SECTION TWELVE
ROOF SYSTEMS

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Building owners and designers have many deck, insulation, and roof covering materials to choose from for low-slope and steep-slope roof systems. The various systems available can fulfill a wide range of functions, such as energy conservation, acoustical and thermal insulation, and water, fire, and wind resistance. Their ability to do this over their expected service life depends on good design, quality materials, good application, and a commitment by building owners to maintenance.

This section is intended to give an overview of the following: materials for low-slope and steep-slope roofing (including deck, insulation and roof coverings), key design considerations, application, warranties, maintenance, and reroofing. At the end of this section, a list of trade associations (Art. 12.20) and a list of publications (Art. 12.21) is given for those readers interested in further specific information.

ROOF MATERIALS

A **roof system** is an assembly of interacting roof components designed to weatherproof and, normally, to insulate a building's top surface. The roof assembly includes the roof deck, vapor retarder and roof insulation (if they occur), and the roof covering.

12.1 ROOF DECKS

A good roof is dependent upon the structural integrity of the deck and compatibility of the deck with the roof covering and other materials attached to it. Following are descriptions of commonly used decks.

Cementitious wood-fiber panels are composed of treated wood fibers that are bonded together with portland cement or other binder and compressed or molded in flat panels. These panels provide some acoustical attenuation and some thermal resistance.

Lightweight insulating concrete roof decks and fills are produced on the job site by combining insulating aggregates, such as perlite or vermiculite, with portland cement and water. Another variation of this type of deck is referred to as ''cellular,'' lightweight insulating concrete. Rather than using aggregate, cellular concrete is produced with a foaming agent that creates small air cells within the matrix. The compressive strength and thermal resistance of lightweight insulating concrete decks depend on the mix design and composition.

Lightweight insulating concrete may be cast over steel decks or bulb-tee and formboard systems. Some types may also be cast atop concrete decks. For enhanced thermal resistance, molded expanded polystyrene (EPS) boards may be incorporated into lightweight insulating concrete.

Venting of these deck types is an important consideration. Excess water, not consumed during the hydration process, can result in a deck system with a high moisture content. The fills which utilize insulating aggregates, such as perlite or vermiculite, typically have a high water-to-cement ratio. These fills generally require a form deck that allows downward drying. This can be accomplished through the use of perforated (slotted) steel decks, or by permeable formboard and bulb-tee deck systems. ''Cellular'' lightweight insulating concrete fills generally require less water in the mixing process and therefore have a lower moisture content. These fills may have the ability to be applied over non-vented substrates.

Poured gypsum concrete decks, although widely used in the past, are now seldom used, except in a few locations in the United States. This type of deck is produced on the job site by combining gypsum with wood fibers or mineral aggregates and water. The mixture is then cast on formboards.

Structural concrete decks can either be cast-in-place, post-tensioned, or precast (tees, double tees, channel slabs, flat slabs, or hollow-core slabs).

Steel decks are fabricated by roll-forming cold-rolled sheets. They are available in a variety of depths, 1½ in being most common. The panels are available in narrow-rib (Type A), intermediate-rib (Type F), or wide-rib (Type B), the wide-rib being most common. Common thicknesses are 22, 20, 18, and 16 ga. The panels are available in a paint (prime coat or prime and finish coat) or galvanized finish. (See also Arts. 8.22 to 8.24.)

Steel decks can be fabricated with slots to allow downward-drying. Slotted decks are often used with certain types of wet-fill toppings. Acoustical decks, which have numerous small perforations, are also available. Batt insulation is usually installed in the flutes on the top side of the acoustical deck.

Thermosetting insulating fill is produced on the job site by mixing perlite aggregate with a hot asphalt binder. The mix is then placed over a structural deck. This fill provides some insulation, and it can be utilized to provide slope for drainage. Although more common years ago, this type of system is still available.

Wood planks or panels can be composed of solid wood planks (usually tongue-and-groove) or sheathing panels. Sheathing was originally composed of all-veneer plywood, but now, oriented strand board (OSB) also is used. OSB is composed of compressed, strand-like particles arranged in layers oriented at right angles to one another. If sheathing is required for roof decking, sheathing intended for this purpose should be specified.

12.2 VAPOR RETARDERS

These comprise a wide range of materials used to control flow of water vapor from the building interior into wall or roof systems. Unless precautions are taken, water vapor in the interior of a building, especially if it has a high-moisture occupancy, may condense within the cold roof system, saturating the insulation and reducing its effectiveness, or will drip back into the building, staining the ceiling or wetting the floor.

A vapor retarder placed in an appropriate location, however, can control such condensation. For many years NRCA has maintained that vapor retarders should be considered when both of the following conditions occur: the outside average January temperature is below 40°F (4°C), and the expected indoor winter relative humidity is 45% or greater. However, these are very simple guidelines. Both the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) and the U.S. Army Corps of Engineers' Cold Regions Research and Engineering Laboratory (CRREL) have developed recognized practices for determining the need for a vapor retarder in a roof system. These methods differ, and designers should choose the methodology which they deem most applicable for a given project.

Situations more likely to require the inclusion of a vapor retarder are those where interior conditions of high humidity exist, such as in textile mills, laundries, canning factories, creameries, breweries, and indoor pools.

Perm Ratings. The effectiveness of a vapor retarder is measured by its perm rating, which is a measure of porosity of material to passage of water vapor. Perm ratings are established by ASTM procedures. To be classified as a vapor retarder, the material should have a perm rating between 0.00 and 0.50 perms.

A perm rating for a material is the number of grains of water vapor (7000 grains equal 1 lb) that will pass through 1 ft^2 of the material in 1 hr when the vapor-pressure differential between the two sides of the material equals 1 in of mercury (0.49 psi).

Retarder Materials. Following are descriptions of some frequently used vapor retarder materials:

Bituminuous vapor retarders are constructed on the job site. They are composed of alternating layers of hot-applied asphalt and asphalt roofing felts (Art. 12.4.1). Generally, two plies of felt and two or three moppings of asphalt are specified.

Kraft paper retarders are typically factory fabricated by adhering two layers of kraft paper together with asphaltic adhesive and glass-fiber reinforcement. At the job site, the rolls of kraft paper are adhered to the substrate and to one another with a cold-applied asphalt adhesive.

Polyethylene sheets (typically 4, 6, or 8 mils thick) are employed in some types of roof systems. In some cases, they are loose-laid, or they may be attached with mechanical fasteners. The laps can be sealed with tape or sealant. In the past, polyethylene or similar types of plastic film materials were adhered with a cold-applied asphaltic adhesive. However, because of difficulties in obtaining secure attachment, plastic-sheet vapor retarders are no longer typically attached in this manner.

Aluminum foil used as a vapor retarder is typically applied to the face of an insulation product in the factory. Aluminum foil is also used as a "reflective insulation system" or a "radiant barrier system" (Art. 12.3). Aluminum-foil facers on rigid insulation boards are usually not considered a vapor retarder, because of the discontinuity at board joints.

12.3 ROOF INSULATION

Many of the insulation products described in the following are available in tapered configurations.

Cellular glass is a rigid insulation composed of heat-fused closed glass cells.

Cellulosic fibers are generally used as loose-fill insulation. They are made of recycled paper.

Glass-fiber batts or blankets (the only difference being the length of the product) are composed of glass fibers and a binding agent. The batts may be finished on one side with a kraft paper or aluminum-foil facer, or they may be left unfaced.

Glass-fiber board is a rigid insulation composed of glass fibers and a binding agent and is faced on the top surface with kraft paper.

Mineral-wool batts are similar to glass-fiber batts, except that they are composed of mineral fibers (produced from molten rock). Mineral-wool batts have high resistance to heat. Typically, they are used for fire-safing; for example, curtain walls or sealing at fire wall or floor penetrations, or steel fireproofing. Mineral batts are typically not used for roofing, except for insulating seismic joints or expansion joints, where enhanced fire resistance is desired.

Mineral-wool board is a rigid insulation similar to glass fiber boards except that it is composed of mineral fibers (produced from molten rock). These boards are available faced or unfaced with aluminum foil.

Perlite rigid insulation is composed of expanded perlite, cellulose, and a binding agent.

Phenolic resin has been formed into a rigid, plastic-foam insulation. It is no longer produced in the United States. It should be noted that phenolic insulation has shown a high potential for causing steel deck corrosion, and in some instances, the structural integrity of the roof deck has been impaired. Deck repair or replacement should be anticipated where phenolic insulation over a steel deck exists.

Polyisocyanurate may be used as rigid, plastic-foam insulation. It resembles, and has essentially replaced, polyurethane board insulation because of better fire resistance. Polyisocyanurate boards have been produced with a variety of facers. Glass-fiber and organic/inorganic are now the most common. The boards are also available as composites, which are factory produced by foaming the insulation to perlite, wood sheathing, or other types of substrates. Currently, the foam is produced by an HCFC (hydrochlorofluorocarbon) blowing agent, which initially is the gas that fills the cells. Over considerable time, oxygen and nitrogen diffuse into the cells, and the HCFC diffuses out, thereby decreasing the thermal resistance. This phenomenon is known as **thermal aging** or **thermal drift.** Polyisocyanurate insulation has the highest *R*-value (thermal resistance) per inch thickness of any insulation currently produced in the United States.

Due to government regulations, the HCFC blowing agents currently used in the manufacture of polyisocyanurate foam insulation are scheduled to be phased-out by the end of 2002. It remains to be seen what type(s) of blowing agents will be used in the next generation of this type of insulation.

Polystyrene made into a rigid plastic foam has two distinctly different forms. Molded expanded polystyrene (EPS) has air-filled cells and hence is not subject to thermal aging. EPS is available with a variety of densities, and its *R*-value is a function of the density. Extruded polystyrene is blown with HCFC; thus it has a higher *R*-value than EPS. Extended polystyrene insulation is very resistant to water and water vapor and is available in very high compressive strengths. Accordingly, it is the only type of insulation recommended for use in protected membrane roofs (PMR) or plaza decks (Art. 12.15).

Radiant barrier system (RBS) utilizes aluminum foil product with a low-emittance (high-reflectance) surface. An RBS is intended to reduce radiant heat transfer between a hot roof deck and cooler floor below (or vice versa).

Reflective insulation system (RIS) employs double-sided aluminum foil product, which is used in combination with bulk insulation, or in lieu of bulk insulation. The system incorporates an enclosed air space that may contribute significantly to the thermal resistance.

Spray-applied polyurethane foam (SPF), in addition to providing thermal insulation, also functions as the roofing system (Art. 12.4.6).

Wood fiberboard is a rigid insulation manufactured from wood or cane fibers and binders.

12.4 LOW-SLOPE ROOF COVERINGS

Roof coverings may be classified into two main groups in accordance with the slope of the roof. Low-slope roof coverings generally utilize a weatherproofing membrane and are designed for slopes on which water proceeds slowly to drainage outlets. Steep-slope roof coverings are designed for roofs with swift drainage. Generally, they are considered "water shedding" and are comprised of many individual pieces or components installed in a shingle fashion to shed water from one course to the next.

12.4.1 Built-Up Roofs (BUR)

This is the traditional low-slope membrane roof covering. It is composed of bitumen (either asphalt or coal tar), usually applied hot, felts (either organic, glass-fiber, or polyester), and a surfacing, such as aggregate, coating, or cap sheet (Fig. 12.1). The membrane is composed of three to five plies of felt (as few as two plies are sometimes specified when polyester felt is used). The first ply is typically either set in a continuous layer of hot bitumen or is nailed to the deck. Subsequent layers of felt are set in a continuous layer of hot bitumen.

An alternative to a traditional BUR is the protected-membrane roofing system. It consists of several layers installed in a sequence different from the usual one in which insulation is placed below the roof deck. First, standard built-up roofing is applied directly to the deck. Then, rigid insulation that is impervious to moisture, such as extruded polystyrene foam, is bonded to the top of the built-up roofing with a mopping of steep asphalt (Fig. 12.2). A layer of ¾-in crushed stone (1000 lb/square) or paving blocks or structural concrete on top of the insulation completes the assembly. Gravel or slag should not be used, because the sharp edges would damage the bare insulation underneath.

The theory is that the insulation, set above the roofing, both insulates the building and protects the built-up roofing from the harmful effects of thermal cycling, ultraviolet degradation, weathering, and roof traffic. Most common defects caused by these elements, such as blistering, ridging, cracking, alligatoring, and wrinkling, are virtually eliminated.

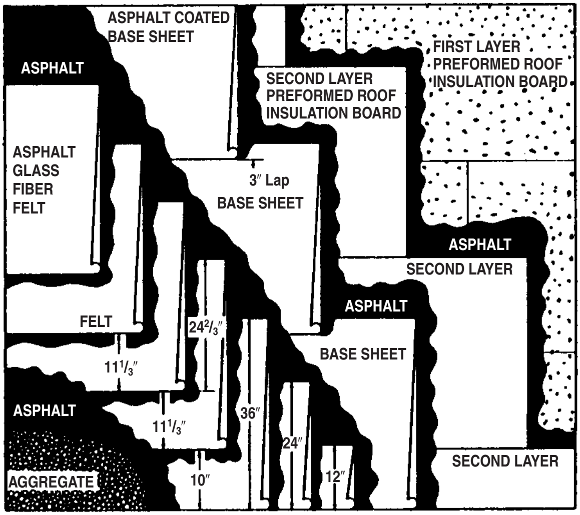


FIGURE 12.1 Built-up roofing over two layers of preformed insulation board. Three plies of asphalt-impregnated glass-fiber felt, embedded in a continuous application of hot asphalt, overlay a base sheet adhered with asphalt to the insulation. Aggregate surfacing, about ⅜ in in diameter, is spread in the top flood coat of asphalt. (*NRCA Roofing and Waterproofing Manual.*)

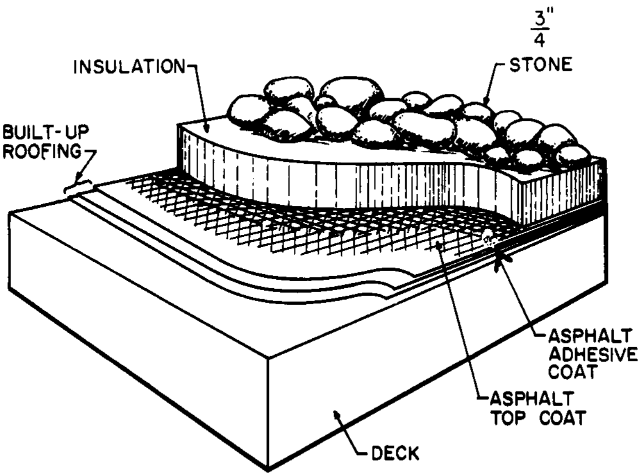


FIGURE 12.2 Protected-membrane roof with aggregate and insulation placed over, instead of under, the built-up membrane.

Bitumen may be asphalt or coal tar. Roofing asphalt is a derivative of petroleum. It is described in ASTM Standard D312, which includes specifications for Types I, II, III, and IV. Each type has a different softening-point range, which should be considered by the specifier when specifying the type of asphalt to be used. Coal tar, described in ASTM D450, is a derivative of the production of coke from coal. Type I is referred to as "old-style pitch." Type II is used for below-grade waterproofing. Type III, or coal-tar bitumen, was developed to be less of an irritant during application than Type I; however, Type III is no longer produced.

Felts are sheet materials used to reinforce waterproofing and roofing membranes. The predominant type of felt used is glass fiber although organic felts are still commonly used in the construction of coal-tar systems. Polyester is an alternative type of felt. Asbestos felts were used in the past but are no longer produced in the United States.

There are two primary categories of felt—base sheets and ply sheets. **Base sheets** are heavier felts that are often used for the first layer of felt to be installed. If the felt is to be nailed, a base sheet is recommended because of its greater strength. **Ventilating base sheets** are intended to allow for the venting of moisture-vapor pressure by lateral (horizontal) movement. However, if a ventilated base sheet is to be used, the designer should take into account the small driving force for horizontal moisture transport and the small amount of moisture that can be moved horizontally.

Surfacings as applied to built-up membranes, are typically small pieces of aggregate or slag, liquid-applied coatings, or a cap sheet. Common coatings include cutbacks and emulsions, which are both cold-applied. **Cutbacks** are composed of asphalt and solvent and often include an aluminum pigment for reflectivity. **Emulsions** consist of clay and asphalt particles dispersed in water. Some emulsions include aluminum pigment or titanium dioxide for reflectivity. The cutback and emulsion coatings are available in fibrated or nonfibrated grades. Latex (acrylic) coatings are also available, but for built-up roofs, these coatings are not used as often as the other types of coatings. **Cap sheets** are heavy coated felts that are factory surfaced with mineral granules.

Cold-process roof coverings (also known as cold-applied) are similar to hot-applied BUR, except that instead of hot bitumen, asphalt-based cutbacks or emulsions are typically used. They are applied by sprayer, brush, broom, or squeegee.

12.4.2 Liquid-Applied Roof Coverings

Liquid-applied systems are supplied as either single or two-component elastomeric materials. They are applied by sprayer, brush, roller, or squeegee. Typically these systems are applied directly over concrete or wood sheathing. Deck joints and cracks normally require special preparation. See also cold-process roof coverings (Art. 12.4.1) and coatings on polyurethane foam roofs (Art. 12.4.6).

12.4.3 Metal Roof Coverings

These are generally used for steep-slope roofs rather than for low-slope roofs. See Art. 12.5.3. However, some standing-seam structural panel systems can be used successfully in low-slope situations. These systems are considered "hydrostatic," that is, they have the ability to resist water intrusion under some pressure. These panel systems generally incorporate a sealant in the seam, or an anti-capillary hem to provide the necessary protection from moisture infiltration through the seams.

12.4.4 Modified Bitumen Membranes

These are typically composed of prefabricated sheets of polymer-modified asphalt with polyester or glass-fiber reinforcement or a combination of these. The polymers most used for asphalt modification are atactic polypropylene (APP) or styrene-butadiene-styrene (SBS). These prefabricated sheets are commonly installed over a base sheet (Art. 12.4.1), which may or may not also be composed of modified bitumen. Sometimes the assembly also includes a ply sheet (Art. 12.4.1).

In the past, modified bitumen membranes were occasionally applied in a single layer. However, two or more layers are now the predominant system (Fig. 12.3).

SBS sheets are generally set in a continuous layer of hot asphalt, but some sheets may be torch-applied or set in cold adhesive. Self-adhering styrene-ethylene-propylene-styrene (SEPS) sheets are also available. SBS and SEPS sheets need protection from ultraviolet light (UV). Protection is typically provided by factory-applied mineral granules. They may also be surfaced with coatings (Art. 12.4.1).

APP sheets are generally torch-applied (Fig. 12.4). When APP sheets were introduced in the United States in the late 1970s, they were generally used without surfacing, since UV protection was reportedly provided by the APP modifier. While some such APP membranes weathered very well, others did not. Hence, coatings (cutbacks, emulsions, or latex) or granules are now often used.

The ASTM material standards for polymer-modified bitumen sheet products are as follows:

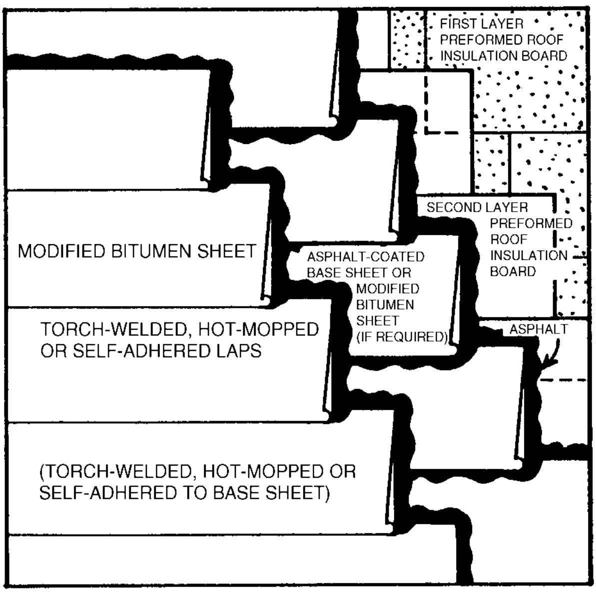


FIGURE 12.3 Modified bitumen roof with a base sheet overlaying two layers of preformed insulation board. (*NRCA Roofing and Waterproofing Manual.*)

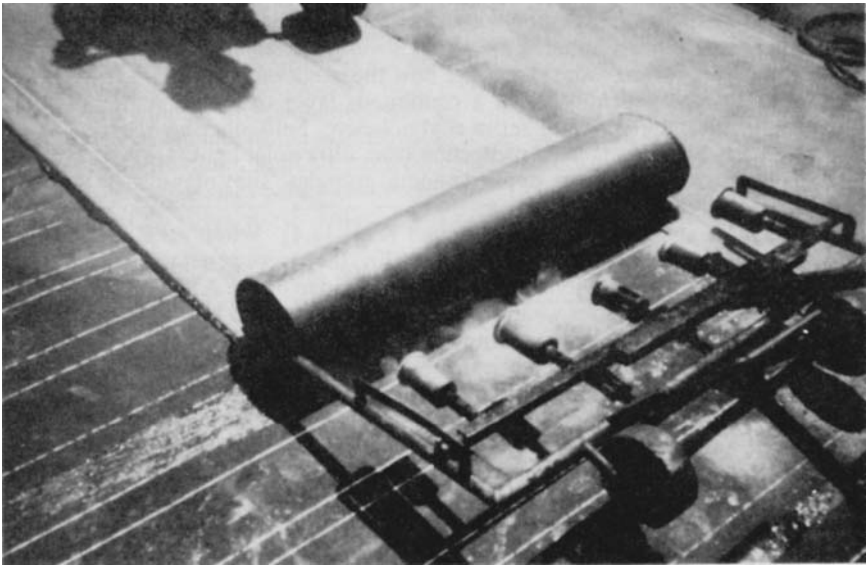


FIGURE 12.4 Torch application of atactic polypropylene (APP) modified bitumen membrane.

- ASTM D6162, "Standard Specification for Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using a Combination for Polyester and Glass Fiber Reinforcements"
- ASTM D6163, "Standard Specification for Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using a Glass Fiber Reinforcements"
- ASTM D6164, "Standard Specification for Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using Polyester Reinforcements"
- ASTM D6222, "Standard Specification for Atactic Polypropylene (APP) Modified Bituminous Sheet Materials Using Polyester Reinforcements"
- ASTM D6223, "Standard Specification for Atactic Polypropylene (APP) Modified Bituminous Sheet Materials Using a Combination of Polyester and Glass Fiber Reinforcements"
- ASTM D6298, "Standard Specification for Fiberglass Reinforced Styrene Butadiene Styrene (SBS) Modified Bituminous Sheets with a Factory Applied Metal Surface"

For each of these standards, except ASTM D 6298, type classifications (e.g., Type I, Type II) differentiate products (covered by the same standard) by the products' dimensions, masses and physical properties. In addition, grade classifications differentiate products by the products' surfacing type: Grade G designates granule surfacing and Grade S designates smooth surfacing.

Instead of incorporating prefabricated modified bitumen sheets, membranes can also be constructed with modified mopping asphalt and felts (of the type used for BUR construction). For modification of asphalt for application by mopping or by mechanical spreaders, styrene-ethylene-butylene-styrene (SEBS) polymers are utilized.

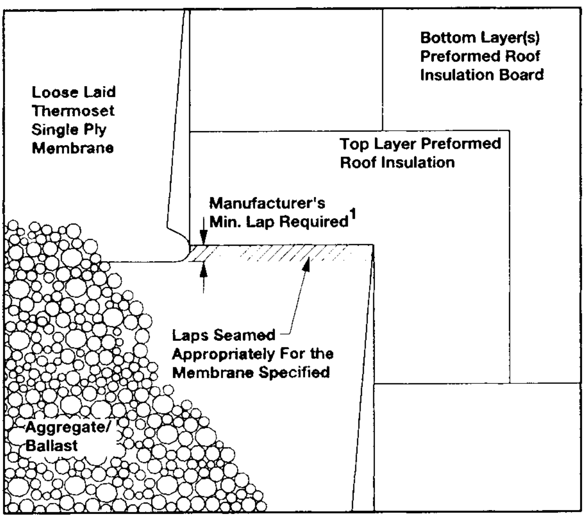
12.4.5 Single-Ply Roof Coverings

The single-ply family of roofing materials includes some distinctly different products. (Modified bitumen products [Art. 12.4.4] are sometimes included in the single-ply category.) The single-plies can be classified as either thermoset or thermoplastic materials. Thermoset materials normally cross-link (cure) during manufacturing. Once cured, these materials can only be bonded to themselves; for example, at a seam. Bonding is accomplished with an adhesive. Thermoplastic materials do not cross-link. Therefore, they should be capable of being welded together throughout their service life. Welding is usually accomplished with hot air.

There are three primary methods for attachment of single-ply membranes to a roof deck. In the ballasted system, the membrane is laid loose over the substrate and then covered with ballast to resist uplift from the wind (Fig. 12.5*a*). The ballast can either be large aggregate or concrete pavers. In the second method of attachment, the membrane is fully adhered in a continuous layer of adhesive (12.5*b*). In the third method, the membrane is mechanically attached to the deck (Fig. 12.5*c*).

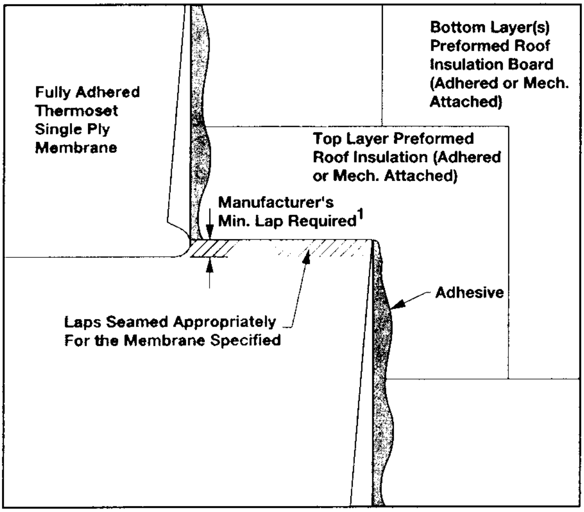
The mechanically attached system generally utilizes screws with stress plates, or metal batten bars, located within the membrane lap (seam). Alternately, the battens may be placed on top of the membrane and covered with a stripping ply of the membrane material. There are other variations of the mechanically attached system, many of which are proprietary to a single membrane manufacturer.

Following are descriptions of single-ply membrane materials.

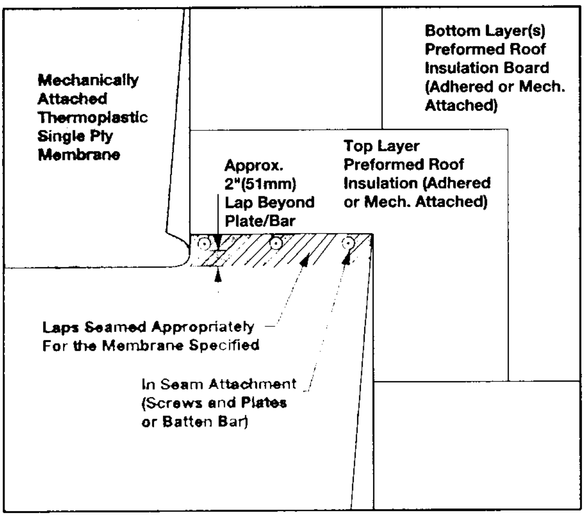


(a)

FIGURE 12.5 Methods of installing single-ply membrane over insulation board: (*a*) ballasted; (*b*) fully adhered; and (*c*) mechanically attached.



(b)



(c)

FIGURE 12.5 (*Continued*)

Chlorosulfonated polyethylene (CSPE) is commonly known by the trade name *Hypalon.* It is a thermoset product, but it cures after installation on a roof. This product is specified in ASTM D5019 (Type I). It is usually supplied in a white color.

Ethylene propylene diene terpolymer (EPDM) is a synthetic rubber membrane. It is a thermoset product specified in ASTM D4637. This standard includes specifications for Type I, non-reinforced; Type II, scrim (or fabric) internally reinforced, and Type III, fabric backed. It is available in a white color, but black is used most often.

Polyisobutylene (PIB) is a thermoplastic product, specified in ASTM standard D5019 (Type II). It is available in a black or white color.

Polyvinyl chloride (PVC) is a thermoplastic product, specified in ASTM D4434. Different types and grades are specified in ASTM D4434 and identify a membrane by the type and location of the reinforcement or fabric backing. It is available in a variety of colors.

PVC blends (also known as *copolymer alloys*) are based on PVC resin. They are similar to PVC membranes. The next revision of ASTM D4434 will probably also cover PVC blends.

Thermoplastic polyolefin (TPO), as the name denotes, is a thermoplastic product containing polyolefin polymers. TPOs are newer to the marketplace in the United States; however, variations of this membrane have been used in Europe for many years. Currently, an ASTM standard is being drafted for this single-ply membrane product.

12.4.6 Spray-Applied Polyurethane Foam (SPF) Roof Coverings

These consist of polyurethane foam insulation, which is spray-applied to the substrate, and topped with a surfacing (Fig. 12.6). Traditionally, the foam is surfaced with a coating of latex (acrylic), polyurethane, or silicone. Mineral granules are sometimes applied to the wet coating for additional abrasion and impact resistance (at traffic walkway areas or throughout the entire roof).

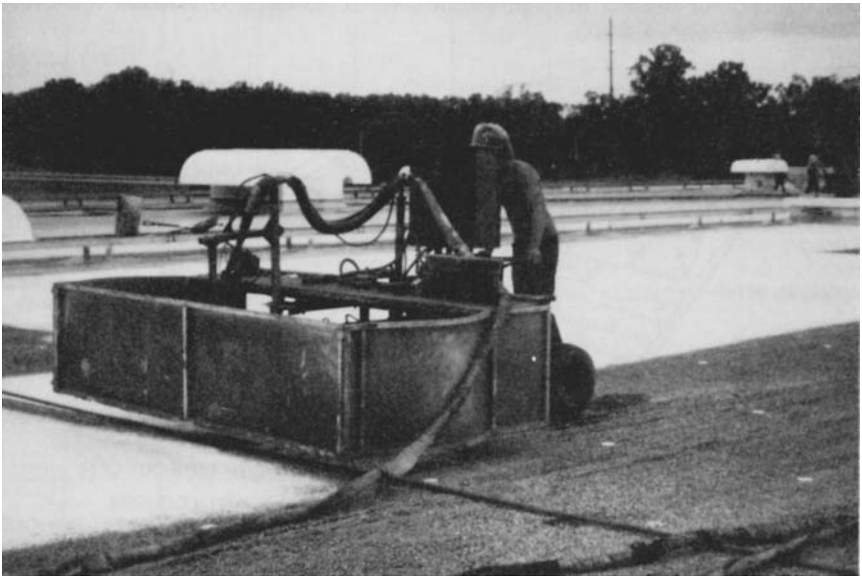


FIGURE 12.6 Robotic sprayer applying polyurethane foam.

An alternative surfacing is aggregate, similar to the type used for BUR placed directly over the foam. In this system, coatings are used only on vertical surfaces, such as parapets or equipment curbs.

See also Art. 12.21, "Roof Systems Bibliography."

12.5 STEEP-SLOPE ROOF COVERINGS

These differ from low-slope roof coverings in that on steep-slope roofs water flows rapidly over exposed units to eaves. Many of the low-slope roof coverings described in Art. 12.4 can be successfully used on steep slopes. Many of the low-slope materials, however, become slick when wet. This should be taken into account before they are specified for steep slopes.

12.5.1 Asphalt Shingles

These are composed of a reinforcing mat (organic or glass fiber), a specially formulated asphalt coating, and mineral granules. (Glass-fiber reinforced shingles are sometimes referred to as *fiberglass shingles.* Organic-reinforced shingles are sometimes referred to as *asphalt shingles,* which is confusing, for this term properly

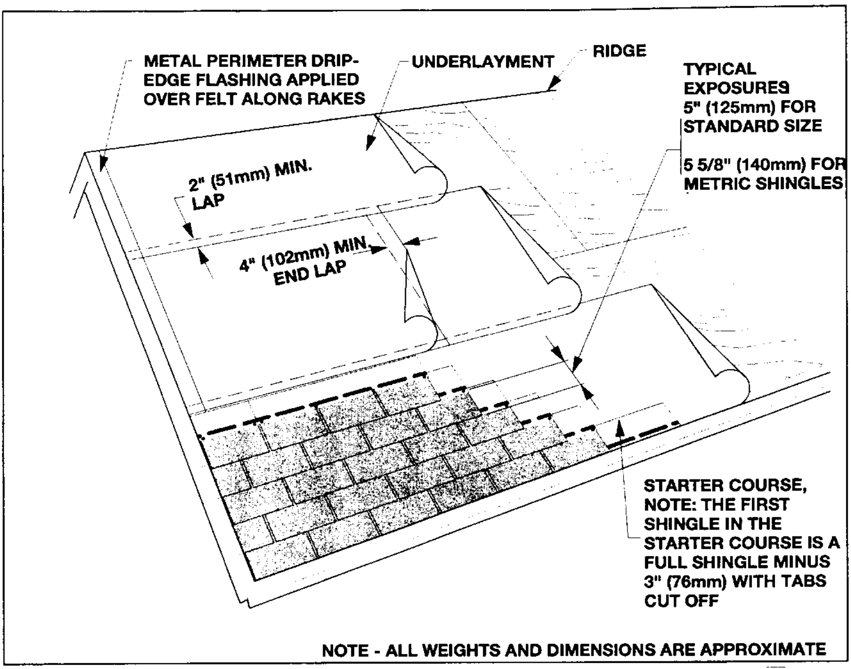


FIGURE 12.7 Three-tab asphalt-shingle roof.

applies to both the organic and glass-fiber reinforced products.) Most asphalt shingles are manufactured with a self-seal adhesive for wind resistance.

Asphalt shingles are available in a variety of weights. (Weight, however, is not necessarily an indicator of product performance.) Also, they are available in a variety of styles and colors, including three-tab strip shingles (Fig. 12.7), strip shingles, shingles without cutouts, and laminated (architectural) shingles. Laminated shingles have a heavy texture. Shingles that enhance the three-dimensional look by adding shadow lines or shading through use of colored granules are also available. Glass-fiber reinforced asphalt shingles are specified in ASTM D3462. Organic-reinforced asphalt shingles are specified in ASTM D225. Shingles are also available which utilize a polymer-modified bitumen in lieu of the more traditional coating-grade asphalt.

12.5.2 Cement-Fiber Shingles

Formerly reinforced with asbestos fibers and hence known as *cement-asbestos shingles,* cement-fiber shingles are now reinforced with fibers other than asbestos. Some of these products are intended to visually simulate other products, such as slate.

It is important to note that some of these products have restrictions in climatic locations where freeze/thaw cycling is experienced. Consult the product manufacturer for specific information regarding appropriate locations.

12.5.3 Metal Roof Coverings

The metal category includes a large variety of products, such as metal shingles and panels. Metals used to form the products include aluminum, copper, galvanized steel, and aluminum-zinc-alloy steel (*Galvalume*). Steel and aluminum panels are available with several different types of pain finishes and colors. Many of the products are formed in a factory, while others are formed on the job site by the roofing contractor.

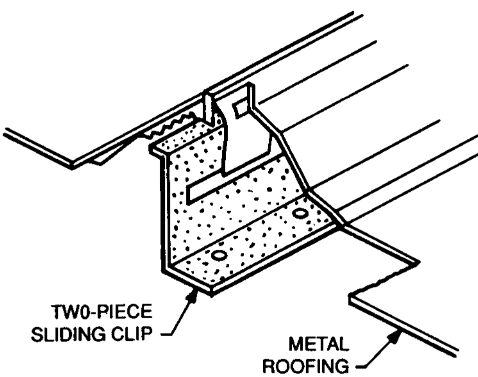


FIGURE 12.8 Trapezoidal-shaped structural metal-panel roofing system with concealed clips at seams.

Metal roof panels include four primary types: structural standing seam, architectural standing seam, exposed fastener, and traditional metal roofing. Standing-seam panels are available with or without battens. The standing-seam and exposed-fastener panels are roll-formed, while traditional panels are typically press-brake formed. The exposed-fastener panels have largely been replaced by standing-seam panels, except for very inexpensive construction.

Architectural and most traditional panels need to bear on a continuous structural substrate (deck) in order to carry live loads, such as snow. However, architectural panels should be designed to accommodate design wind loads.

Structural panels (Fig. 12.8) have the capability of spanning between supports. Accordingly, they can be placed over purlins (as is the case with preengineered metal buildings), as well as over continuous structural substrate. Some structural panels have the capability of being successfully used as low-slope coverings.

12.5.4 Roofing Slate

Slate is a dense durable rock that has a natural cleavage plane. The surface texture and color of slate after it is split depend on the characteristics of the rock from which it is quarried. Roofing slate is a long-lasting but very heavy material.

Slate roofs may be classified as standard slate, graduated slate, and textural slate. The latter is the older form, in which slates are delivered to the job in a variety of sizes and thicknesses, to be sorted by slaters. The longer and thicker slates are placed near the eaves, medium sized at the center, and the smallest at the ridge.

Standard slate roofs have one uniform width and length. The lengths are typically square and laid to a line. Textural slate roofs are composed of textural slate, which is usually rougher than standard slate, have uneven tails, and vary in size and thickness. Roofing slate is specified in ASTM C406 (Fig. 12.9).

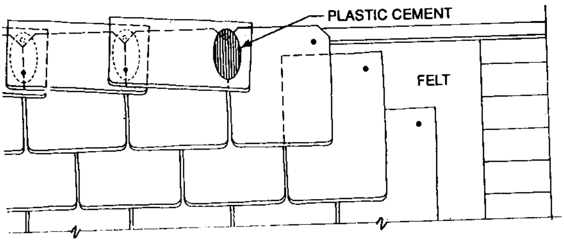
Active roofing slate quarries in North America exist in New York, Pennsylvania, Vermont, and Virginia, as well as the Canadian provinces of Quebec and Newfoundland. Imported slate is available from Spain, Wales, China, Brazil, South Africa, and other countries. Information concerning the quality of slate produced domestically is more readily available than with most imported slate. It may be necessary to test slate, according to ASTM C406, if the quality of the slate's source location (bed or quarry) is unknown or inconsistent.

12.5.5 Synthetics

This class of materials includes a variety of products that are intended to simulate other materials. Typically, synthetics simulate wood shingles or shakes, tile, or slate. The imitation materials include cement-fiber and metal (Arts. 12.5.2 and 12.5.3), and polymer composites.

12.5.6 Roofing Tile

Produced from clay or concrete, tiles (Fig. 12.10) are available in a variety of shapes, colors, and textures. Clay tiles are specified in ASTM C1167. Quality tiles can have a long service life when properly designed and installed.



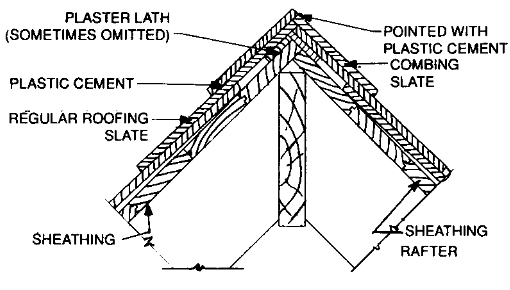


FIGURE 12.9 Slate roof, (*a*) Slates in each course cover joints in those below, have a headlap of 3 in over the lowest course below, and have an exposure (portion not covered by next course above) equal to $\frac{1}{2}(L - 3)$, where L is the slate length, in. (*b*) Section at roof ridge illustrates the saddle-ridge method, in which regular slates extend to the ridge so that slates on opposite sides of the ridge butt flush. Another course of slate, called combing slate, is set on top, butting flush at the ridge.

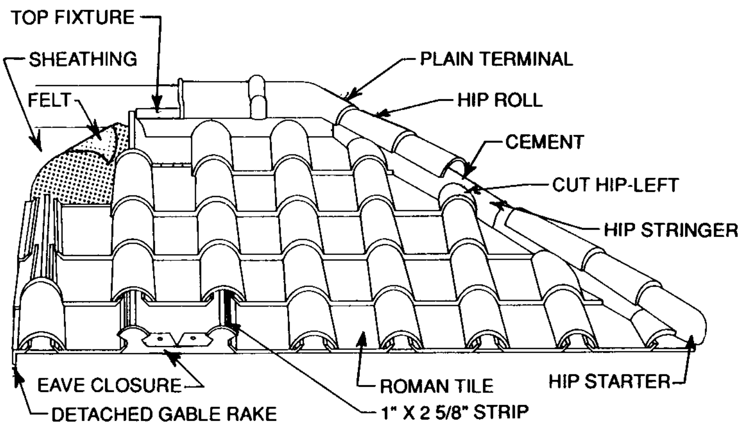


FIGURE 12.10 Roman tile application at hip and ridge of a roof.

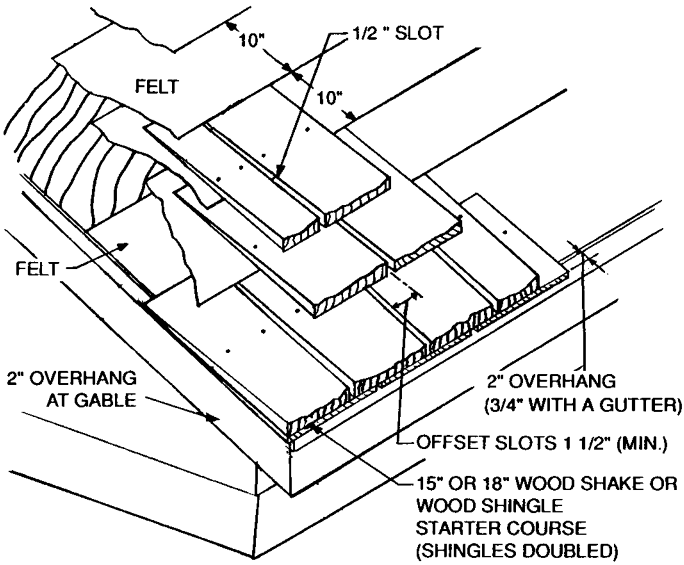


FIGURE 12.11 Wood shake application at the eaves of a roof.

12.5.7 Wood Shingles and Shakes

Shingles are sawn on both sides, while shakes are split on at least one surface. Cedar is typically used for wood roofs, but other species of wood are sometimes used. There are different grades of shingles and shakes, and they can be pressure-preservative treated or pressure treated for fire resistance. See also Art. 12.21, "Roof Systems Bibliography." Figure 12.11 shows a typical wood shake installation.

KEY DESIGN AND APPLICATION CONSIDERATIONS

A complete discussion of design considerations for the primary types of low-slope and steep-slope roofing systems is beyond the scope of this book. However, a few general key considerations are discussed in the following.

12.6 NEED FOR FAMILIARITY WITH ROOF DESIGN

A common pitfall for designers is lack of familiarity with the principles of roof design. This is manifested in selection of inappropriate materials or systems or inadequate details, or use of poorly prepared specifications. To assist designers, several periodicals and books are available (Art. 12.21) and seminars are offered by the Roofing Industry Educational Institute and the National Roofing Contractors Association (Art. 12.20).

In addition to these resources, designers would find it helpful to establish a working relationship with a professional roofing contractor. Many contractors are willing to spend some time with designers. This can be particularly helpful if the designer is working on a project that has some unusual aspect, or if a material or system is being contemplated with which the designer is not familiar. For more extensive input, utilization of a professional roofing consultant may be advantageous.

12.7 BUILDING OWNERS' REQUIREMENTS

It is important for roof designers to determine if the building owner has any specific requirements, such as type of materials; what the building owner's expectations are regarding the roof's longevity; and to what extent the owner is committed to maintenance. If the owner is unwilling to allocate adequate funds for maintenance, a conservative durable system should be selected.

Also, designers should determine how detrimental leakage or a roof flow-off would be. For most buildings, these events are unpleasant but generally manageable. But, if the roof is over very expensive electronic equipment, or a critical facility such as a hospital, a conservative roof design may well be appropriate. It is also desirable to determine if the owner's insurer has specific requirements for the roof system.

Contract documents should be carefully designed and administered. A good roof design should be complemented with comprehensive, unambiguous specifications and drawings, so that the design intent is clearly communicated to the contractor.

12.8 BUILDING-CODE PROVISIONS FOR ROOFS

Designers should be aware of building-code requirements affecting design of the roof. Model building codes and many state and local codes have provisions related to roof systems (for new construction, as well as reroofing).

Fire and wind resistance, material standards, storm water drainage, structural loading, and energy efficiency are some of the many objectives of building codes that are common to roof design. Many local jurisdictions have such requirements for residential and/or commercial construction.

12.9 EFFECTS OF CLIMATE

The climate in the region where the roof will be constructed often plays a key role in design of the roof system. Climate considerations should include the type of weather that will likely be encountered during application, as well as the climatic conditions that follow. For example, if the roof is to be constructed during cold weather or in a location that experiences frequent rains, selection of materials and a system that is more tolerant of these conditions can play a key role in obtaining a successful roof.

12.10 EFFECTS OF ROOF SIZE, SHAPE, AND SLOPE

Roof size and shape often dictate material and system selection. For example, if the roof is only 2 or 3 ft wide and several feet long, a system other than built-up roofing (BUR) would probably be easier to install than BUR.

Roof slope is a major factor in determining the rate of flow of rainwater over a roof to a drainage outlet, and good drainage is essential to good performance of a roof. Hence, regardless of the type of materials or system specified, adequate slope should be provided for drainage.

For low-slope roofs, NRCA recommends that the roof be designed and built to ensure **positive drainage.** NRCA defines positive drainage as ‘‘the drainage condition in which consideration has been made during design for all loading deflections of the deck, and additional roof slope has been provided to ensure drainage of the roof area within 48 hours of rainfall, during ambient drying conditions.’’ Ponding water can be detrimental to roof systems and can result in:

- Deterioration of the roof surface and membrane
- Debris accumulation, vegetation, fungal growth, and resulting membrane damage
- Deck deflections (sometimes resulting in structural problems and other complications)
- Ice formation and resulting membrane degradation or damage
- Tensile splitting of water-weakened organic or asbestos felts
- Difficulties in repair, should leaks occur
- Water entry into the building if the roof membrane is punctured or fails in a ponding area
- Voiding of manufacturers’ warranties

Every roof has its own specific set of drainage criteria. Simply specifying a standard ¼ in/ft (degrees) slope or ⅛ in/ft (degrees) slope will not ensure adequate drainage of the roof system. In order to achieve the necessary slope throughout the entire roof area, many things should be considered, including: the structural framing system, deck type and characteristics, deck deflections between spans, roof insulation, roof membrane type, rooftop penetrations (and additional support or blocking for the deck), and the building and roof layout.

Other items which can assist in positive drainage are: tapered insulation (crickets and saddles) at key points, such as between drain locations and at the up-slope side of penetrations; recessing primary drains and scuppers slightly below the roof membrane surface; and performing maintenance semiannually to help prevent clogged drains.

The use of secondary or overflow drainage devices (e.g., through-wall scuppers) is recommended and, in most cases, required by building codes.

For steep-slope roofs, the minimum recommended slope is a function of the type of roof-covering material used and the type of underlayment. The minimum recommended slope for most steep-slope roof coverings is 4:12 (degrees), unless special provisions are made. Depending on the material, some manufacturers and building codes allow lower slopes. Since most steep-slope materials are water-shedding, rather than waterproofing, a steeper slope typically decreases the likelihood of damaging or other undesirable conditions.

12.11 DECK SUITABILITY

In selection of a deck or the type of roof-covering material and system, it is important to develop a design that incorporates materials that are compatible. For example, if a mechanically attached single-ply membrane is desired, it would be appropriate to specify a deck that can readily accept the fasteners yet have sufficient capacity to hold the fasteners. In this case, a steel deck, wood plank, or thick plywood deck would normally be good options. But if the deck did not readily accept fasteners; for example, a concrete deck, or if the deck possessed minimal strength; for example, a lightweight, insulating-concrete fill, then a system other than a mechanically attached single-ply membrane should be selected.

12.12 EFFECTS OF ROOFTOP TRAFFIC

If there will be periodic traffic on a roof; for example, to maintain mechanical equipment, traffic walkway pads should be specified to protect the roof. Pads can also be beneficial around mechanical equipment, to protect against dropped tools. For aggregate-ballasted systems, use of concrete pavers for walkways can be helpful in protecting the roof and providing a comfortable surface on which to walk.

For heavier rooftop loading, greater protective measures; for example, installation of heavy concrete pavers may be needed. In some cases, window-washing equipment causes damage to roof coverings, because they do not have sufficient resistance to the high impact loads that can result as the equipment is moved around and dropped.

12.13 ESTHETIC CONSIDERATIONS

While esthetics typically is not of concern for low-slope roofs, it generally is with steep-slope roofs. For some low-slope roofs, an attractive roof is also desirable. Where esthetics is an issue, special effort is needed to achieve the desired goal.

For example, a clean white roof may look good for a year or two. But after it has deposits of wind-blown dirt, or from contaminants exhausted from mechanical equipment, or from sediment from ponded water, it may look less attractive. If a more uniform appearance is desired, an aggregate-surfaced built-up roofing or ballasted (with aggregate or pavers) single-ply membrane may be specified.

To be sure that a proposed design will produce the desired look, designers should visit an existing roof that has a similar roof covering to determine if expectations will likely be met.

12.14 EFFECTS OF WIND ON ROOFS

Particularly in those areas subjected to hurricanes or other high winds, provision for resistance to wind in design of roof systems is necessary for successful performance. Different roof systems are loaded differently, and they resist the loads in different ways. For example, loading and load resistance of asphalt shingles, a modified bitumen membrane, a ballasted single-ply membrane, and a mechanically attached single-ply membrane are all different.

An understanding of the loading and load response is needed to design wind-resistant roof coverings for use in high-wind environments. In particular, design of metal edge flashing (gravel stops) is a critical aspect for many types of roof systems. Further information regarding wind design is available from publications listed in Art. 12.21.

12.15 PROTECTED MEMBRANE ROOFS AND PLAZA DECKS

A special type of low-slope roof system is the protected membrane roof (PMR). In this system, extruded polystyrene insulation boards are placed above the membrane. The insulating boards are then covered with aggregate or concrete paver ballast. (If aggregate is used, a fabric mat is first placed over the insulation.) This construction protects the membrane from mechanical damage (dropped tools, wind-blown debris) and from direct exposure to the weather (UV, high and low temperatures). Figure 12.2 illustrates a PMR that incorporates a built-up membrane.

Plaza decks are similar to protected membrane roofs, except that they are designed for heavy traffic loads. Because of the difficulty in repairing these types of roof systems, they should be designed and constructed with care. If this is done, they can provide a long and successful service life.

Application of Roofing. If a roof has been adequately designed and quality materials have been specified and provided, the next step toward achieving a successful roof is to have it installed by a reputable roofing contractor. After a contractor has been retained to perform the work, the following items are of importance.

12.16 PREROOFING CONFERENCE

The project designer should specify a preroofing conference. This meeting is normally attended by the roofing contractor (including the job-site person who will be in charge of the work), the building owner's representatives (including the project designer), and the general contractor. An inspector familiar with the type of roofing being installed, if retained, should also attend. If the project has a lot of rooftop mechanical or electrical equipment, these subcontractors would also normally attend the meeting.

The purpose of the meeting is to review the salient features of the drawings and specifications, to ensure there is understanding by all parties. If there are problems with the design or other aspects of the project, the intent is to identify and resolve them prior to commencement of the field work. As part of this meeting, the roof deck should be reviewed to verify that it is ready for roofing. The need for avoiding damage to the work after its completion should also be discussed.

12.17 WARRANTIES

Long-term roofing warranties are quite common, but often their importance is overemphasized in selection of a roof. Many building owners and designers have focused on specifying warranties rather than on other aspects that are more likely to result in a successful roof. The ''Consumer Advisory Bulletin on Roofing Warranties,'' 1992, National Roofing Contractors Association (NRCA), suggested the following:

> The length of a roofing warranty should not be the primary criterion in the selection of a roofing product or system because the warranty does not necessarily provide assurance of satisfactory roofing performance. The selection of a roofing system for a particular project application should be based upon the product's qualities and suitability for the prospective construction project. A long-term warranty may be of little value to a consumer if the roof does not perform satisfactorily and the owner is plagued by leaks. Conversely, if the roof system is well-designed, well-constructed and well-manufactured, the expense of purchasing a warranty may not be necessary.
>
> Manufacturers who use long-term warranties as a marketing tool have encountered a highly competitive roofing market and have found themselves compelled to meet or exceed warranties of competitive manufacturers. It is suspected that in some cases the length of the warranty was established without appropriate technical research or documentation of in-place field performance.
>
> NRCA believes that the roofing consumer, with the assistance of a roofing professional, should focus his purchase decision primarily on an objective and comparative analysis of proven roofing system options that best serve his specific roofing requirements and not on warranty time frames.
>
> NRCA further advises that the roofing consumer consult the membrane warranty section of the ''Roofing Materials Guide'' for a comparative analysis of the specific provisions, remedies, limitations, and exclusions of the warranties of those roofing systems under consideration. All questions should be addressed to the respective roofing manufacturers for specific written clarification.

12.18 ROOF MAINTENANCE

After a good roof has been delivered to the building owner, it is important for the owner to commit to a program of periodic roof inspections and to follow-up maintenance or repairs as needed. While some systems require less maintenance than others, no roof should be forgotten about after it is installed!

Semiannual inspections are recommended for all roofs. The purpose of these inspections is to determine if debris removal is needed; for example, cleaning of roof drains, and if the roof is showing signs of distress. In many instances, undesirable conditions can be minimized if they are detected and corrected early. Without inspections, a small problem, such as a puncture, can go unnoticed until a large area of the roof is wet and in need of replacement.

To assist in the care of the roof, many professional roofing contractors offer maintenance contracts to building owners. By making a commitment to periodic inspections and appropriate maintenance and repair, the building owner can optimize the roof's service life and maximize the roofing investment.

Maintenance guides specific to low-slope membrane types have been developed by NRCA (Art. 12.22). These guides provide useful information for establishing maintenance programs, emergency and permanent repair procedures, and historical data files; they include a general description of typical maintenance activities by roof system type, as well as inspection checklists.

12.19 REROOFING

Replacement of existing roofing or installation of a new roof covering over it is usually much more complicated than roofing a new building. Besides issues that are normally considered in design of a new roof, may additional issues arise when roof replacement is needed. For example, it is not uncommon to find existing undesirable building conditions including those that contributed to the demise of the existing roof. Unless these are adequately corrected in the new design (which may be difficult or expensive to do), they can also be expected to affect the new roof adversely.

Therefore, as part of the reroofing design process, it is important to determine the reason for the problems with the existing roof. Are they simply a consequence of old age, or are there fundamental conditions that could affect the new roof adversely; for example, migration of water from a curtain wall into the roof system? If there are inherent troubles, they need to be corrected as part of the reroofing work. Also, as part of the design process, the integrity of the roof deck should be assessed by an engineer, if deteriorated deck is suspected. And if the new roof system adds weight to the structure, the capacity of the structure should be evaluated by an engineer.

12.19.1 Reroofing Procedures

There are two primary approaches to reroofing: Either the existing system can be removed down to the deck, or it may remain in place and a new roof covering installed over it. The removal option is the most conservative approach, inasmuch as it allows a complete view of the top side of the deck. If there are deteriorated areas, they will be likely to be found. Also, this approach eliminates entrapment of water in the existing roof. However, this option is often more expensive, and it exposes the interior to water damage during the reroofing process.

The recover option has the advantage of retaining the thermal value of the existing insulation, and the existing roof provides protection against sudden rainfall during the application process. In some parts of the United States, this is not important, but in other areas, this advantage makes the recover option very desirable.

The number of existing roofs will in many instances eliminate the recover option. Generally, no more than two layers of roofing systems are recommended. Model building codes have specific requirements for reroofing, including the maximum number of roof layers allowable. In some instances, complete removal of all existing roof systems (in lieu of removal of the top roof layer only) is required by building codes before installing a new roof system.

Prior to recovering, it is important to determine if there are areas of wet insulation. If so, it is recommended that it be removed. The utilization of nondestructive evaluation (NDE) can be very helpful in identifying areas of wet insulation.

Unless the designer is very knowledgeable of techniques for assessing existing roof systems and of reroofing design, the designer would be well advised to work with a professional roofing contractor or other roofing professional.

12.19.2 Roof Moisture-Detection Surveys

Moisture within a roof membrane system tends to migrate from its point of entry. Thus, blisters, cracks, and splits caused by the moisture are often located at a distance from the source of a leak. Several methods are available for locating such sources. The equipment utilizes infrared photographic techniques, or nuclear or electronic devices, or variations of these systems. Each method has advantages and disadvantages but can be effective if properly used.

In the method employing an infrared roof scanner, an infrared reading is taken of the roof at night using a portable (hand-held) infrared camera. Another method of infrared thermography uses a helicopter to take a reading from a distance. The infrared camera identifies temperature differences (anomalies) across the surface of the roof; these anomalies may be the result of wet insulation.

The electronic and nuclear methods use differing means for locating roof moisture, but the procedures are similar. First, a drawing to scale of the roof is made, showing all projections, roof equipment, etc. A grid is marked on the drawing, then physically reproduced on the roof with ropes or paint. Trained operators take readings at every grid intersection and record the observation. At the same time, the roof is visually inspected and observations are carefully noted. The data collected then are evaluated by a specialist and adjusted for the effects of up to nine different factors, such as gravel depth, roof construction, etc. The information is entered on a final map of the roof, to provide a picture of water-damaged areas, under-membrane water-flow patterns, percentage of moisture in the roof, and locations of moisture. From this map, it is possible to determine where replacement is necessary, where repair will be sufficient, and what to budget for future work that may be needed to maintain the roof or whether to replace it section by section as required. Such moisture detection surveys are valuable tools for saving energy and for management planning.

It is important to note that none of these methods directly determine the presence of moisture in a roof assembly. Instead, they identify potential areas of moisture by assessing certain properties that may be caused by moisture trapped in the roof assembly. All three methods require core sampling (destructive testing) of the roof system to verify the presence of any trapped moisture.

12.20 ROOFING INDUSTRY ASSOCIATIONS AND RELATED ORGANIZATIONS

American Fiberboard Association (AFA)
1210 W. Northwest Highway
Palatine, IL 60067-3609
847-934-8394
FAX: 847-934-8803
E-mail: afa@fiberboard.org
http://www.fiberboard.org

American Iron and Steel Institute (AISI)
1101 17th St. Northwest Ste. 1300
Washington, DC 20036-4700
202-452-7100
FAX: 202-463-6573
E-mail: mjackson@steel.org
http://www.steel.org

American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)
1791 Tullie Circle Northeast
Atlanta, GA 30329
404-636-8400
FAX: 404-321-5478
E-mail: ashrae@ashrae.org
http://www.ashrae.org

American Society for Testing and Materials (ASTM)
100 Barr Harbor Drive
W. Conshohocken, PA 19428-2959
610-832-9500
FAX: 610-832-9555
E-mail: service@astm.org
http://www.astm.org

APA-The Engineered Wood Association
7011 S. 19th St.
P.O. Box 11700
Tacoma, WA 98411
253-565-6600
FAX: 253-565-7265
http://www.apawood.org

Asphalt Institute (AI)
2696 Research Park Drive
P.O. Box 14052
Lexington, KY 40512-4052
606-288-4960
FAX: 606-288-4999
E-mail: asphalti@asphaltinstitute.org
http://www.asphaltinstitute.org

Asphalt Roofing Manufacturers Association (ARMA)
Center Park
4041 Powder Mill Road Suite 404
Calverton, MD 20705
301-348-2002
FAX: 301-348-2020
http://www.asphaltroofing.org

Building Officials & Code Administrator International (BOCA)
4051 W. Flossmoor Road
Country Club Hills, IL 60478-5795
708-799-2300
FAX: 708-799-4981
http://www.bocai.org

The Cedar Guild
P.O. Box 249
Lyons, OR 97358
503-897-2541
800-270-2541
FAX: 503-897-2422
E-mail: cedarinfo@cedar.guild
http://www.cedar-guild.com

Cedar Shake & Shingle Bureau (CSSB)
P.O. Box 1178
Sumas, WA 98295-1178
604-462-8961
FAX: 604-462-9386
E-mail: info@cedarbureau.com
http://www.cedarbureau.org

The Construction Specifications Institute (CSI)
99 Canal Center Plaza, Suite 300
Alexandria, VA 22314-1588
703-684-0300
FAX: 703-684-0465
E-mail: csimail@csinet.org
http://www.csinet.org

Copper Development Association (CDA)
260 Madison Ave.
New York, NY 10016
215-251-7200
FAX: 212-251-7234
http://www.copper.org

EPS Molders Association
2128 Espey Court Suite 4
Crofton, MD 21114
410-451-8341
FAX: 410-451-8343
E-mail: bdecampo@aol.com
http://www.epsmolders.org

Factory Mutual Research (FM)
1151 Boston-Providence Turnpike
Norwood, MA 02062
781-762-4300
FAX: 781-762-9375

Forest Products Laboratory (FPL)
One Gifford Pinchot Drive
Madison, WI 53705-2398
608-231-9200
FAX: 608-231-9592
E-mail: mailroom/fpl@fs.fed.us
http://www.fpl.fs.fed.us/

Gypsum Association
810 First Street, NE #510
Washington, DC 20002
202-289-5440
FAX: 202-289-3707
http://www.gypsum.org

Infraspection Institute (II)
3240 Shelburne Road, Suite 3
Shelburne, VT 05482
802-985-2500
FAX: 802-985-2726
E-mail: support@infraspection.com
http://www.infraspection.com

International Conference of Building Officials (ICBO)
5360 Workman Mill Road
Whittier, CA 90601-2298
562-699-0541
FAX: 562-699-8031
http://www.icbo.org

International Staple, Nail and Tool Association (ISANTA)
512 W. Burlington Ave., Suite 203
La Grange, IL 60525
708-482-8138
FAX: 708-482-8186

Metal Building Manufacturers Association (MBMA)
1300 Sumner Ave.
Cleveland, OH 44115-2851
216-241-7333
FAX: 216-241-0105
E-mail: mbma@mbma.com
http://www.mbma.com

Metal Construction Association (MCA)
104 S. Michigan Suite 1500
Chicago, IL 60603
312-201-0193
FAX: 312-201-0214
jimstanley@metalconstruction.org
http://metalconstruction.org

National Insulation Association (NIA)
99 Canal Center Plaza Suite 222
Alexandria, VA 22314
703-683-6422
FAX: 703-549-4838
E-mail: niainfo@insulation.org
http://www.insulation.org

National Roof Deck Contractors Association (NRDCA)
P.O Box 1582
Westford, MA 01886-4996
800-217-7944
FAX: 978-250-9788
E-mail: nrdca@nrdca.org
http://nrdca.org

National Roofing Contractors Association (NRCA)
10255 W. Higgins Road Suite 600
Rosemont, IL 60018
847-299-9070
FAX: 847-299-1183
E-mail: nrca@nrca.net
http://www.nrca.net

National Tile Roofing Manufacturers Association (NTRMA)
P.O. Box 40337
Eugene, OR 97404-0049
541-689-0366
FAX: 541-689-5530
E-mail: info@ntrma.org
http://www.ntrma.org

North American Insulation Manufacturers Association (NAIMA)
44 Canal Center Plaza Suite 310
Alexandria, VA 22314
703-684-0084
FAX: 703-684-0427
http://www.naima.org

Polyisocyanurate Insulation Manufacturers Association
1331 F Street, NW, Suite 975
Washington, DC 20004
202-628-6558
FAX: 202-628-3856
E-mail: pima@pima.org
http://www.pima.org

Roof Coatings Manufacturers Association (RCMA)
4041 Powder Mill Road Suite 404
Calverton, MD 20705
301-348-2003
FAX: 301-348-2020
http://www.roofcoatings.org

Roof Consultants Institute (RCI)
7424 Chapel Hill Road
Raleigh, NC 27607-5041
919-859-0742
FAX: 919-859-1328
E-mail: rci@rci-online.org
http://www.rci-online.org

Roofing Industry Educational Institute (RIEI)
2305 East Arapahoe Road, Suite 135
Littleton, CO 80122
303-703-9870
FAX: 303-703-9712
E-mail: rieiroof@aol.com
http://www.riei.org

Rubber Manufacturers Association (RMA)
1400 K St. Northwest #900
Washington, DC 20005
202-682-4800
FAX: 202-682-4854
http://www.rma.org

Sealant Waterproofing & Restoration Institute
2841 Main
Kansas City, MO 64108
816-472-SWRI
FAX: 816-472-7765
E-mail: swrionline.org
http://swrionline.org

Sheet Metal and Air Conditioning Contractors' National Association (SMACNA)
4201 Lafayette Center Drive
Chantilly, VA 20151-1209
703-803-2980
FAX: 703-803-3732
E-mail: info@smacna.org
http://www.smacna.org

Southern Building Code Congress International (SBCCI)
900 Montclair Road
Birmingham, AL 35213
205-591-1853
FAX: 205-599-9893
E-mail: info@sbcci.org

Spray Polyurethane Foam Alliance (SPFA)
1300 Wilson Boulevard
Suite 800
Arlington, VA 22209
703-253-0659
800-523-6154
FAX: 703-253-0664
http://www.sprayfoam.org.

SPRI, Inc.
200 Reservoir St. Suite 309A
Needham, MA 02494
781-444-0242
FAX: 781-444-6111
E-mail: lkspri@aol.com
http://www.spri.org

Steel Deck Institute (SDI)
P.O. Box 25
Fox River Grove, IL 60021-0025
847-462-1930
FAX: 847-462-1940
E-mail: steve@sdi.org
http://www.sdi.org

Underwriters Laboratories Inc. (UL)
333 Pfingsten Road
Northbrook, IL 60062
847-272-8800
FAX: 847-272-8129
http://www.ul.com

Western Red Cedar Lumbar Association
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