ePublishing

ΕΘΝΙΚΟ ΚΕΝΤΡΟ ΤΕΚΜΗΡΙΩΣΗΣ
EKT NATIONAL DOCUMENTATION CENTRE

International Symposium on the Conservation of Monuments in the Mediterranean Basin

(2024)

Proceedings of the 11th MONUBASIN (2024)

Rope access monitoring and data management of the monumental complex in Piazza dei Miracoli in Pisa

Sara Chirico, Chiara Di Marco, Ada Rovazzani, Roberto Cela

doi: 10.12681/monubasin.8180

To cite this article:

Chirico, S., Marco, C. D., Rovazzani, A., & Cela, R. (2024). Rope access monitoring and data management of the monumental complex in Piazza dei Miracoli in Pisa . *International Symposium on the Conservation of Monuments in the Mediterranean Basin*, 83–89. https://doi.org/10.12681/monubasin.8180

https://epublishing.ekt.gr | **e-Publisher:** EKT | **Downloaded at:** 14/04/2026 06:49:26

Rope access monitoring and data management of the monumental complex in Piazza dei Miracoli in Pisa

Sara Chirico, *Opera della Primaziale Pisana OPA*, Piazza Duomo 17, Pisa, Italy

Chiara Di Marco, *Opera della Primaziale Pisana OPA*, Piazza Duomo 17, Pisa, Italy

Ada Rovazzani, *Opera della Primaziale Pisana OPA*, Piazza Duomo 17, Pisa, Italy

Roberto Cela, *Opera della Primaziale Pisana OPA*, Piazza Duomo 17, Pisa, Italy.

Abstract. Over the past few years, Opera della Primaziale Pisana has perfected a plan for periodic monitoring of the monuments in the monumental complex of Cathedral Square in Pisa. The monitoring is carried out by a group of OPA conservators specialized in rope access restoration works. The operators lower themselves from the monuments with ropes and safety harnesses to check the state of preservation of all the architectural elements.
This operational choice allows restorers to supervise architectural surfaces in their complexity without scaffolding or mobile elevating work platforms, prioritizing visitor safety. A specific inspection procedure is planned for each monument according to its complexity and features. All surfaces are visually and tactually examined, and critical issues are documented with photos. The data are reported in technical sheets, customized by AFI (Associazione Fabbricerie Italiane), that estimate the state of damage. Since 2020, this systematic approach has been integrated with a GIS (Geographic Information System) for more efficient data management and accessibility. This project simplifies maintenance planning and minimizes emergency interventions by implementing preventive maintenance procedures. Periodic inspection would save resources and be more efficient in preservation compared to sporadic restoration work.

Keywords: Rope access monitoring, Periodical maintenance planning, Piazza dei Miracoli.

1 Introduction

The importance and necessity of monitoring operations are now established issue in conservation practices, strongly connected to the concept of “preventive restoration”.

Preventive restoration focuses on the sustainable management and long-term conservation of artworks by “protecting, eliminating risks, and ensuring favourable conditions"[1] to prevent alterations to the material of the artworks. This means that the main consideration of conservative operation should not be the direct intervention in the material but rather ensuring stability in its environment and physical surroundings.

Prioritising preventive action instead of an occasional or emergency restoration work has become a fundamental part of conservation practice, especially for large monumental complexes like Piazza dei Miracoli Square.

In recent years, Opera della Primaziale Pisana (OPA) has implemented a specific method for monitoring stone surfaces based on the guidelines of the Associazione Fabbricerie Italiane (AFI), an association of major Italian cathedrals of which OPA is an active member.

AFI was founded in Pisa in June 2005, and is a non-profit association that brings together the most important institutes involved in the preservation of cathedrals, monuments, and related museums in Italy. It includes some of the most important Italian Cathedrals such as Veneranda Fabbrica del Duomo of Milan, Procuratoria di San Marco of Venice, Opera di Santa Maria del Fiore of Florence, Opera della Primaziale Pisana, Opera Metropolitana del Duomo of Siena, etc.

Over time, it activated constructive relationships with the Ministry of Internal Affairs, the Ministry of Labour and Social Policies and the Italian Episcopal Conference to clarify the legal nature of the Fabbricerie.

Proceedings of the 11th International Symposium on the Conservation of Monuments in the Mediterranean Basin, 17-19 of June 2024, Athens, Greece
https://doi.org/10.12681/monubasin.8180

In September 2017, a Technical Working Table was set up, composed of engineers and architects from the Fabbricerie, with the specific aim of embarking on a common path and setting up a systematic calendar of opportunities for comparison in order to systemise experiences and specific operations in the field of restoration and conservation interventions.

AFI Working Table focused on preventive action following the tragic accident that took place at the Basilica of Santa Croce in Florence, where a Spanish tourist visiting the Basilica died because of an accidental falling stone fragment from the architecture.

In 2019, the AFI Working Table defined a document outlining criteria and operational methods for managing and scheduling periodic inspections of all the high-located architectural elements and their deterioration, which may pose a danger to public and private safety [2].

The focus of the Monitoring Working Table was the definition of a Code for Scheduled Maintenance, which each Fabbriceria must have in relation to its economic and financial resources.

Inspection procedures were designed by the AFI technical table with the aim of obtaining a unique criterion for reading and interpreting the gravity of the phenomena for each Italian Cathedral. The operative methodology has been structured and perfected considering the complexity of working on historic buildings and the safety of the large number of visitors present in the square. It consists of an initial analytical part, which defines the health status of each monument, and a planning phase, which aims to define intervention strategies to halt the ongoing deterioration.

2 Rope access monitoring and 'AFI Inspection Sheets'

In addition to ordinary structural and conservative monitoring systems, carried out by technical staff in cooperation with the University of Pisa and various research institutions, rope access work has been introduced for monitoring issues.

The operators lower themselves from the monuments with ropes and safety harnesses to check the state of preservation of all the architectural elements.

This type of access to monument surfaces would save time and resources for the company because it would eliminate the cost and time required to set up scaffolding and the cost of hiring specific equipment, such as forklift trucks and suspended platforms.

OPA provided a rope access work training course for a group of employees, mainly restorers and technicians, who have thus become specialized in rope restoration works.

In this way, in-house conservators, through periodic visual inspections directly conduct the monitoring of architectural surfaces. The purpose of the inspection is to assess the state of preservation, identify critical issues, and contribute to the maintenance planning process. To record the observations made during the inspections, it is necessary to use an accurate architectural survey of the object of investigation, such as orthophotos, 3D surveys, and architectonic plans.

The architectural survey is an essential knowledge tool that allows the identification and location of the building's components, the dimensional and morphological features of the monument, the mapping of decay and intervention areas, and the control of the evolution of deterioration over time [3].

Fig. 1-2 The conservator is mapping critical areas on the architectural survey while suspended by ropes.

The monument is divided into 'Architectural Spaces,' made up of architectural and decorative elements called 'Components.' All the components are identified by an alphanumeric code that indicates the architectural characteristics and the position of the element within the entire monument. This code became a kind of Identity Card to which different types of documents are virtually attached: graphic representations, photographs, and descriptive sheets.

The visual inspection phase is carried out by a team of at least two conservators and planned as scrupulously as possible to optimize the space that can be inspected for each rappel, in order to minimize horizontal displacements that could be dangerous for the operator's safety. The inspection starts from the top of the monument and progressively proceeds following the vertical course of the rappel.

The position of the rope access and the number of the rappels are defined according to the morphology of the monument, the types of anchorage available, and the equipment required for working at height. All these considerations must be taken into account during the design phase.

As each monument has its own geometry, thus requiring specific procedures, a site inspection is conducted to organize the work and structure the technical aspects.

The first step is to check the accessibility of each area and create temporary lifelines where they are not present. Anchor points are then identified, and ropes are attached for the rappel down from these points. This moment is essential to ensure their structural suitability to withstand the load to which they are subjected.

According to the geometry of the architecture and possible anchors, each monument is divided into macro sections where the same rope access procedure can be repeated.

Some application examples are described below:

The Leaning Tower is a monument morphologically formed by a cylinder of overlapping rings. Each ring corresponds to an order and is composed of a stone loggia with marble columns, capitals, arches, and cross vaults.

The way to access the last two orders is easy, but in the lower orders, it's necessary to install temporary lifelines. The anchor points that can be used are the pillars of the bell cell or the columns of the lower loggias.

The biggest problems with this monument are first the slope of the surfaces and then the presence of circular lodges built from three-dimensional elements. Because of the slope, a series of additional vertical lifelines are fixed along the inclined side, to which the restorers anchor themselves to follow the incline of the tower.

Three-dimensional components, such as capitals and columns, require inspection from all four sides and therefore a large movement space; consequently, a lanyard system, anchored around the columns, is used to allow inspection from each side.

In the case of the Baptistery building, the procedure is different. The monument consists of three exterior architectural orders where architectural components are not aligned, especially between the 3rd order and the orders below. Therefore, it's necessary to carry out two different rope access procedures.

The first includes the dome and the 3rd order, and the anchorage used is the cylindrical brick element at the top of the dome. The second procedure involves the 2nd and the 1st order, where the anchorages used are the columns of the mullioned windows of the 3rd order. This differentiation is also necessary to avoid the obstacles constituted by the geometry of the building, such as the walkway on the 3rd order, which represents a protrusion of the architecture.

In the first procedure, each rappel horizontally covers a segment of the dome and a span of the 3rd order. In the second procedure, each rappel covers two spans of the 2nd order and one of the 1st order.

During the inspection, the operator proceeds to fill out the 'AFI Inspection Sheets,' which define the parameters that characterize the state of preservation of architectural 'Spaces' and 'Components' and establish the extension of the damage, in particular, the presence of any decay and the risk of elements falling.

To estimate the condition of a single ‘Space’ is considered the ratio between the number of degraded ‘Components’ out of the total number.

The AFI sheets estimate the state of damage and the consequent Alert Level (AL) value through a calculation system. Damage evaluation is classified into 5 levels (from 0 to 5), as shown in the following table [2].

Table 1. Alert level (AL) description.

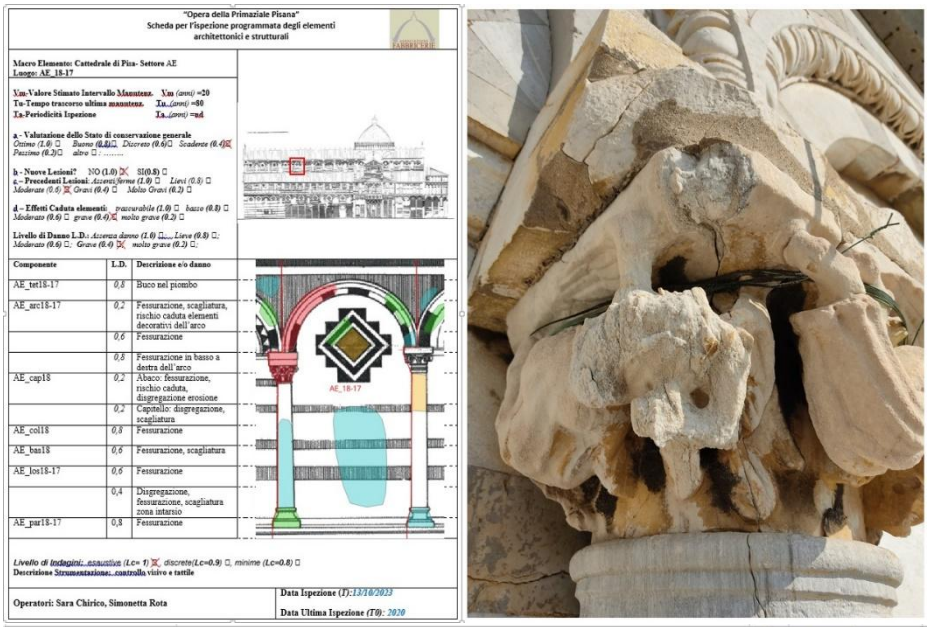
AL	Damage degree	Description
0	No damage	Elements and surfaces are in good condition
1	Light damage	First evidence of damage of limited extent
2	Moderate damage	Damage in the initial phase of development with disruption of limited extent
3	Severe damage	Marked evidence of damage in the intermediate phase of development
4	Very severe damage	Damage with parts on the verge of collapse
5	Collapse	Finds the detachment of a ‘Component’

AFI sheets AL values contents in their topic the state of conservation of each single area, frequency of maintenance and inspection, and the deterioration speed. This process may identify the main critical issues, define the date of the next inspection, and plan the conservation program for the entire monument.

During the monitoring activities, a photographic campaign has been carried out in order to document the different degradations and then digitized them within information systems. The interventions that have been defined are divided into two main classes: *Quick maintenance* activities and more *Comprehensive restoration works*.

Quick maintenance can be carried out in conjunction with inspections, for example: removal of biodeteriogens and vegetation; installation of bird deterrents; checking the condition of the lead roof by welding joints; repositioning the displaced tiles to restore the correct overlap and seal cracks to prevent rainwater infiltration; cleaning the gutters by removing any deposits and other operations.

In urgent situations, such as the presence of detached elements, immediate action can be taken by stabilizing them through anchoring or consolidation or removing them if necessary for safety.


"Opera della Primaziale Pisana"
Scheda per l'ispezione programmata degli elementi architettonici e strutturali

Macro Elemento: Cattedrale di Pisa- Settore AE
Luogo: AE_18-17

Vm-Valore Stimato Intervallo Manutenz. Vm (anni) =20
Tu-Tempo trascorso ultima manutenz. Tu (anni) =80
Ta-Periodicità Ispezione Ta (anni) =nd

a - Valutazione dello Stato di conservazione generale
Ottimo (1.0) ☐ Buono (0.8) ☐ Discreto (0.6) ☐ Scadente (0.4) ☒ Pessimo (0.2) ☐ altro ☐ .....

b - Nuove Lesioni? NO (1.0) ☒ SI(0.8) ☐

c - Precedenti Lesioni: Assenti/ferme (1.0) ☐ Lievi (0.8) ☐ Moderate (0.6) ☒ Gravi (0.4) ☐ Molto Gravi (0.2) ☐

d – Effetti Caduta elementi: trascurabile (1.0) ☐ basso (0.8) ☐ Moderato (0.6) ☐ grave (0.4) ☒ molto grave (0.2) ☐

Livello di Danno L.D.: Assenza danno (1.0) ☐; ... Lieve (0.8) ☐; Moderato (0.6) ☐; Grave (0.4) ☒ molto grave (0.2) ☐.

Componente	L.D.	Descrizione e/o danno
AE_tet18-17	0,8	Buco nel piombo
AE_arc18-17	0,2	Fessurazione, scagliatura, rischio caduta elementi decorativi dell'arco
	0,6	Fessurazione
	0,8	Fessurazione in basso a destra dell' arco
AE_cap18	0,2	Abaco: fessurazione, rischio caduta, disgregazione erosione
	0,2	Capitello: disgregazione, scagliatura
AE_col18	0,8	Fessurazione
AE_ban18	0,6	Fessurazione, scagliatura
AE_los18-17	0,6	Fessurazione
	0,4	Disgregazione, fessurazione, scagliatura zona intarsio
AE_par18-17	0,8	Fessurazione

Livello di Indagini: esaustive (Lc= 1) ☒, discrete(Lc=0.9) ☐, minime (Lc=0.8) ☐
Descrizione Strumentazione: controllo visivo e tattile

Operatori: Sara Chirico, Simonetta Rota

Data Ispezione (T): 13/10/2023
Data Ultima Ispezione (T0): 2020

Opera della Primaziale Pisana

Ispezione Programmata degli elementi Architettonici e strutturali.

Macro Elemento: Cattedrale di Pisa- Settore AE Componente: AE_18-17 Data 13/10/2023

Ta= Periodicità Ispezione (anni)	Ta=1 ☐ Ta=2 ☐ Ta=3 ☐ Ta=4 ☐ altro ☐	Ta =	ND
a - Valutazione dello Stato di conservazione generale:	Ottimo (1.0) ☐ Buono (0.8) ☐ Discreto (0.6) ☐ Scadente (0.4) ☐ Pessimo (0.2) ☐	a =	0,4
b- Nuove Lesioni?	NO (1) ☐ SI(0.8) ☐	b =	1
c- Precedenti Lesioni	Assenti/Ferme (1.0) ☐ Lievi (0.8) ☐ Moderate (0.6) ☐ Gravi (0.4) ☐ Molto Gravi (0.2) ☐	c =	0,6
d – Effetti Caduta elementi (Fattore di Perdita)	trascurabile (1.0) ☐ basso (0.8) ☐ Moderato (0.6) ☐ Grave (0.4) ☐ Molto Grave (0.2) ☐	d =	0,4
e - Nuove Lesioni-Livello di danno L.D.	Assenza danno (1.0) ☐ Lieve (0.8) ☐ Moderato (0.6) ☐ Grave (0.4) ☐ Molto Grave (0.2) ☐	LD=	0,4
Vm = Valore Stimato Intervallo Manutenzione	Vm=Valore stimato Intervallo Manutenzione (anni)	Vm =	20
Tu = Tempo trascorso dall' Ultima manutenzione	Tu= Tempo trascorso dall' Ultima manutenzione (anni)	Tu =	80
Lc = Livello delle Indagini; Strumentazione	esaustive (1.0) ☐ discrete(0.9) ☐ minime (0.8) ☐	Lc =	1
T= Data di ispezione	Data Ispezione (T)	T =	2023,8
T0 = Data Ultima precedente Ispezione	Data Ultima precedente Ispezione (T0)	T0 =	2020,5
Ft = Fattore Tempistica Ispezione	$DT = T - T_0 \Rightarrow Ft = fattore\ Tempistica\ Ispezione = [e^{\frac{DT-Ta}{DT}}]$	Ft =	1,00
Fm = fattore Tempistica Manutenzione	$Fm = fattore\ Tempistica\ Manutenzione = [e^{\frac{Tu-Vm}{Tu}}]$	Fm	2,12
Se = Stato di Esercizio	$Se = Stato\ esercizio = [(a+b\cdot c+e)/3]\cdot L_c\cdot \frac{d}{F_t\cdot F_m}$	Se =	0,09
LA= Livello di Allerta	LA = Livello di Allerta (LA1, ..., LA5)	LA =	LA_5
Ta= Nuova Periodicità di Ispezione (anni)	Nuova periodicità di Ispezione (Anni)	Ta =	1,0
T= Data prossima ispezione (Anni)	data Prossima Ispezione	T	2024,8

I livelli di Allerta (con gradazione di colori) sono attribuiti in base allo stato di esercizio Se. N.B.Con livello LA_5 (Rosso) il periodo di ispezione si riduce a 0.5*Ta

75% < Se	LA_1
45% < Se ≤ 75%	LA_2
20% < Se ≤ 45%	LA_3
10% < Se < 20%	LA_4
Se < 10%	LA_5

Fig. 3 Example of an AFI data sheet of Cathedral's monitoring.

For Comprehensive restoration work, it may be necessary to install scaffolding in the affected areas and modify the frequency of interventions according to the AL recorded, and thus modify the maintenance operations in order to contain the ongoing degradation.

Through this "Modus Operandi," a series of interventions are scheduled in the near future for the Leaning Tower and the Baptistry: the consolidation of the capitals and the treatment of biological patinas; both works will be carried out entirely by rope.

3 GIS data management

The data collected are organized in a GIS (Geographic Information System), which allows identifying the component's location. The peculiarity of the GIS system is to integrate the representation of metric data with the alphanumeric information that characterizes the heritage from a conservation point of view. GIS stores, manages, and visualizes data with spatial identification and links the graphic representation with the informative data in a virtual folder [4]. So, the information about the single monument such as scientific analysis, photos, inspection sheets, documentation of the condition, and restoration work, could be collected in a virtual folder and consultable by all OPA technicians.

The GIS system geo-references data showing the survey geometries, graphical mapping of the state of conservation, in particular the location and type of deterioration of 'Components', and the correspondence of alert levels (AL) for each 'Space'.

Attribute tables are defined to place all information collected during inspections within different fields. The result is a layer of knowledge that characterizes the constituent elements of the object, from which it is possible to obtain graphical maps with different colors and symbols relating to the type of data to be highlighted.

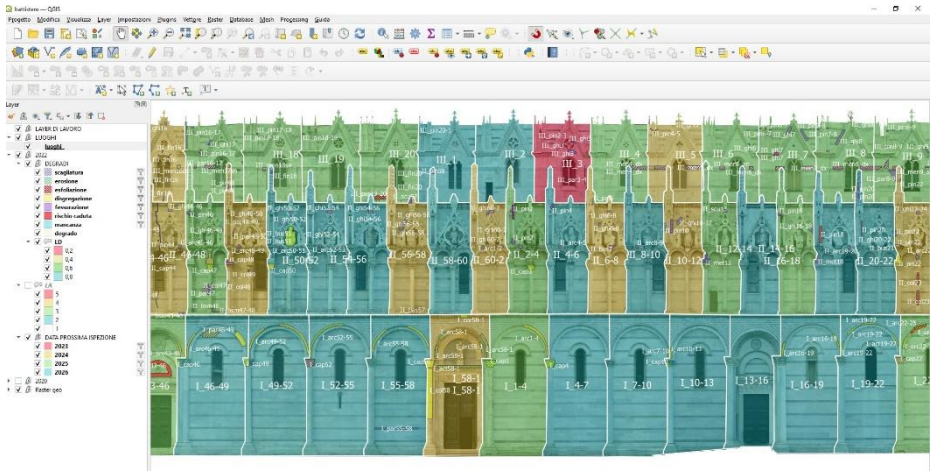


Fig. 4 GIS data management of Baptistery data.

It must be considered that over time, the volume of information will increase considerably. The constant updating of data overlaps with the compilation phase, characterizing the cyclical nature of the conservation and maintenance process and increasing the knowledge of the monument [5].

The use of an Information System is essential for creating a folder of updatable and consultable data, which is fundamental for planning maintenance and understanding the evolution of deterioration processes over time so their evolution can be predicted. This will form the knowledge support for the conservation plan, which aims to minimize emergency interventions and focus on maintenance, replacing restoration with preventive conservation.

4 Conclusions

Drawing up a plan for the programmed conservation of architectural surfaces has been introduced from the perspective of promoting activities aimed at limiting the onset and progression of deterioration, promoting the idea of maintenance as a continuous process of care, rather than resorting to emergency restoration operations [6].

The choice of periodical inspection would definitely be more efficient in conservation issues as it can better mitigate deterioration phenomena, limit the future aggravation of the degradation process, and prevent the emergence of critical conditions. It would also save time and resources for the company because it would eliminate the cost and time required to set up a scaffold and the cost of hiring specific equipment, such as forklift trucks and suspended platforms.

This procedure used in recent years by the restorers of the Opera della Primaziale Pisana, which combines rope access monitoring and data management by AFI sheets and GIS processing, helps to increase maintenance. To improve the monitoring work instead of large-scale restoration works.

References

1. Brandi C., Teoria del restauro, p.54, Einaudi, Torino (1977).
2. Tavolo Tecnico dell'Associazione delle Fabbricerie Italiane (a cura di), Linee guida per le ispezioni periodiche, Pisa (2019).
3. Cecchi R., Gasparoli P., Prevenzione e manutenzione per i beni culturali edificati, Alinea Editrice, Firenze (2010).
4. Baratin L., Bertozzi S., Moretti E., Tecnologia GIS per la manutenzione programmata dei beni culturali. In Della Torre S. (a cura di), ICT per il miglioramento del processo conservativo. Proceedings of the International Conference Preventive and Planned Conservation, vol.5, pp. 73-81, Nardini Editore (2014).
5. Della Torre S., Moioli R., Pili A., Digital tools supporting conservation and management of built cultural heritage. In Van Balen K., Vandesande A. (eds) Innovative built heritage mod-els—reflections on cultural heritage theories and practices, pp. 101–106, CRC Press—Taylor and Francis Group, London (2018).
6. Brandi C., Teoria del restauro, p.142, Einaudi, Torino (1977).