The interior water damage shown here was caused by uncontrolled air flow in the building envelope.

The exterior of north elevation was the cause of façade damage.

DID YOU KNOW?

Canada has been involved with air-barrier applications since the 1980s. Massachusetts adopted an energy code in July 2001, and Wisconsin enacted an air-barrier standard in 2002. Since then, other states are beginning to enact similar codes.

The trend of integrating air barriers into building design in the United States is also being spurred at a federal level. The U.S. government now mandates maximum allowable air leakage at 0.4 cfm/square foot at 75 pascal (Pa) on all government buildings.

Build the Right Barrier

By Marcy Tyler and Fred Kramer

Durable connections are the most important factor in a high-performance air-barrier system

North American building-envelope repair is a multi-billion dollar industry. Most experts conservatively estimate building-envelope failures at between 3 percent and 5 percent of commercial buildings. About 70 percent of construction litigation is related to façade leakage.

Most of these failures and envelope repair are moisture-related, caused by air or moisture leakage. Issues with transitions and terminations account for 90 percent of the failures.

Commercial building owners began to experience the problems of uncontrolled air flow in the building envelope in recently constructed buildings—those built in the 1960s through early 1990s. Façade damage first started to show up across the Northern climate zone of North America. Damage to exterior walls, as well as interior surfaces, was not uncommon.

Many of these buildings did not have a water-leakage problem when it rained. Instead, they had a "spring-thaw problem." What happened was that a large amount of warm, interior air was migrating to the back side of the exterior façade. This warm air condensed and formed ice during the winter months. As temperatures warmed up in spring, the accumulated ice melted, and gravity took its course.

Damage quickly occurred to metal anchors, supports, mortar, caulking, masonry, stone and other finishes of the façade. Simple physics explained the cause, but that aspect had been overlooked in the buildings' design and construction.

In many cases, the melting water flowed toward the buildings' interiors, as well as to their exteriors. While these cases caused more initial damage, they also were likely to be corrected before problems got even worse.

Taking Note of the Problem

The industry eventually realized that most of these buildings' problems were due to a lack of continuity at windows, curtain walls, roofs, soffits, louvers and panel intersections. Those investigating the problem found a pattern of neglect regarding these details. Specifically, original construction crews had not made durable seals around windows, penetrations or brick ties. In many cases, no one had installed any interior air seals at roof-to-wall intersects above dropped ceilings. And buildings with setbacks and changes in plane were even more likely to have air-exfiltration problems.

Building scientists, consultants, architects and contractors studying the issue soon began to realize how important it was to isolate and control buildings' interior air—and how much it impacted not only issues such as the costs of damage repair but also utility fees. In fact, the National Institute for Standards and Technology (NIST) confirmed that energy-savings payback for an air barrier was only five to eight years. Given increased competition for energy resources, that payback should only get shorter in the years to come.

Installation Issues

As the air-barrier industry has evolved, confusion in the marketplace has increased. Regional differences in North American's climate zones, for example, impact how crews should install air-barrier systems. Different types of construction also can require special considerations and different types of material.

Manufacturers provide two types of air barriers: vapor impermeable or vapor permeable (breathable):

- *Impermeable.* These membranes have a rating of 0.1 perm or fewer per ASTM E96 Test Method A.
- *Permeable.* These membranes have a rating of 10.0 perms or greater.

Either type of membrane may be effective as an air barrier as long as you satisfactorily address all connections—roof, below-grade, window/doors, etc.

Regardless of whether the membrane is impermeable or permeable, you must focus on how to cut off the free flow of air; that is what allows the most moisture into and out of a façade. And every little leakage matters; a 1-square-inch hole allows 90 times as much water through a façade as an entire drywall sheet.

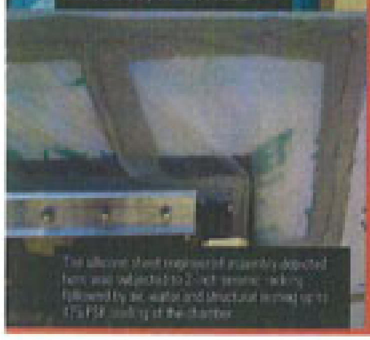
The industry, spearheaded by the Air Barrier Association of America (ABAA), has developed basic criteria and test methods for establishing performance of air-barrier materials and systems. According to ABAA, to qualify as an air-barrier material, building materials must have air permeance of 0.004 cfm/square foot at 1.56 lb/square-foot pressure difference or less. Some building materials that meet this requirement are:

- Precast concrete.
- Glass.
- Treated gypsum board.
- Aluminum panels.

Concrete masonry units (CMUs) do not meet the air-barrier requirement. Therefore, you must treat them with an air-barrier coating or sheet-applied membrane to comply with the ASTM E2178-03 standard noted previously. Only then can you consider CMUs as part of a functioning air barrier.

But you can't simply consider the air permeance of the building materials. ASTM E2357-05 takes it one step further to test air permeance of component materials, too, as part of an air-barrier assembly. The ASTM test system includes stud framing, gypsum board, fasteners, brick ties, various penetrations, a roof connection and a punched window opening. The test measures air leakage after subjecting the test assembly to air-pressure differences. First, researchers subject the assembly to both positive and negative pressures of 12.5 pounds per square foot (psf) for one hour

Connecting to windows with self-adhered membrane is a problematic choice.



The silicone sheet engineered assembly depicted here was subjected to 2-inch seismic racking followed by air, water and structural testing up to 175 PSF loading of the chamber.

HOW LONG WILL AN AIR-BARRIER CONNECTION LAST?

It probably isn't a big mystery why air and water leaks usually occur in the upper levels of many buildings; those areas are typically subject to greater movement and wind pressures than lower levels. On those floors, critical connection points are all impacted by wind drift, deflection, creep, thermal movement, moisture expansion and construction tolerances.

For example, wind drift can be as great as 4 inches on a 10-story building. Wind drift is a concern because it places interstory stress on sealant connections, and buildings are subject to these stresses year after year. Unfortunately, at present, we don't have any tests that truly evaluate the effect of long-term cyclical building stress and movement on air-barrier assemblies, nor do current ASTM standards replicate these conditions. The air barrier industry, therefore, continues to sail through uncharted waters when it comes to predicting how long some of these connections will last.

Engineers usually specify that contractors connect air-barrier systems and adjacent dissimilar materials by way of glue, sealants, polyurethane spray-foam insulation, ethylene propylene diene monomer (EPDM), neoprene or butyl or silicone rubber sheet. (Currently, sealants represent about 90 percent of these connections.) Common industry practice calls for the use of self-adhered membranes as transition wraps in window openings. Crews then use sealants to make the air seal to the window, panel or curtain wall. Most of the self-adhered membranes are rubberized asphalt with a polyethylene outer layer. The major weakness of this widely used method of attachment is the lack of sealant adhesion to the polyethylene backing layer.

The Portland Building Enclosure Council (BEC) conducted an independent study that evaluated adhesion of sealants to polyethylene-backed sheet. The results indicated that adhesion of sealants varied greatly by sheet and sealant manufacturer. Best results were achieved with ultra-low-modulus silicone sealants. Specifically, the study reported, "Because ultra-low-modulus sealants do not place a large amount of stress on the bond line of the backing materials, they are the best candidate for making connections in an air-barrier assembly. They also present less risk in pulling off the membrane and causing air leaks."

Sealant adhesion to polyethylene is a major industry-wide issue. Contractors need to concern themselves with how to make connections that are out of the ordinary. After all, most projects will have a variety of details that are not "perfect world."

A translucent silicone sheet provides a visual indicator that a positive seal has been made on a floor deflection joint application.

to simulate changing conditions. The test is tough, too; peak loads reach 25 psf, the equivalent of 100 mph wind loads.

The ASTM test isn't infallible, though. Specifically, for ASTM purposes, the window opening is in-filled with plywood, thus making the test fall short. That's because window connections are one of the more difficult connections in the envelope, and the test doesn't address this gap. The industry, then, still needs to attend to this problem. Plus, the test is not "real world." So while the ABAA supports the use of ASTM E2357 and requires it of manufacturers as part of the product-approval process, the test is only a useful tool.

How do real-world conditions affect air barriers? In six primary areas in which improper treatment occurs:

- Deflection and expansion joints.
- Window/curtain wall connections.
- Seismic requirements.
- The continuity of the roof to the wall intersect.
- The sequence of installation and constructability.
- Proper details.

All of these factors are very important to ensuring a continuous air-barrier system.

The Most Critical Problem: Sealing Windows

In the past, various industry entities have attempted to bridge unusual window configurations to air-barrier assemblies with poor results. For one, rubberized asphalt sheet presents three problems:

1) It does not have adequate lateral movement.
2) It is difficult to work with.
3) It is not compatible with the silicone used in window frames. (Corner details are difficult at best.)

Various sheet rubber materials don't work much better because they don't adhere to the silicone sealant on the frames, either. Plus, they depend on rubber cement at seams. The problem is that adhesive cement is not a durable seal. Admittedly, if properly shingled, these attachments may keep water out. Eventually, however, they will leak air. And, again, corners are extremely problematic.

Silicone sheet, on the other hand, has advantages the other options lack:

- It is a low-modulus, translucent, high-movement material, making it better-suited for attaching to curtain walls and window/panel assemblies.
- It is available with premolded corners to handle corner stress.
- It is compatible with the silicone sealants used with glazing assemblies.
- It is superior at handling cold-weather movement.
- Its translucent material provides a visual indicator that the worker has created a true seal.

To give proof of the superiority of silicone sheets, testers have successfully integrated the attachments to glazing assemblies and documented their success by way of performance testing consistent with ASTM E2357-05. (The test even used actual window assemblies in lieu of plywood.)

The test also assessed an assemblies' potential for failure when experiencing seismic movement of as much as 2 inches (AAMA 501.4 Modified), followed by air infiltration, static water, dynamic water and structural testing to destruction at 175-psf load per ASTM E330. Premolded corners assured integrity at critical stress areas.

The silicone-sheet assembly and low-modulus silicone sealant also offer the best solution for handling floor deflection joints. Both components marry together to form a high-movement joint seal.

Other new trends are emerging in the air-barrier industry. However, few are as promising or important as the use of the engineered silicone-sheet transition between air-barrier components. Tests have proven that an engineered silicone-transition assembly functions more successfully for longer periods than other options, which is particularly important in areas where failures are unacceptable. After all, no one wants to incur the cost of cladding removal and repair of a failed air-barrier system.

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