Designation: C 981 – 95

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

This standard is issued under the fixed designation C 981; 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 and installation of bituminous membrane waterproofing systems for plaza deck and promenade construction over occupied spaces of buildings where covered by a separate wearing course.

1.2 *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 208 Specification for Cellulosic Fiber Insulating Board[3]
C 717 Terminology of Building Seals and Sealants[4]
C 755 Practice for Selection of Vapor Barriers for Thermal Insulation[3]
D 41 Specification for Asphalt Primer Used in Roofing, Dampproofing, and Waterproofing[5]
D 43 Specification for Coal Tar Primer Used in Roofing, Dampproofing, and Waterproofing[5]
D 173 Specification for Bitumen-Saturated Cotton Fabrics Used in Roofing and Waterproofing[5]
D 226 Specification for Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing[5]
D 227 Specification for Coal-Tar Saturated Organic Felt Used in Roofing and Waterproofing[5]
D 312 Specification for Asphalt Used in Roofing[5]
D 449 Specification for Asphalt Used in Dampproofing and Waterproofing[5]
D 450 Specification for Coal-Tar Pitch Used in Roofing, Dampproofing, and Waterproofing[5]
D 1327 Specification for Bitumen-Saturated Woven Burlap Fabrics Used in Roofing and Waterproofing[5]
D 1668 Specification for Glass Fabrics (Woven and Treated) for Roofing and Waterproofing[5]
D 2178 Specification for Asphalt Glass Felt Used in Roofing and Waterproofing[5]
D 2626 Specification for Asphalt-Saturated and Coated Organic Felt Base Sheet Used in Roofing[5]
D 2822 Specification for Asphalt Roof Cement[5]
D 4022 Specification for Coal Tar Roof Cement, Asbestos Containing[5]
D 4586 Specification for Asphalt Roof Cement, Asbestos Free[5]
D 4601 Specification for Asphalt-Coated Glass Fiber Base Sheet Used in Roofing[5]
D 4990 Specification for Coal Tar Glass Felt Used in Roofing and Waterproofing[5]
D 5295 Guide for Preparation of Concrete Surfaces for Adhered (Bonded) Membrane Waterproofing Systems[5]

3. Terminology

3.1 *Definitions*—The definitions of the following terms used in this guide are found in Terminology C 717: creep; cold joint; compatibility; construction joint; hydrostatic pressure; laitance; reglet; spalling; waterproofing.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cellular (adj).*—having a composition of plastic or rubber with relative density decreased by the presence of cells disposed throughout its mass. In closed-cell materials, the cells are predominantly separate from each other. In open-cell materials, the cells are predominantly interconnected.

3.2.2 *construction joint*—a butt joint formed in a structural slab in order to end one pour and start another pour later. The joint is usually a cold joint and may be held together with reinforcing steel in the slab, or the steel may be discontinuous by design.

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

3.2.4 *deck*—the horizontal structural substrate supporting the plaza deck system. See also *structural slab.*

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

---

[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.

Current edition approved Dec. 10, 1995. Published February 1996. Originally published as C 981 – 83. Last previous edition C 981 – 89.

[2] *Annual Book of ASTM Standards*, Vol 04.02.
[3] *Annual Book of ASTM Standards*, Vol 04.06.
[4] *Annual Book of ASTM Standards*, Vol 04.07.
[5] *Annual Book of ASTM Standards*, Vol 04.04.

3.2.6 *drainage course*—See *percolation layer, geotextile drainage composite,* and Fig. 1.

3.2.7 *dry occupancy*—an occupied space below the plaza deck system in which the computed or anticipated relative humidity is below 30%.

3.2.8 *dynamic*—exhibiting change or movement.

3.2.9 *finish*—the exposed top surface of the plaza deck system, or traffic, or wearing surface.

3.2.10 *flashing*—(*1*) a generic term describing the transitional area between the waterproofing membrane and surfaces above the wearing surface of the plaza. (*2*) a terminal closure to prevent ingress of water into the system.

3.2.11 *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).

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

3.2.13 *geotextile drainage composite*—a performed porous material, usually plastic, with a filter-type fabric over it.

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

3.2.15 *insulating concrete*—a lightweight concrete made with lightweight coarse aggregate and having relatively low insulating characteristics.

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

3.2.17 *ply*—a single layer of membrane reinforcement in the bituminous membrane waterproofing system.

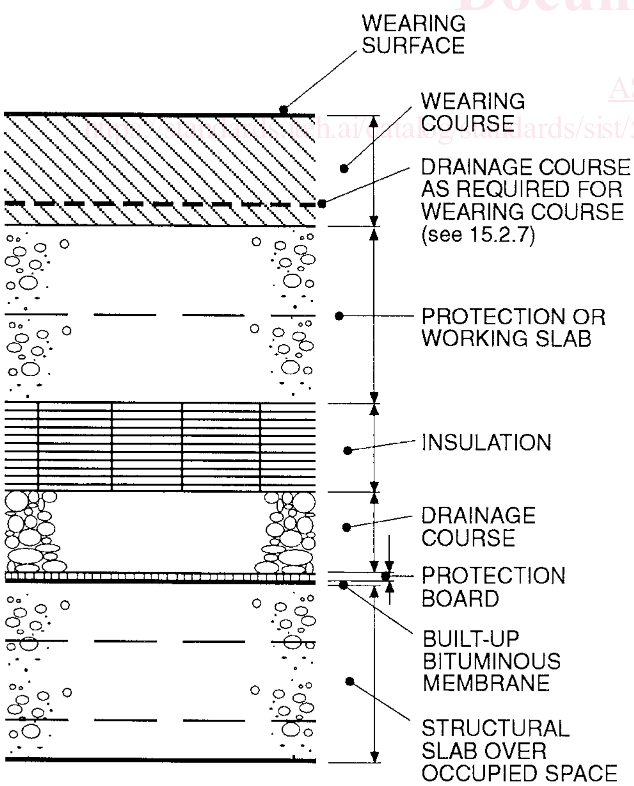

FIG. 1 Basic Components of Built-up Bituminous Membrane Waterproofing System with Separate Wearing Course (see Section 7)

3.2.18 *protection board*—a semi-rigid sheet material placed on top of 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).

3.2.19 *raggle*—same as reglet.

3.2.20 *scaling*—same as spalling.

3.2.21 *static*—exhibiting little or no change or movement.

3.2.22 *structural slab*—a horizontal, supporting, cast-in-place, concrete building deck (see Fig. 1).

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, Sections 5-17, serve as reference and guidance for selection by the designer of the system.

DESIGN CONSIDERATIONS

5. General

5.1 The design of plaza deck waterproofing cannot be satisfactorily determined without 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. Compatibility

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

7. Major Components and Subsystems

7.1 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.

8. Horizontal or Deck Substrate

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

8.1.1 High early strength and 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.

8.1.2 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.

8.2 *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 11 mm/m (⅛ 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.

8.3 *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).

8.4 *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 301-72 (1975) floated finish is required with ACI 301-72 (1975) troweled finish preferred, deleting the final troweling.

8.5 *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.

8.5.1 *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.).

8.5.2 *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 C 755).

8.5.3 *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.

8.6 *Dryness*—Membrane manufacturer's 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.

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

8.7.1 *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.

8.7.2 *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.

8.7.3 *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.

8.8 *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.

9. Membrane Components

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

9.2 *Primers*—Primers (Specifications D 41 and D 43) 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.

9.3 *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 D 312 and D 449, Types I or II) or coal-tar pitch (Specification D 450, Types 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.

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

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

9.3.3 *Modified Bitumens*—Modified bitumens are normally proprietary type products and may not necessarily be classified by organizations such as ASTM. They are designed to develop a particular objective such as extensibility, for example, viscosity variation, strength, reduction of volatiles, etc.

9.3.4 *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.

9.4 *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.

9.4.1 *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, (Specification D 1668, 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.

9.4.2 *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 D 173) is saturated with asphalt or coal-tar saturants.

9.4.3 *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 D 1327) may be saturated with asphalt or coal-tar saturants.

9.4.4 *Saturated Felts*—Dry felts are organic mats saturated with saturating grade asphalt or 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 D 226, Asphalt-Saturated (organic) and Specification D 227, Coal-Tar-Saturated (organic).

9.4.5 *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 (Specification D 2178) are coated with asphalt (Specification D 4990).

9.4.6 *Asphalt-Coated Base Sheets and Coated Felts*—Asphalt-coated base sheets and coated felts, used as membrane reinforcement, consist of asphalt-saturated roofing grade 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 glass fiber base sheet is described in Specification D 4601.

9.5 *Specialty Preformed Membrane*—Specialty sheets may incorporate membrane reinforcement in single or multilayers and be produced as a single preformed sheet. The bitumen is normally modified to provide special characteristics for the composite sheet. These membranes are generally proprietary and not presently classified by reference standards such as those of ASTM.

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

9.6.1 *Bituminous Plastic Cement*—Bituminous plastic ce9ment such as those meeting Specifications D 4022 for coal tar roof cement and D 2822 for asphalt roof cement or D 4586 for asphalt roof cement, asbestos-free (Type I) are made from (*1*) bitumen characterized as self-healing, adhesive, and ductile; (*2*) compatible volatile solvents; and (*3*) mineral stabilizers including asbestos fiber mixed to a smooth uniform consistency suitable for troweling applications. A similar product but which does not contain asbestos is typified by material meeting Specification D 4586 (Type I).

9.6.2 *Reinforced Flashing Felts*—Reinforced flashing felts are composed of asbestos or glass fiber roofing felts impregnated with asphalt, reinforced with a scrim of woven glass fabric or cotton fabric and coated on both sides with asphaltic material compounded with a fine material stabilizer. The reinforced flashing felt with its low flexibility is applicable to gradual transitions.

9.6.3 *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.

9.6.4 *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.

9.7 *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.

9.8 *Membrane Composition and Application*—A built-up bituminous waterproofing membrane consists of components joined together and bonded to its substrate at the site. Paragraphs 9.8.1-9.8.8.5 cover its composition and application on a structural concrete substrate. See Section 13 for insulation considerations.

9.8.1 *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 D 5295.

9.8.2 *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 1 gal/100 ft^2 (0.003 m^3/9.0 m^2). Asphalt Primer (Specification D 41) should be used with asphalt bitumen. Coal-tar primer (Specification D 43) 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.

9.8.3 *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.

9.8.3.1 *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 substracted from 36. The extra 50 mm (2 in.) (36 minus 34) serves as a safety factor to assure that the vertical cross section will contain the designated number of plies.

9.8.3.2 *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 1 of the application of two plies of felt in shingle fashion, in phase 2 of the application of two plies of fabric in shingle fashion, and in phase 3 of the application of the final ply of felt with normal 50 mm (2-in.) single-ply overlaps.

9.8.3.3 *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.

9.8.3.4 *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 10). 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.

9.8.4 *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 kg/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.

9.8.4.1 *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 accomodate the effects of wind chill, sunshine, or ambient temperature. Coal tar pitch should not be heated to or above the actural Cleveland Open Club (COC) flash point.

9.8.5 *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 D 2822, D 4056, or D 4022) (see also 9.6.1) should be applied before application of the bituminous membrane as indicated in Fig. 2.

9.8.6 *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 (see Fig. 3). Where movement is anticipated, these joints should be designed as expansion joints (see 9.8.7).

9.8.7 *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. 4). Flexible support of the membrane is required in each case. Expansion joint details should be considered and used in accordance with their movement capability.

9.8.7.1 *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,

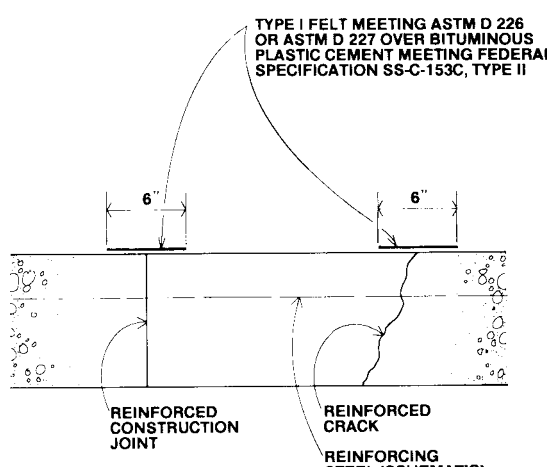

FIG. 2 Treatment at Reinforced Joints (see 9.8.5)