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Making Air Barriers that Work: Why and How to Tighten Up Buildings

An **Executive Summary** is available for this article.

Air leaks may not be as dramatic as water leaks, but they cause plenty of problems. When a new LEED-certified building in New York formed icicles and ice dams, the owners brought in building-science consultant Terry Brennan of Camroden Associates to investigate. "The detailing of the air barrier was actually pretty good," he says. The rafters are sealed with rigid-foam insulation taped at the seams, and the walls are sealed with gypsum board and a polyethylene vapor barrier. "But where they came together there was nothing in the drawings and nothing in the specs," he told *EBN*, "so it's got this crack." With an eighth-inch (3-mm) crack running along the eaves, that gap leaks a lot of heated air, melting snow and causing ice buildup while creating the potential for leaks and moisture damage.

Air-barrier specifications and testing are required in Great Britain, where this blower-door test is taking place at a new commercial building. Large blower doors like these depressurize a building, allowing air-leakage testing.

An air barrier is any material that is impermeable to airflow, including drywall, closed-cell foam insulation, peel-and-stick membranes, oriented-strand board, and many other materials. (It is not to be confused with a vapor barrier, which blocks diffusion of water vapor.) But as Brennan's story illustrates, making an air barrier for a building requires considerations beyond just the type of material. The air barrier needs to be continuous around the space it is designed to enclose, whether that's the entire building or a unit within the building. It needs to be able to maintain its function in the face of stresses like installation and damage during construction as well as changes in pressure due to weather and other factors. It should last as long as the building.

Air barriers have long been neglected in residential and particularly commercial construction, but new codes and standards, along with a push for better energy performance, are making them more of a priority for all building types. Examples and perspectives in this article focus on light-commercial and multiunit-residential construction, but they also apply directly to single-family residential and large commercial projects.

Why Make It Airtight?

The roof air barrier for a new building at

Energy waste and moisture problems are among the most common reasons for paying attention to air barriers. Those problems aren't limited to heating climates. For every air barrier gone wrong, there's a way it could have gone right, and the power to prevent problems is in the hands of the designer and the rest of the project team. Implementation varies from building to building, but basic goals take several common themes, described below.

Energy savings and comfort

Leakage of conditioned air, and infiltration of unconditioned air, is a big cause of heat loss in heating climates. It can be an equally significant cause of energy waste in cooling climates. Incorporating an air barrier at a building's thermal envelope—in the walls, roof, and foundation—keeps conditioned air inside and unconditioned air outside, where it

Dartmouth College is a peel-and-stick membrane. In the lower right, it laps over the eave to the wall, where it will be covered by spray-foam, ensuring continuity. The eave construction will be added outside of the air barrier, simplifying details.

belongs.

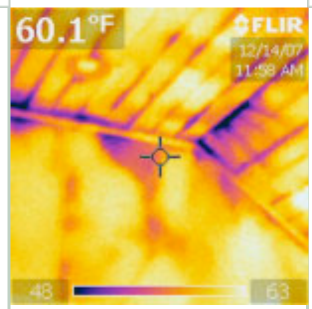
The energy benefits of air barriers are huge. A 2005 study from the National Institute of Standards and Technology, "Investigation of the Impact of Commercial Building Envelope Airtightness on HVAC Energy Use" by Steven Emmerich and others, found that just incorporating an air barrier in a building can reduce its heating and cooling cost by up to 36%. According to Laverne Dalgleish, executive director of the Air Barrier Association of America (ABAA), "You can get savings of 30% by using air barriers only, or by using a whole slew of other things."

Moisture control

Water vapor can condense inside either a building or the building assembly, causing mold, structural deterioration, poor indoor air quality, and other problems. The construction industry has focused more on vapor barriers than on air barriers in preventing moisture damage. But under the same conditions, 100 times more water vapor can flow by air leakage through a one-inch-square hole in a drywall panel than will move by vapor diffusion through the entire sheet. Warm, humid air carried through leaks can, in a heating climate, condense on a cold surface toward the outside of a wall or roof assembly. In a cooling climate the air can move inside and condense on a cool interior surface.

Indoor environmental quality

A poor air barrier can harm indoor environmental quality through more than just mold. Leaky buildings can also lead to poor air quality by causing problems for ventilation systems. It might seem that air leakage would mean more fresh air and better air quality. But that air might not get where it is needed and might not be fresh when it gets there. Air moves when there is an opening for it to move through *and* a pressure difference causing it to move—caused by wind, mechanical systems, or the stack effect. In the stack effect, warm air rises, creating positive, outward pressure in upper parts of a building envelope and negative, inward pressure in lower parts. That often brings in outside air where it is least needed—in a basement. As that air is pulled up through the building, it may carry with it radon gas or combustion gases that should be exhausted directly to the outdoors. A good air barrier also helps the ventilation system operate properly by not creating pressure differences that wreak havoc on those systems. In short, it is the job of a ventilation system, not a leaky building, to bring in fresh air in the right amount, from and to the right places, at the right time.



This infrared image taken during an energy audit of an existing home shows a cathedral ceiling with tongue-and-groove boards. The dark colors indicate infiltration of cold air.

Cold drafts in a leaky building compromise comfort and health, and so does the common practice of blowing in excessive amounts of hot, dry air to compensate. Pollutants are also a concern; toxic chemicals may be used in exterior building materials with the idea that their offgassing won't affect occupants, but air infiltration due to a poor air barrier can bring those chemicals indoors.

Inside multiunit residential buildings, it is common to use air barriers to separate residences so that tobacco smoke or odors generated by one resident don't affect another. Similarly, air barriers are commonly used to isolate indoor spaces such as chemical storage rooms or garages where harmful gases may be generated.

Fire safety

Fire as well as smoke and toxic gases generated from fires spread with air movement. Using air barriers both in the building enclosure and in interior partitions, along with taking other preventative measures, can protect occupants and buildings from fires.

Cost savings

Giving attention to air barriers can lower costs in the long term, but

A renovation of this old New Hampshire town building included 12 inches (300 mm) of cellulose blown into the attic but no effective air barrier. Due to leakage of heated air, severe ice dams built up, causing roof leaks. Clapboards had to be removed to dry out cellulose in the wall cavities.

does installing air barriers during construction save any money up front? Chris Benedict, R.A., of Architecture and Energy Limited, says it does. "Some of the stuff comes in as being code-required," she said. Sound barriers, for example, which can double as air barriers, are required in New York City, so "that's not an extra cost." More significantly, "because we can dramatically reduce our mechanical systems" due to reduced heating and cooling loads, "we have a big savings," she said. Benedict also says she has worked to use low-tech air-sealing products—such as caulk, mop-on masonry sealant, and duct mastic—that don't add a lot of cost. The attention to process required for proper installation has the potential to increase costs; optimizing the design and construction process is discussed later.

How Tight is Tight?

Few building materials are perfectly airtight even before they're transported and stored, perforated by fasteners, penetrated with various parts of the structure, and joined to other materials. Common standards and measurements in the air-barrier world ensure that appropriate materials are used and that they are installed adequately (see sidebar).

Requirements and codes

Specific air-barrier definitions and requirements are increasingly seen in specifications and codes across the industry. In August 2007, the U.S. Army Corps of Engineers adopted air-barrier requirements into its standards for construction, requiring permeance of less than 0.25 cfm/ft^2 @ 75 Pa (1.25 L/s•m^2 @ 75 Pa) for its buildings. With the Army Corps' nationwide reach and multibillion-dollar annual construction budget, observers anticipate that its requirements will have a major impact.

The Army Corps requirements make the general contractor responsible for proper coordination, scheduling and sequencing, meetings, inspections, and tests to ensure that the standard is met. The general contractor must make sure that subcontractors carry out their responsibilities. The contractor must be accredited by ABAA and must carry out an ABAA quality assurance program (QAP).

Additional government agencies, including the General Services Administration (GSA), are in the process of incorporating air barriers into their overall specifications. GSA, which has been a leader in green building, expects this adoption to take place later in 2008 via its general specifications document, referred to as P-100.

A handful of states have brought air-barrier requirements into their building codes. Massachusetts became the first in 2001, setting a very stringent requirement for air-barrier assemblies in commercial buildings at 0.004 cfm/ft^2 @ 75 Pa (0.02 L/s•m^2 @ 75 Pa). That number is ten times tighter than the ABAA standards, and observers have questioned whether Massachusetts intentionally set such a stringent target or simply inserted the wrong number when it adapted the code from Canada. Without a testing requirement in Massachusetts there's no telling how often that target is met. "It's a step forward, but testing and physical observation is the way to really ratchet it up," says Straube. He also notes that Massachusetts hamstrings its own air-barrier requirement by requiring a significant hole at the top of elevator shafts for smoke evacuation in case of fire.

Massachusetts has been joined by Wisconsin and Michigan and, more recently, Minnesota and Georgia. According to Dalgleish, about a dozen more states are moving to adopt standards within the next five years. The patterns of adoption have followed climates where the need is greatest; humid climates with high heating or cooling loads benefit the most, while drier climates with low heating or cooling needs benefit the least.

Model codes and rating systems

If an air-barrier requirement enters the International Building Code (IBC), which is expected eventually, the requirement could appear in many more states. According to Dalgleish, a recent proposal for air barriers in the IBC failed because opponents wanted to wait for the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) to formulate wording. That wording was completed in January 2008 and passed shortly thereafter as Addendum z for ASHRAE Standard 90.1. Addendum z calls for an air-permeance limit equal to the ABAA definition, or 0.4 cfm/ft^2 @ 75 Pa (2.0 L/s•m^2 @ 75 Pa). It is set to become fully integrated into ASHRAE 90.1 by late 2008. Testing is an optional compliance path in the addendum.

This air barrier on a Burlington, Vermont, mechanical penthouse—a spray-applied membrane over plywood sheathing with taped joints—is failing due to water infiltration at the roof-wall intersection. It was under construction and set to be covered by metal siding, which would have concealed the problem.

An air-barrier requirement in ASHRAE 90.1 should have a ripple effect on the industry. The wording from ASHRAE 90.1 will also be proposed for the International Energy Conservation Code, says Dalgleish, and it is likely to enter wider use from there, in state and municipal building codes.

The ASHRAE 90.1 requirement may also raise the stature of air barriers in LEED certification, which has ignored them up to now. With ASHRAE 90.1 compliance as a prerequisite, just introducing the requirement will raise the bar. But Addendum z may also affect how LEED's energy points are calculated.

LEED credit interpretation rulings dating back to 2003 follow ASHRAE in prohibiting project teams from claiming credit for reducing air leakage in their energy models. "Air leakage has to be modeled identically" in the baseline and as-designed buildings, explains Gail Stranske, P.E., director of energy services at CTG Energetics of Irvine, California. "The standard doesn't tell you what leakage rate to model," Stranske notes, "so we generally stick with the defaults in the energy modeling software."

LEED does offer an "exceptional calculation method" that teams can use to claim credit for energy savings that don't show up in energy models, such as occupancy sensor controls on lighting. Without a clearly defined baseline for airtightness, project teams have been prevented from using that option to claim energy savings from enhanced air barriers, but with Addendum z, and actual testing to verify the improvements, that may change.

Picking a target

AIR BARRIERS: KEY TERMINOLOGY	
ACH50	Air changes per hour (ACH) at 50 pascals of pressure difference. One of the most common air-leakage measurements, this metric refers to the number of times the volume of interior air is replaced in an hour under a standard pressurization.
Air Barrier	A continuous system of materials and assemblies in a building intended to stop air leakage, typically to and from the outside but also between units. The Air Barrier Association of America (ABAA) defines an air barrier as having a permeance of less than 0.4 cfm/ft² @ 75 Pa.
Air-Barrier Material	Any material that is relatively impermeable to air and thus can contribute to an air-barrier assembly. ABAA defines an air-barrier material as having a permeance of less than 0.004 cfm/ft² @ 75 Pa. Materials must also withstand the rigors of construction and remain effective for the building's life.
Air Retarder	Technically synonymous with "air barrier" but sometimes used to describe a material slightly more permeable to air.
Blower Door	A mechanism with an adjustable frame and flexible panel that attaches a large fan to an exterior door. The fan pulls air out of the building, lowering the interior air pressure. Calibrated gauges measure the amount of air pulled out. The more air the fan must exhaust to maintain the same pressure, the leakier the building.
Breathable	In building science, refers to a vapor-permeable material or assembly, *not* one that is air-permeable.
CFM50	The most common metric generated by a blower-door test refers to cubic feet of air transfer per minute at 50 pascals, or the amount of air that must be exhausted to maintain the negative pressure on the building shell. Unlike ACH, this measurement must be divided by the area of material or assembly to create a metric comparable between different building types.
Vapor Barrier	A material that stops diffusion of water vapor, as distinct from air. All vapor barriers are also air barriers, but not all air barriers are also vapor barriers.

The codes for air barriers don't converge on a single permeance target. But whether it's because of a requirement or because of a goal of the project team, professionals involved in making buildings airtight agree that project teams should set targets.

"We have to have a specification for what we want," says Marc Rosenbaum, P.E., of Energysmiths in New Hampshire. As for picking a target, Rosenbaum says, "We should set our sights higher and look at what's possible." Rosenbaum encourages a goal of 0.10 CFM50 per square foot of shell for high-performance buildings and personally strives for 0.05 CFM50. Both numbers are significantly lower than common specifications such as ABAA's target of 0.30 CFM50 for buildings.

Choosing Materials and Assemblies

Air barriers can be assembled from a range of materials, including closed-cell foam insulation; drywall, oriented-strand-board sheathing, and other sheet goods; some housewraps or polyethylene sheets; poured or precast concrete (but not concrete blocks); and various peel-and-stick and fluid-applied materials. Materials for specific details include caulks, flashing details, and boxes for sealing ducts and building penetrations.

Common systems

At the whole-building level, air-barrier systems can be distinguished by whether they are installed toward the interior or the exterior of an assembly. Exterior air barriers benefit from simpler installation, without dealing with interior partition walls, electrical ducts, and other penetrations that require special detailing. Exterior systems also protect the wall cavity from moisture and wind. Because exterior systems do not prevent humid interior air from entering the wall cavity and condensing, most systems taking this approach in cold climates use rigid insulation on the exterior of the air barrier, keeping the cavity above the dew point.

Interior systems, while generally more complex to install, protect the wall cavity from interior humid air. They don't, however, protect the insulation and the wall cavity from wind or exterior humid air. According to Joe Lstiburek, Ph.D., P.Eng., of Building Science Consulting, using both interior and exterior air barriers addresses the weaknesses of each. He cautions, however, that interior air barriers that are also vapor barriers, such as sheet polyethylene and vinyl wallcovering, should be avoided in many climates, particularly those requiring air-conditioning.

Airtight Drywall. The most common interior system, especially in light construction, uses sealed drywall and is referred to as the airtight drywall approach, or ADA. This approach builds on the typical drywall installation, in which the drywall and joint compound provide a continuous air barrier. Caulking or sealant and other devices are used to close typical gaps, which occur at the top and bottom plates of exterior walls, between the framing and drywall of partition walls, between window and door frames and drywall, and at service penetrations.

Polyethylene Air-Vapor Barrier. Plastic sheets are attached to the interior wall, under the drywall, and sealed at penetrations. This system suffers from complex detailing requirements and inevitable imperfections, and the integrity of the material is often compromised by jobsite conditions.

Exterior Membrane. An effective system for almost any kind of construction is to install peel-and-stick sheet membranes, or a spray-on or trowel-on barrier, on the exterior of the structure. In this system, the membrane often does triple duty, also serving as a vapor barrier, and an exterior drainage plane. Foam insulation is often installed outside the air barrier. Designers and installers have to pay close attention to ensure continuity at all penetrations and use special assemblies like built-on eaves.

Concrete Panels. Precast, site-cast, or tilt-up concrete panels may be used as air barriers. When appropriate, this approach is straightforward and durable because the air barrier doubles as the structure. Appropriate gasketing and detailing at joints, penetrations, and transitions ensure continuity.

Curtainwalls. With a specialized, detailed approach, curtainwalls can be made airtight. Common components like glass and aluminum are airtight, but connections often leak badly and require specialized components, including seals and gaskets, as well as special care and attention from design through assembly and construction.

Quality Assurance

According to Dalgleish, quality assurance on jobsites is crucial for air barriers. "If you miss some thermal insulation, the amount of heat loss is in proportion to the size of the hole," argues Dalgleish. "With the air barrier, a small imperfection has a bigger impact." Dalgleish likens air movement through a leak to water leaving a garden hose. "If you squeeze the end of a garden hose, you don't proportionally stop the flow of water. When you make the diameter of the hose smaller, the velocity [of the water] increases."

Design for quality

At Dartmouth College in New Hampshire, Rosenbaum consulted on a series of buildings in which the college wanted to avoid the ice problems that plague many of its older buildings. The new steel-framed, pitched-roof buildings use corrugated-steel roof decking. Over that is gypsum-board sheathing topped by a peel-and-stick membrane that functions as the roof's air barrier. One of the virtues of this system is that "it's easy to verify," says Rosenbaum. "Is it there or not? I can ask someone to send me a picture." At the roof-to-wall transition, the same place that bedeviled Brennan's LEED-certified building, the membrane at Dartmouth laps down and is sprayed over with closed-cell foam, continuing the air barrier down the wall.

The peel-and-stick membrane air barrier on this window connects with the housewrap air barrier under the rigid-foam insulation, which is in turn under strapping and vinyl siding.

In frame-construction projects, including student housing at the College of the Atlantic in Maine, Rosenbaum has used the exterior sheathing as the air barrier. In that project, the air barrier starts with the sills, which are sealed to the slab-on-grade. The sheathing is sealed to the sill, and all joints in the oriented-strand-board sheathing are sealed with peel-and-stick tape, the presence of which is easy to verify. As in all his projects, Rosenbaum advocates for having a sheet in the plan set dedicated to the air barrier. "All the details are shown on one sheet," he said of the drawing Coldham & Hartman Architects completed for the College of the Atlantic. "It's described as a system." According to Rosenbaum, an early test result on that project found permeance of 0.04 CFM50 per square foot of shell.

In general, says Rosenbaum, "I have focused on making air barriers that can be installed, verified, and tested as early as possible in the building process." At the College of the Atlantic, "as soon as the windows and doors were in, we had a testable air barrier," he said. These early tests allow the project team to quickly repair any problems that appear during testing. Once a veneer has been built over the air barrier, repairs could require significant and costly disassembly (for this reason, Brennan says "sequencing is the enemy in big buildings"). Furthermore, a construction team can easily apply this kind of straightforward system.

To improve the air-barrier quality, designers may want to consider different assemblies than those they are accustomed to working with. According to Brennan, "Masonry block-and-plank construction is much easier to get airtight than steel framing or fluted steel decking with gypsum-board sheathing."

Even if a project is already committed to a type of construction that is difficult to seal, certain choices can improve the likelihood of establishing a good air barrier. A steel-frame, gypsum-board-sheathed building is tough to get right, says Brennan, so "the first thing I'm going to do is recommend exterior spray foam" as both an air barrier and an insulation. "You can get a specialized contractor to do that, and you don't have to rely on other contractors who are constantly changing out."

Benedict, like Rosenbaum and Brennan, likes low-tech details that are easy to install and verify. In concrete-block structures, she specifies a mop-on cementitious coating to create an exterior air barrier. When using the airtight drywall approach, a key detail is sealing the electrical boxes. "We wipe those with duct mastic," she said, joking, "Even an architect could do it."

The options are more limited for renovations. "It's really nice to get your air barrier on the outside of the building," says Benedict, "but it's not always possible, especially in gut-rehab projects," where any number of aesthetic, historic, budgetary, or technical considerations could interfere. Benedict says she often relies on airtight drywall for gut rehabs.

Trouble spots

Some of the most common building materials, such as drywall, many types of sheathing, and foam insulation, are airtight and can provide

Although this mockup of a building under construction at Dartmouth College tested well for airtightness, with leakage of under 0.05 cubic feet per minute per shell square foot at 50 pascals, when it was pressurized and filled with theatrical fog, leaks were found in the rakes (as shown here) in time to be fixed on the actual building (in the background).

the bulk of an air barrier. But, as Brennan says, "You have to put the pieces together." He describes how to test plans for air-barrier continuity: "Take the sections, figure out where the air barrier is, and you should be able to trace your air barrier all the way from the center of the roof to the center of the foundation without lifting your pen." Benedict is equally straightforward about the designer's responsibility: "If there's a place where one thing is meeting another and you don't know what's sealing it, it's your job to find out what it is." Then, she notes, every one of those details needs to be included in the plans.

Trouble spots in the air barrier usually take on common forms, says Brennan. For example, steel framing with fluted steel decking is a predictable source of trouble because the corrugations make it hard to seal the edges. In a retrofit, he says, he would use spray foam to seal the edges. In new construction he keeps the fluted deck inside, away from the air barrier, to allow a connection around its end. Along those lines, Rosenbaum prefers to keep any structural aspect inside the air barrier, noting that "anytime you send out a rafter tail or decking, you've got a thermal bridge and a more complicated air-sealing task." Brennan says that, in general, curbs around roof equipment are trouble spots: "You leave an inch and a half around the curbs, and it's kind of a big hole."

Construction management

Proper design and attention to potential trouble spots is good preparation for minimizing air leakage. Ensuring that the design intent is followed during construction is also essential. "The heart of that is inspection," says Brennan. "Somebody has to be there all the time." For Brennan, it doesn't matter if that person works for the general contractor, the construction manager, or the commissioning agent. "You have to take photos and inspect every day," he says. If a peel-and-stick membrane is going up, "it has to be sticking. If it's been rained on, they have to dry it out." Details must be implemented—crews need to be trained, and additional trainings are often needed to keep up with mishaps, such as a contractor going out of business. All project team members need to be reminded, as Brennan says, "how small air molecules really are."

However, some, like Benedict, prefer not to delegate the job of tracking jobsite progress. "Either myself or people in my office need to be there," she said. "There's a constant keeping in touch with the process and where it is." Although that is time-consuming, Benedict justifies the practice: "Sometimes I'm the only one who cares about it."

Testing for Tightness

Making Buildings Airtight

DESIGN INTENTION	
Codes	Codes increasingly require air barriers. Check your state requirements or job specifications if you are building for a federal agency.
Goals	Installing a continuous air barrier can improve energy performance by over 30% and often requires no additional materials. To reduce energy use and protect the indoor environment, set ambitious goals, beyond code, for reducing air leakage.
Economy	Choose materials that serve multiple purposes and are inexpensive but durable. Demonstrating adequate energy savings can allow downsizing of mechanical systems.
Ventilation Systems	Use air barriers to improve the performance of ventilation systems. Air-sealing between floors in a high-rise, for example, can counteract the stack effect.
Air Quality	Design air barriers that protect occupants from moisture and mold problems, offgassing of toxic materials, tobacco smoke, combustion gases, and drafts.
ASSEMBLIES	
Assembly Design	Consider assembly types that are easier to make airtight. Masonry block-and-plank construction is easier than steel framing with fluted decking, for example. Exterior assemblies tend to be simpler to install and rely less on failure-prone details. Look for opportunities to combine air-barrier details with other functions.
Design	Create a set of drawings solely for the air-barrier system. Include details for every joint and transition. Trace the air barrier completely around the building in an unbroken line.
Sequencing and Visibility	Use air-barrier designs that can be installed and tested early in the construction process, before they are concealed by additional materials and are hard to inspect and repair. Use methods that are easy to carry out and whose quality is relatively easy to detect.
Vapor Permeability	Many, but not all, air barriers are also vapor barriers. Especially in climates with air-conditioning, take care not to trap water vapor inside the assembly.
Durability	Select air-barrier materials that will withstand the rigors of installation and last as long as the building.
QUALITY ASSURANCE	
Quality Assurance Program	Look for trained contractors or installers. Implement a program that meets your needs for jobsite quality insurance, including inspections when necessary, documentation, and third-party auditing or commissioning.
Mockups	In a larger project, build an on-site mockup incorporating all joints, transitions, penetrations, etc., test it for leakage, and correct any problem areas in the real project. Otherwise test the actual building, or a portion of it, at the first opportunity.
Testing	Test the air barrier with a blower door as soon as possible, and verify performance with a test at completion. Use theatrical fog to find leaks.

For every project team with a target air permeance, there comes a moment of truth. Brennan describes it like this: "You crank up the blower doors and you hope like hell that you made it." A blower door is a mechanism with an adjustable frame and flexible panel that attaches a fan to an exterior door. The blower door pulls air out of the building, lowering the interior air pressure to create a pressure difference with the outdoors—usually 50 or 75 pascals. Calibrated gauges measure the amount of air pulled out. The more air the fan must exhaust to maintain the same pressure, the leakier the building, because it indicates that exhausted air is quickly replaced.

Larger blower doors, and more of them, can be used depending on building size. For high-rise buildings floors can be tested one at a time, or a single floor can be tested as a representative sample. In some large, compartmentalized buildings, it may be advantageous to use the building's own air-handling system to pressurize or depressurize to test for leaks.

Performing a blower-door test as soon as possible creates more opportunities to repair problems. At Dartmouth College, Rosenbaum performed a blower-door test on a mockup that had been built for testing finishes. "It was really tight," says Rosenbaum, noting that the test might have stopped there. But then he reversed direction on the blower door, positively pressurizing the building, and filled it with theatrical fog to find leaks. The test was done soon enough that one detail on the rakes that leaked air could be fixed on the actual building. Using fog is a common way of pinpointing problem areas. "If you set a goal for the building and it misses it by 15%, you have a bunch of guys looking at you and saying, 'Why isn't that good enough?'" Fog is so graphic, though, that "it stops the arguments," he says. Infrared imaging, often used when a building is pressurized by a blower-door, is another useful tool for graphically identifying holes in the air barrier.

For large projects, mockups that incorporate all the key joints, penetrations, and other air-barrier details are helpful for testing assemblies and training the construction crew. For projects where that expense isn't possible, Rosenbaum recommends testing the "first instance." That entails testing a portion of a building, such as a corner room that integrates key pieces of the air barrier, as soon as it is built and while most of the building is still in process. Often the room must be partitioned from other parts of the building with plastic, but the opportunity to pinpoint any problem areas during construction is important.

What's Ahead

The Garthwaite Center for Science & Art in Weston, Massachusetts, a 2008 AIA/COTE Top Ten Green Project, optimized its energy performance with the contribution of a continuous air barrier. Fog testing under pressurization was used to detect air leaks.

"It's way less sexy than photovoltaics and ground-source heat pumps," says Rosenbaum on making buildings airtight. "It requires understanding how buildings are built, and it's very mundane at the design level." But as the goal of energy efficiency is adopted more broadly and deeply, more project teams will be looking for ways to save energy without expensive systems. Ensuring proper installation of air barriers is a good target because it doesn't necessarily call for significantly more materials or labor but simply demands thoughtful design and attention to detail during installation.

With the growth in air-barrier specifications like the Army Corps' and ASHRAE 90.1, Brennan sees a period of innovation ahead. "There are going to be people out there that know how to do this and are figuring out how to do it better," he said. Over the last decade, manufacturers have put more attention into developing products and materials that meet these needs, and organizations like ABAA are helping by writing standards and researching different approaches. In residential construction, airtightness testing is fairly common, for example in the Energy Star program. In commercial buildings, more data, along with specifications, will encourage project teams to focus on air barriers.

There's still a lot to learn about air barriers, says Dalgleish, and the industry has embarked on a two-year study in concert with Oak Ridge National Laboratory and others to construct a test hut that exposes air barriers to real-world conditions. According to Dalgleish, the team hopes to address questions such as the effect of fasteners on housewrap when that housewrap is used as an air barrier, and to generate data to improve computer modeling of air barriers.

By necessity, attention to the air barrier also brings attention to all aspects of the building envelope and potentially improves quality and performance. "I think that the architects who get simultaneous air management, water management, thermal management, and vapor management put together in the most elegant ways are going to come out the winners," says Benedict. Incorporating air barriers into buildings isn't hard, but doing it well, doing it affordably, and ensuring quality and effectiveness is an art as well as a science.

– Tristan Korthals Altes

For More Information:

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www.airbarrier.org

Building Science Consulting
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978-589-5100
www.buildingscience.com

Sidebar: Defining Airtight

If air pressure were equal everywhere, air would not move. Therefore, to measure the air permeance, or leakage, of a barrier between two adjacent spaces, one must assume a pressure difference on either side of the barrier. Using a single common measure for that difference allows air-permeance measurements to be standardized and compared.

In English units, the standard pressure differential for measuring air permeance is 0.3 inches of water, which is equivalent to the pressure differential created by a strong breeze. Almost everyone prefers the equivalent metric of 75 pascals (Pa), however. To further complicate matters, professionals in the field usually measure air permeance at 50 Pa instead of 75 Pa. To roughly convert a 75-Pa permeance number to a 50-Pa result, divide it by 1.3.

The Air Barrier Association of America (ABAA), founded in 2000 and now a leading authority on air-barrier design and specifications, has defined an air barrier material as having a permeance of no more than 0.004 cubic feet per minute (cfm) per ft^2 at 75 Pa. (The metric conversion is 0.02 liters of air per second per m^2, or 0.02 L/s•m^2 @ 75 Pa.) This is the permeance of standard drywall.

As air-barrier materials are combined into larger assemblies, the definitions become more forgiving by factors of ten. An air-barrier *assembly*—which is simply any building assembly, such as a wall, designed to block air leakage—should have a permeance of less than 0.04 cfm/ft^2 @ 75 Pa (0.2 L/s•m^2 @ 75 Pa), according to ABAA. When numerous assemblies are combined into an air-barrier system for a whole building, providing a continuous airtight plane, the maximum air leakage for the whole building should be less than 0.4 cfm/ft^2 @ 75 Pa (2.0 L/s•m^2 @ 75 Pa). Professionals often abbreviate this metric further, as in 0.4 CFM75. Converted to 50 Pa, that is 0.3 CFM50. A very tight building might test at 0.05 CFM50 or less, while a leaky building could test at 1.0 CFM50 or higher.

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