Building Envelope FORUM
Design *** Construction / Installation *** Maintenance / Retrofit *** Material & Components

Solving the Air Barrier Riddle: Permeable or Impermeable?

By: Sonya Santos

Introduction

The problems associated with air infiltration of buildings are well established. In addition to significant heating/cooling energy loss, air leakage through building envelopes can permit moisture and condensation to collect in the walls. This interstitial condensation creates significant problems for buildings and occupants alike, including poor air quality, mold and mildew, and even structural damage.

To prevent these destructive outcomes, no building design today is complete without a continuous air barrier. However, while the need for such a barrier is now well recognized (and required by code in a growing list of jurisdictions), architects and engineers are faced with the challenge of selecting an air barrier from the many types available.

In particular, the choice between vapor permeable and vapor impermeable air barriers presents building designers with puzzling questions. Which is right for their building — and how should their wall be designed to make maximum use of its properties? The stakes could be high: choosing the wrong barrier, or using the right barrier in the wrong way, could result in serious problems that lead to building envelope issues and potentially troublesome call-backs.

Understanding Vapor Drive

To understand how air barriers impact building comfort and integrity, it is important to understand how moisture vapor interacts with wall structures.

Moisture vapor naturally diffuses into and through wall structures — a phenomenon called "vapor drive." The degree of vapor drive is controlled by the porosity of the wall, together with environmental factors, especially:

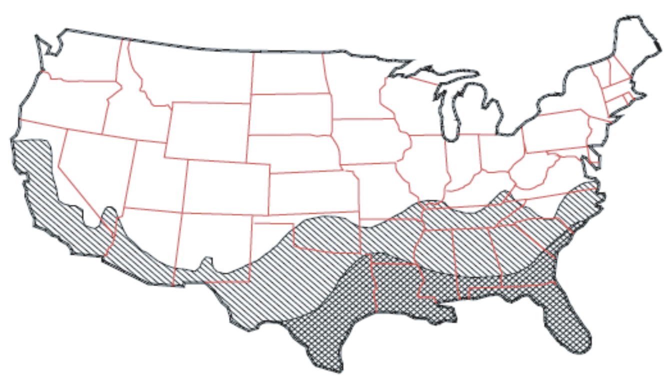
Moisture gradients — Moisture vapor will naturally move from a high concentration to a lower concentration, until it is in balance. If the vapor pressure is high outside the wall and low inside the wall, vapor drive will be directed inward (and vice versa). The greater the difference of this vapor pressure or "concentration gradient," the greater the vapor drive.

Temperature gradients — Moisture vapor will naturally move from the warm side of a wall to the cooler side. If the temperature is high inside the building and lower outside the building, vapor drive will be directed outward(and vice versa). The greater the difference of this "temperature gradient," the greater the vapor drive.

In other words, the movement of moisture via diffusion is a result of differences in vapor pressure that are related to the temperature and moisture content of the air.

Of these two, temperature is the greatest factor impacting vapor drive. In fact, when the temperature differences between indoors and out is great (say, 20 degrees or more), the vapor drive can be quite strong. Add a significant difference in humidity, and the vapor drive becomes even more vigorous.

What this means is that vapor drive will act differently relative to a wall depending on the climate, or even the time of year. Consider the simplified climate map below.



NorthernCold Climate - Vapor Drive Interior to Exterior

Moderate Climate - Vapor Drive Equal Both Directions

Hot/Humid Climate - Vapor Drive Exterior to Interior

Cold climate: Vapor drive primarily from interior to exterior

Mixed climate: Vapor drive approximately equal in both directions

Hot, humid climate: Vapor drive primarily exterior to interior

solving the air riddle continued on page 2

Building Envelope FORUM

Design *** Construction / Installation *** Maintenance / Retrofit *** Material & Components

solving the air riddle continued from page 1

Diffusion vs. Condensation

Of course, temperature and moisture gradients are also the key factors driving condensation. The warmer the air is, the more moisture it can hold in the form of vapor; as it cools, air loses its ability to hold moisture. As moist, warm air moves across a falling temperature gradient, it cools. When the air reaches its dew point — the temperature at which it can no longer hold water — condensation occurs on the surface bordering the temperature gradients.

Think of a glass of ice water sitting on the table on a hot, humid day. The humid air cools as it contacts the cold glass surface, condensing as water droplets. Now imagine that glass is a wall. In most wall structures, the temperature gradient is greatest across the insulation layer, which separates warm air from cool air (and, typically, moist air from dry air). As warm, moist air on one side contacts the cool or cold, dry air on the other side, vapor condenses — right inside the wall cavity. The amount of moisture that can condense inside such an unprotected wall can be quite significant.

What makes the issue a bit more complicated is the fact that, under certain circumstances, some degree of vapor diffusion may actually help keep wall cavities dry by allowing any trapped moisture to escape the same way it got in. For example, because brick acts as a “reservoir” material absorbing rain and condensation, exterior brick walls are often designed with a space to allow air circulation. In this case, moisture moves by diffusion to the surface of the brick, where it can dry by convection, helping keep moisture accumulation in check.

So, while an air barrier is intended to prevent air leakage through a wall, care must be taken to ensure that it also helps minimize the chances for condensation in the wall cavity. And there is no “one size fits all” solution to this challenge.

Air Barrier Alternatives

To address the variables in this vapor drive equation, the construction products industry has responded with two broad types of air barriers: vapor impermeable air barriers and vapor permeable air barriers.

Vapor Impermeable Air Barriers

As the name suggests, these air barriers are designed to block moisture vapor, as well as air. Impermeable air barriers can be either self-adhering sheet membranes or can be fluid-applied membranes.

Vapor Permeable Air Barriers

This type of air barrier is designed to allow moisture vapor to pass through the membrane, promoting diffusion. Permeable air barriers are either sheet membranes or fluid-applied, and offer varying rates of permeability.

Determining whether to use a vapor permeable or vapor impermeable air barrier—and how to use it — depends on a couple of key factors:

•Climate — Where the wall is located
•Wall Design — Where the air barrier and the insulation layer are located in relation to each other in the wall

This may sound simple, but on closer examination, there are many variables that play into these factors. If climate were static and unchanging, the task would be simple. As we know, this is not the case. In some climates, the seasonal differences can be extreme. To understand how climatic changes interact with specific wall structure designs, a good modeling tool can be invaluable.

Modeling Vapor Drive

One such tool is the WUFI® (stands for Wärme und Feuchte instationär or Transient Heat and Moisture), modeling tool used by Grace Construction Products in its Perm-A-View□ exterior wall design modeling service. Developed in Germany by the Fraunhofer Institute for Building Physics (IBP), WUFI is a PC-based hygrothermal modeling tool that calculates the coupled heat and moisture transfer (and accumulated moisture storage) in multi-layer building components exposed to real-world climate conditions for specific climate zones. These calculations are presented as dynamic, graphical displays showing what is occurring inside each layer of a specific wall design, over time. The result is a realistic measurement of wall structure performance, based on the latest science on vapor drive and moisture diffusion.

solving air riiddle continued on page 3

solving the air riddl continued from page 2

WUFI analysis results display temperatures, relative humidity, solar load, and rain load as a function of time over a period of an entire year, based on measured averages. And it takes into account a variety of properties impacting heat and moisture transfer:

•Permeability and moisture storage of specific building materials, accounting for relative humidity

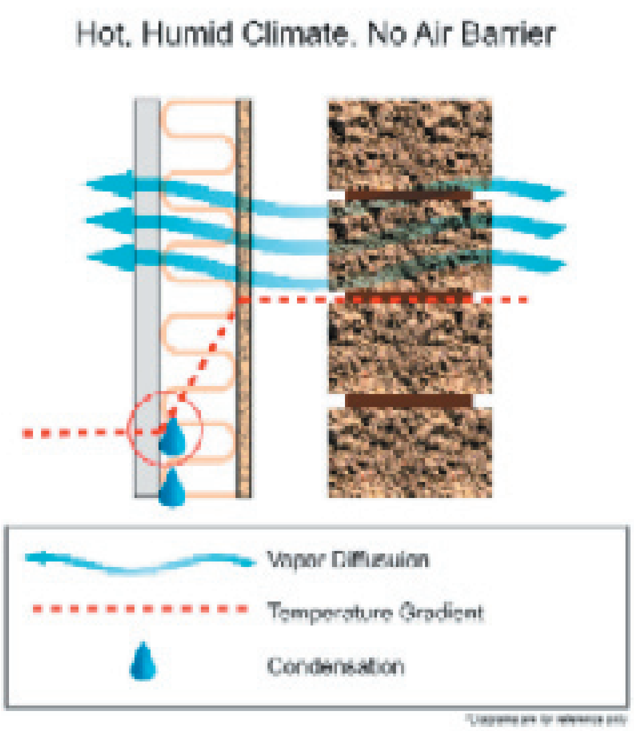
•Thermal conductivity of specific materials and how it changes with humidity

•Phase changes, including vapor to water and freezing

Note that the WUFI does not take into account all environmental factors. For example, it does not account for air leakage; it assumes the air barrier is continuous in its application and performance. While different air barrier products may display similar wall performance results when modeled with WUFI, their actual, real-world performance characteristics may vary in practice due to the nature of the product or application methods. Designers and specifiers should recognize this when evaluating WUFI results.

Despite these limitations, the WUFI provides a useful, dynamic model of the interactions between heat and moisture in response to climatic changes, for specific wall structures. This makes it ideal for viewing how different types of air barriers in different wall locations will impact performance. The following modeling “snapshots” will help illustrate varying air barrier strategies for different climate zones.

Example 1: Hot, humid cbobkerim@rogers.comlimate, no air barrier

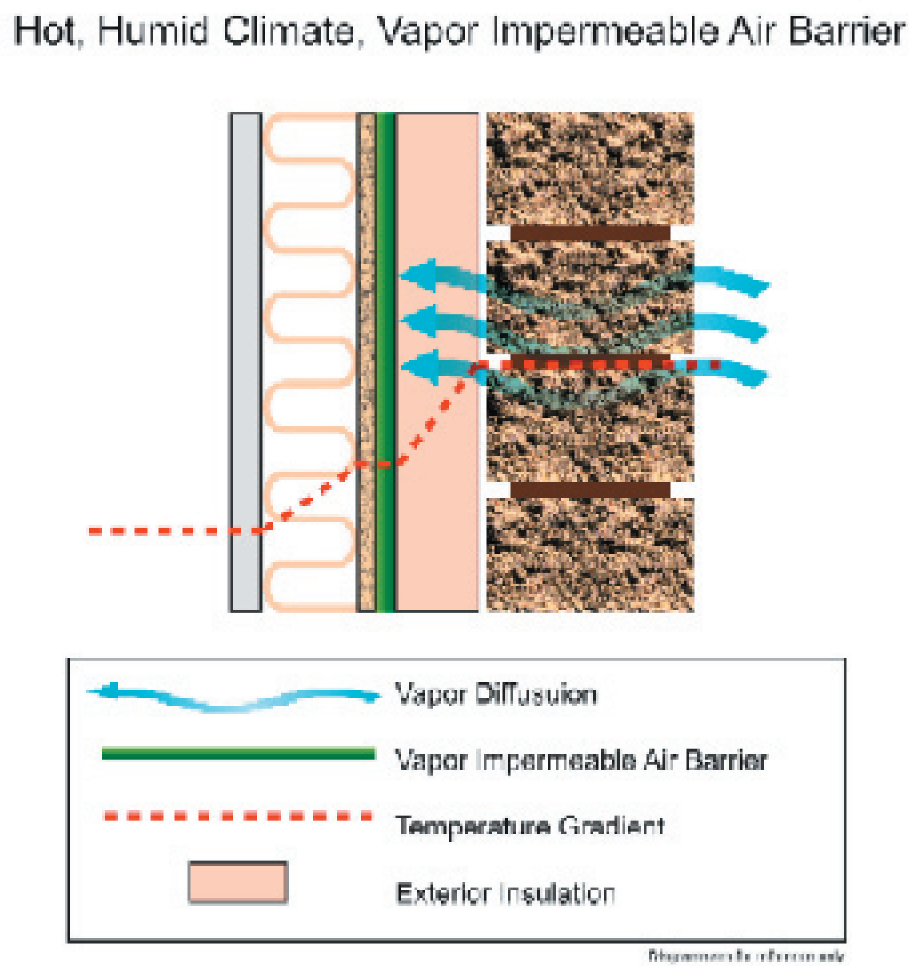


solving the air riddle continued on page 4

solving air riddle continued from page 4

Here's a wall in a hot, humid climate; say, Miami, Florida. As you can see, vapor drive from the hot outside air is driving toward the cooler interior. However, once the vapor reaches the insulation layer, the temperature drops rapidly, creating a steep temperature gradient. The result is condensation on the inside of the wall.

Example 2: Hot, humid climate, impermeable air barrier



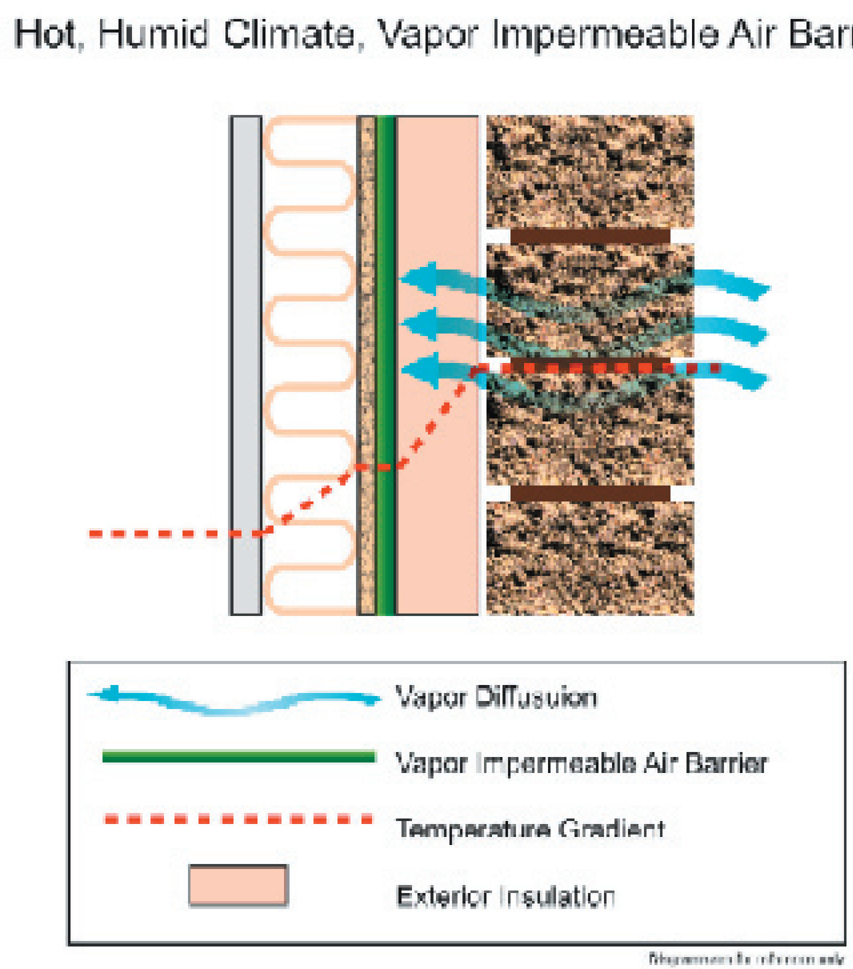
This view shows the same climate and wall, with the addition of an impermeable air barrier added outside of the insulation layer. This "outboard" location is indicated in a hot, humid climate because the vapor drive is moving from outside to inside most of the year. As you can see, moisture vapor is blocked from entering the wall cavity, preventing interstitial condensation.

Because the climate in Miami is generally warmer outside than inside, using an impermeable air barrier with this wall design should perform well year-round.

solving the air riddle continued on page 5

solving the air riddle continued from page 4

Example 3: Cold northern climate, permeable air barrier



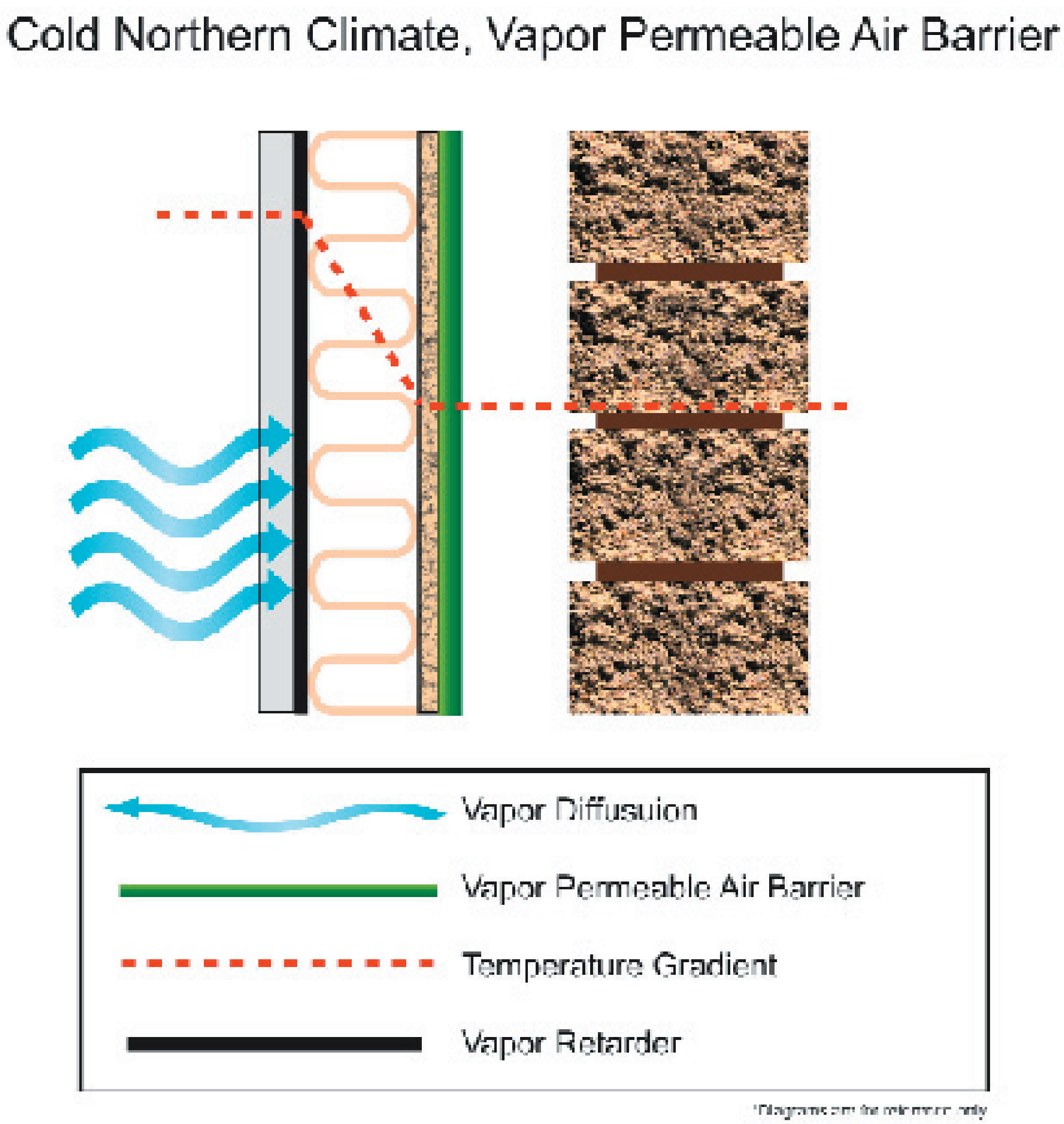
Moving north to, say, Boston, things get more complex due to the seasonal variations in both temperature and relative humidity. However, the most dramatic temperature gradients are generated in the cold months, when the air is warmer inside the building structure and colder outside, creating vapor drive inside to outside.

This model shows a proposed solution to this challenge: a permeable air barrier outboard of the insulation layer, enabling vapor from inside the building to diffuse to the outside. The addition of a vapor retarder between the inside space and the insulation layer helps control the amount of vapor passing into the wall, further minimizing the chances for interstitial condensation.

solving the air riddle continued on page 6

solving the air riddle continued from page 5

Example 4: Mixed climate, permeable air barrier



Between these two extremes is the mixed climate zone. In places like Washington, D.C., we do not find the temperature extremes we find in Miami or Boston (especially the cold outdoor temperatures), though relative humidity can be quite high. This model shows a wall designed to address these conditions: a permeable air barrier outboard of the insulation layer, with no vapor retarder inboard. This design permits vapor to pass through the wall and permits diffusion, allowing any condensation that may occur to escape toward the inside and the outside of the wall.

solving the air riddle continued on page 7

solving the air riddle continued from page 6

As we have seen, designing exterior walls and selecting the best type of air barrier — vapor permeable or vapor impermeable — requires that we consider climate and arrangement of the wall components. A logical approach is to understand the most prevalent direction of vapor drive (toward the inside or outside) for the climate and design the exterior wall to handle this vapor drive, including the selection and location of the air barrier.

However, multi-component wall designs can introduce complexities that are difficult to understand. As we've shown, modeling programs like WUFI and Perm-A-View can help a designer compare the performance of various wall assemblies under certain climatic conditions, helping guide the selection of air barrier type.

Other Important Considerations

In addition to the permeable/impermeable decision, there are some other important considerations that play into a well-planned air barrier strategy.

For any air barrier to be effective in preventing air leakage, it must be continuous. When temperature gradients between indoors and outdoors are steep, vapor drive can be quite strong, finding even the smallest gaps in protection. Therefore, the air barrier must cover the entire building envelope, with special attention paid at window, door and other openings. For this reason, using high-quality flashing systems at all openings is crucial to ensure a continuous air barrier throughout the building envelope.

In addition, the air barrier should be firmly adhered to the wall surface. This is especially crucial in wall designs with an air space between the air barrier and the exterior cladding. In these designs, wrap-type air barriers can "billow" to pump air back into buildings or at fastening points, causing it to stretch or potentially tear free of anchor points when negative wind loads are strong enough, in effect "inflating" the air barrier envelope. Once breached, the air barrier loses its effectiveness.

The prime choices for a firmly adhered air barrier are self-adhered membranes and fluid-applied membranes. Both are available in vapor permeable or impermeable variations, and both can deliver equivalent performance.

Self-adhered membranes offer the advantage of relatively simple application, with no special equipment required. And they ensure a perfectly uniform thickness, for assured performance.

Fluid-applied membranes may be preferable for wall surfaces with complicated shapes or a high number of penetrations, which might be difficult or time-consuming to seal by hand using a self-adhered membrane. Fluid-applied membranes may also be preferable for large open areas. Fluid application should be performed by operators skilled in the application of fluid air barriers to ensure proper, uniform thickness.

Maintaining optimum dry film thickness of a fluid-applied membrane is critical to its performance. The thickness must be sufficient to cover all high and low points of the substrate. This is especially critical on porous, irregular substrates such as concrete block. If the layer is too thin, voids can occur, creating leaks. With permeable air barriers, application too thick can interfere with proper diffusion (though some products, like Grace Perm-A-Barrier® VP, support thicker application, helping eliminate thin spots or voids to ensure proper effectiveness).

solving the air riddle continued on page 8

solving the air riddle continued from page 7

The Value of Professional Guidance

In this overview, we have shown that both vapor permeable and vapor impermeable air barriers play critical roles in modern wall design. The choice of whether to implement one or the other is dependent on a wide range of factors, including climate and wall design. In this article, we have pointed to specific scenarios where a vapor permeable or vapor impermeable air barrier would likely be the preferred choice.

However, there are other variables that factor into the vapor drive equation. Other building components, such as HVAC systems, windows and doors, and roof structures, also play a role in determining how air and moisture vapor interact with building envelopes. Weather conditions such as rain, wind and snow also play a role in wall performance. In addition, building materials are continually advancing, presenting architects with new choices, each with its own pros and cons. Given all of these factors, the choice of permeable or impermeable air barrier can be complex, especially in climates where seasonal temperature and moisture variations are high.

The best way to ensure your air barrier strategy and your wall design achieve the desired performance is to work with a consultant or a product manufacturer that are familiar with various air barrier technologies. Working with a professional or manufacturer who has both the technical expertise and the modeling tools to fully evaluate your design against real-world conditions can save you time during the design phase — and headaches down the road.

About the author

Sonya Santos is Marketing Manager, Building Envelope for Grace Construction Products, a worldwide leader in specialty construction chemicals and materials. She has been involved in the marketing and business development of Grace's building envelope solutions, including waterproofing and air barrier products. She can be reached at sonya.santos@grace.com. Additional information about Grace's air barrier products is available at www.graceconstruction.com.

This article was originally published in the Journal of Architectural Coatings (http://www.paintsquare.com/jac/jac_home.cfm)