Weather Resistive Barriers: Building Science Makes a Case for Two Layers

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Since water intrusion is among the most damaging problems that can affect a building, weather-resistive barriers (WRBs) have become a key component in moisture protection. While two-ply products have been used for a long time in the West, the rest of the nation hasn't caught on. For some time now, building codes across the country have required two layers of building paper behind stucco, but this is not just a stucco issue. As this article will show, building science confirms that two layer systems are useful behind all claddings.

The primary function of a WRB is to prevent water from contacting a building's sheathing and structural components. We all know the damaging effect of water on wood and metal. Soaked wood is subject to rot, metal is subject to rust and excess moisture within a wall creates an environment that promotes the growth of mold and mildew. Keeping wall components, studs and substrates dry is vital to the long-term performance and integrity of wall systems.

The potential for system failure and proper selection of material is of primary concern. The right system should allow vapor to escape the building, prevent liquid water penetration and allow wall components to dry. While there are a few other WRB systems available, asphalt saturated kraft building paper (ASK) and polymeric housewraps (*housewraps*) are the two most prevalent membrane categories. Product ratings, performance, local weather and exterior cladding choice weigh heavily on the decision of which to use. As it turns out, you may even want to use both.

A number of standards organizations have created testing protocols to evaluate the performance qualities of individual building materials and integrated systems (e.g. wall, window, flashing sealant, WRB), to resist the penetration of liquid water. In recent years, building scientists have turned their attention to evaluating moisture management issues as they relate to wall design systems and overall building envelope performance. Through computer modeling and field tests, building science is discovering that properly integrated two layer WRB systems deliver optimal moisture balance properties.

Building Science Validates Two Layer WRB Performance

The consensus among the building science community is that two layers of a WRB are better than one, for a couple of reasons:

1) A two-ply system offers a built-in drainage plane for the wall system, so bulk water can escape.
2) If the outer layer fails, there is still an inner layer of protection.

In 1998, Seattle's Construction Codes Advisory Board (CCAB) approached the Department of Design, Construction and Land Use (DCLU) to report multifamily building envelopes that had significant damage caused by rotting. The buildings being reported were all less than 15 years old; some were less than one year old. The DCLU

undertook an informal survey of 51 multifamily buildings and found that all 51 building owners reported leaks, which cost nearly $100 million in construction repair, not including attorney fees, investigations, designs and relocation during construction.

The DLCU determined that, “The survey confirmed what many area building envelope repair specialists already knew - the main cause of moisture damage stems from water intrusion through interface details, i.e., building envelope penetrations at decks, windows and doors.”

The report also states that, “Upon investigation of structures with moisture damage, investigators commonly found that flashing and weather-resistive barriers did not exist, or if they did exist they were not integrated or installed properly. The lack of weather-resistive barriers exposes the interior portions of exterior walls to more moisture than the components of the walls can safely store and release, which in turn leads to mold growth and eventually rot caused by decay fungi.”

A computer simulation study, conducted for the City of Seattle by the Oakridge National Laboratory (ORNL), recommended two layers of a weather-resistive barrier behind all claddings. According to Dianne Sugimura, City of Seattle/Oak Ridge National Lab, “The report provides some evidence showing beneficial performance of two layers of weather-resistive barrier behind all types of cladding, not just stucco.” Researchers observed that, “Proper installation of weather-resistive barriers and integration with the flashing is one of the most important factors in the successful performance of exterior walls. Two layers of WRB (one layer installed over the other) behind the cladding was shown to provide better drainage control than one layer.”

For both normal interior environments (temp and relative humidity of 30-60%) and those with higher relative humidity conditions (above 60%), the study concluded that, “Two layers of a well-constructed WRB should be used,” to improve drainage and provide additional protection.

The ORNL report also states that, “Using a systems approach, the performance of a building envelope can be optimized based on the exterior and interior environments, the vapor permeability of components, the number of weather-resistive barrier layers, and the moisture storage ability of wall components. This systems approach is based on understanding the hygrothermal performance of each element in a wall and the role that element plays in the overall performance of a building envelope.”

They define hygrothermal performance as, “…the measure of the combined heat, air and moisture flows within a wall system based on the material property characteristics of each component within the wall and the interior and exterior environmental conditions to which the wall will be exposed.”

With well-designed walls as a foundation, two layers of a WRB dramatically increase moisture management in the building envelope, when properly installed and integrated with the flashing.

In 1996, Northwest Wall and Ceiling Bureau sponsored research conducted by Federal Testing Laboratories of Seattle, WA, to test stucco assemblies for water resistance and drainage.

Tests were conducted on three stucco assembly panels, employing a properly mixed and applied, ¾ inch thick cement plaster basecoat and the recommended two layer weather resistive barrier.

After being sprayed with 112 gallons of water per hour at 38mph (wind driven rain speed), for two hours, "…the panels showed no signs of moisture or dampness on the back side of the cement plaster membrane." The cement plaster basecoat was shown to be water-resistant and the stucco assembly drained water down the wall, between the basecoat and the weather-resistive barrier, and then to the outside of the assembly.

When water was sprayed at a designed opening at the top of the stucco wall assemblies, it drained down the full (9 ft.) height of the stucco panel, between the weather-resistive barrier and the back of the stucco basecoat, then out through the bottom, at the weepage area of the panel.

Stucco can bond to weather-resistive barriers. As the stucco cures, shallow vertical waves and grooves form, which are a result of the cement plaster curing and the effect it has on the weather-resistive barrier. These channels act as a drainage conduit for the water. With a two layer WRB system, the stucco can bond to the first layer it contacts, and the second layer remains intact. The Federal Testing Laboratories researchers concluded that, "A stucco assembly performs as a water drainage system."

Joe Lstiburek, of Building Science Corporation, is an internationally recognized authority on moisture-related building problems and indoor air quality. In his article, "Water-Managed Wall Systems," for the March 2003 issue of The Journal of Light Construction, he writes; "West of the Mississippi, they have it figured out. Western applicators use two layers of a Type D coated paper under their stucco instead of one layer of asphalt felt, and drainage occurs between the two layers of paper." Lstiburek points out that "…any building paper will fail if it bonds to the cladding, and the system can't drain without an air space. With stucco, we create the air space by using two layers of paper."

Lstiburek does not support the use of a polymeric WRB in contact with stucco, because of stucco sticking issues. A forensic engineer and investigator of building failures, he conducts the annual Westford Symposium on Building Science (also called "Summer Camp"). At the 2002 symposium, building scientists in attendance tested 21 different wall configurations of cladding and WRB combinations for water leakage; fourteen combinations of vinyl siding and seven combinations of hard-coat stucco, over various sheathings and papers.

Tests proved that the stucco bonded very tightly to the housewrap. This bonding destroys the water repellency of the housewrap. He wrote, "You should never put hard-coat stucco on any plastic housewrap – the stucco defeats the housewrap." The tests revealed that even creped polymeric housewraps, specifically designed for use with stucco, failed. They bonded tightly and actually caused drainage to be lost, along with water repellency.

The tests also showed that applying building paper over the creped housewrap, in contact with the stucco layer, created a system that worked well. The building paper acted as a bond break, the housewrap remained free and retained water repellency.

A Systems View

With all claddings, Lstiburek suggests, "There are four fundamental requirements for water-managed assemblies." These include a continuous drainage plane, drainage space, flashings and weep holes.

A "continuous drainage plane" is created by applying the WRB, and properly overlapping and incorporating all flashings, so that liquid water runs down the outermost surface and cannot work its way behind. Lstiburek writes, "There are no exceptions: One reverse lap or unflashed penetration can ruin your whole wall." Drainage space allows room for water to move down the wall. It can actually be very narrow, but it must be present. Depending on the exterior cladding, space can be created by adding a rainscreen, or second layer of WRB. At the bottom of the wall, weep holes allow water to escape to the outside.

Across the country, building scientists are recognizing and proving the benefits and increased protection provided by a two layer WRB system. They provide better drainage, more redundancy in the system, and the highest water resistance of all Grade D WRBs.

The December 2003 issue of Energy Design Update® recounts the findings of building scientist Mark Bomberg, who tested the integrity of asphalt impregnated paper membranes (asphalt felt and Grade D papers), as well as perforated and non-perforated plastic housewraps.

Bomberg's findings reflect those of Lstiburek. He advises the use and correct integration of flashings and WRBs, weep holes, and drainage space, to permit proper drainage. Bomberg said that preventing collection of moisture behind the WRB eliminates 90% of its failure probability. About the drainage gap, Bomberg said, "It is not proven that I need more than two or three millimeters of drainage gap. A lot of building science has run berserk on the ventilated rainscreen principle. A cost/benefit analysis would probably result in the choice of a narrow gap. To be on the safe side, a builder can select two layers of a WRB. Two layers and cladding attached with mechanical fasteners provide a degree of drainage which is quite substantial. This is not a liquid water drainage - for free drainage, you need more than four millimeters – but the gravity component helps to move moisture downwards."

Further advocating the use of a two layer WRB system, Bomberg said, "Two layers of a membrane – whatever the membrane, as long as it is not perforated* – are better than one layer of any product, even a highly rated product, because it increases the moisture removal potential – the local drainage plus drying potential." (EDU December 2003)

**Bomberg's Liquid Penetration Resistance (LPR) test of perforated housewraps revealed that "Two out of three perforated products failed within a few minutes." This re-confirms the findings Paul Fisette reported in the June 1997 issue of the Journal of Light Construction.*

When it comes to advice to builders, Bomberg echoes the conclusions reached by Achilles Karagiozis, the Oak Ridge National Laboratory scientist who studied wall failures in Seattle: "…two layers of WRB are better than one." (EDU February 2003)

To ensure the best performance, the right WRB product must be properly installed and integrated with the flashing. No matter how good the material is, it must function as part of a complete weather-resistive system. WRB, flashing, window and door installation, etc., must all work together to effectively manage water and moisture in the wall system.

Code Changes Support Two Layers

Recent changes to the International Residential Code and Florida Building Codes now require the use of two layers WRB behind stucco, over moisture sensitive sheathing:

Florida Building Code 2005 Supplement:

1404.2.1 Where cement plaster (stucco) is to be applied to lath over frame construction, measures shall be taken to prevent bonding between the cement plaster and the water resistive barrier. A bond break shall be provided between the water resistive barrier and the cement plaster (stucco) consisting of one of the following:

1. Two layers of an approved water resistant barrier or
2. One layer of an approved water resistant barrier over an approved plastic house wrap or,
3. Other approved methods or materials applied in accordance with the manufacturer's installation instructions.

Cost-Effective Implementation

Some manufacturers offer complete, integrated systems for moisture protection - including WRB, flashings, sealants and tapes. Ideally, these systems will have been tested and rated as individual components and examined for their suitability as a unified system. They can dramatically reduce the amount of time spent researching on your own, to determine that the components are compatible and effective when combined. If you choose to use one of these systems, be sure the company provides adequate technical support and detailed installation instructions.

The evidentiary support for two layer systems is compelling, and product manufacturers are paying attention. Some ASK WRB products are already available in two-ply rolls, to provide material and installation labor savings. Two ply products also provide better continuity of flashing through the building envelope. Some new, two layer WRB systems also include substantial air space. Benjamin Obdyke makes a couple of products that combine a rainscreen with a WRB. They provide the drainage space and water repellency supported by building science, and the cost savings of applying two moisture management products in one pass.