BUILDING ENVELOPE TECHNOLOGY SYMPOSIUM

Rainscreen Walls: Long-Term Performance and Field Monitoring in Coastal British Columbia

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ABSTRACT

As a result of the multi-billion-dollar "leaky condo" problem in the Pacific Northwest of Canada, ventilated rainscreen wall assemblies have emerged as the industry standard on moderate- to high-exposure buildings. In 2001, a monitoring study was implemented on five buildings in Vancouver, Canada, incorporating rainscreen wall assemblies. This presentation summarizes the results from the research study over a five-year period and provides insight into the field performance of rainscreen walls in the Pacific Northwest. The impacts of environmental loads, cladding ventilation, drainage, and construction details are discussed. A hygrothermal computer simulation model is calibrated with the field data and used to analyze potential improvements and design choices. Finally, the relation of the building enclosure performance to the interior and exterior environmental loads, building enclosure airtightness, and mechanical system performance are discussed.

SPEAKERS

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GRAHAM FINCH is a building science engineer with Building Engineering Ltd. He is regarded as an industry leader in evaluating thermal and hygrothermal performance of building envelope enclosure systems. His master's thesis at the University of Waterloo focused on hygrothermal performance of rainscreen wall assemblies in coastal British Columbia. He has spent three years as an engineering consultant in Toronto and is an engineer-in-training (EIT) with Professional Engineers and Geoscientists of BC. He is also a member of ASHRAE.

BRIAN HUBBS is a principal and senior building science specialist with RDH Group. He has over 15 years experience working exclusively as a consulting engineer focused on building enclosure issues across North America. This work has included the design of new building enclosures as well as the forensic investigation, rehabilitation, maintenance, and support of litigation on existing building enclosures. Brian has also been a team member on many of the key building science research and policy projects focused on the Pacific Northwest coastal climate zone. These projects include the Building Envelope Rehabilitation Guides, the Wood Frame Best Practice Guides, the Study of Window Performance, the Cast-In-Place Concrete Study for CMHC, and the Monitoring of Rainscreen Wall Performance for HPO and BC Housing.

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RAINSCREEN WALLS: LONG-TERM PERFORMANCE AND FIELD MONITORING IN COASTAL BRITISH COLUMBIA

This paper is a summary of the "Performance Monitoring of Rainscreen Wall Assemblies in Vancouver, British Columbia," published by RDH Building Engineering, and further graduate research at the University of Waterloo by Graham Finch in his thesis, titled "The Performance of Rainscreen Walls in Coastal British Columbia." The research was funded by the BC Homeowner Protection Office, BC Housing, and Canada Mortgage and Housing Corporation (CMHC). Visit www.rdhbe.com for more information, to obtain a copy of these reports, and for further references on this topic.

OVERVIEW

In the mid 1990s, widespread moisture problems became apparent in the multiunit residential building stock of coastal British Columbia. Unlike historical cold-climate moisture problems caused by vapor diffusion or air leakage, these new failures were attributed primarily to rainwater penetration into face-sealed or concealed barrier wall assemblies. Typically, water infiltrated at interface locations and became trapped within the wall cavities where it could not dry out. The resulting decay and corrosion required the total rehabilitation of many affected buildings.

In response to this leaky building crisis, rainscreen wall assemblies became popular construction practice throughout coastal BC. Most new buildings and many rehabilitated buildings have been clad this way, on the premise that rainscreen wall assemblies are more tolerant of moisture infiltration. Because they provide an unrestricted drainage plane with an increased potential for drying, rainscreen assemblies limit the accumulation of moisture within sensitive materials.

Several Canadian research studies throughout the 1980s and 1990s supported the concept of rainscreen-clad walls; however, the performance of this technology had not been verified for multiunit residential construction in British Columbia. Needing verification of acceptable performance, this large industry-sponsored program was established to monitor the long-term performance of rainscreen walls in five buildings constructed in Vancouver.

Figure 1 – Building 2 of the monitoring study overview: a typical four-story, low-rise structure with rainscreen walls.

This paper presents some of the key findings from the monitoring program for both rainscreen walls and overall building performance. (See *Figure 1*.)

THE MONITORING STUDY

The monitoring study was undertaken in 2000 by RDH Building Engineering Ltd. (RDH), the Canadian Mortgage and Housing Corporation (CMHC), the Homeowner Protection Office (HPO), and the British Columbia Housing Management Commission (BCHMC). The primary purpose of this study was to understand the performance of rainscreen wall assemblies in Vancouver's coastal climate and to provide feedback to the building industry as to whether these walls and details could effectively prevent moisture-related enclosure problems.

To perform the study, five new or rehabilitated multiunit residential buildings (formerly leaky condos) constructed with rainscreen walls were selected from the local housing stock for monitoring. Within each of the five buildings, at least five different wall locations were instrumented with sensors to measure temperature, relative humidity, moisture content (using electrical resistance method, Straube *et al.*, 2002), relative wetness, and pressure differential across the wall assemblies. Temperature and relative humidity levels of interior suites were also monitored, and weather stations were installed on each rooftop to measure wind, rain, temperature, and relative humidity. Driving-rain gauges were also installed at two locations of each building to further understand local driving-rain loads.

The majority of the monitored locations were chosen to be representative of areas most likely to be wetted during severe weather, while a single location was located in the center of the wall, away from openings or penetrations, to act as a control. The monitored locations were generally chosen on the east and south elevations at key details such as vents, windows, balcony transitions, and saddle flashings where historically high moisture levels have been observed. *Figure 2* shows the monitored locations at Building 3. Other buildings are similar.

Figure 2 – Building 3 of the monitoring study, location of monitored walls and sensors.

RAINSCREEN WALLS WORK

Data from six years of field monitoring across five different buildings show that rainscreen walls are generally working well in Vancouver's coastal climate. Seasonal moisture levels in wood and gypsum materials, most sensitive to moisture damage, remain below safe thresholds. However, it was also found that rainscreen walls, like all wall assemblies, are susceptible to damage if exposed to excessive moisture at construction details known to be vulnerable. Insulation placement, ventilation behind the cladding, exterior and interior environments, and detailing all have a large influence on rainscreen wall performance. (See *Figure 3*.)

MOISTURE CONTENT VARIES WITH SEASON

Like the climate in which we live, the microclimate within a wall is variable. In Vancouver's cold and rainy winter months, sheathing behind a rainscreen cladding will be exposed to high RH levels – 80 to 100% for prolonged periods – which results in a moisture content of up to 20% (based on equilibrium conditions with the average RH). During prolonged rainy periods, the moisture content may rise up to 25% for a few days when the cavity RH is closer to 100%.

In the strapping or sheathing, a sustained moisture content greater than one month) of 20 to 30% indicates long-term exposure to high RH levels within the rainscreen cavity. This could result from a rainwater leak into the cavity, condensation, or poor cladding ventilation. A moisture content above ±30% (fiber saturation point of wood) is most likely the result of a rainwater leak directly contacting the affected sheathing or strapping and should be further investigated. During the summer months, on the other hand, moisture content readings above even 20% could indicate abnormal performance. These are important factors to take into consideration when performing building condition assessments at different times of year.

As moisture content field measurements vary with temperature, wood species, and engineered board product, readings must be interpreted accordingly. The wood should be physically examined for staining or damage to verify the conditions indicated by moisture readings.

Figure 4 compares typical seasonal moisture content ranges for sheathing within a wood frame rainscreen wall in coastal BC (similar to that in the generic assembly shown previously). The black line plots average measured values from the monitoring study. Normal, cautionary, and dangerous ranges were developed from field measurements and computer modeling based on commonly accepted thresholds for wood products. For example, a moisture content of 20% would be considered normal in February, but if the same measurement was recorded in July, it should be investigated further (Finch 2007).

DETAILING IS CRITICAL

Even with more moisture-tolerant rainscreen wall assemblies, proper detailing of all penetrations and transitions between materials remains very important. The extent of damage observed in past decades within face-seal or concealed barrier approaches will not likely result with rainscreen wall assemblies; however, localized moisture damage and microbial growth may still result. Therefore, details must ensure that water can drain out and not be trapped within the wall assembly.

Two definitive rainwater leaks were recorded within the conventional strapped-cavity rainscreen walls during the study

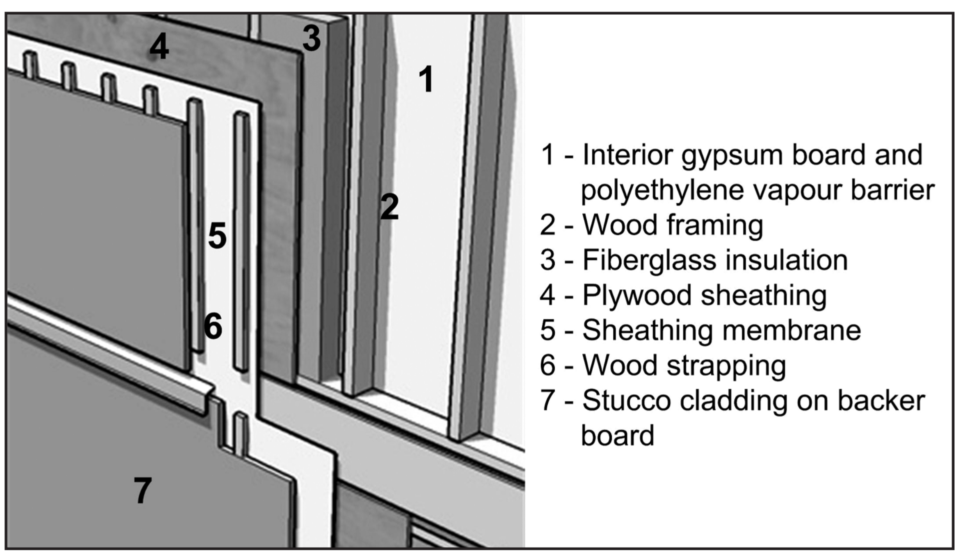

Figure 3 – Typical residential wood-frame rainscreen wall assembly.

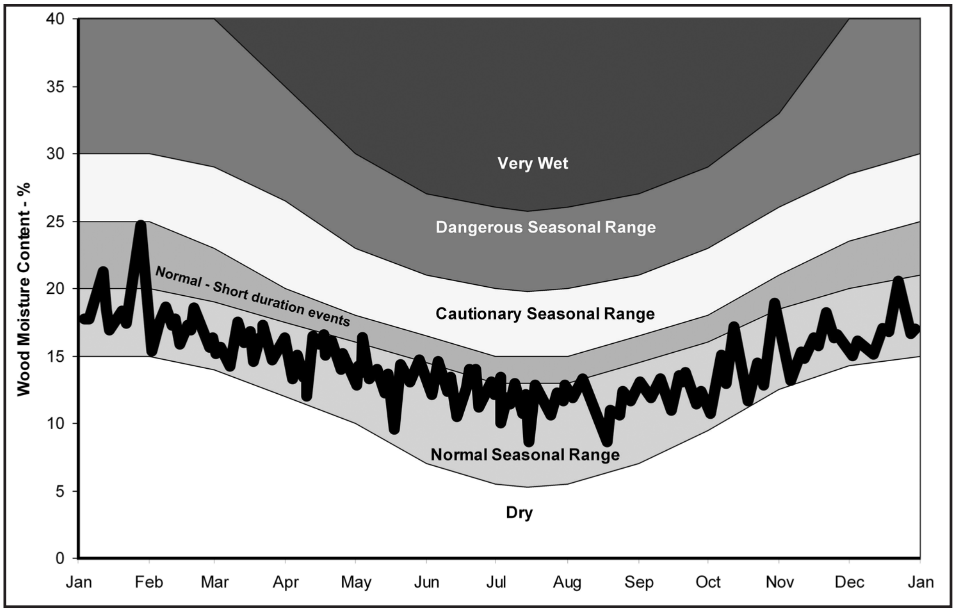

Figure 4 – Typical seasonal moisture content ranges expected for wood-frame rainscreen walls.

period. The first leak occurred at a poorly constructed flashing termination at an exhaust vent behind vinyl siding. Small amounts of water infiltrating over time raised the sheathing moisture content up to 30% for several weeks during the first winter of monitoring. Drying did not occur until spring, only after the detail was disassembled and the deficiency was corrected. Left uncorrected, localized damage to the plywood sheathing would have been likely.

The second leak occurred below a window corner subject to high rainwater runoff. During a severe winter storm, water penetrated the stucco cladding and wetted the wood strapping but not the sheathing. For the remainder of the winter, the strapping sustained elevated moisture levels, drying out in the spring. It is likely that wood strapping will be intermittently exposed to high moisture loads, so wood treatment continues to be recommended.

The type of cladding is less critical to the performance of a drained and ventilated rainscreen wall than traditional wall assemblies. Stucco, cement board, and vinyl siding all had similar performance at the five monitored buildings.

The following recommendations are supported by the results of the study:

- Wood strapping used to create the rainscreen cavity should be alkali copper quaternary (ACQ) treated for exposure to occasional rainwater wetting and a high-humidity environment. If strips of plywood are used, edges will require field treatment. Borate may be an acceptable treatment; however, further research is needed to assess its performance for long-term exposure. Fasteners must be corrosion resistant (i.e., stainless steel).
- Plywood or OSB sheathing will be exposed to high relative humidity and borderline moisture content levels for several months of the year. Consider borate-treated plywood as an additional safety factor.
- An extra one-half inch of insulation at the exterior of the sheathing in a traditional insulated stud frame wall will keep the wall considerably warmer and drier. Vapor-permeable insulation such as mineral fiber is preferred to avoid trapping moisture at the sheathing by allowing diffusion drying through the whole wall. This assembly requires careful design, as discussed in the following section.
- Consider an entirely exterior insulated wall assembly for improved performance and increased moisture tolerance.

EXTERIOR INSULATED RAINSCREEN WALLS WORK BEST

The highly exposed 30-story high-rise building monitored was constructed with an exterior insulated wall assembly. This wall assembly consists of stucco cladding over a ventilated and drained airspace, extruded polystyrene, and a self-adhered air/vapor/water barrier membrane applied directly to fiberglass-faced gypsum sheathing. By putting the insulation outside the sheathing, moisture-sensitive materials are kept warm and dry, close to interior conditions. This rainscreen wall assembly proved most resistant to moisture from driving rain and exterior and interior humidity. All sensors in this building returned dry readings for the entire year. No evidence of exterior moisture penetration or condensation was observed at any of the monitored wall locations. Inward or outward vapor drive is not an issue with this assembly.

Hygrothermal modeling also shows that, in case of small, infrequent leaks past the impermeable air/vapor/water barrier, drying can occur towards the interior when vapor-permeable interior finishes are used. Moisture accumulation and damage is not likely to occur, except in extreme cases of wetting. (See *Figure 5.*)

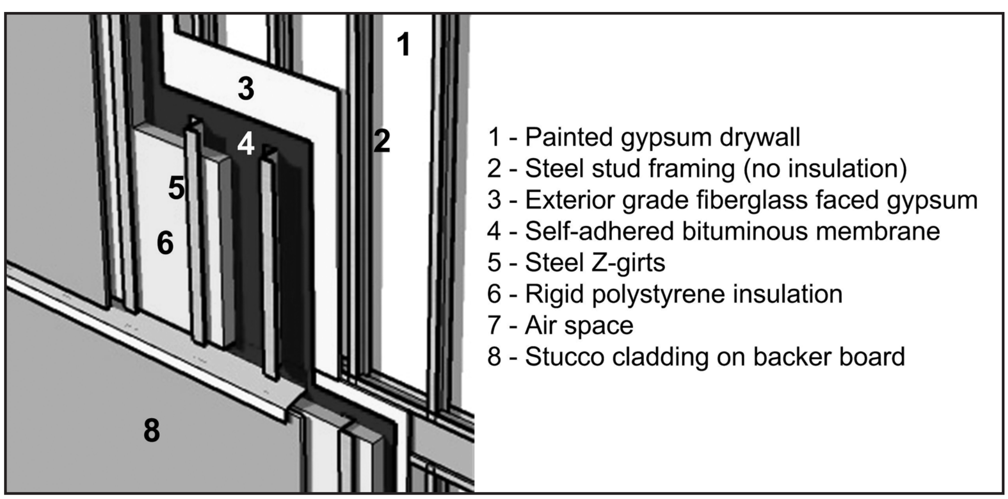

Figure 5 – Exterior insulated assembly at Building 5.

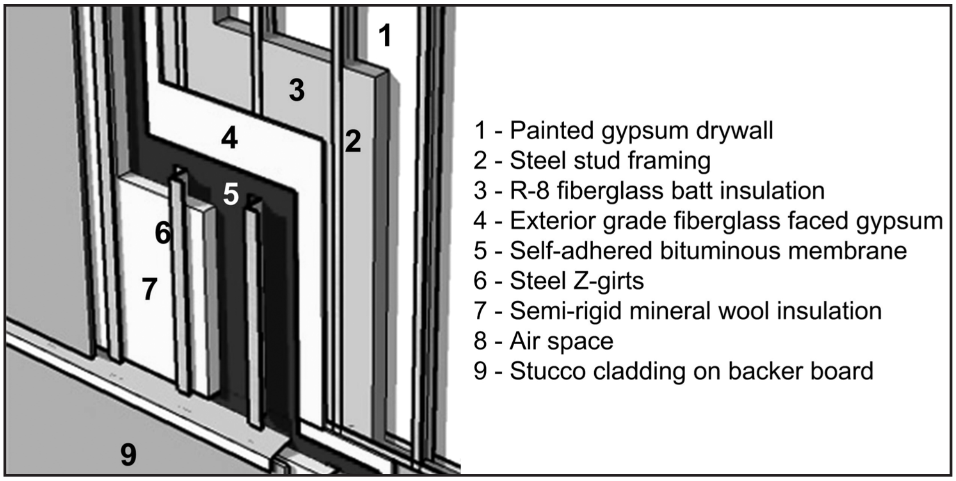

Figure 6 – Split insulated assembly from Building 3.

EXTRA INSULATION REQUIRES DESIGN

Some framed walls use insulation placed both inside the stud space and outside the sheathing to attain required thermal R-values. These wall assemblies are referred to here as dual or split insulated. Interior and exterior climate considerations dictate how insulation and vapor- and air-barrier elements must be used. Airflow, vapor diffusion, and rainwater penetration are more critical for these assemblies, allowing for drainage and drying through the assembly. Due to the large variability of occupant- and HVAC-driven interior conditions, these assemblies may be riskier. When properly designed, split insulated wall assemblies will perform better than traditional insulated stud walls.

Building 3 of the monitoring study was rehabilitated with a dual insulation wall assembly. The original assembly consisted of face-sealed stucco over an insulated steel stud wall backup. During rehabilitation, the polyethylene sheet was removed, but the existing fibreglass batt insulation in the steel stud cavity was retained. New gypsum sheathing, a self-adhered air/vapor/water barrier membrane, 2 in of mineral wool insulation, and new stucco cladding were added to the exterior walls (*Figure 6*).

Following the enclosure rehabilitation, the average wintertime interior RH was in sustained excess of 60%. This level was very high compared to typical wintertime relative humidity levels of 35-50%, measured within the other monitored buildings in the study.

Over several years, monitoring of this building showed seasonal elevated moisture conditions at all eight sensor locations in the building. RH levels of greater than 90% (with peaks up to 100%) within the stud space, and gypsum sheathing moisture contents greater than 1.5% were recorded from October to March every year. Field exploration confirmed the high readings and wet conditions within the wall.

Analysis of the wall assembly and boundary conditions determined that warm, moist interior air leaking into the stud cavity and vapor diffusing through the painted interior gypsum resulted in the constant wetting observed. Since reducing the permeability of the interior finishes would not adequately address the problem and could potentially introduce other problems, the building is currently undergoing a mechanical system retrofit to improve suite ventilation and lower the wintertime RH.

RAINSCREEN WALLS BENEFIT FROM VENTILATION

Simply defined, a “rainscreen” is a method of constructing a wall in which the cladding is separated from the wall by an open air cavity, which allows drainage of any incidental moisture and may allow ventilation of air to further promote drying of the cladding and backup wall assembly. This airspace between the cladding and sheathing membrane effectively increases the durability of both components (*Figure 7*).

The function of the airspace between cladding and backup construction of a rainscreen assembly is to provide drainage, ventilation, and a capillary break (*Figure 7*). Drainage removes any bulk water that penetrates past the cladding. However, drainage alone cannot remove small droplets of bound water or water absorbed into the sheathing, strapping, or cladding. Ventilation is shown to have a significant impact on this aspect of performance in rainscreen walls. A ½-in to ¾-in continuous open gap behind the cladding, which is common for most residential construction, is generally sufficient.

This airspace is typically created using vertical strips of treated wood strapping or light-gauge metal girts. Proprietary products, also available to create this gap, must provide drainage and a capillary break and amust llow for sufficient ventilation. Some proprietary drain-mat products are impermeable to vapor; therefore, ventilation is critical, and extra care must be taken not to block any of the vent openings with these systems.

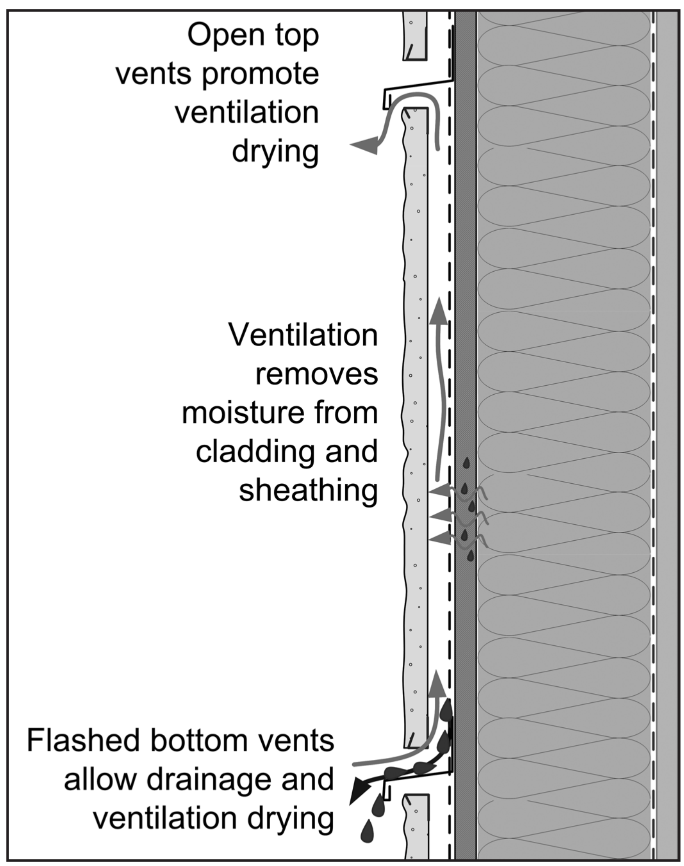

Figure 7 – Ventilation and drainage behind the cladding of a rainscreen wall.

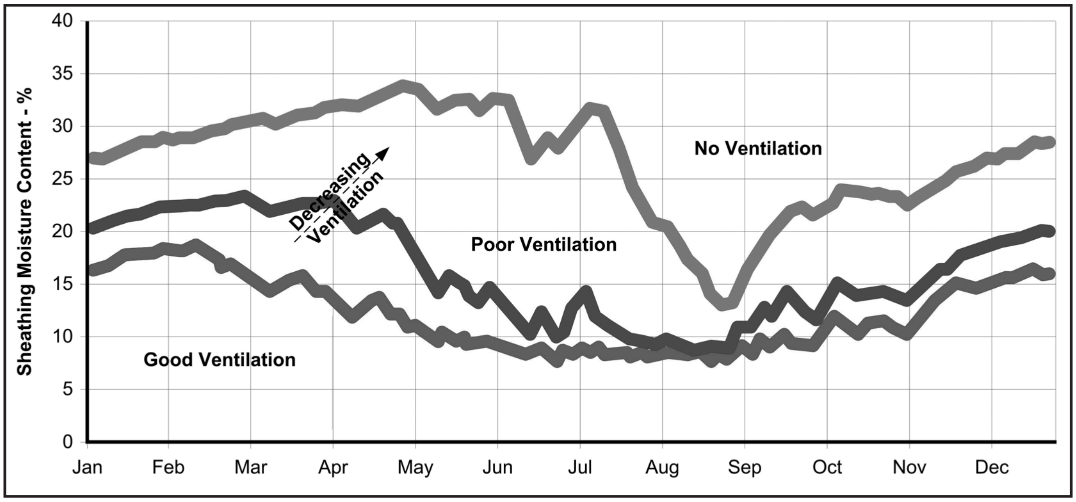

Figure 8 – Impact of ventilation rate behind cladding in rainscreen walls.

Cladding ventilation reduces inward-driven moisture from absorptive claddings such as brick, stucco, or cement board (VanStraaten 2004, Straube 1998). Where ventilation is insufficient, elevated moisture levels may result due to inward vapor drive. To ensure adequate ventilation, large and unrestricted vent openings must be provided at the top and bottom of a wall. Bottom vents or weeps alone in brick veneer walls without top vents do not provide adequate ventilation. Continuous cross-cavity strip vent openings are ideal. Discrete vent openings (such as the ones used in brick veneer) are also effective, but they can reduce the ventilation flow and allow moisture ingress if designed incorrectly. In particular, top vents must also be protected from rainwater penetration, whether by flashing or baffles.

The impact of cavity ventilation is shown in *Figure 8*, comparing conventionally insulated stucco rainscreen walls (*Figure 3*) with good ventilation, restricted ventilation (vents largely blocked), and no ventilation. The increased moisture content is largely caused by inward vapor drive due to solar radiation without a vented release to the exterior. The data shown are simulated using WUFI, a hygrothermal modeling program, calibrated with measured field data from the monitoring program. As shown, higher ventilation rates are directly related to drier walls. The more driving rain a wall is exposed to, the more critical ventilation issues become.

A few final notes on cladding ventilation: The rainscreen cavity must vent directly to the exterior and not into attic or soffit spaces, even if the attic itself is ventilated. Mold growth and moisture damage have been observed in ventilated attics within the Lower Mainland, where cladding moisture has been allowed into the attic space via poorly detailed top rainscreen vents. Finally, consideration for building shrinkage or sustained deflection must be made to prevent cladding ventilation gaps from closing up. Cross-cavity vent openings should be oversized to take into account for normal floor-to-floor height wood shrinkage or concrete slab deflection.

BUILDING OVERHANGS ARE GOOD

Roof overhangs and other projections from the building façade, such as balconies or "eyebrows," reduce the amount of driving rain against sensitive cladding interfaces and details. Restricting the wetting of a wall naturally reduces the risk of moisture damage.

The five buildings in the study have varying roof overhang widths. Driving-rain gauges placed on the vertical façade of the building enclosures provided some insight into the reduction of driving rain with overhang width. While the annual rainfall amounts recorded were similar across all five buildings, wind speed differences – particularly at the four-story buildings – account for the large differences in actual driving rainfall.

Figure 9 compares the effect of roof overhang width versus driving-rain accumulation for all five monitored buildings. The measured driving rain is compared to the maximum potential driving rain, based on wind speed and direction measured at the roof. As shown, those buildings with large overhangs 24-48 in received significantly less driving rain than those buildings with no overhang or overhangs of less than 12 in. A 48-in overhang on a relatively sheltered four-story building can reduce driving rain on its façade to negligible levels. Upper floors received more driving rain than lower floors; however, increased wetting from water cascading down over the lower wall areas is not shown by this figure.

From the plot of the five buildings, the correlation between overhang width and driving-rain load is shown. Large overhangs are effective at reducing the driving-rain load on a wall by influencing the wind against the wall (Straube 1998). As expected, the monitoring data show that the top

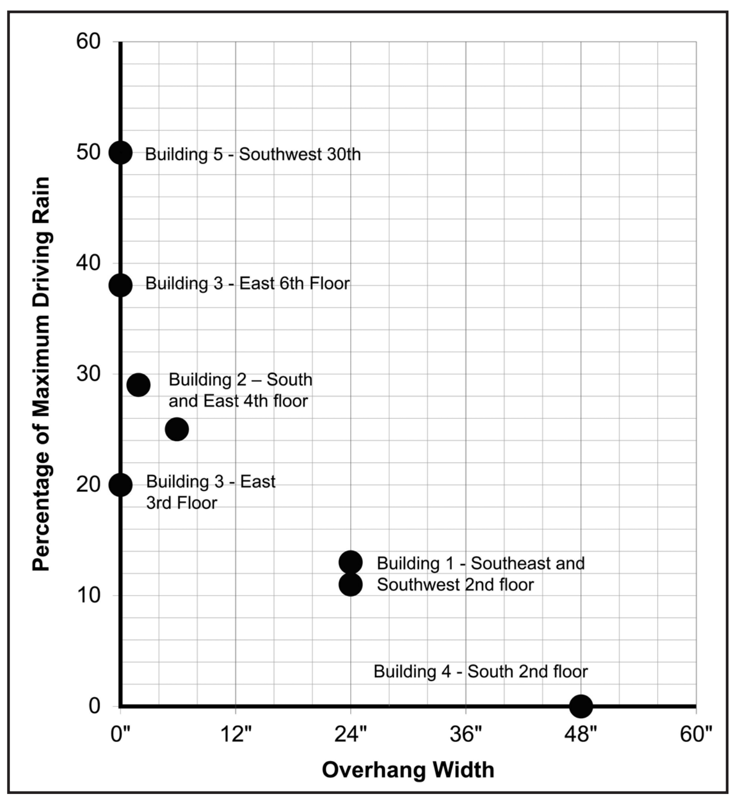

Figure 9 – Plot of overhang width versus percentage of total driving-rain potential.

floors received more driving rain than the lower floors (as seen in Building 3, *Figure 2*), as did the taller buildings. Further information and analysis of the measured driving-rain loads and building geometric effects are provided by Finch (2007).

Driving rain was measured at specific locations on each building and calculated to determine the maximum driving-rain potential as a function of wind speed and wind direction of rainfall. Building 5 (30-story high-rise) had the highest annual driving-rain potential with approximately 850 mm/yr), similar to the airport (YVR) with 800 mm/yr, this was followed by Building 3 (six-story mid-rise) with 550 mm/yr. Buildings 1, 2, and 4 (four-story low-rises) experienced between 200-300 mm/yr. While the annual rainfall amounts were similar across all five buildings, wind speed differences, particularly at the four-story buildings account for the large differences in actual driving rainfall. Driving rain on two-story single-family dwellings would be further reduced. This is relevant when selecting wall and fenestration assemblies for a new building.

MOISTURE FROM THE INSIDE NEEDS CONSIDERATION

Interior conditions within these five multiunit residential buildings were measured and found to vary considerably between suites. Occupant behavior as well as HVAC system design and operation were shown to have the most significant effects on interior humidity and temperature control. Those suites that were poorly ventilated had very high wintertime RH levels; at Building 3, the RH was so high indoors that moisture problems developed within the walls as discussed in the previous section.

The interior environment's impact on wall assemblies is also a critical design factor. This is especially true when modifications are made to traditional wall designs, including increasing the building airtightness and using alternate vapor-retarding layers and insulation strategies.

Interior conditions varied across all five buildings studied, and none could be considered average for design standards (i.e., controlled to 21˚C year round). The temperatures varied largely as the result of occupant behavior; and, in addition, the interior dew-point and relative humidity varied considerably as a function of moisture generation and suite ventilation rates. As none of these buildings has air conditioning systems, average interior suite temperatures of 25-27˚C were normal during July and August. Interior temperatures of up to 34˚C were recorded during the hottest summer days at all buildings and even more often at the penthouse suites of the high-rise building.

It is also possible to achieve low (<40% average) interior wintertime RH levels in Vancouver's temperate climate, since RH varies with interior moisture generation and building ventilation. Suites that had low wintertime RH levels (between 30 and 40%) had sufficient – and in one case excessive – ventilation rates. High wintertime RH levels (between 50 and 70%) were only observed in Building 3 and were found to be primarily from insufficient suite ventilation. *Figure 10* compares the measured interior relative humidity levels for the five buildings.

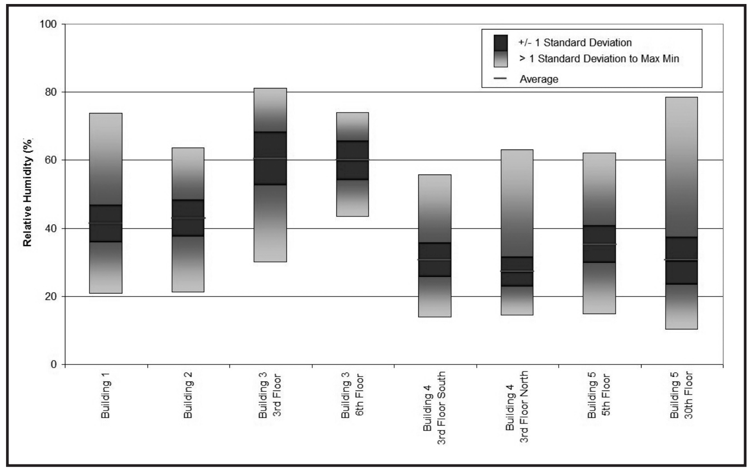

Figure 10 – Interior average wintertime relative humidity, monitored buildings in Vancouver.

WUFI WORKS!

WUFI is a computer program that can model the hygrothermal (moisture and heat) transport within a wall assembly exposed to chosen exterior and interior climatic conditions. WUFI is a powerful design and forensic tool that allows engineers the ability to predict the performance of a wall or roof prior to its design or the ability to simulate a condition leading up to a building problem in forensic applications. This monitoring study provided excellent data for comparison to that simulated in the WUFI 4.1 hygrothermal model.

The different wall assemblies for each of the buildings were all modeled and simulated with the years of measured weather data

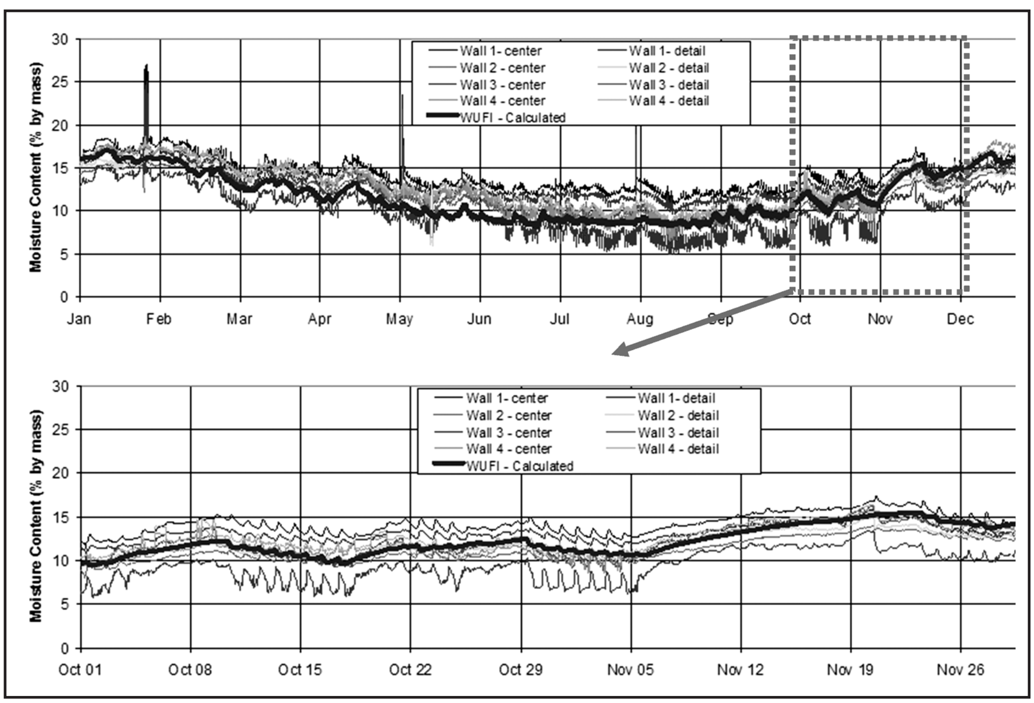

Figure 11 – Comparison of measured and WUFI simulated moisture content – typical wood frame stucco rainscreen wall.

collected from site. WUFI was found to be able to predict the performance of each wall assembly with good correlation (Finch *et al.*, 2007; Finch 2007). This provides comfort that this hygrothermal modeling tool is reasonably accurate for performing preliminary design analyses for rainscreen wall assemblies. *Figure 11* compares four different monitored wall locations at Building 1 (wood frame with hard-coat stucco cladding) to modeled WUFI results. Natural variations in the moisture content readings in the measured data are due to differences in sensor location, thermal bridging effects, and the nonhomogenous nature of plywood when measured with electrical resistance. The WUFI results predict moisture contents and trends following the average of these values.

KEEP GYPSUM SHEATHING WARM AND DRY

Gypsum sheathing is moisture sensitive. When exposed to high RH levels (>90%) for prolonged periods of time or to liquid water wetting, gypsum-based sheathings will deteriorate and lose pullout, bending, and delamination strength. To keep gypsum sheathing warm and dry, exterior insulated rainscreen systems provide the best protection. Fiberglass-faced sheathing products with treated gypsum core offer greater mold resistance than paper-faced products and are recommended for this reason.

To analyze the moisture content of the buildings constructed with gypsum sheathing, the moisture content of gypsum sheathing was correlated with its electrical resistance, similar to the concept applied to wood-moisture meters. This calibration was correlated one step further so that the moisture content of gypsum sheathing can be approximated with a wood-moisture meter and the correction curve to give an indication of wet or dry conditions and possible risk (*Figure 12*).

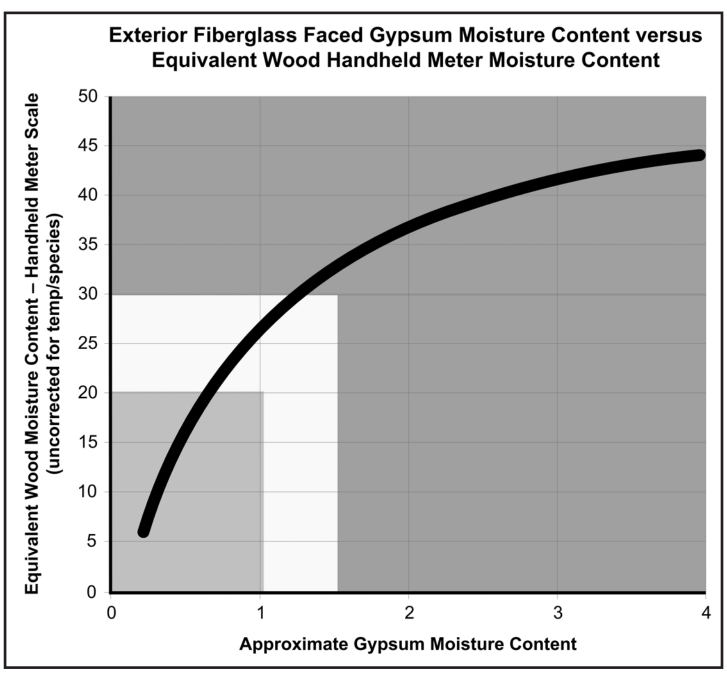

Figure 12 – Wood moisture content scale vs. approximate gypsum moisture content.

AIR LEAKAGE WITHIN MULTIUNIT RESIDENTIAL BUILDINGS IS AN ISSUE

As part of the study, air leakage testing was performed to understand air leakage within and airtightness of multifamily buildings. Three buildings from the monitoring study and a fourth building also affected by interior humidity problems were tested. A test method was developed with Retrotec Energy Innovations Ltd. using multiple fan-doors and pressure neutralizing to isolate and quantify air leakage between adjacent suites, floors, common spaces, and through the exterior enclosure. Results gathered demonstrated the impact intersuite air leakage and enclosure airtightness has on the ventilation rates and interior RH levels and on overall wall performance recorded. These findings are summarized below.

- Modern exterior walls, with a peel-and-stick air/vapor/moisture barrier, were significantly more airtight than traditional walls constructed with polyethylene or housewrap/building paper.
- Significant air leakage was shown between adjacent suites and common areas within multiunit residential buildings. These interfaces should be airtight for smoke, noise, odor, and fire-control reasons.
- The tighter the exterior enclosure (as in new construction or rehabilitation work), the more intersuite air leakage becomes an apparent and significant issue.
- Common residential mechanical systems using pressurized corridors and in-suite mechanical exhaust perform poorly in airtight buildings unless controlled in-suite exhaust and sufficient makeup air is provided. Many occupants apply weatherstripping or block off door undercuts due to complaints of noise and odors. This exacerbates the problem, as air from adjacent suites is drawn in instead. Ideally, fresh air should be ducted into each suite directly, bypassing the corridor spaces.
- Rehabilitated buildings require mechanical-system adjustment and upgrades to account for tighter building enclosures. If they are not adjusted and upgraded, then interior humidity and condensation problems are likely to develop.
- Continuously running timers, and bathroom and kitchen exhaust fans may be necessary to provide adequate ventilation within suites at certain times of the year. In addition, makeup airflow needs to be provided by passive vents or large entry-door undercuts (which cannot be blocked). With continuous ventilation, heat recovery ventilators (HRVs) may be warranted in order to reduce energy costs.

HVAC DESIGN AND REHABILITATION CONSIDERATIONS

While an airtight building enclosure is necessary for energy efficiency and thermal comfort, it requires greater support from mechanical ventilation systems to work properly. Airtight buildings place higher demands on mechanical systems and put a higher demand on the mechanical ventilation systems to actually perform in service. Deficient systems can have serious ramifications on building performance and occupant comfort.

This is an important consideration when rehabilitating to increase airtightness of a building enclosure. In older buildings, relatively high levels of air leakage have typically been allowed, both through and around window and wall assemblies. As a result, mechanical designers could safely assume that a significant portion of a building's overall ventilation requirements would take care of itself. When such a building needs rehabilitation later to reduce water infiltration and repair damage to underlying wall components, the conventional sheathing paper is typically replaced with continuous and sealed air and watertight membranes. The existing windows are often replaced with higher performance air- and watertight windows, and sealant is used around all penetrations and joints.

Air leakage testing of rehabilitated buildings confirms that the rehabilitated building enclosure is much more water- and airtight than the original construction, so any previous assumptions of exterior air leakage are no longer valid. The percentage of intersuite stale air leakage was found to increase after rehabilitation when the air exchange to the exterior was reduced. After the rehabilitation, the interior relative humidity increases unless ventilation capacity is adjusted accordingly or unless occupants keep their windows open. Condensation and mold growth on windows and exterior walls have become issues after some building enclosure rehabilitations because of insufficient interior ventilation.

As part of a building enclosure rehabilitation program, the HVAC system should be checked to confirm it will still function adequately once the new cladding and glazing assemblies are installed. If adequate performance cannot be achieved, upgrades to the building HVAC systems should be included in the rehabilitation program. This often requires the installation of adequate and tamperproof exhaust vents and dedicated fresh-air returns into and within suites or other measures to improve the existing ventilation capacity.

CONCLUSIONS

A monitoring study was set up to measure and understand the performance of rainscreen wall assemblies in Vancouver's coastal climate and to provide feedback to the building industry as to whether these walls and details could effectively prevent moisture-related enclosure problems. Using a combination of detailed long-term field measurements from the five buildings, hygrothermal modeling, and supporting laboratory testing, the following conclusions were made.

Field measurements and modeling suggest that rainwater leaks may still be able to cause damage within rainscreen wall assemblies. Water-shedding details (i.e., around penetrations) still remain important, and a poorly constructed detail can result in moisture problems. The drained and ventilated cavity of the rainscreen wall assembly does reduce the likelihood of moisture coming into contact with sensitive materials within a wall assembly; however, it does not guarantee problem-free performance. In addition, air leakage and vapor diffusion from the interior – even in Vancouver's temperate climate – are ever-present moisture sources and cannot be neglected in design.

Ventilated and drained claddings (i.e., rainscreens) reduce the sensitivity of wood frame buildings to moisture damage. Ventilation of the cladding was shown to be particularly important. Natural buoyancy forces (from temperature and humidity differences between cavity and exterior) are usually sufficient to provide good ventilation drying.

Interior boundary conditions are almost as significant as exterior boundary conditions. Elevated interior humidity, resulting from inadequate ventilation, can be exacerbated by interzonal airflow within multi-unit residential buildings. The airflow measured between adjacent suites was unexpectedly high in several cases. The volume of interzonal air leakage recorded brings the suitability of corridor-supply ventilation systems into question. It is recommended to provide fresh air to each suite directly, to ensure adequate ventilation in suites with modern airtight exterior wall construction.

Airtight building enclosures are desirable for energy efficiency and thermal comfort; however, a high level of performance is required from the mechanical and ventilation systems in these buildings. A higher demand is put on the mechanical ventilation systems to actually perform in service, and deficient systems can have serious ramifications on building performance and occupant comfort.

Hygrothermal computer modeling was proven capable of predicting the performance of ventilation claddings with sufficient accuracy to be very useful for the building industry. Experience and knowledge of how systems function, boundary conditions, and material properties are all necessary for successful modeling.

The moisture content of fibreglass-faced gypsum sheathing was measured using electrical resistance. An equation was developed from laboratory testing and applied to the field measurements with good accuracy.

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