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Restoration of rising damp in the Sassi of Matera through the use of innovative technologies

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Abstract. The millennial bond between the city of Matera and its calcarenite rock is of fundamental importance to understanding the history of the city's architectural heritage.
Calcarenite, a sedimentary limestone rock of biochemical origin, is easily workable but is characterized by low mechanical resistance and significant vulnerability to biological and physico-chemical degradation processes, especially those related to the presence of water.
Starting from the eighties of the last century, when a strategic plan for the recovery of the Sassi was launched, numerous restoration projects have been carried out. Furthermore, improper repair and rebuilding of masonries have profoundly altered the aesthetic and formal value of the buildings. Despite these challenges, Matera's architectural heritage gained significant recognition in 2019 when the city was designated as the European Capital of Culture.
Configuring itself as a laboratory of experimental restoration practices, Matera is well suited for analysis aimed at identifying the best practices currently available in the field of architectural heritage conservation. Therefore the paper is focused on the critical analysis of interventions carried out on three emblematic cases of the city that have suffered significant surface deterioration due to environmental and construction factors, as well as the presence of rising damp in the walls: the Church of San Pietro Barisano, the Church of San Francesco D'Assisi and the Diocesan Museum.
From these studies it was possible to identify the general procedural aspects that lead towards the proposal of a protocol of best conservation practices, which pays attention to every phase of the design process.

Keywords: Sustainable conservation, Calcarenites, Degradation phenomena, Innovative technologies, Non-invasive diagnostic

1 Introduction

The connection between Matera and its calcarenite rock is crucial for understanding the city's architectural heritage. Calcarenite, a sedimentary limestone rock of biochemical origin, consists of limestone granules bound together by calcitic cement or a fine-grained calcareous matrix. It's the unique composition of limestone granules that delineates the properties and characteristics of this stone material. Despite its ease of workability, calcarenite exhibits low mechanical resistance and significant vulnerability to biological and physico-chemical deterioration processes, especially in water content. [1-2-3-4]

The original matrix of Matera consisted of open caves carved into the rock, designed to utilize solar radiation passively for year-round comfort. Over time, these caves evolved into buffered caves, featuring masonry facades with an opening for the entrance door and an overhead light to ventilate and illuminate the interior. Later, the buffered caves were extended outwards with the construction of barrel-vaulted masonry, called *lamioni*, enclosed by front façades with the characteristic scaled tympanum.

Calcarenite is a material in which "nothing is wasted" [2] and the processing waste is used to fill the walls, make mortar, and plaster. The use of a single material gives the Sassi of Matera heritage a uniform appearance and ensures material compatibility, creating a perfect synergy and compactness, even structurally, between the rock and the built environment.

Starting from the eighties of the last century, when a strategic plan for the recovery of the Sassi was launched, numerous restoration projects have been carried out. Various commercial products have been used to consolidate and protect the damaged surfaces of dug and built structures [3-5]. However, many surface treatments were neither effective nor durable, with issues such as yellowing and detachments due to the chemical, physical and mechanical incompatibility of acrylic and siloxane-based materials with the stone substrate. Furthermore, improper repair and rebuilding of masonries have profoundly altered the aesthetic and formal value of the building surfaces. Despite these challenges, Matera's architectural heritage gained significant recognition in 2019 when the city was designated as the European Capital of Culture.

Since any intervention on the built heritage requires a multidisciplinary approach that includes every aspect of the construction, it is interesting to understand how degradation has been treated by analyzing the preliminary diagnostic phases (prior to restoration interventions) and the subsequent monitoring and control of their effectiveness. This consideration takes into account the delicate ecosystem of the Sassi di Matera, which requires understanding the entire context in order to arrive at a restoration protocol that allows for the rehabilitation of this architectural heritage.

Configuring itself as a laboratory of experimental restoration practices, the city of Matera is well suited for an analysis aimed at identifying the best practices currently available in the field of architectural heritage conservation.

Considering the highly variable characteristics of calcarenite, alongside the different construction types incorporating hypogea, excavated and constructed elements, and the rich historical evolution of Matera, the paper is focused on the critical analysis of interventions carried out on three emblematic cases of the city that have suffered significant surface deterioration due to environmental and construction factors, as well as the presence of rising damp in the walls: the Church of San Pietro Barisano, the Church of San Francesco D'Assisi and the Diocesan Museum, which have become the laboratories of numerous restoration experiments. [1-5-6-7-8-9-10].

2 Characterization of materials and forms of degradation

A multi-analytical methodological approach has been adopted for the preliminary evaluation of the conservation status of the case studies, including the characterization of buildings materials. Light microscopy and optical microscopy analyses were carried out on six samples taken by the facade of San Pietro Barisano. These analyses have identified a biocrimite with secondary porosity not filled by cement or matrix and the X-ray diffractometry has also highlighteda significant presence of calcite, dolomite, gypsum, quartz, nitrates and akermanite. [1]

In each of the three case studies, site inspections conducted during previous restoration interventions uncovered a widespread presence of efflorescence, sub-efflorescence and biological patinas. This has been accompanied by detachments of plasters, exfoliation of paint films, alveolization, decohesion and crumbling of stone surfaces. [1-5-7-8-9-10-11-12]

The diagnostic campaign conducted on the buildings' microclimate utilized a thermo-hygrometer Hanna Instruments model HI 18564 to measure environmental thermo-hygrometric parameters; contact thermo-hygrometer Gann model Hydromette BL UNI 11 equipped with an active electrode B 55 Bl, to determine thermo-hygrometric parameters of surfaces. [11]

The results provided by these investigations (Table 1) have shown how the presence of rising damp in the buildings is to be considered a determining factor both for the worsening of the pathological conditions and indoor microclimate.

Table 1. Environmental parameters

Church of San Pietro Barisano		
	Indoor	Outdoor
UR	79,4 %	56,3%
T air	17,5 °C	23,4 °C
T dew	13,8 °C	14,2 °C
U sp	9,81 g/kg	10,01 g/kg
Church of San Francesco D'Assisi		

	Indoor	Outdoor
UR	54,4 %	51,6 %
T air	25,9 °C	25,9 °C
T dew	15,9 °C	15,1 °C
U sp	11,24 g/kg	10,66 g/kg
	Diocesan Museum	
	Indoor	Outdoor
UR	50,4 %	34,8 %
T air	28,8 °C	27,4 °C
T dew	4,8 °C	7,9 °C
U sp	10,31 g/kg	7,80 g/kg

The presence of rising damp within the masonry of the three case studies was confirmed by thermographic surveys conducted with a “Testo” thermal camera model "890-2 Kit", which fully complies with the recommended values and ensures the reliability of the results obtained thanks to its characteristics: the geometric resolution of 640x480 pixels (with super resolution of 1280x960 pixels), and the thermal resolution of 0.04°C, and an IFOV of 0.71mrad.

Due to the widespread presence of capillary rising damp it was decided to intervene with the installation of some CNT® device to monitor the phenomenon. The innovative CNT® dehumidification system patented by Domodry® is a generator of weak impulsive electromagnetic waves, suitably modulated in a defined frequency range and totally harmless, that neutralize water molecules, rendering the polarity effect induced by the capillary's electric field null. [13-14-15-16]

As a result, the molecules can no longer be attracted by the difference in charge of the capillaries in the masonry: the rise of water is therefore interrupted at the cause, while the excess humidity already present inside is gradually expelled by spontaneous evaporation, quickly depending on the construction characteristics of the wall, the amount of water initially present in the masonry itself, and the climatic conditions of the location.

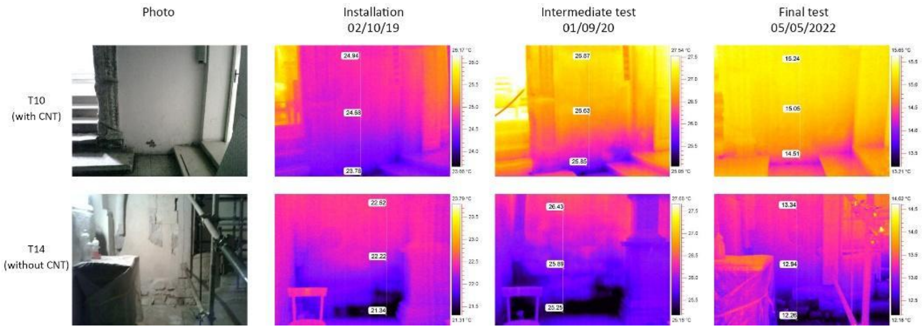

Fig. 1. Results of thermographic investigations in the Church of San Francesco D’Assisi - © 2022, photos of authors.

To monitor the effectiveness over time of this innovative technology, thermographic tests have been carried out after one year and after two or more years from the installation. These results have confirmed the effectiveness of CNT in the area covered by the device (T10), while in the area not covered by the action of the CNT device (T14), the presence of rising damp first detected persists (Fig. 1). However, once rising damp is eliminated, it is also necessary to take action to remove biological colonization and salt efflorescence that compromise the monument’s surfaces.

The buildings’ deterioration induced by the internal microclimate was exacerbated by significant external thermos-hygrometric fluctuations. Particularly with regards to soluble salts, these variations further facilitated cycles of crystallization and dissolution, hastening the disintegration of the stone substrate and the occurrence of surface alveolization.

3 Experimental interventions

In both the Church of San Pietro Barisano and the Church of San Francesco D’Assisi, all the tests carried out to remove biological patinas [8-10-11-12-17] followed the same general procedure: identification of bacterial and fungal species, selection and application of biological and/or fungicidal products, verification of the effectiveness of disinfecting treatments, surface cleaning, consolidation and protection of stone substrate.

In the case of the Church of San Francesco D'Assisi, the most striking degradation was the loss of material (alveolization, erosion), the changing in color of surface, and aesthetical decay for refacing/repair with mortar or protecting material [18].

The experimental phases involved different façade samples (Fig. 2). On the samples SFP1, SFP2, and SFP3 a commercial cleaner was sprayed. For the consolidation of the surface, two types of commercial consolidating agents based on acrylic resins were used: SFC1, SFC3, SFC4, SFC5, SFC7 samples – type 1 (one brush coat and one spray coat until saturation of the surfaces, diluted in water at a ratio of 1:5); SFC2, SFC6 sample – type 2 (one brush coat and one spray coat until saturation of the surfaces, diluted in water at a ratio of 1:10). Before proceeding with the subsequent phases, cleaning was conducted on samples as follows: employing a saggina brush on SFC2 and SFC3, and using a saggina brush followed by washing with demineralized water on surface SFC1.

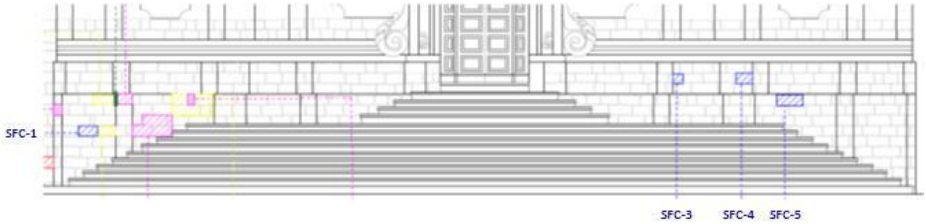

Fig. 2. Main façade of the Church of San Francesco D'Assisi with samples location - © 2022, photos of authors.

Subsequently, we proceeded with the preparation of a grouting mortar to fill a gap and create a joint, mixing tuff and lime in a 3:1 ratio on the sample previously treated with consolidant. On the surfaces of samples SFC10 and SFC12, a spray coat of consolidant with water repellent was applied, while on sample SFC11, a spray coat of consolidant without water repellent was applied.

To verify the effectiveness of the product, six months after application of the products, were carried out non-destructive in situ tests: Colorimetric Test (UNI EN 15886:2010) [19], conducted using a Konica Minolta CM-2600d spectrophotometer; Water Absorption Test (UNI 11432:2011) [20]; Scotch Tape Test (ASTM D3359-08, 2008) [21].

For the Colorimetric test, measurements were executed with an aperture diameter of 8 mm, specular component excluded (SCE), illuminant D65 and viewing angle of 10°. [1] In almost all treated areas, chromatic variations not visually appreciable ($\Delta E<5$) were recorded; the only exceptions are represented by zones SFC-1 and SFC4 treated with consolidant type 1, for which the ΔE values are 7.4 and 13, respectively.

Water Absorption Tests were conducted on both treated and untreated areas, with a water quantity of 5 ml and a contact time of 1 minute. In the samples SFC-1, SFC-6, and SFC-7, the treatments resulted in a decrease of approximately 50% in water absorption compared to the untreated stone; in zone SFC-4, this decrease was limited to 30%.

Scotch Tape Tests (STT), executed with a strip of adhesive paper (50 x 22 mm), are weighed using an analytical balance with a sensitivity of 0.1 mg. It is pressed onto the stone surface and allowed to adhere for 90 seconds. This test was repeated four times at each point [1] and showed that the lowest total weight (TRM) released at the end of the tests was measured in zones SFC-5 and SFC-7 treated with consolidant type 1, which therefore appears to be the most effective. No variation was recorded in zone SFC-6 compared to the untreated stone; also, in zone SFP-4, the application of the products does not seem to have yielded good results. Evaluating the material loss in each individual "tear" of each test, therefore, in terms of RM (released mass, mg/cm2), no significant differences are appreciable in zone SFC-1 compared to the untreated stone; it is also noted that in both cases (untreated stone and treated stone), the highest RM value is obtained with the last "tear," probably following the removal of the most superficial and coherent portion.

4 Discussion of results and conclusion

This study is part of a broader research project that aims to develop a digital protocol of good practices for architectural heritage conservation by promoting preventive and predictive maintenance. The results of the investigation underline the key-role of pre and post intervention diagnostics.

The critical analysis of interventions on building heritage reveals a lack of planned programs of interventions. The prevalent conservation practice envisages emergency actions on a single issue without a multidisciplinary approach focused on preventive and planned maintenance. For all these reasons, the research activities have been focused on procedural aspects for the proposal of a protocol of best conservation practices. This protocol emphasizes attention to every stage of the design process, from the preliminary understanding of the building to the monitoring and verification phases of the interventions.

The effectiveness of an intervention hinges on a thorough understanding of the building's historical context, material, and pathologies. The diagnostic plan should be founded on morphological identification of degradations, detection of thermo-hygrometric parameters and non-destructive analyses, such as IR thermography, colorimetric test, scotch tape test and water absorption test [11-12-22-23]. These analyses should serve as the foundation for any subsequent invasive tests (weight tests, optical microscopy, X-ray diffraction on powders, spectroscopy, X-ray microtomography...).

Furthermore, it is imperative that the conservation process of architectural heritage does not exclusively prioritize isolated, short-term interventions, but instead adopts a forward-looking approach towards long-term preservation. This approach ensures the continual maintenance of the heritage value and its transmission to future generations.

Achieving this goal requires complementary and synergistic interventions. Particularly in cases of rising damp, the initial priority should be the installation of an effective dehumidification system, such as the CNT device. However, it's essential to recognise that this step alone is necessary but not sufficient for fully restoring the conservation status of buildings [13-14].

5 Author contributions

Conceptualization, G.B. and A.G.; methodology, G.B.; resources, G.B. and A.G.; data curation, G.B.; writing and editing, C.R; review G.B. and C.R.; supervision, A.G. All authors have read and agreed to the published version of the manuscript.

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References

1. Bernardo G., Guida A., Porcari V., Campanella L., Dell'Aglio E., Reale R., Cardellicchio F., M. Salvi A., Casieri C., Cerichelli G., Gabriele F., Spreti N. Culture Economy: Culture Economy: Innovative strategies to sustainable restoration of artistic heritage. Part II. In: Atti del XXII Convegno Internazionale Diagnosis for the Conservation and Valorization of Cultural Heritage. p. 325-334, Cervino Edizioni, ISBN: 978 88 95609 61 4, Napoli, 9-10 Dicembre 2021, 2021
2. Giuffrè A., Carocci C. Codice di pratica per la sicurezza e la conservazione dei Sassi di Matera. Edizioni LA BAUTTA, Matera 1997
3. Lettieri M., Calia A., Mecchi A.M., Quarta G.Consolidation treatments on highly porous calcareous stone: a review of methodologies and products. Proceed. 6th International Symposium on the Conservation of Monuments in the Mediterranean Basin, Lisboa, 442-227, 2004
4. Andriani G.F., Walsh N. Physical properties and textural parameters of calcarenitic rocks: qualitative and quantitative evaluations. Engineering Geology 67, 5-15, 2002
5. Bernardo G., Guida A., Porcari V.D., Visone F. The Preventive maintenance of the religious heritage of the city of Matera, Italy. In Palla F., Rusu I., Lanteri L., Pelosi C., Apostolescu N. 12th European symposium on religious art, restoration & conservation. Proceedings Book. Kermes, Torino, 2022
6. Delle Cave V. Metodologie innovative di processo e di prodotto per la conservazione e manutenzione del Patrimonio Architettonico: Architetture Ecclesiastiche nei Sassi di Matera. Tesi di laurea in Laboratorio di Progettazione V: Architettura e Patrimonio. Corso di laurea magistrale a ciclo unico in Architettura, Università degli Studi della Basilicata, A.A. 2017/2018
7. Campanella L., Dell'Aglio E., Reale R. Culture Economy: innovative strategies to sustainable restoration of artistic heritage. Part I – Development of natural gels for cleaning the stone materials of cultural heritage from iron stains and biodeteriogenic microorganisms. In Campanella L., Piccioli C., Rendina A., Romanelli V. (a cura di) Atti del Convegno – XII Convegno Internazionale – Diagnosis for the Conservation and Valorization of Cultural Heritage. Napoli, 9-10 dicembre 2021. Cervino Edizioni, 2021

8. Guida A., Porcari V.D. Innovation of the management process for the recovery and maintenance of cultural heritage. In Villegas L., Lombillo I., Blanco H., Boffill Y. REHABEND 2018. Construction pathology, rehabilitation technology and heritage management (7th REHABEND Congress). Caceres (Spain), May 15th-18th, 2018
9. Cardellicchio F., Bufo S.A., Mang S.M., Camele I., Salvi A.M., Scrano L. The Bio-Patina on a Hypogeum Wall of the Matera-Sassi Rupestrian Church "San Pietro Barisano" before and after Treatment with Glycoalkaloids. Molecules, 2023
10. Gabriele F., Bruno L., Casieri C., Ranaldi R., Rugnini L., Spreti N. Application and Monitoring of Oxidative Alginate-Biocide Hydrogels for Two Case Studies in "The Sassi and the Park of the Rupestrian Churches of Matera". Coatings 12, 462, 2022
11. Falchi A., Slanzi D., Balliana E., Driussi G., Zendri E. Rising damp in historical buildings: A Venetian perspective. Building and Environment 131: 117-127, 2018
12. Lucchi E. Review of preventive conservation in museum buildings. Journal of Cultural Heritage 29: 180-193, 2018
13. AA.VV. Venezia 2021. Indicatori condivisi per la costruzione del modello e del piano di monitoraggio e intervento. Esiti di una ricerca interdisciplinare. In Driussi G. (a cura di). La qualità dell'intervento sui beni culturali - Attualità, Problemi e Prospettive. Giornata di Studi Scienza e Beni Culturali, Venezia, 35-37, 2021
14. Castelluccio R., Vitiello V., Il risanamento delle murature affette da umidità da risalita capillare – Il metodo CNT. Luciano Editore, Napoli, 2019
15. Brevetto CH 718 393 B1 – patent ownership: Leonardo Solutions s.r.l.
16. Franzoni E. Rising damp removal from historical masonries: a still open challenge. Construction and Building Materials, vol.54, 123-136, 2014
17. Relazione sulla sperimentazione. San Pietro Barisano – San Francesco D'Assisi, Matera. D'Alessandro Restauri srl., 2020
18. Gizzi F.T., Sileo M., Biscione M., Danese M., Alvarez de Buergo M. The conservation state of the Sassi of Matera site (Southern Italy) and its correlation with the environmental conditions analyses through spatial analysis techniques. Journal of Cultural Heritage, vol. 17, 61-74, 2016
19. UNI EN 15886:2010 - Conservazione dei Beni Culturali - Metodi di prova - Misura del colore delle superfici
20. UNI EN 15886:2010 - Conservazione dei Beni Culturali - Metodi di prova - Misura del colore delle superfici
21. ASTM D3359-08: Standard Test Methods for Measuring Adhesion by Tape Test
22. SMART CITIES –SCN_00520 – "Innovazione di prodotto e di processo per una manutenzione, conservazione e restauro sostenibile e programmato del Patrimonio culturale": ricerche archivistiche e bibliografiche, Final Report
23. Falchi A., Slanzi D., Balliana E., Driussi G., Zendri E. Rising damp in historical buildings: A Venetian perspective. Building and Environment 131: 117-127, 2018