Building Envelope FORUM

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WATER RESISTANT BARRIERS

By Richard Kadulski

Introduction

Recent building envelope failures of face-sealed claddings, especially Portland cement stucco in the lower mainland of British Columbia and exterior insulation finish systems (EIFS) in North Carolina, have highlighted the importance of doing proper details to control rain penetration.

What is often overlooked is that sheathing membranes play a critical role in managing moisture that penetrates the exterior cladding. As a class of materials, they are sometimes referred to as a water- (or weather-) resistive barrier.

The sheathing membranes are also important in controlling vapour movement and air infiltration and exfiltration. However, there has been relatively little research into their performance, and product standards primarily deal with product manufacturing processes and quality assurance. Spurred on by the questions raised during the research work concerning the building envelope failures in BC, CMHC along with industry partners formed an external research consortium at Montréal's Concordia University. The objective was to study the moisture performance of water-resistant barrier materials.

The research set out to:
- develop a material classification system,
- review laboratory test methods for reviewing properties of water-resistant barrier (WRB) products,
- examine various effects on water-resistant barrier performance, including the effects of:
• various substrates on moisture transfer through selected WRB products
• various boundary conditions,
• outdoor weathering on WRB properties, such as water head,
• various extractives and surfactants,
• weathering on WRB properties,
• fastener penetration on moisture transmission into substrates.
- develop a performance-oriented test method to more realistically describe WRB products.

There are many specialized membrane products with properties tailored to various applications. Those intended for WRB applications vary in the way they are manufactured and in the raw materials from which they are made. The research group developed a classification system for WRB products.

Class C
Asphalt-impregnated cellulose fibre WRB. These include felts and commonly-used building papers. The asphalt material imparts water resistance to the cellulose fibres.

Class P
Polymeric fibrous WRB. These include sheet materials manufactured from spun-bonded polyolefin fibres that are hydrophobic and form a mat that repels water.

Class PP

Perforated polymeric film. These sheet materials are monolithic poly films that are mechanically perforated to permit vapour to pass and to provide some resistance to water penetration.

Class M
Micro-porous film WRB. These sheet materials are monolithic poly films that have particles incorporated into the material. When the film is stretched, some of the particles fall away, leaving a film with micro-pores.

Class LA
Liquid-applied (by spray or trowel) WRB. These films are formed by applying one or two coats of a liquid base-coat material to wood-based or gypsum-based sheathing. When cured, the films provide a water-resistive coating on the sheathing and at joints.

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Most of the research was focused on representative samples of Class C and Class P materials. This reflects that these are the most widely-used WRB products. However, all classes, except the micro-porous films, were included in the research.

Existing test methods

The paper, textile and polymer industries have developed a number of test methods to evaluate membrane products for WRB applications, but their primary purpose is quality control. These include the "boat test," the "dry indicator test," the "ponding test" and the "hydrostatic pressure test." Each test checks certain abilities of WRB to repel or prevent moisture from passing through the material.

The boat test makes a small boat of the material, placing a powder that changes colour when it becomes wet inside the boat, and floating the boat. The time taken for the colour to change is a measure of the material's resistance to passing moisture.

The dry indicator test is a modification of the boat test. The experimental setup consists of an aluminium float or a hollow cylinder with a wire frame clamp for mounting the specimen and a watch glass. The test specimen's lower surface is exposed to water and the time required for moisture to pass through the specimen, as indicated by the colour change of the moisture indicator on the specimen's upper surface is measured.

For the ponding test, a 25 mm (1 in.) head of water is placed on the membrane and researchers measure how long it takes for three drops of water to pass through.

For the hydrostatic pressure test, high water heads are applied against the membrane to determine the pressure needed to overcome the surface tension of water in the pores to allow flow to take place through them.

Water flow has been the dominant consideration and vapour flow a secondary consideration. Some materials appear to perform better in one type of test than another. None of the tests provides direct information about how these materials perform in a wall assembly. As a result of these comparisons, the consortium felt that more fundamental measurements were necessary to better understand how WRB materials function to protect walls.

Existing and new test methods

One test method used to obtain the fundamental properties of membranes is the ASTM E96 "dry cup" and "wet cup" test. The dry cup test exposes the membrane to a differential relative humidity (RH) of 50 percent and measures the weight gain in a desiccant used to establish the low RH (near zero percent). This provides a measure of the water vapour flow through the material. For the wet cup test, water is placed inside the cup instead of desiccant and an RH of 50 percent is maintained on the outer face of the sample. The weight loss of moisture from the assembly is measured.

For the "inverted cup test," a known amount of water is placed on top of the membrane in a test cup and the change in weight is measured as moisture escapes by diffusion through the membrane. Usually, the RH applied on the "dry" side is 50 percent. This test appears to be intuitively correct for assessing vapour flow.

Having the top surface exposed to an inch or so of water, with the bottom surface exposed to a known dry environment, such as that provided by a conditioned space or by a desiccant, provides very well-defined boundary conditions. Under these conditions, the highest possible driving force is created for the diffusion of water vapour through the material. Testing showed that the effect of moderately higher water heads did not significantly affect the results. It showed a constant rate of moisture transfer over time.

When a building material is used as the moisture sink instead of a desiccant, the test becomes an assessment of an assembly or a composite. For example, when the membrane is placed directly over OSB, plywood, gypsum or other sheathing material, the ability of moisture to move through both the membrane and the substrate is a measure of the resistance of the assembly, not just the membrane.

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This reflects the actual use of membranes. While the test cannot be used to obtain fundamental properties directly, it is a useful way to examine order-of-magnitude effects involving penetrations and some other physical parameters. This test method has been designated as a “moisture flux test.”   With this test, the rate of moisture transport varied depending on the properties of the moisture sink used.

The third test measures moisture flow through a membrane when both sides are exposed to water. This represents the situation when water may penetrate through the exterior cladding to wet the outer surface of a WRB and moisture from inside the wall has wet the inner face at the same time.

Air entrapment within the microscopic pores of the WRB normally prevents water from passing through most membranes under most conditions. Water evaporates and diffuses through pores as a vapour. Even when the WRB pores are only partially filled with air, water vapour diffusion was still the dominant moisture transport mechanism.

Direct water movement takes place only when there is a continuous field of water across the WRB product and a high pressure on one side of the membrane. This high differential pressure does not occur in practice.

Testing confirmed that the small water head used in the tests had little influence on the amount of moisture transported through the membrane.

Based on tests of all Class C and P products, it was found that vapour flow was the dominant moisture transmission mechanism through the membranes for one-time wetting. The explanation for the dominance of vapour flow for these products is that the fine porous structure created by the fibrous matrix acted as a filter separating water molecules contained in the liquid from those contained in the vapour phase on the other side of the WRB, but allowed vapour to diffuse freely through the fibrous network.

In the case of liquid applied membranes (LA), these form films that do not have the same pore connectiv-

Effect of surfactants

It is known that chemicals can leach out of materials such as OSB or stucco. As well, when sidings are pressure-sprayed when being washed, the liquid can penetrate the siding and wet the WRB behind.

The surfactants reduce the tension on the surface of a water droplet, making it smaller and easier to flow through small pores. The question is what the effect of surfactants is, and could it affect the performance of WRB materials?

A very significant effect of surfactants such as soap was observed. On the other hand, the soluble parts of wood extracts from some OSB materials were found to have a relatively small effect on the properties of the water on the pores or the WRB. However, this research also found that moisture transfer through Class C and Class P membranes using tap water or a one percent soap solution did not show a significant difference in moisture flow through them. This implies that the reduction in surface tension was still insufficient to break the meniscuses bridging the pores in these membranes, or that more research may be needed to determine that mix of compounds dissolved in the moisture that may penetrate the exterior cladding. The impact of a build-up of contaminants over time from repeated wetting at the WRB could also change these results.

Effect of penetrations

When nails and staples penetrate a WRB membrane, the moisture penetration increases by at least one order of magnitude compared to that without any penetrations. However, the moisture flow for an undisturbed product without the plywood substrate was much higher than when the plywood was present. In other words, when there is air on both sides of the membrane and the vapour pressure drive is high,high; more moisture can be driven through it compared with the liquid flow around the fastener shank into the substrate (without it being clamped by the head of the fastener).

The comparisons with and without fasteners, and with and without substrates simply reflect the reality that the rate of moisture flow through an assembly is controlled by the more resistive elements in it.

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However, more research is needed on whole assemblies to assess the effect of moisture entry at fasteners, especially given the stresses seen by membranes under field conditions.

Effects of weathering

Two batches of materials were aged for four months, one during summer, the other during winter. A small but not significant reduction in measured water vapour transmission was observed.

Some Class C and Class P membranes were also tested for airflow resistance before and after outdoor exposure. The results showed that the weathering did not significantly affect the air permeance. However, there was a significant difference in moisture movement, with the weathered samples between these two cases using a liquid penetration test.

This finding shows that two test methods are needed to evaluate the performance of WRB under different conditions that are more closely aligned to field conditions.

This research has shown that the performance of class C and P membranes used for weather resistive barrier applications is quite different from many other porous materials used in construction.

In practice, WRB materials are intended to block rainwater from passing through them into the wall assembly. They achieve that aim because they have very small pores. In the tests, the pore size was not affected by aging, by weathering, or even by mechanical stretching of the WRB products. The air or vapour permeability was not much affected by weathering conditions expected during construction.

The use of soap or wood extract solutions also did not affect the air or vapour permeability for a one-time wetting because moisture movement through the materials was dominated by the vapour transfer phase. However, under some combinations of weathering in the presence of wood extracts and other solutes significant increases in water transmission resulted - one could observe water droplets passing through some membranes in a time span measured in minutes instead of days.

Some WRB products, which performed sufficiently well when assessed using existing test methods in product standards (for example, some types of PP products), experienced the onset of liquid flow within a few minutes.

To reduce the risk of water penetration, it is important to eliminate the possibility of water contact on both sides of the WRB for prolonged periods. This can be achieved by detailing assemblies that incorporate an air cavity on one side of the WRB. This measure is recommended for climatic conditions where the probability of water penetration is high.

Under moderate climatic conditions even a small air gap of 1 to 3 mm may be enough if it can be maintained. Such an air gap may be enough to allow free water drainage and, in combination with other measures, it may provide a substantial reduction in moisture loads acting on WRB materials.

Summary of Research on Water Resistive Barriers for Canada Mortgage and Housing Corporation, by Dr. Mark Bomberg, Adjunct Professor, Department of Building, Civil and Environmental Engineering Concordia University and Don Onyoko, DMO Associates Limited

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