U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Water Management of Noninsulating and Insulating Sheathings

Final Report

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U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Water Management of Non-Insulating and Insulating Sheathings: Final Report

Prepared for:

Building America

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Unless otherwise indicated, all figures were created by BSC.

Definitions

AATCC Test Method 127	American Association of Textile Chemists and Colorists. Hydrostatic Pressure Test
AC71	An international Code Council (ICC) Acceptance Criteria (AC) titled “Proposed Criteria for Foam Plastic Sheathing Panels Used as Water-Resistive Barriers”
ASTM	ASTM International, formerly known as the American Society for Testing and Materials
EPS	Expanded Polystyrene
IBC	International Building Code
ICC	International Code Council
ICC-ES	ICC Evaluation Service
ICC-ES AC	ICC Acceptance Criteria
IRC	International Residential Code
OSB	Oriented Strand Board
PIC	Polyisocyanurate
UV	Ultraviolet rays
XPS	Extruded Polystyrene

Executive Summary

This report was prepared by the Building Science Corporation (BSC) Building America Research Team for the "Energy Efficient Housing Research Partnerships" project Task Order No. KNDJ-1-40337-02 under Task Ordering Agreement No. KNDJ-1-40337-00.

It is the BSC team's judgment that the lowest cost, highest performing rainwater management technology is rigid polymeric foam sheathing with sealed joints (Baker 2006, BSC 2007). The challenge that remains with this approach is to reliably and durably seal the joints. Taping joints in noninsulating and insulating sheathing has been shown to work, but is by no means an ideal solution. Several liquid (or fluid) applied rainwater management barriers could be used in place of tapes and other self-adhering membranes if applied correctly to increase the long-term durability and effectiveness of the rainwater management system, especially around penetrations in the enclosure. Many of the liquid applied membranes also function as air barrier materials that can be integrated with other components to provide an air barrier system.

This report summarizes current research, serves as an information package, summarizes issues that have been experienced with current best practices, and recommends ways in which the best practices can be improved, including some generic details for typical residential building practices.

This report addresses the following issues:

- What are the issues with current best practice?
- What performance tests are being currently conducted, what tests should be conducted, what do we really need to know, what are the gaps?
- What issues do the construction trades perceive with liquid applied barrier technology?
- What decision criteria do general contractors use to decide on a liquid applied barrier technology?

This report discusses some of the common standard tests that are conducted on liquid applied barriers as well as some laboratory research that is being conducted by a Building America industry partner, a custom home builder in Maryland.

A series of eight detailed drawings that can be used for noninsulating and insulating sheathing are presented that represent some of the most typical residential construction details. This series of drawings will be used as a starting point for a library of liquid applied membrane details to eventually include all relevant residential construction details.

1 Introduction

There is a construction challenge of reliably and durably sealing the joints in rigid polymeric foam sheathing to prevent water ingress.

The goal of this research is to provide durable and long-term water management solutions using liquid applied membranes as part of the water management system on insulating and noninsulating sheathings.

1.1 Background

The building enclosure should control the movement of rainwater, air, vapor, and heat into or out of a building. The foundation, walls, roof, windows, doors and other penetrations form an environmental separator. All of these control functions will be discussed with respect to sheathing membranes, both sheet good products, and liquid applied products, in wall applications for residential buildings.

- **Rainwater control.** Water penetration into the building through the enclosure has been a major contributor to building durability and health issues. A rainwater control layer—a drainage plane integrated with flashings and enclosure elements — is therefore an important focus of this paper.
- **Air control.** Airflow into and out of the enclosure plays a large role in the durability of the enclosure and the energy efficiency of the building. Moisture-laden air moving into the enclosure could potentially cause moisture-related durability issues in hot and cold climates. An effective air barrier is critical to long-term enclosure durability (Lstiburek 2006a).
- **Vapor control.** The vapor control location and level of control in the enclosure is dependent on the geographic region, as well as the wall construction strategy. A Class I vapor barrier (0.1 U.S. perms or less [IRC 2009]) is rarely required, and in fact, in most cases vapor permeable layers are preferred to allow incidental moisture in the enclosure to dry, as long as the amount of vapor movement is controlled to reasonable levels(Lstiburek 2006b).
- **Heat (thermal) control.** Generally speaking, we want to keep heat in our building in cold climates, and out of our building in hot climates. This is largely accomplished with insulation in the enclosure, but airtightness, as well as window specifications and thermal bridging of structural elements, play very important roles in thermal control. This report will address some of the aspects of both insulation and air barrier details.

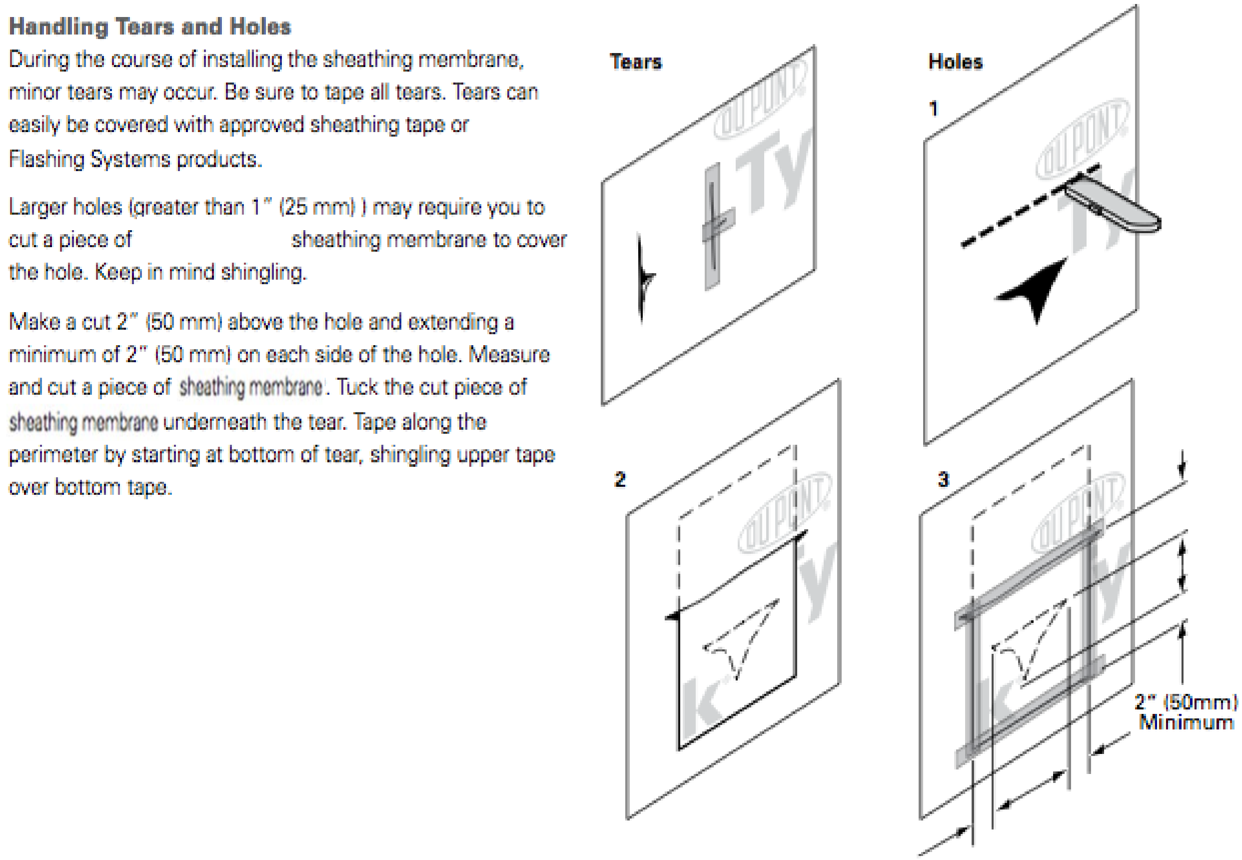
1.1.1 Issues With Walls

The standard of residential construction depends on local building traditions, availability of materials and skilled labor, the demands of the local climate, and specific building codes and other regulations. For most areas of the United States, generally speaking, walls in residential buildings are wood framed, with structural wood sheathing, a sheathing membrane, and a cladding material. Typical sheathing membranes include plastic house wraps, or building paper, but also include self-adhered (peel and stick) membranes, which are more typically used in commercial construction. Typical residential sheathing membranes are usually installed with a staple gun,[1] and the joints are often taped to form an exterior air barrier. This is a building code-approved method in most places, and it is possible to achieve a good enclosure using this method, although like many construction strategies, the quality can vary significantly depending on the knowledge and care of the installer.

Figure 1 shows a plastic house wrap installation in new construction. The obvious issue depicted in the photograph is a large tear in the membrane, but this can be easily fixed with sheathing tape. The less obvious issues that occur quite frequently with all sheathing membranes are gaps around the penetrations that allow air leakage, and in some cases, water entry into the enclosure. For sheathing membranes intended to provide rainwater control and air control, continuity of the layer through these difficult-to-manage details is critical. This obstacle is not impossible to overcome, and can be done correctly, but frequently is not. In many cases, product manufacturers provide detailed instructions on how to repair damage to the sheet membrane product because they are commonly damaged and require adequate repair for air and water barrier continuity (Figure 2).

Figure 1. House wrap installation in new construction. The large tear will likely be fixed before construction continues — see one manufacturer's instructions in Figure 2. The smaller deficiencies (highlighted) are often not addressed.

[1] Even though it appears that generally the plastic house wraps are installed with a staple gun or "slap stapler," this does not necessarily meet the conditions for the product manufacturers.


Handling Tears and Holes

During the course of installing the sheathing membrane, minor tears may occur. Be sure to tape all tears. Tears can easily be covered with approved sheathing tape or Flashing Systems products.

Larger holes (greater than 1" (25 mm)) may require you to cut a piece of sheathing membrane to cover the hole. Keep in mind shingling.

Make a cut 2" (50 mm) above the hole and extending a minimum of 2" (50 mm) on each side of the hole. Measure and cut a piece of sheathing membrane. Tuck the cut piece of sheathing membrane underneath the tear. Tape along the perimeter by starting at bottom of tear, shingling upper tape over bottom tape.

Figure 2. Example manufacturer's instructions for the repair of tears and holes

Figure 3 shows a photo taken during an intrusive investigation on a building with significant water entry through the enclosure. Two different sheathing membrane products are visible, as well as a clear break in continuity between the two membranes revealing the sheathing beneath. The opening is large enough that fiberglass batt insulation in the framing cavity is also visible through the rough opening for the ductwork. This example may seem to be an extreme case, but it is a clear example of the continuity issues that must be addressed with current practices—usually relying on multiple materials performing different functions and the coordination of several different tradespeople to ensure that all of the necessary connections are made.

The poor construction detailing shown in Figure 3, is not directly related to using sheet applied weather-resistant barriers, but rather, is due to poor workmanship, and any type of air/water barrier can be subject to workmanship issues. Some aspects of construction are simplified with liquid applied barrier that may minimize the possible workmanship issues. As an example, the responsibility of the liquid applied membrane is generally the responsibility of one contractor instead of multiple trades. Using only one trade for a specific task can reduce confusion about who is responsible at the intersection details, between the masonry, HVAC, and framing contractors.

Figure 3. Intrusive investigation of the water management details. Note the poor execution of the mechanical penetration, the gap in sheathing membrane continuity, which will allow water and air leakage, and the bonding of the mortar to the membrane.

These sheathing membranes rely on tapes and other adhesives in most cases to complete the air barrier, and these tapes are ideally installed on a clean, dry, warm surface. Surface preparation is an important part of the long term durability of adhesives. Figure 4 is an excerpt from one manufacturer's instructions for surface preparation for tape installation.

GENERAL INSTRUCTIONS:

- [redacted] should be installed on clean, dry surfaces. Wipe surfaces to remove moisture, dirt, grease and other debris that could interfere with adhesion.
- Apply pressure along entire surface for a good bond.
- Remove all wrinkles and bubbles by smoothing surface and repositioning as necessary.

Figure 4. Example surface preparation for tape installation

During site visits and field investigations, it is not uncommon for even newly installed tapes and self-adhered membranes to have issues. Figure 5 shows one installation where the peel and stick membrane has fallen off the wall, and one installation with numerous wrinkles, and fish mouths at the corner between the horizontal and vertical surfaces. Water testing of situations similar to this, where there is a wrinkle in the peel and stick membrane on the horizontal surface, has led to water intrusion because water drains down the surface of the peel and stick and may accumulate on the horizontal ledge. When a self-adhered, or peel and stick membrane, wrinkles to form a pocket that may collect water either on the horizontal or vertical surface, it is referred to as a fish mouth. Some photos and further explanation of this are included later in the report.

Figure 5. Self-adhered membrane installation issues

Figure 6 shows an example of taped exterior insulation that is the drainage plane (liquid water barrier) in the enclosure. In our experience problems similar to this are not uncommon, but with reasonable quality control, can be avoided and tape can be successfully installed for long periods of time (Figure 7).

Figure 6. Taped exterior insulation drainage plane

Figure 7 shows an example of taped exterior insulation being inspected for the first time following 16 years of service in Massachusetts. The tape is still adhered and does not have any adherence issues in the areas inspected. Often, during site investigations, it seems that the level of care and quality control is higher in custom home construction compared to production residential construction.

Figure 7. Exterior insulation tape inspected following 16 years of service

Some products rely on the face of the treated sheathing as the water resistant barrier, and use taped seams (example Figure 8). This addresses some of the issues that can occur with building wrap sheathing membranes (such as ripping, flapping under wind pressures, and reverse laps) but the success or failure of the system ultimately lies with the ability of the tapes to last for the expected service life of the enclosure system without peeling off or fishmouthing to direct water into the gap. The expected service life of the tape should be at least as long as that of the cladding, as it will be impossible to repair and fix unless the cladding is removed.

Fishmouthing is a construction term that relates to tapes and peel and stick membranes, when there is a wrinkle in the material that catches water. This water is often held by the tape or flashing, which greatly decreases the long-term durability, and may even be directed into the enclosure past the water barrier layer of the enclosure. Figure 8 shows an example of fishmouthing the day after the tape was installed on the wall sheathing as the drainage plane and liquid water barrier of the system. It is difficult to see the fishmouth, but by pressing on the tape, water was pushed up from behind the tape, where it had been trapped during a rain event after installation.

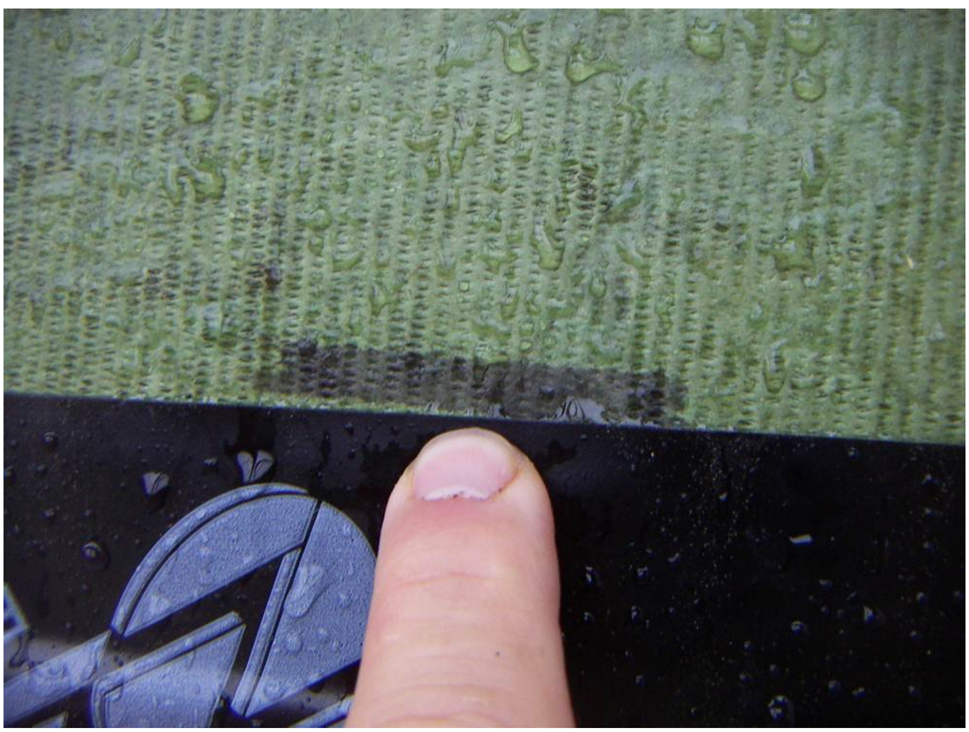


Figure 8. Fishmouth in sheathing tape trapped water against sheathing

Figure 9 is another example of potential issues with peel and stick membranes used on the exterior of the sheathing as a drainage plane. In this example, the peel and stick membrane was installed in the evening, and was completely flat, on a south-facing orientation. On the following day when this photo was taken, the sun had heated the peel and stick, which caused a wrinkle, similar to a fishmouth. This wrinkle was large enough to pass water into the seam of the sheathing over which it was installed as a water barrier.

Figure 9. Wrinkle caused by thermal cycling and expansion/contraction

The peel and stick, or self-adhered membrane, can be very successful as a water and air barrier if installed correctly. (Lstiburek 2008) There are some challenges of adhesion, cold weather application, and use of primers that can complicate installation, and the success of the enclosure is dependent on the long-term durability of the self-adhered membrane. The durability can be increased by adding insulation to the exterior of the membrane to decrease the thermal cycling effects.

1.1.2 Issues With Windows

The field of the wall is relatively easy to detail compared to penetrations such as windows, doors, and mechanical services. Historically, windows were installed in rough openings that may have been lined with polyethylene, or had the house wrap wrapped around the edges (Figure 10). The gap between the window and the rough opening was filled with compressed fiberglass batt, and head flashing, jamb flashing, or sill pan flashing was not often installed.

Unfortunately this still does occur in some cases, but generally speaking, the quality of residential window installations is improving. The window installation method Building Science Corporation (BSC) has been recommending for years includes

- Sill pan flashing (includes back dam and end dams) (Figure 11),
  gravity lapped over sheathing membrane below window
- Jamb flashing overlaps end dams and connects to sheathing membrane on sides
- Head flashing to direct any water in the drainage cavity above the window to the exterior.

Figure 10. Prepared window opening

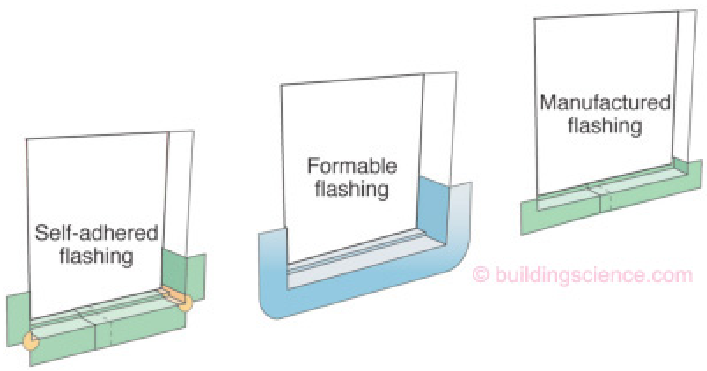


Figure 11. Sill pan flashing examples

How these three criteria are accomplished depends on the type of window and type of wall, but there are many different strategies. (Lstiburek 2006c) Typically these flashings are either a self-adhered membrane; in some cases, pre-manufactured pan flashings are used for the sill pan flashing. At the head of the window, the waterproofing often still relies on tape or peel and stick membranes, which could be problematic over time, as they may not perform adequately for the lifetime of the cladding. Evidence in the field suggests that most peel and stick membranes will separate slightly at the top edge eventually because of gravity and the thermal cycling of the peel and stick, which will eventually allow water behind the peel and stick.

1.1.3 Summary

Problems for traditional construction methods for walls and windows have been discussed, but we have evidence that the current best practices, when constructed well, will work well for a long time, based on a small sample of deconstruction projects. However, building enclosure failures—especially water intrusion and air leakage problems—and simply the desire for decreased risk, even if problems have not been experienced, are changing the construction techniques from what people are used to.

In many locations, newer, nontraditional construction technologies, such as peel and stick membranes and liquid applied membranes, are used instead of traditional house wraps because of the higher performance demands in terms of airtightness and energy conservation. The traditional products were never designed to meet such high standards of construction, but generally performed quite well under the standards that were required for construction in the past.

1.2 Relevance to Building America's Goals

Overall, the goal of the U.S. Department of Energy's Building America program is to "reduce home energy use by 30%-50% (compared to 2009 energy codes for new homes and pre-retrofit energy use for existing homes)." To this end, we conduct research to "develop market-ready energy solutions that improve efficiency of new and existing homes in each U.S. climate zone, while increasing comfort, safety, and durability."

All residential construction in all climate zones will likely benefit from this research project, and depending on the cost/benefit analysis of using liquid applied technology, these details could be immediately implemented on a very large scale.

1.3 Cost Effectiveness

Using liquid applied membranes (defined and discussed further in Section 2) to seal joints and provide flashing details will likely increase the material and installation costs of the wall assembly, but will increase the durability of the assembly against water intrusion and moisture related issues, as well as provide an air barrier that has many benefits including reduced energy consumption.

Based on our project experience, it is expected that using a liquid applied membrane will have approximately a 25% material cost increase over more traditional sheathing membranes. Using a liquid applied membrane will decrease labor and installation costs, so that our predicted worst case scenario is that there will be no increased overall cost to using liquid applied membranes, and likely, it will become more cost effective overall to use liquid applied membranes. As liquid applied membranes are used more often, it is likely that costs will decrease, and there will be more cost data available for comparisons in more regions.

There is currently no information in RS Means for liquid applied barriers used as air and water barriers in wall construction, likely because they have not been used enough to develop accurate construction costs. RS Means is a division of Reed Business Information that provides cost information to the construction industry so contractors in the industry can provide accurate estimates and projections for their project costs. It has become a data standard for government work in terms of pricing, and is widely used by the industry as a whole.

1.4 Tradeoffs and Other Benefits

It is difficult to assign a cost to durability, but the costs and associated issues that occur with enclosure failures resulting in moisture durability issues are very expensive. Our experience with many production homebuilders in the United States has provided us with anecdotal evidence that the costs (on average) to repair a house have increased an order of magnitude from approximately $100 10 years ago, to approximately $1500 today, largely as a result of water management issues. Because this is an average, and some houses have no reported problems, the houses that do have problems cost significantly more than $1500. This increase in cost is also related to an order of magnitude increase in the incidences of water management issues in the last decade from poorly installed and detailed water management systems.

Some of the difficulties in traditional sheet applied sheathing membranes that may have led to the increased incidences of water management issues are ripping at the edges and fasteners due to wind loading, as well as difficult sheathing membrane detailing at complicated details. Figure 12 shows some examples of torn sheathing membranes and discontinuities at difficult details.

Figure 12. Examples of construction issues with traditional sheathing membranes

A similar analogy to this type of tradeoff is a case study of production homes in Las Vegas, where more money was spent by the builder on improving the thermal performance of the attic, which in turn led to decreasing the size of the HVAC system, and overall savings in construction per house. This could be compared to increasing the capital cost of the air and water barrier, which will likely decrease the labor costs, and likely increase the durability of enclosure, which is difficult to quantify.

Ironically, in houses that have increased performance (but decreased construction costs) such as the example case in Las Vegas, Nevada, and likely similarly with liquid applied membranes, the houses often sell for a higher price point than previous construction standards, even though the cost of construction decreased or stayed the same for the higher performing house.

2 Liquid Applied Barriers

Liquid (or fluid) applied barriers are liquids that are applied to the enclosure as an air and water barrier. The liquid is generally part of a system that includes flashings, transition membranes, and joint treatments. The liquid applied barrier is typically installed to various sheathing substrates (oriented strand board [OSB], plywood, glass faced exterior gypsum, etc.), but some liquid applied membranes can be applied to concrete block, and other cementitious materials. The liquid is often applied with either a paint roller or sprayer, and less commonly with a trowel. Figure 13 and Figure 14 show examples of the same liquid applied membrane being applied using both spray applied and roller applied techniques. In some cases, more than one coat is required by a manufacturer.

The vapor permeability of various liquid applied membranes will vary and should be considered based on the building type, geographic location and interior conditions to avoid moisture durability risk caused by vapor diffusion, or the lack of it.

Installation of any liquid applied barrier should follow the manufacturer's instructions with respect to equipment, methods, applied film thickness, and penetration details. These requirements can vary greatly between manufacturers and should be reviewed for each material chosen.

Figure 13. Spray applied liquid applied barrier

Figure 14. Roller applied liquid applied barrier

2.1 Potential for Improvement

Liquid applied barriers (also referred to as fluid applied barriers and liquid applied membranes) can be used in residential construction to address some of the issues of typical residential construction. This does not mean they are without issues of their own, but in many cases, it seems that liquid applied barriers may simplify installation or reduce the risk of moisture related issues. This will be discussed in the following sections.

There are several important characteristics that a liquid applied membrane must have to perform well for the design life of the enclosure system. Many general contractors and owners take these characteristics into consideration when they are choosing a liquid applied barrier. The order of importance can be different for every contractor, and every job based on project specifics, but cost is generally the most important consideration.

- Adhere well to the substrate to which it is being applied
- Control liquid water (water resistive barrier)
- Control air (air barrier)
- May or may not stop vapor (depends on situation)
- Bridge small gaps without extra installation steps
- Compatible with other products as part of a water management system
- Durable (ultraviolet [UV], temperature)
- Long lasting
- Reasonable cost
- Drying as quickly as possible
- Range of application temperature (high and low).

As previously stated, once it has been decided by either the owner or the general contractor that a liquid applied barrier will be used to control air and water in the enclosure, cost is the single greatest influence in a decision by the general contractor as to which type (or brand) of liquid applied membrane to use. Through research for this report, it appears that all of the liquid applied barriers on the market meet the minimum requirements to be approved for use in construction (control air and water when installed properly), but some brands undergo more rigorous and complete testing than others.

Because liquid applied barriers are still gaining market share, it is not uncommon for representatives of multiple brands to make a presentations to the general contractor and owner responsible for deciding on a liquid applied barrier for a project. Based on anecdotal stories from multiple general contractors, these presentations can be critical for deciding which liquid applied barrier to use, and project decisions have been based on the competence and personality of the sales representative when all other comparisons are equal.

2.2 Standard Tests

Several standard tests appear repeatedly in the product literature. Anyone specifying a liquid applied membrane should understand their intricacies.

ASTM[2] E2357 – Standard Test Method for Determining Air Leakage of Air Barrier Assemblies

An air barrier assembly is defined as the air barrier materials and accessories that provide a continuous designated plane to the movement of air through portions of the building enclosure assemblies. In most of the product literature, it is not clear what combination of materials and accessories were tested by the product

[2] ASTM International, formerly known as the American Society for Testing and Materials

manufacturer, although it was reported by a product manufacturer that generally the manufacturer will test and evaluate typical details such as the tops and bottoms of walls, openings, and penetrations.

ASTM E2178 – Standard Test Method for Air Permeance of Building Materials

This method is intended to assess flexible sheet or rigid panel-type materials using a 1 m × 1 m specimen size. It is unclear from the product literature how this test is performed, as the liquid applied barrier is generally applied directly to an air barrier material such as OSB or plywood. According to one manufacturer, this test is usually conducted as a "free film" and is not adhered to any materials.

ASTM E96 – Standard Test Methods for Water Vapor Transmission of Materials

The vapor permeance of the liquid applied membrane could be important to the moisture durability of the enclosure system, as it will determine how much water vapor can get into or out of the wall. This will help dry moisture out of the wall, but may also allow moisture into the wall, so care must be taken in determining the best option. It is important to keep in mind the vapor permeance of the material to which the liquid applied membrane is installed, to avoid possible moisture accumulations in a material that may be far less permeable than the liquid applied membrane.

ASTM D 4541 – Standard Test Method for Pull-off Strength of Coatings Using Portable Adhesion Testers

This test determines either the greatest perpendicular force (in tension) that a surface area can bear before a plug of material is detached, or whether the surface remains intact at a prescribed force (pass/fail). At least one manufacturer prefers to use ASTM C297 – Standard Test Method for Flatwise Tensile Strength of Sandwich Constructions, which uses a larger sample size, and, they believe, more representative results.

ASTM D1970 – Standard Specification for Self-Adhering Polymer Modified Bituminous Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection

This Specification includes many tests, but the most relevant is 7.9, Self Sealability (Head of Water Test) This test method will determine the ability of the underlayment sheet to seal around a roofing nail and prevent standing water from leaking through to the underside of the sheet. This test will show some useful information about a liquid applied membrane, but in most cases, liquid applied membranes used in residential construction are not intentionally designed to address liquid water pressure.

ASTM E84 – Standard Test Method for Surface Burning Characteristics of Building Materials

The purpose of this test method is to determine the relative burning behavior of the material by observing the flame spread along the specimen. Flame spread and smoke developed index are reported. This test is not relevant to the actual performance of the liquid applied membrane as a water and air barrier, but could be used to compare products if this was of concern.

Other tests that appear to be less commonly done include

- ASTMD2370 – Standard Test Method for Tensile Properties of Organic Coatings
- ASTM D2369 – Standard Test Method for Volatile Content of Coatings

- UV exposure and accelerated aging, followed by durability testing – Accelerated aging testing may give us a better indication as to the long-term durability of these current liquid applied barrier systems that have not been used in the field very long, compared to the expected lifetime of a building. UV exposure helps determine overall durability but in practice these barriers are not generally subjected to UV for extended periods. Generally, in the product literature there is a statement regarding the approved length of time the liquid applied barrier can remain uncovered. There are liquid applied barriers on the market that are formulated to be more resistant to UV decay should this be desirable for a project.

Laboratory and standard testing is important as a first step in determining the performance, but full-scale mockups, field testing, and monitoring are even more important for accurately predicting field performance of the materials. Not all standard testing accurately predict field performance. As an example, D4541 determines the pull-off strength, but does not appear to measure how the pull-off strength might change over time when the material is subjected to weathering, extreme temperatures, and UV.

2.3 Building Code Compliance

To meet the requirements of the International Building Code (IBC) and the International Residential Code (IRC), liquid applied membranes must meet the acceptance criteria of International Code Council (ICC) ES AC212. All self-adhering membranes, commonly used as transition membranes with liquid applied membranes must meet ICC ES AC148.

- ICC ES AC 212 – Acceptance Criteria for Water-Resistive Coatings Used as Water-Resistive Barriers Over Exterior Sheathing, June 2011
    - The purpose of this criterion is to establish requirements for recognition of water-resistive coatings, used as water-resistive barriers over exterior sheathing, in ICC-ES evaluation reports under the 2009 IBC, the 2009 IRC, and the 2009 IECC.
- ICC ES AC 148 – Acceptance Criteria for Flexible Flashing Materials, February 2011
    - The purpose of this acceptance criterion is to establish requirements for recognition of self-adhering membranes used as flashings on roof hips and ridges, and self-adhering flashing and mechanically fastened flashing for wall penetrations, in ICC-ES evaluation reports under the 2009 IBC, and 2009 IRC.

2.4 Comparison of Liquid Applied Membranes to Typical Construction

Although there are advantages to liquid applied membranes, there are also challenges and complications relative to current typical residential construction. The product literature for any product being used should always be reviewed thoroughly.

Most liquid applied membranes have limited temperatures for application that make them challenging to apply in colder climates during winter construction compared to traditional house wraps. Some liquid applied membranes aim to address the temperature limitations of other products. These are reportedly more expensive, but costs should be determined on a case by case basis.

The cost of liquid applied membranes is difficult to compare. The capital cost of the material will be more expensive than typical construction practice, almost certainly. Most companies claim that using liquid applied membranes will be faster in complicated geometries, usually requiring self-adhered membrane origami, reducing installation time and therefore labor costs. A few companies use liquid applied membranes around such details as window boxes, and complicated details to minimize the risk of water leakage, but then transition to the more common construction techniques in the field of the wall.

Liquid applied membranes, because they are attached to a rigid material, will not experience any movement (flapping) of the air barrier layer under wind loads. This also means that the enclosure should be the same airtightness under pressurization and depressurization testing.

There are difficulties installing almost any liquid applied membrane in the rain. The liquid generally has a setting time during which it cannot get wet, or it will wash off the building. This must be taken into consideration when planning for a construction job, based on time of year, location, and protection required from the elements.

One example of this challenge was a large residential project near Portland, Oregon, during a very rainy time of year. The project required scaffolding and tenting to keep the building dry during the installation of the liquid applied membrane. These extra measures are not insignificant costs, and effectively make the cost of the liquid applied membrane more expensive. In this case, however, the airtightness and durability concerns for the building were higher priorities than the increased costs of application.

Some liquid applied membranes are marketed as quick set times, and some have additives that can be added to decrease the set time considerably, but the products still cannot be installed in the rain, unlike traditional house wraps and building paper.

The other issue reported by the company on the West Coast is that the order of construction required the liquid applied membrane installer to revisit areas multiple times as more penetrations were made and construction progressed. Revisiting areas is not unique to liquid applied membrane installation compared to traditional construction practices, but it requires specialized people and equipment each time.

The ability to make repairs to damaged areas of the liquid applied membrane should also be considered. If a plastic house wrap is ripped or damaged, it can be taped, or another piece can be added fairly easily. Water based liquid applied membranes bond well to themselves even after they are set (as long as they are clean, dry, etc.), so new product can easily be installed over damaged areas of existing liquid applied barrier. Once the liquid is dry, most of the liquid applied barriers researched felt quite durable to the touch, and appeared much more difficult to damage than traditional house wraps.

2.5 Building America Builder Experience with Liquid Applied Membranes

Horizon Builders in Maryland, one of our Building America industry partners, started exclusively using liquid applied air and water barriers in its custom home construction several years ago, when it had some water ingress issues caused by complicated sheathing membrane details and self-adhered membrane failures. Horizon was also doing repair work on other construction projects caused by water ingress, and decided that using liquid applied membranes was a more reliable and durable system and resulted in fewer complaints and callbacks.

Most importantly, Horizon started acquiring liquid applied membrane materials from different manufacturers and testing them in its laboratory, applying them to mockups, exposing them to the elements, submerging them in water, etc. All of the testing Horizon has done is qualitative in nature, but helps determine preferred products based on testing, as well as how they are applied, because in some cases, where all other things are equal, the decision of which product to use is based on how it easy it is to work with.

The mockups that are built helped Horizon determine sequencing of construction trades and check the compatibility of various products to determine how a specific product is applied in a specified thickness. The mockups and time spent in the shop working with various materials has led to a Horizon Techniques Manual. The manual is approximately 150 pages of photos and written descriptions on water management details, such as windows, doors, foundations, and flashings. Horizon uses this manual to instruct its employees and explain sequencing and details to the site trades to minimize miscommunication and quality control issues that may result in water management concerns. Horizon has found the manual to be an incredibly helpful resource for both staff and the site trades as both construction instruction as well as a quality control tool when a representative visits a site. Horizon also tests prototype liquid applied membranes for some companies, and will give opinions on the products based on its vast experience of many different products. Occasionally, a manufacturer will provide, at Horizon's request, special modifications such as increasing the thickness of an available product, to be able to fill in small cracks and joints without crack or joint treatment.

Figure 15 shows an area of the laboratory used to test various liquid applied membranes by submerging them for weeks at a time. A wood frame is made, and the interior corners are sealed with different products used in the field, and then all of the surfaces are treated with the different liquid applied membranes. Most of the products perform very well, and there are no surprises, but at least one of the products re-emulsifies when it is submerged underwater for a period of time. This is a relatively rigorous test compared to what we design our building enclosures for, but it is possible in some locations for liquid water to be left in contact with the liquid applied membrane, and over time, there may be issues.

Figure 15. Liquid applied membrane water baths

Figure 16 shows a compatibility issue between the sealant used at the inside corners with the liquid applied membrane. The sealant at the corner and the liquid applied membrane were from different manufacturers, and in most cases, products from the same manufacturer will be compatible. It is always good to test the compatibility in the laboratory before using a system in the field, especially if more than one company's products are being used. Compatibility issues usually mean that one of the materials will not adhere to another because of the chemistry of the two materials. This incompatibility could result in compromised air and water barriers through which water could penetrate.

Figure 17 shows mold on the underside of one of the water bath tables. The mold is light green and evenly distributed on the plywood, making it difficult to see. This product is not a vapor barrier, so it is likely that water vapor has migrated into the wood through the liquid applied membrane and increased the relative humidity and moisture content in the plywood.

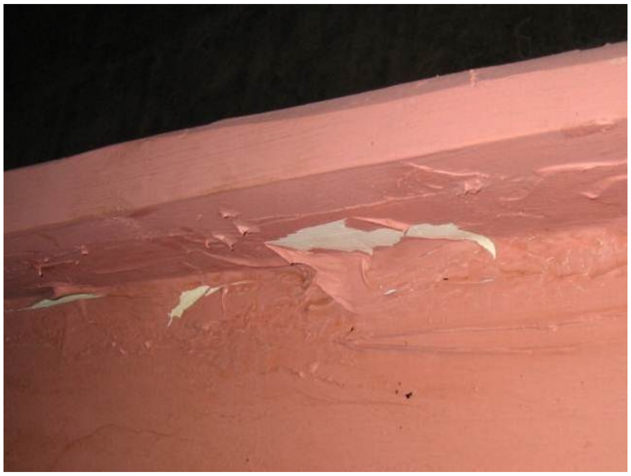


Figure 16. Compatibility issue

Figure 17. Underside of water bath table

Horizon has also started long-term drainage testing between various exterior insulations and liquid applied membranes (see Figure 18). Water is continuously applied from nozzles to the back surface of the insulation. Observations will be made regarding the system performance.

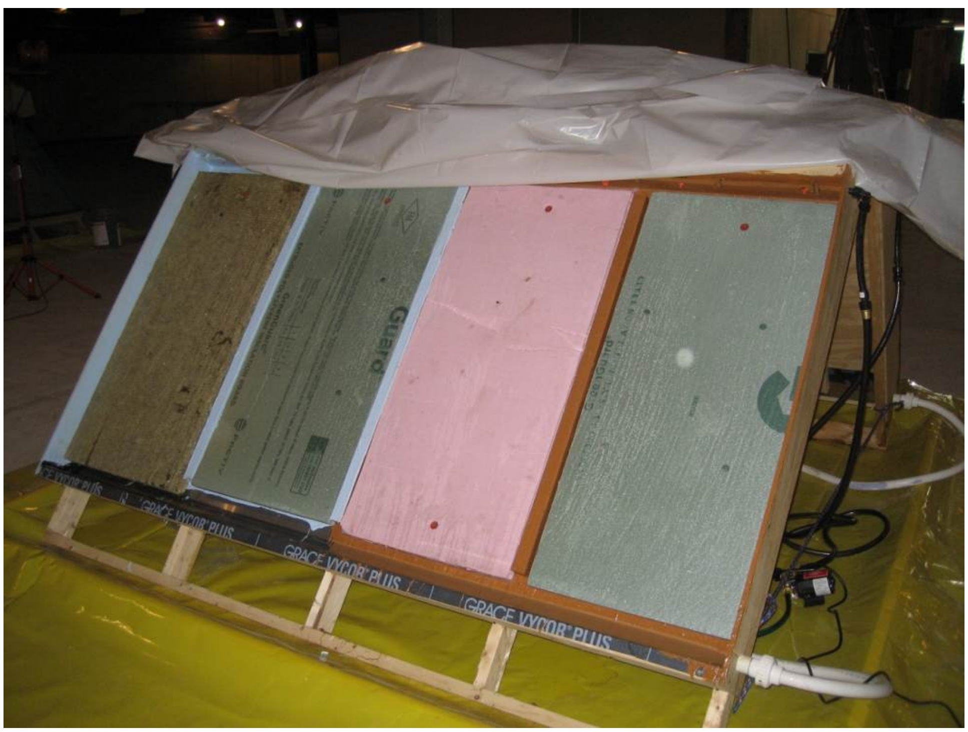


Figure 18. Drainage testing durability spray rack

About dozen mockups in the laboratory use various liquid applied technologies and window installation techniques. Figure 19 shows an example of a mockup of construction that was used on a home, showing all the stages of installation from the liquid applied membrane to window airtightness, head flashing, and trim detail. This was used to instruct the crew on proper technique during construction.

One of the interesting observations during the installation of some liquid applied membranes to mockups was that, in some cases, the liquid applied membrane forms ridges during installation that are deep enough to allow drainage of liquid water, so that water would not be trapped between the exterior insulation and the liquid applied membrane.

Figure 19. Water management mockup with liquid applied membrane and exterior insulation

To simplify construction and improve durability, Horizon is constantly testing different ways of doing construction, including sill pan water management (Figure 20). On the left is the current practice of completely covering the window buck in liquid applied membrane and embedding a plastic pre-manufactured sill pan flashing. On the right of Figure 20 is a tapered sill pan flashing with back dam made of XPS insulation and integrated into the liquid applied membrane of the window buck.

Figure 20. Window sill flashing mockups

More than two years ago, Horizon attached many samples of self-adhered membrane to a large board outdoors behind the laboratory, and has been qualitatively testing the materials for adhesion issues when subjected to exposure weathering in Maryland (see Figure 21). This qualitative testing helped Horizon decide which self-adhered flashings were the most durable under temperature and UV exposure for its construction projects, in places where self-adhered membranes could not be avoided. The compatibility between the chosen self-adhered membranes and liquid applied membranes was always confirmed prior to construction.

Figure 21. Exposure testing of peel and stick membranes

The most important information learned from this exposure testing was that even the self-adhered membranes that performed poorly (peeling, fishmouthing, etc.), in almost every case performed quite well for the entire testing period when terminated along the edge with termination mastic (Figure 22). This testing may seem extreme compared to in-service conditions, but by showing that a material can perform well under these extreme conditions, gives confidence that it will be perform well as a part of the water barrier system for a long time in service, resulting in a durable enclosure system.

Figure 22. Peel and stick membranes with termination mastic

3 Installation Details

The following figures and accompanying descriptions are meant to represent some of the most common enclosure details in residential construction. Some liquid applied membrane manufacturers include detailed drawings on their websites using their specific products, but these drawings are meant to be far more generic. Because there are countless variations on construction practices depending on products, construction strategy, and geographic regions, these details may require modification for a specific detail.

In many colder climates, it is becoming increasingly common to use exterior insulation, also referred to as continuous insulation (CI), although there are benefits to exterior insulation in all climate zones. In some cases, the insulation is installed over the structural sheathing, and the drainage plane of the wall is between the exterior insulation and structural sheathing. This can work quite well, if water management details are well constructed, despite the skepticism in industry related to the moisture-related durability of the structural sheathing.

These drawings do not require any modifications if continuous insulation will be installed directly against the liquid applied membrane on the sheathing, although typically we would recommend that penetrations be flashed to the exterior surface of the foam, or the exterior surface of the wall, instead of between the insulation and the sheathing. If the exterior insulation is quite thick, the rough openings are usually formed with plywood boxes as deep as the insulation is thick, and these boxes are most easily detailed with a liquid applied membrane as water protection.

Another construction technique using exterior insulation is to use a minimum amount of structural sheathing to meet the structural component of the building code (typically at corners), and board foam is attached directly to the framing in most locations (Figure 6 is an example of this). In these systems, using a liquid applied membrane on the exterior may be a preferred option to tapes and peel and stick membranes, but currently very few product manufacturers recommend their products for the exterior of board foam insulation.

The specific topic of liquid applied membranes directly applied to exterior foam insulation requires further research and study before it can be utilized in production home construction, due to the lack of knowledge and lack of testing that has been conducted.

3.1 Field of Wall

Generally speaking the field of the wall (without penetrations or changes in material) is quite straightforward for any liquid applied membrane product, as it is the uninterrupted plane of the noninsulated or insulating sheathing that is flat, and without any obstructions or detailing. It seems that most liquid applied membranes on the market are not approved to be installed on the seams between sheets of sheathing without a joint treatment.[3] This is generally addressed with either a type of mesh tape embedded in the liquid applied membrane, or a specific, compatible type of caulking that is first installed in the gap. Following joint treatment in the sheathing, the

[3] Any joint treatment should be evaluated, as a minimum, as part of the AC212 criteria mentioned earlier.

liquid applied membrane is installed to the entire surface of the sheathing, covering the joint treatment (Figure 23).

Some liquid applied membranes are installed thickly enough that no joint treatment is required in gaps less than a certain width, but visual inspection of the gap treatment seems like a prudent step in the construction process. The required membrane thickness will vary based on manufacturer's recommendations, substrate type, etc.

Few liquid applied membranes are approved for use on exterior insulation or insulating sheathing. The surfaces of various foam board insulation products vary considerably, and some plastic foam insulations are more susceptible to thermal expansion and contraction than noninsulating sheathing. In the case of some plastic foam insulations, the face of the sheet is an approved, drainage plane, and only the joints require treatment.

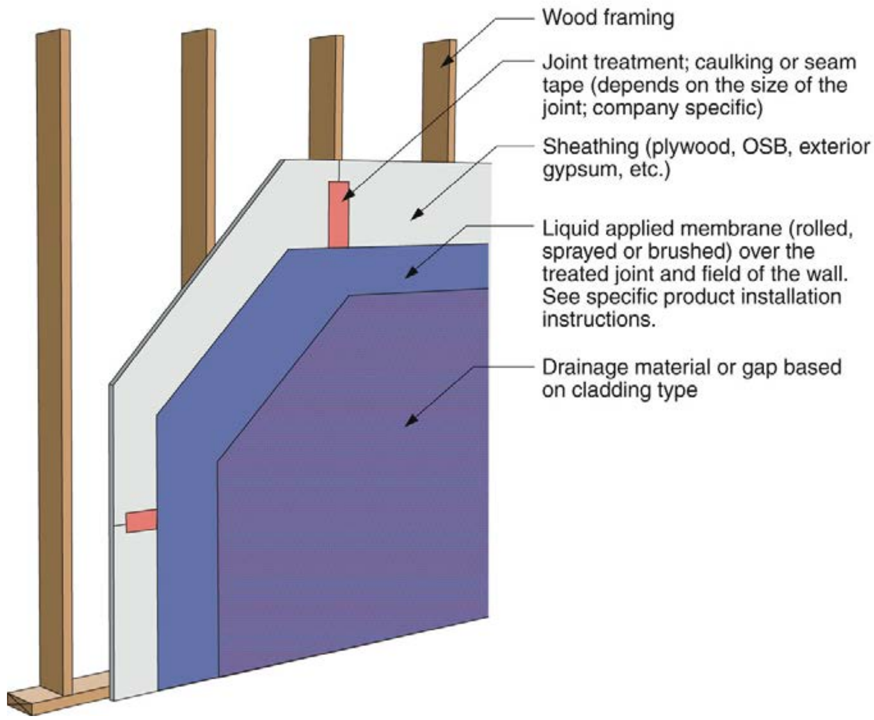


Figure 23. Liquid applied membrane installed in the field of the wall

Once the liquid applied membrane is installed on the sheathing, some claddings that are ventilated and drained, such as vinyl siding or lap siding, could be installed directly. Others are recommended with a drainage/ventilation layer in the system. This drainage/ventilation layer could be wood strapping, drainage mesh, etc.

The reason for promoting drainage/ventilation is to use a rain screen construction approach which is inherently less risky from a moisture durability perspective. (Straube 2010, Lstiburek 2009)

3.2 Interior and Exterior Corners

The corners of the sheathing are treated very similarly as joints in the field of the wall. Typically a seam tape, transition membrane or liquid caulking is specified for the joint (Figure 24).

Typically there is less tolerance in the corners than in the field of the wall, and exterior corners are prone in some areas to getting bumped, so that the liquid applied membrane should be reinforced so that damage can be reduced. Damaged areas should be repaired.

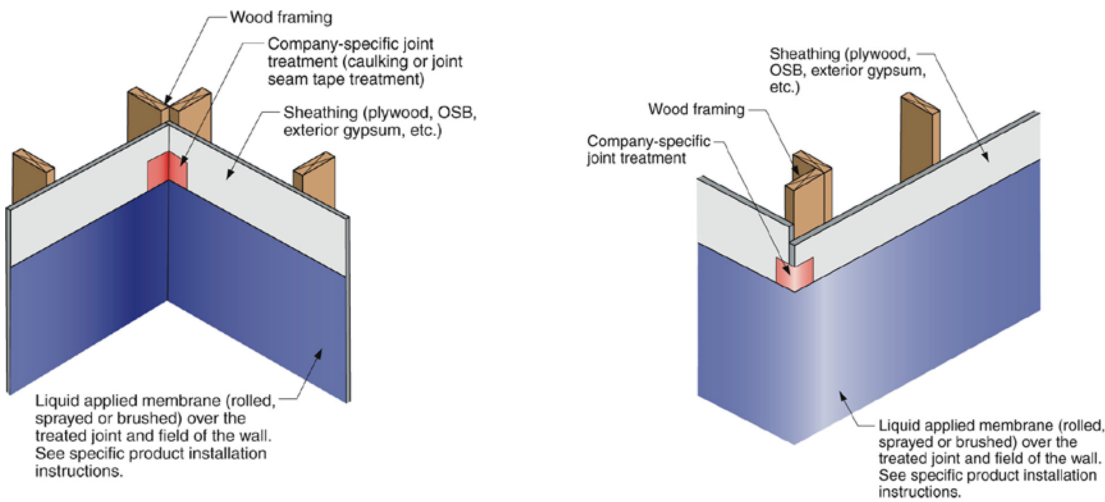


Figure 24. Inside and outside corners

3.3 Windows

Windows are some of the most common pathways for water entry into the building enclosure. Recommended best practice for current typical construction includes a sill pan flashing, with back dam and end dams, jamb flashings, and a head flashing to direct any water in the drainage gap out over the window. (BSC 2007) This general theory for window water management does not change using liquid applied membranes. In many cases, the procedure for water management of window openings is simplified using liquid applied membranes instead of peel and stick membranes that can result in complicated origami to ensure there is no water entry.

In some cases the liquid applied membrane can be used as the sill pan flashing, and with other products, a pre-manufactured sill is recommended as well (Figure 25). If a pre-manufactured sill pan is chosen, the vertical leg must be integrated to the jamb, and a reverse lap is generally unavoidable, which will require quality installation.

The window details appear to change slightly depending on the product used and the specific company recommendations. The most typical window treatment includes a transition membrane from the framed window buck to the exterior face of the sheathing. This appears to be typically done with a mesh tape set into a layer of liquid applied membrane similar to joint treatment, but there are products on the market that are thick enough that do not require a transition membrane. Some manufacturers offer preformed corners to further simplify applications at corners of openings. Sometimes the specifications call for a prefabricated pan flashing to be installed over the liquid applied membrane. Some testing has been conducted using XPS board foam insulation as a sill flashing (Figure 20, right image), as long as the liquid applied membrane is compatible. In the case that water is constantly sitting on the liquid applied membrane, a vapor closed liquid applied membrane may be a better choice for a sill pan flashing.

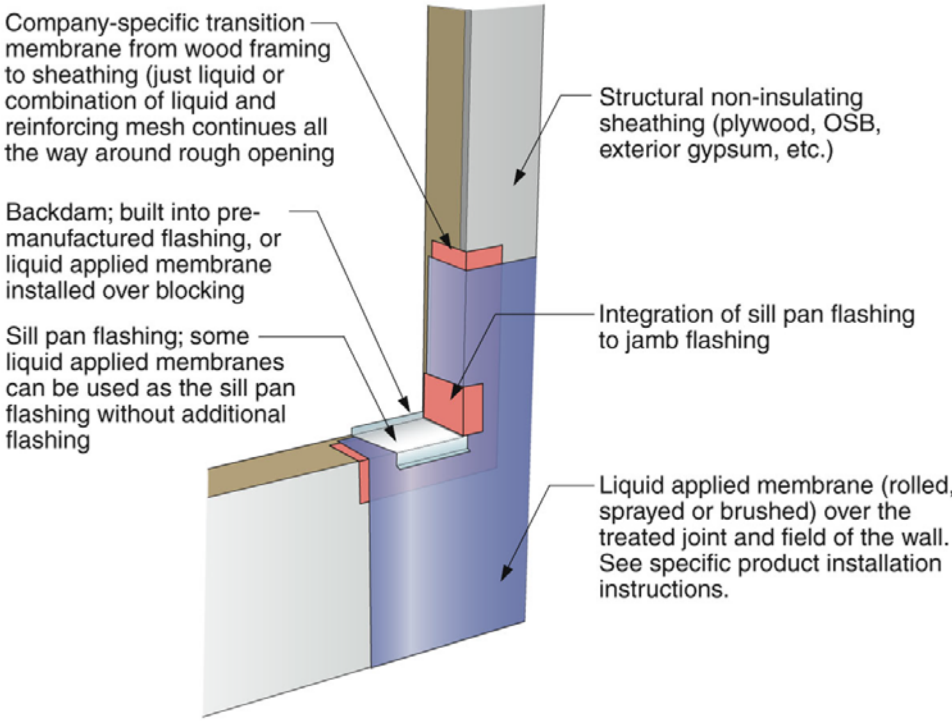


Figure 25. Window sill and jamb

At this time, there are very few liquid applied membrane options to use that transition between the window buck framing and exterior insulation or insulated sheathing, if the drainage plane is the exterior face of the insulation. If the exterior insulation is installed over structural wood sheathing and the drainage plane is between the insulation and the sheathing membrane, all details are installed for noninsulating sheathing. By placing the air and water barrier behind the insulation, it is protected from damage once the insulation is in place, and protected against temperature extremes. There are some concerns that liquid water may become trapped and cause durability issues with the sheathing. Drainage testing is a good indication, and in some cases, required by building codes. Water should still be directed to the exterior of the insulating sheathing from window openings, even if the water control layer is the face of the structural sheathing.

For production builders, it may be more cost effective to use structural strapping on the framing, and install the insulating sheathing against the framing, reducing the capital cost by removing the structural sheathing. For this strategy, the exterior of the insulation must be sealed against air and water. This can prove to be tricky in the field depending on the insulation and tape used. It can perform very well, but field investigations and site visits have demonstrated countless examples of poorly installed or poorly performing joints in insulating sheathing.

At the head of the window (Figure 26), all of the water in the drainage gap should be directed out away from the building with a head flashing that extends past the window jamb trim on the sides. This head flashing can be attached with a compatible transition membrane or peel and stick product. If a peel and stick membrane is used, it is important that the top edge of the peel and stick be terminated properly, either with a termination mastic, or in some cases, house wrap tape can be used. Peel and sticks tend to peel away at the edges, especially with the help of gravity, and water can work its way in, eventually failing the system. Window installation is carried out per usual specifications depending on the type of window.

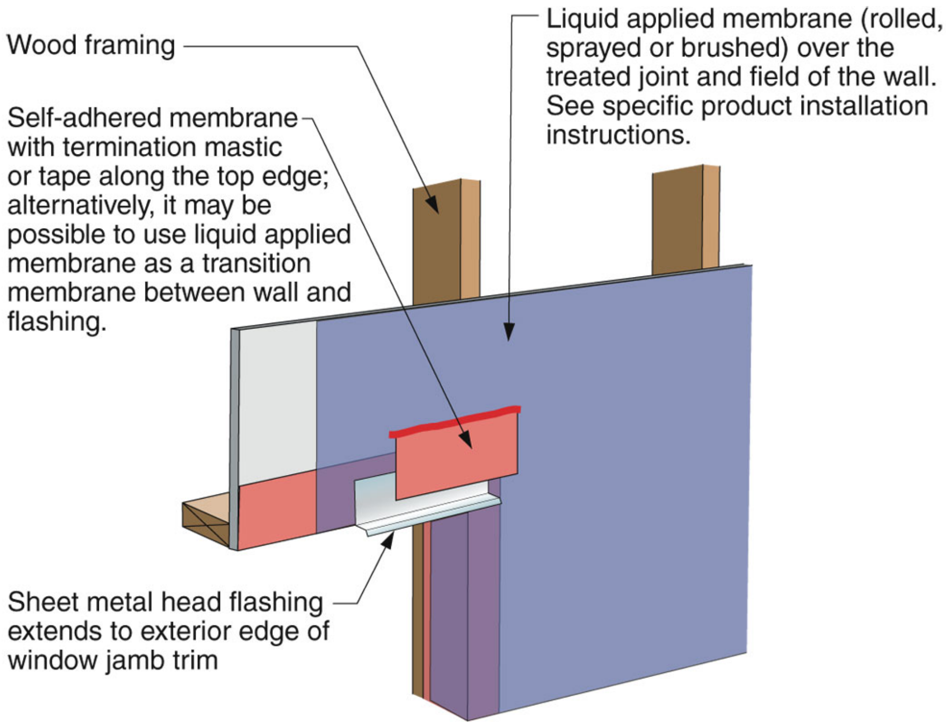


Figure 26. Window head flashing

3.4 Top of Foundation

Another common detail in residential construction is the transition between the foundation and the first-story brick cladding (Figure 27). Ideally, a lower brick ledge is used, which gives structure for the bricks to sit on, and there is much less risk of water sitting on the flashing behind the bricks and finding a way into the interior as with a level top of foundation. This is constructed similarly to a window head flashing, with a through wall flashing that is attached to the liquid applied membrane on the surface of the wall with a transition membrane. It is important that this transition membrane be compatible with the liquid applied air and water barrier, and to be terminated at the top edge correctly.

None of the products researched had any limitations of use behind a brick façade, and the liquid applied membrane is generally far more durable to the unintentional abuse during masonry installation than a sheet product. One important consideration for installation behind brick is the vapor permeability of the coating and the risk of inward vapor drives, although that topic is not included in the scope of this study.

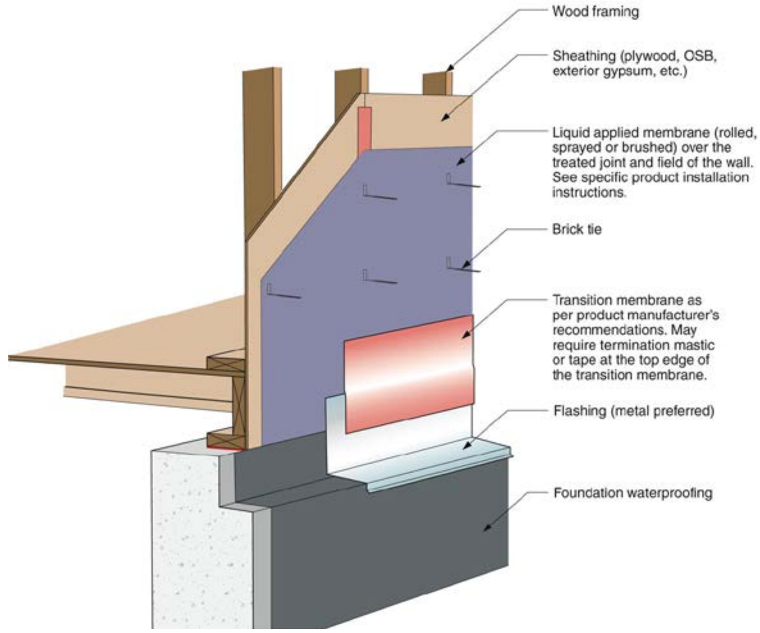


Figure 27. Foundation detail

3.5 Mechanical Penetrations

Mechanical penetrations through the enclosure can be locations of air and water leakage. Figure 28 shows two possible scenarios to seal the penetration depending on the size of the gap between the service and the sheathing. If the gap is large, expanding polyurethane foam can be used to first seal the gap, followed by the transition membrane because it needs a relatively solid surface for good performance. If the gap is small, no gap filler is likely required, but product-specific details should be referenced. Compatible sealants are often another option to seal around penetrations.

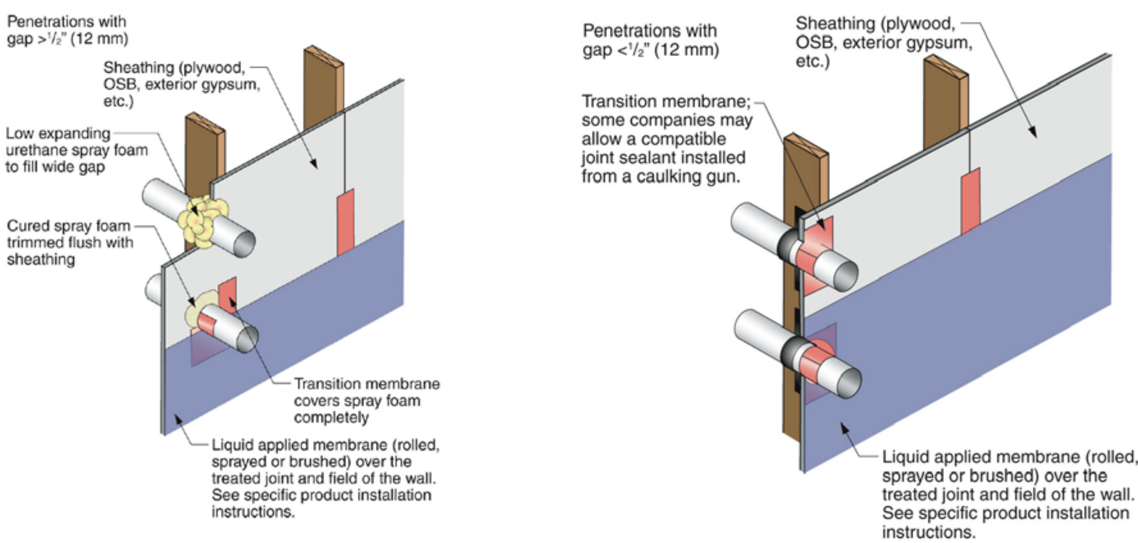


Figure 28. Mechanical penetrations

3.6 Insulating Sheathing

With increased insulation requirements in newer energy codes, and the documented advantages of using exterior insulation on reducing thermal bridging, and wintertime condensation risk (Smegal and Straube 2009), it would appear that exterior insulation will become more popular in areas that still have not started using it in production.

The structural sheathing may be removed (after checking with a structural engineer) in lieu of other structural reinforcement, to save money for the production builder. This will require the drainage plane to be reliably and durably installed over the exterior insulation.

One of the complications of foam plastic insulation is that it typically is less thermally stable, and will expand and contract more than standard structural sheathing. This is the reason that often two layers are specified with joints offsetting, so that gaps that open up do not span the entire thickness of the foam insulation. This also makes it a little more demanding on the physical properties of a liquid applied membrane.

In regard to expanded polystyrene (EPS) board foam, The ICC has acceptance criteria (AC71) for foam plastic sheathing panels used as water-resistive barriers The standard requires testing in accordance with AATCC Test Method 127 where insulation specimens shall be held at a hydrostatic pressure of 21.6 in. (55cm) for a period of 5 hours. There may be a rational reason for this extreme testing, but it seems unreasonable to subject a material that is installed in a vertical orientation to such high water pressures, when in reality the joints are more than likely going to be the weakest links in any foam plastic sheathing system. This is the reason that EPS foam board requires a plastic facer to be used as a drainage plane in the enclosure system when, in reality, it could likely be used safely as a drainage plane in the enclosure with adequately sealed joints. Testing may be required to demonstrate this.

Extruded polystyrene (XPS) and foil-faced polyisocyanurate (PIC) are two other board foam insulations that can be used as exterior insulation and are generally approved to be used as a drainage plane if the joints are sealed. Very few liquid applied membrane options were found during product research that are approved for use on the joints of these two products. One of the common problems with tapes sticking to foil-faced PIC is that there can be an oil residue along the edges of the foil face from manufacturing, and the tapes can lose adhesion immediately. Another insulation that can be used on the exterior is a rockwool insulation, but this is recommended only over an air and water barrier installed against the structural sheathing.

Recently, deep energy retrofits have become more popular, and liquid applied membranes can be used on the existing sheathing once the cladding has been removed resulting in a significantly higher air and water tight enclosure that accommodates existing complicated details

4 Conclusions and Future Work

Liquid applied air and water barriers were developed to address a need for higher performing buildings with less risk of water intrusion and less air leakage into and through the enclosure. These liquid applied barriers are more expensive initially than traditional sheathing membranes, but the paybacks in labor and durability (especially callbacks) appear to decrease the effective cost of the liquid applied barrier. There are very few official data on costs for liquid applied barriers from such programs as RSMeans as of yet, but this information will likely become available as liquid applied barriers become more common. There is also very little information as to the long-term durability of these current liquid applied barriers and coatings because they have not been widely used for very long relative to the expected service life of most buildings.

Liquid applied barriers are most effective on complicated enclosures with geometries that would make traditional sheathing membrane installation difficult and potentially risky from a moisture durability perspective.

Although there is currently no plan or budget to expand on the knowledge and information included in this report, we feel that there are several areas in which study could be conducted, based on research corresponding to this study, to further understand and improve the use of liquid applied barriers in residential and commercial applications.

- As energy codes become more stringent and continuous exterior insulation is required, it may be cost effective to use the minimum amount of structural sheathing required and use liquid applied barriers on the exterior surface of insulating sheathing as the drainage membrane. This may require testing to show that the proposed system does not perform any worse than a code approved enclosure wall, and likely better.

- To increase the rate, and therefore decrease the cost, at which liquid applied barriers can be installed, it would be beneficial for the liquid applied barrier to bridge gaps without fabric tapes or special joint treatments on small joints.

- Although all liquid applied barriers have vapor permeance data (ASTM E96), a better understanding of how the installed thickness affects the expected vapor permeance of the coating is required. This will help determine which geographic locations, if any, may be subject to increased durability risk if the liquid is over- or underapplied.

- There is an industry perception that it is risky to install the drainage plane of the enclosure between the wood-based sheathing and the low-permeance exterior insulation. It could be beneficial, based on this perception, to explore any moisture-related durability risks of water drained intentionally between a low-permeance exterior insulation and liquid applied barrier both in laboratory testing and field testing.

BSC will continue to work closely with Horizon Builders to develop a wider database of liquid applied barrier installation details and answer questions of industry regarding liquid applied barriers. The questions most frequently asked are regarding physical characteristics of the liquid applied barrier such as vapor permeance and the moisture durability of the enclosure in various climates.

References

Baker, P. (2006). Research Report-0604: Incorporating Insulating Sheathing into the Design of the Thermal and Moisture Management System of the Building Enclosure. www.buildingscience.com.

Building Science Corporation. (2007). Water Management Details for Residential Buildings, Building Science Corporation. www.buildingscience.com

Building Science Corporation. (2007). Guide to Insulating Sheathing. www.buildingscience.com.

International Residential Code (IRC). (2009). Chapter 6 Wall Construction, R601.3 Vapor Retarders. © International Code Council Inc.

Lstiburek, J. (2006a). Building Science Digest-104: Understanding Air Barriers. www.buildingscience.com.

Lstiburek, J. (2006b). Building Science Digest-106: Understanding Vapor Barriers. www.buildingscience.com.

Lstiburek, J. (2006c).Water Management Guide. Building Science Press, Westford, MA.

Lstiburek, J. (2009). Building Science Insight-001: The Perfect Wall. www.buildingscience.com.

Lstiburek, J. (2009). Building Science Digest-012: Moisture Control for New Residential Buildings. www.buildingscience.com.

Smegal, J.; Straube, J. (2009). RR-0903 Building America Special Research Project – High-R Walls Case Study Analysis. www.buildingscience.com,

Straube, J. (2010). Building Science Digest-030: Rain Control Theory. www.buildingscience.com.

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