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# Journal

## The Rain Screen Approach

Bradley T. Carmichael, PE

**I**t is often our quest for perfection that breeds our most glaring failures. We have sown wisdom and humility from the failed constructions of the past, but we are still learning to build new cities that endure amidst the stone shadows of our ancestors. To last indefinitely beyond the reaches of rust and erosion would require diamonds, and reality teaches that permanence simply can't be achieved at the scale of our aspirations. Accepting this fact—that we, and so too our buildings, are necessarily imperfect—is the humble origin of rain screen design. Only by acknowledging the inevitable fallibility of our designs and adjusting them to mitigate these shortcomings can we approximate perfection.

This can be a hard truth to face, as admitting imperfection involves incorporating redundancy into our designs. Exterior walls must then become not perfect barriers shielding us from the onslaught of nature,

but rather multi-faceted systems that refine and process natural forces. At first glance, such measures may appear costly and cumbersome. The added bulk and limitation, however, may ultimately allow us to build our elegant cities not as fleeting experiments serving our immediate needs, but as gemstones set into our built environment for ages to come. In this light, let's explore the basic concepts behind rain screen design to further understand how this approach may help bolster the durability and longevity of our buildings.

### Moisture Ingress and Hydrodynamics

Our relationship with water has always been enigmatic. It creates us, nurtures us, cleans us, comforts us, and destroys us. We walk through the rain with little question of harm, yet a constant drip can bore holes through stone and steel. Since water has been responsible for untold levels of damage and destruction to buildings, it is in furthering our understanding of it that we hope to better protect our buildings.

The climate in which a building is constructed will often dictate the extent of moisture protection necessary to the design. Humidity and precipitation data provide key indicators of



▲ Installation of a facade panel system that uses a rain screen approach to control moisture. Prime Architect: CetraRuddy Building Envelope Consultant: Hoffmann Architects, Inc.

Typical Rain Screen Configuration

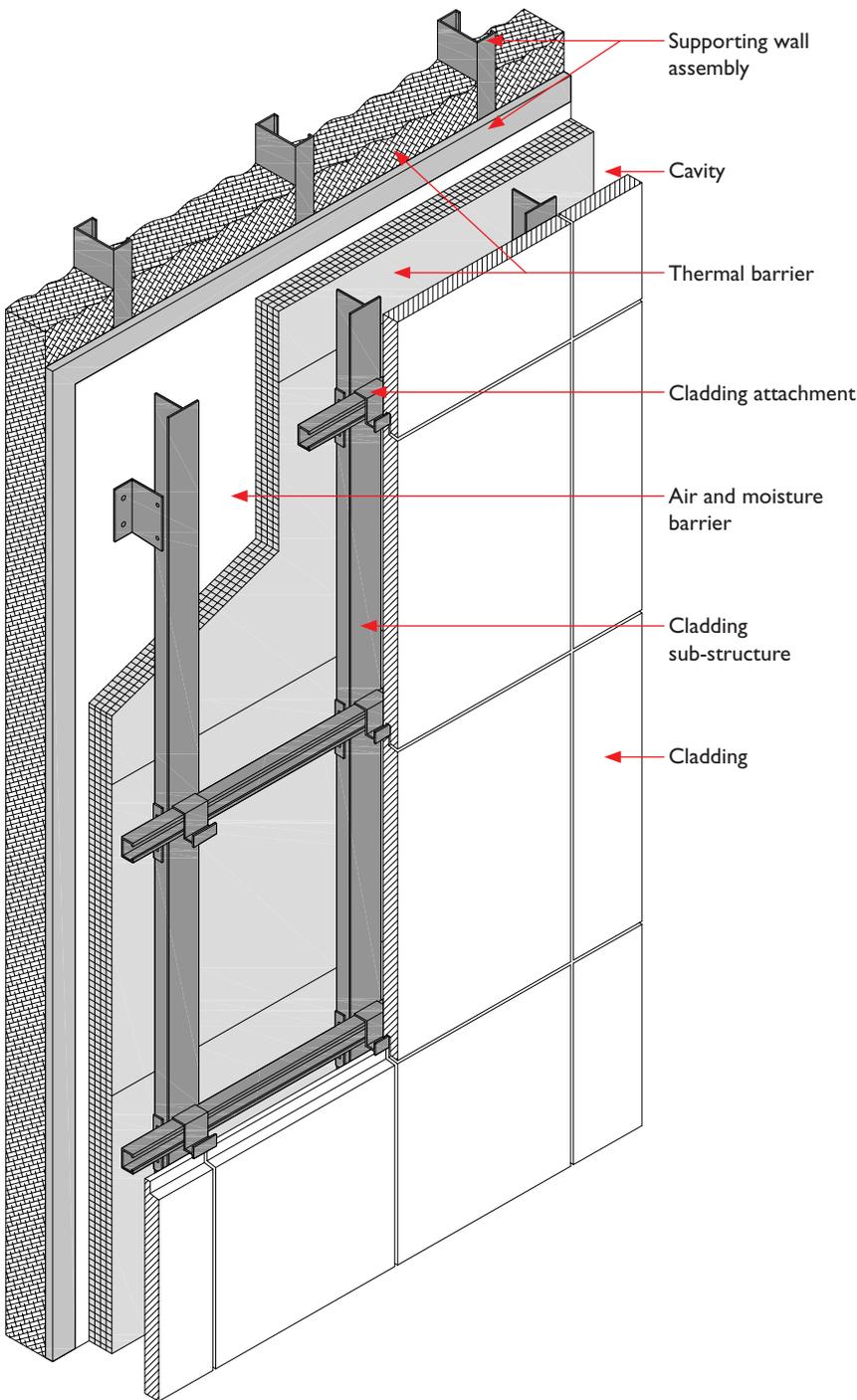


Illustration by Project Manager Erin L. Aichler, Assoc. AIA

the cumulative moisture to which a building will be exposed during storm events and over time, but beyond this, climatic factors such as prevailing wind directions, airborne salinity in coastal regions, the balance of wetting periods to drying periods, and the balance of freezing periods to thawing periods are important additional considerations when establishing the required level of moisture protection.

There are many ways for water to wreak havoc beyond the outer building skin. Leaks through building facades via cracks, gaps, and holes generally offer the first easy avenue for water infiltration. These entry points are more apparent and easier to control than some of the more subtle, yet still damaging, pathways.

Much smaller cracks, holes, and pores in building materials can also effectively move water into the building through a phenomenon called *capillary action*. This occurs when the surface tension of the water reacts with the surface of the surrounding walls of a material opening, in small diameters, to draw itself up against the forces of gravity. This happens naturally in porous construction materials, such as wood, brick and concrete, but it can occur through minute openings in non-porous construction materials, as well.

Water will also find its way into wall assemblies in vapor form. This happens when moisture-laden air passes through an air-permeable wall assembly, and vapor condenses on surfaces within the wall. Water vapor infiltration commonly occurs when moist air is driven into the wall from the outside, or when air from humid building interiors migrates into the wall assembly.

The forces that drive moisture into a wall are varied and may include any combination of *gravity*, *kinetic energy*

from wind, *pressure differentials* across the wall assembly, and even *temperature differentials* causing inward solar vapor drive. Because these forces interact in complex ways, moisture control demands more than simply plugging all of the visible gaps and cracks in the wall. It was not until the building industry had understood and accepted this principle that the notion of abandoning the perfect barrier in favor of a multi-layered approach first began to take hold.

### Moisture Control Strategies

For all their variation in color, texture, and style, most buildings rely on a surprisingly limited set of strategies for keeping water out. Let's look at several of the primary strategies that have been widely implemented for controlling moisture and preventing leaks.

Our earliest buildings were constructed long before the advent of waterproofing membranes, and yet many of them still persist today. The predominant strategy used in historic construction, and still in use today, relies on the mass of the wall material itself for moisture management. This strategy is commonly employed with solid

concrete, stone, brick, and other types of masonry. Provided the wall has sufficient mass to absorb and store moisture during periods of wetting until it can eventually evaporate during periods of drying, the risk of leaks can

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**“The rain screen approach incorporates six basic functions: cladding, cavity, thermal layers, air barrier, moisture barrier, and supporting wall.”**

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be greatly mitigated. One reason this method is so common throughout history is that the mass of the wall was also required for the structural support of the building, something that is

less of a consideration today.

As construction technologies progressed through modern times, the need for massive walls declined, and slimmer and more easily constructed wall types became more prevalent.

Many of these newer wall systems rely on a waterproof cladding surface and impervious sealed joints to eliminate water entry points. In practice, such assemblies rarely achieve a perfect barrier, not only because complexities of the systems make absolute watertightness difficult, but also because the forces of nature and aging lead to eventual degradation and failure of components. This approach to controlling moisture in walls tends to be cheaper to install than other system types, but the cost of ongoing maintenance, damage repair, and eventual replacement can be considerable.

Another approach that has been widely used in lighter wall construction involves a masonry veneer with a cavity between the exterior and interior surfaces, for the purpose of drainage and ventilation. Lacking the storage capacity of their solid-mass counterparts, masonry veneers are designed on the principle that moisture



▲ Water washing down the face of this sandstone veneer facade has led to staining and algae growth.



▲ Evidence of moisture damage at this face-sealed EIFS assembly includes corrosion, delamination, and mold.



▲ A variety of cladding materials can be used with a rain screen design, including thin precast concrete veneer, pictured here.

penetrating the outer layer will dry or drain, via gravity, back to the exterior through weep holes at the bottom of the cavity. The space between the inner and outer layers is large enough to avoid capillary action.

Building upon the cavity wall concept of earlier masonry veneers, the rain screen approach operates on the assumption that water will inevitably find a way into the wall, and so provides multiple, redundant provisions for controlling water infiltration into the building. Like masonry veneers, rain screens incorporate a secondary drainage plane behind the cladding to dissipate moisture through the combined action of gravity and evaporation. What distinguishes rain screen wall systems is the addition of elements that further mitigate moisture ingress by restricting air movement and by balancing pressures across the wall assembly.

When properly designed and detailed, exterior walls incorporating rain screen principles can effectively protect the wall from moisture damage, even in climates prone to significant

rainfall. This is because the rain screen approach doesn't depend on any one element to provide perfect waterproofing protection, but instead relies on the combined effect of a multi-component strategy.

### Anatomy of a Rain Screen

In its most elemental form, the rain screen approach incorporates six basic functions into the design: the cladding, a cavity, thermal layer(s), an air barrier, a moisture barrier, and the supporting wall. In some instances a vapor barrier is also included, but that is largely dependent on the particular facade design and conditions. The applications of this approach are diverse, from walls constructed of individual elements each serving a different function, to pre-fabricated wall cladding systems with components that serve multiple functions, to windows and curtain wall units that perform most or all functions.

### Cladding

The exterior cladding is the visible surface of the wall assembly and the basic water-shedding layer. As the outermost portion of the facade, the cladding is exposed directly to the elements, and so must be designed to withstand long-term weathering. To minimize the amount of moisture that passes into the wall system, the cladding must also shed the majority of water it encounters. The rain screen approach to cladding is unique in that this initial barrier does

not necessarily need to be perfectly watertight. In fact, incorporating open joints and vents into the outer layer is often necessary for ventilation and drying of the cavity behind the cladding, as well as for balancing the pressure across the cladding surface.

### Cavity

The cavity behind the cladding serves as a means to reduce the impact of moisture that passes beyond the outer layer of the wall assembly. The cavity drains incidental moisture via gravity to through-wall flashings, dries the wall assembly through ventilation, and breaks the surface tension of water to stop capillary action. The cavity does take up valuable real estate within the space of the wall, but in return it adds considerably to the longevity of the wall assembly.

In some instances, cavity volumes are compartmentalized and vented to balance pressures across the cladding, minimizing forces driving moisture into the wall. This approach toward achieving a *pressure-equalized rain screen (PER)* has been shown to improve the performance of cladding and curtain wall assemblies, as well as reduce the level of sustained wind loading on certain components within the assembly. In practice, the

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▲ Cladding design should encourage water to drain down the surface of the facade. Here, condensation has led to corrosion and premature degradation of the metal panel system.



## EIFS – A Story of Redemption

Exterior Insulation Finish Systems (EIFS) were first used in the United States in 1969 and became a common cladding throughout the country over the following decades. Early EIFS systems were constructed using the perfect barrier approach, and the difficulties inherent to this type of construction became apparent after widespread incidences of moisture-related damage in wall assemblies clad in this manner. In 2000, the problem gained public awareness after a class-action lawsuit was settled in North Carolina with five major EIFS manufacturers, where claimants were compensated for damages related to moisture ingress in the walls of their EIFS-clad homes.



In response to the tide of claims and damages associated with perfect-barrier installations of EIFS, manufacturers began to develop EIFS systems with secondary drainage and moisture protection. Further development led to a rain screen approach, incorporating ventilation and pressure equalization. The increased durability added by these improvements has allowed the EIFS industry to turn their reputation around. Shaking off the characterization as a material inherently prone to failure, EIFS has become a top wall system for economy and efficiency.

According to tests performed at the Oak Ridge National Laboratory, EIFS wall systems designed according to a rain screen approach exhibited better thermal and moisture performance characteristics than did other wall assemblies, including brick, stucco, and concrete block. When designed and installed correctly, EIFS can be a durable and effective wall cladding material.

As the stigma behind the older generations of EIFS cladding dissolves, and the need for continuous insulation and economic materials increases, the use of rain screen EIFS assemblies as a viable cladding option has returned. ■



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challenge to quantifying the benefits of PERs is that the real-world nature of wind-driven forces is dynamic and often unpredictable on the scale required for compartmentalization.

**Thermal Layer**

Historically, insulation was afforded by the mass of the wall itself and wasn't considered as a distinct element. Eventually, as separate insulation was used in lighter wall assemblies, it would be placed on the interior side or between the wall studs. Contemporary exterior wall designs—and the energy codes that now govern them—generally position continuous insulation outboard of the wall studs, in addition to insulation between the stud framing, so as to provide a more efficient thermal layer. As a result, insulation is often placed within the cavity behind the cladding, or in some instances within the cladding itself.

The prevalence and placement of exterior wall insulation has also increased the exposure and resultant material requirements of that insulation, as we are now positioning it in a much more demanding environment. Properties such as moisture resistance, UV



▲ Insulation in the drainage cavity is often necessary, but adds complexity.

stability, dimensional stability, combustibility, permeability, and density are becoming more and more crucial in how we select the insulating products that we use in our walls.



▲ Mockup of wall and window installation, showing fluid-applied waterproofing and weep tubes.

**Air Barrier**

The purpose of the air barrier layer is to prevent air, often laden with moisture, from migrating across the wall assembly and causing moisture-related damage to the materials within. Preventing air leaks is a complicated endeavor, as it requires a continuous envelope around the building to perform effectively. This means sealing penetrations and gaps, and tying into different assemblies in an airtight manner. Additionally, since the air barrier is commonly concealed within the wall assembly, it needs to be durable enough to withstand forces such as wind and building movement and to last for a very long time.

The standard test procedure for an air barrier material is ASTM E2178 “Standard Test Method for Air Permeance of Building Materials,” and air barriers by definition require an air permeance of less than 0.004 cfm/ft<sup>2</sup> measured at a pressure of 1.57 psf. In practice, wide arrays of construction materials are used as air barriers, often

serving other functions within the wall assembly as well.

**Moisture Barrier**

Behind the cladding, cavity, and other components lies the moisture barrier. The moisture barrier provides a continuous secondary layer of waterproofing protection across the building facade. This layer is the redundancy that prevents the further ingress of incidental moisture that passes beyond the cladding and cavity. Moisture barriers work in conjunction with the cavity and through-wall flashings to direct incidental moisture to the building exterior.

**Supporting Wall**

The foremost function of the wall is to stand up. Be this through backup masonry, studs and sheathing, curtain wall mullions, or other means, support is essential to all walls and provides the backbone for the assembly, which can hardly be overlooked.

Mounting the cladding to the supporting wall presents challenges for rain screen construction and so requires careful attention to detail, as it is one of the most critical design elements of the assembly. Because support anchors often penetrate the layers of the wall system, from the cladding through to the supporting wall, there is potential for issues to arise. The constraints are many: the mounting has to have enough integrity to support the cladding, but the size of the anchorage elements cannot be so great as to compromise thermal resistance across the insulation layer or to obstruct drainage and venting. Where fasteners penetrate the air and moisture barriers, the attachment to the support structure has to have an extremely light touch. Additionally,



▲ Terra cotta facade system incorporating multi-layer water penetration protection.

the cavity behind the cladding is intended to get wet, so the mounting for the cladding needs to be moisture resistant.

All of these challenges can be resolved, but it takes careful planning and coordination in the wall assembly design to prevent the mounting of the cladding from becoming a source for future problems.

### A Constant Evolution

Over the past few decades, the application of rain screen design principles has become more widespread in North America, with success both in new construction and in rehabilitation. The principles are incorporated into most high-performance facade designs today, and continue to see growing use as the benefits of rain screen design become more demonstrable over time.

To many, the value in this approach may already be evident: that it is pragmatic to build contingency into our designs. At the same time, facade design over the past century has tended to push aside conservative

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## Lessons from the Pacific Northwest

The toll of destruction over the past couple of decades waged by the damp climate of the Pacific Northwest is still being tallied. Buildings constructed during the 1980s and '90s in this region, which includes Seattle, Portland, and Vancouver, have experienced widespread damage due to early failure of their building facades.

For example, it is estimated that 45 to 55 percent of condominiums constructed in coastal British Columbia, Canada between 1982 and 1999, which is almost 6,000 condo buildings in the Vancouver area alone, have already suffered from premature building enclosure failure. This has resulted in multiple billions of dollars in repair costs to British Columbia building owners, with similar failures occurring throughout coastal Washington and Oregon.

A conflux of conditions has led to the failures of these building enclosures. The climate has extended periods of wetting, with little drying during those periods, allowing wet walls to remain wet for a long time. The widespread use of perfect barrier cladding assemblies in wall construction, particularly in wood-framed condos but also in concrete and steel framed buildings, provided a massive inventory of walls that have no redundancy for managing incidental moisture ingress. In particular, the use of stucco cladding applied directly over felt building paper and wood sheathing, all permeable materials, easily allowed walls to slowly absorb moisture and fail systemically due to rot, mold, and leaks.

The region has been repairing these facades since the mid-1990s, in many instances removing the cladding and sheathing assembly from an entire building down to the studs, and installing new sheathing and rain screen wall assemblies from the existing studs outward. Recladding the failed buildings with rain screen wall assemblies appears, thus far, to have been successful in managing the moisture in walls. Rain screen wall assemblies are so predominant a rehabilitation solution in the region that they are now mandated in the building codes of British Columbia. ■

*A former resident of Vancouver, Canada, author Bradley Carmichael, PE was a building enclosure consultant on rehabilitation projects after the British Columbia condominium disaster, where he applied rain screen solutions to address premature facade failures.*



Hoffmann Architects, Inc.  
2321 Whitney Avenue  
Hamden, CT 06518

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traditions in wall construction in pursuit of slenderness and construction efficiency in a seemingly limitless and dramatic fashion. Once viewed as inefficient, redundancy is now explicitly incorporated into our most efficient wall assembly designs. This is a pretty radical shift in discourse, and it is due in part to a humble acknowledgement of the difficulty in achieving a perfect outer layer to our buildings.

Ironically, it is through the maxim "perfect is the enemy of good," and the design imperatives this truism imposes, that we may hope to pursue bold designs that last not just for our needs now, but for ages to come. Perhaps the rain screen approach will be the tool that allows our design aspirations to take a humble, imperfect step further in our perpetual quest for perfection. ■

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2321 Whitney Avenue  
Hamden, CT 06518  
203-239-6660

1040 Avenue of the Americas, Ste. 14C  
New York, NY 10018  
212-789-9915

2611 Jefferson Davis Highway, Ste. 200  
Arlington, VA 22202  
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