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The Pennsylvania Housing Research Center

Insulated Concrete Masonry Below-Grade Walls

A report prepared by

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Preface and acknowledgements

This report is the result of the laboratory study on basements recently conducted by the Pennsylvania Housing Research Center (PHRC). The project addresses the issues related to insulated concrete masonry below-grade walls with reference to structures built mostly in cold and mild climates.

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- The Pennsylvania Concrete Masonry Association (PCMA)
- J. A. Kohlhepp Sons, Inc.
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This report is primarily intended for decision-makers in the building industry as well as others who are interested in the sub-grade aspects of home construction – especially hygro-thermal performance of below-grade walls. Current practice, recent development, and methods of insulating of basement walls are discussed.

The report identifies materials used in basement wall construction according to their physical properties and not commercial names.

Help of William Splain in constructing the test specimens and Mark Fortney is gratefully acknowledged.

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1. Introduction

Basement construction and use of basement spaces have changed dramatically over time. Basements were traditionally designed and used as inhabitable spaces but today's market favors the use of basements as living areas. This represents significant changes in expectations of the space performance, which are expected to provide the same level of comfort and environment as the above-grade structure. Basements represent extremely challenging environments where issues of temperature, relative humidity, and water intrusion must be addressed in a complete system that can function over time.

1.1 Background

A large number of moisture-related building problems have occurred during the last few years, with adverse effects on health, building costs, and confidence.

In the United States basement wall insulation started to be implemented in the 1960's due to the market demand and subsequent energy crisis of the 70's. The energy codes require insulation of the below-grade construction designated as conditioned space. From the past research, it is evident that locating the insulation layer on the exterior surface of the wall offers thermal and other advantages. However, there are also some serious practical disadvantages to an exterior location. The two main disadvantages are that the insulation is exposed and vulnerable to damage both during construction (e.g., equipment, people, etc.) and in-service (e.g., people, equipment, animals, termites, etc.)

Significant numbers of below-grade walls, especially in residential buildings, are constructed with concrete masonry units (CMU) with a nominal thickness of 8 in. The CMU units and mortar used in wall construction are moisture permeable and allow penetration of the wall by moisture in liquid or gaseous form. The processes of water penetration, absorption, storage, accumulation, and drying for CMU wall construction are complex and are not fully understood.

The significant drawbacks to below-grade wall research are the experimental difficulty of modeling the soil including the amount of soil, the soil thermal properties (both short and long terms), moisture effects (amount, movement, etc.), and scale. The fact that climate, ground, and groundwater conditions present a large number of undefined variables is another drawback.

Most recently performance guidelines for basements in cold climates were published in Canada [1-5]. The guidelines address exterior and interior insulations for most common walls (cast-in-place concrete, CMU, and permanent wood foundation (PWS)). While the Canadian work shows the effectiveness of the exterior insulation, it does it only for cast-in-place concrete walls and does not give a direct comparison between exterior and interior insulation in the same test. In addition, the tests conducted by Canadians were performed in-situ, therefore, specific "on site" impacts occurred. Concrete masonry units (CMU) are significantly different from the cast-in-place concrete foundations, in that it does not contain large quantities of water after construction.

The cavity in the CMU adds additional parameter that needs to be considered. Therefore, the results from the cast-in-place basement walls are not valid for CMU walls.

In addition, soil represents a specific heat and mass transfer phenomenon. Studies on soil mass under slab and around below-grade structures showed that the soil is warm and moist enough to cause a water vapor flow from the moist base soil toward the relatively dry indoor air [1]. Ground (soil) properties and heat transfer through ground can also account for up to 40% of the heat loss.

The behavior of the above-grade portion of the wall is different from the below-grade portion. Although these two parts of the wall are connected, each structure faces different boundary conditions such as various thermal lags, forces which induce moisture intrusion, physical properties of walls, condition of the surroundings, etc. As a result, the below-grade envelopes are subjected to higher structural, water, and moisture loads than above-grade portions. This often represents challenging issues for the whole below-grade structure and materials participating in the system.

1.2 Objective

The experimental work described in this report focused on the development and documentation of a better understanding of the hygro-thermal performance of wall systems below grade.

Specifically, the following objectives were to be accomplished:

1. Monitoring and development of effective methods of insulating basement walls in cold climates with respect to moisture intrusion.

2. Monitoring and development of effective methods of insulating basement walls in mild climates with respect to moisture intrusion.

3. Monitoring of absorption and mass movement through the CMU components with respect to the whole basement system’s performance

1.3 Scope

The project focuses on the evaluation of various insulation strategies applicable to below-grade CMU wall systems. Final conclusions in the project are stated, based on conducted experimental measurements and available and related literature.

1.3.1 Climate conditions

Two steady state climate conditions were simulated: cold climate representing 5 °C (41 °F), and mild climate representing 20 °C (68 °F). The test results are applicable to structures located in similar climates. The boundary conditions were fully controlled during the experiments.

1.3.2 Damp-proofing

The experimental design included two fundamentally different conditions: (1) walls without damp-proofing, and (2) walls with damp-proofing.

1.3.3 Soil conditions

Because the site conditions for basement construction can vary, the project identified two soil conditions: (1) clay, and (2) sand. These two materials differ in their physical properties. While sand is representing a well-draining soil (water in the soil around the basement percolates downward and has smaller sorption capability), clay may be practically impervious to water (requires efficient foundation drainage system and has higher sorption capability).

1.3.4 Moisture variations

For each test, different external and internal relative water vapor pressure and temperature conditions (see 1.3.1) were simulated in the climate chamber to study and accommodate different moisture migration variations. Relative humidity (RH) of the exterior varied in the range from 50 % to >95 % and the RH of the interior varied between 30 % and 60 %.

1.4 Report organization

The report is divided into six sections. The description of the experiment is presented first, followed by the description of the boundary conditions, measurement of moisture contents, and finally experimental results, conclusions, and recommendations are discussed.

2. Description of the experiment

The experiments were conducted in the climate chamber at the Building Enclosure Testing Laboratory (BeTL) of the PHRC.

2.1 Experimental program

In total four series of tests were conducted. The focus of the project was the performance of the below-grade wall structures under various hygro-thermal conditions.

2.1.1 Experimental parameters

Nine different wall specimens were constructed, instrumented, and tested simultaneously. Four series of tests (cycles) were conducted under preset steady state conditions to monitor the hygro-thermal behavior of the wall specimens. To better understand the behavioral and quantitative aspects, the test parameters were defined as:

- Membrane variations:

    1. Specimens no damp-proofing layer simulating direct contact of the below-grade wall with the surrounding soil. The parged CMU's were in direct contact with the soil.

    2. Specimens with damp-proofing conforming to the building code requirements.

Table 2-1: Test cycles

Test cycle number	Soil type	Exterior coating	Design alternatives
1.	Sand	No damp-proofing	8
2.	Clay	No damp-proofing	8
3.	Sand	With damp-proofing	4
4.	Clay	With damp-proofing	4

- Soil variations:
  1. Sand representing well-drained soil.
  2. Clay representing a low permeance soil.

Table 2-1 represents the test matrix. The tests started with cycles without damp-proofing. The bare wall was tested for both soil conditions (sand and clay). Then, the specimens were coated on the exterior surface and the tests were repeated.

2.1.2 Climate parameters

In contrast to in-situ measurements, the lab experiments conducted in the climate chamber ensured desired steady state conditions. Such uniform conditions permitted comparing and objectively evaluating the hygro-thermal behavior within each test cycle for different designs.

Table 2-2 summarizes the temperature and relative humidity settings for each experiment during the first and second test run. 8 different designs were studied as shown in the Table 2-1.

Table 2-2: Tested designs during the first and second test runs

Design	Temperature		Relative Humidity		Materials moisture gain
	Interior T_I °C, (°F)	*Exterior T_E °C, (°F)	Interior RH_I (%)	Exterior RH_E (%)	
Alt 1	20 (68)	5 (41)	30	70	Sorption
Alt 2	20 (68)	5 (41)	60	70	Sorption
Alt 3	20 (68)	5 (41)	60	>95	Sorption
Alt 4	20 (68)	5 (41)	30	>95	Desorption
Alt 5	20 (68)	20 (68)	30	50	Sorption
Alt 6	20 (68)	20 (68)	60	50	Sorption
Alt 7	20 (68)	20 (68)	60	>95	Sorption
Alt 8	20 (68)	20 (68)	30	>95	Desorption

* Exterior air temperature was set to 3 °C to ensure a soil temperature of around 5 °C, which represents cold climate soil condition.

Table 2-3 summarizes the temperature and relative humidity settings for each design alternative during the third and fourth test runs. Because no significant differences between test runs with various exterior relative humidity were observed, the number of settings in the last two runs was reduced to represent the most significant conditions.

Table 2-3: Tested designs during the third and fourth test runs

Design	Temperature		Relative Humidity		Materials moisture gain
	Interior T_I	*Exterior T_E	Interior RH_I	Exterior RH_E	
	°C, (°F)	°C, (°F)	(%)	(%)	
Alt 1	20 (68)	5 (41)	30	>95	Sorption
Alt 2	20 (68)	5 (41)	60	>95	Sorption
Alt 3	20 (68)	20 (68)	60	>95	Sorption
Alt 4	20 (68)	20 (68)	30	>95	Desorption

* Exterior air temperature was set to 3 °C to ensure a soil temperature of around 5 °C, which represents cold climate soil condition.

Figure 2-1 shows the mean annual earth temperature. The soil temperature is relatively constant, and corresponds roughly to the water temperature measured in groundwater wells 30 to 50 feet deep.

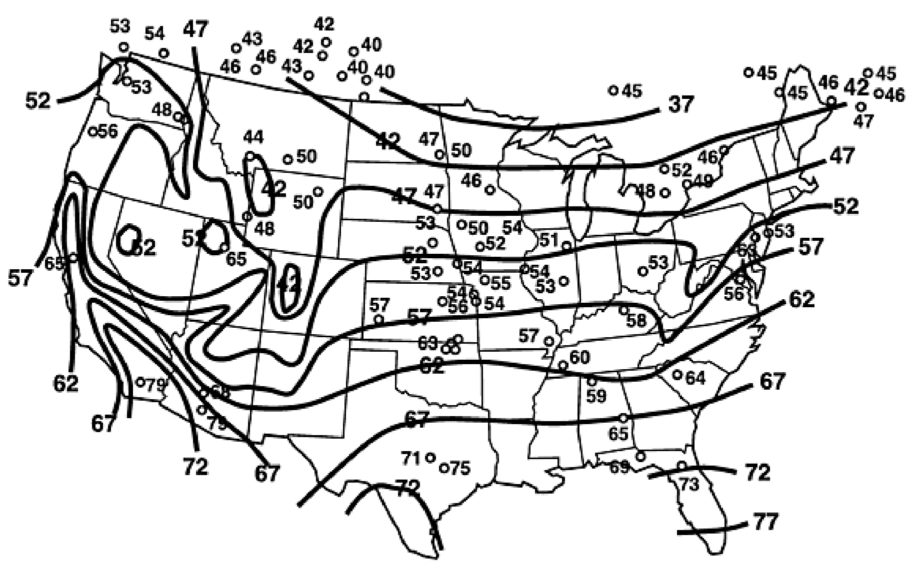


Figure 2-1: Mean annual earth temperature at individual stations, superimposed on well-water temperature contours (°F) [Virginia Department of Mines, Minerals, and Energy]

Since backfill height of foundations can vary, the temperature profiles of the soil surrounding the basement wall will also vary. A temperature of 5 °C (41 °F) represents the northern (cold) climate while the southern mild climate can be simulated by a temperature of 20 °C (68 °F).

2.2 Test setup

2.2.1 Climate chamber test facility

The climate chamber test facility was designed and built in BeTL at Penn State. The climate chamber test facility consists of:

- *The structure.* The dimensions of the insulated climate chamber are 4.9m x 3m x 2.6m (16 x 10 x 9 ft) (length x width x height). The chamber is finished with PVC on both the interior and exterior. This encapsulated form system is filled with foam insulation to ensure high R-value. Nine 1.1m x 0.7m (3.6 x 2.3 ft) test specimens can be simultaneously tested in the chamber.

- *A cooling system for the climate side.* The cooling system consists of two sub-systems: a freezer and a cooler. Each sub-system has a hot-air-bypass valve controlled by the computer to adjust the air temperature in the climate chamber. In case of computer failure, the system is equipped with its own thermostat for each sub-system.

- *A humidifier for the climate side.* The humidifier is a two-way (on/off) system controlled by the computer to produce small water droplets and thus provide moisture to the climate chamber.

- *A lighting system for solar radiation (used to dry the soil).* Ten lamps for each test panel are mounted on a steel rack system to provide evenly distributed radiation energy. The output power of the lights can be adjusted by the computer. A short dry-up cycle program (warm/evaporate-cool/dehumidify) was written to remove the residual water.

- *Two portable humidifiers.* One for the room side and one for the climate side to support the permanent humidifier to attain relative humidity levels close to saturation.

- *A baseboard heater for the room side.*

- *A portable radiant heater* for the climate side to balance temperature swings.

The climate chamber test facility is able to take the input climate-condition profile and control the temperature, relative humidity, and solar radiation when needed. Examples of the climate-condition control profile and the control actually achieved can be found in Section 3.1. Figure 2-2 shows an overall view of the climate chamber test facility.

Figure Error! Style not defined.**-2: Climate chamber test facility**

(a) **(b)**

Figure 2-3: Inside view of the climate chamber test facility; (a) climate side, (b) room side

2.2.2 Wall test specimens and instrumentation

Nine different below-grade wall specimens were constructed, instrumented and installed in the climate chamber. The wall support of eight specimens was built from 8” thick CMU’s with two cores while one segment was made from concrete. The wall specimens’ construction followed the building code requirements [1]. Seven specimens were insulated: three had exterior insulation and the other four had interior insulation. The two remaining specimens were plain CMU and concrete walls. All segments were parged. The walls with exterior insulation were not finished from the interior to simulate unfinished basement and the walls with interior insulation had 3/8’’ (9.5 mm) drywall applied. The drywall was unfinished.

To compare various wall systems’ hygro-thermal behavior, different insulation materials were introduced: *(1) extruded polystyrene, (2) polyisocyanurate, and (3) glass fiber semi-rigid board.* These insulations were applied on six specimens. The seventh specimen had expanded polystyrene insulation applied from the interior. Each of the insulation was at least 2” (50.8 mm) thick to satisfy the building code energy conservation requirement. Because of very similar physical properties of sprayed polyurethane and polyisocyanurate insulations, the polyisocyanurate boards without foil-facing were used.

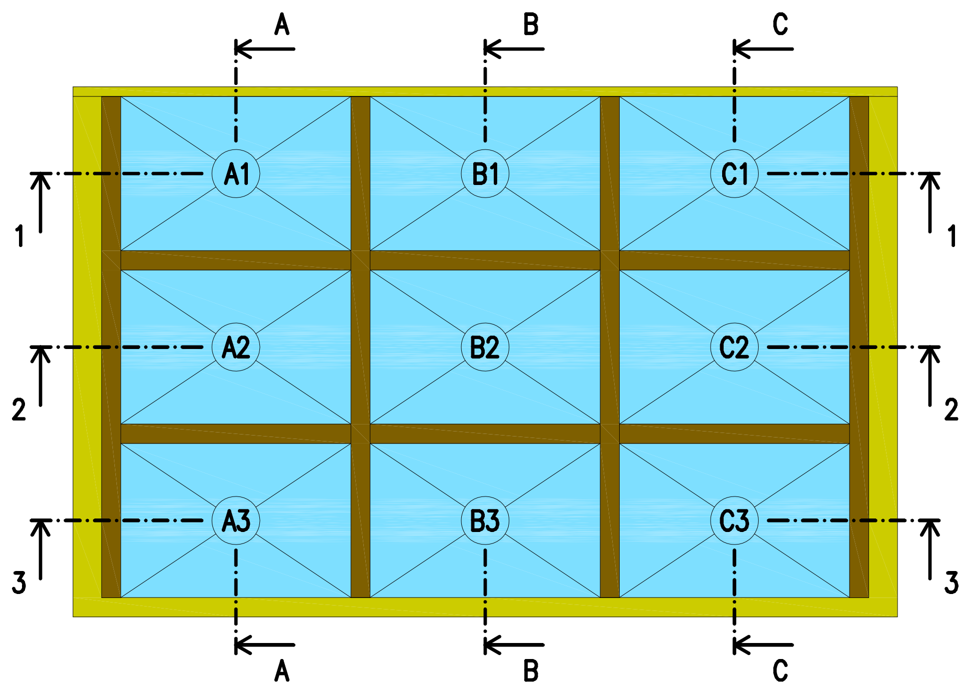


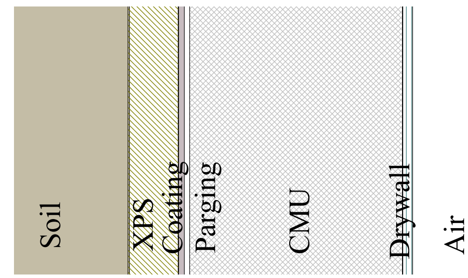
Figure 2-4: Schematic of specimens in the climate chamber

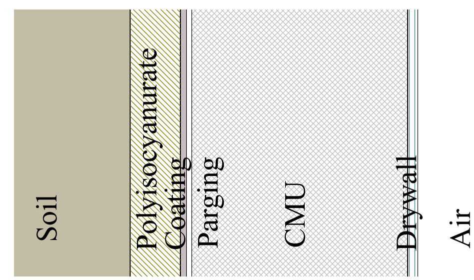
Figure 2-4 shows the configuration of specimens in the climate chamber. Specimens in section A are insulated from the exterior, specimens in section B and C1 have interior insulation applied. The remaining specimens C2 and C3 have no insulation. Table 2-4 summarizes the layer configuration of the test specimens in detail.

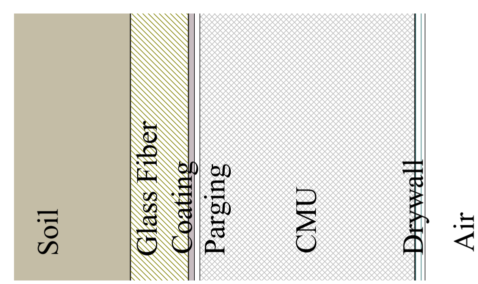
Table 2-4: Configuration of the tests specimens

Specimen	Layer	Thickness (inch)	Thickness (mm)	Comments
A1	Soil	10	254.0	Exterior insulation
	Extruded Polystyrene (XPS)	2	50.8	
	* Damp-proofing (paint coat)	-	-	
	Parging (Stucco)	3/8	9.5	
	Concrete Masonry Unit (CMU)	8	203.2	
	Gypsum Board (Drywall)	3/8	9.5	
A2	Soil	10	254.0	Exterior insulation
	Polyisocyanurate	2	50.8	
	* Damp-proofing (paint coat)	-	-	
	Parging (Stucco)	3/8	9.5	
	Concrete Masonry Unit (CMU)	8	203.2	
	Gypsum Board (Drywall)	3/8	9.5	
A3	Soil	10	254.0	Exterior insulation
	Glass Fiber	2 1/4	57.2	
	* Damp-proofing (paint coat)	-	-	
	Parging (Stucco)	3/8	9.5	
	Concrete Masonry Unit (CMU)	8	203.2	
	Gypsum Board (Drywall)	3/8	9.5	

Cross section







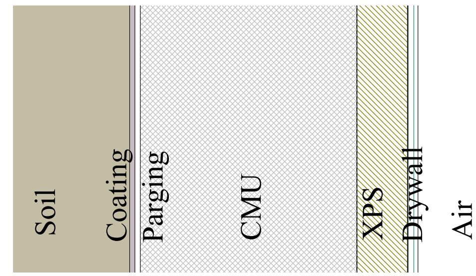
* Damp-proofing is applied only in the third and fourth test cycles

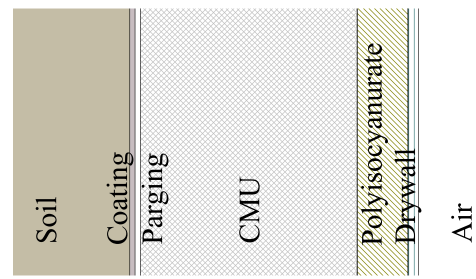
Table 2-4: Configuration of the tests specimens (continued)

Specimen	Layer	Thickness (inch)	Thickness (mm)	Comments
B1	Soil	10	254.0	Interior insulation
	* Damp-proofing (paint coat)	-	-	
	Parging (Stucco)	3/8	9.5	
	Concrete Masonry Unit (CMU)	8	203.2	
	Extruded Polystyrene (XPS)	2	50.8	
	Gypsum Board (Drywall)	3/8	9.5	
B2	Soil	10	254.0	Interior insulation
	* Damp-proofing (paint coat)	-	-	
	Parging (Stucco)	3/8	9.5	
	Concrete Masonry Unit (CMU)	8	203.2	
	Polyisocyanurate	2	50.8	
	Gypsum Board (Drywall)	3/8	9.5	
B3	Soil	10	254.0	Interior insulation
	* Damp-proofing (paint coat)	-	-	
	Parging (Stucco)	3/8	9.5	
	Concrete Masonry Unit (CMU)	8	203.2	
	Glass Fiber	2 1/4	57.2	
	Gypsum Board (Drywall)	3/8	9.5	

* Damp-proofing is applied only in the third and fourth test cycles

Wall specimen's fragment





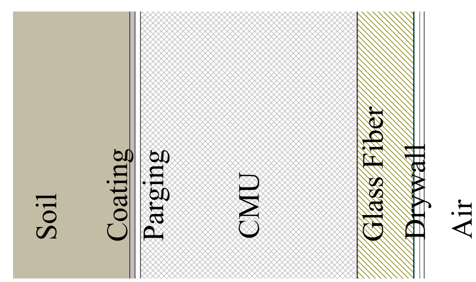
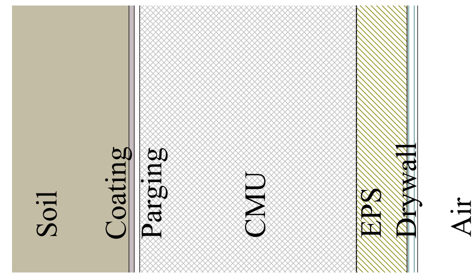
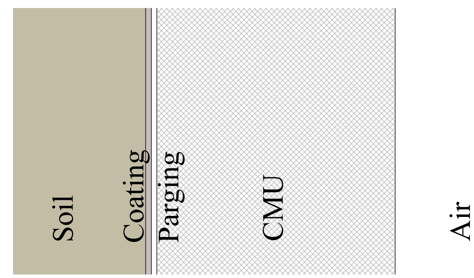
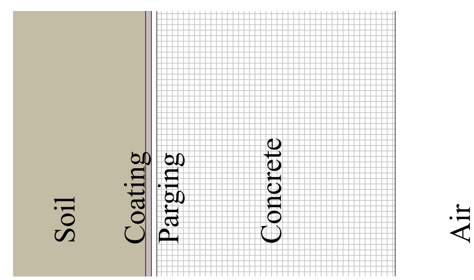


Table 2-4: Configuration of the tests specimens (continued)

Specimen	Layer	Thickness (inch)	Thickness (mm)	Comments	Wall specimen's fragment
C1	Soil	10	254.0	Interior insulation	
	* Damp-proofing (paint coat)	-	-		
	Parging (Stucco)	3/8	9.5		
	Concrete Masonry Unit (CMU)	8	203.2		
	Expanded Polystyrene (EPS)	2	50.8		
	Gypsum Board (Drywall)	3/8	9.5		
C2	Soil	10	254.0	Not insulated (plain)	
	* Damp-proofing (paint coat)	-	-		
	Parging (Stucco)	3/8	9.5		
	Concrete Masonry Unit (CMU)	8	203.2		
C3	Soil	10	254.0	Not insulated (plain)	
	* Damp-proofing (paint coat)	-	-		
	Parging (Stucco)	3/8	9.5		
	Concrete	8	203.2		

* Damp-proofing is applied only in the third and fourth test cycles

The figures shown below document the test wall construction. Frame construction and the use of thermal insulation at specimen boundaries are shown in Figure 2-5. Figure 2-6 shows the hygro protection used to eliminate the lateral moisture movement between specimens.

Figure 2-5: Frame and insulation

Figure 2-6: Moisture barrier

Figure 2-7: Specimens construction

Figure 2-8: Finished test wall

Figure 2-7 shows the CMU placed in the insulated frame. The final test wall construction with all finishes ready for testing is shown in Figure 2-8.

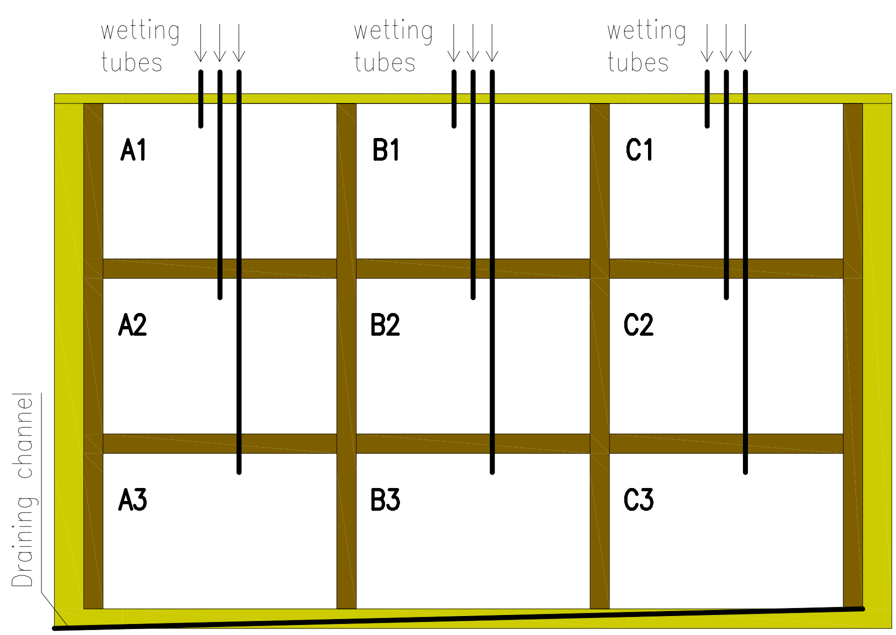
2.2.3 The soil

To simulate the influence of adjacent soil on the hygro-thermal behavior of the basement walls, it was necessary to create a structure that can be easily instrumented with sensors and allow quick soil change. After finishing the wall segments from the exterior (parging and applying thermal insulations to section A), a metal holding frame was constructed. Wire mesh and permeable garden fabric were used to hold the soil in place. The soil was placed into the cage through the opening at the top of the climate chamber. The soil layer was insulated on the boundary from adjacent segments in exactly the same way as the CMU wall.

Draining channel was installed under the soil, to remove the excess water from wetting the soil during the third and fourth test cycle. Known amounts of water were introduced into the soil only at the third and fourth test cycle, and relative humidity of the air was used to control the soil's moisture content during remaining cycles. A tubular wetting system was inserted into the soil, to ensure even water distribution. The moisture contents of soil were measured via taking and evaluating gravimetric soil samples from the top of the soil cage.

Figure 2-9 shows the wetting system installed for the third and fourth test cycles. Known amounts of water were introduced through each tube into the soil to attain saturated conditions.

Figure 2-9: Soil wetting system



The figures below show the soil holding cage construction. Finishing of the exterior side, especially section A, with different types of insulation materials (XPS – at the top, polyisocyanurate and glass fiber – at the bottom) is shown in Figure 2-10.

Figure 2-10: Finishing of the exterior

Figure 2-11: Holding cage construction

Figure 2-12: Soil insulation / separation

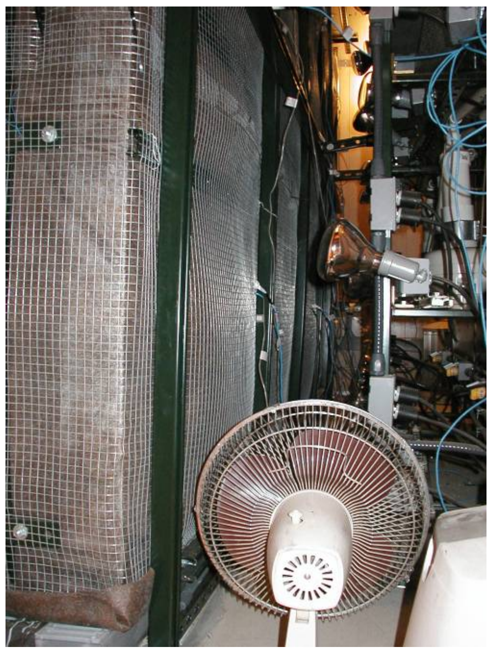


Figure 2-13: Finished soil cage

Figure 2-11 shows the soil holding frame and wire mesh installation. The insulation and separation of soil with XPS boards is shown in Figure 2-12. Figure 2-12 shows the finished soil holding cage.

2.2.4 Construction of the specimens

The construction of the experimental wall specimens consisted of:

1. Construction of the wood frames.
2. Installation of the XPS thermal insulation boards on the frame to separate the boundaries.
3. Wrapping the insulated frame with waterproof self-adhered underlayment.
4. Building the CMU wall segments. Type S mortar was used and the CMU's were not grouted.
5. Construction of concrete form; the concrete was poured into the form; plain concrete was used
6. 9.5mm (3/8 in) white base stucco was applied on the CMU's and concrete specimens
7. Insulation materials were applied to the specimens; thickness of at least 50.8mm (2")
8. The specimens with the interior insulation were finished; drywall 9.5mm (3/8") (unfinished) was fastened through four dowel-joints at each specimen.
9. Soil holding cage was constructed using metal U-type profile and bolted joints; drainage channel was installed to drain the excessive water; parged and exterior insulated test specimens (such as section A) were covered with permeable garden fabric to prevent sensor damage.
10. The garden fabric was stapled and attached to the wire mesh to hold the soil in place.
11. During installing the soil into the cage, insulation and separation of soil was achieved by inserting XPS boards between the test specimens.
12. The wetting system was installed before the third test cycle to achieve saturated soil conditions.

2.2.5 Instrumentation and data acquisition system

Four parameters were measured and recorded during the test: (1) temperature, (2) relative humidity, (3) condensation, and (4) pressure difference. Table 2-5 summarizes the instrumentation used in the experiments.

Of the properties monitored, only temperature, relative humidity, and pressure difference were measured directly. The moisture content of the CMU's was determined indirectly through the equilibrium relative humidity measurements. A relative humidity vs. moisture content curve was developed and the moisture content was calculated. Condensation was detected through a custom built sensor that functioned as a switch. Condensation was not quantified, only the presence or absence of condensation was determined.

Table 2-5: Instrumentation

Parameter	Location	Sensor Type	Manufacturer & model number	Comments
Temperature	Soil	Thermistor	Fenwall 192-103LEW-A01	10k Ohms at 25 degC see Figure 68 pc.
	Exterior side of the wall			
	[1]Wall			
	Drywall			
	Interior side of the wall			
	Environment	Relative humidity a temperature transmitter	Vaisala HMW40Y	see Figure 1 pc.
	Room	Relative humidity a temperature transmitter	Vaisala HMP233	see Figure 1 pc.
Relative Humidity	Soil	R.H. sensor	Honeywell HIH-3610	see Figure 32 pc.
	[1]Wall			
	Environment	Relative humidity a temperature transmitter	Vaisala HMW40Y	1 pc.
	Room	Relative humidity a temperature transmitter	Vaisala HMP233	1 pc.
Equilibrium Relative Humidity	Inside wall cavity	R.H. sensor	Honeywell HIH-3610	18 pc.
Condensation	[1]Wall	Condensation Gages	BeTL	9 pc.
Pressure difference	Environmental / Climate Side	Differential Pressure Transmitter	Omega PX274-30DI	1 pc.

[1] location on the wall – beneath the insulation

Figure 2-14 shows the configuration of specimens and the instrumentation setup. A better view of the instrumentation is shown in Figure 2-15.

Figure 2-14: Configuration of the specimens

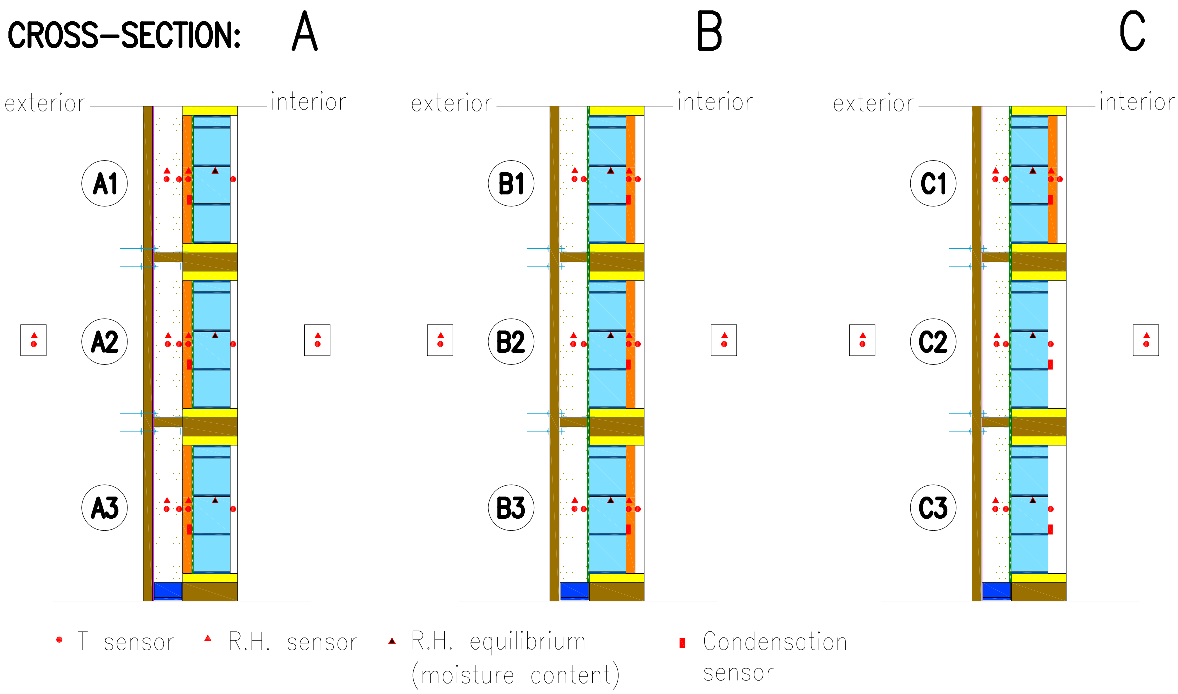
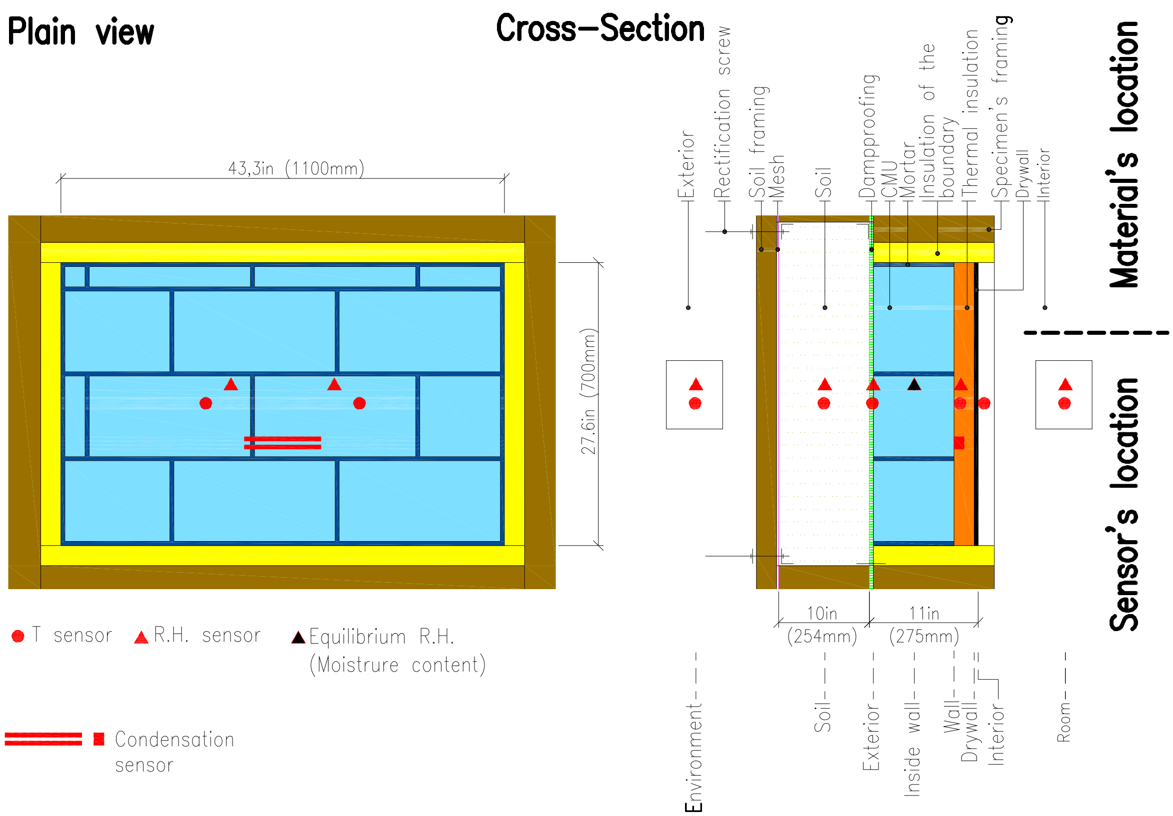


Figure 2-15: Schematic of the test segment and instrumentation



Temperature measurement

Surface and air temperatures were measured with Uni-Curve series interchangeable thermistors. The thermistors did not require individual resistance temperature calibration. The Resistance – Temperature measurement calibration curve is expressed by the following formula:

$$T_i = -0.101(\ln(R_i))^3 + 4.346(\ln(R_i))^2 - 77.18(\ln(R_i)) + 446.05 \qquad (°C) \qquad (1)$$

Temperature measurements were conducted on the NI Field Points (A110, A111 – mentioned below) where the first channel was used to measure the current across the fixed resistance (R_0 = 10kΩ) with a precision of 1%. The applied voltage is:

$$V_s = I_0 / R_0 \qquad (V) \qquad (2)$$

The temperature of the remaining channels was calculated via the measured fixed resistance R_0 and the resistance induced by temperature difference R_T.

$$R_i = R_0 + R_T \qquad (\Omega) \qquad (3)$$

Relative Humidity (or Water Vapor Pressure) measurement

The relative humidity was measured using commercial multi-layer construction capacitance relative humidity sensor. The used RH sensor is a laser trimmed thermoset polymer capacitive sensing element with on-chip integrated signal conditioning. Direct input to a controller (A110 – mentioned below) is done via linear voltage output of the sensor. RH is calculated via linear expression of the voltage output in the form of:

$$RH = (V_{out} - \text{zero offset}) / \text{slope} \qquad (\%) \qquad (4)$$

To prevent sensor damage and erroneous readings caused by water contact, the RH probes were inserted into a perforated plastic tube for measuring RH between the individual layers. Similarly, RH probes inserted into a perforated plastic tube with a larger diameter and wrapped in a permeable garden fabric were used to measure the Equilibrium RH (discussed next) of soil. The tubes were inserted into the soil with a small slope to avoid direct contact of the probe with water.

Equilibrium Relative Humidity (Moisture Content) measurement

As we will discuss in later sections, the moisture storage characteristics of the CMU's and concrete have a significant impact on thermal properties of materials (such as conductivity and heat storage). In order to characterize the disposition of moisture in the CMU and concrete walls, the moisture stored in those layers must be quantified. The most logical way of quantifying the amount of moisture stored in the CMU and concrete layers is the average moisture content. However, no commercially available hardware was found to have this capability. A number of sensors (mostly resistance-based) and moisture meters are available, but lack the necessary sensitivity or are not economical choices for long-term monitoring of moisture content. Therefore, an alternative method is required.

A relative humidity sensor was used to measure the moisture content of the CMU's and concrete. A ¾ in (19.05 mm) hole was drilled into the center of CMU and concrete walls and relative humidity sensor was inserted into the cavity to measure the equilibrium relative humidity. The hole around the protruded wiring was sealed with a silicone-based sealant.

To quantify the moisture content of the test wall assemblies it was necessary to develop the RH – Moisture Content curves (sorption and desorption isotherms). Thus, the moisture content was calculated from the established RH-MC isotherms and potential hysteresis was ignored.

Condensation measurement

Two copper conductors, separated by a 1-2 mm gap, were installed on each of the wall surface. A 5V DC excitation was applied across these terminals and the voltage drop was measured. Dry conditions (no condensation) were indicated by a zero reading and condensation was indicated by a positive reading.

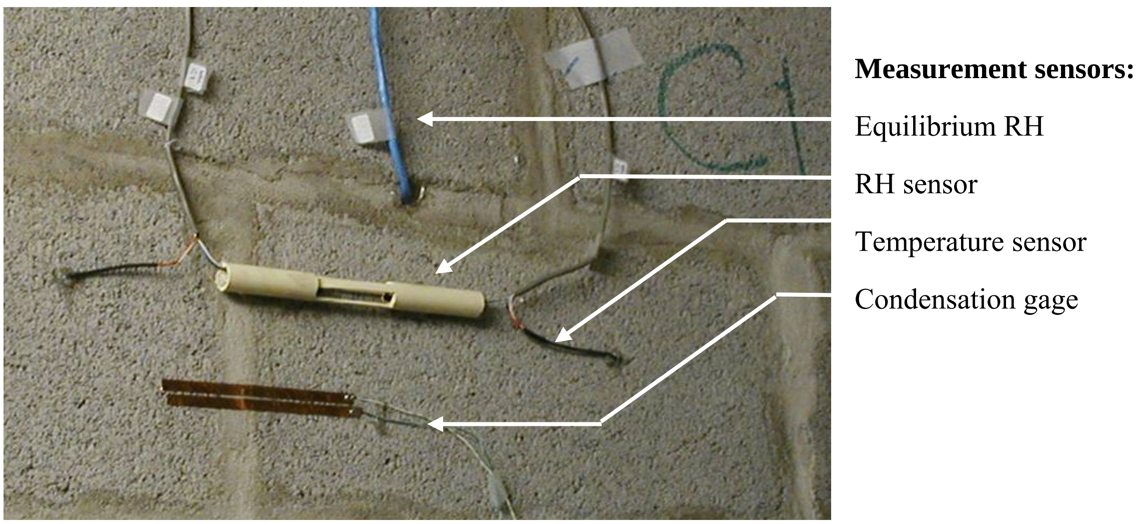


Figure 2-16: Sensors used in the measurement

2.2.6 Instrumentation and data acquisition system

The NI (National Instruments) FieldPoint system and LabVIEW 7.1 were used as the data acquisition hardware and software for the climate chamber tests. The FieldPoint distributed I/O system is a modular data acquisition system for automatic measurement and process control. The modules used in the project were as follows:

FP – 1000/1001

The National Instruments FP-1000/1001 is a network interface module for the FieldPoint I/O system. Each NI FP-1000/1001 connects a node of up to nine FieldPoint I/O modules to an RS-232 or RS-485 network. A FieldPoint network can consist of up to 25 network nodes, for a total of 225 FieldPoint I/O modules. The NI FP-1000/1001 network module manages communications between the host PC and the I/O modules via a local high-speed bus formed by FieldPoint terminal bases. The network module also provides several diagnostic and auto-configuration features, simplifying installation, use, and maintenance. FieldPoint Explorer and server software are included with RS-232/RS-485 FieldPoint systems. These software tools save the basic configuration information of the system and communicate with the application software.

FP-DO-410

The FP-DO-410 module has eight discrete sourcing output channels individually protected from overload conditions with an electronic resettable fuse. The module is designed to have input-output isolation, HotPnP (plug and play) operation, and onboard diagnostics. The main reason for including FP-DO-410 is to power the input modules.

FP-AO-200/210

The NI FP-AO-200 series consists of versatile analog output modules for the FieldPoint I/O system. The FP-AO-200 is an 8-channel analog output module for 4 to 20 mA and 0 to 20 mA current loops while FP-AO-210 is an 8-channel analog voltage output module (0 to 10 V, up to 10 mA per channel). The modules include open-circuit detection for wiring and sensor troubleshooting and short-circuit protection for wiring errors. Both of them incorporate overranging protection, HotPnP (plug and play) operation, and onboard diagnostics to protect the modules. These modules were used in the test to control the equipment in the climate chamber.

FP-AI-110/111

The NI FP-AI-100 series consists of versatile analog input modules for the FieldPoint I/O system. The FP-AI-110 and FP-AI-111 feature 16-bit, filtered low-noise inputs. The FP-AI-110 is an 8-channel single-ended input module for direct measurement of millivolt, low voltage, or milliampere signals from a variety of sensors and transmitters while FP-AI-111 is a 16-channel input module for direct measurement of milliamp current signals from a variety of sensors and transmitters. Both of them incorporate overranging protection, HotPnP (plug and play) operation, and onboard diagnostics to protect the modules. These modules were used in the test to read the sensor measurements.

Figure 2.17 and Figure 2.18 show the configuration of the FieldPoint system, including the communication with the computer.

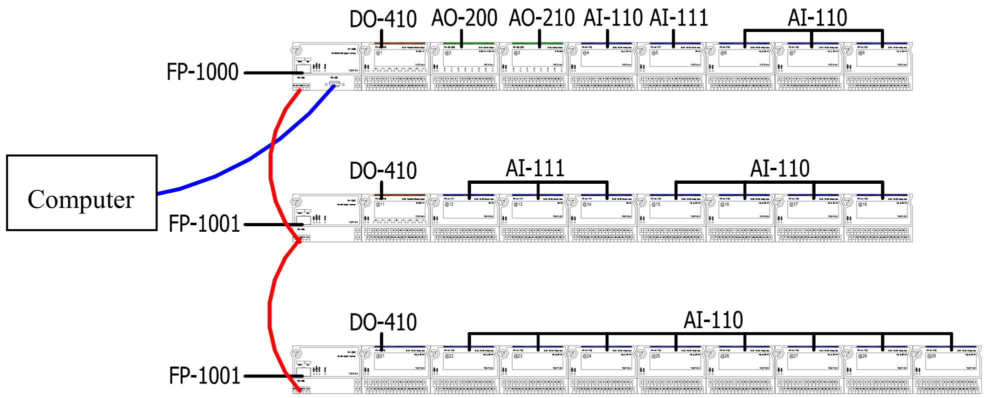


Figure 2-17: Schematic of the data acquisition system

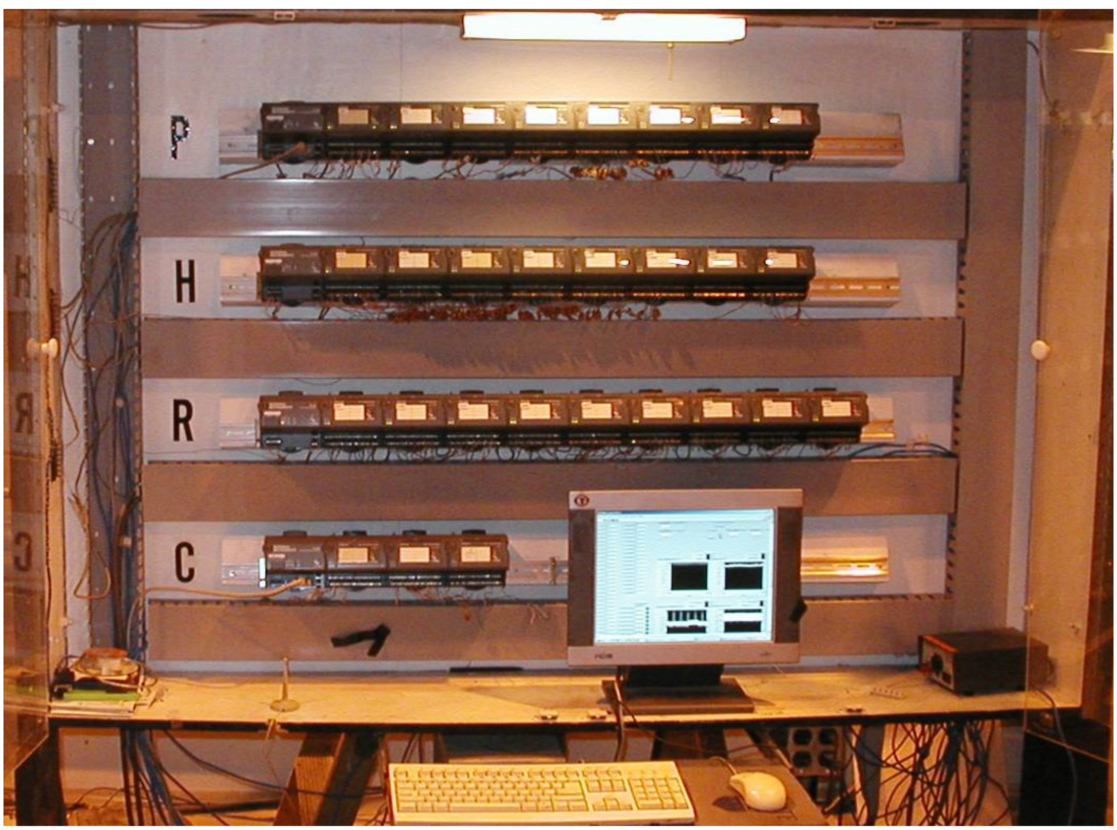


Figure 2-18: Data acquisition system at BeTL

2.3 Testing procedure

The nine wall test specimens were constructed, instrumented, and completely installed prior to the start of testing. The procedure for each test was as follows:

1. Make sure to reach the desired soil condition before the measurement. For the first and second test cycle use the dry-up program to remove water from the soil. For the third and fourth cycle wet the soil to attain saturated soil conditions (add 4 gal. of water to each specimen; check the soil condition by using a gravimetric test)

2. After setting up the specimens turn on the HVAC equipment and set the control parameters according to the proposed settings in Table 2-2 and 2-3. To minimize fluctuations in temperature and RH set the control loop to 1 - 2 min. (60 to 30 time reaction time during an hour)

3. When measuring the cold climate variations hold the ambient air temperature above 3 °C to prevent freezing and to ensure the soil temperature around 5 °C.

4. Allow achieving steady-state conditions and minimize fluctuations, if any.

5. Measure and record the temperature, relative humidity, equilibrium relative humidity, pressure difference, and condensation sensors every 6 minutes until the end of the test (10 measurements during an hour).

6. Evaluate only the latest results, i.e. the last 24 hours of the measurement.

3. Boundary conditions

Steady-state conditions were maintained during the tests. During the experiment the focus was kept on moisture accumulation at the interface of two physically different materials (such as CMU and insulation material).

3.1.1 Boundary conditions on the interior side

The interior temperature was set equally to 20 °C (68 °F) for all tests. The RH was set to either 30 % or 60 %, which represented relatively dry (30%) and humid (60%) conditions. The test setups are shown in Table 2-2 and 2-3 in detail.

3.1.2 Boundary conditions on the exterior side

The exterior boundary conditions were ambient air temperature and relative humidity. The temperature for all four test cycles was either 5 °C (41 °F) representing cold climate or 20 °C (68 °F) representing mild climate. According to the Table 2-2, the RH setup for the first and second cycle included three different values: 50 %, 70 % (for cold climate), and >95 %. Since the first and second test runs did not show any significant influence of the RH difference and the soil in the third and fourth test run was fully saturated, the RH was maintained at a constant level of >95 % (see Table 2-3).

Figure 3-1 shows an example of controlling the interior and exterior boundary conditions.

The boundary conditions were controlled with a precision of ±1 °C for temperature and ±5 % for RH. The peak values of exterior temperature were achieved by defrost cycles during the cold climate. Controlling the exterior relative humidity was difficult due to the high RH values (>95 %). The fluctuations of RH depend on the temperature profile and RH sensor delay. In the third and fourth test runs, the relative humidity was reaching lower values because the soil was wetted through the tubular wetting system. The ambient air RH values were slightly lower to avoid excessive moisture absorption through the exterior side of the chiller and freezer.

When the difference between exterior and interior relative humidities was high, additional dehumidification equipment was required to maintain low RH on the interior.

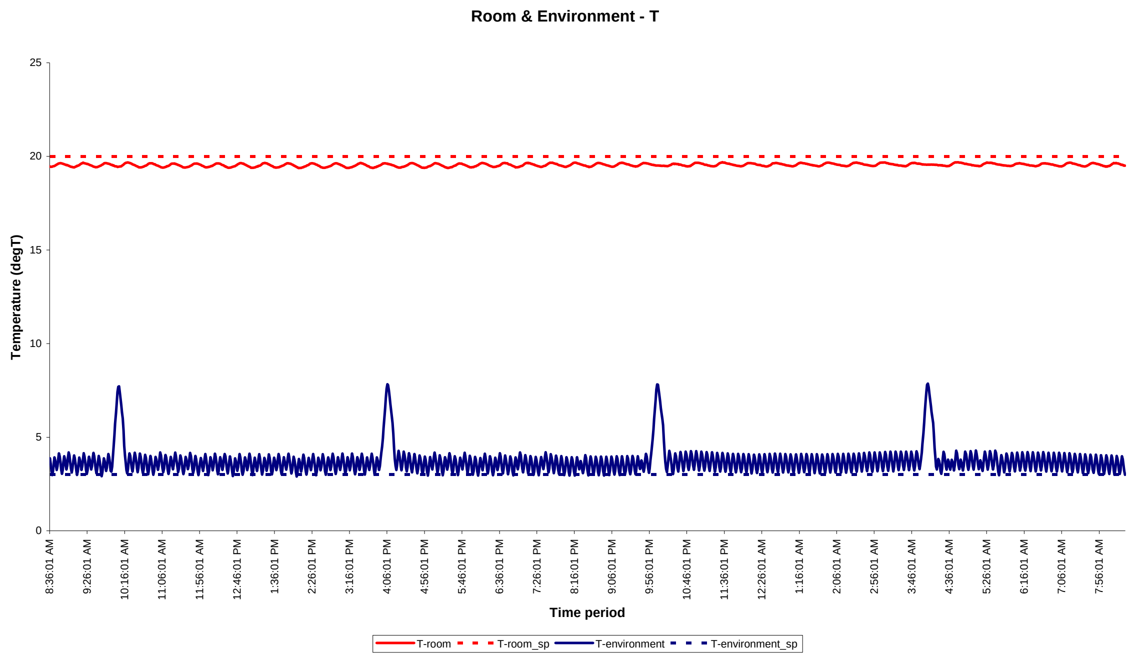


Figure 3-1: Example of temperature control

Figure 3-2: Example of RH control

3.1.3 Material properties

The hygro-thermal properties of materials used in test wall specimens are shown below (Table 3-1). The data from available literature was used to minimize the experimental costs. Ideally, one would like to measure all relevant physical properties in the laboratory to minimize the errors due to inherent material variability.

Table 3-1: Thermal properties of used materials

Specimen	Layer	Thickness		Conductivity "k"	Conductance "C"	Thermal Resistance "R"	
		(inch)	(mm)	(W/(m.K))	(W/(m^2.K))	(m^2K/W)	($ft^2h°F$/Btu)
A1	Extruded Polystyrene	2	50.8	0.0289	0.57	1.758	9.987
	* Damp-proofing	0	1.6	-	-	-	-
	Parging	3/8	9.5	0.7200	75.59	0.013	0.075
	Concrete Masonry Unit	8	203.2	-	2.58	0.388	2.202
	Gypsum Board	3/8	9.5	0.1680	17.64	0.057	0.322
	Total					**2.335**	**13.269**
A2	Polyisocyanurate	2	50.8	0.0222	0.44	2.288	13.002
	* Damp-proofing	0	1.6	-	-	-	-
	Parging	3/8	9.5	0.7200	75.59	0.013	0.075
	Concrete Masonry Unit	8	203.2	-	2.58	0.388	2.202
	Gypsum Board	3/8	9.5	0.1680	17.64	0.057	0.322
	Total					**2.866**	**16.283**
A3	Glass Fibre	2 1/4	57.2	0.0338	0.59	1.691	9.607
	* Damp-proofing	0	1.6	-	-	-	-
	Parging	3/8	9.5	0.7200	75.59	0.013	0.075
	Concrete Masonry Unit	8	203.2	-	2.58	0.388	2.202
	Gypsum Board	3/8	9.5	0.1680	17.64	0.057	0.322
	Total					**2.268**	**12.888**
B1	* Damp-proofing	0	1.6	-	-	-	-
	Parging	3/8	9.5	0.7200	75.59	0.013	0.075
	Concrete Masonry Unit	8	203.2	-	2.58	0.388	2.202
	Extruded Polystyrene	2	50.8	0.0289	0.57	1.758	9.987
	Gypsum Board	3/8	9.5	0.1680	17.64	0.057	0.322
	Total					**2.335**	**13.269**

* Damp-proofing is applied only in the third and fourth test cycle

Table 3-1: Thermal properties of used materials (continued)

Specimen	Layer	Thickness		Conductivity "k"	Conductance "C"	Thermal Resistance "R"	
		(inch)	(mm)	(W/(m.K))	(W/(m^2.K))	(m^{2}K/W)	(ft^{2}h°F/Btu)
B2	* Damp-proofing	0	1.6	-	-	-	-
	Parging	3/8	9.5	0.7200	75.59	0.013	0.075
	Concrete Masonry Unit	8	203.2	-	2.58	0.388	2.202
	Polyisocyanurate	2	50.8	0.0222	0.44	2.288	13.002
	Gypsum Board	3/8	9.5	0.1680	17.64	0.057	0.322
	Total					**2.866**	**16.283**
B3	* Damp-proofing	0	1.6	-	-	-	-
	Parging	3/8	9.5	0.7200	75.59	0.013	0.075
	Concrete Masonry Unit	8	203.2	-	2.58	0.388	2.202
	Glass Fibre	2 1/4	57.2	0.0338	0.59	1.691	9.607
	Gypsum Board	3/8	9.5	0.1680	17.64	0.057	0.322
	Total					**2.268**	**12.888**
C1	* Damp-proofing	0	1.6	-	-	-	-
	Parging	3/8	9.5	0.7200	75.59	0.013	0.075
	Concrete Masonry Unit	8	203.2	-	2.58	0.388	2.202
	Expanded Polystyrene	2	50.8	0.0350	0.69	1.451	8.247
	Gypsum Board	3/8	9.5	0.1680	17.64	0.057	0.322
	Total					**2.029**	**11.528**
C2	* Damp-proofing	0	1.6	-	-	-	-
	Parging	3/8	9.5	0.7200	75.59	0.013	0.075
	Concrete Masonry Unit	8	203.2	-	2.58	0.388	2.202
	Total					**0.521**	**2.959**
C3	* Damp-proofing	0	1.6	-	-	-	-
	Parging	3/8	9.5	0.7200	75.59	0.013	0.075
	Concrete	8	203.2	2.0000	9.84	0.102	0.577
	Total					**0.235**	**1.334**

* Damp-proofing is applied only in the third and fourth test cycle

The R-value of each specimen is shown in Figure 3-3 in SI units and in Figure 3-4 in IP units. Thermal insulation corresponding to Pennsylvania requirements (10 ft^{2}h°F/Btu) was applied to seven specimens (test segments) (A1 to C1). The last two specimens were plain CMU and concrete structures without thermal insulation (C2 and C3) and served as controls.

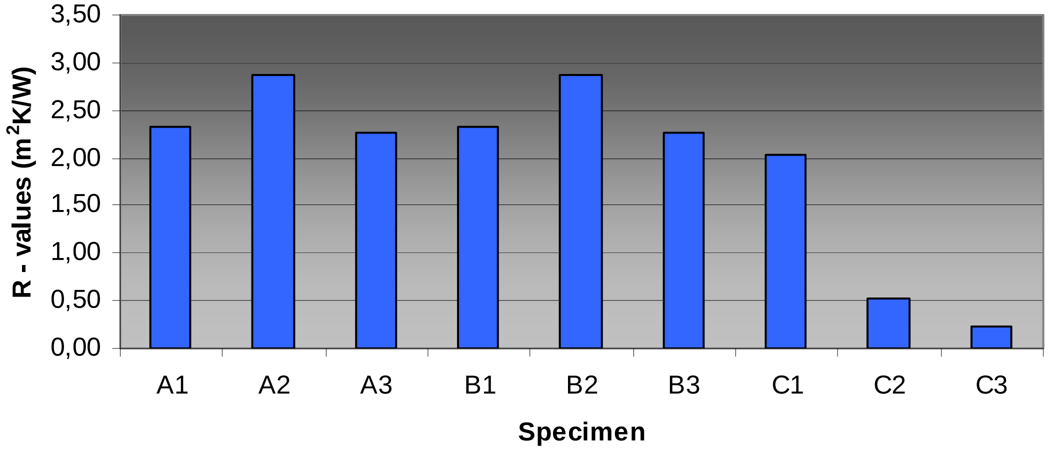


Figure 3-3: R – values used in specimens – SI units

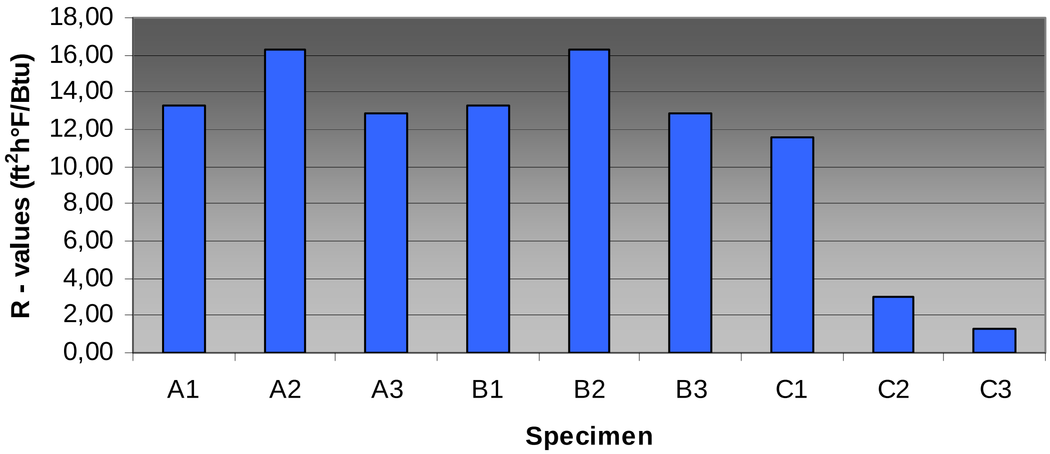


Figure -4: R – values used in specimens – IP units

For calculation of the water vapor diffusion through walls, moisture related physical properties were needed. The properties are listed in Table 3-2.

Table 3-2 Water vapor transmission data

Specimen	Layer	Permeability		Permeance "M"		Diffusion resistance (without coating) "Z"	Diffusion resist. (with coating) "Z"
		(ng/s.m.Pa)	(perm.inch)	($ng/s.m^2.Pa$)	(perm)	($Pa.m^2.s/ng$)	($Pa.m^2.s/ng$)
A1	Extruded Polystyrene	1.605	1.100	31.598	0.550	0.0316	0.0316
	* Damp-proofing	0.013	0.009	8.043	0.140	-	0.1243
	Parging	-	-	333.210	5.800	0.0030	0.0030
	Concrete Masonry Unit	-	-	137.880	2.400	0.0073	0.0073
	Gypsum Board	-	-	2872.500	50.000	0.0003	0.0003
	Total					**0.0424**	**0.1667**
A2	Polyisocyanurate	5.107	3.500	100.538	1.750	0.0099	0.0099
	* Damp-proofing	0.013	0.009	8.043	0.140	-	0.1243
	Parging	-	-	333.210	5.800	0.0030	0.0030
	Concrete Masonry Unit	-	-	137.880	2.400	0.0073	0.0073
	Gypsum Board	-	-	2872.500	50.000	0.0003	0.0003
	Total					**0.0207**	**0.1450**
A3	Glass Fibre	175.108	120.000	3064.000	53.333	0.0003	0.0003
	* Damp-proofing	0.013	0.009	8.043	0.140	-	0.1243
	Parging	-	-	333.210	5.800	0.0030	0.0030
	Concrete Masonry Unit	-	-	137.880	2.400	0.0073	0.0073
	Gypsum Board	-	-	2872.500	50.000	0.0003	0.0003
	Total					**0.0110**	**0.1354**
B1	* Damp-proofing	0.013	0.009	8.043	0.140	-	0.1243
	Parging	-	-	333.210	5.800	0.0030	0.0030
	Concrete Masonry Unit	-	-	137.880	2.400	0.0073	0.0073
	Extruded Polystyrene	1.605	1.100	31.598	0.550	0.0316	0.0316
	Gypsum Board	-	-	2872.500	50.000	0.0003	0.0003
	Total					**0.0424**	**0.1667**

* Damp-proofing is applied only in the third and fourth test cycle

Table 3-2: Water vapor transmission data (continued)

Specimen	Layer	Permeability		Permeance "M"		Diffusion resistance (without coating) "Z"	Diffusion resist. (with coating) "Z"
		(ng/s.m.Pa)	(perm.inch)	(ng/s.m^2.Pa)	(perm)	(Pa.m^2.s/ng)	(Pa.m^2.s/ng)
B2	* Damp-proofing	0.013	0.009	8.043	0.140	-	0.1243
	Parging	-	-	333.210	5.800	0.0030	0.0030
	Concrete Masonry Unit	-	-	137.880	2.400	0.0073	0.0073
	Polyisocyanurate	5.107	3.500	100.538	1.750	0.0099	0.0099
	Gypsum Board	-	-	2872.500	50.000	0.0003	0.0003
	Total					**0.0207**	**0.1450**
B3	* Damp-proofing	0.013	0.009	8.043	0.140	-	0.1243
	Parging	-	-	333.210	5.800	0.0030	0.0030
	Concrete Masonry Unit	-	-	137.880	2.400	0.0073	0.0073
	Glass Fibre	175.108	120.000	3064.000	53.333	0.0003	0.0003
	Gypsum Board	-	-	2872.500	50.000	0.0003	0.0003
	Total					**0.0110**	**0.1354**
C1	* Damp-proofing	0.013	0.009	8.043	0.140	-	0.1243
	Parging	-	-	333.210	5.800	0.0030	0.0030
	Concrete Masonry Unit	-	-	137.880	2.400	0.0073	0.0073
	Expanded Polystyrene	7.296	5.000	143.625	2.500	0.0070	0.0070
	Gypsum Board	-	-	2872.500	50.000	0.0003	0.0003
	Total					**0.0177**	**0.1420**
C2	* Damp-proofing	0.013	0.009	8.043	0.140	-	0.1243
	Parging	-	-	333.210	5.800	0.0030	0.0030
	Concrete Masonry Unit	-	-	137.880	2.400	0.0073	0.0073
	Total					**0.0104**	**0.1347**
C3	* Damp-proofing	0.013	0.009	8.043	0.140	-	0.1243
	Parging	-	-	333.210	5.800	0.0030	0.0030
	Concrete	4.670	3.200	22.980	0.400	0.0435	0.0435
	Total					**0.0466**	**0.1710**

* Damp-proofing is applied only in the third and fourth test cycle

The interior air film resistance was taken for a vertical surface position with horizontal direction of heat flow, according to the ASHRAE Handbook. This represented an R-value of 0.12 m^{2}K/W. Similarly, the permeance of air film of 9200 ng/(s.m^{2}Pa) was used. Permeance of the air film is very large compared of other materials used in the system and therefore does not affect the results significantly.

4. Determination of moisture content

The moisture content of materials was determined using equilibrium RH measurements.

4.1 Soil characteristics

Soil contains solid particles such as sand, silt, and clay and voids or pores. The pores contain air and water. Void or pore volume, which contains air and water, ranges from about 30 % in sand to about 50 % in clay of the total volume of soil. Clay has more pore volume than sand but the pores are smaller because of the smaller particle sizes of clay. Sand has larger pore sizes because of larger particle sizes. Both pore volume and pore size play major roles in water movement and the water retention or water-holding capacity of soil.

Saturated soil has pores completely filled with water but in reality, complete saturation does not occur because some entrapped air exists in saturated soil. No air can flow through the soil. Unsaturated soil has pores partially filled with water so that air can flow through the soil.

4.2 Characteristics of wall assemblies

Regular 8 in thick concrete-masonry units were used and bonded by S-type regular mortar and parged with base white stucco. The moisture content of such wall assembly varies according to water vapor transmission properties of individual material. Therefore, sorption isotherms were determined for each of the wall components.

4.3 Measurement of sorption isotherms

The relative humidity of soils and wall components at equilibrium steady-state were measured in the small environmental chamber. The properties of soil were measured directly and the wall assembly RH was measured in the CMU cavity. As mentioned above the wall assembly contained three different materials. Therefore, the sorption isotherms were measured for each material and the sorption isotherm for the wall assembly was calculated based on its component properties.

The sorption isotherms were developed for the test conditions representing 10°C and 20°C (aproximate temperatures in the middle of the wall).

Separate sorption isotherm data were obtained for materials initially dry and for materials initially saturated (desorption isotherm). The moisture content of all materials was measured gravimetrically. ThermoForma 3911 shown in the figure 4-1 and Watflow series 988 controller were used in the test. Each temperature and water vapor setting was held constant for 5 days prior taking the measurements.

Figure 4-1: ThermoForma 3911 environmental chamber

Prior to the test each sample was dried at 100 °C to obtain the dry weight. The following formulas were used to calculate the moisture content and the bulk density of each material:

1. Gravimetric moisture content:

   $GMC = ((W_w - W_d) / W_d) \cdot 100$ (%) (5)

   W_w = weight of the wet material

   W_w = weight of the dry material (g, kg)

2. Bulk density:

   $BD = W_d / V_s$ (kg/m^3) (6)

   V_s –=volume of the soil sample (m^3)

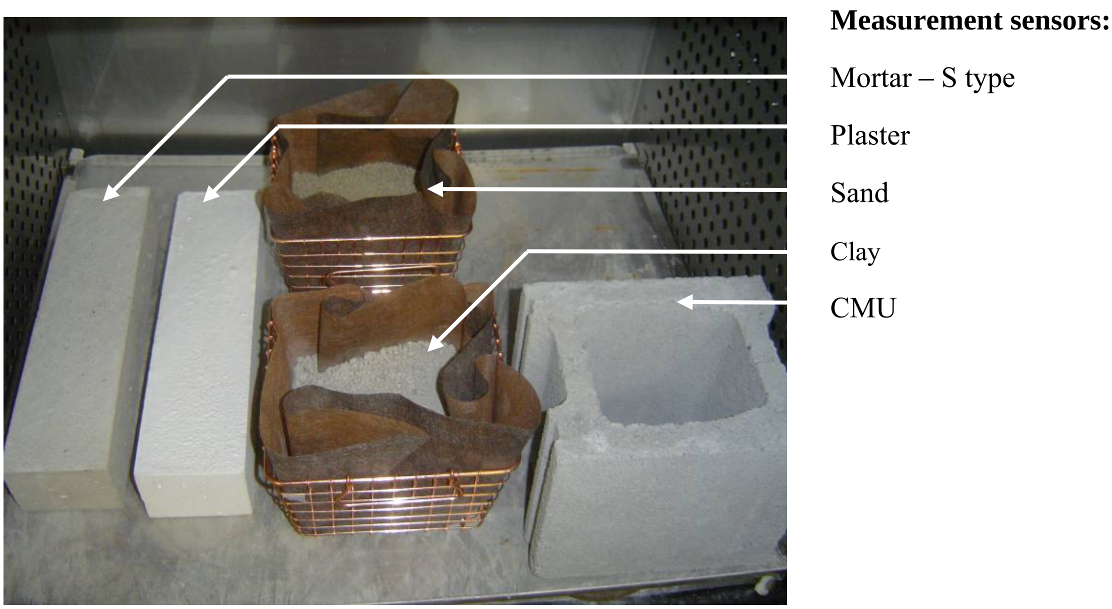


Figure 4-2: Specimens used in sorption isotherm tests

Figure 4-2 shows the sorption isotherm test specimens. The sand and clay was put into a basket. To hold the soil in basket was lined with permeable fabric. ½ of the CMU unit was used to minimize the test time.

Figure 4-3 shows the sorption and desorption isotherms at 10 °C (50 °F) for each tested material. Dry samples were subjected to increased 50% RH and the RH was increased in 10% steps until the upper RH limit (about 99%) was reached. Then the RH in the chamber was stepwise reduced (again in decrements of 10%) until 50% RH was reached. At each step (5 days/step) specimens were weighed.

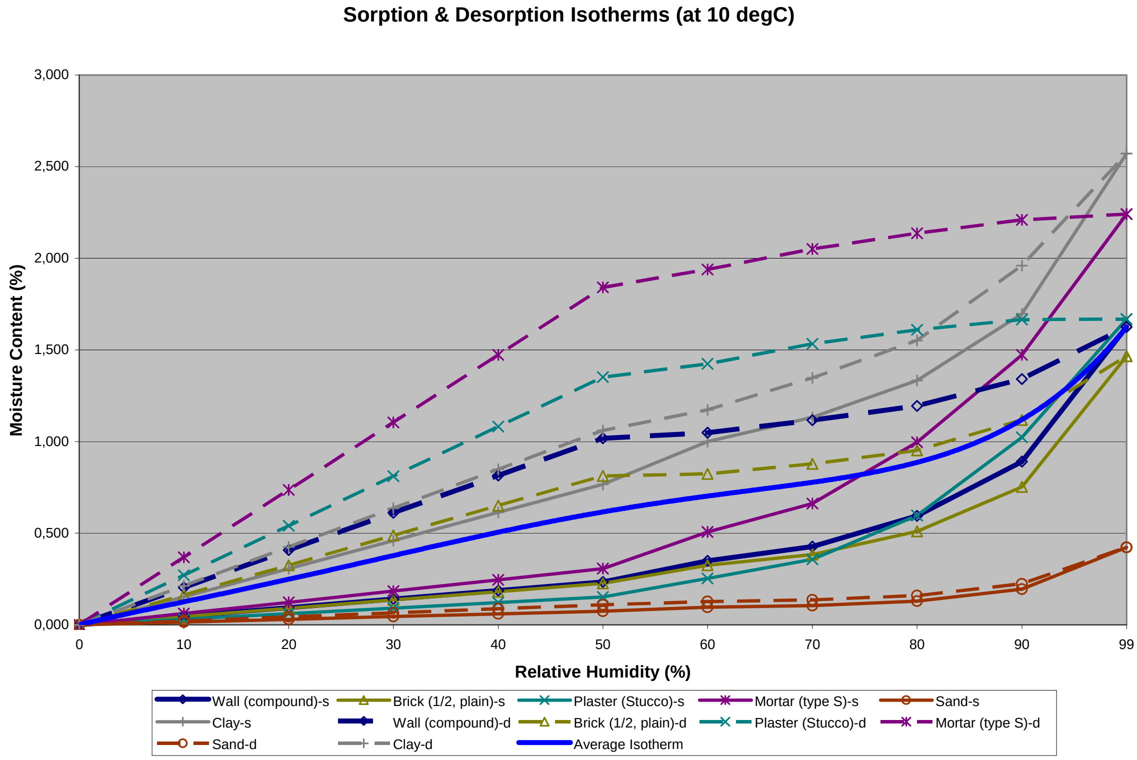


Figure 4-3: Sorption and desorption isotherms at 10 °C (50 °F)

Figure 4-4 shows sorption and desorption isotherms at 20 °C (68 °F) for individual materials. Calculated properties of the wall assembly are also shown. The bold red (10 °C; figure 4-2) and blue (20 °C; figure 4-2) isotherms show moisture content of parged wall without hysteresis. Regression equations can be used to estimate the overall moisture contents of the wall (note that the formula applies to this test assembly only):

1. MC-RH curve for 10 °C (50 °F) is expressed by a following polynomial function:

   $MC_{10} = 10.614x^5 - 18.242x^4 + 9.8522x^3 - 1.9674x^2 + 1.369x + 9E\text{-}05$

   x is the measured level of RH (-)

2. MC-RH curve for 20 °C (68 °F) is expressed by a following polynomial function:

   $MC_{20} = 29.634x^5 - 53.202x^4 + 29.963x^3 - 6.3596x^2 + 2.6556x - 0.0007$

For example, at 100 % of RH and 10 °C the MC of the parged wall is 1.63 % of its dry weight. At about 100 % of RH and 20 °C the MC of the parged wall is 2.69 %.

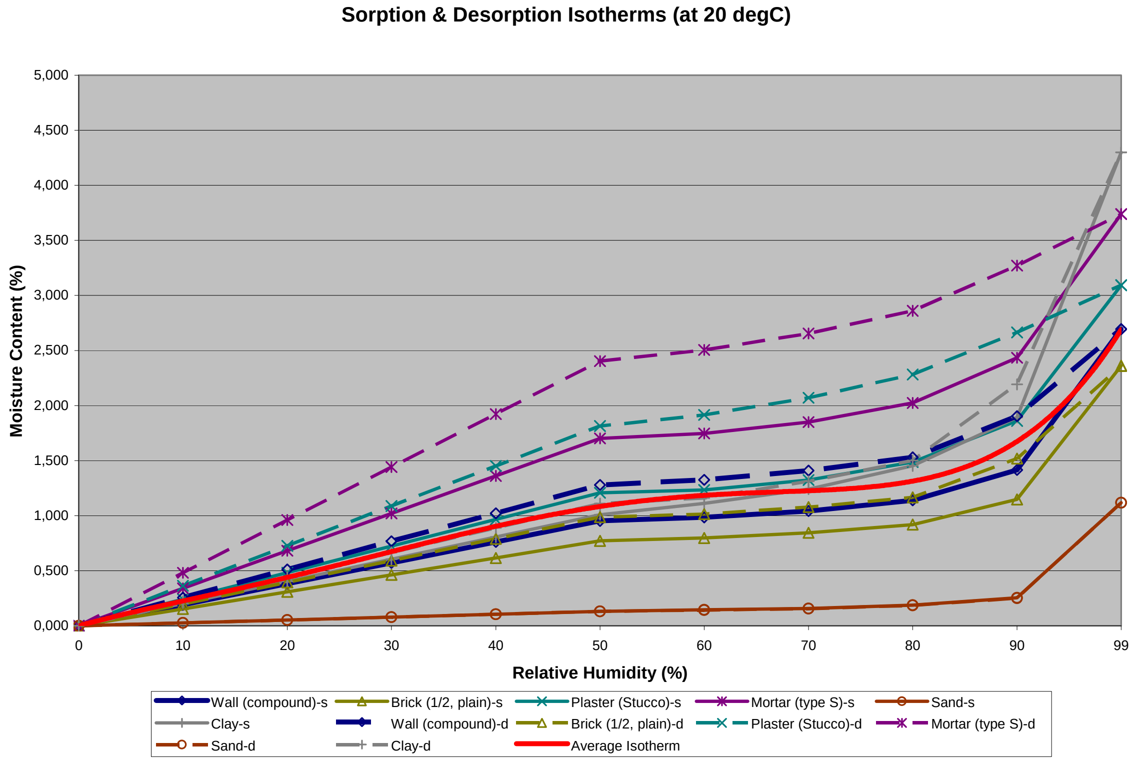


Figure 4-4: Sorption isotherms at 20 °C (68 °F)

From Figures 4-3 and 4-4 it is evident that the lower moisture content is attained by sand compared to clay.

5. Experimental results

The experiments yielded large volume of data and individual results are in the Appendix. The impact of soil, environmental parameters, position of the insulation layer, damp-proofing, sorption and desorption of wall assemblies on wall performance are discussed below. The test cycles and setup are discussed in Chapter 2.

The accuracy of the results was influenced by the following factors:

1. Material properties from manufacturer technical data sheets were used.

2. Finite time was used to declare steady state conditions (steady-state conditions are approached asymptotically and relatively long times are required to achieve them).

3. Significant time to dry the wall assembly is required. In the experiments, this time was kept to a minimum (again, steady-state is reached asymptotically).

4. HVAC equipment was producing suction or overpressure during interior/exterior side conditioning.

5.1 Soil

Soil thermal properties are difficult to measure in the field because soil temperatures are in a constant state of flux from diurnal and seasonal variations. Temperature variations are most extreme at the surface of the soil and these variations are transferred to sub-surface layers at reduced rates as depth increases. Additionally there is a time delay when maximum and minimum temperatures are achieved at increasing soil depth (referred to as thermal lag). To better understand the impact of soil on below-grade walls, our measurements were focusing only on thermal and moisture effects during steady state conditions.

Thermal properties of soils are influenced by soil volumetric water content, volume fraction of solids, and volume fraction of air. Air is a poor thermal conductor and reduces the effectiveness of solid and liquid phases to conduct heat. While the solid phase has the highest conductivity it is the variability of soil moisture that largely determines land temperatures. Soil moisture and thermal properties are closely linked and are often measured and reported together.

Our results indicate that at lower moisture contents the thermal properties of sand and clay are similar. At higher moisture and up to the saturation point, the thermal conductivity of sand is twice higher than the thermal conductivity of clay. This means that clay is a better thermal insulation material compared to sand at higher MC – see figures 5-1 and 5-2 and Appendix C. The measurements show a slight increase in temperature along the vertical axis.

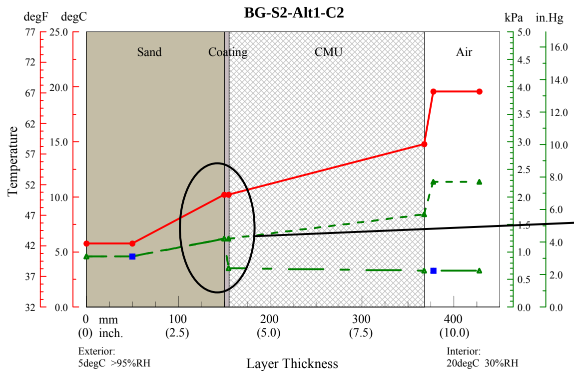


Figure 5-1: Wall diagram of S2-Alt1-C2 (sand – 3rd cycle, damp-proofing, T_i = 20°C (68°F), T_e = 5°C (41°F), RH_i = 30%, RH_e = 70%, uninsulated (plain) CMU structure)

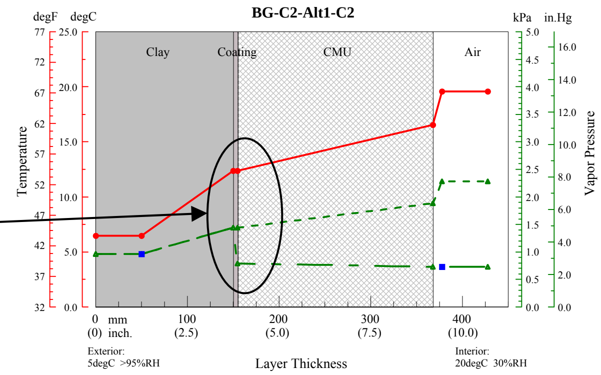


Figure 5-2: Wall diagram of C2-Alt1-C2 (clay – 3rd cycle, damp-proofing, T_i = 20°C (68°F), T_e = 5°C (41°F), RH_i = 30%, RH_e = 70%, uninsulated (plain) CMU structure)

Water can enter basement walls by capillary suction while in contact with wet soil. Clay soils can transfer large volumes of moisture through a basement wall by capillary suction. Installation of a capillary break between the soil and the basement wall will prevent capillary wetting of the structure. Free draining backfill, drainage boards, rigid insulation and especially water-proofing and damp-proofing (shown in figures 5-1 and 5-2) are effective capillary breaks. Soil moisture content was always at the full saturation value.

5.2 Wall components

Each wall component was evaluated using procedures presented in Chapter 2. Individual results are shown in the Appendix. Some of the major findings are summarized in Tables 5-1 to 5-4. According to research studies (ASHRAE Handbook, etc.[3]), surface relative humidity above 70 % is considered to represent a threshold for potential risk of mold growth (marked with green rectangles). The value of ±2 % of >97 % RH defines condensation beneath the insulation layer (marked with red rectangles).

5.2.1 S1 and C1-Alt1 (sand – 1st and clay – 2nd cycle, no damp-proofing, T_i = 20°C (68°F), T_e = 5°C (41°F), RH_i = 30%, RH_e = 70%)

Appendix C is shows that the wall assemblies with an exterior insulation (A1, A2, A3) performed significantly better compared to walls with interior insulation (B1, B2, B3, C1). Exterior insulation absorbs the temperature drop and allows higher interior surface temperature of the wall. The water vapor saturation pressure allows higher indoor RH. Moisture content of specimens was affected by placement of thermal insulation. For example, XPS could be used as a water-proofing layer against bulk water intrusion due to its low permeability. Drying to exterior that is present in cold climates and saturated soil in contact with the wall influences the interface beneath a thermal insulation. Because of the higher permeance of glass fiber, the specimen A3 has slightly higher moisture content compared to specimens insulated from the exterior. Permeable interior insulation allows interior moisture to migrate into the wall. This can only happen, however, of the relative water vapor pressure in the wall is lower then the relative water vapor pressure in the interior (this is the case in 5.2.2). Such a condition is rarely achieved under these circumstances (30 % of RH is maintained in interior) and unless a wall is wall protected in the exterior by a low-permeance material, moisture will migrate from exterior to interior. Plain walls (uninsulated) perform relatively well because they allow drying. The problem with plain walls involves high energy demand.

Thermal behavior of a wall is reflected by the overall R – values shown in Figures 3-3 and 3-4. The plain concrete wall has highest thermal conductivity followed by the plain CMU wall.

5.2.2 S1 and C1-Alt2 (sand – 1st and clay – 2nd cycle, no damp-proofing, T_i = 20°C (68°F), T_e = 5°C (41°F), RH_i = 60%, RH_e = 70%)

Performance of the walls is slightly different due to higher interior RH. Additional moisture introduced to the wall resulted in higher RH in the wall cavity (CMU). A higher value of RH is reached behind the exterior insulation while stopping the moisture transfer. XPS insulation inhibits the moisture entering the wall from interior and has reached lower RH values compared to other test setups (see Table 5-1 and 5-2). This is a consequence of otherwise prevailing influence of indoor R.H. (in this case blocked by low permeance XPS insulation) compared to low gravimetric and/or capillary forces in the soil (dry cycle of the soil preceded). Plain (uninsulated) walls have low condensation potential but will increase the moisture load in the interior dramatically if not equipped with reliable exterior water retarder (and water vapor barrier). If high permeance insulation (glass fiber) is applied from interior condensation can occur when humid air reaches a cold wall surface.

Table 5-1: Measurement results of S1

S1		A1		A2		A3		B1		B2		B3		C1		C2		C3	
		T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH
		(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)
S1-Alt-1	Soil	5,58	100,0	6,29	100,0	6,26	100,0	4,61	98,1	5,70	100,0	5,93	100,0	4,99	100,0	6,56	100,0	6,66	100,0
	*Wall	15,86	55,8	16,47	58,0	16,47	62,3	7,07	77,8	8,42	84,6	8,61	80,3	7,90	76,3				
	Room air	19,07	35,9	2,21	35,9	19,07	35,9	19,07	35,9	19,07	35,9	19,07	35,9	19,07	35,9	19,07	35,9	19,07	35,9
	Cavity		47,1		52,6		52,5		82,7		84,1		82,2		80,6		73,5		100,0
S1-Alt-2	Soil	5,39	100,0	6,08	100,0	6,09	100,0	4,36	91,8	5,49	100,0	5,76	100,0	4,78	99,9	6,50	100,0	6,78	100,0
	*Wall	15,66	55,9	16,30	58,9	16,32	62,3	6,96	82,9	8,12	96,6	8,67	99,8	7,74	90,3				
	Room air	19,02	60,8	2,20	60,8	19,02	60,8	19,02	60,8	19,02	60,8	19,02	60,8	19,02	60,8	19,02	60,8	19,02	60,8
	Cavity		50,4		59,1		58,6		85,6		86,6		84,7		83,1		77,6		100,0
S1-Alt-3	Soil	5,83	100,0	6,33	100,0	6,31	100,0	4,71	100,0	5,72	100,0	6,11	100,0	4,91	95,2	6,68	100,0	7,17	100,0
	*Wall	16,27	56,8	17,04	60,2	17,02	61,0	7,36	83,5	8,51	98,2	9,16	100,0	8,18	94,0				
	Room air	19,52	61,0	2,27	61,0	19,52	61,0	19,52	61,0	19,52	61,0	19,52	61,0	19,52	61,0	19,52	61,0	19,52	61,0
	Cavity		52,1		62,7		61,9		85,8		89,0		87,5		85,6		80,5		100,0
S1-Alt-4	Soil	5,69	100,0	6,43	100,0	6,59	100,0	4,40	99,4	5,55	100,0	5,88	100,0	4,35	100,0	6,29	100,0	6,75	100,0
	*Wall	15,74	56,7	16,77	60,4	16,78	62,4	6,85	78,8	8,13	96,7	8,33	94,3	7,10	86,9				
	Room air	19,49	33,7	2,27	33,7	19,49	33,7	19,49	33,7	19,49	33,7	19,49	33,7	19,49	33,7	19,49	33,7	19,49	33,7
	Cavity		46,5		59,5		58,8		84,6		90,1		89,5		86,6		79,3		100,0

Risk of condensation and potential mold growth

Condensing

Table -1: Measurement results of S1 (continued)

S1		A1		A2		A3		B1		B2		B3		C1		C2		C3	
		T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH
		(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)
S1-Alt-5	Soil	19,35	100,0	19,14	100,0	19,23	100,0	18,88	94,6	17,87	100,0	18,36	100,0	19,51	100,0	19,96	100,0	21,80	100,0
	*Wall	19,87	66,4	19,46	73,0	19,56	88,5	18,22	73,6	17,09	94,3	17,50	66,2	19,54	79,2				
	Room air	20,86	37,0	2,47	37,0	20,86	37,0	20,86	37,0	20,86	37,0	20,86	37,0	20,86	37,0	20,86	37,0	20,86	37,0
	Cavity		56,7		59,3		59,9		86,2		90,7		89,5		87,6		78,1		100,0
S1-Alt-6	Soil	19,58	98,5	19,43	100,0	19,43	100,0	19,83	94,7	19,18	100,0	19,49	100,0	20,40	100,0	20,22	100,0	21,65	100,0
	*Wall	20,17	71,4	19,79	77,5	19,93	86,4	19,80	79,8	19,33	90,8	19,42	70,2	20,60	76,4				
	Room air	20,53	56,8	2,42	56,8	20,53	56,8	20,53	56,8	20,53	56,8	20,53	56,8	20,53	56,8	20,53	56,8	20,53	56,8
	Cavity		59,7		62,0		64,4		86,3		91,2		88,2		87,6		79,5		100,0
S1-Alt-7	Soil	20,57	100,0	21,27	100,0	20,45	100,0	20,87	100,0	20,47	100,0	21,17	100,0	21,41	100,0	21,31	100,0	22,16	100,0
	*Wall	18,68	72,5	18,34	81,7	18,63	100,0	20,07	72,2	19,85	80,7	19,72	69,1	21,10	77,8				
	Room air	19,53	59,7	2,27	59,7	19,53	59,7	19,53	59,7	19,53	59,7	19,53	59,7	19,53	59,7	19,53	59,7	19,53	59,7
	Cavity		69,1		66,2		69,1		85,5		92,2		89,1		88,4		82,5		100,0
S1-Alt-8	Soil	20,32	100,0	20,09	100,0	20,06	100,0	19,68	100,0	20,17	100,0	20,49	100,0	20,50	100,0	20,43	100,0	22,87	100,0
	*Wall	19,51	74,4	19,00	81,5	19,23	100,0	20,29	57,6	20,03	73,1	20,13	43,2	20,81	69,0				
	Room air	19,47	32,4	2,26	32,4	19,47	32,4	19,47	32,4	19,47	32,4	19,47	32,4	19,47	32,4	19,47	32,4	19,47	32,4
	Cavity		67,3		63,2		67,0		81,8		88,6		86,6		89,0		80,6		100,0

Risk of condensation and potential mold growth (green box)

Condensing (red box)

Table -2: Measurement results of C1

C1		A1		A2		A3		B1		B2		B3		C1		C2		C3	
		T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH
		(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)
C1-Alt-1	Soil	5,27	100,0	6,11	100,0	6,71	100,0	4,85	100,0	6,07	100,0	7,11	100,0	5,89	100,0	7,27	100,0	7,07	100,0
	*Wall	16,70	55,1	17,72	57,4	17,71	67,5	7,88	70,1	11,41	74,1	12,29	57,3	9,15	69,3				
	Room air	19,54	30,2	2,27	30,2	19,54	30,2	19,54	30,2	19,54	30,2	19,54	30,2	19,54	30,2	19,54	30,2	19,54	30,2
	Cavity		42,6		53,7		59,6		75,3		88,1		80,7		82,0		70,9		99,6
C1-Alt-2	Soil	5,45	100,0	6,06	100,0	6,55	100,0	4,96	100,0	5,82	100,0	6,84	100,0	5,86	100,0	7,23	100,0	7,04	100,0
	*Wall	16,56	54,6	17,44	55,7	17,48	65,5	7,79	76,4	10,51	91,6	11,82	92,6	9,08	84,7				
	Room air	19,50	57,9	2,27	57,9	19,50	57,9	19,50	57,9	19,50	57,9	19,50	57,9	19,50	57,9	19,50	57,9	19,50	57,9
	Cavity		52,1		57,7		61,6		76,6		89,0		83,2		84,3		73,6		99,5
C1-Alt-3	Soil	6,10	100,0	6,54	100,0	6,84	100,0	5,89	100,0	6,09	100,0	7,04	100,0	5,91	100,0	7,19	100,0	6,88	100,0
	*Wall	16,66	56,7	17,47	57,2	17,49	65,2	8,09	79,1	10,43	97,1	11,59	97,6	9,07	89,5				
	Room air	19,50	58,2	2,27	58,2	19,50	58,2	19,50	58,2	19,50	58,2	19,50	58,2	19,50	58,2	19,50	58,2	19,50	58,2
	Cavity		56,8		61,0		63,4		80,7		91,0		86,7		86,8		76,3		99,7
C1-Alt-4	Soil	6,07	100,0	6,45	100,0	6,70	100,0	5,76	100,0	6,03	100,0	6,82	100,0	5,88	100,0	7,07	100,0	6,73	100,0
	*Wall	16,65	56,6	17,58	57,2	17,56	64,7	8,05	74,7	10,30	93,4	11,07	72,9	8,91	82,1				
	Room air	19,50	32,8	2,27	32,8	19,50	32,8	19,50	32,8	19,50	32,8	19,50	32,8	19,50	32,8	19,50	32,8	19,50	32,8
	Cavity		48,5		57,6		59,6		82,0		92,0		88,4		88,4		74,4		99,6

Risk of condensation and potential mold growth

Condensing

Table -2: Measurement results of C1 (continued)

C1		A1		A2		A3		B1		B2		B3		C1		C2		C3	
		T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH
		(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)
C1-Alt-5	Soil	18,34	100,0	18,60	100,0	18,75	100,0	18,14	100,0	17,93	100,0	18,51	99,8	18,04	100,0	18,69	100,0	21,69	100,0
	*Wall	18,73	66,8	18,58	75,2	18,69	98,4	18,15	66,7	17,41	87,3	17,77	44,6	18,36	66,3				
	Room air	19,51	27,8	2,27	27,8	19,51	27,8	19,51	27,8	19,51	27,8	19,51	27,8	19,51	27,8	19,51	27,8	19,51	27,8
	Cavity		55,4		56,5		60,0		81,8		92,0		84,4		88,5		73,1		100,0
C1-Alt-6	Soil	18,54	100,0	18,91	100,0	19,10	100,0	18,41	100,0	18,31	100,0	19,00	100,0	18,32	100,0	18,86	100,0	21,22	100,0
	*Wall	18,64	67,7	18,51	76,9	18,67	99,9	18,50	74,6	18,16	85,8	18,59	71,8	18,61	76,8				
	Room air	19,56	60,9	2,28	60,9	19,56	60,9	19,56	60,9	19,56	60,9	19,56	60,9	19,56	60,9	19,56	60,9	19,56	60,9
	Cavity		60,7		60,1		64,9		82,1		91,5		84,3		88,1		74,6		100,0
C1-Alt-7	Soil	19,31	100,0	19,44	100,0	19,58	100,0	19,76	100,0	19,45	100,0	19,69	100,0	19,95	100,0	20,70	100,0	23,45	100,0
	*Wall	18,46	73,0	18,05	79,3	18,17	100,0	18,97	79,3	18,60	89,4	18,95	75,3	19,64	79,9				
	Room air	18,36	70,4	2,11	70,4	18,36	70,4	18,36	70,4	18,36	70,4	18,36	70,4	18,36	70,4	18,36	70,4	18,36	70,4
	Cavity		70,4		64,4		69,4		83,4		91,9		85,4		89,0		77,3		100,0
C1-Alt-8	Soil	19,15	100,0	19,25	100,0	19,41	100,0	19,57	100,0	19,54	100,0	19,72	100,0	20,98	100,0	21,08	100,0	23,71	100,0
	*Wall	18,72	76,2	18,46	80,7	18,58	100,0	19,29	75,3	19,21	86,9	19,07	45,0	20,69	68,1				
	Room air	19,43	32,8	2,26	32,8	19,43	32,8	19,43	32,8	19,43	32,8	19,43	32,8	19,43	32,8	19,43	32,8	19,43	32,8
	Cavity		66,6		62,4		67,4		85,3		91,8		82,7		89,2		76,2		100,0

(green box) Risk of condensation and potential mold growth

(red box) Condensing

Table -3: Measurement results of S2

S2		A1		A2		A3		B1		B2		B3		C1		C2		C3	
		T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH
		(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)
S2-Alt-1	Soil	4,62	100,0	5,22	100,0	5,43	100,0	3,69	100,0	5,14	100,0	5,27	100,0	4,11	100,0	5,75	100,0	6,31	100,0
	*Wall	14,70	48,7	16,01	58,6	15,81	66,4	5,92	72,6	7,51	85,2	8,15	68,4	6,58	71,8				
	Room air	19,57	28,9	2,28	28,9	19,57	28,9	19,57	28,9	19,57	28,9	19,57	28,9	19,57	28,9	19,57	28,9	19,57	28,9
	Cavity		49,6		51,1		53,1		79,9		90,2		81,3		81,1		66,8		98,2
S2-Alt-2	Soil	4,76	100,0	5,28	100,0	5,50	100,0	3,83	100,0	5,09	100,0	5,09	100,0	4,27	100,0	5,73	100,0	6,09	100,0
	*Wall	14,74	50,2	16,20	61,3	16,15	74,2	6,20	79,1	7,48	91,5	8,11	100,0	6,82	91,0				
	Room air	19,51	59,2	2,27	59,2	19,51	59,2	19,51	59,2	19,51	59,2	19,51	59,2	19,51	59,2	19,51	59,2	19,51	59,2
	Cavity		66,6		61,2		63,5		83,0		92,1		93,3		86,3		77,9		98,2
S2-Alt-3	Soil	18,70	100,0	18,58	100,0	18,59	100,0	19,49	100,0	19,01	100,0	19,14	100,0	20,64	100,0	20,31	100,0	20,00	100,0
	*Wall	18,30	70,9	17,74	65,4	17,76	70,8	18,97	79,5	18,52	90,8	18,51	75,4	20,39	77,8				
	Room air	18,62	63,4	2,15	63,4	18,62	63,4	18,62	63,4	18,62	63,4	18,62	63,4	18,62	63,4	18,62	63,4	18,62	63,4
	Cavity		71,5		64,1		66,2		87,4		92,9		99,8		88,9		83,1		100,0
S2-Alt-4	Soil	19,03	100,0	18,95	100,0	18,90	100,0	19,59	100,0	19,20	100,0	19,29	100,0	20,71	100,0	20,30	100,0	19,82	100,0
	*Wall	18,66	72,4	17,95	66,9	17,66	70,4	19,28	77,1	18,85	83,0	18,63	56,7	20,51	69,4				
	Room air	19,29	45,2	2,24	45,2	19,29	45,2	19,29	45,2	19,29	45,2	19,29	45,2	19,29	45,2	19,29	45,2	19,29	45,2
	Cavity		62,6		61,1		61,7		91,4		93,2		100,0		89,3		83,7		100,0

Green box: Risk of condensation and potential mold growth

Red box: Condensing

Table -4: Measurement results of C2

C2		A1		A2		A3		B1		B2		B3		C1		C2		C3	
		T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH	T	RH
		(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)	(°C)	(%)
C2-Alt-1	Soil	5,21	100,0	5,78	100,0	6,34	100,0	4,32	100,0	4,73	100,0	5,58	100,0	5,09	100,0	6,45	100,0	5,99	100,0
	*Wall	14,96	60,7	16,76	58,4	16,74	63,6	6,74	85,5	8,50	83,8	8,63	77,0	7,56	81,1				
	Room air	19,59	32,1	2,28	32,1	19,59	32,1	19,59	32,1	19,59	32,1	19,59	32,1	19,59	32,1	19,59	32,1	19,59	32,1
	Cavity		53,5		52,8		53,5		100,0		93,4		98,5		100,0		97,6		97,4
C2-Alt-2	Soil	4,29	100,0	4,73	100,0	5,47	100,0	3,67	100,0	4,38	100,0	5,19	100,0	4,57	100,0	6,13	100,0	5,55	100,0
	*Wall	14,86	61,2	16,76	60,7	16,99	66,3	6,13	91,8	8,05	95,9	9,10	100,0	6,98	95,9				
	Room air	19,48	61,7	2,26	61,7	19,48	61,7	19,48	61,7	19,48	61,7	19,48	61,7	19,48	61,7	19,48	61,7	19,48	61,7
	Cavity		54,0		62,6		62,9		100,0		95,9		99,5		100,0		99,4		97,9
C2-Alt-3	Soil	18,86	100,0	18,70	100,0	18,70	100,0	19,25	100,0	18,63	100,0	19,68	100,0	20,45	100,0	20,27	100,0	19,95	100,0
	*Wall	18,47	84,1	17,92	68,6	17,97	72,4	18,93	93,8	18,27	96,7	18,36	81,4	20,24	88,1				
	Room air	18,90	63,6	2,18	63,6	18,90	63,6	18,90	63,6	18,90	63,6	18,90	63,6	18,90	63,6	18,90	63,6	18,90	63,6
	Cavity		69,5		67,6		68,2		100,0		97,6		99,9		100,0		100,0		100,0
C2-Alt-4	Soil	18,86	100,0	18,74	100,0	18,75	100,0	19,36	100,0	18,81	100,0	19,37	100,0	20,60	100,0	20,46	100,0	20,10	100,0
	*Wall	18,61	84,4	17,98	68,3	17,83	71,6	19,22	88,9	18,73	86,1	18,63	55,8	20,32	81,9				
	Room air	19,22	42,7	2,23	42,7	19,22	42,7	19,22	42,7	19,22	42,7	19,22	42,7	19,22	42,7	19,22	42,7	19,22	42,7
	Cavity		67,8		62,6		62,2		100,0		97,0		92,9		100,0		99,5		99,7

Risk of condensation and potential mold growth

Condensing

5.2.3 S1 and C1-Alt3 (sand – 1st and clay – 2nd cycle, no damp-proofing, T_i = 20°C (68°F), T_e = 5°C (41°F), RH_i = 60%, RH_e = >95%)

This test introduces >95 % RH from the exterior (environmental side) and 60 % from the interior (room side). Exterior insulation that protects the wall structure and keeps it warm performs better under high interior RH. Interior insulation with low-permeance fiber or porous materials increases a risk of condensation.

The results here are very similar to results in Alt1 (see S1 or C1-Alt1). Because of this small differences between Alt3 and Alt1 and Alt4 and Alt2 the remaining test runs (3rd and 4th) used >95 % of RH from exterior. This reduced number of test alternatives.

5.2.4 S1 and C1-Alt4 (sand – 1st and clay – 2nd cycle, no damp-proofing, T_i = 20°C (68°F), T_e = 5°C (41°F), RH_i = 30%, RH_e = >95%)

This test represents desorption cycle. The results indicate that with correct air conditioning system no condensation will occur. An alternate drying mechanism through an above-grade portion of a basement wall can alleviate the energy consumption issues. In cold climates, the drying will be toward the exterior; in warm climates the drying will occur toward the interior making the energy demand high. Interior glass fiber insulation showed the fastest drying because of its high permeance. This makes this material suitable more for mild climate when a drying to the interior is possible.

5.2.5 S1 and C1-Alt5 (sand – 1st and clay – 2nd cycle, no damp-proofing, T_i = 20°C (68°F), T_e = 20°C (68°F), RH_i = 30%, RH_e = 50%)

Mild climate is simulated in alternatives 5, 6, 7 and 8. The mild climate condition facilitates inward drying (or no mass transfer when equal conditions are achieved on both sides). This means that moisture, (gravimetric, capillary, and water vapor diffusion) transfer toward the interior. Again a water vapor retarder such as damp-proofing must be on the outside of the insulation. By using a low permeance thermal insulation, its position can be changed and this will not significantly affect the overall moisture transfer. This is shown in Figures 5-2 and 5-4 where the RH of specimen A1 reached the lowest values. High permeance fiber insulation on the exterior allows moisture migration into a basement wall and a habitable space. Therefore high permeance fiber insulations are more suitable for interior applications. On the other hand low permeance interior insulation does not prevent inward drying and this may result in condensation on the interface of the wall and insulation.

5.2.6 S1 and C1-Alt6 (sand – 1st and clay – 2nd cycle, no damp-proofing, T_i = 20°C (68°F), T_e = 20°C (68°F), RH_i = 60%, RH_e = 50%)

Increased interior RH is mostly influencing the drying process. This case is very similar to the previous one except that the high permeance fiber insulation has attained more moisture due to higher interior RH, which is slowing down the drying process.

5.2.7 S1 and C1-Alt7 (sand – 1st and clay – 2nd cycle, no damp-proofing, T_i = 20°C (68°F), T_e = 20°C (68°F), RH_i = 60%, RH_e = >95%)

High exterior RH resulted in higher RH beneath the insulation. Low permeance insulation boards (XPS, EPS) applied on the exterior performed well. Because of a draining function of glass fiber in specimen A3, the measured RH beneath it showed condensation. Again using high permeance fiber insulation permits drying and condensation should be preventable by dehumidification. The interior insulation resulted in about a 28% moisture increase in the CMU compared to the placement of the insulation on the exterior. For Alt5 test the difference in the CM|U RH was about 40 %.

5.2.8 S1 and C1-Alt8 (sand – 1st and clay – 2nd cycle, no damp-proofing, T_i = 20°C (68°F), T_e = 20°C (68°F), RH_i = 30%, RH_e = >95%)

High permeance fiber insulation on interior side requires dehumidification to permit inward drying of the structure. Exterior insulation constitutes a barrier to forces participating in moisture transfer. In general, low permeance insulation should be used on the exterior surface while high permeance insulation is more suitable for the interior surface. The behavior of each insulation is influenced through their water vapor transmission data and thermal characteristics.

5.2.9 S2 and C2-Alt1 (sand – 3rd and clay – 4th cycle, damp-proofing, T_i = 20°C (68°F), T_e = 5°C (41°F), RH_i = 30%, RH_e = >95%)

The third and fourth test runs included additional wetting of soil. Damp-proofing was applied on the exterior surface. The measurements using sand and clay showed very similar results. Damp-proofing applied on the wall surface is most of the time used as a barrier to block the moisture transfer induced by hydrostatic pressure. This provides a barrier against bulk water that can enter from the exterior. When clay is used as backfill, insulation capable of draining water should be used.

5.2.10 S2 and C2-Alt2 (sand – 3rd and clay – 4th cycle, damp-proofing, T_i = 20°C (68°F), T_e = 5°C (41°F), RH_i = 60%, RH_e = >95%)

When interior RH increases and drying toward the exterior is possible, low permeance insulation is acceptable. Dampproofing and low permeance interior insulation require drying through the above-grade section of the wall to eliminate excessive moisture. Using high permeance fiber insulations increases the risk of condensation since moisture will come in contact with a cold wall beneath the insulation. The best results in the interior insulation strategy were achieved using XPS interior insulation.

5.2.11 S2 and C2-Alt3 (sand – 3rd and clay – 4th cycle, damp-proofing, T_i = 20°C (68°F), T_e = 20°C (68°F), RH_i = 60%, RH_e = >95%)

Insulation technique in a mild climate is different than in a cold climate. When a water vapor retarder is used (such as damp-proofing) it should be located on the outside surface of the insulation. In mild climate all combinations performed well except for B2 and B3, which reached higher RH during the test run. Low permeance insulation on the interior surface can cause accumulation of water in the structure due to inward moisture drive. This leads to condensation on the wall surface and can cause visible water outflow.

5.2.12 S2 and C2-Alt4 (sand – 3rd and clay – 4th cycle, damp-proofing, T_i = 20°C (68°F), T_e = 20°C (68°F), RH_i = 30%, RH_e = >95%)

Dehumidification always reduces the risk of condensation but cannot be used as a tool to control steady influx of moisture from the soil. Again, low permeance insulation installed on interior surface constitutes a barrier for the moisture flow. During the test with no temperature difference the moisture flow resulted in evaporation of water vapor in the cavity of the CMU's. Therefore, the wall cavity can be used as a moisture controlling device if an evaporation path is provided.

5.3 Moisture contents of specimens

The moisture contents of specimens in cold and mild climates differed due to differences in water vapor pressures. From the thermodynamic point of view, naturally higher moisture contents are present in mild climates. The sorption isotherm at 10 °C was used to calculate the moisture contents in cold climates except when exterior insulation was used (i.e. higher wall temperatures were achieved). In that case the sorption isotherm at 20 °C was used. The sorption isotherm at 20°C was used for mild climates. An average value was determined for the plain CMU wall (specimen C2) when the resulting wall temperature was around 15 °C. The water content attained during the preparation of concrete (100%) was used as a moisture content of the plain concrete wall (specimen C3).

Figure 5-3 shows the moisture content of specimens in cold climate. The difference in the MC is caused by the temperature of the wall itself, Figure 5-4 shows the MC in a mild climate. When insulations are applied from the exterior the moisture contents are less as compared to interior insulation strategies

An interesting finding is that the CMU wall attained less moisture when exterior insulation was applied. This is shown in Figures 5-5 and 5-6. The differences became larger in the third and fourth test runs. This was mainly due to the installation of damp-proofing from the exterior and low permeance insulation from the interior. The moisture in walls could not evaporate since no above grade portion of wall was simulated to enable drying.

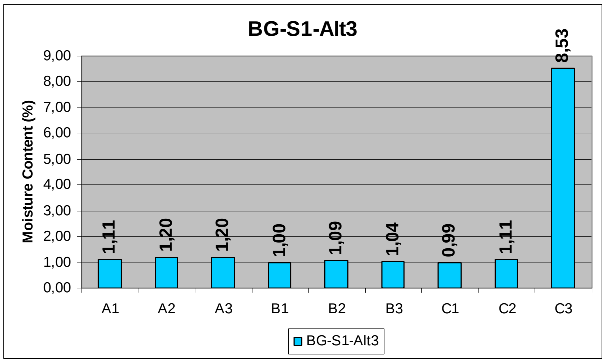


Figure -3: Moisture content of S1-Alt3 (sand – 1st cycle, no damp-proofing, T_i = 20°C (68°F), T_e = 5°C (41°F), RH_i = 60%, RH_e = >95%)

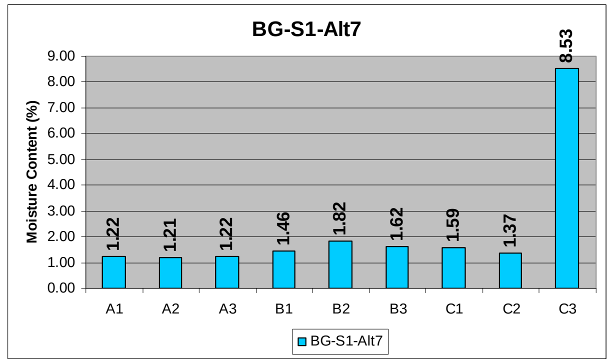


Figure -4: Moisture content of S1-Alt7 (sand – 1st cycle, no damp-proofing, T_i = 20°C (68°F), T_e = 20°C (68°F), RH_i = 60%, RH_e = >95%)

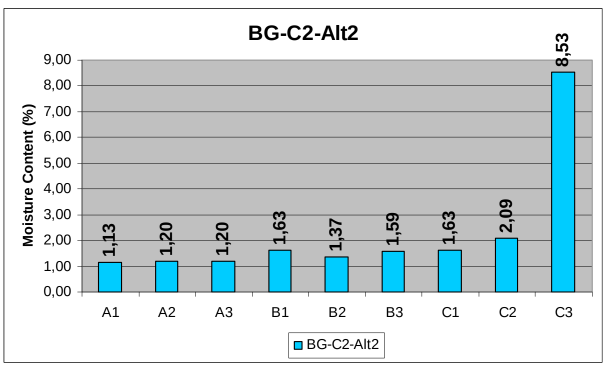


Figure -5: Moisture content of C2-Alt2 (clay – 4th cycle, damp-proofing, T_i = 20°C (68°F), T_e = 5°C (41°F), RH_i = 60%, RH_e = >95%)

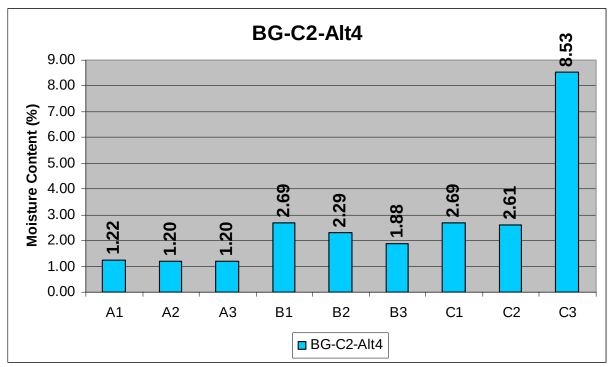


Figure -6: Moisture content of C2-Alt4 (clay – 4th cycle, damp-proofing, T_i = 20°C (68°F), T_e = 20°C (68°F), RH_i = 30%, RH_e = >95%)

6. Conclusions and recommendations

The final conclusions of the test measurements and wall specimens' performances are summarized in this chapter.

6.1 Conclusions

The tests conducted at BeTL showed interesting results and improved our understanding of the hygro-thermal behavior of below-grade basement walls. While the tests did not contain additional devices (such as flux meters) necessary for more conclusive statements, the following conclusions can be drawn:

1. the type of soil had some influence on the overall hygro-thermal behavior of the wall system. From the moisture transfer point of view plain (uninsulated) walls should be used as a basis for objective result comparison. When clay was used the moisture content in the CMU's cavity reached lower values as compared to sand. The difference was about 7 %. Sand had twice higher thermal conductivity as compared to clay. This resulted in a better thermal performance of the structure with clay soil.

2. Less dehumidification and/or drying is needed when low permeance exterior insulation is used. The drying rate depends on the initial stage of material built into the structure. Such an exterior insulation is working as a water-proofing layer as well.

3. High permeance insulation such as semi rigid glass fiber can be used on the exterior in cold climate to drain water away. From the thermal point of view, the conductivity of the wet insulation is higher compared to the dry one. Therefore, in cold climate and exterior insulation, the thermal performance of a wall decreases as the soil approaches saturation . High perrmeance insulation should be used on the interior if inward moisture drive is present. When drying to the exterior, high permeance insulation should be avoided due to the condensation on a cold wall beneath the insulation.

4. The advantage of exterior insulation is in its better thermal behavior (i.e. higher temperature of wall enabling higher saturation), water retardation (i.e. water ingress barrier), and thermal inertia (i.e. accumulation of heat in the wall structure during winter).

5. Plain structures without damp-proofing result in significant moisture flow and dehumidification is necessary. Plain structures with damp-proofing can attain higher MC when outward moisture flow is present.

6. Moisture content of CMU's is significantly lower then the initial water content of concrete.

6.2 Recommendations

Absence of heat flux meters during the experiments reduced the precision of measurements and data from manufacturers had to be used.

In order to finish the tests in a reasonable time, the time needed for steady-state conditions was shortened to a minimum. Ideally, one will need more time between the runs to assure close-to-steady-state conditions. The authors recognize, however, that reaching steady state is nearly impossible.

For future research, a cmparison between laboratory and in-situ experiments is recommended. This will require a concurrent test where outdoor conditions are carefully monitored and reproduced in the laboratory.

1. Future work will focus on the influence of imperfections in the water retarding layer on durability and effects of material aging on system performance.
2. 2006 International Residential Code for one- and two-family dwellings. ICC Country Club Hills. IL. 672. p.
3. 2005 ASHRAE Handbook. Fundamentals. SI Edition. ASHRAE. Atlanta. GA. ISBN 1-931862-71-0.

Appendix A - Terminology and acronyms

The appendix A summarizes the terminology and acronyms used in the report.

- RH: relative humidity or relative water vapor pressure
- MC: moisture content
- BeTL: Building Enclosure Testing Laboratory
- PHRC: Pennsylvania Housing Research Center

Appendix B – Measurement results

Because of the large amount of data the measurement results are summarized in appendix B.

The measurement results and boundary conditions of the climate chamber are shown below in the following order:

1. Measurement series: S1 (Sand; no dampproofing)
   - 1.1. Test cycle: S1-Alt1
   - 1.2. Test cycle: S1-Alt2
   - 1.3. Test cycle: S1-Alt3
   - 1.4. Test cycle: S1-Alt4
   - 1.5. Test cycle: S1-Alt5
   - 1.6. Test cycle: S1-Alt6
   - 1.7. Test cycle: S1-Alt7
   - 1.8. Test cycle: S1-Alt8
2. Measurement series: C1 (Clay; no dampproofing)
   - 2.1. Test cycle: C1-Alt1
   - 2.2. Test cycle: C1-Alt2
   - 2.3. Test cycle: C1-Alt3
   - 2.4. Test cycle: C1-Alt4
   - 2.5. Test cycle: C1-Alt5
   - 2.6. Test cycle: C1-Alt6
   - 2.7. Test cycle: C1-Alt7
   - 2.8. Test cycle: C1-Alt8
3. Measurement series: S2 (Sand; with dampproofing)
   - 3.1. Test cycle: S2-Alt1
   - 3.2. Test cycle: S1-Alt2
   - 3.3. Test cycle: S1-Alt3
   - 3.4. Test cycle: S1-Alt4
4. Measurement series: C2 (Clay; with dampproofing)
   - 4.1. Test cycle: C2-Alt1
   - 4.2. Test cycle: C1-Alt2
   - 4.3. Test cycle: C1-Alt3
   - 4.4. Test cycle: C1-Alt4

Measurement series: **S1** (Sand; no dampproofing)

Test cycle: **S1 – Alt1**

Table B-1: Average data during the last 24 hours for each specimen of S1-Alt1

Specimen Measurement Data

B-G	A		B		C		Sand
1	A1_Soil-T	5.578 degC	B1_Soil-T	4.608 degC	C1_Soil-T	4.992 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	98.138 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	15.864 degC	B1_Wall-T	7.073 degC	C1_Wall-T	7.899 degC	
	A1_Ext-T	6.781 degC	B1_Ext-T	5.887 degC	C1_Ext-T	6.175 degC	
	A1_Int-T	17.453 degC	B1_Int-T	17.601 degC	C1_Int-T	17.326 degC	
	A1_Inside-RH	47.124 %	B1_Inside-RH	82.661 %	C1_Inside-RH	80.593 %	
	A1_Wall-RH	55.775 %	B1_Wall-RH	77.805 %	C1_Wall-RH	76.348 %	
2	A2_Soil-T	6.294 degC	B2_Soil-T	5.703 degC	C2_Soil-T	6.561 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	16.471 degC	B2_Wall-T	8.416 degC	C2_Ext-T	11.097 degC	
	A2_Ext-T	7.735 degC	B2_Ext-T	7.107 degC	C2_Int-T	15.950 degC	
	A2_Int-T	17.362 degC	B2_Int-T	17.788 degC	C2_Inside-RH	73.489 degC	
	A2_Inside-RH	52.612 %	B2_Inside-RH	84.115 %			
	A2_Wall-RH	57.965 %	B2_Wall-RH	84.631 %			
3	A3_Soil-T	6.256 degC	B3_Soil-T	5.931 degC	C3_Soil-T	6.664 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	16.466 degC	B3_Wall-T	8.610 degC	C3_Ext-T	12.265 degC	
	A3_Ext-T	7.842 degC	B3_Ext-T	6.931 degC	C3_Int-T	14.972 degC	
	A3_Int-T	17.510 degC	B3_Int-T	17.541 degC	C3_Inside-RH	100.000 degC	
	A3_Inside-RH	52.480 %	B3_Inside-RH	82.233 %			
	A3_Wall-RH	62.279 %	B3_Wall-RH	80.332 %	**Pressure diff.*	*6.076 Pa*	
No	A		B		C		Alt1

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	19.073 degC
RH-room	35.945 %
T-room_sp	20.000 degC
RH-room_sp	35.000 %
T-environment	4.476 degC
RH-environment	68.171 %
T-environment_sp	3.000 degC
RH-environment_sp	70.000 %

Remarks

Type: B-G
Soil type: Sand
Dampproofing: No
Alternative: Alt1

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

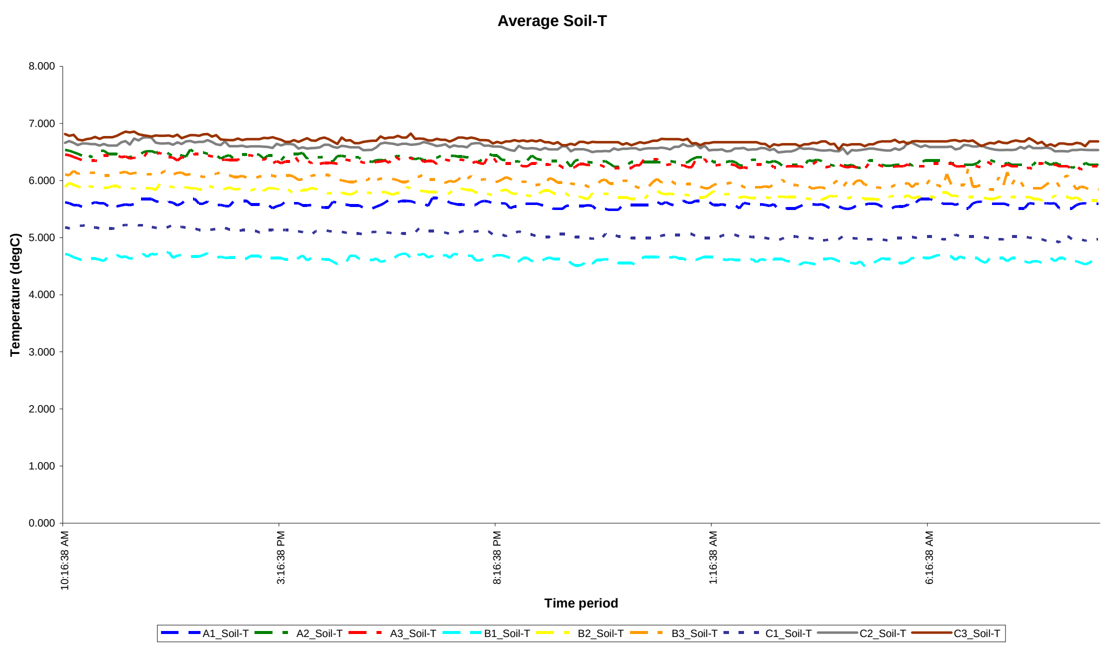


Figure B-1: Average soil temperature of S1-Alt1

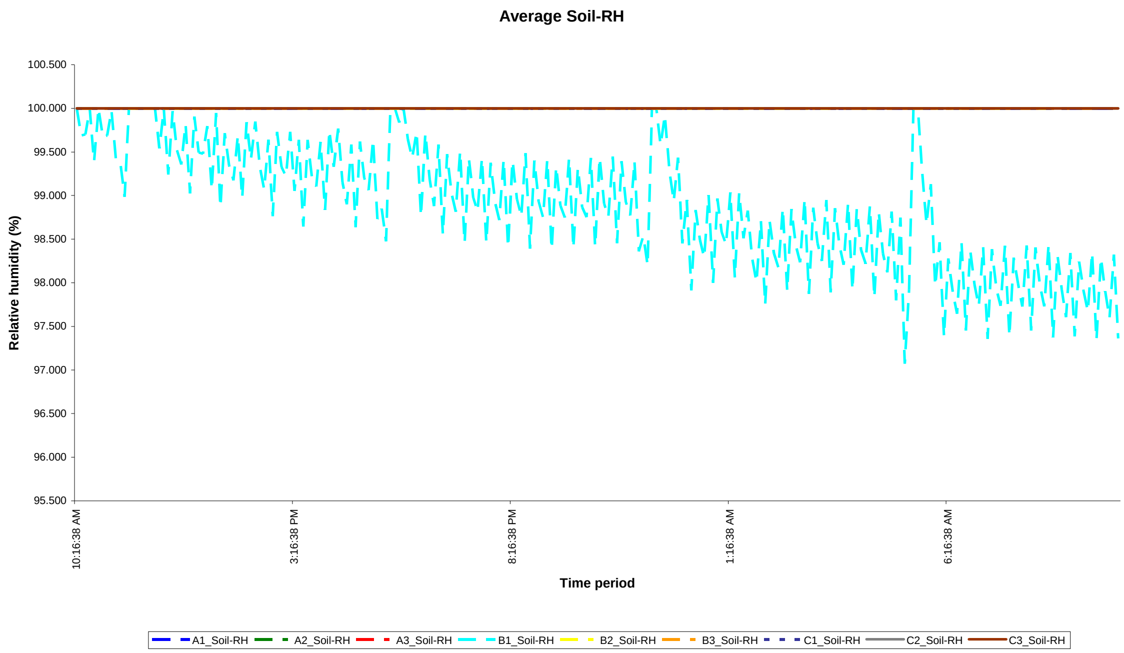


Figure B-2: Average soil relative humidity of S1-Alt1

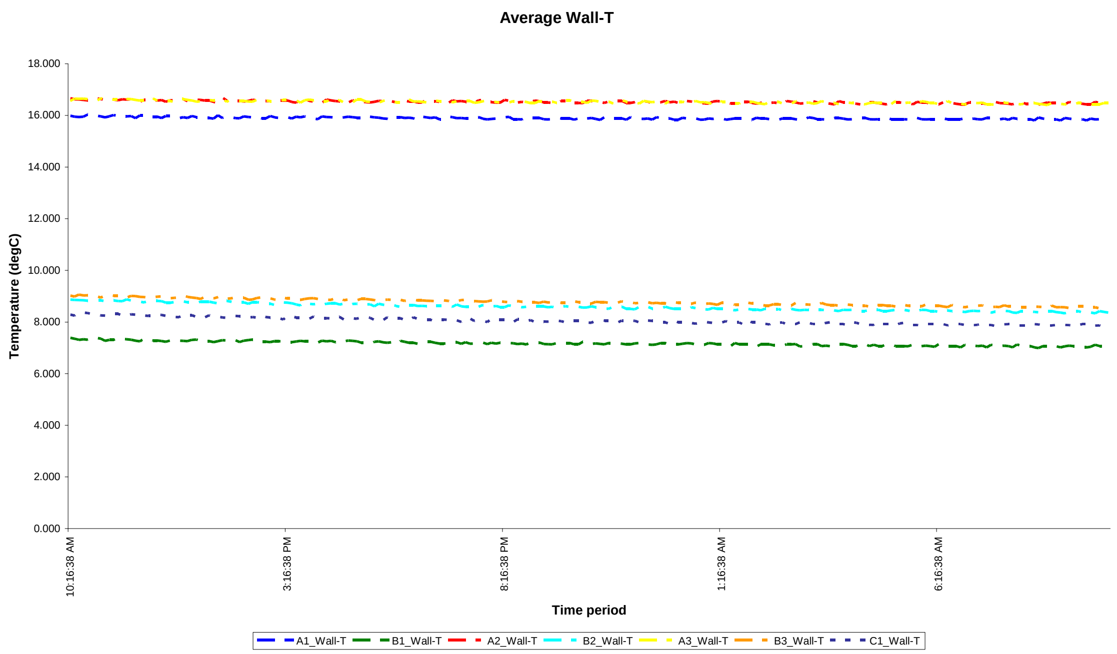


Figure B-3: Average wall temperature of S1-Alt1

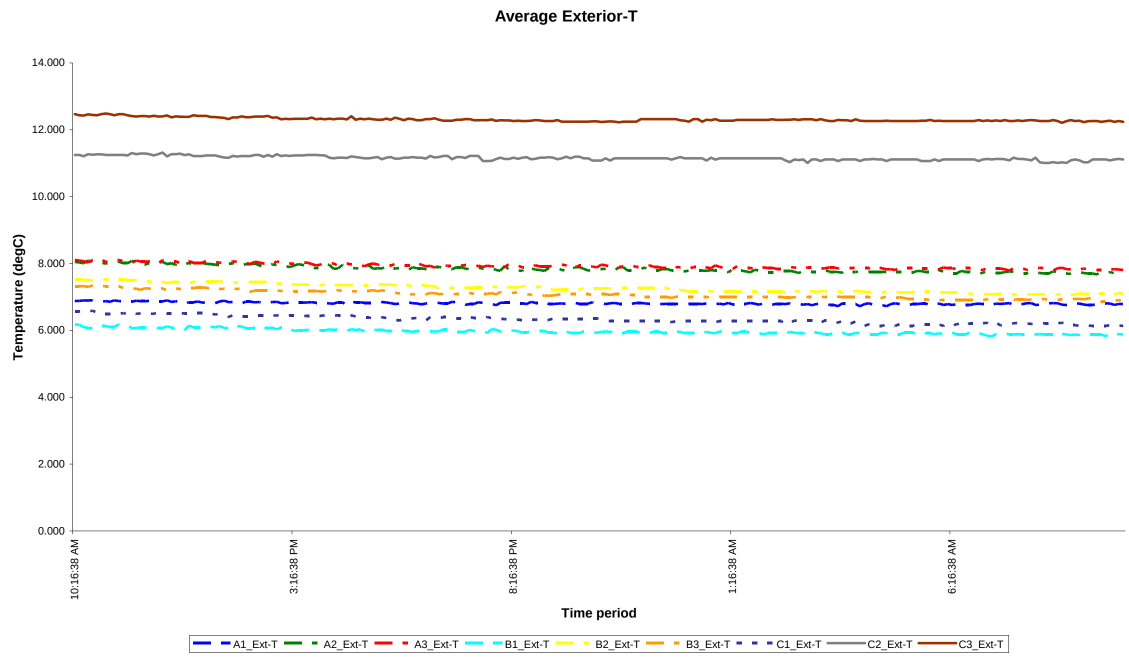


Figure B-4: Average exterior temperature of S1-Alt1

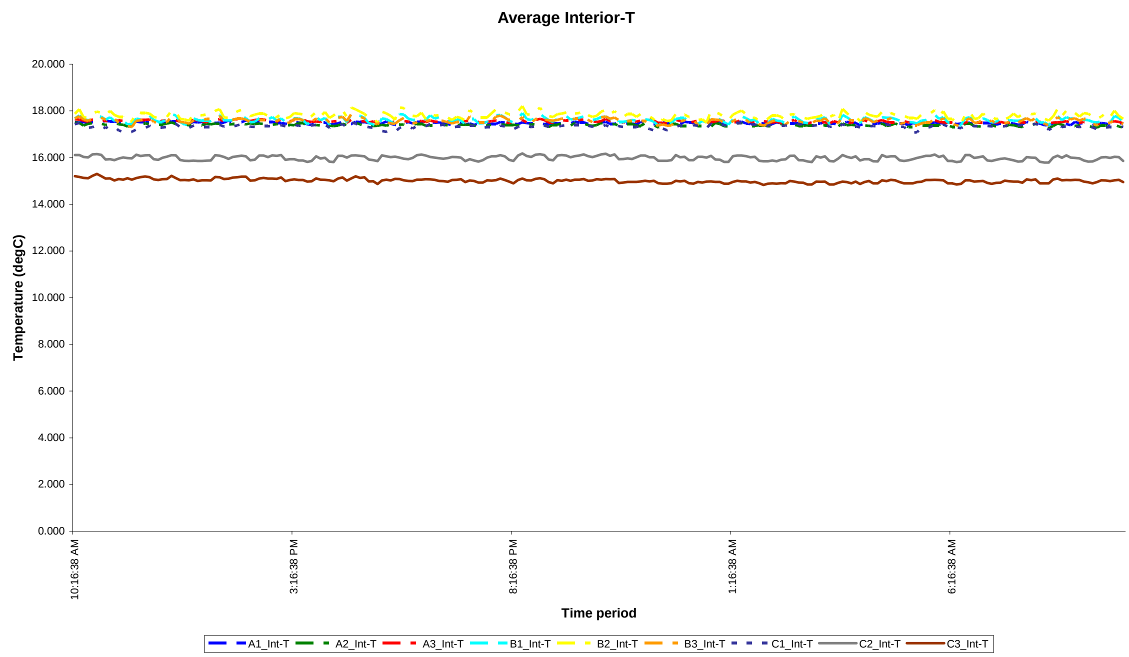


Figure B-5: Average interior temperature of S1-Alt1

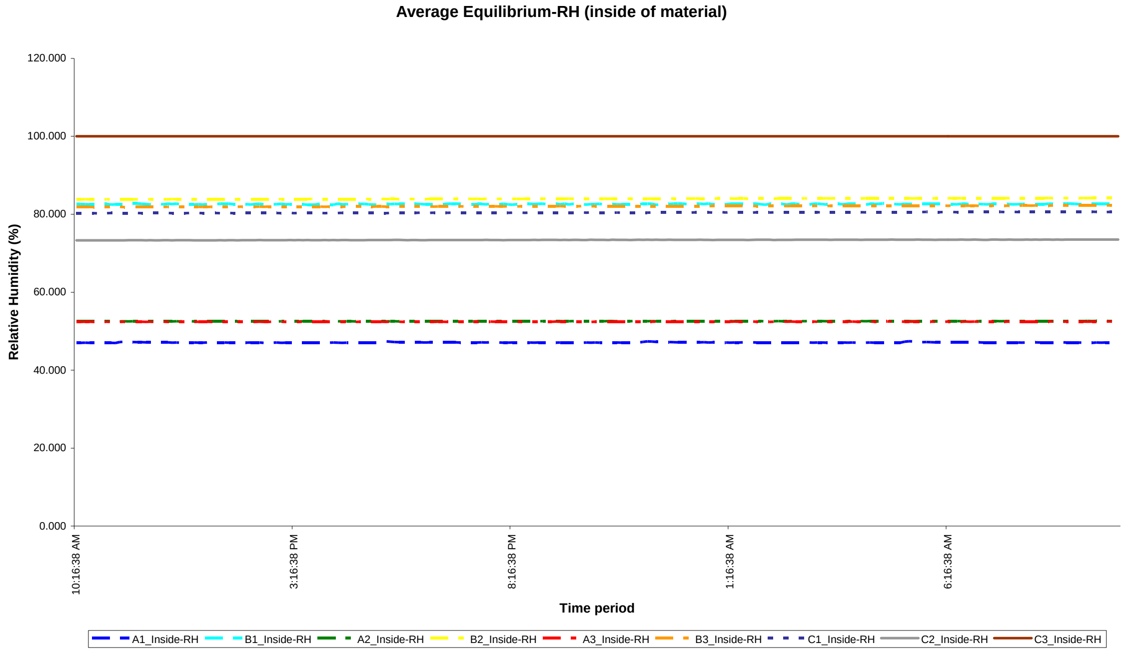


Figure B-6: Average equilibrium of relative humidity in a cavity of S1-Alt1

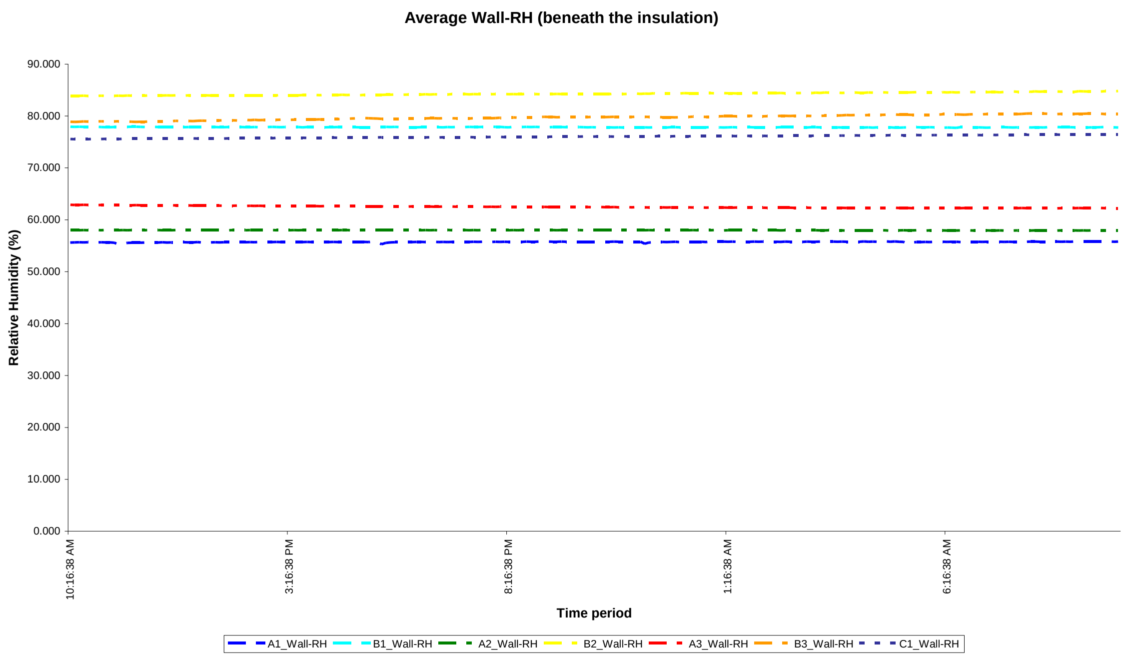


Figure B-7: Average wall relative humidity beneath the insulation of S1-Alt1

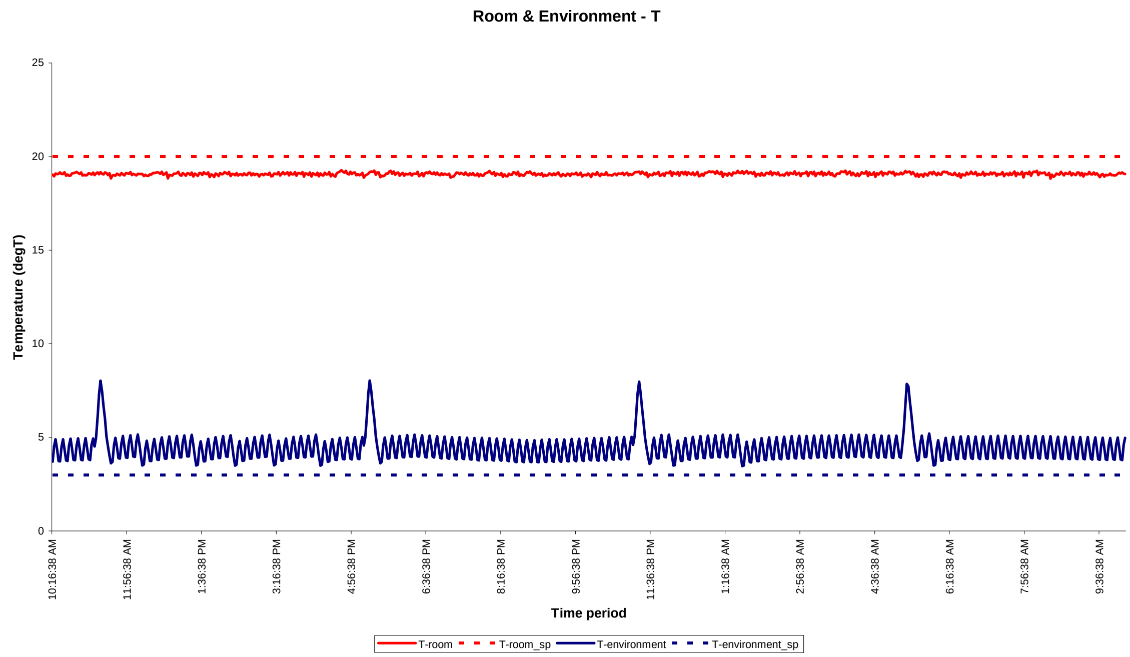


Figure B-8: Temperature of the room and environmental side during S1-Alt1

Figure B-9: Relative humidity of the room and environmental side during S1-Alt1

Test cycle: **S1 – Alt2**

Table B-2: Average data during the last 24 hours for each specimen of S1-Alt2

Specimen Measurement Data

B-G	A		B		C		Sand
1	A1_Soil-T	5.390 degC	B1_Soil-T	4.357 degC	C1_Soil-T	4.781 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	91.794 %	C1_Soil-RH	99.904 %	
	A1_Wall-T	15.665 degC	B1_Wall-T	6.959 degC	C1_Wall-T	7.737 degC	
	A1_Ext-T	6.693 degC	B1_Ext-T	5.742 degC	C1_Ext-T	6.020 degC	
	A1_Int-T	17.281 degC	B1_Int-T	17.651 degC	C1_Int-T	17.360 degC	
	A1_Inside-RH	50.434 %	B1_Inside-RH	85.592 %	C1_Inside-RH	83.122 %	
	A1_Wall-RH	55.896 %	B1_Wall-RH	82.890 %	C1_Wall-RH	90.259 %	
2	A2_Soil-T	6.076 degC	B2_Soil-T	5.492 degC	C2_Soil-T	6.501 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	16.298 degC	B2_Wall-T	8.119 degC	C2_Ext-T	11.206 degC	
	A2_Ext-T	7.525 degC	B2_Ext-T	6.791 degC	C2_Int-T	16.007 degC	
	A2_Int-T	17.214 degC	B2_Int-T	17.940 degC	C2_Inside-RH	77.572 degC	
	A2_Inside-RH	59.132 %	B2_Inside-RH	86.633 %			
	A2_Wall-RH	58.940 %	B2_Wall-RH	96.624 %			
3	A3_Soil-T	6.086 degC	B3_Soil-T	5.764 degC	C3_Soil-T	6.780 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	16.318 degC	B3_Wall-T	8.674 degC	C3_Ext-T	12.344 degC	
	A3_Ext-T	7.694 degC	B3_Ext-T	6.900 degC	C3_Int-T	14.908 degC	
	A3_Int-T	17.361 degC	B3_Int-T	17.766 degC	C3_Inside-RH	99.999 degC	
	A3_Inside-RH	58.569 %	B3_Inside-RH	84.735 %			
	A3_Wall-RH	62.297 %	B3_Wall-RH	99.838 %	**Pressure diff.*	*59.382 Pa*	
No	A		B		C		Alt2

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	19.019 degC
RH-room	60.795 %
T-room_sp	20.000 degC
RH-room_sp	65.000 %
T-environment	4.154 degC
RH-environment	69.763 %
T-environment_sp	3.000 degC
RH-environment_sp	50.000 %

Remarks

Type: B-G
Soil type: Sand
Damproofing: No
Alternative: Alt2

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

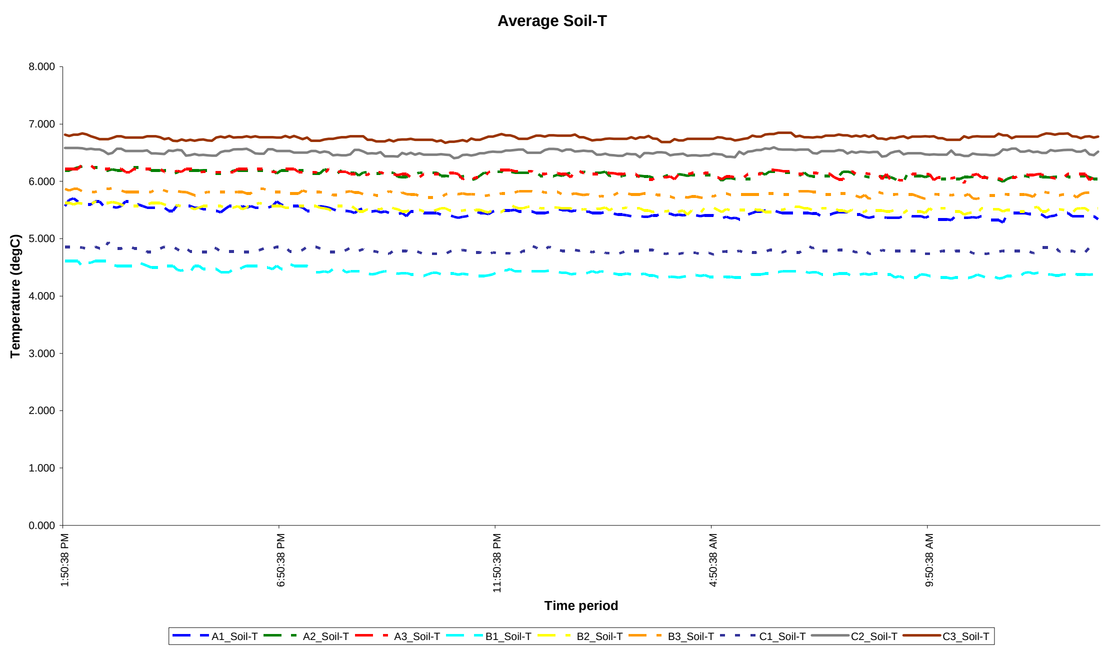


Figure B-10: Average soil temperature of S1-Alt2

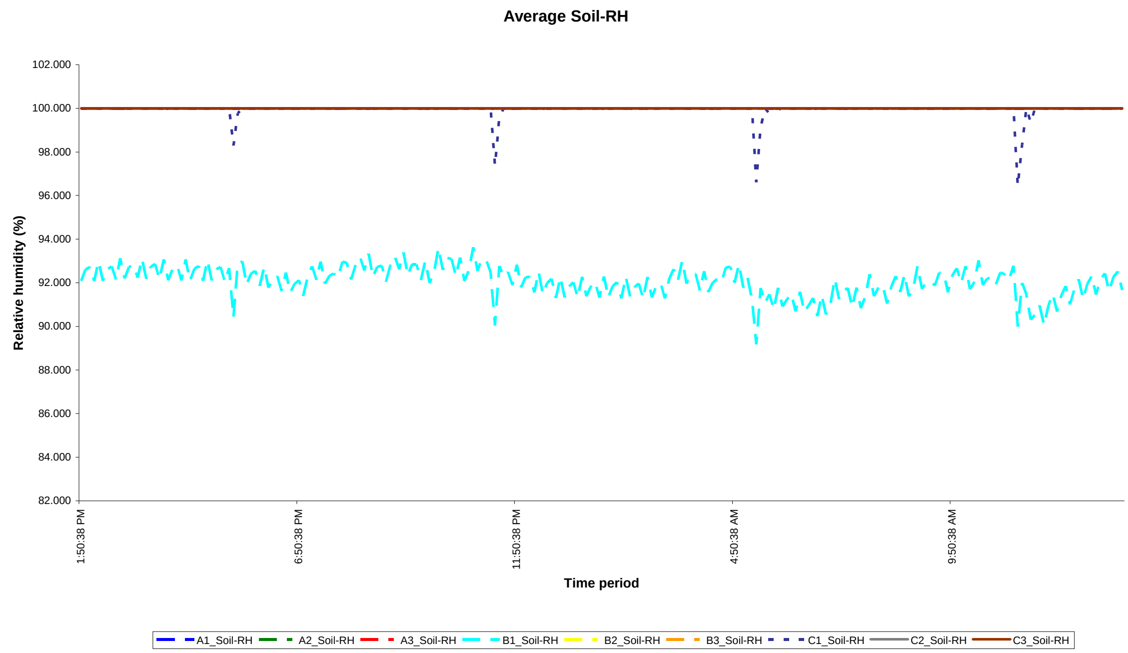


Figure B-11: Average soil relative humidity of S1-Alt2

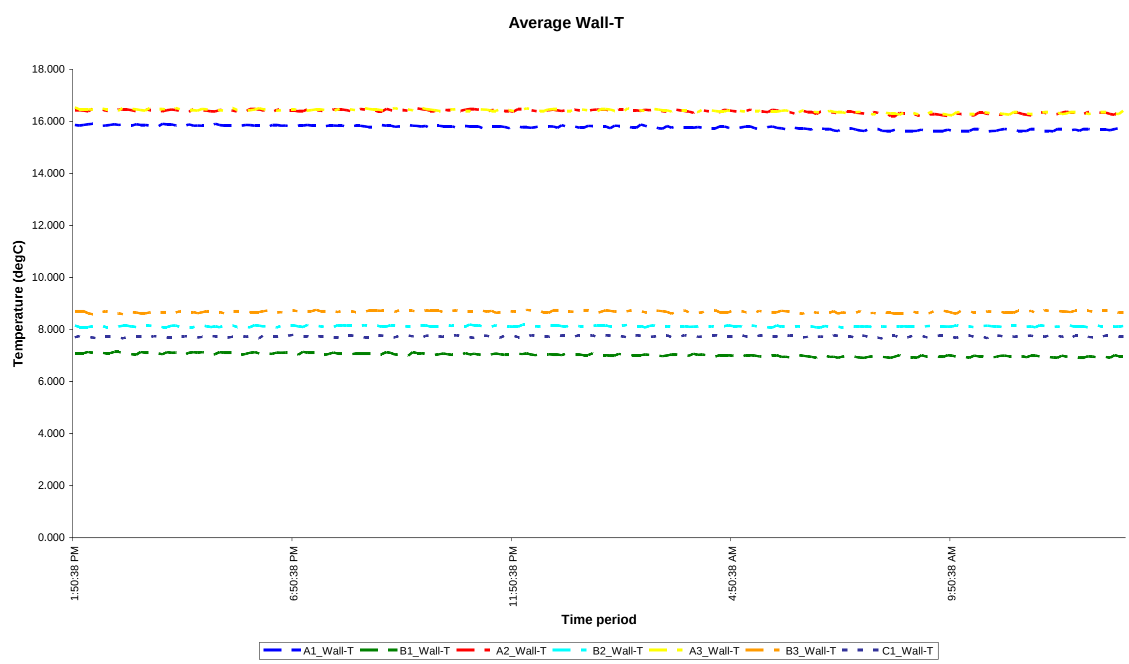


Figure B-12: Average wall temperature of S1-Alt2

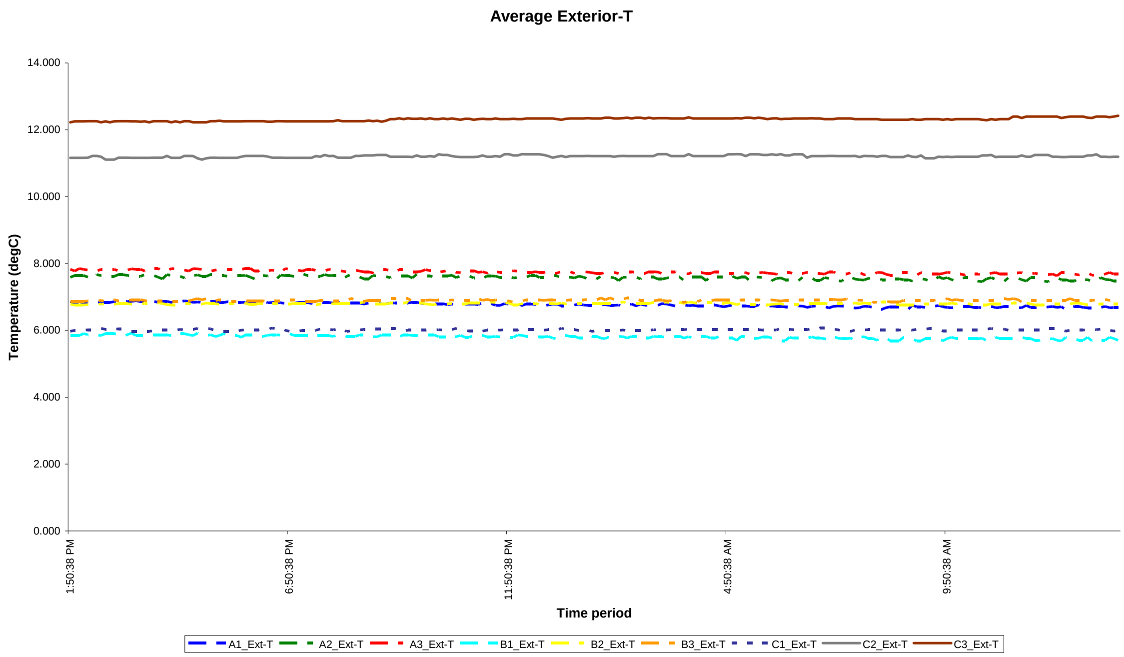


Figure B-13: Average exterior temperature of S1-Alt2

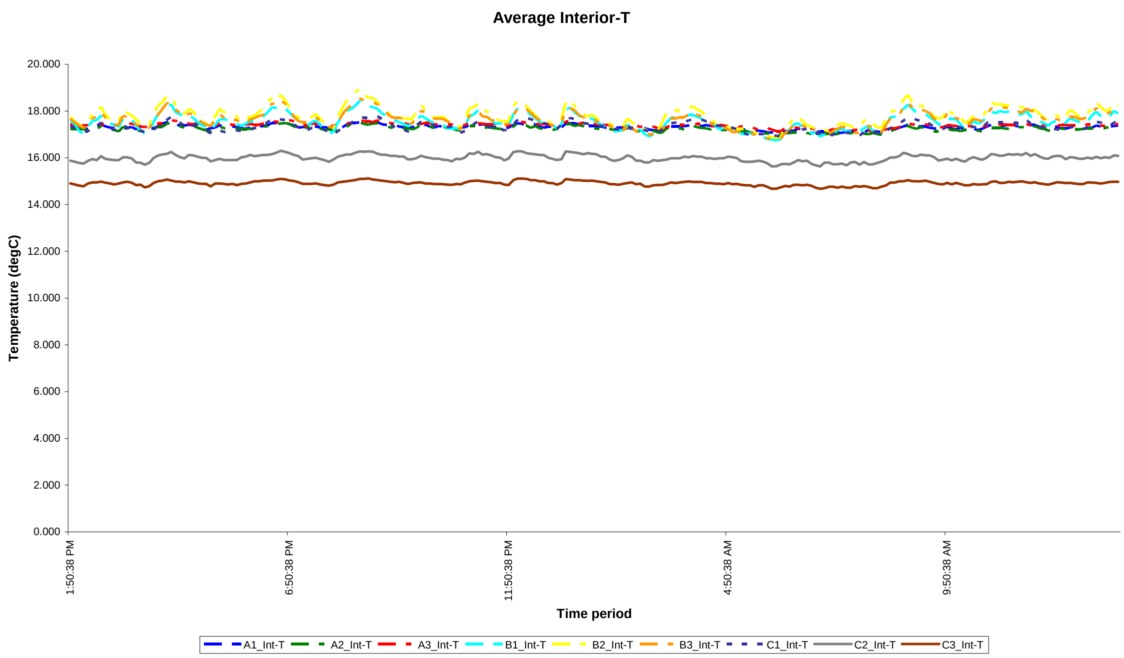


Figure B-14: Average interior temperature of S1-Alt2

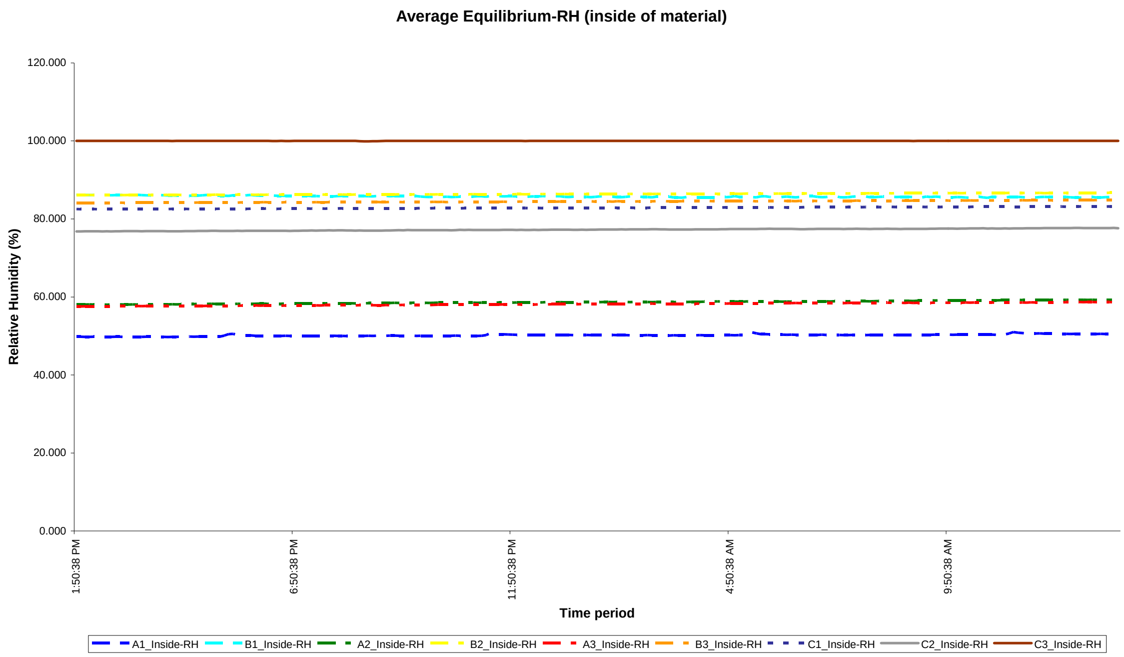


Figure B-15: Average equilibrium of relative humidity in a cavity of S1-Alt2

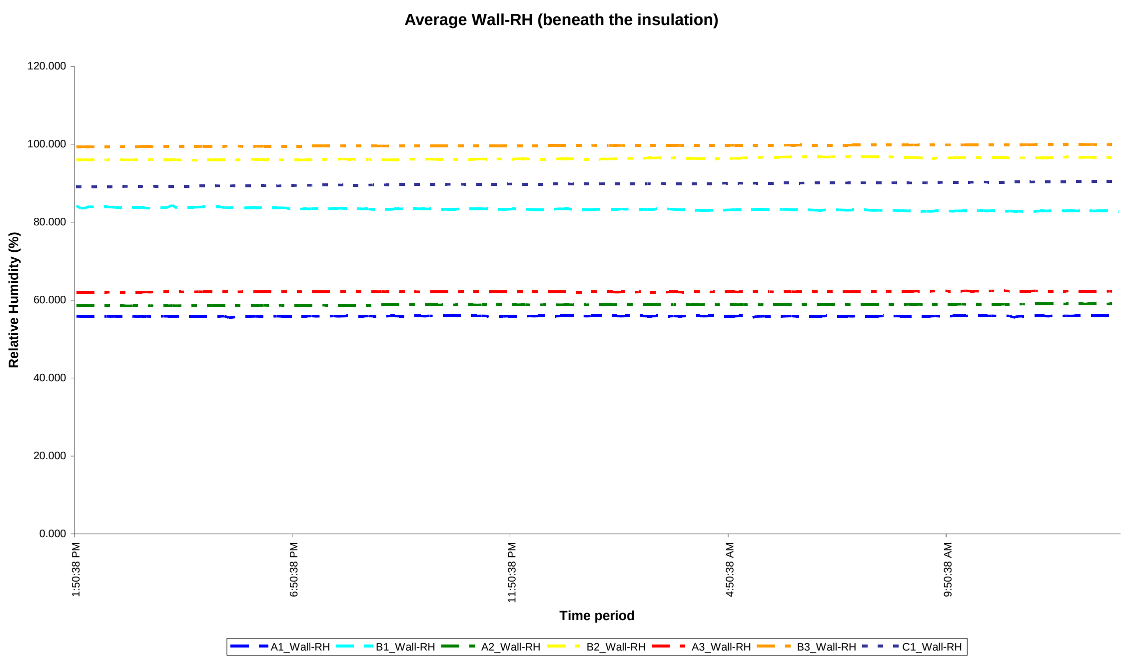


Figure B-16: Average wall relative humidity beneath the insulation of S1-Alt2

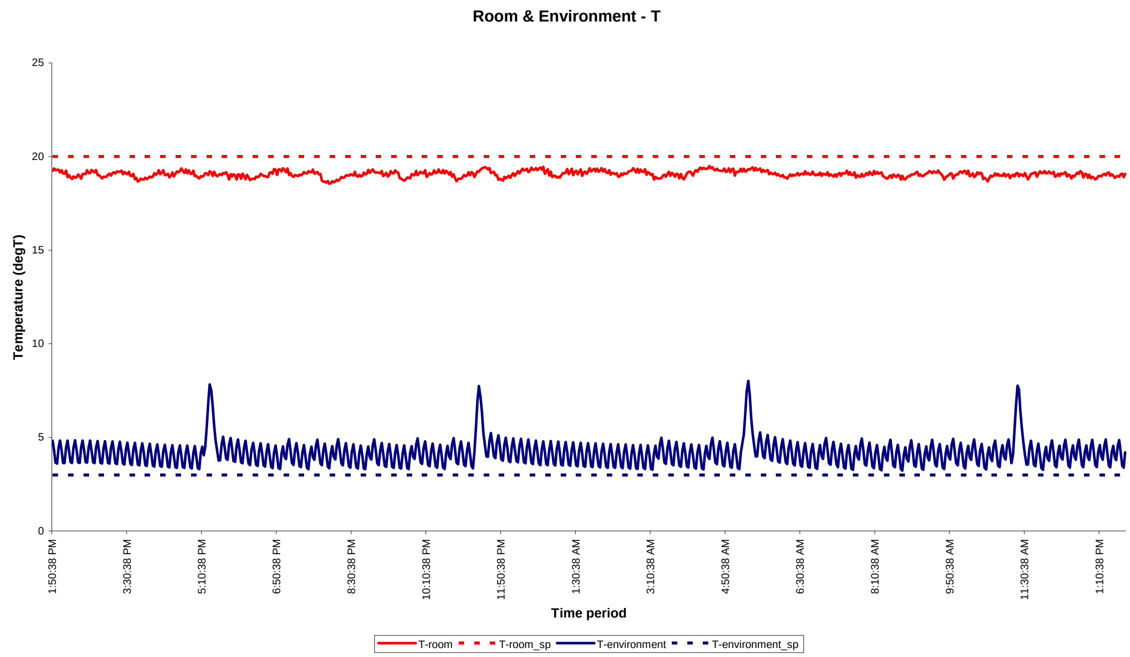


Figure B-17: Temperature of the room and environmental side during S1-Alt2

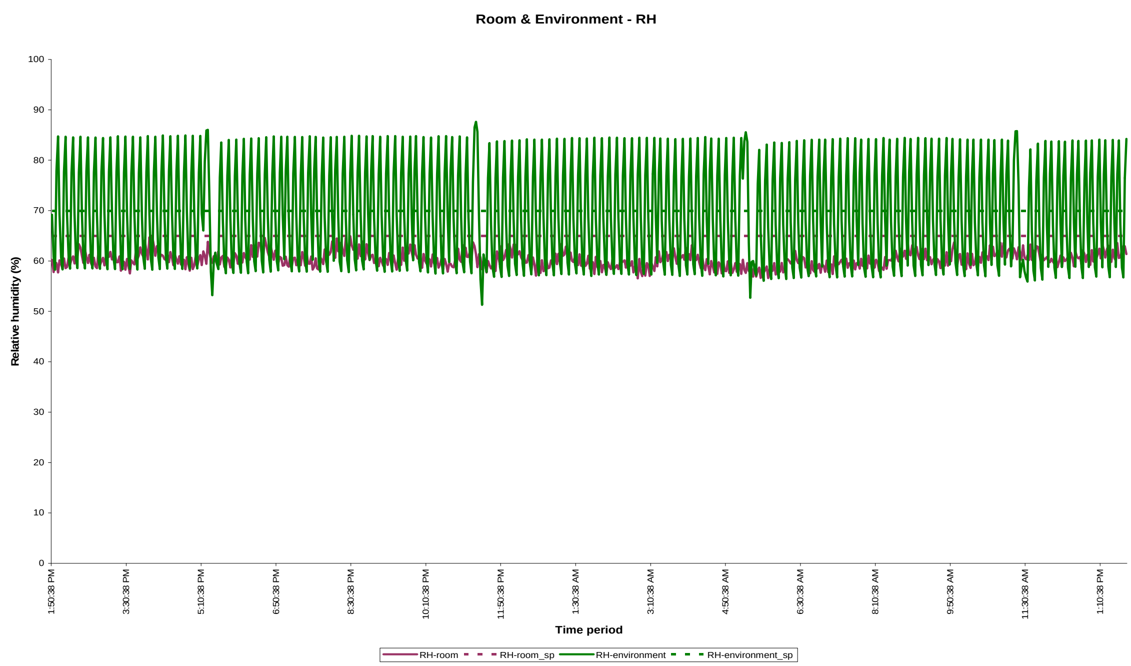


Figure B-18: Relative humidity of the room and environmental side during S1-Alt2

Test cycle: **S1 – Alt3**

Table B-3: Average data during the last 24 hours for each specimen of S1-Alt3

Specimen Measurement Data

B-G	A		B		C		Sand
1	A1_Soil-T	5.831 degC	B1_Soil-T	4.709 degC	C1_Soil-T	4.907 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	100.000 %	C1_Soil-RH	95.199 %	
	A1_Wall-T	16.271 degC	B1_Wall-T	7.361 degC	C1_Wall-T	8.180 degC	
	A1_Ext-T	7.224 degC	B1_Ext-T	6.062 degC	C1_Ext-T	6.315 degC	
	A1_Int-T	17.864 degC	B1_Int-T	18.380 degC	C1_Int-T	18.175 degC	
	A1_Inside-RH	52.142 %	B1_Inside-RH	85.840 %	C1_Inside-RH	85.563 %	
	A1_Wall-RH	56.753 %	B1_Wall-RH	83.484 %	C1_Wall-RH	93.995 %	
2	A2_Soil-T	6.334 degC	B2_Soil-T	5.720 degC	C2_Soil-T	6.680 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	17.041 degC	B2_Wall-T	8.514 degC	C2_Ext-T	11.909 degC	
	A2_Ext-T	7.817 degC	B2_Ext-T	7.111 degC	C2_Int-T	16.818 degC	
	A2_Int-T	17.947 degC	B2_Int-T	18.711 degC	C2_Inside-RH	80.465 degC	
	A2_Inside-RH	62.665 %	B2_Inside-RH	88.974 %			
	A2_Wall-RH	60.229 %	B2_Wall-RH	98.249 %			
3	A3_Soil-T	6.315 degC	B3_Soil-T	6.115 degC	C3_Soil-T	7.175 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	17.024 degC	B3_Wall-T	9.159 degC	C3_Ext-T	13.119 degC	
	A3_Ext-T	7.905 degC	B3_Ext-T	7.303 degC	C3_Int-T	15.923 degC	
	A3_Int-T	18.067 degC	B3_Int-T	18.538 degC	C3_Inside-RH	100.000 degC	
	A3_Inside-RH	61.942 %	B3_Inside-RH	87.476 %			
	A3_Wall-RH	61.034 %	B3_Wall-RH	100.000 %	**Pressure diff.*	*74.841 Pa*	
No	A		B		C		Alt3

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	19.522 degC
RH-room	61.007 %
T-room_sp	20.000 degC
RH-room_sp	65.000 %
T-environment	3.807 degC
RH-environment	86.916 %
T-environment_sp	3.000 degC
RH-environment_sp	97.000 %

Remarks

Type: B-G
Soil type: Sand
Damproofing: No
Alternative: Alt3

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

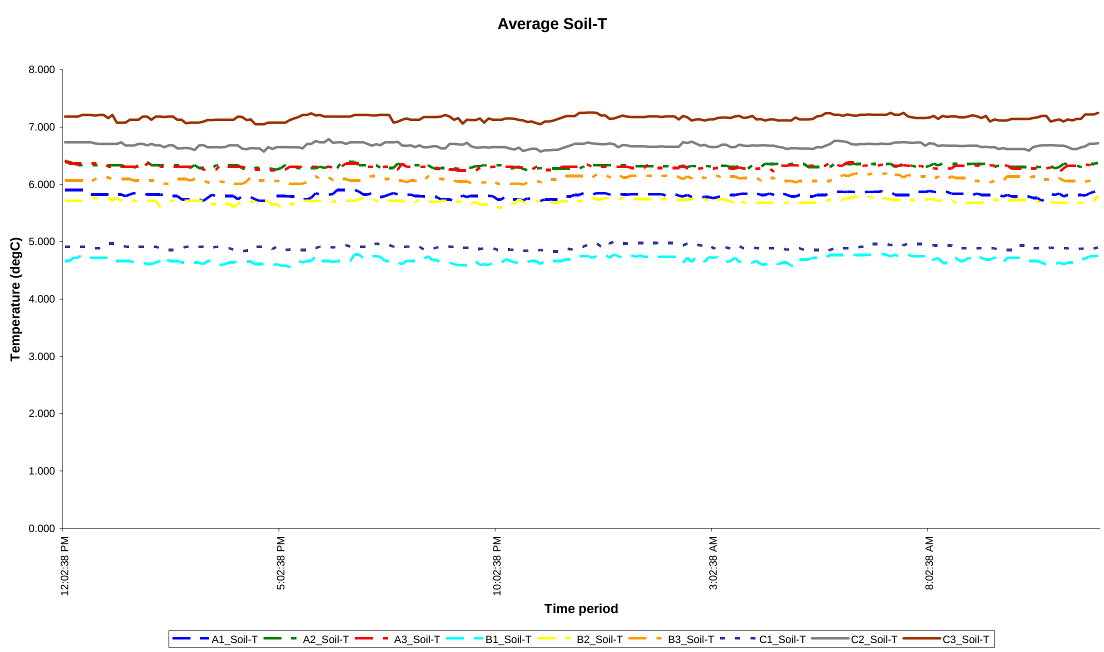


Figure B-19: Average soil temperature of S1-Alt3

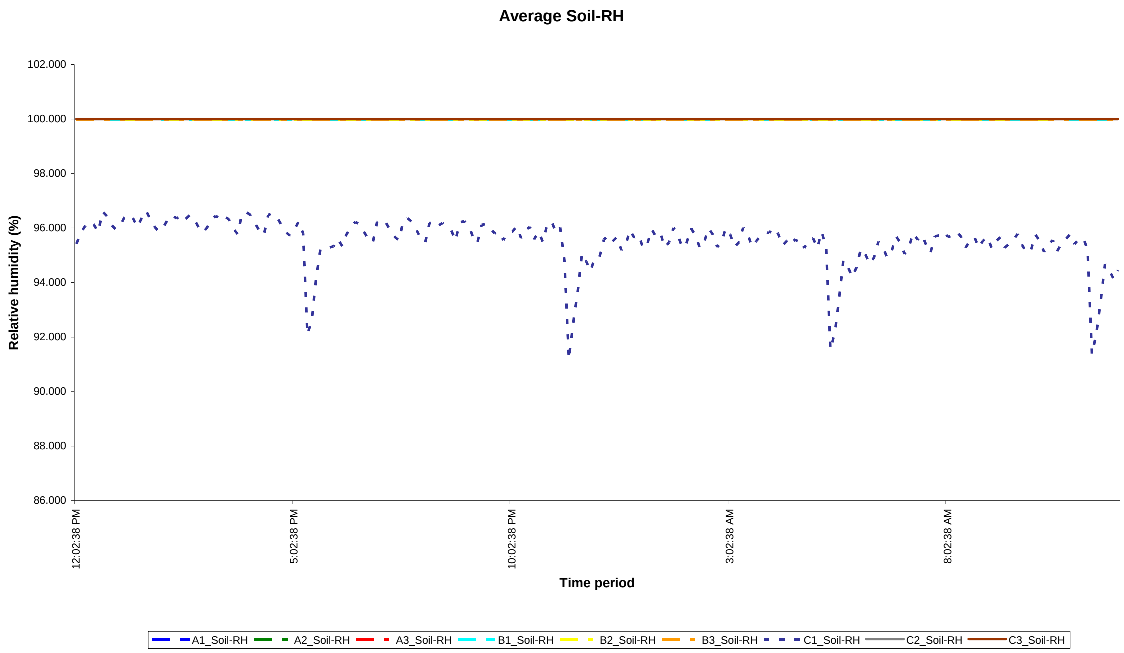


Figure B-20: Average soil relative humidity of S1-Alt3

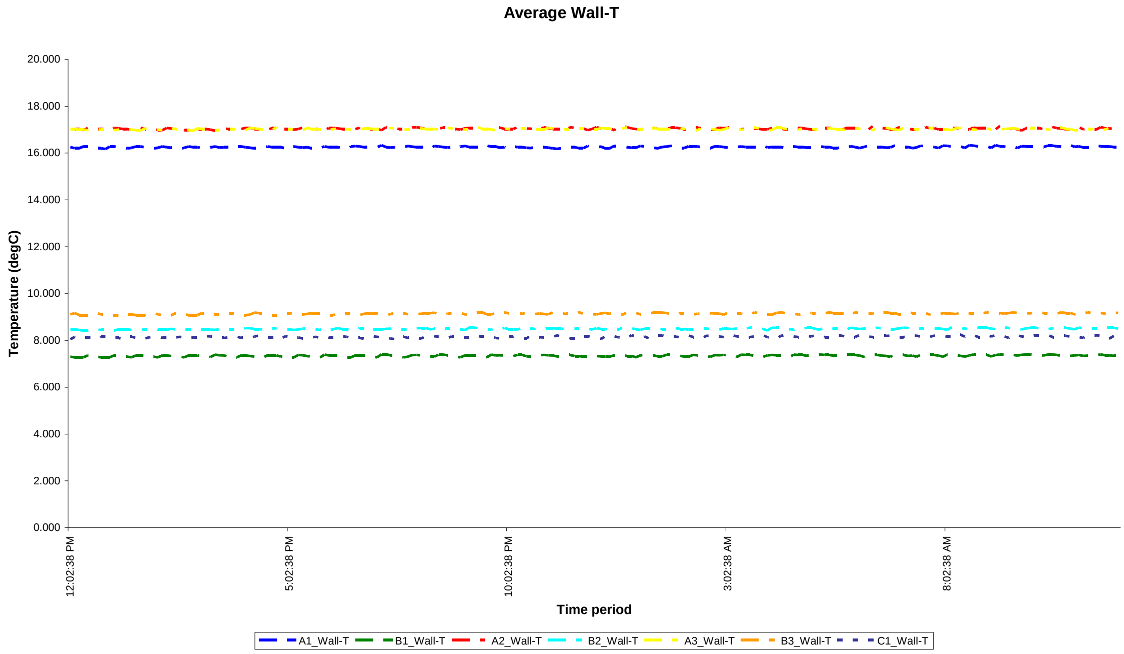


Figure B-21: Average wall temperature of S1-Alt3

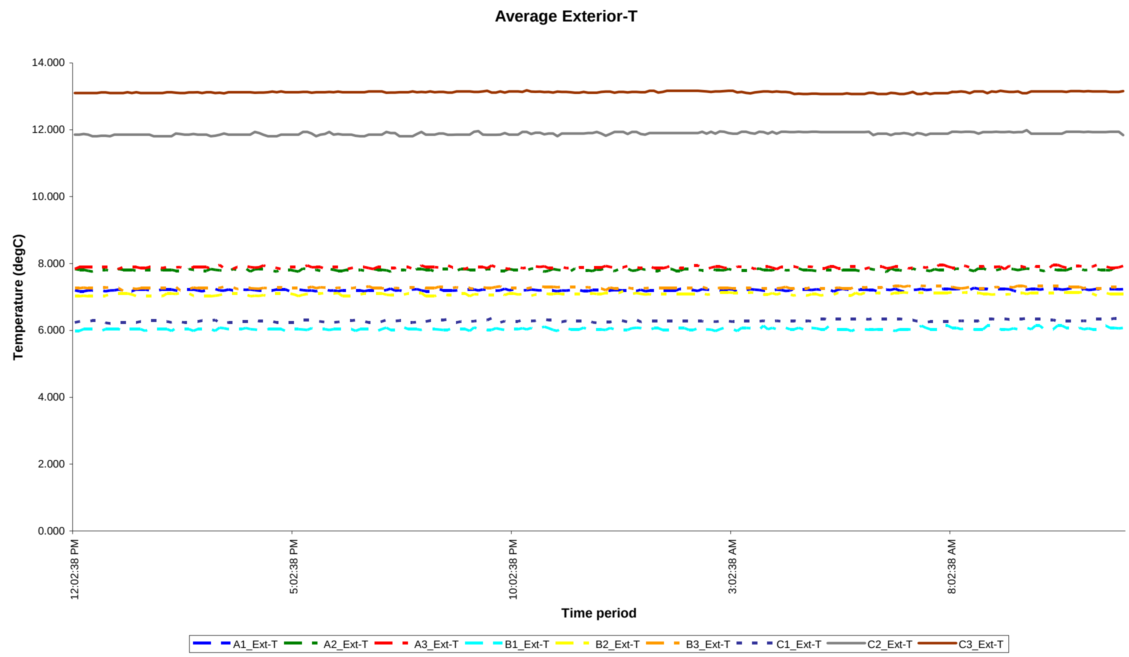


Figure B-22: Average exterior temperature of S1-Alt3

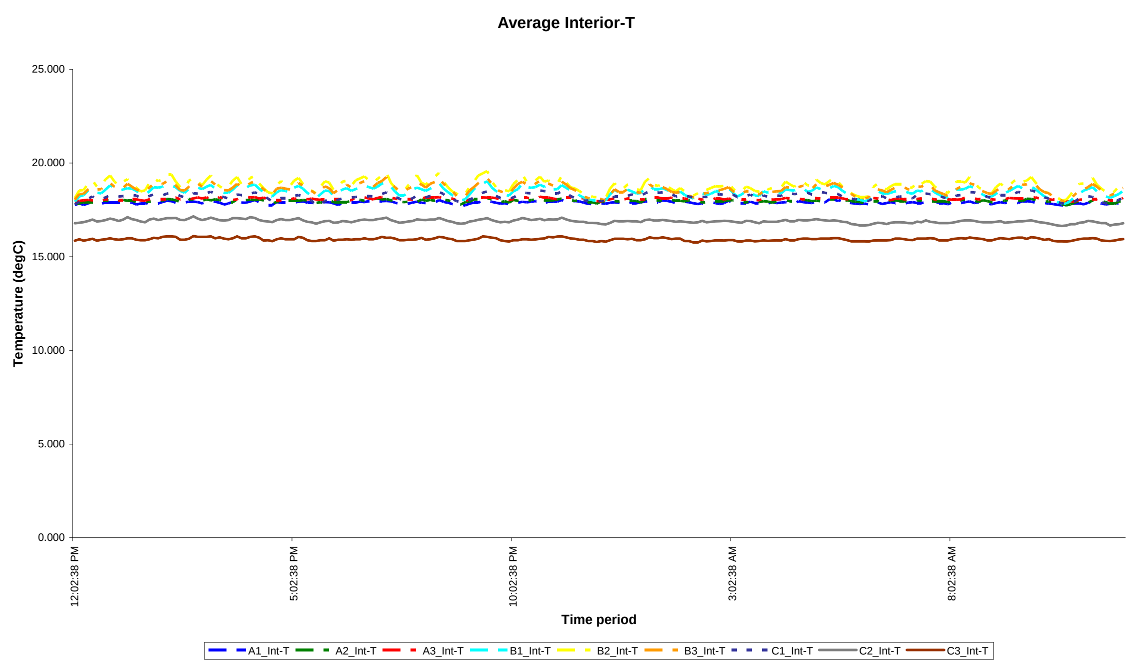


Figure B-23: Average interior temperature of S1-Alt3

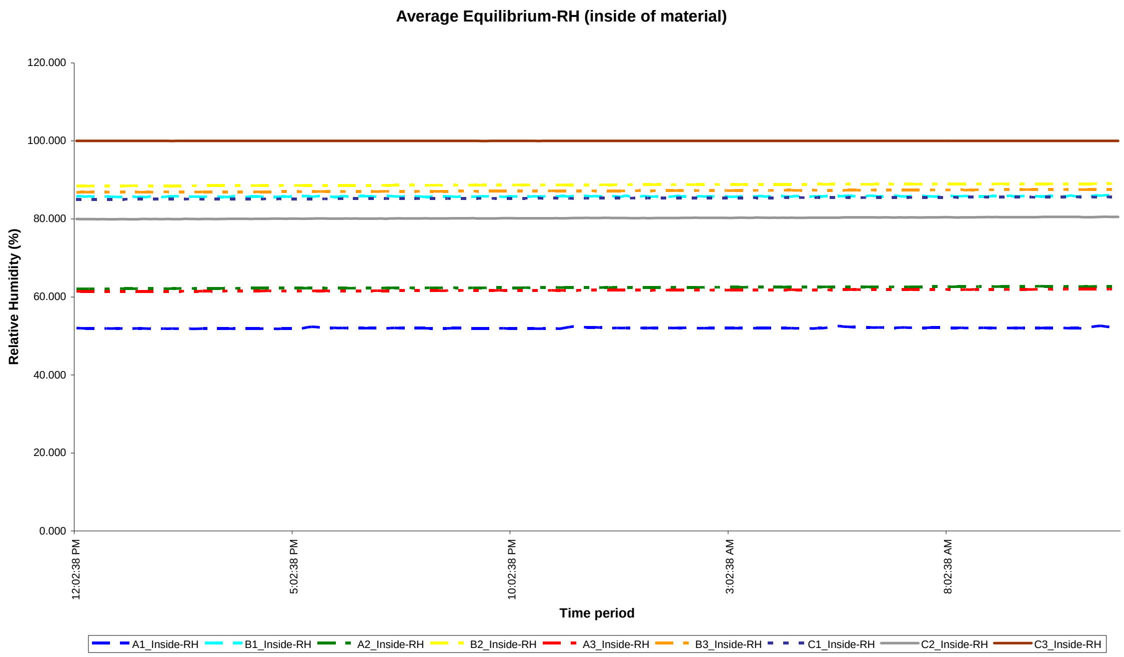


Figure B-24: Average equilibrium of relative humidity in a cavity of S1-Alt3

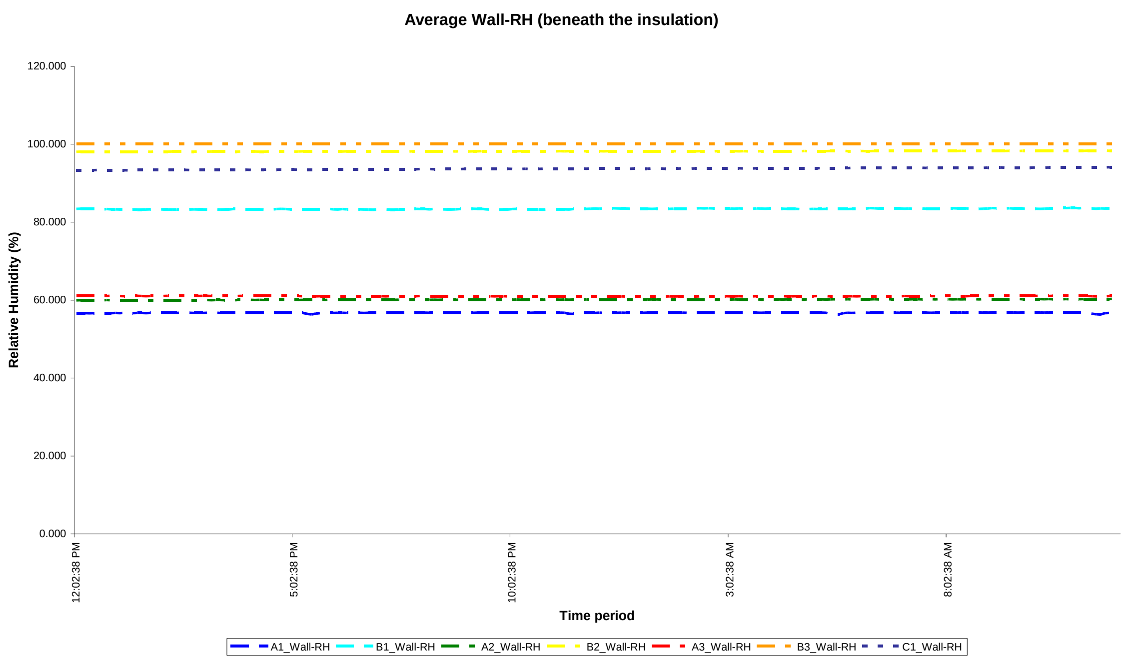


Figure B-25: Average wall relative humidity beneath the insulation of S1-Alt3

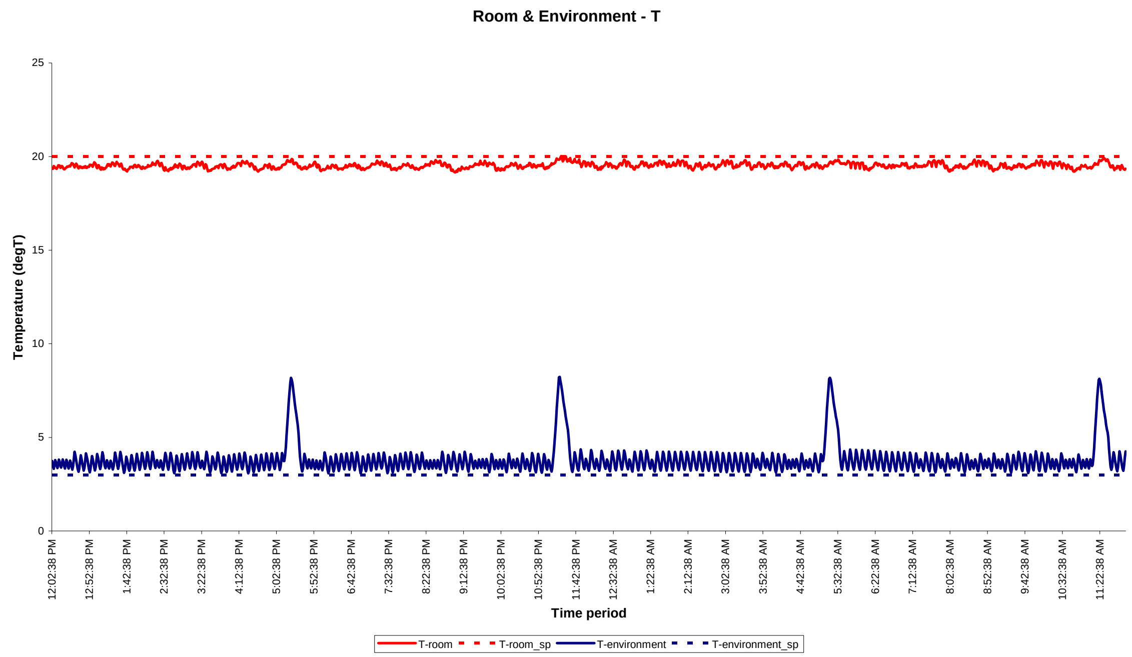


Figure B-26: Temperature of the room and environmental side during S1-Alt3

Figure B-27: Relative humidity of the room and environmental side during S1-Alt3

Test cycle: **S1 – Alt4**

Table B-4: Average data during the last 24 hours for each specimen of S1-Alt4

Specimen Measurement Data

B-G	A		B		C		Sand
1	A1_Soil-T	5.687 degC	B1_Soil-T	4.397 degC	C1_Soil-T	4.350 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	99.381 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	15.742 degC	B1_Wall-T	6.847 degC	C1_Wall-T	7.095 degC	
	A1_Ext-T	7.022 degC	B1_Ext-T	5.676 degC	C1_Ext-T	5.448 degC	
	A1_Int-T	17.740 degC	B1_Int-T	17.765 degC	C1_Int-T	16.585 degC	
	A1_Inside-RH	46.459 %	B1_Inside-RH	84.557 %	C1_Inside-RH	86.613 %	
	A1_Wall-RH	56.697 %	B1_Wall-RH	78.799 %	C1_Wall-RH	86.872 %	
2	A2_Soil-T	6.427 degC	B2_Soil-T	5.551 degC	C2_Soil-T	6.292 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	16.766 degC	B2_Wall-T	8.129 degC	C2_Ext-T	11.258 degC	
	A2_Ext-T	7.903 degC	B2_Ext-T	6.833 degC	C2_Int-T	16.031 degC	
	A2_Int-T	17.684 degC	B2_Int-T	18.090 degC	C2_Inside-RH	79.321 degC	
	A2_Inside-RH	59.535 %	B2_Inside-RH	90.079 %			
	A2_Wall-RH	60.399 %	B2_Wall-RH	96.658 %			
3	A3_Soil-T	6.591 degC	B3_Soil-T	5.882 degC	C3_Soil-T	6.746 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	16.782 degC	B3_Wall-T	8.334 degC	C3_Ext-T	12.562 degC	
	A3_Ext-T	8.042 degC	B3_Ext-T	6.751 degC	C3_Int-T	15.181 degC	
	A3_Int-T	17.822 degC	B3_Int-T	17.778 degC	C3_Inside-RH	100.000 degC	
	A3_Inside-RH	58.777 %	B3_Inside-RH	89.456 %			
	A3_Wall-RH	62.377 %	B3_Wall-RH	94.315 %	**Pressure diff.*	*11.803 Pa*	
No	A		B		C		Alt4

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	19.493 degC
RH-room	33.679 %
T-room_sp	20.000 degC
RH-room_sp	35.000 %
T-environment	3.865 degC
RH-environment	78.919 %
T-environment_sp	3.000 degC
RH-environment_sp	97.000 %

Remarks

Type: B-G
Soil type: Sand
Damproofing: No
Alternative: Alt4

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

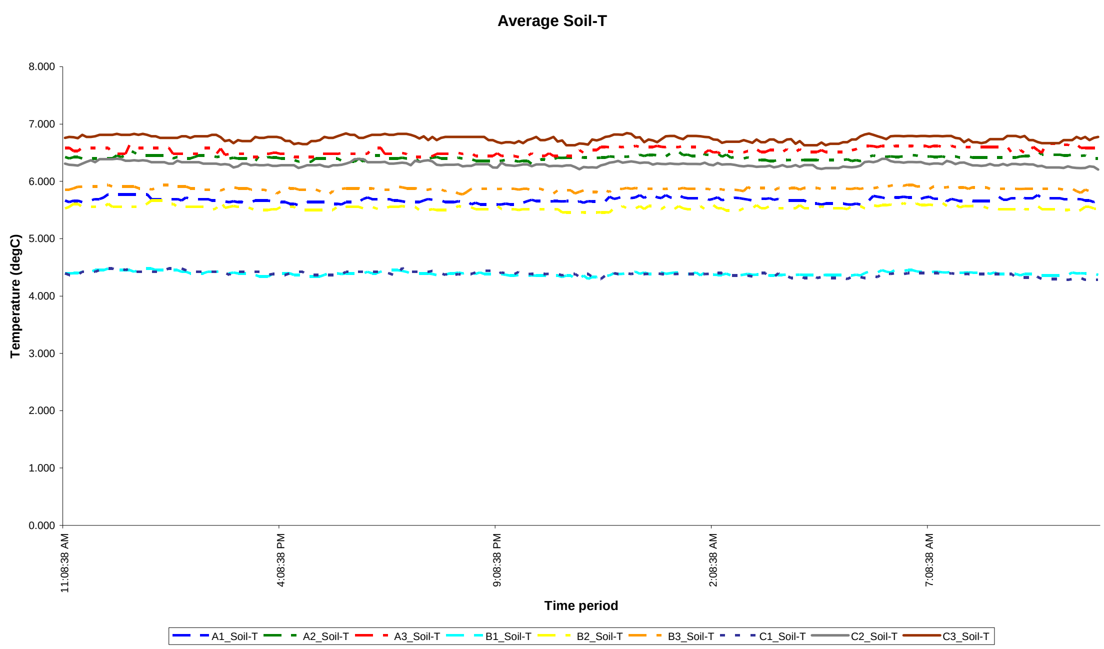


Figure B-28: Average soil temperature of S1-Alt4

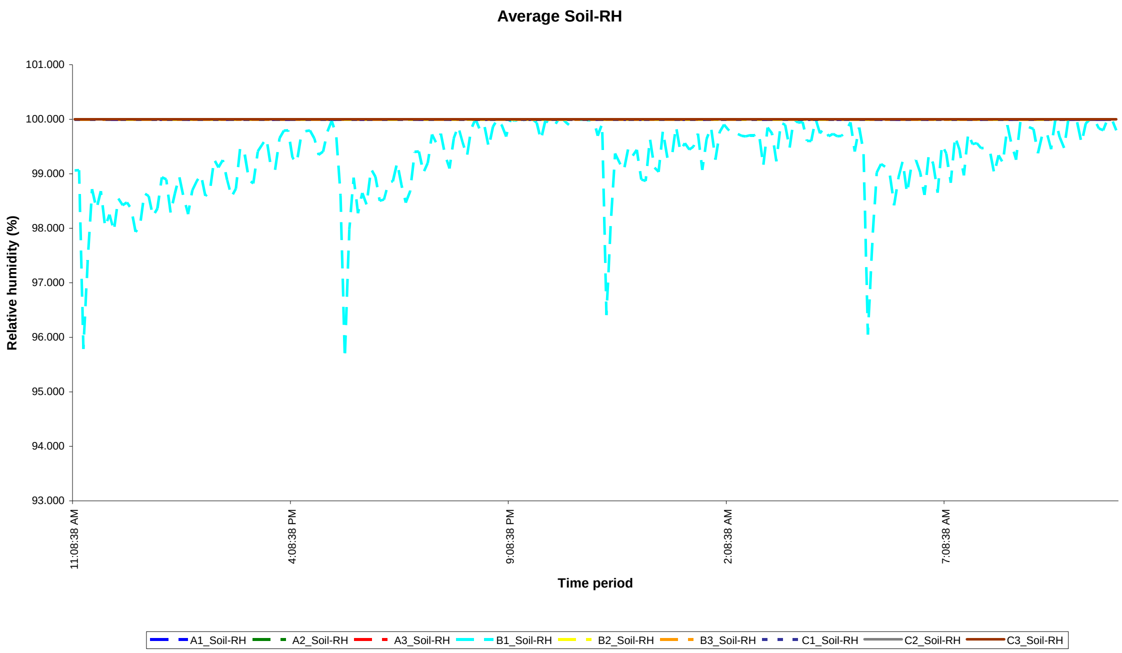


Figure B-29: Average soil relative humidity of S1-Alt4

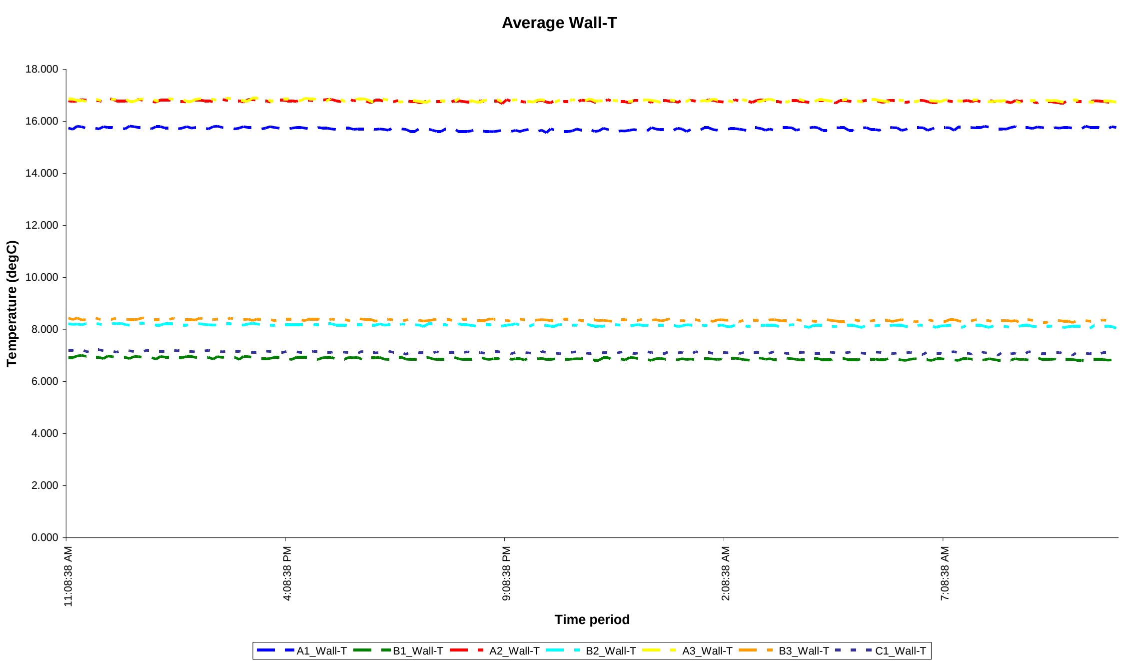


Figure B-30: Average wall temperature of S1-Alt4

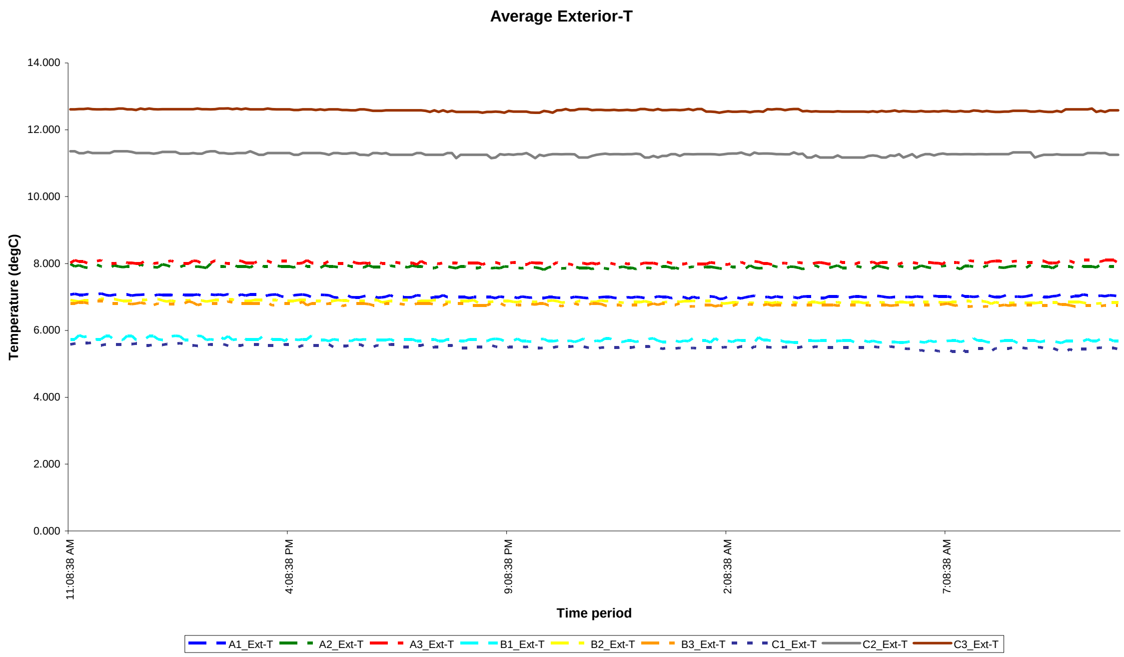


Figure B-31: Average exterior temperature of S1-Alt4

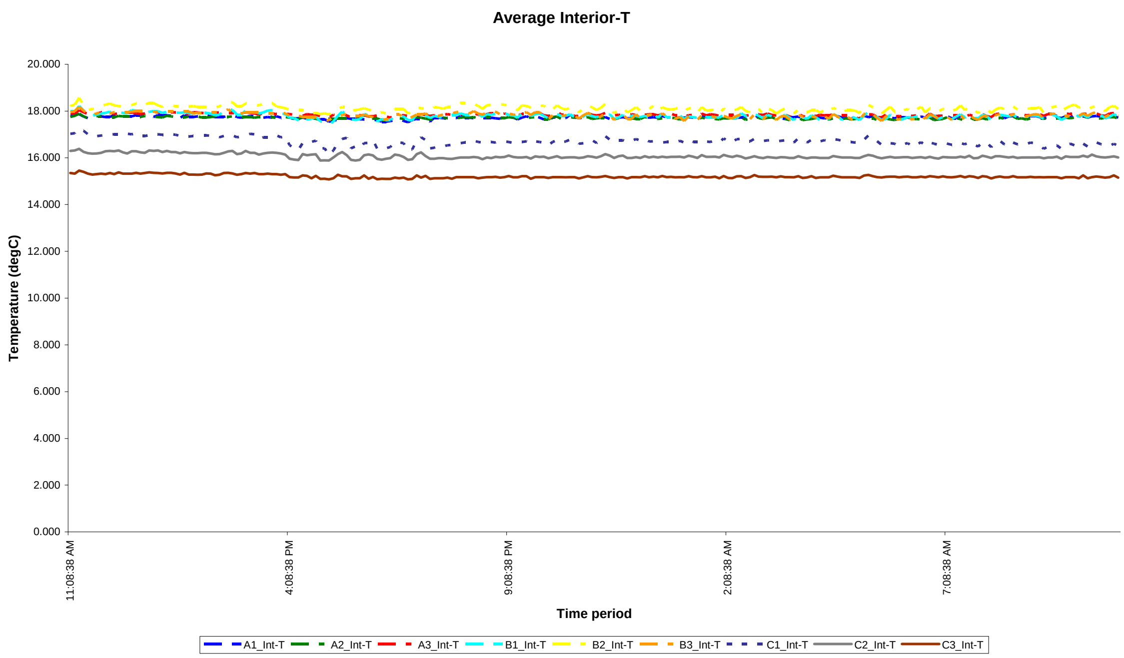


Figure B-32: Average interior temperature of S1-Alt4

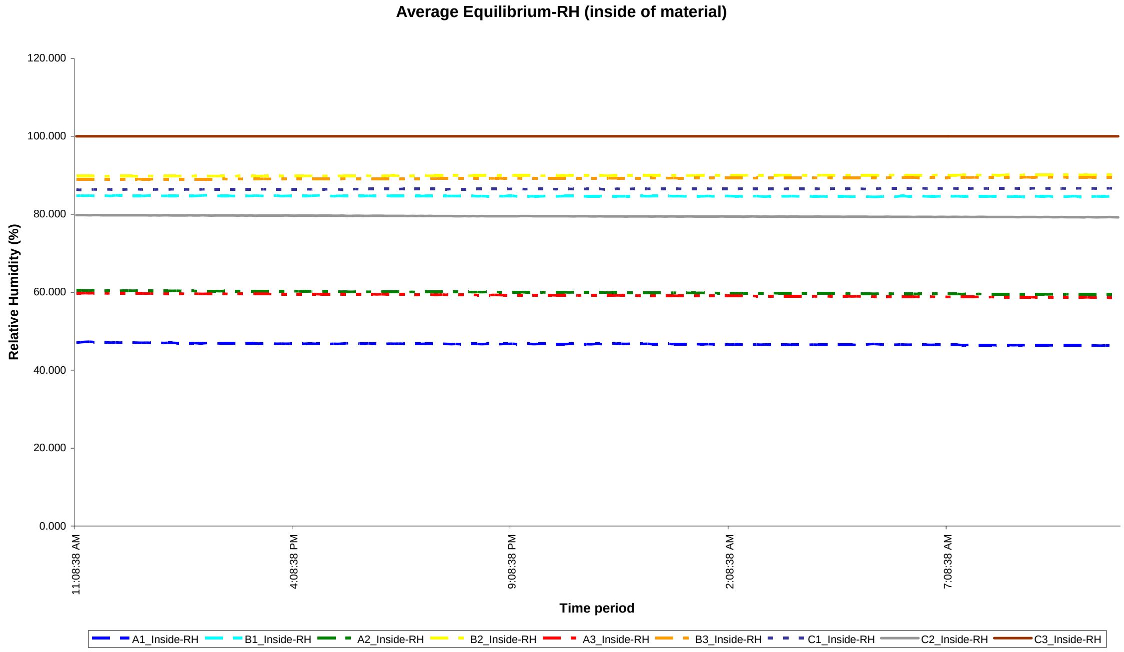


Figure B-33: Average equilibrium of relative humidity in a cavity of S1-Alt4

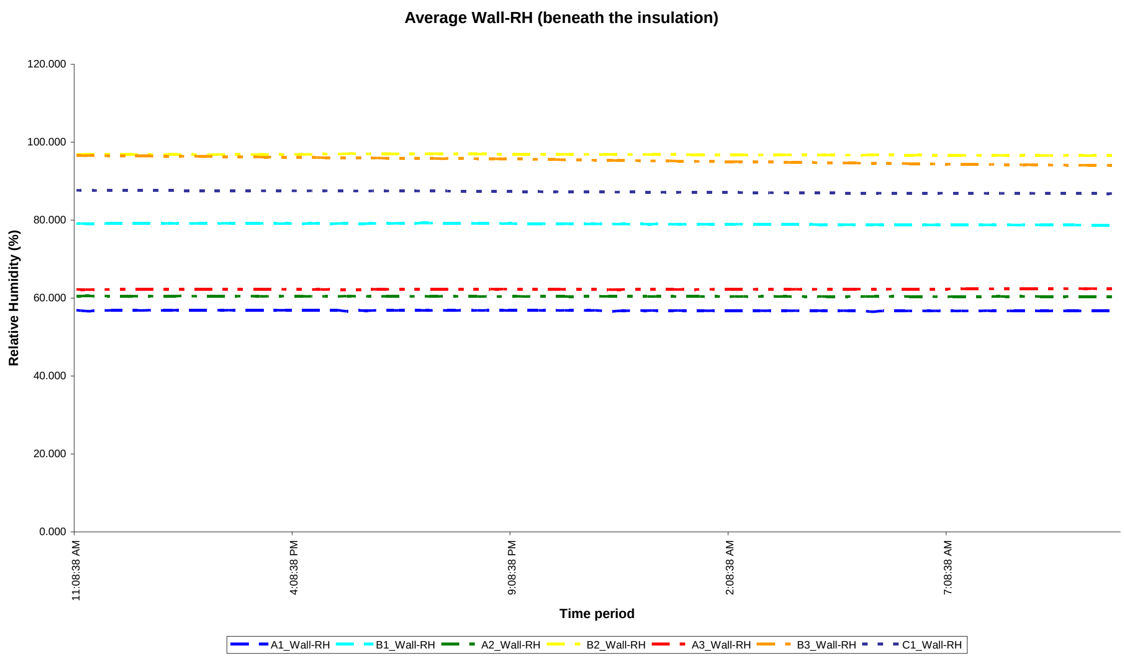


Figure B-34: Average wall relative humidity beneath the insulation of S1-Alt4

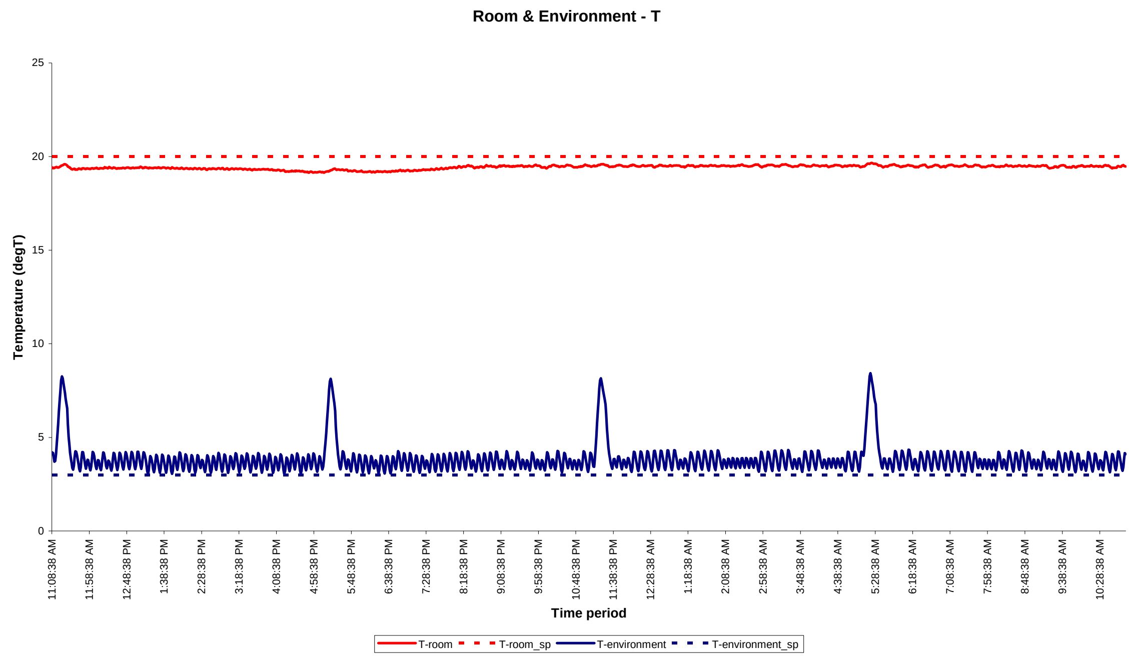


Figure B-35: Temperature of the room and environmental side during S1-Alt4

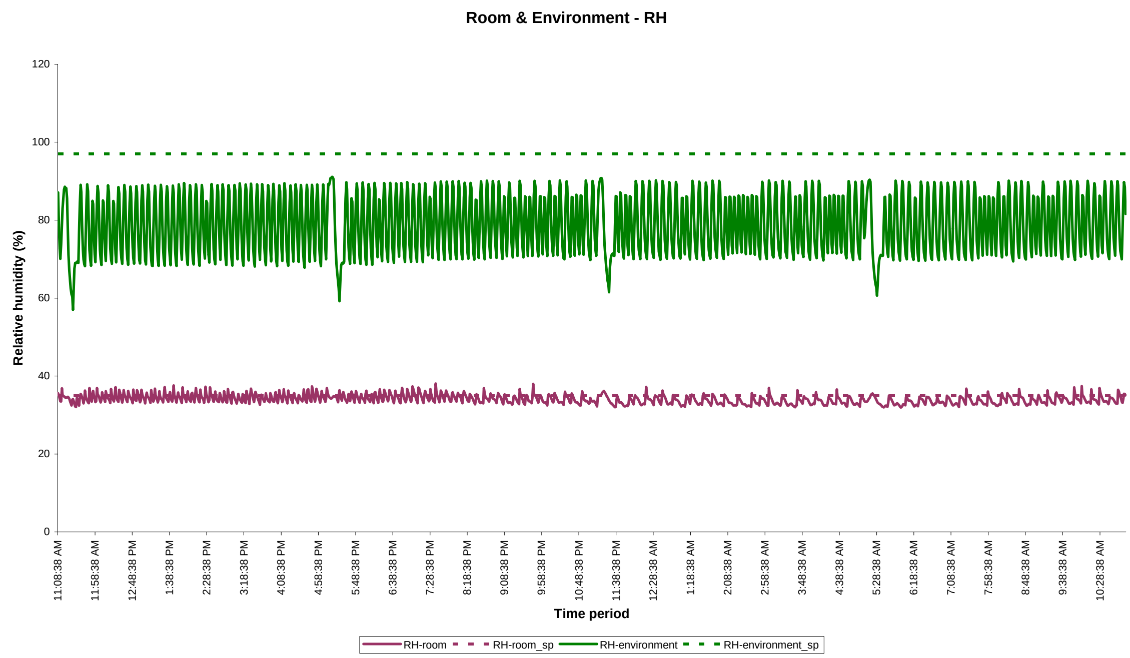


Figure B-36: Relative humidity of the room and environmental side during S1-Alt4

Test cycle: **S1 – Alt5**

Table B-5: Average data during the last 24 hours for each specimen of S1-Alt5

Specimen Measurement Data

B-G	A		B		C		Sand
1	A1_Soil-T	19.355 degC	B1_Soil-T	18.883 degC	C1_Soil-T	19.514 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	94.595 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	19.873 degC	B1_Wall-T	18.223 degC	C1_Wall-T	19.544 degC	
	A1_Ext-T	19.526 degC	B1_Ext-T	18.025 degC	C1_Ext-T	19.171 degC	
	A1_Int-T	19.768 degC	B1_Int-T	19.786 degC	C1_Int-T	20.242 degC	
	A1_Inside-RH	56.747 %	B1_Inside-RH	86.183 %	C1_Inside-RH	87.626 %	
	A1_Wall-RH	66.354 %	B1_Wall-RH	73.578 %	C1_Wall-RH	79.176 %	
2	A2_Soil-T	19.141 degC	B2_Soil-T	17.874 degC	C2_Soil-T	19.961 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	19.458 degC	B2_Wall-T	17.090 degC	C2_Ext-T	20.206 degC	
	A2_Ext-T	19.238 degC	B2_Ext-T	16.888 degC	C2_Int-T	20.170 degC	
	A2_Int-T	19.320 degC	B2_Int-T	19.641 degC	C2_Inside-RH	78.106 degC	
	A2_Inside-RH	59.274 %	B2_Inside-RH	90.710 %			
	A2_Wall-RH	72.951 %	B2_Wall-RH	94.291 %			
3	A3_Soil-T	19.230 degC	B3_Soil-T	18.360 degC	C3_Soil-T	21.799 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	19.558 degC	B3_Wall-T	17.498 degC	C3_Ext-T	21.014 degC	
	A3_Ext-T	18.981 degC	B3_Ext-T	17.364 degC	C3_Int-T	20.384 degC	
	A3_Int-T	19.425 degC	B3_Int-T	19.617 degC	C3_Inside-RH	100.000 degC	
	A3_Inside-RH	59.940 %	B3_Inside-RH	89.458 %			
	A3_Wall-RH	88.533 %	B3_Wall-RH	66.152 %	*Pressure diff.	8.867 Pa	
No	A		B		C		Alt5

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	20.862 degC
RH-room	36.970 %
T-room_sp	20.000 degC
RH-room_sp	35.000 %
T-environment	19.520 degC
RH-environment	48.782 %
T-environment_sp	20.000 degC
RH-environment_sp	50.000 %

Remarks

Type: B-G
Soil type: Sand
Damproofing: No
Alternative: Alt5

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

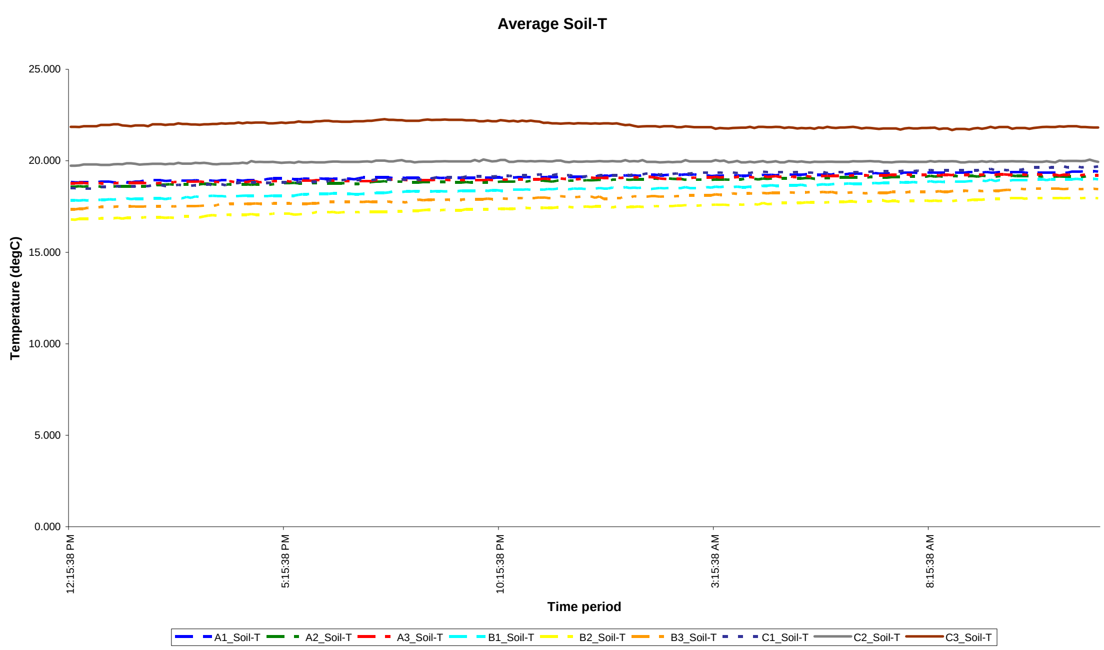


Figure B-37: Average soil temperature of S1-Alt5

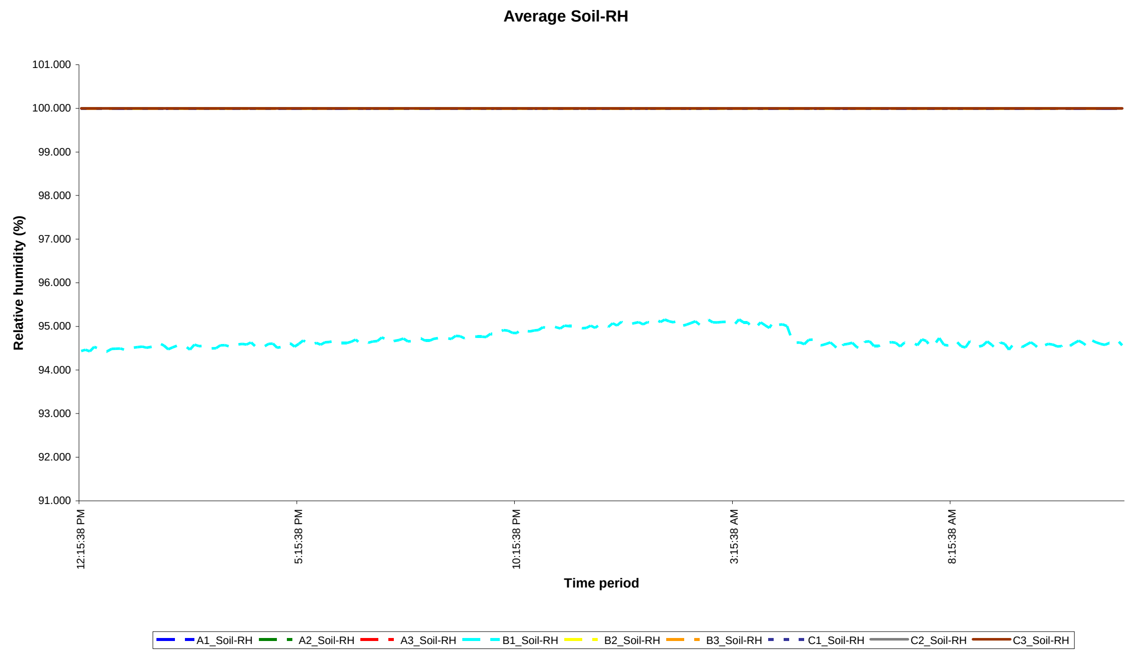


Figure B-38: Average soil relative humidity of S1-Alt5

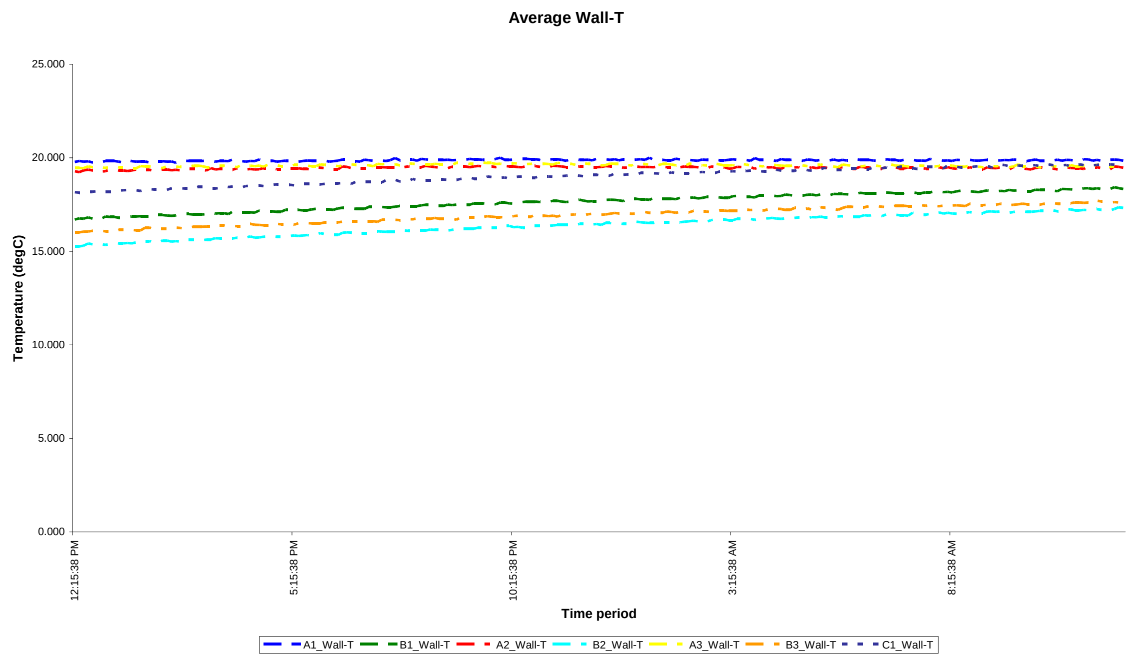


Figure B-39: Average wall temperature of S1-Alt5

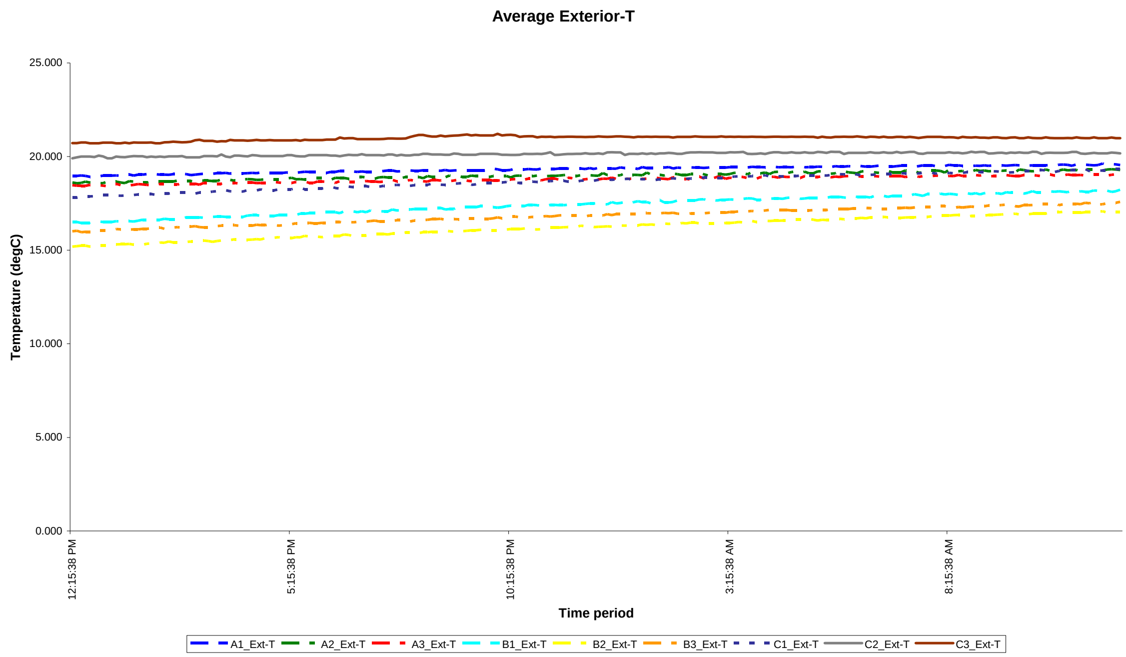


Figure B-40: Average exterior temperature of S1-Alt5

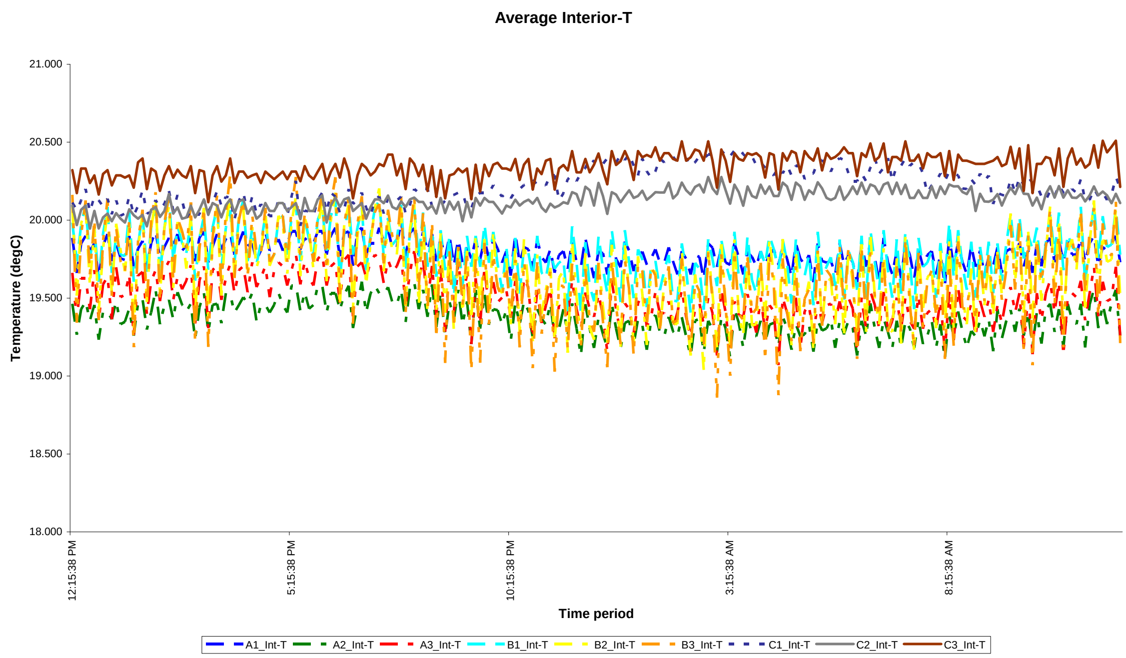


Figure B-41: Average interior temperature of S1-Alt5

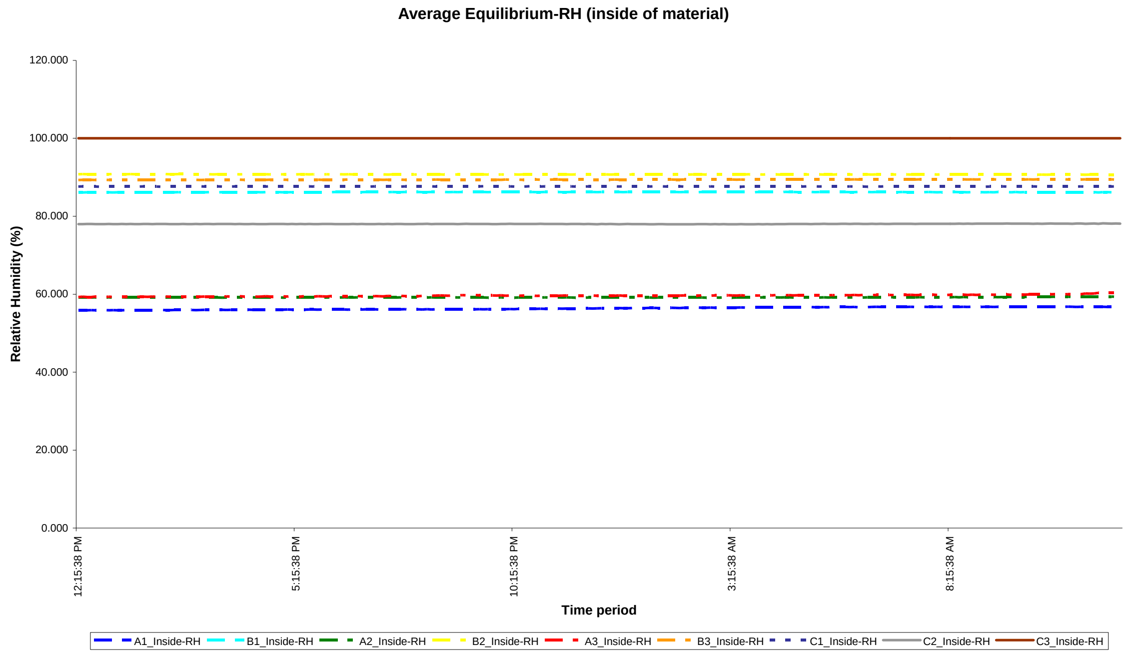


Figure B-42: Average equilibrium of relative humidity in a cavity of S1-Alt5

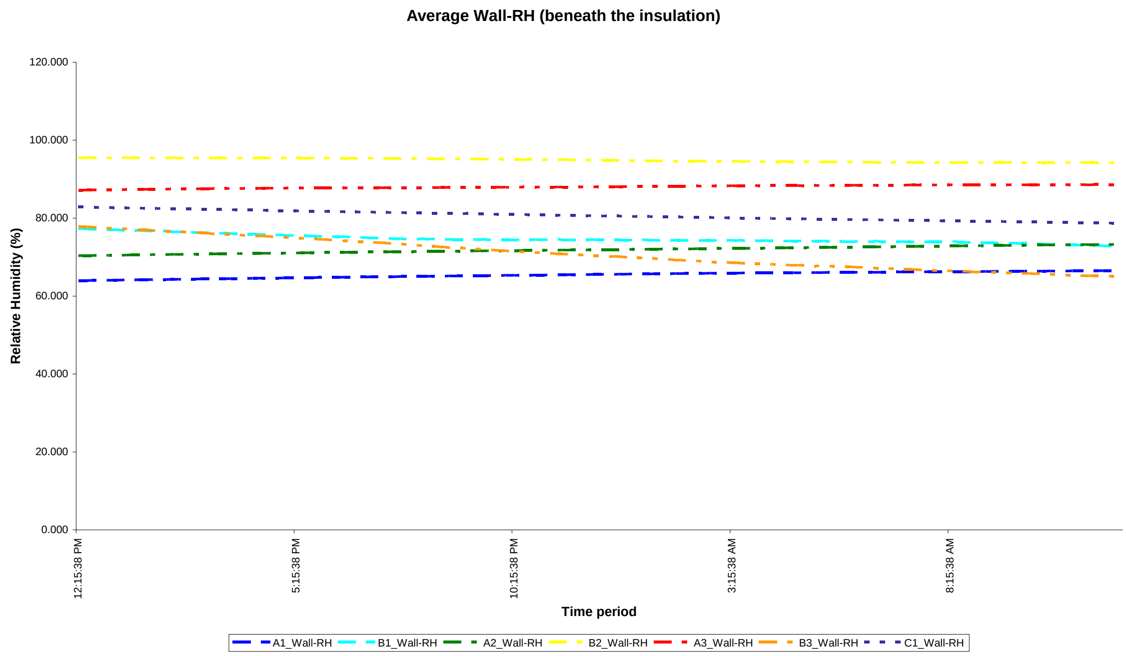


Figure B-43: Average wall relative humidity beneath the insulation of S1-Alt5

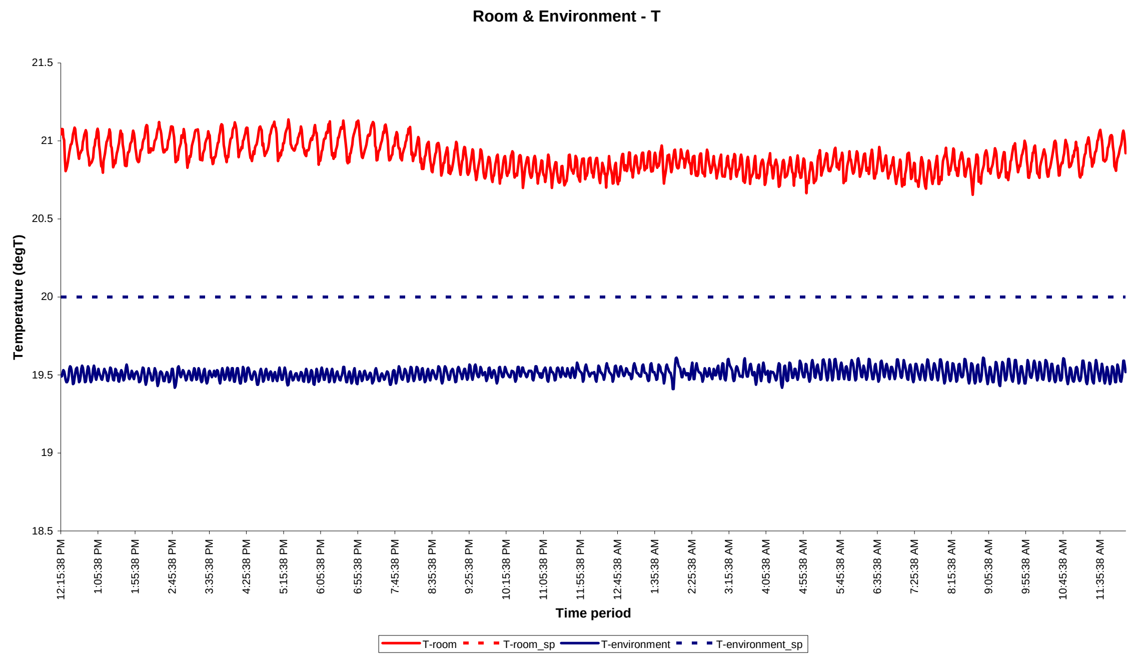


Figure B-44: Temperature of the room and environmental side during S1-Alt5

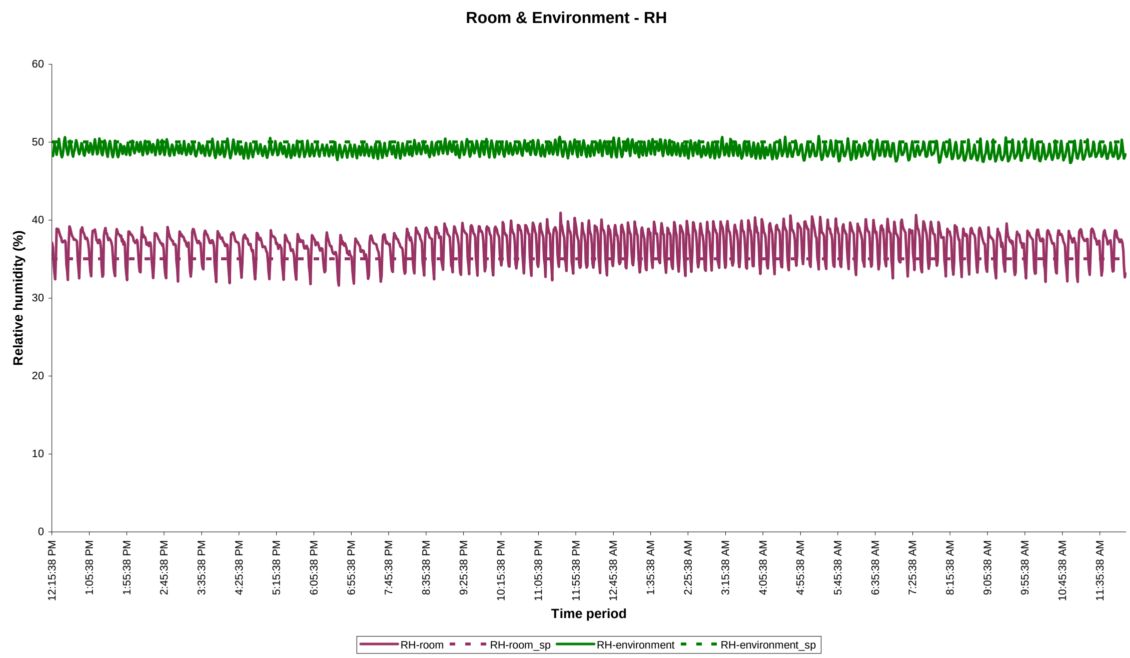


Figure B-45: Relative humidity of the room and environmental side during S1-Alt5

Test cycle: **S1 – Alt6**

Table B-6: Average data during the last 24 hours for each specimen of S1-Alt6

Specimen Measurement Data							
B-G	A		B		C		Sand
1	A1_Soil-T	19.578 degC	B1_Soil-T	19.826 degC	C1_Soil-T	20.400 degC	1
	A1_Soil-RH	98.514 %	B1_Soil-RH	94.729 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	20.172 degC	B1_Wall-T	19.795 degC	C1_Wall-T	20.602 degC	
	A1_Ext-T	19.808 degC	B1_Ext-T	19.645 degC	C1_Ext-T	20.301 degC	
	A1_Int-T	19.886 degC	B1_Int-T	19.189 degC	C1_Int-T	19.461 degC	
	A1_Inside-RH	59.651 %	B1_Inside-RH	86.283 %	C1_Inside-RH	87.614 %	
	A1_Wall-RH	71.394 %	B1_Wall-RH	79.847 %	C1_Wall-RH	76.355 %	
2	A2_Soil-T	19.429 degC	B2_Soil-T	19.183 degC	C2_Soil-T	20.222 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	19.785 degC	B2_Wall-T	19.330 degC	C2_Ext-T	20.161 degC	
	A2_Ext-T	19.685 degC	B2_Ext-T	19.056 degC	C2_Int-T	19.682 degC	
	A2_Int-T	19.484 degC	B2_Int-T	19.205 degC	C2_Inside-RH	79.456 degC	
	A2_Inside-RH	62.048 %	B2_Inside-RH	91.189 %			
	A2_Wall-RH	77.469 %	B2_Wall-RH	90.814 %			
3	A3_Soil-T	19.428 degC	B3_Soil-T	19.488 degC	C3_Soil-T	21.652 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	19.932 degC	B3_Wall-T	19.418 degC	C3_Ext-T	20.880 degC	
	A3_Ext-T	19.425 degC	B3_Ext-T	19.054 degC	C3_Int-T	20.213 degC	
	A3_Int-T	19.656 degC	B3_Int-T	19.516 degC	C3_Inside-RH	100.000 degC	
	A3_Inside-RH	64.422 %	B3_Inside-RH	88.229 %			
	A3_Wall-RH	86.394 %	B3_Wall-RH	70.221 %	*Pressure diff.	*30.542 Pa*	
No	A		B		C		Alt6

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data	
Environmental / Room Side	
T-room	20.534 degC
RH-room	56.761 %
T-room_sp	20.000 degC
RH-room_sp	65.000 %
T-environment	19.506 degC
RH-environment	49.120 %
T-environment_sp	20.000 degC
RH-environment_sp	50.000 %

Remarks

Type: B-G
Soil type: Sand
Damproofing: No
Alternative: Alt6

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

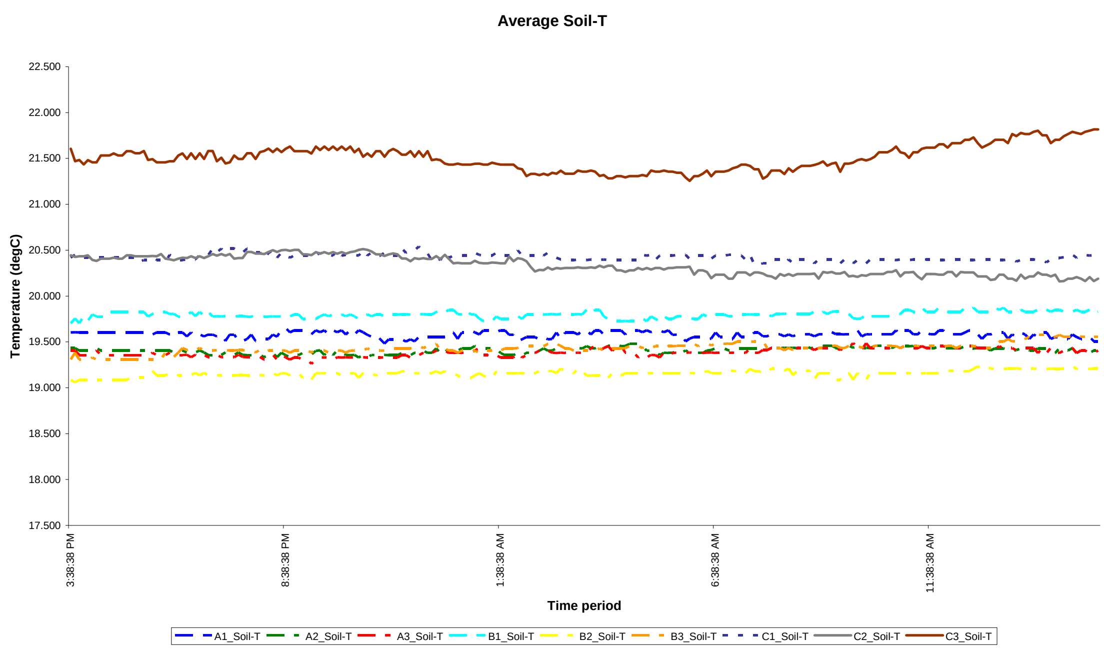


Figure B-46: Average soil temperature of S1-Alt6

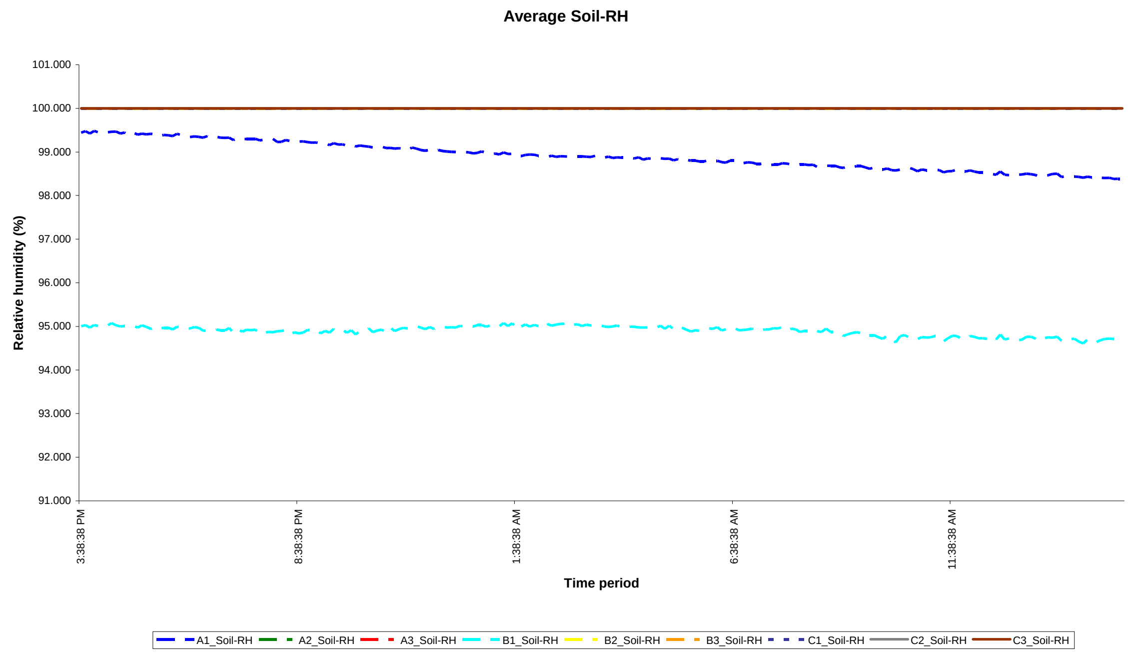


Figure B-47: Average soil relative humidity of S1-Alt6

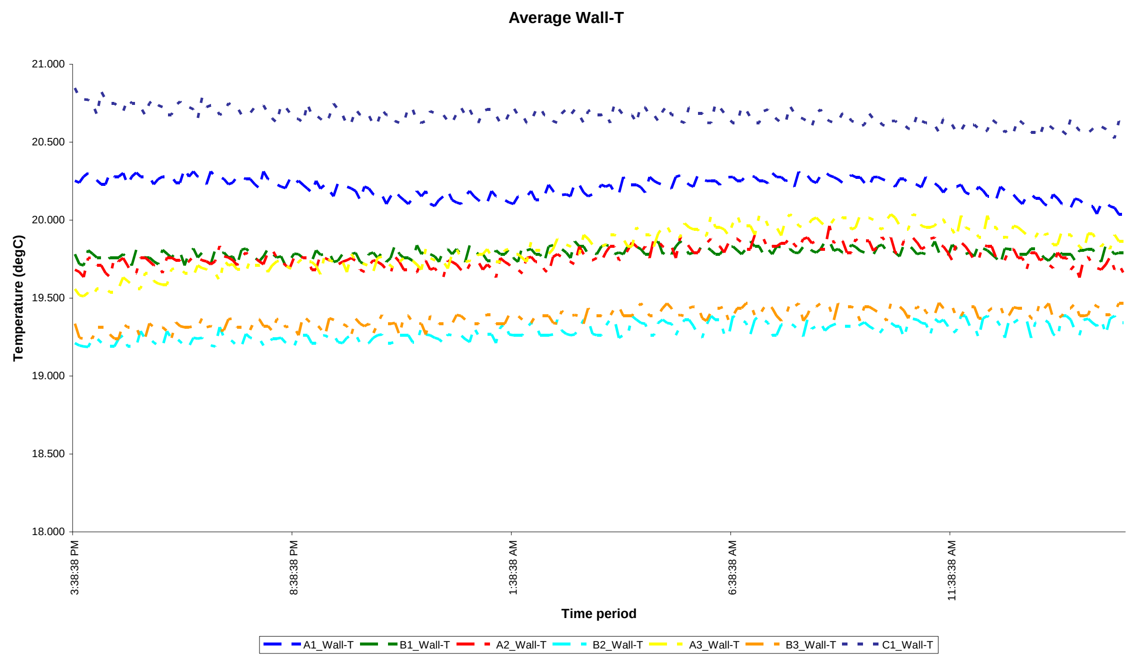


Figure B-48: Average wall temperature of S1-Alt6

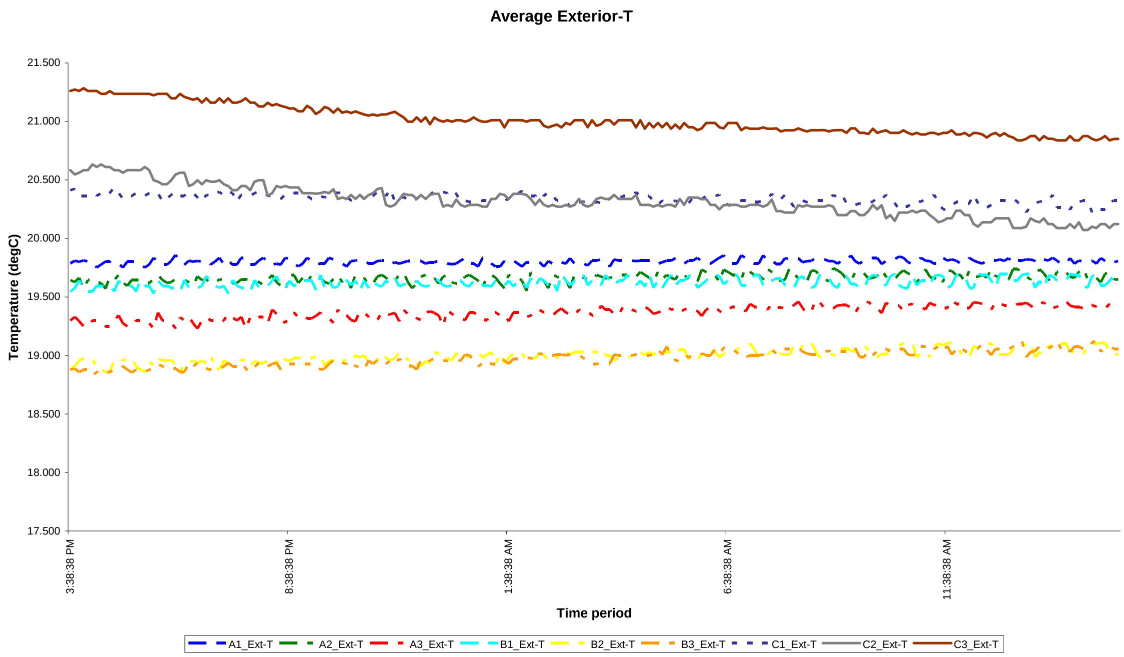


Figure B-49: Average exterior temperature of S1-Alt6

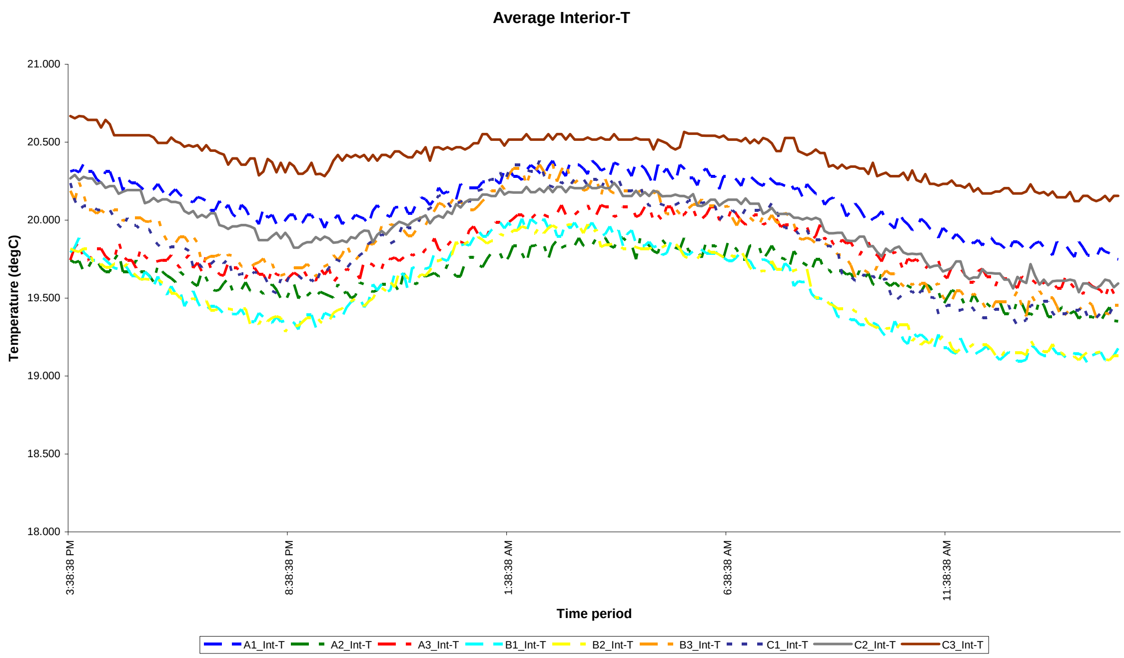


Figure B-50: Average interior temperature of S1-Alt6

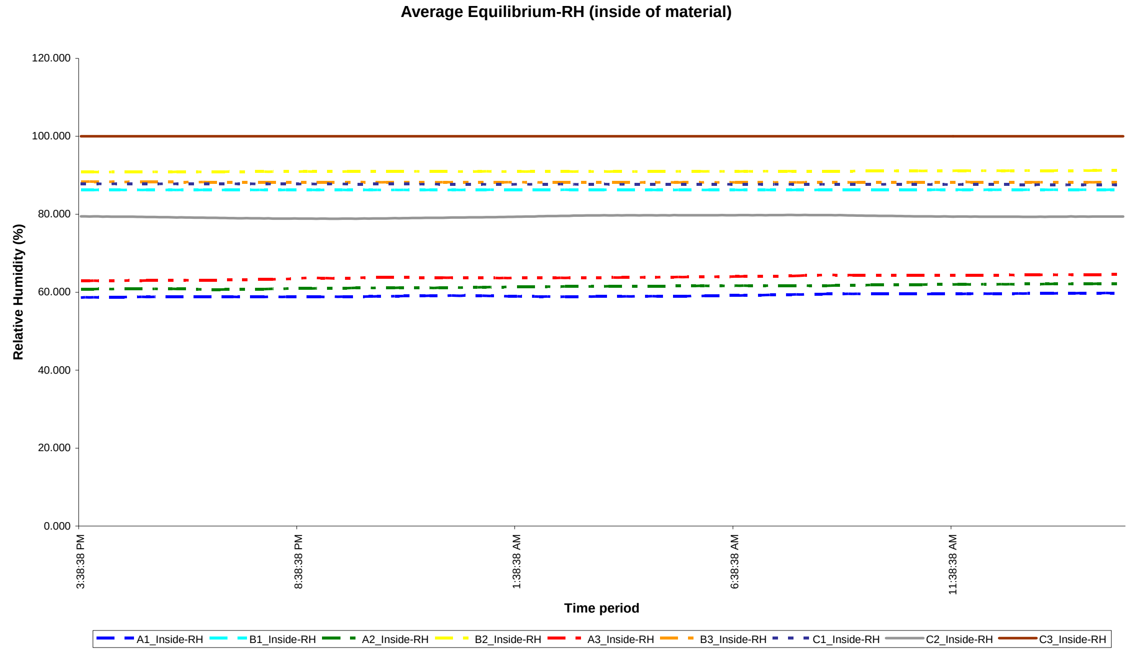


Figure B-51: Average equilibrium of relative humidity in a cavity of S1-Alt6

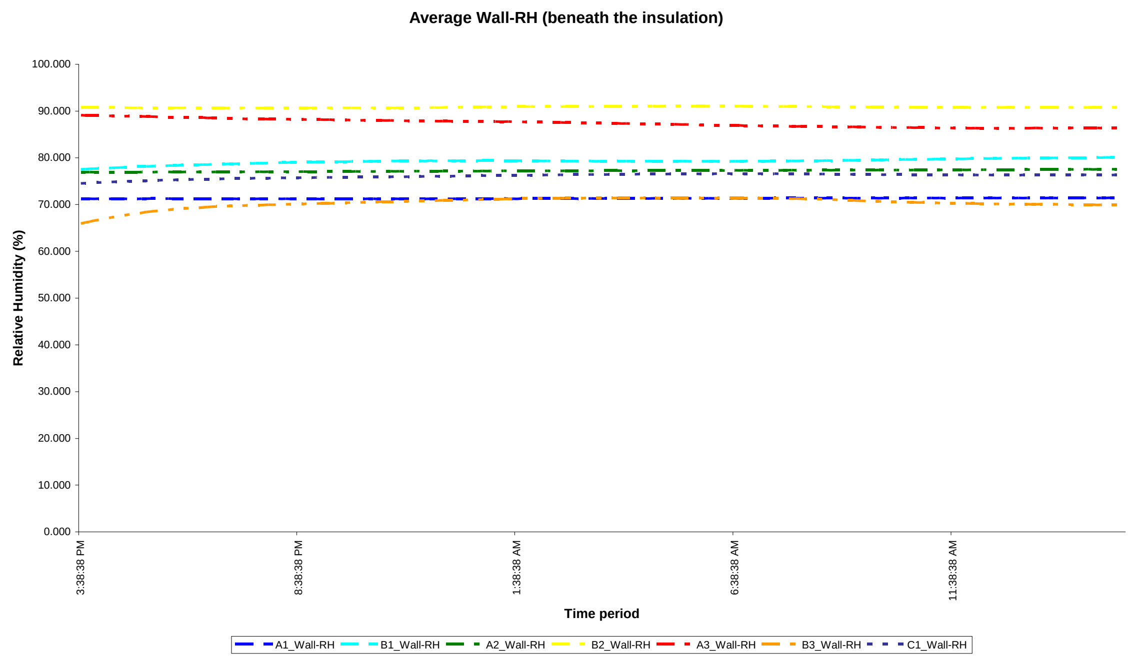


Figure B-52: Average wall relative humidity beneath the insulation of S1-Alt6

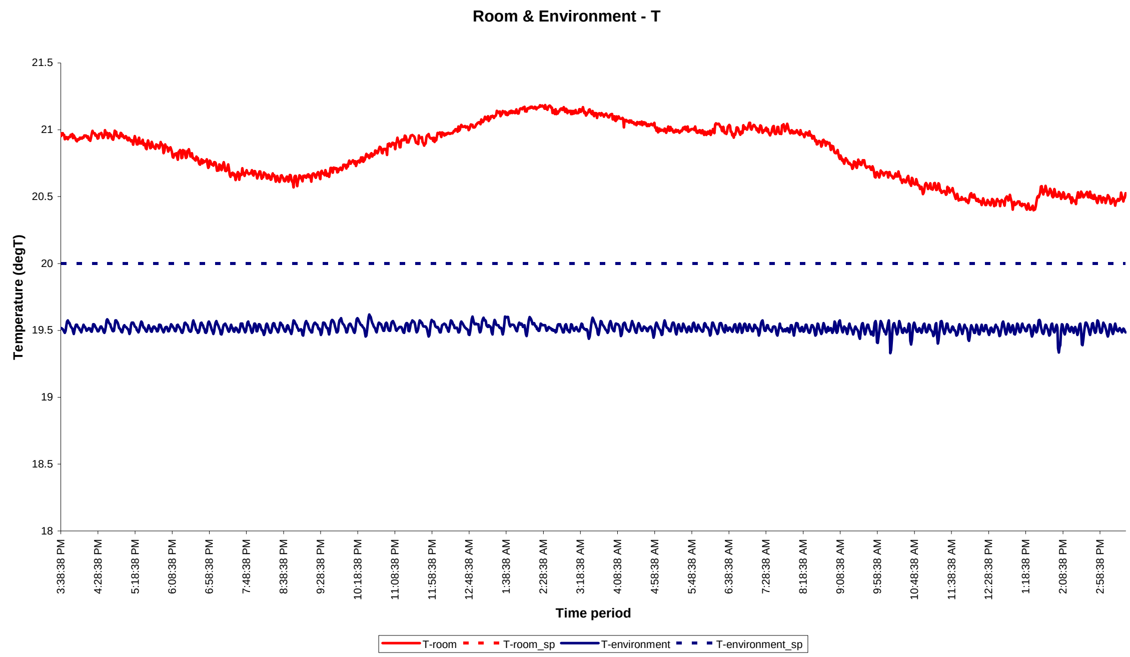


Figure B-53: Temperature of the room and environmental side during S1-Alt6

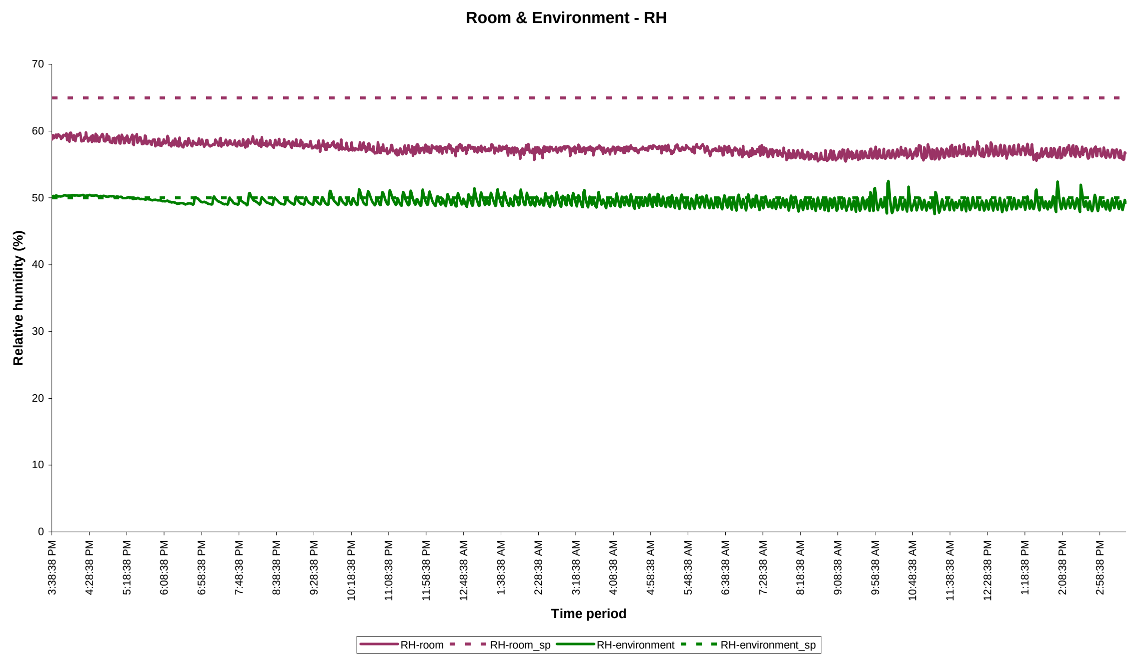


Figure B-54: Relative humidity of the room and environmental side during S1-Alt6

Test cycle: **S1 – Alt7**

Table B-7: Average data during the last 24 hours for each specimen of S1-Alt7

Specimen Measurement Data

B-G	A		B		C		Sand
1	A1_Soil-T	20.567 degC	B1_Soil-T	20.871 degC	C1_Soil-T	21.407 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	100.000 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	18.683 degC	B1_Wall-T	20.075 degC	C1_Wall-T	21.102 degC	
	A1_Ext-T	20.027 degC	B1_Ext-T	20.143 degC	C1_Ext-T	20.931 degC	
	A1_Int-T	18.282 degC	B1_Int-T	18.603 degC	C1_Int-T	19.774 degC	
	A1_Inside-RH	69.127 %	B1_Inside-RH	85.470 %	C1_Inside-RH	88.448 %	
	A1_Wall-RH	72.543 %	B1_Wall-RH	72.221 %	C1_Wall-RH	77.833 %	
2	A2_Soil-T	21.273 degC	B2_Soil-T	20.469 degC	C2_Soil-T	21.307 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	18.343 degC	B2_Wall-T	19.845 degC	C2_Ext-T	20.388 degC	
	A2_Ext-T	20.079 degC	B2_Ext-T	19.790 degC	C2_Int-T	19.524 degC	
	A2_Int-T	17.862 degC	B2_Int-T	18.206 degC	C2_Inside-RH	82.484 degC	
	A2_Inside-RH	66.181 %	B2_Inside-RH	92.199 %			
	A2_Wall-RH	81.701 %	B2_Wall-RH	80.687 %			
3	A3_Soil-T	20.447 degC	B3_Soil-T	21.167 degC	C3_Soil-T	22.160 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	18.629 degC	B3_Wall-T	19.724 degC	C3_Ext-T	20.606 degC	
	A3_Ext-T	19.663 degC	B3_Ext-T	19.606 degC	C3_Int-T	19.875 degC	
	A3_Int-T	18.067 degC	B3_Int-T	18.515 degC	C3_Inside-RH	100.000 degC	
	A3_Inside-RH	69.093 %	B3_Inside-RH	89.069 %			
	A3_Wall-RH	101.351 %	B3_Wall-RH	69.114 %	*Pressure diff.*	*60.531 Pa*	
No	A		B		C		Alt7

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	19.534 degC
RH-room	59.707 %
T-room_sp	20.000 degC
RH-room_sp	65.000 %
T-environment	19.544 degC
RH-environment	93.747 %
T-environment_sp	20.000 degC
RH-environment_sp	95.000 %

Remarks

Type: B-G
Soil type: Sand
Dampproofing: No
Alternative: Alt7

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

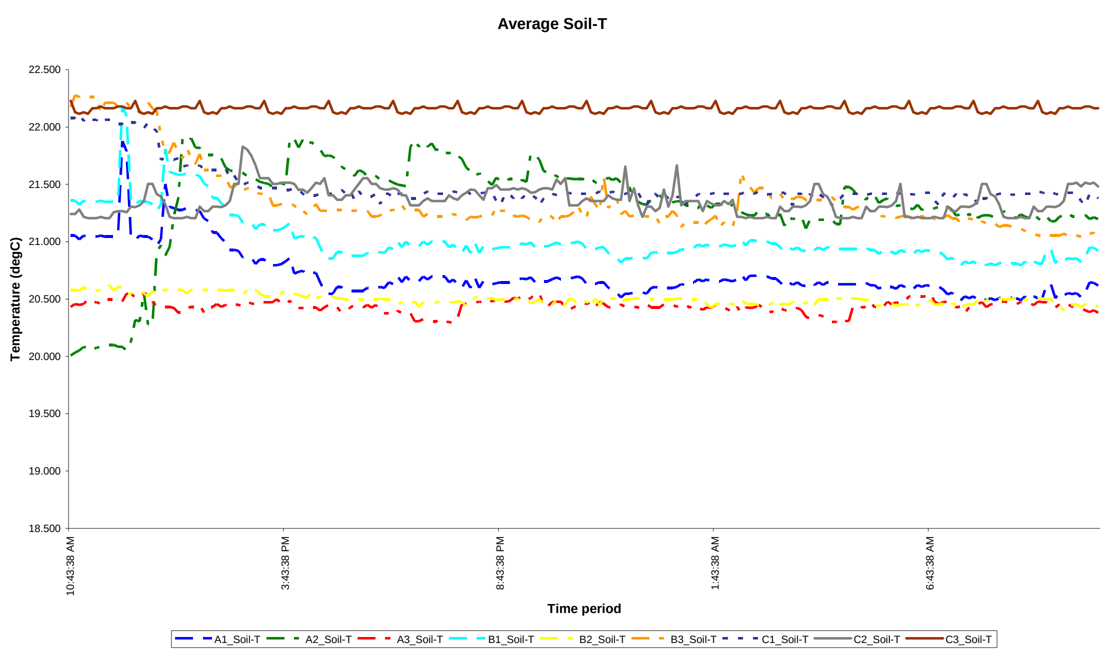


Figure B-55: Average soil temperature of S1-Alt7

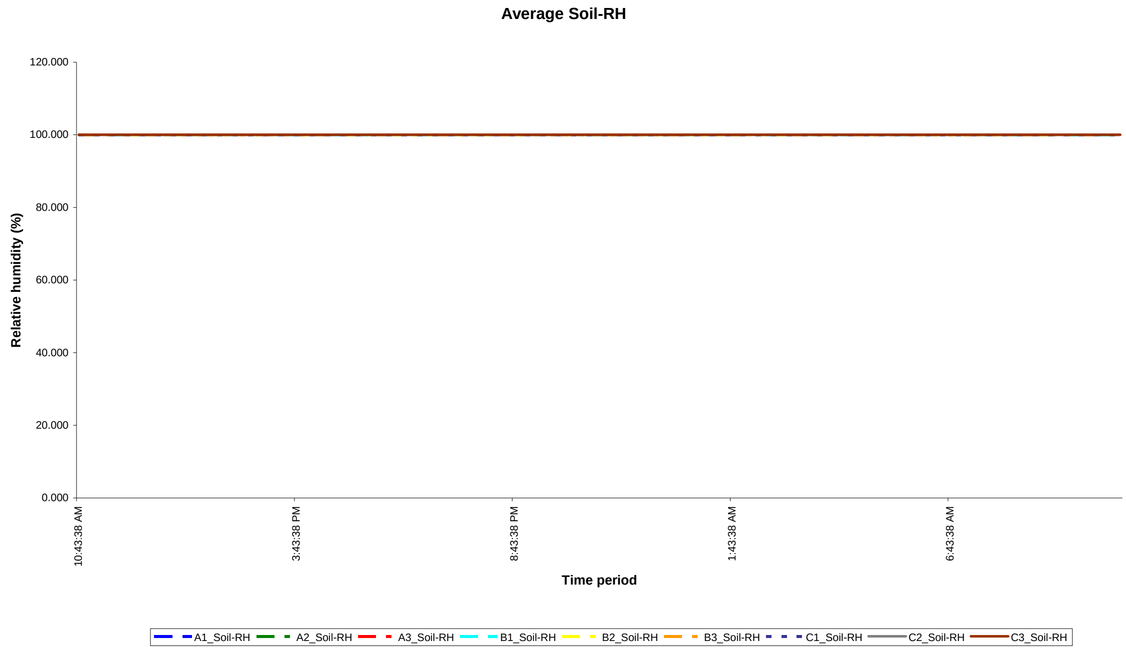


Figure B-56: Average soil relative humidity of S1-Alt7

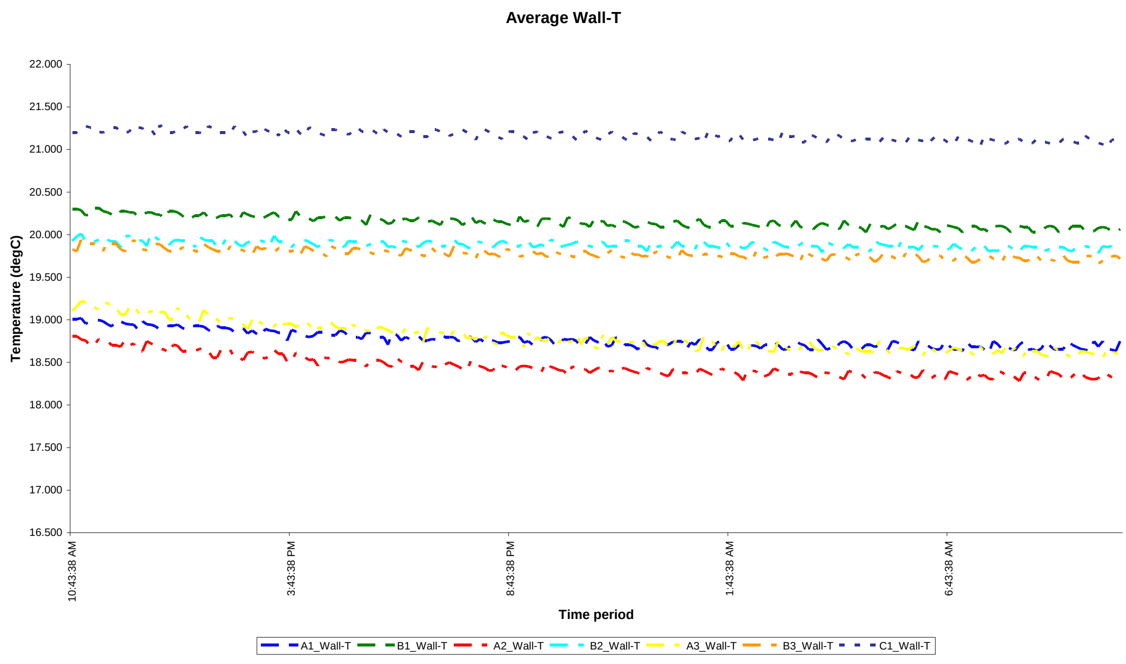


Figure B-57: Average wall temperature of S1-Alt7

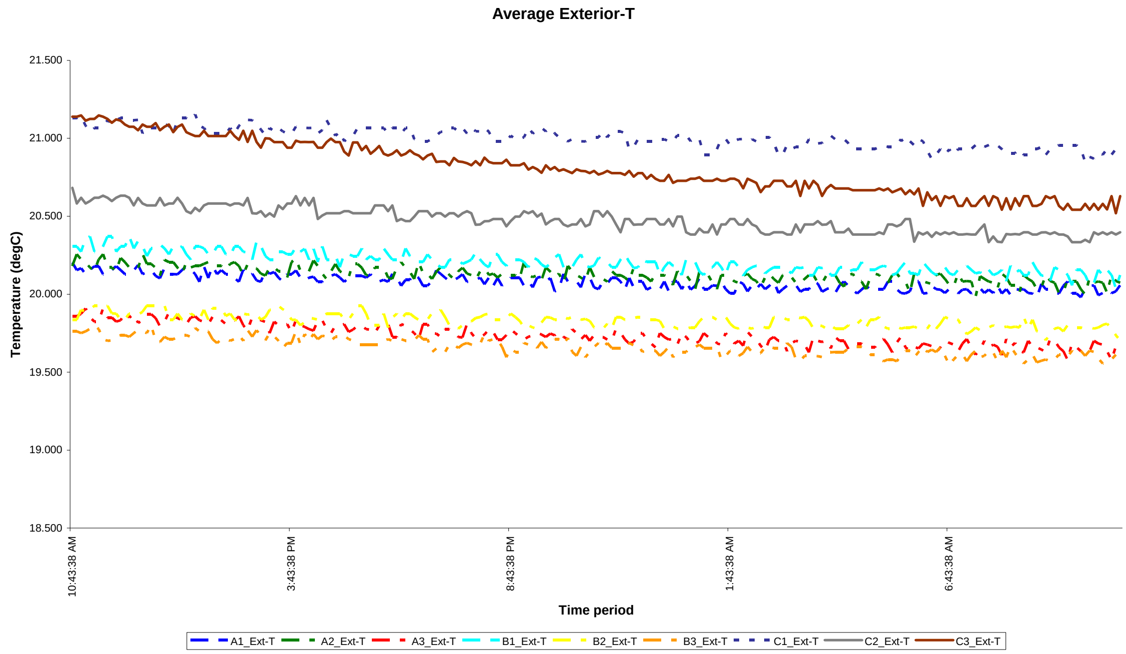


Figure B-58: Average exterior temperature of S1-Alt7

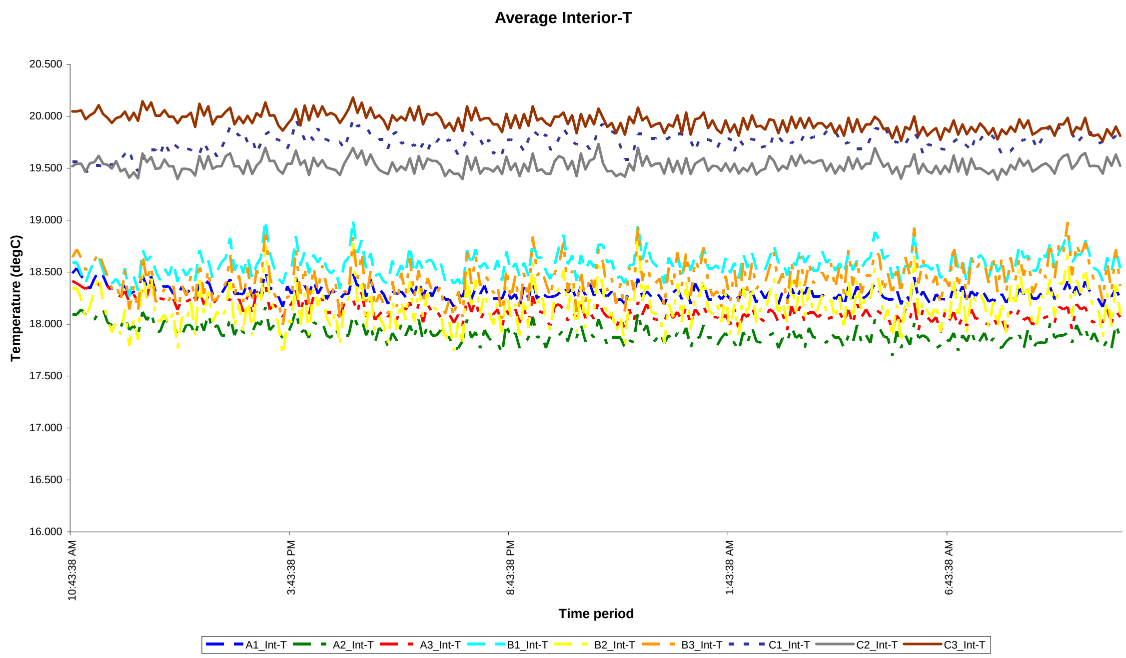


Figure B-59: Average interior temperature of S1-Alt7

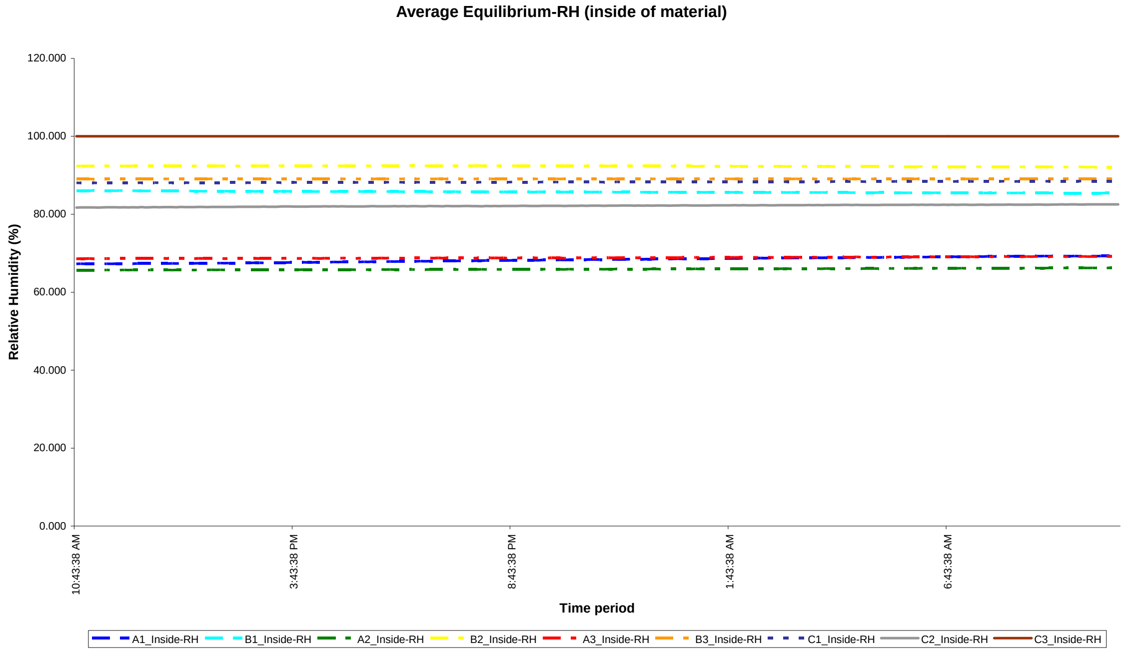


Figure B-60: Average equilibrium of relative humidity in a cavity of S1-Alt7

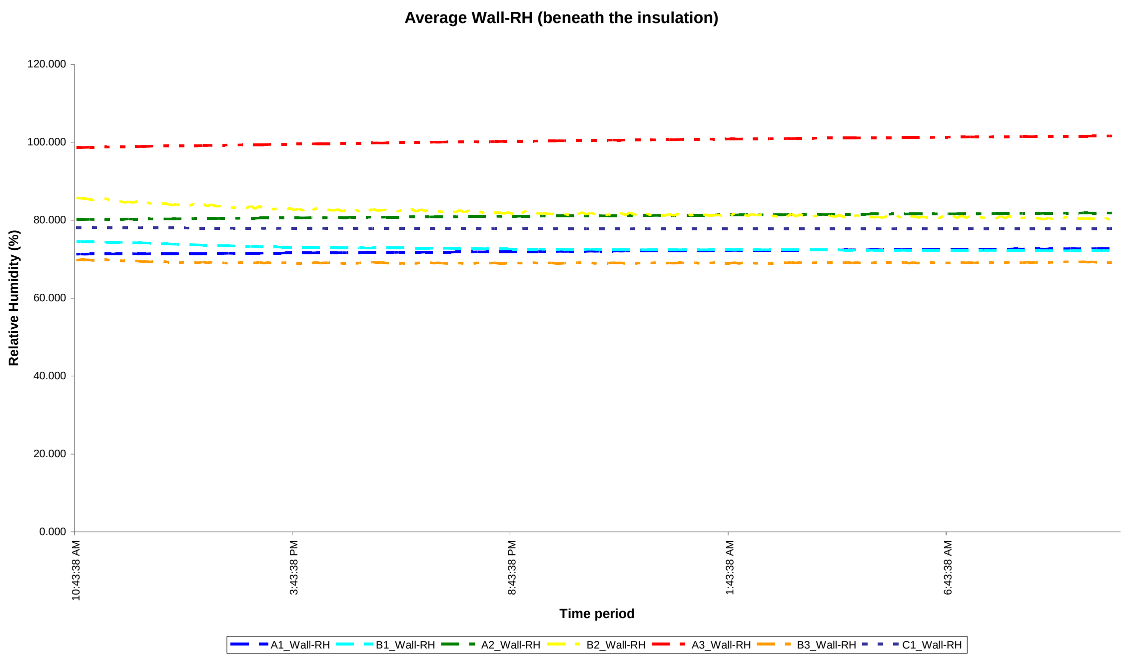


Figure B-61: Average wall relative humidity beneath the insulation of S1-Alt7

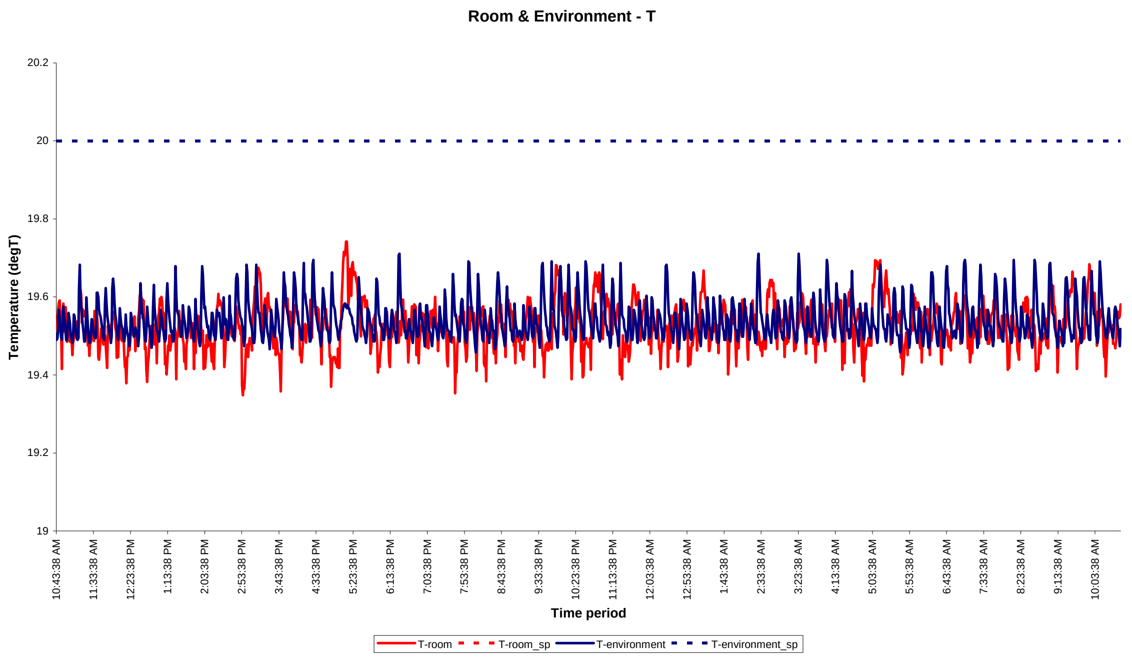


Figure B-62: Temperature of the room and environmental side during S1-Alt7

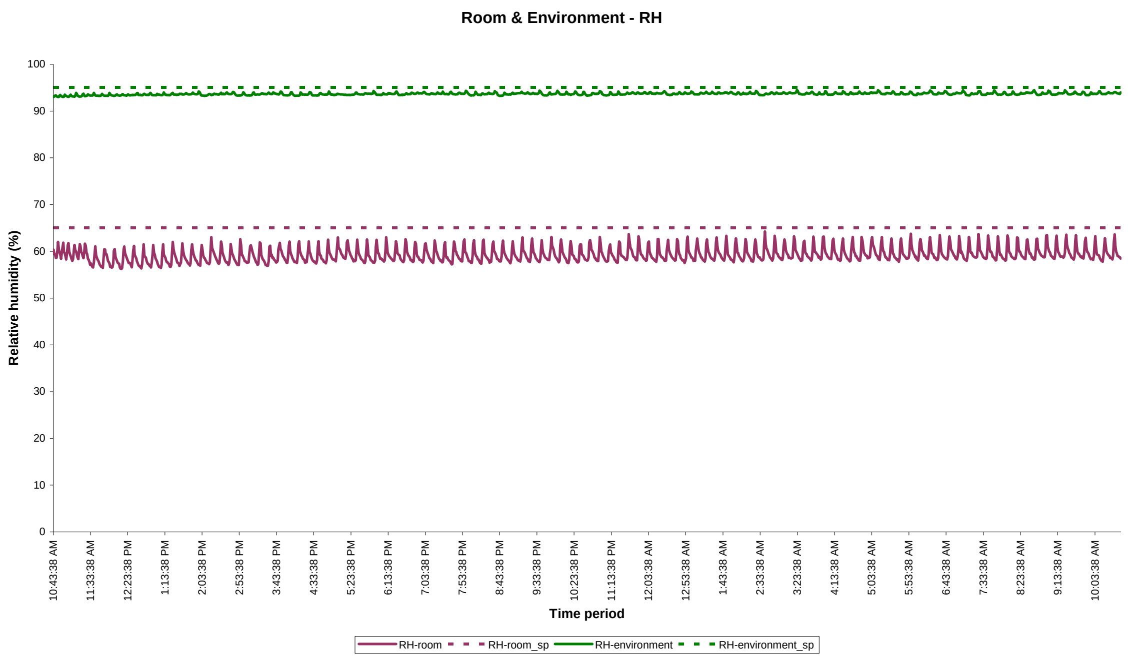


Figure B-63: Relative humidity of the room and environmental side during S1-Alt7

Test cycle: **S1 – Alt8**

Table B-8: Average data during the last 24 hours for each specimen of S1-Alt8

Specimen Measurement Data

B-G	A			B			C			Sand
1	A1_Soil-T	20.322	degC	B1_Soil-T	19.676	degC	C1_Soil-T	20.496	degC	1
	A1_Soil-RH	100.000	%	B1_Soil-RH	100.000	%	C1_Soil-RH	100.000	%	
	A1_Wall-T	19.508	degC	B1_Wall-T	20.286	degC	C1_Wall-T	20.812	degC	
	A1_Ext-T	20.578	degC	B1_Ext-T	20.281	degC	C1_Ext-T	20.503	degC	
	A1_Int-T	19.196	degC	B1_Int-T	19.308	degC	C1_Int-T	20.431	degC	
	A1_Inside-RH	67.310	%	B1_Inside-RH	81.774	%	C1_Inside-RH	88.984	%	
	A1_Wall-RH	74.372	%	B1_Wall-RH	57.588	%	C1_Wall-RH	69.038	%	
2	A2_Soil-T	20.091	degC	B2_Soil-T	20.172	degC	C2_Soil-T	20.428	degC	2
	A2_Soil-RH	100.000	%	B2_Soil-RH	100.000	%	C2_Soil-RH	100.000	%	
	A2_Wall-T	18.999	degC	B2_Wall-T	20.033	degC	C2_Ext-T	20.876	degC	
	A2_Ext-T	20.235	degC	B2_Ext-T	19.931	degC	C2_Int-T	20.259	degC	
	A2_Int-T	18.563	degC	B2_Int-T	18.982	degC	C2_Inside-RH	80.567	degC	
	A2_Inside-RH	63.152	%	B2_Inside-RH	88.565	%				
	A2_Wall-RH	81.492	%	B2_Wall-RH	73.095	%				
3	A3_Soil-T	20.062	degC	B3_Soil-T	20.485	degC	C3_Soil-T	22.867	degC	3
	A3_Soil-RH	100.000	%	B3_Soil-RH	100.000	%	C3_Soil-RH	100.000	%	
	A3_Wall-T	19.226	degC	B3_Wall-T	20.126	degC	C3_Ext-T	22.057	degC	
	A3_Ext-T	19.901	degC	B3_Ext-T	19.970	degC	C3_Int-T	21.021	degC	
	A3_Int-T	18.713	degC	B3_Int-T	18.656	degC	C3_Inside-RH	100.000	degC	
	A3_Inside-RH	67.015	%	B3_Inside-RH	86.620	%				
	A3_Wall-RH	100.000	%	B3_Wall-RH	43.162	%	**Pressure diff.*	*4.387*	*Pa*	
No	A			B			C			Alt8

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side		
T-room	19.471	degC
RH-room	32.374	%
T-room_sp	20.000	degC
RH-room_sp	35.000	%
T-environment	19.514	degC
RH-environment	93.784	%
T-environment_sp	20.000	degC
RH-environment_sp	95.000	%

Remarks

Type: B-G
Soil type: Sand
Damproofing: No
Alternative: Alt8

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

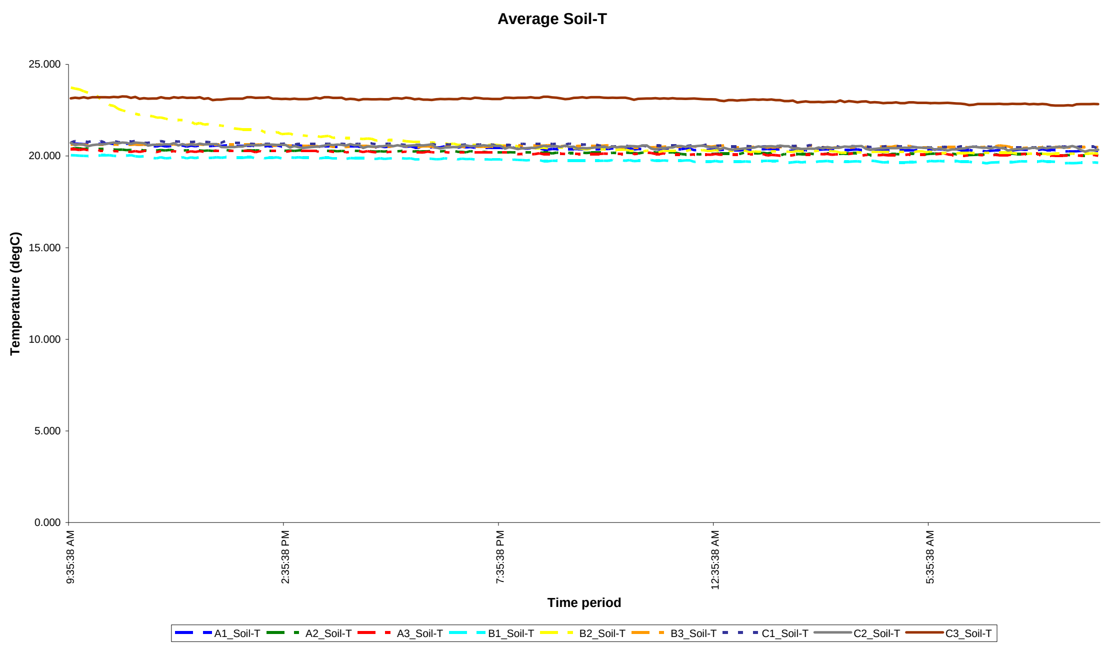


Figure B-64: Average soil temperature of S1-Alt8

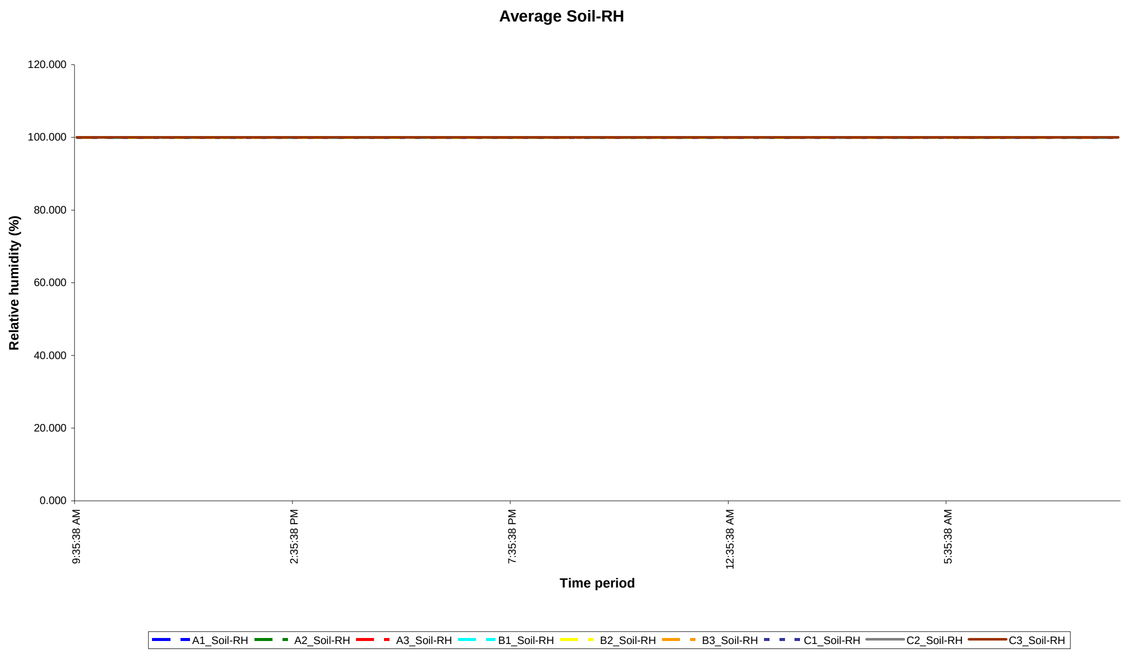


Figure B-65: Average soil relative humidity of S1-Alt8

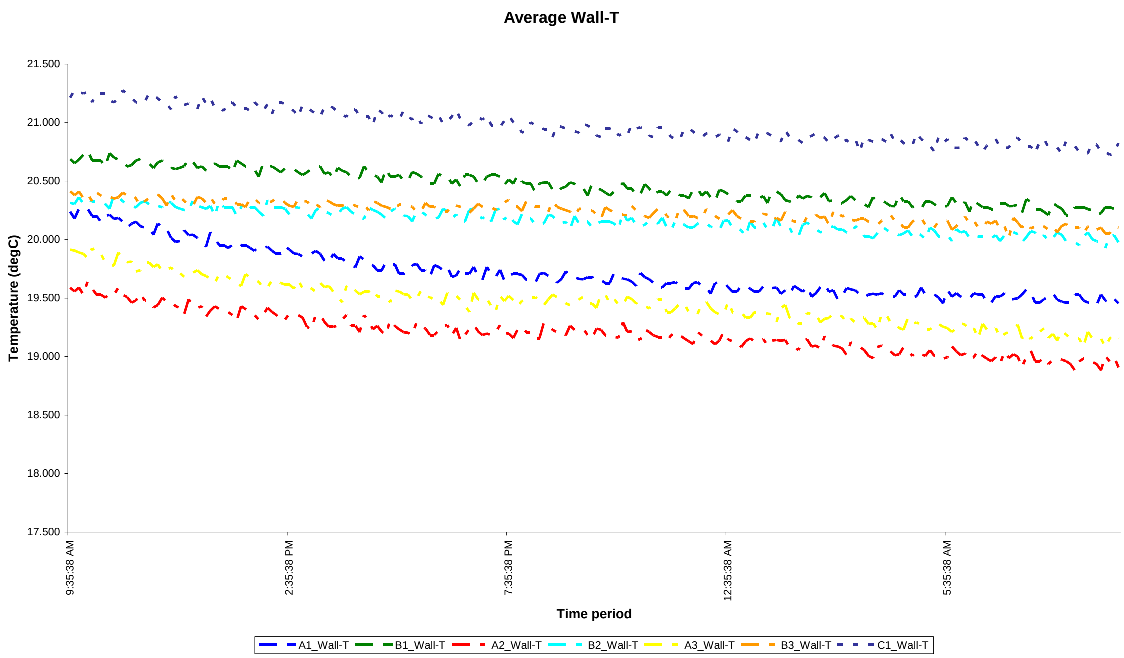


Figure B-66: Average wall temperature of S1-Alt8

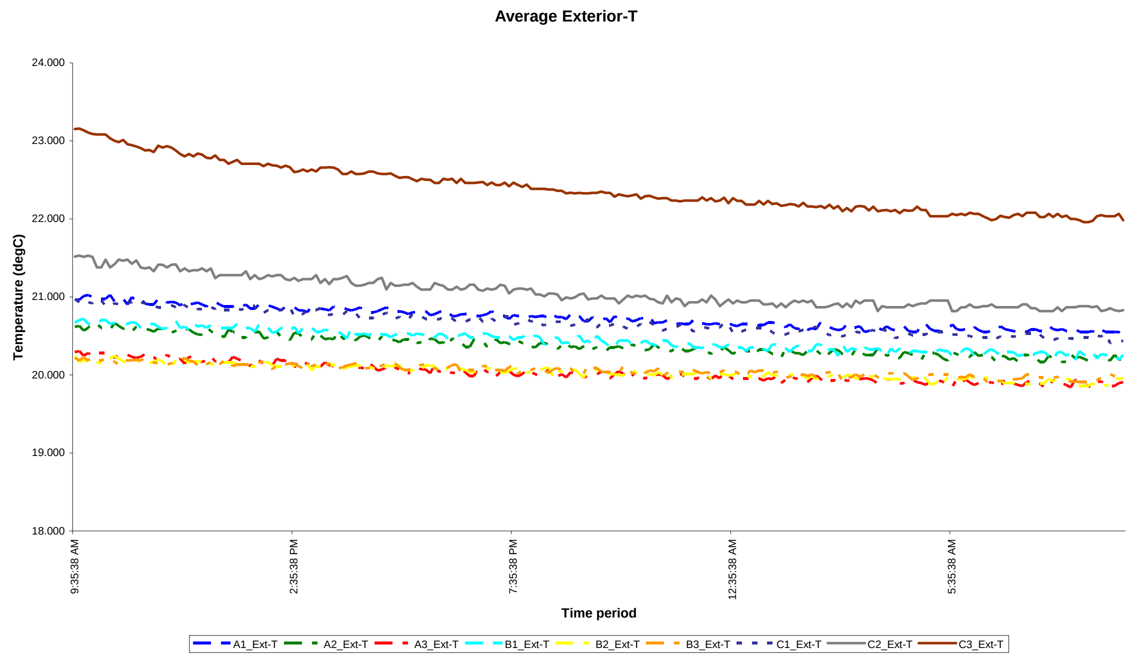


Figure B-67: Average exterior temperature of S1-Alt8

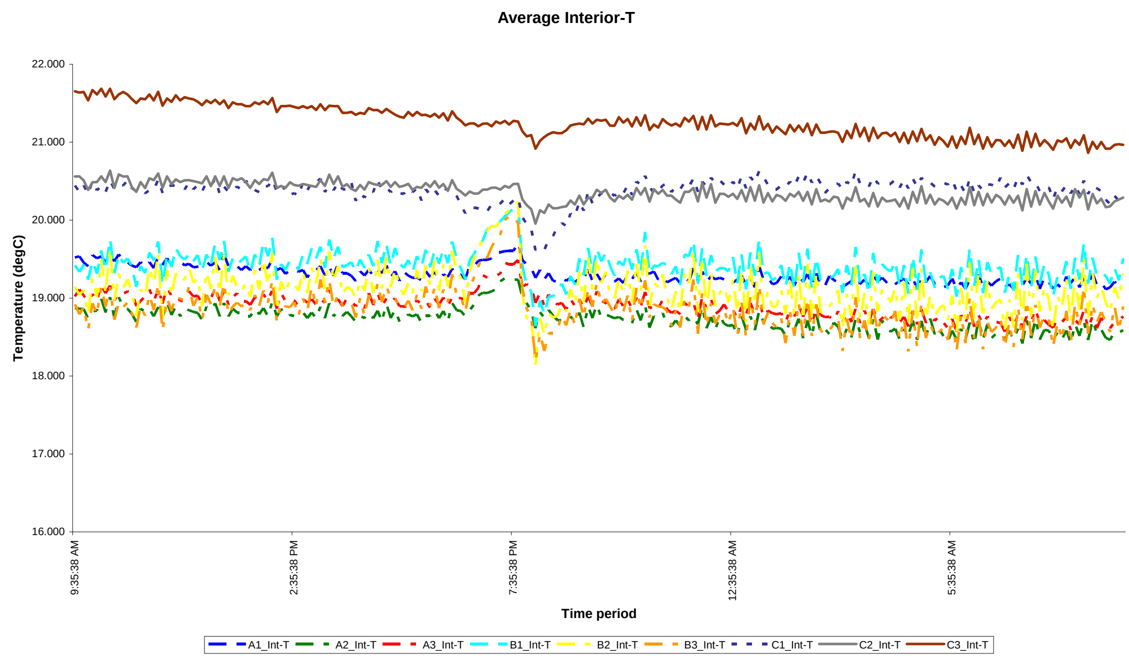


Figure B-68: Average interior temperature of S1-Alt8

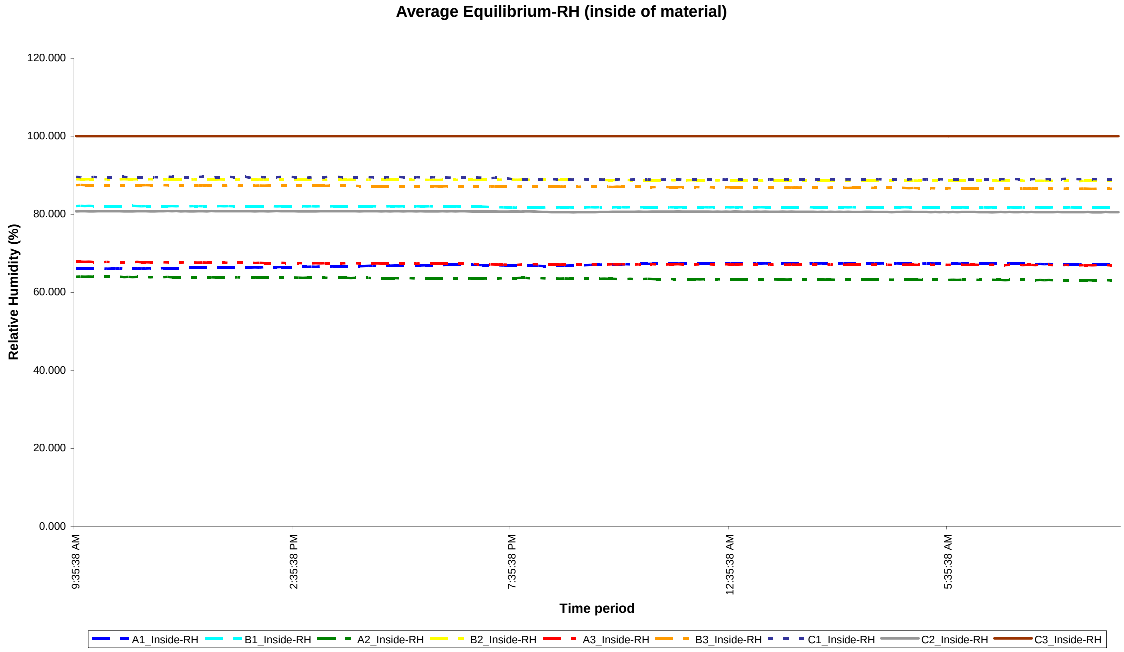


Figure B-69: Average equilibrium of relative humidity in a cavity of S1-Alt8

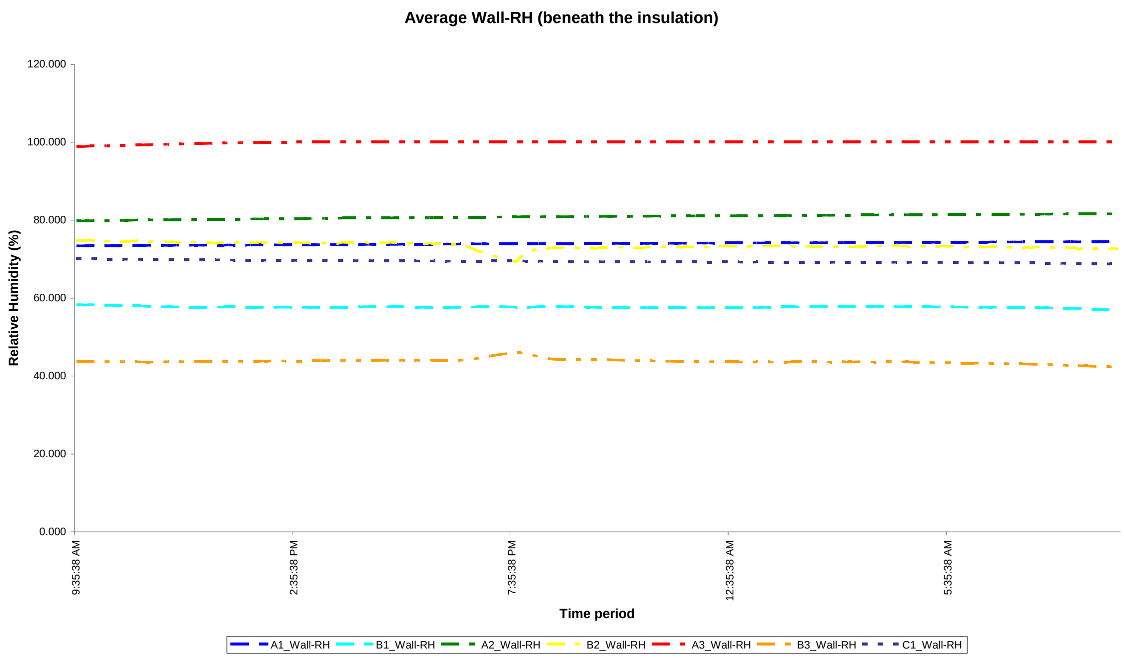


Figure B-70: Average wall relative humidity beneath the insulation of S1-Alt8

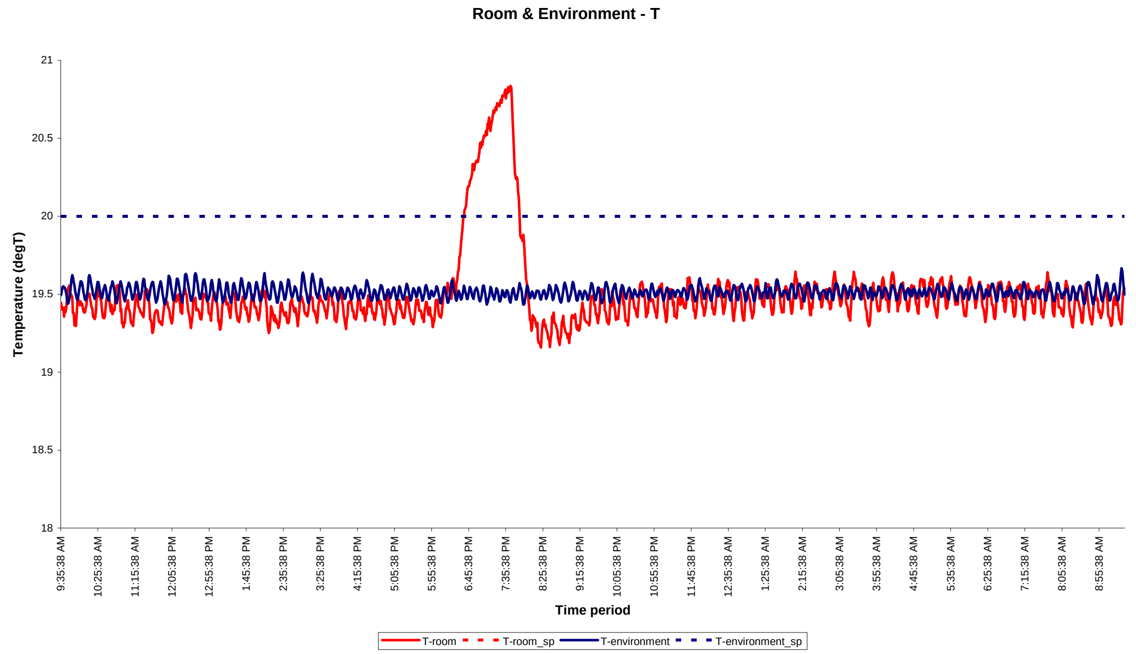


Figure B-71: Temperature of the room and environmental side during S1-Alt8

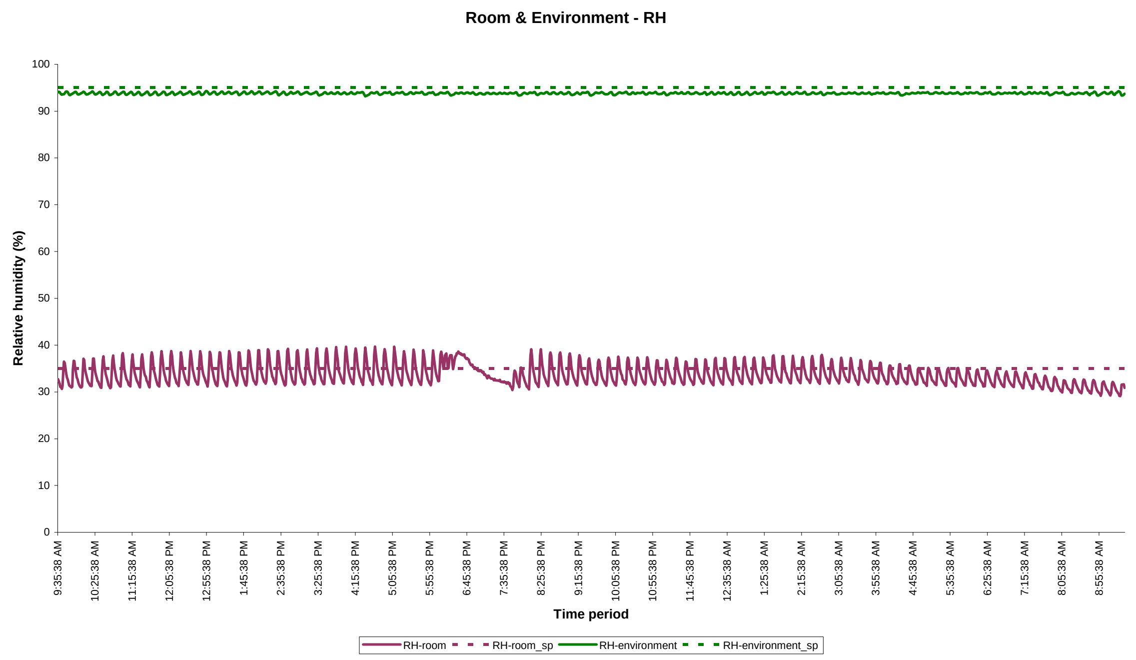


Figure B-72: Relative humidity of the room and environmental side during S1-Alt8

Measurement series: **C1** (Clay; no dampproofing)

Test cycle: **C1 – Alt1**

Table B-9: Average data during the last 24 hours for each specimen of C1-Alt1

Specimen Measurement Data

B-G	A		B		C		Clay
1	A1_Soil-T	5.271 degC	B1_Soil-T	4.853 degC	C1_Soil-T	5.885 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	100.000 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	16.702 degC	B1_Wall-T	7.885 degC	C1_Wall-T	9.146 degC	
	A1_Ext-T	8.522 degC	B1_Ext-T	6.829 degC	C1_Ext-T	7.466 degC	
	A1_Int-T	18.452 degC	B1_Int-T	18.979 degC	C1_Int-T	18.741 degC	
	A1_Inside-RH	42.635 %	B1_Inside-RH	75.328 %	C1_Inside-RH	82.024 %	
	A1_Wall-RH	55.103 %	B1_Wall-RH	70.116 %	C1_Wall-RH	69.263 %	
2	A2_Soil-T	6.111 degC	B2_Soil-T	6.066 degC	C2_Soil-T	7.266 degC	2
	A2_Soil-RH	99.959 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	17.716 degC	B2_Wall-T	11.408 degC	C2_Ext-T	14.312 degC	
	A2_Ext-T	9.575 degC	B2_Ext-T	10.175 degC	C2_Int-T	18.142 degC	
	A2_Int-T	18.599 degC	B2_Int-T	19.152 degC	C2_Inside-RH	70.861 degC	
	A2_Inside-RH	53.689 %	B2_Inside-RH	88.059 %			
	A2_Wall-RH	57.439 %	B2_Wall-RH	74.089 %			
3	A3_Soil-T	6.709 degC	B3_Soil-T	7.110 degC	C3_Soil-T	7.072 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	17.706 degC	B3_Wall-T	12.288 degC	C3_Ext-T	16.207 degC	
	A3_Ext-T	9.969 degC	B3_Ext-T	10.952 degC	C3_Int-T	17.743 degC	
	A3_Int-T	18.633 degC	B3_Int-T	18.965 degC	C3_Inside-RH	99.551 degC	
	A3_Inside-RH	59.578 %	B3_Inside-RH	80.656 %			
	A3_Wall-RH	67.530 %	B3_Wall-RH	57.318 %	*Pressure diff.	1.345 Pa	
No	A		B		C		Alt1

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	19.543 degC
RH-room	30.199 %
T-room_sp	20.000 degC
RH-room_sp	30.000 %
T-environment	3.712 degC
RH-environment	69.952 %
T-environment_sp	3.000 degC
RH-environment_sp	70.000 %

Remarks

Type: B-G
Soil type: Clay
Dampproofing: No
Alternative: Alt1

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

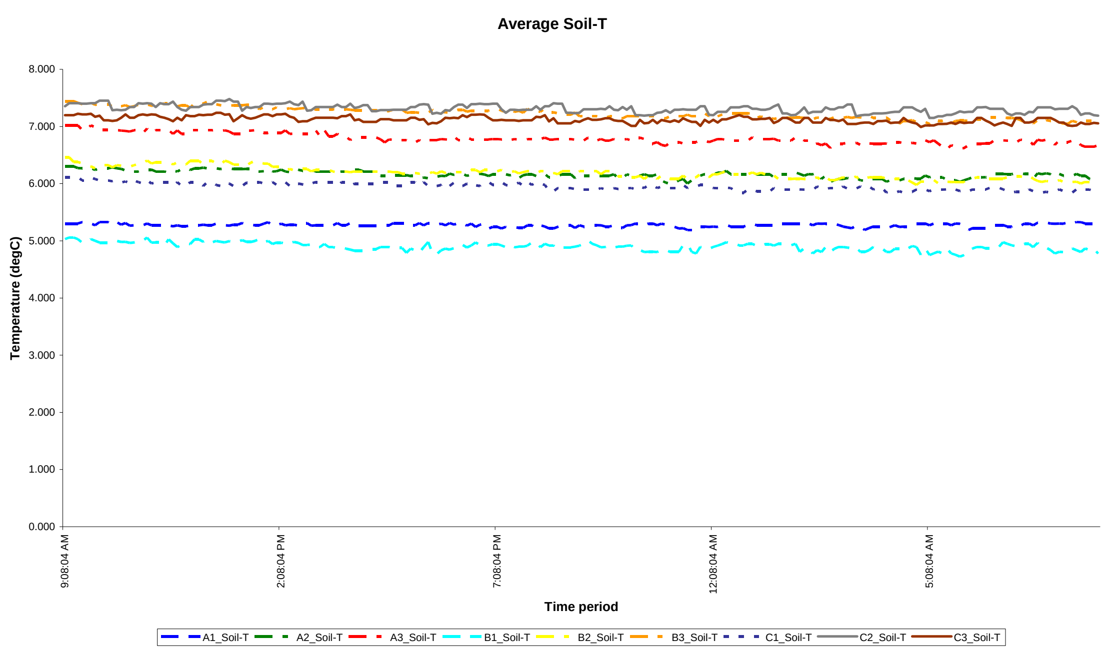


Figure B-73: Average soil temperature of C1-Alt1

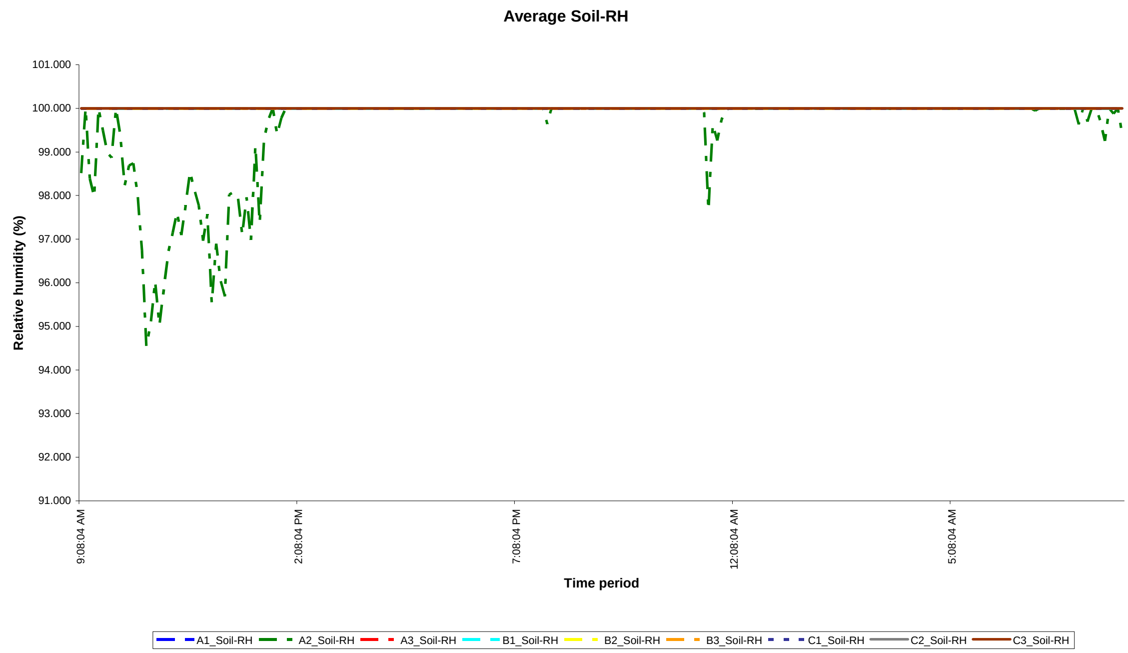


Figure B-74: Average soil relative humidity of C1-Alt1

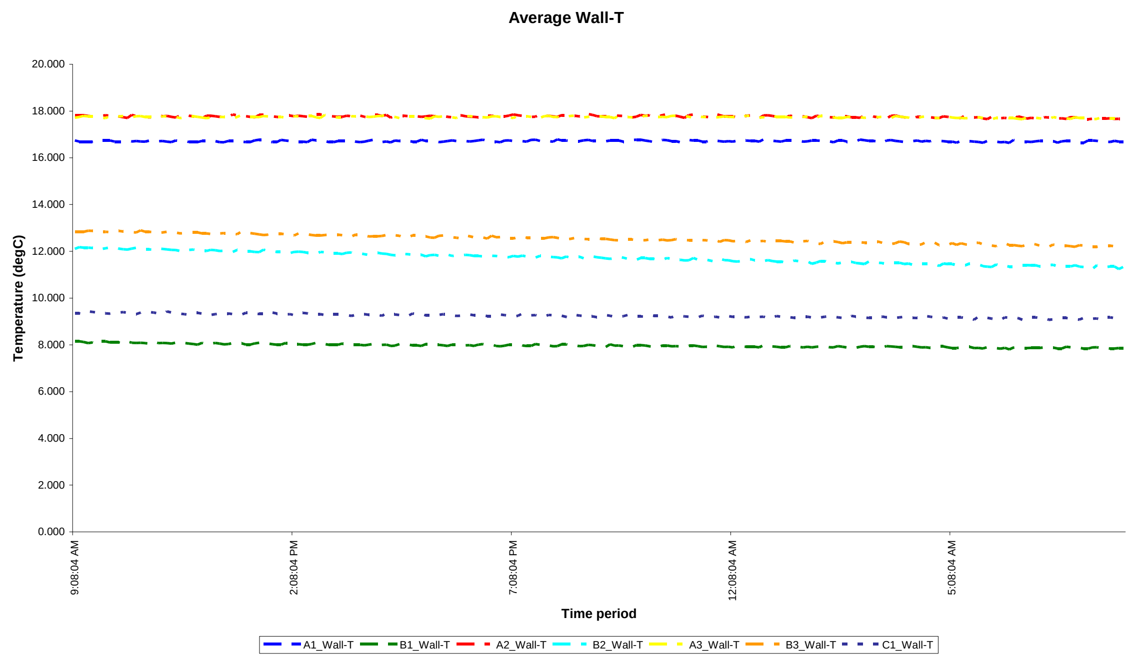


Figure B-75: Average wall temperature of C1-Alt1

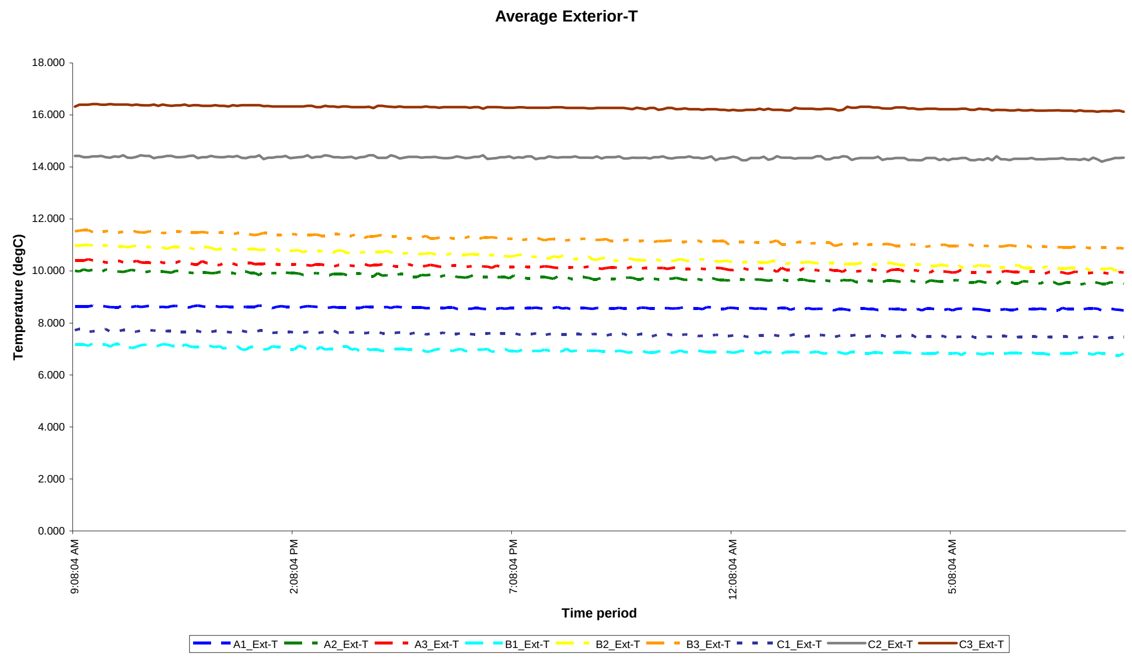


Figure B-76: Average exterior temperature of C1-Alt1

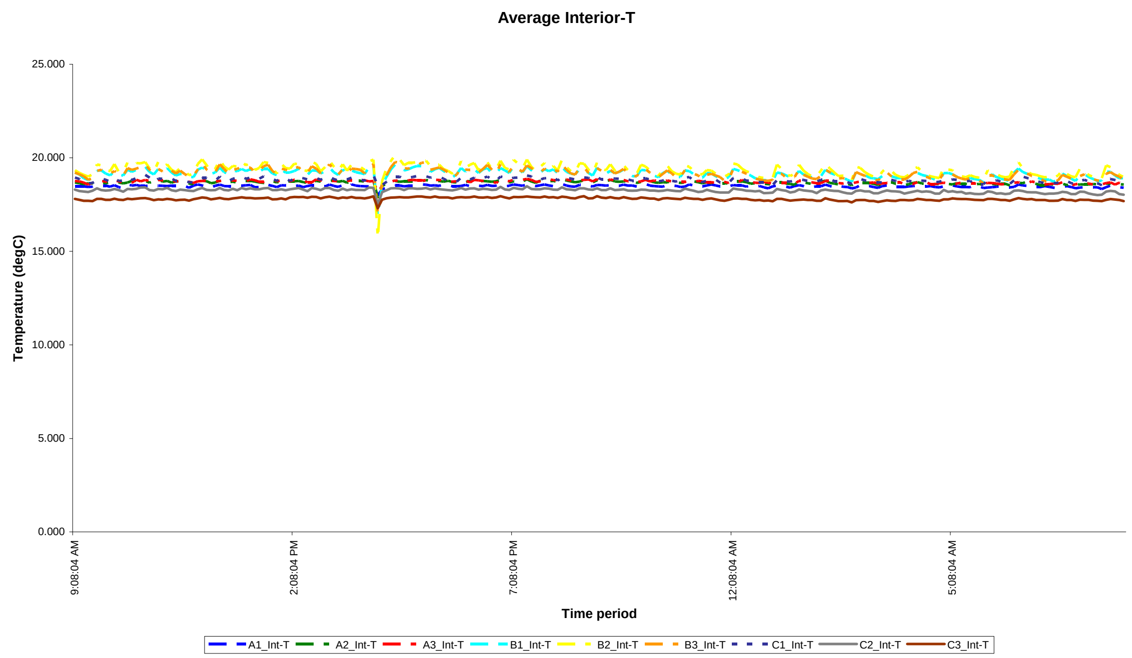


Figure B-77: Average interior temperature of C1-Alt1

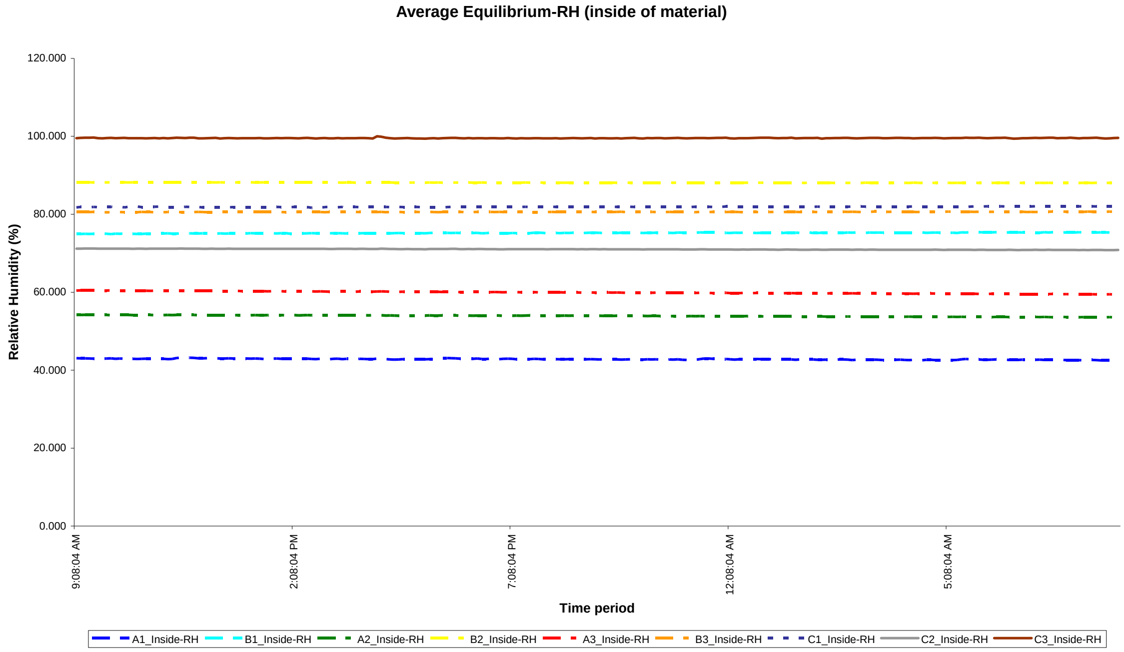


Figure B-78: Average equilibrium of relative humidity in a cavity of C1-Alt1

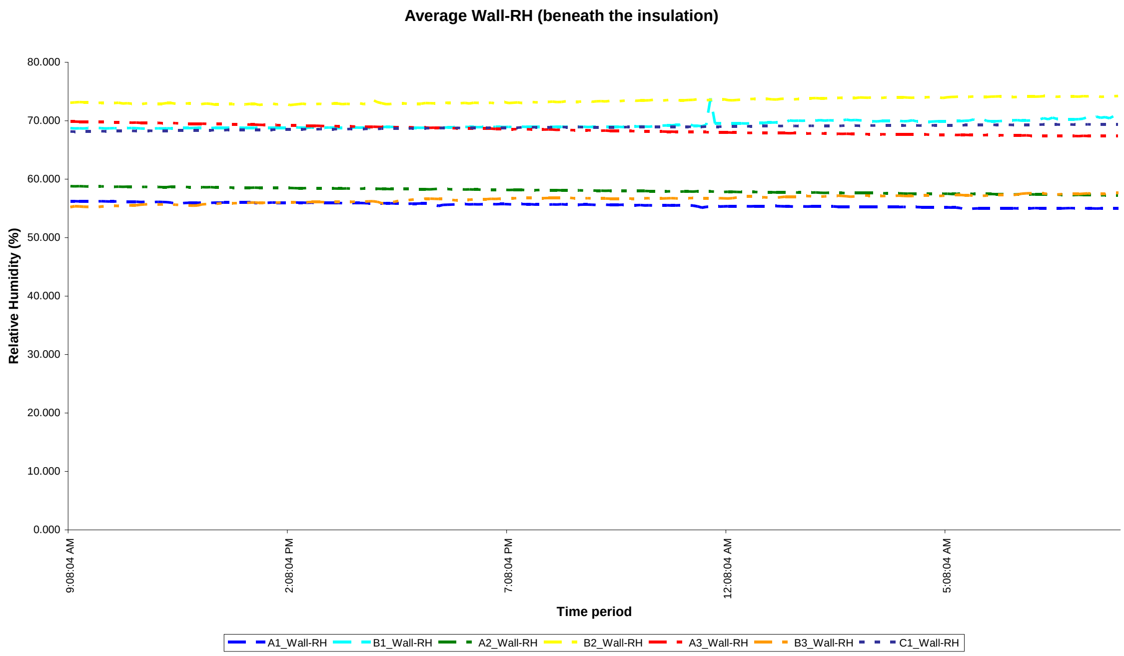


Figure B-79: Average wall relative humidity beneath the insulation of C1-Alt1

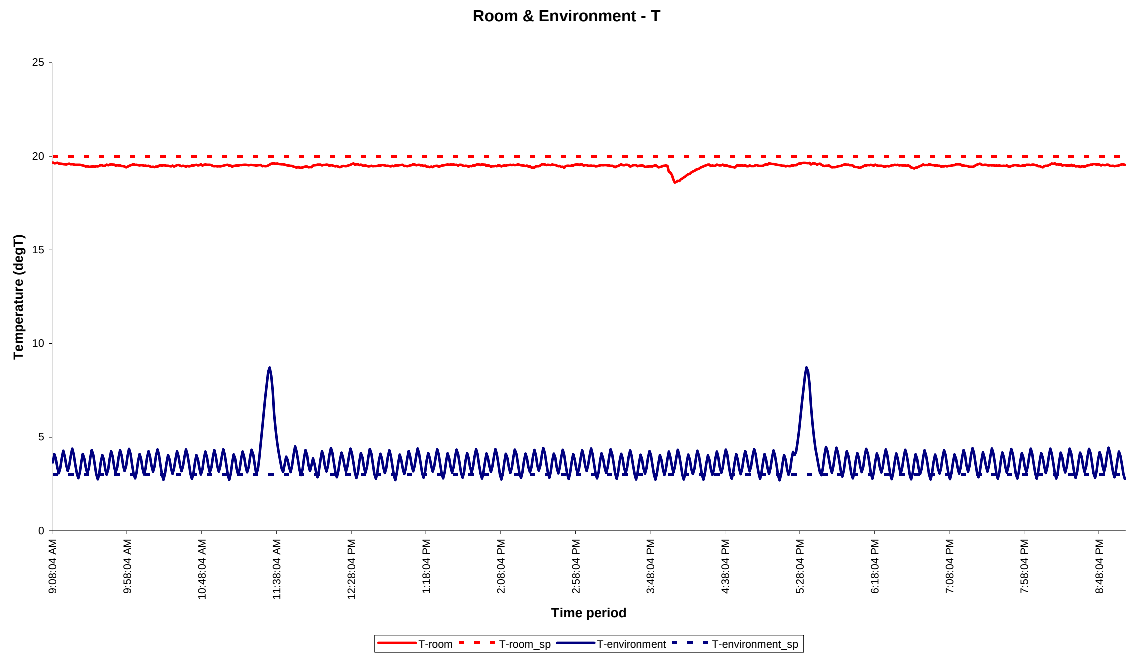


Figure B-80: Temperature of the room and environmental side during C1-Alt1

Figure B-81: Relative humidity of the room and environmental side during C1-Alt1

Test cycle: **C1 – Alt2**

Table B-10: Average data during the last 24 hours for each specimen of C1-Alt2

Specimen Measurement Data

B-G	A			B			C			Clay
1	A1_Soil-T	5.448	degC	B1_Soil-T	4.962	degC	C1_Soil-T	5.856	degC	1
	A1_Soil-RH	100.000	%	B1_Soil-RH	100.000	%	C1_Soil-RH	100.000	%	
	A1_Wall-T	16.561	degC	B1_Wall-T	7.795	degC	C1_Wall-T	9.084	degC	
	A1_Ext-T	8.541	degC	B1_Ext-T	6.704	degC	C1_Ext-T	7.401	degC	
	A1_Int-T	18.264	degC	B1_Int-T	18.946	degC	C1_Int-T	18.679	degC	
	A1_Inside-RH	52.107	%	B1_Inside-RH	76.634	%	C1_Inside-RH	84.251	%	
	A1_Wall-RH	54.603	%	B1_Wall-RH	76.446	%	C1_Wall-RH	84.696	%	
2	A2_Soil-T	6.058	degC	B2_Soil-T	5.816	degC	C2_Soil-T	7.234	degC	2
	A2_Soil-RH	100.000	%	B2_Soil-RH	100.000	%	C2_Soil-RH	100.000	%	
	A2_Wall-T	17.436	degC	B2_Wall-T	10.506	degC	C2_Ext-T	14.264	degC	
	A2_Ext-T	9.189	degC	B2_Ext-T	9.237	degC	C2_Int-T	18.145	degC	
	A2_Int-T	18.389	degC	B2_Int-T	19.198	degC	C2_Inside-RH	73.579	degC	
	A2_Inside-RH	57.687	%	B2_Inside-RH	88.983	%				
	A2_Wall-RH	55.668	%	B2_Wall-RH	91.597	%				
3	A3_Soil-T	6.555	degC	B3_Soil-T	6.839	degC	C3_Soil-T	7.037	degC	3
	A3_Soil-RH	100.000	%	B3_Soil-RH	100.000	%	C3_Soil-RH	100.000	%	
	A3_Wall-T	17.475	degC	B3_Wall-T	11.818	degC	C3_Ext-T	16.051	degC	
	A3_Ext-T	9.629	degC	B3_Ext-T	10.464	degC	C3_Int-T	17.661	degC	
	A3_Int-T	18.473	degC	B3_Int-T	19.018	degC	C3_Inside-RH	99.517	degC	
	A3_Inside-RH	61.584	%	B3_Inside-RH	83.155	%				
	A3_Wall-RH	65.544	%	B3_Wall-RH	92.618	%	**Pressure diff.*	*30.339*	*Pa*	
No	A			B			C			Alt2

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side		
T-room	19.501	degC
RH-room	57.920	%
T-room_sp	20.000	degC
RH-room_sp	60.000	%
T-environment	3.720	degC
RH-environment	72.227	%
T-environment_sp	3.000	degC
RH-environment_sp	70.000	%

Remarks

Type: B-G
Soil type: Clay
Dampproofing: No
Alternative: Alt2

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

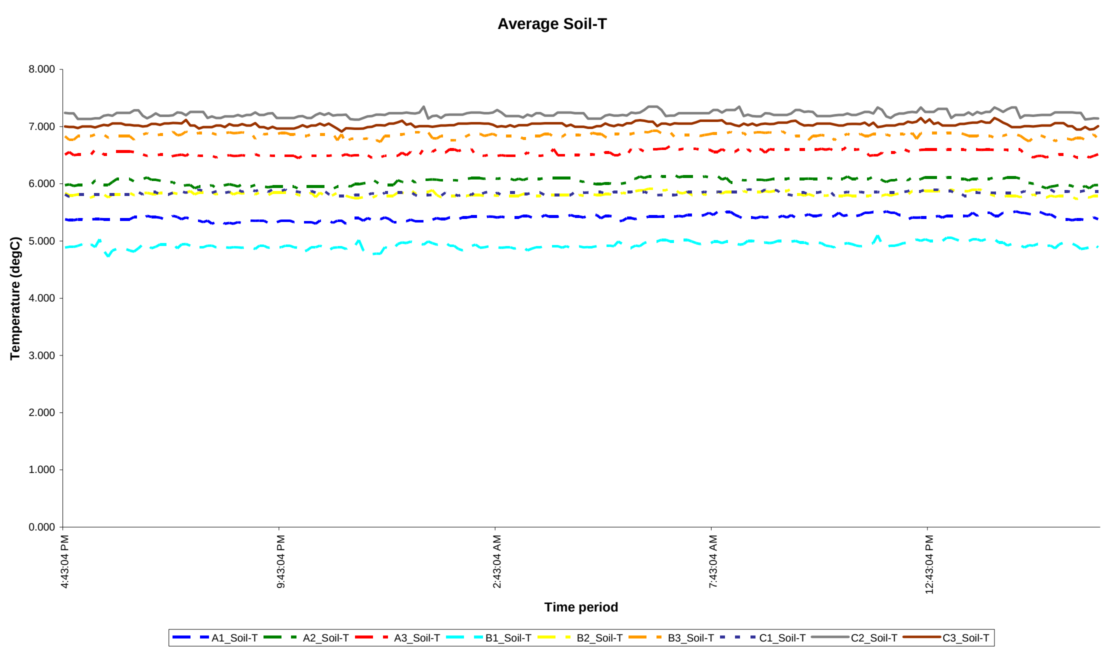


Figure B-82: Average soil temperature of C1-Alt2

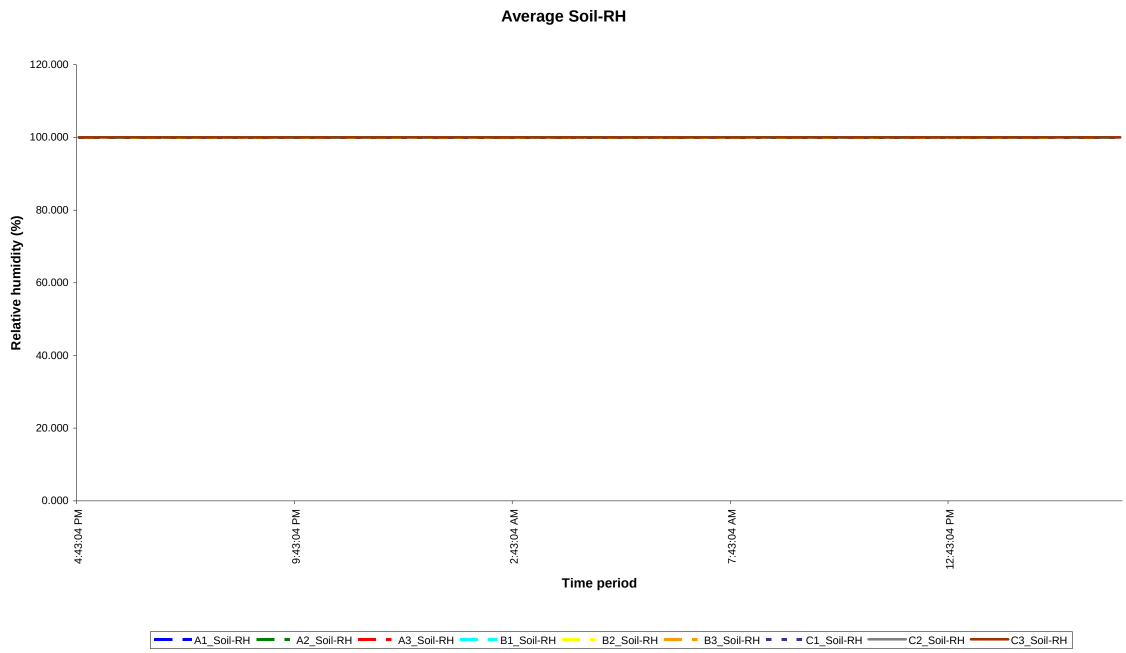


Figure B-83: Average soil relative humidity of C1-Alt2

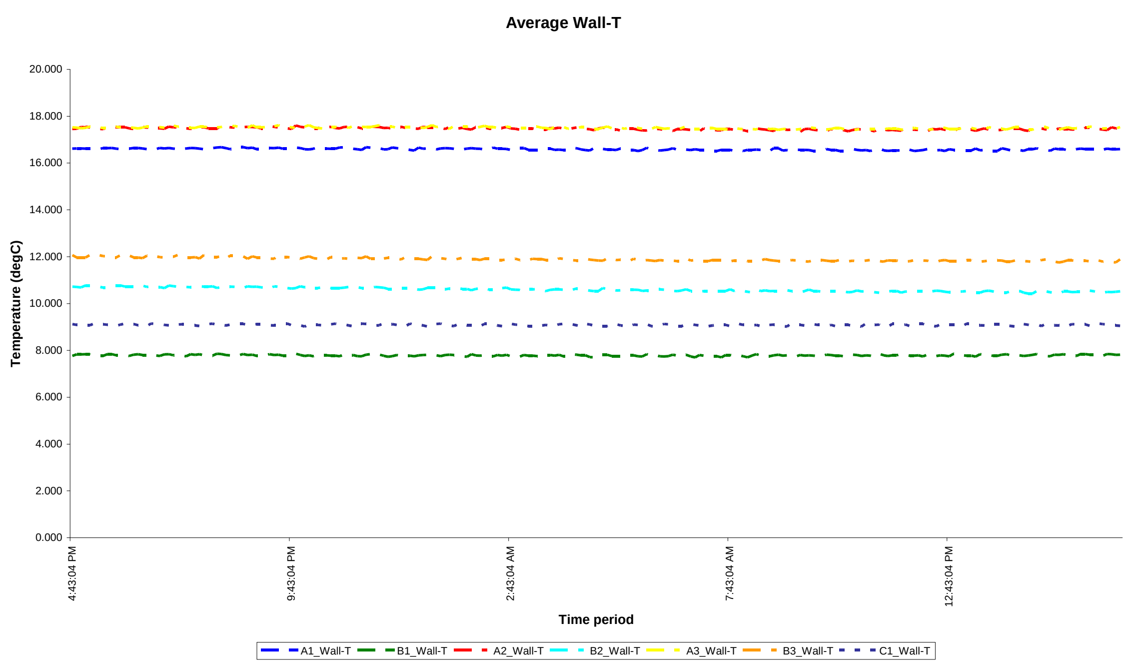


Figure B-84: Average wall temperature of C1-Alt2

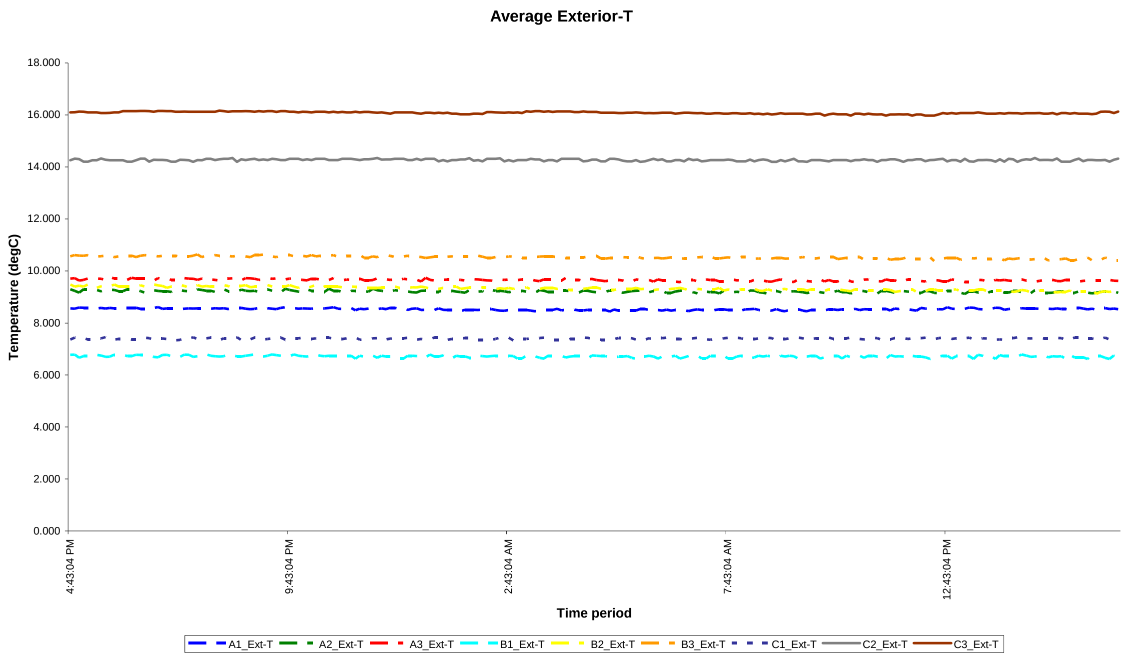


Figure B-85: Average exterior temperature of C1-Alt2

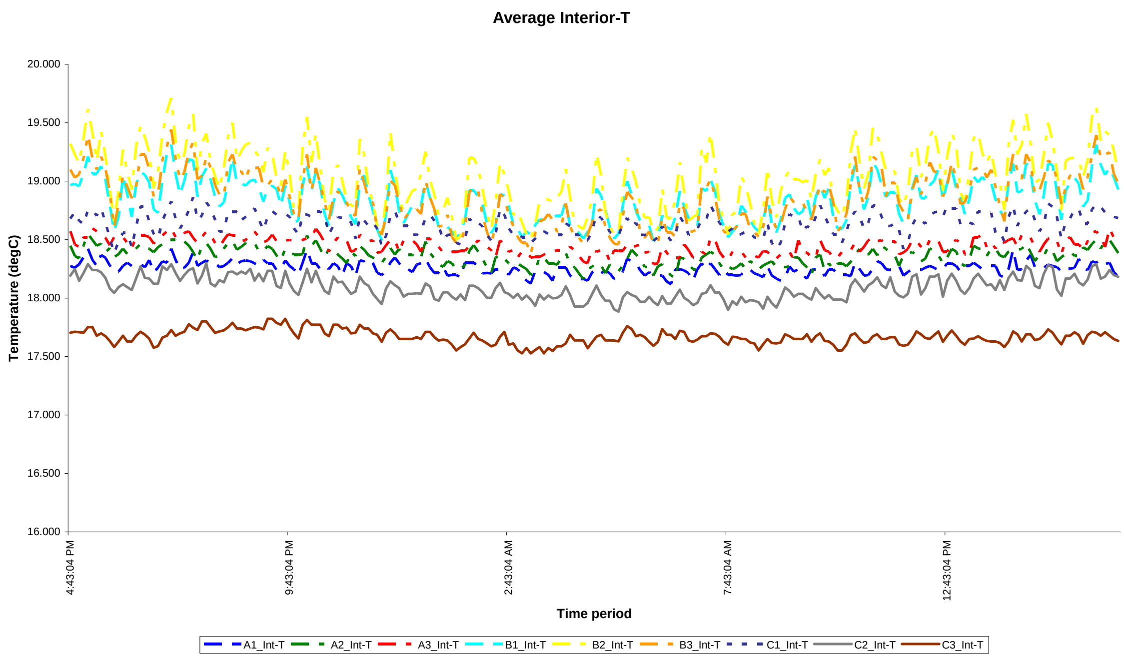


Figure B-86: Average interior temperature of C1-Alt2

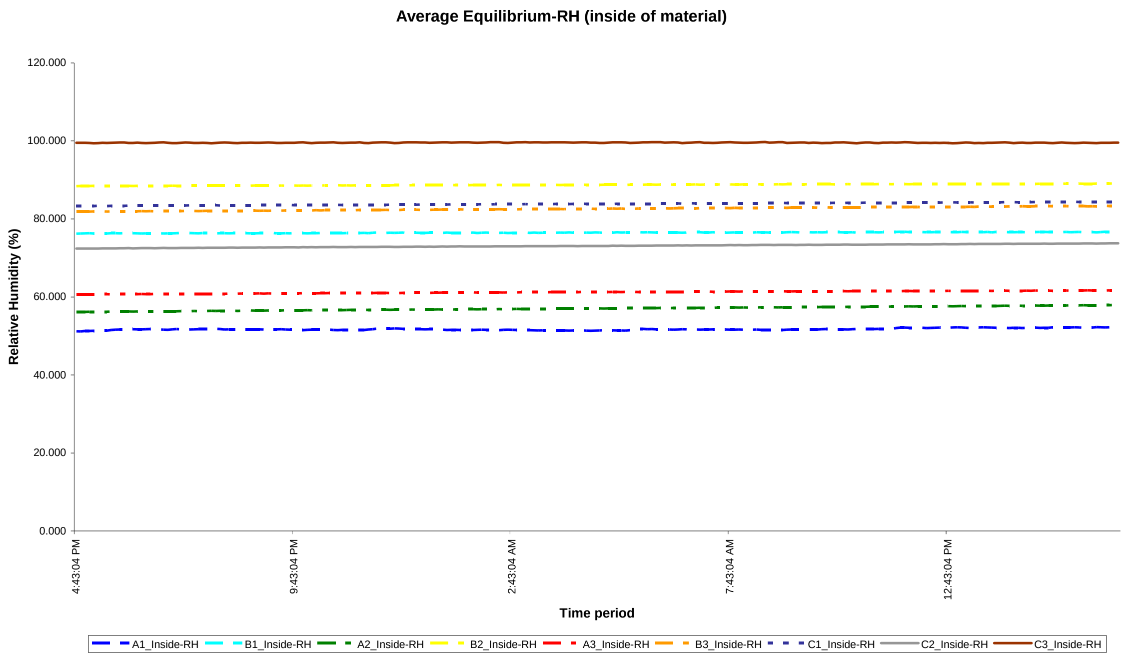


Figure B-87: Average equilibrium of relative humidity in a cavity of C1-Alt2

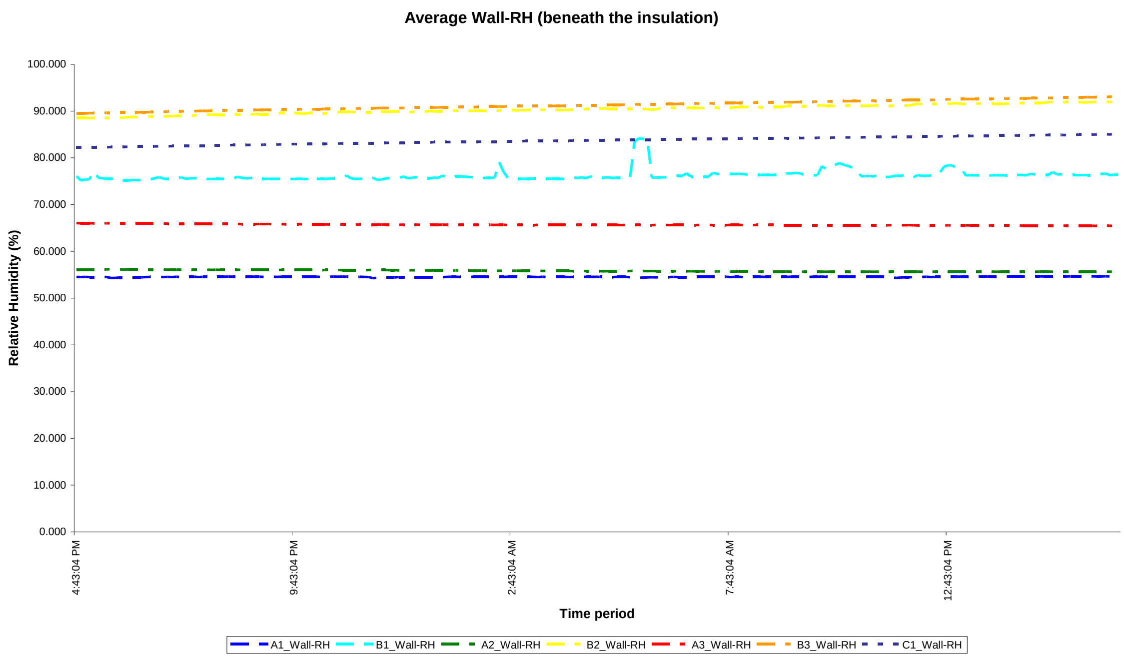


Figure B-88: Average wall relative humidity beneath the insulation of C1-Alt2

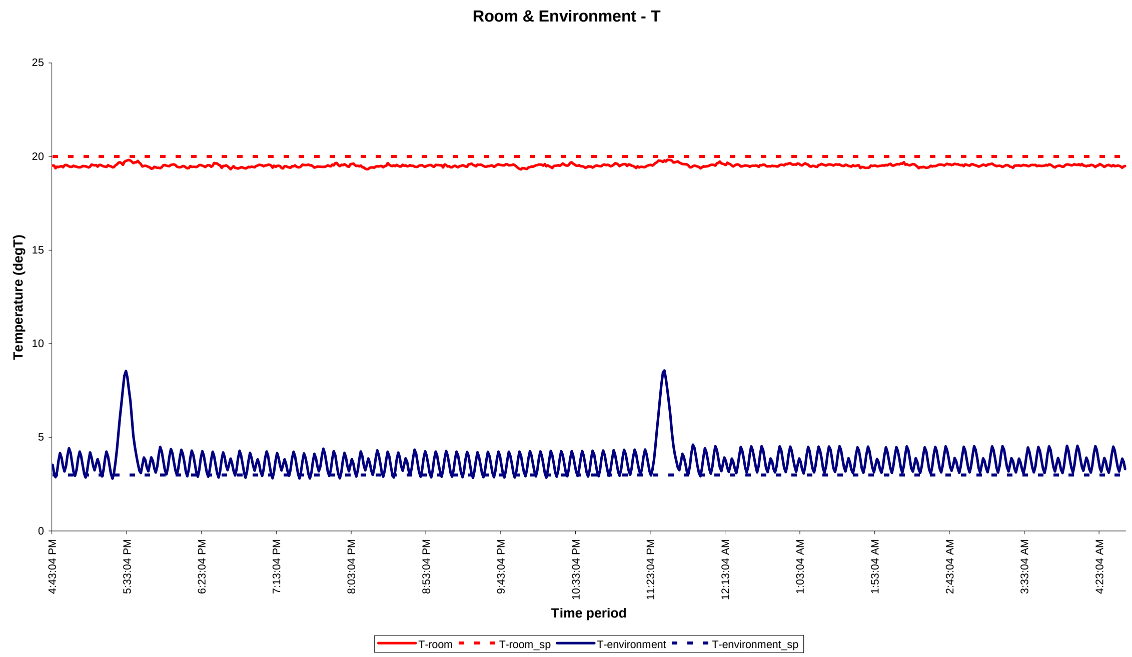


Figure B-89: Temperature of the room and environmental side during C1-Alt2

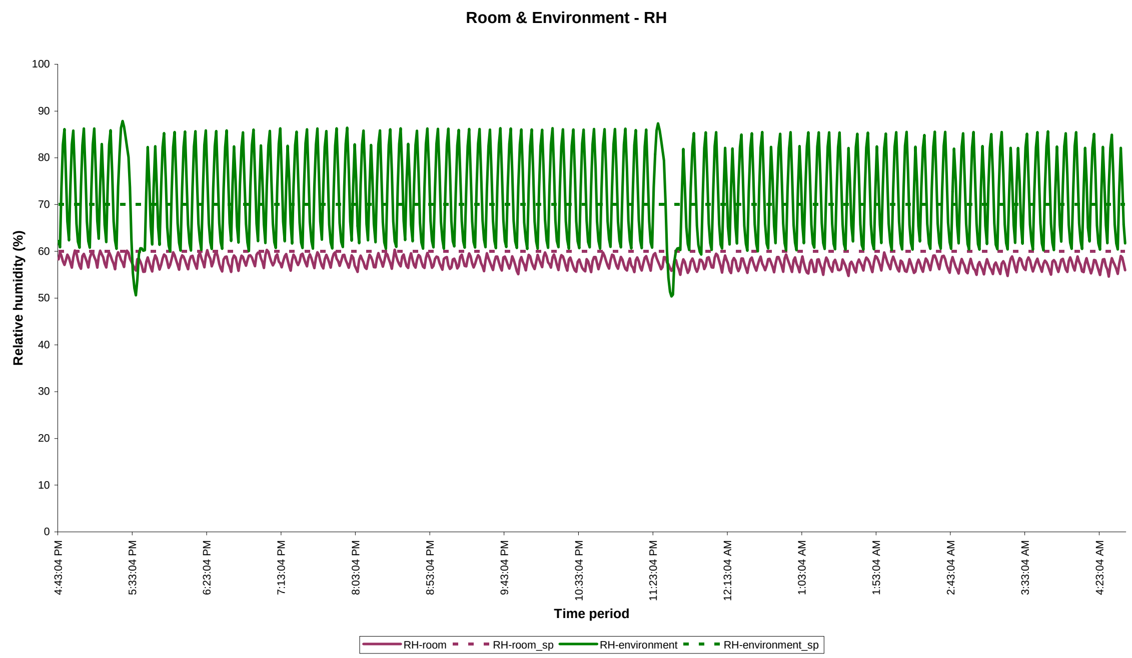


Figure B-90: Relative humidity of the room and environmental side during C1-Alt2

Test cycle: **C1 – Alt3**

Table B-11: Average data during the last 24 hours for each specimen of C1-Alt3

Specimen Measurement Data

B-G	A		B		C		Clay
1	A1_Soil-T	6.103 degC	B1_Soil-T	5.891 degC	C1_Soil-T	5.914 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	100.000 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	16.662 degC	B1_Wall-T	8.091 degC	C1_Wall-T	9.073 degC	
	A1_Ext-T	8.947 degC	B1_Ext-T	7.082 degC	C1_Ext-T	7.436 degC	
	A1_Int-T	18.238 degC	B1_Int-T	18.881 degC	C1_Int-T	18.513 degC	
	A1_Inside-RH	56.756 %	B1_Inside-RH	80.698 %	C1_Inside-RH	86.777 %	
	A1_Wall-RH	56.682 %	B1_Wall-RH	79.060 %	C1_Wall-RH	89.496 %	
2	A2_Soil-T	6.542 degC	B2_Soil-T	6.090 degC	C2_Soil-T	7.186 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	17.472 degC	B2_Wall-T	10.433 degC	C2_Ext-T	14.225 degC	
	A2_Ext-T	9.394 degC	B2_Ext-T	9.136 degC	C2_Int-T	18.049 degC	
	A2_Int-T	18.363 degC	B2_Int-T	19.161 degC	C2_Inside-RH	76.256 degC	
	A2_Inside-RH	60.963 %	B2_Inside-RH	90.970 %			
	A2_Wall-RH	57.172 %	B2_Wall-RH	97.143 %			
3	A3_Soil-T	6.844 degC	B3_Soil-T	7.044 degC	C3_Soil-T	6.876 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	17.489 degC	B3_Wall-T	11.586 degC	C3_Ext-T	15.845 degC	
	A3_Ext-T	9.864 degC	B3_Ext-T	10.229 degC	C3_Int-T	17.469 degC	
	A3_Int-T	18.427 degC	B3_Int-T	18.995 degC	C3_Inside-RH	99.662 degC	
	A3_Inside-RH	63.358 %	B3_Inside-RH	86.742 %			
	A3_Wall-RH	65.237 %	B3_Wall-RH	97.647 %	*Pressure diff.	52.212 Pa	
No	A		B		C		Alt3

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	19.501 degC
RH-room	58.168 %
T-room_sp	20.000 degC
RH-room_sp	60.000 %
T-environment	3.766 degC
RH-environment	88.544 %
T-environment_sp	3.000 degC
RH-environment_sp	95.000 %

Remarks

Type: B-G
Soil type: Clay
Dampproofing: No
Alternative: Alt3

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

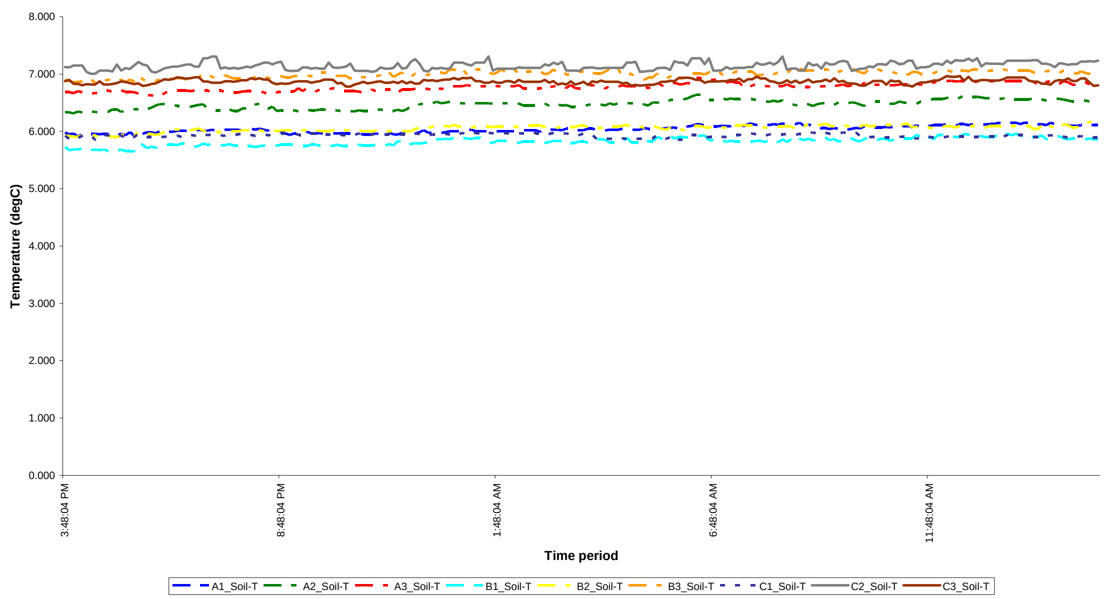


Figure B-91: Average soil temperature of C1-Alt3

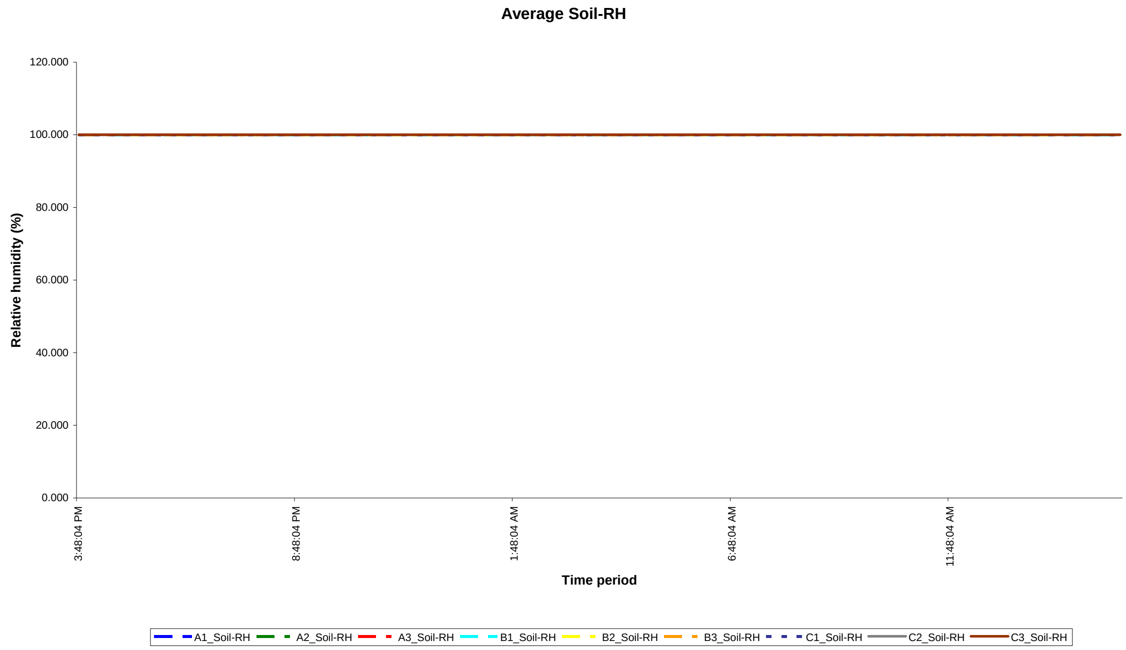


Figure B-92: Average soil relative humidity of C1-Alt3

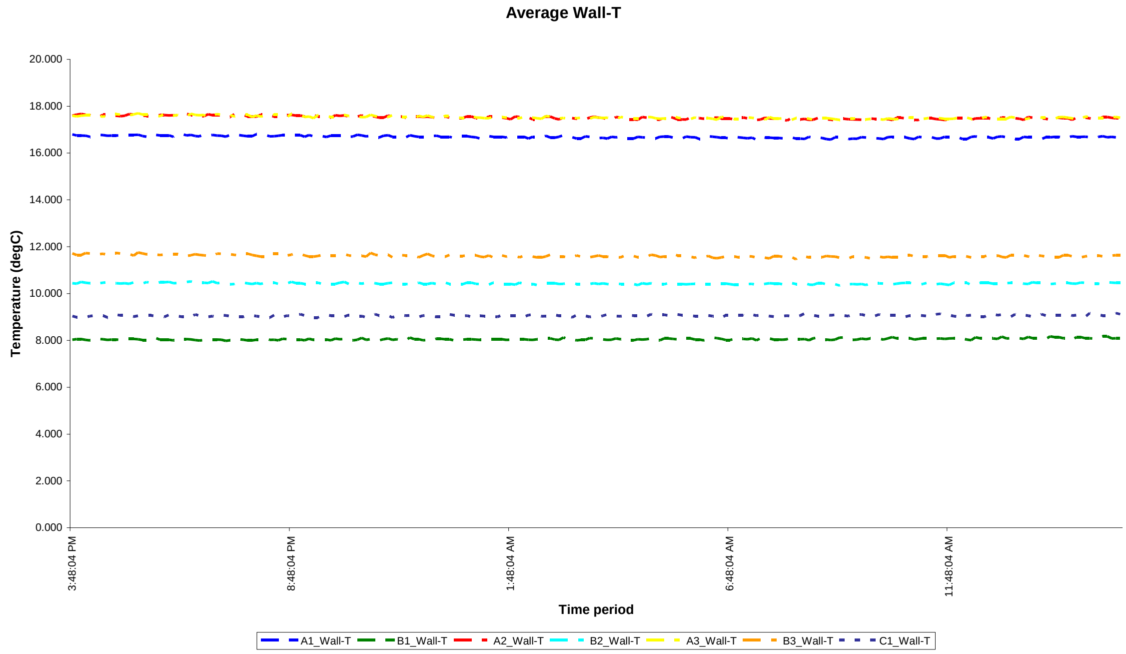


Figure B-93: Average wall temperature of C1-Alt3

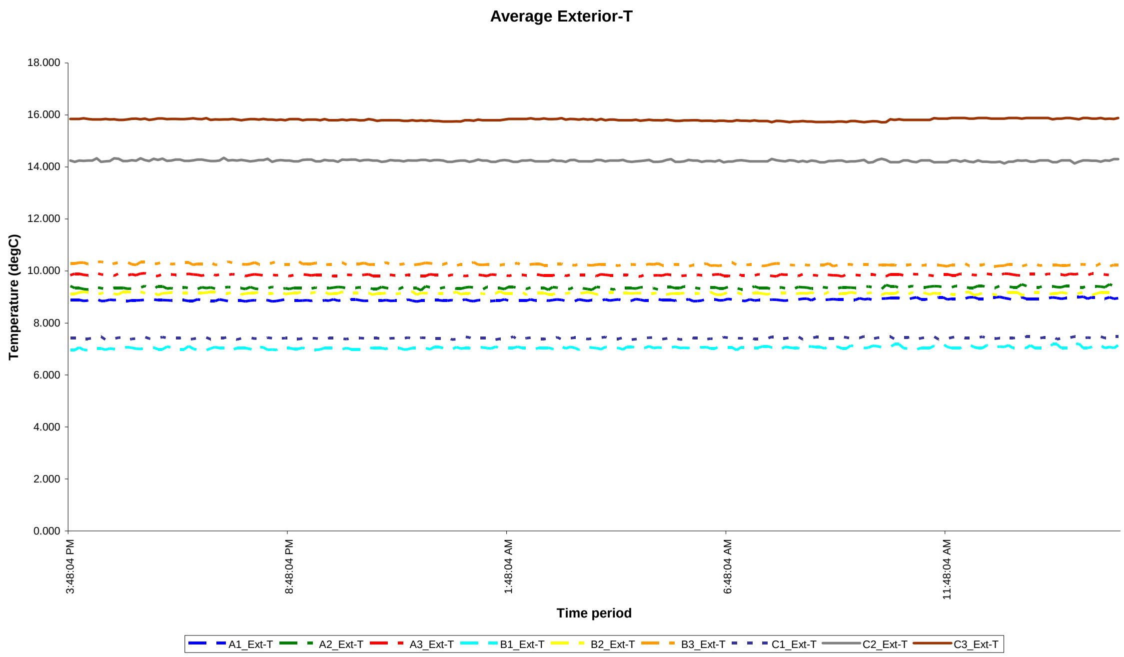


Figure B-94: Average exterior temperature of C1-Alt3

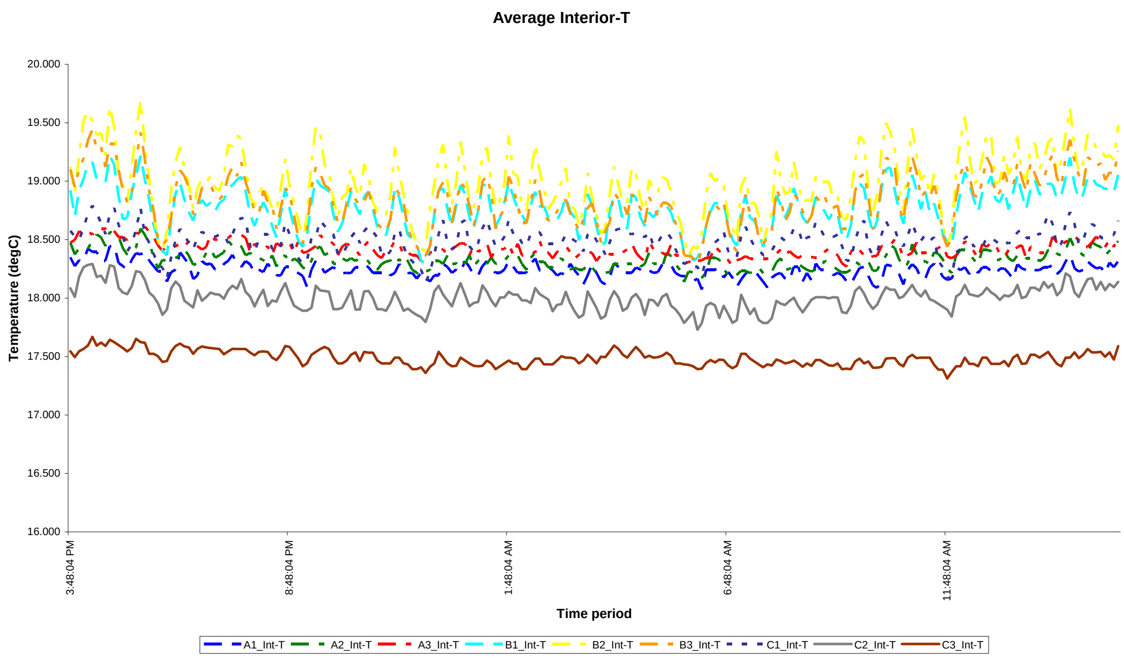


Figure B-95: Average interior temperature of C1-Alt3

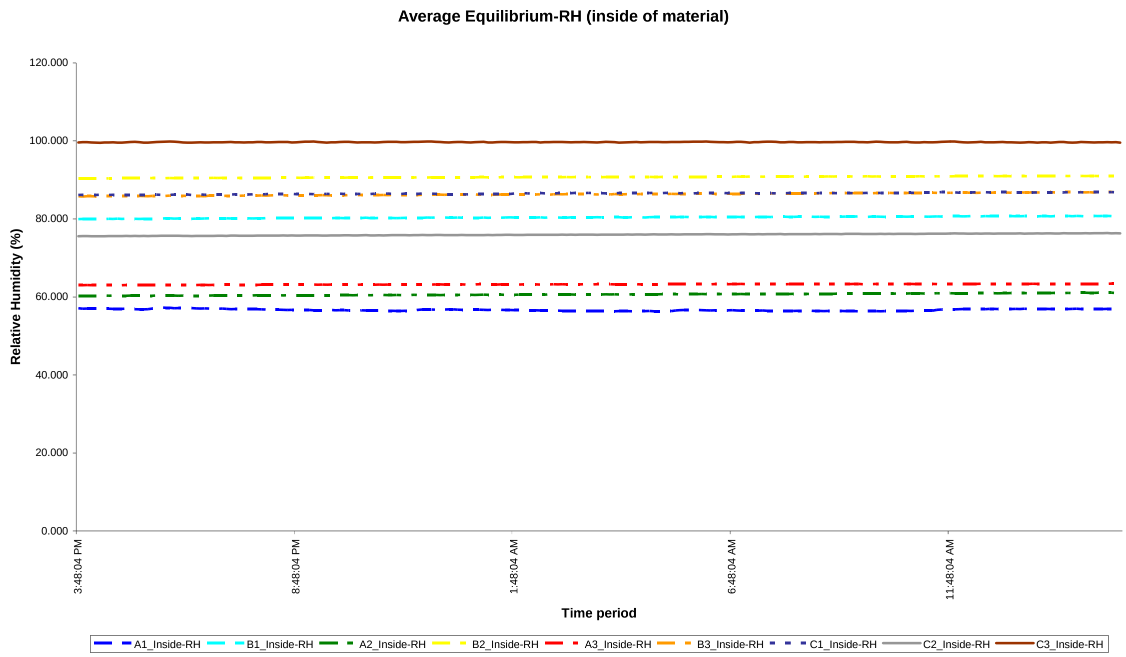


Figure B-96: Average equilibrium of relative humidity in a cavity of C1-Alt3

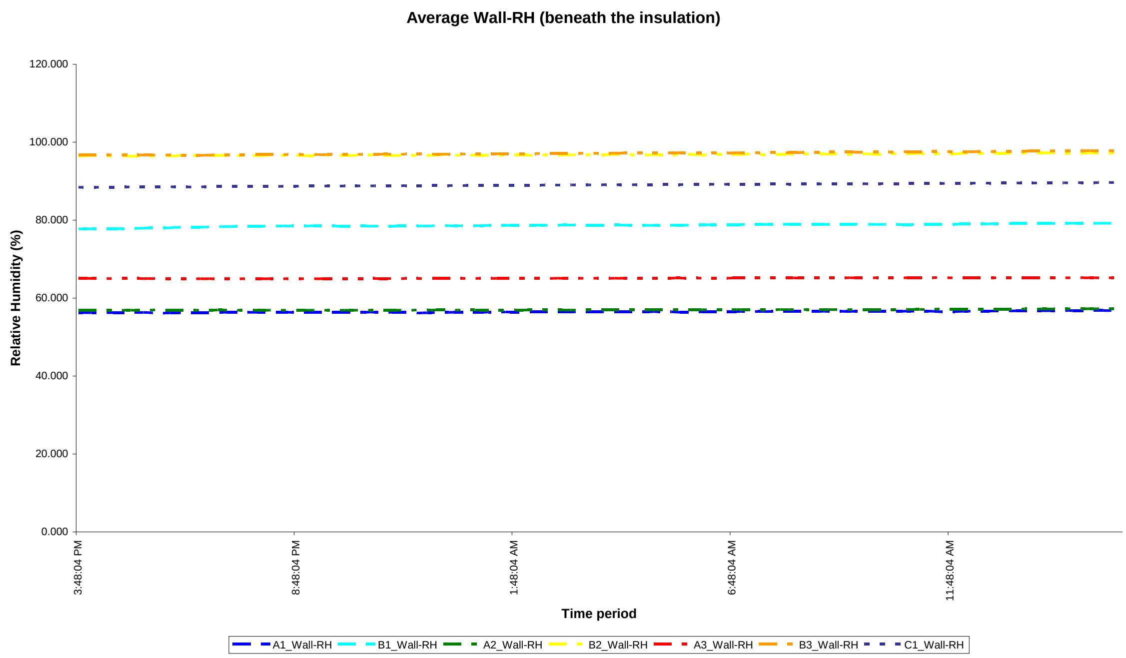


Figure B-97: Average wall relative humidity beneath the insulation of C1-Alt3

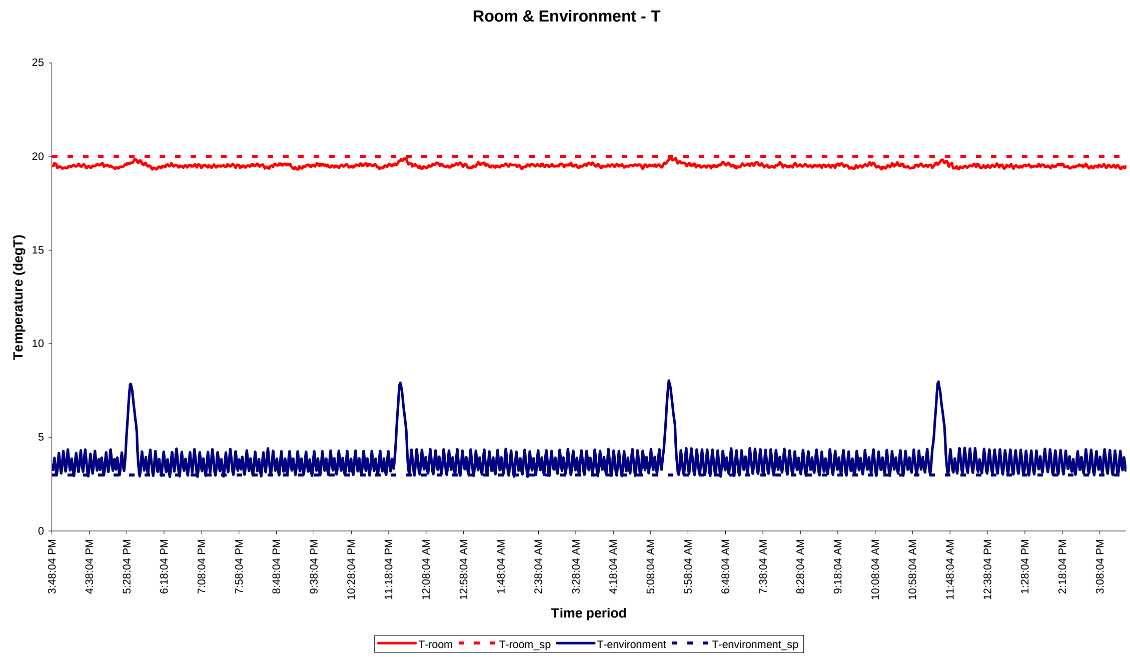


Figure B-98: Temperature of the room and environmental side during C1-Alt3

Figure B-99: Relative humidity of the room and environmental side during C1-Alt3

Test cycle: **C1 – Alt4**

Table B-12: Average data during the last 24 hours for each specimen of C1-Alt4

Specimen Measurement Data

B-G	A		B		C		Clay
1	A1_Soil-T	6.067 degC	B1_Soil-T	5.764 degC	C1_Soil-T	5.875 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	100.000 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	16.653 degC	B1_Wall-T	8.051 degC	C1_Wall-T	8.908 degC	
	A1_Ext-T	9.010 degC	B1_Ext-T	7.067 degC	C1_Ext-T	7.351 degC	
	A1_Int-T	18.310 degC	B1_Int-T	18.887 degC	C1_Int-T	18.364 degC	
	A1_Inside-RH	48.464 %	B1_Inside-RH	82.025 %	C1_Inside-RH	88.386 %	
	A1_Wall-RH	56.611 %	B1_Wall-RH	74.710 %	C1_Wall-RH	82.053 %	
2	A2_Soil-T	6.451 degC	B2_Soil-T	6.032 degC	C2_Soil-T	7.074 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	17.580 degC	B2_Wall-T	10.299 degC	C2_Ext-T	14.154 degC	
	A2_Ext-T	9.474 degC	B2_Ext-T	9.062 degC	C2_Int-T	17.964 degC	
	A2_Int-T	18.499 degC	B2_Int-T	19.232 degC	C2_Inside-RH	74.370 degC	
	A2_Inside-RH	57.558 %	B2_Inside-RH	91.991 %			
	A2_Wall-RH	57.246 %	B2_Wall-RH	93.441 %			
3	A3_Soil-T	6.704 degC	B3_Soil-T	6.822 degC	C3_Soil-T	6.726 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	17.562 degC	B3_Wall-T	11.071 degC	C3_Ext-T	15.627 degC	
	A3_Ext-T	9.892 degC	B3_Ext-T	9.854 degC	C3_Int-T	17.339 degC	
	A3_Int-T	18.537 degC	B3_Int-T	19.090 degC	C3_Inside-RH	99.636 degC	
	A3_Inside-RH	59.636 %	B3_Inside-RH	88.409 %			
	A3_Wall-RH	64.690 %	B3_Wall-RH	72.948 %	**Pressure diff.*	*5.497 Pa*	
No	A		B		C		Alt4

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	19.504 degC
RH-room	32.776 %
T-room_sp	20.000 degC
RH-room_sp	30.000 %
T-environment	3.744 degC
RH-environment	88.346 %
T-environment_sp	3.000 degC
RH-environment_sp	95.000 %

Remarks

Type: B-G
Soil type: Clay
Damproofing: No
Alternative: Alt4

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

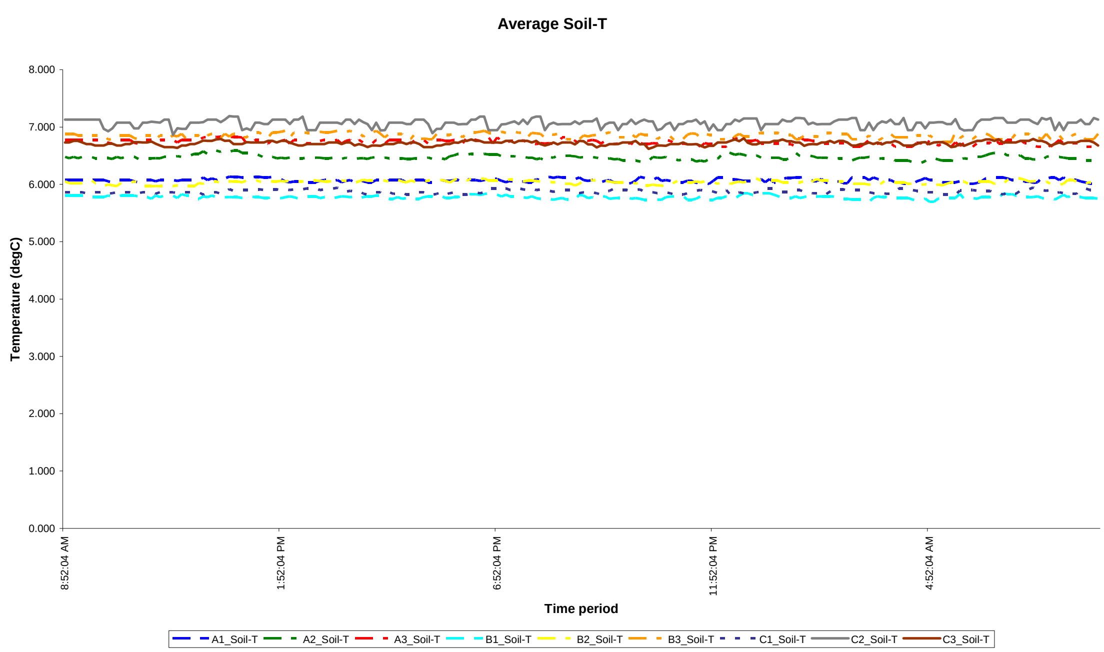


Figure B-100: Average soil temperature of C1-Alt4

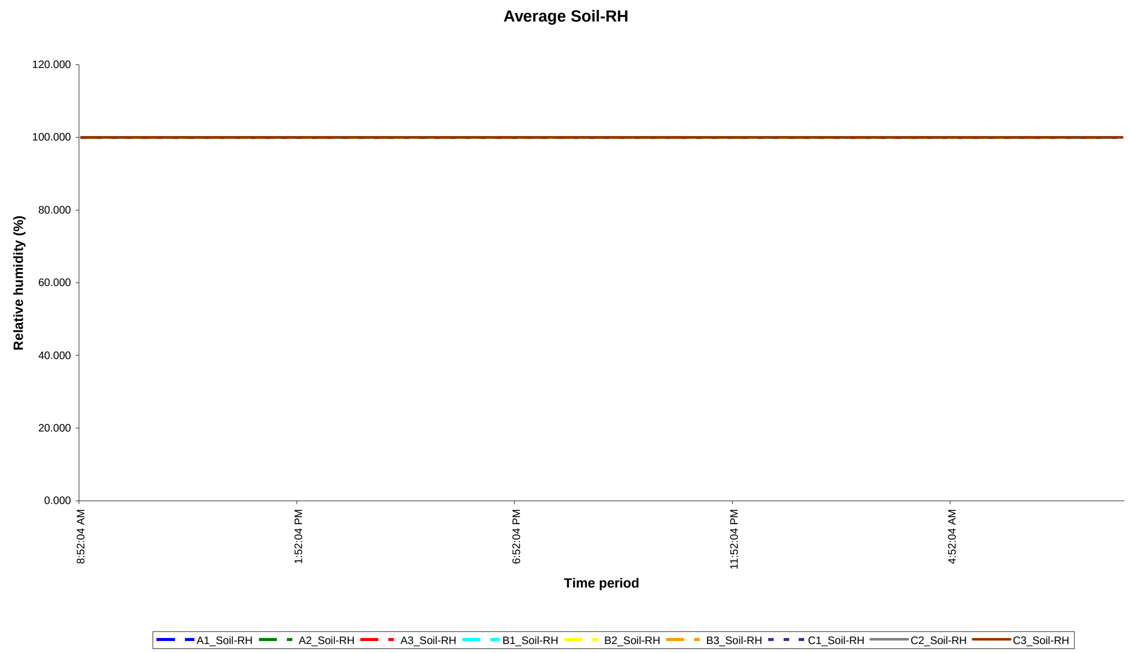


Figure B-101: Average soil relative humidity of C1-Alt4

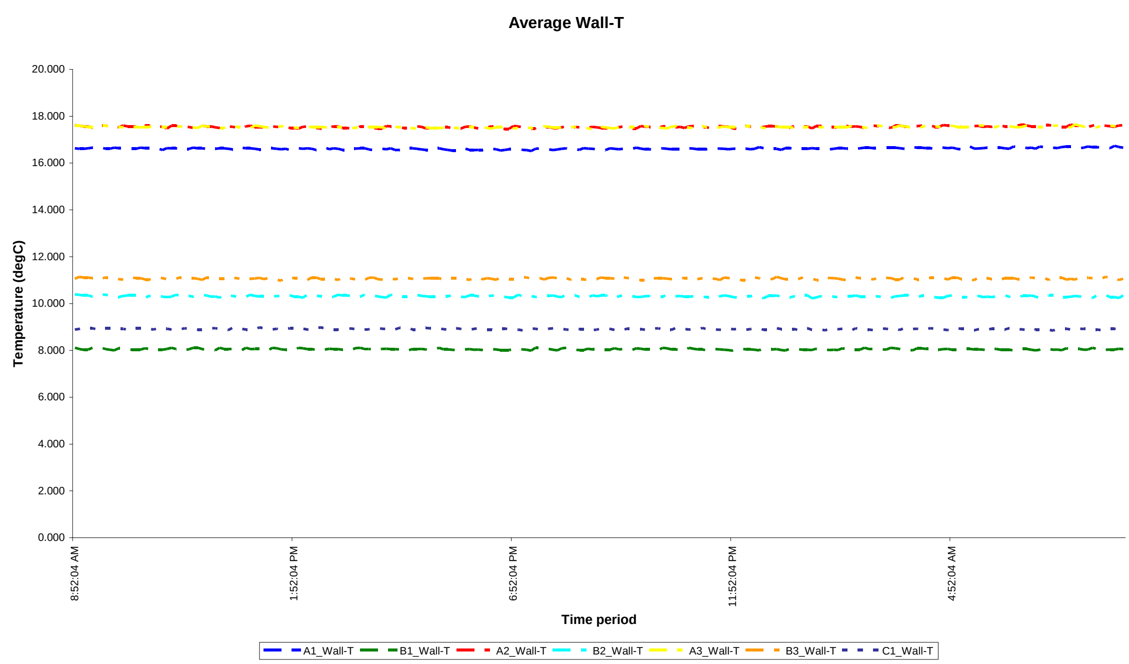


Figure B-102: Average wall temperature of C1-Alt4

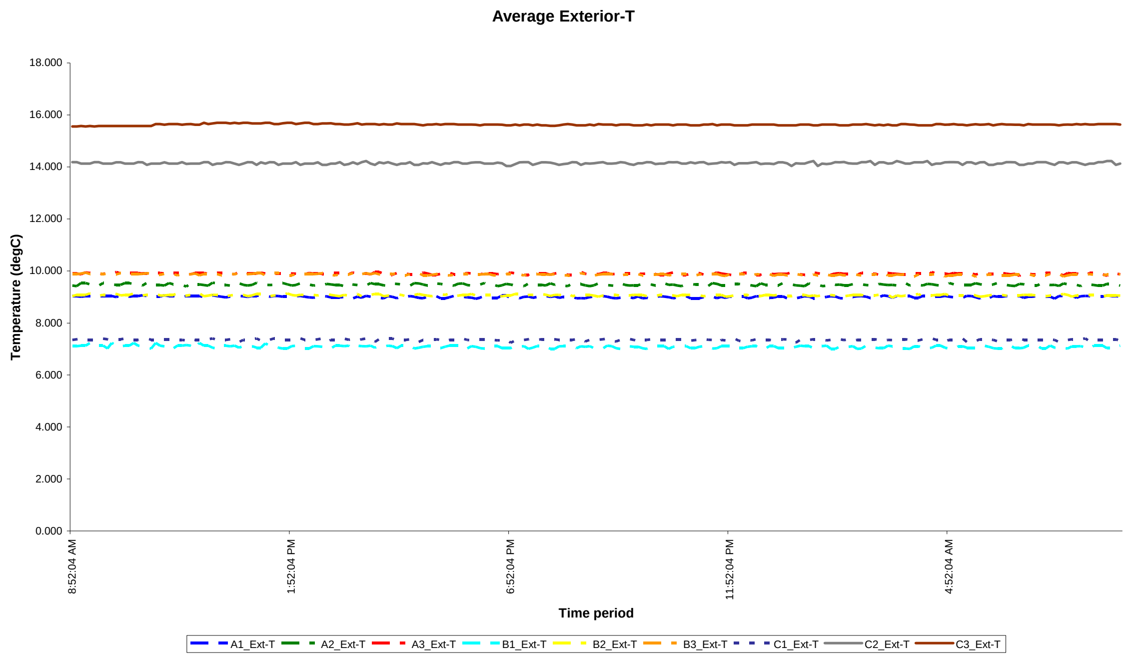


Figure B-103: Average exterior temperature of C1-Alt4

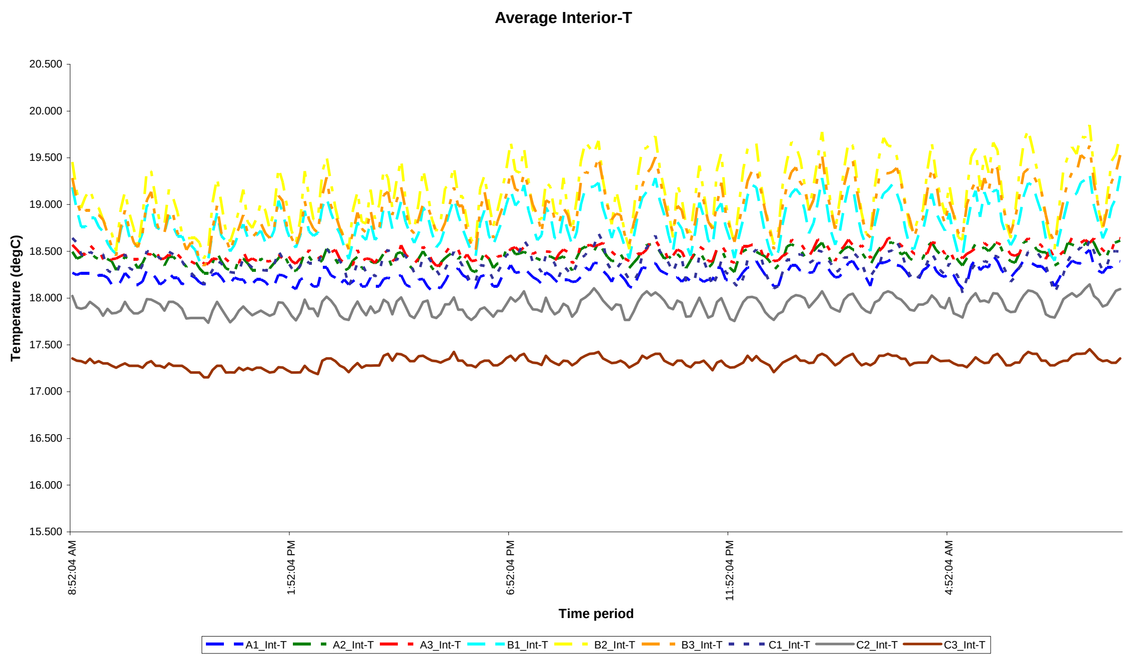


Figure B-104: Average interior temperature of C1-Alt4

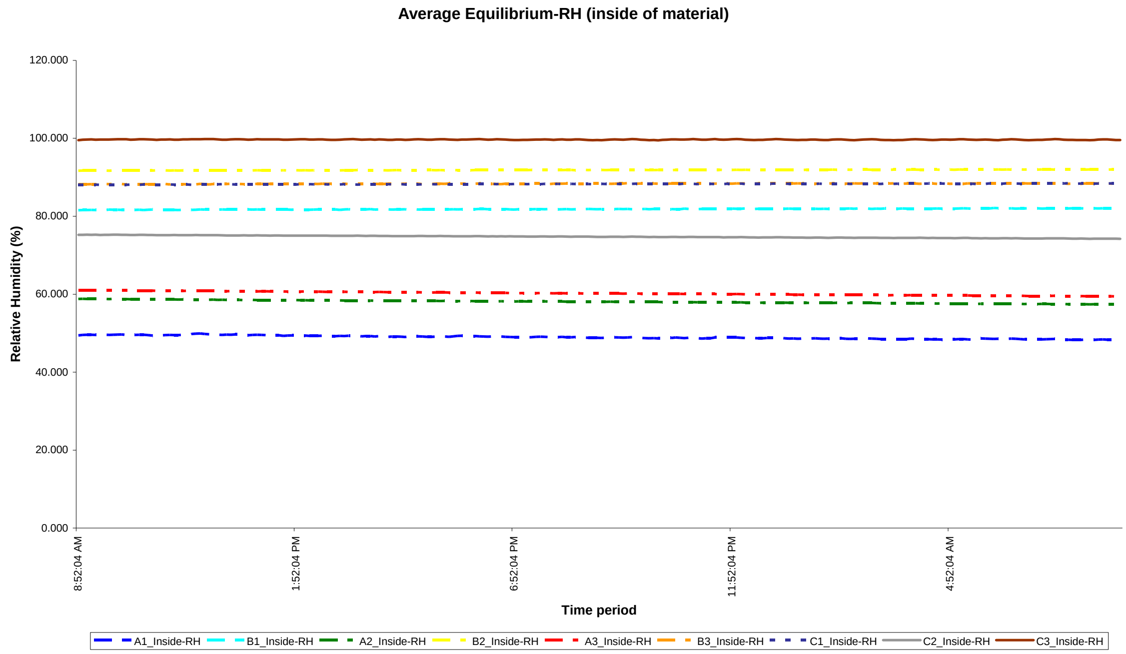


Figure B-105: Average equilibrium of relative humidity in a cavity of C1-Alt4

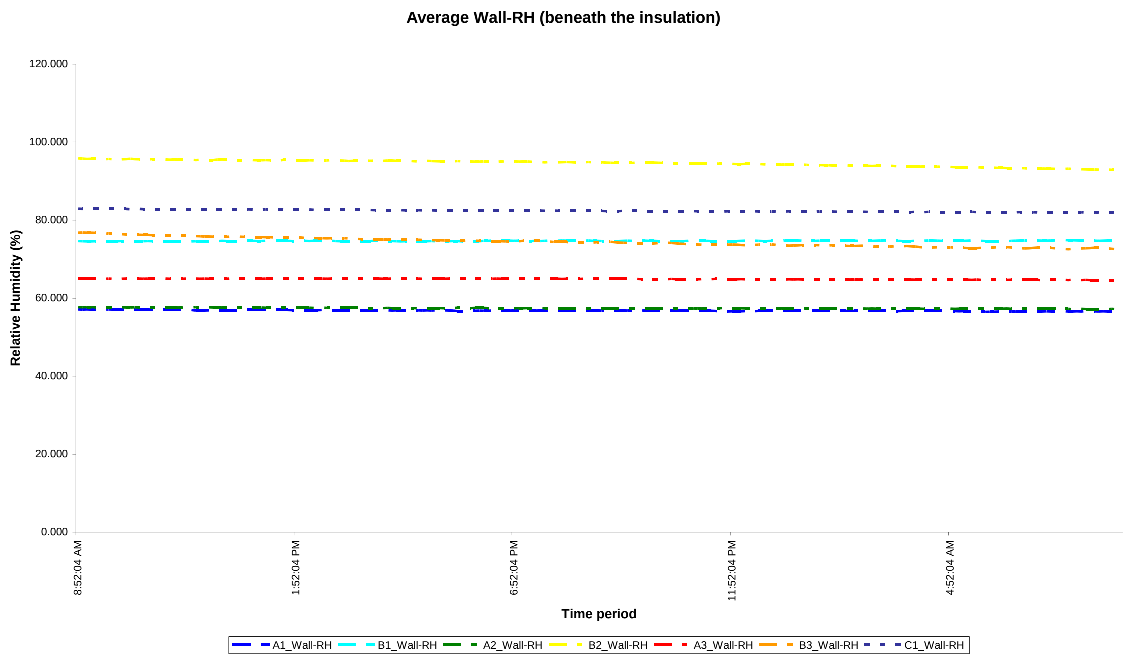


Figure B-106: Average wall relative humidity beneath the insulation of C1-Alt4

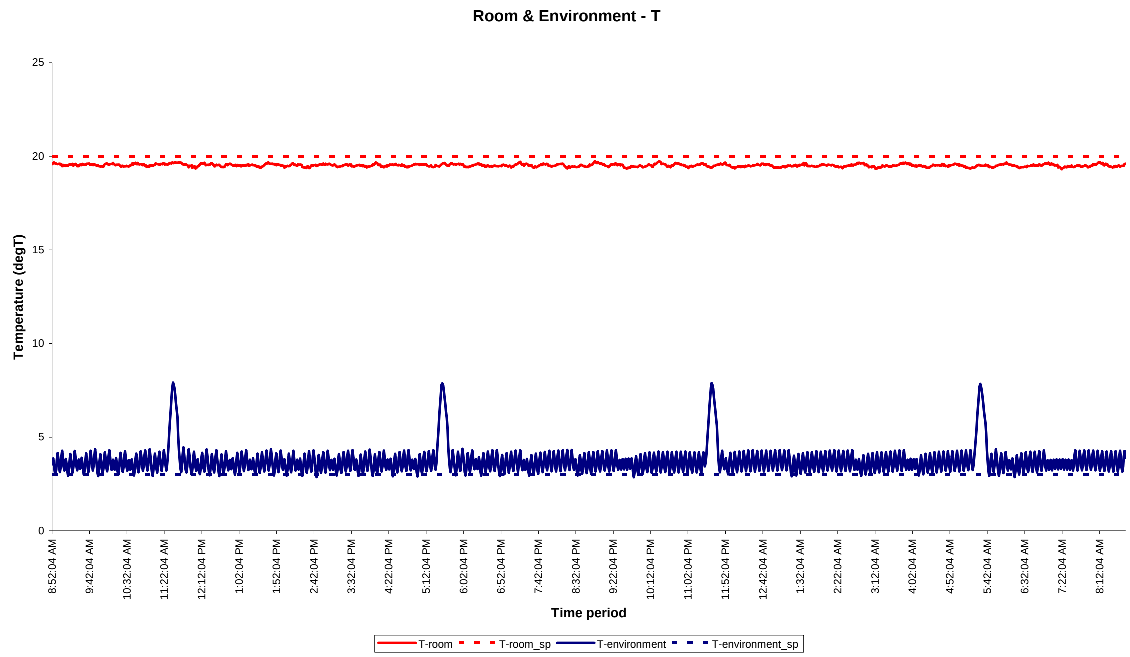


Figure B-107: Temperature of the room and environmental side during C1-Alt4

Figure B-108: Relative humidity of the room and environmental side during C1-Alt4

Test cycle: **C1 – Alt5**

Table B-13: Average data during the last 24 hours for each specimen of C1-Alt5

Specimen Measurement Data

B-G	A		B		C		Clay
1	A1_Soil-T	18.342 degC	B1_Soil-T	18.138 degC	C1_Soil-T	18.044 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	100.000 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	18.733 degC	B1_Wall-T	18.154 degC	C1_Wall-T	18.361 degC	
	A1_Ext-T	19.030 degC	B1_Ext-T	17.966 degC	C1_Ext-T	18.036 degC	
	A1_Int-T	18.828 degC	B1_Int-T	18.987 degC	C1_Int-T	18.697 degC	
	A1_Inside-RH	55.444 %	B1_Inside-RH	81.824 %	C1_Inside-RH	88.459 %	
	A1_Wall-RH	66.760 %	B1_Wall-RH	66.660 %	C1_Wall-RH	66.345 %	
2	A2_Soil-T	18.596 degC	B2_Soil-T	17.927 degC	C2_Soil-T	18.691 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	18.581 degC	B2_Wall-T	17.414 degC	C2_Ext-T	18.736 degC	
	A2_Ext-T	18.560 degC	B2_Ext-T	17.057 degC	C2_Int-T	18.649 degC	
	A2_Int-T	18.554 degC	B2_Int-T	18.885 degC	C2_Inside-RH	73.101 degC	
	A2_Inside-RH	56.455 %	B2_Inside-RH	91.984 %			
	A2_Wall-RH	75.235 %	B2_Wall-RH	87.266 %			
3	A3_Soil-T	18.746 degC	B3_Soil-T	18.510 degC	C3_Soil-T	21.692 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	99.781 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	18.689 degC	B3_Wall-T	17.766 degC	C3_Ext-T	19.548 degC	
	A3_Ext-T	18.472 degC	B3_Ext-T	17.541 degC	C3_Int-T	19.004 degC	
	A3_Int-T	18.663 degC	B3_Int-T	18.672 degC	C3_Inside-RH	100.000 degC	
	A3_Inside-RH	60.005 %	B3_Inside-RH	84.412 %			
	A3_Wall-RH	98.430 %	B3_Wall-RH	44.563 %	*Pressure diff.	8.351 Pa	
No	A		B		C		Alt5

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	19.510 degC
RH-room	27.751 %
T-room_sp	20.000 degC
RH-room_sp	30.000 %
T-environment	19.443 degC
RH-environment	49.641 %
T-environment_sp	20.000 degC
RH-environment_sp	50.000 %

Remarks

Type: B-G
Soil type: Clay
Dampproofing: No
Alternative: Alt5

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

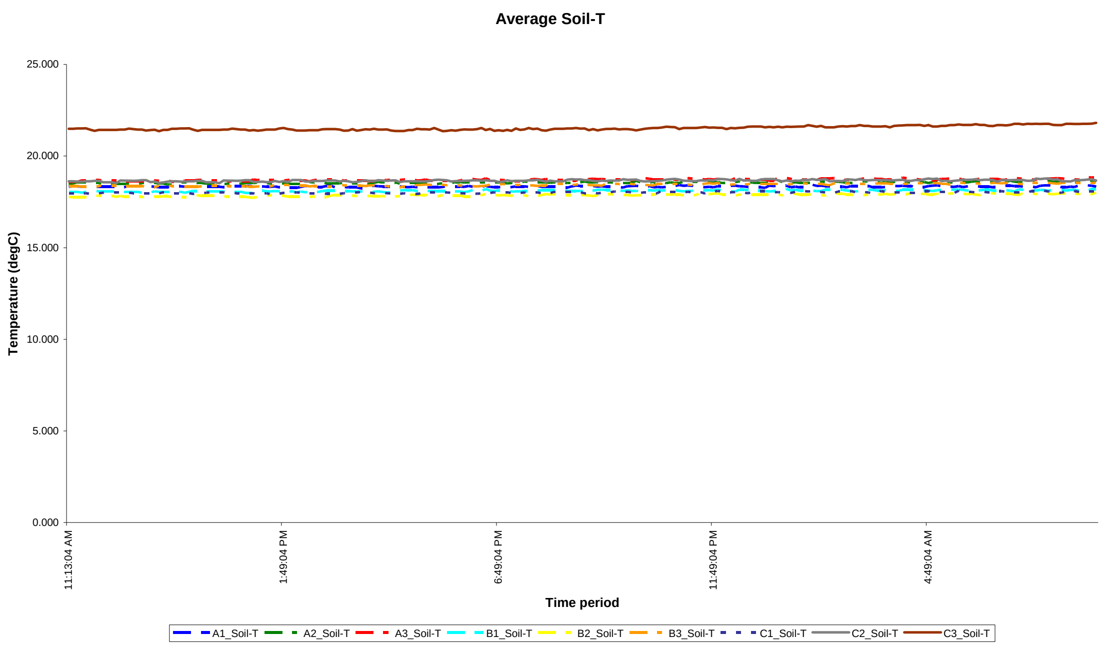


Figure B-109: Average soil temperature of C1-Alt5

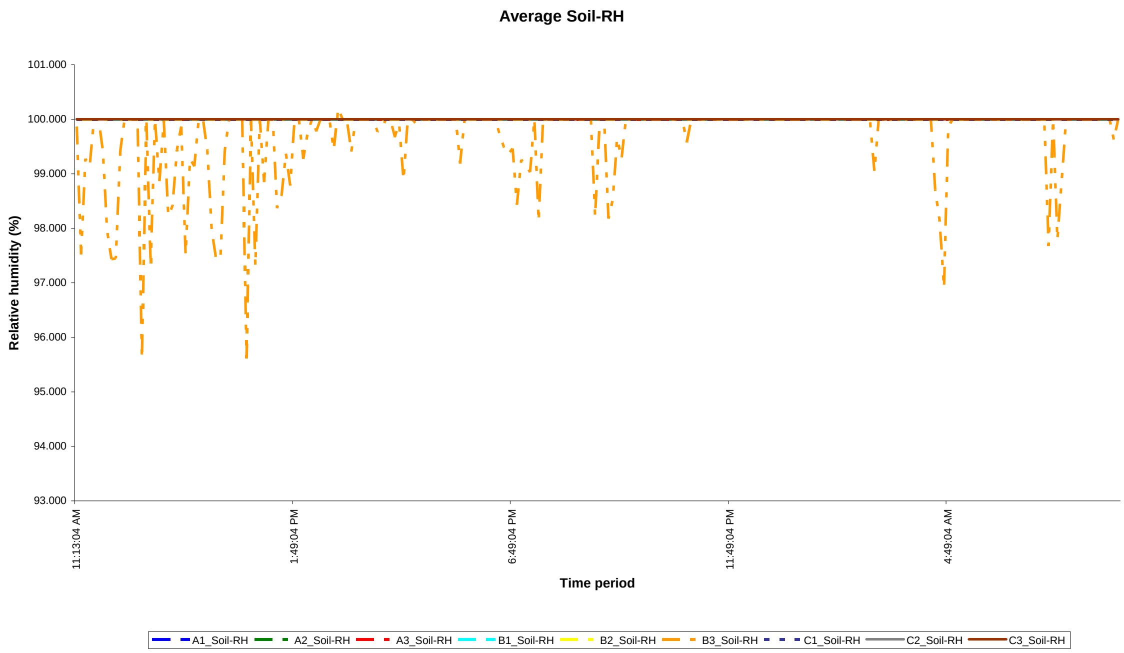


Figure B-110: Average soil relative humidity of C1-Alt5

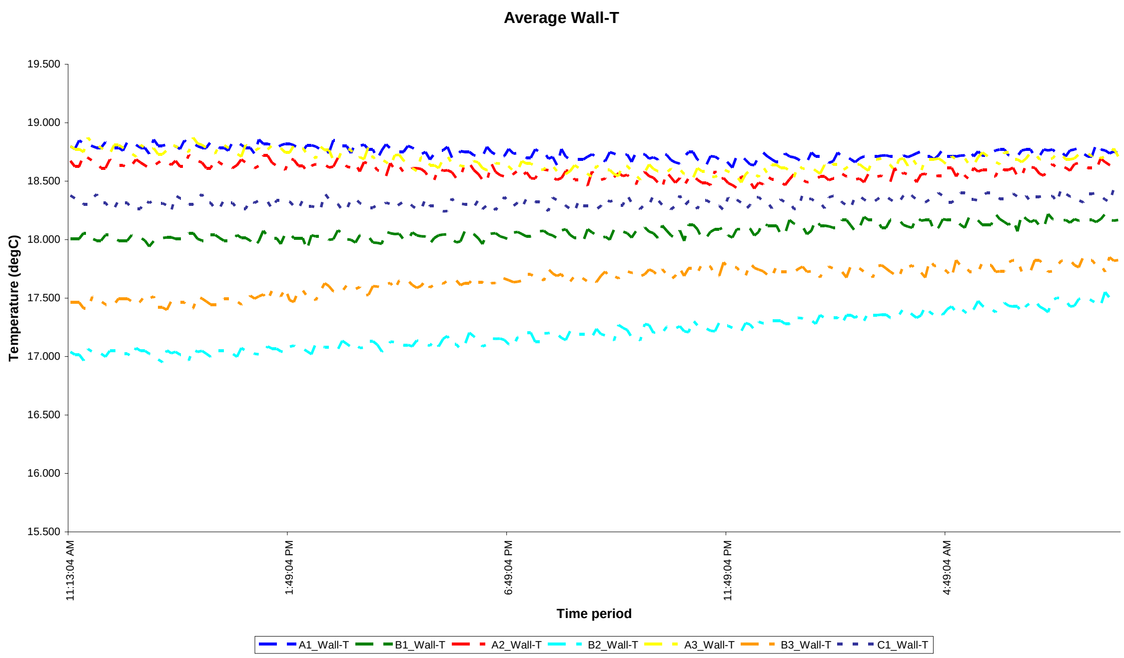


Figure B-111: Average wall temperature of C1-Alt5

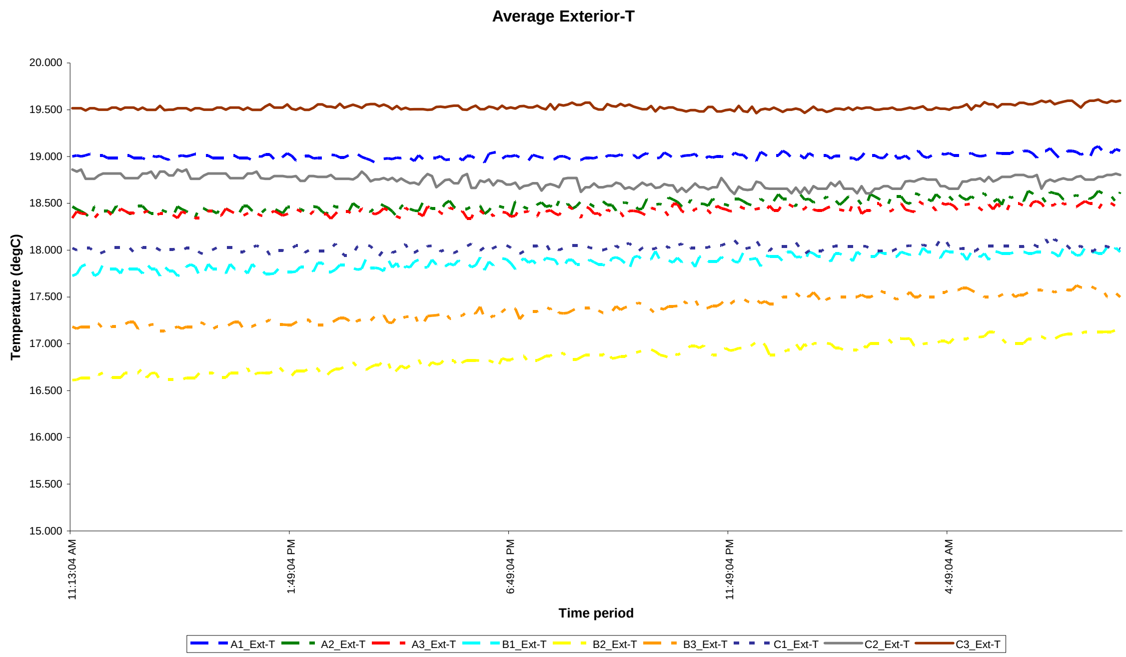


Figure B-112: Average exterior temperature of C1-Alt5

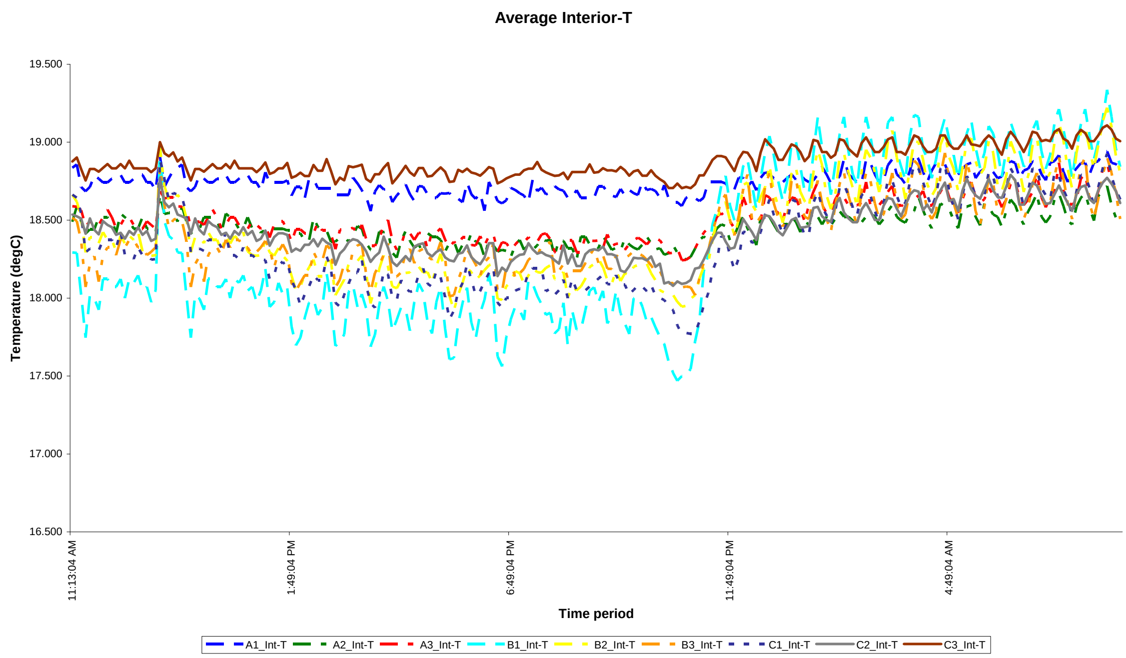


Figure B-113: Average interior temperature of C1-Alt5

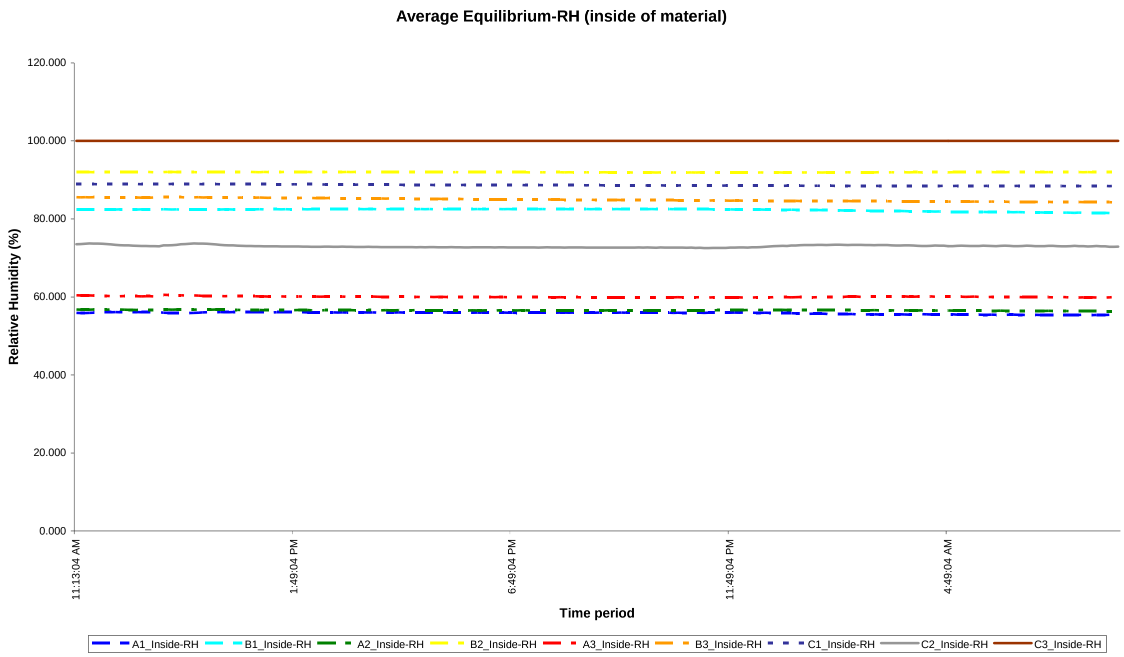


Figure B-114: Average equilibrium of relative humidity in a cavity of C1-Alt5

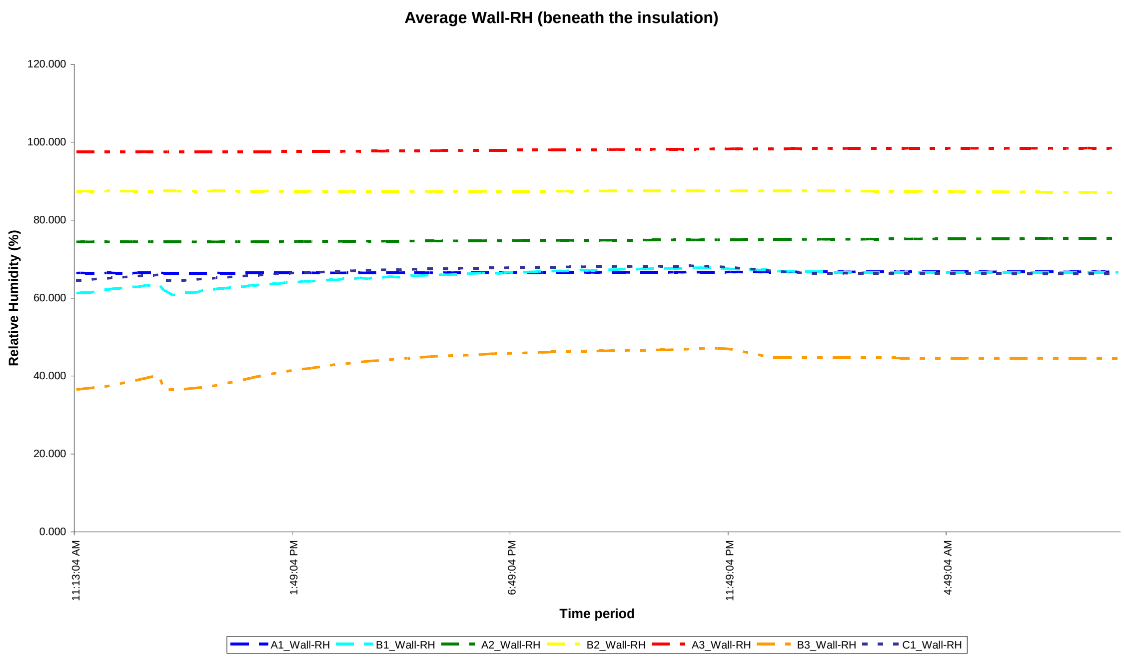


Figure B-115: Average wall relative humidity beneath the insulation of C1-Alt5

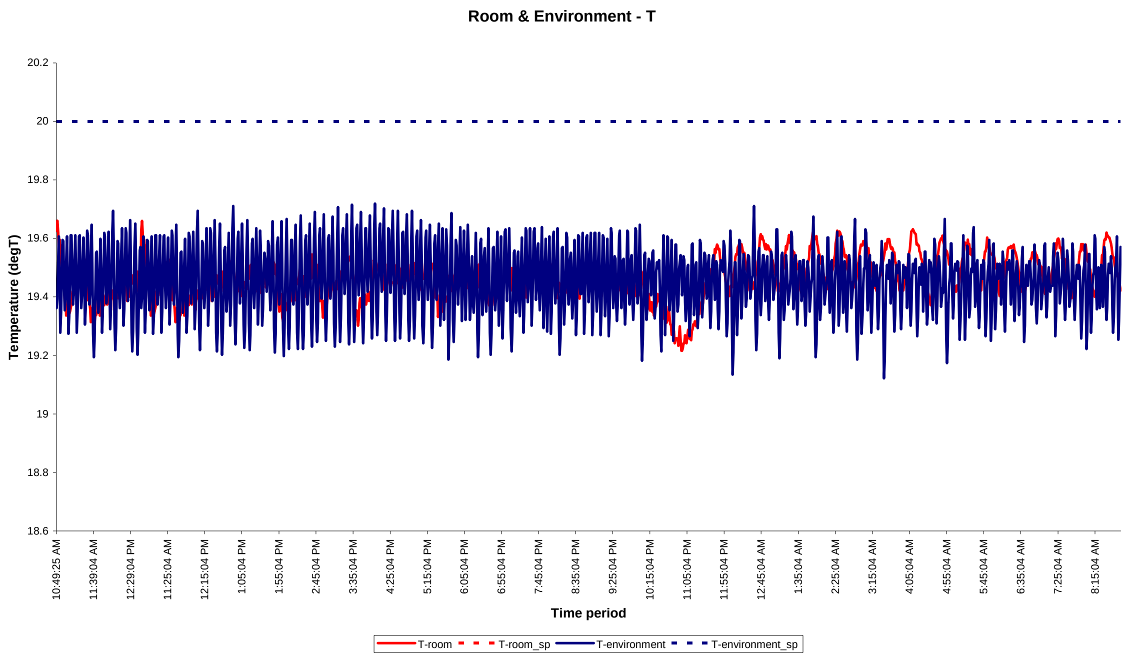


Figure B-116: Temperature of the room and environmental side during C1-Alt5

Figure B-117: Relative humidity of the room and environmental side during C1-Alt5

Test cycle: **C1 – Alt6**

Table B-14: Average data during the last 24 hours for each specimen of C1-Alt6

Specimen Measurement Data

B-G	A		B		C		Clay
1	A1_Soil-T	18.535 degC	B1_Soil-T	18.414 degC	C1_Soil-T	18.316 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	100.000 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	18.645 degC	B1_Wall-T	18.496 degC	C1_Wall-T	18.609 degC	
	A1_Ext-T	19.101 degC	B1_Ext-T	18.349 degC	C1_Ext-T	18.294 degC	
	A1_Int-T	18.529 degC	B1_Int-T	18.680 degC	C1_Int-T	18.449 degC	
	A1_Inside-RH	60.662 %	B1_Inside-RH	82.128 %	C1_Inside-RH	88.078 %	
	A1_Wall-RH	67.717 %	B1_Wall-RH	74.633 %	C1_Wall-RH	76.833 %	
2	A2_Soil-T	18.909 degC	B2_Soil-T	18.311 degC	C2_Soil-T	18.859 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	18.512 degC	B2_Wall-T	18.161 degC	C2_Ext-T	18.866 degC	
	A2_Ext-T	18.815 degC	B2_Ext-T	17.835 degC	C2_Int-T	18.610 degC	
	A2_Int-T	18.286 degC	B2_Int-T	18.661 degC	C2_Inside-RH	74.597 degC	
	A2_Inside-RH	60.079 %	B2_Inside-RH	91.547 %			
	A2_Wall-RH	76.887 %	B2_Wall-RH	85.828 %			
3	A3_Soil-T	19.103 degC	B3_Soil-T	18.996 degC	C3_Soil-T	21.216 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	18.669 degC	B3_Wall-T	18.588 degC	C3_Ext-T	19.684 degC	
	A3_Ext-T	18.723 degC	B3_Ext-T	18.289 degC	C3_Int-T	18.914 degC	
	A3_Int-T	18.408 degC	B3_Int-T	18.580 degC	C3_Inside-RH	100.000 degC	
	A3_Inside-RH	64.856 %	B3_Inside-RH	84.288 %			
	A3_Wall-RH	99.940 %	B3_Wall-RH	71.781 %	*Pressure diff.*	*53.106 Pa*	
No	A		B		C		Alt6

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	19.562 degC
RH-room	60.918 %
T-room_sp	20.000 degC
RH-room_sp	60.000 %
T-environment	19.508 degC
RH-environment	54.023 %
T-environment_sp	20.000 degC
RH-environment_sp	50.000 %

Remarks

Type: B-G
Soil type: Clay
Dampproofing: No
Alternative: Alt6

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

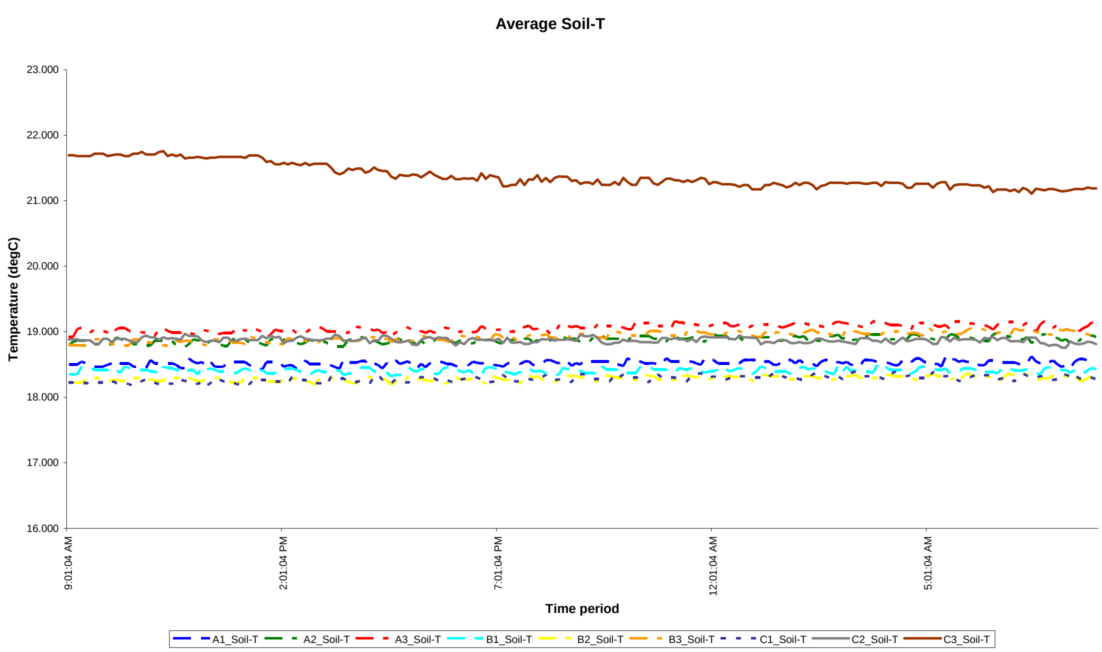


Figure B-118: Average soil temperature of C1-Alt6

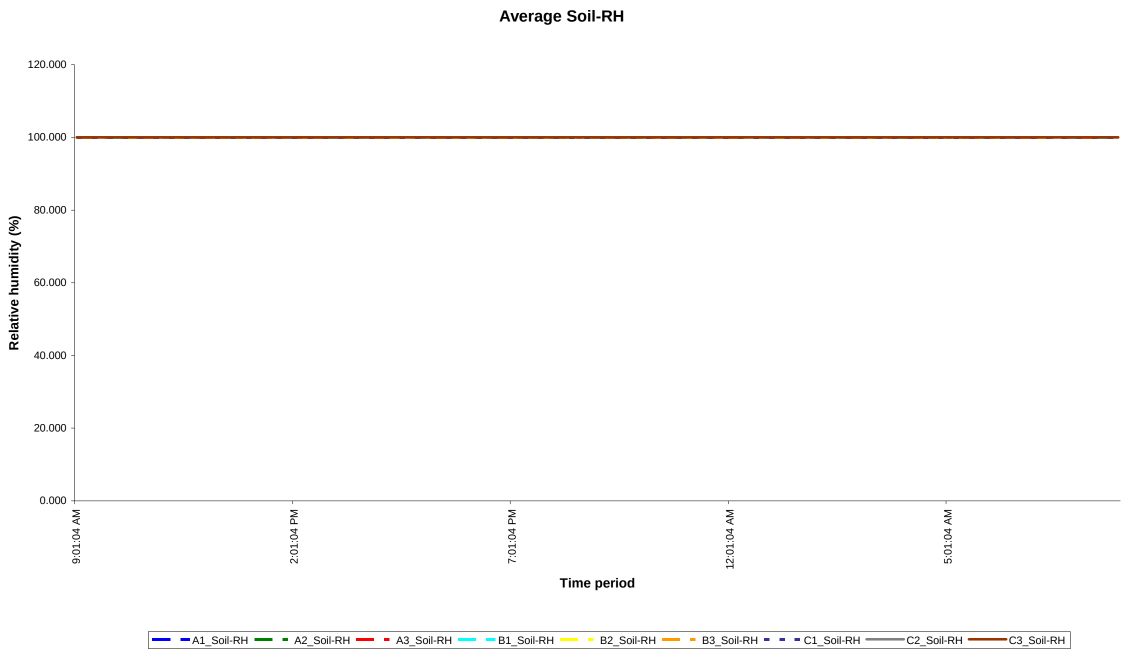


Figure B-119: Average soil relative humidity of C1-Alt6

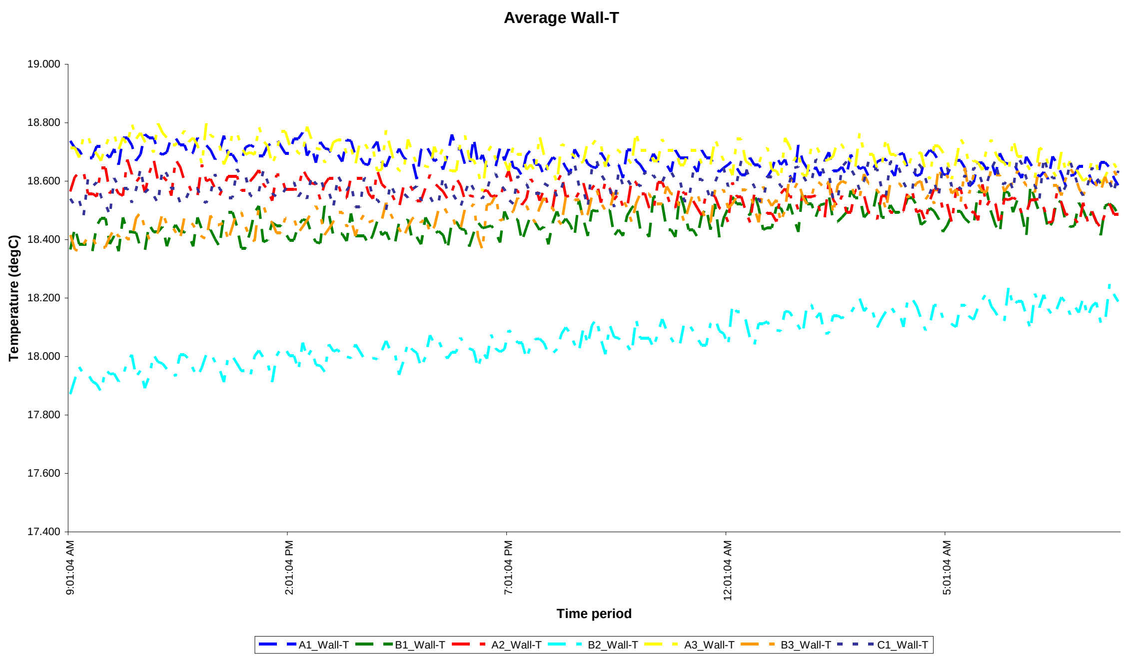


Figure B-120: Average wall temperature of C1-Alt6

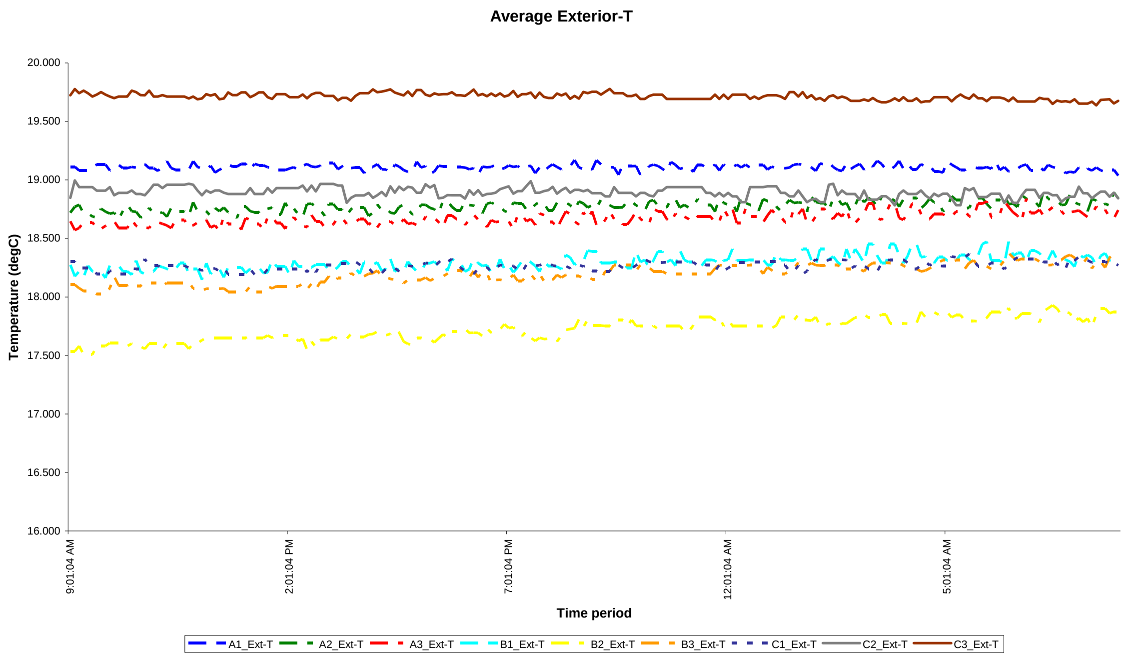


Figure B-121: Average exterior temperature of C1-Alt6

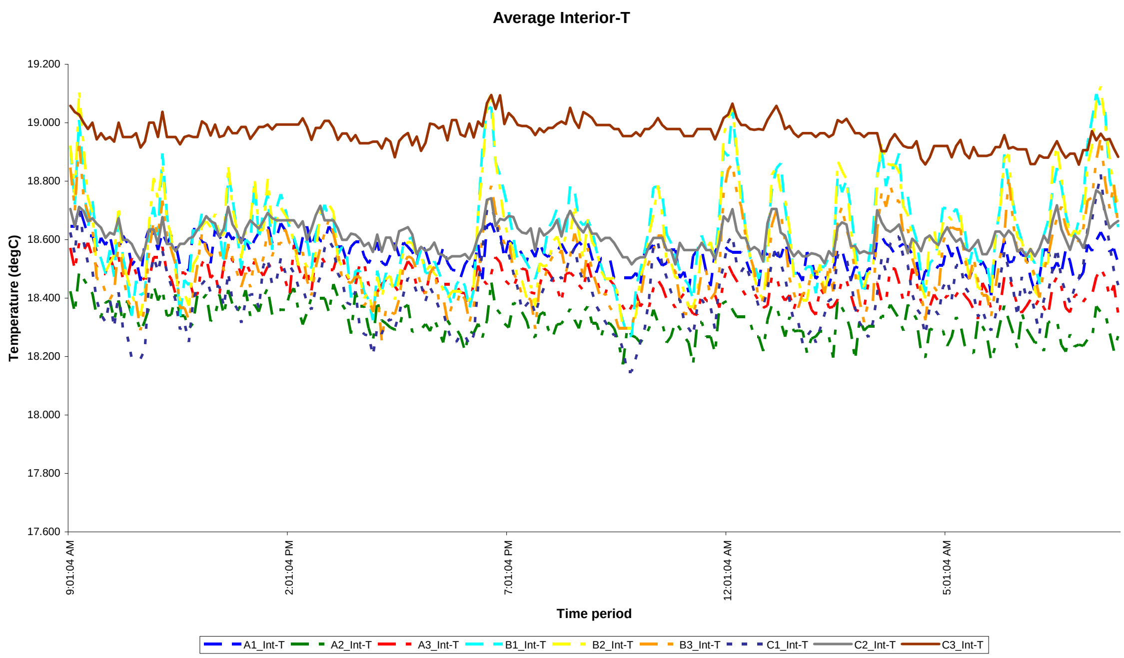


Figure B-122: Average interior temperature of C1-Alt6

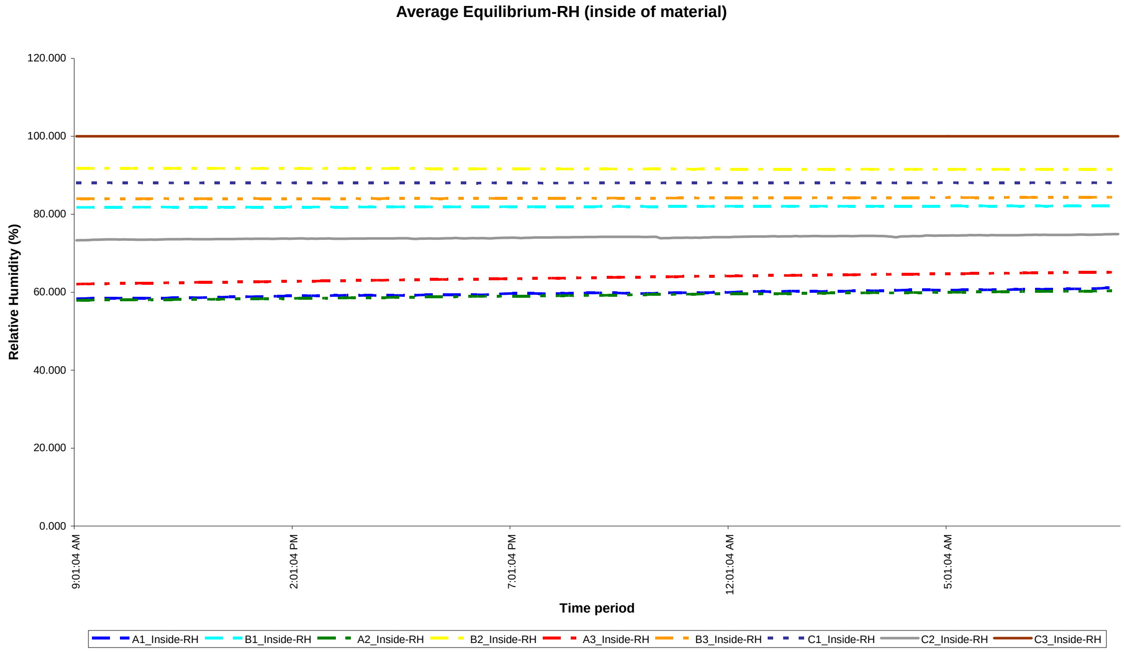


Figure B-123: Average equilibrium of relative humidity in a cavity of C1-Alt6

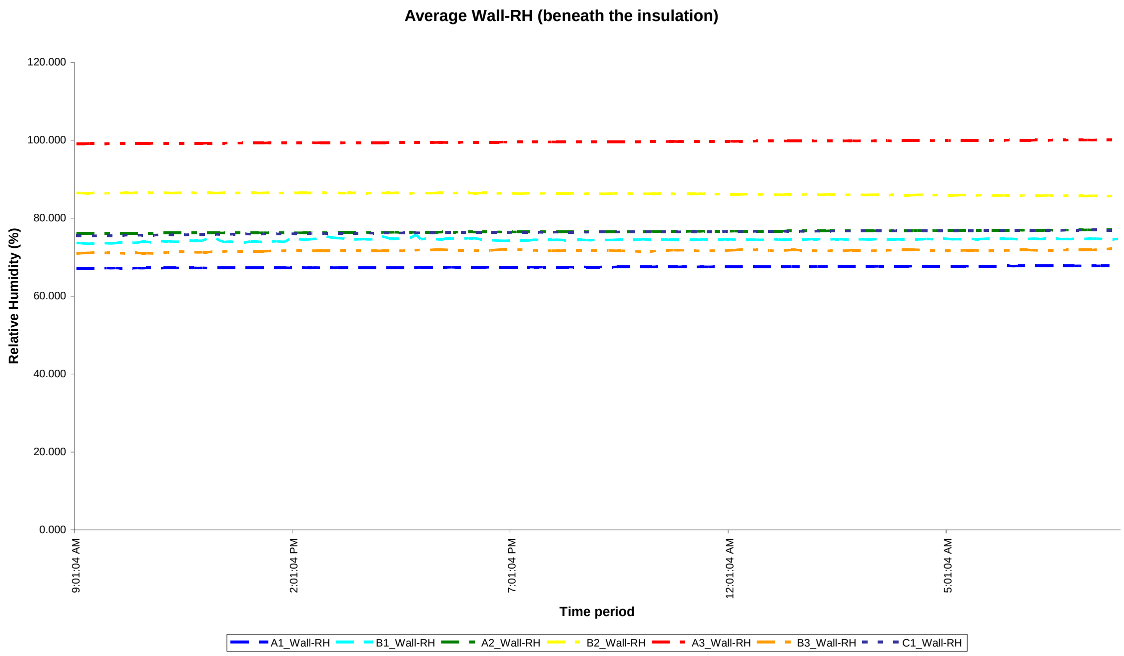


Figure B-124: Average wall relative humidity beneath the insulation of C1-Alt6

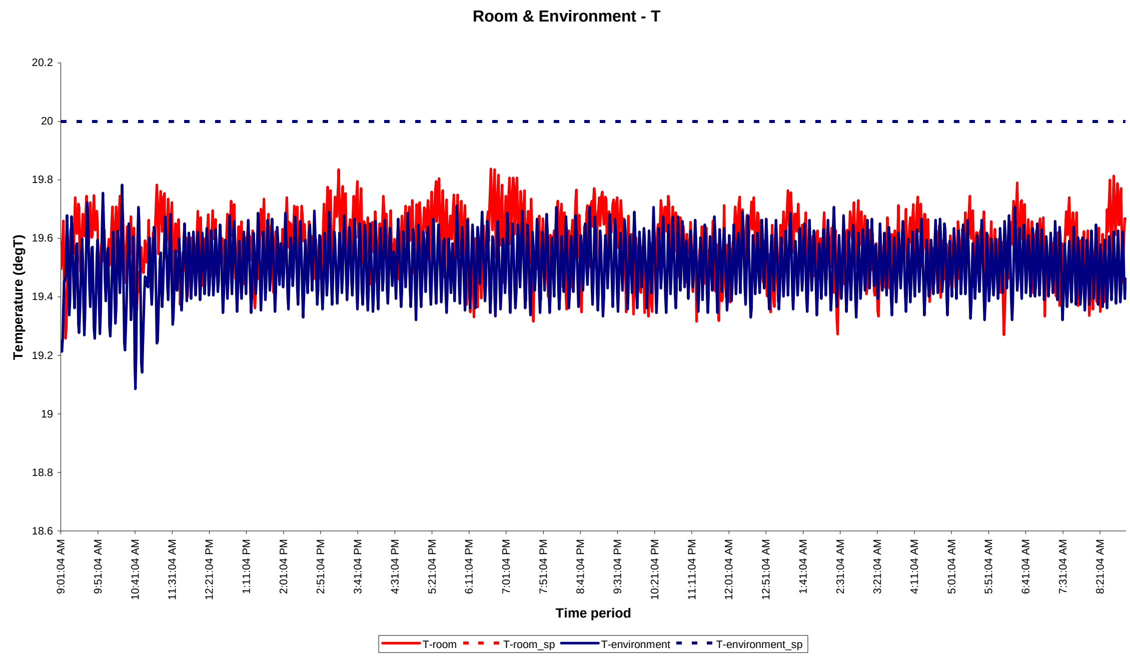


Figure B-125: Temperature of the room and environmental side during C1-Alt6

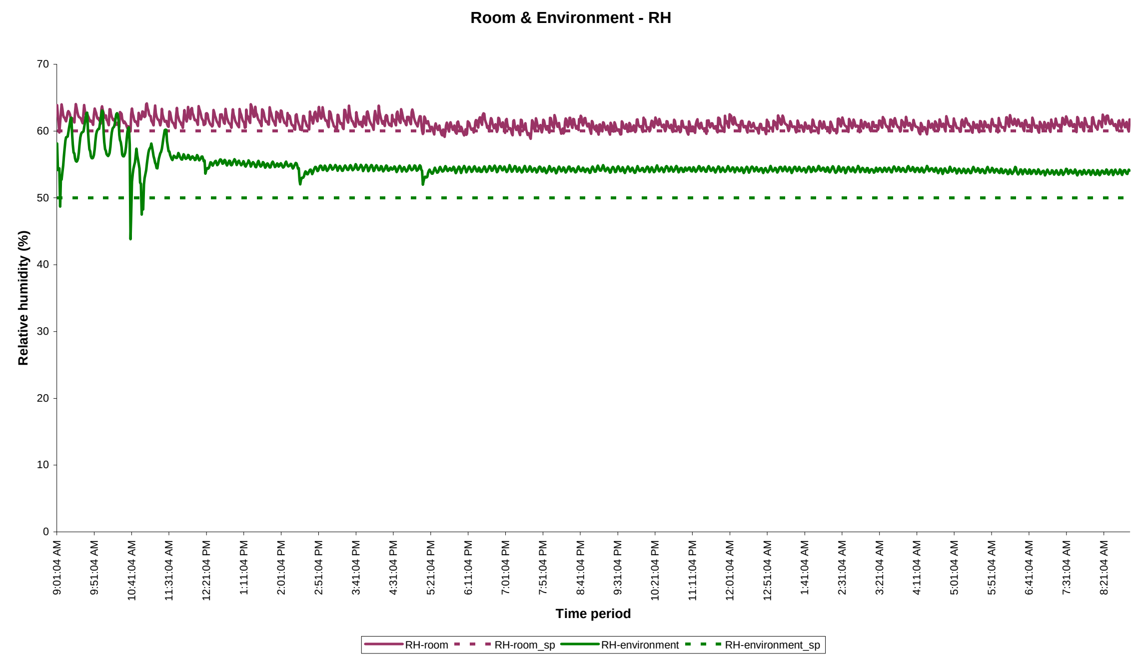


Figure B-126: Relative humidity of the room and environmental side during C1-Alt6

Test cycle: **C1 – Alt7**

Table B-15: Average data during the last 24 hours for each specimen of C1-Alt7

Specimen Measurement Data

B-G	A		B		C		Clay
1	A1_Soil-T	19.312 degC	B1_Soil-T	19.761 degC	C1_Soil-T	19.947 degC	1
1	A1_Soil-RH	100.000 %	B1_Soil-RH	100.000 %	C1_Soil-RH	100.000 %	1
1	A1_Wall-T	18.462 degC	B1_Wall-T	18.974 degC	C1_Wall-T	19.644 degC	1
1	A1_Ext-T	19.629 degC	B1_Ext-T	19.000 degC	C1_Ext-T	19.474 degC	1
1	A1_Int-T	18.046 degC	B1_Int-T	17.503 degC	C1_Int-T	18.032 degC	1
1	A1_Inside-RH	70.444 %	B1_Inside-RH	83.449 %	C1_Inside-RH	88.968 %	1
1	A1_Wall-RH	72.988 %	B1_Wall-RH	79.328 %	C1_Wall-RH	79.880 %	1
2	A2_Soil-T	19.442 degC	B2_Soil-T	19.448 degC	C2_Soil-T	20.695 degC	2
2	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	2
2	A2_Wall-T	18.051 degC	B2_Wall-T	18.600 degC	C2_Ext-T	19.258 degC	2
2	A2_Ext-T	19.245 degC	B2_Ext-T	18.405 degC	C2_Int-T	18.130 degC	2
2	A2_Int-T	17.430 degC	B2_Int-T	17.025 degC	C2_Inside-RH	77.265 degC	2
2	A2_Inside-RH	64.404 %	B2_Inside-RH	91.924 %			2
2	A2_Wall-RH	79.268 %	B2_Wall-RH	89.352 %			2
3	A3_Soil-T	19.575 degC	B3_Soil-T	19.692 degC	C3_Soil-T	23.452 degC	3
3	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	3
3	A3_Wall-T	18.165 degC	B3_Wall-T	18.949 degC	C3_Ext-T	20.057 degC	3
3	A3_Ext-T	18.997 degC	B3_Ext-T	18.785 degC	C3_Int-T	18.735 degC	3
3	A3_Int-T	17.528 degC	B3_Int-T	17.463 degC	C3_Inside-RH	100.000 degC	3
3	A3_Inside-RH	69.353 %	B3_Inside-RH	85.393 %			3
3	A3_Wall-RH	100.000 %	B3_Wall-RH	75.340 %	**Pressure diff.*	*80.437 Pa*	3
No	A		B		C		Alt7

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	18.365 degC
RH-room	70.408 %
T-room_sp	20.000 degC
RH-room_sp	60.000 %
T-environment	19.473 degC
RH-environment	93.520 %
T-environment_sp	20.000 degC
RH-environment_sp	95.000 %

Remarks

Type:	B-G
Soil type:	Clay
Dampproofing:	No
Alternative:	Alt7

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

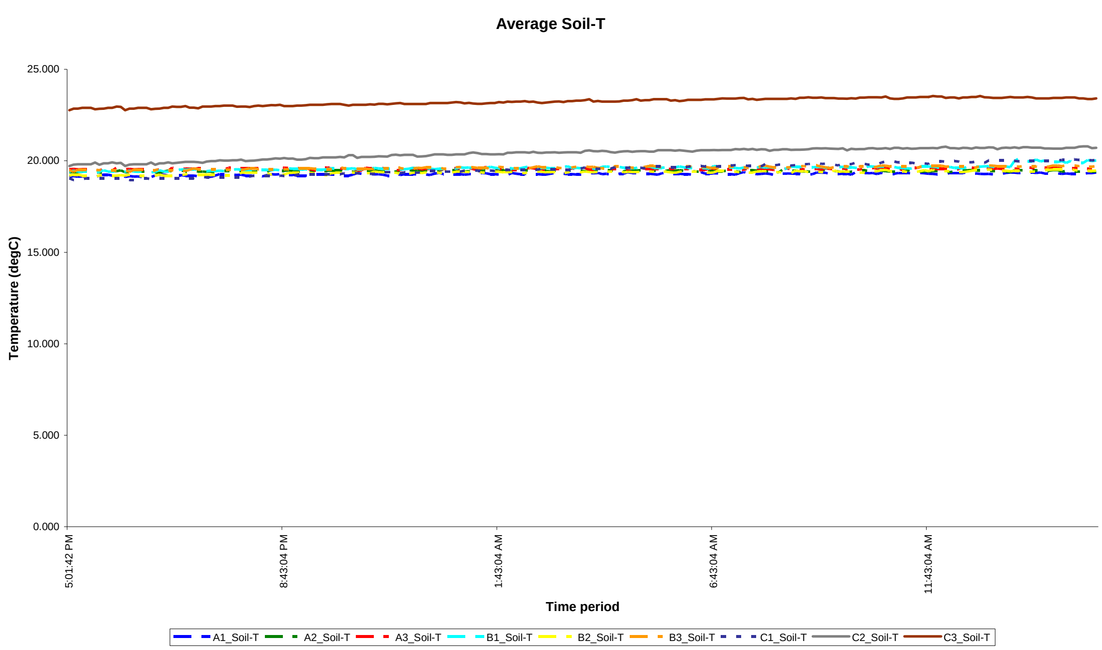


Figure B-127: Average soil temperature of C1-Alt7

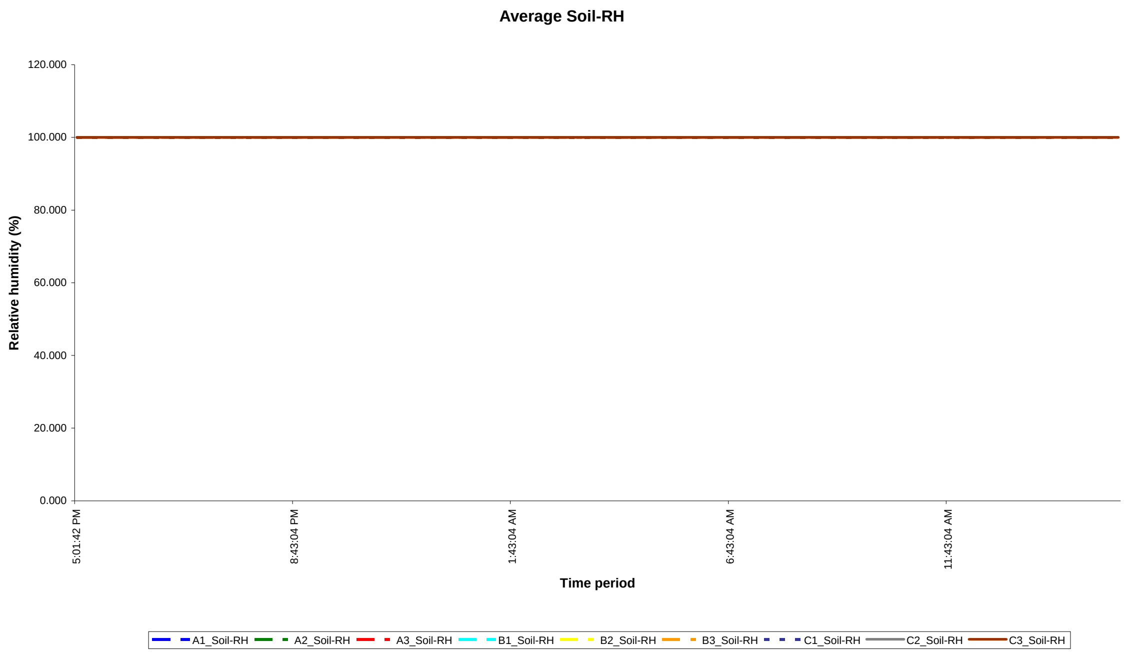


Figure B-128: Average soil relative humidity of C1-Alt7

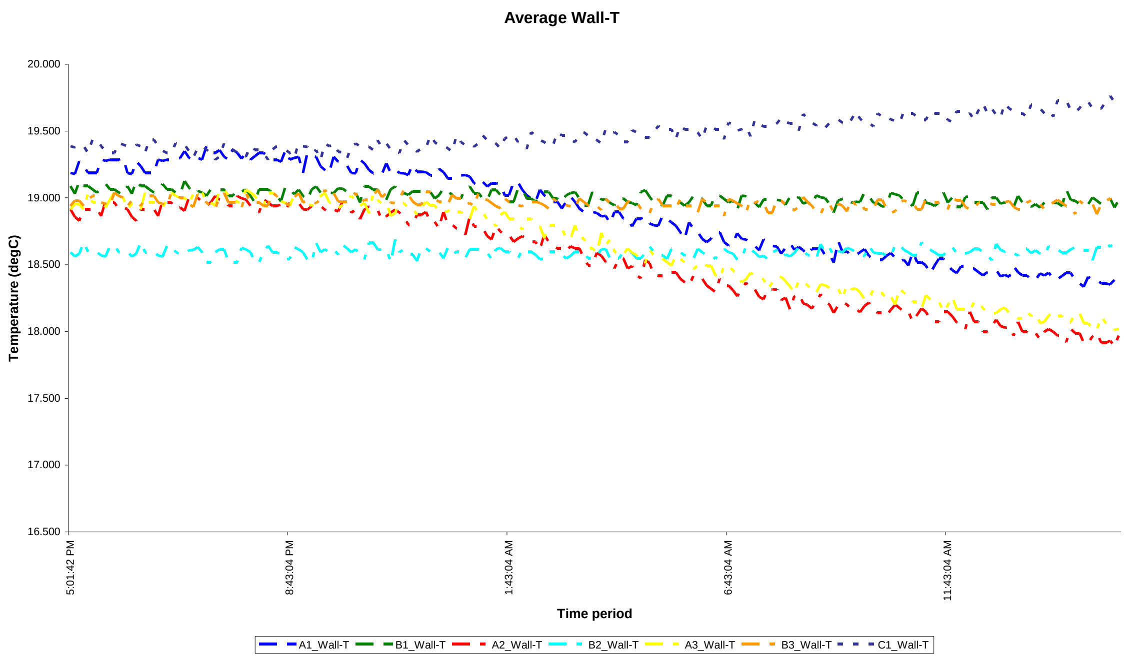


Figure B-129: Average wall temperature of C1-Alt7

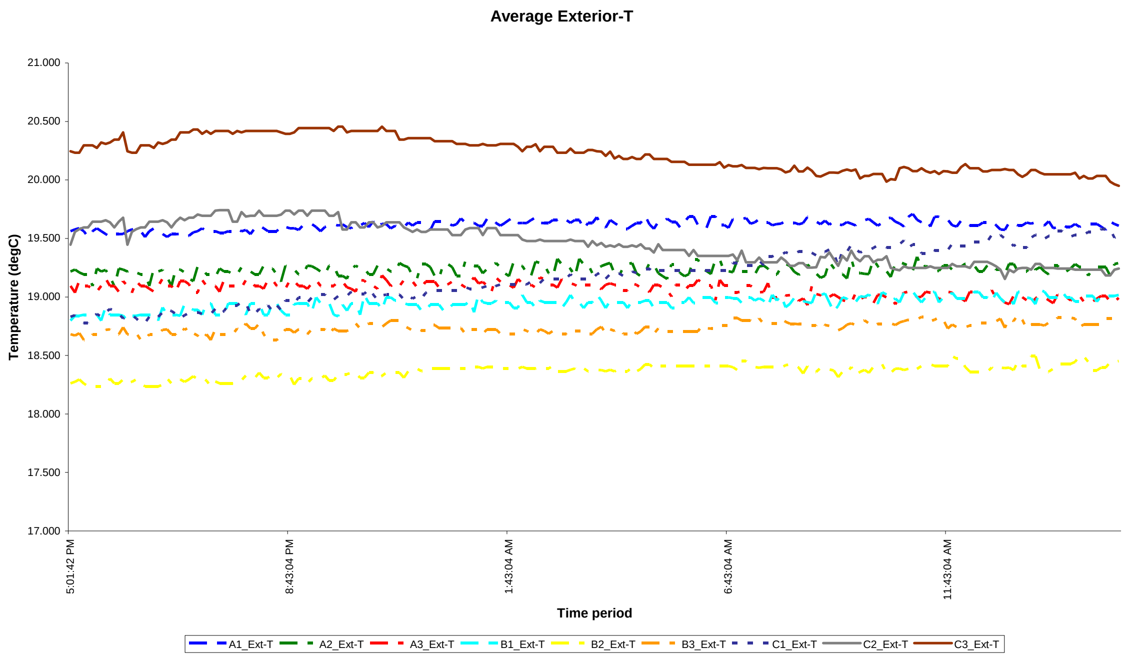


Figure B-130: Average exterior temperature of C1-Alt7

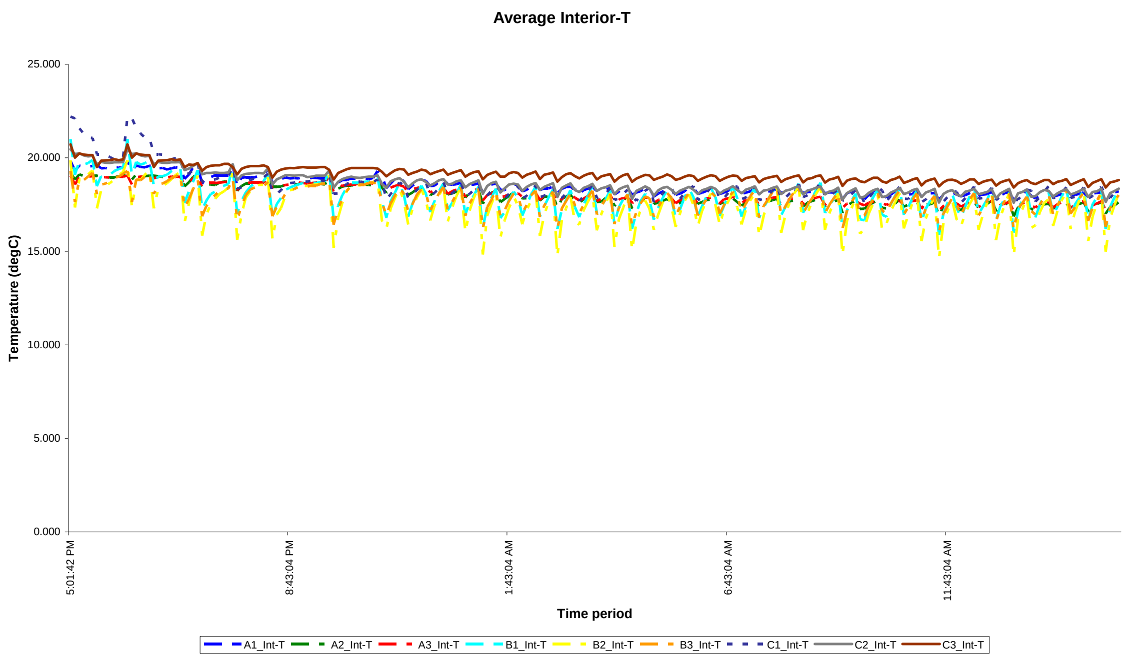


Figure B-131: Average interior temperature of C1-Alt7

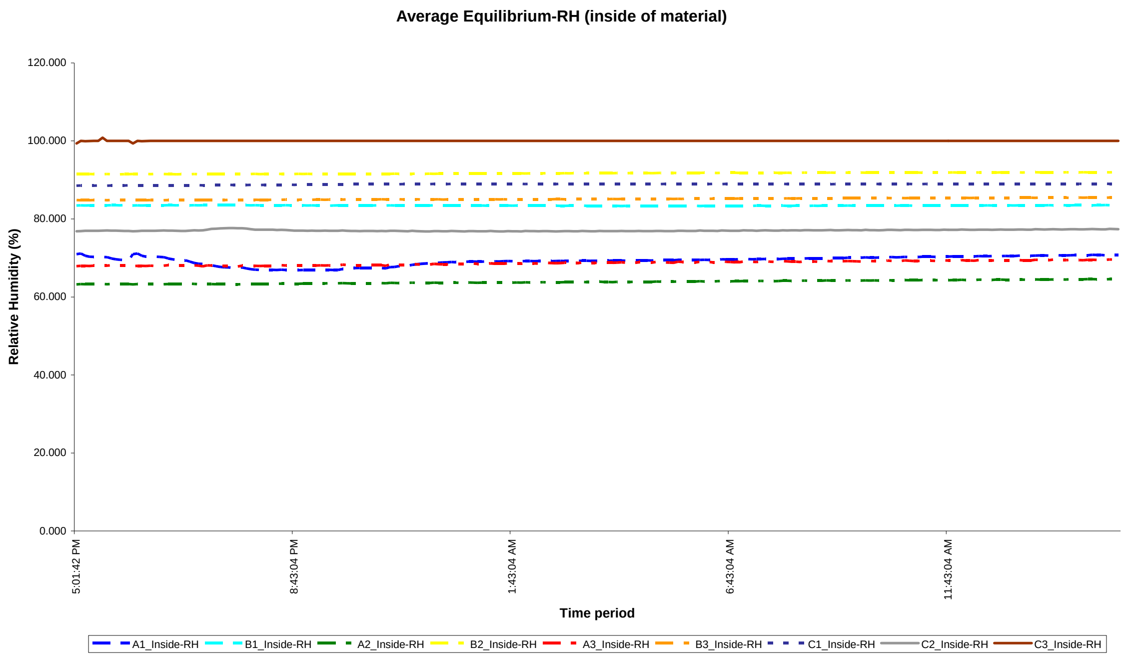


Figure B-132: Average equilibrium of relative humidity in a cavity of C1-Alt7

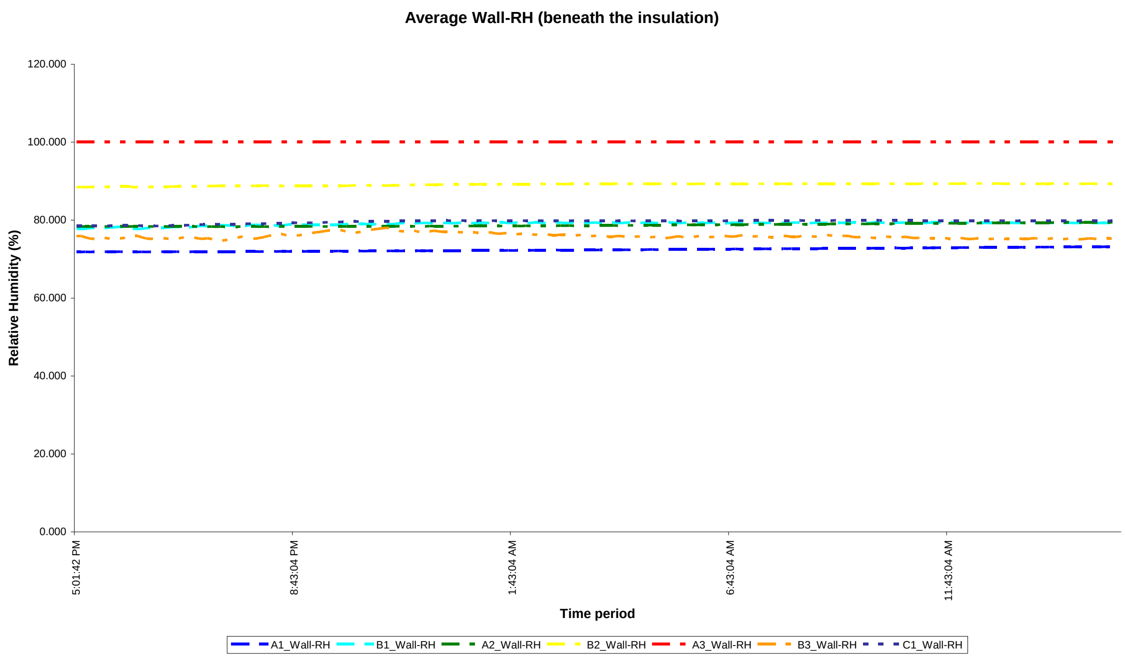


Figure B-133: Average wall relative humidity beneath the insulation of C1-Alt7

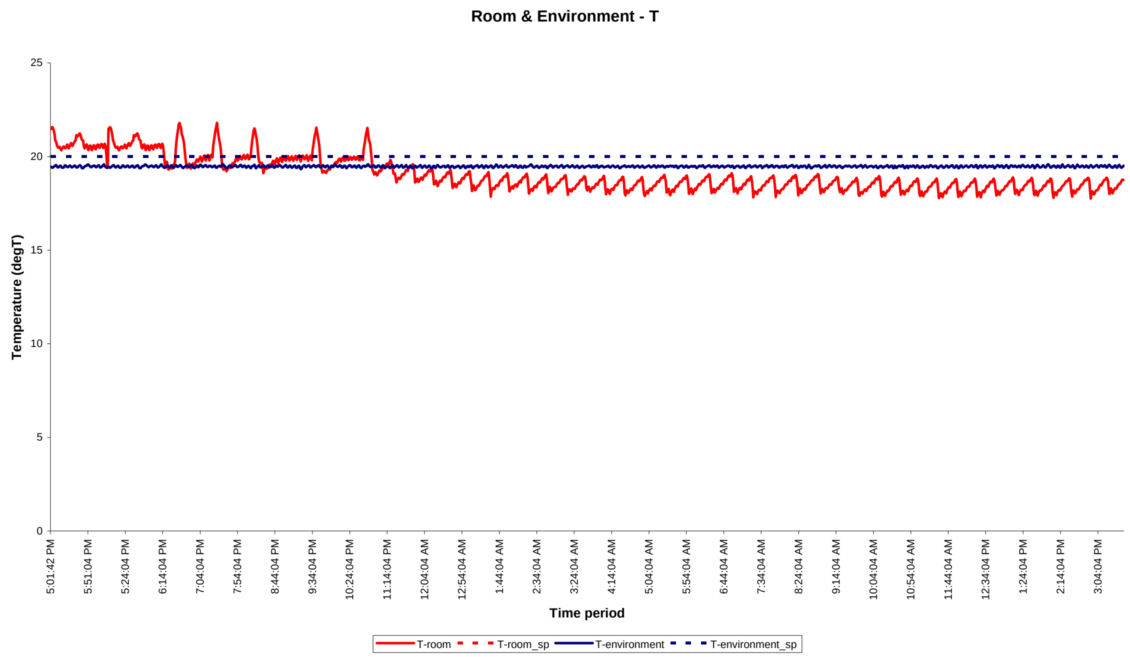


Figure B-134: Temperature of the room and environmental side during C1-Alt7

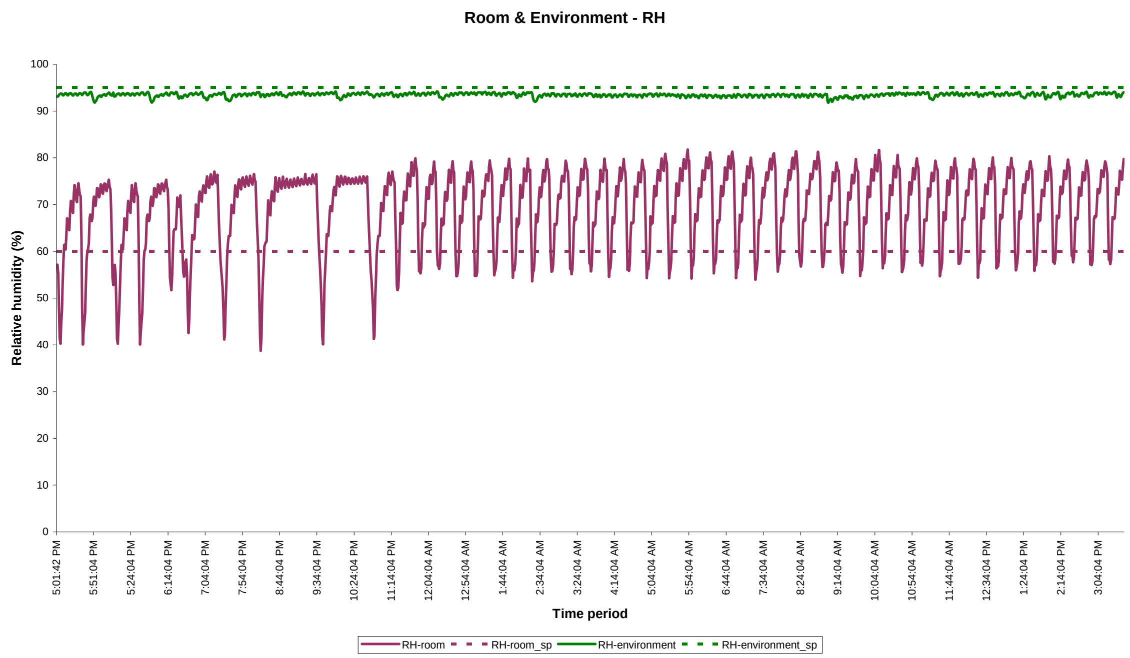


Figure B-135: Relative humidity of the room and environmental side during C1-Alt7

Test cycle: **C1 – Alt8**

Table B-16: Average data during the last 24 hours for each specimen of C1-Alt8

Specimen Measurement Data

B-G	A		B		C		Clay
1	A1_Soil-T	19.150 degC	B1_Soil-T	19.574 degC	C1_Soil-T	20.983 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	100.000 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	18.724 degC	B1_Wall-T	19.290 degC	C1_Wall-T	20.690 degC	
	A1_Ext-T	19.415 degC	B1_Ext-T	19.252 degC	C1_Ext-T	20.630 degC	
	A1_Int-T	18.604 degC	B1_Int-T	18.684 degC	C1_Int-T	18.783 degC	
	A1_Inside-RH	66.613 %	B1_Inside-RH	85.274 %	C1_Inside-RH	89.156 %	
	A1_Wall-RH	76.176 %	B1_Wall-RH	75.279 %	C1_Wall-RH	68.122 %	
2	A2_Soil-T	19.251 degC	B2_Soil-T	19.544 degC	C2_Soil-T	21.079 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	18.460 degC	B2_Wall-T	19.206 degC	C2_Ext-T	19.784 degC	
	A2_Ext-T	19.143 degC	B2_Ext-T	18.963 degC	C2_Int-T	18.930 degC	
	A2_Int-T	18.269 degC	B2_Int-T	18.754 degC	C2_Inside-RH	76.246 degC	
	A2_Inside-RH	62.424 %	B2_Inside-RH	91.825 %			
	A2_Wall-RH	80.730 %	B2_Wall-RH	86.865 %			
3	A3_Soil-T	19.408 degC	B3_Soil-T	19.723 degC	C3_Soil-T	23.711 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	18.575 degC	B3_Wall-T	19.074 degC	C3_Ext-T	20.445 degC	
	A3_Ext-T	18.972 degC	B3_Ext-T	18.867 degC	C3_Int-T	19.192 degC	
	A3_Int-T	18.297 degC	B3_Int-T	18.475 degC	C3_Inside-RH	100.000 degC	
	A3_Inside-RH	67.374 %	B3_Inside-RH	82.745 %			
	A3_Wall-RH	100.000 %	B3_Wall-RH	44.971 %	**Pressure diff.*	*15.696 Pa*	
No	A		B		C		Alt8

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	19.432 degC
RH-room	32.782 %
T-room_sp	20.000 degC
RH-room_sp	30.000 %
T-environment	19.464 degC
RH-environment	91.533 %
T-environment_sp	20.000 degC
RH-environment_sp	95.000 %

Remarks

Type:	B-G
Soil type:	Clay
Dampproofing:	No
Alternative:	Alt8

Legend

T - Temperature (degC)

RH - Relative Humidity (%)

SP - Setpoint (either T or RH)

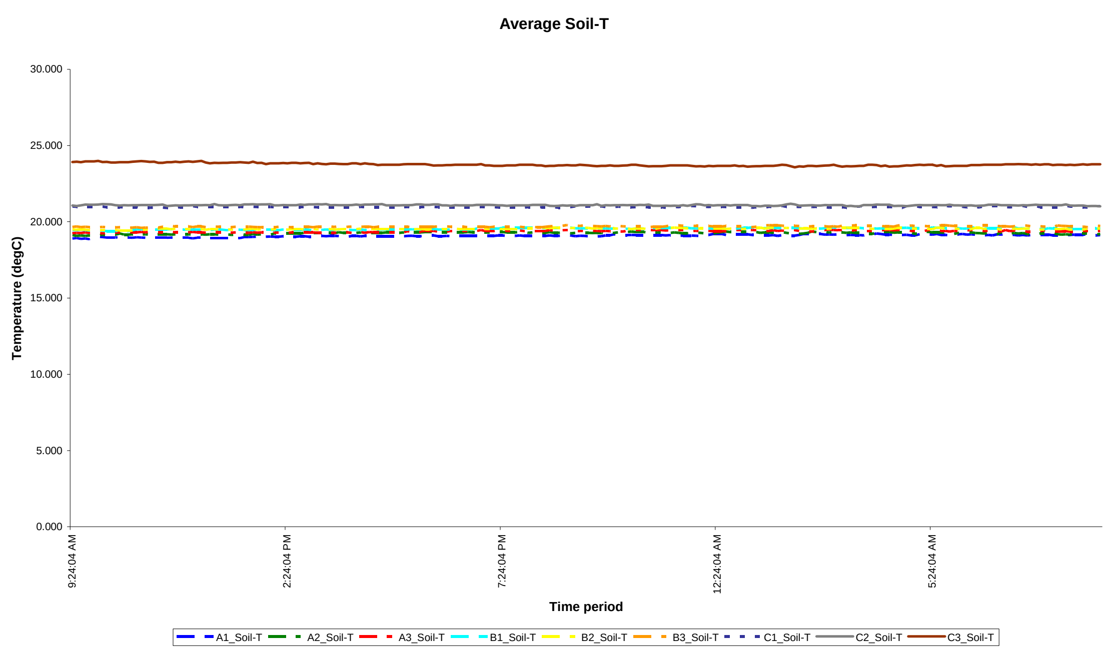


Figure B-136: Average soil temperature of C1-Alt8

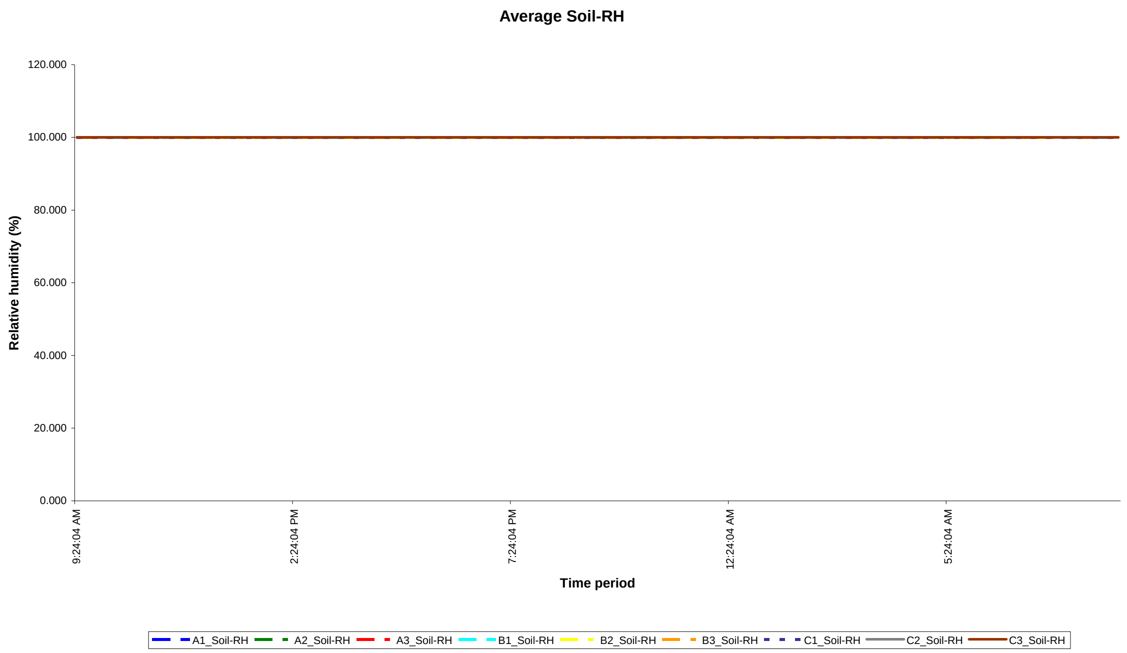


Figure B-137: Average soil relative humidity of C1-Alt8

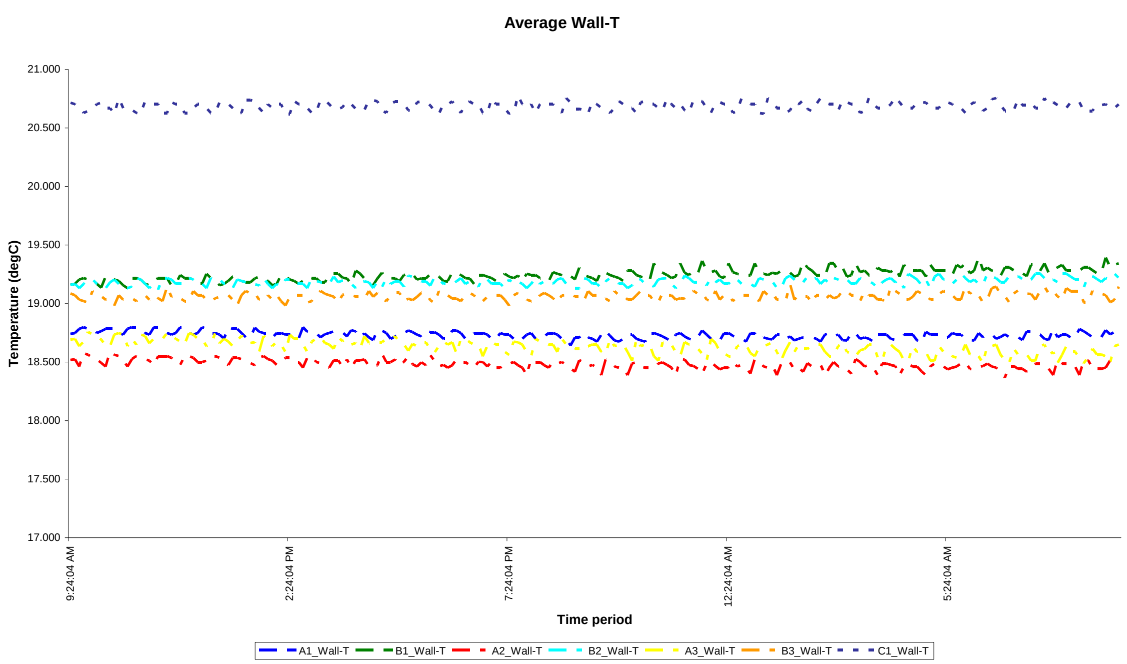


Figure B-138: Average wall temperature of C1-Alt8

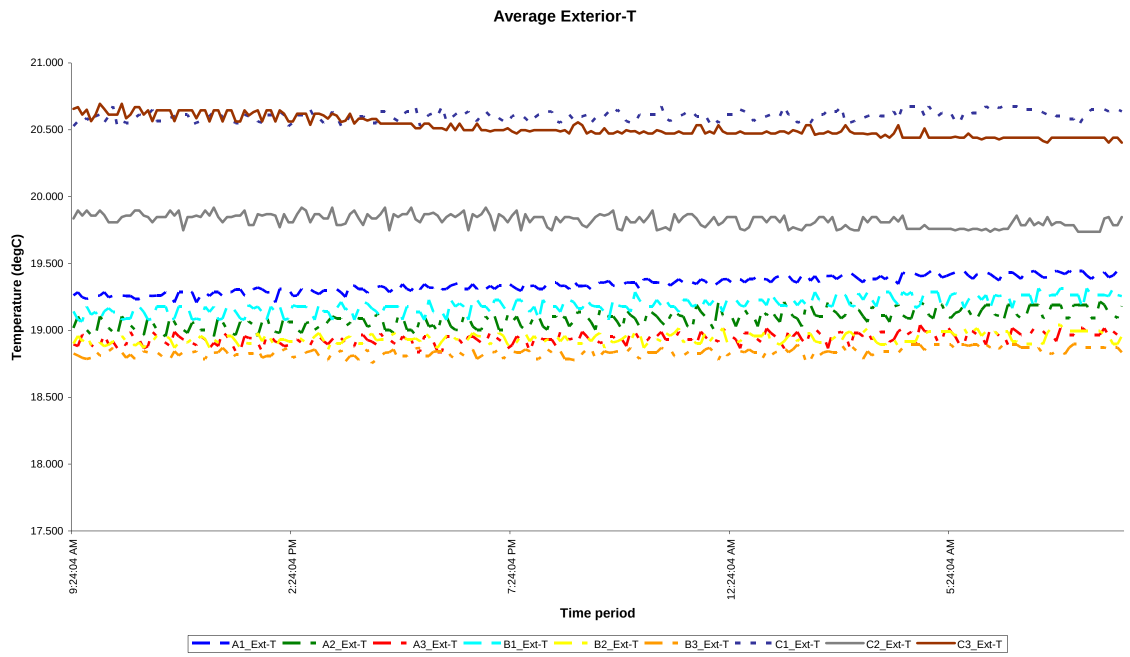


Figure B-139: Average exterior temperature of C1-Alt8

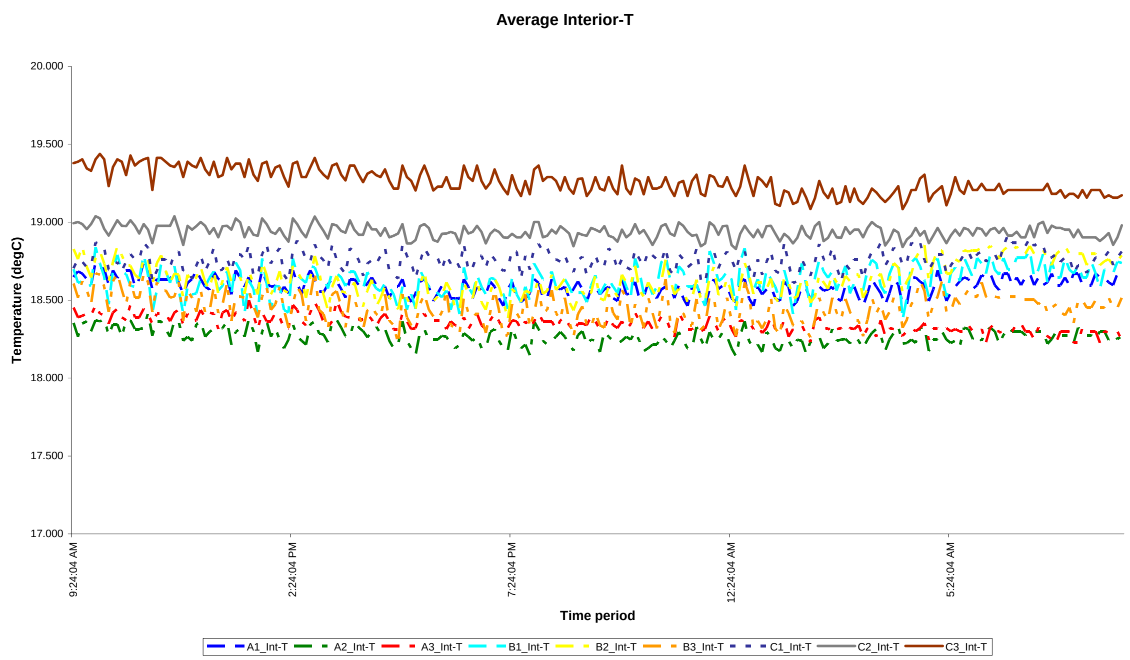


Figure B-140: Average interior temperature of C1-Alt8

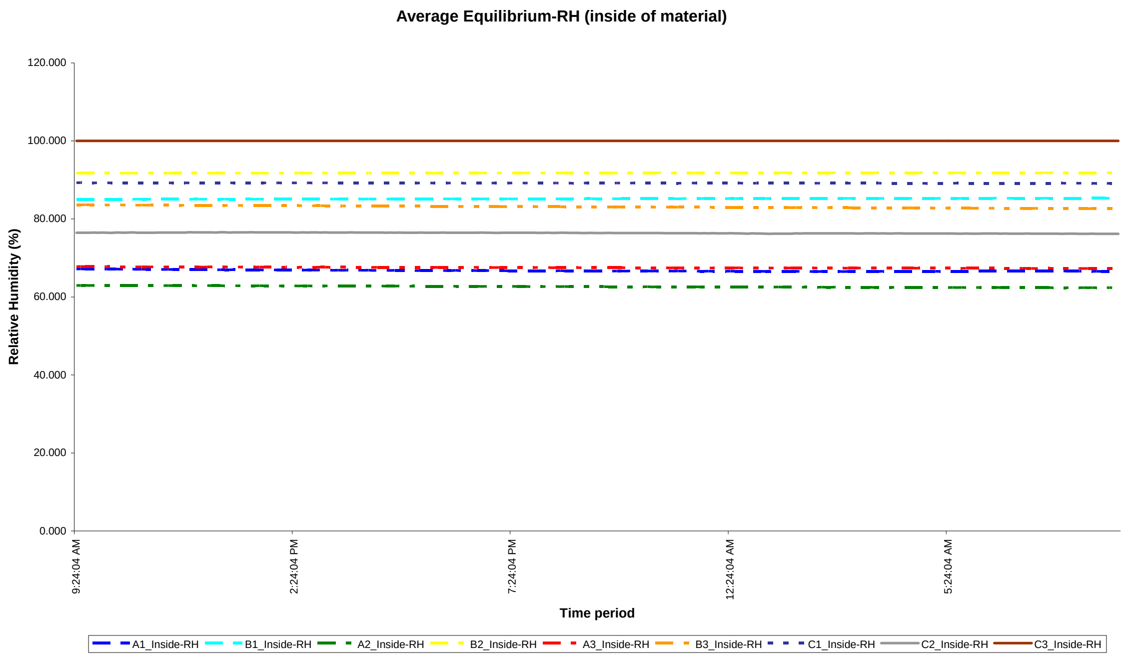


Figure B-141: Average equilibrium of relative humidity in a cavity of C1-Alt8

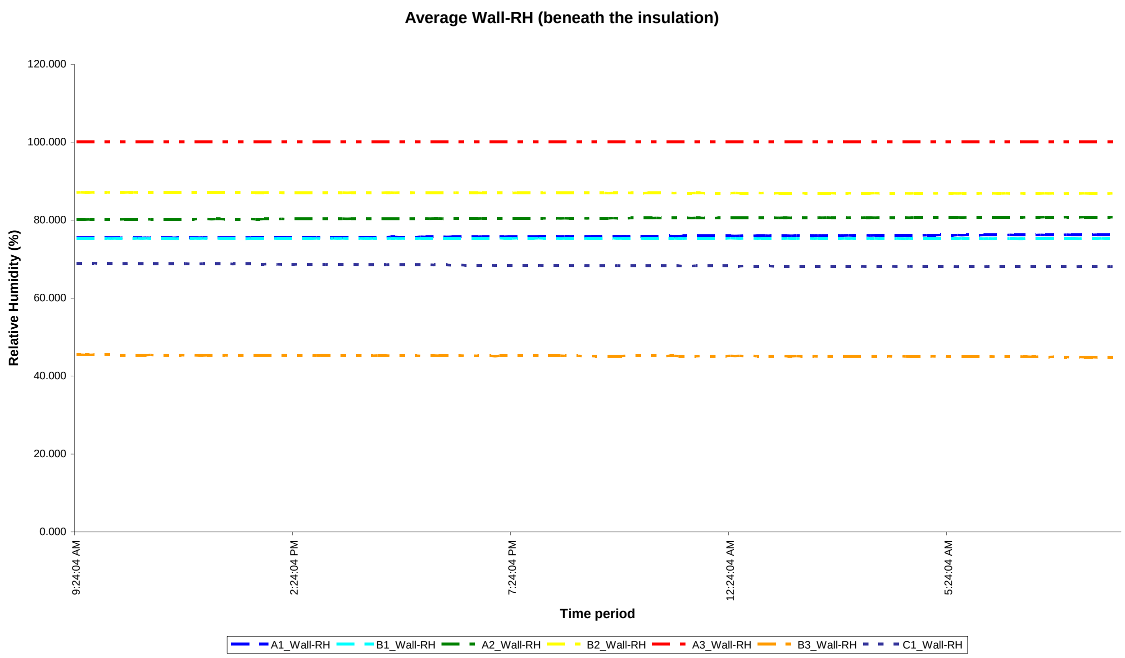


Figure B-142: Average wall relative humidity beneath the insulation of C1-Alt8

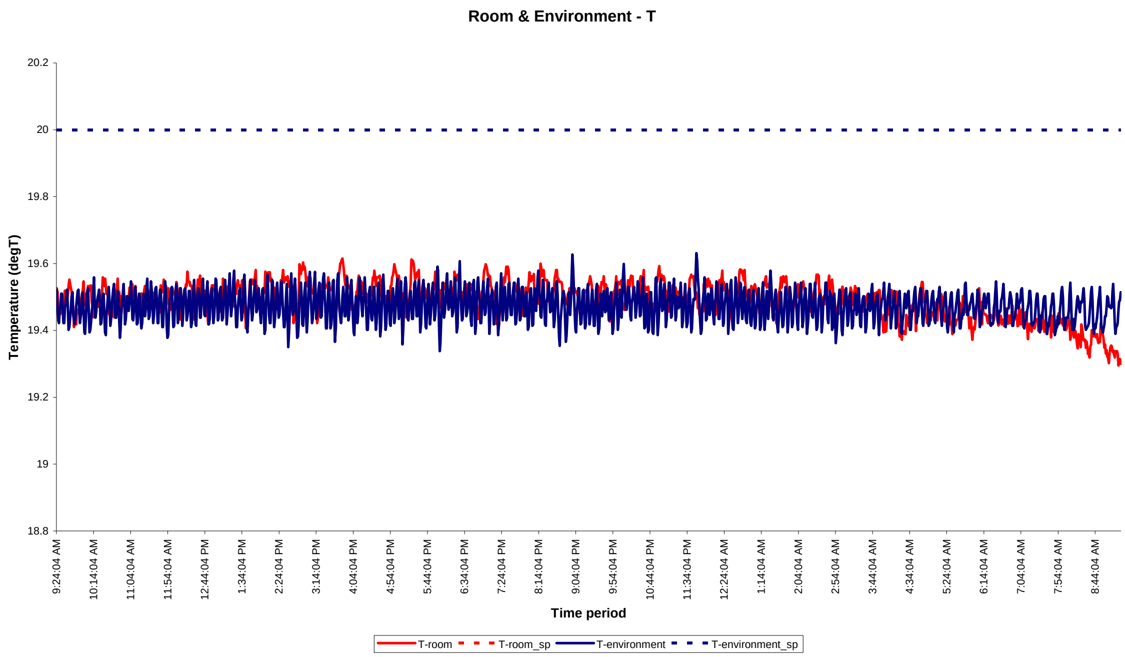


Figure B-143: Temperature of the room and environmental side during C1-Alt8

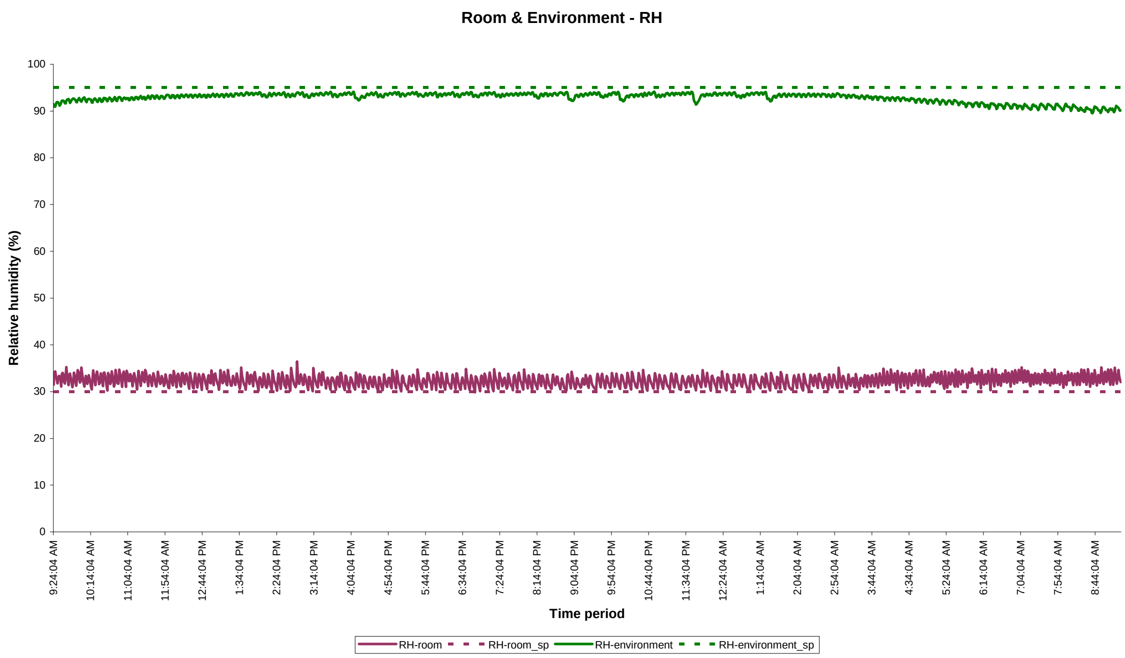


Figure B-144: Relative humidity of the room and environmental side during C1-Alt8

Measurement series: **S2** (Sand; with dampproofing)

Test cycle: **S2 – Alt1**

Table B-17: Average data during the last 24 hours for each specimen of S2-Alt1

Specimen Measurement Data

B-G	A		B		C		Sand
1	A1_Soil-T	4.624 degC	B1_Soil-T	3.692 degC	C1_Soil-T	4.107 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	100.000 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	14.698 degC	B1_Wall-T	5.918 degC	C1_Wall-T	6.578 degC	
	A1_Ext-T	5.780 degC	B1_Ext-T	4.838 degC	C1_Ext-T	4.597 degC	
	A1_Int-T	17.245 degC	B1_Int-T	16.395 degC	C1_Int-T	17.452 degC	
	A1_Inside-RH	49.556 %	B1_Inside-RH	79.851 %	C1_Inside-RH	81.054 %	
	A1_Wall-RH	48.712 %	B1_Wall-RH	72.559 %	C1_Wall-RH	71.804 %	
2	A2_Soil-T	5.224 degC	B2_Soil-T	5.138 degC	C2_Soil-T	5.752 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	16.008 degC	B2_Wall-T	7.507 degC	C2_Ext-T	10.184 degC	
	A2_Ext-T	6.793 degC	B2_Ext-T	6.200 degC	C2_Int-T	14.817 degC	
	A2_Int-T	17.021 degC	B2_Int-T	17.064 degC	C2_Inside-RH	66.834 %	
	A2_Inside-RH	51.112 %	B2_Inside-RH	90.170 %			
	A2_Wall-RH	58.570 %	B2_Wall-RH	85.226 %			
3	A3_Soil-T	5.430 degC	B3_Soil-T	5.274 degC	C3_Soil-T	6.312 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	15.814 degC	B3_Wall-T	8.145 degC	C3_Ext-T	11.391 degC	
	A3_Ext-T	6.656 degC	B3_Ext-T	6.514 degC	C3_Int-T	13.764 degC	
	A3_Int-T	16.919 degC	B3_Int-T	17.020 degC	C3_Inside-RH	98.173 %	
	A3_Inside-RH	53.073 %	B3_Inside-RH	81.294 %			
	A3_Wall-RH	66.430 %	B3_Wall-RH	68.379 %	**Pressure diff.*	*3.973 Pa*	
Yes	A		B		C		Alt1

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	19.569 degC
RH-room	28.890 %
T-room_sp	20.000 degC
RH-room_sp	30.000 %
T-environment	3.786 degC
RH-environment	79.528 %
T-environment_sp	3.000 degC
RH-environment_sp	90.000 %

Remarks

Type: B-G
Soil type: Sand
Dampproofing: Yes
Alternative: Alt1

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

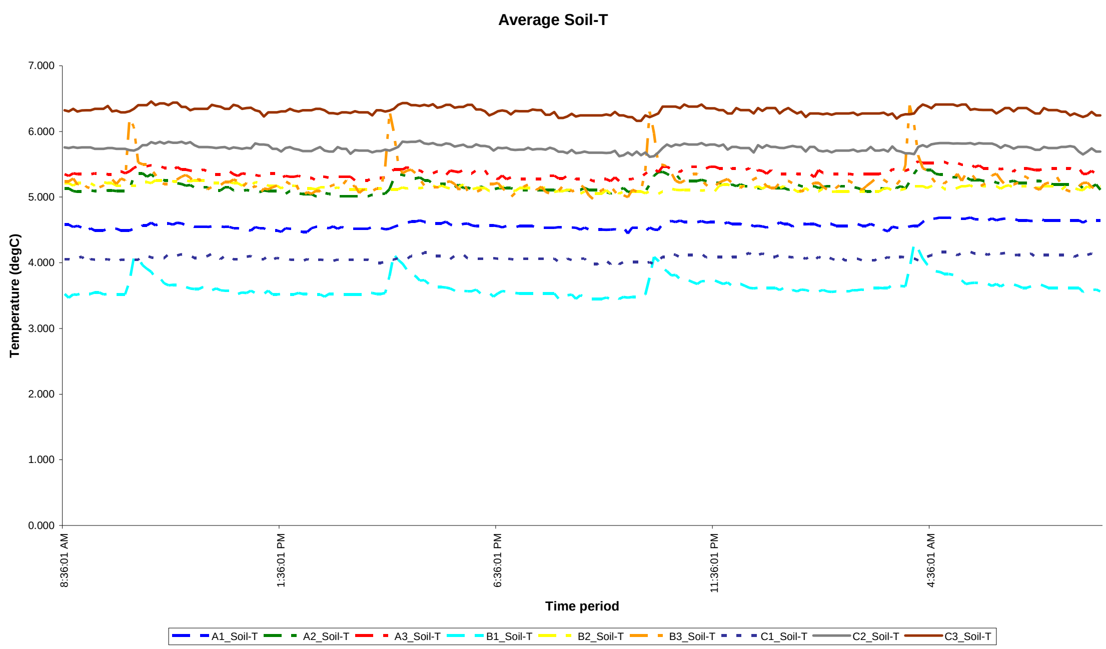


Figure B-145: Average soil temperature of S2-Alt1

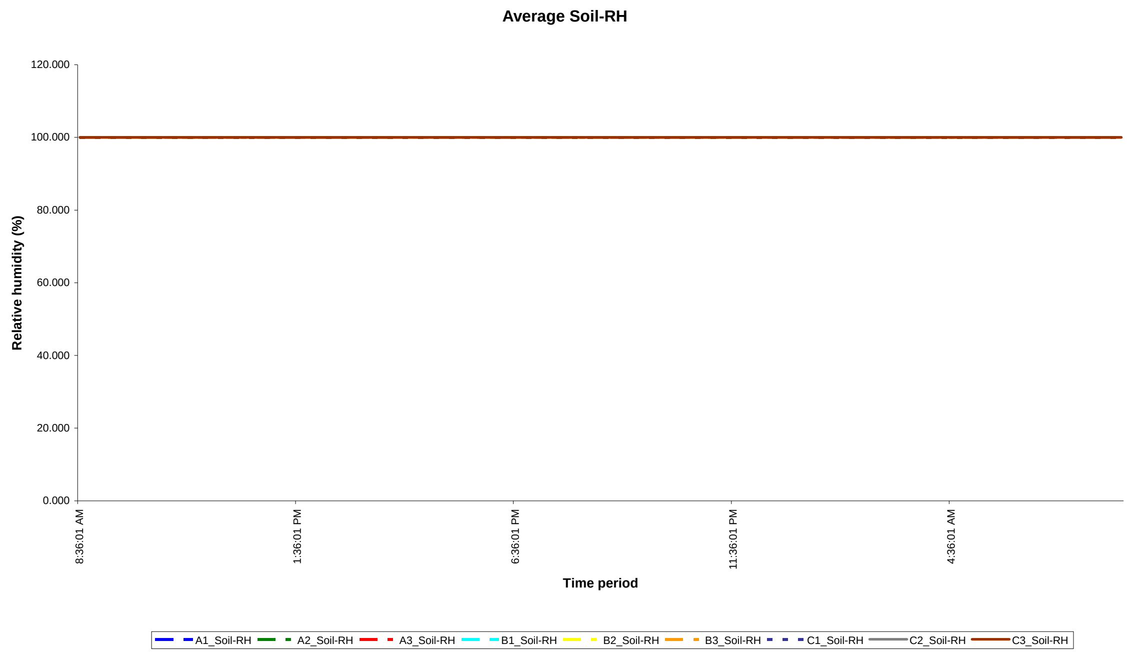


Figure B-146: Average soil relative humidity of S2-Alt1

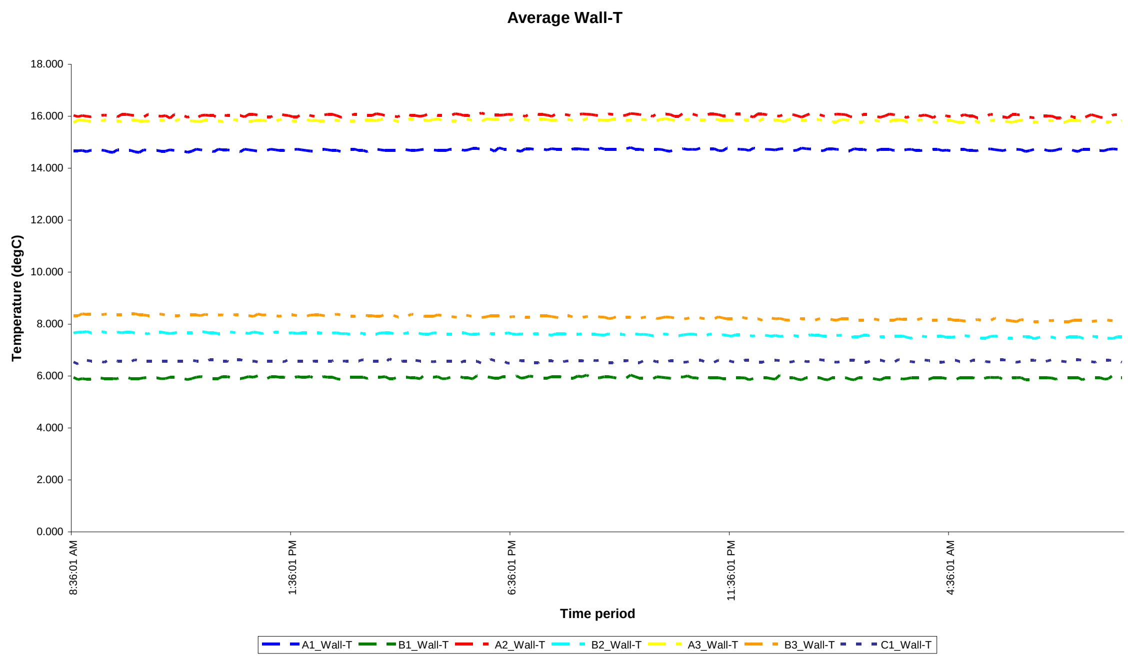


Figure B-147: Average wall temperature of S2-Alt1

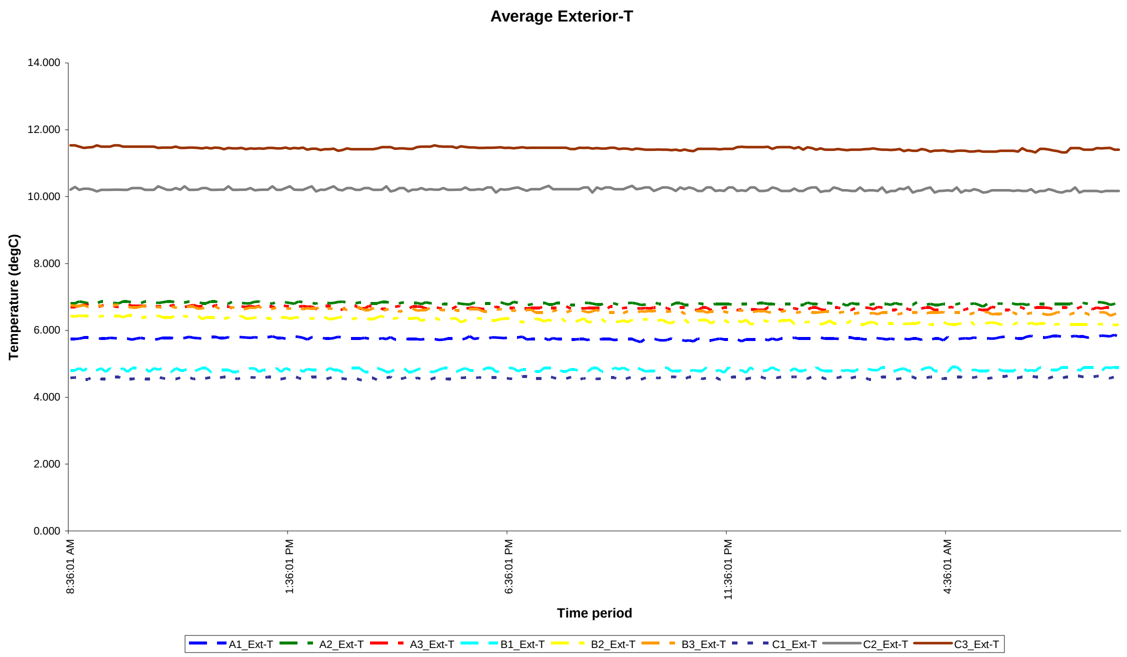


Figure B-148: Average exterior temperature of S2-Alt1

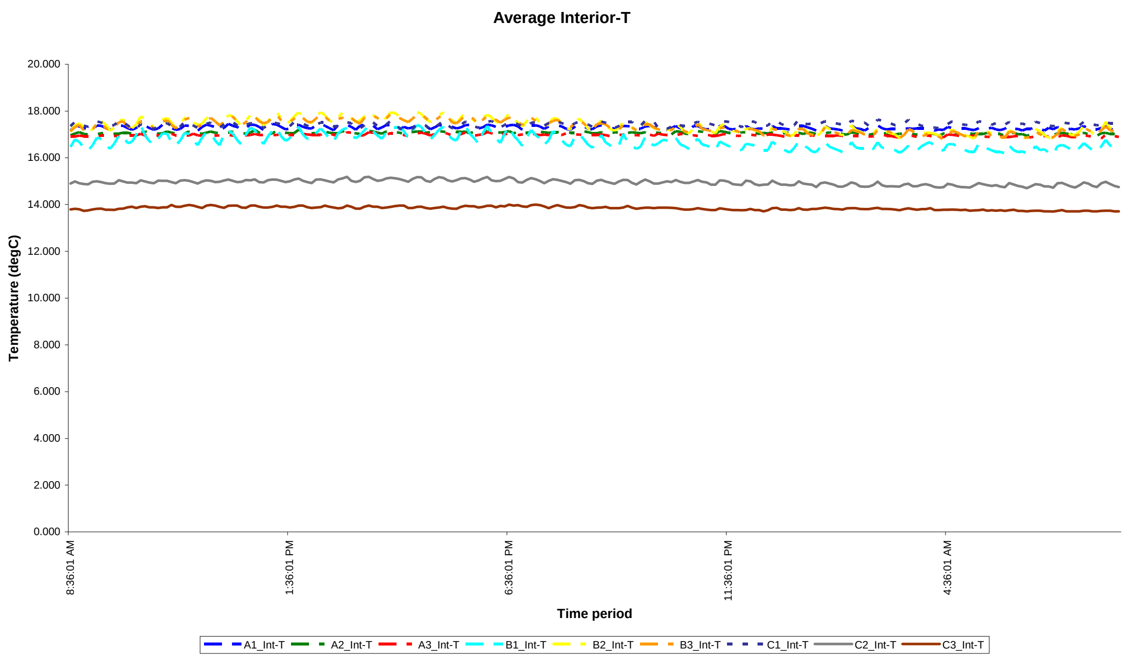


Figure B-149: Average interior temperature of S2-Alt1

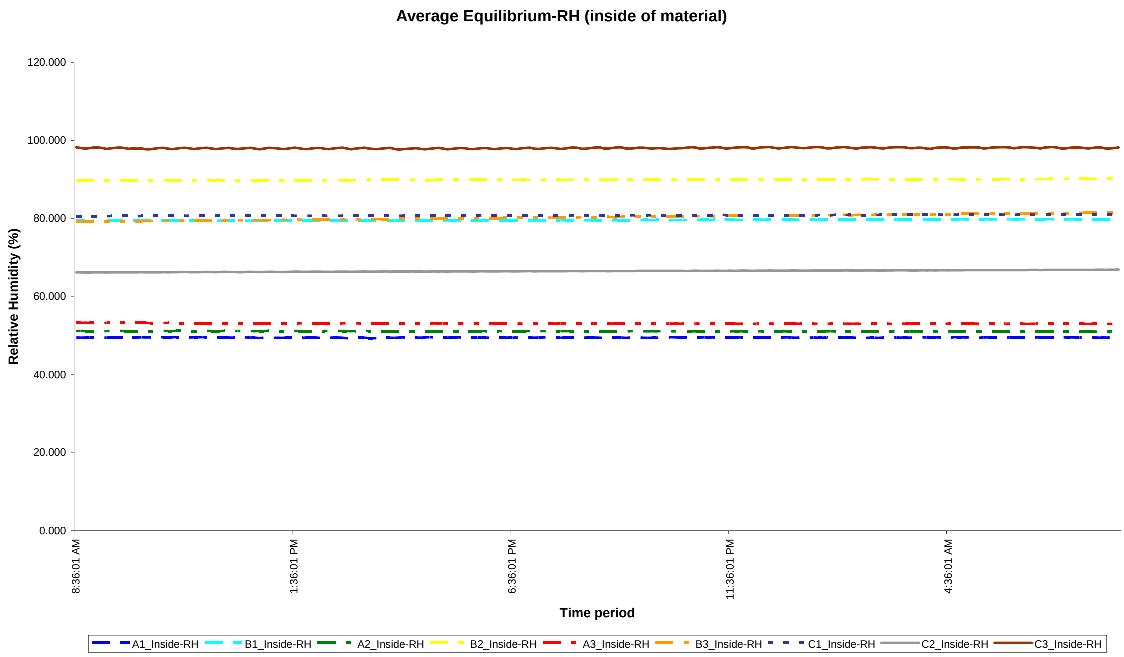


Figure B-150: Average equilibrium of relative humidity in a cavity of S2-Alt1

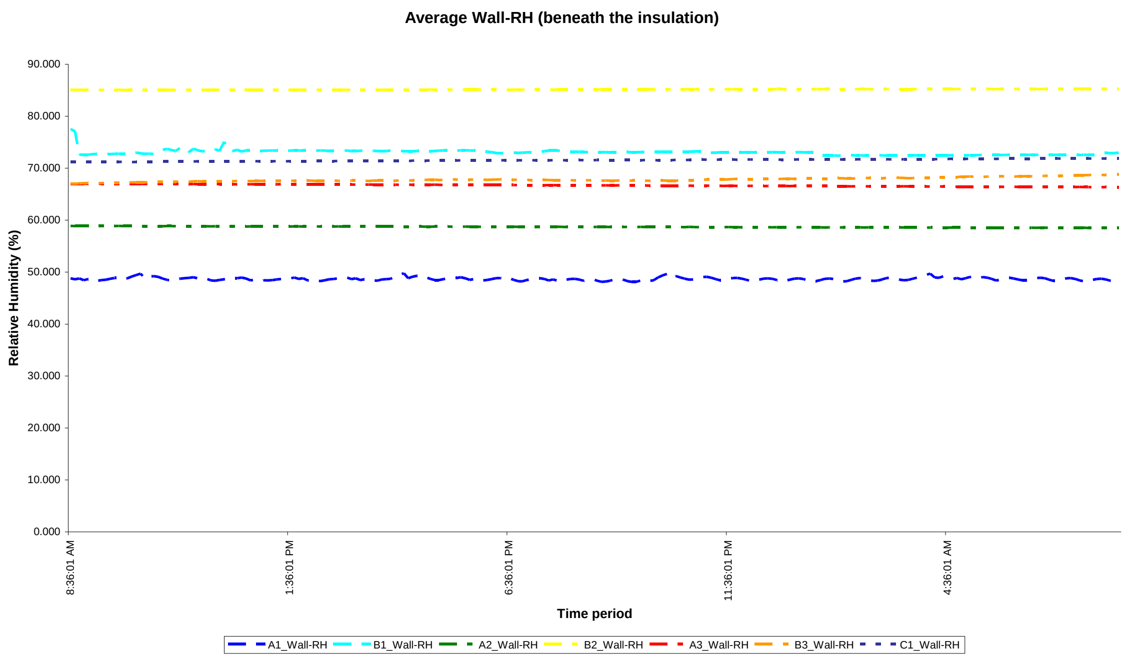


Figure B-151: Average wall relative humidity beneath the insulation of S2-Alt1

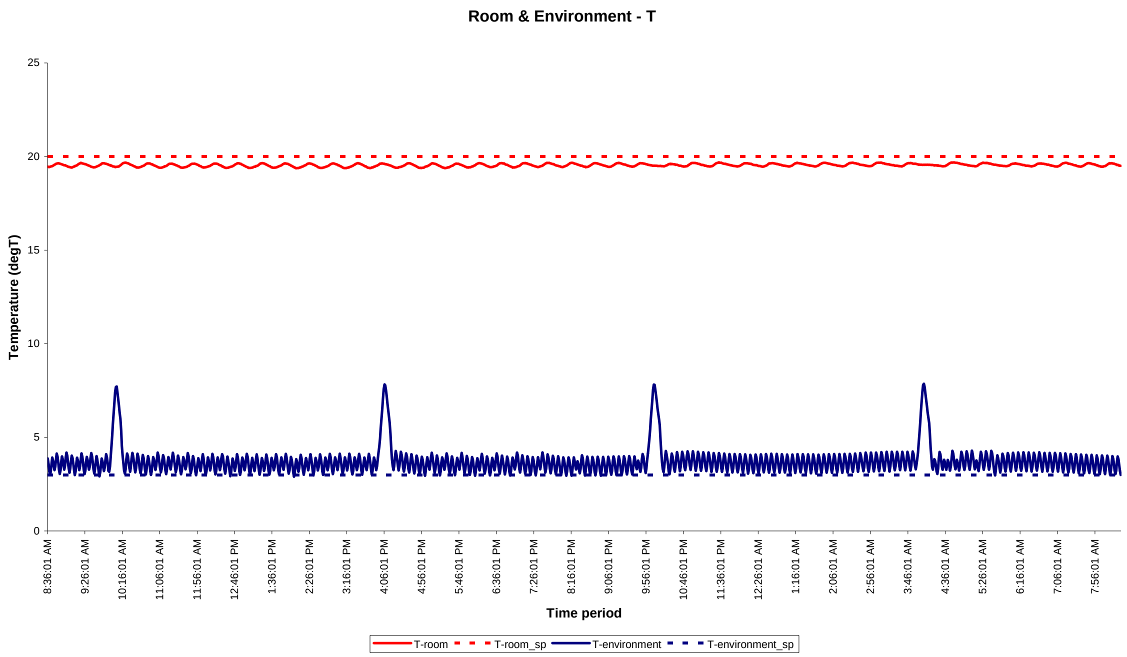


Figure B-152: Temperature of the room and environmental side during S2-Alt1

Figure B-153: Relative humidity of the room and environmental side during S2-Alt1

Test cycle: **S2 – Alt2**

Table B-18: Average data during the last 24 hours for each specimen of S2-Alt2

Specimen Measurement Data

B-G	A		B		C		Sand
1	A1_Soil-T	4.765 degC	B1_Soil-T	3.832 degC	C1_Soil-T	4.267 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	100.000 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	14.741 degC	B1_Wall-T	6.202 degC	C1_Wall-T	6.819 degC	
	A1_Ext-T	5.950 degC	B1_Ext-T	5.010 degC	C1_Ext-T	4.799 degC	
	A1_Int-T	17.220 degC	B1_Int-T	17.327 degC	C1_Int-T	17.703 degC	
	A1_Inside-RH	66.580 %	B1_Inside-RH	83.023 %	C1_Inside-RH	86.288 %	
	A1_Wall-RH	50.208 %	B1_Wall-RH	79.084 %	C1_Wall-RH	90.991 %	
2	A2_Soil-T	5.280 degC	B2_Soil-T	5.092 degC	C2_Soil-T	5.731 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	16.202 degC	B2_Wall-T	7.484 degC	C2_Ext-T	10.110 degC	
	A2_Ext-T	6.883 degC	B2_Ext-T	6.118 degC	C2_Int-T	15.235 degC	
	A2_Int-T	17.225 degC	B2_Int-T	17.804 degC	C2_Inside-RH	77.877 %	
	A2_Inside-RH	61.167 %	B2_Inside-RH	92.068 %			
	A2_Wall-RH	61.282 %	B2_Wall-RH	91.457 %			
3	A3_Soil-T	5.498 degC	B3_Soil-T	5.088 degC	C3_Soil-T	6.094 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	16.148 degC	B3_Wall-T	8.106 degC	C3_Ext-T	11.273 degC	
	A3_Ext-T	6.721 degC	B3_Ext-T	6.279 degC	C3_Int-T	13.990 degC	
	A3_Int-T	17.301 degC	B3_Int-T	17.755 degC	C3_Inside-RH	98.150 %	
	A3_Inside-RH	63.457 %	B3_Inside-RH	93.317 %			
	A3_Wall-RH	74.187 %	B3_Wall-RH	100.000 %	**Pressure diff.*	*54.303 Pa*	
Yes	A		B		C		Alt2

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	19.510 degC
RH-room	59.191 %
T-room_sp	20.000 degC
RH-room_sp	60.000 %
T-environment	3.798 degC
RH-environment	80.614 %
T-environment_sp	3.000 degC
RH-environment_sp	90.000 %

Remarks

Type: B-G
Soil type: Sand
Damproofing: Yes
Alternative: Alt2

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

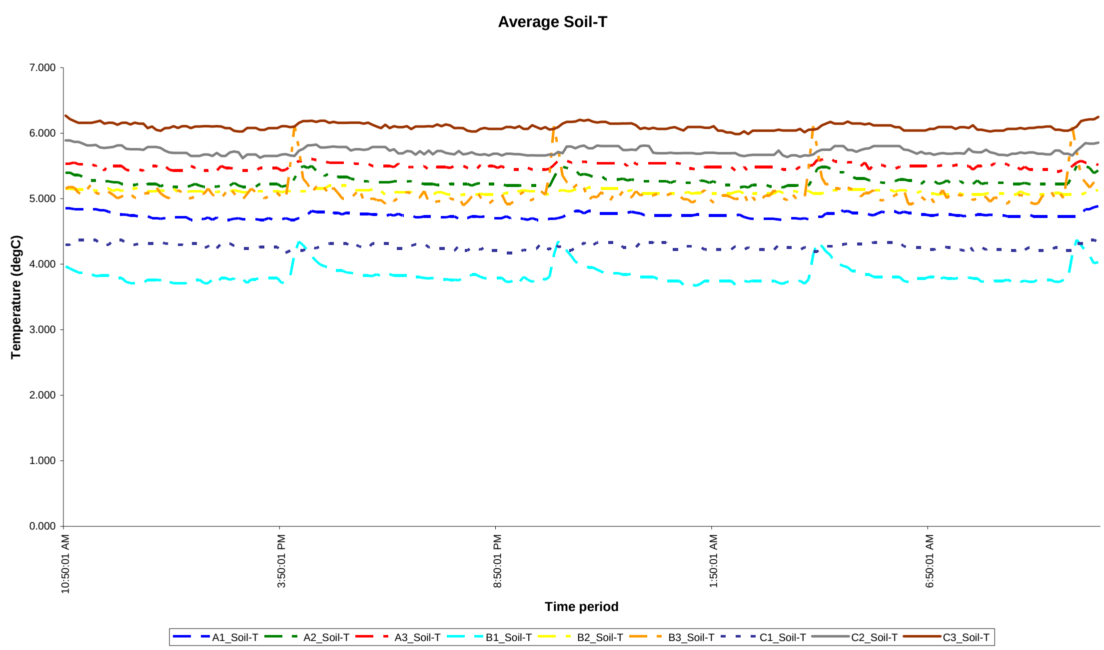


Figure B-154: Average soil temperature of S2-Alt2

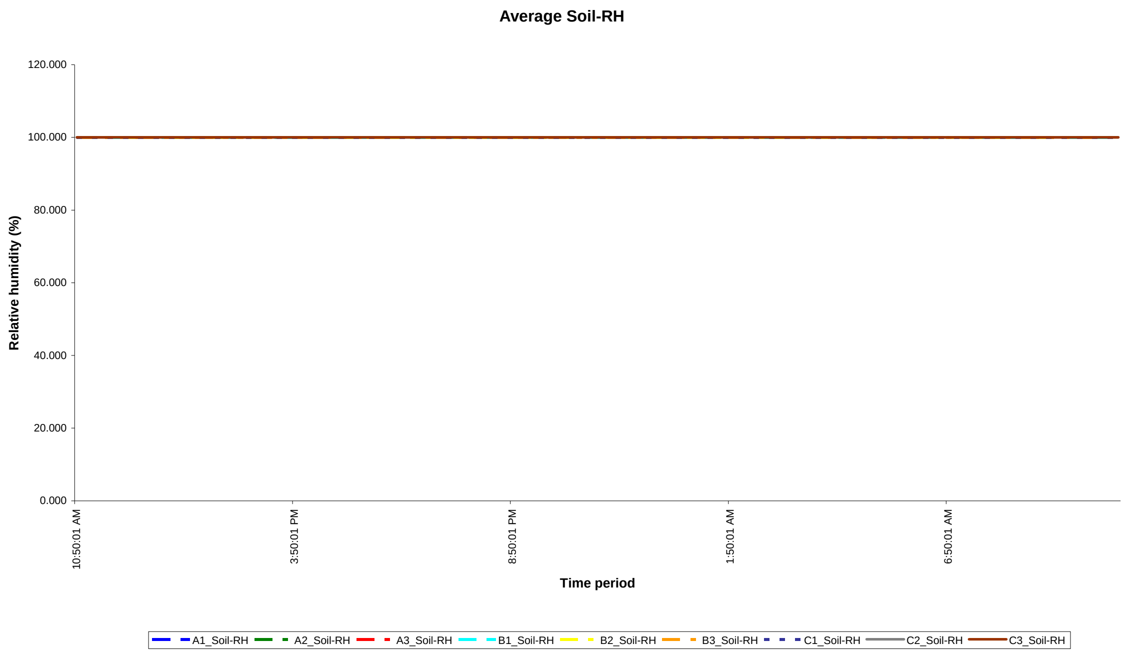


Figure B-155: Average soil relative humidity of S2-Alt2

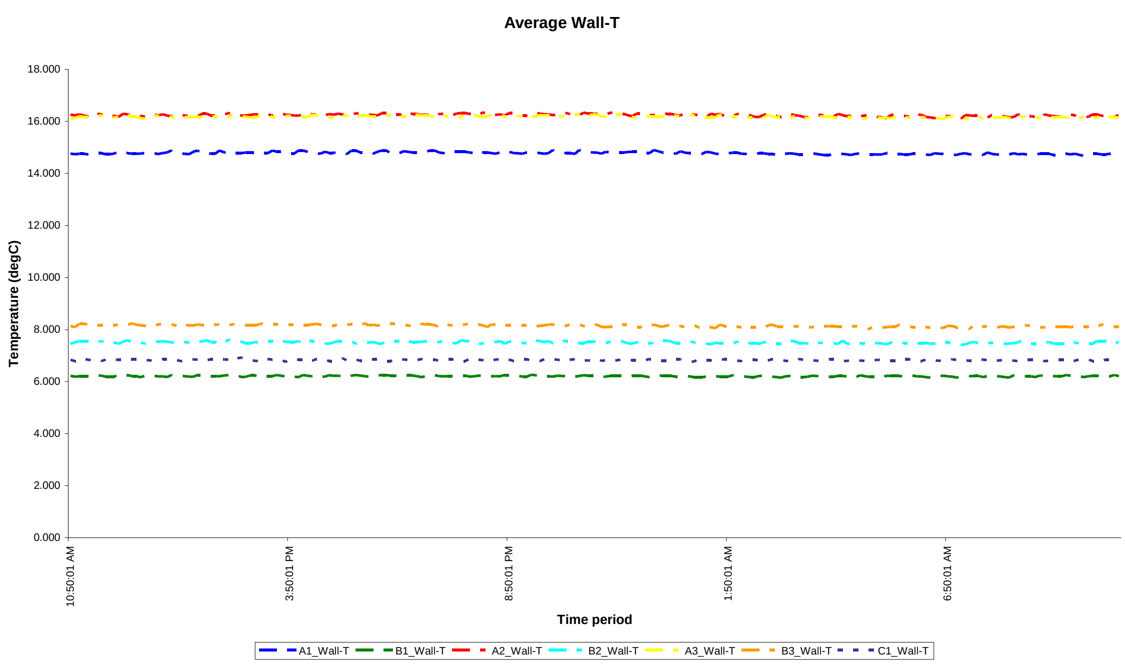


Figure B-156: Average wall temperature of S2-Alt2

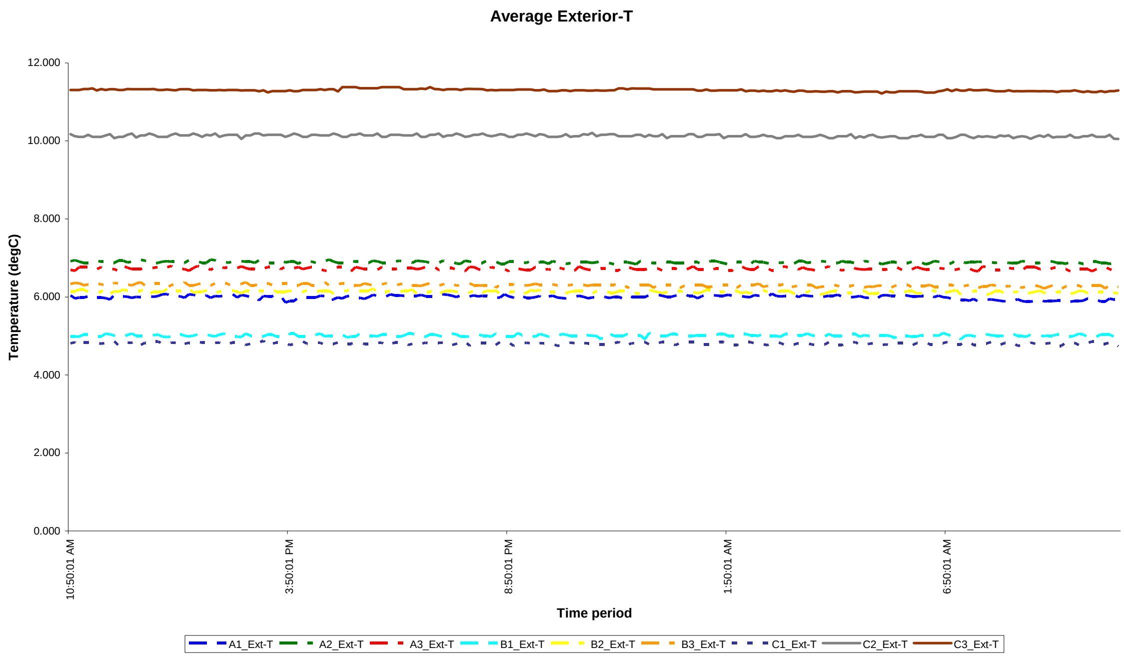


Figure B-157: Average exterior temperature of S2-Alt2

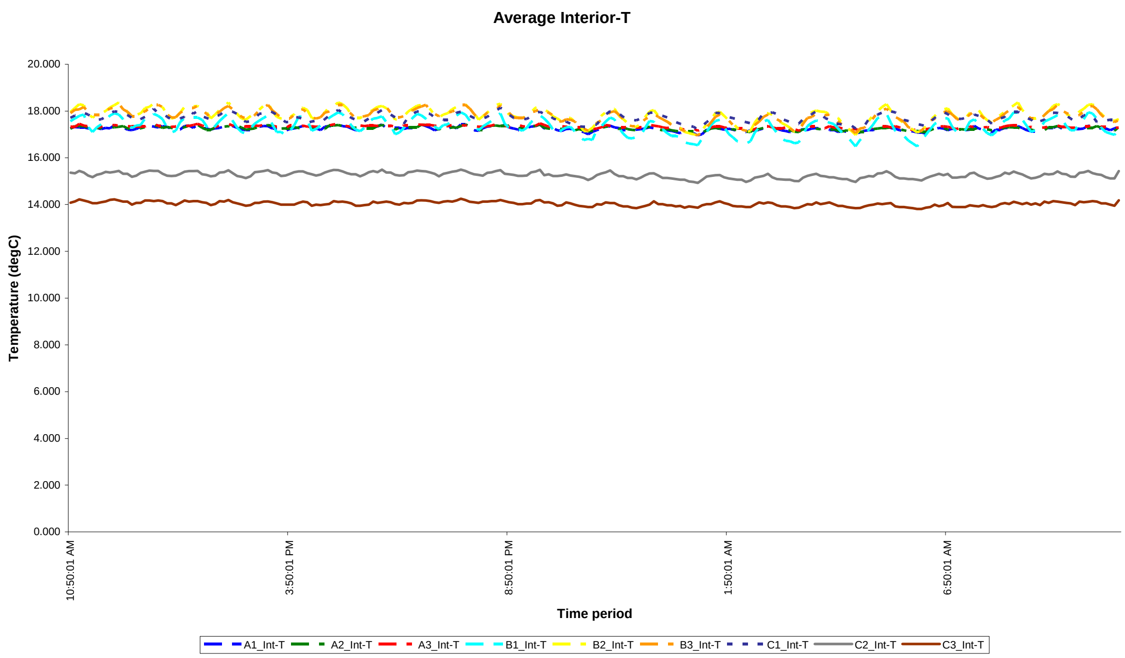


Figure B-158: Average interior temperature of S2-Alt2

Figure B-159: Average equilibrium of relative humidity in a cavity of S2-Alt2

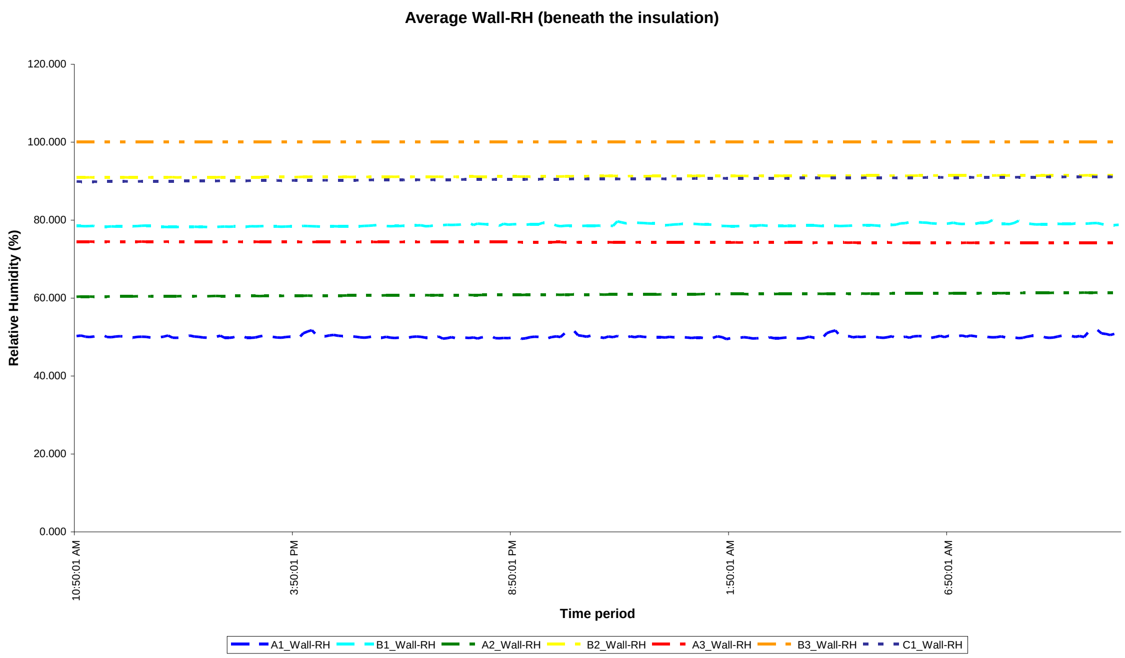


Figure B-160: Average wall relative humidity beneath the insulation of S2-Alt2

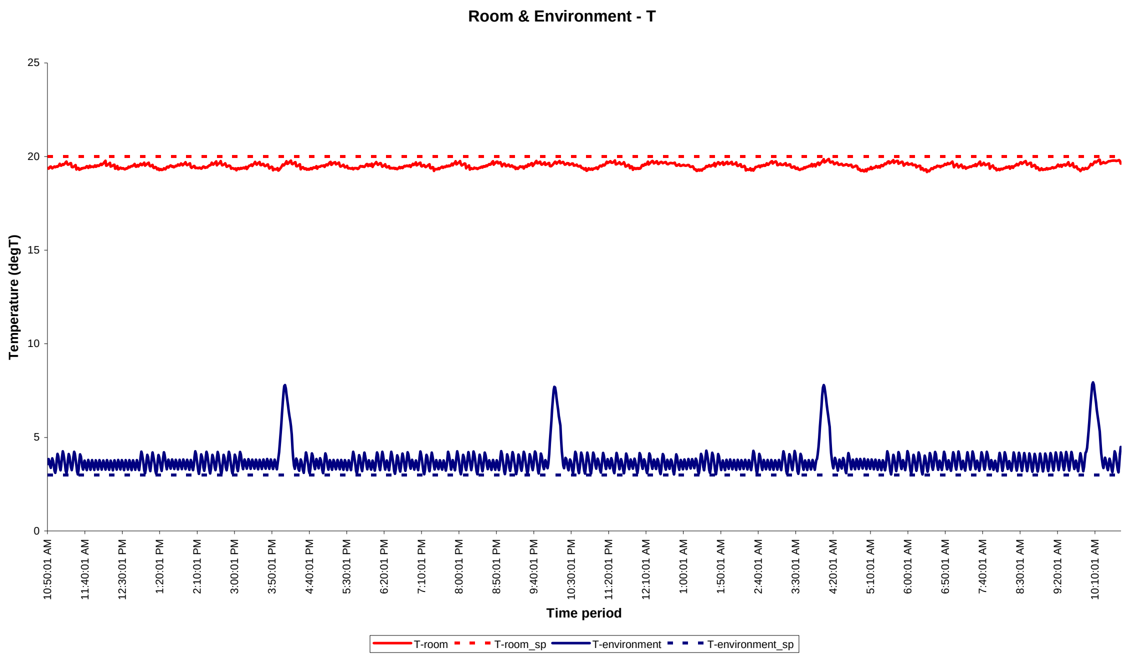


Figure B-161: Temperature of the room and environmental side during S2-Alt2

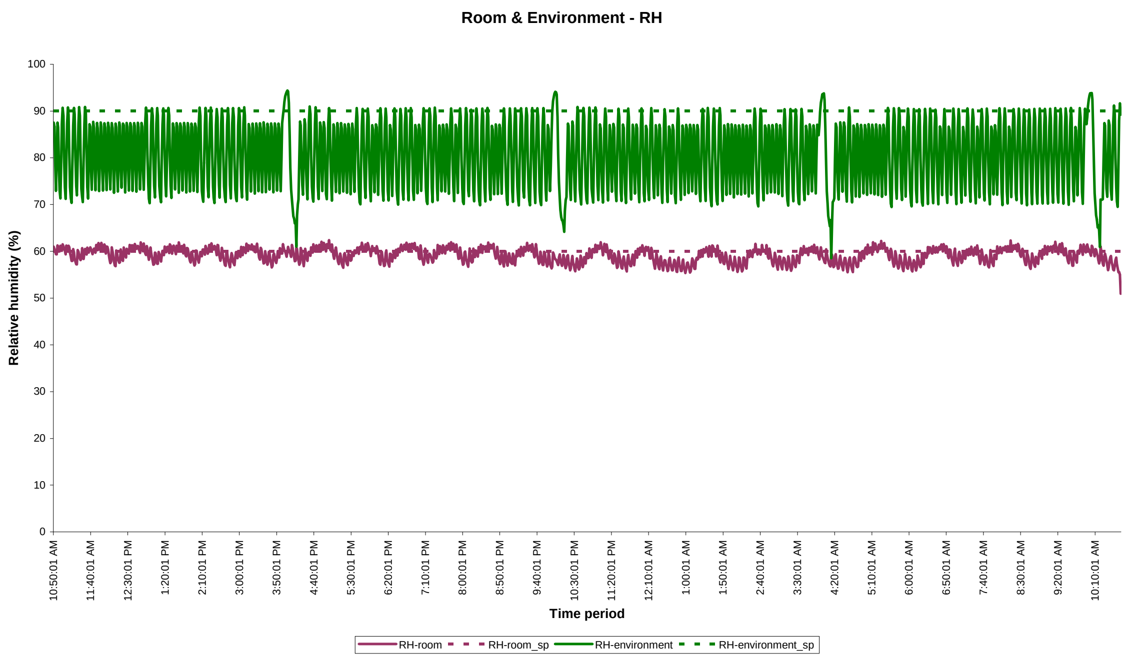


Figure B-162: Relative humidity of the room and environmental side during S2-Alt2

Test cycle: **S2 – Alt3**

Table B-19: Average data during the last 24 hours for each specimen of S2-Alt3

Specimen Measurement Data

B-G	A		B		C		Sand
1	A1_Soil-T	18.696 degC	B1_Soil-T	19.487 degC	C1_Soil-T	20.638 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	100.000 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	18.300 degC	B1_Wall-T	18.974 degC	C1_Wall-T	20.394 degC	
	A1_Ext-T	19.146 degC	B1_Ext-T	18.969 degC	C1_Ext-T	20.324 degC	
	A1_Int-T	18.289 degC	B1_Int-T	17.679 degC	C1_Int-T	18.744 degC	
	A1_Inside-RH	71.486 %	B1_Inside-RH	87.392 %	C1_Inside-RH	88.885 %	
	A1_Wall-RH	70.892 %	B1_Wall-RH	79.519 %	C1_Wall-RH	77.804 %	
2	A2_Soil-T	18.582 degC	B2_Soil-T	19.010 degC	C2_Soil-T	20.313 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	17.737 degC	B2_Wall-T	18.519 degC	C2_Ext-T	19.524 degC	
	A2_Ext-T	18.872 degC	B2_Ext-T	18.352 degC	C2_Int-T	18.500 degC	
	A2_Int-T	17.447 degC	B2_Int-T	16.911 degC	C2_Inside-RH	83.064 %	
	A2_Inside-RH	64.096 %	B2_Inside-RH	92.856 %			
	A2_Wall-RH	65.407 %	B2_Wall-RH	90.822 %			
3	A3_Soil-T	18.590 degC	B3_Soil-T	19.140 degC	C3_Soil-T	19.997 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	17.755 degC	B3_Wall-T	18.512 degC	C3_Ext-T	20.283 degC	
	A3_Ext-T	18.614 degC	B3_Ext-T	18.376 degC	C3_Int-T	18.621 degC	
	A3_Int-T	17.517 degC	B3_Int-T	17.418 degC	C3_Inside-RH	100.000 %	
	A3_Inside-RH	66.171 %	B3_Inside-RH	99.827 %			
	A3_Wall-RH	70.759 %	B3_Wall-RH	75.377 %	*Pressure diff.	80.572 Pa	
Yes	A		B		C		Alt3

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	18.616 degC
RH-room	63.371 %
T-room_sp	20.000 degC
RH-room_sp	60.000 %
T-environment	19.553 degC
RH-environment	83.426 %
T-environment_sp	20.000 degC
RH-environment_sp	90.000 %

Remarks

Type: B-G
Soil type: Sand
Damproofing: Yes
Alternative: Alt3

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

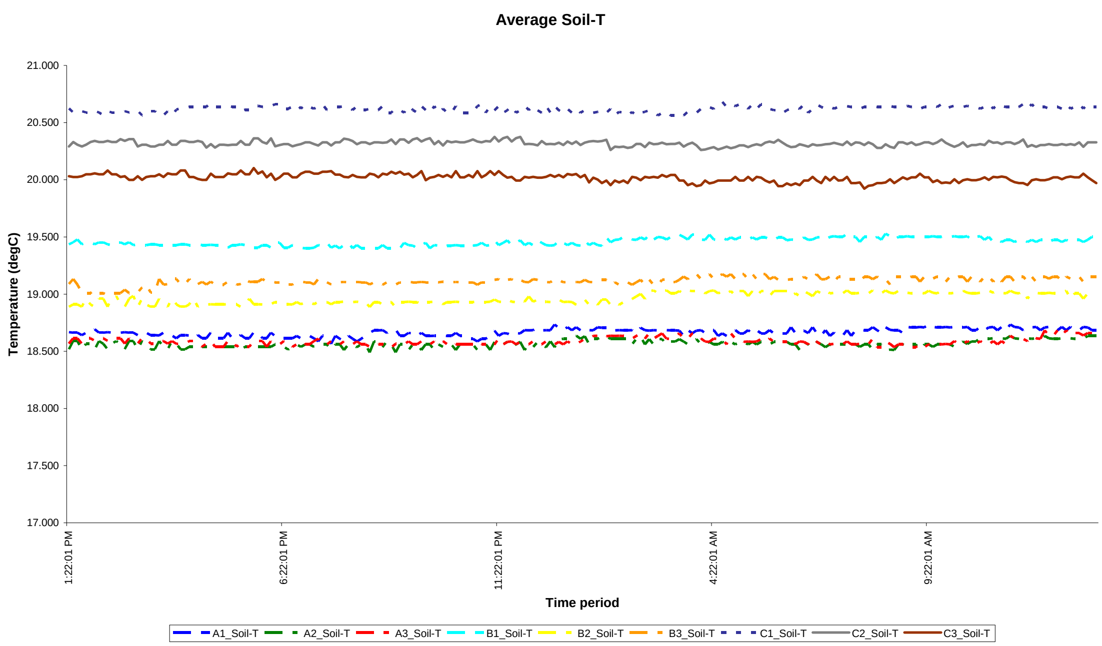


Figure B-163: Average soil temperature of S2-Alt3

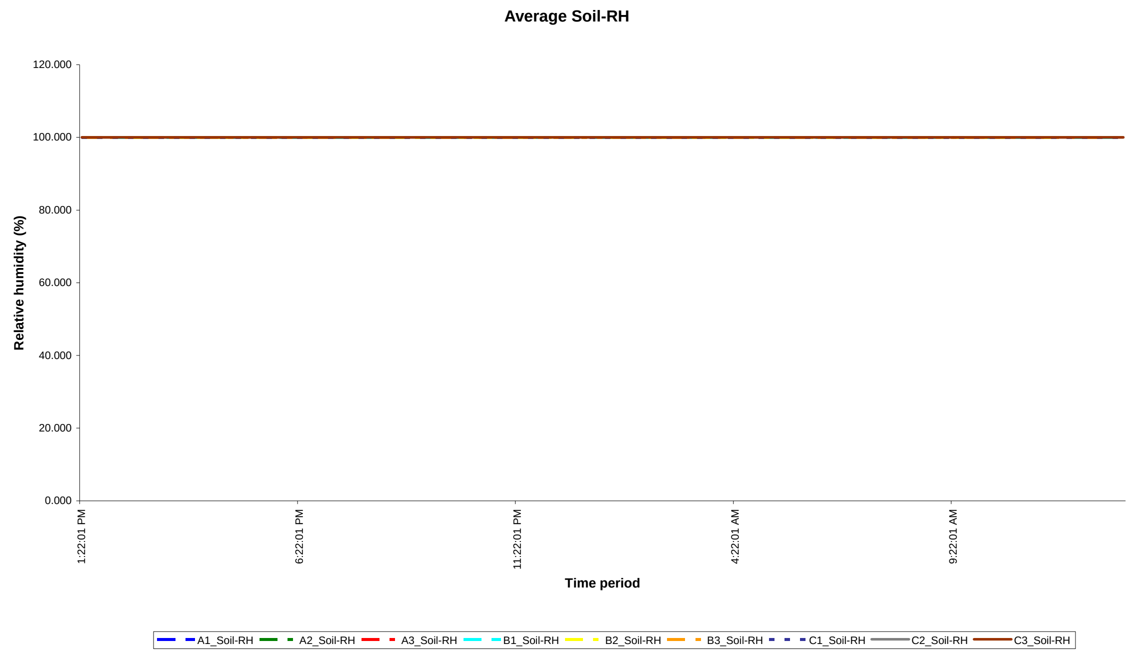


Figure B-164: Average soil relative humidity of S2-Alt3

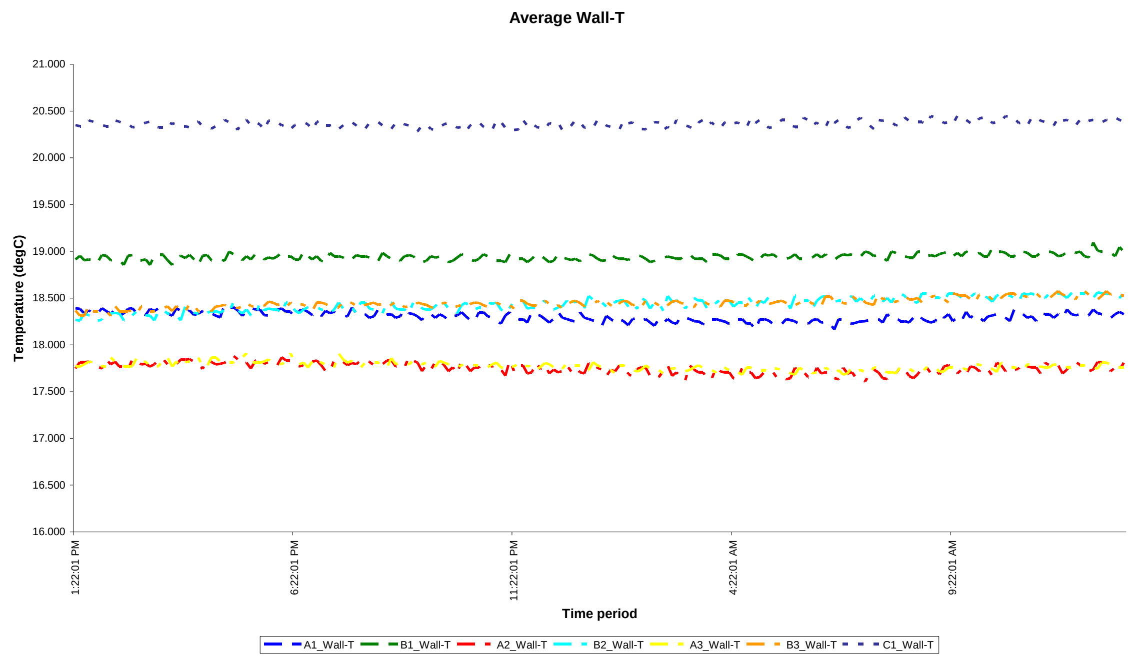


Figure B-165: Average wall temperature of S2-Alt3

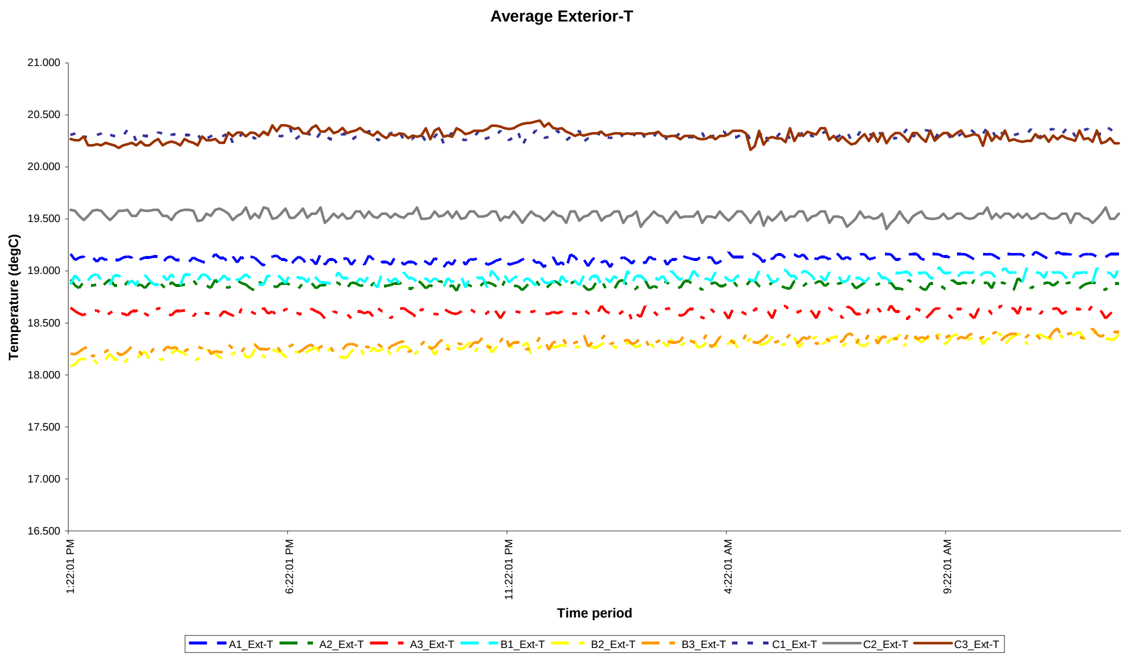


Figure B-166: Average exterior temperature of S2-Alt3

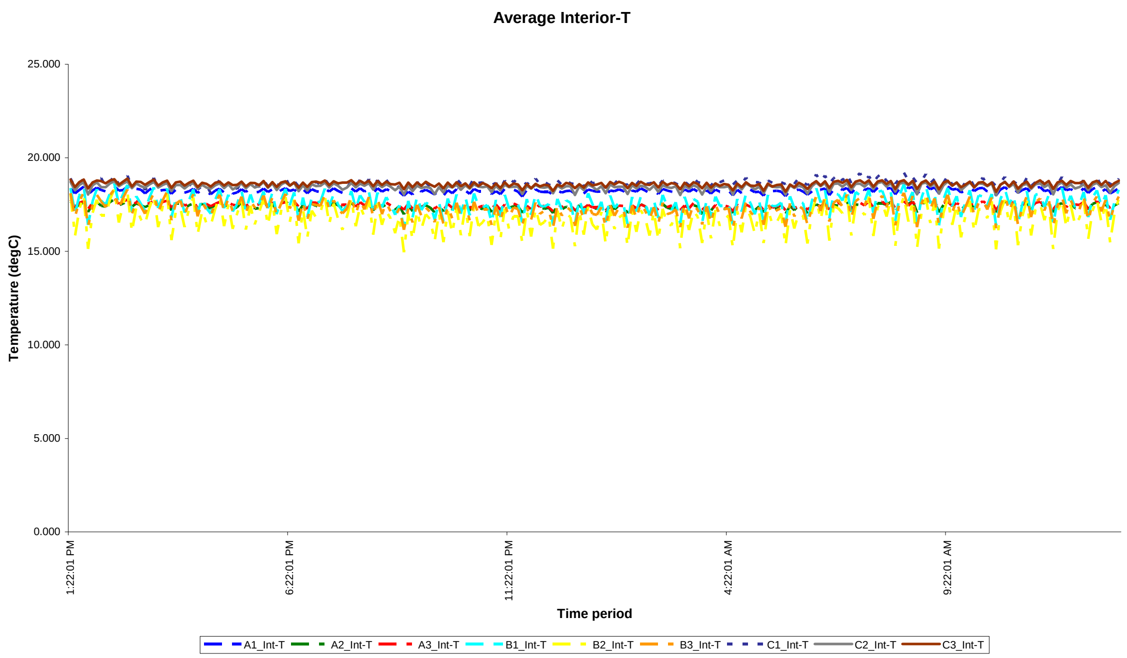


Figure B-167: Average interior temperature of S2-Alt3

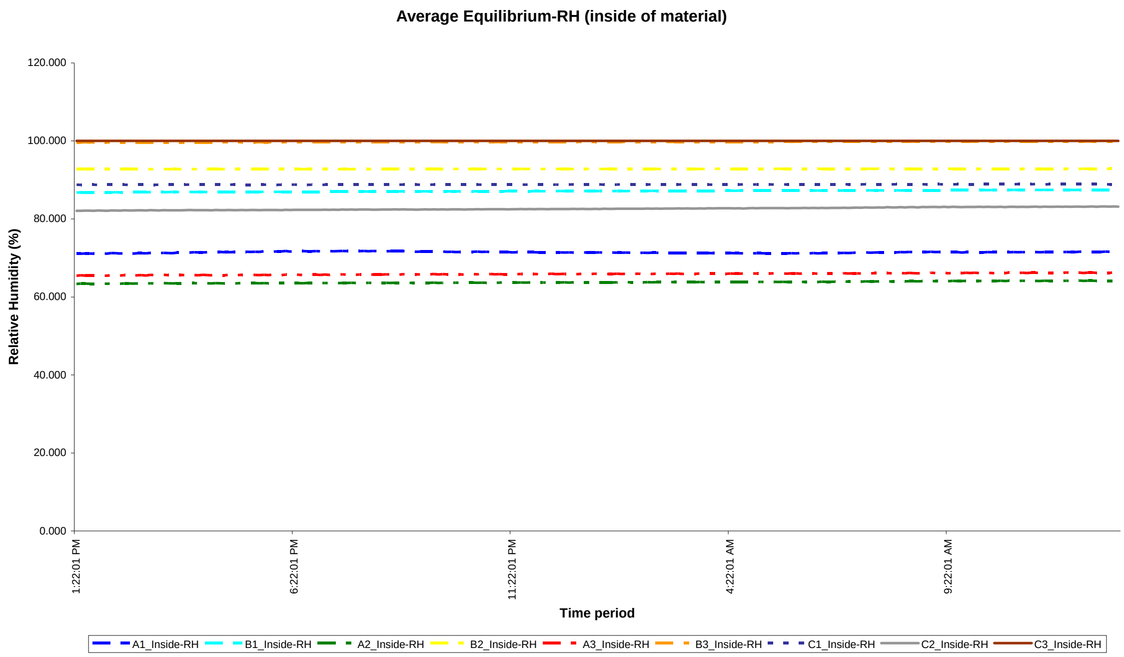


Figure B-168: Average equilibrium of relative humidity in a cavity of S2-Alt3

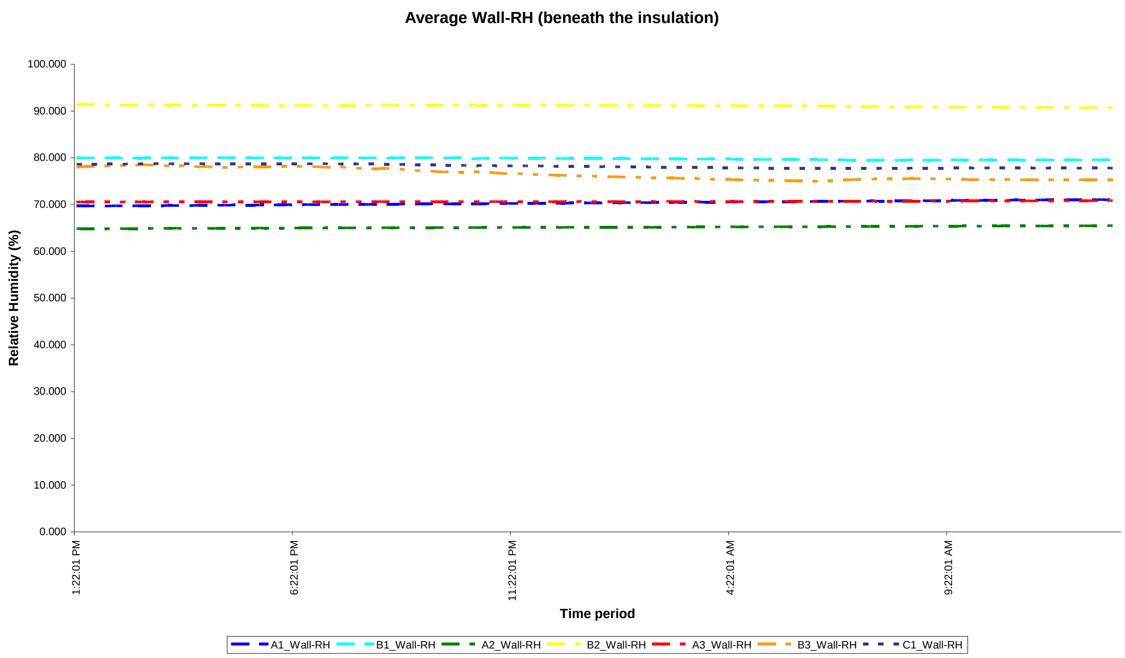


Figure B-169: Average wall relative humidity beneath the insulation of S2-Alt3

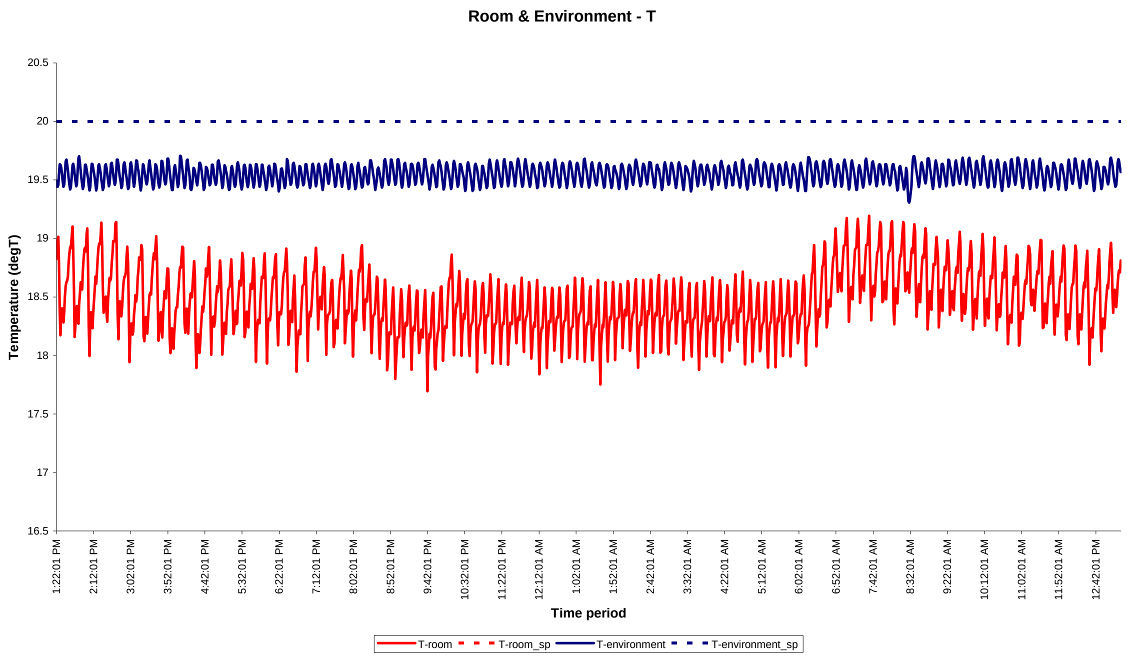


Figure B-170: Temperature of the room and environmental side during S2-Alt3

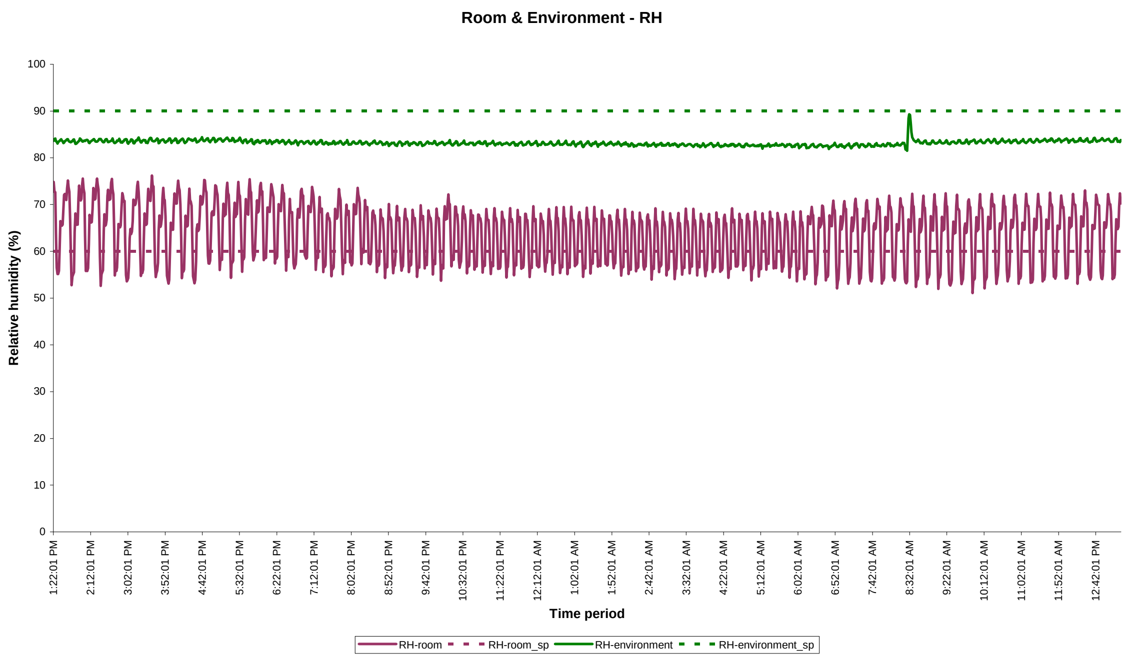


Figure B-171: Relative humidity of the room and environmental side during S2-Alt3

Test cycle: **S2 – Alt4**

Table B-20: Average data during the last 24 hours for each specimen of S2-Alt4

Specimen Measurement Data

B-G	A		B		C		Sand
1	A1_Soil-T	19.030 degC	B1_Soil-T	19.592 degC	C1_Soil-T	20.706 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	100.000 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	18.657 degC	B1_Wall-T	19.278 degC	C1_Wall-T	20.512 degC	
	A1_Ext-T	19.905 degC	B1_Ext-T	19.248 degC	C1_Ext-T	20.302 degC	
	A1_Int-T	18.532 degC	B1_Int-T	18.099 degC	C1_Int-T	19.630 degC	
	A1_Inside-RH	62.646 %	B1_Inside-RH	91.426 %	C1_Inside-RH	89.279 %	
	A1_Wall-RH	72.436 %	B1_Wall-RH	77.081 %	C1_Wall-RH	69.444 %	
2	A2_Soil-T	18.950 degC	B2_Soil-T	19.196 degC	C2_Soil-T	20.305 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	17.947 degC	B2_Wall-T	18.852 degC	C2_Ext-T	19.869 degC	
	A2_Ext-T	19.183 degC	B2_Ext-T	18.645 degC	C2_Int-T	19.231 degC	
	A2_Int-T	17.611 degC	B2_Int-T	16.999 degC	C2_Inside-RH	83.716 %	
	A2_Inside-RH	61.128 %	B2_Inside-RH	93.231 %			
	A2_Wall-RH	66.902 %	B2_Wall-RH	83.030 %			
3	A3_Soil-T	18.896 degC	B3_Soil-T	19.287 degC	C3_Soil-T	19.823 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	17.655 degC	B3_Wall-T	18.631 degC	C3_Ext-T	20.720 degC	
	A3_Ext-T	18.766 degC	B3_Ext-T	18.500 degC	C3_Int-T	18.634 degC	
	A3_Int-T	17.304 degC	B3_Int-T	16.795 degC	C3_Inside-RH	99.956 %	
	A3_Inside-RH	61.710 %	B3_Inside-RH	101.520 %			
	A3_Wall-RH	70.373 %	B3_Wall-RH	56.702 %	*Pressure diff.*	*7.757 Pa*	
Yes	A		B		C		Alt4

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	19.292 degC
RH-room	45.150 %
T-room_sp	20.000 degC
RH-room_sp	30.000 %
T-environment	19.595 degC
RH-environment	84.143 %
T-environment_sp	20.000 degC
RH-environment_sp	90.000 %

Remarks

Type: B-G
Soil type: Sand
Damproofing: Yes
Alternative: Alt4

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

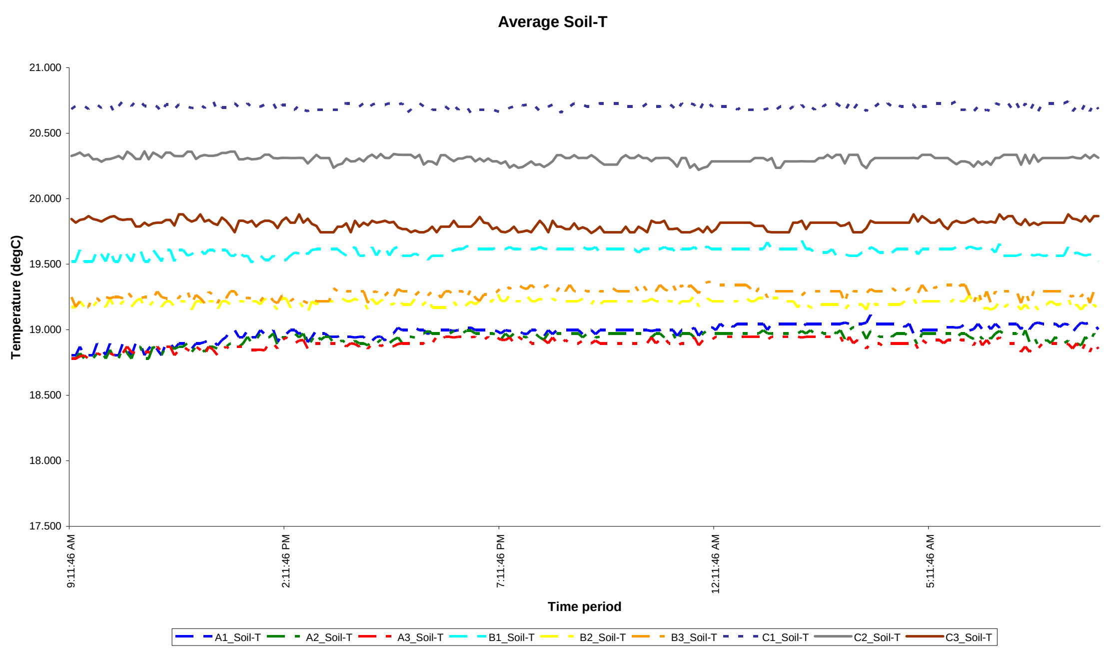


Figure B-172: Average soil temperature of S2-Alt4

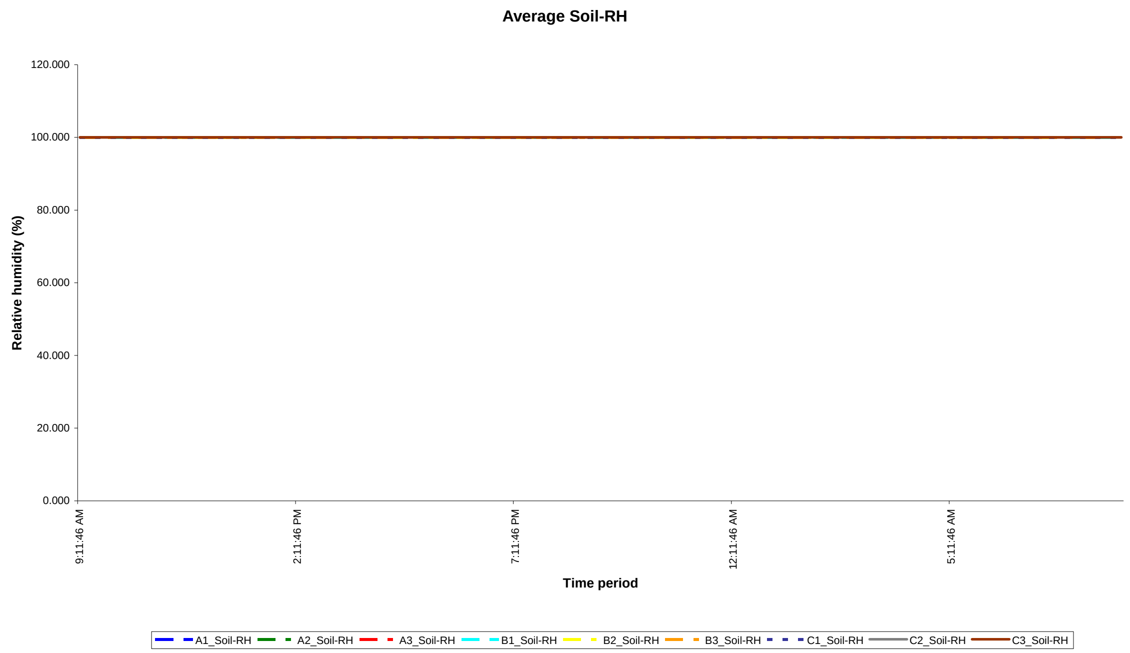


Figure B-173: Average soil relative humidity of S2-Alt4

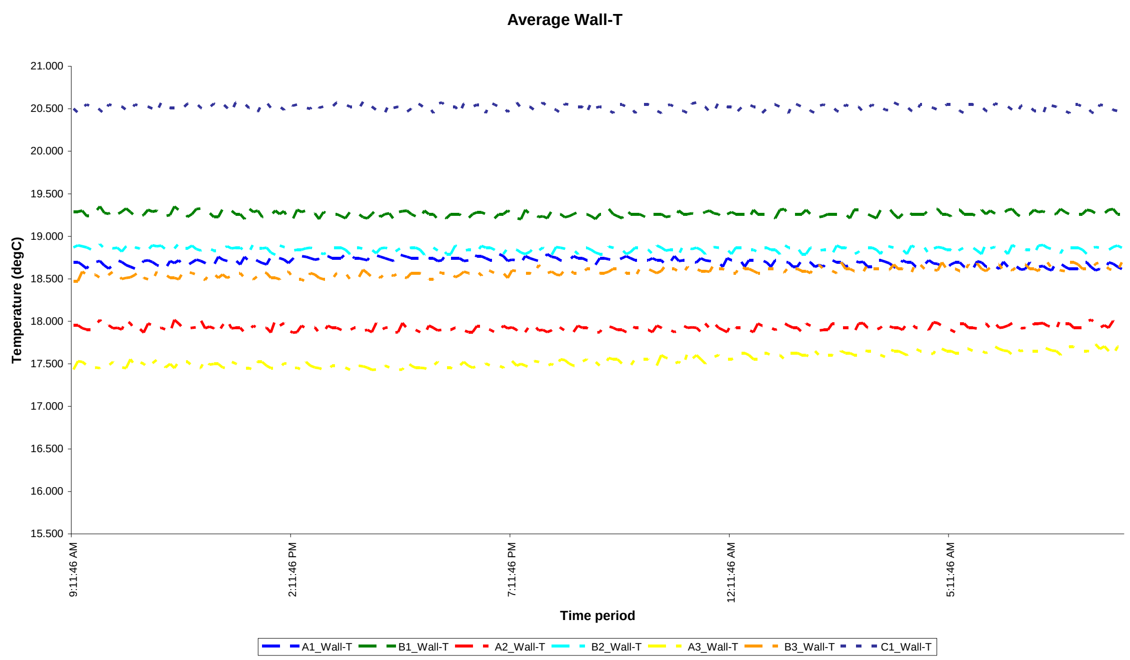


Figure B-174: Average wall temperature of S2-Alt4

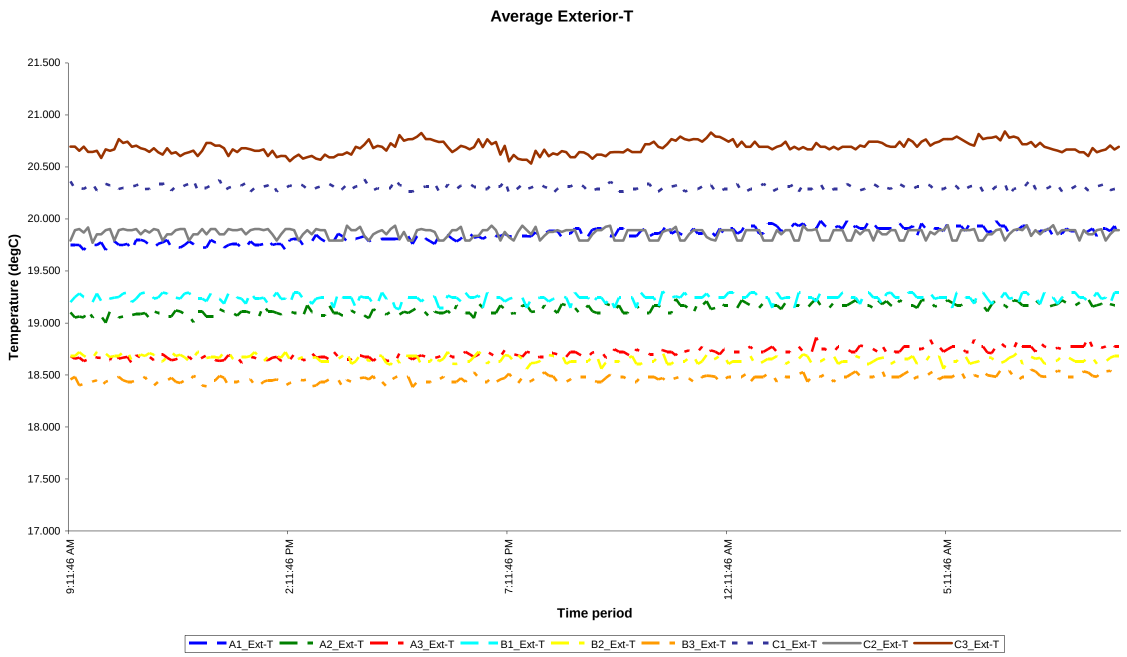


Figure B-175: Average exterior temperature of S2-Alt4

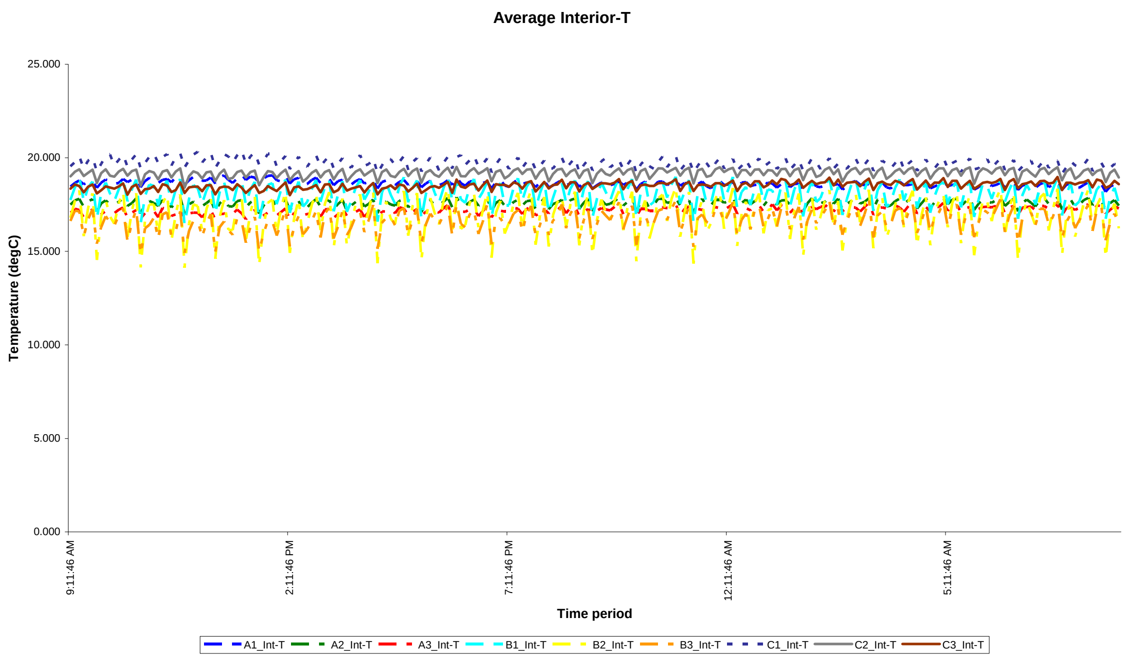


Figure B-176: Average interior temperature of S2-Alt4

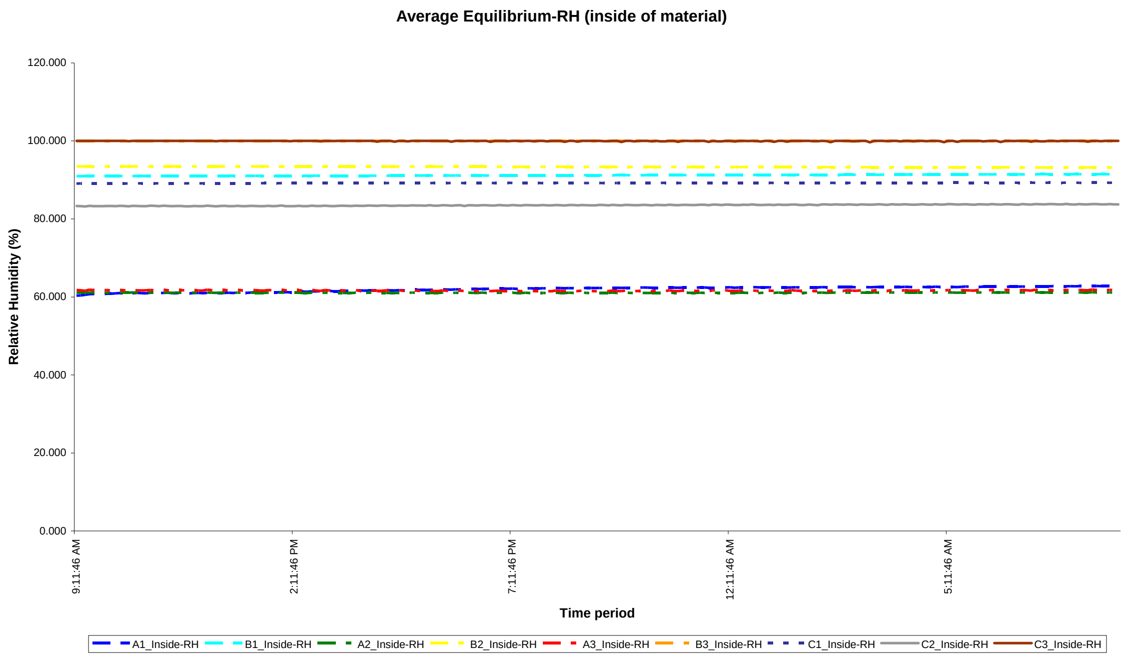


Figure B-177: Average equilibrium of relative humidity in a cavity of S2-Alt4

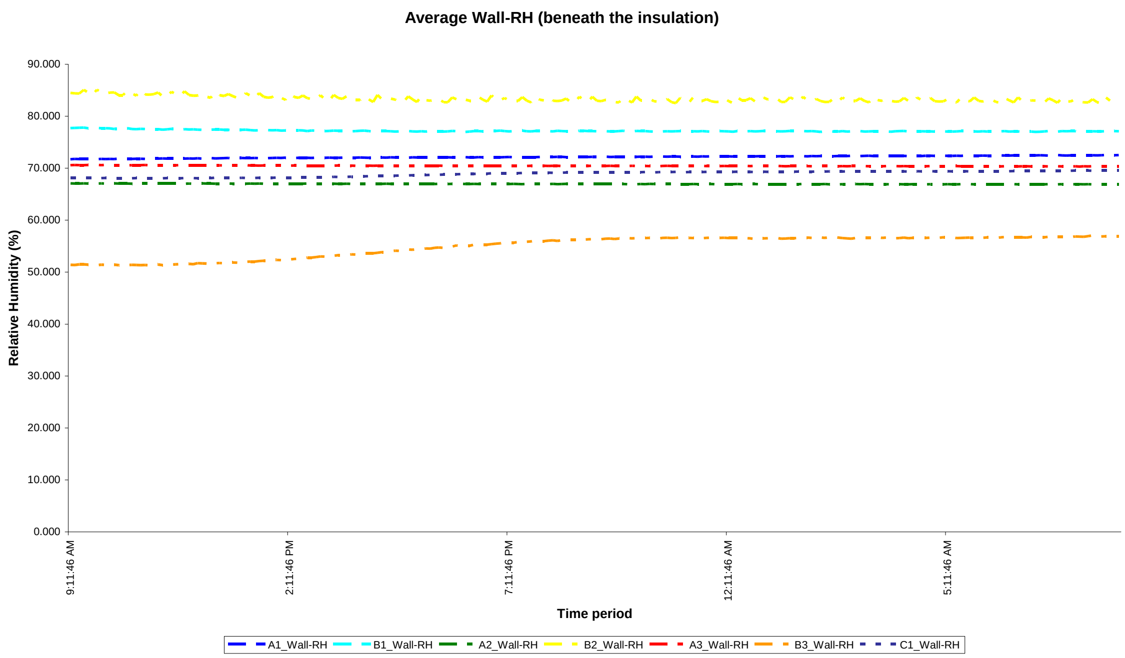


Figure B-178: Average wall relative humidity beneath the insulation of S2-Alt4

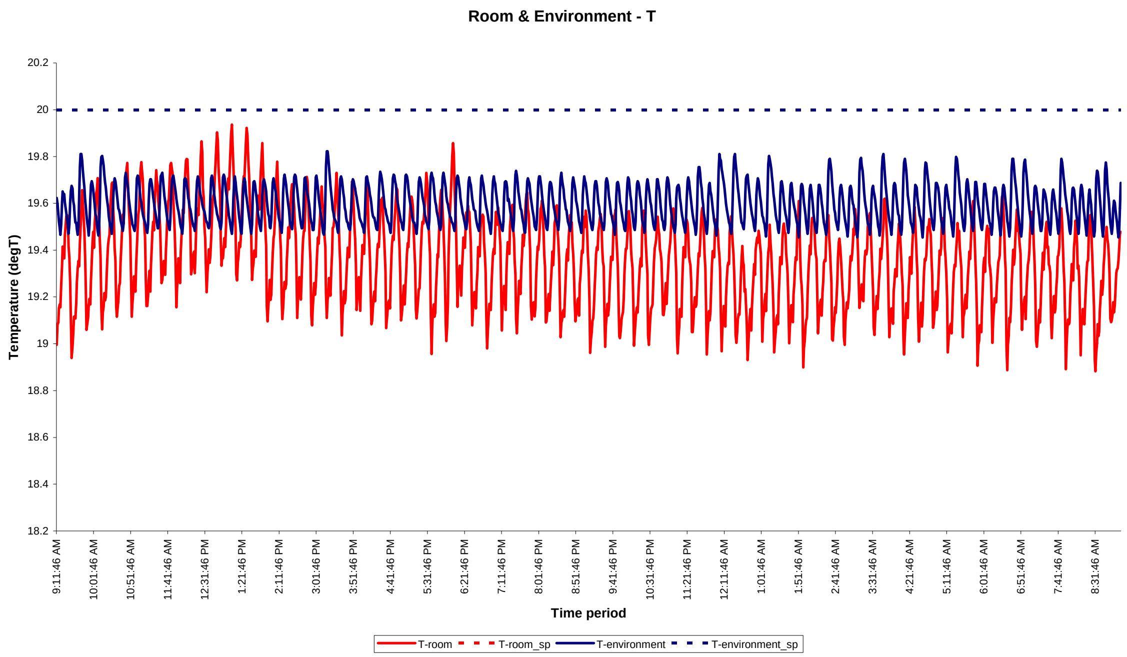


Figure B-179: Temperature of the room and environmental side during S2-Alt4

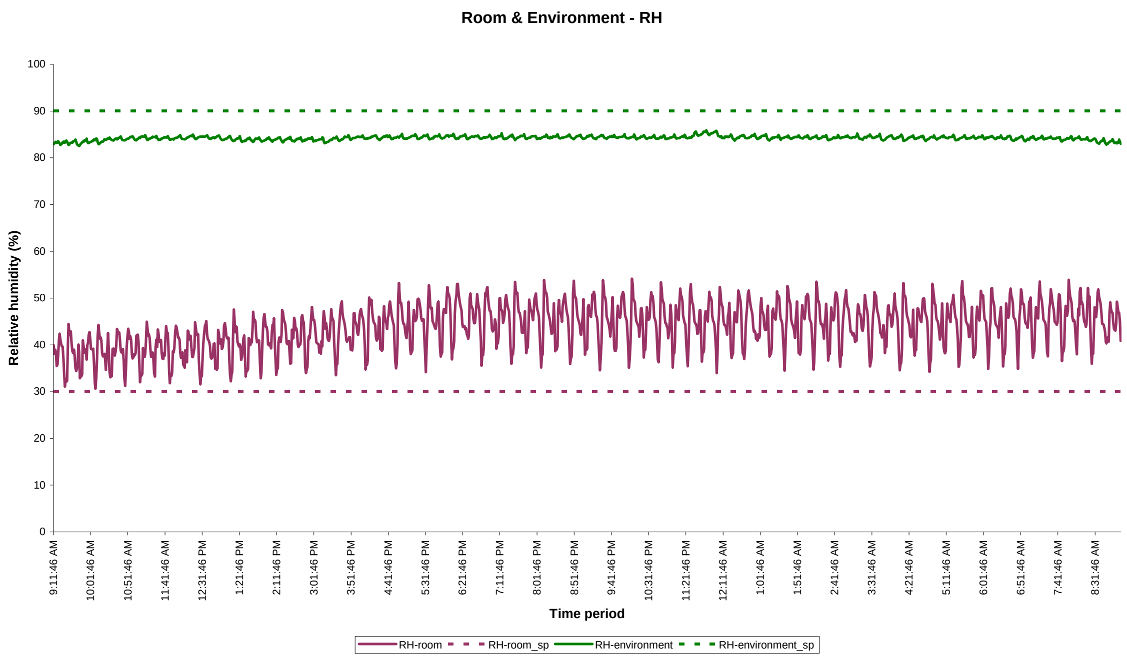


Figure B-180: Relative humidity of the room and environmental side during S2-Alt4

Measurement series: **C2** (Clay; with dampproofing)

Test cycle: **C2 – Alt1**

Table B-21: Average data during the last 24 hours for each specimen of C2-Alt1

Specimen Measurement Data

B-G	A		B		C		Clay
1	A1_Soil-T	5.209 degC	B1_Soil-T	4.316 degC	C1_Soil-T	5.091 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	100.000 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	14.955 degC	B1_Wall-T	6.745 degC	C1_Wall-T	7.560 degC	
	A1_Ext-T	6.822 degC	B1_Ext-T	5.351 degC	C1_Ext-T	5.583 degC	
	A1_Int-T	17.418 degC	B1_Int-T	18.285 degC	C1_Int-T	18.149 degC	
	A1_Inside-RH	53.491 %	B1_Inside-RH	100.000 %	C1_Inside-RH	100.000 %	
	A1_Wall-RH	60.712 %	B1_Wall-RH	85.460 %	C1_Wall-RH	81.092 %	
2	A2_Soil-T	5.781 degC	B2_Soil-T	4.728 degC	C2_Soil-T	6.448 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	16.761 degC	B2_Wall-T	8.497 degC	C2_Ext-T	12.387 degC	
	A2_Ext-T	7.775 degC	B2_Ext-T	7.168 degC	C2_Int-T	16.527 degC	
	A2_Int-T	17.790 degC	B2_Int-T	18.379 degC	C2_Inside-RH	97.572 %	
	A2_Inside-RH	52.818 %	B2_Inside-RH	93.428 %			
	A2_Wall-RH	58.421 %	B2_Wall-RH	83.832 %			
3	A3_Soil-T	6.341 degC	B3_Soil-T	5.581 degC	C3_Soil-T	5.994 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	16.737 degC	B3_Wall-T	8.627 degC	C3_Ext-T	16.606 degC	
	A3_Ext-T	7.807 degC	B3_Ext-T	6.898 degC	C3_Int-T	15.714 degC	
	A3_Int-T	17.879 degC	B3_Int-T	18.106 degC	C3_Inside-RH	97.365 %	
	A3_Inside-RH	53.477 %	B3_Inside-RH	98.456 %			
	A3_Wall-RH	63.552 %	B3_Wall-RH	76.989 %	**Pressure diff.*	*7.836 Pa*	
Yes	A		B		C		Alt1

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	19.588 degC
RH-room	32.094 %
T-room_sp	20.000 degC
RH-room_sp	30.000 %
T-environment	3.459 degC
RH-environment	86.494 %
T-environment_sp	3.000 degC
RH-environment_sp	90.000 %

Remarks

Type: B-G
Soil type: Clay
Dampproofing: Yes
Alternative: Alt1

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

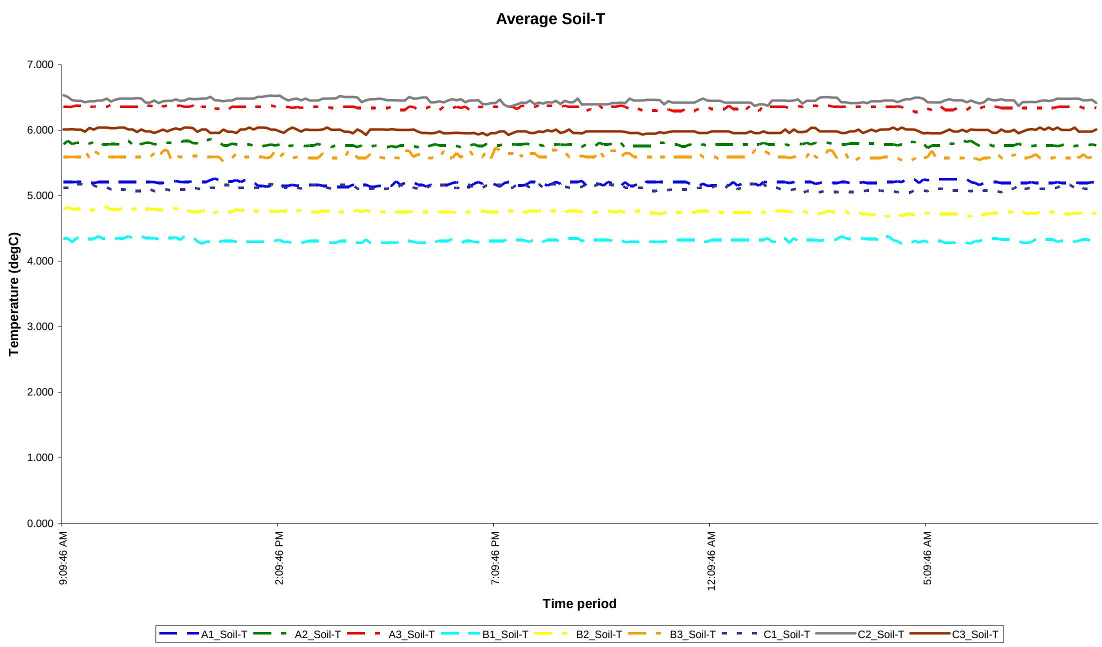


Figure B-181: Average soil temperature of C2-Alt1

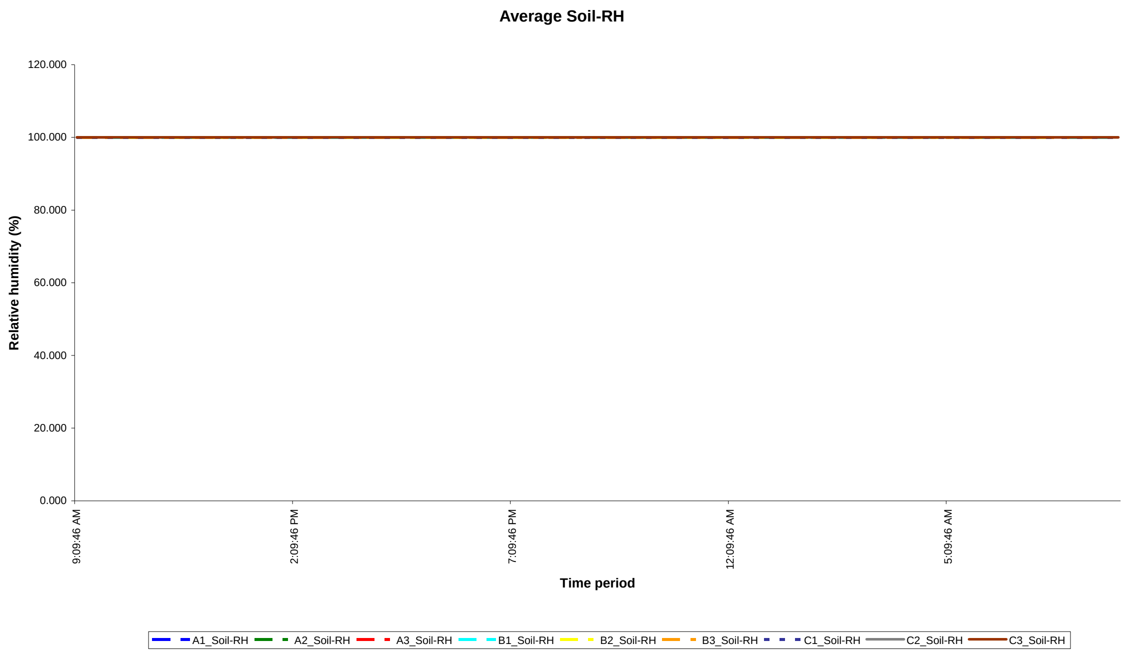


Figure B-182: Average soil relative humidity of C2-Alt1

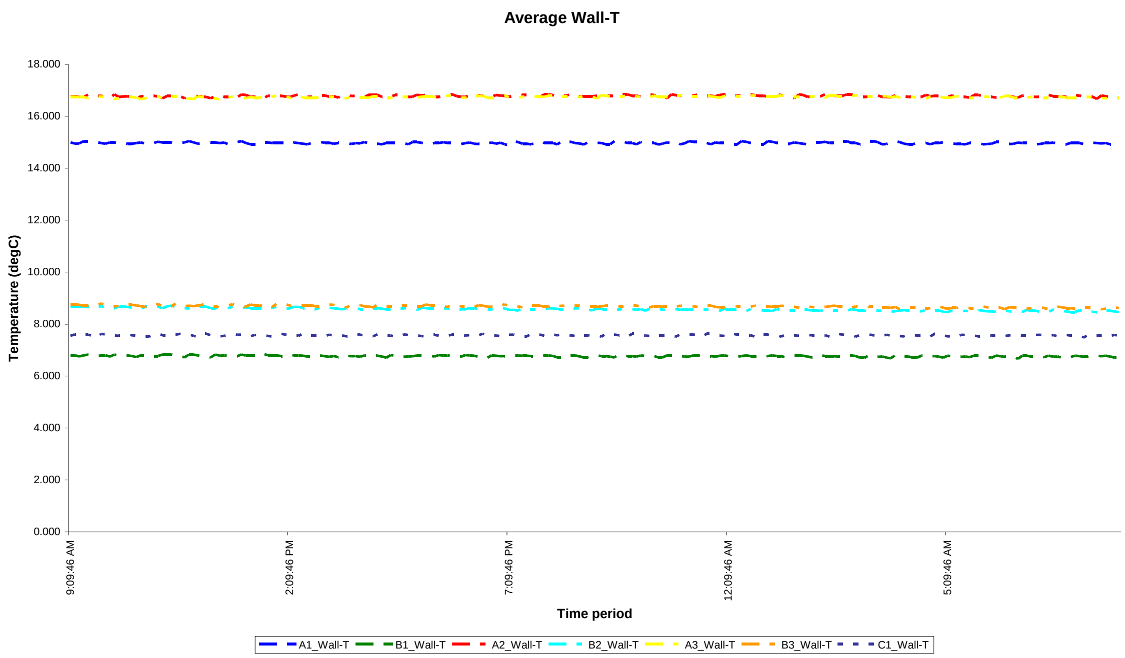


Figure B-183: Average wall temperature of C2-Alt1

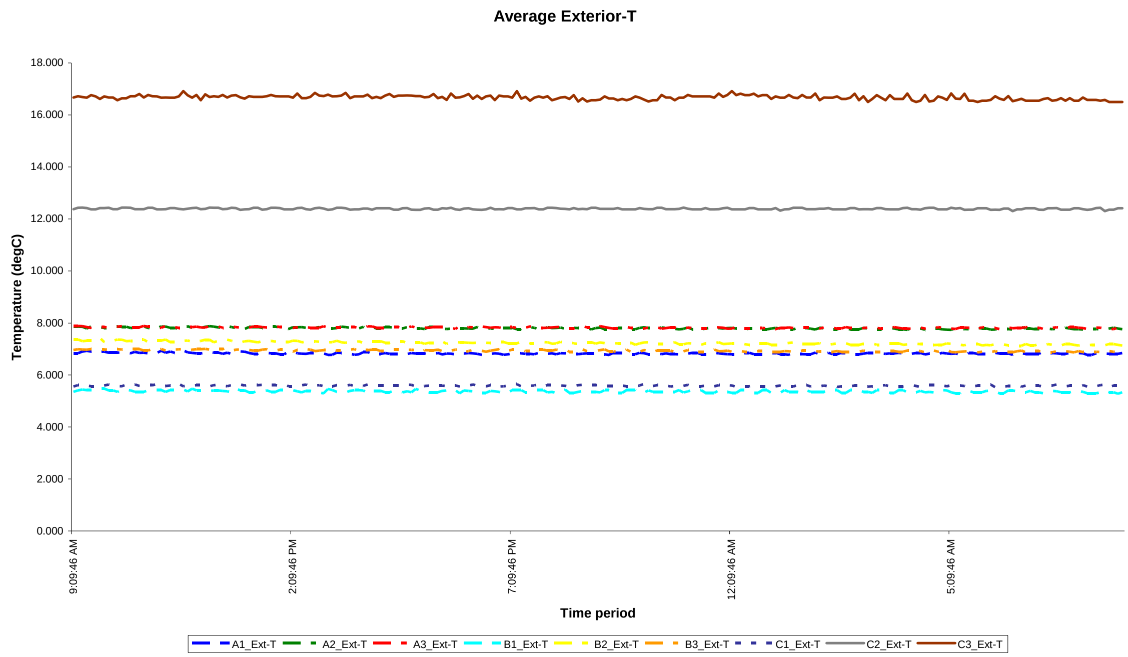


Figure B-184: Average exterior temperature of C2-Alt1

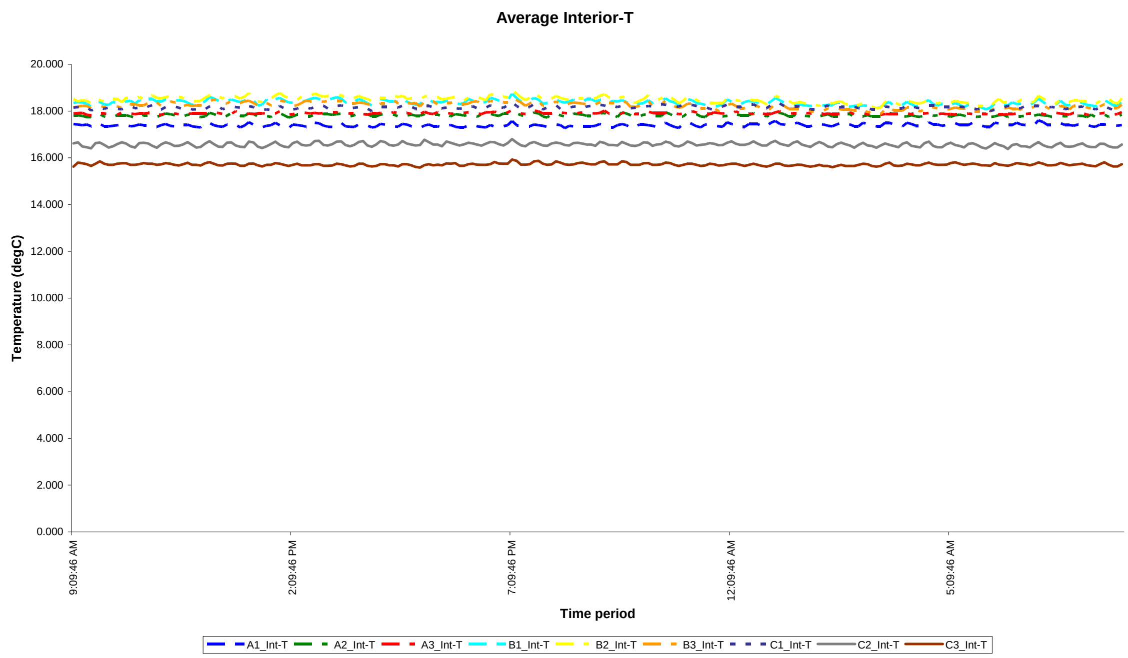


Figure B-185: Average interior temperature of C2-Alt1

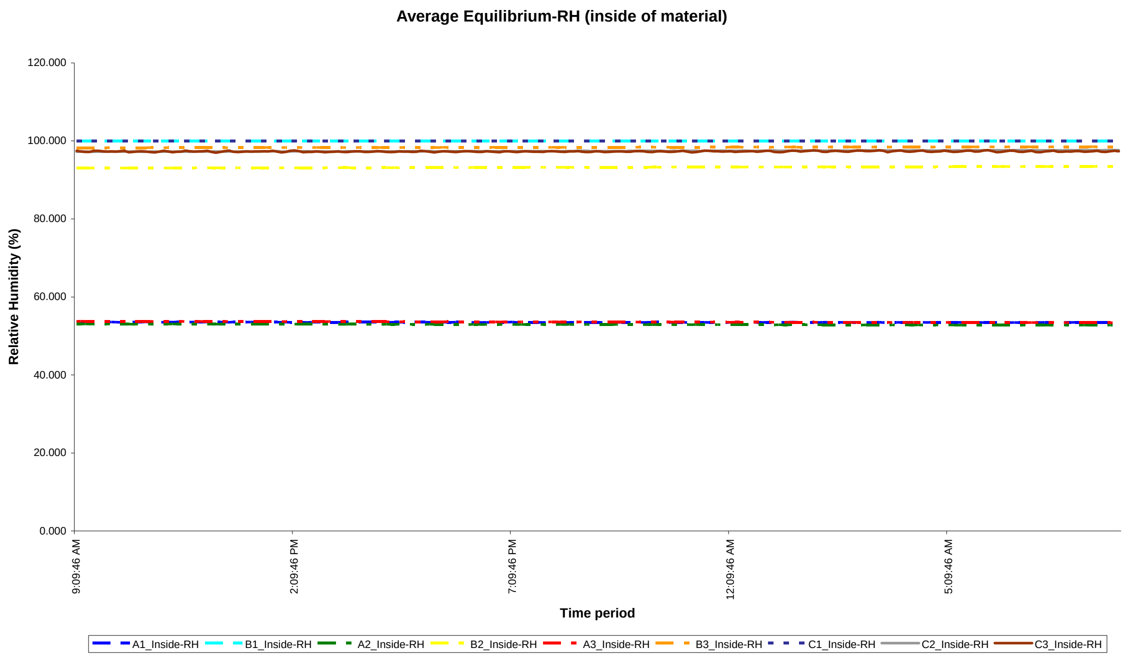


Figure B-186: Average equilibrium of relative humidity in a cavity of C2-Alt1

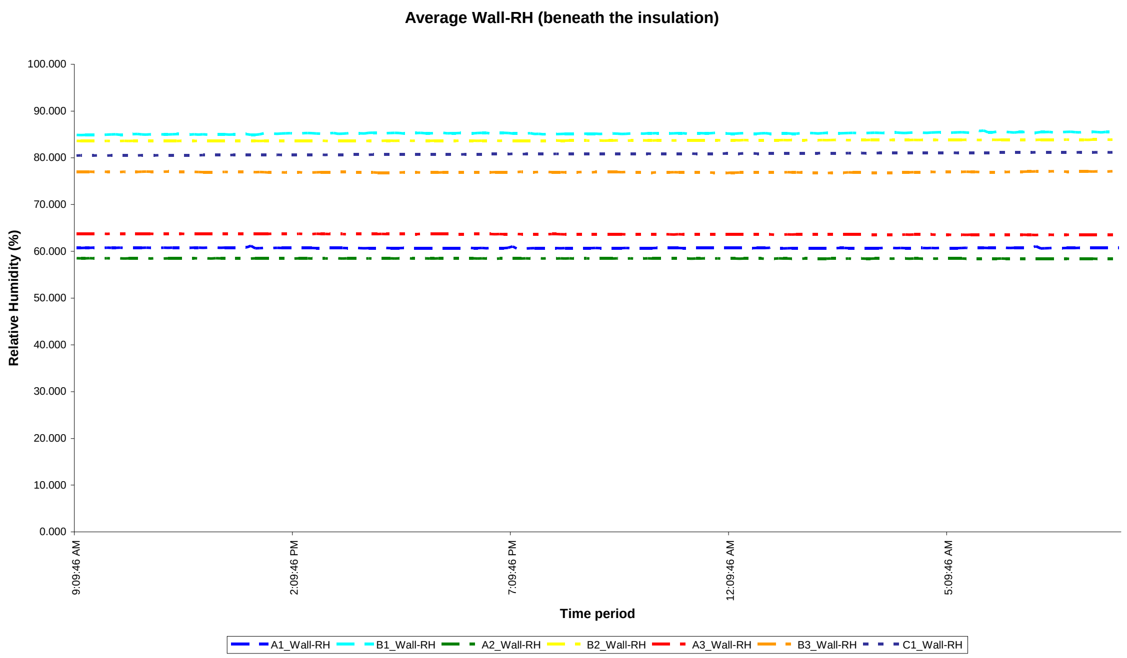


Figure B-187: Average wall relative humidity beneath the insulation of C2-Alt1

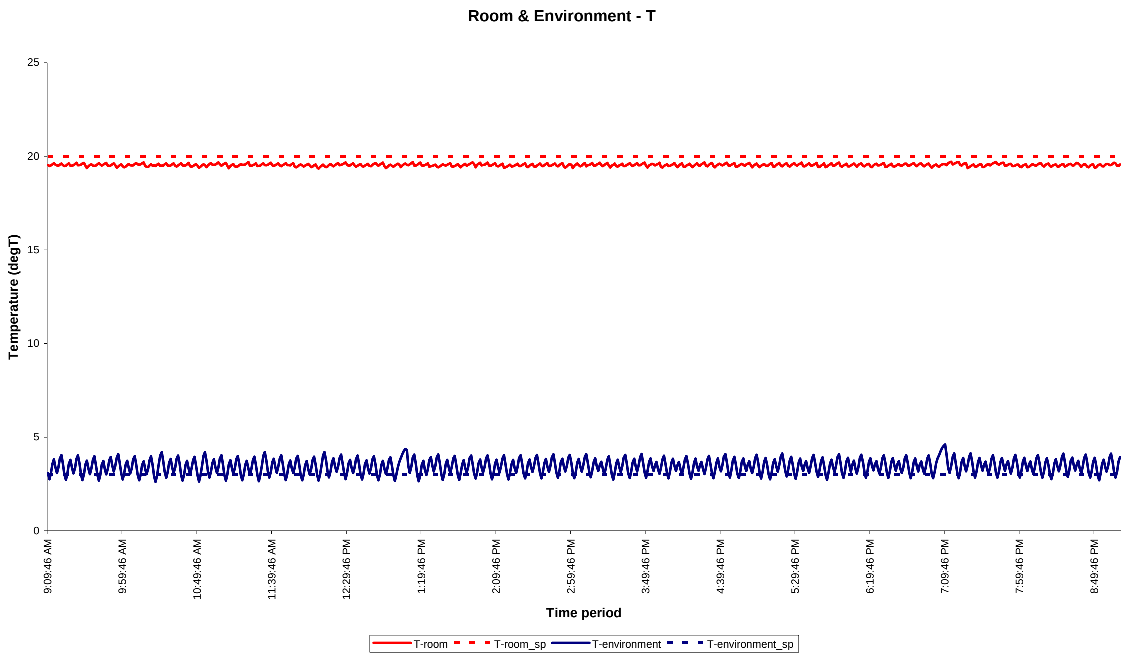


Figure B-188: Temperature of the room and environmental side during C2-Alt1

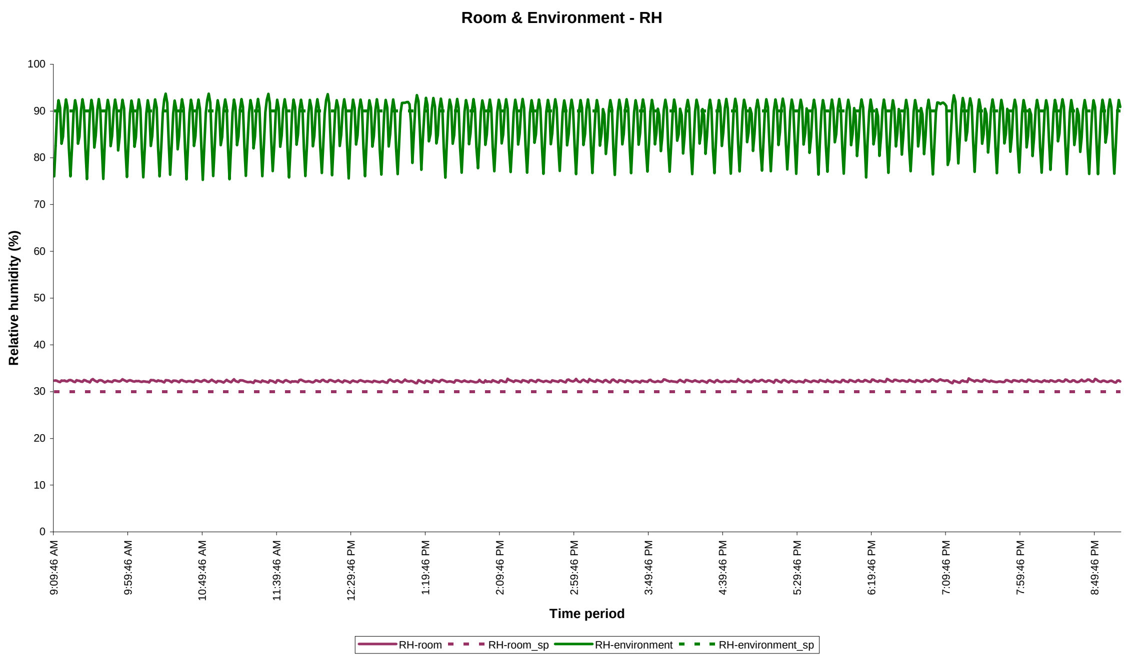


Figure B-189: Relative humidity of the room and environmental side during C2-Alt1

Test cycle: **C2 – Alt2**

Table B-22: Average data during the last 24 hours for each specimen of C2-Alt2

Specimen Measurement Data

B-G	A			B			C			Clay
1	A1_Soil-T	4.286	degC	B1_Soil-T	3.668	degC	C1_Soil-T	4.573	degC	1
	A1_Soil-RH	100.000	%	B1_Soil-RH	100.000	%	C1_Soil-RH	100.000	%	
	A1_Wall-T	14.858	degC	B1_Wall-T	6.132	degC	C1_Wall-T	6.979	degC	
	A1_Ext-T	5.527	degC	B1_Ext-T	4.708	degC	C1_Ext-T	4.894	degC	
	A1_Int-T	17.743	degC	B1_Int-T	18.570	degC	C1_Int-T	18.541	degC	
	A1_Inside-RH	54.006	%	B1_Inside-RH	100.000	%	C1_Inside-RH	100.000	%	
	A1_Wall-RH	61.168	%	B1_Wall-RH	91.850	%	C1_Wall-RH	95.907	%	
2	A2_Soil-T	4.727	degC	B2_Soil-T	4.382	degC	C2_Soil-T	6.128	degC	2
	A2_Soil-RH	100.000	%	B2_Soil-RH	100.000	%	C2_Soil-RH	100.000	%	
	A2_Wall-T	16.761	degC	B2_Wall-T	8.047	degC	C2_Ext-T	12.310	degC	
	A2_Ext-T	6.816	degC	B2_Ext-T	6.677	degC	C2_Int-T	16.909	degC	
	A2_Int-T	18.030	degC	B2_Int-T	18.972	degC	C2_Inside-RH	99.351	%	
	A2_Inside-RH	62.591	%	B2_Inside-RH	95.905	%				
	A2_Wall-RH	60.717	%	B2_Wall-RH	95.897	%				
3	A3_Soil-T	5.466	degC	B3_Soil-T	5.194	degC	C3_Soil-T	5.547	degC	3
	A3_Soil-RH	100.000	%	B3_Soil-RH	100.000	%	C3_Soil-RH	100.000	%	
	A3_Wall-T	16.985	degC	B3_Wall-T	9.102	degC	C3_Ext-T	17.493	degC	
	A3_Ext-T	7.265	degC	B3_Ext-T	7.093	degC	C3_Int-T	16.228	degC	
	A3_Int-T	18.178	degC	B3_Int-T	18.840	degC	C3_Inside-RH	97.875	%	
	A3_Inside-RH	62.948	%	B3_Inside-RH	99.500	%				
	A3_Wall-RH	66.282	%	B3_Wall-RH	100.000	%	**Pressure diff.*	*68.084*	*Pa*	
Yes	A			B			C			Alt2

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side		
T-room	19.480	degC
RH-room	61.734	%
T-room_sp	20.000	degC
RH-room_sp	60.000	%
T-environment	3.713	degC
RH-environment	80.159	%
T-environment_sp	3.000	degC
RH-environment_sp	90.000	%

Remarks

Type: B-G
Soil type: Clay
Dampproofing: Yes
Alternative: Alt2

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

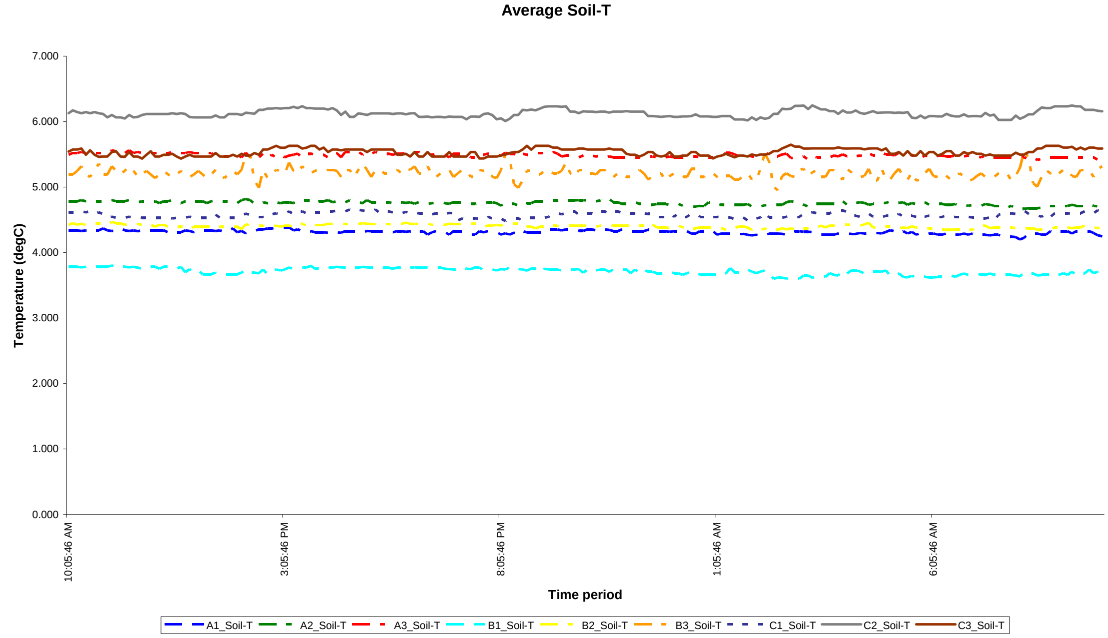


Figure B-190: Average soil temperature of C2-Alt2

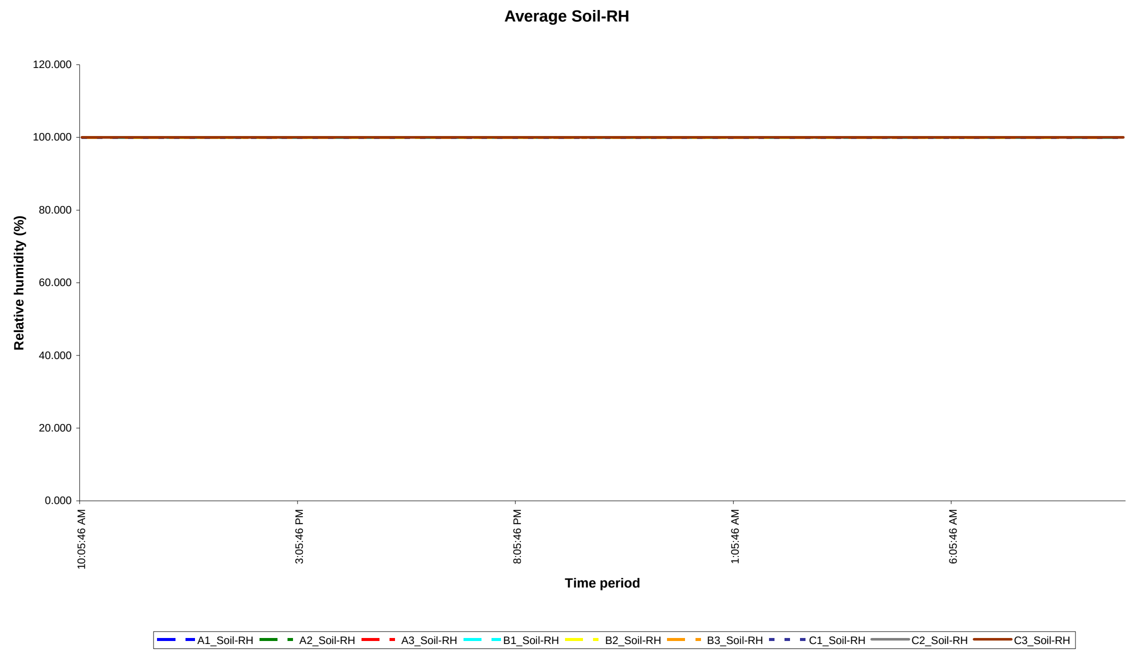


Figure B-191: Average soil relative humidity of C2-Alt2

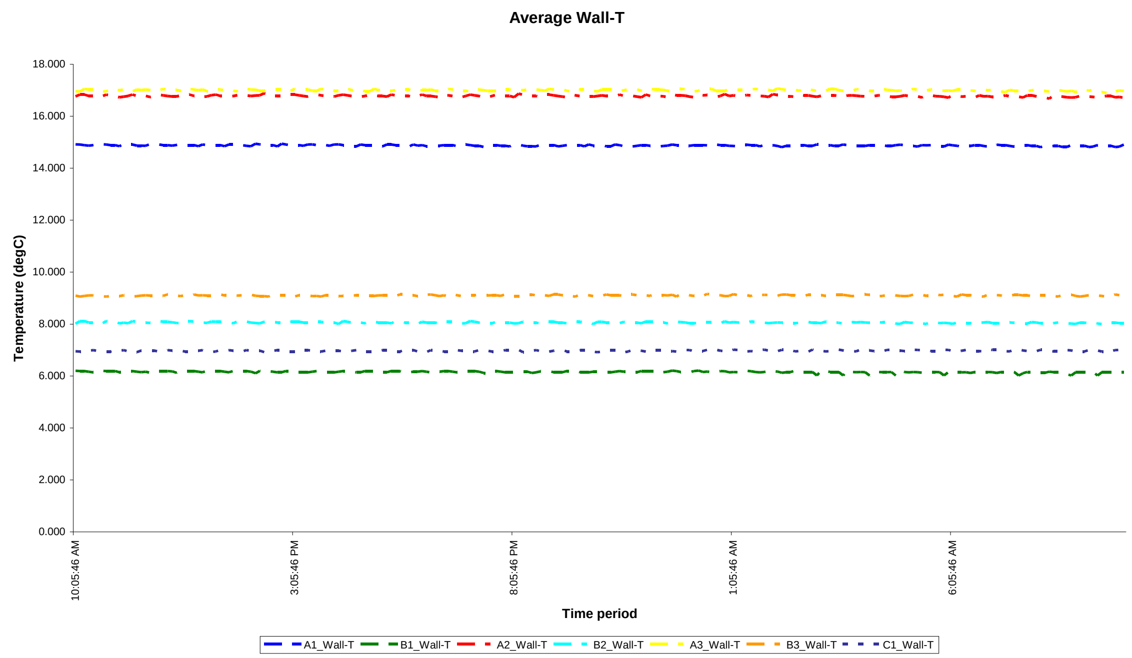


Figure B-192: Average wall temperature of C2-Alt2

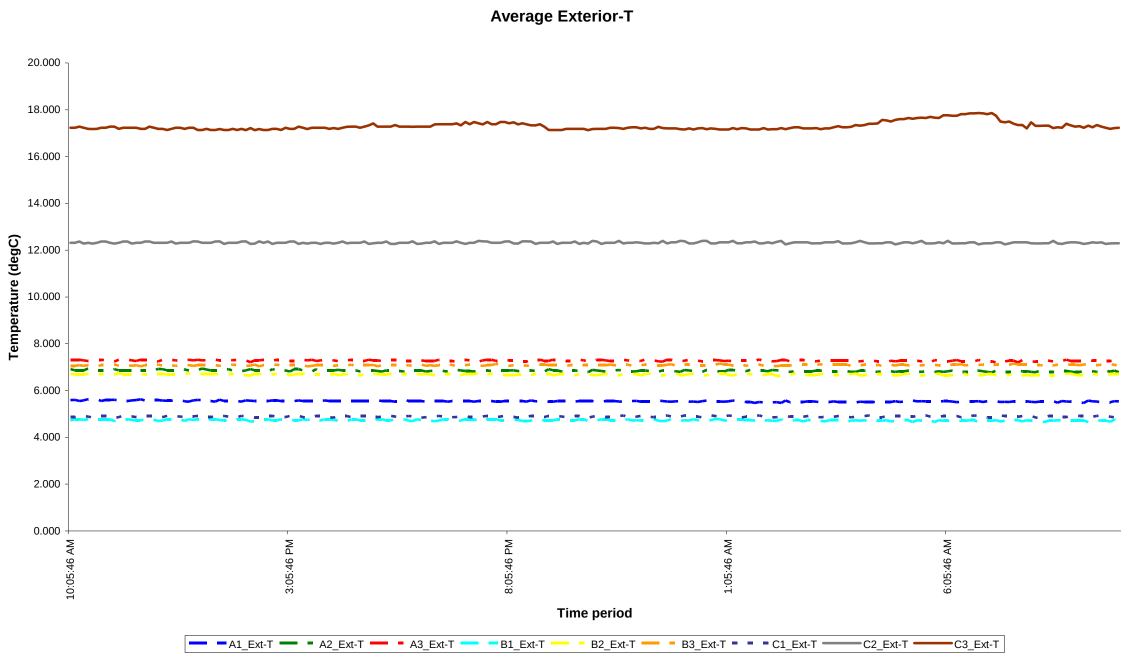


Figure B-193: Average exterior temperature of C2-Alt2

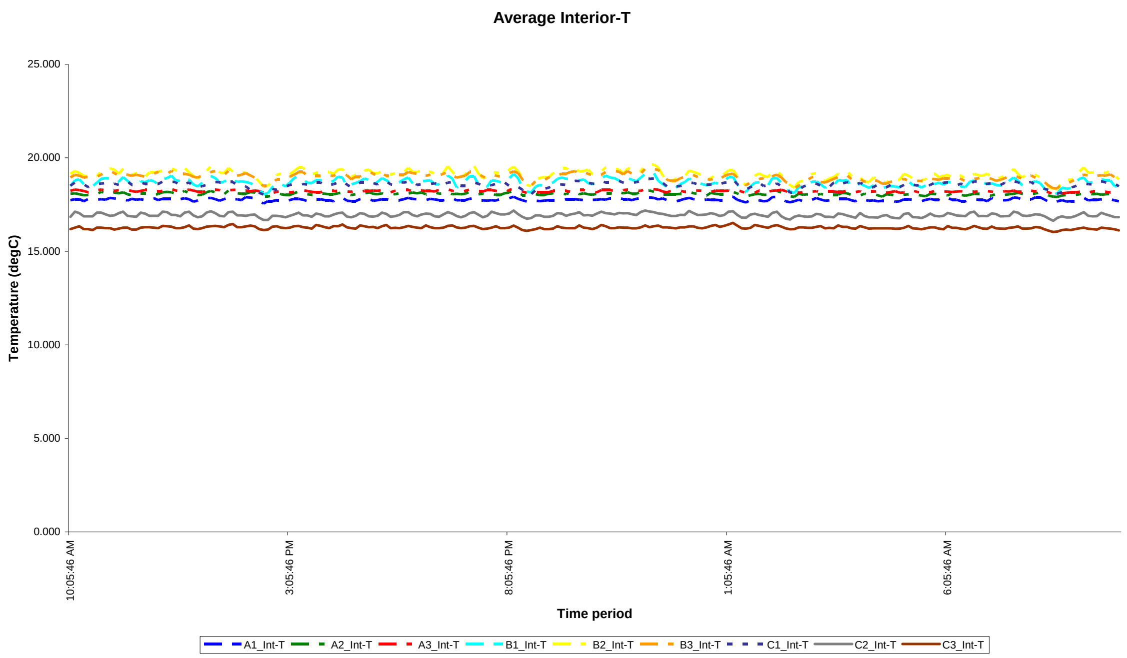


Figure B-194: Average interior temperature of C2-Alt2

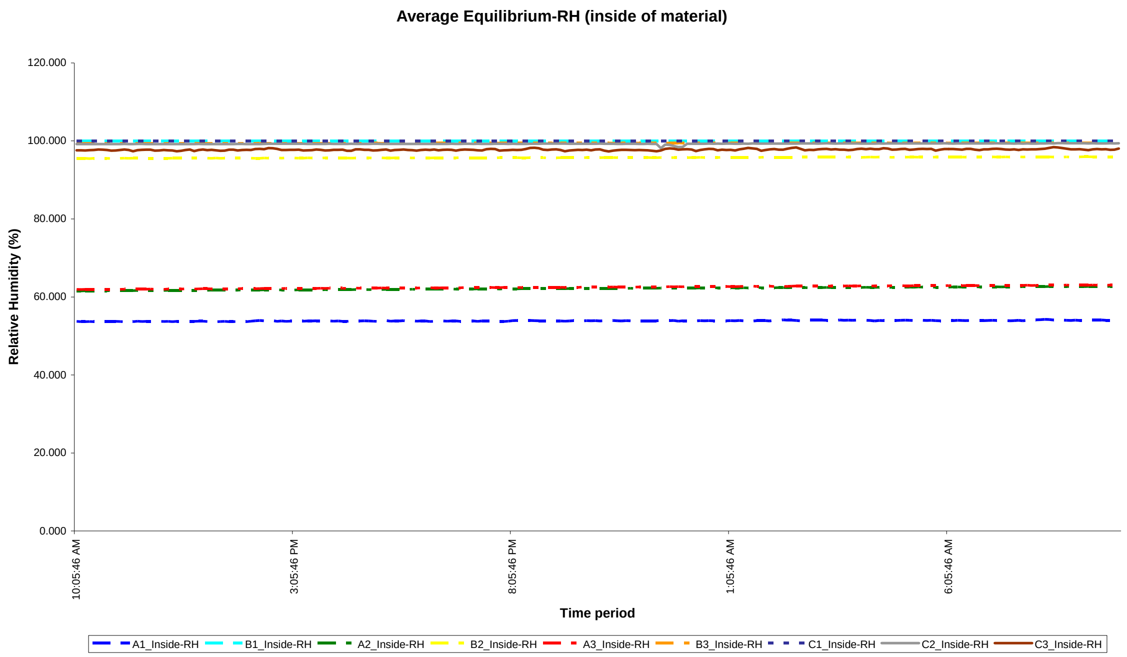


Figure B-195: Average equilibrium of relative humidity in a cavity of C2-Alt2

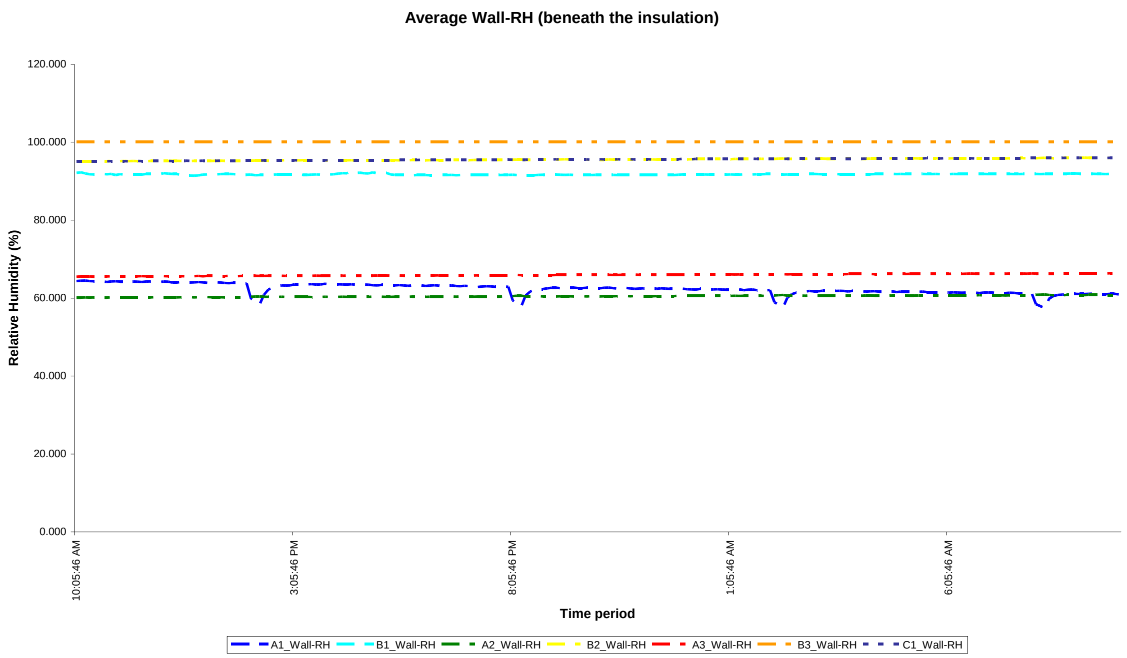


Figure B-196: Average wall relative humidity beneath the insulation of C2-Alt2

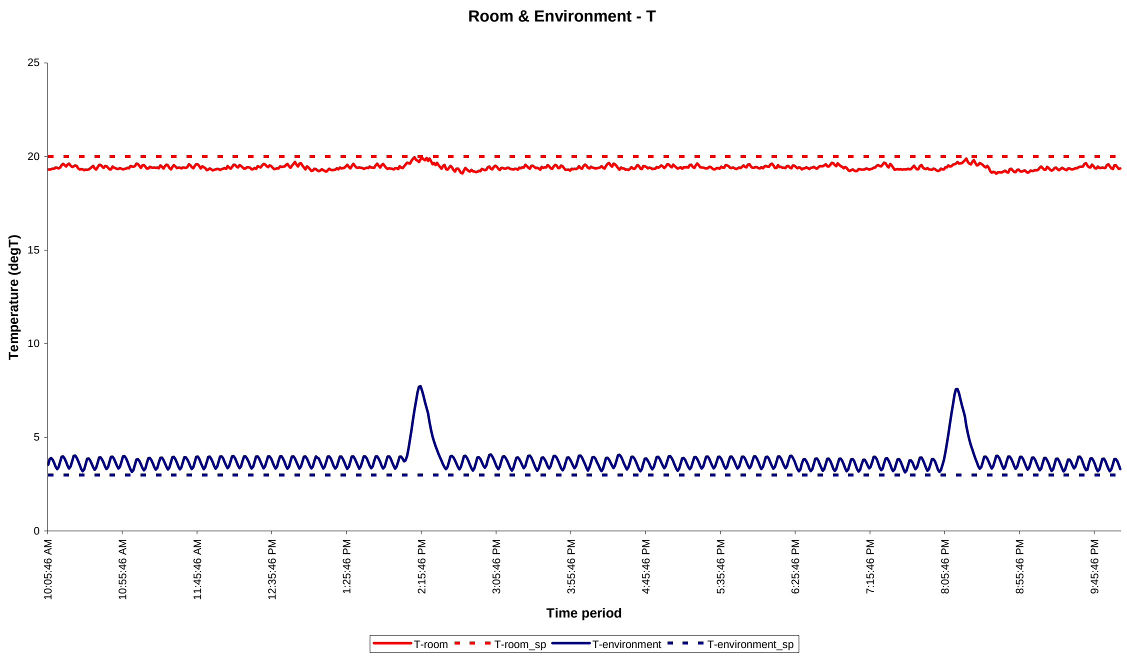


Figure B-197: Temperature of the room and environmental side during C2-Alt2

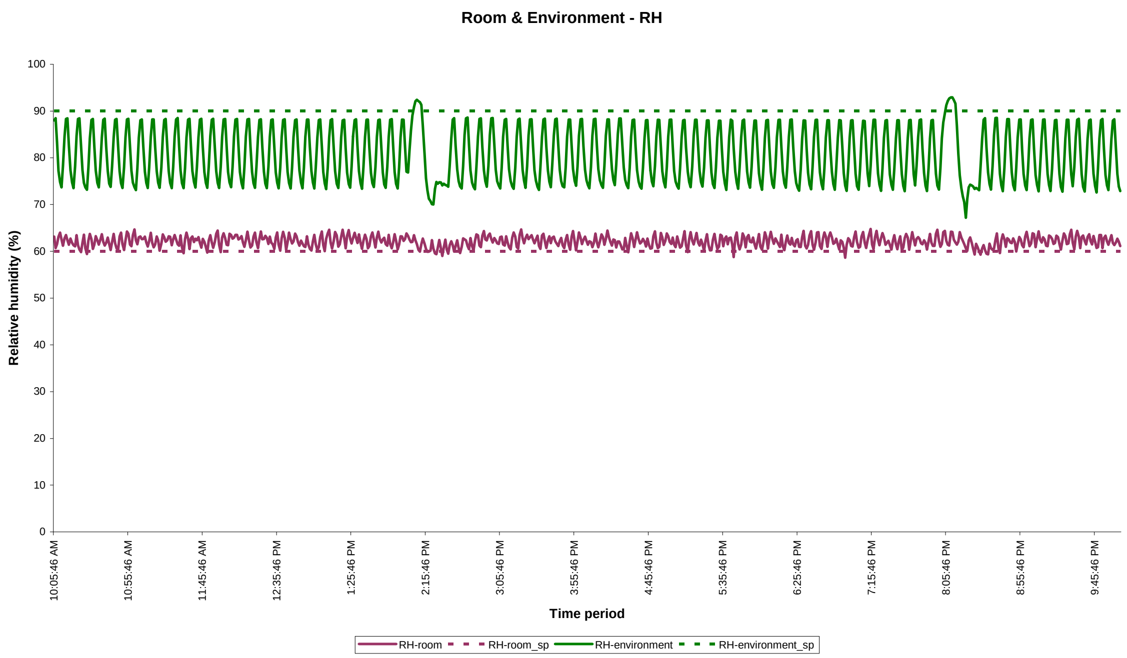


Figure B-198: Relative humidity of the room and environmental side during C2-Alt2

Test cycle: **C2 – Alt3**

Table B-23: Average data during the last 24 hours for each specimen of C2-Alt3

Specimen Measurement Data

B-G	A		B		C		Clay
1	A1_Soil-T	18.856 degC	B1_Soil-T	19.248 degC	C1_Soil-T	20.455 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	100.000 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	18.466 degC	B1_Wall-T	18.927 degC	C1_Wall-T	20.238 degC	
	A1_Ext-T	19.457 degC	B1_Ext-T	18.929 degC	C1_Ext-T	20.083 degC	
	A1_Int-T	18.423 degC	B1_Int-T	17.777 degC	C1_Int-T	18.756 degC	
	A1_Inside-RH	69.532 %	B1_Inside-RH	100.000 %	C1_Inside-RH	100.000 %	
	A1_Wall-RH	84.105 %	B1_Wall-RH	93.842 %	C1_Wall-RH	88.136 %	
2	A2_Soil-T	18.697 degC	B2_Soil-T	18.629 degC	C2_Soil-T	20.272 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	17.916 degC	B2_Wall-T	18.271 degC	C2_Ext-T	19.240 degC	
	A2_Ext-T	18.870 degC	B2_Ext-T	18.042 degC	C2_Int-T	18.496 degC	
	A2_Int-T	17.640 degC	B2_Int-T	17.052 degC	C2_Inside-RH	100.000 %	
	A2_Inside-RH	67.590 %	B2_Inside-RH	97.589 %			
	A2_Wall-RH	68.604 %	B2_Wall-RH	96.712 %			
3	A3_Soil-T	18.703 degC	B3_Soil-T	19.677 degC	C3_Soil-T	19.946 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	17.967 degC	B3_Wall-T	18.363 degC	C3_Ext-T	22.684 degC	
	A3_Ext-T	18.701 degC	B3_Ext-T	18.267 degC	C3_Int-T	18.566 degC	
	A3_Int-T	17.720 degC	B3_Int-T	17.606 degC	C3_Inside-RH	100.000 %	
	A3_Inside-RH	68.170 %	B3_Inside-RH	99.893 %			
	A3_Wall-RH	72.393 %	B3_Wall-RH	81.381 %	*Pressure diff.	*81.752 Pa*	
Yes	A		B		C		Alt3

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	18.895 degC
RH-room	63.570 %
T-room_sp	20.000 degC
RH-room_sp	60.000 %
T-environment	19.571 degC
RH-environment	85.679 %
T-environment_sp	20.000 degC
RH-environment_sp	90.000 %

Remarks

Type: B-G
Soil type: Clay
Dampproofing: Yes
Alternative: Alt3

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

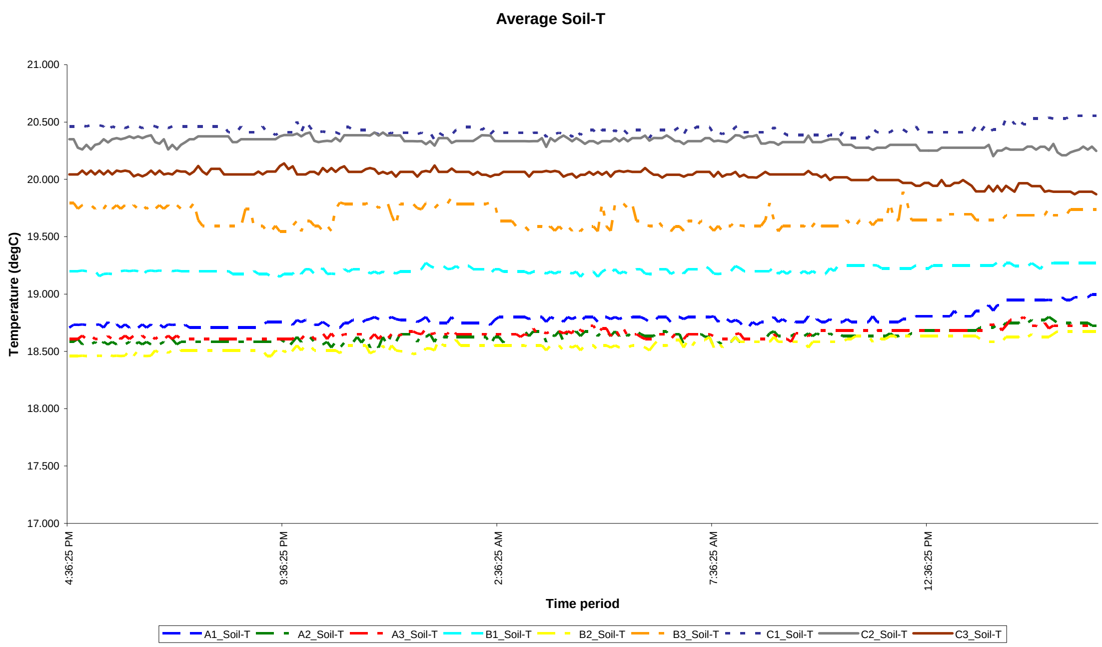


Figure B-199: Average soil temperature of C2-Alt3

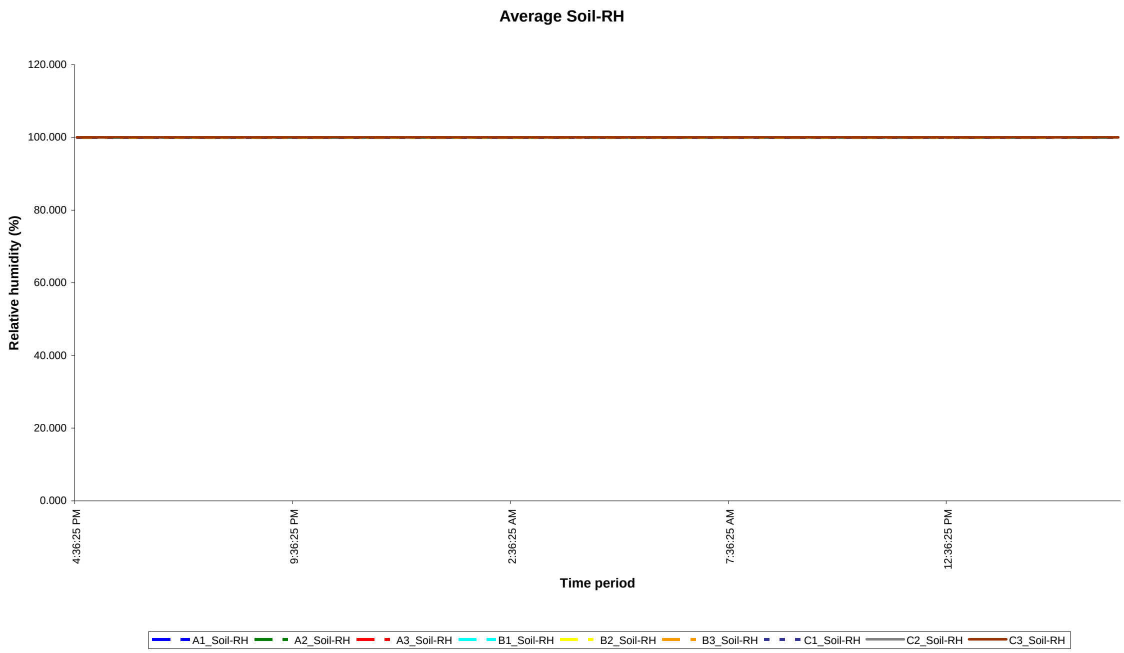


Figure B-200: Average soil relative humidity of C2-Alt3

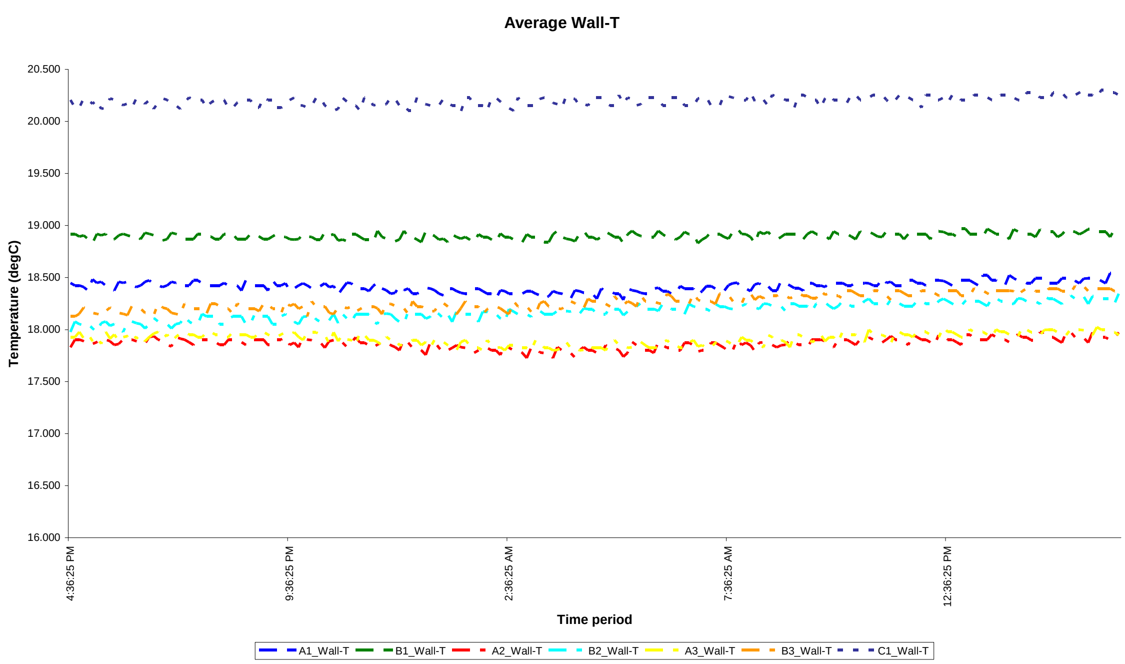


Figure B-201: Average wall temperature of C2-Alt3

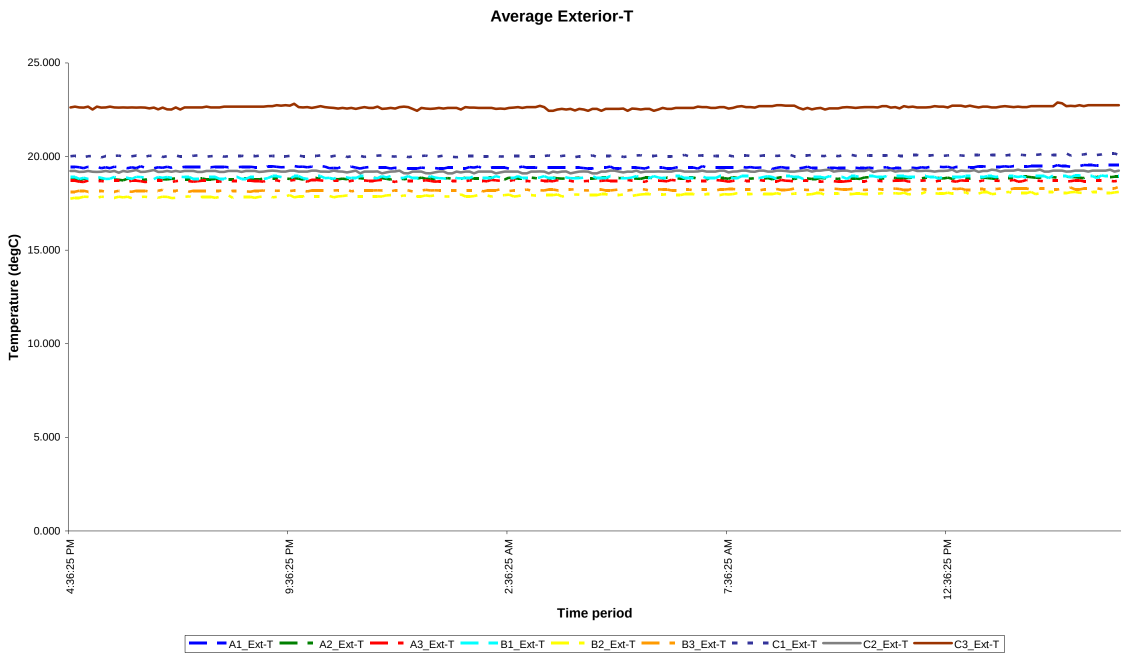


Figure B-202: Average exterior temperature of C2-Alt3

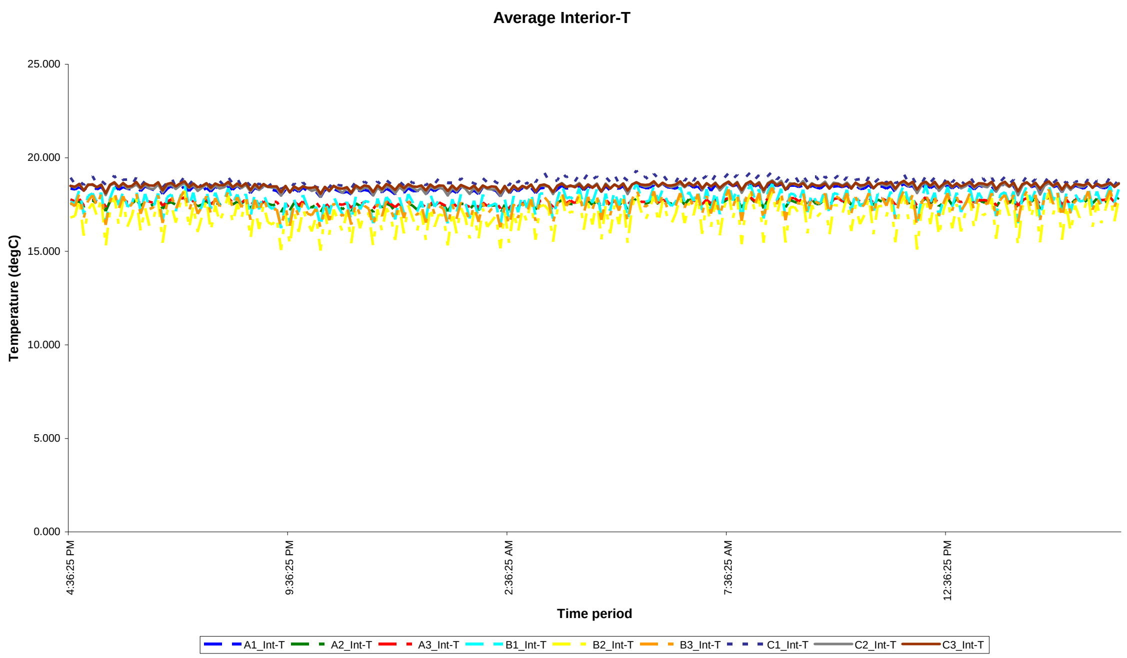


Figure B-203: Average interior temperature of C2-Alt3

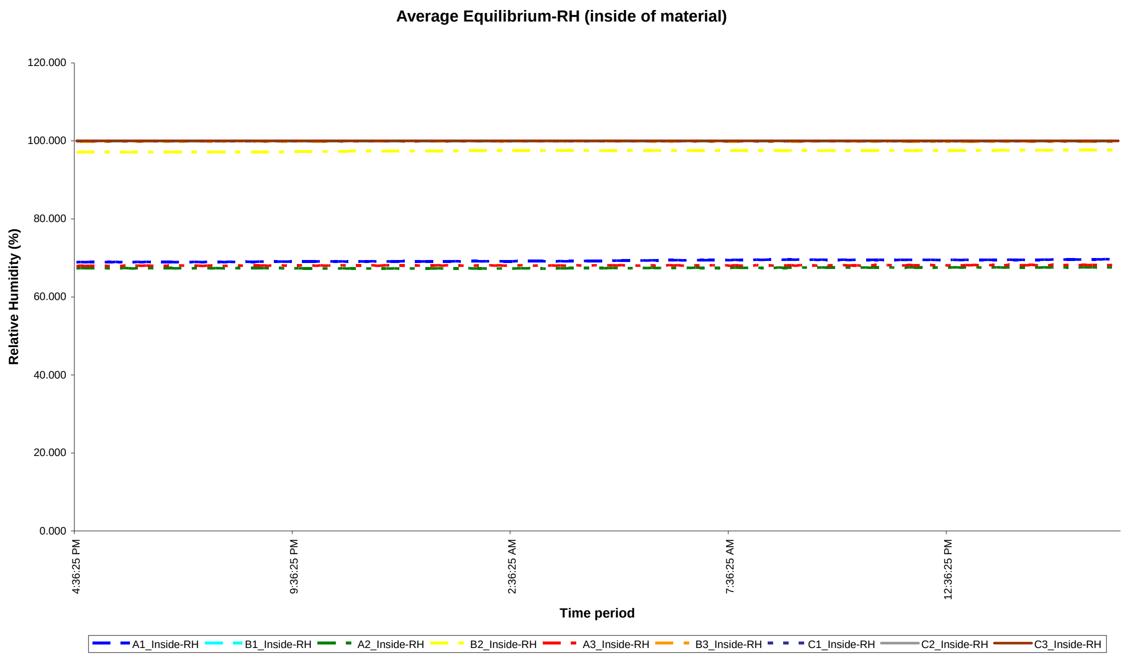


Figure B-204: Average equilibrium of relative humidity in a cavity of C2-Alt3

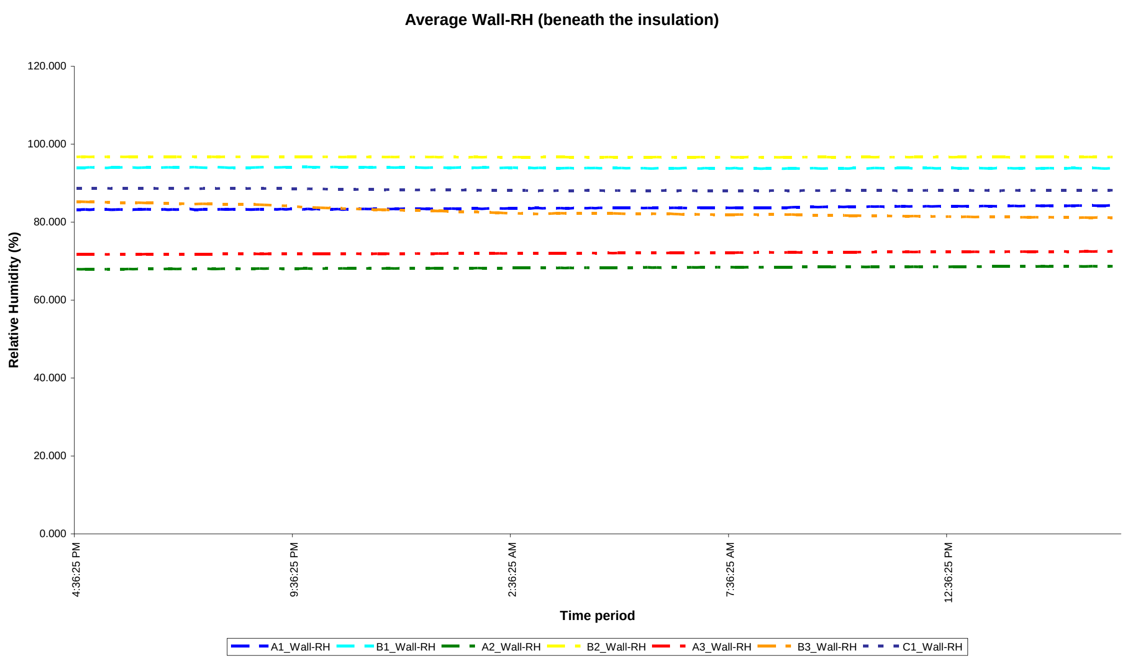


Figure B-205: Average wall relative humidity beneath the insulation of C2-Alt3

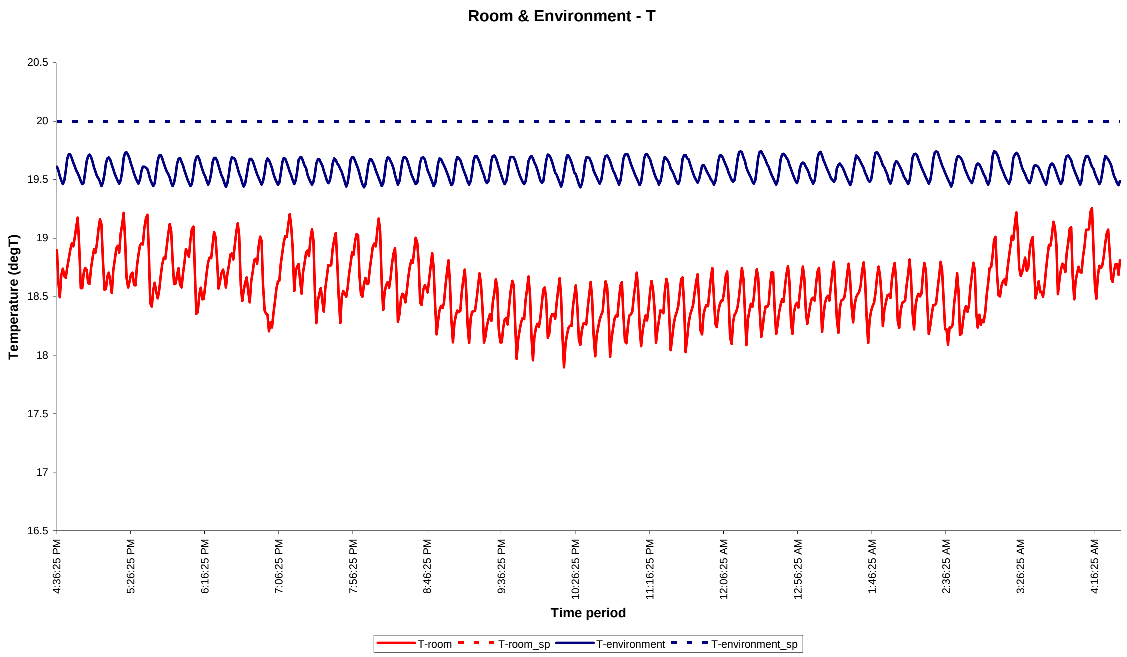


Figure B-206: Temperature of the room and environmental side during C2-Alt3

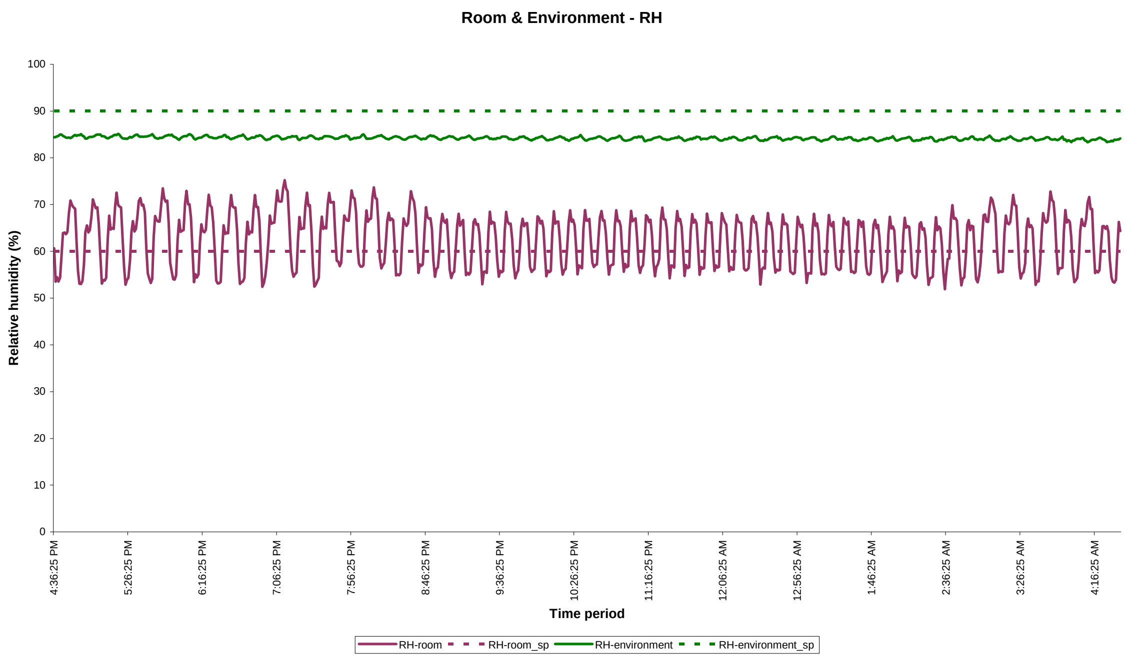


Figure B-207: Relative humidity of the room and environmental side during C2-Alt3

Test cycle: **C2 – Alt4**

Table B-24: Average data during the last 24 hours for each specimen of C2-Alt4

Specimen Measurement Data

B-G	A		B		C		Clay
1	A1_Soil-T	18.861 degC	B1_Soil-T	19.355 degC	C1_Soil-T	20.604 degC	1
	A1_Soil-RH	100.000 %	B1_Soil-RH	100.000 %	C1_Soil-RH	100.000 %	
	A1_Wall-T	18.607 degC	B1_Wall-T	19.215 degC	C1_Wall-T	20.322 degC	
	A1_Ext-T	19.952 degC	B1_Ext-T	19.174 degC	C1_Ext-T	20.171 degC	
	A1_Int-T	18.485 degC	B1_Int-T	17.965 degC	C1_Int-T	19.153 degC	
	A1_Inside-RH	67.821 %	B1_Inside-RH	100.000 %	C1_Inside-RH	100.000 %	
	A1_Wall-RH	84.350 %	B1_Wall-RH	88.876 %	C1_Wall-RH	81.855 %	
2	A2_Soil-T	18.740 degC	B2_Soil-T	18.808 degC	C2_Soil-T	20.458 degC	2
	A2_Soil-RH	100.000 %	B2_Soil-RH	100.000 %	C2_Soil-RH	100.000 %	
	A2_Wall-T	17.983 degC	B2_Wall-T	18.728 degC	C2_Ext-T	19.549 degC	
	A2_Ext-T	19.147 degC	B2_Ext-T	18.501 degC	C2_Int-T	18.855 degC	
	A2_Int-T	17.624 degC	B2_Int-T	17.005 degC	C2_Inside-RH	99.482 %	
	A2_Inside-RH	62.601 %	B2_Inside-RH	97.013 %			
	A2_Wall-RH	68.342 %	B2_Wall-RH	86.105 %			
3	A3_Soil-T	18.746 degC	B3_Soil-T	19.366 degC	C3_Soil-T	20.104 degC	3
	A3_Soil-RH	100.000 %	B3_Soil-RH	100.000 %	C3_Soil-RH	100.000 %	
	A3_Wall-T	17.826 degC	B3_Wall-T	18.628 degC	C3_Ext-T	21.605 degC	
	A3_Ext-T	18.774 degC	B3_Ext-T	18.547 degC	C3_Int-T	18.482 degC	
	A3_Int-T	17.469 degC	B3_Int-T	16.977 degC	C3_Inside-RH	99.656 %	
	A3_Inside-RH	62.177 %	B3_Inside-RH	92.851 %			
	A3_Wall-RH	71.583 %	B3_Wall-RH	55.787 %	**Pressure diff.*	*17.024 Pa*	
Yes	A		B		C		Alt4

* Measured pressure difference between Room Side & Environmental Side

Control Loop Data

Environmental / Room Side	
T-room	19.216 degC
RH-room	42.715 %
T-room_sp	20.000 degC
RH-room_sp	30.000 %
T-environment	19.528 degC
RH-environment	74.025 %
T-environment_sp	20.000 degC
RH-environment_sp	90.000 %

Remarks

Type: B-G
Soil type: Clay
Dampproofing: Yes
Alternative: Alt4

Legend

T - Temperature (degC)
RH - Relative Humidity (%)
SP - Setpoint (either T or RH)

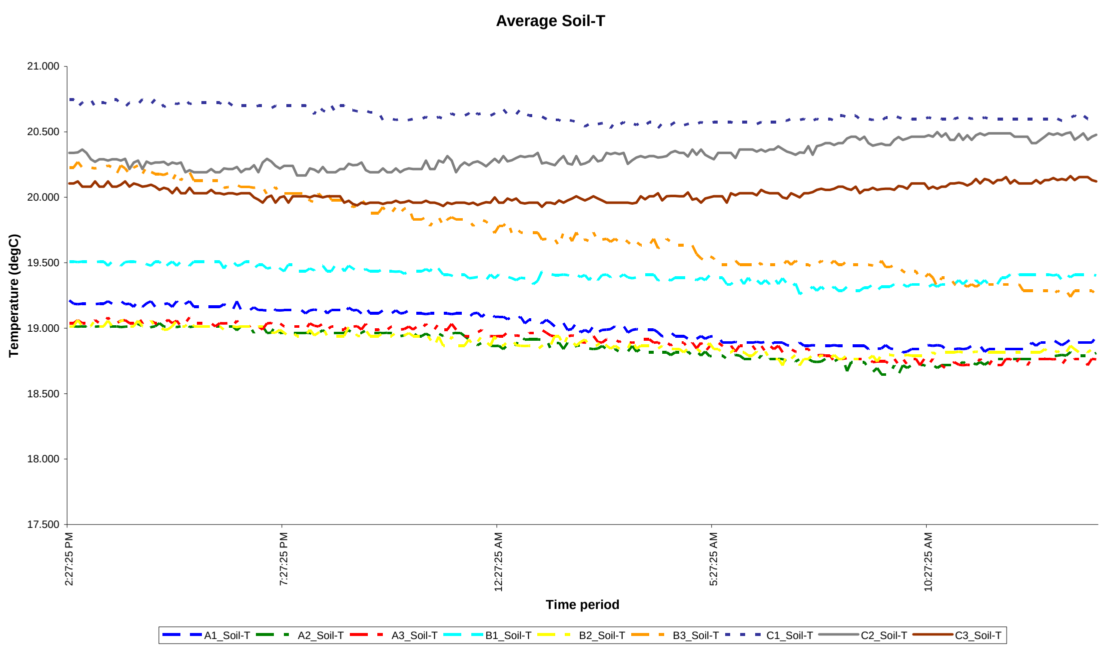


Figure B-208: Average soil temperature of C2-Alt4

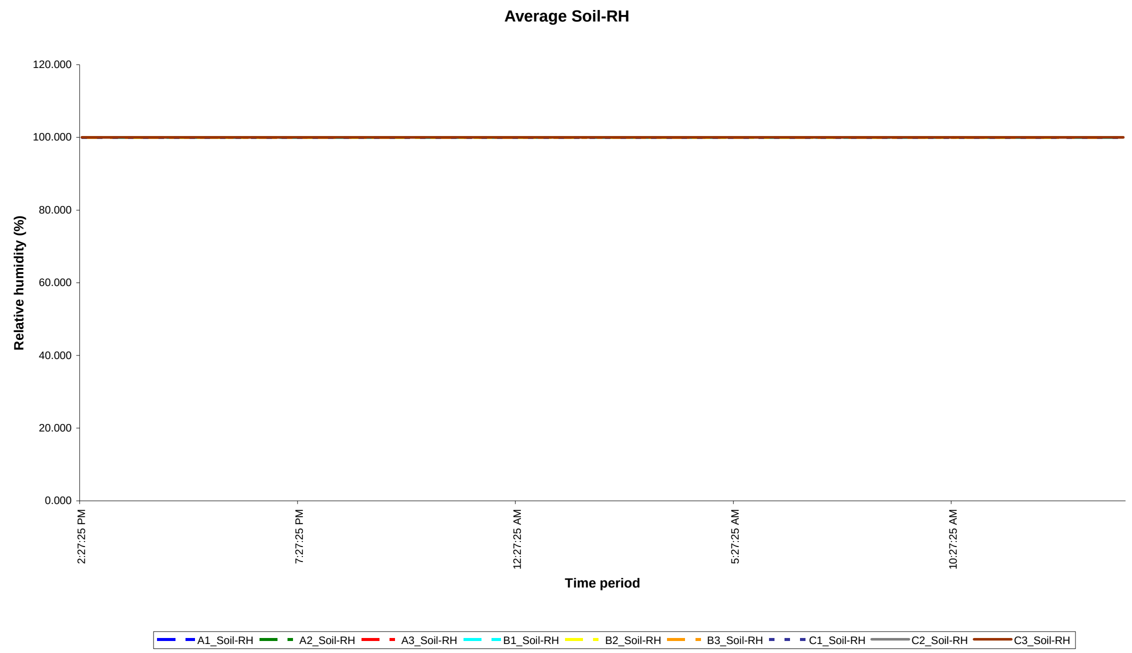


Figure B-209: Average soil relative humidity of C2-Alt4

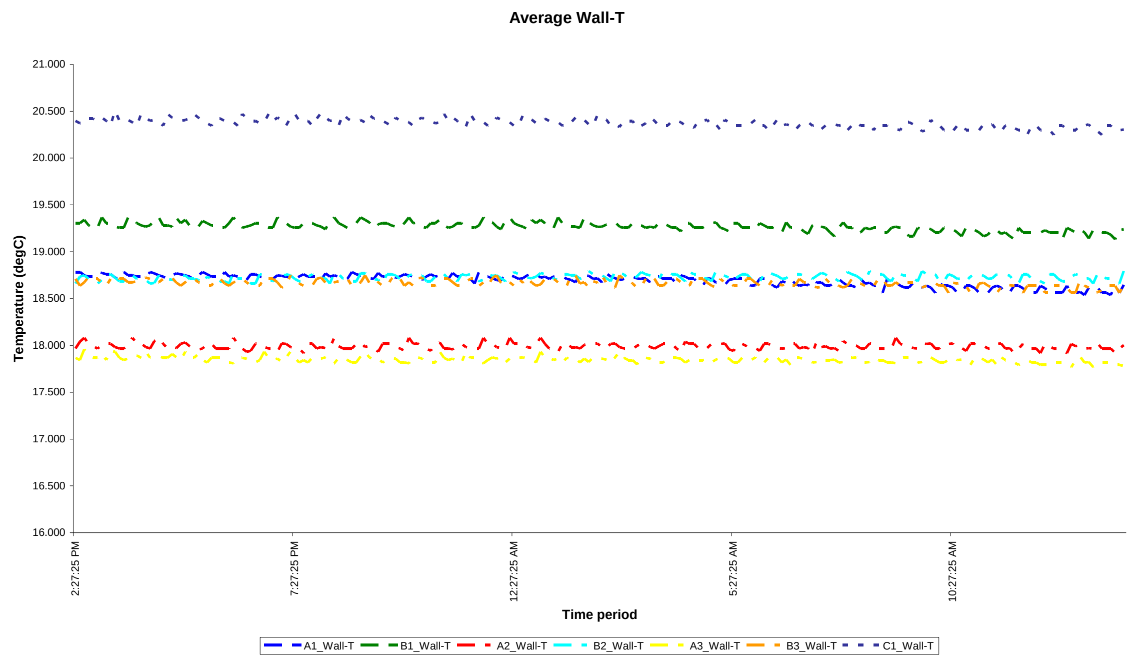


Figure B-210: Average wall temperature of C2-Alt4

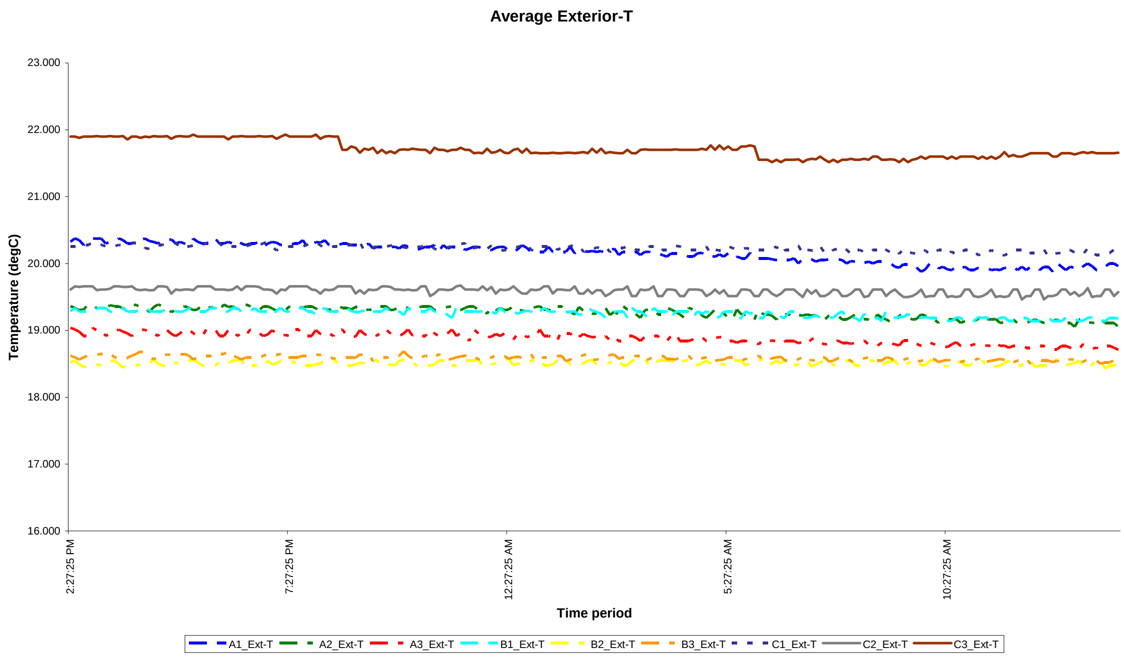


Figure B-211: Average exterior temperature of C2-Alt4

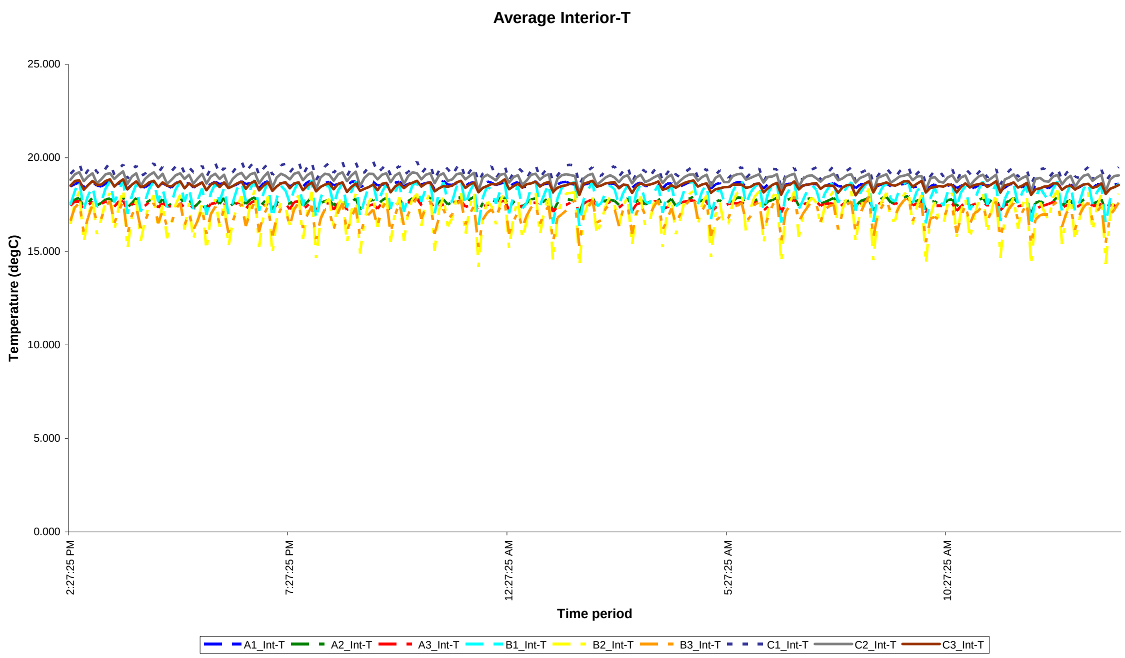


Figure B-212: Average interior temperature of C2-Alt4

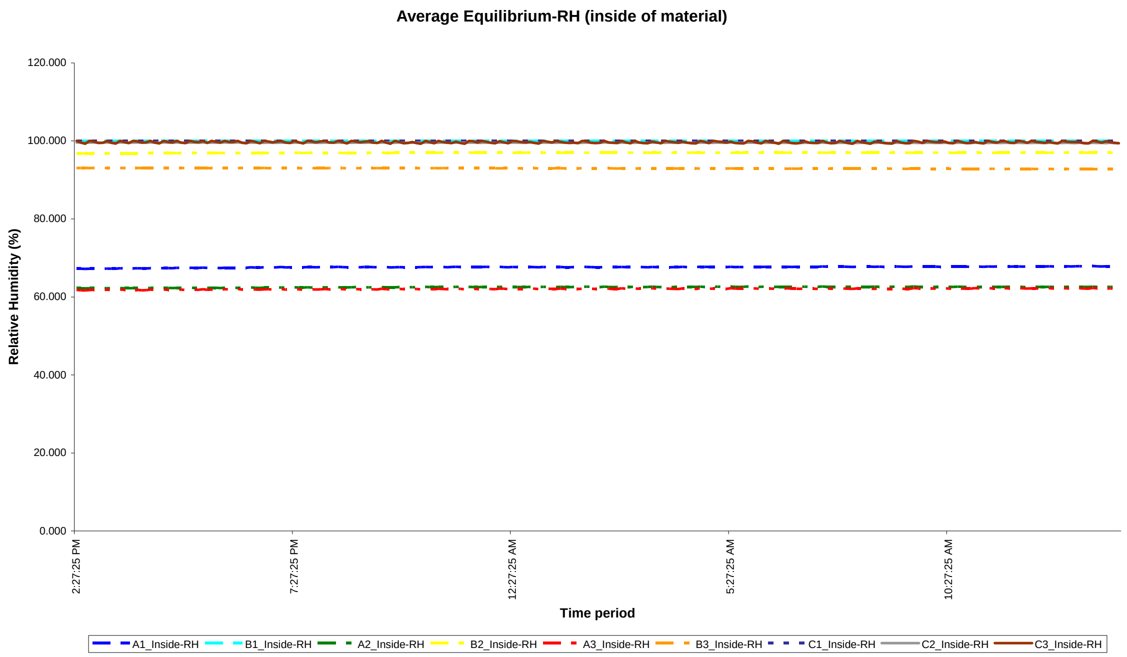


Figure B-213: Average equilibrium of relative humidity in a cavity of C2-Alt4

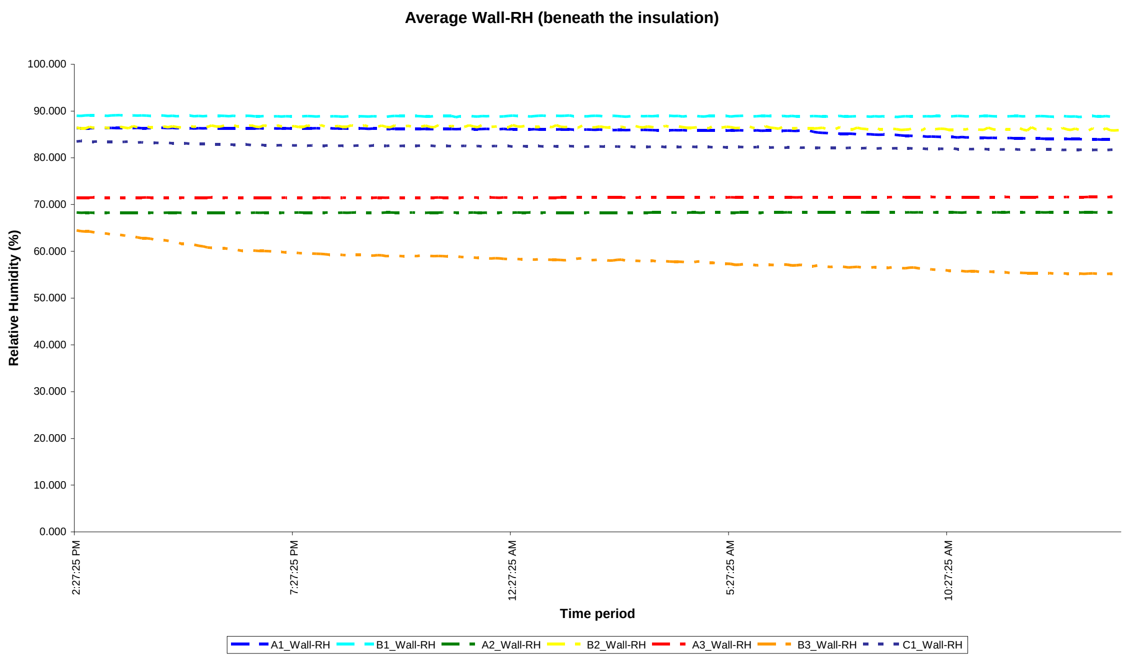


Figure B-214: Average wall relative humidity beneath the insulation of C2-Alt4

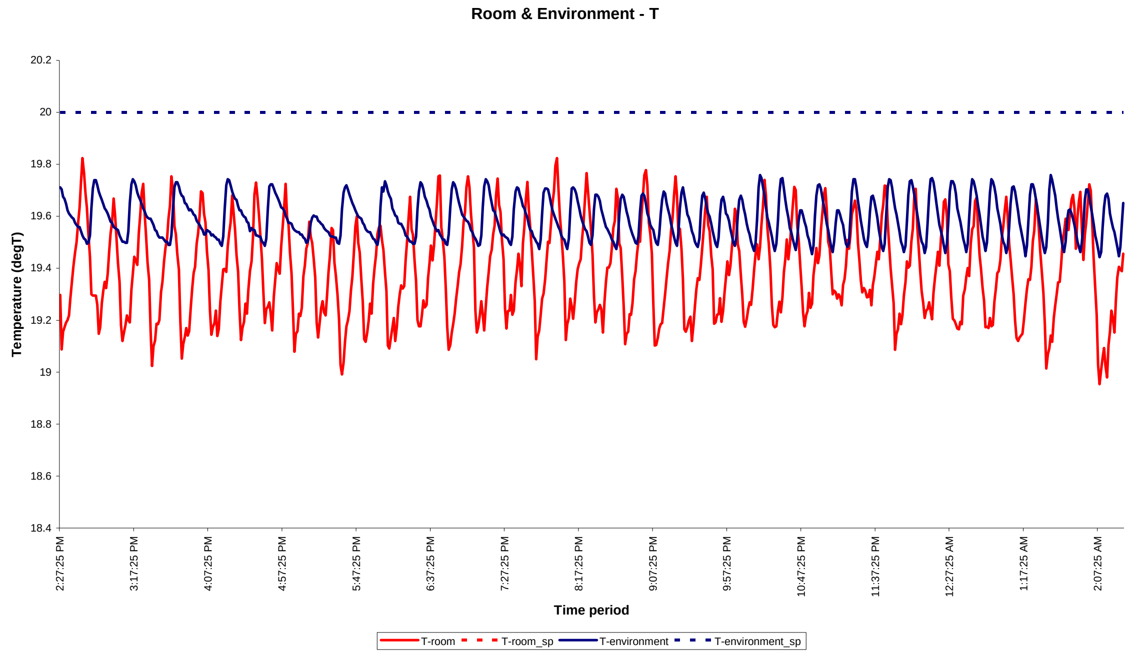


Figure B-215: Temperature of the room and environmental side during C2-Alt4

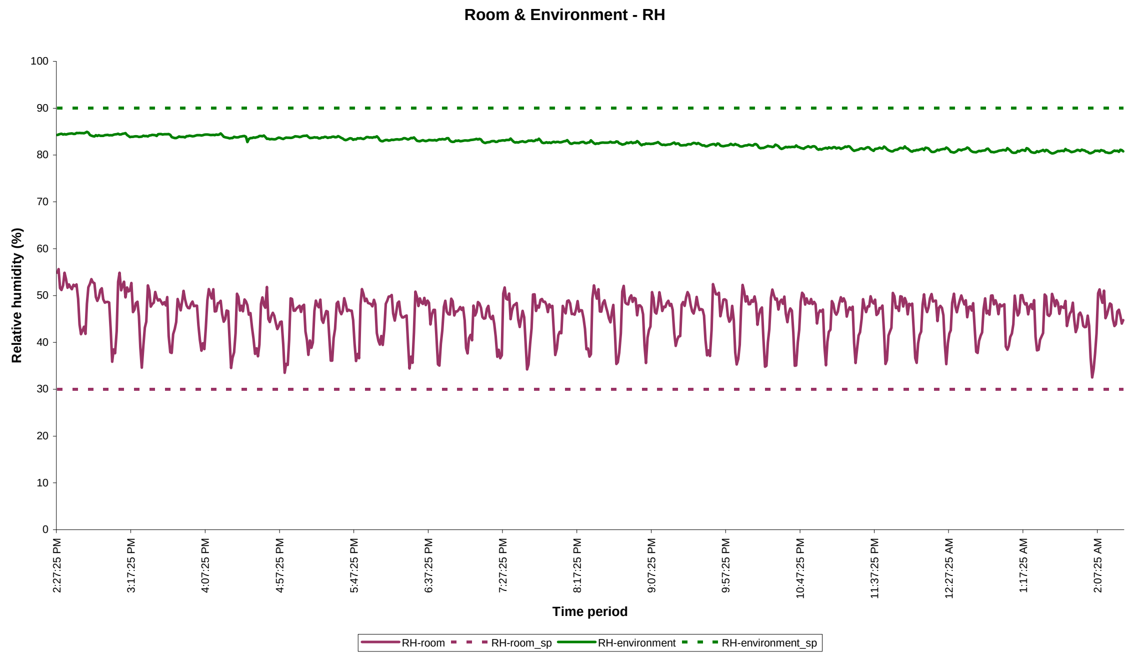
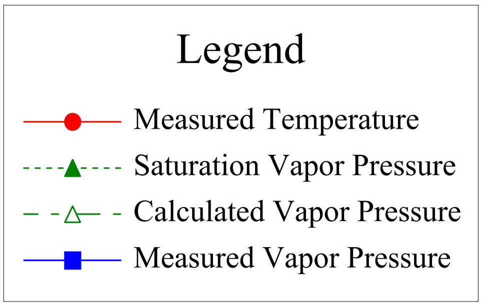


Figure B-216: Relative humidity of the room and environmental side during C2-Alt4

Appendix C – Measurement evaluations

The measured data are graphically summarized in appendix C. Wall fragments depicted, using dew-point method, are shown below. The legend of measured and depicted values is following:



Wall fragments evaluation is shown according to the following order:

1. Measurement series: S1
   1.1. Test cycle: S1-Alt1
   1.2. Test cycle: S1-Alt2
   1.3. Test cycle: S1-Alt3
   1.4. Test cycle: S1-Alt4
   1.5. Test cycle: S1-Alt5
   1.6. Test cycle: S1-Alt6
   1.7. Test cycle: S1-Alt7
   1.8. Test cycle: S1-Alt8
2. Measurement series: S2
   2.1. Test cycle: S2-Alt1
   2.2. Test cycle: S2-Alt2
   2.3. Test cycle: S2-Alt3
   2.4. Test cycle: S2-Alt4
3. Measurement series: C1
   3.1. Test cycle: C1-Alt1
   3.2. Test cycle: C1-Alt2
   3.3. Test cycle: C1-Alt3
   3.4. Test cycle: C1-Alt4
   3.5. Test cycle: C1-Alt5
   3.6. Test cycle: C1-Alt6
   3.7. Test cycle: C1-Alt7
   3.8. Test cycle: C1-Alt8
4. Measurement series: C2
   4.1. Test cycle: C2-Alt1
   4.2. Test cycle: C2-Alt2
   4.3. Test cycle: C2-Alt3
   4.4. Test cycle: C2-Alt4

Measurement series: **S1**

Test cycle: **S1 – Alt1**

Measurement series: **C1**

Test cycle: **C1 – Alt1**

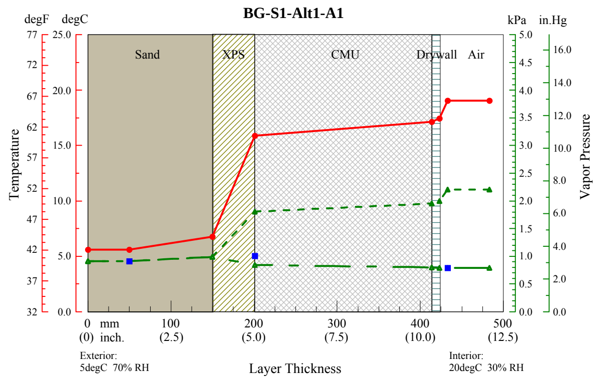


Figure C-1: Wall diagram of S1-Alt1-A1

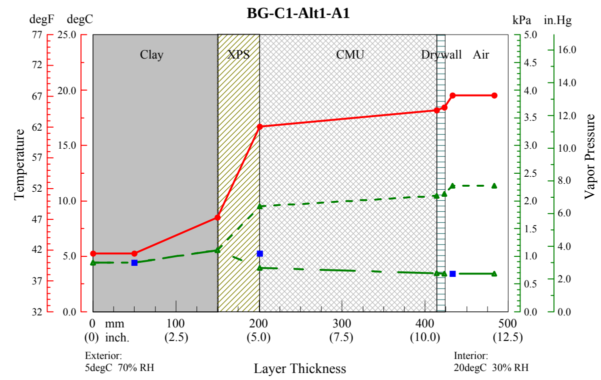


Figure C-2: Wall diagram of C1-Alt1-A1

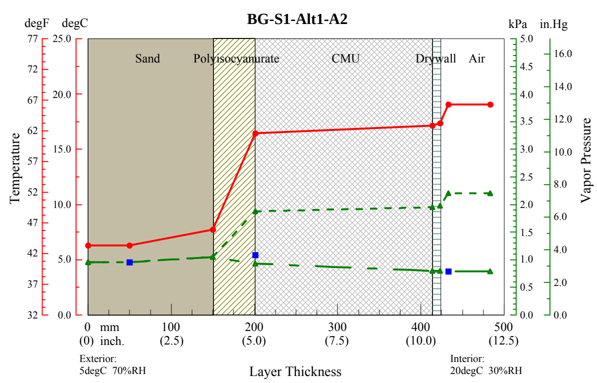


Figure C-3: Wall diagram of S1-Alt1-A2

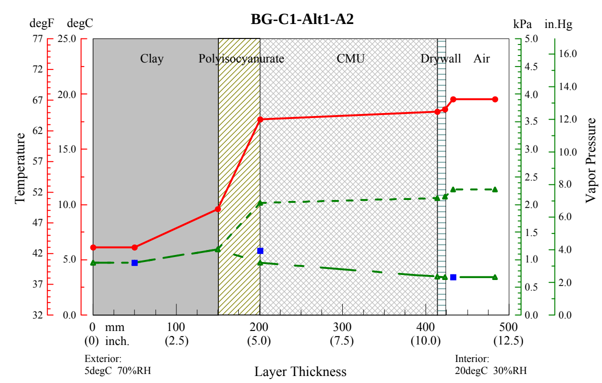


Figure C-4: Wall diagram of C1-Alt1-A2

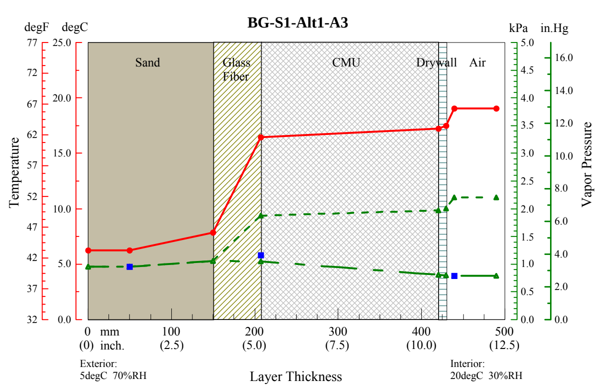


Figure C-5: Wall diagram of S1-Alt1-A3

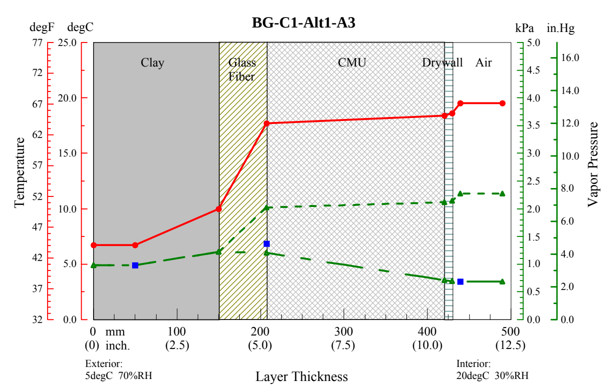


Figure C-6: Wall diagram of C1-Alt1-A3

Test cycle: **S1 – Alt1 (continued)**

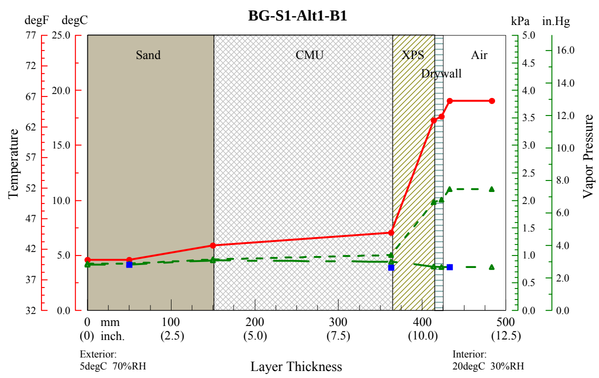


Figure C-7: Wall diagram of S1-Alt1-B1

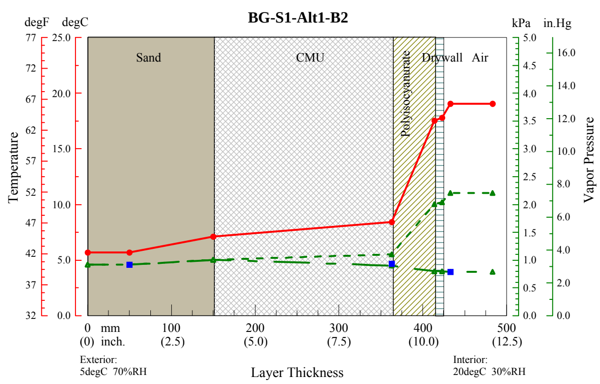


Figure C-9: Wall diagram of S1-Alt1-B2

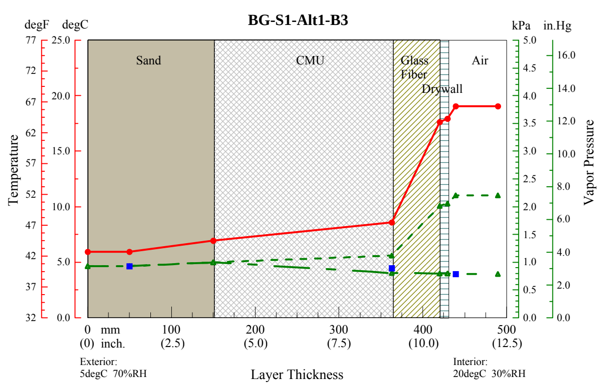


Figure C-11: Wall diagram of S1-Alt1-B3

Test cycle: **C1 – Alt1 (continued)**

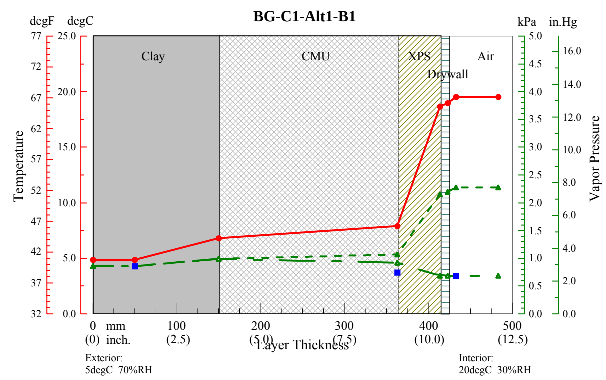


Figure C-8: Wall diagram of C1-Alt1-B1

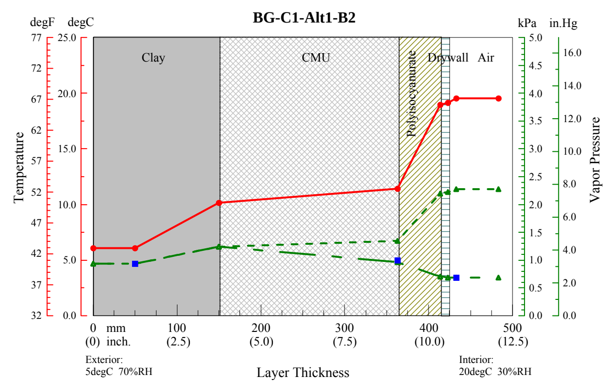


Figure C-10: Wall diagram of C1-Alt1-B2

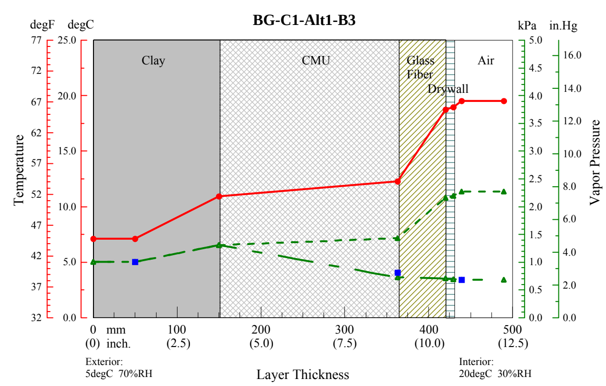


Figure C-12: Wall diagram of C1-Alt1-B3

Test cycle: **S1 – Alt1 (continued)**

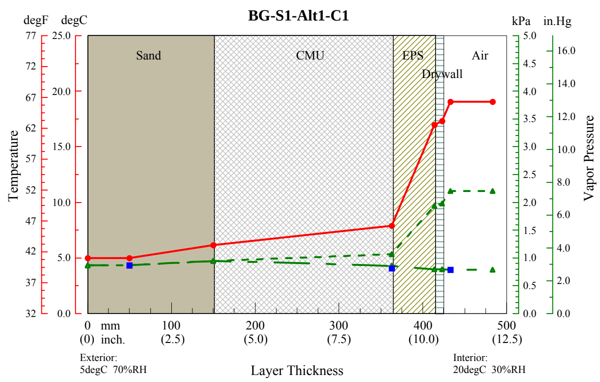


Figure C-13: Wall diagram of S1-Alt1-C1

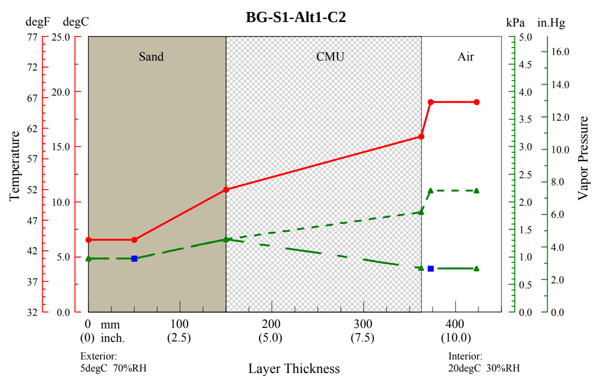


Figure C-15: Wall diagram of S1-Alt1-C2

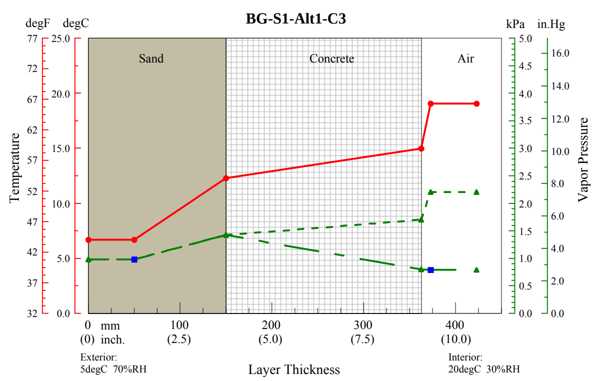


Figure C-17: Wall diagram of S1-Alt1-C3

Test cycle: **C1 – Alt1 (continued)**

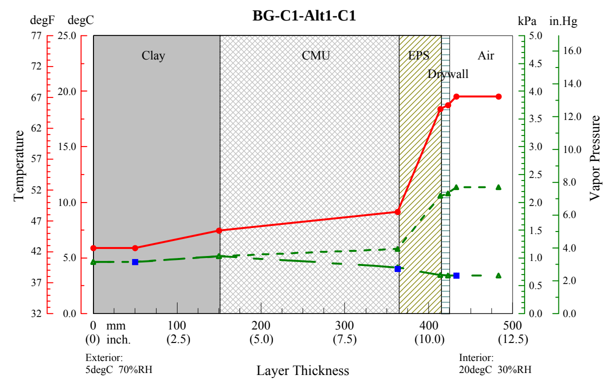


Figure C-14: Wall diagram of C1-Alt1-C1

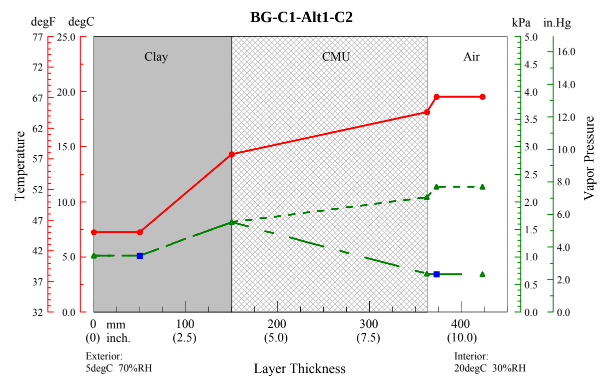


Figure C-16: Wall diagram of C1-Alt1-C2

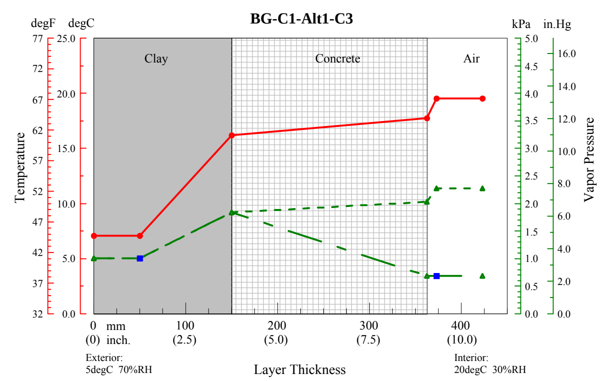


Figure C-18: Wall diagram of C1-Alt1-C3

Test cycle: **S1 – Alt2**

Test cycle: **C1 – Alt2**

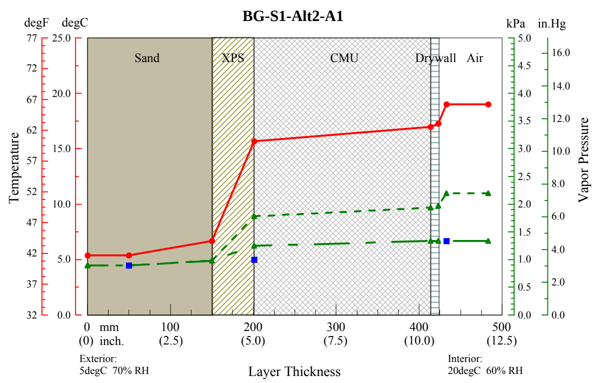


Figure C-19: Wall diagram of S1-Alt2-A1

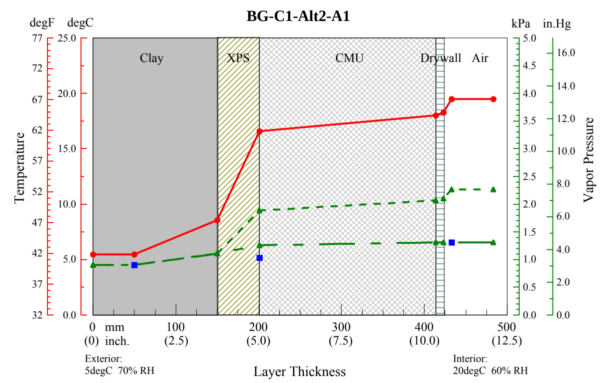


Figure C-20: Wall diagram of C1-Alt2-A1

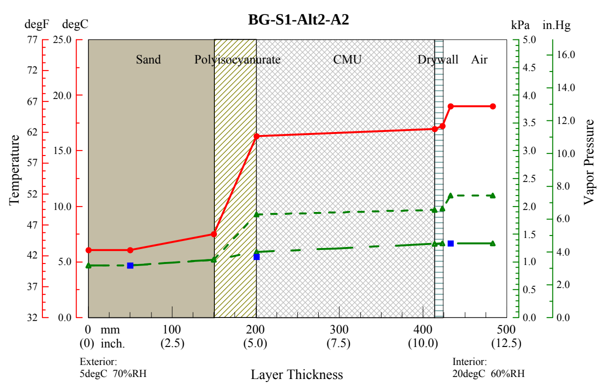


Figure C-21: Wall diagram of S1-Alt2-A2

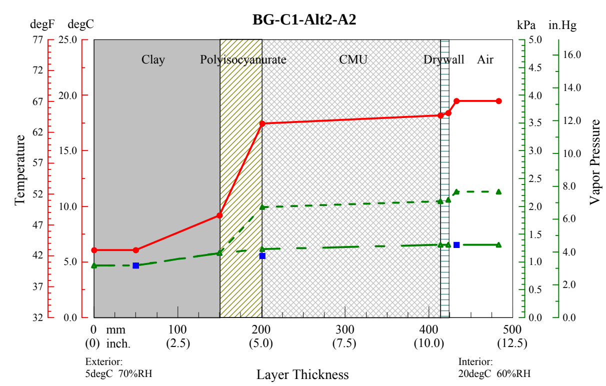


Figure C-22: Wall diagram of C1-Alt2-A2

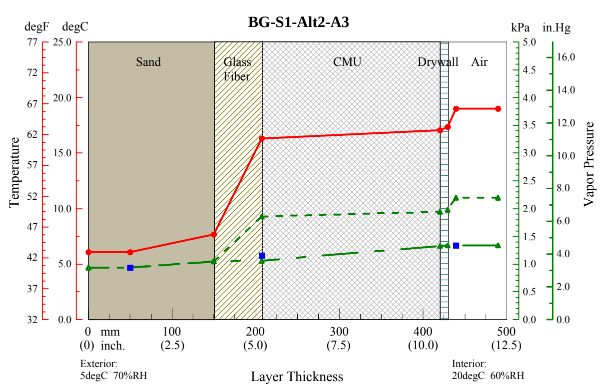


Figure C-23: Wall diagram of S1-Alt2-A3

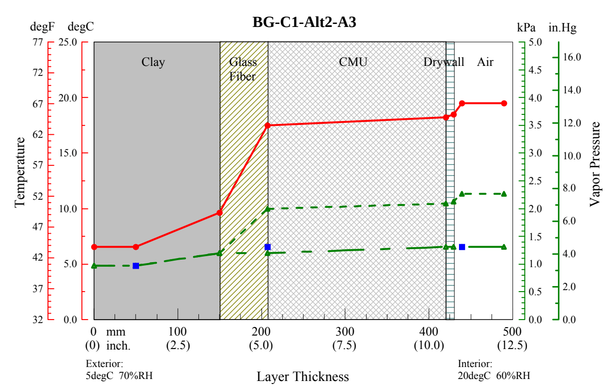


Figure C-24: Wall diagram of C1-Alt2-A3

Test cycle: **S1 – Alt2 (continued)**

Test cycle: **C1 – Alt2 (continued)**

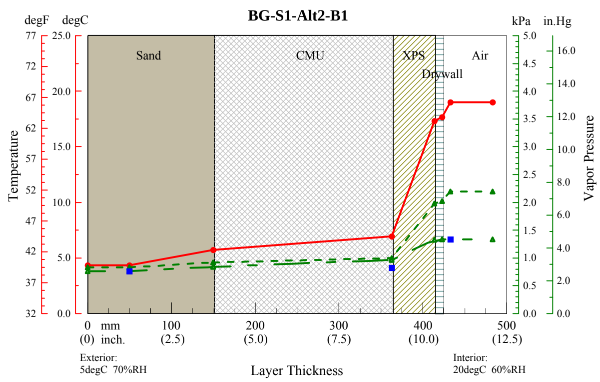


Figure C-25: Wall diagram of S1-Alt2-B1

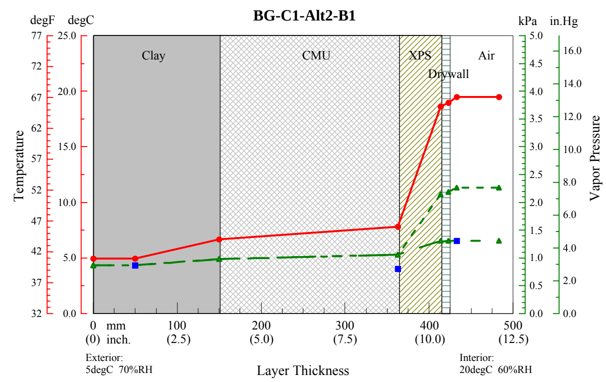


Figure C-26: Wall diagram of C1-Alt2-B1

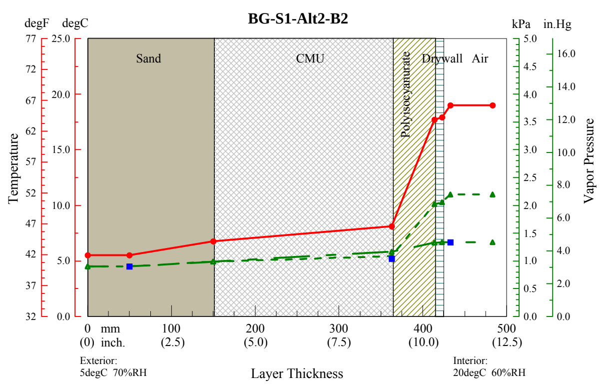


Figure C-27: Wall diagram of S1-Alt2-B2

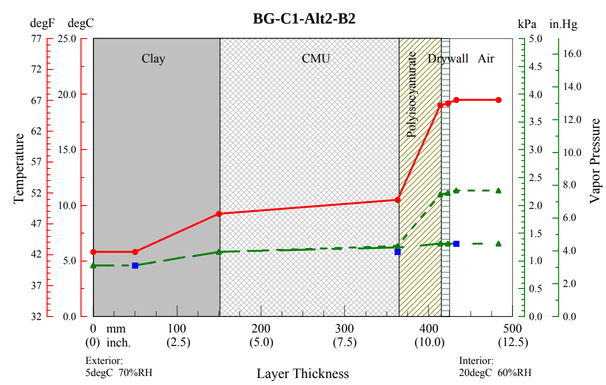


Figure C-28: Wall diagram of C1-Alt2-B2

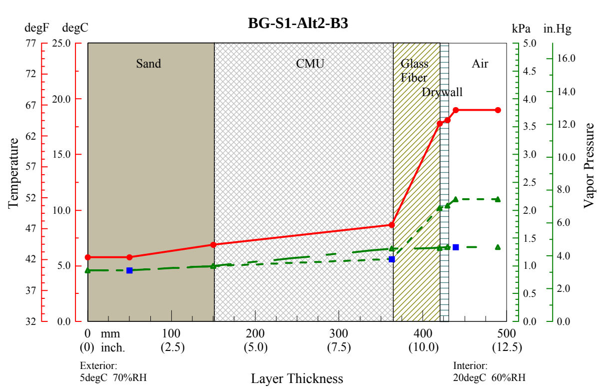


Figure C-29: Wall diagram of S1-Alt2-B3

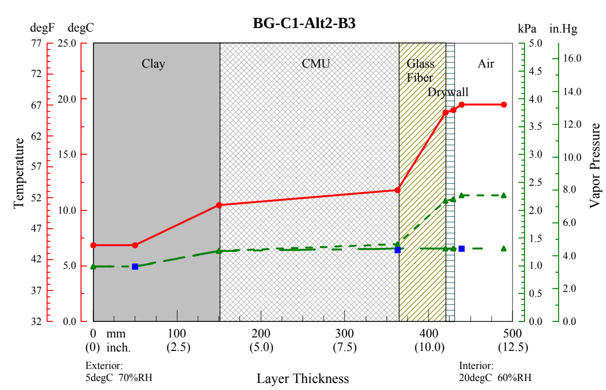


Figure C-30: Wall diagram of C1-Alt2-B3

Test cycle: **S1 – Alt2 (continued)**

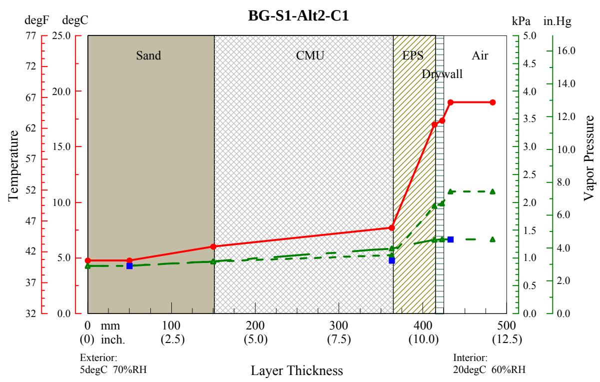


Figure C-31: Wall diagram of S1-Alt2-C1

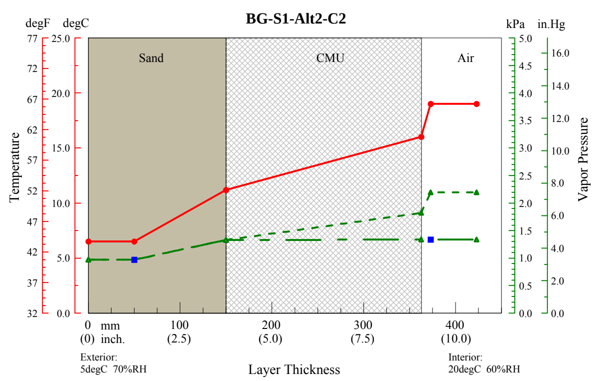


Figure C-33: Wall diagram of S1-Alt2-C2

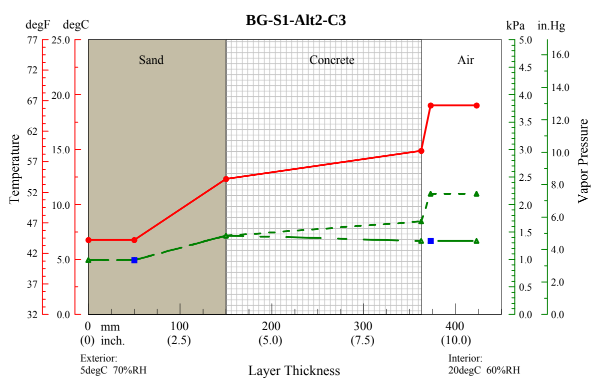


Figure C-35: Wall diagram of S1-Alt2-C3

Test cycle: **C1 – Alt2 (continued)**

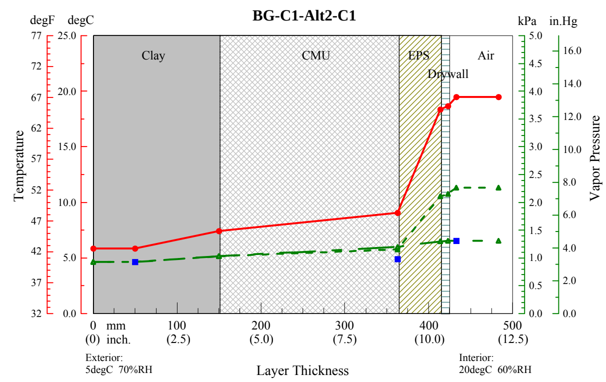


Figure C-32: Wall diagram of C1-Alt2-C1

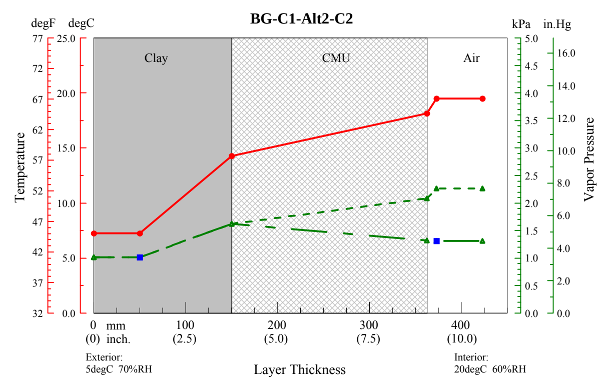


Figure C-34: Wall diagram of C1-Alt2-C2

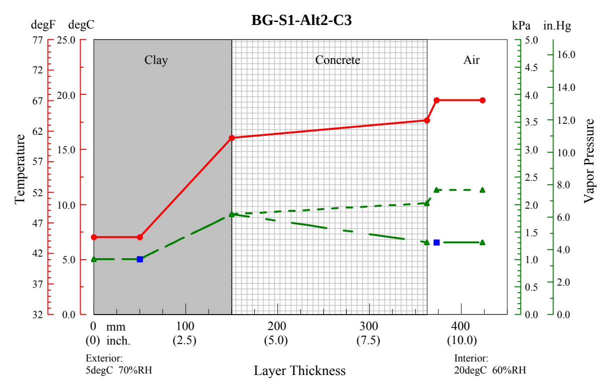


Figure C-36: Wall diagram of C1-Alt2-C3

Test cycle: **S1 – Alt3**

Test cycle: **C1 – Alt3**

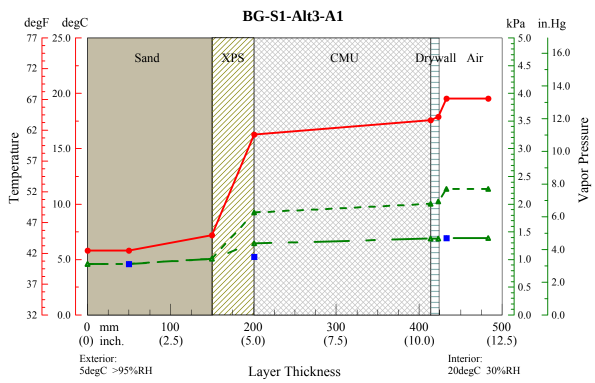


Figure C-37: Wall diagram of S1-Alt3-A1

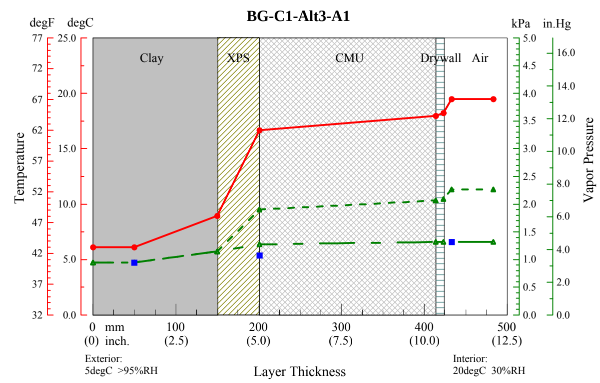


Figure C-38: Wall diagram of C1-Alt3-A1

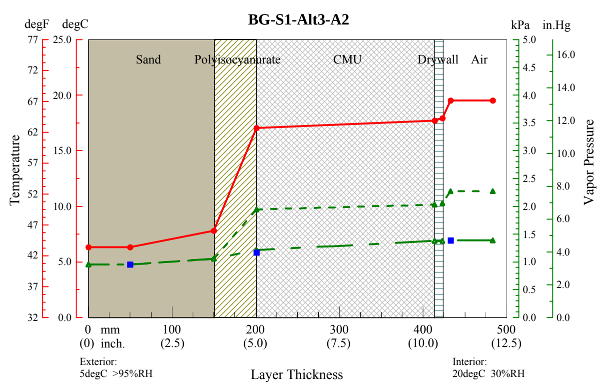


Figure C-39: Wall diagram of S1-Alt3-A2

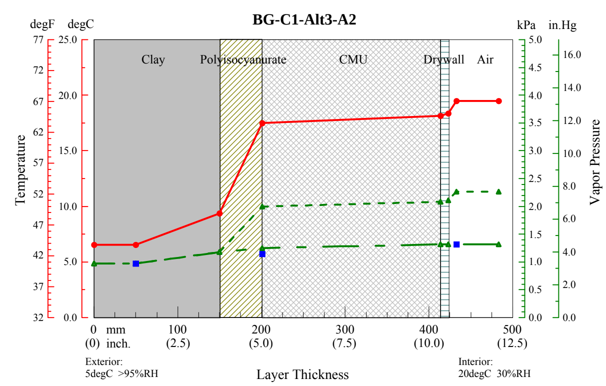


Figure C-40: Wall diagram of C1-Alt3-A2

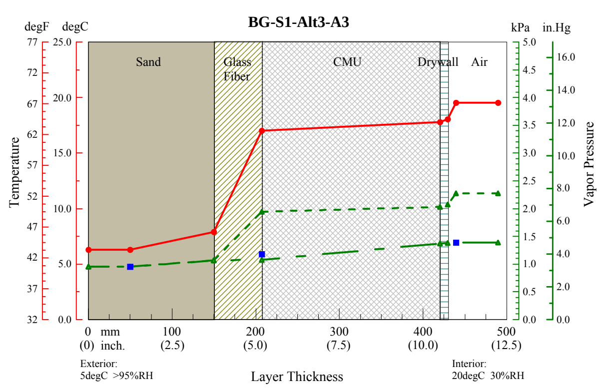


Figure C-41: Wall diagram of S1-Alt3-A3

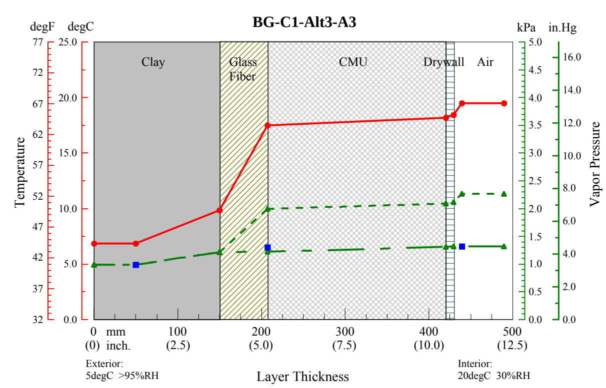


Figure C-42: Wall diagram of C1-Alt3-A3

Test cycle: S1 – Alt3 (continued)

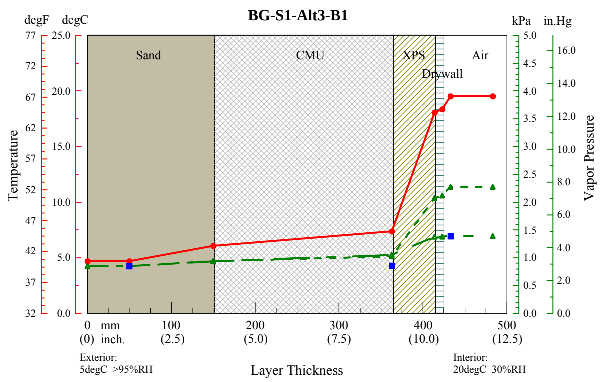


Figure C-43: Wall diagram of S1-Alt3-B1

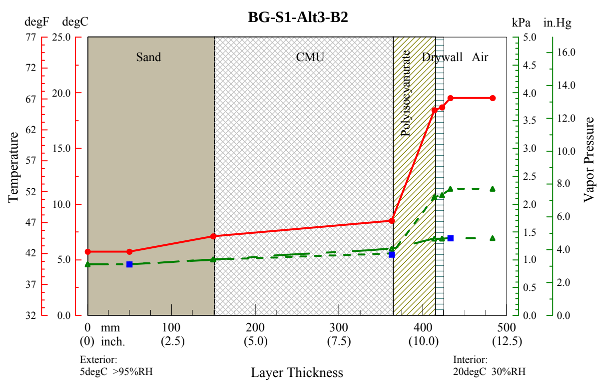


Figure C-45: Wall diagram of S1-Alt3-B2

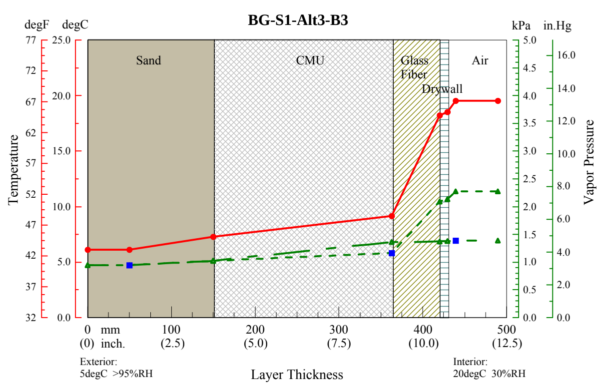


Figure C-47: Wall diagram of S1-Alt3-B3

Test cycle: C1 – Alt3 (continued)

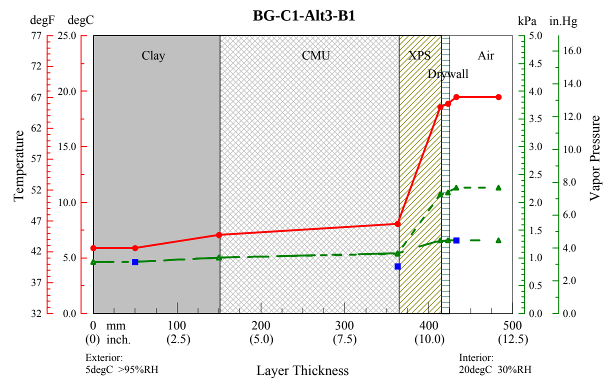


Figure C-44: Wall diagram of C1-Alt3-B1

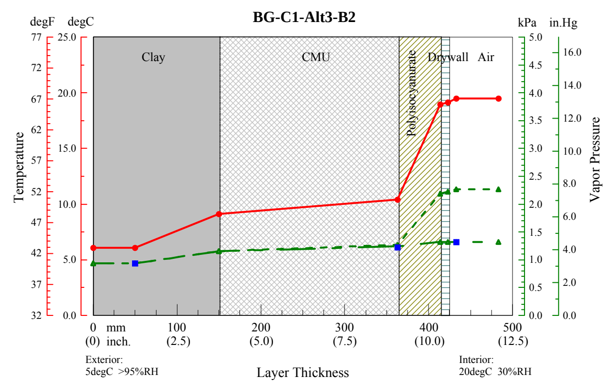


Figure C-46: Wall diagram of C1-Alt3-B2

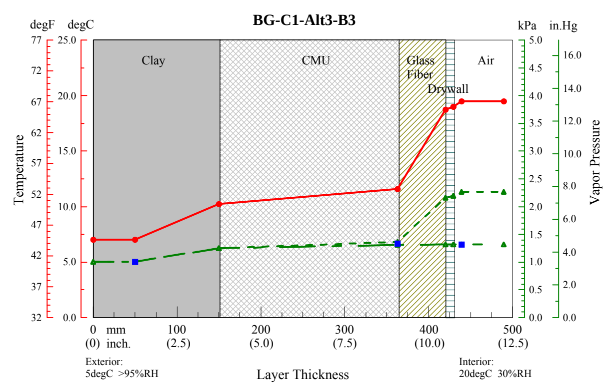


Figure C-48: Wall diagram of C1-Alt3-B3

Test cycle: **S1 – Alt3 (continued)**

Test cycle: **C1 – Alt3 (continued)**

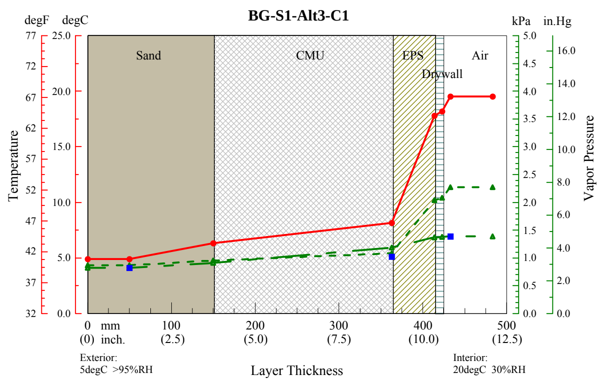


Figure C-49: Wall diagram of S1-Alt3-C1

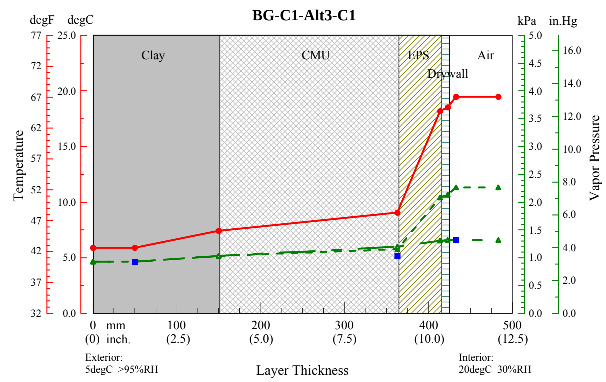


Figure C-50: Wall diagram of C1-Alt3-C1

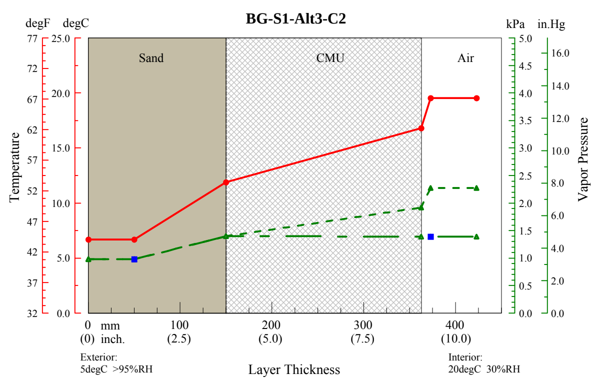


Figure C-51: Wall diagram of S1-Alt3-C2

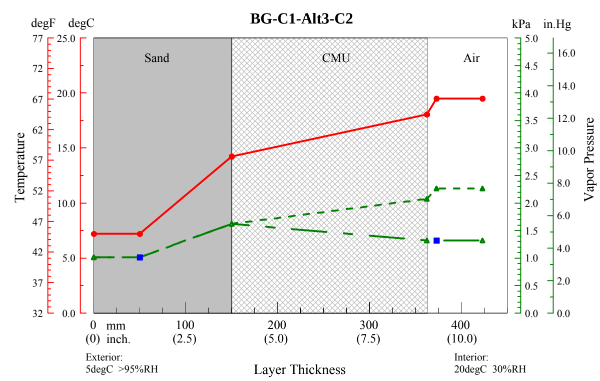


Figure C-52: Wall diagram of C1-Alt3-C2

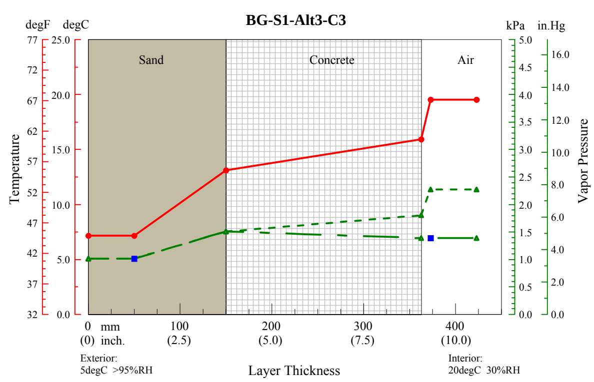


Figure C-53: Wall diagram of S1-Alt3-C3

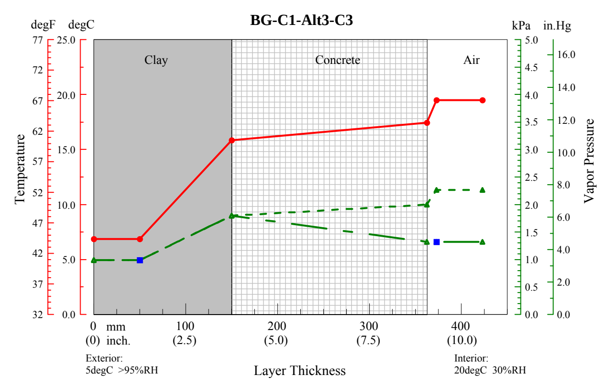


Figure C-54: Wall diagram of C1-Alt3-C3

Test cycle: **S1 – Alt4**

Test cycle: **C1 – Alt4**

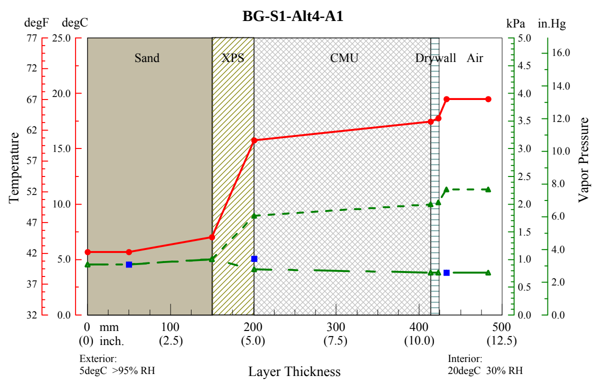


Figure C-55: Wall diagram of S1-Alt4-A1

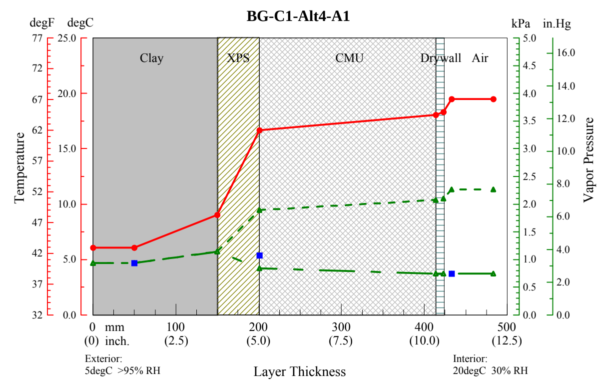


Figure C-56: Wall diagram of C1-Alt4-A1

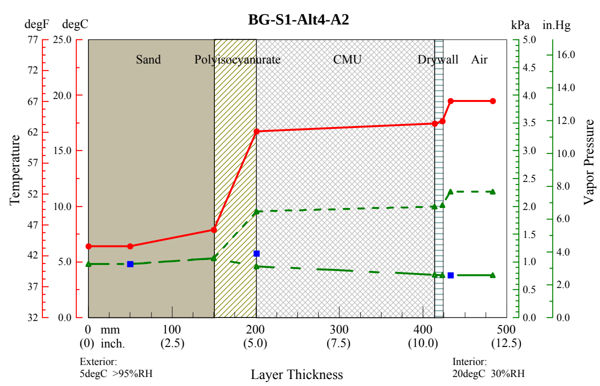


Figure C-57: Wall diagram of S1-Alt4-A2

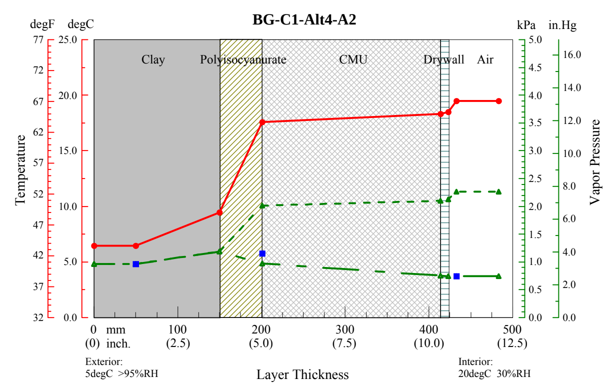


Figure C-58: Wall diagram of C1-Alt4-A2

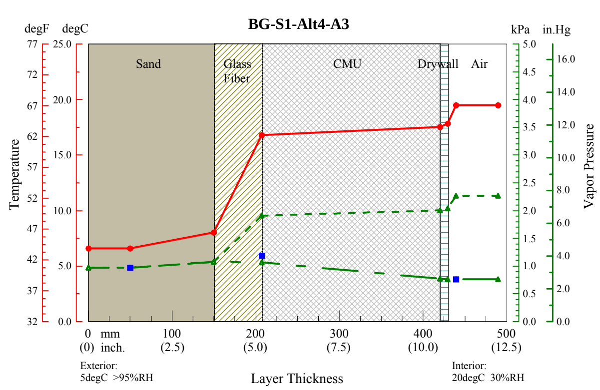


Figure C-59: Wall diagram of S1-Alt4-A3

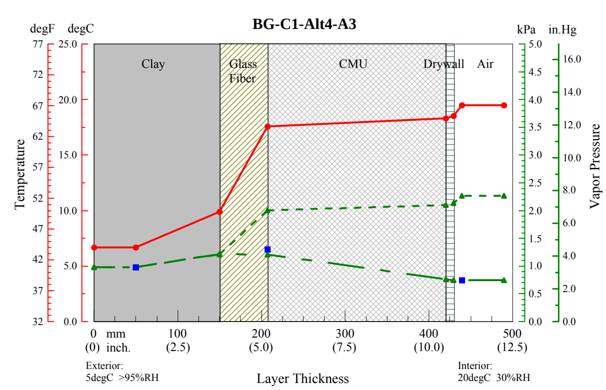


Figure C-60: Wall diagram of C1-Alt4-A3

Test cycle: **S1 – Alt4 (continued)**

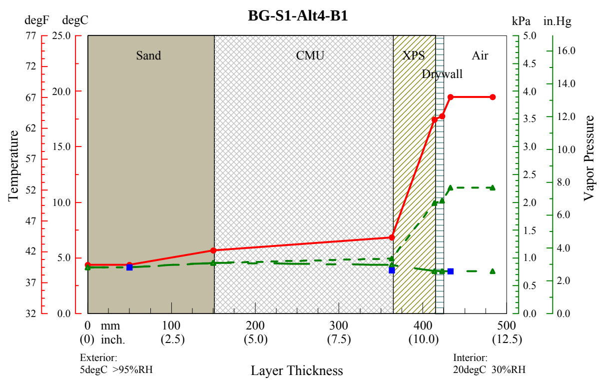


Figure C-61: Wall diagram of S1-Alt4-B1

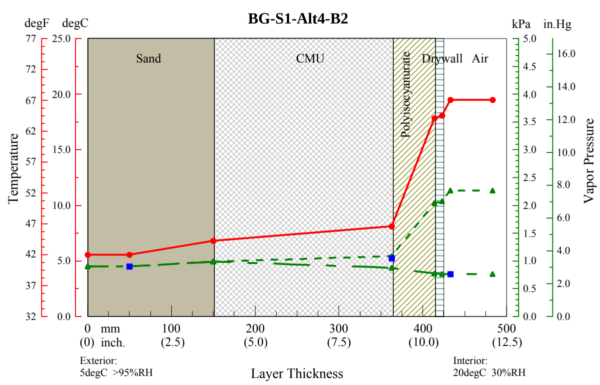


Figure C-63: Wall diagram of S1-Alt4-B2

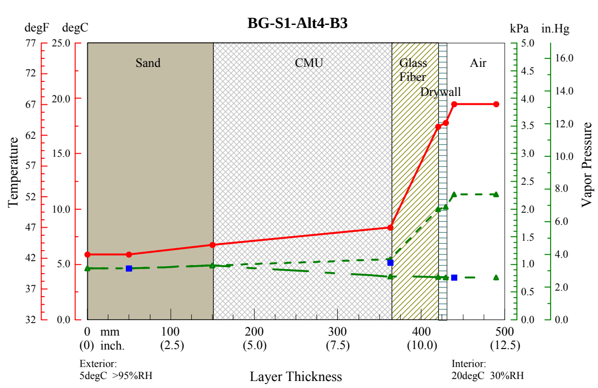


Figure C-65: Wall diagram of S1-Alt4-B3

Test cycle: **C1 – Alt4 (continued)**

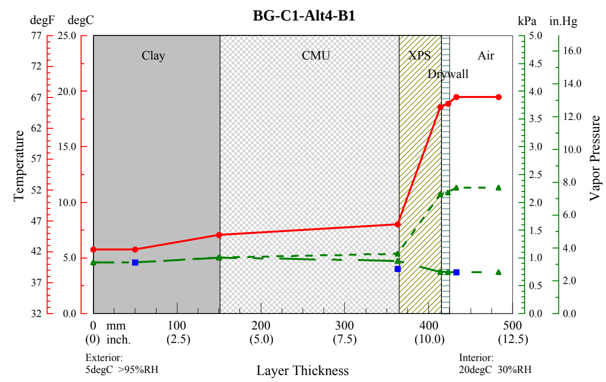


Figure C-62: Wall diagram of C1-Alt4-B1

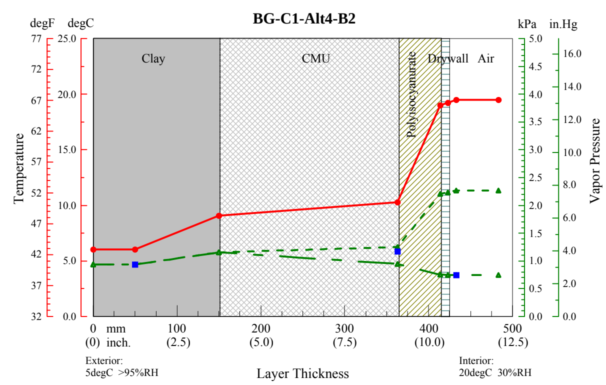


Figure C-64: Wall diagram of C1-Alt4-B2

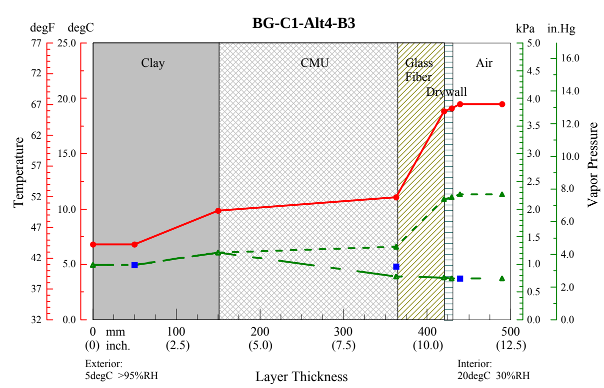


Figure C-66: Wall diagram of C1-Alt4-B3

Test cycle: **S1 – Alt4 (continued)**

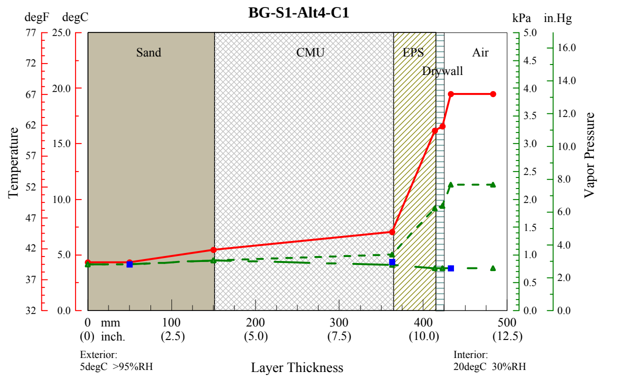


Figure C-67: Wall diagram of S1-Alt4-C1

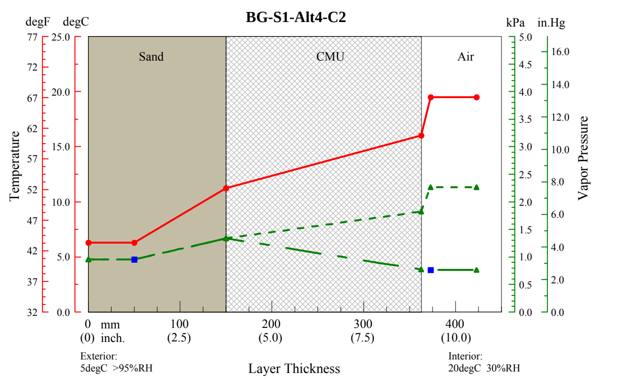


Figure C-69: Wall diagram of S1-Alt4-C2

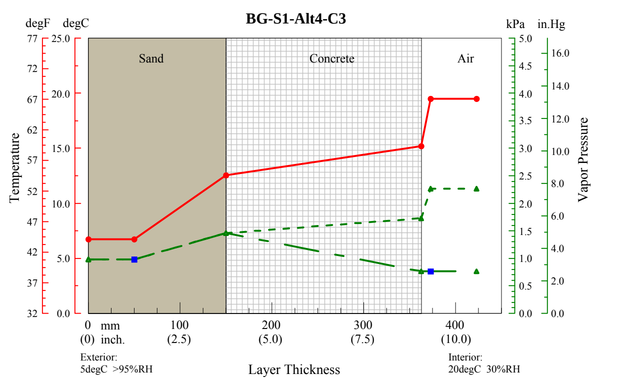


Figure C-71: Wall diagram of S1-Alt4-C3

Test cycle: **C1 – Alt4 (continued)**

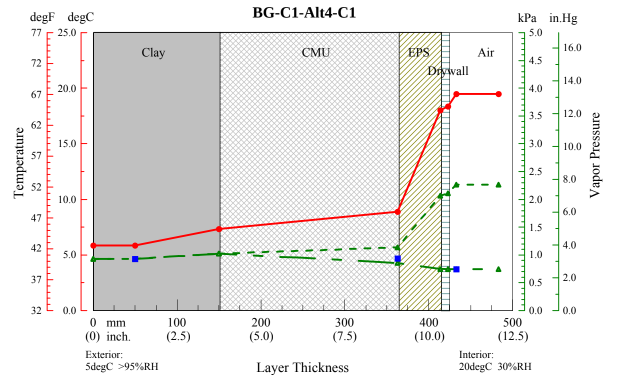


Figure C-68: Wall diagram of C1-Alt4-C1

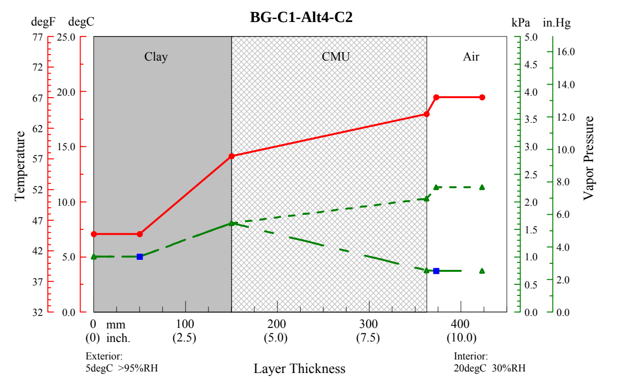


Figure C-70: Wall diagram of C1-Alt4-C2

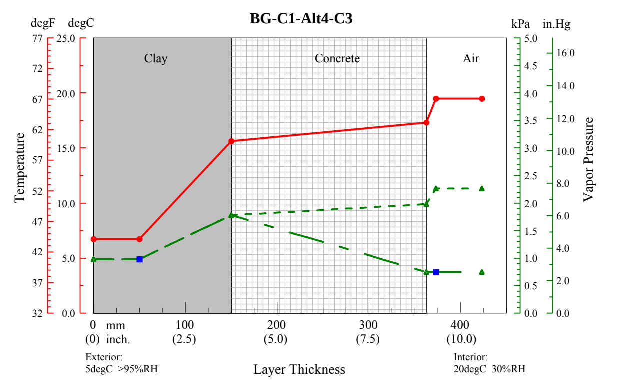


Figure C-72: Wall diagram of C1-Alt4-C3

Test cycle: **S1 – Alt5**

Test cycle: **C1 – Alt5**

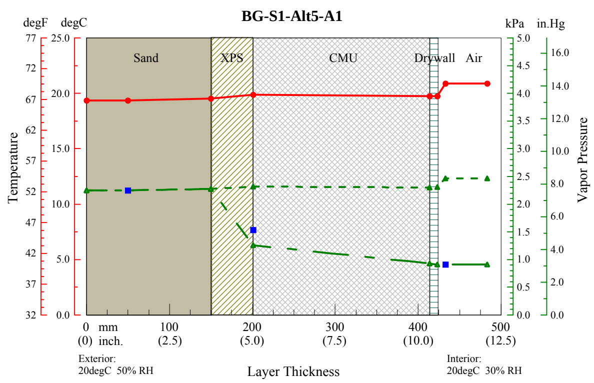


Figure C-73: Wall diagram of S1-Alt5-A1

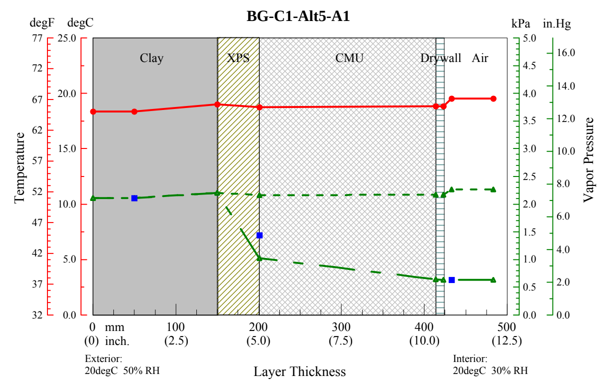


Figure C-74: Wall diagram of C1-Alt5-A1

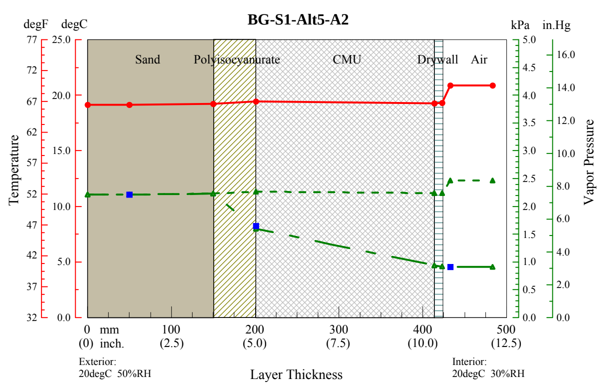


Figure C-75: Wall diagram of S1-Alt5-A2

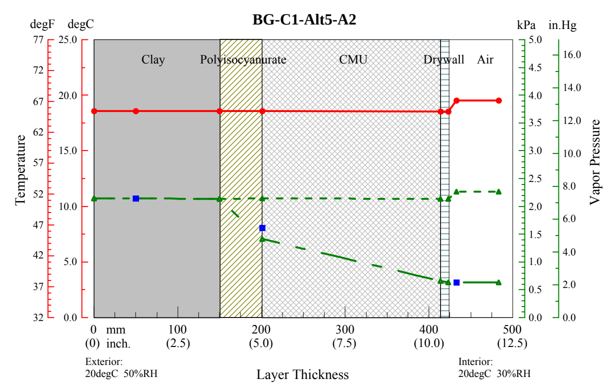


Figure C-76: Wall diagram of C1-Alt5-A2

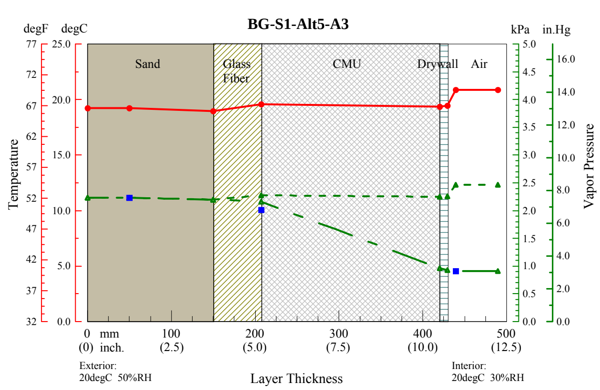


Figure C-77: Wall diagram of S1-Alt5-A3

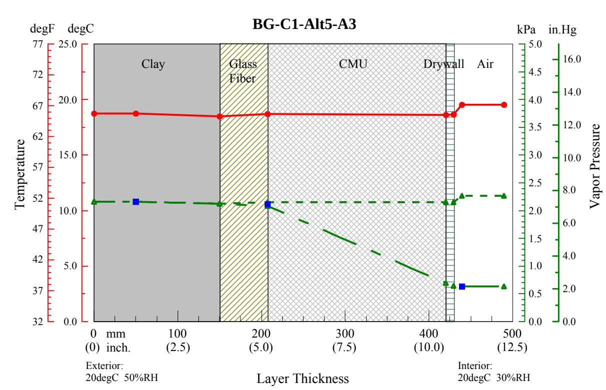


Figure C-78: Wall diagram of C1-Alt5-A3

Test cycle: **S1 – Alt5 (continued)**

Test cycle: **C1 – Alt5 (continued)**

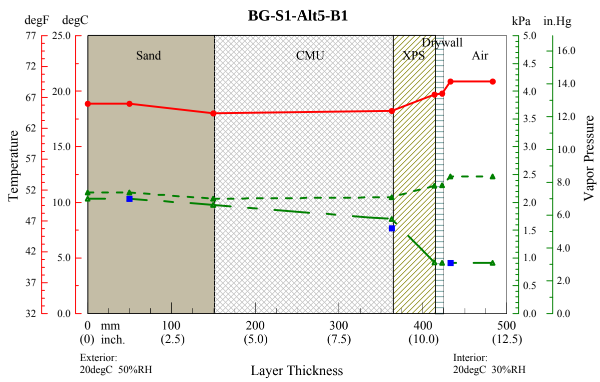


Figure C-79: Wall diagram of S1-Alt5-B1

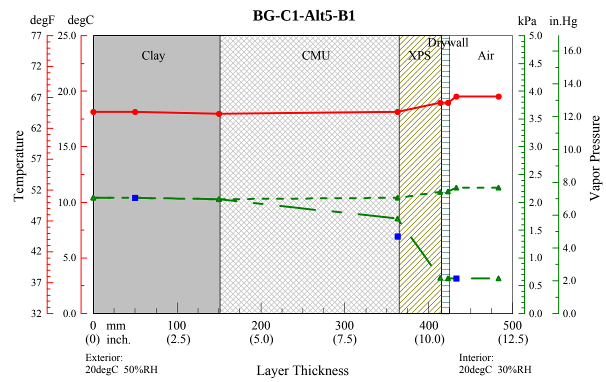


Figure C-80: Wall diagram of C1-Alt5-B1

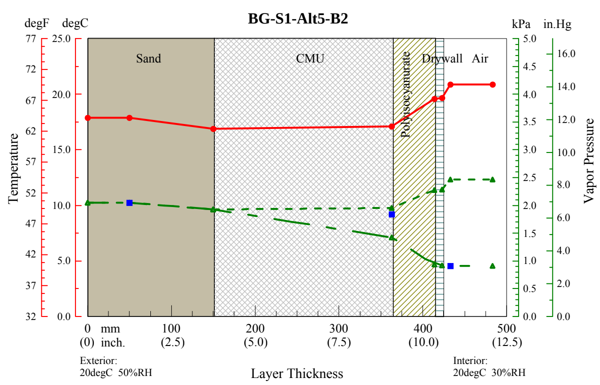


Figure C-81: Wall diagram of S1-Alt5-B2

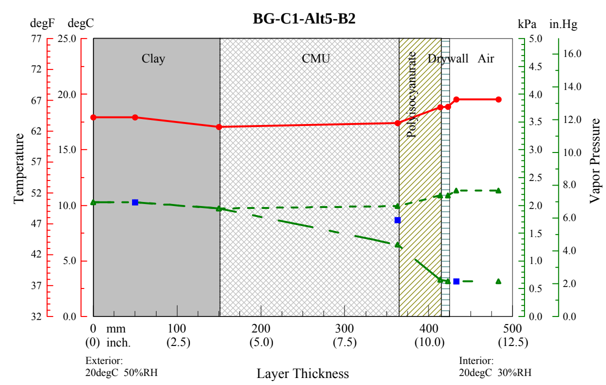


Figure C-82: Wall diagram of C1-Alt5-B2

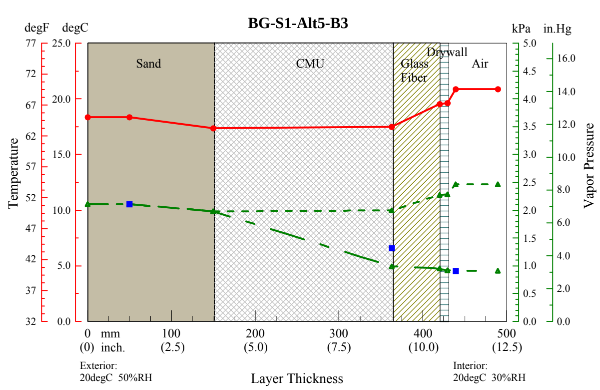


Figure C-83: Wall diagram of S1-Alt5-B3

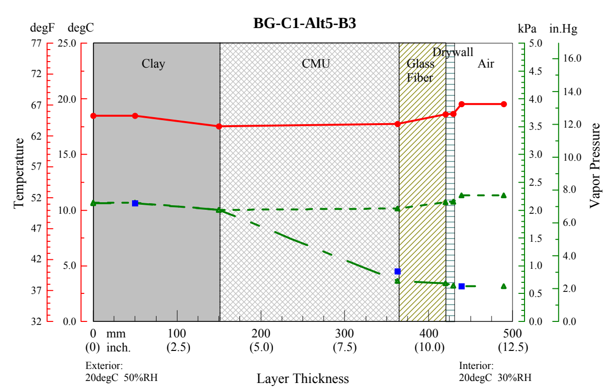


Figure C-84: Wall diagram of C1-Alt5-B3

Test cycle: **S1 – Alt5 (continued)**

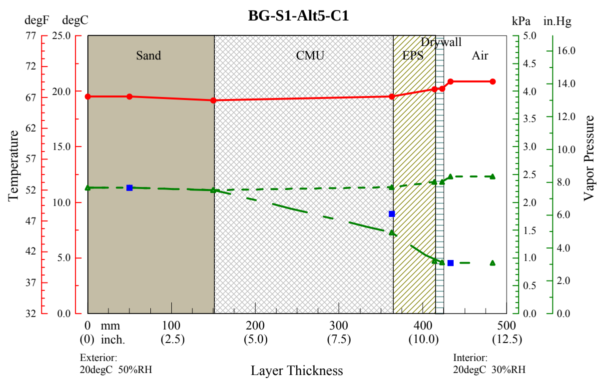


Figure C-85: Wall diagram of S1-Alt5-C1

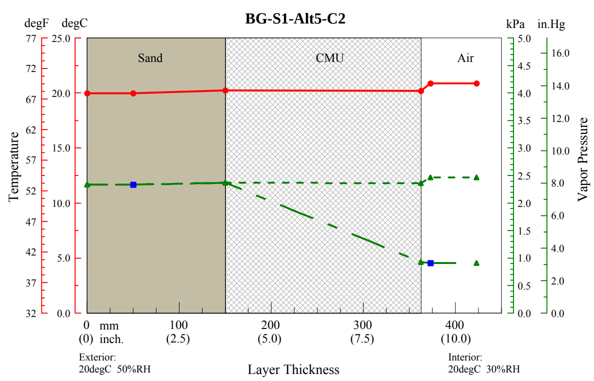


Figure C-87: Wall diagram of S1-Alt5-C2

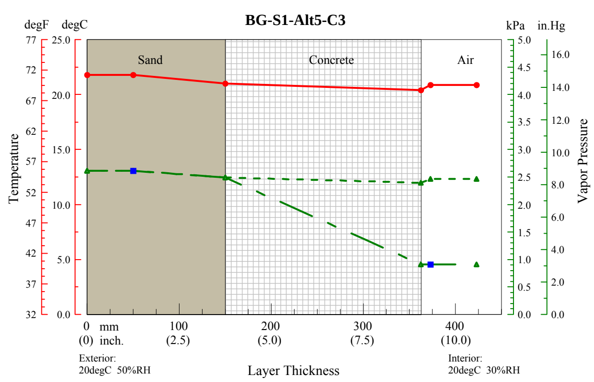


Figure C-89: Wall diagram of S1-Alt5-C3

Test cycle: **C1 – Alt5 (continued)**

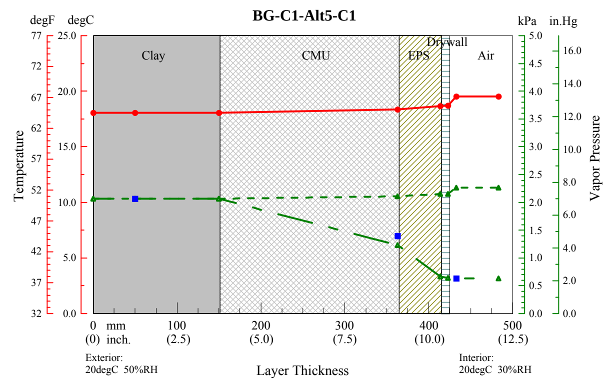


Figure C-86: Wall diagram of C1-Alt5-C1

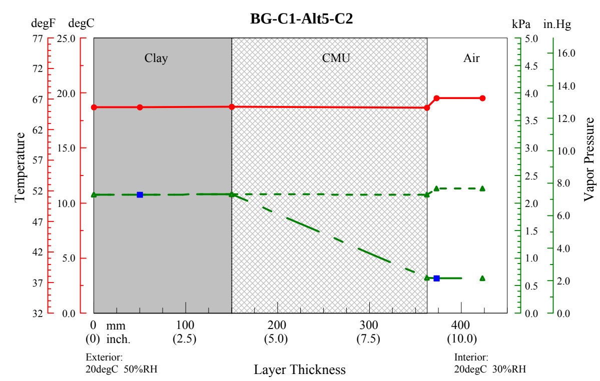


Figure C-88: Wall diagram of C1-Alt5-C2

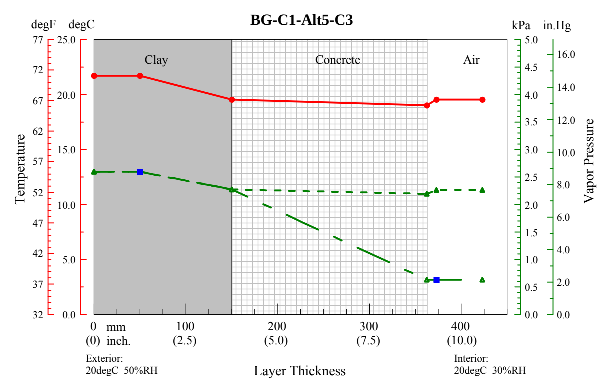


Figure C-90: Wall diagram of C1-Alt5-C3

Test cycle: **S1 – Alt6**

Test cycle: **C1 – Alt6**

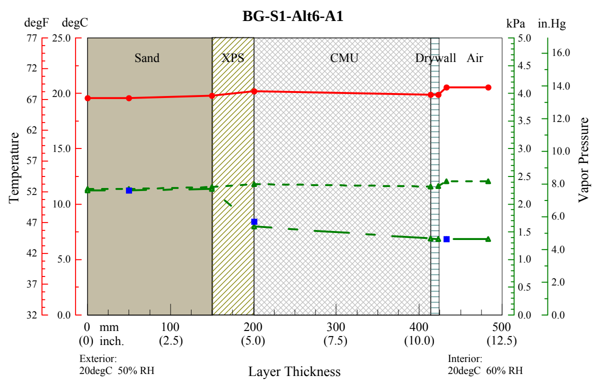


Figure C-91: Wall diagram of S1-Alt6-A1

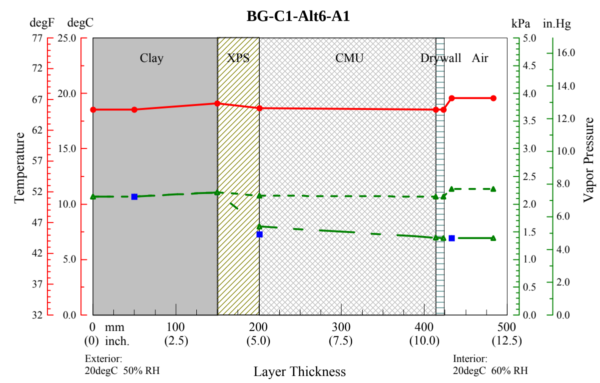


Figure C-92: Wall diagram of C1-Alt6-A1

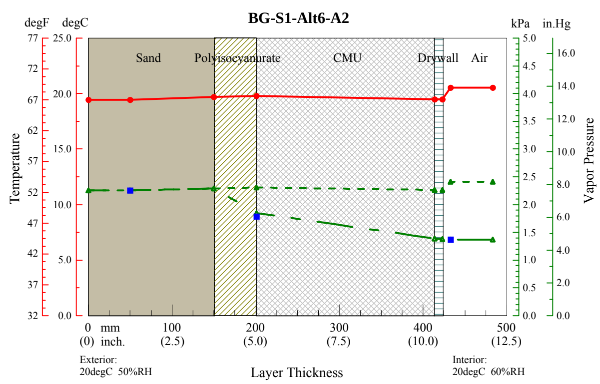


Figure C-93: Wall diagram of S1-Alt6-A2

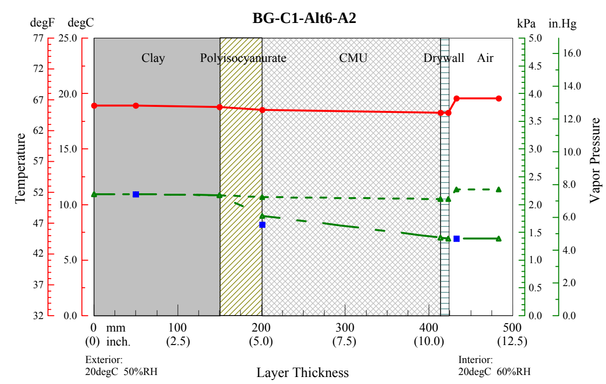


Figure C-94: Wall diagram of C1-Alt6-A2

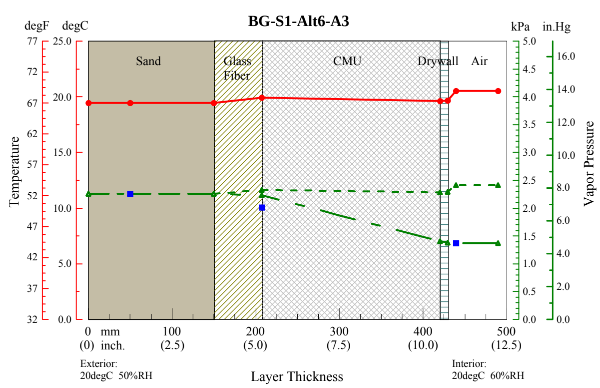


Figure C-95: Wall diagram of S1-Alt6-A3

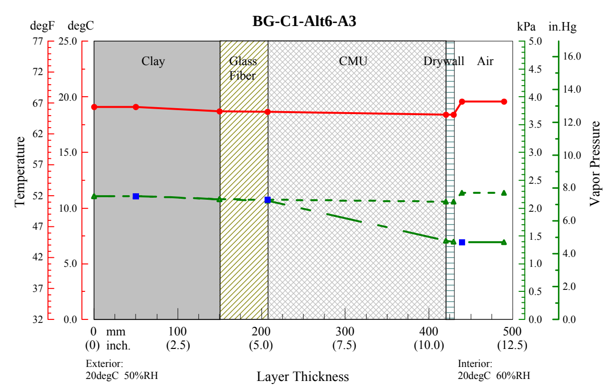


Figure C-96: Wall diagram of C1-Alt6-A3

Test cycle: **S1 – Alt6 (continued)**

Test cycle: **C1 – Alt6 (continued)**

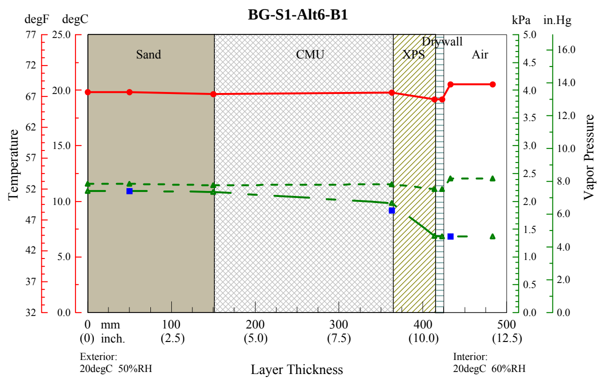


Figure C-97: Wall diagram of S1-Alt6-B1

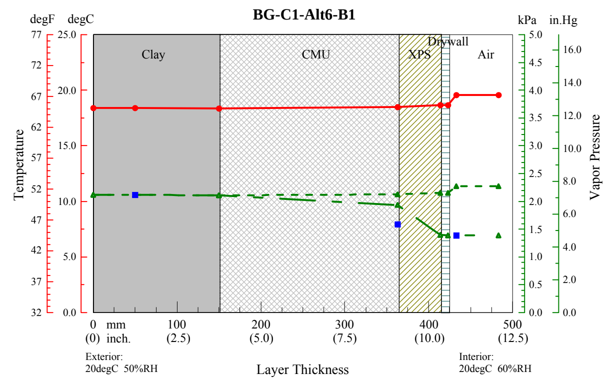


Figure C-98: Wall diagram of C1-Alt6-B1

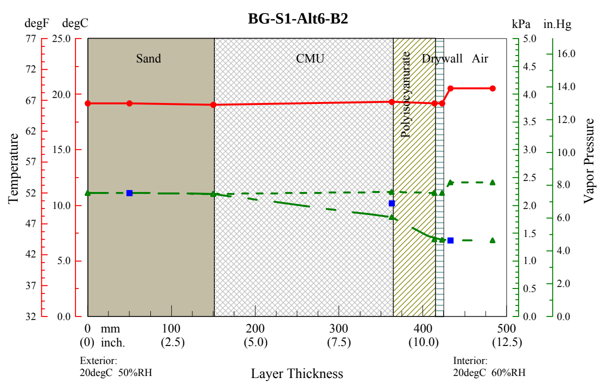


Figure C-99: Wall diagram of S1-Alt6-B2

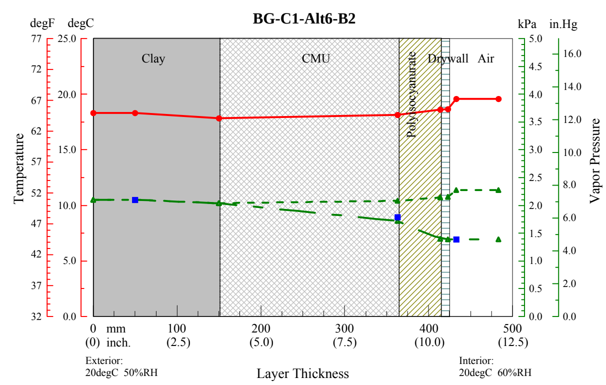


Figure C-100: Wall diagram of C1-Alt6-B2

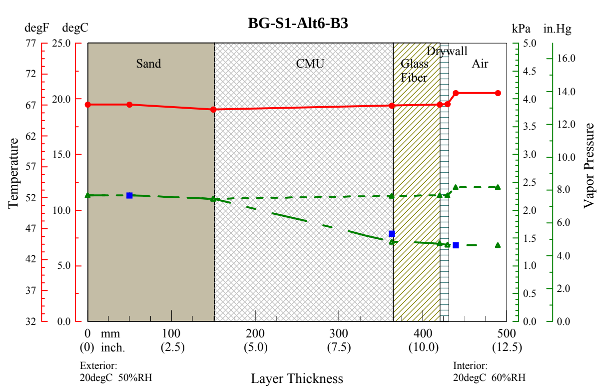


Figure C-101: Wall diagram of S1-Alt6-B3

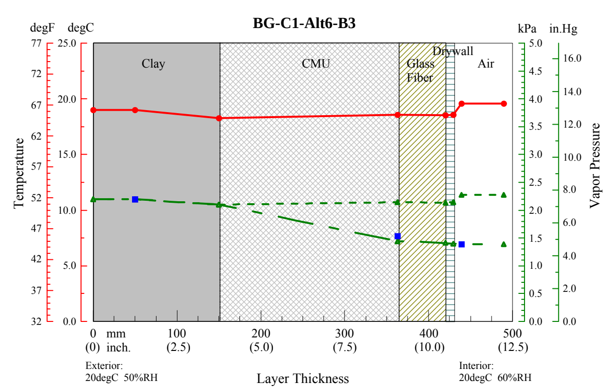


Figure C-102: Wall diagram of C1-Alt6-B3

Test cycle: **S1 – Alt6 (continued)**

Test cycle: **C1 – Alt6 (continued)**

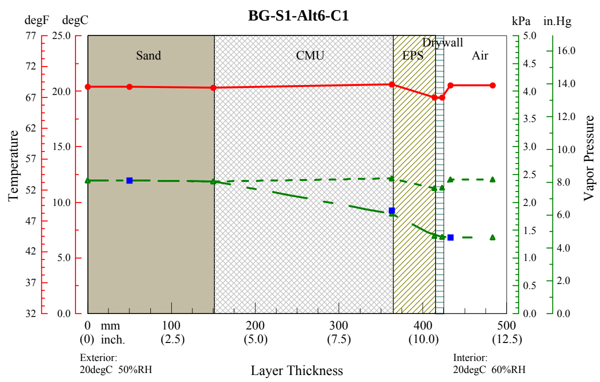


Figure C-103: Wall diagram of S1-Alt6-C1

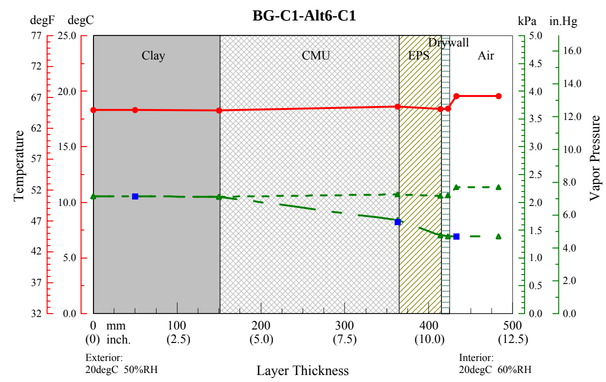


Figure C-104: Wall diagram of C1-Alt6-C1

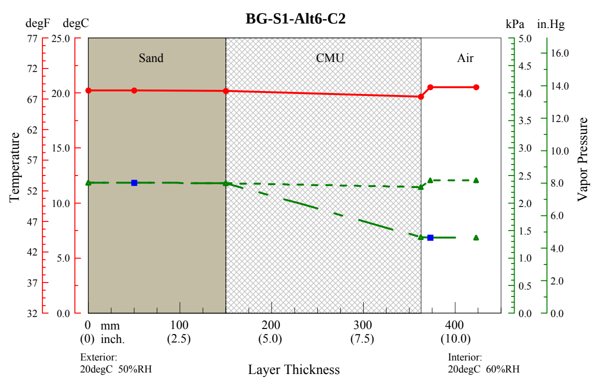


Figure C-105: Wall diagram of S1-Alt6-C2

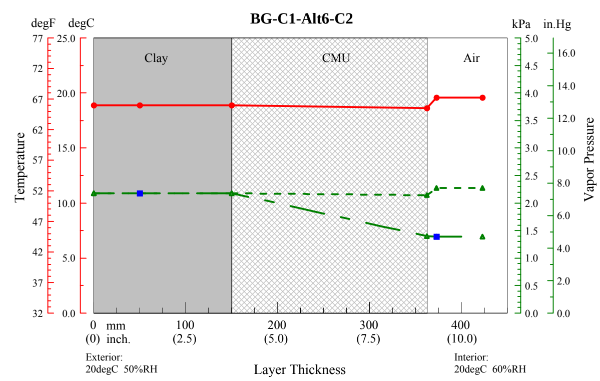


Figure C-106: Wall diagram of C1-Alt6-C2

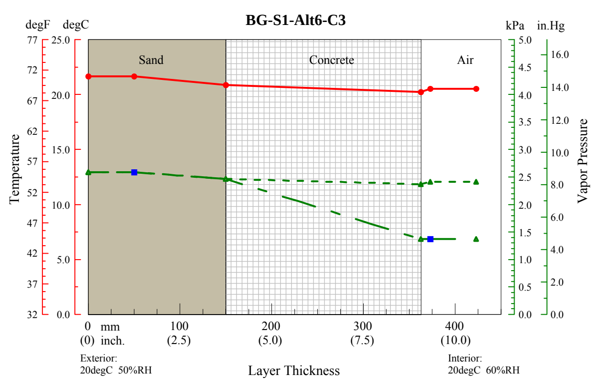


Figure C-107: Wall diagram of S1-Alt6-C3

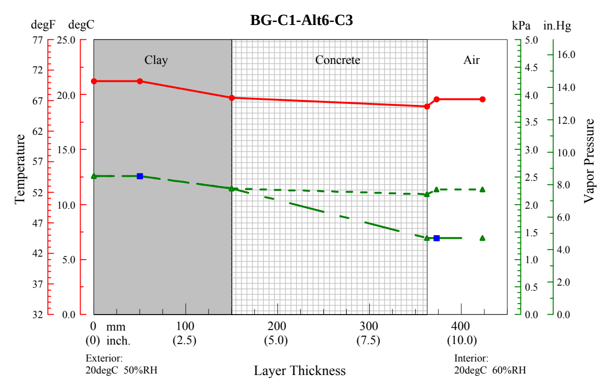


Figure C-108: Wall diagram of C1-Alt6-C3

Test cycle: **S1 – Alt7**

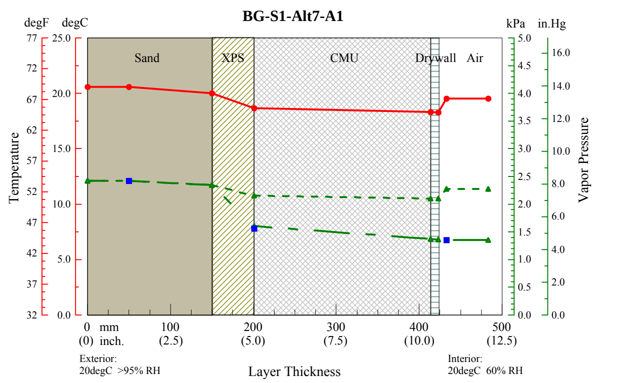


Figure C-109: Wall diagram of S1-Alt7-A1

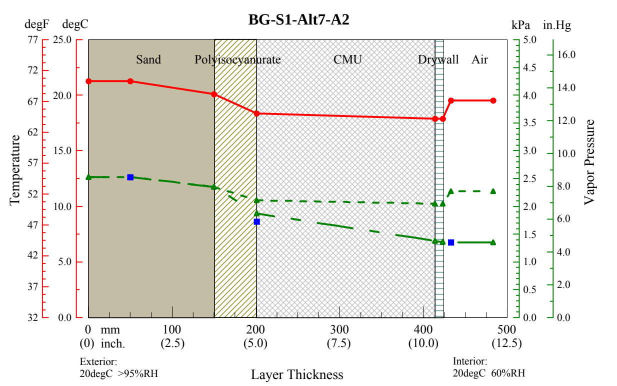


Figure C-111: Wall diagram of S1-Alt7-A2

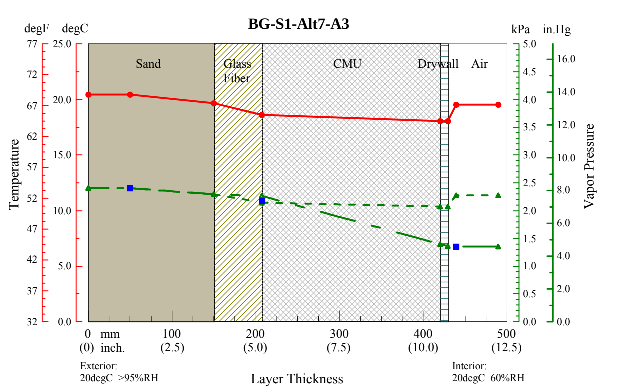


Figure C-113: Wall diagram of S1-Alt7-A3

Test cycle: **C1 – Alt7**

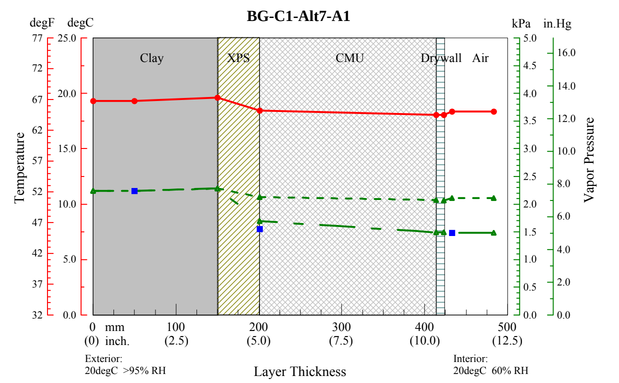


Figure C-110: Wall diagram of C1-Alt7-A1

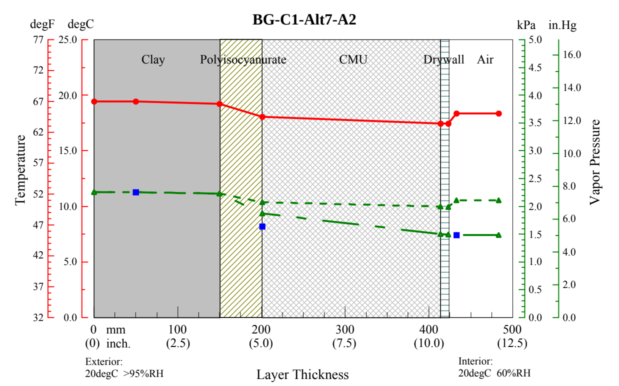


Figure C-112: Wall diagram of C1-Alt7-A2

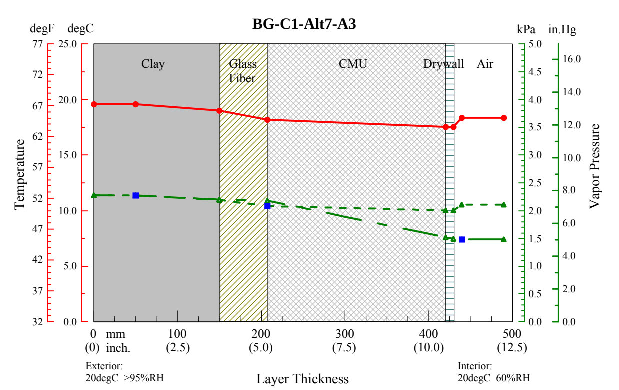


Figure C-114: Wall diagram of C1-Alt7-A3

Test cycle: **S1 – Alt7 (continued)**

Test cycle: **C1 – Alt7 (continued)**

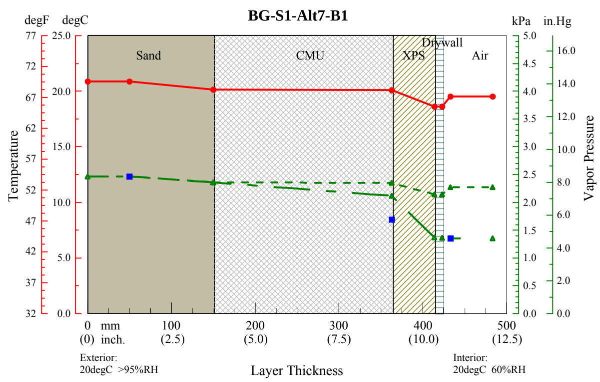


Figure C-115: Wall diagram of S1-Alt7-B1

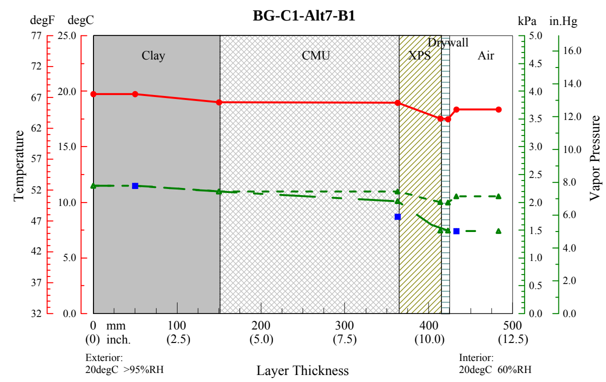


Figure C-116: Wall diagram of C1-Alt7-B1

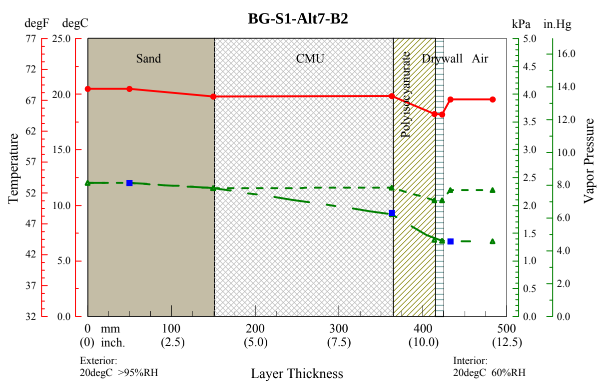


Figure C-117: Wall diagram of S1-Alt7-B2

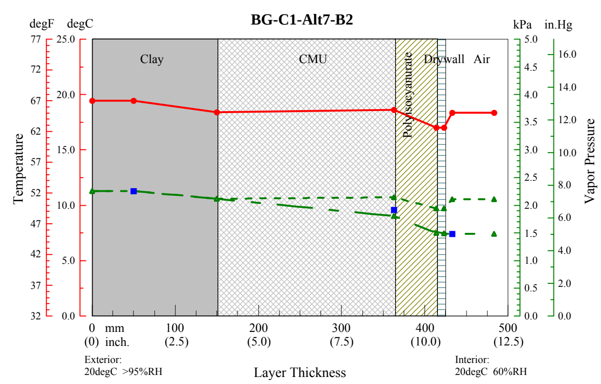


Figure C-118: Wall diagram of C1-Alt7-B2

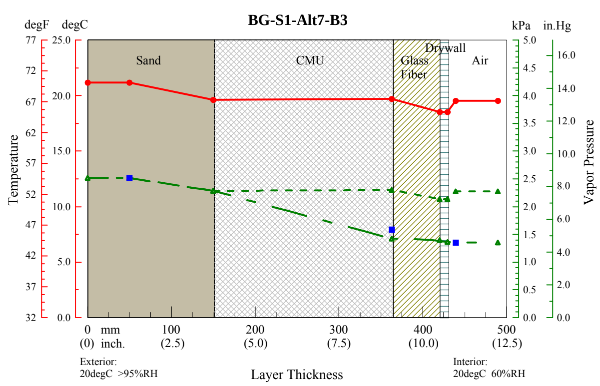


Figure C-119: Wall diagram of S1-Alt7-B3

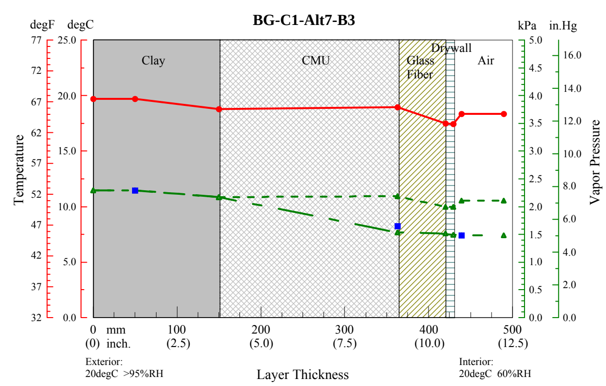


Figure C-120: Wall diagram of C1-Alt7-B3

Test cycle: **S1 – Alt7 (continued)**

Test cycle: **C1 – Alt7 (continued)**

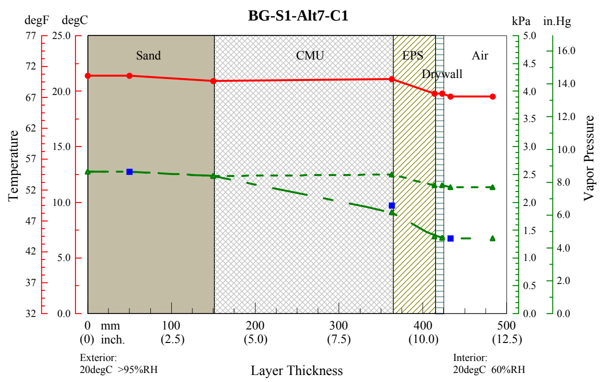


Figure C-121: Wall diagram of S1-Alt7-C1

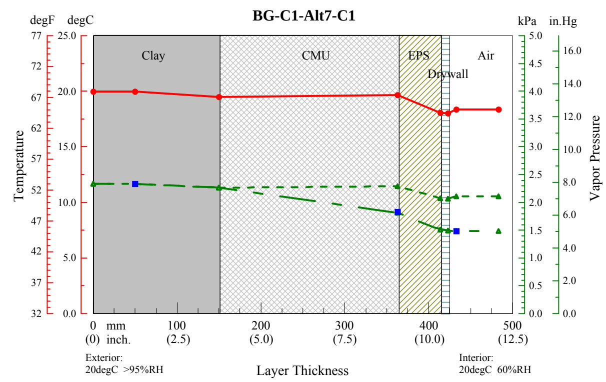


Figure C-122: Wall diagram of C1-Alt7-C1

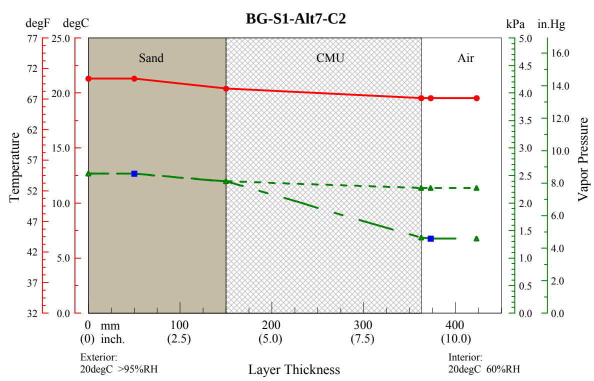


Figure C-123: Wall diagram of S1-Alt7-C2

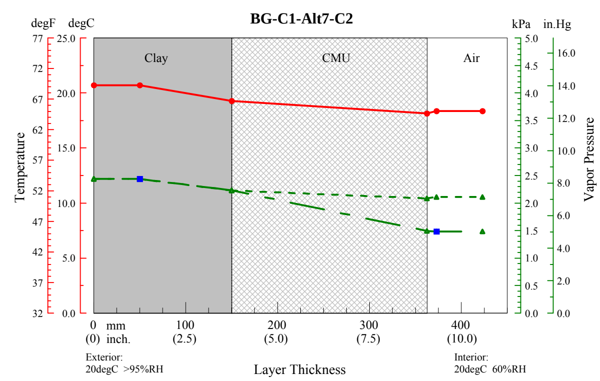


Figure C-124: Wall diagram of C1-Alt7-C2

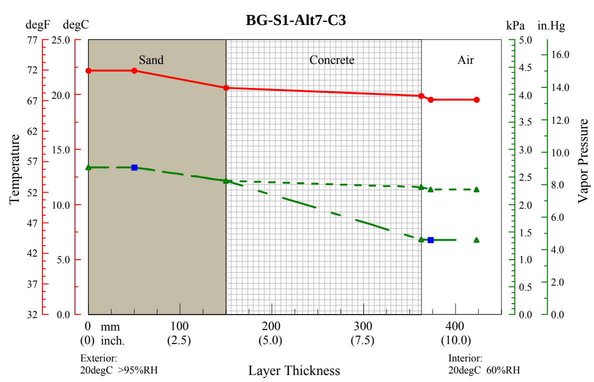


Figure C-125: Wall diagram of S1-Alt7-C3

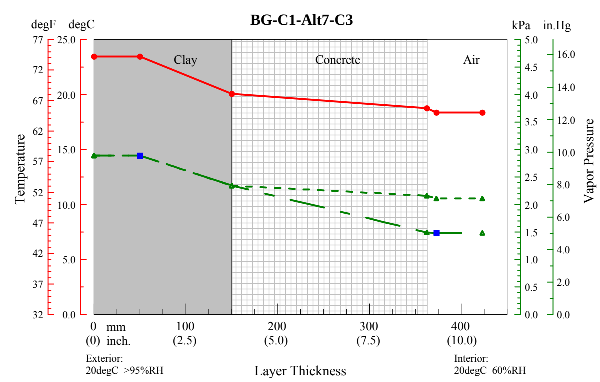


Figure C-126: Wall diagram of C1-Alt7-C3

Test cycle: **S1 – Alt8**

Test cycle: **C1 – Alt8**

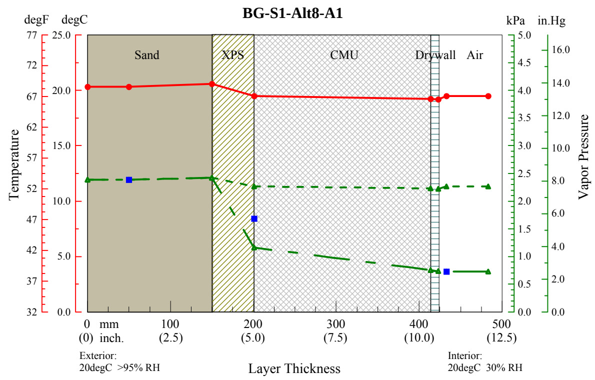


Figure C-127: Wall diagram of S1-Alt8-A1

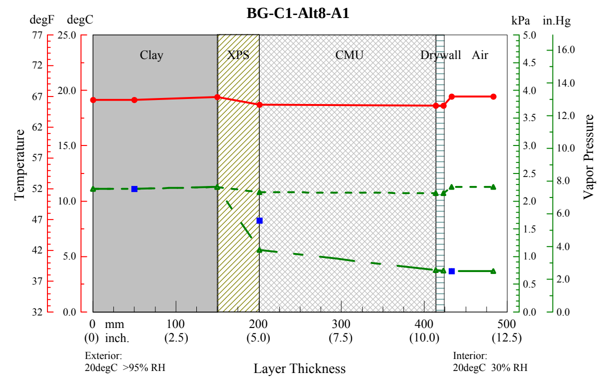


Figure C-128: Wall diagram of C1-Alt8-A1

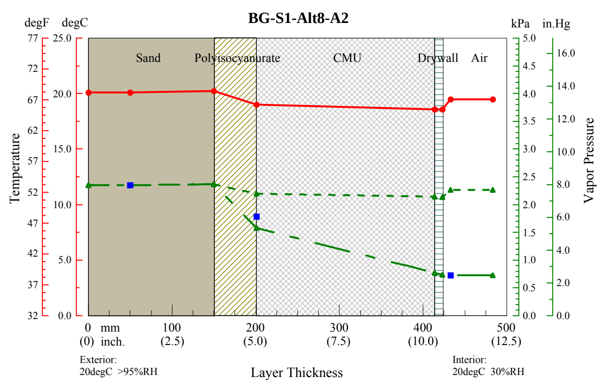


Figure C-129: Wall diagram of S1-Alt8-A2

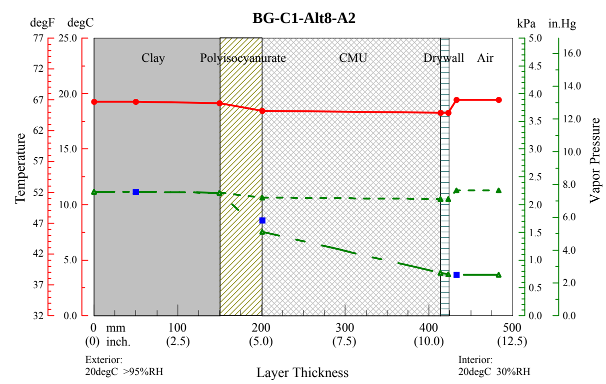


Figure C-130: Wall diagram of C1-Alt8-A2

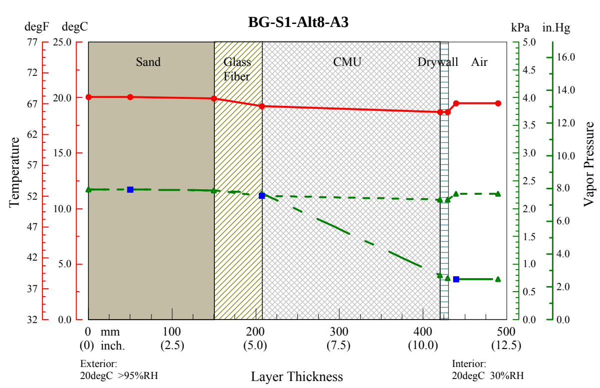


Figure C-131: Wall diagram of S1-Alt8-A3

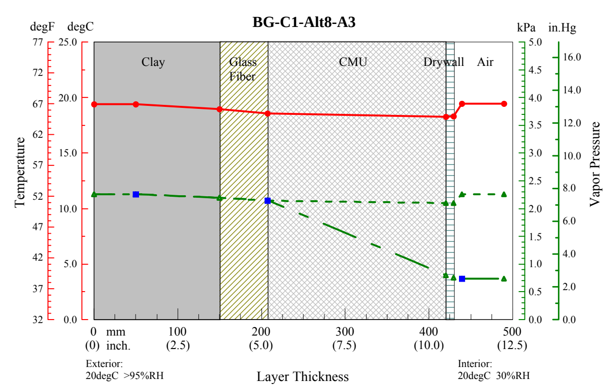


Figure C-132: Wall diagram of C1-Alt8-A3

Test cycle: **S1 – Alt8 (continued)** | Test cycle: **C1 – Alt8 (continued)**

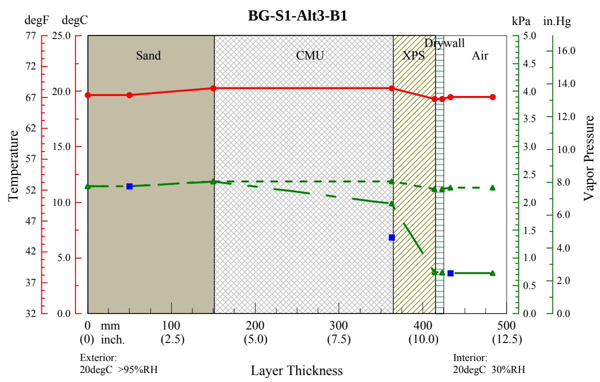


Figure C-133: Wall diagram of S1-Alt8-B1

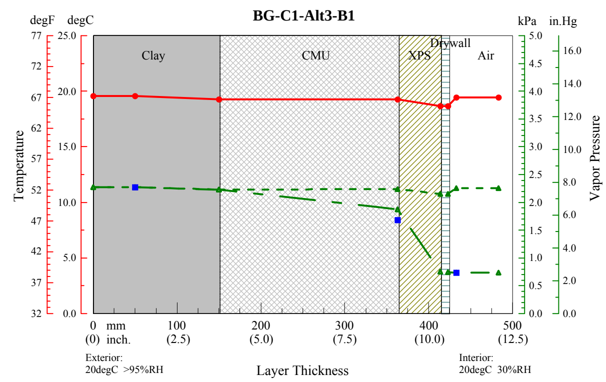


Figure C-134: Wall diagram of C1-Alt8-B1

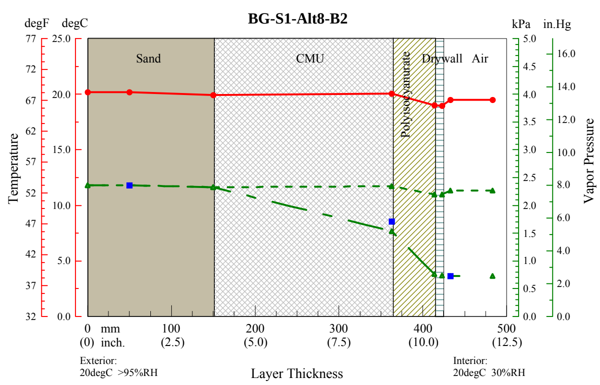


Figure C-135: Wall diagram of S1-Alt8-B2

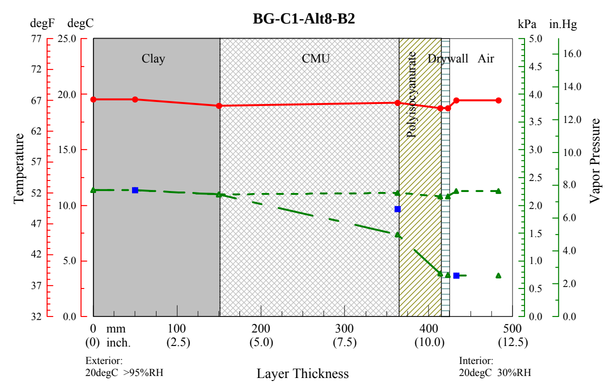


Figure C-136: Wall diagram of C1-Alt8-B2

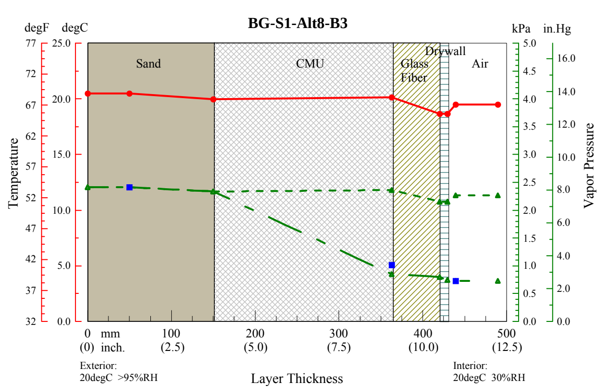


Figure C-137: Wall diagram of S1-Alt8-B3

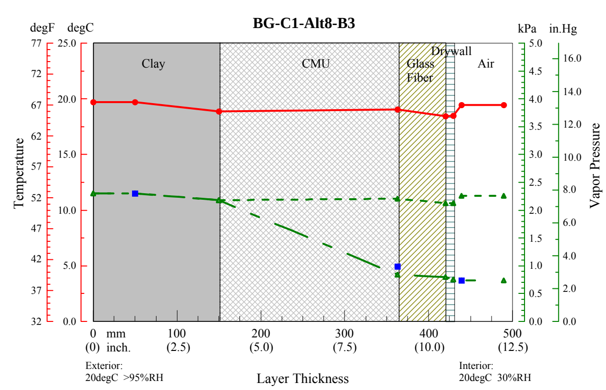


Figure C-138: Wall diagram of C1-Alt8-B3

Test cycle: **S1 – Alt8 (continued)**

Test cycle: **C1 – Alt8 (continued)**

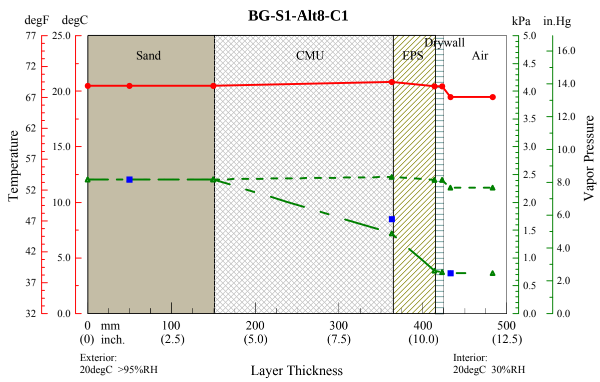


Figure C-139: Wall diagram of S1-Alt8-C1

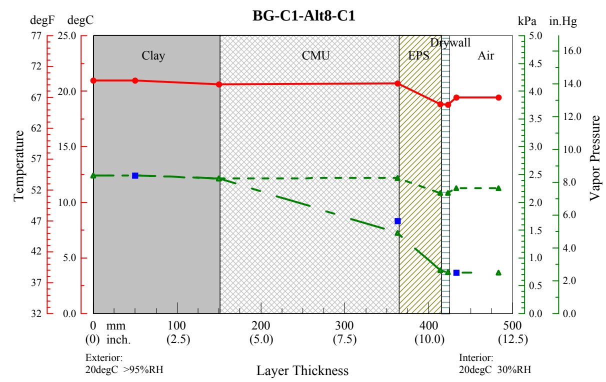


Figure C-140: Wall diagram of C1-Alt8-C1

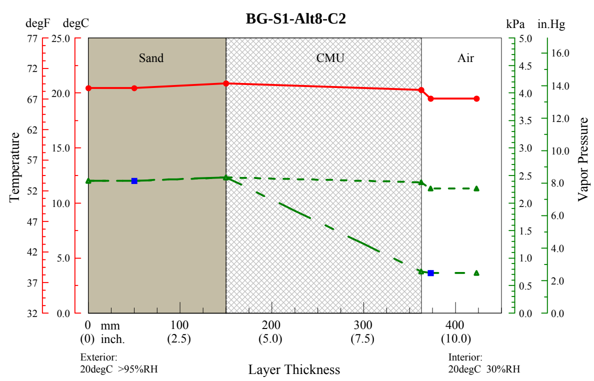


Figure C-141: Wall diagram of S1-Alt8-C2

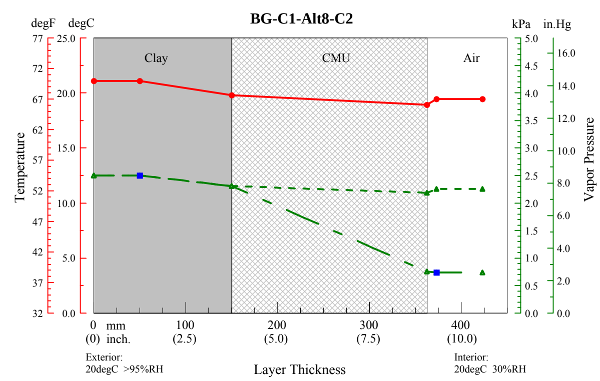


Figure C-142: Wall diagram of C1-Alt8-C2

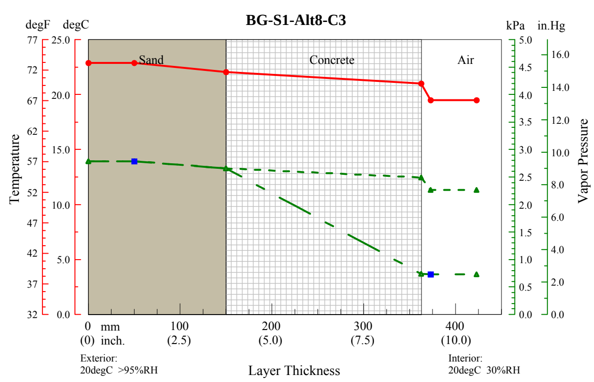


Figure C-143: Wall diagram of S1-Alt8-C3

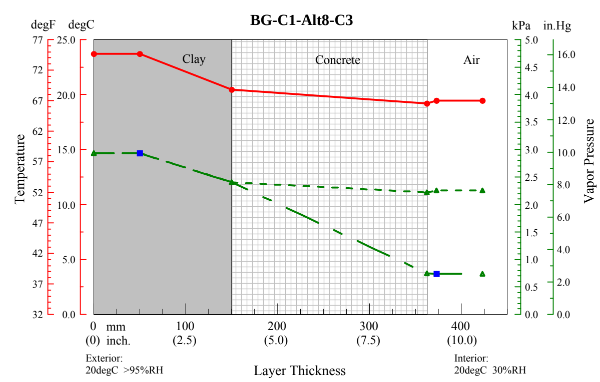


Figure C-144: Wall diagram of C1-Alt8-C3

Measurement series: **S2**

Test cycle: **S2 – Alt1**

Measurement series: **C2**

Test cycle: **C2 – Alt1**

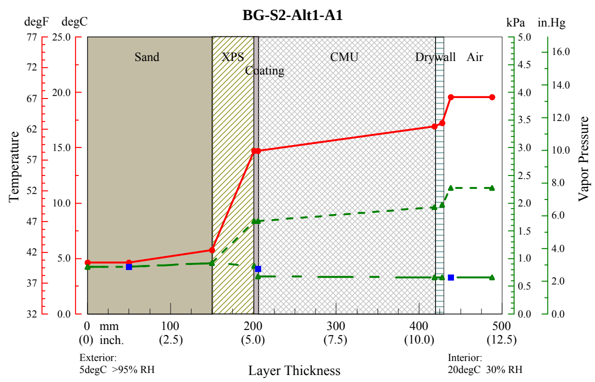


Figure C-145: Wall diagram of S2-Alt1-A1

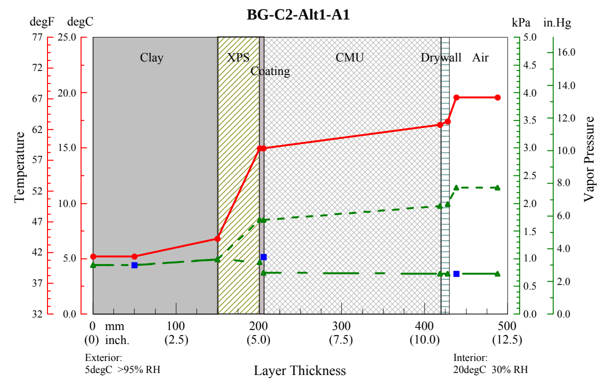


Figure C-146: Wall diagram of C2-Alt1-A1

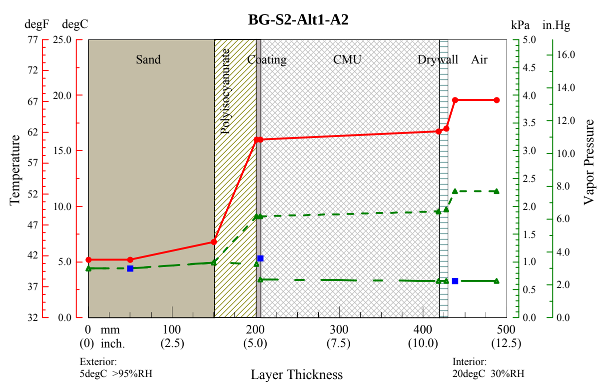


Figure C-147: Wall diagram of S2-Alt1-A2

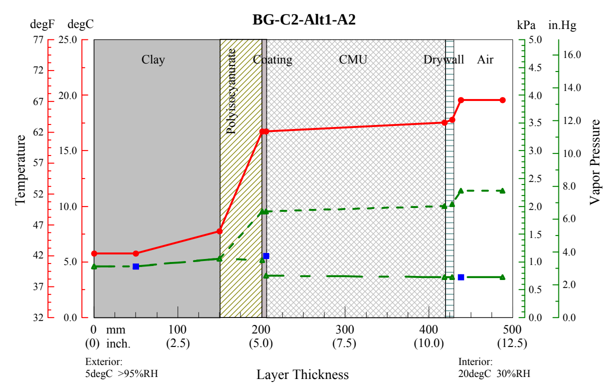


Figure C-148: Wall diagram of C2-Alt1-A2

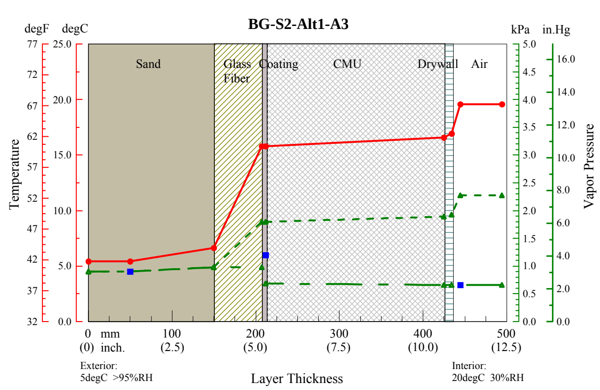


Figure C-149: Wall diagram of S2-Alt1-A3

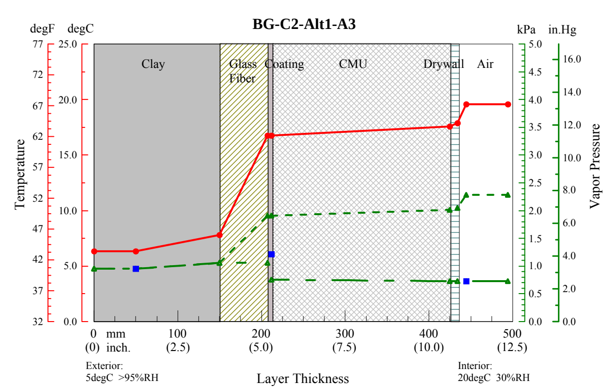


Figure C-150: Wall diagram of C2-Alt1-A3

Test cycle: **S2 – Alt1 (continued)**

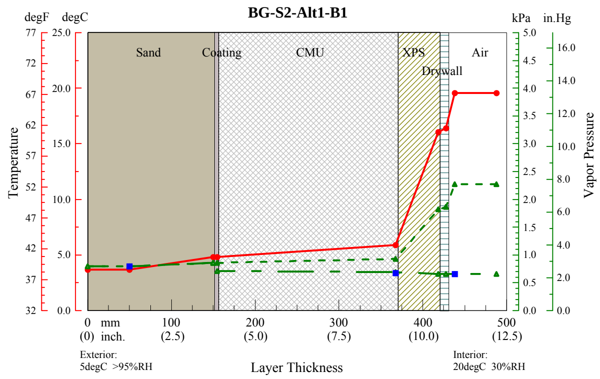


Figure C-151: Wall diagram of S2-Alt1-B1

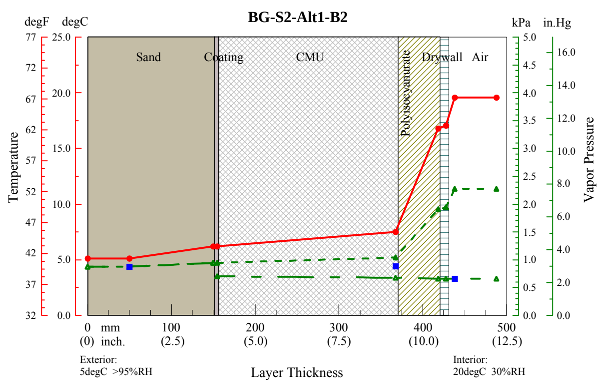


Figure C-153: Wall diagram of S2-Alt1-B2

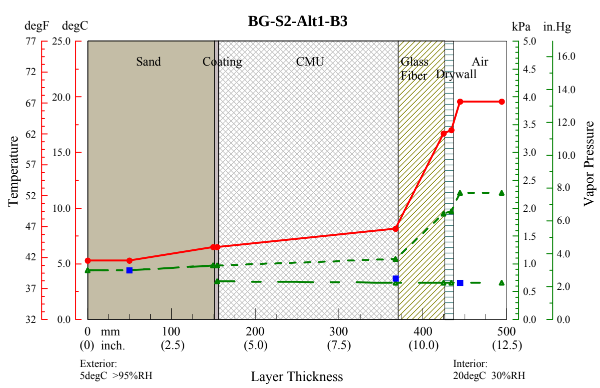


Figure C-155: Wall diagram of S2-Alt1-B3

Test cycle: **C2 – Alt1 (continued)**

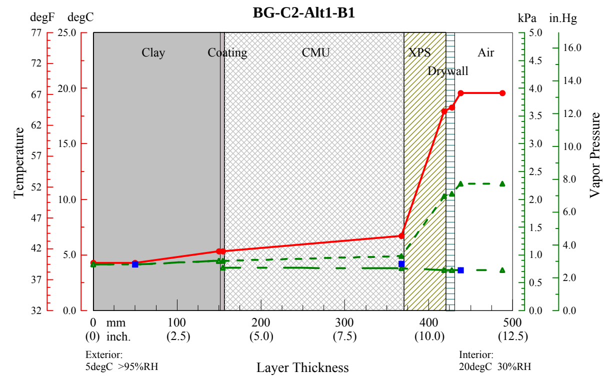


Figure C-152: Wall diagram of C2-Alt1-B1

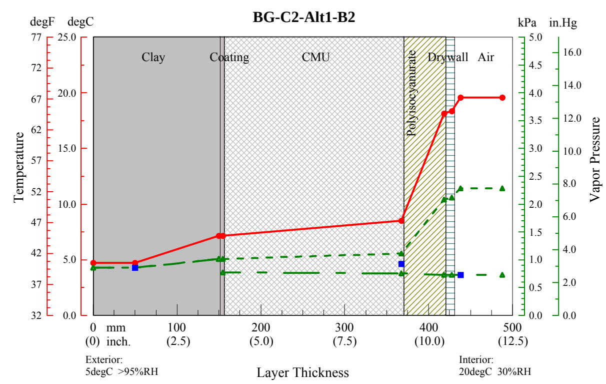


Figure C-154: Wall diagram of C2-Alt1-B2

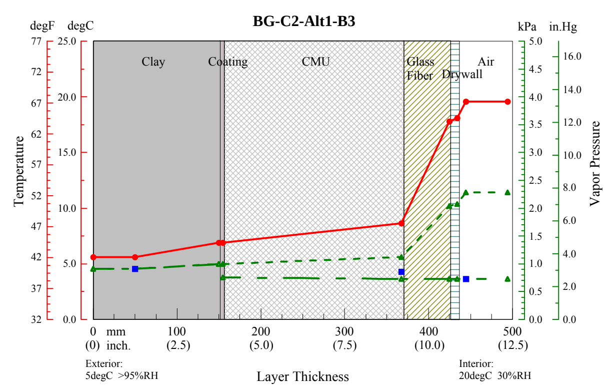


Figure C-156: Wall diagram of C2-Alt1-B3

Test cycle: **S2 – Alt1 (continued)**

Test cycle: **C2 – Alt1 (continued)**

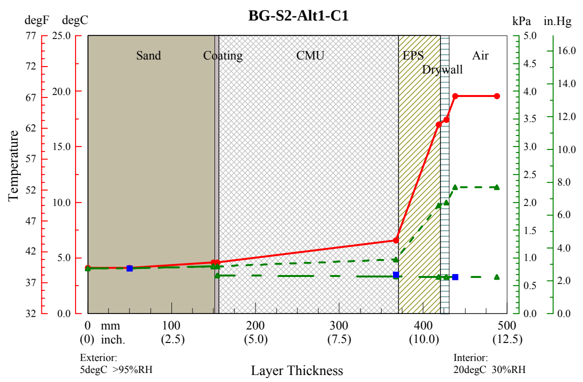


Figure C-157: Wall diagram of S2-Alt1-C1

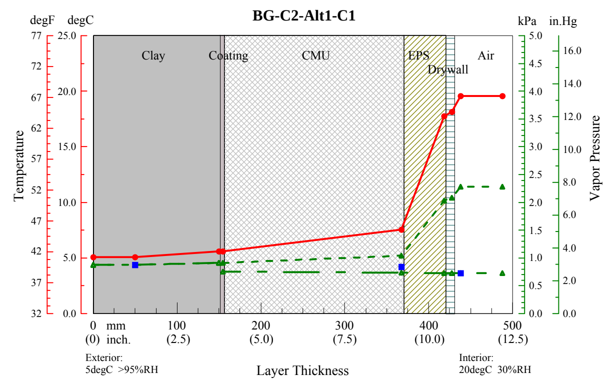


Figure C-158: Wall diagram of C2-Alt1-C1

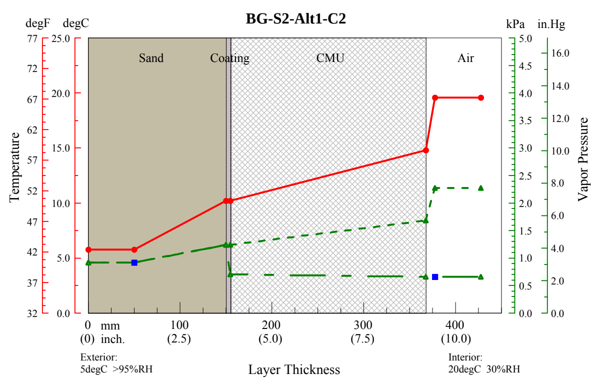


Figure C-159: Wall diagram of S2-Alt1-C2

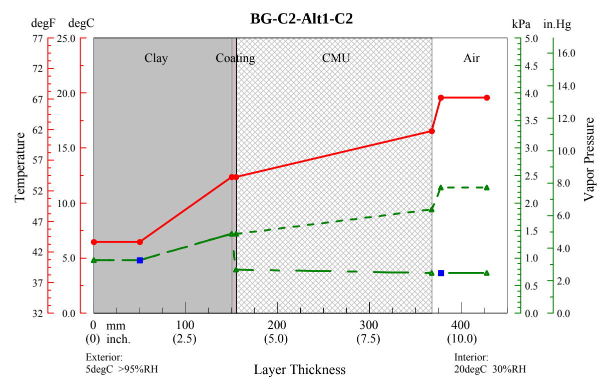


Figure C-160: Wall diagram of C2-Alt1-C2

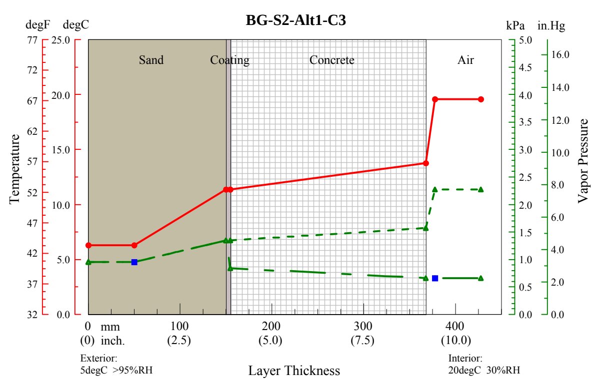


Figure C-161: Wall diagram of S2-Alt1-C3

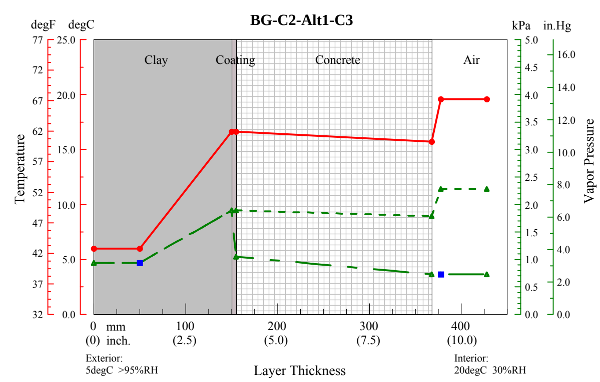


Figure C-162: Wall diagram of C2-Alt1-C3

Test cycle: **S2 – Alt2** Test cycle: **C2 – Alt2**

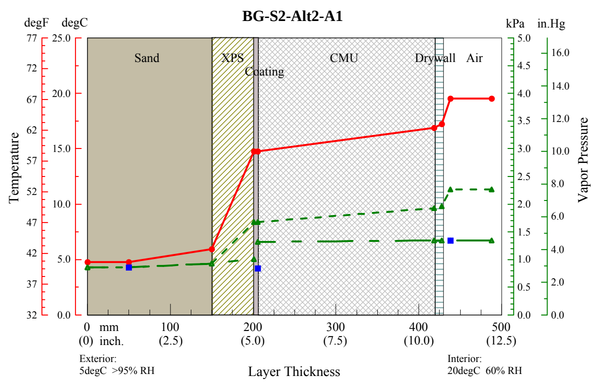


Figure C-163: Wall diagram of S2-Alt2-A1

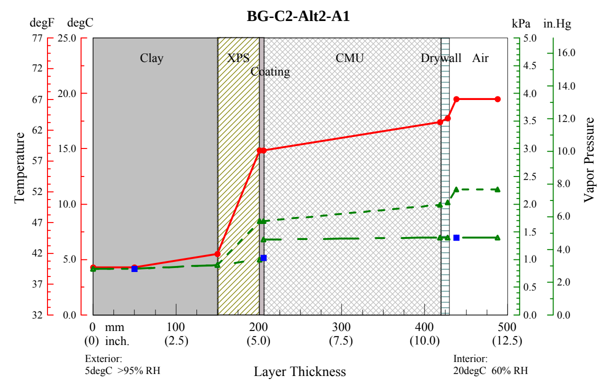


Figure C-164: Wall diagram of C2-Alt2-A1

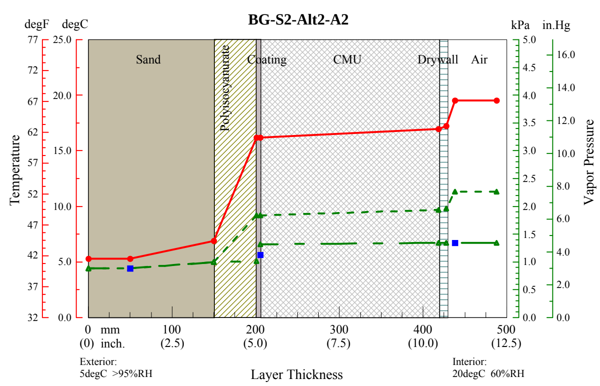


Figure C-165: Wall diagram of S2-Alt2-A2

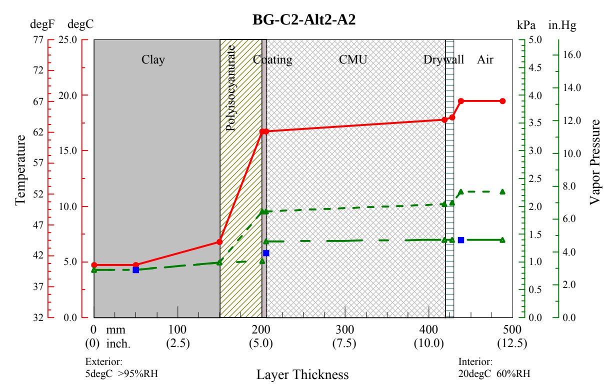


Figure C-166: Wall diagram of C2-Alt2-A2

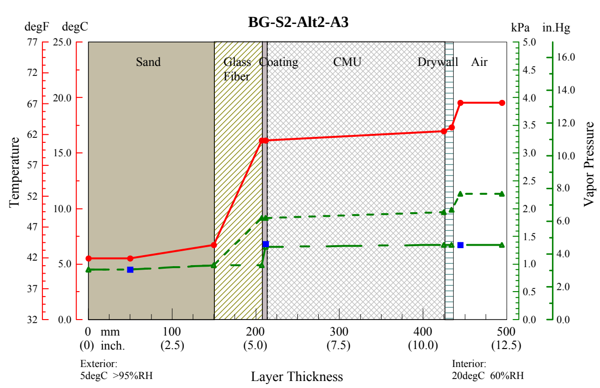


Figure C-167: Wall diagram of S2-Alt2-A3

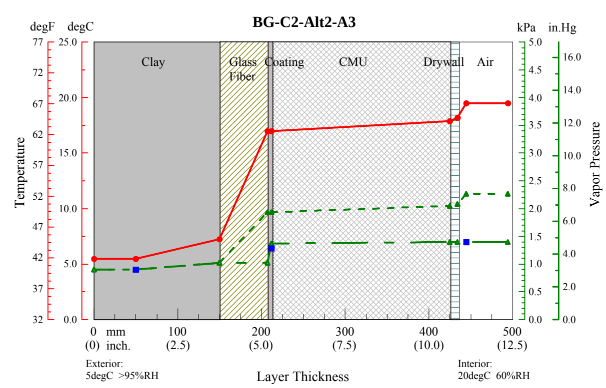


Figure C-168: Wall diagram of C2-Alt2-A3

Test cycle: **S2 – Alt2 (continued)**

Test cycle: **C2 – Alt2 (continued)**

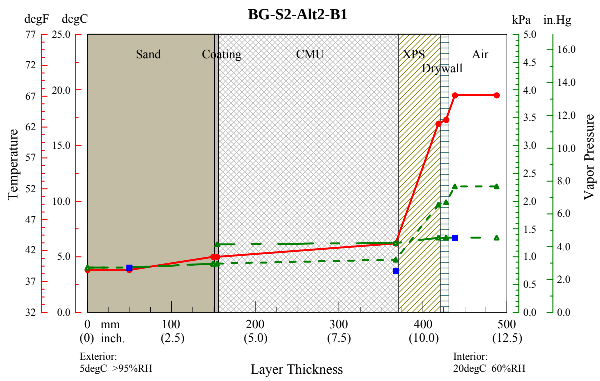


Figure C-169: Wall diagram of S2-Alt2-B1

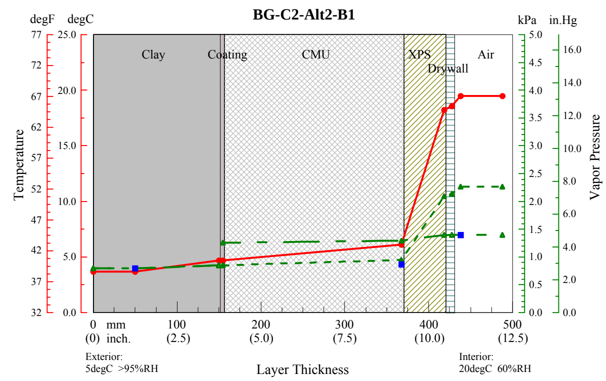


Figure C-170: Wall diagram of C2-Alt2-B1

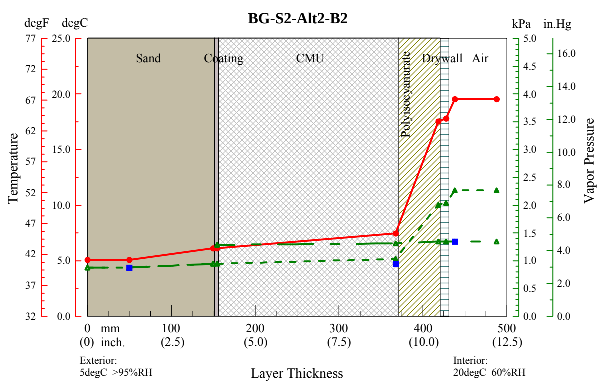


Figure C-171: Wall diagram of S2-Alt2-B2

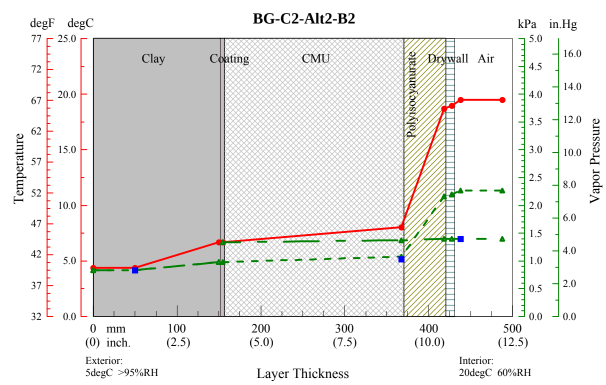


Figure C-172: Wall diagram of C2-Alt2-B2

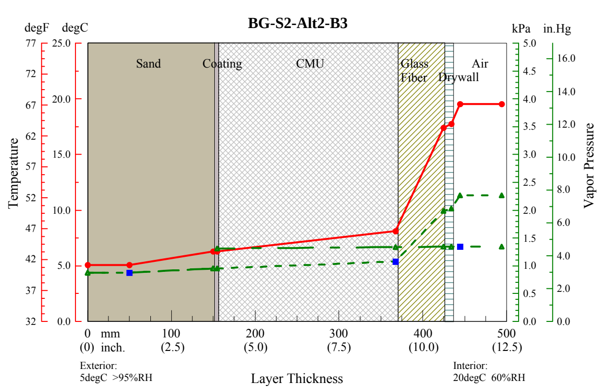


Figure C-173: Wall diagram of S2-Alt2-B3

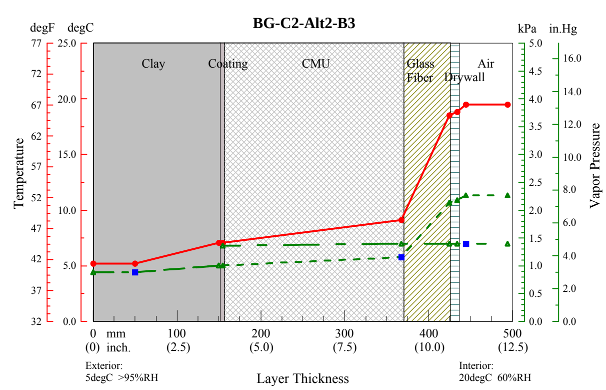


Figure C-174: Wall diagram of C2-Alt2-B3

Test cycle: **S2 – Alt2 (continued)**

Test cycle: **C2 – Alt2 (continued)**

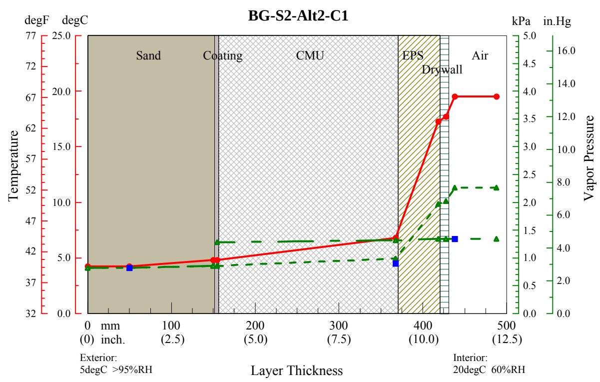


Figure C-175: Wall diagram of S2-Alt2-C1

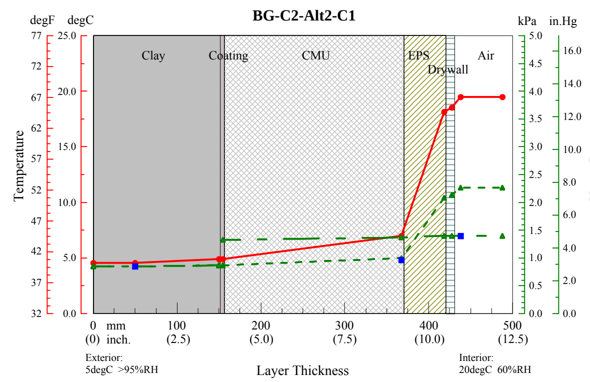


Figure C-176: Wall diagram of C2-Alt2-C1

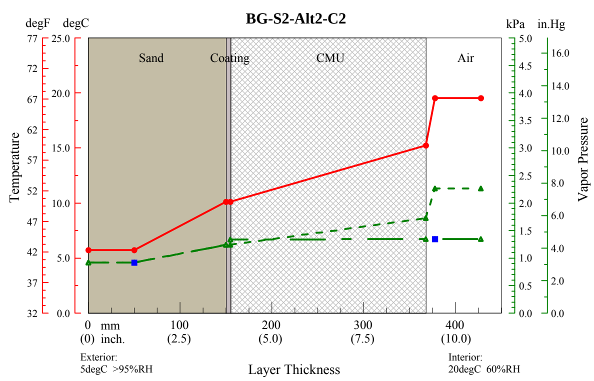


Figure C-177: Wall diagram of S2-Alt2-C2

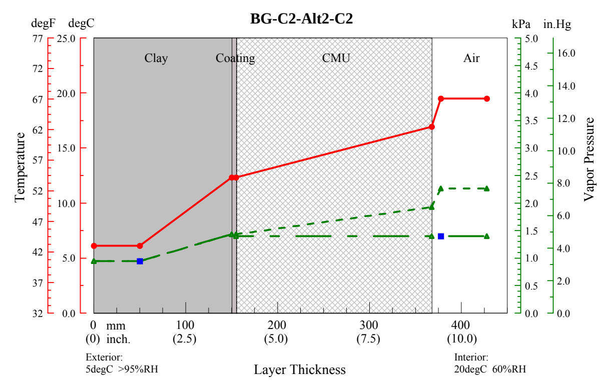


Figure C-178: Wall diagram of C2-Alt2-C2

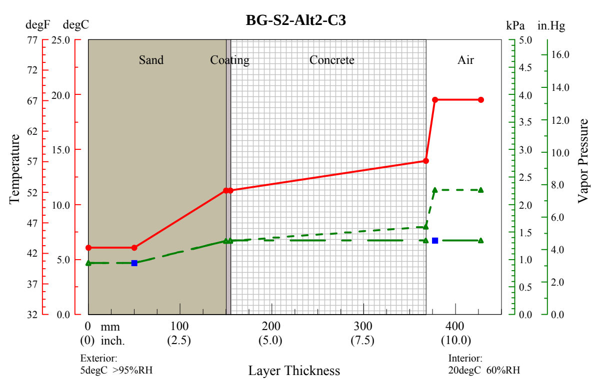


Figure C-179: Wall diagram of S2-Alt2-C3

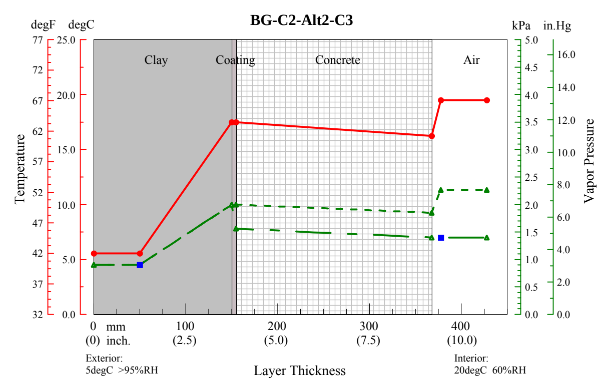


Figure C-180: Wall diagram of C2-Alt2-C3

Test cycle: **S2 – Alt3**

Test cycle: **C2 – Alt3**

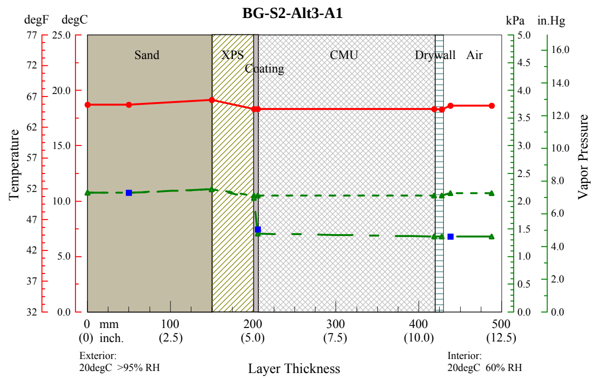


Figure C-181: Wall diagram of S2-Alt3-A1

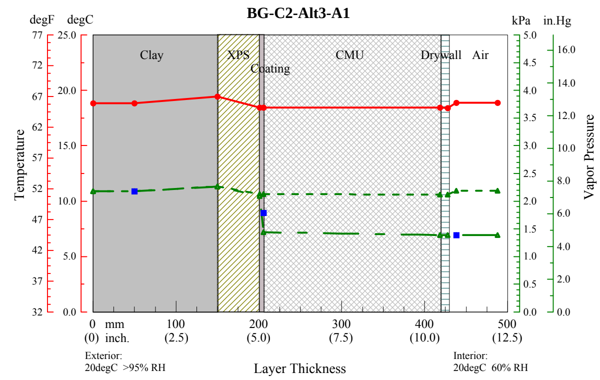


Figure C-182: Wall diagram of C2-Alt3-A1

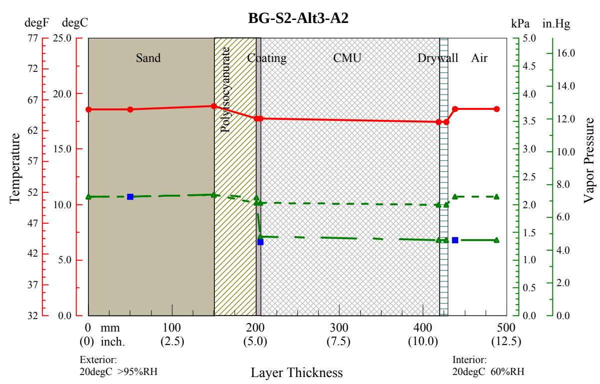


Figure C-183: Wall diagram of S2-Alt3-A2

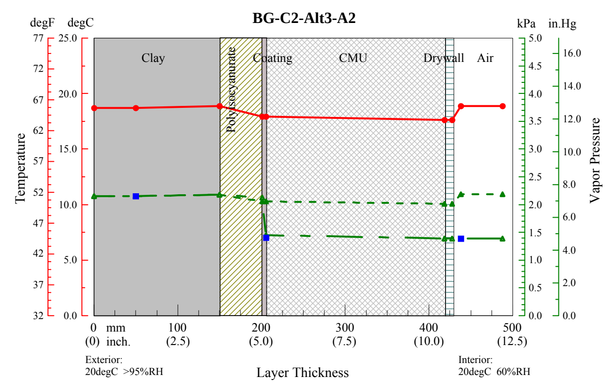


Figure C-184: Wall diagram of C2-Alt3-A2

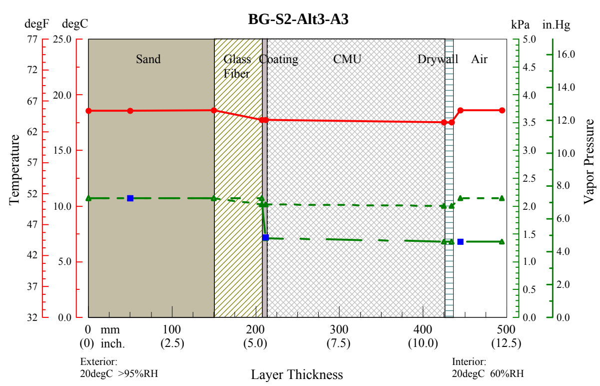


Figure C-185: Wall diagram of S2-Alt3-A3

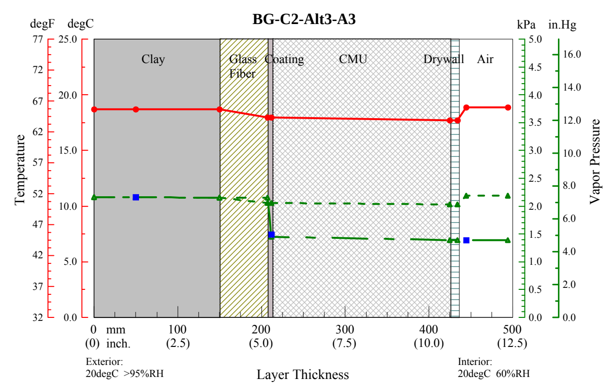


Figure C-186: Wall diagram of C2-Alt3-A3

Test cycle: **S2 – Alt3 (continued)**

Test cycle: **C2 – Alt3 (continued)**

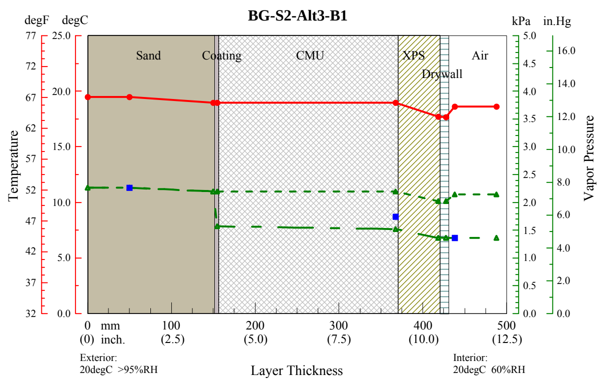


Figure C-187: Wall diagram of S2-Alt3-B1

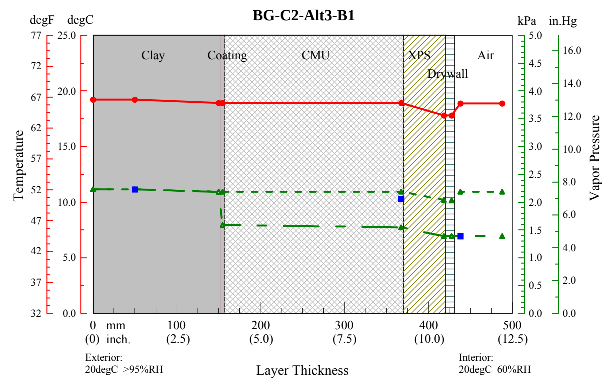


Figure C-188: Wall diagram of C2-Alt3-B1

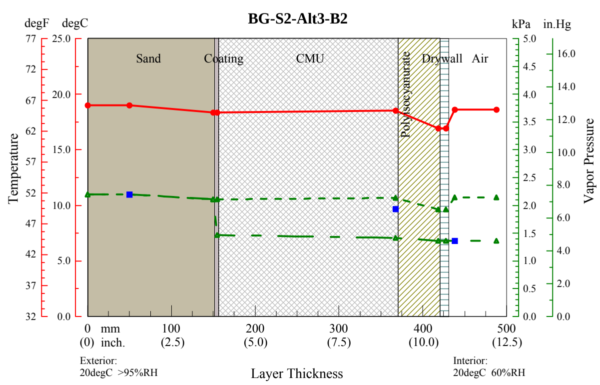


Figure C-189: Wall diagram of S2-Alt3-B2

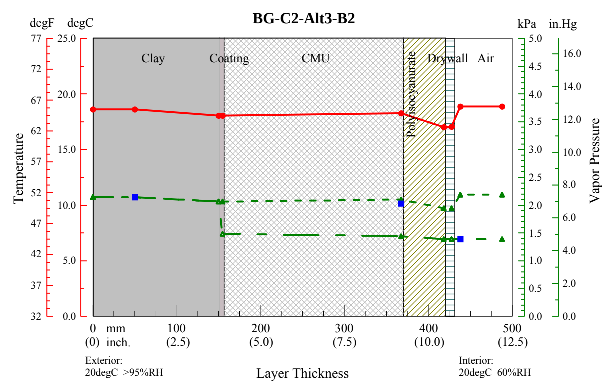


Figure C-190: Wall diagram of C2-Alt3-B2

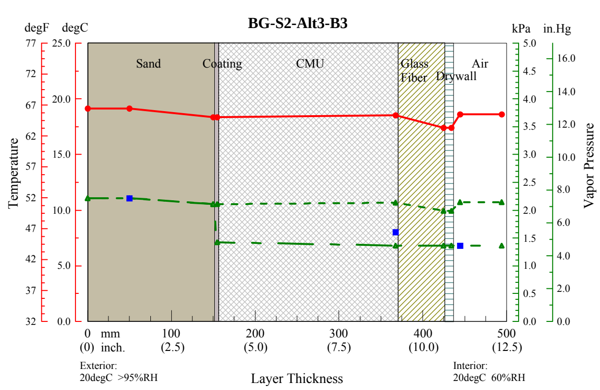


Figure C-191: Wall diagram of S2-Alt3-B3

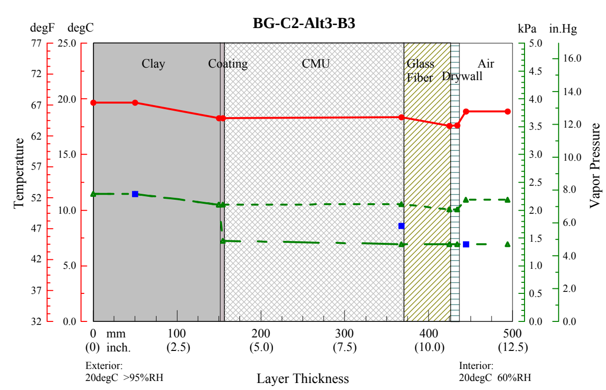


Figure C-192: Wall diagram of C2-Alt3-B3

Test cycle: **S2 – Alt3 (continued)**

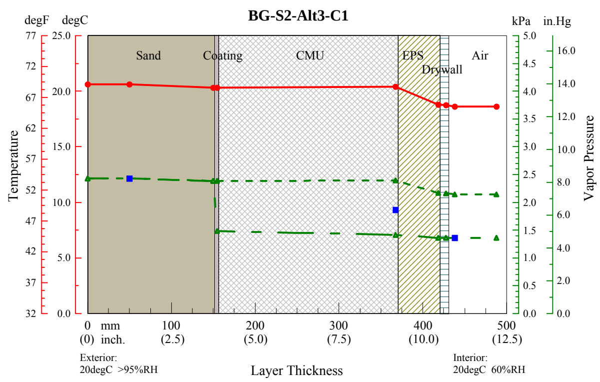


Figure C-193: Wall diagram of S2-Alt3-C1

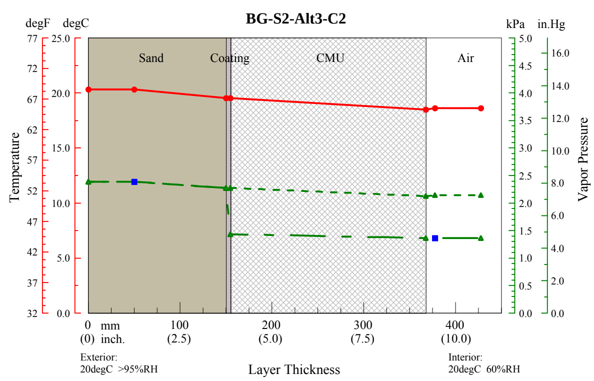


Figure C-195: Wall diagram of S2-Alt3-C2

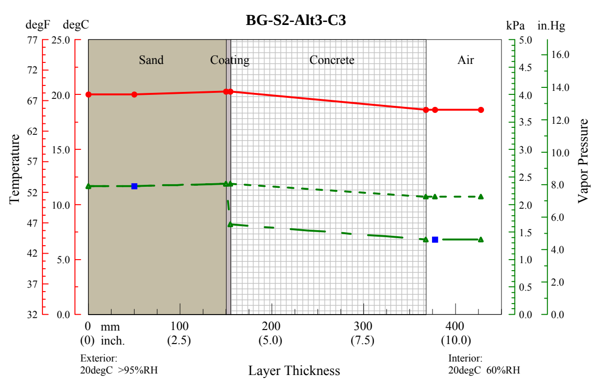


Figure C-197: Wall diagram of S2-Alt3-C3

Test cycle: **C2 – Alt3 (continued)**

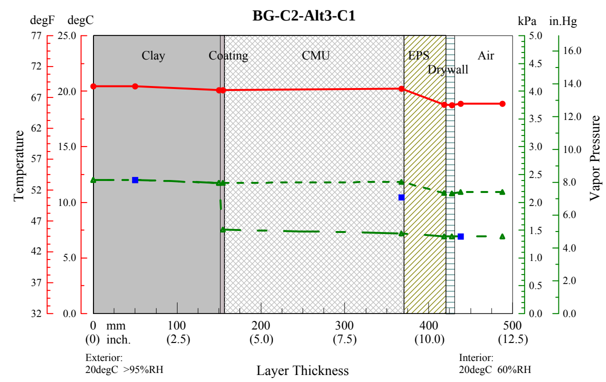


Figure C-194: Wall diagram of C2-Alt3-C1

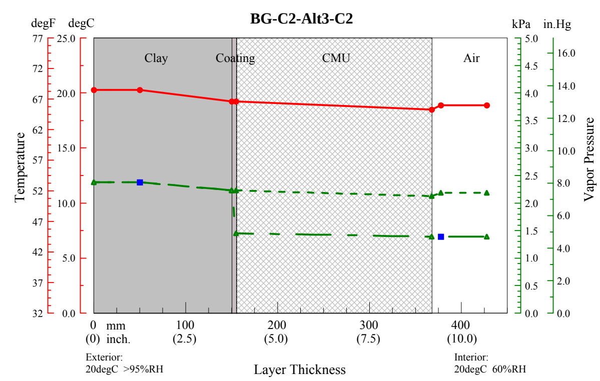


Figure C-196: Wall diagram of C2-Alt3-C2

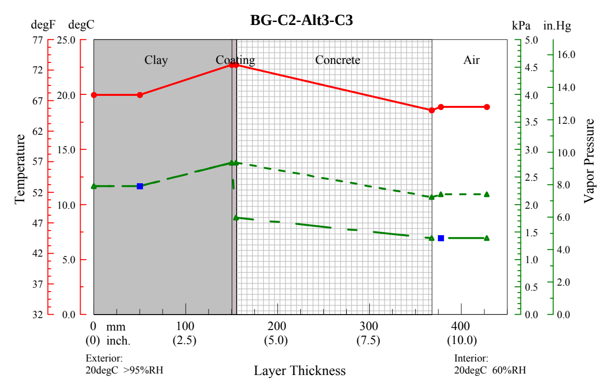


Figure C-198: Wall diagram of C2-Alt3-C3

Test cycle: **S2 – Alt4**

Test cycle: **C2 – Alt4**

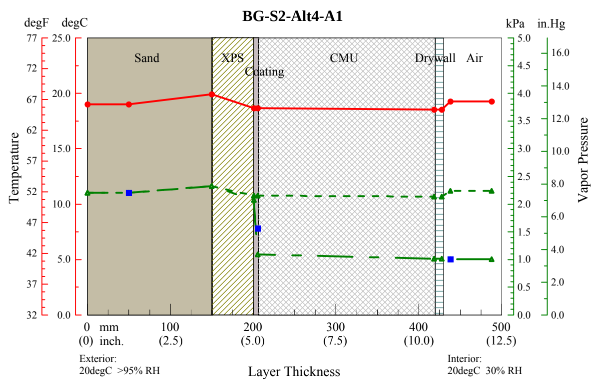


Figure C-199: Wall diagram of S2-Alt4-A1

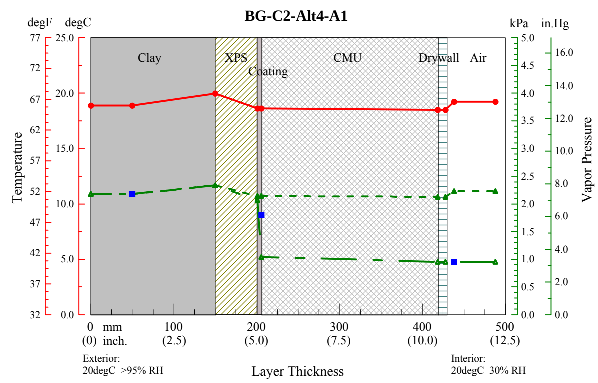


Figure C-200: Wall diagram of C2-Alt4-A1

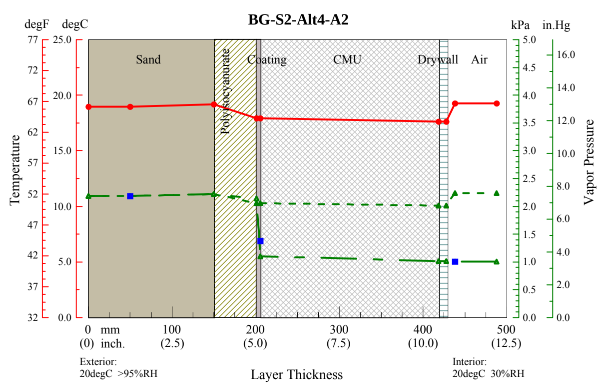


Figure C-201: Wall diagram of S2-Alt4-A2

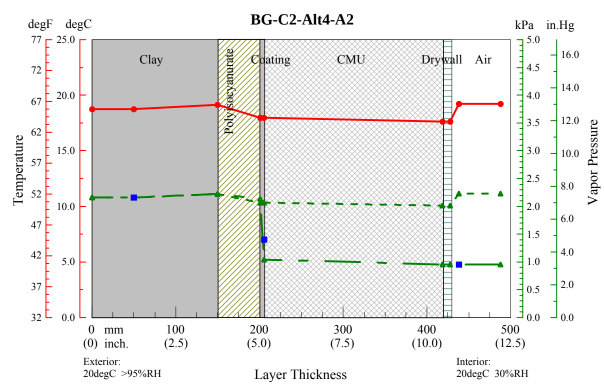


Figure C-202: Wall diagram of C2-Alt4-A2

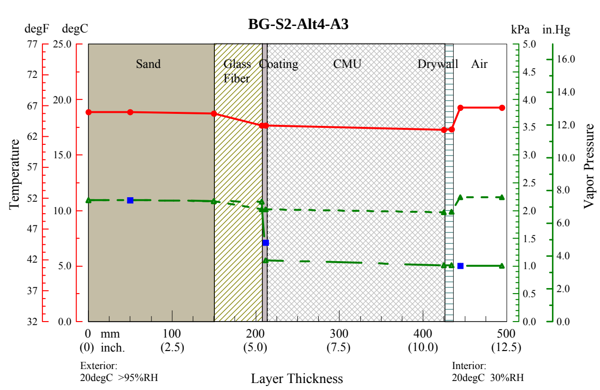


Figure C-203: Wall diagram of S2-Alt4-A3

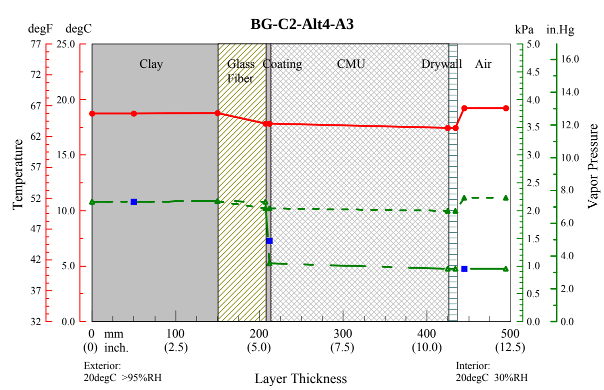


Figure C-204: Wall diagram of C2-Alt4-A3

Test cycle: **S2 – Alt4 (continued)**

Test cycle: **C2 – Alt4 (continued)**

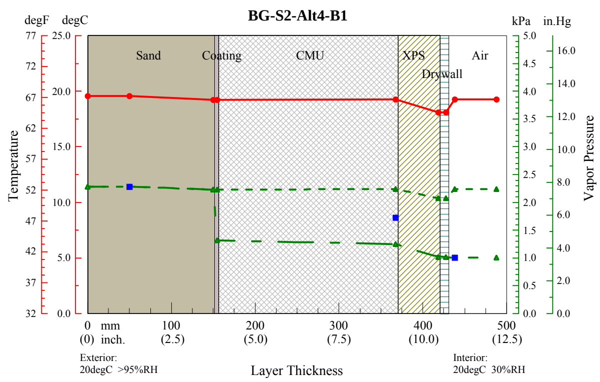


Figure C-205: Wall diagram of S2-Alt4-B1

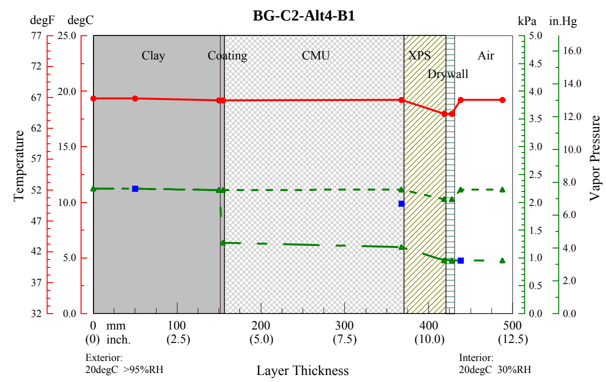


Figure C-206: Wall diagram of C2-Alt4-B1

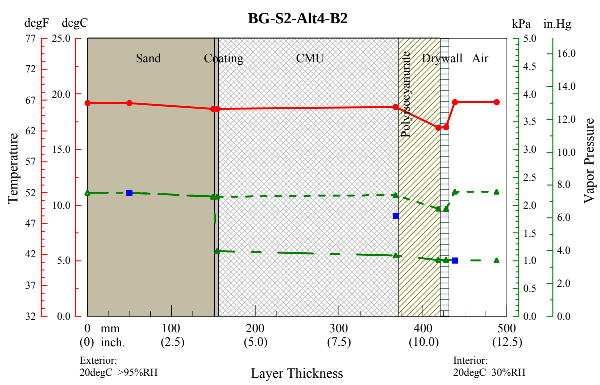


Figure C-207: Wall diagram of S2-Alt4-B2

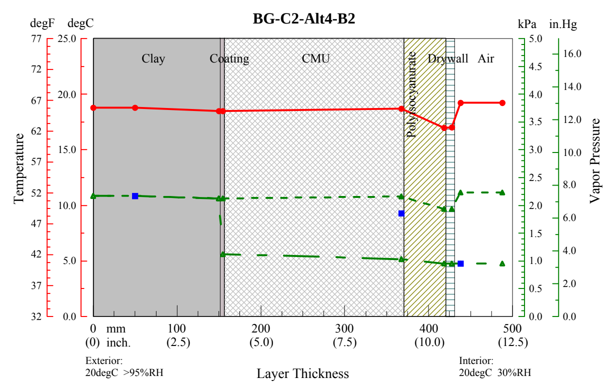


Figure C-208: Wall diagram of C2-Alt4-B2

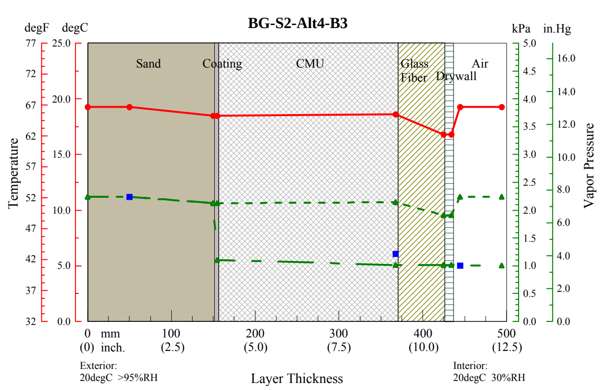


Figure C-209: Wall diagram of S2-Alt4-B3

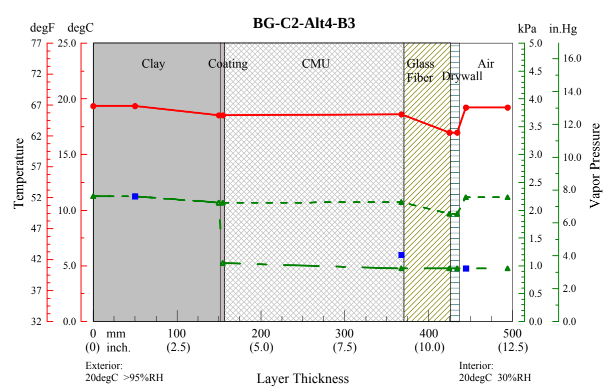


Figure C-210: Wall diagram of C2-Alt4-B3

Test cycle: **S2 – Alt4 (continued)**

Test cycle: **C2 – Alt4 (continued)**

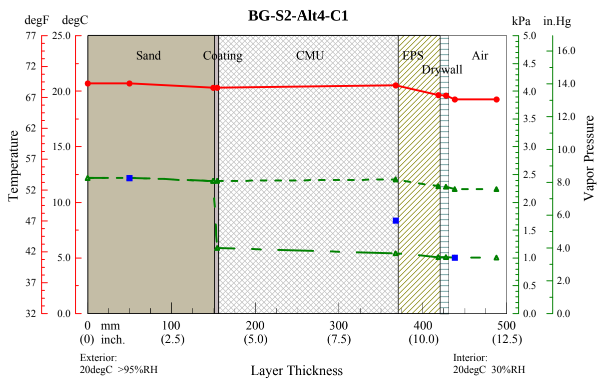


Figure C-211: Wall diagram of S2-Alt4-C1

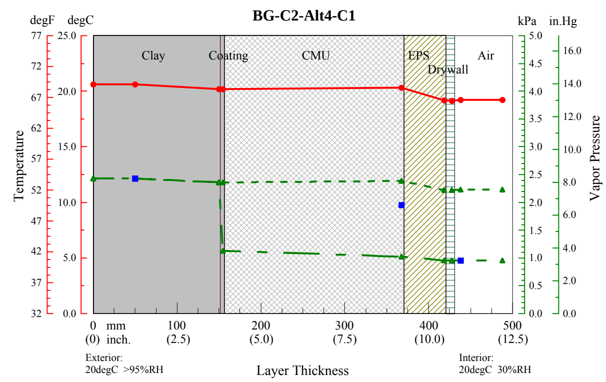


Figure C-212: Wall diagram of C2-Alt4-C1

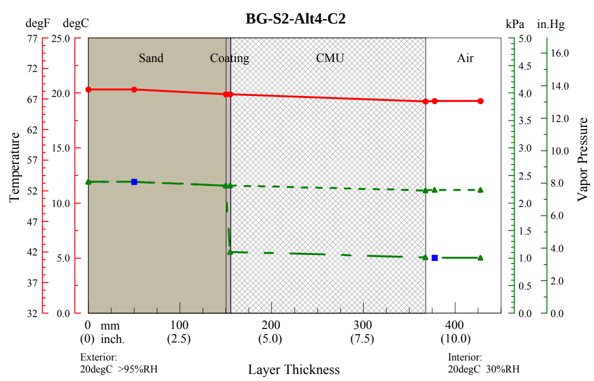


Figure C-213: Wall diagram of S2-Alt4-C2

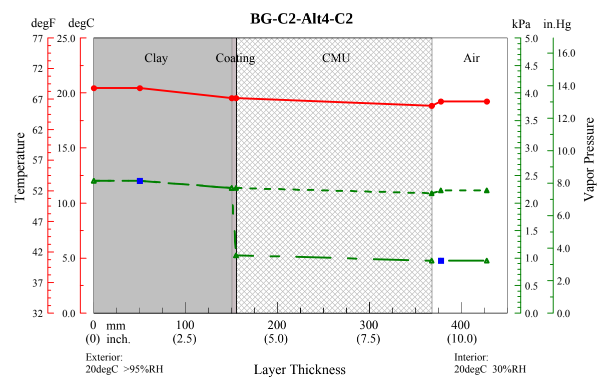
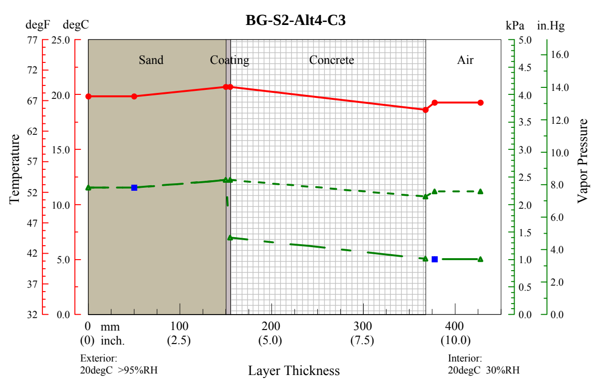


Figure C-214: Wall diagram of C2-Alt4-C2



F Figure C-215: Wall diagram of S2-Alt4-C3

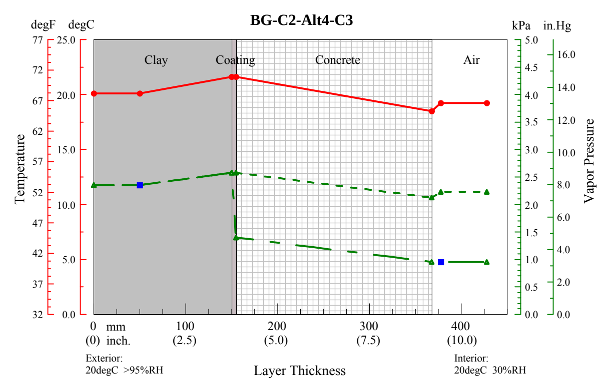


Figure C-216: Wall diagram of C2-Alt4-C3

Appendix D – Moisture content vs. relative humidity charts

The setup moisture content vs. relative humidity charts are in summarized in appendix D.

The moisture content of the specimens of below-grade structure is shown below as follows:

5. Measurement series: S1 (Sand; no dampproofing)
    - 5.1. Test cycle: S1-Alt1 (cold climate)
    - 5.2. Test cycle: S1-Alt2 (cold climate)
    - 5.3. Test cycle: S1-Alt3 (cold climate)
    - 5.4. Test cycle: S1-Alt4 (cold climate)
    - 5.5. Test cycle: S1-Alt5 (mild climate)
    - 5.6. Test cycle: S1-Alt6 (mild climate)
    - 5.7. Test cycle: S1-Alt7 (mild climate)
    - 5.8. Test cycle: S1-Alt8 (mild climate)
6. Measurement series: C1 (Clay; no dampproofing)
    - 6.1. Test cycle: C1-Alt1 (cold climate)
    - 6.2. Test cycle: C1-Alt2 (cold climate)
    - 6.3. Test cycle: C1-Alt3 (cold climate)
    - 6.4. Test cycle: C1-Alt4 (cold climate)
    - 6.5. Test cycle: C1-Alt5 (mild climate)
    - 6.6. Test cycle: C1-Alt6 (mild climate)
    - 6.7. Test cycle: C1-Alt7 (mild climate)
    - 6.8. Test cycle: C1-Alt8 (mild climate)
7. Measurement series: S2 (Sand; with dampproofing)
    - 7.1. Test cycle: S2-Alt1 (cold climate)
    - 7.2. Test cycle: S2-Alt2 (cold climate)
    - 7.3. Test cycle: S2-Alt3 (mild climate)
    - 7.4. Test cycle: S2-Alt4 (mild climate)
8. Measurement series: C2 (Clay; with dampproofing)
    - 8.1. Test cycle: C2-Alt1 (cold climate)
    - 8.2. Test cycle: C2-Alt2 (cold climate)
    - 8.3. Test cycle: C2-Alt3 (mild climate)
    - 8.4. Test cycle: C2-Alt4 (mild climate)

Measurement series: **S1** (Sand; no dampproofing)

Test cycle: **S1 – Alt1 to Alt4** (cold climate)

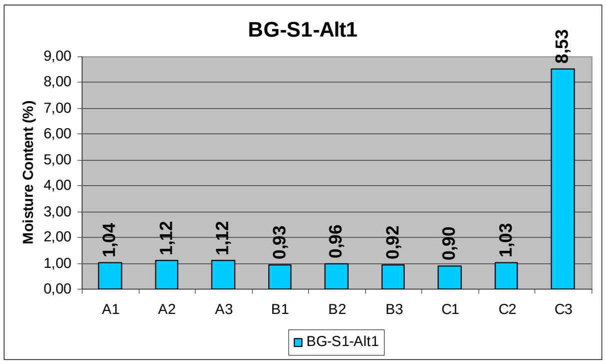


Figure D-1: Moisture contents of S1-Alt1

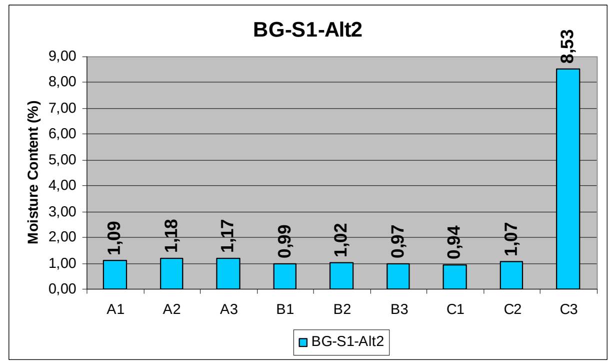


Figure D-2: Moisture contents of S1-Alt2

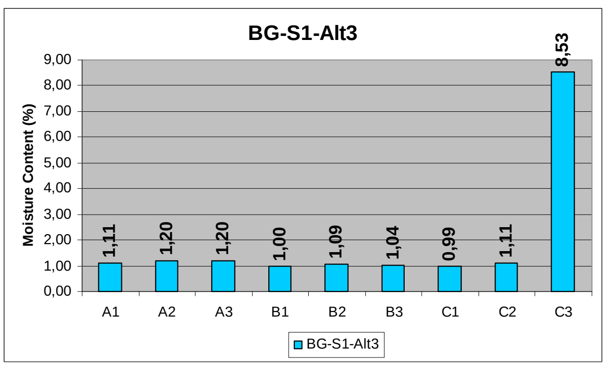


Figure D-3: Moisture contents of S1-Alt3

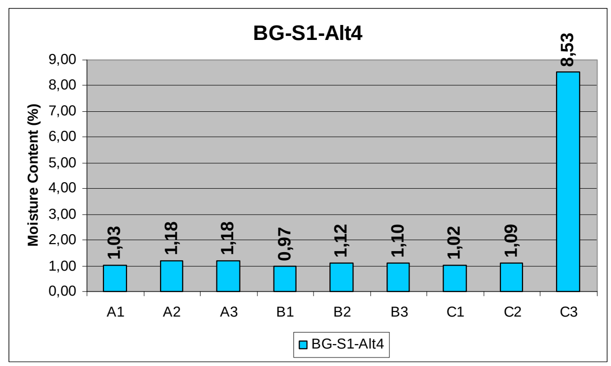


Figure D-4: Moisture contents of S1-Alt4

Measurement series: **S1** (Sand; no dampproofing) - continued

Test cycle: **S1 – Alt5 to Alt8** (mild climate)

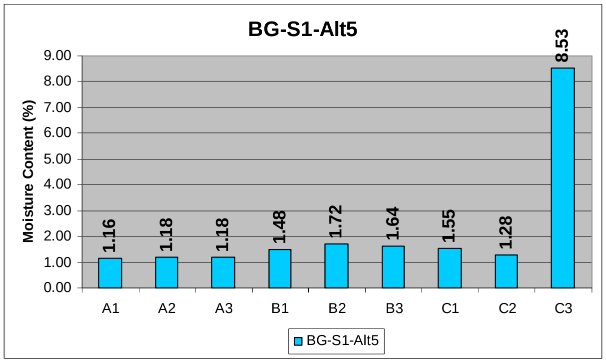


Figure D-5: Moisture contents of S1-Alt5

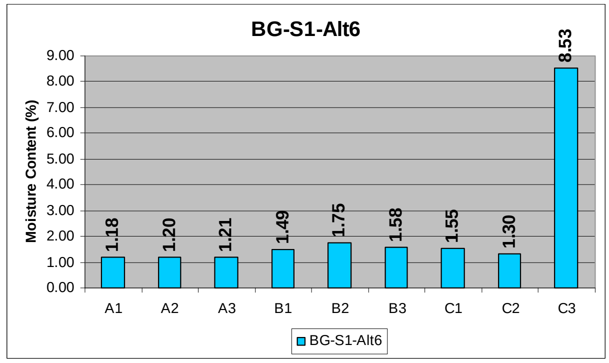


Figure D-6: Moisture contents of S1-Alt6

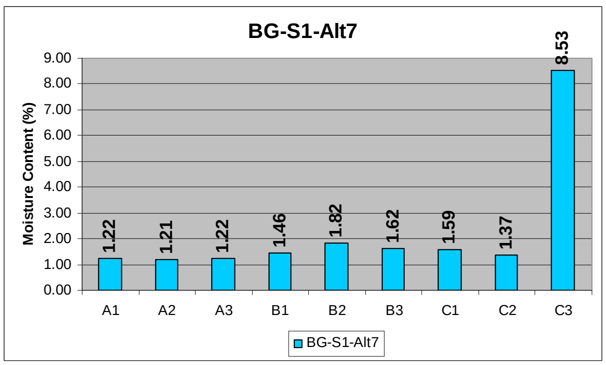


Figure D-7: Moisture contents of S1-Alt7

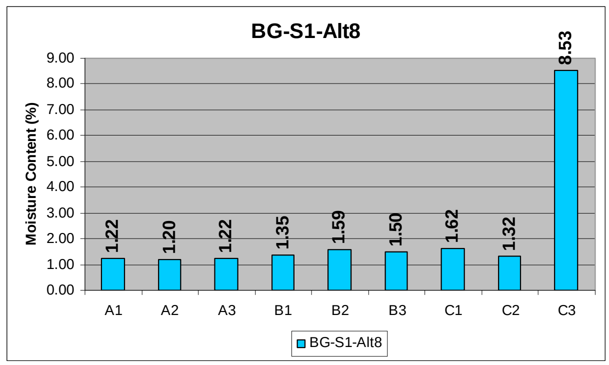


Figure D-8: Moisture contents of S1-Alt8

Measurement series: **C1** (Clay; no dampproofing)

Test cycle: **C1 – Alt1 to Alt4** (cold climate)

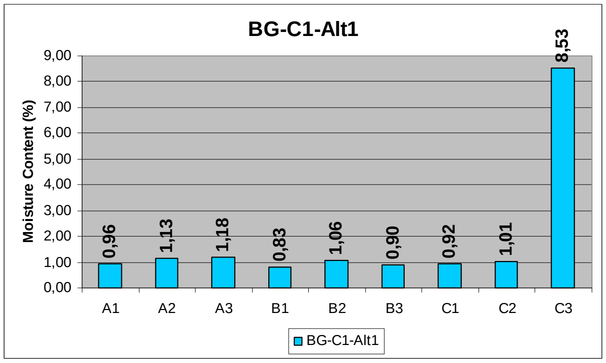


Figure D-9: Moisture contents of C1-Alt1

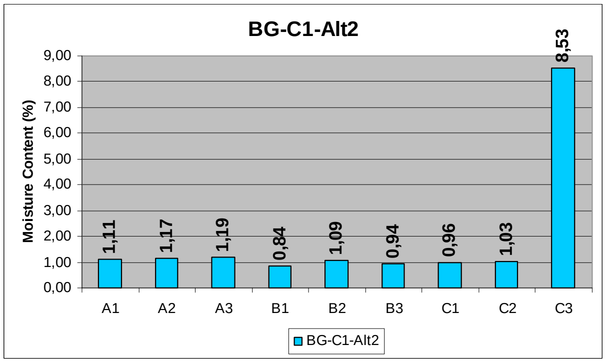


Figure D-10: Moisture contents of C1-Alt2

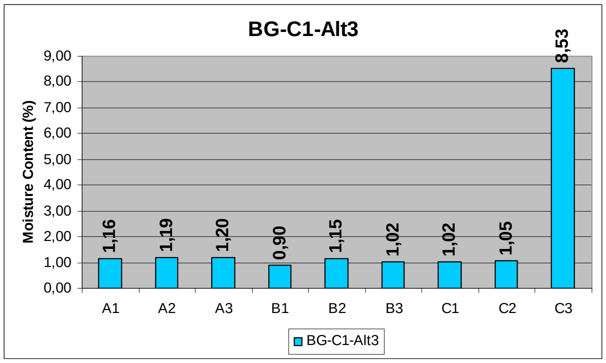


Figure D-11: Moisture contents of C1-Alt3

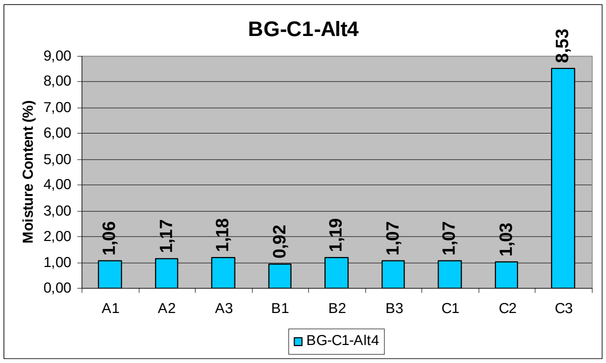


Figure D-12: Moisture contents of C1-Alt4

Measurement series: **C1** (Clay; no dampproofing) - continued

Test cycle: **C1 – Alt5 to Alt8** (mild climate)

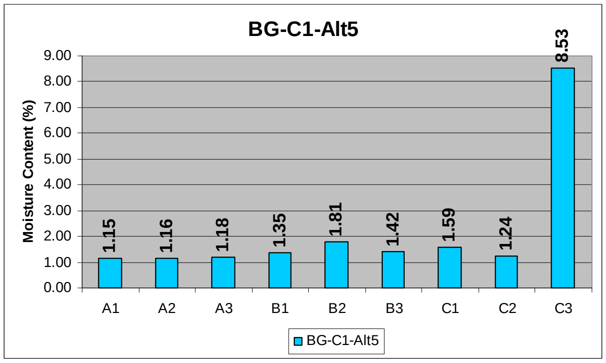


Figure D-13: Moisture contents of C1-Alt5

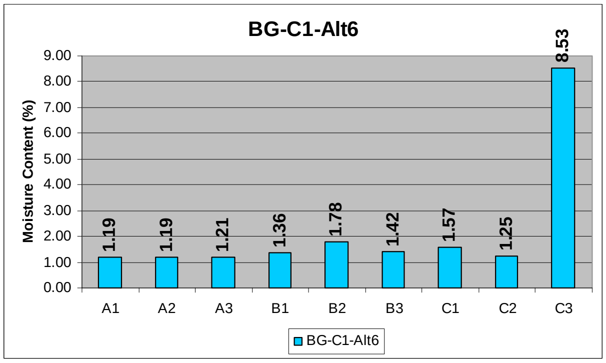


Figure D-14: Moisture contents of C1-Alt6

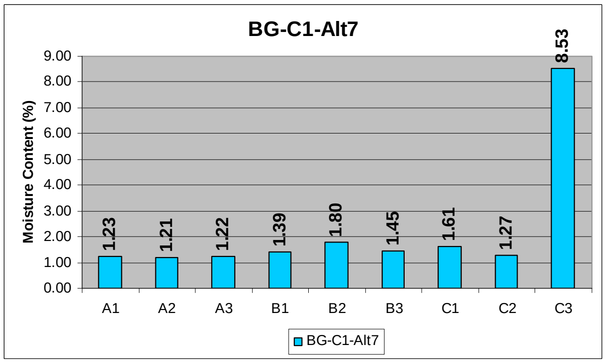


Figure D-15: Moisture contents of C1-Alt7

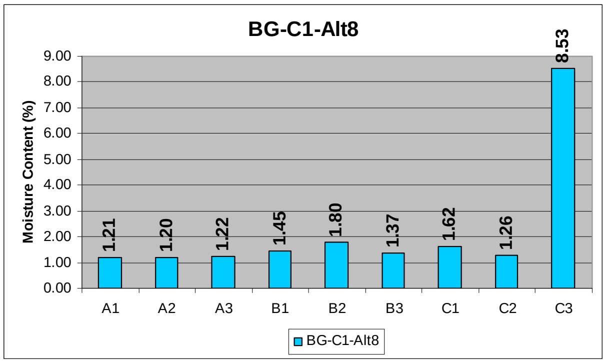


Figure D-16: Moisture contents of C1-Alt8

Measurement series: **S2** (Sand; with dampproofing)

Test cycle: **S2 – Alt1 to Alt2** (cold climate)

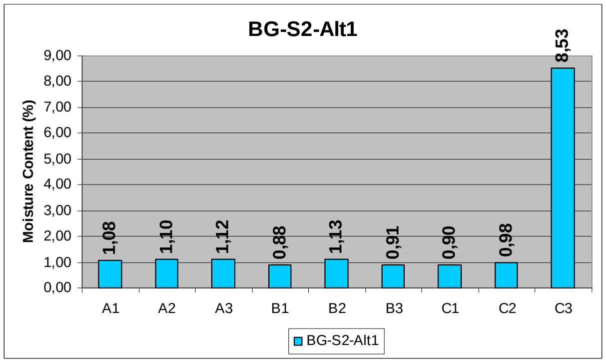


Figure D-17: Moisture contents of S2-Alt1

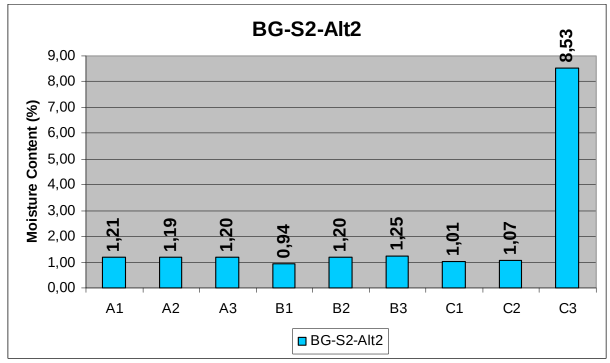


Figure D-18: Moisture contents of S2-Alt2

Test cycle: **S2 – Alt3 to Alt4** (mild climate)

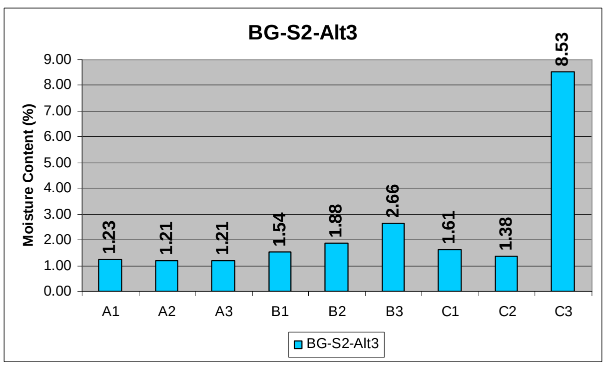


Figure D-19: Moisture contents of S2-Alt3

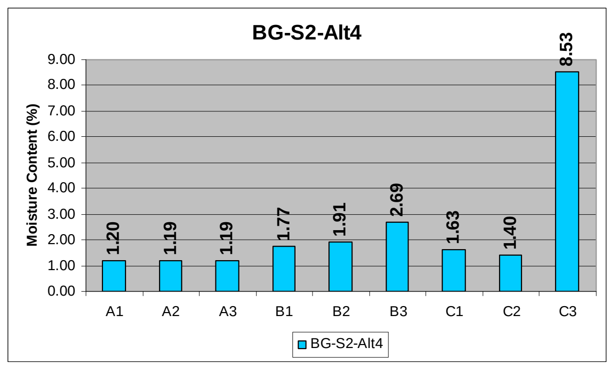


Figure D-20: Moisture contents of S2-Alt4

Measurement series: **C2** (Clay; with dampproofing)

Test cycle: **C2 – Alt1 to Alt2** (cold climate)

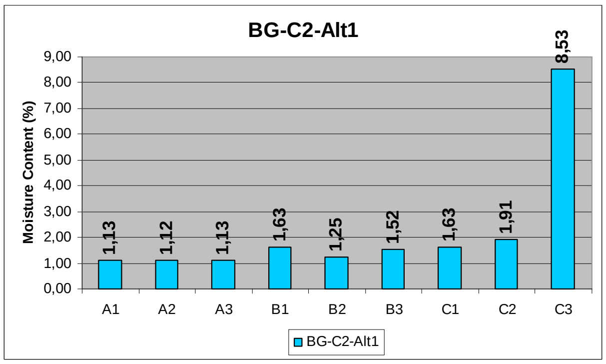


Figure D-21: Moisture contents of C2-Alt1

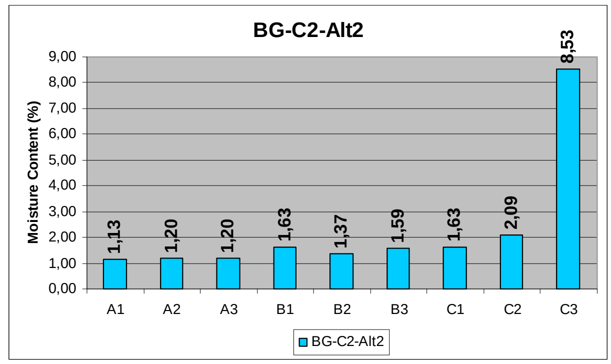


Figure D-22: Moisture contents of C2-Alt2

Test cycle: **C2 – Alt3 to Alt4** (mild climate)

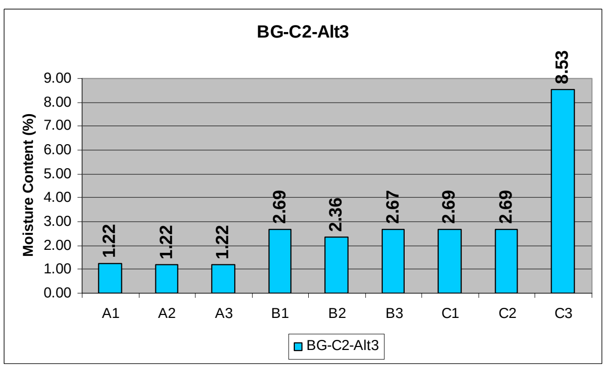


Figure D-23: Moisture contents of C2-Alt3

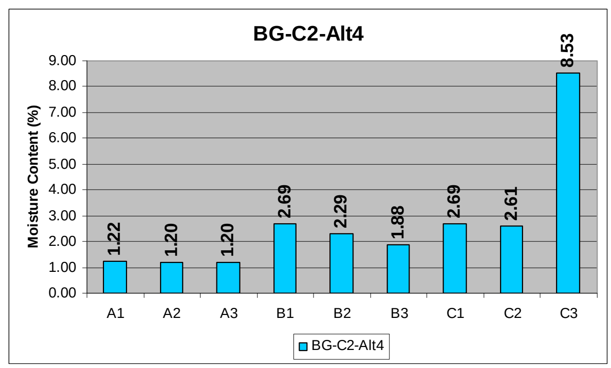


Figure D-24: Moisture contents of C2-Alt4