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Vancouver Field Exposure Facility: Analysis and Comparison of HardiePlank Walls

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Abstract:

This report analyzes the performance of walls clad with HardiePlank fiber cement siding and compares them to traditional stucco assemblies. The data presented is a subset of experimental data from a multi-phase, multi-year research project at the Vancouver Field Exposure Test Facility led by Building Science Corporation (BSC) and Gauvin 2000 Construction Limited. The analysis includes results from normal operating conditions in a high stress exterior moisture environment (typical of the Pacific Northwest climate) and under intentional controlled wettings to the interior and exterior of the sheathing.

VANCOUVER FIELD EXPOSURE FACILITY

Analysis and Comparison of HardiePlank Walls

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1. Introduction

A multi-phase, multi-year research project at the Vancouver Field Exposure Test Facility near Vancouver, British Columbia is being led by Building Science Corporation (BSC) and Gauvin 2000 Construction Limited.

A test hut was constructed in the fall of 2005 in Coquitlam, British Columbia that permits the side-by-side construction and comparison of seven 1.0m x 2.4m (38" x 96") test wall panels on each cardinal orientation (for a total of 28 wall test panels) and three 3.6m x 7.2m (12' x 24') roof panels on the North and South facing roof slopes (for a total of 6 roof test panels). All of the test panels are exposed to the same controlled and monitored indoor conditions. The objective of the test hut was to determine the performance of historical, current and possible future wall assembly configurations under field conditions. Each wall or roof assembly is instrumented with different types of sensors to collect the desired assembly data (e.g. moisture content, temperature relative humidity, etc.) and is stored on a central data logger. Exterior weather data is also collected with a small meteorological tower mounted on the roof.

The third phase of testing started December 17, 2009 and was completed on November 3, 2011. The primary focus of this phase was to simulate wetting events directly against the exterior surface of the wood sheathing instead of the interior of the enclosure as previously tested, while simulating representative interior wintertime relative humidity levels. These test conditions are described in more detail below.

This report is divided into five main sections:

- Section 1 explains the background of the research, the objective of the report, and how the analysis will be conduct.
- Section 2 describes the experimental plan including the test facility, monitoring instrumentation and wetting systems.
- Section 3 is data analysis from the moisture monitoring instrumentation system. The measured sheathing moisture contents are compared following intentional wetting events, and under normal operating conditions.
- Section 4 includes the visual observations from the test wall deconstruction conducted in November, 2011
- Section 5 provides conclusions based on the data analysis and observations.

Objective

This report will analyze the performance of walls clad with HardiePlank fiber cement siding compared to some traditional stucco assemblies. The specific details of the wall assemblies are described in Section 3.

The analysis will include the results from two conditions: performance under normal operating conditions (i.e. without intentionally adding water) in a high-stress exterior moisture environment that is typical of the Pacific Northwest climate, and performance under intentional controlled wettings to the interior and exterior of the wood-based sheathing.

Scope

This analysis will focus on the performance of HardiePlank cladding residential walls on the North and South orientations. The performance results of the HardiePlank walls will be compared side-by-side to the performance of two other wall systems on the North and South orientations.

This analysis is a small subset of all test hut data. Future analysis reports are expected to analyze various performance differences based on other comparison criteria such as vapor control, ventilation, sheathing membrane and interior conditions.

Approach

The analysis of these walls will be done by comparing several criteria. These criteria include:

- Sheathing wood moisture content measurements under normal operating conditions
- Sheathing wood moisture content measurements during the wetting and drying from an interior wetting event
- Sheathing wood moisture content measurements during the wetting and drying from an exterior wetting event
- Qualitative visual observations during deconstruction

2. Experimental Plan

The Test Facility

A 957 sq. ft. (29’x33’) field exposure test facility was designed and constructed in the Coquitlam suburb of lower mainland BC.

Figure 1 : Test hut location in Coquitlam, British Columbia

The facility permits the side-by-side construction and comparison of seven 1.0m x 2.4m (38” x 96”) test wall panels on each cardinal orientation for a total of 28 wall test panels. This building permits all of the test panels to be exposed to the same interior conditions. The test panels were also exposed to the same exterior conditions relative to their orientation, (ie. all North walls can be expected to have the same exterior conditions)

The test facility was constructed on the roof of a low-rise office building which is owned by Gauvin 2000 Construction. This location eliminated the need to buy or rent a large empty site (with free wind and solar approach) in the expensive real estate market of greater Vancouver. It also affords the test facility some protection from vandalism

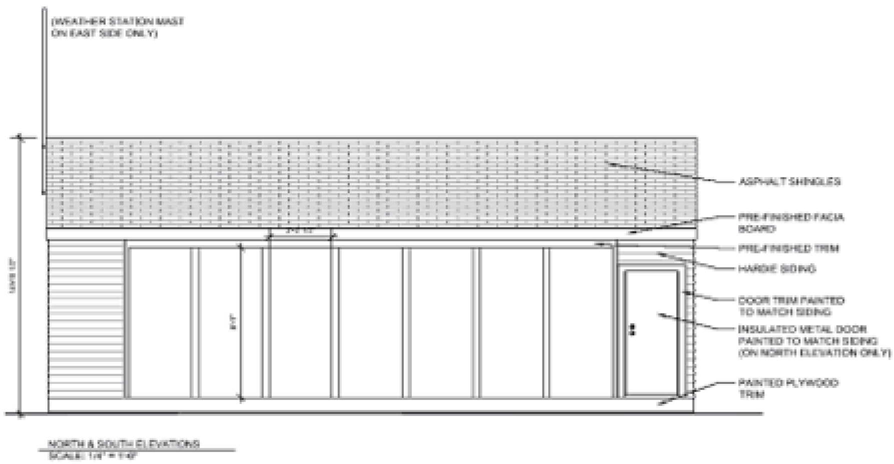


Figure 2 : Elevation drawing of Coquitlam test hut

Instrumentation

Each of the test walls was outfitted with a series of temperature, relative humidity (RH) and wood moisture content (MC) sensors. These sensors were continuously monitored and recorded throughout the testing period using a data acquisition system. Variations on a "typical" sensor package (illustrated Figure 5) were used for each test panel. Photographs of the individual sensors are shown below.

Moisture content pins were installed in the framing lumber and the sheathing (from the interior) in all wall systems (Figure 3). Wood moisture contents can be determined from electrical resistance of wood based on the Garrahan equation[1,2]. These pins can be used to measure moisture content at any depth chosen because the pins are electrically insulated except for the tips. Measurements are most commonly taken at ¼" (6mm) tip depth. In this study, moisture contents were taken at two depths on the lower OSB near the wetting system. The wood moisture content pins were installed in combination with a temperature sensor in all locations. To correct the moisture content readings for temperature effects, a hole was drilled to the same depth as the moisture content pins and a temperature sensor was installed inside.

[1] Garrahan, P. *Moisture meter correction factors.* Ottawa, Canada: Forintek Canada Corp. 1988

[2] Onysko, D. et al. *Field Measurements of Moisture in Building Materials and Assemblies: Pitfalls and Error Assessment*, Building Enclosure Science and Technology (BEST2) Conference. 2010

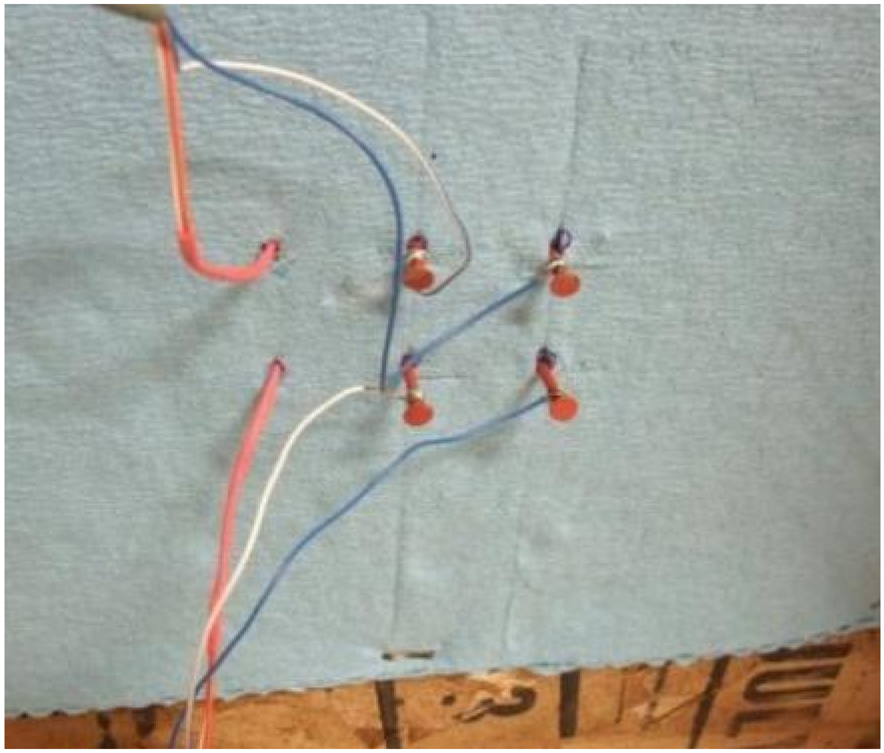
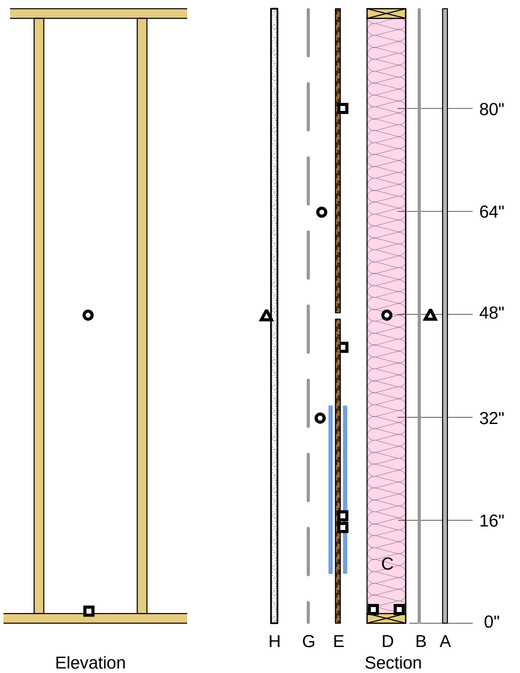


Figure 3 : Moisture content pins installed in plywood sheathing through the wetting system

Relative humidity sensors were installed in the middle of each stud cavity, and in the drainage space of each wall. The relative humidity sensor was always installed in combination with a temperature sensor, both of which are protected by a vapor permeable, water resistant cover (see Figure 4). Relative humidity and temperature sensors were installed at the midpoint of the stud space, between the drywall and the sheathing, as well as some exterior drainage cavities.

Figure 4 : Relative Humidity and temperature sensor installed in a stud bay (with moisture content pins installed below).



Assembly

Layer	Function	Description
A	Interior Finish	gypsum wall board
B	Vapor Control	poly
C	Studspace	fiberglass batt
D	Framing	2x6
E	Sheathing	½" OSB
F	Sheathing Membrane	#15 felt
G	Drainage Gap	none
H	Cladding	stucco

Sensor Package

Layer	Code	Location
A	taem	Interior finish, exterior face, 48"
C	r/tcnm	Studspace, interstitial, 48"
D	m/tdeb	Framing, exterior edge, bottom plate
D	m/tdib	Framing, interior edge, bottom plate
E	m/teem	Sheathing, exterior, 16"
E	m/teim	Sheathing, interior, 16"
E	m/tenm	Sheathing, interstitial, 48"
E	m/tenm	Sheathing, interstitial, 80"
G	r/tgnw	Drainage space, interstitial, 32"
G	r/tgne	Drainage space, interstitial, 64"
H	them	Cladding, exterior surface, 48"

- Relative Humidity and Temperature Sensor Package
- Moisture Content Pins and Temperature Sensor Package
- Temperature Sensor
- Moisture Content Wafer and Temperature Sensor Package
- Moisture Content Pins

Figure 5 : Typical Wall Construction and Sensor Configuration

One of the most significant advantages to using a test hut for analysis compared to instrumenting walls in existing buildings is that the experimenter can deliberately and easily stress the removable/replaceable walls with high moisture loads, either in terms of vapor (eg. >=50% interior RH) or liquid water (e.g. intentional wetting systems). In most cases, building owners are not interested in participating in research conducted on their enclosure walls by adding moisture. In addition, it is often difficult to determine the performance of a wall system without stressing the moisture tolerances of a wall to determine the comparative risk of certain construction techniques.

Enclosure Wetting Systems

A wetting apparatus was installed on both the interior and exterior of the sheathing of each of the test walls to allow a known amount of water to be injected at a controlled time and location. The wetting apparatus consisted of a storage media installed directly against the interior and exterior surface of the sheathing (Figure 6), with a perforated tube connecting each of the storage media to the interior of the test hut for access for water injections. This enables wetting to either the interior or exterior independently without opening and disturbing the wall system. The wetting system is designed to simulate a window leak, and can be used to help determine the drying potential of a wall system. A photograph of an exterior installed wetting apparatus is shown in Figure 6. On the analysis graphs the exterior wetting events are indicated by red vertical dashed lines, the interior wetting events are indicated by blue vertical dashed lines. When an intentional wetting event occurred repeatedly over multiple days, only one line is shown indicating the first wetting. There were five intentional wetting events as shown in Table 1. For each wetting event, 1.5 oz (45 mL) was injected twice a day for five days. This is a total of 15oz (~450mL) into the wetting apparatus directly against the sheathing. For the entire test period 60 oz (~1.8L) was injected against the exterior of the sheathing, and 15oz (~450mL) was injected against the interior surface of the sheathing.

Figure 6 : Exterior wetting apparatus

Table 1 : Intentional wetting event schedule and location for Phase III

	Location	Start Date	Amount
Wetting Event 1	Exterior	July 5, 2010	15oz (450 mL)
Wetting Event 2	Exterior	August 30, 2010	15oz (450 mL)
Wetting Event 3	Interior	Jan 19, 2011	15oz (450 mL)
Wetting Event 4	Exterior	May 9, 2011	15oz (450 mL)
Wetting Event 5	Exterior	August 9, 2011	15oz (450 mL)

Exterior Boundary Conditions

To monitor the exterior weather conditions, a steel mast on the roof of the test facility supports a weather station at a height of 22 ft above the roof of the office building and 50 ft above ground level. The monitoring system continuously collects weather data including: temperature, relative humidity, wind speed and direction, rainfall, and solar energy. A photograph of the installed weather station is shown in Figure 7. It is important to have on-site weather information for comparison and correlation purposes with the data.

Figure 7 : Weather station on the roof of the Coquitlam Test Hut

Figure 8 shows the temperature and RH distribution in Vancouver based on the Environment Canada Canadian Climate Normals from 1971-2000. This distribution shows a relatively moderate climate with a significant portion of the year at high RH, especially at temperatures between zero and 12°C.

To add context to Figure 8, two other temperature and RH distributions are shown in Figure 9 and Figure 10 for Seattle, WA and Toronto, ON. Seattle has a very similar temperature and RH distribution to Vancouver, while Toronto is more evenly distributed through the temperature ranges with significantly less hours at high relative humidities.

The measured exterior temperature and relative humidity for the analysis period are shown in Figure 14 and Figure 15 respectively, further in the report.

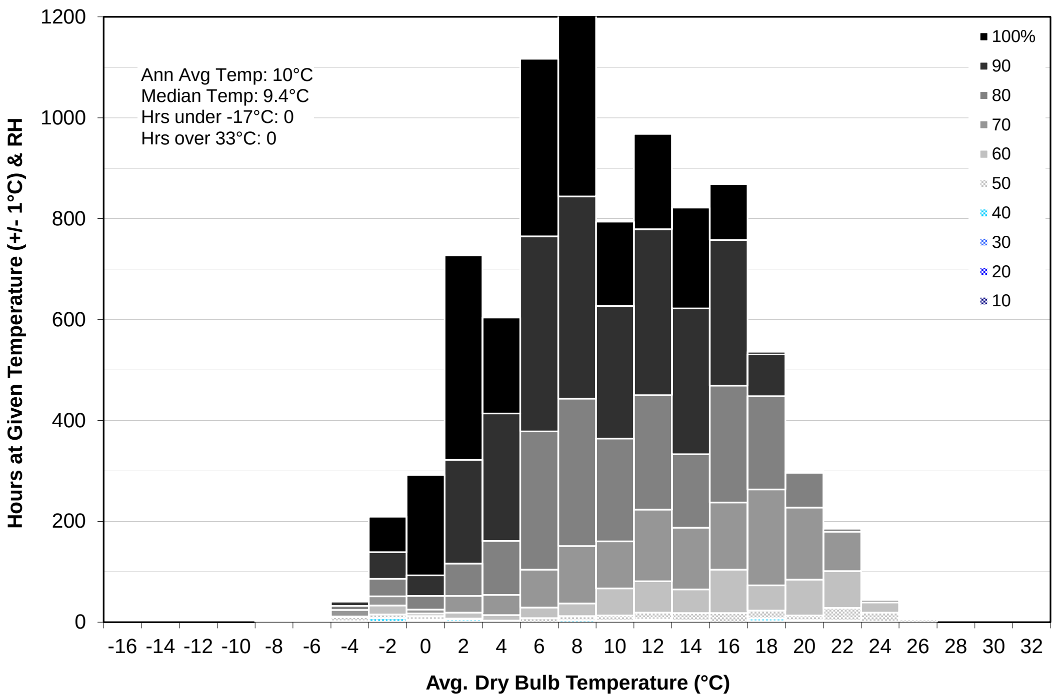


Figure 8 : Vancouver temperature and RH distribution (reproduced with permission by Balanced Solutions Inc 2005)

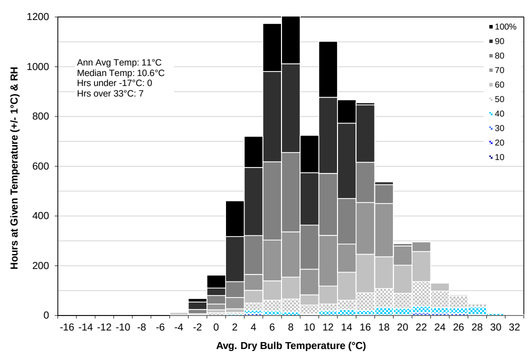


Figure 9 : Seattle, WA temperature and RH (Balanced Solutions Inc. 2005)

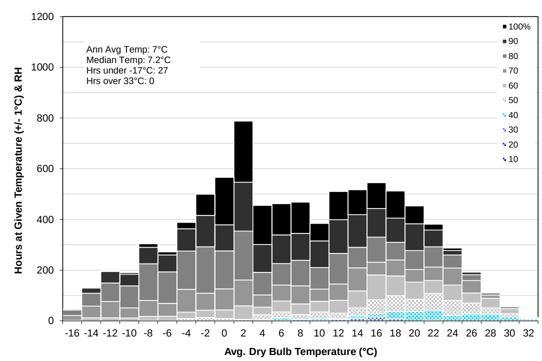


Figure 10 : Toronto, ON temperature and RH (Balanced Solutions Inc. 2005)

The driving rain rose in Figure 11 for Vancouver shows the amount of rain in mm/yr, and the direction of rainfall during the year. The driving rain is predominantly from the East in Vancouver, but this may vary slightly depending on the exact location. Total annual rainfall in Vancouver based on the 30 year average is 1155mm (46”). Again, to add context, the driving rain roses for Seattle, WA and Toronto, ON, are also included using the same scale. The driving rain for Seattle is similar to Vancouver both in shape and volume, but oriented from the South instead of the East. The driving rain rose for Toronto is significantly smaller, indicating much less total rain over the year. Seattle receives approximately 945mm (37”) and Toronto receives approximately 685mm (27”).

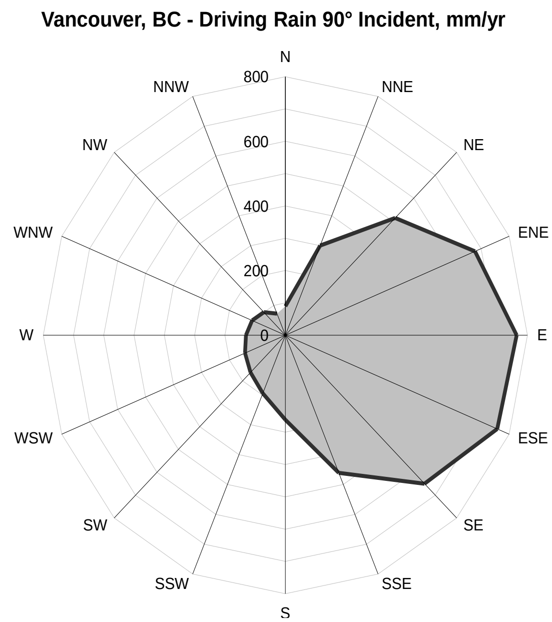


Figure 11 : Vancouver, BC driving rain rose

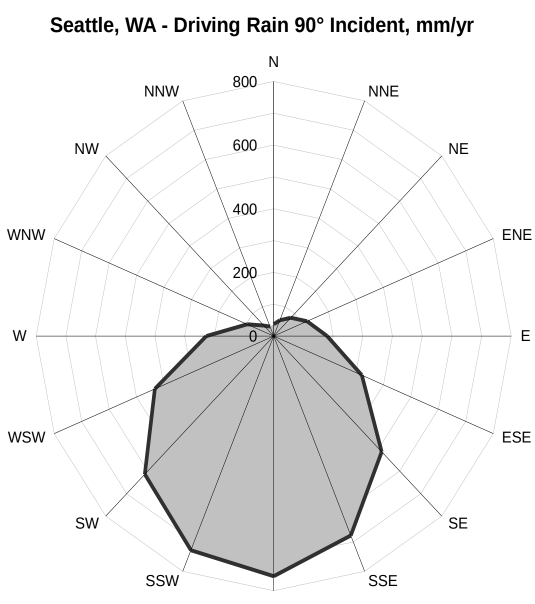


Figure 12 : Seattle, WA driving rain rose

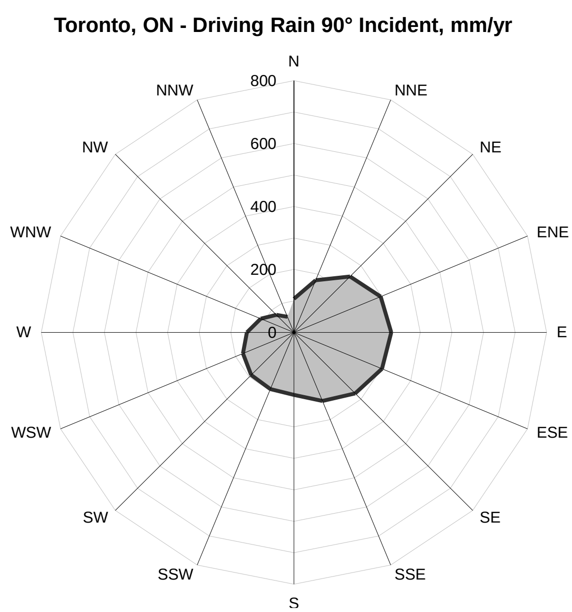


Figure 13 : Toronto, ON driving rain rose

Interior Boundary Conditions

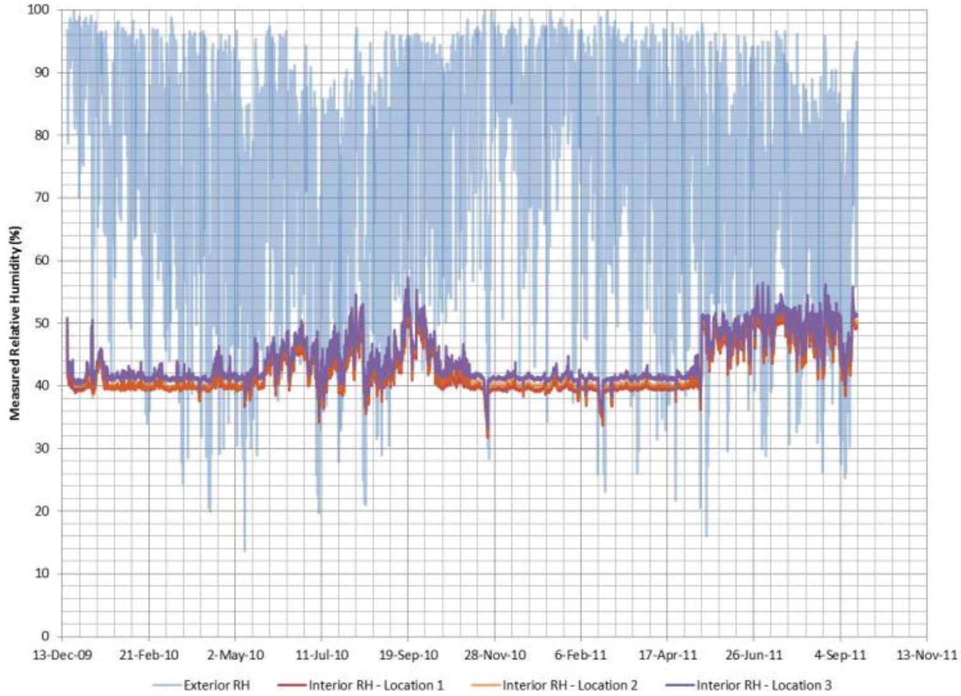


Figure 14 : Measured interior and exterior relative humidity

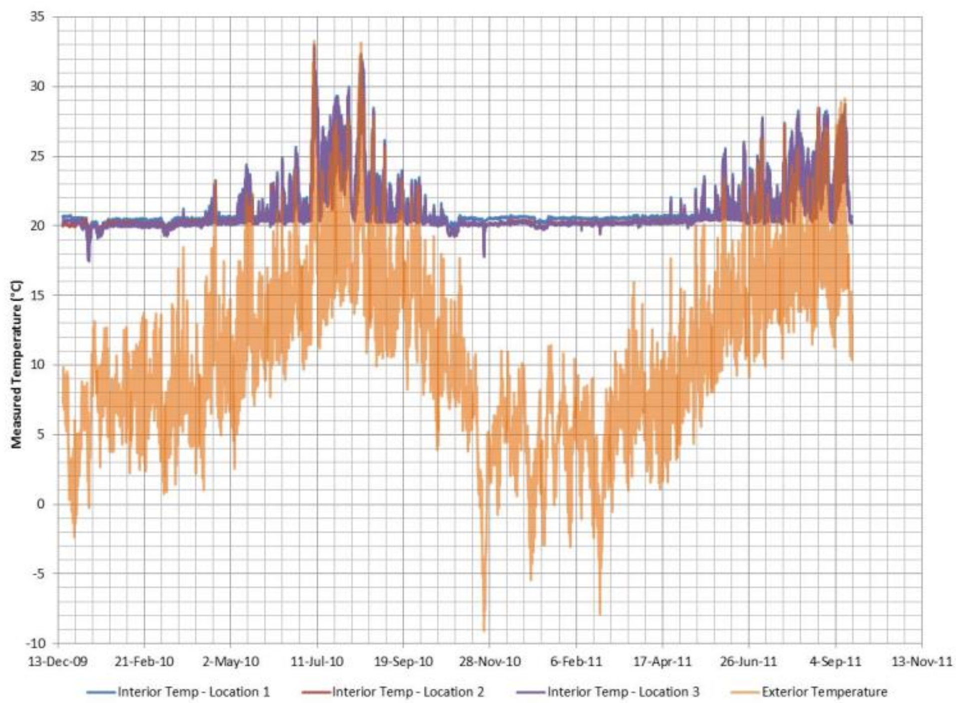


Figure 15 : Measured interior and exterior temperature

3. Observations and Data Analysis

This report and the analysis are limited to observations and data collected during the monitoring period (December 17, 2009 to November 3, 2011) for the following walls:

- North/South Wall 2 – ¾” stucco, 1x30 min paper, OSB, 2x6, poly (Baseline 2x6 wall)
- North/South Wall 4 – ¾” stucco, 1x30 min paper, Tyvek DrainWrap OSB, 2x6, paint
- North/South Wall 5 – HardiePlank on a 3/8” ventilation cavity, Tyvek, OSB, 2x6, poly
- North/South Wall 6 – HardiePlank on a 3/8” ventilation cavity, Tyvek, OSB, 2x6, paint

The original wall numbers were used in this report even though this is only an analysis subset of all of the test wall data, so that it will be less confusing to the reader when reading other analysis reports about Phase III wall testing.

As mentioned in the approach, there are several analysis criteria that will be used for comparing the performance of the test walls. These criteria include:

- Sheathing wood moisture content measurements under normal operating conditions
- Sheathing wood moisture content measurements during the wetting and drying from an interior wetting event
- Sheathing wood moisture content measurements during the wetting and drying from an exterior wetting event
- Qualitative visual observations during deconstruction

For this report, we will focus on the measured moisture content of the sheathing at the four measurement locations.

The four sheathing moisture measurement locations are:

- 16” from the bottom of the test specimen at the interior of the sheathing
- 16” from the bottom of the test specimen at the exterior of the sheathing
- 48” from the bottom of the test specimen at the center of the sheathing
- 80” from the bottom of the test specimen at the center of the sheathing

The two moisture content sensors at 16” will be used to evaluate the performance following wetting events as they are installed in the sheathing in the location of the wetting system (see Figure 3, page 5). The moisture content sensors at 48” and 80” from the bottom plate generally speaking are not affected by either the interior or exterior wetting events, and are a good indication of how the sheathing moisture content is affected by the overall assembly under normal operating conditions.

Sheathing moisture content is used as the performance criteria because the sheathing is the first location where vapor diffusion condensation (and air leakage condensation[3]) would occur in a cold climate during the heating season. In the case of these test walls, the most significant moisture risks were at the locations of the wetting systems, and the sensors in these locations are used to compare the sheathing moisture performance under significant moisture stresses. Moisture contents of the sheathing will be used as a comparison rather than pass/fail criteria for

[3] An effort was made to eliminate air leakage into these walls with a gasket around the entire perimeter of the wall frame between the framing and the drywall, because air leakage is unpredictable and difficult to control

the wall assembly. Generally, under normal conditions, the following criteria are used to assess the risk of various test wall assemblies.

1. Peak sheathing moisture content less than 20%, no mold growth - very little risk
2. Peak sheathing moisture content between 20% and 28% - potential for mold growth eventually, depending on frequency and duration of wetting, and temperatures during wetting. This design can be successful but conservative assessments usually require corrective action be taken.
3. Peak sheathing moisture content >28% - moisture related problems are expected and this design is not recommended.

Predicted wood moisture contents of wood based sheathing are generally assessed with respect to relative risk rather than on a pass/fail criterion. The predicted moisture content should be kept in context and good engineering judgment is required to determine the moisture risk to the sheathing. For example, elevated wood moisture contents in the cold winter months when the wood substrate is on the cold side of the assembly are much safer from a mold growth perspective than similar moisture contents in the summer, when the temperatures are in the correct range for optimal mold growth. Also, high moisture content for a short period followed by drying is not necessarily risky, as wood framed structures are able to manage high moisture contents for short periods without exceeding the safe storage capacity of the assembly.

The safe storage capacity is the amount of moisture an assembly is able to manage without suffering any moisture related issues. The baseline wood moisture content is a factor in the safe storage capacity since the lower the wood moisture content is during normal operation (without wetting events), the more moisture the wood can handle before reaching any durability risks. If the measured wood moisture content is consistently higher, even if there are no moisture durability risks, there is less moisture buffering capacity in the wood before reaching moisture related durability risk levels.

The wall system performance will also be evaluated qualitatively based on photos and observations from the test wall deconstruction on November 2 and 3, 2011 (see page 26).

Wall Assemblies

The HardiePlank clad walls were only installed on the North and South orientations for this round of testing. The HardiePlank was installed over narrow XPS strips to act as a constant spacer to form a drained and ventilated cavity behind the HardiePlank. A photo of the installed XPS strips is shown in Figure 16 with the siding removed. The XPS strips were compressed to approximately ¼” behind the edge of the installed HardiePlank. The compressed section was measured following the disassembly of the wall (Figure 17). The XPS are strips cut from Dow HPU Layflat insulation, which is an XPS insulation board fanfolded into 50’ lengths, and often referred to as “fanfold”.

The difference between HardiePlank Walls 5 and 6 was the vapor control layer. Wall 5 (Figure 21) was constructed with a Class I 6mil polyethylene interior vapor barrier, and Wall 6 (Figure 20) was constructed using latex paint on the interior face of the drywall as the vapor control layer. Latex paint is generally assumed to be a Class III vapor control layer with a permeance between approximately 5 and 10 US perms (285 and 570 ng/Pa·s·m^2).

Wall 2 (Figure 22) had a different cladding system than Wall 5, but all other components were the same including the polyethylene vapor control layer, so analysis was conducted based on the difference between the stucco cladding system and the HardiePlank cladding system.

Similarly, Wall 4 (Figure 19) had a different cladding system than Wall 6, but all other components were the same including the latex paint vapor control layer, so analysis was conducted based on the difference between the stucco cladding system and the HardiePlank cladding system. Wall 4 was constructed with Tyvek DrainWrap, a corrugated housewrap that is considered a drained assembly, but the gap is not large enough to be considered vented.

Figure 16 :3/8" XPS strips installed over sheathing membrane behind HardiePlank

Figure 17 : Measured gap at permanently compressed portion of Dow HPU Layflat Insulation

Figure 18 : Wall 4 - Deconstruction showing building paper over DrainWrap

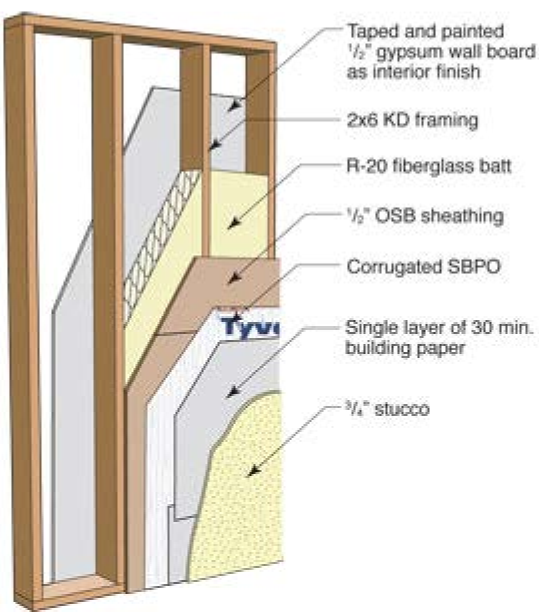


Figure 19 : Wall 4 – drained stucco, no poly

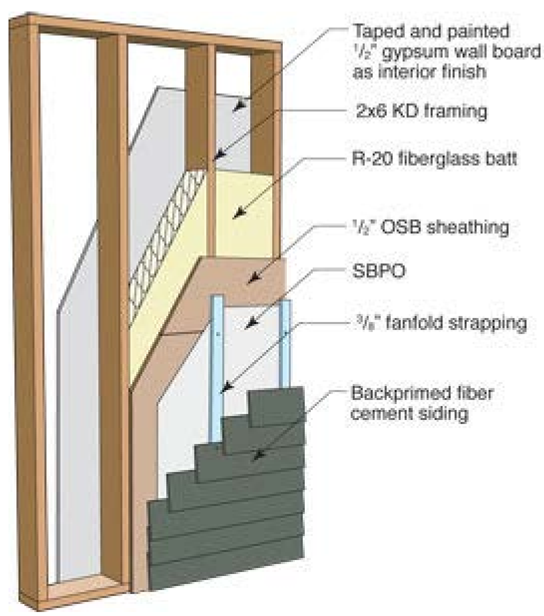


Figure 20 : North/South Wall 6 – drained and ventilated, no poly

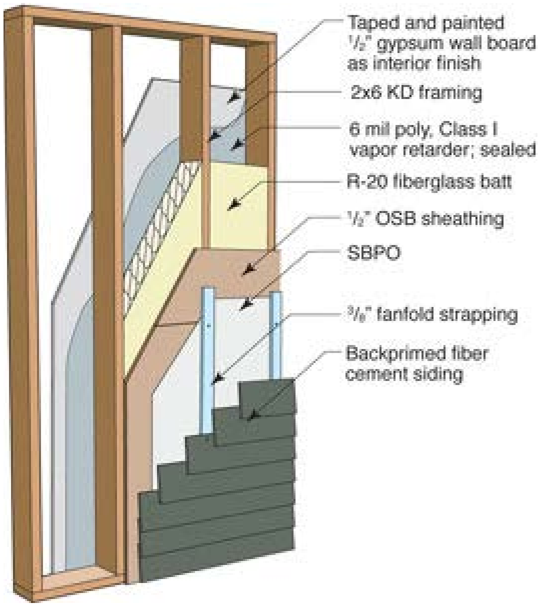


Figure 21 : North/South Wall 5 - drained and ventilated, poly vapor control

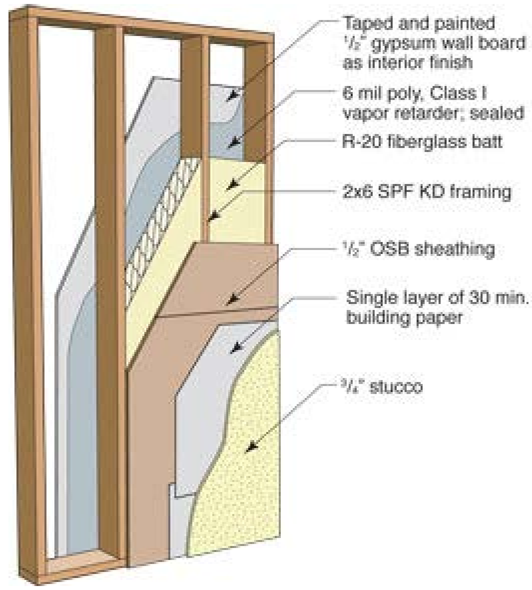


Figure 22 : Wall 2 – stucco, poly vapor control

Comparison of Wall 5 and Wall 6 on the North and South Orientation

The variable for comparison between Walls 5 and 6 on the North and South orientation is the type of interior vapor control as shown in Table 2. Wall 5 was constructed with a Class I polyethylene vapor control layer, and Wall 6 vapor control was latex paint, which is typically a Class III vapor control layer. A Class III vapor control is defined as between 1perm and 10 perms, but latex paint is typically in the 5 perm to 10 perm range.

Table 2 : Test Wall Characteristics for Wall 5 and Wall 6 on the North and South orientation

Wall	Interior Finish	Vapor Control	Insulation	Framing	Sheathing	Shtg membrane	Drain/vent gap	Cladding
NS 5	latex paint	6 mil poly	R-20 batt	2x6	1/2" OSB	Tyvek	3/8" Fanfold	HardiePlank
NS 6	latex paint	latex paint	R-20 batt	2x6	1/2" OSB	Tyvek	3/8" Fanfold	HardiePlank

According to the IRC Table R601.3.1 a Class III vapor control layer (latex paint) is permitted for vented cladding over OSB for climate zone 4C.

Figure 23 shows the measured moisture contents of the mid-height and upper OSB sheathing moisture contents, with no noticeable influence of the wetting events. This is the measured performance under normal operating conditions on the North orientation. Wall 5 with a polyethylene vapor barrier did not exceed 16% and was very safe the entire time. Wall 6 with a latex paint vapor control exceeded 20% for a short time in the winter, and dried completely in the summer. This represents some moisture related risk in the assembly, but can be successful.

The interior relative humidity was maintained at 40% during the winter time (Figure 14, page 11). The North orientation generally had the highest risk of moisture related durability issues as a result of vapor diffusion, because of the lack of solar energy resulting in drying with all other factors being equal.

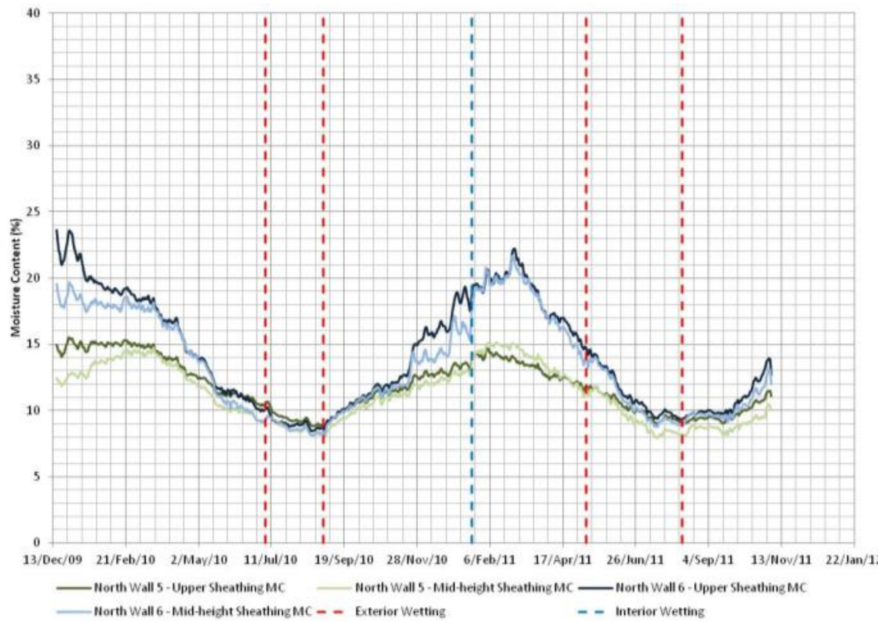


Figure 23 : Middle and upper OSB sheathing measured moisture content comparison between North Wall 5 and North Wall 6

Figure 24 shows a comparison of performance following the intentional wetting events on the North orientation between Wall 5 and Wall 6. Both walls had very similar drying rates following the exterior wetting events (red dashed lines). Following the interior wetting event (blue dashed line), Wall 6 dried more slowly, because the moisture being adsorbed from the interior during the winter overcame the potential drying ability to the interior with a Class III vapor control layer. The timing of the wetting was at the peak sheathing moisture content, under normal conditions, as indicated in Figure 23.

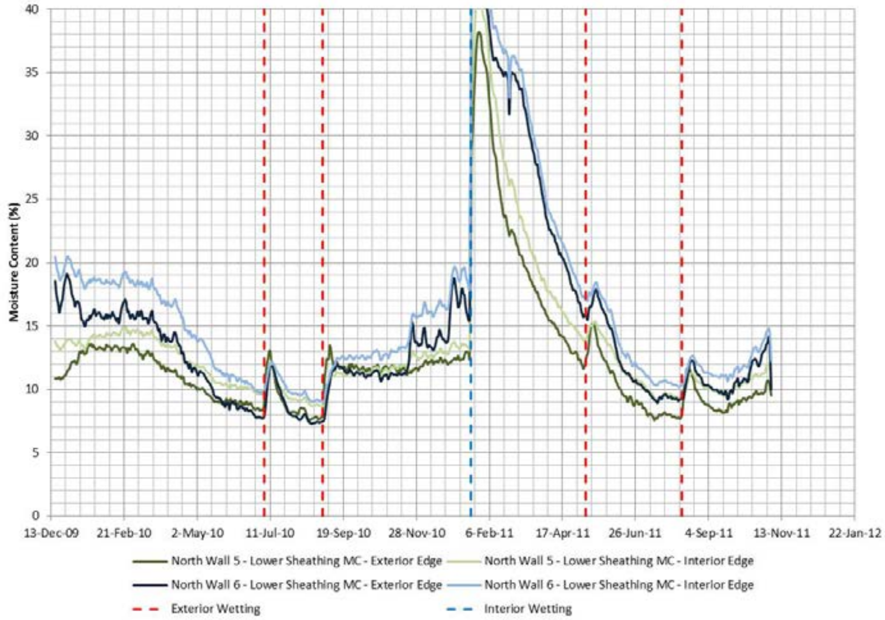


Figure 24 : Lower OSB sheathing measured moisture content comparison between North Wall 5 and North Wall 6

On the South orientation at the mid-height and upper OSB moisture content measurement locations, there was no risk of moisture related issues on Wall 5 or Wall 6 as shown in Figure 25 as a result of the increased solar energy compared to the North orientation in Figure 23.

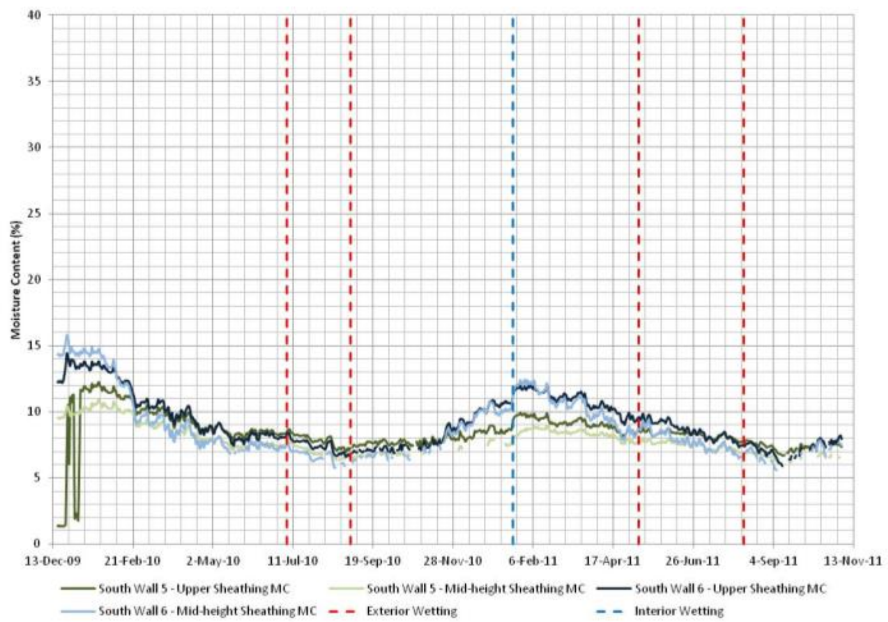


Figure 25 : Middle and upper OSB sheathing measured moisture content comparison between South Wall 5 and South Wall 6

At the lower moisture content measurement location on the South orientation, the exterior wetting events did not result in large moisture content peaks, and dried quickly and very similarly.

Following the interior wetting event, the OSB of both Wall 5 and Wall 6 dried more quickly than the North orientation. There was very little performance difference on the South orientation shown in Figure 25 or Figure 26

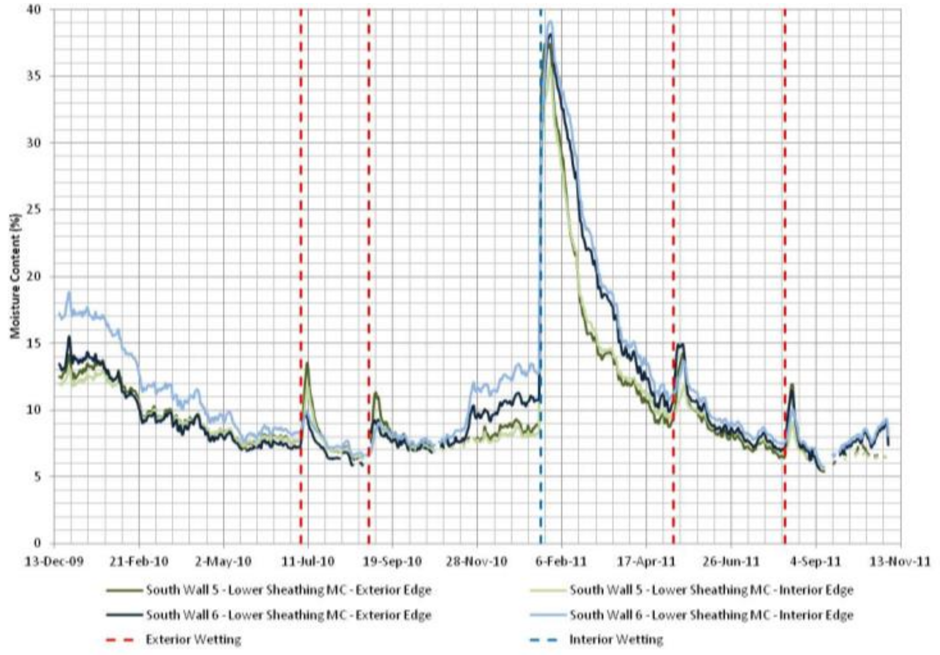


Figure 26 : Lower OSB sheathing measured moisture content comparison between South Wall 5 and South Wall 6

Summary

- On the North orientation, Wall 6 with a latex paint vapor control layer resulted in measured elevated sheathing moisture contents of approximately 22% under normal operating conditions. This could be successful construction even with the elevation in sheathing MC.
- On the South orientation, Wall 6 did not experience any moisture related durability issues under normal operating conditions
- Wall 5 did not experience moisture contents that would indicate any risk of moisture related durability issues under normal operating conditions, on either the North or South orientation.
- Following the exterior wetting events, both Wall 5 and Wall 6 did not experience large moisture content peaks, and both dried quickly. Following the interior wetting event, Wall 5 with poly dried more quickly on both orientations, in part because the wetting event occurred at the peak moisture content caused by vapor diffusion from the interior for Wall 6 through the Class III interior vapor control.

Comparison of Wall 2 and Wall 5 on the North and South Orientation

The variable for comparison between Walls 2 and 5 on the North and South orientation is the cladding system as shown in Table 3. Wall 2 was constructed with ¾” stucco and no drainage/ventilation cavity. Wall 5 was constructed with drained and ventilated HardiePlank cladding over 3/8” Dow HPU Layflat Insulation. Both walls were constructed with a 6 mil polyethylene Class I interior vapor control layer.

Table 3 : Test Wall Characteristics for Wall 2 and Wall 5 on the North and South orientation

Wall	Interior Finish	Vapor Control	Insulation	Framing	Sheathing	Shtg membrane	Drain/vent gap	Cladding
NS 2	latex paint	6 mil poly	R-20 batt	2x6	1/2" OSB	1 x 30 min paper	none	3/4" stucco
NS 5	latex paint	6 mil poly	R-20 batt	2x6	1/2" OSB	Tyvek	3/8" Fanfold	HardiePlank

Figure 27 shows the comparison of mid-height and upper moisture content measurements on the North orientation for Wall 2 and Wall 5. The performance was nearly identical, and no moisture related durability issues were indicated. In approximately April of both years, Wall 5 moisture content did decrease a little compared to Wall 2, indicating some available drying to the exterior caused by the ventilation in Wall 2, which was not available in the direct applied stucco of Wall 5.

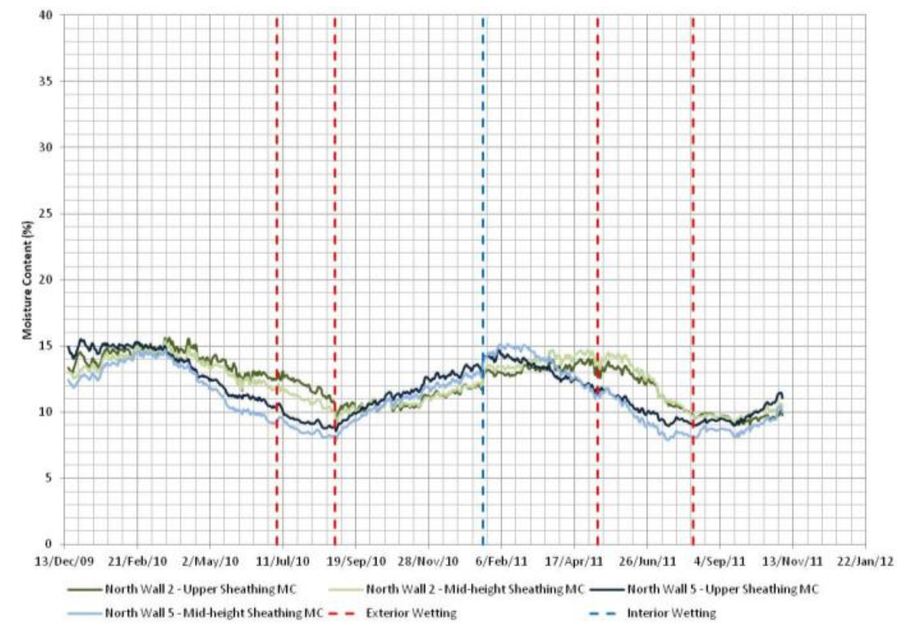


Figure 27 : Middle and upper OSB sheathing measured moisture content comparison between North Wall 2 and North Wall 5

Figure 28 shows that Wall 2, constructed with unventilated stucco on the exterior, dried much more slowly and will experience eventual moisture related durability issues if wetted, because of the lack of drying compared to Wall 5. Wall 5 was able to dry quickly to the exterior, but Wall 2 cannot easily dry to the interior or exterior of the enclosure.

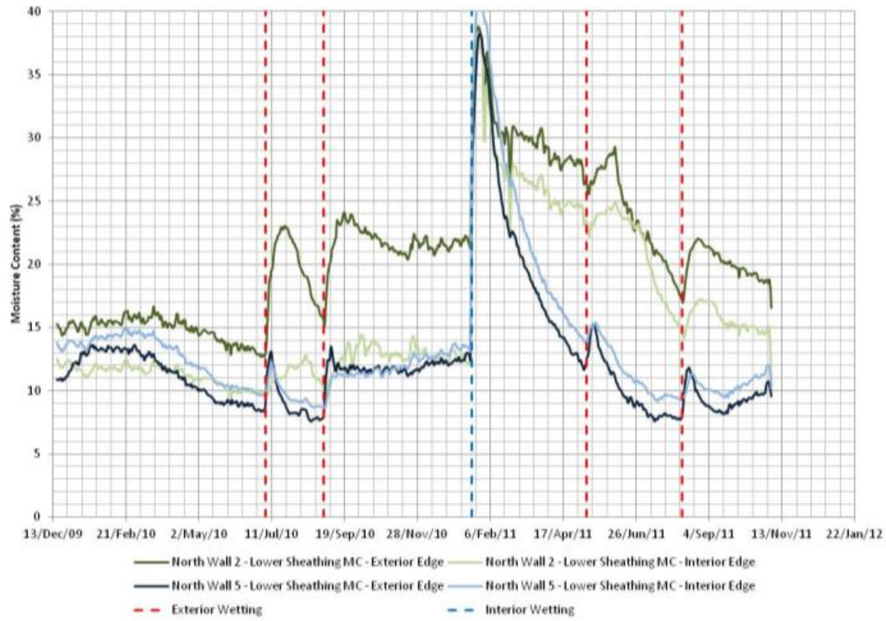


Figure 28 : Lower OSB sheathing measured moisture content comparison between North Wall 2 and North Wall 5

On the South orientation, under normal operating conditions, Wall 5 with HardiePlank cladding generally had a lower sheathing moisture content than Wall 2 with unventilated stucco (Figure 29). With ventilated cladding, the solar energy helps to dry the cladding and sheathing, and the stucco does not benefit from ventilation drying. Neither wall showed potential for long term durability issues under normal operating conditions without intentional wetting.

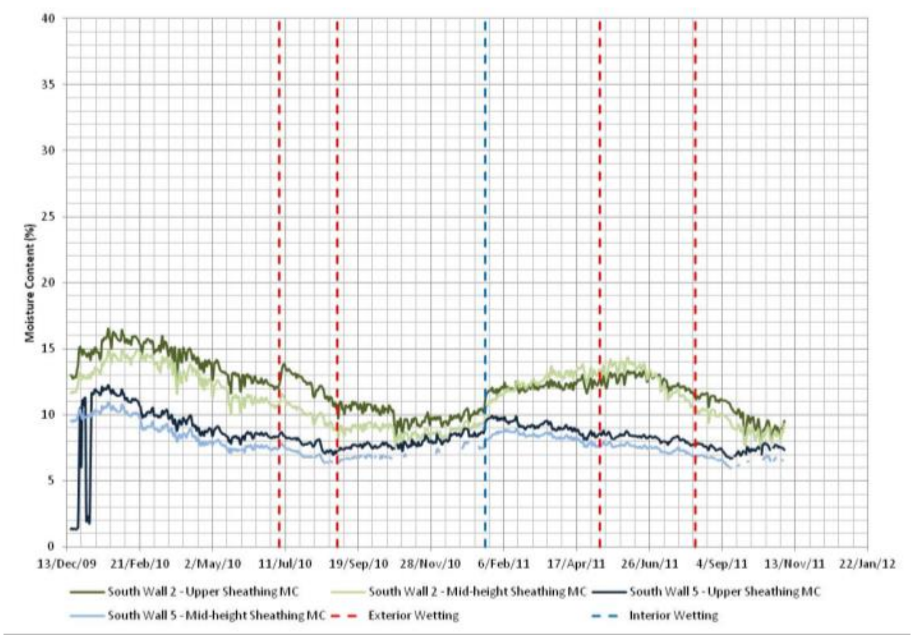


Figure 29 : Middle and upper OSB sheathing measured moisture content comparison between South Wall 2 and South Wall 5

On the North orientation, analysis of the intentional wetting events shows significantly higher moisture content peaks and drying times for Wall 2 with unventilated stucco cladding compared to ventilated HardiePlank cladding (Figure 30). If the sheathing is wetted often enough, long term moisture related durability issues are expected for Wall 2. Wall 2 on the South orientation dried more quickly than the North orientation as expected as a result of solar energy, but still sustains moisture contents in excess of 20% following each wetting event.

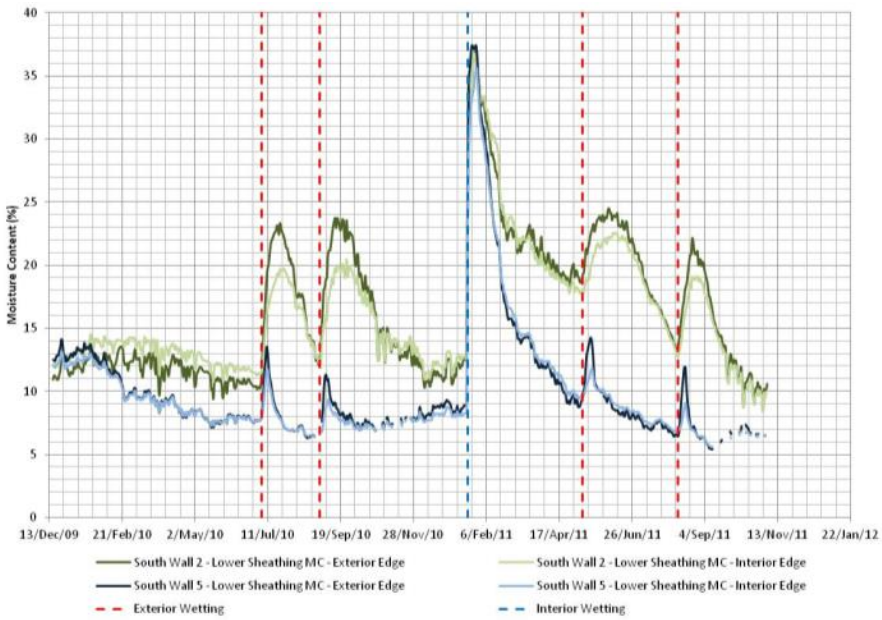


Figure 30 : Lower OSB sheathing measured moisture content comparison between North Wall 2 and North Wall 5

Summary

- Under normal operating conditions without intentional wetting events, both Wall 2 and Wall 5 show no measured indication of long term moisture related durability issues.
- Following wetting events on both the interior and exterior, Wall 2 with unventilated stucco cladding experiences higher moisture content peaks, and longer drying times that could eventually lead to moisture durability related issues compared to ventilated and drained HardiePlank siding.

Comparison of Wall 4 and Wall 6 on the North and South Orientation

The variable for comparison between Walls 4 and 6 on the North and South orientation is the cladding system, as shown in Table 3. Wall 4 was constructed with ¾" stucco and a layer of Tyvek DrainWrap, a corrugated house wrap, between the lathe paper and sheathing. This layer is meant to help with drainage, and act as a very small capillary break between the lathe paper and the OSB sheathing. Wall 6 was constructed with drained and ventilated HardiePlank cladding over 3/8" Dow XPS Layflat. Both walls were constructed with a latex paint Class III interior vapor control layer.

Table 4: Test Wall Characteristics for Wall 4 and Wall 6 on the North and South orientation

Wall	Interior Finish	Vapor Control	Insulation	Framing	Sheathing	Shtg membrane	Drain/vent gap	Cladding
NS 4	latex paint	latex paint	R-20 batt	2x6	1/2" OSB	Tyvek DW under lathe paper	very small	3/4" stucco
NS 6	latex paint	latex paint	R-20 batt	2x6	1/2" OSB	Tyvek	3/8" Fanfold	HardiePlank

There were no significant performance differences based on the comparison of measured OSB moisture content sensors at the mid-height and upper locations in Wall 4 and Wall 6 on the North orientation (Figure 31).

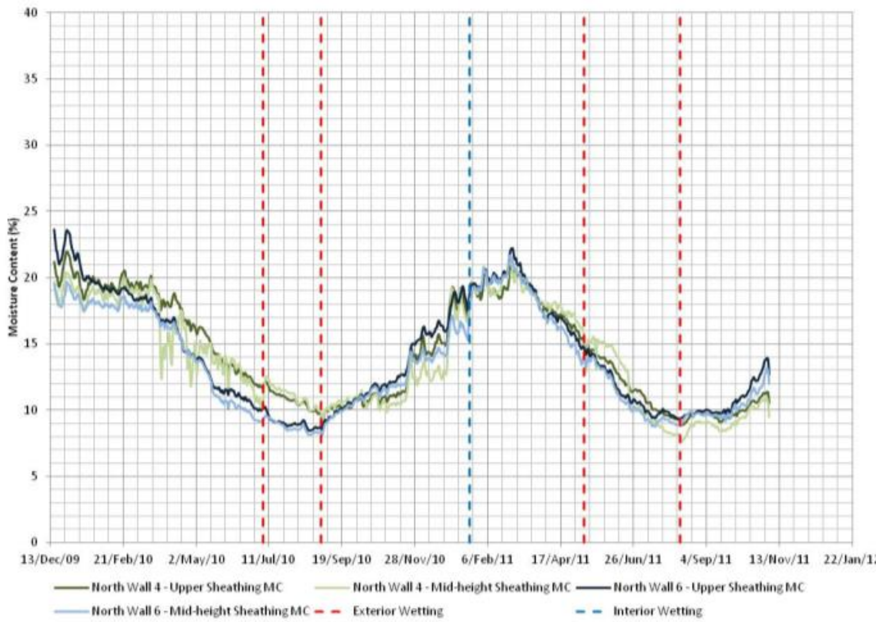


Figure 31 : Middle and upper OSB sheathing measured moisture content comparison between North Wall 4 and North Wall 6

A comparison of the measured lower sheathing moisture contents for Wall 4 and Wall 6 on the North orientation is shown in Figure 32. Wall 6 with ventilated HardiePlank did not experience the same sheathing moisture content peaks, and dried much more quickly during the exterior wetting events. Following the interior wetting event, both walls dried similarly, although at the time of the following exterior wetting, Wall 6 had a 5% lower measured sheathing moisture content.

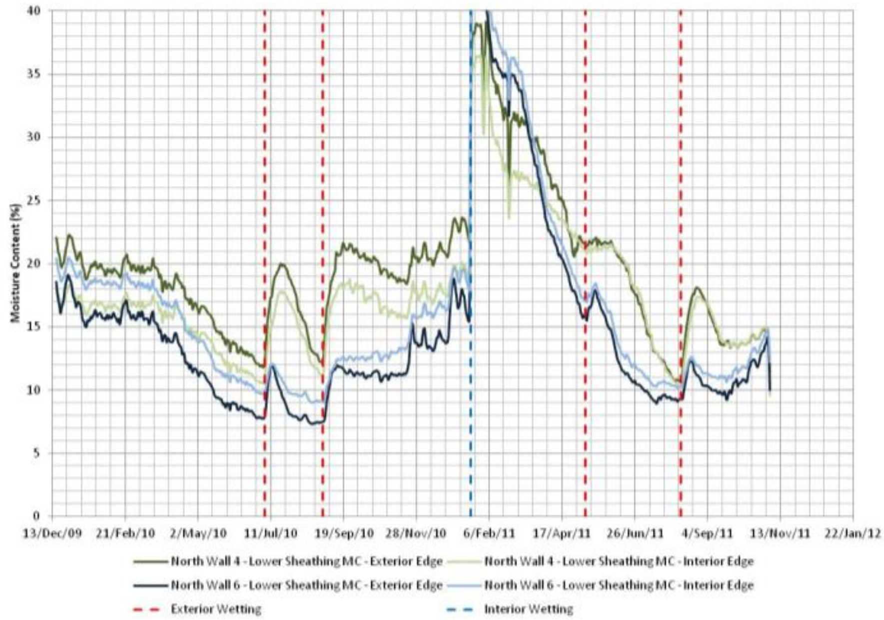


Figure 32 : Lower OSB sheathing measured moisture content comparison between North Wall 4 and North Wall 6

On the South orientation, under normal operating conditions, Wall 6 with HardiePlank cladding generally had a lower sheathing moisture content than Wall 4 with stucco (Figure 33). With a more ventilated cladding, the solar energy helps to dry the cladding and sheathing. The stucco did not benefit from the same magnitude of ventilation drying when using DrainWrap. Neither wall showed potential for long term durability issues under normal operating conditions without intentional wetting.

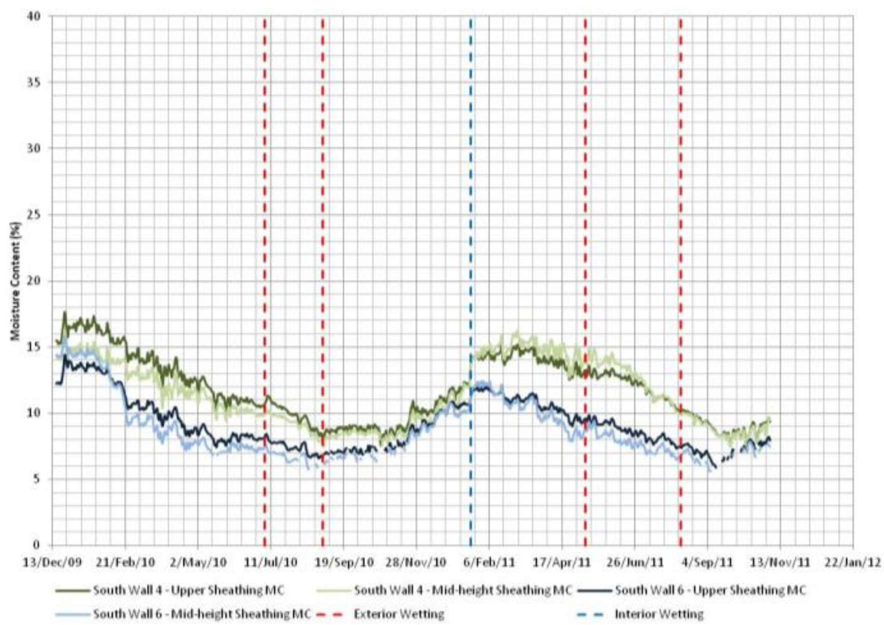


Figure 33 : Middle and upper OSB sheathing measured moisture content comparison between South Wall 4 and South Wall 6

A comparison of the measured lower sheathing moisture contents for Wall 4 and Wall 6 on the South orientation is shown in Figure 32. Wall 6 with ventilated HardiePlank did not experience the same sheathing moisture content peaks, and dried much more quickly during the exterior wetting events. Following the interior wetting event, both walls dried similarly initially, but the increased ventilation of Wall 4 resulted in a much lower measured sheathing moisture content at the time of the following exterior wetting.

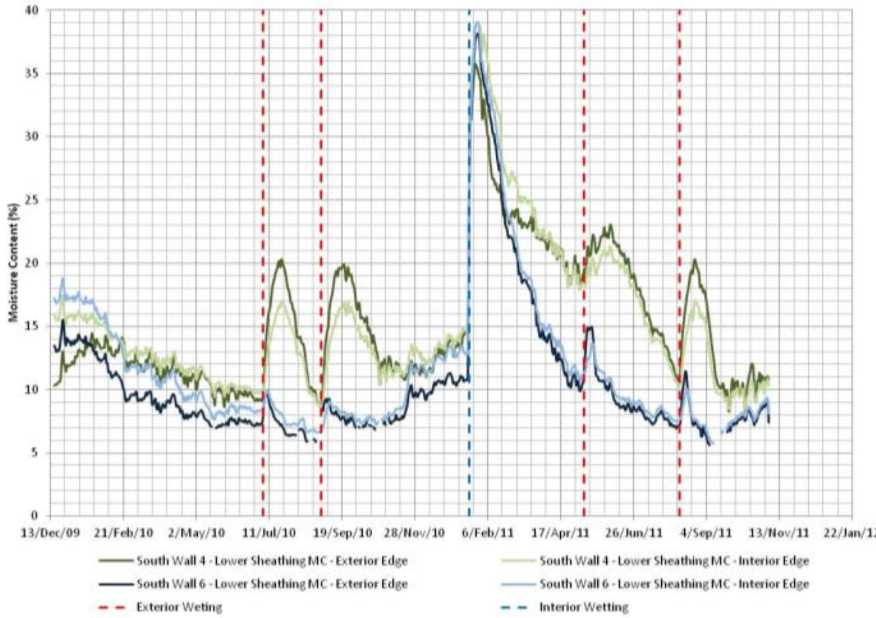


Figure 34 : Lower OSB sheathing measured moisture content comparison between South Wall 4 and South Wall 6

Summary

- Under normal operating conditions without intentional wetting events on the South orientation, both Wall 4 and Wall 6 showed no measured indication of long term moisture related durability issues.
- Under normal operating conditions without intentional wetting events on the North orientation, both Wall 4 and Wall 6 experienced a peak measured moisture content of 22%. The moisture content of 22% occured for a short period at the coldest time of the year, and was followed by complete drying. This assembly can be successful but has increased risk, and is very sensitive to the interior relative humidity and potential air leakage in real building assemblies.
- Following wetting events on both the interior and exterior, Wall 4 with stucco cladding experienced higher moisture content peaks, and longer drying times that could eventually lead to moisture durability related issues compared to ventilated and drained HardiePlank siding.

4. Test Wall Deconstruction

Disassembly is critical in order to inspect all aspects of all layers of the test walls. It is important to see whether the visual observations correlate to, and validate, the measured results.[4]

The deconstruction of Phase III test walls was conducted on November 2 and 3, 2011. The deconstruction was conducted carefully and systematically so that each component of each wall system could be photographed, examined, and compared. The following qualitative analyses are excerpts from the deconstruction report which includes qualitative analysis of all test walls.[5]

For this qualitative comparison analysis, it is important to keep in mind the boundary conditions that the walls were subjected to, both on the interior and exterior, as well as the length of time for the test. Figure 14 and Figure 15 on page 11 show the interior and exterior temperature and relative humidity, and Table 1 on page 8 shows the amount of water added to the surface of the sheathing.

The testing was conducted for approximately 2 years of time, so the conditions require some extrapolation to determine what the OSB might look like after many years in service, although the results of some comparisons are already clearly visible.

North Orientation

On the North orientation, the exterior of the OSB on Wall 2 was quite dark and stained, particularly in the vicinity of the wetting apparatus (Figure 35 and Figure 36). Wall 4 appeared marginally better and not quite as dark over the entire surface as expected. The sheathing of Wall 5 and Wall 6 was in very good condition when visually inspected. These walls had less staining around the wetting system, indicating faster dying rates, and water was not held in contact with the sheathing as long.

On the interior surface of the OSB, Wall 2 had the most staining, again, surrounding the wetting apparatus.

[4] Lstiburek, J,. Parthenon, Eh!, ASHRAE Journal (March 2011)
[5] Publication pending.

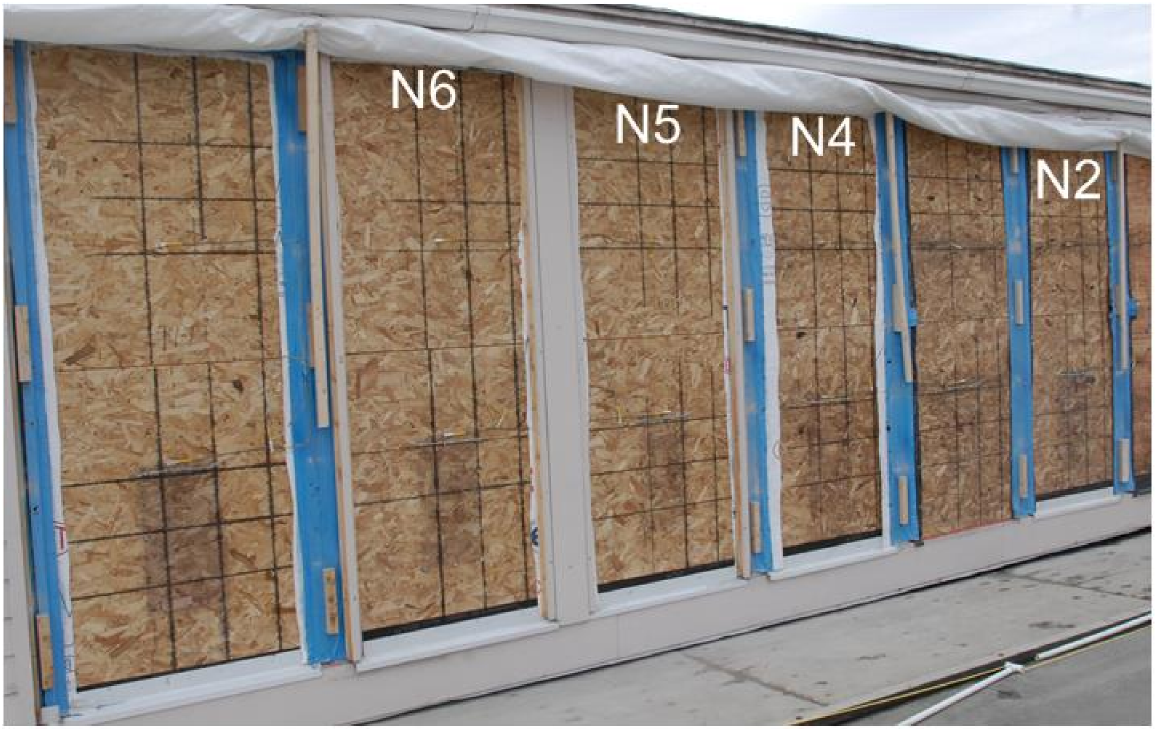


Figure 35 : Exterior OSB sheathing on the North orientation immediately following deconstruction

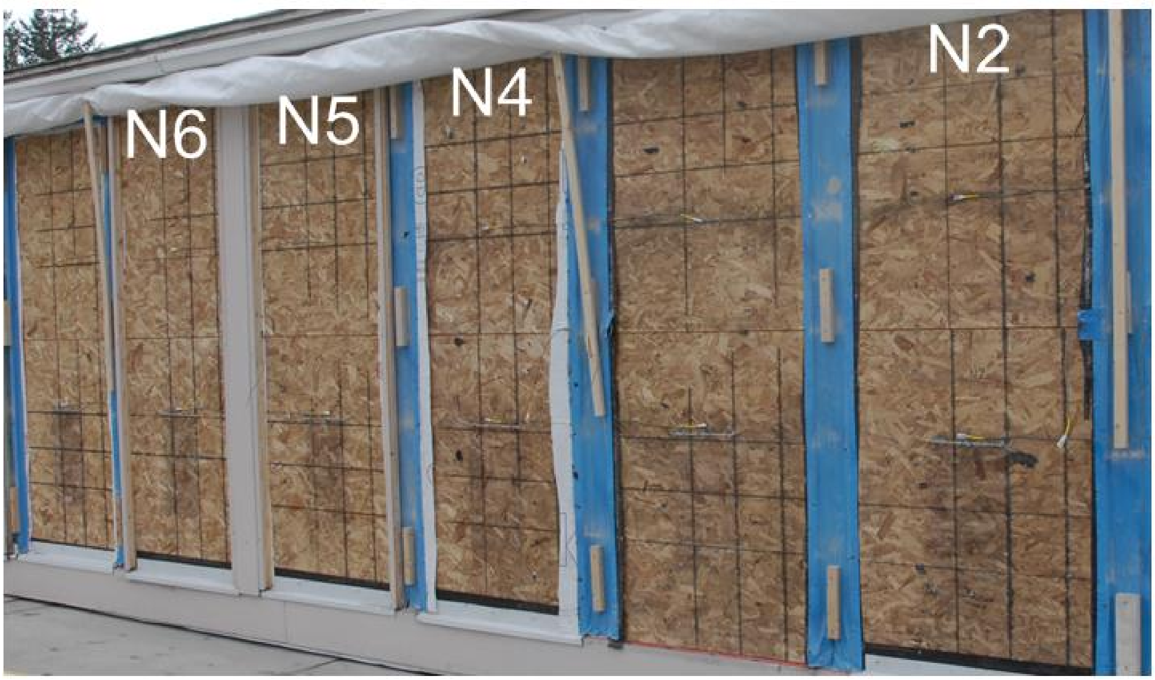


Figure 36 : Exterior OSB sheathing on the North orientation immediately following deconstruction (photo taken from the opposite direction of Figure 35)

South Orientation

The exterior surface of the OSB on South Wall 2 with interior poly and a stucco cladding applied to only one layer of building paper is clearly the darkest and most stained of the three comparison walls (Figure 37). Wall 4 showed less moisture related staining on the South orientation than on the North orientation, but was still darker and more stained than both Walls 5 and 6.

There was some staining in the vicinity of the wetting apparatus on both Walls 5 and 6, but overall, the exterior surface of the sheathing showed no signs of moisture related damage, and looked as good as new OSB often looks on a construction site.

Figure 37 : Exterior OSB sheathing on the South orientation immediately following deconstruction

5. Conclusions

Four wall assemblies were analyzed and compared for this report (Table 5). Comparisons were made between Walls 5 and 6, Walls 5 and 2, and Walls 6 and 4.

Table 5: Test Wall Characteristics for Walls 5, 6, 2 and 4 on the North and South orientation

Wall	Interior Finish	Vapor Control	Insulation	Framing	Sheathing	Shtg membrane	Drain/vent gap	Cladding
NS 5	latex paint	6 mil poly	R-20 batt	2x6	1/2" OSB	Tyvek	3/8” Fanfold	HardiePlank
NS 6	latex paint	latex paint	R-20 batt	2x6	1/2" OSB	Tyvek	3/8” Fanfold	HardiePlank
NS 2	latex paint	6 mil poly	R-20 batt	2x6	1/2" OSB	1 x 30 min paper	none	3/4"stucco
NS 4	latex paint	latex paint	R-20 batt	2x6	1/2" OSB	Tyvek DW under lathe paper	very small	3/4"stucco

This analysis resulted in the following conclusions:

- Wall 5 and Wall 6 constructed with HardiePlank fiber cement siding over 3/8” XPS strips performed very well from a moisture durability perspective.
- The only measured sheathing moisture contents greater than 20% under normal operating conditions were North Wall 4 and North Wall 6 with Class III vapor control, which experienced outward winter time vapor drive and moisture accumulation in the sheathing. This could be decreased to very safe levels by lowering interior RH, increasing interior vapor control (e.g. with Kraft paper), or increasing the R-value of the enclosure to the exterior of the sheathing.
- There were no measured moisture related durability issues for Wall 2 or Wall 5 under normal operating conditions
- Wall 5 showed significantly improved drying compared to Wall 2 during intentional wetting events of the sheathing
- Wall 6 showed significantly improved drying compared to Wall 4 during intentional wetting events of the sheathing
- Walls 5 and 6 have less risk of moisture related durability risk from unplanned wetting events than Walls 2 and 4 respectively with stucco cladding and little or no drainage gap.
- During the deconstruction, it was observed that the exterior surface of the sheathing was darker and more stained on Wall 2, and to a lesser extent, Wall 4, than both of the ventilated HardiePlank walls after two years of exposure in climate zone 4C.

6. Further Analysis

From observations during deconstruction and hypothesized results it is suspected that the stucco that was installed for Phase III testing is much less absorptive than standard stucco, which may have improved the performance of both Wall 2 and Wall 4 in comparison to Walls 5 and 6. Samples were collected, and laboratory analysis is required to determine the absorptivity of the sample, and compare these results to other stucco and masonry testing.

About the Authors

Jonathan Smegal's work at BSC includes laboratory research, hygro-thermal modeling, field monitoring of wall performance, and forensic analysis of building failures.

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