

Roof-to-Wall Connections

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ABSTRACT

Many people feel that a roof assembly is automatically a roof air barrier assembly. A roof can be watertight but not airtight. The difference is the connections. If the roofing material has been connected to all penetrations and terminations, then the result may be a roof air barrier assembly. Places such as pipe penetration, curbs for equipment, and any other hole in the roof can be properly flashed but may also have gaps between the roofing material and the penetration, which can have huge air leaks.

The roof-to-wall connection, which is really a roof membrane-to-air barrier connection, is one of the most critical junction points in today's construction. Done correctly, it is a wonderful thing; done incorrectly, problems with air infiltration/exfiltration will occur. Moisture vapor transport resulting in condensation problems may ensue. A great deal of consideration must be given to how these two product technologies come together. The number of roof membranes, air barriers, and insulations that must come together properly can become overwhelming when divining the correct methods, materials, and sequence of construction. Chemical compatibility is a major concern, as is the correct way to tie-in the edge of the roof-to-wall connections. This paper addresses some of these questions and to provide some general guidance to the construction industry.

SPEAKER



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Roof-to-Wall Connections

As more states, jurisdictions, and design communities require air barriers, the issue of connecting the wall air barrier assembly to other building assemblies, such as below-grade waterproofing, window systems, and roof membranes, must be completely understood to design and construct a functioning building enclosure.

One of the most often missed or poorly executed details is the connection between the air barrier in the wall assembly and the air barrier in the roof assembly (**Fig. 1**). With a myriad of roofing systems and wall configurations and the growing number of wall air barrier materials, it can be difficult to navigate the process of determining which air barrier systems work best with each other and the chemical compatibility of these systems.

This paper will focus on design considerations as well as practical approaches to ensuring a robust connection is constructed and executed.

THE BUILDING SCIENCE

To understand why the roof-to-wall connection is important, we need to start with the basics. The construction industry and building owners are starting to understand the importance of incorporating an air barrier into the building enclosure. An air barrier is important to manage moisture and reduce energy costs, and to act as a barrier to pollen, allergens, noise, smells, insects, pollutants, and the list goes on. The number one reason to put an air barrier in your building is for moisture management; the most critical climate is hot and humid. We always consider moisture in a building that leaks into the building assemblies to be critical in a cold climate. However, if you calculate the amount of moisture transport for the same amount of air leakage in a warm, moist climate, you will get a greater amount of moisture transported. The amount of moisture in the interior air of a building in a cold climate at 70°F (21°C) and 35% relative humidity (RH) is significantly less than the amount of moisture in the exterior air when



Figure 1. Roof-to-wall transition “done incorrectly” with noncompatible materials and numerous voids.

the temperature is 98°F (37°C) and 95% RH.

The Air Barrier Association of America (ABAA) website¹ provides an energy savings and moisture transport calculator. Looking at three cities and three archetypes out of all those available, you can see the difference between water vapor transmission through a material

(referred to as perms) and the amount of water vapor that would go through a 1 in. (25 mm) square hole. Many design professionals want to use a high-permeance material to allow the building to dry. There is nothing wrong with this approach, but there are two problems with only looking at the permeance of a single material to determine whether water vapor could cause a problem in the building enclosure.

First, we must recognize the amount of water vapor diffusion we are talking about. Testing according to the code-required ASTM E96² desiccant test method shows the amount of water that will diffuse through a 10 perm material will be 16.6 oz (491 mL) per year. The desiccant test method uses a dish that must be at least 4.65 in.² (3000 mm²). The dish has a

desiccant in the bottom, creating 0% RH, and the material being tested covers and is sealed to the top of the dish so that any water vapor must go through the material. The dish is then placed in an oven that has a steady-state temperature of 73.4°F (23°C). This means that the material has 0% RH on one side and 50% RH on the other side, which is considered equal to 25% RH atmosphere.

Second, we need to understand that most water problems are not caused by the water vapor transmission rate of the material. Stopping liquid water from leaking into the building is the first line of defense. The second line of defense is to stop moist air from leaking through the building enclosure, which can change to liquid water.

WATER VAPOR TRANSPORTED BY AIR LEAKAGE

The ABAA calculator (**Fig. 2**) shows the amount of water transported by air leakage through the holes and cracks in a building over the period of one year. I randomly chose three different locations and a different archetype (reference building types) for each location (**Table 1**). The materials and construction specified for the U.S. Department of Energy's reference building types are used to determine energy savings for building codes.³

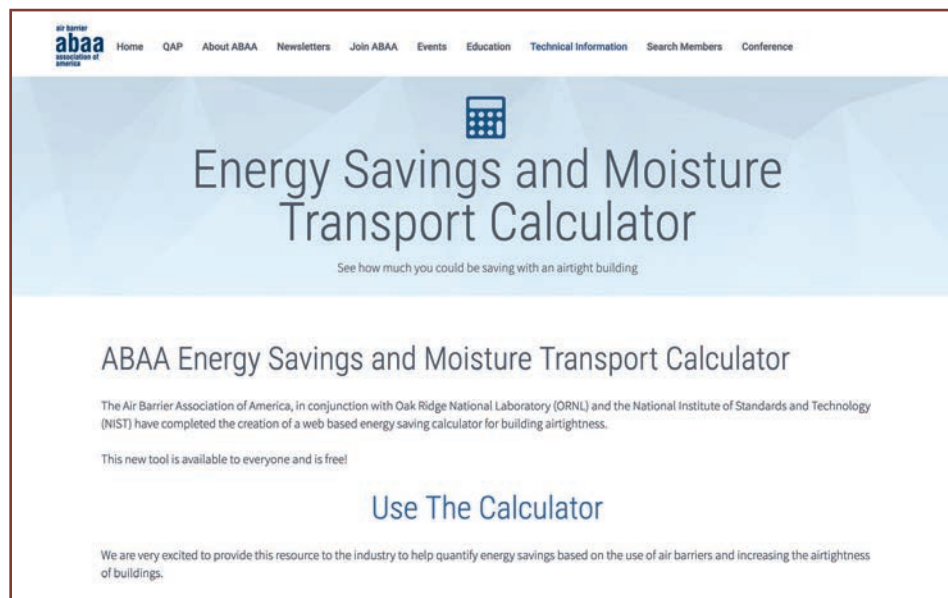


Figure 2. Air Barrier Association of America energy savings and moisture transport calculator.

Location	Building type	Water vapor moved by air transport through a 1 in. ² hole per year, gal.
Tampa, Fla.	Secondary school	77.41
Bismarck, N.D.	Hospital	45.29
Fort Worth, Tex.	Large hotel	340.69

Note: 1 in.² = 645.2 mm²; 1 gal. = 3.785 L.

Table 1. Moisture movement by air transport

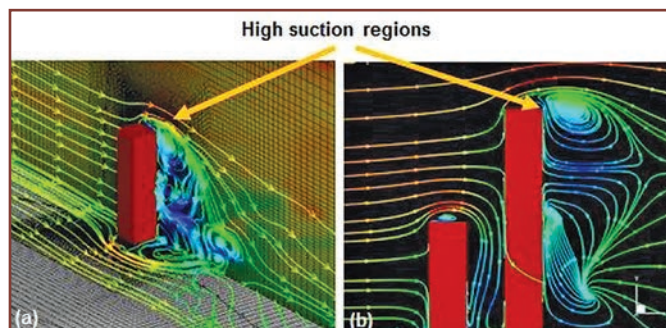


Figure 3. High-suction regions around buildings.



Figure 4. The author's house on the Gulf of Mexico.

Maximum building height above grade, m	Wind	Sustained 1 in 50 hourly wind pressure differences, Pa					
		450	550	650	750	850	1000
12	Cyclic	660	800	950	1090	1240	1460
	Gust	980	1200	1410	1630	1850	2180
20	Cyclic	720	880	1050	1210	1370	1610
	Gust	1080	1320	1570	1810	2050	2410
40	Cyclic	1340	1630	1930	2220	2520	2970
	Gust	2000	2440	2880	3320	3770	4430
60	Cyclic	1440	1770	2090	2420	2740	3220
	Gust	2160	2640	3120	3610	4090	4810
80	Cyclic	1530	1870	2220	2560	2900	3410
	Gust	2290	2800	3310	3820	4330	5090
100	Cyclic	1610	1960	2320	2670	3030	3560
	Gust	2400	2930	3460	3990	4530	5320
120	Cyclic	1630	2030	2400	2770	3450	3700
	Gust	2480	3040	3590	4140	4700	5520

Note: 1 m = 3.281 ft; 1 Pa = 0.021 psf.

Table 2. Sustained, cyclic, and gust wind pressure differences

People do not attribute the amount of water that is transported by air leakage to a building. They see liquid water and assume it is due to a leak or that it has been caused by water vapor transmission through the material.

WIND LOADS BY HEIGHT

If we go back to the physics, we know a hole and a pressure difference are required to move air through a building enclosure. Pressure differences are caused by the wind effect, stack

effect, and mechanical effect. On any given day, these three forces could be cumulative, or they may cancel each other out. As the wind, temperature, and how a building is operated can change by the hour, the amount of air leakage changes with the change in atmospheres.

The wind engineer who provided the calculations for the loading schedule for ASTM E2357⁴ also calculated the loads on a building based on its height (**Table 2**). The table references the 1 year in 50 year wind pressure differences. The work was done for the *National Building Code of Canada*⁵ and is included in its Appendix C.

The pressure difference at the top of a 394 ft (120 m) building is more than five and one-half times the pressure difference at grade. The taller the building, the greater the pressure difference and the greater the air flow through the holes and cracks. The greatest pressure differences on walls are at the top of the building, on the leeward side, and at the corners (**Fig. 3**).

Roof assemblies have different pressure profiles depending on their shape and construction. On the leeward side, the wind tends to pull the material off the building and at the same time, if there is air leaking into the building, that air also tends to push the material off the building. These two forces can not only compromise the air barrier system but also take roofs off buildings.

My Gulf of Mexico coastal house (**Fig. 4**) has weathered direct hits by Hurricane Harvey and Tropical Storm Beta with no damage and no water infiltration, as it has a robust

air barrier that can withstand both loads. Because it was properly constructed to my specifications, which exceeded those of the code, with a properly designed and installed air barrier system on both the roof and walls, my home can withstand high windstorms caused by hurricanes without any damage to the building.

THERE IS AN AIR BARRIER ON THE BUILDING

If a robust air barrier can remain intact even during hurricane conditions, why are we concerned about roof-to-wall connections? Experience from 2000 has shown this is the largest leakage area in the air barrier system.

Table 3 shows the calculation of the total number of component material combinations for wall air barriers. In addition, the ABAA evaluates the materials produced

Wall components	Types of material	Calculation
Three types of back-up walls	Concrete masonry units, oriented strand board, gypsum-based exterior sheathing	3
Seven types of air barriers*	Self-adhered sheet membranes, fluid-applied membranes, medium density closed cell polyurethane foam, mechanically fastened building wrap, boardstock—rigid cellular thermal insulation board, factory-bonded membrane to sheathing, adhesive-backed commercial building wrap	$3 \times 7 = 21$
Four types of insulation	Mineral wool, polyisocyanurate, medium density closed cell spray polyurethane foam, expanded and extruded polystyrene	$3 \times 7 \times 4 = 84$
Four types of cladding	Brick, metal panel, exterior insulation and finish system, cement board	$3 \times 7 \times 4 \times 4 = 336$
Total number of combinations		336

* According to the Air Barrier Association of America, airbarrier.org.

Table 3. Wall air barriers components and materials

by 43 manufacturers. Most manufacturers do not make every type of air barrier listed in Table 3, but there are 25 companies that make a type of fluid-applied air barrier material. The point is that we are dealing with a large group of materials that may not be compatible with one another, and this is just the wall air barrier materials.

As we move to the roof, roofing material may or may not be designated as part of the air barrier system (Fig. 5). Many wall air barrier materials can be used as the roof air barrier, then the roof membrane material can be installed over it. There are many different types of roofing materials; the most common ones are:

- single-ply: polyvinyl chloride (PVC), ketone ethylene ester, thermoplastic polyolefin, and ethylene propylene diene terpolymer;
- fluid-applied: inverted roof membrane assembly and polymer modified asphalt;
- polymer modified bitumen;
- steep slope (metal panels, shingles).

MATERIAL COMPATIBILITY

Roof-to-wall tie-ins have been somewhat problematic since air barriers became a code requirement. Chemical compatibility issues have been present in roof membrane-to-air barrier tie-ins since that time. These issues have been accelerated by the code-mandated use of continuous insulation, which in many instances alleviates the compatibility issue. As

air barrier systems came into use, I had a long conversation with a through-wall manufacturer of copper, stainless-steel, and synthetic flashings regarding this topic. This conversation evolved to become a full-fledged ABAA Technical Committee that is working on a chemical compatibility chart to provide guidance to design professionals. The chemical compatibility issue is a concern with all tie-ins; material suppliers should always provide letters of chemical compatibility of their material to adjacent materials.



Figure 5. Thermoplastic polyolefin membrane functioning as an air barrier in a hot climate zone.

ADDRESS THE PROBLEM HEAD ON

An example is the difference between the front side of the building and the rear side of a parapet on an administrative office building of a Fortune 100 company. The exterior walls are construction with light-gauge steel studs with R-13 batt insulation between the studs, 5/8 in. (16 mm) exterior gypsum sheathing, an ABAA-evaluated liquid-applied air barrier material, 1 in. (25 mm) of an ABAA-evaluated foil-faced polyisocyanurate insulation, and a metal panel façade. This assembly has an effective R-value greater than 13, which exceeds the energy code in the region where it is being built. It is also an ABAA-evaluated air barrier assembly and completely compliant with the code-mandated fire requirement of NFPA 285.⁶ The same manufacturer provided the air barrier and insulation and pro-

vided evidence that chemical compatibility issues are not a concern.

All is well on the front of the building. Unfortunately, all is not well on the back side of the parapet.

The construction detailing of the interior side of the parapet illustrates steel studs, R-13 batts, and 5/8 in. (16 mm) exterior gypsum sheathing, for an effective R-value of 6.6. Undoubtedly, this area is going to be highly energy inefficient. When there are cold exterior temperatures, the materials on the interior side of the parapet will have a colder surface temperature than the front of the parapet, which will cool the air that comes in contact with that surface. If the air is cooled enough, the temperature of the air surrounding the back side of the parapet can be lowered to the dew point—the temperature at which the air is cooled and becomes saturated with water vapor. When warmer, moist air leaks into the parapet and the dew point occurs, condensation will form on the materials and liquid water can work its way into the conditioned space, possibly causing mold and mildew. The

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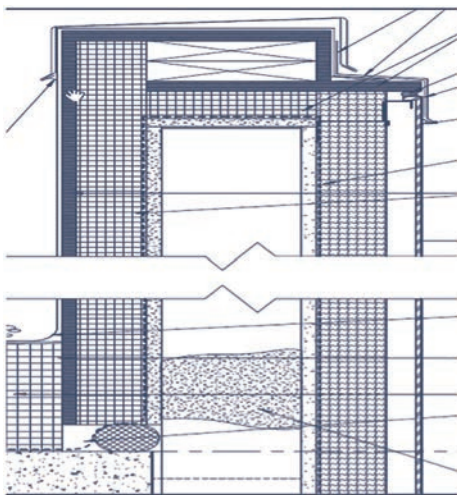


Figure 6. Insulation on both sides of the parapet.

liquid water may cause a stain on the interior finish, leading to reports of a “roof or window leak.”

This fix is a relatively easy design modification. Place 1 in. (25 mm) of the specified continuous insulation over the top and interior side of the parapet and now the entire building has the same thermal enclosure, with the same dew point profile on both sides of the building (Fig. 6).

The wall construction included a polymeric modified asphalt air barrier, which was to be directly connected to the PVC roof membrane. By adding the 1 in. of foil-faced polyisocyanurate insulation, the material can physically separate the asphalt-based air barrier from the PVC roof membrane, avoiding any possible incompatibility problems or premature failure.

LET’S TALK BEFORE STARTING WORK

The roof-to-wall connection at the top of the building is the biggest leakage area in most buildings. This is because 1) there is a high pressure difference, 2) there can be chemical compatibility issues with materials, and 3) this area is seen as the responsibility of “others,” meaning no one has been identified as responsible for doing the work properly.

We cannot change the pressure difference, as we have no control over the environment in which we build our buildings. We have no control, as a contractor, over the height of the building. However, our hands are not tied: we can start a conversation on the proper materials to use in the construction. We can discuss who is responsible for the roof-to-wall connection and what is the proper sequence for construction.

Preconstruction meetings are critical and

should be mandatory. This is where important questions can be identified and resolved, such as compatibility issues, the construction sequence for the project, which trade is responsible for the connection, and what other trades will impact performing the construction. It is much easier to deal with these issues “on paper” and clarify the issues before construction starts rather than having to redo areas after they have been constructed. The use of an ABAA Certified Air Barrier Specialist will go a long way toward ensuring the proper sequencing and details.

ROOFS CAN BE WATERTIGHT BUT NOT AIRTIGHT

Many assume that a roof is automatically an air barrier assembly. The roof must simply drain water. It is not intended to be a swimming pool and it does not have to be airtight; water just needs to be shed or drained off the building. Roof connections to penetrations in the roof are sometimes designed to shed water with flashing but have an opening for the penetration that is larger than the penetration allowing air leakage. These openings include the parapet, equipment curbs, expansion joints, and penetrations. A larger hole through the roof allows some movement of the penetration to properly align with the equipment being installed (Fig. 7).

Each detail must be evaluated for both airtightness and watertightness. There are basic details for these areas, but the actual site conditions will probably be different for each project, requiring a special detail for that building. If you apply the basics for an air barrier design, you can work through the issues and produce a detail that will work.

SOLVING THE PROBLEM

Everyone must be involved in the solution. Manufacturers of air barrier materials and roofing materials must provide the trade contractors with details on how to make the

air barrier part continuous using their materials. Design professionals must be clear on what material is to be a roofing material and if that material is also intended to be the air barrier material. The design team must also provide detailed drawings for the complicated details, preferably in three dimensions. The specification writer must provide detailed specifications as to who does what and what materials

to use where. The general contractor(s) must understand how complex an air barrier system can be and the importance that the air barrier is continuous on all six sides. The air barrier contractor must obtain all possible information and guidance from their supplier and understand the functioning of the air barrier system and location of the critical details. The installers need to have had a comprehensive training course on the type of air barriers that they will be install-

ing. Their knowledge, skills and abilities must be confirmed through an ISO 17024-accredited certification.⁷ The industries representing the air barrier industry and the roofing industry must work together to bring their collective knowledge together to produce materials that will educate and grow the air barrier industry. Figure 8 summarizes the main points to keep in mind.

CONCLUSION

This paper focused on roof-to-wall connections, as this is the largest leakage area in existing buildings. The physics applies to all building assemblies and all climate zones. Even within a single climate zone, there can be



Figure 7. Details for penetrations must be evaluated to ensure that they are airtight and watertight.



Figure 8. Things to remember.

cold winters and hot summers. In warm, moist climates, moisture-laden air is outside and leaks into the building, whereas in cold, dry climates, the moisture-laden air is inside. In both cases, moisture that gets into the building assembly and condenses causes the problem.

A building's mechanical system can add to or reduce the problem. In a warm, moist climate, if all the air is brought into the building through the mechanical system, cooled, and stripped of water, and the building pressurized, the mechanical system is helping to keep the building dry. In the same climate, if the mechanical system causes negative pressure inside the building, the warm, moist air is drawn into the building assemblies and causes the problems of mold, mildew, rot, and corrosion.

In cold, dry climates, the mechanical system has the same effects. If cold, dry air is drawn in through building assemblies and then heated, this air leakage helps keep the building dry. However, if the building is pressurized, warm, moist air is pushed into the building assemblies, where condensation can occur.

There is no single straightforward answer here. Building assemblies have to be properly designed to have the appropriate thermal performance, water vapor transmission rates, and no air or water leaks. The result is a building that performs as intended and does not run into unexpected maintenance and expensive repair costs. In other words, a building you would want to own or be a tenant in. 

REFERENCES

1. Air Barrier Association of America (ABAA). Accessed July 7, 2021. "Energy Savings and Moisture Transport Calculator." airbarrier.org/technical-information/energy-savings-and-moisture-transport-calculator/.
2. ASTM Subcommittee C16.33. 2016. *Standard Test Methods for Water Vapor Transmission of Materials*. ASTM E96. West Conshohocken, PA: ASTM International.
3. U.S. Department of Energy. Access July 7, 2021. "Commercial Reference Buildings." energy.gov/eere/buildings/commercial-reference-buildings.
4. ASTM Subcommittee E06.41. 2018. *Standard Test Method for Determining Air Leakage Rate of Air Barrier Assemblies*. ASTM E2357. West Conshohocken, PA: ASTM International.
5. National Research Council (NRC) Canada. 2015. *National Building Code of Canada*. Ottawa, ON: NRC Canada.
6. NFPA (National Fire Protection Association). *Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Wall Assemblies Containing Combustible Components*. NFPA 285. Quincy, MA: NFPA.
7. International Organization for Standardization (ISO). 2012. *Conformity assessment — General requirements for bodies operating certification of persons*. ISO 17024. Geneva, Switzerland: ISO.