RESEARCH REPORT

Drainage and Retention of Water by Cladding Systems

Part 3 – Drainage Testing of EIFS Wall Systems

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DRAINAGE AND RETENTION OF WATER BY CLADDING SYSTEMS

Part 3 – Drainage Testing of EIFS Wall Systems

Presented to

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SUMMARY

Six EIFS walls from a previous study donated by three manufacturers were subjected to wetting/drainage/drying testing as outlined in Part 2 of this report series. They were selected in pairs to represent walls that retained the least and the most water from initial tests of three walls tested for each manufacturer.

Each wall was tested at least twice, once with water trickles delivered against the liquid applied water penetration barrier (LA-WPB), and once to the back of the EPS foam that had been bonded to the LA-WPB with trowelled adhesive ribbons.

The drainage ability of EIFS built in this way was not in question. Only 0.3% to 1.4% of the total water delivered over a one hour period (8 litres) was retained. The location of retained water was monitored crudely by means of a capacitance based moisture meter after most of the drying had been completed. However, in the period when most of the retained water was largest, at the end of a 1-hr drainage period, some of that water was likely held by storage either in joints or in the starter track, in addition to that retained on surfaces and in materials bounding the drainage cavities.

As they were field-applied, the spacing and number of adhesive ribbons applied was variable and was only measured at the top edge of the assembly where they could be located. Drying rates in the second hour of test were not related to either the ribbon spacing as described, nor on the amount of water that was retained. For these test walls, slightly more water was retained when the trickles were directed to the LA-WPB than to the back of the EPS. Given that the drainage spaces provided were only 2 to 3 mm thick by each assembly, the actual drainage pathways that the trickles chose to follow were not necessarily restricted to those surfaces.

The variation of laboratory temperature and relative humidity conditions affected the drying rates. This was most evident in plots of weight changes over the two-day drying period that followed the 2-hr wetting/drainage phase of the test. However, even during the period after drainage had stopped, there was an apparent correlation between the ambient vapour pressure and the mean drying rates for each group of three walls tested. The variation in vapour pressure means during this period at locations that affected the make-up air entering the bottom of drainage cavities was low compared with the limits on conditions initially considered acceptable in the test protocols. The quotation of drying rates and retention of small amounts of water is subject to a considerable degree of uncertainty, even under these relatively well controlled laboratory conditions – particularly for EIFS walls.

RÉSUMÉ

Six murs à systèmes d'isolation des façades avec enduit (SIFE), qui avaient été utilisés dans le cadre d'une étude antérieure, ont été donnés par trois fabricants pour qu'ils soient soumis à un essai de mouillage/drainage/séchage tel que décrit à la partie 2 de la présente série de rapports. Les murs ont été choisis en paires de manière à représenter ceux qui retenaient le moins et le plus d'eau dans le cadre d'essais initiaux de trois murs mis à l'essai pour chaque fabricant.

Chaque mur a été mis à l'essai au moins deux fois, une fois avec un filet d'eau s'écoulant sur la membrane d'étanchéité à l'eau appliquée à l'état liquide (MEE-EL) et une fois à l'endos du panneau de mousse de polystyrène expansé collé à l'aide de chapelets d'adhésif appliqués à la truelle sur la MEE-EL.

L'aptitude de drainage des SIFE construits de cette façon n'était pas remise en question. Seulement 0,3 % à 1,4 % du volume total d'eau qui s'est écoulée sur une période d'une heure (8 litres) a été retenue. L'emplacement de l'eau retenue été sommairement contrôlé au moyen d'un humidimètre à condensateur une fois que l'échantillon d'un mur avait presque tout séché. Cependant, au cours de la période où l'eau retenue était la plus élevée, à la fin d'une période de drainage d'une heure, une partie de cette eau était vraisemblablement emprisonnée soit dans les joints ou dans la rail de départ, en plus d'être retenue sur les surfaces et dans les matériaux bornant les cavités de drainage.

Étant donné que la pose s'est fait sur place, l'espacement et le nombre de chapelets d'adhésif appliqués étaient variables et les mesures n'ont été prises qu'aux endroits dans la partie supérieure du mur où la disposition était visible. Les vitesses de séchage au cours de la deuxième heure de l'essai n'étaient pas reliées à l'espacement entre les chapelets d'adhésif tel que décrit, non plus que le volume d'eau retenue. Pour ces murs d'essai, une quantité d'eau légèrement plus élevée a été retenue lorsque le filet d'eau était dirigé sur la MEE-EL, plutôt que sur l'endos du panneau de mousse de polystyrène expansé. Compte tenu que les espaces de drainage créés n'avaient que de 2 à 3 mm d'épaisseur sur chaque mur, les voies de drainage réellement empruntées par le filet d'eau n'étaient pas nécessairement limitées à ces surfaces.

Les variations de température et des conditions d'humidité relative dans le laboratoire ont eu une influence sur les vitesses de séchage. Ces conditions étaient le plus manifestes sur les graphiques de changements de poids au cours de la période de séchage de deux jours qui a suivi la phase de mouillage/drainage de deux heures. Cependant, même pendant la période de séchage qui suivait la période de drainage, il y avait une corrélation apparente entre la pression de vapeur d'eau ambiante et les vitesses de séchage moyennes de chaque groupe de trois murs mis à l'essai. La variation dans les moyennes de pression de vapeur au cours de cette période aux endroits qui influençaient l'apport d'air au bas des cavités de drainage était faible en comparaison avec les limites des conditions jugées acceptables au début des protocoles d'essai. L'estimation des vitesses de séchage et de la rétention de petites quantités d'eau comporte beaucoup d'incertitudes, même dans le cadre de conditions relativement bien contrôlées en laboratoire, particulièrement pour les murs SIFE.

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PREFACE

CMHC proposed that a series of drainage tests of exterior cladding assemblies be undertaken to produce data to quantify the ability of several types of cladding and methods of application on wall systems to manage and evacuate water that has intruded behind them. The test program has concentrated on the drainage characteristics of the tested systems, the amount of water that is retained and the drying ability of the cladding tested. The present report details the testing and analysis of the EIFS reports.

The reports are organized by the different phases in the project and by the wall types tested for drainage with additional supplementary tests done in support of the work. In summary, the different "Parts" of reporting in this project are:

Part 1 - Experimental Approach and Plan
Part 2 - Testing and Measurement Methodologies.
Part 3 – Drainage Testing of EIFS Wall Systems
Part 4 - Drainage Testing of Walls with Vinyl Siding
Part 5 - Drainage Testing of Walls with Wood-based and Fibrous Cement Siding
Part 6 - Air Flow Characteristics of Wall Systems Having Drainage Cavities
Part 7 - Air Leakage and Vapour Permeance of Joints in Some Siding Systems
Part 8 - Summary Report

Reporting has been compartmentalized into this series of "Parts" because of the extensive detail involved in reporting on the many wall variants that have been included. Comparisons were considered more manageable for the reader to face by providing the details separately in each segment of the work.

DRAINAGE AND RETENTION OF MOISTURE BY CLADDING SYSTEMS

Part 3 – Drainage Testing of EIFS Wall Systems

1 INTRODUCTION

This portion of the report concentrates on results that were obtained from tests of a particular class of External Insulated Finish System (EIFS) walls. This system is characterized by being adhesively attached to a liquid-applied water penetration barrier applied to sheathing and, by this means, a narrow drainage space is provided at that connection. There are several different EIFS systems currently in use, including direct applied systems which rely on grooves in the foam insulation to provide drainage. The specific system chosen for this study involved adhesively applied EPS insulation.

In Part 1 "Experimental Plan" and Part 2 "Testing and Measurement Methodology" the purpose and goals of the test program were explored. These reports also addressed the development of the test methodologies. Only limited restatement of some of that information will be provided in this report to provide some context for the specific testing of the EIFS wall systems.

2 TEST WALL CONSTRUCTION

The 1200 by 2400 mm wall specimens tested for this portion of the research program were all built at the Forintek laboratory in Sainte-Foy, Quebec in May and April 2004. Ten walls were built and tested for a consortium of EIFS manufacturers. Six (6) out of these ten (10) walls were selected for retesting under this CMHC project. The results of the initial drainage tests and of these retests will be provided in this portion of the report for comparison.

2.1 Materials

Forintek staff fabricated the wood frames and each manufacturer involved in the Consortium built the EIFS test walls according to their specifications. All the 1.22 by 2.44 m (4ft x 8ft) wood frames consisted of nominal 38 x 89 mm (2x4 inches) SPF S-DRY studs at approximate 400 mm (16 inches) spacing. Each had a single bottom sill plate and double top plates. The latter were used to reinforce the wall for being hung from the weight balancing system during drainage/drying testing. The sheathing consisted of 11.1 mm (7/16 inch) OSB manufactured to CSA O325. The sheathing was installed as two half panels of OSB with a 3.2 mm (1/8-inch) gap between them at mid height to simulate a condition that could be expected in the field.

Nailing of the sheathing to the wood-frame was at 150 mm (6 inches) along the perimeter and 230 mm (9 inches) in the field of the panels. No blocking was provided at the butt joints. The principal stiffness orientation of the OSB panels was parallel to the studs. For this thickness of panel and stud spacing, the orientation can be parallel to or perpendicular to the stud direction. The panels were placed with the grade stamps facing the framing so the textured faces of the OSB to which the EIFS was to be installed faced outward. Earlier testing had shown that there was no significant difference in the bonding strength of the liquid applied water penetration barrier coating applied to well manufactured OSB material. The textured face of OSB sheathing is normally applied face up in roofing applications to increase friction for safety of

workmen. Walls are typically built on the flat and tilted up in platform construction and it was presumed that workmen would employ the same practise for walls as they would walk on them during construction, just as they would for floor sheathing which is installed with the grade stamps down.

2.2 Fabrication of the EIFS test walls

The broad class of system these walls represents involves use of a liquid-applied water penetration barrier (LA-WPB) applied to the wood-based sheathing. Both one and two coat applications are represented in the study. After sufficient cure time of the coating, the expanded polystyrene foam (EPS) was adhered to the LA-WPB with ribbons of a cement/adhesive mix. The ribbons were formed with a notched trowel that spaced beads of adhesive mix about 64 mm (2.5 inches) apart. The beads were formed vertically on the back of the EPS panels. In this case, the EPS foam panels used were 50 mm (2 inches) thick. On being pressed against the cured LA-WPB, the beads of adhesive mix were flattened to form ribbons. The thickness of the ribbons and hence the drainage space provided was between 2 and 3 mm. There was sufficient adhesion to keep the panels in place without the use of fasteners. The joint pattern of the EPS foam in the central portion of the wall below the trickle trough was simulated to that which might be encountered in the field. That pattern is shown in Figure 1 and was generally maintained for all EIFS test walls.

One set of walls was built using a narrow starter panel (150 mm) but the same number of vertical and horizontal joints was maintained. The other manufacturers used starter tracks for the bottom edge of the installation. These were designed to provide a starting edge for the installation. They were also designed to capture any water draining down the drainage plane and to redirect it.

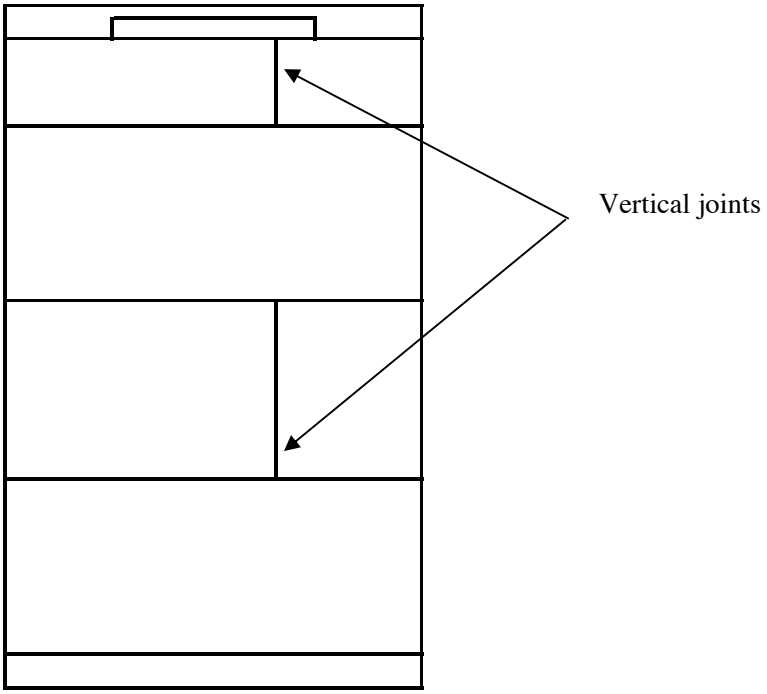


Figure 1 EPS Layout and Position of Vertical joints

Following this procedure, the exposed faces of the EPS panels were rasped to remove discontinuities in the face to better prepare the surface for bonding the base coat to them. The base coating, specific to the individual manufacturer, was towelled on together with glass fibre mesh reinforcement. The edges of the panels were similarly dealt with to seal the edges to the wood framing. The final finish coating, specific to the manufacturer, was applied after curing of the base coating for one day. The minimum cure time of the whole system before initial drainage testing was set at 7 days. In all cases, this was more than adequately exceeded. Testing of walls under the CMHC program was done at least 6 months after their initial construction and drainage testing. Photos taken at different stages in the construction of the EIFS test walls are provided in Appendix I.

2.3 Selection of Walls for Testing

The test walls were originally tested by trickling water into the drainage space built into each wall in a way that allowed drops to form at the edge of the trickle trough and to drop into that narrow space. Some walls were retested and the entire number of tests was examined for this study. As noted in the introductory report to this test program "Part 1 –Experimental Approach and Test Plan", some water penetrating the primary cladding may be retained on the back of the cladding in some way, depending on the type of cladding used. In the case of EIFS walls, water may adhere to or be absorbed in the back the EPS foam that has some residue of adhesive trowelled on it. The ribbons of adhesive will intercept and direct the flow of water and be absorbed by them. Also, bulk storage may occur in joints between the EPS panels. The starter track detail at the bottom of the wall may also be responsible for retaining some water.

To understand how moisture is retained in drainage cavities, besides moisture that may be adhered to the surfaces or absorbed into the materials, it was decided that EIFS walls be selected for this program on the basis of their initial tests. Thus, two walls were selected per manufacturer, representing the walls that retained the minimum and maximum amount of moisture when initially tested using the test protocols on which the current protocols are based. The strategy was to retest these walls by directing the water for drainage to the back of the drainage cavity (against the LA-WPB) and later, after the walls dried, to the front of the drainage cavity (the back of the EPS foam) to the extent that that was possible given the narrow space provided for drainage. The current test program was not designed to examine the exact factors that are responsible for retention of water in each system compared with other systems except in a general way.

The EIFS walls selected that retained the least water in initial tests were:

Wall 1; A-4
Wall 2; B-1
Wall 3; C-1

The EIFS walls selected that retained the most water in initial tests were:

Wall 4; A-1
Wall 5; B-4
Wall 6: C-3

The above designations identify the manufacturer (A, B, or C) and the numbers (1 to 4) represent the test number used in the original test program. In this report, discussion will be focussed on the Wall Number and the group basis by which each wall was chosen.

3 TESTING AND MEASUREMENTS

Photographs of the test set-up are shown in Part 2 Appendix I of the report on testing methodologies. The majority of commentary and description of the test methodology has been described in Part 2 of this report series and will not be repeated in detail here. Some restatement of those details will be provided for context for the benefit of readers who wish to examine only some of the reports in detail.

3.1 Delivery of Water to the Drainage Cavity

As explained in the report on methodology [1], the water was delivered to each wall in turn to a Plexiglas distribution trough which allowed the water to dribble or trickle in the drainage cavity. This trickle trough was 610 mm long (24 inches) and 95 mm wide (3.75 inches) with a bottom slope of 20%. Holes with a diameter of 2 mm (0.08 inch) were drilled every 38 mm (1.5 inch) c/c in the bottom corner to allow drainage. The flow provided for the initial commercial test program was not directed to specific surfaces, but drops of water were merely dropped in about the middle of space provided. The size of drops formed did not ensure where the flow would initially be introduced into the narrow spaces provided. Since the current test program required that flow be directed to either the front or back of the drainage cavity as part of the investigation (other cladding systems being more troublesome in this regard), the troughs were modified to allow the drops to flow down a thin sheet of plastic bonded to the edge of the trough along which flow occurred from the holes drilled in the bottom corner. The plastic sheet was serrated to gather the flow to single locations. Doing so also reduced the size of droplets that could be held at the tips of the serrated sheet (fingers) before they dropped off when surface tension was the only factor controlling the droplet size. With the fingers in actual contact with the surface to which flow was directed, a continuous trickle link was formed from the trough to the wall without the formation of individual drops. Tilting the trickle trough allowed the flow to be directed to specific planes. The adequacy of uniformity of flow into the wall along the length of the trickle trough was previously determined to occur when the pool (or lake) of water in the trough was uniformly wide. By assuring that the trough was installed horizontally, and by observing the uniformity in width of the “lake” while water dripped into the trough, this provided assurance that flow into the wall was uniform along the length of the trough.

3.2 Test Procedure Review

The flow of water was delivered to the top of the drainage cavity of each wall for a period of approximately 1 hour (until 8 kg of water had been delivered to the trickle trough). The flow rate was 133g/min. The water that drained through the drainage cavity was collected by a sloped galvanized gutter installed at the bottom of the wall cladding which directed the water into a pre-weighed container.

For the EIFS walls being tested for the first time in the CMHC test program, the trickle trough was positioned so that the tips of the serrated sheet delivered water droplets to the back of the drainage cavity, i.e., against the LA-WPB surface. In subsequent retesting of these same walls when it was certain that the moisture retained from this test had ample time to dissipate (for a minimum of 7 days), the trickle trough was arranged to deliver the water to the back of the EPS insulation within the drainage cavity. This provided a greater opportunity for water to be retained by storage in joints between the individual EPS panels and to be absorbed by any adhesive residue on the back of the EPS foam. Given the narrow space into which the flow was directed, the attempted bias was only assured at the top of the cavity. Once water enters the cavity, the actual water paths taken are not known.

After supplying water for one hour at the calibrated rate, the water flow to the wall was turned off. The glass carboy was replaced by another container with tempered fresh water (20 kg) to be used for the next two specimens to be tested. Each wall specimen was allowed to drain for one additional hour after flow to it was halted. The water remaining in the trickle trough at the end of this 2-hour test time and water adhered to the collection gutter and the specimen surface (if any) was mopped up delicately with paper tissues. The water collected over this period was weighted with the container, as were the tissues used to mop up water droplets in the gutter, the specimen surface and the trickle trough. This information, together with the load cell data which provided the actual weight gain, was used to determine the quantity of water that was retained within the wall at the end of the two-hour test period.

All three (3) walls were evaluated together over the same period and the data were stored in one file at a sampling rate of 20 samples per second and stored as averages per second. When the drainage test on the third wall was completed, load monitoring was temporarily halted and the storage rate was changed to 3 samples per minute. This data, at the slower sampling rate, was stored in a separate file and monitoring was continued for a period of at least 48 hours. The two files were subsequently combined. The trickle troughs were left in place throughout the entire wetting and drying periods.

The laboratory conditions are set to be maintained at 20ºC and 50% RH on a year-round basis, except temporarily when the large laboratory doors are opened for movement of materials into the laboratory. The monitoring of these conditions was obtained using temperature and RH sensors, and recorded as specified in the next section. Within the large laboratory space in which this work took place, there were variations in the conditions associated with the cycling of the air conditioning system. Radiant heating from the lighting system also affected the temperatures in the laboratory. All lights were automatically turned off at 11:00 PM by the computerized control system for the building, and the control program could not be changed for this study. Some additional discussion about variations in conditions that occurred during the test period for each set of tests is provided later in this report.

The summary tables of results are provided in Section 4 and all drainage/drying plots obtained for individual EIFS walls can be found in Appendix II of this report.

3.3 Measurement of Environmental Conditions

As mentioned in the Section 3.2, the RH and temperature conditions surrounding the tested specimens were monitored during the testing period (in all, for almost 50 hours duration). Four RH and temperature sensors were installed at the top part of each wall specimen to monitor the conditions of air exiting the top of the drainage cavity. These were spaced uniformly across the top of each wall. Two of these sensors were positioned below the trickle trough and the other two were at the same level but symmetrically placed away from both sides of the trough. All sensors were placed at about 25 to 50 mm from the top of the cladding. The aim was to compare these measurements with the ambient conditions in the lab. To monitor these conditions, four additional monitoring stations were installed. Two stations were positioned in the region of the laminated beam supporting the assemblies, one station was on top of a table in the vicinity of the test set-up, and one was attached to one of the supporting columns near the floor at a height corresponding to the bottom of the cladding.

3.4 Measurement of Moisture Contents in the Drainage Cavity

Since moisture gradients in the drainage cavity, and the materials defining that space, were likely to be significant it was recognized early that resistance type moisture meter readings at single points would not provide a reliable assessment of distribution of moisture. Instead, based on earlier attempts to map the retained moisture distribution in the materials contacted by water in the drainage cavity, a qualitative approach to provide that information was taken by using a capacitance moisture meter. The Wagner L620 capacitance based moisture meter used had sufficient data storage capacity to allow numerous readings to be taken. Two vertical scans per stud space were taken at a vertical spacing of about 150 mm for a total of 6 scans and collection of 90 moisture content readings per wall both before and after the drainage test. Together, with assumed zero moisture "change" at the edges and top of the wall, this provided enough information to plot the contours where moisture was being retained. The moisture readings were all taken with the wall laid horizontally exposing the back of the OSB sheathing. For practical reasons, the final moisture measurements were obtained after the walls were dismounted from the balance beam setup and after the 48-hr drying period had ended. The density or frequency of measurement points selected was largely controlled by the amount of time taken to do the measurements, as that was significant. The moisture change contours are provided in Appendix III.

4 RESULTS

Each of the two series of EIFS walls were tested twice. For each series, the walls were first tested by allowing the water to drain down the back surface of the wall along the LA-WPB membrane. They were retested seven days later, after drying, and the water was directed to flow down the back of the EPS insulation inside the drainage cavity, i.e., down the front of the drainage cavity. The following sections describe the results. The bias in flow location applied only to where the water was first introduced. Once inside the cavity, interference with the adhesive ribbons may have caused the water to be dispersed in any number of ways depending on the specific way that each drainage cavity was constructed. The original tests done prior to this investigation involved depositing water directly above the drainage cavity as droplets that may or may not have followed the paths having the above bias. The main characteristics chosen to represent the degree of retention and drying for all wall tests in this test program are; (a) the amount of water retained at the end of the two hour period following start of wetting, and (b) the retention of water at the end of a further 48 hours of drying under prescribed isothermal conditions. The choice of the 2-hr period assures that sufficient time elapsed to allow free water to drain. This period is derived from the ASTM E 2273-03 test method [1]. The 48-hr drying period is derived from the CCMC Technical Guide [2] because it was recognized that some measure was required to assess the capability of a cladding system to dissipate moisture that was retained without damage to the wall system. The permissible level is not yet known but an arbitrary upper limit may eventually be set by comparing some systems to others that have a proven track record.

It was observed that the width of the drainage path out of the bottom of each test wall was slightly wider than the trickle trough. This width was affected by the type of starter track used and the number of holes provided for water to exit the track used. Generally, because the ribbons were substantially vertical, they would be expected to guide flow more directly downward than some other systems.

The numerical reporting of weight of water retained was limited to the nearest gram even though the values were measured to fractions of a gram. Uncertainty associated with the environmental conditions does not justify recording the weights with greater precision.

4.1 EIFS Walls that Originally Retained the Least Water

The three walls in this series were selected because they had retained the least water the first time they were tested after manufacture for commercial testing.

In Table 1 below, the data labelled "Initial Test" represents the results for those initial tests. For comparison, the retained water at the end of 2-hours, and at the end of an additional 48-hour drying period is summarized when water was trickled along the back plane of the drainage cavity. Typical weight gain and loss plots for each period for each wall are provided in Appendix II. Additional comparative plots will be provided in Section 5.

The unit retention is also reported in the tables that follow. Unit retention is defined as the total retention divided by the area of the projected drainage plane. The drainage plane area was defined by the product of the width of the trickle trough by the height of wall between where water entered the drainage plane to the base where the water exited the drainage plane and was collected. For all EIFS walls, this area was 1.3 m^2. Not all wall systems will drain in a similar way and this measure is likely only appropriate for members of the same class of cladding. It has been used for characterizing the retention of EIFS walls.

The results of retests of the same walls by trickling water down the front plane of the drainage cavity (down the back of the EPS) are shown in Table 2.

Table 1 Drainage/Retention results – Water drained down the back of the drainage cavity (WRB/sheathing)

Time	Wall 1 Initial Test	Wall 2 Initial Test	Wall 3 Initial Test	Wall 1 Back	Wall 2 Back	Wall 3 Back
1 hour (reading & retention)	267	102	282	215	117	235
Retained weight of water after 2 hours (g)	**196**	**30**	**189**	**139**	**24**	**109**
Retained weight of water after 48 hours (g)	**86**	**8**	**115**	**101**	**--***	**51**
Unit-retained water after 2 hours (g/m^2)	**151**	**23**	**145**	**107**	**19**	**84**
Unit-retained water after 48 hours (g/m^2)	**66**	**6**	**89**	**78**	**--***	**39**

Table 2 Drainage/Retention results – Water drained down the front of the drainage cavity (EPS insulation).

Time	Wall 1 Initial Test	Wall 2 Initial Test	Wall 3 Initial Test	Wall 1 Front	Wall 2 Front	Wall 3 Front
1 hour (reading & retention)	267	102	283	239	188	119
Retained weight of water after 2 hours (g)	**196**	**30**	**189**	**165**	**47**	**54**
Retained weight of water after 48 hours (g)	**87**	**8**	**116**	**153**	**--***	**34**
Unit-retained water after 2 hours (g/m^2)	**151**	**23**	**145**	**127**	**36**	**42**
Unit-retained water after 48 hours (g/m^2)	**66**	**6**	**89**	**118**	**--***	**26**

* The environmental conditions did not permit a reliable 48-hr weight value to be quoted. This wall retained little water and would have dried to very low level had the environmental conditions been truly steady state throughout the test period. This note also applies to Tables 3 and 4, where a matching wall by the same manufacturer also retained very little water.

4.2 EIFS Walls that Originally Retained the Most Water

In a similar way, the results for three walls selected because they had each retained more water than the other walls in a set of three walls produced by each manufacturer are summarized in Tables 3 and 4.

Table 3 Drainage/Retention results – Water drained down the back of the drainage cavity (WRB/sheathing)

Time	Wall 4 Initial Test	Wall 5 Initial Test	Wall 6 Initial Test	Wall 4 Back	Wall 5 Back	Wall 6 Back
1 hour (reading & retention)	807	504	348	178	134	419
Retained weight of water after 2 hours (g)	**744**	**385**	**305**	**54**	**35**	**95**
Retained weight of water after 48 hours (g)	**574**	**223**	**292**	**19**	**--***	**28**
Unit-retained water after 2 hours (g/m^2)	**572**	**296**	**235**	**42**	**20**	**73**
Unit-retained water after 48 hours (g/m^2)	**441**	**171**	**224**	**15**	**--***	**22**

Table 4 Drainage/Retention results – Water drained down the front of the drainage cavity (EPS insulation)

Time	Wall 4 Initial Test	Wall 5 Initial Test	Wall 6 Initial Test	Wall 4 Front	Wall 5 Front	Wall 6 Front
1 hour (reading & retention)	807	504	348	152	150	141
Retained weight of water after 2 hours (g)	**744**	**385**	**305**	**61**	**59**	**63**
Retained weight of water after 48 hours (g)	**574**	**223**	**292**	**46**	**31**	**44**
Unit-retained water after 2 hours (g/m^2)	**573**	**296**	**235**	**47**	**43**	**48**
Unit-retained water after 48 hours (g/m^2)	**441**	**171**	**224**	**35**	**33**	**37**

The information provided in Tables 1, 2, 3, and 4 are further compared in Table 5 by juxtaposing all test results for direct comparison. All of the wall heights were the same and the so-called "projected area" of the drainage path under the trickle trough is the same (1.3 m^2). Hence only the total weights retained at the key measurements times of 2-hr and 48-hr are compared in Table 5.

Table 5 Overall summary of original and retest retentions

Test Series	Manuracturer	Wall Number	Wall Designation	Location of Trickling	Retained Water (g)		
					1-hr	2-hr	48-hr
Lowest Initial Retention	A	1	A-4	Initial Test	222	115	86
				WPB	215	139	101
				EPS	239	165	153
	B	2	B-1	Initial Test	102	30	8
				WPB	117	24	--*
				EPS	188	47	43
	C	3	C-1	Initial Test	283	163	116
				WPB	235	109	51
				EPS	119	54	34
Highest Initial Retention	A	1	A-1	Initial Test	807	744	574
				WPB	178	54	19
				EPS	152	61	46
	B	2	B-4	Initial Test	504	384	233
				WPB	134	35	--*
				EPS	150	59	46
	C	3	C-3	Initial Test	348	305	291
				WPB	419	95	29
				EPS	141	63	44

* Note: The environmental conditions did not permit reliable 48-hr values to be quoted for these tests. The walls produced by this one manufacturer would have dried to very low levels had conditions been steady enough.

While the walls were selected for these tests on the basis of the 2-hr retained values and those values have some rationale for comparison, the 1-hr values were included in this summary table for information only. These values represent the highest weight gain at the moment that flow of water to the drainage plane was halted. They are not indicative, except in a general way, of the drainage behaviour of the walls. These values include the weight of water that is still in the process of flowing down the internal drainage paths. Some types of walls take longer for free water to dribble down to reach the gutter. Some may have stored part of the water in joints while some may retain water temporarily in the starter track at the base of the wall. During water entry, some flow paths may have lead directly to the bottom, while other flow paths were intercepted by the adhesive ribbon configurations. Once the free water that can drain to the gutter passed out of the wall, the loss in weight was the result of drying alone. In most of the tests of EIFS walls, drainage was completed in less than 15 minutes.

The 2-hour retention values represent the ability of a wall to retain water as adsorbed and absorbed moisture on surfaces of materials in the drainage plane, as well as stored moisture in joints and potential traps in the adhesive ribbons, including retention in the bottom starter joint detail. Each manufacturer used a different type of starter track. Since drainage tests were not on the starter tracks alone we can only deal with the overall retention values.

As a commentary on these results, the following points are noted:

- The 2-hr retentions averaged respectively 111g, 91g, and 89g for the Initial, WPB (back), and EPS (front) modes of water entry for the group of wall systems that had originally retained the **least** water. (Walls 1,2, and 3)
- This similar information for the series that had retained the **most** water initially was 478 g, 59 g, and 60 gm respectively for walls 4, 5, and 6. These retest results are less than those stated above. The conclusion drawn was that the manner that water was delivered to the drainage cavity affected the test results. A re-examination of some of the large retentions for these walls when initially tested concluded this was due to storage and wetting of the materials on both faces of drainage cavities.
- The 2-hr retentions for all walls retested with water draining down either the front or back of the drainage cavity were relatively similar and ranged from 165g to 25g with a mean of 75g.
- The so-called "highest" retention walls ranged from 95 to 27 grams retention and had mean 2-hr retention of 59g.
- When tested initially, the 48-hr retention average was 70g for the "least retention" walls and 362g for the "highest retention" walls. On retesting for this test program, the 48-hr retentions for all walls combined averaged 51g and only 36g if the highest retention wall was left out of the average.
- Most walls lost moisture during the 48-hr drying period. Some, due to variations in conditions lost moisture for a day and then regained it from the environment. An example of that occurrence is the drying curve provided in Appendix II for Wall 1. This is more apparent from the summary table above for Wall 2. A more detailed discussion of drying is provided in Section 5.

5 DISCUSSION OF RESULTS

5.1 Wetting/Drainage Profiles

While the tabular results provide a simple means of comparison, graphical comparisons provide a more intuitive approach to appreciate the differences in behaviour of drainage by similar and dissimilar wall systems.

Of interest is the variability between similar walls produced by similar techniques, and the differences between walls that had initially been tested and retained more or less moisture on retest. Differences are probably attributable to the difference in how water was introduced into the drainage cavity, by free droplets versus directed trickles. Finally, of interest is whether introducing water to the back or front plane of the drainage cavity (at least at the point of entry) has any effect.

Figures 2 and 3 present the results for Manufacturer A. Figures 4 and 5 present a comparison of results for Manufacturer B, while Figures 6 and 7 present a comparison for Manufacturer C. All of these figures are shown with the same scaling. One initial test resulted in a large weight at the close of wetting. This plot was attributed to significant storage in the drainage cavity, likely at joints. The vertical scale was chosen to bias against this plot to allow the other plots to be drawn to a more reasonable scale. The full plots are shown in Appendix III.

A comparison between Figures 2 and 3 shows that the initial test on Wall 4 retained a significantly larger quantity of water that all of the other tests on those two walls. The straight line portion of the gain in weight is a sign that some of the water entering the wall was being stored in joints or in some pocket. Other wetting/drainage profiles that do not involve significant storage are curvilinear reflecting the declining amount of water being absorbed by the surfaces with time.

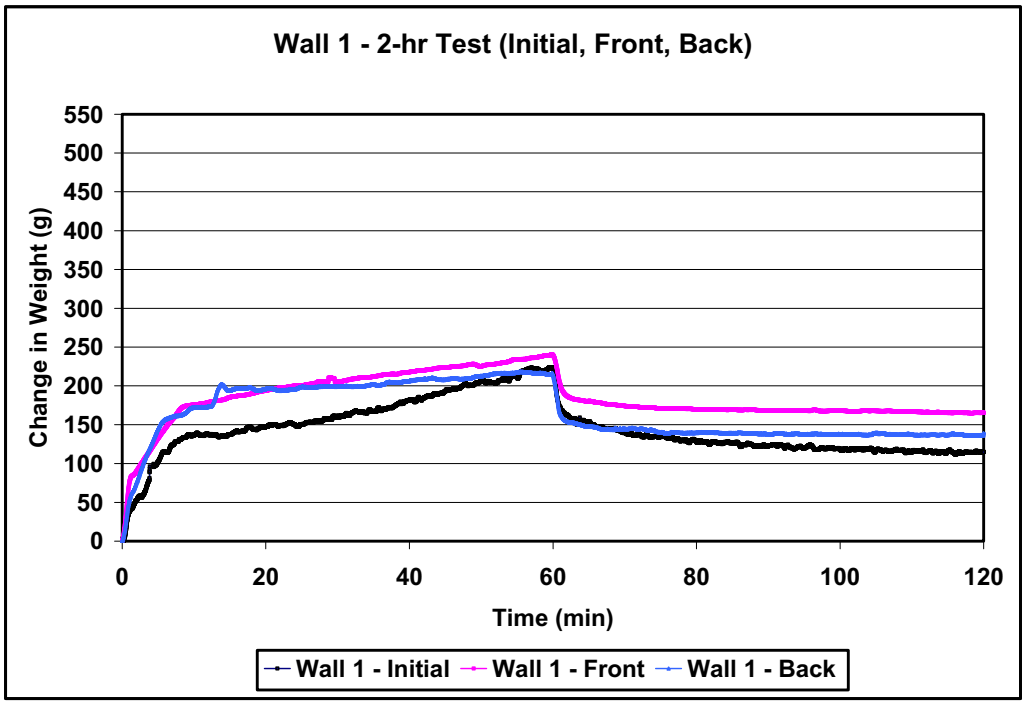


Figure 2 Comparison of results for Wall 1 for the 2-hr test, Manufacturer A

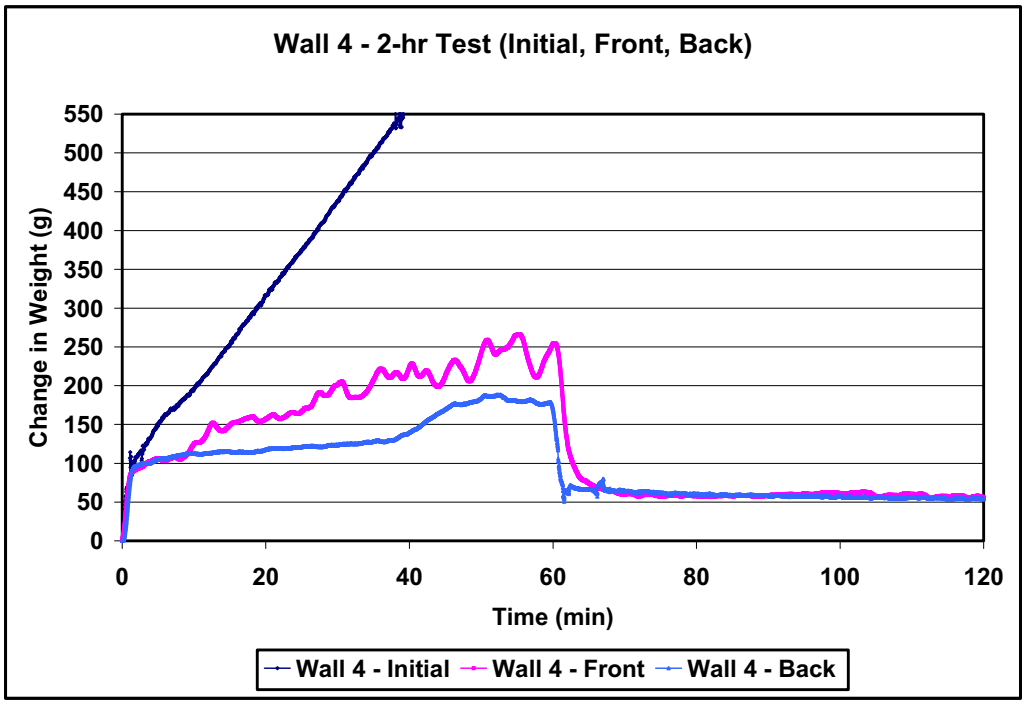


Figure 3 Comparison of results for Wall 4 for the 2-hr test, Manufacturer A

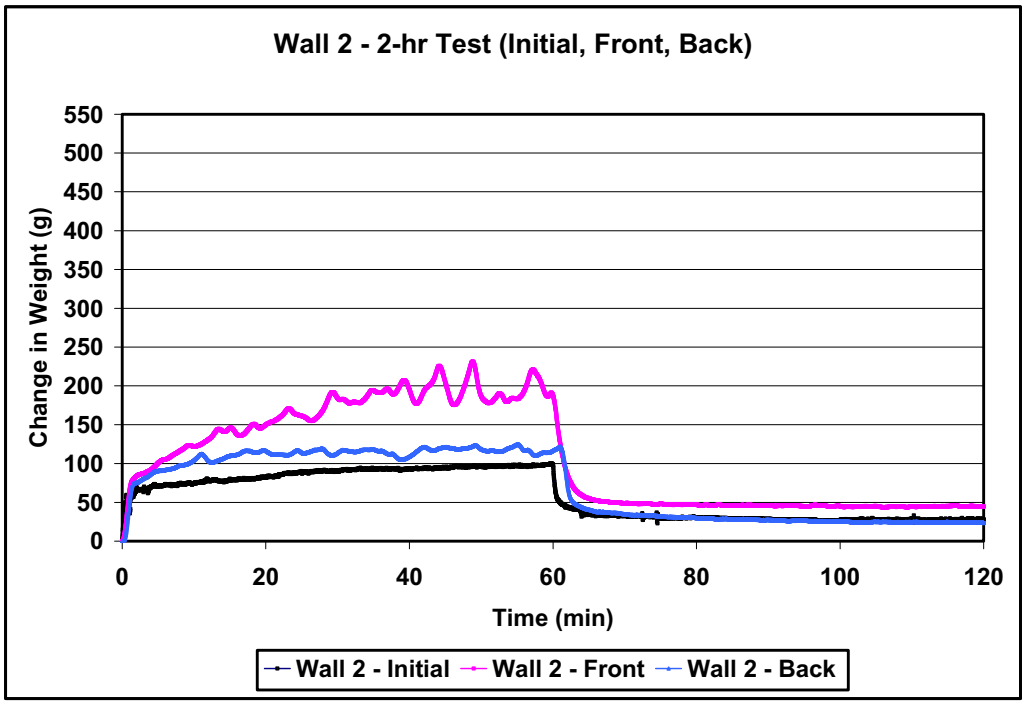


Figure 4 Comparison of results for Wall 2 for the 2-hr test, Manufacturer B

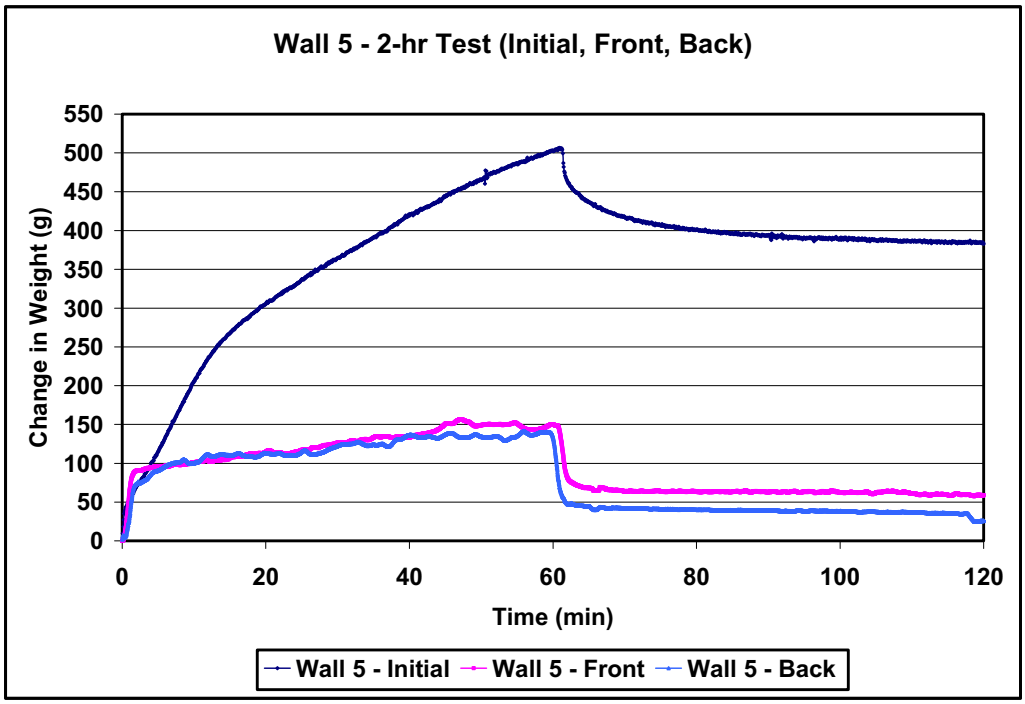


Figure 5 Comparison of results for Wall 5 for the 2-hr test, Manufacturer B

Again, in the comparison between Figure 4 and 5, the initial test for Wall 5 exhibited capacity for significant storage, while the tests which involved wetting against either front or back of the drainage cavity resulted in quite similar wetting and drainage profiles. Finally, Figures 6 and 7 below show similar comparisons for Walls 3 and 6 produced by Manufacturer C.

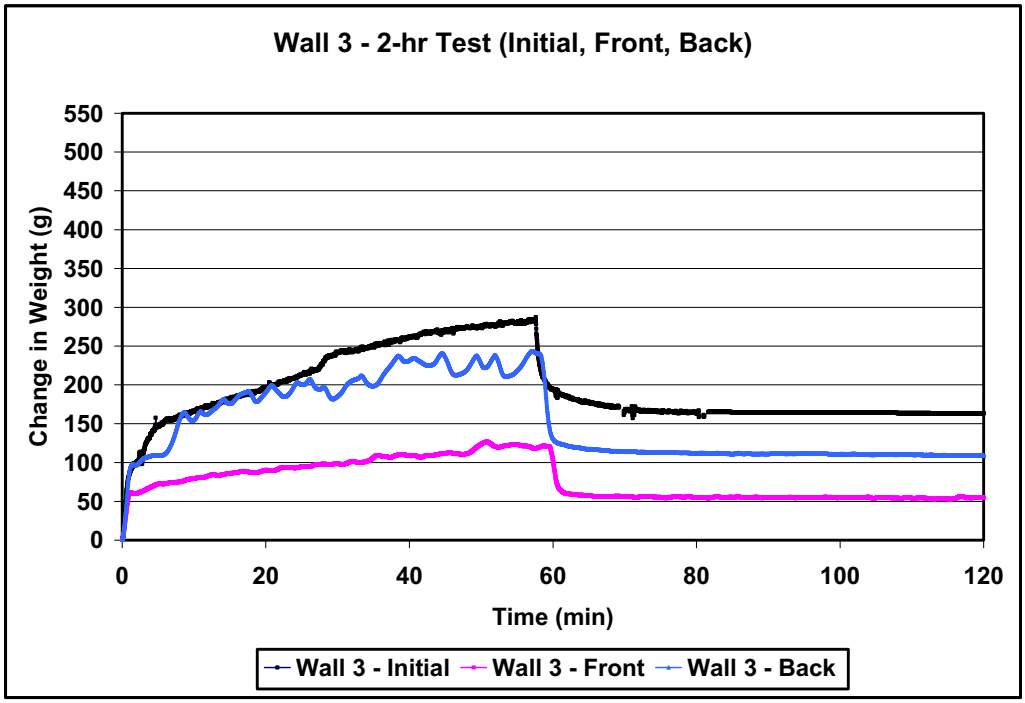


Figure 6 Comparison of results for Wall 3 for the 2-hr test, Manufacturer C

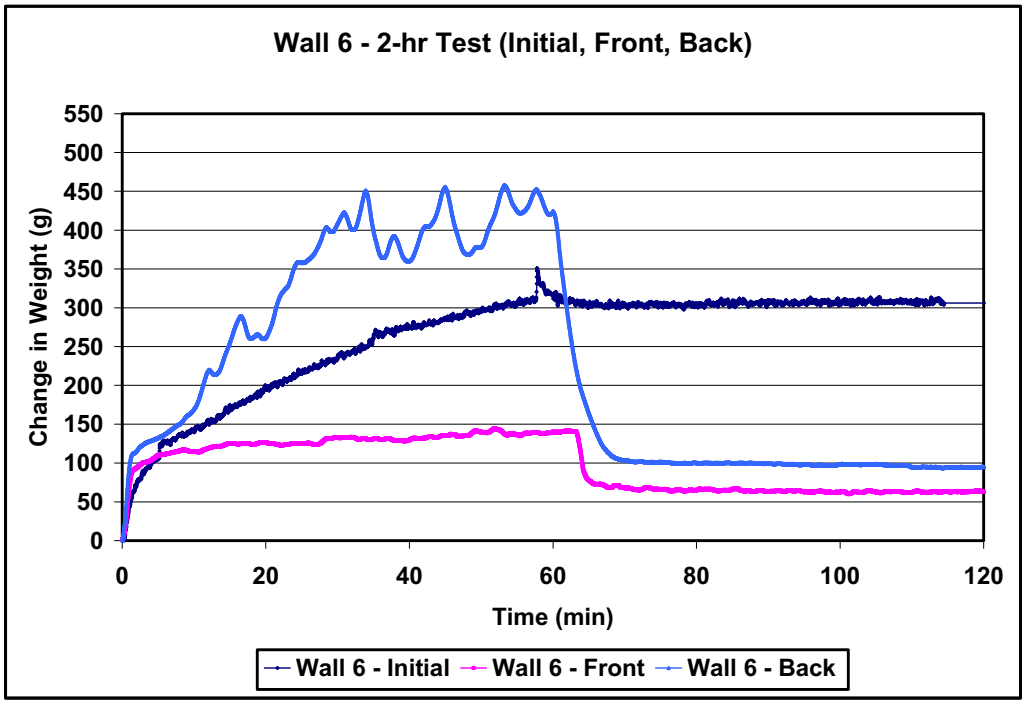


Figure 7 Comparison of results for Wall 6 for the 2-hr test, Manufacturer C

In the above comparisons, there are differences between the initial tests and the wetting/drainage profiles obtained for this project. While there are differences in the quantity of water being held during wetting, the results were not that different once drainage was completed suggesting that the manner that water was introduced to the drainage cavity was not that important for the very narrow cavity provided.

To demonstrate the potential difference in the manner that water was introduced to the drainage cavity, the following Figures 8 and 9 compare the results for all walls tested with water introduced on the back of the EPS (a front test) versus having water introduced against the WPB (the back test)

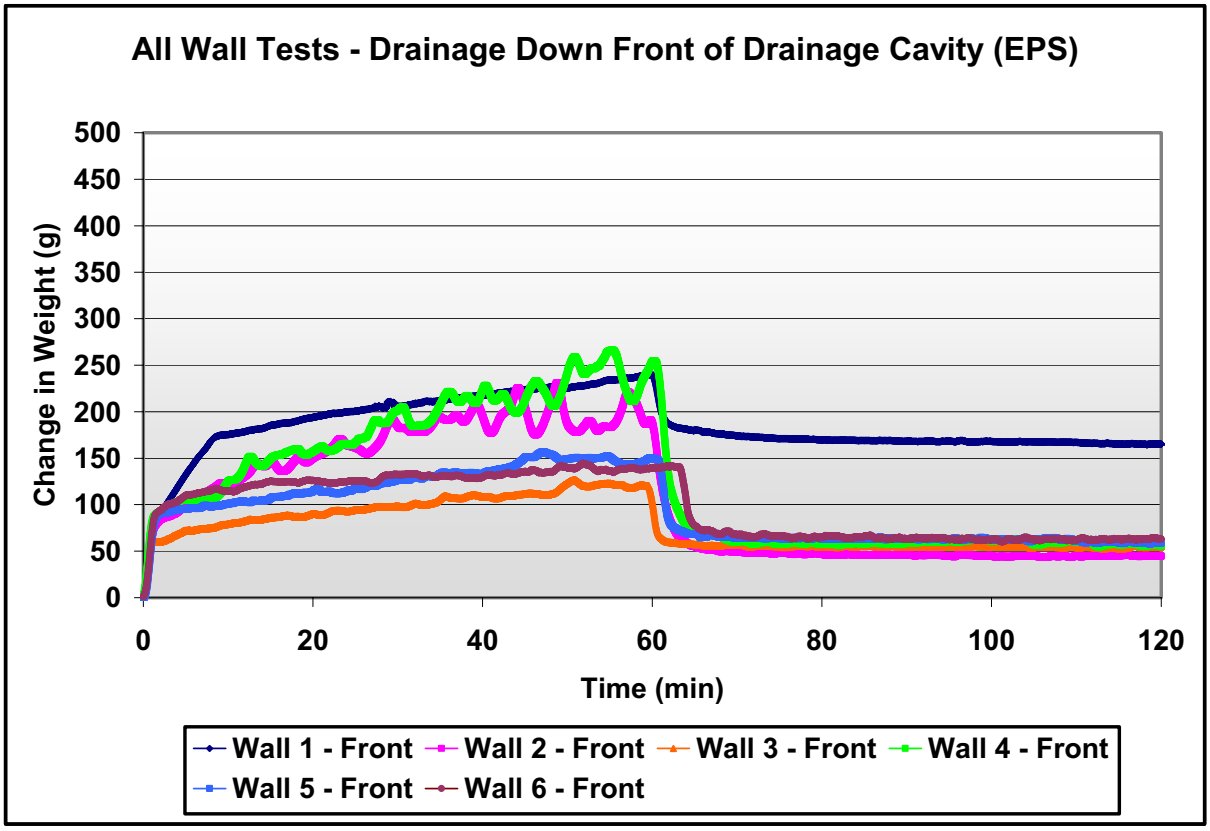


Figure 8 Comparison of results for all walls for the 2-hr test, water introduced down 'Front'

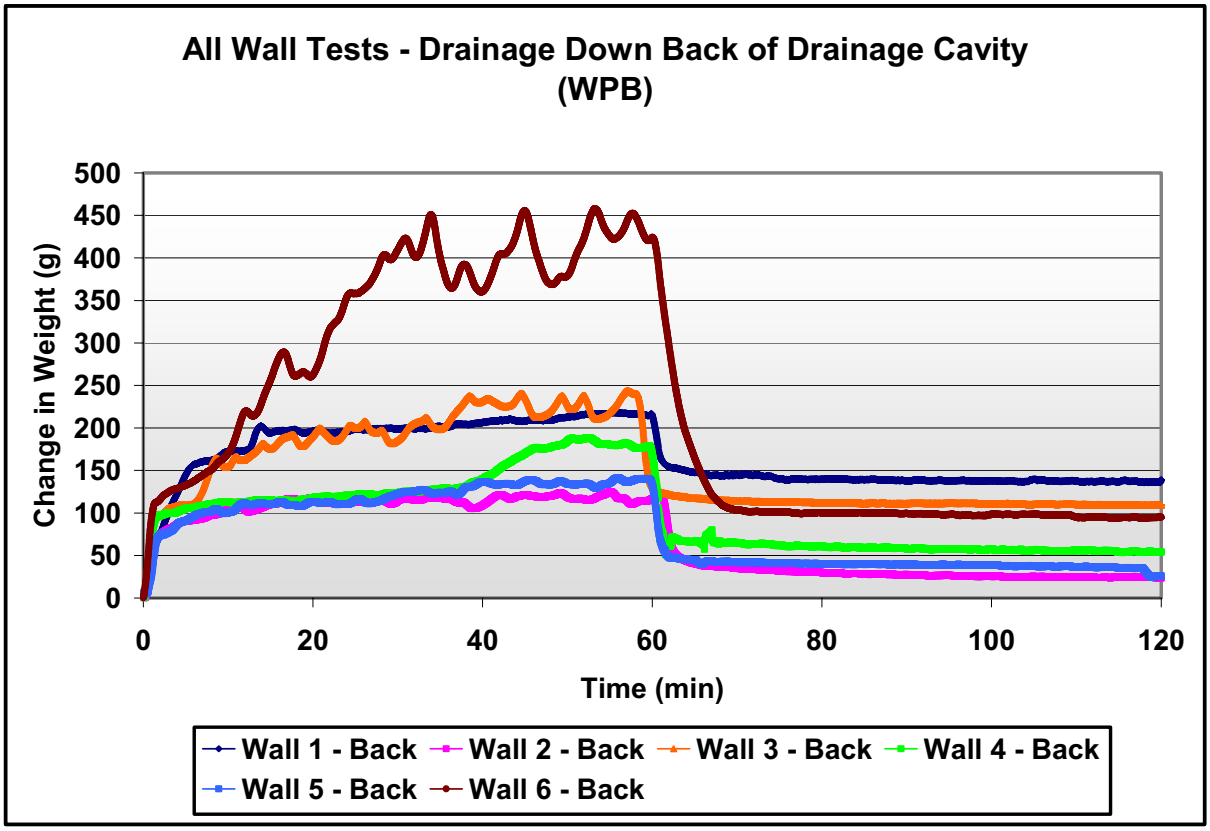


Figure 9 Comparison of results for all walls for the 2-hr test, water introduced down 'Back'

The two comparisons show that the bias resulting by directing water to flow down the back of the EPS resulted in a somewhat "tighter" distribution of wetting/drainage profiles than when water was directed down the back of the WPB. Except for one wall (number 1), the water did not seem to collect in the EPS joints even though flow was biased to flow down the back of the EPS. On the other hand, the differences in weight of water held by trickling water down the back of the WPB showed greater variability in the wetting/drainage profiles. This does not imply that those surfaces were the prime focus for water retention. It is not possible to say where or how the water trickles actually made their way down to the bottom. Nor is it possible to confidently assume that the water collected did so at joints or at pockets between ribbons which may have formed when the adhesive ribbons were flattened during installation.

What appears to have happened is that more water was retained when water was directed to the back of the drainage cavity, but that may only be specific to these walls and it is not possible to generalize because absorption of water by the adhesive ribbons is also involved. Different surfaces absorb different amounts of water and there are too many surfaces involved to say which are responsible for the most retention. Not without merit is the possibility that positioning of the regularly spaced trickles relative to the ribbon pattern may also have had some effect. At this juncture, for field manufactured EIFS installations there are likely more variables than we can anticipate cause and effect explanations for the wetting/drainage profiles that were obtained. Overall, the profiles are more consistent than those obtained in the initial tests.

5.2 Moisture Mapping

The moisture mapping plots with contours are all provided in Appendix III. These represent the change in moisture detected using the capacitance-based moisture meter. The actual contours and their locations allow only very general statements to be made because these are qualitative in nature using measurements that were made when most of the retained moisture had already dissipated. The "back" and "front" tests are positioned beside each other for direct comparison. One important question that may be posed is whether the contour plots and their apparent extent and magnitude correspond in any way with the weight measurements summarized in Table 5.

The first approach is to visually compare the "front" and "back" plots and decide whether one or other plane seems to have retained the most water. An example is provided in Figure 10 below.

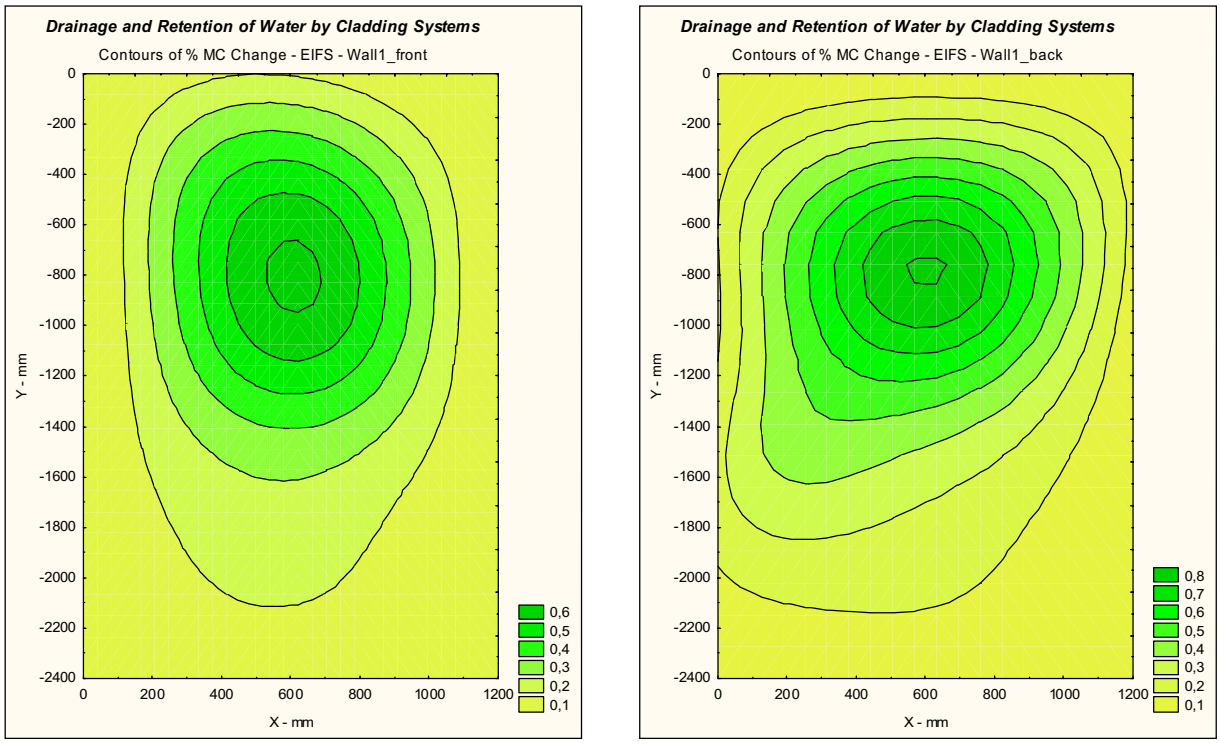


Figure 10 Comparison of moisture mapping for Wall 1 when water was trickled down the 'front' and 'back' of the drainage cavity

In the above figure slightly higher contour levels were computed for the plot on the right corresponding to trickling water down the "back" of the drainage plane, against the WPB. In a similar way, all pairs of plots were examined to see if "back" or "front" plots represented more or less accumulation. This was compared with the weight retention data examined and the results are summarized in Table 6 below.

Table 6 Comparison of visual and measured assessment of largest retention

Wall Number	Visual Highest Retention Front	Visual Highest Retention Back	Measured Highest Retention Front	Measured Highest Retention Back
1	-	yes	yes	-
2	-	yes	-	yes
3	-	yes	-	yes
4	yes	-	yes	-
5	yes	-	yes	-
6	yes	-	yes	-

In all but the first case (Wall 1), there is agreement as to the relative retention of moisture. As for the first case, the difference was not substantial at the 2-hr point in the drainage test as provided in Figure 2. Further, it seems to be more than a coincidence that Series 1-2-3 walls, which had been picked because they had the lowest initial test retention, appeared to have retained relatively more moisture when water was trickled on the WRB face than the EPS face. The Series 4-5-6 walls appeared to retain more water when it was trickled on the Front (EPS) face, and they had all been picked for that series because they had retained the most water in their initial tests,

It is worthwhile recalling that all moisture measurements were made from the back side of the OSB and that the strength of detection of moisture that is farther away from the contact plate of the instrument is less than when the presence of moisture is nearer to it. Despite the small amounts of moisture present and the likelihood that some individual measurements may be false, and based on the calibration work attempted as described in Part 2 of this report, it is telling that this degree of agreement was attained.

As for the actual shape and location of the highest levels of retention, these cannot be identified to have occurred with any specific features. Most peaks or regions of higher moisture retention are located in the central portion of the wall width, which is to be expected. Some contours slip off to one side while others appear elongated and may coincide with horizontal joint locations. Individual small blobs on an otherwise uniform field may simply be due to a single higher test measurement difference.

These plots suggest that to get better resolution on the distribution of moisture, it is necessary that a closer spacing of measurement points be used, or that a modified approach is needed. Moisture mapping was compromised by having to wait until the 48-hr drying period had been completed. One possibility is to take the measurements closer to the time that drainage of free water stops. The 48-hr test result may be useful and may be kept as part of the test protocol, however, once those results have been obtained, the wall could be rewetted a second time and, once drainage of free water has stopped and the decline in weight attains a relatively steady state drying pattern, a complete set of moisture readings could be taken. A more accurate qualitative representation of moisture distribution might then be obtained.

Alternately, thermography may provide a potentially rapid real-time capability and better resolution by adding water that was significantly warmer or cooler than the ambient condition of the wall. The purpose for attempting to monitor moisture distribution is to gain an understanding of the behaviour of individual walls and to determine if there are systemic anomalies. The drainage test on its own does not provide that appreciation. If there happen to be pockets of water trapped inside the drainage cavity, this can only be determined during a drainage test if the technique used provides a sufficiently high resolution picture of that distribution. In the case of EIFS, part of that level of understanding can be determined by stripping the EPS foam off to see whether free drainage was provided or whether pockets that could retain water were formed.

5.3 Environmental Effects

The plots of RH and Temperature variations are provided in Appendix IV for all EIFS wall tested. The results were acquired in two computer files for each set of walls tested. The first file encompassed all data collected during the 2-hr wetting/drainage test for three walls starting with the beginning of wetting for the first wall and ending at the conclusion of the test on the third wall. This phase extended for between 5 and 6 hours of test time. The second file was collected for the 48 (plus) hour period following the 2-hr test on the third wall. The rate of sampling of the loads was changed for the longer drying period but the RH and T measurements were sampled at the same rate as before. RH and Temperature was measured at 4 locations just above the drainage cavity for each wall, but there was no attempt to present these plots separately for each wall relative to the start of wetting as was done for the load cell data. The reason for this is that wetting of each wall in turn tended to modify the local environment and it was desirable to view the entire history from the start of wetting of the first wall. Some walls were affected to a greater extent than others. EIFS walls in particular exhibited a greater degree of responsiveness (as monitored by the load cells) to changes in the local environment than other walls tested in this program.

An example of plots for RH and T measurements obtained during the wetting/drying phase of one wall (Wall 4) are shown in Figures 11 and 12 below. Plots showing both the wetting/drying phase (as below) as well as the conditions experienced for the total test period of 50 to 60 hours are in Appendix IV.

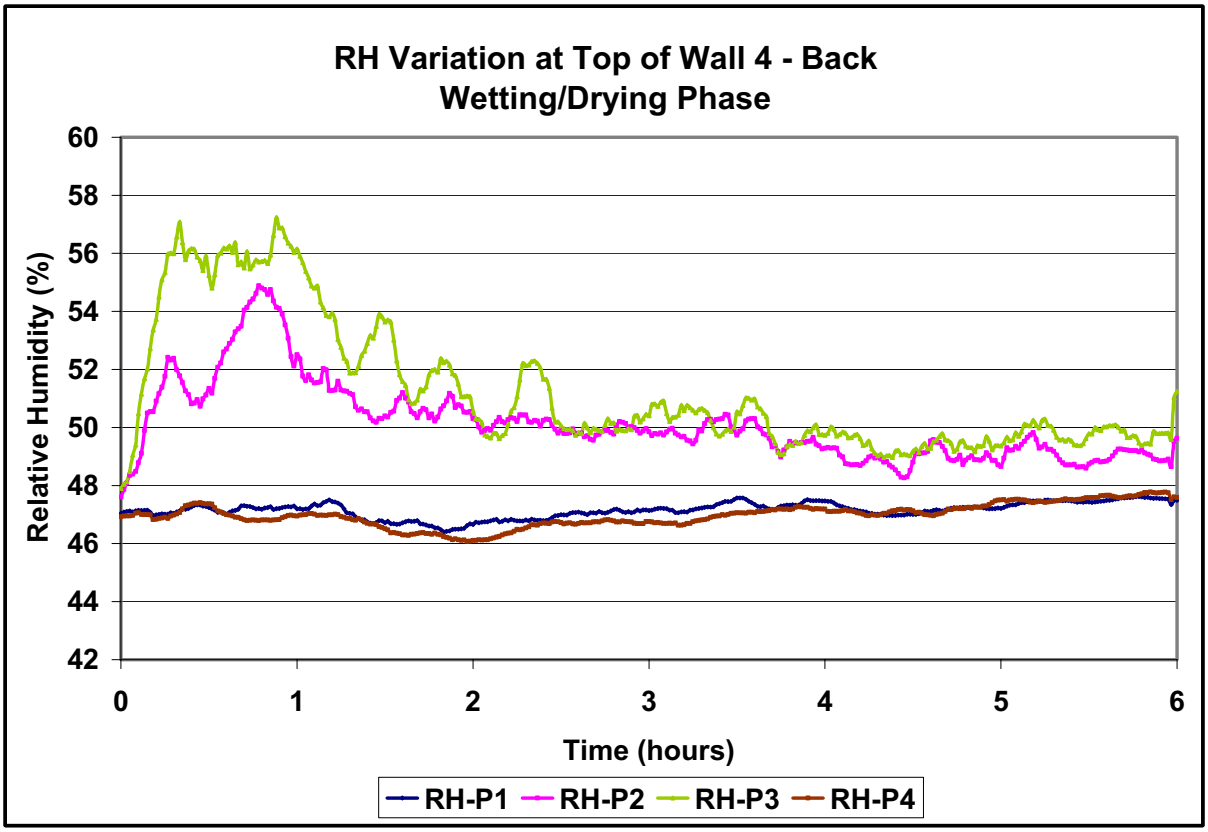


Figure 11 RH measurements at the top of the drainage cavity for Wall 4

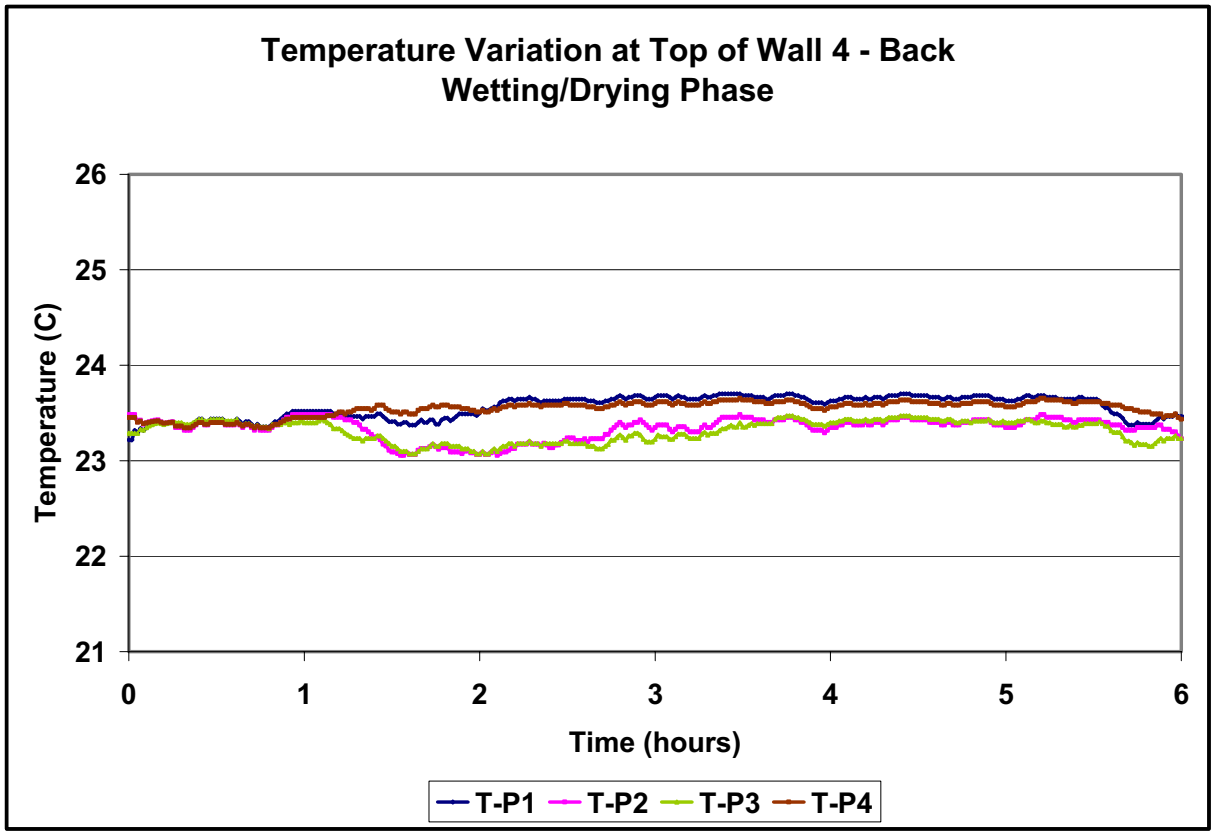


Figure 12 Temperature measurements at the top of the drainage cavity for Wall 4

The recordings for positions P2 and P3 (spaced under the trickle trough) and positions P1 and P4 (on either side of it) show that the side conditions were not directly affected by wetting introduced in the middle half width of the wall.

Typically, the temperature of moist air rising from the drainage space was slightly cooler than ambient. Also typically, the side sensors were not usually affected by the moisture rising from the drainage cavity. The temperature differential of air rising from the drainage cavity during wetting varied depending on the temperature of the water input, and the amount of water that was retained. Two effects are involved, the increase in density caused by the cooling temperature and the decrease in density resulting from the addition of water vapour to the air in the drainage space (moisture buoyancy). An example of a pronounced decline in temperature is shown below in Figure 13 for Wall 6. This degree of temperature decline during wetting suggested that the water had not been sufficiently tempered to ambient conditions in the laboratory before use. Temperature of the water supplied to the trickle troughs was not monitored largely because there were a limited number of channels available for data acquisition.

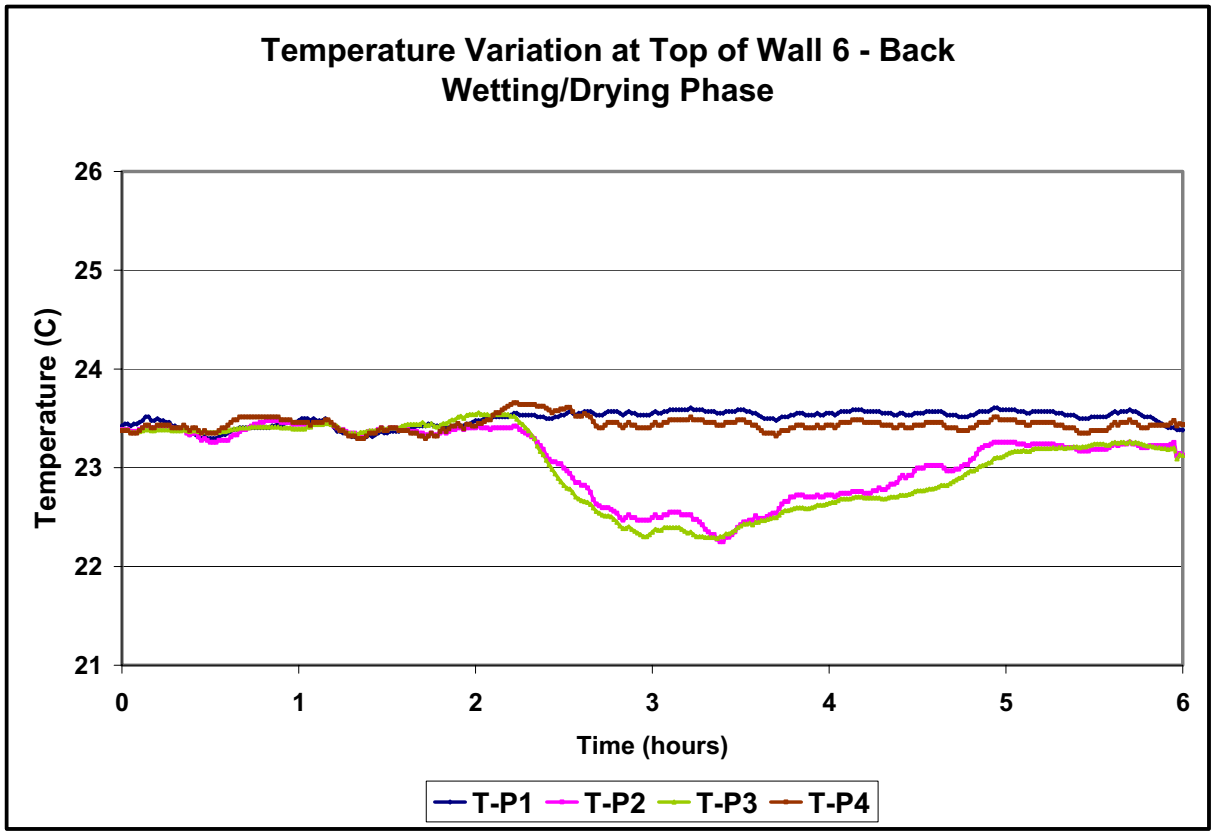


Figure 13 Temperature measurements at the top of the drainage cavity for Wall 6

The RH and T records provided in Appendix IV show that while overall climate control in the large laboratory was generally well maintained for some purposes involved in testing of wood structures (using control recordings as a basis for this statement), the local environmental effects were quite different at times from the hoped for stable isothermal conditions initially expected. To achieve better control, a separate enclosure for the testing may be necessary for future tests. Section 5.7 will address the influence of environmental conditions on drying potential of these test walls.

5.4 Effect of Ribbon Spacing

The actual spacing of ribbons trowelled on each EPS panel was not monitored at time of construction of the walls. However, at the conclusion of these drainage tests, the spacing of ribbons was measured approximately for each wall along the top edge of the EPS. This was done by sliding a steel rule into the drainage space against the edge of each ribbon and penciling in a line for later measurement of the space between them. The results are shown in Table 7.

These measurements show that across the width of each test wall, the regularity of ribbon spacing and ribbon width was different. Hence, the deposition of a regular pattern of trickles from the trickle trough would dump water on top of or into the space between ribbons in a different way from one wall to another. Also, for any one wall, had there been a difference in the position of the trickles relative to the ribbons from one test to another, some difference in retention results could be expected. In this case, the same mounting holes were used for the trough used for each wall, and it is expected that repeat testing for

that position of the trough would result in similar results. For EIFS systems in particular, this does raise a question concerning the influence of trickle spacing relative to ribbon spacing, an effect for which we do not have an answer currently.

Table 7 Spacing of adhesive ribbons for each EIFS wall tested

Number of Spaces from One Edge	Walls With Least Initial Retention			Walls With Highest Initial Retention		
	1 (mm)	2 (mm)	3 (mm)	4 (mm)	5 (mm)	6 (mm)
1	40	27	40	30	25	45
2	35	27	42	24	26	46
3	35	27	45	37	24	43
4	40	27	45	41	54	46
5	40	32	40	48	27	42
6	35	27	42	37	24	42
7	45	30	41	31	27	40
8	45	30	43	45	65	44
9	40	47	45	44	25	43
10	35	32	38	24	26	42
11	45	33	37	38	24	42
12	45	31	33	43	19	46
13	35	34	33	20	33	40
14	40	35	37	43	35	41
15	40	25	40	48	26	45
16	45	42	54	42	68	47
17	35	28	45	25	29	42
18	40	29	50	43	25	45
19	35	33		35	21	28
20	25	33		38	22	
21		28				
22		31				
23		32				
N	21	33	19	21	21	20
Sum	796	753	769	757	646	829
Std Dev.	5.10	5.02	5.34	8.48	14.07	4.11
Average	38.8	31.3	41.7	36.8	31.3	42.6
COV	0.13	0.16	0.13	0.23	0.45	0.10
Estimated Ribbon Width (mm)	20	14	24	22	27	20

5.5 Drying Rates

The rate of drying shortly after drainage had stopped was obtained by regression. The summary of the rates obtained is provided in Table 8 below. The period selected for regression was taken from 10 to 50 minutes after wetting was halted, this being sufficient time for drainage of free water to end, through to the end of the 2-hr test period. End points for data inclusion were selected to avoid disturbances in the drying pattern that may have occurred. The drying rates are reported as g/hr for the whole wall. Also reported in Table 8 is the recorded retained weight at the conclusion of the 2-hr test period. In most cases the rate of drying was steady for a considerable period beyond this time. For some walls, the adequacy of fit as represented by the R-squared statistic was poor. This is not to say that drying was poor, only that the calculated drying rates over that period were not always reliable because of environmental changes that caused increases in weight instead of further declines in weight.

Table 8 Drying rates during the 1-hr drain period

Wall No.	Trickling down Front			Trickling down Back		
	Drying Rate g/hr	R^2	Retention @ 2-hr (g)	Drying Rate g/hr	R^2	Retention @ 2-hr (g)
1	6.6	0.847	165	6.9	0.643	139
2	2.8	0.505	45	12.1	0.886	24
3	1.6*	0.242*	54	4.9	0.913	109
4	0.8*	0.007*	61	11.1	0.928	54
5	6.8	0.607	59	7.8	0.960	27
6	4.0	0.392	63	8.8	0.868	95

* Note that the drying rates for Wall 3 and 4 were low and some walls gained weight during the later part of the 2-hr test period.

Examination of this data showed there was no correlation between the drying rates and water retained at the end of the 2-hr test, nor with the maximum moisture held temporarily when the supply of water for trickling was shut off. There was also no correlation with the ribbon spacing or number of ribbons involved in each wall.

5.6 48-hour Drying Records

The 2-hr file records and the 48-hr file records were concatenated to form single files for each wall that containing data for at least 50 hours of test. The plots for all walls tested by trickling down the front and the back separately are shown in Figure 14 and 15 that follow.

Both of these figures show that there was a diurnal cycle to the conditions in the laboratory, as previously noted. This prevented some walls from fully drying during the total time the walls were supported in the test area. One wall had low retention and would have dried in a relatively short period of time. Another wall (Wall 1) gained more water than most walls and the shape of the wetting portion of the curve suggests that some water was stored in a joint or pocket (Figure 8). The drying portion of the curve in Figure 14 (trickling down the back of the EPS) paralleled the drying curves of the other walls. All of the test series were started in the morning and consequently experienced the similar diurnal pattern even though they were tested with many days between them. When Wall 1 was tested by trickling water down the face of the WPB, it also retained the most of all walls, suggesting that the same feature was involved in retaining water.

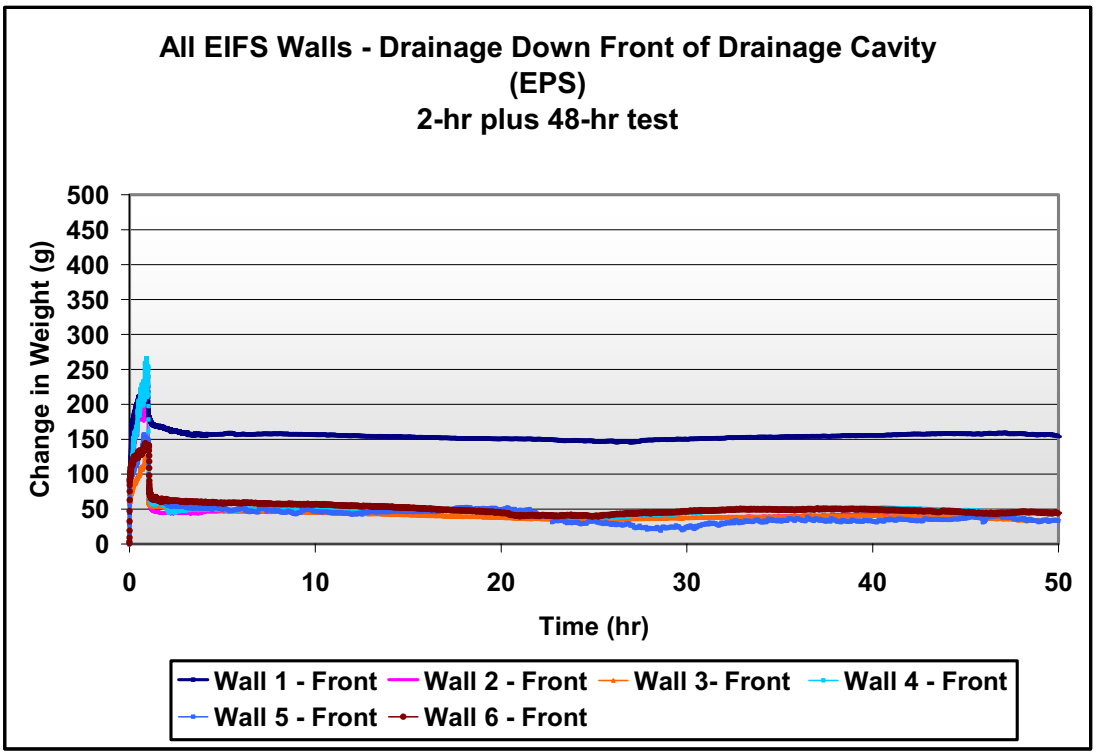


Figure 14 Composite plots for the 2-hr and 48-hr time periods, water trickled down the front of the drainage cavity (EPS).

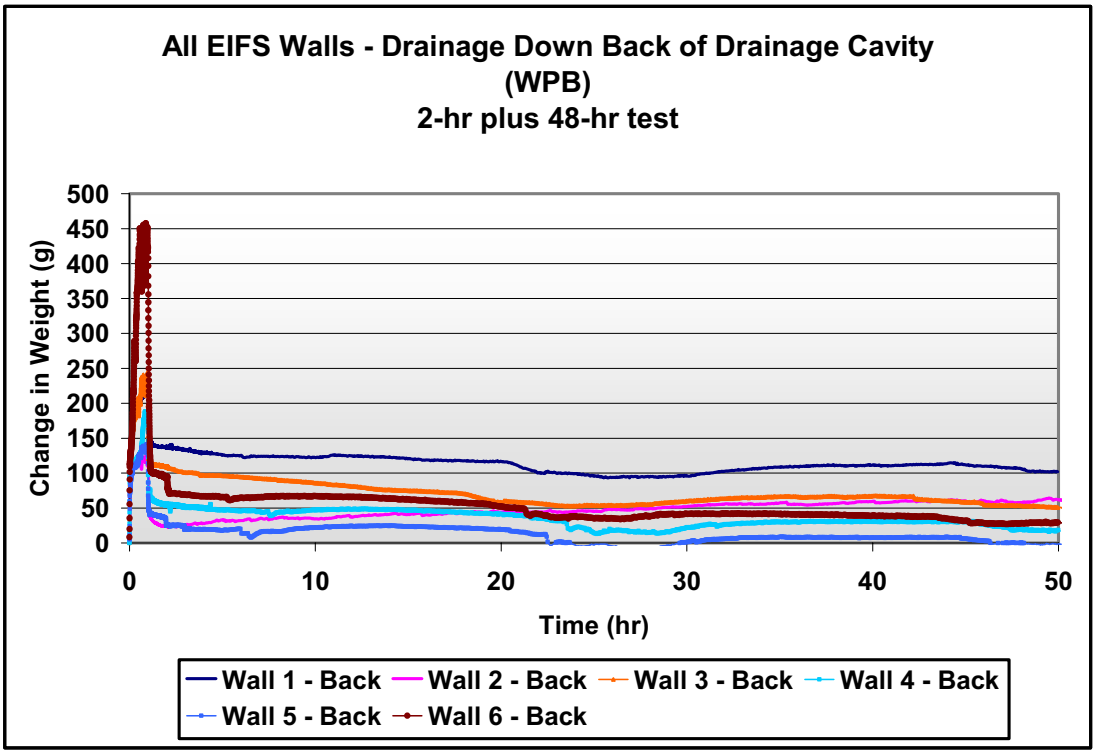


Figure 15 Composite plots for the 2-hr and 48-hr time periods, water trickled down the back of the drainage cavity (WPB).

These plots show that, while a test value for the 48-hr drying time can be quoted, listing an end point on the drying curve at 50 hr would not represent a true level of drying over that period of time. The environmental conditions could not be for maintained sufficiently well for EIFS testing. A further observation may be ventured. The ability of a wall with drainage capability to dissipate retained moisture may be sufficiently described by allowing the test to run in the order of 24 hours instead of 48 hours.

5.7 Effect of Environmental Conditions on Drying Rates

The rates of drying reported in Section 5.5 were affected by several details of the construction of each wall, including the starter track or starter panel each manufacturer used. The drying rates calculated for the latter part of the first hour after wetting stopped are provided in Table 8. Those rates are not sustainable for the longer drying period because the rate of drying decreases once surface water has evaporated. During the early part of the drying phase, the drying rates were relatively regular. Figure 14 and 15, in Section 5.6 for the entire test period show that drying continues but in a way that is affected by the overall variations in environmental conditions. These overall drying rates are much less easy to characterize. In the following, we will examine the drying rates and the mean environmental conditions as represented by the mean vapour pressure in that period.

Since the walls were tested three at a time, the RH and T records for the ambient conditions at different locations and heights in the test area apply to all three walls tested in that particular period. Despite the range in early drying rates, the means for each set was taken. The means for walls 1-2-3 (back) and 1-2-3 (front), 4-5-6 (back) and 4-5-6 (front) were found for comparison with the computed mean vapour pressure at sensor pair #16 over the 1-hr period following termination of wetting. The later was calculated based on the mean RH and T for each period. The resulting plot is shown in Figure 16.

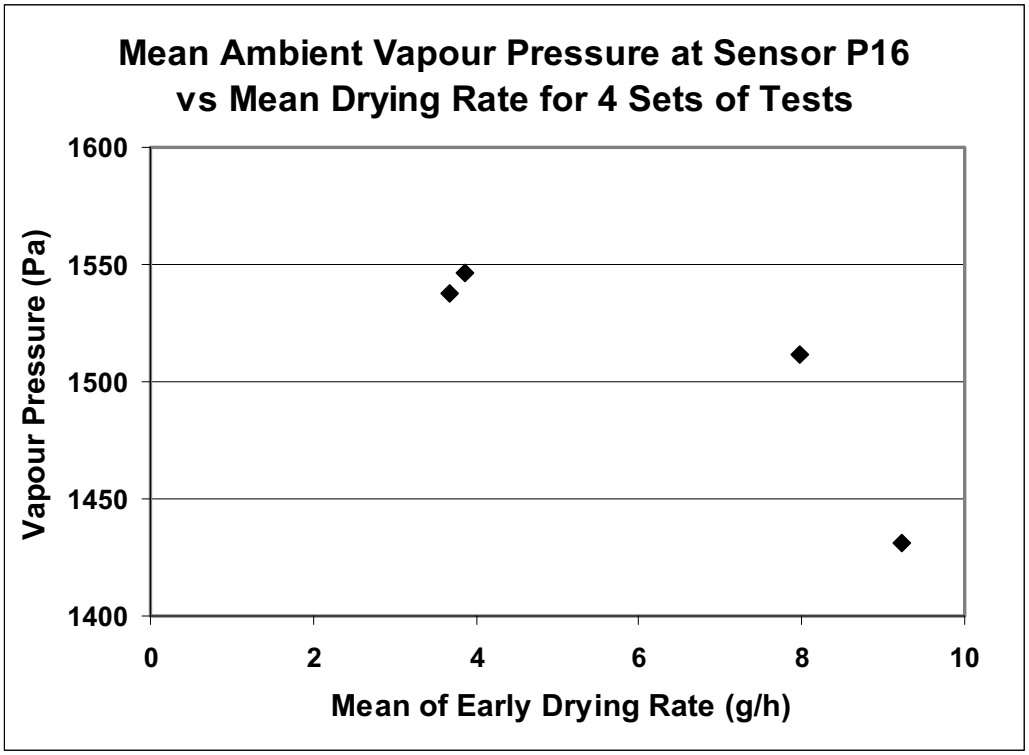


Figure 16 Influence of ambient vapour pressure on mean drying rates for each group of EIFS walls tested.

The above results are insufficient to predict the influence of drying of individual walls, but there is a trend that suggests that the lower the ambient vapour pressure the faster the drying rate. This follows from accepting that a lower ambient vapour pressure results in a higher vapour pressure differential between the wetted cavity and conditions surrounding the test. Measurements for ambient conditions used for this comparison were those for sensor pair P16 which was located at a height of 360 mm above the floor, at about the height of the gutters and the flashing where supply air could enter the drainage cavity. Taking the mean of all tests for sensor pairs P15 (at table level in the vicinity of the test area) and P16 at gutter level resulted in a value of 1516 Pa and a standard deviation of 47 Pa. Despite the variation in conditions experienced, they were well within the original specifications for the environmental conditions required in the CCMC Technical Guide. These were 23ºC +/- 3º and 50% RH +/- 10%. These "permitted" conditions allow the vapour pressure to range between the extremes of 937 and 2021 Pa. The mean vapour pressure for permitted mean RH and T conditions results in a vapour pressure of 1407 Pa while the lab conditions provided a mean of 1516 Pa – a level that would result in slightly slower drying. Clearly, given the trend evident in Figure 16, these permitted variations could result in large measured differences. The variations shown in Figures 14 and 15 for the weight measurements during the 48-hr drying period are evidence that, even in the relatively well controlled laboratory, drying of small amounts of moisture from walls is subject to considerable uncertainty. Clearly, the CCMC permitted variations are too broad for a drying test. Field conditions have yet another order of magnitude effect on weight changes likely to be experienced by EIFS cladding.

6 SUMMARY AND CONCLUSIONS

Some questions arise from this testing. They concern a) the repeatability of drainage performance; b) the impact of wall system curing; c) the impact of having directing drainage to specific surfaces instead of draining water directly into the center of the drainage cavity. Additional comments can be put forward concerning the behaviour of the EIFS system as manufactured and tested for this study.

When looking at the early data obtained from each test performed on these EIFS walls systems in 2004 the primary concern related to the repeatability of performance measured for each system. When individual walls were retested several times the resulting retained quantities of moisture were not necessarily repeated. The reliability of the test set-up was investigated (load cell, water entry, acquisition apparatus, environment, etc.) but eventually it was concluded that the wall systems were sensitive to the way that water was delivered into the drainage cavity. In particular it was felt that water collecting in joints in the EPS was responsible for the largest deviations. Consequently, since other cladding systems might also behave differently depending on how water was deposited, the delivery system was changed for this project to allow water trickles to be delivered to specific surfaces at the point of entry to the drainage cavity. Also, to test this delivery issue for these narrow drainage cavities, EIFS walls were selected on the basis of the least and greatest retention in previous testing for each manufacturer.

The current delivery system provided trickles to intended surfaces led to significantly lowered and repeatable drainage/retention profiles. All walls permitted the bulk of the supplied water to flow through and only 0.3 % to 1.4% of the water input was retained at the end of one hour of draining/drying. Drying took place at essentially steady state room temperature and RH in this period. However longer term drying for an additional 2 days resulted in essentially full drying for some walls. For other walls there was a gain in weight even though they were in an air conditioned environment. These conditions were effectively steady from the point of view of persons working in that environment. Also, from the point of view of wood properties and structures testing, the short term variation in conditions is not an issue. Unfortunately for drainage tests, the EIFS walls more rapidly acclimatized to those changes compared with wood structures. In practice, the normal variation in weather conditions would dominate these

retention levels. The small amounts retained have to be judged in terms of their potential effect on durability.

The EIFS systems were tested without fully knowing how or what surfaces would be most involved in absorption of water draining on to them. The back LA-WPB coating, the adhesive ribbons, the EPS foam and adhesive residue left on that surface, the joints between EPS panels and the starter tracks or starter panels used at the base of the wall are all potential candidates for storing and absorbing or retaining moisture. Given the small space provided for drainage (from 2-3 mm) and the irregular width and spacing of ribbons, it was surprising that the retention was low compared with earlier tests.

Measurement techniques for detecting locations of moisture concentrations made use of a capacitance based moisture meter. The moisture change contours generally reflected the relative retention of water when water was trickled on the front or back of the drainage cavity. The moisture maps also seemed to reflect the basis for the original selection basis – namely, that walls that retained the most in initial tests, also retained more moisture when water was trickled on the back of the EPS. Also, the walls that originally retained the least water generally retained more when water trickled down the coating face of the sheathing. The patterns of moisture accumulation were diffuse signifying relatively good dispersion. Localized accumulation in joints was not detected, which is not to say that some did not accumulate there. Wetted concentrations were located higher up on the wall. The pattern is understandable because detection of moisture differences was only possible after the walls were dismounted after significant drying had already taken place. During drying, the test walls dried from the bottom up since drier make-up air entered the bottom of the drainage cavity and moved upward by buoyancy. The upper wetted areas were the last to dry thoroughly. Detection of moisture retained in starter tracks was not possible because of interference with the vertical leg of the metal gutter. One system had a starter panel that provided least retention of water.

Ribbon spacing at the top of the wall were variable from one wall to another. The fixed pattern for trickling at 38 mm spacing likely contributed to some of the variability. Other means of delivery, such as spraying would likely also have similar variability as trickles would not necessarily form in a predicable way from one time to another. The effect of trickle spacing and positioning compared with other means of delivery is as yet a researched issue.

Drying rates in the first hour after wetting were not found to be correlated with the spacing of ribbons, or the level of retention of water at the conclusion of the 2-hr test period. For large retention differences in earlier testing, higher drying rates corresponded with significantly higher levels of retention than were found in this study. The longer duration drying period of 48-hr was shown to require much greater control on environmental conditions for EIFS walls than could be provided to obtain a monotonic drying curve. There was a trend between drying rates and the ambient vapour pressure as measured by a sensor pair located at a height approximating the base of the walls. Despite the low variation in vapour pressure experienced, especially compared to the prescribed allowable variation in conditions, the drying curves were subject to considerable fluctuations. The end point retention of moisture from these tests must be treated with caution because of considerable uncertainty in the result.

The significance or importance of retention in the order of magnitude found here at the 2-hr time level, between 24 and 109 g, was not the aim of the current test program. What is of relevance is how moisture that is retained is distributed. The ready flow of the water to the base with little lateral dispersion, together with what appeared to be generalized distribution with no apparent accumulation in joints evident in the weight gain wetting/drainage profile characteristic of such accumulation, suggests that these walls managed water entry in the best possible manner to minimize potential high localized absorption or storage that could lead to prolonged hidden wet microclimates. The order of magnitude of the retention at that early stage of wetting was calculated to represent a moisture content change for a wood framed wall

including the OSB but not including the EIFS of only 0.3% and substantially less for the majority of walls tested. There is good evidence from testing EIFS walls together with other wood-based cladding systems that the change in weight gain by the wood framing was miniscule compared with that gained by the EIFS finish system itself.

With respect to the impact of adhesive curing, there has been some research that suggests that the moisture absorbent properties of the adhesive mixture become more impermeable as continued curing and wetting occurs. This matter was not considered sufficiently relevant to this study because early repeated tests on walls did not show consistently better performance on retesting, a factor that would have suggested this needed to be accounted for. Repeat testing of one wall in this test program (3 times) showed a small progression to having less water being retained when there were from 9 to 16 days of drying between start of retesting. For the purpose of classification this matter is of lesser importance than other features that could be researched. Pre-wetting could be considered, but this would extend the duration and cost of doing a full scale test.

The drainage test program on EIFS clad walls formed by adhesively attaching them to a backup wall has been instructive concerning their ability to accept and drain relatively large quantities of water and to retain only a very modest amount of water. Some improvements in monitoring techniques were suggested to be able to detect concentrations of retained moisture better. Some further investigation concerning the influence of the delivery method on retention and other issues is probably warranted.

7 REFERENCES

1. ASTM E 2273-03 Standard Test Method for Determining the Drainage Efficiency of Exterior Insulation and Finish Systems (EIFS) Clad Wall Assemblies. ASTM

2. CCMC. 2004. Technical Guide for External Insulation and Finish Systems, Masterformat No. 07240, Appendix A4 "Exterior Insulation and Finish Systems (EIFS), Class PB on Wood Substrates".

APPENDIX I

EIFS Specimen Fabrication – Example for One Manufacturer

1 – Application of the first coat of LA-WPB

2 – Installation of the metal gutter

3 – Application of filler to flash the gutter

4 – Installation of mesh and filler at joints and track

5 – One of the starter tracks used

6 – Mesh applied on sides and a second LA-WPB coat

7 – Trowel applied adhesive ribbons

8 – Installation of the 50 mm insulation board

9 – Application of base coat on sheathing sides

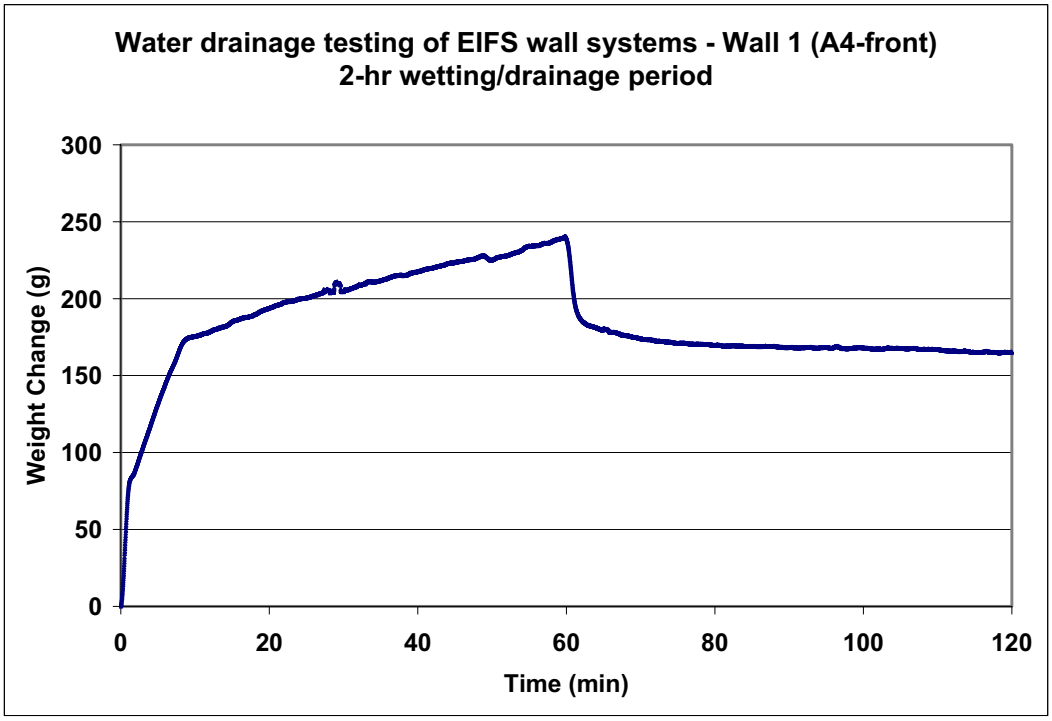
10 – Application of base coat on surface of EPS

11 – Embedding mesh into the base coat

12 – Application of finish coating after base coat cured

APPENDIX II

Plots of Drainage Tests of EIFS Wall Systems



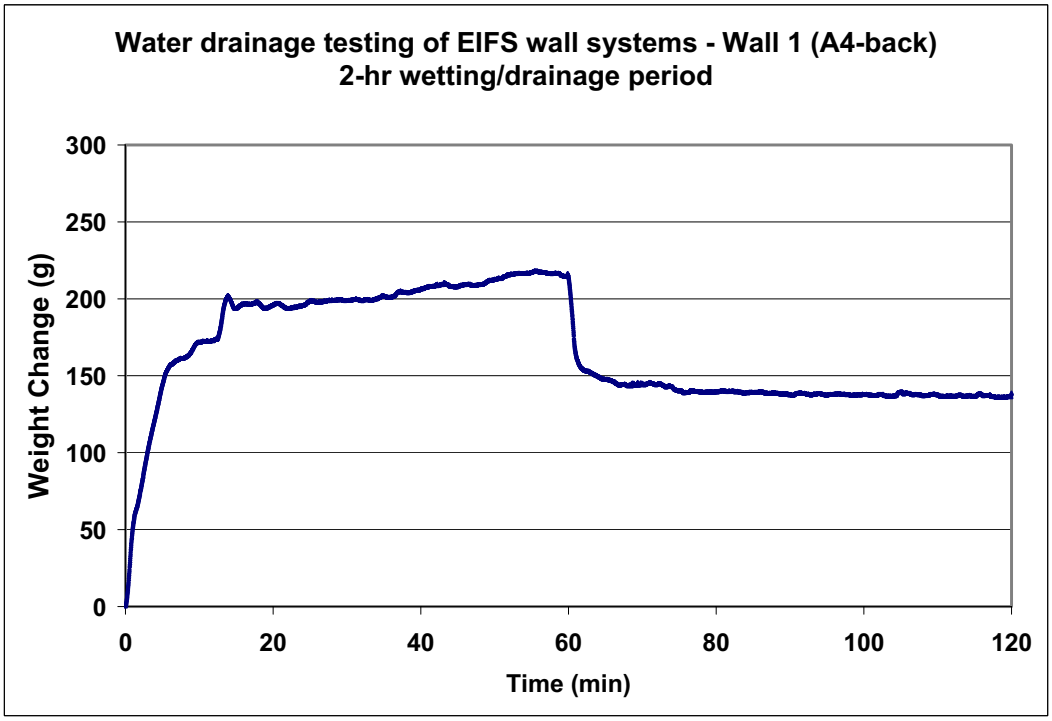
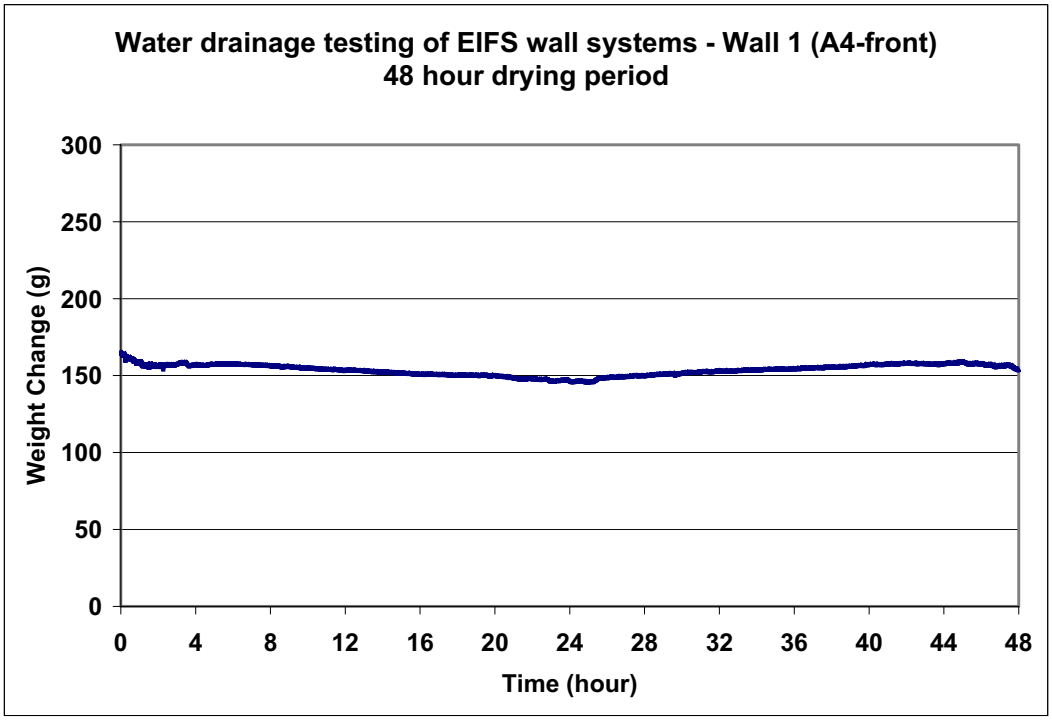


Figure II-1 Wall 1 - 2-hr wetting/drainage test trickling water down front and back of drainage cavity.



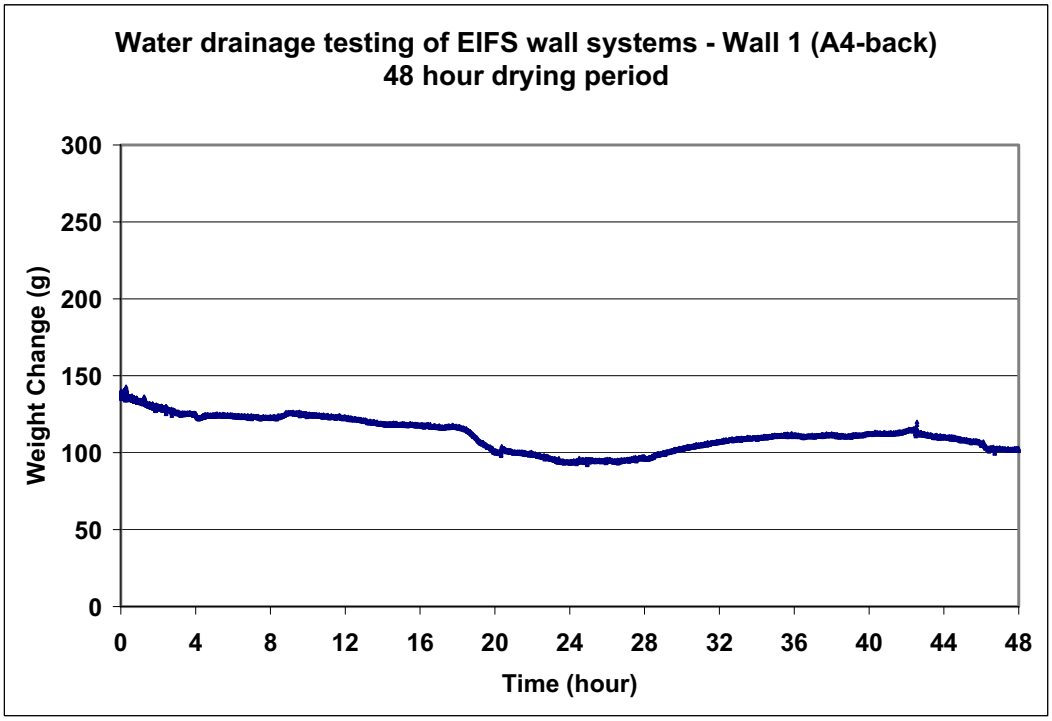
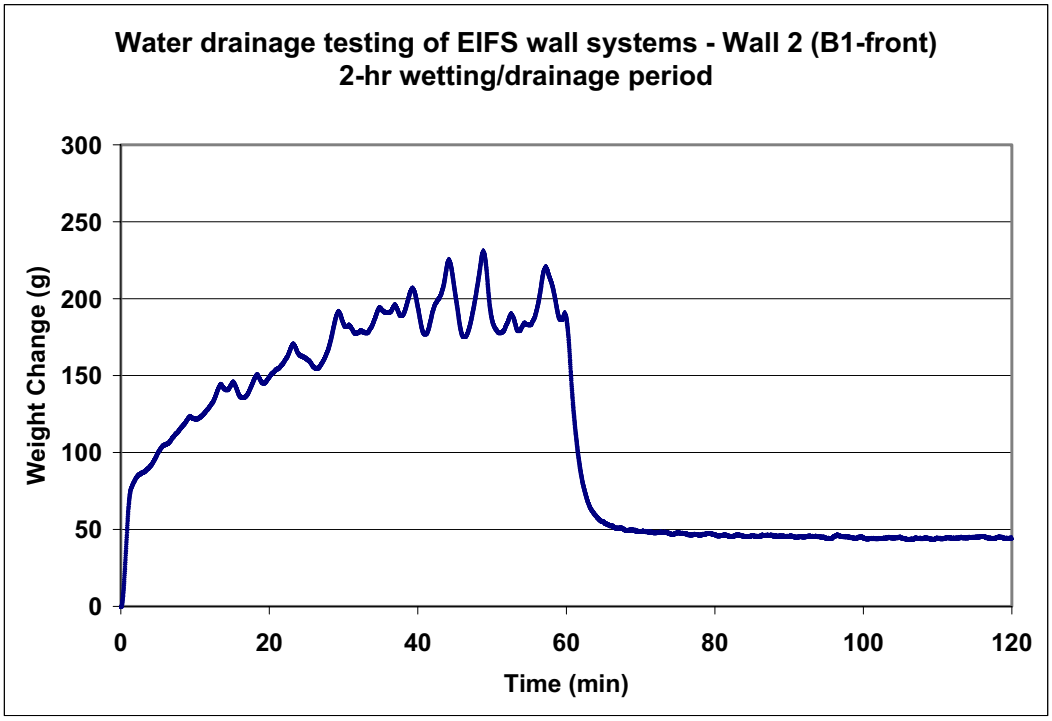


Figure II-2 Wall 1 - 48 hour drying records for drainage tests trickling water down front and back of drainage cavity. The 48 hour period immediately followed the 2-hr wetting/drainage period.



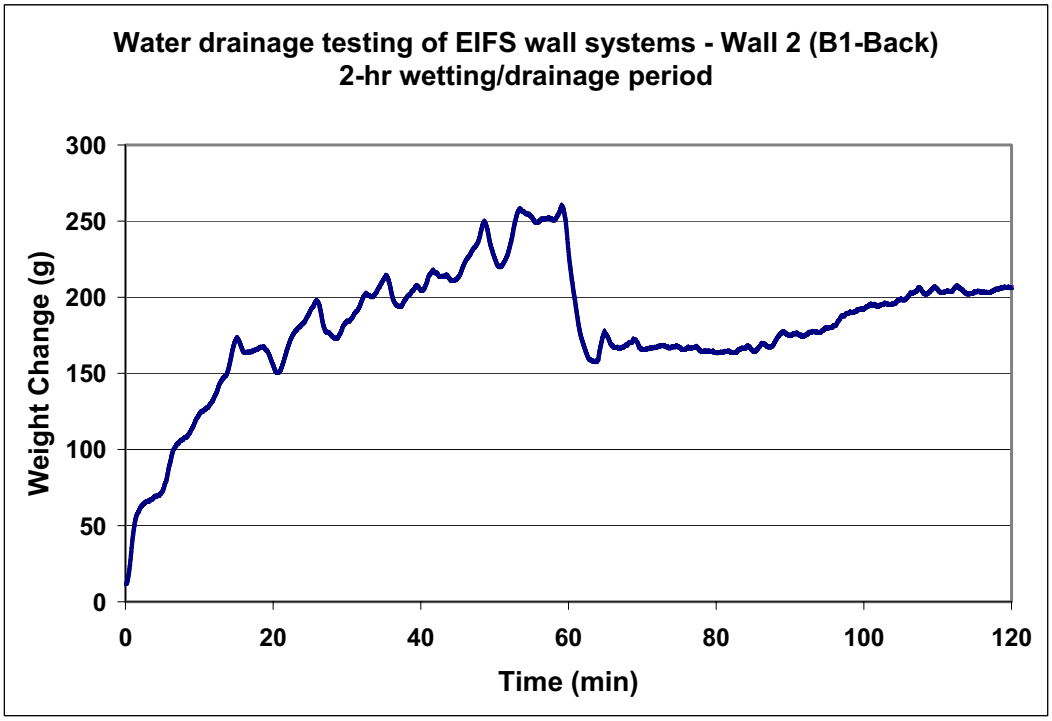
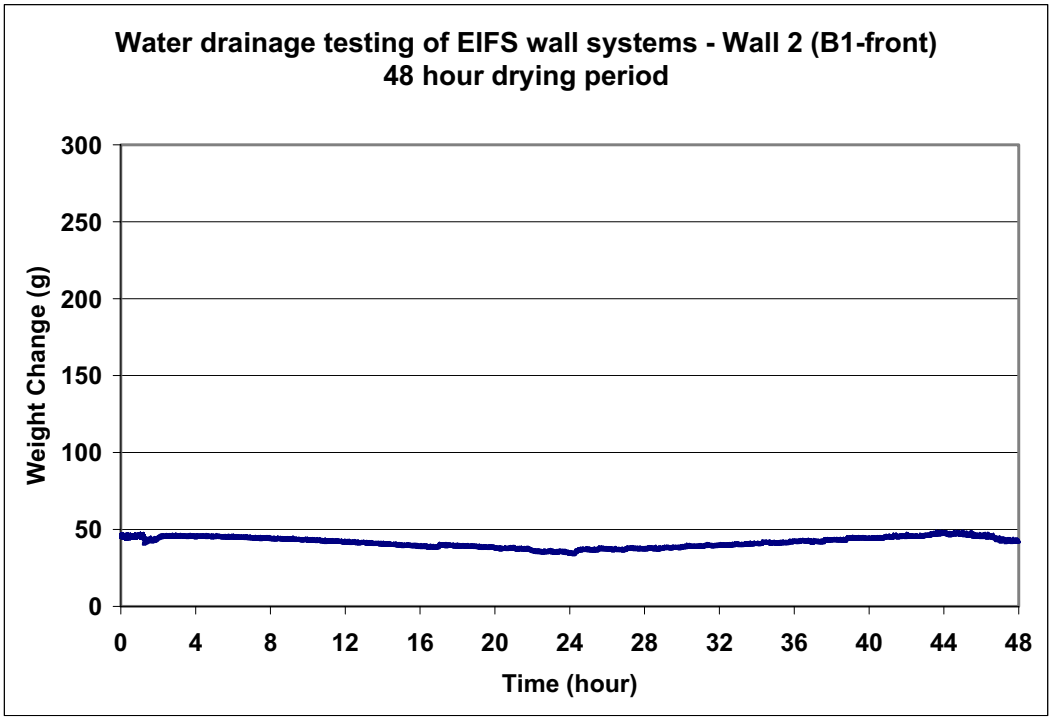


Figure II-3 Wall 2 - 2-hr wetting/drainage test trickling water down front and back of drainage cavity.



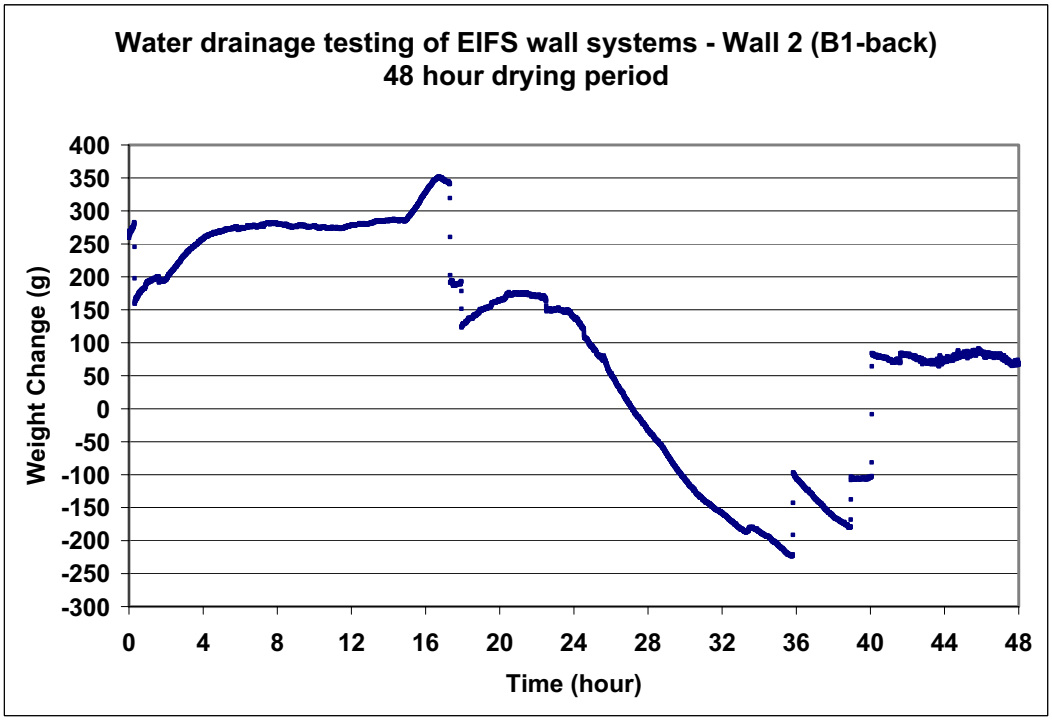
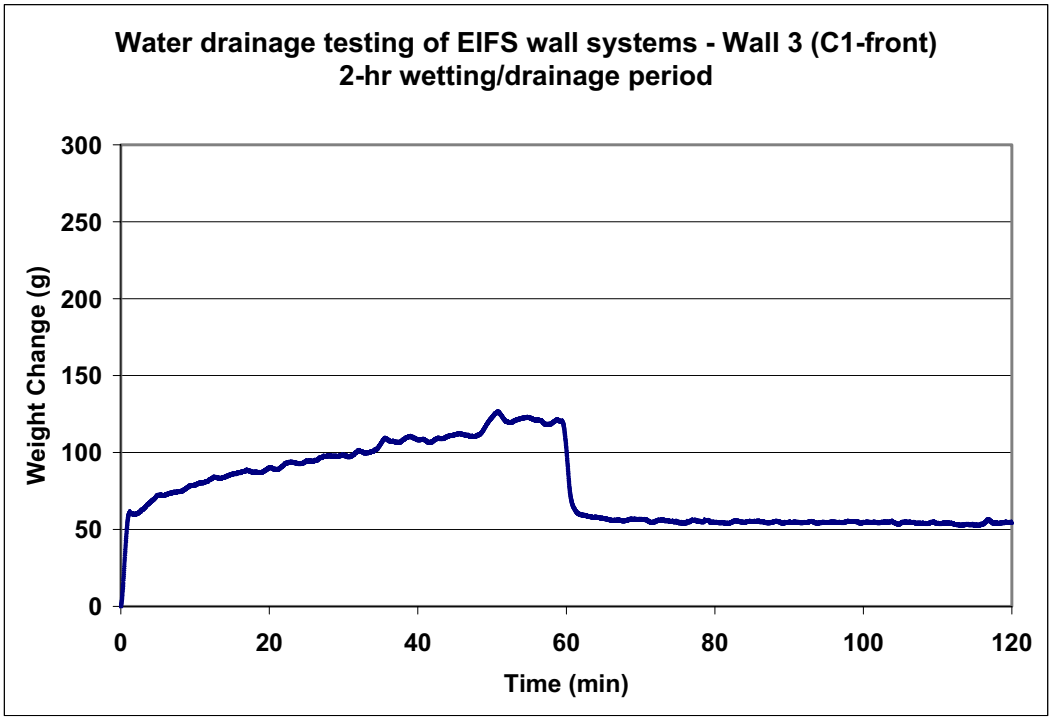


Figure II-4 Wall 2 - 48 hour drying records for drainage tests trickling water down front and back of drainage cavity. The 48 hour period immediately followed the 2-hr wetting/drainage period. This wall was subsequently retested because of the unreliable drying period.



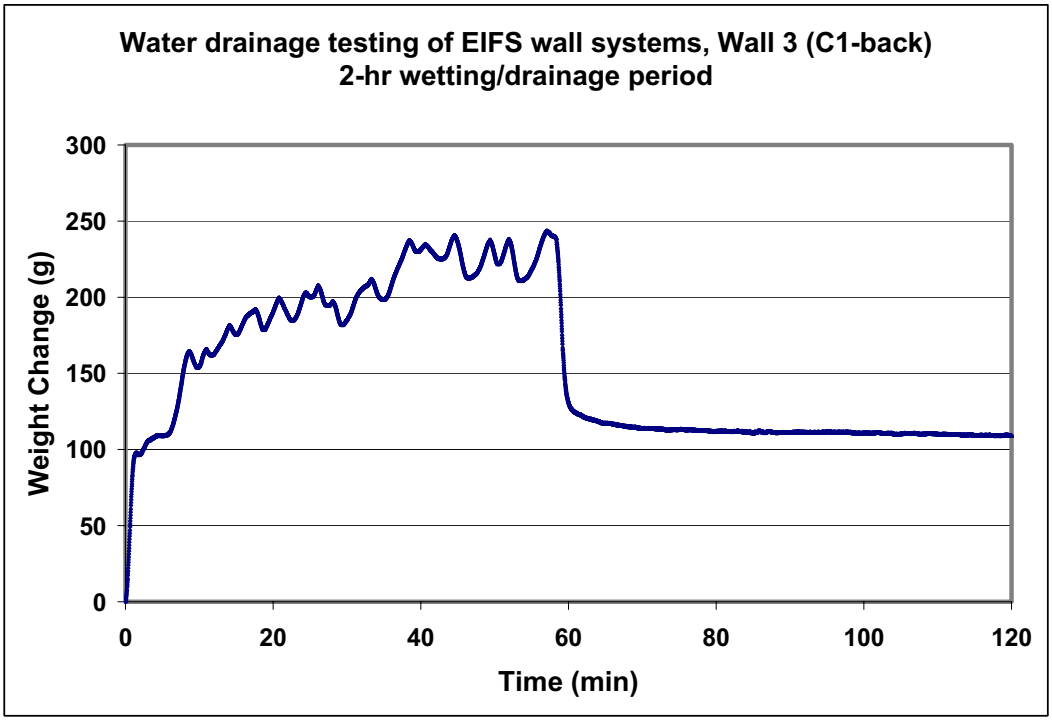
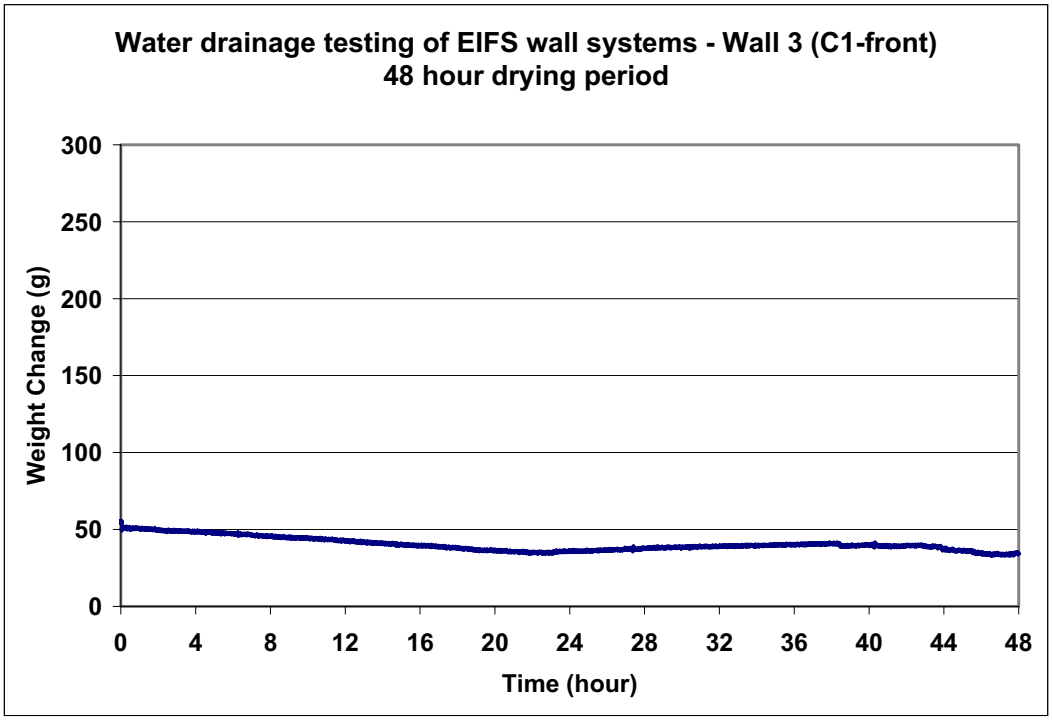


Figure II-5 Wall 3 - 2-hr wetting/drainage test trickling water down front and back of drainage cavity.



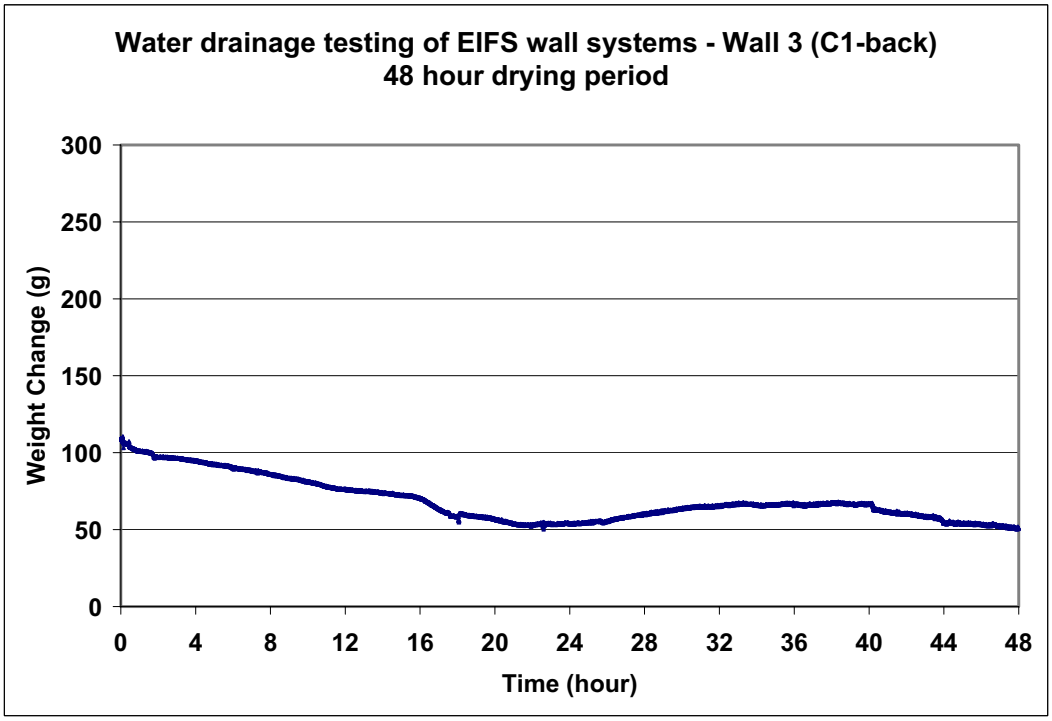
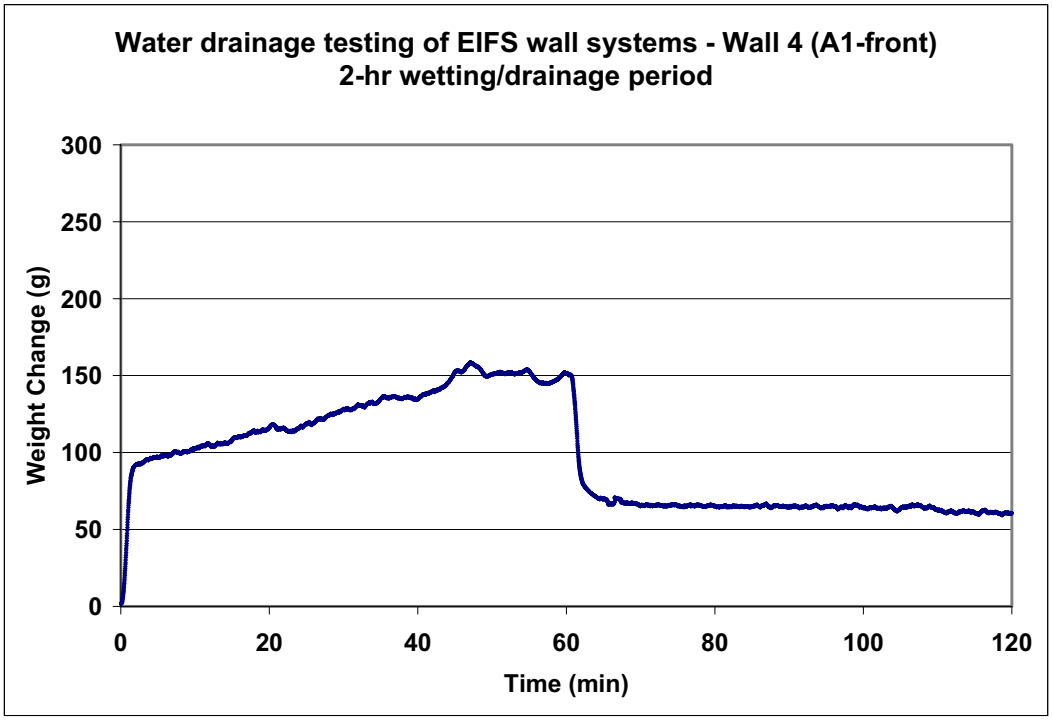


Figure II-6 Wall 3 - 48 hour drying records for drainage tests trickling water down front and back of drainage cavity. The 48 hour period immediately followed the 2-hr wetting/drainage period.



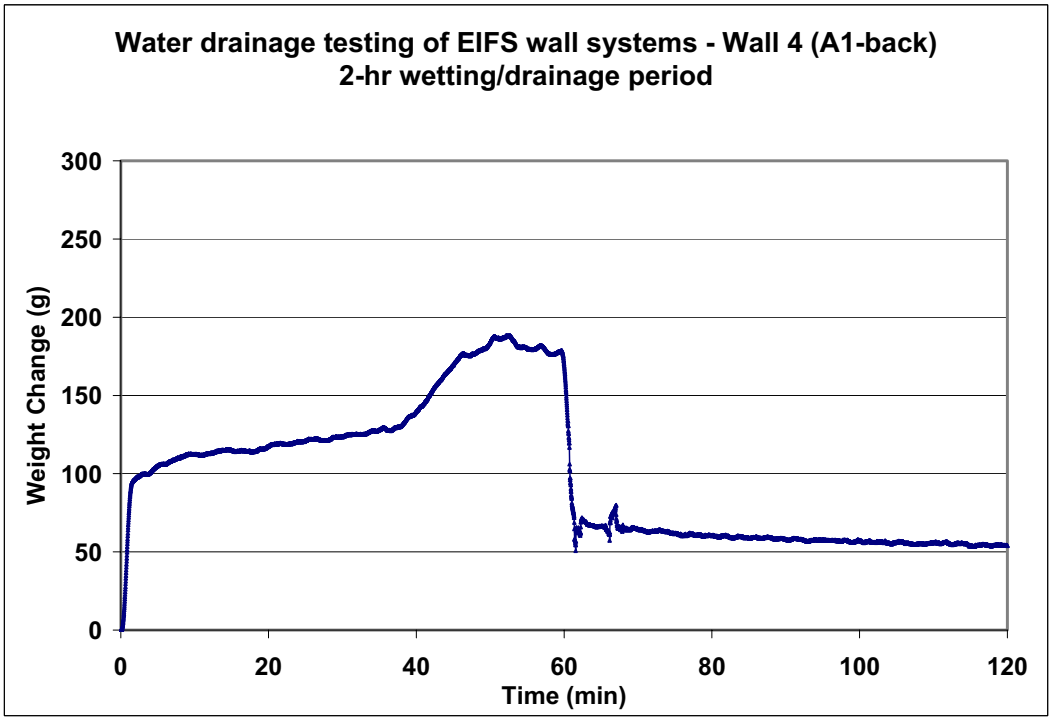
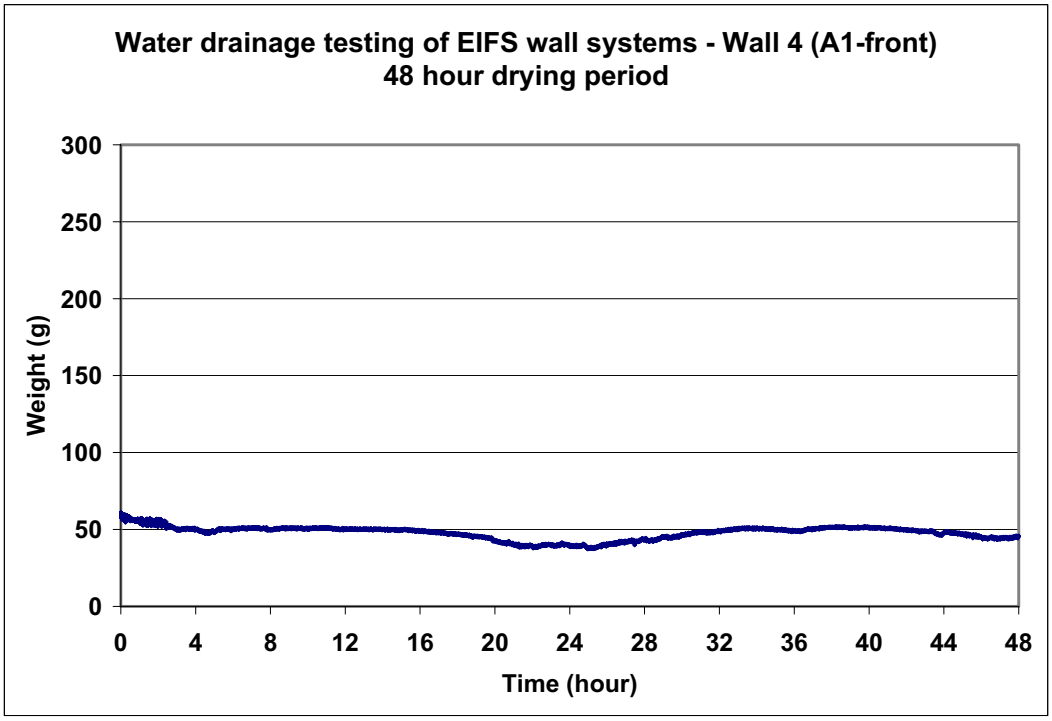


Figure II-7 Wall 4 - 2-hr wetting/drainage test trickling water down front and back of drainage cavity.



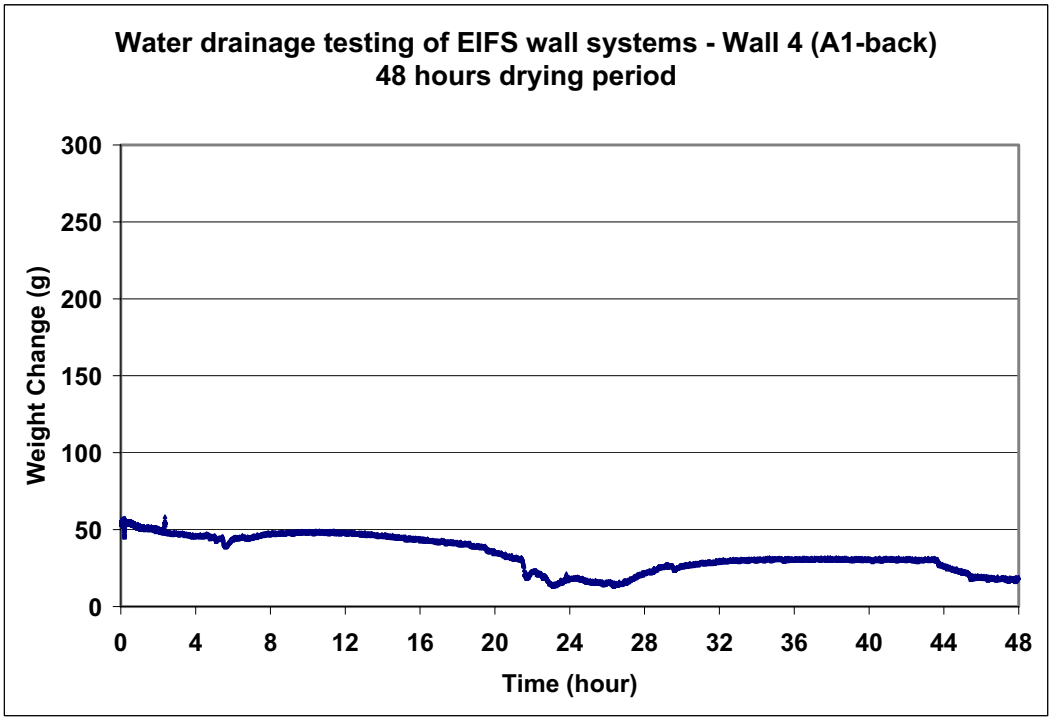
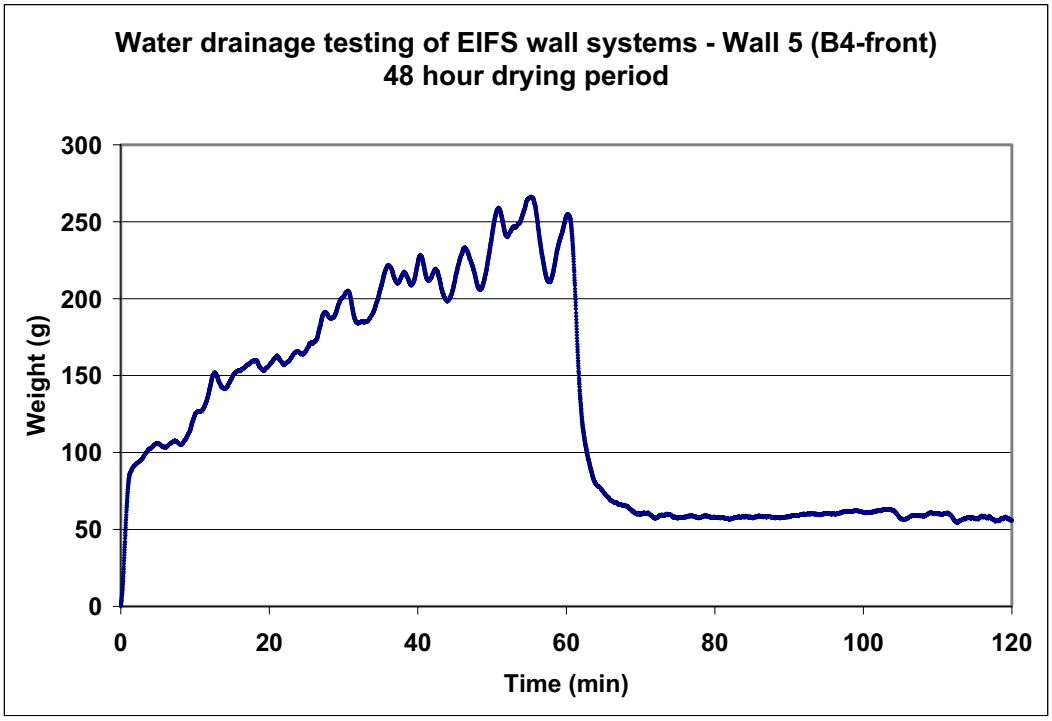


Figure II-8 Wall 4 - 48 hour drying records for drainage tests trickling water down front and back of drainage cavity. The 48 hour period immediately followed the 2-hr wetting/drainage period.



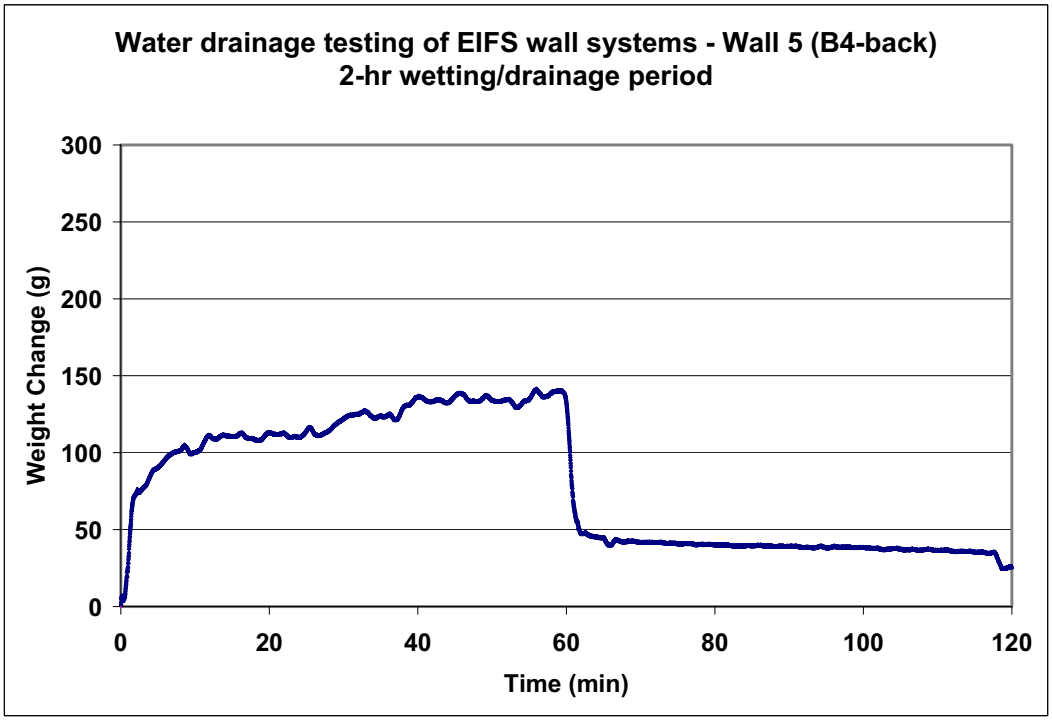
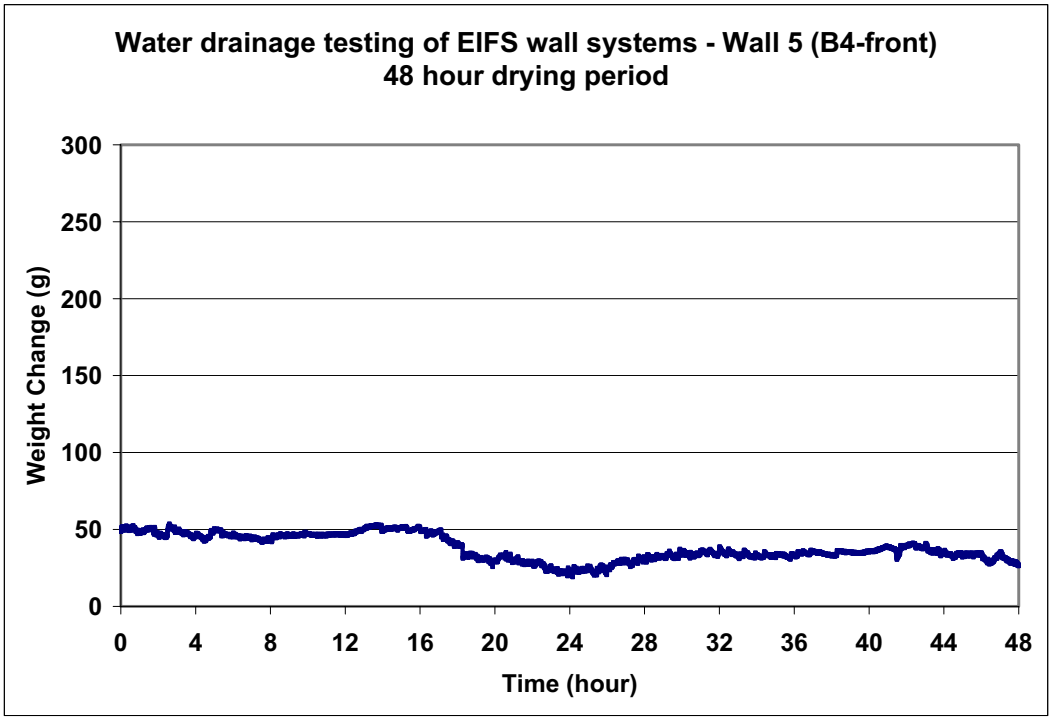


Figure II-9 Wall 5 - 2-hr wetting/drainage test trickling water down front and back of drainage cavity.



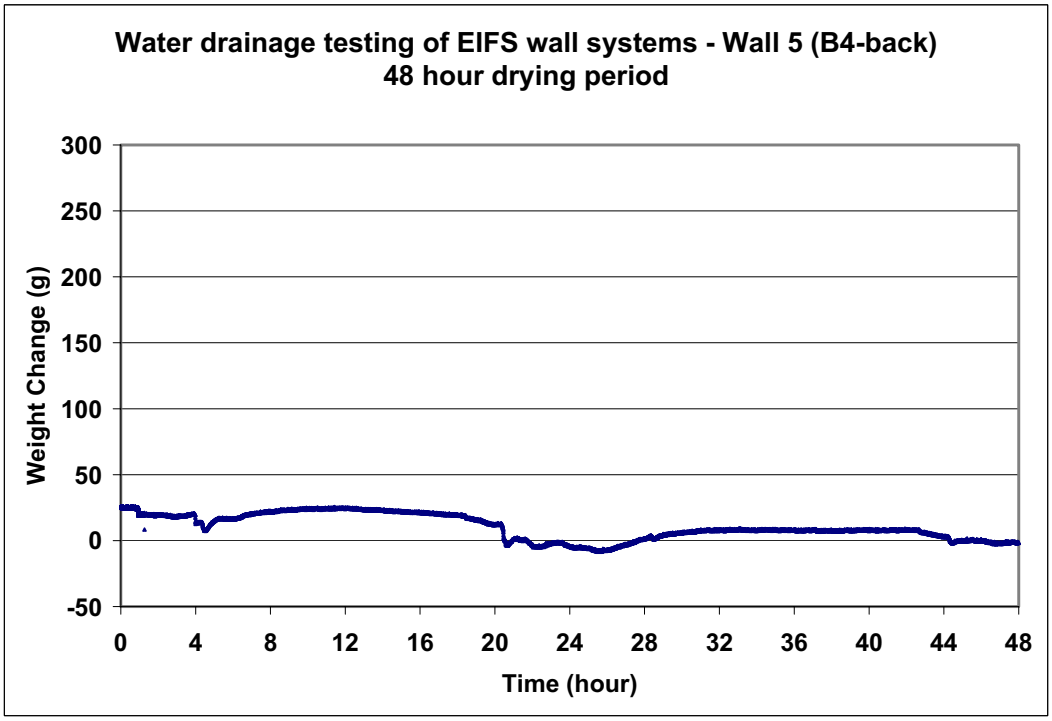
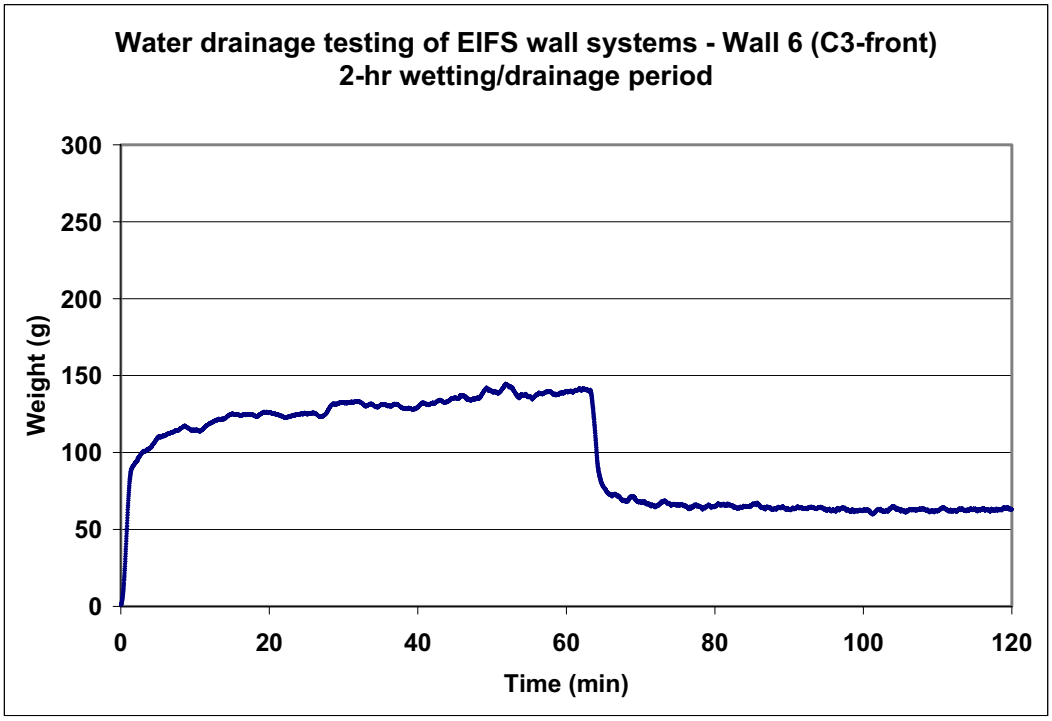


Figure II-10 Wall 5 - 48 hour drying records for drainage tests trickling water down front and back of drainage cavity. The 48 hour period immediately followed the 2-hr wetting/drainage period.



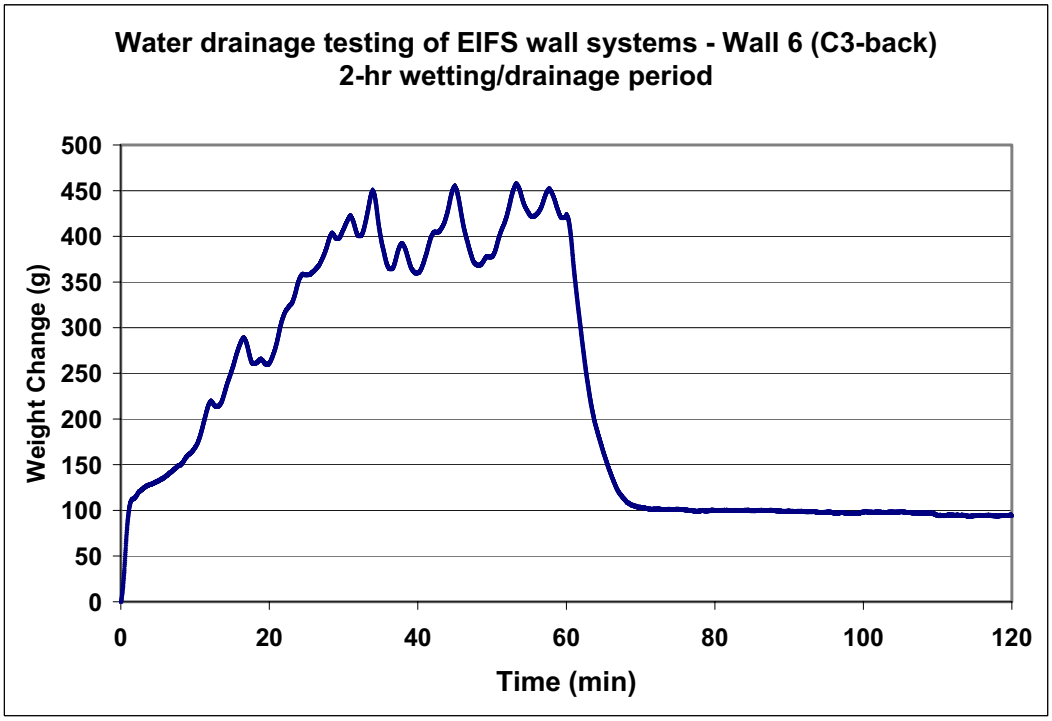
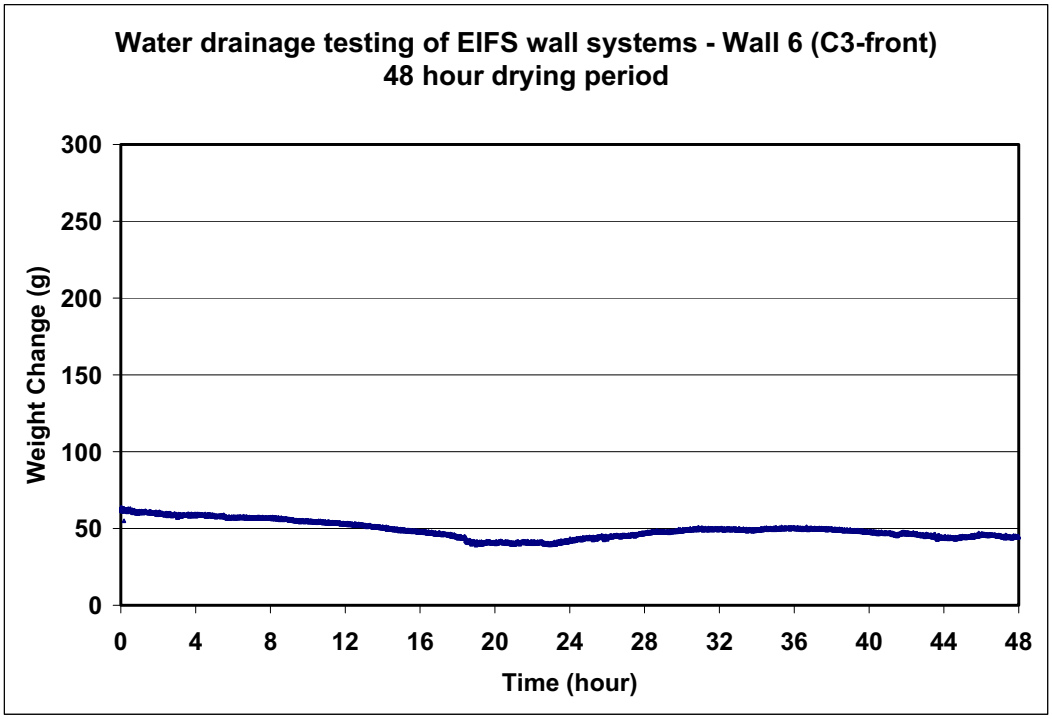


Figure II-11 Wall 6 - 2-hr wetting/drainage test trickling water down front and back of drainage cavity.



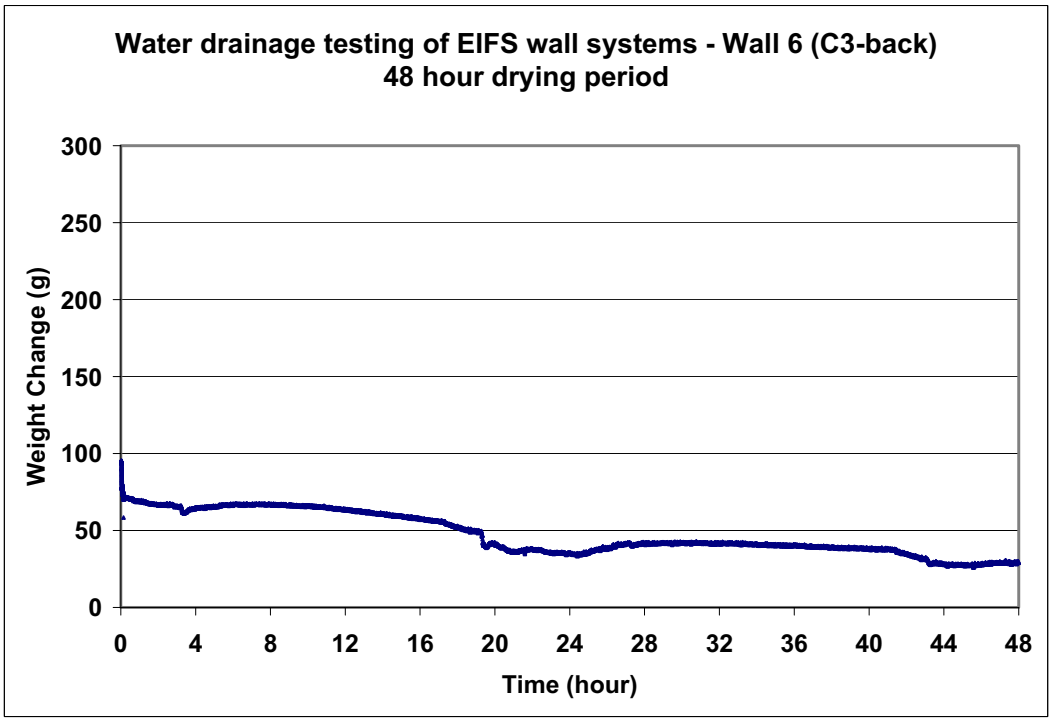
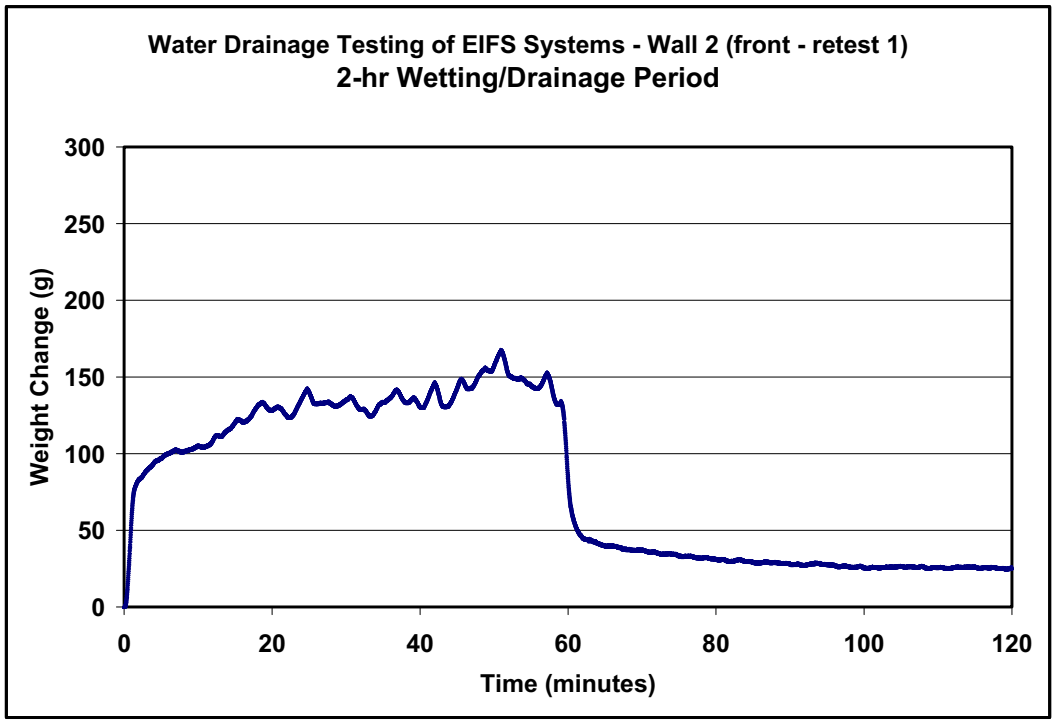


Figure II-12 Wall 6 - 48 hour drying records for drainage tests trickling water down front and back of drainage cavity. The 48 hour period immediately followed the 2-hr wetting/drainage period.



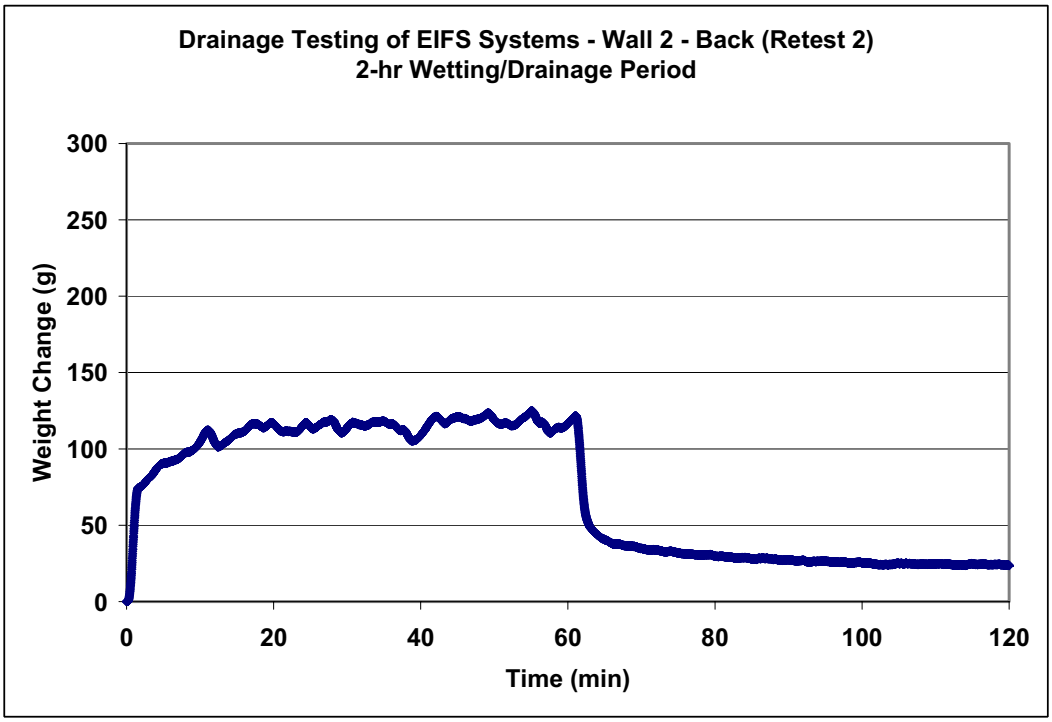
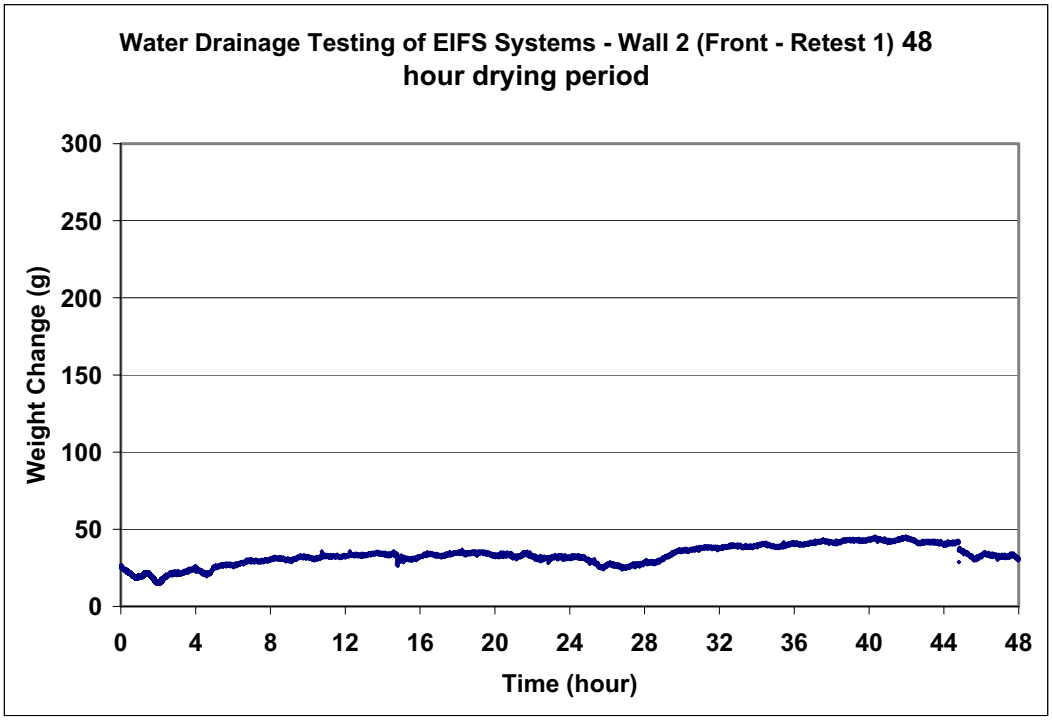


Figure II-13 Wall 2 – Retest 2 - 2-hr wetting/drainage test trickling water down front and back of drainage cavity. These tests were repeated because of the lack of reliability of the initial test shown in Figure II-4.



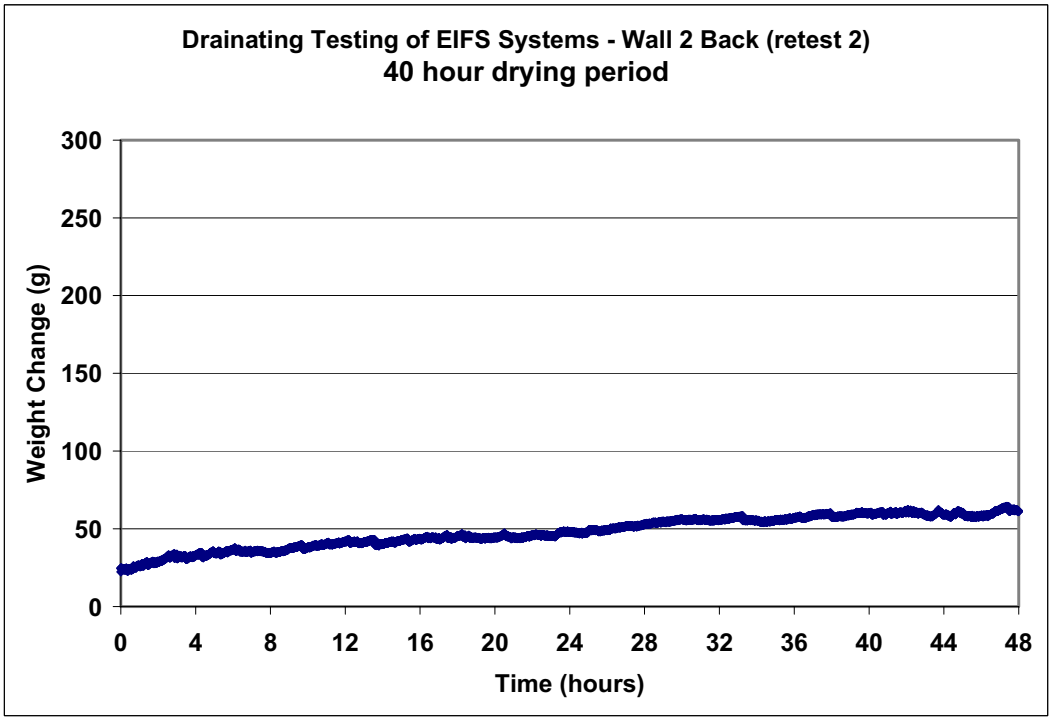


Figure II-14 Wall 2 – Restests - 48 hour drying records for drainage tests trickling water down front and back of drainage cavity. The 48 hour period immediately followed the 2-hr wetting/drainage period. These were done because the initial tests were not considered reliable. In both tests above, the walls gained weight during the drying period of the test.

APPENDIX III

Moisture Mapping of Retained Water

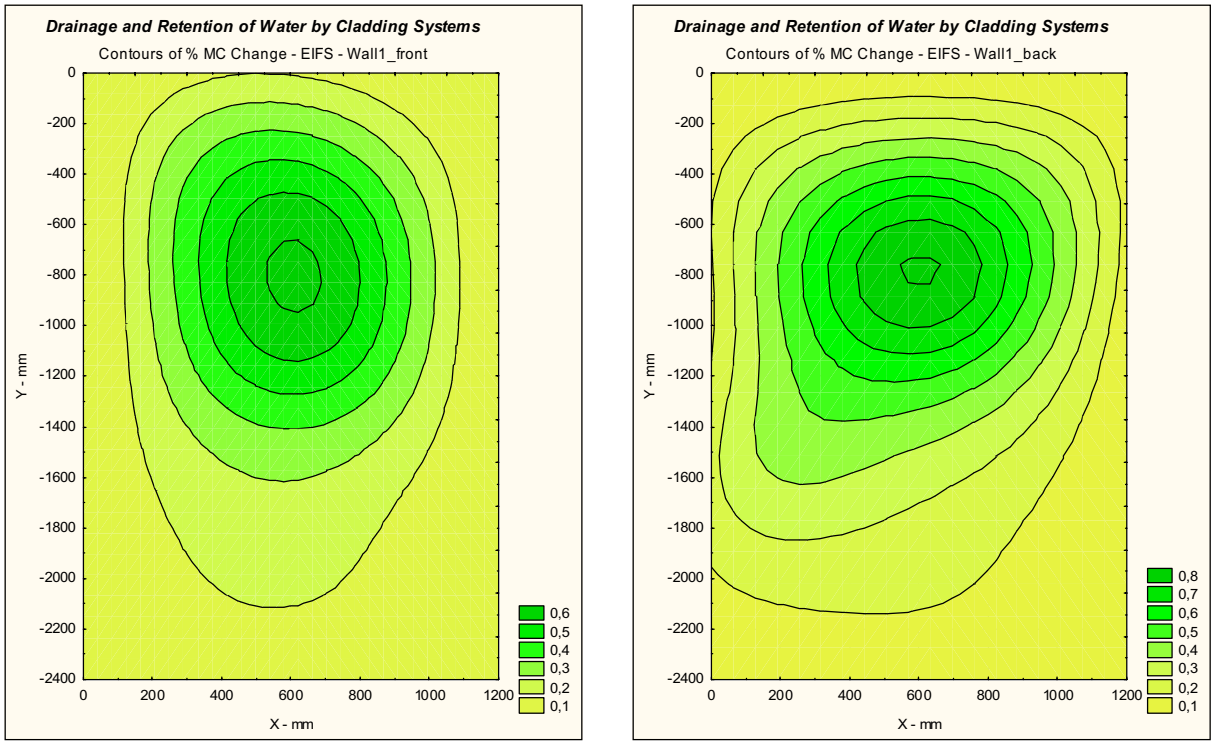


Figure III-1 Wall 1 – contour plots of moisture change for wetting biased to the front or back of the drainage cavity

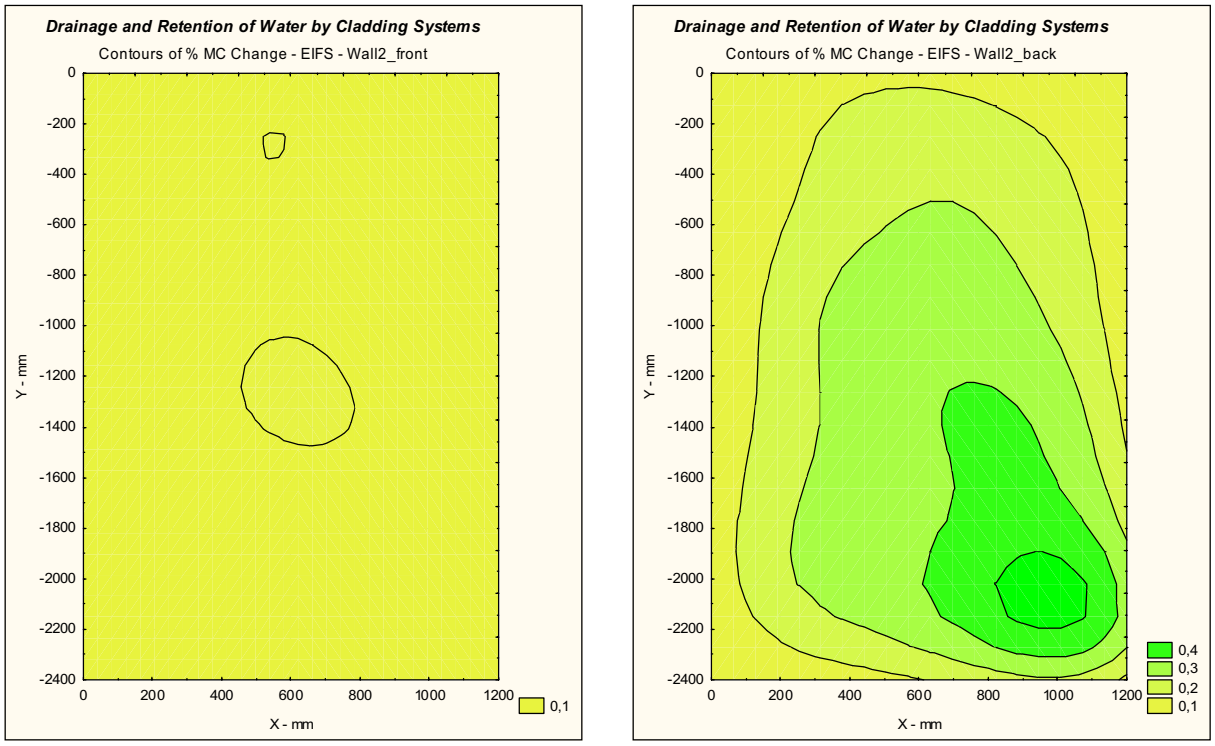


Figure III-2 Wall 2 – contour plots of moisture change for wetting biased to the front or back of the drainage cavity

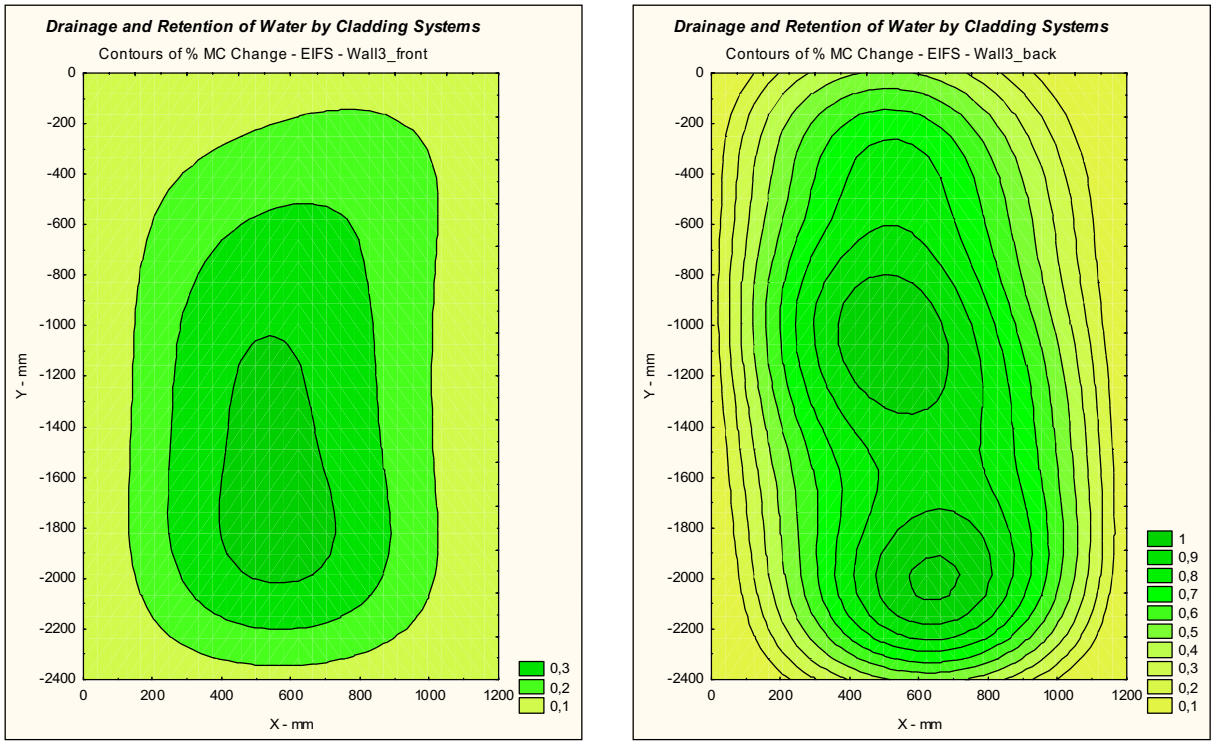


Figure III-3 Wall 3 – contour plots of moisture change for wetting biased to the front or back of the drainage cavity

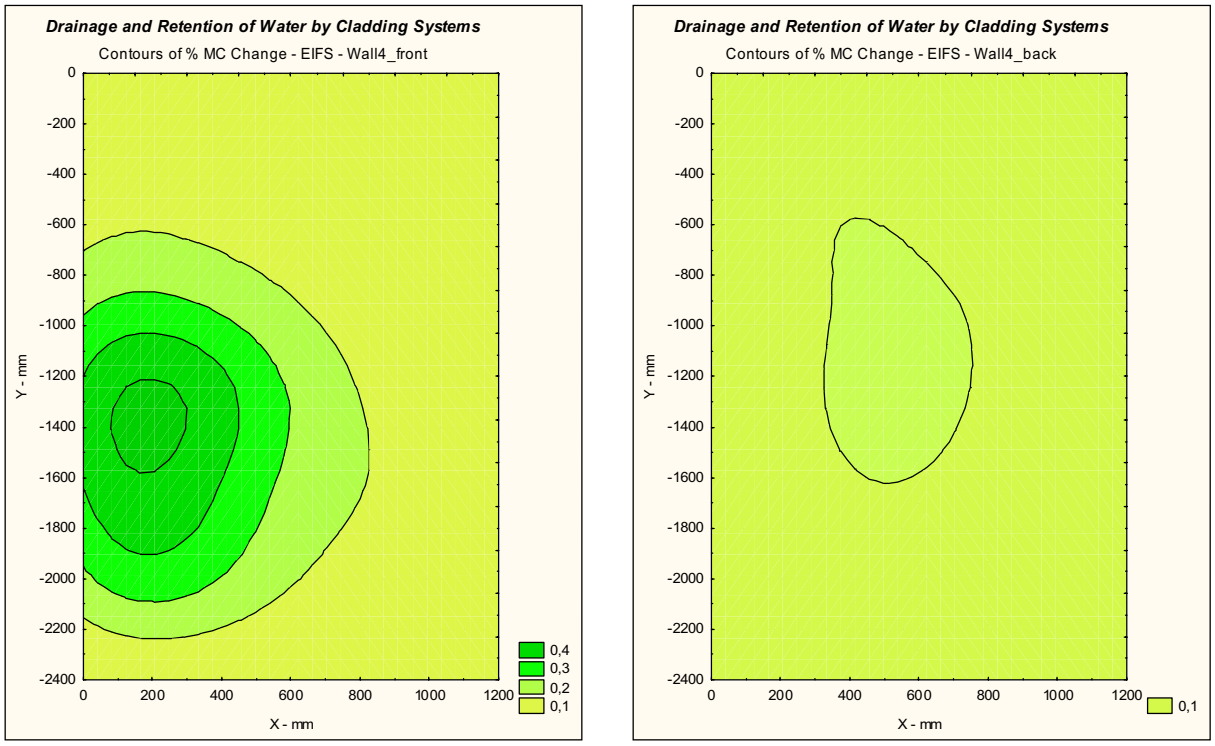


Figure III-4 Wall 4 – contour plots of moisture change for wetting biased to the front or back of the drainage cavity

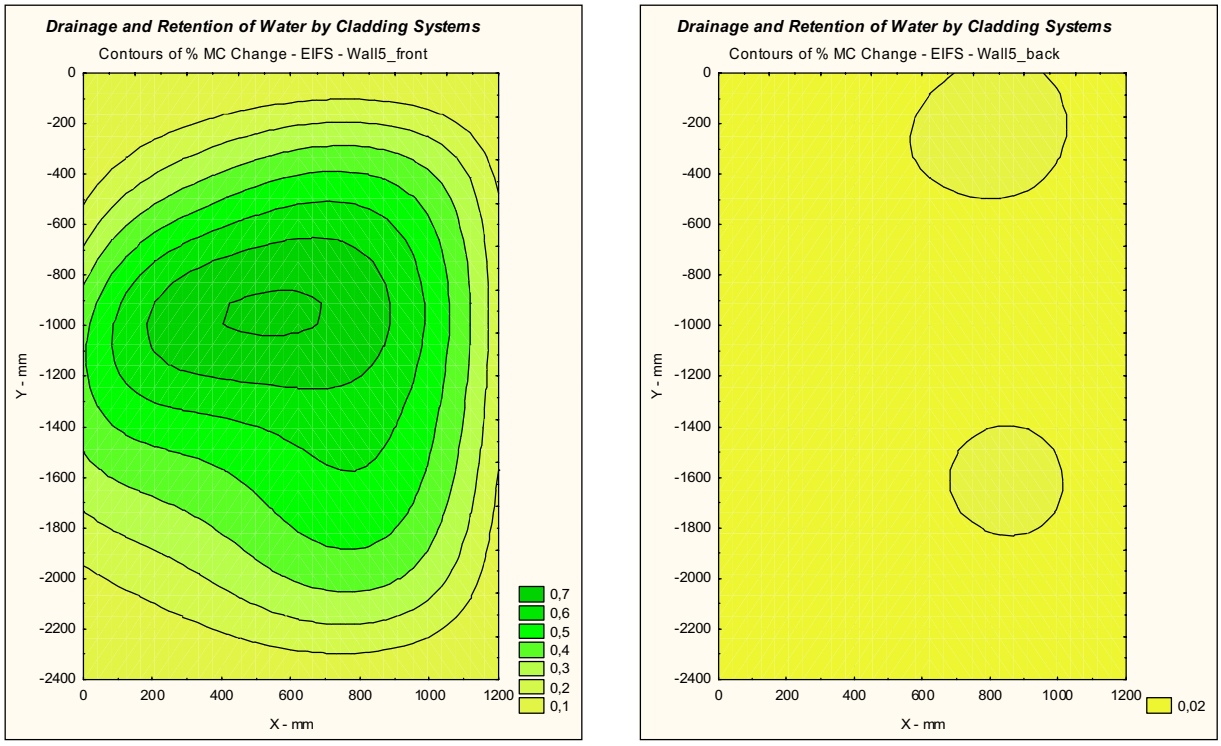


Figure III-5 Wall 5 – contour plots of moisture change for wetting biased to the front or back of the drainage cavity

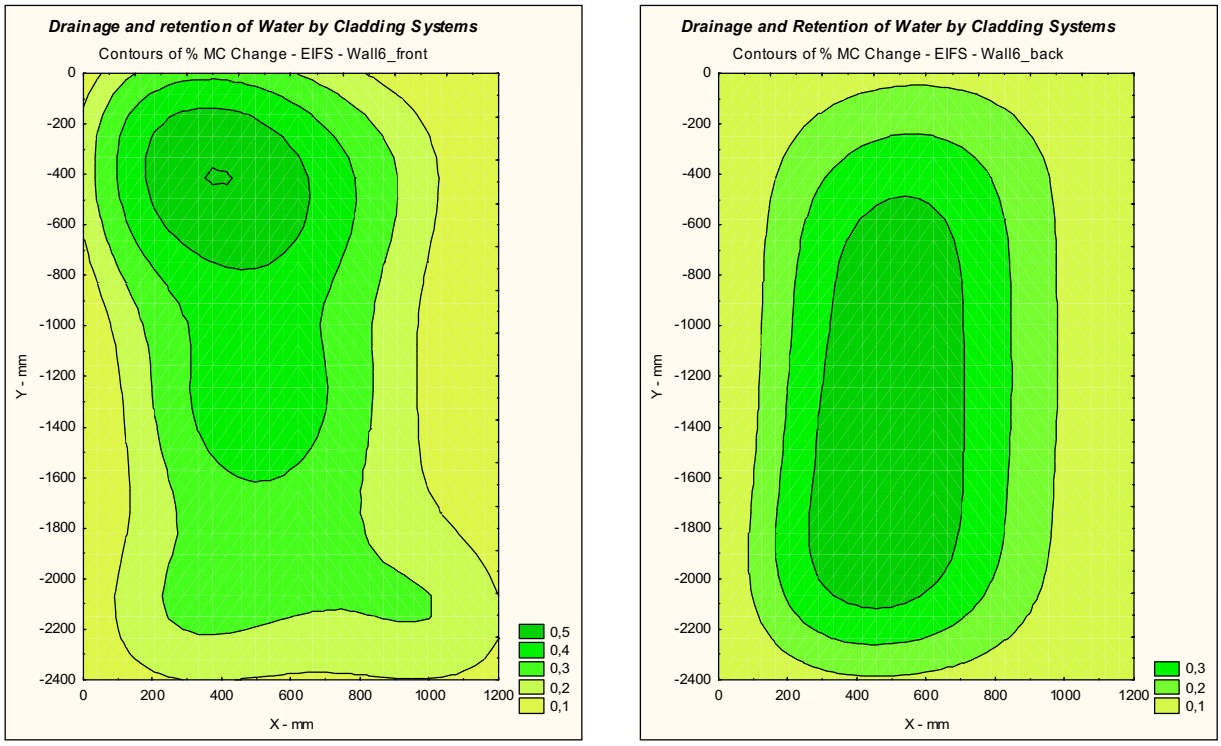


Figure III-6 Wall 6 – contour plots of moisture change for wetting biased to the front or back of the drainage cavity

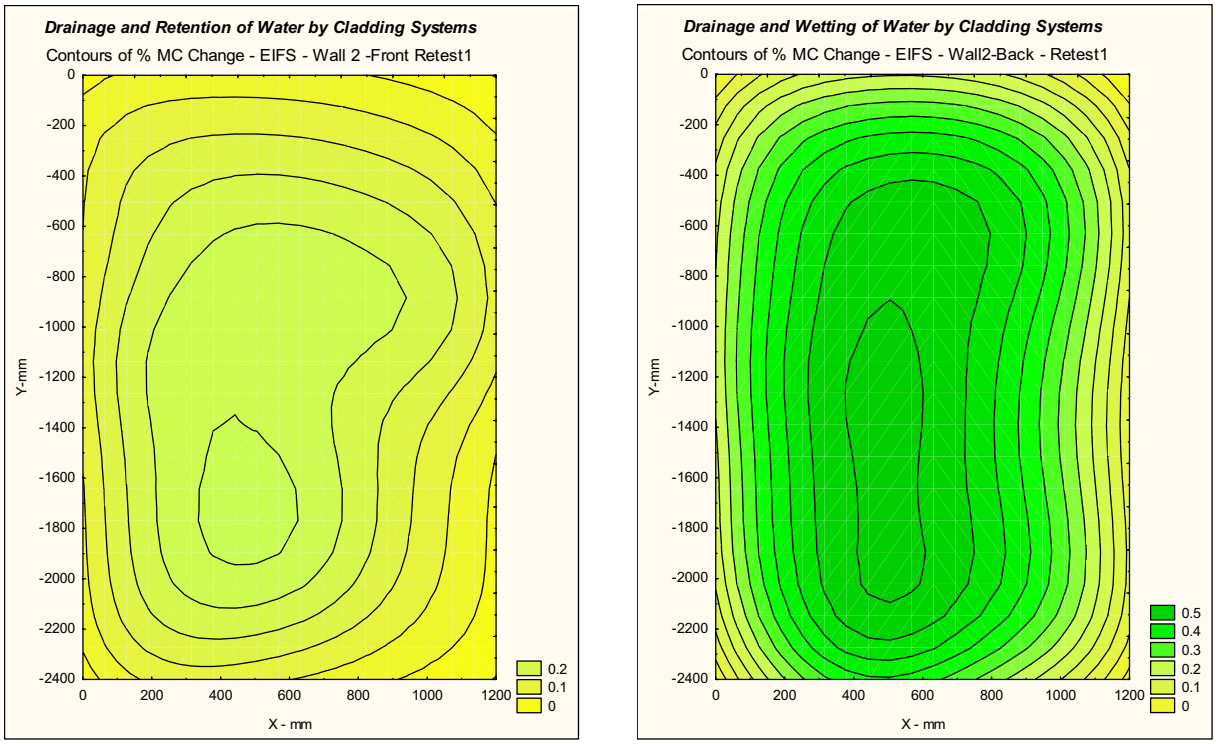
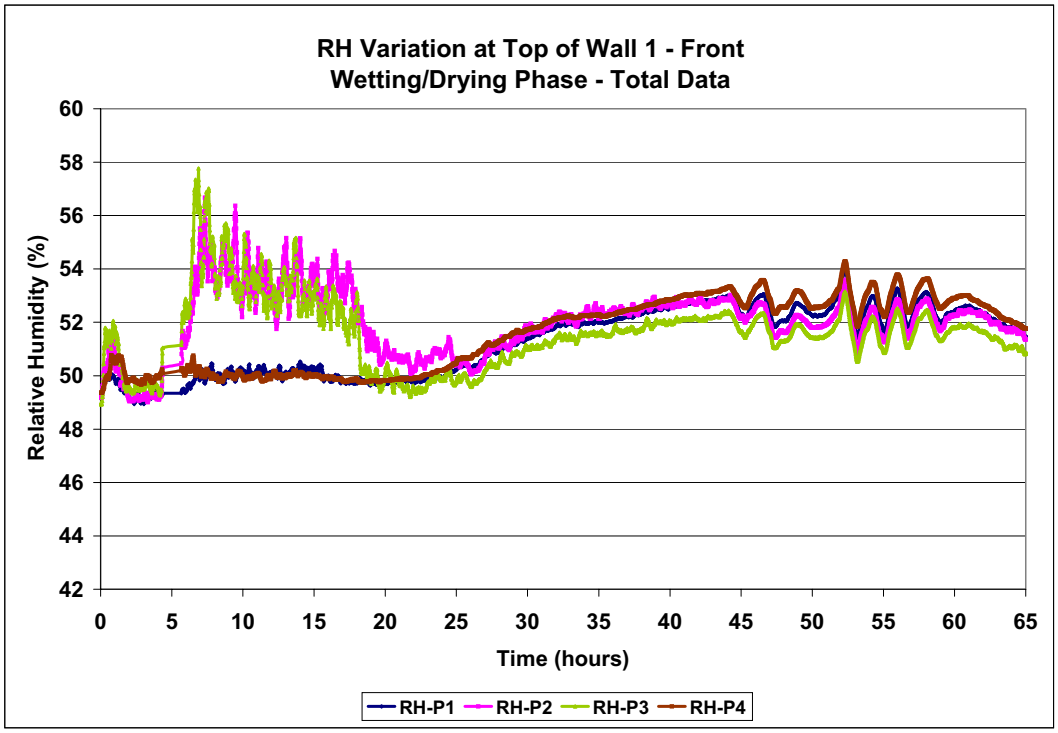


Figure III-7 Wall 2 (retest1) – contour plots of moisture change for wetting biased to the front or back of the drainage cavity. The tests were repeated because of the unreliability of the initial test in Figure II-4

Figure III-8 Wall 2 – Back (retest 2) contour plots of % MC change (a second retest following that shown in Figure III-7).

APPENDIX IV

Plots of Relative Humidity and Temperature during Drainage and Drying Testing of EIFS Walls



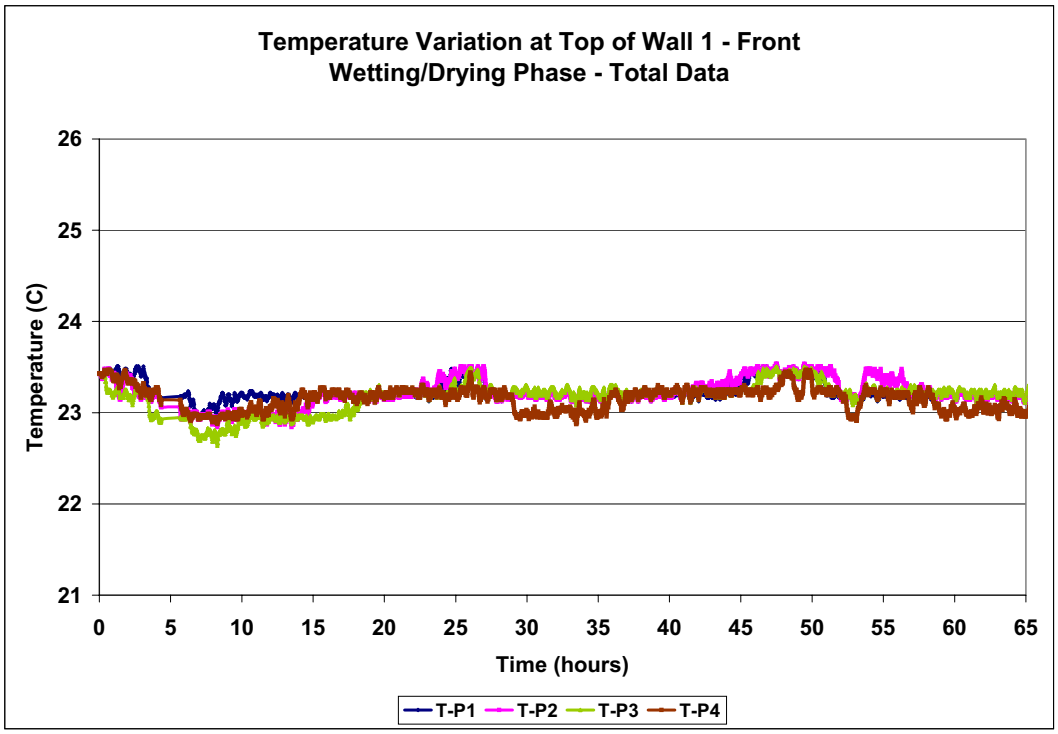
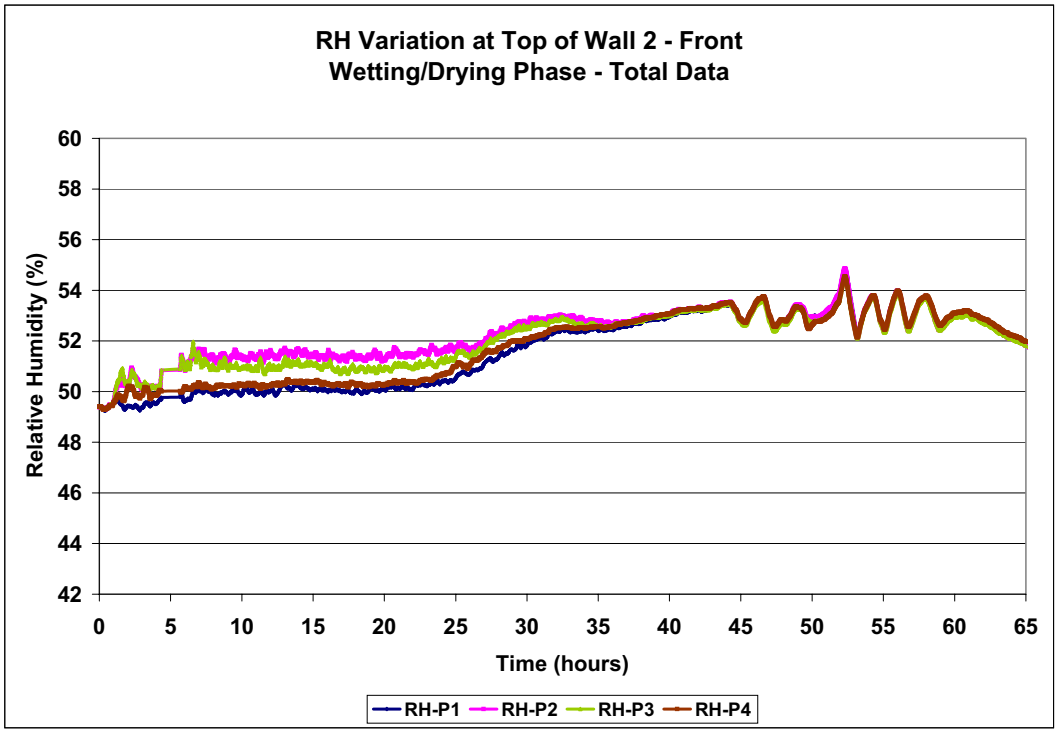


Figure IV-1 Wall 1 – Front - RH and T records at the top of drainage cavity for the TOTAL wetting/drying period.



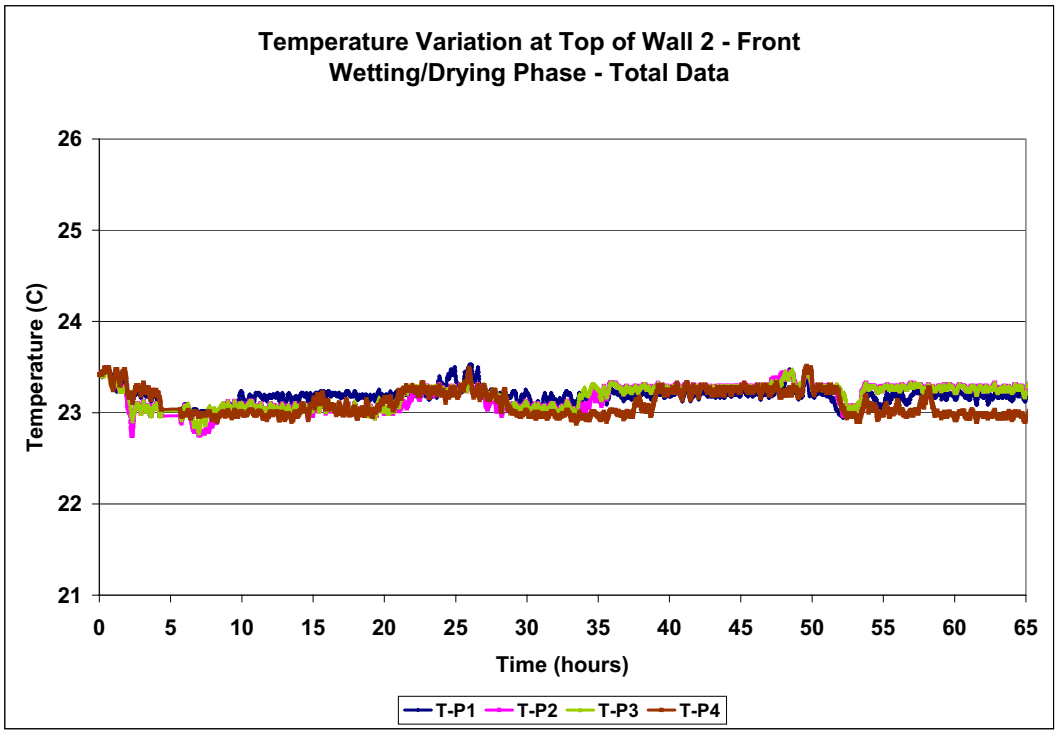
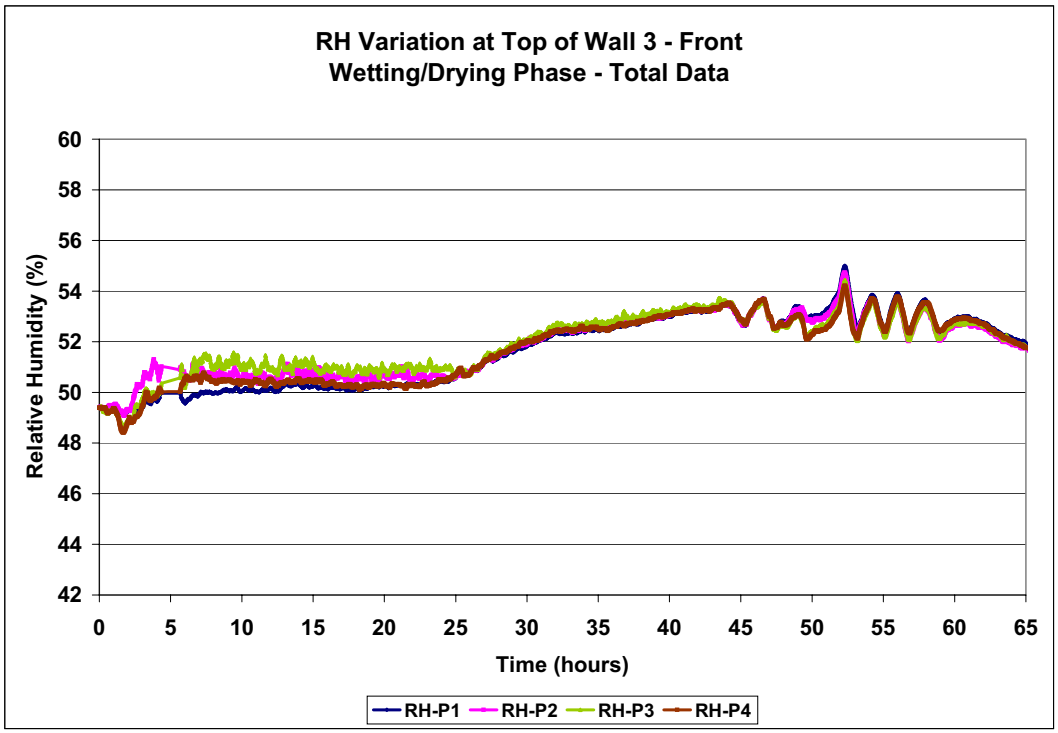


Figure IV-2 Wall 2 - Front - RH and T records at the top of drainage cavity for the TOTAL wetting/drying period.



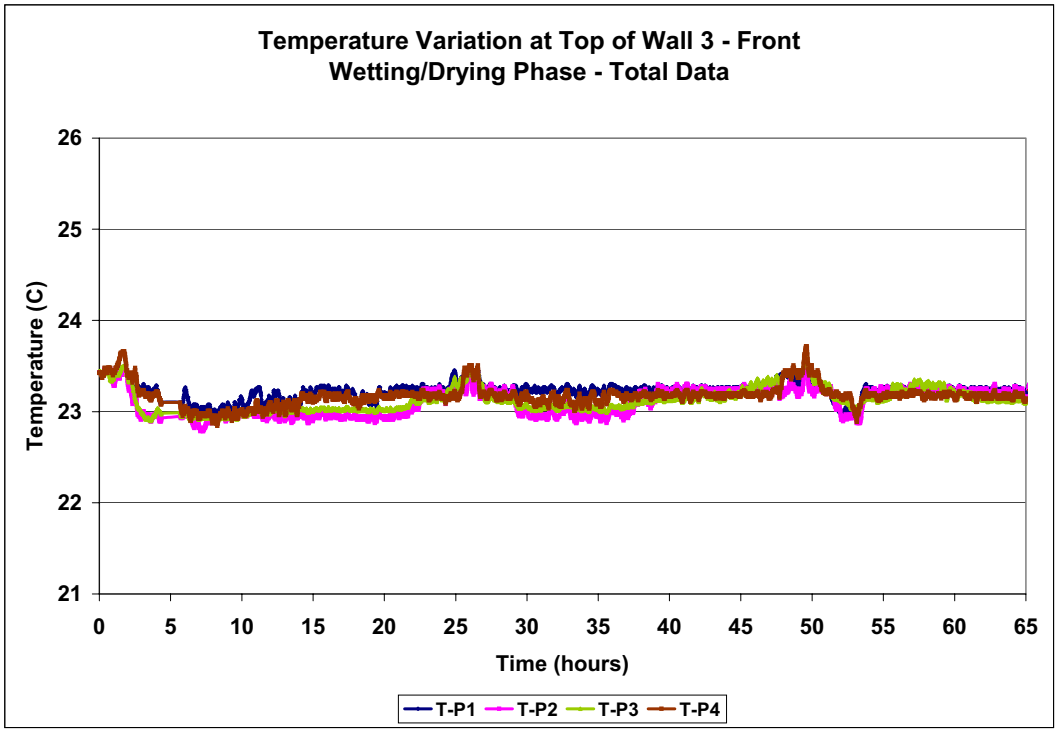
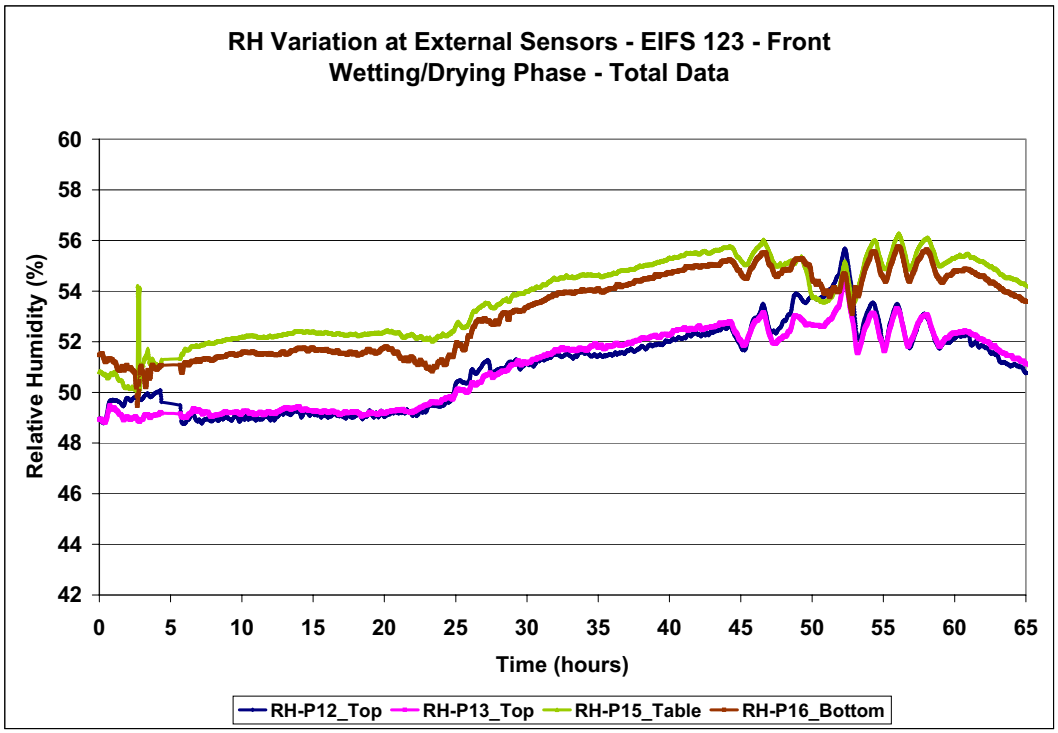


Figure IV-3 Wall 3 – Front - RH and T records at the top of drainage cavity for the TOTAL wetting/drying period.



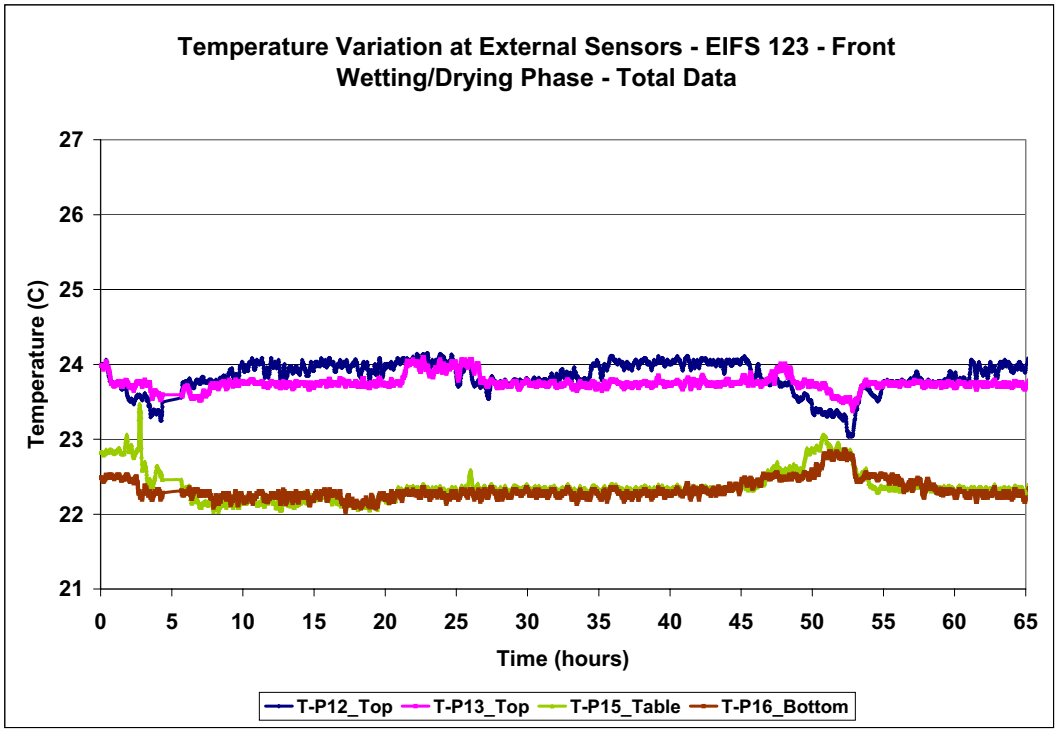
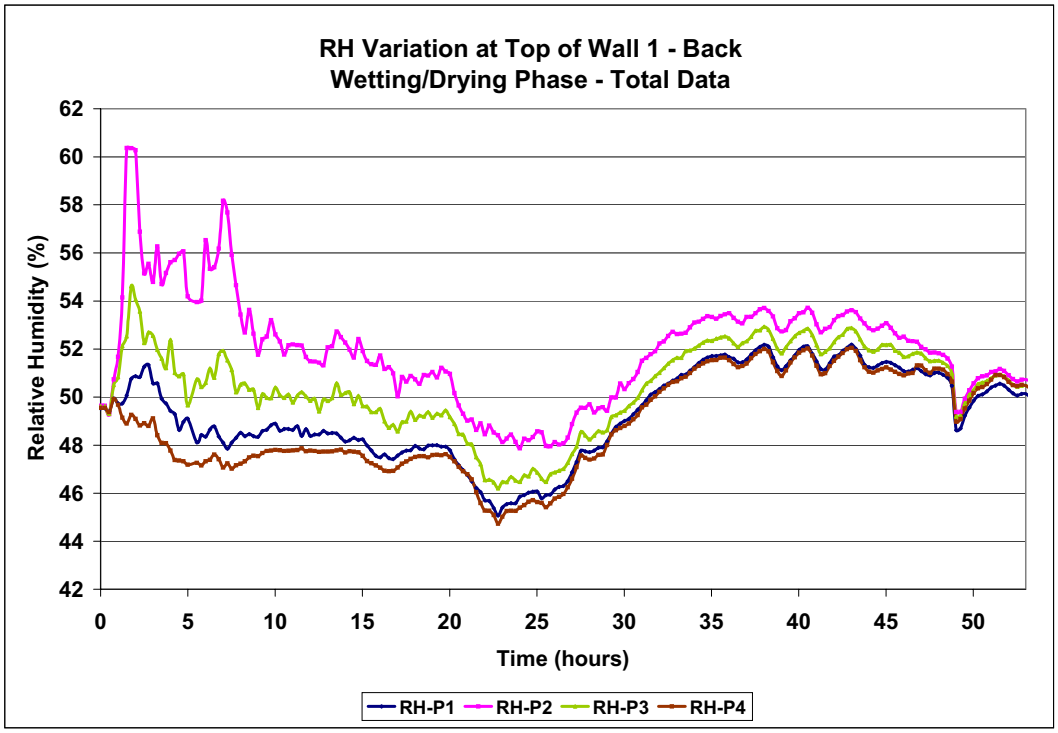


Figure IV-4 Walls 1, 2, and 3 – Front - RH and T records at external sensors the top of drainage cavity for the TOTAL wetting/drying period. These are the external or ambient conditions for tests shown in Figure IV-1 to IV-3.



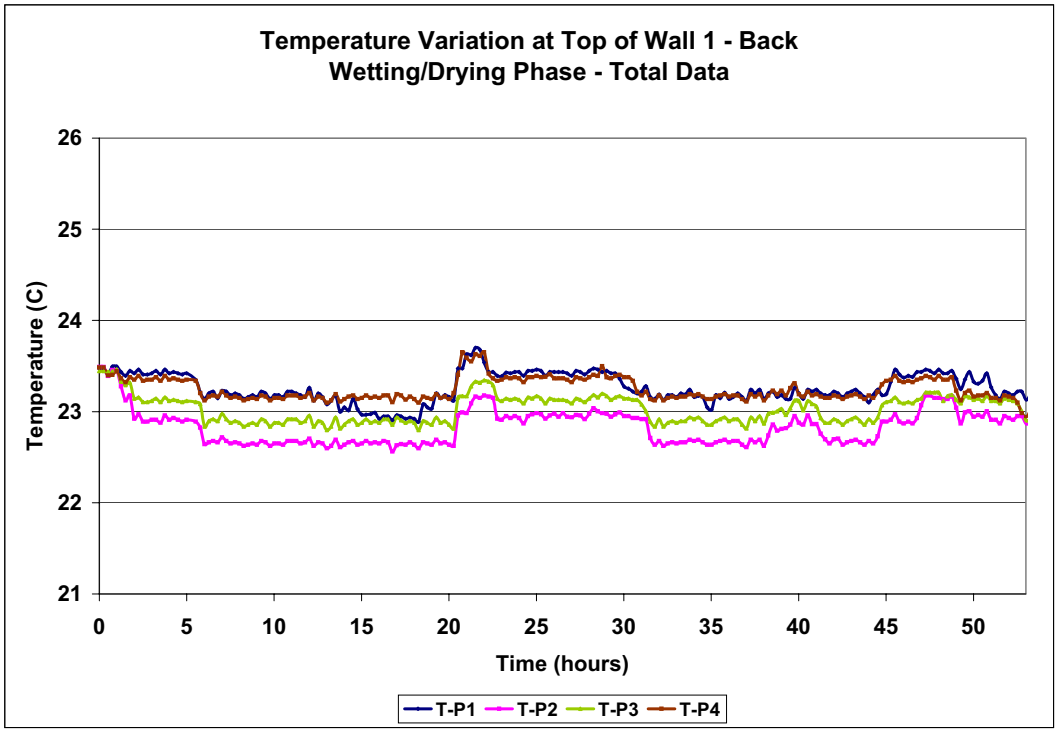
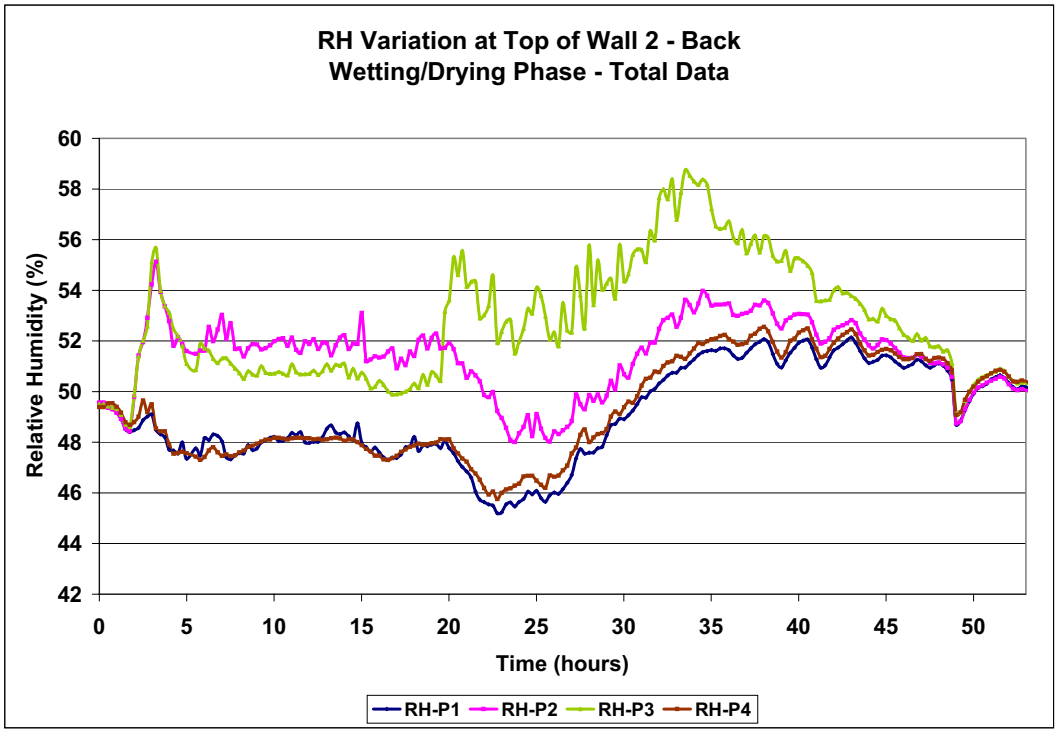


Figure IV-5 Wall 1 – Back - RH and T records at the top of drainage cavity for the TOTAL wetting/drying period.



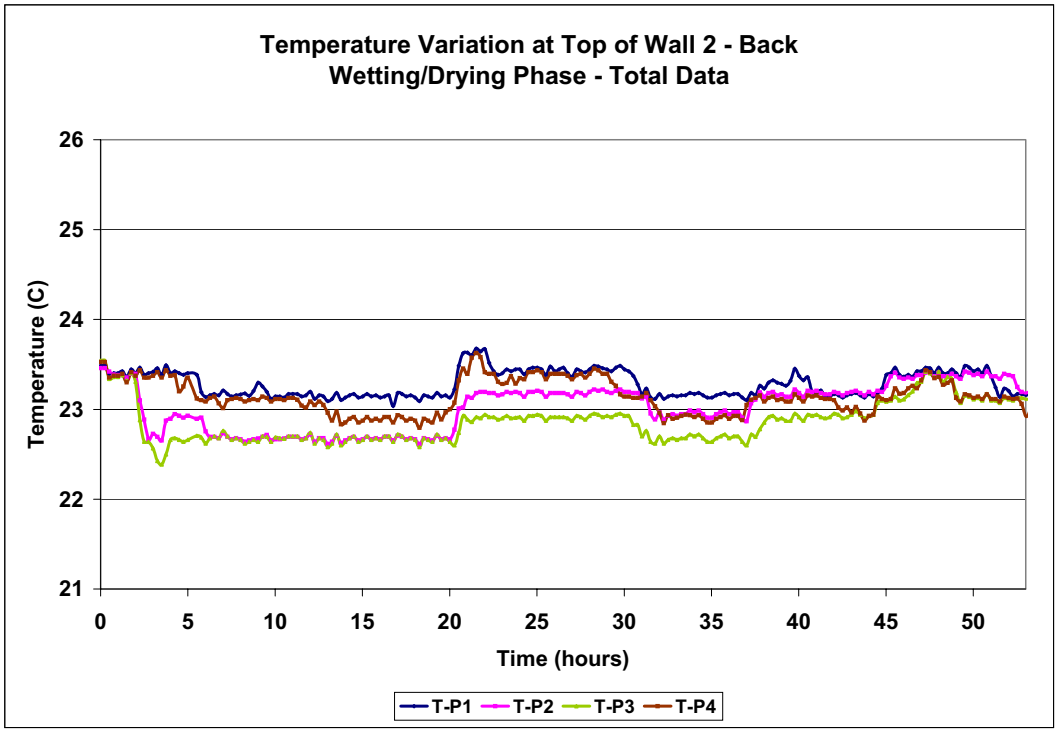
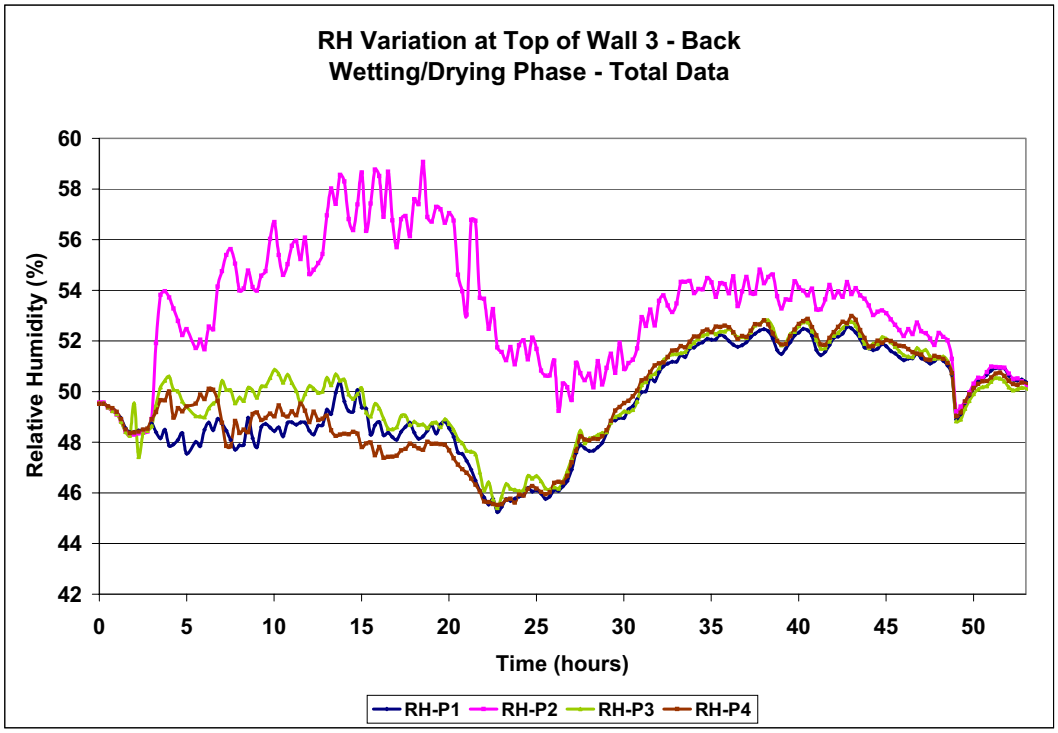


Figure IV-6 Wall 2 – Back - RH and T records at the top of drainage cavity for the TOTAL wetting/drying period.



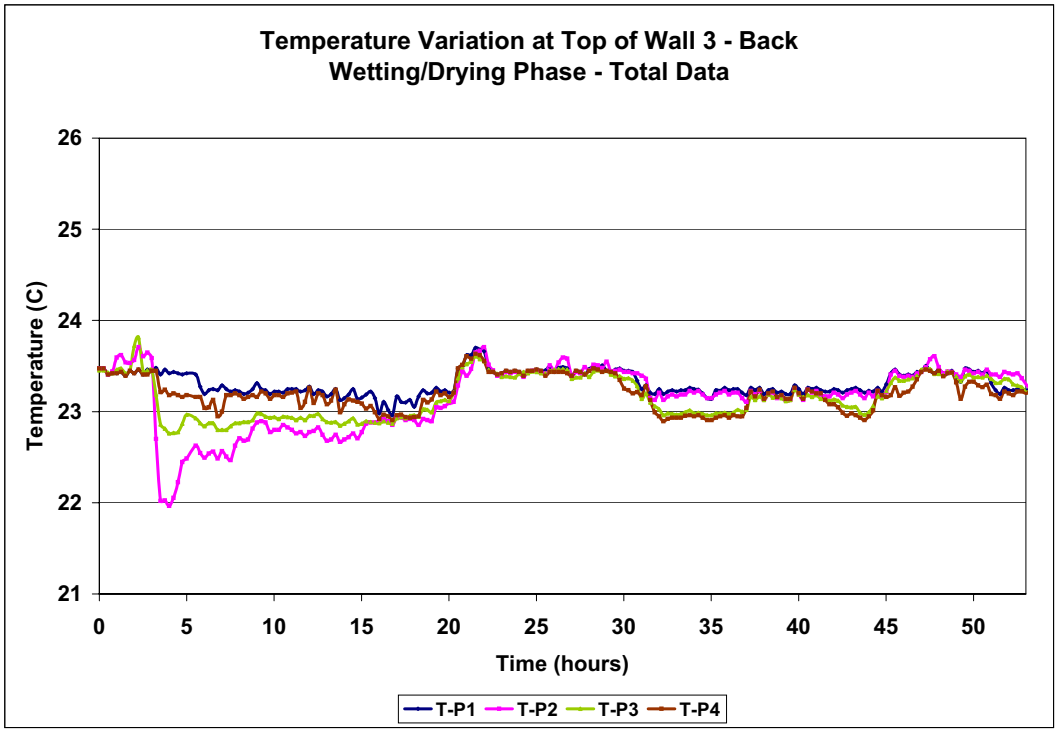
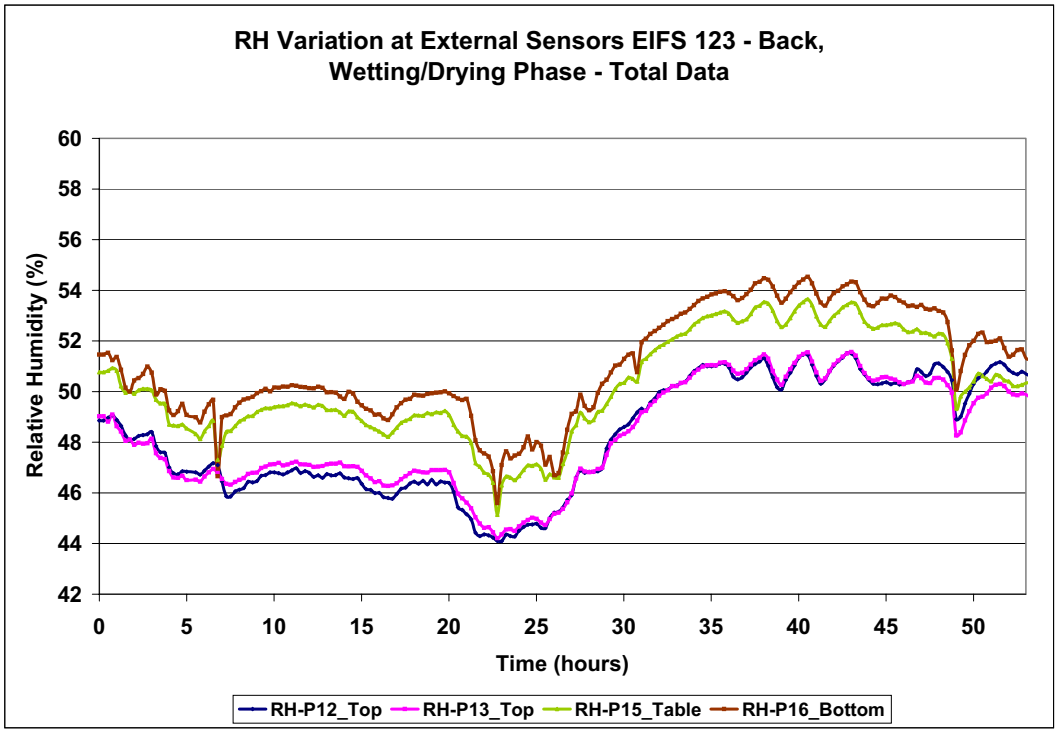


Figure IV-7 Wall 3 – Back - RH and T records at the top of drainage cavity for the TOTAL wetting/drying period.



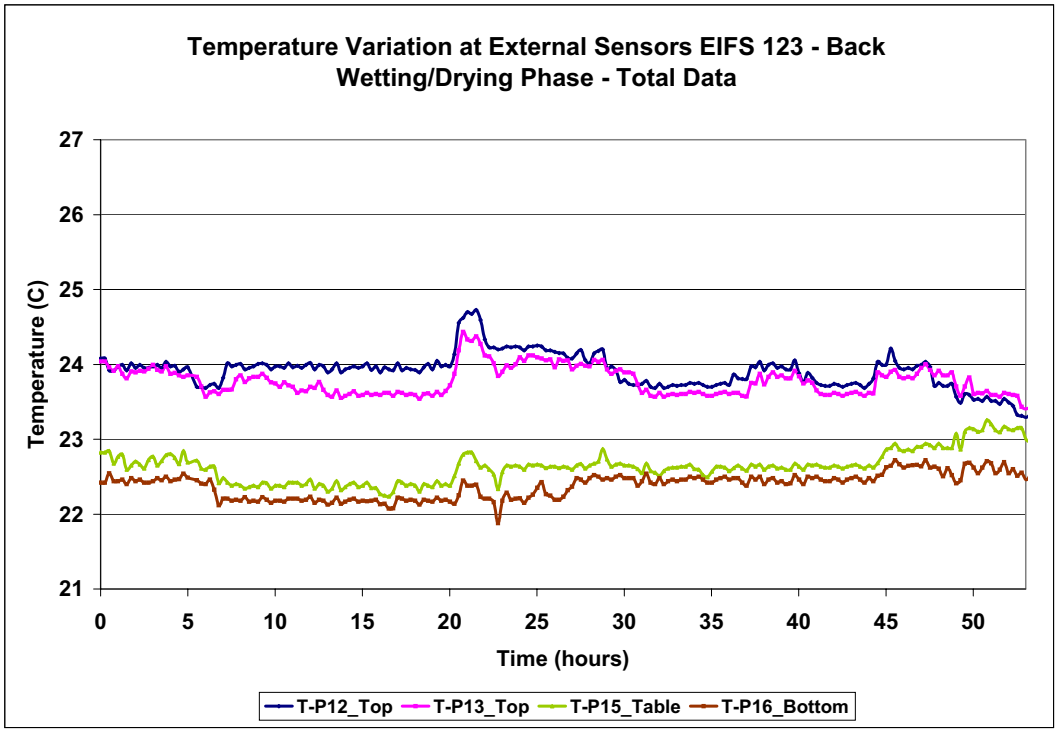
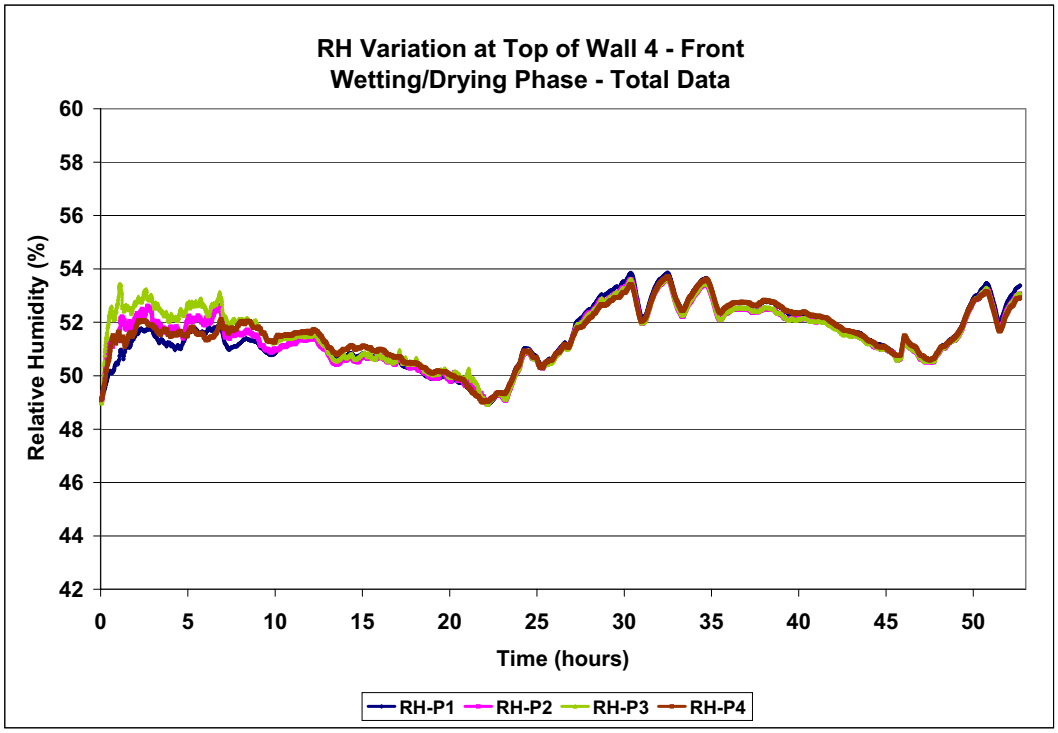


Figure IV-8 Walls 1, 2, and 3 – Back - RH and T records at external sensors the top of drainage cavity for the TOTAL wetting/drying period. These are the external or ambient conditions for tests shown in Figure IV-5 to IV-7.



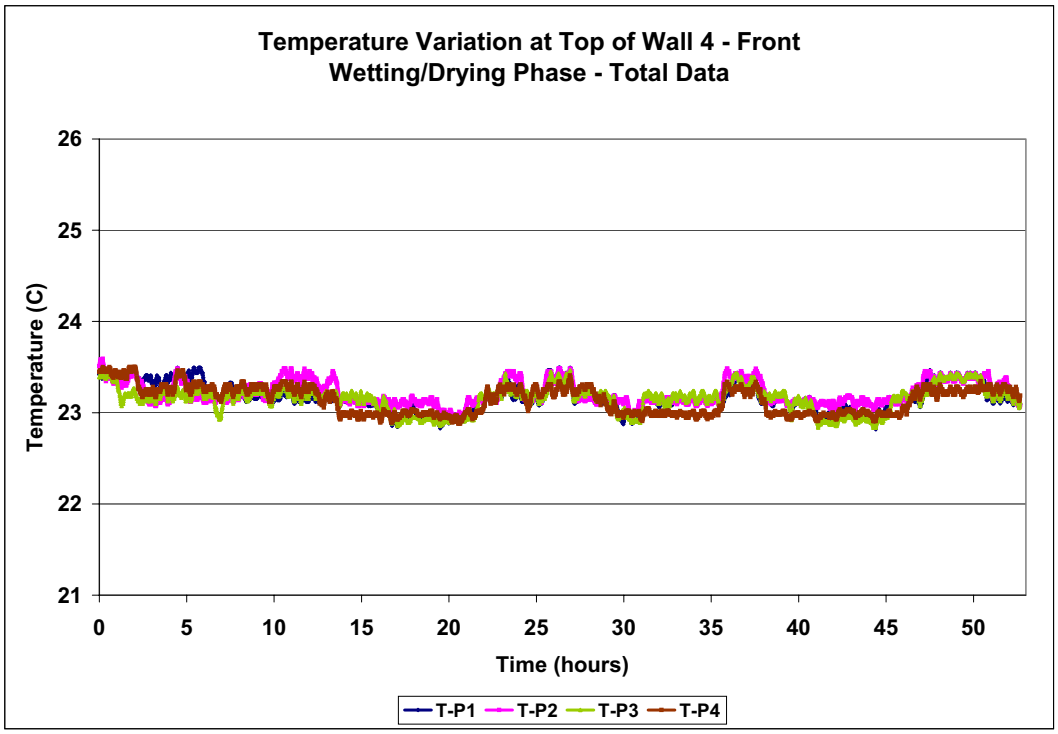
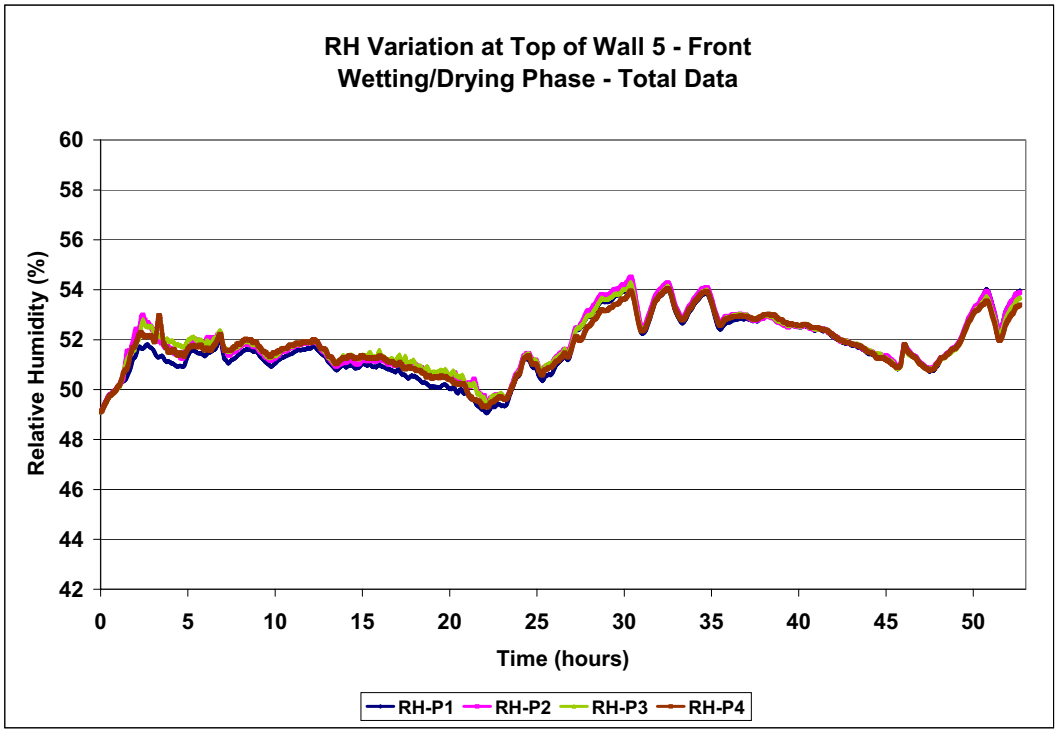


Figure IV-9 Wall 4 – Front - RH and T records at the top of drainage cavity for the TOTAL wetting/drying period.



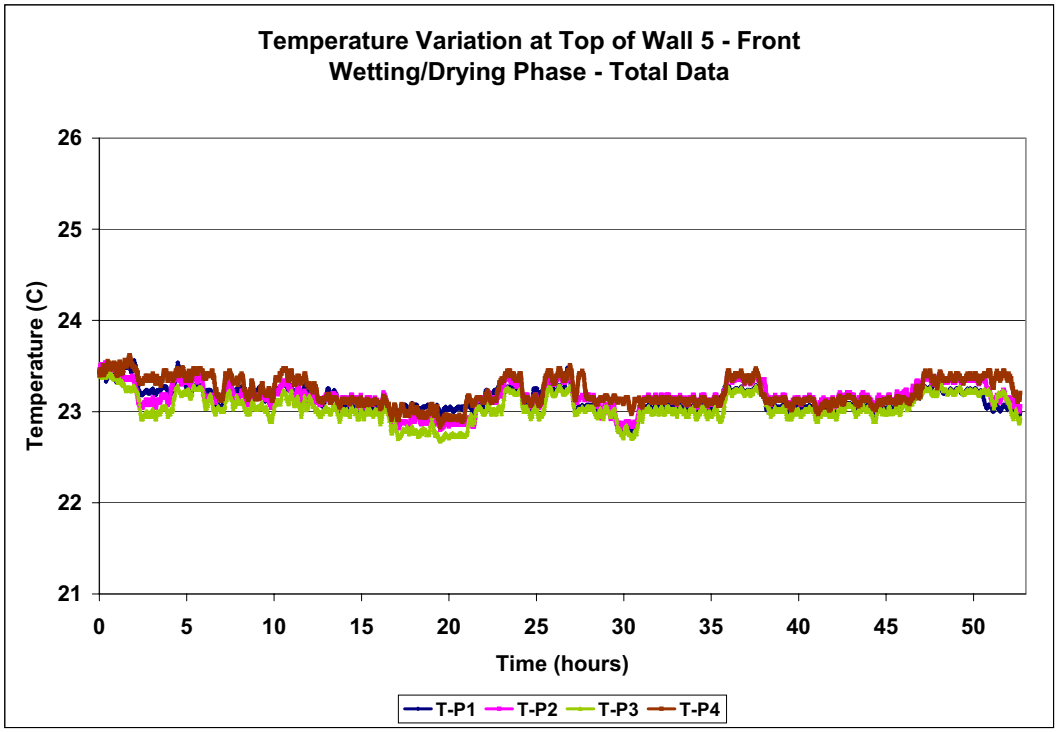
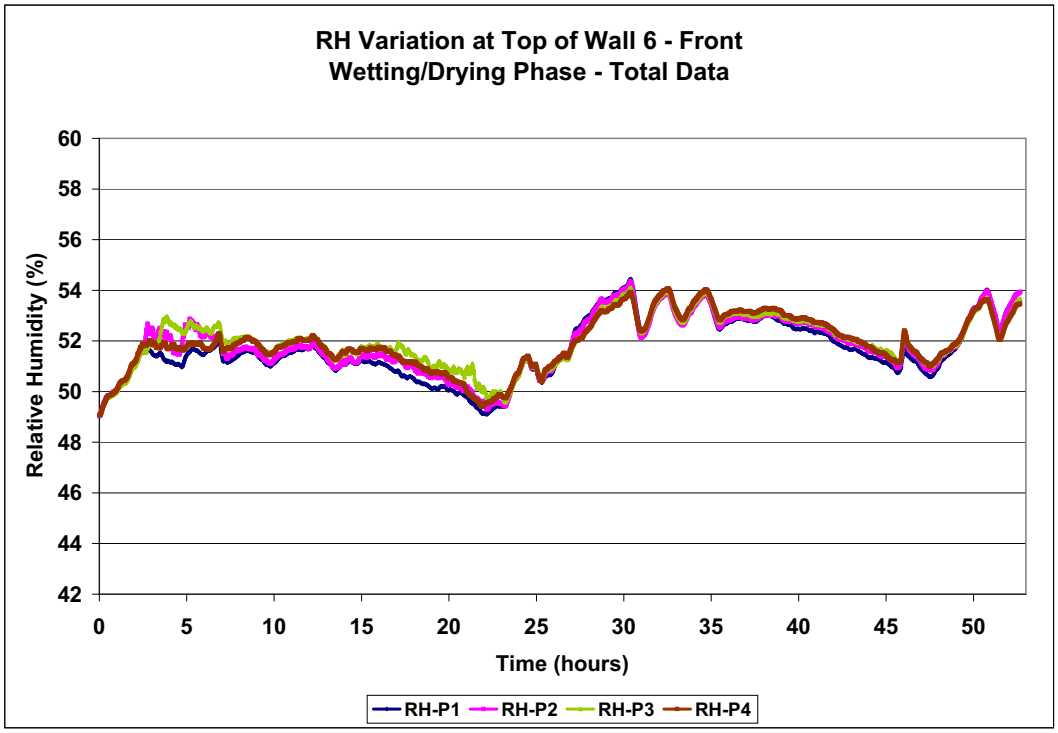


Figure IV-10 Wall 5 – Front - RH and T records at the top of drainage cavity for the TOTAL wetting/drying period.



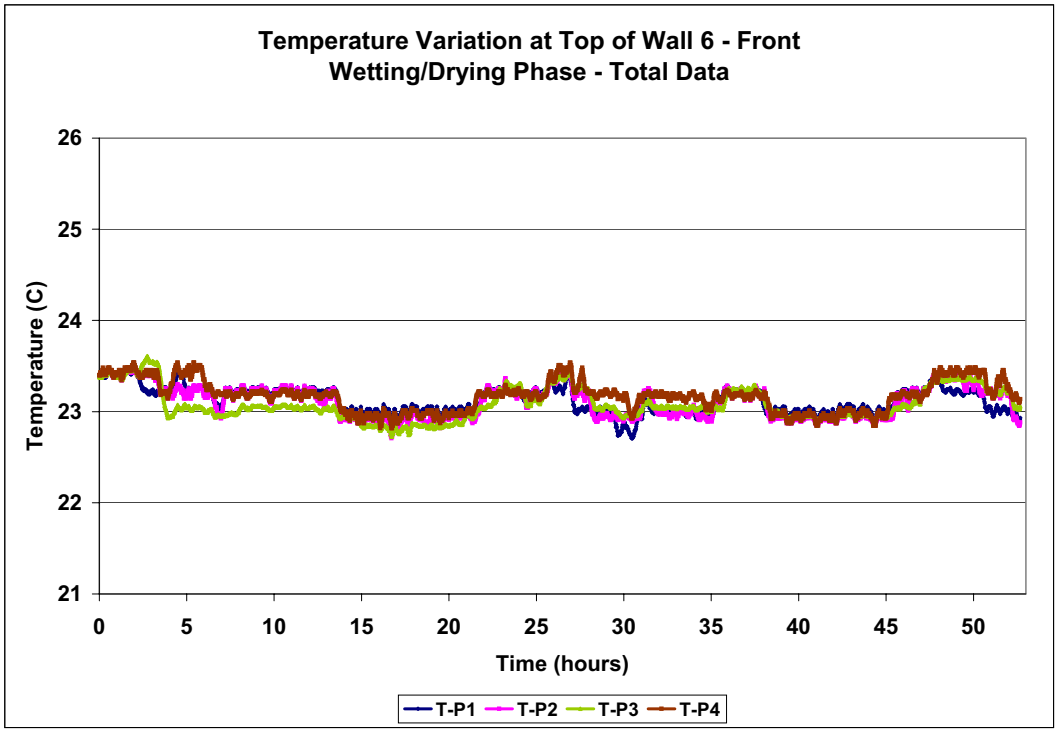
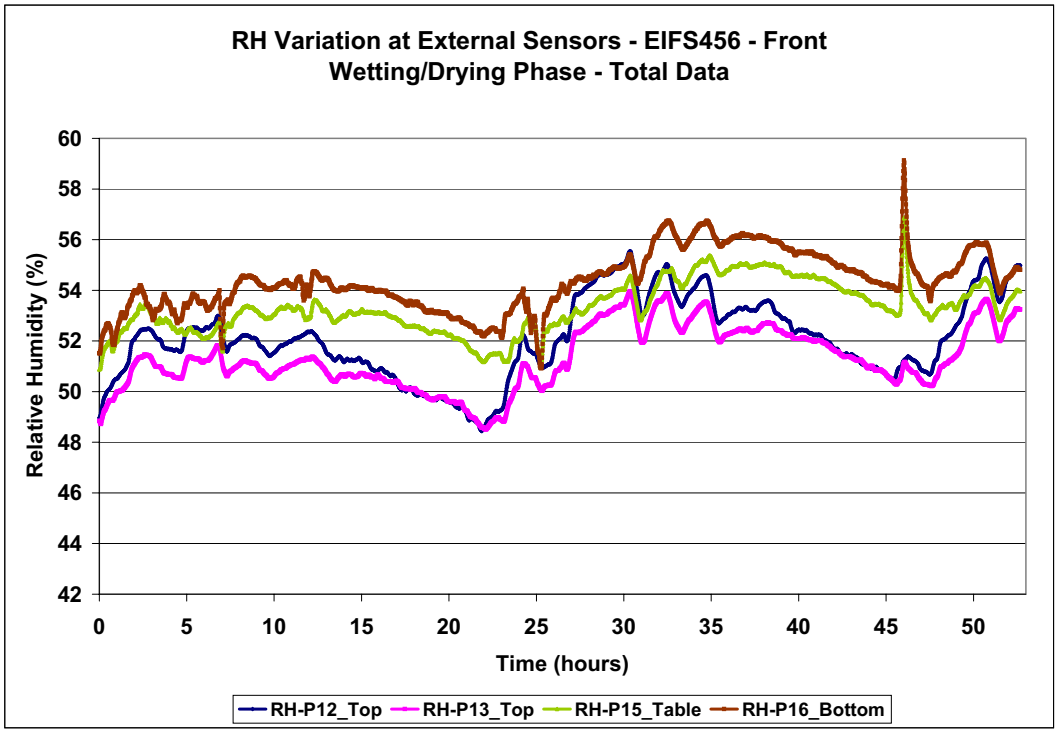


Figure IV-11 Wall 6 – Front - RH and T records at the top of drainage cavity for the TOTAL wetting/drying period.



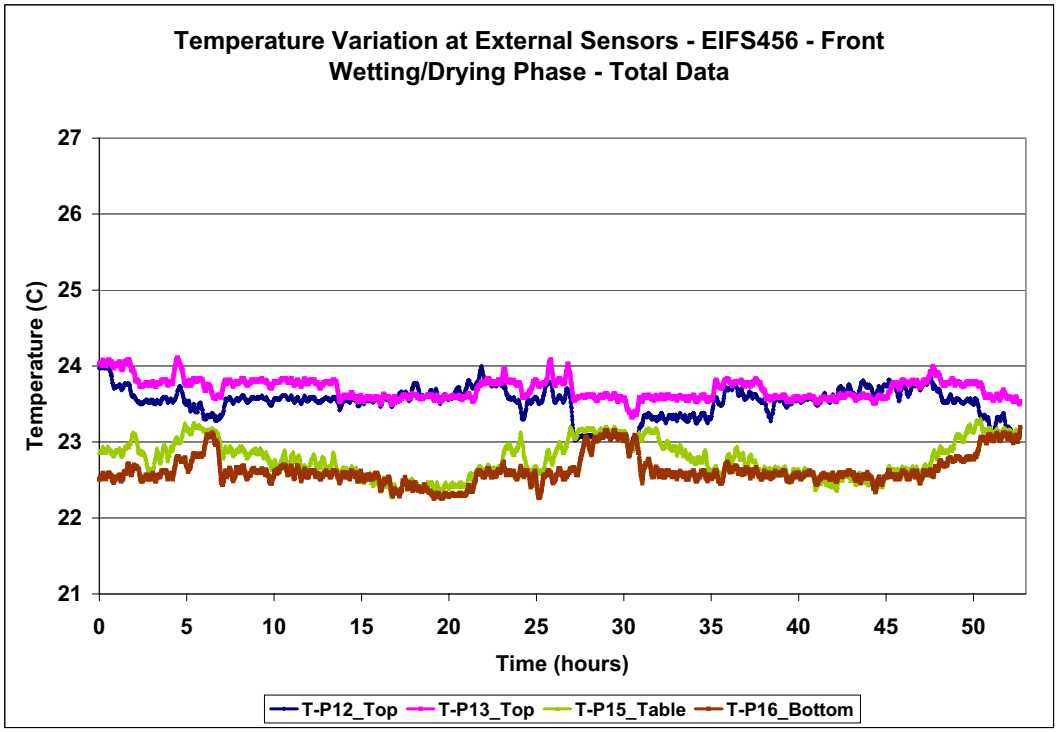
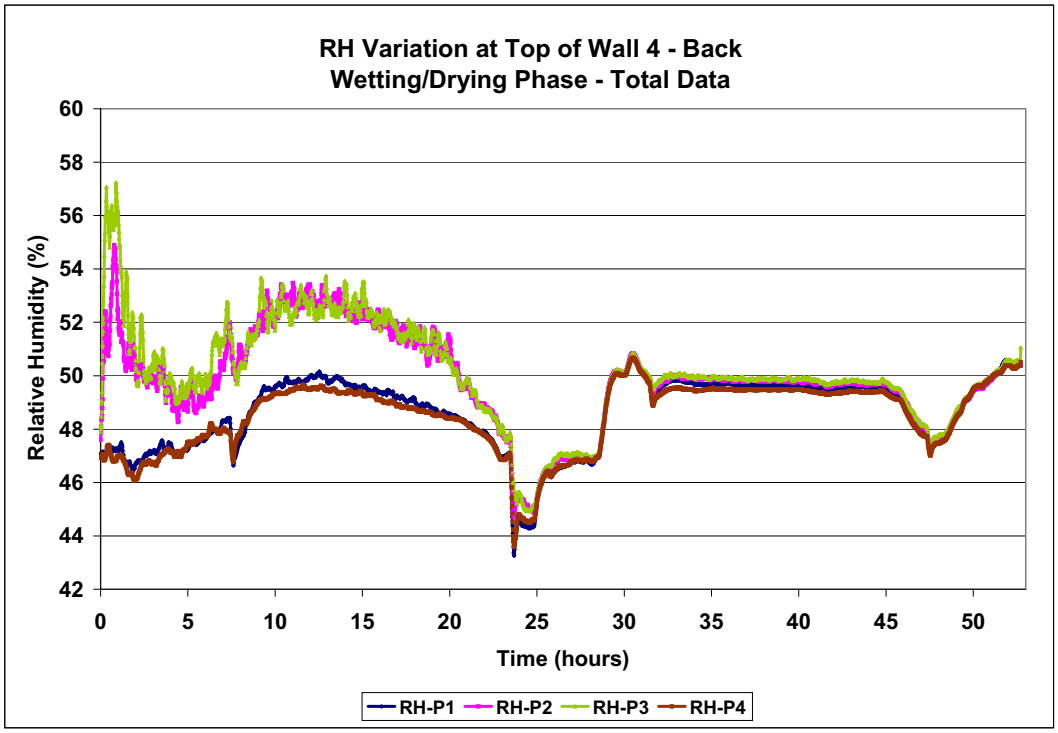


Figure IV-12 Walls 4, 5, and 6 – Front - RH and T records at external sensors the top of drainage cavity for the TOTAL wetting/drying period. These are the external or ambient conditions for tests shown in Figure IV-9 to IV-11.



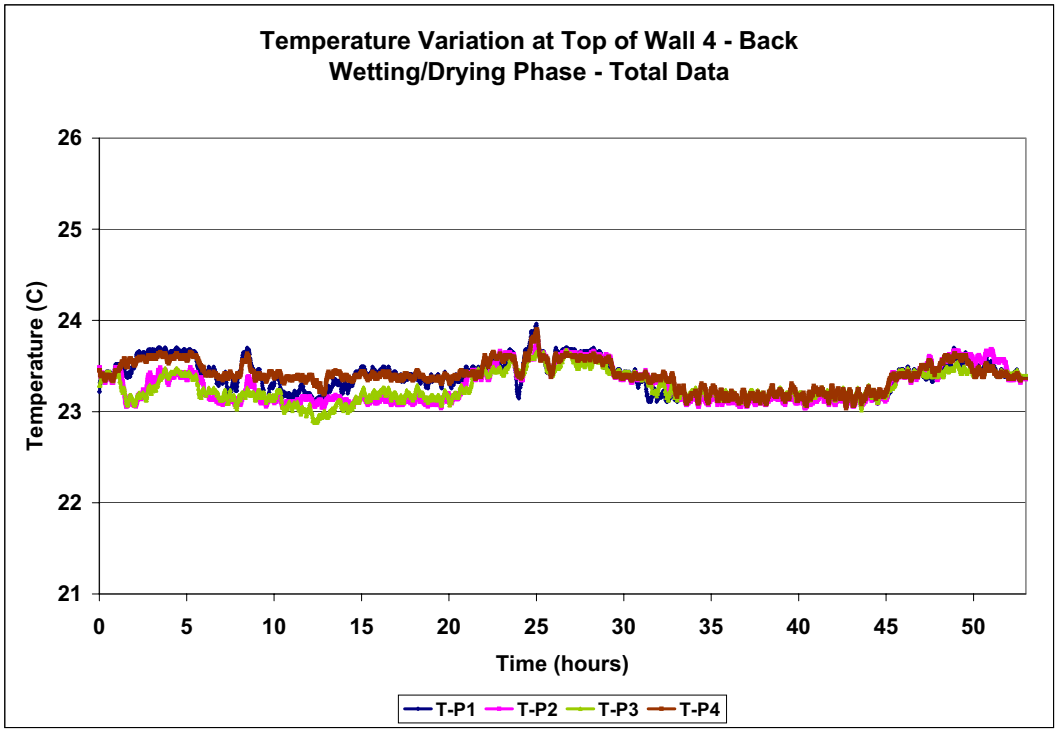
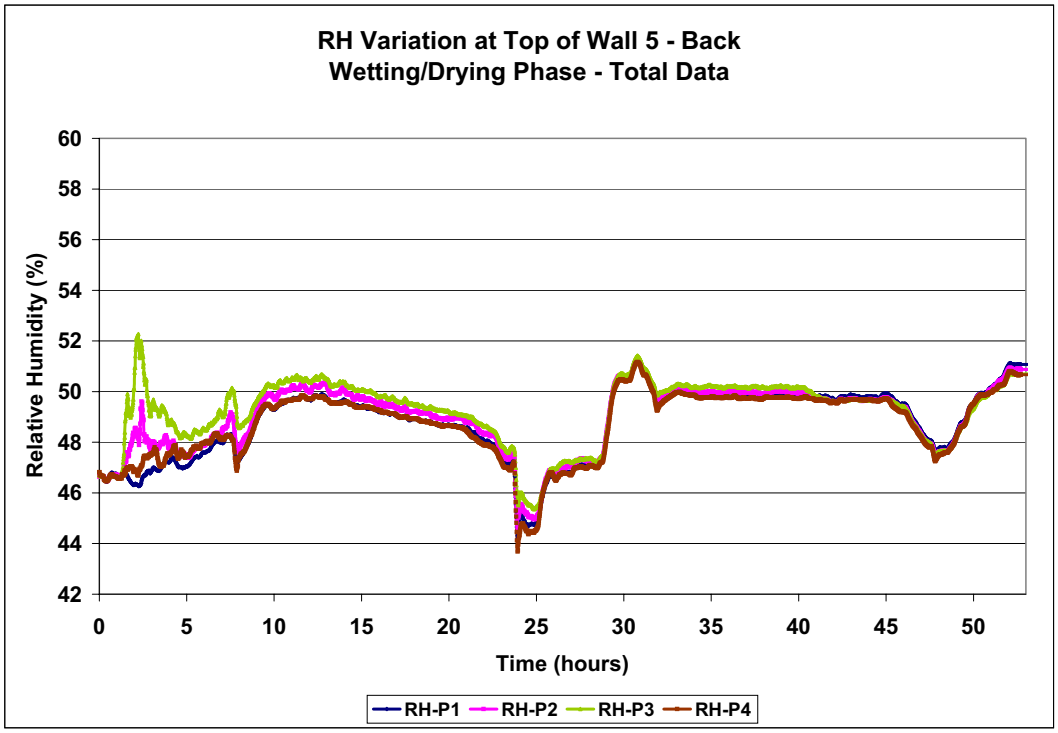


Figure IV-13 Wall 4 – Back - RH and T records at the top of drainage cavity for the TOTAL wetting/drying period.



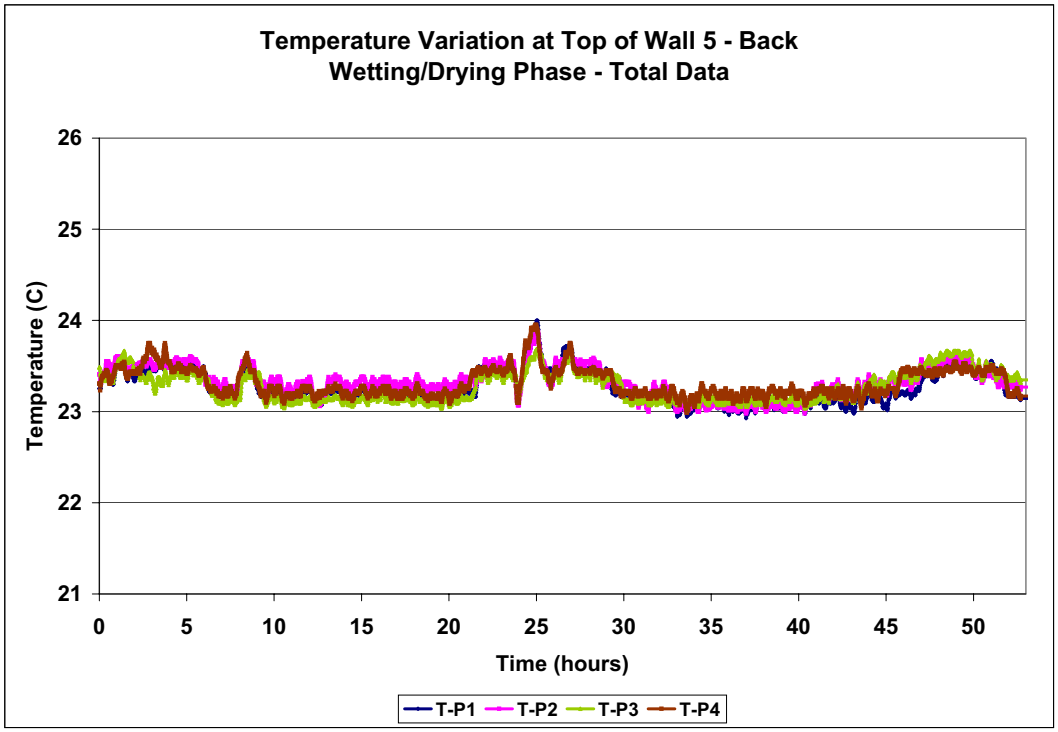
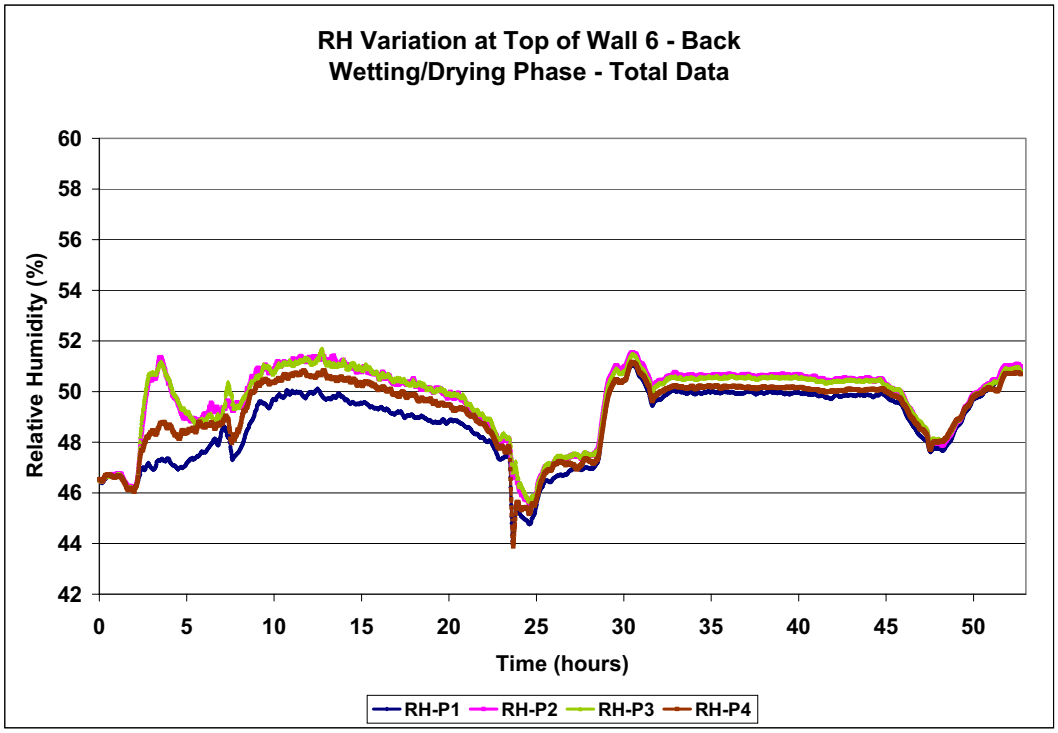


Figure IV-14 Wall 5 – Back - RH and T records at the top of drainage cavity for the TOTAL wetting/drying period.



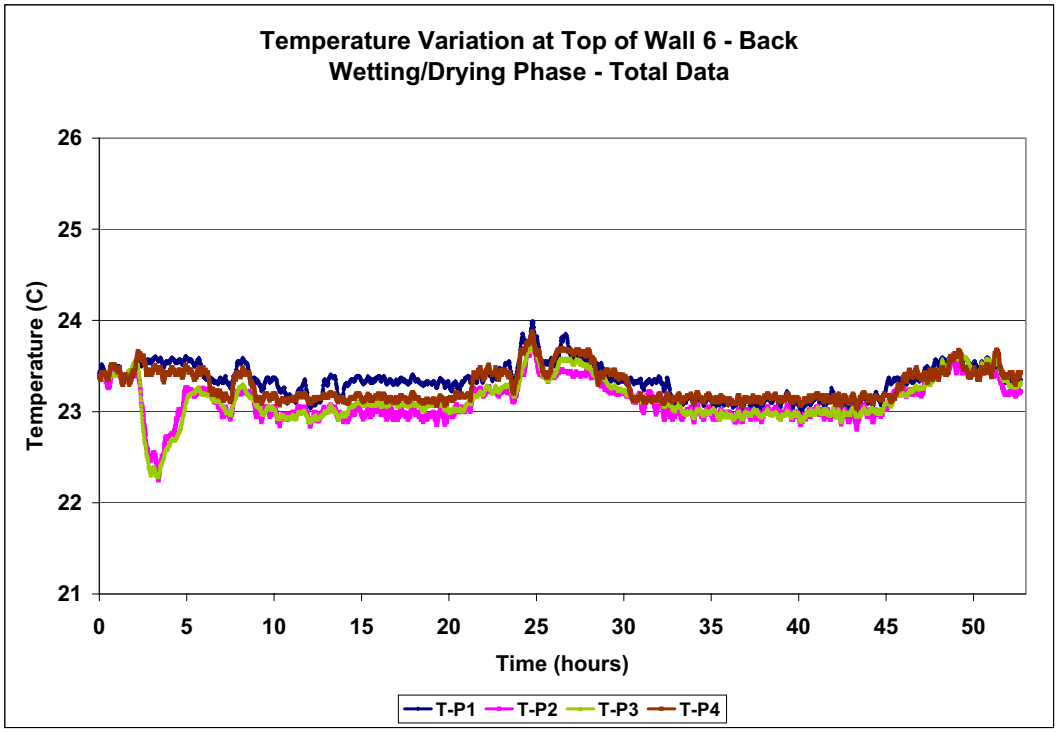
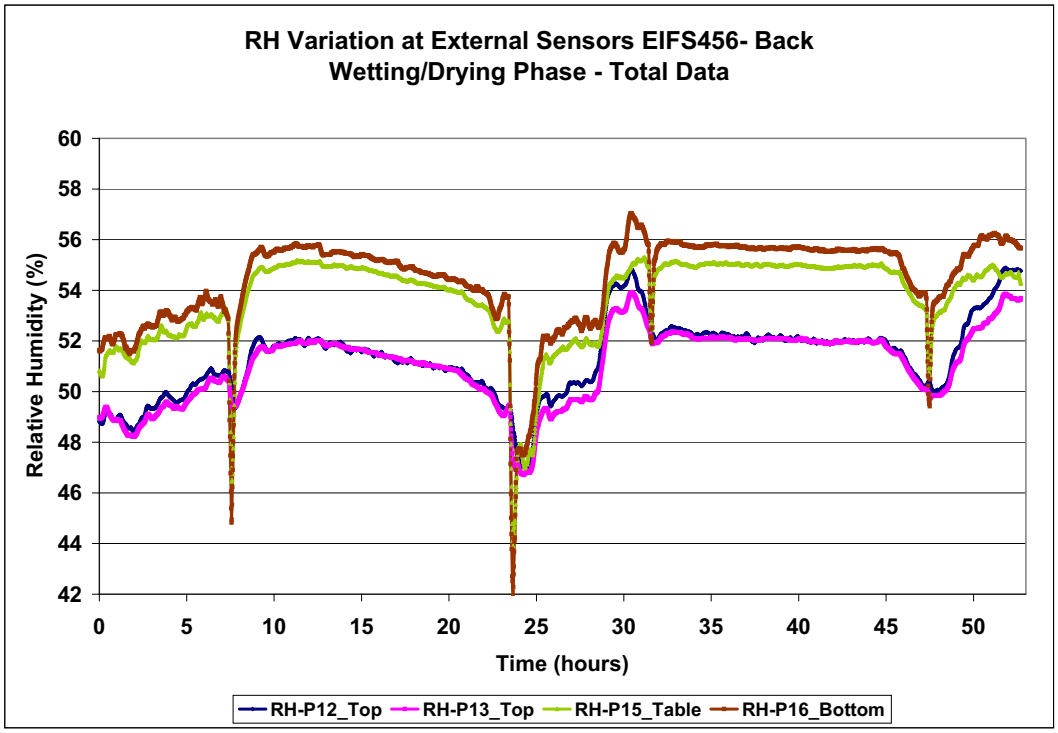


Figure IV-15 Wall 6 – Back - RH and T records at the top of drainage cavity for the TOTAL wetting/drying period.



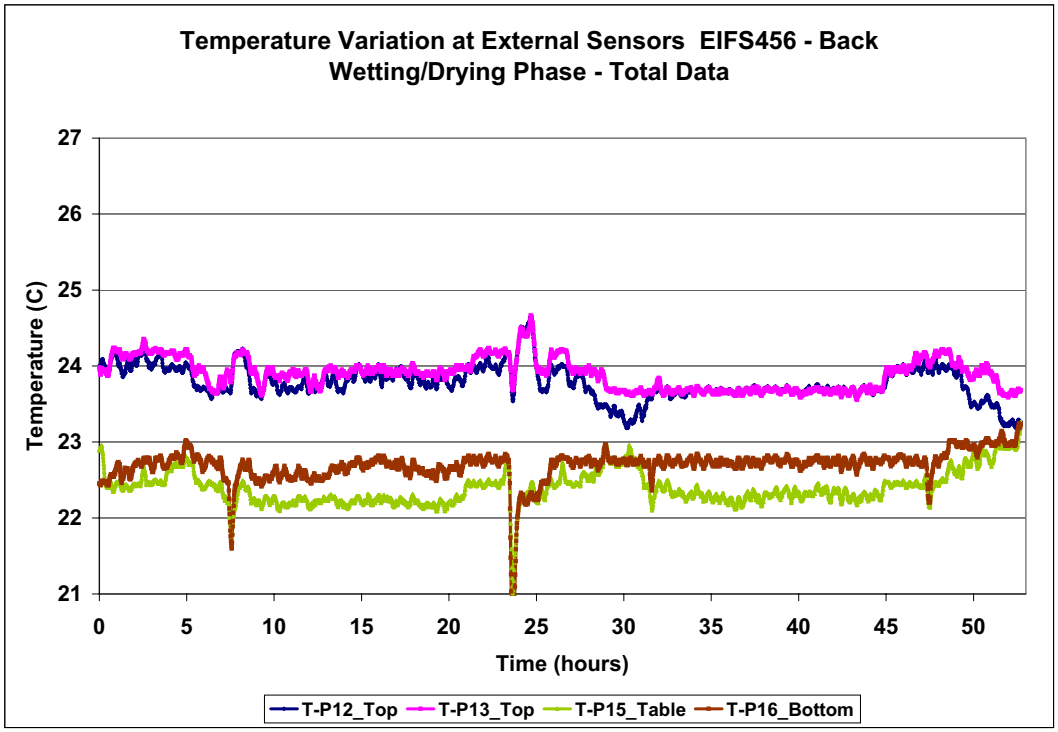


Figure IV-16 Walls 4, 5, and 6 – Back - RH and T records at external sensors the top of drainage cavity for the TOTAL wetting/drying period. These are the external or ambient conditions for tests shown in Figure IV-13 to IV-15.