A METHODOLOGY OF DAMAGE ASSESSMENT IN CULTURAL HERITAGE: MICROCLIMATIC MONITORING

DELIA D’AGOSTINO
ISUFI, University of Salento, Italy, deliadago@libero.it

The main objective of the paper is to identify the influence of the thermohygrometric parameters on decay processes in cultural heritage. A case study is presented focusing on microclimate monitoring to investigate the environmental conditions and to gain a better insight into the state of conservation.

Keywords: environmental conditions, microclimate, cultural heritage.

INTRODUCTION

Physics, and more recently archeometry and microclimatology, are useful sciences with which to diagnose and resolve the problems related to the conservation of cultural heritage (Castellano et al., 2007). The importance of microclimatological surveys is widely recognized in the preservation and restoration of cultural heritage (Baer, 1996).

It is well known that the microclimate is the synthesis of the environmental physical conditions both due to natural (atmospheric variables, i.e. temperature, sunshine, airspeed, humidity) and manmade forcing factors (i.e. exchanges with bodies by infrared emission, heating, ventilation) (Camuffo, 1998).

Daily temperature and relative humidity cycles can be induced by several factors such as heating, air conditioning devices or lighting and cause damage such as mechanical stress in materials (Warscheid, 2000). The main physical cause favoring degradation is moisture transport within the pore system and its changes of state. The thermohygrometric gradients are involved in the dangerous processes leading to irreversible damage above all in delicate works of art (paintings or wooden artifacts) (Gysels et al., 2004).

Many factors are involved in decay mechanisms, a survey cannot investigate all the processes or continue for a time interval representative of all the possible situations, but it should document the major different conditions in order to identify a typical microclimatic assessment (Camuffo et al., 2002).

Therefore a detailed characterization of the indoor microclimate in cultural heritage can lead to improvements in the environmental conditions and the knowledge of the state of conservation (Cataldo et al., 2005).

Here a case study is presented as an example of the application of a methodology to insight into the processes leading to damage focusing on the behavior of the thermohygrometric parameters. This paper proposes microclimatic monitoring to localize space gradients, frequency of oscillations, time and space distributions of temperature and relative humidity on the vertical supporting structure of a cultural building. The results of the surveys can be used to improve the knowledge of the causes of the deterioration and to plan further investigations.
HISTORICAL AND ENVIRONMENTAL CONTEXT

The cultural building under investigation is the Crypt of the Cathedral of Lecce, a Mediterranean city in the Apulia region (Italy) (Figure 1). In order to gain a more detailed knowledge of the historical and artistic nature of the monument, an archive and library research was aimed at discovering the origins, changes and interventions of restoration.

The Cathedral of Lecce, dedicated to the Assumption of the Virgin, is one of the most interesting cultural buildings in South Italy. It was first built in Norman times (1114), reconstructed during the time of the Svevans (1230) and then in the Baroque era, from 1659 to 1670, in a project instigated by Giuseppe Zimbalo to orders by Bishop Luigi Pappacoda (Paladini, 1956).

The Crypt (Figure 1b) is located under the Cathedral and it is built with the local soft limestone called Lecce stone. It dates back to the construction of the first Cathedral, rebuilt at the beginning of the 16th century on the pre-existing structure and over the centuries has undergone numerous transformations (Calvesi-Manieri, 1976). It has a Greek cross plan, with three aisles and 92 monolithic columns with Romanesque capitals and it is situated about 3 meters under the actual street level.

![Figure 1. a) Study site localization, b) the Crypt of the Cathedral of Lecce](image)

The Crypt shows evidence of deterioration on the columns and on the walls made in Lecce stone which make up the vertical supporting structure. The most obvious phenomena, as shown in Figure 2, are efflorescence, moulds, fractures and pulverization of the stone.

![Figure 2. Deterioration in the Crypt: a), c) efflorescence; b) deterioration of a fresco; c) fractures, pulverization of the stone and moulds; d), e) exfoliation and crumbling plaster](image)
As these processes cause damage which over time can compromise the stability of the structure, the monitoring system was designed not only to record the interior microclimate, but also to assess how the building envelope is behaving as a climatic/hygrical buffer, and the possible incidence of condensation (Sawdy & Price, 2005).

MATERIALS AND METHODS

Microclimatic measurements are usually taken by psychrometer on horizontal cross section on selected grid points representative of the environment of a building, in order to see the spatial distribution of the indoor thermohygroscopic parameters (Camuffo, 1998). In this study measurements were taken along the perimeter walls (Figure 2) and in a vertical section of selected areas (Figure 3).

A preliminary survey was aimed at identifying the walls subjected to the most significant variations in temperature and relative humidity. With this aim, measurements were taken by a TECNOEL psychrometer (reading resolution 0.1°C) on a grid of 77 points along the vertical supporting structure of the Crypt (Figure 3a).

![Figure 2. Measurements grid along the vertical supporting structure of the Crypt](image)

In Figure 3 the graph related to the measurements taken along the perimeter walls is reported. The microclimatic condition appears quite stable with temperature values between 12.8 °C and 13.9°C and relative humidity from 62% to 71%. Area D in Figure 2, corresponding to the measurement points numbered from 16 to 24, appeared to be subjected to significant temperature and relative humidity gradients and was chosen for the following investigation.
RESULTS AND DISCUSSION

The collected data on the grid in Figure 4 were interpolated by Kriging method on Arcview GIS to obtain the spatial distribution of the main thermohygrometric parameters on the wall surfaces of the north apse of the Crypt, at different hours during a day.

Figure 5 shows a typical behaviour of temperature and relative humidity distribution in the vertical section of area D, related to February 2009 when outdoor relative humidity was 76% and temperature 11°C.
Figure 5. Spatial distribution of temperature a) at 8am, b) at 4pm, and of relative humidity at c) at 8am, d) 4pm (Area D in Figure 3)

Looking at the areas with the most gradients, corresponding to the darkest colour in the legend in Figure 5, some considerations can be made. The greatest variations in relative humidity occur in the morning while in the afternoon its distribution on the walls appears to be more uniform (Figure 5b and 5d). The values of relative humidity appeared particularly high, reaching 80% near the window above the statue and near the floor (Figure 5b and 5d). This fact suggests a contribution of humidity coming from the subsoil by capillary rising (Hall, 2002). Spatial and temporal temperature variations (Figure 5a and 5c) could be determined by convective motions that bring warm and damp air upward inside the Crypt. Moreover, comparing the data related to this area to that of the surrounding air, it can be seen how the walls have lower temperature and humidity and so evaporative conditions are present on the walls. All these phenomena are favoured by the relatively stable microclimatic conditions inside the Crypt and
suggest two important contributing causes to the evidence of decay (Figure 2): capillary rise of water and infiltration of rain from the windows.

CONCLUSIONS

The microclimatic monitoring surveys in the Crypt allowed us to obtain important and useful information on the damage processes in progress into the cultural building.

The indoor microclimate appeared quite stable and is characterized by high values of relative humidity and air temperature, with a poor air flow through the environment.

An area subjected to significant thermohygrometrical gradients was checked by a psychrometer and it was chosen for other investigations. On the walls of this area the main processes leading to damage were related to the behavior of thermohygrometrical parameters. As the humidity was lower in contact with the walls than in the air, the evaporative conditions appeared to prevail over those of condensation. The presence of water and moisture by capillary rising from the ground and infiltration from the windows was identified as the cause leading to the visible damage in the form of efflorescence, pulverization of the stone, exfoliation and crumbling plaster. All the processes are increased by the porosity and absorption of the Lecce stone (Calia et al., 2008).

The microclimatic monitoring allowed us to assess the processes of environmental damage in the cultural building studied, achieving knowledge of the indoor conditions useful for planning other investigations for the diagnosis of the conservation state of the building.

REFERENCES


