

Let's Rap About Building Wraps!

Sheet membranes used for water or air barriers, and their composition, attachment, and testing

By Scott D. Wood

Even well-designed and properly installed cladding or siding will eventually fail to prevent weather-related water and air intrusion. Therefore, additional barriers are used to reduce the risk of weather-related damage. Because of their many benefits, synthetic building wraps (also known as house-wraps) have replaced asphalt felt as the major material for water- and weather-resistant barriers and air barriers. This article surveys key information about sheet membrane building wraps, including their materials, uses, and testing requirements.

TYPES OF BARRIERS

There are three basic types of weather-barrier systems to keep weather out. They are face-sealed (barrier), drained cavity or vented rainscreen, and redundant or concealed barrier systems.¹ For the vented rainscreen design and the redundant barrier system, the acronym WRB may refer to either a weather-resistant barrier or a water-resistant barrier.² Previous building codes have used WRB to refer to both water-resistant barriers and weather-resistant barriers. Section 1402.5 of the 2021 *International Building Code* (IBC)³ and Section R703.2 of the 2021 *International Residential Code* (IRC)⁴ define WRB as “water-resistant barrier.” However, the term “weather-

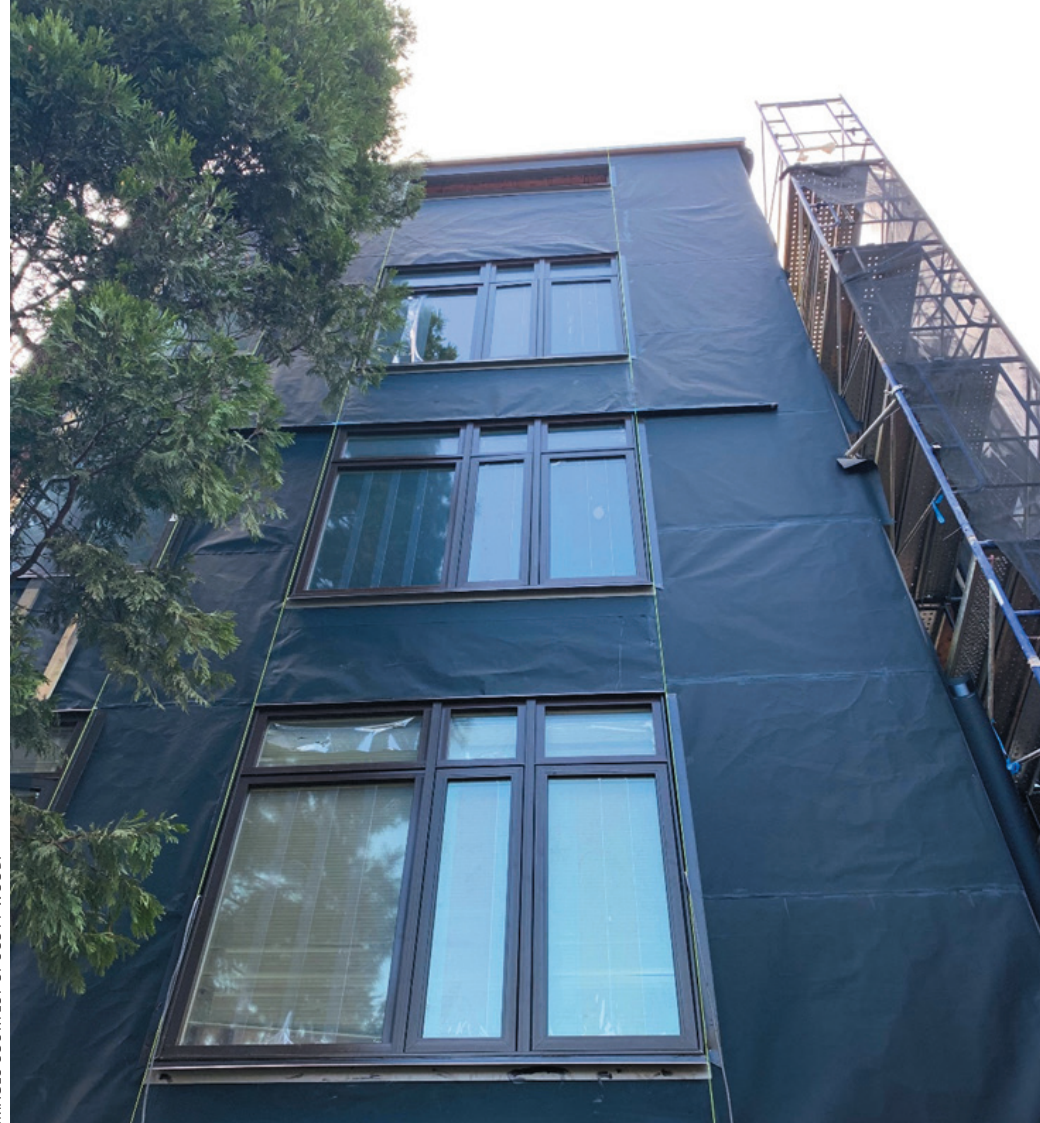


Figure 1. A recent installation of a mechanically attached polymeric sheet membrane building wrap used as both the air and liquid water barrier for a drainable wall system. Fasteners for this membrane were covered by the overlapping sections. An open joint cladding system is to cover this membrane, which is represented to be stable during ultraviolet exposure.

resistant” appears in Section 1402.2 of the 2021 IBC and Section R703.1 of the 2021 IRC, with the codes stating that “exterior walls shall provide the building with a weather-resistant exterior wall envelope.”

In the 2002 edition of the American Architectural Manufacturers Association (AAMA) 2400, *Standard Practice for Installation of Window with a Mounting Flange in Open Stud Frame Construction for Low Wind/Water Exposure*,⁵ the AAMA (now the Fenestration and Glazing Industry Alliance) defined WRB as “weather-resistant barrier,” a surface or wall responsible for preventing air and water infiltration to the building interior. However, the definition in AAMA 2400-10⁶ was changed from “weather-resistant barrier” to “water-resistant barrier.”

The IIBEC *Manual of Practice*⁷ defines WRB as “water-resistant barrier,” which is defined as “a material, generally sheet or liquid applied, behind an exterior wall covering that is intended to resist liquid water that has penetrated behind

the exterior covering from further intruding into the exterior wall assembly.”

Some building wrap manufacturers use the term “weather-resistant barrier” in their product literature for WRBs, and that definition may be used to denote both water and air resistance. Most building scientists and technical publications have now resolved the terminology inconsistency for this internal protective layer, which is used to control water intrusion, and often serves a dual function as an air barrier, is known as the water-resistant barrier (WRB).

A building enclosure is enveloped by environmental separators that must resist the flow of heat, air, moisture (liquid) and moisture (vapor) (HAMM). Though the air gap in a ventilated rainscreen design controls inward conductive heat flow, most WRB systems do not slow conductive heat transfer. A properly installed continuous WRB does stop convective heat transfer (airflow). The WRB for the vented rainscreen and a redundant barrier system provides protec-

tion for the building's internal components from HAMM flow through the enclosure.

Many different systems and material components can be used for a WRB. These materials can be building paper, mechanically fastened or self-adhered synthetic building wraps, fluid-applied systems, cellular plastic insulation, treated substrate systems using sealants and taped joints, and other materials and systems that have been designed to resist liquid water. In many cases, the WRB is also used to restrict air and vapor flows. For this paper, we are focusing on the building wrap or the sheet membrane WRB.

HISTORY OF BUILDING WRAPS

The first WRBs were vapor-permeable, asphalt-impregnated felts (Grade A or D building paper). Asphalt-impregnated products were introduced as early as the 19th century. Although they were easily torn and sensitive to ultraviolet (UV) exposure. Asphalt-impregnated products provided additional protection, slowing water ingress when the cladding leaks and slowing airflow.

Even though most of the current WRBs are an alternative to the original asphalt-impregnated felts, Section 1403.3 of the 2021 IBC and Section R703.1.1 of the 2021 IRC still list asphalt-impregnated material as an appropriate WRB. For the IBC and IRC, approved substitutes now include building wraps as well as many other materials and systems for water control. IBC Section 1403.3 states:

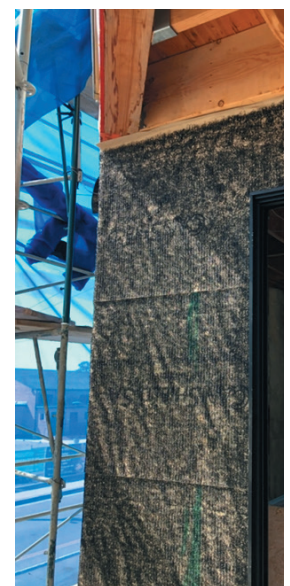
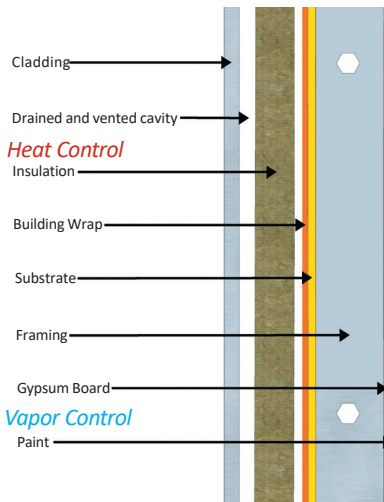
Water-resistive barriers shall comply with one of the following:

1. No. 15 felt complying with ASTM D226, Type 1
2. ASTM E2556, Type I or Type II
3. ASTM E331 in accordance with Section 1402.2
4. Other approved material installed in accordance with the manufacturer's installation instructions.

The wording in IRC Section R703.1.1 is mostly the same as this excerpt from IBC Section 1403.3. However, in IRC Section R703.1.1, item 2 refers to ASTM E2568, Type 1 or 2, and item 3 references Section R703.1.1.

The vapor diffusion theory was introduced in the mid-1930s as the fix for exterior paint failures.⁸ This theory led to the introduction of vapor barriers into wall systems and the initial inclusion in our building codes. Inclusion of vapor barriers have since been updated by many references showing that air-transported moisture, not vapor flow, was the cause of exterior paint failures. As a result, the WRB began to take

Figure 2. Diagram of the rainscreen wall showing the positioning of the building wrap as the controlling layer for liquid water and airflow (left). Image shows a drainage matrix attached to a self-adhered permeable building wrap, creating the drain and vented cavity for the ventilated rainscreen installation (right).



on an additional role of controlling airflow in addition to its original role as a means to keep water out.

In the 1950s, Hutcheon wrote, "Air merits major consideration mainly because of its influence on heat and moisture flow."⁹ In the 1960s, building scientists documented and recognized that air infiltration has a greater impact than vapor diffusion on wall systems and the interior environment.^{10,11} This finding is reflected in the "Build tight, ventilate right" motto coined by Jack Hébert, founder of the Cold Climate Housing Research Center.¹² Since the 1960s, building scientists have continued to cite air infiltration as a prominent transport of nonbulk or nonliquid moisture far exceeding that of vapor diffusion transport.

During the energy crisis of the 1970s, conservationists emphasized that reducing air leakage (convection) through the enclosure would reduce energy consumption for both heating and cooling demands. In the late 1970s, the introduction of airtight, liquid-water-tight, large-width polymeric sheet products, also known as building wraps, provided ease of installation and the continuity requirements for a better-functioning air barrier. Building wraps quickly gained acceptance in the 1980s due to their dual function for water and air resistance, replacing the smaller-width, heavier, asphalt-impregnated WRBs (see Fig. 1).

The 1995 National Building Code of Canada (NBC code)¹³ was the first North American code to require continuous air barriers for all commercial buildings. Massachusetts was the first US state to introduce a similar requirement in 2001, with Wisconsin following in 2003. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1-2010 introduced air barriers in 2010 for commercial buildings.

BUILDING WRAP FUNCTION

Building wrap systems behind the cladding are the secondary plane of protection against water ingress, and—if continuous, detailed, and sealed appropriately—they also enclose the wall assembly as an air barrier. The materials behind the exterior wall veneer now help control heat, air (and its convective heat flow), water infiltration, and water vapor—or heat, air, liquid moisture, and moisture vapor (HAMM). In most cases, the materials are the separator between the exterior and interior environments, blocking HAMM. Their primary function is to resist liquid water that has migrated through the exterior cladding. Building wraps, when installed properly in a drainage cavity wall system (vented rainscreen), prevent liquid water movement into the overall wall assembly by allowing free drainage out of the wall system. When WRB systems are combined with flashing and other supporting materials to ensure that there is a shingled effect, these systems direct liquid water away from the exterior sheathing.

With many state building code requirements now requiring air barriers, building wraps can provide multiple functions that include serving as the building's water barrier, air barrier, and, in some cases, a vapor retarder. This multifunctionality provides a broader range of function for addressing HAMM than is offered by No. 15 asphalt-impregnated felts.

The dual function of the WRB as an air barrier requires air permeance resistance. Air permeance resistance requires the material's air permeability to be less than or equal to 0.004 cfm/ft² at 0.3-in. water gauge (0.02 L/s•m² at 75 Pa) when tested in accordance with ASTM E2178.¹⁵ For air barrier assemblies air leakage must be less than or equal 0.04 cfm/ft² at 0.3-in. water gauge (0.02 L/s•m² at 75 Pa) when tested in accordance with ASTM E2357.¹⁶ The introduction of asphalt-impregnated membranes in the



Figure 3. A woven, microporous building wrap provides vapor permeability.

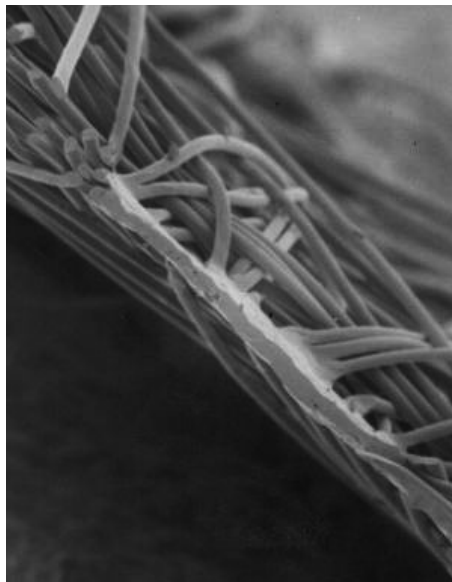


Figure 4. Close-up view of a cross section of a monolithic, spun-bonded, synthetic building wrap.

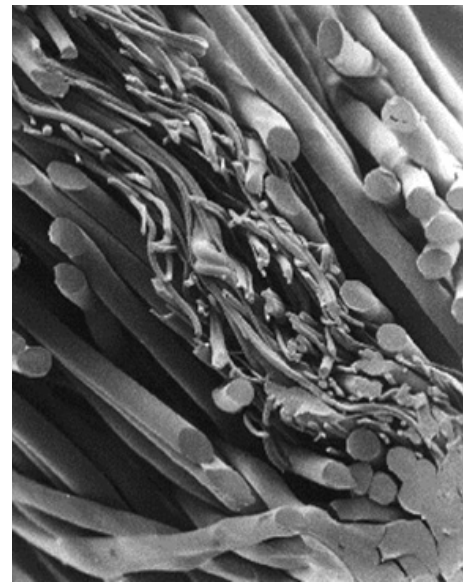


Figure 5. Close-up view of a cross section of a triple-layer, spun-bonded, synthetic building wrap.

19th century did reduce airflow, though not as effectively as properly installed building wraps or the many other alternative WRB materials available for the continuity requirements of an air barrier. Building wraps have large surface areas and are sealed with either self-adhesive membranes or sealant tapes at the seams. These features help building wraps meet the continuity requirements of an air barrier, which asphalt felts do not meet.

When a ventilated rainscreen design is used, a building wrap should provide the following basic functions (Fig. 2):

- A barrier to prevent liquid moisture penetrating through the cladding from intruding into the wall assembly
- Resistance to airflow, slowing air-transported moisture and convective heat transfer (when the building wrap is also used as the air barrier)
- Vapor diffusion drying if the wall becomes wet

BUILDING WRAP COMPOSITION

WRB synthetic sheets, referred to as housewraps or building wraps, are composed of synthetic polyolefin (polyethylene, polypropylene), polyester, polyamide, polyimide polymers, or a combination of synthetic polymers. To create the building wrap, these polymers are spun-bonded, woven, single layer or multilayer films that are laminated or coated. (Fig. 3, 4, and 5).

Self-adhered building wraps use a wide range of compounds, including modified bitumen, butyl-based, styrene-butadiene-styrene rubber, or acrylic compounds for adhesion. Self-adhered synthetic sheet products with high water vapor

permeance typically use adhesives that are water vapor permeable and/or spot applied to provide water vapor permeability.

Other additives or coatings may be incorporated into the manufacturing of the building wrap. For example, fire retardants are added to reduce the building wrap's flame spread and the smoke developed. Coatings or laminated low-emissive materials, such as metals, are used to reduce radiant heat transfer when the building wrap is installed properly. UV-stabilizing compounds may be required if long-term UV exposure is anticipated. Prolonged UV exposure and the associated damage are problematic for many synthetic polymers that are not adequately UV stabilized. Even though the synthetic polymers used for building wraps are in general hydrophobic, hydrophobic compounds may be added to enhance their capability for liquid water resistance.

WATER VAPOR PERMEANCE

Both IRC, in Section R703.2, and IBC, in Section 1403.2, define the water-resistive barrier as No. 15 asphalt felt or other approved water-resistive barrier. IBC Section 1402.2 requires weather protection of the exterior walls to provide the building with a weather-resistant exterior wall enclosure. No. 15 asphalt felt has an approximate permeance of 5 perms (286 ng/Pa•s•m²) when tested using ASTM E96, *Standard Test Methods for Gravimetric Determination of Water Vapor Transmission Rate of Materials*,¹⁷ desiccant method. Procedure A of ASTM E96 is similar to ASTM F1249, *Standard Test Method for Water Vapor Transmission Rate Through Plastic Film and Sheeting Using a Modulated Infrared*

Sensor,¹⁸ using conditions of 23°C (73.4°F) and 50% relative humidity. The ASTM E96 water methods (procedure B) typically provide a much higher permeance value for asphalt felts, as high as 60 perms (3431 ng/Pa•s•m²). Procedure B of ASTM E96 is similar to ASTM E398, *Standard Test Method for Water Vapor Transmission Rate of Sheet Materials Using Dynamic Relative Humidity Measurement*,¹⁹ using conditions of 23°C and 50% relative humidity. This implies a permeance for the WRB and building wraps of 5 to 60 perms (286 to 3431 ng/Pa•s•m²) depending on ASTM permeance testing methods.¹⁷⁻¹⁹ In the past, IBC required ASTM E96 desiccant method testing. The 2021 edition of IBC cites the ASTM E96 water method for use in determining water vapor permeance for vapor retarders.

Selection of appropriate water vapor permeance for a WRB is dependent on the WRB's location within the wall assembly, as well as the interior and exterior environments including vapor pressures. To assist in proper design, an evaluation using a hygrothermal analysis program such as Wärme Und Feuchte Instationär (WUFI) will assist in evaluating long-term hygrothermal performance of the designs in the built environment.

IRC Section R702.7 and IBC Section 1404.3 require vapor retarders to be installed on the interior side of framed walls, which is referred to as the "warm side" of the enclosure during the winter. Because a nonpermeable WRB is a vapor barrier, this requirement suggests that a nonpermeable WRB should not be installed on the exterior of the enclosure, unless hygrothermal analysis provides an approved acceptance for an alternative position. When two vapor retarders are incorporated into a wall design, moisture

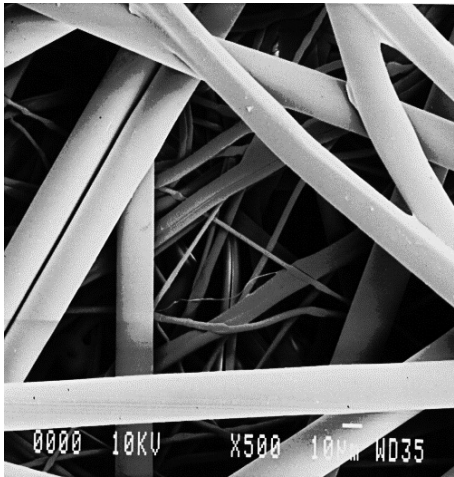


Figure 6. Micrograph of a spun-bonded polyolefin membrane, showing the spaces between the fibers that allow water vapor to travel.



Figure 7. A 100× image of a micropore in a woven building wrap.

that enters the wall system can become trapped between the two retarders.

Vapor diffusion drying is the process of water vapor moving from a higher vapor pressure (wet) to a lower vapor pressure (dry). When moisture accumulates inside the wall, this moisture can be released only by vapor-diffusive drying. Water vapor diffusion drying allows accumulated moisture to escape through a permeable building wrap. A vapor-permeable building wrap next to or a vented rainscreen is essential to allow the release of moisture into the vented cavity and out of the wall system.

Commercially available building wraps can have very high water vapor permeability, 100–200 perms (grains/hr•ft²•in. Hg) (5721–11,442 ng/Pa•s•m²) or greater, thereby offering very high vapor diffusion drying rates. However, because these highly permeable building wraps have larger pore sizes to allow high water vapor permeance, they typically no longer perform as an air barrier.

Water vapor permeability is incorporated into building wraps by two methods: spun-bonded

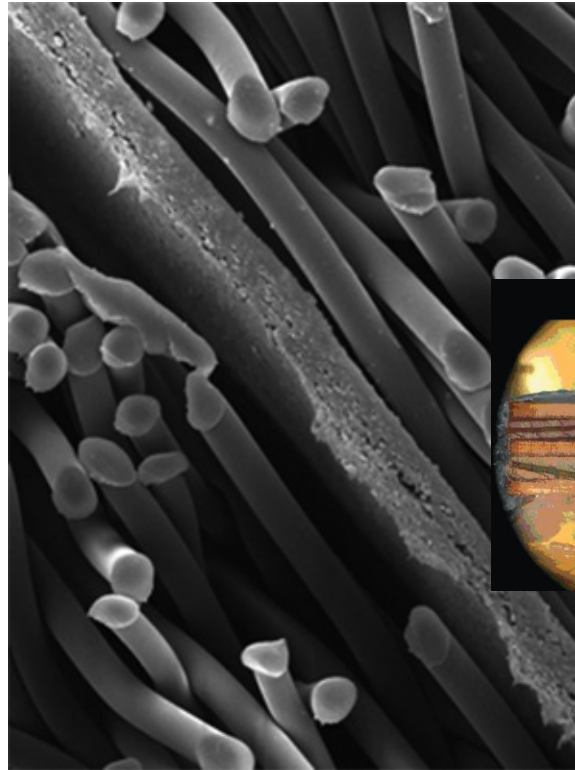


Figure 8. Micrograph of a microporous synthetic membrane thermally laminated between two spun-bonded membranes.

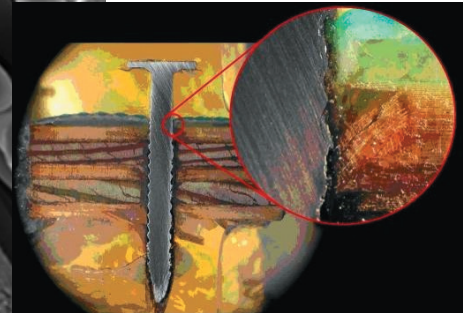


Figure 9. Fastener penetration through spun-bonded building wrap pushes the fibers aside, allowing the fibers to cinch around the fastener.

fibers or microporations. Spun-bonded building wraps allow water vapor to diffuse through the spaces within the structure of the spun-bonded material. These spaces are typically small enough to limit liquid water and air molecules, so spun-bonded building wraps can act as a dual-purpose air and water barrier (**Fig. 6**).

Perforated building wraps are made from vapor-tight polymer films. To provide water vapor permeance, small holes are punched into the film (**Fig. 7**). Laboratory tests have shown that nonperforated building wraps resist liquid water better than perforated building wraps.^{20–22} In addition to greater resistance to liquid water transmission, nonperforated building wraps show higher air resistance than perforated building wraps.²³ Multilayered building wraps have an inner layer containing a microporous film (**Fig. 8**). This combination of a microporous layer sandwiched between two spun-bonded layers helps control liquid water and air resistance, and allow water vapor movement through the building wrap.

ATTACHMENT METHODS

Securing the building wrap to the enclosure is important for the building's water and air resistance. Continuity of the building wrap is critical when it is used as an air barrier and is a key requirement for airtightness. Building wraps typically come in large widths and lengths that help limit the number of seams or overlaps. This offers a distinct advantage over the original asphalt-impregnated WRB materials.

There are two types of attachment methods for building wraps: mechanically fastened and self-adhered. Mechanical attachment uses penetrating fasteners to attach the membrane to the substrate. A self-adhered membrane uses adhesive applied on the inner facing surface during the manufacturing process. When attached, the adhesive bonds the building wrap onto the substrate. This removes the need for tapes or sealants for the seams that ensure watertightness and airtightness for most self-adhered building wraps.

When mechanically attaching synthetic membranes, installers must take care to ensure that the penetrations created by the fasteners do not leak. Leakage is prevented by incorporating gasketed fasteners or sealing over the fasteners. Although sealing fasteners and penetrations are important for all building wraps, leaks are less of an issue with nonperforated, nonwoven, self-adhered building wrap membranes. Spun-bonded, synthetic building wrap membranes are made of a tough, uniform material of fused, fine, high-density polyethylene or polypropylene fibers. When fasteners penetrate a spun-bonded sheet, the fibers separate and cinch around the fasteners, helping to lock out air and water ingress (**Fig. 9**).

Fasteners used should be approved by the building wrap manufacturer and tested to ensure both airtightness and watertightness. For air barrier continuity and water resistance, mechanically attached membranes require sealed laps and penetrations. Given the surface

Low-Energy-Surface Synthetics

Low-energy-surface synthetics used in building wraps have unique surface characteristics that make them hydrophobic. This property allows the openings in spun-bonded materials and the micropores in perforated building wraps to diffuse water vapor while keeping liquid water out.

Permeable low-energy-surface building wraps, especially perforated wraps, are susceptible to surfactants that increase the energy of the surface, causing water to pass through the building wrap.²⁴ A surfactant is a chemical or compound that lowers surface tension (Fig. 10 and 11). Some sealants and fluid-applied compounds contain surfactants, causing water to pass through when applied to permeable building wraps (Fig. 12).

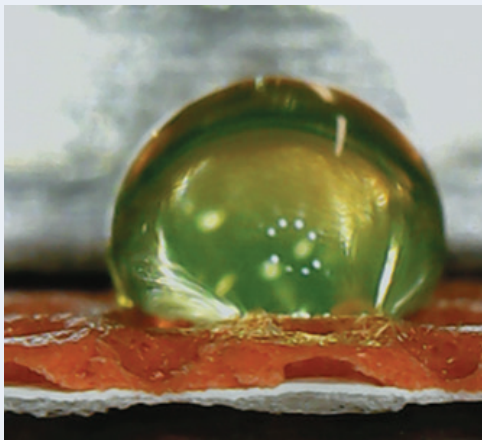


Figure 10. Water on a low-energy surface without surfactants.



Figure 11. Water on a low-energy surface with surfactants.

Low-energy surfaces also make it difficult for pressure-sensitive adhesives to stick. A low-energy surface allows water to bead up, as shown in Fig. 10, as well as causing an adhesive from flowing and beading up on the building wrap's surface. For an adhesive to stick, it needs to be able to "wet out" or "flow" onto the surface. "Wet out" describes the many tiny, interactive bonds that form with the surface of a substrate, which depend on the surface energy and texture (smooth or rough.) Because of the low energy at the surface of the low-energy-surface synthetics, many adhesives cannot achieve adequate interactive bonds and fail to form a robust bond strength. The result is poor adhesion.

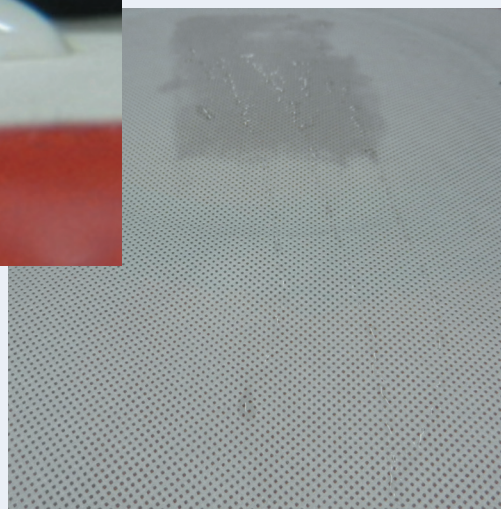


Figure 12. A sealant is applied to the building wrap and allowed to fully cure. An open bucket is sealed to the building wrap to allow the addition of water over the sealant. The underside of the building wrap is monitored for water penetration through the membrane as shown in the image.

characteristics of the synthetics used in building wraps, most notably their low-energy surfaces (see sidebar, "Low-Energy Surface Synthetics"), sealants, adhesives, and tapes for sealing laps and the adhesive used for self-adhered building wraps must be formulated to adhere tightly to the building wrap's surface. Sealants used should be those recommended by the manufacturer and field tested to ensure strong adhesion to the building wrap's surface.

Given the low-energy surface of building wraps, applying adhesives or tapes in the field for overlaps and penetrations to ensure watertightness and airtightness can be difficult. Many manufacturers recommend or offer specially formulated adhesives for both sealants and tapes to ensure a long-lasting bond for a high level of adhesive performance. Tapes, sealants, or both are required for mechanically attached overlapping seams, especially for airtightness.

Modified acrylic adhesive systems were designed to help overcome the obstacles of bonding adhesives to low-energy surfaces without the need to modify the surface with techniques such as flame treatment, corona treatment, or the use of solvent-based adhesive promoters/primers. These treatments add cost and complexity; also, their use may involve environmental or safety issues, and may affect the building wrap's water resistance.

Self-adhered building wraps with adhesive coatings remove the need for penetrating fasteners for attachment, but the adhesive layer used for attachment reduces the permeability of the installed product. When specialized adhesives and special applications are used, many self-adhered building wraps can maintain high water vapor permeability. Asphaltic and butyl (synthetic rubber) adhesives may require the application of primers on the substrate to promote desired adhesion. Any addition of primers reduce the water vapor permeability and drying potential of a wall system. Newer adhesive technologies such as acrylic pressure-sensitive adhesives (PSAs) typically do not require primers for adhesion. These PSAs are usually more UV stable and do not harden, but rather stay fluid and increase adhesion, over time. Modified bitumen, butyl-based, or SBS rubber adhesives dry out and can lose adhesion over time.

Self-adhered building wraps offer several advantages compared with mechanically attached building wraps. Billowing or movement of the mechanically attached building wrap due to pressure differences is reduced for a self-adhered membrane. When fastener penetrations are needed for cladding attachment, the surrounding adhesive inhibits further migration of water or air should it enter through the penetration.

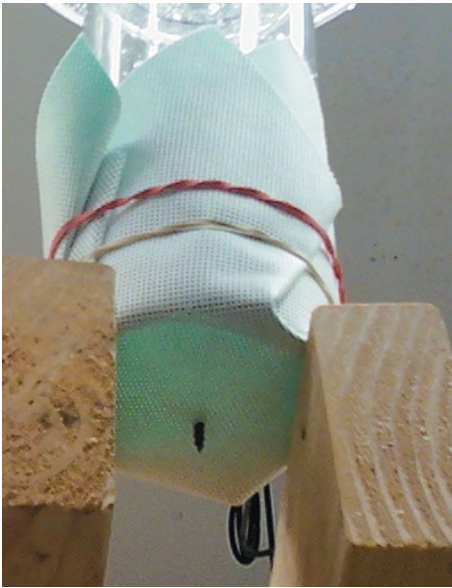


Figure 13. A fastener penetrates building wrap, holding back a head of water in the column above.

TESTING PARAMETERS

Heat, water, and UV exposure are the greatest causes of degradation in building products. Their damaging effects on building wraps are exponential when combined.

Given the detrimental effects of heat, water, and UV exposure, it is critical that WRBs have specific characteristics and are thoroughly evaluated through appropriate testing methods. Published technical information should include all testing methods used, the test results, and exposure limits for the WRB. Most manufacturers publish this information in their technical or product data sheets.

There are many standards, test organizations, and methods used to evaluate building wrap membranes. One notable resource is the International Code Council Evaluation Service (ICC-ES), which reviews and certifies products, components, methods, and materials to ensure they meet requirements of the IBC, the *International Fire Code*,²⁵ and the other model codes. ICC-ES acceptance criteria AC38²⁶ lists the testing methods that manufacturers use as an accepted alternative to the IBC- and IRC-required Type 1 asphalt-saturated membranes. Some of the tests related to synthetic building wraps are tear resistance, UV resistance, moisture tolerance, and air and water vapor permeance.

Tear Resistance

The three tear resistance test methods included in the ICC-ES acceptance criteria AC38²⁶ used to measure membrane dry tensile strength or dry breaking force are ASTM D828,²⁷ ASTM D882,²⁸ and ASTM D5034.²⁹ These methods all provide a gauge of the building wrap's strength (Fig. 13). Usually, building wrap



Figure 14. Open-joint cladding over ultraviolet-stable building wrap applied over mineral wool.

Most building wraps far exceed values determined for the IBC and IRC for their referenced WRB Type 1 asphalt-saturated membranes.

UV Stability Testing

UV exposure can affect a building wrap's tear or puncture resistance as well as its water resistance. Factors that affect the risk of UV damage to building wraps include sun exposure due to geographic latitudinal location, elevation (atmospheric density and ozone levels), and building exposure, including the time until the building is covered by the cladding.

UV environmental exposure is difficult to duplicate in a laboratory setting. The AC38 UV light exposure specifies a minimum of 210 total hours of UV exposure. However, as mentioned above, exposure is dependent on a number of factors. In laboratory testing, a building wrap must be exposed to a UV lamp for a minimum of 500 hours, which is considered to be equivalent to approximately 3 months' full exposure for an installed building wrap. UV lamp exposure for 1000 hours can equate to roughly 6 months' exposure.³⁰ Usually, building wrap

manufacturers provide a maximum window of allowable UV exposure to ensure the building wrap will perform as expected.

At present, a few building wraps that provide long-term UV exposure stability are available. These building wraps should be used when a WRB is expected to have long-term UV exposure. Use of this type of building wrap is especially critical for an open-joint cladding system (Fig. 14) because open-joint cladding exposes underlying materials to environmental risks such as wind washing³¹ and moisture, which can reduce the thermal performance of insulation or degrade underlying materials. A UV-stable building wrap placed over the surface of the insulation will keep weather from affecting an exterior insulation's conductivity and hide the surface with a UV-stable carbon black membrane. In addition to hiding the exposed interior surface, the carbon black also enhances UV stability.³²

This exterior-exposed building wrap is typically used as a cover for the insulation protection. Typically, a secondary permeable building wrap is installed onto the substrate for ease of installation and to ensure continuity for water- and airtightness.

Water-Resistance Testing

Since the building wrap provides the WRB and many times the air barrier, it is critical that the material is tested thoroughly for water resistance.³³ ICC-ES AC38²⁶ provides three methods to test for water resistance: the ASTM D779³⁴ boat method; the water ponding method in Section 6.4.5 of the Canadian Construction Materials Centre's (CCMC's) *Technical Guide for Sheathing* (CCMC 07102),³⁵ and the hydrostatic

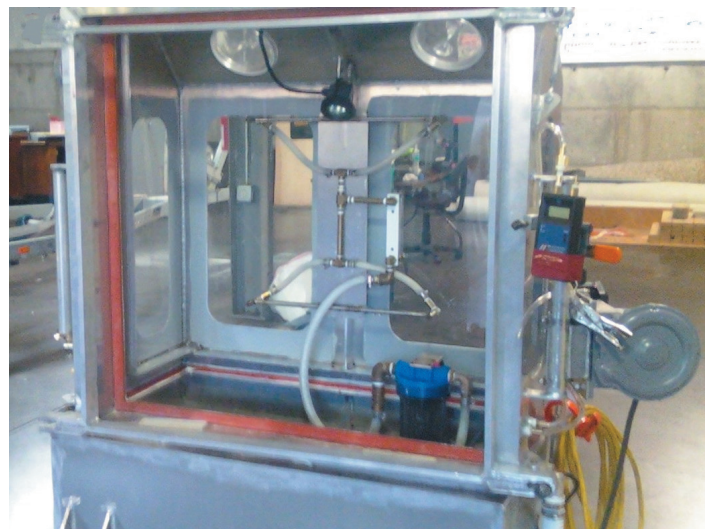


Figure 15. Water testing chamber capable of delivering 8 in. (203 mm) water per hour with a calibrated spray and pressure system that can simulate ± 100 -mph (160 km/hr) wind pressure conditions.

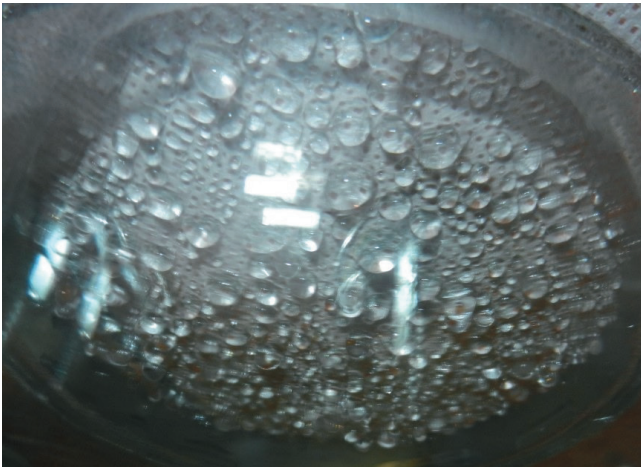


Figure 16. Hydrostatic head test showing failure of a building wrap with poor water resistance.



Figure 17. Equipment used to test air permeance using the ASTM E2178 test method.¹⁵

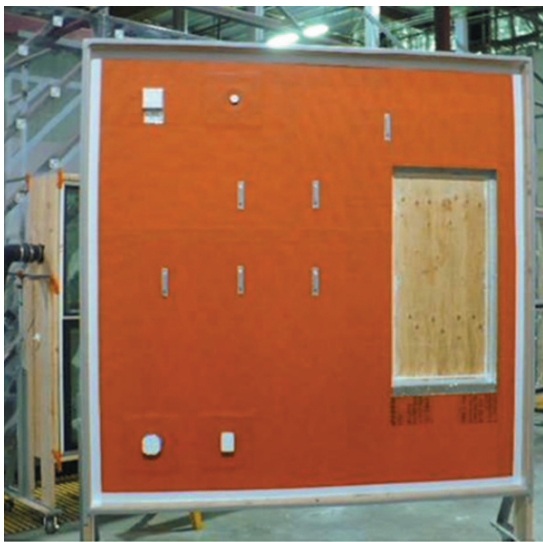


Figure 18. A wall with penetrations is ready for air leakage rate testing of the assembly.

head method in the American Association of Textile Chemists and Colorists' (AATCC's) *Test Method for Water Resistance: Hydrostatic Pressure* (AATCC 127).³⁶

- The ASTM D779 boat method is the least rigorous of the water-resistance test methods. A moisture-detection material is placed in a boat made of the building wrap, which is placed in a water bath. Given the high permeability of building wraps and the sensitivity of this test indicator to high humidity, the boat test may not be an applicable test method for highly permeable WRB membranes.
- The water ponding method in CCMC 07102 uses a waterhead of 25 mm (1 in.) and requires a 2-hour water resistance (Fig. 15).
- The hydrostatic head method in AATCC 127 is the most robust technique; it uses a waterhead of 55 cm (22 in.) and requires a 5-hour water resistance. See an example of a failure in Fig. 16.

Air Permeance

The 2012 edition of IECC³⁷ introduced the requirement for a complete air barrier system to address air leakage surrounding the conditioned space of the building, which is now required in the 2021 IBC and IRC. The model energy code defines "air barrier" as a combination of materials and assemblies that restrict or prevent the passage of air through the building enclosure. Figure 17 shows apparatus that is used to evaluate building wrap for airtightness in the ASTM E2178 test method.¹⁵

Some building wraps when installed as a system can provide airtightness for the wall. To pass as an air barrier system, a wall is tested using the ASTM E2357¹⁶ test method and must not exceed 0.04 cfm/ft² at 3 in. water gauge (0.20 L/sec•m² at 75 Pa) (Fig. 18).

Water Vapor Transmittance

In the past, water vapor transmittance (water vapor moving through a material) was considered to be the primary mechanism for moisture

transport for interstitial condensation. In 1947, F.B. Rowley wrote, "Use of a vapor barrier is the most effective means of preventing interior moisture from getting inside walls and ceilings."³⁸ Soon thereafter, Hutcheon described moisture carried by air leakage as a common issue for inner wall condensation due to its air-transported moisture.⁹ To date, many still confuse air- and vapor-transported moisture and fail to understand their vast differences for water vapor movement.³⁹ Water vapor transmittance is the measurement of water vapor moving through a solid material and not through air movement at holes.

Vapor diffusion is usually many hundreds of times slower than air-transported moisture. However, vapor diffusion is still important for both the possible accumulation of interstitial moisture and the release of that moisture. Because building energy codes greatly restrict both heat flow and airflow that can dry interstitial moisture, vapor diffusion may be the only alternative to remove accumulated moisture. It is important to evaluate vapor diffusion drying and its ability to remove moisture that passes through the WRB into interstitial space.

Both IRC and IBC reference ASTM E96¹⁷ Procedure B, the water or wet-cup method, as a method to test water vapor transmittance measurements of vapor retarders. The use of both the ASTM E96 desiccant and water methods is important to understand vapor diffusion under those very different conditions (Fig. 19). Unlike air movement through joints, seams, holes, and gaps, water vapor transmittance is the rate of water vapor through the material being tested.

The ASTM E96 test was adopted in 1947 and has known issues.⁴⁰ Bomberg's reference

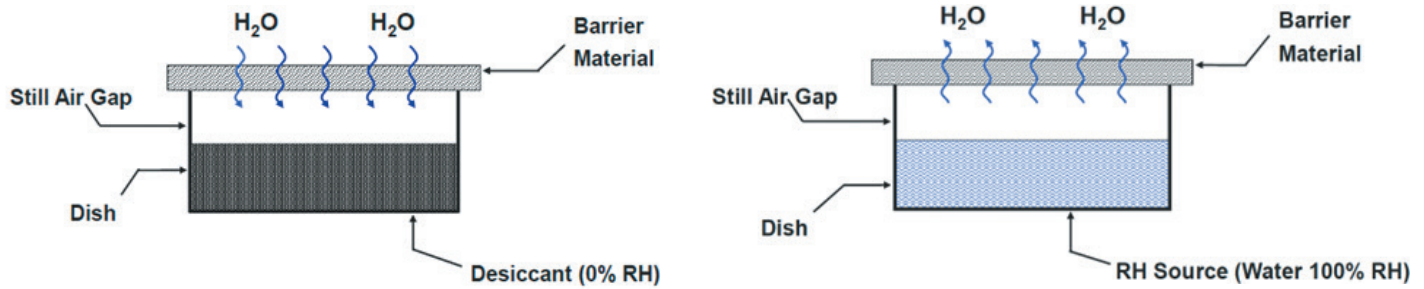


Figure 19. Diagrams of the test dishes for the ASTM E96¹⁷ desiccant (left) and water (right) methods.

notes issues that include temperature and relative humidity variation of the chamber, barometric pressure variations, cup size variation, height of the water or desiccant in the cup, edge mask of the cup, sample test area measurement, and airflow over the cup. Further advances in laboratory equipment have improved testing devices, which now provide faster turnaround and, in some cases, better reproducibility, although results are still quite variable among laboratories (by up to 20%), it is still the most used test method for water vapor permeance determinations.

The ASTM E96 desiccant method provides values for vapor diffusion under dry conditions, or when the vapor difference on either side of the building wrap is between 0% and 50% relative humidity (RH). Although these conditions would seem to be fairly common for a wall, the testing method does not provide information about the vapor movement when the substrate or inner wall is wet. Because permeable building wraps allow water vapor diffusion drying, it is important to also measure the vapor diffusion rates under wet conditions. The ASTM E96 water method provides values for vapor diffusion under wet conditions, or when the vapor difference on either side of the building wrap is between 50% and 100% RH.

The vapor diffusion values for the desiccant method are usually less than the water-method values. Using ASTM E96 water-method values provides a better understanding of the ability of the building wrap to dry the wet underlying surface. The desiccant method values provide information about water vapor transmission in dry conditions.


Two additional water vapor permeance test methods are ASTM E398¹⁹ and ASTM F1249.¹⁸ The ASTM E398 method approximates the ASTM E96 water method, and the ASTM F1249 approximates the ASTM E96 desiccant method. As testing laboratories become familiar with the newer water vapor permeance testing equipment used for the ASTM E398 and ASTM F1249 standards, expect to see more testing data from these testing methods.

SUMMARY

WRB sheet membranes have been used as weather- and water-resistant barriers since the introduction of asphalt-saturated sheet materials in the 19th century. In the 1970s, synthetic membranes that were more durable than asphalt-saturated sheets were introduced. The introduction of building wraps coincided with clear understanding by building scientists that air leakage was the primary mechanism for water moisture transport by airflow and a contributor to energy loss through convection. The industry realized that tough, large sheets of a building wrap have many advantages over the older asphalt-impregnated felt products. In particular, building wraps are easier to install and can perform as both water and air barriers.

Building wraps are manufactured using a variety of polymer formulations and strategies. The polymers can be spun-bonded, woven, single-layer film or multilayer films, laminated or coated. Most building wraps are designed to be durable and resist water. Building wraps can be attached by mechanical fastening or directly adhered to the surface by specially formulated adhesives. They must pass the testing methods to be an acceptable alternative to Type 1 asphalt-saturated membranes. The test methods and results should be provided by the manufacturer to ensure that the building wrap functions as intended. Today, most building wraps are both watertight and airtight, durable, UV stable to some degree, and vapor permeable to allow diffusive drying to occur.

Given the many test methods used to evaluate building wraps and the variable results from these tests, comparisons between the available building wraps can be difficult. Perforated material is likely to be less resistant than nonperforated material to water, especially when surfactants are present. In the author's opinion, installations should always include a ventilated rainscreen design to ensure complete drainage and allow vapor diffusive drying. When considering building wraps to serve as both water-resistive and air barriers, self-adhered membranes can typically provide

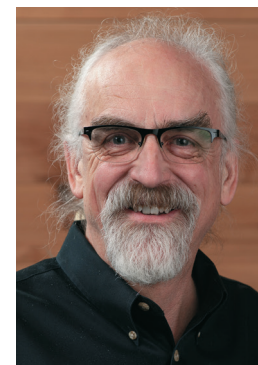
better continuity for the requirement of air barriers. For continuity requirements for airtightness, it is important to ensure that sealants and tapes will perform over the life of the building. 

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