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Vancouver Field Exposure Facility: Phase IV Construction and Instrumentation Report

Research Report - 1305

April 2013

Jonathan Smegal and Aaron Grin

Abstract:

This report describes the construction and instrumentation of Phase IV of a multi-phase, multi-year research project at the Vancouver Field Exposure Test Facility in Coquitlam, British Columbia. The main objective of Phase IV is to determine how various configurations of exterior low vapor permeance insulation affect the moisture durability risk of structural wood-based sheathing. To assist with this analysis, the walls will be subjected to elevated interior relative humidities, and intentional controlled surface wetting of the interior and/or exterior of the OSB sheathing.

VANCOUVER FIELD EXPOSURE FACILITY

Phase IV Construction and Instrumentation Report

April 2013

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Introduction

This multi-phase, multi-year research project at the Vancouver Field Exposure Test Facility in Coquitlam, British Columbia is led by Building Science Corporation (BSC) and Gauvin 2000 Construction Ltd. The objective of the initial test program was to determine the performance of historical, current and possible future wall assembly configurations under field conditions. Phase I and II of the project focused on the role of specific assembly layers. Interior relative humidity conditions were varied, and controlled wetting was used to simulate leaks on the interior face of the sheathing. During Phase III, the focus was on the durability of the wall systems when subjected to exterior wetting. Wetting apparatuses were used on both the interior and the exterior of the sheathing in each assembly, in order to simulate different types of leaks[1].

This report describes the construction and instrumentation of Phase IV of the project, which started September 21, 2012. Phase IV will demonstrate the performance of various exterior insulated residential wall assemblies in a high stress moisture environment that is typical of the Pacific Northwest climate (DOE climate zone 4C). The main research goal is to examine the performance of the various walls under the influence of intentional exterior wetting events in the drainage space. As part of this multi-year test program, walls were subjected to normal interior and exterior stresses during the first winter. Following the first winter, walls will be subjected to intentional wetting events to the surface of the OSB sheathing, both on the interior and exterior. The expected final deliverable will be a research report prepared at the conclusion of the Phase IV testing in the spring of 2014.

Background: The Test Facility

The Vancouver Field Exposure Test Facility was constructed in the fall of 2005, in Coquitlam, British Columbia (see Figure 1). The facility permits the side-by-side construction and comparison of seven 38 ½ ”x 96” (0.98m x 2.4m) test wall panels on each cardinal orientation, for a total of 28 wall test panels, and three 12’ x 24’ (3.6m x 7.2m) roof panels on the North and South orientations, for a total of six roof test panels. All of the test panels are exposed to the same indoor conditions.

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[1] For more information on earlier project phases, see Smegal, Lstiburek, Straube and Grin (2012), *RR-1207: Vancouver Field Exposure Facility: Phase III Exterior Insulation Analysis*, www.buildingscience.com.

Figure 1 - Test Facility Location in Coquitlam, British Columbia

Figure 2 – Test Facility and Immediate Surroundings

The test facility was constructed on the roof of a low-rise office building that is owned by Gauvin 2000 Construction Ltd. (a British Columbia builder who is a co-sponsor of this research project). This eliminated the need to buy or rent a large empty site (with free wind approach) in the expensive real estate market of greater Vancouver. The location also affords the test facility some protection from potential vandalism. Figure 2 shows the location of the test facility relative to other buildings. Figure 3 and Figure 4 provide elevation drawings showing the facility's basic components.

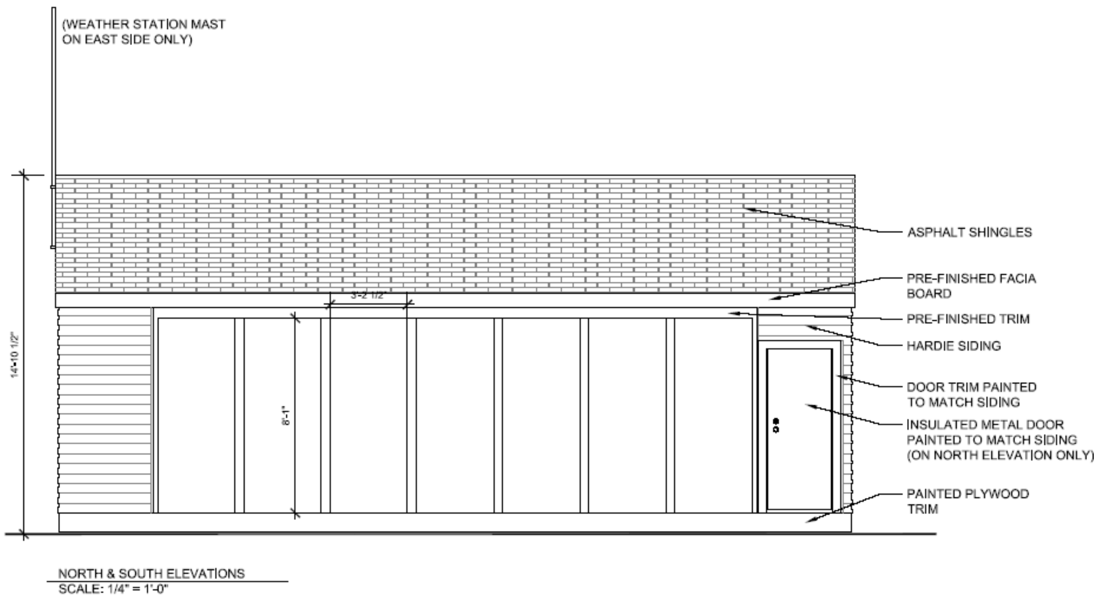


Figure 3 - North & South Elevation

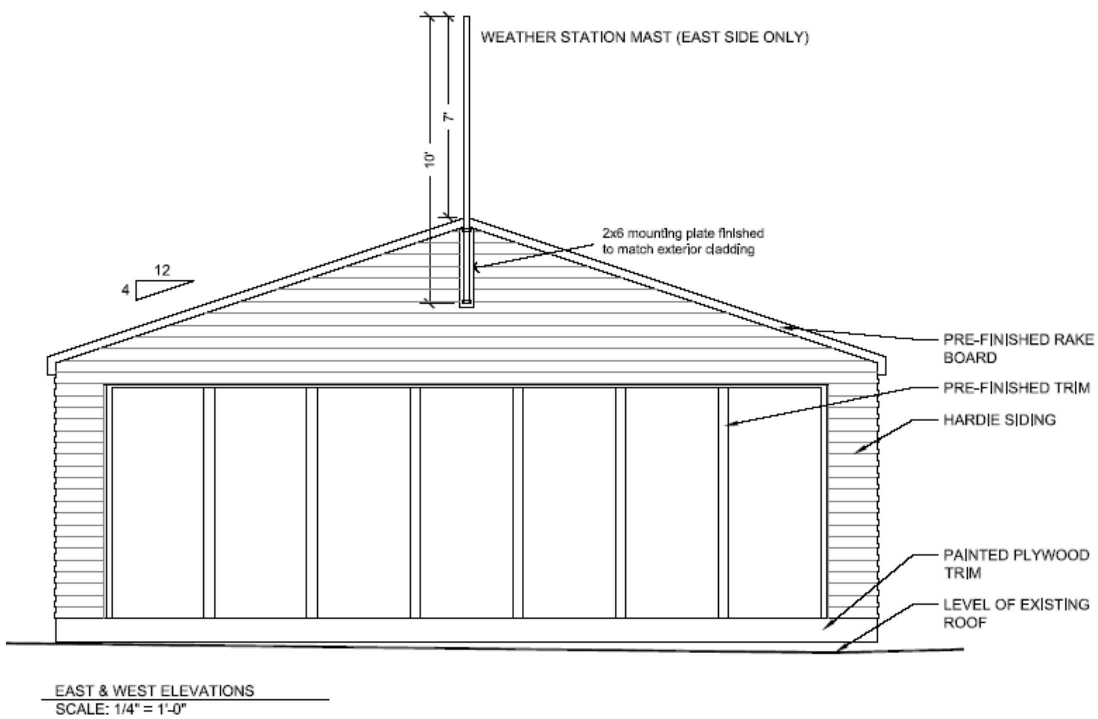


Figure 4 - East & West Elevation

A steel mast on the roof of the test facility supports a weather station at a height of 22 ft (6.7 m) above the roof of the office building and 50 ft (15.24 m) above ground level. The monitoring system continuously collects weather data, including: temperature, relative humidity, wind speed and direction, rain, and solar energy.

An eavestrough (or gutter) was installed on all four orientations of the hut following the first year of analysis in Phase I as it was determined that there was significantly more water draining off of the roof onto the walls on the South orientation and the North orientation than on the East and the West orientations. By installing the eavestrough, the amount of water on the wall was only a result of the driving rain, and not run- off from the roof.

Figure 5 : Weather station on the roof of the Coquitlam Test Hut

Wall Construction and Experimental Plan

This is the fourth phase of testing at the Vancouver Field Exposure Test Facility. The Phase III walls were deconstructed and removed to ensure that the effects from the testing from Phase III would not affect Phase IV testing and observations. The Phase IV walls were built and installed by Gauvin 2000 Construction Ltd. and instrumented by BSC staff during the week of September 18th, 2012. Data acquisition commenced September 21st, 2012. There were no tests conducted on the roof panels in Phase IV.

The main objective of Phase IV is to determine how various configurations of exterior low vapor permeance insulation affect the moisture durability risk of structural wood-based sheathing. To assist with this analysis, the walls will be exposed to intentional wetting events of a known volume at a known time, using a water-storage medium directly in contact with the interior or exterior of the sheathing. Figure 6 shows examples of the exterior wetting storage media. These media are connected to the interior conditioned space with a tube so that water can be injected after all components of the wall assembly are in place.

Figure 6 : Exterior wetting apparatus

Table 1 lists the test walls along with the materials used for Phase IV testing and analysis. The seven wall assemblies are repeated on all four orientations. All of the test walls are constructed of 2x6 wood framing, interior painted drywall, and exterior fiber cement siding. A brief explanation of each wall follows the summary in Table 1.

Table 1 - Wall Construction Details

Assemblies (All four orientations)	Framing	Interior Finish	Vapour Control		Thermal Insulation			Exterior Sheathing		Sheathing Membrane /Drainage Plane			Continuous Exterior Insulation				Exterior Cladding	Installed Insulation R-value	R-value % to the exterior of sheathing
	2x6	1/2" drywall + paint	kraft paper	latex paint	R-21 kraft faced fiberglass batt	R-22 fiberglass batt (unfaced)	2" CC SPF + R13 batt (unfaced)	7/16"OSB	7/16" ZIP'	1 layer 30 minute paper	Tyvek DrainWrap	Taped Continuous Exterior Insulation	None	R7.5 - 1 1/2" XPS - Cladmate	R10 - 1.5" PIR - Thermax	R10 - 1.5" PIR - Vented Thermax	Fiber Cement Plank Siding		
Wall 1	•	•	•		•			•		•			•				•	21	0%
Wall 2	•	•	•		•			•				•		•			•	28.5	26%
Wall 3	•	•	•		•			•			•			•			•	28.5	26%
Wall 4	•	•		•		•			•			•		•			•	29.5	25%
Wall 5	•	•		•			•	•				•				•	•	32	31%
Wall 6	•	•	•		•			•				•			•		•	31	32%
Wall 7	•	•	•		•			•				•				•	•	31	32%

Wall 1

Wall 1 is a baseline case, representing common construction practices in many regions of the USA. Wall 1 is the only wall on each orientation that does not include continuous exterior insulation. The R21 fiberglass batt provides the minimum amount of stud space insulation for climate zone 4C according to the 2012 IECC, Table R402.1.1. Similarly, Wall 1 meets the minimum requirements for interior vapor control as per R601.3 in the 2009 IRC, which requires a Class I or II vapor retarder on the interior side of frame walls in 4C. The Kraft-asphalt facing laminated to the fiberglass is a Class II vapor control layer at lower relative humidities (RH) and actually becomes more vapor permeable at higher RHs. Wall 1 is expected to be the most challenged for cold weather vapor diffusion condensation on the sheathing, as the sheathing temperature will be the coldest of all test walls.

Wall 2

Wall 2 was constructed with 1.5" (3.8 cm) of XPS exterior insulation (R7.5, RSI 1.3) directly applied to the sheathing, with the joints taped as a drainage plane. In this system, the exterior face of the XPS is the drainage plane where all penetrations would be flashed to. The fiber cement siding is installed directly against the XPS insulation through to the wall framing. The stud cavity is insulated with Kraft-faced batt, and this wall will be compared to Wall 1 (Base Case) as well as Wall 3 (with a very small drainage cavity between the XPS and sheathing) and Wall 6 (with direct applied foil-faced polyisocyanurate, which is less vapor permeable than XPS).

Wall 3

Wall 3 is very similar to the exterior insulated wall of Phase III testing (Wall 7, Phase III), with 1.5" (3.8 cm) of XPS exterior insulation installed over Tyvek DrainWrap over the exterior sheathing. The performance of Wall 3 will be compared to the performance of Wall 2, to determine the effect of the addition of the corrugated sheathing membrane. Kraft-faced batt was installed in the stud cavity. A secondary comparison will be with Wall 4, which is also constructed with a small drainage cavity, but with Huber ZIP sheathing instead of standard OSB sheathing.

Wall 4

Wall 4 was constructed with 1.5" (3.8 cm) of taped exterior XPS insulation over Huber Zip sheathing. Zip sheathing is specially designed structural sheathing with the sheathing membrane laminated to the surface of the OSB panel so the exterior surface can act as a drainage plane (WRB); to ensure a drainage plane, taping of the joints with Zip tape is required. In this test, the Huber ZIP sheathing was taped to provide an air barrier and secondary drainage plane, but the primary drainage plane is the exterior taped surface of the XPS insulation. A small drainage gap (approx. 1/8"[3.2 mm]) was formed by installing 2" (5.1 cm) wide strips of blueskin flashing over the Zip.

On the interior, standard fiberglass batt (without Kraft facing) was used, so the latex paint was the only interior vapor control. Using a Class III latex paint as the vapor control layer should allow more water vapor to move through the interior of the wall system, either from the interior environment during elevated interior relative humidities, or from the wall stud cavity to the interior environment during intentional wetting events. This wall will be compared to other test walls to determine what moisture performance differences resulted from using a latex paint vapor control layer. The taped ZIP sheathing with the vertical blueskin peel and stick prior to installing the exterior insulation can be seen in Figure 7.

Figure 7 : Wall 4 - Huber ZIP sheathing with vertical Blueskin spacers

Wall 5

Wall 5 was constructed with 1.5" (3.8 cm) of exterior foil-faced polyisocyanurate insulation (PIR). There is a 1/8" (3.2 mm) drained/vented cavity[2] between the OSB sheathing and foil-faced polyisocyanurate. On the interior of the OSB sheathing, 2" (5.1 cm)of 2 pound per cubic foot (pcf) closed cell spray polyurethane foam (SPUF) was installed. It should be noted that inspection of the spray foam following installation showed that the thickness of the spray foam ranged from approximately 1" to 1.75". The spray foam significantly decreases drying and redistribution to the interior of any water in the OSB sheathing. The interior wetting system was partially protected against direct contact with the spray foam to ensure that water would still distribute against the sheathing for wetting comparison purposes. Closed cell spray foam in the stud cavity is a worst case scenario for inward drying and water redistribution. R13 fiberglass batt was installed in the remaining cavity space to the interior of the spray foam. The performance of Wall 5 will be compared to Wall 7, which is also constructed of vented PIR but without spray foam in the cavity. Wall 5 is shown in Figure 8 and Figure 9.

[2] A vented cavity is open only at the bottom, and a ventilated cavity is open at both the top and bottom to encourage air flow through a space.

Figure 8 : North Wall 5 with approximately 2” of closed cell 2pcf spray foam

Figure 9 : South Wall 5 – Interior Wetting system protected from spray foam

Wall 6

Wall 6 is constructed of 1.5” (3.8 cm) of PIR exterior insulation installed directly against the sheathing and taped on the exterior surface. This wall is nearly identical to Wall 2 but much lower vapor permeance PIR was used instead of XPS. Using PIR (0.03 US perms), which is vapor impermeable compared to the XPS (approximately 0.7 US perms), means that moisture can only dry to the interior in Wall 6. Kraft-faced batt was installed in the stud space. Wall 6 with direct applied PIR will also be compared to Wall 7 with a 1/8” (3.2 mm) vented cavity to the interior of the PIR.

Wall 7

Wall 7 is constructed of 1.5” (3.8 cm) of PIR installed on a 1/8” (3.2 mm) vented gap. The performance of this wall can be compared directly to both Wall 5 and Wall 6. Analysis for Wall 5 and Wall 7 will demonstrate any performance differences as a result of the 2” (5.1 cm) of closed cell spray foam on the interior of the cavity. Analysis for Wall 6 and 7 will demonstrate any performance differences as a result of the 1/8” (3.2 mm) vented cavity between the sheathing and exterior PIR insulation.

Construction details

Based on our experience, it is critical with full scale wall testing to eliminate air movement between the interior conditioned space and the interior of the test wall. This is achieved with a gasket installed around the perimeter of the wood framing (Figure 10).

Figure 10 : Gasket installed on the interior edge of the framing as airseal

Figure 11 shows the interior of test wall panels on the North orientation including the foam gaskets and installation of most fiberglass batt insulation. Walls 4 and 5 were constructed with unfaced fiberglass batt, but all other walls were constructed with a kraft facing vapor control layer.

Figure 11 : Interior of test wall panels on the north orientation

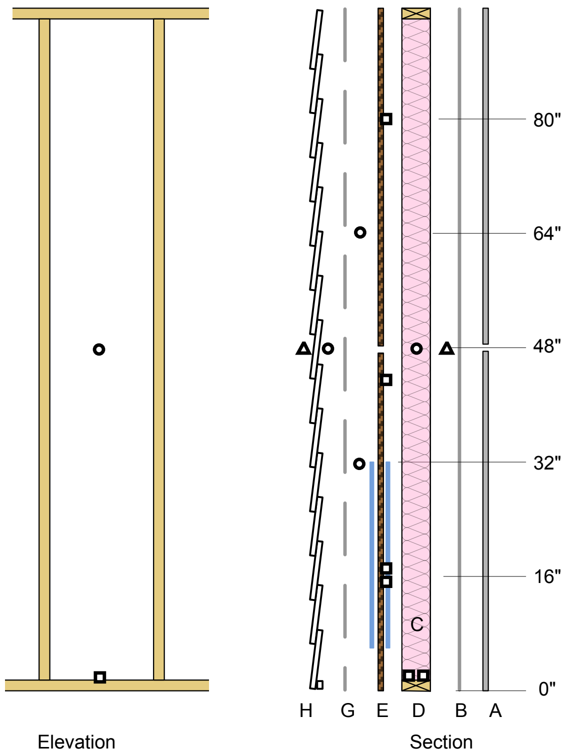
Sealant was used to eliminate any airflow between the wall panel and the adjacent cavity at the interface of the sheathing and exterior insulation (Figure 12). Sealant was also used at the top of the exterior insulation to eliminate any ventilation of the cavity. This is particularly critical on the two walls with a 1/8" drained and ventilated cavity to the interior of the foil-faced polyisocyanurate exterior insulation so that we do not encourage ventilation and outside air bypass of the insulation. Figure 12 also shows the peel and stick used to seal the sheathing of the wall panel to the structure, to ensure an air tight seal between the test wall and structure.

Figure 12 : Sealant installed at the interior surface of exterior insulation

Instrumentation

Each of the test walls was outfitted with a series of temperature (T), relative humidity (RH) and wood moisture content (MC) sensors. These sensors will continuously monitor the test walls and record to the data acquisition system throughout the testing period. All walls received a similar sensor package. This package is illustrated in Figure 13.

Wall 1	FC Siding, 1 x 30 min paper, OSB, 2x6, kraft faced batt, latex paint (Base Wall)



Assembly

Layer	Function	Description
A	Interior Finish	Painted gypsum board
B	Vapor Control	kraft paper
C	Studspace	Fiberglass batt
D	Framing	2x6
E	Sheathing	½" OSB
	Gap	none
F	Membrane/Insulation	1 layer 30 min paper
G	Drainage	Inherent (Lap Siding)
	Cladding	Fiber cement siding

Sensor Package

Layer	Code	Location
A	taem	Interior finish, exterior face, 48"
C	r/tcnm	Studspace, interstitial, 48"
D	m/tdeb (siam)	Framing, exterior edge, bottom plate
D	m/tdib (siam)	Framing, interior edge, bottom plate
E	m/tenu	Sheathing, interstitial, 80"
E	m/tenm	Sheathing, interstitial, 48"
E	m/teel (siam)	Sheathing, exterior, 16"
E	m/tell (siam)	Sheathing, interior, 16"
G	r/tgiw	Drainage space, interior, 32"
G	r/tgie	Drainage space, interior, 64"
G	r/tgem	Drainage space, interstitial, 48"
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 13 - Typical Instrumentation Package

Moisture content pins were installed in the framing lumber and the sheathing (from the interior) in all wall systems. Wood moisture contents can be determined from electrical resistance of wood based on the Garrahan equation[3,4]. 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.

Relative humidity sensors were always installed in combination with temperature sensors, both of which were protected by a vapor permeable, water resistant cover. Relative humidity and temperature sensors were installed at the midpoint of the stud space, between the drywall and the sheathing, behind the drainage material at two heights and outboard of the drainage material at mid height.

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

[4] 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

Example photographs of the individual sensors are shown below in Figure 14 to Figure 18.

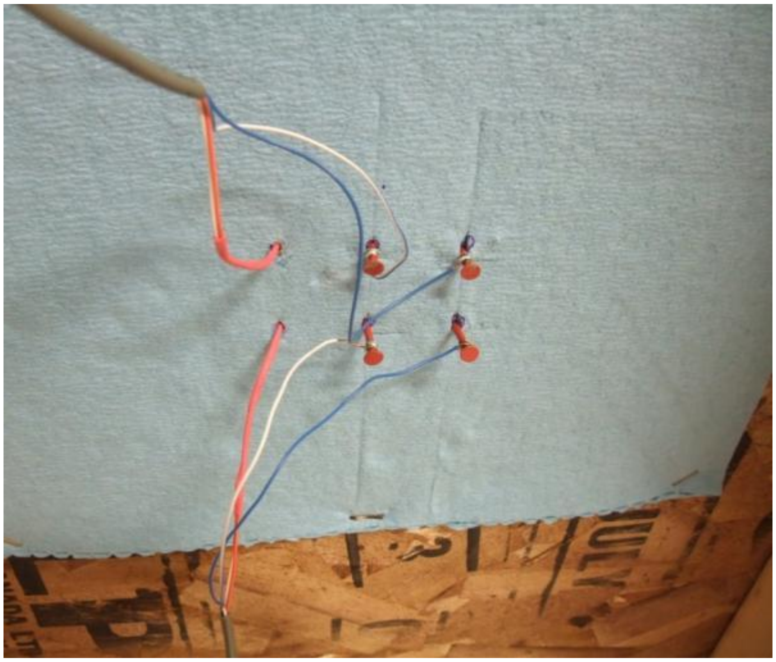


Figure 14 - Interior and Exterior Sheathing MC/T Sensors

Figure 15 - Upper Interior Sheathing MC/T Sensors

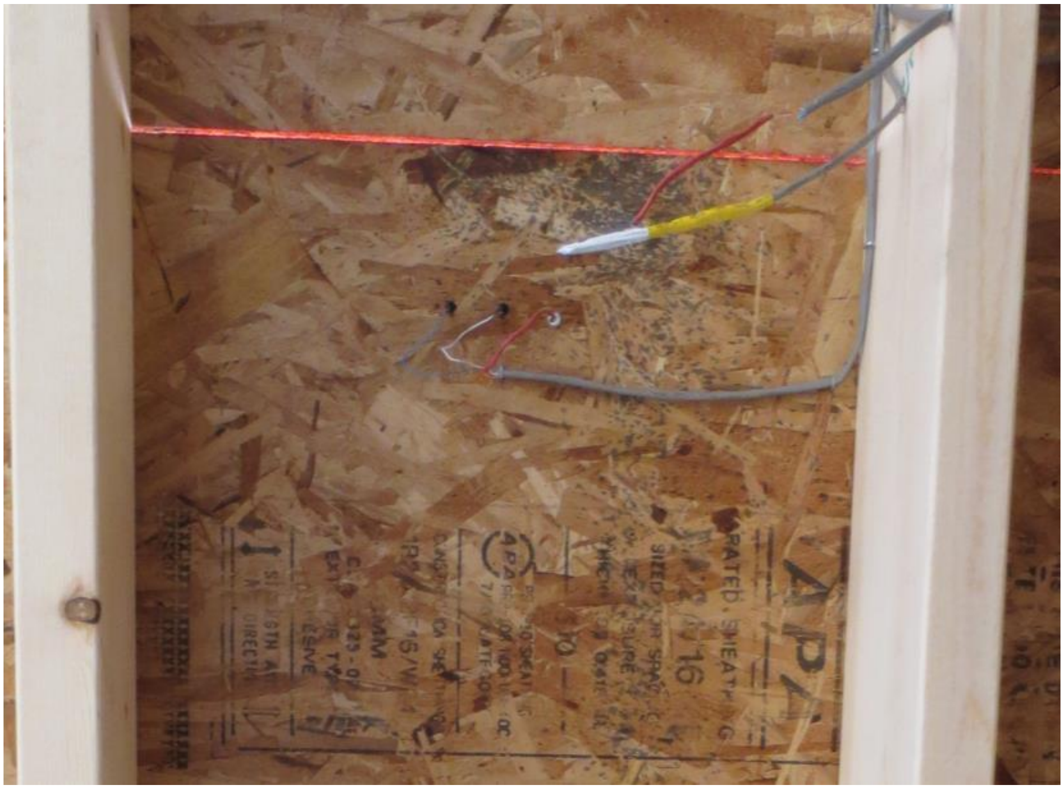


Figure 16 - Interior Mid-Height T, T/RH and MC/T sensors

Figure 17 - Bottom Plate MC/T Sensors

Figure 18 - Exterior Upper and Lower T/RH Sensors

The sensors and wetting apparatus tube on the exterior of the OSB interfered with the direct applied exterior insulation that is typically in contact with the sheathing. Small grooves were carefully cut into the exterior surface of the exterior insulation (Figure 19) where necessary, so that the sensors and wetting apparatus tube did not affect the gap between the sheathing and the insulation. The grooves are shown in detail in Figure 20 with the corresponding tube and RH/T sensor.

Figure 19 – Creating small grooves on the interior surface of board foam insulation

Figure 20 – Sensor and wetting apparatus tube pockets in XPS Insulation

For Phase IV, wetting systems were installed on both the interior and the exterior of the exterior sheathing at locations similar to those in Phase III. These systems were used to help determine the drying potential of specific wall assemblies by allowing a known amount of water to be injected at a controlled time, simulating a window leak. The wetting apparatus consists of a storage medium and a tube connecting the medium to the interior of the test hut to enable wetting without opening the wall system. Photographs of the installed wetting systems are shown in Figure 21 to Figure 23.

Figure 21 - Interior Wetting Apparatus

Figure 22 - Exterior Wetting Apparatus

Figure 23 - Wetting Apparatus Injection Tubes

Data Acquisition System

The data acquisition system consists of the following:

- One Campbell Scientific Power Supply and Campbell Scientific Network Link Interface
- Two Campbell Scientific Data Loggers and ten Campbell Scientific Multiplexers
- 1 Weather Station
- 3 Indoor Conditions Relative Humidity and Temperature Sensors
- 2 Rain Gauges
- 56 Test Specimen Temperature Sensors
- 112 Test Specimen Relative Humidity and Temperature Sensors
- 168 Test Specimen Moisture Content and Temperature Sensors

This Campbell Scientific system allows accurate, remote monitoring of the entire system from anywhere with internet access. Each of the temperature sensors was manually tested during the initial installation to verify that they were functioning. The moisture content and relative humidity sensors were tested using the data acquisition system.

Planned Milestones and Reporting

Wetting events will begin in the early summer 2013 to compare the drying rates of the different walls and the moisture related durability of the sheathing when wet. More intentional wettings will be conducted in the fall, during the typical rainy season of the Pacific North-west, as there is typically less drying potential during the fall than the summer.

An interim report will be written in the fall of 2013, which will provide analysis of data from winter 2012 and summer 2013 with planned intentional wetting and subsequent drying analysis.

The final report will be written at the completion of testing, following the deconstruction of the test walls. The tentative planned completion of Phase IV is summer or fall 2014.

Figure 24 : Vancouver Test Hut - Phase IV - Finished Construction

APPENDIX

Preliminary Data Analysis

Boundary Conditions

The following figures show the measured interior and ambient temperature and relative humidity since testing began.

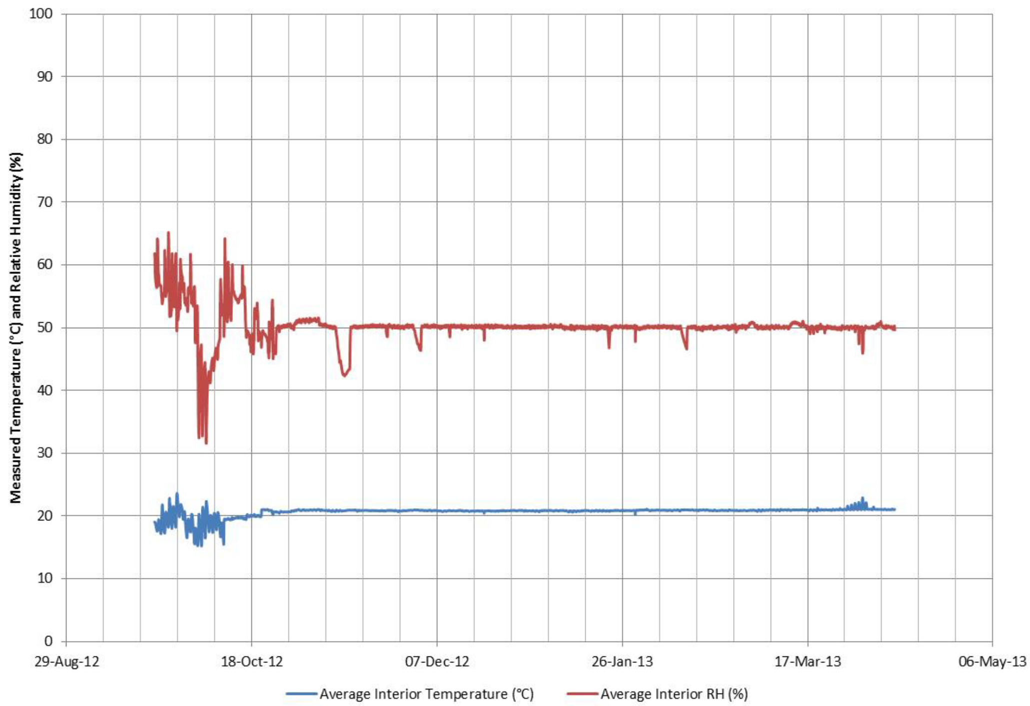


Figure 25 : Measured interior temperature and relative humidity

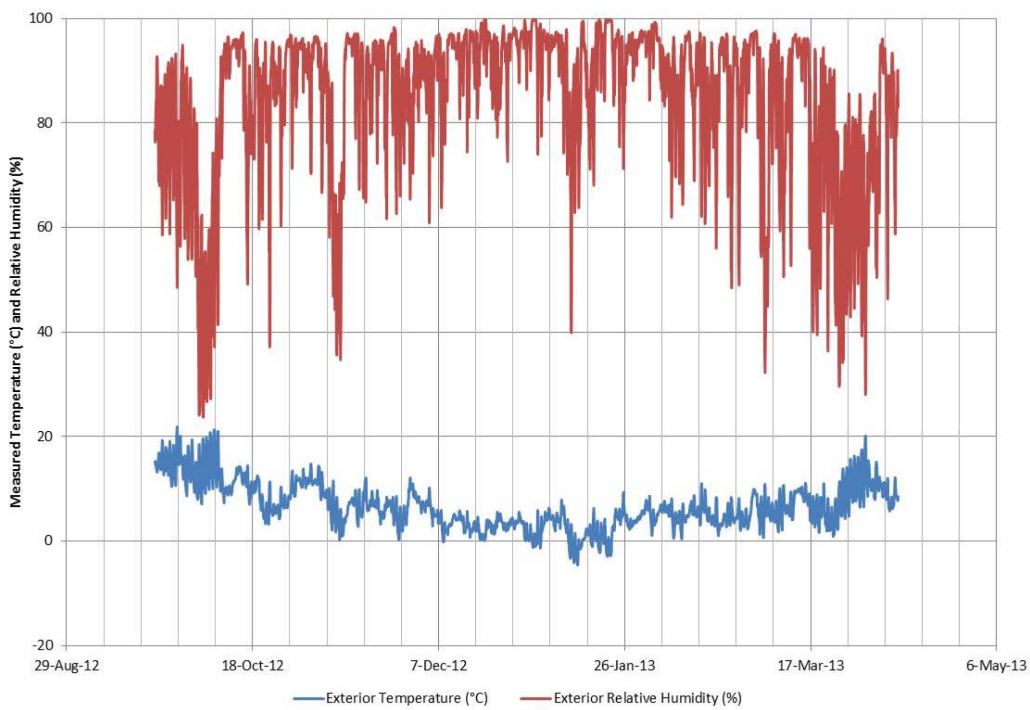


Figure 26 : Measured exterior temperature and relative humidity

Measured Moisture Contents

The following seven figures show the measured moisture contents for every wall on the North orientation as an example of the moisture content data that has been collected since testing began.

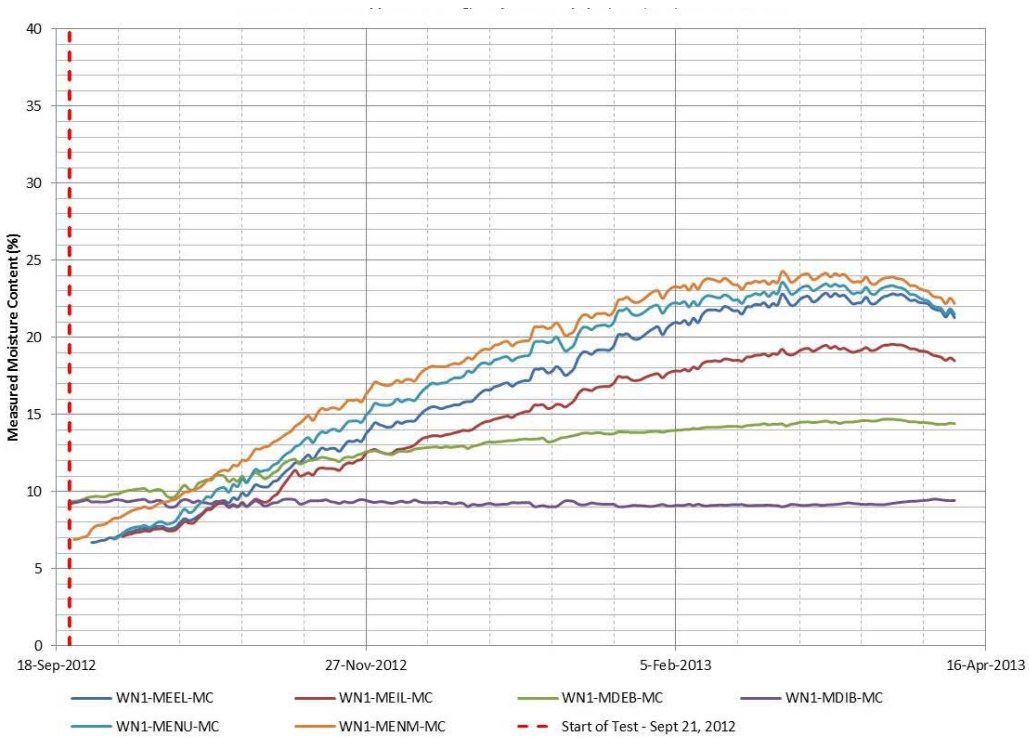


Figure 27 : North Wall 1 measured moisture contents

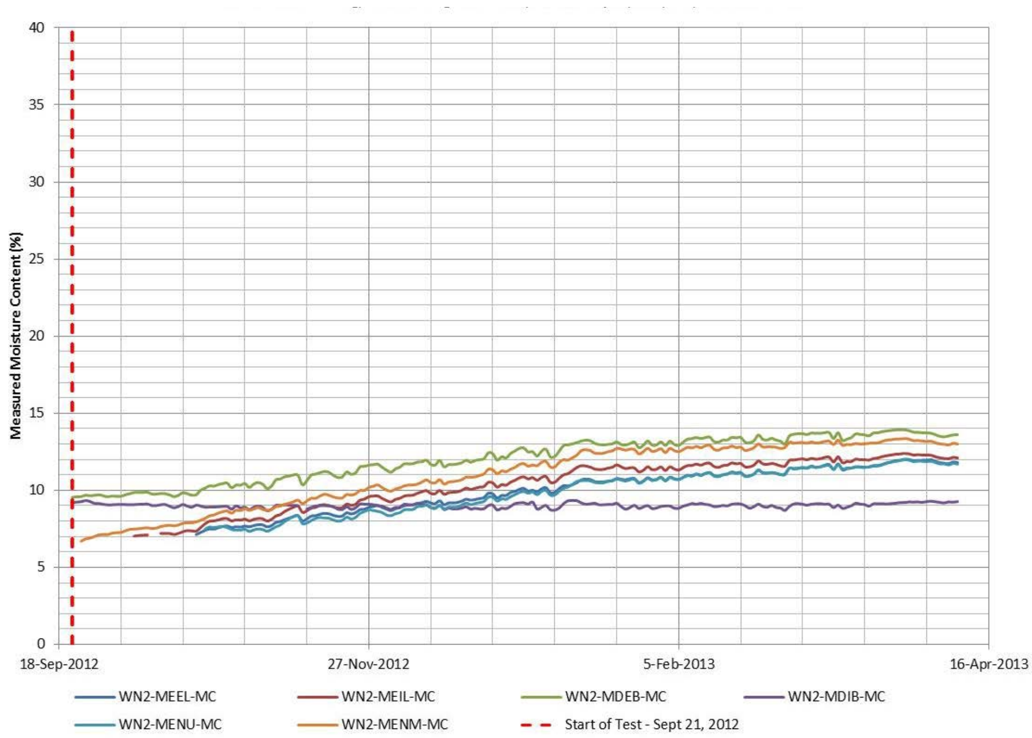


Figure 28 : North Wall 2 measured moisture contents

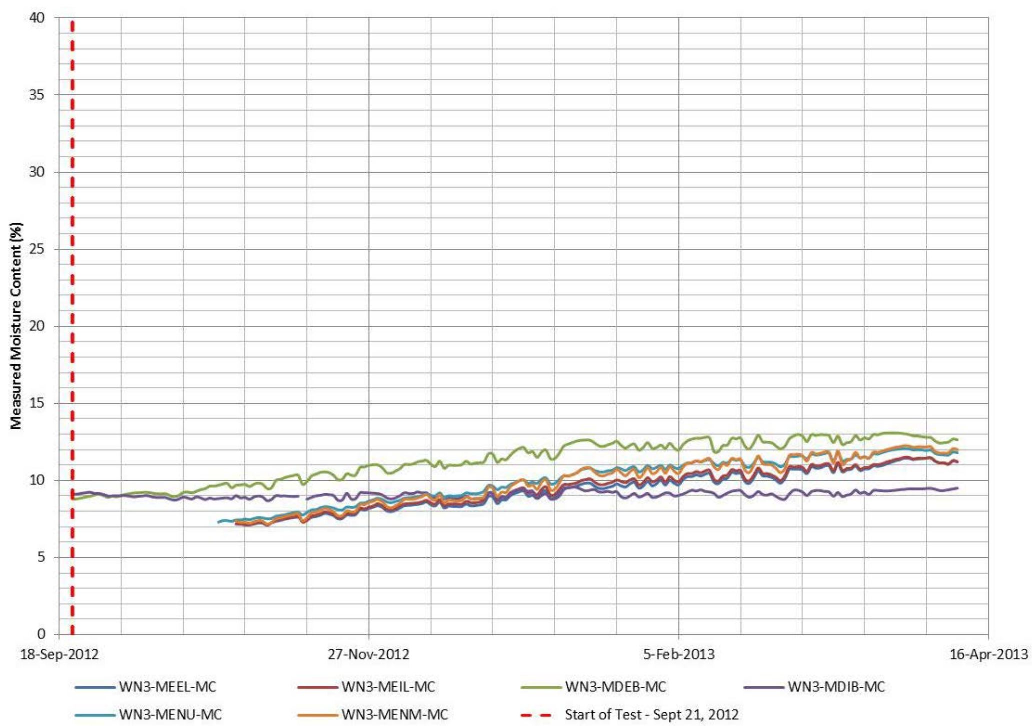


Figure 29 : North Wall 3 measured moisture contents

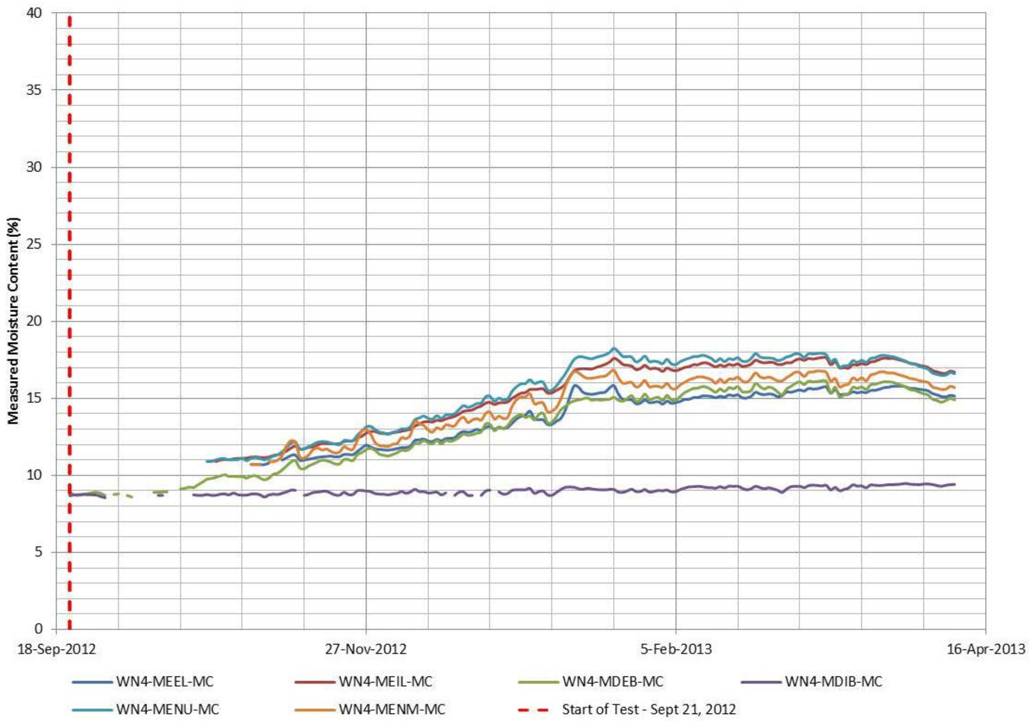


Figure 30 : North Wall 4 measured moisture contents

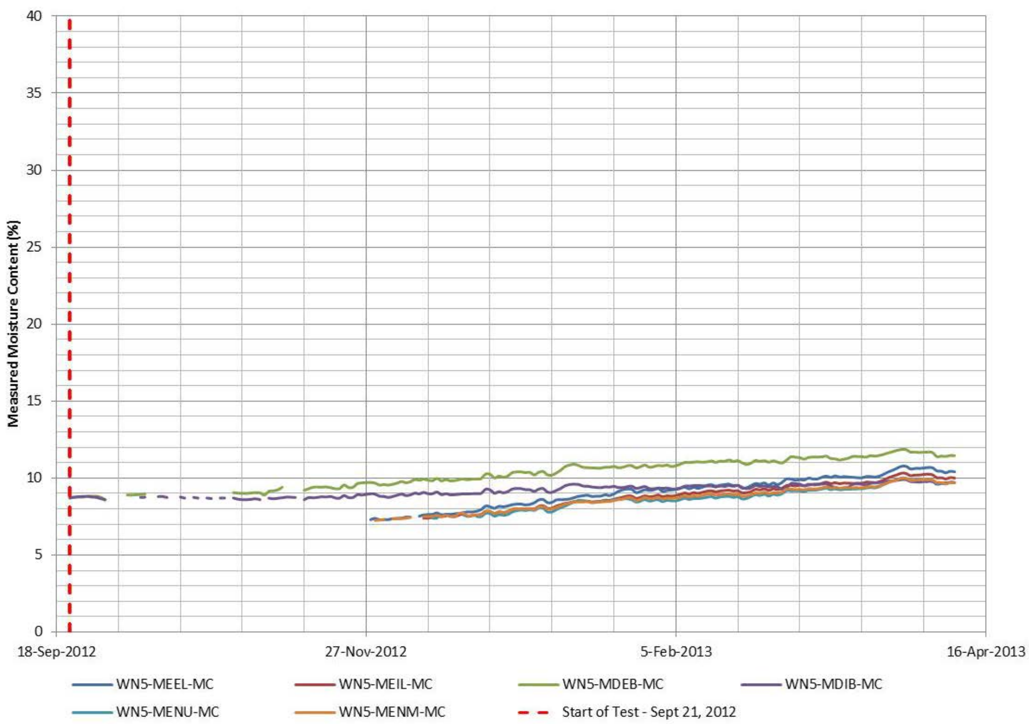


Figure 31 : North Wall 5 measured moisture contents

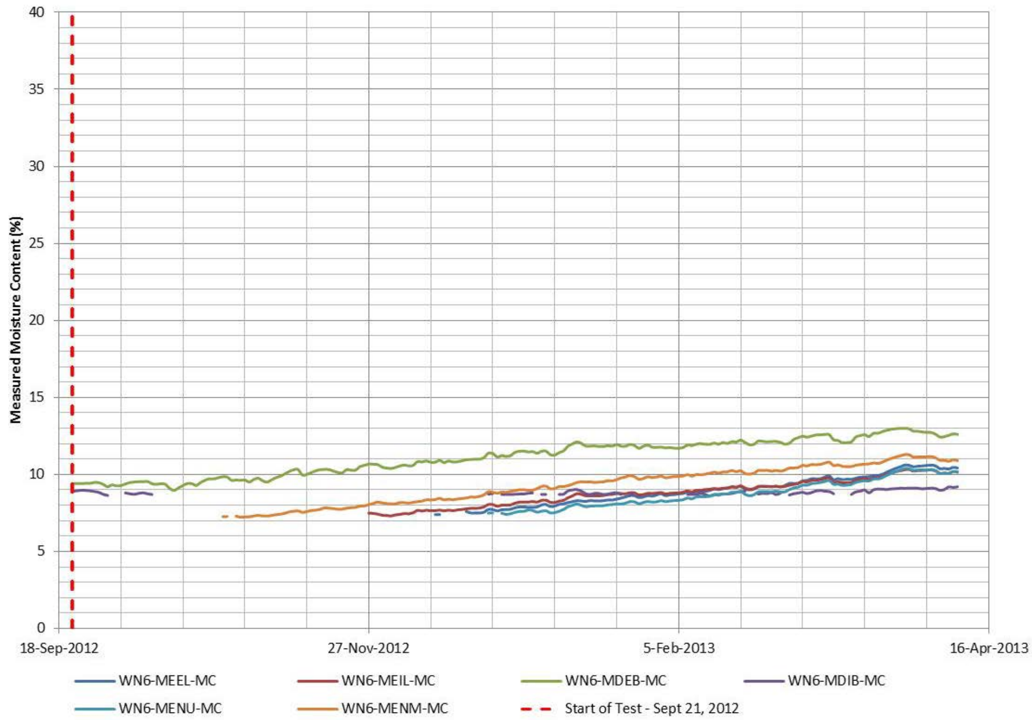


Figure 32 : North Wall 6 measured moisture contents

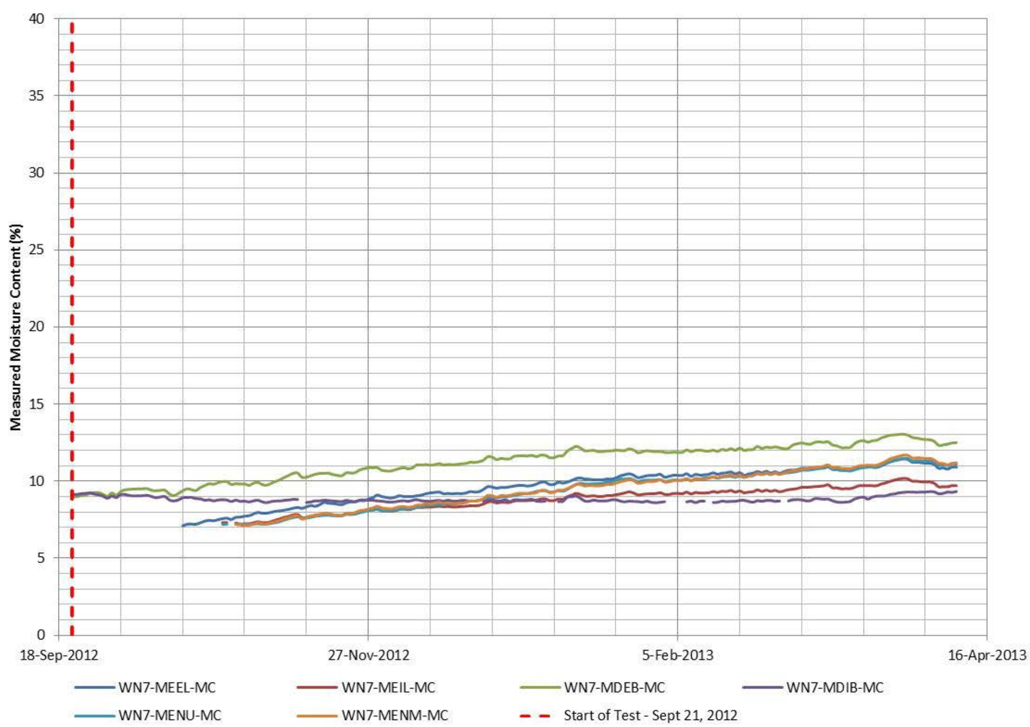


Figure 33 : North Wall 7 measured moisture contents

Measured Relative Humidity

The following seven figures show the measured relative humidity in each wall on the North orientation as an example of the relative humidity data that has been collected since testing began.

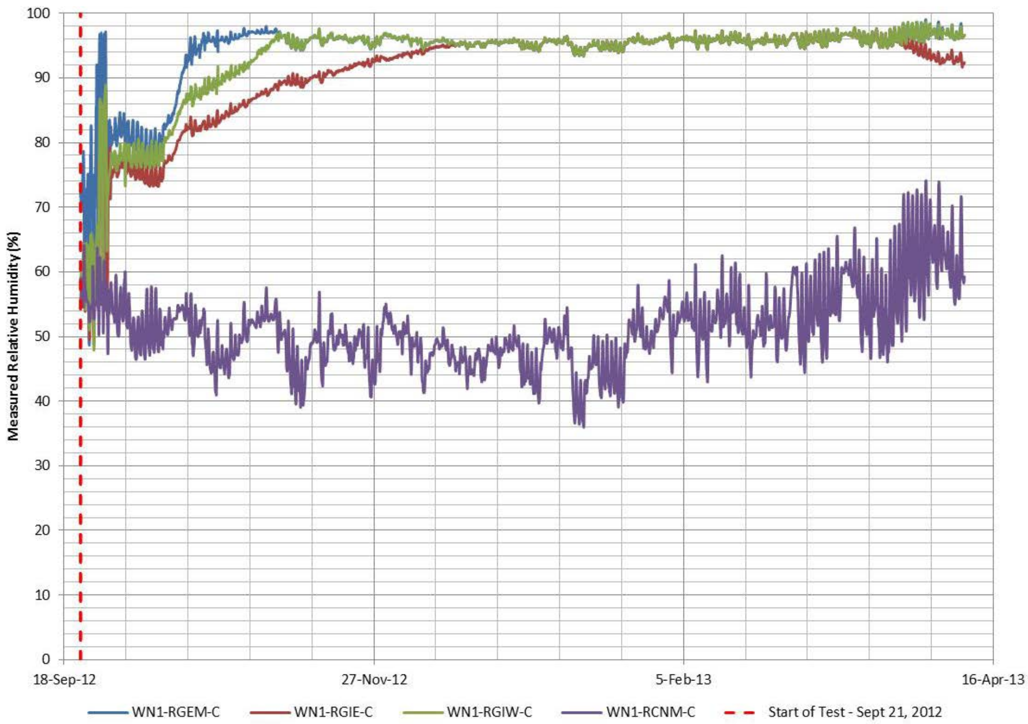


Figure 34 : North Wall 1 measured relative humidity

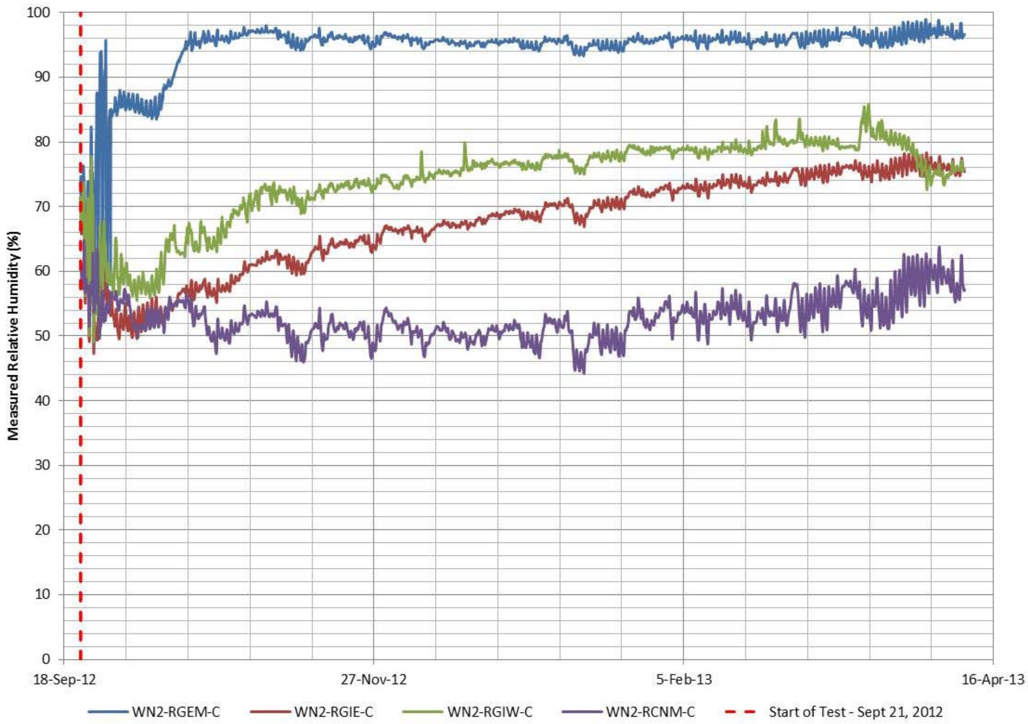


Figure 35 : North Wall 2 measured relative humidity

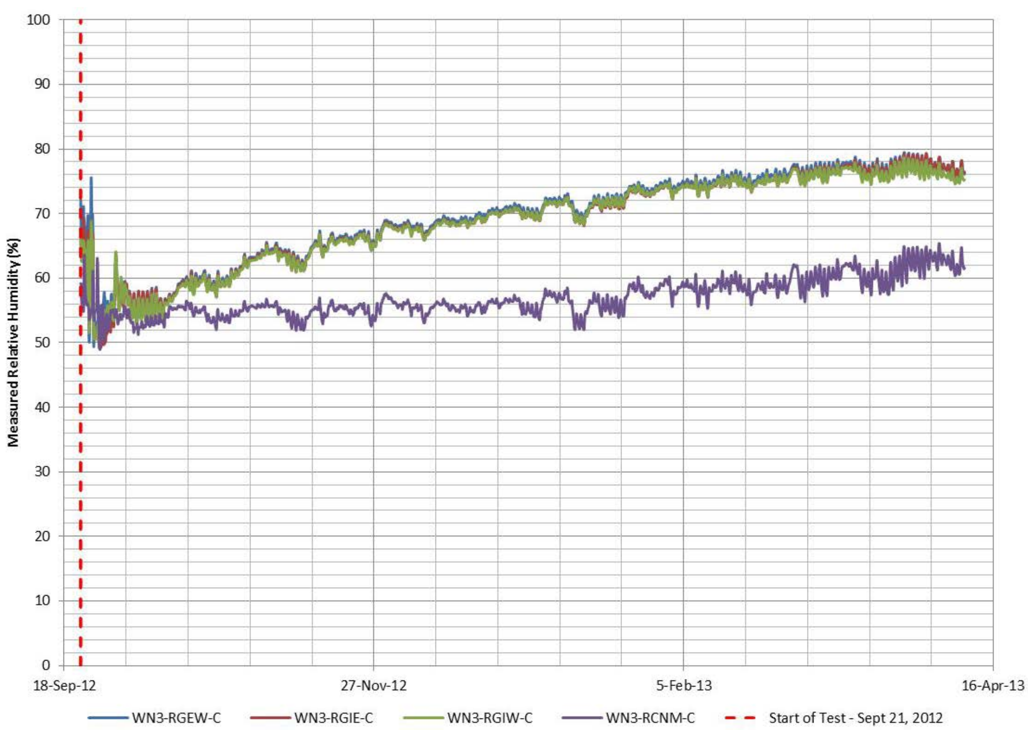


Figure 36 : North Wall 3 measured relative humidity

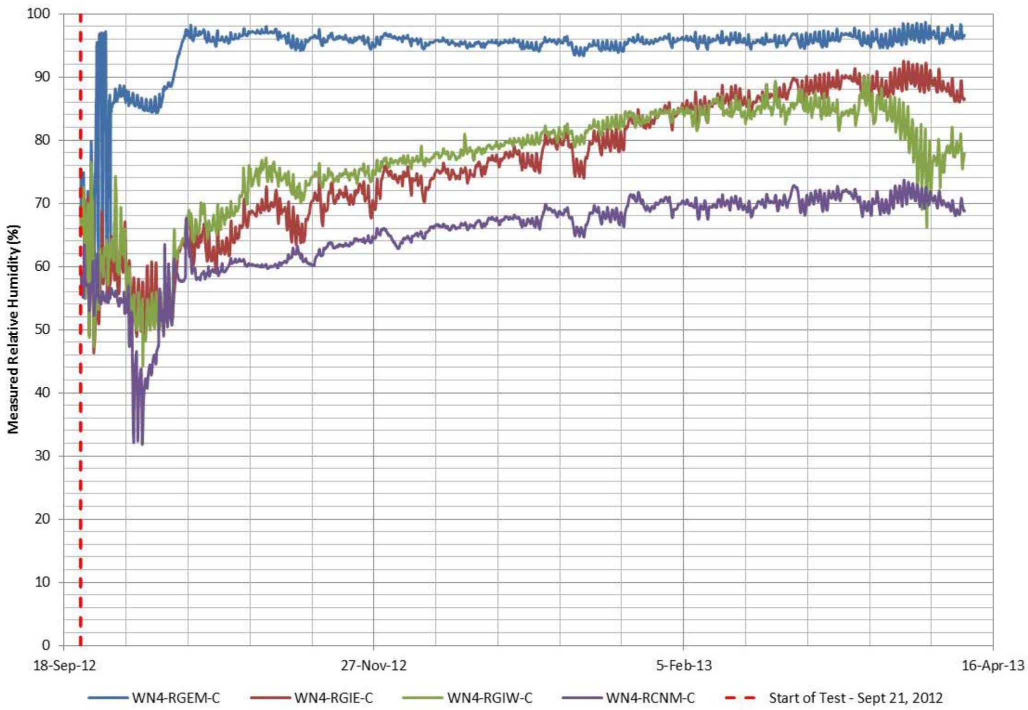


Figure 37 : North Wall 4 measured relative humidity

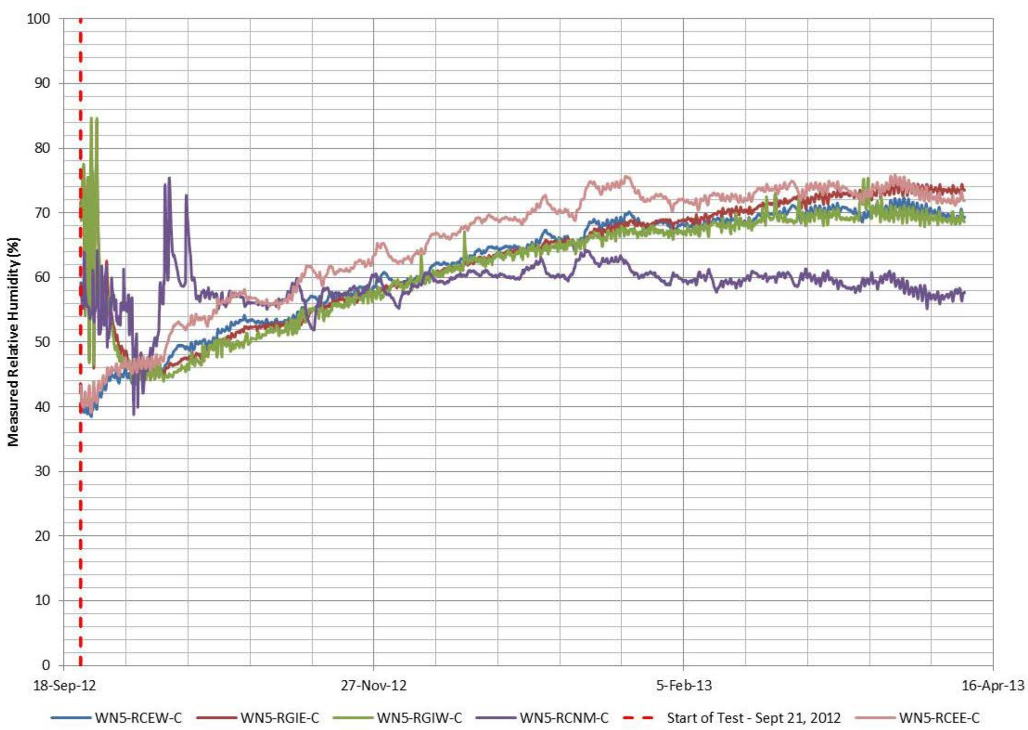


Figure 38 : North Wall 5 measured relative humidity

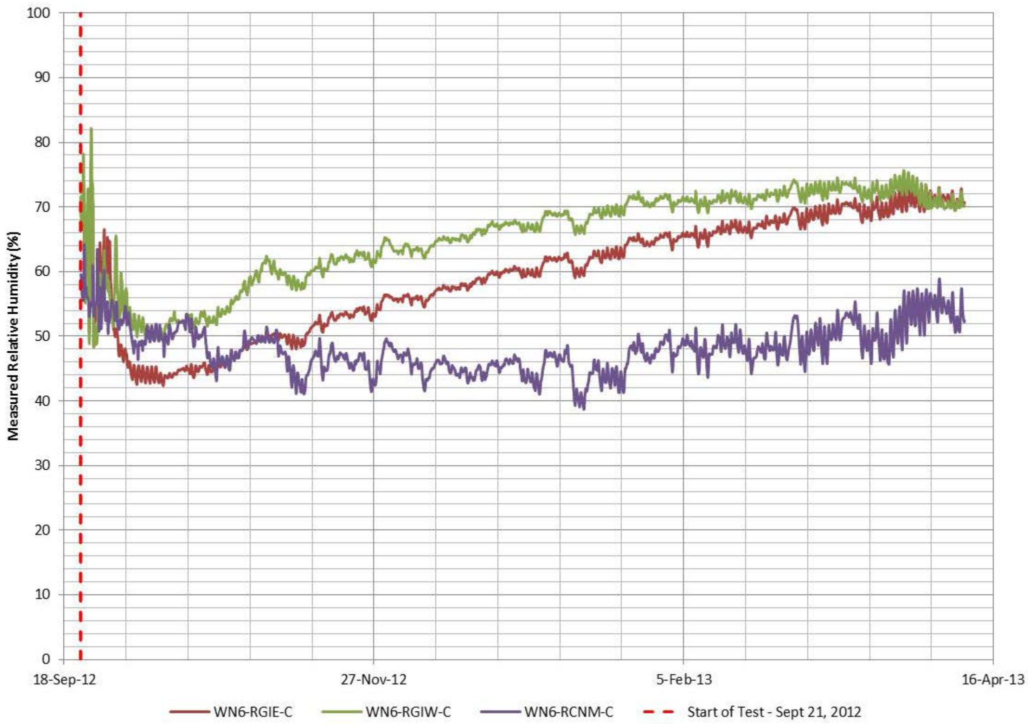


Figure 39 : North Wall 6 measured relative humidity

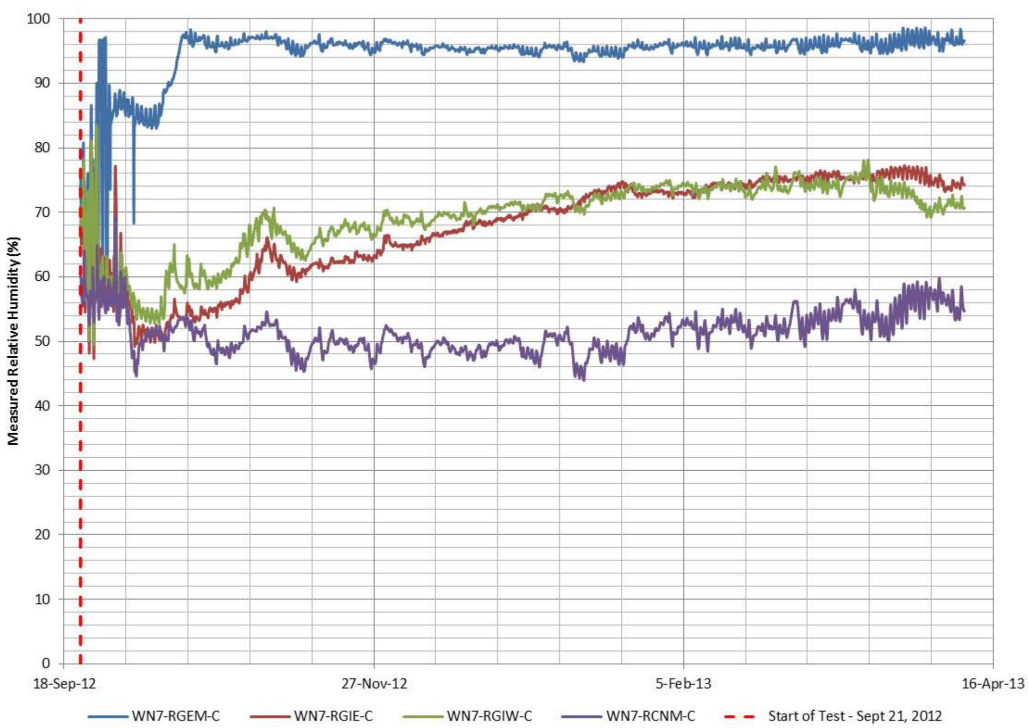


Figure 40 : North Wall 7 measured relative humidity

About the Authors

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