Adhered Veneers and Inward Vapor Drives: Significance, Problems, and Solutions

Conference Paper - 0904
2009

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Abstract:

Adhered veneers, in which masonry units are directly attached to a substrate via mortar and ties without a drainage or ventilation gap, have become a very popular finish in residential and light commercial construction. Typical applications apply masonry over a bed of lath-reinforced mortar over a drainage plane (often of building paper or felt). When used over wood- or steel-framed walls, numerous reports of moisture problems and failures have been received.

The lack of a well-defined drainage space, and warm-weather inward vapor drives have been implicated as the reasons for these moisture problems. Drainage can easily be provided by installing a second layer of building paper and ensuring that flashing and weep holes are included. However, the control of inward vapor drives is more problematic, as two layers or building paper are highly vapor permeable, and both the mortar and the masonry unit can store a significant amount of rain water. During sunny weather following rain, water vapor stored in the masonry can be driven into the sheathing and into the studbay, resulting in wood *decay and condensation on air-conditioned interior surfaces. One proposed solution to moisture problem in masonry veneers is the use of an air gap membrane behind the adhered veneer.*

This paper reports on field measurements collected from over a year of monitoring two types of wood-framed walls, one with an air gap membrane and another installed following standard practice. No penetrations through the test assembly were installed with the goal of reducing bulk rain penetration problems. Each type of wall was faced either north or south in a test hut located in South-western Ontario. The temperature, RH, and the wood moisture content was measured in more than a dozen locations in each wall and recorded on an hourly basis.

The results show that inward vapor drives and summer condensation can be a real concern for typical adhered veneer walls, even when installed in cold climate locations with fully functional drainage. The air gap membrane controlled inward vapor drives well and resulted in low wood sheathing moisture contents, in both summer and winter.

Introduction

Adhered veneers, in which masonry units are directly attached to a substrate via mortar and ties without a drainage or ventilation gap, have become a very popular finish in residential and light commercial construction. Typical applications apply thin masonry units over a bed of lath-reinforced mortar over a drainage plane (often a single layer of building paper, felt, or housewrap).

When used over wood- or steel-framed walls, numerous reports of moisture problems and failures have been reported (Rymell 2007). The lack of a well-defined drainage space, and warm-weather inward vapor drives have been implicated as the reasons for these moisture problems.

Drainage can easily be provided by installing a second layer of building paper, particularly if one layer is a creped housewrap, and ensuring that flashing and weep holes are included. However, controlling inward vapor drives is more problematic, as building papers and housewraps are highly vapor permeable, and both the mortar and the masonry unit can store a significant amount of rain water via capillary absorption. During sunny weather following rain, water vapor stored in the masonry can be driven into the sheathing and into the stud bay, resulting in wood decay and condensation on air-conditioned interior surfaces. Air-conditioned buildings with low-permeance vapor retarders (such as polyethylene, vinyl wall paper, and aluminum foil) exacerbate this problem.

One proposed solution to avoiding the risk of these problems is the use of a vapor-impermeable air gap membrane behind the adhered veneer. A rigid plastic membrane will control inward vapor drives, but will not allow water vapor in the studspace or framing to dry to the exterior. Previous research suggests that a ventilated air space may allow the required drying (Karagiozis et al 2005, Straube et al 2004), but this has not been demonstrated in the field for an impermeable air gap membrane.

Experimental Program

An experimental program was developed to measure and compare the performance of adhered veneer cladding side-by-side with an alternative method that uses a vapour-impermeable rigid polymer-based air-gap membrane. The objective of the study was to compare adhered veneer walls using a rigid plastic dimple sheet in place of asphalt impregnated paper as the sheathing membrane. These walls were installed in a natural exposure field testing facility in Waterloo, Ontario, Canada.

To collect field measurements for over a year of monitoring two types of wood-framed walls, one with an air gap membrane and another installed following standard practice. No penetrations through the test assembly were installed to eliminate the potential of bulk rain penetration problems. Each type of wall was faced either north or south in a test hut located in Water Ontario. Waterloo has an average of approximately 4300 Celsius heating degree days (7800 HDD F). The hut is in an exposed location, free from obstruction by other buildings.

All of the test panels were 8 ft (2.4 m) in height, and 4 ft (1.2 m) in width and shared construction of 2x6 wood framing on approximately 16" (0.4 m) centers with OSB sheathing, a poly interior vapor barrier, drywall finish and air barrier, and R19 (RSI3.5) fiberglass batt insulation.

Instrumentation included a temperature and relative humidity sensor in the drain space, as well as the stud space, moisture content sensors in the sheathing and framing, and temperature sensors on the cladding and drywall. All of the monitored framing is clear eastern white pine (EWP), and the remaining framing is generic SPF framing. Details of the instrumentation, data conversion and other details can be found in Straube et al (2002). The data was measured at 5 minute intervals and the average recorded on an hourly basis. The sensor layout is shown in Figure 1.

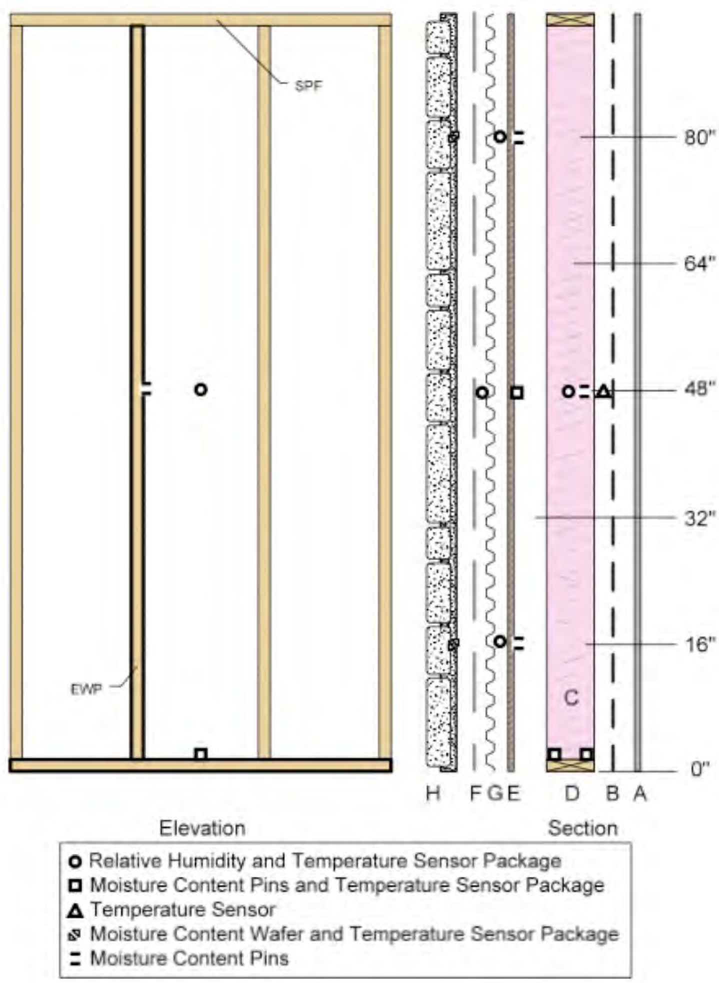

Figure 1 : Typical Wall Construction and Sensor Layout For Full Scale Wall Testing

The opening in the test facility was lined with a wood frame wrapped in a self-adhered flashing to help isolate the test panel from any other moisture sources. All of the instrumentation is located in the centre third of the wall over the entire height. This helps minimize edge effects and simulates accurate field performance of the enclosure system.

Moisture content behind the cladding was measured using a moisture content wafer. These sensors consist of a small piece of wood, of a known species, with moisture content pins installed into it (Ueno et al, 2008). The sensor equilibriates with the liquid or vapor around it, but because of its hygric mass, it does not react quickly. This sensor is generally used in locations where the moisture content is required, and the moisture content does not change quickly, such as masonry work.

Monitoring began on July 16, 2007 and is on-going.

Boundary Conditions

The exterior and interior conditions were both recorded during testing. The exterior temperatures and relative humidity are shown below in Figure 2. The thirty-year average for monthly average temperatures in Waterloo region are indicated by the black lines.

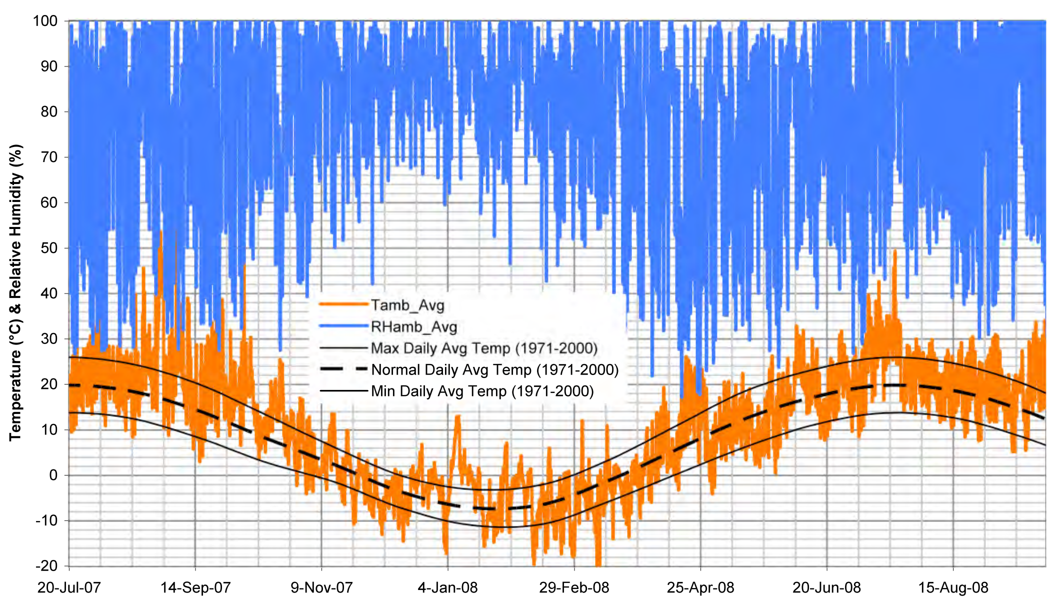

Figure 2: Exterior Temperature and RH During Testing

The interior temperature and relative humidity were controlled for most of the testing period. The relative humidity was kept between 40% and 50% for most of the testing period. As the test walls have sealed drywall air barriers and continuous polyethylene vapor barriers, interior moisture loads do not affect the test wall hygrothermal conditions.

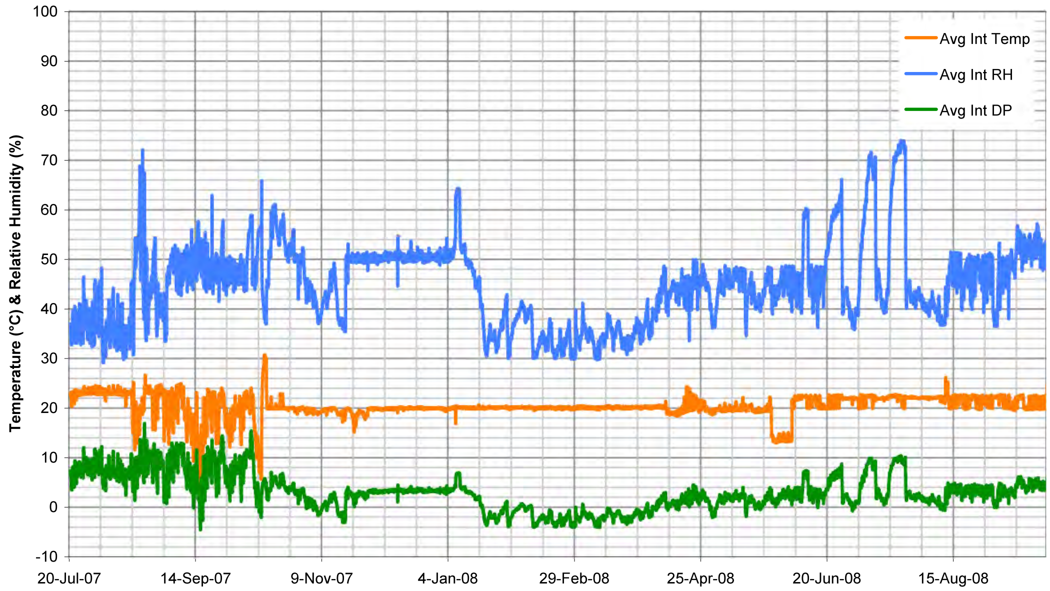

Figure 3: Interior Temperature and RH During Testing

One of the performance criteria for analysis and comparison of the two different wall design approaches is the drying potential. The drying potential was evaluated using a wetting apparatus to inject a known volume of water into a known location in the test wall. The wetting apparatus is shown in Figure 4.

Figure 4: Installed Wetting Apparatus in a Test Wall

The wetting apparatus consists of a water storage and redistribution media (blue material), and an injection tube to inject water without opening the wall, and thereby disturbing the stud space conditions. Only the first intentional wetting event is included in this paper. The wetting event began on the morning of September 16. Each morning and evening 42.5 grams (1.5 ounces) of water was injected for 4 days for a total of 340 grams (12 ounces). This was intended to simulate a small but steady leak into the enclosure from, for example, a small leaky window, or a failed flashing, during a particularly severe storm.

The intentional wetting event is shown on some of the analysis graphs as a dashed red vertical line at the time of the first water injection. Following the analysis of performance under normal conditions, the intentional wetting event is analyzed in detail using the moisture content sensor located in the sheathing at the water storage media location (as can seen in Figure 4)

Figure.

Analysis Results

To compare the performance of engineered stone veneer with and without an air gap membrane, the moisture content of the sheathing, moisture content of the framing and the relative humidity of the stud space were analyzed.

The first comparison, shown in Figure 5, are the sheathing moisture contents of the north orientation of both test walls. There are three moisture content measurement locations in the sheathing on each wall: 16" from the bottom, mid height, and 16" from the top. The data shows that the sheathing moisture content was higher in all three locations in the standard construction wall than in the wall with the air gap membrane. Generally, a moisture content of 16-20% correlates to a surrounding relative humidity of 80-90% (FPL 1999) and is considered the highest moisture content with no risk for moisture-related problems (Morris 1998). Relative humidities well above 80%, and wood moisture contents above 20%, may cause moisture-related problems, especially if sustained for long periods of time without drying. Wood rot and decay does not commence until at least 28% moisture content.

The sheathing moisture content at all three locations in the standard wall was greater than 16%, and approached 20%, from approximately October 2007 to May 2008.

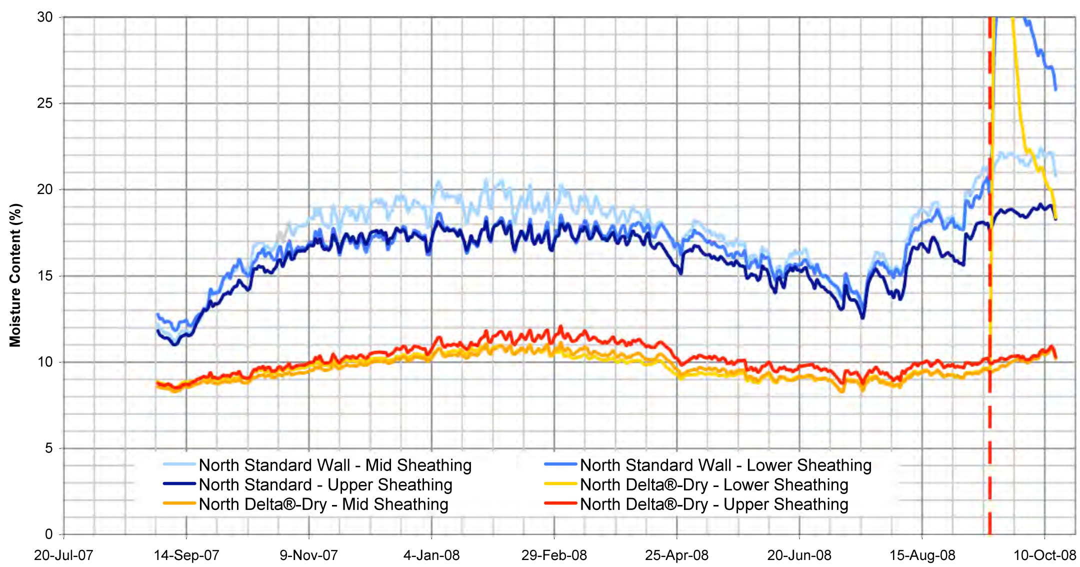

Figure 5: Sheathing moisture content comparison on the north orientation

On the south orientation, the air gap test wall exhibited lower sheathing moisture contents than the standard construction wall (Figure 6). The performance difference is not as great as the north orientation, but there is still evidence of improved performance due to the air gap.

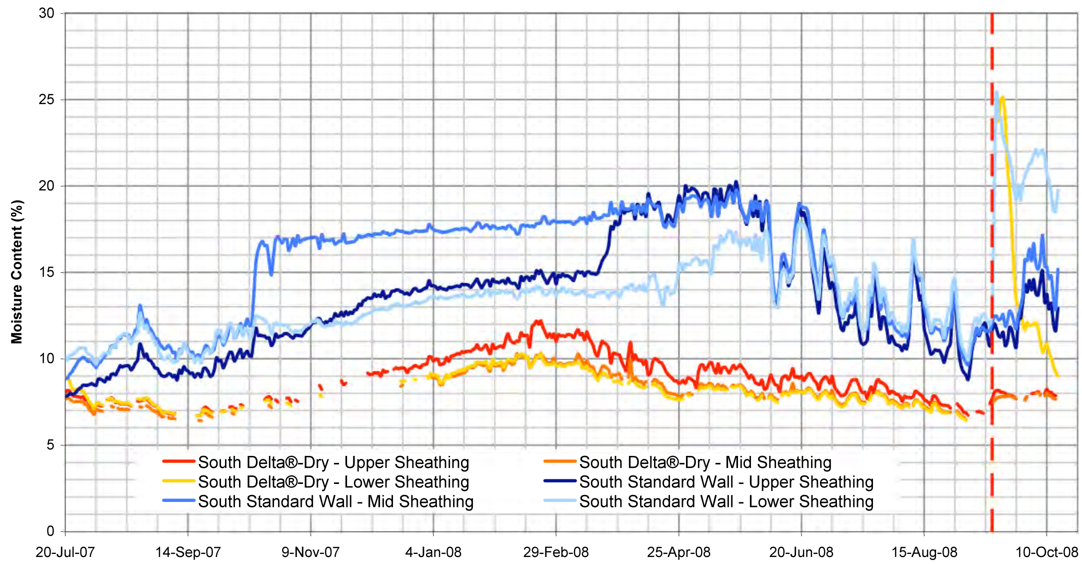

Figure 6: Sheathing moisture content comparison of the south orientation

Figure 7 shows a detailed analysis of the intentional wetting event that started on September 16, 2008. The only sensors included in this analysis are the moisture content sensors located in the lower sheathing, in the middle of the water storage media. The pins are electrically insulated along the shaft so that any only moisture in the sheathing will affect the moisture content readings. The vertical scale in Figure 7 has been changed from the other moisture content analysis to more clearly show the drying rates.

All of the sensors show a response to the increased moisture content within 24 hours of the first water injection. On the north orientation both of the test walls reach a maximum of 33% moisture content approximately one week following the first injection. On the south orientation both of the walls reach 25% moisture content approximately 3 days following the first injection.

The drying performance differences are evident from this analysis. On the north orientation the standard construction wall is still above 26% moisture content four weeks following the initial wetting. The air gap wall on the north orientation quickly dried down to 22% moisture content in approximately two weeks following the intentional wetting event, but the drying rate then changes and it dries more slowly.

On the south orientation the results are similar. The standard construction wall on the south orientation dries from 25% to 20% moisture content in one and a half weeks, but then fluctuates around 20% for approximately three weeks, until the end of the data collection. The air gap membrane wall on the south orientation dries to approximately 13% moisture content in the first week and a half very quickly. Similarly to the north orientation, the drying rate changes following the initial drying phase to a slower drying rate and reaches 9% four weeks following initial wetting.

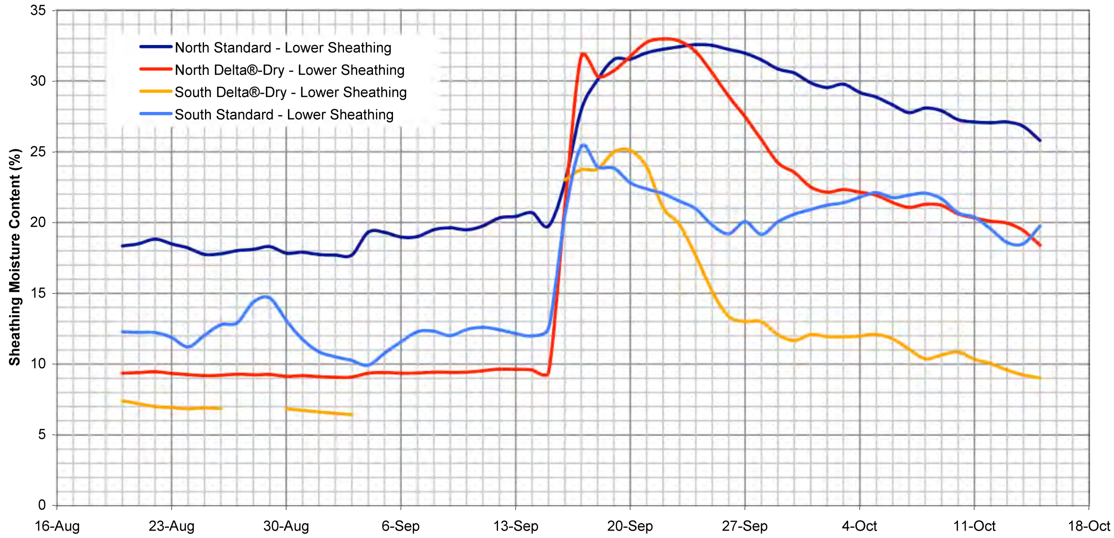

Figure 7: Lower sheathing moisture content comparison during an intentional wetting event

The forgoing analysis convincingly demonstrates that the small gap produced by the air gap membrane provides sufficient ventilation to allow outward drying at a faster rate than traditional adhered veneers. Adhered veneers appear to have relatively little outward drying potential, and rain leaks or condensation within the studbay will dry at a slower rate than other types of walls previously measured (e.g., Straube et al 2004).

The moisture content of the framing lumber was measured at approximately 3/8" from the inside surface of the framing at mid-height. This testing location was specifically included to capture inward vapor driven condensation on a vapor barrier. Vapor pressure is proportional (in a non-linear manner) to the temperature and moisture load. Generally, the south orientation has the greatest solar exposure and also the highest cladding temperatures that often result in the highest inward vapor drives in the summer months. Ventilation and vapor impermeable materials are both strategies to limit inward vapor drives.

Figure 8 shows the framing moisture content for all four test walls. During the summer months of both 2007 and 2008, the standard wall on the south orientation had elevated moisture content levels. The moisture content exceeded 16% on the south standard wall in the first week of June, and had not returned to 16% as of mid October. In 2007, the south standard wall did not return to 16% until the end of October. The moisture content of the standard wall on the north orientation is also elevated, but does not exceed 16% moisture content. The moisture content in the framing of the north standard construction wall is approximately 15% moisture content for the entire summer. These elevated moisture content levels indicate that the relative humidity is also likely elevated inside the test wall.

The air gap membrane walls on the north and south orientation show no significant increase in moisture content in the summer months caused by inward vapor drives.

In the winter months no readings are plotted because the framing is too dry for the equipment to accurately measure (ie, the moisture content is below 7 to 8%).

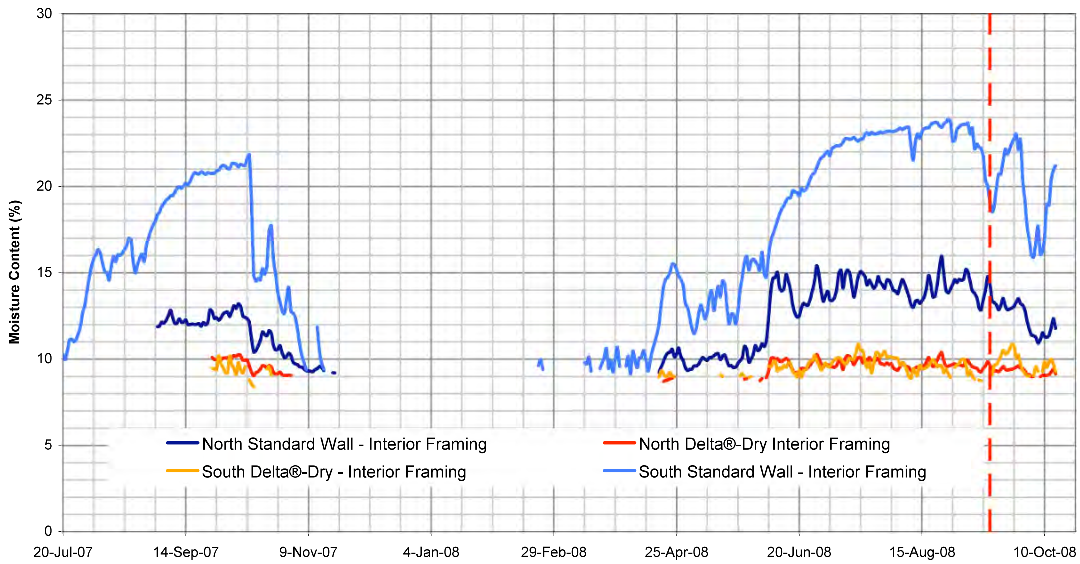

Figure 8 : Framing moisture content comparison of all test walls

The relative humidities of the stud spaces are compared in Figure 9 for all four test walls. The south-facing standard wall has the highest relative humidity of all four walls, greater than 90%, which is also expected given the framing moisture content readings in Figure 8. The relative humidity in the south-facing standard wall began to exceed the other test walls as early as March and was still elevated in mid October at the end of the testing period.

The recorded hourly temperatures of the studspace was measured in the order of 15 to over 30 Celsius during warm and especially sunny weather. Given the daily average center-of-batt RH of 90% in the South standard wall and the 21-25 C temperature of the polyethylene vapor barrier, condensation is predicted to occur on the polyethylene vapor barrier for hundreds, perhaps as much as a thousand hours, during the summer. The only source of the water vapor for this condensation is the exterior masonry, as the vapor impermeable and airtight interior polyethylene-drywall layer eliminates the interior as a source.

The standard wall on the north orientation also experiences elevated relative humidities in the summer months, but generally stays at approximately 80%. This corresponds to the previously analyzed 15% moisture content in the sheathing.

Both of the air gap membrane walls are generally between 60% and 70% relative humidity for the entire summer.

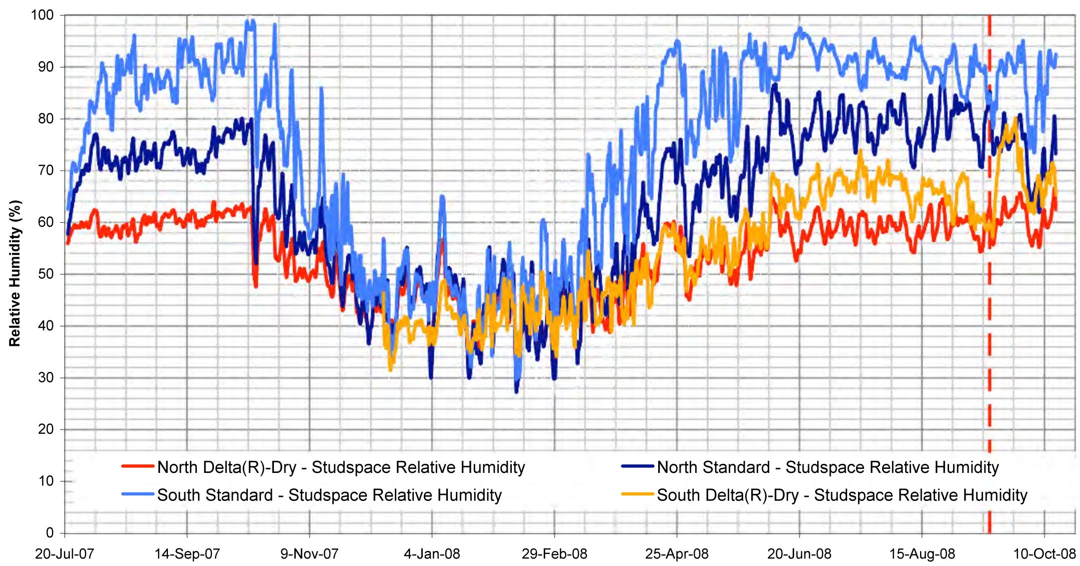

Figure 9: Relative humidity comparison of the stud cavities

Conclusions

After monitoring the test walls for approximately one year, the following conclusions can be drawn.

- The air gap membrane walls experienced lower sheathing moisture content on both orientations at all times than the comparison standard construction walls.
- During normal operation (ie. not during the intentional wetting event), the standard construction-practice walls on both the south and north orientation did cross the generally accepted moisture content threshold where moisture related problems may occur, but the sheathing of the air gap membrane walls was significantly drier (below 12%) at all times under normal operating conditions.
- The air gap membranes walls exhibited faster outward drying following the intentional wetting of the OSB than the standard wall. The air gap, albeit small, allowed significant drying to occur.

- Warm weather inward vapor drives caused elevated moisture content levels in the framing of the standard construction walls. Summer condensation on the vapor barrier likely occurred. The vapor impermeable membrane appeared to decouple the wood framing and sheathing from the moisture in the masonry and transported by inward vapor drives.
- The relative humidities were elevated in both the standard construction walls in the summer months due to inward vapor drives. The elevated humidity levels were high enough (>80%) to cause some moisture related durability problems over time. The air gap membrane walls did not experience relative humidities that would cause moisture related durability problems.

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About this Paper

First published as: Straube, J.F., Smegal, J., Schumacher, C.J., Jablonka, M., "Adhered Veneers and Inward Vapor Drives: Significance, Problems, and Solutions", Proc. of Can. Bldg. Sci. & Tech. Conference, Montreal, May 6-8, 2009, pp. 303-312

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