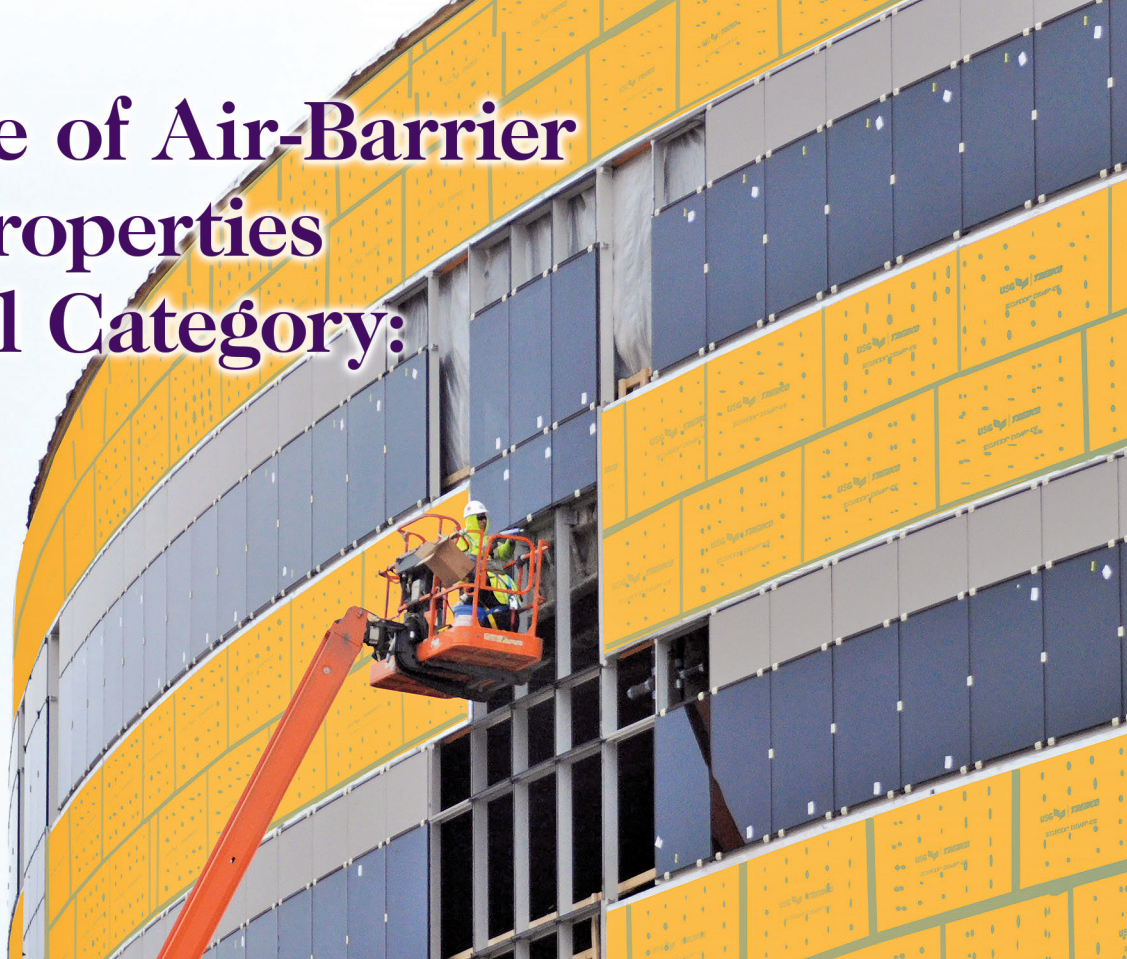


Importance of Air-Barrier Material Properties by Material Category:

What You Need for Them to Work

By Ryan Dalglish



IN THE BEGINNING

In the beginning there was nothing! In 2000, air barriers were a new concept for the building industry across the United States. Even in 2006, when I would call a design professional firm and invite them to a seminar on air barriers, the response was first a pause, and then the person would say, “What’s an air barrier?” There was also major confusion surrounding air barriers, vapor barriers, and water-resistive barriers (WRBs). As I traveled the country, the focus was on educating everyone on what an air barrier is, how it is used, and the benefits of installing an air barrier in the building enclosure.

Over the decades, this has changed. Now as I travel the country, everybody says, “Of course you need an air barrier; everybody knows that.” However, there is still confusion surrounding air barriers, vapor barriers, and WRBs and the functions they provide.

When air barriers were referenced in the *International Energy Conservation Code* (IECC), it was shown that an airtight building could save between 10% and 40% of the energy used to condition the air in the building. As such, everybody related air barriers only to energy efficiency and energy use reduction. People have overlooked the fact that air barriers provide more benefits than simply reduced energy use.

AIR-BARRIER HISTORY

It has been suggested that the work on air barriers began at the University of Minnesota in the 1940s, where they tried to determine why we were getting water in our walls. My understanding is that this work led to the use of #15 felt as a WRB on walls. In those days, the #15 felt was actually felt soaked in asphalt so that the weight of the material was 15 pounds per 100 sq. ft.

With a WRB being installed on the exterior of walls, the amount of water that entered the wall assemblies was reduced but not eliminated. In the 1960s we started putting more insulation into walls, and this was accelerated in the 1970s as the government implemented programs to reduce energy use because of the OPEC oil embargo. In cold climates, people were finding frost and ice in the wall cavity in the winter, which obviously could not be water entering from the exterior.

The building industry jumped on a vapor-barrier bandwagon to solve the problem, as people thought it must be the water vapor inside a building working its way through the different building materials into the wall cavity and then condensing. They were partially right, as the liquid water in the cavity was caused by warm, moist air from the interior getting into the building cavity—but not due to the water vapor transmission rate.

Buildings with a vapor barrier installed were still subject to moisture problems in the walls. In the 1980s, work was done by the National Research Council (NRC) on why moisture was still being found in building assemblies. It was then recognized that air leakage was the chief cause of the moisture problems in the building enclosure. Many research papers were written in those days and, as physics does not change, those papers are still relevant today.

This research showed that an air barrier in the building enclosure (**Fig. 1**) was critical for the reduction of moisture problems in a building. In 1990, a requirement for an air barrier was introduced into the National Building Code of Canada (NBC). The requirement was for the material to have an air leakage rate of 0.02 L/s-m² at a pressure difference of 75 Pa (0.004 cfm/ft² at a pressure difference of 0.3 in. of water). No reference was made to a test method to determine this, and there were no requirements for the air leakage rate of an air-barrier assembly. It was taken that if the material had a maximum air leakage rate, then the building would have the same air leakage rate.

The important thing was that it was finally recognized that to reduce moisture problems in the building enclosure, you required an air-barrier system (all six sides) to provide moisture management.

BENEFITS OF AN AIR BARRIER

An air barrier provides many benefits in addition to reducing the energy use in a building. These benefits include:

- Managing moisture
- Improving fibrous insulation performance
- Reducing air leakage between a window and the rough opening that cools the window frame, resulting in condensation
- Controlling sound
- Abating odors
- Improving HVAC efficiency
- Reducing the amount of pollution that enters the building
- Reducing the number of insects that enter the building

REQUIREMENTS FOR AIR-BARRIER SYSTEMS

The requirements for air barriers are simple, but some are hard to meet. They are:

- Impermeable material (stops air from going through the material)
- Continuous (this is hard to achieve on the construction site, as you cannot see air leaks)
- Strong (resists positive and negative loads or transfers loads to substrate)
- Durable (no standardized test is available for accelerated aging or abuse during construction)

The material property for the air leakage rate is relatively easy to meet and is confirmed through testing done by the manufacturer.

The next requirement (continuous) needs to be addressed on the construction site by an installer who may or may not be properly trained. A building enclosure will leak at the joints, junctions, and terminations, so the installer has the greatest impact on the air leakage rate.

The requirement for strength goes back to the manufacturer; either the material should have the strength to resist the loads applied, or the material should transfer the loads to the substrate. The strength requirement also involves not having the material displace any of



Figure 1. Installed air barrier.

the materials adjacent to it, such as insulation in the wall cavity. An example of this is a flexible membrane (such as a polyethene film) installed on the interior over the studs and insulation and then covered with sheetrock. On the interior side of the polyethene film, as it is up against the sheetrock, the loads can be transferred to the sheetrock. The other side of the polyethene film can be against a fibrous insulation, which can be compressed. When the loads are exfiltrated, the polyethene film does not have the strength to withstand the loads, and the polyethene film will compress the insulation. As the loads on the polyethene film are dynamic, the material will stretch where the fasteners are installed and will create a hole in the polyethene film, which compromises the air-barrier function of the material.

The same applies to mechanically fastened membranes on the exterior of the building. Installation instructions for these materials require 2-in.-diameter plastic-head nails spaced close together. A typical fastening pattern is 16 by 12 in. Even with this close fastening pattern, the material will billow between the fasteners.

Durability over its service life requires a combination of material performance (i.e., how

well the material retains its properties) and proper installation. The industry is currently working on a standardized test method for accelerated aging of materials. The material is typically subject to ultraviolet (UV) exposure, heat exposure, and moisture exposure. Additional tests may include freeze-thaw, chemical resistance, etc. The durability tests will vary depending on the material being tested. An ASTM standard is being developed in the ASTM E06 Committee, but there currently is no agreement on the requirements. As most air-barrier materials are installed in the wall cavity, they can be subjected to extreme conditions. Wall designs where the insulation is installed on the exterior of the air barrier and WRB somewhat protect the air-barrier and WRB materials, but we still cannot predict the life expectancy of installed materials.

IMPORTANT MATERIAL PROPERTIES

If you only look at the functions of an air-barrier material (not the air-barrier system), it is relatively easy to meet the air leakage rate requirement. However, each material also needs specific material properties that define whether that material will perform as intend-



Figure 2. Peanut butter air barrier.



Figure 3. Torch-applied air barrier.

ed. These requirements will be in addition to the air leakage rate of the material. The air leakage rate can be met with thousands of materials, but you may not want to use many of those materials in an air-barrier assembly.

In my presentations, I used to say that if air leakage is the only requirement for an air-barrier material, you can meet that using Jell-O or peanut butter. A testing lab finally agreed to conduct an ASTM E2178 test on peanut butter for me (Fig. 2). As an air-barrier material, the result was about one-tenth of air leakage rate allowed. Even so, this material has a lot of benefits—it can be grown continuously and for many projects, within 100 miles of the construction site, is recyclable (eatable), environmentally friendly (unless you have a peanut allergy), and so on. The bottom line is that you need to identify more material properties than simply its air leakage rate when choosing a material to become part of an air-barrier assembly.

These additional material properties ensure that the material will perform as intended in providing an air-barrier function. A well-developed material specification will include a list of material properties important to the

performance of the material, along with test methods to determine those properties and set a performance requirement.

As an example, for medium-density, rigid, closed-cell spray polyurethane foam (SPF), the most important quality is dimensional stability. There are many other properties that the material needs to have, but the critical one is dimensional stability. A spray foam material

that is not dimensionally stable can have “thermal cracking.” This term has been used for materials that are not dimensionally stable that crack or shrink when the temperature or other environmental conditions change—especially if they change quickly. The thermal cracking that I have heard sounds like a rifle shot. If the material cracks or shrinks, you have lost the air-barrier function of the material.

NEED TO REVISIT THE TYPES OF MATERIALS

In the early 2000s, the most common material used as an air barrier on walls was thermal-fusible or torch-applied (Fig. 3). This was roofing material being marketed as an air barrier. This material performed well—especially when installed on concrete masonry units (CMUs), as the liquid asphalt would flow into the CMU itself and have an extremely high adhesion value. This material is now rarely used across the country because it uses an open flame on the construction site.

The next development was self-adhered membranes, and the first materials were a modified bitumen on a polyethylene carrier sheet (Fig. 1). This increased productivity during the installation process, as you did not have to heat the material to a melting point. Both materials had been on the market for decades, and the material performance was not questioned. There were installation issues over the years, but these were identified and addressed.

As the air-barrier industry grew, new materials came on the market. The use of fluid-applied air barriers increased. The material evaluation process used by the industry was somewhat restricted. The direction provided to manufacturers who brought out a new material was that they needed to fit into an existing category established by the industry. This resulted in materials being evaluated to requirements that were not meant to be used for those specific materials.

The industry realized that trying to establish performance requirements for each new material on a one-off basis would result in a long list of separate material specifications. It was decided to step back and look at all the materials that could be air-barrier materials and then group them together. This work was led by Roy Schaufele, who has extensive experience in both the air-barrier industry and the roofing industry. Under his direction, a more holistic approach was taken to group similar materials together.

DEVELOPMENT OF CATEGORIES OF MATERIALS

It was recognized that there could be a group of materials that were similar but not exactly the same. An ad hoc committee drafted a potential list of categories for materials. The focus was on performance of a material rather than prescriptive requirements. Once a list of categories was established, existing materials were inserted under the appropriate category. As the list of materials under a category was reviewed, it became apparent that the materials

in a category may not have exactly the same material performance requirements. Each category was then subdivided into types when different material properties were required.

This work established different groups of materials (categories) and, within each category of similar material, a separation of the materials into types. The types were established where either different material properties were required or where different performance levels of a property were required. The goal of the exercise was to reduce the size of the list of

material specifications. First, it was determined whether a material could fit an existing type. Where that was not possible, a new type was established.

This all sounded like a quick and easy exercise, but as the work progressed, we found that there was a lot of discussion on where to place various materials and what the description of these materials would be.

The result of this work produced a category/type listing for air- and water-resistive barriers.



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Figure 4. Fluid-applied air barrier.



Figure 5. Self-adhered air barrier.

1. Building Wrap

Commercial building wrap is a flexible sheet air-barrier material intended to be attached mechanically or sandwiched between two other materials, supplied as a roll.

A. Mechanically Fastened

This is a non-adhered flexible sheet material, mechanically attached to structural element(s) with fasteners able to transfer the design loads to the structure. The mechanical fasteners need to withstand both the positive and the negative loads. This material is also a WRB, has a relatively high water vapor transmission rate, and is intended to be installed on the exterior of a building. This material is thermoplastic and is produced in both scrim-reinforced and non-scrim-reinforced, and it is supplied as a roll good.

B. Sandwiched

These materials are intended be sandwiched between two supporting materials (such as two layers of gypsum board), which provide the structural support needed to withstand the loads in an air-barrier application. This material has a relatively low water vapor transmission rate and is not intended to be installed on the exterior of a building as a WRB. These materials are normally polyolefin-based or nylon-based.

2. Fluid-Applied Materials

Fluid-applied materials (Fig. 4) are installed over structural elements by spraying, rolling, or troweling. The material needs to be installed over a structural element when used in an air-barrier application.

A. Membranes

Membranes are materials that can be installed on a release material and then removed for testing.

B. Coatings

Coatings are materials installed on a structural element and, therefore, the structural element is included in the testing.

3. Fully Adhered Sheet Membranes

Fully adhered sheet membrane material is a factory-manufactured flexible sheet that is self-adhering and has a release paper on one side to protect the adhesive until installation. The material needs to be installed over a structural element to be used in an air-barrier application.

A. Bitumen-Based

Bitumen-based fully adhered sheet membranes (Fig. 5) are typically produced on a bitumen base material that has a carrier sheet for handling and installation.

B. Polymeric-Based

Polymeric-based fully adhered sheet membranes include a layer of adhesive on one side of a polymeric material.



Figure 6. Gypsum board stock air barrier.



Figure 7. Spray foam air barrier.

4. Masonry/Stone Composite

Masonry or stone composite is a combination of a masonry/stone unit and mortar.

5. Panels

Panels are materials that are factory-made and then shipped to a construction site for installation. The sizes of the panels can vary in thickness, length, and width. Panels will typically be exposed to weathering and need to be aesthetically pleasing.

A. Metal Panels

Metal panels are manufactured in a plant with one or both sides of the panel being metal.

- a. **Insulating** (R-3.5/in. or higher)
- b. **Non-Insulating** (R-3.49/in. or lower)

B. Composite Panels (non-metallic)

Composite panels are a system of materials made up of one or more materials that are manufactured, tested, and sold as a single product.

- a. **Insulating** (R-3.5/in. or higher)
- b. **Non-Insulating** (R-3.49/in. or lower)

C. Precast Concrete Panel

Concrete panels are preformed at

a factory in a variety of sizes and shipped to the jobsite.

- a. **Insulating** (R-3.5/in. or higher)
 - I. Internal to Concrete
 - II. Precast Sandwich Panel (insulation between two poured concrete panels)
 - III. External to Concrete

6. Sheathing Materials

Sheathing materials are structural elements that are installed over framing or another substrate and will withstand the load applied to them during the life of the building and transfer this load to the superstructure. The material is manufactured in various thicknesses and sizes.

A. Insulating (R-3.5/in. or higher)

B. Non-Insulating (R-3.49/in. or lower)

C. Factory Composite (Air-barrier material applied directly to the face of sheathing at the factory) (See Fig. 6.)

- a. **Fluid-Applied Membrane**
- b. **Sheet Membrane**
- c. **Foam Plastic**

7. Spray Polyurethane Foam

Spray polyurethane foams are composed of two fluid materials that are combined on site under heat and pressure. The combination is then sprayed onto the surface. Depending on the

spray foam material type, the combined materials will expand to between 30 and 100 times their original thickness when sprayed. The material needs to be installed over a structural element, and is used in an air-barrier application. Because the materials are combined on site, the qualifications of the installer are critical.

a. Open-Cell Light-Density Semi-Rigid SPF

This material is a specific type of SPF that has a density of 6.8 to 12 kg/m³ (0.43 to 0.75 lb/ft³) nominal, with a minimum of 80% open cells. It is typically called “half-pound foam” and can be the air-barrier material and a heat barrier (thermal insulation). The material is not a WRB but is a class of vapor retarder.

b. Open-Cell Low-Density Semi-Rigid SPF

This material is a specific type of SPF that has a density of 12.1 to 27 kg/m³ (0.76 to 1.70 lb/ft³) nominal, with 80% open cells. It is typically called “one-pound foam” and can be the air-barrier material and a heat barrier (thermal insulation). Some material can be a WRB and a class of vapor retarder at specific thickness.

c. Closed-Cell Medium-Density Rigid SPF

This material (Fig. 7) is a specific type of SPF with a density of 27 to 39 kg/m³ (1.70 to 2.43 lb/ft³) nominal, with 90% closed cells. It is typically called “two-pound foam” and can be the air-barrier material, a class of vapor retarder at specific thickness, a WRB, and a heat barrier (thermal insulation).

d. Closed-Cell High-Density Rigid SPF

This material is a specific type of SPF that has a density of 40 to 60 kg/m³ (2.5 to 3.75 lb/ft³) nominal, with 90% closed cells. Typically called “roofing foam,” which can be the air-barrier material, a class of vapor retarder at specific thickness, a WRB (watertight roofing material), and a heat barrier (thermal insulation).

8. Roofing Membranes

Roofing membranes include all materials used on a roof to make the roof

watertight and may be also used to make the roof airtight.

A. Single-Ply

- a. Fully Adhered
- b. Mechanically Fastened
- c. Ballasted

B. Built-Up Systems

- a. Fully Adhered (examples include modified-bituminous, asphaltic built-up, and hybrid systems)
- b. Partially Adhered (this would include adhered roof systems over a base sheet mechanically attached to a substrate [for example, base sheet nailed to lightweight insulating concrete or plywood deck])

C. Sheet Metal

- a. Structural Standing Seam
- b. Architectural Standing Seam

D. SPF

9. Waterproofing Materials

Waterproofing materials include all the materials that are used to provide waterproofing for a foundation, plaza deck, split slab, or other structure not left exposed to environmental elements.

THE PRESENT

Once the list of categories and types was established, the industry went to work on developing proper material specifications for each type of material. The industry had a list of material properties for the different types of air- and water-resistive-barrier materials and had established performance levels for these properties, but it was in a simple table format and did not address all of the steps required to properly test a material. In a material specification, there are a lot of details involving sampling, sample preparation, conditioning of the sample, preparing the specimens, the size of the specimen, additional information on how to conduct the test, etc., that are included.

As each material specification was developed, it was found that, in some cases, the description of a type needed to be modified as the material did not quite fit the pre-established description. This was expected, and the list of categories and types are part of a living document that needs to be continually updated.

As more material specifications are developed, it becomes apparent that a specific material property should also be a requirement for an already established material specification. As material specifications are also living documents,

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As we understand the building enclosure better, we will see that there is a need to add more material performance requirements to existing material types or perhaps to add more types as new materials are developed.

the industry will continually update them.

As the air-barrier industry was new, test methods were borrowed from other industries which may or may not completely fit their use in testing air- and water-resistive-barrier materials. It is clear that trying to shoehorn a test method from another industry into the air-barrier industry does not really work. As the industry is growing and maturing, test methods specifically for the air and WRB industry are being developed. The first two test methods that were specifically developed for the air-barrier industry were:

1. ASTM E2178, *Standard Test Method for Air Permeance of Building Materials*
2. ASTM E2357, *Standard Test Method for Determining Air Leakage Rate of Air Barrier Assemblies*

The industry has developed two additional test methods:

1. ABAA T0002, *Standard Test Method for Pull-Off Strength of Adhered Air and Water Resistive Barriers Using an Adhesion Tester*
2. ABAAT0004, *Standard Test Method for Determining Gap Bridging Ability of Air and Water Resistive Barrier Materials*

These two test methods are currently only industry standards, but work will be done to conduct a round robin and then submit them to ASTM to become a regional standard.

This involves a tremendous amount of work, but it ensures that the material specification continues to be relevant to the current materials being produced and addresses new materials as they come on the market.

THE FUTURE

As more air-barrier materials come into the marketplace and changes are made to existing

air-barrier materials, it is important that the categories and types are updated on an ongoing basis to reflect these new materials. As we understand the building enclosure better, we will see that there is a need to add more material performance requirements to existing material types or perhaps to add more types as new materials are developed. As the material specifications are updated by the Air Barrier Association of America (ABAA), we have seen that the existing types need to be modified to better reflect the material properties.

The industry carries out this work through the Research Committee, which focuses on test methods, and the Technical Committee, which focuses on material specifications and project specifications. Manufacturers, contractors, design professionals, and inspectors comprise these committees so that a broad area of expertise goes into the development of the documents.

This work results in a series of documents for use in project specification. The industry will continue to develop a project specification for each type of air- and water-resistive-barrier material. These project specifications are downloadable, free, and in Microsoft® Word so they can be revised for a project. As designers may use different types of materials for different building assemblies, they choose different project specifications to include in the book of specifications for a project.


The project specifications—no matter who developed them—will in turn reference material specifications for the type of material chosen for the project. This ensures that the materials used in a project will function as intended and provides a means for comparing different materials.

The material specifications, in turn, will reference test methods and have performance

requirements so that people know what they are getting and how the material will perform.

An air barrier is a system. That means all six sides of a building; air barriers are needed everywhere. Questions are asked about what materials to use where, and these are not easy questions to answer. There is a lot of confusion about the water vapor transmission rate of materials and whether the material should be permeable or non-permeable. There is no single answer to that question, as it will be different for every project. As test methods and material and project specifications are developed, the next item on the work list will be to provide guidance on what to use where and under what conditions.

As we build more and more complex buildings, demand better and better performance from our buildings, and use more sophisticated material in the construction, we will no longer be able to deal only with materials; we will have to move to the performance of building assemblies, where the whole assembly is tested for thermal transmission, water vapor transmission, water penetration, and air leakage. We will also need to determine the durability of that building assembly. This will start to provide the information that we need to make informed decisions on how to construct our buildings.

We have much work ahead of us as we move to higher-performance buildings, and we need the industry to work together. 

This paper was originally presented at the 2019 IIBEC Building Enclosure Symposium.



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