

Eliminating the Potential for Air and Moisture Infiltration at the Window-Wall Interface

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ABSTRACT

Functional performance at the window-wall interface often has a significant effect on overall building envelope system performance. Building envelope materials, design and construction have exhibited a number of improvements in recent years. Code requirements have become more stringent and there is now general acceptance of air barriers and vapor protection. While most windows and curtain wall systems are designed and constructed to meet or exceed exterior wall performance requirements by code, building envelope repair and replacement costs in North America remains a multi-billion dollar expenditure. One study determined that over half of the building set examined experienced building envelope problems within the initial years of occupancy, and that most of the problems were moisture-related and were caused either by air leakage or exterior moisture penetration. The Construction Waterproofing Handbook published by McGraw-Hill states that “As much as 90% of all water intrusion problems occur within 1% of the total building or structure exterior surface.” These problems typically occur from improper design or construction practices and not material failure itself. Termination and transition details are of critical importance.

There are numerous issues at the window-wall interface that compromise the integrity of the building envelope which will be explored. The reasons for these problems will be discussed as well as curtain wall connection solutions. A logical solution to remedy these issues is the development of pre-engineered transition assemblies. The potential benefits are numerous: reduction or elimination of problems currently faced at the window-wall interface; the ability for the designer to specify one transition assembly flexible enough to be placed in many different locations and under different climactic conditions; and the ability to provide continuity and compatibility of performance layers between adjoining components/assemblies in a structurally sound and durable manner. A description of product and independent laboratory testing for air infiltration, water-resistance, and structural performance as well as vapor permeance and testing protocols will be reviewed. Case studies will also be included.

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Introduction

When Architects design a structure in a design-bid-build approach, their drawings generally show generic window and/or wall systems, which may or may not be the specific system selected by the contractor. This will limit the wall system's ability to show effective connections between the various wall components. Generally, architectural details show a simple sealant bead and/or a single serpentine line making a critical connection with no regard to how this connection is to span over and around shims and anchors and turn ninety degree corners to connect to the window and/or wall assembly. The construction and sequencing of these connections in most cases is left up to the general contractor or construction manager to coordinate the specific trades responsible for the air and moisture barrier[s]. It is essential to make sure these connection materials can be installed in the correct sequence, inspected properly, and possibly tested before the installation of the masonry or metal panel veneer. These connection details in many circumstances get pushed down to the subcontractor of the given trade to develop. Constructability issues, which often arise, may force them to install untested materials to allow them to complete their work.

Michael Kubal¹ reports that 90% of all water intrusion problems may occur within the 1% of the total building exterior surface area which contains the termination and transition details. Because these transitions and connections are generally not well detailed by the architect, they are often overlooked by the adjoining trades. Each trade will often show these connections in their shop drawing and note that they are to be done "BY OTHERS."

Ensuring Continuity at Transitions

Construction sequencing needs to be considered when designing these connections. Cavity wall construction using a brick veneer will typically leave a rough opening for the window or wall to be installed after the masonry is completed to avoid damage to the components. Depending upon the window or wall system selected, the metal assembly may be difficult or nearly impossible to properly seal and inspect during or after installation.

In order to maintain an effective air & vapor barrier (AVB), the barriers must be located within the wall assembly and be continuous from the roof-to-wall-to-foundation. To illustrate this principle, the case of the Sherman Hospital project in Elgin, Illinois, completed in 2007, will be discussed, where the rough opening for the wall terminations and their connections varied in size as a result of component and construction tolerances.

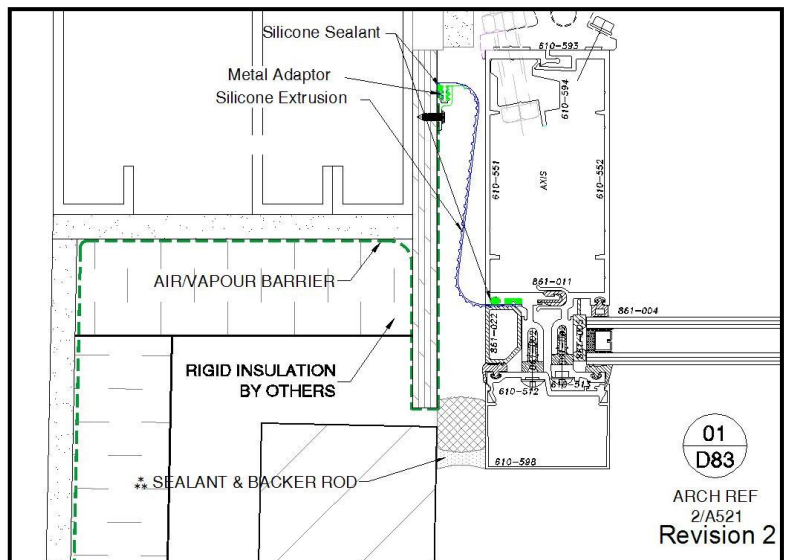
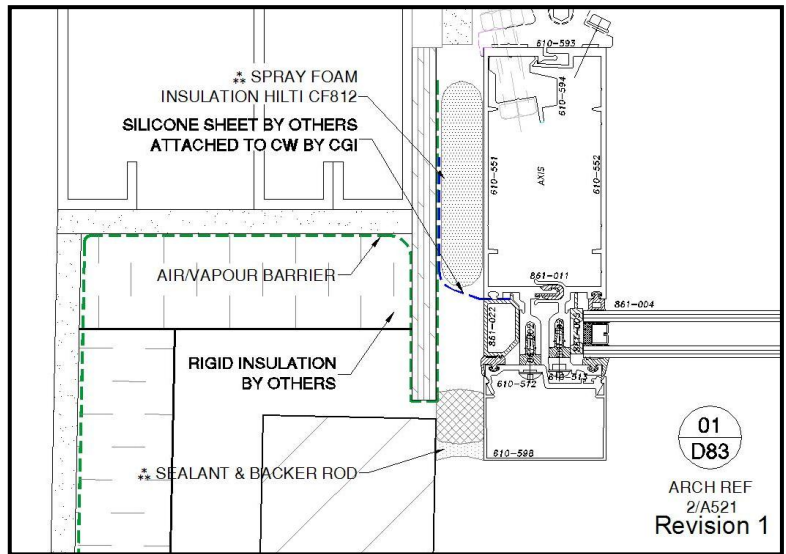
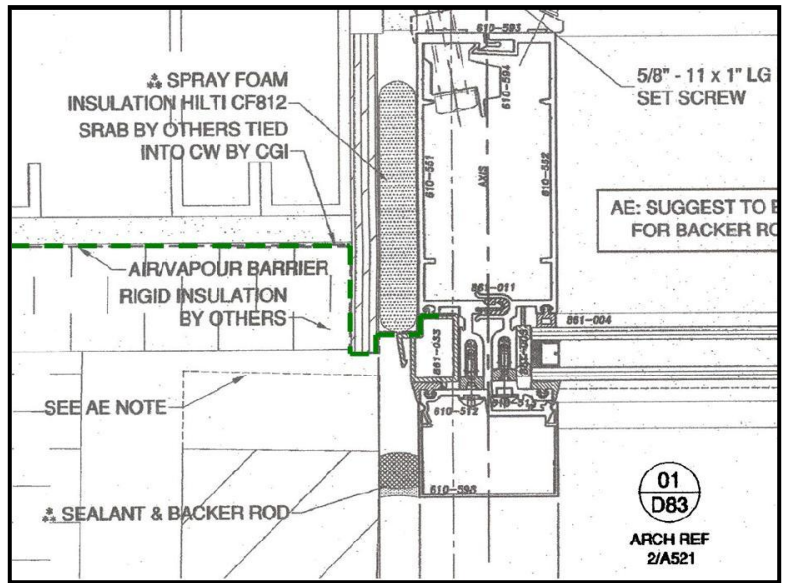


¹ Kubal, Michael T., 2000. Construction Waterproofing Handbook, Chapter 1. New York: McGraw-Hill.

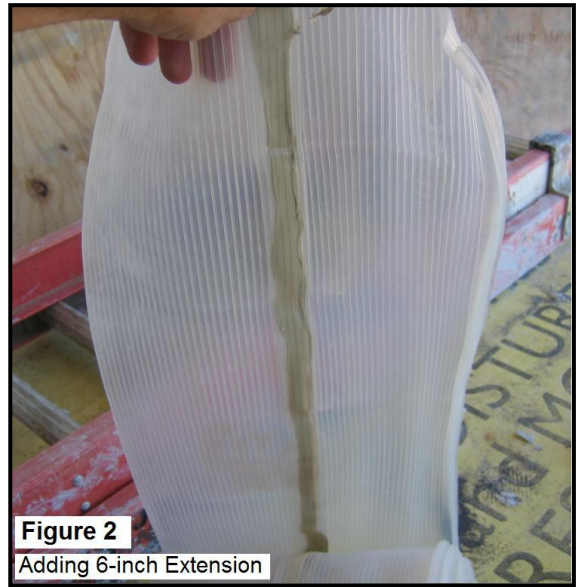
The original design called for the AVB membrane to wrap into the glazing pocket as shown in detail 01/D83. The construction sequence called for the curtain wall system to be installed after the brick veneer. This would leave a portion of the AVB membrane remaining unsupported in the rough opening, which could lead to potential damage. To install the curtain wall, the membrane would have to be cut in each corner to allow it to be folded out of the way. Sealing the cut membrane is difficult to achieve to provide an effective air and moisture barrier. AVB membranes are also not designed to span gaps unsupported, so the detail was revised as shown in Revision 1-01/D83.

A silicone membrane was selected to make the connection between the AVB membrane and the curtain wall system because of the material's flexibility and structural strength to span unsupported from the rough opening into the curtain wall glazing pocket. A silicone sealant was used to bond the silicone membrane to the AVB membrane and curtain wall system.

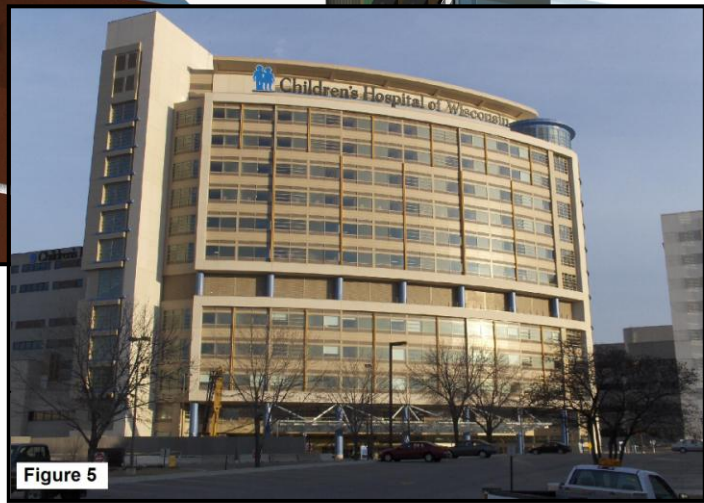
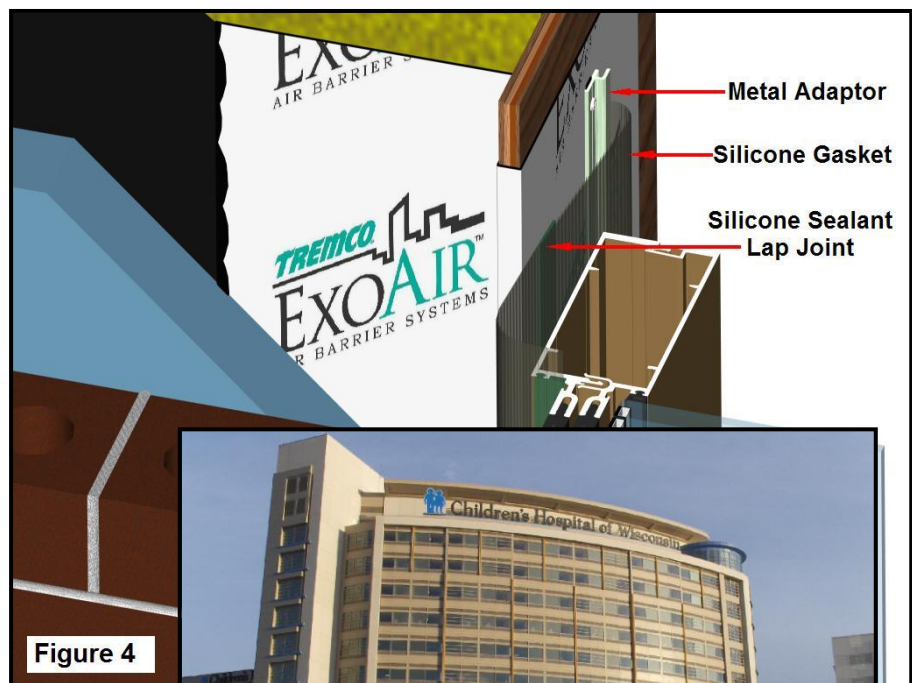
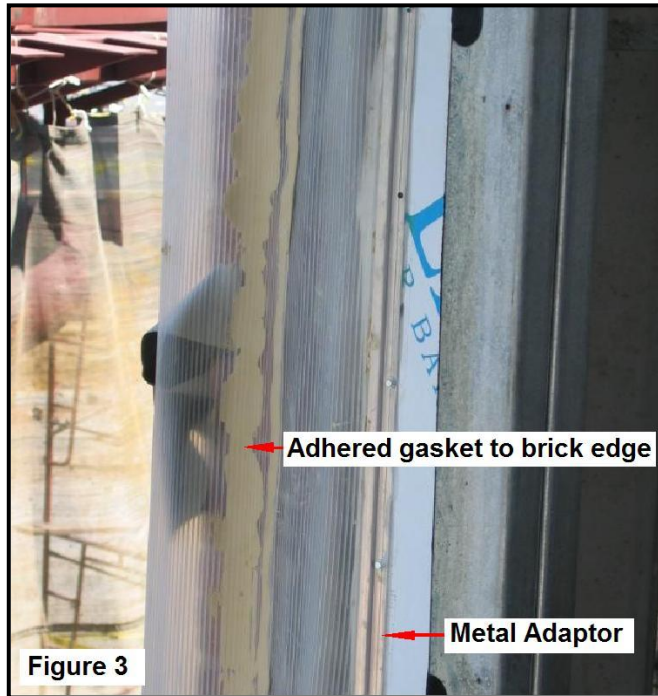
Some jamb conditions spanned over 100 ft. in height, which would have resulted in excessive weight from the silicone membrane and not allowing the sealant bead to properly hold the membrane in place while it was curing. To mitigate this, a metal adaptor was introduced to mechanically hold the silicone membrane in the metal adaptor with sealant while the sealant curing took place. This new detail is shown in Revision 2 – 01/D83.



Because of construction issues and the need to compartmentalize the curtain wall from the cavity behind the brick veneer, it was necessary to bond an additional 6 in. wide silicone membrane (as shown in Figure 2) to the existing silicone membrane. This allowed the material to span from the self-adhered AVB membrane and onto the leading brick edge (as shown in Figure 3) and then into the curtain wall's glazing pocket (as shown in Figure 4).



The adaptability of using a silicone membrane accommodated ever-changing jobsite conditions.



In another case, the general contractor for the Children's Hospital Bed Tower in Wauwatosa, Wisconsin (as shown in Figure 5) knew from previous projects that the connections and transitions for the AVBs were critical. The glazing contractor erecting the unitized curtain wall system had used an engineered transition assembly to connect windows to the AVB membrane on previous projects. They requested that the curtain wall manufacturer pre-apply the metal adaptor in its shop to save field labor and allow the connection to be completed once the unitized curtain wall was erected on-site.

The engineered transition assembly system allowed the glazier to make the field connection to the self-adhered AVB membrane (as shown in Figure 6) before installation of the composite metal panels and to connect onto the surrounding pre-cast conditions while also allowing it to accommodate the wall movement in the expansion joint under the hanging curtain wall (as shown in Figure 7). The silicone membrane easily accommodated construction tolerances and changes in plane with the wall and pre-cast panels to maintain a continuous seal with the AVB within the wall assembly.

The head and jamb shop details show how the metal adaptor was installed and sealed into the glazing pocket in the curtain wall manufacturer's factory. This allowed the installer to apply a small amount of silicone sealant into the metal adaptor race and insert the silicone dart. The dart's engagement in the metal race supported the gasket's weight and allowed the gasket to span onto the AVB membrane where it was adhered with additional silicone sealant to finish the connection. Pre-molded silicone corners allowed a continuous connection from the head, down the jambs, and along the sill by allowing simple 1 in. wide lap joints.

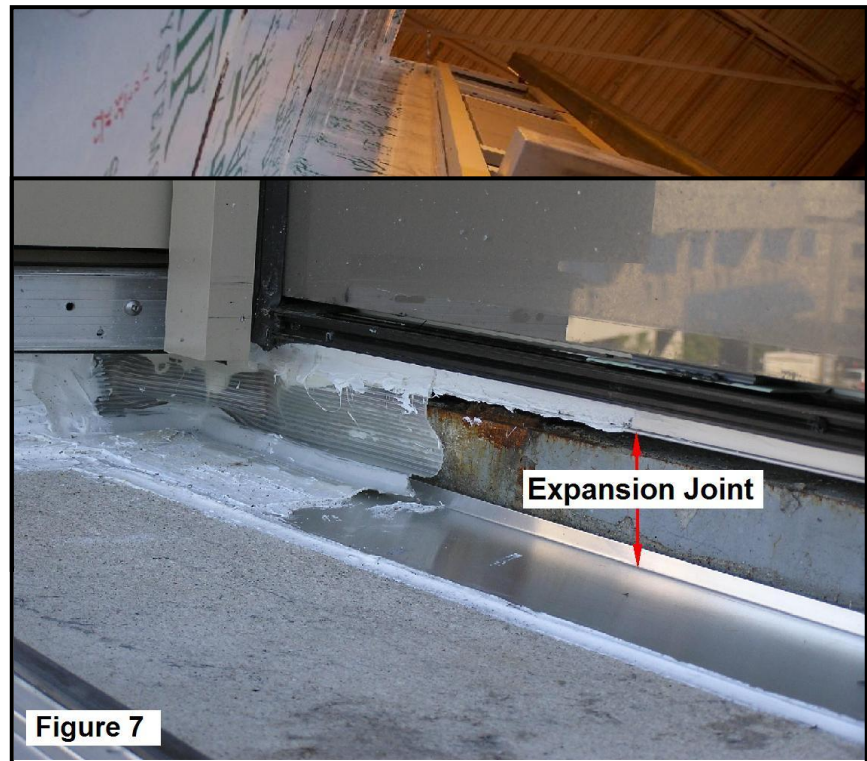
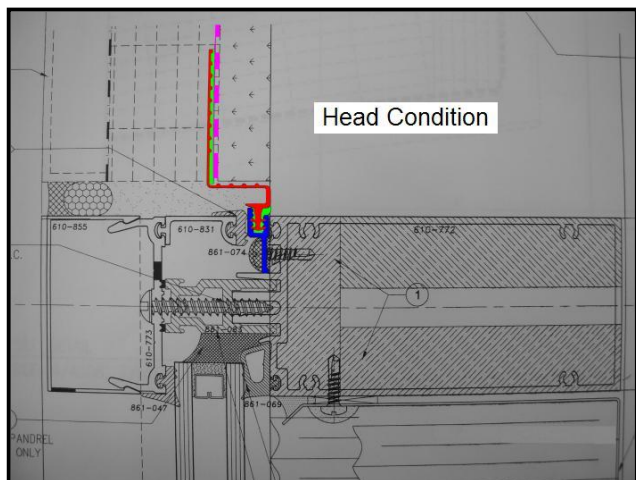
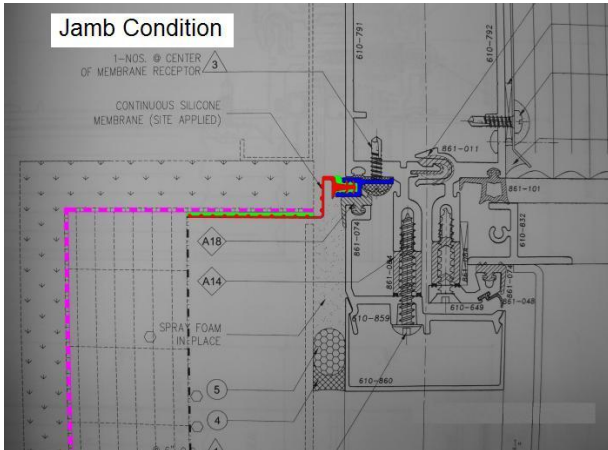


Figure 7





Designing systems with pre-engineered, tested connections allowed the contractors bidding these projects to know, up front, what their material costs would be and how the system would be installed as well as how it would perform. The value of these connections must be carefully considered due to their positive impact on the service life of the structure.

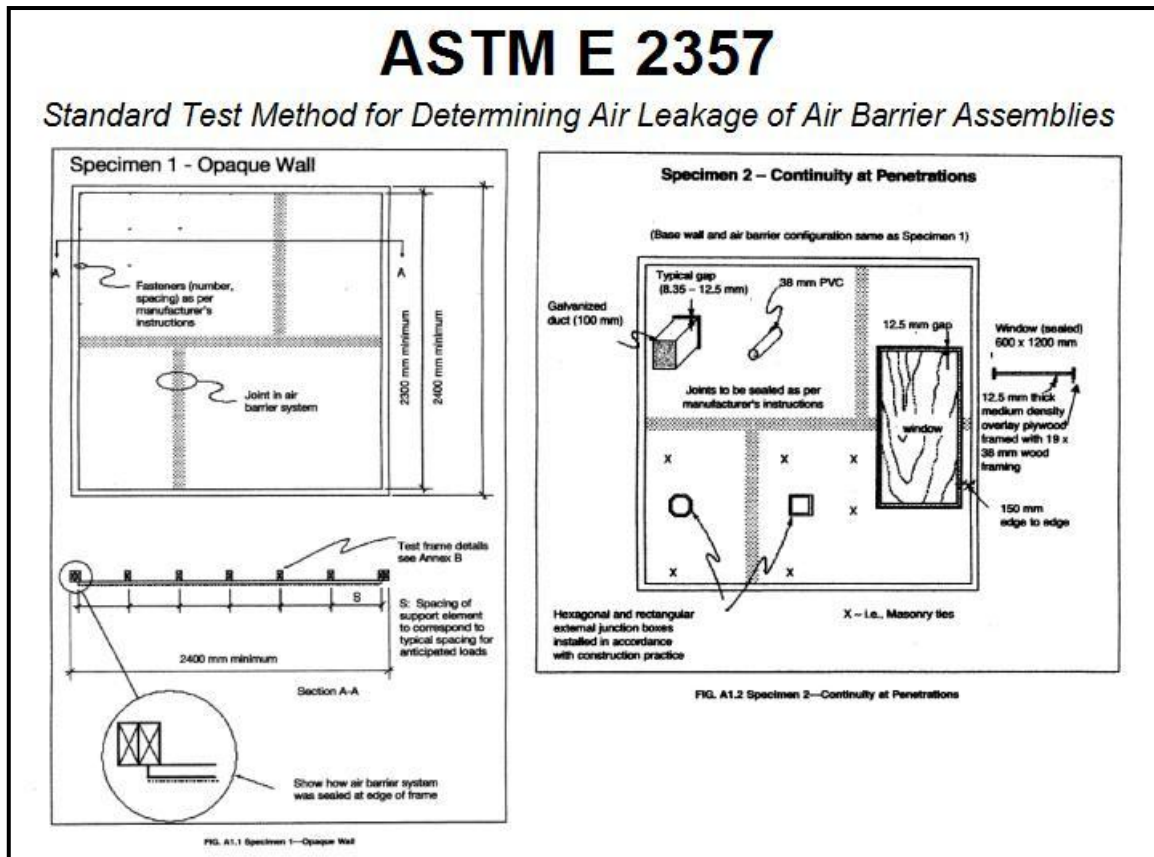
Providing an adequate, durable, consistent connection with a sealant alone may be an economical alternative but in many cases is difficult to properly install, impacting its short- and long-term reliability. Construction tolerances, applicator inconsistencies, as well as movement and deflection, particularly with varying geometries, create the potential for air and moisture infiltration resulting in condensation within the walls with potentially disastrous results.

A properly designed connection anticipates construction and component tolerances, while allowing movement of the wall components. The flexibility of the silicone membrane makes it versatile in multiple applications and the molded corners tend to reduce field installation problems, because of the simple lap joint connections.

Ensuring Performance On-Site

To ensure the performance and quality of a field application, we recommend the following tests:

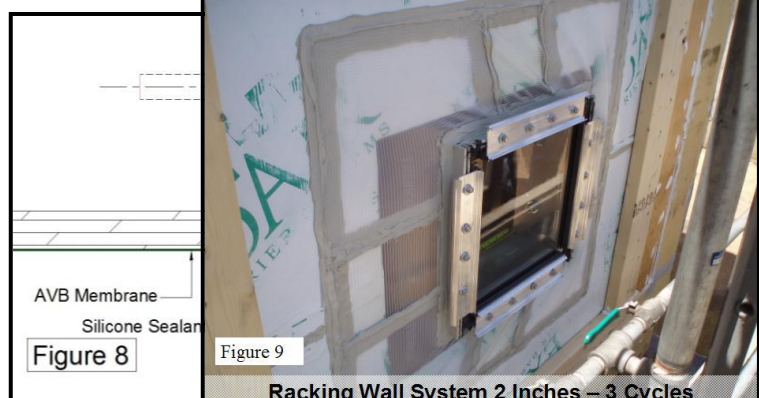
ASTM E2357– *Standard Test Method for Determining Air Leakage of Air Barrier Assemblies* is the first of several test methods to help ensure the air barrier components will work and perform as a system. This test method is accomplished by testing a minimum of two 8 ft x 8 ft wall specimens. The first unit is constructed to form a solid opaque wall with an applied air and vapor barrier with no penetrations. The second wall has a pre-defined window opening, irregular shaped electrical junction boxes, duct work and pipe penetrations, which all must be sealed to the AVB membrane. After cyclic testing these assemblies for both positive and negative air pressure, each wall assembly must not exceed 10% of specimen 1.



This test method is a good starting point to ensure the air barrier materials are compatible and will work as a system, however, the construction of this assembly is done under controlled laboratory conditions and, as a result, does not take into account real world construction practices. It also doesn't take into account real world connections from the air barrier to the window or curtain wall system since a real window is not typically utilized.

The air barrier assemblies utilizing the engineered transition assemblies discussed previously in the case studies were independently tested and surpassed ABA requirements of 0.04 cfm/ft² or less. These test results can be seen in Appendix A.

Movement capabilities of these products, however, are not addressed in ASTM E2357. Additional mockup testing as described in AAMA 501.4 –



Recommended Static Test Method for Evaluating Curtain Wall and Storefront Systems Subjected to Seismic and Wind Induced Interstory Drift should be considered. Modified versions of this test method can help in evaluating the movement capabilities of the connections both thermally and seismically. As shown in Figure 8, a 40 durometer Shore A silicone extrusion with a dart was inserted into a mullion race filled with silicone sealant. This silicone gasket will span the 3 in. gap between the window frame and the rough opening. The end of the gasket is adhered with silicone sealant onto the AVB membrane. This silicone gasket was able to absorb lateral racking movement of 2 in. (as shown in Figures 9 and 10) and withstand structural wind loads of ± 150 psf, without any physical damage (as shown in Figure 11).

Movement capability is specified in the International Energy Conservation Code (IECC) 2009; Chapter 5 Commercial Energy Efficiencies: Sealing of the Building Envelope. “Openings and penetrations in the building envelope shall be sealed with caulking materials or closed with gasketing systems compatible with the construction materials and locations. Joints and seams shall be sealed in the same manner or taped or covered with a moisture vapor-permeable wrapping material. Sealing materials spanning joints between construction materials shall allow for expansion and contraction of construction materials.”

Silicone sealants are an accepted industry standard for sealing in and around windows and wall systems, particularly in commercial applications where aluminum curtain walls are specified. Many silicone sealants, however, do not adhere to the surface of the AVB membranes commonly used in the self-adhered flashing products to wrap the facade’s rough opening. Several tests are utilized to confirm adhesion and compatibility with AVB membranes.

To confirm adhesion, sealant manufacturers will perform adhesion tests to these substrates. One standard test method is **ASTM C794** – *Standard Test Method for Adhesion-in-Peel of Elastomeric Joint Sealant*. This laboratory test method measures the bond strength in pounds per lineal inch (pli) values at a 180 degree pull and describes the type of failure (adhesive or cohesive) to the given substrate. This tests helps determine whether primers are required.

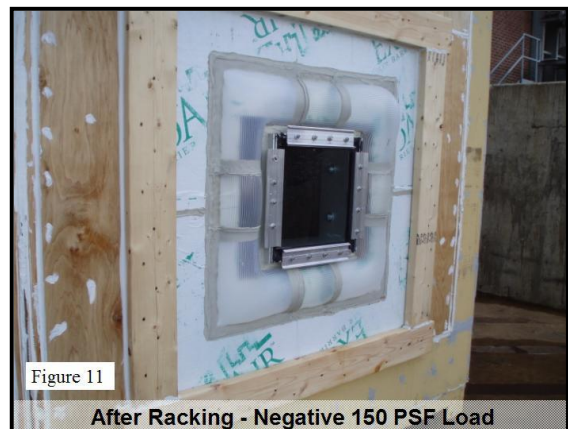




Figure 12 – 1 in. screen mesh embedded in sealant on metal coupon.
 Figure 13 – Test specimen mounted in Instron for 180° pull.



Compatibility must be confirmed with all the wall components in contact with the sealant. Sealant manufacturers may use **ASTM C1087 – Standard Test Method for Determining Compatibility of Liquid-Applied Sealants with Accessories Used in Structural Glazing Systems**. This laboratory screening process, which is often used for non-structural glazing applications, looks for any change in the sealant’s color, as well as change in adhesion of the sealant to the glass and/or accessory material. There are applications where the AVB membrane may extend into an exterior perimeter sealant thus causing an aesthetically unacceptable discoloration. Silicone sealants will discolor from the migration of asphaltic components from the self-adhered flashing into the sealant. Whether this migration will cause a loss of adhesion to the substrates will be evaluated by this testing. The photo shown is an example of a rubber gasket in contact with a silicone sealant and the rubber plasticizers/oils migrating into the sealant (see Figure 14).

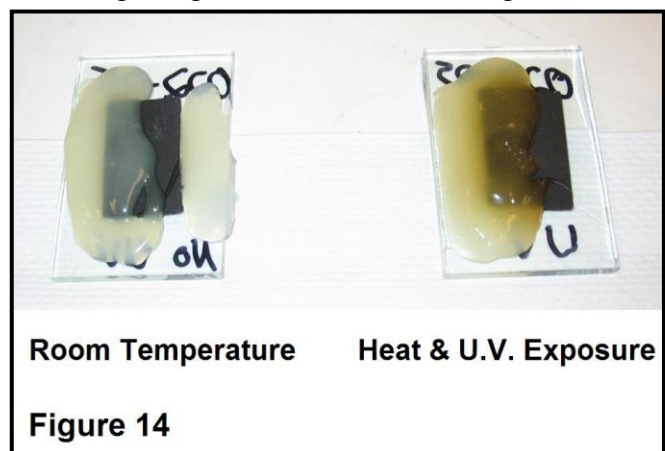


Figure 14 – Sealant in contact with rubber extrusions.

AAMA has recently published a new document titled: **713-08 – Voluntary Test Method to Determine Chemical Compatibility of Sealants and Self-Adhered Flexible Flashings**. This test method was developed to verify compatibility of self-adhered flashings with adjoining sealants. The AAMA task group documented that certain sealants have the potential to cause the self-adhered flashing’s adhesive or sealant to soften, slump and/or even liquefy, resulting in reduced effectiveness of the membrane (as shown in Figure 15). The task group reported cases of

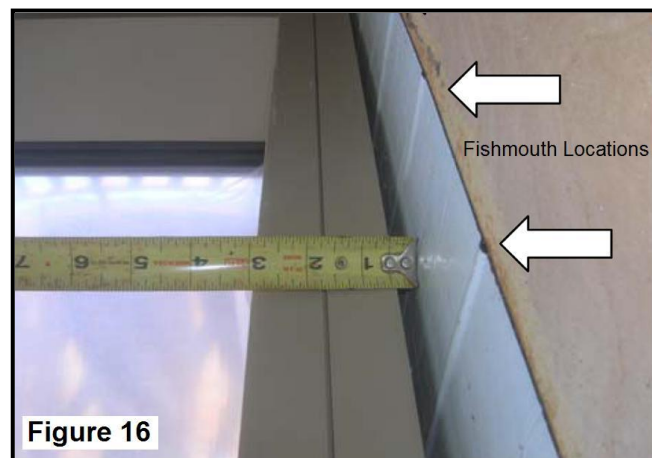
aesthetic degradation associated with the asphaltic material bleeding through porous substrates such as stucco and EIFS. The product manufacturer should perform tests to verify that the components used in their AVB system perform adequately using this test method. Contractors substituting or unknowingly using an untested sealant could compromise the integrity of the system.

In its position paper, *A SINGLE SOURCE IS BEST*, the Air Barrier Association of America (ABAA), states that a unified single source of the main exterior wall air barrier assembly best serves the owner's interests. An ABAA licensed air barrier contractor who is knowledgeable and takes ownership of the air barrier produces the Owner's and Architect's best assurance of quality."²



Self-adhered membranes can provide an effective air and moisture barrier when fully supported. They were not generally designed, however, to bridge joints in excess of 1/2 in. and/or accommodate potential thermal and/or seismic movements within the wall facade. Self-adhered membranes may not meet this requirement in many applications.

Self-adhered membranes generally have an aggressive bond once properly positioned. The process of cutting, notching and folding the flexible membrane around rough openings and penetrations can be difficult and often results in wrinkles and/or "fishmouth" gaps in the membrane, which are difficult to remove or seal (as shown in Figure 16). These conditions can result in air and water infiltration. This is why many manufacturers state in their literature that these conditions or defects must be repaired by replacement, which is often overlooked by the installer.



² Air Barrier Association of America

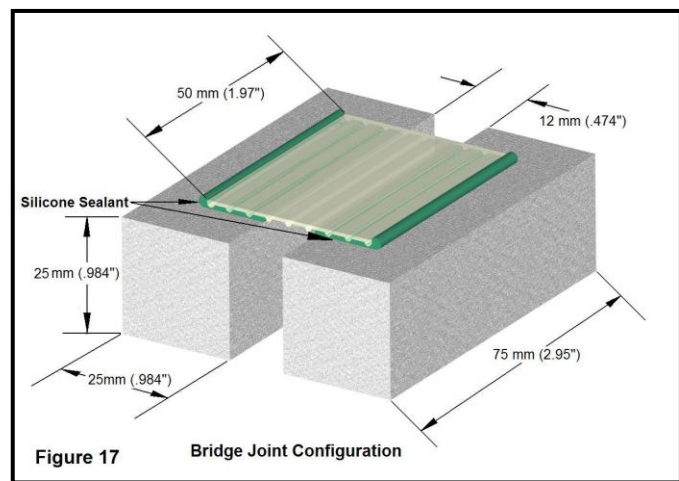
Silicone sealants commonly used in curtain walls and window systems and silicone rubber extrusions are becoming the materials of choice to span gaps within the building facade too large to be filled with silicone sealant. Silicone sealants do an excellent job of bonding to various substrates and are formulated in multiple chemistries to achieve different performance characteristics. For example, high modulus silicones are designed to transfer structural loads from the glass to the metal framing members while providing an air and water barrier. Low

modulus silicones are designed to perform in high joint movement applications without rupturing, while maintaining an air and water seal.

These silicone sealants require a minimum surface contact width to perform properly. Window frames with short metal return legs or open ends of the metal extrusions often do not have bonding surfaces of sufficient width to allow for proper sealant backing to be installed, a condition which may be overlooked by the designer. Joints larger than 1 in. may not allow the installer to achieve the proper 2:1 width-to-depth joint design. By specifying a system incorporating a silicone membrane to bridge these gaps, the installer has the ability to increase the sealant's bonding surface. A translucent silicone membrane helps ensure that the installer is properly applying a continuous bead of sealant at the contact and lap joint conditions. This is not possible with normal opaque pigmented extrusions. Ribs added on the membrane surface also prevent the installer from squeezing the sealant down to a thin film, thus allowing the sealant to retain some volume to stretch as a sealant as well as an adhesive.

ASTM C1518 – *Standard Specification for Precured Elastomeric Silicone Joint Sealants* is used to evaluate these bridge joints, beveled bridge joints or U-joint configurations, and classifies the seal assembly for movement and tear in accordance with **ASTM C1523** – *Standard Test Method for Determining Modulus, Tear and Adhesion Properties of Precured Elastomeric Joint Sealants*.

Our testing used a bridge joint configuration as shown in Figure 17 with the orientation of the extruded ribs running parallel with the joint. This will mimic how the product is used in the field. Once the specimens were constructed they were tested per a modified ASTM C1523 Standard Test Method for Determining Modulus, Tear and Adhesion Properties of Precured Elastomeric Joint Sealants.

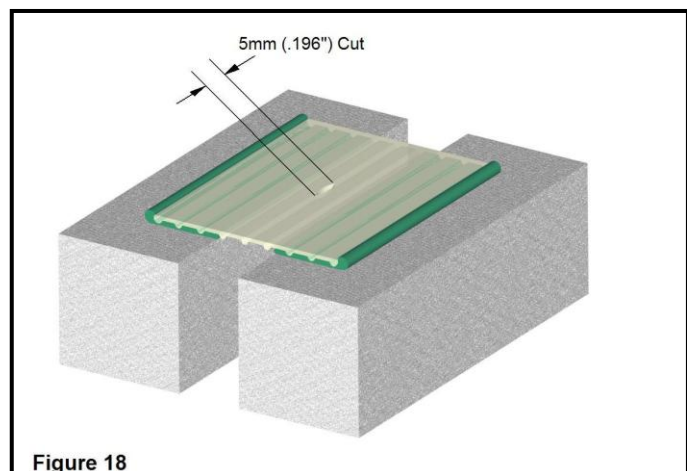


ASTM C1523 test method requires the specimens to be conditioned before testing. The specimens are applied and allowed to cure 21 days at room temperature. These specimens are then tested at each of the following conditions:

1. Dry/Room at 23°C (73.4°F)
2. Water Immersion at 23°C (73.4°F) for 24 hrs
3. Frozen at -18°C (0°F) for 24 hrs
4. Heat at 70°C (158°F) for 24 hrs
5. Artificial Weathering G 151, G 154 or G 155 for 2500 hrs

The test results for **ASTM C1523** include:

- Tensile load over length of joint at 200% elongation after 1 hr
- Loss of tensile load after 1 hr hold time
- Loss of adhesion at 200% elongation



- Loss of cohesion at 200% elongation
- Ultimate elongation at peak load
- Peak tensile load over length of joint
- Description of kind of tear if any after 1 hr hold at 200% elongation
(See Figure 19)

The ASTM C1518 specification requires the specimens to be conditioned at the following conditions and then tested:

1. Frozen at -18°C (0°F) for 24 hrs
2. Heat at 70°C (158°F) for 24 hrs
3. Artificial Weathering G 151, G 154 or G 155 for 2500 hrs

To determine the tear class, the specimens are cut mid-span after cycling (as shown in Figure 18). The type of tear propagation is recorded. As shown in Figure 21, the tear propagated perpendicular to the cut.

Testing was conducted on the single- and double-ribbed extrusions, which all passed the 200% elongation and ten cycles after the one hour hold at 200% extension with no adhesive or cohesive bond loss and very little relaxation within the silicone extrusion. This testing was done at dry/room condition with no other prescribed conditioning. These additional conditioning requirements should have little to no effect on the silicone materials. The silicone sealant and silicone extrusion compound are tested and must pass more stringent temperature requirements than those indicated in ASTM C1518 including low temperature brittleness of -40°C (-40°F) and heat aged temperatures of 150°C (302°F).

This test method and specification are applicable for testing bridge joints. However, the classification as to how the membrane propagates a tear is less important. If the membrane is punctured, air and water have an access point. We evaluated how to repair a puncture or cut to meet the same test criteria. Using the test method prescribed by C1518, we cycled the membrane and placed the specified 5 mm (0.196") cut mid-span (as shown in Figure 20). Applying silicone sealant alone was not sufficient to prevent the tear from propagating at 200% elongation. However,

by applying a small bead of silicone sealant covered with a small 5 mm x 5 mm patch of the same membrane, much like a tire patch, the assembly passed the test (as shown in Figure 22). We allowed the assembly to cure for 7 days and

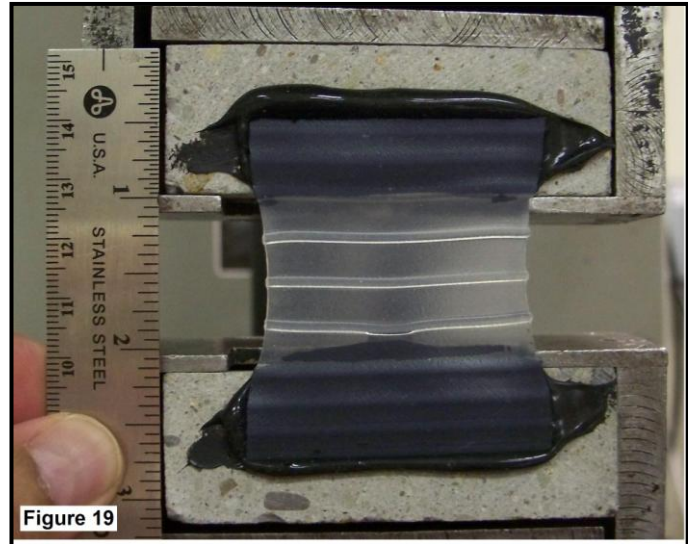


Figure 19 – Test specimen mounted in tensile tester.

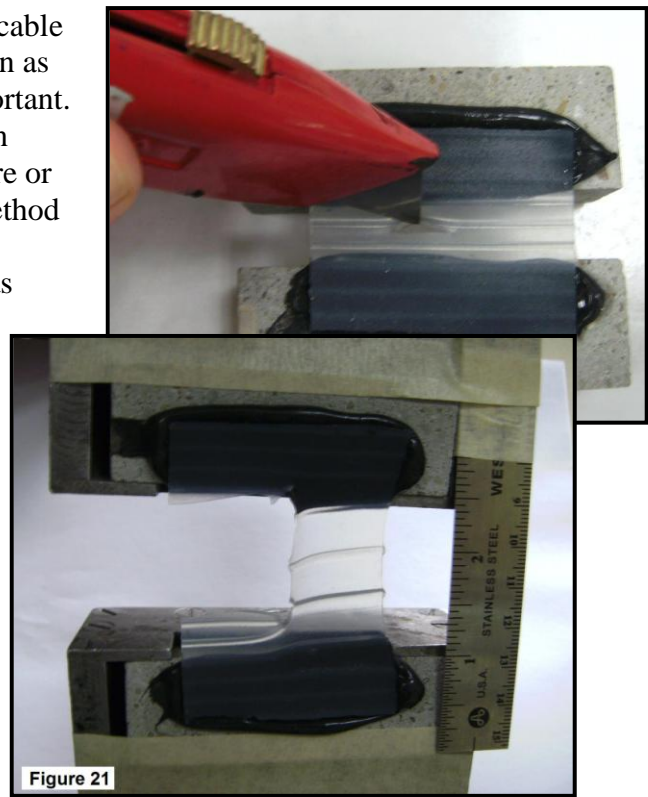
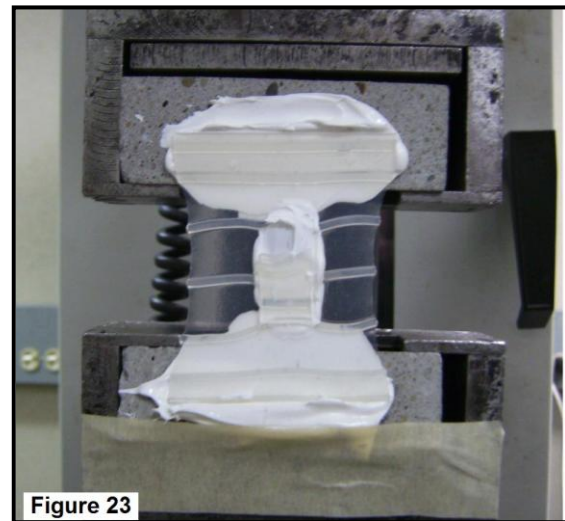
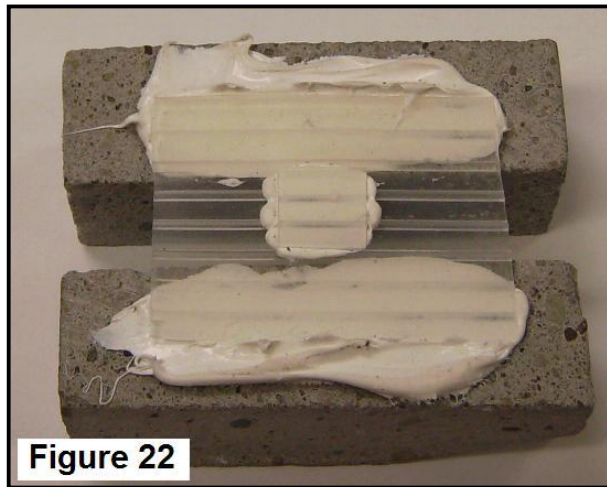


Figure 21

then extended the membrane 200% for one hour, cycled the assembly ten times at 200% and observed no adhesive or cohesive loss (as shown in Figure 23).



Pushing the Envelope

As we move towards greater sustainability of our structures and higher performance standards to ensure greater energy efficiency, the key to successful building envelope performance will be the utilization of integrated design. A whole building design approach optimizes the interactions among building systems and components where they connect, overlap, or abut. Coupling improvements in component connections with innovations in building envelope design, we have the opportunity to dramatically transform today's buildings and enable them to use considerably less energy by managing air and moisture infiltration more effectively.

While the industry has made inroads in proper flashing techniques to stop water leakage, these methods have not always restricted air infiltration, a necessary task to achieve energy savings. Standard sealants and sheet-applied products alone can allow numerous infiltration points. Engineered transition assemblies are designed with proper bonding surfaces and have been tested to help demonstrate the ability to withstand thermal movement, wind loads, and seismic conditions. Visual inspection is facilitated by utilizing a translucent silicone membrane to verify a continuous silicone sealant contact along the length of the connection.

Failure of the joint connections of building envelope components to perform as intended is too costly. Utilizing these proven technologies for improving the performance of the window-to-wall interface and adapting them to the requirements of ever-changing designs provides a proven, tested solution. While the engineered interface solution may not be appropriate for all installations, it gives the designer a proven, technically sound alternative to help achieve high performance building envelopes.

