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Standard Guide for Design of Built-Up Bituminous Membrane Waterproofing Systems for Building Decks[1]

This standard is issued under the fixed designation C981; 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 design of fully adhered built-up bituminous membrane waterproofing systems for plaza deck and promenade construction over occupied spaces of buildings where covered by a separate 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 The committee with jurisdiction over this standard is not aware of any comparable standards published by other organizations.

1.4 *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 safety, health, and healthenvironmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C33C33/C33M Specification for Concrete Aggregates
C578 Specification for Rigid, Cellular Polystyrene Thermal Insulation
C717 Terminology of Building Seals and Sealants
C755 Practice for Selection of Water Vapor Retarders for Thermal Insulation
C1193C920 GuideSpecification for Use of Elastomeric Joint Sealants
C1299C1193 Guide for Use in Selection of Liquid-AppliedJoint Sealants (Withdrawn 2012)
C1472 Guide for Calculating Movement and Other Effects When Establishing Sealant Joint Width
D41D41/D41M Specification for Asphalt Primer Used in Roofing, Dampproofing, and Waterproofing
D43D43/D43M Specification for Coal Tar Primer Used in Roofing, Dampproofing, and Waterproofing
D173D173/D173M Specification for Bitumen-Saturated Cotton Fabrics Used in Roofing and Waterproofing
D226D226/D226M Specification for Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing
D227D227/D227M Specification for Coal-Tar-Saturated Organic Felt Used in Roofing and Waterproofing
D312D312/D312M Specification for Asphalt Used in Roofing
D449D449/D449M Specification for Asphalt Used in Dampproofing and Waterproofing
D450D450/D450M Specification for Coal-Tar Pitch Used in Roofing, Dampproofing, and Waterproofing
D1079 Terminology Relating to Roofing and Waterproofing
D1327D1327/D1327M Specification for Bitumen-Saturated Woven Burlap Fabrics Used in Roofing and Waterproofing
D1668D1668/D1668M Specification for Glass Fabrics (Woven and Treated) for Roofing and Waterproofing
D2178D2178/D2178M Specification for Asphalt Glass Felt Used in Roofing and Waterproofing
D2822 Specification for Asphalt Roof Cement, Asbestos-Containing
D4022 Specification for Coal Tar Roof Cement, Asbestos Containing

[1] This guide is under the jurisdiction of ASTM Committee D08 on Roofing and Waterproofing and is the direct responsibility of Subcommittee D08.22 on Waterproofing and Dampproofing Systems.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

~~D4586~~D4586/D4586M Specification for Asphalt Roof Cement, Asbestos-Free
~~D4601~~D4601/D4601M Specification for Asphalt-Coated Glass Fiber Base Sheet Used in Roofing
D4990 Specification for Coal Tar Glass Felt Used in Roofing and Waterproofing
~~D5295~~D5295/D5295M Guide for Preparation of Concrete Surfaces for Adhered (Bonded) Membrane Waterproofing Systems
D5643/D5643M Specification for Coal Tar Roof Cement, Asbestos Free
~~D5898~~D5898/D5898M Guide for Standard Details for Adhered Sheet Waterproofing
D5957 Guide for Flood Testing Horizontal Waterproofing Installations
~~D6152~~D6152/D6152M Specification for SEBS-Modified Mopping Asphalt Used in Roofing
~~D6162~~D6162/D6162M Specification for Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using a Combination of Polyester and Glass Fiber Reinforcements
~~D6163~~D6163/D6163M Specification for Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using Glass Fiber Reinforcements
~~D6164~~D6164/D6164M Specification for Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using Polyester Reinforcements
~~D6451~~D6451/D6451M Guide for Application of Asphalt Based Protection Board
D6506/D6506M Specification for Asphalt Based Protection Board for Below-Grade Waterproofing
~~D6622~~D6622/D6622M Guide for Application of Fully Adhered Hot-Applied Reinforced Waterproofing Systems
D7492/D7492M Guide for Use of Drainage System Media with Waterproofing Systems

2.2 *Other Documents:*
ACI 301 Specifications for Structural Concrete in Buildings[3]

3. Terminology

3.1 *Definitions*—For definitions of terms used in ~~the~~this guide, refer to ~~Terminologies~~Terminology ~~C717 and~~ D1079.

3.2 *Definitions of Terms Specific to This Standard:*
3.2.1 *prefabricated drainage composite*—a preformed porous material, usually plastic, with a filter-type fabric over it.

4. Significance and Use

4.1 This guide provides information and guidelines for the selection of components and the design of a built-up bituminous membrane waterproofing system in building deck construction. Where the state of the art is such that criteria for particular conditions are not established or have numerous variables that require consideration, applicable portions of ~~Design Considerations,~~ design considerations, Sections 5 – 16, serve as reference and guidance for selection by the designer of the system.

5. Comparison to Other Standards

5.1 The Committee with jurisdiction over this standard is not aware of any comparable standards published by other organizations.

5.2 For application methods, refer to Guide ~~D6622~~D6622/D6622M. For design of typical details not addressed in this guide, refer to Guide ~~D5898~~D5898/D5898M.

6. General

6.1 The design of plaza deck waterproofing cannot be satisfactorily determined without ~~consideratoin~~consideration of the several subsystems, their material components, and interrelationships. The proper selection from a variety of components that form a built-up bituminous membrane waterproofing system must be predicated upon specific project requirements and the interrelationship of components. The variety of the types of surfaces exposed to weather, the difference of climatic conditions to which the deck is exposed, and the interior environmental requirements of the occupied space are major determinants in the process of component selection. Essential to determination of the deck design components is information relative to temperature extremes of the inner and outer surfaces, precipitation rates, solar exposure, prevailing wind direction, the pattern and reflectivity of adjacent structures, anticipated amount and intensity of vibration resulting from function or adjacent occupancies, and design live loads both normal and emergency.

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

6.3 The plaza deck system is normally composed of several subsystems: the structural building deck (membrane substrate), the waterproofing membrane, the drainage subsystem, the thermal insulation, protection or working slab, and the wearing course (see Fig. 1). Fig. 1 as well as details, subsystems, components, and illustrations that follow are intended to illustrate a principle but are not necessarily the only solution for a diversity of environments.

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[3] Available from ACI International, PO Box 9094, Farmington Hills, MI 48333–9094.

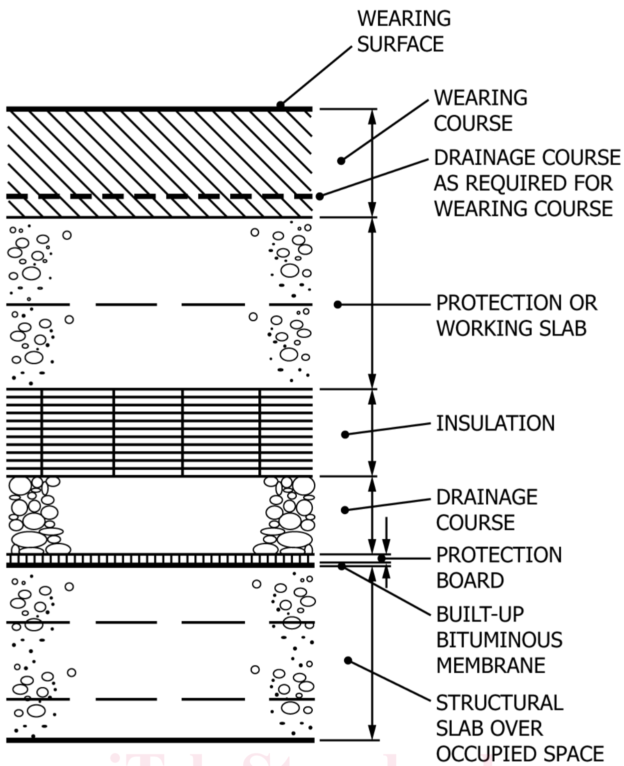

FIG. 1 Basic Components of Built-up Bituminous Membrane ~~Waterproofing~~Waterproofing System with Separate Wearing Course (see ~~Section~~ 6.3)

7. Substrate

7.1 The building deck or substrate referred to in this guide is reinforced cast-in-place structural concrete.

7.1.1 High early strength and lightweight insulating concretes do not provide suitable substrates. Additives made to the concrete mix (such as calcium chloride) to promote curing, reduce water requirements, or modify application temperature requirements should not be used unless the manufacturer of the waterproofing system specifically agrees.

7.1.2 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 that 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.

7.2 *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 2 % (¼ ~~in./ ft.)~~ in./ft) should be maintained. The maximum slope is related to the type of membrane used. Slope is best achieved with a monolithic pour as compared with a separate concrete fill. 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.

7.3 *Strength*—The strength of concrete is a factor to be considered with respect to the built-up bituminous membrane insofar as it relates to finish, bond strength, and continuing integrity. The cast-in-place structural concrete should have a minimum density of 1762 kg/m^3 (110 lb/ft^3).

7.4 *Finish*—The structural slab should have a finish of sufficiently rough texture to provide a mechanical bond for the membrane, but not so rough to preclude achieving continuity of the membrane across the surface. As a minimum, ACI 301 floated finish is required with ACI 301 troweled finish preferred, deleting the final troweling.

7.5 *Curing*—Curing the structural slab is necessary to provide a sound concrete surface and to obtain the quality of concrete required. Curing is accomplished chemically with moisture and should not be construed as drying.

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

7.5.2 *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 the concrete by condensation, thus preventing the surface from drying while curing. Laps of sheets covering the slab should be not less than 50 mm (2 in.) and should be sealed or weighted (see Practice C755).

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

7.6 *Dryness*—Membrane ~~manufacturer's~~manufacturers' requirements for substrate dryness vary from being visibly dry to having a specific maximum moisture content. Since there is a lack of unanimity in this regard, it is necessary to conform to the manufacturer's requirements for the particular membrane being applied. Adequate drying of residual moisture from slabs poured over a permanent metal deck will normally take longer than from slabs stripped of forming. Subsequent underside painting of stripped concrete slabs that might inhibit moisture vapor transmission and possibly cause loss of membrane adhesion should be avoided.

7.7 *Joints*—Joints in a structural concrete slab are herein referred to as reinforced joints, unreinforced joints, and expansion joints.

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

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

7.7.3 *Expansion and Seismic Joints*—Expansion joints, as differentiated from control joints, are designed to accommodate movement in more than one direction, are an integral part of the building structural system, and must be carried through the entire structure. Expansion joints are incorporated in the structural frame (*1*) to reduce internal stresses caused by wide temperature ranges or differential movement, or both, between structural elements as might be the case in large adjoining heated and unheated spaces; (*2*) where there are different foundation settlement conditions between adjacent elements; or (*3*) where movements between high- and low-attached structures are anticipated. Seismic joints are a special case in which the joints are generally quite large and are designed to limit damage to the structural frame during earthquakes. Expansion and seismic joints are best located at high points of contoured substrates to deflect water away from the joint. For expansion joints designed for thermal movement only, the movement is expected to be only in the horizontal plane. Seismic joints are designed to accommodate both vertical and horizontal movement.

7.8 *Flashing Substrate*—The vertical surface that the membrane waterproofing intersects must be sound, with a smooth or floated finish, dry, and free of cracks and loose materials as stated for the horizontal or deck substrate. The vertical surfaces may be of concrete, stone, or masonry, and should be reinforced against shrinkage and cracks.

8. Waterproofing Membrane

8.1 The major membrane components include primers, bitumens, reinforcements, and flashing materials.

8.2 *Primers*—Primers (Specifications ~~D41~~D41/D41M and ~~D43~~D43/D43M) are used to prepare the substrate to obtain maximum adhesion of the bitumen to the substrate. Asphalt derivative primers should be used with asphalt and coal-tar derivative primers with coal-tar bitumen.

8.3 *Bitumens*—Bitumens in a waterproofing system serve two functions. They provide the prime waterproofing component of the system and the adhesive component for the membrane reinforcement. The bitumens used in plaza building deck waterproofing are asphalt (Specifications ~~D312~~D312/D312M and ~~D449~~D449/D449M, ~~Types~~Type I or II) or coal-tar pitch (Specification ~~D450~~D450/D450M, ~~Types~~Type II or III). In some instances these products are modified to serve a particular purpose. In building deck waterproofing, waterproofing grade asphalts and coal-tar pitches, as noted, are primarily used because of their cold-flow (self-healing) properties.

8.3.1 *Asphalt*—Asphalt is derived from the residue of the process of manufacturing light petroleum distillates and further processed into waterproofing and ~~roofing grade~~ roofing-grade asphalts. Asphalts tend to be aliphatic, chain-like hydrocarbon compounds.

8.3.2 *Coal-Tar Pitch*—Coal-tar pitch is derived from crude coal tar, a by-product from ~~high temperature~~ high-temperature coke ovens, by a refining process of distillation and chemical extraction. ~~Coal tar~~ Coal-tar pitches tend to be aromatic, ring-like hydrocarbon compounds.

8.3.3 *Modified Bitumens*—Modified bitumens (Specification ~~D6152~~D6152/D6152M) are designed to develop a particular objective such as extensibility, for example, viscosity variation, strength, reduction of volatiles, and so forth.

8.3.4 *Selection*—The selection of bitumen type for a specific project is related to the numerous variables and options described in this guide and that must be taken into consideration by the designer of the waterproofing system.

8.4 *Reinforcements*—The types of membrane reinforcement used in waterproofing are treated glass fabric, saturated woven cotton and saturated jute fabric, saturated felts, impregnated glass felts, and coated sheets. Specialty preformed sheets are also incorporated in plaza waterproofing. The requirements for plaza deck waterproofing are complex. Thus, the designer knowing his particular building problem must select the membrane component types that will satisfy the design requirements. Combinations of the various membrane reinforcement are commonly used in alternate plies, depending upon the design requirement. Unless otherwise directed by the manufacturer, asphalt bitumen should be used with asphalt-based membranes and coal-tar bitumen with coal-tar based membranes.

8.4.1 *Treated Glass Fabric*—Untreated glass fabrics are lightweight, inorganic, very high in tensile strength, open-mesh, and will not absorb water or any other material. As finished treated ~~products,~~products (Specification ~~D1668~~D1668/D1668M, Type I Asphalt Treated, Type II Coal-Tar Pitch Treated, and Type III Organic Resin Treated), they provide excellent strength in waterproofing and are particularly effective in areas of vibration, deflection, or where heavy loads are applied over the waterproofing system. Their flexibility allows them to be used in corners, in angles, and over irregular surfaces. Due to the open-mesh woven design, they can be applied without entrapment of air.

8.4.2 *Saturated Woven Cotton Fabric*—Saturated woven cotton fabric is an organic material, thus requiring the saturant to penetrate the interstitial cells of the cotton fibers. It has good tensile strength, although not as strong as woven glass fabric, but superior to felts. It is of an open-mesh woven design and is excellent where flexibility and adaptability to irregular surfaces, corners, and angles are a requirement. Woven cotton fabric (Specification ~~D173~~D173/D173M) is saturated with asphalt or coal-tar saturants.

8.4.3 *Saturated Woven Jute*—Saturated woven jute is an organic material, thus requiring the saturant to penetrate the interstitial cells of the jute fibers. It is generally woven with thicker thread than cotton, thus retaining a great quantity of bitumen. It has many of the same characteristics of cotton in relation to waterproofing. Woven jute fabric (Specification ~~D1327~~D1327/D1327M) may be saturated with asphalt or coal-tar saturants.

8.4.4 *Saturated Felts*—Dry felts are organic mats saturated with ~~saturating grade~~ saturating-grade asphalt or ~~coal tars.~~ coal-tars. They provide a container and reinforcement for the interply bitumen. They are of the same type used in roofing systems and are classified as Specification ~~D226~~D226/D226M, Asphalt-Saturated (organic) and Specification ~~D227~~D227/D227M, Coal-Tar-Saturated (organic).

8.4.5 *Glass Fiber Felts*—Glass fiber felts are light in weight. The glass fibers are dispersed at random to form a sheet. The fibers may be continuous or in a jackstraw pattern, depending upon the method of manufacture, and are bonded together with resinous binder. Glass fiber felts are coated with asphalt (Specification ~~D2178~~D2178/D2178M) or coal-tar pitch ~~(~~(Specification D4990).

8.4.6 *Asphalt-Coated Base Sheets and Coated Felts*—Asphalt-coated base sheets and coated felts, used as membrane reinforcement, consist of asphalt-saturated ~~roofing grade~~ roofing-grade felt coated on both sides with coating-grade asphalt filled with mineral stabilizer and finished on the top side with fine mineral surfacing. They are heavier and slightly stronger than saturated felts. Coated felts have less quantity of coating asphalt than coated base sheets. In cold temperatures, a coated felt is difficult to lay flat and avoid edge voids. The felts may be organic or inorganic. ~~Asphalt coated~~ Asphalt-coated glass fiber base sheet is described in Specification ~~D4601~~D4601/D4601M.

8.5 *Specialty Preformed Membrane*—~~Modified-bitumen~~ Modified bitumen sheets (Specifications ~~D6162~~D6162/D6162M, ~~D6163~~D6163/D6163M, and ~~D6164~~D6164/D6164M~~),~~) may incorporate membrane reinforcement in single or multilayers and be produced as a single preformed sheet.

8.6 *Flashing*—The major flashing components for terminal conditions include fibrated troweling roofing cement, reinforced flashing felts, and proprietary elastomeric materials.

8.6.1 *Bituminous Plastic Cement*—Bituminous plastic cement such as those meeting Specifications ~~D4022~~D5643/D5643M~~,~~ ~~D2822,~~and ~~D4586~~D4586/D4586M are made from (*1*) bitumen characterized as self-healing, adhesive, and ductile; (*2*) compatible volatile solvents; and (*3*) mineral stabilizers mixed to a smooth, uniform consistency suitable for troweling applications.

8.6.2 *Reinforced Flashing Felts*—Plies used in flashings should be a material that is compatible with the waterproofing membrane.

8.6.3 *Proprietary Elastomeric Materials*—Proprietary elastomeric materials based on neoprene (cured or cure-in-place), butyl, and ethylene-propylene diene monomer (EPDM) may be set into hot bitumen or a cold-applied adhesive per manufacturer's instructions. Application on roof cement may lead to solvent blistering and softening.

8.6.4 *Selection*—Unless otherwise directed by manufacturers, asphalt-flashing materials should be used with asphalt membranes and coal-tar bitumen flashing materials used with coal-tar bitumen membranes.

8.7 *Handling and Storage*—Proper handling, storage, and protection of waterproofing materials is essential. During application the presence of moisture, dirt accumulation, and damaged materials are primary causes of lack of bond, bond failure, and delamination. Since some waterproofing materials are susceptible to moisture damage and adsorption, optimum storage and protection is in a weathertight enclosure. When job conditions make this unrealistic, materials should, as a minimum, be stored off the ground or deck on pallets and covered above, on all sides, and ends with breathable-type canvas tarpaulins. Plastic sheets should not be used because they permit condensation buildup under them.

8.8 *Membrane Composition and Application*—A built-up bituminous waterproofing membrane consists of components joined together and bonded to its substrate at the site. Paragraphs 8.8.1 – 8.8.8.5 cover its composition and application on a structural concrete substrate. See Section 12 for insulation considerations.

8.8.1 *Substrate Preparation*—Surfaces to receive waterproofing must be clean, dry, reasonably smooth, and free of dust, dirt, voids, cracks, laitance, or sharp projections before application of materials. Refer to Guide ~~D5295~~D5295/D5295M.

8.8.2 *Primer Application*—Concrete surfaces should be uniformly primed to enhance the bond between the membrane and the substrate, and thus inhibiting lateral movement of water. The primer must not be left in puddles. The normal application rate is 0.3 L/m^2 (¾ gal/100 ft^2). Asphalt ~~Primer~~primer (Specification ~~D41~~D41/D41M) should be used with asphalt bitumen. Coal-tar primer (Specification ~~D43~~D43/D43M) should be used with coal-tar pitch bitumen unless waived by the manufacturer of the membrane for the particular project conditions. Primer should be allowed to become tacky or dry before application of bitumen. A wet primer may soften the bitumen.

8.8.3 *Position and Composition of Membrane Plies*—The number of plies of membrane reinforcement required is dependent upon the head of water and strength required by the design function of the wearing surface. Plaza deck membranes should be composed of not less than three plies. The composition of the membrane is normally of a "shingle" or "ply-on-ply" (phased) construction.

8.8.3.1 *Shingle Method*—The "shingle" method is achieved by successive lapping of one ply over another, using prescribed overlaps, until the required number of plies of membrane reinforcements are achieved. For example, a four-ply system is achieved by lapping each successive ply slightly over three quarters of the previously laid ply. Based upon a 914-mm (36-in.) wide membrane reinforcement, each ply overlap is approximately 699 mm (27½ in.), leaving a 216-mm (8½-in.) exposure to the weather. To determine the amount of ply exposed to the weather, using a 914-mm (36-in.) width as a base, divide 864 mm (34 in.) by the number of plies. The resultant is the exposure to the weather. To determine the overlap distance, subtract the exposure obtained from the width of the 914-mm (36-in.) wide roll. For example, a three-ply system would have an "exposure" of 288 mm (11⅓ in.) or 34 divided by 3, and the "overlap" would be 627 mm (24⅔ in.) or 11⅓ subtracted from 36. The extra 50 mm (2 in.) (36 minus 34) serves as a safety factor to ~~assure~~ensure that the vertical cross section will contain the designated number of plies.

8.8.3.2 *Ply-on-Ply (Phased Method)*—"Ply-on-ply" or "phased" construction is a method whereby each ply or group of plies are in a single-connecting layer over which the next phase is applied. The phased method is often employed when different types of membrane are used in the construction of the waterproofing membrane system. For example, a system of two plies of felt plus two plies of fabric plus one ply of felt consists in ~~phase~~Phase 1 of the application of two plies of felt in shingle fashion, in ~~phase~~Phase 2 of the application of two plies of fabric in shingle fashion, and in ~~phase~~Phase 3 of the application of the final ply of felt with normal 50-mm (2-in.) single-ply overlaps.

8.8.3.3 *Comparison of Methods*—Shingle method advantages over the phased method are (*1*) less potential for slippage, (*2*) less susceptibility to moisture entrapment, (*3*) greater potential for ply-to-ply adhesion, (*4*) reduction of potential slippage planes of bitumen, (*5*) any desired number of plies can be laid in a single progressive operation, and (*6*) overall is a faster method. The phased method has an advantage over the shingle method insofar as the operation permits a full layer of bitumen between the entire layer of membrane reinforcements, providing a secondary waterproofing plane.

8.8.3.4 *Placement of Plies*—Membrane reinforcements should start at the low point of the deck working to the high level so that the direction of the flow of water is over the lap. All plies should be firmly embedded into the hot bitumen by brooming, pressing, or other suitable means so that ply shall not touch ply and to prevent formation of wrinkles, buckles, kinks, blisters, or pockets. After plies are in place, the surface of the membrane system should be coated with hot bitumen and, while still hot, a sheet of protection board embedded (see Section 9). Only an area of size that will allow completion of the membrane and placing of protection board upon the membrane in one working day should be undertaken; exposure of membrane reinforcing plies to weather, dew, condensation, or frost can result in membrane failure. Consideration of bitumen flow or creep merits attention to temperature gradients and the estimated maximum temperature of the membrane in the deck system. The slope of the substrate and membrane should also be considered.

8.8.4 *Bitumen Application and Quantities*—The layer of bitumen between plies of the membrane reinforcement should not be excessive. The maximum bond strength is achieved with the thinnest practical, continuous application of bitumen between the plies. There should be sufficient bitumen to penetrate the membrane reinforcing in addition to that required to provide adhesion properties. The criterion is to apply a sufficient quantity of bitumen to provide a full and continuous course of bitumen for embedment of each subsequent ply of membrane reinforcement. The quantities to achieve this may vary from 0.83 kg/m^2 (17 lb/100 ft^2) to 1.47 kg/m^2 (30 lb/100 ft^2) for each course of bitumen between membrane plies. Differences in rates may result from atmospheric conditions, method of application, and temperature at actual time of placement. As the bitumens flow less readily at lower application temperatures, the interply layer of bitumen tends to be higher in weight. The quantity may also vary depending upon the speed the applicator moves mechanically operated bitumen-spreading equipment. These variations are not necessarily troublesome provided the bitumen is hot enough to develop adhesion to the membrane reinforcement, and the interply weights are not excessive or so low as to prevent continuous bond. The use of excessive quantities of bitumen in areas subject to horizontal and vertical loads should be avoided. For estimating purposes, an average quantity of bitumen between plies of membrane reinforcement may be classified as 1.13 kg/m^2 (23 lb/100 ft^2) for asphalt and ~~1.22~~ 1.22 kg ~~kg/m~~/m^2 (25 lb/100 ft^2) for coal-tar pitch.

Glass felts may require greater quantities of interply bitumen due to the interstices of the reinforcement. Use manufacturer's recommendations to ascertain quantities of bitumen required.

8.8.4.1 *Application Temperature*—For the proper application of bitumen in a built-up bituminous membrane, it is important to note that bitumen is a water-resistant, viscous adhesive that depends upon flow for its adhesive and wetting properties. Bitumen flow is best measured by the viscosity of the material. Viscosity changes with temperature; the higher the temperature, the lower the viscosity. ~~(1) Asphalts—Studies have shown that asphalts having a viscosity from 100 to 150 cSt (0.0001 to 0.0002 m^2/s) have optimum wetting and adhesive properties. The optimum application temperature of asphalt is the "equiviscous temperature," the temperature at which asphalt will attain a target viscosity of 125 cSt (0.0001 m^2/s), at the point of application. A tolerance range of ±25°F (±3.9°C) is added for practical application in the field to accommodate the effects of wind chill, sunshine, or ambient temperature. Asphalt should not be heated to or above the actual Cleveland Open Cup (COC) flash point or heated and held above the finished blowing temperature for more than 4 h. (2) Coal Tar Pitches—Studies have shown that coal tar pitches have a viscosity from 12 to 32 cSt or 15 to 40 centipoise have optimum wetting and adhesive properties. The optimum application temperature of coal tar pitch is the "equiviscous temperature," the temperature at which coal tar pitch will attain a target viscosity of 20 cSt or 25 centipoise at the point of application. A tolerance range of ±25°F (±13.9°C) is added for practical application in the field to accommodate the effects of wind chill, sunshine, or ambient temperature. Coal tar pitch should not be heated to or above the actual Cleveland Open Cup (COC) flash point.~~

(1) Asphalts—Studies have shown that asphalts having a viscosity from 100 to 150 cSt (0.0001 to 0.0002 m^2/s) have optimum wetting and adhesive properties. The optimum application temperature of asphalt is the "equiviscous temperature," the temperature at which asphalt will attain a target viscosity of 125 cSt (0.0001 m^2/s) at the point of application. A tolerance range of ±25 °F (±3.9 °C) is added for practical application in the field to accommodate the effects of wind chill, sunshine, or ambient temperature. Asphalt should not be heated to or above the actual Cleveland open cup (COC) flash point or heated and held above the finished blowing temperature for more than 4 h.

(2) Coal-Tar Pitches—Studies have shown that coal-tar pitches have a viscosity from 12 to 32 cSt or 15 to 40 centipoise have optimum wetting and adhesive properties. The optimum application temperature of coal-tar pitch is the "equiviscous temperature," the temperature at which coal-tar pitch will attain a target viscosity of 20 cSt or 25 centipoise at the point of application. A tolerance range of ±25 °F (±13.9 °C) is added for practical application in the field to accommodate the effects of wind chill, sunshine, or ambient temperature. Coal-tar pitch should not be heated to or above the actual Cleveland open cup (COC) flash point.

8.8.5 *Treatment at Reinforced Joints*—Over the reinforced structural slab joints, one ply of 6-in. wide membrane reinforcement embedded in products like bituminous plastic cement ~~(Specifications~~(Specification ~~D2822~~D4586/D4586M~~,~~ ~~D4056,~~ or ~~D4022~~D5643/D5643M) (see also 8.6.1) should be applied before application of the bituminous membrane.

8.8.6 *Treatment at Nonreinforced Joints*—Nonreinforced joints between the structural slab (membrane substrate) and vertical surfaces that are not subject to movement should receive a bead of compatible sealant in a recessed joint before application of the membrane to reduce potential leakage of bitumen through the joint. Where movement is anticipated, these joints should be designed as expansion joints (see 8.8.7).

8.8.7 *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 (*1*) the positive seal concept directly at the membrane level, or (*2*) 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. 2). Flexible support of the membrane is required in each case. Expansion joint details should be considered and used in accordance with their movement capability.

8.8.7.1 *Positive Seal Concept*—The positive seal concept entails a greater risk than the water shed concept since it relies fully on positive seal joining of materials at the membrane level, where the membrane is most vulnerable to water penetration. The materials used, and their joining, must be carefully engineered by the manufacturer of the bituminous membrane waterproofing system, and subsequent field installation requires the best of workmanship for potential success, leaving no margin for error. Therefore, use of this concept is not recommended.

8.8.7.2 *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 joining of differing materials can then be placed at a higher level and treated somewhat in the manner of counterflashing, hence the term ~~"watershed~~ "water shed concept." However, if a head of water rises to the height of the material joined, 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 10.

8.8.7.3 *Provision for Movement*—Generally, expansion joints in a structural slab are seldom less than 30 m (100 ft) apart and may be as much as 91 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~~ 38 mm (1½ in.). Maximum movement generally occurs during the construction phase before insulation and wearing course are installed over the membrane, but the joint should be detailed for maximum movement at any time. Gaskets and flexible preformed sheets are required to absorb such amounts of movement inasmuch as bituminous membranes have little or no movement capability. Since such materials, when used at an expansion joint, must be joined to the bituminous membrane, the ~~watershed~~ water shed concept should be used. Figs. 3-5 indicate expansion joints

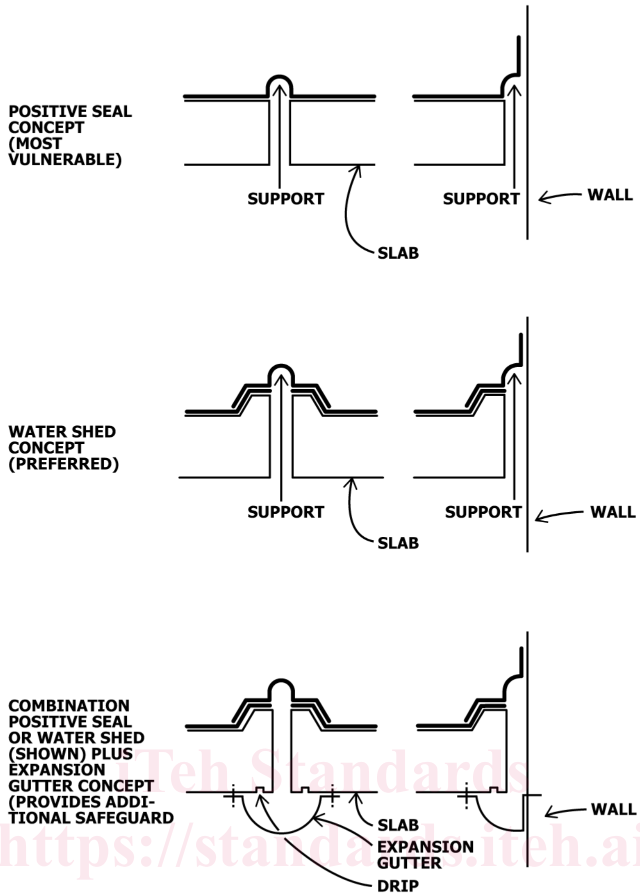

FIG. 2 Schematic Expansion Joint Concepts at Membrane Level (see 8.8.7)

using the ~~watershed~~ 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.

8.8.8 *Transitional Changes and Terminal Conditions* —Transitional changes and terminal conditions should be designed for simplicity of installation and repetitive operations and normally consist of composite sheets of felts, fabrics, and bitumens with a mineral surface. Square corners, sharp edges, and smooth planes are not adaptable to bitumen and bitumen reinforcements. The functional effectiveness results from design simplicity of the field installation, consideration of location, handling, similarity of details, material selection, and method of placement. Bitumens and reinforcing must be compatible with the membrane and substrate. Surfaces to receive waterproofing must be in accordance with Section 7. Masonry surfaces to receive flashings should be primed before application of the flashing (see 8.2). Corners must be designed to allow easy installation using hand tools with consideration of the required system and type of flashing material suitable to the installation. Anchorage of the terminal edge of the membrane system is essential (see Figs. 6-8). Hot bitumen should be applied sparingly at terminal conditions. Temporary terminations of flashing must be provided at the end of each workday to prevent water infiltration and loss of bond. The surface of flashing should be protected by protection board cover against construction damage.

8.8.8.1 *Transitional Changes in Membrane*—Reinforce all intersections with walls, corners, or any location that may be subject to unusual stress, with two layers of woven fabric embedded in hot bitumen. Extend the fabric onto the deck at least 150 mm (6 in.) and extend up the wall the full height to the wearing surface, carrying fully into corners. Woven fabrics are employed in this initial preliminary phase because of their inherent flexibility and because they easily conform to a 90° juncture. Felts and coated sheets do not easily conform to a 90° bend. Cants, when required by the membrane manufacturer, should be cementitious and formed approximately 75 by ~~75 mm~~ 75 mm (3 by 3 in.).

8.8.8.2 *Terminal Flashing Above Membrane*—Flashing membranes should extend above the wearing surface and the highest possible water level and not less than 150 mm (6 in.) onto the deck membrane. Flashing bitumens and reinforcements must be compatible with the deck membrane. These normally consist of a number of plies not less than that of the deck membrane and are tapered from flashing membrane thickness to the terminal edge at the top where they are secured to the substrate by nailing or by a horizontal transition. The terminal edge should be covered by metal counter or through wall flashing. Where the terminal edge is nailed to a wood nailer, greater protection is provided by stripping over the nailed edge before covering with protection board and the metal counter flashing. The latter serves only as a ~~watershed~~ water shed and protection against construction damage

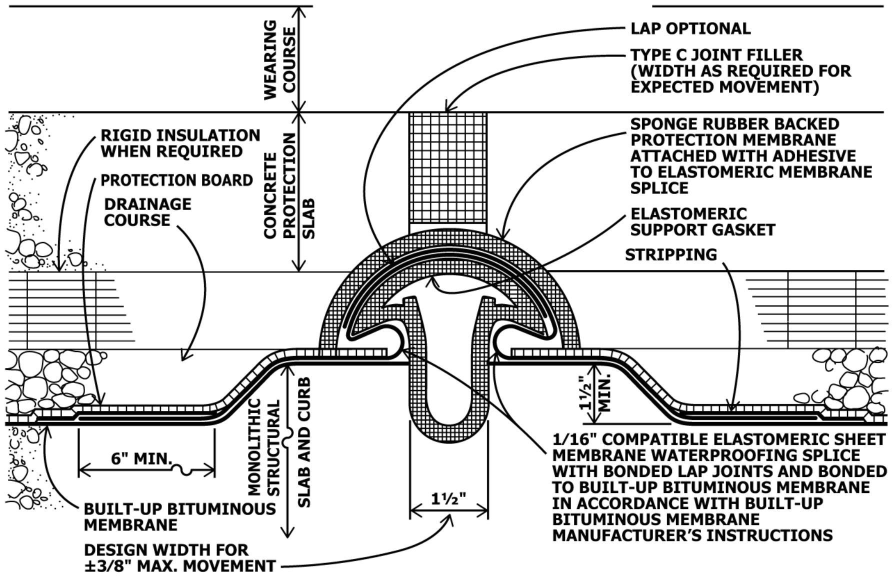

FIG. 3 Water Shed Concept Expansion Joint (see 8.8.7.2)

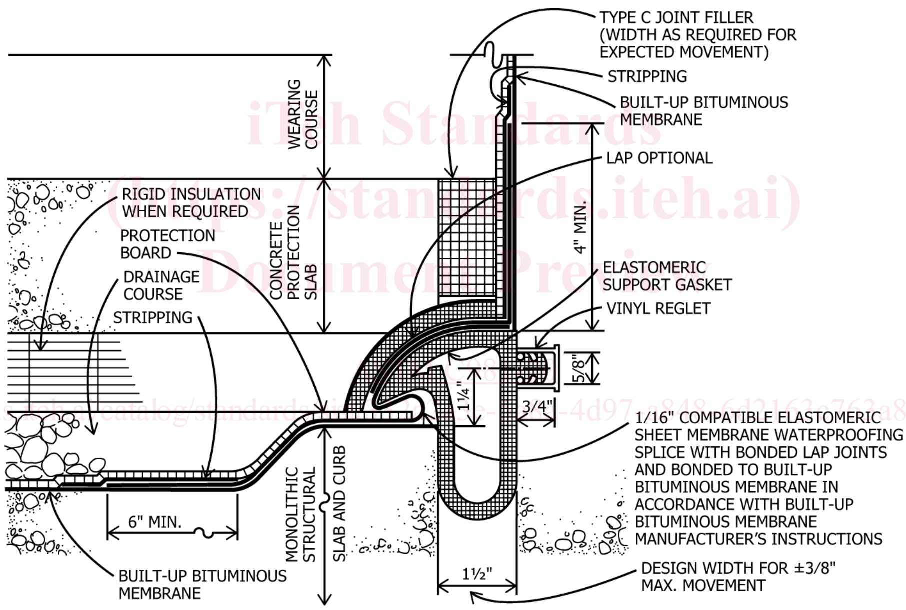

FIG. 4 Water Shed Concept Expansion Joint
(see also 8.8.7.2 and Fig. 5 for ~~Easier Gasket Installation Detail)~~easier gasket installation detail)

or subsequent damage when it becomes vulnerable to finish wearing surface maintenance or physical abuse. Where the metal counterflashing can be punctured, torn, or easily cut and damaged, it is advisable to provide additional protection board over the face during construction and placement of the wearing surface (see Figs. 6-8). Fig. 6 shows how protection is provided above the finish wearing surface and against physical damage from maintenance of the wearing surface. Fig. 7 shows how protection is not provided as well as in Fig. 6 since the terminal edge is below the finish wearing surface but provides for simpler construction. Fig. 8 shows where a masonry or similar facing material is used above the finish wearing surface over a horizontal concrete ledge.

8.8.8.3 *Terminal Flashing Below Membrane*—Turndown flashing of membranes must be treated similarly to turnup flashing, and of similar materials. The flashing should extend over the wall dampproofing or membrane waterproofing not less than 100 mm (4 in.).

8.8.8.4 *Termination at Drain*—Drains must be provided with a wide metal flange or base and set slightly below the drainage level. Metal flashing for the drain, if required, and the clamping ring should be set on the membrane in bituminous plastic cement. The metal flashing is stripped in to provide the primary seal at the periphery of the joint between the metal flashing and the membrane. The stripping consists of a minimum of two plies of membrane reinforcement and three applications of bituminous plastic cement (see Fig. 9).

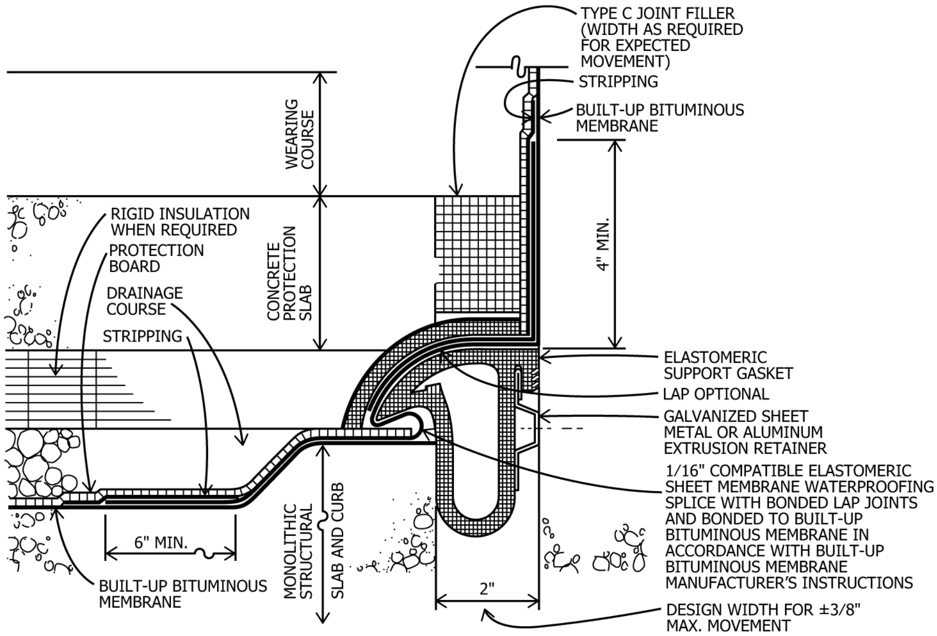

FIG. 5 Water Shed Concept Expansion Joint (see also 8.8.7.2 and Fig. 4)

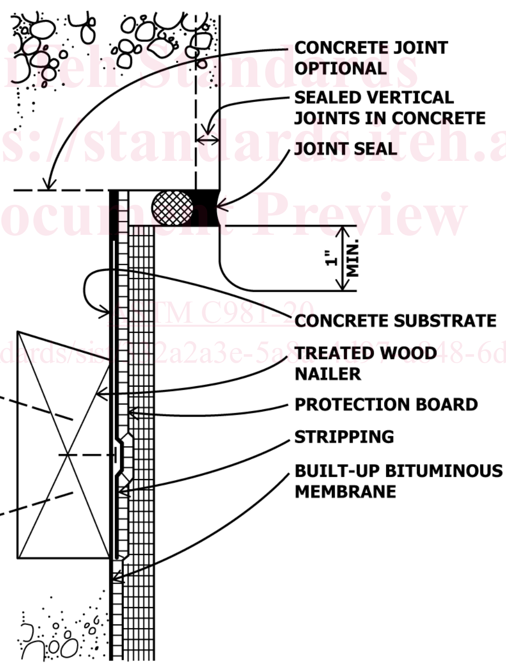

FIG. 6 Terminal Condition Above Finish Grade on Concrete Wall (see 8.8.8 and 8.8.8.2)

8.8.8.5 *Termination at Penetrations*—Penetrations through the membrane such as conduits and pipes should be avoided whenever possible. Penetrations must be flashed to a height above the anticipated water table that may extend above the wearing surface. Proprietary devices are ~~available,~~available which will allow for pipe movements and which provide for the necessary flashing to be knit into the membrane similar to the drainage fitting. It is desirable to cant the surface of the substrate upward to lift the flashing above the surface of the membrane and thus apply the ~~watershed~~ water shed principle (see Fig. 10).

9. Protection Course

9.1 The built-up bituminous membrane should be protected from damage before and during remainder of the deck construction. Protection board should be applied after the membrane is installed. The board also serves to protect the membrane from damage due to movement and penetration of materials above after the deck construction is complete. Protection board should be placed

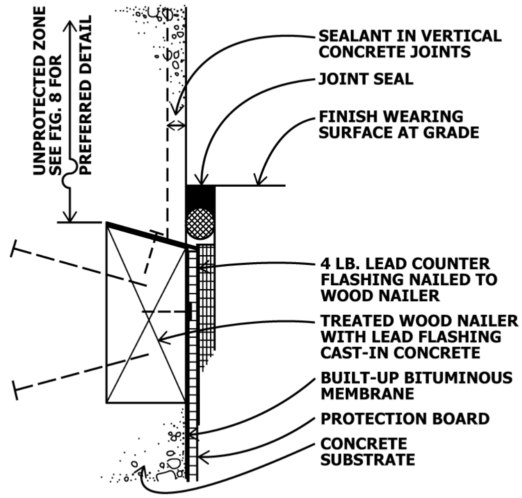

FIG. 7 Terminal Conditions on Concrete Wall Below Finish Wearing Surface at Grade (see 8.8.8 and 8.8.8.2)

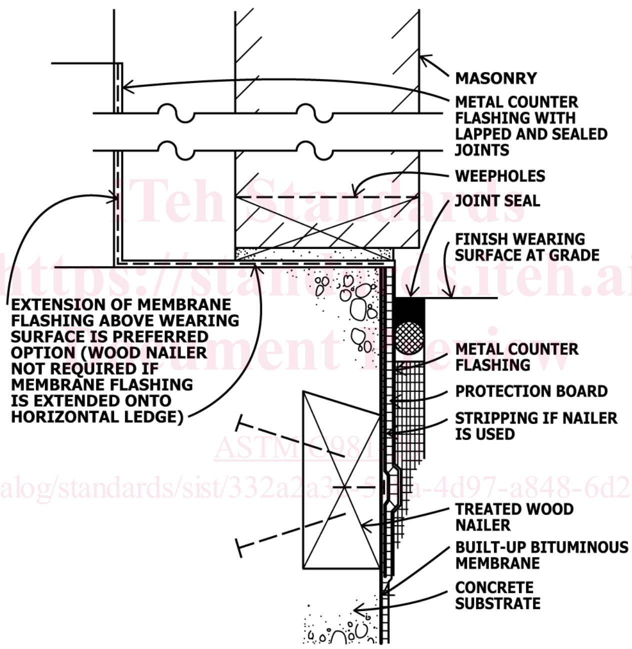

FIG. 8 Terminal Condition with Masonry Above Finish Wearing Surface at Grade (see 8.8.8 and 8.8.8.2)

on the waterproofing membrane as soon as possible after flood testing and any necessary repairs have been completed. Refer to Guide ~~D6451~~D6451/D6451M for protection board installation guidelines. For asphalt-based protection boards, refer to Specification D6506/D6506M.

10. Drainage System

10.1 When the membrane waterproofing is covered over with a wearing course, it is necessarily assumed that water can and will reach the membrane. Otherwise, the membrane below the wearing course would not be needed. Drainage should then be considered as a total system from the wearing surface down to the membrane. The design of the drainage ~~sub-system~~subsystem should be determined considering the probable interior and exterior temperatures, and the rainfall both direct and that which is wind diverted by adjacent structures. The wearing course may consist of such materials as stone, brick or tile, asphalt paving or blocks, and concrete, either as a finish or as a substrate for the above finish materials. Some of these materials can absorb varying amounts of moisture that may cause some to rapidly deteriorate if subjected to freezing temperatures. The plaza drainage system should be designed to minimize cyclic saturation of the wearing surface and its substrate. 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 for functioning both at the membrane level and at the wearing surface. For guidance on the use of drainage media, refer to Guide D7492/D7492M.