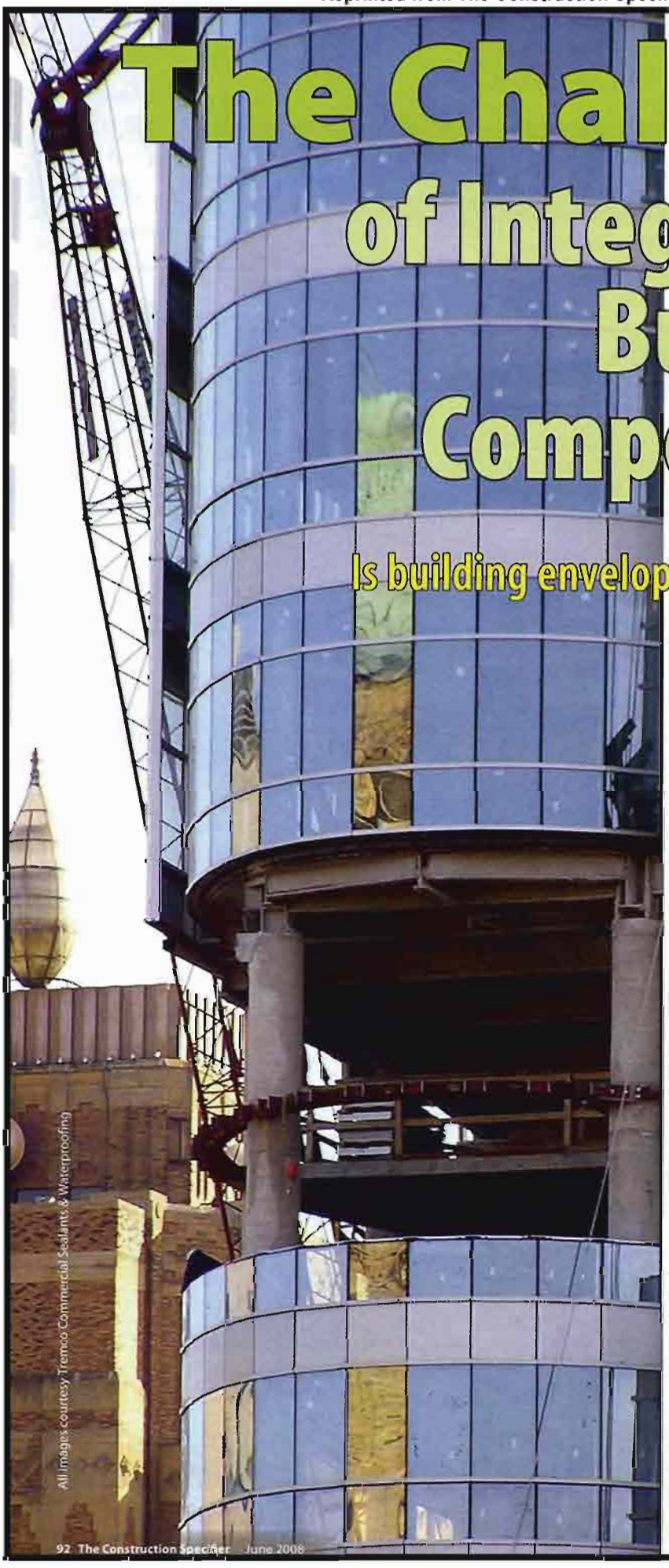
Reprinted from The Construction Specifier - June 2008

The Challenge of Integrating Building Components

Is building envelope integrity at risk?



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by Edward J. Retzbach, CSI, CDT

An increasing focus on fast-track construction means projects are built under accelerated schedules in a range of weather conditions. Under these circumstances, the potential for installing materials to specified tolerances may decrease, while the possibility for errors rises.

As product technology improves and the methods for construction delivery evolve, a greater number of building components must be installed or applied by a variety of specialty contractors. The industry has become more fragmented, while building requirements have become more complex. In many areas, codes demand increased protection against air and moisture infiltration, as well as natural and manmade disasters. Sustainability, too, is a more demanding issue.

Understanding the technologies that help achieve these goals has placed new demands not only on those specifying and installing them, but also on other trades who may be impacted. When it comes to these materials, there are also considerations regarding the abutting or

adjoining components—who becomes responsible for the transitions from one to the other? With myriad components and technologies coming together, how can they be appropriately integrated to provide thermal and moisture protection?

Ensuring connectivity between the substrate and the air barrier, window, or curtain wall may be assigned to a variety of parties—a move that can leave some question as to who becomes accountable for the total building envelope's energy-efficient performance and ultimate integrity.

Despite new material technologies and more stringent codes, a cursory review of industry publications brings forth leaky buildings and their ramifications—premature failures caused by corrosion, mold growth rendering buildings unusable, multi-million dollar repairs, and lost revenue opportunities.

These problems are caused by:

- human error during installation;
- poor attention to details;
- improper system choice for the application;
- inadequate surface preparation;
- poor terminations;
- material incompatibilities;
- improper sequence of installation; and
- inadequate or incomplete details leaving things up to interpretation.

A failure in one area can affect other components in the building. The majority, however, do not appear to come from the materials or systems themselves.[1] While it is impossible to address all these issues in this article, it is worth taking a more in-depth look at a few.

Selecting the right product for the right job

Controlling air and moisture flow into a building is a basic design requirement. However, what works initially may not be appropriate over the building's lifecycle if system performance between all the contiguous assemblies has not been verified. In other words, there may be short-term adhesion, but the question remains whether the systems have been tested for compatibility to ensure enduring performance.

A structural glazing system's lasting adhesion, weatherability, and durability, along with its aesthetic implications, depend on all products being harmonious throughout their projected life span. Compatibility should never be assumed beyond any façade weatherproofing solution. It must always be established by a formal program of testing by the sealant manufacturer as there are no 'always-compatible' formulas.

Quality Care for Wisconsin Children's Hospital

The Children's Hospital of Wisconsin (Milwaukee) was recently expanded with the addition of a 12-story, 39,484-m² (425,000-sf) tower for patient rooms, a larger pediatric intensive care unit (ICU), and an expanded Herma Heart Center. A main concern for the $165-million project was the design and installation of an exterior façade that would not allow moisture or condensation to form within the building.

Any breakdown in the assemblage could allow warm air to enter and condense in the wall cavity, leading to deterioration of envelope components, increased energy consumption, and a negative impact on the indoor air quality (IAQ). If the problem proved systemic, the result could be catastrophic. The owner wanted the potential for rework to be taken out of the picture and a guarantee this building would last 50 to 100 years under even the most extreme conditions.

Project architects Shepley Bulfinch Richardson & Abbott worked with Oscar J. Boldt Construction (and its Enclosure Quality Management [EQM] Program) to provide the owner with a top-of-the-line system for commissioning the building envelope. The tower design incorporated a curtain wall with six-story spans along with projections and recessions in the wall and a continuous vapor barrier.

Areas where dissimilar components meet (*i.e.* curtain wall and various adjacent wall assemblies) normally involve multiple installers. Maintaining control at these intersections to avoid moisture infiltration and potential for mold growth was paramount. Consequently, a single-sourced engineered transition assembly was used to eliminate the possibility of applicator variations.

Installed in the curtain wall manufacturer's shop, the system's extruded aluminum adapter has butyl tape pre-applied on the backside, so the protective release paper is simply removed and adhered to the mullions before mechanical fasteners are installed. In the field, a silicone sealant was applied into the adapter's pre-engineered race, adhering the adapter to the window frame, while adhering the silicone extrusion to the adapter, ensuring a strong bond. Once the lock-in dart of the silicone rubber extrusion was inserted and pressed into the race, the silicone extrusion's web was placed over an adjacent bead of sealant on the mullion; a seam roller was then used to ensure a tight, continuous seal.

At the lap joint between the silicone rubber extrusion and the silicone rubber corners, a sealant connection of

The Children's Hospital of Wisconsin (Milwaukee) was recently expanded with the addition of a 12-story tower. A main concern was the design and installation of an effective exterior façade; engineered transitions helped ensure compatibility.

25.4 mm (1 in.) provided a secure bond and long-term seal. Again, a seam roller was used to ensure firm, continuous contact throughout the length of the seal. The ribs on the silicone extrusion created the space to allow for the correct amount of sealant to maintain the bond between the silicone rubber extrusion and adjacent materials. (The extrusion's translucent nature enabled visual inspection to confirm sufficient sealant was installed where needed.)

A self-adhered air and vapor barrier membrane was used on the adjacent metal panel backup wall, with a silicone rubber extrusion serving as the primary air

and vapor seal between it and the curtain wall. (Long-term performance and compatibility was determined through testing at Architectural Testing Incorporated [ATI].)

The engineered transition assembly also allowed greater control and efficiency during the construction process with enclosure being achieved more quickly. The first five floors of the structure could be erected, sealed off, and waterproofed, allowing interior build-outs to begin sooner. As one supplier provided all the components for transitions, installation of the connections and quality control was simplified.

To ensure the performance and the quality of the field installation for the Children's Hospital, a full-scale mockup of the curtain wall and adjacent exterior wall systems was constructed. A total of 17 different tests were performed at ATI's laboratory in York, Pennsylvania, to measure air infiltration and determine how well the transition assembly would be able to withstand water penetration, thermal changes, and load deflection.

To ensure the lessons learned from the mockup were followed during the actual construction onsite, over 40 independent field tests were performed, all with excellent success. These site tests included:

- ASTM International E 1105-00, *Standard Test Method for Field Determination of Water Penetration of Installed Exterior windows, Skylights, Doors, and Curtain Walls by Uniform or Cyclic Static Air Pressure Difference*;
- American Architectural Manufacturers Association (AAMA) 501.2-03, *Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Sloped Glazing Systems;* and
- AAMA 503-03, *Voluntary Specification for Field Testing of Storefronts, Curtain Walls, and Sloped Glazing Systems.*

Some problems quickly become obvious—paint, coatings, or membranes applied to poorly prepared surfaces show failures almost immediately. However, others can take time to show themselves. Staining, for example, may eventually appear in natural stone substrates at the substrate/sealant interface. A result of plasticizer migration from the silicone sealant into the stone, it typically occurs if materials have not been tested to ASTM International C 1248, *Staining of Porous Substances by Joint Sealants.*

Silicone sealant used at all sill locations, jambs, and head of slider doors must be compatible with urethane deck coatings on balconies and patios to ensure a continuous weatherproof seal.

A sealant should be tested for suitability with other products it meets. Given time and exposure to ultraviolet (UV) light, materials can release plasticizers into a sealant, causing color change or adhesion loss. For example, plasticizers migrating from neoprene and ethylene propylene diene monomer (EPDM) rubber extrusions may significantly deteriorate silicone sealant's strength or adhesion, compromising its ability to limit air and water infiltration. Silicone rubber and silicone-compatible rubber formulations need to be used for full-contact applications.

Building materials abutting sealant may have surface residue or contaminants from manufacturing that can migrate into the product. In these cases, special cleaning techniques, primer, or surface conditioner may be needed to achieve adequate adhesion. A change of sealant color is evidence of a potentially detrimental chemical reaction. While adhesion may not be lost initially, an altered hue could be a predictor of future problems or reduced tensile strength. Other sealant characteristics potentially affected by incompatibility include the ability to cure fully, ultimate strength development, and aesthetic quality.

Manufacturers generally have extensive histories of compatibility testing and can usually indicate if their sealant is compatible with a particular material. However, a sealant or joint accessory is often substituted at the last minute as an 'or equal.' While these products may be equal in ability to meet performance requirements, they may not be equal when it comes to compatibility—consequently, such materials should be tested if sufficient evidence of testing cannot be provided.

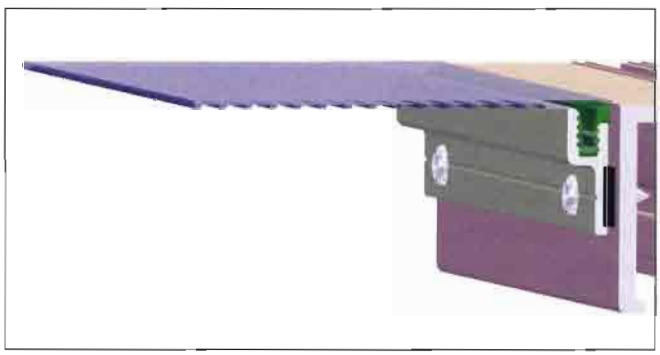
In some cases, a manufacturer may provide complete systems rather than components. These products have been developed and tested to ensure compatibility when used together. That said, the industry typically tends to mix and match components from different manufacturers. While

An acetone spray adhesive approved for use to mount window systems into a rough opening with an air barrier system resulted in a softening and deterioration of the air barrier membrane. Once discovered, the air barrier supplier's technical sales representative worked with the window installer on appropriate detailing and provided a sealant tested by the manufacturer to ensure a compatible, single-source system solution.

these individual products may perform extremely well in certain applications, they are not universally appropriate for all needs.

Ensuring continuity at transitions within an air barrier

To be effective, both air barriers and vapor retarders must be continuous from below the grade to the roofline. Providing continuity at transitions is critical—vapor retarders should not even be considered unless long-term adhesion at the tie-in to the window system can be ensured. Discontinuity means the potential for not only uncontrolled airflow leading to energy inefficiencies, but also deterioration of envelope components, rusting and degradation of structural supports, and damage to exterior finishes.



The ribs on the silicone extrusion component of this engineered transition assembly prevents the silicone sealant from being squeezed to a thin film while the translucency of the material allows for easy inspection through the gasket to confirm sufficient sealant has been applied.

To be continuous, an air barrier must maintain—for the enclosure's intended service life—its desired permeability and airtightness while withstanding air pressure differences on both sides of the wall without displacement or rupturing of other building enclosure systems. Keeping this continuity through movement joints is particularly difficult, especially since many contemporary designs incorporate varying geometries requiring greater movement in different directions and magnitudes.

Locations where transitions occur (*e.g.* at the interface of dissimilar materials of a curtain wall and various adjacent wall assemblies) are also areas of dynamic movement and places where multiple installers generally become involved. Maintaining control at these intersections by coordinating concurrent work of various subcontractors to avoid moisture infiltration is critical.

There are several crucial locations on a building envelope, including corners, wall projections/recesses, and transitions requiring flexibility or between dissimilar components. A survey by Glass Association of North America (GANA) Building Envelope Contractors Division members found half the issues identified as 'leading to window leaks' were attributed to improper details and installation practices.[2] Making connections to an air barrier system around anchors and support shims is extremely difficult to achieve, but essential to maintaining envelope continuity.

Historically, the project architect was responsible for all the details through to completion. This included performance requirements in specifications, shop drawing review/approvals, and details for the structure. Today, the architect may only provide concept drawings on many parts of the project, which are then turned over to a construction manager who, in turn, places responsibility on subcontractors, suppliers, and installers. On many projects, building envelope consultants and/or commissioning agents are responsible for quality assurance. Consequently, many of these critical transitions are open to interpretation.

Unfortunately, traditional sealants and flashings cannot always accommodate the larger gaps resulting from progressive designs incorporating multi-directional planes, multiple projections and recesses, large curtain wall expanses, and varied materials. These materials are also incapable of providing a durable connection able to withstand dynamic movement. Further, sealants mean the possibility of variances in consistency depend on the number of applicators performing the work. If warm air enters through a caulk bead failure and condenses in the wall cavity, the results can be catastrophic.

Further Resources

In addition to discussions with peers in multidisciplinary groups like the Construction Specifications Institute (CSI), more information on building envelope integration and quality assurance can be found on the Web site of the National Institute of Building Science (NIBS) and its Whole Building Design Guide (www.nibs.org or www.wbdg.org, respectively) or through the Building Enclosure Technology and Environment Council (BETEC) at www.nibs.org/betec.html. Two crucial reads are:

- John Straube and Eric Burnett's *Building Science for Building Enclosures* (Building Science Press, 2005); and
- Michael Kubal's *Waterproofing the Building Envelope* (McGraw Hill Professional, 2001).

Since nothing is actually specified or detailed generally by the project architect, the cost of this work is often not even captured in the bid with these existing technologies. For a transition from a window or curtain wall to a wall assembly, both the installers for the air barrier and windows often state 'others' will provide this. If problems occur, where does the responsibility lie?

The use of engineered transition assemblies can help eliminate this guesswork. Mechanically attached to the window or wall assembly to ensure a durable, compatible connection and seal, these systems comprise:

- an extruded aluminum adaptor with pre-engineered race (*i.e.* the opening where the lock-in silicone dart is inserted);
- a butyl tape to temporarily hold the metal adapter in position before mechanical fasteners are installed and serve as a secondary air and water seal;[3]
- pre-molded translucent silicone rubber corners and sheets in varying widths with lock-in rubber darts; and
- a compatible, high-movement, low-modulus silicone sealant for an adhesive and wet seal.

Waterproof tie-ins

When different chemistries 'connect,' the installation sequence has significant impact on the final performance. It is common knowledge adhesion becomes an issue where a urethane deck coating ties into a silicone-based glazing system. However, when one looks at luxury high-rise condominiums across the country constructed with vast amounts of glass, it is clear this interface occurs quite often. Mixing and matching components from different suppliers and not coordinating the sequencing of product application may be asking for trouble.

Tips and Tactics

Finding an easy, universal solution to the problem of integrating building envelope components is difficult. Each project is different and every member of the design/construction team could have a different view on the best way to get things done.

As someone involved with an air and moisture management systems manufacturer, this author can really only recommend some steps to help specifiers and owners maintain more control when ensuring the integrity of their building design.

Building envelope integrity must be a design consideration in the earliest stages of the project. The owner, design, and construction teams should collaborate to share their experiences and be motivated to provide the quality desired.

Involve air and moisture management suppliers at the design development stage.
They should be included in shop drawing reviews, the evaluation of the application itself, generation of project specifications, and evaluation of connection points and compatibilities. This helps ensure the appropriate solution (and application sequence) is specified and eliminates any gaps that may be left to guesswork down the line.

Coordinate the construction schedule with the contractors and design–build firms.
The multidisciplinary nature of building construction requires various fields interact and understand their impact on each other and the end product. Construction managers (CMs), general contractors (GCs), and installers need to have a broader understanding of building science. Where possible, assigning responsibility for components to a single source can ensure greater installation efficiency and accountability.

Select suppliers providing onsite services (e.g. testing protocols) or work with independent consultants or the CM/GC to ensure the performance and quality of the field installation.
Mockups and laboratory testing determine how well the assembly will withstand water penetration, thermal changes, and load deflection, but real-world conditions can be quite different.

By working with a single source, there can be increased accountability as systems have been formulated and tested for compatibility. It can be even more advantageous to work with a manufacturer that also provides:

- appropriate lab testing to ensure long-term compatibility;
- verified field adhesion; and
- onsite personnel offering input regarding detailing and sequence of installation.

Ensuring performance in the real world

A manufacturer's material testing generally deals with a component, as few companies provide comprehensive systems or numerous assemblies throughout the building envelope. Viewing a product's performance independent of the building envelope, however, creates a tremendous challenge. Assignment of responsibility for performance once products are integrated becomes a problem—when issues arise, finger pointing begins. For this reason, demand is increasing for manufacturers to provide systems and single-source accountability.

Prior to construction, samples of all materials that contact or affect (by direct, indirect, or mechanical means) exterior wall joint sealants must be tested for compatibility and adhesion. In addition to manufacturers' proprietary tests and approvals, other tests may include:

- ASTM C 794, *Adhesion and Peel of Elastomeric Joint Sealants*;
- ASTM C 1135, *Determining Tensile Adhesion Properties of Structural Sealants*;
- ASTM C 1248; and
- ASTM C 1087, *Determining Compatibility of Liquid-applied Sealants with Accessories Used in Structural Glazing Systems.*

Full-scale mockups incorporating the actual materials, substrate surfaces, joint sizes, and other conditions should be prepared in accordance with manufacturers' recommendations and proposed methods. This allows problems with sequence or appearance to be resolved prior to construction. The mockup typically stays onsite as a standard for workmanship and appearance, helping ensure lessons learned during its creation are followed during actual construction.

While lab testing can help determine a product's ability to withstand structural loads, water penetration, thermal changes, and air infiltration, it does not replicate what happens onsite. Laboratories are controlled environments, unlike the actual site—thus, there must also be periodic field testing.

Site conditions are continually changing, putting performance to the test in the real world. Buildings creep. In every urban area, certain parts of a building will never see the light of day. Construction conditions and environment

substantially affect long-term performance. Some design professionals are including in their specifications that manufacturers must send a qualified technical representative to the job location when requested to ensure proper installation. Reputable manufacturers conduct adhesion testing at the project site as part of their service.

Other site tests that may be required in the performance specifications for facilitation by the façade consultant or outside testing authority include:

- ASTM E 1105-00, *Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform or Cyclic Static Air Pressure Difference*;
- American Architectural Manufacturers Association (AAMA) 501.2-03, *Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Sloped Glazing Systems*; and
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Pre-construction meetings

The cost of repairing an air barrier system is estimated to be about 50 to 60 times the cost of a correct initial installation, so it is important to get things right. Given the complexity of buildings and the variations in owner requirements, a one-size-fits-all industry checklist cannot take the place of an experienced owner, design team, and construction team working together to deliver a quality project. To that end, pre-construction meetings are critical for ensuring everyone is on the same page.

For these meetings, a representative of every organization involved in the design and installation of the air barrier components should be present. This may include the:

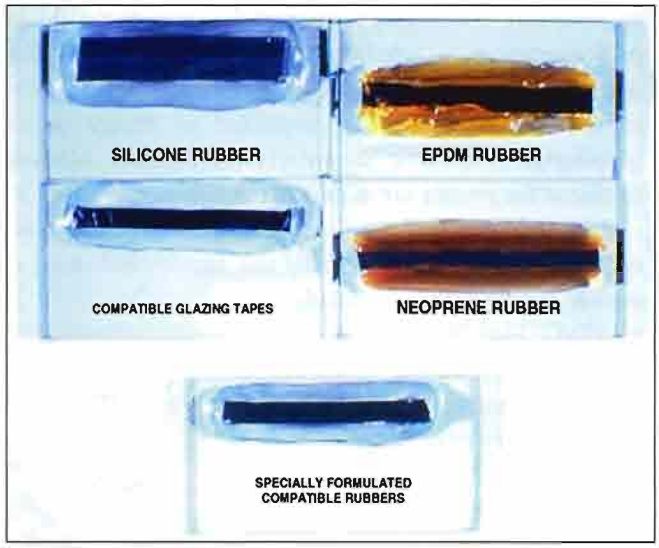
- air barrier manufacturer;
- air barrier installer;
- general contractor;
- architect;
- owner's representative; and
- installers of insulation, windows, waterproofing, roofing, masonry, drywall, panels/metal, and concrete.

The meetings should comprise several parts, as described in the following paragraphs.

Review all project drawings

A review of all project drawings is necessary to determine whether the proposed details are sufficient or can be

Effective specifications require field adhesion testing by the manufacturer and contractor to confirm surface preparation is adequate and materials will adhere under field conditions. The price of envelope failures makes this prudence necessary.



Color changes in the translucent silicone sealant surrounding ethylene propylene diene monomer (EPDM) and neoprene gaskets can generally be attributed to migration of plasticizers into the silicone, indicating incompatibility.

constructed as intended by the specifier. If problems exist, concerns must be addressed and modifications made so all parties understand their responsibilities.

Review system specifications

The type of air barrier system specified for the project should be reviewed; each of its components should be carefully evaluated to make sure no foreseeable compatibility problems will arise.

Declaration by each trade of their selection of materials

Air barrier systems are most successful when a full building envelope is completed without penetrations. A thorough review of all construction details, including construction detail drawings, should be conducted. This is especially important when numerous trades become involved in the tying-in of the air barrier system to all facets of the building envelope. The various trades' responsibilities must be made clear.

Review of construction details

Each trade should come to the meeting with a written list of selected materials and be prepared to discuss potential compatibility problems. This preparation is critical as some membranes decompose when placed in contact with high-solvent-based single component sealants or uncured solvent-based primers.

Sequencing the work of all trades

A comprehensive construction schedule must be developed during the pre-construction meeting to avoid compromising the air barrier system. Failure to sequence allows gaps in the system at major joints such as roof/wall, wall/foundation, and opening frames/wall junctions.

Other project-specific considerations

These include:

- substrate primer considerations;
- substrate preparation (open joints can cause failure at the seams due to positive and/or negative movements/pressures on the wall assembly);
- monitoring installation temperatures;
- protection of the air barrier during the construction process;
- damage repair responsibilities (damage by a trade outside the air barrier installer should be coordinated through the general contractor as per the contract in the bidding document);
- steel stud location;
- exterior rigid insulation installation (the best practice is to use a 1.2 x 2.4-m [4 x 8-ft] sheet shiplapped/installed over the air barrier or substrate); and
- air barrier compatibility with through-wall flashing.

How much risk are we willing to accept?

The cost of project failures can be enormous. If a building's integrity is compromised and moisture is allowed to enter and be captured without draining or drying out, it can necessitate removal of the exterior cladding to locate the source and correct both the leak and damage done. If the problem is systemic, results are often catastrophic.

Owners may want their buildings to last 50 or 100 years; they cannot afford the potential for mold growth and demand guarantees that rework will not be required. Greater control and efficiency during the construction process is imperative. This will only be achievable with a better understanding of building science and objectively looking at installation procedures versus construction schedules or demands.

As we look at continuity of the building envelope, the design team needs to ask itself whether it has sufficient knowledge and details on how to handle the connection between the foundation and the vertical wall. Once waterproofing is buried or the building is occupied, the cost to repair is astronomical. What about sequencing issues and transitions from the vertical wall to the roof, including the fire-rated detailing? From the foundation walls to a plaza deck? Expansion joints in the structural deck? ASTM testing is not meant to be all-encompassing, but if there is no standard, how does a construction team know what works and what does not?

There are no easy answers, but the days of looking at individual portions of a building are coming to a close. Integrated building science solutions are required to respond to the most critical building envelope design challenges, requiring in many cases the pioneering of new technology and system innovation, design integration and collaboration, documentation of system performance, and best practice education.

*After an engineered transition assembly is tested for air penetration, a water spray rack is moved in front of the assembly. Water is sprayed at a prescribed volume while the window is subjected to negative air pressure (*i.e. *positive load), looking for any water penetration.*

Notes

[1] See Michael Kubal's *Waterproofing the Building Envelope* (McGraw-Hill Professional, 2001).

[2] See GANA's glass information bulletin BECD 01-0906, "The Top 10 Items Commonly Missing from Fenestration System Shop Drawings."

[3] In addition to temporarily holding the adapter in position before the mechanical fasteners are installed, the butyl tape also provides a secondary seal between the adapter and the window/wall frame and seals penetrations created by the mechanical fasteners.

Additional Information

Author

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MasterFormat No.
07 27 00—Air Barriers
08 44 00—Curtain Wall and Glazed Assemblies

UniFormat No.
B2010—Exterior Walls
B2020—Glazed Curtain Walls

Key Words
Division 07
Air barriers
Building envelope continuity
Curtain walls
Engineered transitions
Sealants

Abstract

Understanding a new product has not only placed further demands on its installation, but also on the installation of materials surrounding it. Who becomes responsible for the transitions from one to the other? And with myriad components coming together, how can they be appropriately integrated?