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Combining insights from HAM-simulations with case-specific knowledge

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Abstract

Heritage buildings often require renovation to obtain better energy performance. Because their exterior walls are preserved, these buildings need to be insulated from the inside. However, interior retrofits drastically change the hygrothermal behaviour of a wall, which is why installing interior insulation is by no means risk-free. By performing Heat-, Air- and Moisture (HAM) simulations on the wall assembly, the moisture-related risks can be analysed. Although HAM tools such as Delphin and WUFI are commercially available, they are rarely used in practice to perform hygrothermal assessment on facades. How can we ensure that the insights and knowledge gained from using these tools are translated to and applied in the building industry?

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Keywords: HAM-simulations; Interior retrofit; Deterioration risks

1. Introduction

Our built heritage suffers from various degradation risks that are in most cases moisture-related. To assess the effect of climate change and interior retrofits that change the hygrothermal behaviour of building facades, HAM-simulations are useful to perform. These HAM-simulations are computationally expensive and require expertise for running and postprocessing to actually comprehend the risks. Although HAM-tools are commercially available, they are rarely applied in practice. Therefore, there is a need to develop a method to translate insights and results from simulations to the building industry. It is stated that this can be achieved by extracting rules of thumb or decision trees [1]. However, a problem arises when decision trees only provide an answer to one research question. Moreover, the decision trees comprise parameters that may be known in practice and are therefore generic rather than case-specific.

2. Methodology

2.1. Set-up simulations

Around 48.000 simulations were performed using Delphin 6.0, varying 8 different parameters (Table 1). The impact of climate change can be compared by implementing three representative climate pathways (RCP's) [2]. Both a vapour open as a capillary active insulation system were simulated with different thicknesses to take into account different retrofit solutions.

Table 1. Example of a parameter variation for the HAM-simulations.

Parameter	#	Description	Parameter	#	Description
Climate	4	Historical climate (1972-2005), Climate projections RCP 2.6, RCP 4.5 and RCP 8.5 (2066-2099)	Insulation type	3	None, vapour open with vapour control layer, capillary active
Orientation	8	N, N-E, E, S-E, S, S-W, W, N-W	Insulation thickness	3	50 mm, 100 mm and 150 mm
Wall thickness	3	150 mm, 300 mm and 450 mm	Rain exposure coefficient	4	0.5, 1.0, 1.5 and 2
Brick	6	ZH, ZG, ZB, ZK, ZF and ZI	Shortwave absorption coefficient	3	0.4, 0.6 and 0.8

2.2. Performance criteria

Seven different performance criteria were calculated to understand the deterioration risk of the wall assembly given the specific parameter composition. Freeze-thaw damage occurs when water freezes in the pore structure of a brick. The freeze-thaw action was calculated by counting the number of critical freeze-thaw cycles (FTC_{crit}) at a depth of 5mm from the exterior surface. One FTC_{crit} was counted whenever the ice mass density exceeded 25% of the open porosity [3]. Mould growth can

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take place under specific boundary conditions at the interior building surface or behind the interior retrofit. This growth was calculated using the VTT model [4] and defined by the mould index (M). This index varies from 0 (spores not activated) to 6 (100% mould coverage). An index of 3 (mould cover visually recognizable) was used as a threshold value. Wooden beams embedded in the masonry wall can suffer from wood decay. Due to the interior retrofit, the wooden beam heads are exposed to lower temperatures and lower drying potential. The dose-response relationship of Brischke and Rapp [5] was applied to determine the amount of mass loss of the beam head, which can lead to structural failure. The wood decay rating [6] goes from 0 (no attack) to 2 (moderate attack) and ends with 4 (failure). Condensation arises when hot and humid air meets a building surface colder than its dew point. To avoid run-off, and therefore water accumulation, the moisture content should not exceed 0.1 kg/m². Corrosion can affect the metallic reinforcements or steel beams that are embedded in the masonry when exposed to a certain level of humidity [7]. The combined hygrothermal and corrosion model of Zelinka et al. [8] was employed to calculate the corrosion rate R [μm/year]. As a threshold, a current density i [mA/m²] of 1 [9] should not be surpassed. Salt crystallization is a prominent degradation phenomenon due to salt mixture behaviour inside the pore structure of the masonry. It can be parameterized using the number of crystallization-dissolution cycles which is salt-dependent. One phase is counted each time the crystallization pressure exceeds the tensile strength of the material. The criteria for halite and thenardite-mirabilite are stated in Grossi et al. [10]. Lastly, the growth of microorganisms on the surface of a wall is called bio-colonisation. Omnipresent and fast-growing organisms settle on the surface first, after which slower-growing organisms get a chance of accumulating [11]. Conditions that are favourable for the growth of bacteria, lichen and fungi are described in relation to the water activity of the exterior surface [12] and calculated as the hours of optimal growth.

3. Results and conclusions

Using the results of the simulations, a dataset with all the different performance criteria for each set of parameters was developed. A generic decision framework can be generated from this set using decision trees [13]. This generic framework is beneficial but not the utmost refined for practical application because it covers each combination of parameters, even the ones that are not representable for that case. Therefore, the dataset is reduced and specified using a simple online questionnaire for people from the building industry to complete. This reduced and case-specific dataset, where every combination of parameters is actually a possibility for the case in question, creates its own, case-specific decision framework [Fig 1]. All this was developed as a web interface using Shiny [14] where people from the building industry can fill in the questionnaire and create their own case-specific decision framework [Fig 2]. The framework can guide, advise and inform best practice.

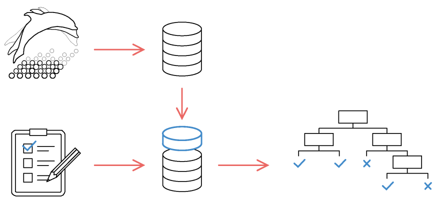

Figure 1. Flowchart methodology

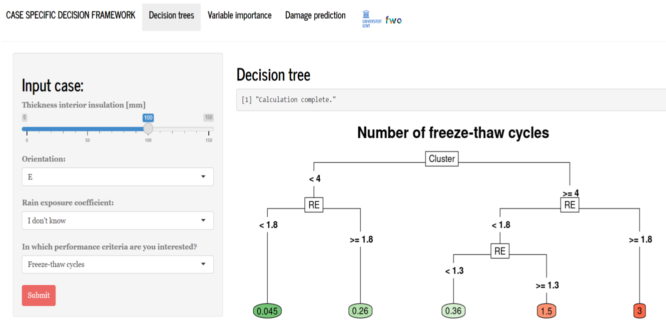

Figure 2. Example web interface consultable online

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