Study of the micro-climatic monitoring on the Saint-Remi Basilica (Rheims, France)

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Historical buildings are subjected to weathering through different factors such as temperature and humidity variations, that have a direct influence on different weathering processes. Insolation produces thermal expansion differences within the stone creating stresses at grain boundaries that can lead to disaggregation. If water is involved, a low temperature can cause the freezing of water inducing ice expansion and cryosuction. These repetitive stresses can damage the stone through fatigue failure. The measurement of environmental parameters on site is essential in order to study the weathering of the stone in its particular environment and anticipate risk areas.
To identify the micro-climatic conditions on a monument, an in situ monitoring was achieved on the Saint-Remi Basilica of Rheims, listed as a UNESCO World Heritage site. A sensor network was set up on the two towers of the monument in December 2017: fourteen temperature-humidity i-Buttons facing different directions, at different heights and recording with a time step of 1 hour, or a time step of 2 minutes for short measurement campaigns.
The data obtained by the sensor network highlighted the microclimates on the building. The height of the measured points had no significant impact on the results, whereas the orientation of the façade had an influence on the surface temperature. This was directly related to the longer solar exposure of the stone throughout the day and allowed to identify micro-climates. The façades exposed to the sun (South, East in the morning, West in the afternoon) present higher temperatures and lower relative humidity compared to the shadowed areas (North, East in the afternoon, West in the morning, other shadowed zones). The relative humidity measured was linked to the temperature: a temperature increase induces a humidity decrease. A mean difference of temperature between South and North of 2,7˚C with a maximum of 18˚C and a mean difference of relative humidity of 4,3% with a maximum of 48% were observed.
Climatic cycles on different time ranges were identified: an annual cycle alternating between winter and summer, a daily cycle due to sun exposure and short cycles identified during short term monitoring. These short abrupt variations of temperature (1-2˚C) on façades lasted between 5 and 40 minutes and were due to cloud cover and/or wind-speed. Four typical days inducing strains were identified: sunny days with a temperature increase superior to 10˚C, rainy days inducing wet/dry cycles, frost days presenting frost/thaw cycles and stormy days where a sudden rain on heated stones caused abrupt temperature and humidity variations. A year can thus be fragmented in those 4 categorized days. This repartition of typical days over a year depended on the micro-climatic variations previously identified: the shadowed zones experienced less sunny days and more rainy days.
This study of climatic monitoring will help anticipate the stone weathering on the Saint-Remi Basilica. The monitoring will continue for the next two years in order to obtain reproducible data and will be coupled with an infrared thermography monitoring. The strains corresponding to the four identified types of day are reproduced through accelerated ageing experiments using the parameters recorded on site. From the repartition of these typical days in one year, this will allow to estimate the behavior of a stone during a year on a sun-exposed façade and on a shadowed zone of the Basilica. The final goal is to be able to anticipate the stone weathering on the monument and identify risk areas.

Keywords: weathering processes, micro-climate, Saint-Remi Basilica, in situ monitoring

