A HOLISTIC EXAMINATION OF WALL ASSEMBLY PERFORMANCE IN MULTI-FAMILY CONSTRUCTION

MOISTURE: A LEADING CAUSE OF MULTI-FAMILY CONSTRUCTION DEFECTS

Building scientists and other experts agree: no matter how tightly a building is constructed, no matter how well it’s insulated, no matter what type of exterior cladding is chosen and how expertly it’s installed, moisture will always find a way into the building enclosure. Moisture infiltration can undermine structural integrity, cause exterior surfaces to deteriorate, and shorten the life of paints and stains.

Moisture can also foster mold and rot that not only cause structural damage to multi-family buildings but also pose serious health hazards. For example, a moisture content pushing 28% exceeds the accepted content of 22%. If sustained, this will inevitably result in fungal decay. New studies have pushed this number lower suggesting that mold can grow on wood at levels above 15%.

Most moisture problems are caused by poor architectural design that traps or directs water back into wall assemblies and does not allow sufficient drainage. At times, there is a lack of a well thought out moisture management plan that includes the right materials and best practices for construction. Additionally, moisture is sometimes generated from building occupants and a lack of ongoing maintenance.

The effect of moisture on a building’s durability and comfort have been well documented with 90% of building and building material failures directly associated to moisture, per ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers). These failures are a significant contributor to a staggering $9 billion spent by the construction industry each year on construction defects related to water intrusion as compiled by ASTM (American Society for Testing and Materials).

WAYS THAT MOISTURE GETS INTO MULTI-FAMILY WALL ASSEMBLIES

There are basic science fundamentals that explain how wetting and drying take place within a multi-family wall assembly. First, heat moves from a warmer state to a colder state. Second, moisture moves from a wetter state to a drier state. And third, pressure moves from a higher level to a lower level.

While exterior cladding usually is considered to be the primary barrier to water entering a building enclosure, no cladding can keep out all water. For this reason, it is important to understand how moisture still gets into wall assemblies.

Condensation

High humidity and extreme temperatures can cause vapor diffusion, with moisture flowing from a warmer state to a colder state. As a
result, condensation occurs on the colder surface. Moisture is often transported by air movement through leaks or penetrations in the wall assembly.

**Wind and Gravity-Driven Rain**

Wind and gravity-driven rain can be forced into small openings in the exterior cladding at joints, laps, utility cut-outs, electrical outlets, nail holes, and other openings. Wind blowing around the building can create a negative pressure within the wall assembly. Because of the pressure difference, the wall assembly siphons water into the wall.

**Solar Drive**

Some “reservoir” claddings, such as brick, stone and stucco, can absorb and store moisture which the sun then drives into the wall assembly (solar drive). For instance, when a brick gets wet and then is warmed by the sun, some moisture moves to the colder, outside air and some moves to the backside of the brick into the exterior wall cavity. This is because there is more moisture in the brick than there is within the wall cavity.

**Surface Gaps and Porosities**

It is commonly understood that siding expands and contracts as outside air temperatures fluctuate. However, the expansion and contraction process can create gaps in the exterior surface of multi-family wall assemblies. This means that intersections, joints, and wall penetrations are all susceptible to moisture infiltration. Furthermore, porosities found in brick, stone and stucco cladding can lead to the absorption of unwanted moisture.

**Capillary Action**

Capillary action refers to the ability of water to travel in tight air spaces against the pull of gravity. In small spaces, gaps, holes, or pores, water molecules like to stick together through the forces of cohesion. For example, when you dip a portion of a paper towel sheet into a bowl of water you can see capillary action by watching water travel up the paper towel sheet. Although not as serious as bulk water movement, capillary action is a powerful force and can lead to moisture problems inside wall assemblies.

**Diffusion**

Diffusion is moisture flow as vapor from a higher humidity environment to a lower humidity environment. This is a process where moisture is absorbed by building materials and then the moisture is released to a drier environment. An example of moisture flow by diffusion is the drying process that would take place if the wall sheathing was damp and the moisture diffused or evaporated through a vapor permeable housewrap.

**Air Currents**

Air contains moisture and there are air currents in and out of wall assemblies. Consequently, moist air currents can dampen building materials, condense on cold surfaces, and create conditions for mold and decay.

### MOISTURE MANAGEMENT CONSIDERATIONS

For multi-family construction, designers should organize their thinking around the four D’s of moisture management:

- **Deflection**
- **Drainage**
- **Drying**
- **Durability**

**Deflection**—This means designing wall assemblies and products that deflect rain water away from a multi-family building. A one-inch rain storm will deposit over 600 gallons of water per 1,000 square feet of roof. Designing to deflect this water away as fast as possible means that there will be less water for a building assembly to have to drain away. Avoid complex designs that make it difficult for water to drain. Instead, design roofs that slope away for fast and easy drainage. Avoid horizontal valleys and surfaces because water tends to be trapped in those areas. Another deflection technique is to use seamless kick-out flashings to divert roof water away from roof wall intersections.

**Drainage**—All cladding systems can leak and allow water to penetrate. The faster water drains from a multi-family building the less water is absorbed by building materials. Fast, efficient drainage reduces the amount of time needed for drying because components are less wet. This means less chance for fungal decay. The key here is to provide as much unrestricted drainage as possible. Eliminate reverse shingling of building wraps and flashings that trap and divert water to the inside. Use drainable housewraps, rainscreen walls, adhesive flashings, and through wall flashings at cladding transitions and at the base of masonry walls.

**Drying**—This means designing wall assemblies and products that allow water to evaporate so that the building materials can dry. To ensure faster drying, use a good drainable weather-resistive barrier (WRB), or building wrap, to prevent water intrusion.
Care must be taken to seal penetrations and openings. It is key to make sure the self-adhered flashings and sealants are compatible with each other and all window, door and penetration materials. Most flashing designs have evolved over time and based on what worked. The minimum requirements for flashings are found in building codes and serve as a useful guide to designers.

**DRAINABLE HOUSEWRAPS: A CLOSER LOOK AT A FAST-GROWING TECHNOLOGY**

There is growing recognition among building scientists and building codes that walls do need to drain and that housewraps will increasingly be judged by how effectively they provide positive drainage of water from the wall. Drainable housewraps, the fastest-growing segment of the market, address this need by using both a water-resistive layer and a drainage gap.

Standard housewraps provide only a water-resistive layer and can trap water behind cladding. In contrast, drainable housewraps help water to drain from behind the exterior cladding system. More specifically, they provide a continuous drainage gap that allows water to quickly escape from the wall system and thereby protect the building enclosure. Compared to standard housewraps, the newest drainable housewraps - especially those that
provide a minimum of a one (1mm) millimeter gap—can be as much as 100 times more effective at removing bulk water from the wall.

Let's examine some of the performance criteria that helped shape the direction of drainable housewrap technology for multi-family wall assemblies.

Water Resistance
As its most basic function, a housewrap must hold out liquid water. ICC-ES allows for three different testing standards: Boat Test, Water Ponding and Hydrostatic Pressure tests.

- The Boat Test, developed for paper and felt, is the least stringent standard. It is overly sensitive to humidity and vapor transfer. Therefore, it is unreliable for plastic housewraps.
- Water Ponding is a test that measures a housewrap’s resistance to a “pond” of 1 inch of water over two hours.
- Hydrostatic Pressure, the most stringent test, exerts significant pressures on a housewrap sample through a column of water (55 cm or higher).

The better approaches are the Water Ponding and Hydrostatic Pressure tests. A premium housewrap should be able to pass both of these tests.

Durability
A housewrap must be able to withstand the handling and application process without compromising its water-resistance performance. The tear resistance, or tensile strength of the product, is the best available indicator of whether or not a housewrap might be damaged.

UV and cold resistance are also tested for housewraps. UV resistance depends on the time between the installation of the housewrap and the application of the siding. Many housewraps provide a 90 to 180 day recommendation for installation of siding. However, in most cases housewrap should be covered within 30 days if possible. The cold resistance test standard is to ensure that housewraps do not start to crack at low temperatures.

Vapor Permeability
Permeability measures the amount of vapor transmission that a housewrap will allow over a period of time, minimizing the potential for accumulation of moisture vapor. The higher the perm number, the more vapor permeable the material. There is debate on the optimal permeance range for housewraps, with 10 to 20 perms considered by some to be optimal.

Although grounded in building science, the debate over appropriate vapor transmission often focuses too much on the perm number. In reality, the permeability of a housewrap varies

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**QUIZ**

1. Water has the ability to travel in tight air spaces against the pull of gravity because of ________.
   a. Solar Drive  
   b. Air Currents  
   c. Capillary Action

2. True or False: Moisture can not only cause structural damage to multi-family buildings but also pose serious health hazards.

3. The four D's that guide the design of a moisture management system are:
   a. Diffusion, Drainage, Drying, Damping  
   b. Deflection, Drainage, Drying, Durability  
   c. Deflection, Design, Decaying, Durability

4. True or False: Without flashing, it is a challenge to control rainwater because most multi-family buildings have transitions between materials or wall assemblies.

5. When designing a moisture management system, use a step and seamless kick-out flashing for:
   a. Material transitions  
   b. Roof-to-wall intersections  
   c. Transition of dissimilar claddings

6. True or False: If the surface tension of water is increased, it can penetrate deeper into a wall material.

7. Drainable housewraps use both a water-resistive layer and a minimum of a ____ drainage gap.
   a. 1mm  
   b. 2mm  
   c. 5mm  
   d. 7mm

8. True or False: Compared to standard housewraps, the newest drainable housewraps can be as much as 100 times more effective at removing bulk water from the wall.

9. Two types of materials commonly used for Continuous Insulation (CI) are:
   a. XPS, Cellulose  
   b. ICF, Mineral Wool  
   c. XPS, Mineral Wool

10. True or False: Continuous Insulation (CI) is an uninterrupted blanket of insulation that covers a building’s structure without thermal bridges other than from fasteners and service openings.

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**SPONSOR INFORMATION**

TAMLYN has brought to market a complete system of enclosure with TamlynWrap™ Drainable Wrap, XtremeSeam™ and the related XtremeFlashing™ tapes to ensure effective water management. This enclosure system compliments our XTremeTrim® line of extruded aluminum profiles for multiple panelized systems. TAMLYN strives to provide high quality design solutions.

This article continues on [http://go.hw.net/AR042017-4](http://go.hw.net/AR042017-4). Go online to read the rest of the article and complete the corresponding quiz for credit.
from lab conditions to installed conditions (particularly after the housewrap is fastened on a wall). For a product to be considered a housewrap (and not a vapor retarder), the permeance rating must be higher than 5. But a higher perm rating doesn’t guarantee a better housewrap. Housewraps with mechanical micro-perforations may allow the passage of more water vapor, but this highly permeable housewrap may allow moisture that is stored in reservoir cladding to be driven into the sheathing and insulation through drainage.

**Drainage**

Drainage is widely accepted as one of the most effective measures for reducing moisture damage due to rain penetration. Drainage is a critical component in allowing the housewrap to do its job, particularly in keeping walls dry. According to some building science research, a 1.5 mm drainage gap will drain water at a considerable rate even in a climate of extreme rain. Because of this, manufacturers are now focusing on drainable housewraps that are designed to provide an integrated gap and drainage plane.

**Surface Tension**

If the surface tension of water is reduced, it can penetrate deeper into a material. Surfactants, which are surface active agents, occur naturally in materials such as cedar, stucco and stone mixes. They are also found in the mixtures used to power wash houses. Water that manages to get into a building system carries these surfactants and allows them to penetrate deeper into the walls. A housewrap can eventually lose its repellency and allow water to soak through to underlying sheathing. Some housewraps are specifically designed with coatings that resist surfactants. Drainable housewraps provide space to carry water away and thereby reduce the risk of surfactant-induced damage.

**Testing Used for Performance Criteria**

The International Code Council (ICC) has an acceptance criterion ICC-ES AC38. AC38 establishes guidelines for evaluation of sheet materials used on exterior walls, such as water-resistive barriers, moisture protection barriers, weather-resistive barriers, and optional air barrier materials. This acceptance criterion is designed to give the industry the following list of tests that evaluate and compare the performance of building wraps.

- **Water Resistance**—The test for this is AATCC Test Method 127: Hydrostatic Pressure Test. During this test three control specimens and three specimens that have been weathered via UV/acceleration are placed under a hydrostatic head of 55 cm for 5 hours. Some manufacturers’ test specimens were observed to have no water leakage, meaning that all met the water resistance requirement of AC38.
- **Drainage Efficiency**—The test for this is ASTM E2273. During this test a wall assembly is built with a housewrap over the sheathing behind the cladding. Water is applied to the assembly with the amount of drainage over time recorded. The AC38 minimum is 90% to pass.
- **Test Method 127: Hydrostatic Pressure Test.**
- **Durability and Tear Resistance**—The test for this is ASTM D5034 Breaking Strength and Elongation of Textile Fabric. During this test a housewrap is put under a constant rate of extension until breakage. The minimum for AC38 is 35 lb. cross direction (CD) and 40 lb. machine direction (MD).
- **Cold Weather Flexibility**—During this test a specimen of housewrap is conditioned to 32°F (0°C) and then bent over a 1/16” diameter mandrel. To pass the test, the housewrap must not crack.
- **Flammability and Smoke Developed**—The test for this is ASTM E84 Surface Burning Characteristics of Building Materials. During this test a housewrap is placed in a tunnel with a burner on one end. Then a draft facilitates flame progression with the spread being calculated. To qualify for Class A, the housewrap needs a flame spread index between 0 and 25 and a smoke developed index of 115.

**Building Code Considerations**

While the performance testing criteria for housewraps promote better moisture
management, the codes are starting to catch up with accumulating research and building science expertise. In the case of multi-family homes, the codes now stress the importance of draining water in order to protect the integrity and performance of the wall assemblies.

The International Residential Code (IRC), for instance, mandates the use of water-resistant barriers, stating that "The exterior wall envelope shall be constructed in a manner that prevents the accumulation of water within the wall assembly by providing a water-resistant barrier behind the exterior veneer...and a means of draining to the exterior water that enters the assembly (R703.1.1 Water Resistance)." The International Building Code (IBC) also requires a means of draining water that enters the wall assembly.

Designers today are faced with many choices for drainable housewraps, flashings and air barriers. The codes are constantly changing and it is important to understand the requirements and the products available to meet the demands for better moisture management on multi-family wall assemblies.

CONTINUOUS INSULATION

Perhaps the most notable quality of XPS is that it is resistant to moisture, thus preventing moisture absorption and a loss of R-value.

In addition to code requirements for moisture and water resistance, recent changes in energy efficiency requirements for homes have increased interest in continuous insulation (CI) because of its thermal efficiency. CI is an uninterrupted blanket of insulation that covers a building's structure without thermal bridges other than from fasteners and service openings. This means code compliance for higher levels of wall assembly performance. In many U.S. states, CI is no longer a value-added option but rather a requirement.

Though control of water, air, and vapor are necessary for a safe and durable wall system, the insulation layer brings big benefits noticed by owners and occupants: comfort and savings, with the latter including both operating costs and planetary resources associated with energy use. Some insulation also provides acoustic benefits.

The type of insulation used in the wall design is highly specific to the application. It must meet the codes and be compatible with all other components in the assembly, from the framing or structural supports to WRB to hardware and more. A century ago, we designed and built with a handful of materials and asked far less of our buildings. Today, there could be a matrix of dozens or even hundreds of combinations.

The best strategy, according to some manufacturers, is to determine the performance goals for a wall assembly and then specify it as "a system" to achieve those goals. From that flows the products that will make up that system. A basic understanding of CI properties helps make sense of proper wall design.

Let's look at two distinctly different types of materials used for CI, extruded polystyrene and mineral wool, and their basic properties.

Extruded Polystyrene (XPS)

Extruded Polystyrene (XPS) insulation, a type of rigid foam insulation, is recommended for exterior above-grade walls and foundation walls. It is easy to install on either the exterior or interior face. XPS insulation typically has an R-value of 5 for a 1-inch thickness.

XPS contains hundreds of millions of microscopic closed cells filled with a captive, low-conductivity blowing agent to provide its legendary thermal control. Perhaps the most notable quality of XPS is that it is resistant to moisture, thus preventing moisture absorption and a loss of R-value. Non-structural XPS weighs quite a bit less than plywood, OSB, or other structural non-insulation materials (which typically have much lower R-values). Because it's rigid, it can be scored and snapped, cut or sawed, with common tools. The material never sags or settles.

XPS is commonly used as CI sheathing, either over an exterior gypsum board sheathing or applied directly to the steel studs, in independently braced steel-stud framing systems. This means more R-value and reduced energy loss in stud framing systems for multi-family construction.

Mineral Wool

In applications where fire resistance is required and is a primary concern to save lives, mineral wool is the insulation of choice. Since it is initially made of naturally occurring rocks, it makes sense that mineral wool has good fire performance. But today, some sustainability minded companies use up to 70 percent slag, a byproduct of the steel industry (what's left over after the iron ore is extracted). Those are melted at 2,600°F and essentially taken back to their original molten state. The next step mimics the making of cotton candy, where the molten rock is introduced into an airstream, creating strands of fiber for the mineral wool. For residential use, some multi-family structures need a firewall and some UL-rated assemblies call out mineral wool.

Mineral wool has a higher density than fiberglass, making it more effective at restricting air currents through the material. Similar to XPS, mineral wool can be produced as boardstock or batt insulation and be rigid enough to work as insulative sheathing. Mineral wool is found to have the following benefits:

- R values up to 4.2 per inch
- Non-combustible and can handle temperatures up to 2,000°F
- Ultraviolet (UV) resistant
- Permeable
- Water and moisture resistant
- Easy to fabricate around irregularities in wall construction
- Sustainable
- Sound control
- Natural dark color provides camouflaging in open-joint facades

The choice of insulation is application specific. When all is calculated, the fire performance of mineral wool insulation is the most important benefit because it helps keep residents safe.
CASE STUDY: TEXAN 26 - AUSTIN, TX

**Architect:** Mark Hart Architecture  
**Builder:** Provenance Constructors

Drainable wrap was used under the wood furred rainscreen to provide drainage for the furring strips should they accumulate moisture.

Texan 26 is a student housing project in Austin, TX that utilized drainable wrap and double-sided seam tape plus needed self-adhered flashings for a full water management system. Then fiber cement lap, panel siding with extruded aluminum trim, and board and batten were used to complete the project giving it distinct façades dependent upon the section of the building. “Drainable wrap was chosen for the effectiveness as a drainage plane under multiple siding products and for maintaining its gap once installed,” said Jon Standley, Project Manager at Provenance Constructors.

**SUMMARY**

Building scientists continue to study the risks associated with the migration of moisture into structures. Building codes are evolving to address the need for moisture management in multi-family home construction. Homeowners are becoming more educated and concerned about moisture-related issues such as mold, rot, and insect infestation that affect the performance of wall assemblies.

Science shows that heat moves from a warmer state to a colder state and that moisture moves from a wetter state to a drier state. It is also known that pressure moves from a higher level to a lower level. Because of these principles, moisture gets into wall assemblies from condensation, wind and gravity-driven rain, solar drive, surface gaps, porosities, capillary action, diffusion and air currents.

To address the moisture issues, advances in building construction and technology have vastly broadened the range of solutions for effective moisture management. Selection of the right solution remains a complex issue, with necessary considerations given to environments, the type of exterior cladding used, the available project budgets, and construction timetables.

The design of an effective moisture management system includes the four D’s: deflection, drainage, drying, and durability. These principles remind designers the key ways to design a multi-family building that manages the redirection of water and moisture on the building’s wall assemblies.

Flashing options also need to be considered for multi-family building designs—particularly at roof-to-wall intersections, base-of-walls, roof penetrations and material transitions. With the aid of flashing, these transitions are bridged and ready for natural building movements that may occur over a long period of time.

As the demand increased over the years for better moisture management, drainable housewraps came into the market. Thanks to the use of both a water-resistant layer and drainage gap, this newer housewrap technology meets stringent performance criteria for water resistance, durability, vapor permeability, air resistance, drainage and surface tension. The evolving standard testing criteria and building codes for moisture management products help ensure proper drainable housewraps are used and applied effectively.

Furthermore, there is an increased level of interest in continuous insulation (CI) because of its thermal efficiency properties. CI is an uninterrupted blanket of insulation that covers a building's structure without thermal bridges other than from fasteners and service openings. Extruded polystyrene (XPS) and mineral wool are two products commonly used to provide CI to increase thermal efficiency and fire resistance, respectively.

Architects, builders and buyers must understand the differences between traditional housewraps and the next-generation drainable products that will provide moisture protection at a cost-effective price. Choosing the right housewrap requires an understanding of the product’s key attributes, including water resistance, durability, vapor permeability and drainage. Housewraps, especially drainable housewraps with enhanced drainage capabilities engineered into them, are increasingly being viewed as essential components of any well-constructed multi-family wall assembly.