MORRISON HERSHFIELD

REPORT

Hygrothermal Analysis of Quik-Therm Solar Dry Insulation

Presented to:

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1. INTRODUCTION

Morrison Hershfield (MH) was contracted by Quik-Therm Insulation Solutions Inc. (Quik-Therm) to evaluate the hygrothermal performance of the Quik-Therm Solar Dry (SDI) insulation for wood-frame wall assemblies. The Quik-Therm SDI insulation system is a metalized polymer expanded polystyrene (EPS) insulation with grooved drainage channels as shown in Figure 1.1. As part of this evaluation, MH evaluated the impact of various conditions on the hygrothermal performance of wall assemblies with SDI Insulation, including perforating the metalized polymer facers. The objectives of the analysis are to:

1. Evaluate the impact of the Quik-Therm SDI insulation with perforated facers with respect to wetting and drying from air leakage, high construction moisture, and incidental rain leaks;
2. Address concerns of moisture issues in assemblies with low vapour permeance exterior insulation and interior vapour control (ie. double vapour barrier).

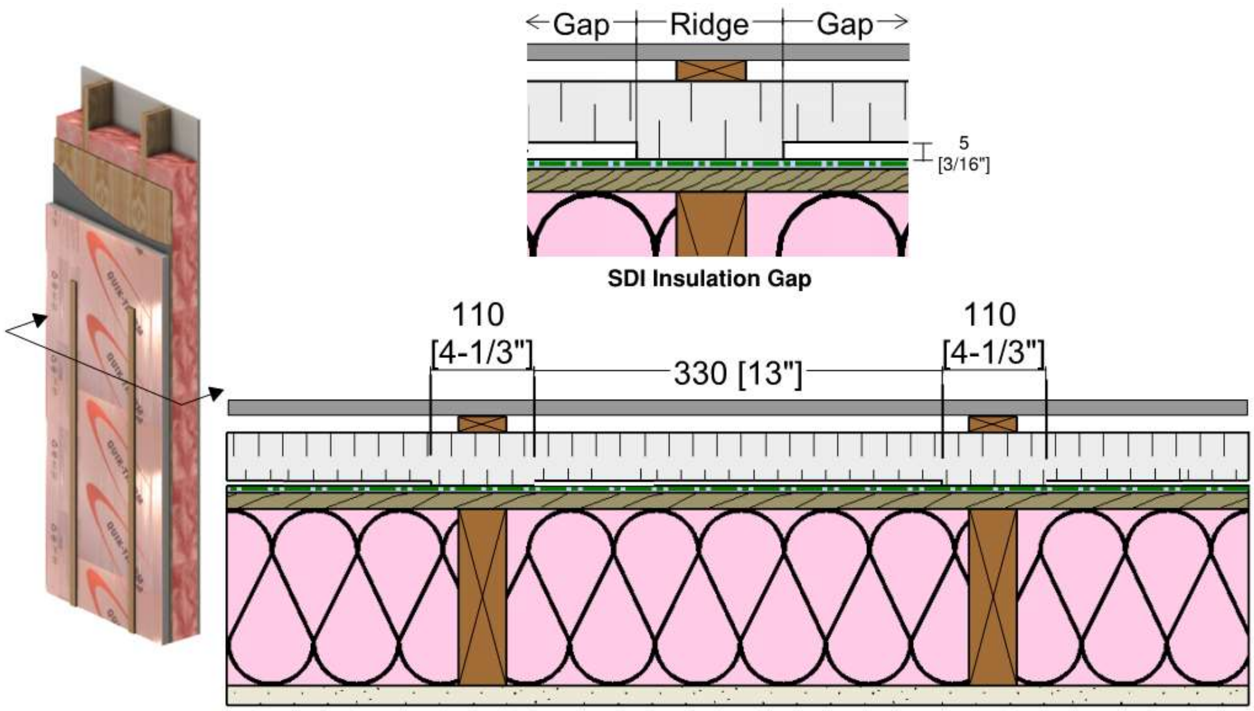

Figure 1.1: Quik-Therm SDI insulation horizontal section

MH evaluated wood frame assemblies for Vancouver and Edmonton climates. Split insulated assemblies (insulation in the stud cavity and outboard of the wood framing) were evaluated and compared to a code minimum wall assembly[1], from a hygrothermal perspective, without exterior insulation and minimum vapour permeability of the moisture barrier (sheathing membrane).

[1] Code minimum wall assemblies designed to meet prescriptive thermal requirements of NECB 2015 with interior insulated 2x6 at wood frame wall with R-20 batt insulation in Vancouver and R-24 batt insulation in Edmonton

Additional comparisons were also made to wood frame assemblies with EPS insulation with metal facers and XPS insulation to evaluate the performance SDI insulation system to other low vapour permeance insulation. Exterior insulation levels are based on achieving effective R-values of R-22 (RSI 3.87) for Vancouver (Zone 5)[2] and R-28 (RSI 4.93) for Edmonton (Zone 7)[3] for 2x6 wood-framed walls with R-19 (RSI 3.35) batt insulation in the stud cavity. An overview of the simulated wall assemblies follows in Figure 1.2.

Overview of Evaluated Wall Assemblies

Exterior

- Generic lightweight rainscreen cladding (fiber cement)
- Exterior insulation: Quik-Therm SDI (metalized polymer EPS with 1%, 3%, and 5% perforation on the polymer facer) insulation, Expanded Polystyrene (EPS) insulation with metal facers, and Extruded Polystyrene (XPS) insulation, (see Table 2.3)
- Weather resistive barrier membrane (15 Perm (858 ng/Pa.s.m^2) for baseline analysis, 3 Perm (172 ng/Pa.s.m^2) for code minimum assembly)
- 1/2" (13 mm) plywood sheathing
- 2 x 6 wood frame stud cavity with R-19 (RSI 3.35) fiberglass batt insulation
- 6 mil polyethylene vapour barrier
- Interior drywall

Interior

Figure 1.2: Example split insulated wood frame wall assembly

The effective vapour permeance of the perforated metalized polymer were based on measurements made by Bauer (1965)[4] and its properties are listed in Appendix A. The effective vapour permeance of the SDI insulation with perforated metalized polymer facers and XPS insulation are listed in Table 1.1.

[2] As per the prescriptive requirements in Vancouver Building Bylaw (VBBL)
[3] As per the requirements in NECB 2015
[4] "Influence of Holes on Water-Vapor Permeability of Vapor-Checking Surface Layers", Bauer, W., Symposium Moisture Problems in Buildings, Helsinki, 1965

Table 1.1: Vapour Permeance of Evaluated Exterior Insulation Scenarios

Insulation Type	**Vapour Permenace** US Perm (ng/Pa.s.m^2)
1.5" SDI Insulation with 1% Perforated Metalized Polymer Facers	1.09 (62)
2" SDI Insulation with 1% Perforated Metalized Polymer Facers	0.85 (49)
2" SDI Insulation with 3% Perforated Metalized Polymer Facers	0.89 (51)
2" SDI Insulation with 5% Perforated Metalized Polymer Facers	0.91 (52)
3" SDI Insulation with 1% Perforated Metalized Polymer Facers	0.59 (34)
3" SDI Insulation with 3% Perforated Metalized Polymer Facers	0.61 (34)
3" SDI Insulation with 5% Perforated Metalized Polymer Facers	0.62 (35)
1.5" XPS Insulation	0.55 (32)
2.5" XPS Insulation	0.33 (19)

2. METHODOLOGY

2.1 Modelling Approach and Assumptions

The hygrothermal performance of the wall assemblies were evaluated using 2D finite element heat-air-moisture program DELPHIN[5]. The wall assemblies were evaluated under time-transient (dynamic) conditions using published material properties and information provided by Quik-Therm. Appendix A lists the material properties used in the simulations.

2.1.1 Climate

The wall assemblies were evaluated using climatic data that are representative of a wet year as determined by the MEWS[6] study as well as a cold year based on heating degree days. A list of the representative wet years is provided in Table 2.1. Table 2.2 summarizes the simulated indoor conditions. Uncontrolled indoor humidity is simulated by applying a vapour pressure elevation to the outdoor air[7]. Appendix B outlines the simulated hourly conditions for the interior and exterior conditions and other modelling assumptions.

Table 2.1: Simulated Climatic Data Compared to NECB 2015 Climatic Data

Climate	Climate Zone	Simulated Climatic Data			NECB - 2015 Climatic Data
		Weather Year	**Annual Rainfall** inches (mm)	**Heating Degree Days** 65°F (18°C)	**Heating Degree Days** 65°F (18°C)
Vancouver, BC	5	1980 (Wet and Cold)	48 (1,211)	5,810 (3,109)	5,085 (2825)
Edmonton, AB	7	1988 (Wet)	18 (460)	9,381 (5,095)	9,216 (5120)
		1996 (Cold)	19 (482)	10,962 (6,090)	

[5] MH has validated the model and approach used for this project to published field studies that evaluated the impact of rain leaks for similar wall assemblies from “Wetting and Drying of Exterior Insulated Walls” by Gauvin et al 2014.
[6] Moisture Management for Exterior Wall Systems (MEWS) Project Task 4 – Environmental Conditions Final Report, NRC, 2002.
[7] We apply this approach following past studies that have demonstrated that realistic design indoor conditions can be simulated by applying a vapour pressure difference (ΔVP) between the indoor and outdoor air in cold climates. The principal reasons for applying this approach is the indoor climate model is reinforced by the principles of building physics and moisture balances, mirrors monitoring data, and does not have a significant bias for any particular climate. (Roppel et al 2009).

Table 2.2: Simulated Indoor Conditions

Climate	Heating Season (October to April)			Shoulder and Summer Seasons (May to September)		
	Temperature °F (°C)	ΔVP (Pa)	Corresponding Indoor RH	Temperature °F (°C)	ΔVP (Pa)	Corresponding Indoor RH
Vancouver, BC	70 (21)	540	35% - 55%	70-77 (21-25)	Varies linearly based on outdoor temperature when above 32°F (0°C)	50% - 75%
Edmonton, AB	70 (21)		25% - 40%	70-77 (21-25)		40% - 75%

2.1.2 Wall Construction

The evaluated wall assemblies meet a minimum effective R-value of R-22 (RSI 3.87) in Vancouver and R-28 (RSI 4.93) in Edmonton and satisfy the minimum insulation ratio required to control moisture accumulation in the sheathing when subject to air leakage for the EPS with metal facer and XPS wall assemblies[8]. The effective R-values were determined with 25% framing factor[9] and the exterior insulation is continuous, except for fasteners[10]. The evaluated wall assemblies and Insulation Ratios[11] are presented in Table 2.3.

Table 2.3: Evaluated wall assembly construction

Climate	Wall Construction	Insulation Thickness inches (mm)	Effective R-value	Insulation Ratio	
				Ratio of Evaluated Wall	Minimum per 2015 NBC Table 9.25.5.2.
Vancouver, BC	R-19 batt + R-8.4 EPS with Metal Facer	2” (51)	R-23	0.47	0.2
	R-19 batt + R-7.5 XPS	1.5” (38)	R-22	0.43	
Edmonton, AB	R-19 batt + R-12.6 EPS with Metal Facer	3” (76)	R-28	0.68	0.35
	R-19 batt + R-12.5 XPS	2.5” (64)	R-28	0.68	

[8] See Section 3.3. for more discussion
[9] Effective R-value calculations referenced from ASHRAE 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings 2016 for 2x6 stud wall with R-19 batt insulation with 16” o.c. wood stud framing practices.
[10] The impact of thermal bridging through the insulation for cladding attachments, such as z-girts, was not included in the analysis
[11] Ratio of the total thermal resistance outboard of the inner surface of the exterior sheathing to the total thermal resistance inboard of the inner surface of the exterior sheathing as defined by the 2015 National Building Code of Canada

2.1.3 Air Leakage

Air leakage through the wall assembly was simulated to evaluate the impact of wetting by air flowing through the wall assembly (exfiltration) in the field area. Air flow was simulated from the top of the wall assembly, through the stud cavity batt insulation, to the bottom of the wall assembly for exfiltration as shown in Figure 2.1. This arrangement was chosen to evaluate the greatest potential of moisture accumulation from air leakage, where air enters the assembly farthest away from the SDI drainage gap opening at the bottom of the assembly.

The airflow rate was calculated based on the pressure difference across the wall assembly based on hourly weather conditions and a characteristic air leakage rate of 0.1 L/s.m at 75 Pa[12]. The air pressure difference was calculated using hourly weather data for wind velocity, stack effect, and an assigned over pressurization of 10 Pa from mechanical equipment.

These assumptions are conservative in nature but are deemed appropriate considering the uncertainties with air leakage analysis.

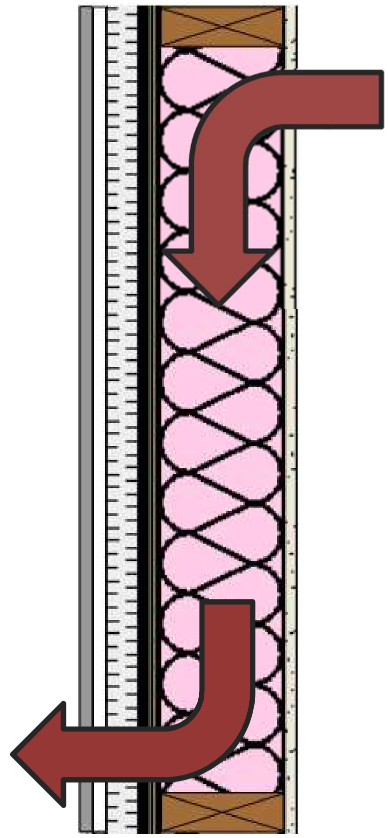

Figure 2.1: Simulated air flow through the field area of the wall assembly

2.1.4 High Construction Moisture

The impact of high construction moisture on the hygrothermal performance of the wall assemblies was simulated by assuming an initial wood moisture content of 19% MC at the start of the simulation. All wall assemblies were evaluated starting in October of the simulated year.

2.1.5 Rain Leaks

Rain leaks were simulated by adding moisture at the exterior face of the sheathing behind the sheathing membrane. The leak location was simulated at the mid-height of the wall, which is a conservative assumption for the SDI system because the drying rate is at a minimum at this

[12] The methodology for the air flow modelling is summarized in a paper entitled "Developing a Design Protocol for Low Air and Vapor Permeance Insulating Sheathings in Cold Climates" by Brown et al. found in the Proceedings for the *Thermal Performance of Exterior Envelopes of Whole Buildings X International Conference*.

location since it minimizes the warming effect of the wood framing due to thermal bridging and drying from the drained gap opening at the bottom of the assembly.

The amount of water introduced at each leak location is based on a percentage of incidental rain on the exterior wall surface from driving rain similar to the approach in ASHRAE Standard 160 (2009)[13] which prescribes a water penetration rate of 1% of the driving rain on the exterior of the sheathing membrane. However, our approach differs from ASHRAE Standard 160 in two ways:

- **Rain penetration introduced behind the sheathing membrane:** Our analysis introduces water behind the sheathing membrane, on the exterior face of the sheathing to simulate a minor deficiency in the sheathing membrane. This approach is more stringent than ASHRAE Standard 160, but has been applied to address concerns related to a leak at the structural framing and acknowledges that a leak outboard the sheathing membrane for the SDI System is not a concern[14].

- **Rain penetration rate dependent on code minimum wall assembly:** We recognize that less than 1% rain penetration will migrate pass the sheathing membrane and many commonly used wall assemblies cannot accommodate 1% rain penetration past the sheathing membrane depending on the climate. Therefore, we have determined the rain penetration rate based on what the code minimum wall assembly can tolerate from a hygrothermal perspective and still meet the acceptance criteria.

A full layout of the monitoring position within the wall assembly and rain leak location is provided in Figure 2.2. Sheathing moisture content were monitored at the middle of the sheathing to represent the average sheathing moisture content.

Scenarios with rain leaks did not include the effects of air leakage and visa versa. Wetting from rain penetration and air leakage were considered separately in the analysis, because air leakage also dries an assembly and cannot be relied upon for drying. All scenarios were also evaluated with an initial wood moisture content of 15% MC, representative of moderate construction moisture.

We recognize our approach for evaluating the assembly's tolerance to rain penetration wetting is much more conservative than what is expected out in the field. This approach assumes water is held against the sheathing and that air leakage is not present. However, the majority of bulk water present within the drainage gap of the SDI insulation system is expected to drain out of the wall assembly as demonstrated by RDH Building Science Laboratories 2018[15]. In addition, some degree of air leakage is expected for all wall assemblies which will increase drying rates in the assembly from rain penetration and initial construction moisture.

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[13] ASHRAE Standard 160 "Criteria for Moisture-Control Analysis in Buildings" (2009) states the default value for water penetration through the exterior surface of the building envelope shall be 1% of the water reaching the exterior surface. This is the quantity of moisture that a designer should consider migrating past the cladding and insulation onto the weather resistive barrier (WRB) of a rainscreen wall system due to a minor deficiency.

[14] Since there is a drainage cavity to the exterior and the materials outboard of the sheathing are not sensitive to moisture

[15] Laboratory testing of drainage performance of Quik-Therm Solar Dry insulation showed nearly all of water applied in the drainage cavity drained out of the assembly

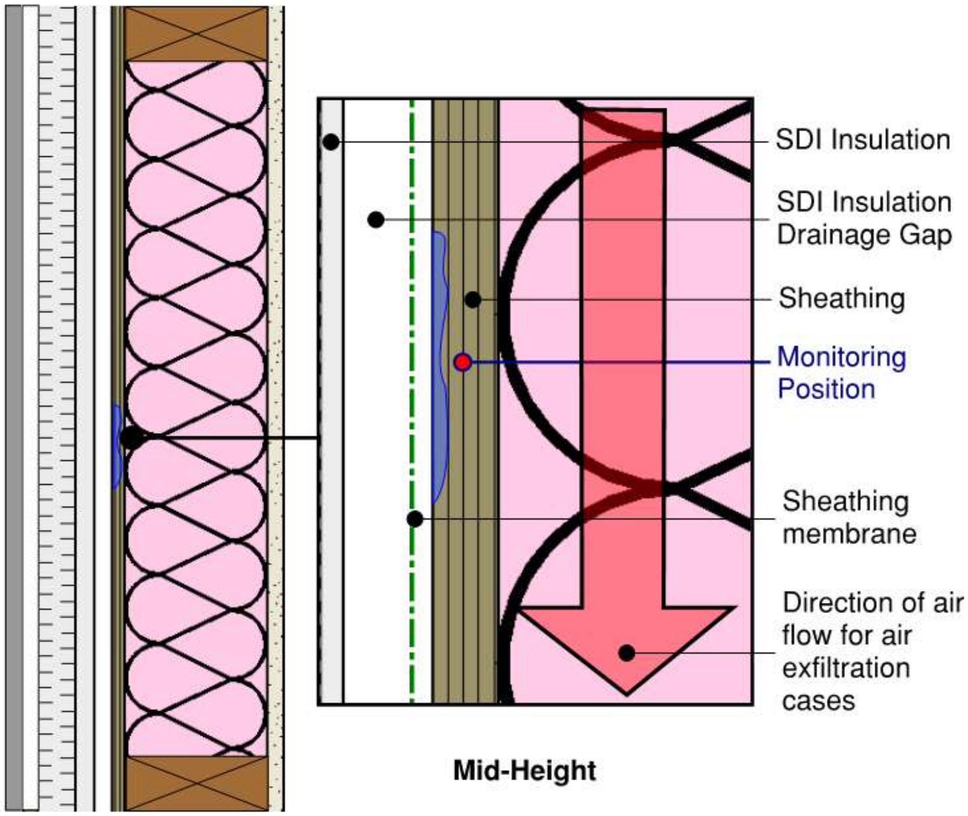

Figure 2.2: Simulated wall assembly monitoring position and rain leak location

2.1.6 Orientation

The wall assemblies were evaluated in orientations with the least drying potential and the greatest exposure to driving rain. For both Vancouver and Edmonton climates, the direction with the least drying potential is north since this orientation has the least solar exposure resulting in lower temperatures within the assembly. In Vancouver, east-facing walls were exposed to the most amount of driving rain, while west-facing walls were exposed to the most amount of driving rain in Edmonton.

3. HYGROTHERMAL PERFORMANCE OF WOOD FRAME WALL ASSEMBLIES WITH QUIK-THERM SDI

This section presents some of the findings of the hygrothermal analysis of split insulated wood frame wall assemblies with Quik-Therm SDI insulation.

3.1 Hygrothermal Performance Acceptance Criteria

To help quantify the hygrothermal performance of the wood frame wall assemblies, the sheathing and wood plate moisture contents were evaluated against an acceptance criteria. Conditions that led to moisture levels above the acceptance criteria were considered failures. This approach allows for design limits of important hygrothermal factors to be established, providing designers with conditions where the wall assemblies will perform in practice.

Hygrothermal Performance Acceptance Criteria

The acceptance criteria for plywood sheathing and wall framing was evaluated by the 7-day average moisture content and a threshold of 28% MC in this study. This threshold was selected since moisture damage occurs after prolonged periods where the wood moisture content exceeds 28% MC.

3.2 Hygrothermal Performance of Quik-Therm SDI Insulation

The hygrothermal performance of the Quik-Therm SDI insulation was evaluated at the stud cavity between the wood studs at mid-height of the wall, because this location was determined to be the peak moisture accumulation within the evaluated wall assemblies[16]. Accordingly, the sheathing moisture levels at mid-height of the stud cavity is the primary location for comparing the evaluated wall assemblies during the heating season.

All assemblies were evaluated with a 15 Perm (858 ng/Pa.s.m^2) sheathing membrane. Assemblies with sheathing membranes less than 0.8 Perm (46 ng/Pa.s.m^2) are expected to have higher sheathing moisture levels as the drying rates will be governed by the vapour permeance of the sheathing membrane rather than the exterior insulation. As such, the evaluated arrangement applies to a broad range of assemblies and components.

3.3 Impact of Air Leakage

Air leakage from exfiltration can have an impact on the hygrothermal performance of wood frame wall assemblies with the potential to add or remove moisture. Air leakage cannot be entirely eliminated and must be taken into account for the design of wall assemblies. The amount of moisture accumulation where the air enters into the wall cavity is relatively the same

[16] Sheathing at the stud cavity at mid-height of the wall results in higher moisture accumulation since it is the coldest location with minimal thermal bridging effect from wood framing and minimal drying benefits of the drainage gap of the SDI insulation

regardless of path, except at cold locations due to thermal bridging through the exterior insulation. However, drying by air leakage cannot be counted on and is dependent on the air flow path. Therefore, in our opinion, the wetting aspect of air leakage needs to be taken into account and the drying benefits need to be discounted by examining the same scenarios without air flow through the cavity insulation.

In our analysis air exfiltration was simulated to bypass the 6 mil polyethylene vapour barrier to directly introduce moisture into the wall cavity. The amount of moisture accumulation in the wall assembly from air leakage is largely dependent on the interior humidity, air leakage rate, and the amount of insulation outboard of the sheathing relative to the amount of insulation in the stud cavity. Wall assemblies with a greater portion of insulation outboard of the sheathing maintain higher sheathing temperatures during the winter and reduces the amount of moisture accumulation.

Figure 3.1 shows sheathing moisture levels for wood frame assemblies in Vancouver with SDI insulation compared to an assembly with EPS insulation with metal facer, an assembly with XPS insulation, and a code minimum wall with minimum vapour permeance of the sheathing membrane and no exterior insulation. The split of exterior and interior insulation for each climate was selected based the minimum amount of exterior insulation that will control moisture accumulation when subject to air leakage. The Insulation Ratio determined for Vancouver is 0.43 and can be satisfied by 1.5” (38 mm) XPS or 2” (51 mm) of SDI insulation or EPS insulation as seen in Figure 3.1. For the Edmonton scenarios, the amount of exterior insulation required to meet an effective R-28 (RSI 4.93) for the wall assembly exceeded the minimum insulation needed to control moisture accumulation when subject to air leakage.

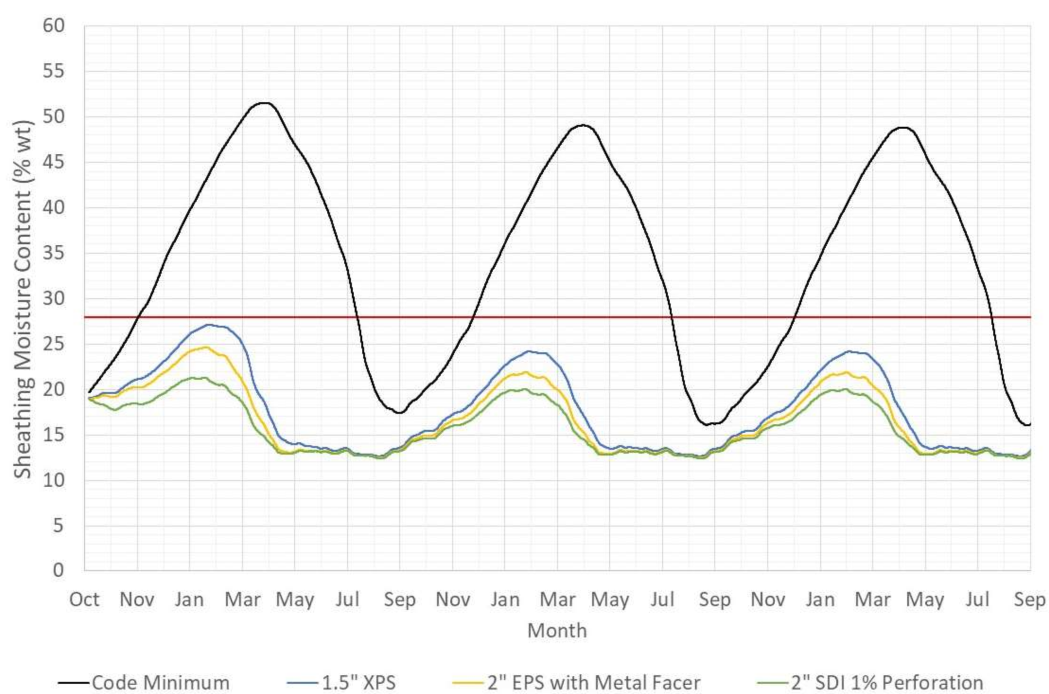

Figure 3.1: 7-day plywood sheathing moisture content at mid-height for north-facing split insulated wall assembly subject to air leakage and uncontrolled interior humidity in Vancouver

As seen in Figure 3.1, the split insulated assembly with 1% perforated SDI insulation has the lowest sheathing moisture levels compared to assemblies with EPS insulation with metal facer and XPS insulation. Similar trends were seen in Edmonton in Figure 3.2 where the peak sheathing moisture content of the perforated scenario remained below 25% MC, but the differences between the exterior insulated scenarios are less because the assemblies have similar exterior insulation R-values and Insulation Ratios. Note, the scenarios in Edmonton were evaluated for a representative cold year which has higher heating degree days than the design year from NECB 2015.

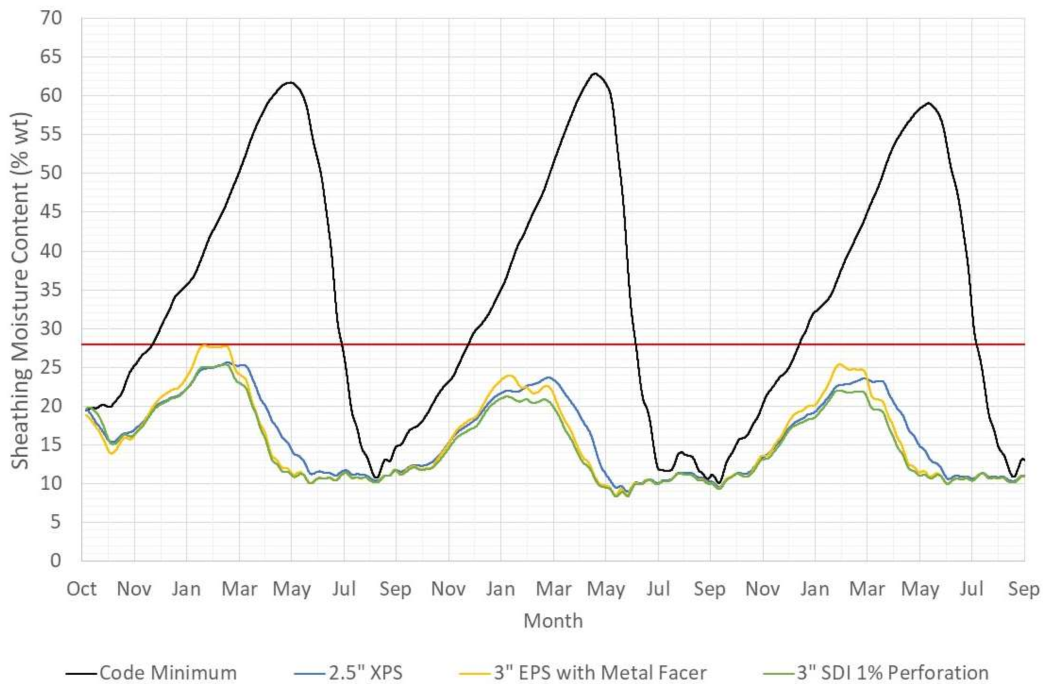

Figure 3.2: 7-day plywood sheathing moisture content at mid-height for north-facing split insulated wall assembly subject to air leakage and uncontrolled interior humidity in Edmonton

The perforations in the metalized polymer facers of the SDI insulation provide marginal hygrothermal benefits for controlling moisture accumulation due to air leakage because the moisture accumulation is largely dependent on the temperature of the sheathing. More significant differences in sheathing moisture levels from the perforated metalized facers are evident when evaluating the impact of high construction moisture and rain leaks, as will be discussed in the following sections.

For all evaluated scenarios, the split insulated assemblies have sheathing moisture levels much lower than the code minimum walls despite having higher vapour diffusion resistance (lower vapour permeance) outboard of the sheathing. This highlights the importance of exterior insulation (Insulation Ratio) in reducing moisture accumulation when subject to air leakage (air exfiltration) in heating dominated climates.

3.4 Impact of High Construction Moisture

One concern of wood-framed wall assemblies with low perm insulation in heating dominated climates is construction moisture. This is problematic for assemblies with interior vapour barriers as it creates the concern of “a double vapour barrier”. To evaluate the impact of construction moisture, wall assemblies were simulated with an initial moisture content of 19% in October.

Figures 3.3 shows the sheathing moisture contents of split insulated wood frame wall assemblies in Vancouver. The plot shows sheathing moisture contents at the stud cavity at mid-height of the wall. Note, all scenarios with high construction moisture were evaluated without air exfiltration and as a result the sheathing moisture levels remain high even during the summer when there is generally more drying. This is a conservative approach since all walls have some degree of air leakage and are typically not expected to have elevated moisture levels for periods for as long as the evaluated scenarios. Due to this approach, results from this and the following rain penetration section should be used as a comparison between different insulation types rather than be directly compared to the acceptance criteria. This highlights some of the drying benefits of air exfiltration as it can help remove moisture from wall assemblies during the summer.

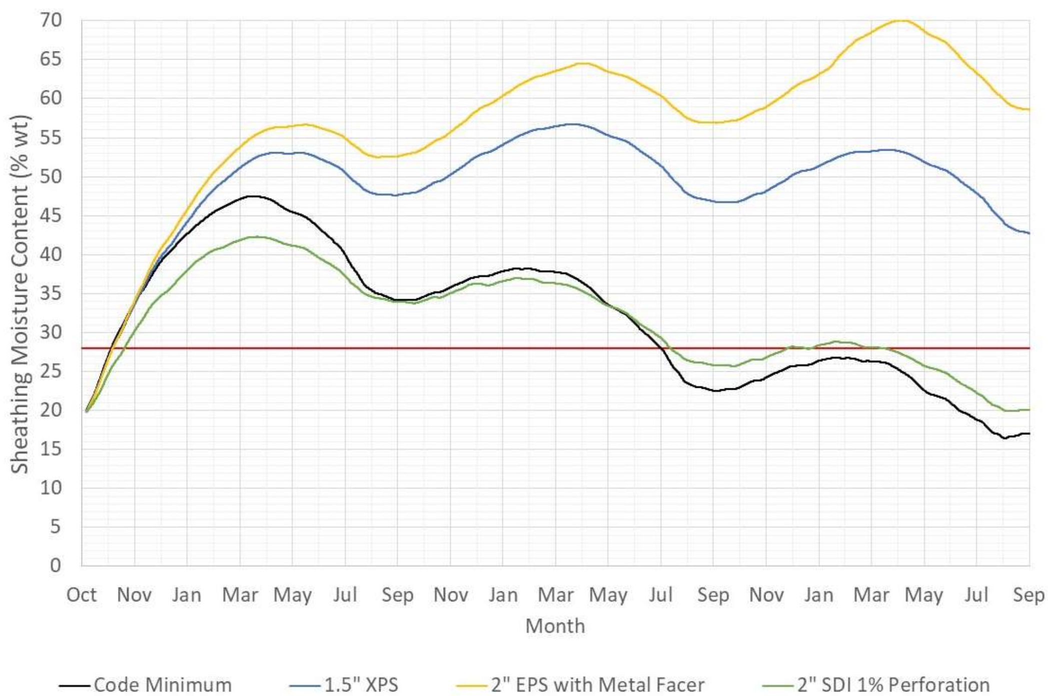

Figure 3.3: 7-day plywood sheathing moisture content at mid-height for north-facing split insulated wall assembly subject to 19% MC initial construction moisture **without air leakage** in Vancouver

All assemblies in Figure 3.3 have elevated sheathing moisture levels during the first year following construction. However, sheathing moisture levels for the code minimum and 1% perforated SDI insulation assemblies begin to decrease after the first year and eventually dry to levels below the 28% MC acceptance criteria within two years after construction. Assemblies with low perm exterior insulation EPS insulation with metal facer and XPS have saturated sheathing moisture levels above 45% MC throughout the simulation period with little drying.

Similar trends were seen in Edmonton, as shown in Figure 3.4. However, the 1% perforated SDI insulation assembly does not dry as quickly as the code minimum wall and sheathing moisture levels remain above the 28% MC acceptance criteria for most of the second year and for a period of the third year following construction. The slower drying rate is due to the lower vapour permeance from the thicker SDI insulation. Even though the sheathing moisture levels are above the 28% MC acceptance criteria after the first year with 1% perforated SDI insulation, the wall generally dries from year to year with sheathing moisture levels generally falling during the simulation period.

Figure 3.4: 7-day plywood sheathing moisture content at mid-height for north-facing split insulated wall assembly subject to 19% MC initial construction moisture **without air leakage** in Edmonton

Overall the assemblies with perforated SDI insulation in Vancouver and Edmonton have elevated moisture levels above 28% MC for the majority of the first and second year following construction. This appears to present risk of deterioration as deterioration may be initiated when moisture levels are greater than 28% MC for periods greater than 21 weeks[17]. However, the perforated SDI assemblies show comparable hygrothermal performance to a code minimum wall in Vancouver, which is deemed acceptable by code as shown in Figure 3.5.

[17] Wood products such as OSB and plywood sheathings are able to withstand decay while subjected to elevated moisture levels greater than 28% MC for periods longer than 21 weeks from “Time of Initiation of Decay in Plywood, OSB, and Solid Wood Under Critical Moisture Conditions” by Wang et al 2010

Air exfiltration was excluded from the analysis to compare how the walls dry out from construction moisture without the benefit from air leakage. However, exfiltration happens in reality and will dry out the walls to moisture levels shown in Figures 3.1 and 3.2.

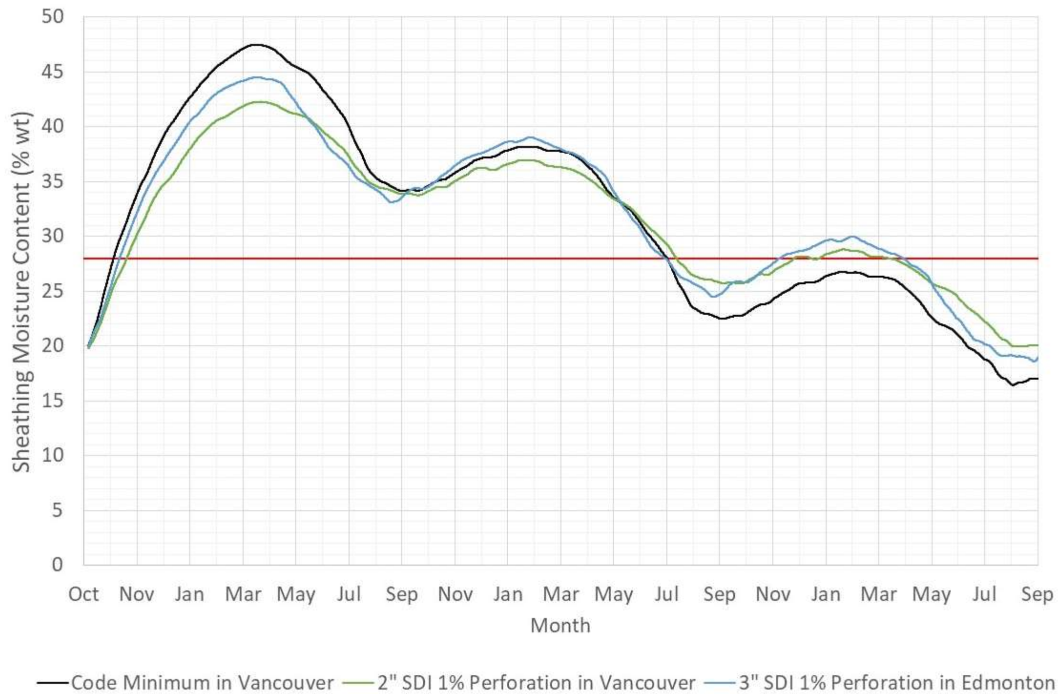

Figure 3.5: 7-day plywood sheathing moisture content at mid-height for north-facing split insulated wall assembly subject to 19% MC initial construction moisture **without air leakage** in Vancouver and Edmonton

The SDI system has similar hygrothermal performance as what is allowed by code for walls without exterior insulation, and sheathing moisture levels may be reduced by increasing the vapour permeance of the interior vapour barrier. Figure 3.6 and 3.7 shows the reduction in sheathing moisture levels by replacing the 6 mil polyethylene vapour barrier with a 1 Perm (60 ng/Pa.s.m^2) vapour control layer.

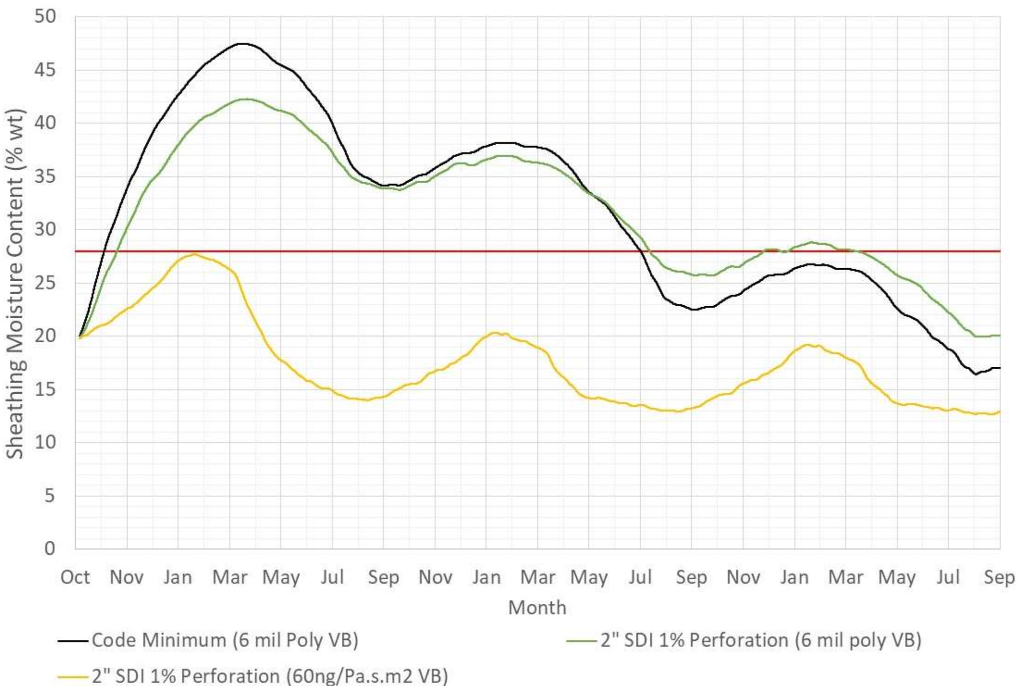

Figure 3.6: 7-day plywood sheathing moisture content at mid-height for north-facing split insulated wall assembly subject to 19% MC initial construction moisture **without air leakage** in Vancouver with 6 mil polyethylene vapour barrier and with 1 Perm (60 ng/Pa.s.m^2) vapour control layer

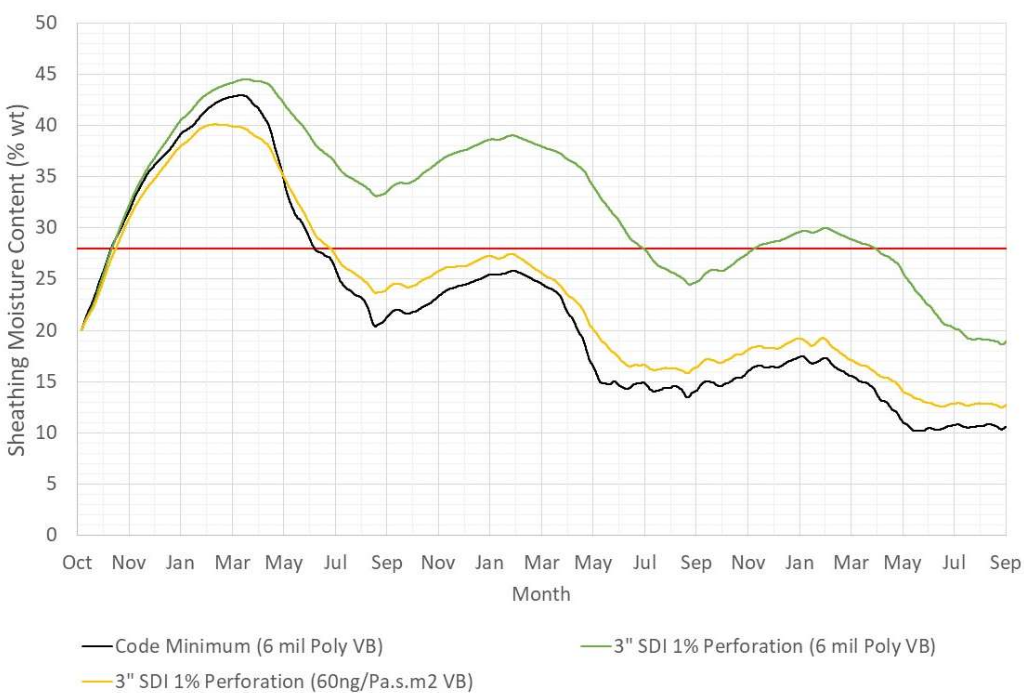

Figure 3.7: 7-day plywood sheathing moisture content at mid-height for north-facing split insulated wall assembly subject to 19% MC initial construction moisture **without air leakage** in Edmonton with 6 mil polyethylene vapour barrier and with 1 Perm (60 ng/Pa.s.m^2) vapour control layer

3.5 Impact of Rain Penetration

The impact of rain leaks on the sheathing moisture content was evaluated by introducing a percentage of the driving rain inboard the sheathing membrane on the outer surface of the plywood sheathing. Leaks were introduced at the centre of the wall cavity at mid-height as shown in Figure 2.2. The moisture introduced into the assembly was based on the percentage of driving rain that the code minimum wall assembly can tolerate without exceeding the 28% MC acceptance criteria. This percentage is based on wall orientations with the highest exposure to driving rain which is east-facing in Vancouver and west-facing in Edmonton. For this analysis, the tolerable rain penetration rate for the code minimum wall in Vancouver is 0.15% which has a peak rain penetration rate of 0.02 L/h.m^2 and 1.5% in Edmonton with a peak rain penetration rate of 0.25 L/h.m^2.

As previously mentioned the approach taken to evaluating the impact of rain penetration in this report is conservative since the analysis assumes rain penetration passes through the sheathing membrane and no air leakage is present in the wall assemblies. In reality, neither are expected as bulk water in these quantities migrating pass the sheathing membrane is rare considering the membrane is shielded from rain by rainscreen cladding and insulation. Furthermore, rain that migrates pass the SDI insulation is expected to drain out of the drainage gap rather than held between the insulation and sheathing as verified by RDH Building Laboratories. As previously mentioned in Section 3.4 all assemblies are expected to have some degree of air leakage which will help remove moisture from the wall assemblies during the summer.

The impact of rain penetration on the sheathing moisture levels varies depending on the location of the leak and climate. In Vancouver, framed wall assemblies are less tolerant to rain penetration since the majority of rainfall occurs during winter when there is little capacity to dry out to the exterior. Figure 3.8 shows this with sheathing moisture levels of wood frame assemblies subject to 0.15% driving rain penetration at the stud cavity. The perforated SDI insulation system has a higher tolerance to rain penetration than any of the other walls evaluated in this analysis, including the code minimum assembly. The difference in sheathing moisture content is significant as the peak sheathing moisture content for assemblies with perforated SDI insulation is 21% MC and the sheathing remains below 20% MC during subsequent years. This is compared to a peak sheathing moisture content of around 28% MC for the code minimum wall assembly during the first year and subsequent peaks of around 22% MC in the following winters.

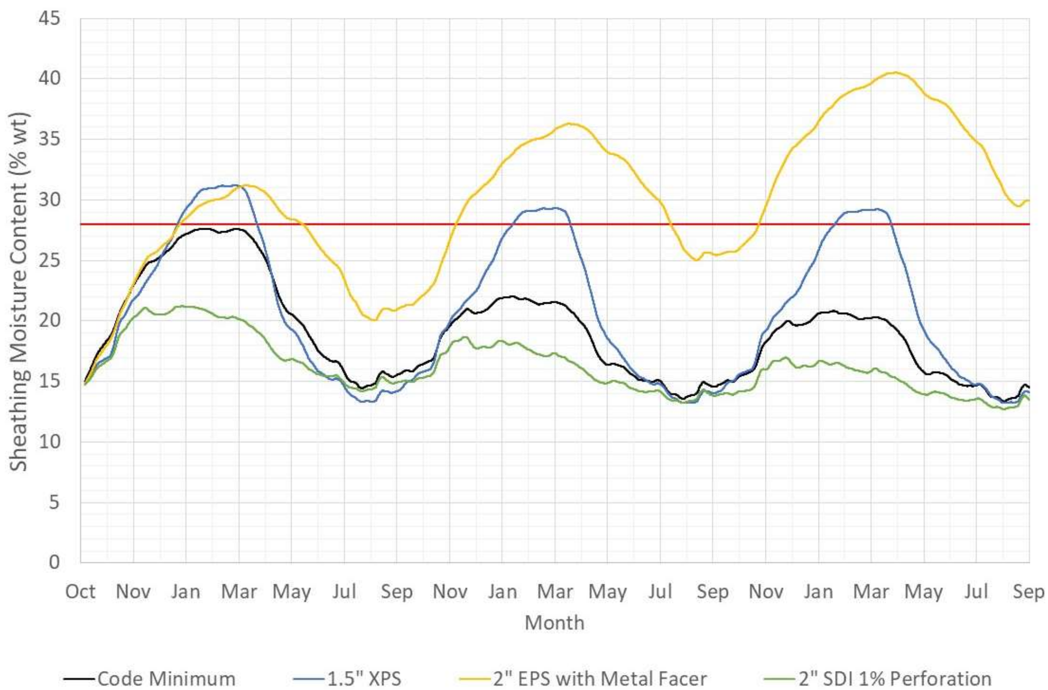

Figure 3.8: 7-day plywood sheathing moisture content at mid-height for east-facing split insulated wall assembly subject to 0.15% (max. 0.02 L/h.m^2) driving rain penetration **without air leakage** in Vancouver

Framed wall assemblies in Edmonton have higher tolerance to rain penetration than Vancouver since the majority of rainfall occurs in summer when there is more capacity to dry out. However, because the wall assemblies are subject to more moisture, based on how much rain penetration a code minimum wall can tolerate, scenarios with low permeance exterior insulation have elevated moisture levels since the sheathing cannot as easily dry to the exterior as the code minimum wall. This is shown in Figure 3.9, where the sheathing moisture levels of assemblies with 2.5” (64 mm) XPS insulation and 3” (76 mm) EPS insulation with metal facer remains above the 28% MC acceptance criteria and continues to rise from year to year.

Sheathing moisture levels for the wall with 1% perforated SDI insulation do rise above the 28% MC acceptance criteria for periods longer than 21 weeks, increasing the risk of deterioration. However, the evaluated rain penetration rate is high and greater than the 1% rain penetration at the outside of the sheathing membrane per ASHRAE Standard 160. Rain penetration rates of 1.5% migrating past the sheathing membrane is a significant amount of moisture and is not expected in reality. Nevertheless, this analysis demonstrates the extra capacity of the SDI system to dry from rain penetration.

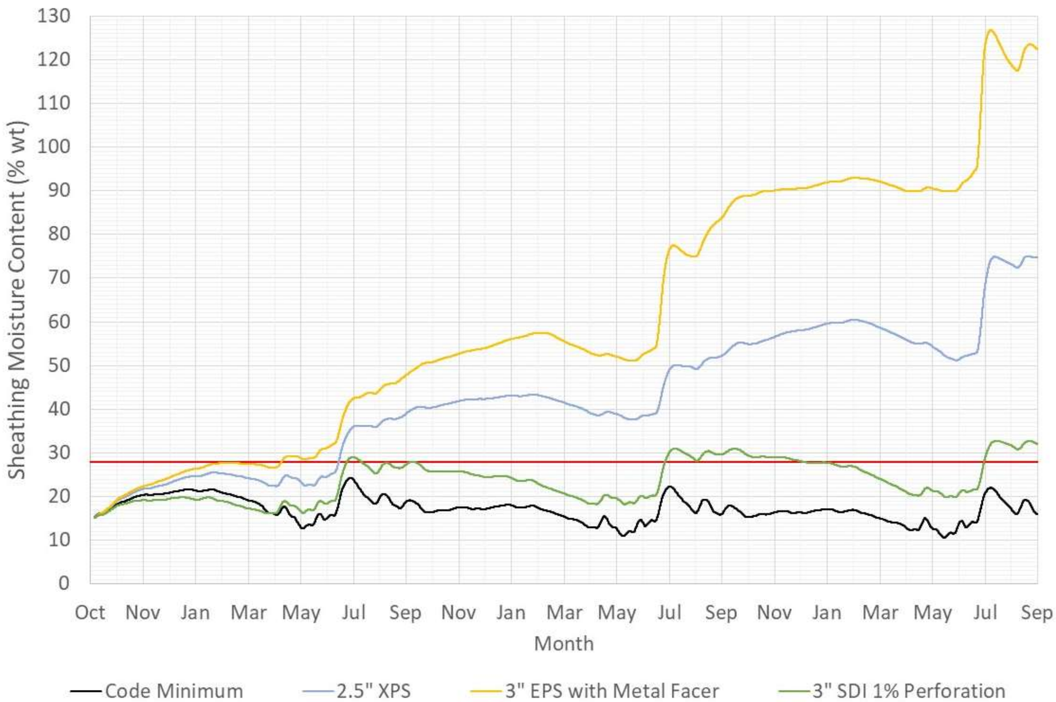

Figure 3.9: 7-day plywood sheathing moisture content at mid-height for west-facing split insulated wall assembly subject to 1.5% (max. 0.25 L/h.m^2) driving rain penetration **without air leakage** in Edmonton

3.6 Impact of Amount of Perforations

Providing a higher degree of perforation through the metalized polymer facer helps to increase drying, but the impact is not significant for the evaluated scenarios as seen in Figures 3.10 to 3.13.

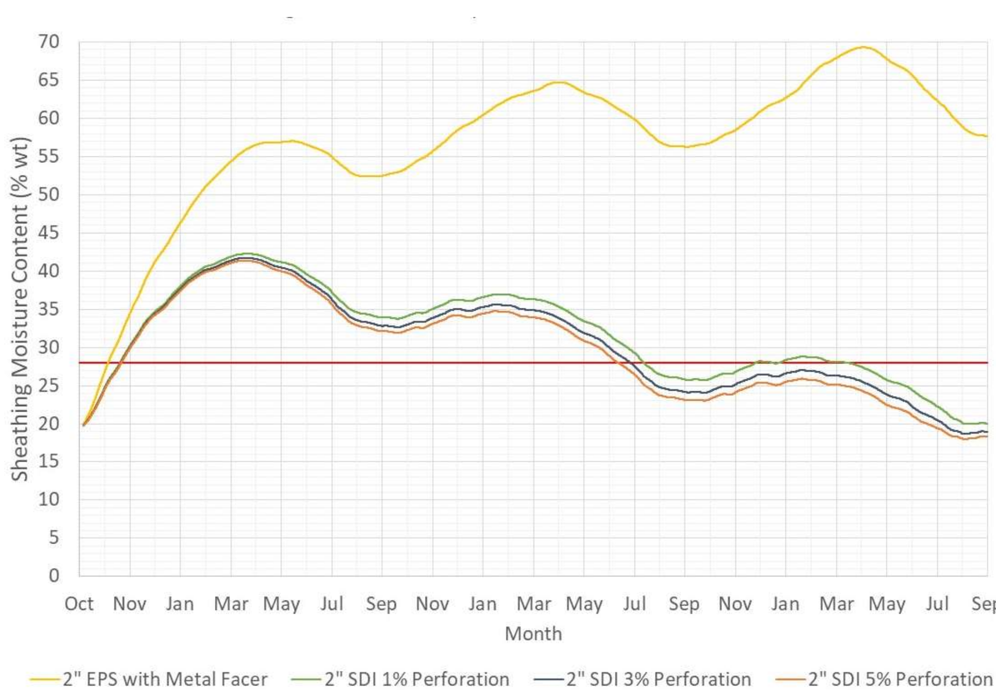

Figure 3.10: 7-day plywood sheathing moisture content at mid-height for north-facing split insulated wall assembly with 2" (51 mm) EPS insulation with metal facer and SDI insulation, with 1%, 3%, and 5% perforation subject to 20% MC initial construction moisture **without air leakage** in Vancouver

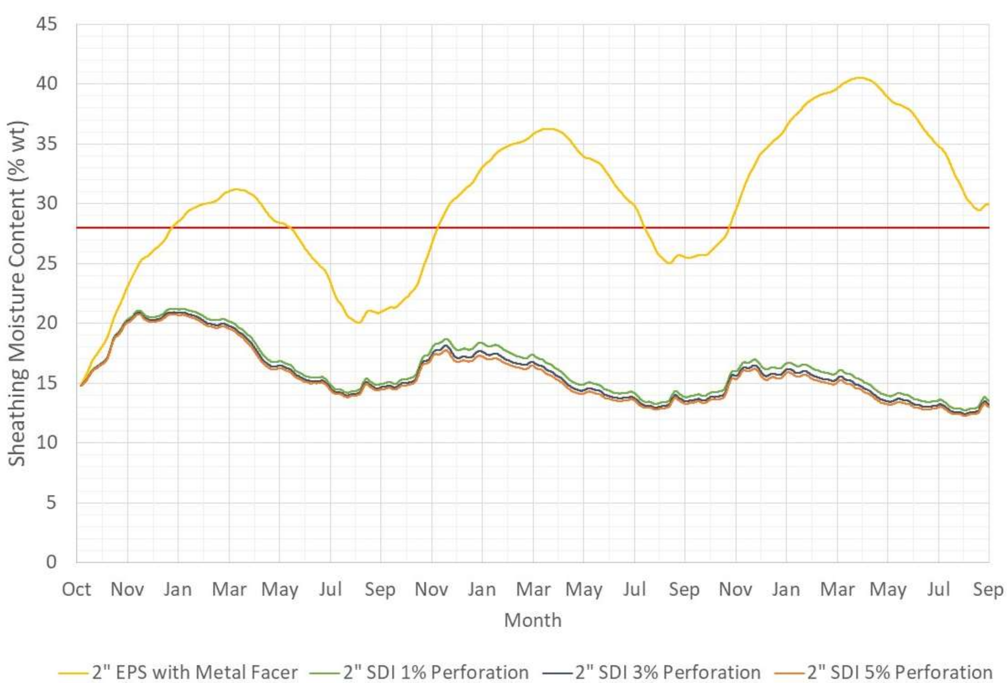

Figure 3.11: 7-day plywood sheathing moisture content at mid-height for north-facing split insulated wall assembly with 3" (76 mm) EPS insulation with metal facer and SDI insulation, with 1%, 3%, and 5% perforation subject to 20% MC initial construction moisture **without air leakage** in Edmonton

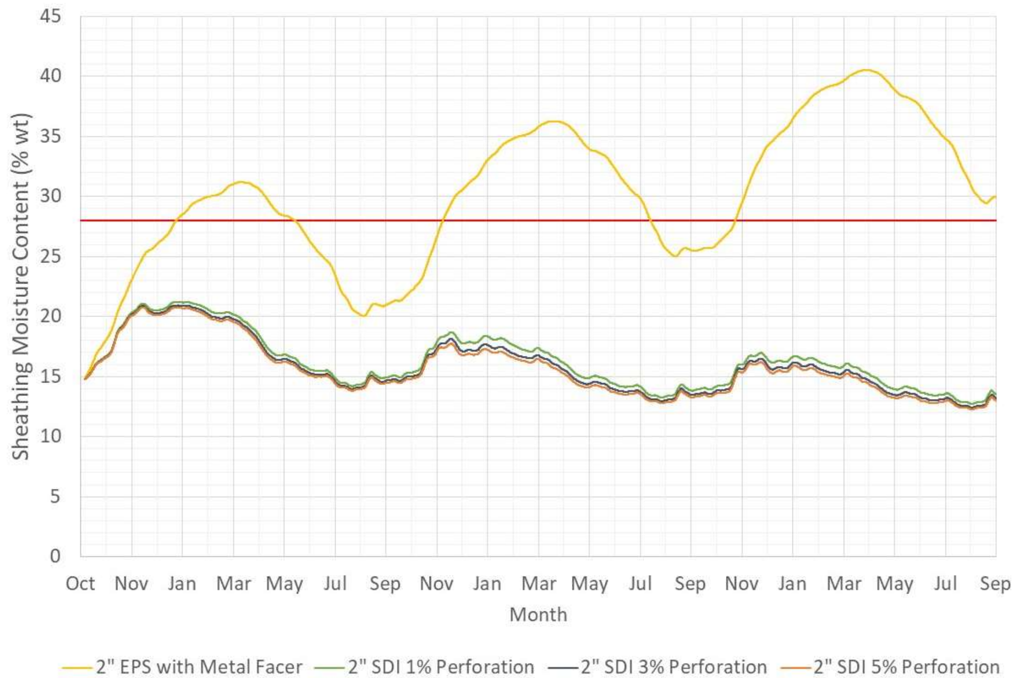

Figure 3.12: 7-day plywood sheathing moisture content at mid-height for west-facing split insulated wall assembly with 2” (51 mm) EPS insulation with metal facer and SDI insulation, with 1%, 3%, and 5% perforation subject to 0.15% (max. 0.02 L/h.m^2) driving rain penetration **without air leakage** in Vancouver

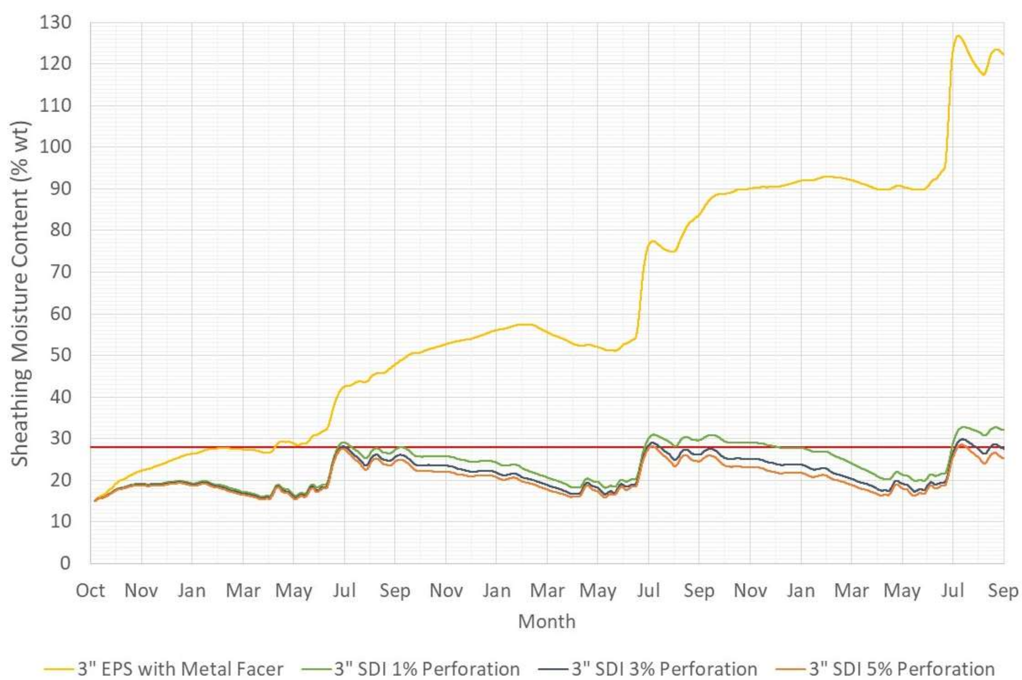

Figure 3.13: 7-day plywood sheathing moisture content at mid-height for east-facing split insulated wall assembly with 3” (76 mm) EPS insulation with metal facer and SDI insulation, with 1%, 3%, and 5% perforation subject to 0.15% (max. 0.25 L/h.m^2) driving rain penetration **without air leakage** in Edmonton

4. CONCLUSIONS

This section summarizes our findings and conclusions of Quik-Therm SDI insulation.

- Perforations in the metalized polymer facers of the Quik-Therm SDI insulation improves the hygrothermal performance of split insulated wood frame wall assemblies, especially with regard to the ability to dry out moisture from rain leaks and high construction moisture. Moreover this system performs as well or better than a code minimum wall with minimum vapour permance of the sheathing membrane and no exterior insulation.

- Interior vapour control has an impact on reducing sheathing moisture levels such that they do not exceed 28% MC for extended periods to allow the initiation of deterioration. Increasing the vapour permenace of the vapour barrier to 1 Perm (60 ng/Pa.s.m^2) reduces sheathing moisture levels and the risk of moisture accumulation.

- The perforations in the metalized polymer facers enhances the drying characteristics of the SDI Insulation compared to EPS insulation with non-perforated metal facers

- The drainage gaps in the SDI system provide extra moisture removal by gravity that was not directly evaluated, but should be recognized as providing additional capacity to mitigate the risk of rain penetration.

- The degree of perforation in the metalized polymer facers of the Quik-Therm SDI insulation had minimal impact on sheathing moisture levels for the evaluated scenarios. Insulation with 1%, 3%, and 5% perforation all showed similar hygrothermal performance.

- Our analysis assumed permeance of the insulation with perforations based on theoretical testing of similar products. These values should be confirmed with permeance testing of the Quik-Therm SDI Insulation system to supplement this evaluation.

5. CLOSING

We trust this report provides an overview of the hygrothermal performance of the Quik-Therm SDI insulation for split insulated wood frame wall assemblies subject to wetting by air leakage, construction moisture, and rain penetration in Vancouver and Edmonton climates.

Morrison Hershfield Limited

FEB 12, 2019

Feb. 12, 2019

Ivan Lee, P.Eng.
Building Science Consultant

Patrick Roppel, P.Eng.
Principal, Building Science Specialist

APPENDIX A: MATERIAL PROPERTIES

Table A1: Material Properties

Material	**Density** (kg/m^3)	**Thermal Conductivity** (W/mK)	**Heat Capacity** (J/kgK)	**Saturation Moisture Content** (m^3/m^3)	**Porosity** (m^3/m^3)	**Vapour Permeability** (ng/Pa.s.m)	**Vapour Permeance** (ng/Pa.s.m^2)	**Moisture Retention Curve**
Sheathing Membrane	-	-	-	-	-	-	Varies	n/a
Extruded Polystyrene Insulation (XPS)	28.6	0.0288	1470	n/a	n/a	1.22	-	ASHRAE 1018 RP
EPS Insulation	14.8	0.0345	1470	n/a	n/a	3.96	-	n/a
Metalized Polymer Facer with 1% Perforation	-	160	-	-	-	-	741	n/a
Metalized Polymer Facer with 3% Perforation	-	160	-	-	-	-	1053	n/a
Metalized Polymer Facer with 5% Perforation	-	160	-	-	-	-	1333	n/a
Quik-Therm SDI Insulation[18]	14.8	0.0345	1470	n/a	n/a	varies depending on perforations	varies depending on perforations	n/a
EPS with Metal Facer	14.8	0.0345	1470	n/a	n/a	-	-	n/a
Plywood	445	0.086	1880	0.65	0.69	1.46	-	ASHRAE 1018 RP
Spruce	400	0.088	1880	0.88	0.90	3.1	-	ASHRAE 1018 RP
Fibreglass Batt Insulation	11.5	0.036	840	0.98	0.99	172	-	ASHRAE 1018 RP
Polyethylene Vapour Barrier	-	-	-	-	-	-	1.7	n/a
Gypsum Drywall	700	0.160	870	0.4	0.45	23	-	ASHRAE 1018 RP

[18] Thermal performance of insulation is based on thermal conductivity equivalent to R-4.2/in based on ASTM C1363-2011 and ASTM C1365-05 testing

APPENDIX B: MODELLING ASSUMPTIONS

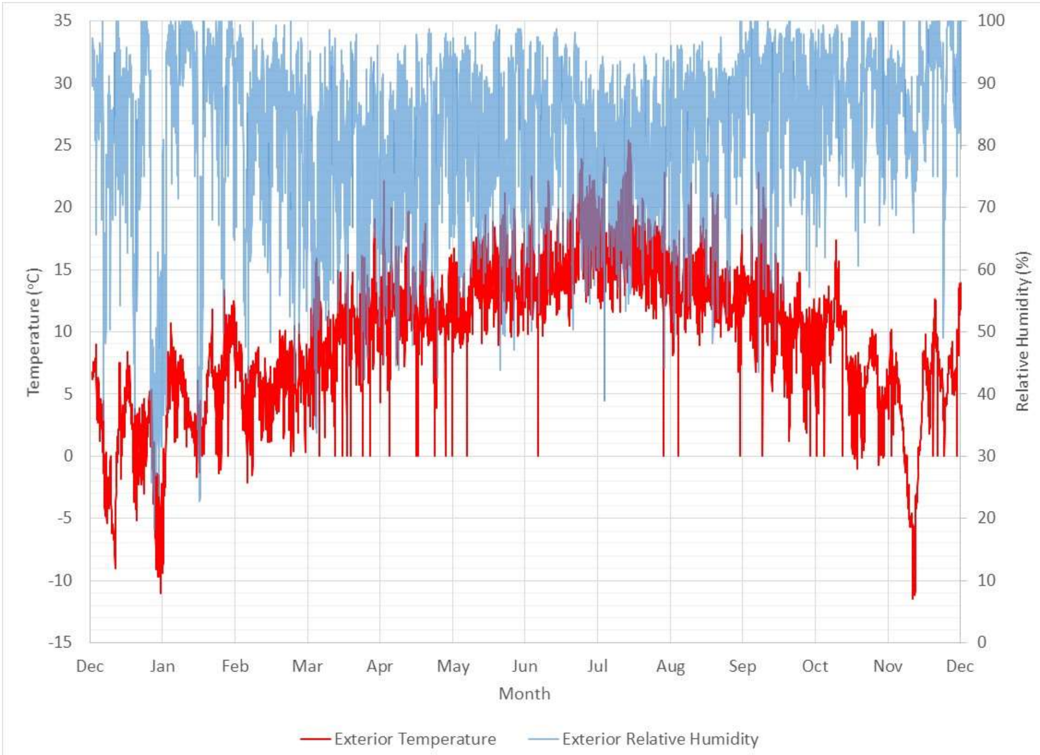

Figure B1: Simulated Exterior Temperature and RH – Vancouver 1980

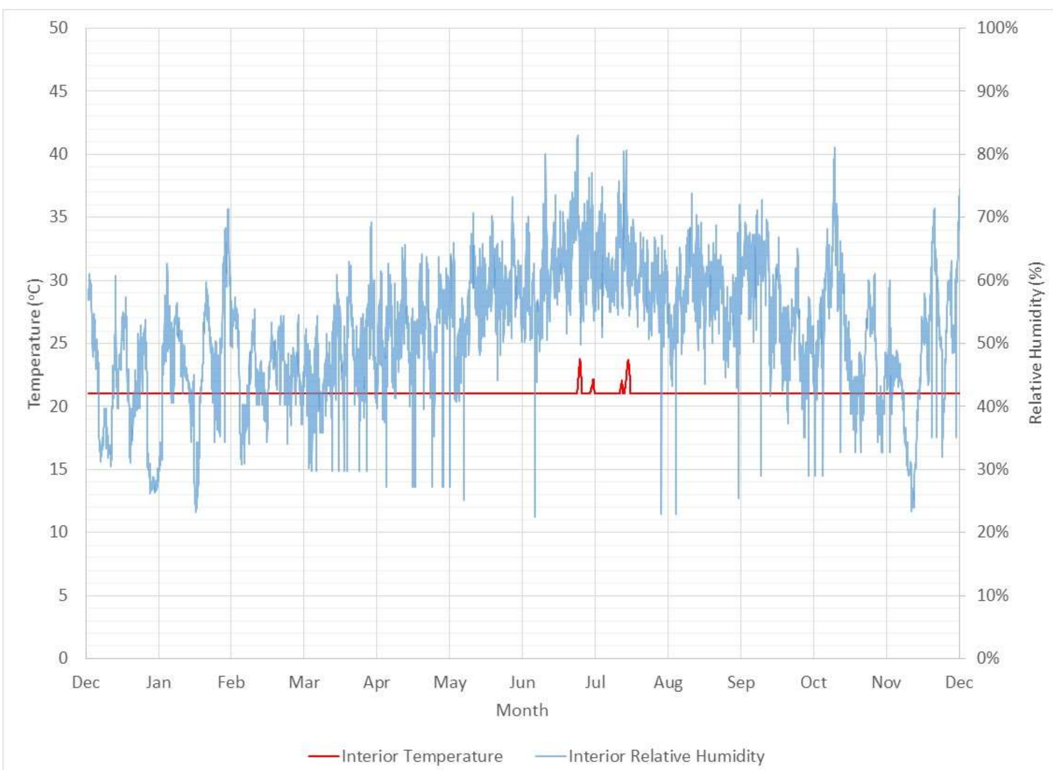

Figure B2: Simulated Interior Temperature and RH – Vancouver 1980

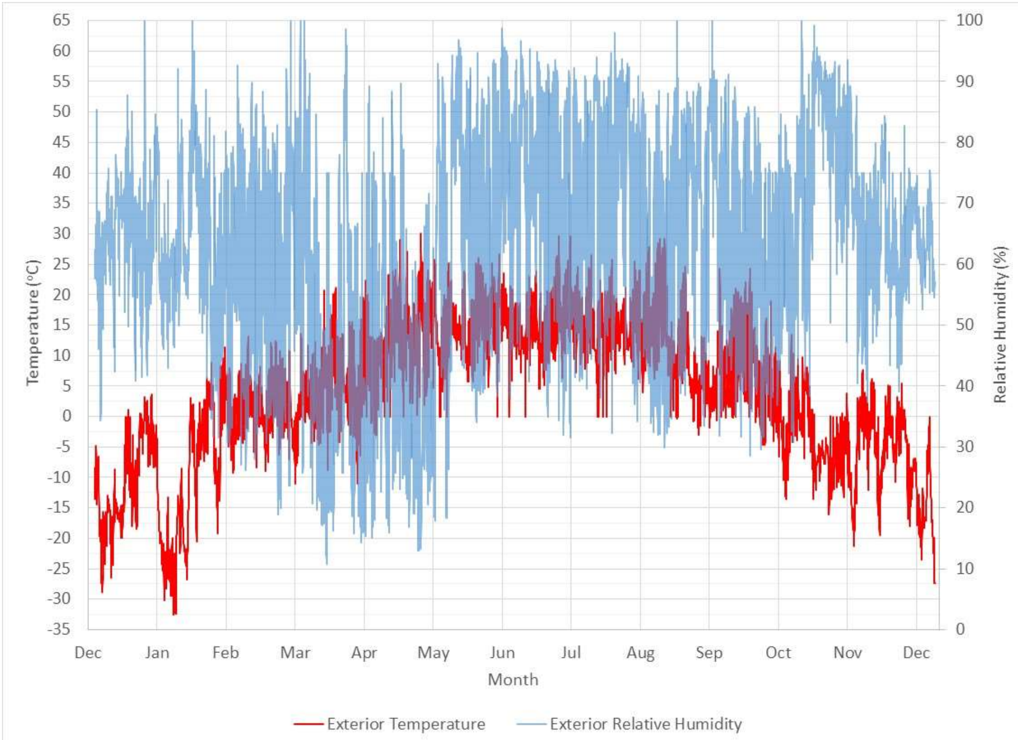

Figure B3: Simulated Exterior Temperature and RH – Edmonton 1988 (Wet Year)

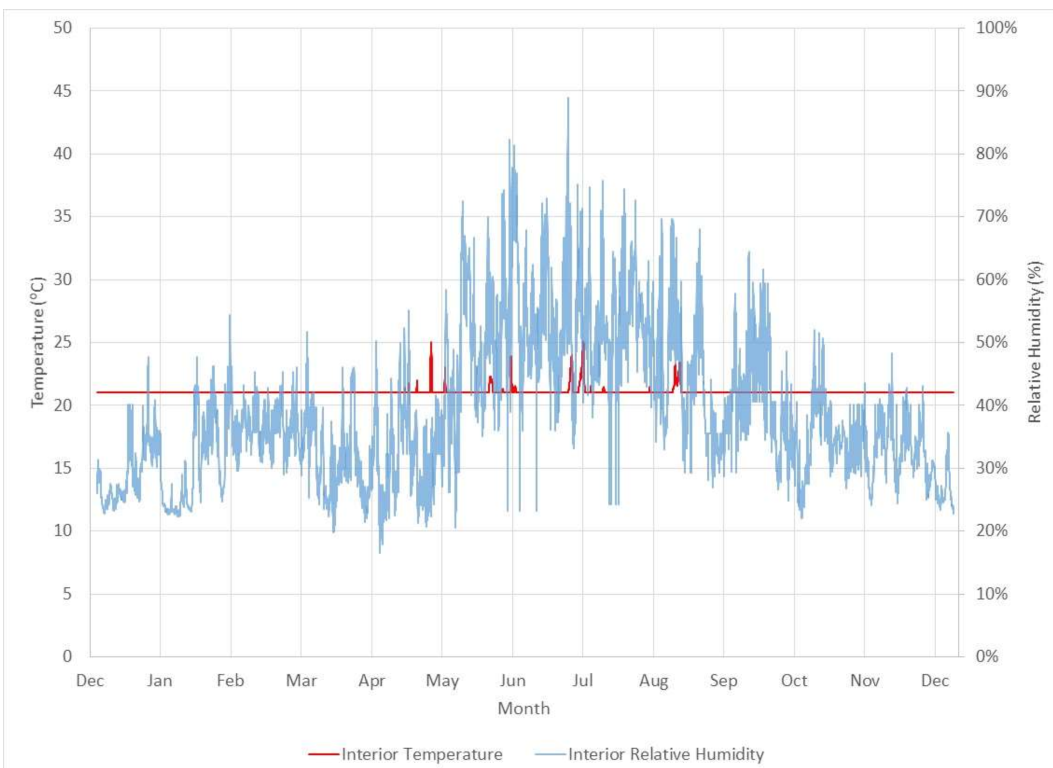

Figure B4: Simulated Interior Temperature and RH – Edmonton 1988 (Wet Year)

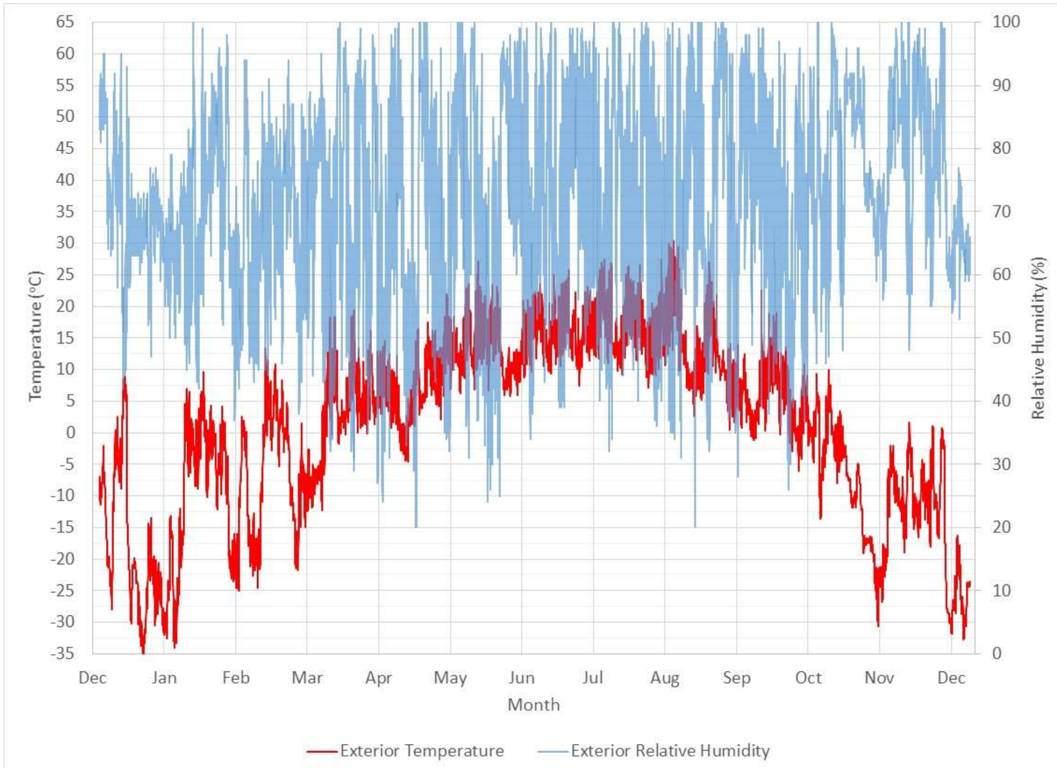

Figure B5: Simulated Exterior Temperature and RH – Edmonton 1996 (Cold Year)

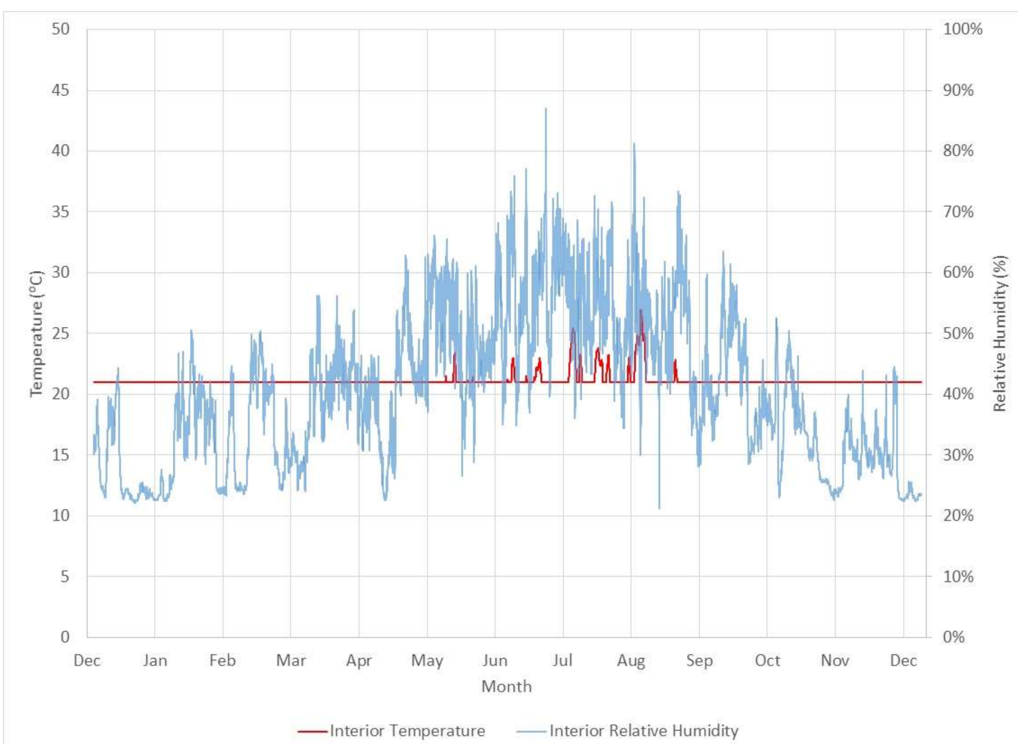

Figure B6: Simulated Interior Temperature and RH – Edmonton 1996 (Cold Year)

Table B2: Boundary Conditions

Boundary	Heat Transfer Coefficient (W/m²K)	Vapour Exchange Coefficient (ng/Pa.m² s)
Exterior Rainscreen Cavity	7.7	30,000
Interior	7.7	18,700

The simulated baseline wood-frame walls were north-facing and completely shaded from the sun to minimize drying from the sun.

Air leakage through the wall assembly was modelled as laminar flow. The airflow rate was calculated based on the pressure difference across the wall assembly and the nominal air leakage area at 75 Pa. The pressure difference was calculated using hourly weather data for wind velocity, stack effect, and assigned over pressurization of 10 Pa from mechanical equipment.