A METHODOLOGY OF DAMAGE ASSESSMENT IN CULTURAL HERITAGE: GRAPHIC DECAY MAPPING

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This study focuses on the characterization of decay in cultural buildings using photographic documentation and in situ observations. A methodology was carried out to investigate both spatial and temporal changes of deterioration evidences. The results are useful to assess the processes of damage in progress.

Keywords: deterioration evidences, graphic documentation, cultural heritage.

INTRODUCTION

Over the last half century, the importance of preservation of historic buildings has risen as the awareness of the sense of identity and continuity they can provide for future generations (Baer, 1996).

Many interdisciplinary studies have been undertaken to find appropriate solutions to environmental and conservation problems for cultural heritage protection (Feilden, 2000). The theme of conservation of cultural heritage seeks to create an ideal balance between protection and use by the public.

In recent decades there has been an increasing focus on all areas of conservation in an interdisciplinary approach. Numerous studies have shown the complexity of relationships between physical, chemical, and biological processes involved in the degradation and the consequent necessity for interaction among the various disciplines involved (Cataldo et al., 2005).

Cultural heritage materials are subject to continuous chemical and physical changes depending on the establishment of a dynamic equilibrium with the environment in which they are placed and their own characteristics (Camuffo, 1998). In particular, changes in relative humidity and temperature play a key role in the activation of biological or salt damage, frequently encountered problems in the field of conservation. Different decay phenomena can occur, leading for example to the formation of deterioration such as black crusts, corrosion of the material, internal cracks (Camuffo, 1995).

Maintenance is considered the most effective way to slow down the unavoidable ageing of stone monuments, but it first needs careful and systematic monitoring to acquire information before planning and designing interventions (Calia et al., 2002). This monitoring should focus on the structure, the architectural surfaces, the decorative elements and the constituent materials.

This paper looks at damage assessment in relation to the environmental conditions in the Crypt of the Cathedral of Lecce (South Italy). This historical building, rebuilt several times from 1114, shows on its walls and columns, made up of the local Lecce stone, efflorescence, pulverization of the stone, exfoliation and crumbling plaster.

A preliminary microclimatic investigation clearly identified the main role of the thermohygrometric parameters on the decay processes in progress. This study determined the indoor microclimate as quite stable and characterized by high values of relative humidity and air temperature, suggesting two important factors contributing to the deterioration: capillary rise of water and infiltration of rain from the windows. But
observations have been coordinated with microclimate measurements to explain the real processes occurring in situ (Arnold & Zender, 1991).

Therefore another accurate investigation for the diagnosis of the conservation state of the building was needed. This work focuses on the approach of a decay mapping methodology obtained by combining photographic documentation and in situ observations.

The discussion of the results can improve the knowledge of the complex dynamics of the monument under investigation. All findings represent a preparatory phase in correctly planning future conservation works in order to mitigate, if possible, the main causes of the processes of deterioration.

MATERIALS AND METHODS

The area in Figure 1, corresponding to a north-facing apse of the Crypt, was chosen to implement the graphic decay mapping. On the walls of this area aspects of conditions were documented both by practical direct observations in situ and photographic elevations.

![Figure 1. The area monitored](image)

The study area in Figure 2 was divided in 7 subareas that were periodically monitored. Each picture was corrected from distortions using graphic software (Gimp image analysis). Photographs taken from non orthogonal positions, such as the subareas numbered 2,3,5,6 in Figure 2, were straightened up and calibrated on the correct scale.

![Figure 2. The studied area: vertical section of the walls of the selected apse of the Crypt (by Autocad 2008)](image)
The images were then exported to the map of the area, reproduced with Autocad 2008, and processed by the same software in order to convert the graphic relief in digital format.

RESULTS AND DISCUSSIONS

The main types of decay were identified following the Normal 1/88 “Macroscopic alterations of stone: glossary” (CNR-ICR) and are reported in Table 1.

In the mapping, aspects of conditions were distinguished according to the kind of substratum: plaster and Lecce stone. This factor is essential for damage assessment as the local limestone constituting the wall’s structure is characterized by high porosity (30-40%) and sorptivity, in the range 0.5 mm/min$^{1/2}$-1.5 mm/min$^{1/2}$ (Calia et al., 2002).

Table 1. Types of decay mapped in the study area

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Lecce stone</th>
<th>Plaster</th>
<th>Type</th>
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<tbody>
<tr>
<td>Efflorescence</td>
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<td>Chromatic alteration</td>
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<td>Detachment</td>
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<td>Fractures</td>
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<tr>
<td>Absence of plaster</td>
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<tr>
<td>Pulverization</td>
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<tr>
<td>Capillary rising</td>
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<td>Water infiltration</td>
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All the types of decay identified are related to the presence of water/moisture and lead to different evidence of damage. Salt efflorescence is the most widespread one but other relevant types of decay are: chromatic alteration, detachment, fractures, absence of plaster, pulverization of the material, capillary rising and water infiltration. The main driving factor in the salts diffusion in the masonry appears to be the environmental conditions and the water migration into the wall corresponding to evaporation-condensation cycles (Hall, 2002).

The maps were reproduced identifying the periods showing more variations (Figure 3) in order to underline the temporal and spatial changes of the manifested decay. The behaviour pattern is illustrated in Figure 3, which reports the distribution of the aspects of conditions on the walls of the apse, related to the mapping of each decay type over a one year period.
The comparison of the maps of the graphic documentation in Figure 3 shows an important amount of change in the distribution and the relative abundance of decay evidence from November 2008 to December 2009.

In general, in comparison to the other seasons, the highest growth of efflorescence is present in the autumn months.

Figure 4 summarizes the percentage of surface area covered by efflorescence, calculated from the graphic documentation by a specific tool of Autocad. The periods showing the highest efflorescence diffusion (about 21%) are between November 2009 and December 2009 and November 2008 and January 2009, followed by February and May 2009 (19%). The period characterized by the lowest efflorescence spreading on the walls is from June 2009 to October 2009 (12% of the total area). After this period, salts
start to grow again showing a comparable diffusion in the period from November 2009 to December 2009 to that of the previous year.

Figure 4. The rate of area covered by efflorescence in the study period

The most probable explanation for the variation observed in salt distribution is that they undergo phase transitions from crystalline to aqueous solution and vice versa, in response to moisture transfer between the building fabric and its environment (Moreno, 2006).

Salt accumulations originate from the ions leached from rocks, soils, stone and other materials used in building, as well as those deposited from the compounds of natural and polluted atmosphere, and generated by the metabolism of organisms (Arnold & Zender, 1991). Analysis of the efflorescence samples showed that the most common salt is nitre (KNO$_3$) with a little gypsum (CaSO$_4$). The presence of nitre as a component in such salt deposits could be attributed both to the fact that the Crypt was built on organic matter, probably to bury noble men and priests (Paladini, 1923), and also to the infiltration of domestic dwellings. From these data, some hypothesis on the origin of the salts can be made. When rain water is absorbed into the stone, it dissolves the CaCO$_3$ of the Lecce stone that constitutes the Crypt and over time the salts deposit on its surface. They originate as the Ca$^+$ in solution mixes with the SO$_4^-$ up into the stone from the ground which dries as gypsum. As water percolates through the material, it accumulates nitre that originated from the ground. The difference in solubility between nitre and gypsum is very significant (Sawdy, 2005). Due to the low solubility of gypsum this precipitates first on evaporation while nitre crystallizes later in the evaporation process, resulting in greater purity. When KNO$_3$ becomes supersaturated and starts to crystallize, Mg$^+$ and Na$^+$ can also become incorporated in the KNO$_3$ lattice.

The situation is particularly dangerous for the plaster-covered walls because transpiration and evaporation of the stone are blocked. The result of this is that capillary rising occurs with maximum intensity without decreasing due to evaporation. This water, reach in salts, leads to detachment, loss and “absence” of the plaster.
CONCLUSIONS

To preserve cultural heritage it is indispensable to understand the genesis and behaviour of the chemical and physical processes damaging the structure and the conditions under which decay occurs.

This paper provided a detailed diagnosis of deterioration evidence in the Crypt of the Cathedral of Lecce, using a graphic documentation methodology obtained by combining observations in situ and photographic elevations converted into digital format.

As in other historical constructions, in the Crypt damage development is favoured by the hypogaeum position and several incorrect interventions, such as the application of plaster on the masonry.

Decay mapping showed that all the types of alteration (chromatic alteration, detachment, fractures, lack, pulverization of the material, capillary rising and water infiltration) were strongly coupled with the presence of water and moisture in the walls. But a closer examination of the nature and processes of the decay phenomena revealed that a principal cause is the activity of soluble salts. The scenario appeared variable during the seasons, with a lower diffusion of efflorescence during the summer months, but closely connected to the microclimate and always enhanced by unsuitable environmental conditions.

The results of this work are essential for the planning of future interdisciplinary investigations and conservation actions.

REFERENCES


