Assessing Freeze-Thaw and Moisture Damage Risks for Heritage Buildings and Unique Constructions

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Abstract

This paper presents hygrothermal case studies that were conducted to ensure durability/occupant comfort/well-being of heritage walls modified with new constructions and added insulation without accelerating deterioration due to moisture accumulation within the wall assemblies. The key findings include: a safe level of insulation to minimize freeze-thaw damage risk within heritage masonry in a cold humid climate; controlling the risk of condensation in a mild, humid climate; preventing moisture accumulation and mould growth risk; and a unique solution to conserve a heritage enclosure. The paper determines sensitive parameters for hygrothermal analyses such as the rain exposure factor, the indoor humidity levels, the effects of adding an exterior protective coating, and remediating existing envelope issues of air leakage and water entry points.

Introduction

Many heritage buildings across Canada are reaching a mid-life refit stage, while the government is targeting energy efficiency and improved occupant comfort/well-being (Treasury Board of Canada Secretariat, 2021). The addition of insulation to heritage walls in a cold humid climate may increase the risk of freeze-thaw damage risk and impact to heritage value (ASHRAE, 2019; Xiaohai Zhou, 2017; Peter Mensinga, 2010). Existing or new wall design options and conditions arise for unique projects which require consideration through hygrothermal analyses to determine the risk of interstitial condensation, mould growth, wood rot, or steel corrosion (J. Zhao, 2017; R. Walker, 2015; D.I. Kolaitis, 2013). This paper presents four different case studies, and the results with regard to the moisture content, mould index, and freeze-thaw damage risk of projects involving insulating heritage buildings and unique new construction. Ensuring a well-designed building enclosure through hygrothermal risk analyses prolongs the durability of the enclosure, improves occupant comfort and well-being without accelerating deterioration due to moisture accumulation within the wall assemblies. The first way to reduce moisture accumulation in the wall is to minimize wind-driven rain or water leaks on the façade or in the walls through careful detailing of water shedding features including overhangs, gutters, flashing, detailing of parapet caps, and proper maintenance of plumbing and hydronic systems (ASHRAE, 2019). Once these parameters are addressed, the source of moisture related deterioration of the building enclosure has been greatly reduced. A detailed hygrothermal analysis can provide reassurance that the envelope design layers are appropriate for the climate and conditions of the building.

Methods

An overview of the hygrothermal analysis methods used in the presented case studies is outlined below.

The first step is to review and validate background information of the project. This includes review of documentation such as record drawings and construction submittals. The analysis involves a review of detailed wall sections and constituents to allow the hygrothermal analysis to be properly conducted. Key material properties that should be tested for heritage masonry are as follows : absorption-value (lb/in^2-$s^{0.5}$ or kg/m^2-$s^{0.5}$), bulk density (lb/ft^3 or kg/m^3), porosity, reference water content (water content at 80% relative humidity, in lb/ft^3 or kg/m^3), free water saturation (lb/ft^3 or kg/m^3), vapor diffusion resistance factor, and critical saturation level (S_{crit}) for masonry in cold climates (Peter Mensinga, 2010; WUFI Pro 6.4: Assessment Criteria, 2022).

The testing standards used to obtain these properties are: ASTM C1794, ASTM C20, AST E96 (wet cup), DIN 12087, ASTM C1498, ASTM C20, and testing for critical freeze thaw saturation (Randy Van Straaten, 2016). If the above information is unavailable, research is conducted into finding published data on similar materials used in the construction of the building, with reference to the time of construction and location.

WUFI Pro 6.4, developed by the Fraunhofer Institute for Building Physics in Germany, was the selected hygrothermal software because of the extensive database of tested materials with detailed moisture curves and allows for dynamic hygrothermal simulations. Other software offer a dew point analysis such as THERM or IES VE but these are not dynamic simulations that consider the changes in moisture behaviour throughout the year. The dynamic calculations of WUFI Pro 6.4 follow the guidelines in ANSI/ASHRAE Standard 160-2021: Criteria for Moisture-Control Design analysis in Buildings (ASHRAE, 2021). In addition, WUFI modelling software has been validated with numerous field studies (Fraunhofer IBP, 2018).

For these studies, clear-field mass construction assemblies were analysed, therefore 1D calculations were appropriate. If the focus of a study is to analyse a section of a wall that contains thermal bridging, then 2D calculations would be more appropriate. A limitation of the WUFI software is that it does not consider ground water capillary uptake through porous materials.

The baseline current conditions are established in the WUFI Pro 6.4 model. The results of modelling the current conditions are compared to the expected behaviour for the type of wall construction and climate based on building science principles, as a first indication to validate the inputs used. In the event the results do not match expected behaviour, the material property values are adjusted until the results do align with the observations (for existing buildings).

The proposed design solutions are modelled in WUFI Pro 6.4, usually considering one or multiple of the following: the effect of exterior coatings; the optimal location of a vapor barrier; and the optimal amount of insulation (in terms of mould risk, corrosion risk, freeze-thaw risk if applicable and energy savings). The key metrics to assess moisture damage risk are: comparing moisture content of exterior layers of wall to the S_{crit} and freeze-thaw cycles to evaluate the risk of freeze-thaw damage; comparing RH to evaluate the condensation risk; and comparing the mould index to asses mould risk with the wall assembly.

Multiple simulations of each scenario including a sensitivity analysis are required to identify the optimal solution for each of the above scenarios.

Case Study 1: Heritage Building in Ontario, Canada

Background Info

The heritage building is located in Ontario, Canada, which is a cold, humid climate (ASHARE climate zone 6) (National Research Council Canada, 2017). The building is about 150 years old with two main wall types built in different periods. Wall Type 1 from exterior to interior is: 300 mm Nepean sandstone, 275 mm concrete rubble stone, 100 mm brick, 50 mm air gap, 100 mm terra cotta, 25 mm plaster (total R-value of 0.8 m^2-K/W). Wall Type 2 from exterior to interior is: 200 mm Nepean sandstone, 135 mm rubble stone core, 200 mm Nepean sandstone, 50 mm air gap, 215 mm brick, 25 mm plaster (total R-value of 0.93 m^2-K/W). The walls have a more severe rain exposure factor of 1.0 to 1.2 according to ASHRAE Standard 160 (ASHRAE, 2021) because the façades are not shielded by nearby buildings and there is a lack of rain shedding details on the building (overhangs, gutters, etc.). The goal of the study was to determine the addition of a safe level of insulation on the interior side of the exterior walls to minimize the risk of freeze-thaw damage to the heritage masonry.

Retrofit Scenarios

The retrofit scenarios considered insulation with mineral wool, cellulose, and extruded polystyrene with a thickness of either 100 mm on the interior of the existing wall (total RSI 3.7-4.9 m^2-K/W) – Retrofit 1 (R1), or 200 mm and removing the inner masonry layer of the existing wall (total RSI 6.2-8.7 m^2-K/W) – Retrofit 2 (R2). Adding a vapour barrier on the interior side of the insulation was also considered.

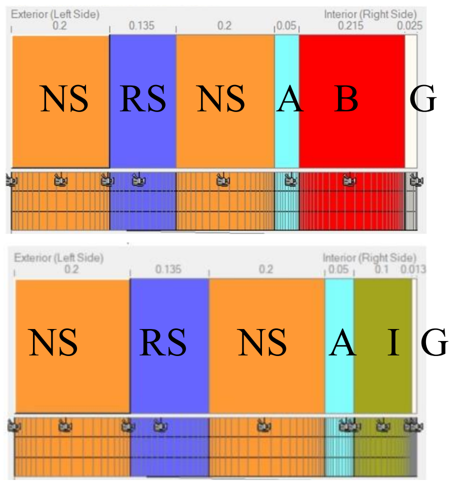

Figure 1: Baseline existing wall type 2 (top) and Retrofit 2 (bottom) wall compositions and monitor points (indicated by grey camera icons). NS – Nepean sandstone, RS – rubble stone, A – air gap, B – brick, G – gypsum board, I - insulation.

Results

For Wall Type 1, adding insulation increases risk of moisture accumulation in the rubble stone core. The critical saturation level for the concrete rubble stone is 189 kg/m^3, determined through testing, and the cellulose insulation option approaches this limit.

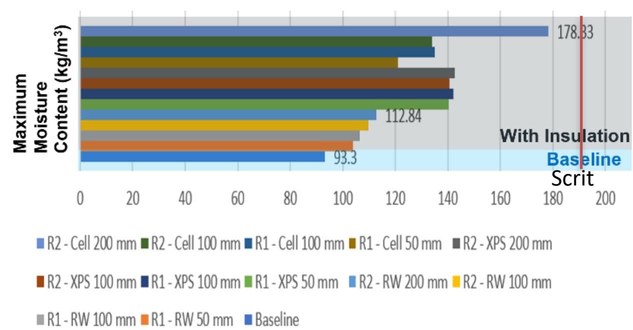

Figure 2: Different retrofit scenario moisture content results for the rubble stone layer (Scrit for concrete rubble stone is 189 kg/m^3). Cell = cellulose, RW = mineral wool, XPS = extruded polystyrene. R# denotes retrofit scenario number.

Wall Type 2 has a different response to additional interior insulation, whereby the relative humidity in the rubble stone core is reduced from the baseline when insulation is added. There is a 15% reduction in hours above RH 85% in the rubble stone core with 100 mm of mineral wool. There are zero critical freeze-thaw cycles for the rubble core layer with any insulation type and either retrofit configuration even though the relative humidity is above 85% for about 5500 hours of the year.

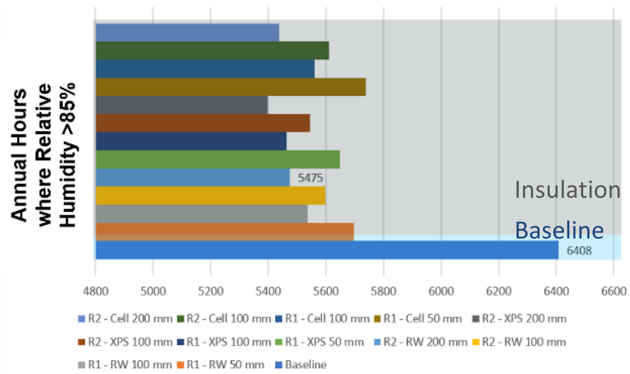

Figure 3: Annual hours where relative humidity is greater than critical level of 85% in the rubble stone core layer.

The mould index was assessed in the insulation layer with a sensitivity class corresponding to the wood studs within this layer (sensitive) for scenarios with and without a vapour barrier. The vapour barrier on the interior side of the insulation increased the risk of mould growth for wood studs above the critical index of 3. The reason for this is because of the high wind-driven rain exposure and high capillary suction of the masonry layers that are driving the moisture flux towards the interior of the building for most of the year. The recommended insulation option for both wall types was 100 mm of mineral wool, while removing the inner non-load bearing masonry layer as it demonstrated safe moisture behaviours that would minimize the risk of freeze-thaw damage and mould growth.

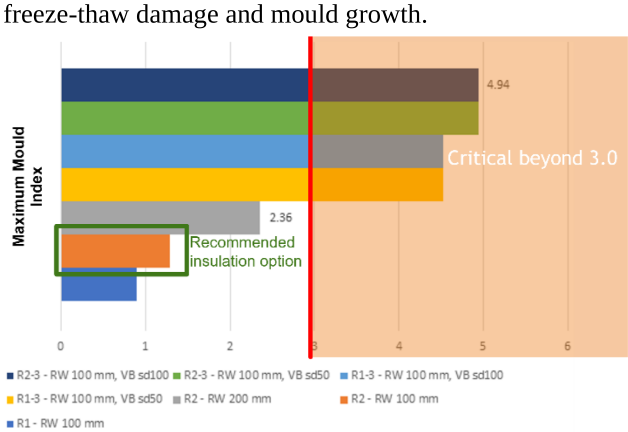

Figure 4: Maximum mould index for insulation with and without a vapour barrier on the interior side of insulation. R1 – add insulation on interior of existing wall. R2 – remove inner masonry, add insulation on interior side.

There was no risk of freeze-thaw damage in the exterior and rubble stone layers as predicted by the simulation and analysis for any of the insulation retrofits because the moisture content in the exterior layers stays below the critical degree of saturation (Scrit) throughout the year. For the baseline wall type 1 scenario, there were 51 freeze cycles in the Nepean sandstone layer, 41 freeze cycles with Retrofit 1, and 41 freeze cycles with Retrofit 2. The Nepean sandstone layer in the baseline wall type 2 scenario had 45 freeze cycles in one year, 43 freeze cycles with Retrofit 1, and 39 freeze cycles with Retrofit 2. The number of freeze cycles decreases with the addition of insulation because the outer layer of the wall stays frozen for more hours of the year rather than cycling above and below zero for a full freeze-thaw cycle.

Case Study 2: Warehouse in Pitt Meadows, BC, Canada

Background Info

The pre-cast concrete warehouse is 40 km East of Vancouver in Pitt Meadows, BC, Canada, which is a humid, mild, marine climate (ASHRAE zone 4). The building has no sheltering from nearby buildings or trees and does not have rain shedding features (e.g. gutters, overhangs). Rain exposure factor (FE) of 1.4 and rain deposition factor (FD) of 1 is assigned according to ASHRAE Standard 160, because of the lack of sheltering and rain shedding features. The building mechanical system did not originally have humidity controls. There are large overhead doors that are anticipated to be open most of the time. Due to budget limitations, an insulated sandwich panel was not considered. The goal of the study was to assess the condensation risk of not insulating the lower 10 ft of the building due to operational reasons and determine an alternative design to protect against condensation.

Design Scenarios

The design scenarios were assessed with indoor winter temperature setpoints of 15°C or 19°C. The design scenarios considered were: baseline scenario: 8” pre-cast panel, no insulation; elastomeric coating as exterior moisture barrier; humidity control: max 60% RH; 50 mm mineral wool with/without foil facer; and 50 mm closed cell spray foam.

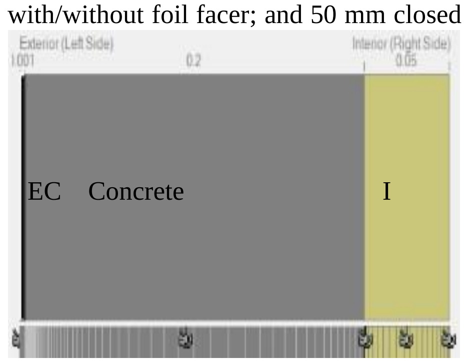

Figure 5: Retrofit with exterior coating and insulation and monitor points (indicated by grey camera icons). EC – elastomeric coating, I - insulation.

Results

The RH at the interior surface of the concrete is above 85% for 53% of the year, which means that condensation will likely occur in Jan/Feb and Nov/Dec (Figure 6).

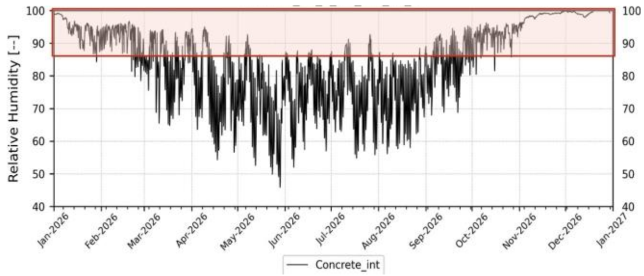

Figure 6: Baseline annual RH profile, 15°C winter temperature setpoint, no dehumidification.

The results of the baseline scenario with dehumidification show that RH is reduced from the baseline without dehumidification. This demonstrates importance of indoor humidity controls on the moisture behaviour of the building envelope, however the RH at the interior surface still increases to above 80% for several months of the year. The RH results are also improved when the indoor temperature is increase from 15°C to 19°C during the winter.

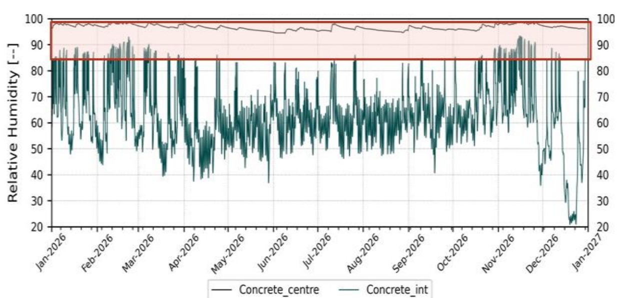

Figure 7: Baseline annual RH profile, 15°C winter temperature setpoint, with dehumidification.

The scenarios that include dehumidification are the best in terms of controlling RH range to be below 70% at the interior surface (Figure 8). The recommended scenarios are outlined in green boxes which are different combinations of no coating or with exterior coating, spray foam, 15 °C or 19°C interior temperature, and dehumidification. The exterior coating does not have much impact on the interior relative humidity, but it does prevent the concrete from accumulating water from wind-driven rain (Figure 9).

When adding insulation without the exterior coating, the moisture content in the concrete increases from the baseline 122 kg/m^3 to 134 kg/m^3. With the exterior coating, the moisture content in the concrete decrease to a range of 62 kg/m^3 to 74 kg/m^3 (outlined by the green box in Figure 9).

In terms of moisture content, it is best to use the exterior coating, no insulation, a setpoint of 19°C for heating, and include dehumidification. However, all the insulation scenarios with the exterior coating significantly improve over the baseline moisture content in the concrete, so the insulation options are the best choice for the additional energy savings especially if heating to the higher setpoint. The mineral wool with a foil facer vapour barrier on the interior causes moisture to accumulate within the insulation because of the moisture flux travelling towards the interior of the walls due to the strong capillary suction of the concrete and high rain exposure on the exterior.

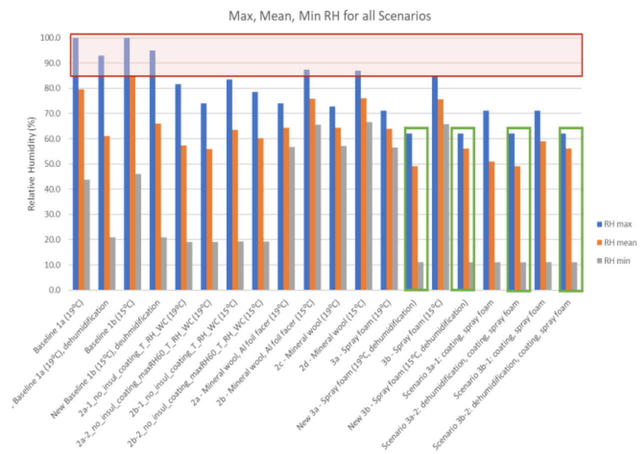

Figure 8: Max, mean, and min RH at the interior surface of wall assembly for all scenarios simulated.

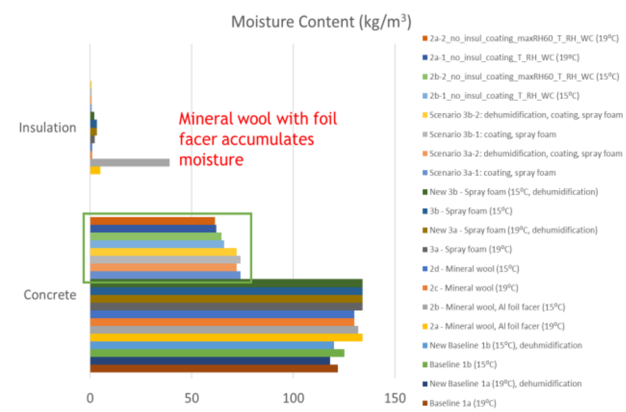

Figure 9: Moisture content results for all scenarios simulated.

Case Study 3: New Academic Building in Tempe, AZ, U.S.A.

Background Info

The new academic building is in Tempe, AZ, U.S.A about 17.7 km from Phoenix, AZ, which has a warm, dry climate (ASHRAE climate zone 2). The function is a typical academic building with offices and classrooms. The indoor temperature setpoints are typical: 21°C for heating, and 24°C for cooling. There will be humidity control within the building to maintain the RH between 45%-55%. The goal of this study was to demonstrate whether the design of the wall was appropriate for the building and climate.

Design

The design of the wall from exterior to interior is: brick masonry veneer finish, 25 mm air space, 125 mm XPS rigid insulation (4.2 m^2-K/W), weather barrier (air and vapour) on interior side of insulation, gypsum sheathing, steel framing and gypsum board. This design follows the same design principles as Figure 5 in (Lstiburek, 2011), which states that it is appropriate for all hygrothermal regions.

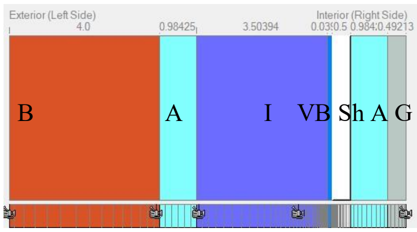

Figure 10: Design wall composition and monitor positions. See nomenclature for layer material names. B – brick, A – air gap, I – insulation, VB – vapour barrier, Sh – sheathing, G – gypsum board.

Results

Based on the overall positive moisture flux through the wall assembly from WUFI, the average total annual moisture flux is from the exterior to the interior of the walls. Figure 11 show the RH annual profile within the baseline wall layers. The relative humidity in the centre of the insulation layer is around 40%-82% during cooler months, 14%-40% during warmer months. The interior gypsum board is around 30% RH during warmer months and 57% during cooler months. The moisture content is highest in the brick layer around 96 kg/m^3 and it is relatively low in the insulation, sheathing, and gypsum board layers (<32 kg/m^3).

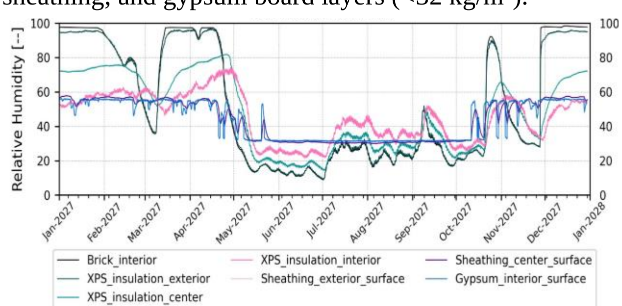

Figure 11: Design wall RH for all monitor points in the wall assembly within WUFI.

Table 1 shows the relative humidity and mould statistics for each monitor in the wall assembly in WUFI. Although the RH is above 80% for 3011 hours in the brick and 2978 hours at the exterior surface of the insulation in a year, this is not a concern because it is on the exterior side of the weather barrier. Any potential condensation will drain to the exterior of the wall. The hours that RH is greater than 80% at the center of the insulation drops to 235 hours in a year and zero hours at the interior side of the insulation. This demonstrates the vapour resistive properties of XPS and that it does not have issues of absorbing moisture. The maximum mould index is either zero or close to zero at all monitors in the wall assembly, with the maximum value being 0.57 at the interior side of the brick. Therefore, there is a low risk of mould growth within the wall assembly.

Case Study 4: Heritage Building in Tempe, AZ, U.S.A.

Background Info

This is a heritage building located in the same climate zone as the case study 3. The existing building is in poor condition because of the cracking in the heritage pre-cast concrete panels and the gaps along panel joints, as well as around windows. The heritage façade required repairs and presented an opportunity to improve the airtightness, thermal and moisture performance. The interior conditions need to be maintained in a narrow window of RH at an average of 45% RH to minimize the costs of maintenance for wooden musical instruments stored in the building. The baseline existing wall composition is: 250 mm pre-cast concrete panels, 63 mm steel studs, 63 mm fiberglass batt insulation in walls (increased thermal conductivity to account for 70-year-old batt insulation), 13 mm drywall. The goal of the study is to determine the impact of using an exterior coating as a moisture barrier, optimal insulation thickness, and the optimal location of a vapour barrier.

Retrofit Scenarios

Scenario 1: exterior coating, 250 mm pre-cast concrete panels, vapour barrier on interior side of concrete, 50 mm mineral wool insulation (1.7 m^2-K/W) or polyisocyanurate (2.3 m^2-K/W), gypsum board.

Scenario 2: exterior coating, 250 mm pre-cast concrete panels, vapour barrier on interior side of concrete, 63 mm mineral wool insulation (2.1 m^2-K/W), or polyisocyanurate (2.8 m^2-K/W), or fiberglass batt (2.0 m^2-K/W), gypsum board.

Scenario 3: Exterior coating, pre-cast concrete panels, no insulation upgrade (0.57 m^2-K/W), gypsum board.

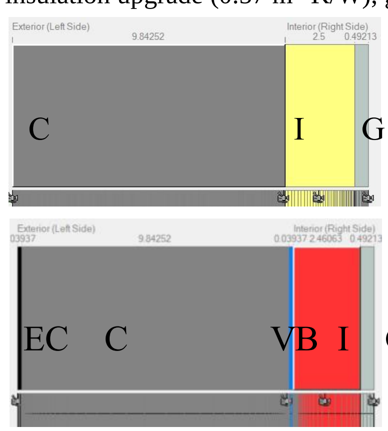

Figure 12: Baseline existing wall (top) and Retrofit (bottom) and monitor positions. C – concrete, I – insulation, G – gypsum, EC – elastomeric coating, VB – vapour barrier.

Results

The overall statistics of the relative humidity results in the insulation layer for all scenarios are presented below in Figure 13. The mean relative humidity in the insulation layer increases from the baseline value of 34% to 44%-45% in the retrofit scenario where there is an exterior coating, a vapour barrier on the interior of the concrete panel and 50-63 mm mineral wool/polyisocyanurate/fiberglass batt. The maximum relative humidity is higher for the options that use mineral wool or fiberglass batt by about 10% over the options with polyisocyanurate. The scenario with the exterior coating, but no modification to the existing insulation (2d) demonstrates almost the same relative humidity results as baseline. Although, it has a lower relative humidity, option 2d would not provide any improvement in energy use, resulting in higher operational costs and poor occupant comfort.

Although the relative humidity is higher in the retrofit scenarios, the risk of mould growth is low since the maximum mould index (based on temperature, relative humidity, and sensitivity class) in all scenarios is zero (below critical level of 3), and the hours where temperature and relative humidity surpass the isopleths are minimal (Table 2). The change in insulation thickness from 50 mm to 63 mm does not have much impact on the results. Therefore, it would be best to select the option with the exterior coating and 63 mm of mineral insulation for the increased energy savings, improved thermal comfort, low risk of mould growth, and consistent thermal performance which does not degrade with temperature differential, unlike polyisocyanurate.

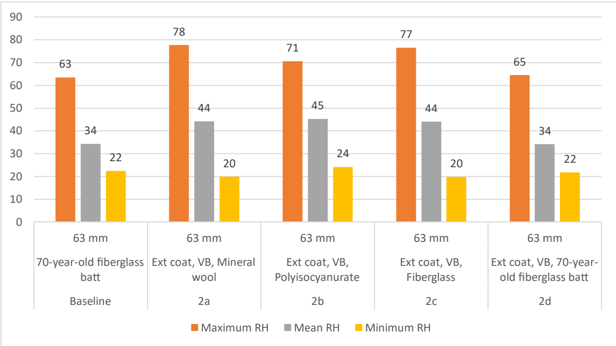

Figure 13: Maximum, mean, and minimum RH for insulation layer in the baseline and retrofit scenarios analysed.

A sensitivity analysis was completed to understand the impact of using the exterior coating and the vapour barrier on the interior side of the concrete panels in the retrofit. Figure 14 shows the maximum, mean, and minimum RH values for the concrete layer in the baseline and 50 mm insulation scenarios with different combinations of either including or excluding the exterior coating and vapour barrier. The worst scenarios with the highest maximum RH values that exceed 80% are the mineral wool scenarios that have no vapour barrier and with/without the exterior coating. The third worst scenario is the polyisocyanurate with a vapour barrier and without the exterior coating. This shows the importance of the exterior coating in controlling the moisture behaviour of the walls.

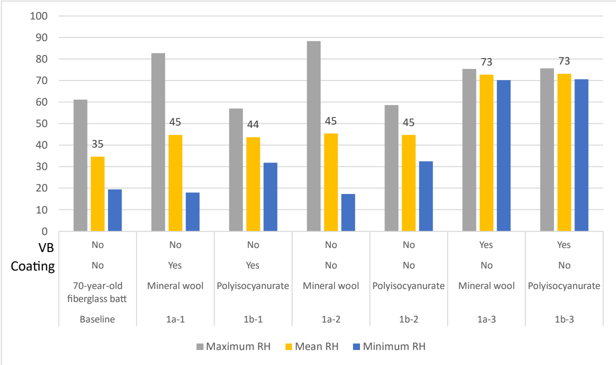

Figure 14: Maximum, mean, and minimum RH for concrete layer in baseline and 50 mm insulation scenarios with different combinations of either including or excluding the exterior coating and vapour barrier.

The maximum mould index and hours that the relative humidity and temperature surpass the isopleths are shown in Table 3 below. These values indicate the same thing as the relative humidity graph above. Although the maximum mould index is zero in most cases, isopleth I is surpassed in three cases: mineral wool with exterior coating but without a vapour barrier; mineral wool without coating and without a vapour barrier; and polyisocyanurate without the coating and with the vapour barrier. Isopleth II is surpassed in two of the sensitivity cases. This further emphasizes the relative increase in mould growth risk if the vapour barrier or the exterior coating are not implemented together with the insulation.

Discussion and Conclusions

How Hygrothermal Modelling was Utilized in Each Case Study

Heritage Building in Ontario, Canada:

The hygrothermal study helped determine a safe level of insulation to minimize freeze-thaw damage risk for the heritage masonry. Without the study, there would have been potential uncertainty and risk to insulate the high heritage value walls and risk of damaging the character defining element.

Warehouse in Pitt Meadows, BC, Canada:

The hygrothermal study helped determine a less common wall design for the client to save costs on insulation, while controlling the risk of condensation in a mild, humid climate.

New Academic Building in Tempe, AZ, U.S.A.:

The detailed design wall assembly with the exterior brick veneer, air gap, 127 mm extruded polystyrene, air-vapour barrier, sheathing, steel studs, and gypsum board on the interior is a good option because the hygrothermal study demonstrates that the design prevents moisture accumulation and mould growth risk within the wall assembly.

Heritage Building in Tempe, AZ, U.S.A.:

The hygrothermal study helped determine a unique solution to conserve the heritage façade of pre-cast concrete panels and reduce cost and frequency of maintenance for musical instruments in the building.

Limitations and Benefits of All Case Studies

Heritage Building in Ontario, Canada:

A 2-D hygrothermal study to determine the freeze-thaw damage risk of insulation for the other stone types used as decorative elements on the façade should be done before the construction phase to minimize the impact on the heritage value of the building. The rain deposition factor can be greatly reduced by implementing larger overhangs at the roof edges and rain gutters, which should be considered as part of the retrofits for the building.

Warehouse in Pitt Meadows, BC, Canada:

The client did not want to insulate the walls or control indoor humidity to save on immediate costs. However, insulating the walls, heating to a higher winter setpoint, adding an exterior coating to the building enclosure, and adding humidity control within the building would provide the best solution for the project to minimize condensation risk, mould risk, and proper indoor conditions for occupant comfort and well-being.

New Academic Building in Tempe, AZ, U.S.A.:

Without prior knowledge of how a specific wall design is intended to perform in terms of heat and moisture transfer, the design wall assembly would appear to have issues of moisture accumulation on the outer layers. However, any moisture outboard of the weather barrier would drain to the exterior based on the design of the wall.

Heritage Building in Tempe, AZ, U.S.A.:

The results of the hygrothermal study are highly dependent on the existing building enclosure being sealed for airtightness and water leakage issues being remediated. This will be achieved using the exterior coating on the pre-cast panels, sealing the joints between panels and gaps around windows with caulking. There is a need for a parapet cap to prevent moisture absorption through the parapets and remediate the issue of water leakage at the roof/wall connections.

Nomenclature

A – air

B – brick

EC – exterior coating

G – gypsum board

I – insulation

NS – Nepean sandstone

RS – Rubble stone

Scrit – critical level of saturation

SF – spray foam

Sh – sheathing

VB – vapour barrier

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Table 1: Case study 3 - Relative humidity and mould statistics for each monitor in the wall assembly in WUFI

Material, monitor position	Max RH (%)	Mean RH (%)	Min RH (%)	RH > 80% (Hours)	Max Mould Index	Hours > Isopleth I	Hours > Isopleth II
Brick, interior	98	52	9	3011	0.57	3122	2994
XPS insulation, exterior	97	52	9	2978	0.11	3101	2945
XPS insulation, center	82	48	14	235	0	589	319
XPS insulation, interior	74	45	22	0	0	0	0
Sheathing, exterior	58	44	30	0	0	0	0
Sheathing, center	58	44	30	0	0	0	0
Gypsum, interior surface	56	44	31	0	0	0	0

Table 2: Case study 4 - Max mould index, hours mould index > 3, hours > isopleth I, hours > isopleth II

Scenario	Insulation	Insulation Thickness (in)	Maximum Mould Index	Hours Mould Index > 3	Hours > Isopleth I	Hours > Isopleth II
Baseline	70-year-old fibreglass batt	0.5	0	0	0	0
1a	Mineral wool	2	0	0	7	0
1b	Polyisocyanurate	2	0	0	0	0
2a	Mineral wool	2.5	0	0	8	0
2b	Polyisocyanurate	2.5	0	0	0	0
2c	New fiberglass	2.5	0	0	0	0
2d	70-year-old fiberglass batt	0.5	0	0	0	0

Table 3: Case study 4 - Max mould index, hours > isopleth I and hours > isopleth II in the concrete layer for the sensitivity analysis with and without exterior coating and/or vapour barrier (VB)

Scenario	Insulation	Coating	VB	Max Mould Index	Hours > Isopleth I	Hours > Isopleth II
Baseline	70-year-old fiberglass batt	No	No	0	0	0
1a-1	Mineral wool	Yes	No	0	243	37
1b-1	Polyisocyanurate	Yes	No	0	0	0
1a-2	Mineral wool	No	No	0.003	409	236
1b-2	Polyisocyanurate	No	No	0	0	0
1a-3	Mineral wool	No	Yes	0	0	0
1b-3	Polyisocyanurate	No	Yes	0	126	0