guidelines for designing
LOW-SLOPE MEMBRANE ROOF SYSTEMS


COURTESY CARLISLE SYNTEC SYSTEMS

BY JASON WILEN, AIA, CDT, RRO

Architect Jason Wilen is Director of Technical Services with the National Roofing Contractors Association. He is a Construction Documents Technologist and Registered Roof Observer.

LEARNING OBJECTIVES

After reading this article, you should be able to:
+ EXPLAIN the design considerations for low-slope membrane roof systems.
+ DISCUSS commonly used low-slope membrane types and general building code-related roof system attributes.
+ LIST general roof system performance criteria, the differences between low-slope membrane types, and applicable material standards.
+ UNDERSTAND the advantages of cover board use with low-slope roof membranes.

Critical aspects of roof system designs are often left unaddressed, resulting in incomplete contract documents. This course identifies the information roofing contractors generally need from roof system designers to provide complete and building code-compliant low-slope roof systems. While generally written from the perspective of new construction, the information presented here can also be applied to roof replacements in most situations.

Guidelines in this article are based on *The NRCA Roofing Manual* and practices compliant with the roofing-related provisions of the 2012 edition of the International Building Code (IBC 2012). Even in jurisdictions that have not adopted IBC, its provisions are often considered an indication of the standard of care for roof system design.

Part 1 of this course covers guidelines applicable to all types of roof membranes. **Part 2** (available at www.BDCnetwork.com/NRCA-roof, along with the 10-question exam), discusses guidelines for specific roof membranes and roof system cover boards.

PART 1. DESIGN GUIDELINES APPLICABLE TO ALL LOW-SLOPE MEMBRANE TYPES

No matter the type of roof system selected, roof system designers should include certain fundamental information in contract documents, notably the roof system's:

- Fire-resistance classification
- Uplift resistance
- Roof slope and drainage attributes

DETERMINE THE CORRECT FIRE-RESISTANCE CLASSIFICATION FOR YOUR PROJECT

The building code contains provisions requiring roof assemblies to have specific fire-resistance properties. IBC 2012 contains provisions for external and internal fire-resistance classifications of roof assemblies. Typically, only provisions for roof assembly performance against external fire exposure are within the roofing contractor's scope of work and thus should be included in roof system-related specification sections in project documents.

IBC 2012 Section 1505—Fire Classification contains provisions for roof assemblies to be tested in accordance with ASTM International E108, or Underwriters Laboratories 790, both titled "Standard Test Methods for Fire Tests of Roof Coverings." ASTM E108 and UL 790 are separate and independently maintained documents that provide the same test protocols and classification criteria. ASTM E108 or UL 790 testing results determine a Class A (most severe fire exposure), Class B (less severe fire exposure), or Class C (lowest level of fire exposure) classification. Roof covering material type and deck type determine the required number of duplicate test assemblies for tested roof coverings.

The assemblies are subject to evaluation during and after testing. When the required minimum number of test assemblies meets the evaluation criteria, assemblies are classified according to the level of fire exposure used. IBC 2012 Table 1505.1 indicates the minimum required roof covering classification based on building construction type as defined in IBC 2012 Chapter 6—Types of Construction.

An important—and often misunderstood—aspect of ASTM E108 and UL 790 is that *roof membrane materials* (called "roof coverings" in IBC 2012) *are always tested and classified as part of complete roof assemblies.* The class designation thus obtained applies to whole roof assemblies and not roof coverings by themselves. Roof system designers should coordinate with roof membrane manufacturers to ensure specified roof assembly components—the roof deck, vapor retarder (if used), substrate or thermal barrier, insulation, and roof covering—have been tested together per ASTM E108 or UL 790 and that the resulting fire classification (A, B, or C) meets or exceeds the minimum fire classification required in IBC 2012 Table 1505.1.

Note: In most instances, the minimum fire classification required by building codes is Class B or C, although building owners may desire Class A for certain projects. Certification of ASTM E108 or UL 790 roof assembly fire classification from roof membrane manufactures is sometimes specified as a required construction submittal.

TEST AND MEASURE UPLIFT RESISTANCE

Construction specifications that address wind design for low-slope membrane roof systems are often inadequate. Roof system designers should not place the responsibility for determining roof system or individual component design wind loads on manufacturers, component suppliers, installers, or roofing contractors. Nor should roof system designers rely on specifying wind speed warranties as a substitute for building-code–required wind design data. Such warranties typically do not address such factors as ultimate and nominal design wind speeds, building height, risk category, wind exposure, and internal pressure coefficients as applied to a specific building—all of which are necessary for properly determining a roof system's design wind loads for building code compliance.

Building code provisions for uplift resistance for roof assembly components are located in IBC 2012 Chapter 15—Roof Assemblies and Rooftop Structures. General wind resistance provisions for roofs are in IBC 2012 Section 1504.1 Wind resistance of roofs. The section states: "*1504.1 Wind resistance of roofs.* Roof decks and roof coverings shall be designed for wind loads in accordance with Chapter 16 and Sections 1504.2, 1504.3 and 1504.4."

IBC 2012 Chapter 16—Structural Design prescribes the minimum structural loading requirements for use in the design and construction of buildings and other structures. The referenced Chapter 15 sections provide category-specific requirements for resisting design

tools for managing WIND LOADS AND ROOF EDGES

To help roof system designers determine wind loads for commonly encountered low-slope roof systems, NRCA, the Midwest Roofing Contractors Association, and the North/East Roofing Contractors Association have developed a free online application, RoofWind Designer. This Web-based app (www.roofwinddesigner.com) allows users to determine design wind loads using American Society of Civil Engineers' standard ASCE 7's "Minimum Design Loads for Buildings and Other Structures" (2005 or 2010 editions).

NRCA has also developed Guidelines for Complying with Building Codes Using ANSI/SPRI ES-1, "Wind Design Standard for Edge Systems Used with Low Slope Roofing Systems" (shop.nrca.net or 866-ASK-NRCA). This document provides guidelines and technical information concerning the design, materials, fabrication, and installation of edge-metal flashings for compliance with ANSI/SPRI ES-1 and the applicable requirements of the International Building Code. It also contains pertinent information from ASCE standard ASCE 7, "Minimum Design Loads for Buildings and Other Structures."

wind loads in roof assemblies, as determined in accordance with Chapter 16. For low-slope membrane roof systems, provisions in IBC 2012 Sections 1504.3 and 1504.4 are relevant.

Section 1504.3 contains the following relevant provisions:

"1504.3 Wind resistance of nonballasted roofs. Roof coverings installed on roofs in accordance with Section 1507 that are mechanically attached or adhered to the roof deck shall be designed to resist the design wind load pressures for components and cladding in accordance with Section 1609.

"1504.3.1 Other roof systems. Roof systems with built-up, modified bitumen, fully adhered or mechanically attached single-ply through fastened metal panel roof systems, and other types of membrane roof coverings shall also be tested in accordance with FM 4474, UL 580 or UL 1897."

Section 1504.3 applies to roof systems that do not use ballast to resist wind-uplift loads, such as adhered and mechanically attached roof systems. Roof system designers are required to demonstrate that the proposed fastening schedules will resist the wind uplift loads. Section 1504.3.1 contains additional provisions for non-ballasted low-slope roof systems (roof systems with slopes less than 2:12). Membrane roof systems are required to demonstrate building code–required uplift load resistance, using one of three referenced testing methods.

FM Approvals (FM) 4474, "American National Standard for Evaluating the Simulated Wind Uplift Resistance of Roof Assemblies Using Static Positive and/or Negative Differential Pressures," provides three test methods for evaluating roof assemblies' resistance to simulated uplift loads. Tested assemblies are assigned a simulated wind-uplift resistance—for example, FM 1-60, FM 1-75, FM 1-90, and so on—in increments of 15. (Note: The leading "1" indicates the tested assembly meets FM 4450's Class 1 fire-resistance requirements and is not relevant to wind uplift.) An FM 4474 rating applies to an assembly characterized by the specific set of components and attachments used in testing.

The rated uplift resistance indicates the assembly's maximum design uplift load multiplied by a safety factor of 2. For instance, an assembly rated FM 1-90 is appropriate for installation in roof areas with a maximum design uplift load of 45 psf in the field of the roof. Design uplift load in perimeter and corner roof areas is required to have higher wind uplift ratings.

UL 580, "Standard for Tests for Uplift Resistance of Roof Assemblies," provides a test method for evaluating a roof assembly's resistance to negative and positive pressures. Tested assemblies are classified UL Class 15, UL Class 30, UL Class 60, or UL Class 90. A UL 580 classification applies to an assembly characterized by the specific set of components and attachments used in the testing. The rating scheme indicates the assembly's maximum design uplift load. Thus, a UL Class 90 assembly is appropriate for installation in roof areas with a maximum design uplift load of 90 psf, with no safety factor included.

UL 1897, "Standard for Uplift Tests for Roof Covering Systems," provides a test method for evaluating roof systems' attachment to roof decks using static differential pressures. Tested roof systems are rated according to the maximum static pressure difference uplift load recorded sustained for one minute without

ROOFING DESIGN TECH MANUAL from NRCA

The NRCA Roofing Manual, NRCA's premier technical publication, updates and supersedes The NRCA Roofing and Waterproofing Manual, Fifth Edition. Its four volumes, each of which is updated every four years, cover:

1. Membrane Roof Systems
2. Architectural Metal Flashing, Condensation and Air Leakage Control and Reroofing
3. Steep-slope Roof Systems
4. Metal Panel and SPF Roof Systems

The NRCA Roofing Manual (available for purchase at shop.nrca.net; 866-ASK-NRCA) presents time-tested, best-practice guidelines for roofing buildings and other enclosed structures. The information has been collected by NRCA from knowledgeable, practicing roofing contractors throughout the U.S.

COURTESY SIKA SARNAFIL

Roof membrane manufacturers recommend that a roof assembly have a positive slope for drainage and should allow for short durations of ponding water. IBC 2012 Section 1507—Requirements for Roof Coverings stipulates that low-slope membrane roof systems like this one have a minimum design slope of one-fourth unit vertical in 12 units horizontal (2% slope) for drainage.

failure in increments of 15 psf. Ratings are assigned without a safety factor. A UL 1897 classification applies to a roof system characterized by the specific set of components and attachments used in testing.

IBC 2012 also contains provisions addressing wind uplift design of ballasted low-slope membrane roof systems. Section 1504.4 states:

"1504.4 Ballasted low-slope roof systems. Ballasted low-slope (roof slope <2:12) single-ply roof system coverings installed in accordance with Sections 1507.12 and 1507.13 shall be designed in accordance with Sections 1504.8 and ANSI/SPRI RP-4."

Sections 1507.12 and 1507.13 provide prescriptive installation requirements for thermoset and thermoplastic single-ply low-slope membrane roof systems. Section 1504.8 addresses the use of aggregate on roofs; it disallows the use of rooftop aggregate in hurricane-prone regions and restricts aggregate use based on wind speed and roof height criteria.

ANSI/SPRI RP-4, "Wind Design Standard for Ballasted Single-ply Roofing Systems," developed by the Single-ply Roofing Industry (SPRI), provides a method of designing wind-uplift resistance of ballasted single-ply roof systems. Central to the design method is the idea that the ballast will not blow off roofs at design wind speeds.

ANSI/SPRI RP-4 provides generic design options for applications categorized as conventional ballasted roof systems and protected membrane roof systems. An appropriate system design may be determined based upon the design wind speed, building height, importance factor, exposure category, and parapet height.

IBC 2012 also contains provisions addressing wind uplift resistance of perimeter-edge flashing for membrane roof systems. Section 1504.5 states:

"1504.5 Edge securement for low-slope roofs. Low-slope built-up, modified bitumen, and single ply-roof system metal edge securement, except gutters, shall be designed and installed for wind loads in accordance with Chapter 16 and tested for resistance in accordance with Test Methods RE-1, RE-2, and RE-3 of ANSI/SPRI ES-1, except V_{ult} wind speed shall be determined from Figure 1609A, 1609B or 1609C as applicable."

Section 1505.4 requires roof system designers to specify the design and fastening of roof system perimeter metal (coping, fascia, and gravel stop) used with membrane roof systems, except gutters, to withstand design wind loads at roof edges. Testing according to the test methods provided in ANSI/SPRI ES-1, "Wind Design Standard for Edge Systems Used with Low Slope Roofing Systems," is required to demonstrate the edge metal design's performance. Design wind loads are required to be determined using the ultimate design wind speed and IBC 2012's Chapter 16, which is based on ASCE 7-10, "Minimum Design Loads for Buildings and Other Structures."

Responsibility for determining and clearly identifying wind design data, including design wind loads for roof systems, is required by building codes. Therefore, roof system designers should note design wind loads for subject buildings in contract documents. Roof systems designers may retain structural engineers or other qualified consultants to help them fulfill their design responsibilities.

DECODING THE ROOFING ASPECTS of IBC 2012

In the U.S. code adoption happens at the state or local government level. The model codes most widely used as the technical basis for adopted codes belong to the International Codes (I-Codes) family. The International Building Code, 2012 Edition (IBC 2012, available at www.iccsafe.org), serves as the basis for the building code references in this article, although roofing-related provisions in other editions of IBC are similar.

Co-branded with ICC, NRCA developed Guidelines for Complying With Building Code Requirements for Roof Assemblies: International Building Code, 2012 Edition (shop.nrca.net; 866-ASK-NRCA). The guide explains the roofing-related provisions of the IBC and provides appendixes where roofing-related provisions from other I-Codes—fire, plumbing, existing building, fuel gas, wildland–urban interface and residential—are addressed.

KEEP ROOF DRAINAGE POSITIVE

NRCA recommends low-slope membrane roof systems be designed to provide positive drainage. The criterion for judging proper slope for drainage is that there be no ponding water on the roof 48 hours after a rain during conditions conducive to drying. Roof membrane manufacturers also generally recommend that a roof assembly have a positive slope to drain and should allow for short durations of ponding water.

IBC 2012 Section 1507—Requirements for Roof Coverings requires that low-slope membrane roof covering systems have a design slope of a minimum of one-fourth unit vertical in 12 units horizontal (2% slope) for drainage, and one-eighth unit vertical in 12 units horizontal (1% slope) for coal-tar built-up roofs.

While IBC 2012 requires that the materials and method of application used for recovering or replacing an existing roof covering shall meet the same requirements as for new construction, there is an exception. Section 1510—Reroofing states that reroofing shall not be required to meet the minimum design slope requirement of one-quarter unit vertical in 12 units horizontal (2% slope) in Section 1507 for roofs that provide positive roof drainage.

Secondary or emergency drainage is also a requirement in IBC 2012. Section 1503.4—Roof Drainage requires that secondary drainage be provided via roof drains or scuppers where the roof perimeter construction extends above the roof in such a manner that water will be entrapped if the primary drains allow buildup for any reason. The section also states that the roof drainage systems shall comply with the International Plumbing Code (IPC 2012). IPC 2012 Section 1108—Secondary (Emergency) Roof Drains requires that secondary roof drain systems have the end point of discharge separate from the primary system.

In general, slope is incorporated into roof assembly design by:

• *Sloping the structural framing or deck.* This method is more complex than for non-sloped structures and requires coordination during the design process to ensure proper placement of roof drains, scuppers, and other drainage components.

- *Designing a tapered insulation system.* This method is appropriate for both new construction and reroofing projects, as well as in cases where a roof deck will not provide adequate slope to drain. The tapered insulation also can contribute thermal resistance as part of meeting the code requirement for minimum insulation value.
- *Using an insulating fill that can be sloped to drain.* Lightweight insulating concrete, thermosetting insulating fill, and spray polyurethane foam (SPF) are examples of systems that can be installed over level or irregular roof assembly surfaces to achieve positive slope. Geographical location, structural considerations, compatibility with other components, and the geometry of the area to be sloped must be considered in determining the feasibility of this option.
- *Proper location of roof drains, scuppers, and gutters.* The roof system designer should determine the location of drainage elements. For reroofing, modifications to existing drainage elements, such as raising or lowering a drain or scupper, may be necessary to provide proper drainage. Adding drains or scuppers can lead to conflict with existing building elements, and the additional drainage elements have to be integrated with existing building systems. There's also added cost to consider.

Most often, a combination of methods will be used to create adequate roof slope and drainage.

Contract documents should clearly indicate the slope and drainage method for roof systems. At a minimum, the following roof slope and drainage-related information should be included by roof system designers in contract documents:

- *Roof slope and drainage elements*, such as roof drains, scuppers, and gutters, should be clearly and completely shown.
- *Mechanical documents* should indicate placement of rooftop equipment. The equipment and associated support elements should not interfere with anticipated drainage paths.
- *Structural documents* should indicate the type of roof deck and may include sloping elements and mechanical equipment supports.
- *Roof-related drawings* should be coordinated. Details should be appropriate for the type of roof system being specified.
- *Roof-related specifications* should include anticipated roof system elements and be consistent with information shown on construction drawings.

This concludes Part 1 of this course. Part 2, which discusses guidelines for specific roof membranes, along with the 10-question exam, can be found at www.BDCnetwork.com/NRCAroof.

> EDITOR'S NOTE

*Additional reading is required for this course. To earn **1.0 AIA CES HSW learning units**, read the full article carefully and take the exam posted at:*
www.BDCnetwork.com/NRCAroof.

NRCAroof AIA/CES MODULE

*Pass this exam and earn **1.0 AIA/CES Discovery learning units**.*
You must go to **www.BDCnetwork.com/NRCAroof** *to take the exam.*

1. True or false: Per ASTM E108 or UL 790, a fire-resistance classification of "Class C" indicates the most severe fire exposure.
   A. True
   B. False
2. Which of the following is NOT a thermoplastic single-ply roof membrane?
   A. Polyvinyl chloride (PVC)
   B. Ketone ethylene ester (KEE)
   C. Ethylene propylene diene M-class rubber (EPDM)
   D. None of the above
3. True or false: The NRCA Roofing and Waterproofing Manual, Fifth Edition, is the current edition of the publication.
   A. True
   B. False
4. Which of the following is the criterion for judging proper slope for low-slope membrane roof systems according to NRCA?
   A. There must be no ponding water on the roof 48 hours after a rain during conditions conducive to drying.
   B. There must be no ponding water on the roof 72 hours after a rain during conditions conducive to drying.
   C. There must be no ponding water on the roof 48 hours after a rain.
   D. None of the above
5. True or false: Secondary or emergency roof drainage is a requirement in the International Building Code (IBC 2012).
   A. True
   B. False
6. Which of the following is NOT a commonly recognized benefit of the use of cover boards as part of low-slope membrane roof assemblies?
   A. As required to achieve a fire-resistance classification for some roof assemblies
   B. Increased roof membrane impact and puncture resistance
   C. To prevent blistering incidences with BUR membranes
   D. None of the above; all are commonly recognized benefits
7. For FM 4474, the rated uplift resistance indicates a roof assembly's maximum design uplift load multiplied by a safety factor of:
   A. 2
   B. 3
   C. 4
   D. FM 4474 does not utilize a safety factor
8. True or false: NRCA does not recommend the use of polymer-modified bitumen roof membranes where only one layer of roofing material is installed.
   A. True
   B. False
9. Which of the following is the minimum thickness that should be specified by roof system designers for TPO membranes, according to NRCA?
   A. NRCA does not recommend a minimum thickness for TPO membranes
   B. 45-mil
   C. 60-mil
   D. 72-mil
10. True or false: Roof system designers requiring wind speed warranties is a reasonable substitute for building code-required wind design data.
    A. True
    B. False

PART 2. MEMBRANE-SPECIFIC GUIDELINES FOR LOW-SLOPE ROOF SYSTEMS

In addition to general guidelines applicable to all low-slope membrane roof systems, roof system designers should provide important product-specific roof membrane information in contract documents.

The following common roof membrane types, including usage guidelines and relevant U.S. product standards, are addressed in this part:

- Built-up roof (BUR)
- Polymer-modified bitumen
- Single-ply roof membranes: thermoset and thermoplastic

Roof system designers should work with roof membrane manufacturers to ensure specified roof systems types are appropriate for the intended building types and uses.

BUILT-UP ROOF (BUR)—MULTIPLE-PLY ROOFING SYSTEMS

BUR systems consist of multiple layers of saturated felts, coated felts, fabrics, or mats assembled in place shingle fashion with alternate layers of bitumen and surfaced with mineral aggregate, bituminous materials, a liquid-applied coating, or a granule-surfaced cap sheet.

BUR reinforcement felts and sheets. Roll-roofing materials described here serve as reinforcing layers in BUR membranes. Fire and wind-uplift test reports for BUR roof systems for mopped (generally hot- or cold-applied bitumen-based products), mechanically attached, or ballasted systems typically are published by the manufacturers.

Roll-roofing materials used as reinforcement in built-up roof membrane construction fall into three categories: base sheets, ply sheets, and mineral-surfaced cap sheets.

Base sheets serve several functions: separating a roof system from a substrate; providing support for a roof system over slightly rough or irregular substrates; serving as an attachment or base layer for adhering rigid insulation board on nailable roof decks; serving as a strengthening first layer in built-up roof membranes, temporary roof systems, and built-up vapor retarders; and serving as a single-layer vapor retarder.

Heavyweight base sheets can help smooth out some substrates that have slightly irregular surfaces, such as cold joints in concrete decks, and provide acceptable surfaces onto which the remainder of built-up roof membranes can be adhered. On wood and other nailable roof decks, base sheets works well to help cover roof deck joints and assist in preventing bitumen drippage into buildings. When mechanically fastened to decks, base sheets can provide an acceptable surface onto which the remainder of BUR systems cans be assembled.

Common varieties of base sheets used in BUR roof systems are:

Asphalt-coated fiberglass-mat base sheets	ASTM D4601, “Standard Specification for Asphalt-Coated Glass Fiber Base Sheet Used in Roofing”
Asphalt-coated fiberglass venting base sheets	ASTM D4897, “Standard Specification for Asphalt-coated Glass-fiber Venting Base Sheet Used in Roofing”

Ply sheets are installed directly over base sheets or over rigid board insulation as interply sheets in BUR membranes. The most common ply sheets in use today are various types of fiberglass-mat ply sheets. Organic-mat reinforced ply sheets have largely disappeared from the U.S. market. Common varieties of ply sheets used in BUR roof systems are:

Asphalt fiberglass ply sheets	ASTM D2178, “Standard Specification for Asphalt Glass Felt Used in Roofing and Waterproofing”
Asphalt-coated fiberglass-mat base sheets	ASTM D4601, “Standard Specification for Asphalt-Coated Glass Fiber Base Sheet Used in Roofing”
Asphalt-coated polyester and fiberglass-mat sheets	No U.S. product standard

Mineral-surfaced cap sheets are sometimes used as components of built-up membrane systems as the topmost layer of BUR membranes. The U.S. product standard for mineral-surfaced sheets is ASTM D3909, “Asphalt Roll Roofing (Glass Felt) Surfaced With Mineral Granules.”

Other membrane surfacing options include liquid-applied coatings or a flood coat of hot bitumen and aggregate.

POLYMER-MODIFIED BITUMEN: ‘PLASTICIZED’ OR ‘RUBBERIZED’ IN NATURE

Polymer-modified roof membranes are composed of reinforcing fabrics, usually polyester, fiberglass, or both, that serve as carriers for polymer-modified bitumen as it is manufactured into a roll material. Reinforcements in polymer-modified bitumen sheets help keep bitumen in place within sheets, provide tensile strength, and allow for varying degrees of sheet elongation.

There are *two general types of polymer-modified asphalts*: 1) those with asphalt that is modified with atactic polypropylene (APP) polymer and 2) those with asphalt that is modified with styrene butadiene styrene (SBS) polymer. These two general types of polymer modifiers give rise to materials that differ in physical characteristics as well as chemical composition. Generally, APP polymers modify the asphalt to give the resultant material a “plasticized” nature. SBS polymers modify the asphalt to give the resultant material a "rubberized" nature.

Most polymer-modified bitumen roof membrane specifications employ multiple-layer configurations consisting of a base layer or plies and a polymer-modified bitumen membrane cap sheet. APP and SBS polymer-modified bitumen products can be used over a multiple-ply fiberglass-reinforced BUR membrane. *Note:* NRCA does not recommend the use of polymer-modified bitumen roof membranes where only one layer of roofing material is installed. Hot- or cold-applied bitumen is used as an adhesive to adhere the polymer-modified bitumen sheets together or to a substrate.

Base sheets. The base layer of APP and SBS polymer-modified bitumen membranes roof systems functions similar to that of BUR base sheets. Common varieties of ply sheets used in polymer-modified roof systems are:

Asphalt-coated fiberglass-mat base sheet	ASTM D4601, "Standard Specification for Asphalt-Coated Glass Fiber Base Sheet Used in Roofing"
Asphalt-coated fiberglass venting base sheet	ASTM D4897, "Standard Specification for Asphalt-Coated Glass-Fiber Venting Base Sheet Used in Roofing"
SBS polymer-modified asphalt-coated base sheet	ASTM D6163, "Standard Specification for Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using Glass Fiber Reinforcements," or ASTM D6164, "Standard Specification for Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using Polyester Reinforcement"
APP Polymer-modified asphalt-coated base sheet	ASTM D6509, "Specification for Atactic Polypropylene (APP) Modified Bituminous Base Sheet Materials Using Glass Fiber Reinforcements"
Self-adhering (SA) polymer-modified bitumen base sheet	No U.S. product standard

Cap sheets. Granule-surfaced and metal foil laminate sheets generally serve as polymer-modified cap sheets; a large variety of reflective cap sheets have recently become available. Products in this category include granule-surfaced sheets with additional factory-applied coating, smooth sheets with factory applied coating, and sheets with factory-applied thermoplastic film surfacing. Common varieties of cap sheets used in polymer-modified roof systems are:

SBS Polymer-modified bitumen cap sheet	ASTM D6162, "Standard Specification for Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using a Combination of Polyester and Glass Fiber Reinforcements"; ASTM D6163, "Standard Specification for Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using Glass Fiber Reinforcements"; ASTM D6164, "Standard Specification for Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using Polyester Reinforcements" or ASTM D6298, "Standard Specification for Fiberglass Reinforced Styrene Butadiene Styrene (SBS) Modified Bituminous Sheets with a Factory Applied Metal Surface"
APP Polymer-modified Bitumen Cap Sheet	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"; or ASTM D6509, "Specification for Atactic Polypropylene (APP) Modified Bituminous Base Sheet Materials Using Glass Fiber Reinforcements"
Self-adhering Polymer-modified Bitumen Cap Sheets	No U.S. product standard

Interply sheets are sometimes used in place of single-layer base sheets in multiple layers beneath APP or SBS polymer-modified bitumen cap sheets. Common varieties of interply sheets used in polymer-modified roof systems are:

Asphalt, fiberglass ply sheet	ASTM D2178, "Standard Specification for Asphalt Glass Felt Used in Roofing and Waterproofing" (typically Type IV or Type VI).
APP Polymer-modified interply sheet	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"; or ASTM D6509, "Specification for Atactic Polypropylene (APP) Modified Bituminous Base Sheet Materials Using Glass Fiber Reinforcements"
SBS polymer-modified bitumen interply sheet	ASTM D6162, "Standard Specification for Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using a Combination of Polyester and Glass Fiber Reinforcements"; ASTM D6163, "Standard Specification for Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using Glass Fiber Reinforcements"; or ASTM D6164, "Standard Specification for Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using Polyester Reinforcements"
Self-adhering (SA) polymer-modified bitumen interply sheet	No U.S. product standard

THERMOSET SINGLE-PLY—ONE LAYER OF MEMBRANE WITH ADHERED SEAMS

Single-ply roof membranes are a category of roof membranes that are field-applied using just one layer of membrane material, either homogeneous or composite, rather than multiple layers. The only thermoset materials commonly used in construction of single-ply roof membranes in North American are ethylene propylene diene terpolymer or ethylene propylene diene M-class rubber (EPDM) sheets.

Thermoset roof membranes are manufactured as cured or vulcanized sheets, or partially cured sheets that are intended to fully cure on the roof. Unlike thermoplastic materials, thermoset polymers, once fully cured, can only be bonded to like materials with a liquid-applied adhesive (glue) or adhesive seam tape because new molecular linkages may not be formed.

The most common thicknesses of EPDM single-ply roof sheet materials are 45 mils and 60 mils. EPDM roof membrane sheets are typically reinforced with a polyester scrim or fabric that is positioned during manufacturing near the middle of the finished thickness of the EPDM sheet. Some EPDM sheets are also manufactured with nonwoven polyester fleece backing adhered to the underside of a (typically) unreinforced sheet. Fabric-backed EPDM may facilitate adhesion to a substrate, serve as a separator from the substrate, or perform both functions.

The U.S. product standard applicable to nonvulcanized (uncured) EPDM used for flashing applications is ASTM D4637, "Standard Specification for EPDM Sheet Used in Single-ply Roof Membrane" (Type I—unreinforced; Type II—reinforced; Type III—fabric-backed).

THERMOPLASTIC SINGLE-PLY—ONE LAYER OF MEMBRANE WITH WELDED SEAMS

With thermoplastic single-ply roof membranes, the chemical and physical characteristics of the component materials allow them to repeatedly soften when heated and harden when cooled. Typically, there is no chemical cross-linking in the molecular composition of a thermoplastic membrane's compound. Due to the chemical nature of thermoplastic materials, thermoplastic sheets typically are seamed by heat welding with hot air.

The three common subcategories of thermoplastic membranes are: 1) polyvinyl chloride (PVC), 2) thermoplastic polyolefin (TPO), and 3) ketone ethylene ester (KEE).

Polyvinyl chloride (PVC) is produced by the polymerization of vinyl chloride monomer, a gaseous substance resulting from the reaction of ethylene with oxygen and hydrochloric acid. The basic chemical resin is a relatively hard material that requires the addition of plasticizers to make it supple and pliable for use as a flexible membrane roofing material. Chemical stabilizers and proprietary ingredients are added to PVC membrane materials by manufacturers.

As with other thermoplastic materials, accurate compounding of PVC is necessary for the PVC roof membranes to achieve the desired physical properties. NRCA recommends designers specify PVC membranes with a minimum thickness of 45 mils for use in conventional single-ply roof systems.

The U.S. product standard applicable to PVC membrane is ASTM D4434, "Standard Specification for Poly (Vinyl Chloride) Sheet Roofing."

Thermoplastic polyolefin (TPO) sheets are compounded from a blend of polypropylene (PP) and ethylene-propylene rubber (EPR) polymers. Flame retardants, pigments, UV absorbers, and other proprietary ingredients may be included in TPO sheet formulations. TPO membranes are typically reinforced with a polyester scrim or fabric that is positioned during manufacturing near the middle of the finished thickness of the TPO membrane. NRCA recommends that roof system designers specify a thickness of at least 60 mils for TPO membranes.

The U.S. product standard for TPO membranes used as single-ply roof membranes is ASTM D6878, "Standard Specification for Thermoplastic Polyolefin Based Sheet Roofing."

Ketone ethylene ester (KEE) was introduced by DuPont (under the Elvaloy brand) in 1973 as a solid-phase plasticizer for single-ply PVC sheet membranes. KEE—sometimes referred to as ethylene interpolymer (EIP)—is a thermoplastic copolymer of ethylene containing carbon monoxide and either vinyl acetate or acrylate monomer, which provides softness and flexibility. Carbon monoxide groups provide polarity, which promotes compounding with PVC. Elvaloy-brand KEE does not leach out of the membrane over time, which enables the KEE sheets to remain flexible and workable.

KEE membranes are reinforced with fabric. Some KEE membranes are manufactured with a polyester fabric backer adhered to the underside of the sheet. Fabric-backed KEE membranes may facilitate adhesion to a substrate, serve as a separator from the substrate, or perform both functions.

The U.S. product standard applicable to KEE membranes used as single-ply roof membranes is ASTM D6754, "Standard Specification for Ketone Ethylene Ester Based Sheet Roofing." This material specification requires that KEE polymer constitute a minimum 50% by weight of the polymer content of the sheet. Some manufacturers market PVC alloy single-ply sheets (also referred to as EIP sheets) with KEE additive that makes up less than the minimum 50% polymer content that distinguishes D6754-compliant sheets.

SPECIFYING LOW-SLOPE ROOF MEMBRANES

Roof system designers should coordinate with roof membrane product manufacturers to ensure associated products such as bitumen, fasteners, adhesive, flashings, surfacings, and accessories are appropriately specified and included in contract documents. Selected roof assemblies should also have test reports showing compliance with building code–mandated performance criteria. Relevant product standards should be referenced in specifications for each roll-roofing products, as well as types, grades, classes, or other defining characteristics used in some product standards. Additional guidance is provided in The NRCA Roofing Manual—Membrane Roof Systems (shop.nrca.net).

COVER BOARDS—NOW STANDARD PRACTICE

Cover boards are flat or tapered stock materials ranging in size from 2X4 feet to 4X12 feet, in thicknesses from one-eighth of an inch to one inch, depending on material composition. Generally, using appropriate cover boards with roof systems, regardless of roof membrane type, should be considered. NRCA has long advocated cover board use as an important roof system design element in low-slope membrane roof systems to enhance overall roof system performance. Originally used as a method to prevent blistering incidents with built-up roof membranes, Cover boards are now recognized as good roofing practice for all low-slope roof system types.

Common cover board types used with low-slope roof assemblies are:

- Wood fiberboard
- Perlite
- Glass-mat-faced gypsum
- Fiber-reinforced gypsum
- Mineral fiber
- High-density polyisocyanurate
- Cement
- Asphalt core

Cover boards are used as part of roof assemblies to achieve the following benefits:

1. To separate membranes from polyisocyanurate insulation, reducing the possible effects of facer-sheet delamination, edge cavitation, cupping or bowing, shrinkage and crushing, or powdering of the polyisocyanurate insulation.
2. To allow for the installation of insulation board layers with staggered board joints, a practice known to reduce stress on membranes and improve a roof assembly's overall thermal performance.
3. To achieve a fire-resistance classification, as required for certain roof assemblies.
4. To provide increased roof membrane impact and puncture resistance.
5. To enhance compatibility when membrane and primary insulation incompatibility is possible, such as PVC membrane and polystyrene insulation.
6. To offer protection when ballasting operations or construction traffic may damage low-density primary insulations.
7. To form a thermal break when installed between roof membranes and primary insulation installed with fasteners.
8. To create a separation layer between existing roof systems and a new roof systems in re-cover situations.

Roof system designers should review the roof membrane manufacturer's literature or consult with the manufacturer's technical staff when determining the type of cover board to use for a specific roof system. Roof membrane manufacturers test roof assemblies for wind uplift and fire classification based on the entirety of the components within the assembly, including cover boards.

Additional guidance is provided in The NRCA Roofing Manual—Membrane Roof Systems (shop.nrca.net).

THE IMPORTANCE OF PREPARING COMPLETE CONTRACT DOCUMENTS

Contract documents should include relevant building-code-related performance criteria values and appropriate U.S. product standard references. Contract documents should be coordinated with specified roof product manufacturers' technical and installation literature in order to provide roofing contractors with the information they need to produce complete and thorough bidding documents.

Properly evaluating, selecting, and specifying roof system attachment method, accessories, flashings, terminations, installation instructions, insulation, and vapor retarders is also important for achieving quality low-slope roof membranes. Roof system designers should coordinate with the technical staffs of roof membrane manufacturer, specialty consultants (when appropriate), and local building code officials to ensure specified roof systems are in compliance with building code requirements and the owner's design goals.

For additional technical guidance, see The NRCA Roofing Manual and NRCA's other technical and code-related publications (www.nrca.net).