# CLIMATE-BASED AND RESPONSE-BASED INDICES FOR THE ASSESSMENT OF FROST DAMAGE ON HISTORIC BRICK WALLS IN TØNSBERG, NORWAY

**Petros Choidis[1,*] and Dimitrios Kraniotis[2]**

[1] Department of Civil Engineering and Energy Technology, OsloMet-Oslo Metropolitan University, Pilestredet 35, Oslo 0166, Norway, petrosch@oslomet.no, https://www.oslomet.no/en/about/employee/petrosch/

[2] Department of Civil Engineering and Energy Technology, OsloMet-Oslo Metropolitan University, Pilestredet 35, Oslo 0166, Norway, dimitrios.kraniotis@oslomet.no, https://www.oslomet.no/about/employee/dimkra/

**Key Words:** *Freeze-Thaw Cycles, Historic Brick, Heritage Buildings, Numerical Modelling, Masonry Structures.*

Frost damage is the most critical degradation factor of historic buildings with brick walls located in areas with a cold and humid climate. The action of this deterioration mechanism causes scaling of the surface and leads to the disintegration of the material [1]. A common method to assess it is by counting the freeze-thaw cycles experienced by the building material of interest. In this framework, climate data for a 70 years period for Tønsberg, Norway, were downloaded from ERA5 [2]. Hygrothermal simulations were employed to calculate the temperature and moisture content inside a typical historic brick assembly. The transient hygrothermal conditions were used to assess the frost risk, given that the critical temperature and degree of saturation for a frost damage event to happen are 0 $^{o}$C [3] and 25% [4], respectively. The freeze-thaw cycles were also calculated using three different climate-based indices described in [5] and [6]. Results show that the examined assemblies experienced significant frost damage, with the worst case being the southwest-oriented wall. This is the orientation with the highest driving rain. The frost risk shows a decreasing trend over the years. Moreover, the frost risk of the assembly of interest is highly overestimated by the climate-based indices compared to the response-based index. The wet-frost index [5], which considers the air temperature and the precipitation, is the climate-based index that best describes the frost risk of the assembly. Overall, it is concluded that a response-based index should be used to assess the frost risk of building elements. In case of lack of information about the building material properties or the climate data, the wet-frost index is suggested to be used. By using data from climate models and one of the two approaches suggested above, it is possible to predict the frost risk for the forthcoming years and take relevant precautionary measures.

## REFERENCES

[1] K. R. Lisø, T. Kvande, H. O. Hygen, J. V. Thue, and K. Harstveit, A frost decay exposure index for porous, mineral building materials. *Building and Environment*, Vol. **42**, no. 10, pp. 3547-3555, 2007.

[2] H. Hersbach et al., The ERA5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society*, Vol. **146**, no. 730, pp. 1999-2049, 2020.

[3] M. van Aarle, H. Schellen, and J. van Schijndel, Hygro thermal simulation to predict the risk of frost damage in masonry; effects of climate change, *Energy Procedia*, Vol. **78**, pp. 2536-2541, 2015.

[4] J. Straube, C. Schumacher, and P. Mensinga, Assessing the freeze-thaw resistance of clay brick for interior insulation retrofit projects. Proceedings of the XI International Conference Thermal Performance of the Exterior Envelopes of Whole Buildings, Clearwater, FL, USA, 2010, pp. 5-9.

[5] C. M. Grossi, P. Brimblecombe, and I. Harris, Predicting long term freeze–thaw risks on Europe built heritage and archaeological sites in a changing climate. *Science of the Total Environment*, **Vol**. 377, no. 2-3, pp. 273-281, 2007.

[6] P. Brimblecombe, C. M. Grossi, and I. Harris, *Climate change critical to cultural heritage*, in Survival and Sustainability, Springer, 2010, pp. 195-205.