Conservation through knowledge: the case study of Parma Botanic Garden

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Abstract. In the restoration field it is well known that the preservation of cultural heritage stands on a deep comprehension of the architectural object, material expression of a complex system made of cultural, technological, historical, social and economic issues. The knowledge of such meaningful structures requires the identification of both typological features and peculiar characteristics, within an interactive dialogue between contributions from different disciplines. Thus, the study of existing buildings is a complex process that needs to be planned: that means conceived, organized and realized with a critical method. The paper aims to show an example of this approach by presenting the knowledge path followed for the analysis of the Botanic Garden in Parma, Italy. This green area is located in the south of the city and hosts several buildings including the school of botany and the elegant greenhouse, built at the end of the 18th century. Recently, the restoration of the architectural complex has been proposed, aiming at its valorisation. The design process was supported by the studies and the analysis of the existing buildings carried out by the research group in Restoration of the University of Parma. In the specific, the constructive phases have been investigated through historical archive researches whereas the current structural systems have been studied through the geometric survey. Moreover, in-situ inspections allowed to define materials, deepening the knowledge of structural elements and their state of conservation. Finally, the survey of the crack pattern and decay allows to highlight vulnerabilities and mechanisms of collapse. In this way, it has been possible to understand the architectural structure thanks to the comparison between all data collected. On the other hand, in order to respect the historical construction, these analyses are required to reach a satisfying level of detail with the minimum action on the material construction, preferring non-destructive investigations. This approach entails assumptions and uncertainties that could be managed thanks to a critical interpretation of the results. Thus, the case study of Parma Botanic Garden shows the importance of planning the knowledge path with awareness in order to progressively deepen the comprehension with an interactive dialogue between the architectural object and the restoration issue.

1. Introduction
The saying “conservation through knowledge” [1-8] refers to the preliminary studies on the historical building aimed at supporting the restoration project. This cognitive process consists in a complex path that take place between scientific and humanistic fields: starting from the geometric survey, it goes from the study of historical documentation to the analysis on building materials and their degradation, up to analysis of damages and their causes. The phase of knowledge in thus considered fundamental to better define objectives, pathways and, in general, strategies of interventions. In the restoration field no one doubts the importance of knowing the building of which a preservation act is intended. [9] Unfortunately, such a statement often does not correspond to congruent actions. The main reasons is
usually connected to the lack of resources and time. In many cases, the preliminary knowledge, required by law, became a superficial report attached to the project without any interaction with it: a duty that the designer has to pay without any benefit. [10] To avoid this approach, it is important to remember that the knowledge is never an end in itself. Working on the cultural heritage, the cognitive process should help recognize values and vulnerabilities to guide preservation actions.

However, the relationship between knowledge and preservation is not easy to manage: just as the restoration must be consistent with the analysis data, the so-called knowledge path must also be consistent with the project’s queries. Therefore, the “knowledge designer” has to identify suitable analytical paths and to correctly interpret the results. It is thus important to reflect on the objectives of the analysis in order to identify the proper tools to effectively answer the questions. All the automatisms that propose a sequence of standardized surveys and investigations, without questioning their effectiveness, should be avoided: the knowledge path need to be planned for each specific case. [10] It is therefore useful to explore procedures and methods to understand existing constructions, questioning about theoretical and operative tools and models that can support the restoration designer.

In the present paper, the case study of Parma Botanic Garden is reported in order to examine the knowledge path followed to identify both the structural composition and the vulnerabilities, supporting the restoration project.

2. The case study: Parma Botanic Garden

Parma Botanic Garden, one of the oldest in Italy, is located on the corner between Strada Luigi Carlo Farini and Stradone Martiri della Libertà, in the south of the city, on the edge of the historic center. This green area, despite its small size - just over one hectare (about 11,500 square meters) – is a very significant place from a botanical point of view: the garden can boast more than 2000 species of plants, including several monumental trees. As shown in (figure 1), several buildings take place in this space: the eighteen-century Serra, the School of Botany and the entrance building. The Garden and the Botanical Institute are today a section of the Department of Evolutionary and Functional Biology of Parma University: their primary purpose is the conservation of biodiversity both in situ and ex situ. The institution, with its exhibits of several animal and plant species, also belongs to the university museum system. Furthermore, the School of Botany preserves, in its library, ancient herbaria and collections of medicinal plants. [11-12]

However, the complex is not able to fully express the potential of such a significant point for the community. The lack of proper spaces to carry out different types of activities – from those related to the care of the vegetation care to those involving the public – makes the structures not completely responding to current needs. Moreover, the historical construction highlighted some structural vulnerabilities. For this reason, a restoration project has recently been proposed, aimed at enhancing this historic site, making it more attractive. To this end, a research was funded by the University of Parma in order to study the structures that arise on this green area, showed in (figure 2). Such a research was carried out by the research group in Restoration of Parma University, Department of Engineering and Architecture. In the specific, this preliminary study aimed at an in-depth knowledge of the architectural complex, defining its construction techniques and identifying its structural resources and vulnerabilities as a support for the optimisation of interventions.

The knowledge path began with the refinement of geometric survey specifically to this purpose. In the meantime, archival research allowed to retrace the constructive evolution of the site. Then, diagnostic analysis were preformed to identify structural elements and their composition. The critical reading of all the data collected by visual analysis and in situ investigations, correlated with historical, material and geometrical information, has progressively led to the identification of the structural
systems of each building. Particular attention has been paid to the crack pattern and decay that prevent the stability of the historic constructions.

Figure 1. Aerial view of Parma Botanic Garden (from Google Earth) with the localization of the main buildings: the eighteen-century Serra (1), the School of Botany (2) and the entrance building (3).

Figure 2. From left to right, front view of the Serra, the School of Botany and the entrance building.

The aforementioned studies are presented in the following headings, explaining objectives, methods and results.

2.1. Geometric and structural survey
The geometrical survey has to be considered the starting point of knowledge project, not its final result. [13] It represents the necessary framework for any further diagnostic analysis on the buildings and it is a fundamental reading moment that allows to deepen the awareness of aspects that are not immediately appreciable. In historic constructions, the geometric survey concerns not only the simple geometries that guide the regularity of the design, but also the irregularities in shape that refuse the proportional rule, rising questions about their causes, whether intentional or accidental. [9] Regular and irregular geometries of the building become keys to reading its history, its stability, its material
texture and its constructive consistency. [14] Thus, architectural survey cannot be performed as a simple mechanical action of measurement. Indeed, a critical geometric survey does not require the same level of detail in all its parts: this means that the aforementioned “knowledge designer” should identify which elements can be surveyed in their general proportions and which need to be investigated with more accuracy, because of their greater importance for the specific aim.

The existing survey of Parma Botanic Garden was firstly verified and corrected. Subsequently it was deepened through on-situ inspections, according to the level of knowledge required for studying the buildings from a structural point of view. The decorative elements were therefore surveyed only in their general geometries whereas particular attentions was paid to the dimensions of the structural elements and the connections between them. Direct survey methods were mainly used to measure the buildings. Only some portions, which presented irregularities in shape, were investigated by means of a topographic survey with a total station (Topcon Image Station IS203) to precisely define the geometrical conformation, highlighting the deformations.

2.2. Historical analysis
The historical analysis is aimed at studying the monument as a material expression of traditional construction technologies and local methods of production and use of materials. This phase is fundamental for the recognition of cultural and architectural value of the building. Moreover, through historical analysis, it is possible to identify the construction phases, with their specific construction techniques and their implications in the structural behaviour. The changes in use occurred over time, for example, allow interpreting the history of loads. [13] Seismic events that damaged the buildings allow identifying vulnerabilities and passed strengthening interventions allow to identify possible structural resources. By consulting archival documents, bibliographic texts and historical cartography the constructive evolution of the Botanical Garden was defined. The main points are reported below.

The origins of the botanical garden in Parma can be traced back to the seventeenth century, when Duke Ranuccio I Farnese (1569-1622) founded the “Orto dei Semplici” (in Latin Hortus Simplicium), located in the complex of San Francesco del Prato as part of the Faculty of Medicine. [15] Between 1768 and 1770, under the auspices of Ferdinand I of Bourbon (1751-1802), the current Botanical Garden was founded by the will of the abbot Giambattista Guatteri (1739-1793). [16] The Botanical Garden was located in the southern and most peripheral region of the city, near the ancient Porta Nuova, in an area where several water channels conveyed into tanks because of the previous destination of the site: a calancà factory or fabrics of cotton printed in Indian use.

The area in which the Botanical Garden was founded can be easily identified thanks to the use of “Atlante Sardi”, the first urban cartographic land registry of Parma, created in 1767. Through this important document it is possible to note that garden involved a larger area, owned by the “Regio Ducal Camera Orti e Case”. There were no buildings but an houses and a tank, no longer existing today. In place of the current entrance building and School of Botany were instead previous buildings, used as residences. The works for the construction of the so-called “Serre”, belonging to the architectural typology consisting of large glazed volumes for the shelter of winter plants, began in 1770 and ended in 1793. The project is traditionally attributed to Petitot even if recent studies assume one of his pupils as the real author. The original layout of the greenhouse had a symmetrical layout: a central body with two side wings, characterized by large windows on the south facade. On the north side, a corridor connects the rooms with each other. The original structure here described, even if partially modified and incorporated into subsequent constructions, is still clearly identifiable in the current building. In the first half of the nineteenth century, the greenhouses underwent several maintenance and repair interventions.
From the Bourbon land registry of 1853 it appears that in the mid-nineteenth century the Garden considerably reduced its surface, taking on the present conformation. Furthermore, buildings were built on the northern edge, near the greenhouse: in particular the so-called “Casa Orsi” was built as a private house. In 1862, the School of Botany was instituted, rebuilding an existing rustic house near the Serra. A few years later, a drawing from 1865, founded in the Historical Archive of the University of Parma, relating to the "Project of a Greenhouse or Stove to originate in the Royal Botanical Garden in Parma", [17] suggests the expansion on the western side of the eighteenth-century greenhouses, if not in its real realization at least in its conception. In any case, in the 1950s, under the direction of Fausto Lona, the building adjacent to the west side of the greenhouses was built in its actual configuration. At the same time, the body parallel to the north corridor of the greenhouses was also built, with the function of laboratories. [18] At the beginning of the 20th century, "Casa Orsi" was annexed to the botanical garden complex with the same function In the 1960s, the connection with the greenhouses was rebuilt. In the same period, two greenhouses were realized on the terrace in front of the main entrance to the eighteenth-century Serra. Moreover, two climate-controlled greenhouses for alpine, tropical and subtropical plants were placed on the existing roofs. [19-20] In the 90s, part of the greenhouses was allocated for the Natural History Museum, requiring some changes in the original conformation, carried out between 1988 and 1994.

The archival documentation made it possible to reconstruct the main stages in the history of Parma Botanical Garden, illustrated in (figure3). Clearly, the data are not completely exhaustive and homogeneous over the centuries. In particular the recently modified entrance building lack of archival documentation. However, the analysis of historical data was fundamental to guide subsequent studies.

**Figure 3.** Main stages of the construction history of Parma Botanic Garden: a) 1770-1793, Realization of the Serra; b) First half of the 19th century, Incorporation of dark gray buildings and realization of a stove; c) 1857-1863, Realization of School of Botany; d) 1865, Project of a stove next to Serra; e) 1950s, Realization of laboratories next to Serra and in Casa Orsi; f) 1960s, Realization of greenhouses and connection with Casa Orsi.
2.3. Diagnostic and in-situ investigations

Historical analysis made it possible to conceive the general structural organization of the complex. However, further analysis was needed to verify such hypothesis and to deepen the knowledge of the most significant structural elements. In-situ investigations were then carried out for each typology of wall and floor in order to identify the stratigraphy, the materials, their state of conservation, highlighting the possible presence of vulnerability. Aiming at reducing the invasiveness of the diagnostic phase, the analysis started with the punctual observation of all visible elements, measuring their geometries, detecting the superficial materials and decay. A first visualization of the stratigraphy was made relating these data to traditional constructive techniques with the support of historical manuals. [21] The knowledge of the main structural elements was deepened through endoscopic investigations, which consist of a video inspection with specific instrumentation (CLY Endoscope 5mm WiFi 1080P HD Wireless 2.0 MP CMOS IP68) through a 2cm diameter hole, made orthogonally to the thickness of the object under investigation. These tests allow to identify the layers of the thickness, thus defining the stratigraphy and evaluating the consistency of the materials and the possible presence of voids, cavities and discontinuities. If necessary, these tests were supported by the removal of a small portion of plaster, in order to evaluate the texture of the walls and floors. Metal elements were also investigated. Firstly they were localized by means of specific instrumentation (Bosch Professional D-tect 120), then studied in detail by means of pacometric survey (Ferroscan RV10 HILTI). This analysis made it possible to identify steel beams in the floors, reinforcing bars in concrete elements and previous strengthening interventions. Finally, foundations belonging to different constructions phases were investigated through excavations to define geometries and techniques.

![Figure 4. In-situ diagnostic: a) endoscopic investigations for defining stratigraphy; b) removal of a small portion of plaster for studying texture; c) pacometric survey for identifying metal elements; d) excavations for investigating foundations](image)

A complex picture emerges from the in-situ investigations, illustrated in (figure 4). The results confirmed the construction phases defined through the historical research and, moreover, changes were identified in detail, defining the characteristics of structural elements. The original core of the greenhouses shows an homogeneous structure made of solid bricks and wooden roof. This part differs from the irregular portions added later, made of perforated bricks and concrete floors. Casa Orsi presents a similar difference between the perimeter walls, realized at the beginning of the 20th century in mixed brick and stones, and the inner walls, recently realized with perforated bricks. The School of Botany maintains a certain homogeneity in the masonry (solid bricks) while it presents a greater variability in floors (vaults, wooden floors, concrete floors). The entrance building is the one that have changed the most from the original structure. Two structural units are identified. One has been completely rebuilt with a reinforced concrete frame while the other has undergone minor changes in the walls (adition of a portion towards the garden) and in the wooden floors (replaced or added with steel beams).

Anyway, the preliminary investigation phase could be deepened by means of analytical techniques in order to define mechanical parameters of masonry and timber structures.
2.4. Crack pattern and vulnerabilities
The investigation of the decay phenomena and crack patterns provide a detailed picture of the state of conservation of the building, supporting the cognitive process in the understanding of the structural behaviour. [13] The goal is to understand the influence of instability phenomena and materials degradation on the structural behavior identified by the previous investigations. It is known that a conservation project, before any other functional or formal actions, should start from the reduction of vulnerabilities in order to ensure homogeneous behavior conditions, according to the rules of art for historic buildings. [22]

First of all, in the north-east portion of Serre significant cracks were found: specifically, the north façade shows horizontal injuries which tilt at the corners of the openings, becoming vertical here. The crack pattern is represented in (figure 5). The correlation with historical information and diagnostic tests, from which emerged that this portion was added in the mid-1900s with small foundations, allow to identify the causes of the damage with subsidence in the foundation.

![Figure 5. Main crack pattern surveyed in Serre.](image)

Damages were also surveyed in the School of Botany. The south elevation of the building has a symmetrical crack pattern characterized by diagonal injuries that involve the openings. These previously filled cracks have recently reappeared. The crack pattern is represented in (figure 6°). Moreover, there are also injuries in inner walls and deformations on the ground floor. This crack pattern appears symptomatic of a differential deformation in the foundation. The mechanism can be influenced by the presence of pre-existing structures in the subsoil, as evidenced by the historical analysis. The injuries also lead to a separation of the east and west walls, entailing the risk of overturning mechanisms in the event of an earthquake, potentially emphasized by the presence of pushing roof system. Another vulnerability of the School of Botany is represented by the first-floor slab: the maximum load limit of ten people has been imposed for this structural element due of its excessive deformation. With the support of in-situ investigations, that identified the SAP typology, and historical manuals, [21] which define maximum dimensions and loads for this type of floor, the cause of deformation phenomena can be identified in the excessive distance covered by the structural element.

The entrance building is also affected by local differential ground deformations. In particular, the portion recently added towards the garden has horizontal cracks at the base and top (probably in correspondence with a top curb). The crack pattern is represented in (figure 6). Such a crack pattern, symptomatic of a ground deformations, is typical of buildings added to exiting one on a soil not consolidated by previous constructions. Furthermore, the new foundations may not have been adequately sized and connected to existing structures. Other cracks appeared on the walls perpendicular to the facade on Via Farini. The inclinations of shuc injuries remains to similar causes: modest settlement of the ground. The mechanism is confirmed by the presence of a diagonal crack on
the barrel vault of the entrance. The in situ investigations identified the vault typology in folio, underlining an intrinsic vulnerability of this element in addition to the activated damage. Moreover, the floors show horizontal cracks parallel to the facade: this phenomena could be partly caused by the settlement of the metal beams but it can also be symptomatic of a slight overturning of the west elevation. The analysis highlight that the floor system, whose direction is always parallel to the facade (with only one exception), increases the risk of the facade overturning. To verify the possible activation of the mechanism, the facade was then surveyed with laser scanner technique: the results highlight the presence of a modest out of plumb.

![Figure 6. Main crack patterns surveyed in School of Botany (a) and in the Entrance building (b)](image)

Finally, as regards the survey of dacy, the main pathology is represented by the presence of humidity at the base, which causes deformation and detachment of plasters and, in the most serious cases, erosion of the masonry, reducing its mechanical characteristics.

### 3. Results and discussions

The knowledge path concerns several aspects: cultural, technological, historical, social and economic. The cognitive process cannot be a simple multiplication of skills and knowledge: it requires a continuous balance between general features (which connect the architectural object to other typologies) and individual characteristics (peculiar to the case study). Historical, geometric, technical, constructive and diagnostic analysis constitute a complex action that need be designed as a whole and not as a simple list of consecutive steps. [13]

Guide line for assessment and reduction of seismic risk in cultural heritage [22] also mentions the planning of an “iterative knowledge”. This phase should conceived as a circular process, made up of the right questions and aware answers that follow one another: it should lead to understanding of the building by progressively deepening the level of detail of the analysis. An extensive and general knowledge is thus necessary to acquire awareness of the current state and then it should become a specific knowledge aimed at solving the peculiar problems identified in the initial phase. [10] To this end, analytical knowledge can be used: the many disciplinary sectors that contribute to the diagnosis of deterioration and instability phenomena provide tools and procedures to study materials and structures in their hidden aspects. Undoubtedly, analytical techniques can help to govern the complexity of existing building but, alone, they are not able to answers to questions of the restoration. [10] Interpretative models that fit the complexity of reality can only be defined through a critical analysis of all the data collected. However, this information differs across disciplines and degrees of detail, becoming thus difficult to compare directly. For this reason the management of data take particular importance. [10-13]
In the case study of Parma Botanic Garden, the knowledge path started from an overall knowledge aimed at identifying the main geometries and typologies and the major failures. Subsequently, further studies and investigations were carried out to deepen the historical evolution and the construction systems (structural elements and connections). The critical correlation between such data allowed to study the crack pattern, searching for its causes and verifying them with subsequent analysis.

A constructive dialogue is therefore essential between all the figures involved in the conservative process, especially between the “restoration designer” and the “knowledge designer”. If the figure investigating the building only perform given tasks without any critical approach, the results would be incomplete and less significant whereas, if the objectives of the restoration are shared, he can choose the proper tools and effectively set up the knowledge planning.

However data sharing is sometimes difficult to perform because of different time and priorities. External influences (financial, administrative, political, etc.) often impose the time of knowledge, not always to the advantage of efficient results. In this regard, it is important to underline that, just as there is no automatism in the steps of the knowledge path, there is no “right” time. Some questions take a long time to answer, requiring a complex investigation phase; others can be solved in a short time with the support of precise analysis. [10]

4. Conclusions
The present paper shows the case study of Parma Botanic Garden as an example of critical approach to the knowledge path aimed at the conservation of the existing buildings, ensuring stability. Knowledge is essential for any respectful and aware intervention on cultural heritage. However, understanding historic buildings is as important as it is complex, as it involves several disciplines. Therefore, the cognitive process need to be specifically planned according to the aim of the intervention, and should develop by progressively deepening the level of detail. All the collected data need to be critically interpreted and correlated. If the required steps are carried out automatically, they do not ensure the definition of a critical and conscious knowledge and consequently of a critical and conscious restoration project. The quality of knowledge depends on the ability to listen. [13]

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