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Freeze-Thaw Risk in Solid Masonry Walls: Impact of Climate Change over Europe and the Mediterranean subjected to RCP 4.5

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Abstract

Climate change has an impact on degradation risks in historical buildings. Most studies are based on climate data alone, even though there is no linear relation between climate variables and the building envelope's response. Therefore, we studied the impact of climate change on the risk for freeze-thaw damage at 10 locations across Europe and the Mediterranean, including a high number of parameter variations. We performed 34560 hygrothermal simulations. The climate change impact is not uniform over the domain. For some locations and parameter combinations, the risk decreases or remains constant, whether for others there is an increase. The impact of climate change is highly sensitive to the specific combination of parameter variations, highlighting the necessity of a response-based analysis.

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Keywords: hygrothermal simulations; climate change; degradation; frost action; full factorial study; moisture-related damage

1. Introduction

The climate system is changing as reported by the Intergovernmental Panel on Climate Change (IPCC) [1]. There is an increase in global temperature, a change of precipitation patterns, and an alteration of the frequency and intensity of extreme events (such as the increase of extreme precipitation, hot spells, droughts…, and the decrease of extreme snowfall and cold spells).

These climatic changes have an important impact on the risk for degradation of building envelopes, as reported by several studies [2]–[4]. Most of these studies are based on climate variables alone, even though there is no linear relation between climate variables and the hygrothermal response of building components. The results of Heat Air Moisture (HAM) simulations are only included in a handful of studies [5], [6]. However, these studies are often limited to one of two locations, and they are often limited to a low number of variations (e.g. a solid masonry wall with and without interior insulation).

Therefore, we studied the impact of climate change on the risk for freeze-thaw degradation in solid masonry walls for 10 locations across Europe and the Mediterranean. The study includes 1728 parameter variations per location and time period.

2. Methodology

The impact of climate change on brick masonry building envelopes is studied by means of a full factorial study. 34560 one-dimensional HAM simulations are performed in Delphin 6. The following parameter variations are considered: 8 wall orientations (every 45° with 0°=north), 3 masonry thicknesses (300, 400, 500 mm), 6 brick materials (ZB, ZE, ZF, ZH, ZI, and ZK from the Delphin library), 1 wall without and 2 with interior insulation (50, 150 mm), and 4 rain exposure coefficients (0.5, 1.0, 1.5, 2.0).

Two climate periods are included, i.e. the historical period (1960-1989) and projection (2070-2099), retrieved from the REMO regional climate model coupled to the ECHAM5 global model for Representative Concentration Pathway (RCP) 4.5 (provided by the Climate Service Center Germany). Furthermore, 10 locations in different climate zones (Köppen-Geiger classification) across Europe and the Mediterranean are studied: Cairo, Bouarfa, Valencia, Athens, Madrid, Milan, Brussels, Berlin, Helsinki, and Bodø.

The change in number of critical freeze-thaw cycles at 5 mm depth in the masonry is studied. For each 30-year time period, the 90th percentile (P90) value is used in the analysis.

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3. Discussion and Results

Climate-based analysis: The change in climate variables is not uniform over Europe and the Mediterranean. The mean temperature increases over the domain between + 1.6°C and + 2.5°C. The mean annual precipitation load only increases for 3 locations (Berlin, Helsinki, and Bodø), i.e. the 3 northern locations. The relative change ranges between -27%, and +7%. Furthermore, the P90 of the wind-driven rain load increases for Brussels, Berlin, Helsinki, and Bodø up to +15%.

Response-based analysis: Several aspects of the change in the risk for freeze-thaw damage in the building envelopes are assessed: i) The change of freeze-thaw action in the building envelopes is not uniform over the domain. ii) Not all studied locations sustain (a change in) critical freeze-thaw cycles, such as the locations in the south of the domain. iii) In the north of Europe, the risk for freeze-thaw damage is projected to increase based on the studied climate projection. iv) The critical orientation for freeze-thaw damage remains constant. v) The change in risk is highly sensitive to parameter variations, especially the brick type, orientation, rain exposure coefficient, and whether the wall is insulated or not. E.g. there is a large spread in the results for Madrid. Many cases in Madrid do not show a risk for damage, yet some particular cases are projected to sustain a large decrease in degradation risk. vi) For some locations, there is an increase in damage risk for some parameter combinations, and a decrease for other combinations. vii) HAM simulations are necessary to assess the change in risk for freeze-thaw damage in solid masonry walls. Future studies should include more climate models and emission scenarios.

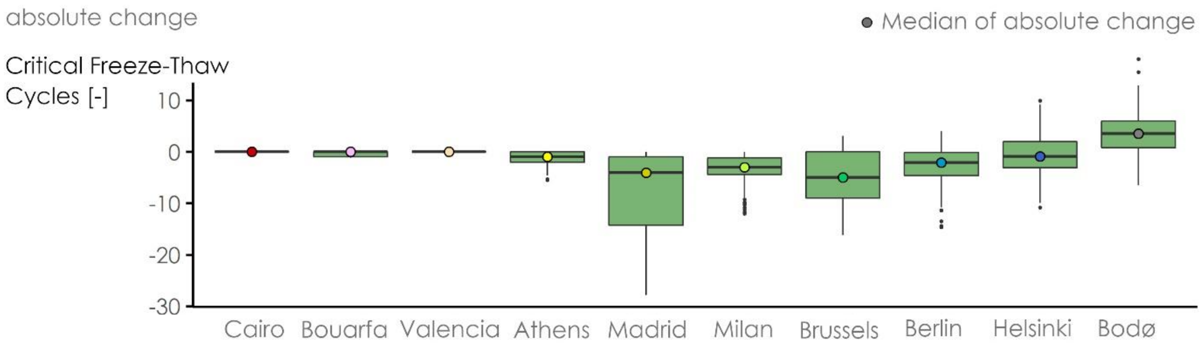

Figure 1. The change in critical freeze-thaw cycles is sensitive to the specific set of parameter variations. For some locations, the freeze-thaw risk may either increase or decrease (especially in the center and north of Europe), whereas there is a decrease in the south of Europe (Figure modified from [7]).

4. Conclusions

It is highly important to include a sensitivity analysis when studying the impact of climate change on freeze-thaw action in building envelopes across Europe and the Mediterranean. The spread of the climate change impact is large when including a large variety of parameters, such as different wall compositions, materials, and exposure conditions. Furthermore, the change in the risk for freeze-thaw damage is not uniform over the studied domain. In addition, the freeze-thaw risk increases for some combination of parameters, and remains constant or decreases for other combinations. To conclude, the impact of climate change on freeze-thaw action in solid masonry walls is very sensitive to specific parameter combinations.

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