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Freeze-Thaw Risk in Solid Masonry: Are 'Hygrothermal Response Based' Analyses Mandatory when Studying the Sensitivity of Building Envelopes to Climate Change?

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1 Introduction

During the 21st century, the climate system is expected to change (IPCC, 2014). Besides rising temperatures, heat waves and intense precipitation events are likely becoming more frequent, and freezing days will probably decrease across Europe. Beside being a contributor, the built environment is largely affected by climate change (de Wilde and Coley, 2012). Many studies focus on the future building's energy efficiency. Along with new technologies, they introduce retrofitting strategies for existing (heritage) buildings. However, these applications may not entail the most durable solutions (Straube and Schumacher, 2006). Interior retrofitting of solid masonry is known to increase the risk of freeze-thaw action, but few studies evaluate the – potential mitigating– effects of climate change. Moreover, no sound methodology exist to implement climate projections in HAM (Heat Air Moisture) simulations. This paper studies the difference between a 'climate based' and 'response based' analysis when evaluating the freeze-thaw risk in solid masonry, before and after internal retrofit, with regards to climate change.

2 Methodology

The climate data (1950-2099) are provided by the ALARO-0 Regional Climate Model (RCM) for Uccle (BE), considering Representative Concentration Pathways (RCP) 2.6, 4.5 and 8.5.

The 300 mm historical masonry is finished on the interior with i) gypsum plaster *(original wall)*, and ii) mineral wool, open vapour barrier and gypsum board *(retrofitted wall)*. The freeze-thaw criterion is based on the worst-case scenario, i.e. 25% ice volume rate.

HAM simulations (1D) are performed in Delphin 5.9.5 for 5 situations: i) south-west (SW) facing original wall (RCP 8.5), ii-iv) SW retrofitted wall (RCP 2.6, 4.5 and 8.5), and v) north-west (NW) retrofitted wall (RCP 8.5). The results are analysed using the moving average per 30 years at a depth of 5 mm in the masonry (exterior side) (Vandemeulebroucke *et.al.*, 2019).

3 Discussion and Conclusion

'Climate based' analysis illustrates that there is a decrease in frost action towards the end of the 21st century. Both the hours of frost and freeze-thaw cycles (FTC) based on T_{air} are decreasing by 33% for RCP 4.5 and 66% for RPC 8.5, potentially leading to a decrease in number of critical FTC in solid masonry walls. Precipitation amounts are increasing by about 10% for both RCP projections, and the fraction of annual precipitation occurring in winter is increasing. Higher future moisture loads, on the other hand, may suggest an increased likelihood for the critical moisture content to be exceeded in the masonry upon freezing.

Resulting the ‘hygrothermal response based’ analysis using the ALARO-0 RCM, the number of critical FTC at 5 mm depth in the masonry is decreasing between 0% and 45%, depending on wall orientation and the presence of interior retrofit (Figure 1). There can be concluded that the decrease in freeze-thaw action over the 21st century may be counteracted by the increase in moisture load, and that orientation and the presence of interior retrofitting result in large uncertainties about the future freeze-thaw risk of solid masonry. ‘Hygrothermal response based’ analyses are required when assessing the freeze-thaw behaviour of solid masonry, before and after retrofitting, with regards to climate change.

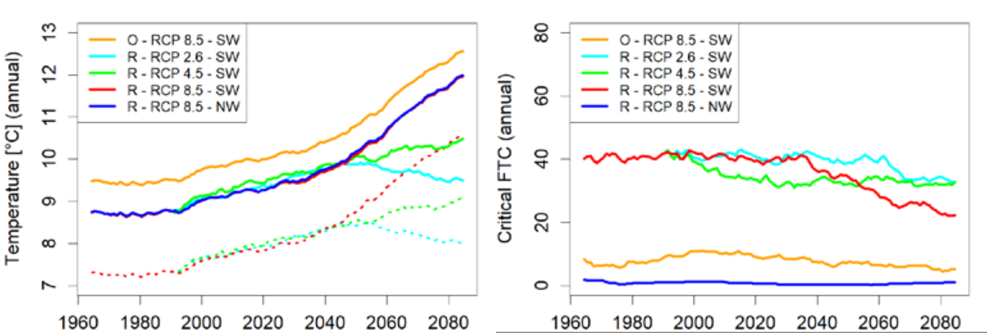

Figure 1. Moving average of the annual mean T (left) and the number of critical FTC (right). (O: original, R: retrofitted). The dotted lines illustrate the climate data (cyan: RCP 2.6, green: RCP 4.5 and red: RCP 8.5).

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