

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.

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 be seen in **FIGURE 4**).

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 inches from the bottom, mid height, and 16 inches from the top. The data shows that the sheathing moisture content was higher in all three locations in the standard construction wall

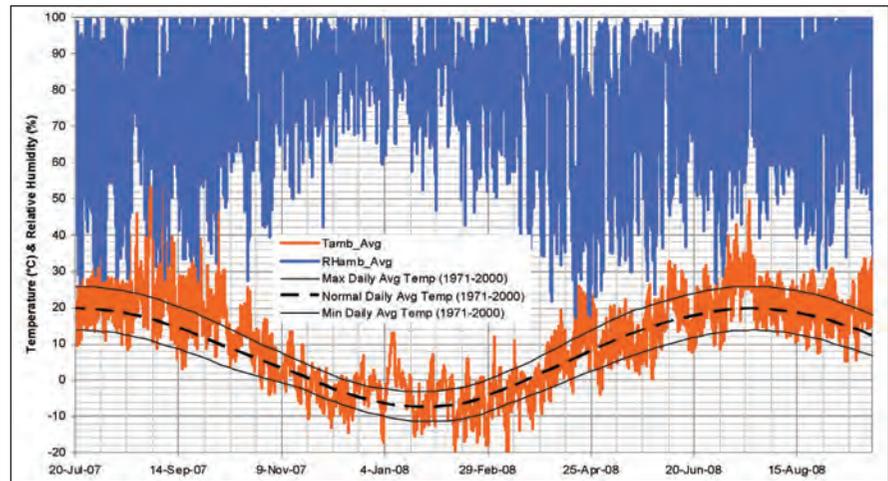


Figure 2. Exterior temperature and RH during testing. The interior temperature and relative humidity were controlled for most of the testing period. The relative humidity was kept between 40 percent and 50 percent for most of the testing period. As the test walls have sealed drywall air barriers and continuous polyethylene vapor barriers, interior moisture loads do not affect the test wall hygrothermal conditions.

than in the wall with the air gap membrane. Generally, a moisture content of 16 to 20 percent correlates to a surrounding relative humidity of 80 to 90 percent (FPL 1999) and is considered the highest moisture content with no risk for moisture-related problems (Morris 1998). Relative humidities well above 80 percent, and wood moisture contents above 20 percent, 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 percent moisture content.

The sheathing moisture content at all three locations in the standard

wall was greater than 16 percent, and approached 20 percent, from approximately October 2007 to May 2008.

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 percent moisture content approximately one week following the first injection. On the south orientation both of the walls reach 25 percent 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 percent moisture content four weeks following the initial wetting. The air gap wall on the north orientation quickly dried

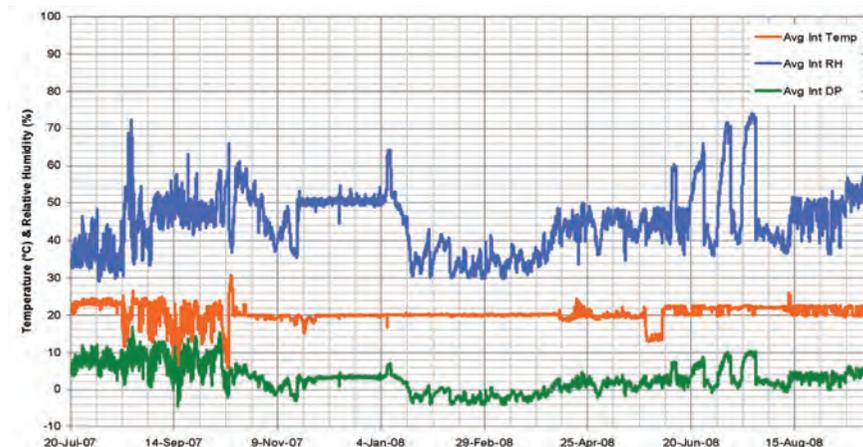


Figure 3. Interior temperature and RH during testing. One of the performance criteria for analysis and comparison of the two different wall design approaches is the drying potential. The drying potential was evaluated using a wetting apparatus to inject a known volume of water into a known location in 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.

down to 22 percent 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 percent to 20 percent moisture content in one and a half weeks, but then fluctuates around 20 percent for approximately three weeks, until the end of the data collection. The air gap membrane wall on the south orientation dries to approximately 13 percent 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 percent four weeks following initial wetting.

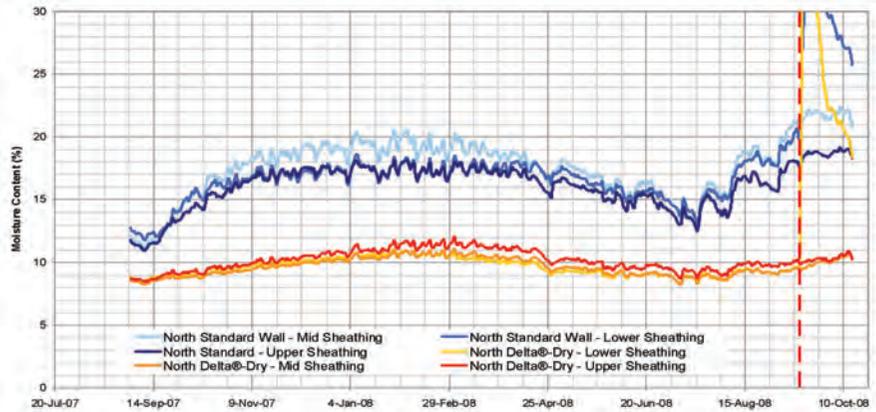


Figure 5. Sheathing moisture content comparison on the north orientation. On the south orientation, the air gap test wall exhibited lower sheathing moisture contents than the standard construction wall (Figure 6). The performance difference is not as great as the north orientation, but there is still evidence of improved performance due to the air gap.

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 stud-bay 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 inch 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 percent on the south standard wall in the first week of June, and had not returned to 16 percent as of mid October. In 2007, the south standard wall did not return to 16 percent until the end of October. The moisture content of the standard wall on the north orientation is also elevated, but does not exceed 16 percent moisture content. The moisture content in the framing of

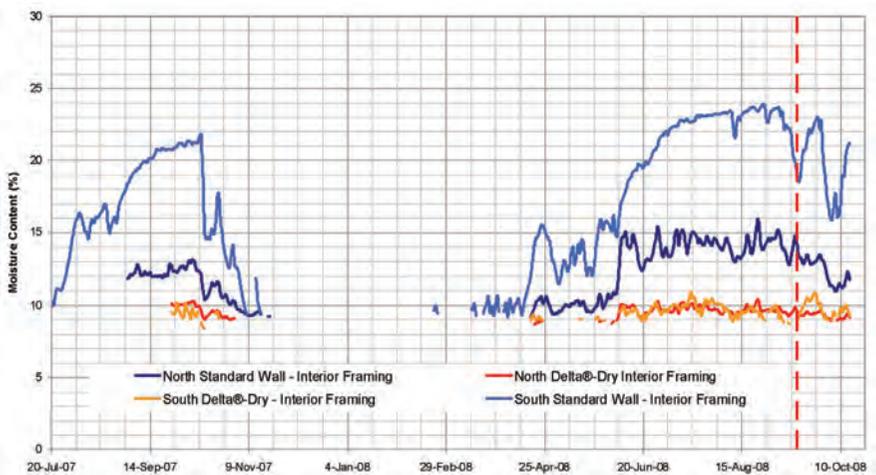


Figure 7. Lower sheathing moisture content comparison during an intentional wetting event.

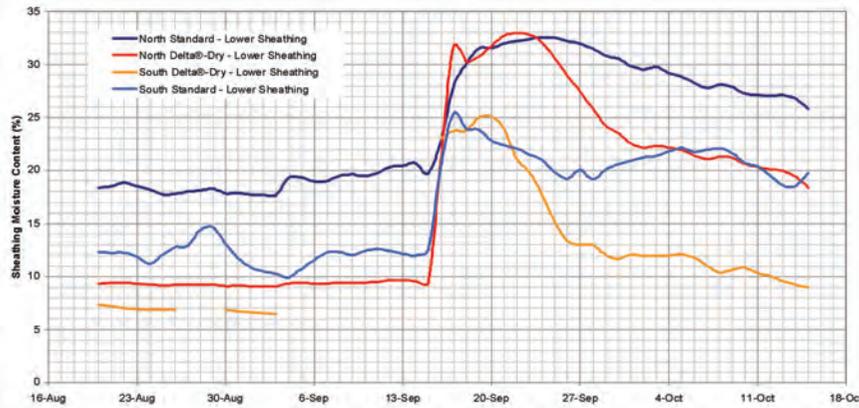


Figure 8. Framing moisture content comparison of all test walls.

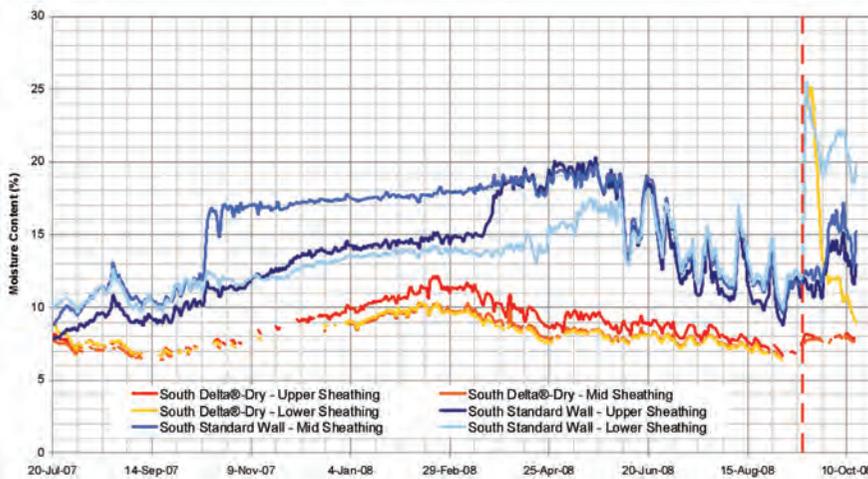


Figure 6: Sheathing moisture content comparison of the south orientation event.

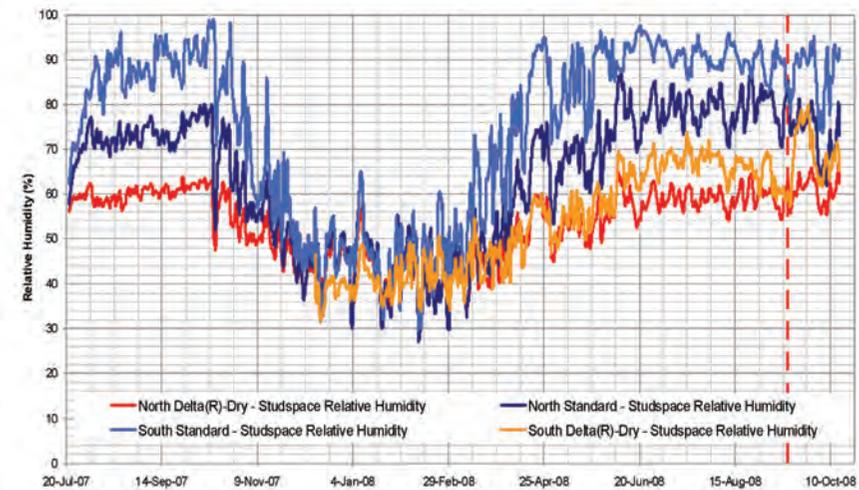


Figure 9. Relative humidity comparison of the stud cavities.

the north standard construction wall is approximately 15 percent 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 percent).

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 percent, 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°C (59 to over 86°F) during warm and especially sunny weather. Given the daily average center-of-batt RH of 90 percent in the South standard wall and the 21 to 25°C (69 to 77°F) 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 percent. This corresponds to the previously analyzed 15 percent moisture content in the sheathing.

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

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 percent) 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 percent) 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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EDITOR'S NOTE: For a full list of references for this article email shannonl@matrixgroupinc.net.

A Healthier Interior Starts At The Skin.

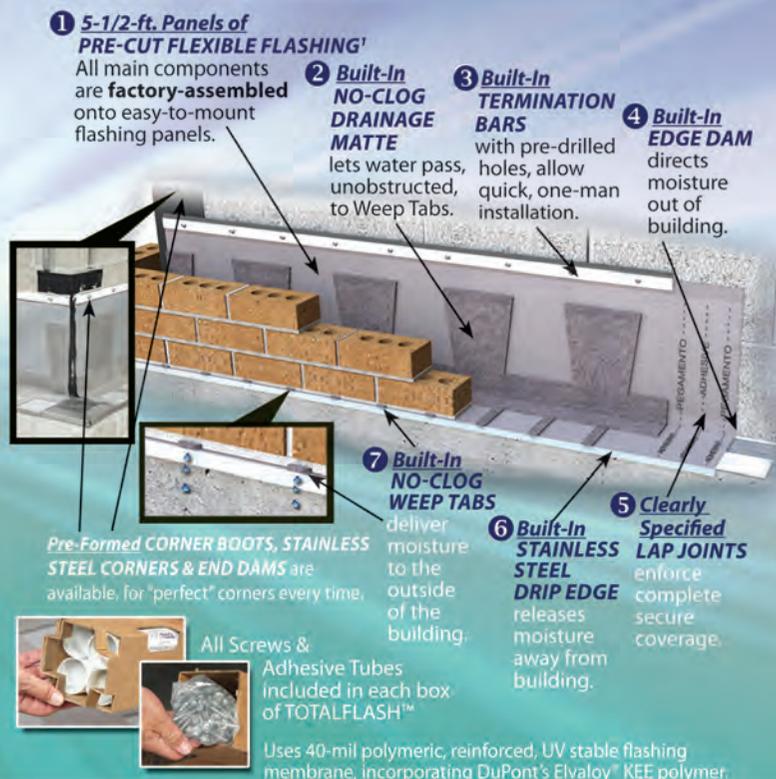
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