Performance evaluation of proprietary drainage components and sheathing membranes when subjected to climate loads, task 5: characterization of water entry, retention and drainage of components

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Performance Evaluation of Proprietary Drainage Components and Sheathing Membranes when Subjected to Climate Loads

Task 5 — Characterization of Water Entry, Retention and Drainage of Components

Travis Moore and Michael Nicholls

15 March, 2014

National Research Council Canada
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Canada

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HAL Industries Incorporated

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Keene Building Products™

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Roxul Incorporated

STO Corporation

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Summary

A benchmark wall assembly and a series of eleven client wall assemblies were developed as part of the project “Performance Evaluation of Proprietary Drainage Components and Sheathing Membranes when Subjected to Climate Loads”.

The purpose of this project is to assess the performance of wall drainage components and sheathing membranes (drainage system) in respect to their ability to provide sufficient drainage and drying in Canadian climates having a moisture index (MI) greater than 0.9 and for degree-days < 3400, or MI greater than 1.0 for degree days ≥ 3400 (primarily coastal areas). In these locations, the 2010 National Building Code requires a capillary break behind all Part 9 claddings. Currently, acceptable solutions to the requirement for a capillary break as given in the NBC include:

- A drained and vented air space not less than 10 mm deep behind the cladding;
- An open drainage material, not less than 10 mm thick and with a cross-sectional area that is not less than 80% open, behind the cladding;
- A cladding loosely fastened, with an open cross section (i.e. vinyl, aluminum siding)
- A masonry cavity wall or masonry veneer constructed according to Section 9.20 (i.e. 25 mm vented air space)

In this project, the performance of proposed alternative solutions for the capillary break were compared through laboratory evaluation and modeling activities to the performance of a wall built to minimum code requirements; the benchmark wall assembly is one that incorporates a NBC-compliant stucco cladding. If the wall system exhibits adequate performance, it will be deemed an alternative solution to the capillary break requirement in the NBC for use with all code compliant Part 9 claddings.

In This Report — The research conducted for Task 5 of the project is described in which the water entry through the stucco cladding is characterized, both due to deficiencies and through the porous cladding itself, as well as the drainage-retention characteristics of each drainage system. The water entry characteristics of the cladding and the drainage-retention characteristics were used by the numerical simulation to permit linkage between the climate loads, to which the wall were subjected, to that of moisture loads within the drainage cavity. Additionally, in this report, details are provided of results from a drying experiment on NRC-compliant stucco, and in which is provided data to which the numerical simulation were compared to permit benchmarking the simulation results.

Performance Evaluation of Proprietary Drainage Components and Sheathing Membranes when Subjected to Climate Loads

Task 5 – Characterization of Water Entry, Retention and Drainage of Components

Authored by:

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A Report for the

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15 March, 2015

Performance Evaluation of Proprietary Drainage Components and Sheathing Membranes when Subjected to Climate Loads –

Task 5 – Characterization of Water Entry, Retention and Drainage of Components

Final Report Water Entry forming part of Task 5

Travis Moore and Michael Nicholls

1 Introduction

A benchmark wall assembly and a series of eleven client wall assemblies were developed as part of the project "Performance Evaluation of Proprietary Drainage Components and Sheathing Membranes when Subjected to Climate Loads"[1].

The purpose of this project is to assess the performance of wall drainage components and sheathing membranes (drainage system) in respect to their ability to provide sufficient drainage and drying in Canadian climates having a moisture index (MI) greater than 0.9 and for degree-days < 3400, or MI greater than 1.0 for degree days ≥ 3400 (primarily coastal areas). In these locations, the 2010 National Building Code[2] requires a capillary break behind all Part 9 claddings. Currently, acceptable solutions to the requirement for a capillary break as given in the NBC include:

- A drained and vented air space not less than 10 mm deep behind the cladding;
- An open drainage material, not less than 10 mm thick and with a cross-sectional area that is not less than 80% open, behind the cladding;
- A cladding loosely fastened, with an open cross section (i.e. vinyl, aluminum siding)
- A masonry cavity wall or masonry veneer constructed according to Section 9.20 (i.e. 25 mm vented air space)

In this project, the performance of proposed alternative solutions for the capillary break will be compared through laboratory evaluation and modeling activities to the performance of a wall built to minimum code requirements; the benchmark wall assembly is one that incorporates a NBC-compliant stucco cladding. If the wall system exhibits adequate performance, it will be deemed an alternative solution to the capillary break requirement in the NBC for use with all code compliant Part 9 claddings.

In this report, details are provided of the research conducted in Task 5 of this project that relates to the characterization of water entry to, and the retention and drainage from wall components purportedly used to promote the drainage and drying of moisture from within a vented or ventilated cavity of the wall assembly.

[1] List of all project Reports provided in Appendix 1
[2] National Building Code of Canada

A description of the test methods are given and results are provided for:

- Water entry tests;
- Depth measurements of the drainage cavity following the fabrication of stucco cladding mock-ups for each of the Client drainage systems;
- Tests to determine drainage from and retention within drainage cavities of the respective Client drainage systems, and;
- Test to characterize the moisture dissipation rate of a saturated NBC-compliant stucco plate, representative of stucco cladding.

Each of these results provided inputs to the numerical simulation model, with the exception of the test to characterize the moisture dissipation of a stucco plate which was used as an experimental benchmark to which the numerical simulations were validated; the results of the benchmarking exercise are given in the Task 3 Report (see Appendix 1).

2 Approach

The approach used for this evaluation was to characterize all of the elements that contribute to water accumulation in the drainage cavity and thereafter these would be combined as inputs to the numerical simulation model. An overall perspective of the moisture loads within a wall assembly that occur from rainfall on the exterior surface of a wall is provided in Figure 1. As can be seen in this figure, some of the wind-driven rain impinging on the surface of a wall during a rain event may penetrate the cladding and enter the cavity directly behind it. The water entry may occur through the cladding proper and for stucco cladding, as for any cladding comprised of porous materials, this may be through cracks and other similar openings that invariably exist on the exterior surface. Water entry may also occur at through-wall penetrations such as ventilation ducts, pipes, and electrical outlets or at windows. Whichever manner

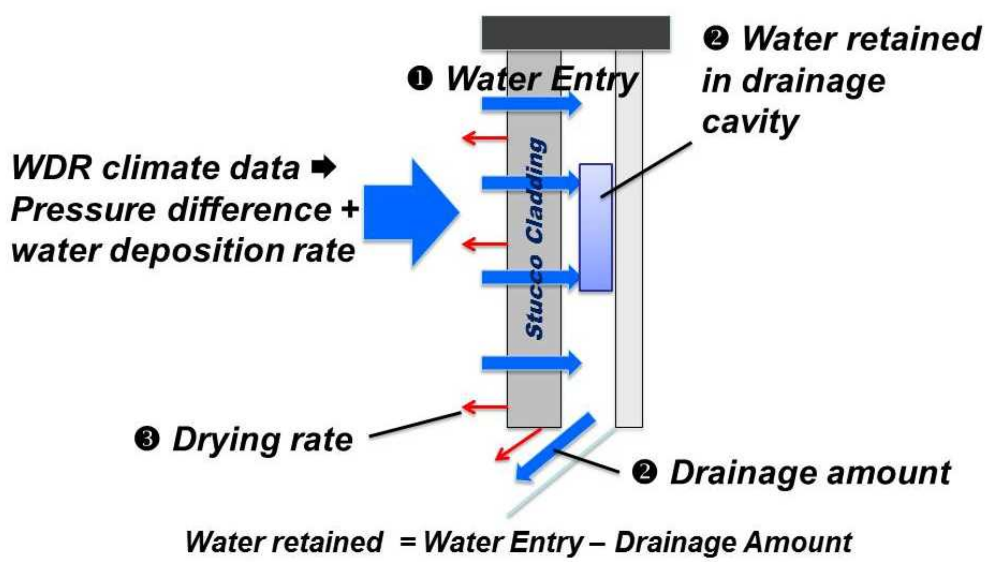

Figure 1 – Overview of Elements to be characterized for Numerical Simulation

water enters the cavity behind the cladding, there is a portion that may be retained in the cavity by direct absorption of the porous cladding, or by adsorption to the surface of the sheathing membrane or drainage components located in the cavity. To determine the amount of water accumulation in the drainage cavity and thus to establish the moisture load to the wall assembly, consideration must be taken of the amount retained due to sorption into and adsorption on components in the cavity, and also the amount that may drain from the cavity. There is also consideration of the amount of moisture that may dissipate from the porous cladding due to differences in temperature and relative humidity at its surface as compared to that within the bulk of the material.

Thus, as depicted graphically in Figure 1, there are several effects that must be characterized to adequately represent the hygrothermal performance of drainage systems of wall assemblies clad with porous materials; these include:

(i) Wind-driven rain (WDR) loads as might occur in locations across Canada for which MI is > 1[3];
(ii) Range of water deposition rates and pressure differences corresponding to WDR loads;
(iii) Water entry rates as result from testing at given water deposition rates and pressure differences;
(iv) Characterization of the size of actual drainage spaces behind NBC-compliant stucco cladding incorporating drainage systems (drainage component and sheathing membrane) of interest to project partners, and;
(v) Water drainage from and retention within cavity that incorporates different drainage systems;
(vi) Moisture dissipation from a stucco plate representative of a NBC-compliant stucco cladding.

Each of these effects was characterized in this study and some of these are reported elsewhere (see Appendix 1). Specifically, the WDR loads, item (i), as derived from climate data, were determined for several different locations across Canada and the US and can be found in the Task 5 Report on "Defining Exterior Environmental Loads". Likewise for item (ii), the range of water deposition rates and pressure differences that were subsequently used to define the water entry loads that correspond to WDR loads, are found in the Task 5 Report on Exterior Environmental Loads. The pressure difference that drives water into openings on the cladding and subsequently into the drainage cavity were also derived from climate data based on average wind speeds of selected locations.

In the following section, details are provided of the work that was conducted to characterize:

- Water entry of the cladding (item iii);
- Depth measurements of venting and drainage cavity following the fabrication of several stucco cladding mock-ups (item iv);
- Drainage of water from and retention within the venting and drainage system (item v).

Thereafter, in a subsequent section, information is provided on moisture dissipation from a stucco plate as representative of a NBC-compliant stucco cladding (item vi).

[3] See also § 1.0

2.1 Moisture Loads due to Water Entry to Drainage Systems

2.1.1 Water Entry Rates of the cladding

The characterization of water entry rates (item iii) across the cladding when subjected to simulated wind-driven rain (WDR) loads was undertaken in two separate tests: water entry due to deficiencies at selected penetrations in the cladding, and; water entry of the cladding proper and through the porous stucco plate. Water entry due to deficiencies present at penetrations of the cladding might arise due to improperly designed components, inadequate installation practices, or long term exposure to climate effects that damage products used to seal the penetrations. In this project deficiencies were assumed to be the result of an improperly sealed ventilation pipe located in the cladding for which the perimeter seal was compromised and through which water could enter. Water entry of the cladding proper was also determined on the basis of water entry tests and this is described in the subsequent sections.

The results derived from water entry tests resulted in obtaining rates of water entry as a function of simulated WDR conditions impinging on an exterior wall, and more specifically, water deposition on the cladding surface and pressure difference across the assembly. As such, the rates of water entry could be used to establish moisture entry loads to the drainage cavity providing input to the: (i) numerical simulation model as a load at given water deposition and pressure conditions; (ii) drainage and retention testing, the characterization of the latter item being described in a subsequent section.

2.1.1a — Water Entry Rates at Deficiencies

The water entry tests were conducted using the midscale Dynamic Wind and Wall Test Facility (DWTF), for which a photo of the test apparatus is shown in Figure 2. The apparatus is configured to subject test

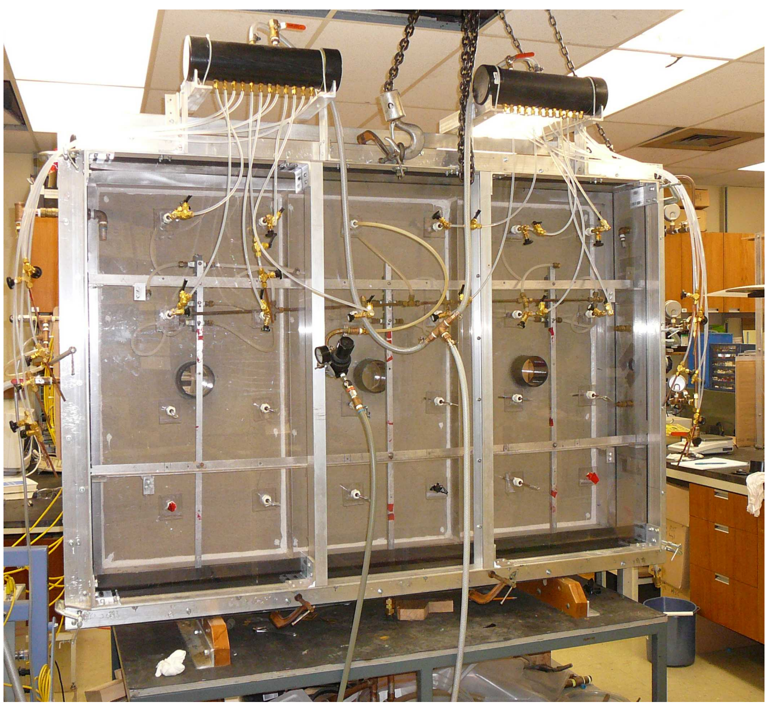

Figure 2 – Midscale DWTF

specimens, the height and length not exceeding, 1220 mm and 1830 mm (4-ft. by 6- ft.) respectively, to simulated conditions of WDR. Thus, specimens can be subjected to water deposition rates of up to 3.4L/min-m^2 and pressure differentials reaching 1.2 kPa. As well, test specimens can be exposed to static and sustained pressure conditions or, if required, dynamic sinusoidal pressure fluctuations at rates less than 2 Hz.

Initial tests trials consisted of exposing three adjacent test specimens to water entry testing; the test set up can be seen in Figure 3. Each test specimen was comprised of a ca. 610 mm wide and 1220 m high (2-ft by 4-ft) polycarbonate plate that was mounted in the mid-scale DWTF; the use of a polycarbonate plate permitted capturing water entry in isolation of a stucco cladding. Installed in each test specimen was a 4-in. diameter ABS ventilation pipe located approximately mid-height and along the center line of the test specimen.

As previously mentioned, deficiencies were assumed to be the result of an improperly sealed ventilation pipe; the manner in which this was implemented can be seen in Figure 4, and photos specific to the polycarbonate testing can be seen in Appendix 2. Openings of ca. 2.9 mm diameter were made in the joint seal above the ventilation duct to permit entry of water behind the cladding. Water was deposited with a spray nozzle on the area directly above the pipe and in this initial set of water entry tests both dynamic and static pressures were applied to determine the effect of pressure fluctuations on water entry at the ventilation pipe.

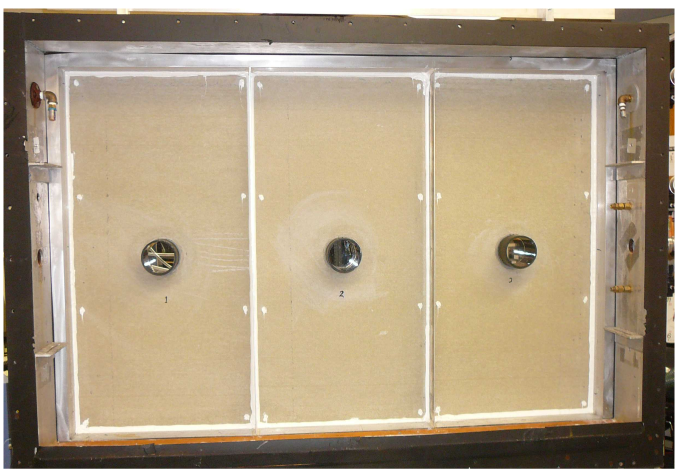

Figure 3 – Water Entry Rate at deficiencies test samples

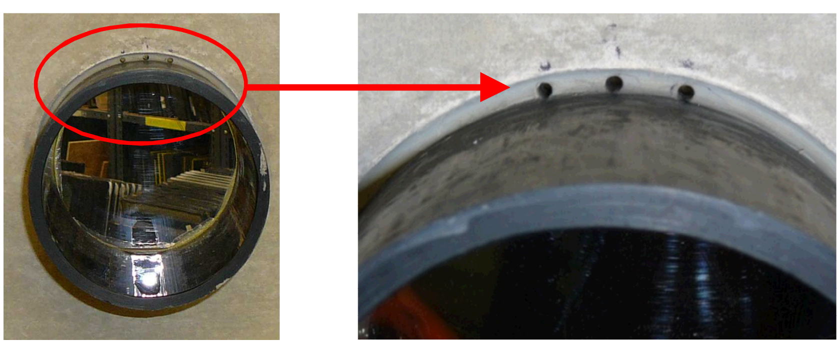

Figure 4 – Number and size of deficiencies located above ventilation pipe

The tests were conducted for clear cavity depths of 5 mm, 10 mm and 20 mm. The results from these initial trials are provided in Appendix 2. It was determined that the dynamic pressure fluctuations did not have a determinable difference in water entry rates as compared to those obtained under static test conditions, and likewise the depth of the cavity did not affect water entry results. It was concluded, as a consequence, that any subsequent water entry tests would all be conducted under static pressure conditions and additionally, rates of water entry to a cavity would be applicable for all cavity depths of interest.

In a subsequent series of water entry tests, test specimens consisted of a fiber cement panel as cladding, a 4-in diameter ABS ventilation pipe as a typical through-wall penetration, and three openings of ca. 2.9 mm diameter representative of local deficiencies above the pipe, as was previously described. Using the Midscale DWTF, a set of three adjacent test specimens were subjected to static applied pressures ranging from 0 to 1150 Pa, and three different water deposition rates of: 0.58, 1.16, and 1.74 L/min-m^2. The results for the average water entry rates in relation to given simulated WDR conditions of several trials are given in the subsequent section.

2.1.1b — Water Entry Rates through Stucco Cladding

Water entry rates through the cladding proper were characterized for the stucco cladding itself. The results used in this project were those acquired in a previous study[4] in which a relationship was developed for the water entry rate in relation to the water deposition rate on and pressure difference across NBC-compliant stucco cladding. This study consisted of testing a full scale stucco wall specimen (2.44-m x 2.44-m) for water entry with pressures ranging from 0 to 700 Pa, and water deposition rates of 1.0, 2.0, and 3.4 L/min-m^2. Results for this work are provided in Appendix 3.

As previously mentioned, the water entry characteristics of the cladding due to entry at selected deficiencies or through the cladding proper, were used to determine the amount of water to inject into the drainage cavity, either for simulation purposes, or to characterize the capacity of a drainage system (drainage component and sheathing membrane pair) to permit drainage and to retain moisture. The net result of the quantity injected less the quantity drained was used as the moisture load on the wall assembly outboard of the sheathing membrane. The capacity of a given drainage system to drain and likewise its propensity to retain water is necessarily affected by the size of the drainage gap, that is, the depth of the drainage cavity. Accordingly, a description of the methods used to characterize this gap is given in the subsequent section.

2.1.2 Depth Measurements of Drainage Cavity

For a given drainage system, the depth of the cavity through which water may drain depends on the design of the drainage system, more specifically, the selection of products that line the drainage cavity, the extent to which the stucco is restrained by the metal lath, or otherwise pressed through openings in the lath during fabrication of the system, and the resulting depth of cavity. As such, several test specimens were constructed to determine the depth of cavity for each drainage system. In addition, and apart from

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[4] Saber, H.H.; Lacasse, M.A.; Moore, T.V.; Nicholls, M. (2014), Mid-rise wood constructions: investigation of water penetration through cladding and deficiencies; Client report A1-100035-03.; Report to Research Consortium for wood and wood-hybrid mid-rise buildings; RR-375; Construction; National Research Council Canada; 23 p.

informing on the depth of cavity to which the drainage and retention test specimens were built, knowledge of the cavity depth was also a useful input to the numerical simulations for individual wall configurations.

The resulting cavity depth, or drainage gap, from stucco installation was characterized by fabricating 914 mm by 914 mm (3-ft. by 3-ft.) specimens in accordance with the respective specifications of each of the wall assemblies as provided in the Task 1 Report (see Appendix 1) to which NBC Stucco is applied. The stucco was applied and cured in exterior conditions (from September to October, 2014) on the West facing wall of a local building, as shown in Figure 5; the work was undertaken by professedly knowledgeable and experienced stucco contractors.

Figure 5 – Samples for Drainage Gap Analysis

After curing for 28 days, the specimens were then cut at the centre vertically and horizontally so that the interior gaps could be measured to estimate the cavity depth, as seen in Figure 6.

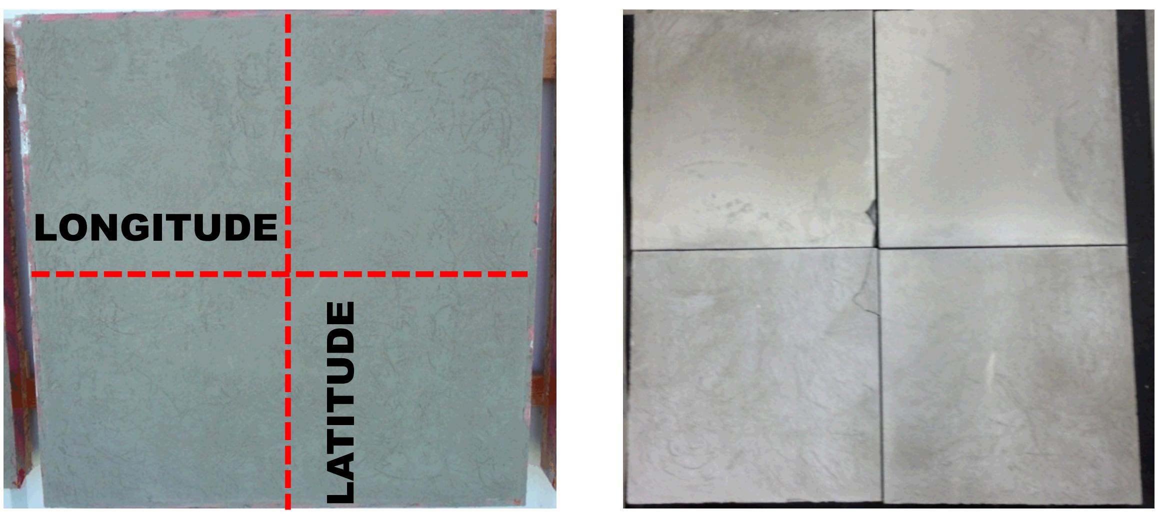


Figure 6 – Cut Lines for Gap Measurement

The gaps were then measured using computer analysis of vertical photographs taken along each edge. An example of the digitization of the drainage gap process of the NBC benchmark wall configuration is shown in Figure 7; the analysis of the digital photo is shown in Figure 8.

Figure 7 – Photo showing gap analysis on NBC Benchmark wall

Figure 8 – Computer Analysis of Drainage Gap

The size of the drainage gap was then calculated by comparing the number of black as compared to white pixels, and comparison to a scaled ruler captured in the first photo. This procedure was followed for each of the wall configurations investigated. The results from this work are given in §3.2 of this report. Knowledge of the cavity depth was used in the simulations as well as to fabricate specimens for the drainage-retention tests (item v).

2.1.3 Drainage and Retention of Wall Assemblies

After determining the cavity depths for each wall configuration, test specimens were constructed to determine the drainage and retention characteristics of each drainage system. Results from these tests were used as moisture loads to the drainage cavity in the numerical simulations. The drainage-retention relation is based on the percentage of water that remains in the cavity for a given water entry rate given in mL/h-m^2.

To determine the drainage-retention characteristics for a given drainage system, the boundary of the system was defined with two parallel panels, the sheathing board panel consisting of exterior grade OSB, and the cladding panel consisting of a polycarbonate plate, as opposed to the use of a stucco plate. This helped ensure that the drainage retention results were not affected by the absorption and desorption of moisture of the stucco plate over the course of a test; the moisture uptake and dissipation phenomena was in any case be taken into account in the numerical simulations.

The test specimens were 1220 mm wide by 1830 mm high (4ft by 6ft), and water was dosed to the drainage cavity along the entire width of the cavity (i.e. 1220 mm / 4ft.). For evaluation purposes the water was dosed onto the “front” side of the sheathing membrane, which is at the “back” of the drainage cavity, assuming the front of the cavity is towards the exterior of the wall and the back of the cavity towards the interior. This was intended to simulate a “worst case” condition whereby water entry to the cavity has entirely been deposited onto the surface of the sheathing membrane. To direct water to the back of the cavity a metal tray was used that permitted depositing water onto the front surface of the sheathing membrane, as shown in Figure 9. Water was evenly directed along the length of the metal tray from a 1220 mm (4-ft.) long copper tube in which small uniformly spaced openings of ca. 0.5 mm Ø had been made to permit a consistent rate of deposition of water across the opening to the drainage cavity. Water was provided to the copper dosing tube by use of a centrifugal pump, capable of dosage rates ranging from 0 L/h to 10 L/h.

The test consisted of injecting water into the drainage cavity at a constant rate and for a duration of one hour. The quantities of water that drained from the system were monitored gravimetrically during the test, and were subsequently used to determine the retention rate of the drainage system. The water entry rates to the cavity were determined by comparing the water entry correlations developed from results obtained from the water entry tests, as described in § 2.1.1.

Tests were conducted at water entry rates of 3, 4, 5, 6 and 8L/hour. It was determined that of the rates tested, the retention and drainage quantities were not affected by the water entry rate, rather they depended on the quantity of water being injected. As such, the final test rates were determined to be 6L/hr for one hour, and 8L/hr for one hour. The dosage levels were determined from maximum water entry rates that could occur in selected Canadian locations. A comparison of the dosage levels to water entry rates derived from climate loads for different cities in Canada can be found in Appendix 3.

Figure 9 – Water Entry to Drainage Cavity Apparatus

2.2 Test to characterize moisture dissipation from NBC-Compliant stucco plate

A laboratory test was completed to determine the moisture dissipation rate from a saturated NBC-compliant stucco plate to permit the results to be benchmarked against those derived from numerical simulation. The stucco plate was saturated in a water basin and thereafter placed on a weigh scale, whereby its weight and change in weight over time could be monitored continuously over the course of the test. NRC-Construction's Wall Weighing System (WWS), as shown in Figure 10, was used to measure the weight changes in the stucco plate. The weigh scale is capable of measuring loads of up to 200 kg with an accuracy of ± 2 g. Temperature and relative humidity sensor pairs (Vaisala HTM2500; ± 3% RH) were placed in close proximity to the top and bottom extremities of the exposed surface of the stucco plate and as such, permitted determining the laboratory conditions under which the moisture dissipation occurred.

The test protocol consisted of imposing one-dimensional moisture dissipation from the plate. Accordingly, the perimeter edges of the plate were sealed with wax (Figure 10) and the backside of the plate was subsequently sealed with an impermeable sheathing once mounted in the WWS. The test specimen was weighed and then submerged in a water basin until saturation was achieved (Figure 10), this being determined by successive weighing of the plate until no weight change was evident for three successive trials. Thereafter, the stucco plate was mounted in the WWS where it was weighed for the duration of the test.

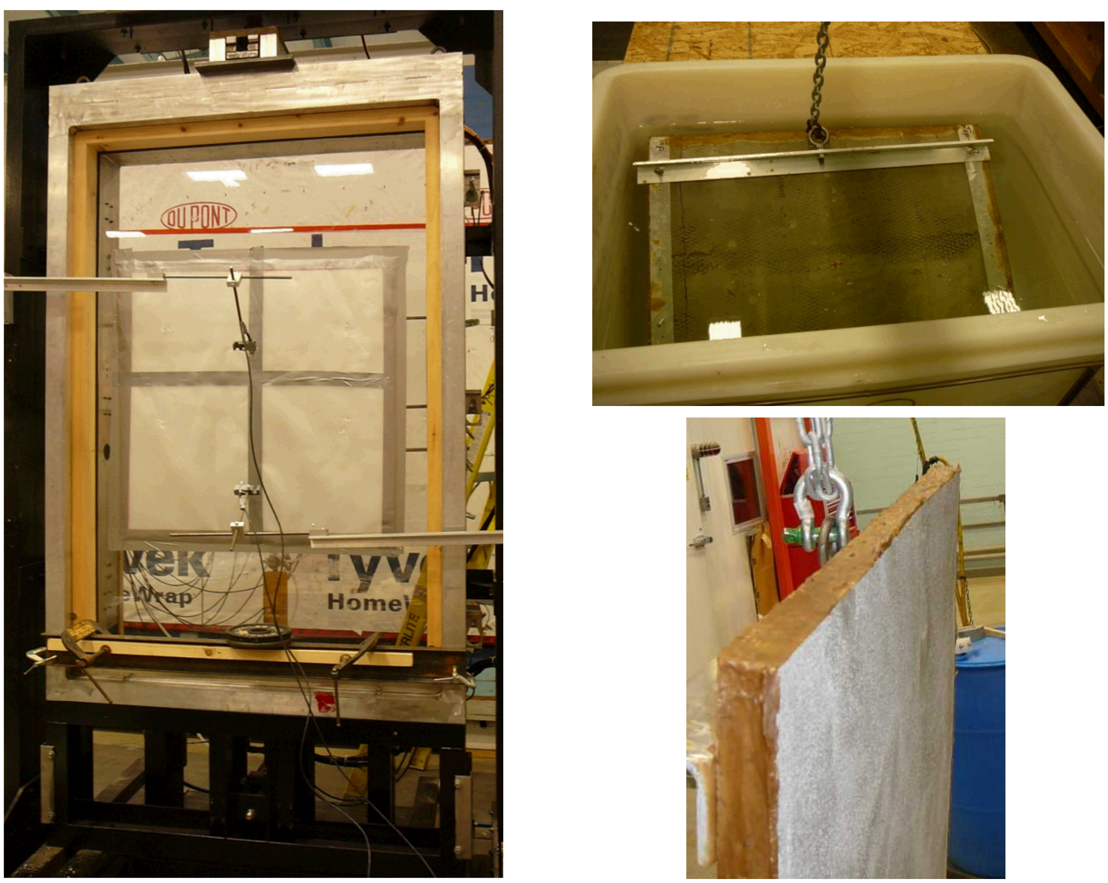


Figure 10 – Wall Weighing System and Stucco Plate Wetting

3 Results

Four (4) sets of results are provided; results of:

(i) Water entry tests as obtained from deficiencies and through fibre-cement cladding are first provided and thereafter, results on water entry through stucco cladding are given; the relative importance between moisture loads is also discussed;
(ii) Depth measurements of the venting and drainage cavity;
(iii) Tests on drainage from and retention in drainage systems, and;
(iv) Laboratory test for moisture dissipation from a NBC-compliant stucco plate

3.1 Water Entry Results

3.1.1 Water Entry due to Deficiencies

As discussed, the water entry at deficiencies was conducted for deficiencies located above a ventilation pipe for pressure differences ranging from 0 to 1150 Pa and water spray rates of 0.58, 1.16, and 1.74 L/min/m^2. The results of testing completed on deficiencies and with fibre-cement panel cladding test specimens are given in Figure 11. The water entry rate was evaluated as a percentage of the water deposition rate on the surface of the cladding.

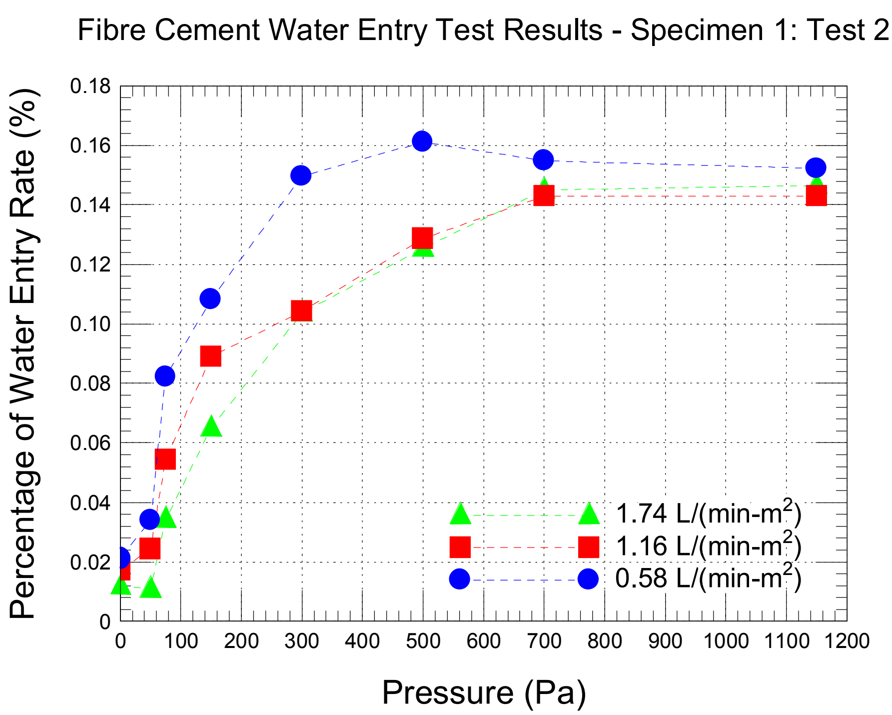


Figure 11 – Water Entry Rates at Deficiency Locations

Figure 11 shows that the water entry rates are dependent on the deposition rate (equivalent to wind driven rain) and the pressure difference acting across the wall assembly. In general, for increasing deposition rates at a given pressure difference, water entry rates increase, and for increasing pressure differences at given water deposition rates, water entry rates likewise increase. For this deficiency type and for each deposition rate, the water entry rate reaches a plateau at approximately 700 Pa; thus increasing the pressure difference to 1150 Pa has no appreciable effect on the water entry rate. From these water entry rates, correlations were developed that allowed calculation of water entry rates for any given wind driven rain and pressure condition.

3.1.2 Water Entry through Stucco Cladding

The water entry rate through the Stucco cladding was determined by analyzing results from previous work and these are presented in Figure 12.

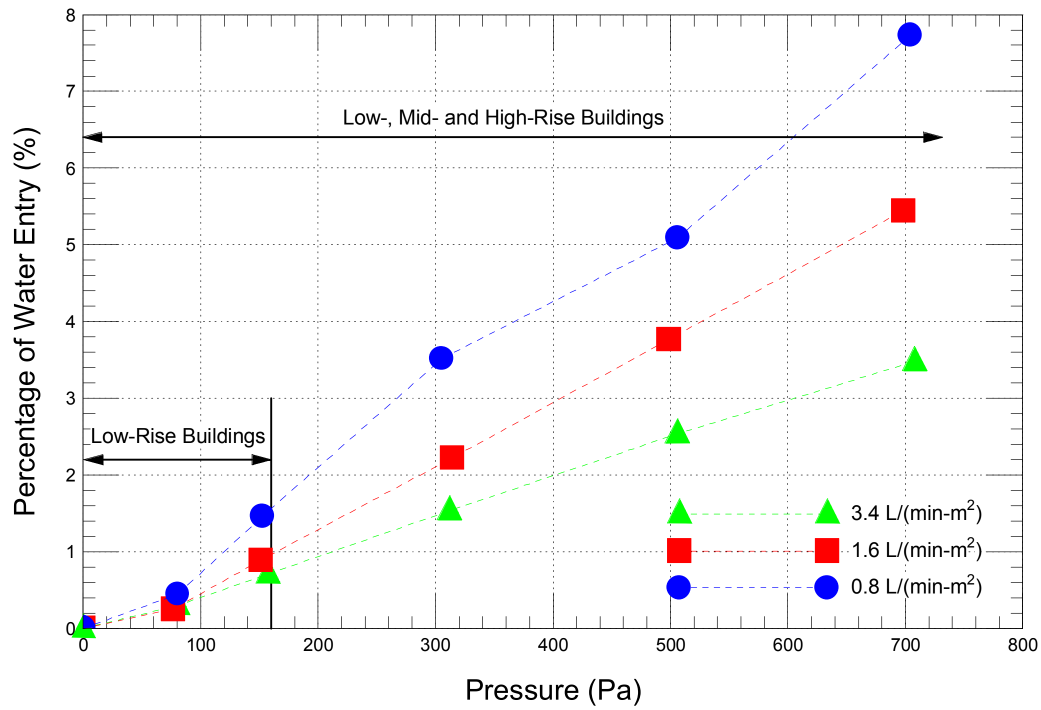


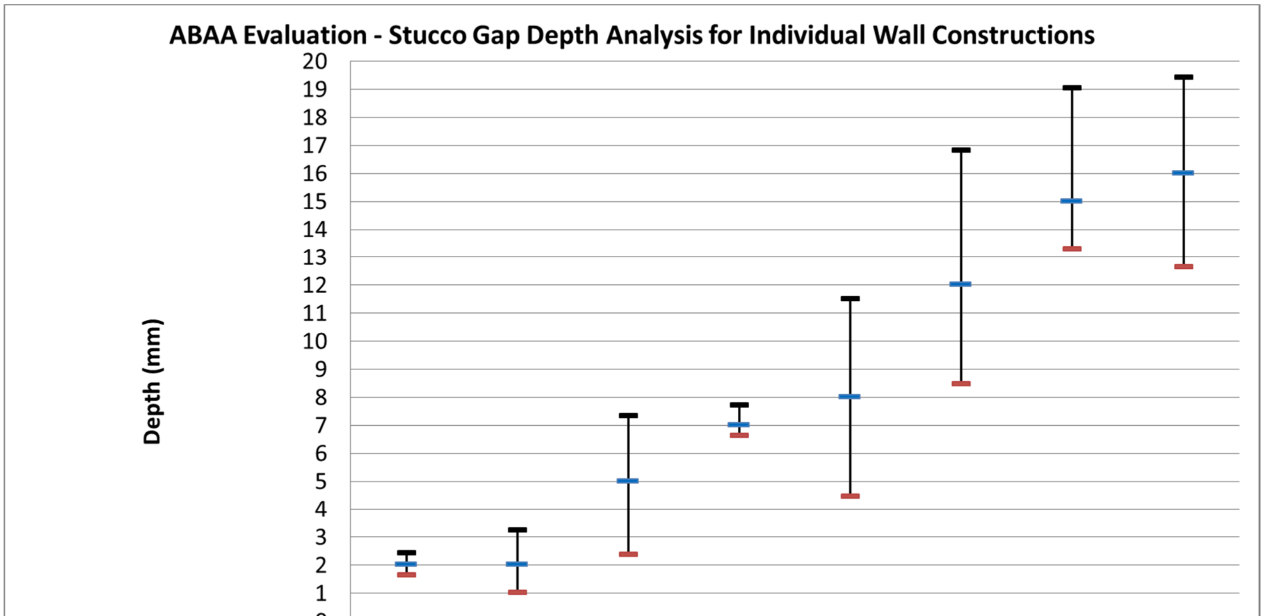
Figure 12 – Water Entry Rates through Stucco Cladding

A correlation was also derived from the result of water entry tests that relates the water entry rate through stucco cladding for any given wind driven rain condition, that is, for selected water depositions rates (i.e. 0.8, 1.6 and 3.4 L/min-m^2) and at a range of pressure differences (0 – 700 Pa) acting across the wall assembly.

Water entry results obtained from deficiencies in the stucco cladding are extremely small as compared to that of water entry through the cladding proper. The approximate maximum percentage water entry rate derived from deficiency testing was 0.16%, whereas this maximum is approximately 8% for the cladding proper. Whereas for the numerical simulations both water entry conditions were included in the analysis, for the drainage retention testing only the quantity of water through the stucco cladding was considered when estimating water entry rates to the drainage opening; as well, these water entry rates were rounded to the nearest litre per hour.

3.2 Results from Depth Measurements of Venting and Drainage Cavity

The effect of stucco being pressed through openings in the metal lath during construction and the resultant drainage cavity for each wall configuration is presented in Figure 13.



	Client A	Client D	Client B	Benchmark	Client I	Client G	Client E	Client C
Average Depth(mm)	2	2	5	7	8	12	15	16
Max Measured Depth (mm)	2	3	7	8	12	17	19	19
Minimum Measured Depth (mm)	2	1	2	7	4	8	13	13

Figure 13 – Effect of Stucco installation practice on depth of venting and drainage cavity

Figure 13 depicts the resulting measurements of cavity depth for client specimens A, B, C, D, E, G, I and the NBC reference wall; Client F was not evaluated in this exercise. Client H had a cavity depth the same as its nominal depth, and the wall configuration details for Client J and K were not available at the time of testing. However, the cavity depths for the drainage systems of Clients I and J were nonetheless estimated and these estimates are presented in Table 1 together with the results of the other wall configurations.

The information provided in Table 1 brings attention to the fact that there were some drainage systems whose nominal cavity depth, as provided in the specifications, was smaller than that obtained from measurements of a cured stucco cladding (i.e. Clients C, E, G, I) as were fabricated for the purpose of estimating the depths of these cavities. It was surmised that such type of variations arose due to movement of the metal lath following the dissection of specimens into quarter panels (Figure 7). The movement was preferentially to enlarge the depth of the cavity, although this was not the case for the reference specimen, nor for configurations of Clients A, B, D and H. The results provided in Table 1 show the nominal cavity depth, the cavity derived from measurement of the digitized profile of the cavity and the cavity depth used in the numerical simulations and for the fabrication of drainage-retention test specimens. In instances where the measured depth was larger than the nominal depth, the nominal cavity depth was used in the numerical simulations and for the fabrication of drainage-retention test specimens.

Table 1 –Summary of Results Obtained for Depths of Venting and Drainage Cavities

NRC Client #	Nominal Cavity Depth mm	Cavity Depth Stucco Applied mm	Cavity Depth for Simulation mm
Benchmark	10	7	7
Client A	2	2	2
Client B	89	75	75
Client C	10.5	16	10.5
Client D	2	2	2
Client E	10.6	15	10.6
Client F	25	25	25
Client G	9.3	12	9.3
Client H	51	51	51
Client I	3.8	8	3.8
Client J	9.5	-	5.5
Client K	19.5	-	15.5

* Distance between sheathing membrane and inboard of stucco cladding

3.3 Results from Tests on Drainage from and Retention in Drainage Systems

From the data generated on the depths of the drainage cavity, as provided in the previous sections, 1220 mm wide by 1830 mm high (4-ft. x 6-ft.) test specimens were constructed for each drainage system (with the exception Client J and K) from the sheathing board to the exterior (not wood stud frame) and subjected to drainage and retention testing. The intent of the test was to determine, from a given water entry rate, what quantity of water was retained in the drainage system. This quantity nominally formed the moisture load to which the cavities of wall system were subjected in numerical simulations.

The results of the drainage-retention tests, shown in Figure 14, depict the retention characteristics all of the respective drainage systems evaluated. The retention characteristics of the respective drainage systems are given in Appendix 4. The results suggest that for greater amounts of water deposited in the drainage cavity, given in mL/h-m^2, a smaller proportion (% retained) of that dosage is retained in the cavity. Additionally, the numerical simulation used the data provided in Figure 14 as input to the simulation. Dosage amounts to the cavity derived from water entry correlations that were between values on the moisture retention curve were linearly interpolated.

The wall configurations of Clients J and K were not available at the time of the construction of the test specimen for determining the depth of venting and drainage cavity; however, the drainage-retention characteristics of the drainage system for Clients J and K can be derived from the test results provided. The information provided in the Task 1 Report (Appendix 1) indicates that the drainage system for the NBC reference wall has similar construction details to that of wall assemblies of Clients J and K. Also, for this particular test, Client F had similar test specimen fabrication details as that of the NBC reference, Client J and K given that the proxy for the cladding was a polycarbonate panel. The similarity in results of the drainage retention tests (Figure 14) of the NBC reference and that of Client F is also clearly evident. As such, given the similarity amongst the water retention curves, it was entirely reasonable to apply the drainage-retention curves for the NBC reference to the drainage system of Clients J and K.

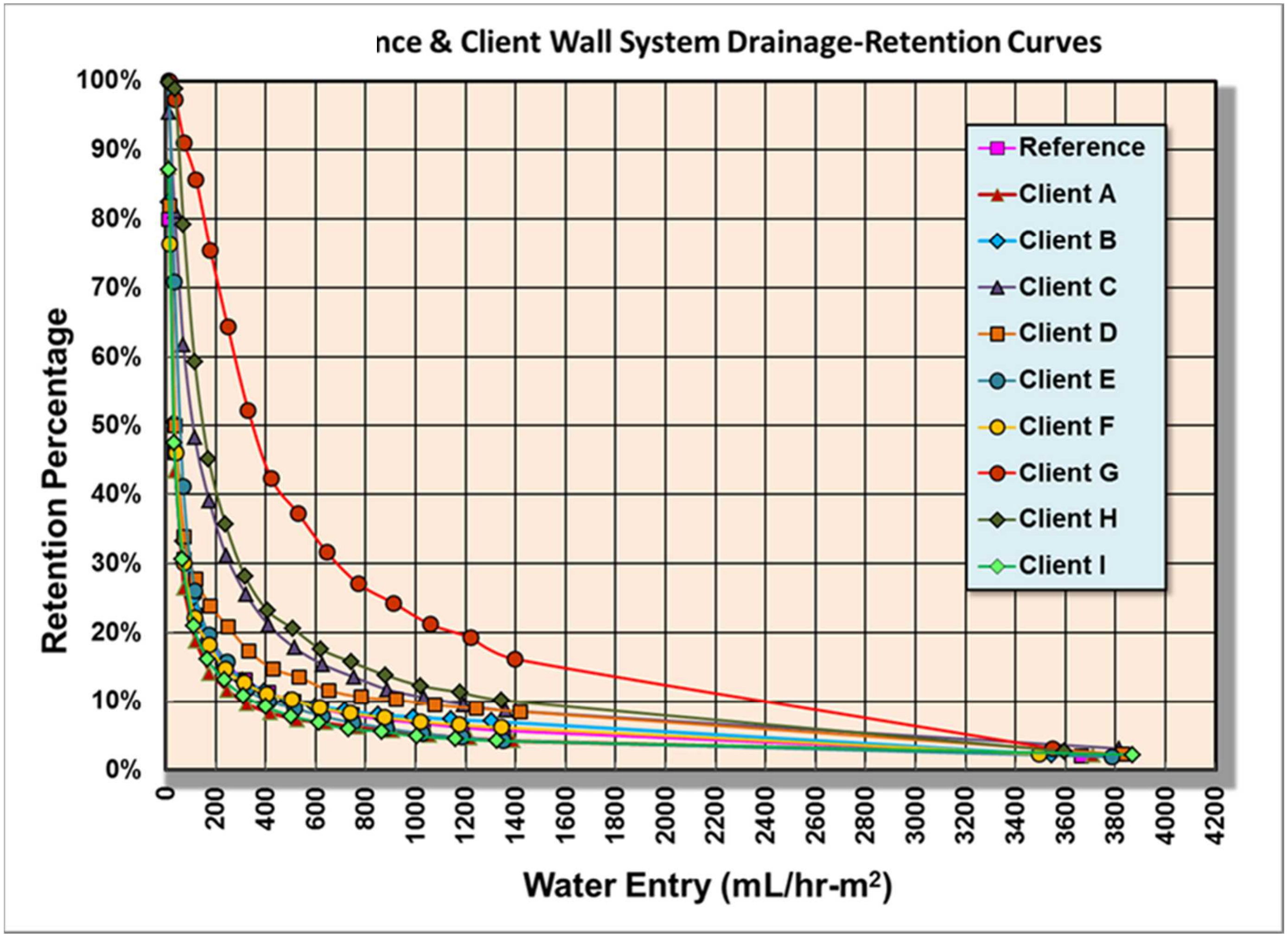


Figure 14 – Overall Results of Retention Testing

3.4 Results of Moisture Dissipation from Stucco Cladding

To permit benchmarking the numerical model, a laboratory test was conducted to monitor the moisture dissipation rate from a saturated NBC-compliant stucco plate. The stucco plate was saturated and thereafter its weight monitored using the Wall Weighing System to help determine the moisture dissipation rate in laboratory conditions. The humidity and temperature were monitored during the experiment to provide boundary conditions for the numerical simulations. The resulting moisture dissipation curve by weight is presented in Figure 15. For the purposes of numerical simulation the weight was converted to moisture content with the initial weight of the specimen at 100% moisture content. The moisture content drying curve is given in Figure 16.

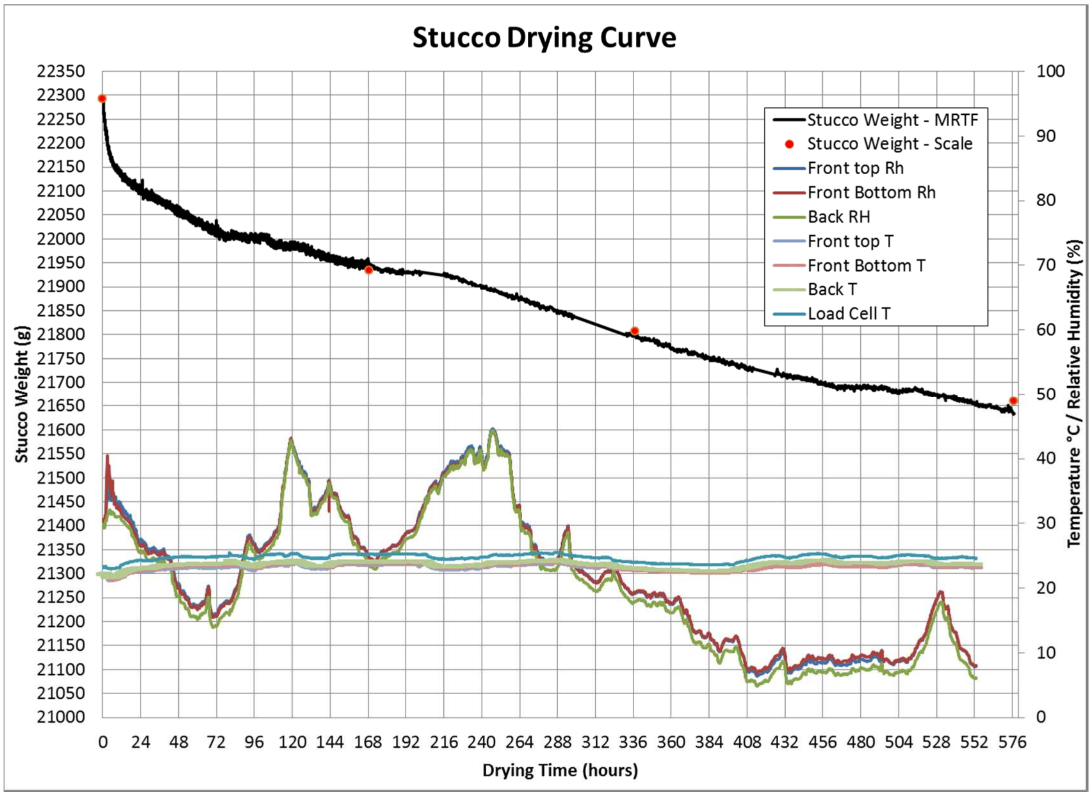


Figure 15 – Stucco Drying Rate Results by weight

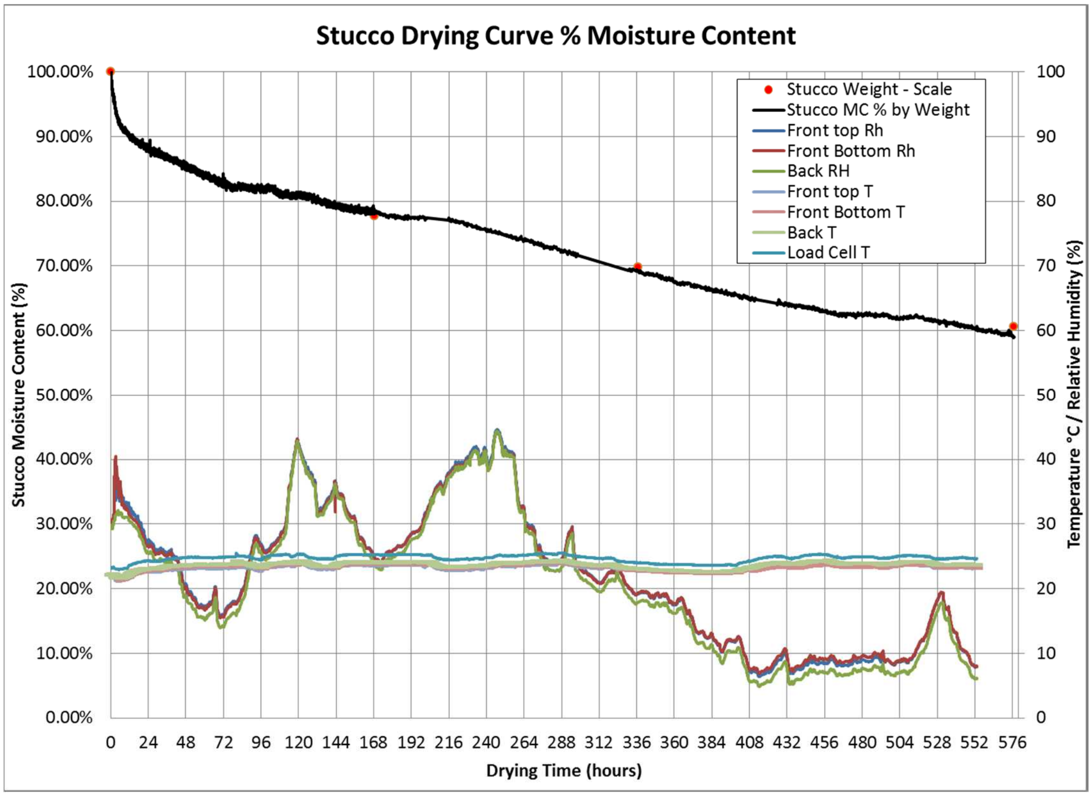


Figure 16 – Stucco Drying Rate in Moisture Content

4 Conclusion

This report provides details of the work undertaken to characterize moisture loads to a venting and drainage cavity of wall assemblies as input to a numerical model. Additionally it provides details of a benchmark laboratory test to characterize the moisture dissipation from a saturated stucco plate, the plate being representative of a NBC-compliant stucco cladding; these results were used for validation of the numerical simulation model. The NBC-compliant Stucco cladding which is applied to each drainage system was characterized for water entry, both due to deficiencies and through the porous cladding itself. The results of these water entry tests were used as an input to the drainage-retention testing as well as the numerical model. Drainage-retention testing was conducted on drainage systems for which the depth of the cavity was based on a review of the nominal depth as provided in the construction specifications, and that measured of specimens specially fabricated by knowledgeable stucco contractors, to determine the range depths to which such configurations could be made. The drainage-retention testing was conducted to establish the extent of moisture retention of the respective drainage systems when water was admitted to the cavity over a range of rates and consistent with those that could be expected due to climate loads in the representative Canadian cities; the results from these tests also provided input to the numerical simulation model. The results provided in this report provide the numerical simulation model inputs on moisture loads to the drainage cavity and moisture dissipation of components. Specifically, moisture loads to due to water entry to the drainage system through the cladding, through deficiencies, and that retained in the system following a rain event for each of the respective drainage systems of interest to this project.

Appendix 1 – List of Task Reports

Report	Reference
Task 1	M. Armstrong and B. Di Lenardo (2014), Performance Evaluation of Proprietary Drainage Components and Sheathing Membranes when Subjected to Climate Loads – Task 1 – Wall Assembly Specifications; Client Report A1-000030.01; National Research Council Canada; Ottawa, ON; 52 pgs.
Task 2	P. Mukhopadhyaya, D. van Reenen and S. Bundalo-Perc (2014), Performance Evaluation of Proprietary Drainage Components and Sheathing Membranes when Subjected to Climate Loads – Task 2 – Building Component Hygrothermal Properties Characterization; Client Report A1-000030.02; National Research Council Canada; Ottawa, ON; 58 pgs.
Task 3	H. H. Saber, W. Maref, and G. Ganapathy, (2015) Performance Evaluation of Proprietary Drainage Components and Sheathing Membranes when Subjected to Climate Loads – Task 3 –Hygrothermal Model Benchmarking; Client Report A1-000030.04; National Research Council Canada; Ottawa, ON; 63 pgs.
Task 4	W. Maref, H. H. Saber and G. Ganapathy (2015), Performance Evaluation of Proprietary Drainage Components and Sheathing Membranes when Subjected to Climate Loads – Task 4 – Characterization of Air Flow within Drainage Cavities; Client Report A1-000030.05; National Research Council Canada; Ottawa, ON; 115 pgs.
Task 5	Steven M. Cornick and Khaled Abdulghani (2013), Performance Evaluation of Proprietary Drainage Components and Sheathing Membranes when Subjected to Climate Loads – Task – Defining Exterior Environmental Loads; Client Report A1-000030.03; National Research Council Canada; Ottawa, ON; 99 pgs.
Task 5	T. Moore and M. A. Lacasse (2015), Performance Evaluation of Proprietary Drainage Components and Sheathing Membranes when Subjected to Climate Loads – Task 5 – Characterization of Water Entry to, Retention and Dissipation from Drainage Components; Client Report A1-000030.06; National Research Council Canada; Ottawa, ON; 43 pgs.
Task 6	H. H. Saber and M. A. Lacasse (2015) Performance Evaluation of Proprietary Drainage Components and Sheathing Membranes when Subjected to Climate Loads – Task 6 – Hygrothermal Performance of NBC-Compliant Reference Walls for Selected Canadian Locations, Client Report A1-000030.07; National Research Council Canada; Ottawa, ON; 59 pgs.
Task 6	H. H. Saber et al. (2015) Performance Evaluation of Proprietary Drainage Components and Sheathing Membranes when Subjected to Climate Loads – Task 6 – Hygrothermal Performance of Wall Assemblies with Cavities or Incorporating Drainage Components for Selected Canadian Locations; Client Report A1-000030.08; National Research Council Canada; Ottawa, ON.
Task 7	M. A. Lacasse (2015) Performance Evaluation of Proprietary Drainage Components and Sheathing Membranes when Subjected to Climate Loads – Task 7 – Summary Report on Experimental and Modelling Tasks and Recommendations; Client Report A1-000030.09; National Research Council Canada; Ottawa, ON.

Appendix 2
Water Entry Test Results under Static and Dynamic Loads

Table 2 – Water Entry Test Protocol under Static and Dynamic Loads

Water Deposition rates	0.97, 1.94, 2.98 [L/min/m^2]
Static Pressure Applied	0, 50, 75, 150, 300, 450 [Pa]
Dynamic Pressure Applied	300+- 60,100,150,240 [Pa] at 0.1, 0.5 and 1.0 Hz
Air Leakage	0.02 and 0.20 L/s/m^2 @75Pa
Vent Sizes	256 mm^2, 187mm^2, 132mm^2, 32mm^2

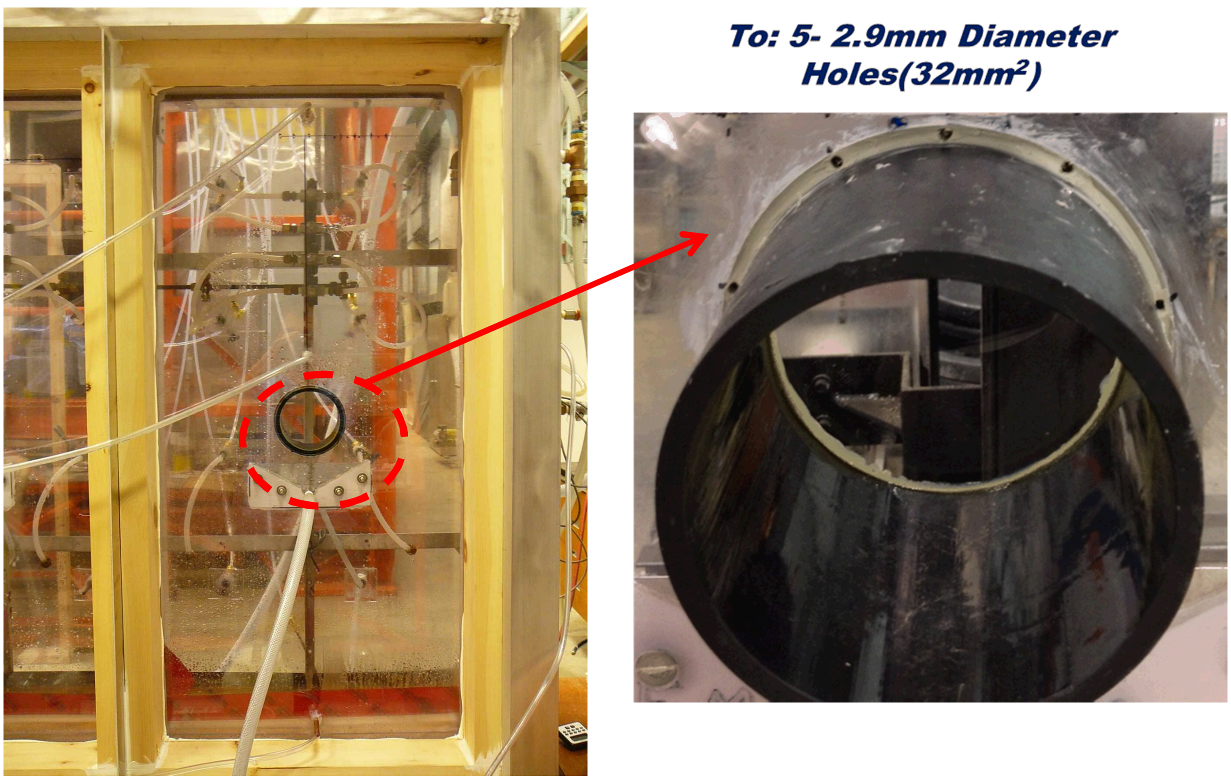


Figure 17 – Water entry above pipe - Showing location and size of opening

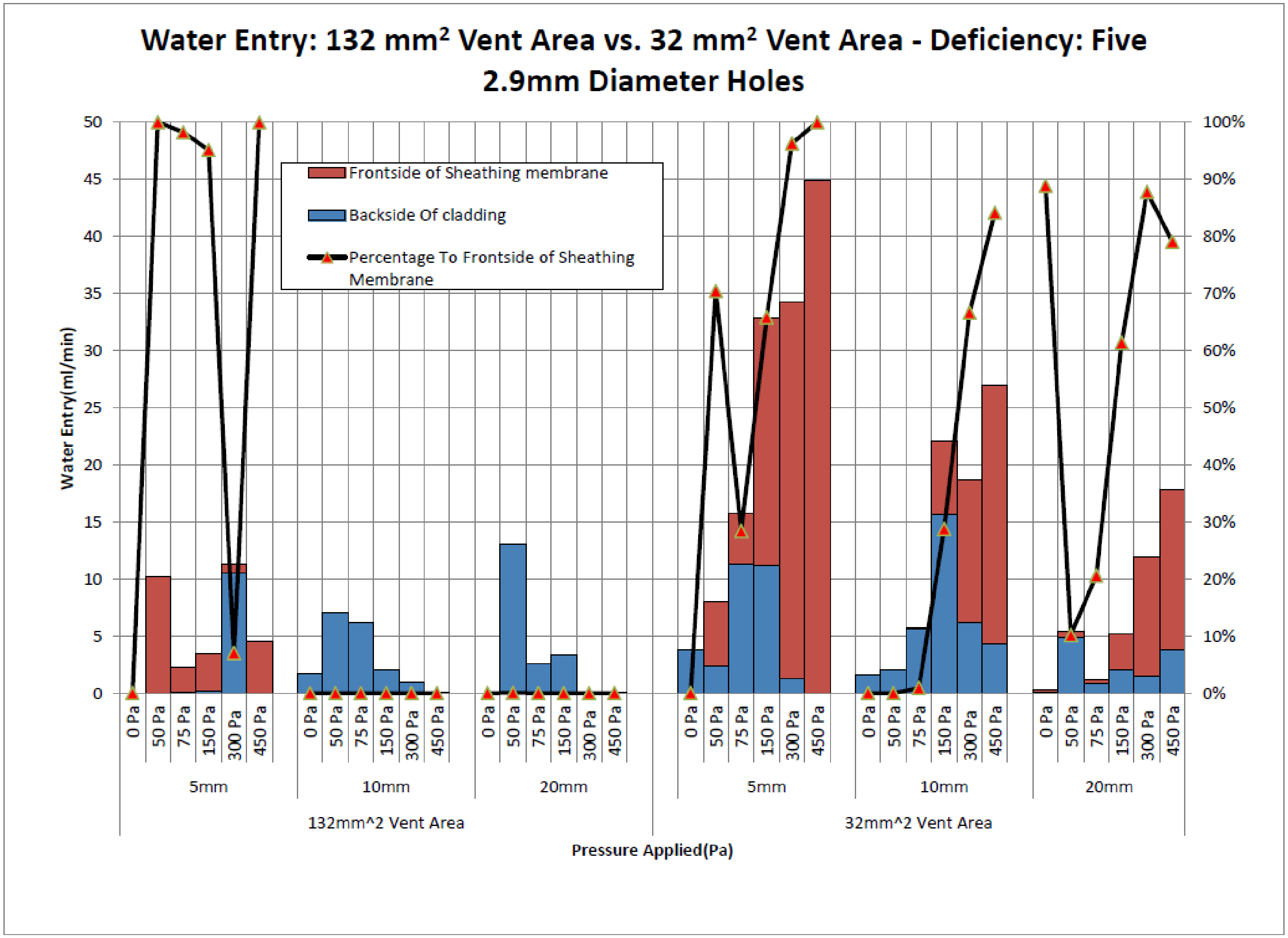


Figure 18 – Static Water Entry Test Results

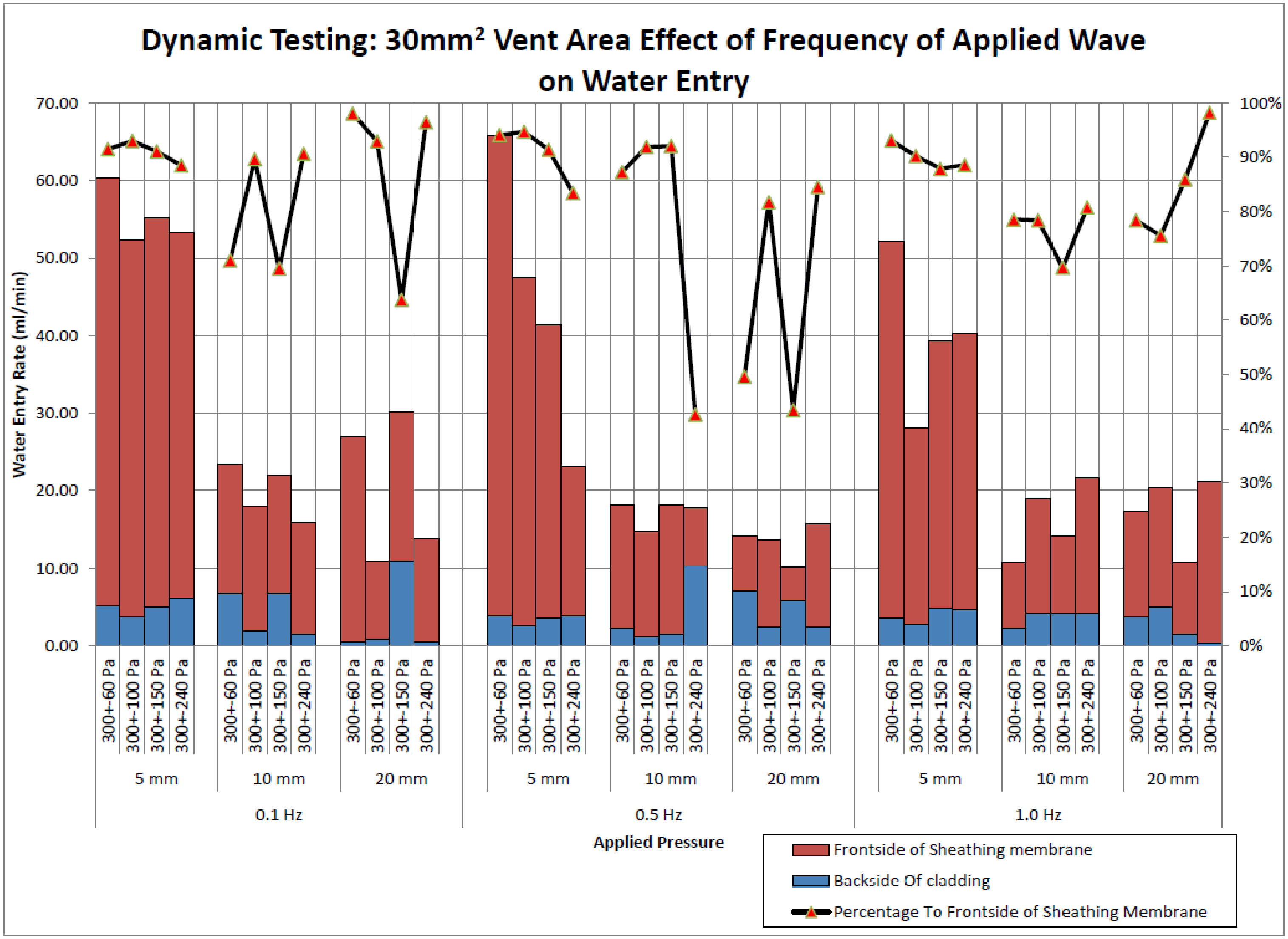


Figure 19 – Dynamic Water Entry Results

Appendix 3
Climate Load Comparison to Water Retention Test Levels

Location		MI	1 in 50 DRWP (Pa)	1 in 50 WDR (L/min-m^2)	%WE as %WD*	Water Entry rates**	
						L/min	L/hr
Vancouver	BC	1.44	183	0.41	2.5	0.02	1.7
Abbotsford	BC	1.59	278	0.35	4.3	0.03	2.0
Terrace	BC	1.08	298	0.53	3.7	0.04	2.6
Port Hardy	BC	1.92	324	0.50	4.2	0.05	2.8
Stephenville	NL	1.19	340	0.61	4.0	0.05	3.3
Saint John	NB	1.27	354	0.77	3.7	0.06	3.8
Halifax	NS	1.49	362	0.81	3.7	0.07	4.0
Tofino	BC	3.36	418	0.64	4.9	0.07	4.2
Summerside	PE	1.03	442	0.72	4.9	0.08	4.7
Sydney	NS	1.36	422	0.84	4.3	0.08	4.8
St John's	NL	1.41	438	0.93	4.3	0.09	5.3
Bonavista	NL	1.11	515	0.93	5.1	0.11	6.3
*From "Cladding Study" Correlations; % Water Entry as % of Water Deposition rate **From WE% correlation normalized to 4ft x 6ft specimen size					EIFS Drainage Evaluation Rate Injection Rate (L/hr)		8.0

Figure 20 - Comparison of 6L/hr and 8L/hr injection rates for the retention tests to maximum expected water entry rates from climate loads.

Appendix 4
Results of Moisture Retention of Client Drainage Systems

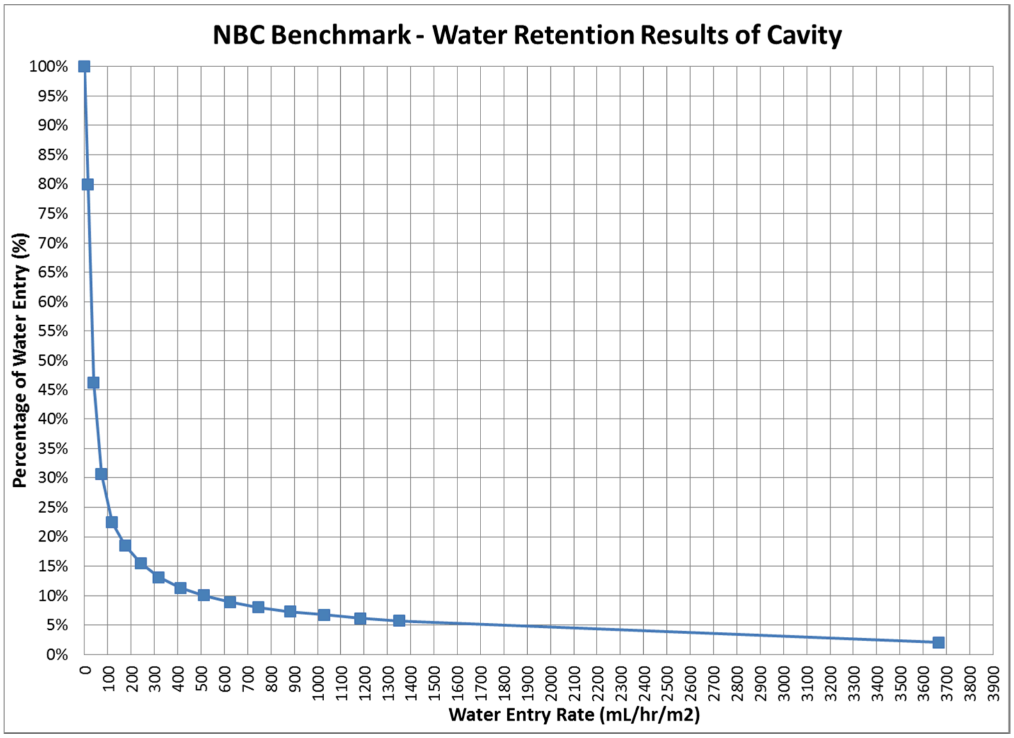


Figure 21 – NBC Benchmark Retention results

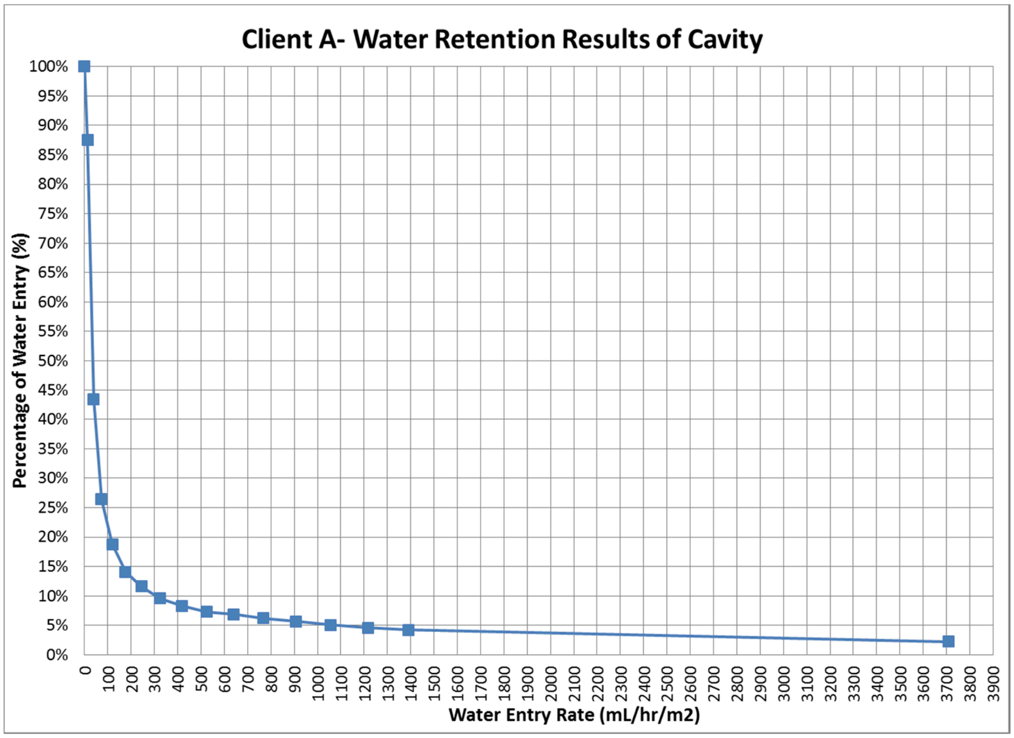


Figure 22 – Client A Retention Results

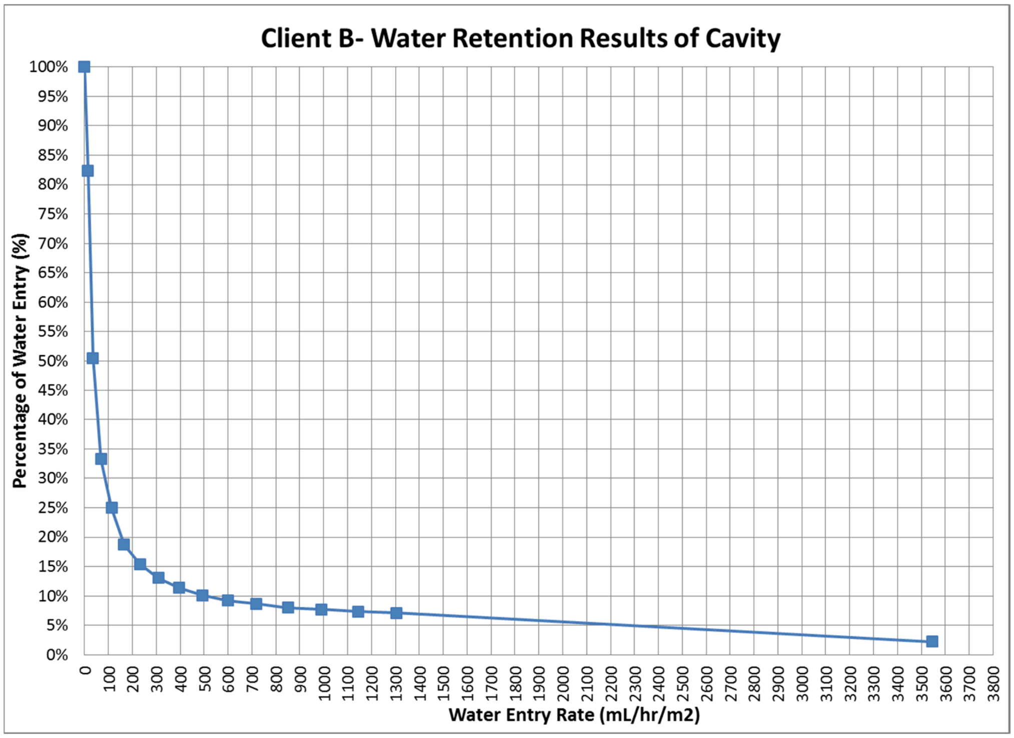


Figure 23 – Client B Retention Results

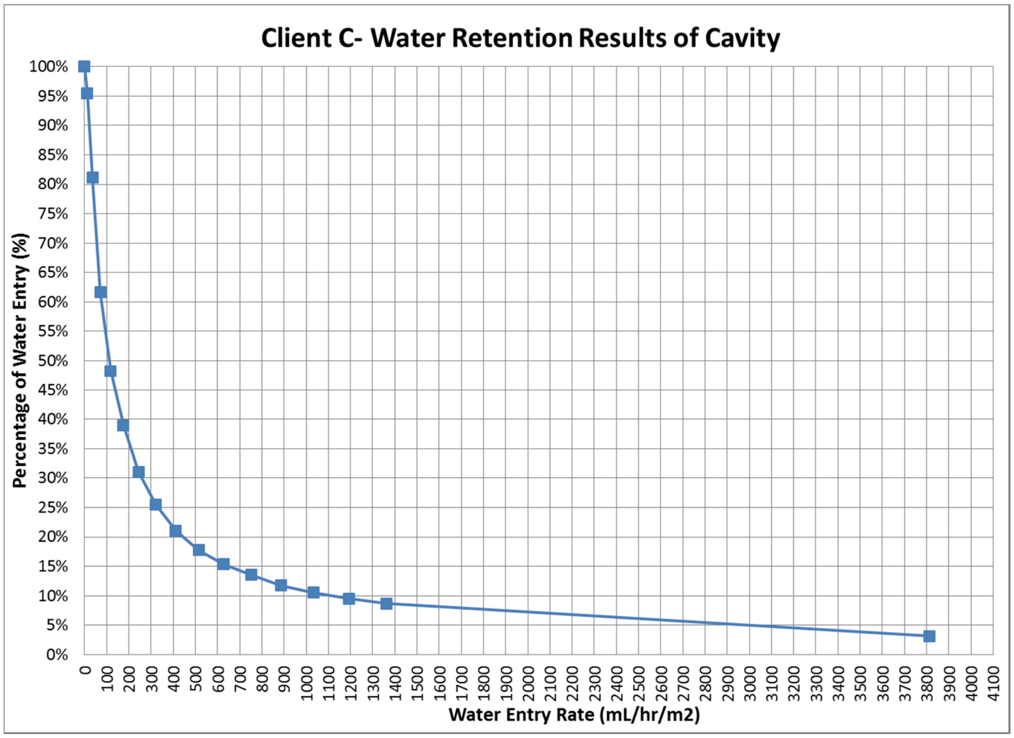


Figure 24 – Client C Retention Results

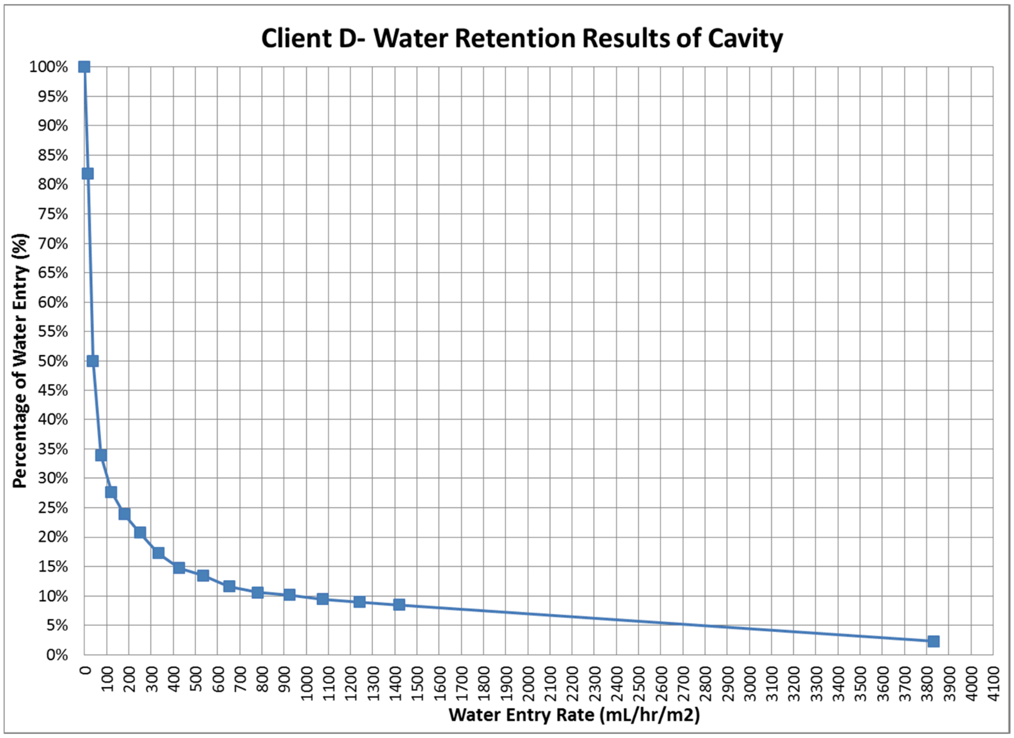


Figure 25 – Client D Retention Results

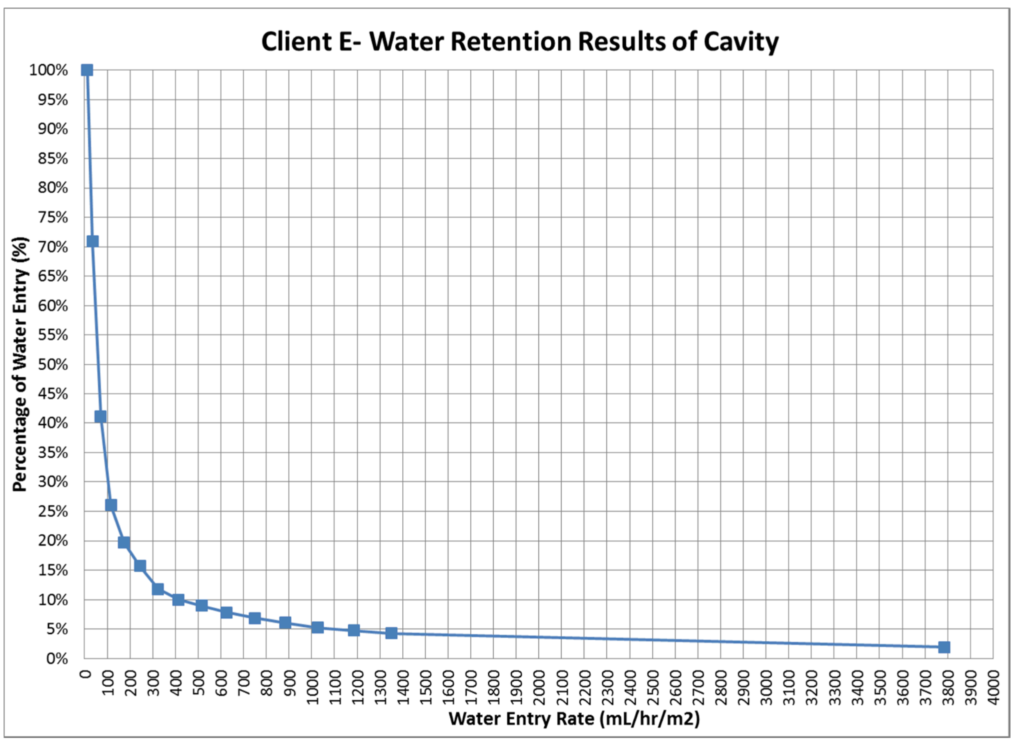


Figure 26 – Client E Retention Results

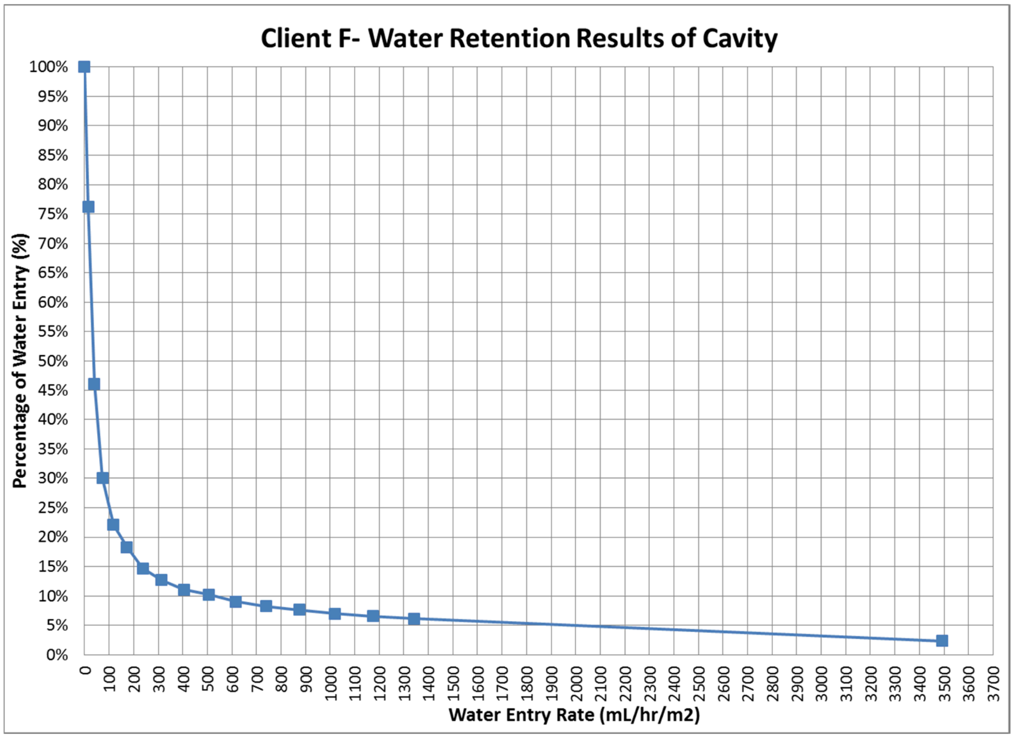


Figure 27 – Client F Retention Results

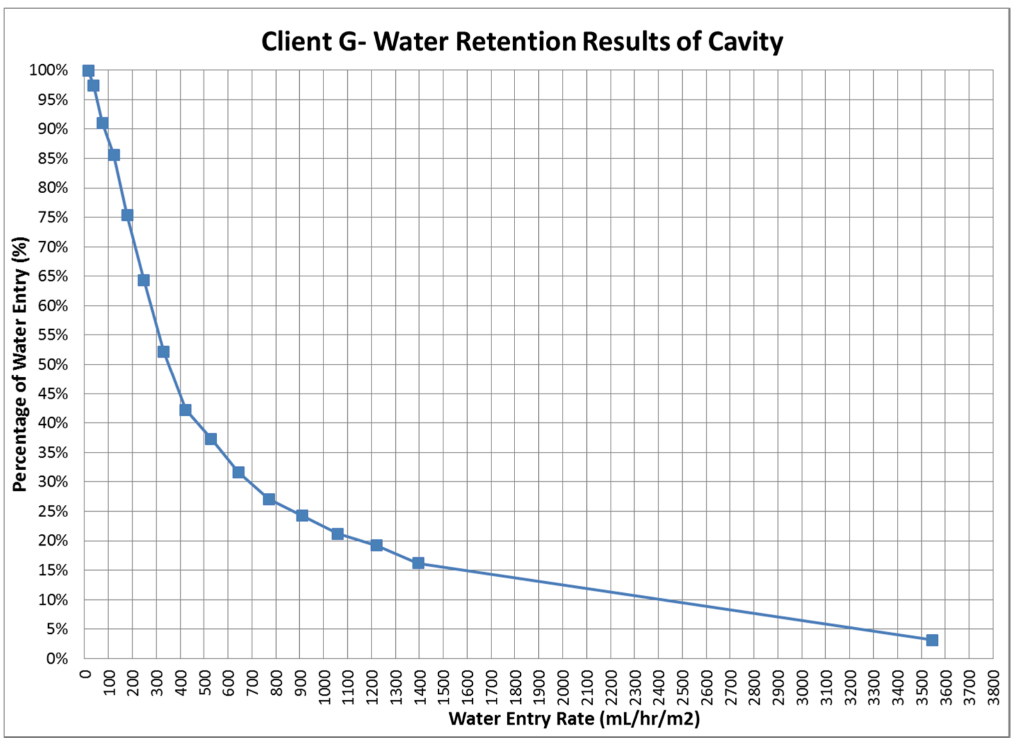


Figure 28 – Client G Retention Results

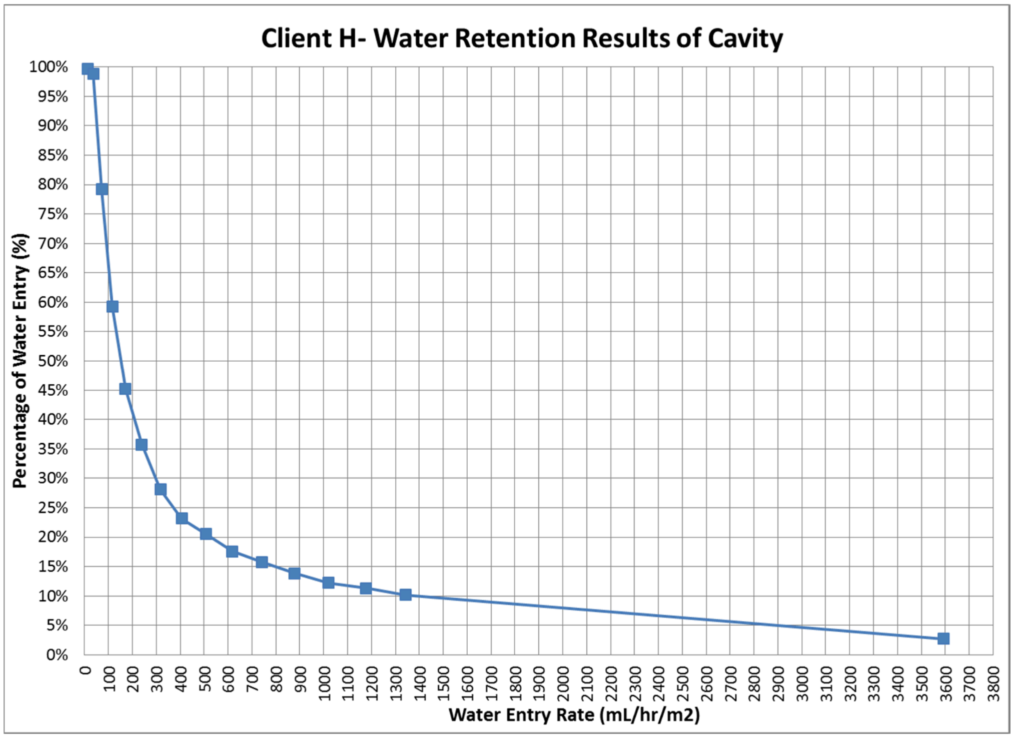


Figure 29 – Client H Retention Results

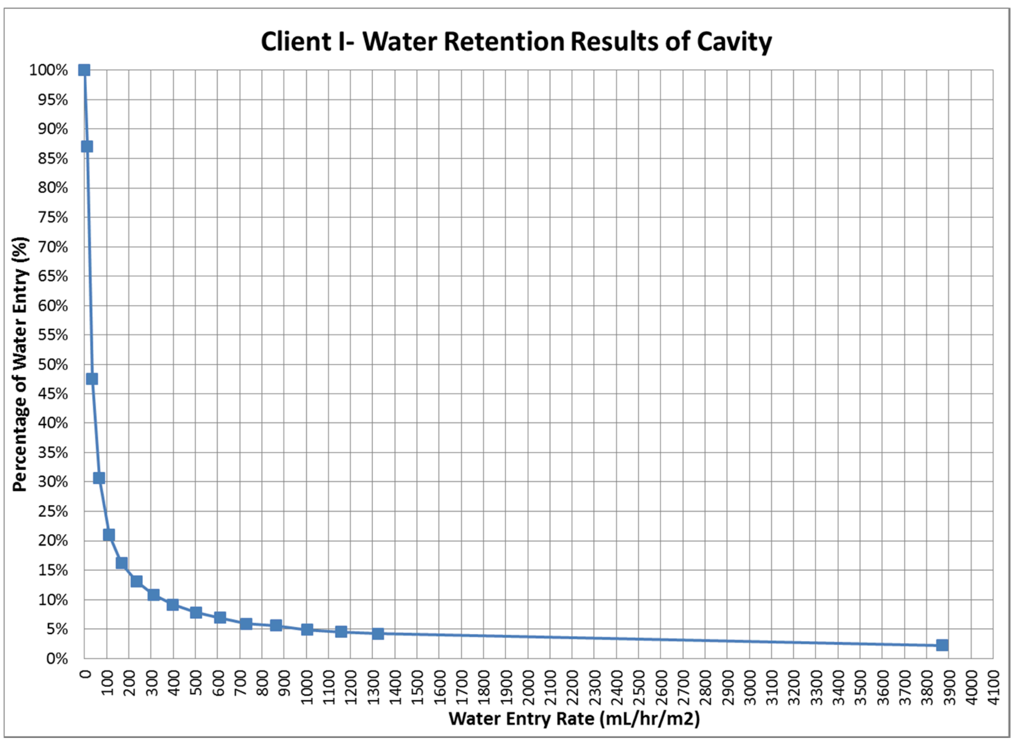


Figure 30 – Client I Retention Results