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Case study

Microclimatic monitoring for the investigation of the different state of conservation of the stucco statues of the Longobard Temple in Cividale del Friuli (Udine, Italy)

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ABSTRACT

A microclimatic monitoring of the Longobard Temple in Cividale del Friuli, Udine (Italy), was performed between 2011 and 2012 aimed at investigating the causes of the different damage features observed in the stucco statues located in the opposite sides of west-south-west wall. The thermo-hygrometric conditions of the air close to the statues were continuously monitored for one year and the surface temperature of the statues was investigated by means of thermography. According to the results, no remarkable differences in the current microclimatic conditions measured at the two sides of the west-south-west wall were found, hence the cause of the different state of conservation of the statues has to be ascribed to phenomena occurred in the past. Nevertheless, the thermo-hygrometric values measured close to the statues are not fully in compliance with respect to the ranges indicated in literature for the conservation of the stucco ornaments.

1. Research aims

A microclimatic monitoring [1–4] inside the Longobard Temple of Cividale del Friuli in Udine (Italy) was performed in the period 2011–2012 to assess the microclimatic conditions close to the stucco statues of the west-south-west wall (referred as "west wall") and investigate if the microclimate could be the cause of the different damage features observed in the two sides of that wall (referred as "right" and "left" sides) (Fig. 1). This study was included in a multidisciplinary project aimed at assessing the general state of conservation of the Temple, identifying the risks for its long-term conservation and finding sustainable solutions to improve its management. The present paper is focused on the results of the microclimatic monitoring, whilst the results of the whole project are out of the aims of this paper.

2. Introduction

The Longobard Temple in Cividale del Friuli, an extraordinary testimony of the architecture of the high Middle Ages, was declared world heritage site by UNESCO in 2011. Among the numerous stucco decorations, the six female figures standing alongside the central window of the west wall have made the Temple world-famous (Fig. 1 and Supplementary data, Fig. S1) [5]. Now they are white all over, but faint traces of colour indicated that they were painted [6].

The history of the Temple is pretty turbulent. Following an earthquake in 1222–1223, the oratory stood unroofed for more than 20 years. Rain and snow come into the building and the moist atmosphere had led to vegetal growth, corrupting both pigments and surfaces [5].

Since the mid nineteenth century, the Temple has undergone a complex series of preservation works and several investigations. The stucco statues nowadays show signs of disgregation and abrasion, detachment, dilavation and changing colour. During the restoration carried out in 1860, the intervention on the last statue on the right side was different from the others, being it in the worst conservation conditions. Wide areas on the face, neck, nimbus and

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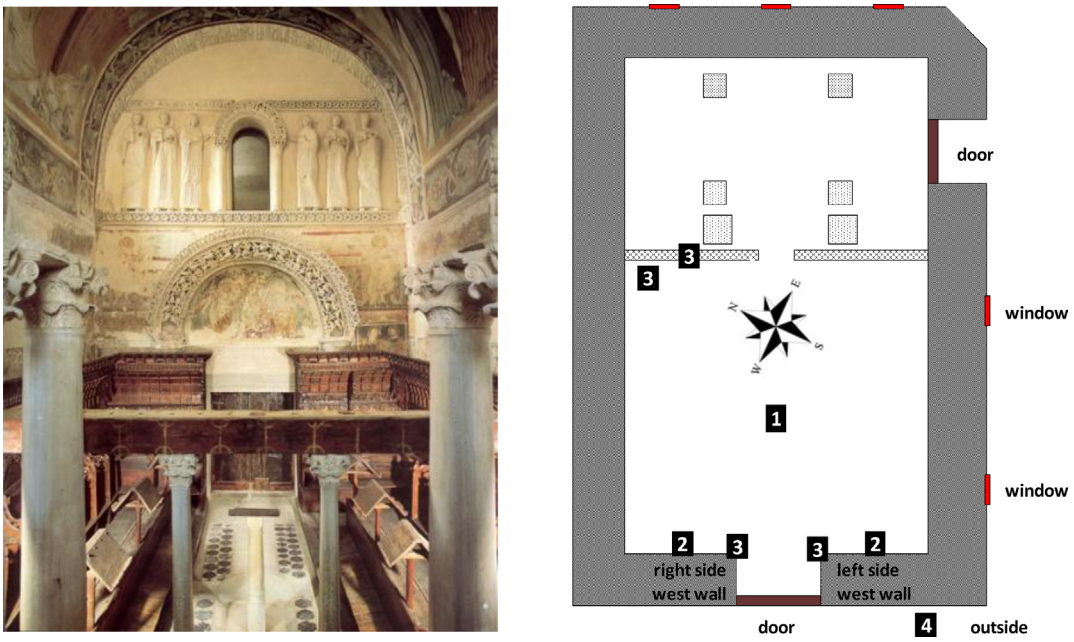

Fig. 1. Internal view of the Temple from north-east (left) and map (right) indicating the positions of the sensors for the microclimatic monitoring: (1) air thermal vertical profile; (2) T and RH sensors at the bottom of the statues; (3) anemometers.

dress were redone and thus they seem more cohesive compared to the rest of the figure [6].

3. Experimental apparatus and methodology

The thermo-hygrometric conditions of the air close to the statues of the west wall were monitored continuously for one year. Moreover, the distribution of the surface temperature of the statues was studied with manual thermographic campaigns [7–10], to point out differences between the left and right sides. The impact on the statues of the solar radiation coming through the south wall windows (Fig. 1) was also investigated by means of thermography. In addition, the air circulation inside the Temple was studied by means of anemometric measurements to evaluate the risk for inertial deposition of particles on the statues.

Details on the monitoring system and instruments are described in the e-supplement (3.A). In the present work, only the results of the measurements related to our research aims are reported and specified in the e-supplement (3.B).

The description of the whole experimental apparatus and monitoring campaign are included in the final report to the Municipality [11].

4. Results

4.1. Air temperature and humidity

The comparison between the thermal behavior of the air close to the surface of the statues at the two sides of the west wall showed remarkable differences only in the maximum values from the beginning of autumn until the end of winter (Supplementary data, Fig. S2). In fact, in that period peaks of several degrees were observed alternatively in the right and left sides of the west wall, depending on the month and hour of the day, combined with the geometry of the building (in particular the position, height and width of the windows) [1]: from middle September to November in the left side, whilst from November to January in the right side, then from February to end March again in the left side (Supplementary data, Fig. S3). The peaks were detected in the morning due to the impact of solar radiation passing through the windows of the south wall (Fig. 2).

As for temperature, there was no remarkable difference in the RH average values measured at the bottom of the statues at the two sides (Supplementary data, Fig. S4), but only in the minima, related to the maxima of temperature.

The natural climate change throughout the year influenced also the thermal vertical profile inside the Temple, where the impact of the seasonal thermal wave was smoothed by the roof mass. As a consequence, the thermal vertical profile showed conditions of stability or instability [12] depending on season, hour (day or night) and position (low-middle-high levels). The analysis of the thermal profile related to the low and high levels indicated that for more than a half of total time (59%) there was instability. This condition favors the transport of the pollutants that enter the Temple through the doors or that are brought in by the visitors towards higher levels where the most valuable works of art are located.

The results of the anemometric measurements indicate that the wind generally came in through the southeast door and went out through the door located just below the statues (Fig. 1) [11], blowing mainly on the right side of that wall.

4.2. Thermographic measurements

The spatial distribution of the surface temperature (Ts) of the stucco statues of the west wall was investigated by thermographic measurements in different seasons and moments of the day. In particular, the analysis of the thermograms resulted in two horizontal and six vertical profiles described in details in the e-supplement (4.2.A).

In general, when the sun was not hitting the west wall, the thermal horizontal profiles were quite uniform, whilst the vertical profile of each statue showed Ts slightly decreasing from the head to the feet (Supplementary data, Fig. S5). The temperature of the feet was strongly influenced by the thermal inertia of the wall beneath, whilst the temperature of the more protruding heads was the result of their thermal exchanges with the nearby atmosphere. Besides this general tendency, the absolute values of the gradients