PSA Technology and testing requirements for water vapor permeable air barriers

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Abstract

There are a couple of reasons why you would want to have a more air-tight building: It will be more comfortable due to reduced drafts, have lower heating bills due to less heat loss, have fewer mold and rot incidences due to a lowered likelihood of trapped moisture and have a better performing HVAC system.

Air barriers have evolved from roofing felt creeping down the wall to protect the building, i.e. tar paper; and water proofing materials, polyethylene film with modified bitumen adhesive creeping up the wall. Whereas the building paper (nonwovens) are water vapor permeable, the self-adhered waterproofing membranes are water vapor impermeable. Until recently there were no self-adhered water vapor permeable membranes available on the market.

A major advantage with a self-adhered air barrier is that any installer made defects (holes, cuts or tears) are limited to the defect, air movement through the defect into other parts of the building is restricted due to the adhesive effectively blocking access to the rest of the wall, whereas a mechanically fastened material with holes allows complete access to the wall and the energy savings performance of the air barrier material and insulation is reduced.

This paper will talk about the adhesive technology used in the market today and the testing of the PSA and backing required for self-adhered water vapor permeable air barrier materials.

Introduction

With a growing world population and middle class, demand for conditioned buildings is increasing. Meanwhile the energy and sustainability megatrends are continuously affecting and improving the building code. Today, heating and cooling of buildings account for 40% of US energy use[1].

Adding air barriers to a building can reduce a conditioned buildings energy use substantially. Conditioned air leaking out of a building must be replaced with unconditioned outdoor air which requires energy to condition it. The different mechanisms for air leakage are due to pressure differentials across the building envelope, and these arise from

- wind loads generating higher pressure on the windward side and lower pressure on the leeward side of the building,
- stack pressures due to hot air rising, causing a higher pressure higher up in the building and a lower pressure at the bottom of the building and,
- heating, cooling and ventilation pressure differentials in a building.

There are a couple of different ways that water moisture can move through the building envelope, the first two being related to liquid water which are flow by gravity - water finding its way down the side of a building and potentially into the building, capillary - where liquid water is absorbed and moved through a porous building material due to capillary forces. These problems are often found quickly due to the large amount of liquid water that can move through the building materials. Moisture will also move through diffusion, albeit at a low rate that does not usually cause any problems. The most problematic moisture flow is through convective flows of moist air, where warm moist air condenses on a cooler surface and creates an environment that is conducive to mold and rot. This is the area where a well-designed wall assembly with an air barrier is most effective at mitigating hidden moisture problems. An air barrier will also protect against the first two water intrusion cases by forming a continuous barrier that prevents water from entering the structure.

Approximately 30% to 50% of space conditioning energy consumption in many well-insulated buildings is due to air leakage through the building enclosure(2). Air barriers not only reduce the energy costs of a conditioned building, but properly designed and installed they also eliminate the risk of mold growth and structural degradation.

Types of Air Barriers and their construction

The use of roofing membranes to provide additional water leakage protection is intuitive, but water shedding on vertical walls, even though it seems like it would not be necessary as there is cladding on the finished wall, is also very important. It started with tar paper coming down from the roof underlayment as a wind shield, asphalt based materials were introduced from the adjacent foundation water proofing as a means to better seal the walls and prevent water and air intrusion. Combination of the two led to the air and vapor barrier materials in the form of 4 mil polyethylene film with 36 mils of modified bitumen based adhesives. The air and vapor barrier materials are almost all the same, the same exact film with slight variation in the adhesives between the products. But these all require priming and can only be applied in above freezing temperatures. There is one product on the market which consist of a 5 mil multilayer self-sealing film with 5 mils of high performance acrylic adhesive that can be applied in temperatures as low as 0 ºF. This somewhat natural evolution of materials have dominated the commercial air barrier market over the last couple of decades, especially in Canada where the adoption of energy efficient building codes has been years ahead of the US. Fortunately, the US is starting to catch up, but there is still difference state to state with respect to requirements and testing of finished buildings.

The wall assembly, placement of insulation in the wall and climate dictate which type of air barrier to use. The air and water vapor barriers do not work in all wall types, which has forced the development and adoption of water vapor permeable air barriers for such wall systems. In contrast to the vapor barrier membranes, the water vapor permeable air barriers are all different in how they are constructed. Whereas you get the benefit of two non-permeable materials in the vapor barrier product construction, the vapor permeable products are stacks or composites of multiple somewhat vapor permeable materials, where the adhesive usually is the least permeable layer. These composites can be modeled as resistors in parallel where the total resistance is equal to the inverse of the sum of the inverses of the individual component resistance.

$$\frac{1}{Permeability_{Combined}} = \frac{1}{Permeability_{Component1}} + \frac{1}{Permeability_{Component2}} + \frac{1}{Permeability_{Component3}} + \ldots$$

Therefore if one individual component in the air barrier material has a high resistance to water vapor transmittance, the whole air barrier membrane will have a high water vapor resistance, or very low permeability.

When investigating the product construction of water vapor permeable self-adhered air barrier membranes, one finds that the majority of the products consist of a spunbond nonwoven, a water vapor permeable air and water barrier layer and an adhesive layer. The spunbond nonwovens strength layer(s) are open to air flow and therefore have very high water vapor permeability and no barrier properties, the water vapor permeable air and water permeable layer has significantly lower water vapor permeability, but are designed to achieve the desired permeability of the full product construction while also blocking air flow and liquid water. The greatest water vapor resistance is usually that of the adhesive layer. The more nonpolar the adhesives are, the lower the permeability. A workaround for these non-permeable adhesives is to create discontinuous coatings of the adhesives where the non-coated areas serve as conduits for water vapor thereby reducing the overall water vapor resistance of the adhesive layer. The discontinuous adhesives have been utilized in the medical field for a long time to reduce maceration under bandages and wound dressings and these technologies are directly applicable here. The main difference however is that the air barrier products need a thicker adhesive and higher adhesion levels than what is desired for a medical wound dressing, so the same coating technologies are not necessarily applicable. There are water vapor permeable adhesives on the market today, but they usually are not performing as well as the non-permeable versions, resulting in lift off of the product and poor lap adhesion levels.

While a few producers supply self-adhered water vapor permeable materials that do not require a primer, most require priming of the substrates prior to application. In addition to creating an extra step in installation, the use of a primer can affect the permeability of the wall assembly adversely. The newer air barrier materials with acrylic based adhesives achieves high and low temperature application, long term adhesion, and performance without the priming step, but they do for the most part require discontinuous coatings in order to achieve the desired permeability.

Air Barrier Material and Assembly Testing

To qualify as an air barrier there are a couple of standard tests that the material needs to meet in addition full wall assembly testing. Table 1 discloses some of the important requirements of air barrier materials. The first set of requirements pertain to product essentials: The air barrier material needs to not leak any air through the material, secondly it should not allow for any liquid water to pass through the material and lastly the vapor permeable materials need to be able to pass water vapor through the material at rate greater or equal to 10 US Perms.

Vapor Permeable Self-Adhered Air Barrier Material Requirements:

Property Measured	Test Standard	Requirement
Air Permeance	ASTM E2178	<0.02 L/m^2*s
Water Resistance	AATCC 127	>22 in
Water Vapor Permeance	ASTM E96	>10 Perms
Lap Adhesion	AMAA 711-05	>18 oz/in
Peel Adhesion	AMAA 711-05 ASTM D3330	>18 oz/in
Nail Sealability	ASTM D1970	Pass
Assembly Air Permeance	ASTM E2357	<0.2 L/m^2*s
Fire Testing	NFPA 285/ASTM E84	Pass

Table 1: Test methods for self-adhered air barrier materials

Self-adhered air barriers need to stay attached to the wall after they are put up, and also withstand pull off forces incurred by the stack effect or pressure differentials across the building envelope for their life time. Additional features that are requirements for these materials is that they self-seal around nails that are driven through the material, something that can be hard to achieve for the vapor permeable air barriers. For the more traditional non-permeable materials, with polyethylene films and 36 mils of adhesive goop, the test is not hard to pass as the adhesive flows and seals around the nails, the one thinner product on the market has a multi-layer film that self-seals around the nail, not relying on the thick adhesive to do the work. The vapor permeable products consisting of nonwovens, very thin films and thin adhesives (<10 mils) have a much harder time passing the nail sealability tests. Most of the products on the market claim to pass this test.

The ASTM E2357 test method is intended to simulate the performance of various air barrier materials/accessories when combined into an assembly and measures the air leakage of a standardized air barrier assembly before and after exposure to specific pressure cycles. The test procedure measures and compares the air leakage through an 'opaque' or blank non-penetrated wall assembly and the air leakage through a wall assembly with pipe penetrations, brick ties, electrical boxes, foundation transitions and lap seams and flashings. The walls are subjected to extreme positive and negative wind load conditions and the measured air leakage recorded. If the measured air leakage rate passing through the wall with penetrations is greater than 10% of the opaque wall, the assembly fails. If the air leakage through the opaque wall is greater than 0.2 l/(s m^2) at 75

Pa pressure differential, the air barrier assembly fails and the material cannot be considered an air barrier.

Some of the material properties that will not be covered in this paper that are often declared for air barrier products are the tensile, puncture and tear properties. These properties are extremely important to mechanically fastened materials as these move with the wind and with differential pressures across the membrane and have a tendency to tear or rip in high winds when they are not seemed properly. For a material that is intimately bound to the sheathing material of the wall, these properties are not that relevant as they do not experience those forces or situations when they are applied to the wall.

Methodology/Experimental

The objectives of these experiments were to compare various membranes and their properties.

<u>Air Permeance</u>

Since all materials used in this market pass the air barrier materials requirements, there is little use in comparison of these properties as the differences would be miniscule. The maximum air leakage under the test pressures is equivalent to a hole the size of 1/8" x 1/8", so provided the various bonded, extruded or coated layers don't have any defects, this is an easy test to pass.

<u>Hydrohead</u>

The same goes for the water resistance as spelled out per the AATCC 127 test method, which is a static test run for 5 hours at 22" water column. A substitute for testing of this property that facilitates rapid screening of multiple samples utilizes an automatic hydrostatic test machine such as the Textest FX3000. This machine detects when enough water pressure has been applied to allow for liquid water to penetrate the membrane, resulting in droplets of water forming on the other side of the membrane. Once three droplets have been detected, the test is complete. This test is essential to reducing water problems that are due to gravitational or capillary flows of water, even if liquid water is running down the building envelope surface.

Sample ID	Hydrohead (Inches water)
White	64
Orange	141
Blue	81
Green	18

Table 2: Hydrohead Pressure Resistance

Even though all of these samples passed the static 22" water test for 5 hours without any water penetrating, the dynamic test shows that there are substantial differences between the different products' performance.

<u>Water Vapor Permeance</u>

This is a test where a change in weight of a sample protected by the air barrier under constant temperature and humidity. In the dry cup test, the weight gain of a desiccant in a petri dish covered by the air barrier in a constant temperature and humidity (CTH) room

is recorded over time. In the wet cup test, the weight reduction of a wet sponge in a petri dish covered by the air barrier in a CTH room is recorded over time.
For air barrier materials, the most relevant method for measuring the water vapor permeance is the wet cup method, as it is related to how quickly a moist material can dry out. The wet cup usually has a higher permeance value than a dry cup measurement.

Adhesion tests

The true differentiator between the different products lies in their adhesion. The adhesion tests are very important as they ensure that the air barrier materials applied are continuous, i.e. the material is held in place and the seams are holding together. If this is not the case, the air barrier becomes discontinuous and convective flows of moist air can cause substantial problems in the building over time and the effectiveness of the insulation will be reduced.

The peel adhesion value ensures that the material won't peel back or fall off the wall. The adhesives on these materials don't need much shear strength, as they only need to hold the backing stuck to the wall. What is more important is that the material does not peel off the wall if it is not stuck down well enough from the start.

The lap adhesion ensures that the material sticks to itself well enough to create a seal at each of the seams between different laps of the air barrier material. These materials are put up in a shingled fashion in order to ensure that water drains off the surface. A two inch overlap is the standard recommendation for all products on the market.

The pull adhesion test ensures that the material sticks well enough to the building substrate so that it can withstand the pressure differences discussed in the introduction section. If the material does not stick to the building well enough during high wind loads, then the material can be lifted off the building to create discontinuities in the air barrier, leading to air leakage, water penetration and poor performance of the building.

When considering air barrier materials, most of the products meet all the basic requirements of being an air barrier, water barrier, water vapor permeable (though getting adequate permeability is hard with a continuous layer of adhesive which also meets low application temperature needs). The deciding factor often comes down to how well the material sticks to the building substrates and how compatible it is with other building components or accessories.

Sample ID	Peel Adhesion Oz force/ inch			
	Concrete	Densglass	Plywood	Lap
White	63	76	43	32
Orange	29	30	30	16
Blue	35	41	18	36
Blue Primed	122	92	77	X
Green	53	43	35	46
Green Primed	69	97	107	X

Table 3 Peel adhesion

Table 3 discloses peel values of leading products on the market. While some of them don’t require a primer, adhesion levels are relatively low, but still above the minimum requirement. The blue and green samples require a primer, so comparing the data values for the unprimed samples might not be fair, so the primed values are also incorporated in the table. When the substrates are primed, adhesion levels are excellent.

To prime or not to prime…

The 40 mil non-permeable air barriers all require a primer, or spray on adhesive in order to get the “self-adhered” air barrier to stick to the wall in all but optimal conditions. The minimum application temperature for all of these is 40 ºF. Until recently that has been the only option for these products, but there is one new product discussed earlier that does not require priming for the non-permeable application and can be applied at 0 ºF. For non-permeable systems, it is not an issue to have additional layers of adhesive on the wall as it would only reduce the permeability of the air barrier. Table 4 describes some of the manufacturer’s minimum installation temperatures and primer requirements for the vapor permeable products.

Sample ID	Minimum Application Temperature	Priming Requirements		
	(ºF)	Concrete	Densglass	Plywood
White	0	No	No	No
Orange	20	No	No	No
Blue	40	Yes	Yes	Yes
Green	40	Yes	Yes	Yes

Table 4: Low temperature application data and priming requirements

The application of a primer adds, extra cost, labor, a tight installation window due to primer drying and open time, VOC and messes to clean up. It also requires additional skill by the applicator to ensure that appropriate amount of primer goes on, different building substrates absorb more or less primer due to surface area and morphology differences. Application temperature is also affected when utilizing a primer system. If low VOCs are desired, then water based primers are the only choice and application temperatures over 32 ºF is needed. When considering vapor permeable products, it is also imperative that the surface does not gets covered by an additional layer of impermeable adhesive thereby reducing the water vapor permeability of the assembly.

Summary

There are many required tests for the self-adhered water vapor permeable air barriers, and new products are coming out meeting these requirements. As long as the air barrier material meets the minimum requirements for the above tests, user experience and the architect’s confidence and experience with installation on buildings is what really sells the product into this market space. The true differentiator between products will appear in adhesion levels, durability and ease of application of the product.

The argument for priming often is that the substrate is “cleaned” by the primer prior to application, and that adhesion levels go up. These claims are irrefutable, but with acrylic adhesives, some of the adhesion level concerns diminish.
Canada is still years ahead of the US in terms of durability testing of these materials as part of code requirements. Canada ULC-S741 Is very similar to the ASTM D2178, but it also includes a heat aging and UV exposure portion which provides some more long term durability confidence for the products which are expected to last for at least 50 years. There is still room for improvement and efforts are ongoing in different standard setting organizations to improve durability testing to ensure that the products meet long term performance expectations.

In terms of ease of application, the holy grail of air barrier products would be a self-adhered linerless product that can be installed in any weather without a primer. More and more air barrier manufacturers are coming out with acrylic based adhesives which do not require priming. A current deficiency of many products on the market today is low (and high) temperature adhesion, especially for the products that require priming since they can only be applied at above freezing temperatures. All products require that temperatures remain over the minimum installation temperature for 24 hours after installation. This requirement effectively prevents application of self-adhered air barriers on job sites in the northern US and Canada for many months of the year. All products on the market today require a dry surface for application, which eliminates any days with rain for application of air barriers on walls, a product with wet stick capabilities would be desired to make the installation of air barriers something that can be done in any weather.

Achieving a linerless product that also meets lap adhesion requirements is virtually impossible and there are no products like it on the market to date. The handling of the air barrier and release liner essentially makes the installation a two person job, so anything that can be done to simplify the installation is worth a lot of money where labor costs are high. The unwind force of a linerless product of 16” width (normal product widths are 30” or greater) meeting the lap adhesion requirements of 24 Oz/in is greater than 24 pounds, which would be impossible to apply. A recent product introduction that meets all of the air barrier requirements has achieved a pseudo linerless application by temporarily bonding the liner to the backing. The product can be applied to the building structure with a low unwind force, without having to handle both the roll being applied and the release liner at the same time. Once the product has been applied to the wall, the liner can be removed quickly and with low force.

References:

1: *Energy Efficiency Trends in Residential and Commercial Buildings, US DOE*
2: *BSD-014: Air Flow Control in Buildings, John Straube, October 15, 2007*