PROCEEDINGS

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Vented Cladding Assemblies Prevent Reverse Vapor Drive and Allow Vapor-Permeable Water-Resistive and Air Barrier (WRB/AB) Membranes To Enhance Wall Assembly Drying

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Abstract

The demand for higher-performance wall assemblies that reduce energy consumption, increase sustainability, and effectively reduce heat, air, and water movement is altering assembly design. Low-permeance vapor barriers once thought to improve performance may, in fact, increase interior condensation and trapped moisture in the assembly. Ventilated cladding increases wall drying, reduces the wet time of absorptive claddings, and mitigates reverse vapor drive, allowing permeable WRB/AB membranes to enhance the wall assembly performance. Current design has now changed from a barrier approach to a vapor-open WRB/AB system with a vented cavity to mitigate water intrusion and enhance drying potential.

Speaker

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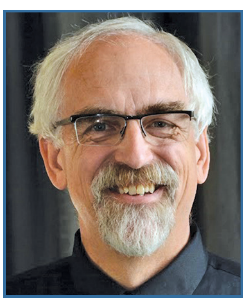

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ABSTRACT

The current demand by design professionals for higher-performing wall assemblies is at an all-time high. The quest to reduce energy consumption and increase sustainability in order to effectively reduce heat, air, and water movement is altering wall assembly design. Low-permeance vapor barrier design from the 1990s and early 2000s—once thought to improve performance—may, in fact, increase interior condensation and trapped moisture in the wall assembly.

Recent studies have shown that cladding ventilation has the potential to increase drying, reduce the wet time of absorptive claddings, and mitigate reverse vapor drive. With these factors, the permeable WRB/AB membranes are allowed to enhance the wall assembly performance. In a majority of the populated climate zones of North America, inward vapor drive for absorptive claddings is thought to be an issue, promoting a false demand for vapor barrier installation. The current research using both modeling and in-field performance has now changed the barrier approach of a WRB/AB to a vapor-open system with vented cavities that mitigate water intrusion by enhancing drying potential. This paper investigates the current research on vapor-open, vented cladding wall assemblies and their impacts on performance.

INTRODUCTION

In a simple explanation, the wall system must separate the exterior from the interior environment. A more exhaustive list was provided by Hutcheons in 1963:[1]

Principal requirements of a wall:

1. Control heat flow.
2. Control airflow.
3. Control water vapor flow.
4. Control rain penetration.
5. Control light, solar, and other radiation.
6. Control noise.
7. Control fire.
8. Provide strength and rigidity.
9. Be durable.
10. Be aesthetically pleasing.
11. Be economical.

From the large number of differing wall systems and components, the vented cladding systems typically meet Hutcheons' principal requirements. Though there are differing types of vented cladding systems (*Figure 1*), the focus will be on the general rainscreen system as described by Hutcheons (*Figure 2*). A typical rainscreen wall assembly used in today's commercial construction projects provides similar requirements, though with newer materials (*Figure 3*).

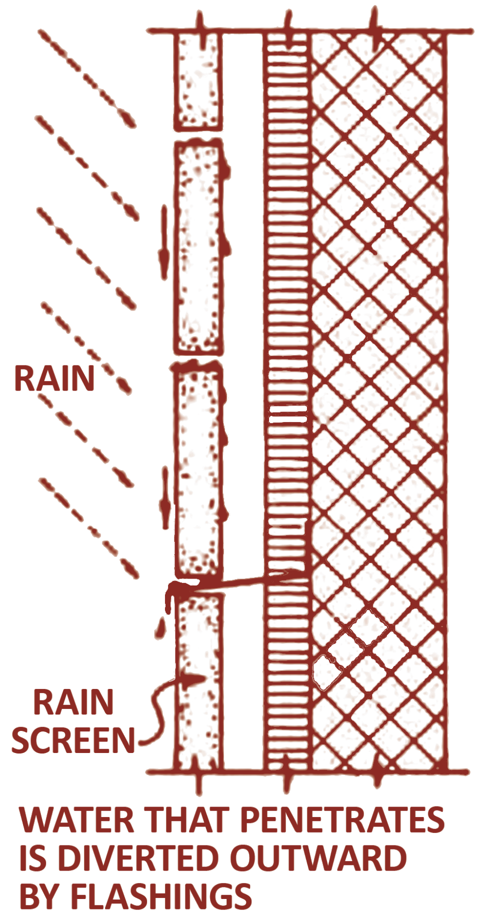

Figure 2 – Hutcheons' details of a rainscreen system and a typical wall overview.[24]

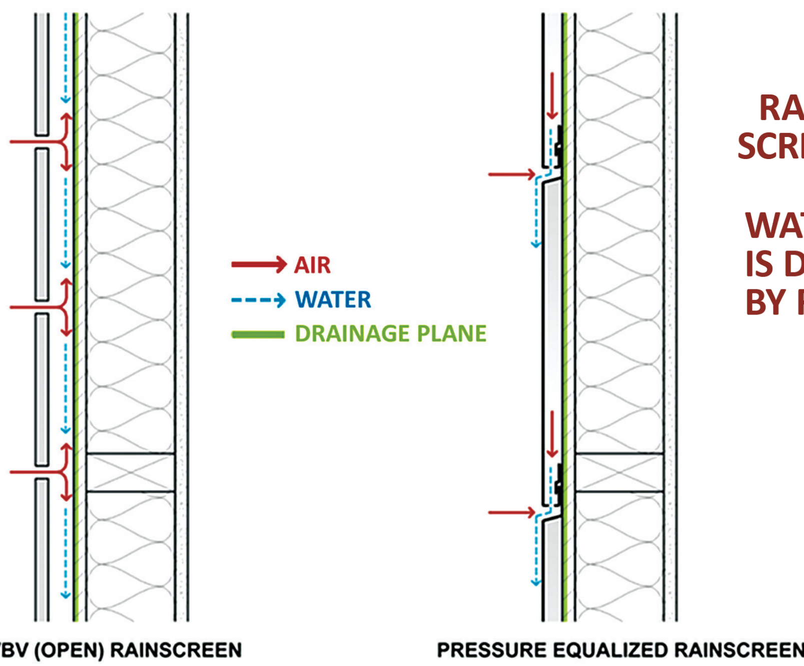

Figure 1 – Two examples of rainscreen wall systems.

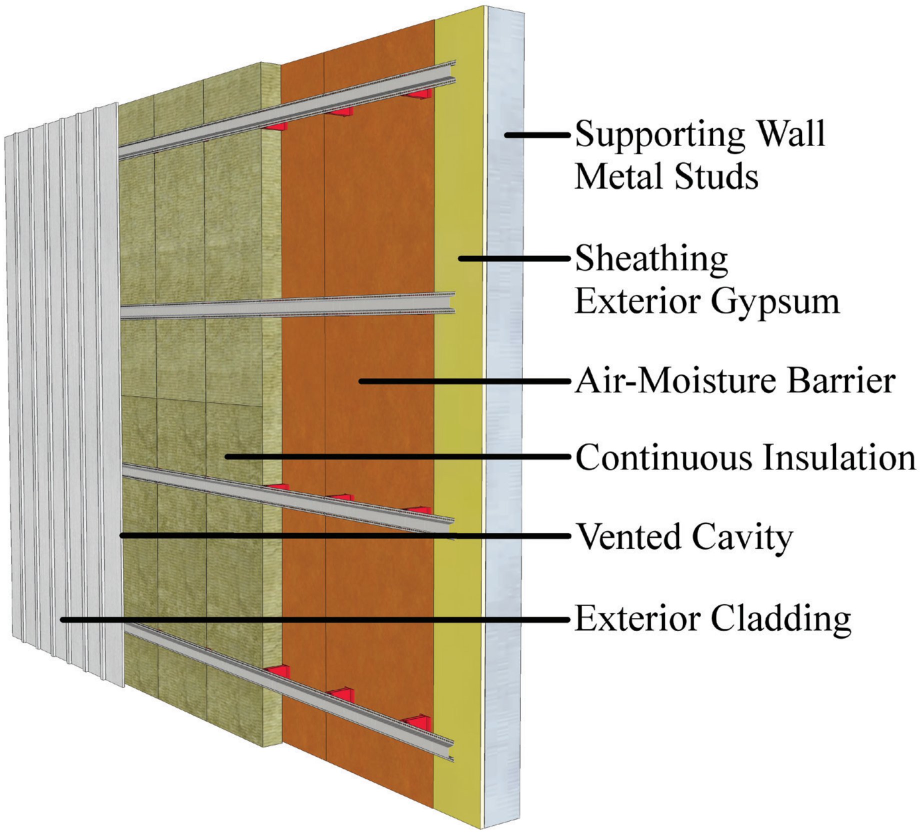

Figure 3 – Common commercial wall assembly overview of a rainscreen system.

At a minimum, the rainscreen system provides multiple benefits. These include an initial water barrier, vented cavity for pressure equalization that serves as a capillary break, and drainage for liquid water transport. Uncontrolled water penetration is the most common threat to building performance and durability, contributing to up to 80% of all construction-related claims in the United States.[2] The exterior cladding of the rainscreen system provides the first line of defense by limiting water intrusion into a vented cavity. The second line of defense would be the WRB/AB, which intercepts water that gets past the exterior cladding. The WRB/AB should also act as an air barrier to stop air infiltration through the wall system. It also allows free drainage of liquid water, as well as vapor diffusion through the WRB/AB and into the vented cavity. This provides a thermally protected, well-drained, vented, and pressure-moderated exterior screen.

DEVELOPMENT OF VENTED CLADDING

For centuries, the "open-jointed barn technique" or vented cladding design has been used extensively in Norwegian construction (*Figure 4*). This type of design has the ability to protect the building from water damage by allowing moisture that gets past the cladding to drain and dry.[3] In the 1940s, research began recognizing the vented cladding design (more commonly referred to by then as a rainscreen system) and its superiority in protecting the building from moisture.

> It is clearly unwise to allow walls, whether of brick or porous cement, to be exposed to heavy rain. They absorb water like a blotting paper, and it would therefore be a great step forward if an outer, water-repelling screen could be fitted to brick walls, with satisfactory characteristics from the point of view of appearance, mechanical strength, and cost. This screen could be applied so that water vapor coming from within is automatically removed by ventilation of the space between the wall and the screen.[4]

The rainscreen system became popular in many European building designs and was introduced to North America in the 1940s. This system has proven to be particularly well suited for Canada's wetter climates. As described in Johansson's 1946 paper,[5] a "water-repelling screen" would provide protection of the walls from excess moisture, and its vented cavity would allow "...water vapour coming from within [to be] automatically removed by ventilation of the space between wall and screen." In the 1960s, Canadian building scientists noted the importance of air barriers[6] and an "open rainscreen" that minimized rain penetration and wetting of the interior of the wall assembly.[7]

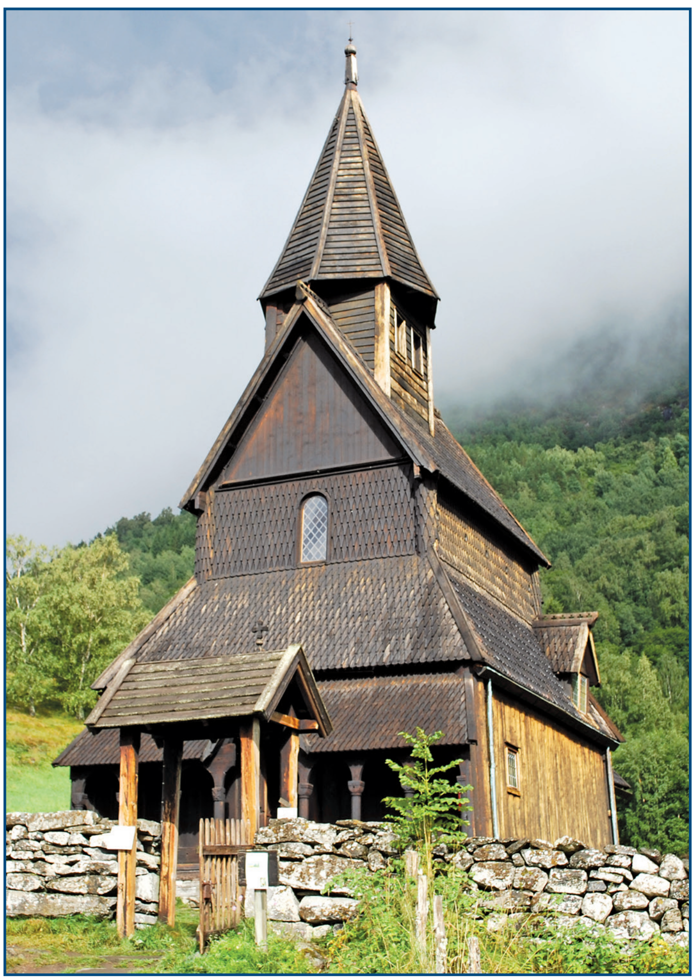

Figure 4 – Stave church in Urnes, Norway, built around 1130 using a rainscreen system. Image from Concierge.2C.

Currently, rainscreen systems are incorporated into many cladding details.

THE AIR CAVITY: DRAINING AND VENTING

The rainscreen system offers many protections for the interior of the wall assembly. The air cavity in particular provides:

1. Capillary break
2. Drainage plane
3. Ventilation channel
4. Pressure equalizer for the siding

DRAINING

When water ingress gets past the cladding, drainage must be allowed to prevent long-term moisture accumulation and its resulting damage. This is accomplished by the drainage plane and gap of the rainscreen system. Research determined a uniform minimum gap size of 1 mm (1/32 in.) provides sufficient drainage that should not exceed water entry for most drained cladding systems.[8] Measurements show a uniform gap of 0.5 mm (0.02 in.) will easily drain 1 L/min – meter width.[9] It should be noted that even the separation of two layers of building paper may provide a 0.5-mm gap that could drain intruding water. This is true for the vertical wrinkles or the dimples provided by some membranes. However, because separation can be quite variable, it should not be assumed sufficient for effective overall drainage.[10]

With a gap of 3 mm (⅛ in.), capillary rise or suction is prevented. It is common to use a 3- to 6-mm (⅛- to ¼-in.) gap as an effective capillary break. This gap prevents capillary suction between building components, uncoupling the cladding from the WRB/AB, and allowing free drainage.

During the draining process, some water remains within the rainscreen's cavity, adhering to surfaces by surface tension, and is absorbed into absorbent building materials (*Figure 5*). Measurements show that with non-absorptive materials such as acrylic and a gap greater than 3 mm (⅛ in.), one can expect to retain over 60 g/m^2 (0.2 oz./ft^2) of water.[11]

VENTING

To remove remaining water, dry the absorbent cladding, and allow vapor diffusion drying through the vapor-open WRB/AB, a vented drainage cavity is required. In general, venting of the rainscreen system is provided by two mechanisms that are wind-induced and buoyancy-induced due to convection or stack effect. Wind-induced airflow venting is highly variable due to multiple components. These components include wind direction, building geometry, and the proximity of other buildings, as well as other obstacles such as vegetation and terrain. Buoyancy-induced venting is dependent on air temperature differences of the cavity and outdoor air.[12]

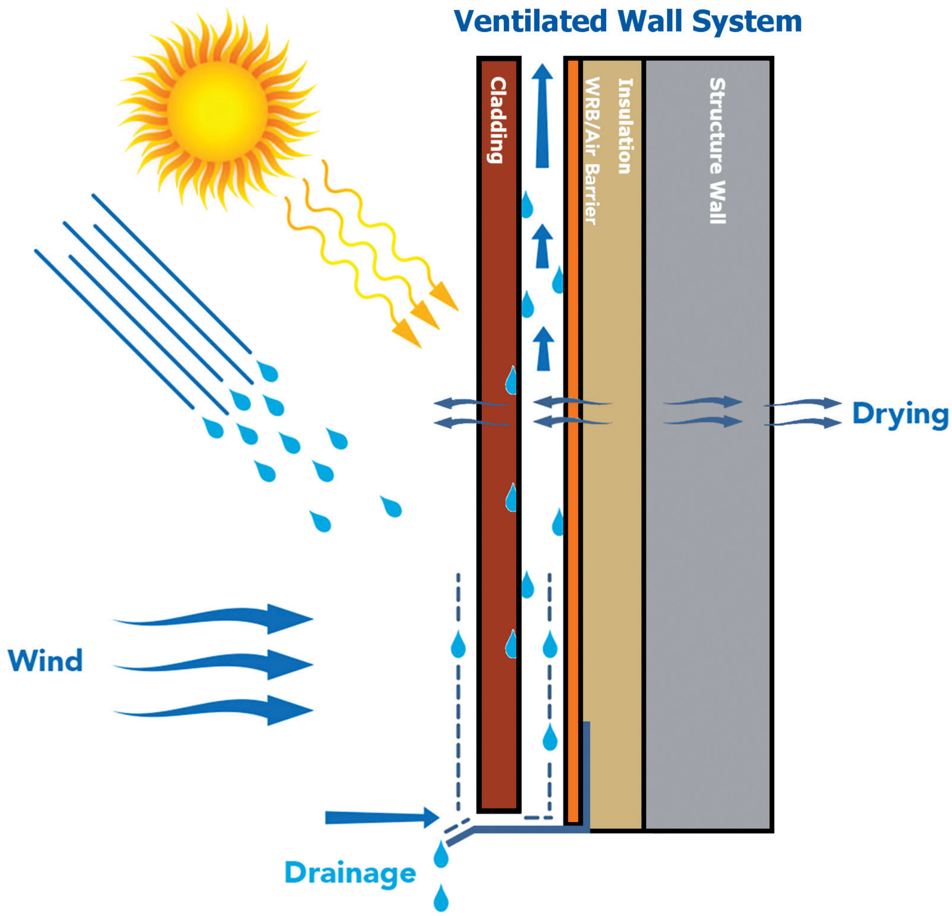

Figure 5 – Vented rainscreen system, providing additional drying by vapor diffusion and venting.

Moisture content also plays a factor in buoyancy-induced venting, but only when cavity vapor pressures are significantly higher than exterior vapor pressures. This is the case when an absorbent cladding such as brick or stucco is wetted during summer rains and heated by the sun. The buoyancy-induced venting provides a release for the solar-induced vapor pressure. A vented rainscreen reduces hydrostatic pressure, enhancing drying of the cladding and outward drying of the interior substrate, provided a vapor-open WRB/AB is used.

The size of the ventilation space behind the cladding is important as it must provide a capillary break, free drainage, and effective venting. In studies noted previously for draining, a minimum uniform gap size of 1 mm (1/32 in.) was sufficient to drain intruding water. A larger gap size is necessary to allow sufficient air movement to dry the remaining water. Drying studies of a wood framing and plywood or OSB substrate wall system showed a 19-mm (¾-in.) gap dried faster than walls having 10-mm (⅜-in.) gaps.[13]

Measurements of the rate of air movement in a vented rainscreen system show that air exchange rates of as little as 15 air changes per hour (ACH) provided enough ventilation to dry the wall cavity.[14] For a stucco-clad wall with a 10-mm (⅜-in.) air gap between, felt and house wrap vented at 30 ACH. These conditions reduced the moisture content of the sheathing and the system.[15]

Ventilation studies indicate that a 10-mm (⅜-in.) vented air gap is sufficient to provide vented drying of the rainscreen system, though it is unclear what minimum air gap is required for ventilation. This can be compounded by the constantly changing environmental conditions that influence either buoyant or wind-induced venting.

REVERSE VAPOR DRIVE

After a rainfall, the sun can heat the exterior of a wall system, enhancing evaporation and drying the cladding. This is problematic for absorptive cladding such as brick veneer, stucco, and manufactured stone. Solar heating enhances evaporation, increasing the vapor pressures on both the exterior and interior of the cladding. If a vented air gap is not present in the wall system, the inward solar-driven moisture can drive the vapor into the wall assembly, causing condensation when dew point is reached (*Figure 6*).

Figure 6 – Example of inward vapor driven condensation on the cooler interior vapor barrier.

Inward vapor drive resulting in summer condensation has been reported by several researchers.[16,17,18] In the absence of a vented rainscreen system, the solar-driven vapor pressure increase can migrate inward through a vapor-open WRB/AB. However, when a vented rainscreen is incorporated in the design, the summer heating generates significant thermal differences that drive buoyancy-induced venting, negating the inward vapor pressure drive. It is important to reduce inward solar-driven moisture, especially when absorptive claddings are used with vented rainscreen systems—especially in combination with vapor-open WRB/AB or interior vapor barriers.[19,20] Many claddings have a relatively low vapor permeance, which inhibits drying of the cladding material. The interior venting provides the drying to both the interior and exterior surfaces of the cladding, helping reduce the moisture load of material.

When a properly vented rainscreen system is incorporated, solar heating and its buoyance-induced venting reduces inward drive, as well as increases drying of the cladding and interior wall components. This lack of ventilation may have been a significant reason for the previously noted inward vapor drive problems and interstitial condensation.[21]

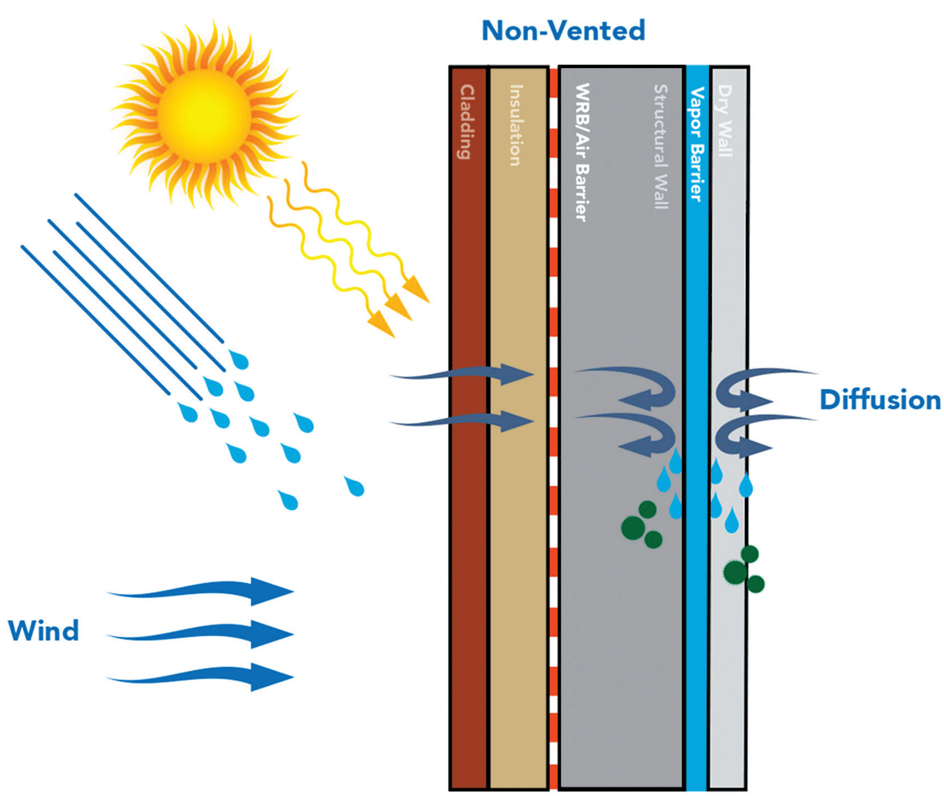

Figure 7 – A non-vented wall system with internal vapor barrier showing condensation due to lack of vapor diffusion at the vapor barrier.

VAPOR-OPEN WRB/AB-ENHANCED WALL DRYING

Due to building code requirements, a demand for reduced energy consumption, and material and installation costs, many of today's commercial buildings are constructed with metal studs and gypsum-supported continuous insulation with directly attached cladding enclosures. With a vapor barrier included in design, the drying ability of inward vapor diffusion is blocked (see *Figure 7*). This results in the lack of vapor diffusion drying and accumulation of interstitial moisture. If moisture presence is long-term, the moisture-induced physical, chemical, and biological reactions are enhanced, causing degradation of the susceptible building components.

To provide effective drying, wet materials should have higher permeability the closer they are to the ventilated cavity of the rainscreen system. The higher permeability allows vapor movement to the vented cavity. This should include a vapor-open WRB/AB to allow moisture that may accumulate in interior wall components of the enclosure the ability to dry to the vented cavity (*Figure 8*).

Drying studies were performed on water-saturated 12.5-mm (½-in.) plywood

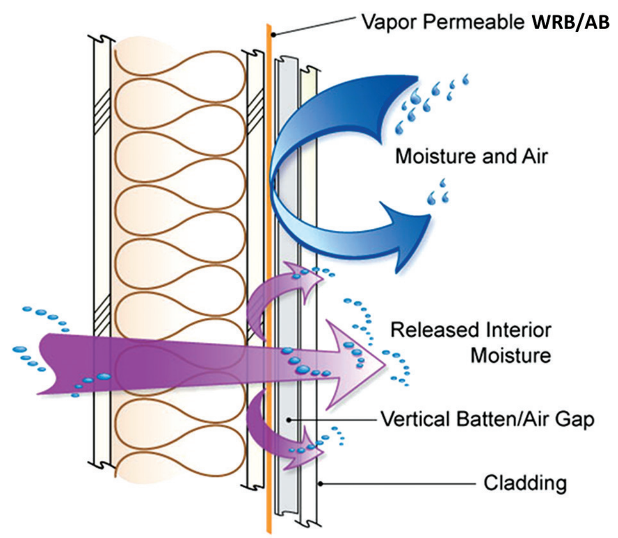

Figure 8 – Vapor-permeable WRB/AB membrane, allowing wetted interior materials to dry to the exterior via vapor diffusion. In addition, both sides of the cladding can dry, reducing any moisture loads.

Figure 9 – Image of the test chamber used in drying studies of plywood samples wrapped in WRB material. Air exchange rate of 50 ACH was used, as it represents the likely flows associated with a properly vented ½-in. rainscreen cavity, based on previous research by others accounting for thermal-induced convection buoyancy and typical wind-driven air pressures.[24,25]

samples.[22] Samples were wrapped or coated with various WRB materials and subjected to 50 ACH to simulate a ventilated rainscreen system (*Figure 9*).[23] The results of this drying study show that higher-permeable WRB materials typically dry faster than low permeable materials (*Figure 10*).

In a vented rainscreen system, a highly permeable WRB/AB allows wet interior materials to dry to the outside. This drying reduces the moisture exposure of the building materials and the degradation-associated long-term moisture presence.

CONCLUSION

A vented rainscreen has been shown to control moisture ingress by shielding the interior systems from the direct impact of rain. It provides draining and drying of moisture that has intruded past the cladding. Even though a 1-mm (1/32-in.) gap can drain most cladding systems, to accommodate construction tolerances, a larger gap of 3 mm (⅛ in.) is incorporated in the design.

Many sufficiently large variables exist: environmental, design, materials, and installation. A specific gap size for effective and beneficial venting, drying, and reduced reverse vapor drive has yet to be precisely determined for all conditions. A minimum 10-mm (⅜-in.) air cavity would ensure all the benefits were provided.

Unlike masonry wall designs, metal stud, gypsum substrate, insulation, and nonabsorptive claddings provide little hygric buffering and scant ability to store moisture. For absorptive claddings, the vented cavity can reduce reverse vapor drive and allow vapor diffusion drying from the interior through a vapor-permeable WRB/AB.

Incorporating the rainscreen system into the design minimizes moisture exposure and its negative long-term degradation effects. The vented air space controls water penetration by allowing intruding moisture to drain and dry before it can cause damage to the interior wall components.

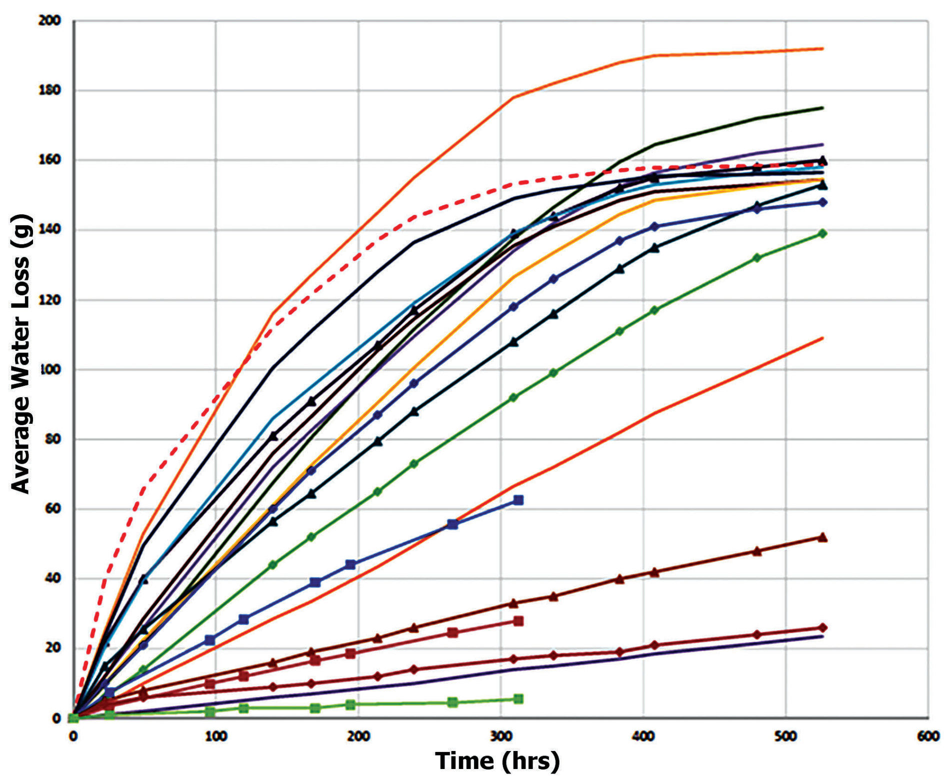

Figure 10 – Plot of sample weight versus time (0-600 hours), demonstrating moisture loss of drying plywood wrapped or coated with common fluid-applied and membrane WRBs.

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