Non-Destructive Techniques coupled to environmental monitoring to assess the decay of building stones in urban area

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Historic building stones are vulnerable to climatic conditions and atmospheric pollutants. For that reason, the cultural, societal and economic interests to make restorations as durable as possible are undeniable in an aggressive and evolving atmospheric environment, particularly in areas with important human activities (traffic, housing, agriculture and industry).
In this context, to carry out a more effective restoration management, the aim is to be able to predict the surface state of the stones according to the evolution of their environment. For this purpose, we used the combination of non-invasive micro-environmental monitoring and non-destructive techniques (NDT) on a newly restored monument.

The studied monument, Saint Joseph Chapel, is a neogothic style monument built in 1876 and constituted from local limestones. The main façade is located in front of a very busy road in the center of Reims (France) and restored from March to September 2012. Two façades of the Chapel Saint Joseph were studied, the restored one and a non-restored, especially isolated from the street.
Two different wireless sensor platforms, were used for each façade. Temperature (T) and relative humidity (RH) were monitored by Smartmote and Waspmote (Libellium), while O_3, NO, NO_2 and SO_2 levels were measured only by Waspmote. The frequency measurement was: every minute for Smartmote and every hour for Waspmote.
In addition, magnetic susceptibility and colorimetry were used to follow the evolution of building stone surface. The colorimetry was set up to control and quantify the evolution of the surface color. If blackening is observed, traffic pollutants will be the main agent of decay, whereas if it is greening, biological activity will be the most important decay factor. The magnetic susceptibility is directly linked to the level of soiling because of the presence of metals constituting the atmospheric particles. The value is also different from a material to another such as stone and mortar. The measurements, established on 200 points on each façade, were repeated at one year intervals.

The first information extracted from the environmental monitoring was that the annual temperature variations could be divided in two periods of interest: high T and low RH from April to September, and the reverse from October to March. The concentrations of the pollutants were higher on the street oriented façade than on the courtyard façade. The highest NO_2 concentrations were recorded along the first period except during spring holiday when the traffic was limited. However, the ratio of SO_2 was higher in winter during the second period, especially when daily temperature decreased.
These observations confirmed the correlation between NO_2 and both temperature and traffic, between SO_2 and household heating, and finally a higher risk of weathering for the façade directly exposed to street pollution.

Initial measurements showed that the weathering features of the non-restored façade were soiling, greening and material losses.
The magnetic susceptibility data were higher in areas with little or no leaching by rainwater and prone to

particle deposits. Magnetic susceptibility also allowed distinguishing natural stones from restoration mortars.
The surface of the non-restored part had a higher minimum-maximum deviation of luminance due to the soiling, with luminance values ranging from 40 to 83. This parameter ranged between 70 and 85 for the restored part.
Comparing the two monitoring campaigns, May 2015 and May 2016, there was no significant evolution of the magnetic susceptibility. By contrast, luminance varied much more on the non-restored façade than on the restored one, especially on surfaces where the humidity was high and constant.

Even if the first NDT results showed that the surface of the street façade evolved slower than the protected façade, environmental monitoring pointed the risk for the façade in front of the street to be more affected by pollution despite of its recent restoration. Thus, those first results showed the necessity to use NDT measurements and microscale monitoring over the long term to precise the weathering kinetics and to anticipate future restorations.

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