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CONSTRUCTION

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

Task 6 — Hygrothermal Performance of Client Wall Assemblies for Selected Canadian Locations

Hamed H. Saber and Michael A. Lacasse

17 August, 2015

National Research Council Canada
Conseil national de recherches Canada

Table of Contents

Table of Contents

Table of Contents

Table of Contents

List of Figures

List of Figures

List of Figures

List of Figures

List of Figures

List of Figures

List of Tables

List of Tables

List of Tables

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Summary

A Reference assembly and a series of 11 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 was to assess the performance of walls with drainage components and sheathing membranes (drainage system) in their ability to provide sufficient drainage and drying in Canadian climates with a moisture index (MI) greater than 0.9 and less than 3400 degree-days, or MI greater than 1.0 and degree days ≥ 3400 (primarily coastal areas). In these regions, the 2010 National Building Code of Canada (NBC) requires a capillary break behind all Part 9 claddings and conforming to the requirements given in § 9.27 (Cladding) of the NBC. Currently, acceptable solutions to the NBC capillary break requirement include:

(a) A drained and vented air space not less than 10 mm deep behind the cladding;

(b) 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;

(c) A cladding loosely fastened, with an open cross section (i.e. vinyl, aluminum siding)

(d) 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 was compared through laboratory evaluation and modeling activities to the performance of a wall built to minimum NBC requirements (Reference wall assembly). The proposed drainage system would be deemed an alternative solution to the capillary break requirement in the NBC for use with current code compliant Part 9 claddings provided it exhibited better or equal moisture performance as compared to a NBC-compliant Reference wall assembly.

In This Report — Results from hygrothermal simulation have been presented in which the response of the respective Client walls to climate conditions of Tofino and Vancouver (BC), and St. John's (NL), have been described. The results, as provided by information on the mould index and RHT index within the assembly, permitted comparisons of the response of the respective Client walls to the Reference wall.

For each of the Client wall assemblies, an overview of the Client's drainage system was first provided to permit assessing the expected response of wall components to moisture loads within the drainage cavity, given the moisture loadings conditions and the performance attributes of the cavity, that included the size and drainage-retention response of the cavity as well as the type and water vapour permeance of the sheathing membrane used to protect the exterior surface of the OSB sheathing panel.

Thereafter, the results from simulation of the Client's and the Reference wall are provided over a two year period to climate conditions of Tofino (BC), Vancouver (BC), and St John's (NL). For each of these locations, results are provided using the two performance criteria; the: (i) Mould index (M_{IDX}) criterion (risk to mould growth), and; (ii) Relative Humidity-Temperature RHT(x) criterion (risk to the growth of wood rot fungi).

Summary information has also been provided regarding the inputs required to complete hygrothermal simulations and included information on:

- Description of the reference wall assembly,
- Description of wall assemblies in regard to their respective drainage component characteristics,
- Hygrothermal property characteristics,
- Defining climate loads for three (3) Canadian locations,
- Defining the moisture loads acting on components within the wall assembly in consideration of the amount of water entry to and drainage from wall assemblies,
- Water retention in drainage systems, and
- Defining performance attributes of wall components in terms of selected performance criteria including the mould index and RHT index.

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

Task 6 – Hygrothermal Performance of Client Wall Assemblies for Selected Canadian Locations

Authored by:

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A Report for the

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17 August, 2015

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

Task 6 – Hygrothermal Performance of Client Wall Assemblies for Selected Canadian Locations

Final Report Forming Part of Task 6

Hamed H. Saber and Michael A. Lacasse

1.0 Background and Introduction

The objective of this project was to assess the hygrothermal performance of wall assemblies incorporating drainage components. More specifically, it was of interest to evaluate the ability of wall assemblies to provide sufficient moisture dissipation through the process of drainage and drying of water from these components when subjected to Canadian climates having a moisture index (MI) greater than 0.9 and less than 3400 degree-days, or MI greater than 1.0 and degree days ≥ 3400 (primarily coastal areas).

In these climates, the 2010 National Building Code of Canada (NBC) requires a capillary break behind all Part 9 claddings [1]. Currently, acceptable solutions to the NBC requirement for a capillary break include:

a) A drained and vented air space not less than 10 mm deep behind the cladding;
b) 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;
c) A cladding loosely fastened, with an open cross section (i.e. vinyl, aluminum siding);
d) A masonry cavity wall or masonry veneer constructed according to Section 9.20 (i.e. 25 mm vented air space).

In this project, the hygrothermal performance of proposed alternative solutions for the capillary break was compared through laboratory evaluation and modeling activities to the performance of a wall (NBC code-compliant Reference wall) built to minimum NBC requirements using the following performance criteria:

(a) RHT criterion, and;
(b) Mould index (M_{IDX}) criterion.

If a proposed wall system incorporating a drainage component exhibited a level of performance equal to or better than the NBC-compliant Reference wall, it would be deemed an alternative solution to the 2010 NBC requirement for a capillary break and could be used with all presently recognized code compliant Part 9 claddings as acceptable solutions [1].

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[1] NBCC 2010 Part 9; Housing and Small Buildings; Cladding conforming to § 9.27

The hygrothermal performance of wall assemblies incorporating drainage components was assessed on the basis of the results obtained from numerical simulation of a NBC code-compliant Reference wall assembly when subjected to environmental loads for selected locations in Canada and conforming to interior boundary conditions as described in the ASHRAE Standard S-160 [2].

In this report, information is provided on the results from hygrothermal simulation for each of the Client (partner) wall assemblies (A to K inclusive) for mould growth sensitivity class rated as Sensitive “S”. The results for mould growth sensitivity class rated as “Medium Resistant” (MR) are provided in the companion Task 6 report A1-000030.10 [3], whereas the details of results from hygrothermal simulation of the Reference wall are given in the Task 6 report A1-000030.07 [4].

2.0 Overview of Hygrothermal Simulation Model, hygIRC-C

The NRC’s hygrothermal model, hygIRC-C was used in this project to predict the hygrothermal performance on the basis of the risk of moisture related effects within wall assemblies having different drainage components when these walls were subjected to different climatic conditions as might occur across Canada. It is important to emphasize that the predictions by such a model for the airflow, temperature, and moisture (or relative humidity) distributions within a wall assembly, when subjected to a pressure differential (and resulting air leakage rate) across the assembly, are necessary to accurately determine the moisture response in different layers of the wall assembly.

The hygIRC-C model simultaneously solves the highly nonlinear and coupled two-dimensional and three-dimensional Heat, Air and Moisture (HAM) equations for both porous and non-porous media that define values of heat, air and moisture transfer across the various building component layers. The HAM equations were discretized using the Finite Element Method (FEM) as provided in the COMSOL Multi-physics software package that was used as a solver. The use of the FEM is important as it permits modeling complicated wall geometries with fewer discretizing errors.

A detailed description of the governing equations used in the hygrothermal model, hygIRC-C, can be found in the companion Task 6 report [4].

2.1 Hygrothermal Simulation Model Validation

The hygIRC-C model has been extensively validated in a number of other projects in which the thermal and hygrothermal performance of different systems and components of the building envelope (e.g. roofing, wall and fenestration systems) were evaluated; a review of the different projects in which the model was benchmarked is given in the Task 3 Report [4] (A1-000030.04).

Additionally in this project, two specific benchmarking exercises were conducted to verify whether proper assumptions had been made as regards the mathematical and numerical representation of physical

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[2] ASHRAE Standard S-160

[3] See Appendix 1: List of Task Reports

[4] See Appendix 1: List of Task Reports

phenomena within the hygIRC-C model and that permits capturing the hygrothermal response of components within wall assemblies; these included benchmarking the:

- Moisture dissipation from a nominally saturated stucco plate conforming to NBC compliant stucco construction details when subjected to ambient laboratory conditions; the results from this work, reported in the Task 3 Report, indicated that the model correctly estimated the degree and rate of moisture dissipation over time with a variation in values of moisture content not exceeding ± 5% from that predicted by the simulation model.
- Air flow through clear cavities and cavities incorporating highly porous media used as drainage components in wall assemblies; the results from these tests are provided in the Task 4 Report (A1-000030.05) [4].
    - Clear Cavities — A comparison of test results to those derived from simulation showed that the majority of air velocity measurements were within the margin of uncertainty associated with the results derived from simulation for air velocity profiles obtained of cavities having depths of 10, 20 and 25 mm.
    - Non-homogenous highly porous media (drainage components) — The air permeability, κ_a, was shown to be pressure dependent and deviations from the test values were minimized provided the value for κ_a was selected in relation to the pressure difference acting along the length of the cavity incorporating the drainage media. As such, values for the effective permeability coefficient, κ_{eff} and corresponding values for the permeability factor, F, were provided in relation to the pressure difference across the drainage components.

3.0 Description of Wall Assemblies & Hygrothermal Property Characterization

3.1. Description of Wall Assemblies (Task 1)

The purpose of this project was to assess the performance of wall drainage components and sheathing membranes in their ability to provide sufficient drainage and drying in Canadian climates with a moisture index (MI) greater than 0.9 and less than 3400 degree-days, or MI greater than 1.0 and degree days ≥ 3400 (primarily coastal areas), as described in Table 1. In these regions, the 2010 National Building Code requires a capillary break behind all Part 9 claddings.

The approach used in this evaluation had a benchmark wall assembly against which the various client wall assemblies incorporating wall drainage components and sheathing membranes were compared in respect to their hygrothermal performance. A brief description of the benchmark wall assembly and client assemblies follows.

Table 1 – 2010 National Building Code requirements for Capillary Breaks in Coastal areas (degree-days < 3400 and MI > 0.9, or degree days ≥ 3400 and MI > 1.0)

Coastal areas (degree-days < 3400 and MI > 0.9, or degree days ≥ 3400 and MI > 1.0)			
Sheathing	**Number of Sheathing Membranes**	**Capillary Break**	**Part 9 Claddings**
NO Sheathing	2	10-mm vented air space (80% open) or drainage material (80% open) or Alternative Solution	Lumber siding Wood shingles & shakes Fiber cement shingles and sheets(n/a) Plywood OSB and waferboard Hardboard Metal siding (horizontal or vertical) Vinyl siding (horizontal or vertical) Stucco
OSB/Plywood (Installed but not required)	1		
OSB/Plywood (Required and installed)	2		
OSB/Plywood	1 or, 2	25-mm vented air space	Masonry veneer

3.1.1 Reference Wall Assembly

The reference wall assembly was developed based on minimum code requirements. Stucco cladding was chosen from among the Part 9 claddings (listed in Table 1), as the “worst case scenario” for water penetration. This selection was based on previous work at NRC on the moisture management for exterior wall systems [5], in which it was demonstrated that stucco resulted in the highest moisture load behind the primary line of protection, due to its absorptive properties, and rain penetration at cracks.

Two alternative code compliant solutions for stucco installation were considered (see Figure 1):

- A solution predominantly practiced on the West Coast, with paper-backed welded wire mesh lath, and a 10 mm clear cavity;
- A solution predominantly practiced on the East Coast, with expanded metal lath (no paper backing) installed on 19 mm strapping.

The East Coast solution was selected for the Reference wall assembly, and deemed to be the “worst case scenario” due to the ability for stucco to pass through the metal lath and into the drainage cavity. Unlike the West Coast solution, this East Coast wall has no layer of building paper behind the lath to reduce the possibility of stucco compromising the required clear 10 mm capillary break between the stucco cladding and back-up wall.

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[5] NRC, Final Report from Task 8 of MEWS Project (T8-03) - Hygrothermal Response of Exterior Wall Systems to Climate Loading: Methodology and Interpretation of Results for Stucco, EIFS, Masonry and Siding-Clad Wood-Frame Walls; Research Report, NRC Institute for Research in Construction, 2002-11-01

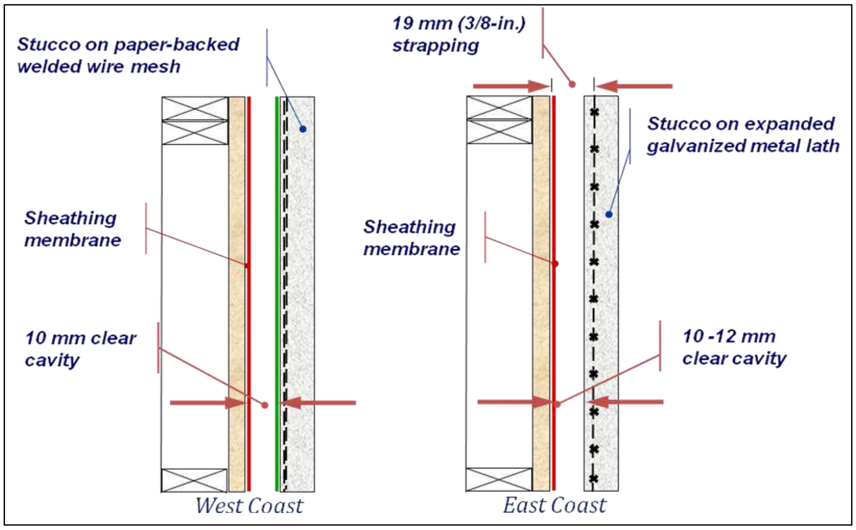

Figure 1 – West and East coast solutions for stucco installation with capillary break

The NBC additionally requires the wall to be vented and flashed at the bottom of the wall every 3.5 storeys. Whereas the constructed wall assemblies for lab evaluation were 1.83 m (6 ft.) in height, subsequent modeling activities took into account the performance of the full 3.5 storey assembly, including the influence of associated rain and wind loads on hygrothermal performance.

A duct penetration detail is included in the assembly drawings. Experimental work in this project examines and quantifies the potential for water to enter at a deficiency in the sealant around a duct penetration. This information is then used to determine realistic amounts of water to be introduced in the drainage and drying evaluation of the different assemblies.

A cross sectional view of the selected NBC code-compliant reference wall assembly is presented in Figure 2. Full details of the reference wall assembly and components are provided in the Task 1 report [4].

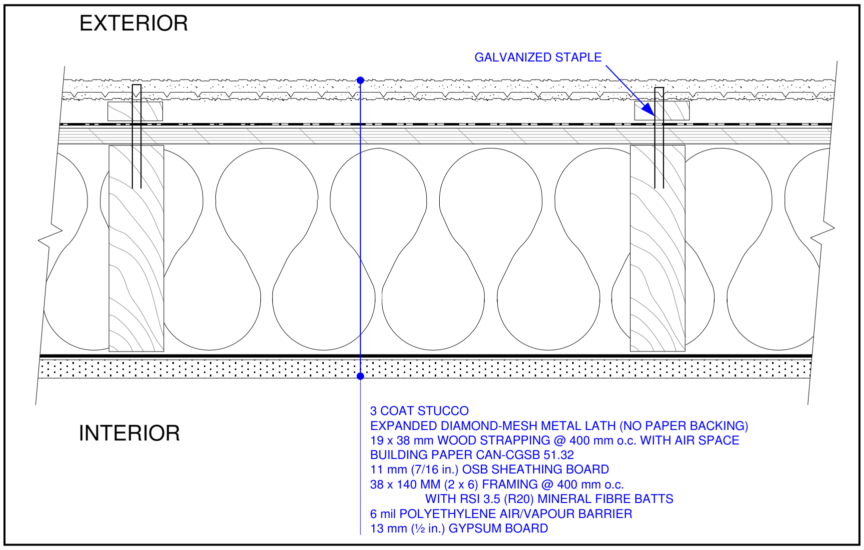

Figure 2 – NBC code-compliant reference wall - Horizontal cross section

3.1.2 Client Wall Assemblies

Client assembly designs were based on consultations between the individual clients and NRC-Construction; a list of client wall assemblies and their respective characteristic drainage component is provided in Table 2. Of note is that all client walls featured the same stucco cladding as the Reference wall. This cladding was chosen as a "worst case scenario". Thus, if the drainage element of the assembly demonstrated the ability to manage the water loads introduced by the stucco cladding, it was deemed an acceptable drainage solution suitable for use with all NBC-compliant claddings, as given in Table 1. In the Task 1 report, cross sectional diagrams are provided for each wall assembly together with a table describing the elements that differ from the NBC-compliant Reference wall assembly.

3.2 Task 2 (Characterization of Hygrothermal Properties)

To carry out hygrothermal performance assessments of wall assemblies using the numerical simulation tool hygIRC-C, the hygrothermal properties of all materials used for the construction of the different wall assemblies was required as input to the model. Given that a number of the hygrothermal properties of materials of the respective wall assemblies were available in NRC's material properties database, only the hygrothermal properties and air flow characteristics of materials that were not available were completed as part of this study.

A detailed account of the tests methods used to characterise and the resulting values obtained from tests of the hygrothermal properties of wall assembly components and air flow characteristics of the drainage components, are given in the Task 2 report (A1-000030.02) [4].

3.3 Defining Climate Loads on Wall Assembly & Drainage Systems (Task 5)

There were two primary objectives for this Task that included determining the:

- Climate loads to be used for testing wall assemblies;
- Weather data for the hygrothermal simulation task of the project (Task 6).

The information on climate loads for testing wall configurations is summarised in the companion report to Task 6 [4] and detailed information is provided in the Task 5 report on climate loads [4].

3.3.1 Weather data for hygrothermal simulation

This portion of the task required providing the Moisture Design Reference Years (MDRYs) data for the hygrothermal simulation task of the project. After reviewing several published methods for selecting weather years for hygrothermal simulation, a small comparison study was undertaken. It was concluded that the MI MEWS method was appropriate to use for this project [6]. Rankings were produced for all the years in the climate record for each location selected. Three years, *wet* (maximum), *average* (median), and *dry* (minimum), were generated and converted to an acceptable format for hygrothermal analysis.

Some climate information for each of these locations is provided in Figure 3 in which values are given of

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[6] Cornick SM, Djebbar R, Dalgliesh WA., Selecting moisture reference years using a moisture index approach. Building and Environment 2003; 38(12): 1367-1379.

Table 2 – List of Wall Assemblies and Respective Characteristic Drainage Component

Designations	Description of Drainage Component	Description of component tested for hygrothermal properties
NBC-compliant Reference wall	Air space created by 19 mm plywood strapping; on NBC Code-compliant building paper*	NBC Code-compliant stucco
Client A Wall	Code compliant building paper* / cap fasteners provide 2 mm gap / SBPO** sheathing membrane	SBPO sheathing membrane
Client B Wall	10 mm air space / Water repellent insulation board (76 mm) / liquid applied membrane	Water repellent insulation board
Client C Wall	Code compliant building paper* / Nylon mesh (10 mm; open matrix) / PP† nonwoven sheathing membrane	Nylon mesh (10 mm; open matrix) bonded to PP nonwoven sheathing membrane
Client D Wall	Code compliant building paper* / Cap fasteners provide 2 mm gap / Cross woven, micro-perforated polyolefin sheathing membrane with polyolefin coating	Cross woven, micro-perforated polyolefin sheathing membrane with polyolefin coating
Client E Wall	PP† fabric (stucco screen) / Dimpled HDPE‡ (11 mm) membrane / Code compliant building paper*	PP† fabric bonded to dimpled HDPE‡ membrane
Client F Wall	Wall having 25 mm air space	Nil (25 mm air space)
Client G Wall	Non-woven PP† fabric (stucco screen) / PP† mat (10 mm; 3-dimensional extruded PP mono-filament mesh) / Code compliant building paper*	Non-woven PP† fabric (stucco screen) / PP† mat (10 mm; 3-dimensional extruded PP mono-filament mesh)
Client H Wall	Porous PS†† insulation board (52 mm) / liquid applied membrane	Porous PS†† insulation board (52 mm)
Client I Wall	2 ply, corrugated asphalt impregnated paper*; Grade D!! (3.8 mm) / Code compliant building paper*	2 ply, corrugated asphalt impregnated paper* - Grade D!!
Client J Wall	Building paper*; Grade D!!; 60 Minute / Air space created by 9.5 mm plywood strapping / 2 layers of Code compliant building paper*	Three coat stucco with paper backed welded-wire mesh lath
Client K Wall	Building paper*, Grade D!!; 60 Minute / Air space created by 9.5 mm plywood strapping / 2 layers of Code compliant building paper*	Three coat stucco with paper backed welded wire metal lath

* CAN-CGSB 51.32; ** SBPO – Spun bonded polyolefin; † PP – poly propylene; ‡ HDPE – high-density polyethylene; †† PS – polystyrene; !! Grade D – Building paper conforming to
US Federal specification UU-B-790a, Type 1 (barrier paper), Grade D (water-vapor permeable), Style 2 (uncreped, not reinforced, saturated).

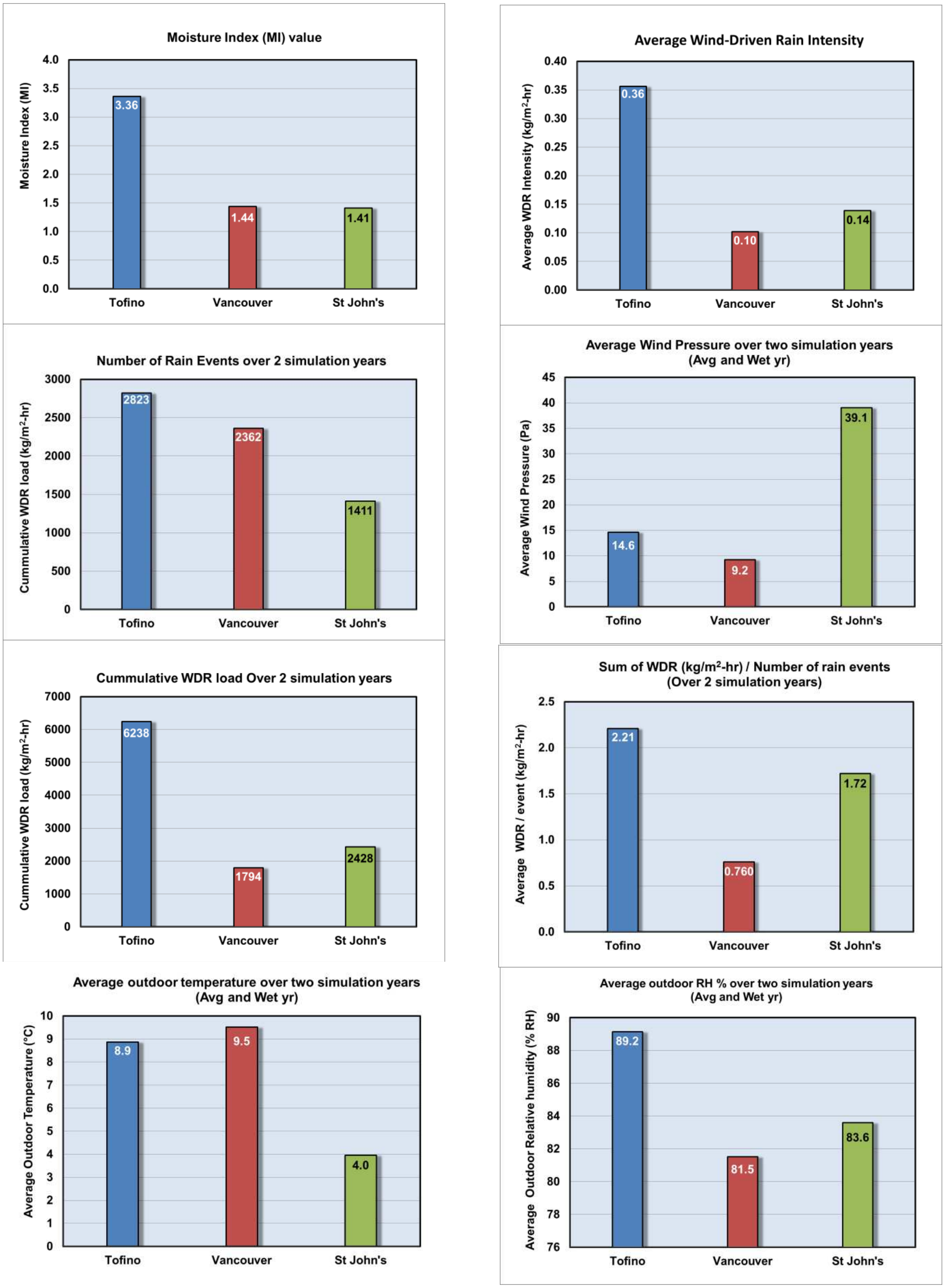

Figure 3 – Moisture Index; Avg. WDR intensity; No. of rain events; Avg Wind pressure; Cumulative Total WDR; Avg. outdoor t & RH (%) over 2 yrs (Avg; Wet yr.) for Tofino & Vancouver (BC), & St. John's (NL)

the: Moisture Index; Average WDR intensity; Number of rain events; Average wind pressure (Pa); Cumulative Total WDR; Average outdoor temperature (°C) and relative humidity (%).

Of these sets, hygrothermal simulations for selected locations were undertaken for an *average* (median), followed by a *wet* (maximum) year. The locations of interest were:

- St. John's (East coast climate – wet and cool, MI = 1.41);
- Vancouver (West coast climate – wet and mild, MI = 1.44), and;
- Tofino (Extreme coastal climate having MI = 3.4).

Each of these values with the exception of the moisture index which is an annual value averaged over several years, is for a 2 year period for which the first year was an average year and the second a "wet" year. This allows appreciating the significance and differences amongst the different climate loads for these three locations and to which they were subjected in simulations.

It is clearly apparent that Tofino (MI = 3.36) has the most severe climate in respect to WDR loads as the cumulative total WDR is ca. 2.5 and 3.5 times more significant (6238 kg/m^2hr) than that of, respectively, St. John's (2428 kg/m^2hr) and Vancouver (1794 kg/m^2hr). This is likewise reflected in respect to the rain events for which Tofino (2833) has twice the number of events as that of St. John's (1411) although it is the same order of magnitude and thus comparable to that of Vancouver (2362).

The average values for outdoor relative humidity over a 2-year period (Average year followed by a wet year) are all in the same order of magnitude for the three locations however, the highest value is found in Tofino (89% RH), thereafter the next highest is St. John's (84% RH), followed by Vancouver (82% RH). Hence, for any of these coastal locations, the ability of moisture to dissipate from wetted wall assemblies is delimited by the capacity of the ambient air to absorb moisture; evidently, this is more difficult to achieve in climates having higher average relative humidifies.

A detailed description of the WDR intensities for the locations studied can be found in the companion Task 6 report [4].

3.4 Response of Wall Assemblies & Drainage Systems to Climate Loads (Task 5)

3.4.1. From climate loads to wind-driven rain loads acting on wall assembly and cladding

The scenario considered in estimating the hygrothermal response of wall assemblies and drainage systems to climate loads takes into account the wind-driven rain (WDR) and driving-rain wind pressure (DRWP) loads acting on the walls.

Detailed descriptions and the governing equations for WDR and DRWP are included in the companion Task 6 report [4].

3.4.2 Water entry behind cladding due to permeation of cladding and deficiencies

Water entry to the drainage system behind the cladding may come about due to water permeation through the cladding itself (e.g. due to cracks in the cladding), or through imperfections at the periphery of cladding penetrations such as at ventilation ducts, pipes or windows. Thus at each story, water may enter the drainage system located behind the cladding either through the cladding or through deficiencies at through-wall penetrations of the cladding.

The experimental procedure and empirical relationships for water entry behind cladding is provided in the companion Task 6 report [4].

3.4.3 Water retention in respective drainage systems

Tests were also carried out to characterise the drainage-retention of each drainage system. The depth of drainage cavities for all the different wall assemblies was first determined from the construction of mock-ups that incorporated the stucco cladding and drainage system of the respective wall assemblies and 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-compliant stucco was applied. The work was undertaken by professedly knowledgeable and experienced stucco contractors. 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.

The results provided in Table 3 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 3 –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

After determining the cavity depths for each wall configuration, test specimens were constructed to determine the drainage and retention characteristics of each drainage system. The drainage system was that previously described in §3.1.2 and as provided in Table 2.

The test specimens of width and height, respectively of 1220 mm by 1830 mm (4ft by 6ft), were dosed with water to the drainage cavity along the entire width of the cavity (i.e. 1220 mm) and at constant rates of 3, 4, 5, 6 and 8L/hour for a duration of one hour. The dosage levels were determined from maximum water entry rates that could occur in selected Canadian locations as provided in the Task 5 Report on climate loads (Appendix 1). 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 drainage-retention relation was based on the percentage of water that remained in the cavity for a given water entry rate given in $mL/h\text{-}m^2$.

The results of the drainage retention tests suggest that for greater amounts of water deposited in the drainage cavity, a smaller proportion (% retained) of that dosage is retained in the cavity as compared to the greater proportion retained for lower dosage rates. Further details can be found in the companion Task 6 report [4].

3.4.4 Moisture loads in drainage cavity at given storey heights

Having determined the water entry rates to the drainage systems on the basis of correlations developed for WDR rain loads acting on the cladding, and having assessed the quantity of moisture that might drain from a cavity given the dosage to the cavity, the moisture load within the cavity was then estimated for each storey level. The moisture load for a given storey results from the percentage of WDR that enters from permeation of water through the cladding and through deficiencies and from the water that drains from the storey above. Further details on how the total moisture load for a storey is calculated can be found in the companion Task 6 report [4].

3.4.5 Distribution of moisture loads within drainage cavity

The manner in which Moisture Loads (ML) within a cavity were distributed depended on the presence of a nominal capillary break, as might be assumed for those drainage systems having cavity depths of at least 10 mm. In these instances, the ML was applied to the backside of the cladding, if there was a clear cavity, or when the drainage cavity included a drainage component of at least 10 mm in depth, for these components it was assumed that 50 % of the ML remained on the backside of the cladding whereas the remaining 50% found its way to the surface of the sheathing membrane. For those drainage components having a depth of less than 5 mm, it was assumed that 100 % of the ML found its way to the surface of the sheathing membrane.

It was surmised that in the case of a clear cavity, the capillary break would prevent any substantial ML from reaching the sheathing membrane, whereas in the presence of a drainage component of at least 10 mm in depth, it was supposed that there was an equal risk that the ML would remain on the backside of the cladding, or percolate to the surface of sheathing membrane over a storey height. For those drainage components having a depth of less than 5 mm, water entry was supposed to have occurred at fastener locations and thereafter readily bridged the gap between the sheathing membrane and the drainage component thereby wetting the surface of the sheathing membrane.

For those drainage components having a depth of less than 5 mm, it was assumed that all of the ML reached the sheathing membrane. This was deemed a plausible scenario given that any water that would permeate the cladding would ultimately find its way to the drainage space at fastener locations and thus quickly bridge the interstitial space between the sheathing membrane and the drainage component of these systems.

3.4.6 Other assumptions in respect to undertaking of hygrothermal simulations

Initial Conditions

The initial temperature in all layers of the wall assemblies were taken equal to 21°C and the initial moisture content of all material layers corresponded to a relative humidity of 50%. Simulations were started on the first day of the month of January of the average climate year for the specified locations.

4.0 Defining Performance Attributes

This section describes the definition of performance attributes of specific components of the wall assembly and how the code compliant reference wall was assessed in relation to the client wall assemblies incorporating drainage components. Of particular interest are the locations within the wall assembly that were used to assess the performance of wall assemblies.

4.1 Locations of interest in assessing performance of wall assemblies

Within the wall assembly there are locations that are of interest given that these may be prone to moisture uptake and given appropriate temperature conditions and an adequate gestation period, give rise to the risk of formation of mould or, in the case of wood-based components, wood rot fungi. Focus is placed at the sheathing membrane, the sheathing panel (OSB), and the insulation within the stud cavity of the wall. There is heightened risk to the formation of mould (or wood rot in the case of wood-based components) at these locations given their proximity to the sheathing membrane and drainage cavity where the moisture loads have been applied.

Accordingly, emphasis has been placed on determining the local temperature and relative humidity conditions, as might be extracted from the information provided from simulating the response of the wall assembly to selected climates, at the following four (4) locations in the wall section:

- Interface between the exterior surface of the sheathing panel (OSB/gypsum board) and cavity
- Exterior portion of sheathing panel of depth 1 mm
- 10 mm portion of sheathing panel (remaining portion of 11 mm panel)
- Interface between the interior surface of the sheathing panel (OSB/gypsum board) and fibrous insulation

Further details on the locations of interest can be found in the companion Task 6 report [4].

4.2 Performance criteria

Two (2) criteria were used to assess the performance of wall assemblies: (i) RHT index, as was used previously in other projects for which the performance of wall assemblies was sought [5], and; (ii) the Mould Index developed by Hukka and Viitanen [7], Viitanen and Ojanen [8] and Ojanen et al. [9]. Each of these criteria is described in turn.

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[7] Hukka, A., and Viitanen, H. A. (1999), A mathematical model of mould growth on wooden material, Wood Science and Technology, Volume 33, Issue 6, pp 475-485

[8] Viitanen and Ojanen (2007), Improved Model to Predict Mold Growth in Building Materials, Proceedings of the Buildings X International Conference on the Thermal Performance of the Exterior Envelopes of Whole Buildings (December 2-7), Clearwater Beach, Florida, 8 p.

4.2.1 RHT index

The RHT index is a measure of the risk of formation of mould on surfaces or wood rot of wood-based components given the relative humidity and temperature profile over a specified time period over which the index is used. The value of the index is the sum of the product of the relative humidity and temperature at specfided values of relatrvie humidity (e.g. 80, 92, 95, 97% RH) and for temperatures of at least 5°C. The value of the index increases monotonically and thus represents at the end of the period, the maximum cumulative value of the index.

Details in respect to calculating the value of this index can be found in the companion Task 6 report [4].

4.2.2 Mould index

The development of the mould index has been on-going for several years with the most recent work, as was used in this project, having being provided by Ojanen et al. [9].

A description of the mould index levels that relate to growth rates is provided in Table 4, whereas the mould growth sensitivity classes for specified materials and corresponding minimum levels of relative humidity needed for mould growth are provide in Table 5. The mould index levels range in value from 0 to 6, with 0 being equivalent to no growth and 6 indicating 100% coverage of either heavy or tight mould growth. The visual identification of mould growth on surfaces is given an index level value of 3.

As provided in Table 5, the sensitivity of different construction materials to the formation of mould growth was divided into four (4) classes: very sensitive, sensitive, medium resistant and resistant. The assumed correspondence of sensitivity class for materials located within a wall assembly as modelled in this study is given in Table 6. More specifically, the sensitivity class for the sheathing panel (e.g. OSB) was considered “Sensitive”, whereas the sensitivity class of materials in the cavity insulation (i.e. fiber-based insulation) was considered “Medium Resistant”.

In this project, only the “Sensitive” mould growth sensitivity class was considered when comparing the relative performance of the respective wall assemblies; however, information has also been provided on the “Medium Resistant” mould growth sensitivity class in a companion Task 6 Report
(see: Report A1-000030.10 [3])

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[9] Ojanen, T., Viitanen, H.A., Peuhkuri, R, Lähdesmäki, K., Vinha, J., and Salminen, K., "Mold Growth Modeling of Building Structures Using Sensitivity Classes of Materials", 11th Itnl. Conference on Thermal Performance of the Exterior Envelopes of Whole Buildings XI (Clearwater, (FL), USA, December-05-10), 10 p., 2010.

4.2.3 Comparison of RHT index to Mould index

A comparison between the limits of applicability of the RHT index to that of the mould index for the "sensitive" and "very sensitive" class of materials is provided in the companion Task 6 report [3].

Table 4 - Description of Mould Index (M) levels [18, 19, 20]

M	Mould Index (M) - Description of Growth Rate
0	No growth
1	Small amounts of mould on surface (microscope), initial stages of local growth
2	Several local mould growth colonies on surface (microscope)
3	Visual findings of mould on surface, < 10% coverage, or < 50% coverage of mould (microscope)
4	Visual findings of mould on surface, 10%–50% coverage, or > 50% coverage of mould (microscope)
5	Plenty of growth on surface, > 50% coverage (visual)
6	Heavy and tight growth, coverage about 100%

Table 5 - Mould growth sensitivity classes and some corresponding materials [20]

Sensitivity Class	Materials	RH_{min} (%)*
Very Sensitive	Pine sapwood	80
Sensitive	Glued wooden boards, PUR with paper surface, spruce	80
Medium Resistant	Concrete, aerated and cellular concrete, glass wool, polyester wool	85
Resistant	PUR with polished surface	85

* Minimum relative humidity needed for mould growth

Table 6 - Mould growth sensitivity classes for different materials of wall assemblies

Sensitivity Class	Layers within Wall Assemblies	RH_{min} (%)*
Very Sensitive		80
Sensitive	Top plate, bottom plate, OSB, foam	80
Medium Resistant	Mineral or glass fibre, gypsum, membranes	85
Resistant		85

* Minimum relative humidity needed for mould growth

5.0 Results Derived from Hygrothermal Simulations

For each of the client wall assemblies, an overview of the Client's drainage system is first provided to permit assessing the expected response of wall components to moisture loads within the drainage cavity, given the performance attributes of the cavity, that includes the size and drainage-retention response of the cavity as well as the type of sheathing membrane used to protect the exterior surface of the OSB sheathing panel.

Thereafter, the results from simulation of the Client's and the Reference wall are provided over a two year period, first for Tofino (BC) (MI = 3.36) and afterwards for Vancouver (BC) (MI = 1.44), and finally, St. John's (NL) (MI = 1.41). For each of these locations, results are provided using the two previously described performance criteria; the: (i) Mould index (M_{IDX}) criterion (risk to mould growth), and; (ii) Relative humidity-temperature RHT(x) criterion (risk to the growth of wood rot fungi). The RHT(x) index is a value that is cumulated over the period of interest and the values of RHT(x) are based on averaging the Temperature (T) and Relative Humidity (RH) over a period of 10 days. The simulation results provided are for the 4th storey of a building for which the response of the wall assembly is the most significant as compared to that of the other three storeys. In all figures in this report that provide the dependence or change of the performance as a function of time (e.g. plots of Mould Index or relative humidity and temperature), time = 0 corresponds to January 1st at 00.00 AM of the average year.

Plots of all results of M_{IDX} values as a function of time are for a 1 mm thick "sliver" located on the exterior surface of the OSB sheathing panel and represent values for a mould sensitivity class "S". Likewise, all of the relative humidity-temperature plots from which are derived the values for RHT index performance are for the 1 mm thick "sliver" on the exterior surface of the OSB panel and are for threshold values of 5°C for temperature and 92% relative humidity (RH). The derived values for RHT(x) are provided for RHT(80), RHT(85), RHT(92) and in some instances for RHT(95).

5.1 Client A Drainage System

Overview of Drainage System

A sectional view of the wall configuration incorporating Client A's product, a drainable SBPO (Spun-bonded polyolefin) sheathing membrane, is shown in Figure 4. The water retention characteristics of this drainage system (i.e. Code compliant building paper [10]; cap fasteners providing 2 mm gap; drainable SBPO sheathing membrane) that incorporates this sheathing membrane suggest that for given water entry rates, the drainage system retains less water as compared to the reference drainage system.

A plot of the water vapour permeance (WVP) of various sheathing membranes, including that of Client A, is also provided; it is apparent that the WVP of Client A's product is significantly greater than that of a NBC-compliant sheathing membrane, denoted as 30 min building paper in the plot but also conforming the CGSB standard [10]. Client A's sheathing membrane has a WVP that is almost two orders of magnitude greater than the limit distinguishing between breathable and non-breathable membranes; i.e. the WVP of Client A's membrane is 2760 ng/Pa•s•m^2 as compared to 170 ng/ Pa•s•m^2, the lower limit for a breathable membrane. However, the water absorption coefficient for this membrane is not

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[10] CGSB standard CAN2-51.32-M77

measureable (see Task 2 Report; [3]) suggesting that there is little or no liquid water transfer across the membrane by liquid diffusion. As such, the performance would be related to the extent to which water vapour permeates the membrane and this would in turn depend on the amount of moisture that is retained on the membrane following a rain event and the prevailing temperature in the drainage cavity.

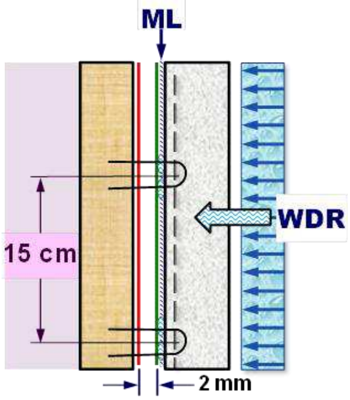
The moisture load in this instance was assumed to be placed on the drainable SBPO sheathing membrane whereas the placement of the load for the reference wall was assumed to be retained on the backside of the cladding given that for the reference wall, there is a capillary break between the cladding and the sheathing membrane and water cannot readily traverse this gap in the drainage cavity. In the case of Client A's wall, any water penetrating the cladding and migrating to the backside would in turn find its way to the drainage cavity. However, given that the drainage gap for Client A's wall is only 2 mm, water would necessarily bridge this gap and thereafter wet the surface of the sheathing membrane.

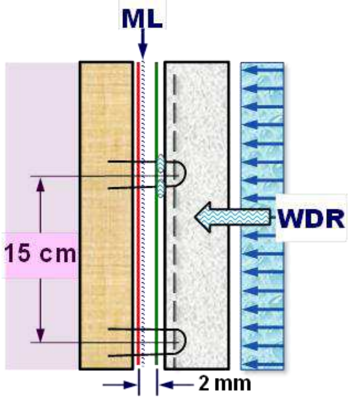
Thus the moisture load in the case of Client A's wall is placed directly on the sheathing membrane whereas for the reference wall, the load is retained behind the cladding; as well, the WVP of the sheathing membrane of Client A's wall is many times greater than that of the reference wall. Combining these two elements, that is, differences in WVP between sheathing membranes and placement of the moisture load in the drainage cavity, suggests that Client A's wall, as compared to the reference wall, would be somewhat disadvantaged in respect to managing moisture ingress to the drainage cavity.

Results from Simulation – Client A Drainage System

Hygrothermal response of wall components to climate loads of Tofino; M_{IDX} criterion

The response of the Client A wall assembly to the climate loads of Tofino (BC) are provided in Figure 5 to Figure 7 and in Table 7. More specifically, the variation in values for M_{IDX} over the course of the two year simulation and in respect to the different locations in the wall, are provided in two plots of Figure 5. The upper most plot shows the variation over the two year simulation when the moisture load (ML) was placed between the cladding and the building paper, whereas the lower most plot shows the variation when the ML was placed on the sheathing membrane, in this instance the membrane being a spun bonded polyolefin membrane. The location of the moisture load for both these conditions is shown in the adjacent inset.





In both plots of Figure 5, the values for M_{IDX} over the course of the two year simulation increase over time depending on the propensity for mould growth given the moisture and temperature conditions in the different locations within the sheathing panels (OSB); the moisture conditions at the different panel locations are related to their respective proximity to the moisture load. Plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB-glass fibre interface), the one closet to the moisture load, in these plots, being the "OSB Sliver", representative of a 1 mm thick sliver of the exterior face of the 11 mm thick sheathing panel and the component in closest contact with the sheathing membrane.

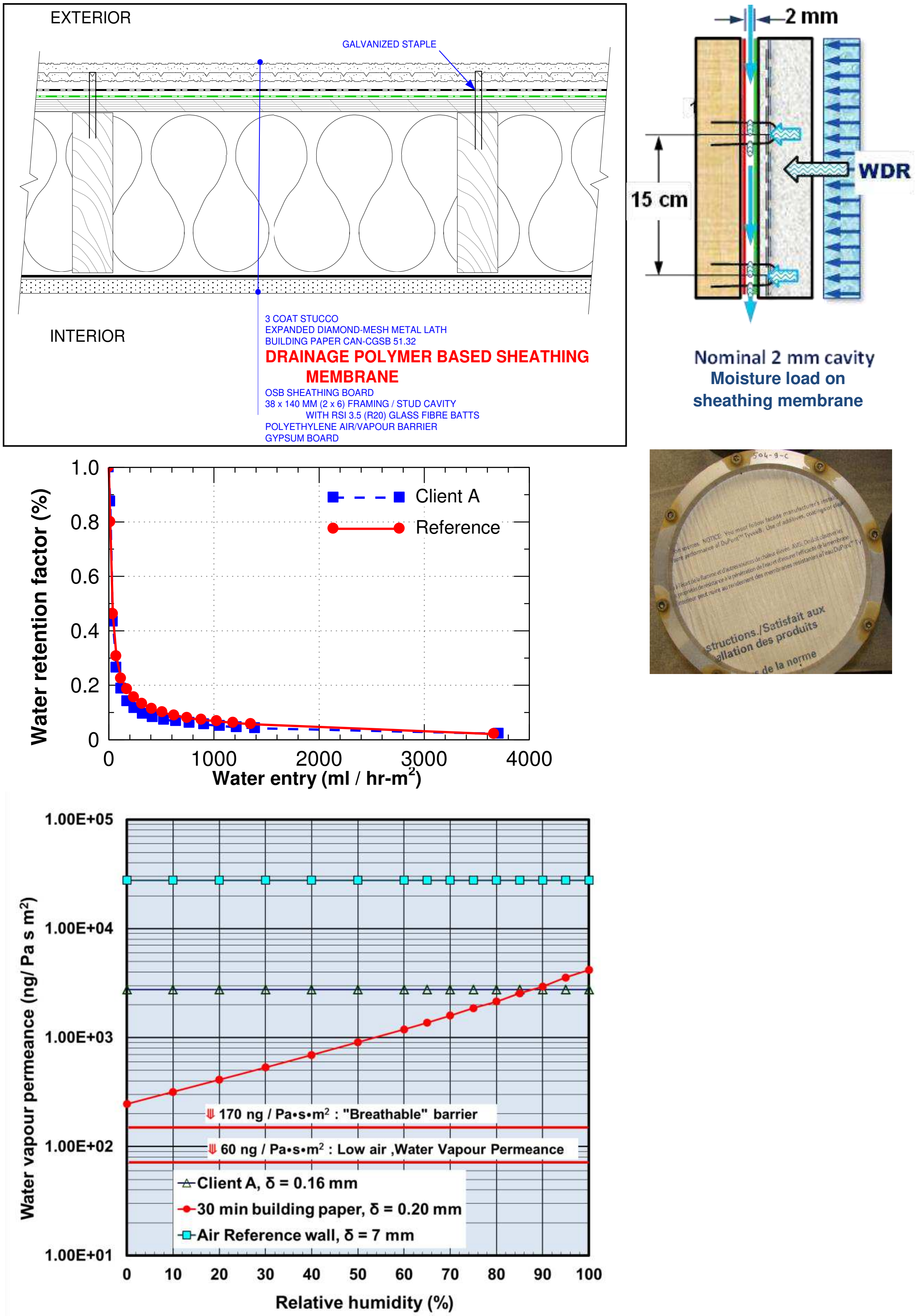


Figure 4 – Client A Wall: Sectional view, placement of ML in 2 mm drainage cavity; water retention characteristic; WVP of sheathing membrane for membrane of thickness δ

The values of M_{IDX} diminish in relation to the distance from where the moisture load is applied to the location of interest for which a response has been given. Thus the higher values of M_{IDX} are those closest to the sheathing membrane and the location where the moisture load was applied and thereafter diminish as the location of interest recedes from the exterior face of the sheathing panel to the interior face of the OSB panel, and where this surface is at the interface between the OSB and the interior insulation.

Another observation is that the average and maximum values for M_{IDX} of the entire OSB panel (i.e. “whole” OSB 11 mm thick) are always greater than the 10 mm portion of OSB behind the 1 mm sliver (i.e. “back” of OSB, 10 mm thick) given that the average value and maximum values for M_{IDX} of the 1 mm sliver are always the greatest values for M_{IDX} amongst the different locations in the wall. As such, the values provided for the 1 mm OSB sliver are the critical values from which the response of the wall assembly is measured in respect to managing moisture ingress to the drainage cavity. Whereas, if the risk of condensation is the measure of importance in respect to wall performance, then the focus ought to be on the interface between the insulation and the OSB panel, that is, the “OSB-fibre interface” as given in Figure 5 and Figure 6.

The differences in response of the OSB component (1 mm sliver on exterior OSB surface) to the location of the ML in the wall assembly is apparent from the lower values of M_{IDX} obtained in the instance where the ML is placed between the cladding and the building paper as compared to being placed on the sheathing membrane; the ML being in direct contact with the sheathing membrane brings it in closer proximity to the wood-based and moisture sensitive components of the wall assembly.

The response of the Reference and Client A Walls of the OSB component (1 mm sliver on exterior OSB surface) to climate loads of Tofino (BC) over the same two (2) year period are shown in Figure 6; values for M_{IDX} as a function of time for the left-hand plot are for the condition where the ML is placed between the cladding and building paper (BP), whereas those for the right-hand plot are for where the ML has been placed on the sheathing membrane.

When the ML was placed between the building paper and the cladding (left-hand plot Figure 6), the Client A wall had average and maximum values for M_{IDX} less than that of the Reference wall. Whereas when the ML was placed on the sheathing membrane, it is perhaps evident from the right-hand plot provided in Figure 6 that Client A’s wall did not manage moisture ingress to the drainage cavity as well as the Reference wall.

For the instance in which the ML was placed on the sheathing membrane (right-hand plot; Figure 6), the progression in values for M_{IDX} over the course of the simulation indicate that in the fall of the 1st year (~ day 270) of simulation, Client A’s wall did not manage moisture ingress to the drainage cavity as compared to the Reference wall (i.e. Client A’s wall had higher values of M_{IDX} at any given time as compared to that of the Reference wall) and thereafter throughout the remainder of the simulation period, the Reference wall provided better management of moisture ingress as compared to Client A’s wall.

The information provided in Table 7 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client A's wall. For instances where the ML was placed on the SBPO sheathing membrane (vz. Client A (ii)), the values for M_{IDX} of Client A's wall are all greater than that of the Reference wall, irrespective of the value for M_{IDX} of the layer or interface.

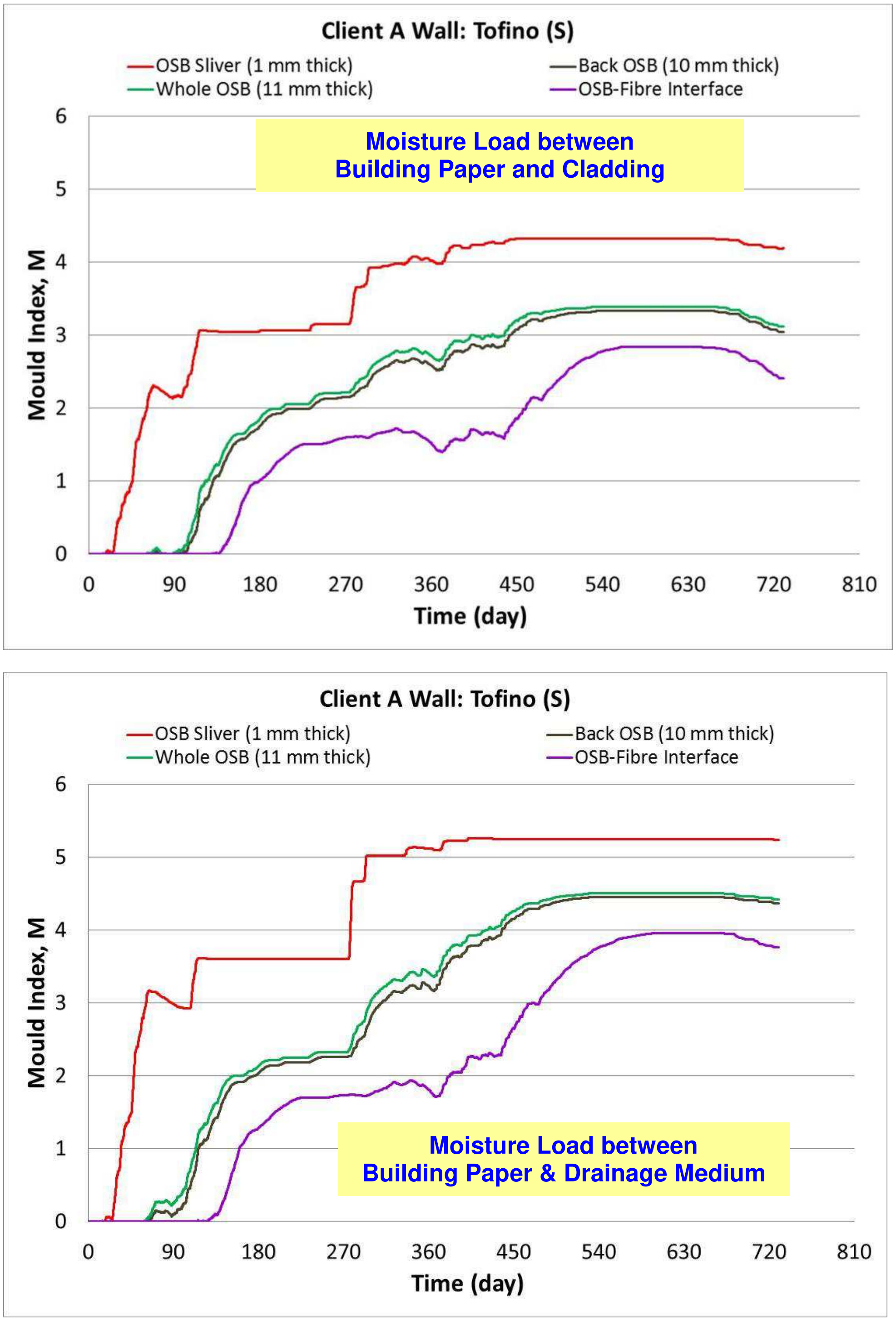


Figure 5 - Client A Walls: Response of OSB component to climate loads of Tofino (BC); response given as M_{IDX} value for sensitivity class "S"

Hygrothermal response of wall components to climate loads of Tofino; RHT(x) criterion

The response of Client A's wall to climate loads of Tofino (BC) as determined by the value of the RHT(x) index is shown in Figure 7. The left-hand plot of Figure 7 shows values for relative humidity and temperature over the simulation period for the instance where the ML was placed between the building paper and the cladding; the right-had plot for instances where the ML was placed on the sheathing membrane.

The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client A walls and for different threshold values of RH are given in the tables located above the plots of Figure 7.

A review of the right-hand plot as compared to the left-hand plot shows that the RH in the 1 mm sliver attained greater levels on the right-hand side (> 95% at day ~270), and the side for which the ML was placed on the sheathing membrane; this result is consistent with that provided from the plots of values of M_{IDX}.

As well, in the table located above the right-hand plot of Figure 7, the respective values for RHT(x) are all greater for Client A's wall as compared to the Reference wall for the instance where the ML was placed on the sheathing membrane; this also is consistent with that which was determined from a comparison of M_{IDX} values as was made available in Table 7.

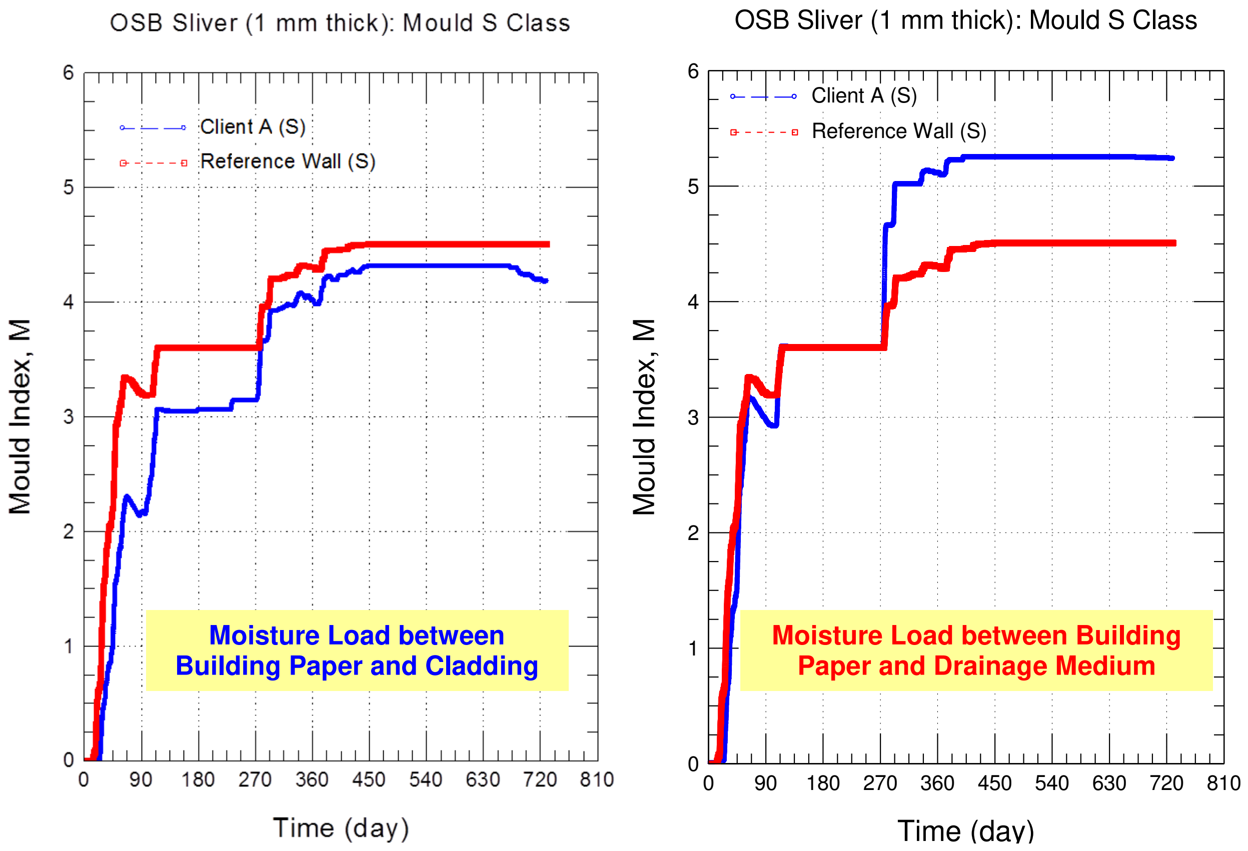


Figure 6 – Reference and Client A Walls: Response of OSB component (1 mm sliver on exterior OSB surface) to climate loads of Tofino (BC); response given as M_{IDX} value for sensitivity class "S";

Table 7 – Average & maximum values of M_{IDX} for different locations in Reference (REF.) and Client A Walls; Moisture Load placed between the Building paper and: (i) Cladding; (ii) Drainage medium

	REF. - Layer or Interface				REF. - Layer or Interface			
M_{IDX}	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
Average	3.910	2.506	2.597	1.819	3.910	2.506	2.597	1.819
Maximum	4.508	3.475	3.538	2.984	4.508	3.475	3.538	2.984
	Client A (i) - Layer or Interface				Client A (ii) - Layer or Interface			
M_{IDX}	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
Average	3.515	2.270	2.355	1.617	4.323	2.937	3.032	2.156
Maximum	4.314	3.324	3.386	2.836	5.249	4.450	4.497	3.954

	Tofino			
	RHT(80)	RHT(85)	RHT(92)	RHT(95)
Ref Wall	5263	3015	435	37
Client A	4488	2439	263	6

	Tofino			
	RHT(80)	RHT(85)	RHT(92)	RHT(95)
Ref Wall	5263	3015	435	37
Client A	5687	3638	1220	490

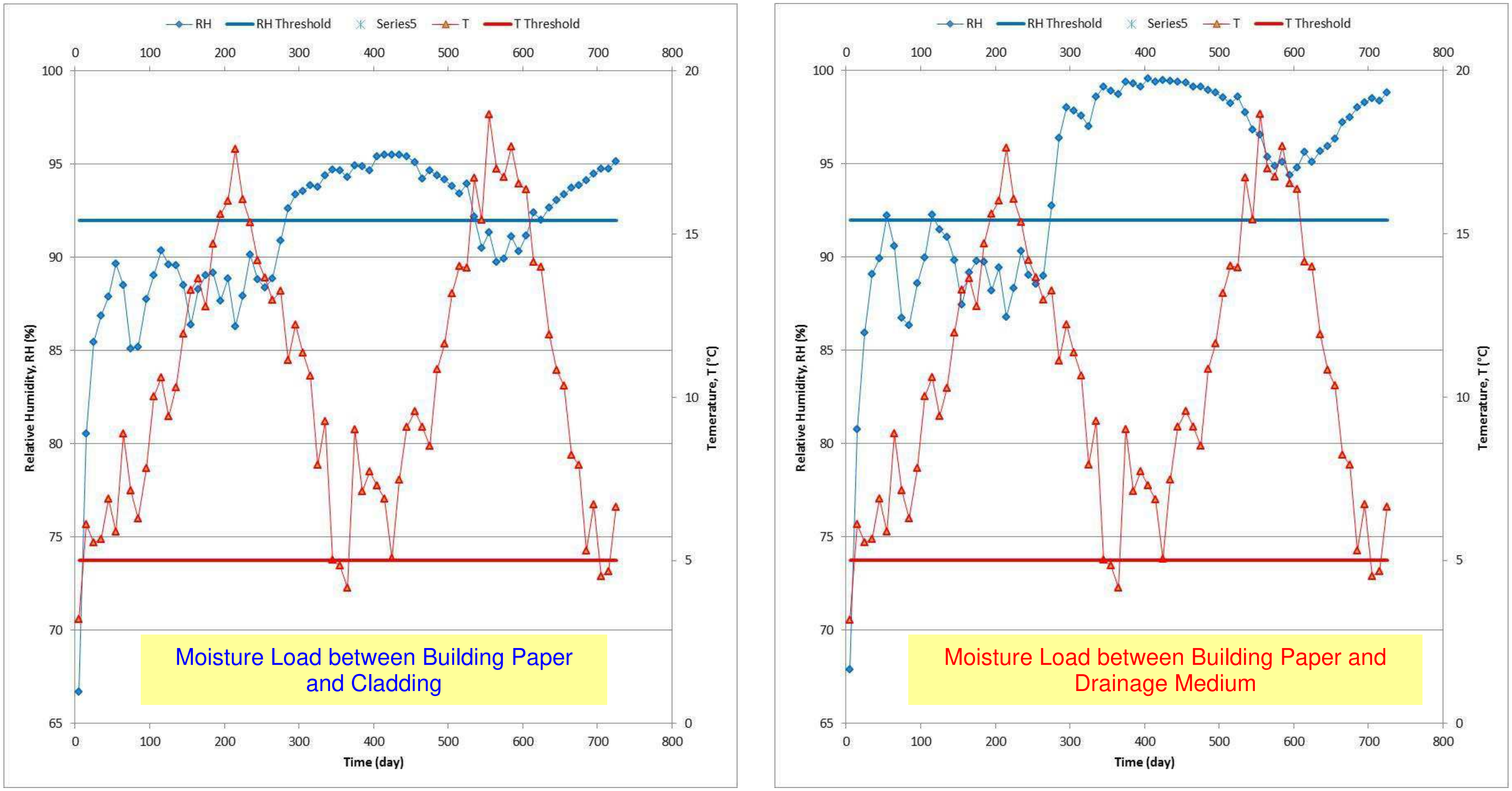


Figure 7 - Client A Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of Tofino (BC); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

Hygrothermal response of wall components to climate loads of Vancouver; M_{IDX} criterion

The response of the Client A's wall assembly to the climate loads of Vancouver (BC) are provided in Figure 8 to Figure 11 and in Table 8. The variation in values for M_{IDX} over the simulation period and in respect to the different locations in the wall, are provided in the two plots of Figure 8. The upper most plot shows the variation over the simulation period when the moisture load (ML) was placed between the cladding and the building paper; the lower most plot, the variation when the ML was placed on the spun bonded polyolefin sheathing membrane.

In both plots of Figure 8, and as was the case for the wall response to the climate loads of Tofino (BC), the values for M_{IDX} over the simulation period increased over time depending on the propensity for mould growth for the different locations within the sheathing panels (OSB); again, plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB-glass fibre interface), and recalling that the "OSB Sliver" (1 mm thick sliver at exterior face sheathing panel) is closest to the moisture load, and in contact with the sheathing membrane.

The values of M_{IDX} as a measure of the response to the climate loads of Vancouver (BC) diminish in relation to the distance from where the moisture load is applied to the location of interest, as was the case for the response of the wall to the climate loads of Tofino. Differences in response of the OSB component to the location of the ML in the wall assembly are similar to that previously reported for Tofino; i.e. lower values of M_{IDX} obtained in the instance where the ML is placed between the cladding and the building paper as compared to the ML being placed on the sheathing membrane.

The response of the Reference and Client A Walls of the OSB component (1 mm sliver on exterior OSB surface) to climate loads of Vancouver (BC) over the same period are shown in Figure 9; values for M_{IDX} for the left-hand plot are for the ML placed between the cladding and building paper (BP); the right-hand plot for the ML placed on the sheathing membrane.

When the ML was placed between the building paper and the cladding (left-hand plot Figure 10), the Client A wall had average and maximum values for M_{IDX} less than that of the reference wall. Whereas Client A's wall did not manage moisture as well as the reference wall when the ML was placed on the sheathing membrane; this is consistent with the results for Tofino. When the ML was placed on the sheathing membrane (right-hand plot; Figure 10), the progression in values for M_{IDX} over the course of the simulation indicate that Client A's wall did not manage moisture ingress to the drainage cavity as well as the reference wall.

The information provided in Table 8, shows the average and maximum values for M_{IDX} of different locations within the Reference and Client A's wall, including values for M_{IDX} at the OSB-Cavity Interface. For instances where the ML was placed on the SBPO sheathing membrane (vz. Client A (ii)), the values for M_{IDX} of Client A's wall are all greater than that of the reference wall, irrespective of the value for M_{IDX} of the layer or interface.

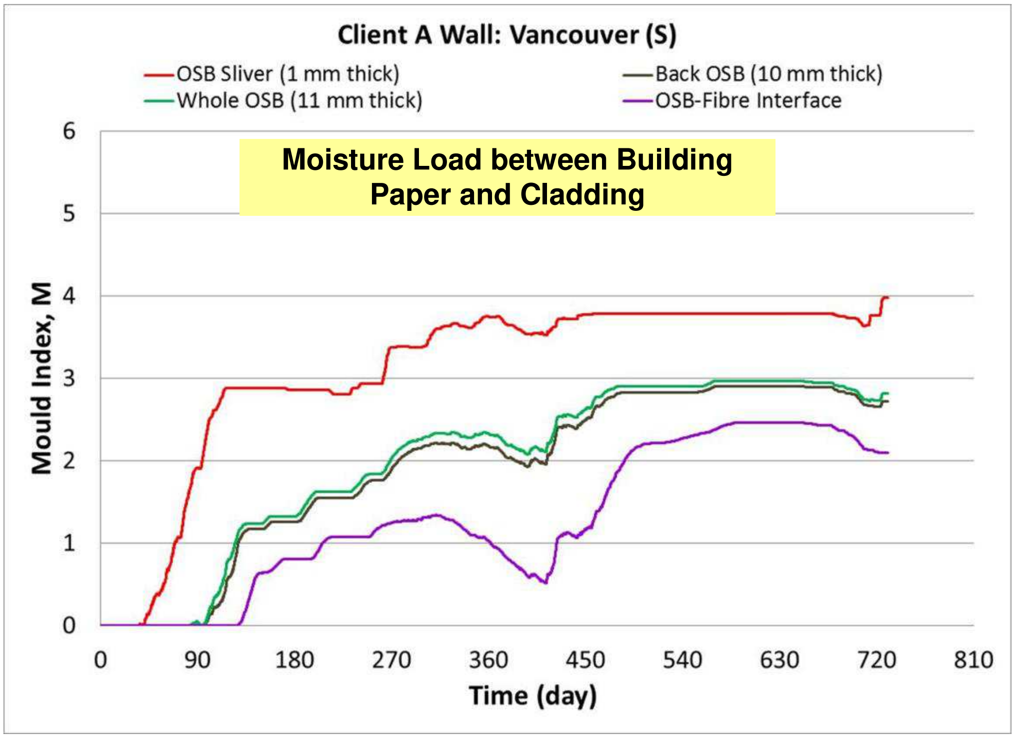


Figure 8 - Client A Walls: Response of OSB component to climate loads of Vancouver (BC); response given as M_{IDX} value for sensitivity class "S"

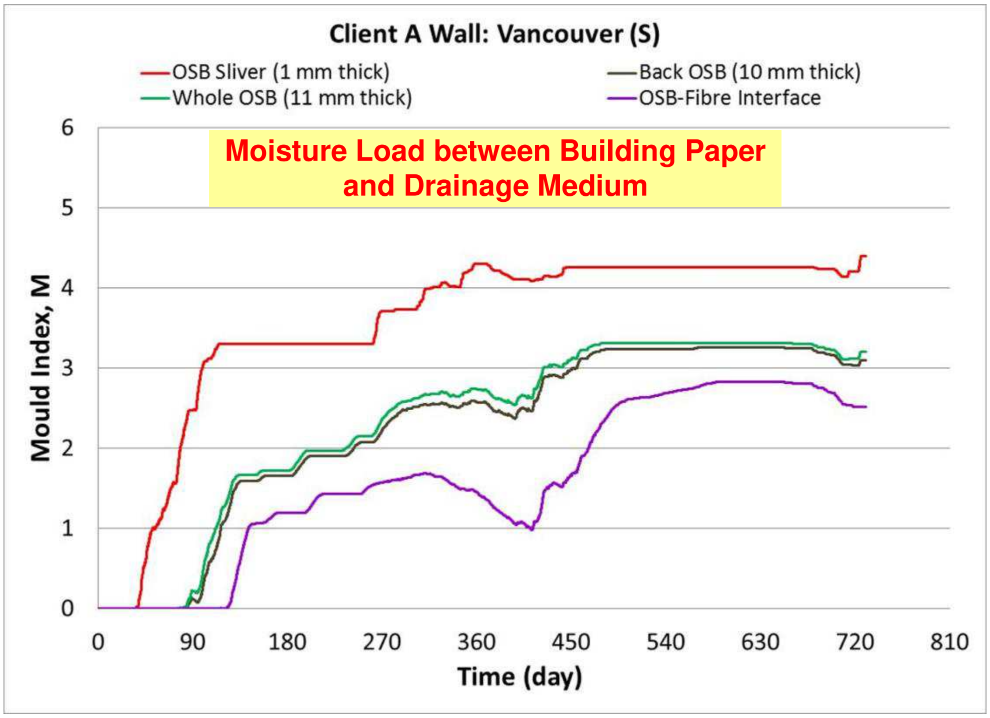


Figure 9 - Client A Walls: Response of OSB component to climate loads of Vancouver (BC); response given as M_{IDX} value for sensitivity class "S"

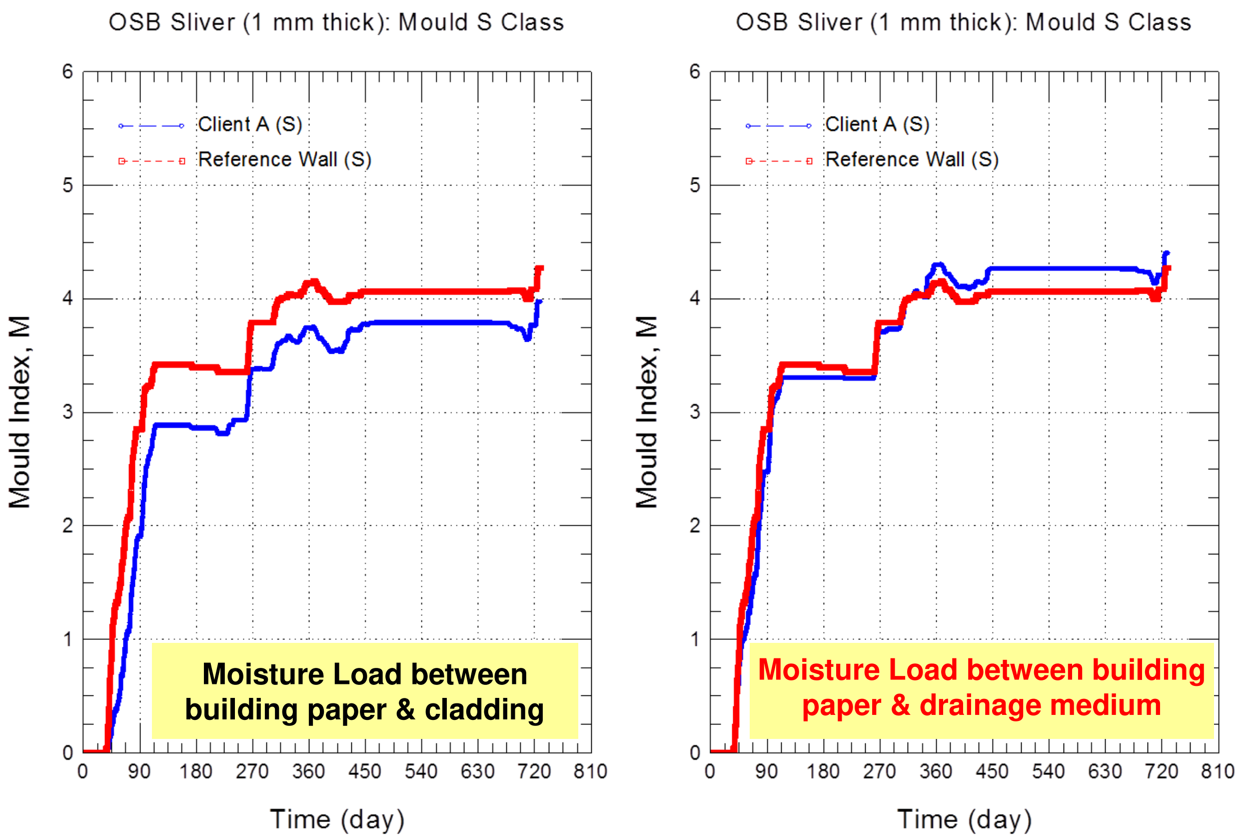


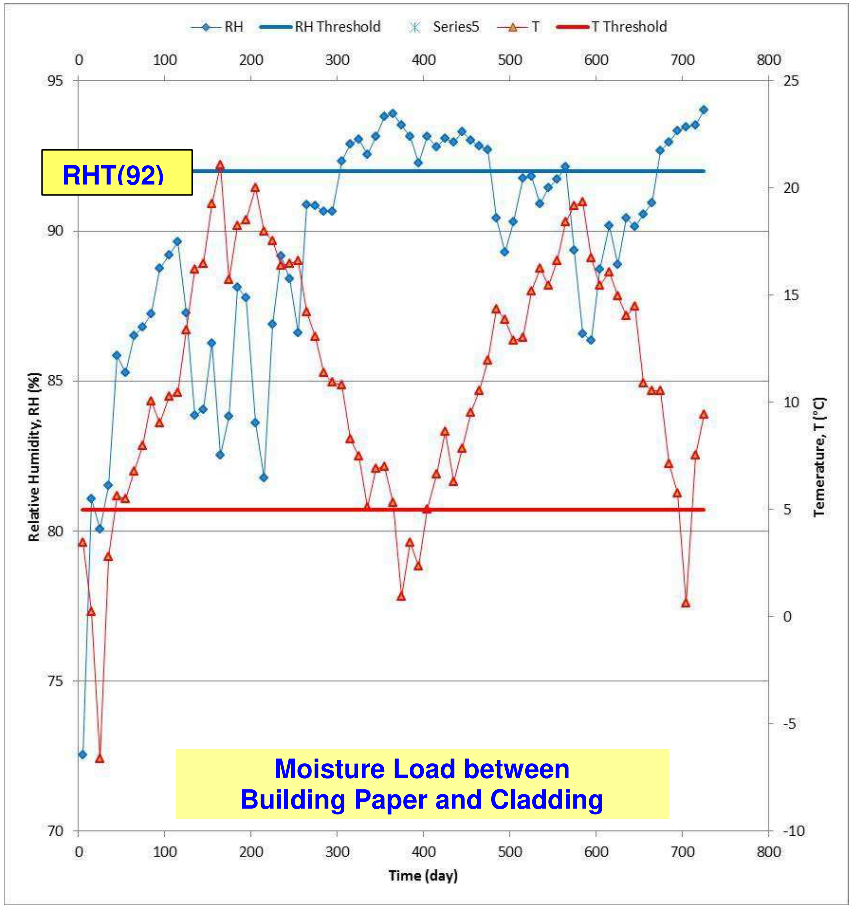
Figure 10 – Reference and Client A Walls: Response of OSB component (1 mm sliver on exterior OSB surface) to climate loads of Vancouver (BC); response given as M_{IDX} value for sensitivity class "S"

Table 8 - Average and maximum values of M_{IDX} for different locations in the Reference (REF.) and the respective walls of Client A in which the Moisture Load was placed between the Building paper and: (i) Cladding; (ii) Drainage medium

	REF. - Layer or Interface				REF. - Layer or Interface			
M_{IDX}	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
Average	3.500	2.181	2.271	1.518	3.500	2.181	2.271	1.518
Maximum	4.270	3.082	3.149	2.633	4.270	3.082	3.149	2.633
	Client A (i) - Layer or Interface				Client A (ii) - Layer or Interface			
M_{IDX}	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
Average	3.091	1.910	1.993	1.277	3.531	2.247	2.334	1.604
Maximum	3.971	2.899	2.959	2.457	4.397	3.250	3.308	2.821

	RHT(80)	RHT(85)	RHT(92)	RHT(95)
Ref Wall	4958	2493	192	2
Client A	4183	1922	60	-

	RHT(80)	RHT(85)	RHT(92)	RHT(95)
Ref Wall	4958	2493	192	2
Client A	4841	2491	224	6



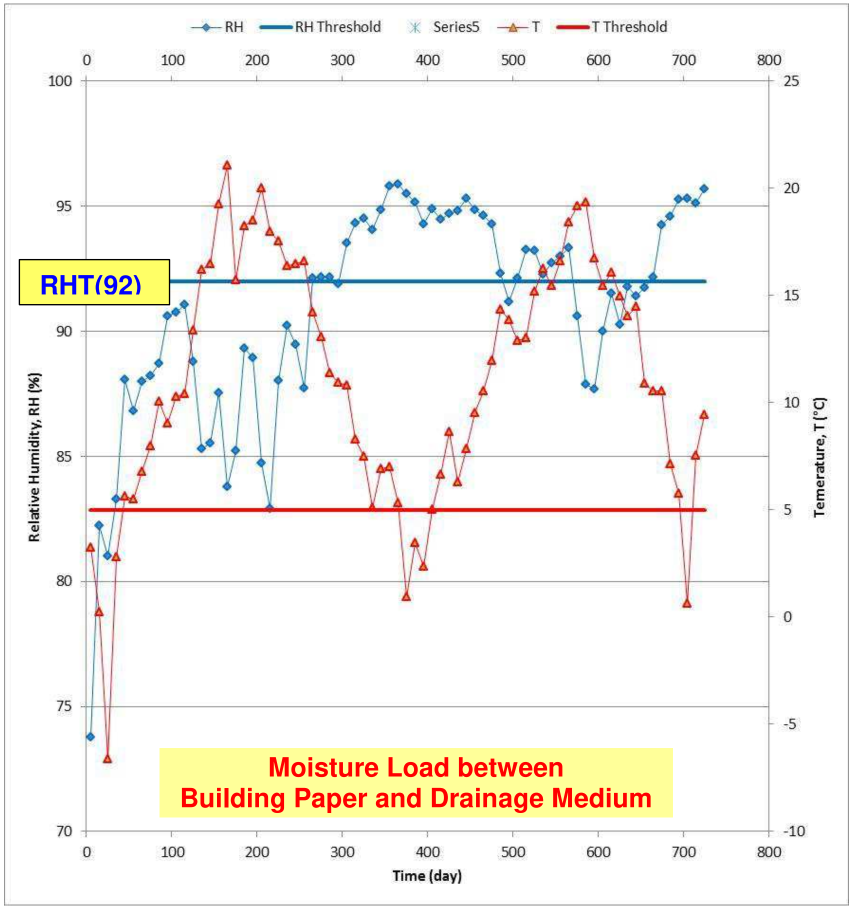


Figure 11 - Client A Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of Vancouver (BC); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

Hygrothermal response of wall components to climate loads of Vancouver (BC); RHT(x) criterion

The response of Client A's wall to climate loads of Vancouver (BC) as determined by the value of the RHT(x) index is shown in Figure 11. The left-hand plot of Figure 20 shows values for relative humidity and temperature over the simulation period for the instance where the ML was placed between the building paper and the cladding; the right-had plot for the ML placed on the sheathing membrane. The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client A walls and for different threshold values of RH are given in the tables located above the plots of Figure 10.

A review of the right-hand plot and the side for which the ML was placed on the sheathing membrane, as compared to the left-hand plot shows that the RH in the 1 mm sliver attained greater levels on the right-hand side (> 95% at day ~350), whereas in the left-hand plot the 95% RH level was never attained.; this result is consistent with that provided from the plots of values of M_{IDX}.

As well, in the table located above the right-hand plot of Figure 11, the respective values for RHT(x) are all greater for Client A's wall as compared to the Reference wall for the instance where the ML was placed on the sheathing membrane; this also is consistent with that which was determined from a comparison of M_{IDX} values as was made available in Table 8.

Hygrothermal response of wall components to climate loads of St John's NL; M_{IDX} criterion

The response of the Client A's wall assembly to the climate loads of St John's NL, are provided in Figure 12 to Figure 15 and in Table 9. Plots of the variation in values for M_{IDX} over the course of the simulation period and in respect to the different locations in the wall are provided in Figure 12 and Figure 13; in Figure 12 is the plot for the ML was placed between the cladding and the building paper and in Figure 13, the ML was placed on the sheathing membrane

The plots show similar features to that previously described for both Tofino and Vancouver (BC); specifically:

- The values for M_{IDX} over the course of the simulation increase over time depending on the propensity for mould growth for all of the different locations within the sheathing panels (OSB);
- The values of M_{IDX} diminish in relation to the distance from where the moisture load is applied to the location of interest; the critical wall element being the exterior surface of the OSB panel.
- Lower values of are M_{IDX} obtained in the instance where the ML is placed between the cladding and the building paper as compared to the ML being placed on the sheathing membrane.

The response of the OSB component in the Reference as compared to the Client A wall for climate loads of St John's (NL) are shown in Figure 14; values for M_{IDX} for the left- and right-hand plots are for the ML placed, respectively, between the cladding and building paper and on the sheathing membrane. Again, these plots have similar features of response as were evident for Tofino and Vancouver (BC).

- For a ML placed between the building paper and cladding (left-hand plot, Figure 14), the Client A wall had average and maximum values for M_{IDX} less than that of the reference wall. Whereas Client A's wall did not manage moisture as well as the Reference wall when the ML was placed on the sheathing membrane.

- When the ML was placed on the sheathing membrane (right-hand plot; Figure 14), Client A's wall did not manage moisture ingress to the drainage cavity as well as the reference wall.

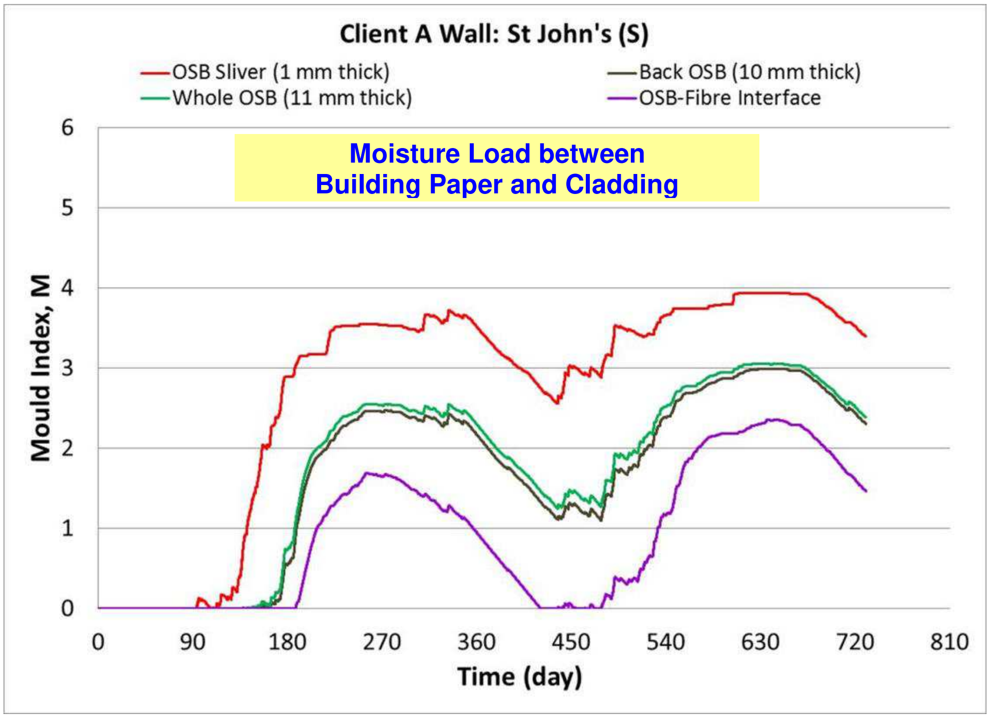


Figure 12 - Client A Walls: Response of OSB component to climate loads of St John's, NF; response given as M_{IDX} value for sensitivity class "S"

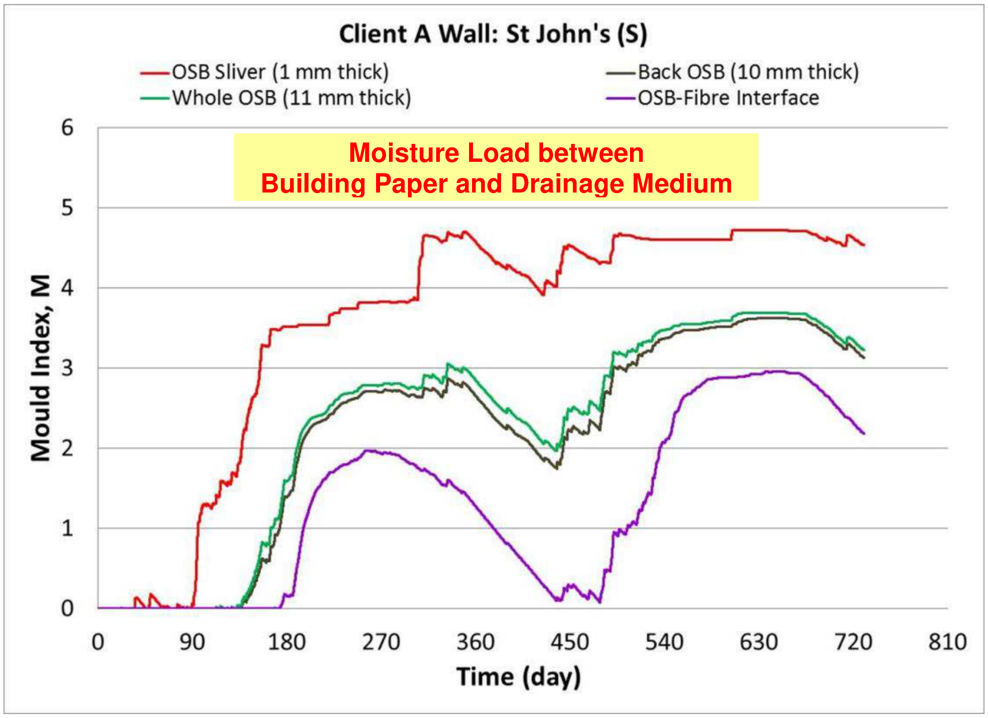


Figure 13 - Client A Walls: Response of OSB component to climate loads of St John's, NL; response given as M_{IDX} value for sensitivity class "S"

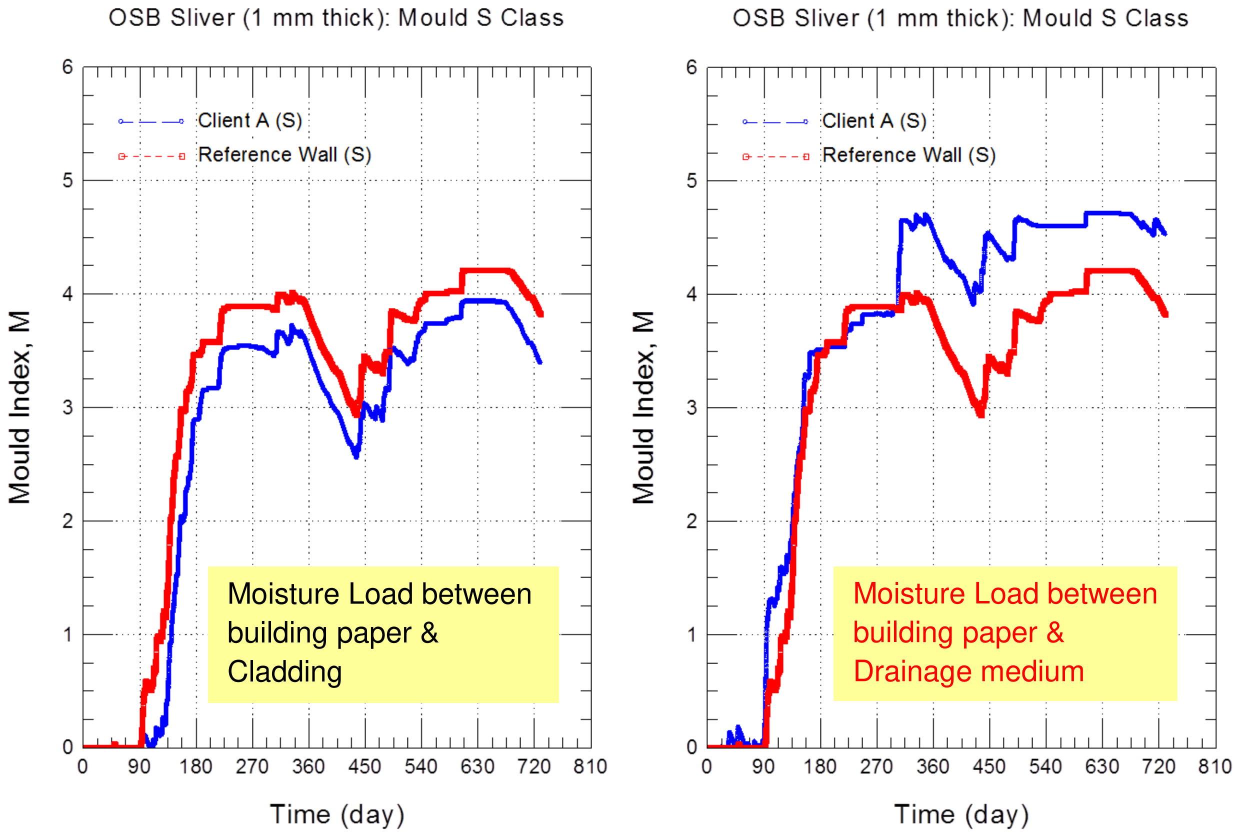


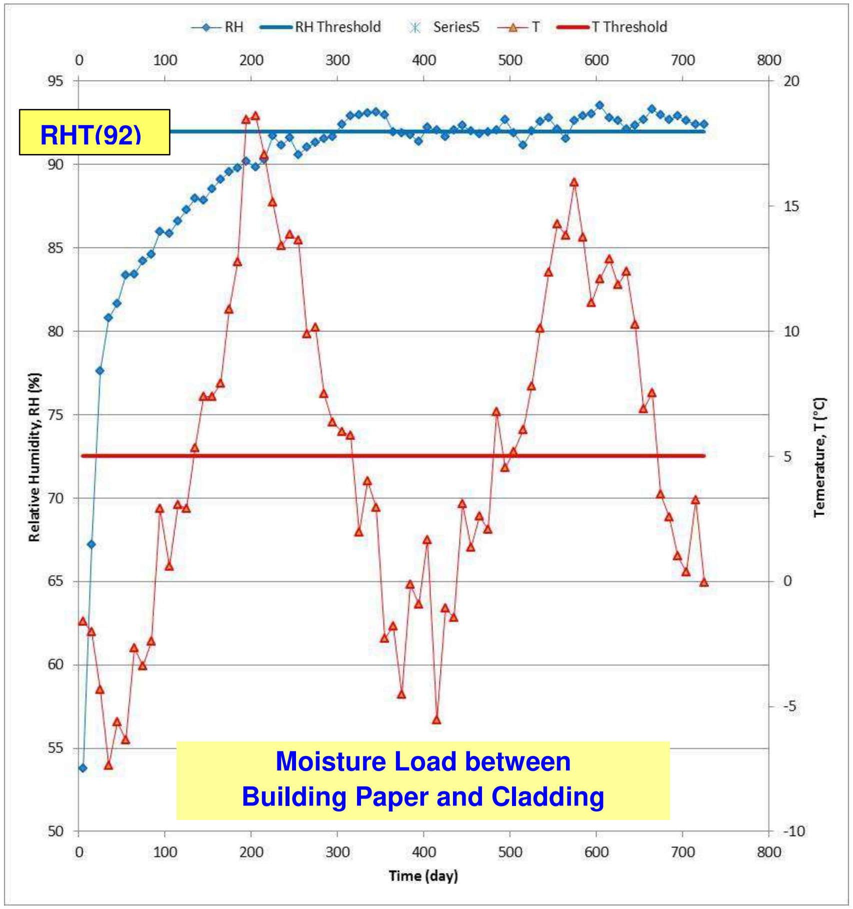
Figure 14 – Reference and Client A Walls: Response of OSB component (1 mm sliver on exterior OSB surface) to climate loads of St John's, NL; response given as M_{IDX} value for sensitivity class "S"

Table 9 - Response of Reference (REF.) and Client A Walls to climate loads of St John's, NL: Average and maximum values of M_{IDX} for different locations in walls in which the Moisture Load was placed between the Building paper and: (i) Cladding; (ii) Drainage medium

	REF. - Layer or Interface				REF. - Layer or Interface			
M_{IDX}	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
Average	3.085	1.941	2.035	1.147	3.085	1.941	2.035	1.147
Maximum	4.210	3.191	3.261	2.562	4.210	3.191	3.261	2.562
	Client A (i) - Layer or Interface				Client A (ii) - Layer or Interface			
M_{IDX}	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
Average	2.730	1.654	1.743	0.911	3.536	2.178	2.287	1.277
Maximum	3.935	2.987	3.051	2.354	4.713	3.616	3.687	2.954

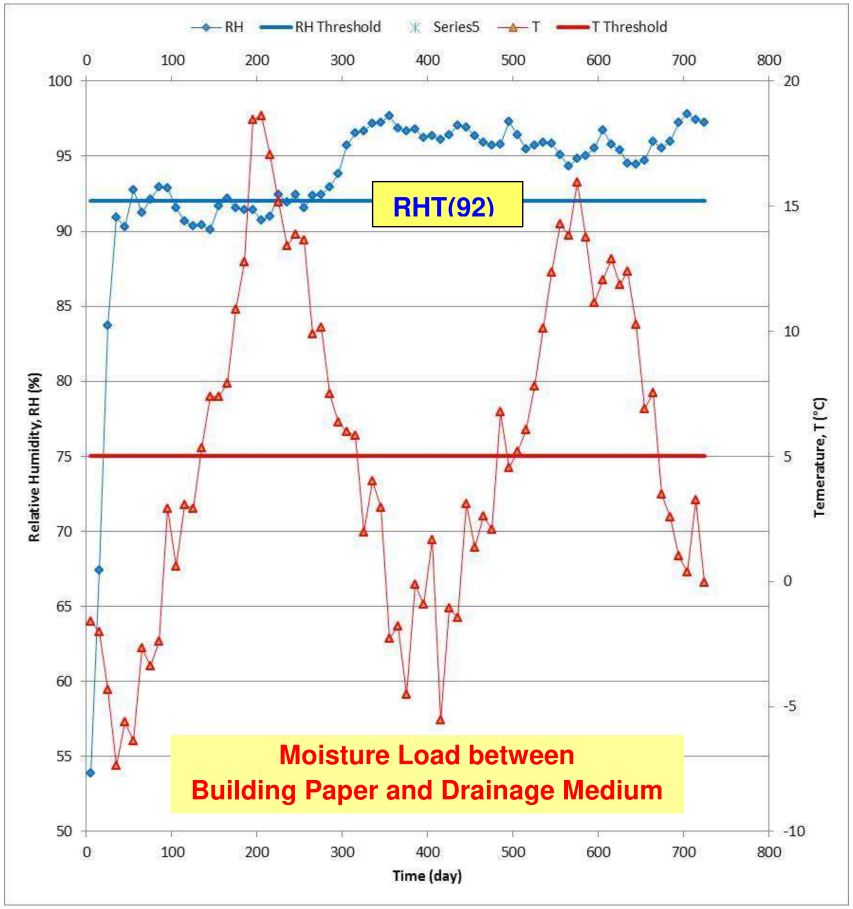
Wall	RHT(80)	RHT(85)	RHT(92)	RHT(95)
Ref Wall	2961	1786	193	0
Client A	2453	1384	62	-

Wall	RHT(80)	RHT(85)	RHT(92)	RHT(95)
Ref Wall	2961	1786	193	0
Client A	2869	1800	358	46



RHT(92)

Moisture Load between Building Paper and Cladding



RHT(92)

Moisture Load between Building Paper and Drainage Medium

Figure 15 - Client A Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of St John's, NL; response given as RHT(x) where x relates to the RH threshold value at which the index is provided

The information provided in Table 9, shows the average and maximum values for M_{IDX} for different locations within the Reference and Client A's wall for the climate loads of St John's, NL.

- For instances where the ML was placed on the sheathing membrane (vz. Client A (ii)), the values for M_{IDX} of Client A's wall are all greater than that of the reference wall, irrespective of the value for M_{IDX} of the layer or interface.

Hygrothermal response of wall components to climate loads of St John's, NL; RHT(x) criterion

The response of Client A's wall to climate loads of St John's, NL as determined by the value of the RHT(x) index on exterior surface of OSB panel is shown in Figure 15; the left-hand plot of shows values for relative humidity and temperature over the simulation period for the ML placed between the building paper and cladding; the right-had plot for the ML placed on the sheathing membrane.

The actual values for the RHT(x) index for the Reference and Client A walls and for different threshold values of RH are given in the tables located above the plots of Figure 15.

A review of the right-hand plot and the side for which the ML was placed on the sheathing membrane, as compared to the left-hand plot shows that the RH in the 1 mm sliver attained greater levels on the right-hand side (> 95% at day ~350), whereas in the left-hand plot the 95% RH level was never attained.; this result is consistent with that provided from the plots of values of M_{IDX}.

As well, in the table located above the right-hand plot of Figure 15, the respective values for RHT(x) are all greater for Client A's wall as compared to the Reference wall for the instance where the ML was placed on the sheathing membrane; this also is consistent with that which was determined from a comparison of M_{IDX} values as was made available in Table 9.

5.2 Client B Drainage System

Overview of Drainage System – Client B

A sectional view of the wall configuration incorporating Client B's product, water repellent insulation board and fluid applied membrane, is shown in Figure 16. The water retention characteristics of the drainage system (i.e. 10 mm air space on wood furring strips and water repellent insulation) indicates that for given water entry rates, this drainage system retains as much water as compared to the Reference drainage system. A plot of the water vapour permeance (WVP) of membranes, including that of Client B, and Client B's insulation board, is also provided; it is apparent that the WVP of Client B's membrane product is significantly less than that of and the NBC-compliant sheathing membrane, denoted as 30 min building paper in the plot (conforming the CGSB standard [10]). Client B's membrane has a WVP that is (~80 ng/ Pa•s•m^2) the same order of magnitude as the 170 ng/ Pa•s•m^2, the lower limit for a breathable membrane and at 50% RH, an order of magnitude less than that of a NBC-compliant sheathing membrane. However, the water absorption coefficient for this membrane is not measureable [3] suggesting that there is no liquid water transfer by liquid diffusion across the membrane. As such, the performance would be related to the extent to which water vapour permeates both the insulation board and the membrane and this would in turn depend on the amount of moisture that is retained on the membrane following a rain event and the prevailing temperature in the drainage cavity.

The difference for this assembly, as compared to all other wall assembly drainage systems evaluated, is the use of gypsum board (Type X) as the sheathing panel. The water vapour permeability of the board as compared to an OSB panel is almost two orders of magnitude greater at low values of RH and at higher RH attains perhaps 1½ orders of magnitude difference in relation to the OSB.

In respect to the placement of the moisture load in the cavity, (ML), in this instance the ML was assumed to be placed on the backside of the cladding the same as for the reference wall given that for both wall assemblies, there is a capillary break between the cladding and the adjacent component in the drainage cavity (i.e. sheathing membrane for Reference wall; insulation board for Client B's wall) and water cannot readily traverse this gap.

Give that the moisture load is retained behind the cladding and as well, the WVP of the fluid applied membrane of Client B's wall is many times less than that of the reference wall, this suggests that Client B's wall, as compared to the reference wall, would be somewhat comparable to the Reference wall in respect to managing moisture ingress to the drainage cavity as will perhaps be evident in reviewing the subsequent results.

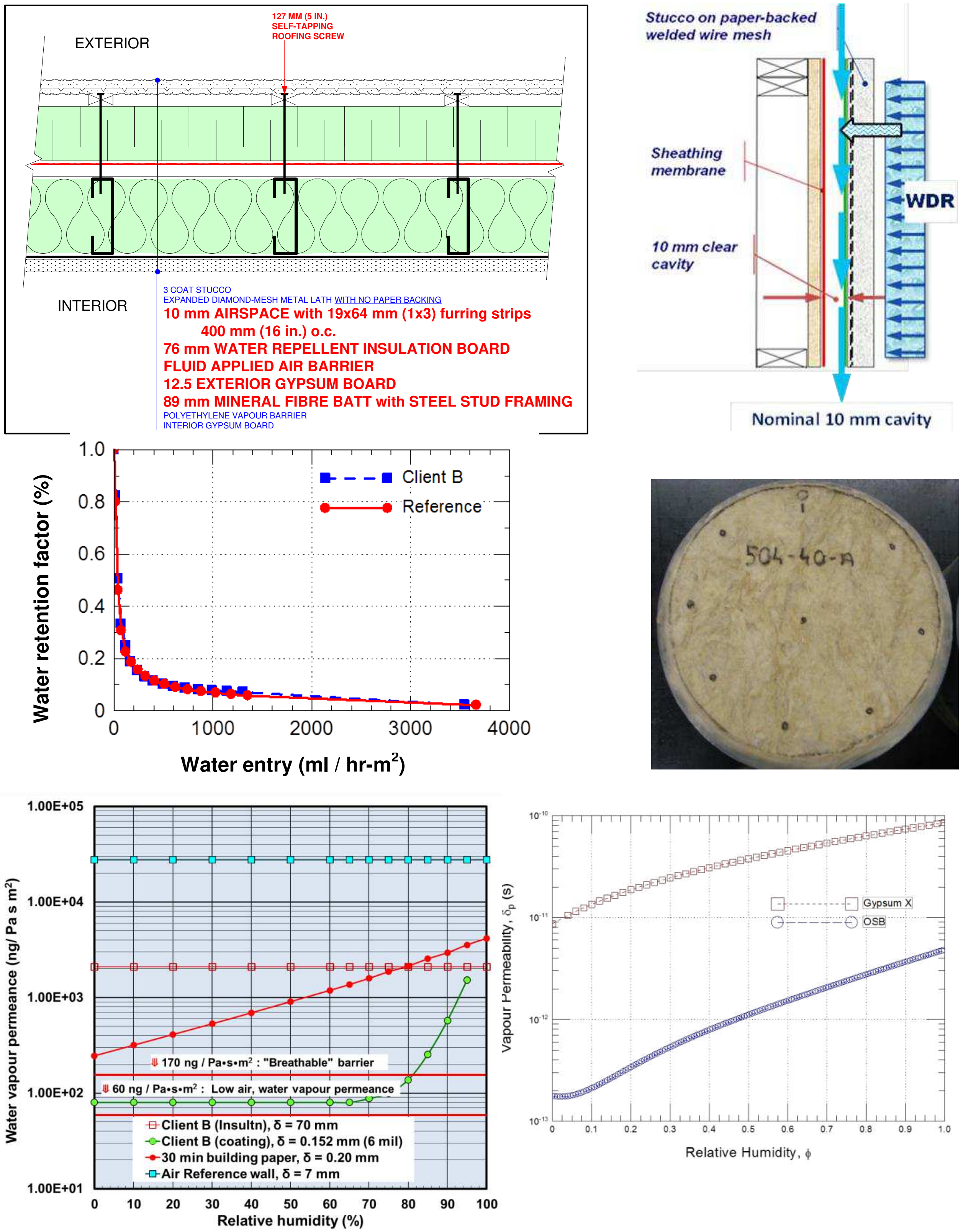


Figure 16 – Client B Wall: Sectional view, placement of moisture load in nominal 10 mm drainage cavity; water retention characteristics; water vapour permeance of sheathing membrane

Results from Simulation – Client B Drainage System

Hygrothermal response of wall components to climate loads of Tofino and Vancouver (BC) and St John's (NL); M_{IDX} criterion

The response of the Client B's wall assembly to the climate loads of Tofino and Vancouver (BC) and St John's (NL) are provided in Figure 17 to Figure 19 and in Table 10 and Table 11. More specifically, the variation in values for M_{IDX} over the simulation period and in respect to the different locations in the wall, are provided in three (3) plots of Figure 17 for each of the respective climate locations.

In all plots of Figure 17, the values for M_{IDX} over the course of the simulation, in general, increase over time in relation to the propensity for mould growth given the moisture and temperature conditions in the different locations within the sheathing panels (Gypsum); the moisture conditions at the different panel locations are related to their respective proximity to the moisture load. Plots are provided for four (4) locations in the wall assembly (i.e. "Gypsum Sliver"; back 11.5 mm portion of Gypsum; "Whole" 12.5 mm thick Gypsum panel, and; Gypsum -glass fibre interface), the one closet to the moisture load, in these plots, being the "Gypsum-sliver", representative of a 1 mm thick sliver of the exterior face of the 12.5 mm thick sheathing panel and the component in closest contact with the membrane.

In respect to the values of M_{IDX} in relation to the location of interest for which a response has been given there is little difference in values amongst the different locations within the wall although the greatest value is nonetheless that which is closest to the membrane and the ML. These values are all approximately the same given the high values for WVP of the gypsum panel; the higher values of M_{IDX} are those is closest to the membrane and the location where the ML was applied and thereafter diminish as the location of interest recedes from the exterior face of the sheathing panel to the interior face of the gypsum panel, and where this surface is at the interface between the OSB and the interior insulation. Thus the critical values in respect to assessing the management of moisture ingress to the drainage cavity are those provided for the 1 mm gypsum sliver. Whereas, if the risk of condensation is the measure of importance in respect to wall performance , then the focus is on the interface between the insulation and the OSB panel, that is, the "Gypsum-fibre interface" as given in Figure

The response of the Reference and Client B Walls of the gypsum panel component (1 mm sliver on exterior gypsum surface) over the same two (2) year period are shown in Figure 18; values for M_{IDX} as a function of time are provided for three plots in which the simulation are given, for the respective locations, from left to right, for the climate loads of Tofino and Vancouver (BC), and St John's (NL).

The information provided in Table 10 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client B's wall, including values for M_{IDX} at the gypsum-cavity Interface. As is evident from these plots and from the information provided in the table, the values for M_{IDX} of Client B's wall are all less than that of the Reference wall, irrespective of the value for M_{IDX} of the layer or interface and the locations for which the simulations were completed.

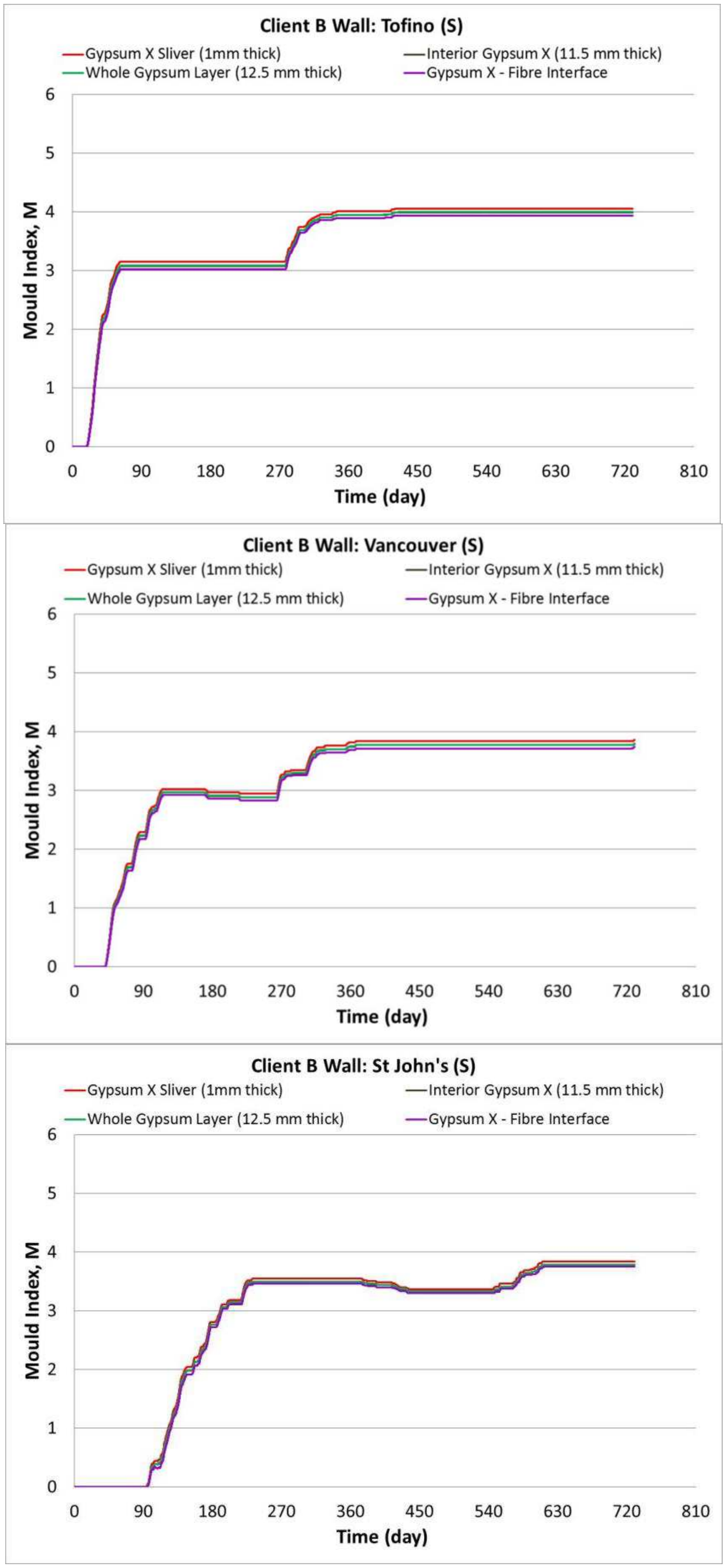


Figure 17 – Client B Walls: Response of OSB component to climate loads of Tofino, and Vancouver (BC) and St John's NF; response given as M_{IDX} value for sensitivity class "S"

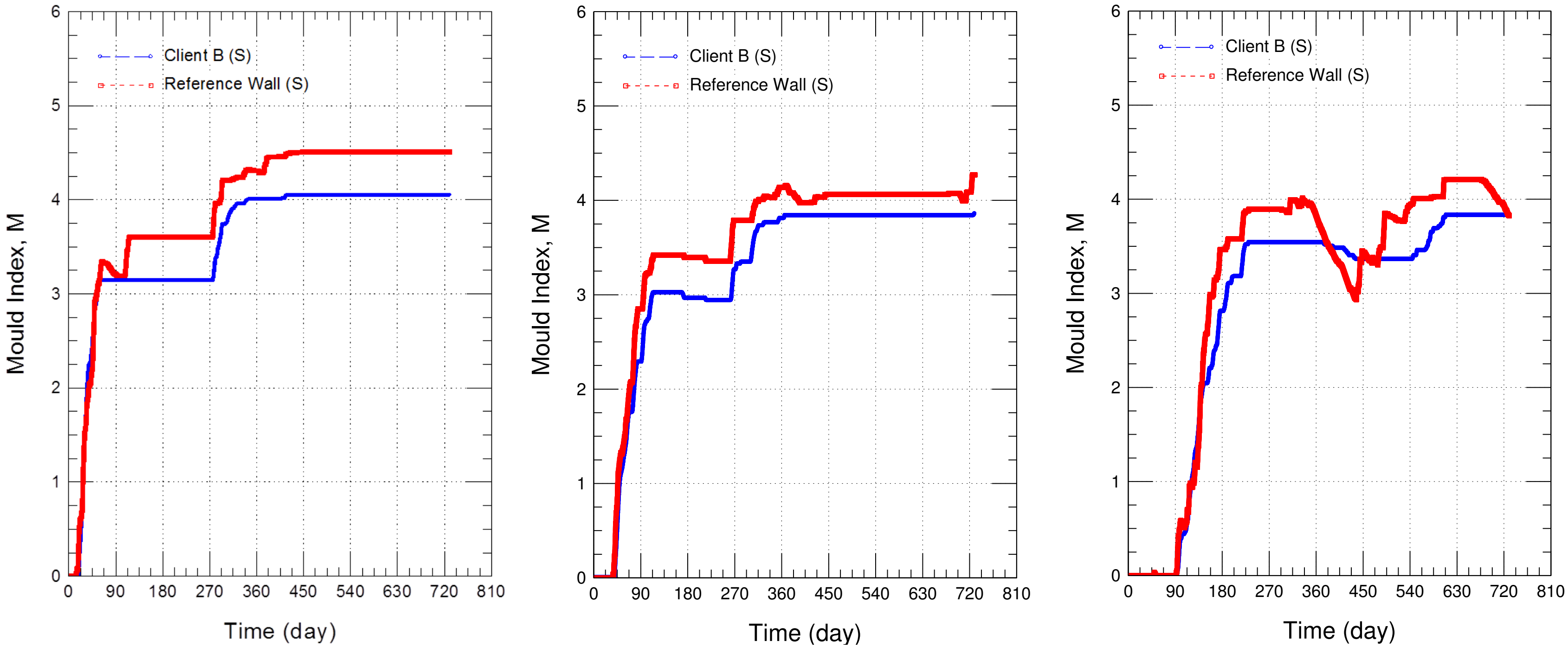


Figure 18 – Reference and Client B Walls: Response of Gypsum component (1 mm sliver on exterior Gypsum surface) to climate loads of (from left to right) Tofino and Vancouver (BC) and St John's NF; response given as M_{IDX} value for sensitivity class "S"

Table 10 – Response of Reference (REF.) and Client B Walls to climate loads Tofino and Vancouver (BC) and St John's NF Average and maximum values of M_{IDX} for different locations in walls in which Moisture Load was placed between Building paper and cladding

	Tofino					Vancouver				St John's			
	Gypsum X Sliver (1mm)	Interior Gypsum (11.5 mm)	Gypsum Layer (12.5 mm)	Gypsum-Fibre Interface	Gypsum-Roxul Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
REF-Avg	3.910	2.506	2.597	1.819	2.764	3.500	2.181	2.271	1.518	3.085	1.941	2.035	1.147
REF-Max	4.508	3.475	3.538	2.984	3.279	4.270	3.082	3.149	2.633	4.210	3.191	3.261	2.562
Client B-Avg	3.523	3.460	3.465	3.408	4.018	3.210	3.147	3.152	3.096	2.835	2.793	2.796	2.759
Client B-Max	4.048	3.987	3.991	3.935	4.409	3.855	3.787	3.793	3.738	3.831	3.781	3.785	3.744

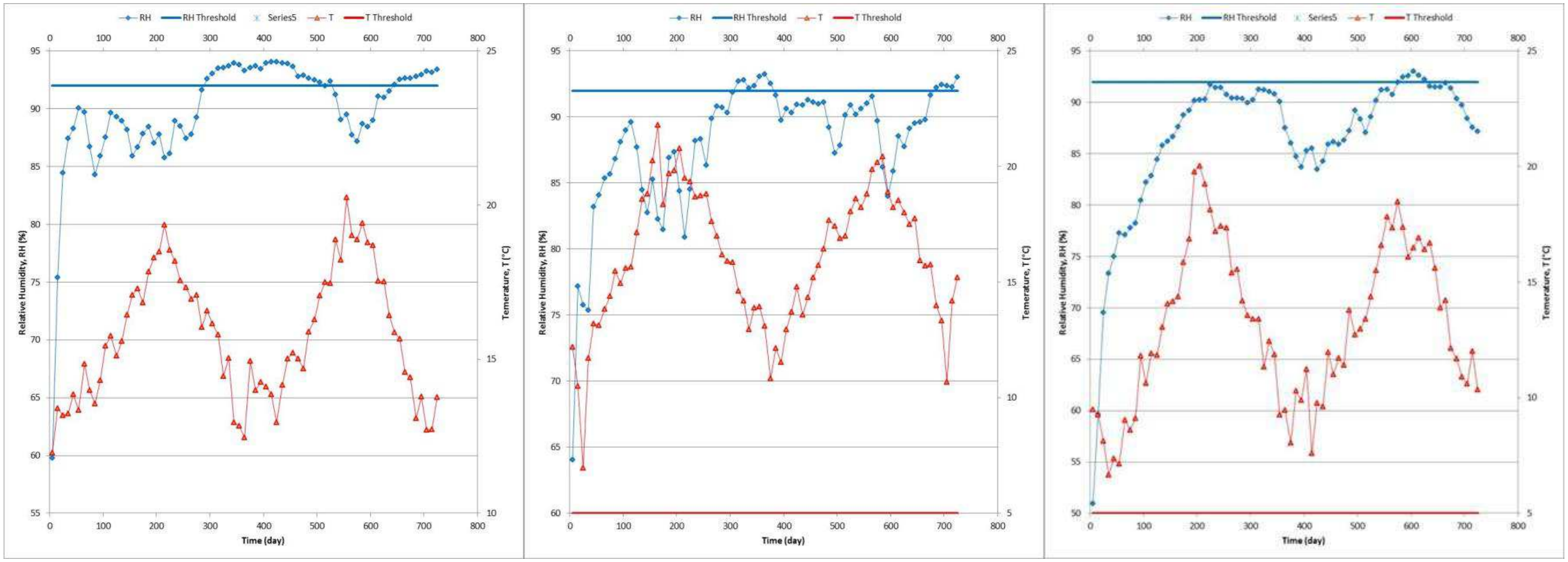


Figure 19 – Client B Wall: Response of Gypsum component (1 mm sliver on exterior surface of Gypsum panel) to climate loads of (from left to right) Tofino and Vancouver (BC) and St John's NF; response given as RHT(x) where x relates to the RH threshold value at which the index is provided

Table 11 – Reference and Client B Wall: Response of Gypsum component to climate loads of Tofino and Vancouver (BC) and St John's (NL); response given as RHT(x) where x relates to the RH threshold value at which the index is provided

Tofino					Vancouver			St John's			
Wall	RHT(80)	RHT(85)	RHT(92)	RHT(95)	RHT(80)	RHT(85)	RHT(92)	RHT(80)	RHT(85)	RHT(92)	Wall
Ref Wall	5263	3015	435	37	4958	2493	192	2961	1786	193	Ref Wall
Client B	7938	4103	359	0	6724	3041	62	5277	2558	34	Client B

Hygrothermal response of wall components to climate loads of Tofino and Vancouver (BC) and St John's, NL; RHT(x) criterion

The response of Client B's wall to climate loads of Tofino and Vancouver (BC) and St John's, NL as provided by plots of the temperature and relative humidity levels and from which are determined values for RHT(x) index, are shown in Figure 19.

The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client B walls and for different threshold values of RH are given in Table 11.

The values for RHT(80) and RHT(85) for the Client B wall are all greater than that of the Reference wall whereas values for RHT(92) and RHT(95) are all less than that of the Reference wall. The values for RHT(92) and RHT(95) are consistent with values determined for M_{IDX} as was made available in Table 10.

5.3 Client C Drainage System

Overview of Drainage System – Client C

A sectional view of the wall configuration incorporating Client C's product, consisting of a code compliant building paper, an open matrix nylon mesh bonded to a nonwoven PP sheathing membrane, is shown in Figure 20. The following hygrothermal property characteristics of Client C's drainage system are noted:

- The water retention characteristics of the drainage system indicate that for given water entry rates, this drainage system retains more water as compared to the Reference drainage system.
- A plot of the water vapour permeance (WVP) of the nonwoven PP sheathing membrane indicates that the WVP of this membrane product is significantly less than that of the NBC-compliant sheathing membrane, denoted as 30 min building paper in the plot (conforming the CGSB standard [9]). Client C's membrane has a WVP that is (~16400 ng/ Pa•s•m^2) almost two (2) orders of magnitude greater than the NBC-compliant sheathing membrane at 50% RH and at 100 % RH an order of magnitude greater than the NBC-compliant sheathing membrane. It is roughly two (2) orders of magnitude greater than the 170 ng/ Pa•s•m^2, the lower limit for a breathable membrane.
- The water absorption coefficient for this membrane was not measureable [see Task 2 Report [3]) suggesting that there is no liquid water transfer across the membrane by liquid diffusion.

Given these hygrothermal property characteristics, the performance of the wall incorporating this drainage system would be related to the extent to which water vapour permeates the sheathing membrane and this would in turn depend on the amount of moisture that is retained on the membrane following a rain event and the prevailing temperature in the drainage cavity.

In respect to the placement of the moisture load (ML) in the cavity for the purposes of simulations, the ML was assumed to be placed either on the backside of the cladding, between the cladding and the building paper, or on the sheathing membrane. The rationale for placement of the ML on the sheathing membrane was as follows: water would enter the drainage space at the many fastener locations across the wall and by gravity would percolate downwards within the open matrix nylon mesh and ultimately find its way to the surface of the sheathing membrane; a plausible scenario was deemed to be for 50 % of the ML attaining the surface of the sheathing membrane.

Give that 50 % of the ML was retained on the sheathing membrane and that the membrane, although impermeable to liquid water, was less permeable to water vapour as compared to that of the reference wall, suggests that in respect to managing moisture ingress to the drainage cavity, Client C's wall could be somewhat advantaged as compared to the Reference wall.

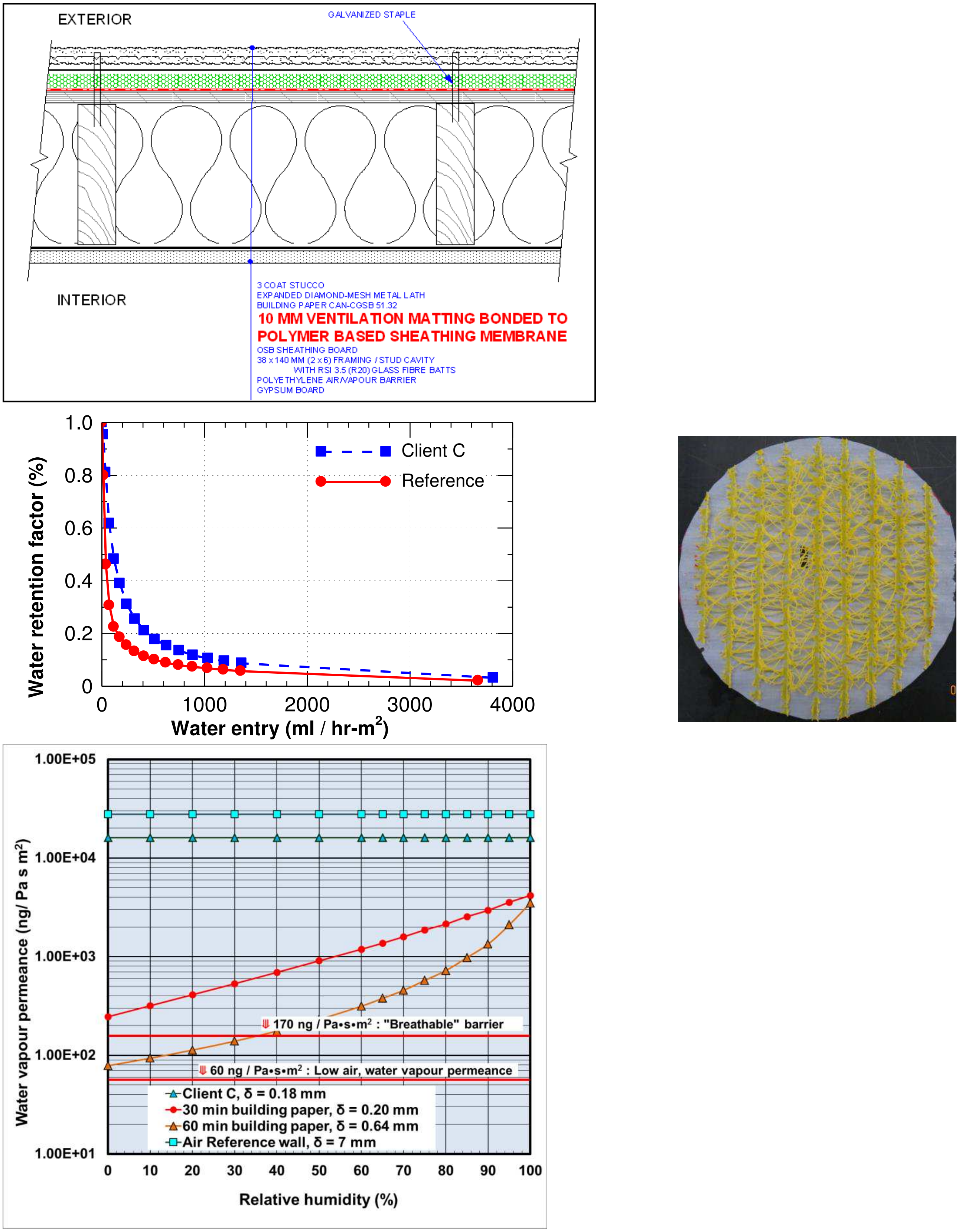
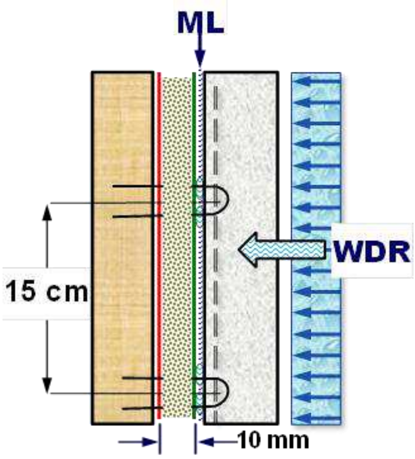


Figure 20 – Client C Wall: Sectional view, placement of ML in 10 mm drainage cavity; water retention characteristics; water vapour permeance of sheathing membrane; δ = membrane thickness

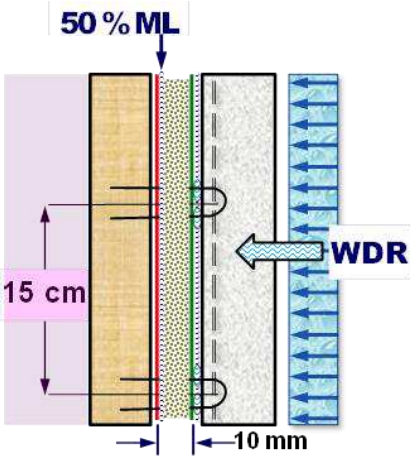
Results from Simulation – Client C Drainage System

Hygrothermal response of wall components to climate loads of Tofino; M_{IDX} criterion

The response of the Client C wall assembly to the climate loads of Tofino (BC) are provided in Figure 21 to Figure 24 and in Table 12 and Table 13. More specifically, the variation in values for M_{IDX} over the course of the simulation period and in respect to the different locations in the wall, are provided Figure 21, in which the variation in values for M_{IDX} are for the moisture load (ML) placed between the cladding and the building paper, whereas the in Figure 31, is shown the variation in values for M_{IDX} for 50 % of the ML placed on the sheathing membrane; both these ML conditions are illustrated in the adjacent schematics.



In Figure 21 and Figure 22, the values for M_{IDX} over the course of the simulation increase over time depending on the propensity for mould growth given the moisture and temperature conditions in the different locations within the sheathing panels (OSB); the moisture conditions at the different panel locations are related to their respective proximity to the moisture load. Plots are provided for four (4) locations in the wall assembly the one closet to the moisture load, in these plots, being the “OSB Sliver”, representative of a 1 mm thick sliver of the exterior face of the 11 mm thick sheathing panel and the component in closest contact with the sheathing membrane.



Observations common to both plots provided in Figure 21 and Figure 22:

- The higher values of M_{IDX} are those closest to the sheathing membrane and the location where the moisture load was applied and thereafter diminish as the location of interest recedes from the exterior face of the sheathing panel to the interior face of the OSB panel, and where this surface is at the interface between the OSB and the interior insulation;
- The average and maximum values for M_{IDX} of the entire OSB panel (i.e. “whole” OSB 11 mm thick) are always greater than the 10mm portion of OSB behind the 1 mm sliver (i.e. “back” of OSB, 10 mm thick) given that the average value and maximum values for M_{IDX} of the 1 mm sliver are always the greatest values for M_{IDX} amongst the different locations in the wall.
- The values provided for the 1 mm OSB sliver are the critical values from which the response of the wall assembly is measured in respect to managing moisture ingress to the drainage cavity, whereas;
- If the risk of condensation is the measure of importance in respect to wall performance , then the focus ought to be on the interface between the insulation and the OSB panel, that is, the “OSB-fibre interface” as given in Figure 21 and Figure 22.

The differences in response of the OSB component (1 mm sliver on exterior OSB surface) to the location of the ML in the wall assembly is apparent from the lower values of M_{IDX} obtained in the instance where the ML is placed between the cladding and the building paper (Figure 21) as compared to being placed on the sheathing membrane (Figure 22); the ML being in direct contact with the sheathing membrane brings it in closer proximity to the wood-based and moisture sensitive components of the wall assembly.

The response of the Reference and Client C Walls of the OSB component (1 mm sliver on exterior OSB surface) to climate loads of Tofino (BC) over the same period are shown in Figure 23; values for M_{IDX} as a function of time for the left-hand plot are for the condition where the ML is placed between the cladding and building paper (BP), whereas those for the right-hand plot are for the ML placed on the sheathing membrane.

When the ML was placed between the BP and the cladding (left-hand plot Figure 23), the Client C wall had values for M_{IDX} over the simulation period less than that of the Reference wall. Likewise, when the ML was placed on the sheathing membrane (right-hand plot Figure 23), Client C's wall managed moisture ingress to the drainage cavity at least as well as the Reference wall given that values for M_{IDX} were less than that of the Reference wall.

The information provided in Table 12 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client C's wall. For instances where the ML was placed on the sheathing membrane (Tofino / 50 % ML) the values for M_{IDX} of Client C's wall are all less than that of the Reference wall, irrespective of the value for M_{IDX} of the layer or interface; this was the same for when the ML was placed between the BP and the cladding.

Hygrothermal response of wall components to climate loads of Tofino; RHT(x) criterion

The response of Client C's wall to climate loads of Tofino (BC) as determined by the value of the RHT(x) index is shown in Figure 24. The left-hand plot of Figure 24shows values for relative humidity and temperature over the simulation period for the instance where the ML was placed between the BP and the cladding; the right-had plot for instances where the ML was placed on the sheathing membrane. The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client C walls and for different threshold values of RH are given in Table 13.

A review of the right-hand plot as compared to the left-hand plot shows that the RH in the 1 mm sliver attained greater levels on the right-hand side (> 92% at day ~400), and the side for which the ML was placed on the sheathing membrane; this result is consistent with that provided from the plots of values of M_{IDX}.

As well, the respective values for RHT(x) in Table 13 are all less for Client C's wall as compared to the Reference wall irrespective of where the ML was placed; this also is consistent with that which was determined from a comparison of M_{IDX} values as was made available in Table 12.

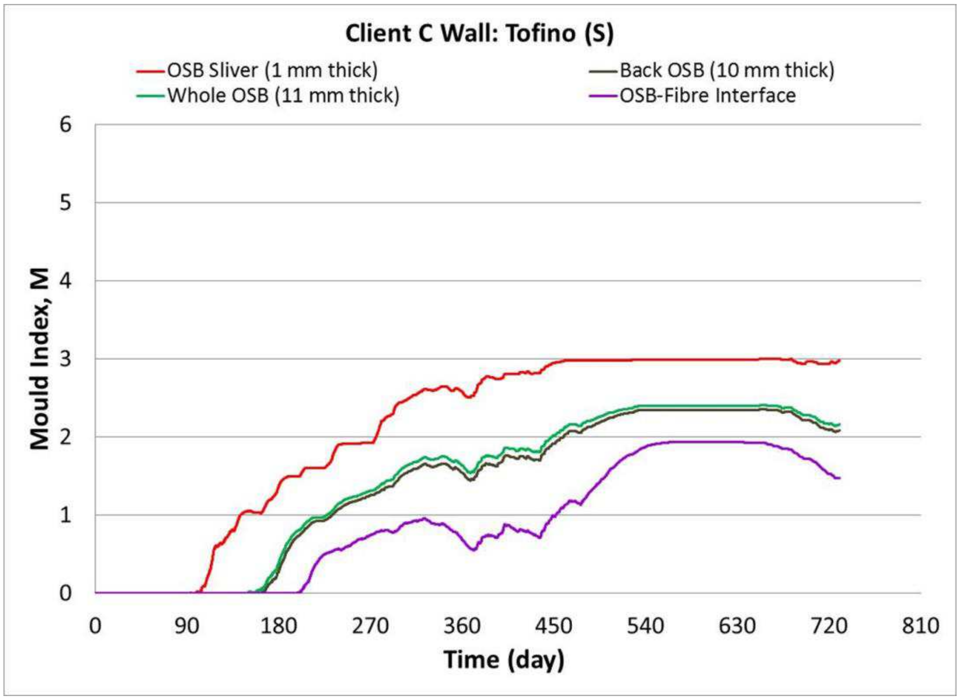


Figure 21 - Client C Walls: Response of OSB component to climate loads of Tofino (BC) for Moisture load applied between Building Paper and Cladding; response given as M_{IDX} value for sensitivity class "S

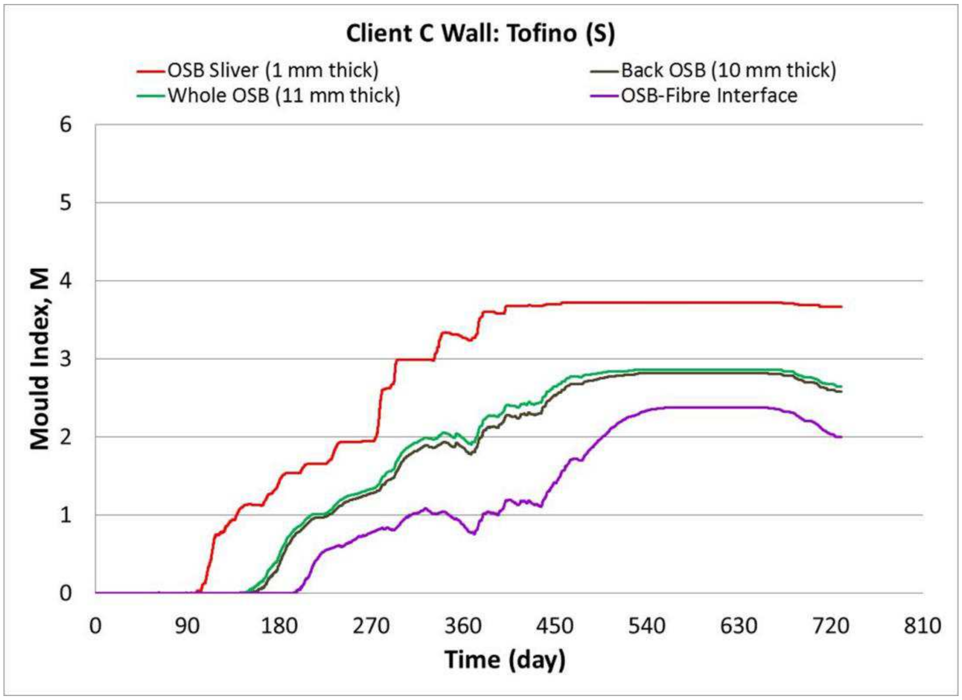


Figure 22 - Client C Walls: Response of OSB component to climate loads of Tofino (BC) for 50% of Moisture Load applied to sheathing membrane; response given as M_{IDX} value for sensitivity class "S

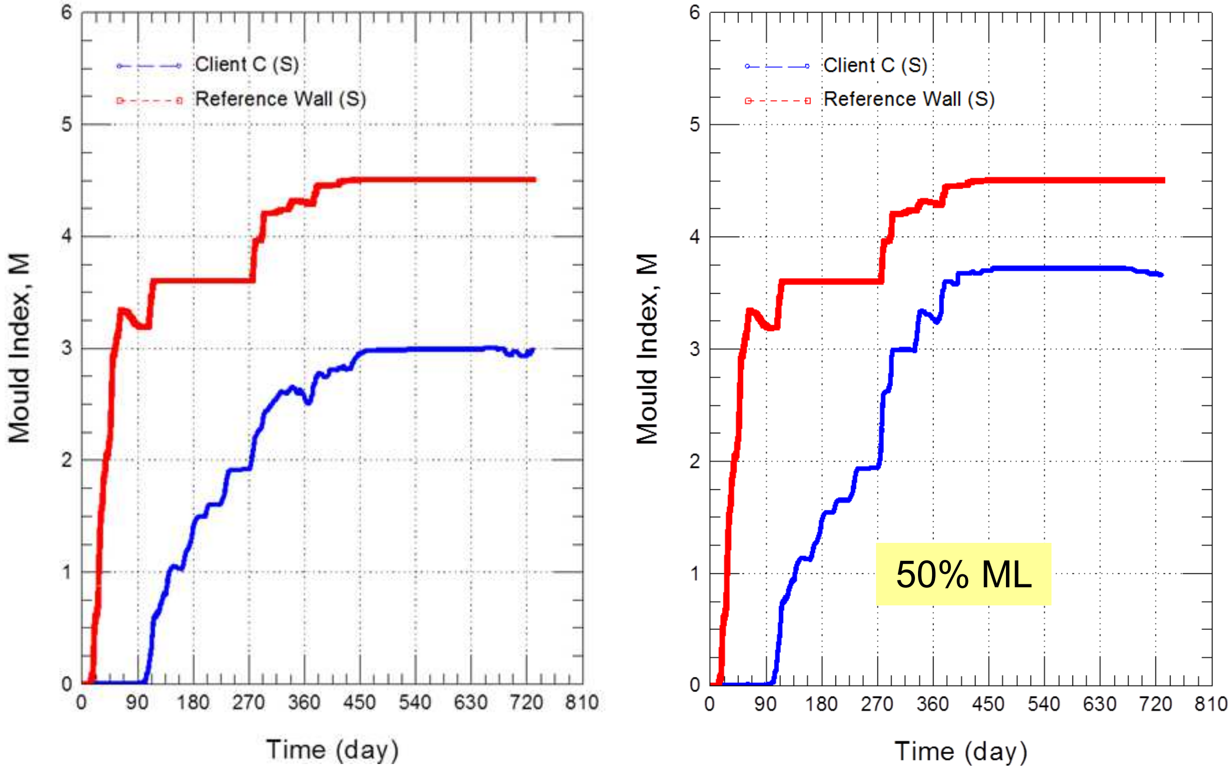


Figure 23 – Client C Walls: Response of OSB component (1 mm sliver on exterior OSB surface) to climate loads of Tofino (BC); response given as M_{IDX} value for sensitivity class "S"

Table 12 – Client C Walls: Average and maximum values of M_{IDX} for different locations of Client A in which the Moisture Load was placed between the Building paper and: (i) Cladding; (ii) Drainage medium

	Tofino				Tofino / 50 % ML			
	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
REF-Avg	3.910	2.506	2.597	1.819	3.910	2.506	2.597	1.819
REF-Max	4.508	3.475	3.538	2.984	4.508	3.475	3.538	2.984
Client C Avg	2.080	1.376	1.432	0.901	2.536	1.662	1.726	1.142
Client C Max	2.998	2.350	2.403	1.927	3.715	2.811	2.861	2.375

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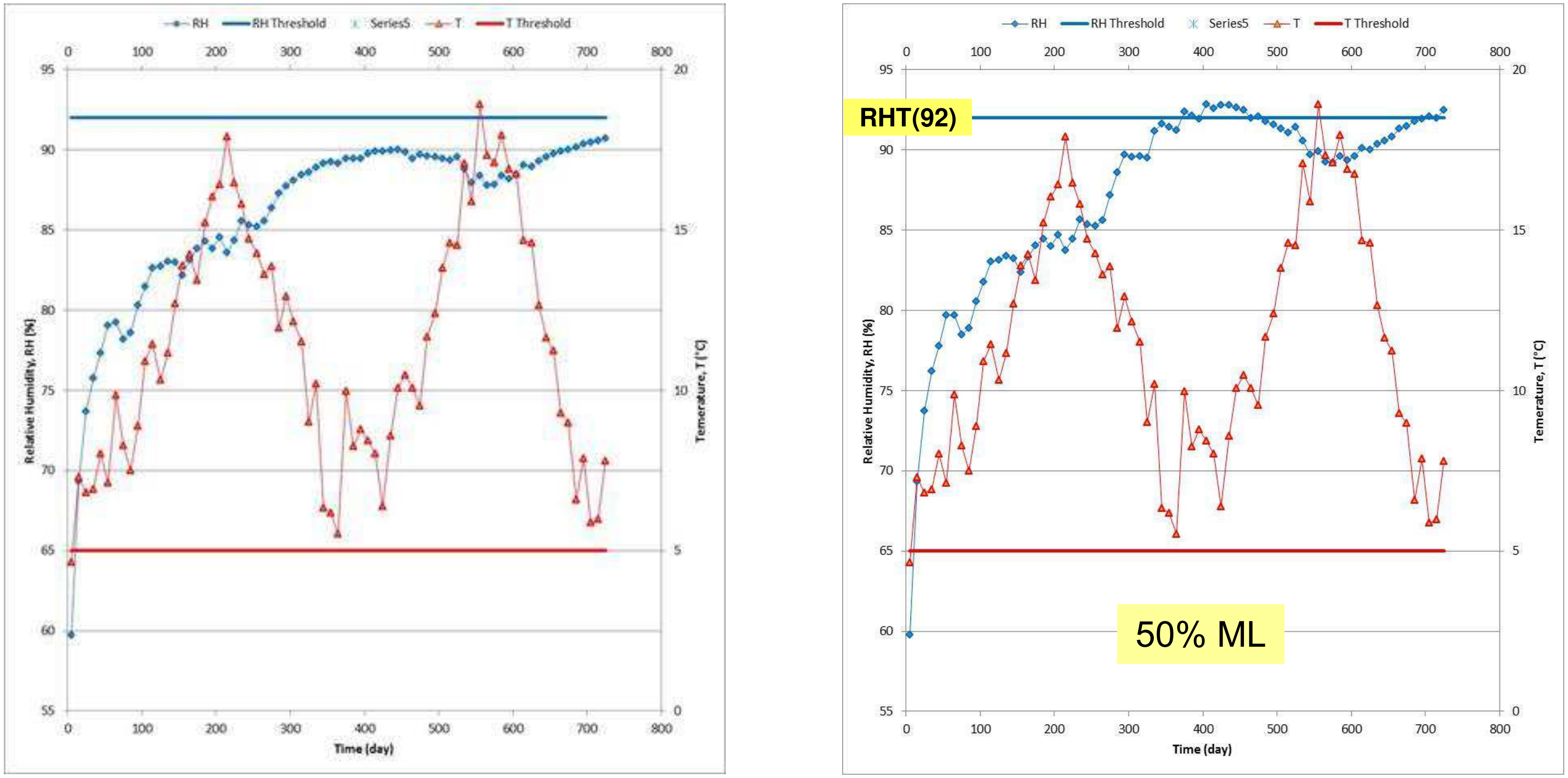


Figure 24 – Client C Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of Tofino (BC); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

Table 13 – Client C Wall: Response of OSB component to climate loads of Tofino; response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

	Tofino:					Tofino / 50% ML			
	RHT(80)	RHT(85)	RHT(92)	RHT(95)		RHT(80)	RHT(85)	RHT(92)	RHT(95)
Ref Wall	5263	3015	435	37		5263	3015	435	37
Client C	3172	1129	0	0		3679	1611	19	0

Hygrothermal response of wall components to climate loads of Vancouver; M_{IDX} criterion

The response of the Client C's wall assembly to the climate loads of Vancouver (BC) are provided in Figure 25 to Figure 28 and in Table 14 and Table 15. The variation in values for M_{IDX} over the simulation period and in respect to the different locations in the wall, and when the moisture load (ML) was placed between the cladding and the BP are provided in Figure 25; in Figure 26 the variation when 50% of the ML was placed on the sheathing membrane.

In both plots given in Figure 25 and Figure 26, and as was the case for the wall response to the climate loads of Tofino (BC) the values for M_{IDX} over the simulation period increased over time depending on the propensity for mould growth for the different locations within the sheathing panels (OSB); again, plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB-glass fibre interface), and recalling that the "OSB Sliver" (1 mm thick sliver at exterior face sheathing panel) is closest to the moisture load, and in contact with the sheathing membrane.

The values of M_{IDX} as a measure of the response to the climate loads of Vancouver (BC) diminish in relation to the distance from where the moisture load is applied to the location of interest, as was the case for the response of the wall to the climate loads of Tofino. Differences in response of the OSB component to the location of the ML in the wall assembly is similar to that previously reported for Tofino; i.e. lower values of M_{IDX} obtained in the instance where the ML is placed between the cladding and the BP as compared to the ML being placed on the sheathing membrane.

The response of the Reference and Client C Walls of the OSB component (1 mm sliver on exterior OSB surface) to climate loads of Vancouver (BC) over the same period are shown in Figure 27; values for M_{IDX} for the left-hand plot are for the ML placed between the cladding and BP; the right-hand plot for the ML placed on the sheathing membrane.

When the ML was placed between the build BP and the cladding (left-hand plot Figure 27), or when it was placed on the sheathing membrane (right-hand plot) the Client C wall had values for M_{IDX} less than that of the reference wall; this is consistent with the results for Tofino. The progression in values for M_{IDX} over the course of the simulation indicate that Client C's wall adequately managed moisture ingress to the drainage cavity as compared to the Reference wall.

The information provided in Table 14, shows the average and maximum values for M_{IDX} of different locations within the Reference and Client C's wall. The values for M_{IDX} of Client C's wall are all less than that of the Reference wall, irrespective of the value for M_{IDX} of the layer or interface.

Hygrothermal response of wall components to climate loads of Vancouver (BC); RHT(x) criterion

The response of Client C's wall to climate loads of Vancouver (BC) as determined by the value of the RHT(x) index is shown in Figure 28. The left-hand plot of Figure 28 shows values for relative humidity and temperature over the simulation period for the ML was placed between the BP and the cladding; the right-had plot for 50% of the ML placed on the sheathing membrane. The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client C walls and for different threshold values of RH are given in Table 15.

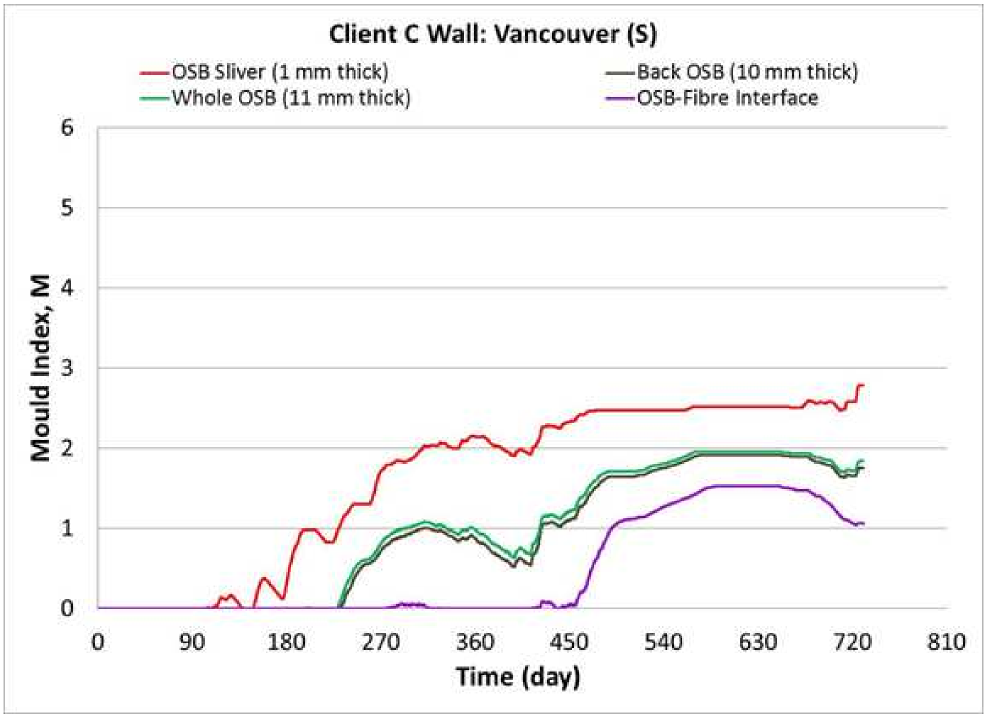


Figure 25 – Client C Walls: Response of OSB component to climate loads of Vancouver (BC); response given as M_{IDX} value for sensitivity class "S"

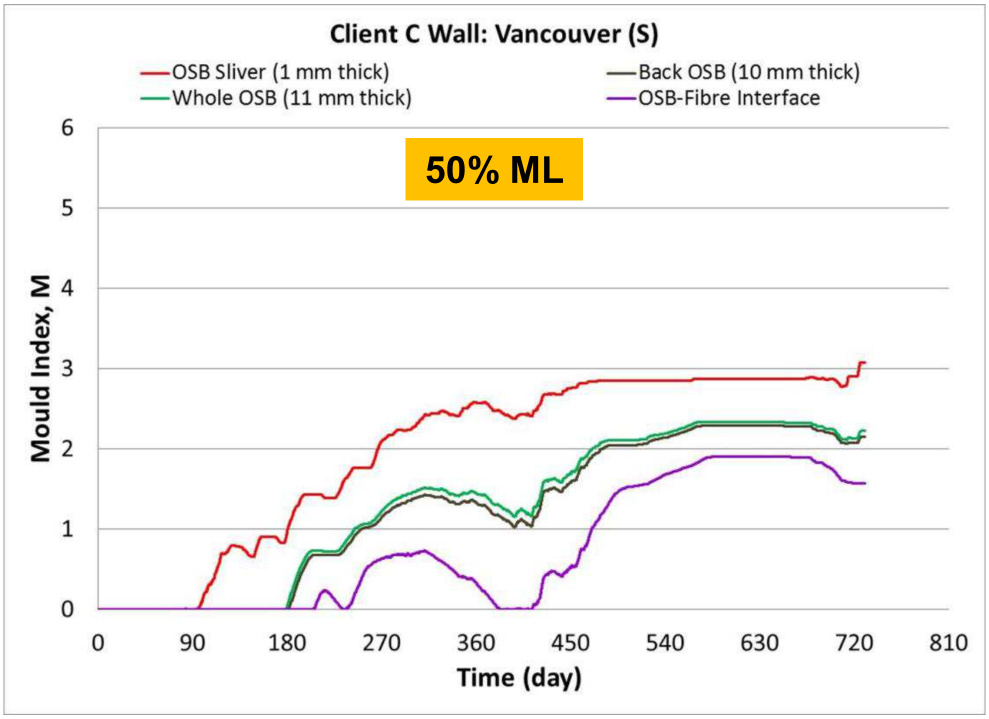


Figure 26 - Client C Walls: Response of OSB component to climate loads of Vancouver (BC); response given as M_{IDX} value for sensitivity class "S"

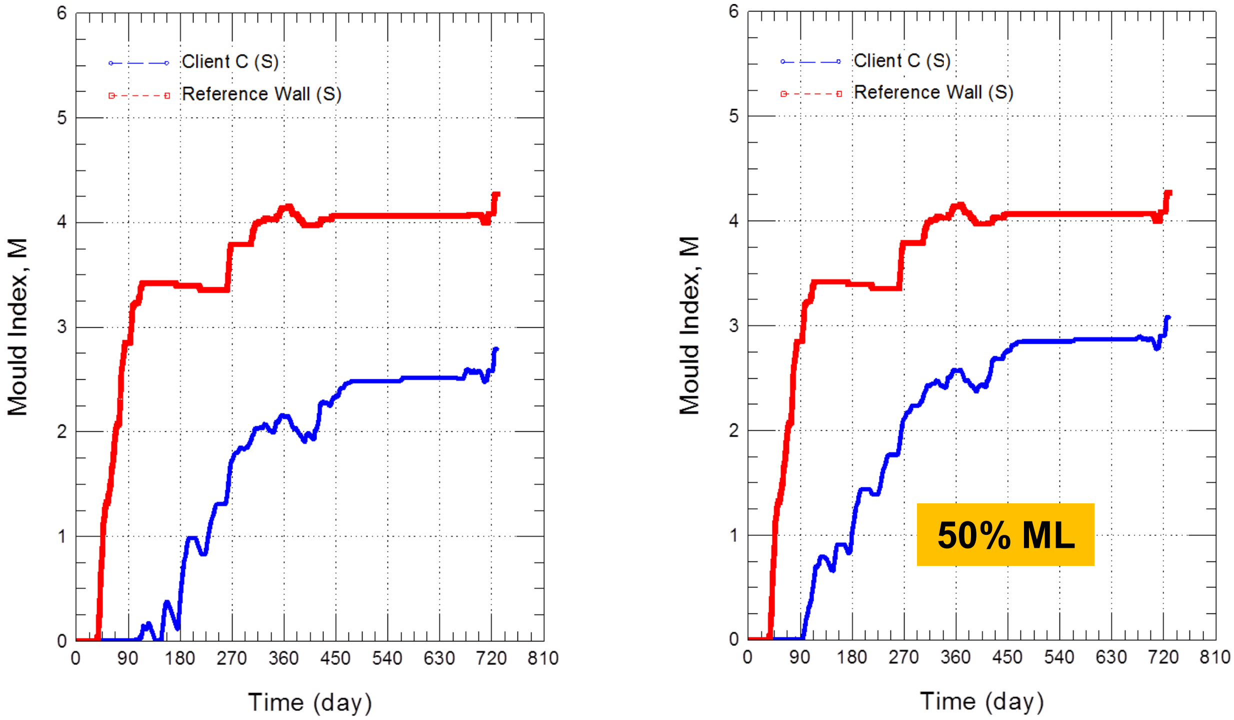


Figure 27 – Reference and Client C Walls: Response of OSB component (1 mm sliver on exterior OSB surface) to climate loads of Vancouver (BC); response given as M_{IDX} value for sensitivity class "S"

Table 14 – Average and maximum values of M_{IDX} for different locations in the Reference (REF.) and the respective walls of Client C in which the Moisture Load was placed between the Building paper and: (i) Cladding; (ii) Drainage medium

	Vancouver					Vancouver / 50% ML			
	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface		OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
REF-Avg	3.500	2.181	2.271	1.518		3.500	2.181	2.271	1.518
REF-Max	4.270	3.082	3.149	2.633		4.270	3.082	3.149	2.633
Client C-Avg	1.603	0.903	0.955	0.471		1.966	1.232	1.289	0.748
Client C-Max	2.786	1.907	1.954	1.519		3.076	2.281	2.327	1.905

Hygrothermal response of wall components to climate loads of Vancouver (BC); RHT(x) criterion (cont'd)
A review of the right-hand plot and the side for which the ML was placed on the sheathing membrane, as compared to the left-hand plot shows that the RH in the 1 mm sliver attained greater levels on the right-hand side (> 90% at day ~700), whereas in the left-hand plot the 90% RH level was never attained.; this result is consistent with that provided from the plots of values of M_{IDX}.

As well, in Table 15 the respective values for RHT(x) are all lower for Client C's wall as compared to the Reference wall for both instances for placement of the ML; this also is consistent with that which was determined from a comparison of M_{IDX} values as was made available in Table 14.

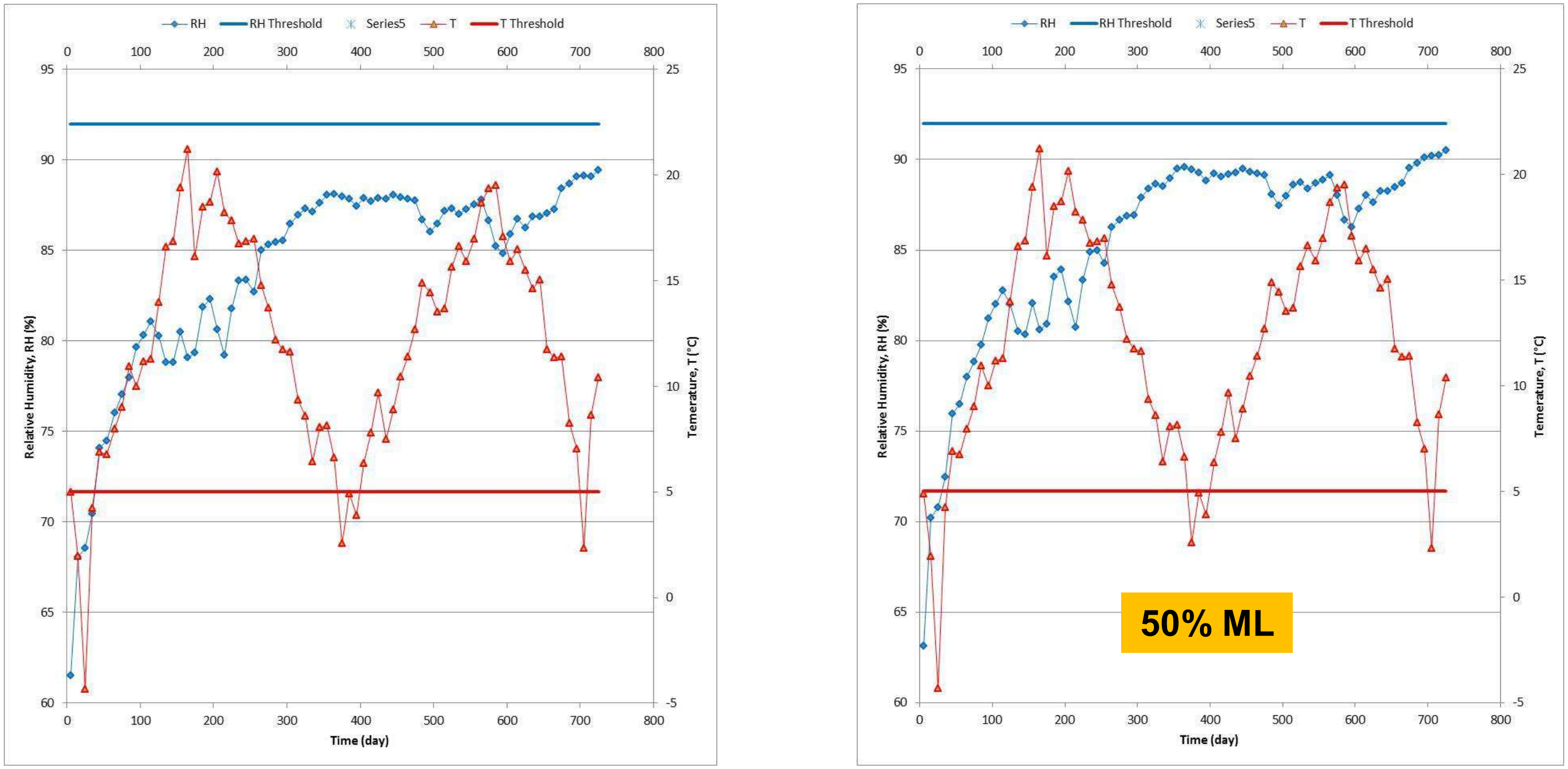


Figure 28 – Client C Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of Vancouver (BC); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

Table 15 – Client C Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of Vancouver (BC); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

	Vancouver			Vancouver / 50 % ML			
	RHT(80)	RHT(85)	RHT(92)	RHT(80)	RHT(85)	RHT(92)	
Ref Wall	4958	2493	192	4958	2493	192	Ref Wall
Client C	2363	577	0	3037	1003	0	Client C

Hygrothermal response of wall components to climate loads of St John's NL; M_{IDX} criterion

The response of the Client C's wall assembly to the climate loads of St John's (NL), are provided in Figure 29 to Figure 32 and in Table 16 and Table 17. Plots of the variation in values for M_{IDX} over the course of the simulation period and in respect to the different locations in the wall are provided in Figure 29 and Figure 30; in Figure 29 is the plot for the ML placed between the cladding and the BP and in Figure 30, for the ML placed on the sheathing membrane. The plots show similar features to that previously described for both Tofino and Vancouver (BC); specifically:

- The values for M_{IDX} over the course of the simulation increase over time depending on the propensity for mould growth for all of the different locations within the sheathing panels (OSB);
- The values of M_{IDX} diminish in relation to the distance from where the moisture load is applied to the location of interest; the critical wall element being the exterior surface of the OSB panel.
- Lower values of are M_{IDX} obtained in the instance where the ML is placed between the cladding and the BP as compared to 50% of the ML being placed on the sheathing membrane.

The response of the OSB component in the Reference as compared to the Client C wall for climate loads of St John's (NL) are shown in Figure 31; values for M_{IDX} for the left- and right-hand plots are for the ML placed, respectively, between the cladding and BP and on the sheathing membrane. Again, these plots have similar features of response as were evident for Tofino and Vancouver (BC).

- For a ML placed between the building paper and cladding (left-hand plot, Figure 31), the Client C wall had values for M_{IDX} less than that of the Reference wall; this same result was found when 50% of the ML was placed on the sheathing membrane (right-hand plot; Figure 31).

The information provided in Table 16 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client C's wall for the climate loads of St John's (NL).

- For instances where the ML was placed on the sheathing membrane the values for M_{IDX} of Client C's wall are all less than that of the Reference wall, irrespective of the value for M_{IDX} of the layer or interface.

As is apparent from this information, Client C's wall managed moisture ingress to the drainage cavity as well as the Reference wall.

Figure 29 – Client C Walls: Response of OSB component to climate loads of St John's (NL); response given as M_{IDX} value for sensitivity class "S"

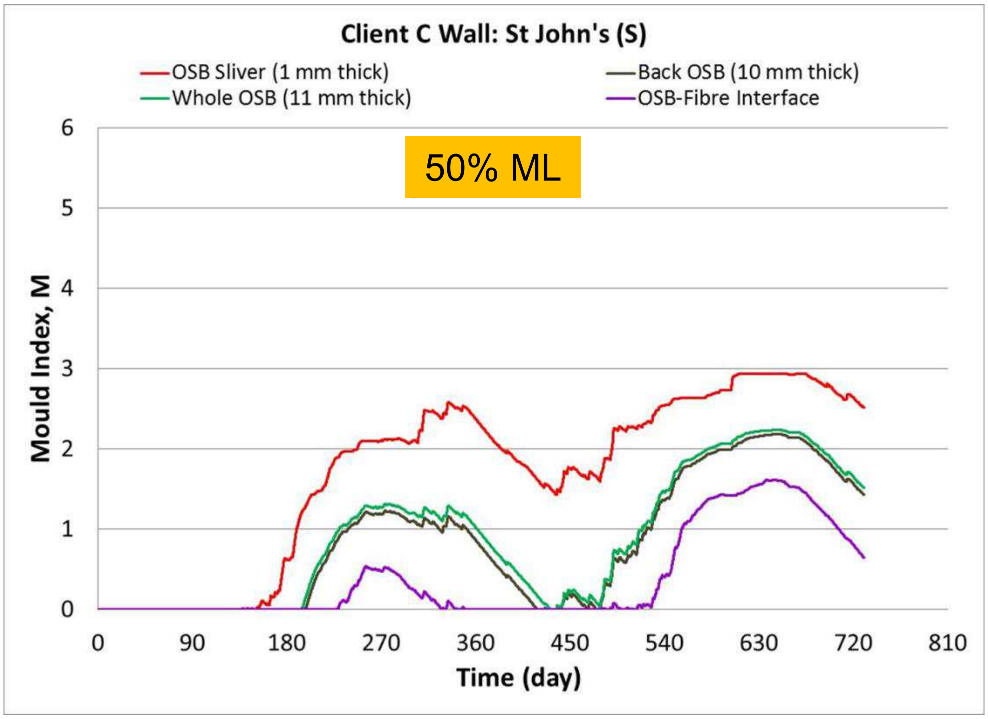


Figure 30 – Client C Walls: Response of OSB component to climate loads of St John's (NL); response given as M_{IDX} value for sensitivity class "S"

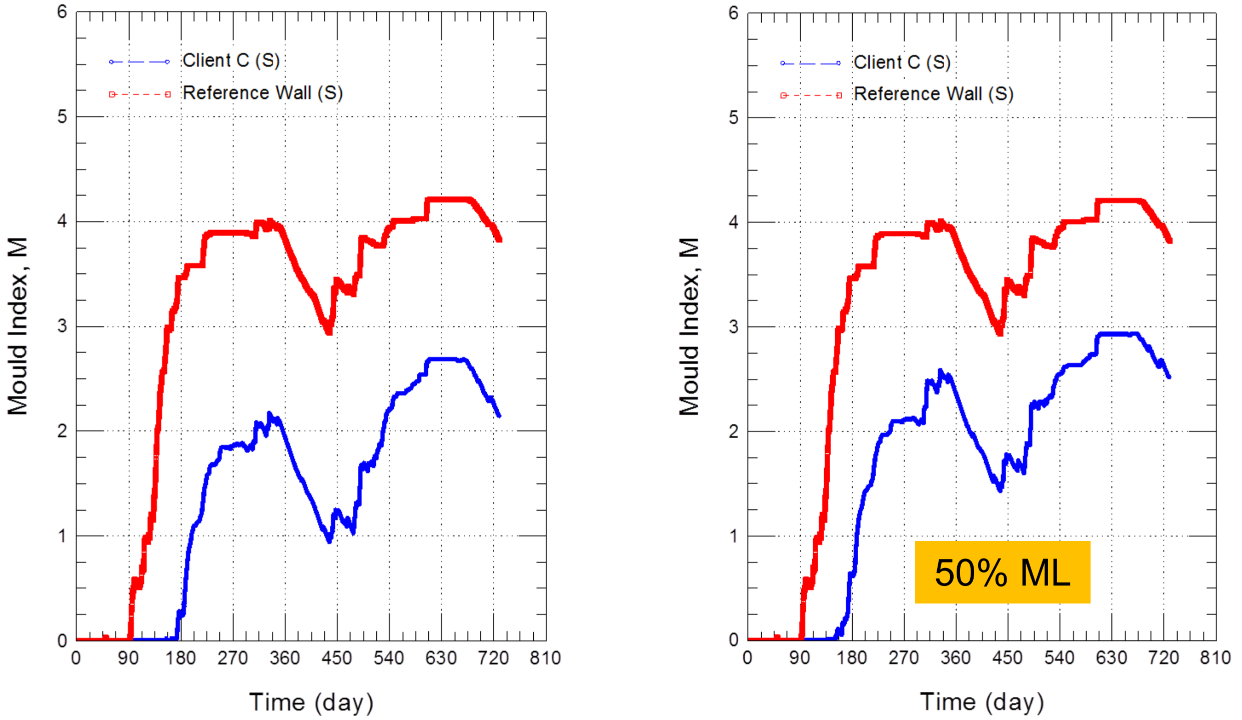


Figure 31 – Reference and Client C Walls: Response of OSB component (1 mm sliver on exterior OSB surface) to climate loads of St John's (NL); response given as M_{IDX} value for sensitivity class "S"

Table 16 – Response of Reference (REF) and Client C Walls to climate loads of St John's (NL): Avg. & Max. values of M_{IDX} for different locations in wall: ML between BP & Cladding; 50% ML on SM

	St John's				St John's / 50% ML			
	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
REF-Avg	3.085	1.941	2.035	1.147	3.085	1.941	2.035	1.147
REF-Max	4.210	3.191	3.261	2.562	4.210	3.191	3.261	2.562
Client C-Avg	1.418	0.630	0.684	0.252	1.697	0.815	0.884	0.373
Client C-Max	2.683	1.934	1.991	1.348	2.931	2.176	2.231	1.611

Hygrothermal response of wall components to climate loads of St John's, NL; RHT(x) criterion

The response of Client C's wall to climate loads of St John's (NL) as determined by the value of the RHT(x) index on exterior surface of OSB panel is shown in Figure 32; the left-hand plot of shows values for relative humidity and temperature over the simulation period for the ML placed between the BP and cladding; the right-had plot for 50% of the ML placed on the sheathing membrane. The actual values for the RHT(x) index for the Reference and Client C walls and for different threshold values of RH are given in Table 17.

A review of the right-hand plot and the side for which 50% of the ML was placed on the sheathing membrane, as compared to the left-hand plot shows that the RH in the 1 mm sliver attained greater levels on the right-hand side (> 90% at day ~700), whereas in the left-hand plot the 90% RH level was never attained.; this result is consistent with that provided from the plots of values of M_{IDX}.

As well, in Table 17, the respective values for RHT(x) are all lower for Client C's wall as compared to the Reference wall for both instances pf placement of the ML; this also is consistent with that which was determined from a comparison of M_{IDX} values, as was made available in Table 16.

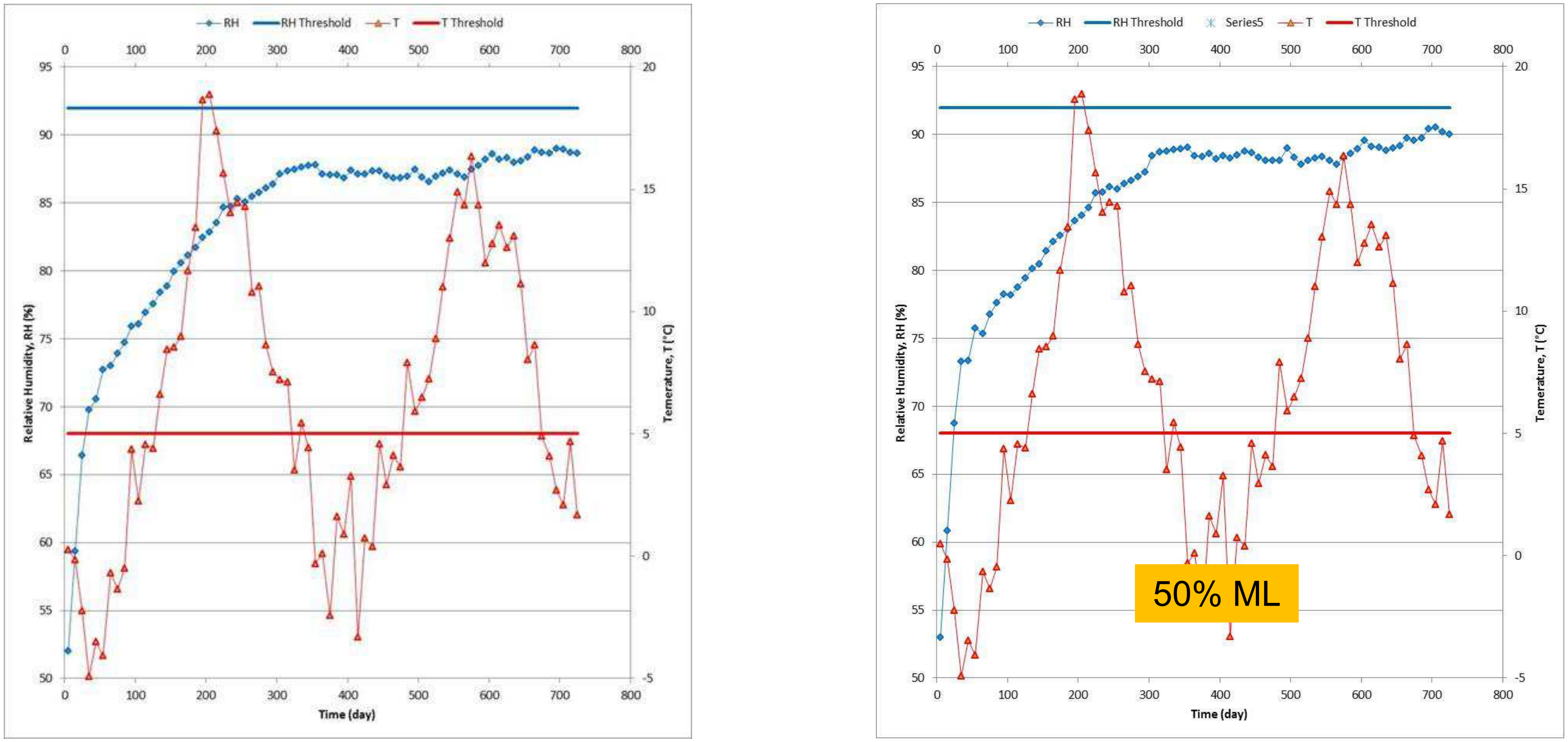


Figure 32 - Client C Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of St John's (NL); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

Table 17 - Client C Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of St John's (NL); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

	St John's				St John's / 50 % ML		
	RHT(80)	RHT(85)	RHT(92)	RHT(95)	RHT(80)	RHT(85)	RHT(92)
Ref Wall	2961	1786	193		2961	1786	193
Client C	1372	345	0		1620	506	0

5.4 Client D Drainage System

Overview of Drainage System

A sectional view of the wall configuration incorporating Client D's product, a cross woven micro-perforated polyolefin sheathing membrane with polyolefin coating, is shown in

Figure 33. The water retention characteristics of this drainage system (i.e. Code compliant building paper [9]; cap fasteners providing 2 mm gap; polymer-based sheathing membrane) that incorporates this sheathing membrane suggest that for given water entry rates, the drainage system retains more water as compared to the Reference drainage system.

A plot of the water vapour permeance (WVP) of various sheathing membranes, including that of Client D, is also provided; it is apparent that the WVP of Client D's product is, at 50% RH, equal to that of a NBC-compliant sheathing membrane (denoted as 30 min building paper in the plot). Client D's sheathing membrane has a WVP that is almost one (1) order of magnitude greater than the limit distinguishing between breathable and non-breathable membranes; i.e. the WVP of Client D's membrane is 820 ng/Pa•s•m^2 as compared to 170 ng/ Pa•s•m^2, the lower limit for a breathable membrane. However, the water absorption coefficient for this membrane is not measureable (see Task 2 report [3]) suggesting that there is r no liquid water transfer across the membrane. As such, the performance would be related to the extent to which water vapour permeates the membrane and this would in turn depend on the amount of moisture that is retained on the membrane following a rain event and the prevailing temperature in the drainage cavity.

The moisture load in this instance was assumed to be placed on the sheathing membrane whereas the placement of the load for the reference wall was assumed to be retained on the backside of the cladding given that for the reference wall, there is a capillary break between the cladding and the sheathing membrane and water cannot readily traverse this gap in the drainage cavity. In the case of Client D's wall, any water penetrating the cladding and migrating to the backside would in turn find its way to the drainage cavity. However, given that the drainage gap for Client D's wall is only ~2 mm, water would necessarily bridge this gap and thereafter wet the surface of the sheathing membrane.

Thus the moisture load in the case of Client D's wall is placed directly on the sheathing membrane whereas for the Reference wall, the load is retained behind the cladding; as well, the WVP of the sheathing membrane of Client D's wall is equal to that used in the Reference wall at 50% RH and less than that of sheathing membrane of the Reference wall above this threshold value, and conversely, greater than the sheathing membrane of the Reference wall below this threshold. Combining these two elements, that is, differences in WVP between sheathing membranes and placement of the moisture load in the drainage cavity, suggests that Client D's wall, as compared to the reference wall, would be somewhat disadvantaged in respect to managing moisture ingress to the drainage cavity.

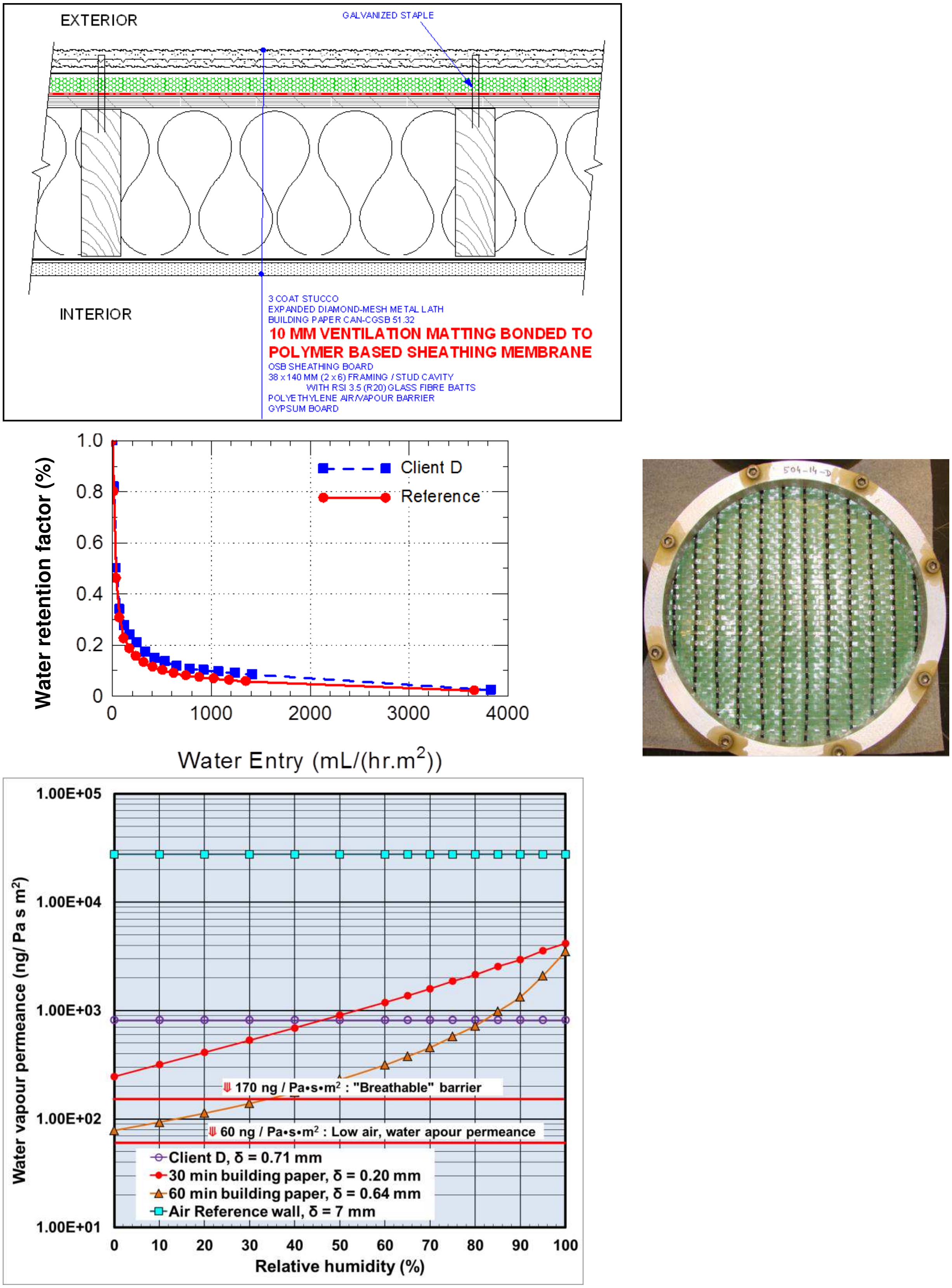
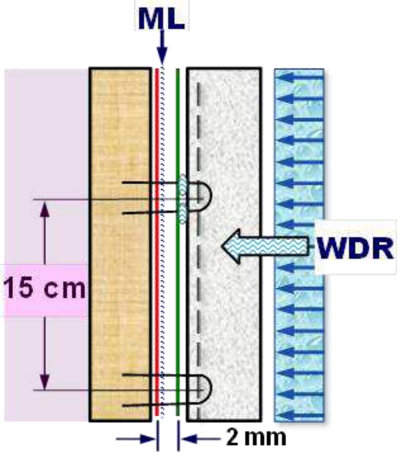


Figure 33 – Client D Wall: Sectional view, placement of ML in 10 mm drainage cavity; water retention characteristics; water vapour permeance of sheathing membrane; δ = membrane thickness

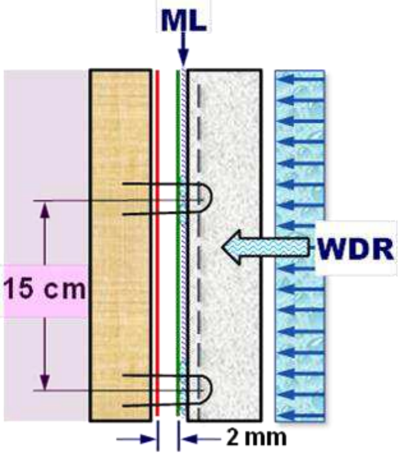
Results from Simulation – Client D Drainage System

Hygrothermal response of wall components to climate loads of Tofino; M_{IDX} criterion

The response of the Client D wall assembly to the climate loads of Tofino (BC) are provided in Figure 34 to Figure 36 and in Table 18. More specifically, the variation in values for M_{IDX} over the course of the simulation period and in respect to the different locations in the wall, are provided in two plots of Figure 34. The upper-most plot shows the variation over the simulation when the moisture load (ML) was placed between the cladding and the building paper (BP), whereas the lower-most plot shows the variation when the ML was placed on the sheathing membrane (SM), in this instance the SM being a cross-woven, micro-perforated polyolefin product. The location of the ML for both these conditions is shown in the adjacent inset.



In both plots of Figure 34, the values for M_{IDX} over the course of the simulation increase over time depending on the propensity for mould growth given the moisture and temperature conditions in the different locations within the sheathing panels (OSB); the moisture conditions at the different panel locations are related to their respective proximity to the moisture load. Plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB-glass fibre interface), the one closet to the moisture load, in these plots, being the "OSB Sliver", representative of a 1 mm thick sliver of the exterior face of the 11 mm thick sheathing panel and the component in closest contact with the SM.



Observations common to both plots of Figure 34:

- The values of M_{IDX} diminish in relation to the distance from where the ML is applied to the location of interest for which a response has been given.
- The higher values of M_{IDX} are those closest to the SM and the location where the ML was applied and thereafter diminish as the location of interest recedes from the exterior face of the sheathing panel to the interior face of the OSB panel, and where this surface is at the interface between the OSB and the interior insulation.
- The values for M_{IDX} of the entire OSB panel (i.e. "whole" OSB 11 mm thick) are always greater than the 10 mm portion of OSB behind the 1 mm sliver (i.e. "back" of OSB, 10 mm thick) given that the values for M_{IDX} of the 1 mm sliver are always the greatest values for M_{IDX} amongst the different locations in the wall.
- The values provided for the 1 mm OSB sliver are the critical values from which the response of the wall assembly is measured in respect to managing moisture ingress to the drainage cavity, whereas,

- If the risk of condensation is the measure of importance in respect to wall performance , then the focus ought to be on the interface between the insulation and the OSB panel, that is, the "OSB-fibre interface" as given in Figure 43.

The differences in response of the OSB component (1 mm sliver on exterior OSB surface) to the location of the ML in the wall assembly is apparent from the lower values of M_{IDX} obtained in the instance where the ML is placed between the cladding and the BP as compared to being placed on the SM; the ML being in direct contact with the SM brings it in closer proximity to the wood-based and moisture sensitive components of the wall assembly.

The response of the Reference and Client D Walls of the OSB component (1 mm sliver on exterior OSB surface) to climate loads of Tofino (BC) over the same period are shown in Figure 35; values for M_{IDX} as a function of time for the left-hand plot are for the condition where the ML is placed between the cladding and BP, whereas those for the right-hand plot are for where the ML has been placed on the SM.

When the ML was placed between the BP and the cladding (left-hand plot; Figure 35), the Client D wall had values for M_{IDX} less than the Reference wall. Whereas when the ML was placed on the SM (right-hand plot; Figure 35) Client D's wall did not manage moisture to the drainage cavity as well as the Reference wall.

For the instance in which the ML was placed on the SM (right-hand plot; Figure 35), the progression in values for M_{IDX} over the simulation indicate that the 1st year (~ day 270) of simulation, Client D's wall did not manage moisture to the drainage cavity as well as the Reference wall (i.e. Client D's wall had higher values of M_{IDX} at any given time as compared to the Reference wall) and thereafter throughout the remainder of the simulation, the Reference wall provided better management of moisture as compared to Client D's wall.

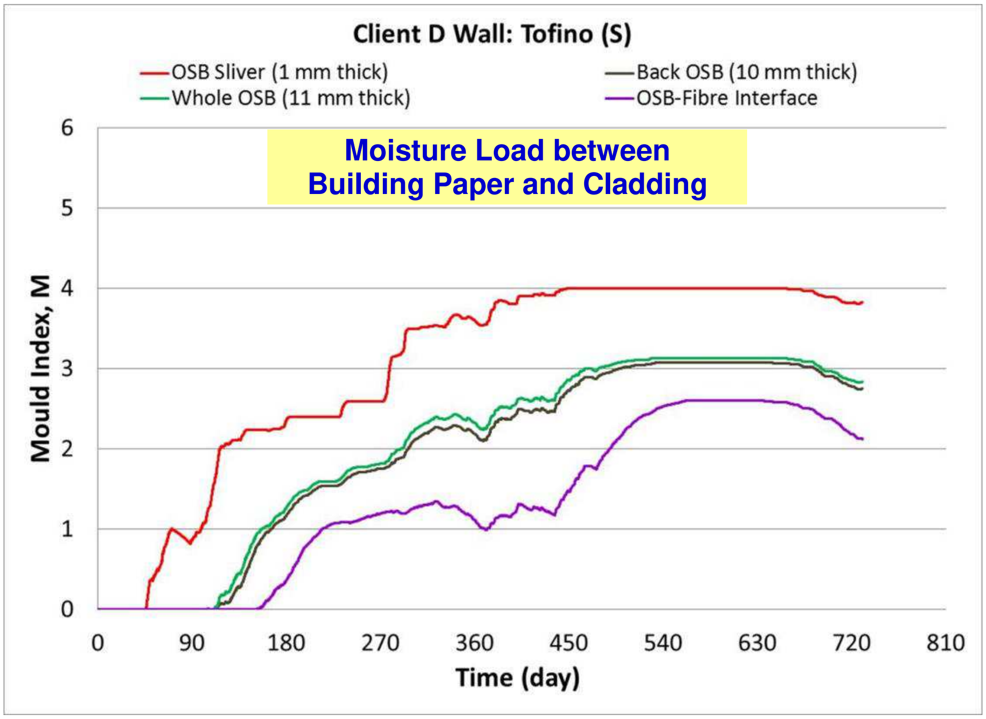
The information provided in Table 18 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client D's wall, including values for M_{IDX} at the OSB-Cavity Interface. For instances where the ML was placed on the SM, values for M_{IDX} of Client D's wall are all greater than the Reference wall, irrespective of the value for M_{IDX} of the layer or interface.

Hygrothermal response of wall components to climate loads of Tofino; RHT(x) criterion

The response of Client D's wall to climate loads of Tofino (BC) as determined by the value of the RHT(x) index is shown in Figure 36. The left-hand plot of Figure 36 shows values for relative humidity and temperature over the simulation period when the ML was placed between the BP and the cladding; the right-had plot when the ML was placed on the SM. The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client D walls and for different threshold values of RH are given in the tables located above the plots of Figure 36.

A review of the right-hand plot as compared to the left-hand plot shows that the RH in the 1 mm sliver attained greater levels on the right-hand side (> 95% at day ~270), and the side for which the ML was placed on the SM; this result is consistent with that provided from the plots of values of M_{IDX}.

As well, in the table located above the right-hand plot of Figure 36, the respective values for RHT(x) are all greater for Client D's wall as compared to the Reference wall for the instance where the ML was placed on the SM; this also is consistent with that which was determined from a comparison of M_{IDX} values as was made available in Table 18.



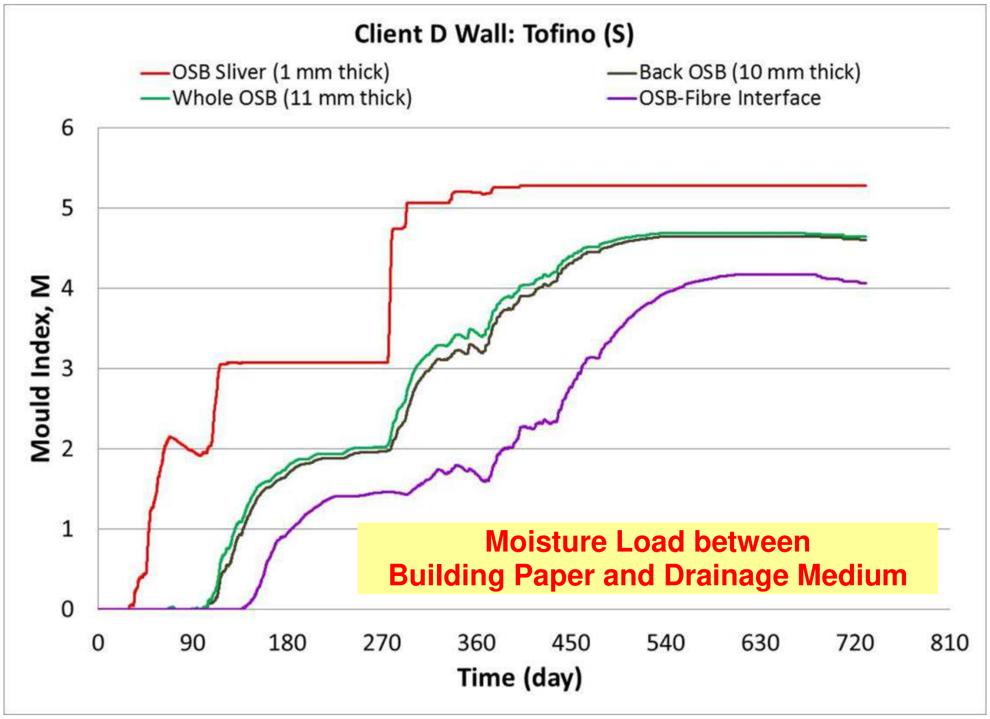


Figure 34 - Client D Walls: Response of OSB component to climate loads of Tofino (BC); response given as M_{IDX} value for sensitivity class "S"

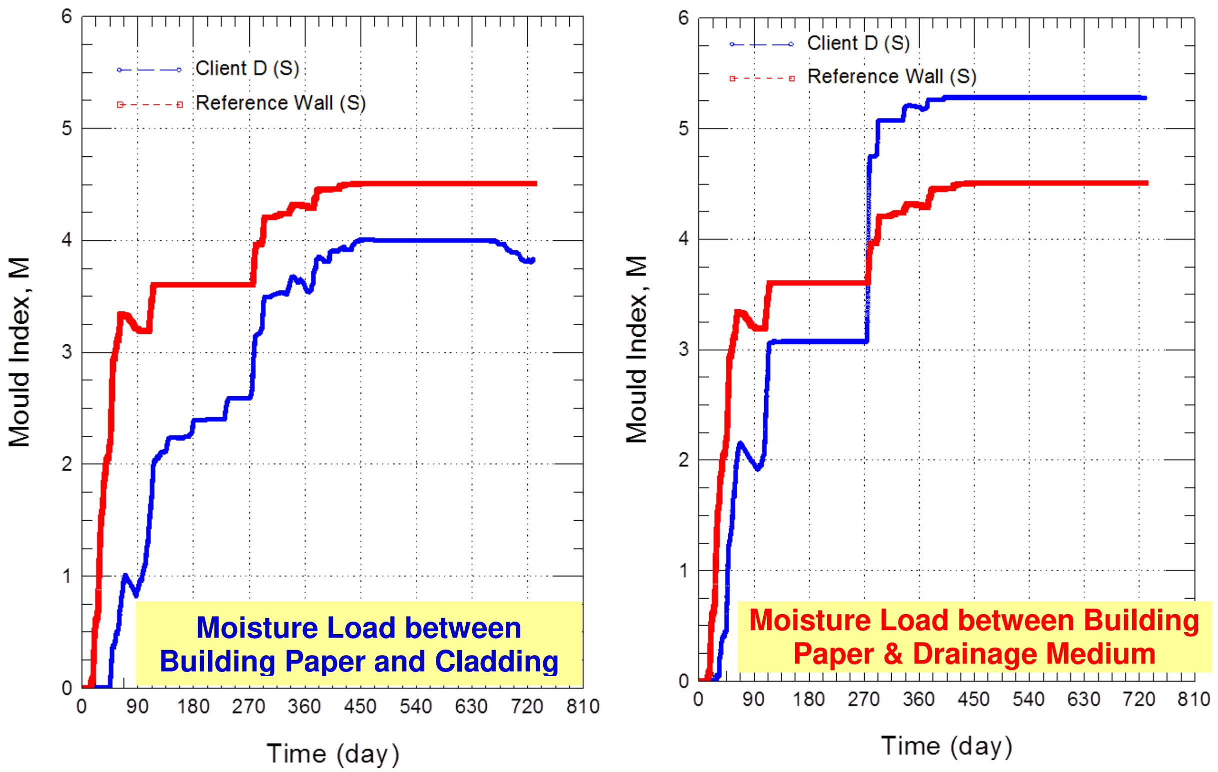


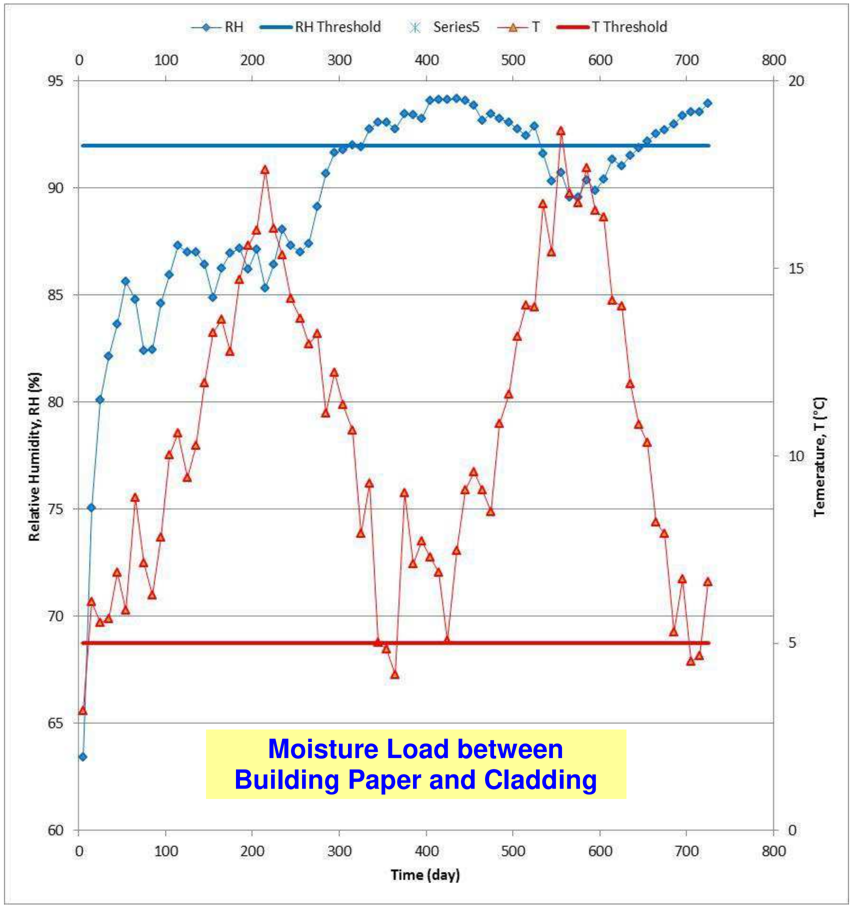
Figure 35 – Reference and Client D Walls: Response of OSB component (1 mm sliver on exterior OSB surface) to climate loads of Tofino (BC); response given as M_{IDX} value for sensitivity class "S";

Table 18– Average & maximum values of M_{IDX} for different locations in Reference (REF.) and Client D walls; Moisture Load placed between Building paper and: (i) Cladding; (ii) Drainage medium

REF.	Layer or Interface						Layer or Interface				
M_{IDX}	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB-Cavity Interface		OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB-Cavity Interface
Average	3.910	2.506	2.597	1.819	4.539		3.910	2.506	2.597	1.819	4.539
Maximum	4.508	3.475	3.538	2.984	5.004		4.508	3.475	3.538	2.984	5.004
	Client D (i) - Layer or Interface						Client D (ii) - Layer or Interface				
M_{IDX}	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB-Cavity Interface		OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB-Cavity Interface
Average	2.998	1.948	2.026	1.333	3.442		4.111	2.919	2.998	2.150	4.511
Maximum	4.000	3.069	3.127	2.594	4.473		5.276	4.645	4.680	4.172	5.300

	Tofino			
	RHT(80)	RHT(85)	RHT(92)	RHT(95)
Ref Wall	5263	3015	435	37
Client D	3925	1896	101	0

	Tofino			
	RHT(80)	RHT(85)	RHT(92)	RHT(95)
Ref Wall	5263	3015	435	37
Client D	5788	3743	1532	798



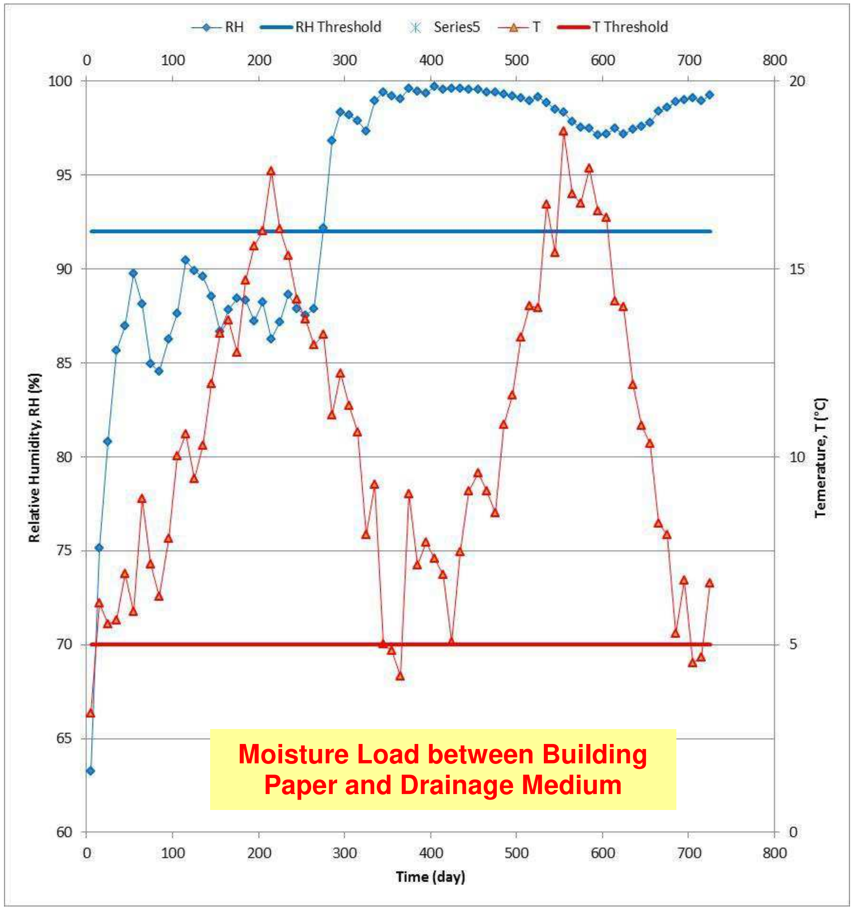


Figure 36 - Client D Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of Tofino (BC); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

Hygrothermal response of wall components to climate loads of Vancouver; M_{IDX} criterion

The response of the Client D's wall assembly to the climate loads of Vancouver (BC) are provided in Figure 37 to Figure 40 and in Table 19. The variation in values for M_{IDX} over the simulation period and in respect to the different locations in the wall, are provided in the two plots, respectively, in Figure 37 and Figure 38. In Figure 37 is shown the variation over the simulation period when the moisture load (ML) was placed between the cladding and the building paper (BP); in Figure 46 the variation when the ML was placed on the sheathing membrane (SM), a cross-woven, micro-perforated polyolefin-based product.

In both Figure 37 and Figure 38, and as was the case for the wall response to the climate loads of Tofino (BC) the values for M_{IDX} over the simulation period increased over time depending on the propensity for mould growth for the different locations within the sheathing panels (OSB); again, plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB-glass fibre interface), and recalling that the "OSB Sliver" (1 mm thick sliver at exterior face sheathing panel) is closest to the ML, and in contact with the SM.

The values of M_{IDX} as a measure of the response to the climate loads of Vancouver (BC) diminish in relation to the distance from where the ML is applied to the location of interest, as was the case for the response of the wall to the climate loads of Tofino. Differences in response of the OSB component to the location of the ML in the wall assembly is similar to that previously reported for Tofino; i.e. lower values of M_{IDX} obtained in the instance where the ML is placed between the cladding and the BP as compared to the ML being placed on the SM.

The response of the Reference and Client D Walls of the OSB component (1 mm sliver on exterior OSB surface) to climate loads of Vancouver (BC) over the same period are shown in Figure 38; values for M_{IDX} for the left-hand plot are for the ML placed between the cladding and BP; the right-hand plot for the ML placed on the SM.

When the ML was placed between the building BP and the cladding (left-hand plot Figure 38), the Client D wall values for M_{IDX} less than that of the Reference wall. Whereas Client D's wall did not manage moisture as well as the Reference wall when the ML was placed on the SM; this is consistent with the results for Tofino. When the ML was placed on the SM (right-hand plot; Figure 38), the progression in values for M_{IDX} over the simulation indicate that Client D's wall did not manage moisture ingress to the drainage cavity as well as the Reference wall.

The information provided in Table 19, shows the average and maximum values for M_{IDX} of different locations within the Reference and Client D's wall. For instances where the ML was placed on the SM (vz. Client D (ii)), the values for M_{IDX} of Client D's wall are all greater than that of the Reference wall, irrespective of the value for M_{IDX} of the layer or interface.

Hygrothermal response of wall components to climate loads of Vancouver (BC); RHT(x) criterion

The response of Client A's wall to climate loads of Vancouver (BC) as determined by the value of the RHT(x) index is shown in Figure 40. The left-hand plot of Figure 40 shows values for relative humidity and temperature over the simulation period for the instance where the ML was placed between the BP and the cladding; the right-had plot for the ML placed on the SM. The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client D walls and for different threshold values of RH are given in the tables located above the plots of Figure 40.

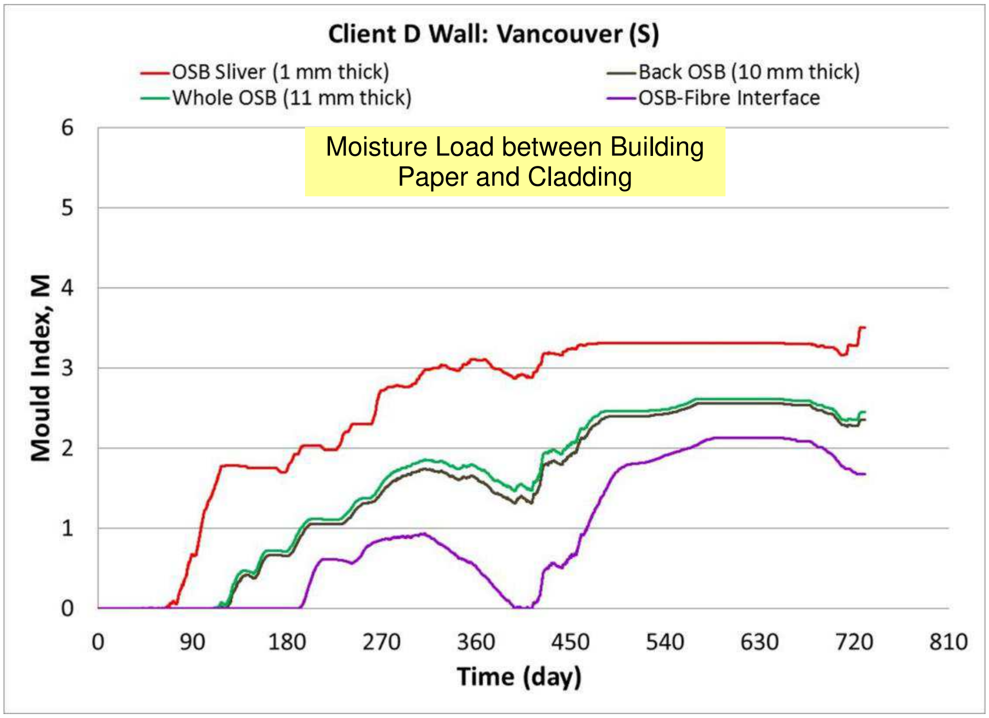


Figure 37 - Client D Walls: Response of OSB component to Moisture Load placed between building paper and Cladding for climate loads of Vancouver (BC); response given as M_{IDX} value for sensitivity class "S"

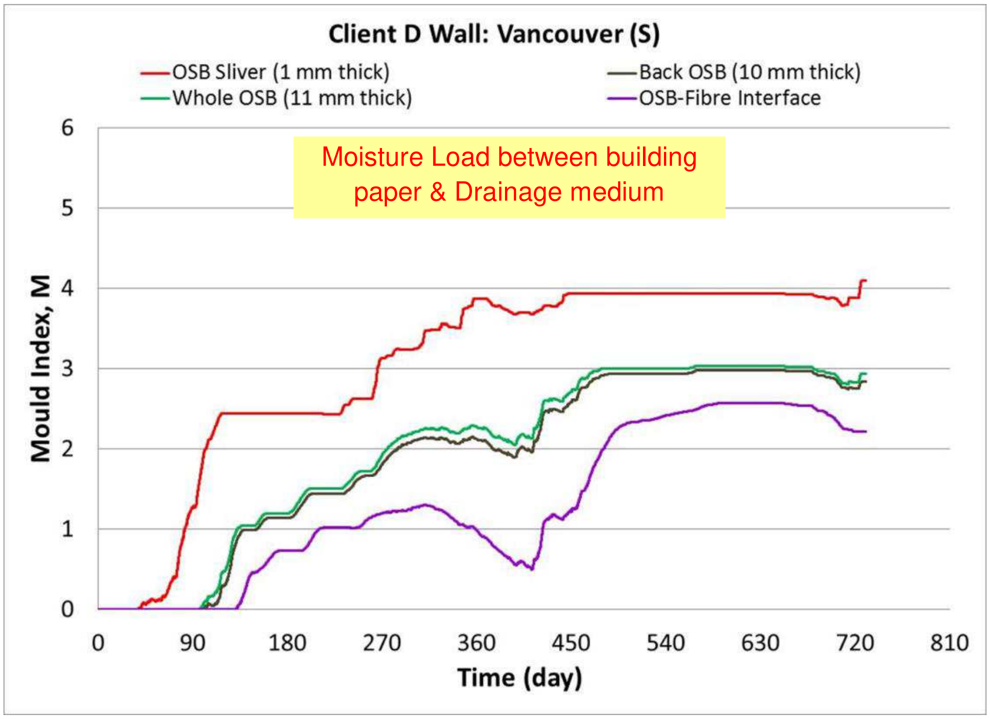


Figure 38 - Client D Walls: Response of OSB component to Moisture Load placed between building paper and Cladding for climate loads of Vancouver (BC); response given as M_{IDX} value for sensitivity class "S"

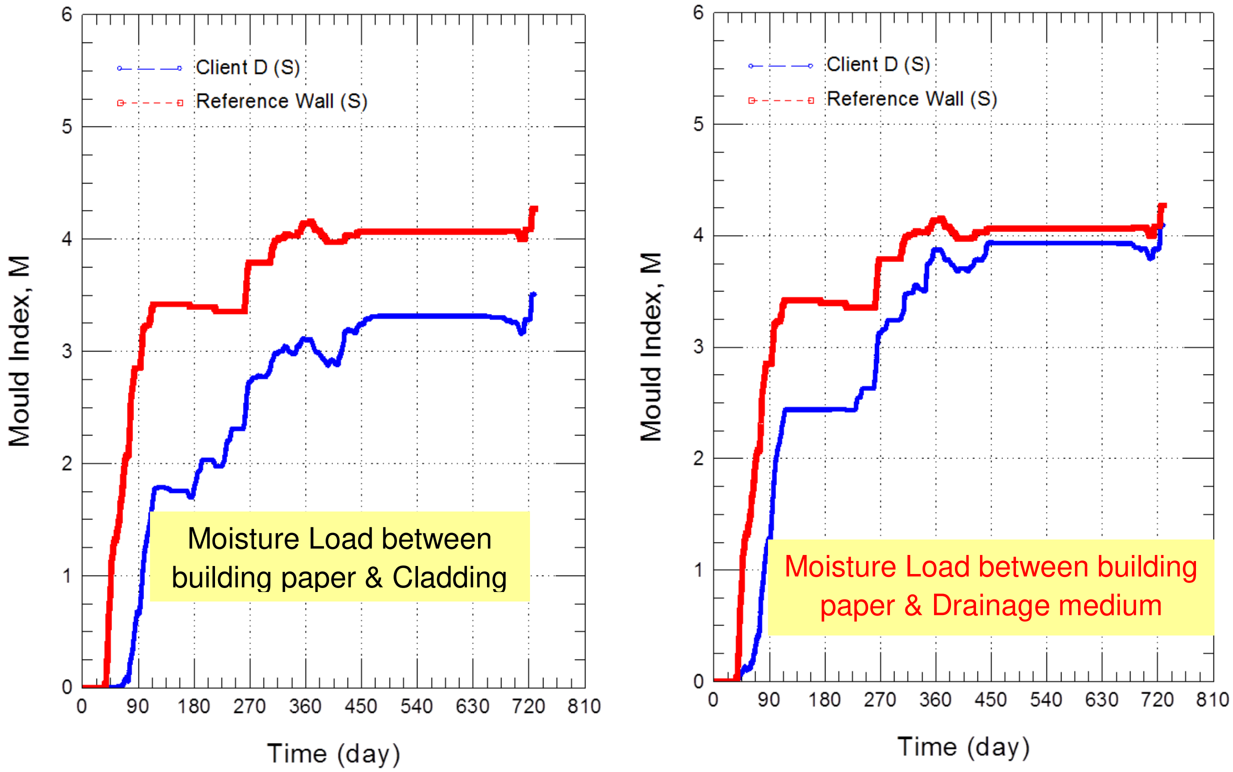


Figure 39 – Reference and Client D Walls: Response of OSB component (1 mm sliver on exterior OSB surface) to climate loads of Vancouver (BC); response given as M_{IDX} value for sensitivity class "S"

Table 19 - Response of Reference & Client D Walls to climate loads of Vancouver (BC): Avg. & Max. M_{IDX} values for locations in walls for: (i) ML between BP & Cladding; (ii) on Sheathing membrane

REF.	Layer or Interface					Layer or Interface			
M_{IDX}	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface		OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
Average	3.910	2.506	2.597	1.819		3.910	2.506	2.597	1.819
Maximum	4.508	3.475	3.538	2.984		4.508	3.475	3.538	2.984
Client D (i)	Layer or Interface				Client D (ii)	Layer or Interface			
M_{IDX}	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface		OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
Average	2.465	1.498	1.573	0.905		3.012	1.901	1.979	1.299
Maximum	3.504	2.554	2.609	2.129		4.088	2.976	3.028	2.561

Hygrothermal response of wall components to climate loads of Vancouver (BC); RHT(x) criterion (cont'd)

A review of the right-hand plot and the side for which the ML was placed on the SM, as compared to the left-hand plot shows that the RH in the 1 mm sliver attained greater levels on the right-hand side (> 95% at day ~350), whereas in the left-hand plot the 95% RH level was never attained.; this result is consistent with that provided from the plots of values of M_{IDX}.

As well, in the table located above the right-hand plot of Figure 40, the respective values for RHT(x) are all greater for Client D's wall as compared to the Reference wall for the ML placed on the SM; this also is consistent with that determined from a comparison of M_{IDX} values as was made available in Table 19.

	RHT(80)	RHT(85)	RHT(92)	RHT(95)
Ref Wall	4958	2493	192	2
Client D	3408	1285	1	0

	RHT(80)	RHT(85)	RHT(92)	RHT(95)
Ref Wall	4958	2493	192	2
Client D	4184	1911	72	0

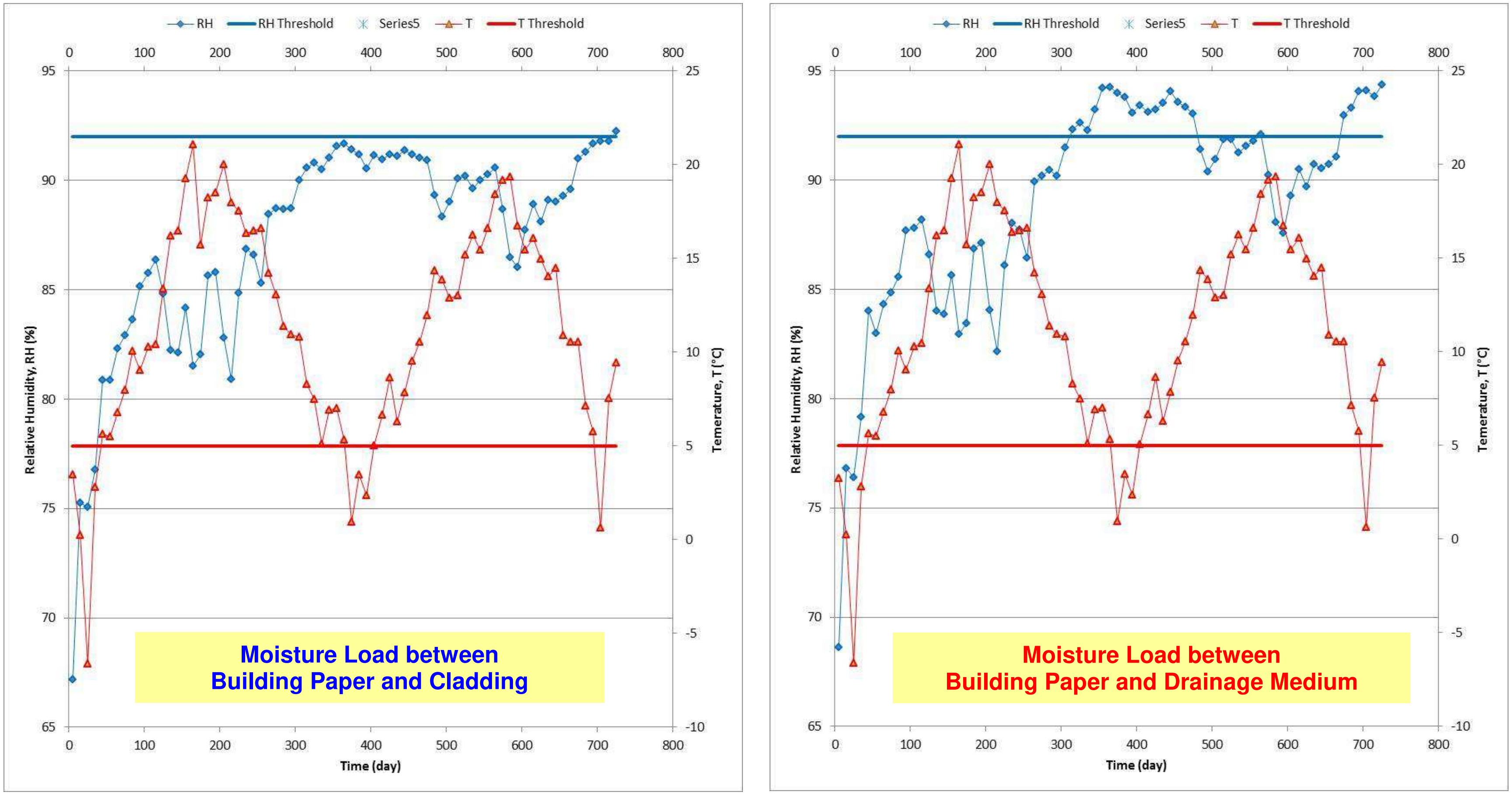


Figure 40 - Client D Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of Vancouver (BC); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

Hygrothermal response of wall components to climate loads of St John's NL; M_{IDX} criterion

The response of the Client A's wall assembly to the climate loads of St John's (NL), are provided in Figure 41 to Figure 44 and in Table 20. Plots of the variation in values for M_{IDX} over the course of the simulation period and in respect to the different locations in the wall are provided in Figure 41 and Figure 42; in Figure 41is the plot for the moisture load (ML) placed between the cladding and the building paper (BP) and in Figure 42, the ML was placed on the sheathing membrane (SM).

The plots show similar features to that previously described for both Tofino and Vancouver (BC):

- The values for M_{IDX} over the course of the simulation increase over time depending on the propensity for mould growth for all of the different locations within the sheathing panels (OSB);
- The values of M_{IDX} diminish in relation to the distance from where the moisture load is applied to the location of interest; the critical wall element being the exterior surface of the OSB panel.
- Lower values of are M_{IDX} obtained in the instance where the ML is placed between the cladding and the BP as compared to the ML being placed on the SM.

The response of the OSB component in the Reference as compared to the Client D wall for climate loads of St John's (NL), are shown in Figure 43; values for M_{IDX} for the left- and right-hand plots are for the ML placed, respectively, between the cladding and BP, and on the SM. Again, these plots have similar features of response as were evident for Tofino and Vancouver (BC); specifically:

- For a ML placed between the BP and cladding (left-hand plot, Figure 43), the Client D wall had average and maximum values for M_{IDX} less than that of the Reference wall. Whereas Client D's wall did not manage moisture as well as the Reference wall when the ML was placed on the SM.
- When the ML was placed on the SM (right-hand plot; Figure 43), Client D's wall did not manage moisture ingress to the drainage cavity as well as the Reference wall.

The information provided in Table 20, shows the average and maximum values for M_{IDX} for different locations within the Reference and Client D's wall for the climate loads of St John's (NL).

- For instances where the ML was placed on the SM (vz. Client A (ii)), the values for M_{IDX} of Client D's wall are all greater than that of the Reference wall, irrespective of the value for M_{IDX} of the layer or interface.

Hygrothermal response of wall components to climate loads of S. John's (NL); RHT(x) criterion

The response of Client D's wall to climate loads of St John's (NL) as determined by the RHT(x) index value on exterior surface of the OSB panel is shown in Figure 44; left-hand plot shows values for relative humidity and temperature over the simulation for the ML placed between the BP and cladding; right-had plot for the ML placed on the SM. Actual values for RHT(x) index of the Reference and Client D walls and for different threshold values of RH are given in the tables above the plots of Figure 44.

A review of the right-hand plot and the side for which the ML was placed on the sheathing membrane, as compared to the left-hand plot shows that the RH in the 1 mm sliver attained greater levels on the right-hand side (> 95% at day ~350), whereas in the left-hand plot the 95% RH level was never attained.; this result is consistent with that provided from the plots of values of M_{IDX}.

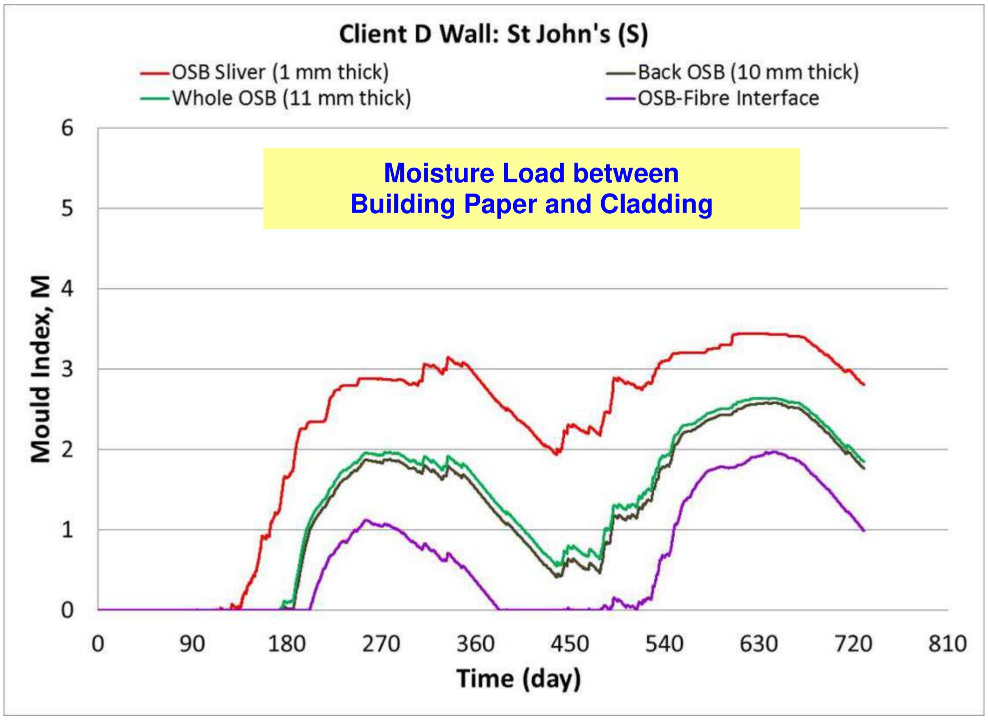
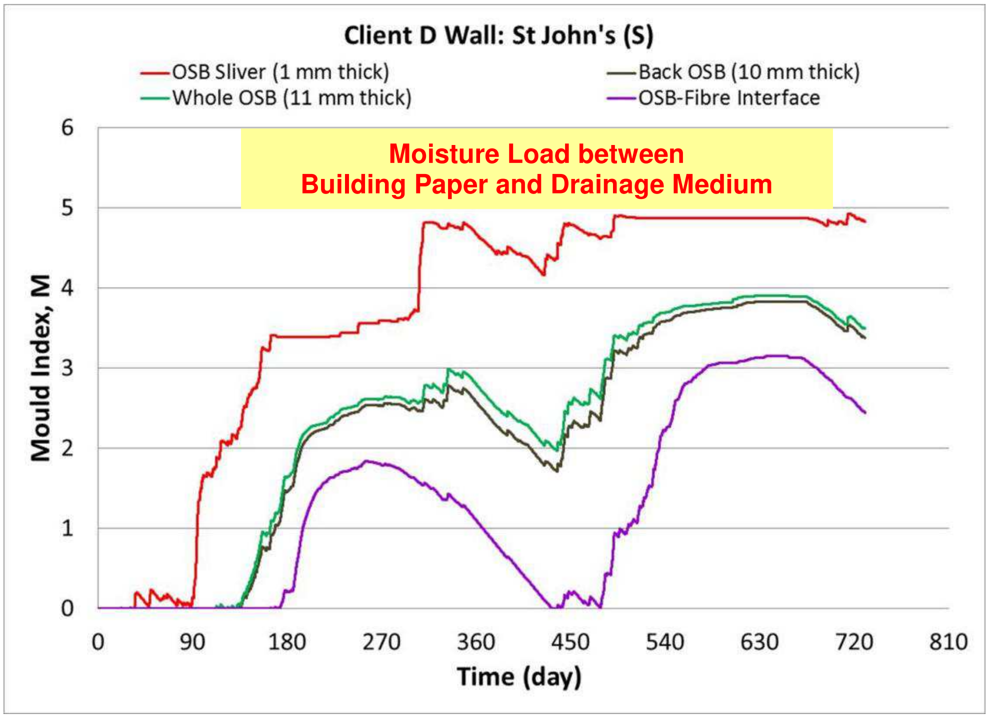
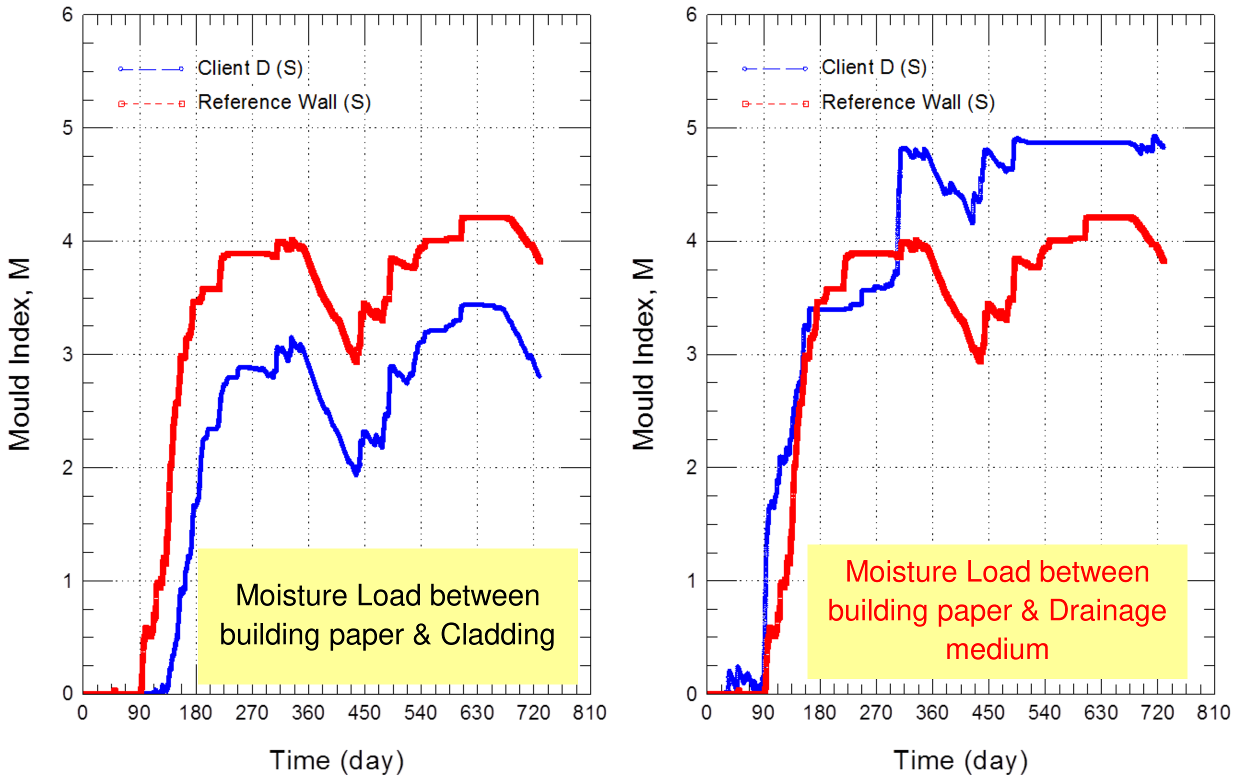


Figure 41 - Client D Walls: Response of OSB component to Moisture Load placed between building paper and Cladding for climate loads of St John's (NL); response



given as M_{IDX} value for sensitivity class "S"

Figure 42 - Client D Walls: Response of OSB component to Moisture Load placed between building paper and Drainage Medium for climate loads of St John's (NL); response given as MIDX value for sensitivity class "S"



Moisture Load between building paper & Cladding

Moisture Load between building paper & Drainage medium

Figure 43 – Reference and Client D Walls: Response of OSB component (1 mm sliver on exterior OSB surface) to climate loads of St. John's (NL); response given as M_{IDX} value for sensitivity class "S"

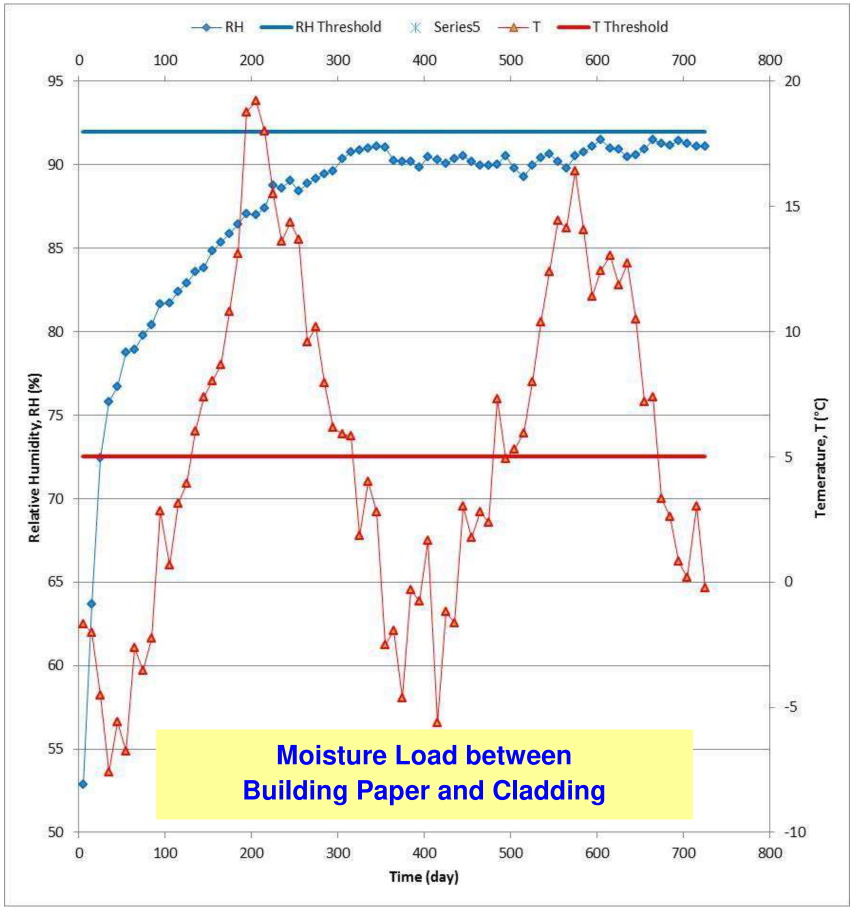
Table 20 – Response of Reference (REF.) and Client D Walls to climate loads of Vancouver (BC): Average and maximum values of M_{IDX} for different locations in walls in which Moisture Load placed between Building paper and: (i) Cladding; (ii) Drainage medium

REF.	**Layer or Interface**					**Layer or Interface**			
M_{IDX}	**OSB Sliver (1 mm)**	**Back OSB (10 mm)**	**Whole OSB (11 mm)**	**OSB-Fibre Interface**		**OSB Sliver (1 mm)**	**Back OSB (10 mm)**	**Whole OSB (11 mm)**	**OSB-Fibre Interface**
Average	3.910	2.506	2.597	1.819		3.910	2.506	2.597	1.819
Maximum	4.508	3.475	3.538	2.984		4.508	3.475	3.538	2.984
Client D (i)	**Layer or Interface**				**Client D (ii)**	**Layer or Interface**			
M_{IDX}	**OSB Sliver (1 mm)**	**Back OSB (10 mm)**	**Whole OSB (11 mm)**	**OSB-Fibre Interface**		**OSB Sliver (1 mm)**	**Back OSB (10 mm)**	**Whole OSB (11 mm)**	**OSB-Fibre Interface**
Average	2.186	1.207	1.289	0.600		3.658	2.226	2.341	1.282
Maximum	3.434	2.574	2.634	1.964		4.924	3.828	3.895	3.151

Hygrothermal response of wall components to climate loads of St John's (NL); RHT(x) criterion (cont'd)

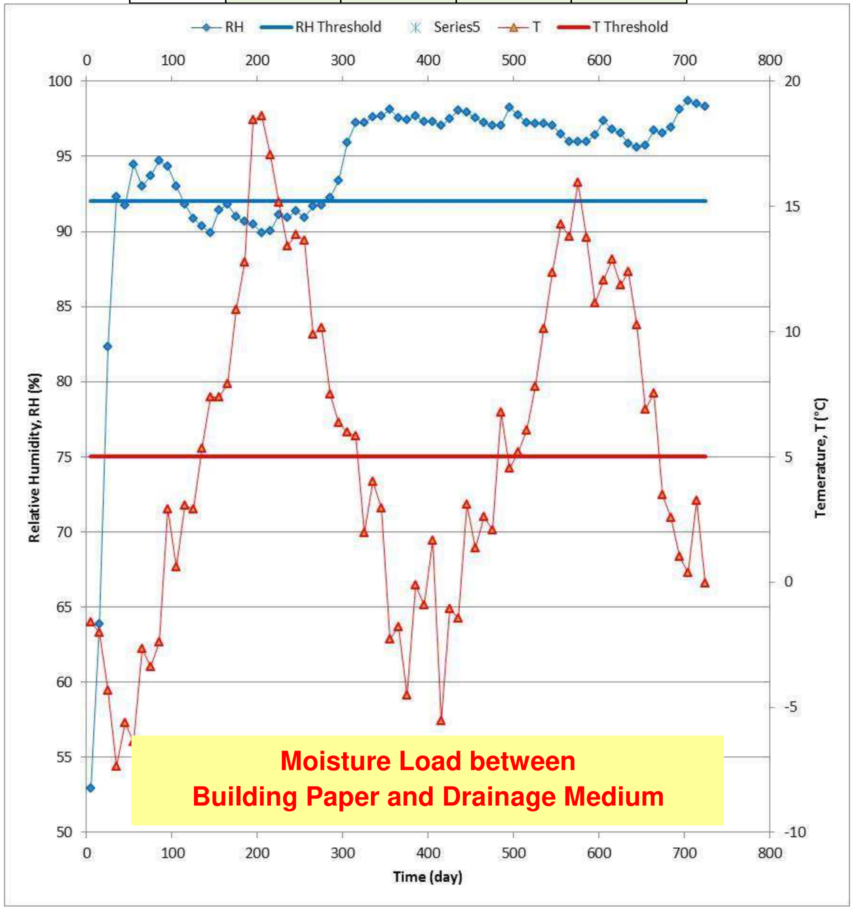
As well, in the table above the right-hand plot (Figure 44), the respective values for RHT(x) are all greater for Client D's wall as compared to the Reference wall where the ML was placed on the SM; this also is consistent with that which determined from a comparison of M_{IDX} values as made available in Table 20.

	RHT(80)	RHT(85)	RHT(92)	RHT(95)
Ref Wall	2961	1786	193	0
Client D	2008	899	0	-



Moisture Load between Building Paper and Cladding

	RHT(80)	RHT(85)	RHT(92)	RHT(95)
Ref Wall	2961	1786	193	0
Client D	2891	1822	459	148



Moisture Load between Building Paper and Drainage Medium

Figure 44 Client D Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of St John's (NL); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

5.5 Client E Drainage System

Overview of Drainage System

A sectional view of the wall configuration incorporating Client E's product, a PP fabric bonded to a HDPE (11 mm) dimpled membrane and NBC-compliant building paper, is shown in Figure 45. The water retention characteristics of this drainage system that incorporates suggest that for given water entry rates, the drainage system retains as much water as compared to the Reference drainage system.

A plot of the water vapour permeance (WVP) of various sheathing membranes, including the PP fabric of Client E, is also provided; it is apparent that the WVP of Client E's fabric product is more vapour permeable than a NBC-compliant sheathing membrane (denoted as 30 min building paper in the plot but also conforming the CGSB standard [12]). Client E's sheathing membrane has a WVP that is well below the limit distinguishing between breathable and non-breathable membranes; i.e. the WVP of Client E's membrane is 24 ng/Pa•s•m^2 as compared to 170 ng/ Pa•s•m^2, the lower limit for a breathable membrane. However, the water absorption coefficient for this membrane is not measureable [3] suggesting that there is little or no liquid water transfer across the membrane. As such, the performance would be related to the extent to which water vapour permeates the sheathing membrane (SM), for which in this systems is an NBC-compliant building paper (BP). This would in turn depend on the amount of moisture that is retained on the SM following a rain event and the prevailing temperature in the drainage cavity.

A portion of the moisture load in this instance was assumed to be placed on the SM whereas the placement of the load for the reference wall was assumed to be retained on the backside of the cladding given that for the reference wall, there is a capillary break between the cladding and the sheathing membrane and water cannot readily traverse this gap in the drainage cavity. In the case of Client E's wall, a plausible scenario for water penetrating the cladding was deemed to have water flow downwards and migrate to openings between adjacent sheets of the dimpled membrane where in turn water would find its way to the back side (i.e. facing the building paper, see the insert in the figure below) of the sheathing membrane.

Thus a portion (50%) of the moisture load in the case of Client E's wall was placed directly on the back side of the sheathing membrane whereas for the Reference wall, the load was retained behind the cladding. Combining these two elements, that is, the equivalence of WVP between sheathing membranes and placement of the moisture load in the drainage cavity, suggests that Client E's wall, as compared to the Reference wall, would be somewhat disadvantaged in respect to managing moisture ingress to the drainage cavity.

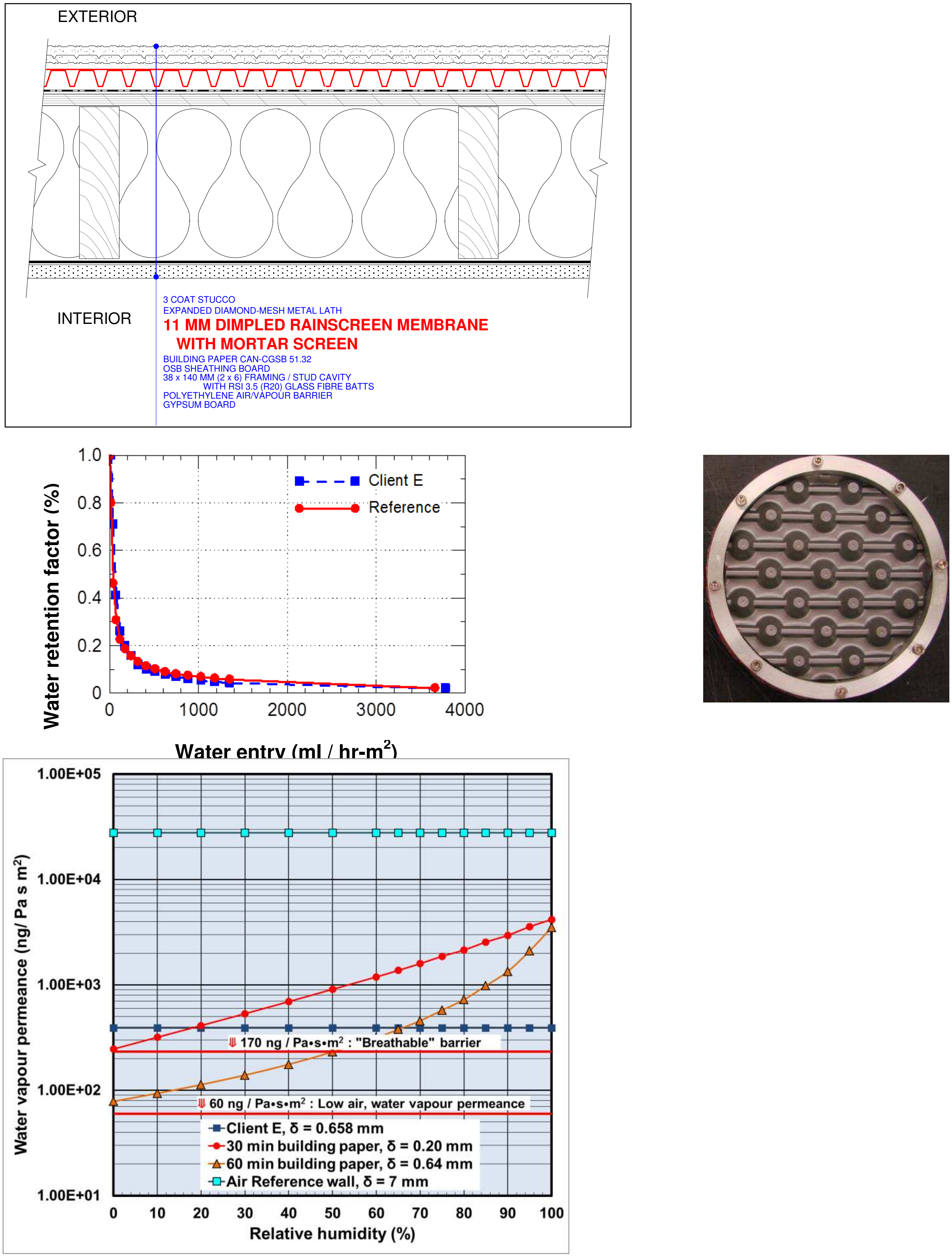
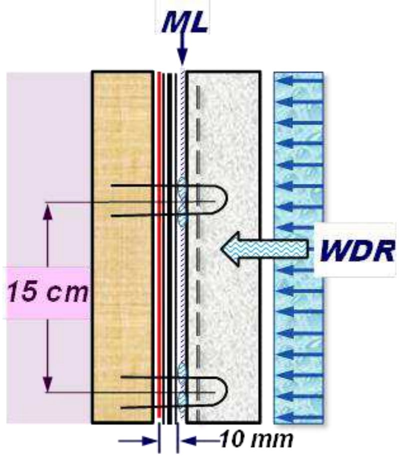
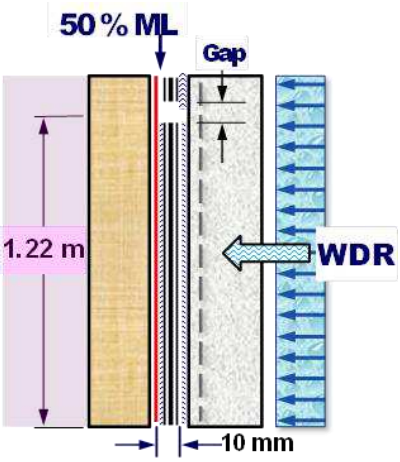


Figure 45 - Client E Wall: Sectional view, placement of moisture load in drainage cavity; water retention characteristics; water vapour permeance of sheathing membrane; δ = membrane thickness

Results from Simulation – Client E Drainage System

Hygrothermal response of wall components to climate loads of Tofino; M_{IDX} criterion





The response of the Client E wall assembly to the climate loads of Tofino (BC) are provided in Figure 46 to Figure 48 and in Table 21 and Table 22. More specifically, the variation in values for M_{IDX} over the course of the simulation period and in respect to the different locations in the wall, are provided in three plots of Figure 46. The upper-most plot shows the variation over the simulation when the moisture load (ML) was placed between the cladding and PP fabric; the middle plot shows values of M_{IDX} over the simulation when 50% of the moisture load (ML) was placed on the sheathing membrane (SM) along a lower 1.22 m portion of the dimpled membrane and the remaining 50% between the cladding and PP fabric, whereas; the lower-most plot shows the variation for 50% of the ML placed on the SM and the drainage system "ventilated". The location of the ML for all these conditions is shown in the adjacent inset.

The variations given in the middle and lower-most plots resulted from attempting to find solutions for which the drainage system could adequately accommodate the ML to which it was subjected. As a consequence of these efforts, the variations shown here also include the drainage system either "vented" or "ventilated".

In the plots of Figure 46, the values for M_{IDX} over the course of the simulation period increase over time depending on the propensity for mould growth given the moisture and temperature conditions in the different locations within the sheathing panels (OSB); the moisture conditions at the different panel locations are related to their respective proximity to the moisture load. Plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB-glass fibre interface), the one closet to the moisture load, in these plots, being the "OSB Sliver", representative of a 1 mm thick sliver of the exterior face of the 11 mm thick sheathing panel and the component in closest contact with the SM.

Observations common to all plots of Figure 46:

- The values of M_{IDX} diminish in relation to the distance from where the ML is applied to the location of interest for which a response has been given.
- The higher values of M_{IDX} are those closest to the SM and the location where the ML was applied and thereafter diminish as the location of interest recedes from the exterior face of the sheathing panel to the interior face of the OSB panel, and where this surface is at the interface between the OSB and the interior insulation.
- The values for M_{IDX} of the entire OSB panel (i.e. "whole" OSB 11 mm thick) are always greater than the 10 mm portion of OSB behind the 1 mm sliver (i.e. "back" of OSB, 10 mm thick) given

that the values for M_{IDX} of the 1 mm sliver are always the greatest values for M_{IDX} amongst the different locations in the wall.

- The values provided for the 1 mm OSB sliver are the critical values from which the response of the wall assembly is measured in respect to managing moisture ingress to the drainage cavity, whereas,
- If the risk of condensation is the measure of importance in respect to wall performance , then the focus ought to be on the interface between the insulation and the OSB panel, that is, the "OSB-fibre interface" as given in Figure 46.

The differences in response of the OSB component (1 mm sliver on exterior OSB surface) to the location of the ML in the wall assembly is apparent from the lower values of M_{IDX} obtained in the instance where the ML is placed between the cladding and PP fabric as compared to having 50% of the ML placed on the SM; the ML being in direct contact with the SM brings it in closer proximity to the wood-based and moisture sensitive components of the wall assembly. As well, the contribution of "ventilation" of the drainage cavity is evident when comparing the values of M_{IDX} for the "OSB-sliver" of the middle and lower-most plots of Figure 46; there is an evident reduction in values of M_{IDX} brought about with "ventilation" of the system, and its impact is important.

The response of the Reference and Client E Walls of the OSB component (1 mm sliver on exterior OSB surface) to climate loads of Tofino (BC) over the same period are shown in Figure 47; values for M_{IDX} as a function of time for the:

- Left-hand plot is for the ML placed between the cladding and the PP fabric;
- Middle plot is for 50% of the ML placed on the SM and 50%, between the cladding and PP fabric, the SM consisting of 1-layer of NBC-compliant BP;
- Right-hand plot is for the same ML load conditions as provided in the middle plot and the system "ventilated".

When the ML was placed:

- Between the PP fabric and the cladding (left-hand plot; Figure 47), the Client E wall had values for M_{IDX} less that the Reference wall;
- 50% on the SM, and 50% between the cladding and PP fabric (Middle plot; Figure 47), the Client E wall had values for M_{IDX} less than that of the Reference wall up to day 270 and thereafter had higher values, whereas;
- 50% on the SM, and 50% between the cladding and PP fabric (right-hand plot; Figure 47), and the system "ventilated", Client E's wall had values for M_{IDX} less than that of the Reference wall.

The information provided in Table 21 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client E's wall. When the ML is placed on the SM and the drainage system is "vented", average values for M_{IDX} are generally less than the Reference wall whereas maximum values are greater than the Reference wall. For a "ventilated" drainage system, all values for M_{IDX} are less than the Reference wall.

Given these results it is evident that for the climate loads of Tofino (BC) Client E's wall did not manage moisture ingress to the drainage cavity as compared to the Reference wall if "vented" but did if "ventilated".

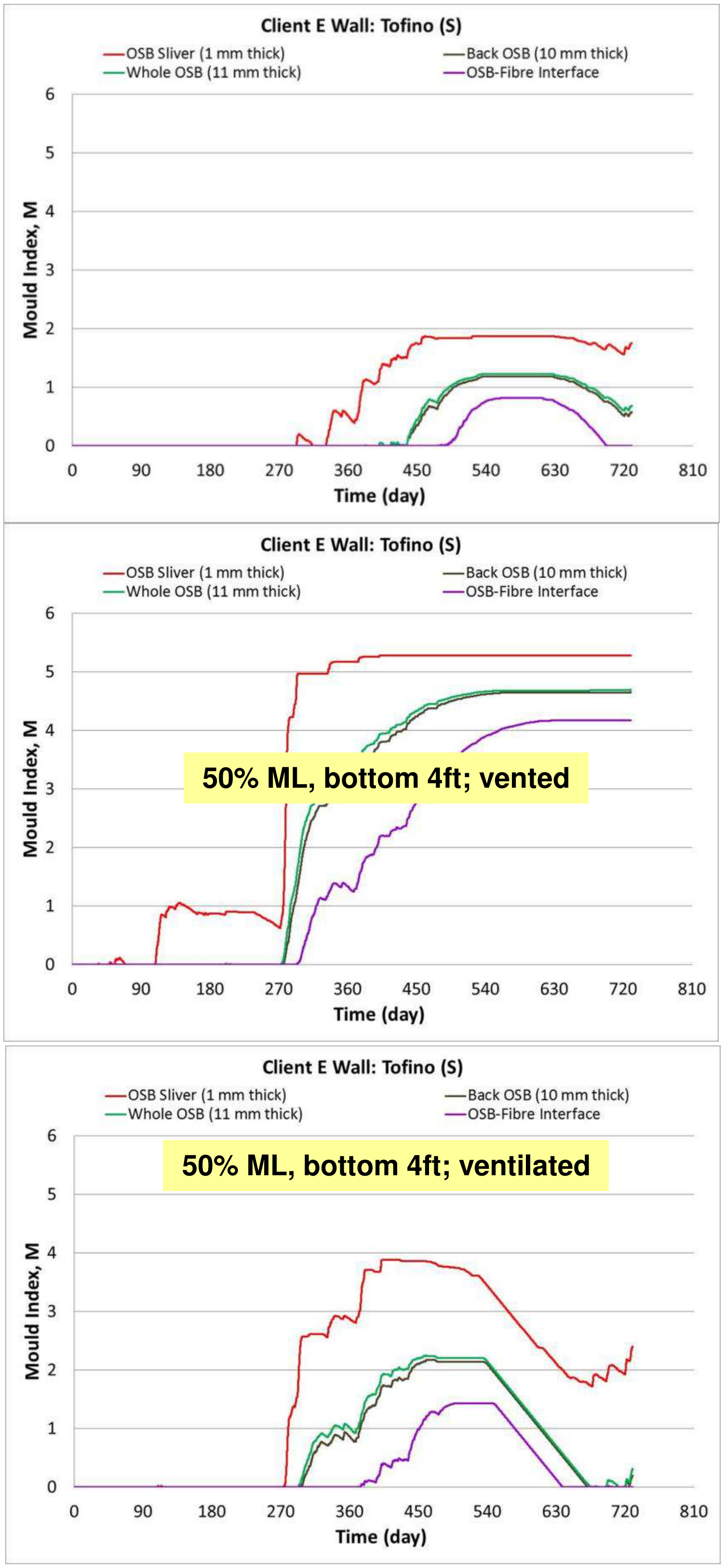


Figure 46 - Client E Wall: Response of OSB component to climate loads of Tofino (BC); response given as M_{IDX} value for sensitivity class “S”

Hygrothermal response of wall components to climate loads of Tofino; RHT(x) criterion

The response of Client G's (in the 1 mm "OSB-sliver") wall to climate loads of Tofino (BC) as determined by the value of the RHT(x) index is shown in Figure 48.

The values for relative humidity and temperature over the simulation period for the ML placed: (i) Left-hand plot - Between the cladding and PP fabric; (ii) Middle plot - 50% on the SM and 50%, between the cladding and PP fabric; (iii) Right-hand plot – same conditions as middle plot and the system was "ventilated".

A review of the different plots in Figure 48 provide some insight into the importance of "ventilation" as a strategy to attenuate the rise in RH of the "OSB-sliver"; without "ventilation" (middle plot), the RH of the "OSB sliver" attains exceedingly high levels (i.e. >98% RH) whereas with "ventilation", the 92% RH threshold is exceeded only very few items at about day 400.

The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client E walls and for different threshold values of RH are given in Table 22. The respective values for RHT(x) are all greater for Client E's wall as compared to the Reference wall for the "vented" system whereas these values are all less than the Reference wall for the "ventilated system; these results are also consistent with that determined from a comparison of M_{IDX} values as was made available in Table 21.

Hygrothermal response of wall components to climate loads of Vancouver; M_{IDX} criterion

The response of the Client E's wall assembly to the climate loads of Vancouver (BC) are provided in Figure 49 to Figure 51 and in Table 23 and Table 24.

More specifically, the variation in values for M_{IDX} over the course of the simulation period and in respect to the different locations in the wall, are provided in three plots of Figure 49. The upper-most plot shows the variation over the simulation period when the moisture load (ML) was placed between the cladding and PP fabric; the middle plot shows values of M_{IDX} over the simulation period when 50% of the moisture load (ML) was placed on the sheathing membrane (SM) along a lower 1.22 m portion of the dimpled membrane and the remaining 50% between the cladding and PP fabric, whereas; the lower-most plot has the same ML conditions as in the middle plot but for the drainage system "ventilated". The location of the ML for all these conditions is the same as was previously given for Tofino.

As was the case for Tofino, the variations given in the middle and lower-most plots resulted from attempting to find solutions for which the drainage system could adequately accommodate the ML to which it was subjected; variations thus also include a "ventilated" drainage system.

In the plots of Figure 49, the values for M_{IDX} over the course of the simulation period would generally increase over time depending on the propensity for mould growth given the moisture and temperature conditions in the different locations within the sheathing panels (OSB); the moisture conditions at the different panel locations are related to their respective proximity to the moisture load. Plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB-glass fibre interface), the one closet to the moisture load, in these plots, being the "OSB Sliver", representative of a 1 mm thick sliver of the exterior face of the sheathing panel. Observations common to all plots of Figure 49are the same as those provided for plots of Figure 45 for Tofino.

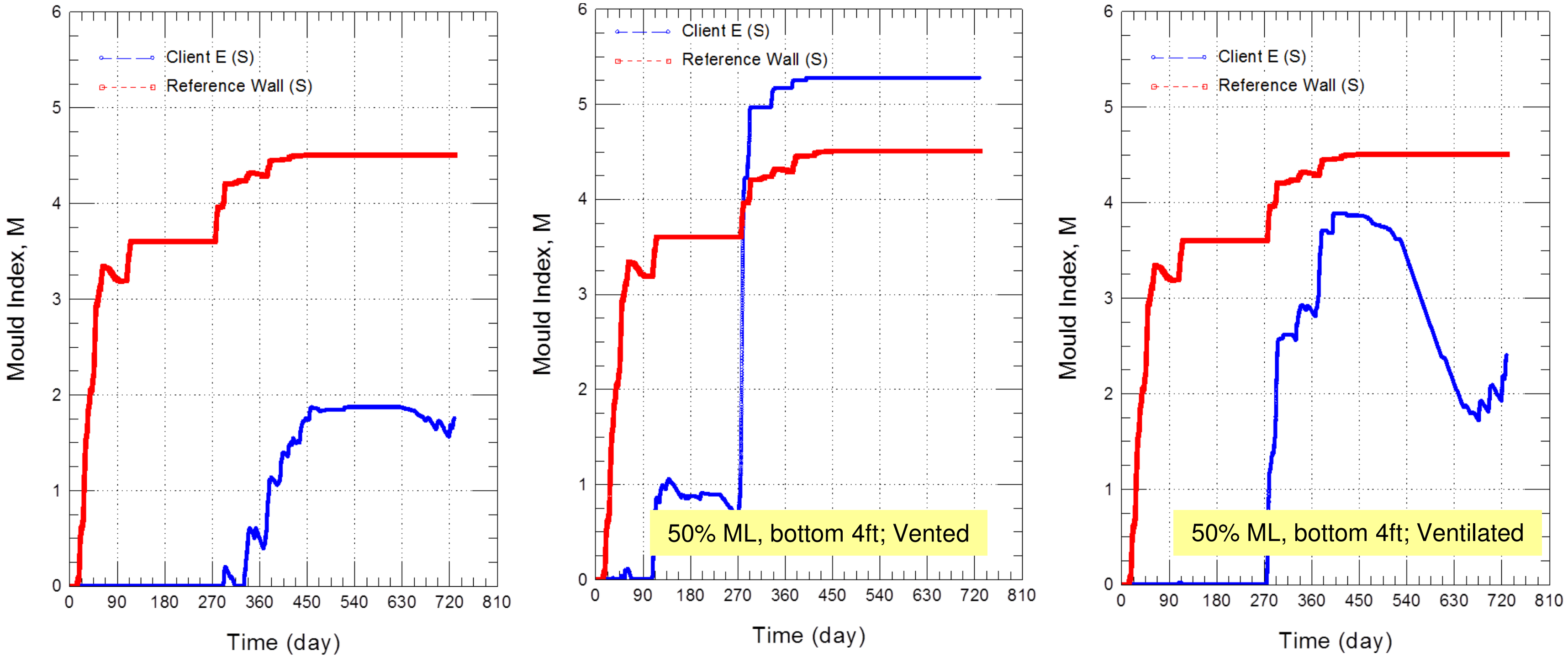


Figure 47 – Reference & Client E Walls: Response of OSB to climate loads of Tofino (BC); response given as M_{IDX} value for sensitivity class “S

Table 21 – Response of Reference & Client E Walls to climate loads of Tofino (BC); Average & maximum values of M_{IDX} for wall locations where: (i) ML* placed between building paper & Cladding; (ii) 50 % ML on building paper; system vented; (iii) 50 % ML on building paper; system ventilated

	Tofino				**Tofino / 50% ML, Lower 4ft; Vented**				**Tofino / 50% ML, Lower 4ft; Ventilated**			
	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
REF.-Avg	3.910	2.506	2.597	1.819	3.910	2.506	2.597	1.819	3.910	2.506	2.597	1.819
REF.-Max	4.508	3.475	3.538	2.984	4.508	3.475	3.538	2.984	4.508	3.475	3.538	2.984
Client E-Avg	0.866	0.378	0.403	0.170	3.414	2.464	2.529	1.831	1.785	0.700	0.754	0.309
Client E-Max	1.868	1.179	1.222	0.817	5.273	4.650	4.692	4.165	3.882	2.168	2.243	1.427

*ML: Moisture Load

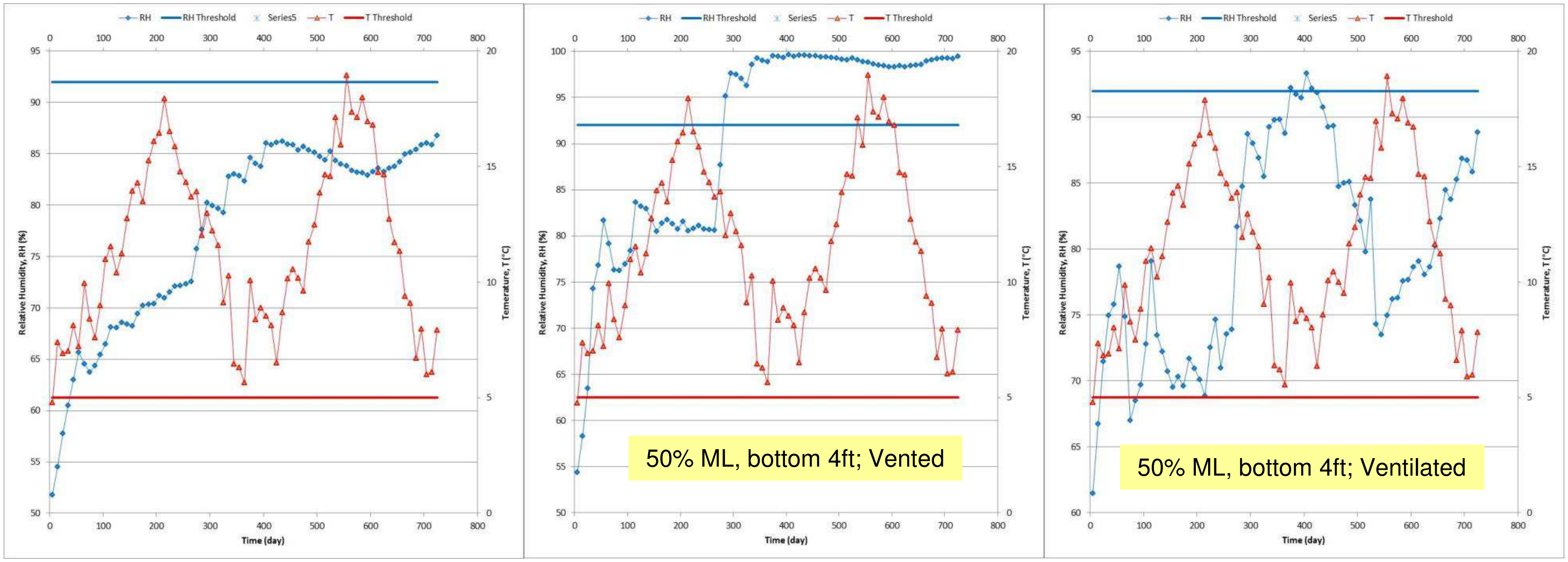
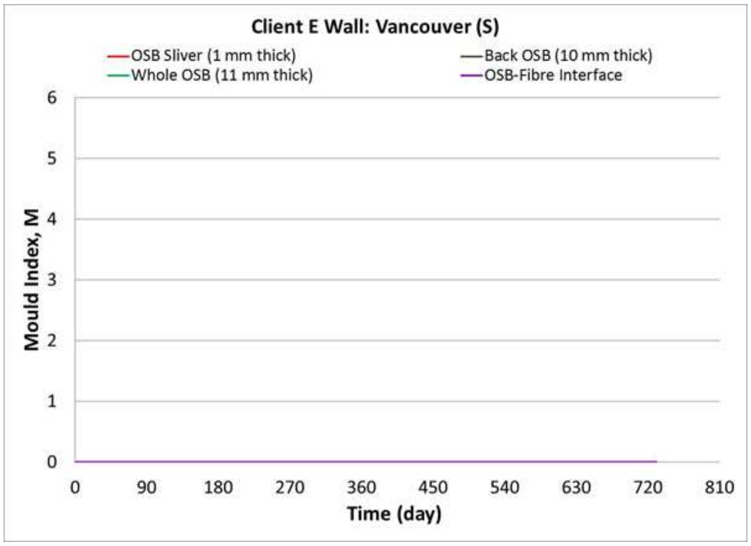
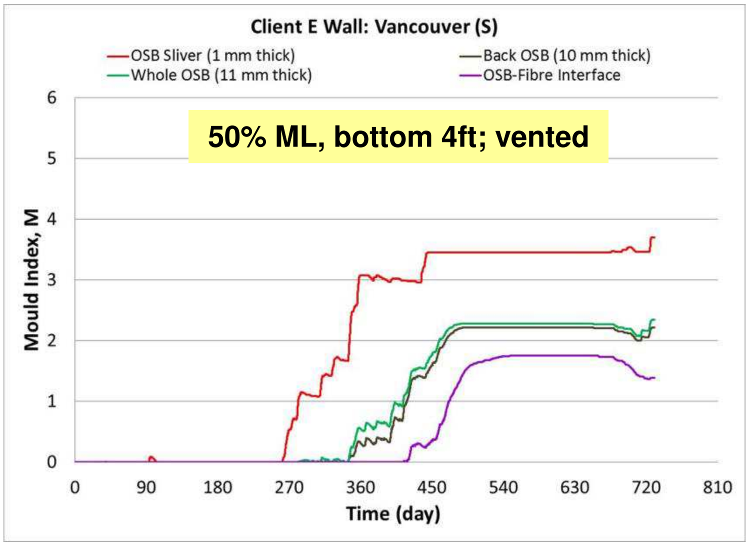


Figure 48 – Client E Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of Tofino (BC); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

Table 22 – Response of Reference & Client E Walls to climate loads of Tofino (BC); values of RHT(x) where x relates to the RH threshold value at which the index is calculated where:(i) ML* placed between building paper & Cladding; (ii) 50 % ML on building paper; system vented; (iii) 50 % ML on building paper; system ventilated

	Tofino				Tofino / 50% ML, Lower 4ft; Vented				Tofino / 50% ML, Lower 4ft; Ventilated			
	RHT(80)	RHT(85)	RHT(92)	RHT(95)	RHT(80)	RHT(85)	RHT(92)	RHT(95)	RHT(80)	RHT(85)	RHT(92)	RHT(95)
Ref Wall	5263	3015	435	37	5263	3015	435	37	5263	3015	435	37
Client E	1068	44	0	0	5589	3919	1897	1041	975	331	6	0





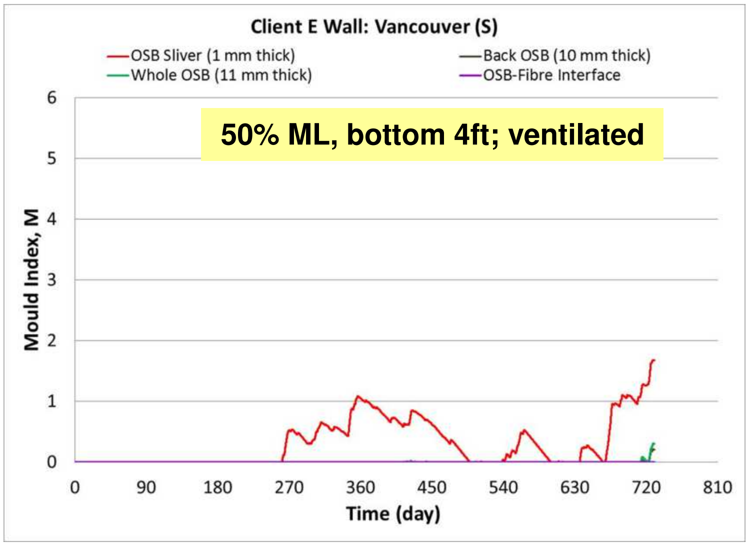


Figure 49 Client E Wall: Response of OSB component to climate loads of Vancouver (BC); response given as M_{IDX} value for sensitivity class "S

The differences in response of the OSB component (1 mm sliver on exterior OSB surface) to the location of the ML in the wall assembly is apparent from the lower values of M_{IDX} obtained in the instance where the ML is placed between the cladding and PP fabric as compared to having 50% of the ML placed on the SM; the ML being in direct contact with the SM brings it in closer proximity to the wood-based and moisture sensitive components of the wall assembly. As well, the contribution of "ventilation" of the drainage cavity is evident when comparing the values of M_{IDX} for the "OSB-sliver" of the middle and lower-most plots of Figure 49; there is an evident reduction in values of M_{IDX} brought about with "ventilation" of the system, and its impact is important.

The response of the Reference and Client E Walls of the OSB component (1 mm sliver on exterior OSB surface) to climate loads of Vancouver (BC) over the same period are shown in Figure 50; values for M_{IDX} as a function of time for the:

- Left-hand plot is for the ML placed between the cladding and the PP fabric;
- Middle plot is for 50% of the ML placed on the SM and 50%, between the cladding and PP fabric, the SM consisting of 1-layer of NBC-compliant BP;
- Right-hand plot is for the same ML load conditions as provided in the middle plot and the system "ventilated".

When the ML was placed:

- Between the PP fabric and the cladding (left-hand plot; Figure 50), the Client E wall had no values for M_{IDX};
- 50% on the SM and 50%, between the cladding and PP fabric (Middle plot; Figure 50), the Client E wall had values for M_{IDX} less than that of the Reference wall, whereas;
- 50% on the SM and 50%, between the cladding and PP fabric (right-hand plot; Figure 50), and the system "ventilated", Client E's wall had values for M_{IDX} less than that of the Reference wall.

The information provided in Table 23 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client E's wall. When the ML is placed on the SM and the drainage system is "vented", values for M_{IDX} are less than the Reference wall. For the case for a "ventilated" drainage system, all values for M_{IDX} are less than the Reference wall.

Given these results it is evident that for the climate loads of Vancouver (BC) Client E's wall adequately managed moisture ingress to the drainage cavity as compared to the Reference wall whether "vented" or "ventilated".

Hygrothermal response of wall components to climate loads of Vancouver (BC); RHT(x) criterion

The response of Client E's (in the 1 mm "OSB-sliver") wall to climate loads of Vancouver (BC) as determined by the value of the RHT(x) index is shown in Figure 51. The values for relative humidity and temperature over the simulation period for the ML placed: (i) Left-hand plot - Between the cladding and PP fabric; (ii) Middle plot - 50% on the SM and 50% between the cladding and PP fabric; (iii) Right-hand plot – same conditions as middle plot and the system was "ventilated".

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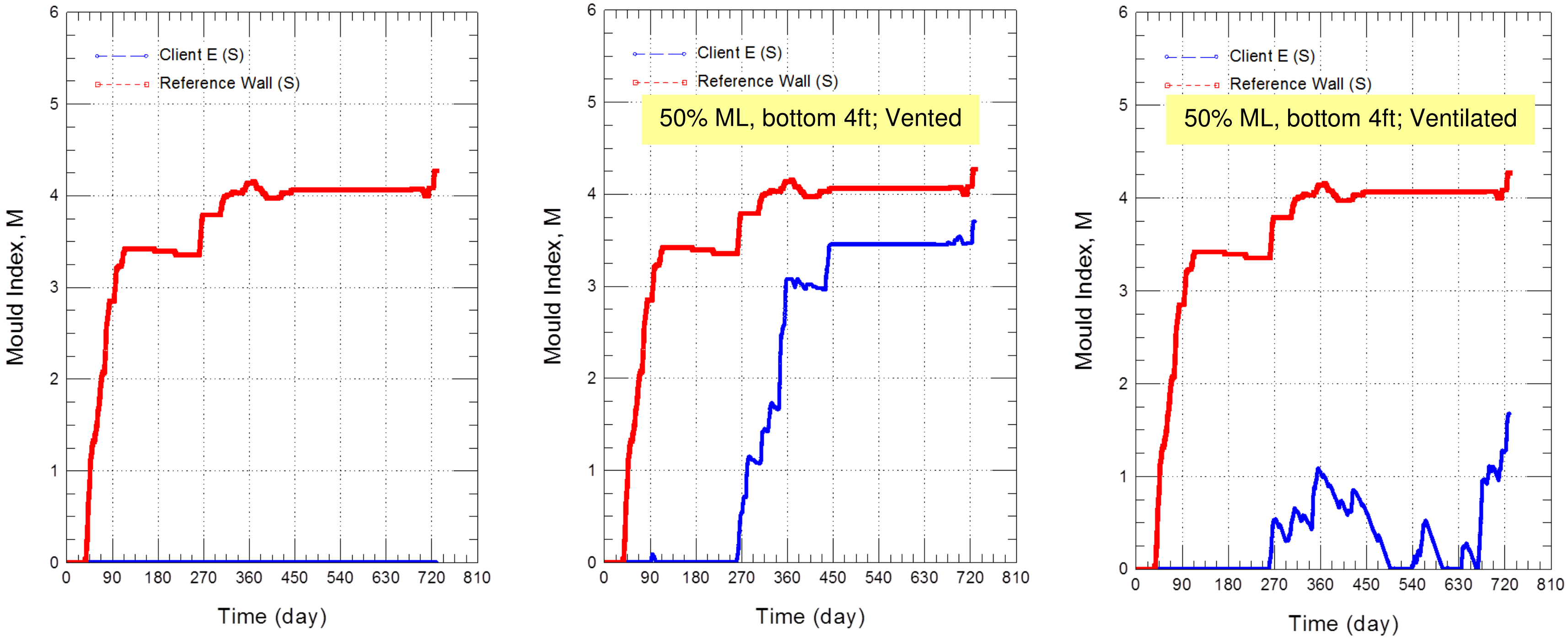

Figure 50 – Reference & Client E Walls: Response of OSB to climate loads of Vancouver (BC); response given as M_{IDX} value for sensitivity class “S

Table 23 – Response of Reference & Client E Walls to climate loads of Vancouver (BC); Average & maximum values of M_{IDX} for wall locations where: (i) ML* placed between building paper & Cladding; (ii) 50 % ML on building paper; system vented; (iii) 50 % ML on building paper; system ventilated

	Vancouver				Vancouver / 50% ML, Lower 4ft; Vented				Vancouver / 50% ML, Lower 4ft; Ventilated			
	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
REF.-Avg	3.910	2.506	2.597	1.819	3.085	1.941	2.035	1.147	3.500	2.181	2.271	1.518
REF.-Max	4.508	3.475	3.538	2.984	4.210	3.191	3.261	2.562	4.270	3.082	3.149	2.633
Client E-Avg	0	0	0	0	1.889	0.930	0.989	0.611	0.303	0.002	0.003	0.000
Client E-Max	0	0	0	0	3.697	2.211	2.337	1.754	1.672	0.212	0.305	0.000

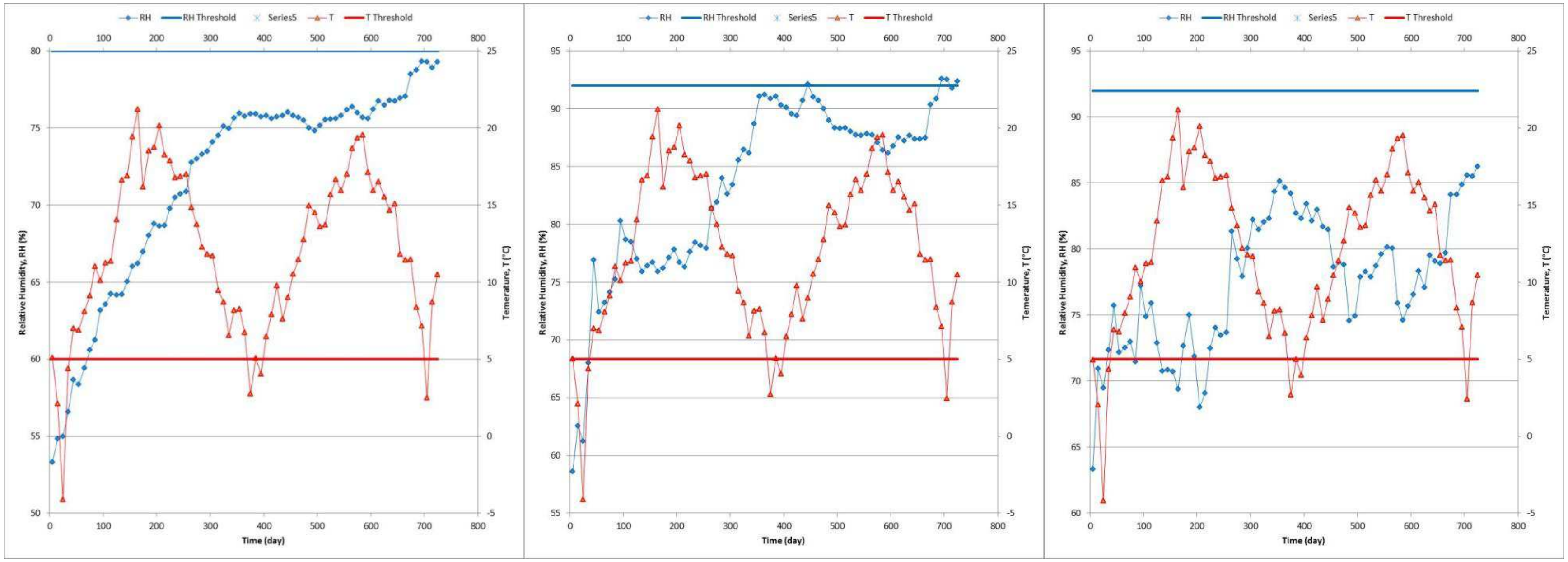

Figure 51 – Client E Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of Vancouver (BC); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

Table 24 – Response of Reference & Client E Walls to climate loads of Vancouver (BC); values of RHT(x) where x relates to the RH threshold value at which the index is calculated where:(i) ML* placed between building paper & Cladding; (ii) 50 % ML on building paper; system vented; (iii) 50 % ML on building paper; system ventilated

	Vancouver				Vancouver 50% ML, Lower 4ft; Vented				Vancouver 50% ML, Lower 4ft; Ventilated			
	RHT(80)	**RHT(85)**	**RHT(92)**	**RHT(95)**	**RHT(80)**	**RHT(85)**	**RHT(92)**	**RHT(95**	**RHT(80)**	**RHT(85)**	**RHT(92)**	**RHT(95**
Ref Wall	4958	2493	192	2	4958	2493	192	2	4958	2493	192	2
Client E	0	0	0	0	2386	897	4	0	226	9	0	0

Hygrothermal response of wall components to climate loads of Vancouver (BC); RHT(x) criterion (cont'd)

A review of the different plots in Figure 51 provide some insight into the importance of "ventilation" as a strategy to attenuate the rise in RH of the "OSB-sliver"; without "ventilation" (middle plot), the RH of the "OSB sliver" attains levels of ca. 92% RH only occasionally whereas with "ventilation", the 85% RH is only occasionally attained.

The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client E walls and for different threshold values of RH are given in Table 24. The respective values for RHT(x) for Client E's wall are all less than the Reference wall for both the "vented" and "ventilation" system; these results are also consistent with that determined from a comparison of M_{IDX} values as was made available in Table 23.

Hygrothermal response of wall components to climate loads of St John's (NL); M_{IDX} criterion

The response of the Client E's wall assembly to the climate loads of St John's (NL), are provided in Figure 52 to Figure 54 and in Table 25 and Table 26.

More specifically, the variation in values for M_{IDX} over the course of the simulation period and in respect to the different locations in the wall, are provided in three plots of Figure 52. The upper-most plot shows the variation over the simulation when the moisture load (ML) was placed between the cladding and the PP fabric, the middle plot for values of M_{IDX} when 50% of the ML was placed on the sheathing membrane (SM) and the remaining 50% between the cladding and PP fabric, whereas; the lower-most plot shows the variation for 50% of the ML placed on the SM and the system was "ventilated". The location of the ML for all these conditions is the same as was previously given for Tofino and Vancouver.

As was the case for Tofino and Vancouver, the variations given in the middle and lower-most plots resulted from attempting to find solutions for which the drainage system could adequately accommodate the ML to which it was subjected; variations for this system thus include a "ventilated" system as compared to a "vented" system, as specified for this system.

In the plots of Figure 52, the values for M_{IDX} over the simulation in general are expected to increase over time depending on the propensity for mould growth given the moisture and temperature conditions in the different locations within the sheathing panels (OSB); the moisture conditions at the different panel locations are related to their respective proximity to the ML. Plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB-glass fibre interface), the one closet to the moisture load, in these plots, being the "OSB Sliver", representative of a 1 mm thick sliver of the exterior face of the sheathing panel. Observations common to all plots of Figure 52 are the same as those provided for plots of Figure 46 for Tofino and Figure 49 for Vancouver.

The differences in response of the OSB component (1 mm sliver on exterior OSB surface) to the location of the ML in the wall assembly is apparent from the lower values of M_{IDX} obtained in the instance where the ML is placed between the cladding and PP fabric as compared to having 50% of the ML placed on the SM; the ML being in direct contact with the SM brings it in closer proximity to the wood-based and moisture sensitive components of the wall assembly.

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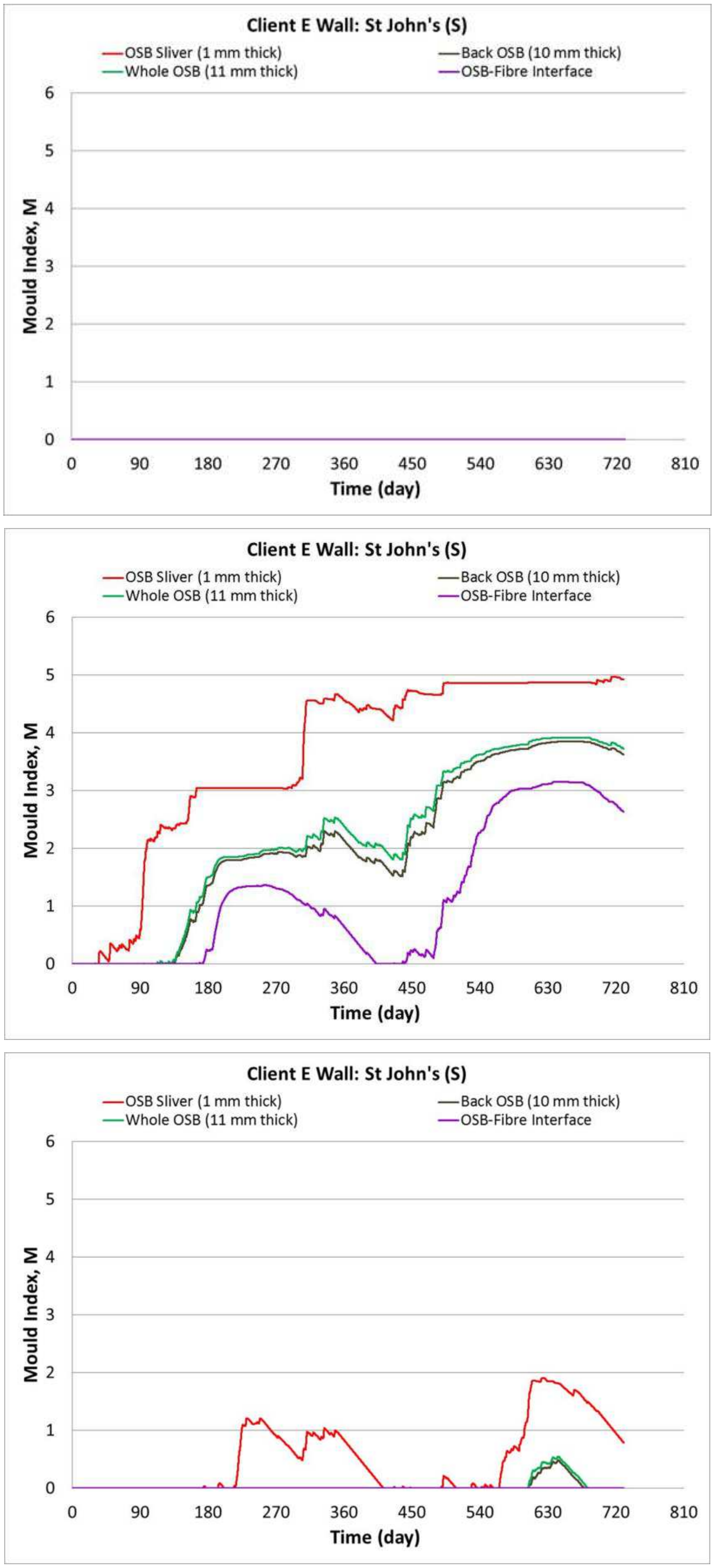


Figure 52 - Client E Wall: Response of OSB component to climate loads of St John's, NF; response given as M_{IDX} value for sensitivity class "S

As well, the contribution of "ventilation" of the drainage cavity is evident when comparing the values of M_{IDX} for the "OSB-sliver" of the middle and lower-most plots of Figure 52; there is an evident reduction in values of M_{IDX} brought about with "ventilation" of the system, and its impact is important.

The response of the Reference and Client E Walls of the OSB component (1 mm sliver on exterior OSB surface) to climate loads of Vancouver (BC) over the same period are shown in Figure 53; values for M_{IDX} as a function of time for the:

- Left-hand plot is for the ML placed between the cladding and the PP fabric;
- Middle plot is for 50% of the ML placed on the SM and 50%, between the cladding and PP fabric, the SM consisting of 1-layer of NBC-compliant BP;
- Right-hand plot is for the same ML load conditions as provided in the middle plot and the system "ventilated".

When the ML was placed:

- Between the PP fabric and the cladding (left-hand plot; Figure 53), the Client E wall had no values for M_{IDX};
- 50% on the SM and 50%, between the cladding and PP fabric (Middle plot; Figure 53), the Client E wall had values for M_{IDX} greater than that of the Reference wall;
- 50% on the SM and 50%, between the cladding and PP fabric (right-hand plot; Figure 53), and the system "ventilated", Client E's wall had values for M_{IDX} less than that of the Reference wall.

The information provided in Table 25 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client E's wall. When the ML is placed on the SM and the drainage system is "vented", values for M_{IDX} are greater than the Reference wall. Whereas when the ML is placed on the SM and the drainage system is "ventilated", all values for M_{IDX} are less than the Reference wall.

Given these results it is evident that for the climate loads of St John's (NL), Client E's wall will adequately managed moisture ingress to the drainage cavity provided the system is "ventilated".

Hygrothermal response of wall components to climate loads of St. John's, NL; RHT(x) criterion

The response of Client E's (in the 1 mm "OSB-sliver") wall to climate loads of Vancouver (BC) as determined by the value of the RHT(x) index is shown in Figure 54. The values for relative humidity and temperature over the simulation period for the ML placed: (i) Left-hand plot - Between the cladding and PP fabric; (ii) Middle plot - 50% on the SM and 50%, between the cladding and PP fabric; (iii) Right-hand plot – same conditions as middle plot and the system was "ventilated".

A review of the different plots in Figure 54 provide some insight into the importance of "ventilation" as a strategy to attenuate the rise in RH of the "OSB-sliver"; without "ventilation" (middle plot), the RH of the "OSB sliver" readily attains levels > 95% RH whereas with "ventilation", 85% RH is rarely attained.

The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client E walls and for different threshold values of RH are given in the Table 26. The respective values for RHT(x) for Client E's wall are all greater than the Reference wall for the "vented" system and less than the Reference wall for the "ventilation" system; these results are also consistent with that determined from a comparison of M_{IDX} values as was made available in Table 25.

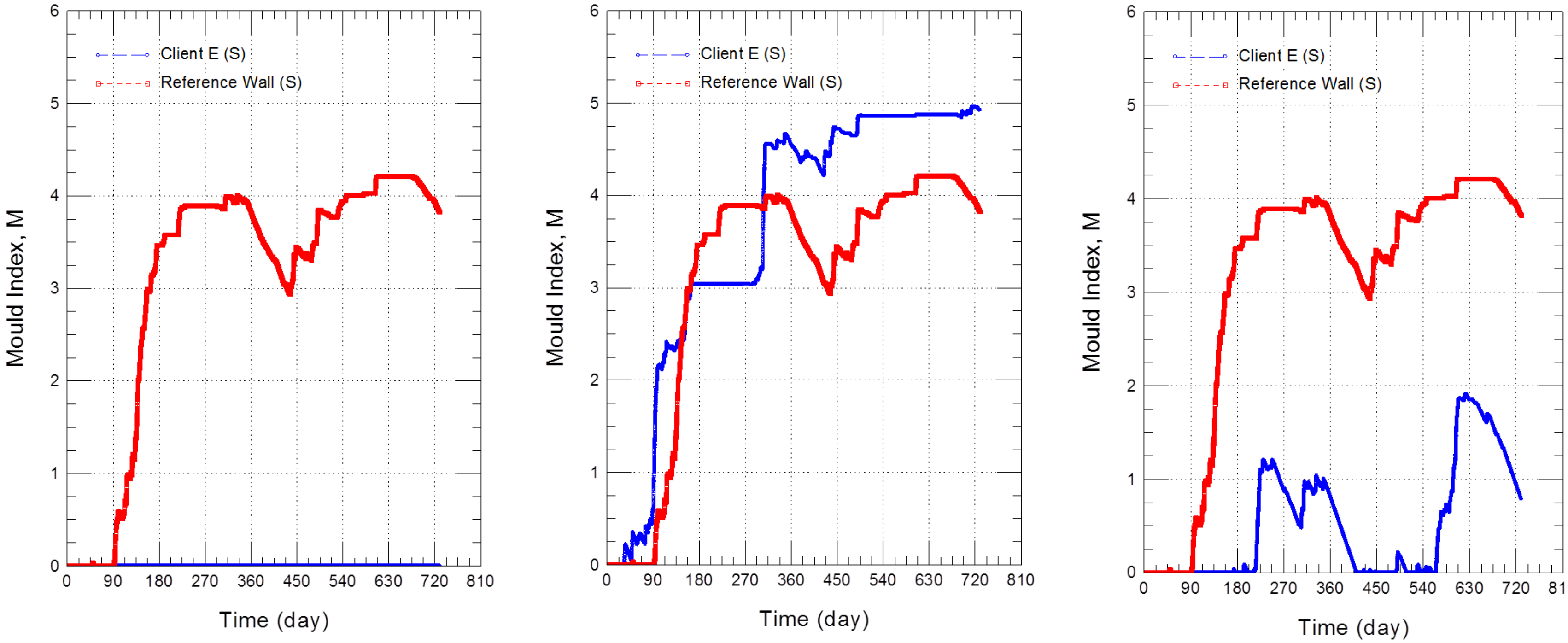


Figure 53 – Reference & Client E Walls: Response of OSB to climate loads of St John's, NF; response given as M_{IDX} value for sensitivity class “S

Table 25– Response of Reference & Client E Walls to climate loads of St John's, NF; Average & maximum values of M_{IDX} for wall locations where: (i) ML* placed between building paper & Cladding; (ii) 50 % ML on building paper; system vented; (iii) 50 % ML on building paper; system ventilated

St John's					St John's 50% ML, Lower 4ft; Vented				St John's 50% ML, Lower 4ft; Ventilated			
	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
REF.-Avg	3.085	1.941	2.035	1.147	3.085	1.941	2.035	1.147	3.085	1.941	2.035	1.147
REF.-Max	4.210	3.191	3.261	2.562	4.210	3.191	3.261	2.562	4.210	3.191	3.261	2.562
Client E-Avg	0	0	0	0	3.586	2.065	2.181	1.172	0.508	0.027	0.036	0.000
Client E-Max	0	0	0	0	4.962	3.844	3.909	3.147	1.905	0.479	0.543	0.000

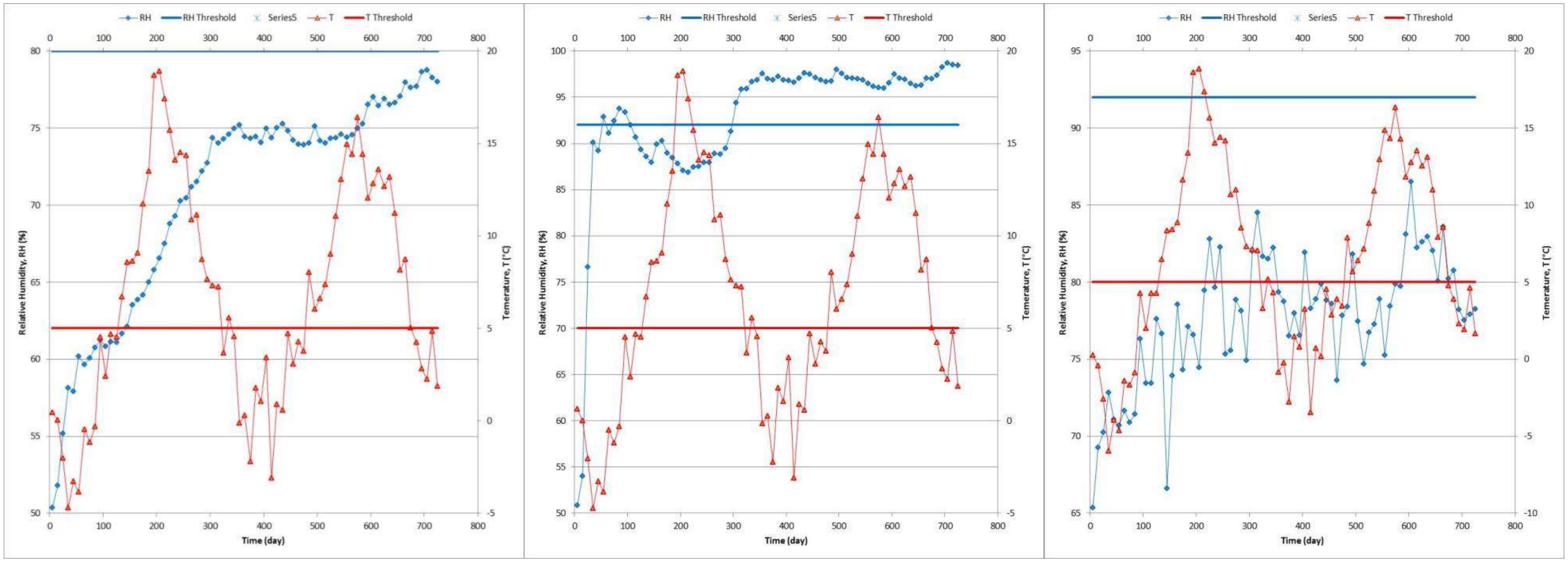


Figure 54 - – Client E Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of St John's, NF; response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

Table 26 – Response of Reference & Client E Walls to climate loads of St John's, NF; values of RHT(x) where x relates to the RH threshold value at which the index is calculated where:(i) ML* placed between building paper & Cladding; (ii) 50 % ML on building paper; system vented; (iii) 50 % ML on building paper; system ventilated

St John's					**St John's 50% ML, Lower 4ft; Vented**				**St John's 50% ML, Lower 4ft; Ventilated**			
	RHT(80)	**RHT(85)**	**RHT(92)**	**RHT(95)**	**RHT(80)**	**RHT(85)**	**RHT(92)**	**RHT(95)**	**RHT(80)**	**RHT(85)**	**RHT(92)**	**RHT(95)**
Ref Wall	2961	1786	193	0	2961	1786	193	0	2961	1786	193	0
Client E	0	0	0	0	3071	1825	569	198	226	12	0	0

5.6 Client F Drainage System

Overview of Drainage System – Client F

A sectional view of the wall configuration incorporating Client F's drainage system, an open 25 mm air space cavity and a code-compliant building paper (BP) as sheathing membrane (SM), is shown in Figure 55. The water retention characteristics of the drainage system (i.e. 25 mm air space and NBC-compliant BP) indicates that this drainage system is entirely similar to the Reference wall drainage system. A plot of the water vapour permeance (WVP) of the NBC-compliant BP is also provided (30 min building paper); it is apparent that the WVP of Client F's SM varies in accordance with the RH, and at 40% RH, is almost an order of magnitude greater than the 170 ng/ Pa•s•m^2, the lower limit for a breathable membrane and at greater values of RH, almost attains another half order of magnitude than the lower limit of a breathable membrane.

As such, the performance would be related to the extent to which water vapour permeates the SM and this would in turn depend on the amount of moisture that is retained on the membrane following a rain event and the prevailing temperature in the drainage cavity.

In respect to the placement of the moisture load in the cavity, (ML), in this instance the ML was assumed to be placed on the backside of the cladding the same as for the reference wall given that for both wall assemblies, there is a capillary break between the cladding and the adjacent component in the drainage cavity (i.e. sheathing membrane for Reference wall) and water cannot readily traverse this gap.

Give that the moisture load is retained behind the cladding and as well, the WVP of the SM is equivalent to the reference wall, suggests that the response of Client F's wall would entirely comparable to that of the Reference wall in respect to managing moisture ingress to the drainage cavity.

Results from Simulation – Client F Drainage System

Hygrothermal response of wall components to climate loads of Tofino and Vancouver (BC) and St John's (NL); M_{IDX} criterion

The response of the Client F's wall assembly to the climate loads of Tofino and Vancouver (BC), and St John's (NL) are provided in Figure 56 to Figure 58 and in Table 27 and Table 28. More specifically, the variation in values for M_{IDX} over the simulation period and in respect to the different locations in the wall, are provided in three (3) plots of Figure 56 for each of the respective climate locations.

In those plots of Figure 56 for of Tofino and Vancouver (BC) the values for M_{IDX} over the course of the simulation, in general, increase over time in relation to the propensity for mould growth given the moisture and temperature conditions in the different locations within the sheathing panels (OSB); the moisture conditions at the different panel locations are related to their respective proximity to the moisture load. Whereas for the plot of St John's (NL), there is first a marked increase in the first simulation year followed by a decrease (~300 -500 d) and thereafter another increase over the second simulation year (~ 500-600 d). Plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB -glass fibre interface), the one closet to the moisture load, in these plots, being the "OSB-sliver", representative of a 1 mm thick sliver of the exterior face of the 11 mm thick sheathing panel and the component in closest contact with the membrane.

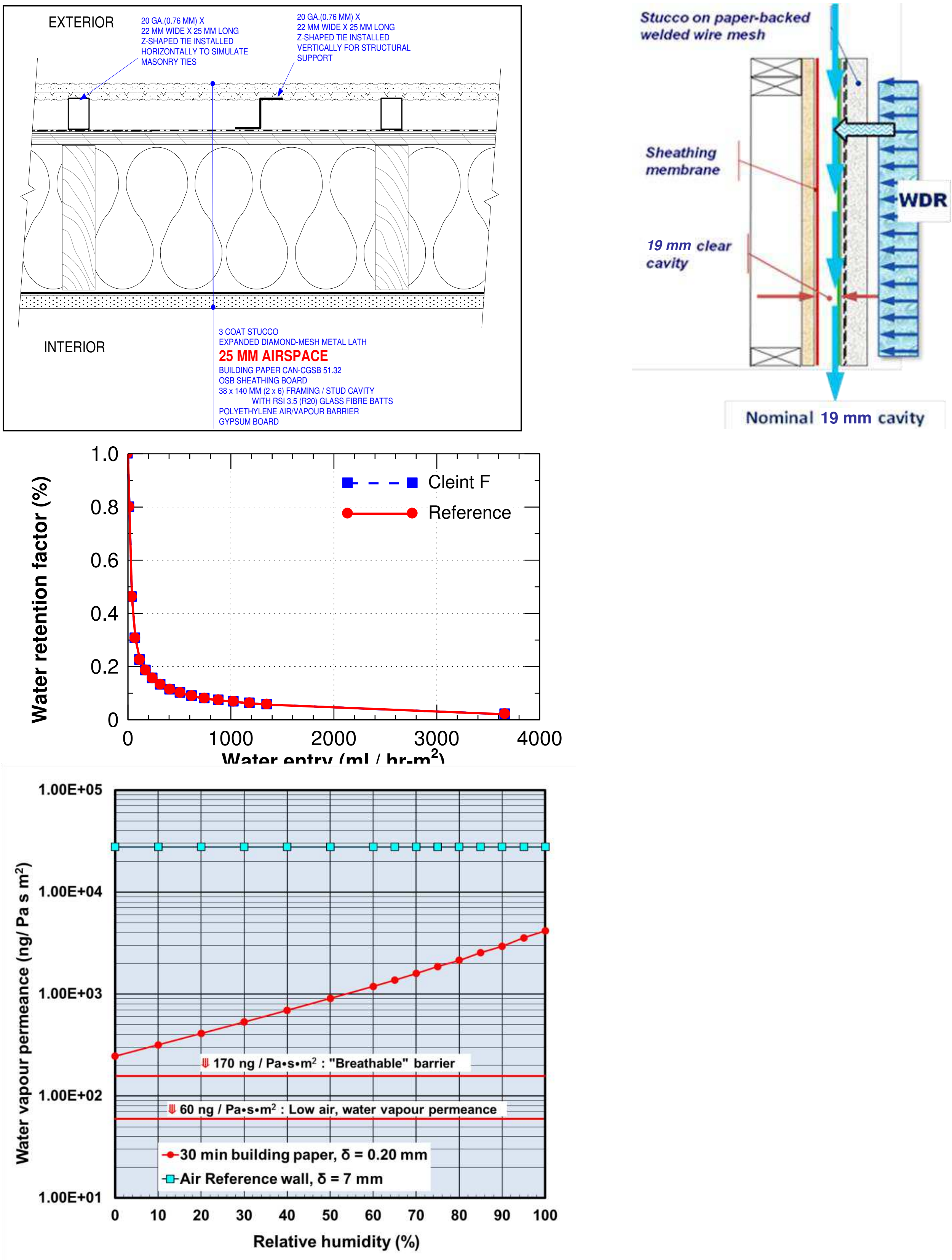


Figure 55 - Client F Wall: Sectional view; and water retention characteristics; water vapour permeance of sheathing membrane; δ = membrane thickness

In respect to the values of M_{IDX} in relation to the location of interest for which a response has been given, the greatest value is that which is closest to the membrane and the ML and the lowest value, furthest from the membrane and the ML. The higher values of M_{IDX} are those closest to the SM and the location where the ML was applied and thereafter diminish as the location of interest recedes from the exterior face of the sheathing panel to the interior face of the gypsum panel, and where this surface is at the interface between the OSB and the interior insulation. Thus the critical values in respect to assessing the management of moisture ingress to the drainage cavity are those provided for the 1 mm gypsum sliver. Whereas, if the risk of condensation is the measure of importance in respect to wall performance , then the focus is on the interface between the insulation and the OSB panel, that is, the "OSB-fibre interface" as given in Figure 56.

The response of the Reference and Client F Walls of the OSB panel component (1 mm sliver on exterior OSB surface) over the same period are shown in Figure 57; values for M_{IDX} as a function of time are provided for three plots in which the simulation are given, for the respective locations, from left to right, for the climate loads of Tofino and Vancouver (BC) and St John's (NL). The similarity of the plot of values over time between the Reference and the Client F walls suggests that the Client F walls have a similar response to the Reference walls when subjected to the climate loads of the respective locations.

The information provided in Table 27 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client F's wall. As is evident from these plots and from the information provided in the table, the values for M_{IDX} of Client F's wall are all less than that of the Reference wall, irrespective of the value for M_{IDX} of the layer or interface and the locations for which the simulations were completed.

Hygrothermal response of wall components to climate loads of Tofino and Vancouver (BC) and St John's(NL); RHT(x) criterion

The response of Client F's wall to climate loads of Tofino and Vancouver (BC) and St John's (NL) as provided by plots of the temperature and relative humidity levels and from which are determined values for RHT(x) index, are shown in Figure 58. The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client F walls and for different threshold values of RH are given in Table 28.

The values for RHT(80) and RHT(85) for the Client F wall are all greater than that of the Reference wall whereas values for RHT(92) and RHT(95) are all less than that of the Reference wall. The values for RHT(92) and RHT(95) are consistent with values determined for M_{IDX} as were made available in Table 27.

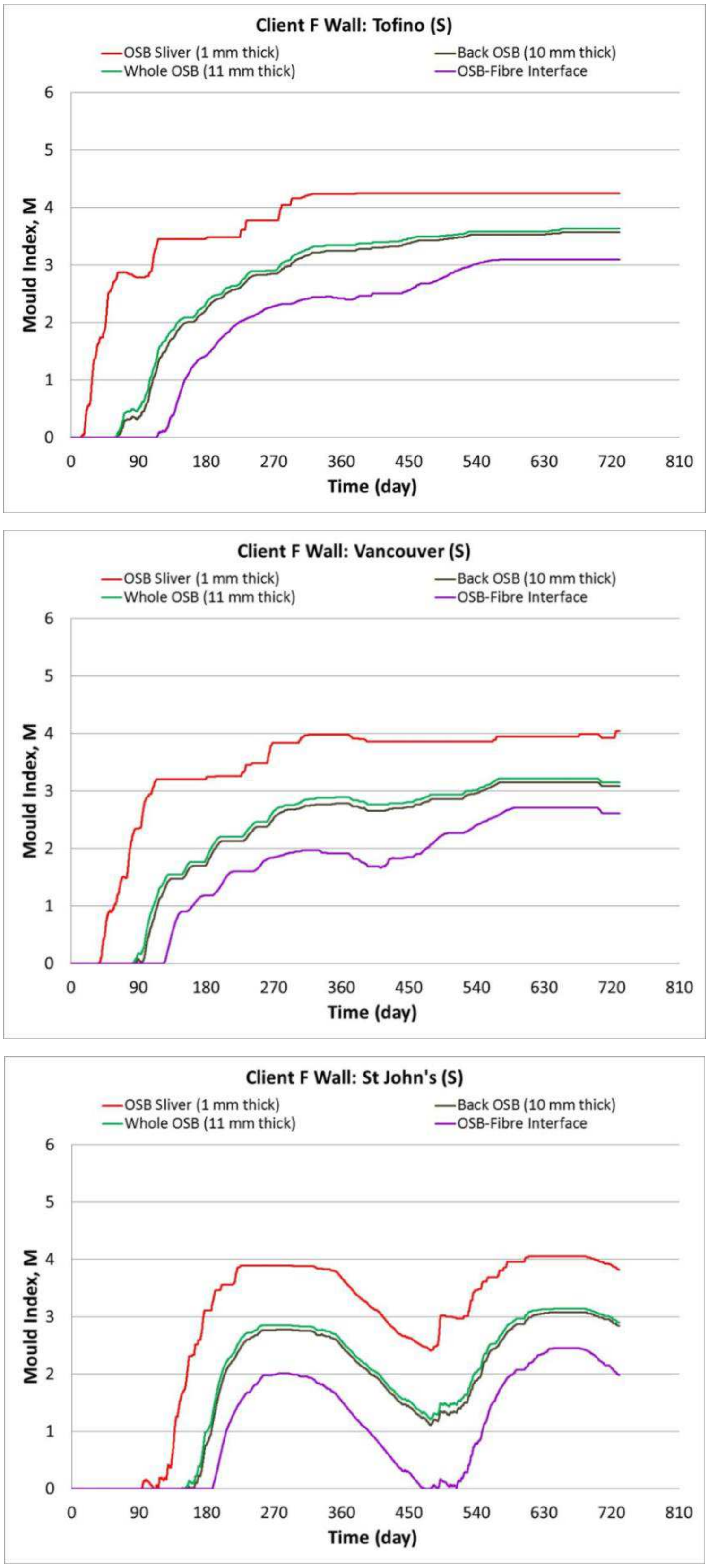


Figure 56 - Client F Walls: Response of OSB component to climate loads of Tofino, and Vancouver (BC) and St. John's (NL); response given as M_{IDX} value for sensitivity class "S

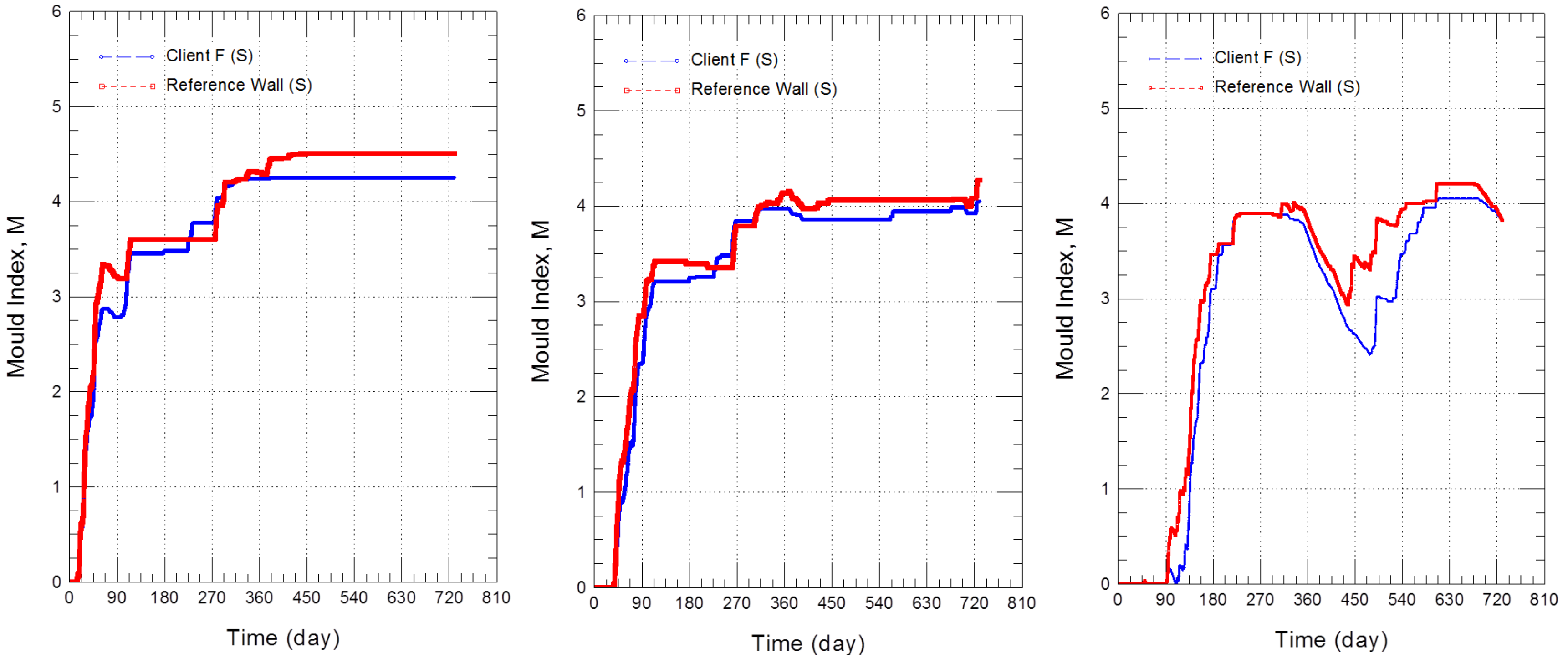


Figure 57 - Reference and Client F Walls : Response of OSB component (1 mm sliver on exterior OSB surface) to climate loads of (from left to right) Tofino and Vancouver (BC) and St. John's (NL); response given as M_{IDX} value for sensitivity class "S"

Table 27 - – Response of Reference (REF.) and Client F Walls to climate loads Tofino and Vancouver (BC) and St John's (NL) Average and maximum values of M_{IDX} for different locations in walls in which Moisture Load was placed between Building paper and cladding

	Tofino				Vancouver				St John's			
	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
REF-Avg	3.910	2.506	2.597	1.819	3.085	1.941	2.035	1.147	3.500	2.181	2.271	1.518
REF-Max	4.508	3.475	3.538	2.984	4.210	3.191	3.261	2.562	4.270	3.082	3.149	2.633
Client E - Avg	3.726	2.659	2.736	2.054	3.350	2.247	2.326	1.665	2.820	1.764	1.842	1.058
Client E-Max	4.247	3.565	3.626	3.089	4.043	3.147	3.207	2.702	4.047	3.076	3.135	2.448

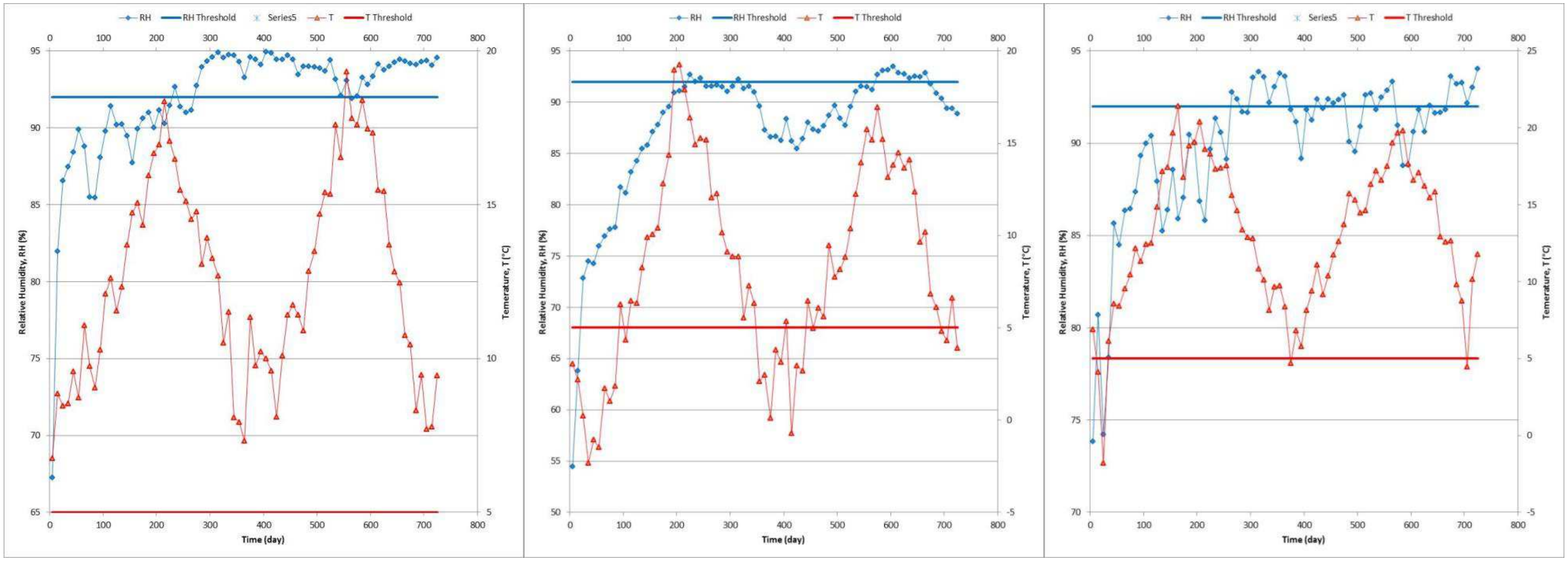


Figure 58 – Client F Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of (from left to right) Tofino and Vancouver (BC) and St. John's (NL); response given as RHT(x) where x relates to the RH threshold value at which the index is provided

Table 28 – Reference and Client F Wall: Response of OSB component to climate loads of Tofino and Vancouver (BC) and St John's (NL); response given as RHT(x) where x relates to the RH threshold value at which the index is provided

	Tofino				Vancouver			St John's			
	RHT(80)	RHT(85)	RHT(92)	RHT(95)	RHT(80)	RHT(85)	RHT(92)	RHT(80)	RHT(85)	RHT(92)	
Ref Wall	5263	3015	435	37	4958	2493	192	2961	1786	193	Ref Wall
Client F	6809	4058	616	0	6189	3222	167	3536	2007	120	Client F

5.7 Client G Drainage System

Overview of Drainage System – Client G

A sectional view of the wall configuration incorporating Client G's product is shown in Figure 59; the drainage system is comprised of a non-woven PP fabric bonded to a 10 mm mat of extruded PP mono-filament mesh, and NBC compliant building paper. The water retention characteristics of this drainage system suggest that for given water entry rates, the drainage system retains more water as compared to the Reference drainage system.

I think it might be important to add a paragraph to explain that the water retention of Client E is much greater than that for the Reference.

A plot of the water vapour permeance (WVP) of various sheathing membranes (SM), including that of Client G, is also provided; it is apparent that the WVP of Client G's product and that is in contact with the backside of the stucco, is ca. 2 orders of magnitude greater than NBC-compliant SM (30 min. building paper (BP) conforming to CGSB standard [12]). Client G's SM is NBC-compliant 30 min BP. As such, the performance would be related to the extent to which water vapour permeates the SM and this would in turn depend on the amount of moisture that is retained on the SM following a rain event and the prevailing temperature in the drainage cavity.

In regard to placement of the moisture load (ML) in the drainage cavity, for the purposes of simulations, ML was assumed to be placed either on the backside of the cladding, between the cladding and the building paper, or on the SM. The rationale for placement of the ML on the SM was as follows: water would enter the drainage space at the many fastener locations across the wall and by gravity percolate downwards within the mono-filament mesh, and ultimately find its way to the surface of the SM; a plausible scenario was deemed to be for 50 % of the ML attaining the surface of the SM.

Thus 50% of the moisture load in the case of Client G's wall is placed directly on the sheathing membrane and remaining portion behind the cladding as was done for the Reference wall; as well, the WVP of the SM of Client G's wall is the same as that used in the Reference wall. Combining these two elements, that is, equivalent SM and placement of the moisture load in the drainage cavity, suggests that Client G's wall, as compared to the Reference wall, would be somewhat disadvantaged in respect to managing moisture ingress to the drainage cavity.

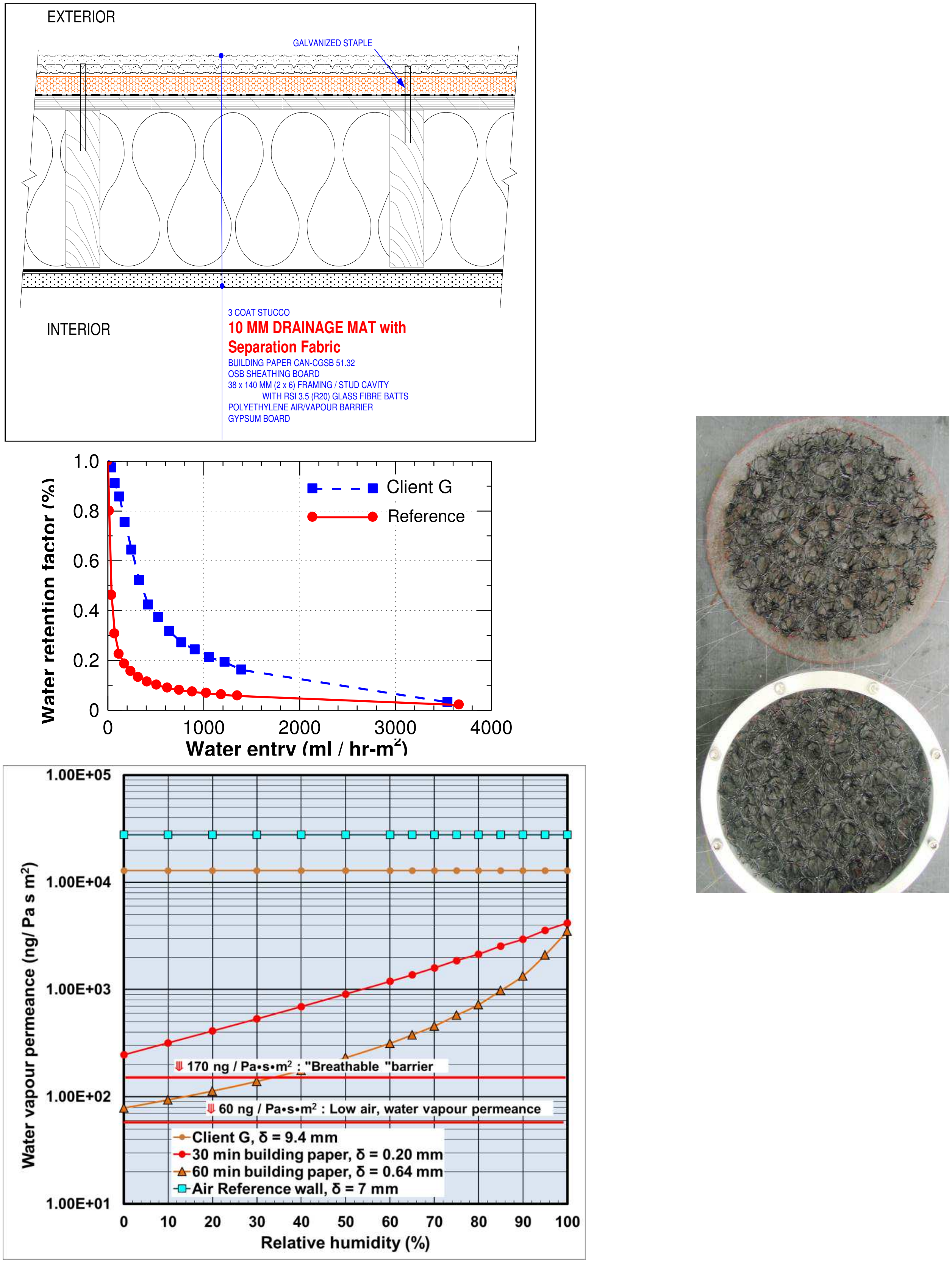
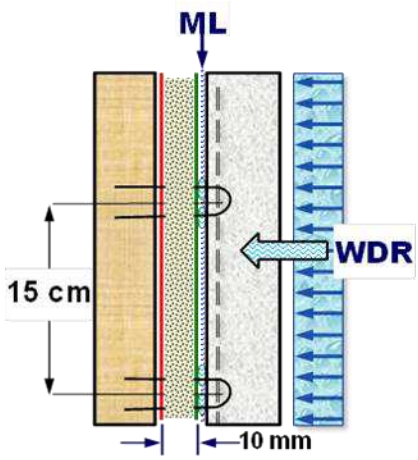


Figure 59 – Client G Wall: Sectional view, placement of ML in 10 mm drainage cavity; water retention characteristics; water vapour permeance of sheathing membrane; δ = membrane thickness

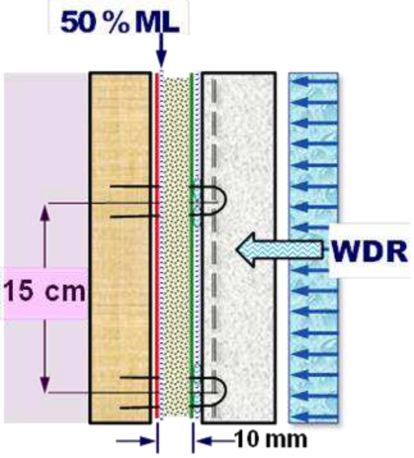
Results from Simulation – Client G Drainage System

Hygrothermal response of wall components to climate loads of Tofino; M_{IDX} criterion

The response of the Client G wall assembly to the climate loads of Tofino (BC) are provided in Figure 60 to Figure 62 and in Table 29 and Table 30. More specifically, the variation in values for M_{IDX} over the course of the simulation period and in respect to the different locations in the wall, are provided in three plots of Figure 60. The upper-most plot shows the variation over the simulation when the moisture load (ML) was placed between the cladding and the building paper (BP); the middle plot shows values of M_{IDX} over the simulation when 50% of the moisture load (ML) was placed on the sheathing membrane (SM) and remaining 50% between the cladding and the PP fabric, whereas; the lower-most plot shows the variation for 50% of the ML placed on the SM and the system was "ventilated". The location of the ML for all these conditions is shown in the adjacent inset.



The variations given in the middle and lower-most plots resulted from attempting to find solutions for which the drainage system could adequately accommodate the ML to which it was subjected. As a consequence of these efforts, the variations shown here also include 2-layers of BP as compared to the 1 layer specified for this system.



In the plots of Figure 60, the values for M_{IDX} over the course of the simulation period increase over time depending on the propensity for mould growth given the moisture and temperature conditions in the different locations within the sheathing panels (OSB); the moisture conditions at the different panel locations are related to their respective proximity to the moisture load. Plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB-glass fibre interface), the one closet to the moisture load, in these plots, being the "OSB Sliver", representative of a 1 mm thick sliver of the exterior face of the 11 mm thick sheathing panel and the component in closest contact with the SM.

Observations common to all plots of Figure 60:

- The values of M_{IDX} diminish in relation to the distance from where the ML is applied to the location of interest for which a response has been given.
- The higher values of M_{IDX} are those closest to the SM and the location where the ML was applied and thereafter diminish as the location of interest recedes from the exterior face of the sheathing panel to the interior face of the OSB panel, and where this surface is at the interface between the OSB and the interior insulation.
- The values for M_{IDX} of the entire OSB panel (i.e. "whole" OSB 11 mm thick) are always greater than the 10 mm portion of OSB behind the 1 mm sliver (i.e. "back" of OSB, 10 mm thick) given

that the values for M_{IDX} of the 1 mm sliver are always the greatest values for M_{IDX} amongst the different locations in the wall.

- The values provided for the 1 mm OSB sliver are the critical values from which the response of the wall assembly is measured in respect to managing moisture ingress to the drainage cavity, whereas,
- If the risk of condensation is the measure of importance in respect to wall performance , then the focus ought to be on the interface between the insulation and the OSB panel, that is, the "OSB-fibre interface" as given in Figure 60.

The differences in response of the OSB component (1 mm sliver on exterior OSB surface) to the location of the ML in the wall assembly is apparent from the lower values of M_{IDX} obtained in the instance where the ML is placed between the cladding and the BP as compared to having 50% of the ML placed on the SM; the ML being in direct contact with the SM brings it in closer proximity to the wood-based and moisture sensitive components of the wall assembly. As well, the contribution of "ventilation" of the drainage cavity is evident when comparing the values of M_{IDX} for the "OSB-sliver" of the middle and lower-most plots of Figure 60; there is an evident reduction in values of M_{IDX} brought about with "ventilation" of the system, although its impact is minor.

The response of the Reference and Client G walls of the OSB component (1 mm sliver on exterior OSB surface) to climate loads of Tofino (BC) over the same period are shown Figure 61; values for M_{IDX} as a function of time for the:

- Left-hand plot is for the ML placed on backside of the cladding (i.e. between cladding and fabric);
- Middle plot is for 50% of the ML placed on the SM (i.e. building paper) and 50% between the cladding and fabric, the SM consisting of 2-layers of NBC-compliant BP;
- Right-hand plot is for the same ML load conditions as provided in the middle plot and the system "ventilated".

When the ML was placed:

- Between the PP fabric and the cladding (left-hand plot; Figure 61), the Client G wall had values for M_{IDX} equivalent to the Reference wall;
- 50% on the SM and 50% between the cladding and PP fabric (Middle plot; Figure 61), the Client G wall had values for M_{IDX} less than that of the Reference wall up to day 270 and thereafter had higher values, whereas;
- 50% on the SM and 50%, between the cladding and PP fabric (right-hand plot; Figure 61), and the system was "ventilated", Client G's wall had values for M_{IDX} less than that of the Reference wall up to day 270 and thereafter had higher values for the M_{IDX}.

The information provided in Table 29 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client G's wall. For all instances, irrespective of where the ML was placed, values for M_{IDX} of the layer or interface of Client G's wall were all greater than the Reference wall.

Given these results it is evident that for the climate loads of Tofino (BC) Client G's wall did not manage moisture ingress to the drainage cavity as well as the Reference wall.

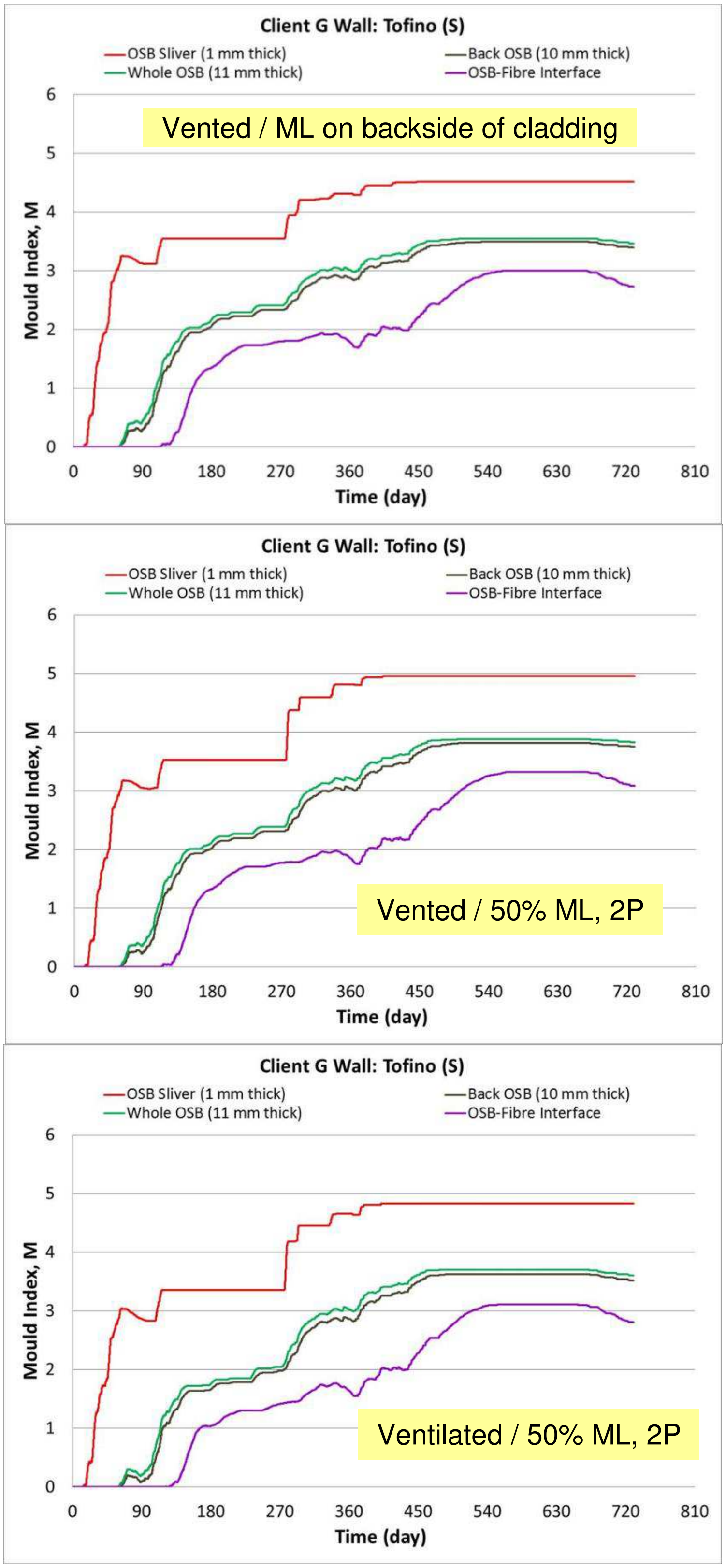


Figure 60 - Client G Wall: Response of OSB component to climate loads of Tofino (BC); response given as M_{IDX} value for sensitivity class "S

Hygrothermal response of wall components to climate loads of Tofino; RHT(x) criterion

The response of Client G's (in the 1 mm "OSB-sliver") wall to climate loads of Tofino (BC) as determined by the value of the RHT(x) index is shown in Figure 62.

The values for relative humidity and temperature over the simulation period for the ML placed: (i) Left-hand plot - Between the PP fabric and the cladding; (ii) Middle plot - 50% on the SM and 50%, between the cladding and PP fabric; (iii) Right-hand plot - 50% on the SM and 50%, between the cladding and PP fabric, and the system was "ventilated".

A review of the different plots in Figure 62 provide some insight into the importance of "ventilation" as a strategy to attenuate the rise in RH of the "OSB-sliver"; without "ventilation" (middle plot), the RH of the "OSB sliver" attains exceedingly high levels (i.e. >98% RH) whereas with "ventilation", the 92% RH threshold is exceeded only very few items at about day 400.

The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client G walls and for different threshold values of RH are given in Table 30. The respective values for RHT(x) are all greater for Client G's wall as compared to the Reference wall for all instances of placement of ML, each component and every interface of the assembly, and regardless of the venting strategy; this also is consistent with that which was determined from a comparison of M_{IDX} values as was made available in Table 29.

Hygrothermal response of wall components to climate loads of Vancouver; M_{IDX} criterion

The response of the Client G's wall assembly to the climate loads of Vancouver (BC) are provided in Figure 63 to Figure 65 and in Table 31 and Table 32.

More specifically, the variation in values for M_{IDX} over the course of the simulation period and in respect to the different locations in the wall, are provided in three plots of Figure 63. The upper-most plot shows the variation over the simulation when the moisture load (ML) was placed between the cladding and the PP fabric; the middle plot shows values of M_{IDX} over the simulation when 50% of the moisture load (ML) was placed on the sheathing membrane (SM) and remaining 50% between the cladding and the PP fabric, whereas; the lower-most plot shows the variation for 50% of the ML placed on the SM and the system was "ventilated". The location of the ML for all these conditions is the same as was previously given for Tofino.

As was the case for Tofino, the variations given in the middle and lower-most plots resulted from attempting to find solutions for which the drainage system could adequately accommodate the ML to which it was subjected; variations thus include 2-layers of BP as compared to the 1 layer specified for this system and a "ventilated" system as compared to a "vented" system, as specified for this system.

In the plots of Figure 63, the values for M_{IDX} over the course of the simulation increase over time depending on the propensity for mould growth given the moisture and temperature conditions in the different locations within the sheathing panels (OSB); the moisture conditions at the different panel locations are related to their respective proximity to the moisture load. Plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB-glass fibre interface), the one closet to the moisture load, in these plots, being the "OSB Sliver", representative of a 1 mm thick sliver of the exterior face of the sheathing panel.

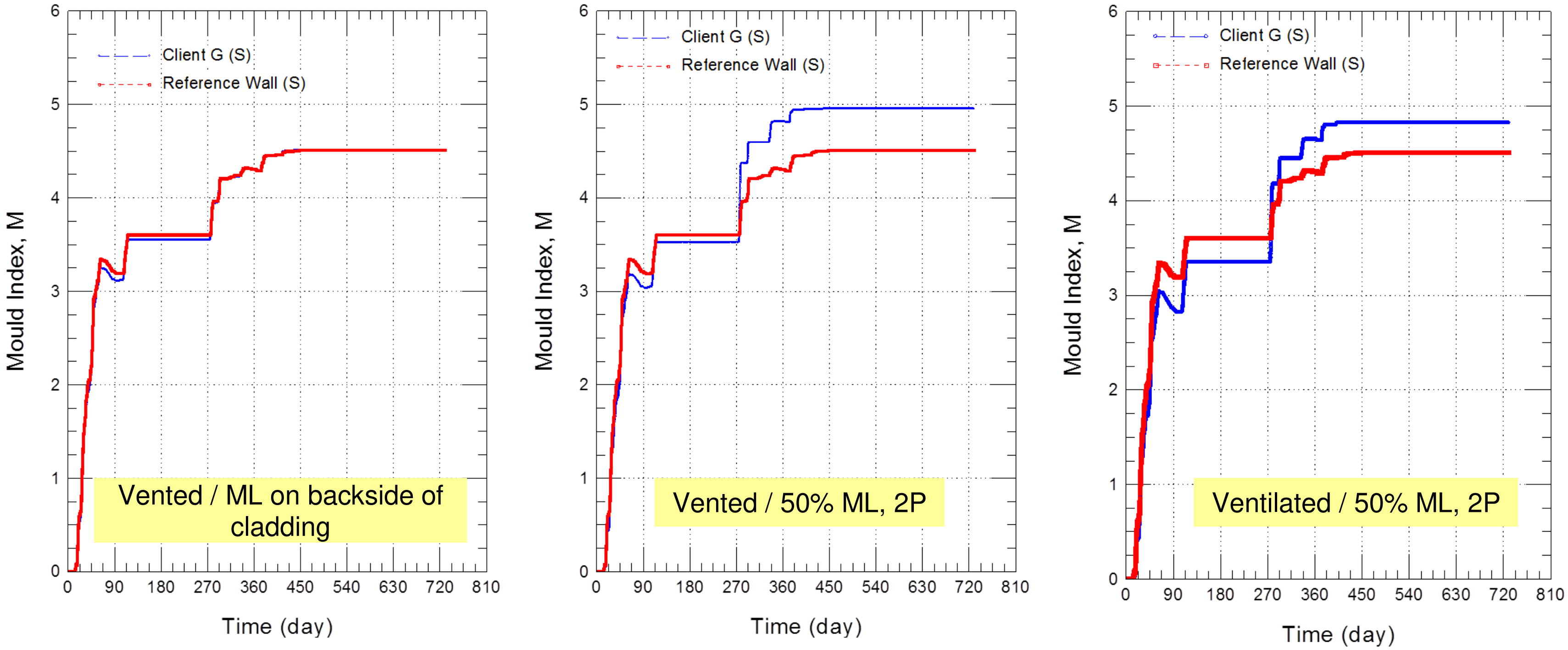


Figure 61 – Reference & Client G Walls: Response of OSB to climate loads of Tofino, BC; response given as M_{IDX} value for sensitivity class “S

Table 29 – Response of Reference & Client G Walls to climate loads of Tofino, BC (BC); Average & maximum values of M_{IDX} for wall locations where: (i) ML* placed between PP fabric & Cladding; (ii) 50 % ML on building paper; system vented; (iii) 50 % ML on building paper; system ventilated

	Tofino: Vented				**Tofino: Vented / 50% ML, 2P**				**Tofino: Ventilated / 50% ML, 2P**			
	OSB Sliver (1 mm)	**Back OSB (10 mm)**	**Whole OSB (11 mm)**	**OSB-Fibre Interface**	**OSB Sliver (1 mm)**	**Back OSB (10 mm)**	**Whole OSB (11 mm)**	**OSB-Fibre Interface**	**OSB Sliver (1 mm)**	**Back OSB (10 mm)**	**Whole OSB (11 mm)**	**OSB-Fibre Interface**
REF Avg	3.910	2.506	2.597	1.819	3.910	2.506	2.597	1.819	3.910	2.506	2.597	1.819
REF Max	4.508	3.475	3.538	2.984	4.508	3.475	3.538	2.984	4.508	3.475	3.538	2.984
Client G Avg	3.886	2.506	2.597	1.825	4.144	2.671	2.766	1.957	4.001	2.464	2.562	1.764
Client G Max	4.512	3.486	3.548	2.996	4.950	3.813	3.874	3.314	4.823	3.623	3.692	3.098

* ML: Moisture Load; 1P: 1 layer of code-compliant building paper as sheathing membrane; 2P: 2 layers of code-compliant building paper as sheathing membrane

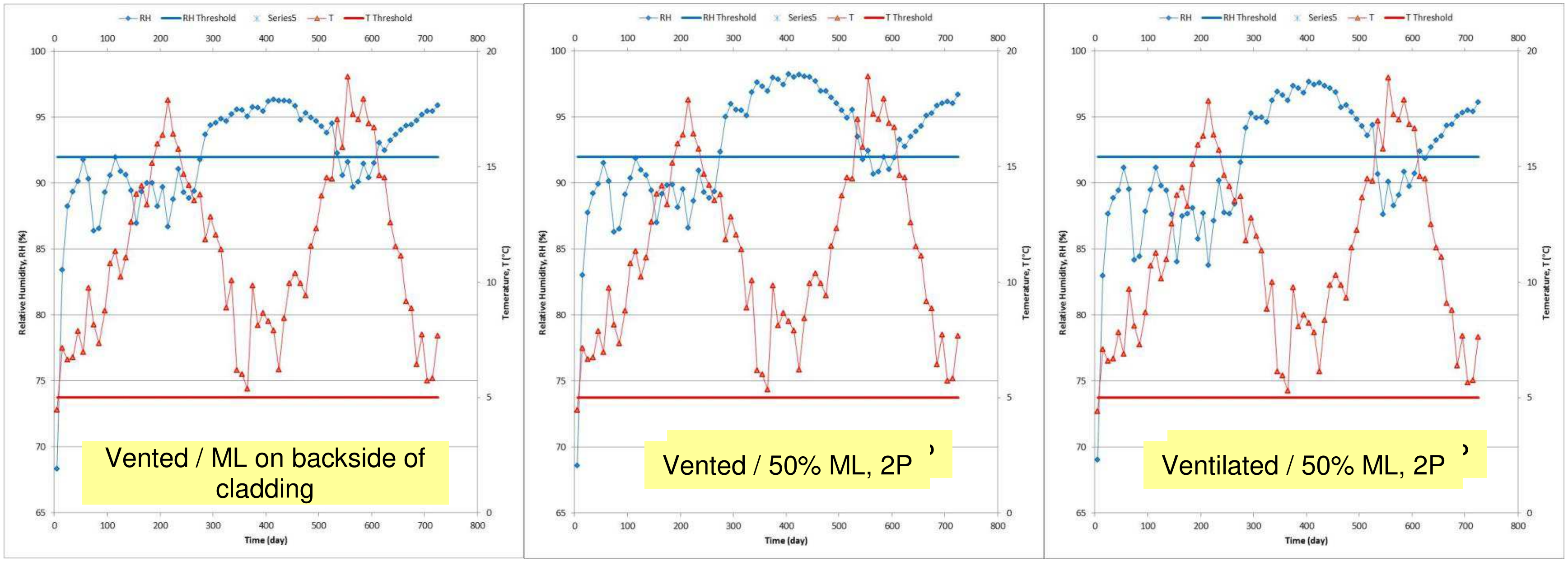


Figure 62 – Client G Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of Tofino (BC); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

Table 30 – Response of Ref. & Client G Walls to climate of Tofino (BC); values of RHT(x) where x is RH threshold value at which index calculated: (i) ML* placed between PP fabric & cladding; (ii) 50 % ML on 2 layers of BP ; system vented; (iii) 50 % ML on 2 layers of BP; system ventilated

	Tofino:				Tofino: Vented / 50% ML, 2P				Tofino: Ventilated / 50% ML, 2P			
	RHT(80)	RHT(85)	RHT(92)	RHT(95)	RHT(80)	RHT(85)	RHT(92)	RHT(95)	RHT(80)	RHT(85)	RHT(92)	RHT(95
Ref Wall	5263	3015	435	37	5263	3015	435	37	5263	3015	435	37
Client G	5414	3106	461	39	5683	3375	688	183	4986	2728	501	99

*ML: Moisture Load; BP: building paper

Observations common to all plots of Figure 63 are the same as those provided for plots of Figure 60 for Tofino.

The differences in response of the OSB component (1 mm sliver; exterior OSB surface) to the location of the ML in the wall assembly is not entirely apparent given that essentially the same values for M_{IDX} were obtained in the instance where the ML is placed between the cladding and PP fabric, as compared to having 50% of the ML placed on the SM. However, the contribution of "ventilation" of the drainage cavity is perhaps more evident when comparing the values of M_{IDX} for the "OSB-sliver" of the middle and lower-most plots of Figure 63; there is an evident reduction in values of M_{IDX} brought about with "ventilation" of the system, although its impact is minor.

The response of the Reference and Client G Walls of the OSB component (1 mm sliver on exterior OSB surface) to climate loads of Vancouver (BC) over the same period are shown in Figure 64; values for M_{IDX} as a function of time for the:

- Left-hand plot, are for the ML placed between the cladding and PP fabric;
- Middle plot are for 50% of the ML placed on the SM and 50%, between the cladding and PP fabric, the SM consisting of 2-layers of NBC-compliant BP;
- Right-hand plot are for the same ML load as provided in the middle plot and "ventilated" system.

When the ML was placed:

- Between the PP fabric and the cladding (Left-hand plot; Figure 64), the Client G wall had values for M_{IDX} equivalent to the Reference wall;
- 50% on the SM and 50%, between the cladding and PP fabric (Middle plot; Figure 64), the Client G wall had values for M_{IDX} less than that of the Reference wall from day ~90, whereas;
- 50% on the SM and 50%, between cladding and PP fabric (Right-hand plot; Figure 64), and system was "ventilated", Client G's wall had values for M_{IDX} < Reference wall from day ~90.

The information provided in Table 31 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client G's wall. Values for M_{IDX} of Client G's wall were ca. equivalent to the Reference wall when the ML was placed between the PP fabric and cladding. Whereas values for M_{IDX} of Client G's wall for the ML placed on 2 layers of SM and either vented or ventilated, were all less than that of the Reference wall.

Given these results it is evident that for the climate loads of Vancouver (BC) Client G's wall could manage moisture ingress to the drainage cavity as well as the Reference wall provided the system had at least 2 layers of NBC-compliant SM and preferably also incorporated a "ventilation" strategy.

Hygrothermal response of wall components to climate loads of Vancouver (BC); RHT(x) criterion

The response of Client G's wall to climate loads of Vancouver (BC) as determined by the value of the RHT(x) index is shown in Figure 65. The left-hand plot of Figure 65shows values for relative humidity and temperature over the simulation period for the instance where the ML was placed between the PP fabric and the cladding; the middle plot for the ML is on the SM (50%) and incorporates 2-layers of SM; the right-hand plot, the ML is on the SM (50%), incorporates 2-layers of SM and also a "ventilation" strategy.

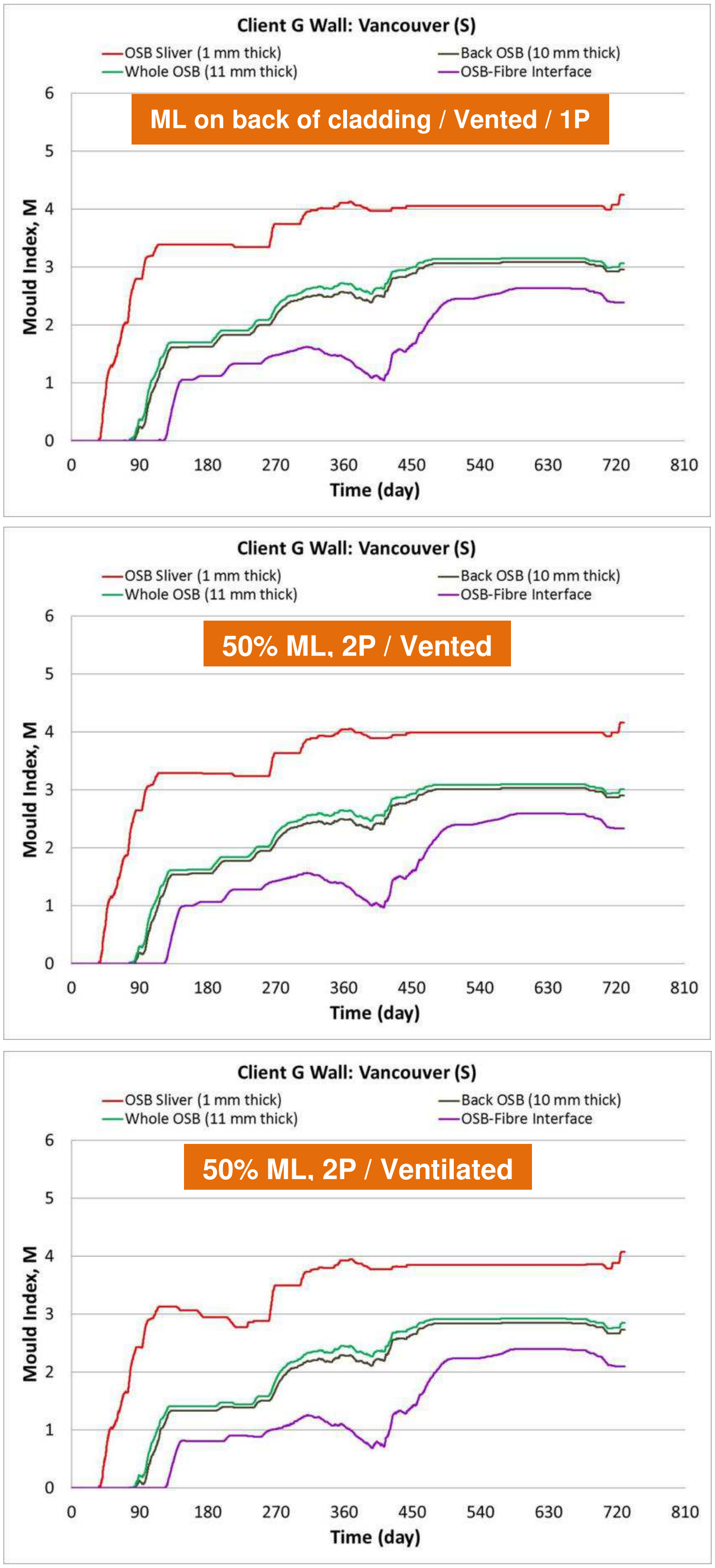


Figure 63 - Client G Wall: Response of OSB component to climate loads of Vancouver (BC); response given as M_{IDX} value for sensitivity class "S

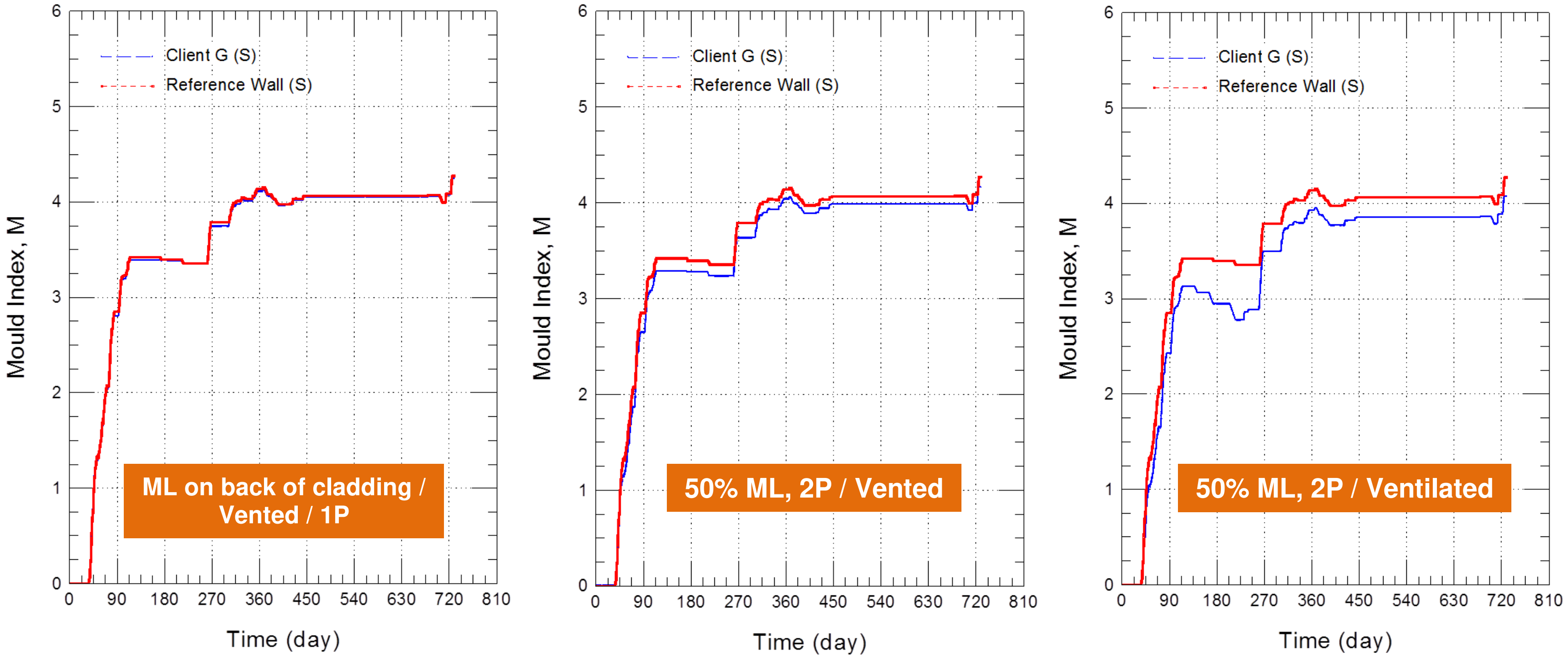


Figure 64 – Reference & Client G Walls: Response of OSB to climate loads of Vancouver (BC); response given as M_{IDX} value for sensitivity class “S

Table 31 – Response of Reference & Client G Walls to climate loads of Vancouver (BC); Average & maximum values of M_{IDX} for wall locations where: (i) ML* placed between PP fabric & Cladding; (ii) 50 % ML on building paper; system vented; (iii) 50 % ML on building paper; system ventilated

	Vancouver				Vancouver / 50% ML; 2P; Vented				Vancouver50% ML; 2P; Ventilated			
	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
REF.-Avg.	3.500	2.181	2.271	1.518	3.500	2.181	2.271	1.518	3.500	2.181	2.271	1.518
Ref.-Max.	4.270	3.082	3.149	2.633	4.270	3.082	3.149	2.633	4.270	3.082	3.149	2.633
Client G-Avg.	3.479	2.179	2.267	1.525	3.395	2.123	2.210	1.476	3.232	1.931	2.021	1.276
Client G-Max.	4.246	3.080	3.143	2.633	4.161	3.028	3.090	2.583	4.071	2.845	2.916	2.392

***ML: Moisture Load; BP: building paper; 2P: 2 layers of building paper**

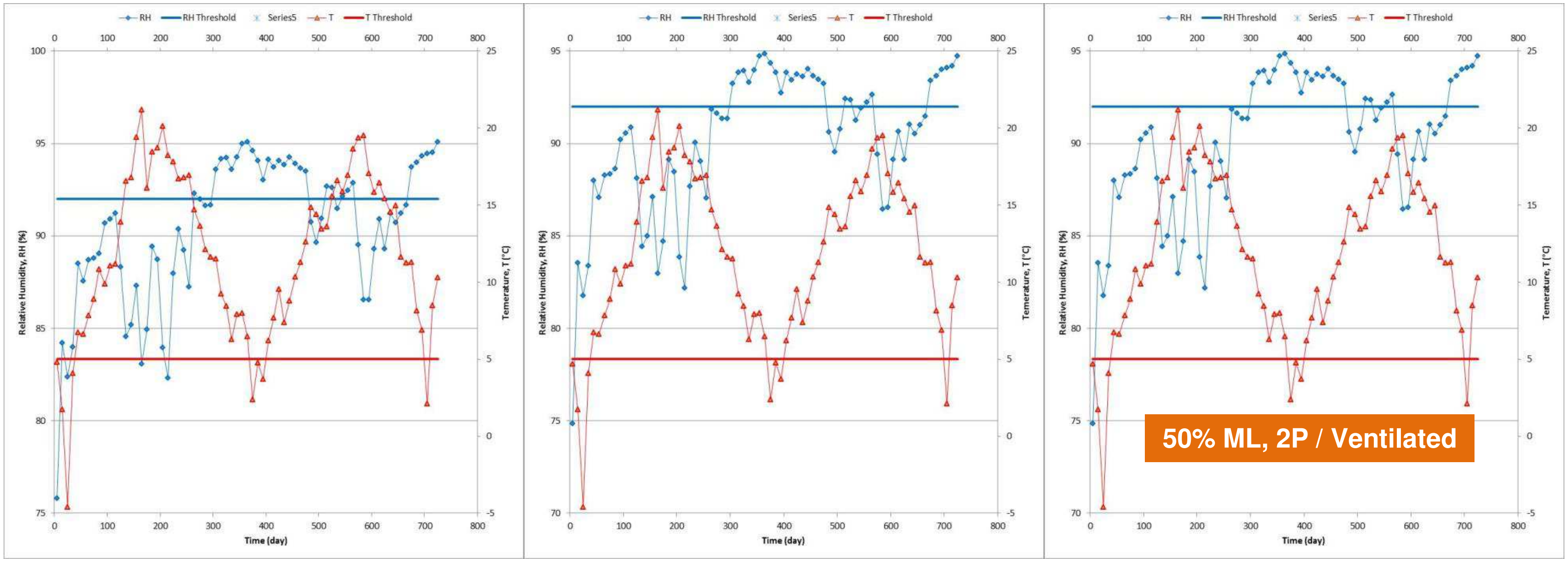


Figure 65 – Client G Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of Vancouver (BC); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

Table 32 – Response of Ref. & Client G Walls to climate loads of Vancouver (BC); values of RHT(x) where x is RH threshold value at which index calculated: (i) ML* placed between PP fabric & cladding; (ii) 50 % ML on 2 layers of BP; system vented; (iii) 50 % ML on 2 layers of BP; system ventilated

	Vancouver / ML - back of cladding				Vancouver / 50% ML; 2P; Vented				Vancouver / 50% ML; 2P; Ventilated			
	RHT(80)	RHT(85)	RHT(92)	RHT(95)	RHT(80)	RHT(85)	RHT(92)	RHT(95)	RHT(80)	RHT(85)	RHT(92)	RHT(95)
REF.-Wall	4958	2493	192	2	4958	2493	192	2	4958	2493	192	2
Client G-Vented	5055	2541	191	1	4938	2433	154	0	-	-	-	-
Client G-Ventilated	-	-	-	-	-	-	-	-	4229	1953	90	0

*** ML: Moisture Load; BP: building paper; 2P: 2 layers of building paper**

Hygrothermal response of wall components to climate loads of Vancouver (BC); RHT(x) criterion (cont'd)

The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client G walls and for different threshold values of RH are given in Table 32.

The values for RHT(80) and RHT(85) are all greater than that of the Reference wall when the ML is placed on the backside of the cladding and are essentially equivalent to the Reference wall for RHT(92). Values of RHT(80), RHT(85), RHT(92) and RHT(95) for Client G's wall having 50% of the ML placed on 2 layers of NBC-compliant SM are all less than the Reference wall irrespective of whether the wall is vented or ventilated; these results are consistent with those of M_{IDX} provided in Table 32.

Hygrothermal response of wall components to climate loads of St John's (NL); M_{IDX} criterion

The response of the Client G's wall assembly to the climate loads of St John's (NL), are provided in Figure 66 to Figure 68 and in Table 33 and Table 34.

More specifically, the variation in values for M_{IDX} over the course of the simulation period and in respect to the different locations in the wall, are provided in three plots of Figure 66. The upper-most plot shows the variation over the simulation when the moisture load (ML) was placed between the cladding and the PP fabric the middle plot for values of M_{IDX} when 50% of the moisture load (ML) was placed on the sheathing membrane (SM) and the remaining 50% between the cladding and the PP fabric, whereas; the lower-most plot shows the variation for 50% of the ML placed on the SM and the system was "ventilated". The location of the ML for all these conditions is the same as was previously given for Tofino and Vancouver.

As was the case for Tofino and Vancouver, the variations given in the middle and lower-most plots resulted from attempting to find solutions for which the drainage system could adequately accommodate the ML to which it was subjected; variations thus include 2-layers of BP as compared to the 1 layer specified for this system and a "ventilated" system as compared to a "vented" system, as specified for this system.

In the plots of Figure 66, the values for M_{IDX} over the simulation increase over time depending on the propensity for mould growth given the moisture and temperature conditions in the different locations within the sheathing panels (OSB); the moisture conditions at the different panel locations are related to their respective proximity to the ML. Plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB-glass fibre interface), the one closet to the moisture load, in these plots, being the "OSB Sliver", representative of a 1 mm thick sliver of the exterior face of the sheathing panel. Observations common to all plots of Figure 66 are the same as those provided for plots of Figure 60 for Tofino and Figure 63for Vancouver.

The differences in response of the OSB component (1 mm sliver; exterior OSB surface) to the location of the ML in the wall assembly is not entirely apparent given that essentially the same values for M_{IDX} were obtained in the instance where the ML is placed between the cladding and the PP fabric , as compared to having 50% of the ML placed on the SM. However, the contribution of "ventilation" of the drainage cavity is perhaps more evident when comparing the values of M_{IDX} for the "OSB-sliver" of the middle and lower-most plots of Figure 66; there is a reduction in values of M_{IDX} brought about with "ventilation" of the system, although its impact is minor.

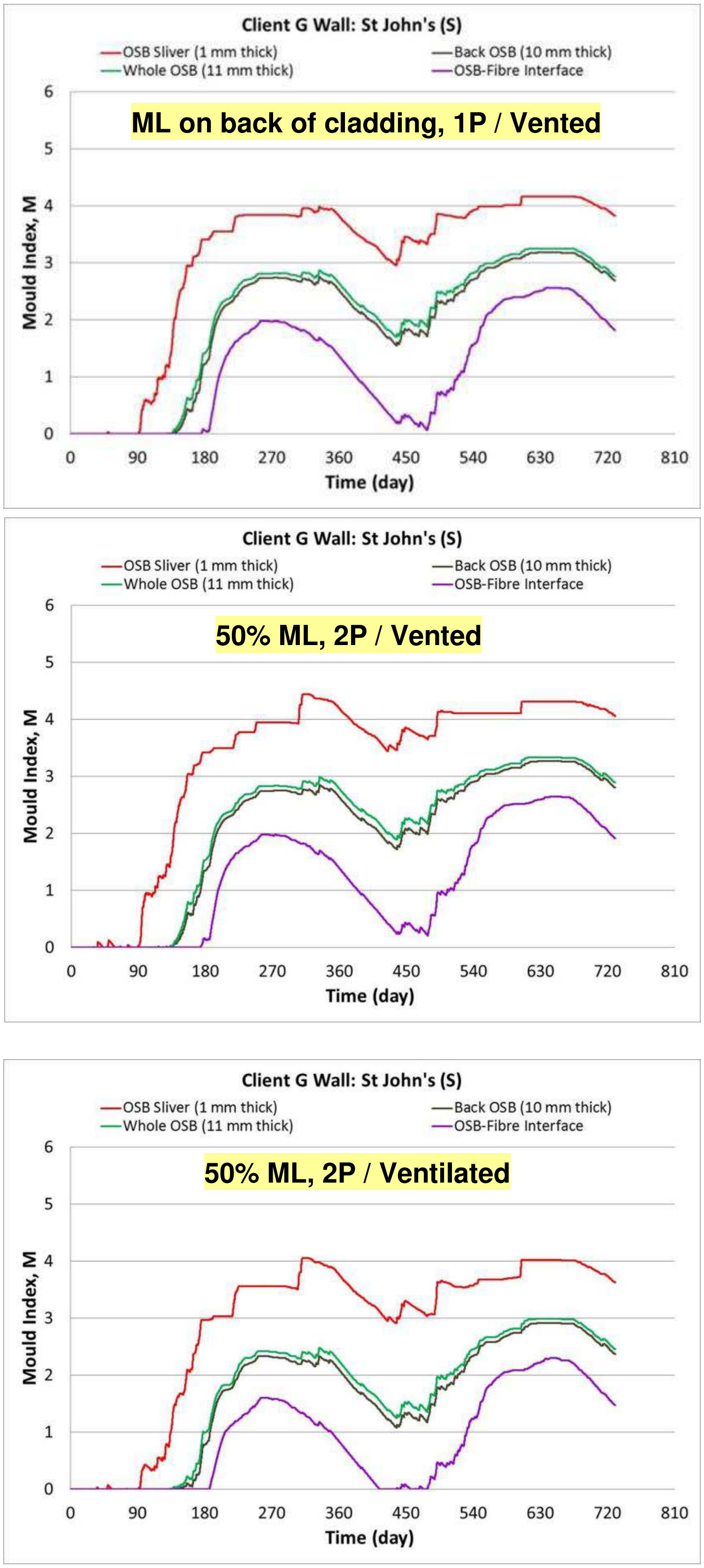


Figure 66 - Client G Wall: Response of OSB component to climate loads of St John's (NF); response given as M_{IDX} value for sensitivity class “S

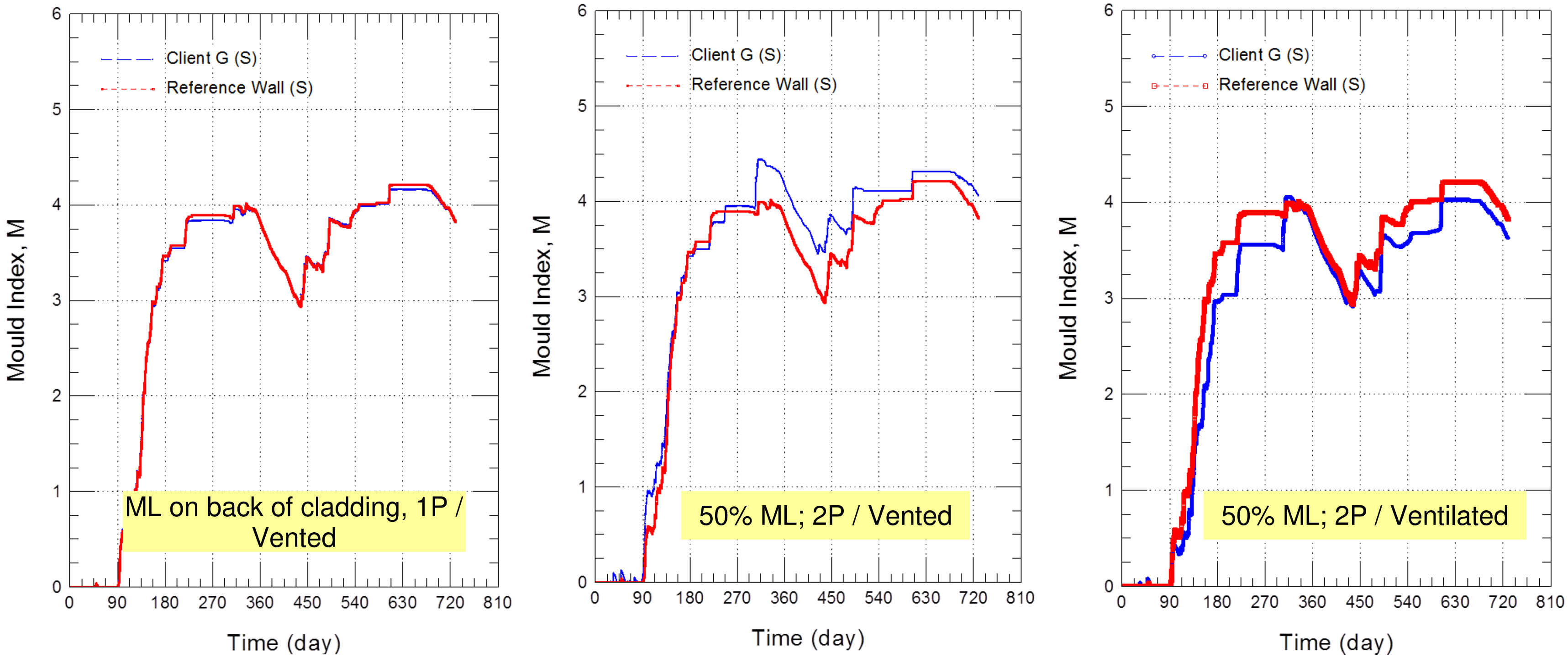
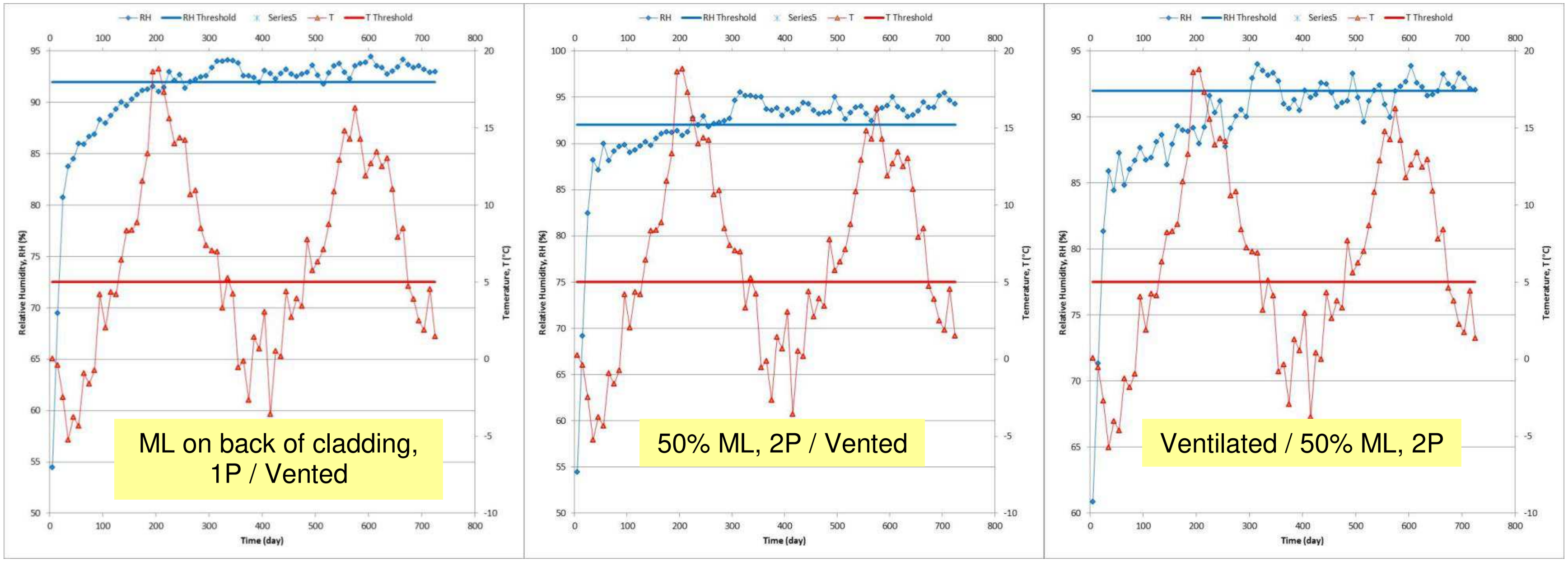


Figure 67 - – Reference & Client G Walls: Response of OSB to climate loads of St John's (NL); response given as M_{IDX} value for sensitivity class "S

Table 33 – Response of Reference & Client G Walls to climate loads of St John's (NL); Average & maximum values of M_{IDX} for wall locations where: (i) ML* placed between PP fabric & Cladding; (ii) 50 % ML on building paper; system vented; (iii) 50 % ML on building paper; system ventilated

St John's					St John's / 50% ML; 2P / Vented				St John's / 50% ML; 2P / Ventilated			
	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
REF.-Avg	3.085	1.941	2.035	1.147	3.085	1.941	2.035	1.147	3.085	1.941	2.035	1.147
REF.-Max	4.210	3.191	3.261	2.562	4.210	3.191	3.261	2.562	4.210	3.191	3.261	2.562
Client G-Avg	3.066	1.941	2.033	1.151	3.254	2.036	2.132	1.216	2.851	1.619	1.717	0.885
Client G-Max	4.157	3.179	3.248	2.560	4.432	3.263	3.332	2.642	4.049	2.914	2.985	2.294



ML on back of cladding, 1P / Vented

50% ML, 2P / Vented

Ventilated / 50% ML, 2P

Figure 68 - – Client G Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of St John's (NL); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

Table 34 - Response of Ref. & Client G Walls to climate of St John's (NL); values of RHT(x) where x is RH threshold value at which index calculated: (i) ML* placed between PP fabric & cladding; (ii) 50 % ML on 2 layers of BP ; system vented; (iii) 50 % ML on 2 layers of BP; system ventilated

	St John's			St John's / 50% ML; 2P / Vented				St John's / 50% ML; 2P / Ventilated			
	RHT(80)	**RHT(85)**	**RHT(92)**	**RHT(80)**	**RHT(85)**	**RHT(92)**	**RHT(95)**	**RHT(80)**	**RHT(85)**	**RHT(92)**	**RHT(95)**
REF Wall	2961	1786	193	2961	1786	193	0	2961	1786	193	0
Client G-Vented	3024	1814	186	3060	1850	222	1	-	-	-	-
Client G-Ventilated	-	-	-	-	-	-	-	2545	1349	42	0

The response of the Reference and Client G Walls of the OSB component (1 mm sliver on exterior OSB surface) to climate loads of Vancouver (BC) over the same period are shown in Figure 67; values for M_{IDX} as a function of time for the:

- Left-hand plot, are for the ML placed between the cladding and PP fabric;
- Middle plot are for 50% of the ML placed on the SM and 50%, between the cladding and PP fabric, the SM consisting of 2-layers of NBC-compliant BP;
- Right-hand plot are for the same ML load as provided in the middle plot and "ventilated" system.

When the ML was placed:

- Between the PP fabric and the cladding (Left-hand plot; Figure 67), the Client G wall had values for M_{IDX} perhaps equivalent to the Reference wall;
- 50% on the SM and 50%, between the cladding and PP fabric (Middle plot; Figure 67), the Client G wall had values for M_{IDX} greater than that of the Reference wall at day ~90 and thereafter day ~240, whereas;
- 50% on the SM and 50%, between cladding and PP fabric (Right-hand plot; Figure 67), and drainage system was "ventilated"; Client G's wall had values for M_{IDX} < Reference wall from day ~90.

The information provided in Table 33 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client G's wall. Values for M_{IDX} of Client G's wall were ca. equivalent to the Reference wall when the ML was placed between the BP and cladding. Whereas values for M_{IDX} of Client G's wall for the ML placed on 2 layers of SM and either vented or ventilated, were all less than that of the Reference wall.

Given these results it is evident that for the climate loads of St. John's (NL) Client G's wall could manage moisture ingress to the drainage cavity as well as the Reference wall provided the system had at least 2 layers of NBC-compliant SM and preferably also incorporated a "ventilation" strategy.

Hygrothermal response of wall components to climate loads of St. John's, NL; RHT(x) criterion

The response of Client G's wall to climate loads of St. John's, NL as determined by the value of the RHT(x) index is shown in Figure 68. The left-hand plot of Figure 76 shows values for relative humidity and temperature over the simulation period for the instance where the ML was placed between the PP fabric and the cladding; the middle plot for the ML on the SM (50%) and incorporates 2-layers of SM; the right-hand plot, the ML is on the SM (50%), incorporates 2-layers of SM and also includes a "ventilation" strategy. The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client D walls and for different threshold values of RH are given in Table 34.

The values for RHT(80) and RHT(85) are all greater than the Reference wall when the ML is placed on the backside of the cladding whereas values of RHT(92) for the same ML condition are less than the Reference wall. Placing 2 layers of NBC-compliant SM on a "vented" is not sufficient to reduce values of RHT(x) to the level of the Reference Wall, whereas a wall that includes a "ventilation" strategy does reduce values of RHT(80), RHT(85), RHT(92) and RHT(95) below that of the Reference wall; these results are consistent with those of M_{IDX} provided in Table 33.

5.8 Client H Drainage System

Overview of Drainage System – Client H

A sectional view of the wall configuration incorporating Client H's drainage system, a porous polystyrene (PS) insulation board adhered to a liquid applied membrane (LAM), is shown in Figure 69. The water retention characteristics of the drainage system (i.e. 54 mm thick porous PS insulation board adhered to a LAM) indicates that this drainage system retains more water in relation to the amount of water entry to the system as compared to the Reference wall drainage system. A plot of the water vapour permeance (WVP) of the porous PS insulation board indicates that the WVP of this product is ~700 ng/ Pa•s•m^2 and almost four (4) times greater than the 170 ng/ Pa•s•m^2, the lower limit for a breathable membrane and having approximately the same WVP at 50 % RH as a NBC-compliant BP (30 min. BP). Whereas the WVP of the LAM (40 ng/ Pa•s•m^2) is well below the limit for a breathable membrane, although the WVP increases as a function of RH, being approximate equal to a breathable membrane at ~ 80% RH and an order of magnitude greater than the lower limit for levels of RH ranging between 90 and 100 % RH.

As such, the performance of the wall would be related to the extent to which water vapour permeates the LAM and this would in turn depend on the amount of moisture that is retained on the LAM following a rain event and the prevailing temperature in the drainage cavity. Given the lack of permeance to water vapour of the LAM, the elements inboard of the LAM of Client H's wall system wall would not readily respond to variations in climate loads.

In respect to the placement of the moisture load in the cavity, (ML), in this instance the ML was assumed to be placed on the backside of the cladding the same as for the Reference wall given that for both wall assemblies.

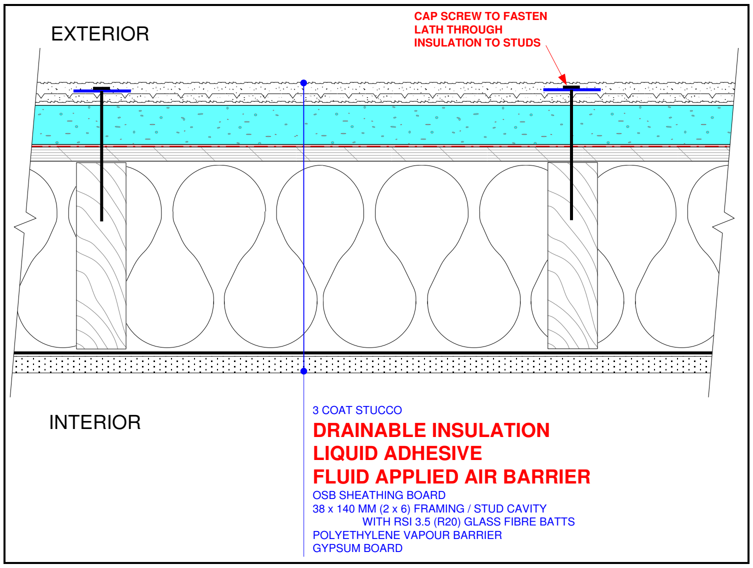
Give that the moisture load is retained behind the cladding and as well, the WVP of the LAM is much less than that of the Reference wall, suggests that the response of Client H's wall would be lessened and performance in respect to managing moisture ingress to the drainage cavity surpass that of the Reference wall.

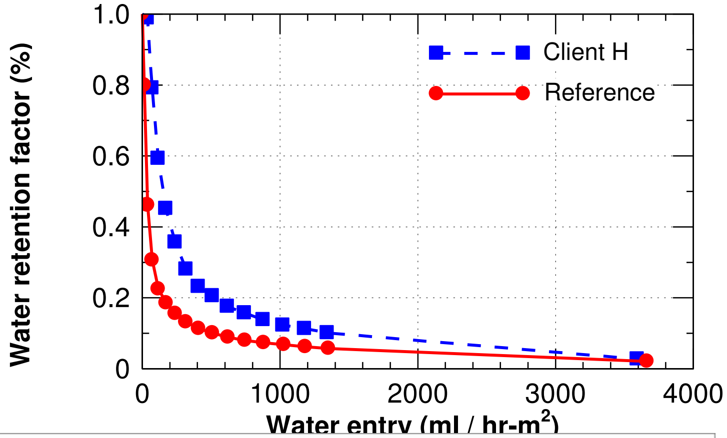
However, given that the LAM is below limit for a breathable membrane, the insulation value (R-value) of the porous insulation board is of importance as there is a risk to the formation of condensation on the interior surface of the OSB sheathing panel at the interface with the glass-fibre insulation. The average thermal conductivity of the board was reported as 0.035 W m^{-1} K^{-1} (or 0.5 W m^{-2} K^{-1} for the 51 mm thick specimen); this represents an R-value of 8.3and likely sufficient to ensure that there is no risk to the formation of condensation on the OSB sheathing panel for the three climate locations investigated.

.Results from Simulation – Client H Drainage System

Hygrothermal response of wall components to climate loads of Tofino and Vancouver (BC) and St John's (NL); M_{IDX} criterion

The response of the Client H's wall assembly to the climate loads of Tofino and Vancouver (BC), and St John's (NL) are provided in Figure 70 to Figure 72 and in Table 35 and Table 36. More specifically, the variation in values for M_{IDX} over the simulation period and in respect to the different locations in the wall, are provided in three (3) plots of Figure 78 for each of the respective climate locations. Plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB -glass fibre interface), the one closet to the moisture load, in these plots, being the "OSB-sliver", representative of a 1 mm thick sliver of the exterior face of the OSB panel.





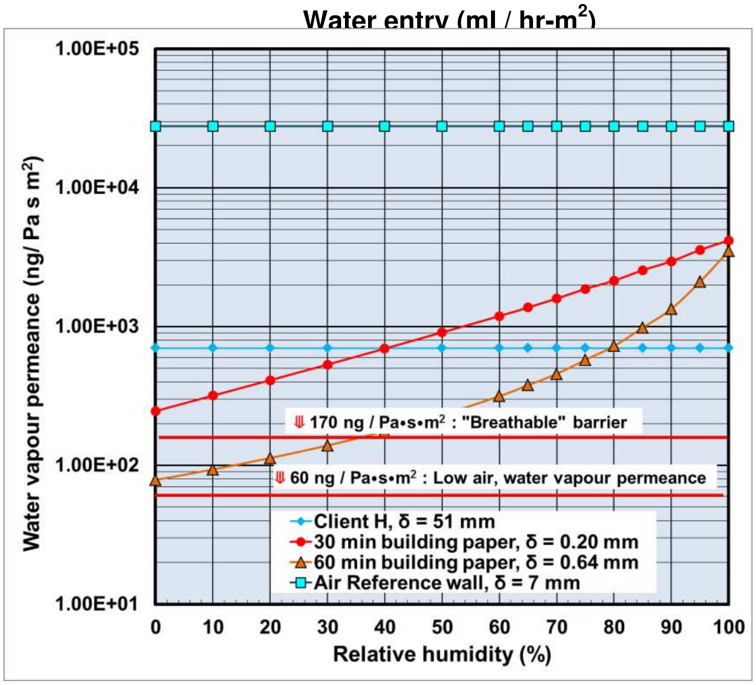


Figure 69 - Client H Wall: Sectional view, placement of moisture load in drainage cavity; water retention characteristics; water vapour permeance of sheathing membrane; δ = membrane thickness

In those plots of Figure 70 for of Tofino and Vancouver (BC) the values for M_{IDX} over the course of the simulation, in general, increase over time in relation to the propensity for mould growth given the moisture and temperature conditions in the different locations within the sheathing panels (OSB); the moisture conditions at the different panel locations are related to their respective proximity to the moisture load. Whereas for the plot of St John's (NL), there is little response in the first simulation year although over the second simulation year there is an gradual increase in value for M_{IDX} for the "OSB-sliver"; the "OSB-sliver"; attains a maximum value of < 3 at ~ 600 d of simulation. For the other portions of the OSB panel, in particular at the OSB -glass fibre interface, the M_{IDX} values at this location are first observed at ~ 540 d where it increases (~ 540-660 d) and then thereafter decreases (~660 -750 d).

In respect to the values of M_{IDX} in relation to the location of interest for which a response has been given, the higher values of M_{IDX} are those closest to the LAM and the location where the ML was applied and thereafter diminish as the location of interest recedes from the exterior face of the sheathing panel to the interior face of the gypsum panel. Thus the critical values in respect to assessing the management of moisture ingress to the drainage cavity are those provided for the 1 mm OSB sliver. Whereas, if the risk of condensation is the measure of importance in respect to wall performance , then the focus is on the interface between the insulation and the OSB panel, that is, the "OSB-fibre interface" as given in Figure 70.

The response of the Reference as compared to Client H Walls of the OSB panel component (1 mm sliver on exterior OSB surface) over the same period are shown in Figure 71; values for M_{IDX} as a function of time are provided for three plots in which the simulation are given, for the respective locations, from left to right, for the climate loads of Tofino and Vancouver (BC), and St John's (NL). The plot of values over time clearly shows that Client F walls have lower values of M_{IDX} as compared to the Reference wall over the course of the simulation. This plainly suggests that the Client H walls have a much lessened response and thus a performance in respect to managing moisture ingress to the drainage cavity that surpassed that of the Reference wall when subjected to the climate loads of the respective locations.

The information provided in Table 35 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client H's wall. As is evident from these plots and from the information provided in the table, the values for M_{IDX} of Client H's wall are all less than that of the Reference wall, irrespective of the value for M_{IDX} of the layer or interface and the locations for which the simulations were completed.

Hygrothermal response of wall components to climate loads of Tofino and Vancouver (BC), and St John's (NL); RHT(x) criterion

The response of Client H's wall to climate loads of Tofino and Vancouver (BC), and St John's (NL) as provided by plots of temperature and relative humidity levels and from which are determined values for RHT(x) index, are shown in Figure 72. The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client H walls and for different threshold values of RH are given in Table 36.

All values RHT(80), RHT(85), RHT(92) and RHT(95) as provided in Table 39 for the Client H wall are all less than that of the Reference wall and these values are consistent with those determined for M_{IDX} as were made available in Table 35.

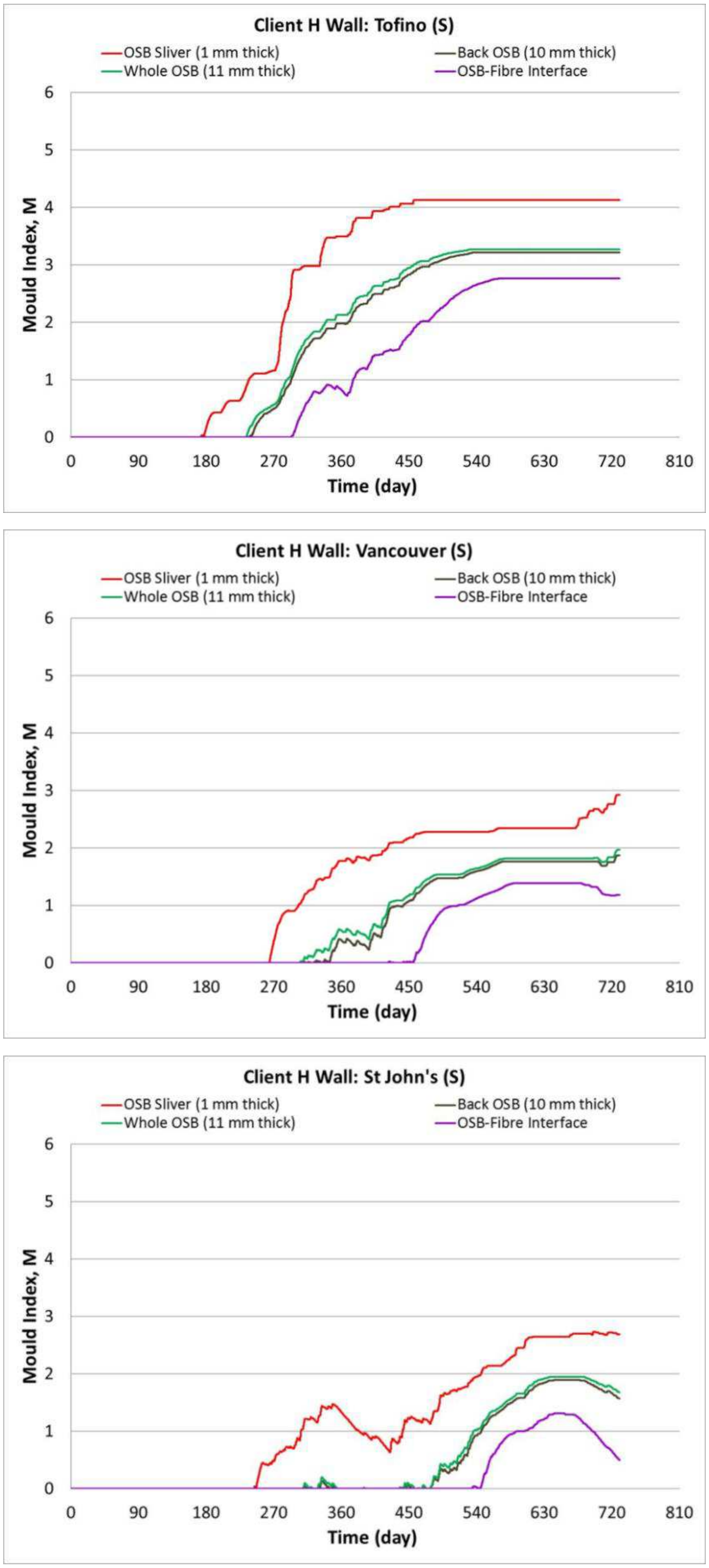


Figure 70 - Client H Walls: Response of OSB component to climate loads of Tofino, and Vancouver (BC), and St John's (NL); response given as M_{IDX} value for sensitivity class "S

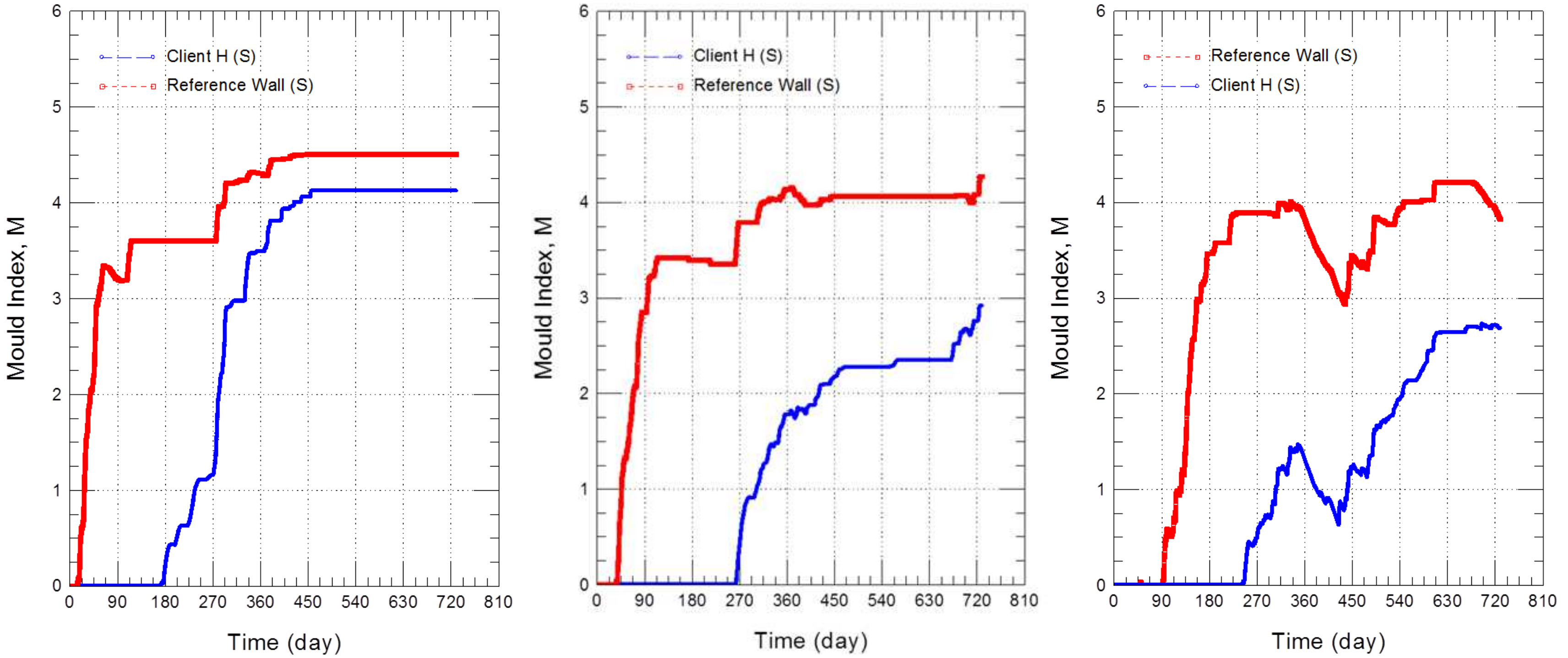


Figure 71 - – Reference and Client H Walls: Response of OSB component (1 mm sliver on exterior OSB surface) to climate loads of (from left to right) Tofino and Vancouver (BC) and St John's (NL); response given as M_{IDX} value for sensitivity class "S"

Table 35 – Response of Reference (REF.) and Client H Walls to climate loads Tofino and Vancouver (BC) and St John's (NL)
Average and maximum values of M_{IDX} for different locations in walls in which Moisture Load was placed between Building paper and cladding

	Tofino				Vancouver				St John's			
	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
REF-Avg	3.910	2.506	2.597	1.819	3.500	2.181	2.271	1.518	3.085	1.941	2.035	1.147
REF-Max	4.508	3.475	3.538	2.984	4.270	3.082	3.149	2.633	4.210	3.191	3.261	2.562
Client H-Avg	2.497	1.700	1.763	1.215	1.296	0.707	0.759	0.434	1.100	0.464	0.495	0.243
Client H-Max	4.124	3.214	3.270	2.759	2.916	1.869	1.964	1.389	2.728	1.887	1.946	1.308

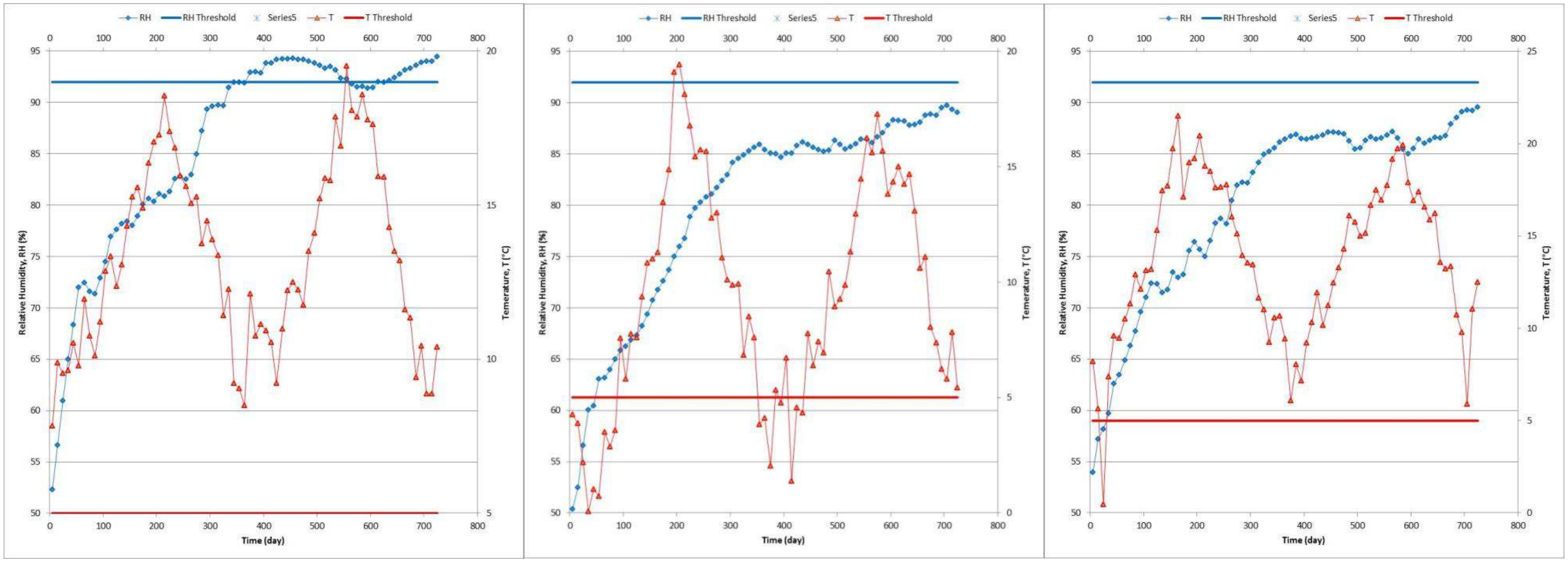


Figure 72 – Client H Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of Tofino and Vancouver (BC) and St John's (NL); response given as RHT(x) where x relates to the RH threshold value at which the index is provided

Table 36 – Reference and Client H Wall: Response of OSB component to climate loads of Tofino and Vancouver (BC) and St John's (NL); response given as RHT(x) where x relates to the RH threshold value at which the index is provided

	Tofino				Vancouver			St John's			
	RHT(80)	RHT(85)	RHT(92)	RHT(95)	RHT(80)	RHT(85)	RHT(92)	RHT(80)	RHT(85)	RHT(92)	
Ref Wall	5263	3015	435	37	4958	2493	192	2961	1786	193	Ref Wall
Client H	4775	2715	300	0	2348	527	0	1390	368	0	Client H

5.9 Client I Drainage System

Overview of Drainage System – Client I

A sectional view of the wall configuration incorporating Client I's product is shown in Figure 73; the drainage system is comprised of a 2 ply, corrugated asphalt impregnated paper (Grade D), and NBC compliant building paper. The water retention characteristics of this drainage system suggest that for given water entry rates, the drainage system retains less water as compared to the Reference drainage system.

A plot of the water vapour permeance (WVP) of various sheathing membranes (SM), including that of Client I, is also provided; it is apparent that the WVP of Client I's product is dependent on relative humidity (RH) conditions; the WVP is less than NBC-compliant SM (30 min. building paper (BP) conforming to CGSB standard [12]) at low RH, and essentially the same value at RH > 50% given that the NBC-compliant SM is also RH dependent. In this system, an NBC-compliant BP is used as SM. As such, the performance would be related to the extent to which water vapour permeates the SM and this would in turn depend on the amount of moisture that is retained on the SM following a rain event and the prevailing temperature in the drainage cavity.

In regard to placement of the moisture load (ML) in the drainage cavity, for the purposes of simulations, the ML was assumed to be placed either on the backside of the cladding and in contact with Client I's product, or on the SM. The rationale for placement of the ML on the SM was as follows: water would enter the drainage space at the many fastener locations across the wall and by gravity percolate downwards within the corrugated channels, and ultimately find its way to the surface of the SM; a plausible scenario was deemed to be for all of the ML attaining the surface of the SM.

Thus 100% of the ML in the case of Client I's wall was placed directly on the SM; as well, the WVP of the SM of Client I's wall is the same as that used in the Reference wall. Combining these two elements, that is, equivalent SM and placement of the moisture load in the drainage cavity, suggests that Client I's wall, as compared to the Reference wall, would be somewhat disadvantaged in respect to managing moisture ingress to the drainage cavity.

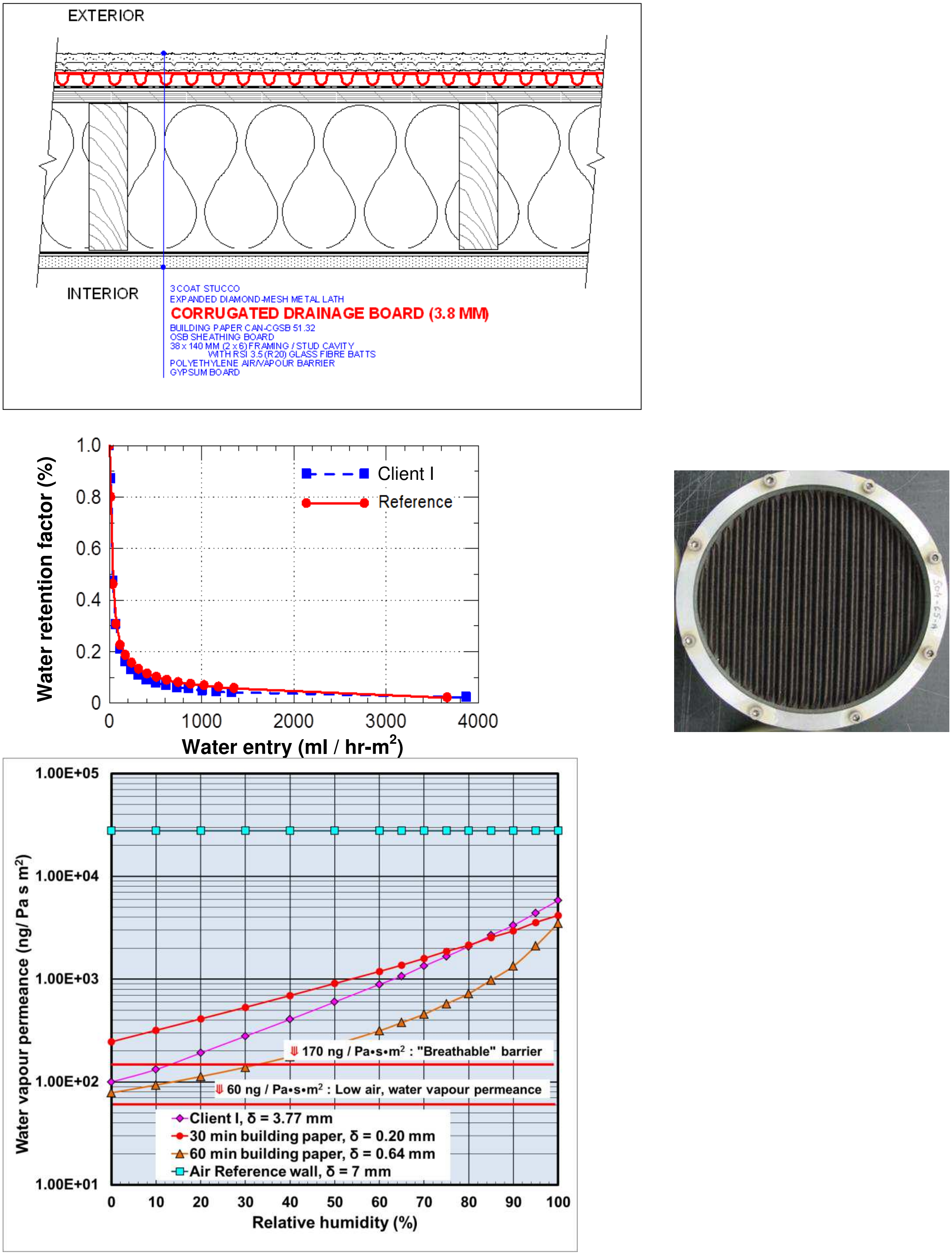
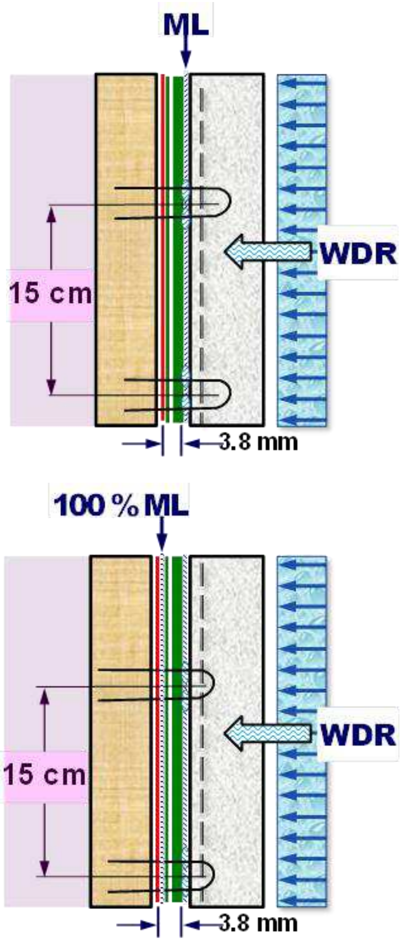


Figure 73 Client I Wall: Sectional view, placement of ML in 10 mm drainage cavity; water retention characteristics; water vapour permeance of sheathing membrane; δ = membrane thickness

Hygrothermal response of wall components to climate loads of Tofino; M_{IDX} criterion

The response of the Client I wall assembly to the climate loads of Tofino (BC) are provided in Figure 74 to Figure 76 and in Table 37 and Table 38. More specifically, the variation in values for M_{IDX} over the course of the simulation period and in respect to the different locations in the wall, are provided in three plots of Figure 74. The upper-most plot shows the variation over the simulation when the moisture load (ML) was placed between the cladding and Client I's product; the middle plot shows values of M_{IDX} over the simulation when 100% of the moisture load (ML) was placed on the sheathing membrane (SM) and 1 layer of SM was used to protect the sheathing panel, whereas; the lower-most plot shows the variation for the same ML but the drainage system with 2-layers of SM as protection. The location of the ML for all these conditions is shown in the adjacent inset. For all conditions, this drainage system incorporated a "ventilation" strategy.



The variations given in the middle and lower-most plots resulted from attempting to find solutions for which the drainage system could adequately accommodate the ML to which it was subjected. As a consequence of these efforts, the variations shown here also include 2-layers of NBC-compliant SM as compared to the 1 layer specified for this system.

In the plots of Figure 74, the values for M_{IDX} over the course of the simulation increase over time depending on the propensity for mould growth given the moisture and temperature conditions in the different locations within the sheathing panels (OSB); the moisture conditions at the different panel locations are related to their respective proximity to the moisture load. Plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB-glass fibre interface), the one closet to the moisture load in these plots, being the "OSB Sliver", representative of a 1 mm thick sliver on the exterior face of the 11 mm thick sheathing panel and the component in closest contact with the SM.

Observations common to all plots of Figure 74:

- The values of M_{IDX} diminish in relation to the distance from where the ML is applied to the location of interest for which a response has been given.
- The higher values of M_{IDX} are those closest to the SM and the location where the ML was applied and thereafter diminish as the location of interest recedes from the exterior face of the sheathing panel to the interior face of the OSB panel, and where this surface is at the interface between the OSB and the interior insulation.
- The values for M_{IDX} of the entire OSB panel (i.e. "whole" OSB 11 mm thick) are always greater than the 10 mm portion of OSB behind the 1 mm sliver (i.e. "back" of OSB, 10 mm thick) given

that the values for M_{IDX} of the 1 mm sliver are always the greatest values for M_{IDX} amongst the different locations in the wall.

- The values provided for the 1 mm OSB sliver are the critical values from which the response of the wall assembly is measured in respect to managing moisture ingress to the drainage cavity, whereas,
- If the risk of condensation is the measure of importance in respect to wall performance , then the focus ought to be on the interface between the insulation and the OSB panel, that is, the "OSB-fibre interface" as given in Figure 74.

The differences in response of the OSB component (1 mm sliver on exterior OSB surface) to the location of the ML in the wall assembly is apparent from the lower values of M_{IDX} obtained in the instance where the ML is placed between the cladding and Client I's product as compared to having 100% of the ML placed on the SM; the ML being in direct contact with the SM brings it in closer proximity to the wood-based and moisture sensitive components of the wall assembly. As well, the contribution of the second layer of SM is evident when comparing the values of M_{IDX} for the "OSB-sliver" of the middle and lower-most plots of Figure 74; there is a reduction in values of M_{IDX} brought about with the use of a second layer of SM although its impact is minor.

The response of the Reference and Client I Walls of the OSB component (1 mm sliver on exterior OSB surface) to climate loads of Tofino (BC) over the same period are shown in Figure 75; values for M_{IDX} as a function of time for the:

- Left-hand plot is for the ML placed between the cladding and Client I's product;
- Middle plot is for 100% of the ML placed on SM and using 1-layer of NBC-compliant SM;
- Right-hand plot is for the same ML load condition as provided in the middle plot, but with 2-layers of NBC-compliant SM.

When the ML was placed:

- Between the cladding and Client I's product (left-hand plot; Figure 75), the Client I wall had values for M_{IDX} less than the Reference wall;
- 100% on the SM (Middle plot; Figure 84), the Client I wall had values for M_{IDX} greater than the Reference wall from day ~ 50 onwards, whereas;
- 100% on the SM and had 2-layers of NBC-compliant SM (right-hand plot; Figure 75), Client I's wall had values for M_{IDX} less than r the Reference wall up to day 270 and thereafter had higher values for the M_{IDX}.

The information provided in Table 37 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client I's wall. For all instances, where 100% of ML was placed on the SM, values for M_{IDX} of the layer or interface of Client I's wall were all greater than the Reference wall.

Given these results it is evident that for the climate loads of Tofino (BC) Client I's wall did not manage moisture ingress to the drainage cavity as well as the Reference wall.

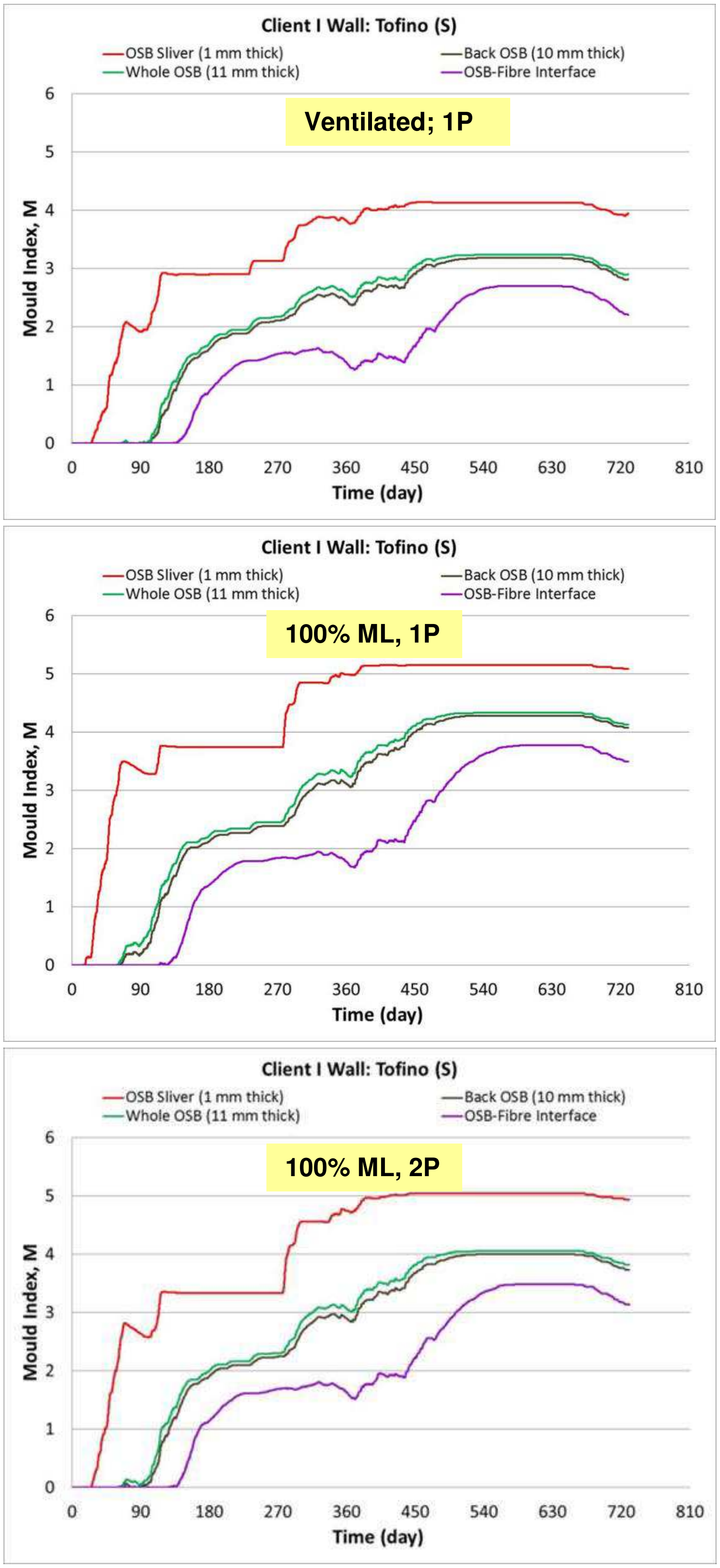


Figure 74 - Client I Wall: Response of OSB component to climate loads of Tofino (BC); response given as M_{IDX} value for sensitivity class "S

Hygrothermal response of wall components to climate loads of Tofino; RHT(x) criterion

The response of Client G's (in the 1 mm "OSB-sliver") wall to climate loads of Tofino (BC) as determined by the value of the RHT(x) index is shown in Figure 76.

The values for relative humidity and temperature over the simulation period for the ML placed: (i) Left-hand plot - Between Client I's product and the cladding; (ii) Middle plot - 100% on the SM, 1 layer of BP; (iii) Right-hand plot - 100% on the SM and 2- layers of BP; all drainage systems "ventilated".

The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client I walls and for different threshold values of RH are given in Table 38. The respective values for RHT(x) are all greater for Client I's wall as compared to the Reference wall for 100 % of ML placed on the SM; these values are consistent with that determined from a comparison of M_{IDX} values as was made available in Table 38.

Hygrothermal response of wall components to climate loads of Vancouver; M_{IDX} criterion

The response of the Client I's wall assembly to the climate loads of Vancouver (BC) are provided in Figure 77 to Figure 79 and in Table 39 and Table 40.

More specifically, the variation in values for M_{IDX} over the course of the simulation period and in respect to the different locations in the wall, are provided in three plots of Figure 77. The upper-most plot shows the variation over the simulation when the moisture load (ML) was placed between the cladding and Clinet I's product; the middle plot shows values of M_{IDX} over the simulation when 100% of the moisture load (ML) was placed on the sheathing membrane (SM), whereas; the lower-most plot shows the variation for 100% of the ML placed on the SM and a second layer of SM (2P) to protect the sheathing panel; all drainage systems were "ventilated". The location of the ML for all these conditions was the same as was previously given for Tofino.

As was the case for Tofino, the variations given in the middle and lower-most plots resulted from attempting to find solutions for which the drainage system could adequately accommodate the ML to which it was subjected; variations thus include 2-layers of BP as compared to the 1 layer specified for this system.

In the plots of Figure 77, the values for M_{IDX} over the simulation increase over time depending on the propensity for mould growth given the moisture and temperature conditions in the different locations within the sheathing panels (OSB); the moisture conditions at the different panel locations are related to their respective proximity to the moisture load. Plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB-glass fibre interface), the one closet to the moisture load, in these plots, being the "OSB Sliver", representative of a 1 mm thick sliver of the exterior face of the sheathing panel. Observations common to all plots of Figure 77 are the same as those provided for plots of Figure 74 for Tofino.

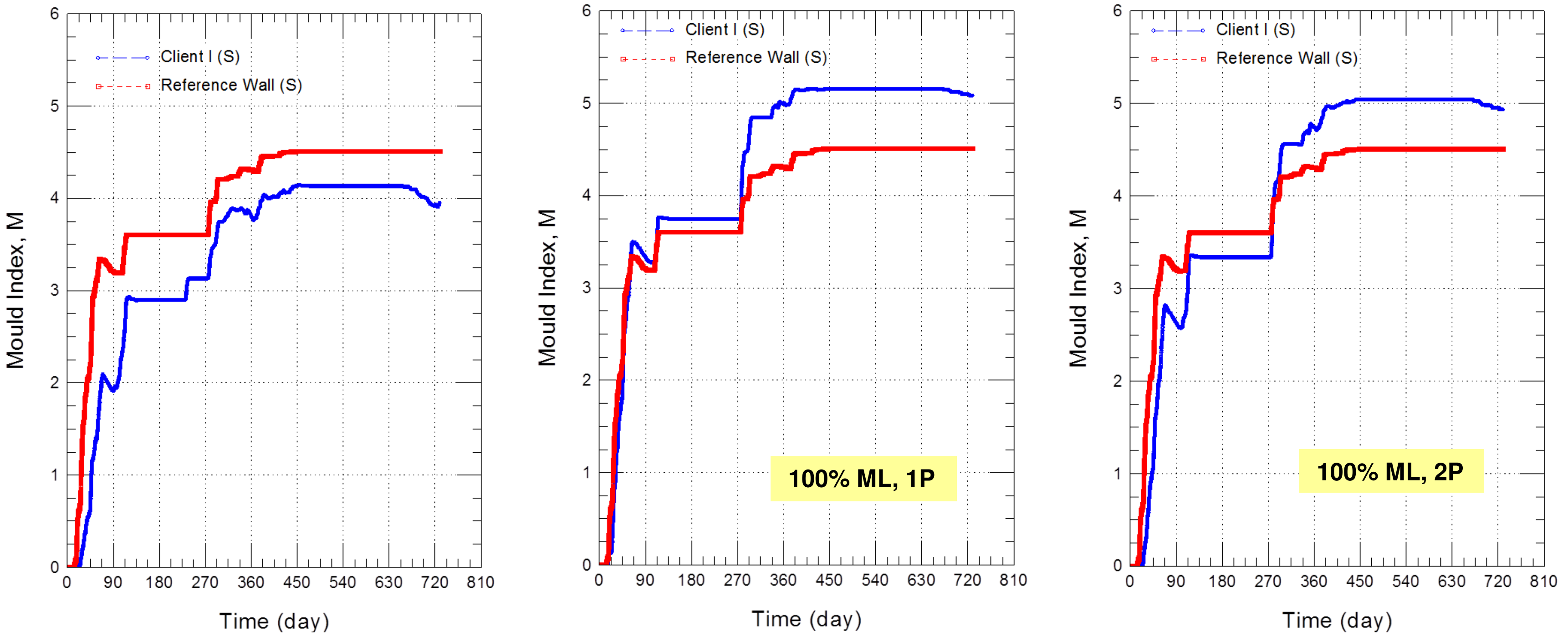


Figure 75 – Reference & Client I Walls: Response of OSB to climate loads of Tofino (BC); response given as M_{IDX} value for sensitivity class “S

Table 37– Response of Reference & Client I Walls to climate loads of Tofino (BC); Average & maximum values of M_{IDX} for wall locations where: (i) ML* placed between building paper & Cladding; (ii) 50 % ML on building paper; system vented; (iii) 50 % ML on building paper; system ventilated

	Tofino: 100% ML on back of cladding, 1P				**Tofino: 100% ML, 1P**				**Tofino: 100% ML, 2P**			
	OSB Sliver (1 mm)	**Back OSB (10 mm)**	**Whole OSB (11 mm)**	**OSB-Fibre Interface**	**OSB Sliver (1 mm)**	**Back OSB (10 mm)**	**Whole OSB (11 mm)**	**OSB-Fibre Interface**	**OSB Sliver (1 mm)**	**Back OSB (10 mm)**	**Whole OSB (11 mm)**	**OSB-Fibre Interface**
REF.-Avg	3.910	2.506	2.597	1.819	3.910	2.506	2.597	1.819	3.910	2.506	2.597	1.819
REF.-Max	4.508	3.475	3.538	2.984	4.508	3.475	3.538	2.984	4.508	3.475	3.538	2.984
Client I-Avg	3.332	2.150	2.230	1.508	4.314	2.875	2.973	2.096	4.035	2.640	2.736	1.905
Client I-Max	4.137	3.176	3.235	2.694	5.151	4.281	4.332	3.774	5.038	3.995	4.055	3.480

* ML: Moisture Load; 1P: 1 layer of NBC-compliant building paper (BP) as sheathing membrane; 2P: 2 layers of NBC-compliant BP as sheathing membrane

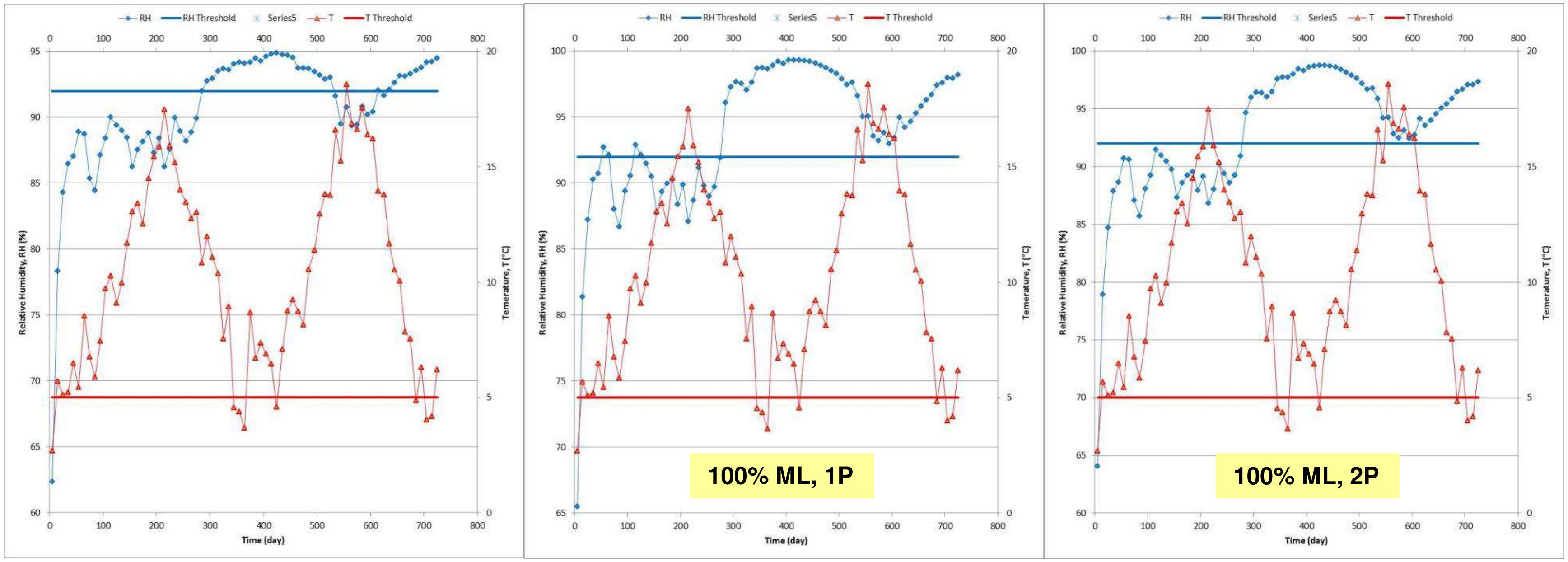


Figure 76 – Client I Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of Tofino (BC); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

Table 38 – Response of Reference & Client I Walls to climate loads of Tofino (BC); values of RHT(x) where x relates to the RH threshold value at which the index is calculated where:(i) ML* placed between building paper & Cladding; (ii) 50 % ML on building paper; system vented; (iii) 50 % ML on building paper; system ventilated

Tofino: 100% ML on back of cladding, 1P					Tofino: 100% ML, 1P				Tofino: 100% ML, 2P			
	RHT(80)	RHT(85)	RHT(92)	RHT(95)	RHT(80)	RHT(85)	RHT(92)	RHT(95)	RHT(80)	RHT(85)	RHT(92)	RHT(95)
Ref Wall	5263	3015	435	37	5263	3015	435	37	5263	3015	435	37
Client I	4094	2137	162	0	5267	3311	932	330	4966	3011	743	227

* ML: Moisture Load; 1P: 1 layer of code-compliant building paper as sheathing membrane; 2P: 2 layers of code-compliant building paper as sheathing membrane

The differences in response of the OSB component (1 mm sliver; exterior OSB surface) to the location of the ML in the wall assembly is entirely apparent given the increase in values of M_{IDX} obtained in when the ML was on the SM as compared to the ML placed between the cladding and Client I's product. As well, when comparing the middle and lower-most plots of Figure 77, there was an evident, yet minor reduction in values of M_{IDX} with the addition of a second layer of SM.

The response of the Reference and Client I Walls of the OSB component (1 mm sliver on exterior OSB surface) to climate loads of Vancouver (BC) over the same period are shown in Figure 78; values for M_{IDX} as a function of time for the:

- Left-hand plot is for the ML placed between the cladding and Client I's product;
- Middle plot is for 100% of the ML placed on the SM, consisting of 1-layer of NBC-compliant BP;
- Right-hand plot is for the same ML load as provided in the middle plot and 2-layers of NBC-compliant BP; all drainage systems were "ventilated".

When the ML was placed:

- Between the cladding and Client I's product (Left-hand plot; Figure 78), Client 's wall had values for M_{IDX} less than the Reference wall;
- 100% on the SM (Middle plot; Figure 87), the Client I wall had values for M_{IDX} about equivalent to that of the Reference wall, whereas;
- 100% on the SM and 2 –layers of SM (Right-hand plot; Figure 78), Client I's wall had values for M_{IDX} < Reference wall.

The information provided in Table 39 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client I's wall. Values for M_{IDX} of Client I's wall were ca. less than the Reference wall when the ML was placed between cladding and Client I's product. Whereas values for M_{IDX} of Client I's wall for 100 % of the ML placed on the SM and using 1 layer of SM were generally all less than the Reference wall for the average values of M_{IDX} and all greater than the Reference wall for maximum values of M_{IDX}. Values for M_{IDX} of Client I's wall for the same loading conditions but when using 2 layers of SM were all less than the Reference wall.

Given these results it is evident that for the climate loads of Vancouver (BC) Client I's wall could manage moisture ingress to the drainage cavity as well as the Reference wall provided the system had at least one (1) but preferably 2-layers of NBC-compliant SM.

Hygrothermal response of wall components to climate loads of Vancouver (BC); RHT(x) criterion

The response of Client I's wall to climate loads of Vancouver (BC) as determined by the value of the RHT(x) index is shown in Figure 79. The left-hand plot of Figure 88 shows values for relative humidity and temperature over the simulation period for the instance where the ML was placed between the cladding and Client I's product; the middle plot for 100% of the ML on the SM and 1-layer of SM; the right-hand plot, 100% of the ML on the SM and 2-layers of SM. The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client I walls and for different threshold values of RH are given in Table 40. All values for RHT(x) index for Client I walls when 100% of the ML placed on the SM were less than the Reference; this is consistent with that provided in Table 40 for comparative values of M_{IDX}.

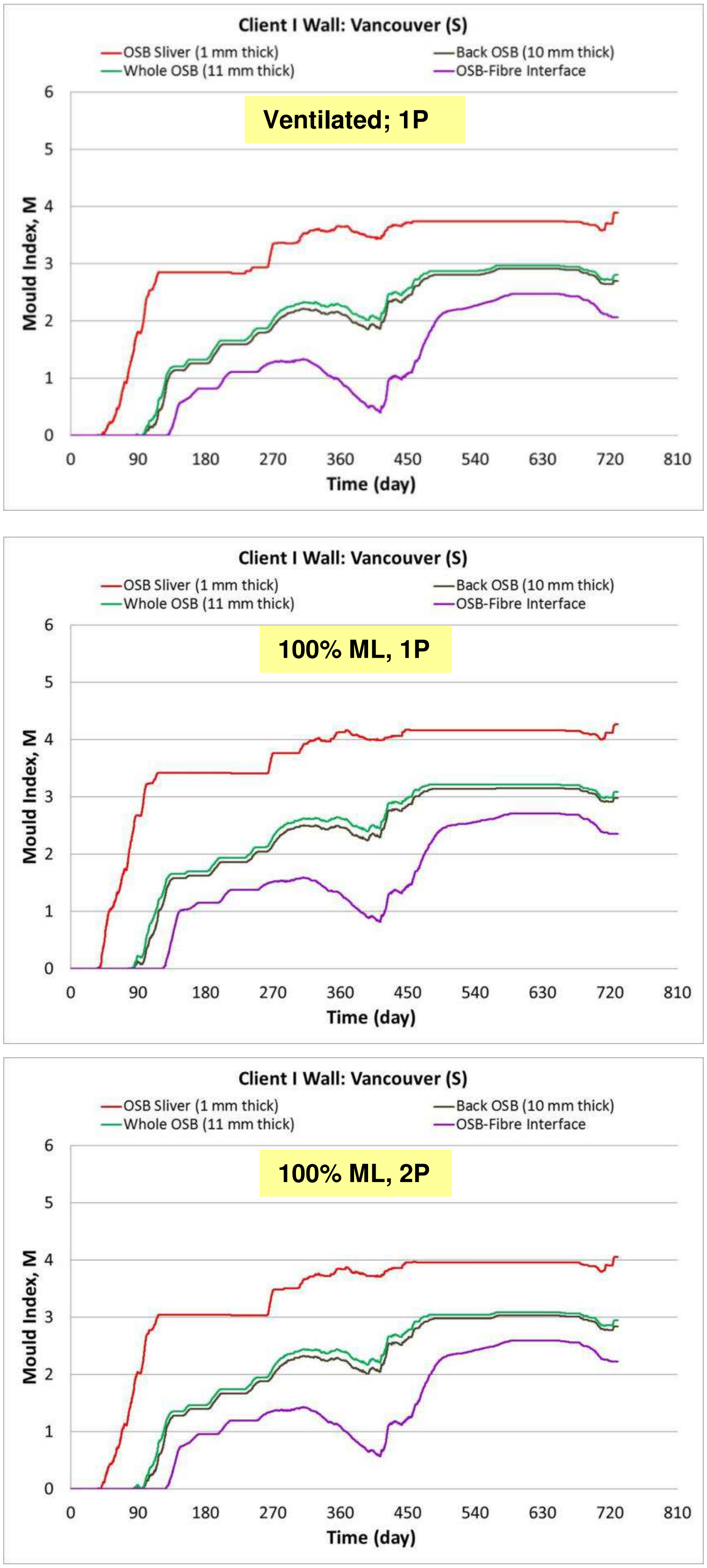


Figure 77 Client I Wall: Response of OSB component to climate loads of Vancouver (BC); response given as M_{IDX} value for sensitivity class “S

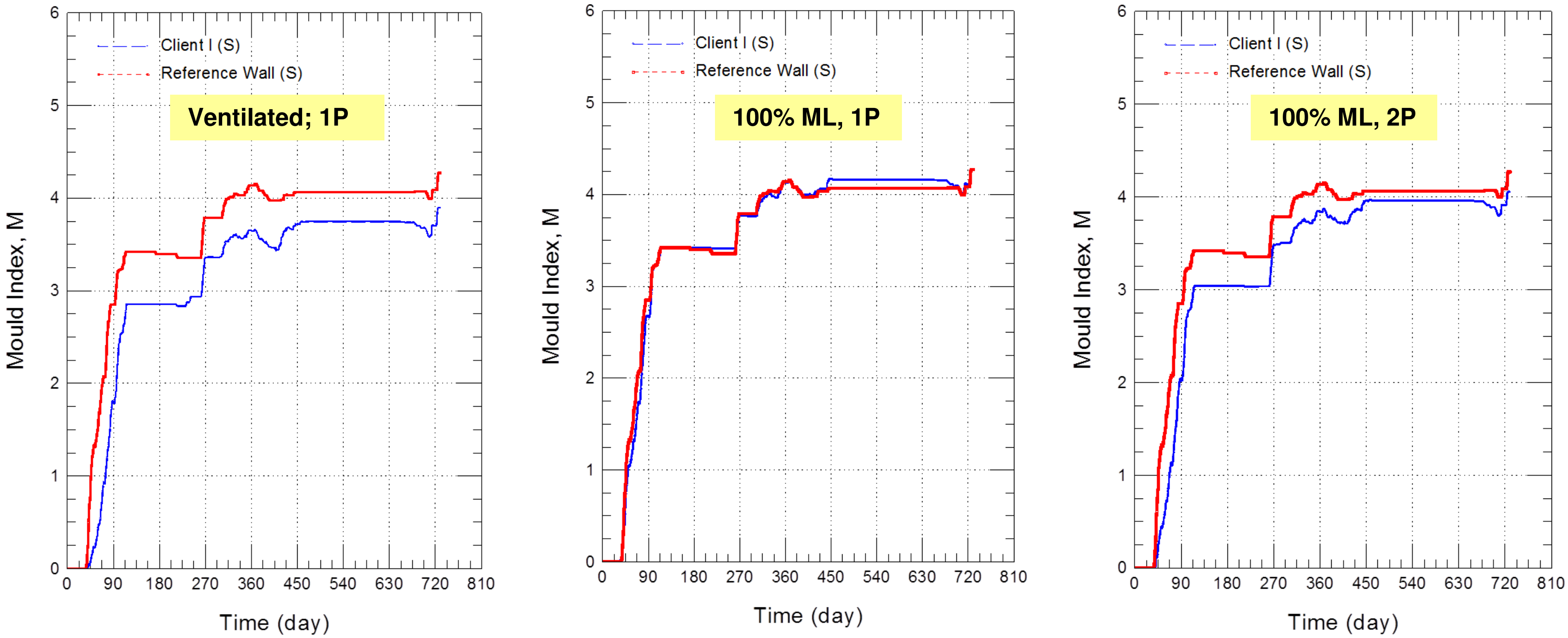


Figure 78– Reference & Client I Walls: Response of OSB to climate loads of Vancouver (BC); response given as M_{IDX} value for sensitivity class “S

Table 39 – Response of Reference & Client I Walls to climate loads of Vancouver (BC); Average & maximum values of M_{IDX} for wall locations where: (i) ML* placed between building paper & Cladding; (ii) 50 % ML on building paper; system vented; (iii) 50 % ML on building paper; system ventilated

	Vancouver: 100% ML on back of cladding, 1P				Vancouver: 100% ML, 1P				Vancouver: 100% ML, 2P			
	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
REF.-Avg	3.500	2.181	2.271	1.518	3.500	2.181	2.271	1.518	3.500	2.181	2.271	1.518
REF.-Max	4.270	3.082	3.149	2.633	4.270	3.082	3.149	2.633	4.270	3.082	3.149	2.633
Client I-Avg	3.038	1.893	1.976	1.260	3.503	2.175	2.265	1.510	3.224	2.010	2.094	1.369
Client I-Max	3.891	2.906	2.965	2.466	4.263	3.152	3.214	2.709	4.051	3.028	3.086	2.590

* ML: Moisture Load; 1P: 1 layer of code-compliant building paper as sheathing membrane; 2P: 2 layers of code-compliant building paper as sheathing membrane.

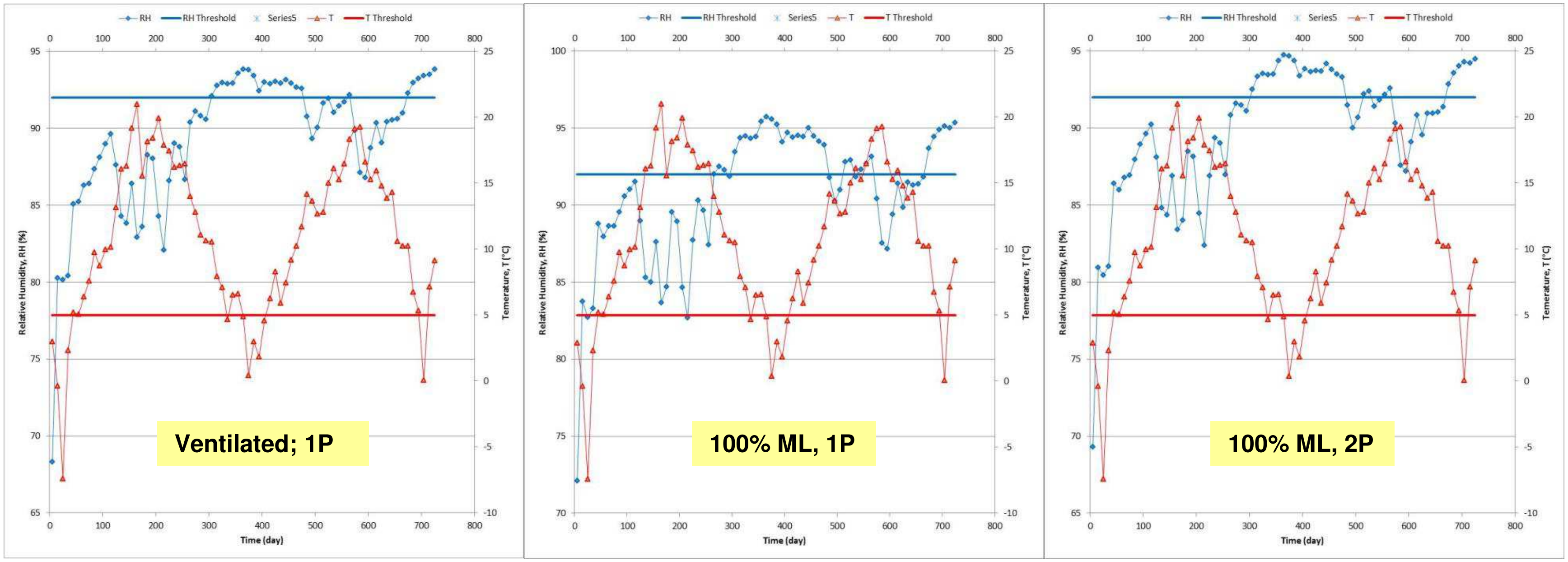


Figure 79– Client I Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of Vancouver (BC); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

Table 40 – Response of Reference & Client I Walls to climate loads of Vancouver (BC); values of RHT(x) where x relates to RH threshold value at which index calculated:(i) ML* placed between BP & Cladding; (ii) 50 % ML on BP; system vented; (iii) 50 % ML on BP; system ventilated

Vancouver: 100% ML on back of cladding, 1P					Vancouver: 100% ML, 1P				Vancouver: 100% ML, 2P			
	RHT(80)	RHT(85)	RHT(92)	RHT(95)	RHT(80)	RHT(85)	RHT(92)	RHT(95	RHT(80)	RHT(85)	RHT(92)	RHT(95
REF. Wall	4958	2493	192	2	4958	2493	192	2	4958	2493	192	2
Client I	4069	1864	45	-	4556	2293	167	2	4283	2047	93	0

* ML: Moisture Load; 1P: 1 layer of code-compliant building paper as sheathing membrane; 2P: 2 layers of code-compliant building paper as sheathing membrane

Hygrothermal response of wall components to climate loads of St John's (NL); M_{IDX} criterion

The response of the Client I's wall assembly to the climate loads of St John's (NL), are provided in Figure 80 to Figure 82 and in Table 41 and Table 42.

More specifically, the variation in values for M_{IDX} over the course of the simulation period and in respect to the different locations in the wall, are provided in three plots of Figure 80. The upper-most plot shows the variation over the simulation when the moisture load (ML) was placed between the cladding and Client I's product; the middle plot shows values of M_{IDX} over the simulation when 100% of the moisture load (ML) was placed on the sheathing membrane (SM), whereas; the lower-most plot shows the variation for 100% of the ML placed on the SM and a second layer of SM (2P) to protect the sheathing panel; all drainage systems were "ventilated". The location of the ML for all these conditions was the same as was previously given for Tofino and Vancouver.

As was the case for Tofino and Vancouver, the variations given in the middle and lower-most plots resulted from attempting to find solutions for which the drainage system could adequately accommodate the ML to which it was subjected; variations thus include 2-layers of BP as compared to the 1 layer specified for this system.

In the plots of Figure 80, the values for M_{IDX} over the simulation increase over time depending on the propensity for mould growth given the moisture and temperature conditions in the different locations within the sheathing panels (OSB); the moisture conditions at the different panel locations are related to their respective proximity to the moisture load. Plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB-glass fibre interface), the one closet to the moisture load, in these plots, being the "OSB Sliver", representative of a 1 mm thick sliver of the exterior face of the sheathing panel. Observations common to all plots of Figure 80are the same as those provided for Tofino and Vancouver, respectively, in plots of Figure 74 and Figure 77.

The differences in response of the OSB component (1 mm sliver; exterior OSB surface) to the location of the ML in the wall assembly is entirely apparent given the increase in values of M_{IDX} obtained in when the ML was on the SM as compared to the ML placed between the cladding and Client I's product. As well, when comparing the middle and lower-most plots of Figure 80, there were evident, yet minor reductions in values of M_{IDX} with the addition of a second layer of SM.

The response of the Reference and Client I Walls of the OSB component (1 mm sliver on exterior OSB surface) to climate loads of St John's (NL), over the same period are shown in **Figure** 81; values for M_{IDX} as a function of time for the:

- Left-hand plot is for the ML placed between the cladding and Client I's product;
- Middle plot is for 100% of the ML placed on the SM, consisting of 1-layer of NBC-compliant BP;
- Right-hand plot is for the same ML load as provided in the middle plot and 2-layers of NBC-compliant BP; all drainage systems were "ventilated".

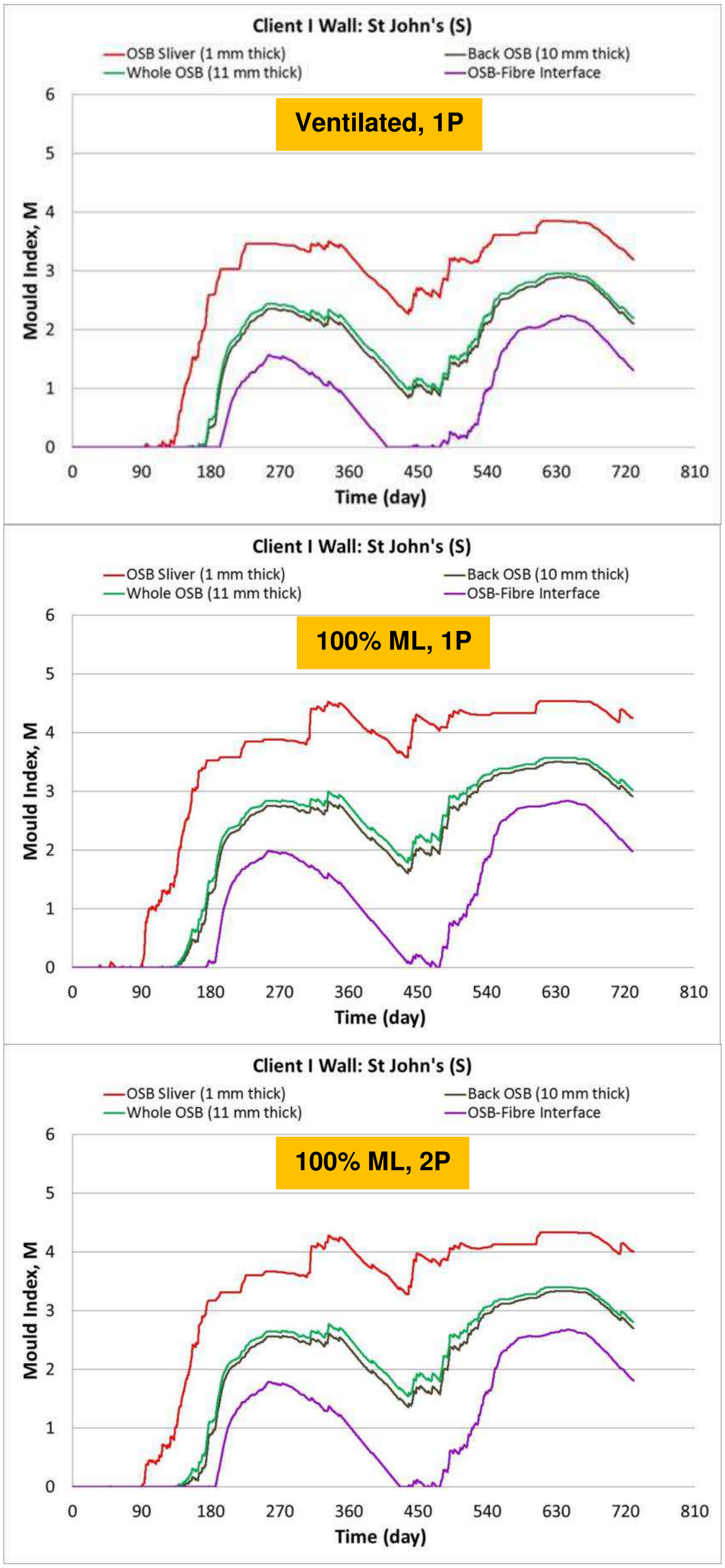


Figure 80 - Client I Wall: Response of OSB component to climate loads of St John's (NL); response given as M_{IDX} value for sensitivity class "S

When the ML was placed:

- Between the cladding and Client I's product (Left-hand plot; **Figure** 81), Client 's wall had values for M_{IDX} less than the Reference wall;
- 100% on the SM (Middle plot; **Figure** 81), the Client I wall had values for M_{IDX} in excess to that of the Reference wall, at ca. day 300, whereas;
- 100% on the SM and 2 –layers of SM (Right-hand plot; **Figure** 81), Client I's wall had values for M_{IDX} in excess to that of the Reference wall, at ca. day 300.

The information provided in Table 41 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client I's wall. Values for M_{IDX} of Client I's wall were ca. less than the Reference wall when the ML was placed between cladding and Client I's product. Whereas values for M_{IDX} of Client I's wall for 100 % of the ML placed on the SM and using 1 layer of SM were generally all greater than the Reference wall. Values for M_{IDX} of Client I's wall for the same loading conditions but when using 2 layers of SM were all greater than the Reference wall for the "OSB-sliver"; for all other locations in the wall, all the average values of M_{IDX} of Client I's wall were less than the Reference wall whereas all the maximum values of M_{IDX} were all greater than the Reference wall.

Given these results it is evident that for the climate loads of St John's (NL), Client I's wall did not manage moisture ingress to the drainage cavity as well as the Reference wall.

Hygrothermal response of wall components to climate loads of St John's (NL); RHT(x) criterion

The response of Client I's wall to climate loads of Vancouver (BC) as determined by the value of the RHT(x) index is shown in Figure 82. The left-hand plot of Figure 82 shows values for relative humidity and temperature over the simulation period for the instance where the ML was placed between the cladding and Client I's product; the middle plot for 100% of the ML on the SM and 1-layer of SM; the right-hand plot, 100% of the ML on the SM and 2-layers of SM. The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client I walls and for different threshold values of RH are given in Table 42. All values for RHT(80) and RHT(85) for Client I walls when 100% of the ML placed on the SM were less than the Reference wall, whereas all values for RHT(92) and RHT(95) were greater than the Reference wall; these values is are consistent with that provided in Table 41 for comparative values of M_{IDX}.

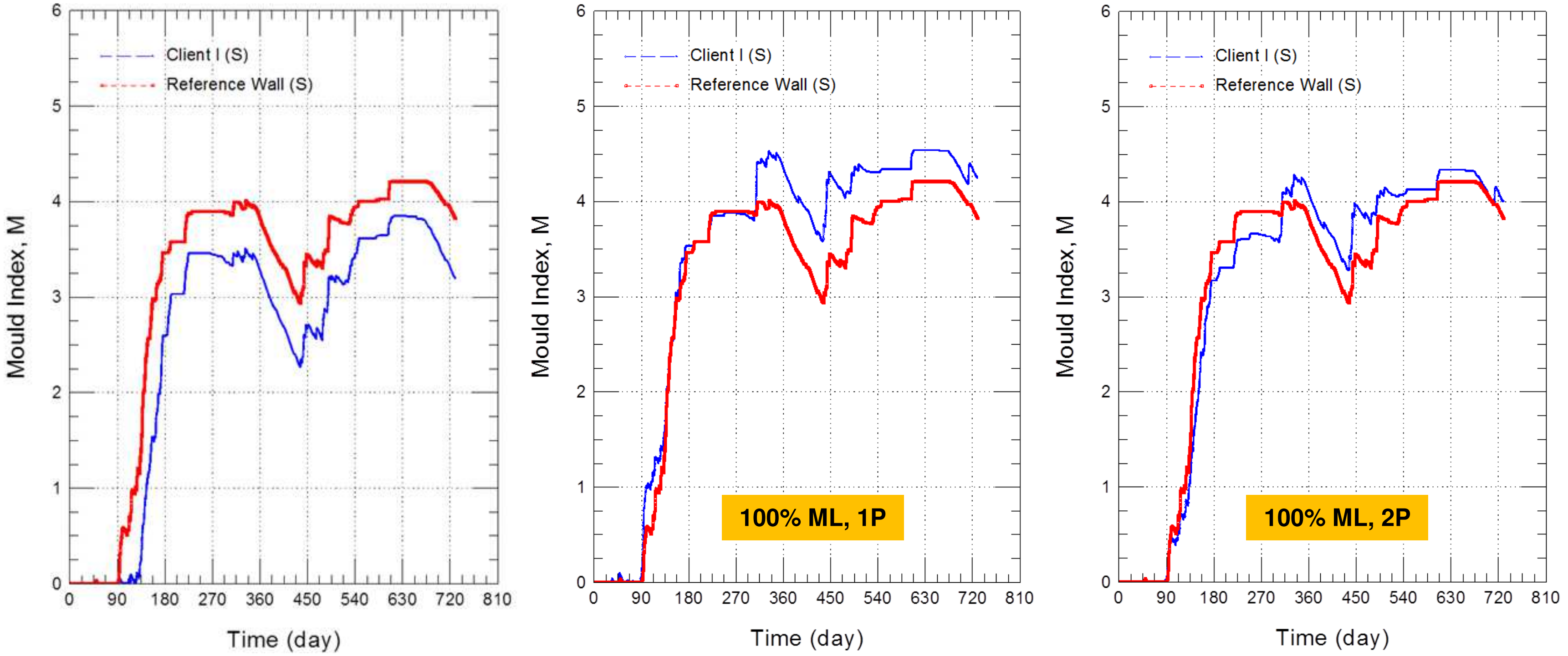


Figure 81 – Reference & Client I Walls: Response of OSB to climate loads of St John's (NL); response given as M_{IDX} value for sensitivity class "S

Table 41 – Response of Reference & Client I Walls to climate loads of St John's (NL); Average & maximum values of M_{IDX} for wall locations where: (i) ML* placed between building paper & Cladding; (ii) 50 % ML on building paper; system vented; (iii) 50 % ML on building paper; system ventilated

St John's: 100% ML on back of cladding, 1P					St John's: 100% ML, 1P				St John's: 100% ML, 2P			
	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
REF.-Avg	3.085	1.941	2.035	1.147	3.085	1.941	2.035	1.147	3.085	1.941	2.035	1.147
REF.-Max	4.210	3.191	3.261	2.562	4.210	3.191	3.261	2.562	4.210	3.191	3.261	2.562
Client-Avg	2.563	1.506	1.584	0.808	3.373	2.084	2.189	1.209	3.117	1.893	1.997	1.068
Client-Max	3.843	2.894	2.956	2.238	4.535	3.500	3.570	2.832	4.331	3.332	3.399	2.669

* ML: Moisture Load; 1P: 1 layer of code-compliant building paper as sheathing membrane; 2P: 2 layers of code-compliant building paper as sheathing membrane

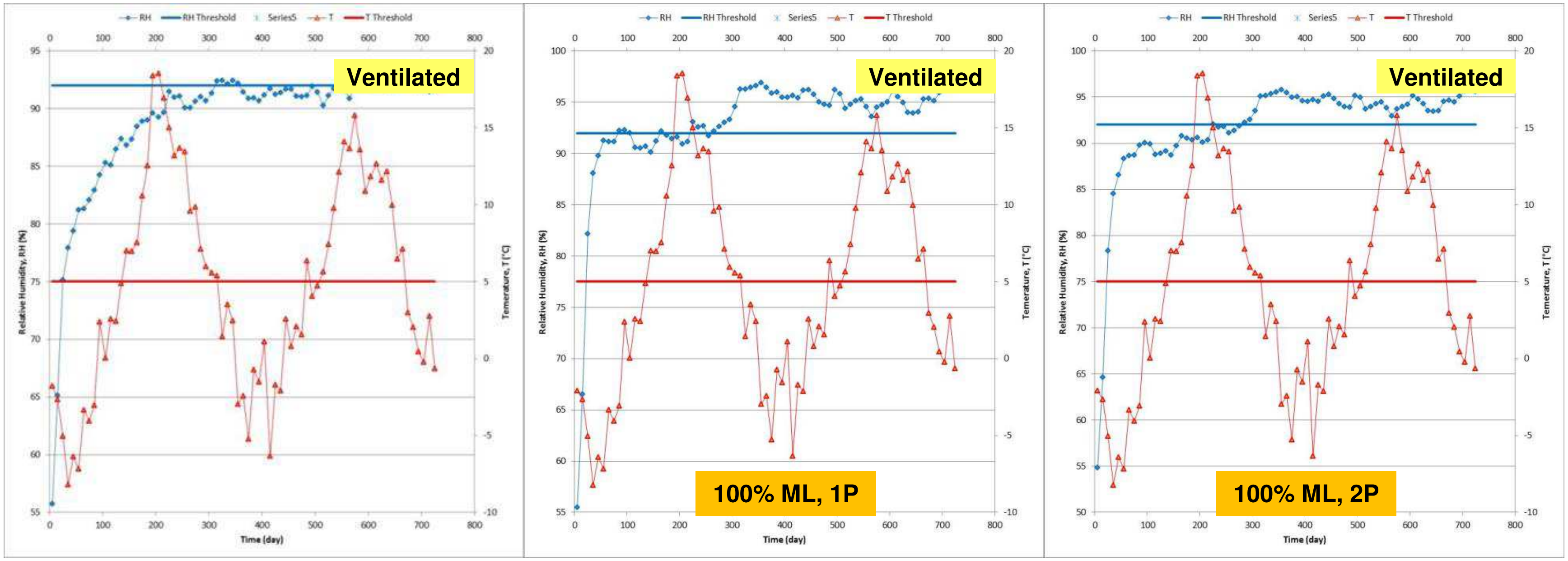


Figure 82 - Client I Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of St John's (NL); response given as RHT(x) where x relates to the RH threshold value at which the index is calculated

Table 42 – Response of Reference & Client I Walls to climate loads of St John's (NL); values of RHT(x) where x relates to the RH threshold value at which the index is calculated where:(i) ML* placed between building paper & Cladding; (ii) 50 % ML on building paper; system vented; (iii) 50 % ML on building paper; system ventilated

	St John's: 100% ML on back of cladding, 1P				St John's: 100% ML, 1P				St John's: 100% ML, 2P			
	RHT(80)	RHT(85)	RHT(92)	RHT(95)	RHT(80)	RHT(85)	RHT(92)	RHT(95)	RHT(80)	RHT(85)	RHT(92)	RHT(95)
Ref Wall	2961	1786	193	0	2961	1786	193	0	2961	1786	193	0
Client I	2226	1209	28	-	2692	1675	296	16	2523	1506	197	1

* ML: Moisture Load; 1P: 1 layer of code-compliant building paper as sheathing membrane; 2P: 2 layers of code-compliant building paper as sheathing membrane

5.10 Client J Drainage System

Overview of Drainage System – Client J

A sectional view of the wall configuration incorporating Client J's drainage system and that consisted of paper-backed welded wire metal lath (Grade D; 60 Minute), an air space created by 9.5 mm plywood strapping, and 2 layers of NBC compliant building paper (BP), is shown in Figure 83. The paper backing of the welded wire metal lath prevented stucco entry to the drainage cavity but nonetheless was shown from the construction of mock-ups to reduce the cavity depth to 5 mm; this depth is what was used in the model.

The water retention characteristics of the drainage system indicate that this system is entirely comparable to the Reference wall drainage system and has similar water retention characteristics to the Reference wall system. A plot of the water vapour permeance (WVP) of both the Grade D, 60 Minute BP and 1 and 2 layers of the NBC compliant BP is given; from the plots it can be seen that both the WVP of these products vary with RH. Focusing on the product used at the sheathing membrane (SM), the 2 layers of NBC compliant BP at low RH has a WVP in the same order of magnitude as a breathable membrane (i.e. ~100 ng/ Pa•s•m^2) and at 80% RH the WVP of the SM is approximately an order of magnitude greater than a breathable membrane. As such, the performance of the wall would be related to the extent to which water vapour permeates the SM and this would in turn depend on the amount of moisture that is retained on the SM following a rain event and the prevailing temperature in the drainage cavity. Given the WVP of the SM, Client J's wall system would readily respond to climate loads.

In respect to the placement of the moisture load (ML) in the cavity, in this instance the ML was assumed to be placed on the backside of the cladding between the building paper (Grade D; 60 Minute) and the stucco cladding; this is the same as for the Reference wall, as both have capillary breaks of 5-10 mm. As well, The paper backing of the welded wire metal of Client J's wall was more robust than the Reference wall (i.e. the WVP of an NBC compliant BP is > than that of Grade D, 60 min. BP; at 50% RH, respectively, ~ 900 vs. ~ 230 ng/ Pa•s•m^2).

Give that the moisture load was retained behind the cladding and given as well the WVP of the 2 layers of NBC compliant BP, suggests that the response of Client J's wall to climate loads would be lessened as compared to the Reference wall and its performance in respect to managing moisture ingress to the drainage cavity, would surpass that of the Reference wall.

Results from Simulation – Client J Drainage System

Hygrothermal response of wall components to climate loads of Tofino and Vancouver (BC) and St John's (NL); M_{IDX} criterion

The response of the Client J's wall assembly to the climate loads of Tofino and Vancouver (BC), and St John's (NL), are provided in Figure 84 to Figure 86 and in Table 43 and Table 44. More specifically, the variation in values for M_{IDX} over the simulation period and in respect to the different locations in the wall, are provided in three (3) plots of Figure 84 for each of the respective climate locations. Plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB -glass fibre interface), the one closet to the moisture load, in these plots, being the "OSB-sliver", representative of a 1 mm thick sliver of the exterior face of the OSB panel.

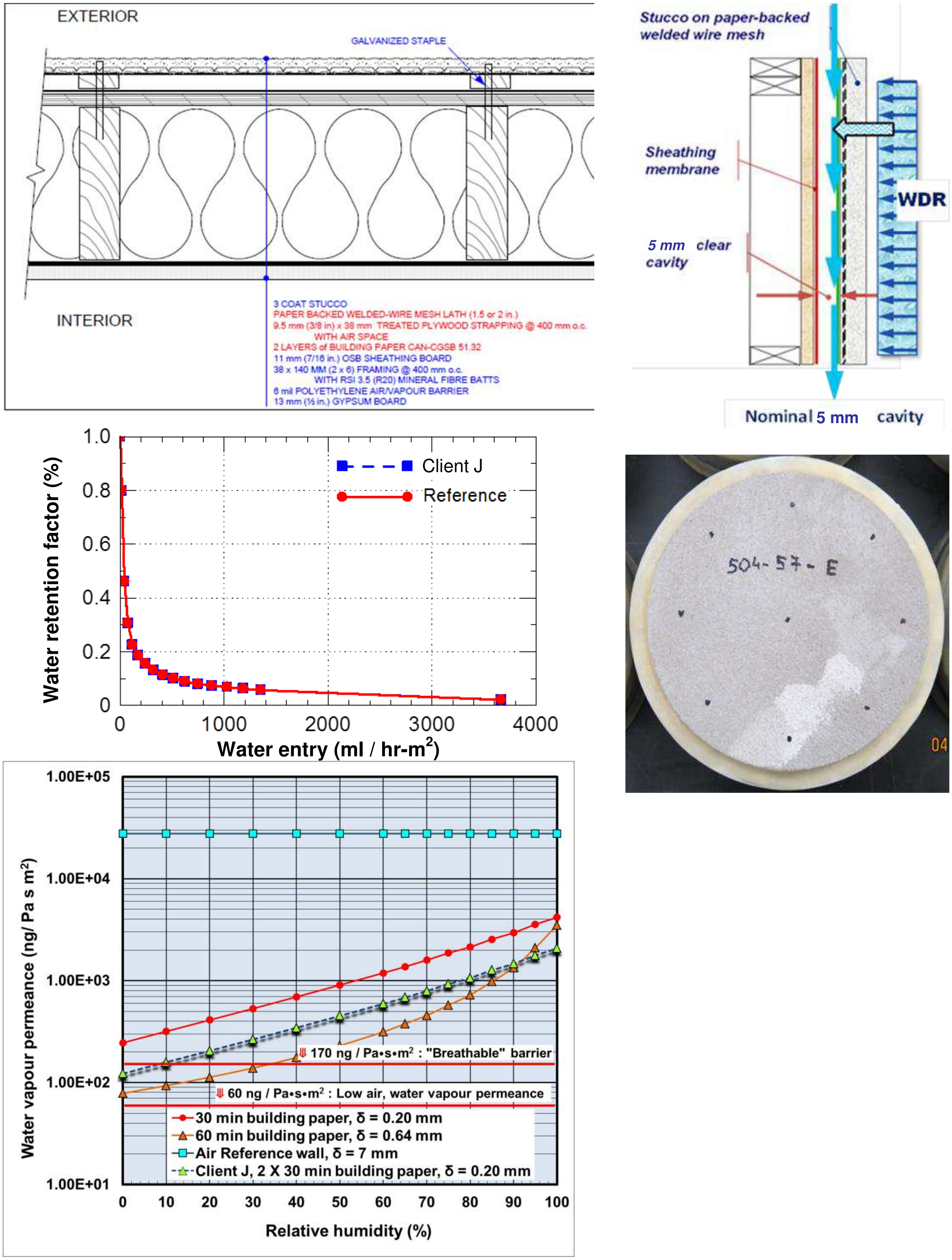


Figure 83 - Client J Wall: Sectional view, placement of ML in 10 mm drainage cavity; water retention characteristics; water vapour permeance of sheathing membrane; δ = membrane thickness

In those plots of **Figure** 84 for of Tofino and Vancouver (BC) the values for M_{IDX} over the course of the simulation, in general, increase over time in relation to the propensity for mould growth given the moisture and temperature conditions in the different locations within the sheathing panels (OSB); the moisture conditions at the different panel locations are related to their respective proximity to the moisture load. Whereas for the plot of St John's (NL), there is no response in the first simulation year until day 180 of the simulation period and at that point there is a gradual increase to day ~220 and thereafter the values decrease and again increase at day 500; the pattern appears to follow the average annual temperature of the location. Over the second simulation year the value of M_{IDX} for the "OSB-sliver" attains a maximum of ~2.5 at ~ 630 d of the simulation; the M_{IDX} for the "OSB-fibre interface does not register until day ~ 550 of simulation..

In respect to the values of M_{IDX} in relation to the location of interest for which a response has been given, the higher values of M_{IDX} are those closest to the SM and the location where the ML was applied and thereafter diminish as the location of interest recedes from the exterior face of the sheathing panel to the interior face of the gypsum panel. Thus the critical values in respect to assessing the management of moisture ingress to the drainage cavity are those provided for the 1 mm "OSB-sliver". Whereas, if the risk of condensation is the measure of importance in respect to wall performance , then the focus is on the interface between the insulation and the OSB panel, that is, the "OSB-fibre interface" as given in **Figure** 84.

The response of the Reference as compared to Client K Walls of the OSB panel component (1 mm sliver on exterior OSB surface) over the same period are shown in Figure 85; values for M_{IDX} as a function of time are provided for three plots in which the simulation are given, for the respective locations, from left to right, for the climate loads of Tofino and Vancouver (BC), and St John's (NL). The plot of values over time clearly shows that Client J walls have lower values of M_{IDX} as compared to the Reference wall over the simulation period. This plainly suggests that the Client J walls have a much lessened response and thus an enhanced performance in respect to managing moisture ingress to the drainage cavity that surpassed that of the Reference wall when subjected to the climate loads of the respective locations.

The information provided in Table 43 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client J's wall. As is evident from these plots and from the information provided in the table, the values for M_{IDX} of Client J's wall are all less than that of the Reference wall, irrespective of the value for M_{IDX} of the layer or interface and the locations for which the simulations were completed.

Hygrothermal response of wall components to climate loads of Tofino and Vancouver (BC) and St John's (NL); RHT(x) criterion

The response of Client J's wall to climate loads of Tofino and Vancouver (BC), and St John's (NL) as provided by plots of temperature and relative humidity levels and from which are determined values for RHT(x) index, are shown in Figure 86. The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client K walls and for different threshold values of RH are given in Table 44.

As provided in Table 44, all values of RHT(80) and RHT(85), RHT(92) and RHT(95) for the Client K wall were less than the Reference wall; these values are consistent with those determined for M_{IDX} as were made available in Table 43.

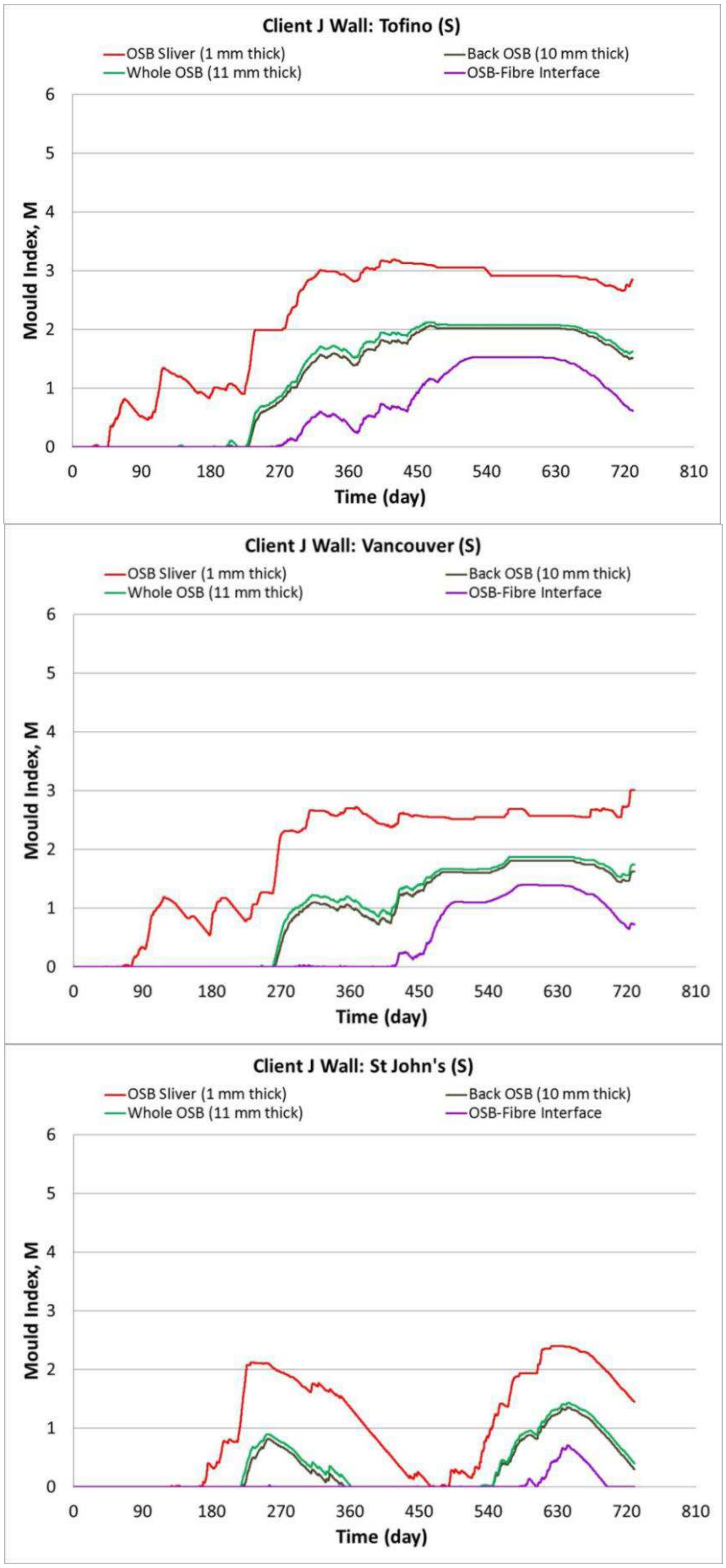


Figure 84 - Client J Walls: Response of OSB component to climate loads of Tofino, and Vancouver (BC) and St John's (NL); response given as M_{IDX} value for sensitivity class "S"

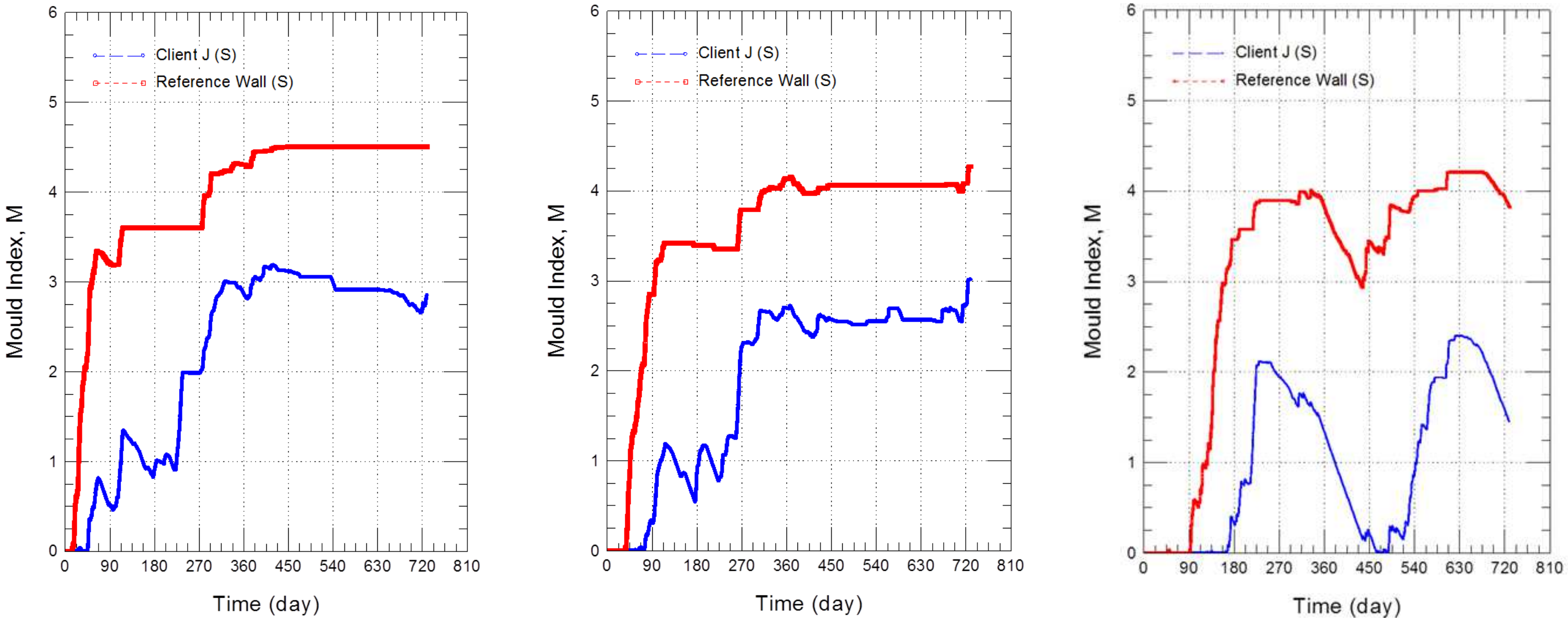


Figure 85 – Reference and Client J Walls: Response of OSB component (1 mm sliver on exterior OSB surface) to climate loads of (from left to right) Tofino and Vancouver (BC) and St John's (NL); response given as M_{IDX} value for sensitivity class "S"

Table 43 – Response of Reference (REF.) and Client J Walls to climate loads Tofino and Vancouver (BC) and St John's (NL)
Average and maximum values of M_{IDX} for different locations in walls in which Moisture Load was placed between Building paper and cladding

	Tofino				Vancouver				St John's			
	OSB Sliver (1 mm)	**Back OSB (10 mm)**	**Whole OSB (11 mm)**	**OSB-Fibre Interface**	**OSB Sliver (1 mm)**	**Back OSB (10 mm)**	**Whole OSB (11 mm)**	**OSB-Fibre Interface**	**OSB Sliver (1 mm)**	**Back OSB (10 mm)**	**Whole OSB (11 mm)**	**OSB-Fibre Interface**
REF-Avg	3.910	2.506	2.597	1.819	3.500	2.181	2.271	1.518	3.085	1.941	2.035	1.147
REF-Max	4.508	3.475	3.538	2.984	4.270	3.082	3.149	2.633	4.210	3.191	3.261	2.562
Client J-Avg	2.161	1.149	1.211	0.621	1.866	0.876	0.937	0.431	1.004	0.290	0.334	0.049
Client J-Max	3.187	2.060	2.119	1.522	3.011	1.805	1.871	1.389	2.393	1.356	1.428	0.705

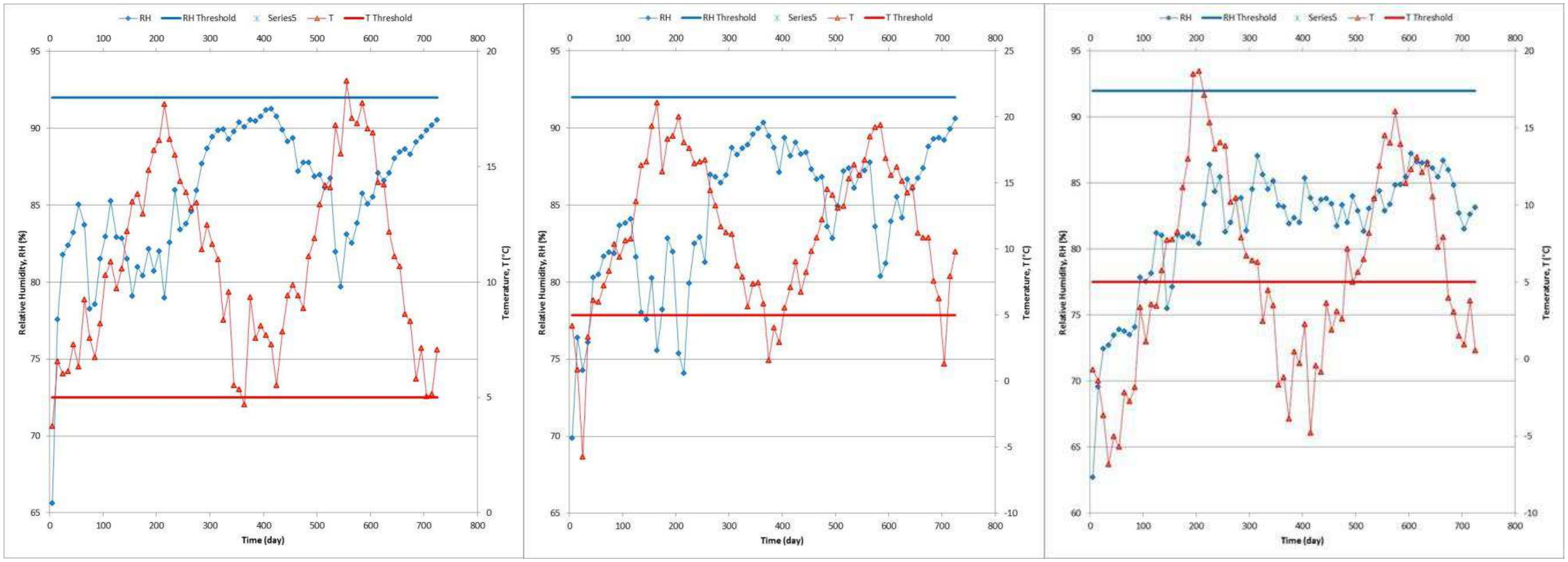


Figure 86 – Client J Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of Tofino and Vancouver (BC) and St John's (NL); response given as RHT(x) where x relates to the RH threshold value at which the index is provided

Table 44 – Reference and Client B Wall: Response of OSB component to climate loads of Tofino and Vancouver (BC) and St John's (NL); response given as RHT(x) where x relates to the RH threshold value at which the index is provided

	Tofino				Vancouver			St John's			
	RHT(80)	RHT(85)	RHT(92)	RHT(95)	RHT(80)	RHT(85)	RHT(92)	RHT(80)	RHT(85)	RHT(92)	
Ref Wall	5263	3015	435	37	4958	2493	192	2961	1786	193	**Ref Wall**
Client J	2092	554	0	0	2005	484	0	834	89	0	**Client J**

5.11 Client K Drainage System

Overview of Drainage System – Client K

A sectional view of the wall configuration incorporating Client K's drainage system and that consisted of paper-backed welded wire metal lath (Grade D; 60 Minute), an air space created by 19 mm plywood strapping, and 2 layers of NBC compliant building paper (BP), is shown in Figure 87. The water retention characteristics of the drainage system indicate that this system is entirely comparable to the Reference wall drainage system and has similar water retention characteristics to the Reference wall system. A plot of the water vapour permeance (WVP) of both the Grade D, 60 Minute BP and 1 and 2 layers of the NBC compliant BP is given; from the plots it can be seen that both the WVP of these products vary with RH. Focusing on the product used at the sheathing membrane (SM), the 2 layers of NBC compliant BP at low RH has a WVP in the same order of magnitude as a breathable membrane (i.e. ~100 ng/ Pa•s•m^2) and at 80% RH the WVP of the SM is approximately an order of magnitude greater than a breathable membrane.

As such, the performance of the wall would be related to the extent to which water vapour permeates the SM and this would in turn depend on the amount of moisture that is retained on the SM following a rain event and the prevailing temperature in the drainage cavity. Given the WVP of the SM, Client K's wall system would readily respond to climate loads.

In respect to the placement of the moisture load (ML) in the cavity, in this instance the ML was assumed to be placed on the backside of the cladding between the building paper (Grade D; 60 Minute) and the stucco cladding; this is the same as for the Reference wall, although the Reference wall did not have as robust a BP (i.e. the WVP of an NBC compliant BP is > than that of Grade D, 60 min. BP; at 50% RH, respectively, ~ 900 vs. ~ 230 ng/ Pa•s•m^2).

Give that the moisture load was retained behind the cladding and given as well the WVP of the 2 layers of NBC compliant BP, suggests that the response of Client K's wall to climate loads would be lessened as compared to the Reference wall and its performance in respect to managing moisture ingress to the drainage cavity, would surpass that of the Reference wall.

Results from Simulation – Client K Drainage System

Hygrothermal response of wall components to climate loads of Tofino and Vancouver (BC) and St John's (NL); M_{IDX} criterion

The response of the Client K's wall assembly to the climate loads of Tofino and Vancouver (BC), and St John's (NL), are provided in Figure 88 to Figure 90 and in Table 45 and Table 46. More specifically, the variation in values for M_{IDX} over the simulation period and in respect to the different locations in the wall, are provided in three (3) plots of Figure 88 for each of the respective climate locations. Plots are provided for four (4) locations in the wall assembly (i.e. "OSB Sliver"; back 10 mm portion of OSB; "Whole" 11 mm thick OSB panel, and; OSB -glass fibre interface), the one closet to the moisture load, in these plots, being the "OSB-sliver", representative of a 1 mm thick sliver of the exterior face of the OSB panel.

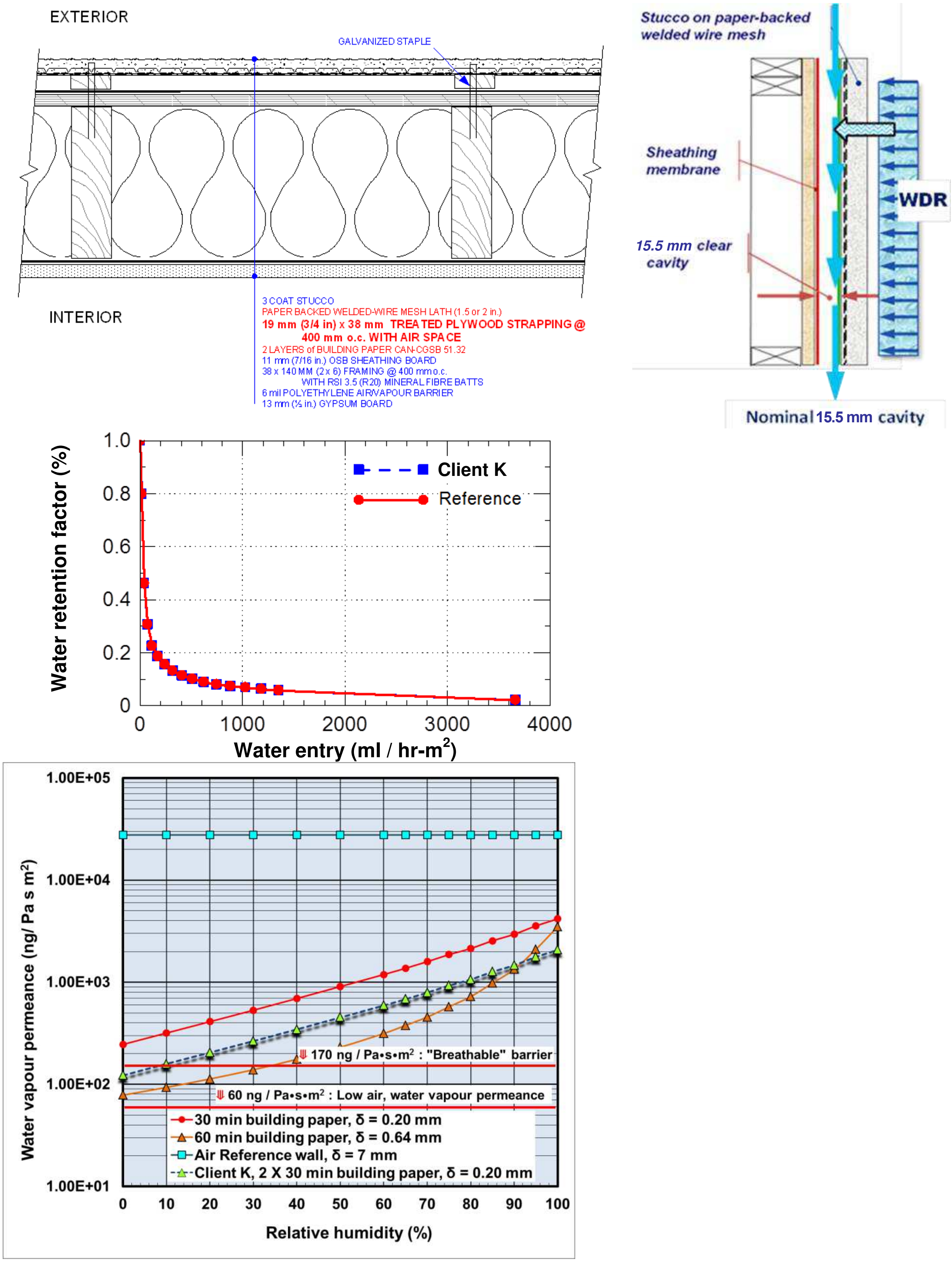


Figure 87 - Client K Wall: Sectional view, placement of ML in 10 mm drainage cavity; water retention characteristics; water vapour permeance of sheathing membrane; δ = membrane thickness

In those plots of Figure 88 for of Tofino and Vancouver (BC) the values for M_{IDX} over the course of the simulation, in general, increase over time in relation to the propensity for mould growth given the moisture and temperature conditions in the different locations within the sheathing panels (OSB); the moisture conditions at the different panel locations are related to their respective proximity to the moisture load. Whereas for the plot of St John's (NL), there is no response in the first simulation year until day 90 to 180 of the simulation period and at that point there is a gradual increase to day 270 and thereafter the values decrease and again increase at day 450; the pattern appears to follow the average annual temperature of the location. Over the second simulation year the value of M_{IDX} for the "OSB-sliver" attains a maximum of ~4 at ~ 630 d of the simulation.

In respect to the values of M_{IDX} in relation to the location of interest for which a response has been given, the higher values of M_{IDX} are those closest to the SM and the location where the ML was applied and thereafter diminish as the location of interest recedes from the exterior face of the sheathing panel to the interior face of the gypsum panel. Thus the critical values in respect to assessing the management of moisture ingress to the drainage cavity are those provided for the 1 mm "OSB-sliver". Whereas, if the risk of condensation is the measure of importance in respect to wall performance , then the focus is on the interface between the insulation and the OSB panel, that is, the "OSB-fibre interface" as given in Figure 88.

The response of the Reference as compared to Client K Walls of the OSB panel component (1 mm sliver on exterior OSB surface) over the same period are shown in Figure 89; values for M_{IDX} as a function of time are provided for three plots in which the simulation are given, for the respective locations, from left to right, for the climate loads of Tofino and Vancouver (BC), and St John's (NL). The plot of values over time clearly shows that Client K walls have lower values of M_{IDX} as compared to the Reference wall over the simulation. This plainly suggests that the Client K walls have a much lessened response and thus an enhanced performance in respect to managing moisture ingress to the drainage cavity that surpassed that of the Reference wall when subjected to the climate loads of the respective locations.

The information provided in Table 45 shows the average and maximum values for M_{IDX} for different locations within the Reference and Client H's wall. As is evident from these plots and from the information provided in the table, the values for M_{IDX} of Client K's wall are all less than that of the Reference wall, irrespective of the value for M_{IDX} of the layer or interface and the locations for which the simulations were completed.

Hygrothermal response of wall components to climate loads of Tofino and Vancouver (BC) and St John's (NL); RHT(x) criterion

The response of Client K's wall to climate loads of Tofino and Vancouver (BC), and St John's (NL) as provided by plots of temperature and relative humidity levels and from which are determined values for RHT(x) index, are shown in Figure 90. The actual values for the RHT(x) index at the end of the simulation period for the Reference and Client K walls and for different threshold values of RH are given in Table 46.

As provided in Table 46, values of RHT(80) and RHT(85), were greater for the Client K wall as compared to the Reference wall whereas values of RHT(92) and RHT(95) we less than those of the Reference wall; those values given for RHT(92) and RHT(95) are consistent with those determined for M_{IDX} as were made available in Table 45.

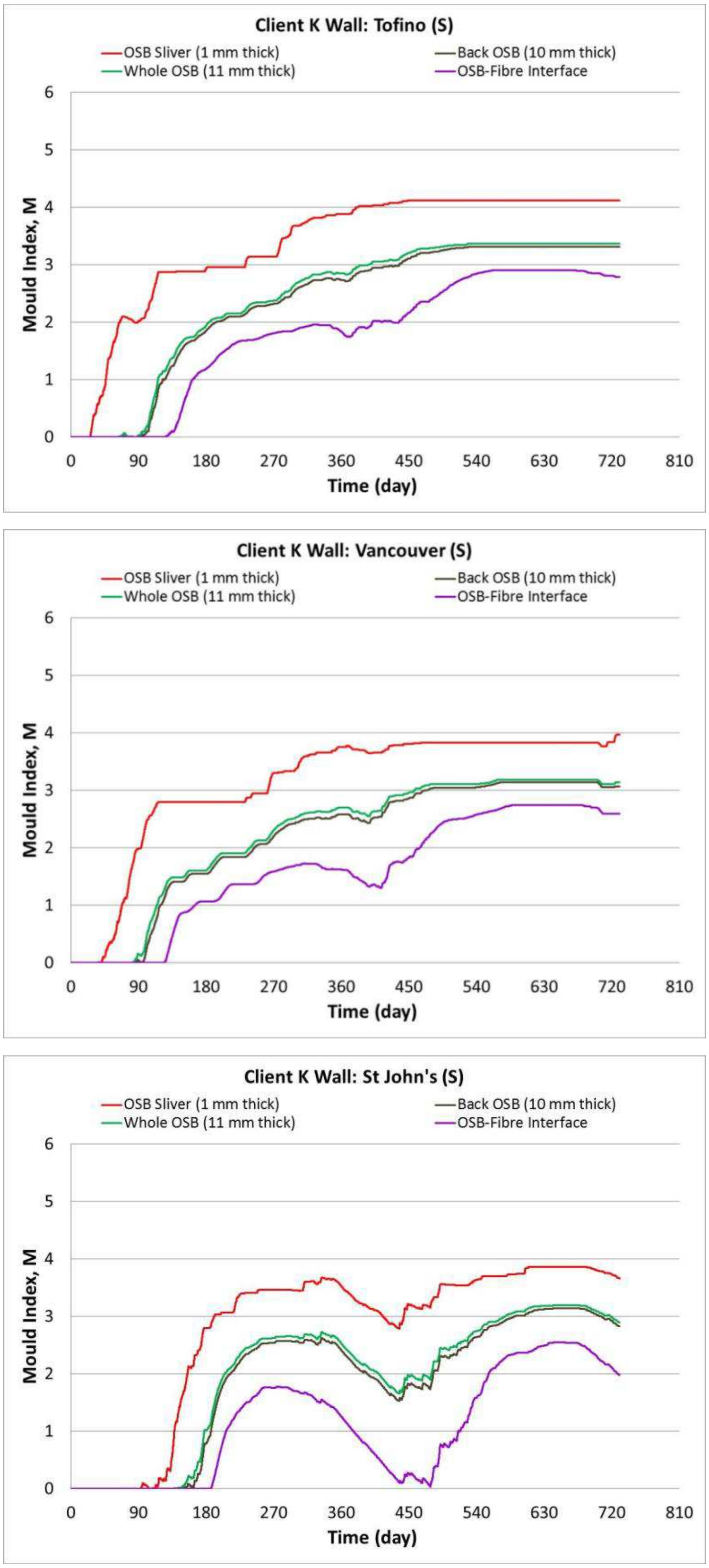


Figure 88– Client K Walls: Response of OSB component to climate loads of Tofino, and Vancouver (BC) and St John's (NL); response given as M_{IDX} value for sensitivity class "S"

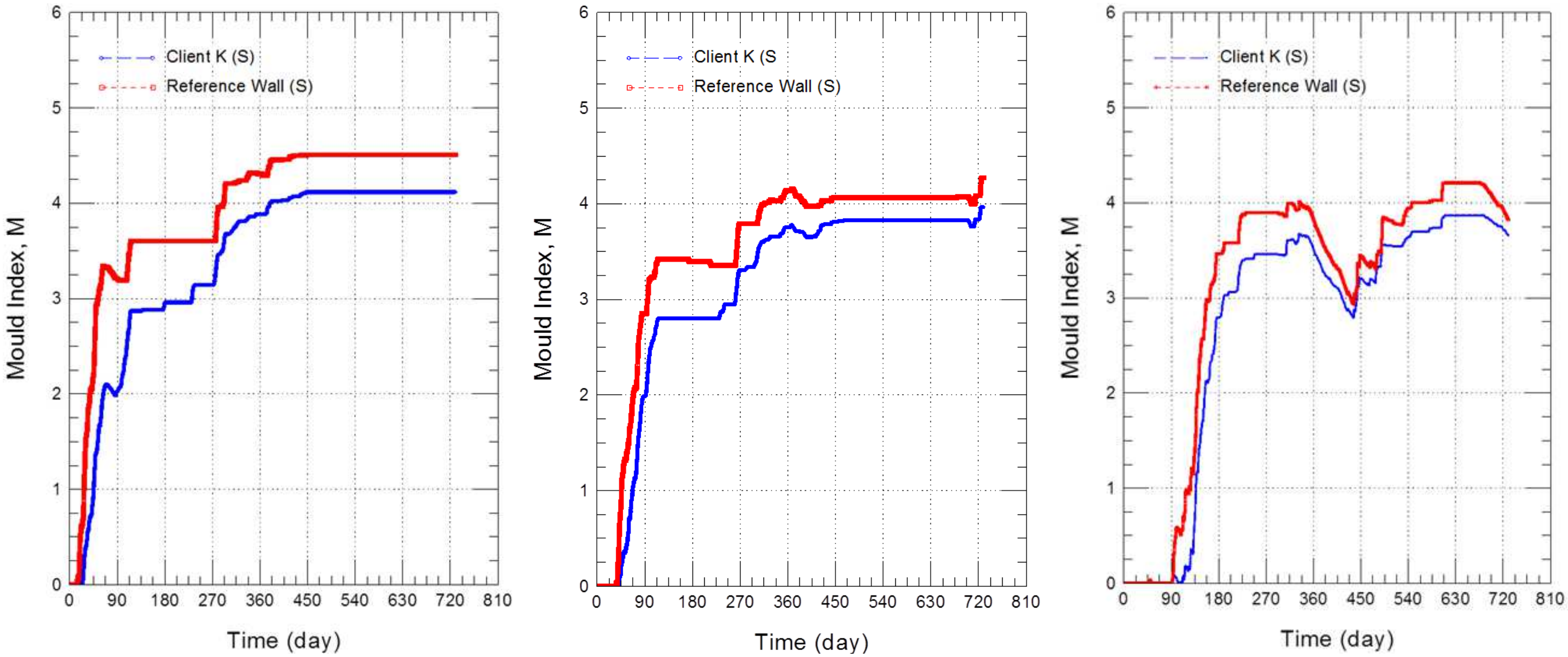


Figure 89 – Reference and Client K Walls: Response of OSB component (1 mm sliver on exterior OSB surface) to climate loads of (from left to right) Tofino and Vancouver (BC) and St John's (NL); response given as M_{IDX} value for sensitivity class "S"

Table 45– Response of Reference (REF.) and Client K Walls to climate loads Tofino and Vancouver (BC) and St John's (NL) Average and maximum values of M_{IDX} for different locations in walls in which Moisture Load was placed between Building paper and cladding

	Tofino				Vancouver				St John's			
	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface	OSB Sliver (1 mm)	Back OSB (10 mm)	Whole OSB (11 mm)	OSB-Fibre Interface
REF-Avg	3.910	2.506	2.597	1.819	3.500	2.181	2.271	1.518	3.085	1.941	2.035	1.147
REF-Max	4.508	3.475	3.538	2.984	4.270	3.082	3.149	2.633	4.210	3.191	3.261	2.562
Client K-Avg	3.358	2.338	2.408	1.776	3.104	2.172	2.245	1.602	2.750	1.858	1.941	1.096
Client K-Max	4.112	3.312	3.362	2.895	3.959	3.132	3.180	2.741	3.859	3.136	3.189	2.543

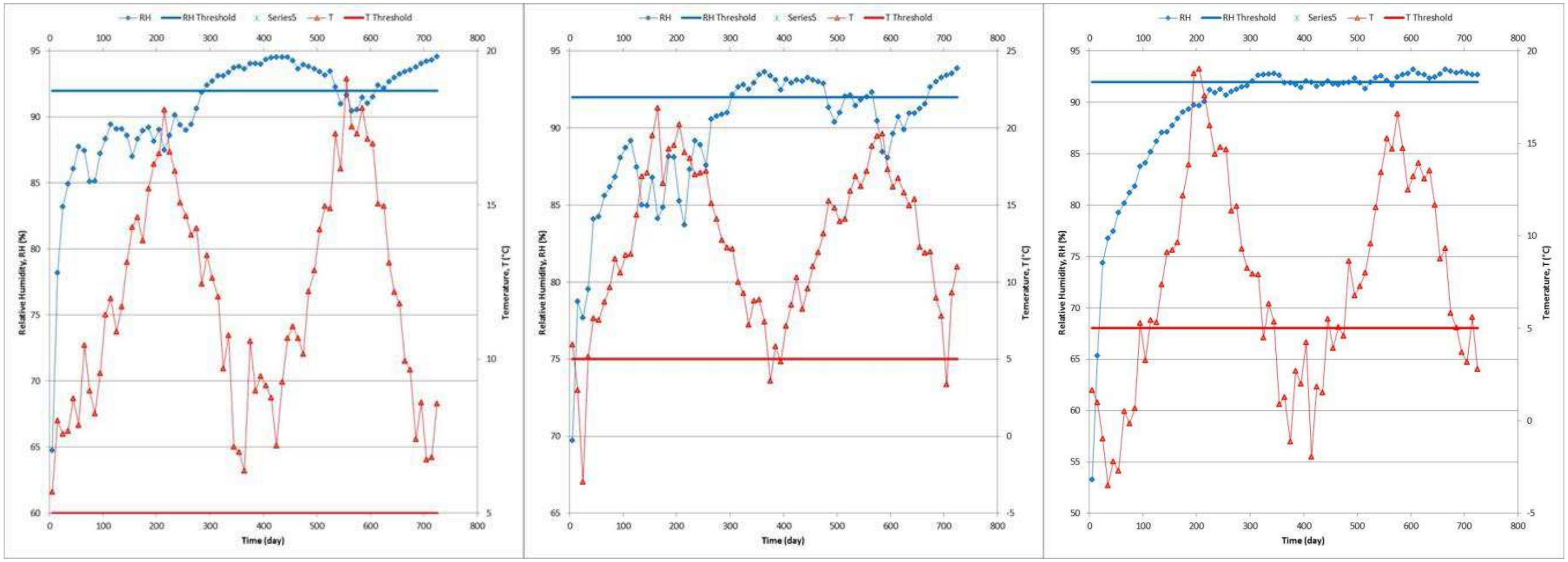


Figure 90 – Client K Wall: Response of OSB component (1 mm sliver on exterior surface of OSB panel) to climate loads of Tofino and Vancouver (BC) and St John's (NL); response given as RHT(x) where x relates to the RH threshold value at which the index is provided

Table 46 – Reference and Client K Wall: Response of OSB component to climate loads of Tofino and Vancouver (BC) and St John's (NL); response given as RHT(x) where x relates to the RH threshold value at which the index is provided

	Tofino					Vancouver				St John's			
	RHT(80)	RHT(85)	RHT(92)	RHT(95)		RHT(80)	RHT(85)	RHT(92)		RHT(80)	RHT(85)	RHT(92)	
Ref Wall	5263	3015	435	37		4958	2493	192		2961	1786	193	**Ref Wall**
Client K	5558	3042	290	0		5283	2542	102		3050	1698	70	**Client K**

6.0 Summary

Results from hygrothermal simulation have been presented in which the response of the respective Client walls to climate conditions of Tofino (BC), Vancouver (BC), and St John's (NL) have been described. The results, as provided by information on the mould index and RHT index within the assembly, permitted comparisons of the response of the respective Client walls to the Reference wall.

For each of the Client wall assemblies, an overview of the Client's drainage system was first provided to permit assessing the expected response of wall components to moisture loads within the drainage cavity, given the moisture loadings conditions and the performance attributes of the cavity, that included the size and drainage-retention response of the cavity as well as the type and water vapour permeance of the sheathing membrane used to protect the exterior surface of the OSB sheathing panel.

Thereafter, the results from simulation of the Client's and the Reference wall were provided over a two year period to climate conditions of Tofino (BC), Vancouver (BC), and St John's (NL). For each of these locations, results are provided using the two performance criteria; the: (i) Mould index (M_{IDX}) criterion (risk to mould growth), and; (ii) Relative humidity-temperature RHT(x) criterion (risk to the growth of wood rot fungi).

A summary of the simulation results from each of the client wall assemblies and the reference wall assembly is provided in Table 47.

To summarise the wall specifications, wall assemblies had:

- Cladding, a 3 coat Stucco with expanded diamond-mesh metal lath with no paper backing;
- The sheathing panel for each of the wall assemblies was an 11 mm OSB panel with the exception of Client B for which the sheathing panel was a 12.5 mm exterior grade gypsum board.
- Wall assemblies were assumed to be wood framed with 28 x 140 mm (2x6) wood stud framing @ 600 mm o.c.; the exception to this was Client B for which the framing was steel stud.
- Wall assemblies had RSI 3.5 (R20) mineral fibre batts as insulation, with the exception of Client B that incorporated a mineral fibre batt (89 mm).
- Other elements that permit describing the specifications of the walls and relate to the drainage system are provided in Table 48.

The average and maximum values of the mould index (M_{IDX}) obtained from simulations for the 1 mm "OSB-sliver", for each of the locations and for each Client wall as well as the reference wall is provided in the table; the average value is atop the maximum value. Likewise, the corresponding values for the RHT(x) index, specifically, RHT(92) and when available, RHT(95) are also provided; the value of RHT(92) is atop that of RHT(95). The values provided for the respective Client walls are those that were the lowest attainable for a given solution amongst the different solutions simulated.

The respective values for in Table 47 for M_{IDX} and RHT(x) that have been highlighted indicate when these values exceed that of the Reference wall.

Table 47 – Summary of Simulation Results of Reference and Respective Client Wall Assemblies

Assembly	Layer separating cladding from drainage layer	Drainage layer	Sheathing membrane	Ventilation Strategy	Placement of ML*	M_{IDX} Average M_{IDX} Maximum			RHT(92) RHT(95)		
						Tofino	Van.	St. J	Tofino	Van.	St. J
Reference (R)	None	Air space created by 19x38 mm wood strapping	1 layer of BP	Vented at base of wall every 3.5 storeys	**BC**	3.9 4.5	3.5 4.3	3.1 4.2	435 37	192 2	193 0
Client A	**BP**	SBPO sheathing membrane		**R**	**SM**	4.3 5.2	3.5 4.4	3.5 4.7	1220 490	224 6	358 46
Client B	**R** (none)	10 mm air space 76 mm water repellent insulation board	Fluid applied air barrier	**R**	**BC**	3.5 4.0	3.2 3.9	2.8 3.8	359 0	62 -	34 -
Client C	**BP**	Nylon mesh (10 mm; open matrix) bonded to PP nonwoven sheathing membrane		**R**	50% **SM**	2.5 3.7	1.9 3.1	1.7 2.9	19 0	0 -	0 -
Client D	**BP**	Cross woven, micro-perforated polyolefin sheathing membrane with polyolefin coating		**R**	**SM**	4.1 5.3	3.0 4.1	3.7 4.9	1532 798	72 0	459 148
Client E	PP fabric bonded to dimpled HDPE membrane		**R**	Option 1: **R** Option 2: VTLD**	50% **SM**	1.8 3.9	1.9 3.7	0.5 1.9	6^{VLTD} 0	4^{V} 0	0^{VLTD} 0
Client F	**R** (none)	25 mm air space	**R**	**R**	**BC**	3.7 4.2	3.4 4.0	2.8 4.0	616 0	167 -	120 -
Client G	Non-woven PP fabric (stucco screen) / PP mat (10 mm; 3-dimensional extruded PP mono-filament mesh)		**R**	**R**	50% **SM**	4.0 4.8	3.2 4.1	2.9 4.1	501 99	90^{VTLD} 0	42 0
Client H	**R** (none)	Porous PS insulation board (52 mm)	Fluid applied	**R**	**BC**	2.5 4.1	1.3 2.9	1.1 2.7	300 0	527 0	0 -
Client I	**R** (none)	2-ply (3.8 mm) corrugated asphalt impregnated paper (Grade D)	**R**	**VTLD top & bottom every storey**	**SM**	4.0 5.0	3.2 4.1	3.1 4.3	743 227	93 0	197 1
Client J	**BP**	9.5 mm (3/8 in.) Air space.	**2 layers of BP**	**R**	**BC**	2.2 3.2	1.9 3.0	1.0 2.4	0 0	0 -	0 -
Client K	**BP**	19 mm (3/4 in.) Air space	**2 layers of BP**	**R**	**BC**	3.4 4.1	3.1 4.0	2.8 3.9	290 0	102 -	70 -

***ML: Moisture Load; BP: Building paper conforming to CAN-CGSB 51.32; R – Same as Reference wall assembly; V: Vented;**

****VTLD - Ventilated top & bottom every 2 storeys**

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. Nicholls (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 (2015) Performance Evaluation of Proprietary Drainage Components and Sheathing Membranes when Subjected to Climate Loads – Task 6 – Hygrothermal Performance of NBC-Compliant Reference Wall for Selected Canadian Locations; Client Report A1-000030.07; National Research Council Canada; Ottawa, ON; 59 pgs.
	H. H. Saber (2015) Performance Evaluation of Proprietary Drainage Components and Sheathing Membranes when Subjected to Climate Loads – Task 6 – Hygrothermal Performance of Wall Assemblies Incorporating Drainage Components for Selected Canadian Locations; Client Report A1-000030.08; National Research Council Canada; Ottawa, ON; 167 pgs.
	H. H. Saber (2015) Performance Evaluation of Proprietary Drainage Components and Sheathing Membranes when Subjected to Climate Loads – Task 6 – Hygrothermal Performance of Wall Assemblies Incorporating Drainage Components: Results for wall components having Medium Resistant (MR) Mould Growth Sensitivity Class; Client Report A1-000030.10; National Research Council Canada; Ottawa, ON; 85 p.
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; 43 pgs.

Appendix 2 – Hourly WDR intensity for selected Canadian locations

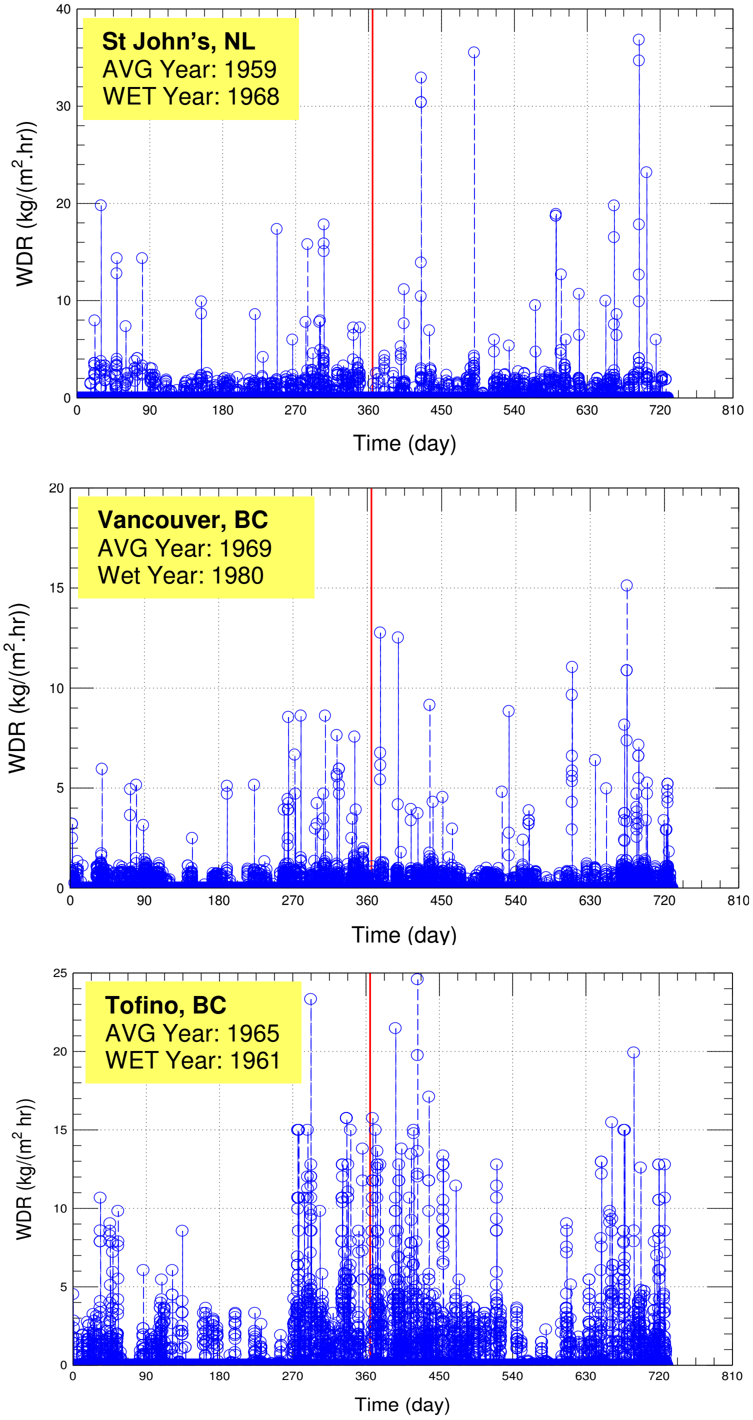


Figure A91 – Hourly WDR intensity for (a) St John's (NL), (b) Vancouver and (c) Tofino (BC) over an "average" year