84 hours.
Do	do	do	135 hours.
None	Alumina cement and latex paste (*P*).	do	24 hours.
Cement-latex	do	do	96 hours.
None	"Cut-back" rubber cement (*U*).[a]	do	120 hours.
Do	Resin and oil cement (*K*).[a]	do	50 days.
Do	Cumar resin cement (*I*).	do	Do.
Do	Alumina cement and latex paste (*P*).	Asphalt-laminated sheathing paper, *ZZ*.[b]	72 hours.
Do	do	Asphalt-laminated sheathing paper, *Z*.[c]	Unchanged at 115 days.[d]
Do	"Cut-back" rubber cement (*U*).	do.[c]	Unchanged at 50 days.[d]
Do	None	Asphaltic-concrete slab, No. 1, 1½ in. thick.[e]	Unchanged at 115 days.
Do	do	Asphaltic-concrete slab, No. 2, 1½ in. thick.[e]	Do.

[a] Adhesive was stripped from the concrete without difficulty.
[b] See report BMS35 [4], sample designated *ZZ*.
[c] See report BMS35 [4], sample designated *Z*.
[d] Ability of adhesive to adequately bond membrane to concrete exposed to dampness over a large area is questionable. Membrane was stripped from concrete slab without difficulty.
[e] Experimental slab furnished by the Asphalt Institute. Consisted of a mixture of approximately 12 percent asphalt with graded aggregate. Slab itself placed in water to within ¼ inch of top surface.

IV. SUMMARY AND CONCLUSIONS

Many of the adhesives tested possess high adhesive strengths under dry conditions. None, however, show adequate resistance to moisture to be satisfactory for bonding linoleum to basement subfloors where moisture conditions are prolonged or severe. Even though the surface of a concrete floor in a basement may appear dry, it may become wet after the application of a floor covering. The floor covering causes an appreciable lowering in the rate of evaporation of moisture in the concrete.

Lignin paste, which is much lower in cost than most other floor-covering adhesives, appears satisfactory for bonding such floor coverings as linoleum, rubber, and felt base to subfloors in dry locations. It is partially soluble in water and should not be used where contact with moisture is probable.

The cumar resin cement (*I*) and the resin and oil cements (*J*, *K*) showed fair resistance to moisture in that their adhesive strengths were only moderately lowered by exposure to water and they were fairly impervious to moisture. They should prove satisfactory where moisture conditions are not severe, for example, concrete floors having contact with the ground where drainage conditions are excellent.

The adhesive strengths of the alumina cement and latex paste (*P*) and the "cut-back" rubber cement (*U*) were only moderately affected by exposure to moisture. However, they transmit moisture quite readily and would not be satisfactory in damp locations with floor coverings that would be damaged by prolonged exposure to water, such as linoleum with a burlap backing.

The asphaltic and coal-tar adhesives appeared unsatisfactory for bonding linoleum to concrete subfloors exposed to dampness. In conjunction with asphalt tile, the "cut-back" asphalt cement showed fair resistance to moisture. The ability of asphaltic cements to remain tacky and rebond is their principal advantage.

The behavior of lignin paste with various primers served to establish the ineffectiveness of priming coats as moisture barriers. It should not be concluded that priming coats are of no benefit. Used in conjunction with adhesives of a similar nature, they are of benefit, especially on concrete subfloors which are extremely dry, dusty, or porous.

There are asphalt sheathing papers on the market which have adequate imperviousness to moisture. However, the problem of finding a means of bonding the membrane to concrete exposed to severe dampness, other than by a weight placed over it, such as a concrete topping, has yet to be solved.

Properly proportioned asphaltic concrete of sufficient thickness placed over a cement-concrete subfloor or structural slab should serve as an adequate moisture barrier.

In locations where drainage conditions are poor and considerable dampness is likely to prevail, it would be advisable to waterproof concrete floors which are in contact with the ground. One method of doing this is to use a bituminous membrane placed between two concrete slabs. Such an installation can be more cheaply and conveniently made at the time of construction. Although not included in this study of adhesives, this type of waterproofing has been successfully used and is described in the literature [5, 6].

V. SELECTED REFERENCES

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Washington, June 14, 1940.

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BMS29	Survey of Roofing Materials in the Northeastern States	10¢
BMS30	Structural Properties of a Wood-Frame Wall Construction Sponsored by the Douglas Fir Plywood Association	10¢
BMS31	Structural Properties of "Insulite" Wall and "Insulite" Partition Constructions Sponsored by The Insulite Co	15¢
BMS32	Structural Properties of Two Brick-Concrete-Block Wall Constructions and a Concrete-Block Wall Construction Sponsored by the National Concrete Masonry Association	10¢

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BUILDING MATERIALS AND STRUCTURES REPORTS

[Continued from cover page III]

BMS33	Plastic Calking Materials	10¢
BMS34	Performance Test of Floor Coverings for Low-Cost Housing: Part 1	10¢
BMS35	Stability of Sheathing Papers as Determined by Accelerated Aging	10¢
BMS36	Structural Properties of Wood-Frame Wall, Partition, Floor, and Roof Constructions with "Red Stripe" Lath Sponsored by The Weston Paper and Manufacturing Co	10¢
BMS37	Structural Properties of "Palisade Homes" Constructions for Walls, Partitions, and Floors, Sponsored by Palisade Homes	10¢
BMS38	Structural Properties of Two "Dunstone" Wall Constructions Sponsored by the W. E. Dunn Manufacturing Co	10¢
BMS39	Structural Properties of a Wall Construction of "Pfeifer Units" Sponsored by the Wisconsin Units Co	10¢
BMS40	Structural Properties of a Wall Construction of "Knap Concrete Wall Units" Sponsored by Knap America, Inc	10¢
BMS41	Effect of Heating and Cooling on the Permeability of Masonry Walls	10¢
BMS42	Structural Properties of Wood-Frame Wall and Partition Constructions with "Celotex" Insulating Boards Sponsored by the Celotex Corporation	10¢
BMS43	Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 2	10¢
BMS44	Surface Treatment of Steel Prior to Painting	10¢
BMS45	Air Infiltration Through Windows	10¢
BMS46	Structural Properties of "Scot-Bilt" Prefabricated Sheet-Steel Constructions for Walls, Floors, and Roofs Sponsored by The Globe-Wernicke Co	10¢
BMS47	Structural Properties of Prefabricated Wood-Frame Constructions for Walls, Partitions, and Floors Sponsored by American Houses, Inc	10¢
BMS48	Structural Properties of "Precision-Built" Frame Wall and Partition Constructions Sponsored by the Homasote Co	10¢
BMS49	Metallic Roofing for Low-Cost House Construction	10¢
BMS50	Stability of Fiber Building Boards as Determined by Accelerated Aging	10¢
BMS51	Structural Properties of "Tilecrete Type A" Floor Construction Sponsored by the Tilecrete Co	10¢
BMS52	Effect of Ceiling Insulation upon Summer Comfort	10¢
BMS53	Structural Properties of a Wall Construction of "Munlock Dry Wall Brick," Sponsored by the Munlock Engineering Co	10¢
BMS54	Effect of Soot on the Rating of an Oil-Fired Heating Boiler	10¢
BMS55	Effects of Wetting and Drying on the Permeability of Masonry Walls	10¢
BMS57	Roofing in the United States—Results of a Questionnaire	10¢
BMS59	Properties of Adhesives for Floor Coverings	10¢