Analysis of Mould Risk for Design for Deconstruction Assemblies

Summary of findings

The basic wall assemblies—with either bio-based or mineral insulation and without a specifically detailed vapour retarder—are suitable for the vast majority of light-wood frame applications where indoor relative humidity is maintained at standard levels (30-55%). However, when constructing for high humidity applications or for extra surety of moisture performance a simple vapour retarder in the form of acrylic latex paint layer on interior wall surfaces is fully sufficient for managing moisture transport throughout the assembly. Further to this, the inclusion or exclusion of a vapour-permeable WRB membrane outboard of exterior WFI insulation has no significant impact on mould growth either at the interior face of the sheathing or on the exposed face of the insulation.

Introduction

The following presents an assessment of the risk of mould formation in a selection of design for deconstruction light wood frame assemblies at climate zone 4 and climate zone 7 (i.e. the end ranges of climate zones for Canada's major cities). The assessment of mould risk gives designers and builders comparative knowledge for selecting appropriate construction assemblies based on the exterior climate and indoor use expected for a project.

The hygrothermal simulation of the wall sections uses the following conditions: Zone 4 exterior climate is calculated based on Vancouver, BC weather data for a cold year. Zone 7 exterior climate is calculated based on Edmonton, AB weather data for a standard year. All assemblies are simulated in north facing exposure. The interior moisture conditions for both are set based on EN15026/DIN4108/WTA6-2 which assumes an interior temperature maintained at a minimum of 20°C and uses both the medium moisture load +5% design value for standard construction with interior relative humidity (RH) fluctuations of 35-65% and high moisture load profile of 40-70% RH (i.e. worst-case scenario moisture load for high occupancy or irregular moisture loading from kitchen/bathroom use). The medium moisture load is in line with typical residential RH levels and within with Health Canada's maximum recommended RH levels (though ideal indoor RH is between 30-50%).[1] The simulation is calculated for a 3 year period starting with an assumed new building completion from Oct 10 2024 to Oct 10 2027, to account for the first year drying time and to allow the simulated assembly to establish a year-to-year moisture equilibrium. All moisture assessment were carried out using WUFI Pro 6 software and the WUFI Bio mould analysis tool.

Analysis

The first set of comparisons are for constructions in climate Zone 4.

These simulations were done on 3 variations of an R22 light-wood frame wall assembly as well as the R30 roof and R22 foundation which are the minimum prescriptive insulation requirements per City of Vancouver Building Code.

The basic organization of these walls is as follows:

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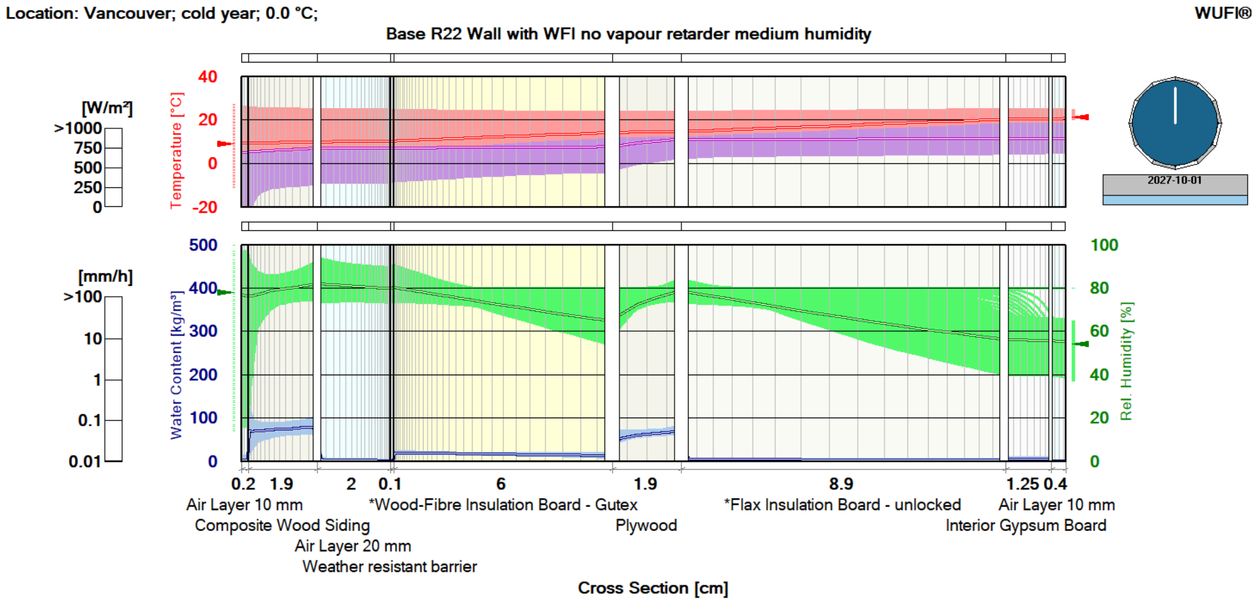
[1] Health Canada, *Relative Humidity Indoors : Factsheet*, [Page #], 2016, https://publications.gc.ca/collections/collection_2018/sc-hc/H144-33-2016-eng.pdf.

	Component	Thickness (mm)	Effective RSI (m^2K/W)	Effective R ($ft^2 \cdot °F \cdot h/BTU$)
Exterior	Air Layer	2	0.019	0.11
	Composite Wood Siding	19	0.17	0.97
	Ventilation Air Gap	20	0.19	1.1
	Vapour Permeable WRB	1	n/a	n/a
	Rigid Fibrous insulation (Wood Fibre Insulation [WFI] or Rockwool)	60-64	1.43-1.88	8.1-10.6
	Structural Plywood	19	0.19	1.1
	38 by 89mm wood stud wall at 400mm o/c with batt insulation (Hemp or Rockwool)	89	2.12	12
	Gypsum Drywall	13	0.08	0.45
Interior	Air Layer	9	0.09	0.48
		Total	4.29-4.74	24.4-26.9*

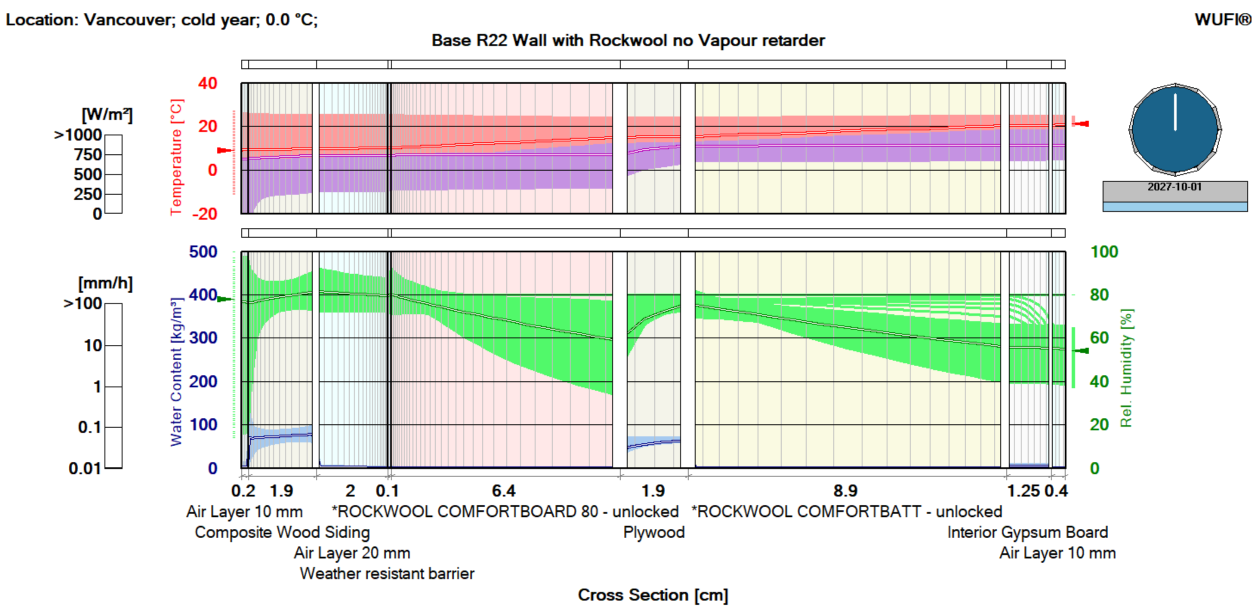
*By using standard sized insulation the actual effective insulation is higher than the minimum required R22.

The following images show the mean temperature, dew point, moisture content, and RH levels across the wall assemblies during the 3-year calculation period for medium interior RH conditions. The figure is arranged with the interior surface to the right and exterior surface to the left. The key point to look at in these figures is the RH level at the interior surface of the plywood sheathing which—at the transition point from interior to exterior insulation--is the most susceptible region of the wall to mould growth. In these two diagrams the mean level of relative humidity at this point is below 80% which is the threshold for concerning mould growth. This indicates that both of these assemblies have adequate drying through the assembly and the sheathing is sufficiently protected from low temperatures by the ratio of exterior insulation.

Simulation Mean levels R22 Wall with WFI and Hemp Insulation and no VR under Med Interior RH

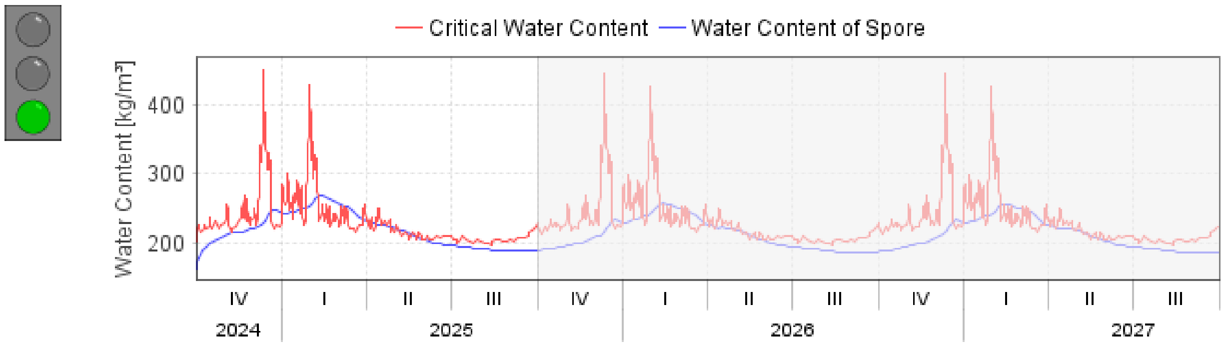


Simulation Mean levels R22 Wall with Rockwool Insulation and no VR under Med Interior RH

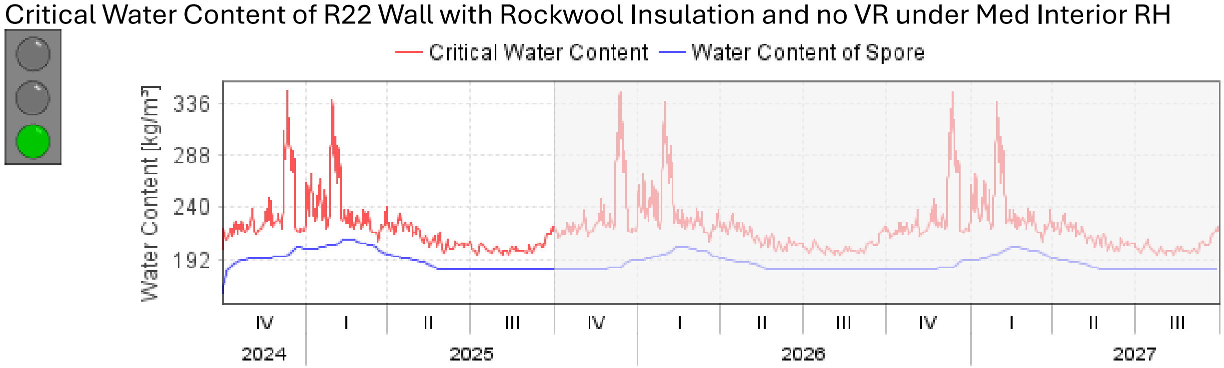


To confirm this finding one can refer to the mould growth index produced in WUFI Bio which estimates the rate of mould growth based on the fluctuation of critical moisture content in the assembly over the course of the simulation period, the position of the monitoring point within the assembly relative to indoor air, and the composition of the substrate at the monitoring point (i.e. do the selected materials support or inhibit mould growth). These mould risk assessments are evaluated on the basis of a monitoring position on the interior surface of the plywood sheathing and therefore not in contact with interior air and Class I materials which are organic materials which can support mould growth. Though Rockwool is an inorganic Class II material the monitoring point is in contact with the plywood which is a Class I material.

Critical Water Content of R22 Wall with WFI and Hemp Insulation and no VR under Med Interior RH



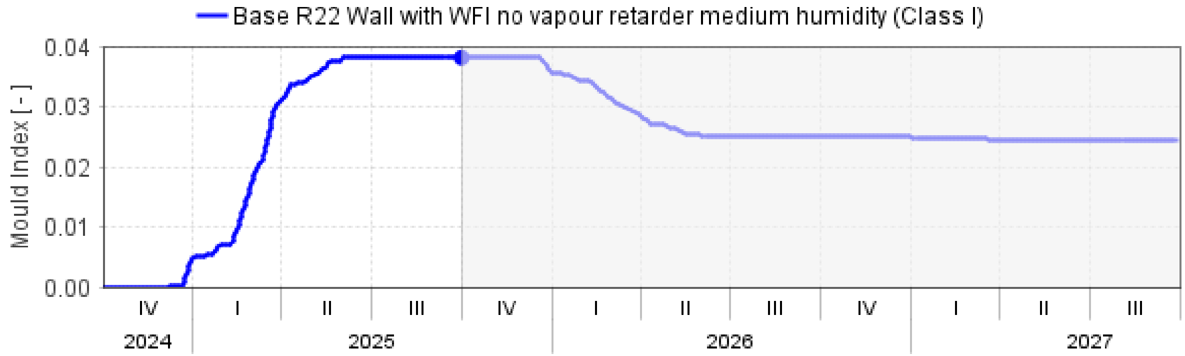
Critical Water Content of R22 Wall with Rockwool Insulation and no VR under Med Interior RH



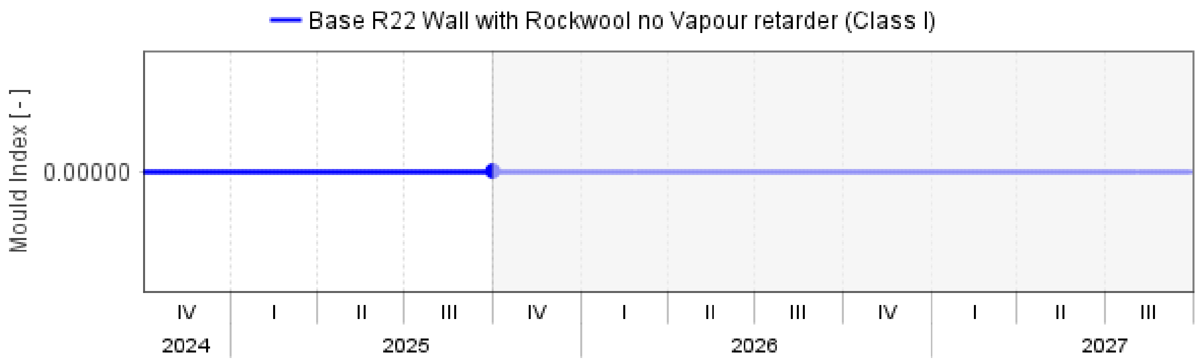
The critical water content diagrams give a simple assessment of mould growth risk and indicate this risk through a traffic light system; Green = Mould Growth < 176 mm/year; Yellow = 176 < Mould Growth ≤ 239 mm/year; Red = Mould Growth > 239 mm/year. As evident in the previous figures the mould risk for both of these assemblies under medium interior RH conditions have low risk of hazardous mould formation. The risk can be further assessed by the Mould Index assessment. For these diagrams the mould risk for the simulation period is assessed on a 6 point scale.

Index	**Description**
0:	No growth.
1:	Some growth visible under microscope.
2:	Moderate growth visible under microscope, coverage more than 10%.
3:	Some growth detected visually, thin hyphae found under microscope.
4:	Visual coverage more than 10%.
5:	Coverage more than 50%.
6:	Tight coverage, 100%.

Mould Index of R22 Wall with WFI and Hemp Insulation and no VR under Med Interior RH



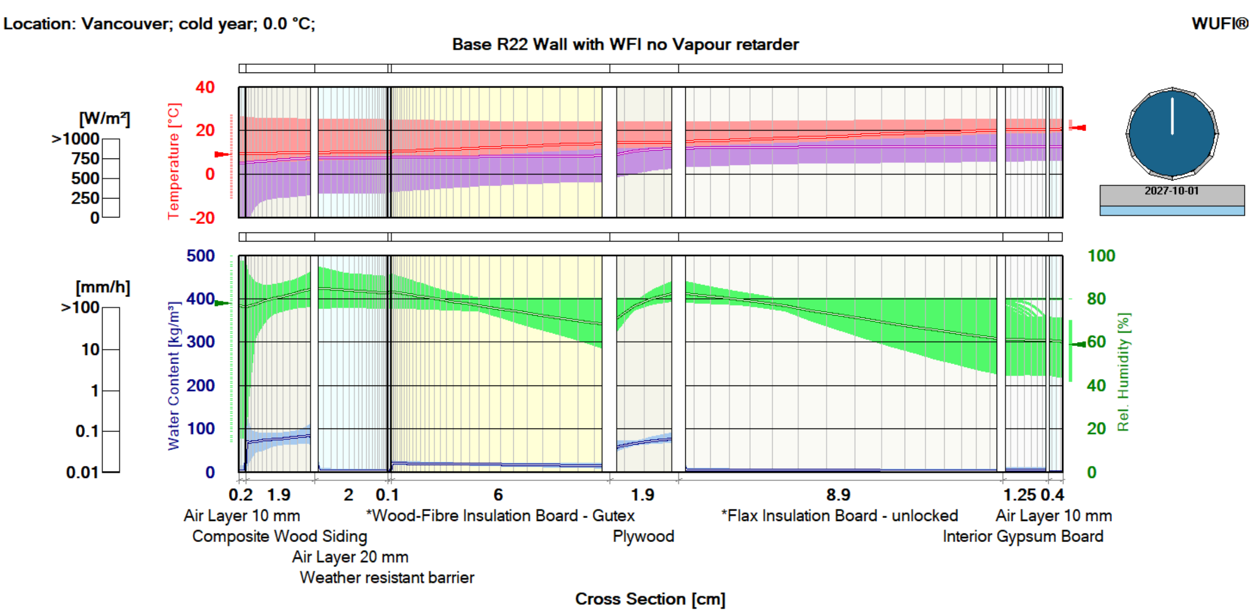
Mould Index of R22 Wall with Rockwool Insulation and no VR under Med Interior RH



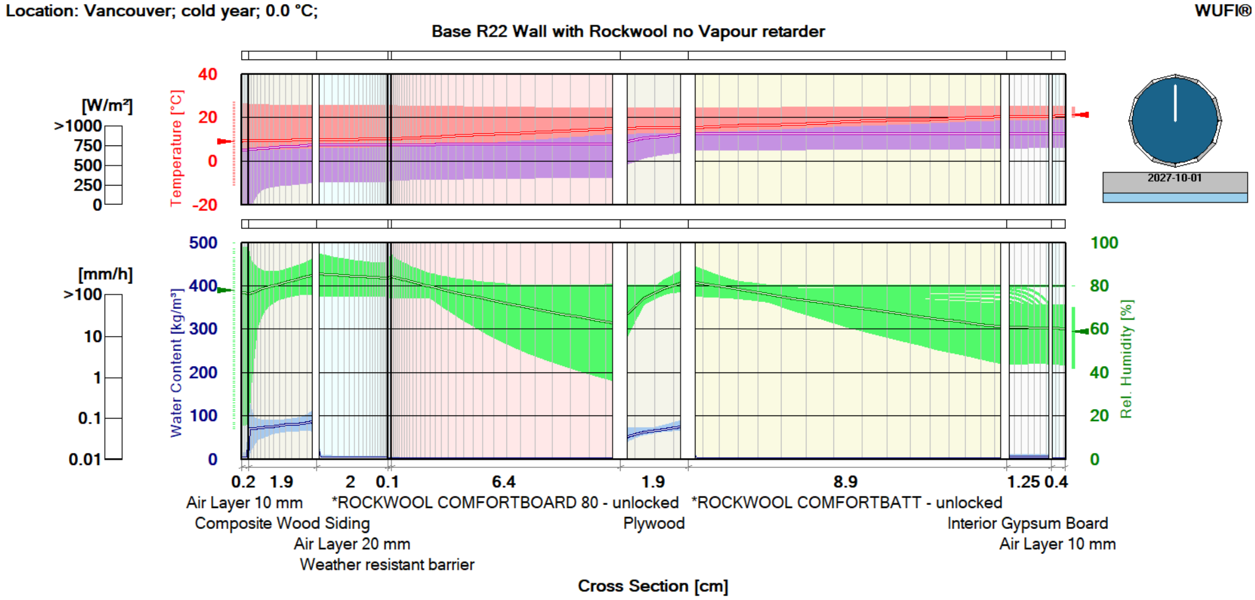
As seen in these figures the mould index for both wall assemblies is <0.05 which indicates limited-to-no mould growth across the simulation period. The increase in the mould index for the wall built with WFI is due to the high initial moisture content of the insulation materials, however after the first year during which the wall achieves moisture equilibrium, and the any further mould growth is unsustained.

For the same assemblies under high interior RH, the mould growth risk is more concerning.

Simulation Mean levels R22 Wall with WFI and Hemp Insulation and no VR under High Interior RH



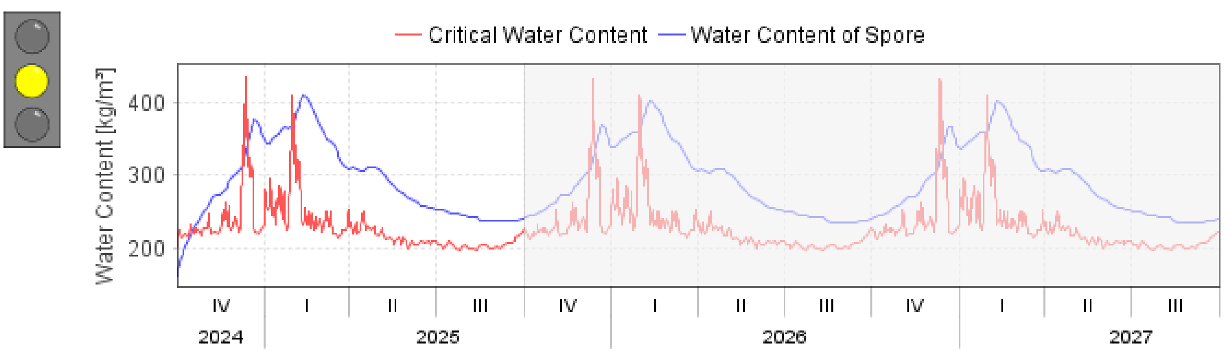
Simulation Mean levels R22 Wall with Rockwool Insulation and no VR under High Interior RH



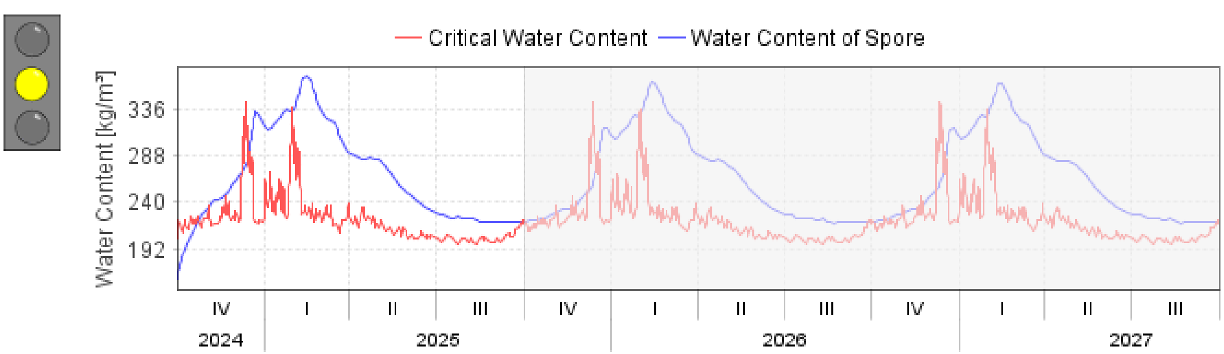
As evident in the figures, the mean RH levels at the interior surface of the plywood sheathing exceeds 80% in both cases indicating a potential mould growth risk.

The critical water content and mould index for both cases further supports this finding.

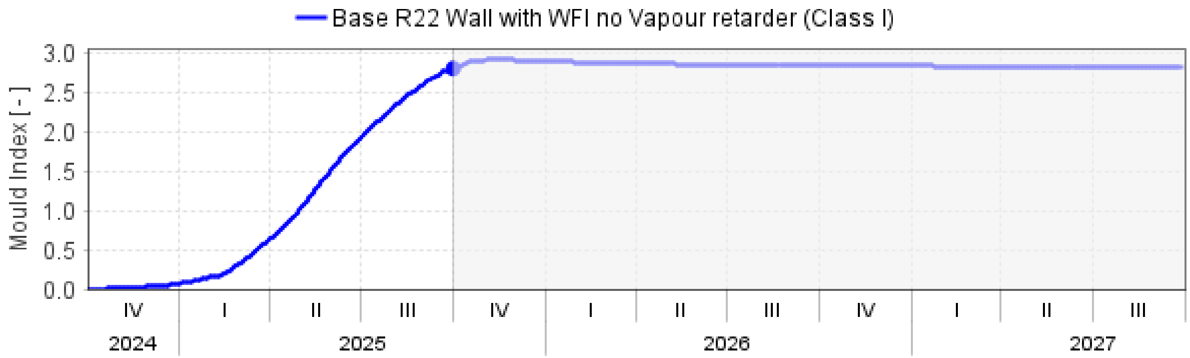
Critical Water Content of R22 Wall with WFI and Hemp Insulation and no VR under High Interior RH



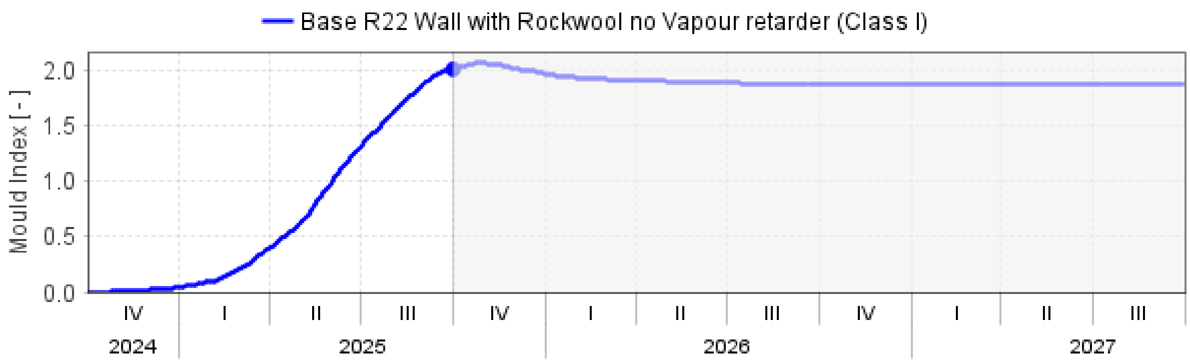
Critical Water Content of R22 Wall with Rockwool Insulation and no VR under High Interior RH



Mould Index of R22 Wall with WFI and Hemp Insulation and no VR under High Interior RH

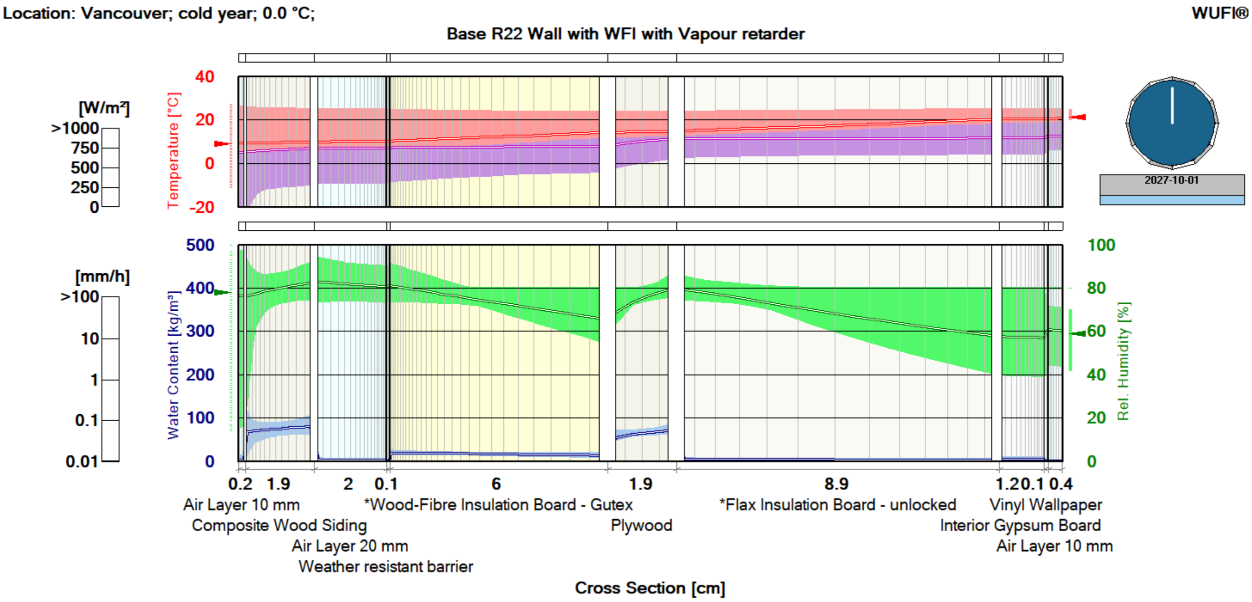


Mould Index of R22 Wall with Rockwool Insulation and no VR under High Interior RH

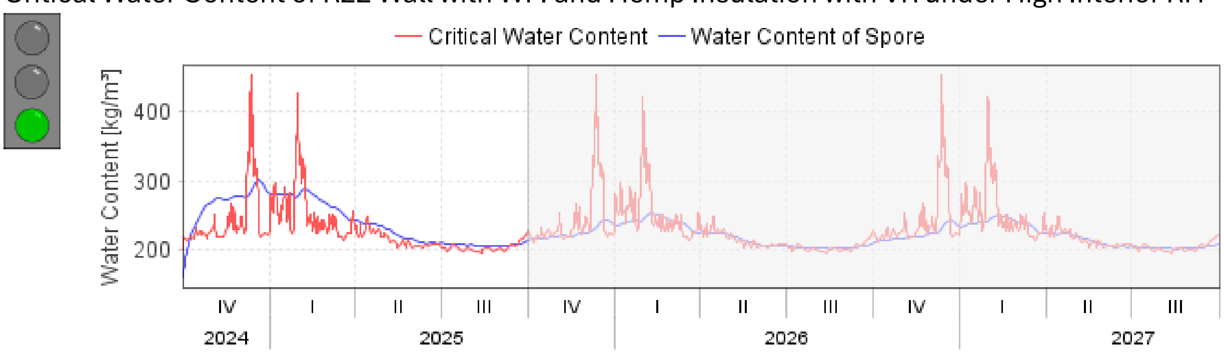


Fortunately both assemblies only require a simple amendment in order to prevent hazardous levels of mould growth. The addition of a vapour retarding layer to the interior surface of the assembly, such as the addition of a vapour retarding acrylic latex paint, is sufficient to slow moisture ingress into the wall assembly and prevent moisture accumulation at the sheathing. The following diagrams show the results and the reduction of mould growth risk levels when adding a vapour retarder treatment to the interior surface of the gypsum wall board in the R22 wall assembly built with WFI and hemp insulation.

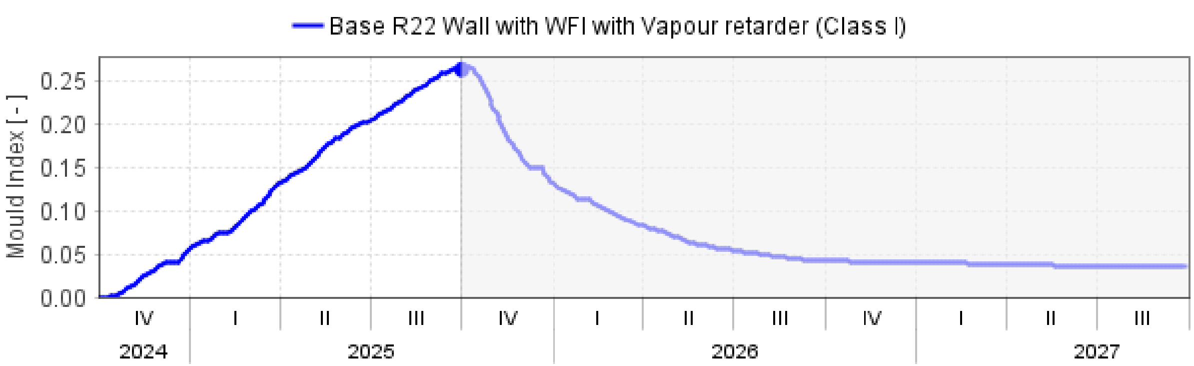
Simulation Mean levels R22 Wall with WFI and Hemp Insulation with VR under High Interior RH



Critical Water Content of R22 Wall with WFI and Hemp Insulation with VR under High Interior RH



Mould Index of R22 Wall with WFI and Hemp Insulation with VR under Med Interior RH

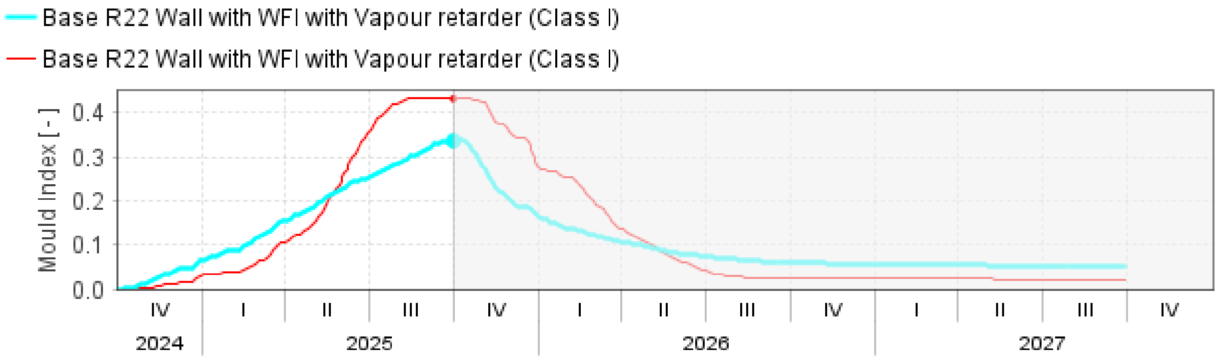


As evidence by these figures, the mean RH at the interior surface of the plywood sheathing remains below 80% and the mould growth even during the first year drying period never achieves a concerning level.

Addendum:

the inclusion or exclusion of a WRB outboard of the exterior insulation does not seem to impact mould growth. This indicates that a WRB could be excluded in properly detailed split insulation wall assembly designs. (see graphs below for analysis)

Mould Index of R22 Wall with WFI and Hemp Insulation with VR and no WRB under High Interior RH [Red line = monitor point at insulation exterior surface, Blue line = monitor point at interior sheathing surface]



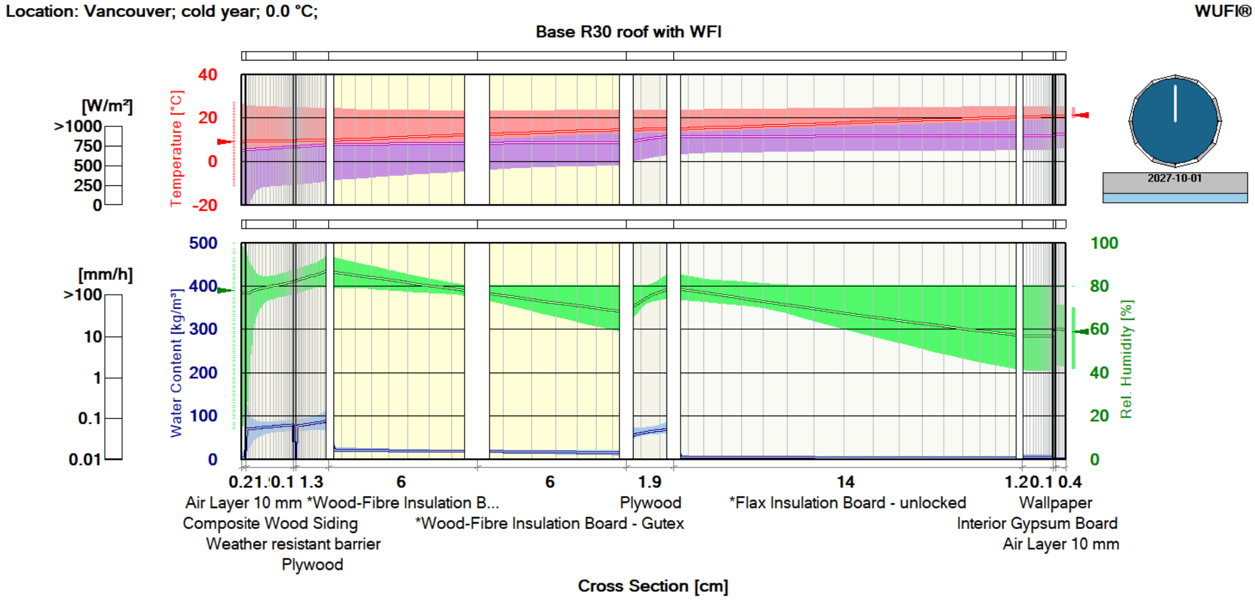
We can further assess the mould risk of a building constructed to the design-for-deconstruction specifications for Zone 4 by analysing the roof and foundation assemblies.

The roof assembly is modeled according to the as-built assemblies for the DfD wall mock-up and is constructed as follows:

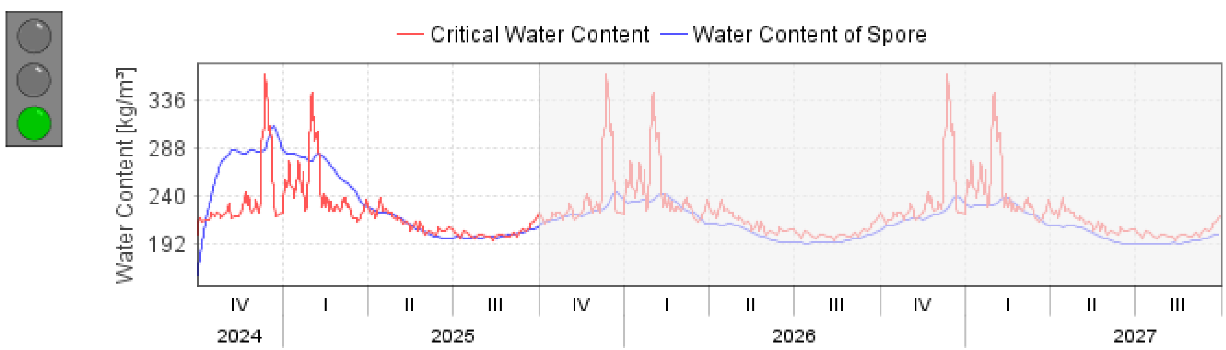
	Component	Thickness (mm)	Effective RSI (m^2K/W)	Effective R ($ft^2 \cdot {}^\circ F \cdot h/BTU$)
Exterior	Air Layer	2	0.019	0.11
	Roofing finish	3	n/a	n/a
	Vapour Permeable WRB	1	n/a	n/a
	Plywood	13	0.13	0.75
	WFI	120	2.86	16.2
	Structural Plywood	19	0.19	1.1
	38 by 140mm wood rafters at 400mm o/c with hemp batt insulation	140	3.33	18.9
	Gypsum Drywall	13	0.08	0.45
	Vapour Retarder Layer (Latex Acrylic Paint)	1	n/a	n/a
Interior	Air Layer	9	0.09	0.48
		Total	6.70	38*

*By using standard sized insulation the actual effective insulation is higher than the minimum required R30.

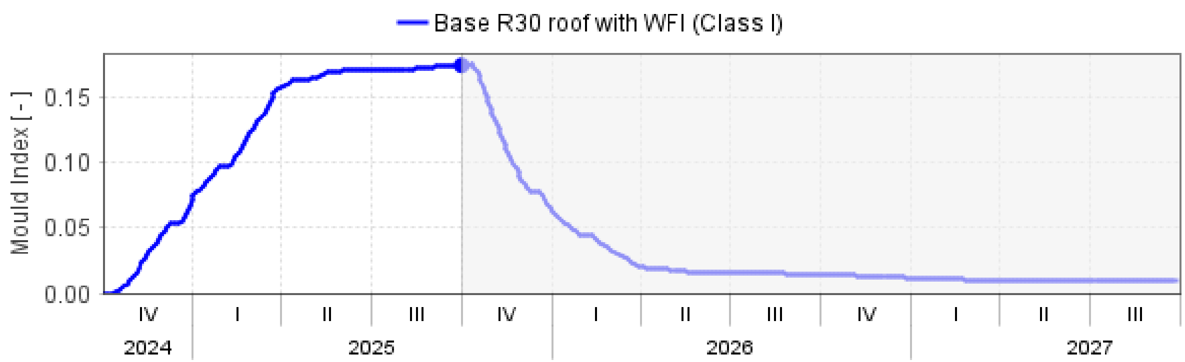
Simulation Mean levels R30 Roof with WFI and Hemp Insulation with VR under High Interior RH



Critical Water Content of R30 Roof with WFI and Hemp Insulation with VR under High Interior RH



Mould Index of R30 Roof with WFI and Hemp Insulation with VR under High Interior RH



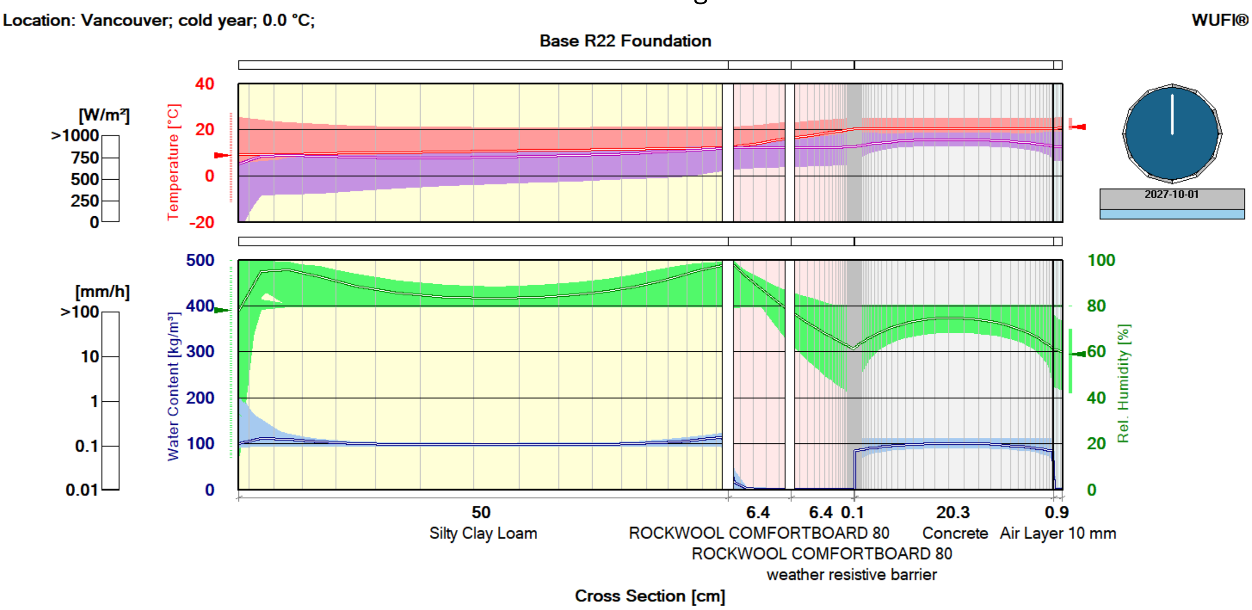
The foundation detail is built to R22 standards and is constructed as follows:

	Component	Thickness (mm)	Effective RSI (m^2K/W)	Effective R ($ft^2\cdot°F\cdot h/BTU$)

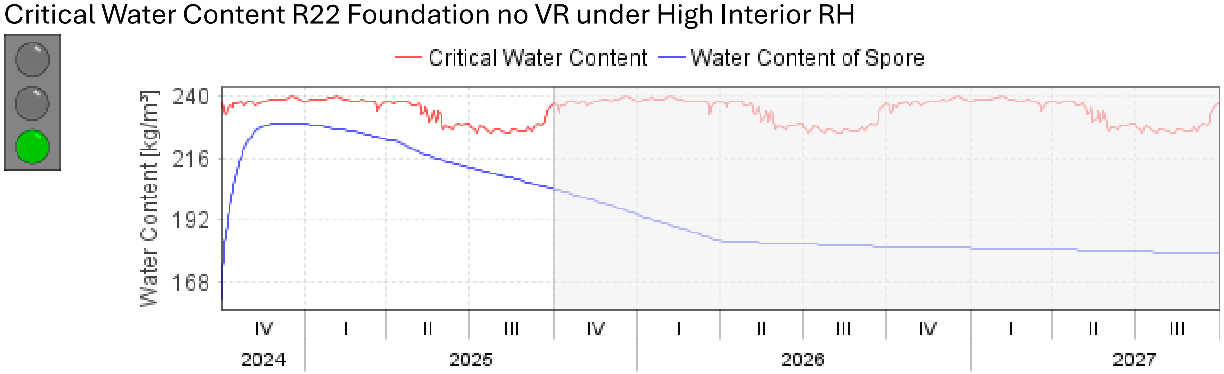
Exterior	Soil (silty clay loam, a common soil type in Vancouver) **included for moisture modelling*	50	n/a	n/a
	Roofing finish	3	n/a	n/a
	Rockwool board	128	3.76	21.4
	Vapour Permeable WRB	1	n/a	n/a
	Concrete Foundation Wall	203	0.15	0.84
Interior	Air Layer	9	0.09	0.48
		Total	4.0	22.7

Note that the sediment control layers are omitted from this assembly list as they do not impact the hygrothermal modelling behaviour of the foundation. For the simulation assessment the monitoring point is taken within the concrete foundation wall where RH peaks within the wall and the substrate is Class II (inorganic material that resists mould growth). The interior condition of the assembly is assumed to be a finished and habitable basement with heating.

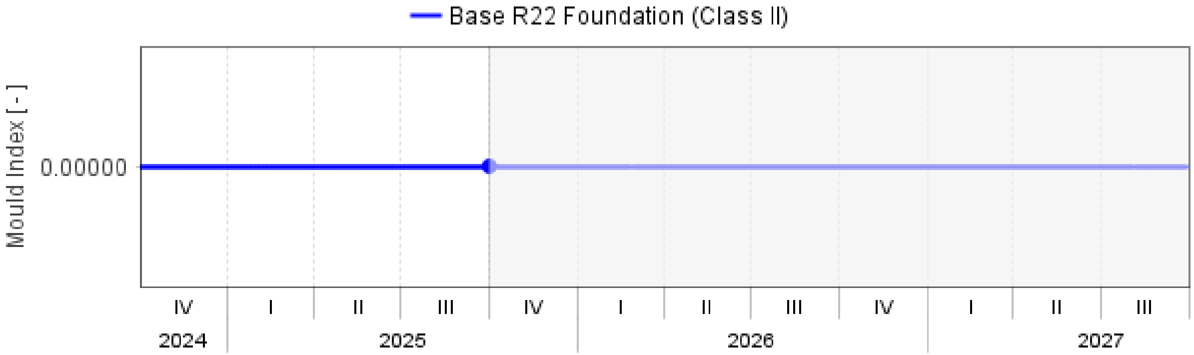
Simulation Mean levels R22 Foundation no VR under High Interior RH



Critical Water Content R22 Foundation no VR under High Interior RH



Mould Index R22 Foundation no VR under High Interior RH



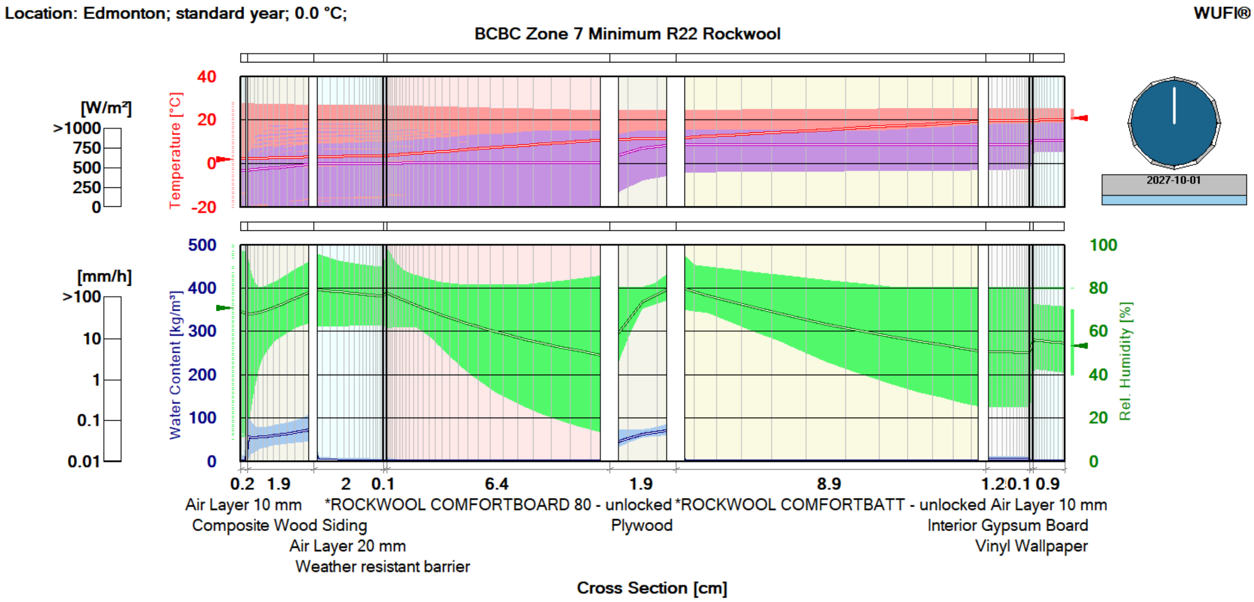
The foundation assembly has excellent performance in terms of resisting mould growth even under high interior RH conditions. This is likely attributed to the outboarding of all insulation which keeps the concrete wall warm and allows moisture to dry outwards even in wet conditions below-grade.

Lastly, we can assess the mould growth risks for our standard wall assemblies in a more extreme. Climate zone 7 with data from Edmonton, Alberta is used for comparative assessment of three wall assemblies with varying levels of insulation. The first is our basic wall with rockwool which at an effective value of R26.9 achieves the minimum of R26.8 set out by the national building code for that climate zone. There is an additional wall of the same component assembly, but which varies the insulation amounts to achieve the recommended NRCan energy performance recommendations of R30-60 for zone 7.

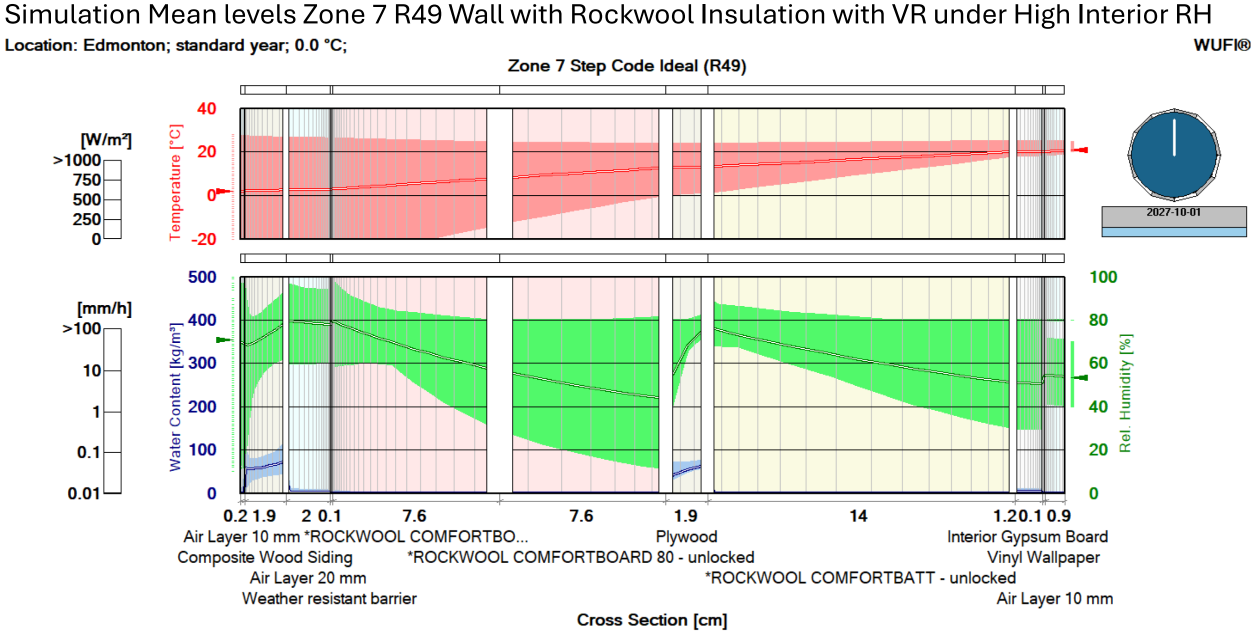
The assembly of the variant is as follows:

	Component	Thickness (mm)	Effective RSI (m^2K/W)	Effective R ($ft^2 \cdot °F \cdot h/BTU$)
Exterior	Air Layer	2	0.019	0.11
	Composite Wood Siding	19	0.17	0.97
	Ventilation Air Gap	20	0.19	1.1
	Vapour Permeable WRB	1	n/a	n/a
	Rockwool	152	4.47	25.4
	Structural Plywood	19	0.19	1.1
	38 by 140mm wood stud wall at 400mm o/c with Rockwool batt insulation	140	3.33	18.9
	Gypsum Drywall	13	0.08	0.45
	Vapour Retarder Layer (Latex Acrylic Paint)	1	n/a	n/a
Interior	Air Layer	9	0.09	0.48
		Total	8.54	48.5

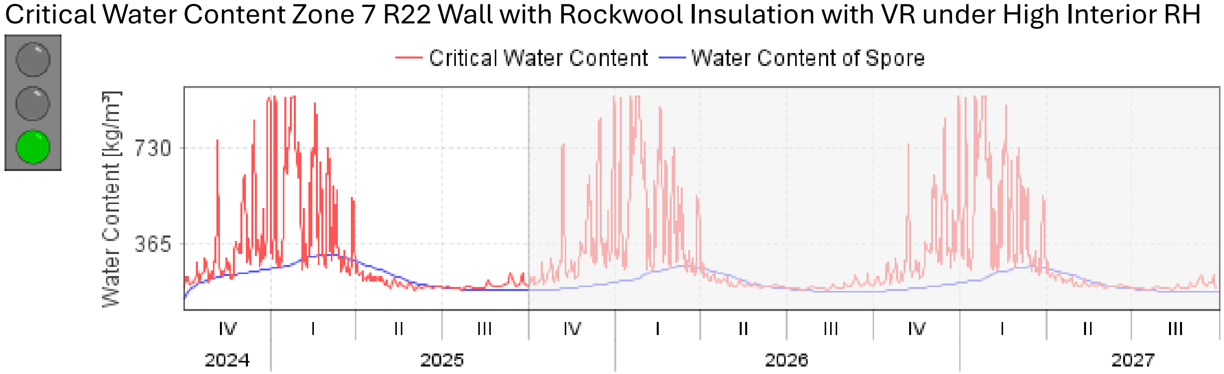
Simulation Mean levels Zone 7 R22 Wall with Rockwool Insulation with VR under High Interior RH



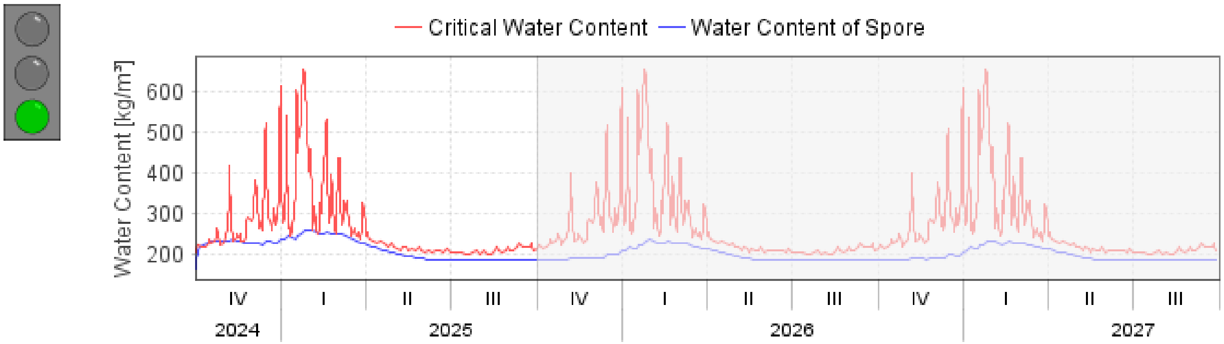
Simulation Mean levels Zone 7 R49 Wall with Rockwool Insulation with VR under High Interior RH



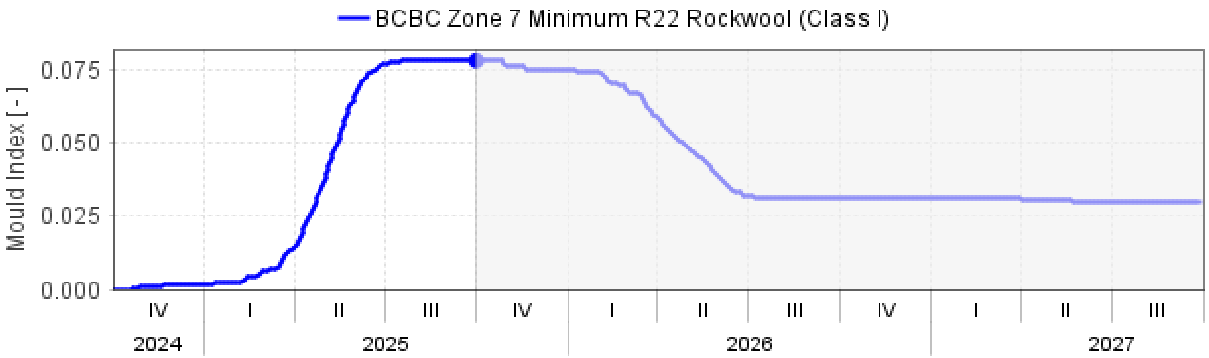
Critical Water Content Zone 7 R22 Wall with Rockwool Insulation with VR under High Interior RH



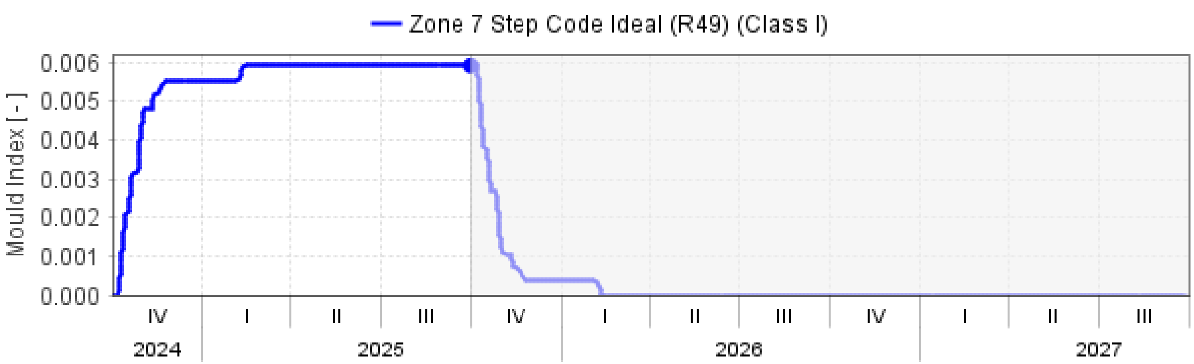
Critical Water Content Zone 7 R49 Wall with Rockwool Insulation with VR under High Interior RH



Mould Index Zone 7 R22 Wall with Rockwool Insulation with VR under High Interior RH



Mould Index Content Zone 7 R49 Wall with Rockwool Insulation with VR under High Interior RH



As seen in these figures, safe moisture levels are maintained for both insulation cases, however, the water content, and mould index are lower for the higher insulation value. Furthermore, the higher insulation value would offer much better energy performance that the minimum required insulation.

Conclusion

The basic wall assemblies—with either bio-based or mineral insulation and without a specifically detailed vapour retarder—are suitable for the vast majority of light-wood frame applications where indoor relative humidity is maintained at standard levels (30-55%). However, when constructing for high humidity applications or for extra surety of moisture performance a simple vapour retarder in the form of acrylic latex paint layer on interior wall surfaces is fully sufficient for managing moisture transport throughout the assembly.

2D modelling (as opposed to WUFI Pro's 1D modelling) would be helpful to assess moisture transport for interstory details and examine the necessity of a continuous vapour retarder through floor transitions. However, for normal interior humidity conditions this should not be necessary. This guide is intended to present the moisture performance of design-for-disassembly light wood frame construction under generalized conditions; specific mould risk analysis should be carried out for every construction project to determine the risks of individual projects.