Fasteners and Self-Sealability of Weather-Resistive Barriers

By Karl Schaack, RRC, PE

BACKGROUND

The basic function of the envelope or enclosure of a building or structure is to protect the covered or otherwise conditioned interior spaces from the surrounding environment.

Basic Exterior Wall Types

Exterior wall types commonly associated with above-grade, commercial building enclosure design and construction in North America can generally be classified as follows: cavity wall, barrier wall, or mass wall. For the purposes of this article, the topic will only include the cavity wall assemblies (*Diagram 1*).

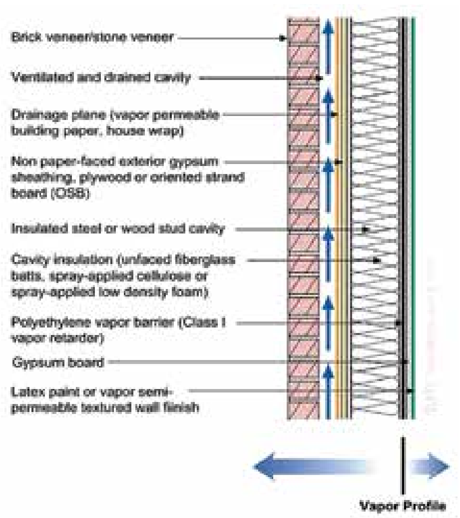


Diagram 1 – Cavity wall.

Cavity Wall

A cavity wall (also referred to as "screen" or "drained" wall systems) is considered by many to be the preferred method of construction in most climatic zones in North America. This is due primarily to the pressure-equalization that can be achieved and the redundancy offered by this type of wall assembly to resist uncontrolled water penetration. "Cavity wall" is used more generically to define any wall system or assembly that relies upon a partially or fully concealed air space and drainage plane to resist water penetration and, depending upon the design, to improve the overall thermal performance of the building enclosure. Drained cavity walls typically include the following general characteristics:

- An exterior cladding element that is intended to either shed or absorb the majority of water penetration before it enters the cavity spaces of the wall assembly
- A drainage cavity or air space that is intended to collect and control moisture that passes through the exterior cladding element and to redirect that water to the building exterior. The cavity can also facilitate the drying of a wall assembly.
- An internal drainage plane is intended to function as the primary line of defense against water penetration into the building interior. This plane serves functionally as the dividing line between the "wet" and "dry" zones of the exterior wall assembly. This layer can be created using a variety of sheet-goods—spray-applied, roller-applied, or trowel-applied products depending upon the climate in which the building is to be located and the desired level of performance necessary to prevent condensation and potential biological growth on the dry side of the exterior wall assembly.
- An insulating layer, which can be located inboard, outboard, or a combination of both, of the internal drainage plane, depending upon the geographic region and climate in which the building is located

The internal drainage plane is either any element exposed to weather or otherwise located at the line between the "wet" and "dry" zones of an exterior wall system. This plane is generally intended to be vapor-impermeable, vapor-permeable, or water-resistant, depending upon wall type, material selection, and climate. This plane is designed to move liquid water and/or condensation downward and outward in a manner that will prevent uncontrolled water penetration into conditioned spaces of a building. In cavity wall construction, the principal drainage plane and primary line of defense against water penetration is located inside the wall cavity, generally

Photo 1 – Application of emulsion dampproofing.

Photo 2 – Application of liquid-applied WRB.

on the inboard side of the air space (either directly applied to the outboard surface of the exterior sheathing layer or, in the case of insulated cavity walls, on the outboard surface of the rigid or otherwise moisture-impervious insulation layer).

CURRENT TRENDS

The composition of exterior building cavity wall or stud-framed commercial construction has changed over the years from the common use of plywood to a significant and almost exclusive use of glass-faced gypsum board for the exterior sheathing, commonly referred to as the "backup wall." Terminology for the material applied to the backup wall or exterior sheathing has also changed from "dampproofing" to materials commonly referred to as "weather-resistive" or "water-resistive barriers" (WRBs) and "air barriers." The exterior gypsum sheathing serves as the substrate for the application of the WRB at the drainage plane.

The exterior wall assembly has changed from the application of dampproofing on exterior sheathing such as traditional bituminous-based emulsions that were troweled, rolled, or sprayed onto the backup wall (*Photo 1*) to now include elastomeric sheets, synthetic building wraps, spray-applied polyurethane foam, rigid foam board, and liquid-applied synthetic materials that are either mechanically attached or adhered to the backup wall.

The use of air barrier materials within exterior wall assemblies of commercial buildings, as well as single- and multifamily housing, has become widespread in the construction industry as a practice for reducing heating/cooling energy consumption and to improve the overall energy efficiencies of buildings. As defined by ASTM, an air barrier is a "material or system in building construction that is designed and installed to reduce air leakage either into or through the wall." Although the material is selected and used to reduce air leakage, another primary function is its ability to restrict water infiltration. For the purposes of this article, the primary emphasis will be on liquid-applied (*Photo 2*) and self-adhered sheet products, and the issues associated with permeability of air or vapor will not be considered.

Air barrier materials have product-specific properties that must be tested to ensure they will meet rigors encountered during their service life and under the buildings' imposed loads. An air barrier assembly is a collection of air barrier materials and air barrier accessories (i.e., sealants, tapes, and transition membranes) assembled together to form a continuous barrier to air infiltration into the conditioned space.

One of the performance characteristics that the Air Barrier Association of America (ABAA) requires for fluid-applied membranes, self-adhered membranes, and factory-bonded membranes to sheathing is self-sealability or fastener sealability. This property is determined by the test procedure outlined in paragraph 7.9, Self Sealability (Head of Water Test), of ASTM D1970 *Standard Specification for Self-Adhering, Polymer-Modified Bituminous Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection.*

This test method specifically refers to self-sealability of self-adhered sheet-applied membranes that are commonly used for ice dam protection in roofing, but it is also used for testing the performance characteristics of both liquid-applied and self-adhering sheet materials in weather-resistive barriers. The test consists of driving two galvanized nails positioned 1 to 2 inches apart through the air barrier material that is applied to a 3/8-in.-thick by 12-in. x 12-in. piece of plywood. Then the pointed ends of the nails are tapped so that the heads of the nails are backed out approximately ¼ in. from the surface of the air barrier membrane. A 1-gallon container is attached over the nail heads and sealed to the air barrier material applied on the plywood.

A second container is positioned below the pointed ends of the nails. The upper

Photo 3 – Holes in sheet WRB from fastener attachment of lath.

Photo 4 – Brick tie depressed into and damaging WRB.

container is filled to a depth of 5 inches with water (which equates to a 101-mph wind speed), and the specimen remains in this position for three days at 4± 2°C (40 ± 5°F). After the test, the lower container, shanks of the nails, and underside of the plywood are inspected for the presence of water. The upper container is removed from the air barrier material, and then the air barrier is peeled or removed from the plywood back to the nails. The underside of the removed portion of air barrier material is inspected for the presence of water. Evidence of water at any of these inspected locations constitutes a test failure.

CONSTRUCTION

Current construction practices of exterior cavity wall assemblies on commercial buildings commonly include the installation of glass-faced gypsum sheathing mechanically attached to light-gauge metal stud framing, with an air barrier applied over or onto the gypsum sheathing. A variety of cladding or finish materials is then installed over the air barrier. These cladding materials can include, but are not limited to, such items as: metal lath and stucco, metal panels on furring strips, mechanically attached Exterior Insulation and Finish Sysems (EIFS), masonry with metal ties or anchors, and other similar systems that require the use of mechanical fasteners to secure to the structure.

The intention during construction and as required by manufacturers and code is to install the various cladding materials so that fasteners penetrate through the WRB and gypsum sheathing, and into the underlying metal-stud framing. However, this intention is not always achieved due to dimensional issues or ill-fated installation procedures.

For example, the various accessories that are common in plaster systems such as prefabricated sheet metal reveals, control joints, casing and corner beads, and expanded metal latch are designed to be mechanically attached to underlying studs, but often the fasteners for securing these components are installed through the WRB material and do not penetrate into a metal stud (*Photo 3*).

It is believed to occur because of the lack of an

Photo 5 – Steel brick tie not conforming to substrate.

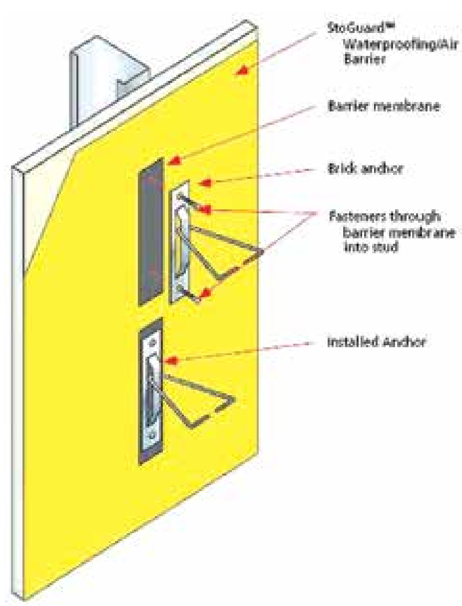


Diagram 2 – Brick tie color (courtesy of Sto).

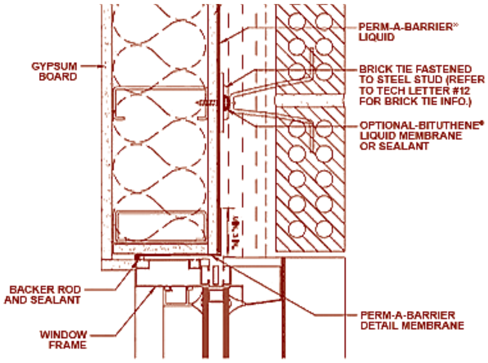


Diagram 3 – Brick tie plan view (courtesy of W.R. Grace).

actual metal stud in the selected fastener placement location or at an assumed or believed location of an underlying metal stud. It may also be that in the haste to meet critical construction timeframes, the attention to fastener placement, positioning, and embedment, and the overall quality of installations have become diminished. Furthermore, the fact that these WRB materials are often promoted as having "self-sealing" characteristics creates a false sense of comfort regarding fastener installation.

Unlike securement into a plywood substrate that has historically been used in exterior wall construction (particularly for plaster applications), when a fastener is installed into and through gypsum sheathing that does not penetrate into a sound substrate, the fastener continues to spin, reaming out the hole. The density of gypsum sheathing is not substantial enough to allow the fastener to "bite" and attain adequate compression against the WRB material (either liquid-applied or self-adhering sheets); consequently, the fastener hole becomes enlarged as the fastener spins. With a plywood backup, a fastener could be placed in almost any location to achieve adequate compression, even though it may not penetrate into a framing member. In addition, variabilities introduced during field installation of fasteners can create conditions that result in inadequate application. For example, if the fastener or other element is not installed straight and true or is installed over-aggressively, the WRB can be damaged, which can result in water leakage, even if the fastener is driven into a framing member (*Photo 4*).

Damage to the WRB may also occur due to poorly installed fasteners, removed fasteners, or fastener length for attachment of cladding components exceeding the depth of the sub-framing member (i.e., hat channel). When light-gauge steel framing, sub-girts, hats, and masonry ties are installed on top of the WRB, and fasteners are secured into the backup structure, the rigid steel sub-framing or steel tie typically cannot conform to uneven areas in the substrate, and the fastener cannot develop full compression against the WRB to achieve an adequate seal (*Photo 5*).

Some manufacturers of liquid-applied WRBs recommend installation of cut strips of self-adhering sheet between the steel girt or tie and the WRB to aid in achieving an adequate seal at fastener penetrations (*Diagram 2*).

Additionally, the heads of fasteners may need to be treated with a dollop of compatible sealant or trowelable version of the liquid membrane to provide a more suitable

Photo 6 – Sealant applied over fastener heads securing brick ties.

Photo 7 – Multiple fastener holes in flange of hat channel.

Photo 9 – Calibrated water spray rack on wall.

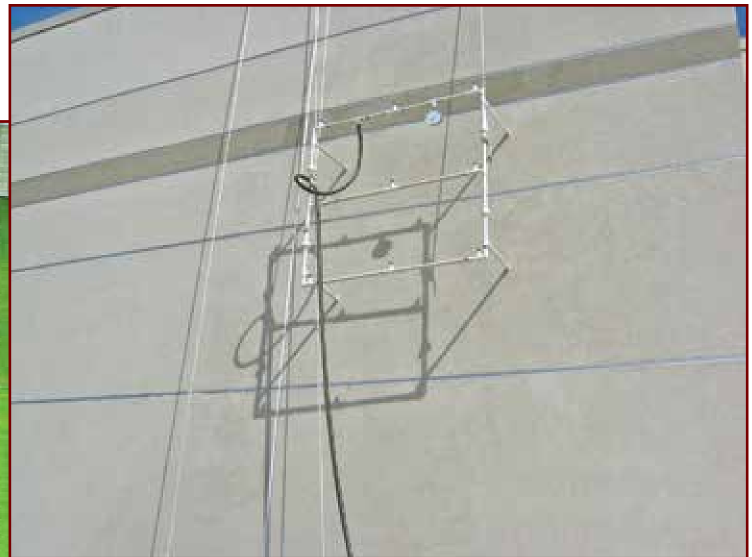
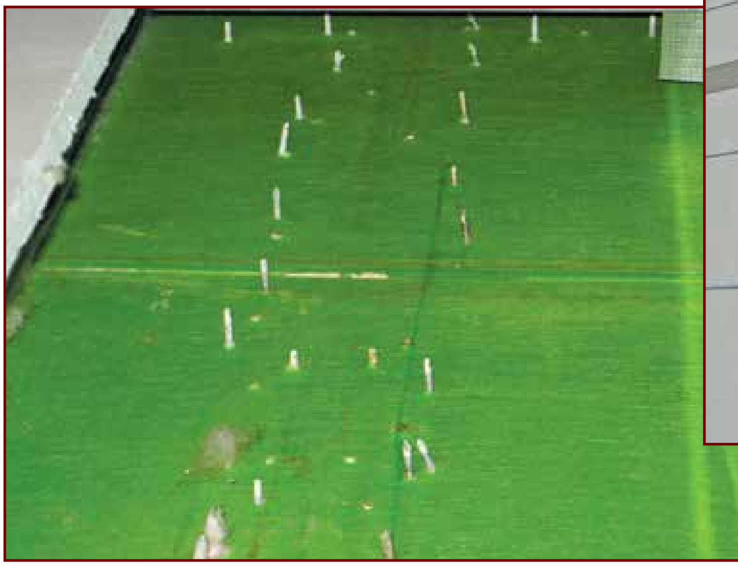


Photo 8 – Fasteners missing studs.



seal (*Diagram 3* and *Photo 6*). Another practice could include setting the masonry tie in "wet" liquid-applied WRB when securing to the substrate.

Once the WRB has been applied over the sheathing, screw heads used to attach the sheathing to the studs are concealed and the actual location of the stud is not readily visible or known by the installer of the cladding. Furthermore, if the actual stud placement varies from the project drawings or specified spacing due to large or excessive tolerances or construction variances, then locating the stud becomes a "hit-or-miss" target practice by the installer (*Photo 7*).

CONSTRUCTION OBSERVATIONS

Price Consulting, Inc. (PCI) was involved in an investigation of a newly constructed multistory office building where water infiltration had been reported. The exterior wall construction consisted of metal stud framing, glass-faced exterior-grade gypsum sheathing, liquid-applied air barrier material, metal lath, and a three-coat Portland-cement plaster. The plaster system incorporated standard metal accessories, including control joints, casing beads, and corner beads. Additional metal accessories, including expansion joints and aesthetic reveals, were also incorporated into the plaster. The exterior walls included curtain wall systems installed in punched openings in each floor elevation. Several of the floors of the subject building had yet to have their interior finishes completed; therefore, the backside of the exterior sheathing was readily accessible and visible at numerous locations.

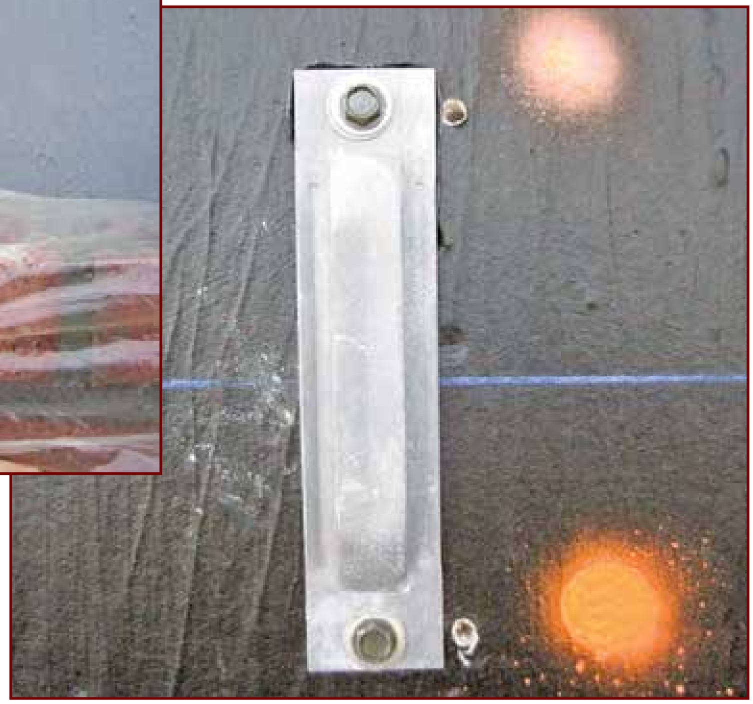
Upon initial visual inspection of the interior, the pointed ends of many screw fasteners were protruding through the exterior gypsum sheathing and not penetrating into any metal stud framing at numerous locations throughout the floors that did not have any interior finishes (*Photo 8*). These "missed" fasteners were typically located at

Photo 11 – Water leak at missing fastener hole in gypsum sheathing.

Photo 10 – Water dripping from fastener installed through gypsum sheathing.

Photo 12 – Multiple holes in WRB.

Photo 13 – Holes in WRB adjacent to brick tie.



the reveals and expansion joints in the plaster. Some were located along corner and casing beads, and others were located in the field of the wall believed to be for general securement of the lath.

Water spray testing was performed by others using a calibrated water spray rack as specified in ASTM E1105, *Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Wall by Uniform or Cyclic Static Air Pressure,* on the subject exterior walls in an attempt to recreate the leakage that had recently occurred during rain events (*Photo 9*).

The spray rack was suspended on the exterior of the building, and water was directed onto suspect areas while observations were gathered in the building interior. The water spray testing was directed at various locations, including the punched window openings, control and expansion joints in the plaster, and reveals in the plaster. Water infiltration was observed almost immediately to within a few minutes after commencement of the water testing at the exposed fastener penetrations through the exterior sheathing at each of the tested locations.

Further investigation revealed that water infiltration occurred through the actual curtain wall systems and at sealant joints at the perimeters of the curtain wall system that migrated back to the surface of the WRB. Unsealed joints in the reveals and expansion joints were found to be sources of water infiltration that also migrated back to the WRB surface. Minor separation cracks between the plaster and the metal accessories were also believed to be allowing similar moisture migration. Regardless of

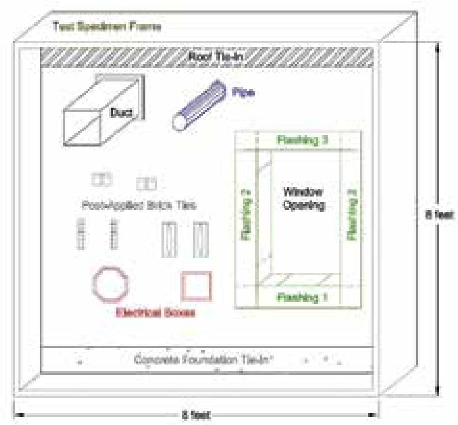


Diagram 4 – Test panel (courtesy of ABAA).

the source, the moisture manifested itself in the building interior at the many "unsealed" fastener penetrations that were not installed into metal studs (*Photo 10*).

Other obvious entry points for moisture were unrepaired small holes through the air barrier material and sheathing where fasteners were presumably originally installed and subsequently removed—apparently due to their lack of contact with an adequate substrate (*Photo 11*).

In the process of performing on-site inspections for building envelope commissioning or for general project requirements, PCI has observed many of the air barrier conditions noted in this article. One of the most common issues PCI observed has been holes in the WRB due to installation and removal of fasteners and lack of a subsequent suitable repair (*Photos 12* and *13*).

Another issue that PCI has observed that could result in potential water migration is the placement of horizontally oriented steel subgirts/framing on top of the WRB. This placement could create a "damming" effect, whereupon moisture that accumulates at the surface of the WRB migrating downward could be prevented or dammed by the steel element, allowing the moisture to be directed and concentrated at the fastener penetrations. Installing properly positioned shims between the steel element and the WRB could create an adequately sealed drainage plane.

DISCUSSION

ASTM E283, *Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*; and E2357, *Standard Test Method for Determining Air Leakage of Air Barrier Assemblies*, go beyond material testing and measure air leakage through an assembly of air barrier materials. In doing so, these tests encompass fastener penetrations—at least those that exist at the plane of the air barrier or those that are installed and can be sealed at the time the air barrier is being installed. The specimen is a realistic, 8- x 8-ft. wall mock-up, complete with typical wall penetrations, including a window, galvanized duct, PVC pipe, post-applied brick ties, and hexagonal and rectangular electrical junction boxes (*Diagram 4*).

Most of the materials that are currently identified as air barrier materials successfully pass this test published by ABAA. However, the test does not encompass fastener penetrations that are not installed into a suitable substrate (i.e., metal stud) or ones that are improperly installed.

The potential for water intrusion through fastener penetrations—particularly with claddings like siding, stucco, and adhered masonry veneer, where thousands of fasteners can be used to attach the components through the WRB—can be minimized by following these common practices:

- Confirm fasteners engage with studs/framing or a sound substrate.
- Avoid the use of supplemental fasteners, sometimes used incorrectly to attach accessories between studs like control joints and other accessories in stucco (required to be wire-tied between studs).
- Avoid errant fasteners that do not go through studs or that spin and create a larger opening and a loose connection (particularly in gypsum-based sheathing).
- Remove "loose" fasteners and seal the holes.
- Avoid the use of powder-actuated fasteners.

Another concern is that the extent of water that migrates through these unsealed fasteners/holes may not be of sufficient quantity to be readily detectable by building users/occupants. Water leakage may occur for many years without notice until the occupants encounter some other unintended consequences.

In summary, while lab tests demonstrate the ability of properly installed fasteners to seal to some extent where they penetrate liquid-applied or sheet WRBs, penetrations can become sources of water intrusion, depending on many variables: the type of fastener, the angle at which the fastener is driven, and the amount of water and pressure at the fastener penetration, regardless of material type and claims that may be made about self-sealing characteristics. Use air barriers that are fully and independently qualified as water-resistive barriers to diminish the risk of water penetration through fasteners.

REFERENCES

ASTM D1970, *Standard Specification for Self-Adhering, Polymer-Modified Bituminous Sheet Materials Used as Steep-Roofing Underlayment for Ice Dam Protection*

ASTM E2357, *Standard Test Method for Determining Air Leakage of Air Barrier Assemblies*

ASTM E1105, *Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Wall by Uniform or Cyclic Static Air Pressure*

ASTM E283, *Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*

RCI Technical Advisory RCI-TA-005-2014, *"Fasteners and Self-Sealability of Weather-Resistive Barriers"*

Karl Schaack, RRC, PE

Karl A. Schaack, RRC, PE, is president of Price Consulting, Inc., located in Houston, Texas. A graduate of Clemson University, Schaack is currently a member of RCI's Technical Advisory, RRC Exam, RWC Exam, Document Competition, and Nominating Committees. He was awarded the Richard Horowitz Award for Excellence in Writing for Interface *by RCI in 2007. Schaack is an AWCI-Certified Inspector for EIFS and has successfully completed the Tile Roof Institute's Certified Tile Installation program.*