Air Cavities Behind Claddings—What Have We Learned?

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ABSTRACT

Wall cavity ventilation has been studied and investigated by numerous researchers both numerically using computer tools and experimentally using laboratory and field investigations. Results have not always been conclusive and recommendations in which cladding types, and under what climatic conditions the air cavity provides benefits, are not well understood. This paper first discusses the functions of an air cavity behind various cladding types and its effect on the thermal and moisture performance. Benefits and drawbacks of an air cavity applied to various types of clad walls in various US climates are examined. Numerical simulations of various degrees of complexities were critically evaluated in terms of what is actually modeled and how these results relate to real field performance. Laboratory and field tests are compared to the simulation results. Conclusions from past and currently ongoing research projects are discussed with a perspective on the knowledge acquired that could aid in optimizing the design of air cavity ventilation with respect to thermal and moisture performance. Guidelines for selection and proper design of vented or ventilated cavities are highlighted. A thorough review of the needed research, and the critical information still missing, is discussed in order to highlight the correct application of ventilated cladding systems for future building envelope construction.

INTRODUCTION

During the past decades, a significant amount of knowledge and building science insight has been gained related to the pros and cons of vented/ventilated cavities behind various types of cladding systems. Wall systems that incorporate cladding ventilation strategies have been proposed for the next generation of zero net energy buildings. Past research findings have been contradictory in nature, having both opponents and proponents of cladding ventilation. The scientific knowledge remains largely scattered, missing a definitive explanation for how and why a system works or fails when utilizing cladding ventilation. The intention in this paper is to provide a comprehensive summary of the current state-of-the-art knowledge base related to the benefits of vented/ventilated cavities from a thermal and moisture performance point of view. We define the term "moisture performance" as the ability of the wall system to balance moisture loads. A comprehensive literature review is performed to present both the current academic knowledge base as well as anecdotal information describing the benefits of vented cavities. A number of hygrothermal simulations are conducted to address various issues and discuss how well these results compare with field data.

PAST RESEARCH FINDINGS

Decades of research have generated a significant knowledge base in the area of building envelope performance. Building envelopes have evolved from a monolithic mass type designs to multi-layered lightweight system designs. Today, building envelopes are complex to assemble, sophisticated, and require considerable fine tuning for good performance. Within the context of hygrothermal performance, the combined transport of heat, air and moisture throughout the whole system cannot be overemphasized. In multilayered walls, adjacent elements can have a significant impact on the performance of the system as a whole. In such instances, the

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risk for potential failure of the system increases with the increased complexity, i.e., increased number of the elements as well as junctions and terminations within the system. To minimize the potential for failure, redundancy measures are often incorporated into the systems. For example, air cavities separating exterior and interior masonry wythes are designed to reduce environmental loads, thus prolonging the service life of the envelope.

In retrospect, air cavities provide a multitude of functions. They 1) provide a capillary break for water penetration into the wall cavity, 2) provide an effective drainage space, 3) reduce direct moisture bridges, 4) allow for the removal of moisture that might have penetrated the cladding, and 5) can potentially permit pressure equalization of the system to prevent water infiltration through the inner wythe and into the inner wall structure.

With respect to moisture removal, several mechanisms are applicable including a gravity drainage plane for the bulk moisture and removal of moisture through convective and diffusive air transport processes. Drainage due to gravity is relatively easy to understand because it occurs independently of the local environmental conditions such as temperature, relative humidity, wind velocity and wind pressure, and solar radiation. The interdependencies of the various highly variable environmental factors are not well understood. Much research has been conducted under field and laboratory settings in an attempt to better understand the highly complex functionality of air cavities behind claddings for a limited number of parameters. The following sections review these findings.

Air Cavity Ventilation

Walls. Air exchange rates measured behind brick veneer, with open head joints and with a full brick removed every 1200 mm, ranged from 0.3 to 8 and from 3 to 25, respectively (Sandin, 1993). These results indicated that wind was likely the primary ventilation mechanism. A series of field and laboratory studies conducted in Belgium showed that ventilation had an insignificant effect on heat transmission within the air space (Hens, 1984). In the same study, it was found that quantifying the benefit of ventilation in relation to moisture performance (i.e., moisture removal rate) was difficult. Field studies conducted in Germany showed that high ventilation rates, averaging a measured 100 air changes, had no effect on the thermal performance of the air cavity (Jung, 1985). The data also indicated quicker drying of the cladding material on the cavity side than on the exterior side of the cladding. Contradictory results were reported by Fraunhofer-Institut for Building Physics (Kunzel, 1983), indicating that the presence of an air space had no effect on the moisture content of the brick veneer. These findings highlighted a significant dilemma and question the benefits of cavity ventilation in brick clad walls.

Similar research has also been performed on walls with other types of cladding, sheathing, and insulation. Pressure gradient measurements within the air cavity of a wood-framed, siding-clad wall filled with low density fibrous insulation were performed by Norwegian Research Institute (Uvslokk, 1988). The results indicated that a wind barrier installed on the exterior side of the insulation was necessary to reduce convective heat losses. It was also found that the mean pressure gradient behind the siding correlated with the wind speed and wind direction. Average pressure gradients measured range between 0.1 and 0.5 Pa/m. In Denmark, theoretical and empirical studies examining the potential for ventilation in a panel clad wall system showed that air movement velocities within the range of 0.5 to 3 m/s can be attained (Akestisch Advies Bureau Peutz & Associates B.V., 1984). It was concluded that such velocities could prevent condensation on the backside of the panel. In an analytical study of stack effect driven ventilation (venting) behind wall cladding, Guy and Stathopoulus (1982) reported a 35% cooling load reduction for a vent area that was 100% of the cross sectional area of the cavity. Reduction in the size of the vent reduced these savings. They have also demonstrated that reducing the emissivity within the cavity from (0.9 to 0.4) with a simultaneous 25% reduction of vent size area led to a 50% cooling load reduction. This has obvious implications for arid and hot climates having a significantly higher number of cooling degree days than heating degree days. In a field study of an 18 story apartment building, there was no correlation found between the height of the cavity and ventilation velocity (Schwartz, 1973). For wind speeds ranging between 0 and 5 m/s, the measured velocities ranged between 0.2 and 0.6 m/s, with lower and more stable velocities (i.e., 0.2 m/s) measured in the cavity on the leeward side of the building. Research findings relating to the benefits of venting/ventilating appear to be contradictory. If this is not the case, then the question arises under what climatic conditions and in which types of building envelopes does the air cavity provide a beneficial moisture and thermal performance. Tenwolde, et al., (1995) noted that conditions inside the cavity are not always dry enough to provide sufficient moisture exchange, i.e., drying. In such instances, the cavity can actually have a negative effect by contributing to an additional source of hygroscopic moisture load.

Hansen, et al., (2002) performed field experiments with 12 wall assemblies. The constructed assemblies included different cladding, sheathing and air barrier types and were either ventilated, non-ventilated or had no cavity. Moisture contents of wood dowels mounted behind the air barrier showed greater moisture in assemblies with ventilated cavities than in non-ventilated cavities. Accounting for the time lag, changes in moisture content correlated well with the outdoor relative humidity. This indicates that in cool and moist climates, and for construction having highly vapor permeable exterior sheathings, ventilation could impede rather than improve moisture performance. The authors did cite that the presence of a cavity is important for proper rain control, as it provides pressure equalization and serves as a capillary break for liquid water transport.

Roofs. Research has been performed by Miller (2006) for field-testing stone-coated metal roofs with shake and S-mission profiles. All roofs were equipped with ridge and soffit vents for attic ventilation. The objective of this project aimed to document the potential energy savings of stone-coated metal roofs with and without infrared-blocking color pigment (IrBCPs) as well as the benefits of venting between the underside of the roof cover and the roof deck. The evaluation enabled a direct side-by-side comparison of the affects of IrBCPs, fascia and deck venting, underside thermal emittance, roof profile (whether moderately flat or S-mission), and a retrofit application over an existing cedar shake roof. To compare deck and ceiling heat transfer rates, a control assembly with a conventional asphalt shingle roof was used. The combined results for both IrBCPs and above-sheathing ventilation showed that ventilating the deck is just as important as the boost in solar reflectance, and may be a greater contributor to reducing the heat gain to the attic assembly. It should be noted that the heat flow due to above-sheathing ventilation of the hotter dark-gray shake was more than double the amount of heat flow swept away from the deck of the light-gray shake. The hotter that the dark-gray shakes were, the greater buoyancy-induced airflows. Therefore, the above-sheathing ventilation was somewhat self-regulating and offsets the effect of the darker, less reflective color. In addition, the stone-coated metal with above-sheathing ventilation lost less heat during the evening hours than the stone-coated metal attached directly to the roof deck. Hence results showed that an open free-flowing channel is the best configuration for reducing the roof heat gain and for minimizing roof heat loss. Tracer gas decay tests, using CO_2 gas, were performed to characterize the flow in the above sheathing ventilation cavities resulting in velocities of 0.09 m/s.

Beal and Chandra (1995) demonstrated a 45% reduction in daytime heat flux penetrating a counter-batten concrete tile roof in comparison to a direct-nailed shingle roof. Parker, Sonne, and Sherwin (2002) observed that a barrel shaped terra-cotta concrete tile with moderate solar reflectance reduced a test home's annual cooling load by 8% of the base load measured for an identical home with asphalt shingle roof. The reported savings are attributable in part to a thermally driven airflow occurring above the sheathing within the air channel formed by the underside of the tile and roof deck; this airflow is referred to in this paper as above-sheathing ventilation. The air flow is driven by buoyancy and/or wind forces. In a recent paper by Miller et al (2006), the above sheathing ventilated roof assembly was found to hygrothermally outperform a non-ventilated roof assembly by employing the MOISTURE-EXPERT model developed by Karagiozis (2001). The ventilated roof deck was able to handle many times greater wetting loads than the unvented one.

Pressure Equalized Rainscreen

A critical review related to pressure equalization of rainscreen walls has been conducted by Kumar (2000). He highlighted that pressure equalized rainscreen (PER) has three main components including rainscreen, cavity and air barrier. Different materials can comprise each of these components. The rainscreen contains vents to provide quick pressure equalization within the air cavity in order to minimize/reduce wind induced air pressures difference across the cladding. Factors that must be considered in the design of the rainscreen include: total venting area, vent location and dimensions, rainscreen stiffness, and design loads on the rainscreen (or outer cladding) (Kumar 2000). Much of the pioneering work on PER was conducted in the 60s on high-rise buildings. Venting the cavity behind the rainscreen was proposed as a method of pressure equalization and was initially suggested by Birkeland (1962). At National Research Council of Canada (NRCC), Garden (1964) introduced the rain screen principle as an approach leading towards the reduction of rain water penetration. In his approach he promoted compartmentation of the cavity to achieve excessive cross flow within the cavity. Subsequently, extensive studies have been conducted in wind tunnel experiments (Irwin et al., 1984; Morrison and Hershfield Ltd., 1990, Gerhardt and Janser, 1994; Inculet 1990 and 1994; Surry et al., 1994) and full-scale laboratory experiments (Inculet, 1994; Straube, 1994 and 1998; Brown et al., 1991; Ganguli and Dalgliesh, 1988) to examine different aspects of PER design.

Ganguli and Dalgliesh (1988) determined that wind load is transferred onto the air barrier. Pressure measurements showed that pressure drop across the entire panel was in agreement with a pressure drop across the air barrier. They also found that the rainscreen could be subjected to 200 Pa pressure variations, i.e., 75% of the design pressure for the entire assembly. Similar findings were observed in a field study performed by NRCC. Brown (1991) found that brick veneer will carry up to 60% of the instantaneous loads under positive pressure and up to 90% of the load under negative peak gusts (Brown, 1991). Inculet (1990) reported that high ratio of 'air leakage area' to 'venting area' of the openings in the rainscreen contributed to poor pressure equalization. He also found that a large venting to cavity volume ratio, small compartment size, and well sealed air barriers improved the pressure equalization characteristics of the system. In such instances, it was found that high frequency pressures in excess of 1 Hz were transferred onto the rainscreen.

Drying Capability of Wall Systems

Several projects have been conducted by the Canada Mortgage and Housing Corporation (CMHC) to examine the drying capability of different wall systems (Hazleden 2001; 2002). One project focused on a parametric analysis of drying stucco clad walls with ventilated cavities (CMHC, 1999). The study found that the depth of the cavity was of greatest significance, even more important than the size of the vents. Drying of the cavity was accelerated when the cladding was vapor permeable or when it was not covered with impermeable coating. The study also reported that complete closure of the vented cavity considerably slowed the drying rate. However, a very small 1mm-wide-gap behind the cladding was sufficient to provide drying rates comparable to those attained with top and bottom vents of equal size. In addition, it was found that vinyl siding and back-primed painted wood siding retained moisture in the wall for longer durations than permeable stucco. In recent findings by CMHC (2007), it was reported that vinyl siding had lower air leakage rates than hardboard based and fiber cement based types of cladding products. In the “Envelope Drying Rates Analysis” (EDRA) study conducted by CMHC (2001), the effect of wall design on the drying capability of wood framing was investigated. Wall systems with different components and different configurations were tested with and without the effect of simulated solar exposure. The study found that all panels with cavities dried faster than comparable panels without cavities. Plywood sheathing dried faster than oriented strand board (OSB) sheathing. The study showed that cavities with top and bottom openings dried faster than cavities with bottom vents only. Furthermore, findings indicated that greater cavity depths were a significant contributor to moisture performance, with 19mm gaps drying out faster than walls having 12mm and 0mm gaps.

Recently, a comprehensive study was undertaken by CMHC to examine characteristics of the drainage/ventilation cavity in retaining moisture, the rate at which moisture can be dissipated and factors which affect this process, air flow resistance within drainage channels, and air flow water vapor resistance of intermediate joints in the cladding (CMHC, 2007). The results showed that vinyl lap-siding with its inter-locking system exhibited the lowest air and vapor flow rates, followed by hardboard and fiber cement board sidings. Laboratory results showed that air flows and vapor flows are 2 to 4 times greater for hardboard and cement board sidings than for the vinyl siding. In terms of drainage capability of the tested systems, no conclusive results were drawn. One of the more comprehensive studies for ventilation drying was performed for ASHRAE 1091 by Burnett et. al. (2005) and Straube et. al. (2004). The benefits of ventilated wall systems were studied for three brick claddings and two vinyl sided claddings for walls being wetted three times during the year. Drying rates varied significantly during different weather conditions, with ventilation increasing the drying potential for some walls and the nature of the sheathing membrane influencing the drying rate. The ventilated brick wall with top and bottom vents clearly was shown to be beneficial. The vinyl siding profile tested allowed significant ventilation-induced drying, whether applied with or without furring.

Infiltration Induced Wall Cavity Ventilation

Bassett et. al. (2006) measured ventilation rates in water managed wall cavities and reported that air infiltration through walls (whole house leakage, approximately 20% attributed to walls) appeared to play an important role in the water management capability of open rainscreen walls. The air leakage through the walls passed through the ventilation cavity thus ventilating the cavity. Salonvaara et. al. (1998) carried out full-scale laboratory experiments and numerical simulations using advanced multidimensional hygrothermal modeling and found that reasonably small air exchange rates (<15 air changes per hour) had a significant affect on the moisture performance of the wall cavity. These minimal air exchange rates can exist even without designed openings through the siding and to the cavity.

ANALYSIS OF VENTILATED AIR CAVITIES USING NUMERICAL MODELS

Simulations show that highly permeable water resistive barriers in wood frame walls do not provide the optimum solution in achieving adequate moisture performance. In the case of absorptive claddings such as brick clad walls, the absorbed wind driven rain can be further pushed into the exterior sheathing through highly vapor permeable water resistive barriers. With non-absorptive sidings such as vinyl or painted cement board, water can penetrate behind the siding causing similar moisture problems unless this water can be quickly drained and/or vented. When an attempt was made to keep the exterior sheathing dry, the engineers had to look at the primary wetting planes in the wall structure and water removal paths out of the wall either by drainage, venting or diffusion. Siding leaks (around windows and other penetrations) are very common and the water resistive barrier is designed to act as the second level of defense against moisture loads. Therefore, the exterior surface of the WRB can be considered one of the primary wetting planes. ASHRAE’s newly proposed standard SPC 160P acknowledges this and suggests that 1% of the wind driven rain hitting the wall surface shall penetrate through the wall surface. The desired direction for the drying process is in the outdoor direction. Thus the effective permeance between the wetting plane and the exterior should be higher than the permeance between the wetting plane and the sheathing with an exception of hot and humid climates where vapor drive is generally in the indoor direction. This limits the effectiveness of permeable water resistive barriers, i.e., higher permeance is not always desired. This means that sidings that are often very low in permeance or can absorb wind driven rain more readily, may remain wet for long periods of time if they are inadequately ventilated.

Furthermore, in hot and humid climates, summertime condensation problems indicate that the exterior layers of the wall need to have resistance to limit moisture intrusion in a form of bulk liquid and vapor water. In many cases, higher air exchange introduces more moisture into the wall cavity, and reduces the efficiency of the drying mechanism. However, since the ventilation rates are typically not controlled, high ventilation rates are preferred as a redundancy measure to provide faster drying rates for cases where high moisture loads are introduced into wall cavities. The affect of ventilation is still beneficial when significantly high moisture leaks are present. Ventilation in the wall cavity reduces the pressure difference across the cladding in most cases. This further reduces the amount of absorbed (or leaked) water in absorptive cladding materials. Many North American buildings, however, are built with walls that do not incorporate a ventilation cavity, and often not even a drainage plane. In such instances, the cladding is attached directly on top of the water resistive barrier and exterior sheathing with no furring strips or spacers to create a gap. Future wall systems may incorporate smart functional materials that provide controlled venting and pressure equalization when necessary.

Stovall and Karagiozis (2004), employing computational fluid dynamics (CFD), performed an extensive analysis to model the air movements within a wall cavity caused by thermal buoyancy and wind forces. Results were then correlated to exterior weather loads (wind speed, solar radiation, and air temperature) and construction details (cavity depth and vent slot size). Simple to use correlations were developed to estimate the mass flow, and pressure drops in the cavity for use in more general hygrothermal models using typical weather data files.

Effects of Wall Cavity on Thermal and Moisture Performance

The wall cavity located behind the cladding has several ways in which it affects the performance the wall structure. Figure 1 visualizes the functionality of the wall cavity and its effect on thermal and moisture behavior of the material layers and on the wall system as a whole. The air cavity in the wall acts as 1) a capillary break, 2) a drainage plane, 3) a ventilation channel, and 4) a pressure equalizer for the siding.

SIMULATION STUDY CASES

Effect of Cavity Ventilation Rate and Water Resistive Barrier (WRB) Vapor Permeance on the Moisture Content of OSB

Light weight wood framed walls were simulated with a highly water absorptive cladding (brick) and with a non-absorptive cladding (painted fiber cement board) to carry out a parametric study examining the affects of WRB vapor permeance and cavity ventilation rates on the moisture content of the exterior OSB sheathing. The widely used hygrothermal simulation model WUFI-ORNL, WUFI-Pro (Karagiozis et al, 2001, Kuenzel et al, 2001) was used in the study. Even though the model is one-dimensional, it has the capability of simulating air exchange between the outdoor and the air cavity in the wall.

The simulations were carried out for two year duration starting in October. Wilmington, NC, a location known for its high exposure to wind driven rain, was selected for the first case. Highly permeable housewraps, including building papers and felts, having a high vapor permeance at high relative humidity and a low vapor permeance at lower relative humidity may expose the exterior sheathing to high humidity for prolonged periods of time. It is a common understanding that the higher the vapor permeance, the better the performance. However, this is only true under certain conditions, i.e., walls consist of several layers that have differing functions and these layers form a system. A single material layer is rarely the only key factor in adequate performance. A highly permeable WRB allows high water vapor transport rates into and out of the exterior sheathing, which may result in large swings in the sheathing moisture content.

The permeance of the cladding layer is about 4 perms for brick and about 15 perms for fiber cement board. For a 25mm (1 inch) wide air cavity, an apparent permeance of 11 and 43 perms is expected for 5 and 20 air changes per hour (ach), respectively. In order to show the impact of the cladding material on the effect of venting on moisture performance, the same air gap and air exchange rates were assumed to exist behind the fiber cement board in the simulations. In real building practice a 1” cavity is typically not used behind fiber cement boards. However, a narrower air gap behind fiber cement siding with the air gap open to the outdoors along the whole wall width can easily provide the same venting/ventilation rates in the air gap as in the brick wall cavity. It is the air flow rate (m^3/s, wall-m^2) between the cavity and outdoors that can transport moisture. The airflow rate equals to air exchange rate multiplied by the wall cavity volume which means that higher air exchange rates in a narrower cavity can create the same effect as lower air exchange rates in a larger cavity.

Brick cladding. Figure 2 shows how ventilation of the air cavity behind a brick cladding can radically change the performance of the exterior sheathing. Two different levels of WRB permeance (5 and 50 perms) and two cavity air exchange rates (5 and 20 ach) were used. A higher ventilation rate reduces the humidity in the air cavity, which results in lower sheathing moisture contents. Similarly, the semi-permeable WRB (5 perms) slows down water vapor intrusion into the exterior sheathing panel and allows the brick layer to dry out before causing moisture problems in the interior wall structure.

Figure 5 shows the sheathing moisture contents for a brick-clad wall in another locale, Philadelphia (PA). Results are similar to those in Wilmington. Figure 6 presents the relative humidity on the interior side of the exterior sheathing (facing the insulation in the wall cavity). The highly permeable WRB causes the relative humidity at the interior surface of the sheathing to increase to greater levels than in a wall with semi-permeable WRB. Less variation in the moisture content of the sheathing results in less dimensional change due to swelling and shrinking. This may reduce cracking and subsequently prevent water and air leakage through the wall.

Fiber cement siding. Figure 3 shows exterior sheathing moisture content for a wall with painted fiber cement siding in the same locale, Wilmington, NC (with no wind-driven rain absorption into the cladding). A lower overall moisture content level was achieved for the higher wall cavity ventilation rate (50 ach) than for the lower ventilation rate (5 ach). Again, using the semi-permeable WRB provides more balanced moisture contents in the exterior sheathing. Figure 4 shows the structure of the brick-clad wall.

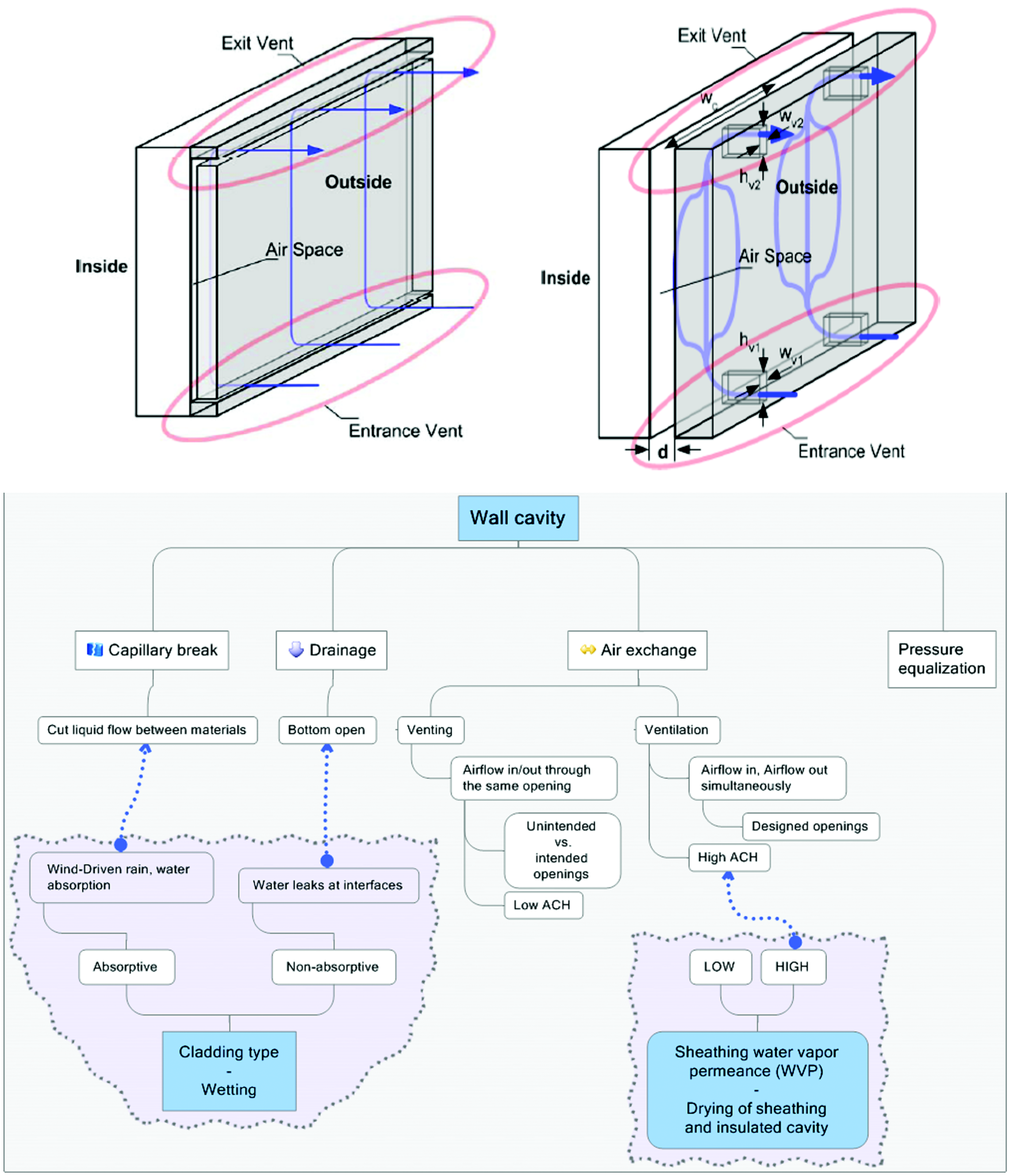

Figure 1 *Functions of a wall cavity on thermal and moisture performance of a wall system.*

Stucco wall in Seattle. A stucco-clad wall with a 10 mm air gap between the two layers of WRB (felt and housewrap, with housewrap toward the sheathing) was simulated in Seattle, WA for four different orientations (North, East, South and West). The air cavity was either unvented or vented at 30 ach. Figure 7 shows the moisture content in the exterior sheathing as a function of orientation and ventilation rate (vented vs. unvented). The effect of venting the wall cavity is clear. Air exchange in the cavity behind the stucco reduces the overall the moisture content of the sheathing. South facing walls get the most rain in Seattle according to the weather file in WUFI-Pro and when the wall has no ventilation, the sheathing moisture content creeps to high levels during the three years of simulation. However, ventilating the air gap in the wall brings the sheathing moisture content at all three orientations to approximately the same level, which is due to both the air gap and ventilation acting to disconnect the sheathing from the absorptive cladding when exposed to wind-driven rain.

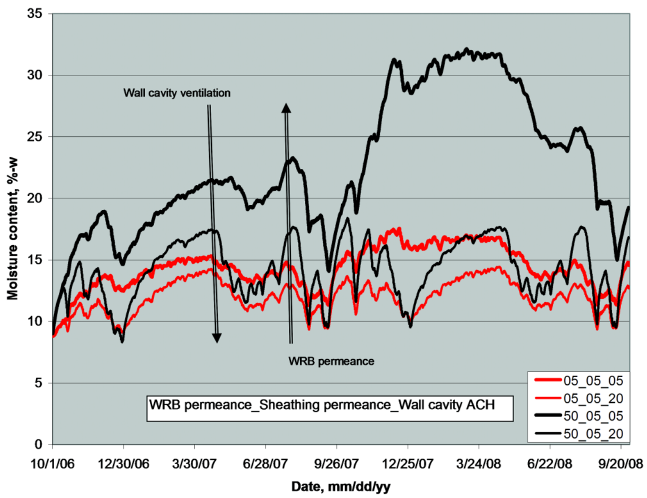

Figure 2 *Effect of the WRB permeance and wall cavity ventilation on the moisture content of OSB sheathing. Wilmington, NC. South facing brick wall.*

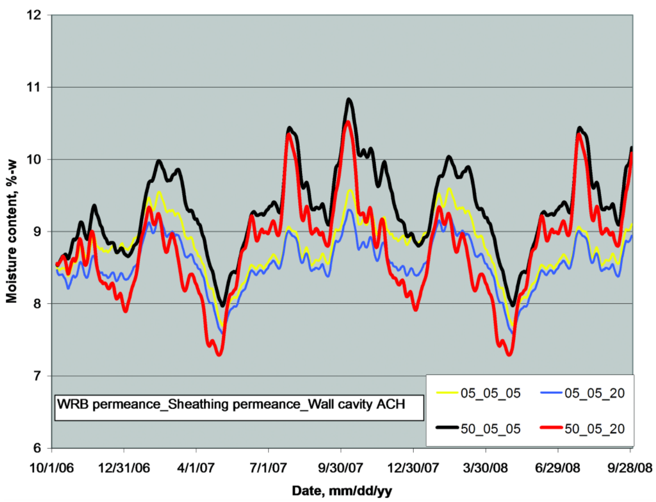

Figure 3 *Effect of the WRB permeance and wall cavity ventilation on the moisture content of OSB sheathing. Wilmington, NC. South facing Fiber Cement siding wall.*

Vinyl clad wall in Seattle. Ventilating vinyl clad walls is also beneficial. Figure 8 shows that a steady-state cyclic condition is reached in one year for walls with cavity ventilation. Walls without ventilation take longer to dry the initial moisture. It is evident that ventilation is less needed for this kind of wall than for walls that have water absorptive claddings. As always, water leakage behind the siding should be avoided. If leakage finds a path to the cavity, then the wall should have the ability to drain most of the water and ventilate (dry out) the residual moisture.

Stucco walls in Minneapolis. In colder climates, ventilated cavities are usually much more common than in mixed

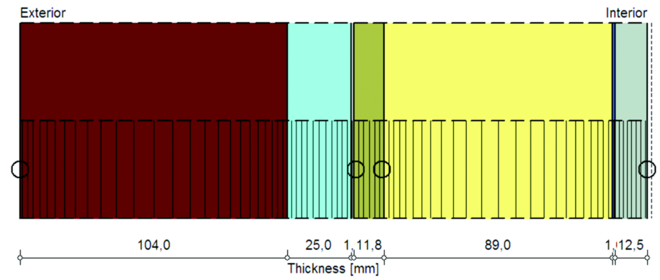

Figure 4 *Simulated wall structure: Brick (104 mm,[4"]) clad wall with (25 mm, [1"]) air gap, water resistive barrier, oriented strand board (11.1 mm [7/16"]), fiberglass insulation (89 mm, [3.5"]), kraft paper and gypsum board (12.5mm, [1/2"]), listed from exterior to interior.*

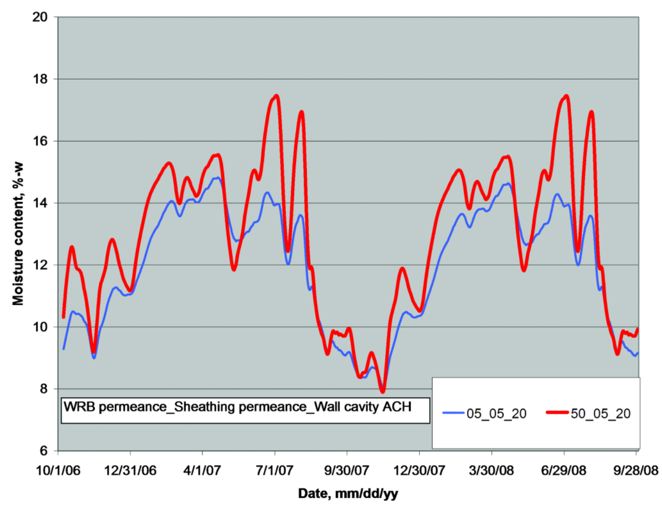

Figure 5 *Effect of WRB permeance on the moisture content of OSB sheathing in Philadelphia, PA for a south facing brick-clad wall.*

or hot and humid climates. In heating climates such as in Minneapolis, MN, the risk of having summer condensation is small. Figure 9 shows the results in Minneapolis for the moisture content of the exterior sheathing, for north and south facing walls, with and without cavity ventilation. The beneficial effect of ventilation drying is very clear in this climate.

CONCLUSIONS

The air cavity in a light-weight, wood framed wall has several important functions. The cavity can act as a capillary break, a drainage plane, a ventilation channel, and a pressure equalizer for the cladding. The ability of the air cavity to perform depends not only on the air cavity itself, but also on the other material layers and wall details such as openings to the cavity. While acting as a capillary break, a narrow or wide cavity usually provides the drainage channel for incidental water leakage behind the cladding. In practice, many walls have drainage cavities, and some venting within the air cavity,

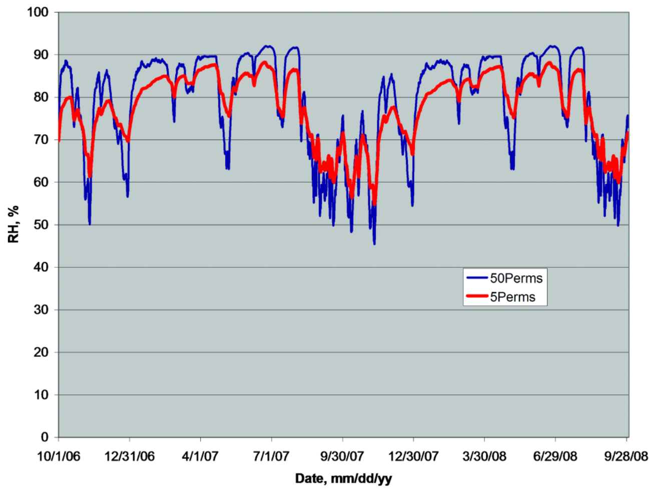

Figure 6 *Relative humidity at the exterior surface of OSB sheathing when a highly permeable (50 perms) or semi-permeable WRB is used in a ventilated (20 ach) brick-clad wall, facing south in Philadelphia, PA.*

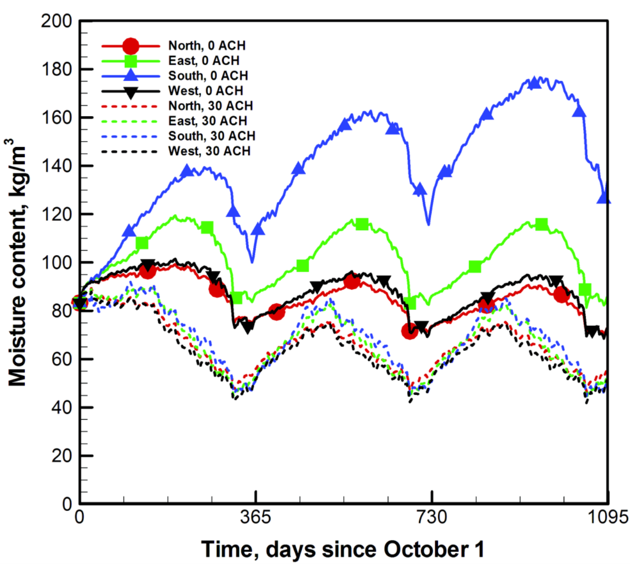

Figure 7 *Moisture content of exterior OSB sheathing in a stucco-clad wall with an unvented (0 ach) and vented (30 ach) air cavity behind the stucco for four orientations. Seattle, WA. Results simulated with WUFI-PRO hygrothermal model.*

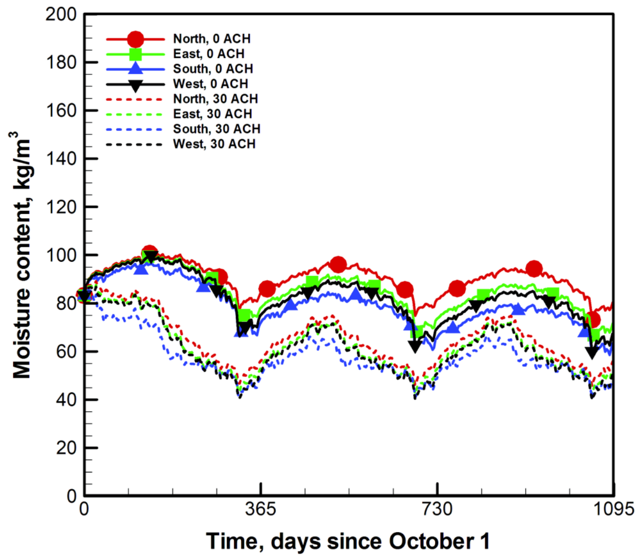

Figure 8 *Moisture content of exterior OSB sheathing in a vinyl-clad wall with an unvented (0 ach) and vented (30 ach) air cavity behind the siding for four orientations. Seattle, WA. Results simulated with WUFI-PRO hygrothermal model.*

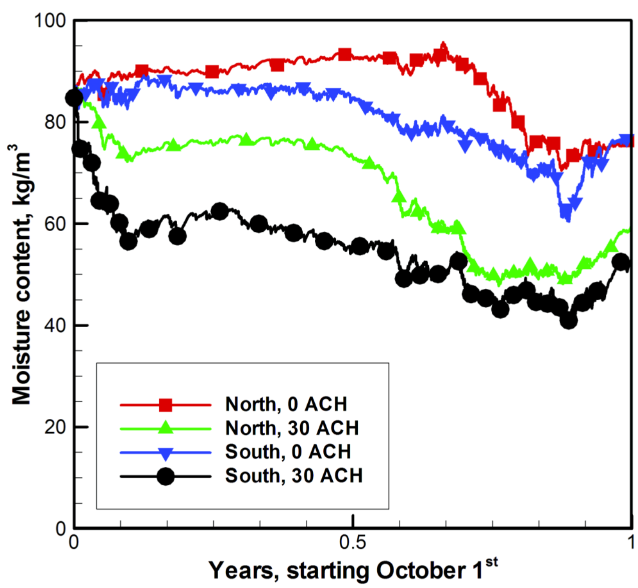

Figure 9 *Moisture content of OSB sheathing behind stucco cladding, for north and south facing walls with and without cavity ventilation. Minneapolis, MN.*

even if they were not designed for ventilation. Field studies and theoretical analyses using advanced simulations tools have shown that cavity ventilation does not always improve drying. The local weather and material layers adjacent to the air cavity play an important role in the actual performance. In order for the air cavity to be able to dry out, the materials exposed to the air cavity must be capable of transporting moisture from the surrounding materials. This means that wet materials should have higher permeability the closer they are to the ventilated cavity. On the other hand, the cavity behind the cladding is often the layer where leakage occurs due to poor detailing and typical penetrations through in the cladding. Even if the wall cavity drains water, it will still retain part of the leaked water. Depending on the outdoor temperature, humidity and available solar radiation on the wall, conditions may be favorable for so called summer condensation to occur, which is water vapor driven through the WRB and into the inner wall. In this scenario, the optimum permeance for the WRB is not the highest permeance possible, but instead a lower permeance (i.e., the semi-permeable WRBs seem to have a balanced drying and wetting capability).

Results show that wall cavity ventilation is generally beneficial for most all wall structures, allowing them to dry out from incidental moisture leakage into the wall cavity. At times, cavity ventilation can help bring moisture into the wall. In an ideal world, a perfectly air, water, and water vapor tight wall would remain dry even in wet and humid conditions. If this ideal wall is suddenly ventilated, the ventilation will bring in humid outdoor air and thus increase the moisture content of the materials in the wall. However, in the real world we have to be prepared to dry out incidental water leakage that is introduced into the wall. Therefore, wall cavity ventilation is primarily beneficial with occasional minor drawbacks. Wall cavity ventilation is especially important for walls with high water absorptive claddings, such as bricks and stucco claddings.

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