RESEARCH REPORT

Drainage and Retention of Water by Cladding Systems

Part 5 – Drainage Testing of Wood and Fibre-Based Siding Wall Systems

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DRAINAGE AND RETENTION OF WATER BY CLADDING SYSTEMS

Part 5 – Drainage Testing of Wood and Fibre-Based Siding Wall Systems

Presented to

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SUMMARY

The results of drainage testing of 10 walls are included in this report. The cladding used was wood and hardboard siding, as well as fibre-cement boards. Application of siding was both direct-applied and with a drainage medium between the siding and the wall. Traditional 19-mm batten strips were included in the construction of one wall. The WRB used in almost all cases in this series was a spun-bonded polyolefin membrane.

The siding systems tested in this portion of the study can be grouped into two main types, those in which the siding was direct-applied to the wall, and those in which some type of drainage medium was used to facilitate drainage.

As expected, the systems with drainage mats, consisting of mesh like materials or a dimpled solid sheet, permitted most of the water that was trickled into the top of the wall behind the cladding to drain directly to the bottom where it was collected by the gutter. The interference that the mesh or dimpled sheet provided to water running down the drainage cavity caused some dispersion of the flow and caused wetting of all surfaces in that space. The retained water was relatively high. The ratio of the retention at the conclusion of the monitoring period (50-hr) versus that at 2-hr was generally greater than 0.6 but the space provided would eventually allow drying to take place. Much of the retained water was held in joints in the siding because moisture held on surfaces would likely dry relatively quickly. The siding materials involved were relatively non absorbent due to their makeup and finishing. The system having ship lap joints, despite being installed on a drainage medium, allowed some of the water to flow out on to the face of the wall. Trickling water intentionally down the front or back of the drainage cavity did not seem to result substantially greater or lesser retained water. When a solid sheet mat was used, it prevented the WRB was being wetted, and the retained water ratio was less than for the mesh types.

In the case of the wall having batten strips on which only one test was performed, some water trickled on the top ends of both batten strips in the 610 mm wide section of wall where water was input. Absorption into the end grain resulted in a relatively large amount of water retained. The highest level of retention resulted at those local sites. However, due to their exposed position at the top of the drainage cavity, drying of the retained water also occurred more rapidly. The case, while instructive about one form of wetting, is not representative of the efficacy of batten strips to provide protection against excessive wetting and enhanced drying inside the drainage cavity.

Direct-applied wood, hardboard, and cement board are themselves distinguished as to their performance by the way they are designed and/or fabricated. All types retained substantial quantities of water at the end of the 1-hr drainage period but this was concentrated in the upper courses of siding where water was introduced. Most of the water trickled in re-emerged from the top siding joint. The drying ability apparent from the weight plots showed that further drying was facilitated by not having most of the back of the siding directly in contact with the WRB. Neither of the two profiles involving wood siding were recommended for direct-applied installations, however, one wall was built this way to demonstrate that tight installation, once water was introduced and retained, would take relatively longer to dry. This was confirmed. The fibre-cement direct-applied board siding retained comparable water quantities but they also dried more rapidly than most walls. The 50-hr to 2-hr retention ratio for most walls was 0.3 or less. The system that was acknowledged to provide poor performance based on experience had a retention ratio of about 0.7, in the same order of magnitude as the siding systems with mat drainage mediums. At this time, it does not appear that the retention ratio on its own would serve as a good indicator of durable performance.

RÉSUMÉ

Le présent rapport fait état des résultats des essais de drainage sur dix murs avec bardage de bois, de panneau dur et de fibrociment, posés directement sur le support ou dotés d'un revêtement qui constituait la cavité de drainage entre le parement et le mur. Dans l'un des murs, le bardage était posé sur des fourrures traditionnelles de 19 mm. Dans cette série d'essais, une membrane de polyoléfine laminée recouvrait le revêtement intermédiaire utilisé dans la plupart des cas.

Les systèmes de bardage mis à l'essai dans cette partie de l'étude peuvent être catégorisés en deux types principaux : ceux où le bardage était appliqué directement sur le support de mur et ceux où un certain type de membrane de revêtement facilitait le drainage de l'eau.

Comme prévu, les membranes de drainage, constituées d'un matériau à treillis ou d'une membrane pleine à fossettes, permettaient à la plus grande partie de l'eau qui s'écoulait en filet depuis le haut du mur, derrière le parement, de se drainer directement au bas dans la gouttière. L'interférence causée par le treillis ou les fossettes faisait en sorte que l'eau qui s'écoulait dans la cavité de drainage produisait une certaine dispersion dans l'écoulement et mouillait toutes les surfaces constituant la lame d'air. Le volume d'eau retenue était relativement élevé. La rétention à la fin de la période de contrôle (50 heures), par rapport à la période de deux heures, était généralement supérieure à 0,6 %, mais la lame d'air favorisait le séchage du mur. Une grande partie de l'eau semblait s'emprisonner dans les joints du bardage parce que l'humidité retenue sur les surfaces séchait relativement rapidement. La composition et les matériaux de finition du bardage étaient relativement non absorbants. Le système doté de joints à recouvrement, même s'il était installé sur un support drainant, permettait à une partie de l'eau de s'écouler sur la face du mur. La rétention de l'eau dirigée intentionnellement ne semblait pas être vraiment plus grande ou plus faible sur le devant ou l'arrière de la cavité de drainage. Lorsqu'une membrane en feuille pleine était utilisée, elle empêchait le mouillage de la MRI et le rapport de l'eau retenue était inférieur à celui des revêtements du type à treillis.

Dans le cas du mur doté de fourrures, sur lequel un seul essai a été effectué, une partie de l'eau versée a coulé sur les extrémités supérieures des deux fourrures dans la section de mur de 610 mm de largeur. L'absorption dans le bois de bout a produit une rétention d'eau relativement importante. Le niveau le plus élevé de rétention s'est manifesté à ces endroits. Mais, comme les fourrures étaient exposées dans le haut de la cavité de drainage, l'eau retenue a séché plus rapidement. Ce cas, même s'il informe sur un genre de mouillage, n'est pas représentatif de l'efficacité des fourrures à assurer la protection contre un mouillage excessif, non plus qu'une amélioration du séchage à l'intérieur de la cavité de drainage.

La performance des bardages de bois, de panneau dur et de fibrociment posés directement sur le support se distinguait dans la conception et/ou la fabrication. Tous les types retenaient une importante quantité d'eau à la fin de la période de drainage d'une heure, mais elle était concentrée dans les rangées supérieures de bardage où l'eau avait été introduite. La plus grande partie de l'eau versée a remonté dans le joint supérieur de bardage. La capacité de séchage qui apparaissait dans les tracés de poids laissait croire que le séchage a été facilité en partie par le fait que tout l'endos de bardage n'entrait pas directement en contact avec la MRI. Le pose du bardage directement sur le support n'est pas recommandée pour les deux profils en bardage de bois; cependant, un mur a été construit de manière à démontrer qu'une installation « moins lâche », une fois que l'eau aurait été introduite et retenue, prendrait plus de temps à sécher. Cette hypothèse a été confirmée. Les bardages en panneau de fibrociment posés directement sur le support ont retenu une quantité d'eau comparable, mais ont aussi séché plus rapidement que la plupart des murs. Le rapport de rétention à 50 heures et à 2 heures pour la plupart des murs était d'au plus 0,3 %. On a trouvé que le système qui avait la moins bonne performance dans l'expérience avait un rapport de rétention d'environ 0,7, soit le même ordre d'importance que les systèmes de bardage dotés d'une membrane de drainage. Pour le moment, il ne semble pas que le rapport de rétention proprement dit serait un bon indicateur de performance durable.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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 provides the results of tests on wood based siding and fibre-cement board siding.

The reports are organized by the wall types tested and 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 WATER BY CLADDING SYSTEMS

Part 5 – Drainage Testing of Wood and Fibre-Based Siding Wall Systems

1 INTRODUCTION

This report concentrates on results that were obtained in drainage tests of wood and wood-fibre based siding systems. Two solid wood siding profiles, two hardboard siding profiles, and one fibre-cement based siding system were tested. In addition several drainage strategies were employed – three different drainage mat materials, and wood battens.

In Part 2 of this report series (Testing and Measurement Methodologies) the test procedures used were described. A limited restatement of some of that information will be repeated in this report to provide a context for the specific test results obtained for each of the different systems and combinations of materials employed. In all, data for 10 drainage tests and one retest will be presented. There were eight unique walls specimens built. Those with distinct drainage capability were tested by trickling the water against the weather resistive barrier. Later after drying, they were retested by trickling water down the back of the siding as had been done for the EIFS wall systems reported in Part 3 of this report series. Walls with direct-applied siding were only tested once.

The earlier reports in this project addressed the test methodology and the purpose and goals of the test program. The third and fourth reports examined the drainage/retention and drying performance of six EIFS walls and three vinyl siding wall systems, respectively.

In the present report we will identify the specific commercial or trade names of the materials employed. It should not be construed that there is acceptance or not of the performance of these materials in the applications employed. They were chosen for this project to provide a range of drainage performance mainly because of their type. In some cases, some of the siding materials were used in a way that was not recommended by the manufacturer. This was done to replicate how some of these materials have been used in the past. Also, some drainage mat materials included in the study are recommended for use under shingles and not specifically for cladding. Our intent was to employ these materials to serve that function and, in that event, would provide a result that could be attributed to that kind of material used in that way. Some of the systems tested, while appropriate for a “cooling” Southern climate, would not be entirely suitable for a primarily “heating” Northern climate. That distinction will be made at key points in this report.

2 TEST WALL CONSTRUCTION

2.1 Materials

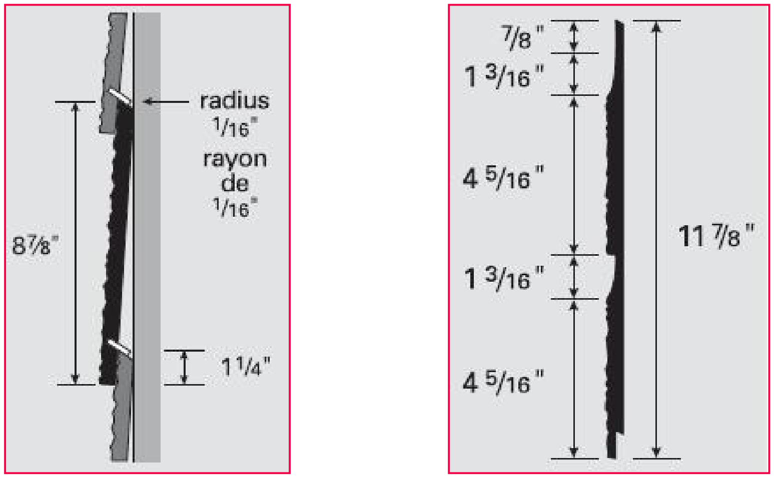
Materials required for the manufacture of the different wall systems were purchased in Quebec City and shipped to Forintek facilities during the second week of January 2005. Wood framing and OSB panels required for construction of the test walls was purchased by Forintek sufficiently prior to the assembly of the test walls to allow all materials to reach moisture equilibrium in the laboratory space where tests were to be conducted.

The wall specimens were all fabricated at the laboratory in Sainte-Foy by Forintek staff. The wood frames fabricated and siding systems installed on them (hardboard, solid wood and fibre cement siding) along with the water resistant barrier followed the experimental plan, as specified by the manufacturer's requirements or as modified by discussion with the Project Leader for the project at CMHC. All of the 1.22 by 2.44 m (4ft x 8ft) wood frames consisted of 38 x 89 mm (2 x 4-inch) SPF S-DRY studs at 400 mm (16-inch) spacing including a single bottom sill plate and double top plates. The double top plates were used to reinforce the walls as they were hung from the weight balancing system during drainage/drying testing. The structural sheathing consisted of 11.1mm (7/16-inch) OSB manufactured to the CSA O325 construction sheathing standard.

The OSB sheathing was nailed to the wood-frame at a spacing of 150 mm on the perimeter of the OSB sheathing panels and at 230 mm in the field of the panel. The principal orientation of the OSB panel was parallel to the studs. These test frames acted to provide the structure to which the cladding systems were attached and they were made to be as similar as possible to allow the comparisons on performance to be made attributable to the cladding systems and not to the wood framing employed. Both paper-based sheathing membrane (15 lbs) (WRB) and spun bonded polyolefin sheathing membrane (SBPO) were used in the project to represent two common types of products used for this purpose. Although both can be referred to as WRB materials, the above abbreviations will be used to distinguish them in this report.

Hardboard siding – Profiles details

Hardboard siding used for this study was manufactured by Canexel. Two (2) profiles were selected. The first was a 9-inch fastening-spline system (Ced'R-Vue^{TM}) and the second was a 12-inch lap siding with an interlocking system (Ridgewood D-5^{TM}). Installation instructions recommended by the manufacturer were followed and are provided on the manufacturer's internet web site. The link to that site is provided in Appendix I. They will be referred to as H1 and H2 respectively hereafter in this report. The profiles shown in Figure 1 were taken from the manufacturer's web page where the dimensions were shown in Imperial units.

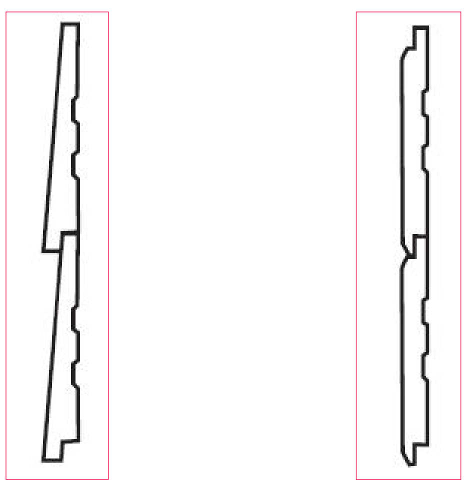


H1 H2

Figure 1 Hardboard siding profiles

Wood siding – Profiles details

Wood siding used for this study was manufactured by Maibec. Two (2) profiles were selected. The first was a 6-inch rabbetted bevel and the second was a 6-inch shiplap profile with "V" joint. Installation instructions recommended by the manufacturer were followed and are provided on the manufacturer's internet web site. The link to that site is provided in Appendix I. They will be referred to as W1 and W2 respectively hereafter in this report. These profiles are depicted in Figure 2.



W1 W2

Figure 2 Wood siding profiles tested

Fibre cement siding – Profiles details

Fibre cement siding used for this study was manufactured by James Hardie North America. Only one profile was selected for this project. The profile in question was a 6¼-inch Hardiplank® lap siding (Colorplus Select Cedarmill©). Installation instructions recommended by the manufacturer are provided on the manufacturer's internet web site. The link to that site is provided in Appendix I. This siding will be referred to as CF hereafter in this report. A photo of this siding applied to a test wall is shown in Figure 3.

Figure 3 Fibre cement siding applied to a test wall

Drainage Mats

Three types of underlayment (or mats) were used in the fabrication of some of the wall systems. In all cases, installation instructions are provided by the manufacturers on their internet web sites the links to which are all provided in Appendix I. Those referred to for use as underlayment for wood shingles, have been chosen for this study because of their ability to act as a spacer, yet allow ventilation and drainage on one side of the mat. They may also be suitable for use in exterior walls in combination with some siding materials and in some climates. Photos of the fabrication of test walls, including use of these mats, are included in Appendix II.

The first mat, referred to hereafter as Mat 1 in this report, was manufactured by Benjamin Obdyke and it is called Home Slicker®. The Home Slicker® product is a ventilating and self-draining rainscreen material intended for use in exterior walls that offers a thermal break and some moisture protection. The manufacturer's literature states that one version of the product meets the CCMC requirement for performance equivalent to a 10 mm rainscreen. However, that distinction could not be determined from the supply firm from which it was purchased. The thickness of this mat is reported to be 6.7 mm (0.264 inches).

The second mat, referred to hereafter as Mat 2 in this report, was also manufactured by Benjamin Obdyke. The Cedar Breather® underlayment is a mat forming a three dimensional matrix made of nylon 6. It has a mat thickness of 6.9 mm (0.27 inch). The Cedar Breather® is used as an underlayment for wood shingles. It provides a continuous air space which allows shingles and shakes to dry more readily when they get rained on.

The third "mat", referred to hereafter as Mat 3 in this report, was provided by American Wick Drain Corporation and is called CedarSaver™. CedarSaver™ is a formed solid sheet underlayment which uses polystyrene for its core and has dimples on one face that provide an overall thickness of 6.3 mm (¼ inches).

2.2 Construction of Test Walls

Three hardboard, three wooden and two fibre-cement siding wall systems were built for this phase of the test program. A description of each test wall and the steps involved in the fabrication are as follows (illustrated by photos taken during fabrication, some of which are provided in Appendix II);

Hardboard Siding;
Wall 1; Hardboard siding H1 direct-applied to the wall against SBPO.
Wall 2; Hardboard siding H2 applied on a drainage mat (Mat1: Home Slicker®) and SBPO.
Wall 3; Hardboard siding H2 applied on a drainage mat (Mat2: Cedar Breather®) and SBPO.

Wood Siding;
Wall 1; Wood siding W2 direct-applied on SBPO.
Wall 2; Wood siding W1 applied on a drainage mat (Mat3: CedarSaver™) and SBPO.
Wall 3; Wood siding W2 applied on wood batten strips and SBPO. The batten strips were nominal 1 x 4 wood straps that were trimmed to a width of 64 mm and had a thickness of 19 mm. These battens were attached to the wall directly opposite the stud lumber framing in the wall.

Fibre cement;
Wall 1; Fibre cement siding CF1 direct-applied on SBPO.
Wall 2; Fibre cement siding CF2 direct-applied on WRB.

- *Application of WRB:* Two specimens were built with black building paper and six were built using SBPO membrane. The sheathing membrane used covered the specimen completely and the membrane was returned around the edge of the specimens. The bottom edge of the membrane was stopped about 125 mm from the bottom of the wall. The WRB materials overlapped the top edge of the metal gutter to allow the drained water to be collected by the gutter. The building paper WRB was overlapped about 100 mm, as required, to allow water in the drainage space to not drain behind the WRB.
- *Installation of the metallic gutter at the bottom of the wall:* The top edge of the metal gutter was installed about 150 mm from the bottom of the specimens directly against the sheathing using four standard wood screws. The top of the gutter was sealed with a Mono super latex sealant.
- *Installation of the starter strip for siding on top of the WRB (when required).* The starter strip specified for use with the 152 mm fastening-spline hardboard siding was applied on top of the WRB materials above the metal gutter location. The starter strip was used to align and hold the bottom edge of the first course of siding to the wall.
- *Installation of the **hardboard** siding:* The hardboard siding was attached (with or without a drainage mat) to the OSB sheathing through the WRB with electro-galvanised 32 mm (1.25-inch) roofing nails. Nailing of each sidling course was done at 400 mm c/c (~16 inches), in most cases directly into the lumber studs. Wood wedges were used temporarily as spacers between the siding and the mats (both hardboard and wood siding) to prevent over-compression of the mats while nailing was done.
- *Installation of the **wood** siding:* The wood siding was attached to the OSB sheathing (with or without a drainage mat) through the WRB with electro-galvanised 32 mm (1.25-inch) nails provided by the wood siding manufacturer. Nailing of each siding course was done at 400 mm c/c (~16 inches) directly into the lumber studs (or battens).
- *Installation of the **fibre cement** siding:* The fibre cement siding was direct-applied to the OSB sheathing through the WRB with electro-galvanised 32 mm (1.25-inch) roofing nails. Nailing of each sidling course was done at 400 mm c/c (~16 inches), in most cases directly into the lumber studs.

- *Sealing the ends of each siding course:* The ends of each siding course were sealed with an expanding polyurethane foam sealant. This was done to block the ends of each course of siding to prevent lateral flow of water out of the test walls. The sealant bonded to both the WRB and siding to prevent leakage. This product conformed to the variable space between the siding and the edge of the wall more satisfactorily than by the use of caulking, as had been tried in earlier tests of vinyl siding.
- *Application of construction tape over the edges:* The construction tape was used as a second layer of protection for the sealing of the edges between the siding and the sheathing along with the sealant. Based on test experience with vinyl siding, this treatment was largely cosmetic in nature; however that was not yet apparent at the time of fabrication of these test walls.
- *Top gap opening:* Water entry behind the siding was allowed by providing a gap between the top edge of the top course of siding and the WRB. The gap was standardised for all siding installations in this test program at 4 mm except for the specimens having drainage mats that provided a space of approximately 6 to 7 mm.

3 TESTING AND MEASUREMENTS

A set-up composed of three weight-balancing systems was used to accurately measure the weight of water added and retained in each test wall during the wetting test. Full details are provided in the Part 2 report on testing methodologies used. This allowed three 1.22 m x 2.44 m (4ft x 8ft) wall systems to be evaluated at essentially the same time.
The load cells used each had a 30 kg capacity (Tedea-Huntleigh model 1040) and they were positioned directly under the center of the bottom plate of each test wall. Any change in weight beyond a zeroed tare load represented the change in weight during the test. Load cell calibration was verified in-place prior to each test.

The water was piped to each wall through a small plastic tube which allowed the metered water to drain into the trickle trough attached to the test wall at the top edge of the EIFS. The water was metered using a pressure system described more completely in the above noted report on testing methodologies.

3.1 Instrumentation

The data acquisition system included Tracker Series 240 signal conditioners for each channel with 18 bit A/D to provide a high degree of resolution (0.1 g), and an RS 485 to RS 232 output to transfer the data to a notebook computer. The software used to control sampling rate was designed by Intertechnology.

3.2 Water Flow Rate

The water for drainage was piped to the trickle trough at each wall by an air pressure system. Twelve (12) kg of water was put in a glass carboy which was continuously weighed on a calibrated scale [Mettler Model PM 30000-k] having a resolution level of 0.1g. This amount of water was sufficient for testing one wall. Controlled air pressure was supplied to this container to expel water from within it through tubing to the wall being wetted. The change in weight of the carboy was monitored on a minute by minute basis and the weight increments were automatically stored in a computer file. In parallel to this monitoring, the flow rate was calculated and the flow was adjusted with a micro valve to ensure that a total of 8 kg of water was delivered to each wall within the 1-hour wetting period. To make certain that the water used for each wall was at the same ambient temperature another glass carboy was filled with 20 kg of water in sufficient time before test to reach those conditions. This amount of water was sufficient for testing the remaining two walls.

3.3 Trickle Trough

As explained in the Part 2 report on testing methodologies, the water was delivered to each wall in turn to a Plexiglas distribution trough which allowed the water to dribble or trickle into 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 test program required that flow could be directed to either the front or back of the drainage cavity. The troughs used in an earlier study were modified to allow the drops to flow down a thin sheet of plastic bonded to the face along which flow occurred from the holes drilled in the bottom corner. The bottom edge of the sheet was serrated to gather the flow out of each hole to single locations. Tilting the trickle trough allowed the flow of droplets to be directed to specific planes. A photo showing this is provided in Appendix II of this report.

3.4 Test Procedure

The flow of water was delivered into 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 galvanized gutter installed at the bottom of the wall cladding which directed the water into a pre-weighed container.

For walls having direct-applied siding, with no specific provision for drainage, the water was directed into the standardized opening at the top course of siding. For all other tests, there was an attempt to direct the flow either to front or back of the drainage medium provided. When a particular wall was intended to be tested twice, sufficient time was allowed for the initial retained water to dissipate (for a minimum of 7 days) before the second test was performed. This was done to study if more or less water could be retained by the cladding system.

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, was used to determine the quantity of water that was retained within the wall at the end of the two-hour test period. This test period has been referred to in the report and plots as the wetting/drainage phase.

The change in weight for each wall was sampled at the rate of 20 samples per second, averaged and stored at the rate of one sample a second for all walls. 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 to avoid creating an excessively large data file during the next stage of the test protocol. This data, at the slower sampling rate, was stored in a separate file and monitoring was continued for a period of at least an additional 48 hours.

The laboratory conditions were 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 conditions at each wall were monitored 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 some variations in the conditions associated with the cycling of the air conditioning system. Some additional discussion about variations in conditions that occurred during the test period for each set of tests is provided in the discussion section of this report.

Plots for each wall system for both the wetting/drainage phase and the combined wetting/draining period of 50 hours are provided in Appendices assigned to each type of siding in this report.

3.5 Measurements of Environmental Conditions

As noted in the previous section, the RH and temperature conditions surrounding the tested specimens were monitored constantly during the testing period (in all, for at least 50 hours duration). Four RH and temperature sensors were installed at the top part of each wall specimen to monitor the condition of air exiting the top of the drainage cavity. These sensors were spaced uniformly (at about 300 mm) across the top of each wall. Two sensors were positioned below the trickle trough and the other two were at the same level but placed symmetrically away from both sides of the trough. All sensors were placed at about 1 to 2 inches from the top of the cladding. The aim was to compare these measurements with the ambient conditions in the lab. To monitor these ambient conditions, four additional monitoring stations were installed. Two stations were positioned above the top of the test frame area, one station was on a table top in the vicinity of the test area, and one station was near the floor and attached to one of the test frame columns at approximately the same height as the gutters in which drainage was collected at the base of each wall. The relative humidity and temperature records for both the wetting/drainage phase and the total combined test time are included in the Appendices assigned for each wall siding type.

3.7 Measurement of Moisture Contents in the Drainage Cavity

It was recognized that there were likely to be significant moisture gradients in both the siding and sheathing materials as a result of moisture retention. It was not considered prudent to rely on specific point determinations of moisture content in materials. Instead, based on earlier attempts to map the retained moisture distribution in materials contacted by water in the drainage cavity, a qualitative measurement approach was taken using a capacitance-based moisture meter.

The meter used was a Wagner L620 meter that had sufficient data storage capacity to allow numerous readings to be taken. The meter was employed manually to take readings at a spacing of 150 mm on each vertical scan on the back of the OSB sheathing. Two vertical scans per stud space were taken for a total of 6 scans resulting in collection of 90 moisture content readings per wall both before and after the drainage test. The moisture readings were taken after the wall was laid horizontally exposing the back of the OSB sheathing. For practical reasons, the final measurements were obtained after the walls were dismounted from the balance beam setup. The difference between the initial and final set of readings was imputed to be due to the retained moisture at that time.

The grid arrangement for measurements was the same for all wall systems. However, the top and bottom positions of the siding varied depending on the width of siding courses. This information was needed to define edges where zero change in moisture content was assumed. Dimensions used for establishing the coordinates for each point including the perimeter of the test wall are provided in Figure 4.

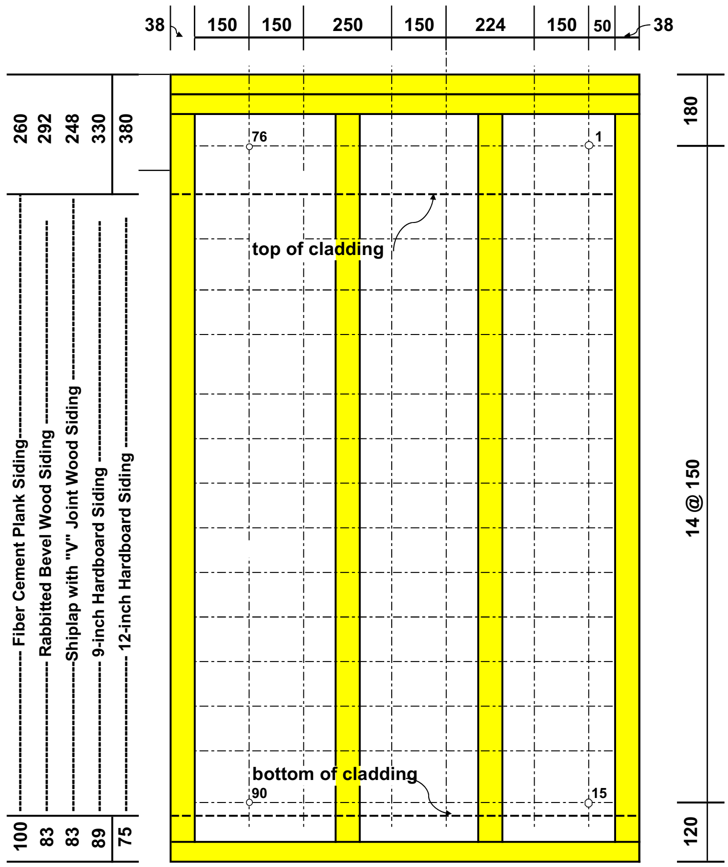


Figure 4 Gridline dimensions for moisture measurements using a capacitance-based moisture meter.

During the drainage testing of direct-applied siding test samples, it was found that water entering the wall did not appear to get past several of the upper courses of siding. The majority of water came out of joints in the siding. Any water retained would likely have a greater residual concentration in the upper areas of the wall. Due to the passage of time and drying before the second set of readings was taken, the conditions were less than optimum for detecting the variation in moisture at the time water was still largely retained in each system. The moisture mapping contour maps for the retained moisture are included in the Appendices assigned for each type of siding.

4 RESULTS

Walls with direct-applied siding (1 hardboard, 1 wood and 2 fibre cement specimens), were tested only once. The water drained into the wall was simply allowed to drip behind the top siding course through the 4 mm space provided at the top edge of the siding. Walls that were built with an intentional drainage cavity were studied to determine if water retention might be a function of the design of the siding or other characteristics of the test walls. For these wall specimens, the trickle trough was deployed to direct the water down either the back of the drainage space against the WRB or to the back of the top edge of the siding as was done for the EIFS test walls (except for the wood-battens specimen which was tested only once with water applied to the WRB surface)

The intent of these tests was to have all water enter the 1200 mm wide wall and be available for drainage/retention. The use of urethane spray foam to seal the ends (edges) proved to be far more successful in preventing lateral leakage than the use of caulking tried in tests of vinyl siding. While this does not simulate building practice, it was necessary that this be done. In the case of the hardboard, wood and fibre-cement siding reported in this report, the ability of water to drain from behind the siding through joints was significantly greater than for vinyl siding, and the sealing was more of a precaution that flow would not take place laterally out of the test walls than an attempt to form a substantial head of water within the upper portion of the drainage cavity. In contrast, all walls with drainage cavities permitted water to drain to the bottom of the wall where it was collected by the gutter attached to each wall at the base. Most of the water that escaped through joints in the siding dribbled down the face of the siding and was collected as well.

The results for the drainage tests will be reported in several ways. One approach to characterizing the performance of a cladding system involves reporting the weight of water held in the wall at specific points in time during the test. The other avenues for reporting used in this report involve comparisons between the drainage plots for different types of siding, both by the materials used and as a function of the construction of the wall assembly. This includes a review and observations on a variety of data forms to help explain different ways that test walls managed the water that was put in them. The Appendices to this report have been organized in a way to facilitate this review. The drainage plots for both the 2-hr wetting/drainage phase and the longer duration monitoring for an additional 48-hrs have been segregated by each siding material type. Accompanying these plots are the moisture change contour maps, and the corresponding relative humidity and temperature plots for these same test walls. Since there are quite different characteristics involved, with virtually no test replicates, except for the some materials used, this juxtaposition of information makes it less difficult to make comparisons. Appendix III provides photos of four test walls with water spilling out of joints near the top of the wall and flowing down the face of the siding. Appendices IV, V, and VI are each devoted to presentation of data plots for the hardboard, wood and fibre-cement siding, respectively.

4.1 Water Retention Summaries

The summaries of key retention information are provided in Tables 1 to 4 in this section. Three values have been quoted for each test. These values were also provided for tests on the EIFS walls in the Part 3 report, and the vinyl siding walls in Part 4 report. The first value labelled as the peak weight at 1-hr is a relatively temporary value which provides the peak weight of water held in the wall while the water was being delivered to the wall on termination of water delivery. This value may not necessarily be the largest amount of water held during that test. The amount held at any one time includes all water absorbed in the materials as well as free water that is adhered to the surfaces of material it has come in contact with as well as water held in storage and water films that are moving under gravity to the bottom of the wall. Some walls displayed a jagged weight gain curve which was a result of the different ways that water moved through the drainage cavity. At times, water cascaded through the drainage cavity and between those times, it built up. Due to its temporal nature, on its own, the value of the retention at the 1-hr point in the test is not a matter of importance. What is of more importance is the shape of the weight gain curve in arriving at that point.

The second key value quoted is the amount of retained water at the end of the 2-hr time period from the start of a test. The choice of this time as a reference value is derived from the ASTM test method. It represents the weight of water retained after drainage of free water is complete. In fact, drainage was usually complete about 10 to 15 minutes after the delivery of water was halted. The loss in weight from that point in time includes evaporation from within the drainage cavity and its removal by air movement, diffusion of water through joints, evaporation from the face of the siding if water spilled down over the face of the wall, and evaporation from the collection gutter. The latter value is believed to be small because the V-shape of the gutter forced free water to flow rapidly to the bottom of the V and to flow directly to the container into which water was collected. The weight of water held in the gutter was very small at the 2-hr point and, in any case, was collected by wiping the gutter with tissues as well as the trickle trough and from the face of the siding where water may still have adhered to it. Given all of the locations from which retained water dissipated, the value at the 2-hr point is merely a convenient point in time to assess the level of retained water. If water retained only in the drainage cavity were to be of primary interest, changes to the test protocol would be needed. Outer siding surfaces that are absorbent would be problematic. Fortunately most siding systems, by nature of the materials used, were relatively non absorbent. Adhered water may be easily wiped away if desired at an earlier stage of the test once drainage down the face of the siding stops.

Finally, after an additional drying period of 48 hours, a concluding weight of retained water is quoted. For walls that have retained a significant amount of moisture, there is no question what that value might be. However, for walls that have retained very little water or have dried more quickly, the low value quoted may not be that reliable because of the variation of RH and temperature conditions within the laboratory space. There are always vertical gradients in such spaces and the drying walls themselves contribute to local alteration on conditions that may affect other walls being tested in the vicinity. Fortunately, most of the siding cases reported here (including the exposed wood framing and sheathing) were relatively insensitive to those changes, unlike what was found for the EIFS walls tested earlier.

With the above as background, the weight values at each stage in the wetting/drainage/drying period are quoted in the following tables for each material and each method of delivery of water (back versus front).

It is worth noting that building paper was used for only one of these walls. For all other walls, SBPO was used. The experimental plan included many variants of siding types and means of providing drainage cavities. It was not realistic to include water retention by the WRB material as one of the key variables. It is believed that for the short period of test time, given the rates of drying found, that little difference would have been found related to WRB type relative to the uncertainty of results from any one test. That statement should not be construed to imply that the properties of the WRB are not important to the field performance of outer wall systems. The vapour permeability of the WRB has an influence on the moisture flow from a drainage space to wood-based (and other) sheathing and, in climatic locations where chronic wetting can be expected, that variable would have to be accounted for in design of such walls.

A second point to note is that Mat 1 and Mat 2 were wiry type products that were relatively open for the flow of water and vapour. Mat 3, intended for use on roofs under wood shingles, was a dimpled polyethylene sheet and is impermeable to vapour and liquid flow through it. The protruding dimples were directed outward towards the siding. The flat side of the dimpled sheet was placed against the WRB and acted as a vapour barrier for the inner wall. While this location for that function would not be suitable for Northern construction it would be permissible in hot humid climates. The use of Mat 3 in this project was primarily intended to illustrate the level of retention that might be attained by this class of product in combination with that cladding.

Table 1 *Drainage performance evaluation results for Hardboard siding wall systems with water draining down the back of the drainage plane (down the WRB)*

Time	Wall 1* H1/DA/SBPO	Wall 2 H2/Mat1/SBPO	Wall 3 H2/Mat2/SBPO
1 hour (peak reading)	372	368	446
Retained weight of water at 2 hours (g)	117	231	284
Retained weight of water after 48 hours (g)	35	156	229

Table 2 *Drainage performance evaluation results for Hardboard siding wall systems with water draining down the front of the drainage plane (down the back face of the cladding)*

Time	Wall 1 (retest)* H1/DA/SBPO	Wall 2 H2/Mat1/SBPO	Wall 3 H2/Mat2/SBPO
1 hour (peak reading)	383	276	371
Retained weight of water at 2 hours (g)	130	183	254
Retained weight of water after 48 hours (g)	0	109	221

Table 3 *Drainage performance evaluation results for Wood siding wall systems*

Time	Wall 1* W2/DA/SBPO	Wall 2 W1/Mat3/SBPO	Wall 3 W2/battens/SBPO
1 hour (peak reading)	842	415	603
Retained weight of Water at 2 hours (g)	426	260	467
Retained weight of water after 48 hours (g)	294	123	0

Table 4 *Drainage performance evaluation results for Fibre Cement siding wall systems*

Time	Wall 1* Fibre Cement/DA/SBPO	Wall 2 Fibre Cement/DA/BP
1 hour (peak reading)	412	284
Retained weight of water at 2 hours (g)	340	197
Retained weight of Water after 48 hours (g)	50	0

- Note for Tables 1-4: For drainage tests of all direct-applied siding, water was not specifically directed to the back or front of the cladding. It was allowed to enter in the middle of the space provided for water entry.

4.2 Direct Applied Siding

Individual plots for increase in weight gain during drainage testing are provided in the appendices for each wall type. In this section we will compare the behavior of all siding systems that were directly applied to the base wall without intentionally providing a drainage plane. In all cases a SBPO weather resistant barrier was employed. Also included in this comparison will be a retest of one wall. The combined plots are included in Figures 5 and 6 below.

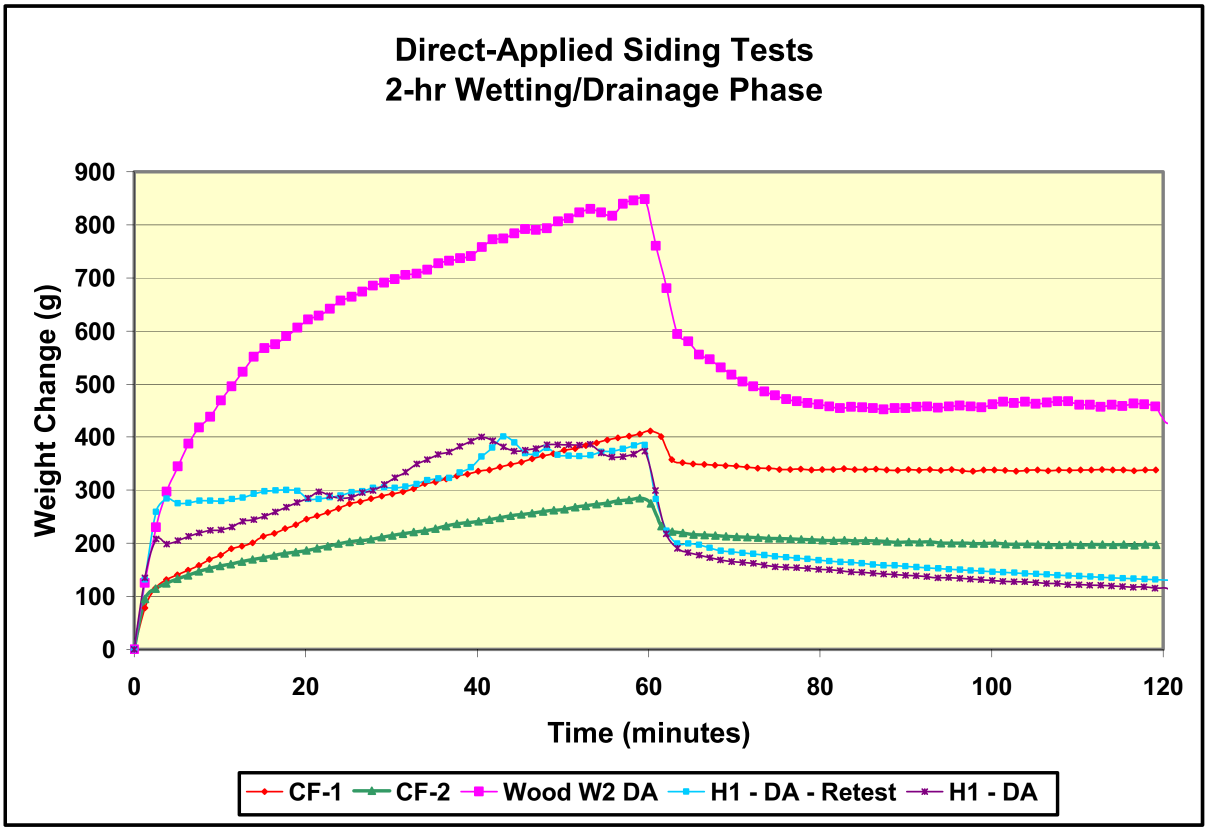


Figure 5 Composite plot of weight changes during the wetting/drainage phase for all walls with siding that was applied directly to the basic wall.

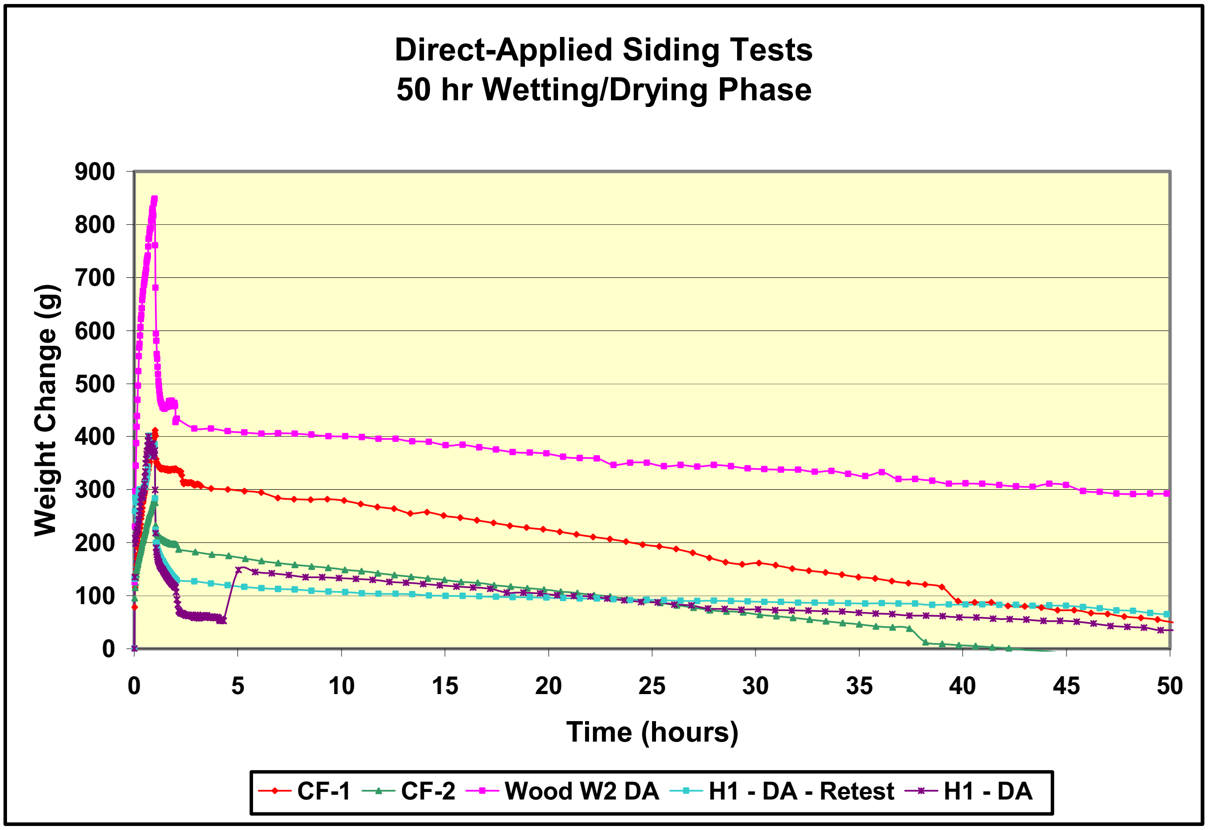


Figure 6 Composite plot of weight changes during the 50-hr wetting/drainage/drying test period for all walls with siding that was applied directly to the basic wall.

The singular behavior of direct-applied siding is that clamping of the siding against the wall does not appear to allow a significant amount of water to flow down to siding courses below the one behind which water was trickled in at the top. Mismatch at contact points and overlaps, depending on the profiles, permitted most of the water to escape through and over the face of the siding below the first joint encountered by the water. Some retention of water in the joint profiles likely occurred, but that level of detail could not be investigated in this study.

All the siding employed was factory prefinished with at least a prime coat finish on the back of the siding. The following observations are based on the above plots:

- The H1 profile for initial and retest performance was very similar. The retest was done because the linkages were disturbed during the 48-hr drying period and a step occurred in the plot (Figure 6). There was only a 4-day period between the start of each test. Drying of the wall on retest occurred below the starting zero for that test because of some residual retained moisture from the first wetting.
- The most water retained was by the W2 wood siding that had a shiplap profile. The vertical scale for the figures shown was based on the peak weight recorded for this wall.
- The water retained by the hardboard siding increased rapidly at the start of wetting and then tapered off. The fibre-cement sidings, on the other hand, continued to gain moisture at a steady rate to the end of the wetting period. The drying of the fibre-cement siding was initially slow, but at the conclusion of the 48-hr drying period, both walls had dried to quite low levels.

- The water take-up rate for the first few minutes of the test appeared to be identical for all walls tested.
- The two relatively identical fibre-cement walls retained quite different amounts of water right from the beginning of the drainage tests. These plots do not assist in explaining how the moisture is distributed, but this issue will be addressed in Section 4.4 following.
- The total amount of water retained in these tests is likely concentrated in relatively small areas associated with the contact between the siding and SBPO sheathing membrane. Siding profiles H1 and both fibre-cement siding wall samples were lapped and only the top edge of each course was in direct contact with the SBPO with the back of the siding exposed to air. The wood siding on the other hand, was installed flat against the SBPO and was capable of retaining more water. It must be stated that the manufacturer of this siding recommends this siding be installed on batten strips only. That recommendation, using this profile, was also included for one wall in this study.

4.3 Siding Applied on Drainage Mats and Batten Strips

In contrast with direct-applied siding, all siding installed on materials intended to allow drainage performed as expected. Most of the water that was trickled into the top of the drainage space flowed within that space to the bottom where it was collected. The composite plots for these test walls are provided in Figures 7 and 8. As a result of the greater surface area wetted by the water on its way to the bottom of the wall, the amount of water retained was likely dispersed over a larger total area and the unit concentration is likely lower.

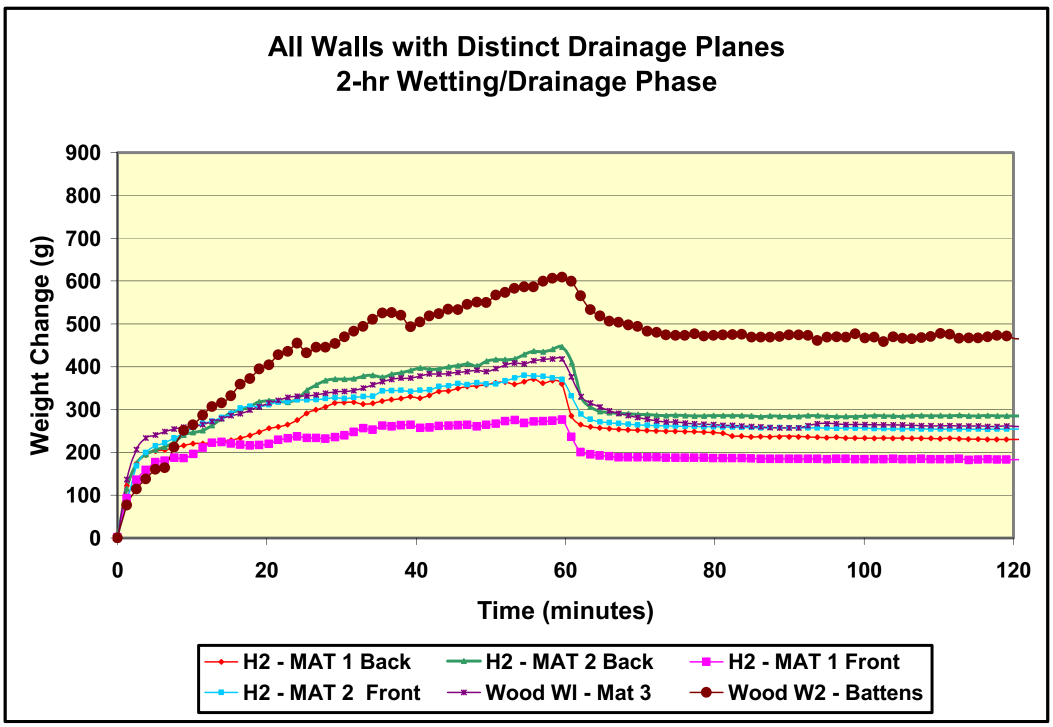


Figure 7 Composite plot of weight changes during the 2-hr wetting/drainage phase period for all walls with siding that was applied over some form of drainage matrix or batten strips.

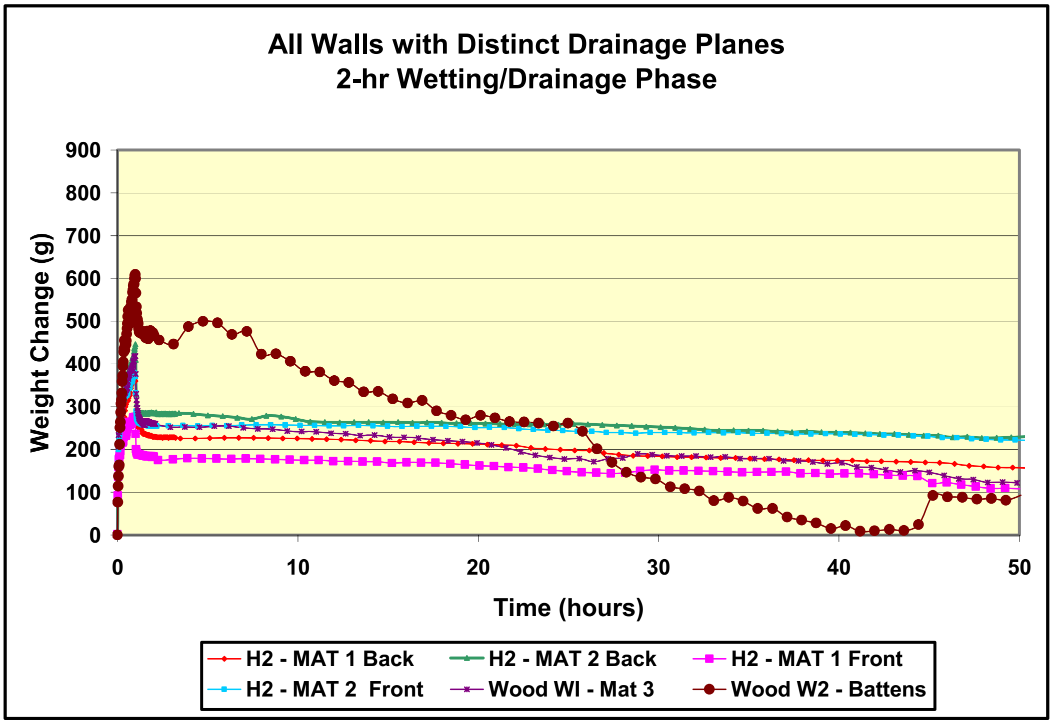


Figure 8 Composite plot of weight changes during the 50-hr wetting/drainage/drying test period for all walls with siding that was applied over some form of drainage matrix or batten strips.

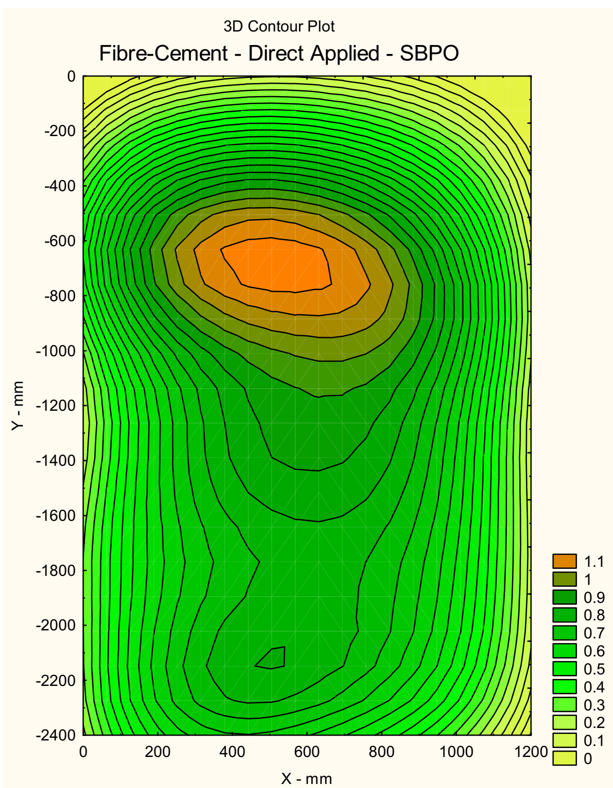
The following observations were drawn from the plots shown in Figure 7 and 8:

- The system for which the largest initial retention occurred was for the wood siding profile W2 installed on wood batten strips (19 mm x about 64 mm). The effect of the wood siding profile was immaterial in this case because the trickling of water was done to the back side of the drainage space. The trickle trough was attached directly to the wall and the fingers on the drip edge were very close to the SBPO sheathing membrane. The droplets from the trough slid down between the plastic sheet and the SBPO so it was likely dribbled down that membrane. Retention by SBPO is relatively low. However at least one trickle of water deposit occurred directly on top of each batten strip and this water was absorbed into the end grain. Despite the higher retention, this wall dried more quickly than the others on drainage mats whether water was directed down the back or front of the drainage cavity, because of the larger drainage space. The exposed ends of the batten strips were at the top of the drainage cavity and were able to dry quickly.
- The ripple in the drying curve for the wall with batten strips suggests that this wall was more sensitive to variations in the environmental conditions in the lab as recorded during this test (shown in Appendix V). This would be expected to occur because the ventilation space provided was relatively large compared to that provided for other walls, and the space was also unobstructed. The data was decimated for the purpose of clarity in the above plot and the ripple variation is not obvious. However the full data files were used for the plots in the Appendices. The air conditioning cycle was 1.3 hours and its effect on drying rates could be detected.

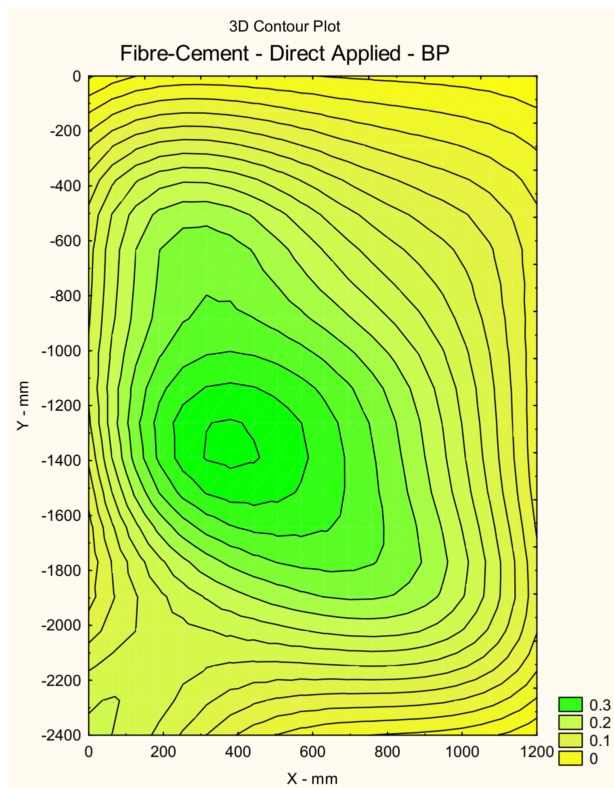
- The wood siding installed on Mat 3 was wetted with the tips of the serrated plastic drip edge positioned in the middle of the space between the siding and the back of the dimpled plastic sheet. The positioning of the dimples dispersed the incoming droplets and likely wetted all surfaces to some extent. It was wetted as much as siding on other mats, and dried as quickly as any of the other mat systems. This drainage medium did not allow any moisture to be transferred to the OSB and drying occurred only from the mat itself and the wood siding installed flat against it.

4.4 Location of Retained Water

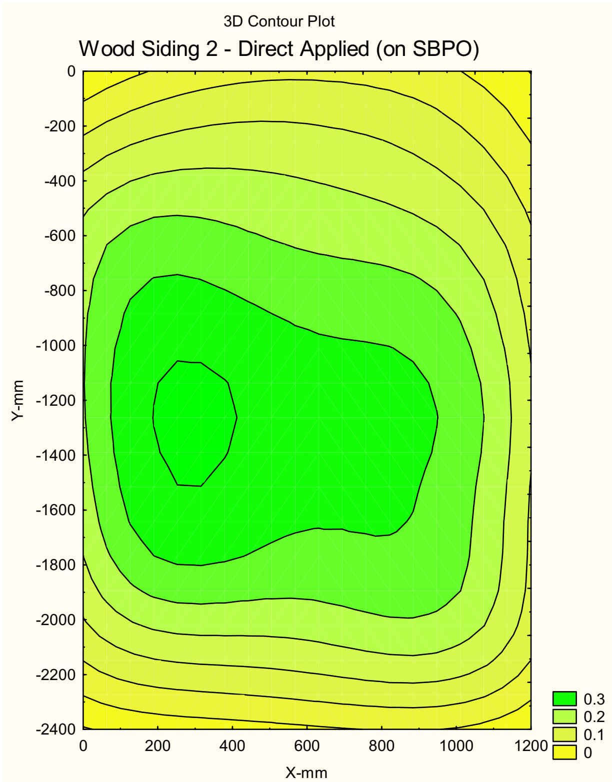
Relatively little can be surmised about the location of retained moisture from the weight measurements alone. The moisture maps provide some indication although as noted in the earlier testing on EIFS and Vinyl siding; these plots are relatively crude. The moisture change plots for these siding walls do provide some additional information. The full moisture maps are provided in the Appendices to this report, but some will be provided in reduced scale here to illustrate what can be learned from them. In the case of direct-applied siding:



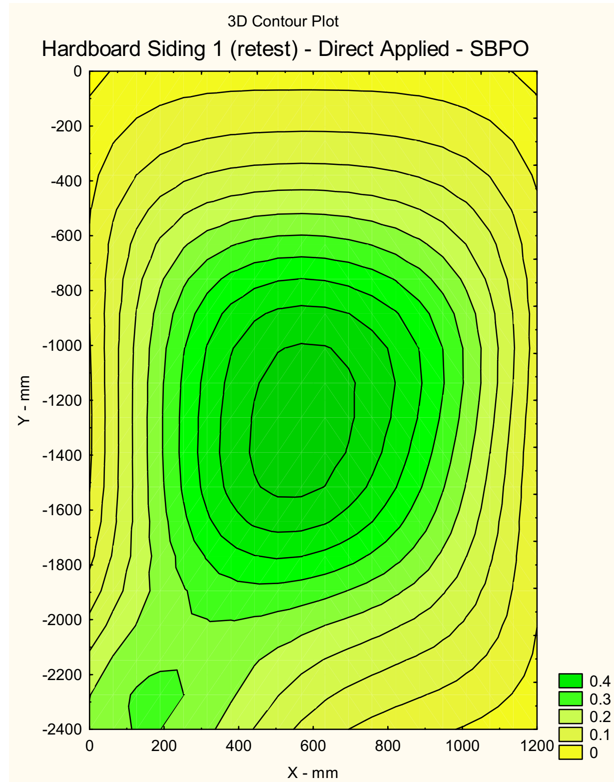
(9a) FC-1



(9b) FC-2



(9c) W2



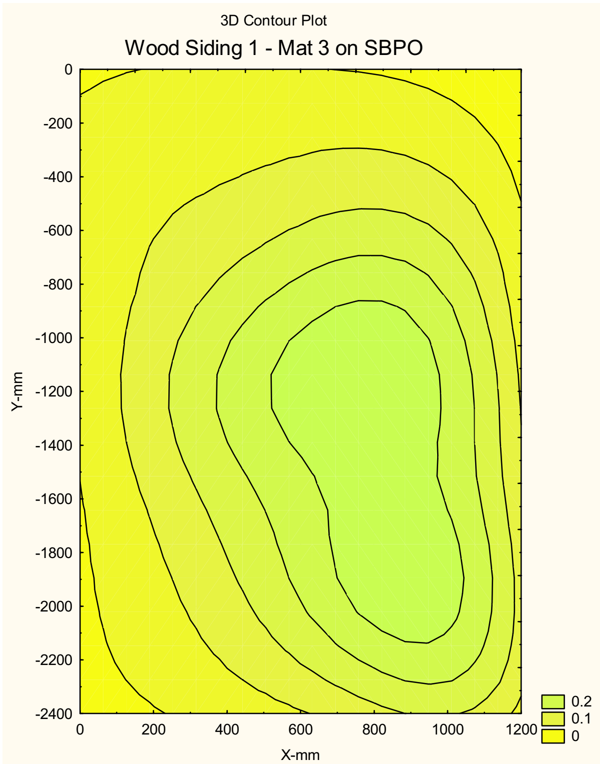
(9d) H1

Figure 9 Moisture change maps for several cases involving direct-applied siding

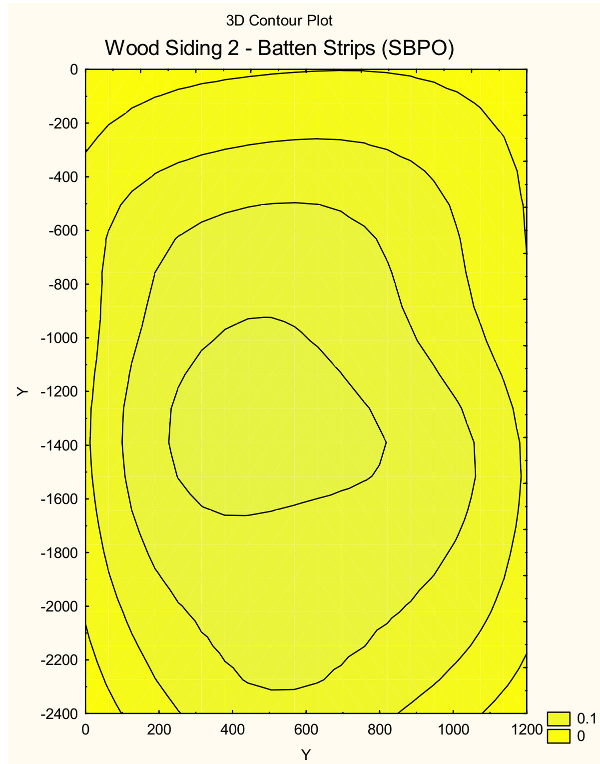
Several observations can be made about these distributions.

- One of the direct-applied fibre-cement siding walls that retained the most moisture did so in the upper edge of its installation. The retention contours for the second wall are lower down suggesting that some of the moisture found its way to a lower level, where the water was more distributed and from which it was able to dissipate more broadly. All siding systems that are direct-applied clamp the WRB tightly against the sheathing at the contact lines. However this ability must be highly dependant on installation factors, and subsequent shrinkage effects at fastener locations.
- The direct-applied wood siding also retained more moisture at mid-height by the end of the drying period. The direct-applied lapped hardboard siding also retained more moisture at mid height. Exactly how that moisture was held cannot be determined from this crude level of detection. However, of all siding systems reported on here, this was the only direct-applied siding that was installed with the back face fully in contact with the WRB and it was expected to retain more moisture.
- In most of the above cases some moisture appears to have migrated downward even though the siding should have been tightly clamped to the wall. In typical walls, there can be discontinuities in the exterior surface at joints in the sheathing and this increases the possibility of mismatching.

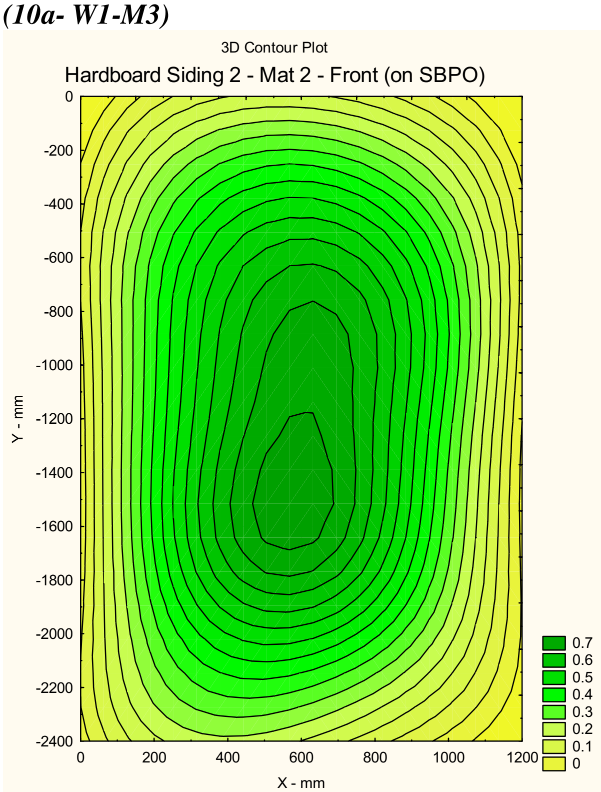
In the case of siding applied with distinct drainage cavities:



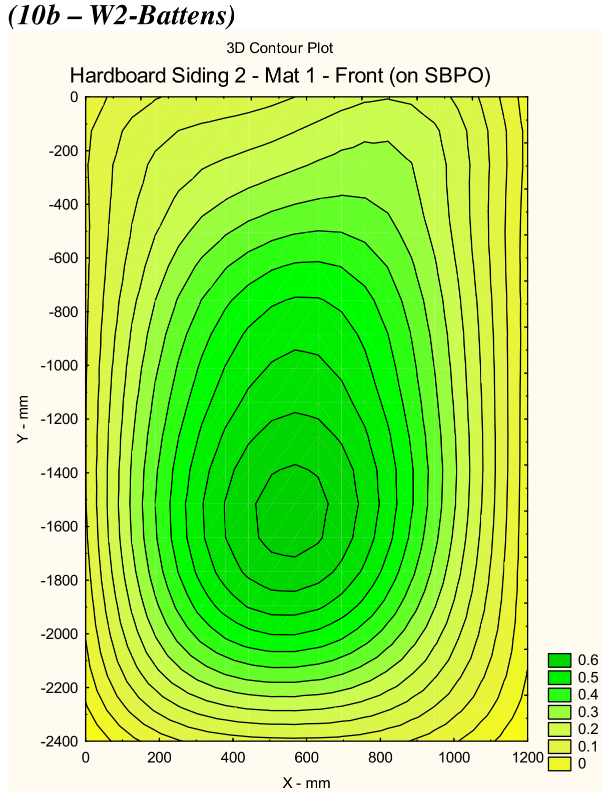
(10a- W1-M3)



(10b – W2-Battens)



(10c-H2-M2)



(10d-H2-M1)

Figure 10 Moisture change maps for siding systems applied over defined drainage cavities

Several observations may be made about these distributions:

- Whether water was trickled down the front or back of the drainage cavity involving mat systems the maps were very similar. This signifies that about the same degree of wetting occurred in both cases. The comparisons that led to the above observation are provided in Appendix IV for hardboard siding and only one of each plot per mat type is shown above.
- The case involving wood siding applied to batten strips, with the application of water directed near the back of the drainage cavity and partly over the batten strips themselves, dried very well, but some residual retained moisture appears about mid-height and in line with one of the vertical battens.
- The residual moisture in all cases appears to be concentrated more at mid-height of the test walls. It was surmised that this was likely due to the way that drying took place. Fresh air from the laboratory entered the bottom of the drainage cavity and moisture evaporated more quickly there. As the moist air moved upward it was less able to take on additional moisture from the mid-height level and that moisture would be the last to dissipate to low levels. The upper portion of the wall was slightly warmer than the lower portion due to stack effect in the laboratory air and with a shorter distance to the upper end of the drainage cavity it was also able to dry more quickly.
- We have no knowledge about the circulatory action taking place in the drainage cavity. We do know, from the RH records, that the portion of wall width below the trickle trough during wetting and drying has a higher RH than ambient and was particularly different from the sensors on either side of the trough. The temperature was either higher or lower than ambient depending on the temperature of water fed into the wall. The temperature of the air rising from the wall was usually warmer than on either side of the trickle trough. Two possible symmetric local convective loops would have air enter the wall at the top on either side of the trickle trough and pick up moisture and then rise, hence drying out the upper portion of the wall. If fresh air for drying was only available from the bottom of the wall, drying might only occur from the bottom to the top with the last residual moisture to be removed from the top of the drainage cavity.

5 DISCUSSION

The main objectives of these tests was to determine, to the greatest extent possible, the behaviour of walls with and without drainage cavities involving wood and fibre based siding systems that were expected to be quite different from the EIFS and vinyl siding walls tested earlier. Going back to Tables 1 to 4 and summarizing the moisture retentions in another way, we have the following in Tables 5 and 6 for direct-applied siding versus siding on drainage cavities.

Table 5 Examining retention ratios for direct-applied siding

Trickling on front or back	Siding type	Mat type	2-hr Retention	50-hr Retention	Ratio 50-hr/ 2-hr	Mean per material
mid	H1	DA	117	35	0.30	0.30
mid	H1(retest)	DA	130	0	0.00	
mid	W2	DA	426	294	0.69	0.69
mid	FC-1	DA	340	50	0.15	0.15
mid	FC-2	DA	197	0	0.00	

The above ratios reveal that systems that dried rapidly were characterized by having low retention at the conclusion of the test and had a 50-hr to 2-hr ratio of 0.3 or less. The direct-applied wood siding had a high ratio, and it is worth repeating that the retained moisture was likely concentrated in the upper part of the wall and in joints in the siding. The manufacturer does not recommend this installation practice.

In the case of siding with drainage cavities, the summary is shown in Table 6.

Table 6 Examining retention ratios for siding with drainage cavities

Trickling on front or back	Siding type	Mat type	2-hr Retention	50-hr Retention	Ratio 50-hr/ 2-hr	Mean per material
back (WRB)	H2 H2	M1 M2	231 284	156 229	0.67 0.80	0.73
front (siding)	H2 H2	M1 M2	183 254	109 221	0.60 0.87	0.74
back (WRB)	W1 W2	M3 Battens	260 467	123 0	0.47 0.00	0.47

The 50-hr to 2-hr ratios tend to be over 0.6 and the comparison of means for trickling down the front versus the back of the drainage cavity are essentially the same. The two mesh type mats (M1 and M2) likely dispersed water to wet all surfaces in the path, while M3 (dimpled solid sheet) prevented the WRB and main wall from being wetted and retained less. The wood siding involved in this test had a shiplap profile which facilitated shedding of water from the outside, but not from the inside. During the test some water slipped out through joints in the siding and it is likely that some water was retained in the joints, despite the primed finish.

To a large extent, most of the discussion concerning the ability of these wall systems to manage water that enters these types of walls has already been provided in the presentation of results. From the above observations it is clear that provision of drainage planes leads to a more direct path for the water to flow to the bottom. But, in the process, a greater area of wetted surfaces becomes involved. Also, a greater total weight of water was retained. However, since the moisture mapping showed that significantly larger areas of wall were affected, it is possible that the concentration of moisture was lower. But, the moisture mapping done may have been too insensitive to locate high local concentrations of moisture where the siding was clamped to the walls, or in the interlocking joints between siding courses. Overlaps and other joints in the siding are designed to shed water that is on outside surfaces of the siding, and they are not particularly designed to shed water easily that may enter and flow down behind the siding.

For siding that is absorbent to some degree it is not possible to claim that the moisture was only held in the drainage mat or in the other surfaces (the siding and the WRB and the backup wall) defining the space. The dimpled drainage mat that prevented moisture from being transmitted into the structural sheathing dried more rapidly than did walls having matrix type mat systems. This suggests that at least one pathway was omitted and the result was better. For this experimental plan only a limited variety of cases and siding systems could be included and the effect of the properties of the WRB was not included.

Clearly, since even the walls with siding that was directly applied dried, ventilation loops through the upper open edge of siding contributed to that drying. When some water appeared to penetrate to lower reaches of a wall, drying by other means would take precedence, namely vapour diffusion through the materials and the air gaps between courses of siding, small though they may be. The short time frame for the tests and knowledge about the vapour resistance of finished hardboard and OSB suggests that substantial loss of moisture directly through the siding materials was not a significant transfer mode out of the wall leading to the weight loss observed.

While the moisture mapping, as performed in this study, assisted in identifying general areas of moisture retention, the contours are relatively crude. They very probably infer moisture content changes in some locations that did not gain moisture due to some uncertainty in the individual measurements, as described in the Part 2 report.

6 SUMMARY AND CONCLUSIONS

The experimental testing of the ability of walls with siding to manage water that enters the space behind the siding has taught us that despite lack of provision of drainage cavities, siding joints can permit drainage close to the source of moisture. The ability to do so safely has not been assessed in this study because knowledge about the detailed concentration of moisture resulting from that form of entry and escape was not available. In any case, a study directed at that subject would require additional detailed measurements that could not be undertaken in this study. The variability in retention from one wall to another of the same construction could only be observed for the apparently similar walls with fibre-cement siding. Their relative performance suggests that installation variables of all such walls may have much to do with the reliability of their drainage and retention performance.

Provision of a drainage plane behind siding is the surest way to dissipate moisture despite the potential that a greater area (height) of wall might be exposed to water on the back of siding. The concentration of moisture and its location is likely a more important determinant of durability. The ability of the cladding construction to assist in dissipating moisture from behind it and the choice of materials inside the drainage cavity can provide a near fail-safe construction under real weather conditions. The current study was limited to essentially isothermal drying conditions. Drying under real weather conditions may be highly accelerated or slowed depending on the weather conditions at the time and exposure. Researching the performance of siding experimentally must be limited to examining relative conditions. However, if the mechanics of all the air, moisture and thermal paths are understood and properly characterized, it may be possible to employ computer modelling to parametrically assess relative performance of siding systems in widely differing climates. Testing of walls, as was done in this study, is a valuable way of assessing the influence of some construction variables, something that computer modeling cannot provide. Some additional information that can assist in undertaking parametric analyses, specific to walls in this test program, is provided in Part 6 and 7 in this report series. That data will be re-examined in the Summary Report in this series.

APPENDIX I

Links to Manufacturers' Web Sites

APPENDIX I – Links to Manufacturers' Web Sites

This appendix contains reference to publicly available web links and specification sheets for some of the materials utilized for constructing the test walls. The web links provide recommended details and specification sheets by each manufacturer for the applications they recommend their products are suitable for. As noted in the body of this report, some of the products (specifically the drainage mats under cedar shingles) were used in a wall application that is not necessarily supported by the manufacturer. Two of these were used because they provided a means for drainage and ventilation and, at the time of wall construction, these were the only products that could be obtained. Some of these mats may be suitable for use in walls in some climates.

There is a wide range of siding products available on the market and it was necessary to limit the number of different products actually used for this project to illustrate expected typical drainage and retention behavior. The inclusion of these particular products in the study was intended to assist in describing how wall systems constructed in different ways manage water that may be introduced behind the cladding.

Wood Siding:
www.maibec.com

Hardboard Siding (LP Canexel®) Louisiana-Pacific Corporation
http://www.lpcorp.com/lpsidingproducts/lpscanexel/productinformation/productinformation.aspx

Fibre Cement Siding: Hardiplank® Lap Siding – James Hardie North America
http://www.jameshardie.com/

Mat 1 – CedarSaver™ – American Wick Drain Corporation
http://www.benjaminobdyke.com/html/products/cedar.html

Mat 2 - Cedar Breather® – Benjamin Obdyke
http://www.americanwick.com/cedarsaver.shtml

Mat 3 - Home Sliker – Benjamin Obdyke
http://www.benjaminobdyke.com/html/products/slick10.html

APPENDIX II

Fabrication of Test Walls

Figure A-II-1: Installation of Mat 3 on base wall with SBPO.

FigureA-II-2: Installation of Mat 2 on base wall with SBPO.

FigureA-II-3: Installation of Mat 1 on base wall with SBPO.

Figure A-II-4: Close-up of Mat 2

Figure A-II-5: Staple attachment of Mat 1

Figure A-II-6: Installation of wood siding W2 on 19 mm batten strips.

Figure A-II-7: Caulking the top edge of the gutter to the SBPO.

Figure A-II-8: Sealing the ends of siding with spray polyurethane foam.

Figure A-II-9: Sealing the siding ends with polyurethane foam

Figure A-II-10: Hardboard siding with a spline registered in a starter strip.

Figure A-II-11: Excess polyurethane foam trimmed off.

Figure A-II-11: Applying construction tape over the sealed siding ends.

Figure A-II-12: Lapped fibre-cement siding.

Figure A-II-13: Cutting of fibre-cement siding outdoors.

Figure A-II-14: Wood shiplap siding applied directly to the wall.

Figure A-II-15: Prefinished wood siding using shorts of the same profile from different lots.

Figure A-II-16: Location of Trickle Trough showing serrated plastic strip directing location of trickles relative to the top of a batten strip

APPENDIX III

Some Photos Taken During Drainage Tests

Figure A-III-1: Hardboard siding wall undergoing test showing water flowing over the face of the siding. [H1 direct-applied]

Figure A-III-2: Wood siding wall undergoing test. [W2 direct-applied]

Figure A-III-3: Wood siding wall undergoing test. [W1 Mat 3].

Figure A-III-4: Fibre-cement siding wall undergoing test. [direct-applied].

APPENDIX IV

Data Plots for Hardboard Siding Tests

Notes to Appendix IV – Tests on Walls with Hardboard Siding

The plots provided in Appendix IV include retests of some walls to make up for tests in which full environmental data was not collected. Individual plots for the 2-hr wetting/drying phase, and for the combined data consisting of the 2-hr and 48-hr drying period are included. One plot shown in Figure A-IV-2 demonstrated the importance of not disturbing the wall for the current set-up arrangement of linkages. A step change in weight occurred which allows that record to be discounted. Effectively, the zero setting changed.

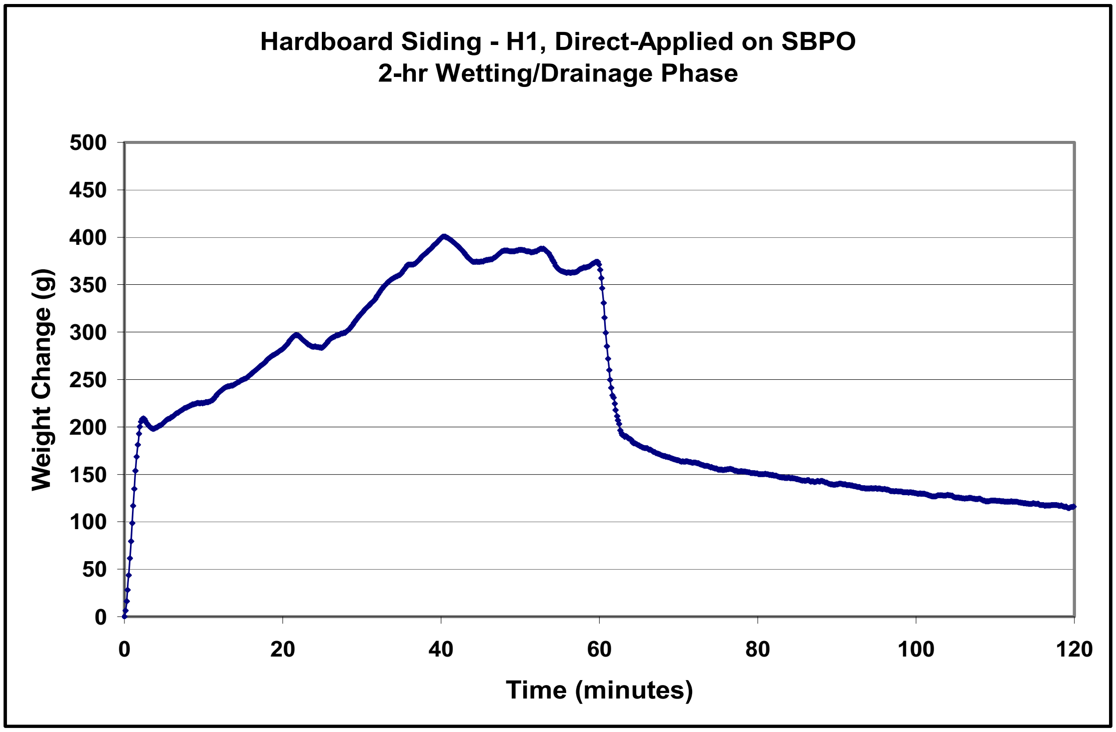
Mapping of moisture content changes have been included for each case when water was intentionally directed to the front or back of the drainage cavity involving two different spacer products as well as when the siding was direct-applied. These plots are only qualitative indications of moisture retention and should not be interpreted as representing true moisture content changes in any of the components of the walls.

The identification of test material and types are provided below:

H1 = 9-inch, spline system (Ced'R-Vue™)
H2 = 12-inch lap siding with an interlocking joint system (Ridgewood D-5™)
Mat 1 = Home Slicker®
Mat 2 = Cedar Breather®
DA = Direct Applied
SBPO = Spun Bonded Polyolefin WRB
BP = Building Paper (paper based) WRB
Front = trickling of water down front of drainage cavity (on the back of the siding)
Back = trickling of water down back of drainage cavity (on the back of the WRB)

Table A-IV-1: Summary of Plots included in Appendix IV

Data Form	Page	Figure A-IV	2hr W/D	48hr W/D	Mat/DA	Front Trickle	Back Trickle
Drainage	35	1	H1		DA		
			H2		M1		√
	36	2		H1	DA		
				H2	M1		√
	37	3	H1		DA retest		
			H2		M2		√
	38	4		H1	DA retest		
				H2	M2		√
	39	5	H2		M1	√	
			H2		M2	√	
	40	6		H2	M1	√	
				H2	M2	√	
Moisture Mapping	41	7		H1	DA		
		8		H1	DA retest		
		9		H2	M1	√	
		10		H2	M1		√
	42	11		H2	M2	√	
		12		H2	M2		√
RH&T	43	13	H1		DA		
	44	14	H1		DA retest		
	45	15		H1	DA		
	46	16		H1	DA retest		
	47	17	H2		M1	√	
	48	18	H2		M1		√
	49	19		H2	M1	√	
	50	20		H2	M1		√
	51	21	H2		M2	√	
	52	22	H2		M2		√
	53	23		H2	M2	√	
	54	24		H2	M2		√
External Conditions	55	25	√		H1-DA + H2-Mat 1-Back		
	56	26		√			
	57	27	√		H1-DA (Retest) + H2-Mat 2-Back		
	58	28		√			
	59	29	√		H2-Mat 1-Front + H2-Mat 2-Front		
	60	30		√			



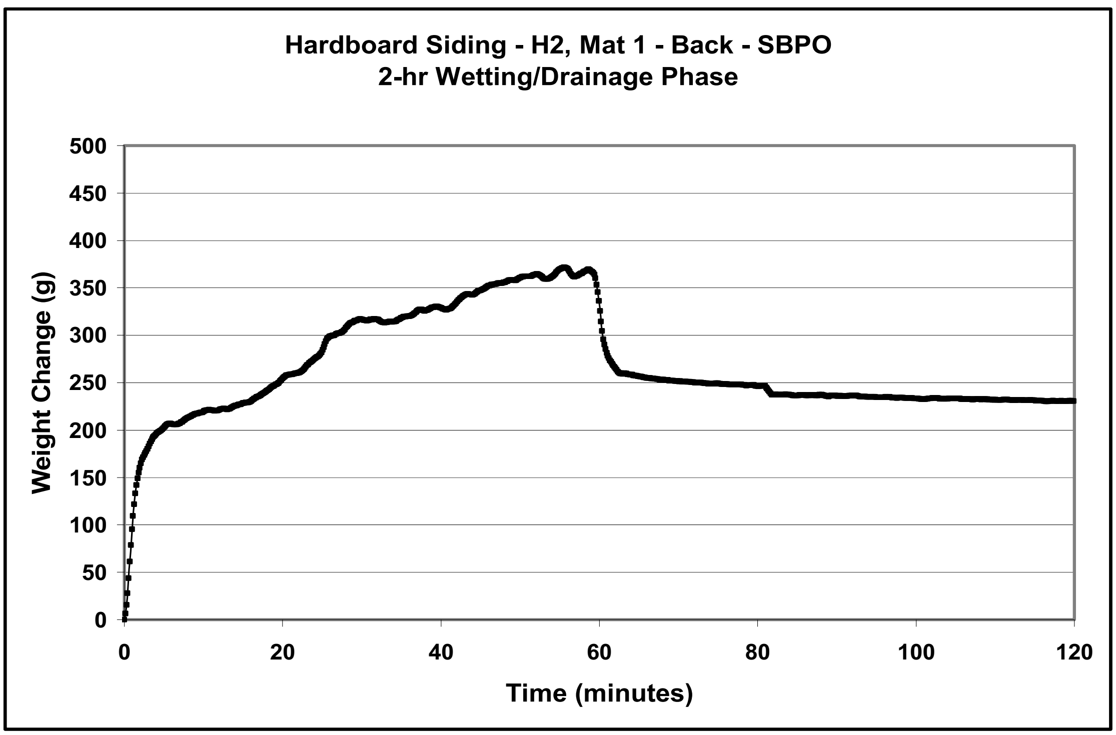
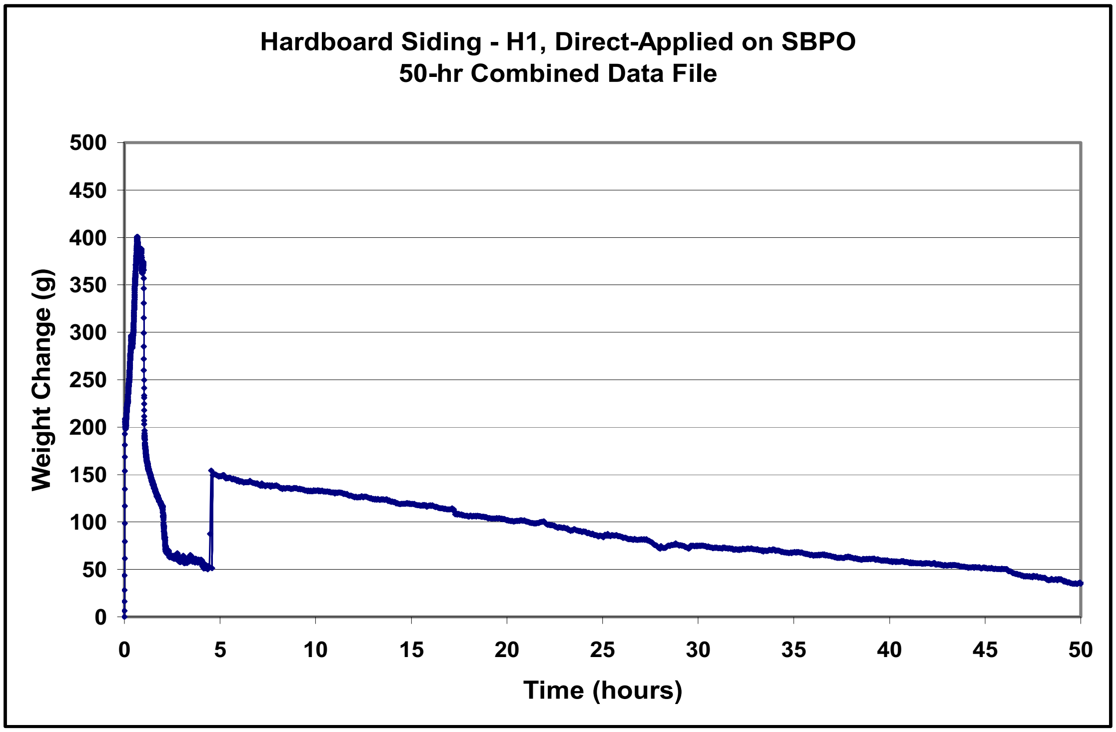


Figure A-IV-1: 2-hr Wetting/Drainage Phase for Direct Applied (DA) Hardboard (H1), and for Hardboard (H2) on Mat 1 with drainage down BACK of cavity.



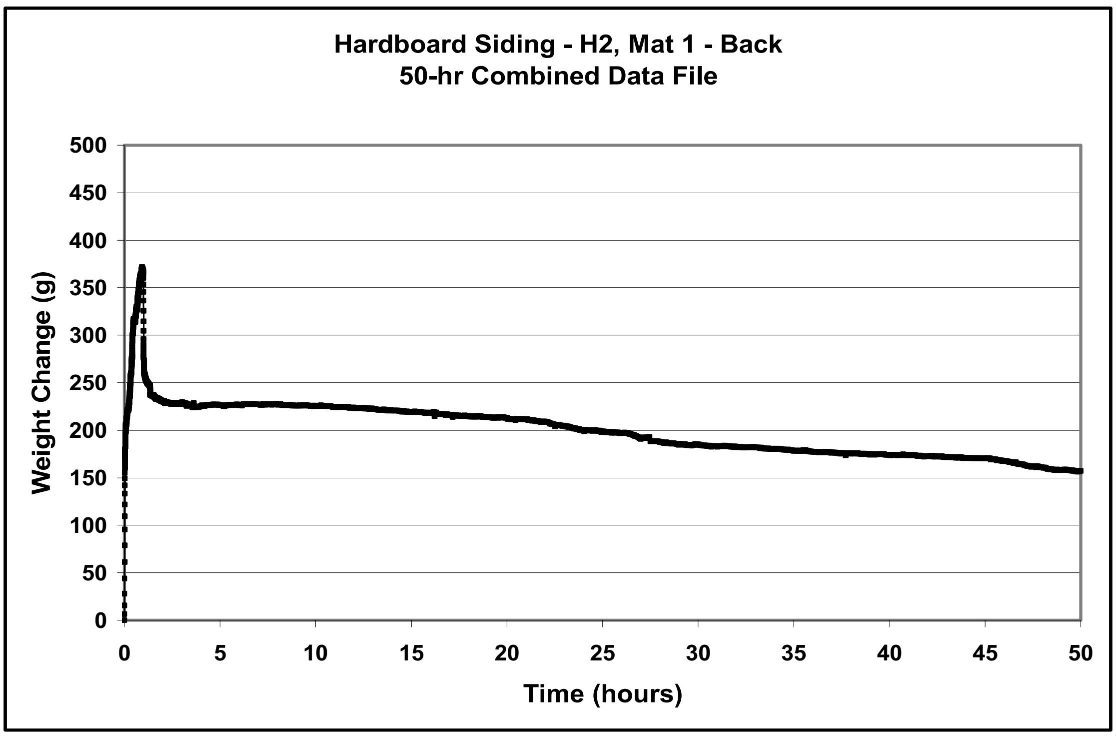
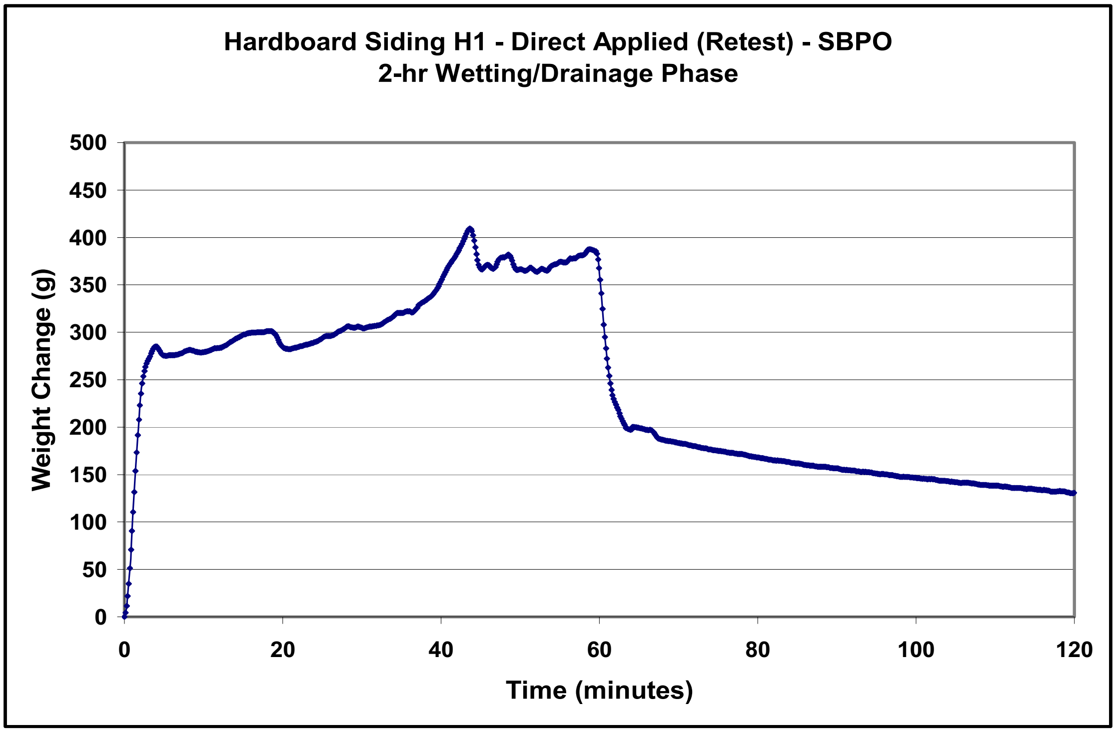


Figure A-IV-2: 50-hr combined Wetting/Drainage/Drying for Direct Applied (DA) Hardboard (H1), and for Hardboard (H2) on Mat 1 with drainage down BACK of cavity.



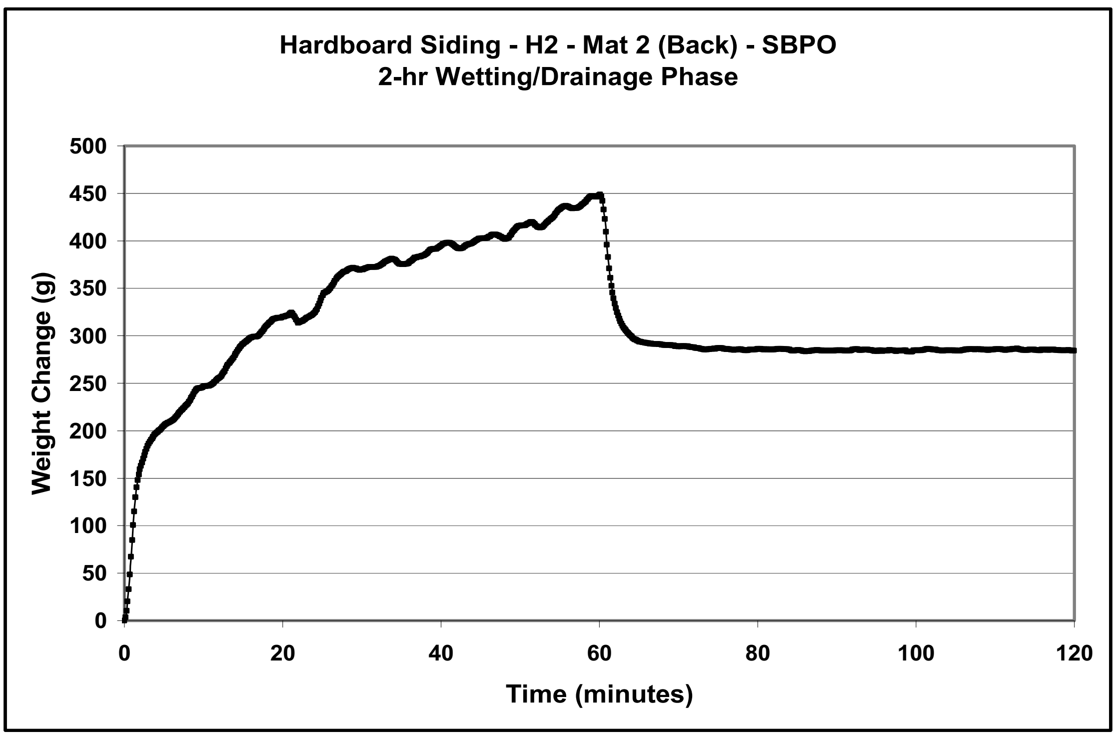
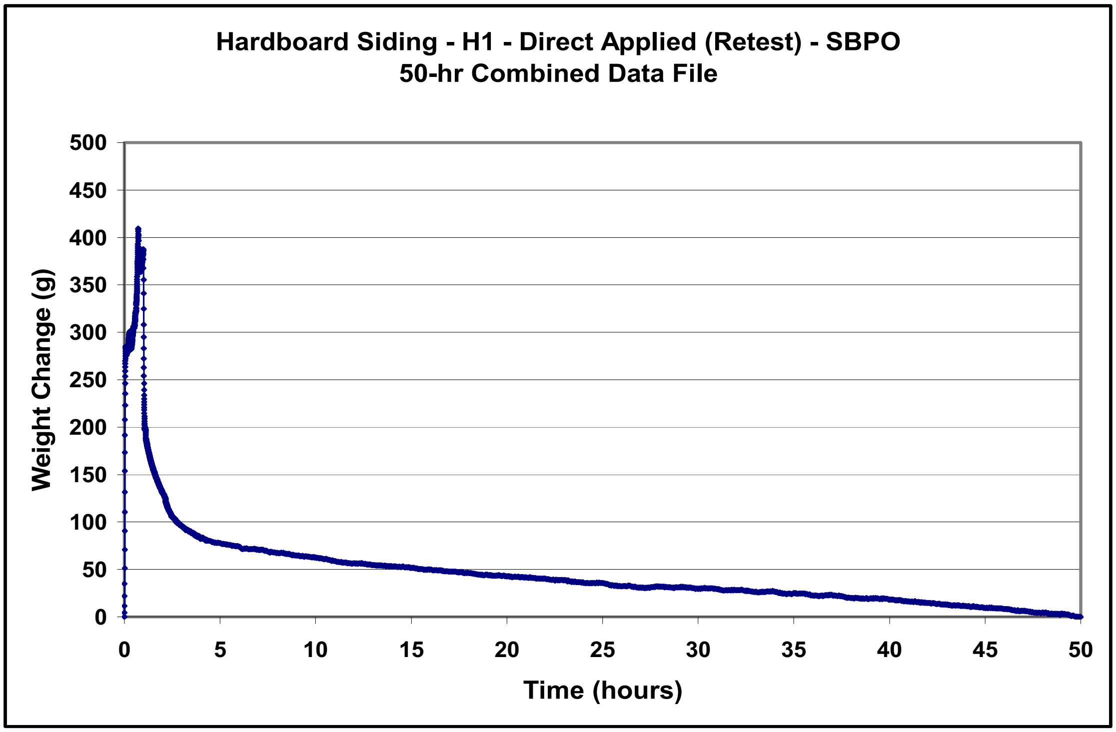


Figure A-IV-3: 2-hr Wetting/Drainage Phase for repeat of Direct Applied (DA) Hardboard (H1), and for Hardboard (H2) on Mat 2 with drainage down BACK of cavity.



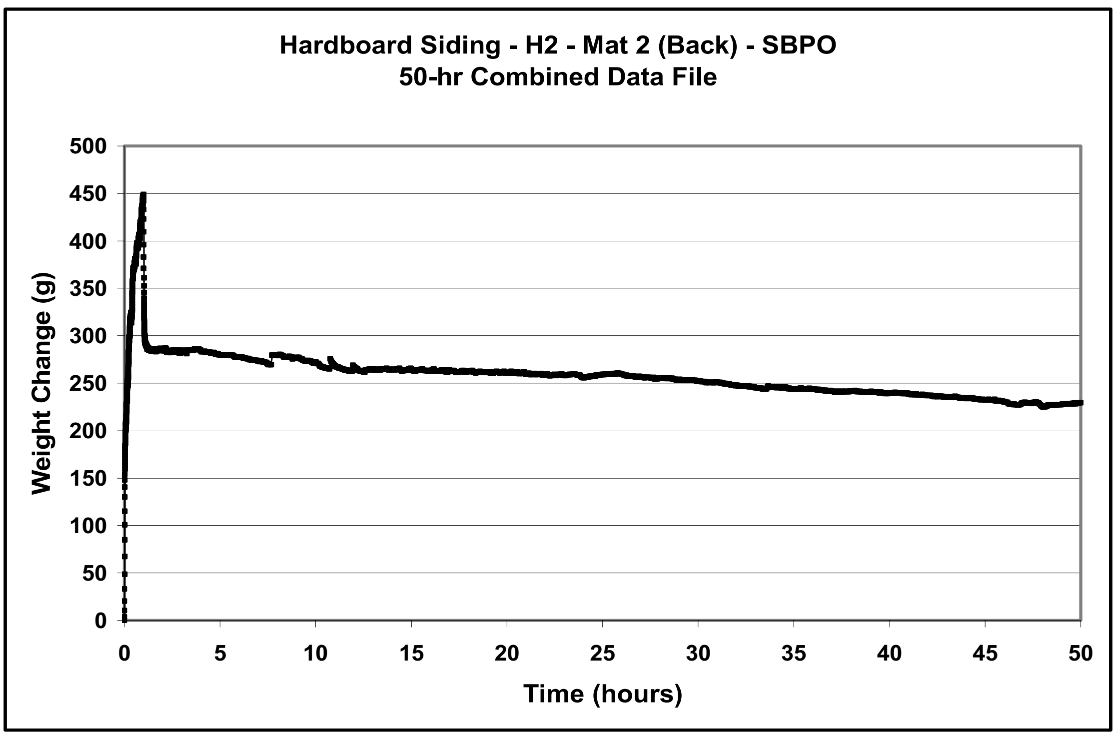
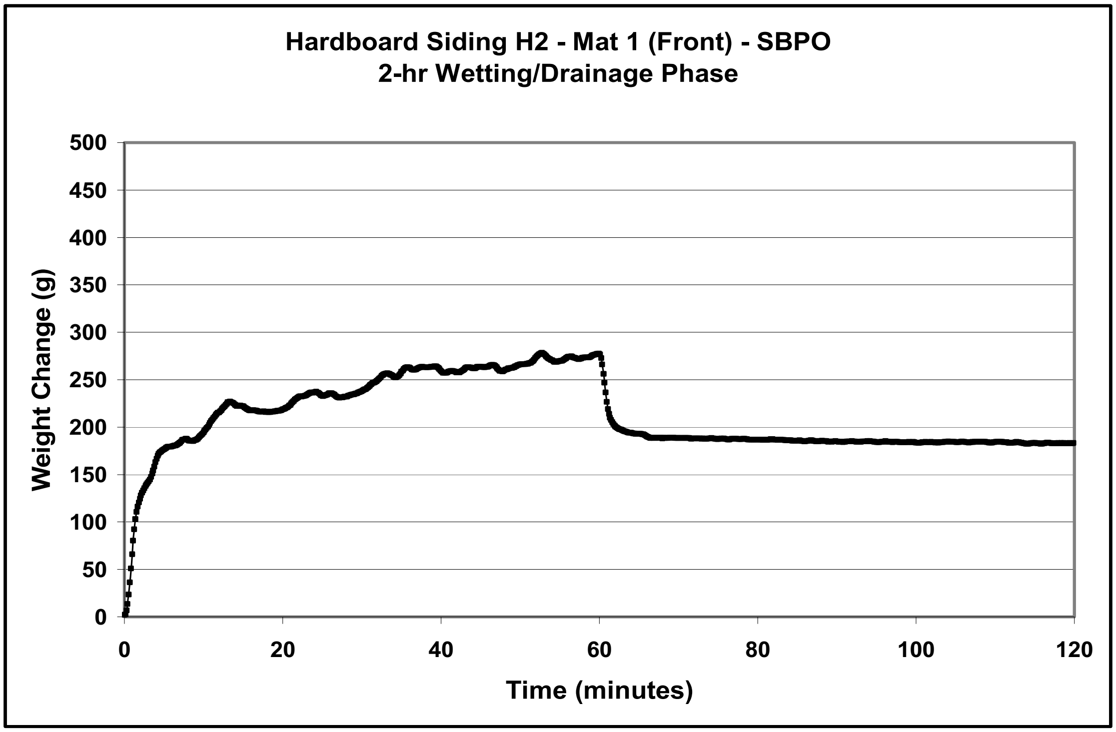


Figure A-IV-4: 50-hr combined Wetting/Drainage/Drying for repeat of Direct Applied (DA) Hardboard (H1), and for Hardboard (H2) on Mat 2 with drainage down BACK of cavity.



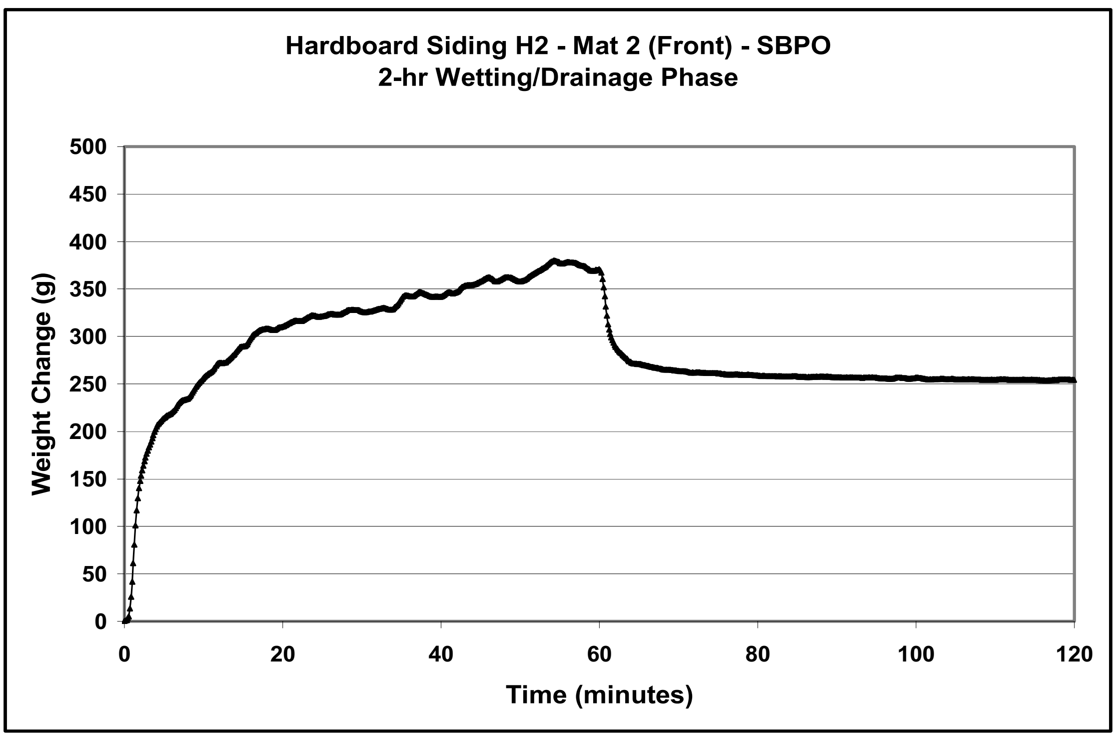
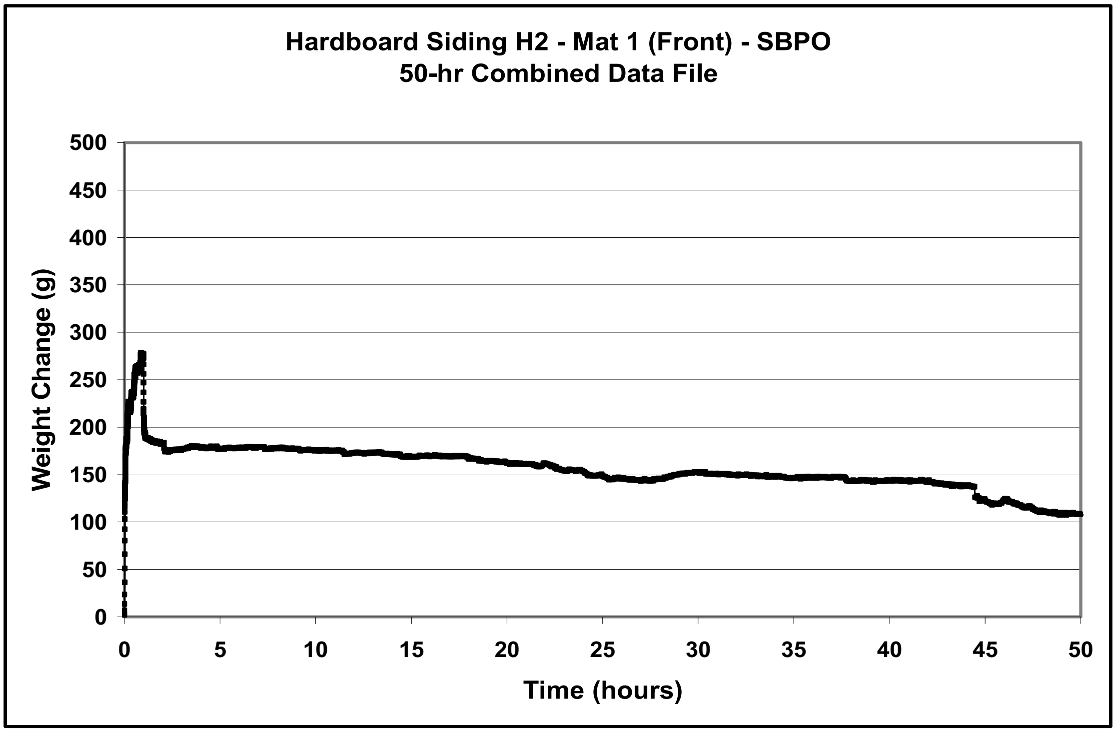


Figure A-IV-5: 2-hr Wetting/Drainage Phase for Hardboard (H2) on Mat 1 and for Hardboard (H2) on Mat 2 with drainage down FRONT of cavity in each case.



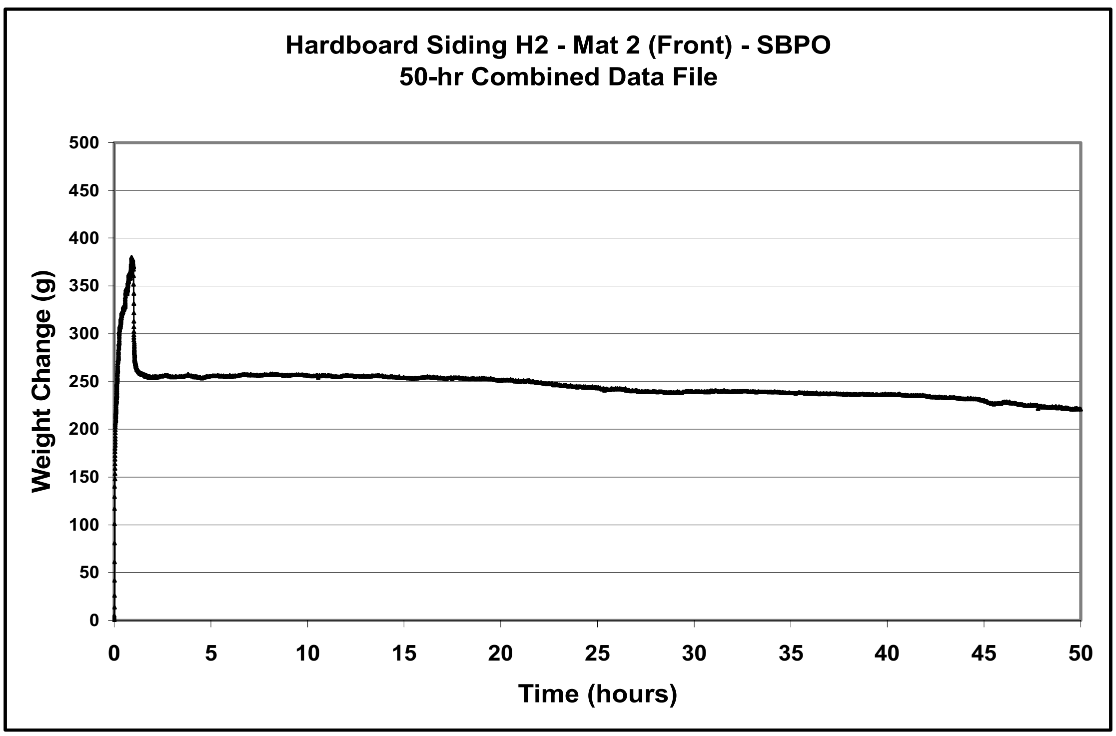


Figure A-IV-6: 50-hr combined Wetting/Drainage/Drying for Hardboard (H2) on Mat 1 and for Hardboard (H2) on Mat 2 with drainage down FRONT of cavity in each case.

Figure A-IV-7: Moisture difference map, Hardboard H1-DA

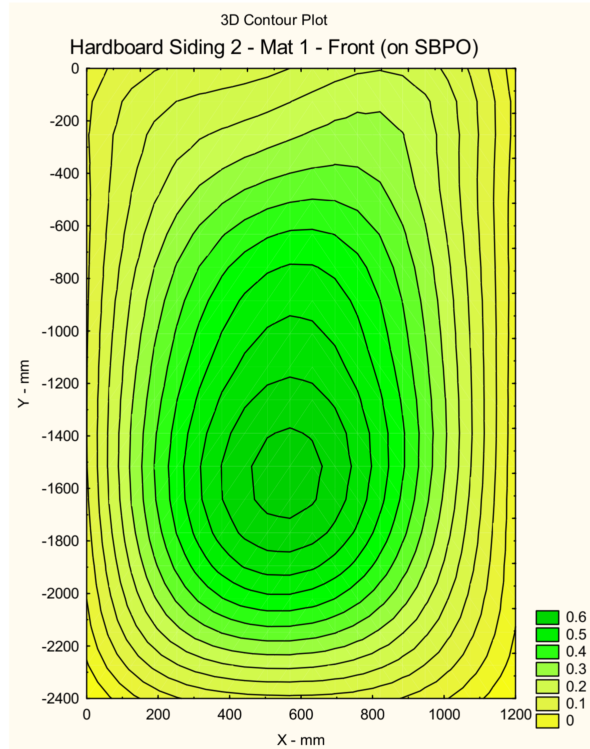


Figure A-IV-9: Moisture difference map, Hardboard H2 on Mat 1, drainage on Front.

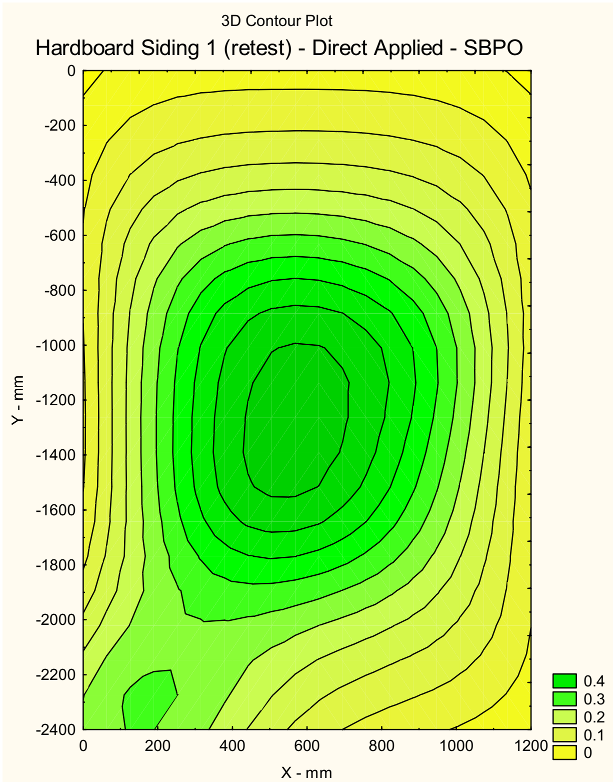


Figure A-IV-8: Moisture difference map, Hardboard H1-DA (repeat)

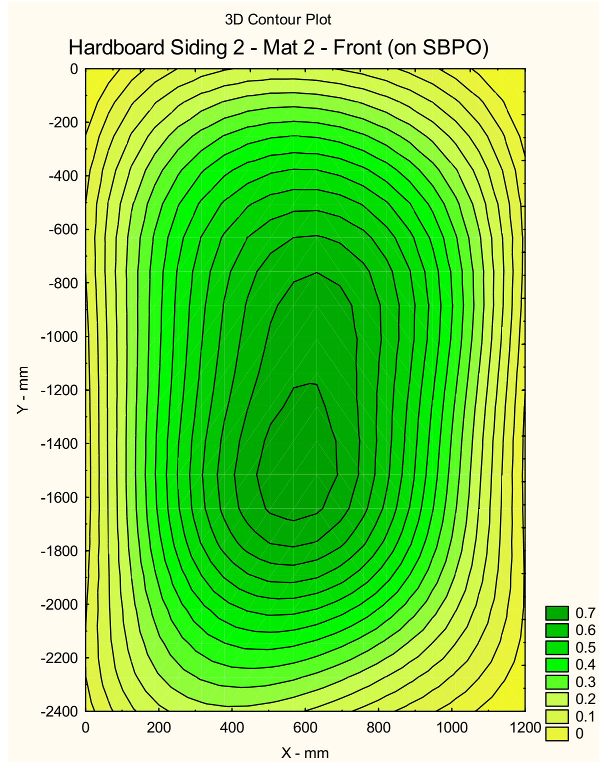


Figure A-IV-11: Moisture difference map, Hardboard H2 on Mat 2, drainage down front.

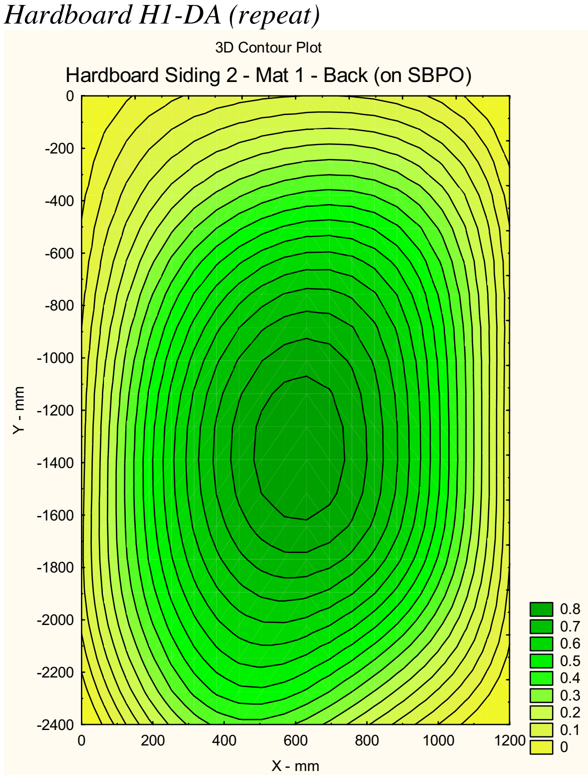


Figure-IV-10: Moisture difference map, Hardboard H2 on Mat 1, drainage on Back

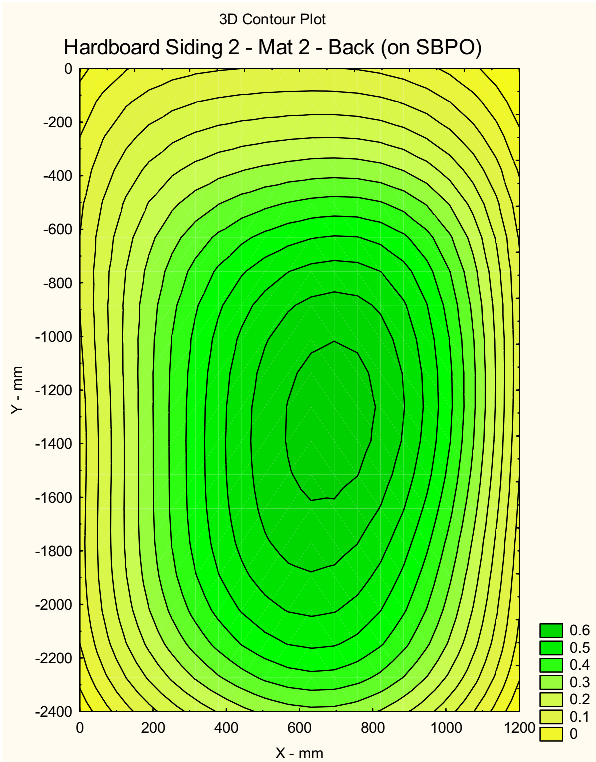
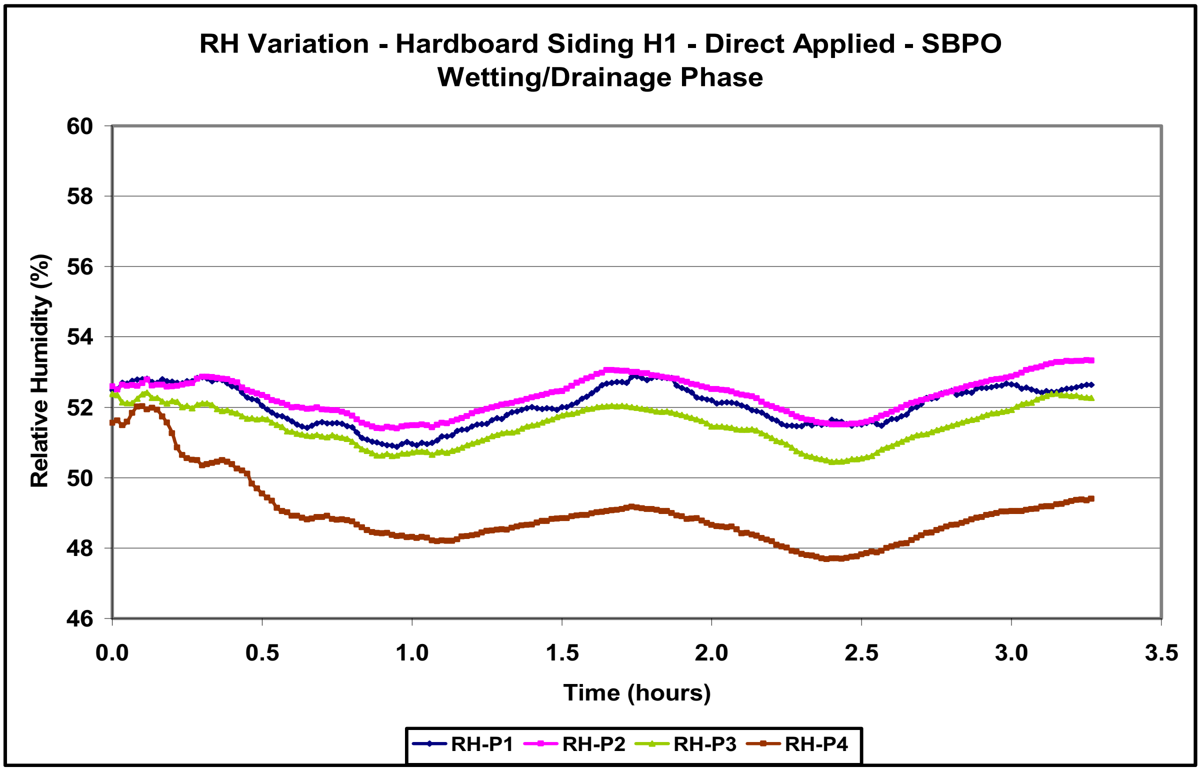


Figure A-IV-12: Moisture difference map, Hardboard H2 on Mat 2, drainage down back.



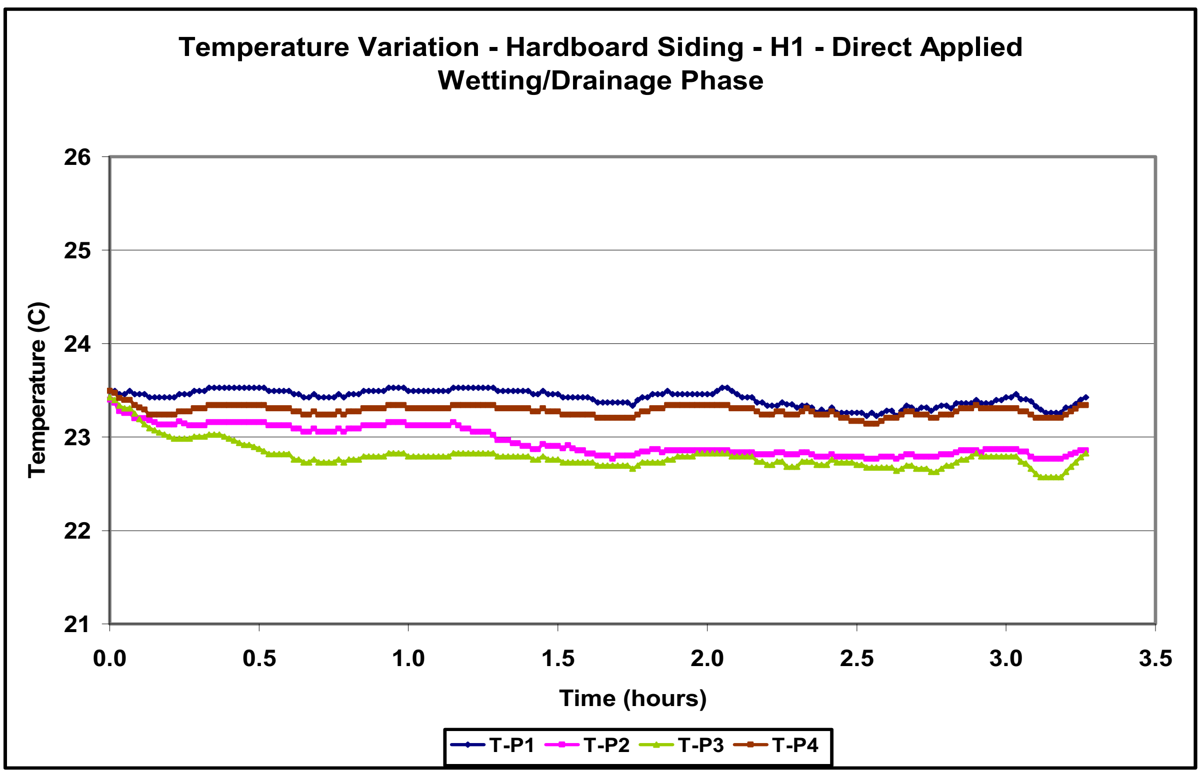
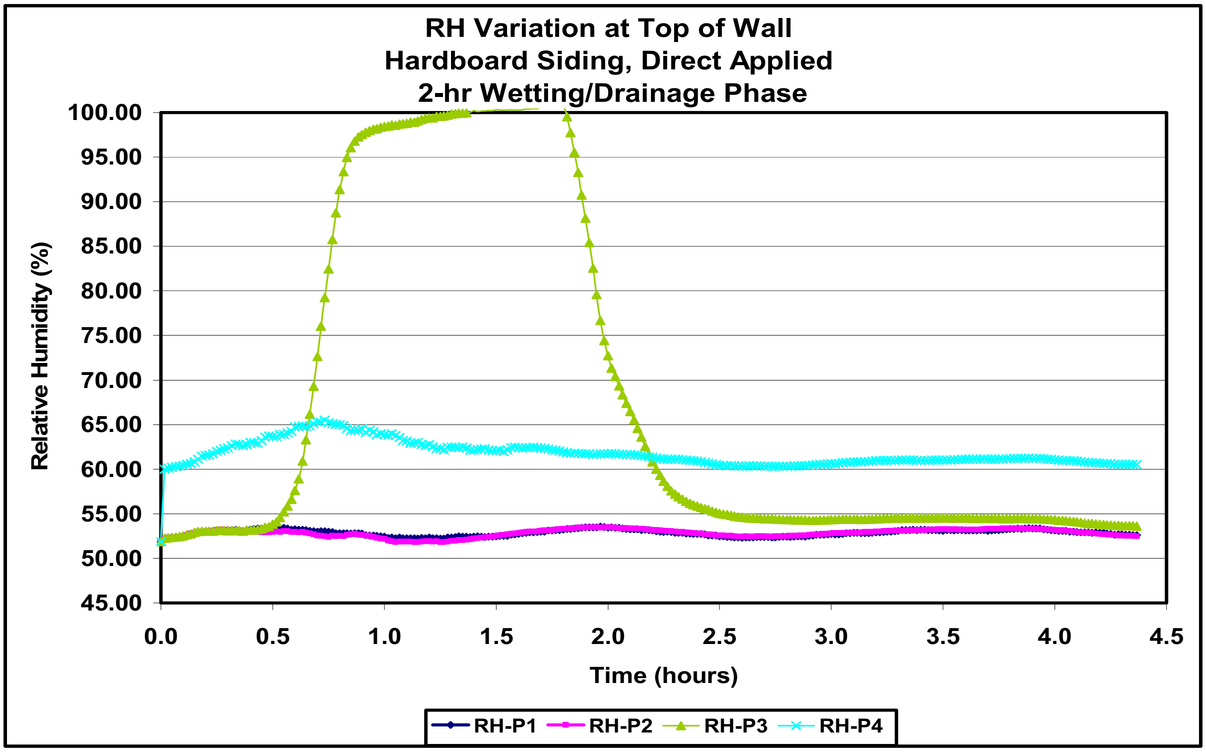


Figure A-IV-13: RH&T plots for siding H1-DA during wetting/draining.



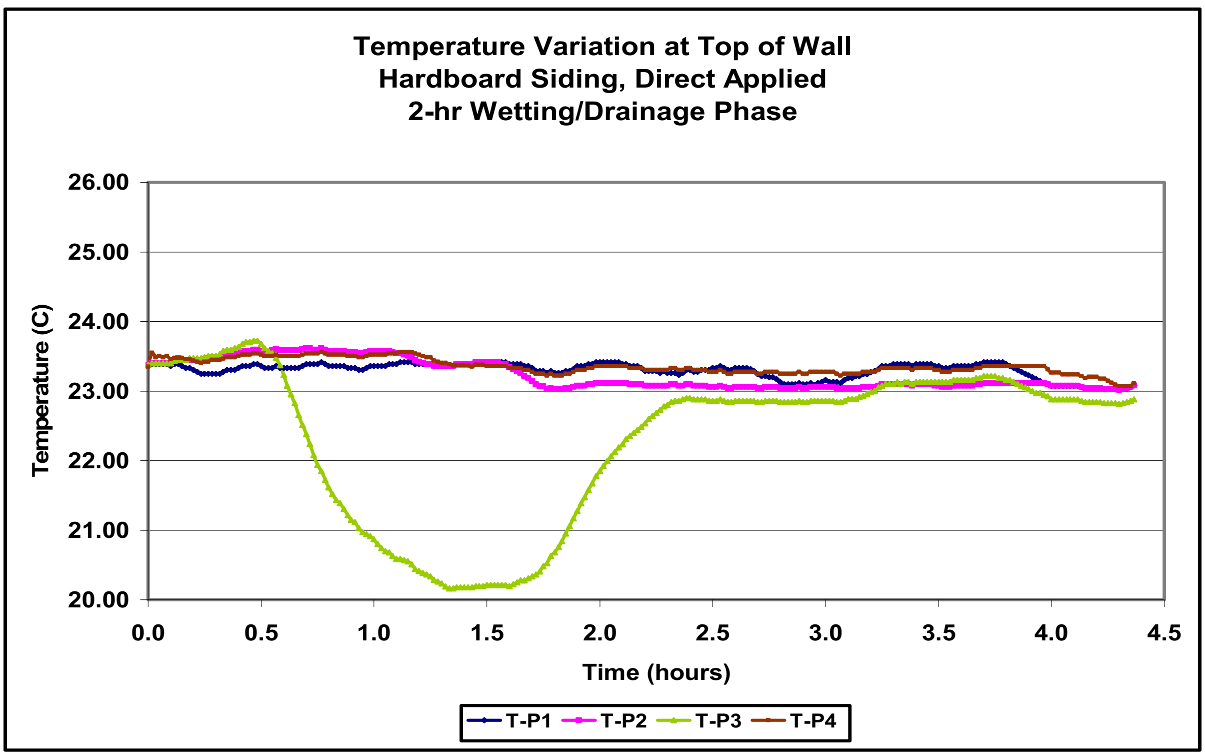
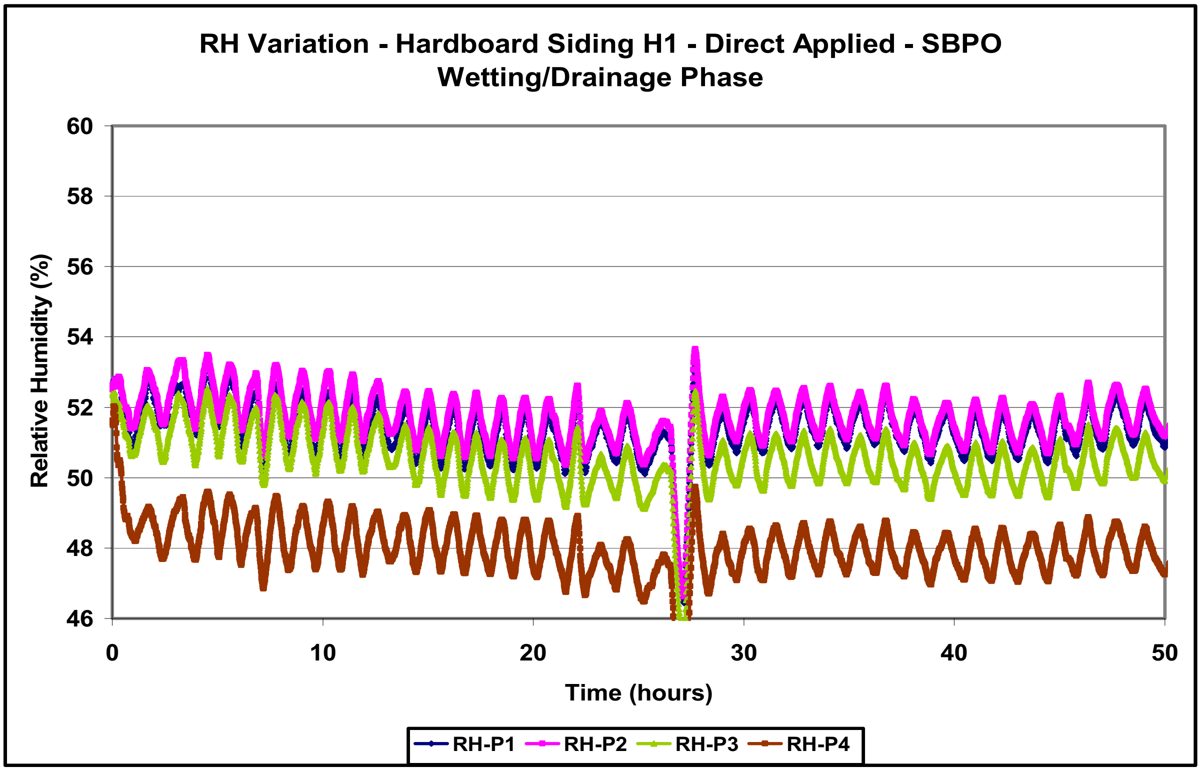


Figure A-IV-14: RH&T plots for siding H1-DA-retest, during wetting/drainage.



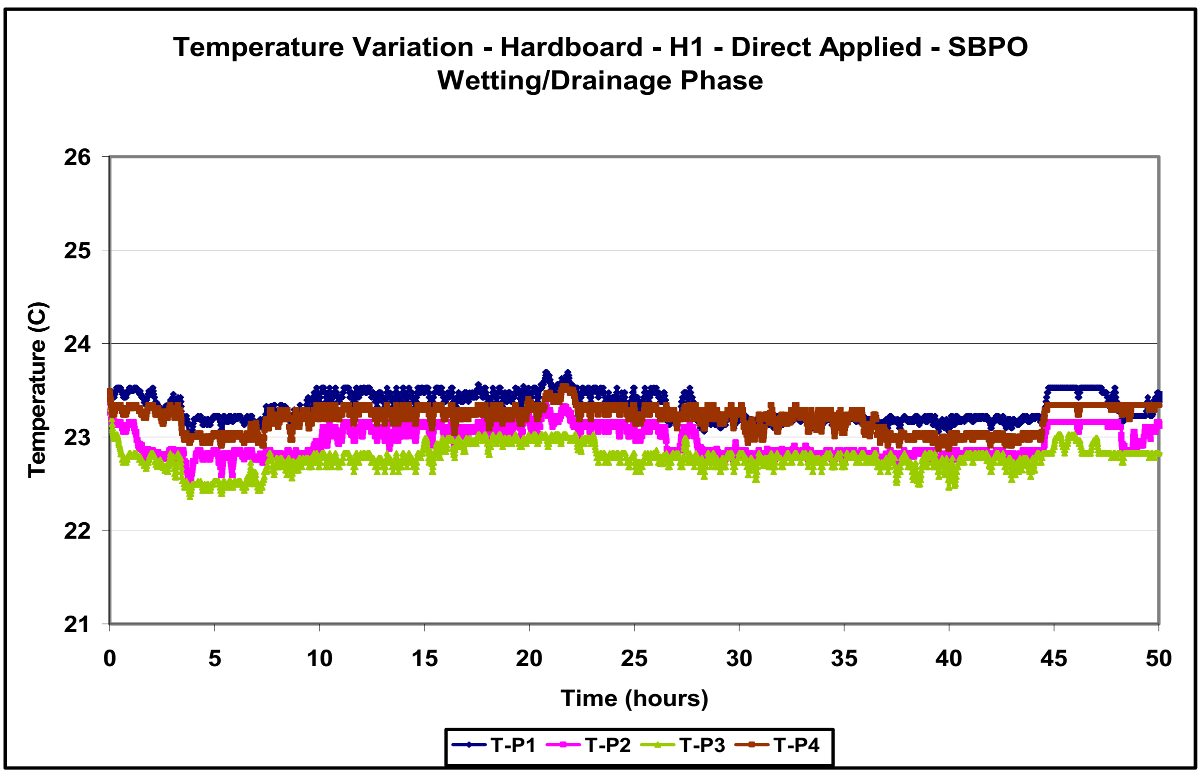
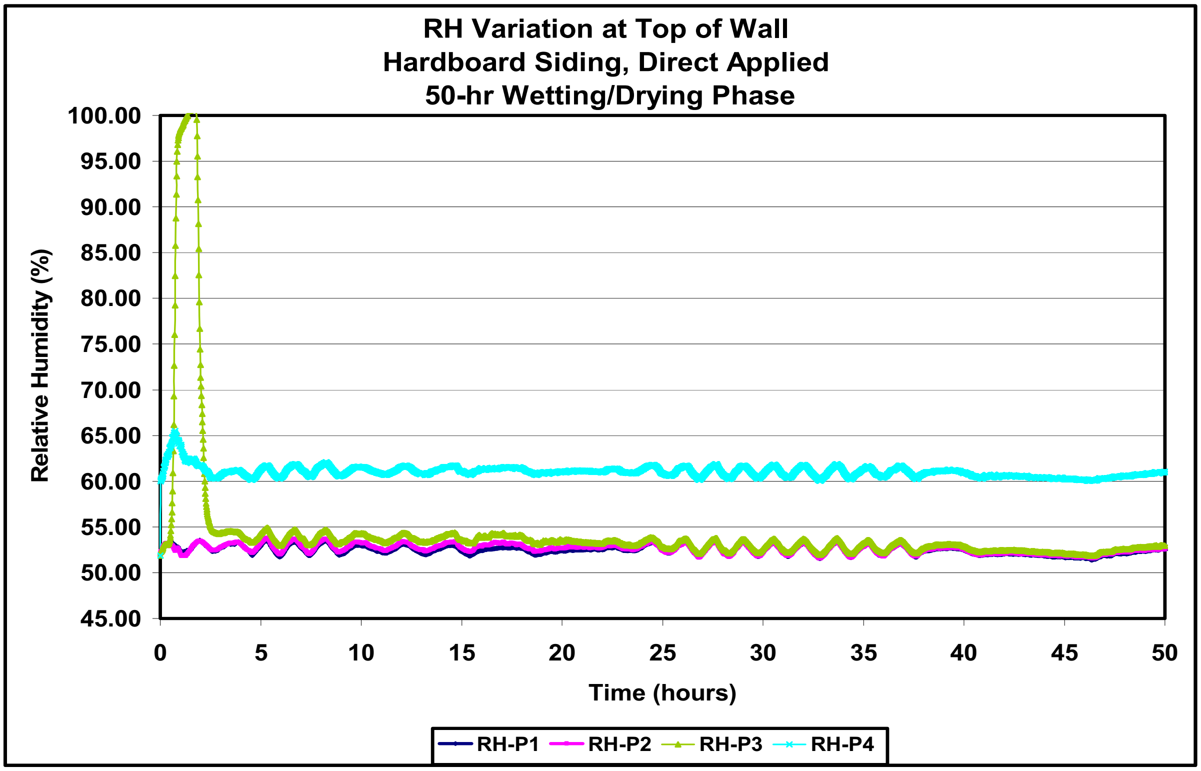


Figure A-IV-15: 50-hr RH&T plots for siding H1-DA



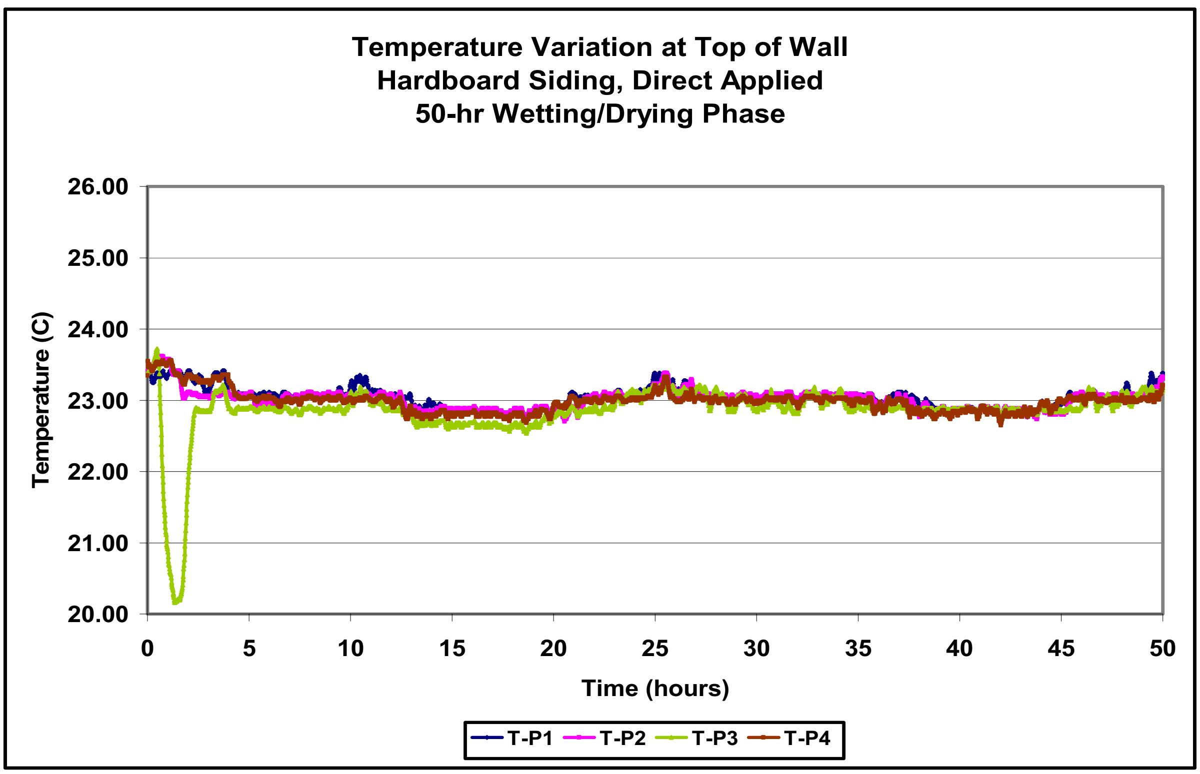
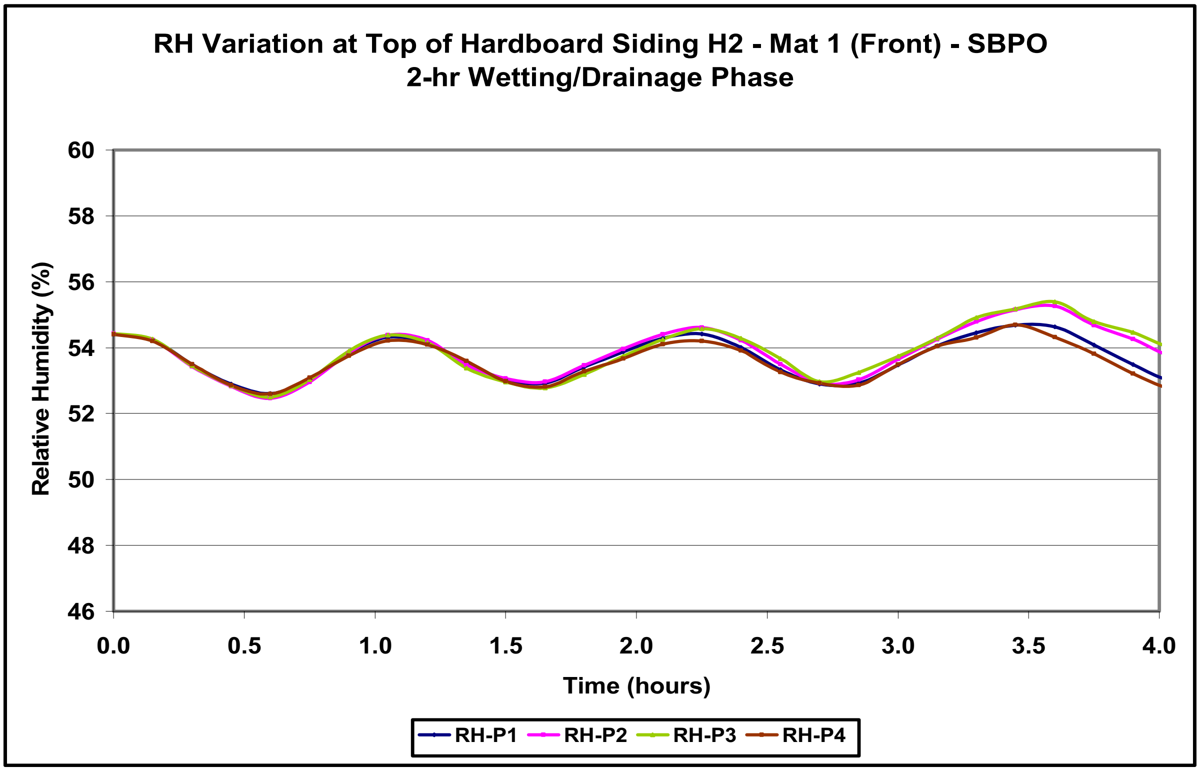


Figure A-IV-16: 50-hr RH&T plots for siding H1-DA (Retest)



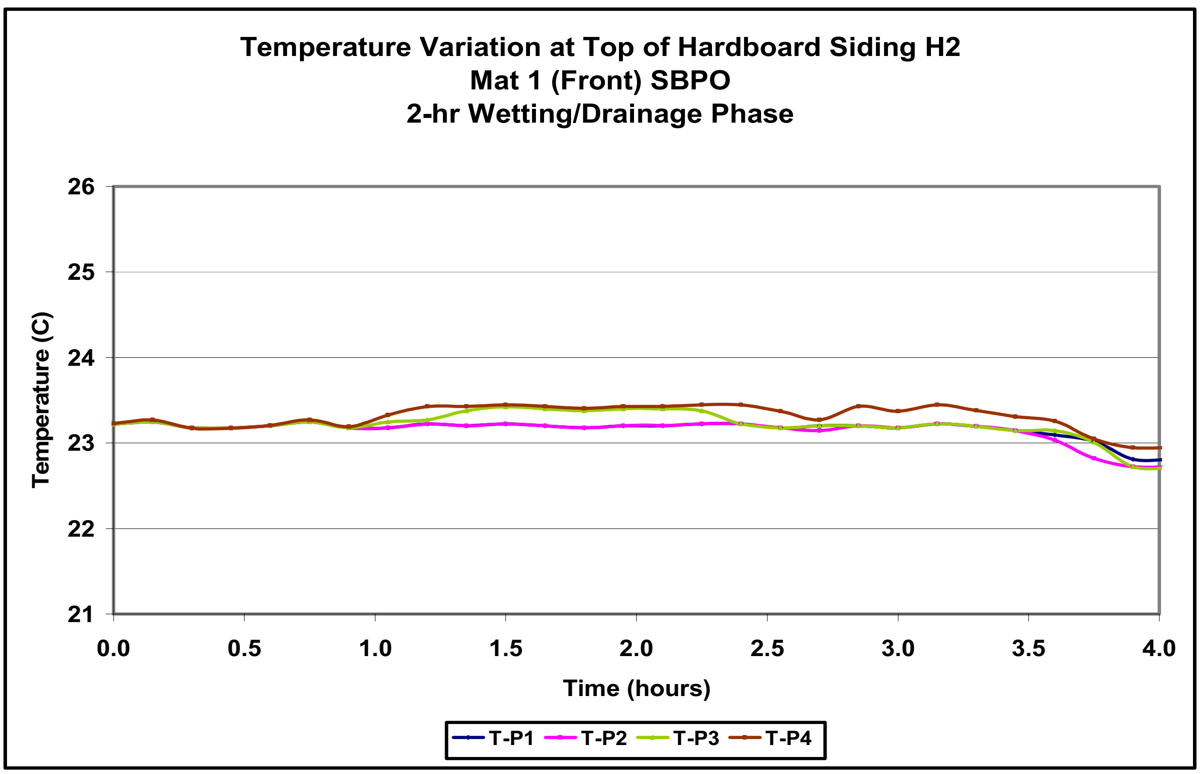
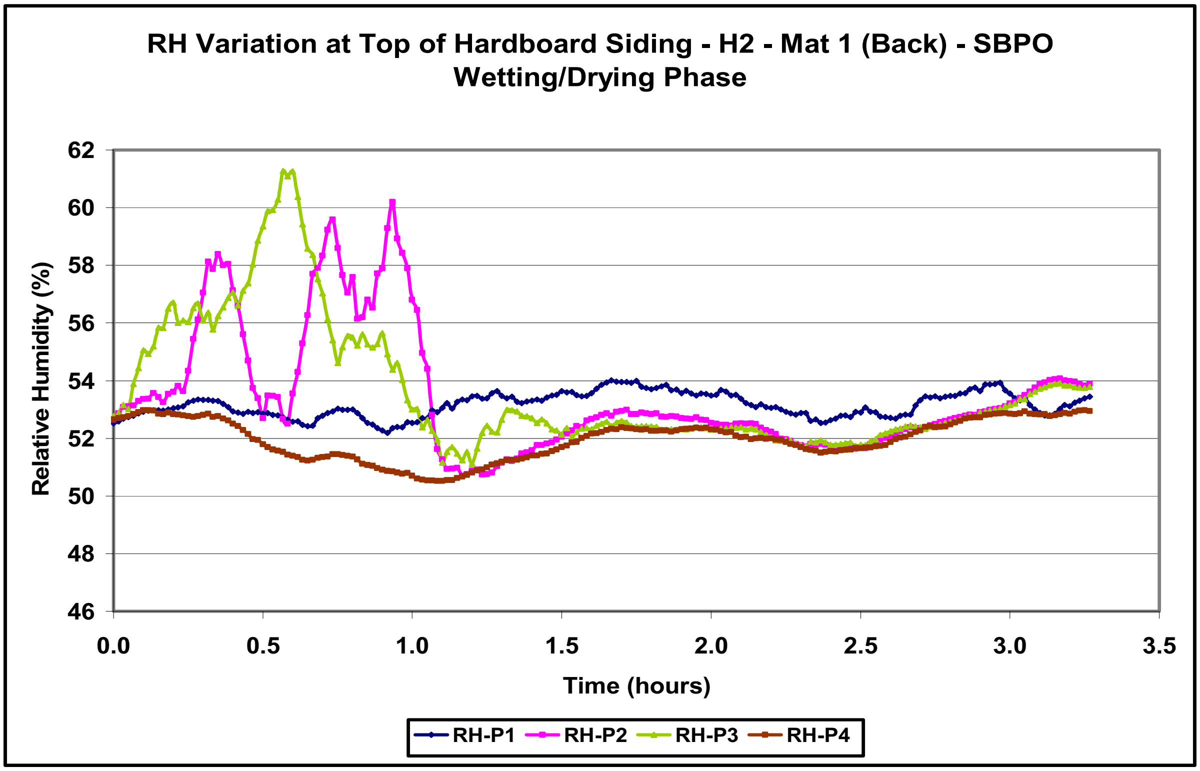


Figure A-IV-17: RH&T plots for siding H2-Mat 1-Front during wetting/drainage.



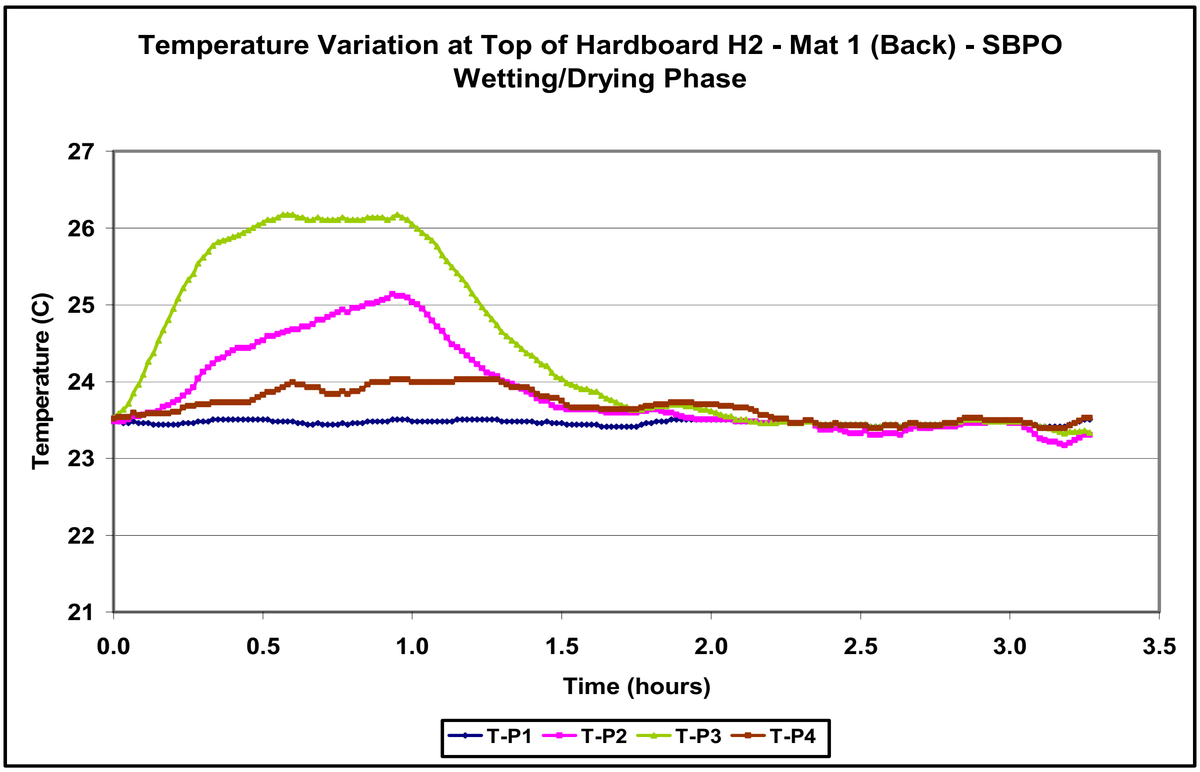
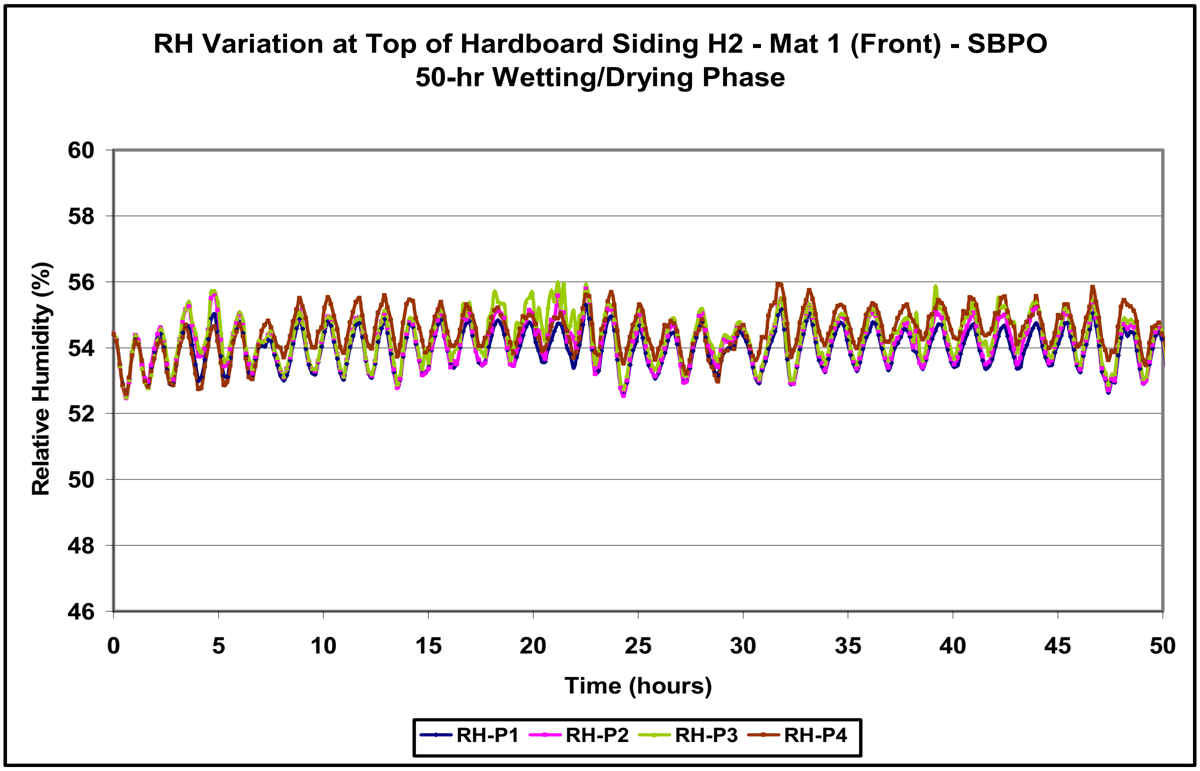


Figure A-IV-18: RH&T plots for siding H2-Mat 1-Back during wetting/draining.



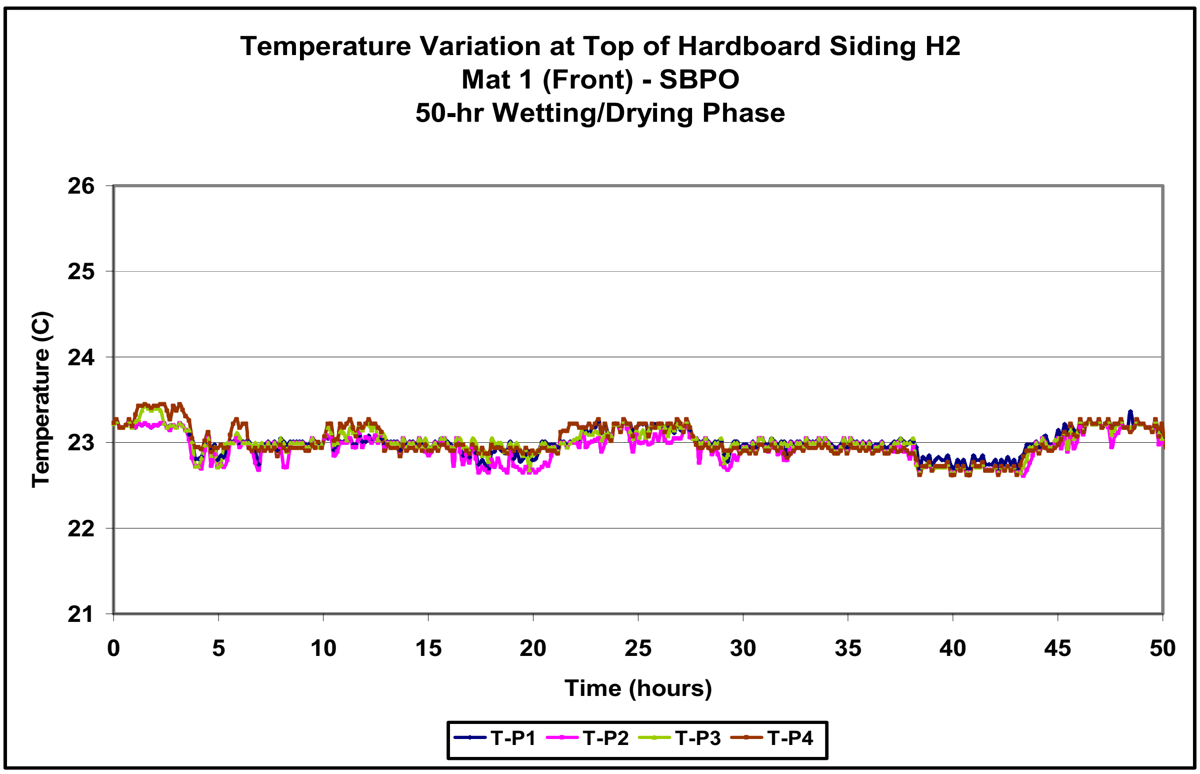
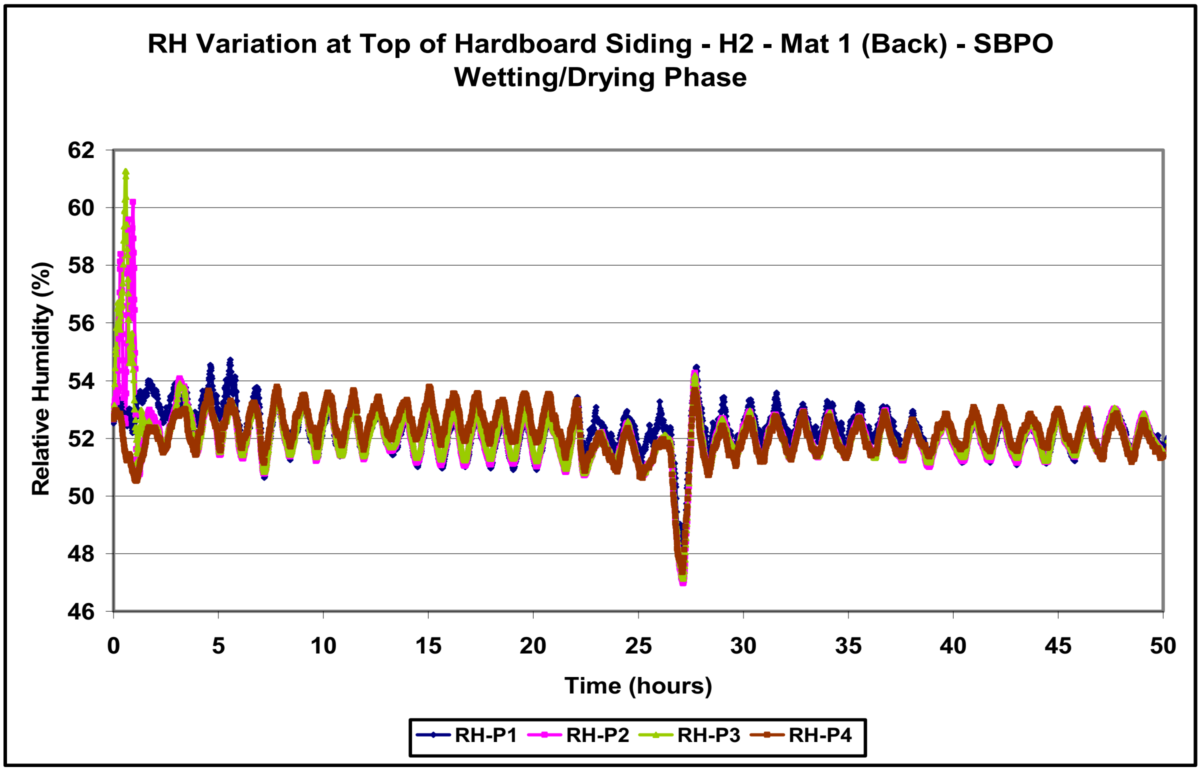


Figure A-IV-19: 50-hr RH&T plots for siding H2-Mat 1-Front.



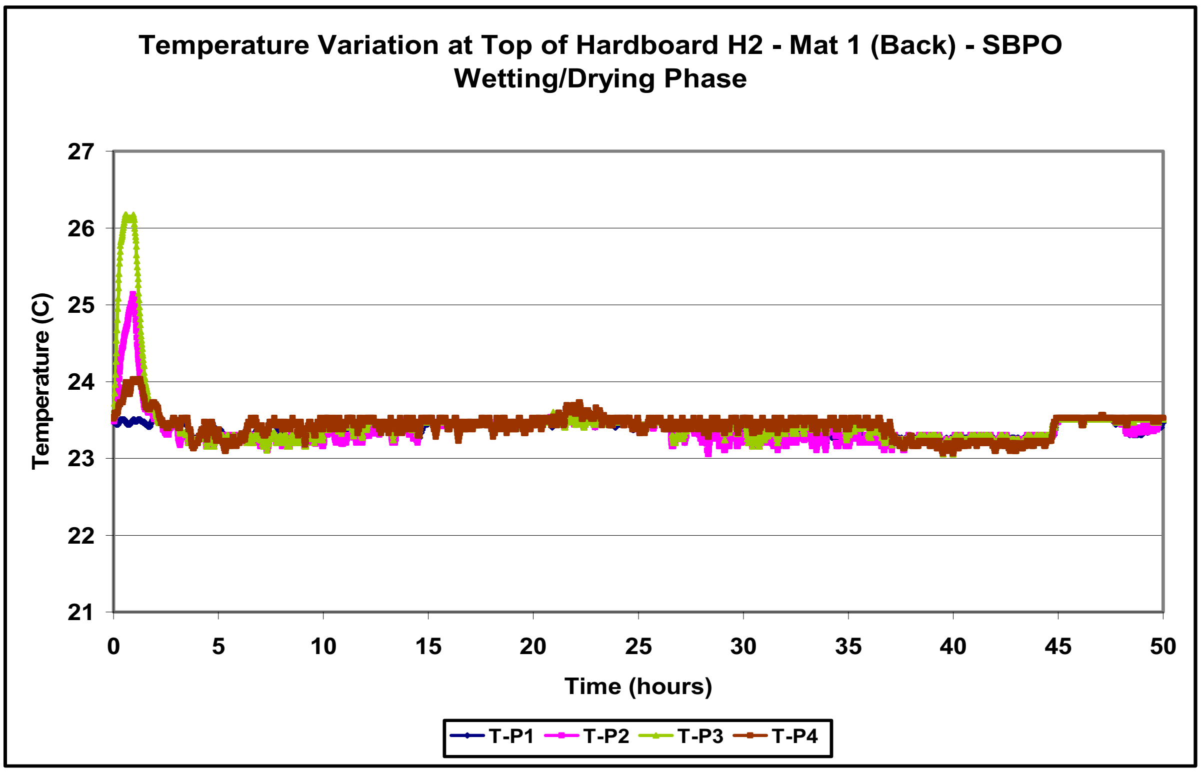
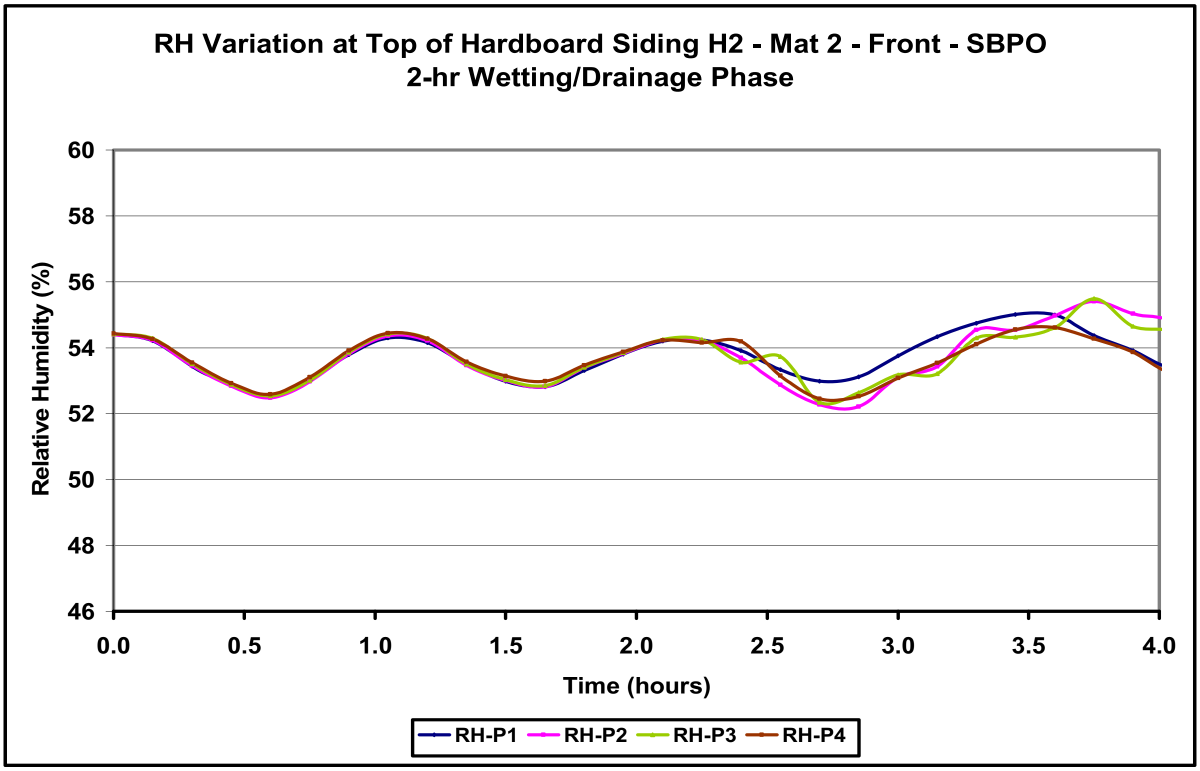


Figure A-IV-20: 50-hr RH&T plots for siding H2-Mat 1-Back.



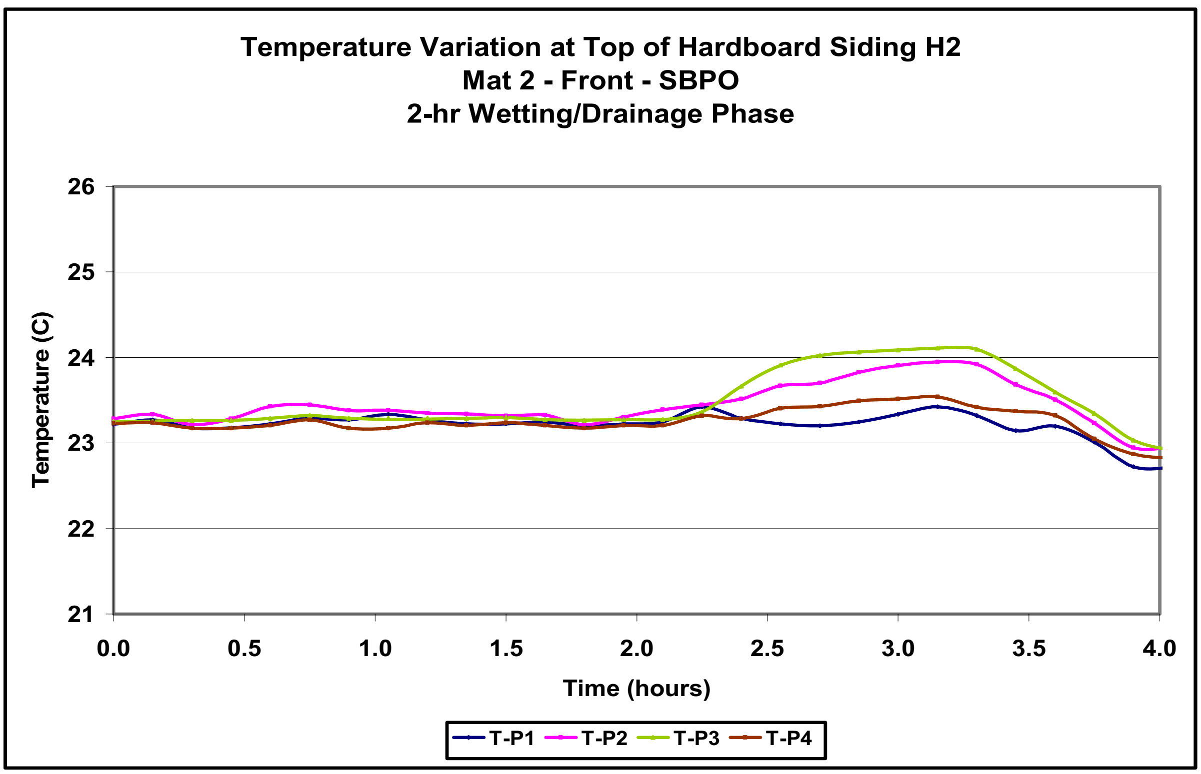
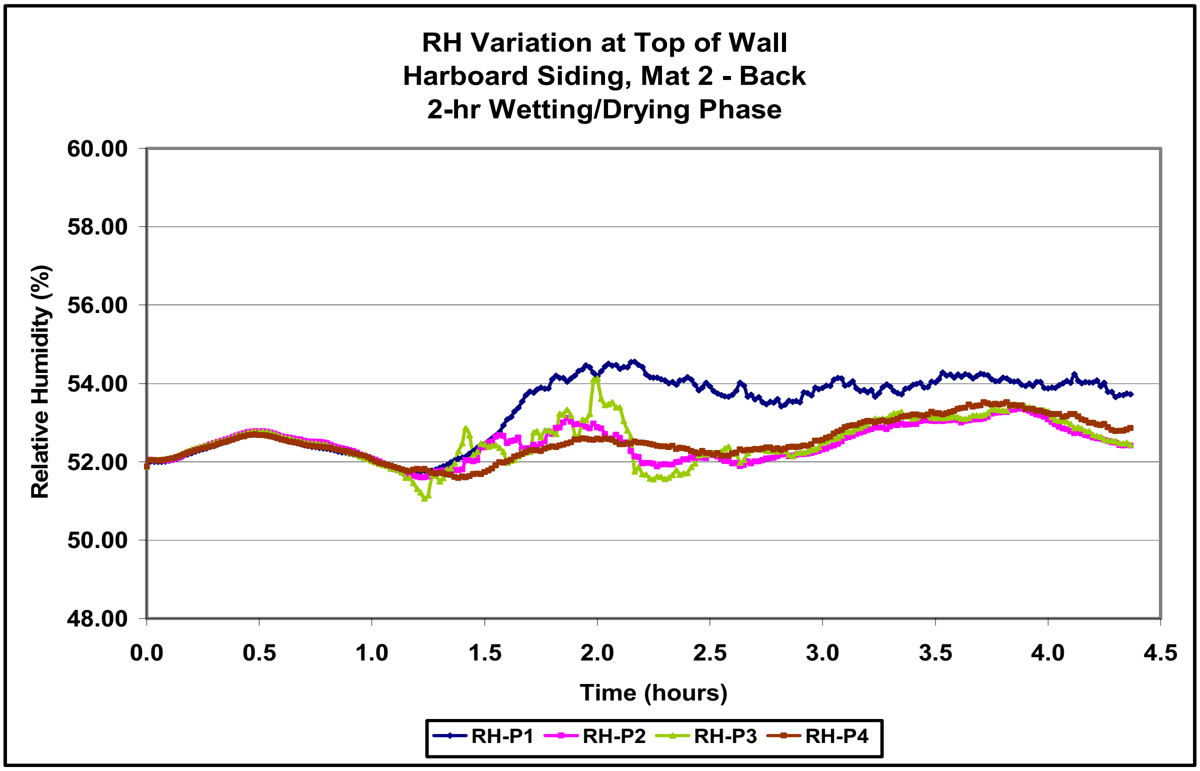


Figure A-IV-21: RH&T plots for siding H2-Mat 2-Front during



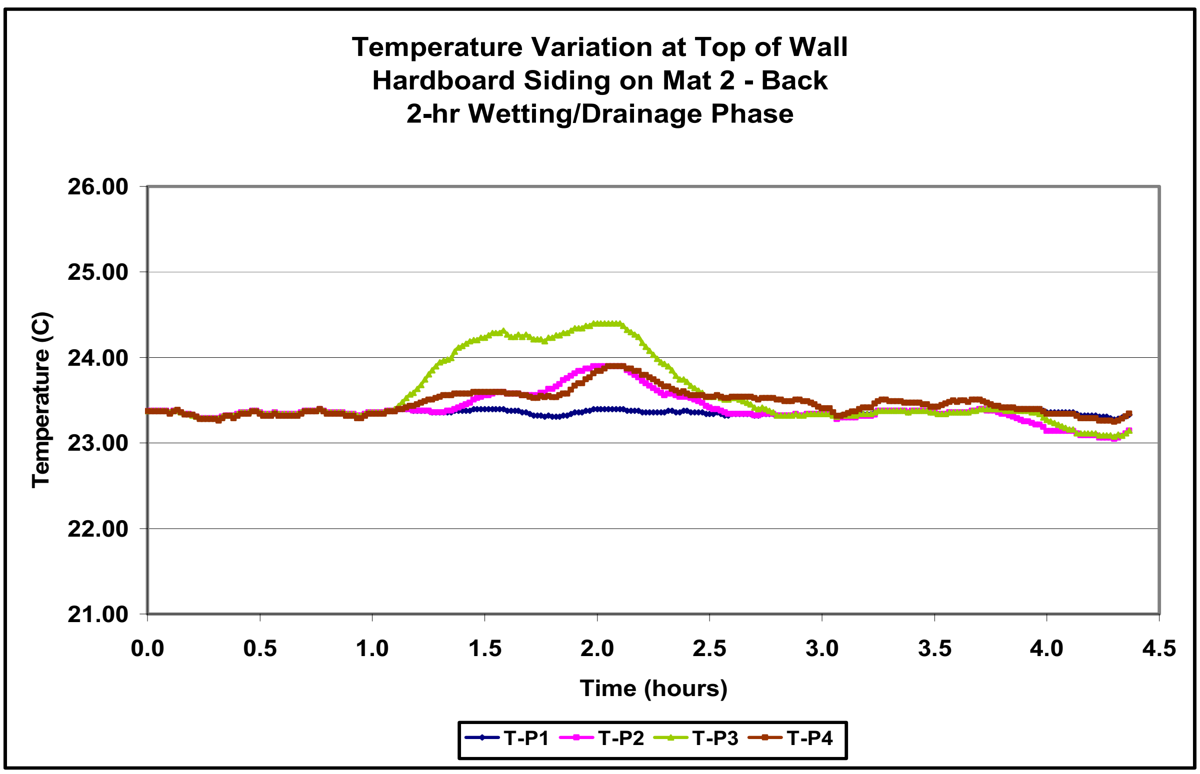
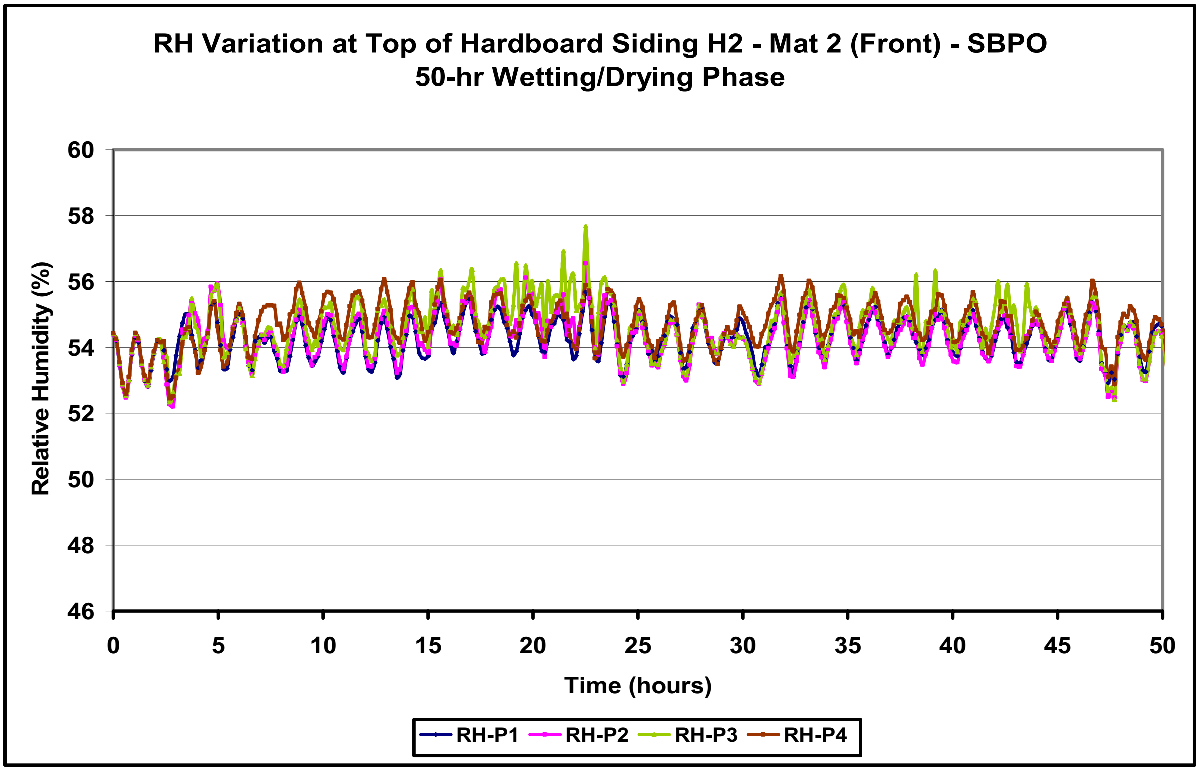


Figure A-IV-22: RH&T plots for siding H2-Mat 2-Back during



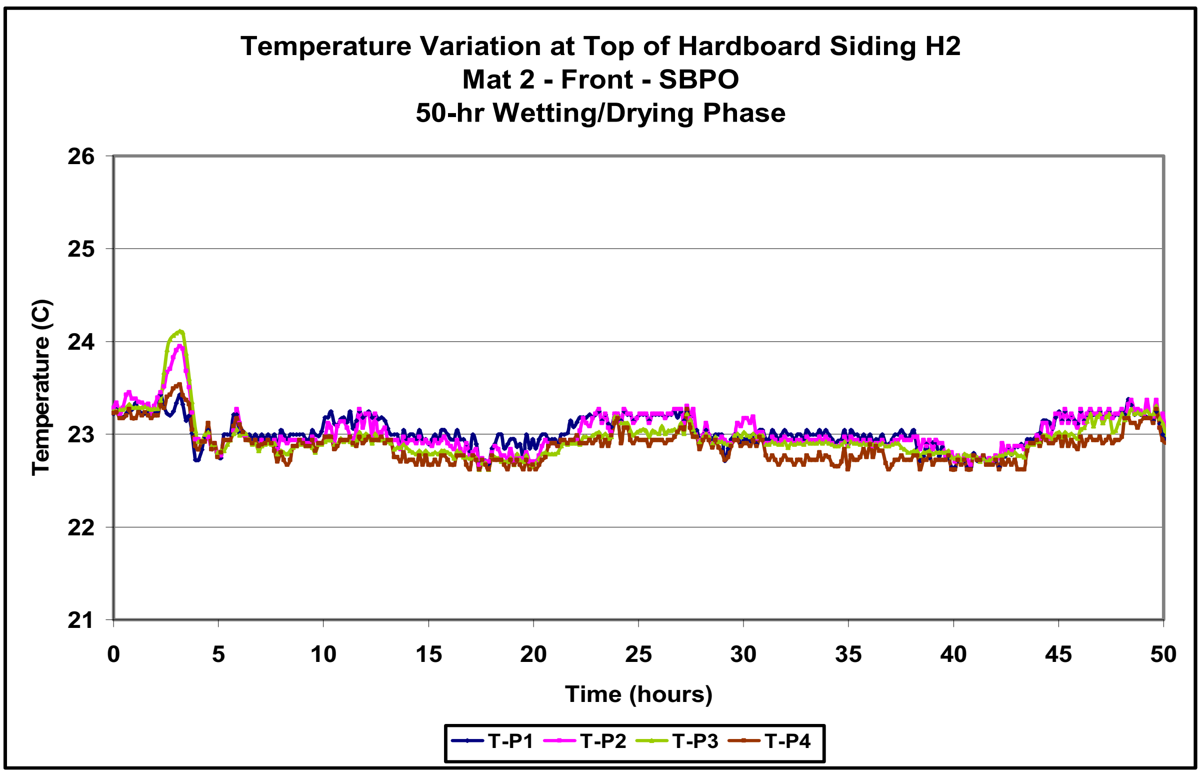
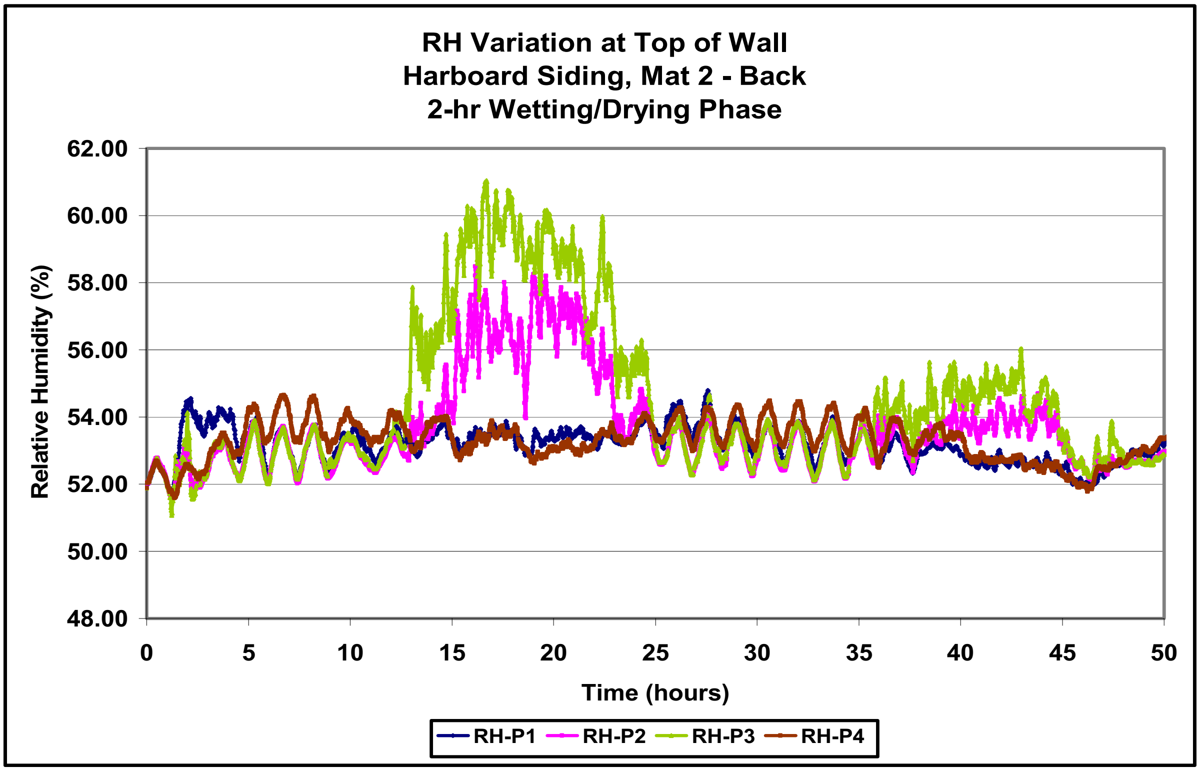


Figure A-IV-23: 50-hr RH&T plots for siding H2-Mat 2-Front



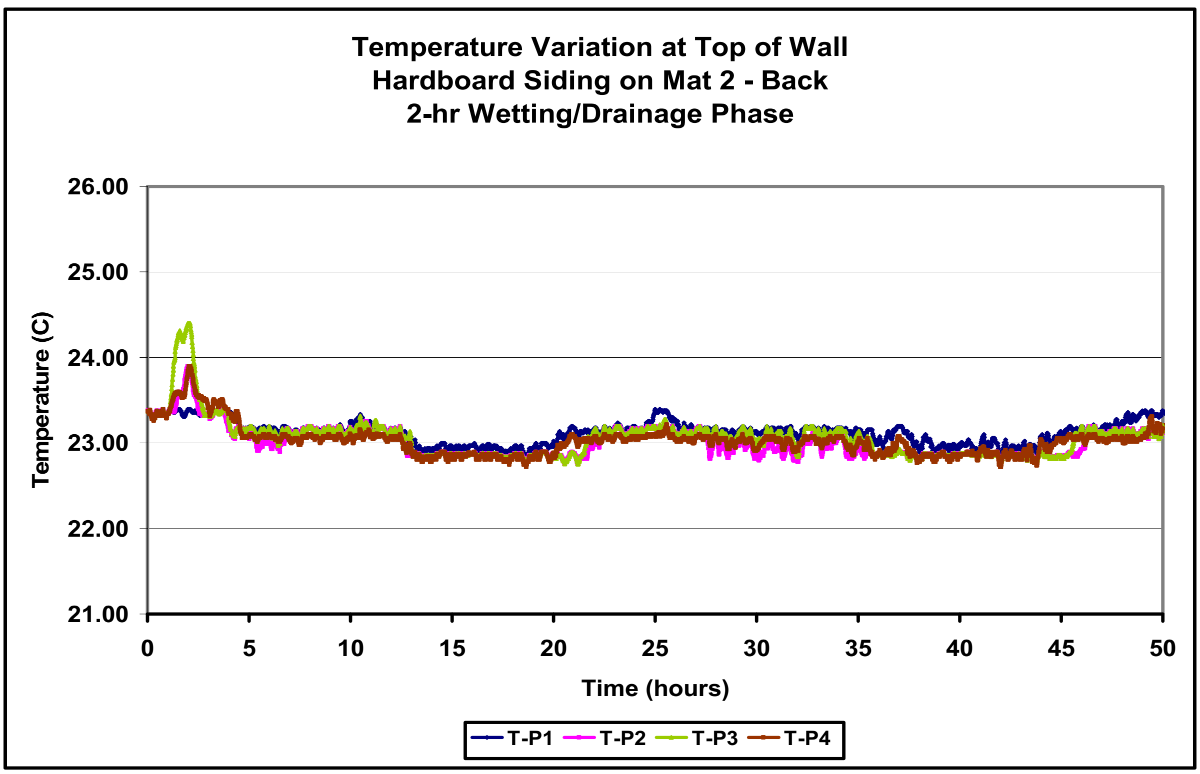
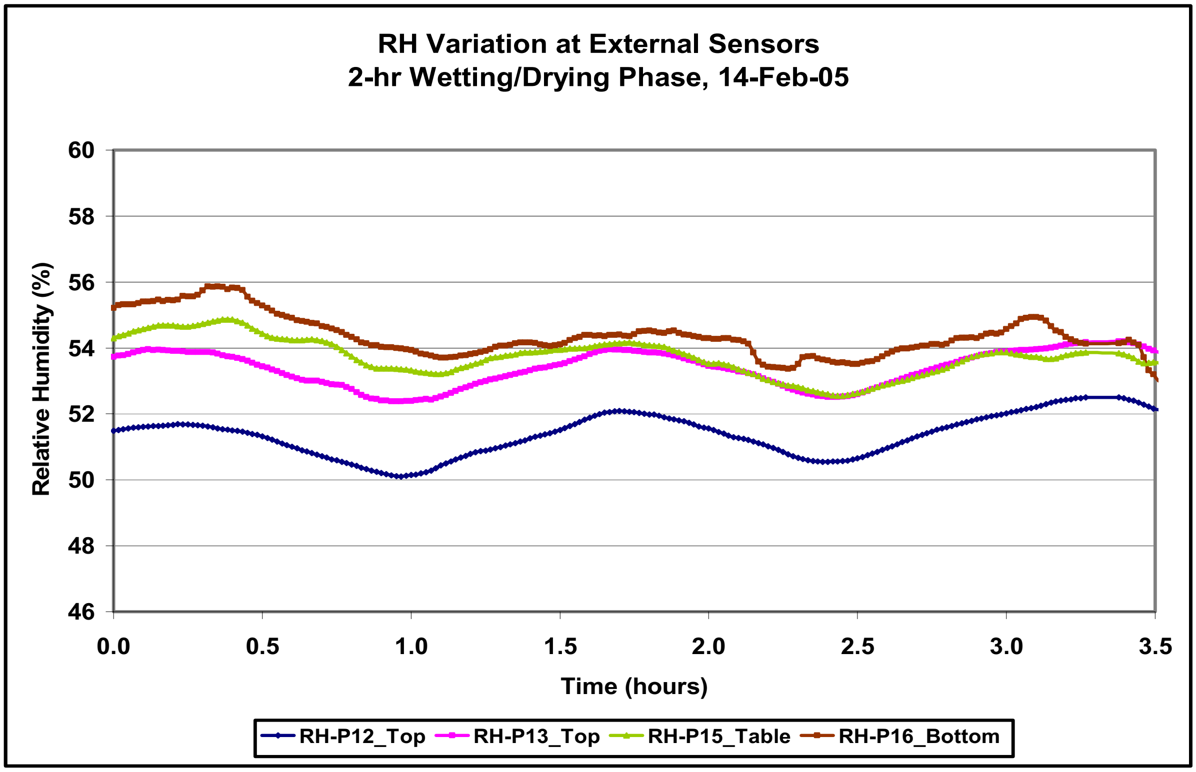


Figure A-IV-24: 50-hr RH&T plots for siding H2-Mat 2- Back



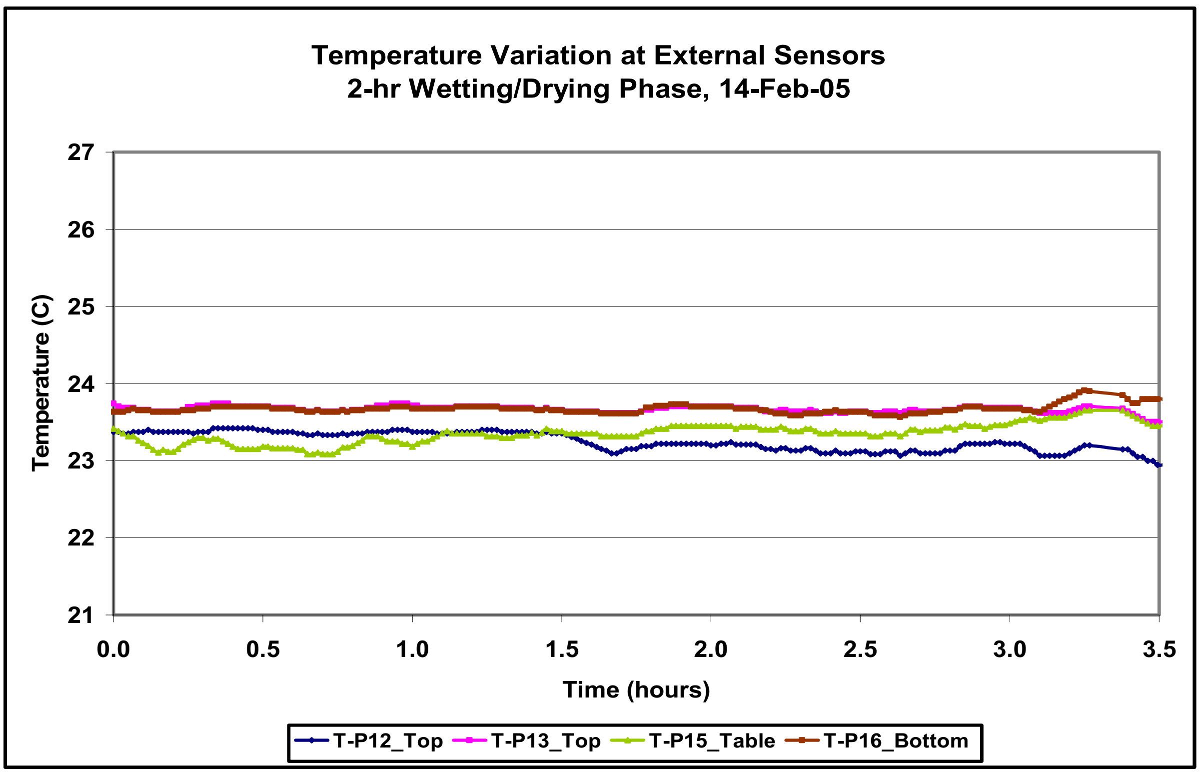


Figure A-IV-25: RH&T plots for external sensors during wetting/drainage test on 14-Feb-05 (corresponding to Figures A-IV-13 and A-IV-18)

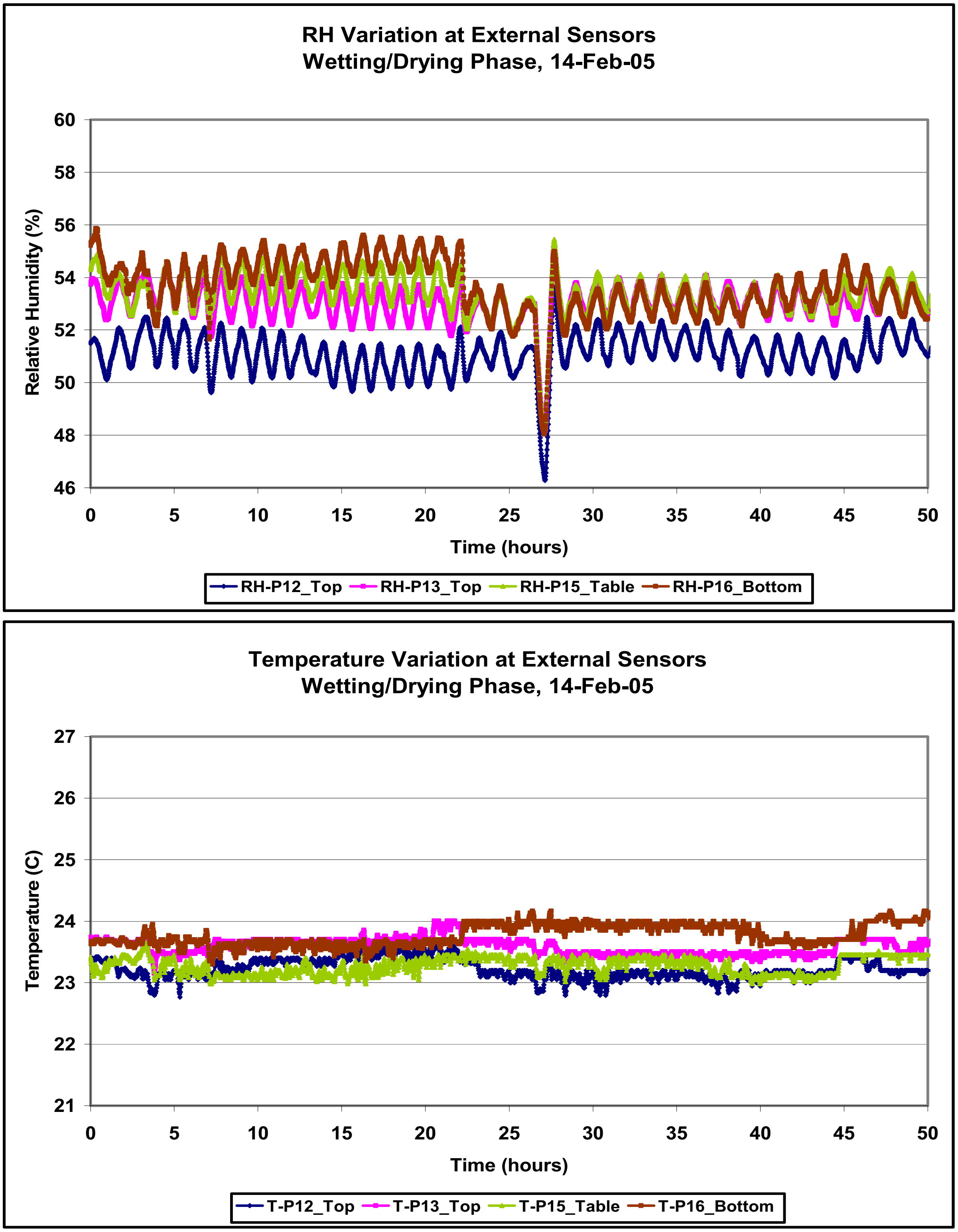
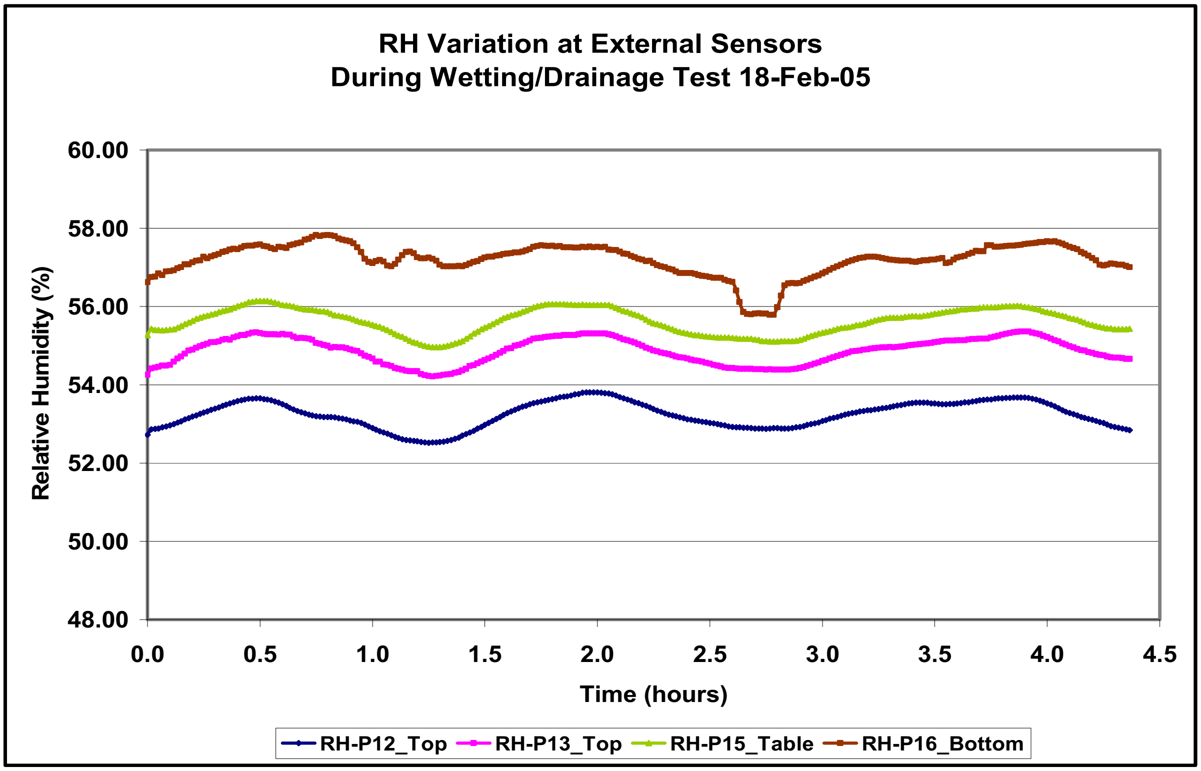


Figure A-IV-26: 50-hr RH&T plots for external sensors during wetting/drying tests on 14-Feb-05 (corresponding to Figure A-IV-14 and A-IV-19)



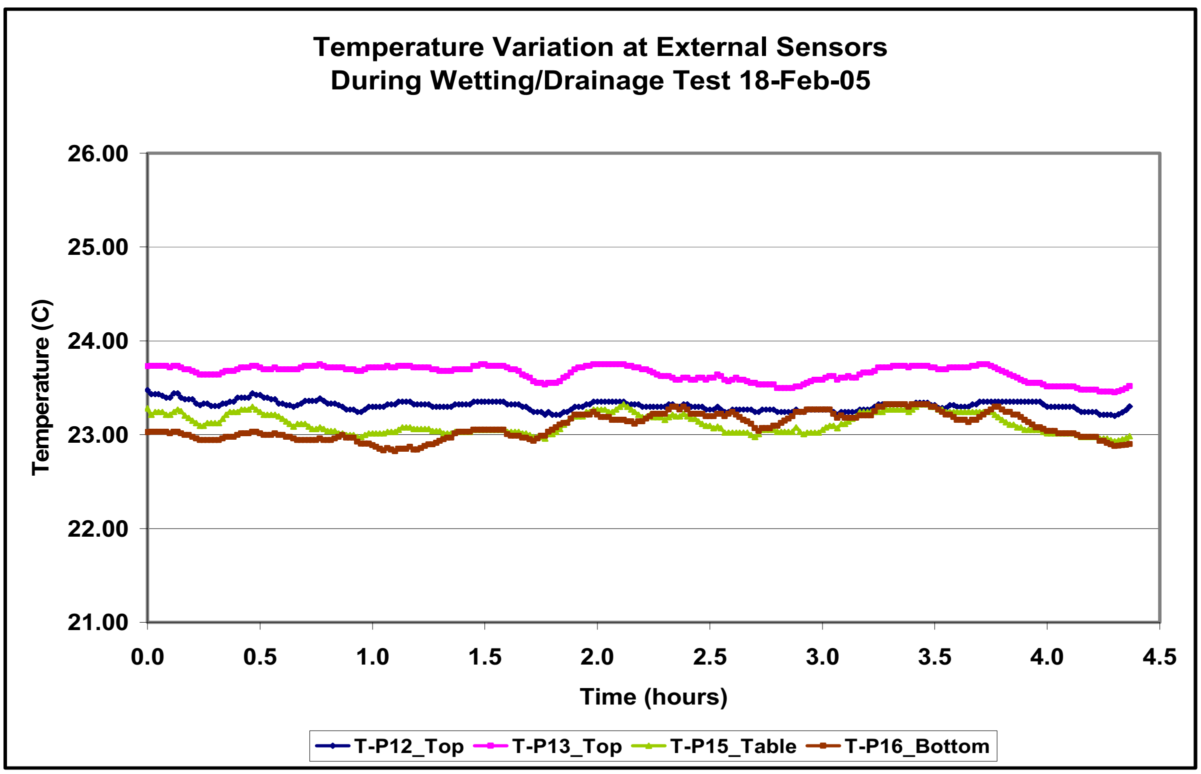
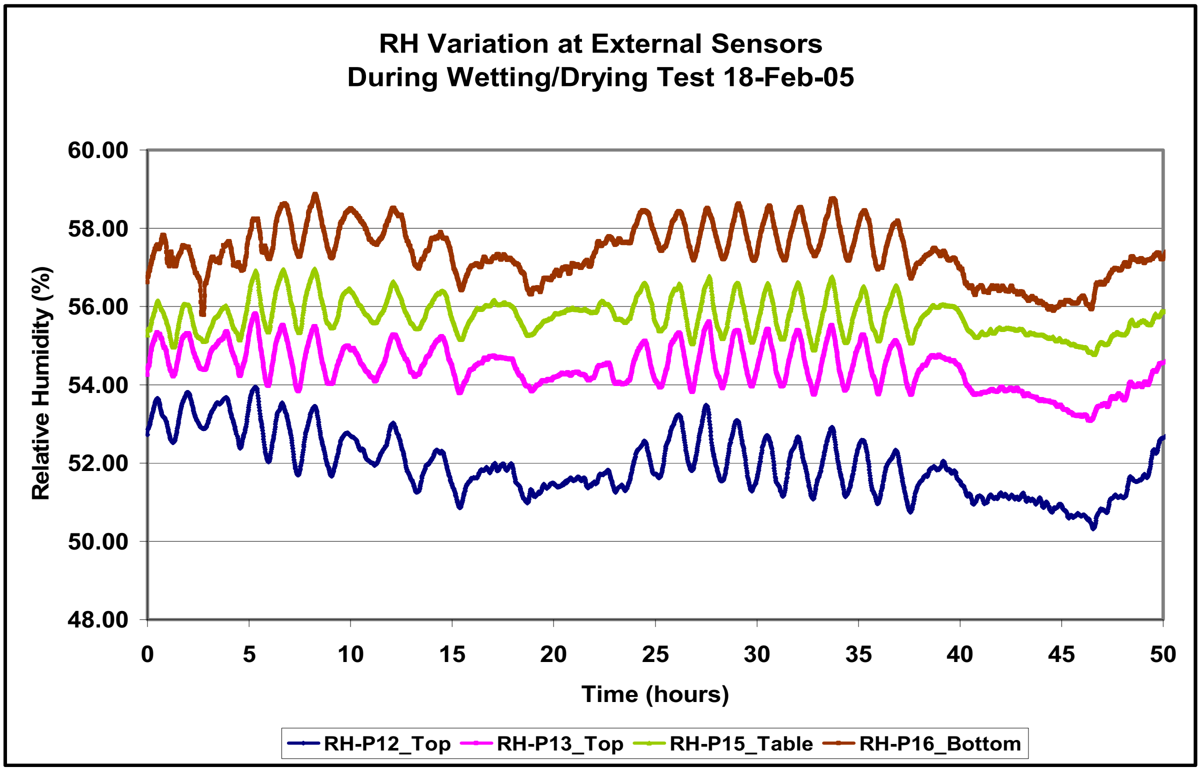


Figure A-IV-27: RH&T plots for external sensors during wetting/drainage test on 18-Feb-05 (corresponding to Figures A-IV-14 and A-IV-22)



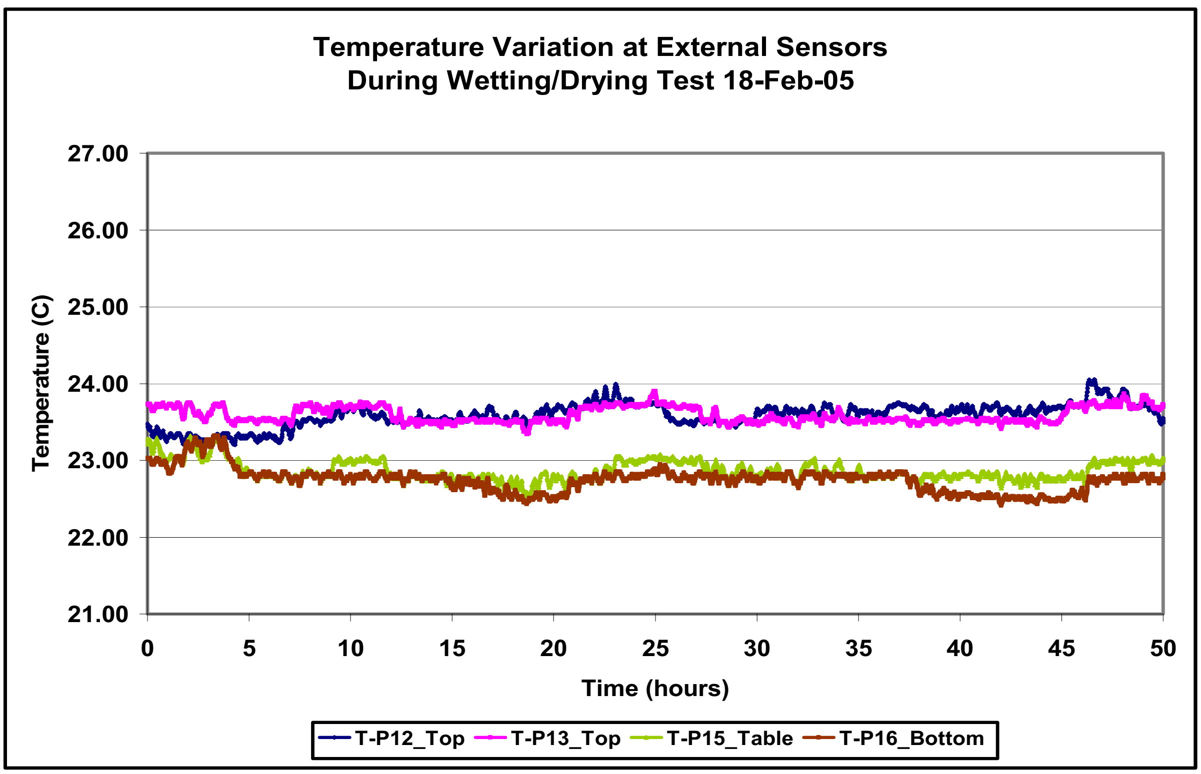
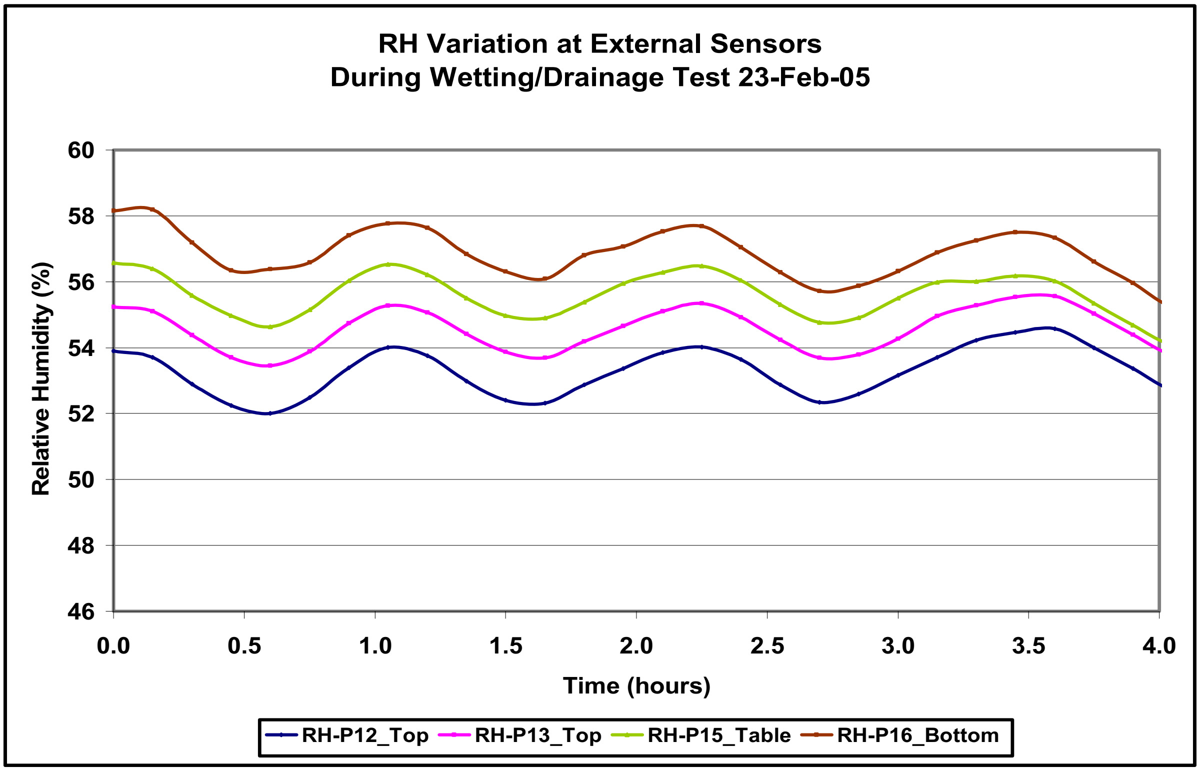


Figure A-IV-28: RH&T plots for external sensors during wetting/drying tests on 18-Feb-05 (corresponding to Figure A-IV-16 and A-IV-24)



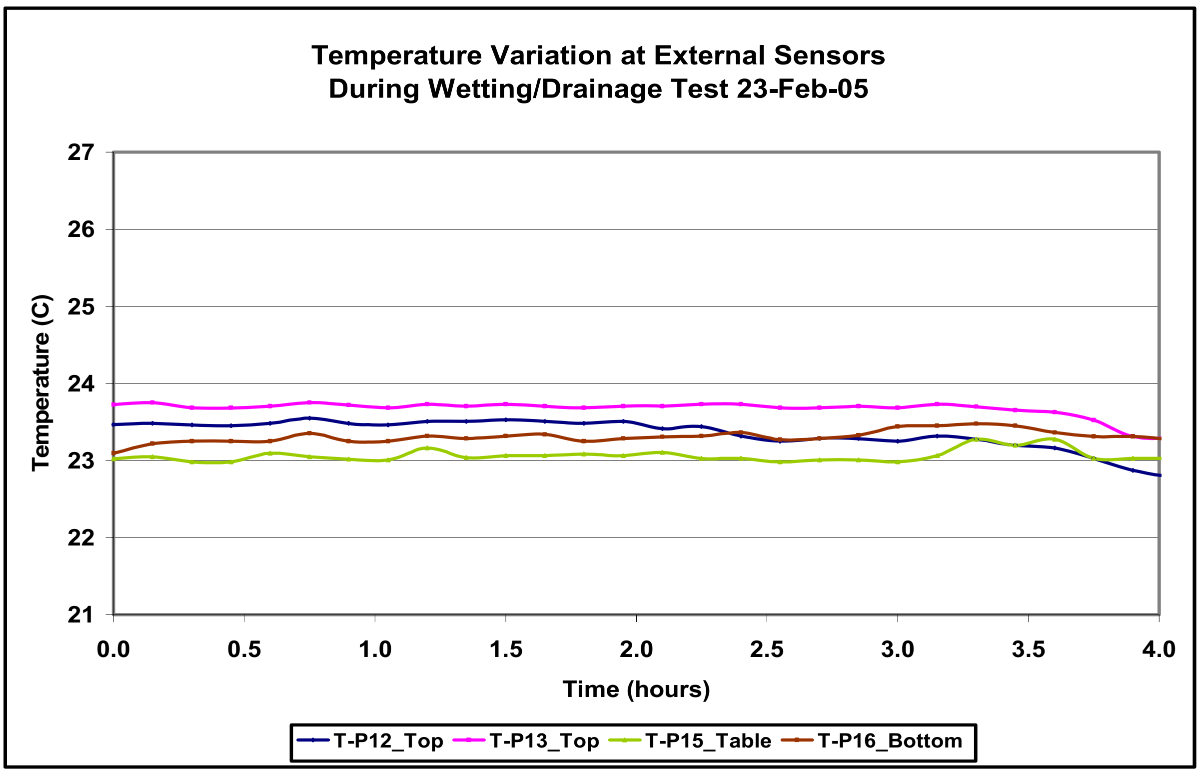
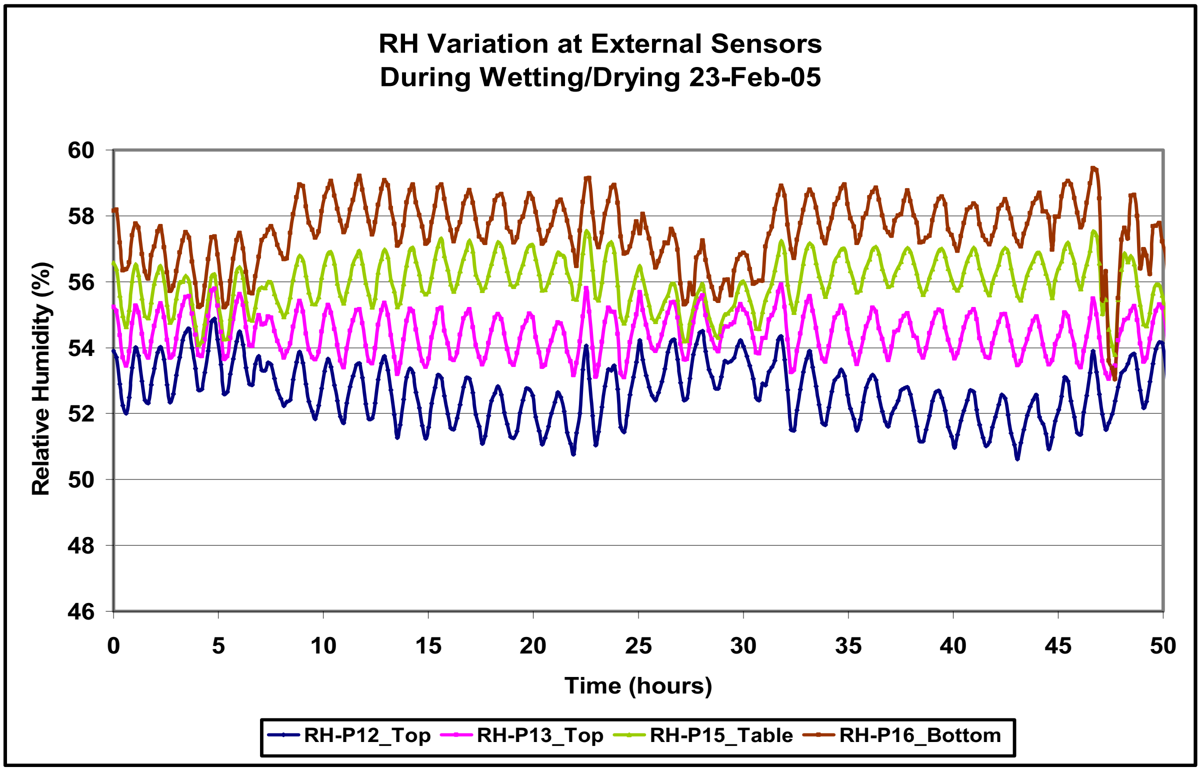


Figure A-IV-29: RH&T plots for external sensors during wetting/drainage test on 23-Feb-05 (corresponding to Figures A-IV-17 and A-IV-21)



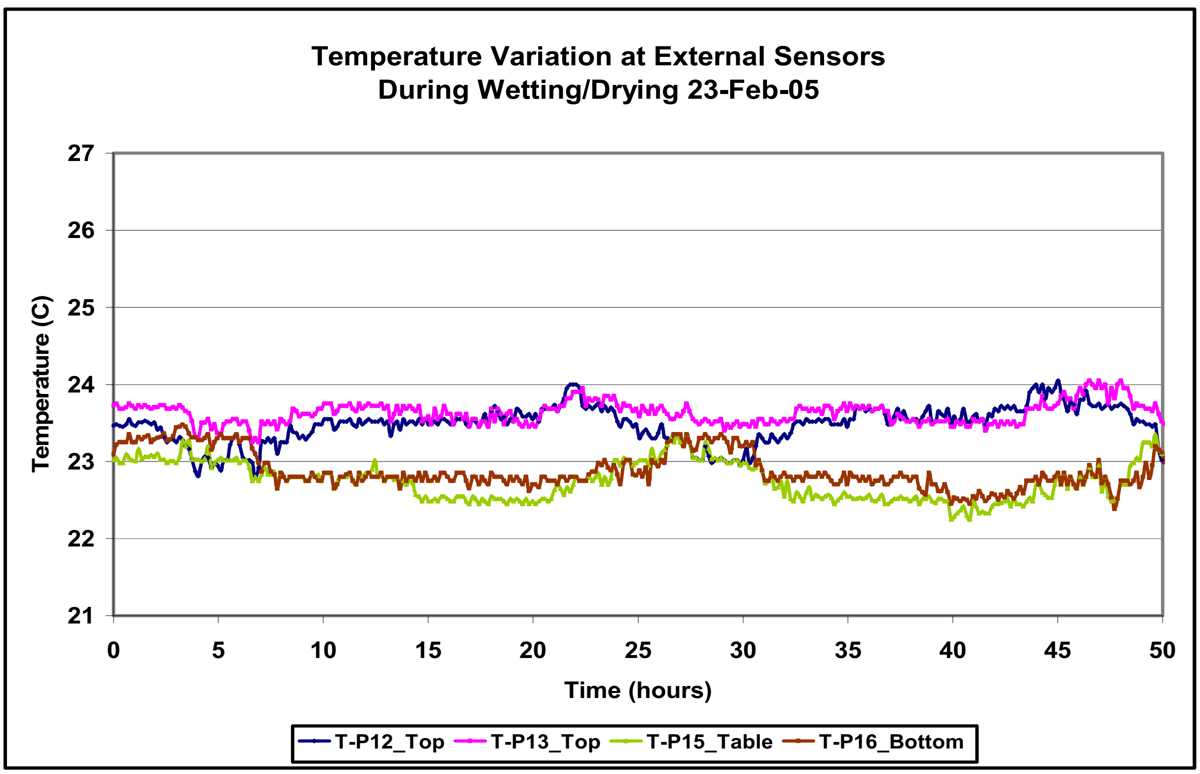


Figure A_IV-30: RH&T plots for external sensors during wetting/drying tests on 23-Feb-05 (corresponding to Figures A-IV-19 and A-IV-23)

APPENDIX V

Data Plots for Wood Siding Tests

Notes to Appendix V – Tests on Walls with Wood Siding

The plots provided in Appendix V are for three cases involving wood siding. Individual plots for the 2-hr wetting/drying phase, and for the combined data consisting of the 2-hr and 48-hr drying period are included.

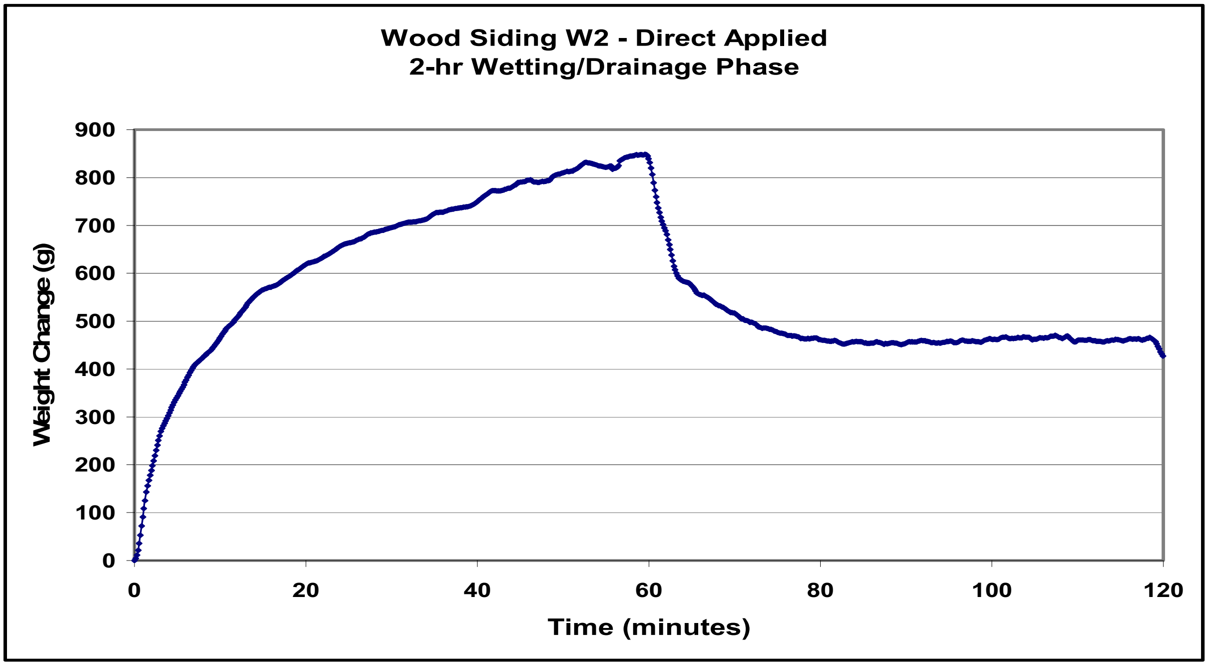
Mapping of moisture content changes have been included for each case. Water was introduced into the middle of the gap provided in the case of the direct-applied siding and the case involving the use of Type 3 mat. In the case of wood siding on batten strips, the water was introduced to the back of the drainage space. The case involving drainage down the back of the siding was omitted. The plots are only qualitative indications of moisture retention and should not be interpreted as representing true moisture content changes in any of the components of the walls.

The plots of Relative Humidity and Temperature variations for each of the 2-hr, and 48-hr periods are all included. The longer term drying periods are generally regular and demonstrate that the fluctuation in background conditions did not have an important effect on the drying of moisture retained in the drainage cavities, nor when the siding was direct-applied.

The identification of test material and types are provided below:
W1 = 6-inch Rabbetted bevel
W2 = 6-inch Shiplap profile with a "V" joint
Mat 3 = CedarSaver™
Battens = 10-mm wood batten strips
DA = Direct Applied
SBPO = Spun Bonded Polyolefin WRB
BP = Building Paper (paper based) WRB
Front = trickling of water down front of drainage cavity (on the back of the siding)
Back = trickling of water down back of drainage cavity (on the back of the WRB)

Table A-V-1: Index of data plots for wood siding wall tests.

Data Form	Page	Figure A-V	2hr W/D	48hr W/D	Mat/DA	Front Trickle	Back Trickle
Drainage	63	1	W2		DA		
				W2	DA		
	64	2	W1		M3		
				W1	M3		
	65	3	W2		Battens		√
				W2	Battens		√
Moisture Mapping	66	4		W2	DA		
	67	5		W1	M3		
	68	6		W2	Battens		√
RH&T	69	7	W2		DA		
	70	8		W2	DA		
	71	9	W1		M3		
	72	10		W1	M3		
	73	11	W2		Battens		√
	74	12		W2	Battens		√
External Conditions	75	13	√		W2-DA + W1-Mat 3 + W2-Battens		
	76	14		√			



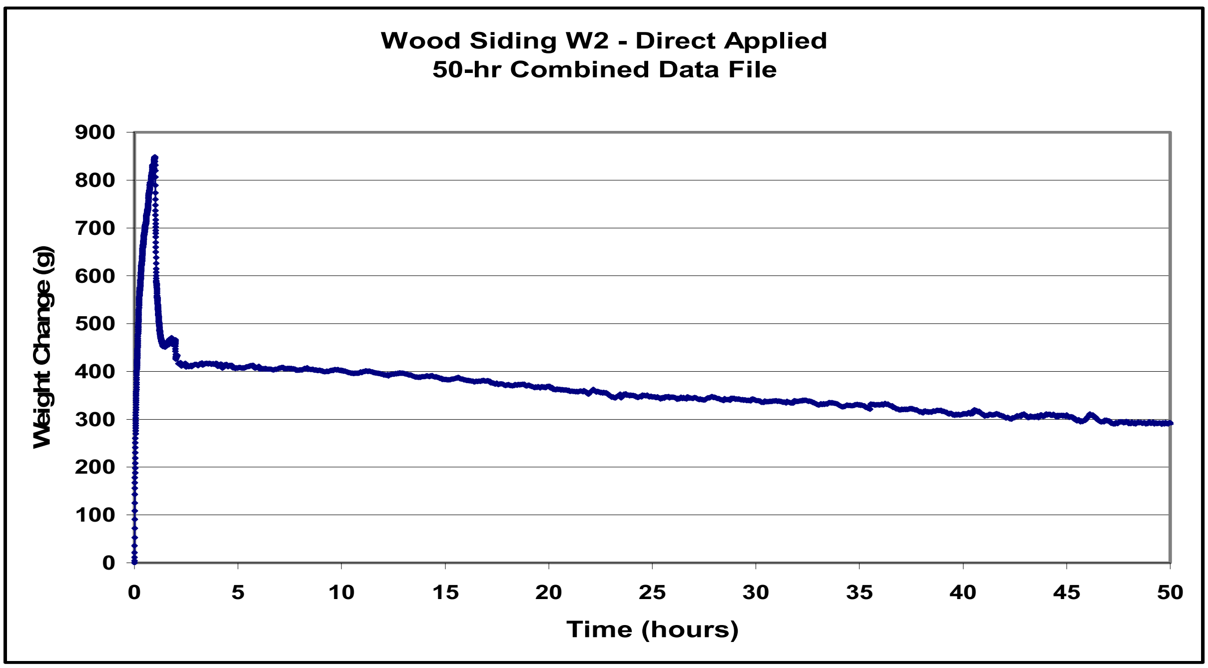


Figure A-V-1: Wetting/Drainage test on wood siding, Profile 2 wood siding direct-applied to the base wall showing both the 2-hr test period and the combined 50-hr period.

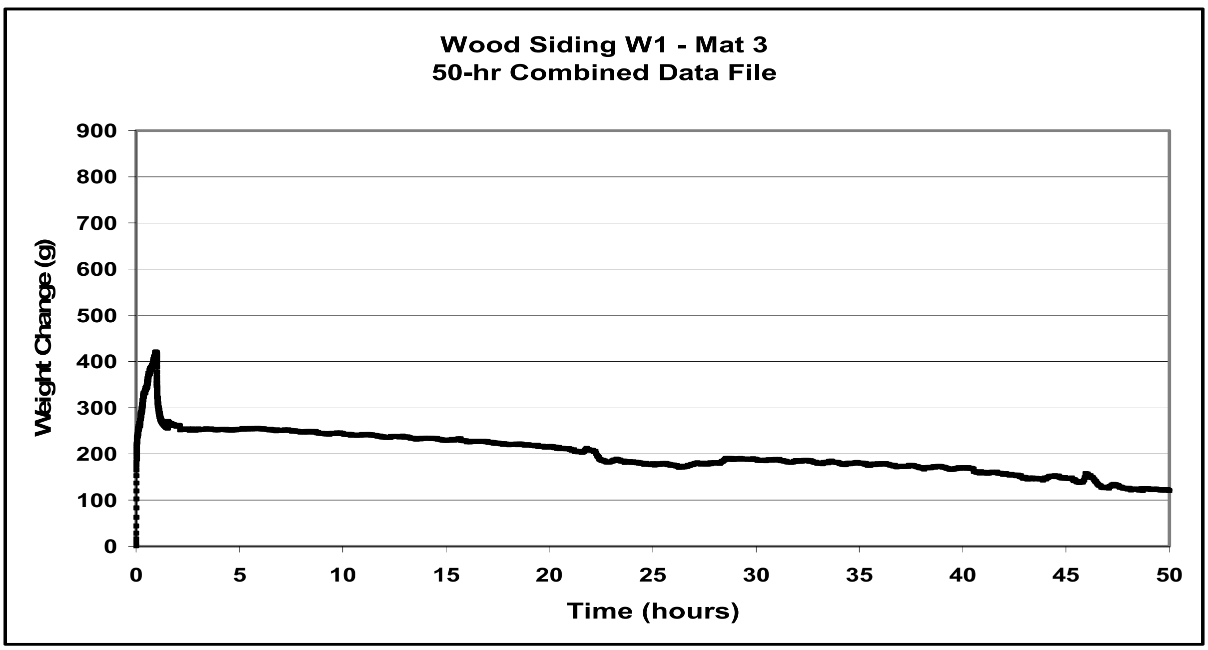
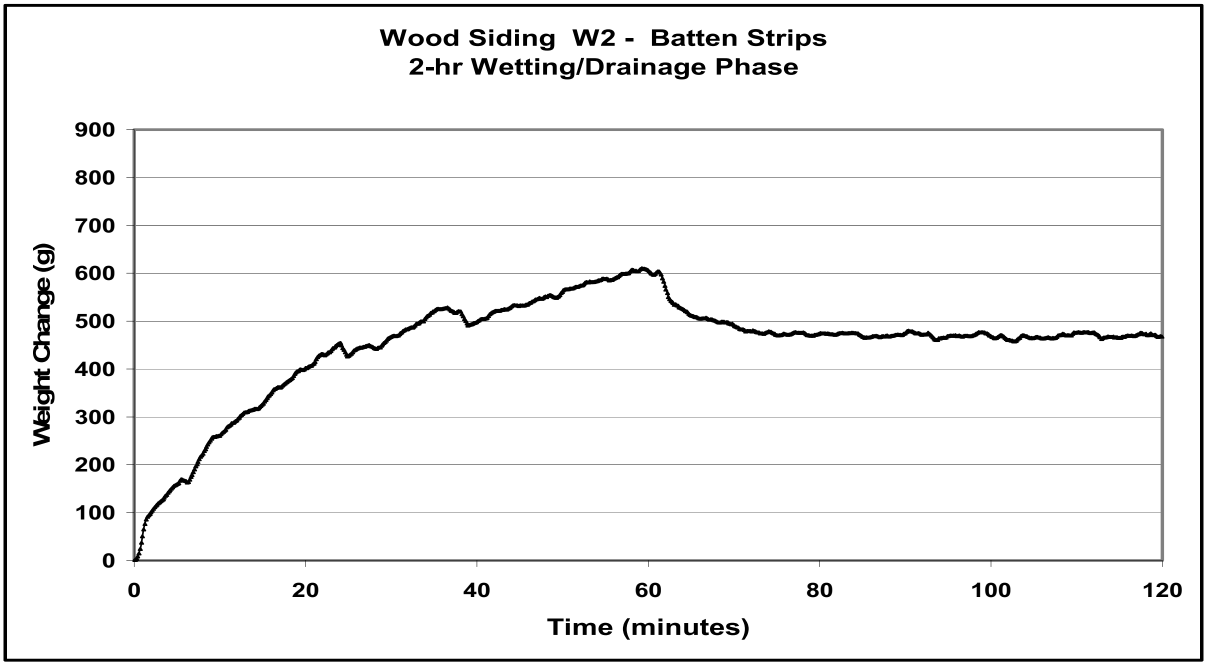


Figure A-V-2: Wetting/Drainage test on wood siding, Profile 1 wood siding applied to a drainage mat (Mat 3) showing both the 2-hr test period and the combined 50-hr period.



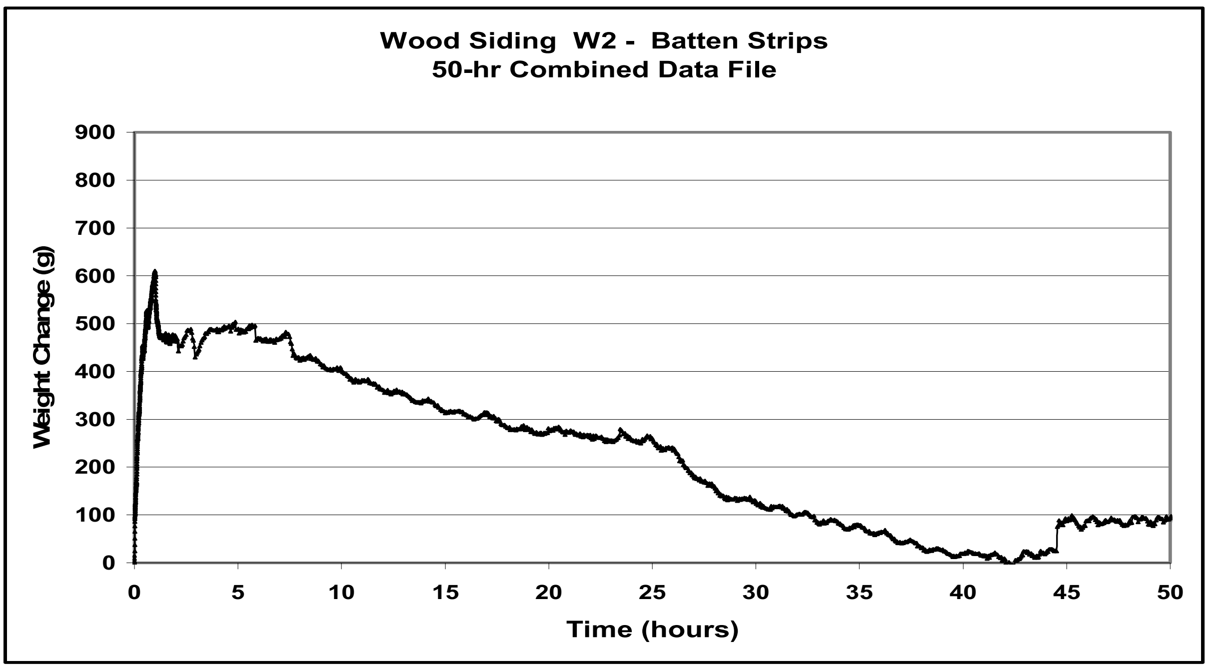


Figure A-V-3: Wetting/Drainage test on wood siding, Profile 2 wood siding applied to 10-mm wood batten strips located opposite studs showing both the 2-hr test period and the combined 50-hr period.

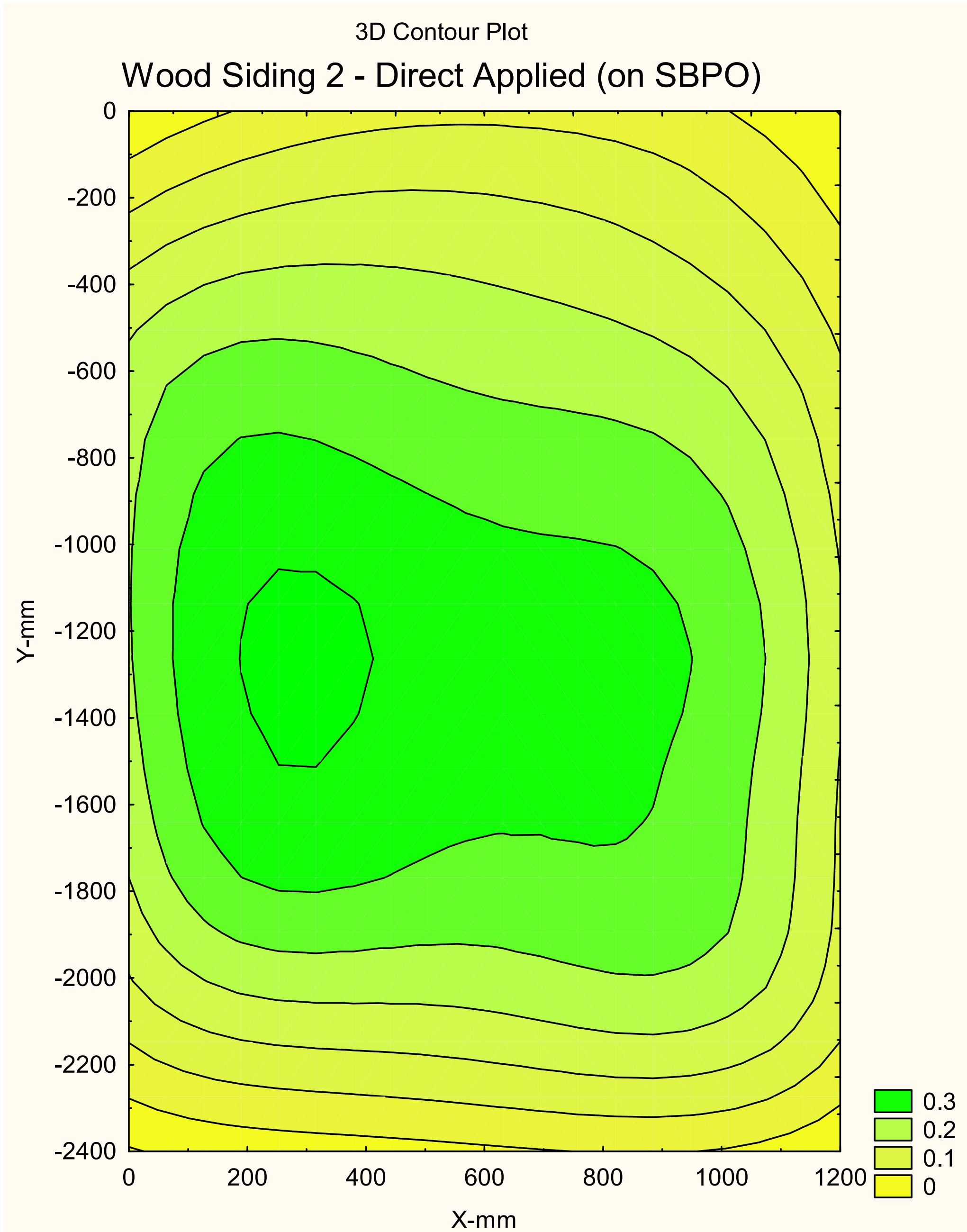


Figure A-V-4: Moisture difference contour map at the end of the 50-hr test period for Profile 2 wood siding direct-applied to the base wall.

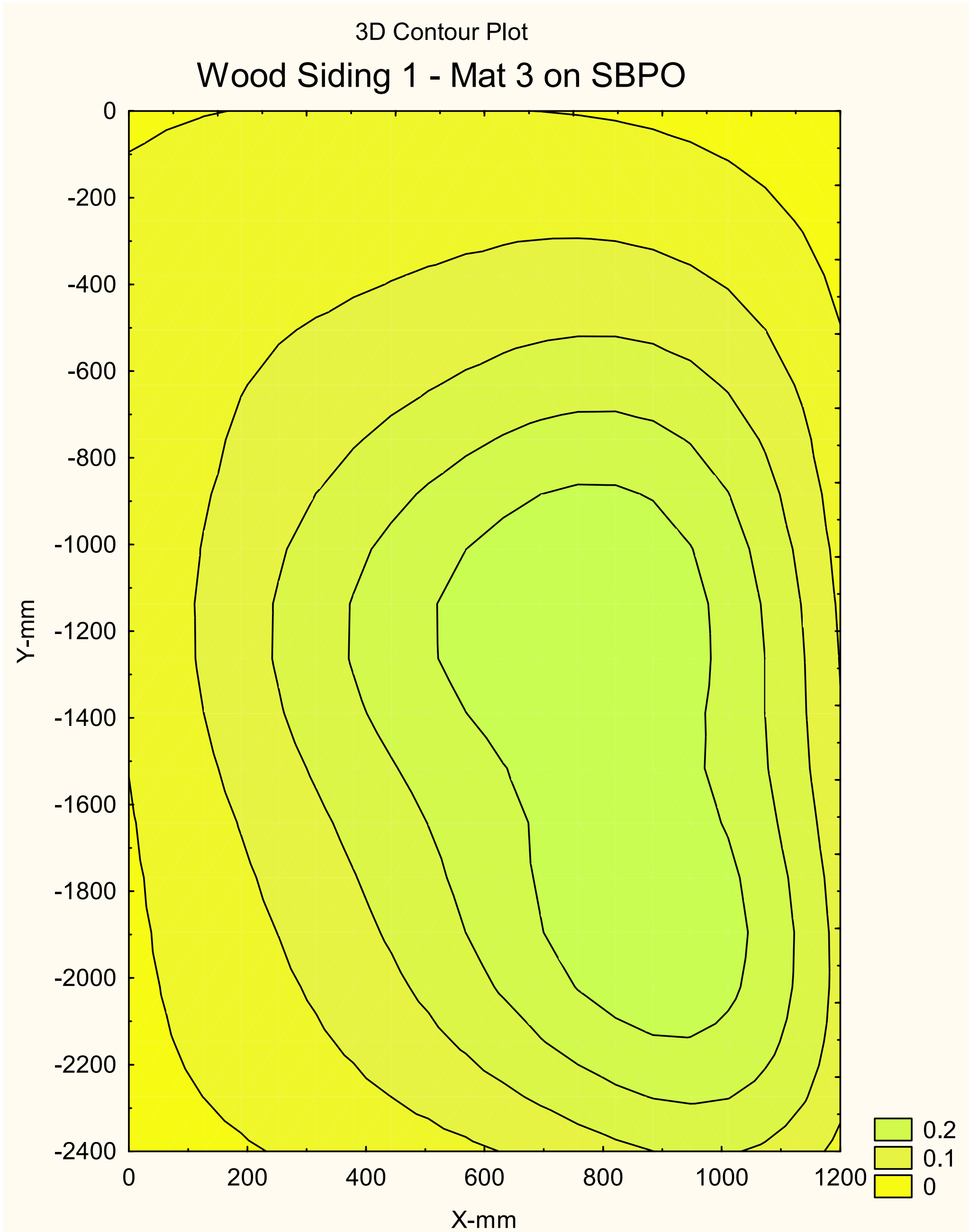


Figure A-V-5: Moisture difference contour map at the end of the 50-hr test period for Profile 1 wood siding applied on a drainage mat (Mat 3).

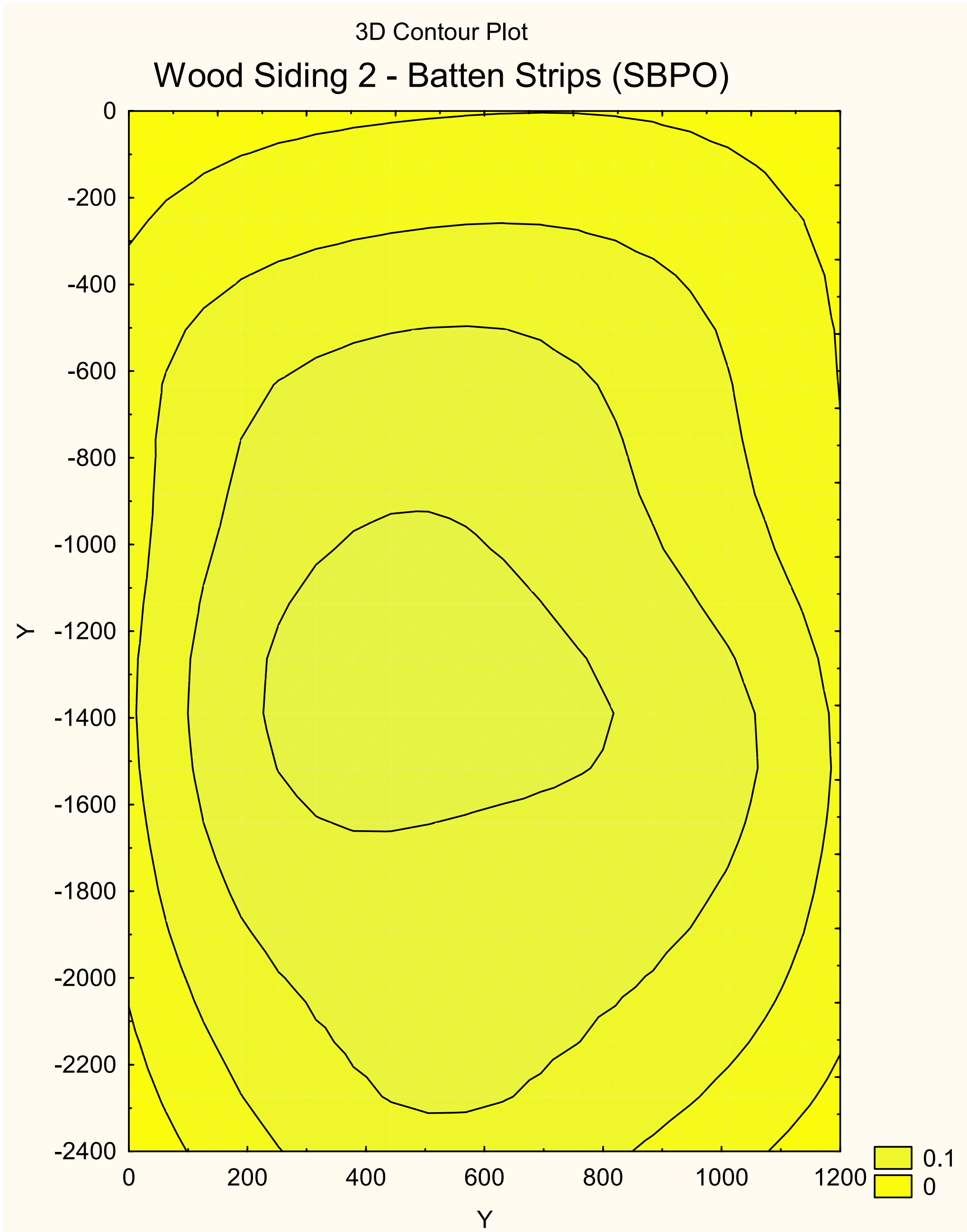
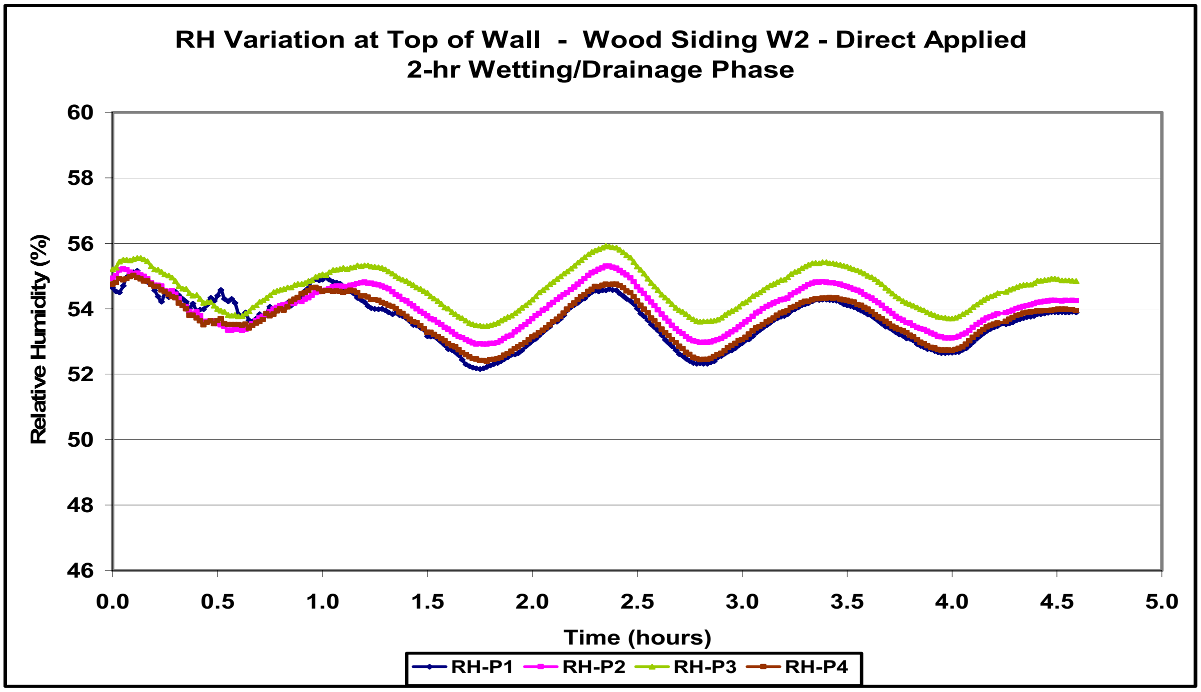


Figure A-V-6: Moisture difference contour map at the end of the 50-hr test period for Profile 2 wood siding applied on 10 mm x 64-mm wood batten strips located at stud positions.



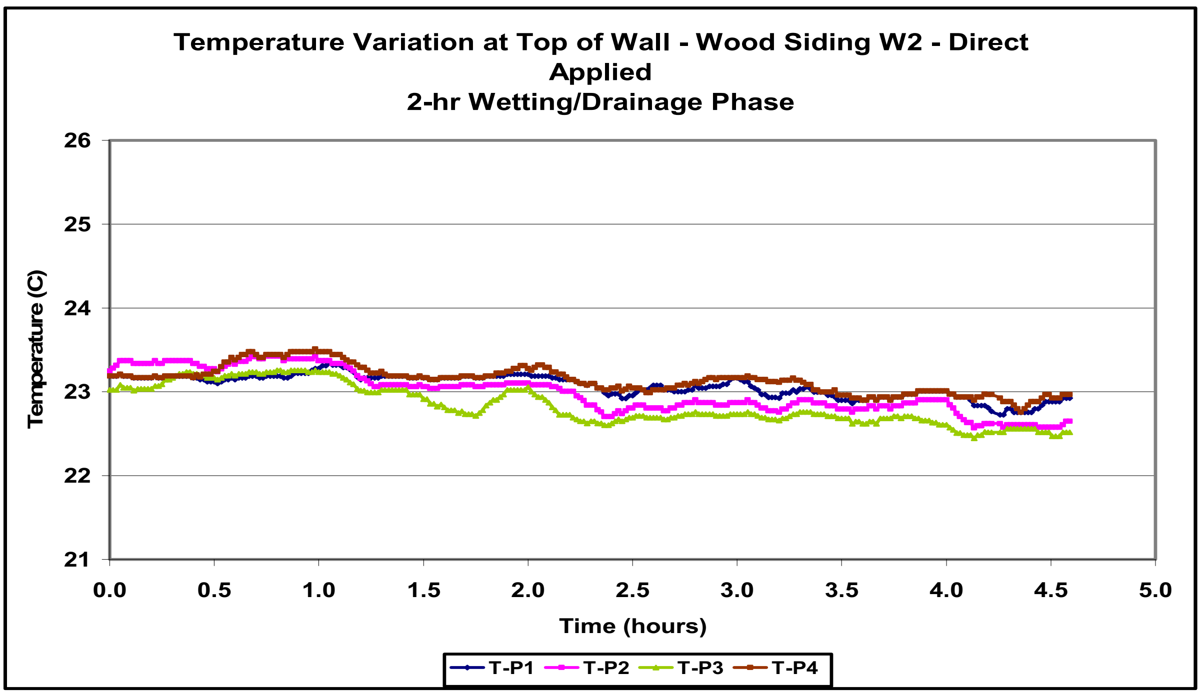
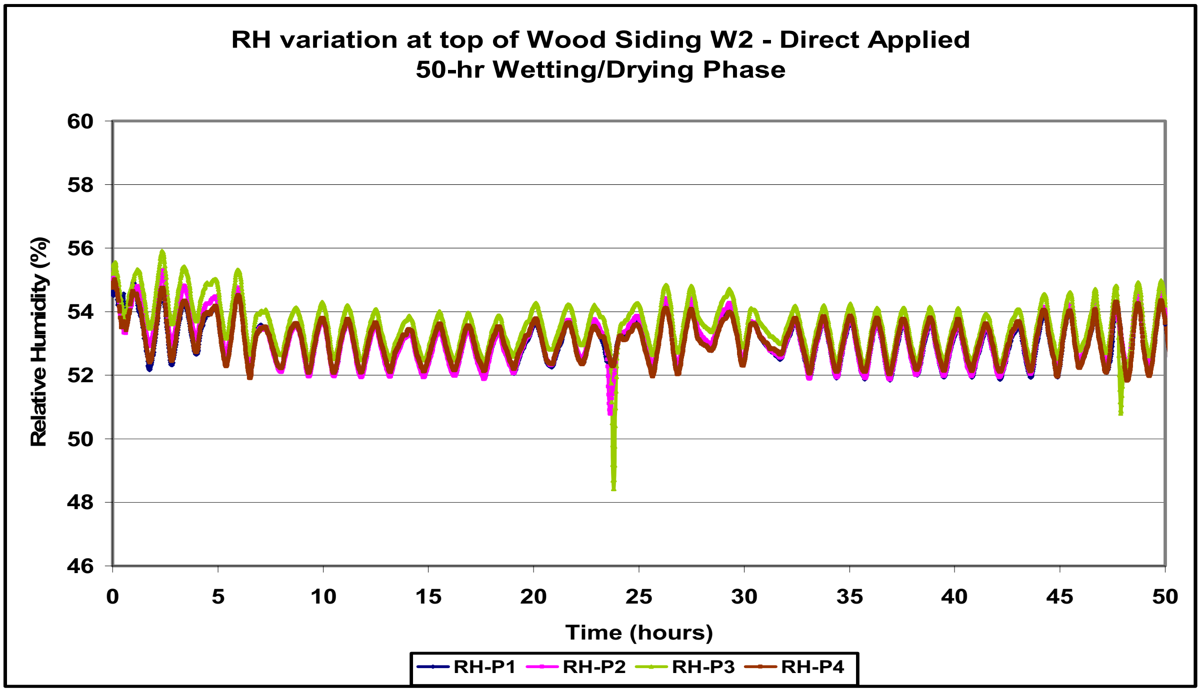


Figure A-V-7: RH&T plots for wood siding, profile W2 at 4 positions at the top of siding direct applied to the base wall during the wetting/draining phase.



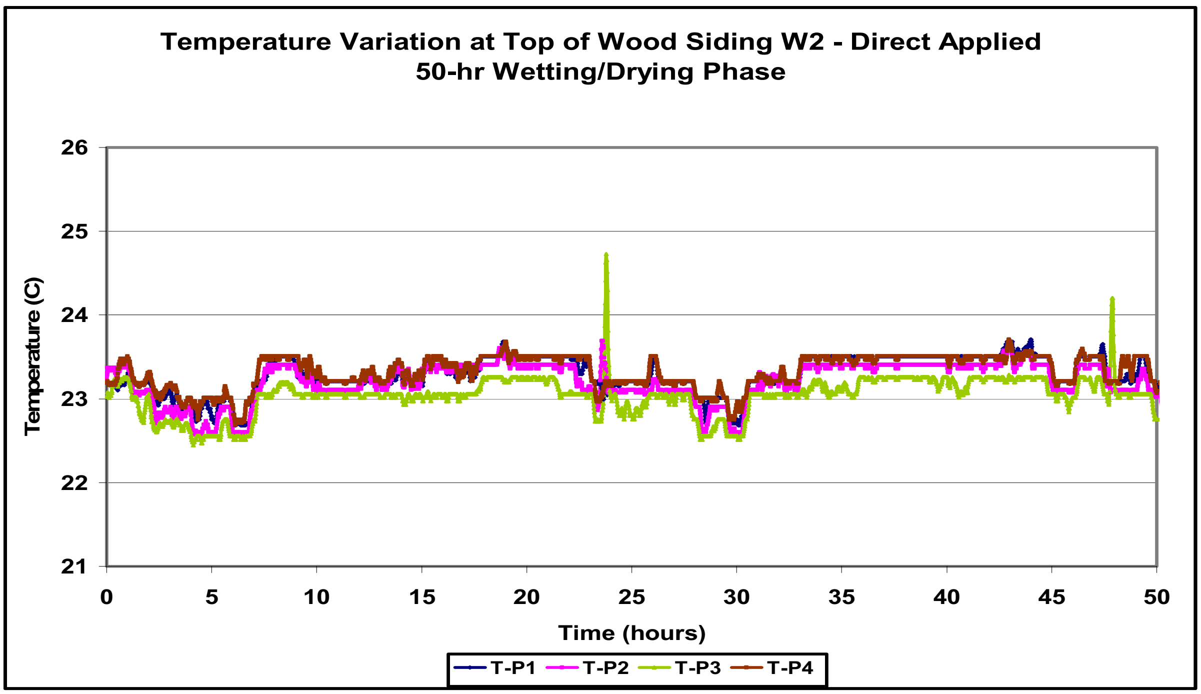
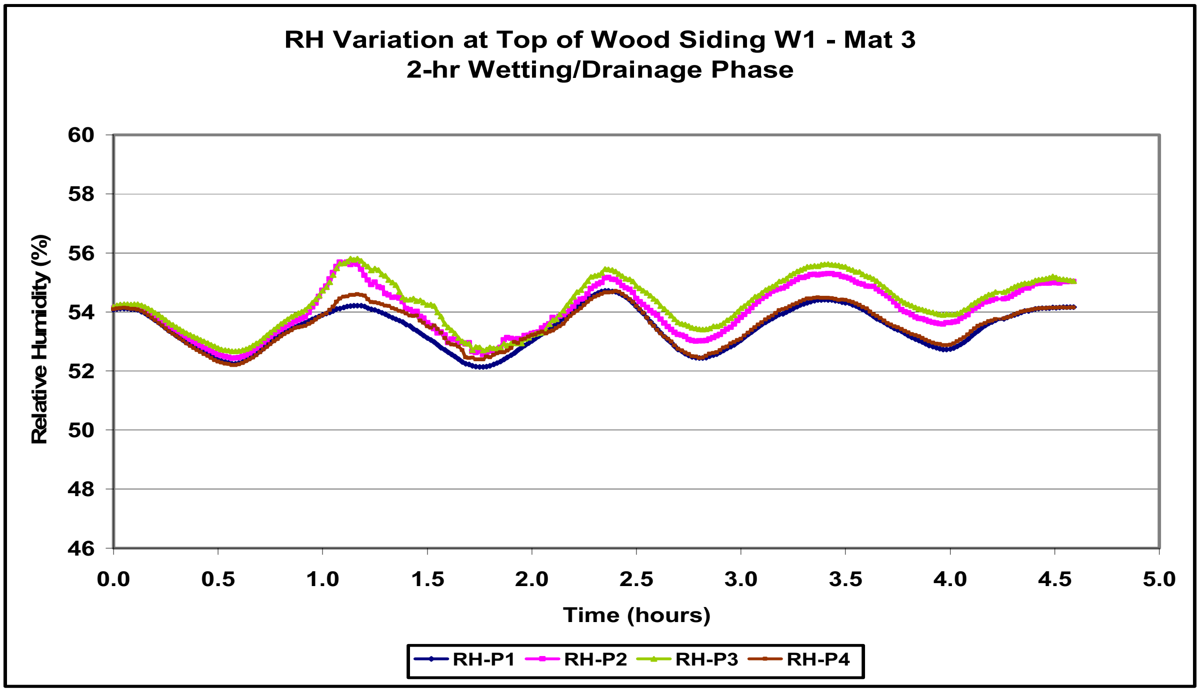


Figure A-V-8: RH&T plots for wood siding, profile W2 at 4 positions at the top of siding direct applied to the base wall during the total test period including the 48-drying period.



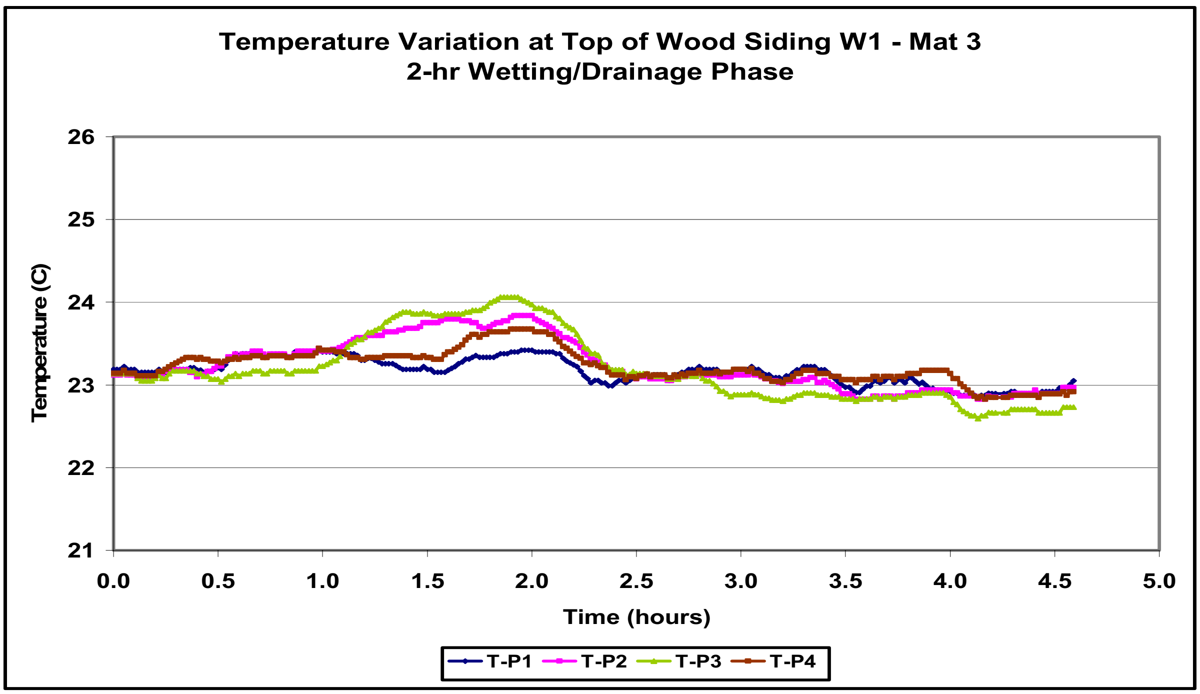
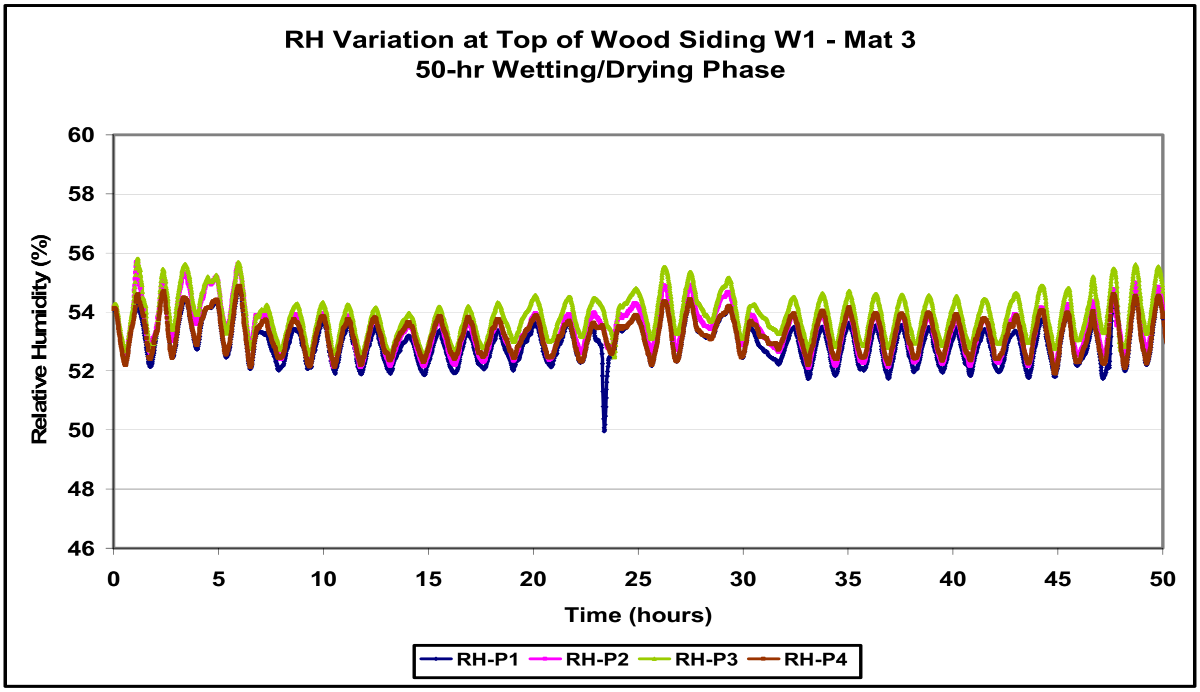


Figure A-V-9: RH&T plots for wood siding, profile W1 at 4 positions at the top of siding applied to a drainage mat (Mat 3) during the wetting/drainage test period.



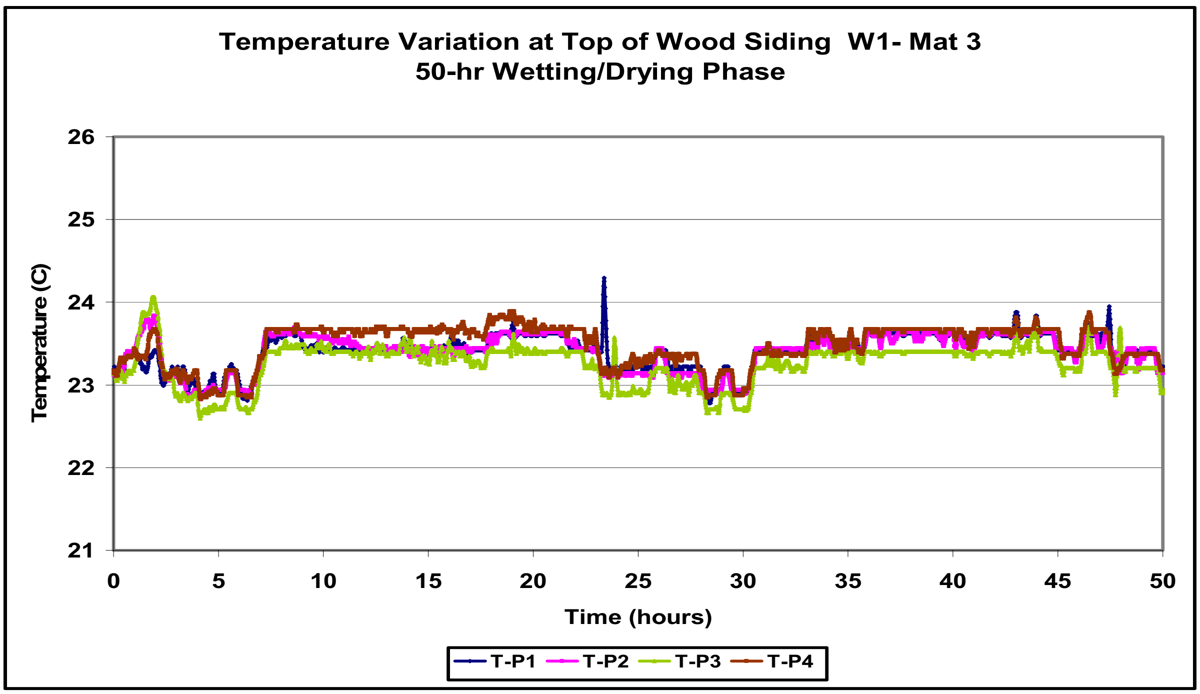
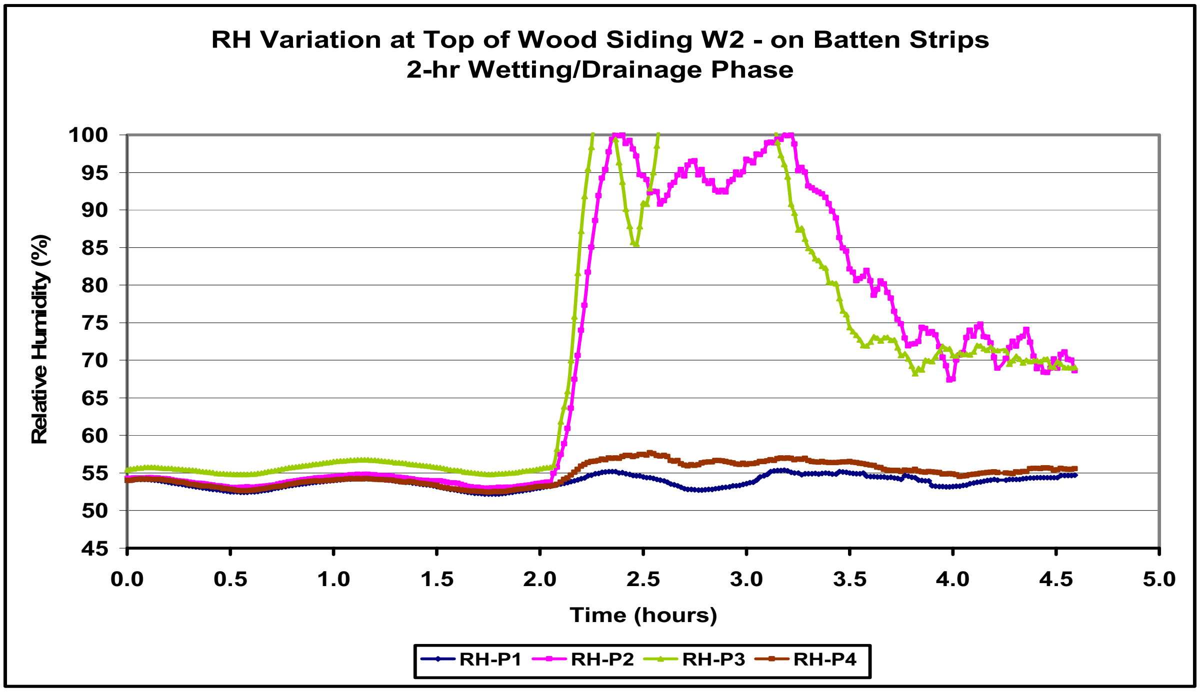


Figure A-V-10: RH&T plots for wood siding, profile W1 at 4 positions at the top of siding applied to a drainage mat (Mat 3) during the total test period including the 48-drying period.



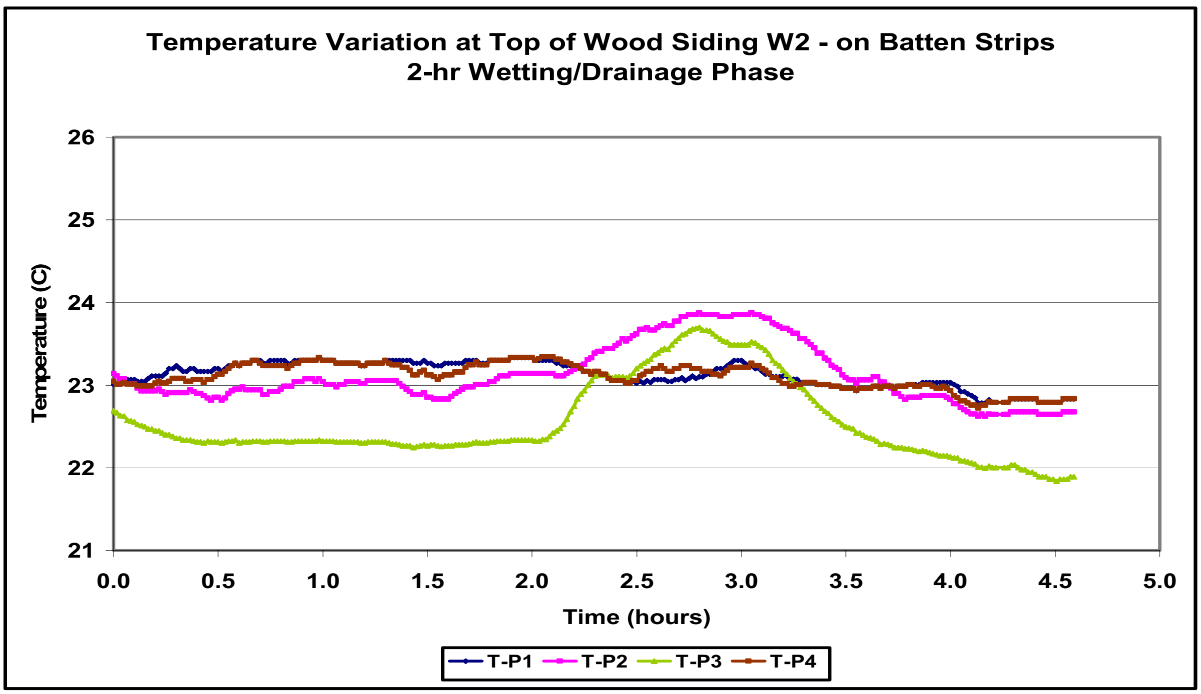
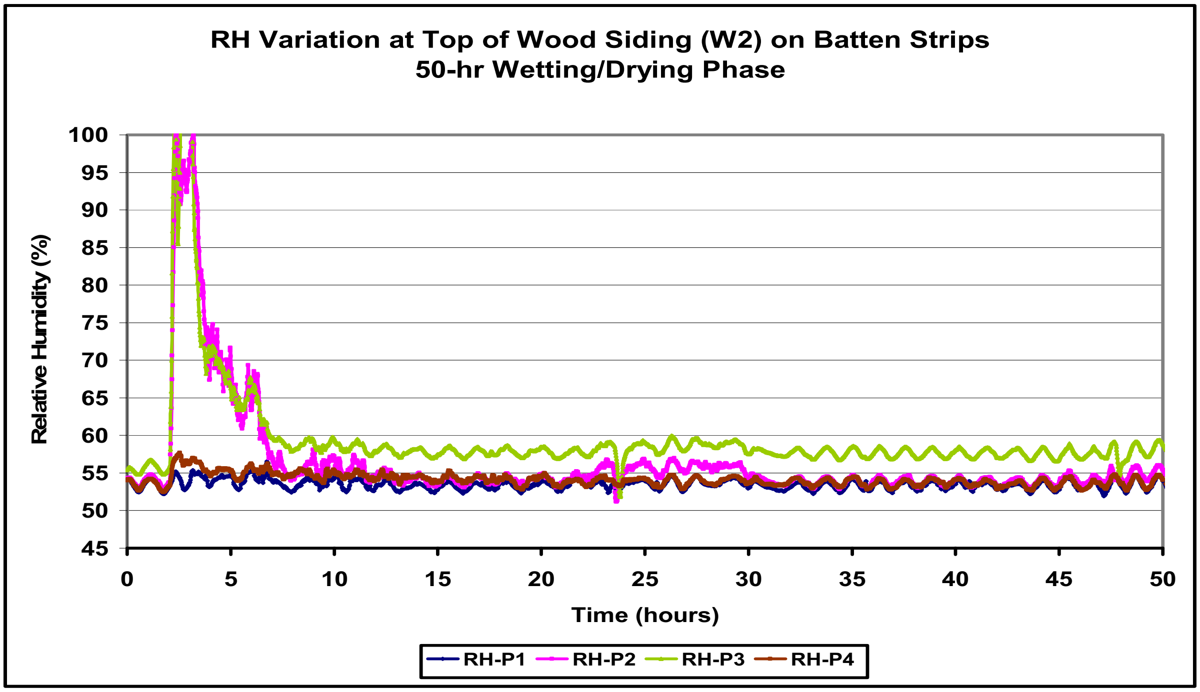


Figure A-V-11: RH&T plots for wood siding, profile W2 at 4 positions at the top of siding applied to 10-mm by 64-mm wood batten strips during the wetting/drainage test period.



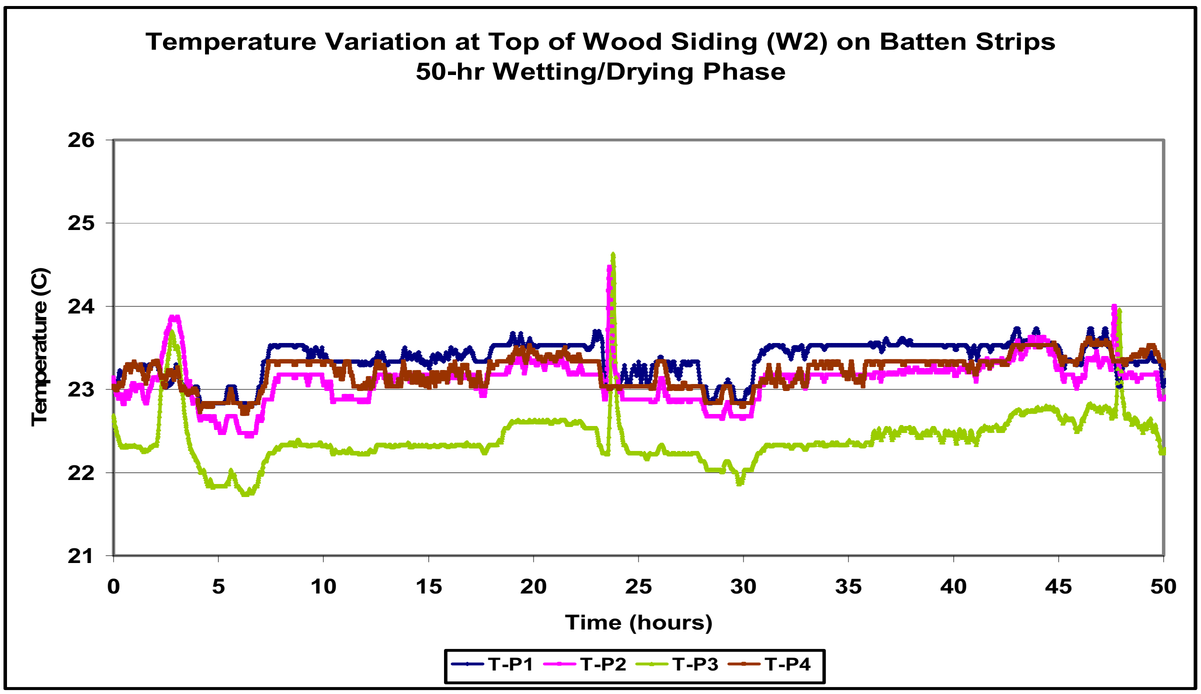
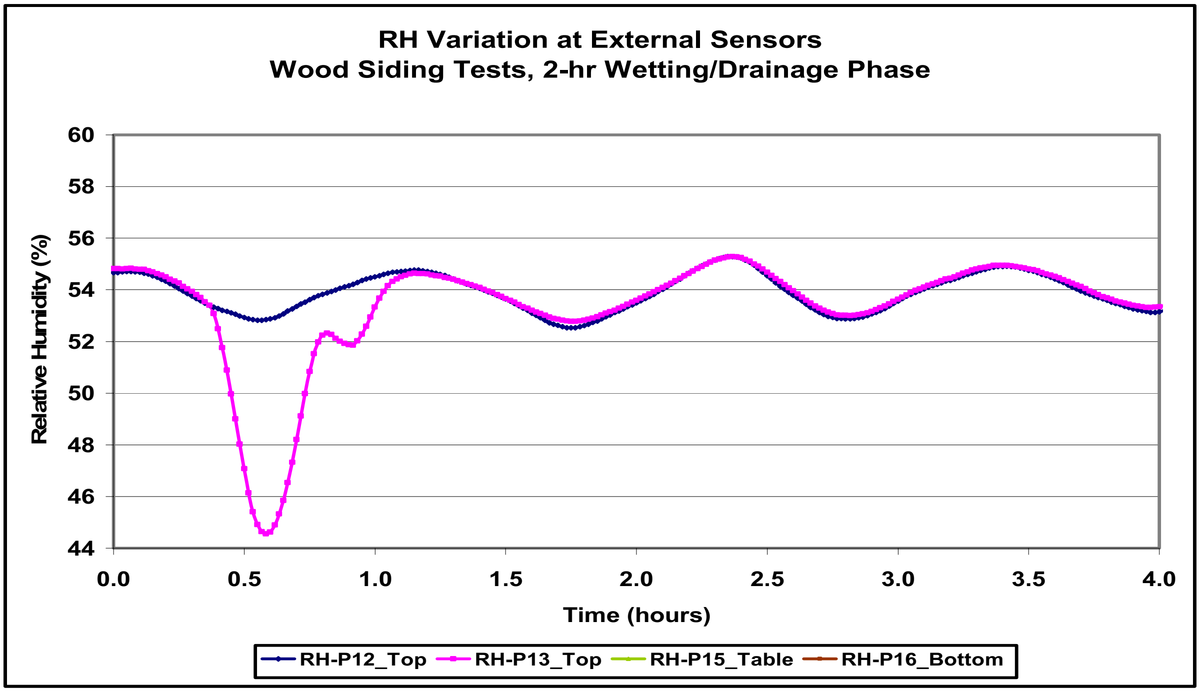


Figure A-V-12: RH&T plots for wood siding, profile W2 at 4 positions at the top of siding applied to 10-mm by 64-mm wood batten strips during the total test period.



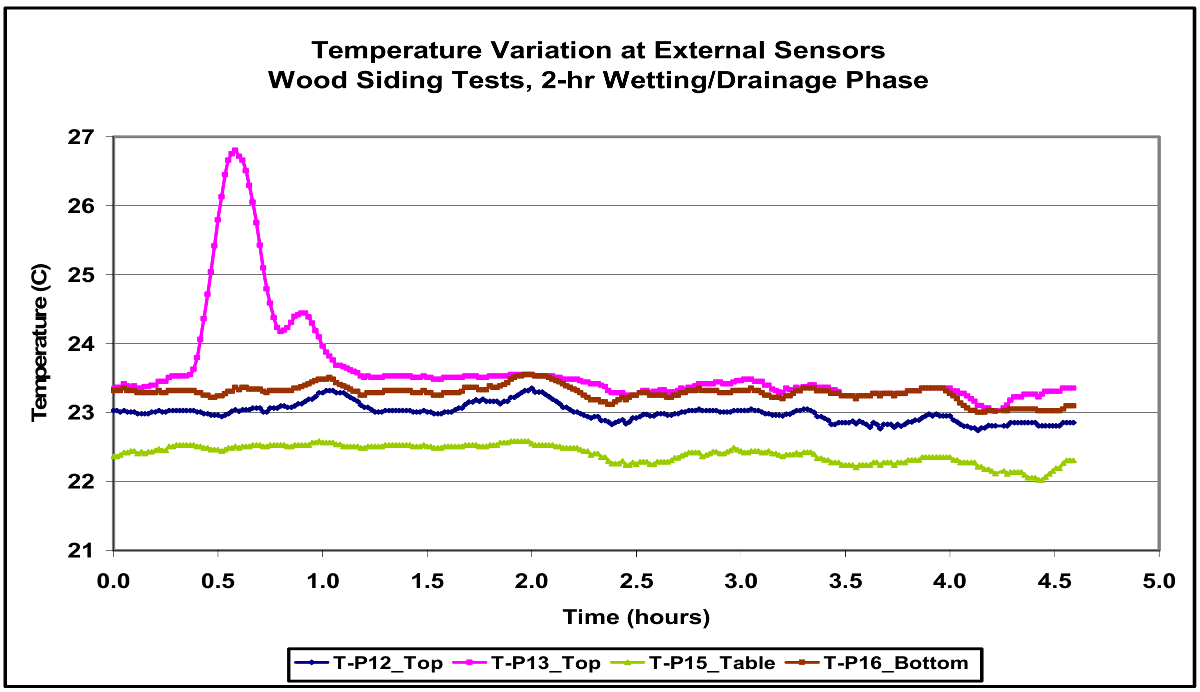
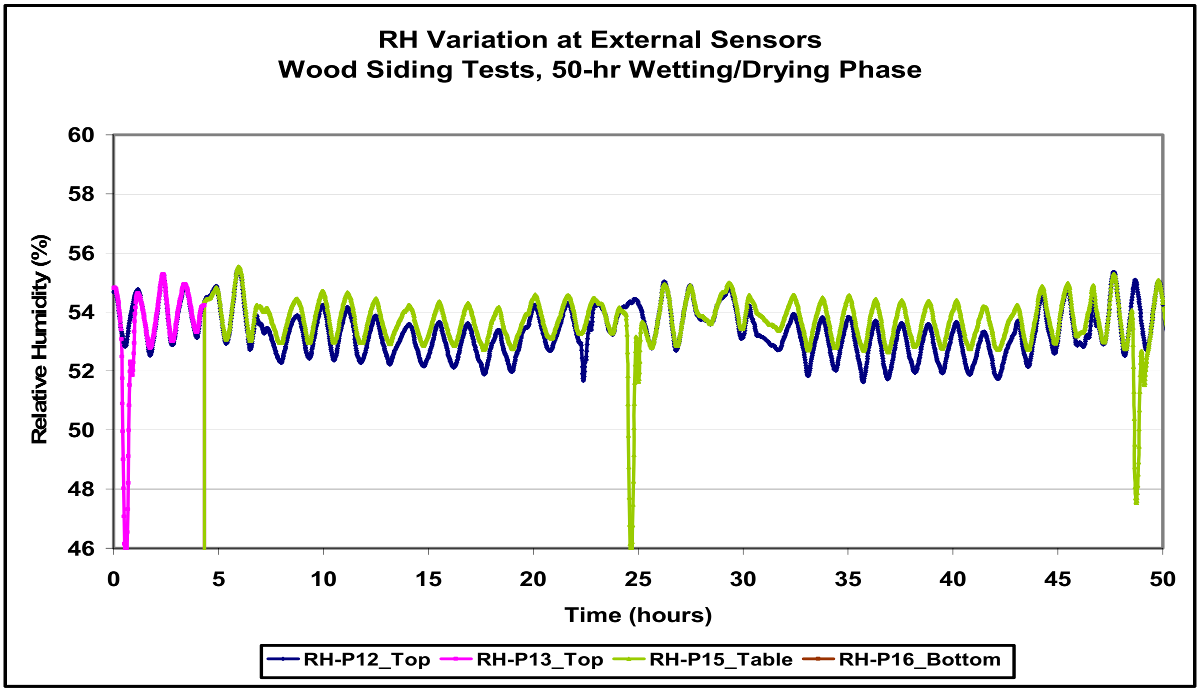


Figure A-V-13: RH&T plots for 4 external sensors during wetting/drainage test period on 22-Mar-05



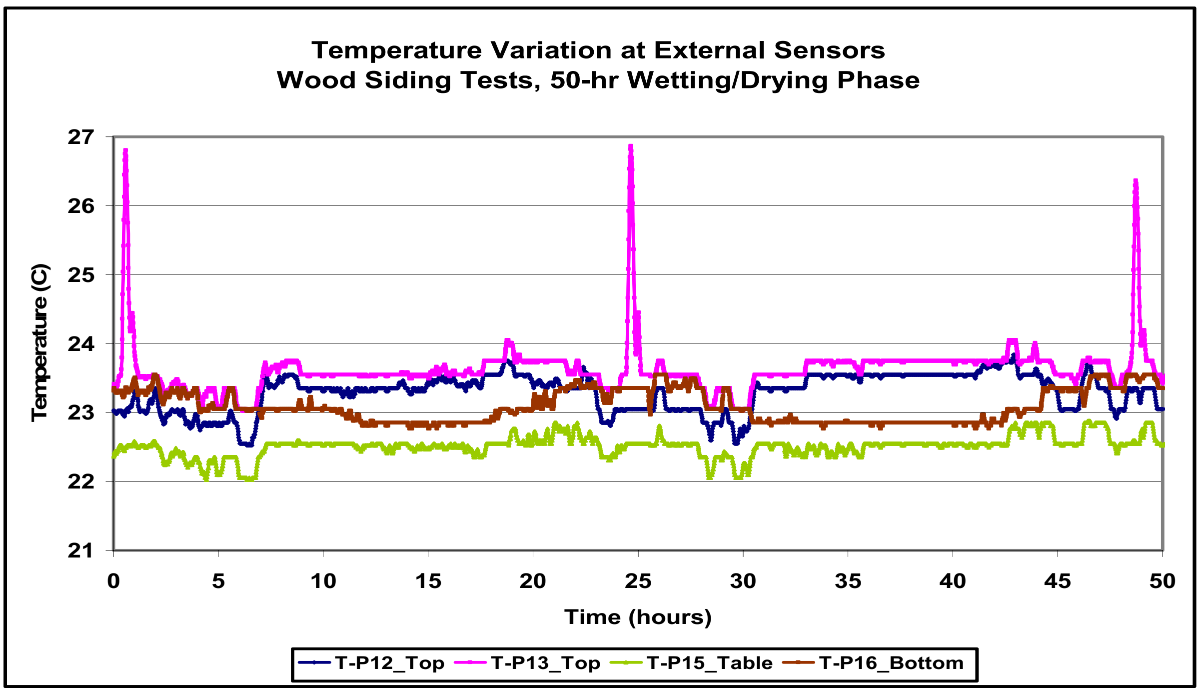


Figure A-V-14: RH&T plots for 4 external sensors during the total wetting/drying test period on 22-Mar-05.

APPENDIX VI

Data Plots for Fibre-Cement Siding Tests

Notes for Appendix VI

The plots provided in Appendix VI are for two walls with fibre-cement siding. Both were direct applied to the wall, one with building paper and one with SBPO WRB. Individual plots for the 2-hr wetting/drying phase, and for the combined data consisting of the 2-hr and 48-hr drying period are included.

Mapping of moisture content changes have been included for each case. Water was introduced into the middle of the gap provided at the top of direct-applied siding. The plots are only qualitative indications of moisture retention and should not be interpreted as representing true moisture content changes in any of the components of the walls.

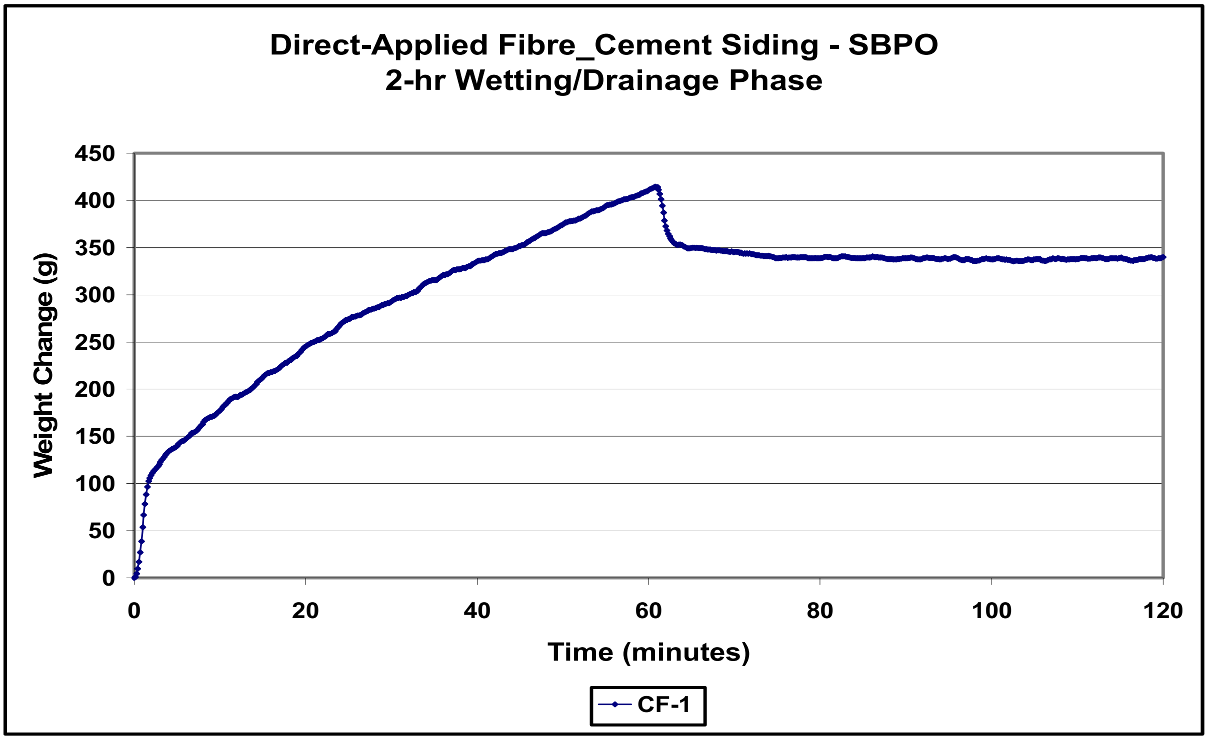
The plots of Relative and Humidity and Temperature variations for each of the 2-hr, and 48-hr periods are all included. The longer term drying periods are generally regular and demonstrate that the fluctuation in background conditions did not have an important effect on the rate of drying.

The identification of test material and types are provided below:

CF-1 = fibre-cement siding wall with Building Paper
CF-2 = fibre-cement siding wall with SBPO
DA = Direct Applied
SBPO = Spun Bonded Polyolefin WRB
BP = Building Paper (paper based) WRB

Table A-VI-1: Organization of data plots for 2 walls with fibre-cement siding.

Data Form	Page	Figure A-VI	2hr W/D	48hr W/D	Application
Drainage	79	1	CF-1		DA-BP
			CF-2		DA-SBPO
	80	2		CF-1	DA-BP
				CF-2	DA-SBPO
Moisture Mapping	81	3		CF-1	DA-BP
	82	4		CF-2	DA-SBPO
RH&T	83	5	CF-1		DA-BP
	84	6	CF-2		DA-SBPO
	85	7		CF-1	DA-BP
	86	8		CF-2	DA-SBPO
External Conditions	87	9	√		
	88	10		√	



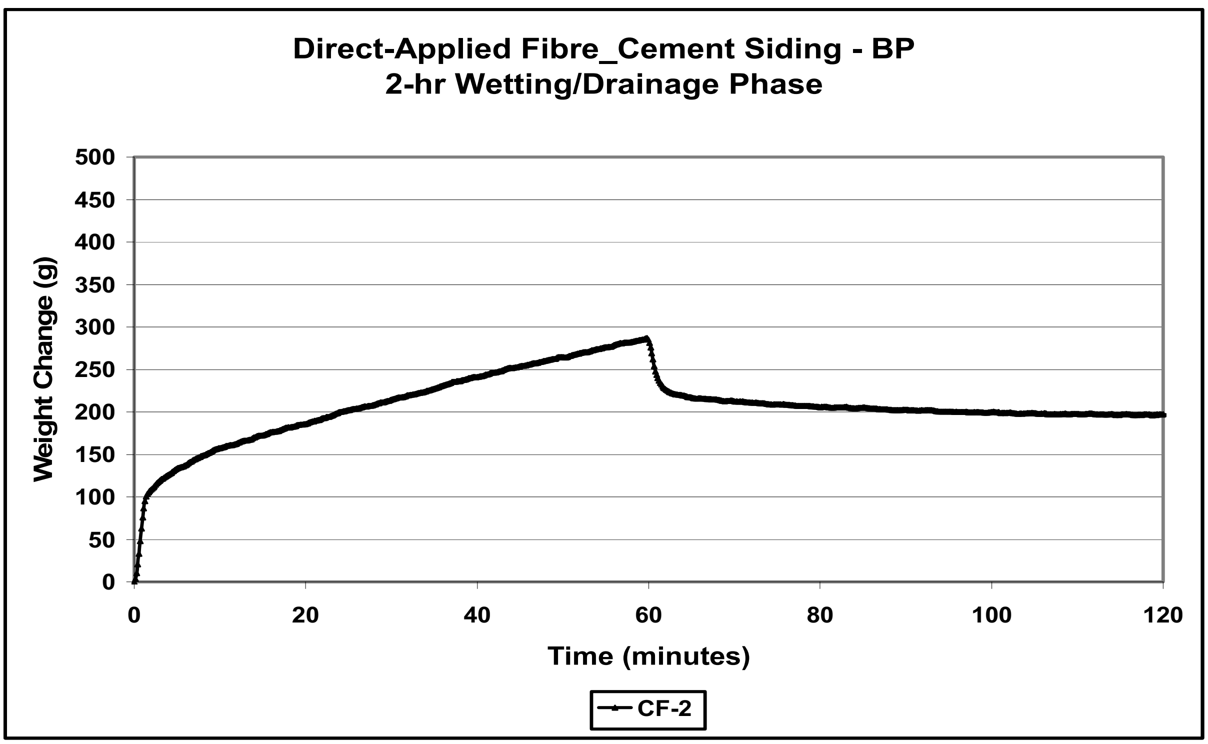
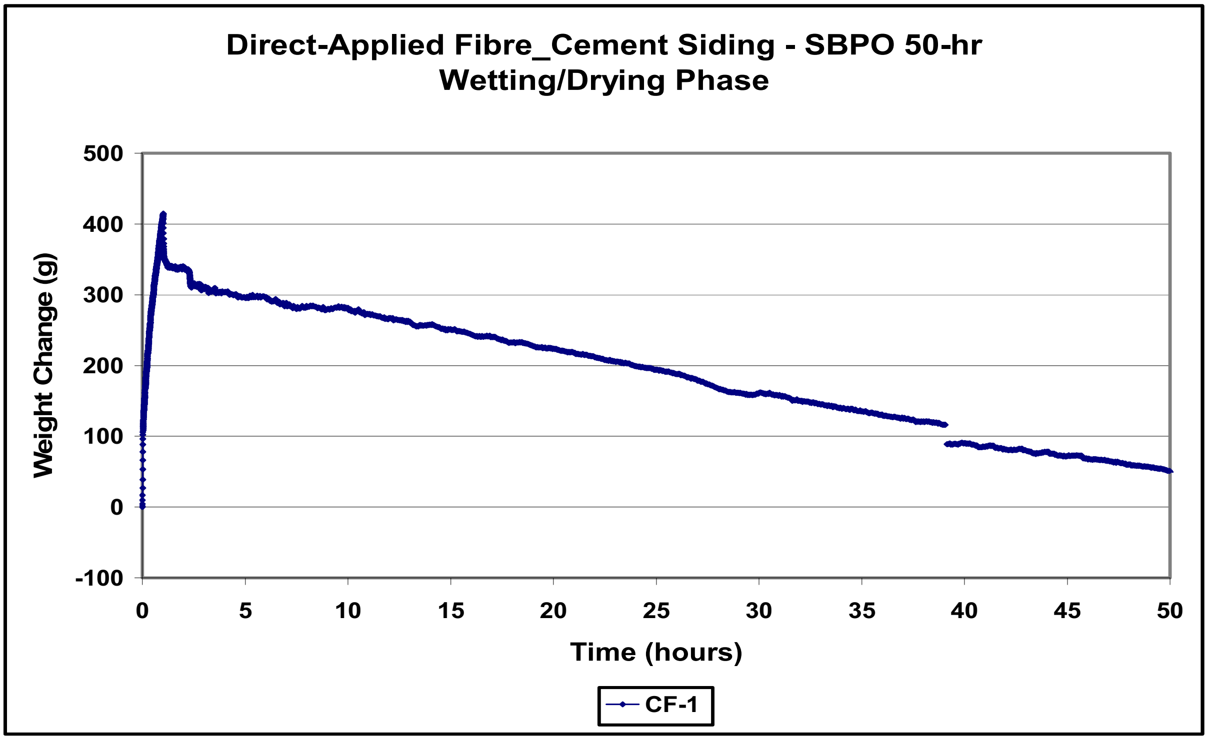


Figure A-VI – 1 Wetting/Drainage plots for two test walls with fibre-cement siding.



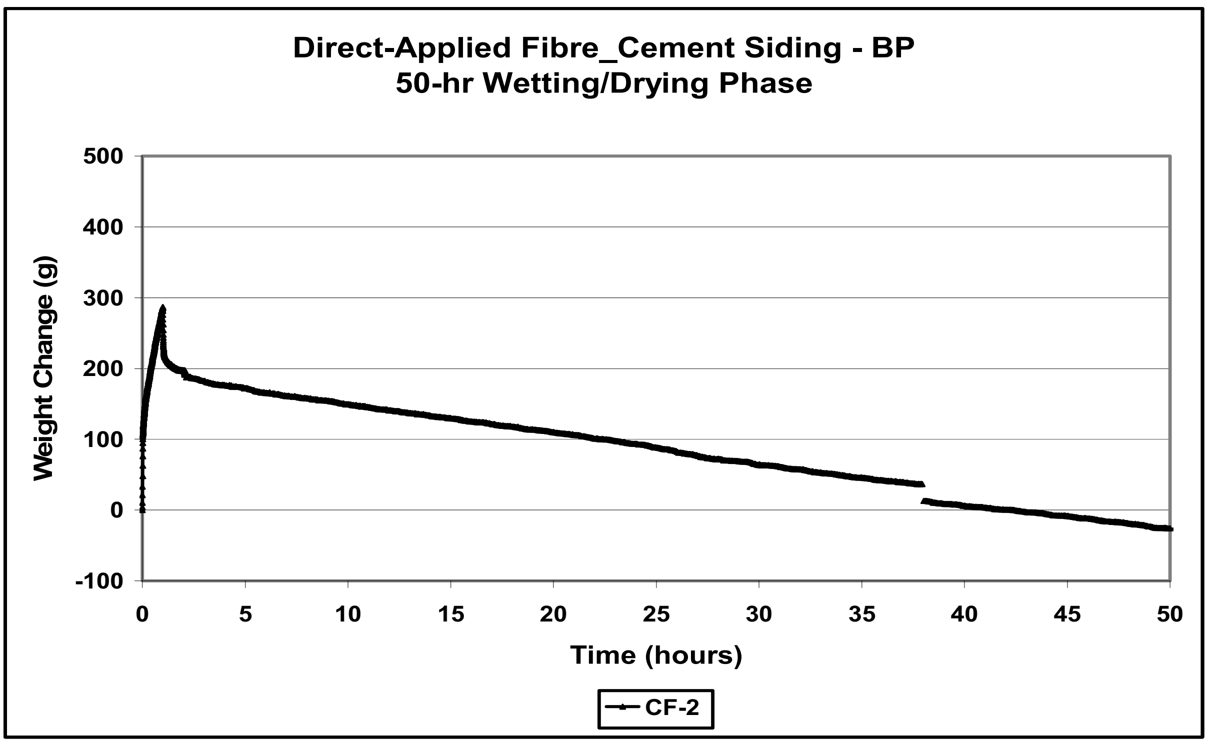


Figure A-VI -2 Wetting/Drying plots over the full 2-hr plus 48-hr time period for two walls with fibre-cement siding. The shift in the recording at about 37 hours was the result of a disturbance to the test frame.

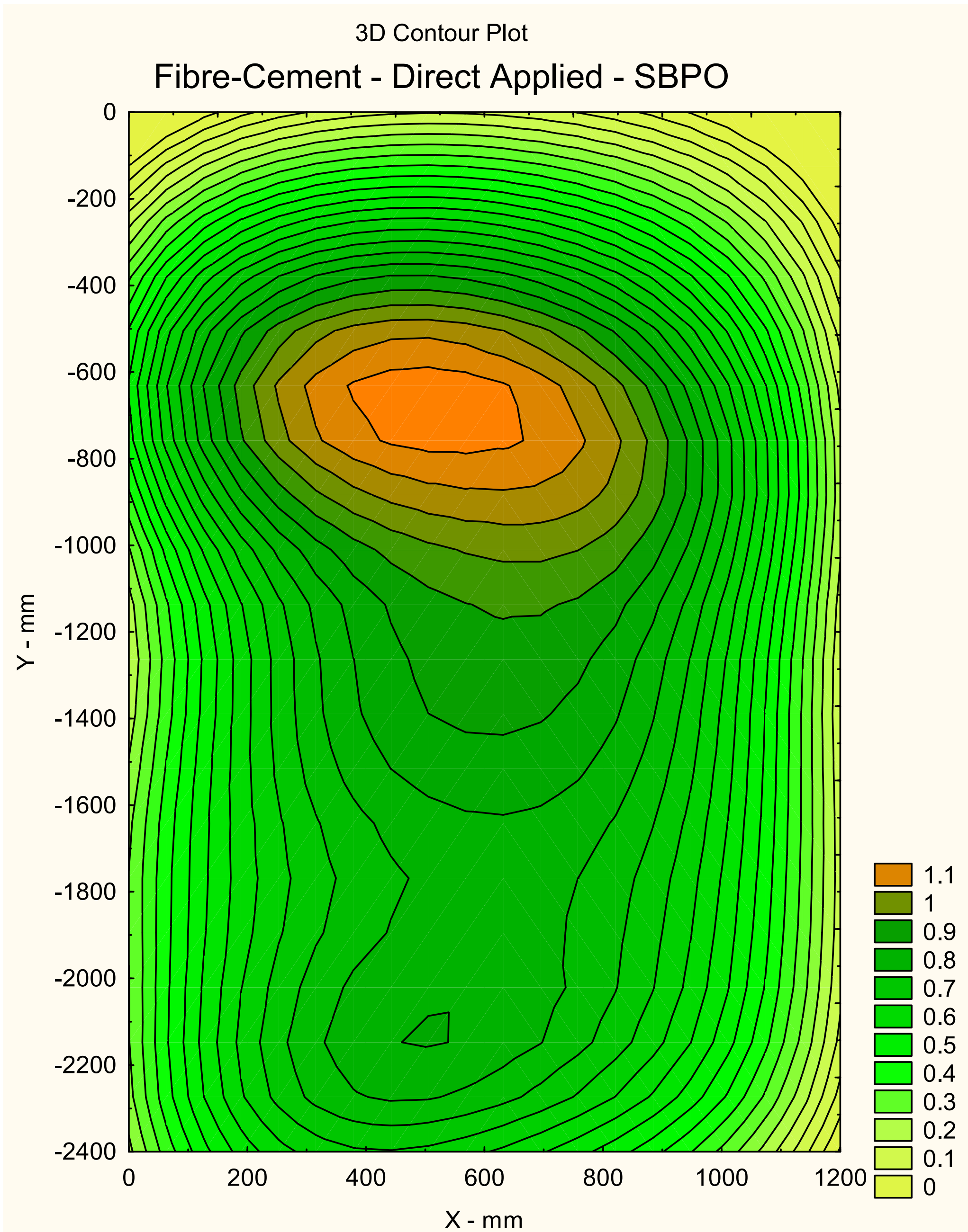


Figure A-VI- 3 Map of moisture differences resulting from wetting of test wall with fibre-cement siding, applied directly to the base wall with SBPO weather resistive barrier (WRB).

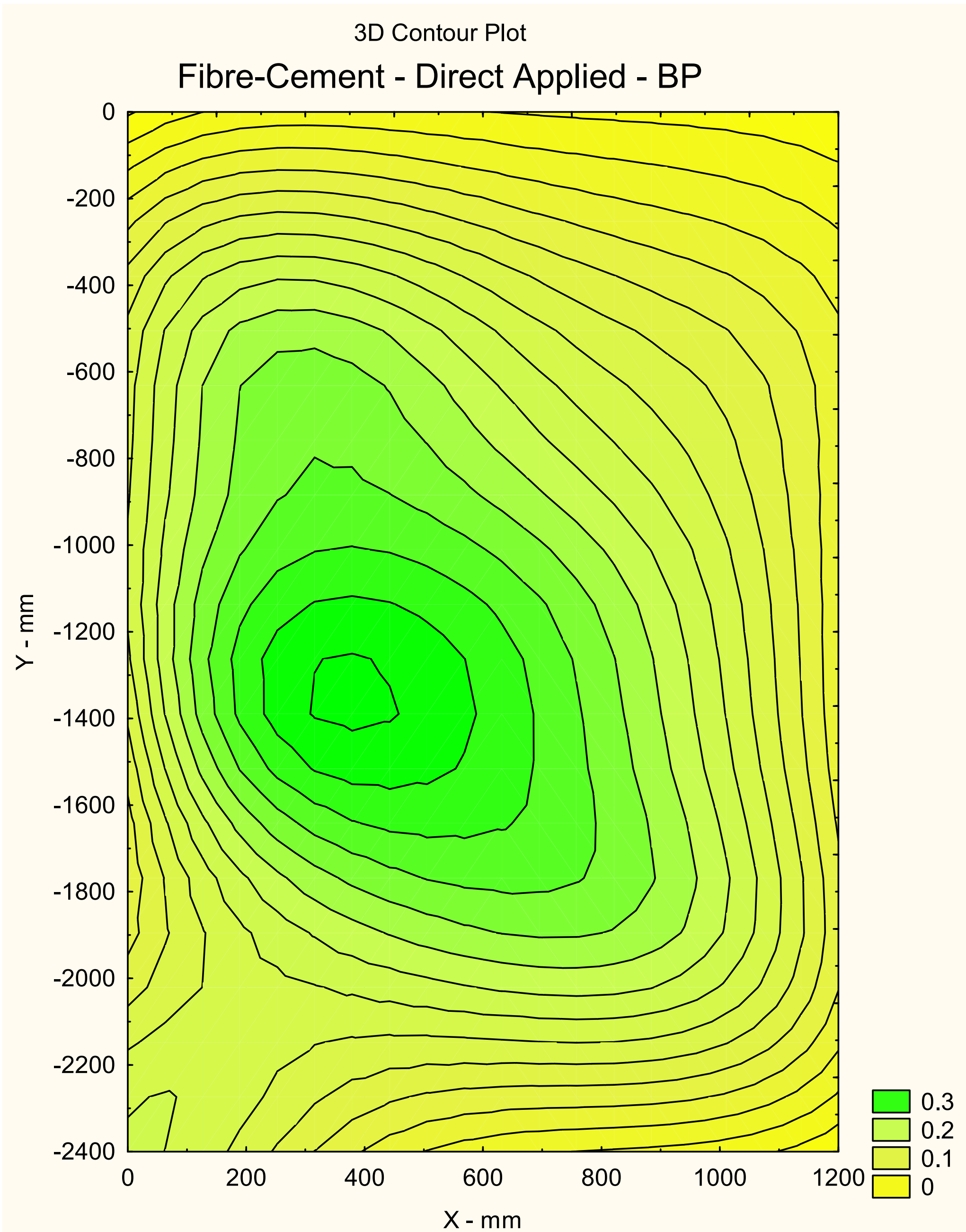


Figure A-VI- 4 Map of moisture differences caused by wetting of a test wall with fibre-cement siding direct-applied to a base wall with building paper WRB.

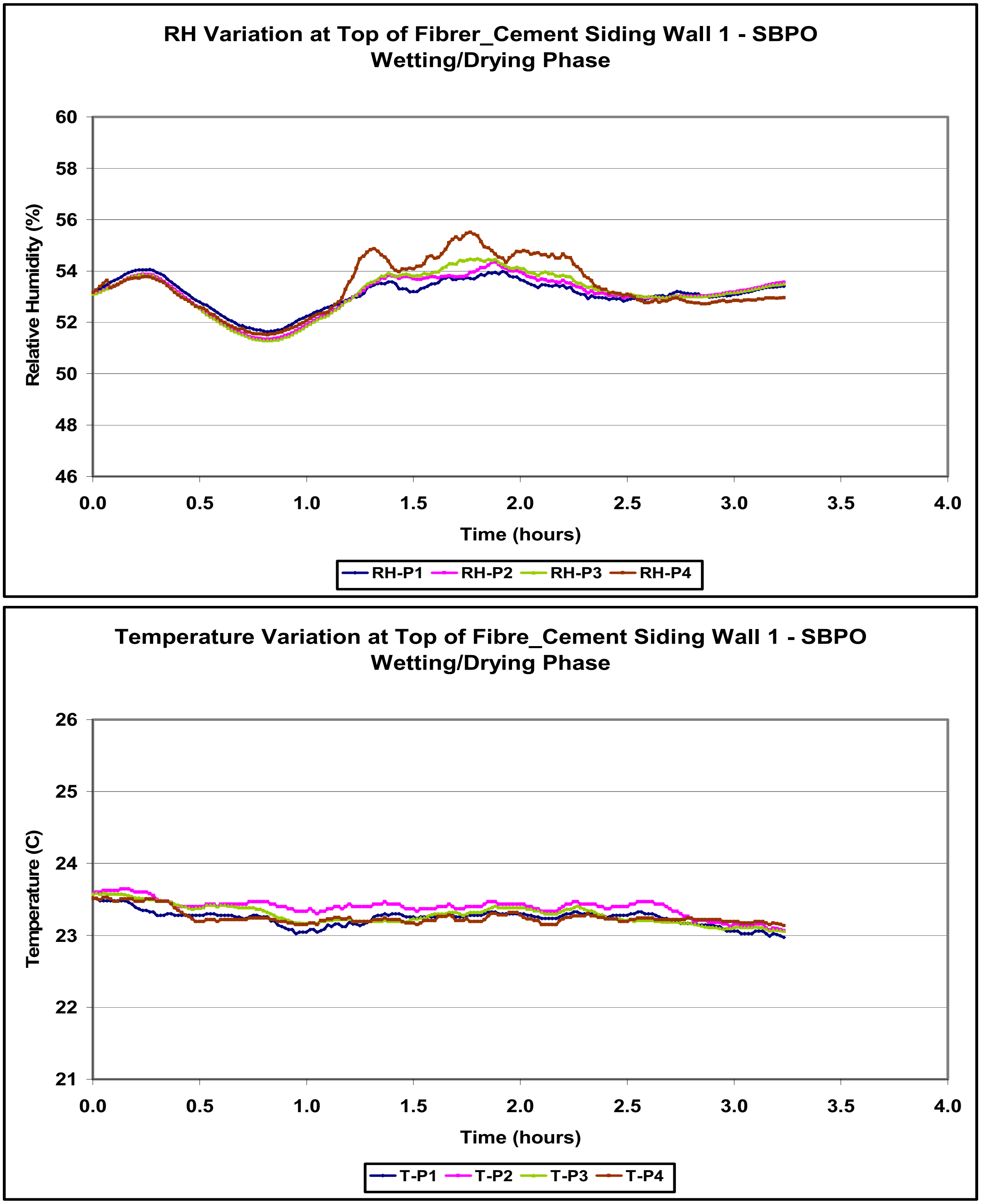
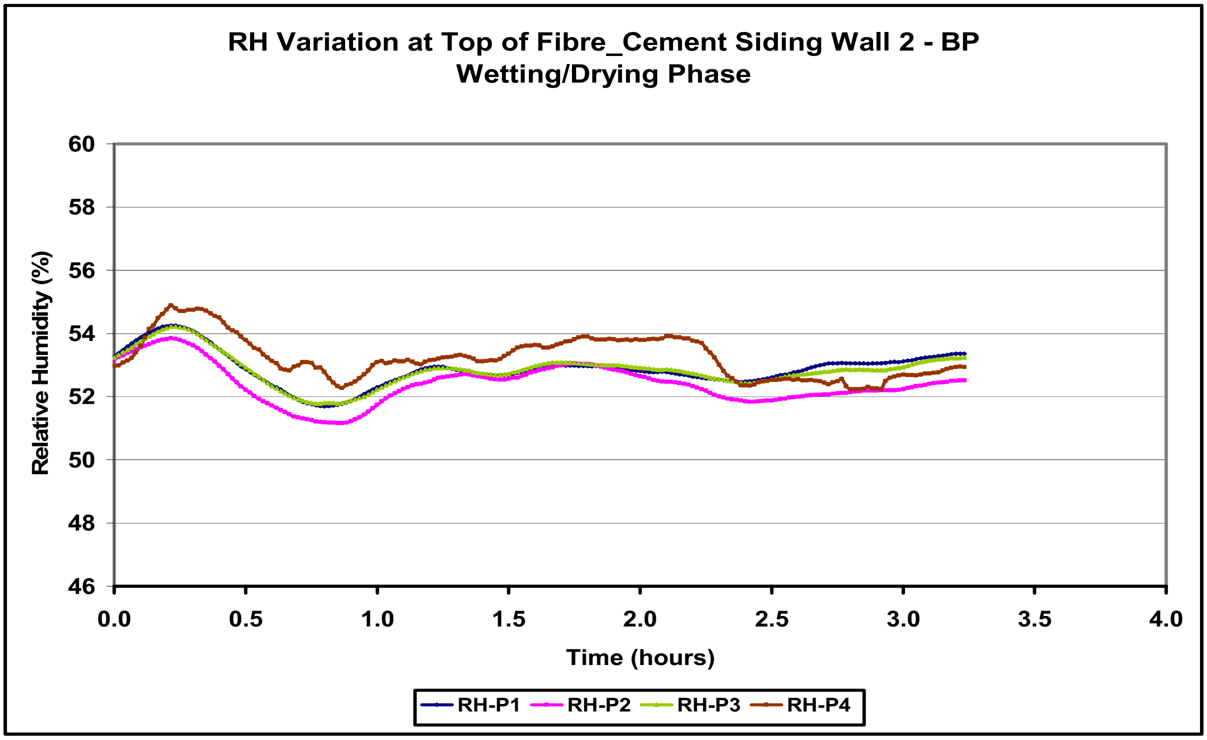


Figure A-VI- 5 Records of RH and T at four locations across the width of the test sample above the top level of fibre-cement siding installed against a wall with SBPO. The duration was over the period taken for Wetting/Drainage involving two test walls.



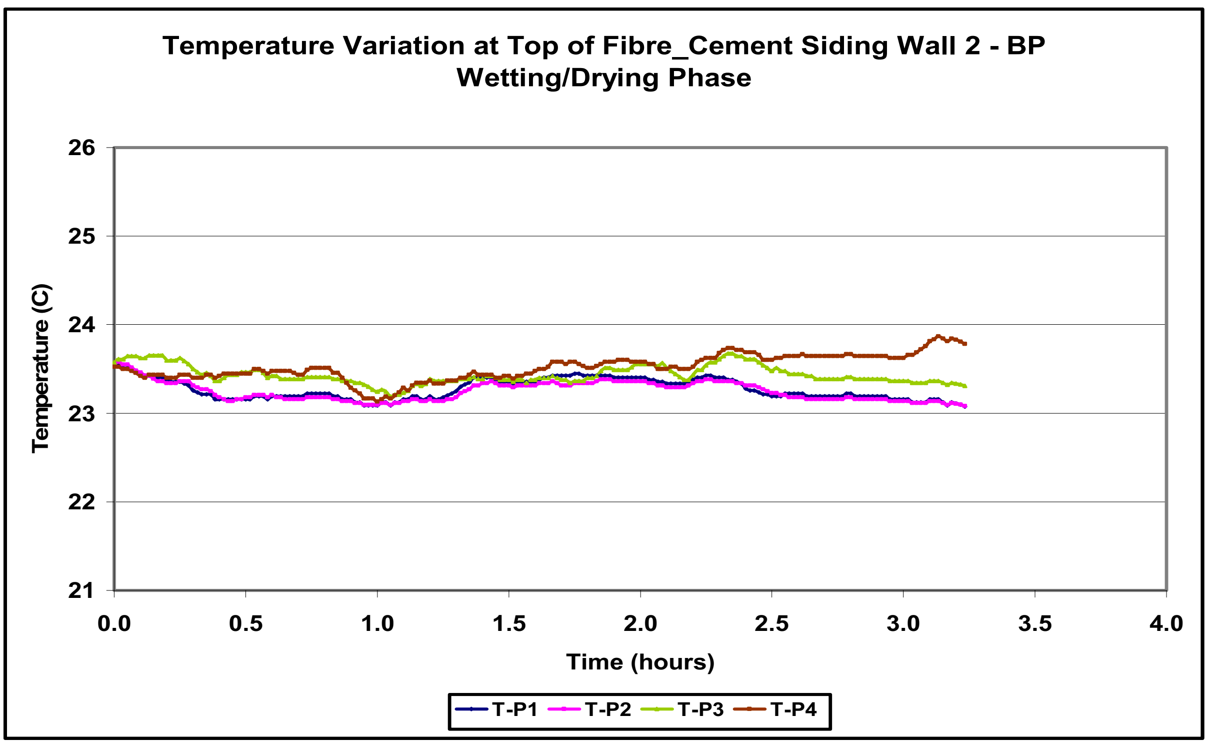
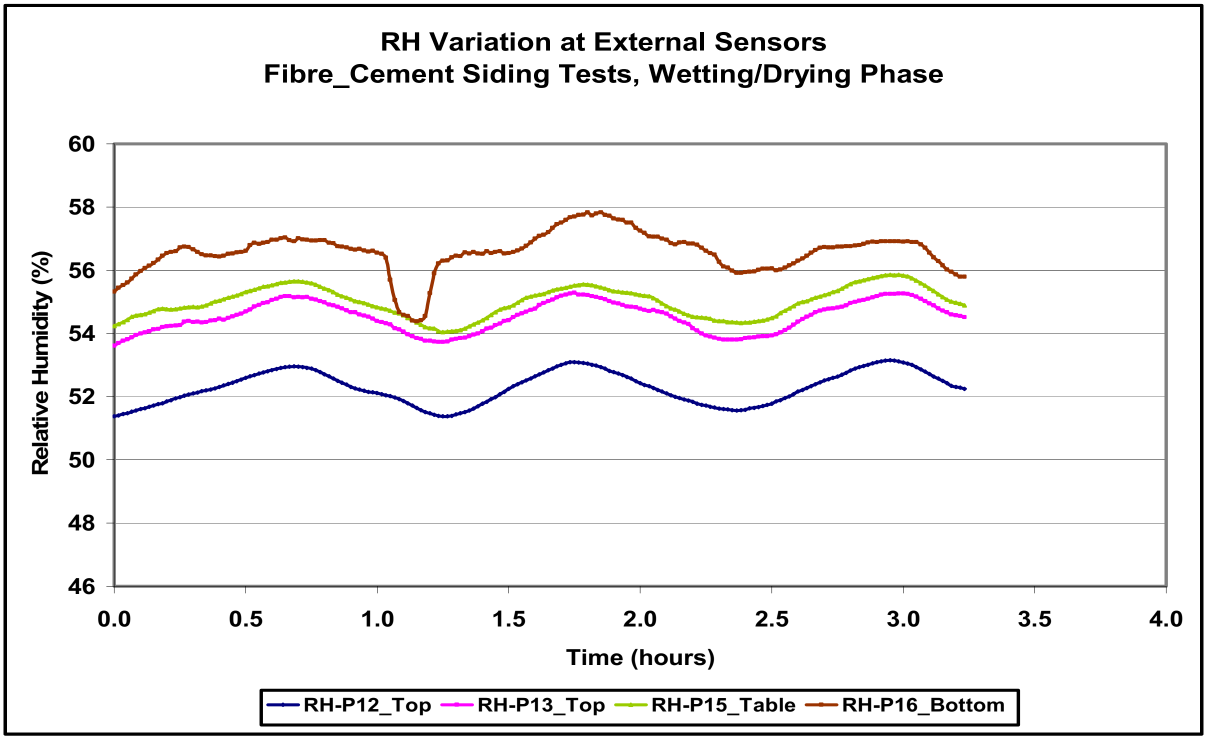


Figure A-VI- 6 Records of RH and T at four locations across the width of the test sample above the top level of fibre-cement siding installed against a wall with building paper. The duration was over the period taken for Wetting/Drainage involving two test walls.



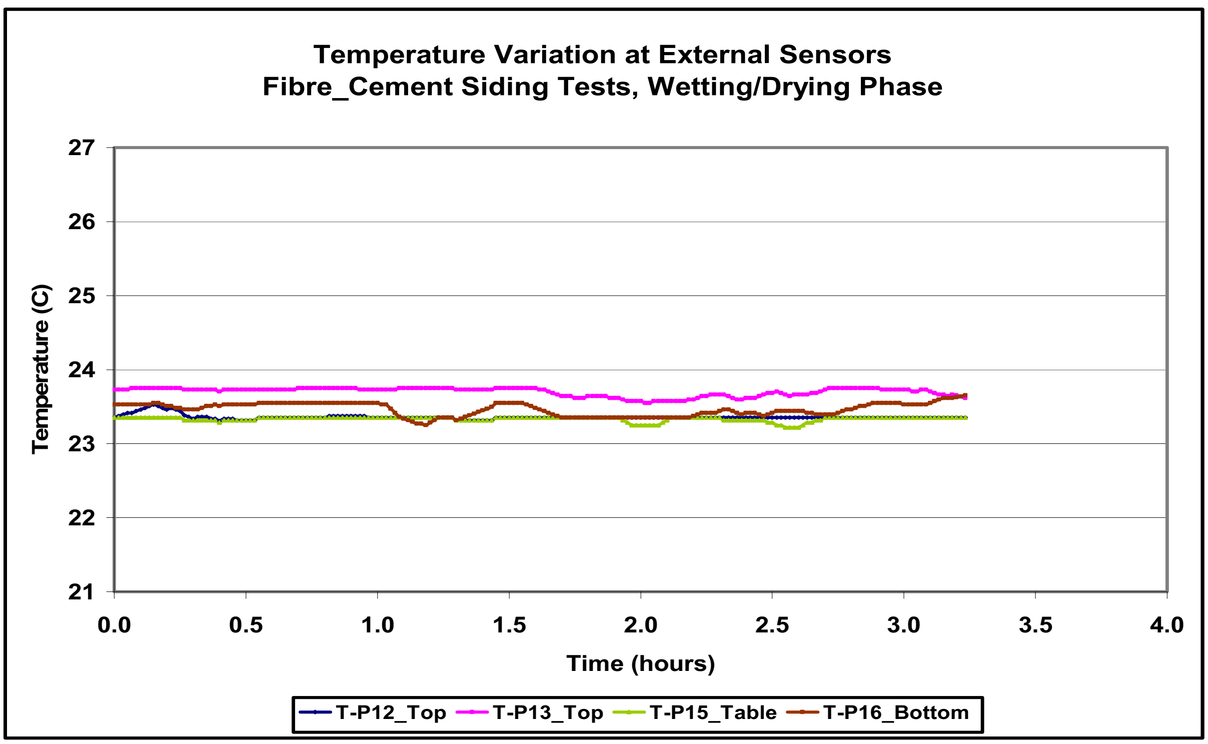
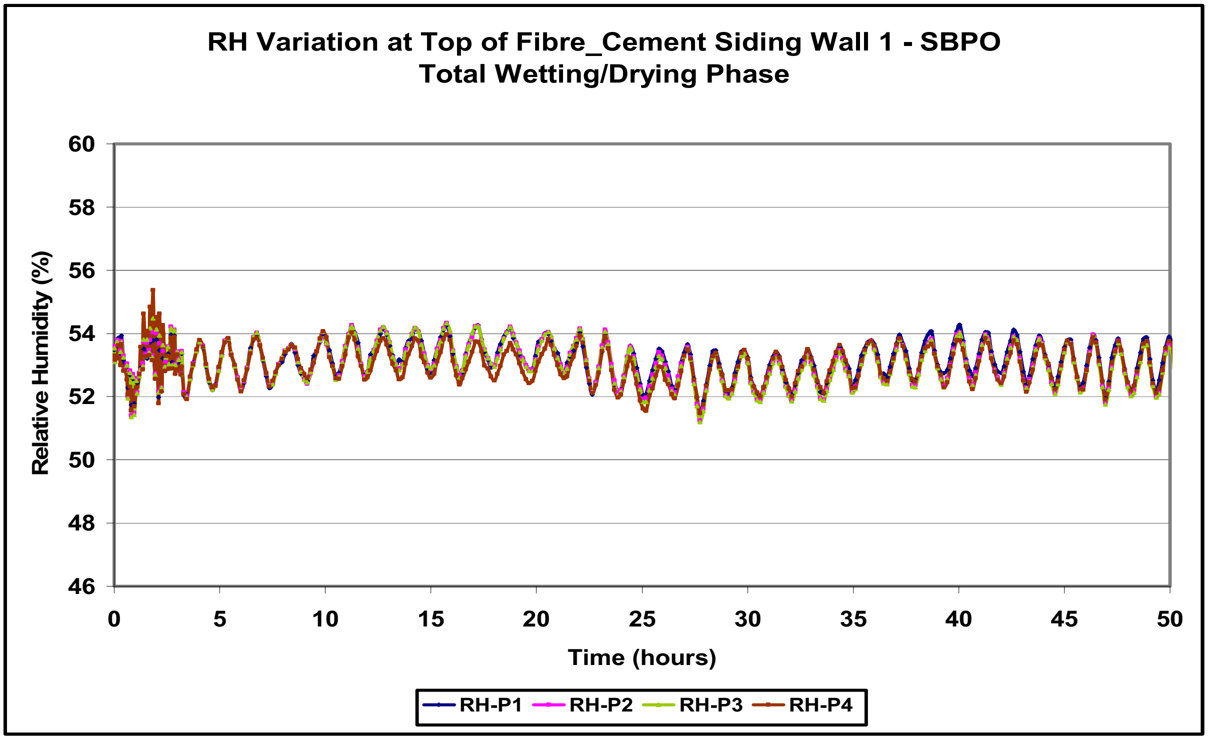


Figure A-VI- 7 Records of RH and T at four locations in the vicinity of the test walls during the initial period of Wetting/Drainage involving the two test walls with fibre-cement siding.



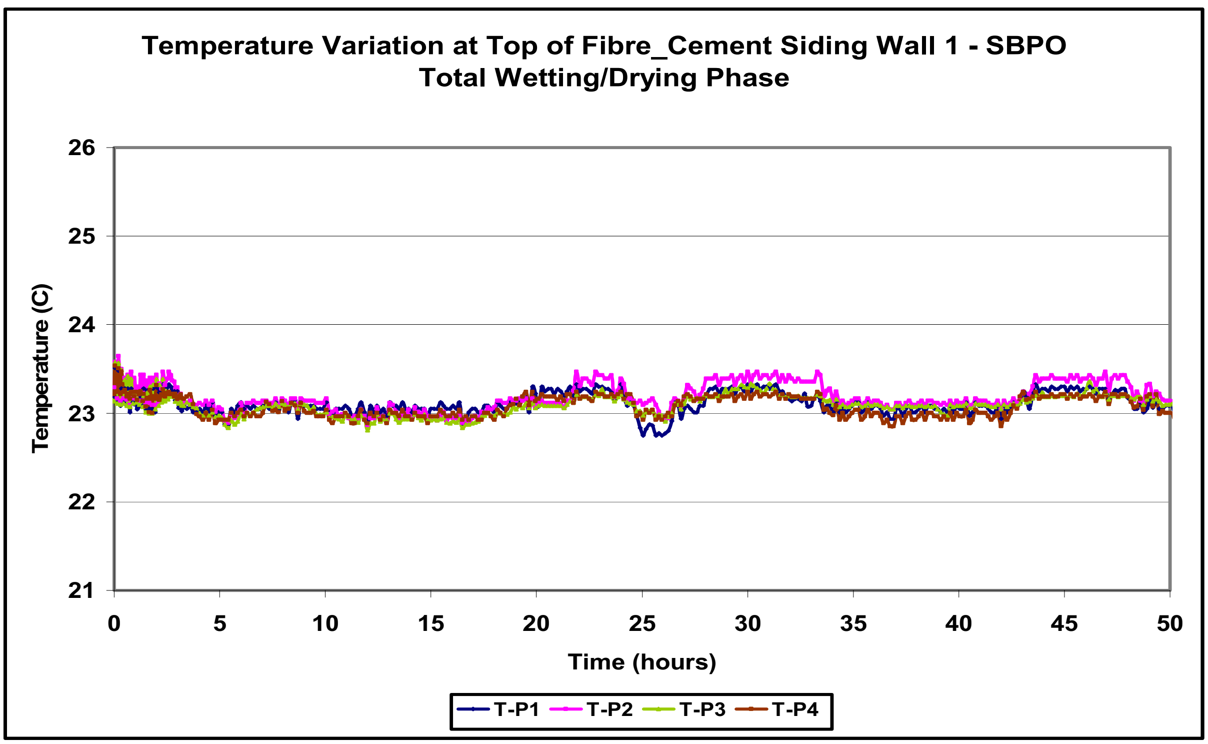
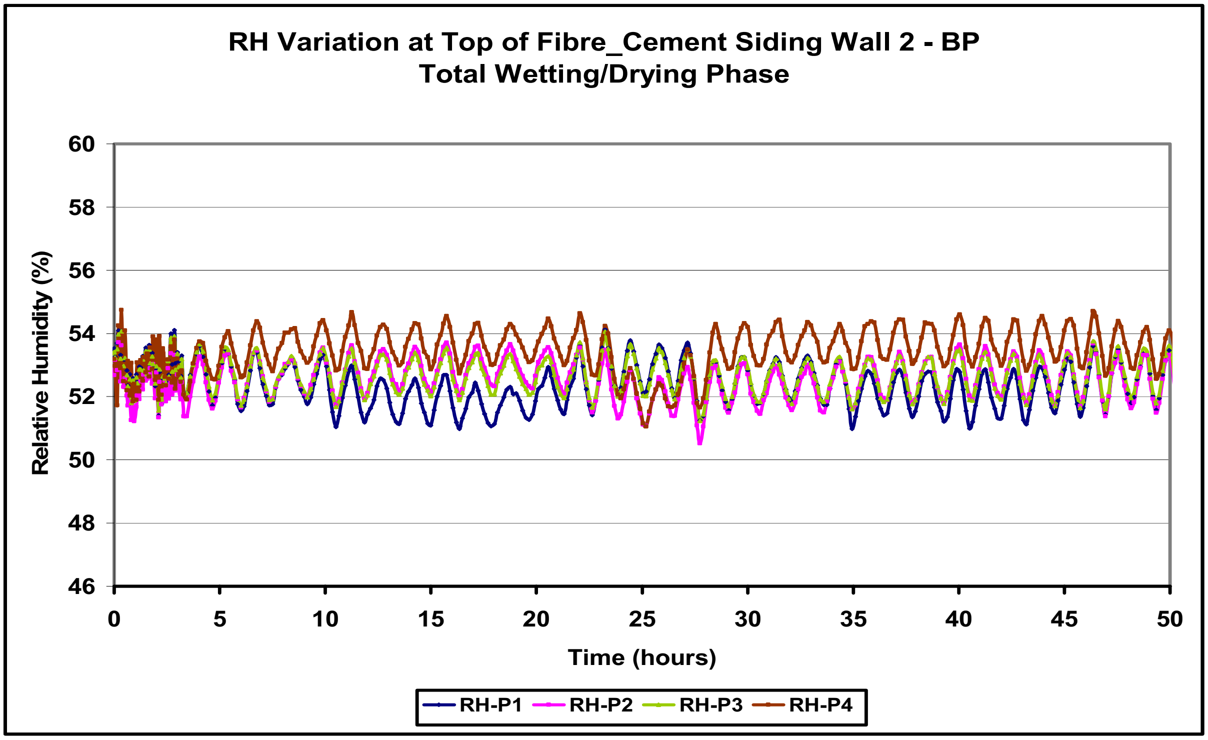


Figure A-VI- 8 Full Duration records of RH and T at four locations across the width of the test sample above the top level of fibre-cement siding installed against a wall with SBPO WRB.



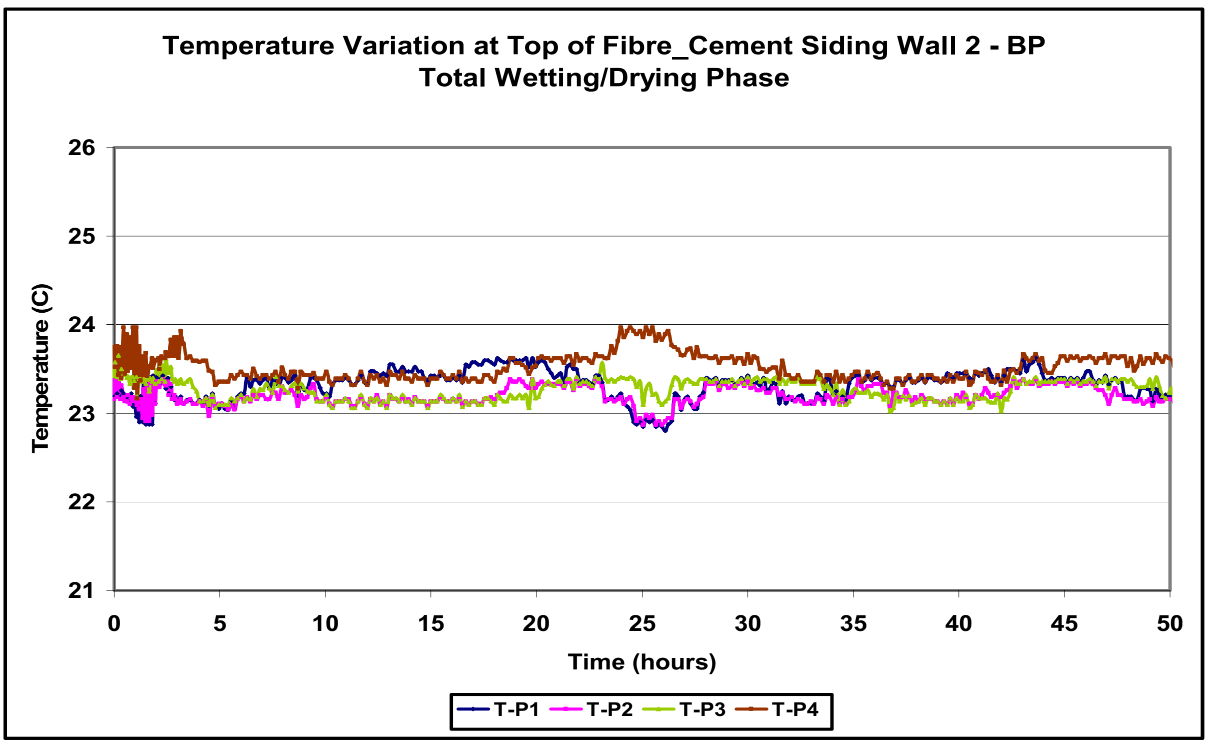
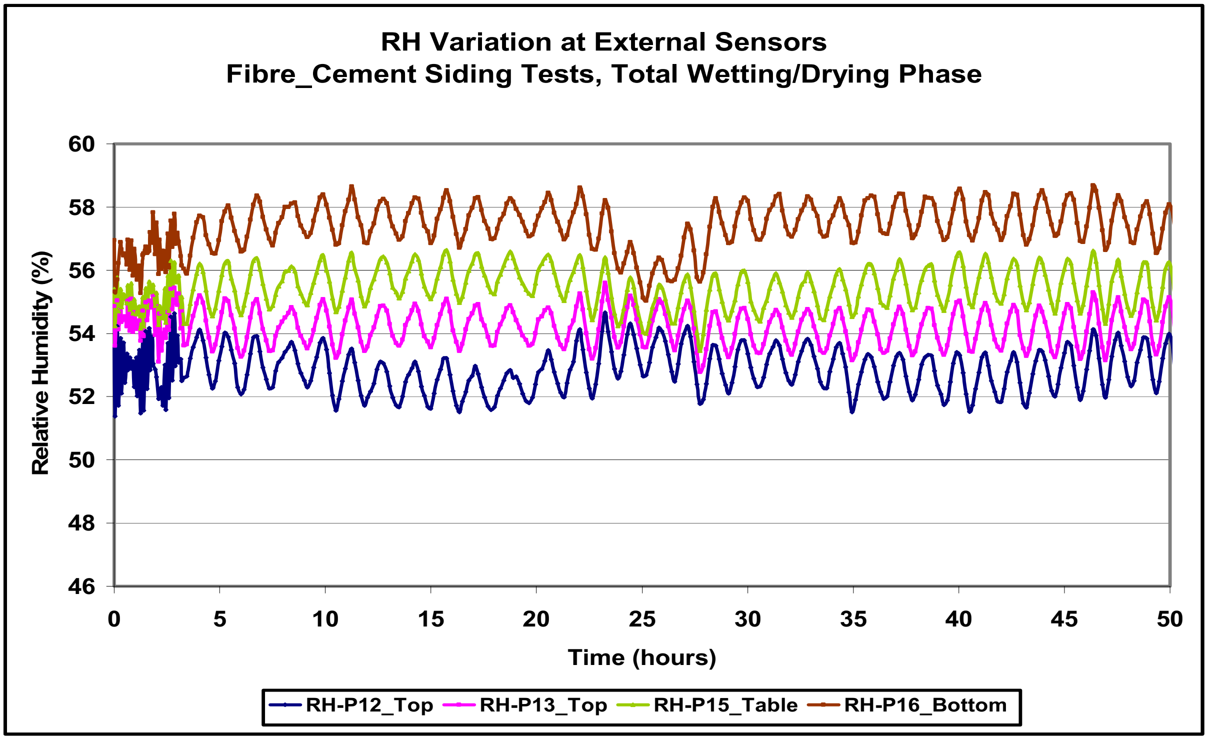


Figure A-VI- 9 Full Duration records of RH and T at four locations across the width of the test sample above the top level of fibre-cement siding installed against a wall with building paper WRB.



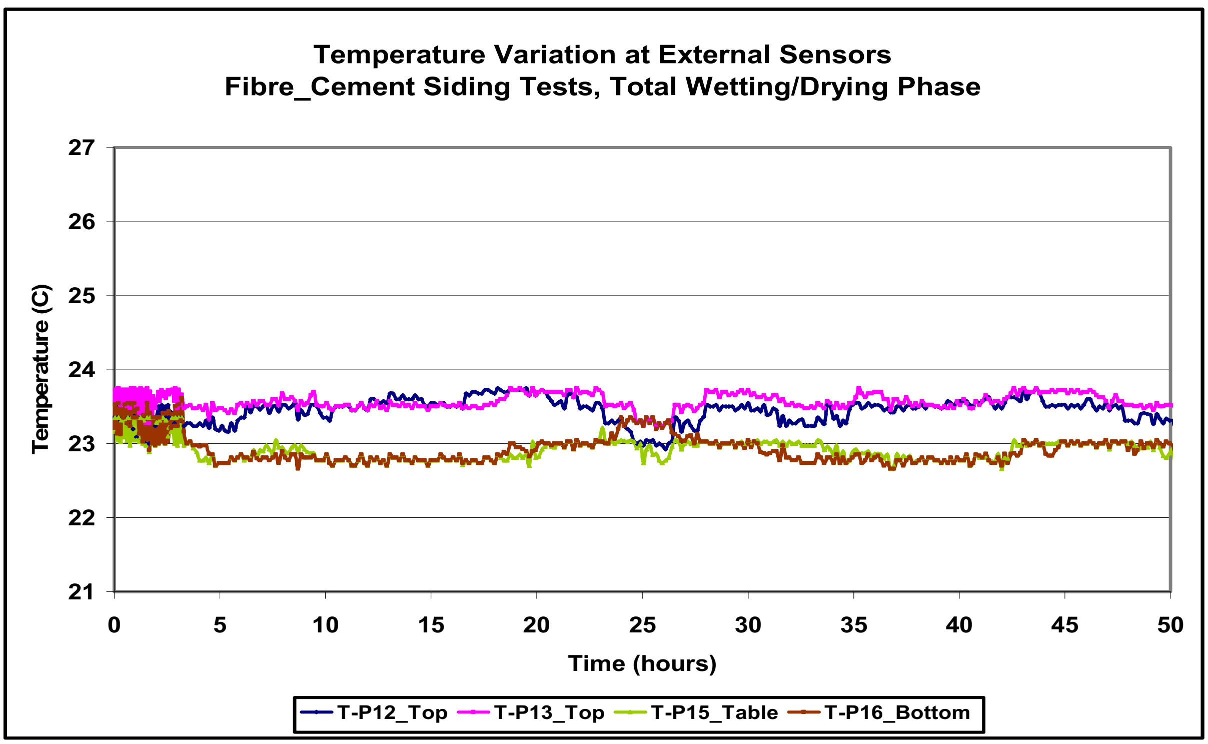


Figure A-VI- 10 Full Duration records of RH and T in the vicinity of the test area during the wetting/drying tests of two walls with fibre-cement siding.