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• Selection and Field Application

• Pressure-Sensitive Tapes

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BRI Executive Director

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Abstracts of Conference Papers

ADHESIVES FOR CERAMIC, PLASTIC AND METAL TILE
By Alex O'Hare, Miracle Adhesives Corp.

Discussion in this paper is limited to one type of material used for bonding ceramic tile to a supporting medium, i.e., the thin-set, organic type of adhesive. Development of this type of material is traced through experimental work beginning about 1935 up to the present time. Results of comparative tests made on 51 different commercially available adhesives are shown in a table. Three types of thin-set adhesives and their properties are discussed in detail: resin-base adhesives; synthetic or natural rubber latex base adhesives; and rubber-resin base adhesives. Principles of application of tile to accepted back-up materials are stated, and recommendations are made as to the application of the adhesives and the grouting of thin-set applications. Attention is called to some slight variations from general usage as applied to ceramic tile, when plastic or metal tile is installed.

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ADHESIVES FOR WALLBOARD
By Sidney Lauren, Johns-Manville Research Center

Five kinds of adhesives for wallboard are discussed in terms of their individual characteristics and recommendations are made as to their use. Tape joint cement is described as the simplest adhesive suitable for gypsum wallboard lamination, and specifications are given for nailing such installations when using tape joint cement, showing a reduction of 50% in the number of nails used. The use of mastic cements in single-layer installation of wallboard on studs, ceiling joists, etc., is described, and details of its application stated. Advantages and disadvantages of emulsion-type, or white glues, are cited, and it is mentioned that their use as structural adhesives in the field is increasing. Urea resin adhesives and contact cements are also discussed briefly.

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ADHESIVES FOR RESILIENT FLOORING INSTALLATIONS
By Carl L. Carlson, Armstrong Cork Co.

The characteristics and uses of the major types of resilient flooring adhesives and related matters such as preparation of the subfloor, moisture problems, temperature during installation, and application of adhesive are outlined briefly. Six basic types of resilient flooring adhesives are then discussed individually, including linoleum paste, asphaltic adhesives, resin-type waterproof adhesives, latex adhesives, chemical-setting adhesives and asphalt-rubber adhesives. Types of resilient materials and installation techniques suitable to each are described. Existing specifications in this field are reported, and there is a discussion of testing for moisture in concrete subfloors and for relative humidity conditions which can affect bonding and subsequent performance of the flooring.

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SELECTION AND APPLICATION OF ADHESIVES FOR PLASTIC LAMINATES
By George J. Schulte, Minnesota Mining & Manufacturing Co.

The two popular types of adhesives used today for plastic laminates are delineated as the thermoplastic contact bond adhesives and the thermosetting urea formaldehydes. The contact bond type is more generally used for on-the-job and field applications where costly investment in presses is not practical. The ureas are used in shops where adequate equipment is available. The importance of mixing is stressed, especially in the case of the urea formaldehyde and resorcinol types of adhesives. Recommendations for proper application are made, and users are cautioned against the flammable properties of some types of adhesives.

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ADHESIVES FOR ACOUSTICAL TILE
By Francis S. Branin, ASCO Products Corporation

The tentative specification for adhesives for acoustical materials adopted and published in 1960 by the American Society for Testing and Materials is quoted in part as background for establishment of requirements for the performance of such materials, and adherence to these specifications is noted as vitally important. Proper application methods with attention to positive wetting in each instance of contact are discussed and illustrated. Types of failure and their causes are mentioned, and also the importance of following directions and using skilled craftsmen.

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ADHESIVES FOR THERMAL INSULATION
By Wayne P. Ellis, Benjamin Foster Company

Eight design criteria to govern selection of proper adhesives for use with thermal insulation are set forth in this report. Considered are the nature of insulation and other surfaces to be bonded, strength and durability desired, limiting temperatures in service, fire hazard properties, performance of dual functions in one application, methods of application, curing conditions, and economy. Types of thermal insulation are classified generally as: roof and wall insulation; insulation for hot piping, ducts and equipment; insulation for cold piping, air conditioning ducts and equipment; and cold storage insulation. Three types of adhesives and their uses in these applications are then discussed: adhesives for insulation lagging, bonding, and facing and jacketing. Designers are cautioned to give consideration not only to the method of attaching thermal insulation, but also to the complete system of materials, which includes adhesive, insulation and surface finish, if the design is to be completely successful.

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NEW ADHESIVES AND THEIR FIELD APPLICATION
By Jerome L. Been, Rubber and Asbestos Corporation

Merits of new adhesives for use in building are stated as their unusually high strengths, versatility of specific adhesion, and proven stability in service under severe environmental conditions. Comparison is made between compressive, shear and tensile strengths of a cured epoxy resin and conventional mortar, illustrating that the epoxy resin can outperform mortar as a structural material, as well as an adhesive. Use of epoxy compounds as bonding agents for cementing concrete blocks, for thin-setting ceramic tile, for bonding steel dowels into concrete, etc. are mentioned as illustrations of versatility. Ease of mixing in the field is discussed, including hand mixing, mixing with drill press or cement mixer, and the use of specialized automatic mixing, metering and proportioning equipment. A number of new applications of conventional rubber adhesives in building are described. Entirely new families of epoxy as well as neoprene contact-type adhesives with very high immediate "green strength" and resistance to humidity; a number of recent developments which have improved quality and durability of the new adhesives; and one single-component, acrylic-based material which cures at room temperature to an immediate, strong bond are also noted.

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APPLICATIONS OF PRESSURE-SENSITIVE TAPES IN BUILDING
By Donald A. Wallace, Johnson & Johnson

A prime consideration as regards the use of pressure-sensitive tapes in building is stated as the ability of the tape to resist water transmission. A table shows the average moisture vapor transmission rates for various types of tape. Importance of the ambient temperature to the ultimate performance of the tape when applied is discussed as a primary factor in good application procedures, with the recommendation made that tapes be applied whenever possible in temperatures above 40°F. The various different uses made in building of pressure-sensitive tapes are then listed, and the appropriate tapes for each application detailed. A recently introduced tape compound which performs adequately in a greatly increased range of temperatures is described briefly.

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RECENT FIELD HISTORY OF PRESSURE-SENSITIVE TAPES FOR SEALING APPLICATIONS
By Paul H. Wilson, Minnesota Mining & Manufacturing Co.

Several experimental buildings erected recently in which pressure-sensitive tapes were used as the weather seal for panel joints are described. Included are a building faced with corrugated cement-asbestos-siding; a roof system composed of plastic roll roofing; plywood roof panels sealed with a plastic tape; an aluminum geodesic dome; and aluminum-backed tape used on steel roofing.

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Adhesives for Ceramic, Plastic and Metal Tile

By Alex O'Hare,* Vice President, Research and Development
Miracle Adhesives Corporation

HISTORICAL BACKGROUND

For bonding ceramic tiles to a supporting medium, three broad classes of materials are in general use today. These are: a full thick (3/4-1 1/2") portland cement mortar bed; a thin-set (1/32-1/8") organic adhesive; and a newly developed dry-set mortar. This paper will cover only the second method, namely thin-set organic adhesive tile installations.

In the past, many types of glues or adhesives were used to repair or patch ceramic tile originally set in conventional portland cement mortar beds. The adhesives used for these repair jobs were animal glues, silicates, asphaltic compounds, and linoleum pastes. None of these materials showed much promise, or ability to do the complete job of tile setting, and none is being used for that purpose today. Their very inadequacy, however, spurred extensive research, and about 1935 one of the first rubber-resin, mastic type adhesives was used experimentally for setting tile on the walls of old concrete shower stalls in an institutional building. This early test work was still in almost daily use when last inspected in 1959.

The same adhesive was also tested extensively in a 10-year research program directed by Dr. Kaufman of the Ceramics Department of Rutgers University, who found it one of the first adhesives to show real promise for both permanent and practical ceramic tile work. At the end of this long and thorough testing program, Dr. Kaufman wrote, in 1947:

> "As a matter of interest, I'm sure you will be pleased to learn that the test panels of glazed wall tile set with adhesive on an exterior wall of the Ceramics Building at Rutgers University, are still in excellent condition after ten years of outdoor exposure to the elements.
>
> I happened to be down at Rutgers last week and made a close inspection of these panels, which were installed by me back in 1937, during my investigation of thin-setting tile work as Director of Research and Senior Fellow of the Tile Industry Research Bureau. It is gratifying to note that our efforts at that time have proven the practicability of setting tile with adhesives. . . . and that such installations do stand up, even under severe conditions."

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*O'HARE, ALEX, President, Miracle Adhesives Sales Corp.; Treasurer, Products & Process Development Laboratories; educated at Northwestern University; Member, Building Research Institute, Producers' Council.

From that very modest beginning in 1937, with one adhesive manufacturer working on thin-set ceramic tile adhesives, there are now approximately 60 manufacturers producing many types of these adhesives. Because of excellent water resistance, flexibility and tenacious bond strengths, the rubber-resin, solvent type adhesives have earned an excellent reputation and have been widely accepted over the intervening years by owners, architects and tile contractors alike.

Satisfactory tile adhesives can be made with a wide variety of rubbers, resins, fillers and solvents. Due to a rapidly expanding and competitive early market, many adhesives manufacturers down-graded their products to such a point that, finally, a research program was started on an industry-wide basis at the Battelle Memorial Institute to determine minimum standards for a good ceramic tile adhesive.

The preliminary results of this investigation, completed by N. Z. Schofield and C. R. Austin in 1946, served, after three years of committee work, as the basis for establishing the present Commercial Standard, CS 181-52 for a "water resistant organic adhesive for setting clay tile." Any specifying agency, contractor or owner should always insist on ceramic tile adhesives that qualify under this industry-approved standard.

Commercial laboratory tests indicate that only about half the tile adhesive brands commercially available actually conform to these industry standards. It therefore behooves the specifier or contractor to consider not only the product in question but also the responsibility of the manufacturer in guaranteeing its performance. Most adhesive manufacturers will, on request, certify that any of their recommended adhesives are right and proper for the job under consideration.

For special service or unusual tile work, the adhesive manufacturer should always be consulted, as for example, in the production of tile-faced curtain wall panels. Figure 1 shows adhesive being applied to a panel made of metal sheets, cellular glass cores and an asbestos board back-up. Because of the use of mesh-back mounted tile (Fig. 2) a trowel with notches deeper than usual must be used to secure adequate adhesive bond. A flexible grouting system (Fig. 3) was also recommended for best results. The finished building is certainly a striking example of what can be accomplished by utilizing organic-type adhesives to set ceramic tiles on an "out of the ordinary" tile installation.

Fifty-one different commercially available ceramic tile adhesives were recently tested by a national organization in accordance with the requirements of CS 181-52. Shear strengths of these tests are analyzed in Table I which shows how widely these adhesives vary in their qualifications and properties. In obtaining the mean figures shown, shear strengths taken at 73.5°F varied from 1 lb. psi to 450 lbs. psi. Many adhesives that show excellent dry strengths failed badly on seven-day wet immersion tests. Obviously, considering the wide variations shown, no single adhesive group or type can be the perfect answer under all conditions.

TYPES OF ADHESIVES

The three basic types of widely available adhesives are: 1) resin base, 2) synthetic or natural rubber latex base, and 3) a natural, synthetic, or reclaim rubber-resin combination base.

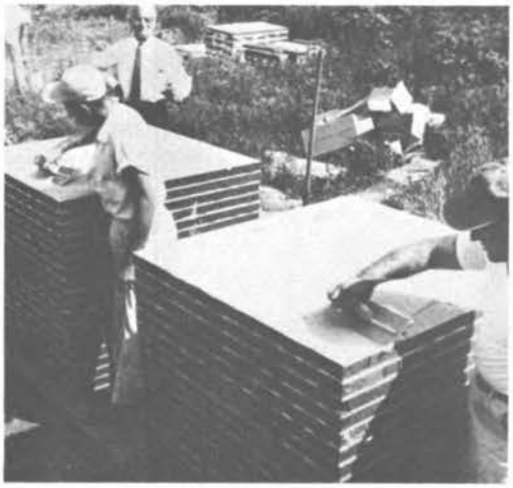

Figure 1

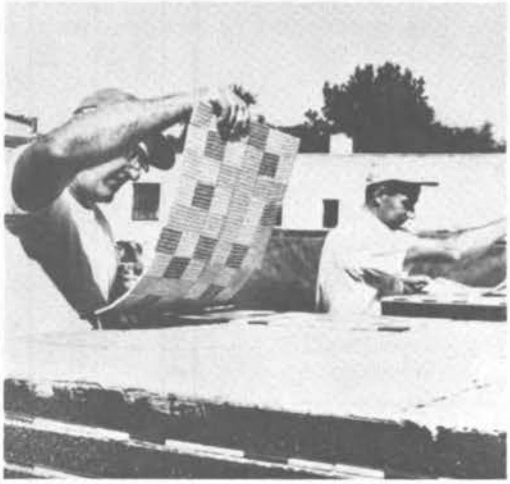

Figure 2

Resin Base Adhesives

Many of the straight resin adhesives lack complete water resistance, and many current brands of these materials are described as unsuitable for ceramic tile installations in areas subject to constant moisture. Most oleoresinous adhesives fail to conform to CS 181-52. Easy trowelability and simple soap-and-water cleaning of tools and hands are reasons for their wide use in speculative home building and apartment work. Unfortunately, the whims and dictates of the tile mechanic all too often decide for the contractor which adhesive will be used on the job, regardless of the suitability of the product for a long-term, permanent installation.

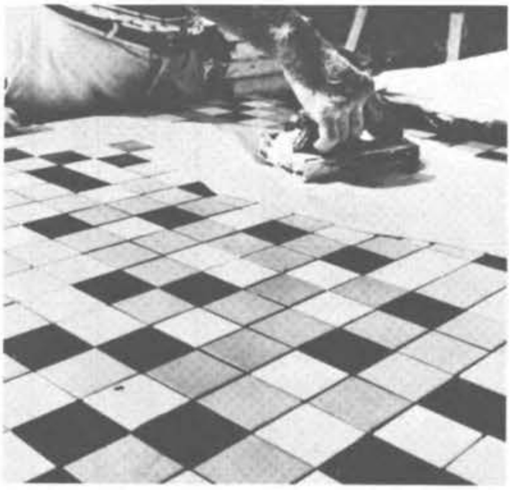

Figure 3

It has been suggested by several low-cost adhesive manufacturers that, because of the field performance record of their adhesives, present requirements of CS 181-52 should be lowered to permit these materials to qualify under the standard. Actually, at the moment, after many years of laboratory research and field experience, there is still no general agreement among all parts of the tile industry as to what actually is required of a good ceramic tile adhesive.

The Tile Council Research Laboratory, as the result of work done in collaboration with Battelle Memorial Institute, is suggesting that, instead of lowering the present CS 181-52, some of its requirements should be raised to insure greater reliability and uniformity in thin-set tile work.

Also currently, the Tile Contractors Association of America has formed a committee to discuss a research program designed to eliminate from the tile-setting trade all adhesives which do not meet its qualifications. They seem to be encountering the same problems in determining quality specifications and testing methods as is the Rubber and Plastic

TABLE I

Tests of 43 Organic Adhesives Used in Setting Ceramic Tile

	No. Brands Tested	Room Temp. $\pm 75^{o}F$	Warm $125^{o}F$	Cold $-20^{o}F$	Wet, 7 days	Aged at room temperatures: 16 hrs	7 days	28 days	7 days, Wet
CS 181-52		Mean Shear Bond Strengths in Pounds per Square Inch							
Requirements		40	30	40	40	0.5	10	40	10
All Adhesives	43	111	41	264	49	4	48	112	28
Adhesives Bearing Seal of Compliance to CS 181-52	29	133	41	352	60	4.6	60	133	39
Adhesives Bearing Seal and Actually Complying	11	184	73	369	93	7	95	199	66
Adhesives Bearing Seal and Not Complying	18	112	217	341	48	3	39	92	23
Resin Base Adhesives	13	78	36	97	16	5	29	82	6
Latex Base Adhesives	5	209	114	422	51	10	162	179	28
Rubber Base Adhesives	25	116	34	347	69	3	58	124	42

Adhesive and Sealant Manufacturers Council which is also working at improving and standardizing test methods.

The proposed new tests by the Tile Council of America, and its suggested increased performance requirements, are shown in comparison with present CS 181-52 specifications in Table II.

TABLE II

Comparison of Proposed New Shear Bond Strength Standards with CS 181-52

	Tile Council	CS 181-52
$\pm$ 75° F	100 psi	40 psi
-20°F	100	40
125°F	35	30
10 cycles, 75° to 125°F	100	none
10 cycles, 75° to -20°F	100	none
Aging 16 hr.	1.5	0.5
Aging 7 days	25	10
Aging 28 days	100	40
Wet 24 hr.	100	none
Wet 7 days		10
Soaking 10 cycles	70% dry strength	none
Oxygen 144 hr.	100 psi	none
Skinning 30 min.	70	none

Many will question the necessity of requiring a bond strength of 100 psi to carry the weight of a 4-1/4 x4-1/4" piece of ceramic tile. Most currently used back-up materials do not have surface strengths to match this. The 30-minute skinning test is also not practically geared to the tile setters' requirement of a two-hour minimum open, or working, time for the adhesive.

Several adhesives manufacturers are currently working on new ceramic tile adhesives that they hope will meet these new requirements and still be products that the tile mechanic will like and use. Of course, another major problem for the manufacturer is to convince both the owner and the contractor to pay for and use these better adhesive products in an effort to up-grade the quality of thin-set tile installations. When better or higher cost adhesives are specified by the architect, regular job-site inspections by the specifying office are always necessary to insure their proper use. Today, policing of this nature and subsequent enforcement by the inspectors of many well written specifications are often lacking. A good tile job depends at least as much on the quality of supervision and inspection of labor practices as it does on the quality of the adhesive.

Synthetic or Natural Rubber Latex Base Adhesives

Ceramic tile adhesives compounded with synthetic and natural rubber latices and resins comprise the second group under consideration. The one-part compounds develop high initial strengths and are considered satisfactory for use in normally dry areas. Due to their rubber content, in addition to the resins, they have a considerable degree of moisture resistance. Good qualities also include white or near-white color, nonflammability during installation, freedom from solvents (therefore non-toxic), and easy to clean up with soap and water. When using adhesives of this type over nonwaterproof back-up materials, a waterproof primer is generally recommended by the manufacturer.

Several two-component adhesive rubber latex systems are also commercially available. They generally consist of a measured quantity of a dry cementitious powder, and a natural or synthetic rubber latex compound. Cured bond strengths range from 80 to over 200 psi, depending on the mix and the type of latex used in the formulation. This major disadvantage is the fact that the two separate components must be properly mixed in reasonably exact proportions by the mechanic in the field. During cold weather, another major disadvantage is a possible continuing freeze-thaw cycle sufficient to affect the useful life of the latex compound during shipment, storage and installation.

Rubber-Resin Base Adhesives

The third, and most available, type of thin-set tile adhesive is the modern version of the old, original rubber-resin base adhesive. Materials of this formulation are basically similar to the original material tested by Dr. Kaufman in 1937. Many of the these adhesives do meet Commercial Standard CS 181-52. Naturally, improvements in rubbers, resins, fillers and solvent mixes, as well as manufacturing methods, have developed far better products than the original one.

New types of fillers are used that add the necessary body to achieve adequate film thickness without causing drag, separation or balling during trowel application. Mixing of solvents having different evaporation rates allows for greater control of open, or working, time. Still, many currently possible improvements in rubber-resin type adhesives are not being made available to the trade because of the competitive price situation.

In other segments of the construction industry, $15 to $25 per gallon is not considered too high a price for a good, modern, structural-type rubber-resin adhesive, but in the tile setting field, the present price goal of most large tile contractors is about $2.00 - $2.50 per gallon. It is quite obvious that the best high quality adhesives cannot be manufactured, sold and properly serviced at these low figures.

BACK-UP MATERIALS

The quality of any thin-set ceramic tile installation is directly influenced by the stability, permanence and precision of the installation of the backing or base material. A ceramic tile surface is not deteriorated in any way by hot or cold water, but many backing materials are definitely affected, and if used in wet areas, must be primed for satisfactory results. Care must be taken to use the primer and to apply it as advised by the adhesives manufacturer. All primers and tile adhesives must be compatible to achieve proper results. Most asphaltic base primers cannot be used in combination with organic tile adhesives.

There are two reasons for priming: first, the primer reduces the likelihood that any water penetrating the grout and adhesive layer might soak and possibly deteriorate the backing. Second, the back-up material may absorb essential plasticizers or other ingredients from the adhesive and consequently shorten its effective life. It is therefore wise to prime any absorbent or water-soluble back-up, when used in thin-set tile work.

Generally used and accepted back-up materials are:

1) In areas subject to regular wetting and drying, such as in industrial gang showers, portland cement plaster or formed concrete is most suitable.

2) Gypsum wallboard and plaster are widely used in residential work as a tile back-up in bathroom showers and tub recess areas. For proper, lasting installations, work should be done in accordance with the Gypsum Association's recommended ASA specification, available on request from the Association, many wallboard manufacturers, or your adhesive supplier.

   Construction of the stud line back-up for the wallboard must be proper. The studs must be set in a straight plane and should be cross-braced at midpoint with 2 x 2" herringbone bridging cut between 20 and 30° with the horizontal (Fig. 4). This keeps studs from the twisting and warping that may later cause trouble in the tile installation. This method of bracing has been recommended for years on thick-set tile jobs but is rarely used on thin-set applications.

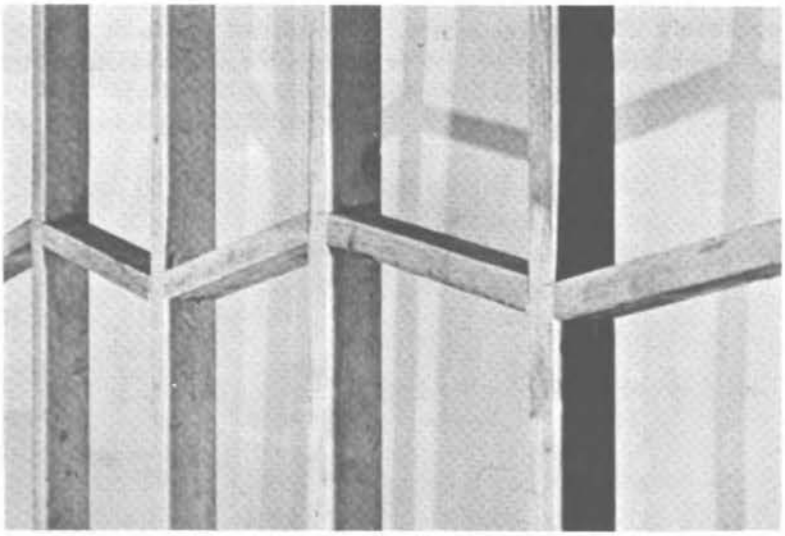

Figure 4

Unpainted gypsum plaster, white coat or brown coat, is the back-up used in most apartment and institutional work. These materials must be primed in all wet areas. If brown coat is used, as it may be in flush tile wainscot jobs, care must be taken to insure a true and plumb surface. It should also be steel troweled and a sufficiently rich mix used to prevent a crumbly, sandy finish that will not provide proper adhesive bond to support the tile work.

New plaster walls should always be checked for moisture before applying primer or setting tile. If it is dry enough to paint, it is dry enough to proceed with tile work (5.5% is the recommended maximum moisture content for good results.)

Painted plaster provides a satisfactory base, if paint is well bonded and not water soluble. Some paints can be affected by adhesive solvents and, if so softened, may cause adhesive failure and tile or grout staining. If there is any doubt, the contractor should test the application in advance.

Other satisfactory back-ups, most not widely used, are exterior grade plywood, cement-asbestos board, old brick masonry, marble, metal and old tile, or terrazzo walls and floors. Many of these surfaces, although satisfactory, require special treatment. For example, exterior grade plywood is listed as acceptable, but in wet areas it should be well primed and all edges of cut-outs protected. When used in floor work, adequate sub-floor construction must be provided to prevent any deflection greater than 1/360 of the span due to live loads or impact. Ceramic tile in combination with a cement grout is a rigid surfacing material, and therefore cannot be used over a springy substrate.

In summary, back-up surfaces must be firm, level and plumb. They must be rigid, dry and free of dirt, scale, rust, grease, oil, waxy or asphaltic curing compounds or poorly bonded paint.

APPLICATION OF ADHESIVE

Most thin-set adhesives manufacturers recommend applying or floating the adhesive on the wall with a deep notch trowel or sawtooth trowel.

A trowel with 1/4 x 1/4" notches spaced approximately 1/2" apart (Fig. 5) is best for adhesives that tend to form a quick skin when exposed to air. Adequate pressure when applying the tile, or subsequent use of a beater block, is required to break the skin and to spread the adhesive over the back of the tile. Trade practices and workmanship are such that this is seldom accomplished in the field today.

Figure 5

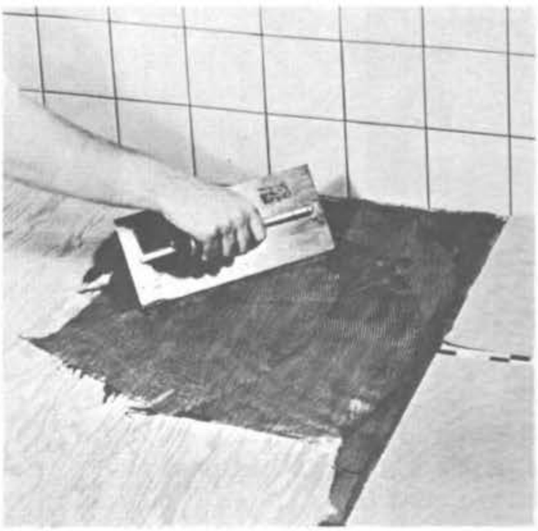

Figure 6

A sawtooth trowel with 1/8" deep serrations (Fig. 6) gives a better spread of adhesive generally, and covers tile better. This trowel is also recommended for mosaic floor work. Thin notch asphalt tile or linoleum spreaders should not be used. Care should be taken to replace worn trowels or to file notches after using on abrasive back-ups, to insure proper adhesive thickness.

In an attempt to get greater daily production, the contractor has demanded and has received adhesives with a working time of two to four hours. This is necessary, to permit the mechanic to spread the adhesive over a large area and then concentrate on tile setting. Although designed for slow, thin skinning under ideal laboratory conditions, it is conceivable that site conditions of low humidity and rapid air movement could cause fast, thick skinning. A study has been made to determine the effect of skinning caused by long exposure to air on the resulting bond strengths.

In practically all tests, the longer the exposure of the adhesive, before applying tile, the poorer the bond. Better bond strengths are obtained when tiles are set in a reasonably short time after spreading the adhesive.

GROUTING OF THIN-SET APPLICATIONS

Although the grout or joint filling material is not an adhesive as such, it is an important factor and shares much of the responsibility for the final success of thin-set tile work.

Available grouts fall into three general classifications. Straight portland cement, portland cement and sand, and commercially produced grouts containing cement, fillers, lime and waterproofing compounds. These are called "wet" grouts. To insure proper hydration of the cement, care must be taken to wet the tile joints thoroughly and to moist cure for at least three days. This means applying a moist spray or covering with a vapor barrier material.

The second type is a "dry" grout, recently developed to permit grouting of dry tile, and also to eliminate moist curing. These grouts are expensive, but labor saved on installation may offset their higher costs.

The third classification would be those grouts classified as alkali- and acid-resistant. These materials include among others epoxy systems, silicate materials, furfuryl alcohol products and hot sulphur compounds. All require special installation techniques, and are used mainly on floors and countertops. A new epoxy base grout that permits removal of excess material from the tile face with water is now commercially available.

In their effect on thin-set tile applications, all grouting materials have one problem in common—if joints are not completely filled and properly cured, deleterious materials may enter the joints and harm either the adhesive bond or the back-up material. Good grouting is an essential part of a good thin-set adhesive tile job.

PLASTIC AND METAL TILE

The foregoing information has dealt with ceramic tile work, because this material is used in the majority of tile installations. However, much of the data regarding back-up materials applies equally to plastic and metal tile work.

The early rubber-resin mastic adhesives were not satisfactory for use with plastic tile because of solvent attack on the plastic. Oil-based, putty-like mastics were first used with metal tiles, but priming was necessary to prevent drying out of the mastic. A high solids content, varnish-type mastic containing both oils and resins, based on blown oils, styrenated oils and combinations of these with resins, butyl rubber and polybutene, has become the accepted standard today.

A sometimes overlooked problem in plastic tile installation is the expansion of the tile when closely set over a large area. This is especially true of the 8-1/2" tile. A 5' long piece of extruded polystyrene has been shown to expand as much as 1/8" when mounted with mastic and subjected to a $40^{\circ}F$ rise in temperature. Under certain conditions, where tile has been installed at low temperatures, the tile has buckled off the wall with a subsequent rise in temperature.

Because plastic tile, unlike ceramic tile, has a cavity in the back, it is necessary that a trowel be selected that will give mastic ridges sufficiently high to compress slightly when the tile is installed, and to give a proper coverage pattern of mastic on the tile. Many installations put up with insufficient mastic because of a wrong or worn trowel have resulted in early failures. However, there are millions of square feet of satisfactorily installed plastic and metal tile, and these products enjoy a large share of the total tile market.

In conclusion, although a great quantity of ceramic tile is installed annually by the thin-set method, using organic-type adhesives, continuing development and research in this field are still vital. The vast majority of these jobs are completely satisfactory, but some poorly policed field installations, often labeled "adhesive failures," do exist and tend to reflect adversely on the adhesives industry. People sometimes forget the unexplained failures in portland cement jobs, but they never seem to forget those in which adhesives are used.

Ceramic tile is a "life-time" product in a building. It certainly follows that we need a "life-time" adhesive with which to set it.

It is because of these facts that higher bond strengths with more resilient bonds are being sought. Better tests for evaluating the aging of rubber-resin compounds in moist, alkaline conditions are needed. Continued flexibility of bond after long-time use and exposure is important, because the relative movement among the components of modern buildings is greater than in conventional and older constructions.

Certainly, in the adhesives industry, as large and as well equipped with research and development facilities as it is, answers to these questions are bound to be forthcoming in the near future.

Adhesives for Wallboard

By Sidney Lauren,* Research Technologist
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INTRODUCTION

Use of adhesives by the construction industry for installation of all types of wallboard has, until recently, lagged far behind the routine and successful use of adhesives for manufacture of laminated and sandwich panel assemblies. Thus, builders have readily accepted the many types of wall panel materials that depend upon effective glue lines for structural integrity, yet have been comparatively slow to adopt methods of installation that involve use of adhesives rather than mechanical fastening alone.

If this difference in attitude toward structural adhesives does reflect, in part, some of the traditional conservatism both of the construction industry and of approving authorities, it must be admitted that there is considerable justification for a more cautious approach to adhesives by builders than by manufacturers of construction materials.

When adhesives are used in a factory for fabrication of plied panels, the vital conditions for a successful adhesive performance can be controlled. These conditions include cleanliness, moisture content, temperature, smoothness (or controlled roughness) and flatness of the mating surfaces; the amount of adhesive applied; the open time, and any special predrying requirements. It is obviously impossible to exercise equally precise control of these variables on a construction job. Further, in a factory, ability to use heat and pressure, when required, has made possible utilization of types of adhesives that could not perform as well, or at all, when used under field conditions, and that were unmatched in performance by any that could be applied on the job.

Through alertness to the newest developments in synthetic resin technology, and by exercise of inventiveness in formulating with the older raw materials as well as the new ones, the adhesives industry is causing builders to change their outlook on adhesives as a functional element in building construction. The growing number of effective and dependable adhesives for structural uses includes types designed specifically for wall panel installation. Relatively tolerant of normal variations in installation conditions, some of these adhesives have now accumulated records of years of successful service.

The increasing sophistication of the construction industry, and the ability and willingness of its craftsmen to follow instructions, have been key factors in this, as in other advances in building construction.

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PRINCIPAL TYPES OF WALLBOARD AND PANELS

Although variations in the treatment of the exposed surfaces—with coatings, laminates and physical textures—yield great differences in decorative appearance, the principal types of wallboard and panels now in common use may be classified as follows:

1) Gypsum wallboard, the universal "drywall" material
2) Plywood
3) Hardboard and semihardboard
4) Asbestos-cement board
5) Insulating board (low density wood fiber board).

Among the factory-applied surfacings now available on all or some of the wallboards in these five categories are: rigid plastic laminates; porcelain enameled metals; textured metals; embossed and imprinted plastic films; decorative papers; organic enamel coatings; and hardwood veneers, prefinished with lacquers.

The advantage obtained by glueing, rather than nailing, is obvious in installation of panels with these decorative facings. On some of these surfaces, nail holes can be concealed only with difficulty; on others, face nailing cannot be done at all without conspicuous and irreparable damage.

Special Problems of Gypsum Wallboard

The combination of efficient patching compounds and skillful craft practices has made it possible to conceal nail holes perfectly on gypsum wallboard, but at a substantial cost in labor, as was made clear during the 1960 Spring BRI Conference on Adhesives in Building. Marring of the gypsum wall surface by nail popping after the walls are finished and decorated, an occurrence which is all too common, remains one of the principal sources of consumer dissatisfaction with drywall construction, and one of the major problems of the industry.

While some of the trouble encountered with gypsum drywall results from warpage of green framing lumber, even properly kiln-dried lumber responds to temperature and humidity cycling within a structure, thus leading to some occurrence of nail popping.

The approach to use of adhesives for gypsum drywall is predicated on the simple concept that nails which aren't used can't pop. Although use of adhesives alone, without nailing, is so far rarely encountered in commercial practice, reduction in nail usage by as much as 75% has been accomplished successfully with a combined adhesive and nailing method for gypsum wallboard installation.

On-the-job Lamination of Gypsum Wallboard

Another approach to elimination of nail popping, and to considerable reduction in need for nail spotting, is the practice of gypsum panel lamination. In this procedure, the first ply is installed conventionally with nails directly on studs or ceiling joists; then a second panel is glued to the first, using as few nails as possible to maintain pressure until the adhesive sets. This type of laminated construction yields a more rugged wall or ceiling, with less "drumming" and sound transmission than is obtained with single-layer construction of equivalent thickness.

ADHESIVES FOR WALLBOARD

Tape Joint Cement for Gypsum Wallboard Lamination

The simplest adhesive suitable for gypsum wallboard lamination is tape joint cement, mixed on the job and used promptly without retempering. Only the joint cements are suitable for this use; the topping and finishing cements are considered lacking in adhesive power for this application. Furthermore, tape joint cements can be used only to laminate one gypsum drywall panel to another, not for cementing gypsum wallboard to wood framing.

To get the most benefit out of the lamination technique, layout patterns for the gypsum wallboards should be planned thoughtfully, in order to keep end joints to a minimum. Thus, on side walls in rooms not over 8'3" high, the first ply is fastened vertically to the studs, using a conventional nailing technique. When the face ply is then installed at right angles to the first layer, fewer end joints occur than could be obtained with the reverse procedure. In higher rooms, however, the reverse type of installation—horizontal first ply and vertical face ply—results in fewer end joints. Since many helpful suggestions for layout patterns appear in the technical literature available from manufacturers of gypsum wallboard, further detailed discussion will be omitted here.

For lamination, tape joint cement is applied to the back surface of the face ply. A trowel with notches not smaller than 1/4" x 1/4", spaced not more than 2" apart, has been found satisfactory. The cement should be applied in an irregular pattern, but over the entire wallboard surface and right up to the extreme edges. Immediately after the cement is applied, the face ply should be pressed tightly against the base layer and held in place at least 24 hours.

While pressure can be maintained with headers and props, reliance on this method alone is rare in the usual installation of laminated gypsum wallboard. In most cases, nailing is resorted to, using as few nails as possible to maintain pressure until the adhesive sets. If conventional box or cooler nails are used, they may be driven below the surface of the facing panel after the adhesive takes hold; if two-headed nails are used for temporary fastening, they are withdrawn, with due precaution taken by use of a wood block under the hammer head to avoid crushing the gypsum board. In either case, the nail holes that remain are spotted with spackling cement in the usual way.

Typical nailing specifications for two-ply, 3/8" gypsum wallboard installations using tape joint cement as the laminating adhesive, are as follows:

1) On sidewalls—4d cooler nails:
   First ply, 6-8" o.c.
   Face ply, 16-24" o.c.

2) On ceilings—First ply, 5-7" o.c.
   Face ply, 12" o.c.

With this method, combining use of tape joint cement and nails for laminating gypsum wallboard, only 50% of the usual number of nails is used in the face ply. As indicated earlier, even lower nail usage has been achieved on sidewalls with a variety of cements.

Lamination of gypsum panels on ceilings naturally focuses more critical attention on the entire chain of adhesive performance. The bond between the gypsum core and the paper facing; the strength of the paper; specific wetting of the paper; and cohesive strength, resilience and cold flow characteristics of the glue line all are part of the adhesion chain which reflects the proverbial weakness of the weakest link.

Mastic Cements

A variety of high-solids compositions, based on reclaimed rubber and resins or various asphaltic bases, comprise the class of mastic cements that have found wide use in a single-layer installations of wallboard on studs, ceiling joists, furring strips, and solid backing surfaces.

The asphaltic compositions are always identifiable by their black color, while the more expensive rubber-resin materials are usually tan. Some very cheap types of asphalt compositions, which may be effective enough as adhesives, contain oily substances that can migrate through wallboards such as asbestos-cement, and stain the panel face.

Good mastic cements are characterized by fast "grab" and reasonable gap-filling capability. They are thus more tolerant of minor misalignment of framing members, and of some irregularities in solid backing surfaces, than are the contact cements which will be mentioned later.

As with other solvent-thinned materials that are immiscible with water, mastic cements should not be applied on damp surfaces. For installation of wallboard in single layers on wood framing, the best tool for application of mastic cements is a refillable caulking gun. On a stud or joist in contact with only one panel, a straight line of cement 1/4" thick is laid down through an angled tip designed to deposit a bead 3/8" wide. On framing members over which the edges of two panels meet, the cement is extruded in a zig-zag bead. In either case, the cement need be applied only to the framing. Approximately 150 to 170 lin. ft. of cement bead can be deposited from one gallon of typical commercial mastics.

Installation of the wallboard should be made within 10 to 30 minutes after application of the mastic, unless a particular product bears other specific directions. It is good practice always to "wiggle" a panel into contact with the adhesive in order to break any dry skin that might have formed, and thus to insure good wetting of the panel surface by the adhesive.

Recommendations for nailing of single-ply gypsum wallboard installed with mastic cement on wood framing are similar to those mentioned earlier for the second layer in two-ply construction. In other words, sidewall panels are nailed on 16" centers and ceiling panels on 12" centers. Some venturesome applicators use slightly wider spacing than 16" on sidewalls.

When the recommended mastic application procedure is followed, the bead of cement 3/8" wide by 1/4" thick will be squeezed down, by nailing or shoring pressure, to just about the full width of a nominal 2" wide stud, joist or furring strip, and to a thickness of about 1/16".

For installation of wallboards on solid backing surfaces, it is preferable to apply the cement, either on the base surface or on the panel, with a notched trowel, rather than a caulking gun. Notched trowels with square, U, or V notches, 3/16" x 3/16", spaced 3/8" apart, are suitable for most commercial mastic cements, unless the manufacturer specifies otherwise. In most cases, a trowel application angle of 30 to 45° is recommended; this is an important point to observe, since viscous cements can be "metered" onto surfaces at various spreading rates depending upon the trowel contact angle, even with fixed notching.

Despite their initial fast "grab," the ultimate strength of most mastic cements develops slowly. For example, the tensile strength of the bond produced with a typical commercial cement was increased by a factor of 4.5 when it was tested after aging for a week at elevated temperature (which drives off solvent), in comparison with a one-day-old bond at room temperature. Thus, when shoring pressure can be maintained for a sufficient length of time over the face of a panel, decorated wallboard can be installed unmarred, with but minimum mechanical fastening at edges.

The volatile portion of solvent-thinned mastics is petroleum naphtha, the vapors of which are very easily ignited by flames and sparks. Good ventilation should be provided, and sources of ignition eliminated during work with these materials. To clean application tools after use with mastic cements, ordinary paint thinner—mineral spirits—should be used instead of unleaded gasoline, which is much too hazardous for use as a cleaner on construction jobs.

These precautions are, of course, not applicable to the water-emulsion types of mastics. While they are free of flammability hazard, the emulsion products lack the quick "grab" and high degree of water resistance of the solvent-thinned materials.

White Glues

Dispersions in water (so-called emulsions) of polyvinyl acetate resin, with plasticizers and occasionally with other resin modifiers, constitute the types of adhesives known as white glues, due to their milky-white appearance in bulk. In dry films, they are water-white, and either completely transparent or only slightly hazy. In recent years, the white glues have become the practically universal household cement, and with good reason. They are ready-mixed, take hold quickly with only moderate and short clamping pressure, are nonstaining, provide very strong bonds on cellulosic and many other surfaces except smooth metals, and permit cleanup of tools and spills with water, if the cleaning is done before the glue dries.

When properly formulated, white glues are reasonably water-resistant, but not waterproof. They are also thermoplastic, but give no trouble on this score in ordinary service.

White glues may be applied by brush, as though they were a viscous paint (which they resemble), or they can be poured onto a horizontal panel surface and spread with a notched trowel. Although they can also be sprayed, the danger in spraying lies in the possibility of overthinning with water.

In cementing with white glues, it is best to apply the adhesive to both mating surfaces, which should then be joined promptly, while the glue is still wet and tacky. It is necessary to have some pressure, obtained by nailing or shoring. On reasonably absorptive surfaces, such as plywood, gypsum panels, hardboard and framing lumber, good bonds develop at normal temperatures and humidity in several hours.

Tools used for application of white glues should not be allowed to dry before cleaning. While the glue is wet, it is completely removable with water. When it dries, although it is not waterproof enough to maintain high bonding strength when soaked, it is nevertheless not water soluble and also not easily soluble in commonly available solvents.

Despite the fact that they cost more than rubber-resin cements, white glues have begun to invade the structural adhesives market for field use on a modest scale. In factory fabrication of such components of buildings as flush paneled doors, they already have a long and good service record.

Urea Resin Adhesives

A number of powdered urea resin adhesives, familiar to the home handyman as "plastic resin" glues, are available on the market. When mixed carefully with a recommended quantity of water and stirred to a smooth, creamy paste, they can serve effectively for attaching plywood wallboards to wood framing. These glues do not have much tack, but do cure in about 10 hours under pressure, to yield strong, water-resistant bonds. Supplementary nailing or sustained shoring pressure are needed until the glue cures.

The urea resin glues solidify irreversibly in several hours, so it is desirable to mix only as much as can be used up promptly, without further thinning with water. These glues are not widely used by professionals in wallboard installations.

Contact Cements

Solvent dispersions of mixtures of neoprene synthetic rubber, certain resins and fillers yield a type of cement that is applied to two mating surfaces and allowed to dry until the films just lose their tackiness to the touch. When the coated surfaces are then brought together in intimate contact, they bond instantly and strongly enough to make repositioning impossible.

When one works with large panels such as wallboards, the disadvantage of the need for absolute precision in positioning before contact is too obvious to require emphasis. Since contact cements are low-solids, thin film adhesives, they also have no gap-filling capacity, and thus demand complete conformity of the mating surfaces. Until the recent appearance of emulsion types of this cement, the solvent dispersions represented a great flammability hazard.

Despite these limitations, contact cements have been, and will continue to be, used in considerable volume in wallboard installations, particularly prefinished, hardwood-veneered plywood panels.

In summary, it is apparent that although great progress has been made in the technology of adhesives for wallboard installation, the simple, bulk-stable, inexpensive cements that will permit positioning of wall panels after contact, yet develop enough bond strength almost instantly to eliminate completely the need for mechanical fasteners, has not yet appeared. We are, nevertheless, approaching that ideal. Indeed, some of our adhesives are now becoming so good that they are focusing attention on another link in the chain—the cohesive strength of some of the structural elements in cemented assemblies. The building industry as a whole is thus bound to benefit from the regenerative effect of advances in associated technologies.

Adhesives for Resilient Flooring Installations

By Carl L. Carlson,* Manager,
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Prior to World War II there were four basic types of resilient flooring products on the market: linoleum, asphalt tile, rubber tile and cork tile. With the exception of asphalt tile, all were intended for use on suspended subfloors only. In the years following World War II the new elastomeric and resinous materials (chiefly polyvinyl chloride) began to find wide use in resilient flooring products. Furthermore, considerable attention was given to the supporting layers or backings of resilient flooring products and, as a result, the industry now has some additional products available, many of the newer ones being suitable for on- and below-grade, as well as suspended subfloor, use. The principal types of resilient flooring products currently available are:

1) Oil bonded (linoleum)
   - a) Supported (cellulose backing)—sheet and tile
   - b) Unsupported—tile
2) Vinyl
   - a) Supported
     1. Cellulosic backing—tile and sheet
     2. Vinyl backing—tile
     3. Rubber backing—tile
     4. Asbestos felt backing sheet
   - b) Unsupported—tile
     1. Flexible
     2. Vinyl asbestos
3) Rubber (homogeneous)—tile
4) Asphalt tile
5) Cork—tile

Subfloors also offer more complications today than in the preceding years. In addition to strip wood flooring and concrete, we now have plywood, hardboard and a host of other boards used as underlayments. Even concrete subfloors have undergone some changes. Today, in addition to conventional concrete mixes, we have lightweight concrete, and concrete which has been surface treated with curing agents or breaker compounds. Some of the types of bases for resilient flooring frequently encountered are:

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1) Concrete

   a) Conventional mix (suspended, on- or below-grade)

      1. Treated with curing compound or breaker compound
      2. Untreated

   b) Lightweight concrete

2) Stripwood flooring
3) Hardboard
4) Plywood (certain types)
5) Metal
6) Mastic underlayments

As one might expect, when there are approximately 12 different types of resilient flooring products and six to eight different types and conditions of subfloors, there exists a complex installation situation providing a variety of adhesive problems. During the past 15 years some of the problems have been solved; some remain to be solved.

This paper will describe the characteristics and uses of the major types of resilient flooring adhesives available today. However, since adhesives are only one factor in a complex installation picture, the need to discuss a number of related matters is inevitable. Such factors as preparation of the subfloor, the moisture problem, temperature during installation, methods of application, and performance specifications will be included. Also, some factors pertaining to moisture testing and to the effect of concrete curing compounds on adhesion will be presented.

Preparation of the Subfloor

It is absolutely essential that the subfloor be put in a mechanically and structurally sound condition prior to beginning the installation. From the standpoint of proper adhesive bonding, however, the most important requirements are that the surface be smooth, clean, dry and free from surface coatings which might prevent adhesion. In the case of concrete subfloors it is highly desirable that the concrete be well cured and dry.

The Moisture Problem

Of course, no concrete slab is absolutely dry, and the degree of wetness that can be tolerated varies among the available types of resilient flooring products and adhesives. Some flooring materials are inherently more water-resistant than others, and certain adhesives have been developed and marketed primarily to combat the moisture problem. These obviously have the best chance of succeeding under adverse conditions. The more moisture-sensitive resilient flooring products include linoleum, cork tile, and products having a cellulosic backing. These should not be installed on subfloors which are wet or likely to become wet.

Under severe moisture conditions it is probably true that no adhesive, no matter how waterproof, is capable of preventing all types of moisture-related problems, since the problems may be simply the oozing of water between the joints of the flooring or the deposition of salts carried to the surface by water. In this connection, it should be pointed out that flooring adhesives do not function as moisture barriers and, therefore, do not protect the resilient flooring from moisture. The use of an effective barrier, i.e., polyethylene, sheet rubber, roofing felt sealed with asphalt, etc., is advisable under all concrete slabs in contact with the ground.

Drying of new concrete subfloors should be considered an essential part of their preparation. The length of time required for a concrete slab to dry depends upon a number of factors including the thickness of the slab, temperature, humidity, degree of ventilation, type of aggregate used (lightweight aggregates require more water and, therefore, require longer to dry), type of construction (concrete placed on a metal pan can dry only from the upper surface), and whether or not the concrete is kept covered by piles of sand or other building materials. Methods for detecting moisture in concrete are described in another section of this paper.

Once the concrete has been placed and allowed to cure, accelerating further drying can best be accomplished by keeping the building well ventilated and warm, and by removing stored building materials from the floor.

The effect of air conditioning on the rate of concrete drying is a subject of interest. During humid weather, operating an air conditioning system which removes moisture from make-up and recycled air should accelerate drying. On the other hand, during dry weather the operation of a system which adds moisture to the building should be avoided.

Temperature During Installation

Most resilient flooring adhesives are designed to be used at approximately 70^{o}F measured at the subfloor. Temperatures higher than this, up to about 90^{o}F, might not be particularly harmful, but most adhesives will dry or "set" faster at higher temperatures, thus reducing working time. On the other hand, temperatures lower than 70^{o}F will cause some adhesives to be excessively slow in setting, and indentation of the flooring material may result from traffic, or furniture placed on the floor while the adhesive is soft. Also, asphaltic adhesives tend to lose their tack or bonding characteristics at low temperatures.

Application of Adhesive

Virtually all resilient flooring adhesives used in the United States today are manufactured to a viscosity suitable for application by means of a notched trowel. The principal exceptions are the adhesives made brushable to appeal to the home mechanic. Trowelling is a surprisingly rapid means of application, and the notched trowel is a reasonably effective device for gauging the quantity of adhesive spread.

Attempts have been made on a commercial basis to eliminate the use of troweled-on adhesives in resilient flooring installation. Principal among the techniques used are:

1) The factory application of the adhesive to the back of the flooring. (Both rewettable and pressure sensitive adhesives have been used.)

2) Use of adhesives in film or sheet form to be placed on the subfloor prior to installing the flooring. (In at least one case the carrier for the adhesive serves also as a lining felt.)

Products embodying these techniques have not been widely accepted to date.

Characteristics and Uses of Resilient Flooring Adhesives

The basic types of resilient flooring adhesives available today are:

1) Sulfite liquor based adhesives (linoleum paste)

2) Asphaltic adhesives

   a) Emulsion
   b) Cut-back

3) Resin-type waterproof adhesives (solvent type)

4) Latex adhesives (SBR)

5) Chemically-setting adhesives

   a) Latex (NR)
   b) Epoxy

6) Asphalt-rubber adhesives (water-dispersed, brushable consistency)

Linoleum Paste (Sulfite Liquor Based)—The linoleum paste type of adhesive is so named because, since its inception, it has been associated with the installation of linoleum. However, today it is used to install not only linoleum but also rubber tile, certain vinyls, cork tile, lining felt, etc. Linoleum pastes are of trowelable viscosity, and are tan to dark brown in color. Their liquid component is water, and they present no special hazards or handling problems during installation. Once this type of adhesive has been applied to the subfloor, the flooring must be installed and rolled with a 100 lb. roller within approximately 15 minutes to insure intimate contact with both subfloor and flooring. The adhesive film will normally dry to a firm film within 24 hours, and become quite hard and rigid within a few days. The rigid nature of the film is a desirable characteristic, since it restrains sheet floorings dimensionally and prevents tiles from curling. The binder portion of the adhesive remains forever water soluble, which facilitates clean-up of tools and spillage, but which renders this type of adhesive unsuitable for use on concrete slabs in contact with the ground, on- or below-grade, as well as on wet suspended slabs. It enjoys the largest volume of sale, and is the lowest-cost type of resilient flooring adhesive in use today.

Asphaltic Adhesives—Asphaltic adhesives, both emulsion and cut-back types, have been used for many years for the installation of asphalt tile, and also for the installation of vinyl asbestos tile, since its introduction several years ago. These tiles differ physically from other types of resilient flooring in that they are relatively rigid but show a high degree of cold flow. Because of these physical characteristics, they require the long tack retention characteristic of an asphaltic adhesive for their installation. Asphaltic adhesives should not be used to install other types of resilient flooring. In service, they remain soft and tacky for a long period of time, eventually becoming hard due to oxidation. These adhesives are quite low in cost.

An asphalt emulsion adhesive consists essentially of a suspension of tiny asphalt particles in water. The proportion of asphalt in such adhesives is usually in the range from 50 to 60%. These products are trowelable in consistency, and dark brown to black in color. They present no flammability or toxicity hazards in use. Application to the subfloor is accomplished by means of a notched trowel, after which the adhesive must be allowed to become substantially dry, which may require 30 minutes to one hour, or even more on humid days, before the tile can be installed. Once dry, the film is suitable for the installation of tile for up to 24 hours or more, as long as it remains dry and free from dust and dirt. Pressure applied by means of a roller is not generally required, since this type of adhesive will retain tack until the tile conforms to the subfloor under use. Asphalt emulsion adhesives are used on suspended, on-grade and below-grade concrete, as well as on suspended wood subfloors over lining felt. The practice of applying them directly to wood subfloors, thereby eliminating the use of lining felt, is also becoming increasingly prevalent.

An asphalt cut-back adhesive is a solution of asphalt in hydrocarbon solvents, and contains fibrous fillers to give the composition a trowelable consistency. They are black in color and, because of their solvent content, present some slight flammability and toxicity hazards. Good ventilation should be provided where they are used. Like the emulsion adhesives, the cut-backs require approximately 30 minutes open, or working, time before the tile can be installed. However, the working life of the set film is definitely limited in the case of the cut-backs. Most of these become too dry for installation after four to seven hours.

Asphalt cut-backs were originally used for installations on grade-level and below-grade concrete subfloors back in the days when emulsions were not generally recommended for use on such areas. During the early 1950's, as emulsions took over the on- and below-grade jobs, cut-back adhesives were on the verge of becoming obsolete. However, when the service gauge vinyl-asbestos tile began to appear, manufacturers and installers found that cut-backs were superior to emulsions for its installation.

Asphalt-rubber (Water-dispersed, brushable)—Currently, this type of adhesive is enjoying considerable success in the do-it-yourself market where its use is usually limited to the installation of asphalt tile and vinyl-asbestos tile. Although this type of product is designed for brush application, its working characteristics as well as its film characteristics are similar to those of asphaltic adhesives.

Not all brushable adhesives for asphalt and vinyl-asbestos tiles are based on combinations of asphalt and rubber. Both latex adhesives and solvent rubber adhesives are available for this purpose.

Resin-Type Waterproof Adhesives (Solvent type)—Originally, adhesives in this classification were intended almost entirely as substitutes for linoleum paste on suspended subfloor installations where surface spillage of water was likely to occur. They are likely to be based on alcohol soluble resins and to contain alcohol as a solvent, and they have approximately the same application and working characteristics as linoleum paste. The dried film of these adhesives is usually quite hard and, while insoluble in water, the adhesives are likely to be attacked readily by alkaline water. For this reason they are unsuitable for use on- or below-grade. As general purpose waterproof adhesives, these are good candidates to become obsolete, since their function can be better performed by the newer, more popular latex adhesives which are currently used primarily for on- and below-grade installations.

Latex Adhesives—Prior to about 1950, rubber and vinyl tiles were not widely recommended for on- and below-grade installation. However, in December 1950 the first of the chemical-setting, NR latex-powder adhesives appeared on the market and, performance-wise, was an immediate success in the on- and below-grade installation of these tile. This type of product is marketed as a two-package unit consisting of one gallon of a compounded natural rubber latex and an equal volume of a hydraulic-setting cement powder. These two components must be mixed on the job just prior to use, since the setting reaction begins upon mixing and proceeds to the point at which it is impractical to apply the adhesive after 30 to 40 minutes. After the adhesive has been troweled on the subfloor, tile must be installed within less than 10 minutes. From the viewpoint of the installers, this type of product left something to be desired; however, they used it because nothing else was available to do the on- and below-grade installations. There was an immediate demand for a one-package adhesive to serve this need.

In 1954 the one-package SBR latex adhesives began to appear on the market, and these have become very popular. Such adhesives are currently being used to install rubber tile and vinyl tile, as well as certain types of sheet floorings, on grade-level and below-grade subfloors. In addition, they are finding use on suspended subfloors, as well as in areas where the use of a waterproof adhesive is indicated.

The procedures for using these adhesives may vary somewhat from product to product. In general, the tiles may be installed on the wet film any time up to 10 minutes after the adhesive has been applied. In the case of one product of this type, sheet flooring is installed after an open time of approximately 15 minutes. A linoleum roller is used to insure good contact.

Latex adhesives dry or set to a somewhat rubbery film which gradually hardens with time. The film has excellent resistance to water and has remarkably good adhesion to a wet concrete surface. The use of the chemical-setting latex adhesives has declined markedly since the introduction of the one-package products.

Epoxy Adhesives—Epoxy adhesives are the latest type to receive attention as flooring adhesives. These are unique two-component adhesives based on a liquid reactive resin and activator which must be mixed on the job just prior to application. After the components are mixed, the pot life of the adhesive may be as long as several hours. It will then set to a hard film in 24 hours. Whether or not they are going to play a significant part in the installation of resilient flooring cannot be definitely predicted at this time. Performance-wise they are generally good; however, it is not yet known whether their superior performance on wet subfloors will offset their undesirable working characteristics. Durability, good adhesion, high strength and good aging characteristics are the strong features of these products. From an application standpoint, epoxy adhesives have even more drawbacks than do the chemically-setting latex adhesives. Principal among these are: 1) Need for mixing; 2) Difficulty in spreading; 3) Excessive slippage in tile goods; 4) Possible allergic reaction thereto of some individuals; 5) High cost.

A summary of the typical adhesive uses is given in Table I. With the variety of types of adhesives available, it is essential for the installer to have guidance in selecting the proper type for each specific application. This guidance is available from adhesive manufacturers and resilient flooring manufacturers.

TABLE I

Summary of the Types of Adhesive Used to Install Resilient Flooring Products

	Wood and Underlayment Board (Suspended)	Concrete (Suspended)	Concrete On- and Below-Grade
Linoleum (all types)	Linoleum paste Waterproof cement	Linoleum paste Waterproof cement	Do not install.
Vinyl (cellulosic backing)	Linoleum paste Waterproof cement	Linoleum paste Waterproof cement	Do not install.
Vinyl (vinyl or rubber carrier)	Linoleum paste Waterproof cement Latex (SBR)	Linoleum paste Waterproof cement Latex (SBR)	Latex (SBR) Chemical-setting latex (NR)
Vinyl (asbestos carrier)	Latex (SBR) Linoleum paste	Latex (SBR) Linoleum paste	Latex (SBR)
Vinyl (unsupported)	Waterproof cement Latex (SBR)	Waterproof cement Latex (SBR)	Latex (SBR) Chemical-setting latex (NR) Epoxy
Rubber tile	Linoleum paste Waterproof cement	Linoleum paste Waterproof cement	Latex (SBR) Chemical-setting latex (NR) Epoxy
Asphalt tile	Asphalt emulsion Asphalt cut-back Asphalt-rubber	Asphalt emulsion Asphalt.cut-back Asphalt-rubber	Asphalt emulsion Asphalt cut-back Asphalt-rubber
Vinyl-asbestos tile	Asphalt emulsion Asphalt cut-back Asphalt-rubber	Asphalt emulsion Asphalt cut-back Asphalt-rubber	Asphalt emulsion Asphalt cut-back Asphalt-rubber
Cork tile	Linoleum paste Waterproof cement	Linoleum paste Waterproof cement	Waterproof cement (On-Grade Only)

Specifications

Federal specifications have been established for most types of resilient flooring. However, only three types of resilient flooring adhesives are covered by Federal specifications. Two of these, "SS-A-00138 Asphalt, Emulsion Type" and "SS-A-128 Asphalt, Cut-Back Type," which are interim specifications, have never been officially adopted. The third, "OP-106 Paste, Linoleum," has not been revised since it was issued in 1939.

There are some military specifications covering resilient flooring adhesives. "MIL-C-21016C Adhesive, Linoleum and Plastic Tile," is used by the Navy to procure latex-type adhesives for the installation of fire-retardant vinyl-asbestos tile. Adhesives meeting this specification are available to commercial installers, but they are used commercially to install rubber tile, flexible vinyl tile, and certain sheet flooring products on-grade and below-grade. "MIL-C-15200A Cement, Linoleum" has been used by the Navy to procure waterproof flooring adhesives of the resin type.

Currently, efforts to establish specifications for resilient flooring adhesives are being made by the Asphalt and Vinyl Asbestos Tile Institute and the American Society for Testing and Materials' Committee D-14 on Adhesives.

Testing for Moisture in Concrete Subfloors

Several methods have been used to determine whether or not concrete subfloors are sufficiently dry to receive a resilient flooring installation. Three of the methods to be described have been in use for a number of years, while the fourth method, the Relative Humidity Test, is new to the resilient flooring industry.

Since the degree of dryness of a concrete slab is frequently different at different points in the slab, it is necessary to perform tests in a number of locations chosen along the walls, as well as near the center of the slab, in order to get a true indication of its dryness. In the case of an on- or below-grade slab, an indication of dryness at any given time is no assurance that the slab will always remain dry.

The Nairn Moisture Detection Test—This test makes use of the reaction of calcium carbide with water to form acetylene with the liberation of considerable heat. To conduct this test samples of the subfloor are obtained in a finely powdered form by drilling into the concrete with a star drill. Drillings from the upper 1/4" of the subfloor are discarded. At every 1/4" thereafter of the upper 2" of concrete a sample of finely powdered concrete is collected. Material from the upper inch is kept separate from material from the second inch. Each sample is thoroughly mixed, and a measured portion of each is mixed thoroughly with an equal portion of calcium carbide in a glass calorimeter tube. Any moisture present in the concrete then reacts with the calcium carbide, heat is liberated, and the temperature rises. The temperature rise is noted using a maximum-type thermometer. If the difference between this temperature and the temperature of the subfloor is greater than 80^{o}F, the concrete is considered wet. This method is used to test suspended, on-grade and below-grade slabs. The advantages offered by this test are: 1) results are available immediately; and 2) the method yields a quantitative result which does not require a judgment on the part of the operator.

The Calcium Chloride Test—The use of anhydrous calcium chloride in moisture testing is an application of the well-known characteristic of this material to deliquesce in a moist atmosphere. The test is conducted as follows:

Drill a 1/2" diameter hole one-half to two-thirds of the way through the concrete slab and form a ring of putty at least 6" in diameter and 1/2" high around the hole. Place approximately a teaspoonful of anhydrous calcium chloride in a small glass dish within the putty ring. Cover the ring with a sheet of glass and press it down on the putty to form a seal. If the floor is wet, beads of moisture will appear on the small glass dish in from 24 to 48 hours, and the calcium chloride will be at least partially dissolved.

For the more moisture-susceptible types of resilient flooring, this test is not sufficiently sensitive. A variation of this test has been proposed which involves weighing the calcium chloride before and after exposure to determine moisture pick-up. This procedure undoubtedly improves the sensitivity of the test, provided the weighings are made with a high degree of accuracy. However, the calcium chloride test is likely to become obsolete.

The "Mat" Moisture Test—This test is based on the principle that a concrete slab which is dry enough to accept water from a water-containing adhesive, and permit the adhesive to dry, is dry enough to receive an installation of all but the most water-sensitive resilient floorings. It is used on both on-grade and below-grade slabs, as well as on suspended slabs on which the less moisture-sensitive products are to be used. The test is conducted by sealing a moisture barrier such as sheet vinyl flooring (face side down) over several patches of freshly applied linoleum paste on the surface of the concrete. After a period of 72 hours, the linoleum paste is inspected to determine whether or not it has dried. If the adhesive is still in a fluid condition, the subfloor is considered wet.

Relative Humidity Test—This test method is new to the resilient flooring industry. It is likely to be useful on suspended, on-grade and below-grade slabs, but is intended primarily as a reliable method for evaluating the moisture condition of suspended slabs, where moisture-sensitive products are to be installed.

If a small volume of air in contact with a concrete slab is isolated from the remainder of the air in the room, the moisture in this isolated air will soon be in equilibrium with the moisture in the slab. A measure of the relative humidity of the isolated air is a measure of the moisture content of the slab.

The test is conducted by placing a relative humidity indicator on the surface of the slab, and sealing it under a sheet of polyethylene. An equilibrium relative humidity reading may be obtained, even with slabs 12" thick, in 72 hours. On new suspended slabs which are in the process of drying, a relative humidity reading of 80% or below is considered "safe" for the installation of all products. Safe relative humidity readings for the less moisture-sensitive types of flooring have not yet been established.

The relative humidity meter can be checked for accuracy by placing it in a sealed polyethylene bag with a wet cloth. An accurate meter should read 100% in about four hours.

The Effect of Concrete Curing Compounds and Breaker Compounds on Adhesion

As a result of two of the advances which are constantly being made in building techniques, resilient flooring installers are encountering concrete slabs which have been treated with coating-type curing compounds or breaker compounds. These products are used to form a coating over the surface of the concrete. The function of curing compounds is to help retain sufficient water in the concrete to cure it properly, while the breaker compounds act as release agents in hydraulic lift construction. Individual products differ widely in composition, being based on a variety of materials such as resins, waxes, silicones, asphalts, etc. The question most frequently asked is, Will flooring adhesives bond to them? There is, as yet, no final answer to this question, since new products of these types are appearing on the market constantly. However, based on examination of a large number of them, it can be said that flooring adhesives of the linoleum paste and waterproof cement classes will not bond reliably to concrete slabs which are known to have such coatings on them. Asphaltic adhesives bond to all such coatings tested thus far in our laboratory. Latex adhesives appear to bond initially, but the long-range durability of such bonds has not been established.

It is almost certain that, in a building of any size, some of the concrete curing agent will be abraded during construction of the building. However, the degree to which this occurs is still a matter for speculation or, better, for careful investigation. Most flooring manufacturers today prefer to recommend more positive methods of removal. It is possible to make a simple test for the presence of these coatings by installing a resilient flooring such as rubber tile with linoleum paste and allowing the paste to dry for about four weeks. If, upon removal of the tile, the paste strips readily from the concrete, it is probable that a coating is present. The coating should be removed by sanding or grinding before installing any resilient flooring except asphalt tile or vinyl-asbestos tile with asphaltic adhesives.

Adhesives for Plastic Laminates

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The purpose of this paper is to help specifiers and users of adhesives for decorative plastic laminates to know what adhesives are available, what advantages and disadvantages they have, and how they should be applied. It will cover adhesives for several types of plastic surfacing materials.

One type of laminate is composed of several sheets of plastic with a surface sheet of a melamine resin used for its clarity, and a backing sheet of paper impregnated with a phenolic plastic. This unit is formed under high pressure and temperature, hence its name, high-pressure laminate. Because of its stiffness, a high-pressure laminate is usually furnished in flat sheet form. The other type of plastic surfacing material is the polyester type plastic, or low-pressure laminate, which usually comes rolled or coiled up. This paper will not discuss adhesives for soft plastics such as vinyl and polyethylene, as their requirements for adhesives are quite different.

Adhesives manufacturers have a real job to do in the education of specifiers and contractors in the use of the right adhesive on the proper surface in the best possible manner. An adhesive, like Swiss cheese in a sandwich, is always in the middle—everything depends upon it for proper performance. The adhesives manufacturer depends upon the specifier to select the right adhesive and upon the applicator to apply it correctly.

Types of Adhesives

The more than a half-dozen different adhesives used for bonding various plastic surfacing materials can be classified into two general types: thermoplastic (those which can be repeatedly softened with application of heat); and thermosetting (those which cure chemically to a state from which they will not soften on application of moderate heat). Table I gives some of the properties of the more popular adhesives in use today.

By way of explanation of the data in Table I, the popular contact adhesives are amber or cream colored, synthetic rubber cements with either a volatile, lacquer-type solvent base or a water base. There are three types of contact cements: regular semi-curing, solvent type with fair heat resistance; fast-drying, full-curing, solvent type with good heat resistance; and the water base type with fairly good heat resistance.

The contact adhesives are popular for in-shop use, and particularly for on-the-job applications where the plastic surfacing material is bonded in place in the building or

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TABLE I

Properties of Plastic Laminate Adhesives

Common Name	*	Base	Physical Form	Method of Bonding	Heat Resistance	Water Resistance	Advantages	Disadvantages
Contact Adhesive, Regular Type	T. P.	Neoprene Rubber Resin (semi-curing at room temperature)	Thin amber liquid	Cold** Contact Pressure	Fair (to 160°F)	Good	No mixing, presses or equipment needed; may be used on job.	Cannot slide into position; mediocre heat resistance; does not restrict movement of laminate.
Contact Adhesive, Fast-Dry Type (Military spec. MIL-A-21366 applies on aluminum.)***	T. P.	Neoprene Rubber Resin (full-curing at room temperature)	Thin amber or cream-colored liquid	Cold** Contact Pressure	Good (to 200°F)	Excellent (when cured)	Same, plus flexible, tough bond prevents warping of surface.	Cannot slide into position; does not restrict movement of laminate.
Contact Adhesive, Water Solvent Type	T. P.	Neoprene Rubber Resin (semi-curing at room temperature)	Thin white liquid	Cold** Contact Pressure	Fair to Good (when cured to 180°F)	Good	Same, plus noninflammable and no odor.	Same, plus slower drying rate.
White Glue	T. P.	Polyvinyl Acetate Resin	Thin white paste	Cold-Wet-High Pressure	Fair (to 150° F)	Poor to Fair	No mixing, fast setting, excellent adhesion to wood, nonflammable.	Pressing or clamping required; weakened by high humidity or water; softened by heat.

TABLE I (continued)

Common Name	*	Base	Physical Form	Method of Bonding	Heat Resistance	Water Resistance	Advantages	Disadvantages
Casein Glue	T. P.	Casein	Powder (mixed with water)	Cold-High Pressure (150 psi +)	Good (to 200°F)	Poor	Good adhesion to wood; lower cost; non-inflammable.	High clamping pressure needed; weakened by humidity and water; raises wood grain.
Urea Glue	T. S.	Urea Formaldehyde Resin in one of two forms:	Powder (mixed with water)	Cold or hot (to 220°F) Pressure	Excellent (over 250°F)	Good	Very strong rigid bond; fills gaps; can position panel.	Can cause warped panel; pressing or clamping needed.
			Liquid syrup plus powder catalyst	Same	Same	Good	Same plus faster setting	Same
Resorcinol Glue (Military Spec. MIL-A-297B, Class I)	T. S.	Resorcinol Resin	Syrup plus powder catalyst	Same (heat cures at lower temp. 150-180°F)	Good	Excellent	Very durable; moldproof; very waterproof; good for outdoor use.	Clamping required; very expensive.
Mastics	T. P.	Reclaimed or synthetic rubber-resin	Thick paste	Cold - must be braced 24 hours	Fair	Good	Good for walls and backsplashes.	Clamping or bracing required until set; only fair bond strength.

*T. P. — Thermoplastic
T. S. — Thermosetting

**Heat reactivation bonding may be used.

***Federal specification proposed.

Note: These are average properties. Any particular brand may exceed or fall below limits given.

home. This type of cement varies in properties from manufacturer to manufacturer, but generally has one feature common to all, that of bonding to itself on contact; hence the name, contact bond cement. While it is able to bond tenaciously to itself for a period of time after spreading, it does not stick to most other surfaces, allowing for proper indexing or positioning (using spacers) before bonding. Contact adhesive gives an instantaneous bond of quite high strength without the use of clamps or presses. This bond may improve in strength as some of these synthetic cements continue to cure at room temperature (after solvent has evaporated) for a period of weeks. Some fast-drying types have superior heat resistance because of this curing mechanism.

The water base contact cements usually are synthetic rubber emulsified in water. When dry, most of them have very good water resistance and excellent bonding properties. They are generally very easy to apply because of their somewhat creamy consistency. They have the advantage of being non-inflammable, and the disadvantage of requiring a longer drying period before bonding. These adhesives are white, but usually dry to a lighter, more transparent color than the regular or fast-drying contact cements.

Of the other thermoplastic adhesives used, such as the white glues and caseins, the white glue (polyvinyl acetate) seems to be popular with some table-top manufacturers because of its fast-setting properties when clamped. It has excellent adhesion to wood, is nonflammable, has poor to fair water resistance and mediocre heat resistance. The caseins are used where cost is held to a minimum and where no water is going to come in direct contact with the glue line. Caseins tend to allow the plastic to slide out of position when placed in a press, since they have little tack or stickiness. They may also raise the grain of plywood. Their bond strengths are relatively good, but they may have only fair adhesion to nonporous plastic surfaces. They require mixing of a powder with water, and pressure overnight.

The thermosetting or curing urea resin adhesives such as the urea formaldehyde types are used only in the shop because they require a press to hold materials in position at room temperature for a period of time (usually overnight) before setting occurs. A heated press (up to 220°F) may be used instead, to give sufficient heat to cure the resin adhesive faster. This type of adhesive may come as a powder (resin and catalyst) which is mixed with water, or as a powder (catalyst) and syrupy liquid (resin) which is mixed before application. It is used because of its strong rigid bond and good heat resistance.

Resorcinol resin glues (two parts—liquid and powder catalyst) are the Cadillacs of the trade. They are the strongest and most waterproof of the adhesives mentioned. However, they are very expensive and require mixing and clamping or pressing, as do the ureas. They are used for outdoor applications where the best water resistance is required.

Several types of mastics are used. A mastic may be defined as a thick, trowelable adhesive in this case. The rubber-resin base mastics are popular for bonding sink backsplashes. Mastics have also been used for some wall and ceiling applications, usually with shoring and bracing until the adhesive has set. A metal molding is usually used around the edges.

Application of Adhesives

The solvent base contact adhesives, although one-part products, usually require shaking or stirring just as the average household paint. While the settling or separation is often not great, it is most important to stir in the little bit of white powder that is found on the bottom of the can. If this is not done, an important part of some adhesives, namely, an agent which cures the rubber and resin and helps performance of the adhesive, is lost. Many manufacturers make several types of contact adhesives. One may have little or no curing agent and require little stirring, and does not become as strong. The other (fast-drying type) may contain a curing agent and require stirring. The latter is the stronger product which is often preferred by the professional.

For best results adhesives should be applied only to clean, dry, warm (above $60^{\circ}F$) surfaces, after removing all old adhesives and other foreign material. The adhesive has only as much strength as the surface to which it is bonded. Most contact cements may be used on wood, plastic, drywall, plaster and other surfaces. Only the fast-drying type should be used on metal.

Contact bond cements may be applied by spreading with a small metal trowel (Fig. 1), brushing with a paint brush, rolling with a hand paint-roller or mechanical roll-coater, or spraying with paint spray equipment. As usual, the application tool used depends upon the preference of the applicator and the job to be done. For large, flat surfaces, the trowel is fast, provides a very smooth film to give maximum contact, and spreads sufficient adhesive on porous plywood and particle board in one coat.

Figure 1. Trowel Application.

Figure 2. Spray gun application.

The brush is often popular for edges and small areas where a trowel is either impractical or too difficult to use. When wall surfaces are done, for example, the brush is one of the preferred methods. If a trowel is used, the adhesive will run down the wall. Two brush coats are usually required with fast-drying or regular cements on porous surfaces such as wood or drywall. The first coat must dry completely, and then the second coat is applied. It is most important to use enough adhesive. Water base contact cements have twice the percentage of solids, so only require one coat.

The paint roller is used with contact bond adhesives with long open times (slow-drying), so that the cross-rolling does not cause sticky peaks of adhesive to protrude from the surface. This technique works very well with water base products. On porous surfaces, such as plywood or drywall, several coats of the adhesive may be required with solvent base types. The first coat must dry until it is tack free, or the roller will stick to it on the second application. This can be determined by noting a change in color of the adhesive.

Spraying is popular for shop application of contact adhesives (Fig. 2). Usually, a spray booth is required to take away solvent vapors (unnecessary with water base). The adhesive may be kept in a pressure pot and applied with a conventional paint-spray gun; sometimes with a paint-type cup gun. The cup must be filled frequently, but it eliminates the need for a pressure pot. It is particularly important when spraying contact bond adhesives to use a very fine spray pattern, to achieve as smooth a film as possible. This smooth film is, of course, the objective of any device for spreading this type of adhesive. Smooth, straight passes should be used, in logical, progressive order from left to right and right to left, across the particle board or plywood until the entire surface is covered. Then adhesive should be sprayed at right angles to this, using the same procedure. This helps to eliminate spots having too little adhesive, and also provides an even film thickness. The back of the plastic should be sprayed in the same way, using less adhesive as this surface is not as porous and absorbent. After the adhesive has dried so that it has lost its glossy appearance but still has a tack, it is ready to assemble. Another way to tell when the adhesive is dry is to press a piece of heavy kraft paper firmly into the adhesive. If it doesn't tear the paper, the solvent has left the adhesive and is ready to bond.

Coverage with most solvent base contact cements is about 80 sq. ft. of finished decorative laminate per gallon of adhesive. Water base contact cements will do about 160 sq. ft. per gallon.

The drying time will vary with the weather and the method of application. If the temperature is cool and moist, it will require a longer period of time. A word of caution—on damp days, fast-drying cements may "blush" or condense moisture on the surface. This appears as a dull, misty film, and heat lamps or hot air blowers should be used to evaporate it before bonding. Most contact adhesives require about 20 minutes to dry and then can be bonded for at least another 60 minutes. Spraying makes the adhesive dry the fastest; the trowel coat usually dries the most slowly.

The next step is to place separators on top of the base surface to facilitate positioning of the laminate. For this purpose, 4" wide strips of plastic laminate, wood dowel rods or prices of heavy kraft paper may be used (Fig. 3). The spacers are placed at regular intervals along the counter. Then, the laminate is placed on top of the spacers and worked into position. About a 2" spread of mastic adhesive is useful at the mouldings (between top and backsplash) to give better contact, and also to facilitate the sliding action of the plastic into the moulding. This is applied before the contact cement in most cases. The laminate is then positioned and slid into place carefully.

The spacers are then removed (Fig. 4) and the laminate pressed down, working either from the center outward to each edge, or from one side outward. A rubber covered hand

Figure 3

Figure 4

roller (Fig. 5) not over 3" wide is used to secure contact between each square inch of the plastic and the base surface. Some mechanics beat the surface with a wood block and a hammer, but the roller is a better method.

Figure 5

Various finishing operations to fit the board properly come next, such as cutting and trimming of edges.

The excess adhesive is cleaned up with a suitable solvent. Most manufacturers make a solvent for this purpose. Care should be taken not to use one that will mar the surface of the plastic. Most of these solvents are inflammable so precautions must be exercised, as with contact cements.

The finished laminate must be kept out of the sun or heat for at least 24 hours, because trapped solvent vapors expand with heat and can cause a bubble or blister to appear. This may be repaired by heating the surface of the plastic with a flatiron set at about 250°F to reactivate the adhesive beneath and pressing it down while hot.

If the plastic laminate is incorrectly aligned and bonded, it may be removed by squirting the proper solvent into the glue line to soften the adhesive and permit removal of the plastic.

The contact adhesives available today are vastly superior to those of several years ago, in that they are much easier to apply in a very smooth film to obtain maximum contact and strength. They now have superior water resistance and heat resistance. This is particularly true of the curing fast-drying type and the new water base type. They hold seams and edges down better than ever before, making them an indispensable tool for bonding plastic laminates, particularly in on-the-job applications. There is, however, quite a variation in strength and performance properties between different manufacturers' products. Your best guarantee is to specify and use one made by a reputable manufacturer.

Polyvinyl acetate white glues are applied with a brush, trowel spreader or roll-coater to one surface. These dry very quickly, so assembly must be made soon after spreading the adhesive on each surface. The time varies with the product, but generally is within 10 minutes. They require some pressure in a press for at least an hour or two, and some may require overnight pressure, particularly if it is extremely cool and damp. They provide a bond as strong as the contact adhesives, but lose a portion of their strength under conditions of either humidity or heat. They are frequently used for edges where a small strip of plastic laminate is used on the front of the counter.

Casein comes as a powder which is mixed with water and applied with either trowel spreader, brush or roll-coater to base surface. It permits positioning and "waltzing" of the surface sheet. Caseins require pressure at least overnight, as the water must evaporate before this product gains its strength. They may be cleaned with water before setting. Low material cost makes them desirable, but they are not generally used because they:

1) Require clamping overnight
2) May raise wood grain of plywood
3) May induce warp in long, flat surfaces.

The curing-type adhesive such as the urea formaldehyde is used by many shops for in-shop application because of its good ultimate strength and high heat resistance. These adhesives generally have somewhat higher strength than most of the others. They are used primarily where the plastic is post-formed, or bent by heating and rolling the edges. They sometimes cause warped panels, particularly on heat bonding, and there is the problem of presses, heat and time. This usually results in higher cost per square foot of finished laminate. The curing type is popular with those preferring the post-formed sink top.

There are two forms of ureas. In one, the powder (containing resin and catalyst) must be mixed with water; in the other, the liquid urea formaldehyde resin is mixed with powder catalyst carefully in the same proportion as furnished. After mixing, it is strained through a screen to remove lumps. Ureas have a limited working life after mixing. In hot weather it may be necessary to cool the glue mix to slow up the set. This type of adhesive is spread with a trowel or brush on one or both surfaces. The plastic laminate may be positioned and indexed in contact with the adhesive before placing the entire assembly in a press and holding it under pressure overnight. This may be speeded up by using a hot press and giving it sufficient heat to speed the set. Many times this is done after the plastic is post-formed (in which a semi-cured, post-formed type plastic laminate is heated and bent to make coved backsplashes, round front edges, etc.). During the forming operation, the plastic is heated to 310°F-320°F so that it will bend and cure without cracking. The adhesive is then spread, and the bond is assembled and heated to 180°F-220°F for about 10 minutes. When the plastic and adhesive cure, the adhesive becomes fairly solid and holds the plastic

Figure 6. Application of mastics

securely. The urea adhesives will mar the surfaces of the plastics unless they are previously waxed or covered for protection. Care must be exercised to keep the adhesive off the surface of the plastic.

Resorcinol resin glues have two components, a syrupy liquid and a powder catalyst. These are mixed as with the ureas and are spread with a brush or trowel on both surfaces. They require clamping or pressing as do the ureas overnight at room temperature. They may be heat cured in a press at 180°F for fastest cure.

The mastics are usually applied with a spreader or small notched trowel on the base surface (Fig. 6). The laminate may be positioned by moving as desired, providing the adhesive is not too dry. One may bond with most mastics almost immediately after spreading the adhesive. Most of them require some amount of pressure for at least a few hours until the adhesive sets by solvent evaporation. They may be cleaned up with mineral spirits or special solvents. Some of these products are inflammable, so precautions should be taken, particularly where they are used in confined areas. For best results moldings should be used to hold the edges.

Most of this paper has related to sinks, counter tops, tables, etc. Plastic laminates and plastic surfacing materials are becoming increasingly popular for walls and ceilings, in kitchens, bathrooms, hallways and other areas of homes and commercial buildings. For this application, the adhesives industry is working to provide an adhesive that will be strong enough to hold the plastic sheet almost immediately, and yet allow it to be positioned and moved into place. Both the contact bond type and the mastic type have been used. The contact bond type permits little or no movement, once it has bonded. This is a disadvantage, but it can be overcome by various tricks of the trade such as the spacer idea mentioned previously. In some cases, the plastic is bonded to plywood or wallboard first, and then installed on the wall or ceiling.

The mastic adhesives are used particularly on ceilings where it is difficult to get the plastic placed exactly. Here, it is usually necessary to spread the mastic with a trowel either on the back of the plastic laminate, on the ceiling, or on both surfaces; allow a short waiting time before bonding; and roll securely to the surface. This is followed by bracing or shoring using padded boards to hold the laminate in position at least overnight. Again, moldings are used on the edges.

Summary

1) The two popular types of adhesives used today are the thermoplastic contact bond adhesives and the thermosetting urea formaldehydes. The contact bond type is popular for on-the-job (field) and shop applications where a costly investment in presses isn't practical. It is providing a very satisfactory bond. The ureas are used in some shops which can afford presses and equipment. This has a higher per square foot cost, but is most satisfactory with post-formed or bent plastic edges.

2) Mixing is important. While contact cements are one part mixes, it is best to stir them. It is especially important to proportion and mix the urea formaldehyde and resorcinol types carefully.

3) The contact adhesive should be spread in a generous, uniform layer to form a smooth, glossy film (which is dry and ready to bond when it loses its gloss). It is important to use enough adhesive!

4) With the solvent base contact cements, caution must be exercised because of their inflammability. The new water base contact cements should be used where flames or sparks cannot be extinguished.

5) It is necessary to roll the plastic carefully, getting contact pressure at every point with the contact types, and uniform high pressure with the ureas.

Open Forum Discussion

Moderator—D. Kenneth Sargent, Dean, School of Architecture, Syracuse University

Panel Members—Messrs. Carlson, Lauren, O'Hare and Schulte, and S. D. Kirsch, Development Manager, Adhesives and Chemicals Division, The Borden Chemical Company

D. J. Kelly, E. I. duPont de Nemours & Co.: Who issued the CS 181-52 specification referred to and how can a copy be obtained?

Mr. O'Hare: Actually, the specification was not issued by any government body. It is a specification that was formulated by the members of the adhesives industry, the Tile Contractors Association of America, the Tile Manufacturers Association, and other interested parties. It is a U. S. Department of Commerce approved Commercial Standard. I will be happy to see that you get a copy of it if you can't get one through any of the tile manufacturers.

Mr. O'Hare: Do you recommend bonding wallboards direct to masonry walls?

Mr. Lauren: It depends on where the masonry walls are. If they are basement walls below grade, I would say definitely not. The standard practice in the use of adhesives for the fastening of wallboards to masonry walls is to install furring strips to the masonry walls first, and then bond to the furring strips. That is the soundest practice either above grade or below grade. Even the cheapest forms of adhesives are reasonably costly, and the very cheapest ones should not be used at all for this purpose. Many masonry walls which might be considered for the installation of wall panels would be rough, coarse aggregate walls, such as cinder and cement blocks. The application of an adhesive to a surface like that runs into the same economic limitation as the application of a paint to such a surface. You use a good part of the organic material to fill the rough spots in the aggregate, and that is not an economical thing to do. The installation of furring strips, followed by bonding to the furring strips probably is the soundest and most economical method for installing wallboard on masonry walls.

A. C. King, Central Mortgage & Housing Corp.: The various types of adhesives were presented very fully. Would it be possible to give a list of commercial brands as examples of each type?

Mr. Schulte: I don't think it would be appropriate for me to list all the competitive products. If the individual wants to talk to me privately, I will be glad to talk to him about it.

W. S. Wieting, Perkins & Will: Are reports available that identify which concrete curing agents affect the resilient flooring cements?

Mr. Carlson: I am not aware of any reports available that identify products by their names. In our work with curing compounds we try to get hold of as many different products as possible, and we test them for our own information only, but we do not publish this information.

Mr. Sargent: I don't have a formal question, but I know there has been a question raised concerning cementing vinyl plastic to plaster and the difficulties encountered in humid, warm climates.

Mr. Kirsch: The installation of flexible vinyl wall coverings is quite a large industry and, although difficulties have arisen in very few applications, percentage-wise there have been occasions where fungus growth has caused some trouble. The only thing that I might caution about is that we try to eliminate the conditions which are most favorable toward promoting fungus growth. High humidity is always a bugaboo leading to fungus growth in conjunction, perhaps, with nutrient present on the adhesive interface; a slightly acid pH, perhaps in the neighborhood of 5 or 5-1/2; undisturbed incubation period; darkness; etc. These conditions all help to promote fungus growth and can lead to problems with the installation. Fungus, of course, will often weaken the adhesive bond by directly degrading the adhesive, or it may attack some of the backings used, such as flock, fabric, or paper. It can cause very unsightly staining, particularly when the growth is extensive. It produces some weird colors. I have seen a few of them that you would never attribute normally to a fungus attack, but the over-all surface has been very badly discolored. Conditions of the sort that promote fungus growth have to be eliminated if possible, or at least reduced by proper use of fungicides and proper backings. Many manufacturers have attempted to use backings that actually help promote fungus growth due to their moisture vapor transmission rates. A very low moisture vapor transmission rate in an interface will help promote fungus growth. These are some of the points that one has to be aware of when installing vinyl-backed wall coverings.

Howard E. Phillips, American Telephone & Telegraph Co.: With thin set organic adhesives, can ceramic tile be placed satisfactorily on subfloors of plywood or other wood materials?

Mr. O'Hare: Plywood can very definitely be used as a substrate in adhesive work. However, as I mentioned earlier, that floor must be protected from any springing because, if you do get deflection in the floor, you will either grind out the grout or crack the tile or break the adhesive bond. Something has to give, because your tile and adhesive are rigid and if the plywood bends, something will give. It can be used satisfactorily provided proper precautions are taken and proper preparation is made.

Unsigned question: 1) What are suitable adhesives for vinyl tiles which are not dimensionally stable? 2) How can it be determined, in advance, whether a vinyl tile is dimensionally stable?

Mr. Carlson: This problem of stability in vinyl tiles is an old one. Many of the products on the market obviously do shrink, and when they do so, there isn't much that can be done about it. The adhesives that have been used with this type of product simply have not been successful in restraining shrinkage in these products. As to ways of determining whether or not they will shrink, there are various accelerated aging tests. For example, you can measure the tile very accurately and then expose it to elevated temperatures of perhaps 158°F or more for a period of time, and then measure it again. Any tendency to shrink will certainly be brought out by this type of exposure. There are Federal Specifications covering vinyl tiles that describe a shrinkage test, but I can't tell you exactly what this test is.

H. R. Young, E. I. duPont de Nemours & Co.: One of the contact adhesives you mentioned develops heat resistance of about 200°F after aging for several weeks. Could this heat resistance be developed at once by post-curing or supplying additional heat at the time of lamination?

Mr. Schulte: Generally, yes. If you apply the right amount of heat and some pressure, you will obtain practically the same strength as you will by waiting about three weeks with materials held in a bond.

James A. Scott, Raybestos-Manhattan, Inc.: How much industry acceptance or tolerance would there be for a higher cost, higher performance wallboard adhesive other than those mentioned in your talk?

Mr. Lauren: In my opinion, using two-part epoxy adhesives to meet the adhesive requirements of most wall panels is almost like swatting a fly with a baseball bat. The two-part epoxy adhesives give a great deal higher adhesive performance than is required in wall panel installation. The demands of the situation are not great enough to justify the inconvenience and limited pot life characteristic of these adhesives. I can foresee possibilities in the installation of 1/4" thick asbestos-cement panels, which are quite heavy and which require a really high strength adhesive. That might justify the use of an epoxy adhesive, but gypsum panels, 1/4" plywood, or even rigid plastic laminate faced 1/4" plywood, or 3/8" or 1/2" plywood do not justify the use of this expensive and inconvenient-to-use adhesive for wall panel installation.

Mr. Scott: What would you suggest as a maximum acceptable price level for a wallboard adhesive per unit application?

Mr. Lauren: That's very hard to say. It depends on the nature of the panel you are working with, as well as other factors. Generally speaking, I think the cost of the adhesive should not exceed, at the maximum, about 10¢ per sq. ft. of wall surface, or about $3 to $5 a gallon. Actually, the only sensible way to look at it is in terms of the cost per unit of surface, either coated or adhered.

Mr. Scott: What are the accepted performance standards for wallboard adhesives?

Mr. Lauren: In general, the accepted performance criteria for adhesive performance are tensile, shear and peel strength and, except for cases of the use of thin, springy wall panels set in plywood, peel strength does not often enter into account. I can't give any definite, quantitative figures. The best thing the questioner can do is to refer to the applicable Dept. of Commerce specifications, and I would be very much surprised if those figures were definitely clarified even there.

Mr. O'Hare: The same situation exists in relation to gypsum wallboard adhesives used in the adhesive nail-on system. We have been trying to work out a standard specification for this adhesive, and also standard test methods. Committee work has now been going on for a period of almost three years and the results are still far from complete. Various manufacturers are unable to reproduce the same test results in their laboratories, using the same test methods and the same adhesives.

A. S. Best, Dept. of Commerce: Does the thickness of ceramic tile have any bearing on its successful application with thin set adhesives?

Mr. O'Hare: Within reasonable limits. For example, we've set quarry tile and ceramic mosaic floors with the same adhesive. However, due to the difference in the backup of the tile (that is, whether it has a ribbed back or combed or flat back) it will take more or less adhesive. In the case of some, you trowel the floor and also must butter the back of the tile. The heavy, deeply ribbed-back quarry tile really should not be used with thin set adhesive work. The tile manufacturers have made available flat back or combed back tiles for this purpose, but, basically, the same adhesives can be used. Of course, when you install some of the heavy marble tile, 1 or 1-1/2" thick, on a wall, you run into the possibility of physical injury in case of poor workmanship. If a piece of tile falls down and strikes someone, you're in trouble.

Howard Phillips, American Telephone & Telegraph Co.: What resilient floor coverings can be used on grade besides asphalt tile, where curing compounds have been used on the floor?

Mr. Carlson: If there are actually curing compounds still on the floor, and this should be established by the type of test that I described earlier, these curing compounds must be removed if you are going to install anything other than asphalt tile or vinyl-asbestos. This removal should be accomplished by sanding, grinding, or whatever means you have available to remove the top surface of the concrete. Once this is done, then any of the products ordinarily used on grade could be installed, including rubber tile, vinyl tile, certain sheet vinyl products with special backings, and, of course, asphalt or vinyl-asbestos. There are at least five different types of products that could be installed, but the curing compound should be removed before anything other than vinyl-asbestos or asphalt tile is installed.

J. A. Scott, Raybestos-Manhattan, Inc.: In the "white glue" category, how do the acrylic adhesives compare with the polyvinyl acetate type for plastic laminating?

Mr. Schulte: Acrylic adhesives are not being used for this purpose, to my knowledge. They are special products which have unique properties. They have ultraviolet resistance; they are colorless, clear products; they are plastic in nature, and are quite moisture sensitive. If you did use an acrylic for this purpose, chances are you would have poor water resistance. The water would tend to go through it and lift it. Also, they are definitely more expensive. They are, today, used as coatings and specialty materials. There are acrylic sealers for use where you want optical clarity. There are acrylic coatings where you want clear, colorless products. We have acrylic sealers, but generally they don't have the necessary adhesion and water resistance. The polyvinyl acetates are quite strong and they are water sensitive also, but I would say, less water sensitive than the acrylic and definitely much less expensive.

Arthur Tisch, Independent Nail & Packing Co.: Since box nails have been proven far more likely to "pop" than properly threaded nails, how can you justify their use in place of the threaded nail?

Mr. Lauren: I couldn't justify them, and I wouldn't recommend them. In reviewing this subject of gypsum drywall lamination, I referred to the existing literature of major suppliers of the gypsum panels. I must say that the recommendations in the literature available still do not conform to the consensus on proper nailing procedure included in NAS-NRC Pub. 830, Adhesives in Building, based on the BRI 1960 Spring Conference. Definitely, threaded nails should be used but, in order not to confuse the issue and introduce any non-standard commentary on nailing procedure, I made the decision just to mention the types of nailing recommended and currently available in gypsum drywall manufacturers' literature. I wouldn't be a bit surprised if the next issues of these will mention threaded nails, because the use of threaded nails seems to be general practice by an increasingly large number of conscientious contractors and applicators.

Harry H. Batchelor, Society of Residential Appraisers: In view of lack of accuracy by mechanics in applying plastic wall tiles, is it not best to fill in space between gypsum wallboard and bath tub with a good caulking compound?

Mr. O'Hare: This is very definitely recommended. The only problem is that some of the tile sealing or tubcrack sealing compounds do contain solvents that will affect the tiles.

G. Sierer, Prack & Prack, Architects: Have any difficulties been encountered in the adhesion of resilient flooring where used over the recently available cellular steel floor system, through the cells of which are delivered hot and cooled air? If problems have arisen, are there available adhesives which give satisfactory results?

Mr. Carlson: I take it that this question refers to floors of the type described which have a concrete layer over them. I am not acquainted with any problems that have developed as a result of installing resilient floors over this type of base.

L. P. Smith, Rubber and Plastics Age: Has any use been made in the U. S. A. of the foamed plastic "stick-pads" that have been developed in Sweden?

Mr. Schulte: I have heard of these, but I am not familiar with the subject. I haven't seen them used.

Mr. Lauren: If the question refers to polyurethane foam with a pressure-sensitive adhesive, our own company has done some work on this for specialized uses. I recently saw some samples consisting of a 3/16" fine cell foam with the pressure-sensitive adhesive backing, which seemed to be a very effective adhesive backing. Although the samples looked very good and looked as though they perform well, I don't believe that they have been accepted to any considerable extent in any installations in this country so far.

William C. Lend, Stran-Steel Corp.: What category of adhesives would you recommend for satisfactory application of wallboard to metal (steel) framing systems. What, if any, experience have you in this area?

Mr. Lauren: I have no personal experience with anything but mechanical fastening to hollow steel studs. There is a great deal of asbestos-cement panel fastening with spring-loaded devices of that nature. The gypsum drywall manufacturing industry recommends some definite implements and procedures using clips for the fastening of the gypsum panels to steel studs. Usually, these are laminated panel installations. In other words, the first layer is a clipped, mechanically fastened layer, and the second layer is cemented to the first and secured further by runners at the top and bottom. It would be quite possible to use a contact cement effectively, bearing in mind that the positioning problem has to be met with precision. A definite second choice, for my part, would be some type of mastic cement, although run-of-the-mill mastic cement might easily be found lacking in good adhesion to the metal as compared to the usual cellular surface over which it is applied. So, my first choice would be contact cement; second, a mastic cement if it is specifically recommended for that application by the manufacturer.

Unsigned question: Can plastic laminates be removed from plywood after being bonded with contact adhesives or urea glues?

Mr. Schulte: Yes. Contact adhesives can be removed. I assume that this means that, when the plastic was put in position, they made a mistake and had to remove it, or later wanted to replace the top and had to remove the plastic. This is done by using the proper solvent, which is usually the one produced by the adhesives manufacturer. It is put in little squirt guns, like an oiler gun or plastic squeeze bottle. You pry the edge loose and squirt the solvent under the plastic. Gradually, the plastic will work loose due to the dissolving of the adhesive. Another way is to apply heat, but this is dangerous because, after the fast-drying adhesive has been there a while, you may scorch the plastic in bringing the temperature up sufficiently high to remove it.

As to the ureas, I know of no way to get them loose because, if you apply enough heat, you will scorch the plastic, and it would be difficult to get a solvent which would remove them effectively.

F. R. Olson, Carlisle Corp.: What type of waterproof membrane, if any, do you recommend for installation of tile below grade?

Mr. Carlson: I don't necessarily recommend any type, but I think it's wise with any slab in contact with the ground, whether it's on grade or below grade, to use such a membrane. This is good insurance against moisture problems, and I would encourage its use. Of the types that are used, the polyethylene film is one of the most common. There are also sheet rubber and butyl rubber films available for this purpose, but they are somewhat more expensive than the polyethylenes. Quite often 55-lb. roofing felt or something of that sort, properly sealed with asphalt, can be used. However, the long-term durability of the polyethylene or the rubber is probably to be preferred.

A. C. King, Central Mortgage & Housing Corp.: White contact adhesives recommended by suppliers for gluing 1/16" plastic laminate to plywood work-table tops frequently de-laminate upon fully drying and curing. Is this likely to be due to lack of sealer on the plywood, to insufficient adhesive, or other causes?

Mr. Schulte: I am going to assume this question refers to contact cement, rather than white glue. If it comes loose, this could be due to a number of reasons. The usual one is that they didn't put on enough adhesive and it soaked in. One thick brush coat on plywood is not enough. You must let that dry and then put on another coat to have sufficient adhesive. The adhesive has to contact itself on the plastic, or else you don't have a bond.

The second cause is just the reverse of this. The workmen put so much adhesive on, and they didn't let it dry before they put it together. A very typical thing I've seen done in a warm climate, is to put them together, trap the solvent in, and then put them up on a truck, out in the hot sun and a big blister will show up. Fortunately, with contact cement this can be repaired usually by the application of heat and pressure. It can actually be ironed down, if it's done carefully and if there is enough adhesive.

The only other reason I can think of for its coming loose is that either they exceeded the temperature limits, put something very hot on it, or they didn't get a bond in the first place, by allowing it to dry too long. This is a good point; we call it tack and bond range. After the contact cement is dry to the touch so that you can bond it, then usually you have a period of about two hours to work with. This will vary with some products. In Los Angeles, for example, they only have 30 or 35 minutes on a dry day.

With the polyvinyl acetates generally it's a matter of the amount of glue. You have to put a fair amount on and they vary in solids, depending upon the product. The adhesive might soak in too much, and thus not bond, or you may disturb the bond before you clamp it, or remove the clamps too soon and disturb it before it sets.

Unsigned question: What can be done to eliminate or materially reduce failures in the field caused by mold growth?

Mr. Kirsch: An attempt to eliminate moisture being trapped behind the wall covering at the adhesive interface is one important step. The proper use of fungicides, both in the adhesive and in the laminate wall covering itself, will help. In other words, one should attempt to cut down on the nutrient available for the mold growth, by proper preparation of the wall surface. Often an alkali wash is used to help in getting the pH to a point that is not conducive to mold growth. I believe these are the most important factors in removing conditions which are favorable for mold growth, and thus avoiding it.

Adhesives for Acoustical Tile

By Francis S. Branin,* President
Asco Products Corporation

It is difficult to determine the exact beginning of the use of adhesives for the application of acoustical materials to inside walls and ceilings, but it might be noted that it has been general practice since the early 1930's. At that time, most common acoustical materials were produced from organic fibers, and the adhesives so developed as to be compatible both with the substrate and the adherend. However, as general building design practices and material compositions developed further, new adhesives became necessary.

Manufacturers of adhesives and/or acoustical materials, working with representatives of the U. S. Department of Commerce, recognized the growth of the acoustical industry, and therefore sought through means of an established nongovernmental agency an approach to some minimum standards by which architects and builders could obtain satisfactory application methods and performance standards for finished installations. The American Society for Testing and Materials was consulted, and it assigned the development to task forces in Committees D-14 on Adhesives and C-20 on Acoustical Materials.

The preamble of the draft of a proposed tentative specification for an adhesive to attach acoustical materials (tiles) to ceiling substrates, walls, etc., as submitted by the Subcommittee of Committee D-14 to the American Society for Testing and Materials reads:

> "The adhesive described.... is intended to bond prefabricated acoustical materials to the inside walls and ceilings of rooms in buildings. This adhesive is not required to have high bond strength, but it is required to maintain adhesion for a long period of time under the temperature and moisture conditions likely to be encountered and to maintain sufficient plasticity to adjust for movement of parts of the building as it ages."

Under the paragraph, "Scope in the Tentative Specification for Adhesive for Acoustical Materials," adopted and published in 1960 (ASTM Designation D1779-60T) a portion of the foregoing was amended to read: "This adhesive is required to maintain a tensile adhesion (bond strength) of not less than one half pound per square foot for a long period of time..."

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The Federal Specification MMM-A-00150 published in 1953 through the General Services Administration as an interim specification is, as indicated, a tentative document to be used as an optional guide. As such, this specification appears to be the first attempt to coordinate the recommendations of the adhesives manufacturers, and to establish a foundation and guide for minimum control of the existing products and the application of organic fibrous acoustical materials. The vast operations of the Federal Government provide a sizable market for the use of acoustical materials; hence, the recognized need by it for a guide for its agencies in the procurement of materials for new and renovation projects.

The need for adherence to these specifications as a guide cannot be overemphasized. By their very concept they represent, to a degree, the sophisticated thinking of an industry. It is true that the standards presuppose certain conditions to exist as a prerequisite; however, these are generally qualified by the test procedures described therein, and of course these premises do not preclude the faulty judgment, poor workmanship and/or uninformed supervision which so often spoil a well developed job. As one tile adhesive manufacturer says in his published handbook, quoting Julius Caesar so aptly, "We are all at the mercy of a falling tile."

Let us look at some of the requirements, i.e., Number One: "To attach acoustical materials to inside walls and ceilings." For the substrate to comply with this requirement it must be "clean, sound, and dry." This is stated simply and forthrightly. Of course, there are widespread conditions of acceptance implied to achieve this ultimate state. There are many good precautions described in Note 1 of the ASTM specification, and in all adhesives manufacturer's literature, but the underlying reason for this simple statement is to afford a substrate which can be wetted by the adhesive and which will structurally support the added weight of the acoustical tile and the adhesive under static loading.

Acoustical adhesive is essentially nonstructural and is used primarily to support acoustical tile in cleavage; however, for ceiling as well as wall installation, peel and shear stresses are also involved. Because, in practice, it has been found that the unevenness of the substrate dictates the necessity for the adhesive also to serve as a leveling or bedding compound, it therefore becomes a construction material.

Application of the adhesive to both adherend and substrate requires positive wetting in each instance of contact. This contact, once made and set, should not be disturbed through movement which would cause cleavage. Acoustical adhesives of this type are considered to have a lower elastic modulus than the materials to which they bond; therefore, cohesive failure is likely to occur through rupture of the matrix, rather than at the properly wetted glue line. Of course, under tension tests, this is the condition of determining whether proper wetting was obtained, and therefore is favorable. It certainly is a definite indication, at maximum stress, whether or not the adhesive is suitable for this type of application.

This leads up to the next statement: "The adhesive is required to maintain a tension adhesion of not less than one half pound per square foot for a long period of time."

The implication here is that the adhesive per se does accomplish a construction feat, because the recommendation is that four spots of adhesive, properly applied to a 12" x 12" acoustical tile, should cover a rather minimum face (15%) surface, and yet support

Figure 1. Four pats of adhesive properly placed.

Figure 2. Initial contact with prepared substrate.

Figure 3. Pressure and slide from opposite or adjacent quadrant.

Figure 4. Final slide into place.

Figure 5. Final adjustment by hand pressure for leveling and setting.

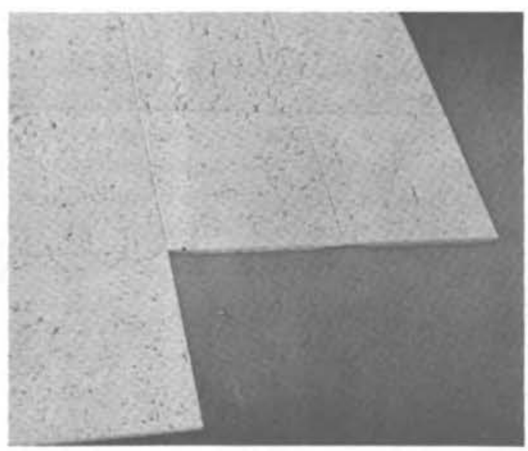

Figure 6. Completed operation.

under stress up to a 2-1/2 pound load. Where level and even substrates do not require the adhesive to be used as a bedding and leveling substance, a strictly bonding-type adhesive may be substituted. Application to the substrate may be accomplished by brush or trowel, adhering the acoustical substance much as in floor tile or wallboard application, perhaps involving only light stapling while the adhesive sets or cures.

The requirement that adhesion must be maintained "for a long period of time" is by no means clearly defined; this phrase could literally be taken to mean for the life of the building. We must assume that, as the standard relates, it is not necessarily meant to reflect aging on an absolute basis.

As an example, one of our large government office buildings, which undergoes periodic sectional renovation, attests to the complete and satisfactory service of acoustical tile applied by adhesive means over a 12 to 15 year span. An observation of the removal of tile during renovation demonstrated the excellent long life-expectancy which can be achieved by our present acoustical adhesives. In this case, removal of tile necessitated actually tearing or breaking away the tile from the adhesive pat, then cutting the balance away from its glue line on the undersurface or substrate. This left adhesive films which actually presented no problem in adhering the new surface finish. As a matter of fact, they acted, in a sense, as a primer, because they were still sound.

This example is mentioned simply to point out that a properly formulated adhesive did not throw off its plasticiser in the aging process, which is as it should be. Ceiling temperatures, over a long period of time, did not dry out the acoustical adhesive nor cause it to harden, shrink, or (as a result) break the bond. An installation holding well over a long period of time, and which gives no evidence of corners leeting down, speaks well for the wetting and workmanship which went into the initial placement of the tile.

If a break in bond occurs on the tile surface, this is due to not wetting the surface properly. This can occur readily in several different types of tile made from different substances. Ideally, tile surfaces should be as impervious to moisture as possible. A bond fault is easily prevented, and can be tested at the very start of the job simply by applying a couple of pats of adhesive in the usual fashion, and turning the tile upside down over a protected floor for a few minutes. If the pats release, you can be sure that the surface of the tile is at fault, in that it is of a drier texture, not easily wetted. It will then require some working in of the pat, or a blade smear under pressure, to prime the surface. A fair proportion of bonding is accomplished by a mechanical keying action. Therefore, application to the ceiling or wall should be accomplished by a reciprocal movement—forward, back and then into place, keeping pressure against the tile equally distributed, and finally bringing the tile to a level position in place by the final slide. (See Figs. 1 through 6.)

If the tile should release from the properly prepared substrate at all four adhesive locations, you may be sure that something is preventing adhesion, and the first thing to look for is moisture. A moisture tester is a desirable instrument to have available as an accessory, or the calcium chloride watchglass apparatus should be installed for a check.

No job should be started by a competent contractor without first making a few simple tests on the ceiling, including observations for other factors of which he should be aware, and which are mentioned either on labels or in the adhesive manufacturer's literature.

Although the brands of adhesives for acoustical tile are of the same general characteristics, each manufacturer is responsible for his formulation, and as such, writes his own instructions and gives his own warranties as to its compliance with the Federal Standards and ASTM Specifications. It is strongly urged that the user consult these data to avoid making errors in judgment or application.

We have all heard the excuse, when confronted by a failure: "Well, I used my best applicator on this job, and he's been putting up tile for 15 years." This means that the best applicator is the fellow who installs the largest area per day and doesn't need to read instructions, rather than the skilled worker who pays strict attention to directions and to whose job the boss doesn't have to return.

As to the future, almost monthly we see new developments in the decorative acoustical materials industry. There is a different trend arising in the preparation of ceiling and wall subsurfaces, and along with the new trends, there are complex material compositions which will form these substrates. Fire-resistant materials and new methods of construction are being more highly stressed in commercial, public and industrial buildings. This trend will spread to the residential building industry as economics prove its worth. In each of these areas, adhesive-applied acoustical materials will play a big part. Where formerly one type of adhesive was generally sufficient, in the future additional types will be required. Already, one manufacturer catering to the semi-finished gypsum board market, has added a brush-on type for decorative tile.

It was shown recently that a suspended ceiling of gypsum board with adhesive-applied acoustical tile was instrumental in protecting steel beams during a fire by preventing them from buckling. Also, this type of suspended ceiling has prevented breathing, and consequently adds to the utility of the decorative surface, as well as reducing maintenance and replacement or renovation costs.

When acoustical tile ceilings are applied by adhesive against a firm surface, the decorative face may be easily cleaned and repainted by brush, spray, or roller process without harm to the tiles, because the joints are matched and the surface generally level. The first draft of an acoustical repainting standard is at present being considered by Subcommittee III of ASTM Committee C-20.

It is our opinion that more architects and builders are becoming adhesive-conscious. Consequently, the percentage of use of this method for applying acoustical materials will increase. And, as we are able to educate users and supervisors in the fundamentals of its application and use, more satisfactory results will be obtained.

Adhesives for Thermal Insulation

By Wayne P. Ellis,* Director of Research,
Benjamin Foster Company

Introduction

The use of adhesives for the attachment of thermal insulation in building construction goes back at least to the early part of this century when hot asphalt was used to fasten corkboard insulation in cold storage warehouses. While both of these materials are still in use, they have been followed by many other useful adhesives and insulation materials. Adhesives are used for the attachment of thermal insulation in several fields, but the scope of this paper is limited to a description of those materials useful in building construction.

There are at least 12 different types of thermal insulations used with adhesives. Within these 12 there are several variations in composition and physical properties affecting the choice of adhesive. There are also innumerable adhesives offered for use with thermal insulation. Confronted by this "jungle" of materials, it becomes difficult for the architect or engineer to choose the proper insulation and adhesive.

Selection of Proper Adhesive

Fortunately, informative data newly published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers in the 1961 ASHRAE Guide in the chapter "Thermal Insulation and Vapor Barriers" are very helpful in selecting thermal insulation.

Unfortunately, few data of an unbiased nature concerning insulation adhesives have been published. To help fill this void and to aid in the selection of such adhesives, the following criteria should be used to govern selection of proper insulation adhesives.

Design Criteria

1) Nature of insulation and other surfaces to be bonded—the compatibility and affinity of adhesives for the specified insulation and for the other surfaces to be bonded are of major importance. The porosity and surface roughness of insulation affect selection of the type of adhesive to be used. The effect of the adhesive upon the insulation material cannot be disregarded, since some plastic foam materials are attacked by solvents used in adhesives. Conversely, strongly alkaline surfaces may cause deterioration of some types of adhesives. Adhesives must not be corrosive to metals.

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2) Strength and durability desired—In general, high strength is not required of insulation adhesives because of the low density and loosely bound construction of many insulations. For these, it is only necessary that the strength of the adhesive exceed by a safe margin the cohesive value of the insulation itself. For insulation materials of higher density and integrity, it is obvious that the adhesive selected must be designed to carry the required load plus an ample safety factor. Since a performance life of many years is expected from insulation adhesives in building service, the bond must resist deterioration from aging influences, such as exposure in thin films to atmospheric oxidation, heat and humidity. Adhesives used with insulation in dual temperature service, such as on air-conditioning ducts and in roof and wall construction, must withstand temperature changes resulting from climate variations or operating conditions. These changes generally are more harmful than continuous exposure to steady temperatures.

3) Limiting temperatures in service—Listed service temperature limitations of the adhesive must be observed. Temperature limits are set by the adhesives manufacturer, depending upon composition, laboratory evaluation and field experience. Although some adhesives may withstand extreme temperatures for short times, the careful manufacturer establishes conservative limits based on long time tests and experience.

4) Fire hazard properties—Consideration of the fire hazard properties of adhesives for insulation deserves serious attention. A prime fire hazard exists when adhesives containing volatile flammable solvents are used in building construction. This statement seems axiomatic, yet failure to protect against this hazard has led to serious fires which involved loss of life, property damage and construction delays. For maximum fire safety only nonflammable adhesives should be used to attach insulation materials. In construction areas where welding and burning are in progress, or during winter construction when temporary heating devices may provide an ignition source, flammable solvent vapors should not be tolerated.

   Also of importance is the specification of adhesives which are fire-resistive in service. The use of combustible adhesives, especially in connection with insulation on air conditioning ducts and in piping stacks or chases, should be prevented. Such adhesives could cause spread of fire from an area initially exposed to other locations through concealed or inaccessible spaces. The nature of this hazard has been recognized by the National Fire Protection Association in its Standard No. 90A, which covers safe practices in the installation of air conditioning and ventilating systems. The General Services Administration, Public Buildings Service, likewise has recognized this hazard in its Standard Specification for Nonconducting Covering, which now requires that all insulation materials and accessories used for refrigerating and air conditioning equipment and ducts, as well as for air heating and ventilating, "will have a fire hazard rating not to exceed 25 for flame spread and 50 for fuel contributed or smoke developed."

   It is expected that such restrictions on the fire hazards presented by insulation adhesives and other accessories will appear more frequently in building codes, state and city ordinances in the near future. Fortunately, insulation adhesives which are nonflammable and fire-resistive are available when specified, although they are sometimes more costly than the hazardous types.

5) Dual functions—It is often necessary or desirable that insulation adhesives perform dual functions. For example, the adhesives used for applying canvas lagging to pipe insulation are required not only to cement the lap of the cloth but also to seal and size the canvas in preparation for painting. Another example is in the attachment of vapor barrier jackets, where it is necessary that the adhesive hold the jacket laps securely and, at the same time, have a low water vapor transmission rate to prevent ingress of water vapor to cold piping and ducts.

6) Methods of application—In some instances, the permissible method of application will influence the type of adhesive selected. Most varieties of insulation adhesives are available in different viscosities for application by brush, roller, spray, trowel or palming.

7) Curing conditions—The curing conditions which exist on the job also may affect the selection of a suitable insulation adhesive. Extremes of temperature during application will affect the method and rate of application, as well as the rate of cure. Where building operations must proceed in extreme cold or heat, it is usually necessary to specify a special viscosity adhesive, or to permit modification of the standard types to meet these conditions.

8) Economy—Economy is always of interest in selecting the proper insulation adhesive. However, since the cost of adhesive ordinarily is low in relation to both the labor cost for application and the finished cost of the building unit, it is most economical to specify the best adhesive available which meets all of the design criteria.

9) Minor considerations—Other considerations, usually minor, may at times affect the selection of the insulation adhesive. These include such factors as color, odor, toxicity; resistance to weather, water and chemicals; hardness or flexibility; potlife and storage stability.

Intelligent selection of the proper insulation adhesive, therefore, depends upon a correct understanding of the application and service requirements. As with the choice of any engineering material, these design criteria should always be brought to the attention of the adhesives manufacturer when requesting a product recommendation. Casual choice of an adhesive is often unfortunate and is also unnecessary, since most manufacturers have readily available factual data about the performance of their adhesives under specific conditions.

Types of Thermal Insulation and Uses

For convenience in considering insulation and adhesives, building applications are classified as follows:

1) Roof and wall insulation
2) Hot piping, ducts and equipment insulation
3) Cold piping, air conditioning ducts, and equipment insulation
4) Cold storage insulation.

Table I lists the commonly used thermal insulation materials according to this scheme, which is necessarily general, and should not be considered as limiting.

TABLE I

Principal Thermal Insulation Materials Used in Building Applications

Insulation Type	Roof and Wall	Hot Piping, Ducts and Equipment	Cold Piping, Air conditioning Ducts and Equipment	Cold Storage
Calcium Silicate 85% Magnesia Molded Asbestos		X		
Fibrous Glass Mineral Wool	X	X	X	X
Cellular Glass Cellular Plastics	X		X	X

Types of Insulation Adhesives and Uses

The adhesives used with insulations are not different in composition from the broad variety used in other forms of building construction. Table II shows the composition and uses in the building applications previously listed.

TABLE II

Adhesives for Thermal Insulation—Composition and Uses

Composition	Insulation Lagging	Insulation Bonding	Facing and Jacket
A. Water Base			
Polyvinyl Acetate	X		
Starch (Wheat Paste)	X		
Asphalt Emulsion		X	
Reclaim Rubber		X	
Latex-cement		X	
Portland Cement		X	
Sodium Silicate		X	
B. Solvent Base			
Rubber Resin		X	X
Reclaim Rubber		X	X
Resin		X	
Asphalt		X	X
C. Hot Melt			
Asphalt		X	
Wax		X	
D. Convertible			
Epoxy		X	

Adhesive uses fall into three main categories: insulation lagging, insulation bonding, and insulation facing and jacketing. The term, lagging, as commonly understood in the insulation trade, refers to the application of a cotton fabric jacket on insulated piping. Until about 15 years ago most lagging was applied with a sewed seam. Wartime construction, however, required increased speed of application, and lagging adhesives were developed which eliminated the need for sewing. Today practically all lagging is applied with adhesive. Such adhesives also serve to size and seal the fabric covering, prior to painting.

The term, insulation bonding, is used to describe the attachment of insulation to rigid structures (piping, ducts, tanks and vessels) and for the lamination or preassembly of portable insulation units, such as for valves and pipe fittings.

Certain sheet materials often are attached with adhesives to thermal insulation for protection from damage, or for weatherproofing, vapor sealing, or to reduce fire hazard. These materials are described as facings or jackets, and consist usually of laminations of aluminum foil and treated papers or felts. Plastic films also are used for insulation facing.

TABLE III

Adhesives for Thermal Insulation—Types in Common Use

Application	Roof and Wall	Hot Piping, Ducts and Equipment	Cold Piping, Air conditioning Ducts and Equipment	Cold Storage
Insulation Lagging		Polyvinyl Acetate Starch	Polyvinyl Acetate	
Insulation Bonding	Asphalt (hot or cold) Epoxy Rubber	Sodium Silicate	Rubber/Resin Rubber/Asphalt	Asphalt (hot or cold) (nonsolvent) Latex-Cement Portland Cement
Facing and Jacket		Rubber/Resin	Rubber/Resin Rubber/Asphalt Asphalt (solvent)	

Table III lists the general uses and composition of insulation adhesives according to the type of building service.

Current Practice in Selection of Adhesives

As can be seen from Table III, many kinds of adhesives are used with thermal insulation. The most suitable types currently in use are described below.

For insulation lagging over all types of insulation, the most popular, serviceable and economical adhesives are compounded from water emulsions of polyvinyl acetate. The use of PVA adhesives for both lap-sealing and sizing of canvas jackets provides a nonflammable finish which is strong, tight, light in color, sanitary, and an ideal base for painting or color coding. To carry this concept one step further, insulation coatings are now available in attractive colors which are suitable for lap adhesive, sizing and coating in a single product. The use of wheat paste adhesive is declining because of bond failures in the presence of water, steam leaks and high humidity.

Insulation bonding on roofs is often done with hot asphalt. However, since the fire at the General Motors Livonia plant, in which dripping asphalt adhesive and vapor barrier contributed to the conflagration, fire-resistive or nondripping adhesives are specified when a large roof area is insulated. Asphalt emulsion or solution adhesives are commonly used for attaching fibrous glass, mineral wool, corkboard and cellular plastic insulation materials in ceiling and sidewall construction. Where high temperature adhesive is specified, epoxy or phenolic modified elastomer adhesives should be used.

For hot piping and hot air duct insulation, mechanical fasteners ordinarily are used because this method is more economical than special high temperature-resistant adhesive attachment. Alternate forms of fastening insulation materials, such as mechanical methods of attachment are also used at times. These methods include wires and bands of metal for holding insulation on piping and cylindrical vessels, as well as welded pins or clips for holding insulation on large ducts or other extensive flat areas. A combination of adhesive and mechanical fastening is sometimes used, involving adhesive attachment of flat perforated-base metal or plastic hangers to the primary surface. Insulation is then impaled over the pin or prong, and secured in place by bending the prong or applying a flat retaining washer. (Fig. 1).

The most widely used insulation for air conditioning ducts is low density fibrous glass in the form of flexible mats or blankets. Attachment is readily accomplished by brush-coating the metal duct with quick-drying, rubber/resin/solvent-type adhesive. When higher density insulation is used for duct work, thicker mastic-type adhesives are required, and these may be compounded from reclaimed rubber, asphalts and/or resins. When bonded hangers are used, the metal-base type is applied with a trowel-consistency rubber cement and the plastic-base type is attached with a semi-fluid synthetic cement, usually made from neoprene rubber.

Selection of adhesives for installing insulation in cold storage rooms requires exclusion of any materials which would contribute odor- or taste-contamination to stored foodstuffs. This usually precludes the use of any adhesive which contains a volatile solvent. Therefore, hot asphalt or asphalt/wax adhesives are used, as are asphalt emulsions, latex-cement adhesives and portland cement. A good water vapor barrier is required on the warm side of cold storage insulation, and it is advantageous if this property can be included in an otherwise suitable adhesive.

For insulating cold or dual-temperature piping and air conditioning ducts, the insulation usually is supplied with a vapor barrier jacket, and is applied to the pipe by cementing the flap of the longitudinal joint. Wide strips of the jacket material are cemented around the butt joints. For this purpose the resin/rubber/solvent-type adhesives are the most popular and economical. However, the higher viscosity mastic-type insures a bond with

Figure 1. Insulation impaled on hangers attached to corrugated sheet with adhesive.

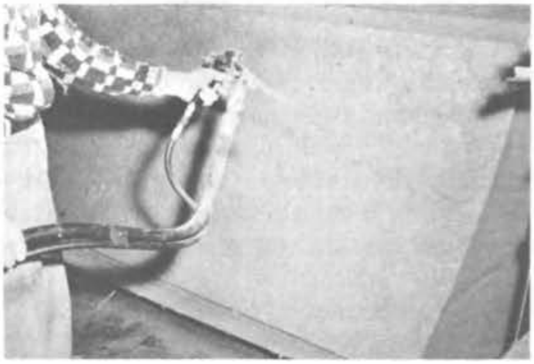

Figure 2. Spray equipment used to apply adhesive to fibrous glass insulation for air conditioning ducts.

Figure 3. Pointing trowel used to apply adhesive on small insulation job.

Figure 4. Gob application of adhesive on polystyrene foam for cooler-room insulation.

Figure 5. Push-box application of adhesive on cellular glass insulation.

Figure 6. Bare-hand application of mastic adhesive on polyurethane foam pipe covering.

(Photos courtesy of: Benjamin Foster Co., Miracle Adhesives Corp., Union Asbestos Co.)

better water vapor resistance. Where flexible cellular plastic insulation is used on pipe and tubing, the slit joint is bonded with quick-setting rubber/resin adhesives.

Application of Adhesives

The application of insulation adhesives may be done by conventional techniques. No unusual tools are required since the paint brush, roller and spray gun, as well as the broad trowel or pointing trowel, are well known to the building trades.

Figures 2 through 6 illustrate methods of field and shop application of insulation adhesives. No special surface preparation is normally required. Surfaces to be bonded must usually be dry and reasonably clean. Very porous or dusty surfaces may require a primer coating; this will be noted by the adhesives manufacturer.

Summary

Adhesives are available for the installation or attachment of all forms of thermal insulation. While it would be absurd to state that the choice of the insulation material should depend upon the adhesive to be used, it is important that the adhesive chosen be suitable not only for the service intended, but for the type of insulation specified. The choice of adhesive should be based upon successful experience, as well as on engineering data available from the manufacturer. To insure successful installation, it is necessary that the application instructions furnished by the manufacturer be followed in detail.

In conclusion, it is wise to emphasize that the method of attaching thermal insulation is only one element in the design of an insulation system. The other two equally important elements of the system are the insulation itself, and the surface finish. All three elements must be considered together in design, if a successful, serviceable installation is to result.

New Adhesives and Their Field Application

By Jerome L. Been,* Vice President
Rubber and Asbestos Corporation

For thousands of years, the building industry has assembled the bulk of its major structures in the field with an adhesive. This is undoubtedly the largest single adhesive usage in our world. If this adhesive were to be characterized in modern terms as an inorganic, filled, thixotropic, long-pot-life, two-part, room-temperature-setting, void-filling, nonflammable, 100%-reactive paste adhesive, there are probably quite a few people who would hesitate before considering its use, but if we call it by its more common name of mortar, whether based on portland cement, lime or gypsum, we will all recognize this as an adhesive of major commercial significance.

There are available today other and more recently developed room-temperature-setting, void-filling, 100%-reactive paste adhesives, based on synthetic organic resin and rubbery ingredients. There are many organic chemical systems to choose from in this relatively new adhesive technology. We chemists call them epoxy, polysulfide, phenolic, furane, polyurethane, etc., and they include combinations and mixtures of these types. Their properties as adhesives are in many ways far superior to those of portland cement and mortars. Their application characteristics are quire similar, i.e., they have to be proportioned and mixed, with attention to ratio and temperature, used within a known time limit, and applied with specialized tools by fairly skilled labor.

These new adhesives merit attention because of their unusually high strengths, their versatility of specific adhesion, and their proven stability in service under severe environmental conditions.

A cured epoxy resin, such as would be used in adhesive formulation, would far outperform mortar as a structural material, as well as an adhesive. For example, ultimate compressive strength is 19,000 psi for the epoxy versus 3,000 psi for Type M mortar; shear and tensile are about 13,000 psi for the epoxy versus about 300 psi for the mortar. The impact strength of an epoxy would be 0.5 psi and the flexural strength 20,000 psi. With epoxy adhesives, tensile shear strengths of 4,000-5,000 psi and flatwise tensile strengths of 8,000-10,000 psi are readily attainable in metal-to-metal joints. The tensile bond strengths of mortars, on the other hand, may be from 75-250 psi.

Note that the order of magnitude of strengths of these resinous adhesives is far, far greater than the inherent strength of many of the components of standard buildings, particularly wood and inorganic components such as brick and concrete block. Where these materials have to be bonded, there is plenty of leeway for modifying and extending

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the inherently too-strong organic adhesive, in the interest of economy or of special application characteristics. However, their ability to bond to glass, metal and other nonporous and basically stronger materials, stimulates their use in applications where the full range of available strength characteristics of these adhesives is put to the test.

These new resinous mortars can be used as binders and as bonding agents. The binder applications, in road and floor surfacing, terrazzo, etc., are now being used on an increasing scale, and are being adapted to conventional construction industry equipment.

A "resinous mortar" is made up of resin, catalyst and sand. The basic compounding of an epoxy mortar is similar to that of an inorganic mortar. The resin serves as a binder, and is compounded with flexibilizers and extenders such as sand. A hardener is added so that the resin will set at a reasonable room temperature in a reasonable time.

Epoxy materials can be mixed in equipment familiar to all of you, such as cement mixers, a hoe in a pan, or a simple hand-powered or motor-powered paddle. They can be handled under field conditions. Previous applications have been surfacing and void-filling, where these materials are used as resinous binders. Now let us consider some of the adhesive bonding agent applications of these new materials. Perhaps the closest parallel is the use of an epoxy-based mortar, adapted for cementing concrete blocks together. Figure 1 illustrates this application and clearly demonstrates the superior strengths obtained with the epoxy. Because of the thin glue line, especially smooth concrete blocks must be used, and they must be especially faced for fit. Another application of an epoxy mortar is its use in the so-called "thin-setting bed technique" for application of ceramic tile developed under the auspices of the Tile Council of America. In neither of these systems is there a toxic hardener or a flammable solvent.

Figures 2 and 3 illustrate the use of a rather heavy, thixotropic epoxy adhesive for applying junction boxes on concrete and other walls. This replaces drilling and conventional anchor bolts. The strength is greater than that of the concrete. The adhesive can bond to glass, wood, etc. Other applications include the bonding of steel dowels into concrete in an aircraft runway assembly; bonding of a preformed concrete car stop to a concrete floor; bonding of cast steel traffic bars to concrete and asphalt roadways; bonding extruded curbing on highways; and splicing of concrete piles.

These adhesives are also used in the repair of concrete structures, for bonding concrete to concrete. The bonding of new concrete to old can be accomplished with a polysulfide epoxy. One such bond has weathered two winters without detrimental effect. Coverage was reported to be 120 square feet per gallon. Yucatan stone, a lightweight aggregate concrete which is supplied in decorative pieces 12" x 12" by 2" thick, is usually applied to a wall with a thick application of chicken wire-reinforced concrete mortar. Successful applications of this product have been made with thin glue lines of both epoxy and reclaim types of adhesives.

Clear epoxy resin has also been used to bond glass to glass and glass to aluminum. Polysulfide and polysulfide epoxy caulking compounds serve as adhesives as well as sealants, and have been the subject of discussion at previous BRI conferences.

Figure 4 shows the Monsanto Disneyland House of the Future. An epoxy adhesive was used to hold the plastic wings to the center shell with an overlapping splice plate. It is carrying the horizontal or bending movement of the structure. Sandwich panel floors were bonded to the shell.

Figure 1.

Figure 2.

Figure 3.

(Photos courtesy: (left) Raybestos-Manhattan; (right) Permacel Corp.)

All of the above applications have been accomplished with fairly simple equipment—hand mixing, mixing in a pail, with a drill press, or with a cement mixer in the case of the road applications. Specialized pieces of equipment have been developed for automatic mixing, metering and proportioning of two-, three- or four-part adhesive, sealant and coating formulations which are being adopted for field use. The value of equipment of this type in future adaptation to building industry applications of epoxy and urethane, and other materials for adhesion, sealing, insulation and coating, is obvious.

Other than the proven field applications of the new adhesive types based on synthetic resins, there have been many new and interesting applications of conventional rubber adhesives in the building industry. Some typical illustrations are:

1) Application of polyurethane foam slab insulation under a bridge deck. This bond was made with a reclaim rubber based adhesive, and a urethane coating was applied over the insulation from a field equipment mixmeter machine on a truck. This same machine has been used to spray urethane insulation into place in the field.

2) A glass block wall which was bonded with a thin glue line of a reclaim rubber adhesive has been giving good performance for ten years.

3) A new concrete veneer applied over existing building finish by bonding anchors to the old wall with an adhesive, and then applying the new concrete.

4) Partition runners installed on a concrete slab floor using adhesive-bonded anchors.

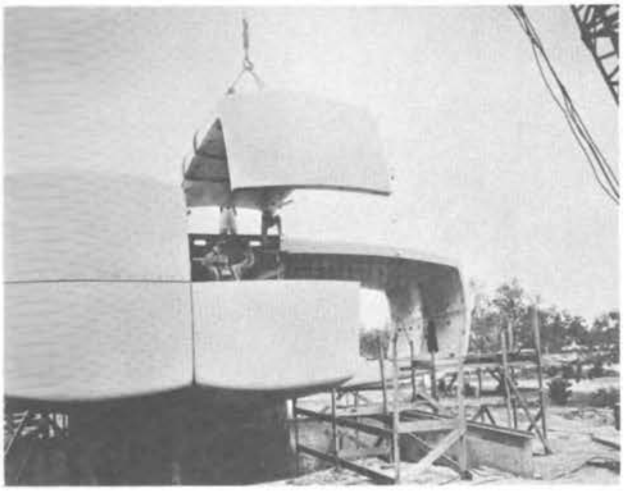

Figure 4

(Photo courtesy: Monsanto Chemical Co.)

5) Aluminum siding applied on the outside of a hospital building, using a reclaim adhesive.

6) Vinyl vapor barrier bonded to foundation walls with a nonflammable reclaim rubber-based adhesive.

By incorporating a new resinous ingredient, one adhesive formulator has developed an entirely new neoprene contact-type formulation, which has been substantially upgraded in immediate "green strength" and resistance to humidity. In the application shown in Figures 5 and 6, the adhesive provides sufficient strength to prevent lifting of the edges of the attractive wall tiles throughout a wide range of humidity and temperature cycling, water immersion and drying cycles, etc.

The term, green strength, is important to the understanding of adhesives. While a nail, a staple, or a paper clip forms its bond immediately, solvent- or water-dispersed adhesives usually offer little or no contribution to the strength of the assembly until after the physical process of drying takes place. (In the case of hot melt adhesives, the physical process involved is cooling.) Thus, most assemblies utilizing such materials must be clamped together for an extended period of time while strength develops.

Mortar, and the usual types of epoxy-polysulfide or urethane adhesives, require time to set chemically, during which the bond is relatively weak. On the other hand, the contact bond cements, such as are used in decorative laminate assembly or for bonding sandwich panels, offer an advantage in that they provide a very high proportion of their ultimate bond strength immediately upon contact after a very short drying period. These, then, are formulations which would be described as having high green strength.

It will soon be within the technological capability of the adhesive formulator to provide epoxy resin adhesives with a high measure of green strength. It is anticipated that some of the most important applications for these new adhesives in the building industry will be wood-to-wood, wood-to-metal and concrete-bonding.

Other new adhesive developments include:

1) Substantially upgraded contact bond cements providing better ultimate strengths and resistance to higher temperatures.

Figure 5.

Figure 6.

(Photos courtesy: Formica Corp.)

2) Epoxy adhesives in film form which are premixed, stable at room temperature, and which can be cured either by electronic means at room temperature or at fairly low temperatures (below 200°F).

3) Many "conventional" adhesives dispersed in nonflammable, nontoxic solvents, and those which are also nonflammable in the dried state.

4) Room-temperature-cured epoxy resin adhesives which yield 3,000 psi in tensile shear strength when tested at room temperature, and 2,000 psi when tested at 180°F, and which also pass all of the environmental test specifications of MIL-A-5090B.

5) Newly-developed foaming techniques for adhesive application which provide substantial economies by increasing the spread rate of the adhesive, now under extensive evaluation within the plywood industry.

6) Optically clear epoxy adhesives for bonding glass.

7) At least one adhesive which fulfills the "impossible" requirement of being single-component (no hardener to mix in), but which cures at room temperatures to an immediate strong bond. This is an acrylic-based material. Although both economic and technical reasons so far have limited the use of this particular product, it has stimulated the imagination, leading to extensive research along many lines throughout the adhesive industry which will undoubtedly have a practical payoff within the next few years.

How will the building industry make use of these new developments as well as find further use for the many adhesives already introduced? The value of epoxy formulations for the bonding of concrete has received recognition to the extent that a committee of the American Concrete Institute is currently engaged in evaluating them to serve as shear connectors for composite T-beams employing concrete and steel, and as joining agents for beams to columns (Fig. 7).

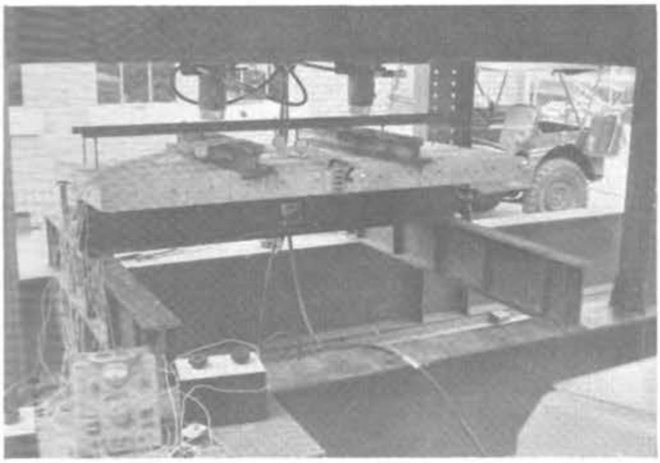

Figure 7.

(Photo courtesy: University of Arizona)

Many experimental buildings are being assembled which are at least partially "chemically welded, " from the Disneyland all-plastic "House of the Future" to the "Chemosphere" discussed in the May 1961 issue of Adhesives Age magazine, to a truly all-bonded building designed by Richard Sharpe, A. I. A., which has just been completed in Connecticut. In this latter building, wood and plastics were fabricated into panels and mounted in the field, largely through the use of epoxy adhesives. Details of this construction will soon be released for publication.

It is becoming increasingly difficult to separate the adhesive, sealant, coating and structural properties of the newer resinous materials as they can be applied to building construction. Their adhesive properties are all-important since, essentially, the function of the construction industry is one of assembly. It can be said that the most important single advantage of adhesives, as against other fastening methods, is distribution of stress over larger areas, a most important consideration.

It is anticipated that the use of unit prefabrication in every phase of building construction will increase considerably, and many such applications are bound to involve the more widespread use of adhesives. Expanded use will, of course, bring with it the development of more new formulations for field assembly and fabrication, as well as further modifications of existing adhesives directed toward easier and more foolproof application in the field.

The construction industry may be assured of the interest and dedication of the adhesives industry toward this end. The spirit of cooperation and the cross-fertilization induced by conferences of this type will certainly spur us both onward toward effective solutions for our many mutual problems. It is hoped that this paper and the others presented have helped to reduce any fears based on the esoteric and complicated nature of some of our new adhesives. These materials are related in many ways to the portland cement mortar with which the construction industry is so familiar, and they can be handled satisfactorily and effectively in the field. They are new tools for producing better buildings.

Open Forum Discussion

Moderator—D. Kenneth Sargent, Dean, School of Architecture, Syracuse University

Panel Members—Messrs. Been, Branin, Carlson, Ellis, Lauren, O'Hare and Schulte, and S. D. Kirsch, Development Manager, Adhesives & Chemicals Division, The Borden Chemical Company

J. A. Scott, Raybestos-Manhattan: Do you know of any "epoxy mortar" using epoxy resin as the sole binder that has qualified for a satisfactory fire rating?

Mr. Been: No, I do not. All of the epoxy mortars in current use are extended with cementitious binders as well as the epoxy, so there really is not a single mortar on the market using epoxy resin only.

Mr. Scott: By way of reporting, it might be mentioned that the thin bed mortar referred to in your presentation, composed of both inorganic and organic binders, has recently received a four-hour fire endurance and hose stream rating under load-bearing conditions.

Unsigned question: What is the most reliable adhesive for bonding to glass in field application?

Mr. Been: I would say that an epoxy adhesive would be the most reliable. The bond strength of epoxy to glass is higher than the cohesive strength of glass. There are epoxies, as was illustrated, which have light stability, and can be used in windows. They have been used for several years now in the front of television tubes where the radiation from the TV tube almost matches accelerated aging radiation and actinic radiation.

Mr. O'Hare: We've had some field experience with bonding of 1/2" thick plate glass with a very light colored epoxy, and it has proven successful over about 1-1/2 years to date. To these comments I can add the story that is often told by Dr. J. S. Long of the University of Louisville, in whose laboratories at the Devoe & Raynolds Company some of the early work on the epoxy resins was done. He tells about how films of these resins were cast on glass plates before they really realized what kind of product they had, and attempts to remove these resins resulted in gauging out of the glass plates, indicating that the adhesion of the resins to the glass exceeded the cohesive strength of the glass itself.

Mr. Schulte: Some of the earliest glass adhesives were the vinyl butyrates that are used with safety glass and the butyl phenolics which are used quite widely for the adhesion of glass to glass.

Mr. Sargent: What progress has been made in development of acoustical adhesives with sufficient plastic life that dissimilar materials of varying dimensional stabilities may be successfully joined?

Mr. Branin: I think that we will continue to use the present type of acoustical adhesive in remodeling work. On new work, we are going to see many different types of application of adhesives, where the levelling and bedding compound will not be required to achieve a level ceiling. You will probably find in the future that these adhesives will gradually change in character, and will change according to the types of materials which they are going to bond.

A. W. Chapman, B B Chemical Co.: You mentioned an application tool which you could describe in detail. Would you please describe this tool?

Mr. Branin: This tool is a piece of 2" steel conduit, cut longitudinally about 3/4 of the way up. The resulting trough is filled with the acoustical material. The trowel is shaped to fit the contour of the tube and the operator measures off his pats as he goes along. Over a period of time, you can see that a skilled operator can actually place four pats (minimum) of adhesive from this tool onto a tile with a reasonable amount of accuracy in weight, and that, we feel, is quite important.

Howard Phillips, American Telephone & Telegraph Co.: In bonding old concrete to new, will the adhesive develop the same strength as the concrete? How long can you wait after the adhesive has been placed on the old concrete before pouring the new concrete and still obtain a good bond?

Mr. Been: Generally speaking, the bond strength between the adhesive and the concrete is greater than the cohesive strength of the concrete. This is not always true, as Prof. Eugene Nordby of the University of Arizona so rightfully called to my attention by showing pictures of composite specimens which he had made up, where he had a fair percentage of failures which were as yet unexplained. These are new materials and there are things about them which we probably don't yet know. The bulk of the specimens which Prof. Nordby had prepared showed cohesive failures within the concrete. Virtually all of the specimens taken in the road surfacing programs show cohesive failures within the concrete, and where this is not the case, generally the failure is due to poor surface preparation. A test technique has been developed for use during road surfacing where an epoxy-based mortar is applied over a concrete road. A test patch is cut out and a metal plate is adhered by the epoxy mortar in the area chosen as a test spot. The metal plate is then pulled up, and if it doesn't break the concrete, something is wrong. Then it must be tried again until the concrete breaks. This shows the strength is there. It is desirable that the epoxy adhesive not be fully cured before the new concrete is poured on top of it, which means that it must be done within the pot life of the epoxy adhesive. This varies, of course, from a half hour to 2 hours, but the pouring should be done before the epoxy adhesive has set.

H. R. Young, E. I. du Pont de Nemours & Co.: One of your slides showed a urethane foam being applied to some bridge member. What does this installation accomplish?

Mr. Been: I am told that the water on a bridge will always freeze faster than the water on the roadway adjacent to the bridge and that, by applying insulation on the underside of the bridge, freezing can be delayed, eliminating a road hazard.

Mr. Sargent: How can an architect or engineer learn the physical properties of adhesives in order that he may judge the qualities of a material to meet his problem, rather than attempt to determine the company whose integrity he believes greatest with respect to furnishing the proper material?

Mr. Ellis: First of all, the architect or engineer has to understand his own problem. He has to analyze it to know what properties, what performance he needs from the adhesive he is going to use. Secondly, the adhesives manufacturer must be able to present engineering data, showing that his products conform to the service requirements. If you don't have these two factors, no intelligent selection of an adhesive can be made.

Mr. Sargent: I am very much concerned because the profession which does the designing has little knowledge of these materials. That's one of my keen interests, and I really believe that we must develop a greater understanding. To come back to Mr. Been's statement about concrete products, there are good reasons why they are used. We know what they will do, how long they will last and how they will act under various conditions most of the time. But, when you start handling new materials with very little information other than a name which signifies the principal component, designers are reluctant to use them. There must be more information fed to the users as to the physical properties of these materials, if they are going to be used intelligently and more widely.

J. A. Robertson, U. S. Gypsum Co.: In finishing epoxy-type terazzo, is grinding done in a manner similar to that used for surface finishing of portland cement terazzo?

Mr. Been: Yes.

W. A. Kulik, Rohm & Haas Co.: How would you compare epoxy mortars to acrylic sand-cement mortars, the advantages and disadvantages of each? Also, how would you compare acrylic adhesives to epoxy adhesives?

Mr. Been: They are both void-filling. It is characteristic of 100% solids adhesives or binding agents that they perform fairly well in very heavy glue lines. If it doesn't have that particular property, the material cannot be considered a mortar at all. The epoxy materials are essentially stronger. The formulations that can be produced with the epoxies range from a pure epoxy resin, which has strength properties many times those of cementitious materials, to an epoxy material which is, for all practical purposes, a small amount of epoxy used to fortify a cementitious adhesive. Properties range all the way in between. You would not use an epoxy-containing material unless it had sufficiently high properties to justify its higher cost.

Mr. Lauren: I would like to supplement Mr. Been's remarks with a correction of the question. I think the questioner meant to ask about acrylic resins. With the exception of several types very recently developed for surface coating uses, acrylic resins are thermoplastic resins. They are permanently solvent-soluble, that is, soluble in the original solvents from which they are deposited. In contrast with this, the epoxy resins are curing-type, thermosetting resins. When we use the term, thermosetting, we don't mean that they necessarily must have heat to cure; they can be cured chemically under ambient temperature conditions. The degree of thermoplasticity and permanent solvent solubility that would be introduced by a resinous binder combined with sand, in contrast with the curing nature of epoxies, would be an obvious disadvantage in many applications. As a matter of fact, I don't know of any instances in which acrylic resins have been used with sand except possibly some surface coating applications for fill coats, but not in heavy duty applications, such as floor surfacing requirements. There is no comparison between conventional acrylic resins and epoxy resins for the kind of end uses you have in mind. The epoxy resins are very clearly superior.

Unsigned question: How expensive per gallon or per square foot of application is this miracle adhesive you mentioned?

Mr. Been: I believe the original price was around $6 an ounce, which puts it in the neighborhood of $600 to $700 a gallon.

A. D. Yazujian, Thiokol Chemical Co.: In the adhesive-bonded block what consideration has been made to compensate for dimensional changes or differences in the units? How does the installer remedy levelling errors?

Mr. Been: It's my understanding that those blocks have been specially prepared. You can't use this kind of a system with a conventional concrete block right out of stock. These are smooth blocks which will fit together with a thin glue line. Otherwise, you would have to use such a large amount of the relatively expensive epoxy-containing mortar that it would be uneconomical. With this thin glue line and with a closely fitting block lock, the adhesive is so much stronger than the block that problems arising from dimensional changes due to environmental exposure are minimized as compared with a conventional mortar.

Mr. Lauren: The simple specification of the manufacturer of this resin adhesive mortar requires that the blocks must be treated by grinding, so that, if the block wall were assembled on a level surface without any mortar, it would build up to a level and plumb wall just by stacking. In other words, the surfaces have to be smooth, true and square. That's the only way in which they can be assembled into a plumb and level and square wall with this very thin line adhesive-mortar combination.

Mr. Branin: This type of construction is ideally modular construction. Maybe we are approaching the technique of the Egyptians.

Unsigned question: What are the principal components of the mastic cement to which you referred, and what is the life expectancy of its plastic-resilient quality as an aid to overcoming future building movement of a typical wood frame structure?

Mr. Lauren: There are two general types of mastic cements. The less expensive type is based either entirely or predominantly on an asphaltic component with a filler that gives it viscous and mastic properties. The fillers can be ground mineral components plus, often, asbestos fiber for thickening and reinforcing efficiency.

A more expensive type of mastic cement will consist typically of reclaimed rubber in combination with certain resins and organic solvents and, again, fillers. In general, these mastics can easily be formulated for long-lasting flexibility or plasticity. The best of them are not necessarily the most expensive. Either can easily be formulated to serve usefully without embrittlement failure throughout the expected life of an average frame building. On the other hand, with an improper selection of raw materials, and this is entirely dependent on the skill and knowledge of the manufacturer of the adhesive, some of these cements will ultimately become embrittled, and in instances of extreme movement, there can be bond failure due to embrittlement.

Mr. Schulte: In the case of mastics, probably the best from the durability standpoint are the synthetic rubber types which are specifically compounded to resist oxygen with anti-oxidants. Some of these products are used as high quality adhesives for ceramic tile applications. The Commercial Standard 181-52 which Mr. O'Hare mentioned doesn't have a test for this property in it. That is now being considered by several groups—a test for durability and oxygen resistance which would reproduce long exposure to oxygen, since this element has a pronounced effect on an adhesive.

W. Klugman, A. C. Horn Co.: Do you know of a field application of foamed epoxy adhesive, or can this material only be used under the controlled conditions inside a plant?

Mr. Been: At the moment I don't know of an application of a foamed epoxy. The foamed epoxies are experimental. The foamed urea formaldehyde and phenol formaldehyde plywood glues are just becoming production materials. To produce a foamed epoxy would require an automatic mix-meter machine to introduce a foaming agent along with the components. This kind of machine can be used in the field; however, no such application has yet been developed, to my knowledge.

S. B. Twiss, Chrysler-Cycleweld: What types of elastomers, resins and plasticizers are used in adhesives for acoustical tile? What is the preferred type of adhesive from the viewpoint of good aging and performance?

Mr. Branin: There are installations of acoustical tile, the organic fiber type, which have been in service for some 25 years. The basic component of this adhesive is resin modified by certain plasticizers. The amount of solvent must be low in proportion, to afford the least amount of shrinkage. The most important factor of this type of adhesive is its ability to retain the plasticizer over a long period of time. You will also find a lot of petroleum resins, as well as other synthetics, being used as the basic material.

Mr. Twiss: Due to the different thermal expansion coefficients of glass and epoxy resins, bonds between the two cannot go through wide temperature changes without breaking the glass. What solutions to this problem do you have to offer?

Mr. Been: I do not have any data on relative thermal coefficients but, by compounding of the epoxy, the difference can be reduced substantially. There have been successful electronic component assemblies made with glass components potted, that is, submerged, in a casting operation in epoxy resins, and they have served under fairly wide temperature variations. I don't know what the questioner had in mind as a temperature variation, but these electronic component assemblies have withstood as high as 150° to $200^{\circ}F$ temperature differences without failure of the bond between the glass and the adhesive. With special formulation techniques even higher temperature variations can be withstood.

Unsigned question: Do you agree with Mr. Lauren and Mr. O'Hare about epoxies being overdesigned for ceramic tile and wallboard bonding?

Mr. Been: I know of one application of ceramic tile bonding that requires every bit of bond the adhesive can provide. In 1957 there was a test installation of ceramic tiles on the ceiling of the Holland tunnel. They used reclaimed rubber adhesives, and they also used an epoxy adhesive. The service requirements called for frequent and continued washing with strong detergents.

There's always some moisture present and there's some condensation of petroleum hydrocarbon materials from the automobile exhaust. The Port Authority does not seem to have a very complete report on this 4-year-old application, but they did say that in a suction cup test, where they applied between 50 and 65 lbs. of load on the tiles trying to pull them off, a few of the tiles set with reclaimed rubber adhesives failed. None of the tiles set with the epoxy adhesives failed, but this is by no means a complete test. It is obvious that there are applications where the full strength of the material is required.

One of the other points made by Mr. Lauren was that on drywall construction, where the wallboard was used with an epoxy, there would be an objection to the epoxy because of the requirement to mix the two components. As far as the excessive strength of the epoxy as against the reclaimed or asphaltic adhesive, again, there may be cases where the strength is required.

Mr. O'Hare: I would also like to comment on the Holland tunnel ceiling experiment. We were involved in this, and the test panel using reclaimed rubber resin adhesives was put up against our specific recommendations, because we did not feel that it was the proper material for a job having such severe service conditions.

Mr. Lauren: I vote in favor of epoxy adhesives for vehicular tunnels, but I think that Mr. Been, and almost anybody who is familiar with industrial applications of adhesives, will agree that in the selection of adhesives as in the selection of other industrial products, it is not sound from an engineering nor from an economic viewpoint to overdesign excessively. Where cost is no object, and the installation expense is not important one way or another, I suppose it's a good idea to use the very best of everything that you possibly can. But, in that case, you wouldn't be using gypsum wallboard, either. In these vehicular tunnels there is a lot of unburned fuel expelled from exhausts, and the reclaimed rubber materials are soluble for a long time in hydrocarbon solvents. That's one reason for these failures. But, by and large, epoxy adhesives should be exploited and reserved for the heavy-duty fastening applications that we encounter in the construction industry.

W. S. Wieting, Perkins & Will: Architects are anxious to use new adhesive materials, but hesitate to do the testing in their new buildings at the expense of their reputations and the client's money. Is there any clearing-house for evaluation of test results in the industry?

Mr. O'Hare: There is some work being done on that by the Technical Committee of the Rubber & Plastic Adhesive and Sealant Manufacturers Council, but this organization is only a few years old. You have to give them time.

Mr. Branin: Wherever applicable, a review of an ASTM test specification should be made. ASTM specifications represent the collective thinking of the industry.

Mr. O'Hare: There is no question about the ASTM specifications; the only difficulty encountered is that it usually takes years to get an answer to any particular problem.

Mr. Schulte: BRI is also holding a conference on weatherproofing thin shell concrete roof construction, and this very subject is a good example of how the architectural profession is going in different directions. They don't know all the details of design that are needed. They design the building, and then ask the coating and sealant people to provide a product which will do the required job. It would be much better if the architects could band together, work together on the design principle, and call the adhesive and sealant manufacturers in early enough so they could have sufficient background. The problem is that a building is designed, something is slapped on it which has perhaps six months or a year field history, and the product doesn't work—it fails. Then the architects point fingers at the people who made the coating or sealant because it failed, even though the manufacturer had only six months to a year experience with it. It would be best to have five years or more, if possible, by working in advance on these problems.

PRESSURE-SENSITIVE TAPES FOR BUILDING

Session Chairman—Charles O. Pike, Plant Manager,
Tape Division, Shuford Mills

Application of Pressure-Sensitive Tapes in Building

By Donald A. Wallace,* Market Manager,
Construction Trades, Permacel Division, Johnson & Johnson

Pressure-sensitive tape is a fast and convenient means of affixing in position, either permanently or temporarily, the various types of backing materials from which tapes are manufactured. Such backing materials as plastic films, cloth fabrics, paper and metal foils give each individual tape product its primary characteristics: moisture, chemical and temperature resistance, electrical insulating qualities, conformability and many others. A wide selection of pressure-sensitive tapes is used in the building industry as a means of sealing, waterproofing, electrically insulating, holding and protecting. The permanent or temporary nature of a pressure-sensitive tape is determined by the building contractor on the job site. Tape can be left in position, to be built permanently into the building construction, or removed prior to a subsequent building operation.

One of the most important technical considerations in the building industry, as regards a pressure-sensitive tape application, appears to be its ability to resist moisture. This is measured by the ability of the tape to resist water transmission through it and the longevity of the tape under exposure to moisture conditions. In the tape industry the ability of a tape to withstand water passing through is measured in terms of moisture vapor transmission rate. This is the amount of water measured in grams which the tape backing will allow to pass through within a specified period of time, usually 24 hours. Of the various types of tape commonly available, aluminum foil pressure-sensitive tapes are superior to all others in resistance to water. Aluminum foil will resist water corrosion excellently, and has a moisture vapor transmission rate of zero. Polyethylene-coated cotton cloth tapes are also excellent in both respects. Table I shows various generally used types of tape backing materials and their average moisture vapor transmission rates:

TABLE I

Average Moisture Vapor Transmission Rates

Tape	Grams/100 sq. in./24 hrs.
Aluminum Foil	0
Lead Foil	0
Polyethylene Plastic	.15 - .25 grams
Polyethylene Coated Cotton Cloth	.7 - .9 grams
Polyester Plastic	1.2 - 1.5 grams
Vinyl Plastic	2.0 - 3.0 grams
Vinyl Impregnated Cotton Cloth	1.5 - 3.0 grams
Cotton	2.0 - 6.0 grams
Glass Cloth	4.0 - 6.0 grams

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Proper Tape Application

The sealing quality of a tape, its ultimate holding power and over-all performance are directly affected by how well the tape is originally applied. The proper application of tape can be summed up as "good, intimate contact with a clean surface." A clean surface is one which is dry, and free from dirt and/or oily films and grease. Good surface contact is achieved by pressing the tape firmly into position, excluding all entrapped air and thus giving 100% surface contact.

The temperature at which tape is applied has not been too great a problem in most areas, because the tape is normally applied at room temperatures. In the building trades, however, it is sometimes necessary to work in outdoor temperatures as low as 0°F. Pressure-sensitive tapes will adhere well when applied in ambient temperatures from about 40°F up to the highest expected outdoor temperatures. In fact, the higher the temperature at which the tape is applied the better will be its ultimate adhesion to the surface, since at higher ambient temperatures the adhesive flows more readily, providing a more intimate contact. At temperatures below 40°F, the adhesive mass of the tape becomes increasingly stiffer as the temperature decreases. This loss in flow characteristic of the pressure-sensitive adhesives impairs the initial tackiness and holding power of the tape. Almost all tapes will stick, to a varying degree, to a surface when applied at below 40°F, but performance will not be up to expectations. However, if the tape has been applied at normal room temperature, its holding power is not affected upon exposure to below freezing temperatures. Specialized adhesives, generally higher in cost, have been designed for critically cold temperature work, but the selection of such products is very limited.

There are three main rules to remember for proper tape application:

1) Cleanse the surface of oil, grease, loose dirt, dust, water and rust.

2) Press the tape firmly in position, eliminating all entrapped air.

3) Apply the tape, whenever possible, in ambient temperatures above 40°F.

Tape Applications in Building

There are a great number of tape applications in modern building (Table II). This paper will deal with the well established applications within individual building trade groups. For instance, in the heating, ventilating and air conditioning trade, several types of pressure-sensitive tapes are used to seal sheet metal duct joints and the butted seams of faced thermal insulation. Sheet metal duct joints are sealed with either aluminum foil, silver-colored cotton cloth, or vinyl plastic pressure-sensitive tape, to give a positive seal at each joint or seam. A 2" wide tape is generally used for this application.

The application of silver-colored cotton cloth tape and aluminum foil tape by the thermal insulation contractor has become a widespread and accepted trade procedure. Pressure-sensitive tape is used in this application to seal all of the butted and overlapped seams of the various types of thermal insulation facing material in order to achieve a continuous and positive moisture vapor seal. Any moisture condensation within the thermal insulation, i.e., between the ducting and the facing material, is detrimental to the life and efficiency of the insulation system (Fig. 1).

TABLE II

Tape Applications in Building

Trade	Application	Tape
Piping and Plumbing	Pipe Protective, Wrap-Threaded Pipe Joint Sealant	Vinyl or Polyethylene Plastic Inert Plastic Tape Dope
Heating, Ventilating and Air Conditioning	Insulation Sealing Tape Insulation Sealing Tape Aluminum Foil Facing Sealing Metal Duct Sealing Metal Duct Sealing Metal Duct Sealing Sheet Metal Flange Gasket	Polyethylene - Cotton Cloth Glass Cloth - Noninflammable Aluminum Foil Polyethylene - Cotton Cloth Vinyl Plastic Aluminum Foil Sealing Compound Tape
Electrical	Wire Splicing and Insulating Wire Splicing and Insulating Heavy Duty Electrical Insulating	Vinyl Plastic Glass Cloth - High Temperature Heavy Gauge Vinyl Plastic
Masonry	Polyethylene-Coated Paper Liners or Coated Wood for Concrete Forms Splicing and Sealing	Polyethylene - Cotton Cloth Polyethylene Plastic
Windows, Doors and Curtain Walls	Waterproof Gasketing Simulated Leaded Glass Windows	Sealing Compound Tape Lead Foil
Decorative Surfaces	Protection of Polished Metal, Finished Wooden, or Decorative Plastic Surfaces	Protective Paper Protective Cloth
Roof and Wall Insulation	Sealing of Seams of Rigid Insulation Composition Board before Waterproofing	Cotton Cloth
Painting and Plastering	Masking off, Prior to Painting and Plastering	Paper Masking Tape

Also used by sheet metal fabricators in the heating, ventilating and air conditioning trade is a noncuring, synthetic rubber sealing tape which serves as a gasket between sheet metal flanges in duct systems. The noncuring, synthetic rubber compound is extruded onto a cotton cloth equally on both sides of the fabric. The tape comes in various widths, and in thicknesses ranging from 1/32" to 3/16". Being quite tacky in nature and of a relatively heavy gauge, it can effectively seal stand-up flanges in sheet metal ducting, regardless of differences in alignment.

In the installation of pre-assembled window sections the same sealing tape has been used to make an air- and watertight joint between the window assembly and the building structure. The same is true of door frames inserted in masonry, poured concrete, or cinder block walls. The original aluminum window manufacturers also use this sealing tape to seal the window pane within its frame.

Residential builders and some window manufacturers have found a very inexpensive way to simulate leaded glass windows with tape. By taking a narrow-width, lead foil, pressure-sensitive tape and stripping the windows in the same fashion as leaded windows, an inexpensive leaded glass window may be simulated for a fraction of the usual cost (Fig. 2).

The use of pressure-sensitive tapes in electrical wiring to splice wires and insulate them electrically is historical. Vinyl electrical tapes have largely replaced the old friction and rubber tape combinations in modern wire splicing. The vinyl electric tapes provide a neater, less complicated way of insulating wire splices. Recently, a new cold weather type of electrical vinyl tape for outdoor work was introduced to the electrical construction trade. This new vinyl tape will remain flexible down to temperatures as low as -50°F. This is a low enough temperature resistance to do such jobs, even in Alaska (Fig. 3). At the opposite end of the temperature scale, a glass cloth electrical wire-splicing tape for high temperatures, 160° to 300°F, is available. This tape is currently used in ovens, toasters, irons and furnaces.

One of the more recent uses for pressure-sensitive paper tape products has been as a protective paper. Protective paper is a heavy duty paper coated with an easy-release, pressure-sensitive adhesive. The protective paper is applied over highly finished or polished surfaces to protect them from scratches, dirt and staining. When such surfaces as polished metal, highly finished plastics and wood decorative materials are installed, there is a need to protect them temporarily, during the remaining construction. Once the building has been completed and is ready for occupancy, the easy-release, pressure-sensitive adhesive allows the protective tape to be removed without leaving a residue of adhesive on the surface. Paper protective tape is the most widely used; however, the ultimate in mar and damage resistance is a heavy duty cotton cloth protective tape, for use in areas subject to heavy working loads during construction of the building, such as elevator doors and entrance frames. Special protective papers are available for exterior building applications where sunlight and other elements adversely affect normal indoor protective tapes.

In modern construction methods, the application of rigid roof and wall insulation made from composition board has become relatively widespread. The rigid insulation is laid in position between metal channels, such as in a roof, and then these are overcoated to give a watertight seal. This overcoating may be an elastomeric combination or gypsum. To seal the seams between the butted joints of the rigid insulation, prior to this overcoating, a pressure-sensitive cotton cloth tape has been used. The tape physically

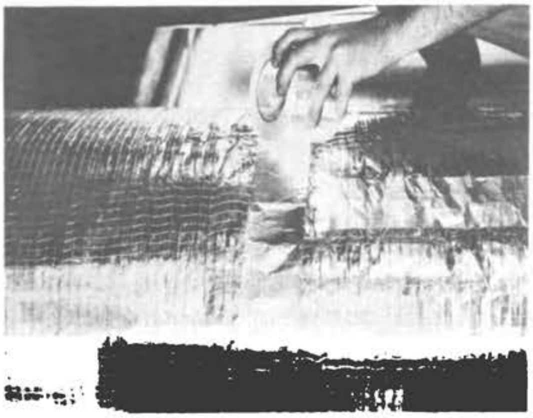

Figure 1. Aluminum foil tape is used to seal butted joint on aluminum foil scrim cloth reinforced thermal insulation.

Figure 2. Lead tape is used to simulate leaded windows or diamond wood grilles.

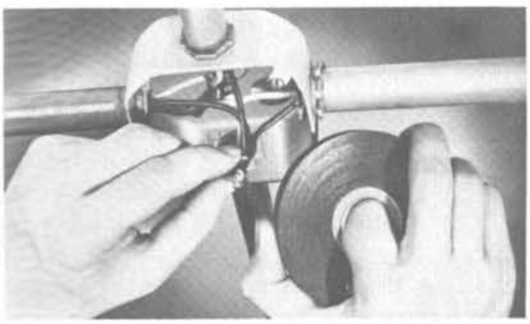

Figure 3. Plastic vinyl tape used to electrically insulate wire splice.

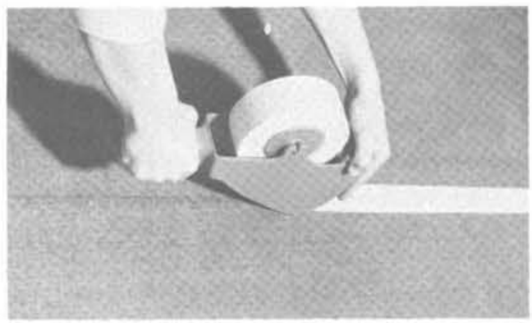

Figure 4. Cotton cloth tape used to seal and unite rigid insulation.

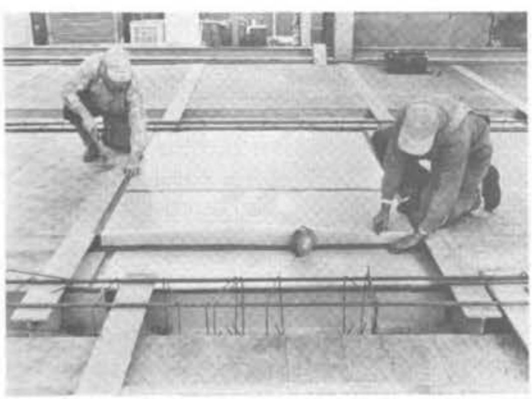

Figure 5. Polyethylene coated paper liner is spliced and sealed with polyethylene coated cloth tape.

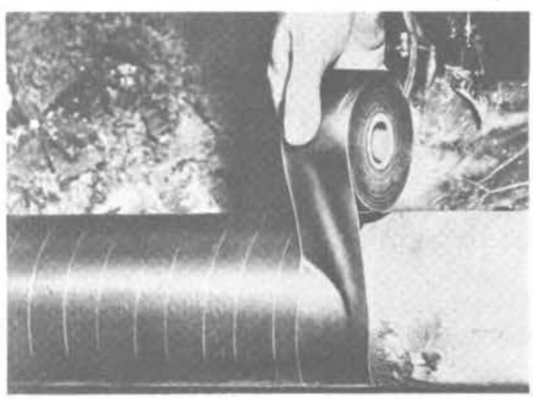

Figure 6. Vinyl tape is wrapped around metal pipe for protection.

unites one board to the other, yet allows enough stretch to permit building expansion and contraction. This cotton cloth tape can easily be applied by the use of tape applicators such as a floor push-along type for roofs, and a hand dispenser for taping wall joints (Fig. 4).

When concrete is poured into wooden forms, the ultimate finish on the concrete is not always completely satisfactory and requires time-consuming hand reworking. Recently, polyethylene-coated paper liners for concrete forms, or polyethylene-coated wood forms have been used to alleviate the necessity for reworking the finish. With paper liners and coated wood, polyethylene plastic tape and polyethylene-coated cotton cloth tape have been used to splice the paper together and seal off all corners and joints. Using this system, the ultimate finish obtained on the poured concrete is excellent with little, if any, excess concrete left at the corners. The resulting labor savings in terms of refinishing are substantial (Fig. 5).

A polyethylene or vinyl tape is used to protect piping buried in acidic or alkaline soil, or exposed to chemical corrosive fumes. The tape is wrapped spirally around the pipe. For best results in this application a clean, rust- and scale-free pipe, treated with a clear pipe-wrap primer, will give the ultimate in protection and adhesion of the tape to the pipe. The chemical, water and galvanic protection provided by the pipe-wrap tape extends the life of the piping far beyond normal, and economically more than justifies the initial cost.

This is a nonpressure-sensitive tape extruded from an unfilled or extended inert plastic. A number of things make this product truly unique. Once this tape has been applied at room temperature, its temperature resistance and the temperatures at which it will effectively seal a threaded pipe joint range from $-300^{\circ}F$ and lower to at least $+500^{\circ}F$. The chemical resistance of this ribbon or tape is so outstanding that it is much easier to name the handful of unusual chemicals it will not resist, than to cite the thousands it will resist. The nature of this material is such that not only will it not harden, so that it always effectively seals the threaded joint, but it also remains self-lubricating throughout its life, so that connections can always be opened and remade. So far, there has not been a sealing problem on any type of threaded pipe in the building industry or chemical process piping field that this product has been unable to solve. This is truly a revolutionary product for the construction industry.

Last are the paper pressure-sensitive tapes, both creped and flat back. This class of tape includes the general all-purpose tapes which are widely used in any building project. These are used for masking during painting, coating or caulking operations to give a clean, neat-appearing, finished job, for temporary holding, as a temporary seal and splicing material, or for many other applications.

Pressure sensitive tapes are widely used in the building industry and have proved to be useful and helpful tools. New applications are being uncovered every day, and new tapes to serve the building industry better are being announced continuously by tape manufacturers.

Recent Field History of Pressure-Sensitive Tapes for Sealing Applications

By Paul H. Wilson,* Supervisor
Industrial Tape Construction Projects
Minnesota Mining & Mfg. Company

In December, 1957, the future of pressure-sensitive tapes as a new type of panel sealant was discussed during the BRI Conference on Adhesives and Sealants in Building. This report will cover the progress made since that time in the evaluation of permanent-type pressure-sensitive tapes on a number of experimental structures which have been erected during the last 2-1/2 years.

Long-aging tapes were developed primarily in response to a desire for a new answer to the problem of joints in curtain wall and other structures. The principal advantage of a tape seal is that it permits a much wider range of movement between adjacent panels, and still maintains a more weatherproof seal than is possible with conventional sealants. The principal concern, of course, is that since the traditional market for pressure-sensitive tapes has been for those used in temporary applications (I hope your children all use cellophane tape), it is understandable that a permanent-type pressure-sensitive tape might encounter some skeptic reaction.

Some mention should be made of heat-activated adhesive tapes for building. A natural question arises: would they be preferable as a seal? Without discussing the pros and cons, let me say that we believe there are a number of major problems to be overcome before they would be as effective as pressure-sensitive tapes in their present state of development.

In our work we have considered two completely different basic backings for tape seals: plastic and metal. Figure 1 shows a factory building in Decatur, Alabama, sealed with a polyvinylfluoride pressure-sensitive tape. The building walls are of a commercially available, corrugated cement-asbestos siding, and we are fortunate that the structure has four almost identical companions, erected at the same time, with conventional joints. Thus, direct cost comparisons are possible.

Figure 2 compares the details of the two joints. The principal difference is that the panels were butted for the tape joint, and overlapped conventionally in the control joint. The following comparative savings were obtained:

1) The labor used in erecting the taped walls was one-third less. This saving was composed of a number of factors, the principal one being the elimination of any need to line up holes for bolting.

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2) Reduction of the normal breakage of 20% down to 3% for the test building. The conventional joint requires some springing of panels into place which tape eliminates. Breakage on the control buildings would have been higher, but the contractor requested permission to use tape joints several times on the control buildings, where otherwise an uneconomical erection sequence would have been necessary to avoid excessive springing (for example, when an outside steel staircase was erected before the panel facing was placed behind it).

3) There is an obvious saving of 8%, in that the overlap of the panels is eliminated.

4) Although not done in this building, it appears possible that the center line of stiffening girts could have been eliminated because of the ability of the tape to take a high degree of relative movement.

An experimental roof system erected by the du Pont Company in Wilmington, Delaware, is composed of polyvinyl fluoride roll roofing. The joints of this roofing are sealed with a tape of the same material. This roof has been in place since the fall of 1959.

A different type of plastic tape, a chlorosulfonated polyethylene, was utilized in a school shelter erected in Tacoma, Washington, under the sponsorship of several companies headed by the Douglas Fir Plywood Association. The roof panels are plywood covered with a layer of the same plastic in a variety of colors. After placement, the joints of the structure, both top and bottom, are sealed with pressure-sensitive tape. Figure 3 shows a tape dispenser which permits a man to apply this tape while walking erect, which greatly speeds application since the only other requirement is a clean surface. The second man is rolling the tape edges down firmly with a rubber roller.

The plywood panels are nailed to the bents so that the heads are later covered with the tape. Figure 4 shows how the tape is applied by hand to the steeply sloping portions of the roof. A hand dispenser controls the tape roll and the protective liner is pulled back as the roll unwinds. The men are supported by a 2" x 4" nailed at the bents, where the holes will later be covered with a vertical tape strip. The tape edges are wiped down with an inexpensive, extruded plastic wiper blade to insure good adhesion. Since this tape is about .009" thick, a small spot of the basic plastic emulsion is also placed on the corners where the tape strips cross, to insure against a capillary leak.

A building sealed with a pressure-sensitive tape made with a soft aluminum backing was erected in 1960 by International Paper Company in Bastrop, Louisiana. The siding material is a high-density overlay plywood. Figure 5 is a direct view of the roof showing the tape pattern, which will fade as the bright aluminum finish weathers. A workman dries the joint with a portable torch before tape application, and the tape edges are later pressed down firmly against the plywood with a putty knife. Care must be taken in this operation not to work-harden the aluminum edge, or it will tend to lift.

Figure 6 shows a geodesic dome which has been erected by Kaiser Aluminum Company in several cities around the country. Two of these structures were sealed with an aluminum-backed tape. Although these buildings are sealed successfully with conventional sealant today, the tape seals failed for an important reason that is worth mentioning. Figure 7 shows the detail, and you will note that the tape must span a 3/4" gap with no support. Gaps of this width are often required when conventional sealants are used, however the ability of pressure-sensitive tapes to take high elongations without failure makes such a gap unnecessary which, as in this case, often produces premature failure.

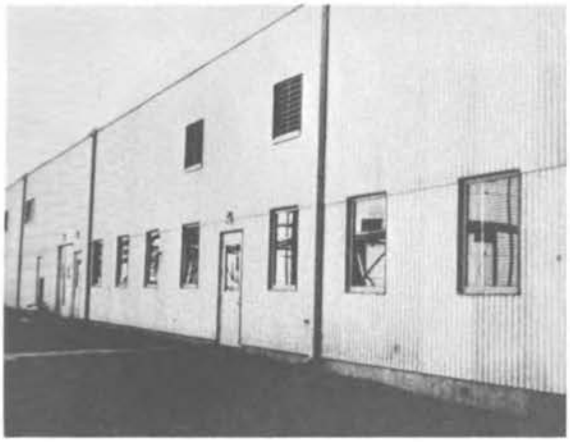

Figure 1

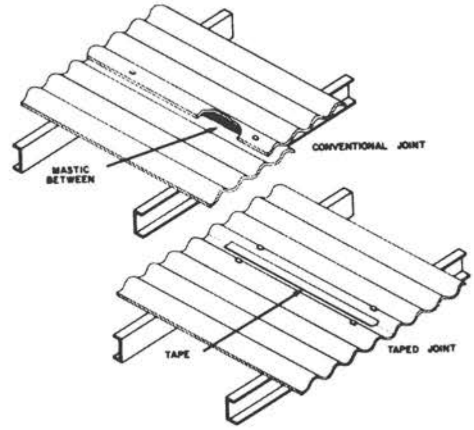

Figure 2

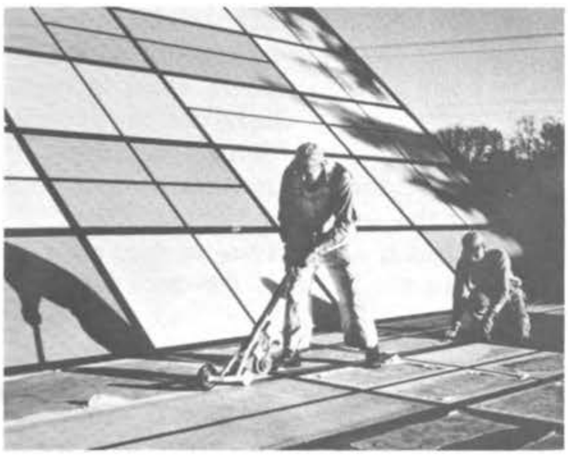

Figure 3

Figure 4

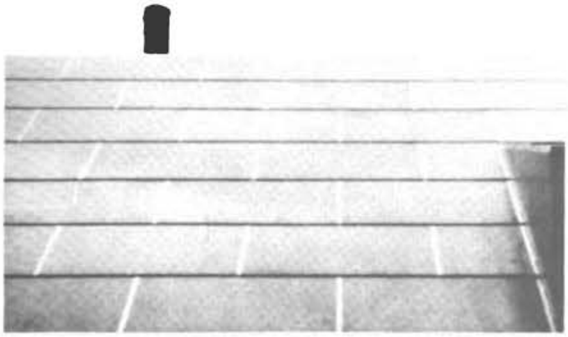

Figure 5

Figure 6

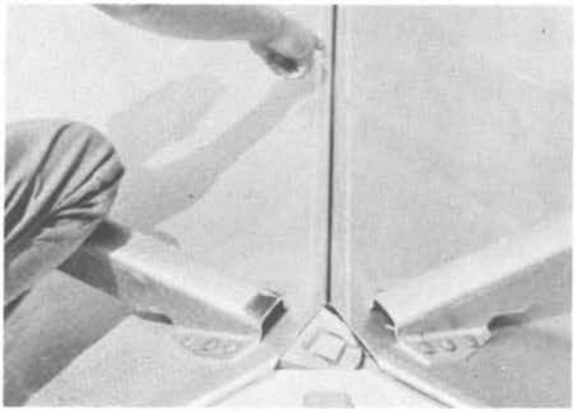

Figure 7

Figure 8

Figure 9

Figure 8 shows a warehouse roof in Minneapolis which is being sealed with aluminum-backed tape to prevent asphalt leaks in case of fire. Since steel is impervious, it is obviously not necessary to cover the whole roof with a sealing membrane, if adequate protection can be obtained at the seams and holes. The hatchet is used, of course, to press the tape down in the folds of the decking.

Figure 9 shows a penthouse containing air conditioning equipment on a factory building in Chicago. The joint detail was a conventional batten and sealant type for prevention of air leaks, which in this case was unsatisfactory. The tape was therefore applied over the edges, bolts and all, as shown. This tape could have been painted, if desired, for better appearance.

In conclusion I would like to emphasize that this is an experimental program. We do not have a long history to guide us when new applications are considered. The uniformly favorable economics and the improved design properties apparent in these examples lead us to believe that tapes will take their place in the family of sealants for the construction industry.

Open Forum Discussion

Moderator—Charles O. Pike, Plant Manager, Tape Division, Shuford Mills

Panel Members—Messrs. Wallace and Wilson

J. W. Prane, Pecora, Inc.: Did you say this was polyvinyl fluoride or polyvinyl chloride tape?

Mr. Wilson: I said polyvinyl fluoride. I'm glad this question was raised because it is very important. Only within the last few months have plastic polymers come out in the quality necessary to provide for a 15 to 20-year seal out of doors. These are very unusual materials, and the classic materials that we are accustomed to talking about will not do the same job. This is not a case where we have obtained some little additive and combined it with a conventional polymer to produce this new tape. We started right with the basic polymer itself.

Mr. Prane: What is the rate of water penetration into the side of the tape joint, particularly under total immersion?

Mr. Wilson: The standard test for pressure-sensitive adhesives measures the rate of moisture penetration through the adhesive as well as the backing. A piece of tape is placed over a hole with only 3/8" contact around the edge so that moisture can run over the adhesive and the width of the flange. This tape will pass the requirement of less than one gram of water per 100 sq. in. per 24 hours. This means flow through the adhesive as well as the backing. This is different than measuring in perms. In perms you do not measure the flow of adhesive at the edge, but rather you measure something per unit of thickness. The tape obviously can't be rated per unit of thickness, because there is only one layer of it, and there is the flow of moisture through the edge as well.

L. P. Smith, Rubber & Plastics Age, London: What type of adhesive is used with the plastic tape used for screw thread sealing?

Mr. Wallace: There is no adhesive applied to the plastic ribbon or tape. It is strictly nonpressure-sensitive; it has no adhesive, no other coating, no back-sizing or anything of that nature. It's just pure 100% extruded plastic. There are pressure-sensitive plastic tapes available which utilize a silicon type of adhesive for other applications, but they are not used for pipe sealing.

Mr. Smith: Which groups of synthetic rubbers are used in the USA for sealing ducts?

Mr. Wallace: The duct-sealing adhesives are permanently flexible, and have a butyl rubber base. Neoprene gaskets are frequently used, but neoprene is not used as the basis of the adhesive. These tapes have a very loose cotton cloth backing, and the adhesive material is extruded around it. It's really a sealant in tape form without backing, so it must be of the butyl type. Where you have a flexible backing put in place with an adhesive, usually these aren't in tape form. These applications are usually at a break in a duct line to afford flexibility and reduce noise. Here you use a separate piece of tape, frequently a neoprene-impregnated material.

Unsigned Question: Would you describe the application of the tape to the threaded joints.

Mr. Wallace: The technique is a very simple one. If you hold one end of the tape and wrap it around the thread, you find that about 1/4 of the way around the thread, the material conforms very readily. It fits mechanically and snugly around the thread so that you can then let go of the end. The only problem that has arisen in using this plastic as a sealant occurs where the joint is backed up. This is one difficulty—tetrafluoroethylene does flow. If you are making a pressure thread, for instance, and this is used on screws threaded at 10,000 psi, you have to be careful not to back it up. If you do, you have to take it off and put on fresh material.

Thomas Christiano, Voorhees Walker Smith Smith & Haines, Architects: In construction, it is difficult to maintain a clean surface upon which to apply tapes. Since this is important for the effective seal of the tape, are there any solvents or other means available to insure a clean surface?

Mr. Wallace: The only accepted solvents in the tape industry are methyl ethyl ketone and toluene. Either one of these may be used effectively to clean the surface prior to applying tape, if a precaution of this type is necessary. A slightly dusty surface will not impair the tape to the point where it will not adhere. The cleaner the surface, however, the better the tape will adhere. If the surface is extremely dirty or covered with oily or greasy films, M.E.K. or toluene will remove this effectively and is quite compatible with the normally available pressure sensitive adhesives.

Mr. Wilson: I agree completely, but in all of the experimental buildings I described, no solvents were used. This includes cement-asbestos, high-density overlay plywood, metal surfaces, and painted surfaces of various types. All we did was wipe them down with a rag, or wipe the dust off.

Mr. Wallace: There is an increasing popularity of aluminum foil-faced thermal insulation, either scrimcloth-reinforced, or kraft paper-reinforced, or embossed aluminum foil. The foil manufacturers use some sort of an oil for embossing or handling the aluminum foil itself, which leaves a very slight, almost unnoticeable film of oil on the aluminum foil facing of thermal insulation. This has been a particular bugaboo, because it isn't apparent that this oily film is on the aluminum foil, and we have received many complaints that the tape doesn't stick. No pressure-sensitive tape will stick to oil. It must be wiped off or removed.

R. C. Hall, Sherwin-Williams Paint Co.: You mentioned polyvinyl fluoride as lasting 15 to 20 years. How did you project this life?

Mr. Wilson: Since the film hasn't yet been available for 15 or 20 years, of course there is a certain amount of guesswork, but we do know the rate of failure. The various polymers that I discussed all fail by different mechanisms. The polyvinyl fluoride fails by gradual embrittlement, and the rate of embrittlement can be measured and projected. We have natural aging life of, I believe, 6 or 7 years. The chlorosulfonated polyethylene fails by erosion, like a paint film. This can be projected; you can measure the rate of erosion and get a thick enough tape to last. We do have technical projection, and obviously, we have some projections based on accelerated aging tests.

Mr. Pike: This is also supported by work of firms like the duPont Company in their studies on the aging of polyvinyl fluoride films.

Mr. Hall: Is this tape paintable?

Mr. Wilson: Yes, but not with every kind of paint. I believe that the vinyl based paints are most effective for the polyvinyl fluoride. This is a subject I don't know too much about. We've had questions on it, and we have referred most of them to the duPont people, who have done much more work on it than we have. I do know of some installations that have been painted successfully.

Mr. Prane, Pecora Paint Co.: Will you please enlarge on your comments regarding the spot of latex material used in crossing one tape joint over another on a roof job?

Mr. Wilson: The polyvinyl fluoride tape is 2-1/2 mils thick. As a result, the adhesive will fill that capillary and seal it. We have no problem, when there is .004" of overlap, and the chlorosulfonated polyethylene actually is .0085 to .009" thick. As the tape is drawn over mechanically, it bridges, and there is a little spot there that can have a little capillarity, so we take a spot of the basic emulsion and seal the corners. This stops the capillary leak. It is done with a toothpick, I believe.

S. B. Twiss, Chrysler-Cycleweld: How easy is it to replace or reseal taped structures? Must the old tape be removed? How is the old tape removed?

Mr. Wallace: This depends on how the tape was exposed during its original life. As the tape is exposed to weathering, and particularly sunlight, the adhesive mass becomes increasingly stiffer, more brittle, and, of course, a more intimate part of the surface. My first suggestion, if it were a cloth or metal foil type of tape, would be to lift up one corner and attempt to strip it. I am sure, if it has been left there for a number of years, that some of the pressure-sensitive adhesive mass will transfer from the original backing onto the surface to which it was applied. Any residue of adhesive left on the original structure can be removed by mek or toluene solvent. I would not recommend, if retaping becomes necessary leaving the old tape in position. It should be removed and fresh tape applied.

Mr. Pike: We generally warn people concerning the application of masking tape to glass. If you leave it on for several days, exposed to sunlight, you will have considerable difficulty in getting it off. However, pointing out some of these bad features may give people the impression that pressure-sensitive tapes do not have permanency. You have to design a tape for permanency, and there are tapes which are designed for permanency, but this problem concerns those temporary types of tapes which should never be used where extreme exposure to sunlight is involved.

W. S. Wieting, Perkins & Will, Architects: Do you have any suggestions for easily removing protective tape which has been left on an exterior surface during construction of a building?

Mr. Wallace: Protective paper is meant for temporary application. We have not encountered many problems where protective paper has been used within the interior of a building. There have been some reactions between certain types of plastic decorative surfaces and the adhesive mass. The best suggestion there is to consult your tape supplier.

On the exterior of buildings there are special considerations. Sunlight, in particular, is detrimental to pressure-sensitive adhesives. If protective paper is used on a building exterior and allowed to weather over a period of time so that it has more or less cured in position, it would be extremely difficult to remove. The paper also would be difficult to strip off, because of its lack of strength. I don't know what the answer is, other than soaking in a solvent which might attack the coating beneath the protective paper, and then scraping it off.

Mr. Wilson: The National Assn. of Architectural Metal Manufacturers has, very foresightedly, tackled this problem and, in its Curtain Wall Handbook, has defined the three levels of protection needed for protective tapes; the interior types, the limited exterior types, and the heavy-duty exterior types. If you follow those standards, you will stay out of trouble. There are protective tapes you can use outdoors. They cost a little bit more, so they are not specified automatically by your architect or metal supplier, unless you request them, because he thinks you are going to take the tape off right away. I will be glad to make available the names of some of the better stripping materials to solve this problem. Not only are solvents used, but certain types of paint strippers are very effective also.

R. T. Hess, Hess Mfg. Co.: Is carbon-tetrachloride suitable for cleaning aluminum surfaces prior to taping?

Mr. Pike: Carbon tetrachloride is effective for cleaning surfaces, but it's a toxic solvent and in our particular type of operation we avoid it since it can be hazardous to handle. I would not recommend carbon tet. I would stick to the conventional napthas or something that's less toxic.

B. Mittman, Elm Coated Fabric Co.: Would an unplasticized polyvinyl chloride tape be effective in extending the life expectancy beyond six months?

Mr. Wilson: I was talking about an unplasticized PVC when I talked about 3 or 4 months outdoors. The plasticized types of PVC are usually copolymers and have to be very highly pigmented in order to have any aging life outdoors. It depends on which side of the building it is on, and whether it is in Texas or Minnesota, etc. The intensity of ultraviolet rays, temperature, many things affect its aging life. An unplasticized PVC is, speaking from a semi-prejudiced standpoint, a very poor outdoor aging polymer. It has nowhere near the aging life of the polymers we were discussing.

G. K. Garden, National Research Council of Canada: Are there any pressure-sensitive paper tape protective coatings which will permit four to six months of exposure to sun and weather and still be easily removable?

Mr. Wallace: We are beginning to approach this life for protective paper, but from the evidence we have, I do not know of any commonly available paper protective tape that can be guaranteed for six months of outdoor exposure. Usually, some other type of material is used for protection on exterior surfaces of a building.

Mr. Wilson: One of the NAAMM standards covers this, and the most permanent type for use outdoors will actually take six months of exposure. We have had no problem even with two years of outdoor exposure, but this tape is a little more expensive than the interior type.

Mr. Pike: There are paper tapes with special coatings or of special composition which will take in the neighborhood of six months exposure outdoors, and probably more.

Carl J. Ebert, Construction Specification Institute: What is the life expectancy of exterior pressure-sensitive tapes?

Mr. Wilson: When you speak of an exterior exposure life, you must refer to a given climate, and you must refer to the exposure of the building—whether it's a northern or southern exposure, etc. We are expecting out of these new polymers, based on accelerated tests, 15 to 20 years, but this is a tremendous generalization, of course.

O. L. Pierson, Rohm & Haas Co.: Have tapes, folded lengthwise, ever been used to set or seal glazing or spandrel panels in place of caulking compounds?

Mr. Wallace: Yes, several applications have recently come to our attention where a tape was used lengthwise along one edge of sliding glass doors, the type used in residential areas, prior to inserting the glass panels within their aluminum framework. Usually a plastic variety, silver in color to match the aluminum, has been applied, and then set into the frame. This is not, however, an application that I would recommend. I would prefer to see a more flexible, longer life material used, such as the extruded sealing compound tapes of the butyl base used in the heating, ventilating and air conditioning systems.

Mr. Pike: If you have problems, I would suggest that you contact the tape companies directly. You can get a list of various companies from the Pressure-Sensitive Tape Council. These companies have numbers of technical people on staff, and they are quite willing to tackle problems of economic value. In this way, you will avoid some of the pitfalls that come from using materials without proper advice.

H. A. Segalas, Procter & Gamble: Are there any pressure-sensitive tapes that block out either some light or all of the light?

Mr. Wilson: Such a product is available experimentally. It blocks out some 90% of the infrared rays and some 70% of the visible light. The idea is to pass some of the visible light, but block out as much of the heat from that visible light as possible. This is a permanent application of tape to the glass, and I would not care to speculate as to how long it will last. We hope it is permanent.

Mr. Wallace: Applying a pressure-sensitive tape to the interior of the window, thus exposing the pressure-sensitive adhesive to the direct sunlight would, in almost all cases, be quite detrimental to the adhesive in terms of embrittlement. It would also be quite difficult, if not impossible, to remove it in cases where desired. There are special adhesives that can be formulated for this type of application, as well as the outdoor type of application.

W. E. Kemp, Koppers Co., Inc: Is there any mold problem in Florida with the adhesive?

Mr. Wilson: No, we worked this through with the fungicide experts. This was a question of the plasticizer and some other things that we have gradually learned to leave out. Most of the advanced adhesives now are single-component systems which are fungi-inert technically.

Mr. Wallace: Waterproof cloth tapes, and cloth tapes in general, have been impregnated with agents to combat growth of this nature since World War II. These were developed in coordination with the Army Engineers, etc., so they are commonly available. This property is built into most modern adhesives.

S. B. Twiss, Chrysler-Cycleweld: Are there tapes specifically developed for use with masonry or concrete that are alkali resistant?

Mr. Wilson: The cement-asbestos siding on the first building I discussed was applied with such an adhesive. These are really not very difficult to use, technically. In fact, you can take advantage of a little free alkali sometimes to achieve a better bond. The problem with these types of surfaces is that often the surface finish is inadequate for a really watertight seal with the tape. In talking about a taped joint on concrete surfaces, what we want to know is not whether the tape is adequate, but how is the finish, and how do you guarantee that the finish is going to be right. The problem of adhesion is relatively simple.

Unsigned question: Has a pressure-sensitive roof flashing been developed?

Mr. Wilson: Flashings take two different forms: one you lay in place, and the other you slide into place, and you have to smear it in, to be sure it is smooth. Pressure-sensitive adhesive normally is so firm that you can't do that; all you can do is lay it. In the typical installation where you slide flashing in place, you should use a conventional adhesive which, at the point of setting up, has a very short molecular chain length, is quite viscous, and will flow. Pressure-sensitive adhesive is designed not to flow, so you can't ever slide it. Exploration of adhesive for applications where you lay the flashing in place is under way, but this is a different technique and calls for different details.

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