Mould growth investigation

Prepared for NZGBC

Risk assessment for mould growth on concrete floor to brick veneer wall detail

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1 DISCLAIMER

Analysis and simulation conducted in this document is based on several assumptions drawn from provided information to the issue date. To suit the purpose of system & design comparison, and reduction of lead time, simplification and several assumptions have been implied on the model. Hence, the result of the modelling shall be used as an indicative guideline, rather than an exact replication of a physical model.

2 INTRODUCTION

Babbage Consultants Limited ("Babbage") was engaged to investigate the risk for mould growth in a typical construction detail. The detail consists of a concrete floor slab with a rainscreen brick veneer cladding on footing and timber framing with internal insulation at a higher upstand.

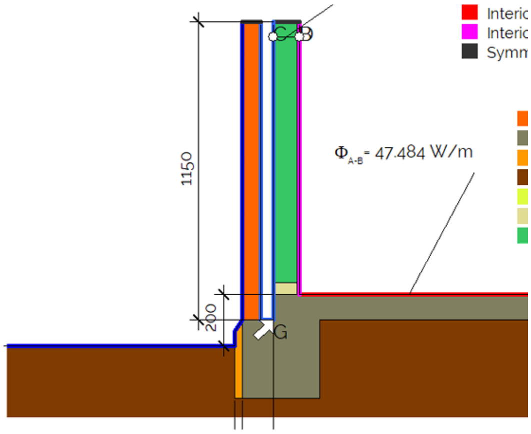


Figure 1: Section of the researched detail

3 INFORMATION RECEIVED

Babbage Façade conducted this hygrothermal WUFI® analysis using the above sketch and used material information available from the WUFI® materials database as well as climatic data. Material and climate information and assumptions are explained in detail in below report.

We also note that a similar detail with 25mm XPS was verified in the HPCD handbook from the Passive House Institute to have a f_{RSI} factor of 0.58[1]. That is just above the minimum requirement as required by the Passive House Institute for the region of Auckland.[2]

[1] High Performance Construction Details Handbook, Passive House Institute, version 04.22, pgs 147-148
[2] High Performance Construction Details Handbook, Passive House Institute, version 04.22, pgs 25

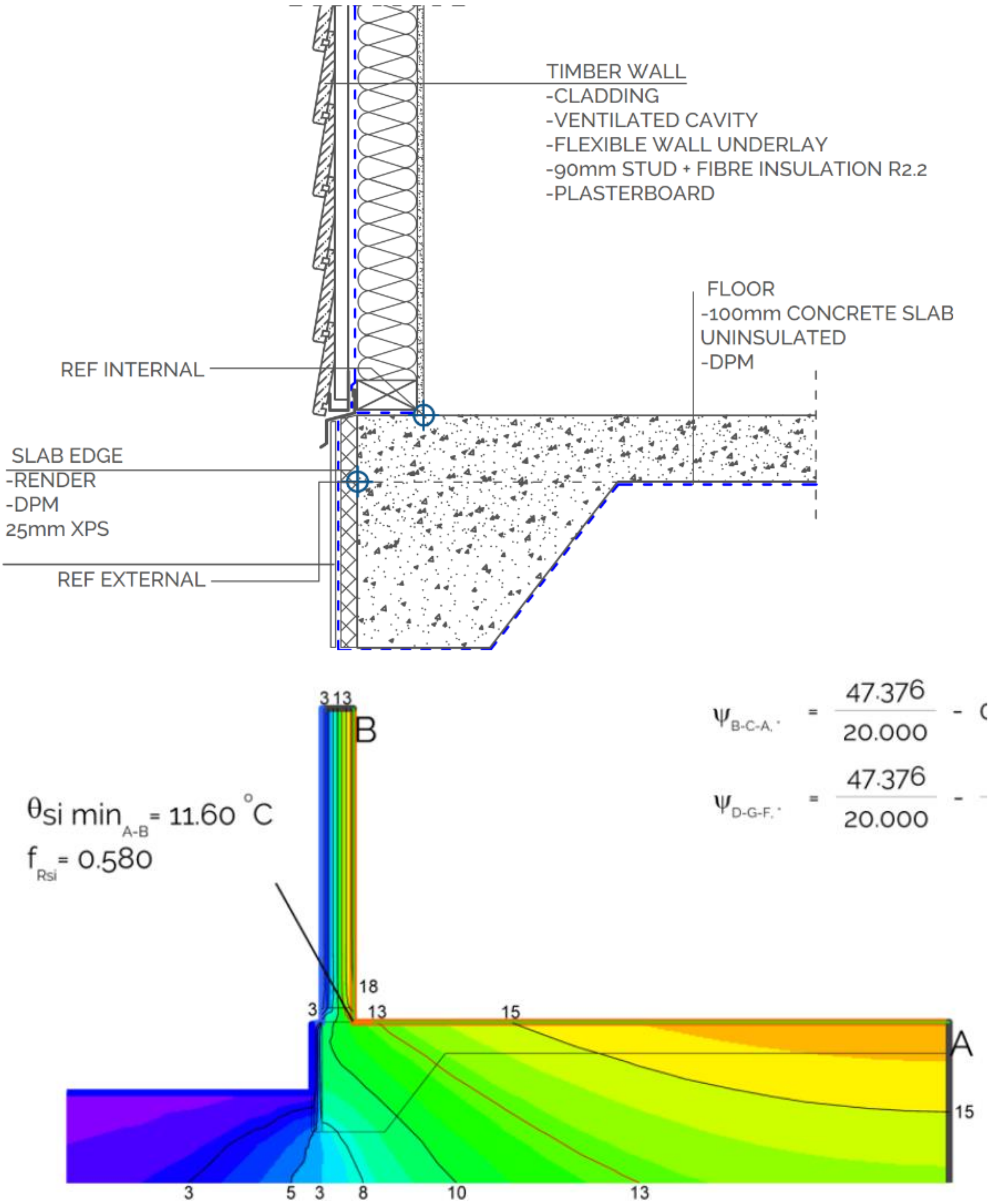


Figure 2 Isotherms and lowest internal surface temperature

4 MOULD GROWTH ASSESSMENT – 2-MODEL APPROACH

To assess the risk for mould formation in building materials, while considering the underlying biological and hygrothermal factors that contribute to its growth, a comprehensive framework for predicting and preventing mould growth was required. There are two models available to assist with this:

- **Isopleth Model:** This model leverages existing knowledge of fungal species, their growth requirements in terms of temperature and relative humidity (only these 2), and their classification into xerophilic (dry-loving) to hydrophilic (moisture-loving) categories. It relies on isopleths (curves representing constant values) to assess the likelihood of mould growth based on the prevailing hygrothermal conditions. This model is included in the standard WUFI® Pro and WUFI® 2-D software. The resulting LIM curves (LIM = lowest Isopleth for mould) are an indication of the risk or germination of fungi on internal surfaces. In the WUFI® software, they are distinguished between LIM I and LIM II where the Roman number represents the nature of the substrate, with I being the category combining biologically recyclable materials, such as wall papers and also permanent elastic joints. Category II is less prone to mould growth and combines building materials with porous structure, mineral building materials, certain woods etc. [3]

- **Bio-hygrothermal Model:** This model employs a more sophisticated approach, integrating building physics principles and a detailed understanding of spore germination. It is based on the idea that a fungus spore has a certain osmotic potential (similar to filtering membranes, creating differentials in solutions). It accounts for the diffusion of moisture through the spore septum, the critical water content needed for fungal activation, and the interaction of moisture with building materials. In our modelling we will use 2 add-on software packages called BIO and VTT to simulate moisture movement and predict potential mould growth. While BIO is a theoretical model using temperature and relative humidity, VTT (which was developed in Finland specifically for the use of timber) is an empirical model and was developed with the substrate material as an input for the simulation.

A range of factors beyond just humidity and temperature are important. These include the specific types of mould species, their nutrient requirements, the material properties of building components, and the potential influence of thermal bridges. It emphasizes the need for comprehensive assessment, considering both the hygrothermal conditions and the biological characteristics of the fungal species involved. When combining the two models mentioned above, we provide a more robust and accurate assessment of mould risk in buildings with benefits and challenges.

Benefits:

- **Enhanced Accuracy:** Combining the models leads to a more accurate prediction of mould growth by considering both hygrothermal conditions and biological factors influencing fungal behaviour. The isopleth model provides information on the growth requirements of different mould species based on temperature and humidity, while the bio-hygrothermal model simulates moisture movement and spore germination, taking into account building physics principles.

- **Improved Understanding:** The combined approach provides a deeper understanding of the complex interplay between building physics, fungal biology, and environmental factors influencing mould growth. This allows for a more nuanced assessment of mould risk and informed decision-making regarding preventive strategies.

- **Wider Applicability:** The combined model can be applied to a wider range of building structures and climatic conditions, encompassing complex constructions like wall-ceiling connections, room corners,

[3] Vorhersage von Schimmelpilzbildung auf und in Bauteilen, Sedlbauer, 2001

and window constructions. It offers a more versatile tool for assessing mould risk in different building environments.

Challenges:

- **Data Requirements:** The combined model demands extensive data inputs, including detailed information on building materials, hygrothermal boundary conditions, fungal species, and their growth characteristics. Gathering and analysing this data is more resource intensive.
- **Model Complexity:** The combined approach involves complex calculations and simulations, requiring specialized software and expertise. This can pose a barrier to its widespread adoption, especially for practitioners without advanced knowledge in building physics and fungal biology.
- **Difference between modelling and reality:** performance parameters such as air tightness, 3-D detailing around windows, corners etc will affect the results arrived from the software. Typically, we would recommend verifying the results with field studies, and experiments to ensure its accuracy and reliability. Continuous refinement of the model is essential to incorporate new findings and enhance its predictive capabilities.

Overall, combining the isopleth and bio-hygrothermal models holds promise for providing a more robust and comprehensive assessment of mould risk in buildings. However, addressing the challenges associated with data requirements, model complexity, and validation is crucial for its successful implementation.

5 ASSUMPTIONS

This hygrothermal WUFI® analysis being a desktop review and simulation, has its associated assumptions and limitations. This is mainly due to the complex nature of buildings with varying components, makeups, junctions, terminations, construction methods and tenancies. WUFI® simplifies these contributing factors and estimates the likely building performance, highlighting possible hazardous zones. Please refer to below sections for more detailed description of assumptions and limitations.

5.1 PRODUCTS

The building materials in the wall to floor detail connection forming the detail of the wall and floor connection are in-situ cast concrete, with a 30mm XPS insulation to the external face. The wall consists of pine framing, with fibre glass insulation in between the studs and nogs. A vapour-open building paper is installed to the outside and gypsum board to the interior. Between the timber framing and the concrete floor slab, a small strip of DPC separates both materials. To the outside of the timber framing, a drained and vented brick veneer rainscreen cladding is constructed with a minimum 50mm deep cavity. The gypsum board has a timber skirting in contact with the concrete. The material characteristics are derived from the WUFI® database, predominantly used in Europe and North America. At the discretion of Babbage, small adjustments were made to replicate the characteristics of local materials.

5.2 WUFI® MODEL

The WUFI® models developed for this specific analysis has taken the following into assumption:

- WUFI® simulations do not account for details such as joinery openings, fixings, 3-D details, etc
- All concrete assumed to be casted to a suitable standard and experience cracks within a reasonable tolerance
- Mechanical unit (Cases 3A, 3B, 3C and 3D) is being operated 24/7, ensuring the ventilation and temperature control
- WUFI® is a dynamic simulation of coupled heat and moisture transfer through assemblies, but does not specifically account for air tightness. The effect of loss of air tightness will almost always worsen the results, as cold external air can decrease the surface temperatures, inject additional moisture in the envelope and promote mould growth (by supplying moisture and nutrients to the fungi).

5.3 STANDARDS

5.3.1 ISO13788

This WUFI® analysis is conducted using the standard ISO 13788 to define the internal conditions. The standard assumes static internal conditions which Babbage believes will sufficiently accurate replicate the conditions to predict mould growth. ISO 13788 defines the continuous additional internal vapour pressure (over the vapour pressure set by the external conditions) in relationship to the use of the dwelling. More information about the assumptions made for this report can be found in Paragraph 6.1.5. Internal Climate.

5.3.2 ASHRAE 160

This WUFI® analysis is conducted using ASHRAE 160 to rain adhesion factors and for the internal regime in case of a mechanically ventilated dwelling (see case 3). We refer to Handbook 7 Section 4.2 edition 2007. More about the assumptions made for this report can be found in the Paragraphs 6.1.2. External Climate and 6.1.5. Internal Climate. It is important to note that based on this standard, the internal relative humidity is assumed to not exceed 70% due to the release of moisture whether it be mechanically driven or from occupant discomfort. Effects of air pressure differentials and airflows are optional and have been excluded in this analysis.

6 CALCULATIONS

WUFI® 2D models a standard wall – floor connection in a 2- dimensional geometry, determining the interactions between materials such as moisture transfers based on varying temperatures and exposures.

6.1 DESIGN PARAMETERS

6.1.1 External climate

The external climate is simulated using typical data provided by NIWA. We have decided for these simulations and in line with the recommendations of EN15026 5.2.1.c) there is no requirement for a temperature shift (a 2K temperature shift or "buffer", used when there is a lack of measured or historic data).

The NIWA data include external temperature, Relative Humidity, rainfall, sun radiation, cloud index etc.

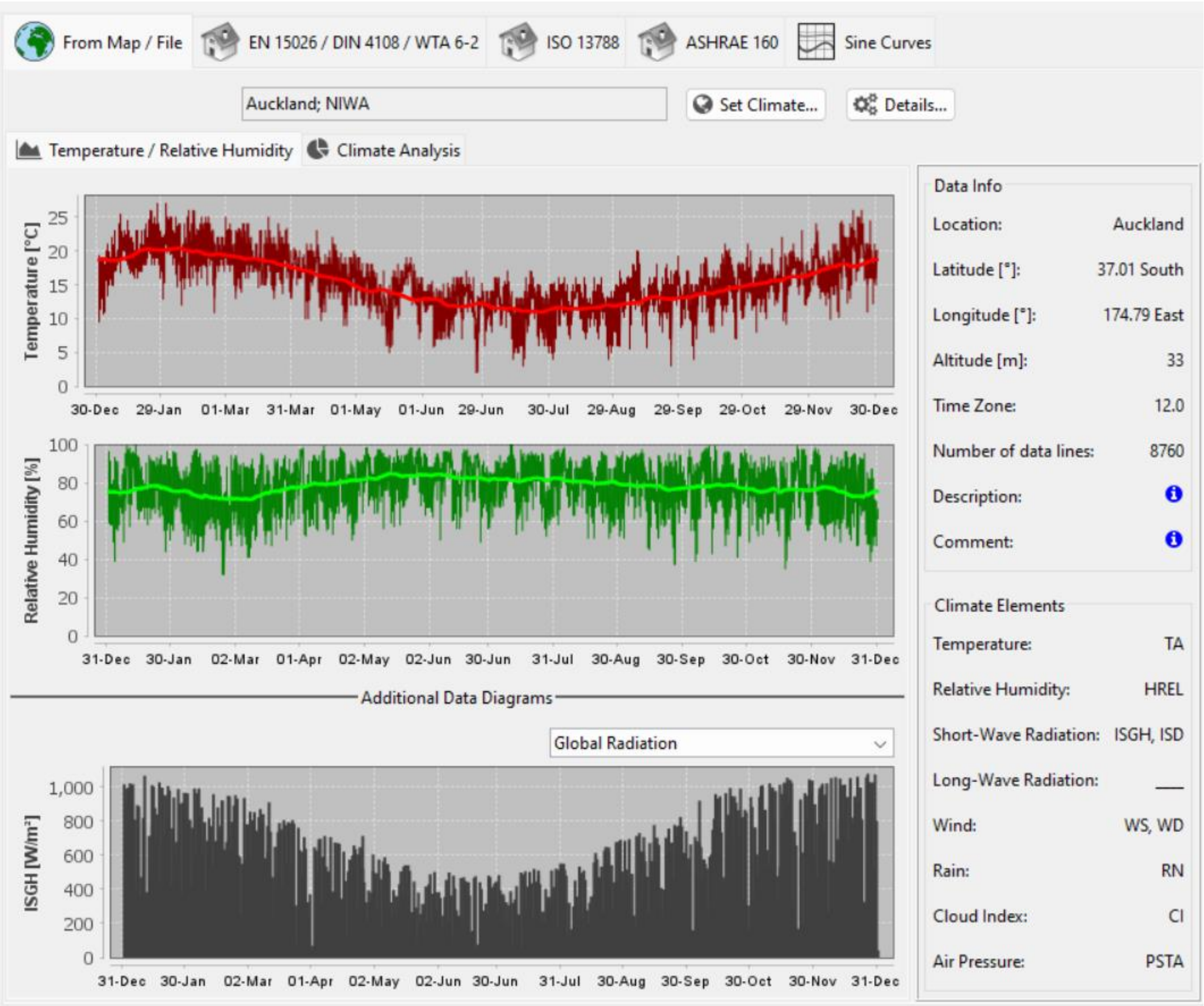


Figure 3 External climatic conditions

6.1.2 Orientation

We have simulated a south facing wall, which will result in lower surface temperatures. Figure 4 shows annual rate of driving rain and solar radiation factors for Auckland, based on NIWA data input.

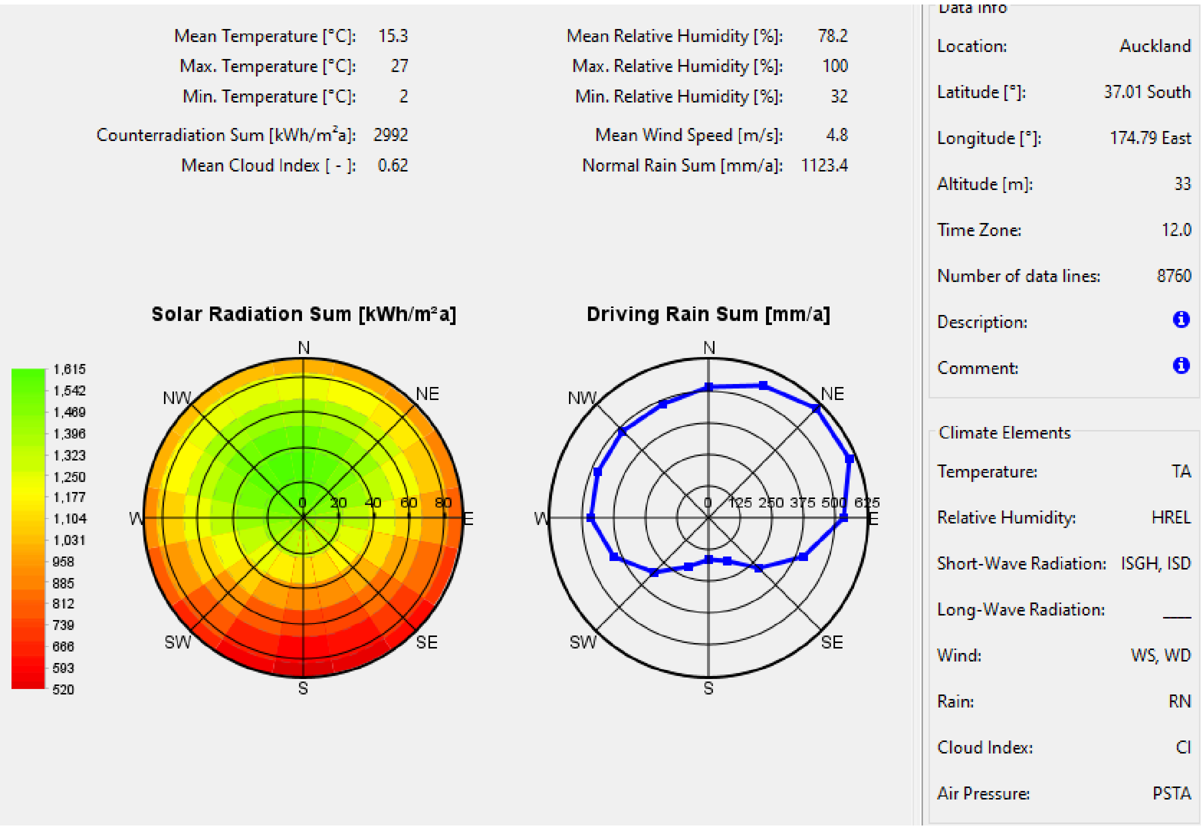


Figure 4: Solar Radiation & Driving Rain

The inclination of the wall is 90 degrees from horizontal.

The driving rain coefficient as calculated by ASHRAE 160 determined that the rain exposure factor (FE) and rain deposition factor (FD) to be 1.2 and 1 respectively. This assumes that the wall is exposed to rain fall and not protected by an overhang or canopy.

6.1.3 Material properties & Initial conditions

Material properties were based on information provided by the WUFI® material database.:

Products	Density $\left[\frac{kg}{m^3}\right]$	Thickness $[mm]$	Specific Heat Capacity $\left[\frac{J}{kgK}\right]$	Thermal Conductivity $\left[\frac{W}{mK}\right]$	Initial Moisture Content $\left[\frac{kg}{m^3}\right]$	Water Vapour Diffusion Resistance Factor
Brick veneer	1,952	70	863	0.955	2.4	19
Air Space 80mm w.o additional moisture capacity	1.3	100	1000	0.13	0.01	0.32
Timber framing	510	45	1,600	0.13	251	50

XPS insulation	40	30	1,500	0.03	3.6	100
Concrete	2,100	100	776	1.373	126.5	76
Insulation	30	140	840	0.06*	3.8	1.3
Building paper	280	1.0**	1,500	2.3	0	144
DPC	130	1	2,300	2.3	0	50,000
Soil***	1,500	Var	2,000	1,5	0.3	50
GIB Standard 10mm thick	850	10	870	0.163	11	6

Table 1 Material characteristics

*^ Adjusted value to cater for combination of timber and insulation

**^ Min thickness in WUFI® of 1.0mm

*** All materials have initial temperatures set at 18˚C except for the soil, with an initial temperature of 10˚C.

All construction materials are assumed to have an initial moisture content of twice the moisture content at 80%. For concrete the moisture content is set at 90% RH and soil at 99%.

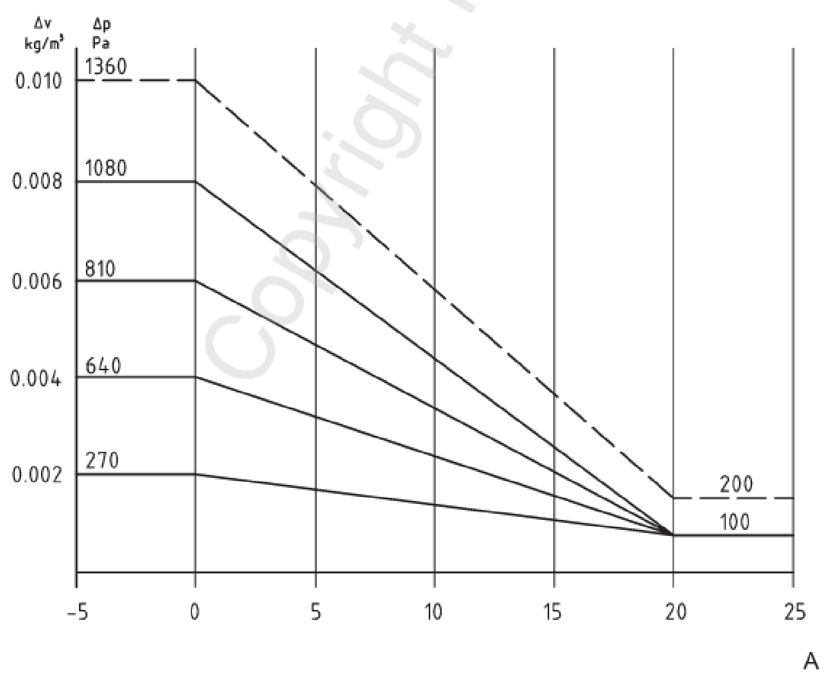
6.1.4 Duration

ASHRAE 160 recommends a minimum of 10-year duration cycle, yet due to the extensive calculation times required this was reduced to 5 years on the condition that systematic patterns can be observed.

6.1.5 Internal climate

The climate definition for internal conditions is based on ISO 13788 which defines a relationship between partial vapour pressure to temperature, depending on the use of the building. We have assumed that the dwelling falls within Class 2 for normal residential dwellings. ISO 13788 provides a profile of temperature and Relative Humidity for maritime climates (such as Auckland) that locks in the internal temperature (set at 18˚C) and creates a profile with a constant internal temperature and with a vapour pressure differential over the external vapour pressure depending on the monthly outdoor temperature. This is illustrated in the Figure below. The vapour pressure differential depends on the expected humidity class defined by the use of the dwelling, ranging from Class 1 (unoccupied) to Class 5 (swimming pools etc). We have assumed Class 2 defined as Offices, dwellings with normal occupancy and ventilation which is a realistic choice but probably not high enough for social housing with high occupancy or limited ventilation.

Further research will focus on adjusting the internal climate files to simulate the effect of variable internal conditions on the mould growth assessment. Viitanen (developer of VTT software) studied the growth of moulds under changing climatic conditions.



Key
A monthly mean outdoor temperature, expressed in °C

Figure 5 ISO 13788 Vapour pressure differential versus temperature

We have assumed the internal temperature to be 18˚C and have investigated the effect on the results of a different internal temperature (by simulating 16˚C internal temperature). See more in Paragraph 6.3 Case 2: Effect of Internal Temperature.

The research contains cases where the use of mechanical ventilation is simulated. We have used ASHRAE 160 with the following variables: heating temperature set at 18 ˚C, no cooling, moisture production of 0.105 g/s moisture production (using ASHRAE Handbook 2007 section 4.2) and a ventilation rate of 0.35 ACH. That is in line with the requirements of Homestar, yet this value may be low as the unintended ventilation due to air leakage through the joinery, cladding, roof etc in most New Zealand housing exceeds this value. Branz studied the air tightness in typical New Zealand apartment buildings and concluded that the measured value is similar for apartment buildings and stand-alone houses at approx. 5 ACH @ 50 Pa (although the results varied significantly).[4]

For Auckland with an average wind speed of 4 m/s or pressure of 9.6 Pa, that would translate in an expected ACH of 1.66. Simulating 0.35 will underestimate the effect of ventilation. See more in Paragraph 6.4 Case 3: Ventilation.

[4] BRANZ Study SR455 [2020], Greg Overton and Stephen McNeil

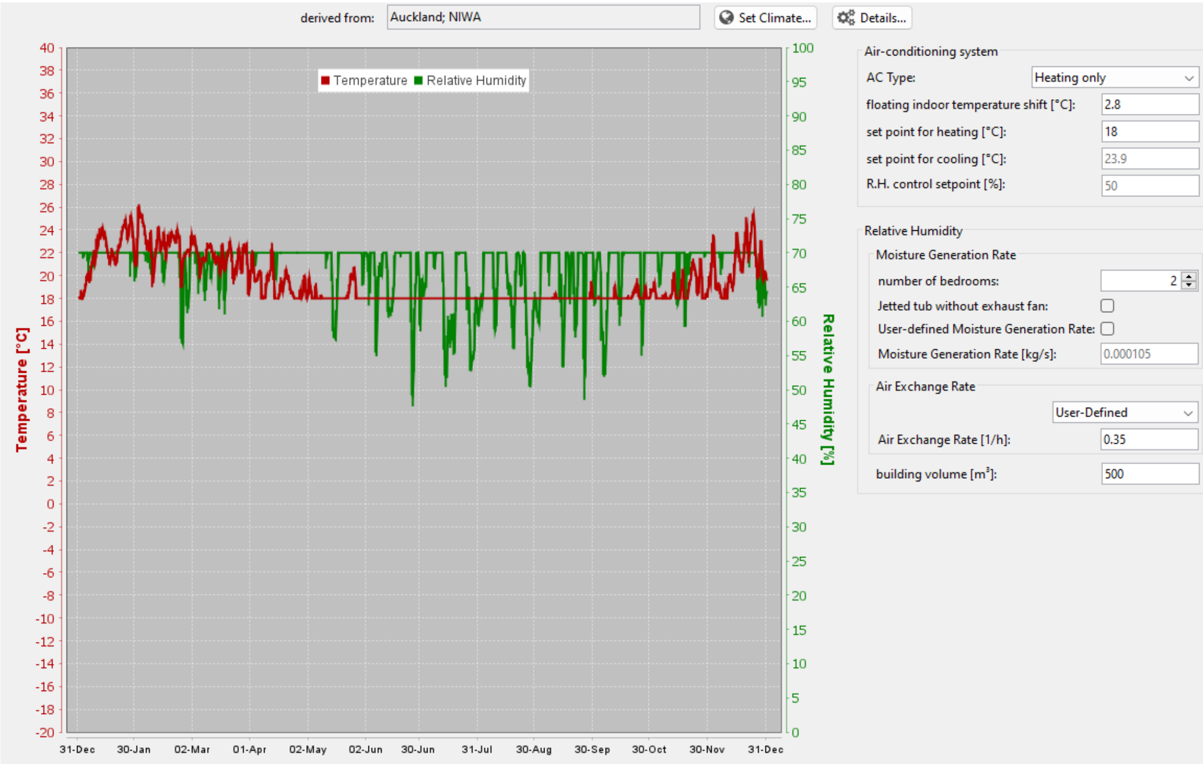


Figure 6 ASHRAE Internal conditions for mechanically ventilated dwelling

6.1.6 Water leakage

To simulate the infiltration of a rainwater through the wall cladding, we have assumed 0.1% of the rainwater to pass the cavity and end up on the building paper. That is less conservative than the recommendations from DIN 4108-3 driving rain penetration (1%) but due to the width of the cavity, we believe is more realistic, on the condition that the brick veneer works as a pressure-equalised with sufficient weep holes to the bottom and front of the cladding.

6.1.7 Ventilation

Brick veneer works as a drained and ventilated rainscreen cladding and will have some ventilation behind it. This ventilation is of importance as it aids to dry out the cavity and regulate the moisture content in the cavity and its adjacent materials. We have assumed 10 constant air changes per hour.[5]

6.1.8 WUFI® Bio

Simulations are made assuming an indoor surface, an initial humidity of 0.5 in the spore.

6.1.9 WUFI® VTT

The following assumption was made: the occupant exposition class is according to ASHRAE 160 and the material is pine sapwood.

[5] Buildingscience.com Ventilated Wall Claddings: Review, Field Performance, and Hygrothermal modelling – research report – 0906 ; John Straube and Graham Finch

6.2 Case 1 – Basic Detail

6.2.1 Design

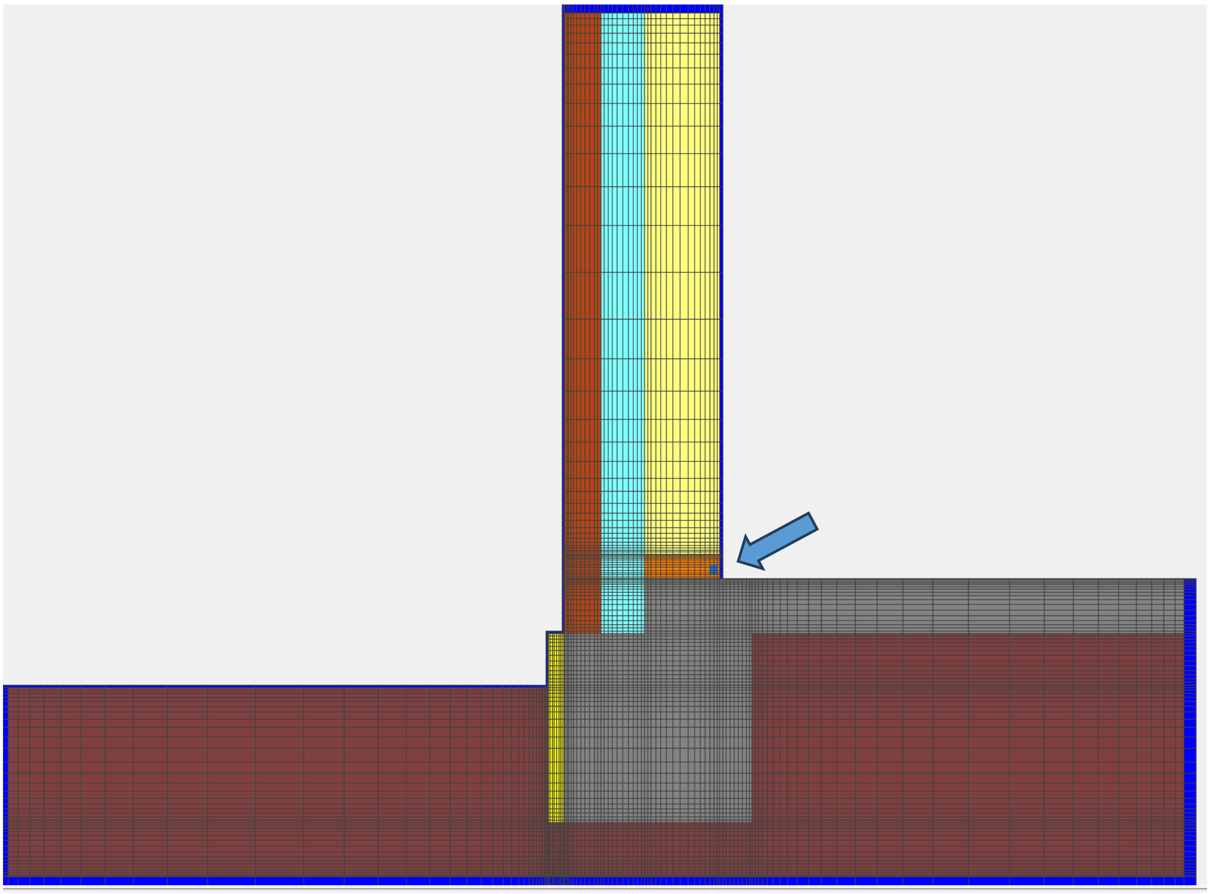


Figure 7 Mesh WUFI® model

The above Figure shows the model that was used in the simulations in WUFI® 2D. The arrow indicates the internal surface that was located as being the most prone to mould growth because it has the lowest surface temperature. It is important to note that the risk for mould growth reduces in tight air gaps within the wall assembly as it is hard to provide new spores and nutrients. The same applies for mould growth on alkaline surfaces such as concrete. For that reason, the combination of both coldest surface temperature and internally oriented surface was made our critical point of concern; in this particular scenario the highlighted timber within Figure 7.

6.2.2 Results

6.2.2.1 Relative Humidity

The Relative Humidity in the skirting confirms the explanation above and shows the seasonal fluctuation of the moisture content in the skirting (after the initial drying out). Seasonal peaks at the highlight of summer appear even after a 5-year period. The decline from year-on-year is minimal.

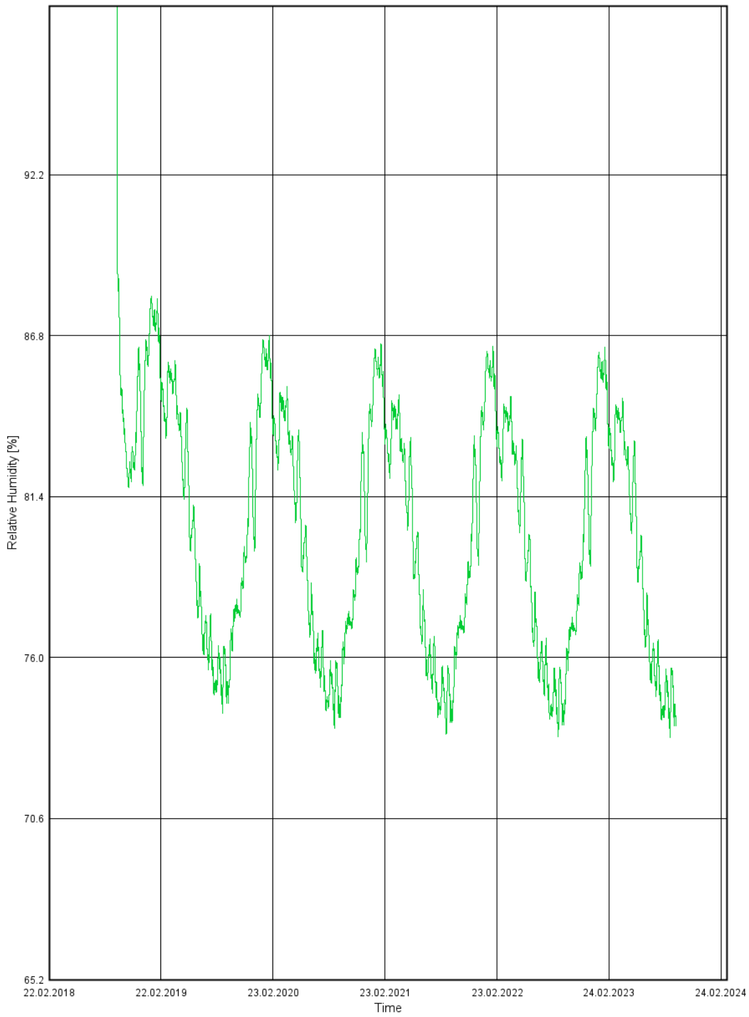


Figure 8 Relative Humidity in skirting over simulation period

6.2.2.2 Isopleths

Isopleths are a visual tool that provides information about a specific variable, in this case the risk for mould growth over time. The isopleth provides both temperature and relative humidity in a material at the same time, which is then compared to 2 reference curves. LIM I and LIM II provide a reference curve: in simple words when the isopleth is located above the LIM I and II curve, the climate is set for mould growth. When above LIM I alone, it means mould growth will occur on more sensitive surfaces, such as porous, mineral building materials or certain timbers. For more detail see Paragraph 4.0

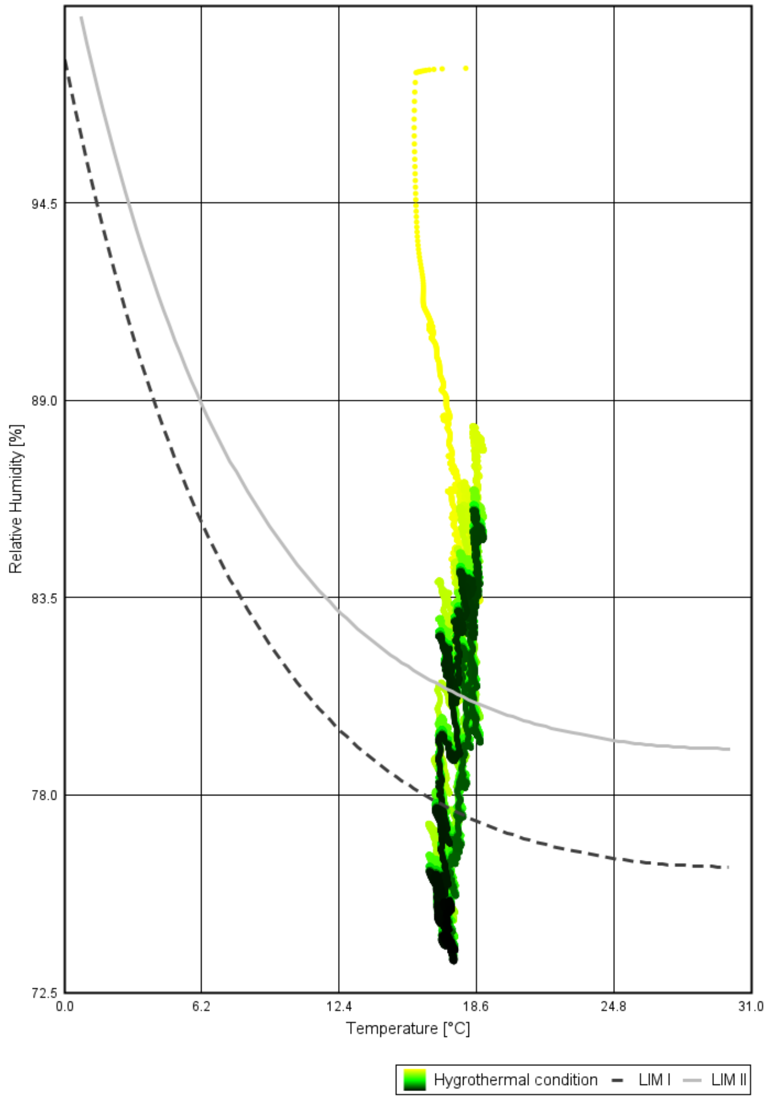
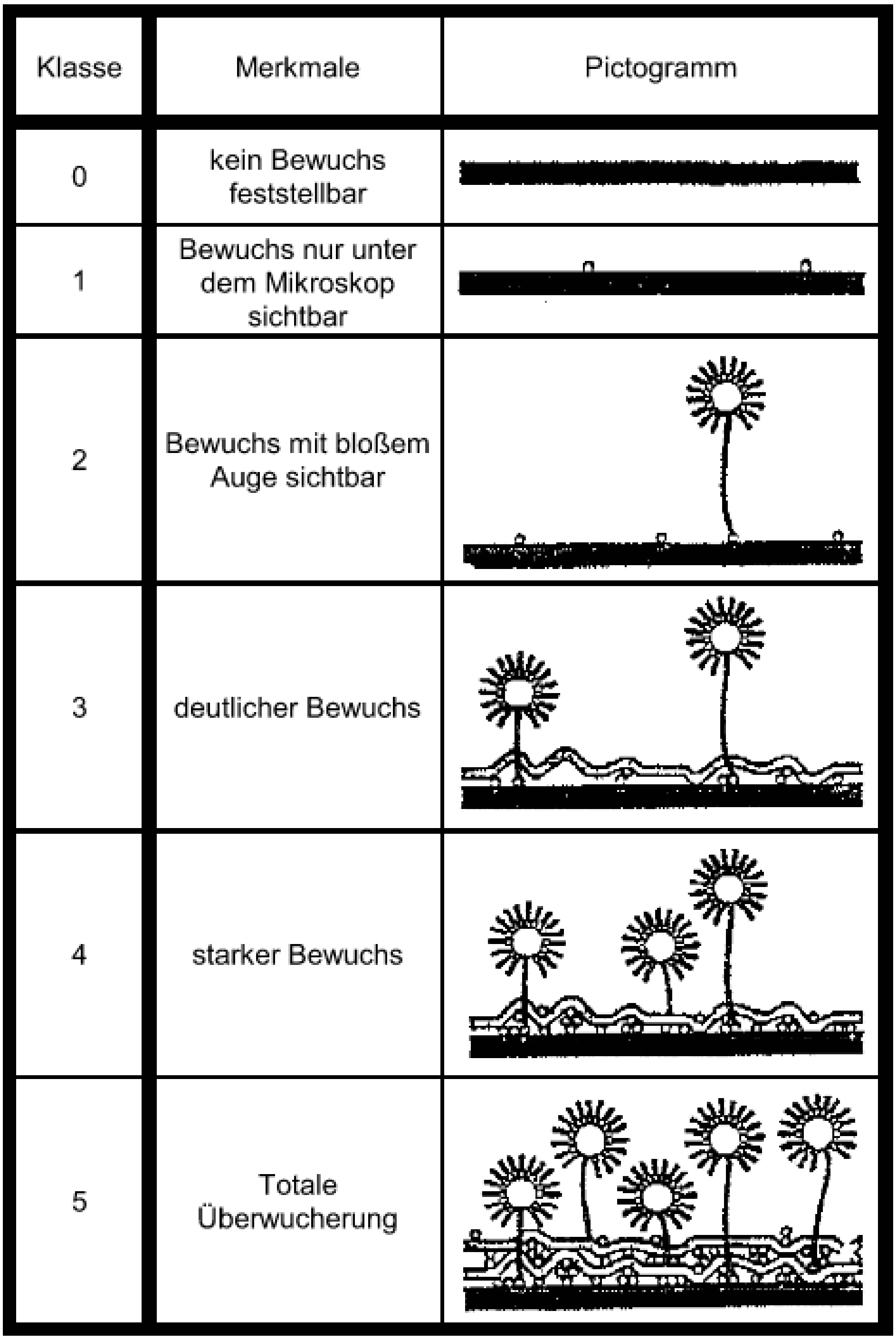


Figure 9 Isopleths in skirting

The oldest data entries of the isopleth are coloured lighter than the (chronologically) newer data entries. The initial (yellow points) indicate the assumed higher initial moisture content of the building materials and how these materials dry out relatively quick. After that the isopleth periodically runs above and below the LIM I and II criteria, which means that there will be long periods of mould growth and potentially drying out (approx. 6 months each). The more sensitive period will be the months between October till April. This is not surprising as during the winter months in Auckland the outside air is heated for internal use, which reduces the Relative Humidity and gives the air some drying capacity. In the summer months, the outside air is not heated but still has a relatively high moisture content (RH typically on average between 80 and 85%) which limits the capacity of this air to dry out the wall.

6.2.2.3 BIO

WUFI® BIO results in a Mould Index for the selected location. The Mould Index ranges from 0 (none) to 5 (completely overgrown) and can be visually represented in Figure 10. [6]



Klasse	Merkmale	Pictogramm
0	kein Bewuchs feststellbar	
1	Bewuchs nur unter dem Mikroskop sichtbar	
2	Bewuchs mit bloßem Auge sichtbar	
3	deutlicher Bewuchs	
4	starker Bewuchs	
5	Totale Überwucherung	

Figure 10 Classification mould growth

[6] Vorhersage von Schimmelpilzbildung auf und in Bauteilen, Sedlbauer, 2001

WUFI® BIO generally over-estimates the growth rates but gives useful data based on theoretical analytics. We will therefore compare the results against the VTT model which takes into consideration the experimental/tested data.

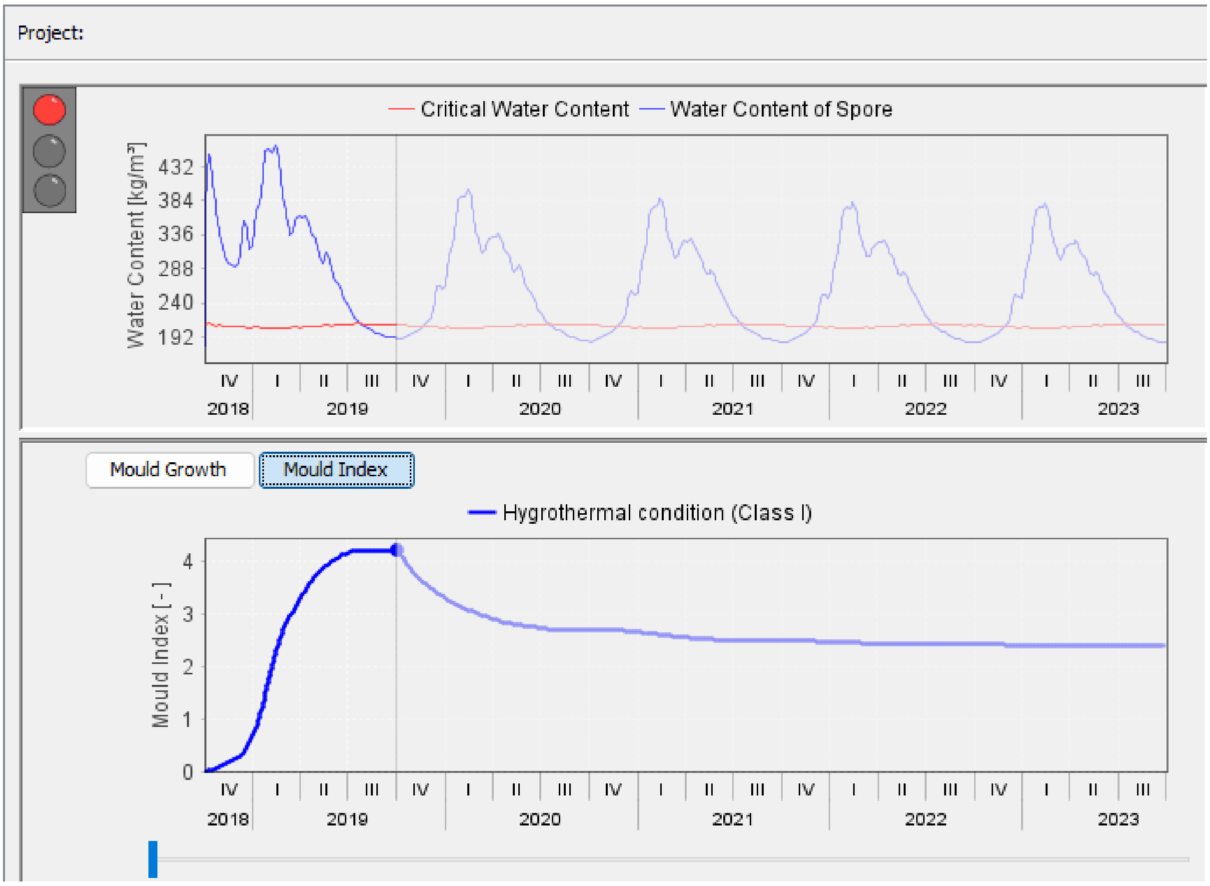


Figure 11 WUFI® BIO Mould Index in skirting

The Mould Index for the selected location as per Figure 11, indicates that the chance for Mould Growth is substantial. In fact, most of the time the conditions would promote mould growth in the location, while the dry-out periods are relatively short. The mould Index does not decrease below 2.0 at any given time.

6.2.2.4 VTT

WUFI® VTT results in a Mould Index for the selected location as indicated in Figure *12*. The Mould Index uses AHRAE 160 criteria for mould growth and ranges from 0 (none) to 6 (completely overgrown). VTT sketches a similar negative scenario where the Mould index quickly reaches a value of over 3.0.

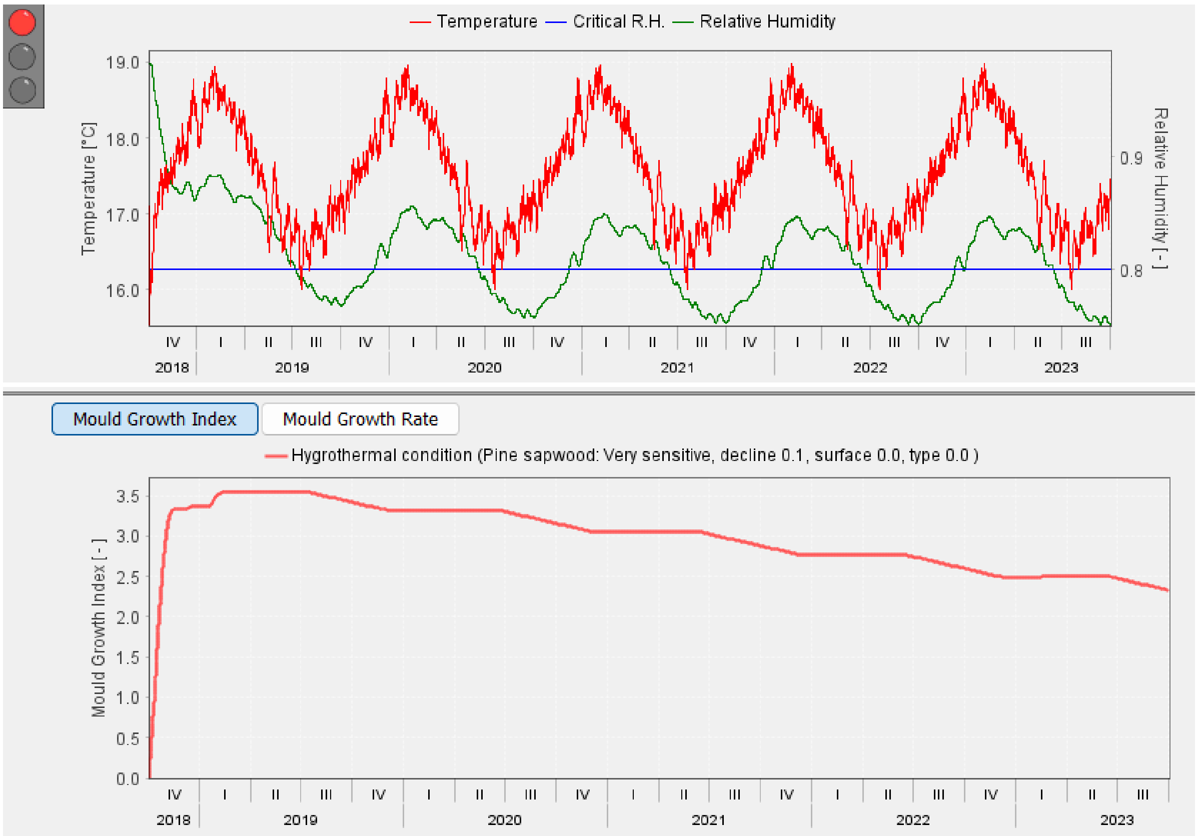


Figure 12 WUFI® VTT Mould growth Index

6.2.3 Conclusions

It is clear that the internal skirting struggles to handle the low surface temperatures and high relative humidity. Even after the initial drying, the skirting stays for more than half of the year in conditions that promote mould growth. The drying periods provided are too short to avoid mould growth, even after the initial recovery from the increased moisture content in the building materials. The seasonal peaks show the most sensitive periods to be from spring to autumn, when average daily temperatures increase and the external air has little drying capacity.

6.3 CASE 2 – EFFECT OF INTERNAL TEMPERATURE

6.3.1 Design

To simulate the effect of the internal temperature on the risk for mould growth, this case assumes the same conditions to case 1, yet we decrease the minimal internal temperature from 18°C to 16°C

6.3.2 Results

6.3.2.1 Relative Humidity

As expected, the Relative Humidity in the skirting increases with values that are constantly over 80%.

6.3.2.2 Isopleths

Due to the high Relative Humidity, mould growth is even more prominent than in the first case. It is obvious from the Isopleth model, that mould growth is promoted the entire year.

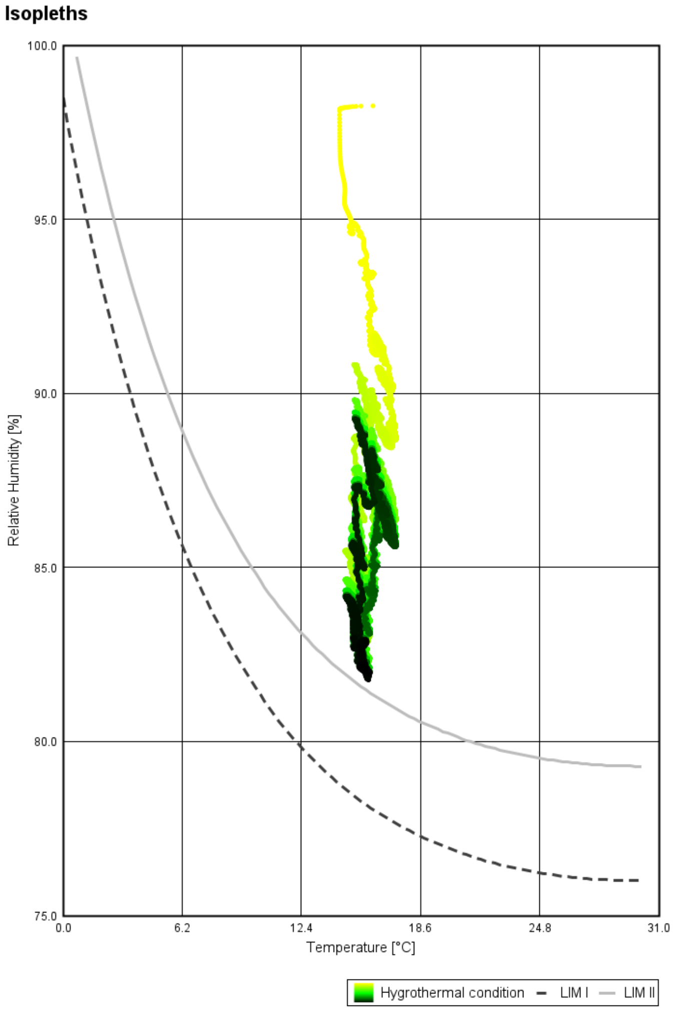


Figure 13 Isopleths in skirting

6.3.2.3 VTT

Both WUFI® BIO and WUFI® VTT confirm that this is an extremely negative scenario and that extensive mould growth is to be expected. The Mould Growth Index jumps to its maximum and stays at its maximum value for the entire period of the simulation.

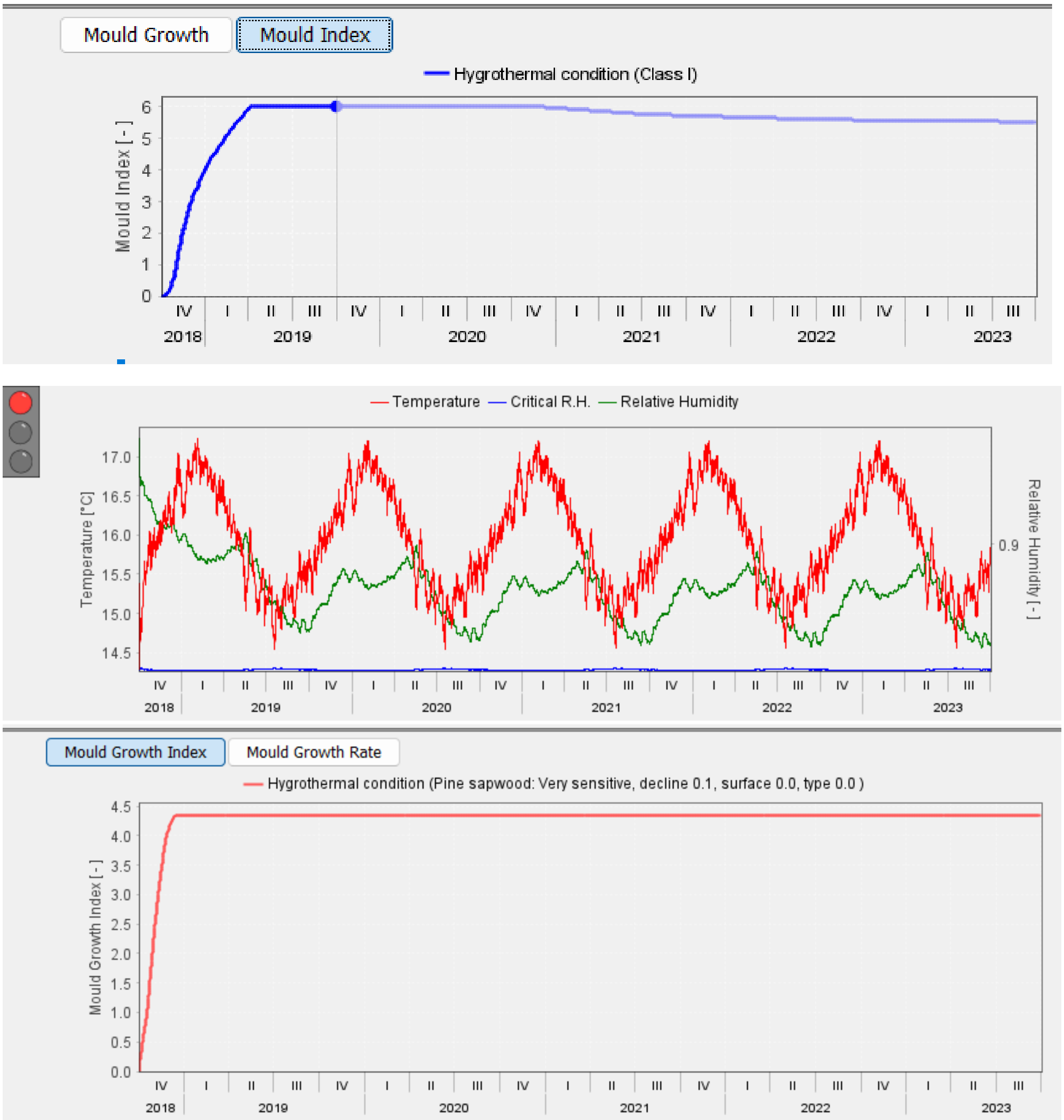


Figure 14 WUFI® VTT Mould Index in skirting

6.3.3 Conclusions

By lowering the average internal temperature by a merely 2°C, the results show an extremely negative outcome. Mould growth is promoted the entire year (independent of external temperatures) without any periods that would allow the assembly to dry out and recover.

6.4 CASE 3A – EFFECT OF VENTILATION 0.35 ACH AND INSULATED SLAB

6.4.1 Design

In this scenario, we introduce mechanical ventilation to the inside of the building. To simulate ventilation, the internal conditions are adjusted as described in Paragraph 6.1.5. Internal climate.

Initially, we simulated with a minimum ventilation rate of 0.35 ACH as required in Homestar. This number resents the air changes per hour between interior and exterior, independent of what system is used to achieve this: it is the combination of mechanical, natural ventilation and air leakage. In practical conditions air leakage will happen mostly through joinery, roof and construction details. We have assumed in this calculation, that there is no uncontrolled air leakage through the cladding to floor connection. Any air leakage that would add to the combined number of 0.35ACH would occur through other construction details. In case that such leakage would happen in this specific location, the results would be affected negatively and increase the chance for mould growth.

6.4.2 Results

6.4.2.1 Relative Humidity

The Relative Humidity in the skirting stays below the critical 80% RH as excessive moisture is eliminated through ventilation. Even during warmer summers, there is sufficient drying capacity to avoid moisture being absorbed in the skirting.

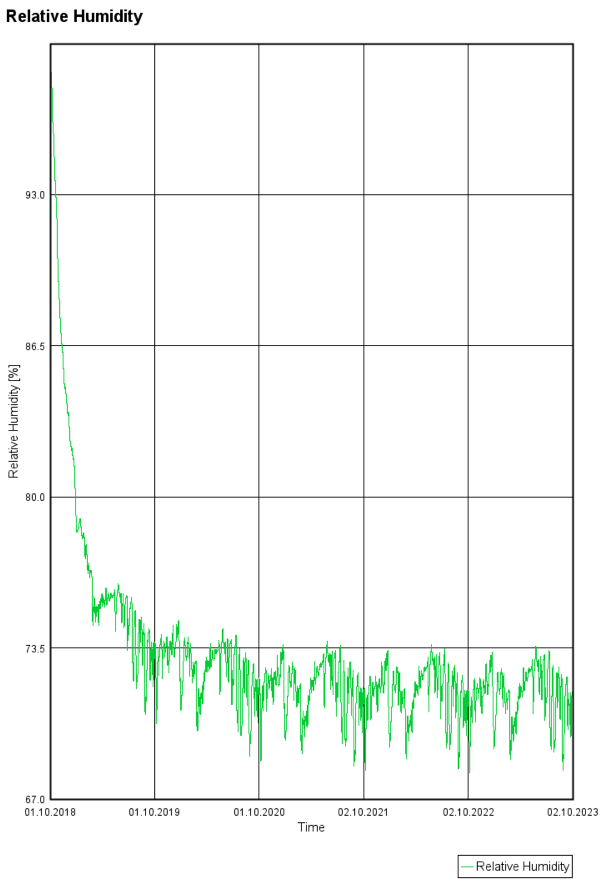


Figure 15 Relative Humidity in skirting over simulation period

6.4.2.2 Isopleths

The Isopleths in the simulation initially appear in the sensitive area above the LIM curves but drop off as the initial artificial high moisture content in the building materials drops. Once dried out, the Isopleth does not rise above the LIM curves, which means that the system recovers from a high moisture load and performs from then onwards.

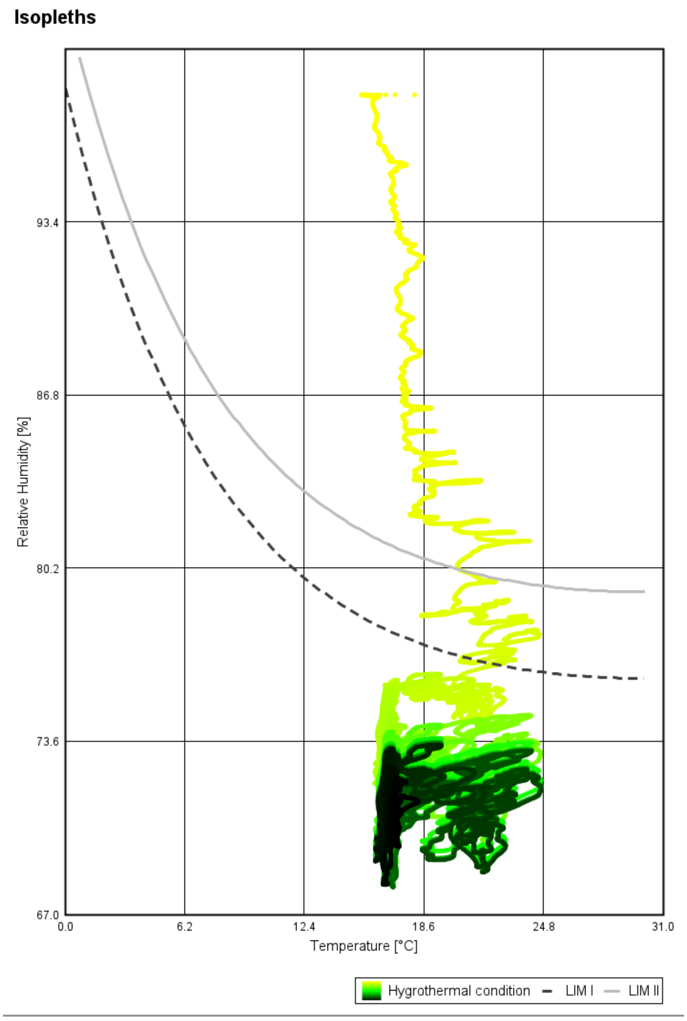


Figure 16 Isopleths in skirting

6.4.2.3 BIO

WUFI® BIO and WUFI® VTT provide similar results influenced by the initial higher moisture load. Once the initial moisture has dried out of the wall, the water content of the spores stays below the critical water value, and the risk for mould growth disappears. It is very important though to keep the moisture in the original spores at 0.5, because when raised only slightly mould growth will initiate, causing a "Red Light" assessment. In practical terms that means, the building needs to be dried out sufficiently within the first months of its use (even behind curtains or furniture).

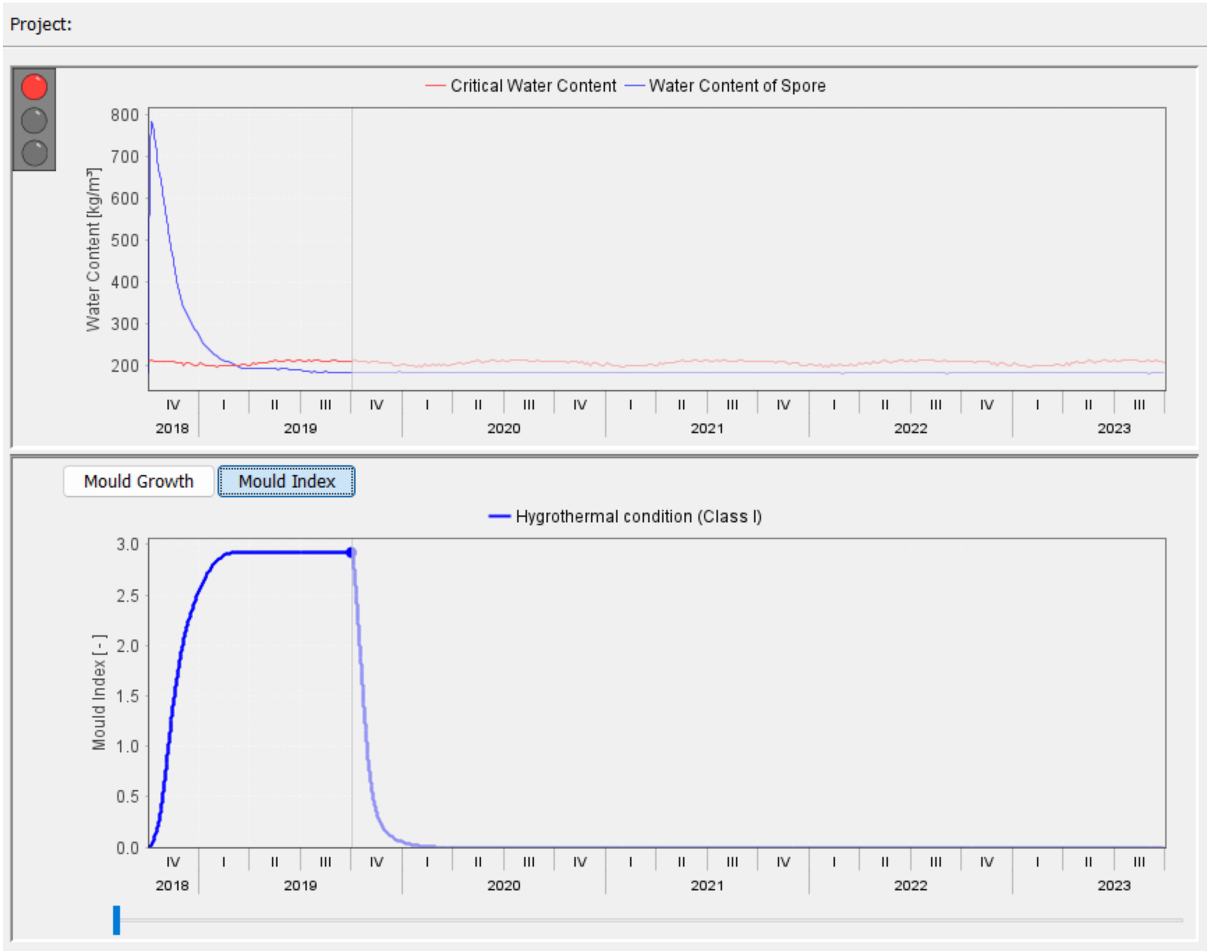


Figure 17 WUFI® BIO Mould Index in skirting without sufficient ventilation

6.4.2.4 VTT

WUFI® VTT results in a similar conclusion. Again, the initial moisture content causes some initial mould growth, but after that period of time the critical RH (blue line) stays above the actual RH (Green line).

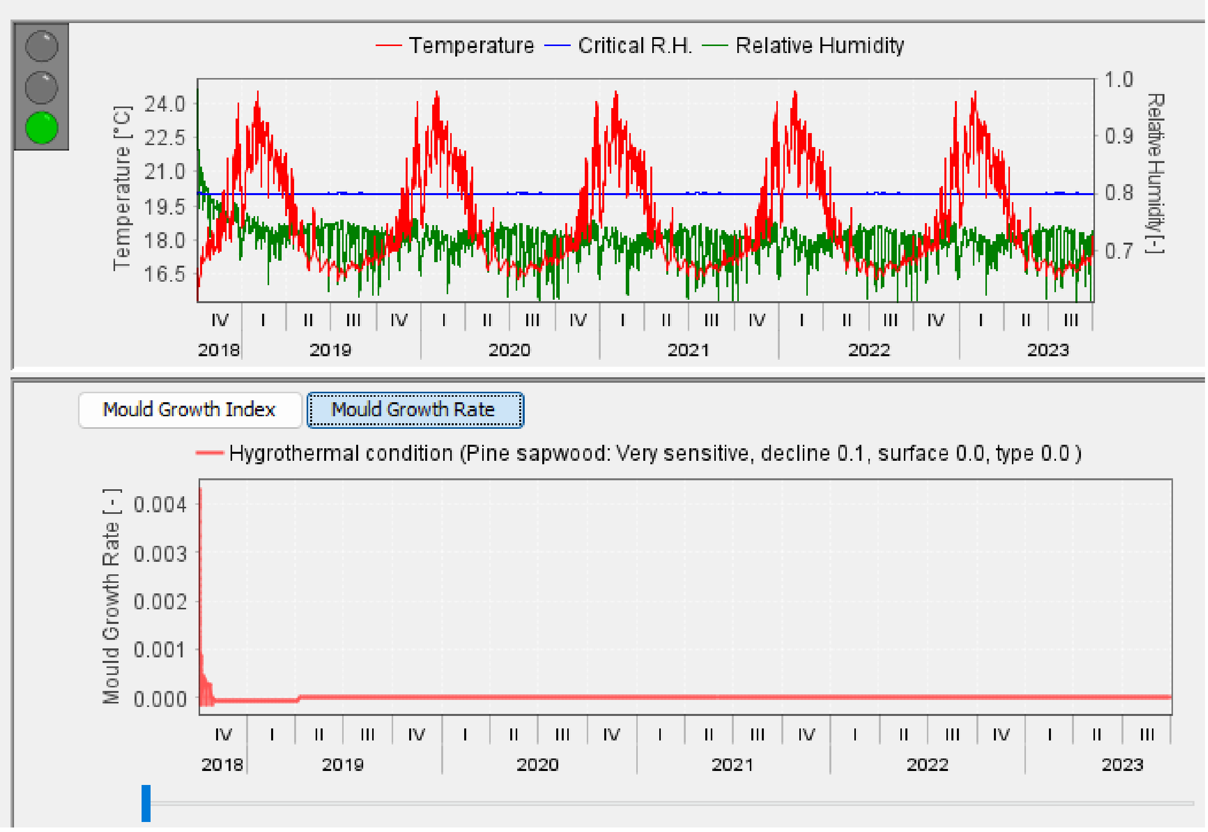


Figure 18 WUFI® VTT Mould growth Index

6.4.3 Conclusions

In this scenario, the parameters are so sensitive to either fail or pass that it isn't safe to recommend in real-life conditions. As we know, a new building contains a lot of moisture and it is recommended to provide sufficient drying to the building for the first months. To simulate this effect, we have increased the ventilation rate in the following simulation.

6.5 CASE 3B – EFFECT OF VENTILATION 0.35 ACH AND UNINSULATED SLAB EDGE

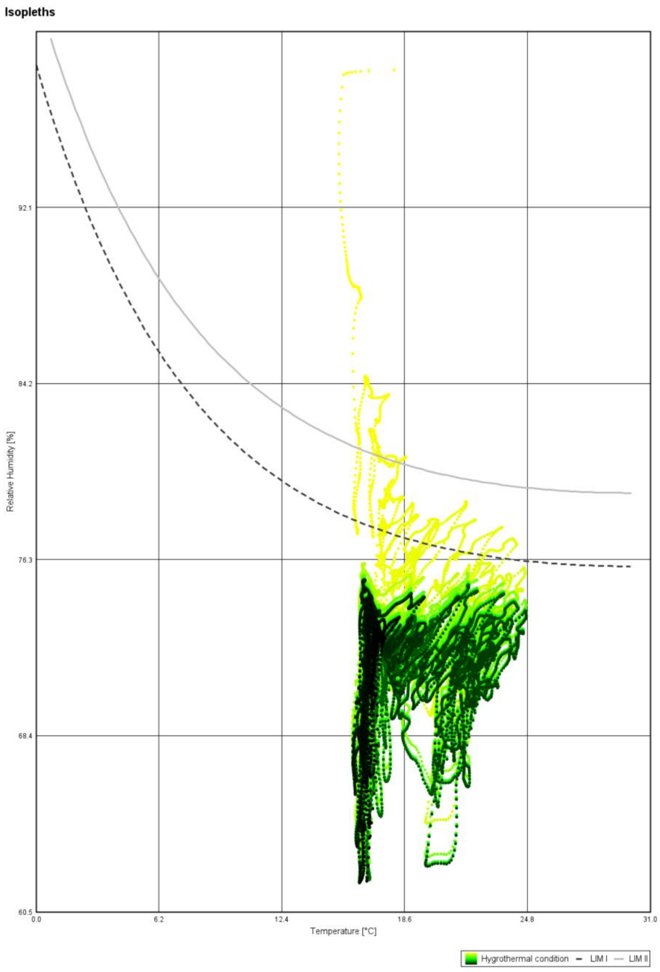
6.5.1 Design

In this scenario, we simulate the same scenario as in 6.4 Case 3A, but we have removed the 30mm thick external insulation layer to the floor slab. The internal temperature factor f_{RSI} is 0.46 [7] (compared to a value of 0.58 for the insulated floor slab, as indicated in paragraph 3 – Information received)

6.5.2 Results

6.5.2.1 Isopleths

Identical to scenario 3A, the Isopleth drops below the LIM curves. Nevertheless, it surges again from time to time across the LIM I curve.



6.5.3 Conclusion

This scenario delivers almost identical results to the one with the external insulation with a slightly higher chance of mould growth. As such we need to conclude that once again in this scenario mould growth may cause a fail in the first year of the analysis. Although the external insulation is important to reduce energy consumption, the internal temperature and ventilation are significant factors to avoid mould growth and the material's temperature at the skirting will not differ significantly if the insulation is present or not. Building Physics and energy efficiency render different results here.

[7] High performance Construction Details handbook, PHINZ, ver 04.22, case 41 , page 169/268

6.6 CASE 3C – EFFECT OF VENTILATION 2.00 ACH AND INSULATED SLAB EDGE

6.6.1 Design

In this scenario, we provide more ventilation with a number that is more in line with the calculations provided in Paragraph 6.1.5. Internal climate.

With a ventilation rate of 2.00 ACH we want to verify if it allows us to eliminate the initial higher moisture content of a new building.

6.6.2 Results

6.6.2.1 Relative Humidity

The Relative Humidity in the skirting stays below the critical 80% RH just as in case 3A.

6.6.2.2 Isopleths

As in scenario 3A, the Isopleth drops quickly below the LIM curves. Again, this was expected as higher ventilation assists to dry out the wall assembly.

6.6.2.3 BIO

WUFI® BIO indicates that the shorter period of high humidity in the skirting, will not create a significant risk for mould growth. In fact, the Mould Index is as low as 0.1 which is indicative of relatively low risk to mould growth. With the higher ventilation rate, it becomes clear that the critical and actual water content in the spores are well apart, which indicates that mould growth will not happen.

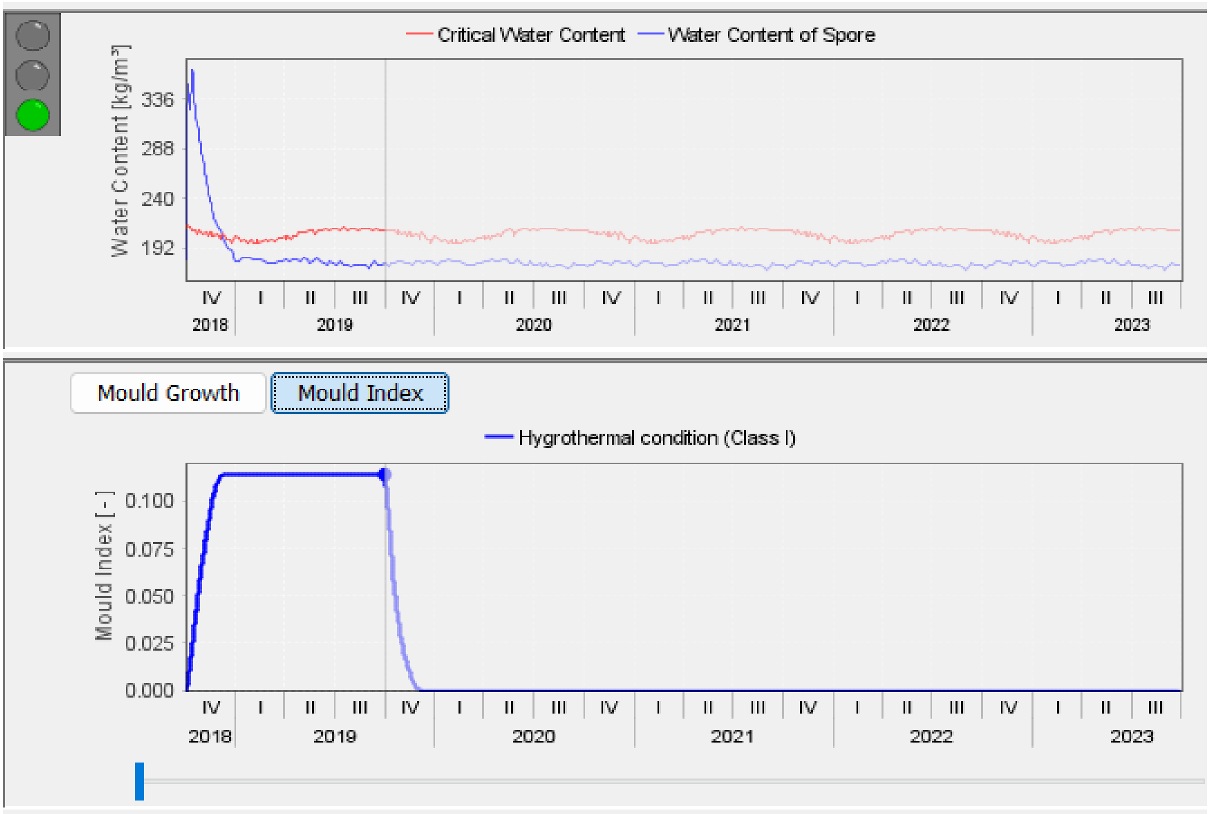


Figure 19 WUFI® BIO Mould Index in skirting

Note the "Green Light" assessment.

6.6.2.4 VTT

WUFI® VTT confirms what BIO results in a similar conclusion. Mould growth Index is 0.30 at its maximum and for a very short period of time. We get an overall "Green Light" situation.

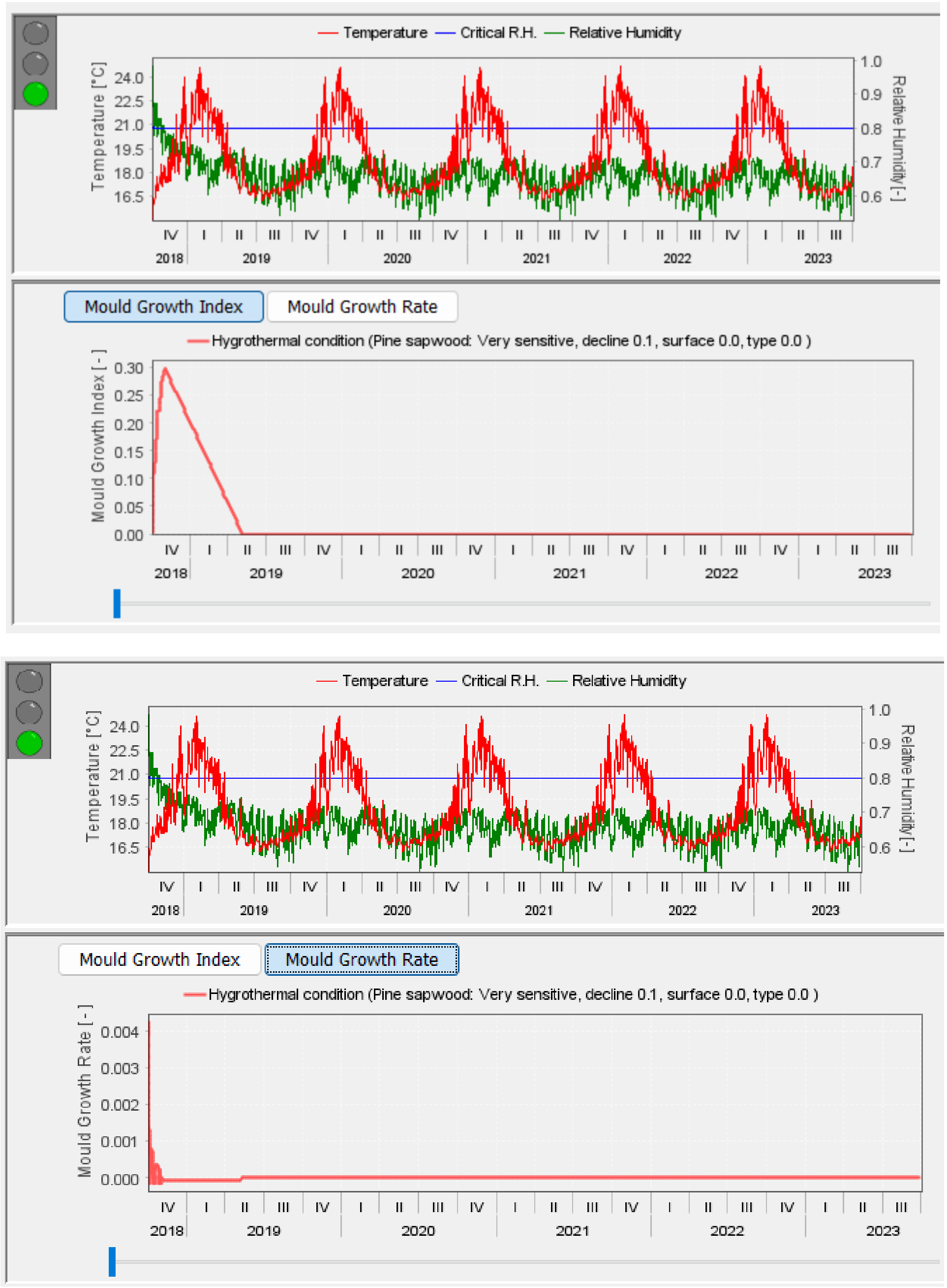


Figure 20 WUFI® VTT Mould growth Index

6.6.3 Conclusions

This scenario underlines the importance of sufficient ventilation in order to avoid mould growth. If it wasn't for the artificial high moisture content of the (floor) assembly at the start of the simulation; the 0.35 ACH ventilation would suffice to avoid mould growth in this specific detail. Also, the simulation indicates that new construction should get well-ventilated at the start, especially when significant volumes of concrete are used.

6.7 CASE 3D – EFFECT OF VENTILATION 2.00 ACH AND UNINSULATED SLAB EDGE

6.7.1 Design

In this scenario, we remove the external insulation to the floor slab while maintaining the other parameters of case 3C.

6.7.2 Results

6.7.2.1 Isopleths

Identical to what we saw when comparing scenarios 3A and 3B (ventilation rate of 0.35 ACH with and without insulation), the results are almost identical. The isopleths are almost copies from case 3C

6.7.2.2 Conclusions

As expected, we can conclude again that the ventilation and internal temperature are more important factors than the presence of the thin layer of external insulation.

6.8 CASE 4 – SLAB EDGE INSULATION

6.8.1 Design

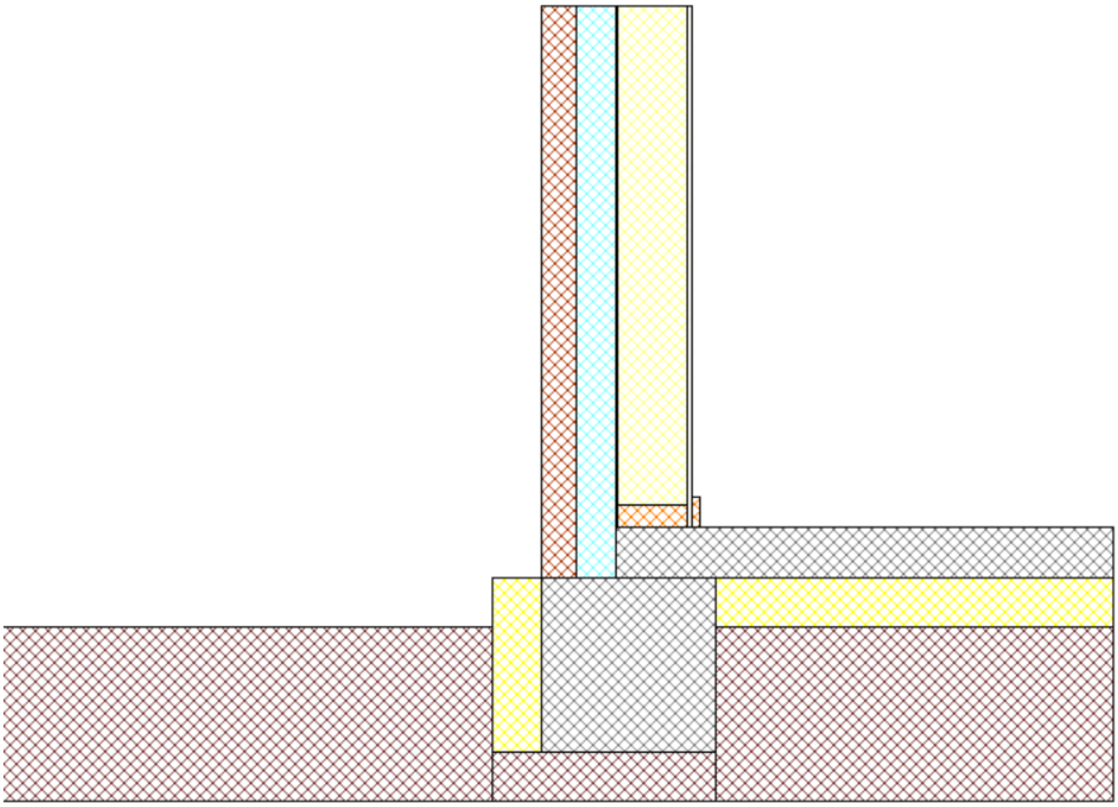


Figure 21 Additional insulation model

In an attempt to improve the results by providing better thermal resistance at this detail, Babbage simulated the above scenario with a thicker external 100mm XPS layer as well as 100mm XPS underneath the concrete floor slab. The expected effect is that the internal surface temperature will improve and therefore the risk on mould growth would decrease. Note that the thermal bridge is not eliminated in this scenario, only improved.

All other parameters of the simulation, are as to the very first case, including ventilation and internal temperature (18°C).

6.8.2 Results

6.8.2.1 Relative Humidity

The Relative Humidity in the skirting fluctuates to a similar pattern as the original case, with slightly better values. Nevertheless, the RH exceeds 80% RH for longer periods of time during the summer months.

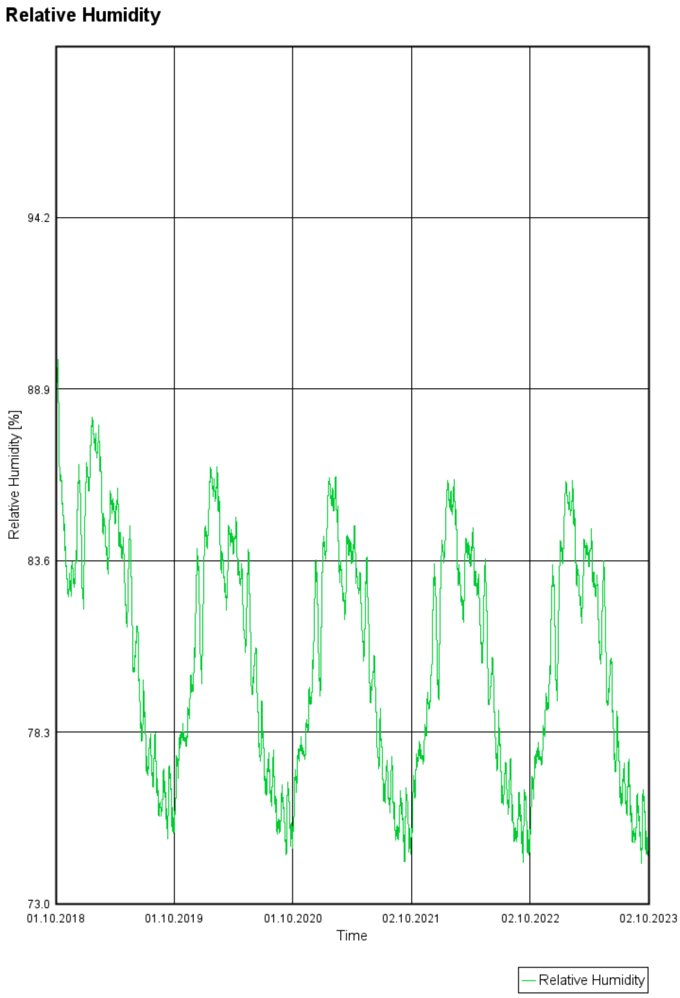


Figure 22 Relative Humidity in skirting over simulation period

6.8.2.2 Isopleths

The isopleths show a very similar image as to the result we got in Case 1 with the standard detail. The isopleth has periods of time both above and below both LIM curves.

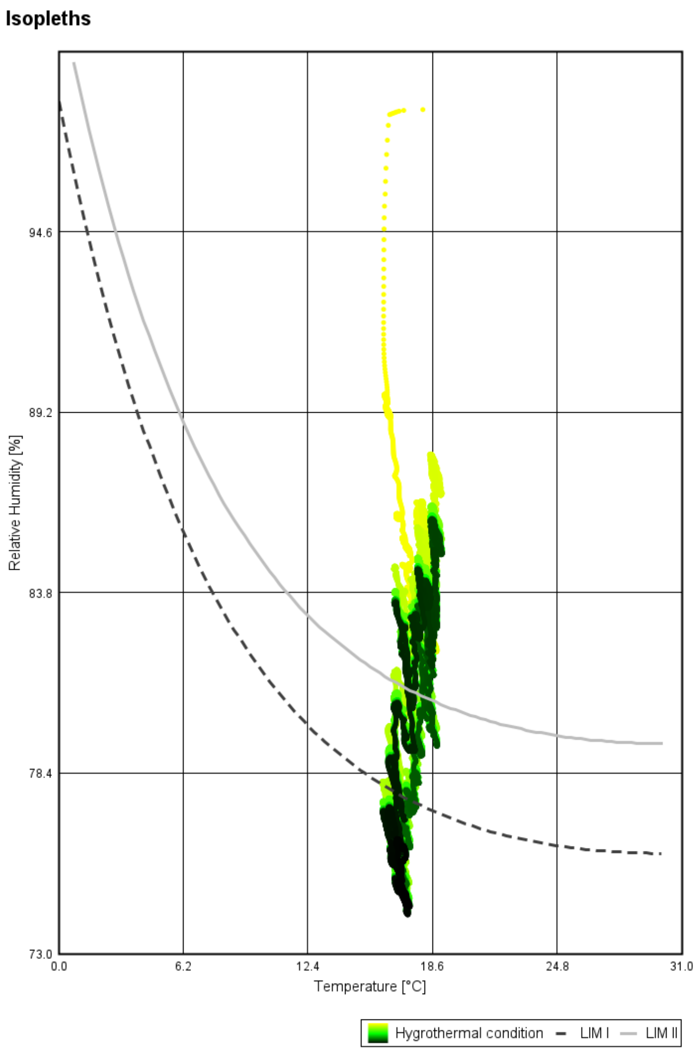


Figure 23 Isopleths in skirting

6.8.2.3 BIO

As expected, WUFI® BIO confirms that there is not much difference due to the additional insulation.

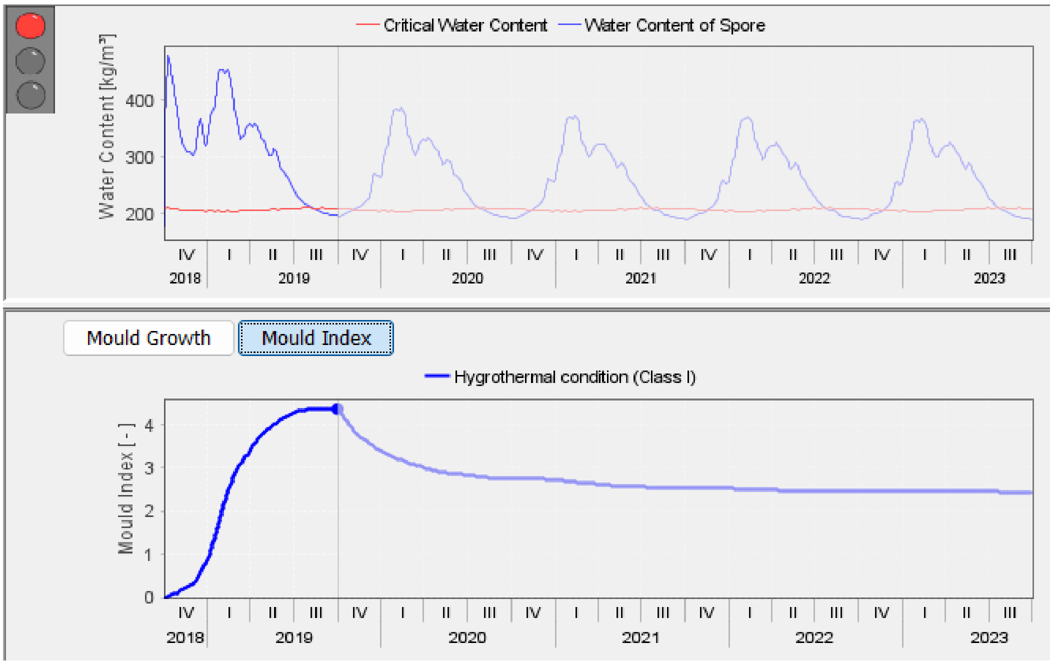


Figure 24 WUFI® BIO Mould Index in skirting

The Mould Index reaches equally a value of 4, which is well above the accepted range.

6.8.2.4 VTT

WUFI® VTT results in similarly negative values, slightly better than the original Mould Index of 3.5, but yet well above what is accepted.

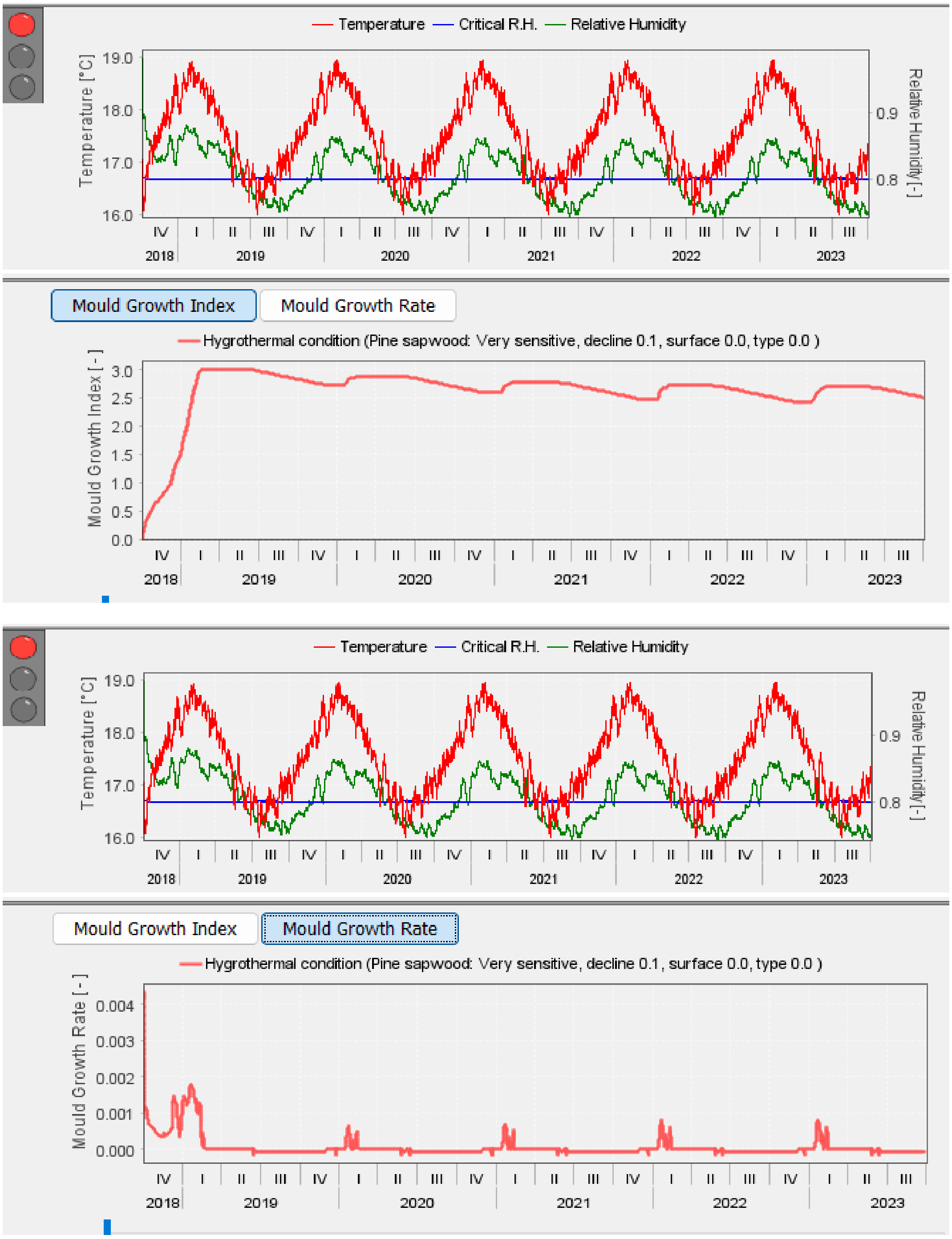


Figure 25 WUFI® VTT Mould growth Index

6.8.3 Conclusions

The solution with additional insulation may provide a better outcome for energy efficiency, yet it does not resolve the danger for mould growth.

7 ADDITIONAL TOPICS OF DISCUSSION

7.1 AUCKLAND VERSUS THE REST OF NEW ZEALAND

The Relative Humidity in Auckland (and even so in Northland) remains at very high levels throughout the year. When compared with other warm-moderate climates around the world, in Auckland there are no significant periods of time where RH drops. This is important in warm moderate climates, as the external air does not need significant heating, where the external air would dry out. In other words, the external air will be less useful in drying out our buildings, and even then, that would only be for limited periods of time (when heating is required). In the Figure below, one can appreciate the fluctuation of RH in other warm moderate climates in the world (Northern hemisphere offset by 6 months).

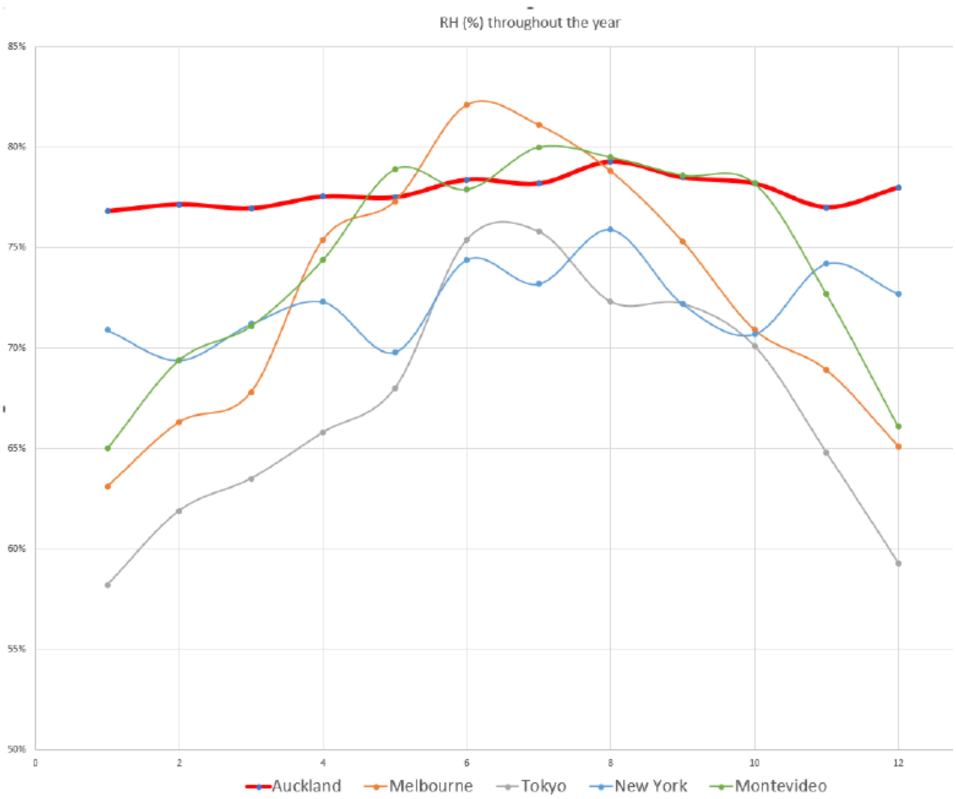


Figure 26 RH throughout the year in global warm moderate cities

In other regions of New Zealand, where the heating season is more severe and longer, drying out the houses will therefore be easier to achieve.

7.2 FLOOR FINISH

Note that the simulations assumed a concrete floor. If this floor would be tiled the results would be similar. Carpet or timber flooring probably would provide worse results. It is impossible to assess all situations or list all potential risks, but this document hopefully makes a first step to understanding the important drivers to avoid mould growth.

8 CONCLUSIONS

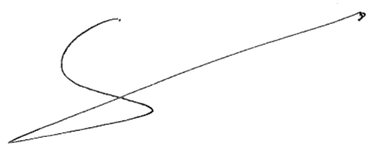
Babbage was asked to assess the risk for mould growth in a typical connection between a concrete floor slab and a brick veneer wall cladding. WUFI® 2D software was used and several simulations were run.

The results of the research underlines that the internal living conditions of our houses are highly influential on the risk on mould growth. Both internal ventilation and the room (air) temperature prove to be directly related to the chance on mould germination and growth. To verify how each factor influences the risk, Babbage ran different simulation scenarios. Even a small decrease in internal air temperature, increased the risk for mould growth significantly. Ventilation of internal air, reduces the moisture load that is driven into the wall assembly and proved to be a strong candidate to avoid problems with mould.

Materials such as concrete add potentially high initial moisture loads to a building, and sufficient ventilation is required to dry these buildings out in short periods of time after the construction. Insulation will not necessarily provide a solution, although insulation will obviously improve the energy efficiency. Note that Building Physics and Energy Efficiency not always require the same improvements. We concluded that the presence of a thin external insulation layer to the floor slab does not affect the risk for mould growth, although it will improve the energy efficiency.

Finally, in the Auckland climate, it is specifically harsh to provide the conditions to dry out the buildings with external air, especially during the warmer months. It can be assumed that when people are actively involved in the regulation of the interior climate of their habitats, ventilation and minimum room temperature are provided. Nevertheless, if that is not the case, it is safe to assume that very often negative climatic conditions will promote mould growth. To provide solutions that will work in all situations, is a challenging task.

Author:

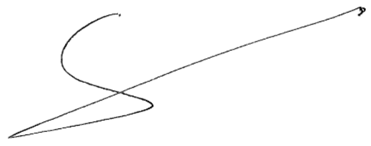


Stijn Van den Eeden
Associate Principal External Envelopes
Babbage Consultants Limited

Reviewer:

Leonard Low
Façade Engineer
Babbage Consultants Limited

Reviewed & Approved by:



Stijn Van den Eeden
External Envelope Lead
Babbage Consultants Limited

APPENDIX A