TECHNICALBULLETIN #16

AIR BARRIERS

Spray-applied liquid air barrier being installed over a gypsum-based sheathing.

INTRODUCTION

The movement of moisture[1] can cause problems with the performance of the building envelope through two mechanisms; condensation of water vapor and bulk water intrusion. As such, controlling the movement of moisture through the building envelope depends on controlling moisture vapor diffusion, limiting the unwanted movement of airborne water vapor, and preventing water penetration in liquid form.

While eliminating the risk of water vapor condensation within wall assemblies under all climatic conditions may be difficult, the goal should be to prevent water accumulation, and to ensure that short-term exposure to water does not affect wall components adversely. In order to understand the function of air barriers in exterior wall assemblies, one should understand the differences and common features of air barriers, water-resistive barriers, vapor barriers and vapor retarders.

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

Over the past several years, the design and construction of the building envelope 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. Other design and construction trends such as green construction have contributed to the attention air barriers have received.

Increasing the energy efficiency of the building envelope 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 of water vapor.

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 increasing energy efficiency and reducing water vapor condensation the design of exterior wall or roof assemblies must include provisions for controlling the penetration of bulk water (i.e., rain and snow melt).

For barrier type walls systems, (such as a face-seal non-drainable EIFS) the prevention of rain penetration is controlled at the outside face of the wall. However, in drainage type or pressure equalized rain screen wall systems (such as a masonry cavity wall), the wall requires a primary rain screen and secondary rain screen to control water penetration. The outside face of the masonry facade is the primary rain screen, the secondary rain screen is the water-resistant barrier located at the outside face of the interior wythe or back-up wall. The traditional masonry walls do not utilize 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.

To understand how exterior walls control water vapor movement, condensation and restrict bulk water penetration, one has to understand how thermal barriers, vapor retarders, air barriers, and water-resistive barriers function. This technical bulletin summarizes the functional aspects of these components.

Although the complexities of water vapor condensation and bulk water intrusion may not appear to be relevant to some building owners, 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 water vapor condensation and bulk water intrusion affects the performance of the exterior walls, and where air barriers, vapor retarders and water-resistive barriers can be used.

AIR BARRIERS

The Air Barrier is a series of components within the building assembly installed to effectively

1. Moisture can be found in form of bulk water or water vapor

Air barrier installed as a drainage plane in a cavity wall system.

Small defects in air barriers can lead to leaks, energy loss, and other problems.

resist the air movement through the building envelope and are a system: a combination of products and materials that create a continuous plane of air tightness. The air barrier system can be located anywhere within the building assembly. The more common and most effective location of an air barrier membrane is over the outside face of the sub-structure so as to achieve continuity and wrap the building assembly. In this location, a single system often functions as both an air barrier and as a water resistive barrier.

The primary function of the air barrier is to prevent the unwanted movement of air through the building envelope. By doing so, air barriers provide the following benefits:

• Reduces air movement through the wall assembly, thereby reducing the amount of water vapor that travels through the wall assembly and can lead to condensation.

• Reduces the unwanted movement of conditioned air and the infiltration of external air through the wall assembly, thereby reducing the amount of energy lost through the building envelope.

Air barriers can be designated as vapor permeable and allow vapor diffusion to occur. Subject to their location, air barriers may also be designated to be impermeable to bulk water and be the water-resistive barrier. Given consideration to these two performance objectives the air barrier is more often located in a location on the outside face of the back-up wall system. However, properly locating the air barrier in the wall assembly requires careful consideration.

In many cases, the air barriers should not prevent water vapor diffusion (see discussion below on air barriers, vapor retarders, and water resistive barriers). However, there are cases where an air barrier can resist vapor transmission as well resist penetration of liquid water, functions that are primarily served by vapor retarders and weather-resistive barriers, respectively.

Air moves through exterior walls with differential pressure. 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

• Wind

Differentials in temperature and water vapor concentration (water vapor pressure) also lead to gradients that cause air to move. Air will tend to move from warm to cold, and water vapor will tend to move from warm to cold and from high concentration to low concentration.

Research and experience has shown that the vast majority of water vapor condensation within wall assemblies can be due to movement of humid air from the warm side of the assembly to the cold side of the assembly. As air moves through the assembly, it carries the water vapor with it. Once the humid air reaches colder sections of the wall assembly, the water vapor has the potential to condense. Since air can move large quantities of water vapor, 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. This is further complicated by increased flow at small defects in the air barrier.

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 exterior wall constructions, there is an increased awareness on the part of building designers for the use of air barriers as it relates to long term wall performance and energy efficiency. As an example, the Massachusetts Energy Code, adopted in 2002 mirrors the requirements of the Canadian National Building Code to include measure to increase building performance.

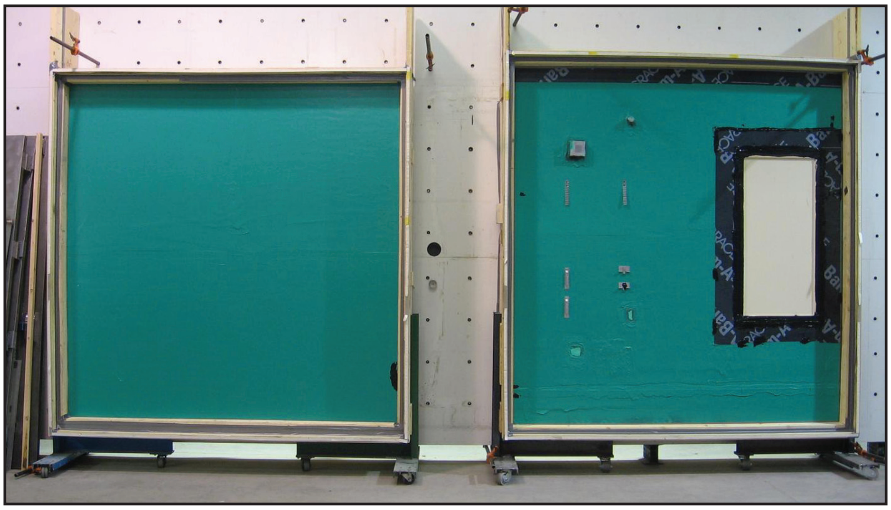
TYPES OF AIR BARRIERS

Materials for air barrier construction are either sheet applied membranes or liquid applied membranes. Sheet membrane systems can be mechanically fastened, self-adhered or torch applied. Liquid membranes are either solvent based or water based and may be elastomeric or cementitious in nature. Mechanically fastened air barriers (also known as building wraps) are typically spunbond polyolefin. Polyolefin building wraps were introduced as an alternative to roofing felt used as a sheathing paper or a moisture barrier in cavity wall construction. Installed in a traditional overlapping shingle manner, these wraps are predominantly used as "water-resistive barriers" that maintain a degree of vapor permeability.

While building wraps can be installed to function as air barriers, installation methods required to provide air barrier performance are more elaborate than is commonly employed with such sheet wraps. Self-adhered membranes are manufactured as either vapor permeable or non-vapor permeable. In the majority of conditions, a primer is required to condition the substrate surface prior to the placement of the membrane. Self-adhered vapor permeable sheet membranes are designed for the purposes of limiting air movement, allow the passage of water vapor and prevent bulk water intrusion. The typical location for the placement of vapor permeable air barriers is on the outside face of interior wall sheathing panels over insulated stud spaces. Self-adhered non-vapor permeable sheet membranes are designed for the purposes of limiting air movement, restricting vapor diffusion and prevent water intrusion. The typical location for the placement of non-vapor permeable air barriers is on the outside face of interior wall surfaces under the plane of insulation.

Torch applied membranes are manufactured as non-permeable air barriers, the use of torch applied systems have become less popular and seen as a risk for reasons of fire safety.

Liquid applied membranes are equally designed as either vapor permeable or non-vapor permeable. The conditions and locations under which they are installed run parallel with sheet applied membranes. Liquid applied membranes are typically not capable of spanning gaps, voids or connections of dissimilar materials. Therefore, liquid applied membranes usually require the use



Air barrier laboratory testing per ASTM E 2357 standard.

VAPOR IMPERMEABLE	0.1 or less
VAPOR SEMI-IMPERMEABLE	1 perm or less and greater than 0.1 perm
VAPOR SEMI-PERMEABLE	10 perms or less and greater than 1 perm
VAPOR PERMEABLE	10 perms or greater

of sheet membranes as transitions at such locations to insure continuity and integrity of the membrane as a system.

The Air Barrier Association of America has recognized and established ASTM E2178 "Standard Test Method for Air Permeance of Building Materials."as the base standard for air barrier performance. ASTM E 2357 "Standard Test Method for Determining Air Leakage of Air Barrier Assemblies" is a more aggressive standard to evaluate wall assemblies complete with connections and penetrations by applying air pressure differentials across the specimens in stages.

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 X 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.

The degree of membrane vapor permeability is classified as vapor permeable or vapor impermeable depending on hygrothermal region and location of the thermal barrier (insulating layer). Permeability ratings have been established by ASHRE to further classify the range of permeability (See Table 1, above).

Recognizing these values, products that have a permeance of less than 0.1 perms should be deemed a vapor barrier and should be placed on the warm-in-winter side of insulation. Products that have a permeance of 0.1 or greater to 1.0 perms should be deemed a vapor retarder as they allow a percentage of vapor to pass through the material and into the wall assembly. The term hydrothermal (The change in properties due to moisture absorption and temperature change) suggests that building materials within the assembly have the ability to absorb moisture and release it over time: dry out. Therefore, vapor retarders are ok as they allow limited vapor diffusion. Vapor retarders should be placed on the warm-in-winter side of insulation. Products with a vapor permeance greater 10 perms are "breathable", they allow moisture vapor to pass through them.

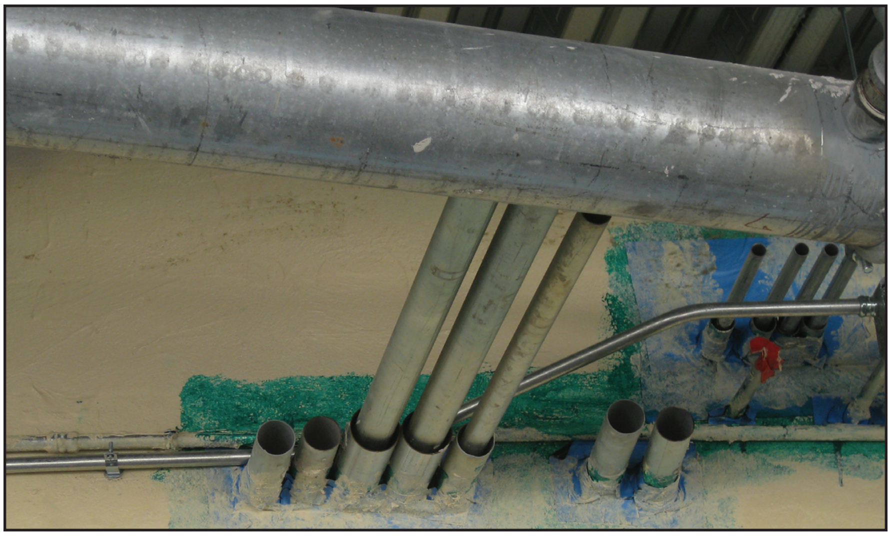
Although vapor diffusion does not play as significant of a role in moisture control as air movement, the use of a vapor retarder behind interior sheathing in an exterior wall assembly has been required by many model building codes including IBC[2]. In its 2006 version, IECC (which is adopted by reference in IBC) requires the use of vapor retarders in cold climates with certain exceptions[3].

WATER-RESISTIVE BARRIERS[4]

While vapor retarders and air barriers are intended to control water vapor condensation within wall assemblies, water-resistive barriers are intended to prevent the penetration of bulk water through the exterior walls. As such, they are typically made of materials that can resist water and are not damaged by exposure to water.

With the exception of certain types of walls (such as solid concrete or masonry walls) IBC requires the installation of a water-resistive barrier in exterior wall assemblies with drainage provisions. Such water-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 water -resistive barriers. The most traditional type of water-resistive barrier for wood frame and light commercial construction is asphalt saturated felt installed in a shingle fashion or building wraps as previously discussed. Many of the air barriers available on the market today can also act as a water-resistive barrier.



Achieving "continuity" of the water-resistive barrier can be difficult and detailing must be considered at locations such as pipe penetrations.

The water-resistive barrier should be placed within the drainage cavity of the wall (typically 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 water-resistive barrier with flashing materials is critical for providing good resistance to water penetration. The water-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 water-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 wall construction with CMU back-up, incorporation of a water-resistive barrier on the exterior face of the back-up is important. While IBC does not clearly state that CMU back-up is required to have a water-resistive layer, it is the authors' opinion that CMU is not a water-resistant material and can absorb large quantities of moisture that can harm other building components including interior sheathing and insulation materials.

WHERE TO LOCATE AN AIR BARRIER, VAPOR RETARDER AND WATER-RESISTIVE BARRIER

Locating the air barriers, water-resistive barriers and vapor retarders within a wall assembly should be performed by the designer. When a dew point analysis shows there is potential for condensation to occur within the wall assembly, choose a vapor permeable air barrier that will facilitate drying in both directions. The proper location of these components is critical in thermal, water vapor condensation, and water intrusion 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 water-resistive barriers. As previously described mentioned, there are many materials that can function as all three, or two out of the three.

In order to properly evaluate the performance of exterior walls that incorporate air barriers, vapor retarders and water-resistive barriers, simple dew point analysis may not suffice.

2. Required by International Energy Conservation Code which is referenced in IBC

3. Exceptions includes 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.

4. Water-resistive barriers are sometimes referred to as Weather-Resistive Barriers

Application of a spray-applied liquid air barrier over a gypsum-based sheathing, note the use of self-adhering sheet membranes used as flashings at the shelf angle.

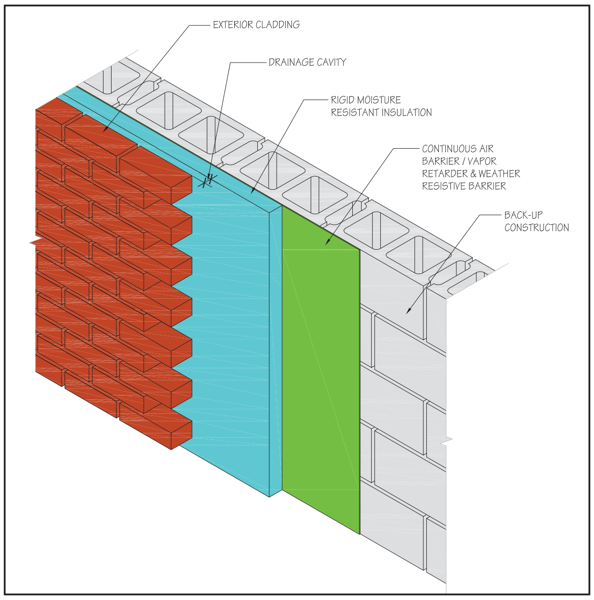


Figure 1

More sophisticated computer modeling tools can be used to better evaluate the potential for condensation within wall assemblies, and to predict water accumulation. Sophisticated modeling of vapor permeable air barriers have shown their suitability for use without external insulation in all continental US climates except the extreme coastal areas of the Pacific Northwest where the use of external EPS insulation modeled well[5].

The use of such sophisticated modeling tools is more critical 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.

Although there are countless variations of exterior building envelope assemblies that can perform satisfactorily in various climate conditions, some designers recommend considering the following wall assembly that can perform well in all climate conditions. This assembly is depicted in Figure 1 (above). As shown, a material that can perform as an air barrier, vapor retarder and water-resistive barrier[6] is installed on the exterior face of the back-up material and is integrated with all wall flashings. Water-resistant insulation (such as extruded polystyrene) insulation is then placed on the outside of this layer. The drainage cavity (air space) and cladding then complete 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, water-resistive barrier, and air barrier are all combined into one material. (Check with your local building inspector to make sure they agree the vapor retarder will satisfy the Code requirement when placed in this configuration. Since the code requirement was created to address migration of internal water vapor outward through batt insulation, some may require a vapor retarder behind interior dry wall. This would result in a double vapor retarder which would not allow the wall assembly to dry in either direction and which all agree is not acceptable.) Also, this wall assembly, when properly constructed without defects, does not pose any risk of water vapor condensation or accumulation regardless of the climate zone.

However, some designers take the position that non-design defects in construction should be anticipated and accommodated by the design. They have the concern that exterior insulation seams will not be or remain permanently taped and also that the external insulation will not remain laminated to the vapor retarder/water-resistive barrier/air barrier. This would allow the vapor retarder/water-resistive barrier/air barrier to cool below the dew point in the colder months and provide a basis for condensation inboard of the vapor retarder. Some are also concerned about thermal bridging through masonry ties creating cold spots on the vapor retarder under the insulation. So, these designers recommend a variant of the wall assembly described above that utilizes an air barrier that is vapor permeable rather than a vapor retarder. In such assembly, the extruded polystyrene acts as a vapor retarder to the extent it remains in place. However, in the event of air barrier cooling due to failure of taped seams, delamination, or thermal bridging, rather than having a vapor retarder exposed to winter cold on the outside and a warm and humid interior on the inside with resulting tendencies for condensation, the assembly is a forgiving one that is vapor permeable and will allow water vapor

5. See PROSOCO R-GUARD Technical Report – WUFI and Moisture Expert Demonstration of Successful Hygrothermal Performance through Computer Modeling at the U. S. Department of Energy's Oak Ridge National Laboratory.

6. Many products such as self-adhering rubberized asphalt sheets or liquid-applied membranes and some mechanically-attached sheet membranes can perform this function.

to exit the building, avoid condensation, and promote drying of the wall assembly.

As previously mentioned, many other types of wall assemblies can provide adequate 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 towards 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 towards 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 water 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 water-resistive barrier in the wall is critical.

CONSTRUCTION CONSIDERATIONS

There are several issues that need to be noted regarding the application of air barriers:

1. Some air barrier materials can also act as water-resistive barriers. In some cases, they can act as water-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 of the air barriers membrane system can render them the system ineffective.

3. If an air barrier is also used as a water-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.

SUMMARY

With the emphasis on long term thermal performance of the building exterior walls, the proper design, selection, and installation of thermal insulation, vapor retarders, air barriers, and water-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 water numerous problems including mold, mildew and deterioration of building materials, increased energy consumption and building maintenance.

The proper placement of air barriers, vapor retarders and water-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.

Proper selection of building materials, well written specification followed by detailed drawings will limit the risk and improve the construction phase.

Detailing of laps in the flashing of an air barrier.

Reinforcing a corner detail for a liquid applied air barrier which will also act as a flashing.

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