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ADHESIVES FOR FLOOR COVERINGS

The following report on adhesives for bonding floor coverings to sub-floors represents a preliminary study of the subject, based on a review of literature and information furnished by manufacturers and others, concerning the laying and maintenance of floors. In some instances the information available warrants definite recommendations. In other cases, however, it is not possible to say which adhesive is the most suitable or to tell how it should be applied to secure the best results. There are many questions which can be answered only on the basis of thoroughgoing experimental studies and systematic observations on floors in service. Pending the time when such investigations can be made, the present report is offered for such assistance as it may afford the architect, the builder, and the owner in connection with flooring problems.

I. Preparation of Sub-floors

1. Condition of Sub-floors:

The condition of the sub-floor is the most important single factor in satisfactory installation of floor covering. The sub-floor should be hard, firm, level, smooth, clean, and dry, in order that it will not detract from the wearing qualities of floor covering or cause cracks and irregularities therein. The dryness of the sub-floor is essential for successful bonding of wood, linoleum, cork tile and rubber tile. Therefore, such floor coverings should not be laid until appropriate tests show that sub-floor is sufficiently dry.

New concrete sub-floors should be troweled to a true, even surface, at a level below the finished grade equal to the thickness of floor covering to be applied.

Wooden sub-floors should not be installed on or below grade without adequate provision for waterproofing. The surface of a new wooden sub-floor should be brought up to a level below the finished floor grade of 1/16 inch plus thickness of floor covering.

2. Tests for Dampness:

The presence of moisture in concrete may be determined as follows: Form a ring of putty about 6 inches in diameter and 1/2 inch high at each point on the floor to be tested. Sprinkle a small amount of anhydrous copper sulphate or calcium chloride within these rings, covering each ring with a piece of dry window glass, pressing the glass down on the putty to seal enclosed chemical from outside air. Leave in place from 12 to 24 hours. Anhydrous copper sulphate, which is white when dry, will turn blue if moisture is present. Calcium chloride will be dissolved by moisture, leaving a stain.

The moisture content in wood may be determined in a few seconds by the electrical resistance method. "The instruments for this purpose have two pairs of sharp metallic terminals that can be quickly embedded in the wood, batteries for supplying an electric current through the wood intervening between the two terminals, and a means for reading the resistance in the electric circuit directly in terms of the moisture content of the wood holding the terminals."[1]

3. Use of Felt over Wooden Sub-floors:

In the installation of resilient floor covering on a wooden sub-floor, use of felt lining is generally considered necessary (except for wooden floor coverings) to take up irregular movements caused by expansion and contraction of the wood.

The felt ordinarily employed for this purpose is 1/16 inch thick and may be either dry or asphalt-saturated, according to kind of floor covering and contemplated use. A lignin paste is frequently used to bond felt to sub-floor.

II. Kinds of Adhesives

1. Properties:

An adhesive is a combination of a binder, a filler, and a carrier. The binder supplies the adhesive properties; the filler contributes to the mechanical strength, reduces the shrinkage in cooling or drying, and improves the resistance to shock; and the carrier imparts a consistency to the adhesive which makes it easy to apply, after which it evaporates.

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[1] Forest Products Laboratory "Wood Handbook" (1935) may be obtained from the Superintendent of Documents, Washington, D. C. (Price 25 cents)

An ideal adhesive should have the following characteristics:

(1) It should be easily and quickly applicable at ordinary temperatures, without having to apply prolonged pressure.

(2) It should permit a normal "set-up" after application to sub-floor within a short period, and it should have high adhesive strength to properly adhere to sub-floor and to the particular type of floor covering for which it is intended.

(3) It should retain its adhesive properties under various conditions, particularly where there is moisture caused by flooding of floor in cleaning, and at the same time be impervious to moisture.

(4) It should be sufficiently elastic to hold floor coverings in place, sufficiently plastic to withstand shocks without fracture, and should retain these qualities for any length of time at any temperature to which the floor may be subjected.

(5) It should be sufficiently plastic at ordinary temperatures so that the bond will not break when the floor covering and sub-floor expand or contract differentially in varying atmospheric conditions.

(6) It should have good self-healing properties so that, in case the bond is broken, it will reseal readily.

(7) It should not have a permanent odor, no volatile solvents to be locked in, and should contain no substances to discolor or injurethe floor coverings.

(8) Its cost should be reasonable.

2. Adhesives for Floor Coverings:

Adhesives in general use are:

(a) Portland Cement Mortar

A stiff, rather dry mortar of portland cement and sand in the proportions of one part cement to one and one-half or two parts sand is widely used.

(b) Asphalt Cement

Either native or petroleum asphalt, or a mixture of the two, may be used as a base for asphalt cement. A mineral filler, such as clay, or a fibrous material, such as asbestos, is often added to bind the base and form a tougher mass when set.

Asphalt cement may be applied to the sub-floor in any one of three forms: hot; "cut-back" with light petroleum hydrocarbons, such as mineral spirits; or emulsified with water.

Hot: The hot application is limited in scope and it appears to be best adapted to the small unit type of floor covering or to repair work. There is probably less danger of "bleeding" with a hot application than there is with a cold. See AB-5-25 and AP-5-25, Federal Specification SS-A-706, "Asphalt; (For Use in) Road and Pavement Construction".[1]

Cut-back: The solvent for the cut-back form of application must have a comparatively narrow distillation range, and must not contain heavy ends which might leave the asphalt cement soft when floor covering is laid or cause progressive deterioration of the covering.

One advantage claimed for cut-back cement is that in being compounded at the source, a premixture of this type is more likely to produce good results in the hands of ordinary floor layers, since no complicated instructions or precautions are necessary. This argument, however, is equally applicable to the emulsion type.

Emulsion: An asphalt emulsion must set, i.e., the water vehicle must evaporate, before floor coverings can be laid over it. The time for this action may be controlled largely by the amount of water used to emulsify the asphalt. Under favorable conditions, an emulsion will become tacky in from 20 to 40 minutes, and will retain this tackiness indefinitely. One advantage of the emulsified cement is that there is plenty of time to get it well leveled off before it sets.

Several objections have been raised against the emulsion type. One is that it shrinks upon drying, the amount of shrinkage depending upon the quantity of water in the emulsion when it is applied. But, it should be remembered that the shrinkage largely takes place before floor covering is laid. Another objection is that it will re-emulsify if water reaches it before it is thoroughly set, although, under favorable conditions it will set in a short time. Still another objection is the difficulty of determining just when the water has evaporated sufficiently to produce the best results. This source of trouble, however, according to floor experts, is over-emphasized. An experienced floor layer is able to determine the proper time for laying floor covering by the way the adhesive sticks to the finger when pressed lightly on the surface.

Primers: Asphalt primers, which contain more water or solvents than corresponding asphalt cements, are often used to increase penetration of asphalt into the concrete sub-floor, thereby strengthening mechanical anchorage. Either type of primer must be allowed to thoroughly set before cement is applied. For cut-back primer see Federal Specification SS-A-701, "Asphalt-Primer; (for) Roofing and Waterproofing".[1]

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[1] May be obtained from Superintendent of Documents, Washington, D. C. (Price 5 cents)

(c) Lignin Paste

Lignin obtained from waste sulphite liquor in the manufacture of paper, is widely used as a base for linoleum paste with clay added as a filler. Evaporation of the water leaves a tenacious mass which sets in a relatively short time, has good adhesion, and is flexible and durable. It is soluble in water, however, and should not be used where water is likely to be present.

Lignin paste does not become hard and brittle in service, a serious objection to dextrin paste which it has replaced.

(d) Resin Cement

Solutions of shellac, resins, and gums, in alcohol, acetone, etc., to which a filler is added, such as clay or short-fiber asbestos, form a group of "resin cements" for use with some of the more resilient floor coverings. These cements are sometimes claimed to be waterproof, but are really so only to a limited extent.

They are more elastic than lignin paste, and do not appear to crystallize under conditions of light traffic.

(e) Rubber Cement

Rubber cement is a solution of rubber in gasoline, benzene, carbon tetrachloride or other organic solvent. Because of the high viscosity, rubber concentrations in excess of 12 percent are not generally employed. In making cements the raw rubber is first masticated or "broken down" by milling. This process has a marked effect on the properties of the resulting solution. The best cement is produced when the rubber is given a small amount of hot milling.

(f) Latex Cement

Latex cements are made from natural rubber latex which is a suspension of rubber particles in an aqueous medium. They have a much lower viscosity than rubber cements and yield stronger and better aging films on drying. Centrifugally concentrated latex, containing about 60 percent of solids, is used extensively in making latex cements. "However, these concentrates are relatively unstable and quick-drying, so that protective agents must be used when compounding".[1]

> "The adhesive properties of latex can be modified within wide limits by compounding with emulsions of certain materials capable of producing tackiness, such as casein, resins, etc. Casein is a protective colloid and when put into solution with a weak alkali (0.5 percent NH_3) it is very effective as a stabilizer for latex. The use of casein results in an absorbed film or coating around each latex particle very similar to the natural protein sheath. Thus, it increases the effective size of the particles, and hence, in general, increases the viscosity of the system. It also

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[1]See "Latex in Industry", by R. J. Noble

makes the particles more resistant to coagulative influences. Casein has the property of increasing the stiffness of a latex film, but it also decreases its resistance to water. A softening agent, such as stearic acid, mineral oil, or paraffin wax is often added to reduce the excessive toughness of latex."[1]

Fillers, such as clay or zinc oxide, are added for the purpose of modifying properties of the rubber film obtained, and in order to give the latex compound suitable working characteristics, as for spreading.

IV. Floor Coverings

1. Materials:

Materials for floor coverings may be divided according to resilience and warmth into five groups:

(1) Non-resilient floors of concrete, ceramic mosaic tile, stone mosaic, terrazzo, etc., which are good conductors of heat.

(2) More resilient floors, such as asphalt tile, but which are nearly as good conductors of heat as concrete.

(3) Semi-elastic floors, such as wood, which are comparatively non-heat-conducting, but not as resilient as linoleum or rubber.

(4) Resilient floors, such as linoleum or rubber, which are not as good non-conductors of heat as wood.

(5) Resilient floors, such as cork, which are the best non-conductors of heat and the most resilient of all floor coverings.

2. Selection of Floor Coverings:

The choice of materials to be used for floor coverings is determined by kind of sub-floor, by the location of the floor area in the building, and by the type of occupancy of the room. The adhesive to be used is determined largely by the type of floor covering to which it is to be applied. (See Table 1, page 7)

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[1] See "Latex in Industry", by R. J. Noble.

TABLE I - FLOOR COVERINGS AND ADHESIVES

Floor Covering		Sub-floor		Adhesive
Material	Form	Material	Location	
Asphalt	Tile or plank	Concrete or wood	Any[1]	Asphalt emulsion
Ceramic (mosaic)	Tile	Concrete Setting-bed	Any	Portland cement mortar
Cork	Carpet or tile	Concrete or wood	Above grade[1]	Lignin paste
Linoleum	Strip or tile	Concrete or wood	Above grade[1]	Lignin paste or resin cement
Rubber	Strip or tile	Concrete or wood	Above grade[1]	Lignin paste or resin rubber or latex cement
Wood	Strip or block	Concrete or wood	Any[2]	Asphalt cement for hot application or cut-back

[1]With layer of felt over wood sub-floor.

[2]On membrane-waterproofed concrete sub-floor, on or below grade.

V. Use of Adhesives

1. Choice of Adhesives:

Adhesives, as indicated in Table 1, should be selected according to the type of floor covering with which they are to be used.

(1) For ceramic mosaic tile; portland cement.

(2) For asphalt tile and wood; asphalt cement.

(3) For linoleum and cork; lignin paste or resin cement.

(4) For rubber; lignin paste, resin cement, rubber cement, or latex cement.

2. Method of Application:

(a) Ceramic Mosaic Tile[1]

Ceramic mosaic tile is bonded monolithically to a special concrete base 2 1/2 inches to 4 inches thick by means of a mortar setting-bed from 1/2 to 1 1/4 inches thick of rather dry mix. This bed is smoothed off and leveled with a straight edge, and dry portland cement is "dusted" over the surface. The mortar reaches its initial set in a few minutes, and the tile may then be laid and "beaten in".

(b) Asphalt Tile

Asphalt tile is laid in asphalt emulsion. Concrete sub-floors should first be treated with a primer which should be allowed to dry before cement is applied. Asphalt emulsion should be applied with a straight-edged trowel and spread very thinly (about 0.01 inch) to prevent the adhesive from oozing up between the tiles and causing discoloration.

One brand of emulsion cement has an average spreading capacity of 150 square feet per gallon. Tile may be laid on this cement after a drying period of half an hour.

Asphalt tiles are bonded directly to concrete sub-floors; but on wooden sub-floors they should be installed over saturated felt or its equivalent, while the felt may be attached to the wood with lignin paste.

(c) Wood

Wooden floor coverings are bonded directly to either concrete or wooden sub-floors with hot or cut-back asphalt cement. The thickness of cement should be kept less than 1/8 inch to prevent "bleeding", although agreement on thickness is lacking.

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[1]Associated Tile Manufacturers' Related Study.

Drying periods for cements will necessarily be greater for laying wood floors than for asphalt tile, because of the greater thicknesses of cement employed.

(d) Linoleum, Cork Composition Tile, Cork Tile, and Cork Carpet

Lignin paste is used almost exclusively to bond each of the four basic types of cork floor coverings to concrete or wooden sub-floors. It is usually applied with a notched spreader to insure uniform thickness, and has an average spreading capacity of 120 square feet per gallon.

The use of dry lining felt is recommended over wooden sub-floors, to which it is cemented with lignin paste.

Where there is likely to be excessive spillage of water, asphalt-saturated felt is substituted for dry felt, and resin cement is used to bond floor covering to felt. Resin cement is usually spread with a straight-edged trowel, and it has an average spreading capacity of 70 square feet per gallon.

Finished cork-base floors must be thoroughly rolled and should be weighted down for several hours to insure complete adhesion.

(e) Rubber

Tools required and method employed for installing rubber floor coverings are identical with those used for first-class linoleum installations. Lignin paste is used for applying saturated felt to wood sub-floors.

Various adhesives such as, lignin paste, resin cement, rubber cement, and latex cement, are used to bond rubber floor coverings to the felt or directly to concrete sub-floors. The adhesives should be spread somewhat thinner than for laying linoleum, because rubber does not absorb the adhesive. Detailed information regarding the application of rubber and resin cements is given in "Adhesion Problems in Connection with Rubber Flooring", International Rubber Association, The Hague (1930).

VI. Types of Failures Due to Lack of Bond

Frequent failures of floor coverings to give satisfactory adhesion to sub-floors are, almost without exception, the result of the unsuitable condition of sub-floor or, to a far less extent, to the unsuitable condition of floor covering when laid, or to improper maintenance afterwards, although faulty workmanship and poor quality of materials contribute to such failures.

There is at present no successful method of dealing with a sub-floor that is not dry at time of laying floor covering. Neither is there an adhesive which will withstand flooding or improper maintenance of finished floor.

1. Expansion and Contraction:

Expansion and contraction of a floor covering in plane of floor, resulting from normal changes of temperature or humidity, do not cause failure of a good bond, if proper expansion joints are provided.

2. Buckling and Curling:

Lack of expansion joints, or unequal expansion of sections of floor covering because of its unsuitable condition when laid, may produce displacement of parts of floor covering out of its plane in the form of buckling, cupping, curling, doming, warping, etc. This displacement invariably destroys bond with sub-floor, but is not the result of a poor bond. No adhesive can be so elastic that it will hold floor covering rigidly to sub-floor and still retain certain other desirable properties of the ideal adhesive.

3. Loosening of Pieces of Floor Covering:

Single tiles or unit wooden blocks occasionally become loose, especially during the early life of the floor, because of lack of bond, poor laying, or excessive traffic. Such pieces when taken up and carefully relaid, seldom give further trouble. In the case of rubber flooring, moisture is an important factor contributing to the loss of bond. This and other factors are dealt with in the book, "Adhesion Problems in Connection with Rubber Flooring", International Rubber Association, The Hague, (1930).

4. Maintenance Precautions:

There should be proper coordination in the choice of adhesives with the materials used to finish and maintain the floor covering. Obviously, it is best to use stains or waxes dissolved in liquids which are non-solvent to adhesives, in order to prevent solvent action if seepage should occur through joints in floor covering. Moreover, the use of too much water in cleaning floor should be avoided. (See Bureau of Standards Letter Circular LC 388, "The Care of Floors").[1]

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[1] May be obtained free upon request from the National Bureau of Standards, Washington, D. C.