# Protecting the Building from Moisture: Air Barriers, Vapor Retarders and Weather-Resistive Barriers

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Moisture can cause problems with building envelope performance through two mechanism, condensation and bulk water intrusion. As such, proper moisture control in the exterior envelope of buildings primarily depends on controlling moisture flow in vapor form, and preventing moisture penetration in liquid form. While complete elimination of moisture condensation within wall assemblies under all climatic conditions may be difficult, the goal should be to prevent moisture accumulation, and to ensure that short-term exposure to moisture does not affect wall components adversely.

Since the quantity of liquid moisture (bulk water) penetrating through the exterior wall deficiencies can be significantly larger than moisture condensation, the primary goal for building envelope design is to prevent moisture penetration through the exterior surface, or the back-up materials.

In the past several years, design and construction of building exterior walls with energy efficiency in mind has received much attention. Although model energy conservation codes have been in existence for many years, their adoption by various states and municipalities has made energy efficient design mandatory.

Increasing energy efficiency in the exterior walls involves the use of more insulation (higher R-Value) and various measures to reduce energy loss due to air infiltration/exfiltration. The use of more insulation increases the temperature gradients across the wall and roof assemblies, thereby increasing potential for condensation.

For this reason, the proper use of vapor retarders and air barriers is critical for proper performance of the building envelope assembly.

In addition to issues with energy efficiency and moisture condensation, the design of any exterior wall or roof assembly should also include provisions for controlling penetration of bulk water (i.e., rain). In barrier type walls, such penetration is resisted entirely on the outer surface of the wall (such as a non-drainable EIFS system). However, in drainage type systems (such as a masonry cavity wall), resistance to water infiltration is primarily provided within the wall assembly through the use of a weather-resistive barrier. The traditional masonry walls do not ude any of the above principals. Instead, they rely on their large mass and the ability to absorb large quantities of water during wet conditions, and allowing the water to re-evaporate to the interior or exterior environment.

Air barriers and weather-resistive barriers can only be effective if all of their penetrations are properly sealed. Discontinuities in the material can cause problems.

To understand how exterior walls (or roofs) can resist moisture penetration through condensation and bulk water penetration, one has to understand how vapor retarders, air barriers and weather-resistive barriers function. This article summarizes the functional aspects of these components.

Although the complexities of moisture movement through the exterior walls may not appear to be relevant to some SWR Institute members, it is important to note that many buildings being constructed today will soon require exterior wall remediation. As such, it is imperative that our industry understand how moisture movement affects the performance of the exterior walls, and where air barriers, vapor retarders and weather-resistive barriers can be used.

## Air Barriers

There are many factors that produce differential air pressure between the interior and exterior of a building. These factors include stack effect on tall buildings, mechanical pressurizations/ depressurization, and wind. Differential air pressure results in air movement through the building envelope. Research and experience has shown that the vast majority of moisture condensation within wall assemblies can be due to movement of moist air from the warm side of the assembly to the cold side of the assembly. As air moves through the assembly, it carries the humidity with it. Once the humid air reaches colder sections of the wall assembly, the humidity condenses. Since air can move large quantities of moisture, condensation associated with air movement can be very significant. In addition to potential problems with condensation, air movement through exterior walls also significantly reduces their thermal performance and energy efficiency.

Air barriers are primarily designed to prevent the movement of air through the building exterior walls. In many cases, the air barriers should not prevent moisture permeance *(See Sidebar on location of air barriers, vapor retarders, and weather resistive barriers)*. However, there are cases where an air barrier can prevent moisture permeance as well resist penetration of liquid water, functions primarily served by vapor retarders and weather-resistive barriers, respectively.

Although the 2006 (and prior versions of) International Building Code (IBC) published by International Code Council (ICC) does not require the use of air barriers in building exterior walls, their use has been previously mandated in Canada as of 1995. IBC adopts by reference International Energy Conservation Code (IECC) which dictates the use of vapor retarders, but not air barriers. Subsequently, a few states in the United States have also required the use of air barriers in exterior walls. With current trends in evolution of the model building codes, it appears that IBC will eventually mandate the use of air barriers in the future.

Air barriers come in a wide range of materials. The most popular air barriers have been in use in residential and commercial applications for many years. These air barriers (also known

In some cases, one product can serve as the weather-resistive barrier, air barrier and a vapor retarder. This photo depicts a spray-applied product intended to function as all three.

as building wraps) are mechanically fastened sheets, typically flash spun polyethylene. Other types of air barriers include self-adhered rubberized asphalt sheets and liquid-applied membranes of various chemical compositions. Performance criterion for air barriers are specified in various standards including ASTM E 1677 "Standard Specification for an Air Retarder (AR) Material or System for Low-Rise Framed Building Walls." Other standards such as ASTM E 2357 "Standard Test Method for Determining Air Leakage of Air Barrier Assemblies" help in the evaluation of wall assembly performance in controlling air movements.
There are several issues that need to be noted regarding the application of air barriers:

1. Some air barrier materials can also act as weather-resistive barriers. In some cases, they can act as weather-resistive barriers AND vapor retarders, as well as their primary function as an air barrier. As such, it is imperative that the wall designer evaluate the proper location of the air barrier within the wall assembly and specify the correct type of air barrier for the application.
2. Air barriers can only be effective if they are installed with all penetrations and seams laps. Unsealed penetrations or laps through air barriers can render them ineffective.
3. If an air barrier is also used as a weather-resistive barrier (such as a building wrap), all penetrations through it have to be sealed and properly flashed to resist water penetration.
4. Air barriers will have to be designed and installed to resist wind loads. While they are concealed within the wall cavity, wind loads can transfer to the air barrier causing it to separate from its substrate. This is particularly a problem with mechanically-attached air barriers. Typically, stapling a mechanically-attached air barrier will not be sufficient to do this.

### Vapor Retarders

All building materials except metals are permeable to water vapor (i.e., they allow movement of water vapor molecules through them when subject to differential water vapor pressure). This phenomenal is called vapor diffusion. Some materials such as polyethylene are less permeable than others such as CMU or gypsum. Certain coatings are less permeable than other coatings.

IECC defines a vapor retarder as a "A vapor resistant material, membrane or covering such as foil, plastic sheeting, or insulation facing having permeance rating of 1 perm ($5.7 \times 10^{-11}$ kg/PA.s.m$^2$) or less when tested in accordance with the desiccant method using Procedure A of ASTM E 96. Vapor retarders limit the amount of moisture vapor that passes thorough material or wall assembly."

Most common vapor retarders in construction include polyethylene sheets (typically 6 mils thick or thicker), aluminum foil and Kraft paper. Aluminum foil and Kraft paper are typically bonded to insulation materials to reduce installation costs.

Although vapor diffusion does not play as significant of a role in moisture control as air movement, the use of a vapor retarder in an exterior wall assembly has been required by many model building codes including IBC (Required by International Energy Conservation Code which is referenced in IBC). In its 2006 version, IECC (which is adopted by reference in IBC) requires the use of vapor retarders in cold climates with certain exceptions, including Climate Zones 1 through 3, cases where moisture or its freezing do not damage construction materials and where other means of condensation control in unventilated walls is provided. It should be noted that a vapor retarder can also act as an air barrier if all of its penetrations and terminations are properly sealed.

### Weather-Resistive Barriers

While vapor retarders and air barriers are intended to control moisture condensation within wall assemblies, weather-resistive barriers are intended to prevent the penetration of bulk water

## Where to Locate an Air Barrier, Vapor Retarder and Weather-resistive Barrier

Locating the air barriers, weather-resistive barriers and vapor retarders within a wall assembly should be performed by the designer. The proper location of these components is critical in thermal and moisture performance of the building envelope. Given the changing requirements of model building codes, building envelope designers should be thoroughly familiar with the building code requirements and industry standards regarding these components.

In addition, designers and contractors should be aware of the different performance characteristics of various materials that are marketed as air barriers, vapor retarders and weather-resistive barriers. As previously mentioned, there are many materials that can function as all three, or two out of the three.

To properly evaluate the performance of exterior walls that incorporate air barriers, vapor retarders and weather-resistive barriers, simple dew point analysis may not suffice. More sophisticated computer modeling tools can be used to better evaluate the potential for condensation within wall assemblies, and to predict moisture accumulation. The use of such sophisticated modeling tools is more critical when specifying new wall assemblies without long-term track records, or when specifying building envelope assemblies for special use buildings such as cold storage facilities and swimming pools. Buildings located in severely cold or hot and humid climates should also receive special attention during the design phase.

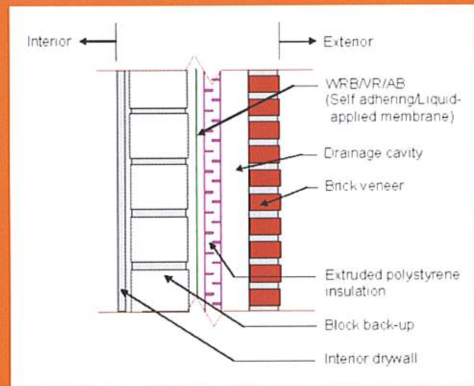



*Figure 1 – A conceptual wall assembly that resolves moisture condensation issues in combined climates where both warm humid and cold conditions are encountered.*

Although there are countless variations of exterior building assemblies that can perform satisfactorily in various climate conditions, the authors recommend considering a particular wall assembly that can perform well in all climate conditions. This assembly is depicted in Figure 1. As shown, a material that can perform as an air barrier, vapor retarder and weather-resistive barrier is installed on the exterior face of the back-up material and is integrated with all wall flashings. Many products such as self-adhering rubberized asphalt sheets or liquid-applied membranes and some mechanically-attached sheet membranes can perform this function.

Moisture-resistant insulation (such as extruded polystyrene) insulation is then placed on the outside of this layer. The drainage layer and cladding are then placed on the outer side of the wall assembly. While this wall assembly can add to the overall thickness of the wall, it presents several advantages. One major advantage is that the vapor retarder, weather-resistive barrier and air barrier are all combined into one material. Also, this wall assembly does not pose any risk of moisture condensation or accumulation regardless of the climate zone.

As previously mentioned, many other types of wall assemblies can provide adequate moisture performance. However, they are more susceptible to moisture condensation than the example provided above. For instance, in cold climates, the vapor retarder is typically placed on the warm side of the wall, directly behind the interior finishes. During cold weather, warm and moist interior air is driven toward the exterior, but is stopped by the vapor retarder. Since the vapor retarder is on the warm side of the insulation, the moist air will not condense.

On the other hand, during warm weather, the warm moist exterior air is driven toward the interior. Again, the vapor barrier stops the movement. However, since is it now on the cold side of the insulation, condensation can form within the wall. In this case, it is important that any weather resistive barrier or air barrier placed over the exterior sheathing be permeable (not act as a vapor retarder), to allow water vapor to escape the wall cavity.

For these reasons, proper placement of the vapor retarder, air barrier and weather-resistive barrier in the wall is critical.

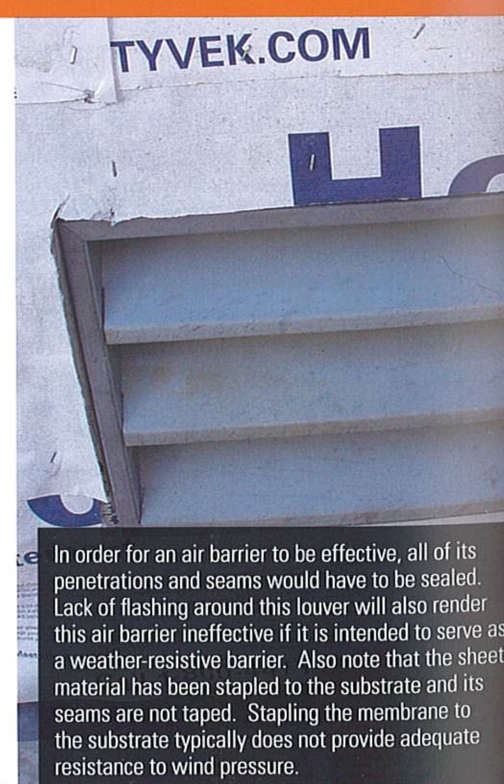
Asphalt saturated felt can be used as a weather-resistive barrier (but not an air barrier or vapor retarder). However, to function properly, penetrations through it should be properly flashed. In this photo, the louver penetration through the back-up renders the weather-resistive barrier ineffective where it is most susceptible to water intrusion.

through the exterior walls. As such, they are typically made of materials that can resist water and are not damaged by prolonged exposure to water.

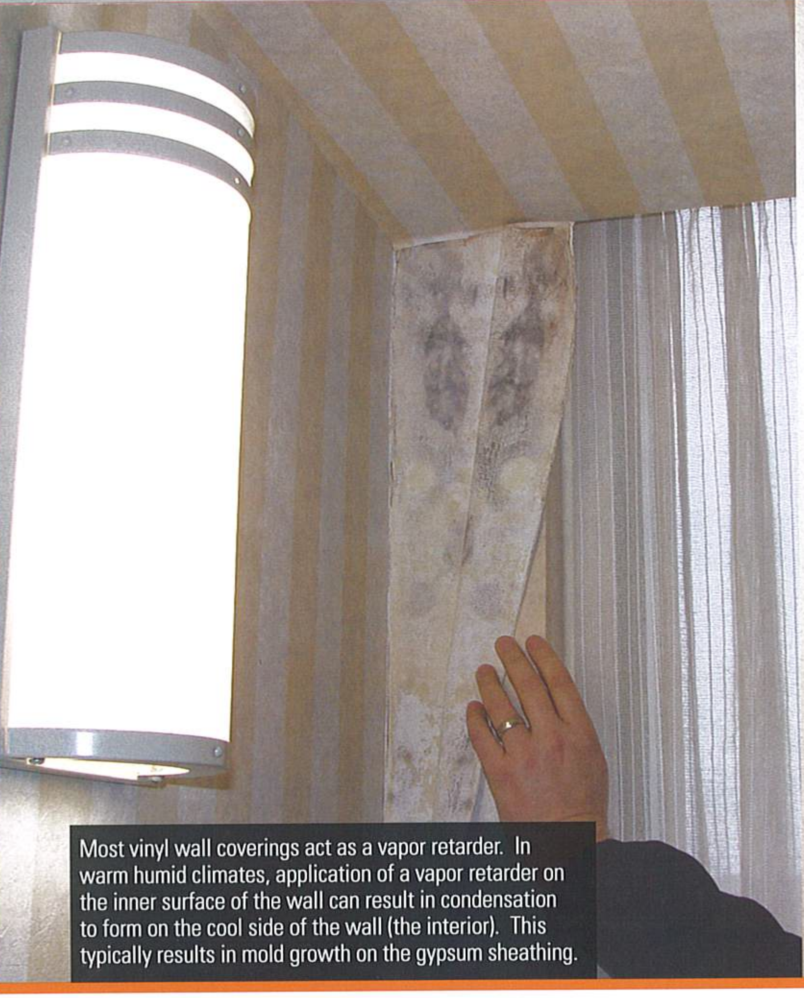
With the exception of certain types of walls (such as solid concrete or masonry walls) IBC requires the installation of a weather-resistive barrier in exterior wall assemblies with drainage provisions. Such weather-resistive barriers should be integrated with the mandated flashings to provide for *"a continuous weather-resistive barrier behind the exterior wall veneer"*.

There are many types of weather-resistive barriers. The most traditional type of weather-resistive barrier is asphalt saturated felt installed in a shingle fashion. Many of the air barriers available on the market today can also act as a weather-resistive barrier.

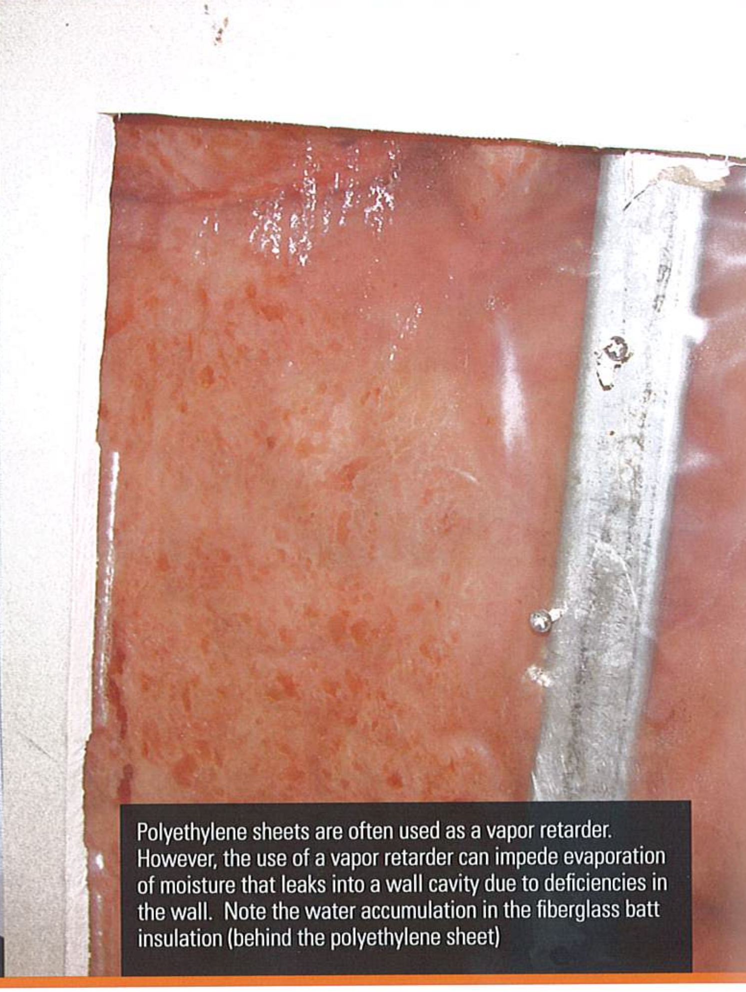
The weather-resistive barrier should be placed within the drainage cavity of the wall (typically




In order for an air barrier to be effective, all of its penetrations and seams would have to be sealed. Lack of flashing around this louver will also render this air barrier ineffective if it is intended to serve as a weather-resistive barrier. Also note that the sheet material has been stapled to the substrate and its seams are not taped. Stapling the membrane to the substrate typically does not provide adequate resistance to wind pressure.



Most vinyl wall coverings act as a vapor retarder. In warm humid climates, application of a vapor retarder on the inner surface of the wall can result in condensation to form on the cool side of the wall (the interior). This typically results in mold growth on the gypsum sheathing.



Polyethylene sheets are often used as a vapor retarder. However, the use of a vapor retarder can impede evaporation of moisture that leaks into a wall cavity due to deficiencies in the wall. Note the water accumulation in the fiberglass batt insulation (behind the polyethylene sheet)

attached to the back-up material) and integrated properly with the flashings and drainage system at various locations within the wall. The proper integration of the weather-resistive barrier with flashing materials is critical for providing good resistance to water penetration. The weather-resistive barrier, flashings and the drainage system should be considered as a system of various components that work together to prevent water penetration through the exterior walls. One method to envision proper installation of the weather-resistive system is to consider the exterior cladding as only a decorative layer, such that if the exterior cladding material is removed, water could still not penetrate the exterior walls.

In masonry cavity construction with CMU back-up, incorporation of a weather-resistive barrier on the back-up is important. While IBC does not clearly state that CMU back-up is required to have a weather-resistive layer, it is the authors' opinion that CMU is not a weather-resistant material and can absorb large quantities of moisture that can harm other building components including interior sheathing and insulation materials.

## Summary

With the emphasis on thermal performance of the building exterior walls, the proper design, selection, and installation of vapor retarders, air barriers, and weather-resistive barriers is important. While these three components are intended to serve three distinct functions, they can be combined into one or two materials depending on the properties of the material. Improper selection or placement of these materials can lead to moisture problems. The proper placement of air barriers, vapor retarders and weather-resistive barriers requires an analysis and understanding of the moisture movements through various wall components. Proper selection of the materials for these components also requires a thorough understanding of each material's physical properties.

## About the Authors

Kami Farahmandpour is the principal of Building Technology Consultants, PC. His expertise is concentrated in the evaluation and repair of building envelopes including various types of exterior walls, waterproofing systems, and roofs. Among his many professional activities, he is the past president of Chicago Area Chapter of RCI Inc., and is currently serving a three-year term as an Associate Director of Sealant, Waterproofing and Restoration Institute. He has published several articles on various topics related to building envelopes, and speaks routinely on topics related to building envelopes.

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