Designation: C 898 – 95

Standard Guide for Use of High Solids Content, Cold Liquid-Applied Elastomeric Waterproofing Membrane with Separate Wearing Course[1]

This standard is issued under the fixed designation C 898; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide describes the use of a high solids content, cold liquid-applied elastomeric waterproofing membrane in a waterproofing system subject to hydrostatic pressure for building decks over occupied space where the membrane is covered with a separate protective wearing course.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 33 Specification for Concrete Aggregates[2]

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates[2]

C 717 Terminology of Building Seals and Sealants[3]

C 755 Practice for Selection of Vapor Retarders for Thermal Insulations[4]

C 836 Specification for High Solids Content, Cold Liquid-Applied Elastomeric Waterproofing Membrane for Use with Separate Wearing Course[3]

C 920 Specification for Elastomeric Joint Sealants[3]

C 962 Guide for Use of Elastomeric Joint Sealants[5]

D 1056 Specification for Flexible Cellular Materialsù-Sponge or Expanded Rubber[6]

D 1751 Specification for Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)[7]

D 1752 Specification for Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction[7]

D 3253 Specification for Vulcanized Rubber Sheeting for Pond, Canal, and Reservoir Lining[8]

2.2 *American Concrete Institute Standard:*

301-72 (1975) Specifications for Structural Concrete for Buildings[9]

3. Terminology

3.1 Refer to Terminology C 717 for definitions of the following terms used in this guide: bond breaker; cellular; cold joint; compatibility; compound; construction joint; control joint; creep; dry film thickness; elastomer; expansion joint; gasket; isolation joint; joint; laitance; primer; reglet; reinforced joint; sealant; spalling; waterproofing.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cold-applied*—capable of being applied without heating as contrasted to hot-applied. Cold-applied products are furnished in a liquid state, whereas hot-applied products are furnished as solids that must be heated to liquefy them.

3.2.2 *curing time*—the period between application and the time when the material reaches its design physical properties.

3.2.3 *deflection*—the deviation of a structural element from its original shape or plane due to physical loading, temperature gradients, or rotation of its supports.

3.2.4 *drainage board—see prefabricated drainage composite*, the preferred term.

3.2.5 *drainage course*—see *percolation layer* and Fig. 1.

3.2.6 *finish wearing surface*—see *traffic surface*.

3.2.7 *flashing*—a generic term describing the transitional area between the waterproofing membrane and surfaces above the wearing surface of the building deck; a terminal closure or barrier to prevent ingress of water into the system.

3.2.8 *floated finish*—a concrete finish provided by consolidating and leveling the concrete with only a power driver or hand float, or both. A floated finish is coarser than a troweled finish. For specifications, see ACI 301-72 (1975).

3.2.9 *freeze-thaw cycle*—the freezing and subsequent thawing of a material.

[1] This guide is under the jurisdiction of ASTM Committee C-24 on Building Seals and Sealants and is the direct responsibility of Subcommittee C24.80 on Building Deck Waterproofing Systems.

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.07.

[4] *Annual Book of ASTM Standards*, Vol 04.06.

[5] Discontinued. See 1992 *Annual Book of ASTM Standards*, Vol 04.07. Replaced by C 1193.

[6] *Annual Book of ASTM Standards*, Vol 08.01.

[7] *Annual Book of ASTM Standards*, Vol 04.03.

[8] Discontinued. See 1988 *Annual Book of ASTM Standards*, Vol 04.09.

[9] Available from American Concrete Institute, P.O. Box 19150 Redford Station, Detroit, MI 48219.

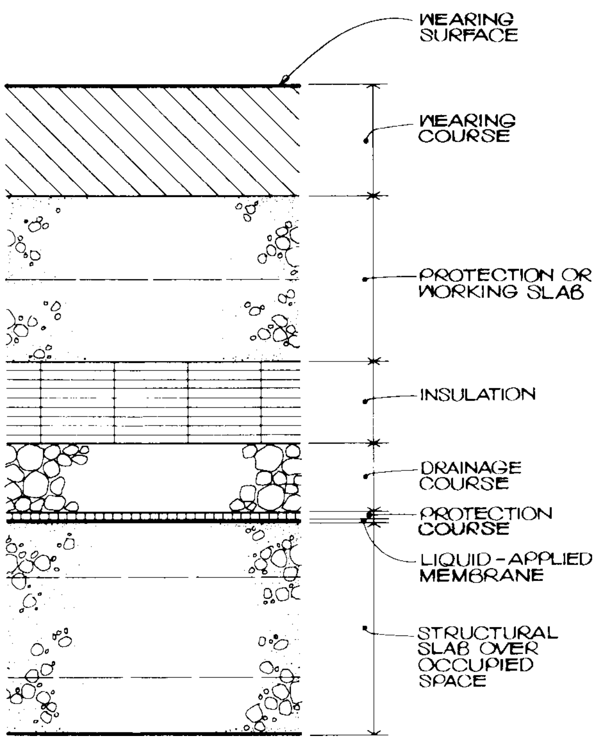

FIG. 1 Basic Components of Cold Liquid-Applied Elastomeric Membrane Waterproofing System with Separate Wearing Course

3.2.10 *grout*—concrete containing no coarse aggregates; a thin mortar.

3.2.11 *percolation layer (drainage course)*—a layer of washed gravel or of a manufactured drainage media that allows water to filter through to the drain (see Fig. 1).

3.2.12 *prefabricated drainage composite*—proprietary devices to facilitate drainage, usually a composite laminate of more than one material including filter fabric.

3.2.13 *protection board*—see *protection course*.

3.2.14 *protection course*—semi-rigid sheet material placed on top of the waterproofing membrane to protect it against damage during subsequent construction and to provide a protective barrier against compressive and shearing forces induced by materials placed above it (see Fig. 1).

3.2.15 *structural slab*—a horizontal, supporting, cast-in-place, concrete building deck. See Fig. 1.

3.2.16 *traffic surface*—a surface exposed to traffic, either pedestrian or vehicular, also described as finish wearing surface.

3.2.17 *troweled finish*—a concrete finish provided by smoothing the surface with power driven or hand trowels or both, after the float finishing operation. A troweled finish is smoother than the floated finish. For specifications, see ACI 301-72 (1975).

3.2.18 *wearing surface*—see *traffic surface*.

3.2.19 *wet-film thickness*—the thickness of a liquid coating as it is applied.

3.2.20 *wet-film gage*—a gage for measuring the thickness of a wet film.

4. Significance and Use

4.1 This guide provides design considerations for the design of the waterproofing system as well as guide specifications. The intent of Sections 5-14 is to provide information and guidelines for consideration of the designer of the waterproofing system. The intent of the remaining sections is to provide minimum guide specifications for the use of purchaser and seller in contract documents. Where the state of the art is such that criteria for a particular condition is not as yet firmly established or has numerous variables that require consideration, reference is made to the applicable portion of Sections 5-14 that covers the particular area of concern.

DESIGN CONSIDERATIONS

5. General

5.1 *Major Components, Subsystems, and Features*—The major components to be considered for a building deck waterproofing system are the structural building deck or substrate to be waterproofed, waterproofing membrane, protection of the membrane, drainage, insulation, and wearing course (see Fig. 1). Additional features to be considered are membrane terminal conditions and expansion joints.

5.2 *Compatibility*—It is essential that all components and contiguous elements be compatible and coordinated to form a totally integrated waterproofing system.

6. Substrate

6.1 *General*—The building deck or substrate referred to in this guide is reinforced cast-in-place structural concrete. Precast concrete slabs pose more technical problems than cast-in-place concrete, and the probability of lasting watertightness is greatly diminished and difficult to achieve because of the multitude of joints which have the capability of movement and must be treated accordingly. Moving joints are critical features of waterproofing systems and are more critical when sealed at the membrane level than at a higher level with the use of integral concrete curbs. Such curbs are impractical with precast concrete slabs and necessitate an even more impractical drain in each slab. Other disadvantages of precast concrete slabs are their inflexibility in achieving contoured slope to drains and the difficulty of coordinating the placement of such drains.

6.2 *Strength*—The strength of concrete is a factor to be considered with respect to the liquid-applied membrane insofar as it relates to finish, bond strength, and continuing integrity (absence of cracks and other defects that could affect the integrity of the membrane after installation).

6.3 *Density and Moisture Content*—Density of concrete and moisture content when cured are interrelated and can affect adhesion of the membrane to the substrate with an excessively high moisture content, moisture may condense at the membrane and concrete interface and cause membrane delamination. This is particularly so if the top surface is cooler than the concrete below. Lower moisture contents are achieved with the use of hard, dense, stone aggregate. This type of coarse aggregate will generally provide structural concrete with a moisture content from 3 to 5 % when cured. Lightweight aggregate, such as expanded shale, will generally provide lightweight structural concrete with a moisture content from 5 to 20 % when cured. Lightweight insulating concrete made with a weaker expanded aggregate, such as perlite, has a relatively low compressive strength and can contain over 20 % moisture when cured. The concrete used for the substrate should have a minimum density of 1762 kg/m^3 (110 lb/ft^3) and have a maximum moisture content of 8 % when cured. From this it can be seen that only certain lightweight aggregates can be considered for use and no lightweight insulating aggregates can be used.

6.4 *Admixtures, Additives, and Cement/Concrete Modifiers*—Admixtures, additives, and modifiers serve many functions in mixing, forming, and curing concrete, such as to retard or accelerate the cure rate; reduce the water content required; entrain air; increase strength; create or improve the ability of the concrete to bond to existing, cured concrete; permit thin topping overlayers; and improve workability. Some admixtures and modifiers (particularly polymeric, latex, or other organic chemical based materials) may coat the concrete particles and reduce the ability of the waterproofing membrane to bond to the concrete. The membrane manufacturer should be consulted if the concrete used for the deck will contain any admixtures, additives, or modifiers in order to determine the compatibility of the membrane with the concrete.

6.5 *Underside Liner and Coating*—The underside of the concrete deck should not have an impermeable barrier. A metal liner or coating that forms a vapor barrier on the underside can trap moisture in the concrete and destroy or prevent the adhesive bond of the membrane to the upper surface of the concrete. Uniformly spaced perforations in metal liners may provide a solution to the vapor barrier problem but as yet there are no definitive data on the requirements for the size and spacing of the perforations. It should also be recognized that this method would preclude any painting of the metal liner after the concrete is poured on it.

6.6 *Slope for Drainage*—Drainage at the membrane level is important. When the waterproofing membrane is placed directly on the concrete slab a monolithic concrete substrate slope of a minimum 11 mm/m (⅛ in./ft) should be maintained. Slope is best achieved with a monolithic structural slab and not with a separate concrete fill layer. The fill presents the potential of additional cracks and provides a cleavage plane between the fill and structural slab. This cleavage plane complicates the detection of leakage in the event that water should penetrate the membrane at a crack in the fill and travel along the separation until reaching a crack in the structural slab.

6.7 *Finish*—The structural slab should have a finish that facilitates proper application of the liquid-applied membrane. The surface should be of sufficiently rough texture to provide a mechanical bond for the membrane but not so rough as to preclude achieving continuity of the membrane of the specified thickness across the surface. As a minimum, ACI 301-72 (1975) floated finish is required with ACI 301-72 (1975) troweled finish preferred, deleting the final troweling.

6.8 *Curing*—Curing of the structural slab is necessary to provide a sound concrete surface and to obtain the quality of concrete required. The concrete should be cured a minimum of 7 days and aged a minimum of 28 days including curing time, before application of the liquid-applied membrane. Curing is accomplished chemically with moisture and should not be construed as drying.

6.8.1 *Moist Curing*—Moist curing is achieved by keeping the surfaces continuously wet by covering them with burlap saturated with water and kept wet by spraying or hosing. The covering material should be placed to provide complete surface coverage with joints lapped a minimum of 75 mm (3 in.).

6.8.2 *Sheet Curing*—Sheet curing is accomplished with a sheet vapor retarder that reduces the loss of water from the concrete and moistens the surface of concrete by condensation, preventing the surface from drying while curing. Laps of sheets covering the slab should not be less than 50 mm (2 in.) and should be sealed or weighted (see Practice C 755).

6.8.3 *Chemical Curing*—Liquid or chemical curing compounds should not be used unless approved by the manufacturer of the liquid-applied membrane as the material may interfere with the bond of the membrane to the structural slab.

6.9 *Dryness*—Membrane manufacturer's requirements for substrate dryness vary from being visibly dry to passing a 4-h glass test with no condensate, or having a specific maximum moisture content as measured by a moisture meter. Since there is a lack of unanimity in this regard, it is necessary to meet the manufacturer's requirements for the particular membrane being applied.

6.10 *Joints*—Joints in a structural concrete slab in this guide are referred to as reinforced joints, nonreinforced joints, and expansion joints.

6.10.1 *Reinforced Joints*—Reinforced joints consist of hairline cracks, cold joints, construction joints, isolation joints, and control joints held together with steel reinforcing bars or wire fabric. These are considered static joints with little or no anticipated movement because the slab reinforcement is continuous across the joint.

6.10.2 *Nonreinforced Joints*—Nonreinforced joints consist of butted construction joints and isolation joints not held together with steel reinforcing bars or wire fabric. These joints are generally considered by the designer of the structural system as nonmoving or static joints. However, they should be considered as capable of having some movement, the magnitude of which is difficult to predict.

6.10.3 *Expansion Joints*—Expansion joints are designed to accommodate a predetermined amount of movement. Such movement could be due to thermal change, shrinkage, creep, deflection, or other factors and combinations of factors. In the detailing of expansion joints to achieve watertightness, the amount of movement anticipated should be carefully determined using a reasonable factor of safety. The opening size and configuration should then be related to the capability of the joint seal materials to accommodate the anticipated movement. Expansion joints are best located at the high points of a contoured slab to permit water to flow away from the joint.

7. Membrane

7.1 *Adherence to Substrate*—A liquid-applied waterproofing membrane has the capability of adhering to the structural slab and should be applied to take optimum advantage of this inherent characteristic. The detection of leakage in a building deck waterproofing system that is covered over with a separate wearing course could be a significant problem when the waterproofing membrane is not bonded to the structural slab or when additional layers of material separate the membrane from the structural slab. Water penetrating an unbonded membrane could migrate laterally under the membrane until reaching a crack or defect in the structural slab and then leak through to the space below. Leakage through the slab, therefore, would not necessarily indicate the location of the water entry in the membrane above. That point could be at a considerable distance away, and the costly removal of large areas of the wearing course might be required before it is located.

7.2 *Placement Protection*—The membrane should be applied under dry, frost-free conditions on the surface as well as throughout the depth of the concrete slab. Excessive moisture in the substrate (see 6.3) or moisture on the surface (see) as from frost or rain will result in a defective membrane with such deficiencies as an improper cure with formation of excessive gas pockets and little or no adhesion to the substrate. Should rain or snow interrupt the application after at least one coat of material has been applied, the instructions of the membrane manufacturer should be followed pertaining to any necessary treatment of the cured, already applied material prior to continuation.

7.3 *Terminal Conditions*—Four locations where a liquid-applied membrane is normally terminated or interrupted are on walls, at drains, at penetrations, and at expansion joints having relatively large movement. The important consideration at terminal conditions is to prevent water from penetrating into the substrate or behind the membrane at its edge.

7.3.1 *Termination on Walls*—When the membrane is turned up on a wall, it is preferable to terminate it above the wearing surface to eliminate the possibility of ponded surface water penetrating the wall above the membrane and running down behind it into the building. The minimum safe height of such a termination is dictated by the opportunity for conditions such as ponding and drifted snow presented by the building's geometry and environment. A liquid-applied membrane, because of its inherent adhesive properties, may be terminated flush on the wall without the use of a reglet. However, the use of a reglet in a concrete wall has the advantage of providing greater depth protection at the terminal. The reglet should be a minimum of 6.3 mm (¼ in.) deep and 6.3 mm (¼ in.) wide. Termination on a masonry wall will require counterflashing (see Figs. 2-4).

7.3.2 *Termination at Drains*—Drains should be designed with a wide flange or base as an integral part. The drain base should be set flush with the structural slab. The wide flange provides a termination point for the liquid-applied membrane

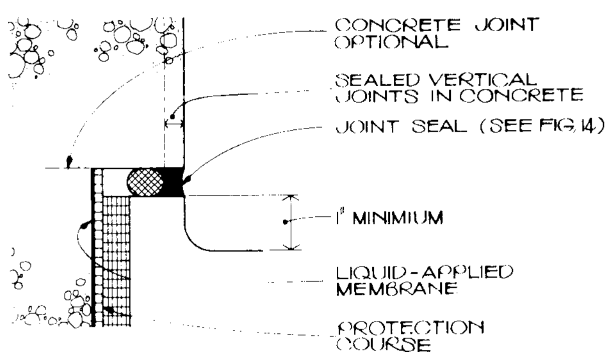

FIG. 2 Terminal Condition Above Finish Grade on Concrete Wall (see 7.3.1)

without endangering the function of the membrane or the drain (see Fig. 5).

7.3.3 *Termination at Penetrations*—Penetrations or protrusions through the slab by such items as conduits and service pipes create critical problems and should be avoided wherever possible. For protection at such critical locations, pipe sleeves should be cast into the structural slab against which the membrane can be terminated (see Fig. 6). Core drilling to provide openings for penetrations is not recommended.

7.4 *Treatment at Joints*—Joints in the structural slab should be treated as follows, depending upon whether they are reinforced joints, nonreinforced joints or expansion joints:

7.4.1 *Treatment at Reinforced Joints*—Fig. 7 indicates one recommended treatment of reinforced concrete joints in the structural slab. The designer should realize that the elongation capacity of this type of detail is quite limited and implicitly relies on the membrane's crack-bridging ability to withstand the strains imposed by the opening of cracks and reinforced joints. An alternative approach that may be considered is to prevent the membrane from adhering to the substrate for a finite width centered on the joint or crack by means of a properly designed compatible bond-breaker tape.

7.4.2 *Treatment at Nonreinforced Joints*—Nonreinforced joints that are in reality nonmoving could be treated in the same manner as reinforced joints. However, since the joints are not held together with reinforcing steel, some movement, however slight, should be anticipated and provided for, since the liquid-applied membrane has limited ability to take movement. Nonreinforced joints could open due to such factors as shrinkage, creep, and thermal contraction. Fig. 8 shows a nonreinforced butted joint that is capable of expanding 3.2 mm (⅛ in.), the minimum that should be provided for when using a sealant capable of ± 25 % movement. The minimum sealant width should be correspondingly wider with a sealant having lesser movement capability. If the designer of the structural system feels that greater movement than 3.2 mm (⅛ in.) could occur in such joints, they should be treated as expansion joints.

7.4.3 *Treatment at Expansion Joints*—There are basically two concepts that could be considered in the detailing of expansion joints at the membrane level of membrane waterproofing systems. These are the *positive seal concept* directly at the membrane level and the *water shed concept* with the seal at a higher level than the membrane. Where additional safeguards are desired, a drainage gutter under the joint could be considered (see Fig. 9). Note that flexible support of the membrane is required in each case. Expansion joint details should also be considered and used in accordance with their movement capability.

7.4.3.1 *Positive Seal Concept*—The positive seal concept entails a greater risk than the water shed concept since it relies fully on positive seal joinery of materials at the membrane level, where the membrane is most vulnerable to water penetration. The materials used, and their joinery, must be carefuly engineered by the manufacturer of the liquid-applied waterproofing system, and subsequent field installation requires the best of workmanship with no margin for error for potential success. Since the precision required is not always attainable, this concept is best avoided.

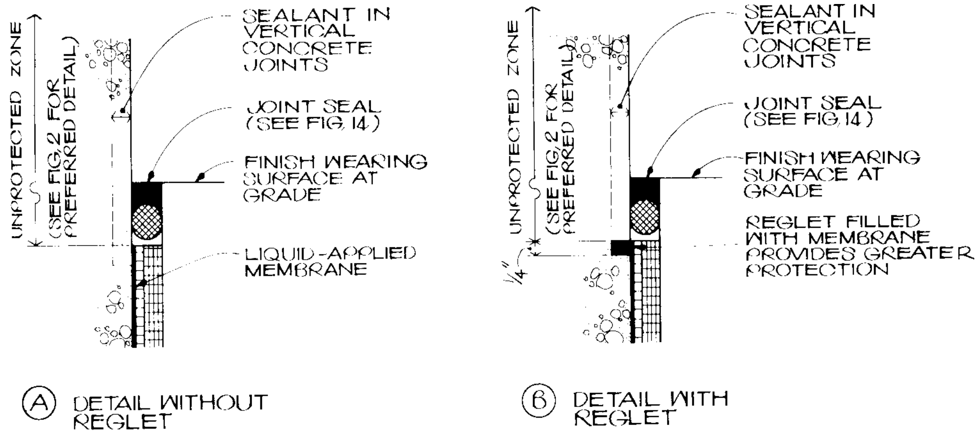

FIG. 3 Terminal Conditions on Concrete Wall Below Finish Wearing Surface at Grade (see 7.3.1)

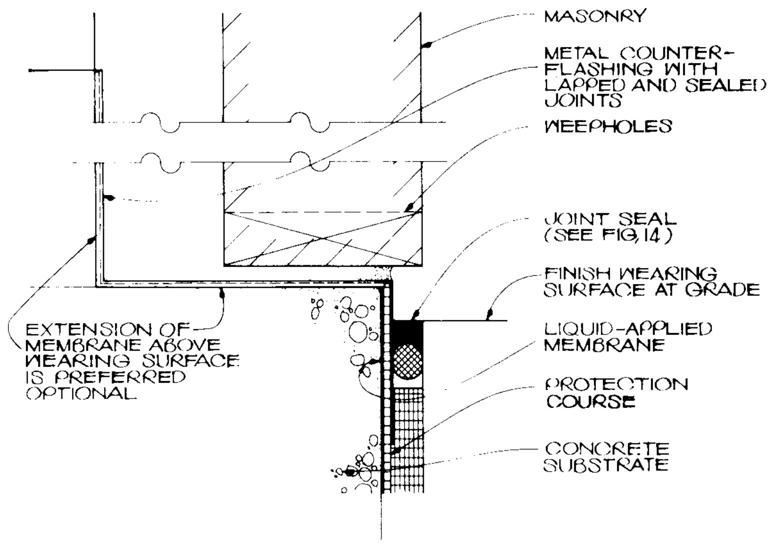

FIG. 4 Terminal Condition with Masonry Above Finish Wearing Surface at Grade (see 7.3.1)

7.4.3.2 *Water Shed Concept*—The water shed concept, although requiring a greater height and more costly concrete forming, is superior in safeguarding against leakage, having the advantage of providing a water dam at the membrane level. The joinery of differing materials can then be placed at a higher level and treated somewhat in the manner of counterflashing, hence the term "water shed concept." However, if a head of water rises to the height of the material joinery, this concept becomes almost as vulnerable as the positive seal concept. Therefore, drainage is recommended at the membrane level and is further analyzed in Section 9.

7.4.3.3 *Provision for Movement*—Generally, expansion joints in a structural slab are seldom less than 30.5 m (100 ft) apart and may be as much as 91.4 m (300 ft) or more apart. Therefore, relatively large amounts of total movement are to be dealt with, generally in the range from 13 mm (½ in.) up to 38 mm (1½ in.). Maximum movement generally occurs during the construction phase before insulation and wearing course are installed over the membrane. However, the joint should be detailed for maximum movement at any time. Since it is unpredictable when the membrane will be installed, taking opening and thermal conditions into consideration, an expansion joint detail that cannot take ± 9 mm (⅜ in.) of movement is hardly worth considering. Such movement, when treated as a sealant joint and using the positive seal approach, requires a joint width of 75 mm (3 in.), and this is considered impractical. Gaskets and flexible preformed sheets lend themselves better to absorbing such amounts of movement. Since such materials, when used at an expansion joint, must be joined to the liquid-applied membrane, the water shed concept should be used. Figs. 10-12 indicate expansion joints using the water shed concept that have a movement capability of ± 9 mm (⅜ in.) when installed in a designed concrete opening of the width indicated. These details could be increased in movement capability with a larger gasket and concrete opening if so desired.

8. Protection Course

8.1 *General*—The liquid-applied membrane should be protected from damage prior to and during the remainder of deck construction. A protection course should be applied after the membrane is installed. The protection course, which is most commonly a protection board, also serves to protect the membrane from damage due to movement and penetration of materials above after the deck construction is complete. The proper timing of the application of the protection course after

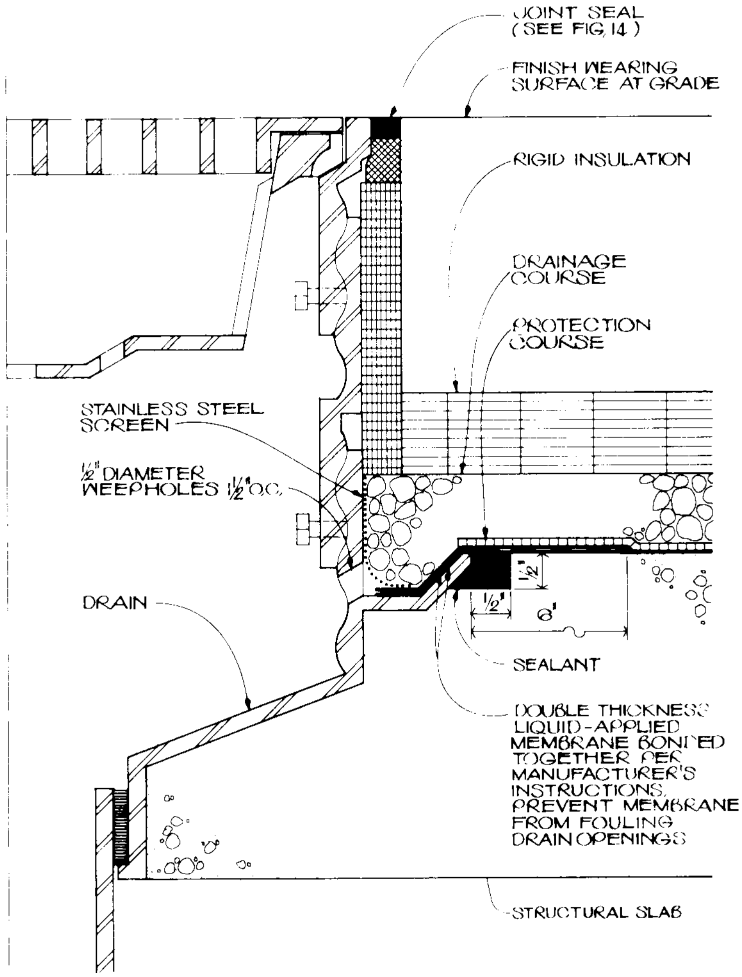

FIG. 5 Termination at Drain

placement of the membrane is important and could vary with the proprietary type of membrane used. The manufacturer's printed instructions should be followed.

9. Drainage System

9.1 *General*—When the membrane waterproofing is covered over with a wearing surface, it is necessarily assumed that water can and will reach the membrane; otherwise, the membrane below the wearing surface would not be needed. Drainage should then be considered as a total system from the wearing surface down to the membrane. Since it would be undesirable to permit water to build up below the wearing surface, multilevel drains should be used, with particular emphasis on rate of flow into the drain at the membrane level. Basically, the drainage system is analyzed as to how it functions both at the membrane level and at the wearing surface.

9.2 *Requirements for Drainage at Membrane Level*—It is essential that water be removed from the membrane level for the following reasons:

9.2.1 To avoid building up a pressure head against the membrane and particularly against the more vulnerable splices and joints in the system.

9.2.2 To avoid freeze-thaw cycling of trapped water which could heave and disrupt the wearing course.

9.2.3 To minimize the deleterious effect prolonged undrained water could have on wearing course materials.

9.2.4 To minimize thermal inefficiency of wet insulation and of water under the insulation.

9.3 *Recommendations for Drainage at Membrane Level*:

9.3.1 Slope the monololithic concrete substrate under the membrane a minimum of 11 mm/m (⅛ in./ft).

9.3.2 Slope the monolithic concrete substrate under the membrane so as to drain away from expansion joints and walls.

9.3.3 Use a drainage course to increase the rate of flow to drains.

9.3.4 Avoid undrained pockets such as downward loops of flashing into expansion joints.

9.3.5 Use multilevel drains capable of draining all layers of the building deck. The drain should have an integral flange at least 50 mm (2 in.) for adherence and bonding with the concrete slab and to provide for termination of the liquid-applied membrane with sufficient room for an adhesive bond. The flange should be set level with the structural slab surface.

9.4 *Drainage Concepts at Wearing Surface*—Drainage at the wearing surface is generally accomplished in one of two ways: (*1*) by an open-joint system permitting most of the rainwater to penetrate rapidly down to the membrane level and subsurface drainage system, or (*2*) by a closed-joint system

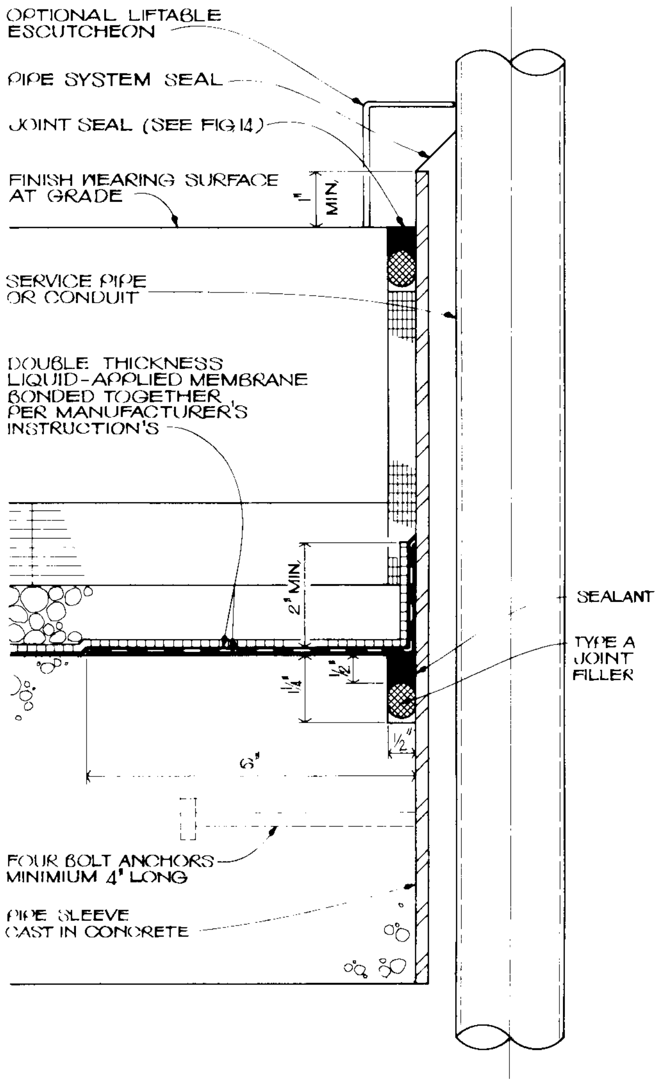

FIG. 6 Termination at Pipe Penetrations (see 7.3.3 and 17.9)

designed to remove most of the rainwater rapidly by slope to surface drains and allowing a minor portion to infiltrate gradually down to the membrane level. Either system may be used over a lower-level membrane, the choice generally being governed by the materials desired for the wearing course.

9.4.1 *Open-Joint System*—The vertical joints in the horizontal wearing course could be left open (unsealed) provided the joints are less than 6.3 mm (¼ in.) wide and do not present a walking hazard, and if proper drainage is provided at the membrane level. This is generally accomplished by what is known as a pedestal system discussed in 9.4.2.

9.4.1.1 *Advantages and Disadvantages*—An open-joint system eliminates the cost and maintenance of sealant joints and compression seals. Another advantage is that the wearing surface can be designed to be level, but it is advisable for each individual panel to have a slight crown upward at the center to avoid possible ponded water for a period of time after a rainfall. An option would be a weephole in the center of each panel. A disadvantage is the problem of debris which can collect in the joints and in subsurface drains. In the deck design, drain maintenance methods should be carefully considered. Another design problem presented by open joints in the wearing course is the possibility of inducing condensation on the interior ceiling of the space below the plaza deck. This potential problem can be minimized by placing the insulation as close to the waterproofing membrane as possible so that cold water is not continually taking heat out of the structural slab.

9.4.2 *Pedestal System*—Pedestals are used to support relatively large areas of such materials as precast concrete slabs, natural stone slabs, and prefabricated masonry. The space below the wearing course is left open and the varying height is accommodated by varying the height of the pedestals. Although left open, the joints should have resilient spacers to avoid problems of creeping or shifting panels. In a design where pedestals are intended to bear directly on the protection board, the designer of the system should consult the membrane and protection board manufacturers and determine that the imposed loads will not have damaging effects on the membrane and protection board under the service conditions anticipated. The amount of compression deflection expected should also be analyzed as to the possibility of creating uneven settlement of the wearing course panels. Consideration should also be given to the possible damaging effects on the membrane and protection board caused by initial installation of pedestals as well as subsequent traffic, emergency vehicles, or thermally induced lateral loads transmitted to the pedestals from the wearing course panels. In no case should the pedestals be placed directly on the membrane, and where insulation is required and the designer considers placement of the pedestals directly on the insulation, a type should be used that has, as a minimum, the following characteristics:

9.4.2.1 Extremely low absorptivity.

9.4.2.2 A specific gravity greater than water.

9.4.2.3 Sufficiently high compressive strength to resist reduction in thickness or penetration by the pedestals under the imposed dead and live loads.

9.4.2.4 Long-term resistance to water immersion and freeze-thaw cycling.

9.4.2.5 The ability to sustain construction damage while work is progressing at the site until such time as the final wearing course can be installed.

(a) (*a*) An insulating material meeting the requirements in 9.4.2.1-9.4.2.5 would be difficult to find. The present state of the art dictates using a concrete protection slab over a suitable insulation. See Section 11. Should it be determined that a concrete protection course may not be needed for the specific conditions of a given project (see Section 12), consideration shall still be given to precluding damage and compression deflection to the insulation. In some applications, a single course protection board may be adequate for this purpose.

9.4.3 *Closed-Joint System*—A closed joint system is normally used with a wearing course of relatively small prefabricated units, impractical to support on pedestals, or with larger areas of cast-in-place concrete. Dynamically moving joints in such systems are filled with sealant or compression seals. The wearing course materials are relatively impermeable. The wearing surface is sloped to drains, but provisions should be made for the infiltration of water down to the membrane level and the subsurface drainage system.

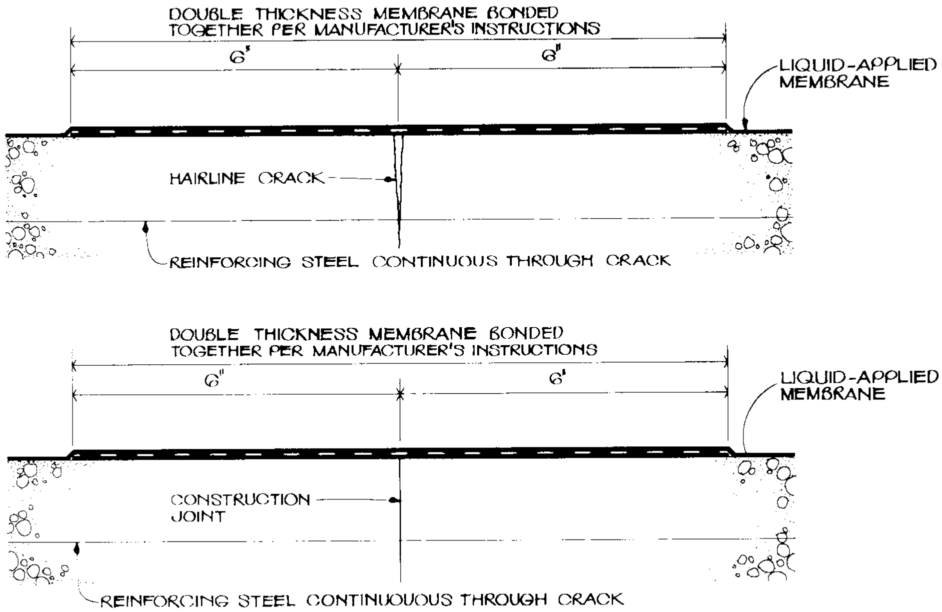

FIG. 7 Treatment of Reinforced Cracks and Joints in Concrete Slab (see 7.4.1)

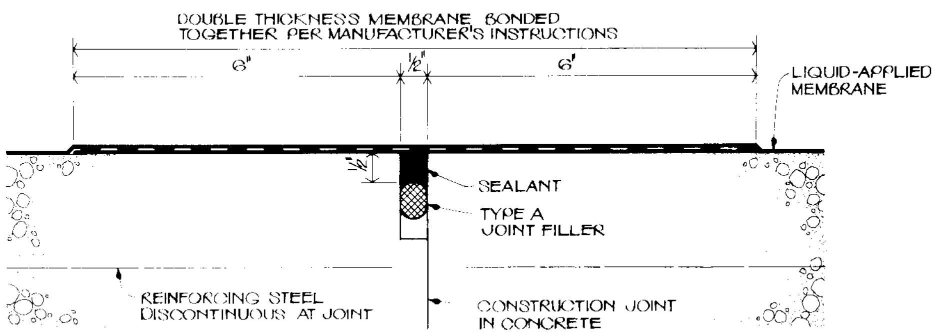

FIG. 8 Treatment of Nonreinforced Butted-Joint in Concrete Slab (see 7.4.2)

10. Drainage Course

10.1 Recognizing that water may infiltrate below the wearing course to be carried off on top of the membrane to the drains, a drainage course of washed, round gravel should be provided above the protection board, over the liquid-applied membrane. This permits water to filter to the drain and provides a place where it can collect and freeze without potential damage to the wearing course. If concrete is to be placed as the wearing course, a minimum 0.1 mm (4-mil) perforated polyethylene layer should be placed over the drainage course to prevent concrete from filling up the drainage course voids. Also, the drainage course should be stabilized if the deck is to withstand vehicular traffic, because of the likelihood of lateral shifting under thrust, even without vehicular traffic, if free to move laterally on a sloping surface. One method of stabilizing aggregate, while still maintaining its percolation characteristics, is to use a controlled amount of epoxy binder, thoroughly mixed with the aggregate before installation. The quantity to be used is related to aggregate size and gradation. Several proprietary binders are available, and the manufacturer's instructions should be followed regarding use and installation. A cement binder is also used for this purpose in a material known as no-fines concrete. Sufficient binder is necessary to stabilize the aggregate, but an excessive amount could overly restrict drainage through the voids which could become clogged with loose, fine particles. Further research and evaluation of existing installations is required to determine proper methods of construction and suitability of cement as a binder. As an alternative, a prefabricated drainage composite with filter fabric may be used if determined to be of adequate structural capacity, drainage capacity, durability, and non-damaging to the protection board and insulation.

11. Insulation

11.1 *General*—When required, insulation should be located above the liquid-applied waterproofing membrane but not in direct contact with it. Its use and quantity should be predicated on precluding the possibility of the dew point occurring at or below the level of the membrane as well as limiting thermal transfer through the deck. The requirement for a protection board directly on the membrane precludes the possibility of direct contact of insulation and membrane. Because of the numerous drainage and moisture problems associated with insulation placed directly over the protection board, it is preferred to have a drainage course between the protection board and insulation (see Fig. 1).

11.2 *Placement Over Protection Course*—If insulation is placed directly on the protection board, a distinct drainage

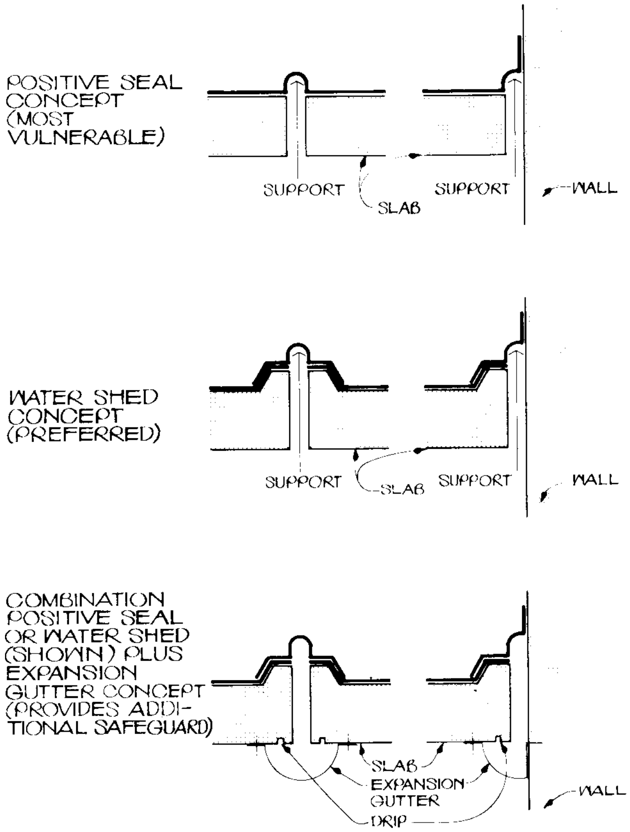

FIG. 9 Schematic Expansion Joint Concepts at Membrane Level

problem may exist in the flow of water laterally to the drains. Grooves on the underside of the insulation are generally not sufficient in themselves to provide adequate membrane drainage. Primary considerations for insulation selection when placed over the protection board, below the drainage course (if any) and wear surface are as follows:

11.2.1 Thermal properties due to its water absorptivity under conditions of substantially continual wetness.

11.2.2 The impact of water absorptivity upon the dimensional stability and structural properties of the insulation.

11.2.3 The possibility that the insulation or one of its constituent materials could provide nutrients for destructive organisms which thrive in the environment of the insulation.

11.2.4 The compressive strength needed to withstand the dead and live loads which will be imposed, especially potential concentration of loads.

11.2.5 The long-term effect of the projected loading in terms of the structural fatigue of the insulation.

11.2.6 Compatibility of the insulation and the substrate materials which it contacts.

11.2.7 Available adhesive systems for the effective bonding of the insulation to itself (if multilayer) and to its immediate substrate.

11.3 *Placement Over Drainage Course*—When insulation is to be placed between a drainage course and wearing course or protection slab, selection of the type to be used must be based upon the following considerations:

11.3.1 Thermal properties due to its water absorptivity as water drains down to the drainage course.

11.3.2 The impact of water absorptivity upon the dimensional stability and structural properties of the insulation.

11.3.3 The possibility that the insulation or one of its constituent materials could provide nutrients for destructive organisms which thrive in the environment of the insulation.

11.3.4 The compressive strength needed to withstand the dead and live loads which will be imposed, especially potential concentration of loads.

11.3.5 The compressive strength needed to withstand the dead and live loads that will be imposed, especially potential load concentrations.

11.3.6 The flexural strength to accommodate the lack of uniform and permanently stable substrate, unless the drainage course has been effectively stabilized by the use of a substantial binder (as in "no fines concrete").

11.3.7 The shear strength to accommodate the lateral thrust of potential traffic without failure, unless the wear surface is a structurally stabilized concrete slab, or rests on such a slab as a substrate.

11.3.8 Structural properties that will not be compromised by fatigue, possible moisture absorption levels, or the temperature extremes to which the insulation will be subjected.

11.3.9 Stability problems which may be imposed on a high-compression strength insulation with high coefficient of thermal expansion under climatic conditions that will subject the wearing surface to high-amplitude thermal cycling—unfortunately characteristic of the more structurally suitable insulation.

12. Protection or Working Slab

12.1 *General*—A major problem in the waterproofing of building decks is that the waterproofing is usually required early in the construction phase so that finishing materials could be installed in the occupied spaces below. For large structures, construction may continue long after waterproofing of the adjacent building deck is required. Storage of materials as well as vehicular and pedestrian traffic can impose an intolerable strain on a membrane covered only with protection board. A concrete slab, intended for the final wearing surface, installed shortly after the membrane is installed could provide the necessary protection but could also be abused and damaged. Methods by which the problem can be resolved are (*1*) temporary waterproofing requiring lateral removal; (*2*) temporary protection of the waterproofing (the quality and maintenance of which could cause disputes among the various interested trades), or (*3*) by a permanent concrete protection slab. This slab could be placed soon after the membrane, protection course, drainage course, and insulation, if required, have been installed. It would serve as protection for the permanent waterproofing materials and insulation below, provide a working platform for construction traffic and storage of materials (within weight limits), and provide a substantial substrate for the placement of the finish wearing course materials near the completion of the project when they would be less vulnerable to damage. The protection slab should be reinforced and of sufficient thickness and strength to withstand the imposed loads. The slab would be the foundation substrate for the final wearing course materials and should not be less than 76 mm (3 in.) in thickness (see Fig. 1).

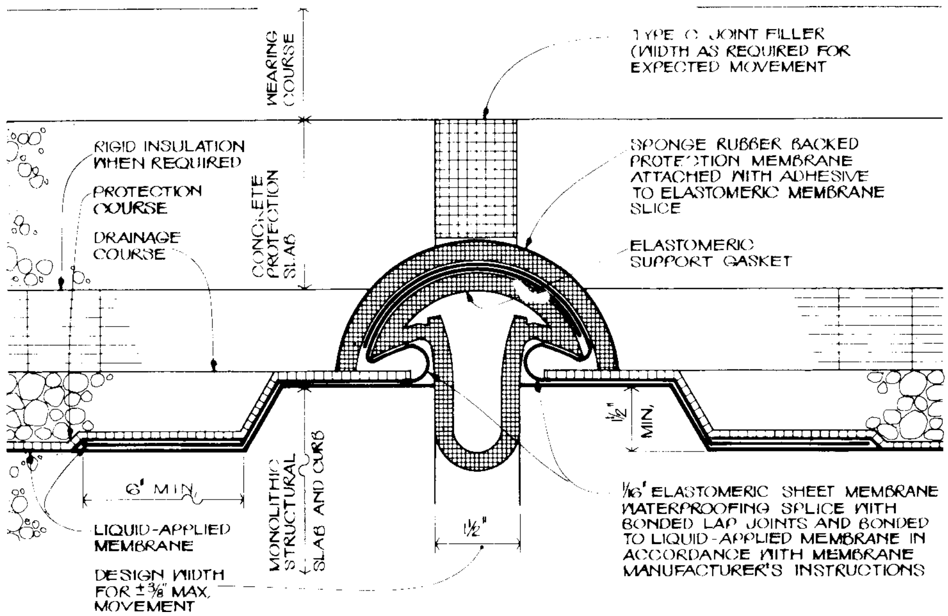

FIG. 10 Water Shed Concept Expansion Joint

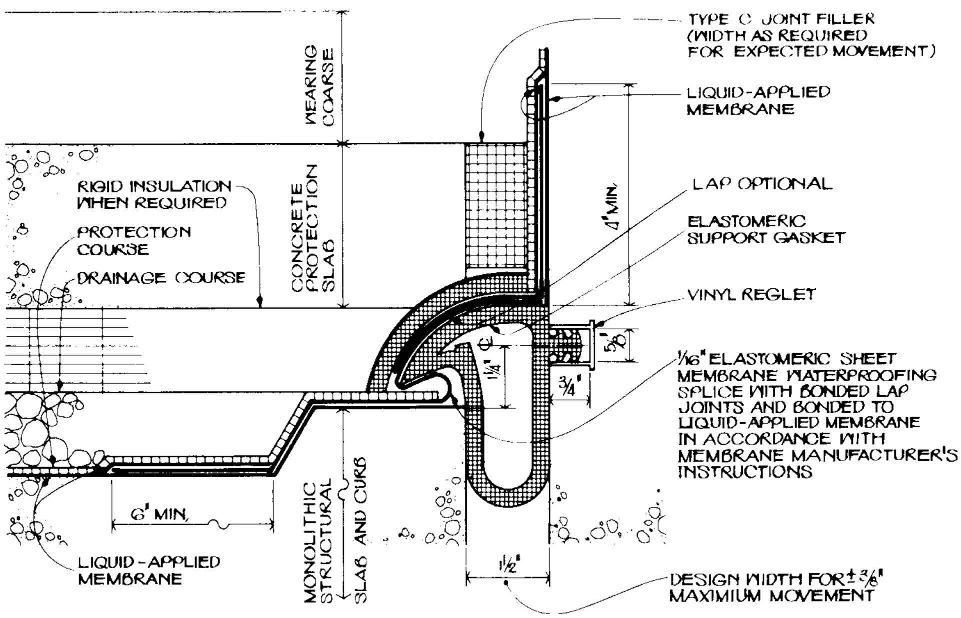

FIG. 11 Water Shed Concept Expansion Joint (see also Fig. 12 for Easier Gasket Installation Detail)

12.2 *Joints*—It is not necessary to seal the joints in the protection slab but only to provide premolded resilient joint fillers. The downward filtration of water through these joints should be permitted so that the water can be drained away through the drainage course. Since cracks, joints, and movement in the protection slab affect the wearing course, joints in the two should be aligned and coordinated. A protection slab module of about 6 by 6 m (20 by 20 ft) is reasonable to minimize cracking and to keep the joint size minimal. Larger modules would require increased thickness and wider joint widths, which would have to be continued through the wearing course.

13. Wearing Course

13.1 *General*—It is beyond the scope of this guide to cover in depth the many technical considerations of the wearing course except those which are directly governed by the part of the system below the wearing course. The major concerns are a stable support of sufficient strength, lateral thrust, adequate drainage to avoid ponding of water on the surface, and proper treatment of joints in the wearing course. With some applications such as a mortar setting bed under brick pavers, a prefabricated drainage composite with filter fabric could aid in facilitating drainage away from the mortar and help to diminish freeze-thaw damage to the mortar and paver installation.

13.2 *Joint Treatment*—The main concern in the wearing course is the joints in which movement is anticipated. These should be treated as expansion joints (see Fig. 13 for variations) with the following considerations:

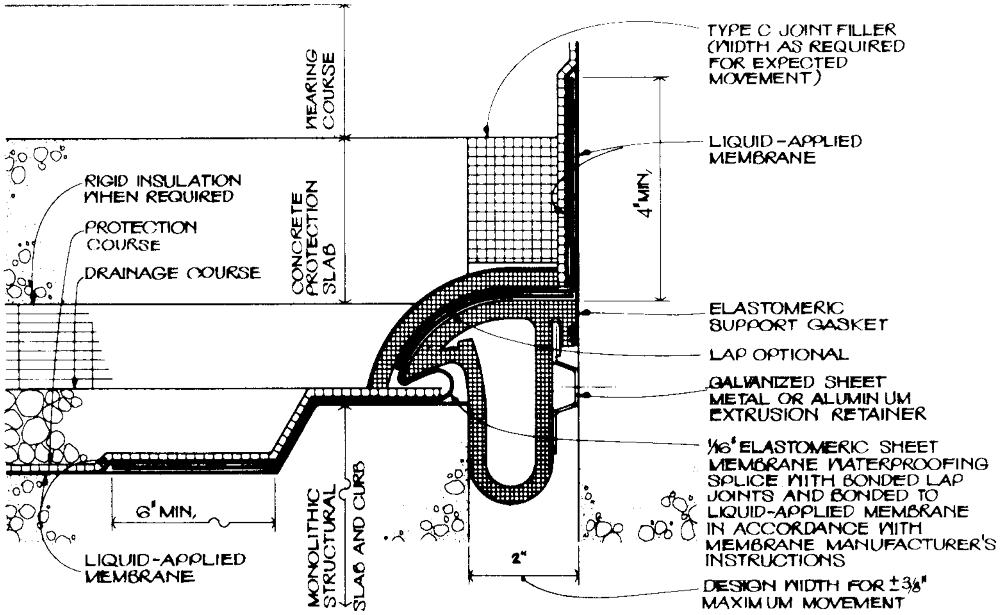

FIG. 12 Water Shed Concept Expansion Joint (see also Fig. 11)

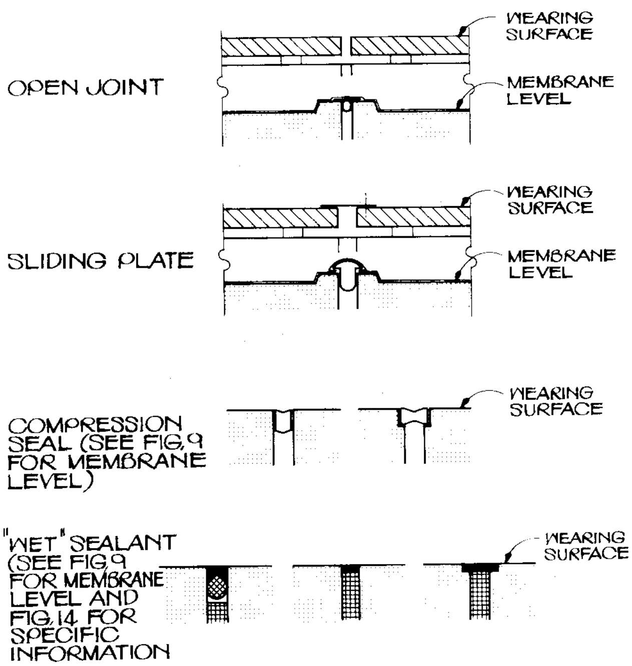

FIG. 13 Schematic Expansion Joint Concepts at Wearing Surface Level

13.2.1 The matter of appearance can influence the joint spacing and the type of joint design to be used. Widely spaced joints must be wider than those with a lesser spacing. Joints 100 to 130 mm (4 to 5 in.) wide designed to accommodate possibly 25 mm (1 in.) of movement may be undesirable from an appearance standpoint. Joint spacing is therefore usually limited so as to reduce the required width of the joint, even though it may be technically feasible to use a wider spacing.

13.2.2 Special problems are encountered with expansion joints in an open-joint drainage system. As all the joints are open, it would seem normal to have an open expansion joint. The design certainly is simple but could create a hazard for small heels that could be caught in the open joints. Attempting to provide a closed expansion joint in an open-joint drainage system also creates problems at the transverse joints when wet sealants are used. Compression seals or sliding plates could serve as solutions.

13.2.3 Sealed joints should be as durable and free of maintenance as possible. Premature deterioration of wet sealant joints due to faulty design or installation can cause hazardous, unsightly conditions and result in high maintenance costs.

13.2.4 The expansion joint in the wearing course, which of necessity, is over the structural slab expansion joint below, does not necessarily have to be designed to accommodate the same amount of movement as designed for in the structural slab expansion joint. The important question to consider in designing the expansion joint is whether the space below is to be heated and air-conditioned, or opened to the outside, as in the case of an underground unheated parking space. If the space is to be heated below and insulated above, the greatest movement in the joint would occur while the structure is unfinished, uninsulated, and not heated or air-conditioned. After the insulation is installed and the space below is heated, the movement will be decreased significantly. With a controlled sequence of construction, a smaller and less costly joint can be used in the wearing course portion of the expansion joint even though the slab joint below may show greater movement during earlier construction. The key to this is to install the joint in the wearing course after the space below is heated. There is always the risk, however, that the mechanical system can fail or will be shut down and thereby cause greater movement than designed for. In the case of an open or unheated parking space below, the movement in the wearing course portion of the joint will continue after occupancy and its width cannot be reduced. Intermediate joints in a protection slab or a wearing course supported by a structural slab are normally spaced at closer intervals than those in the latter, and their widths are related to the movement anticipated for them as well as their joint treatment.

13.2.5 Various proprietary compression seals are available that can be inserted into a formed joint under compression. Most of these, however, are not flush at the top surface and could fill up with sand or dirt.

13.2.6 Wet sealants are the materials most commonly used in moving joints at the wearing surface level. Fig. 14 shows various ways in which they may be installed. Dimension *A* is the design width dimension or the dimension at which the joint will be formed. The criteria normally used for determining this dimension with sealants capable of a movement ± 25 % is to multiply the maximum expected movement in one direction by 4. Generally, this is expected to be about three fourths of the total anticipated joint movement, but if there is any doubt, multiply the total anticipated joint movement by 4. It is better to have the joint too wide than too narrow. Dimension *B* (sealant depth) is related to Dimension *A* and is best established by the sealant manufacturer. Generally, *B* is equal to *A* for widths up to 13 mm (½ in.), 16 mm (⅝ in.) for widths up to 19 mm (¾ in.), and a maximum of 19 mm (¾ in.) for wider joints. This allows some tolerance for self-leveling sealants. See Guide C 962.

14. Testing

14.1 *General*—Testing the membrane for leakage before additional materials are placed on it has the advantage of permitting any necessary corrections to be made without having to remove any of the materials placed above it. On the other hand, the placement of materials above can sometimes damage an already tested membrane. One matter of concern is the flow characteristics of the water as it gravitates down to the membrane and then to the subsurface drainage system. A slow restricted flow, either by design or improper construction, can cause buildup of water pressure above the membrane before it is drained away.

14.2 *Requirements*—If testing is desired, the requirements should be carefully considered to simulate realistic conditions. Some testing requirements are difficult to achieve. To be of significant value, it is generally felt that minimum head requirements are a head of water of 51 mm (2 in.) for 24 to 48 h on a cured membrane (consult manufacturer for cure time). With a sloping membrane, a considerable head of water and resultant weight on the structure could develop at the drain low points, depending on their spacing. Intermittent water dams above the membrane may be required to keep the head of water down to the desired testing height. The flood test should best be conducted on the waterproofing membrane alone, if proper protection can be provided prior to placement of the protection board. As an alternative, the test could be held with the protection boards in place.

14.3 *Value of Testing*—There are those that feel that money should not be spent for sophisticated testing since natural rainfall will reasonably have tested the system long before final acceptance. Some feel that testing of the membrane should be optional by the contractor since he generally has most to lose by covering a membrane that is suspect. On the other hand, many architects and owners feel that they would like to be convinced of the integrity of the membrane before materials are placed over it so that schedules are not disrupted in the event repairs are required after the membrane is covered.

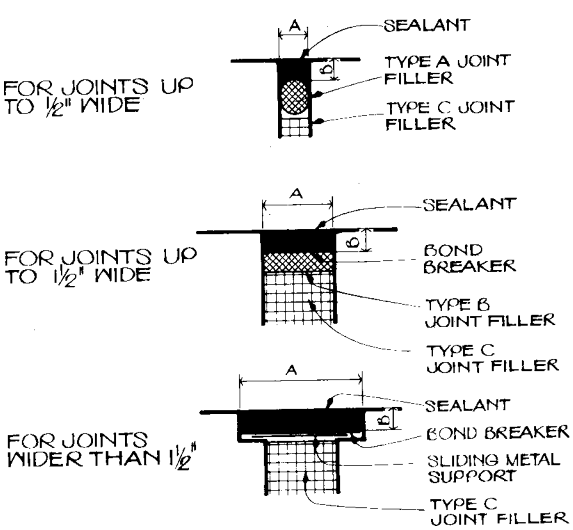

FIG. 14 Wet Sealant Details at Wearing Surface

GUIDE SPECIFICATIONS

15. Certification, Marking, Shipping, Preservation, and Safety

15.1 *Certification*—Testing laboratory certification from a laboratory acceptable to the purchaser and containing complete test results shall be made available before delivery of materials to the project site, attesting that the materials conform to the specification requirements. Such certification shall be current with results obtained from tests performed no earlier than one year from the award of contract.

15.2 *Marking and Shipping*—The liquid-applied membrane materials shall be delivered undamaged to the project site in original, sealed containers, clearly identified as to contents, the manufacturer's name, date of manufacture, shelf life, precautions on flammability and toxicity, and shall include instructions as to application procedures.

15.3 *Preservation*—Materials shall be stored and protected from damage and weather in accordance with the manufacturer's instructions and shall be used within the period noted as their shelf life.

15.4 *Safety*—Where hazardous materials are involved, rigid adherence to the special precautions of the manufacturer as modified by local, state, and federal authorities shall be followed.

16. Materials

16.1 *Drains*—See analysis in Section 8.

16.2 *Pipe Sleeves*—See analysis in 7.3.3.

16.3 *Membrane*—The liquid-applied membrane shall be in conformance with Specification C 836.

16.4 *Membrane Primer*—Primers, when required or recommended by the manufacturer for optimum performance of the liquid-applied membrane, shall be as recommended and supplied by the manufacturer of the liquid-applied membrane.

16.5 *Sealant*—Sealant for use in nonreinforced butted joints in a structural concrete slab shall be an elastomeric sealant compatible with the liquid-applied membrane conforming to Specification C 920. The compatibility of the liquid-applied membrane and the sealant shall be determined by the manufacturer of the liquid-applied membrane.

16.6 *Sealant Primer*—A primer when required or recommended by the manufacturer of the sealant for optimum adhesion of the sealant to the joint interface shall be as recommended by or supplied by the sealant manufacturer and shall be compatible with the liquid-applied membrane. The compatibility of the sealant primer with the liquid-applied membrane shall be determined by the manufacturer of the liquid-applied membrane.

16.7 *Joint Filler Type A*—Joint filler shall be a closed-cell, polyethylene or premolded cellular elastomeric rod with integral bond breaker of a diameter 25 % larger than the joint width when compressed into the joint and, if greater, shall be in accordance with the manufacturer's recommendations.

16.8 *Joint Filler Type B*—Joint filler shall be a closed-cell, polyethylene strip of the depth indicated and 25 % wider than the joint at the time of installation.

16.9 *Joint Filler Type C*—Joint filler shall be a premolded strip in conformance with Specifications D 1751 or D 1752.

16.10 *Bond Breaker*—Bond breakers shall be compatible types as recommended by the manufacturer of the liquid-applied membrane. The bond breaker shall not interfere with the curing process or other performance properties of the liquid-applied membrane.

16.11 *Preformed Elastomeric Sheet*—The preformed elastomeric sheet shall be a minimum of 1.2 mm (3⁄64 in.) in nominal thickness and be compatible with the liquid-applied membrane as tested by the manufacturer of the liquid-applied membrane. Bond strength between the liquid-applied membrane and the preformed elastomeric sheet shall be no less than 6.9 kPa (1 psi) when tested in accordance with Specification C 836.

16.12 *Sponge Rubber-Backed Elastomeric Sheet*—Sponge rubber-backed elastomeric sheet for protection over preformed elastomeric sheet at expansion joints shall be 13 mm (½ in.) thick sponge rubber in conformance with Specification D 1056, Type RE-42 or RE-43, bonded to 1.6-mm (1⁄16-in.) thick preformed elastomeric sheet in conformance with Specification D 3253.

16.13 *Protection Board (Protection Course)*—Protection board shall be compatible with the liquid-applied membrane being used and capable of withstanding continuous immersion. It shall be a 3.2-mm (⅛-in.) nominal thickness, premolded bitumen composition board or other material capable of protecting the membrane and approved by the manufacturer of the liquid-applied membrane.

16.14 *Drainage Course*—The drainage course aggregate shall be washed round river gravel conforming to gradation size No. 8 in Specification C 33 when tested in accordance with Method C 136, or shall be a manufactured drainage media recommended or approved by the manufacturer of the liquid-applied membrane and shall be compatible with the membrane.

16.15 *Drainage Course Stabilizer*—See analysis in Section 10.

16.16 *Insulation*—See analysis in Section 11.

17. Installation

17.1 *Substrate*—Concrete surfaces shall be free of laitance, loose aggregate, sharp projections, grease, oil, dirt, curing compounds, or other contaminants that could affect the complete bonding of the liquid-applied membrane to the concrete surface. Application shall not proceed until all protrusions and projections through the structural slab are in place, or sleeves placed through the slab, and provision has been made to secure their watertightness. See 17.9. Concrete surfaces shall be visibly dry and pass any additional dryness tests recommended by the liquid-applied membrane manufacturer prior to application.

17.1.1 *Finish*—See analysis in 6.7.

17.1.2 *Joints*—See analysis under 6.10.

17.1.3 *Examination*—The applicator of the liquid-applied membrane shall inspect the substrate including all penetrations and terminal conditions to determine the suitability for application of the liquid-applied membrane waterproofing. Installation shall not proceed until corrections have been made of any adverse conditions. Any unforeseen but unacceptable conditions shall be brought to the attention of all parties concerned for resolution prior to proceeding.

17.2 *Environmental Conditions*—Waterproofing work shall not commence at ambient temperatures below 5ºC (40ºF) or when there is any threat of inclement weather (rain or snow) unless precautions are taken to eliminate frost from the substrate or prevent its formation during the application. See analysis in 7.2.

17.3 *Surface Preparation*—All preparation of surfaces, cracks or joints, and termination points, including priming, if required, shall be completed before the application of the monolithic liquid-applied membrane. If required, priming shall be done not more than 24 h before the membrane is placed. Reinforced joints or cracks in the structural slab may be pretreated by cleaning and coating with a 1.5-mm (60-mil) dry film application of liquid-applied membrane extending 76 mm (3 in.) from each side of the joint or crack (see Fig. 7). See also analysis in 7.4.1. For nonreinforced joints see analysis in 7.4.2. For expansion joints see analysis in 7.4.3.

17.4 *Primer*—Priming of the overall substrate prior to application of the liquid-applied membrane is not required except as described under 17.3 unless a primer is a requirement of the liquid-applied membrane manufacturer. In such case, the primer shall be applied in strict accordance with the membrane manufacturer's published instructions.

17.5 *Membrane*—The liquid-applied membrane shall be applied directly to the slab in order to obtain 1.5 ± 0.1 mm (60 ± 5 mils) dry film thickness. The 1.5 mm is in addition to any previously applied material. Application shall be made by means of trowel, squeegee, roller, brush, spray apparatus, or other method acceptable to the membrane manufacturer. Wet film thickness shall be checked every 9 m^2 (100 ft^2) by the applicator. Where possible the surface to be coated shall be marked off, in even units, to facilitate proper coverage. At the expansion joints and terminators, the membrane shall be carried over the preformed elastomeric sheet in a uniform 2.5-mm (100-mil) dry thickness to provide a monolithic coating. When work has stopped long enough for the membrane to cure, the first operation of the next application shall be to wipe the previously applied material with a proper solvent to remove the dirt and dust that has accumulated, a condition that could inhibit adhesion of the overlapping membrane coat. Solvent should be as recommended by the membrane manufacturer. Dry-film thickness is relative and depends upon the solids content of the specific membrane selected. To obtain the required wet-film thickness to provide 1.5-mm dry-film thickness, divide the 1.5-mm thickness by the volume solids content of the coating to obtain the wet-film thickness required. Rule of thumb is 15 L/9 m^2 (4 gal/100 ft^2).

17.6 *Turnup at Walls*—Where the deck-to-wall intersection is a monolithic concrete pour or of reinforced concrete joint construction, (a) preparation coat(s) totaling 2.5 mm (100 mils) of liquid-applied membrane shall be applied that extends 150 mm (6 in.) onto the horizontal deck and up the vertical wall to the termination height (see Fig. 15). At the applicator's option, a cant strip formed with the liquid-applied membrane having a 45º beveled face of 13 mm (½ in.) may be applied (see Fig. 15).

17.7 *Termination on Walls*—See analysis in 7.3.1.

17.8 *Termination at Drains*—Drain flanges shall have been set flush with the surface of the structural slab. The liquid-applied membrane shall be applied 1.5 mm (60 mils) thick over the drain flange or collar with care not to plug any drainage or weep holes. The doubled membrane shall extend 150 mm (6 in.) beyond the flange onto the structural slab (see Fig. 5).

17.9 *Termination at Penetrations*—Protrusions or projections through the structural slab, such as vents and service pipes, shall be treated before application of the liquid-applied membrane. An application of 2.5 mm (100 mils) of liquid-applied membrane shall be made over a sealant joint and up the pipe sleeve and extended 150 mm (6 in.) onto the structural slab (see Fig. 6).

17.10 *Treatment at Reinforced Joints*—See Fig. 7.

17.11 *Treatment at Nonreinforced Joints*—See analysis in 7.4.2.

17.12 *Treatment at Expansion Joints*—See analysis in 7.4.3.

17.13 *Membrane Protection with Protection Board*—The liquid-applied membrane shall be protected by placement of protection board over the membrane. The timing of the protection board placement is left to the discretion of the applicator within the parameters established by the liquid-applied membrane manufacturer. The membrane application must be otherwise protected if the protection board is not placed immediately. Protection boards shall be butted together, and not overlapped. Overlapping can cause shear points on the membrane leading to resultant punctures. The membrane over the expansion joints shall be protected as indicated.

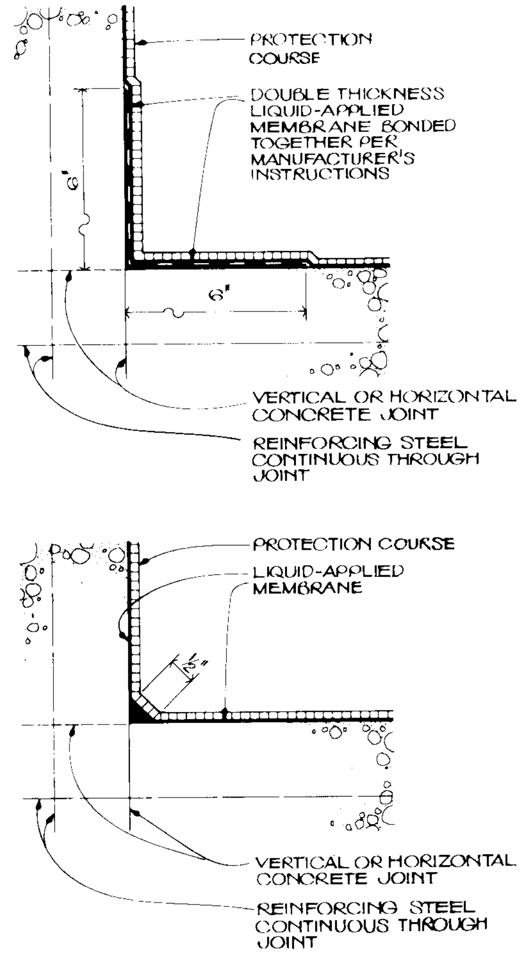

FIG. 15 Turnup Details at Reinforced Joint (see 17.6)

17.14 *Testing*—See analysis in Section 14.

17.15 *Drainage Course*—After the flood tests (if required) are completed and the concrete protection slab or wearing course is ready to be installed, the drainage course should be placed at the indicated thickness.

17.16 *Insulation*—After the drainage course is placed, the insulation, if specified or indicated, shall be placed on top of the drainage course.

17.17 *Protection or Working Slab*—See analysis in Section 12.

17.18 *Wearing Course*—See analysis in Section 13.

18. Keywords

18.1 joint; membrane; waterproofing; wearing course