



Micro-climatic monitoring to optimize ageing test methodology: application 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. 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 achieved through a sensor network was set on the Saint-Remi Basilica of Rheims, listed as a UNESCO World Heritage site. Fourteen temperature-humidity i-Buttons were placed on the two towers of the building 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.

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.

The strains corresponding to the four identified types of day were reproduced through ageing experiments using the parameters recorded on site. Accelerated tests were also carried out in order to assess the effect of thermal stress on the long term. The setting of the tests simulated a façade exposed to external environment where variations of temperature and humidity creating thermal and hydric strain in the stone were controlled. The behavior of the stone was monitored with thermocouples and strain gages measuring heat transfer and differential micro-dilatation. Two types of limestone found on the Basilica were tested, presenting different properties and different durability.

The first results, with mild condition of daily cycles, already induced significant strains in the stones showing different intensity depending on the stone and the type of test. These strains have a relative low intensity compared to the mechanical properties of the stones, but can be damageable on the long term through fatigue effect. The different tests will allow to estimate weathering kinetics in order to predict stone alteration over time for the two limestones. In order to anticipate the weathering of a stone on the monument, the orientation of the stone will have to be taken into account. In fact, the monitoring showed micro-climatic variations according to the orientation: façades exposed to the sun presented higher temperatures and lower relative humidity compared to the shadowed areas. These variations will have an influence on the type of strain induced and stone weathering prediction will be adapted accordingly. This will allow us to anticipate the weathering of a stone on the monument and identify risk areas.