Monitoring and Conservation plans for monumental stone buildings. The case study of the Baptistery of San Giovanni in Corte in Pistoia

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Abstract. In preventive conservation of cultural heritage, regrettably, only a few concrete examples of conservation and maintenance plans for monumental assets are available. This is attributable both to the particularity of each case, which makes it difficult to draw up a standard conservation plan and to the difficulty of finding specific data to program the cyclicity of the interventions, which requires us to resort almost exclusively to continuous monitoring of monuments. On the Baptistery of San Giovanni in Corte in Pistoia, after a major restoration carried out on the occasion of the Jubilee of 2000, a series of conservation interventions on various fronts have been repeated from 2000 to today. This case was deemed particularly interesting precisely because of this peculiar palimpsest of documented interventions and has, therefore, become the subject of a doctoral research (conducted in collaboration between the University of Florence and the Superintendency of Archaeology, Fine Arts and Landscape), focused on the in situ evaluation of the durability of water-repellent treatments on stone. Starting from the results already obtained with the tests of 2108, and collected in the doctoral thesis, was organized a monitoring plan of water repellent treatments commonly used on white marble, serpentine and Tuscan grey sandstone. The monitoring data should thus merge into the assessments on which the Monument Conservation Plan is founded. This essay presents the choice of the monitoring plan, the designing of test points, the performed treatments, and the planning of the monitoring; it also shows the expected results and how datasets will converge into the drafting and management of the conservation plan. As a result, the study provides useful promptings for implementing a ‘final scientific report’ and a Conservation Plan and, in general, it deepens knowledge on preventive conservation and contributes to the systematization of data for real usefulness for the maintenance of monuments.
1. Introduction

Preventive conservation of cultural heritage is based on the principle of constant maintenance, preventing the triggering of degradation phenomena by carrying out minimal conservative interventions. This process presupposes that maintenance cycles of minimum intervention should be identified, carried out with the economic resources at disposal and, most importantly, in suitable times (before the degradation phenomena are renewed). However, this simple precept is difficult to implement when preventive conservation concerns outdoor monuments and decorated surfaces of the architecture; a plurality of factors (context, environmental factors, pollution, anthropic degradation, usability, etc.) introduces a large number of operational problems.

Among these, this study focuses on which the possibilities of programming the maintenance cycles of water-repellent treatments of stone surfaces of architecture could be. The research conducted by Martelli [1] has highlighted a lack of data concerning the durability of water-repellent treatments of stone. Such data would be on the contrary very useful for drawing up a maintenance protocol, to intervene before the protection is completely lost and the monument is, anew, subject to all pathologies related to water penetration (such as development of microorganisms, corrosion of the metallic elements present in the structure, dissolution of the carbonate matrix, moving of the salts and, following drying, their crystallization) [2], [3]. In situ tests carried out on three different lithological types (white marble, serpentine and Tuscan gray sandstone) of the walls of the complex formed by the Cathedral and the Baptistery of Pistoia, have provided [1] a first series of data, useful for assessing the durability of water repellent treatments used on these monuments. This survey was, therefore, the starting point for setting up the monitoring and conservation plan that will be illustrated below.

2. The case study

The problems of Preventive Conservation, and the drafting of Conservation plans, are numerous and heterogeneous. This research aims to investigate which tools and data can be used to schedule the cyclicity of the interventions. The case of water-repellent protective products (in particular siloxane polymers and fluorine polymers) has thus appeared emblematic: we know an intervention must be repeated but not when.\footnote{The durability assessments of traditional water-repellent protective products do not report homogeneous data. Studies on the durability of traditional water-repellent protective products provide rather uneven data. Prolonged studies have been presented by [4], [5], [6] and [7]. More structured studies can refer to [8] and [9]; some studies report an average duration of 7 (from 1-2 to 15) years [10], others a maximum of 17 years [11], others still over 20 years [12]. A summary can be found in [13].}

The case study of this research is the Baptistery of San Giovanni in Corte in Pistoia; several reasons led to this choice:

- available information on the various restorations of the last decades (from 1999-2000 to 2018),
- the presence of three different lithological types (white marble, serpentine and Tuscan gray sandstone),
- the different states of degradation of the various fronts documented over the years,
- the experimental investigation (Contact Sponge Water Absorption Test, figure 1) on the effectiveness of water-repellent treatments carried out in 2018 [1] before the last restoration,
- the last restoration carried out at the end of 2018,
- the agreement of the Superintendency and the Cathedral Church of Pistoia to carry out the tests on the monument.

![Figure 1. Contact Sponge Water Absorption Test on gray sandstone, 2018](image)
2.1. **State of conservation before the last restorations (2014 and 2018)**

The external walls of the Baptistery are mainly made of two types of metamorphic rocks, with different colors: white marble and green marble, known as the serpentine of Prato; the base is made up of a band of gray sandstone. At the time of the restorations, the facades had a very homogeneous conservative situation. The stones showed the degradation phenomena typical of these lithotypes: exfoliation, detachment of fragments and an evident biological attack. Although the diffusion of this degradation was quite ubiquitous, some parts were marked by purplish stripes (dark gray and green in correspondence with the gargoyles). The most evident alteration phenomenon manifested itself in the upper areas of the facade (pinnacles, balustrade, arches, etc.), with a vast biological attack, mainly on the north fronts, with proliferations of algal cells (pioneers in the colonization of a substrate as extremely adaptable). The growth of the microflora was evident in correspondence with the preferential flow routes of rainwater (the stagnation of humidity, together with the protection from direct sunlight, is a necessary condition for its development).

3. **The starting point and the monitoring plan**

The research mentioned above [1], has focused on determining the residual efficacy of different types of water repellent treatments for stone (polysiloxanes, fluorinated elastomers) applied on marble, serpentines and Tuscan gray sandstone, performing the Contact Sponge Water Absorption Test as a comparison test between treatments with different and known aging. The results of the research (2018 tests), shown in figure 3, [1], refer to Contact Sponge Water Absorption Test performed on different slabs. The slabs had treatments carried out in the years:

- 2000 (treatment seniority 18 years), called time \( T_c \)
- 2014 (4 years seniority), called time \( T_b \)
- 2017 (1-year seniority), called time \( T_a \)
- 2017 (1-year seniority) high anti-writing treatment with Hexafluoropropene-vinylidene fluoride on all three lithological types.

The tests have revealed significant decays in the effectiveness of water-repellent treatments even in rather short times (a few years); that would imply, wanting to pursue the path of stone protection with water repellents, close maintenance cycles (mild cleaning and repetition of treatments, biocides / protective products, within 5-6 years) to maintain high levels of protection.

These results are still not enough to estimate the confident durability of the treatments, nonetheless, they have revealed that further research progress could result and were taken as a starting point for the setting up of the new monitoring plan. More data would provide a more reliable line of decay of the protective efficacy of treatments. Thus, after the restoration carried out at the end of 2018 (consisting of the complete cleaning of the stone apparatus with the removal of patinas and consolidation of detached parts, without subsequent drafting of water repellents), in agreement with the Superintendency, it was organized a monitoring plan.

2 For this and above: white marble: polysiloxanes, serpentines: Hexafluoropropene-vinylidene fluoride, gray sandstones: polysiloxanes / Hexafluoropropene-vinylidene fluoride.
For each lithological type, a monitoring slab has been chosen, and treated (2019), only on a half, thus to have a time $T_0$ (maximum effectiveness of the treatment) and a $T_F$ (equal to 0 effectiveness of the treatment).

In the coming years, at a rate to be established (probably annually), the effectiveness of the treatments could be easily monitored by comparison of the two parts treated/untreated and the slabs with treatments performed in previous years (2014, 2017) by mean of the Contact Sponge Water Absorption Test (UNI 11432: 2011).

In detail, the monitoring plan has been organized as follow:

- identification of the sample slabs,
- application of treatments on half slab:
  - white marbles: Polymethylsiloxanes (SILO 111), figure 4,
  - serpentines: Hexafluoropropene-vinylidene fluoride (Fluorophase 3), figure 5,
  - Tuscan gray sandstone: various: as shown in the following table 1 and figure 6 and 7,

| Slab   | Treatment                              | Commercial product | Product type                                                                 |
|--------|----------------------------------------|--------------------|-------------------------------------------------------------------------------|
| A12 A  | Consolidating                          | ESTEL 1000         | ethyl esters of silicic acid (in mineral ray)                                |
| A12 A after 15 days | Water repellent                     | SILO 111           | organosiloxanes oligomers (in mineral rays)                                 |
| A12 B  | Consolidating                          | ESTEL 1000         | ethyl esters of silicic acid (in mineral ray)                                |
| A12 C  | Consolidating with water-repellent properties | ESTEL 1100   | ethyl esters of silicic acid and polysiloxanes oligomers (in mineral rays) |
| A12 D  | No treatment                           |                    |                                                                               |
| A12 E  | Water repellent                        | SILO 111           | organosiloxanes oligomers (in mineral rays)                                 |

- annually, starting from 2020, in climatic conditions similar to those of 2018 (summertime, temperature 30-35°, relative humidity 40-60%, sunny and stable conditions):
  - Contact Sponge Water Absorption Test (UNI 11432: 2011) on the new sample slabs: treated/untreated parts;
  - repetition of the Contact Sponge Water Absorption Test (UNI 11432: 2011) on the points already investigated in 2018 (figure 8).

Table 1: Water repellents treatments on Tuscan gray sandstone slab.

Figure 4. White marble

Figure 5. Serpentines

Figure 6. Gray sandstone

Figure 7. Gray sandstone
4. Assessment of the durability of water repellent treatments

As has been stated above, point 3, the available data (Ta, Tb, Tc), are not yet enough to determine the decay curves of the effectiveness of the water-repellent treatments. However, in analogy to the studies of Ferreira and Delgado [8], starting from the absorption data were obtained the percentages of the effectiveness of the treatments.

Figure 9 shows a hypothetical decay (concerning the first data collected for white marble in 2018). The new monitoring will complete the forecasting framework with a ‘Time 0’ of maximum efficacy (figure 9).

The first phase of the new monitoring plan will provide in the first year of monitoring (expected summer 2020):

- T0 (Time 0) of maximum effectiveness: slabs with 2019 treatment
- Intermediate times: slabs with known treatments performed in past years (2000 - 2014 – 2017)
  - Ta treatment 2017 (3-year seniority)
  - Tb treatment 2014 (6 years seniority)
  - Tc treatment 2000 (20 years seniority)
- TF (Final time) of zero water repellent efficacy: untreated slabs.

The transposition of the results on a time scale will provide a more reliable estimate of the decay of the effectiveness over time; in figure 10 are displayed different decay prediction curve that, at this moment, can only be hypothesized. Performing the Contact Sponge Water Absorption Test as a comparison test between treatments with different and known aging, the next measurements, would provide 5 different water-repellent efficacy landmark (T0 - Ta - Tb - Tc - TF), outlining a first protection durability curve.
4.1. Additional considerations on the state of conservation of the monumental complex

Although the Baptistery of San Giovanni in Corte is a best practice case (various interventions that have followed from 1999-2000 to today), it must be noted that these were still curative rather than preventive conservation interventions, always performed downstream of phenomena of degradation already re-triggered (Sides 1 and 2 intervention 2014 and Sides 3 and 4 intervention 2017, also with strong presence of vegetation, and Side 8 intervention 2018 strong presence of patinas and lichens).

Nevertheless, this manifestation of degradation, today (concerning the contemporary potential of cataloging, documentation: photographic/scientific, georeferencing, in short, the final scientific report), provides useful information for the Conservation Plan: from the intervention of overall

Figure 1. Degradation before the restoration of the Baptistery, 2014. North-East side

Figure 2. Degradation year 2018, South-East side

Figure 10. Hypothetical trends of decay of water repellent efficiency
restoration of 1999-2000 in fact, a major degradation was on the north sides (with presence of moss, vegetation, and algae), showing how on those sides (North exposure), the local climatic conditions are profoundly different than on the south fronts, which, even with the same or older treatment, have patinas and lichens but not excessive proliferation of vegetation and algae, figures 10 and 11.

4.2. Additional considerations on the final scientific report for monuments

Here, it is also important to reiterate the value of the final scientific report. In the restoration of works of art, the final report of the intervention takes on an increasingly important role; only a few years ago, the need to draw up a "final scientific report" has become pressing.

Our historic buildings and artistic heritage require cyclical maintenance interventions and each intervention must be calibrated on the previous one; however in the past, for the absence of any form of technical report, it was often impossible to know which treatments had been carried out and which materials had been used and this did not help the restorer to maintain correct behavior towards the work to be preserved.

Besides, the current, confused, legislation in the public procurement sectors in Italy, in which conservation of monumental cultural heritage is often confused with other construction sectors, or in which it is possible to assign assignments to figures with inadequate experience or technical preparation (not randomly, the professional figure of the restorer was also the subject of the last discussions of the law), has not allowed the monitoring of the restorations, nor the scientific research on these methods; in addition to knowing how to carry out the restoration work with skill, this figure must also be able to provide scientific documentation of the work that has been carried out. This documentation is basic because it leaves testimony of what has been done and which materials have been used, allowing better evaluations of operational choices in future interventions.

However, it is interesting to note that no remuneration is normally provided for this drafting, while certainly, the preparation of such reports entails the use of additional time outside the working hours of the restoration site. A "good" scientific report must report the analysis of the state of conservation, the technical procedures and phases of the intervention, the constituent materials, and be accompanied by adequate graphic and photographic documentation in consideration of the fact that the intervention must not be aimed only at achieving an adequate level of safety of the monument, but must guarantee compatibility and durability, integration, respect for the original conception and techniques, as well as non-invasiveness and minimization of the intervention.

5. Conclusions

The present research develops on a double observation and reflection layer: one regarding the theme of the final scientific report/monitoring plan/conservation plan, and the other regarding the specific theme of the durability of water-repellent treatments for stone.

As anticipated in the abstract, this system provides an important element of the final scientific report. On the other hand, this case proves to be an excellent test bench for some of the traditional water-repellent treatments for stone. A more reliable durability forecast can be determined; this could allow establishing when a treatment efficacy decays and must, if necessary, be repeated, both for this specific monument and, with enough approximation, also for other monuments in which analogous treatments have been carried out on similar lithotypes.

Thus, for the information collected so far, and the upcoming ones, this study will ultimately allow establishing the cyclicity of the interventions, providing a very important element for the implementation of Preventive Conservation and future investigations and comparisons with similar cases.

Finally, regarding the transfer of knowledge and method, the publications of this and similar analysis and results on freely accessible platforms are certainly to be encouraged, to make it possible to compare cases and systematize data useful for estimating the durability of treatments and for scheduling cyclical interventions.
Author Contributions
M Martelli Conception and design, collection and assembly of data, and data analysis and interpretation, M J Ybañez Worboys: performing of monitoring-slab’s treatments; M Martelli performing of experiments; V Tesi provided support, authorizations and accessibility to the monuments; MM wrote the paper (excluded MJYW’s parts), MJYW wrote paragraph 2.1, table of paragraph 3, figure 7 and paragraph 4.2.

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