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From the context knowledge to Assessment of the Architectural Heritage decay: the case of Santa Maria di Vezzolano rectory (AT)

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***Abstract* – The rectory of Santa Maria di Vezzolano in Albugnano (Asti, Italy) has recently been the subject of a restoration project aimed at solving the deterioration involving the external walls and in particular the main façade. In order to support the plan of restoration project, geophysical and chemical investigations were carried out with the aim of investigating and understanding the causes of decay phenomena. The diagnostic campaign was aimed at documenting the water paths and at understanding which saline species were formed as a result of the progress of the degradation, understanding their origin (linked to capillary rising phenomena and consequent dissolution of constituent and/or restoration materials). Salts migration and consequently stone material erosion were correlated with the evidence provided by non-invasive techniques: the presence of water in the internal walls detectable in IR thermography, and in the subsoil, detectable by geoelectric investigation.**

I. INTRODUCTION

The rectory of Santa Maria di Vezzolano in Albugnano (Asti, Italy) was founded in 1095 AD. The Romanesque façade is made of bricks alternating with horizontal bands of sandstone, on the side buttresses, and by a sculptural decoration of transalpine connotation arranged on several registers and concentrated in the central part of the façade (Fig. 1). Between the 12th and 13th centuries the structure experienced its period of maximum magnificence, followed by a phase of progressive decline which lasted until 1800.

Fig. 1. Façade of rectory of Santa Maria di Vezzolano in Albugnano (Asti, Italy).

In 1937 the complex was handed under the management of the Italian State and is now part of the cultural heritage sites of the Regional Directorate of Piedmont Museums, peripheral institute of the Ministry of Culture.

After several campaigns of monitoring for verifying the progressive worsening of the state of decay of the constituent stone materials, it was necessary to start a deep diagnostic study of the façade and its environmental context with the aim of defining an intervention method for the maintenance in safety of the constituent elements in order to safeguard their material integrity. Rocks composing the façade are mainly of sedimentary nature, with a marked clay component, whose continuous exposure to atmospheric phenomena and humidity has compromised its physical stability. In 2022, to support the executive project of the conservation intervention, geophysical and chemical investigations were carried out with the aim of investigating and understanding the causes of decay phenomena. The geophysical investigations planned for the technical-scientific study of the building and its context were aimed at:

- to verify the current state of conservation of the internal and external masonry structure, with particular reference to the main façade, through the localization of detachments, decohesion, water infiltrations and other phenomena of alteration of the constituent materials that compromise the structural and aesthetic integrity;
- to identify any causes of previous or ongoing degradation possibly related to the presence of underground water in the context in which the rectory stands.

Furthermore, to identify the degradation products widely visible in the lower portion of the façade, ion chromatography analyzes were carried out on three samples for the characterization of the saline efflorescence visible at different altitudes from the ground level.

This investigation was aimed at understanding which saline species were formed as a result of the progress of the degradation, understanding their origin (linked to capillary rising phenomena and consequent dissolution of constituent and/or restoration materials) and possibly correlating them with the evidence provided by non-invasive techniques, in particular the presence of water in the structure itself, detectable in IR thermography, or in the subsoil, detectable by geoelectric investigation. For these purposes, the following investigation methodologies were applied: Electric resistivity tomography (ERT) or geoelectric with laying along part of the external perimeter to evaluate the presence of groundwater that may affect the Canonica complex; IR thermography for the verification of thermal anomalies correlated to water infiltrations from the roofs, capillary rising phenomena or other deteriorations in the masonry.

II. MATERIALS AND METHODS

The Ion chromatography analysis (IC) provided a quantitative characterization of the different samples analyzed. In particular, degradation products namely salt efflorescence, widely visible in the lower portion of the façade were taken at three different heights of the investigated façade (Table 1; Fig. 2).

IC is a method that enables determination of the concentrations of analytes in an unknown sample [1].

Table 1. Details of salt efflorescence sampling.

Sample ID	Location	Height above the ground level
Vez_01	main façade, right side	90 cm
Vez_02	main façade, right side	40 cm
Vez_03	counter-façade (corresponding internal side)	95 cm


a) b) c)

Fig. 2. Sampling areas of the three saline efflorescence samples analysed by ion chromatography: a) Vez_01; b) Vez_02; c) Vez_03.

A Dionex DX 120 equipment on filtered supernatant (filter Minisart RC 25, diameter = 0.45mm) provided ion-chromatography data on analyzed samples, determining ionic species such as SO_4^{2-}, $NO3^-$, Cl^-, F^-, Br^-, Li^+, NH_4^+, Na^+ K^+, Ca^{2+}, and Mg^{2+}.

Infrared thermography (IRT) is a non-destructive technique widely employed in the analysis of Cultural Heritage [3] [4]. In fact, IRT represents a fundamental tool in the CH diagnostic field for the conservation state assessment thanks to the possibility of deter-mining the temperature of a surface by measuring the IR radiation emitted by each object as a function of the T°C. This technique is useful, for example, in the detection of superficial cracks, detachments, material differences, or moisture presence within structures. Indeed, the compositional or structural inhomogeneities, at or below the investigated surface, locally affect the homogeneous heat propagation and result in thermal contrast in the thermogram. In the present case, a FLIR model B335 thermal imaging camera equipped with an uncooled microbolometric thermal sensor (320 × 240 pixel resolution, from -20°C to + 120°C thermal range, +/- 2% of the detected temperature accuracy; 7.5 ÷ 13 µm spectral range; 1.36 mrad spatial resolution; embraced field 25° × 19°) was used (Fig. 3a). The camera is also equipped with a 3.1 Mpixel photographic sensor that allows the acquisition of the thermal image at the same time as the visible one, with the same shooting conditions. The IRT investigation was performed without induced artificial warming of the surfaces, acquiring the data under different climatic conditions in order to take advantage of the natural heat exchange between the structure and the environment.

The 3D electrical tomography was acquired using the Iris Syscal Pro Switch georesistivimeter with 72 steel electrodes and multipolar cables with interelectrode spacing up to 3 m (Fig. 3b).

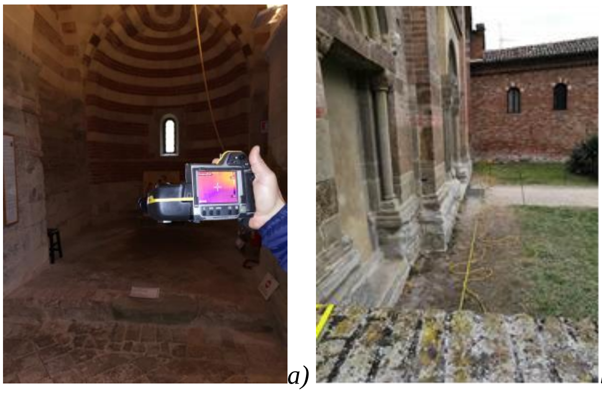

Fig. 3. Example photographic documentation of the geophysical survey methodologies: a) Geoelectric and b) IR thermography carried out for the diagnostic study of the Vezzolano Rectory.

Given the geological characteristics of the site and the slopes of the land surrounding the Rectory, it was not possible to arrange the electrodes according to a uniform grid, therefore we opted for a "C" survey created by positioning the electrodes along the elevation, the side nave and the apse of the rectory, according to the scheme shown in figure 4a. The locations of each electrode along the "C" array were georeferenced through a detailed topographic survey (Fig. 4b).

The use of the full-range gradient technique allowed a large part of the volume to be investigated with good resolution, although obviously the greatest resolution is obtained in the areas close to the electrodes.

A total of 2831 apparent resistivity measurements were acquired.

The data inversion was performed using the RES3DINVx64 v. 3.13 of Geotomo Software. For the discretization of the inverse model, a grid of 27x34 nodes, equidistant 1.7m, was chosen so as to cover a rectangular area of 44.2m by 56.1m, including the positions of all used electrodes. Topographical correction was done using a GPS positions.

Finally, a 3D rendering of the resistivity data (Fig. 6) was performed using Voxler software (Goldensoftware LLC).

Fig. 4. ERT: position of the "C" array (a) and topographic survey of the measurement points (b).

III. RESULTS AND DISCUSSION

The IR thermographic investigation allowed to document:

1. the absence of damp fronts along the external perimeter;
2. the immediate location of the areas of greatest deterioration (detachment, decohesion, fractures) of the

sandstone blocks that make up the base of the elevation. Such areas are sharply differentiable from contiguous more cohesive areas because they appear as warmer areas in the thermograms;

3. that neither the vault nor the walls are currently affected by water infiltration from the roofing system; slight capillary rising fronts can be observed along the lower part of the internal wall of the lateral nave;

4. rising damp along part of the side nave flooring, along the portion closest to the apse area (Fig. 5).

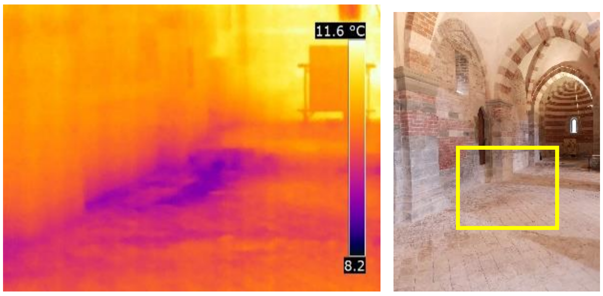

Fig. 5. IRT and localisation of the investigated area: The lower part of the internal masonry and the flooring show the presence of rising damp.

The geoelectrical investigation found the presence of underground water, providing useful elements for understanding the evident and continuous process of degradation involving the sandstone ashlars of the elevation as well as the other perimeter walls and which caused the ineffectiveness of the previous consolidating treatments (Fig. 6).

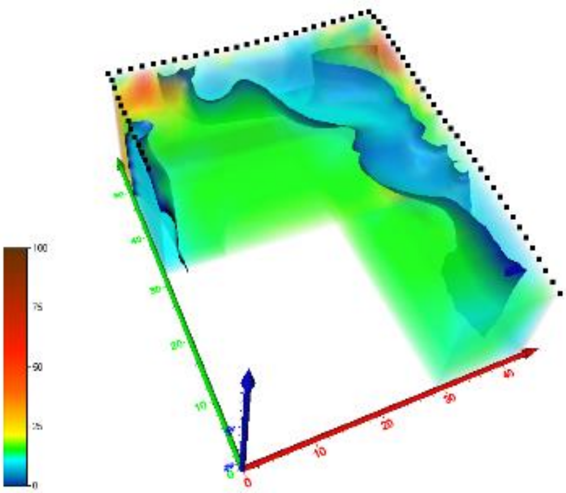

Fig. 6. 3D rendering of the resistivity data

The inverse model of electrical resistivity showed, in fact, the presence of two lines of water flow which run following the two natural slopes of the site and induce an accumulation of underground water along the road which flanks the side nave up to the main elevation and along the slope that flanks the apse area.

The accumulation of water present in the subsoil found by the geoelectrical analysis on the inspected portion of the perimeter can be correlated to the evidence of capillary rise revealed in thermography along the pavement and the lower portion of the internal walls. The total absence of rain [5] in the months prior to the investigation period (April 2022) and the lack of other thermal anomalies associated with the presence of rainwater further confirm the correlation between the presence of water in the subsoil and the degradation which has induced evident exfoliation, detachments and loss of material of the sandstone blocks constituting the lower part of the elevation directly in contact with the ground.

The efflorescence and sub-efflorescence salts formation, characterized by ion chromatography analyzes (in order of abundance sulphates, chlorides and nitrates of calcium, magnesium, sodium and potassium), is therefore to be associated with capillary rising phenomena within about 1 meter from the floor level.

These phenomena of exfoliation and decohesion of the stone structure in some cases in the thickness immediately below the surface are explained both by the typical degradation of the stone used and by the effects of the ethyl silicate consolidation (applied to waste) carried out in the nineties with a consequent increase of sub-surface porosity and acceleration of material loss, as demonstrated by studies conducted 10 years after restoration [4].

IV. CONCLUSIONS

The diagnostic program defined and carried out to support the planning of the restoration works of the regular rectory of Santa Maria in Vezzolano - Albugnano (AT) had the aim of identifying data and information both on the building and on the context useful for understanding the phenomena of previous and ongoing degradation.

The illustrated case underlines that the knowledge of the territory, of the context and of the constituent and degradation materials, allows possible to steer the methodological choices for defining the correct restoration project, starting to the understanding of whole degradation phenomenon, in order to make the conservation interventions on the façade and external walls of Santa Maria di Vezzolano rectory as more sustainable, effective and durable.

REFERENCES

[1] OSU Chemistry REEL Program. Available online:

https://research.cbc.osu.edu/reel/research-modules/environmentalchemistry/instrumentation/instrument-calibration/ion-chromatography-theory/ (accessed on 19 June 2023)

[2] Mercuri, F.; Cicero, C.; Orazi, N. et al.; Infrared Thermography Applied to the Study of Cultural Heritage. Int. J. Thermophys. 2015, 36, 1189–1194. https://doi.org/10.1007/s10765-014-1645-x

[3] Moropoulou, A.; Avdelidis, N.P.; Karoglou, M.; Delegou, E.T.; Alexakis, E.; Keramidas, V. Multispectral Applications of Infrared Thermography in the Diagnosis and Protection of Built Cultural Heritage. Appl. Sci. 2018, 8, 284. https://doi.org/10.3390/app8020284

[4] Cantisani et al. "L'arenaria utilizzata nell'Abbazia di S. Maria di Vezzolano (AT): verifica dei trattamenti di consolidamento", Atti del convegno "Scienza e Beni Culturali XVI 2000, pp. 151-162.

[5] http://www.arpa.piemonte.it/pubblicazioni-2/relazioni-tecniche/analisi-eventi/eventi-2022/rapporto-siccita-in-piemonte-2022