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The influence of the urban heat island on frost risk of natural building stones: a case study in Ghent

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Freeze-thaw cycles can result in the decay of natural building stones used in the building envelope. The severity of freeze-thaw cycles in cities can be mitigated through the development of an urban heat island (UHI). This is manifested by elevated temperatures resulting from the physical properties of building materials and pavements, the release of anthropogenic heat, the trapping of radiation in urban canyons and the decreased availability of moisture. Here, the UHI of Ghent, Belgium, is taken as a case study to study on the influence on the freeze-thaw risk of natural building stones. Analysis of climatic data of different locations in and around Ghent indicates temperature differences up to 6 °C between the historical city center and the rural surroundings. These temperature differences are influenced by the amount of clouds, suggesting a more intense UHI during clear sky conditions. In addition, a decrease in wind speed is observed in the city center, implying a decreased wind-driven rain impact.
Freeze-thaw cycles of both urban and rural environments are simulated in a climate chamber on an insulated Savonnières limestone sample (Tithonian, Oolithe Vacuolaire stratigraphical unit in the Meuse and Haute-Marne areas in France). The climate chamber simulations indicates a zero-curtain effect in wet samples, resulting from the release of latent heat throughout freezing. Breaching of the zero curtain only occurs when temperatures are sufficiently low or when relatively high negative temperatures prevail long enough. This is observed in some of the rural freeze-thaw cycles, indicating a higher freeze-thaw risk in a rural environment.
To assess the influence of the UHI on natural building stones over several years, hygrothermal modeling of the measured urban and rural climates is performed on Savonnières limestone in the heat, air and moisture program Delphin. Temperature, relative humidity, water content, ice volume and freeze-thaw cycle outputs are generated and indicate a lower frost risk in building stones situated in urban landscapes. This corresponds to the observations of the climatic analysis and the laboratory simulations, and suggests a mitigation of the frost risk by the UHI in cities with a Cfb climate such as Ghent.