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Methodology for the Study of the Vulnerability of Historic Buildings: The Reconstruction of the Transformation Phases of the Church of the Abbey-Castle of Santo Stefano in Monopoli in Puglia (Italy)

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Abstract: The study presented here concerns an analysis of the structural vulnerability of the arm of the church of the Castello di Santo Stefano Abbey in Monopoli in Puglia (Italy). The ancient monument is located on a small "Peninsula" between two ancient natural harbors, 3 km from Monopoli and 5 km from the archaeological site of Egnazia. Studies on the abbey-castle, have revealed different construction and deconstruction phases relating to historical periods of the Roman age, late antique age, medieval age, modern and contemporary age. The castle is typically attributable to a closed courtyard with four arms. The last one, close to the wall on the port of Tramontana, was added at a contemporary time. The arm of the church is characterized by the crypt with opus reticulatum walls from the two surviving bays of the former Benedictine church, from the residential palace of the 18th century, and from the residential extensions of the 20th century. The north-east and north-west arms, born in the 16th century as defensive earth-filled walls with respective bulwarks (north-east pentagonal and north-west at the tip of a spear), were redeveloped between the 17th and 18th centuries into residential buildings with panoramic loggias and overlooking new ditches enclosed by high walled defenses. The study was conducted with non-invasive methods such as: thermographic surveys; archaeological survey; stratigraphic survey of the walls; stratigraphic survey of plants; photogrammetric survey; 3D returns; Morpho-typological survey of the building material making it possible to acquire data on degradation, on the historicization of instability, on the phases of "growth" of the 18th century and of stylistic "reconstructions" of the 19th century. The data acquired, compared with each other, documented: the deterioration and instability of the foundation wall structures (the crypt) and that of the elevated structures: surviving spans of the church and residential building. Alveolization of the building material, deformations, variations in the geometric shape, lack of resistance of the foundation walls due to the typological and qualitative characteristics of the material (opus reticulatum in soft tuff) with high porosity and problems of the church roof system.

Keywords: construction phases; stratification; vulnerability; stone material

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1. Introduction

Preventive conservation (i.e., the set of actions and measures aimed at avoiding or minimizing future deterioration or loss) provides us with tools for sustainable conservation [1]. The constant monitoring of the state of an asset, in fact, can avoid subsequent interventions that can be costly in terms of money, time and invasiveness. The evaluation of the state of conservation of historical architecture therefore requires analytical tools that allow us to synthesize and elaborate parameters for the formulation of an opinion on the state of conservation of the same. The study presented here, which was carried out with restoration tools and non-invasive archaeological analysis, refers to systematic research launched in 2013 that was aimed on the one hand at the global knowledge of the monument, and on the other at the definition of intervention strategies for maintenance already applied in other case studies [2]. The Castle of Santo Stefano is the result of a complex material stratification of different eras, the result of different construction sites [3]. In this type of monument it is common to identify wall sections characterized by phases of disassembly and reconstruction. A peninsular area of limestone where the difficulty of transport in ancient times favored the on-site extraction of building material and the practice of reuse [4]. The phases of disassembly of the material for reuse included the demolition of ancient abandoned structures up to the recognition of portions of the building resulting from the reuse of elements of previous wall facades [5]. The reasons for the reuse are linked to the deterioration of the building material, the change in intended use and the inefficiencies caused by alterations to the original project or by incorrect design choices. From the studies carried out in Santo Stefano, characteristics of deterioration and instability emerged which are closely linked to the place, to the recovery of the building material on site and to the material stratification of the construction phases [6] (Figure 1). The wall structures in opus reticulatum, probably attributable to a maritime villa documented in the crypt of the church in late antiquity, were reused for a cult building, while in the Middle Ages (11th–13th century) they were integrated into the crypt of the upper Benedictine church (Figure 2). The church, rebuilt and embellished during the 13th century, subsequently underwent alterations: the first and fourth bays were incorporated into inhabited areas at the beginning of the 19th century, when the castle became private property. In 1317 the Benedictine Abbey passed to the Knights of Jerusalem who initially did not make any changes to the building. In the 16th century, in analogy with the fortifications of the time, two embankments with bastions were added to the ancient block of the Benedictine church (Figure 3). In the 17th century the embankment east was reused as a "palace" by the Balì Marulli, and in the 18th century the bastion west became the hanging garden of the new residence of the Balì Francone, built next to the church to counteract its instability (Figure 4). The latest data on the church block have highlighted the crypt with the monks' lodgings, mostly characterized by opus reticulatum masonry in a poor state of conservation [7]. The 60-cm-thick wall section and the 10 × 10 cm calcareous cubilia, laid on both rows with a core of shapeless stones, sea pebbles, sea sand and cocciopesto, has been greatly compromised over time by deterioration. By comparing the opus reticulatum of the crypt with the opus of the pilae of the submerged port of Egnatia, characterized by cubilia of the same material, the erosion dynamics of the stone material can be observed [8]. The opus reticulatum installed with porous calcarenite, coming from our territorial sector, appears unsuitable for structures surrounded by the sea, or, as in Santo Stefano, in closer contact with the sea. In the Middle Ages the crypt was enriched with pillars, arches and semi-columns to support the upper church. However, the news on the reconstruction of the upper church already begins in the Middle Ages, and in the 18th century are documented by the interventions of the Balì Francone. In the 19th century, with the subtraction of the two spans of the church, the local craftsmen reconstructed the roofing planes of the vaults and positioned the tie rods on the building. The studies carried out, supported by thermographic investigations, highlighted the design solutions and the use of building materials unsuitable for the structures. For example: the lack of attention in planning for the construction of the crypt and the monks' quarters; the recovery of walls in opus reticulatum (built in Roman times with soft tuff); the structural relationship between the crypt and the upper church; and the vulnerability due to direct contact with the sea [9].

Figure 1. Aerial view of L.C.A. of the Abbey of Santo Stefano Castle.

(**a**) (**b**)

Figure 2. Reconstruction of the construction phases: Roman (**a**); and Late antiquity (**b**).

(**a**) (**b**)

Figure 3. Reconstruction of the construction phases, Medieval (**a**); and 17th century (**b**).

(**a**) (**b**)

Figure 4. Reconstruction of the 18th century construction phase (**a**); Castle today (**b**).

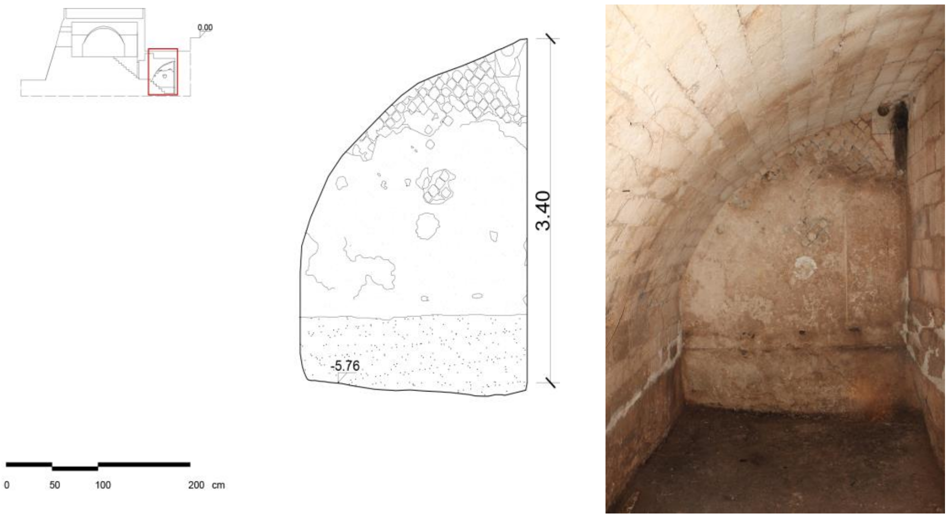
2. Materials and Methods

The preliminary investigations for the restoration and/or maintenance of the church of Santo Stefano were conducted through a non-invasive interdisciplinary study aimed at identifying and analyzing the different constructive, deconstructive and reconstructive phases of the arm of the church to analyze its natural effects and induced vulnerabilities of the building. The investigation methods used were those of restoration, landscape archeology and architectural archeology: the critical architectural survey, intended not only as a cognitive investigation tool but as a preparatory phase for the assessment of the building's vulnerability; the photo-interpretation of aerial images, at low altitude, in the visible and infrared, made available by the Consortium of Aerophotographic Center Laboratories of the University of Bari, 2015 [10]; the photogrammetric surveys of the elevations returned with Agisoft Photoscan; thermal images taken with a Testo 872 thermal imaging camera and returned with the testo IRSoft software; stratigraphic, morphological—typological surveys and archaeological surveys returned in Autocad; 3D reliefs of the church; and finally the critical analysis of published and unpublished sources.

3. Results

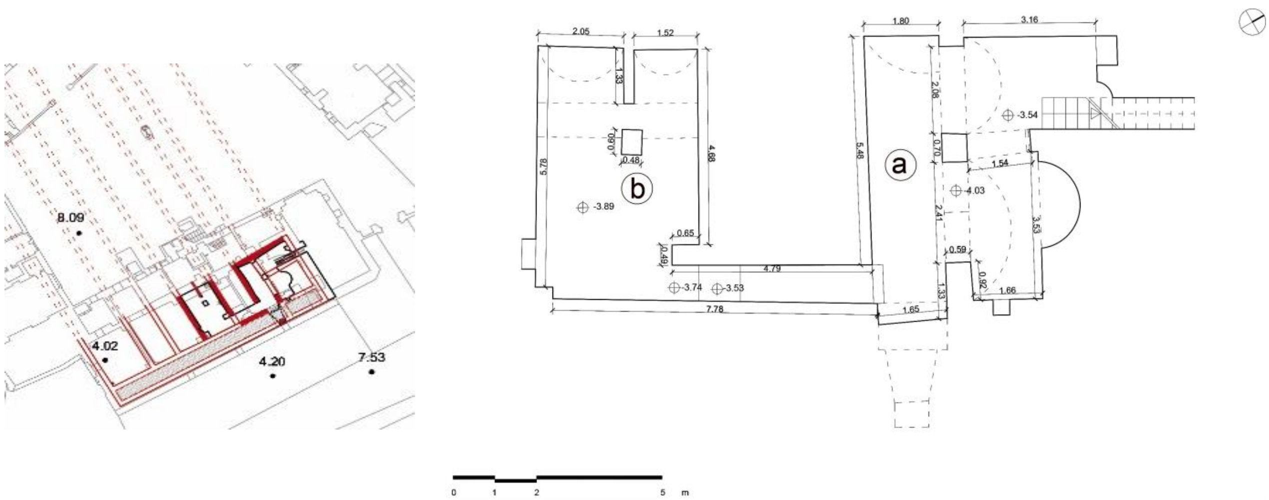
3.1. Analysis of the Underground Rooms of the Church

The base of Santo Stefano is characterized by various wall partitions in opus reticulatum, which can be placed chronologically between the 2nd century BC and the 2nd century AD [11]. Over time, these walls have been incorporated into structures with functions different from those for which they were built. An example is the wall partition found under the courtyard, which in modern times was part of a "pool for oil" as described in the cabrei [12] (Figure 5). In the basement of the arm of the church, other more-articulated rooms, attributable to ancient corridors in opus reticulatum, ran along the base of the church. From the studies carried out it emerges that the corridors can be traced back to an ancient water cistern from the Roman era (Figure 6). Some of these, already in late antiquity, were reused through cuts in the wall structures for the construction of a first place of worship. In the Middle Ages, with the arrival of the Benedictines in Santo Stefano, the rooms (a) became the crypt of the church, three arches placed on a side column, a central column and on a fragment of wall opus reticulatum was added (Figure 7). The intervention aimed at supporting the transept of the upper church was not structurally adequate; in fact, between 1236 and 1296, as described in two inscriptions preserved in the castle walls, the abbots Riccardo and Matteo reconstructed the church. In the wall section BB′ of the crypt there is a small passage which, through a corridor, leads to the rooms (b) attributable to the dwellings of the Benedictine monks. Two small rooms in opus reticulatum, with the shutters of the original vaults still visible, are divided by a wall partition in opus reticulatum. In the background, two infill walls, whose thickness we do not know, are placed in correspondence with the inner perimeter wall of the upper church to act as a foundation on the north front (Figure 8). The flooring resulted in slabs of opus incertum resting on a deteriorated wooden base with a thickness of 2–3 cm to detach the rooms from the rocky bank. In one of the two rooms the negative stratigraphic unit of a large stone slab can be observed. A wall built in the last century rests on fragments of opus reticulatum and divides the two rooms from other adjacent ones blocked by a filling. During the pre-diagnosis phase, aerial thermography data were acquired which documented traces of wall structures below the courtyard of the castle (Figure 9). Furthermore, the evident change in elevation in the section of the courtyard, in correspondence with the 18th-century well, and the support surface of the Benedictine portal (repositioned in the 20th century) allow us to argue that the Roman cisterns reused as monks' lodgings ran through the basement of the upper church. In our opinion, the reuse of the cisterns to house the monks prevented the creation of an adequate system in the underground rooms to support the upper church.



(**a**) (**b**)

Figure 5. Opus reticulatum wall of the eastern basement incorporated in the oil pool: (**a**) Relief; (**b**) View of the state of conservation of the cocciopesto that protects the wall.



(**a**) (**b**)

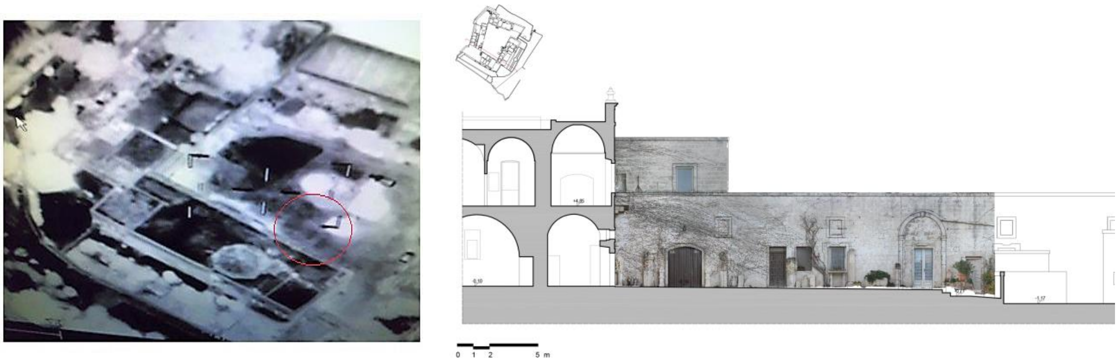
Figure 6. (**a**) Structures in opus reticulatum of the arm of the church; (**b**) Relief of the crypt.

(**a**) (**b**)

Figure 7. (**a**) View of the aisles; (**b**) View of the corridor.

(**a**) (**b**)

Figure 8. (**a**) Monks' lodgings; (**b**) Detail of the negative us of a stone slab and the floor (undocumented restoration work referable to the last century).



(**a**) (**b**)

Figure 9. (**a**) Helicopter thermography with (high definition FLIR vision system) highlighting the traces of underground structures; (**b**) Perspective section of the western arm showing the different heights in the courtyard.

3.2. Analysis of the Vulnerability of Underground Environments

3.2.1. The Plasters

The analysis of the vulnerability of the underground areas of the church has highlighted their precariousness and strengths. This analysis was conducted with investigative methods aimed at recognizing the construction techniques, the connections, the configuration of the environments, the evolutionary phases and the transformations. The perimeter walls of the crypt characterized mostly by wall sections in opus reticulatum 10 × 10 resting directly on the rocky bank, are covered with several layers of gray cement plaster. The state of conservation of the plaster appears precarious. From the comparison with the one found in the "tub for oil", not far from the crypt, completely different chromatic characteristics emerge (Figure 5). From direct observation of the wall partition of the basin, the plaster shows traces of pink cocciopesto which, unlike the gray one of the crypt, has kept the wall in good state of conservation.

3.2.2. The Degradation

Inspection of the first wall section of the corridor brought to light the core of wall BB′ of the crypt. The wall has a thickness of 60 cm with 10 × 10 cm cubilia arranged on both rows and a core with shapeless stones, sea pebbles, marine sand and cocciopesto (Figure 10). The opus reticulatum is very degraded. A state of alveolization is observed. Overall, the state of conservation of the crypt premises is compromised by various factors. The first cause of deterioration of masonry in opus reticulatum is attributable to rising damp. In fact, both in the crypt and in rooms (b) the opus reticulatum masonry rests directly on the rocky bank of the peninsula. In the rooms of the crypt the walls are covered with several layers of gray plaster (with great effort we have reconstructed the texture of the walls). In rooms (b) the side walls, in opus reticulatum, have no plaster and show the cubilia deformed by the crystallization of the salts. The cocciopesto joints have almost completely disappeared. Another cause of deterioration that could have caused instability even in the upper rooms is the type of construction material of the opus reticulatum. A soft "tuffaceous" calcarenite predisposed to absorb salt, recovered in neighboring quarries already compromised by the saltiness.

(**a**) (**b**)

Figure 10. (**a**) Entrance of the corridor in wall BB′; (**b**) Thickness of wall BB′ in opus reticulatum with morphological characteristics.

3.2.3. The Comparison

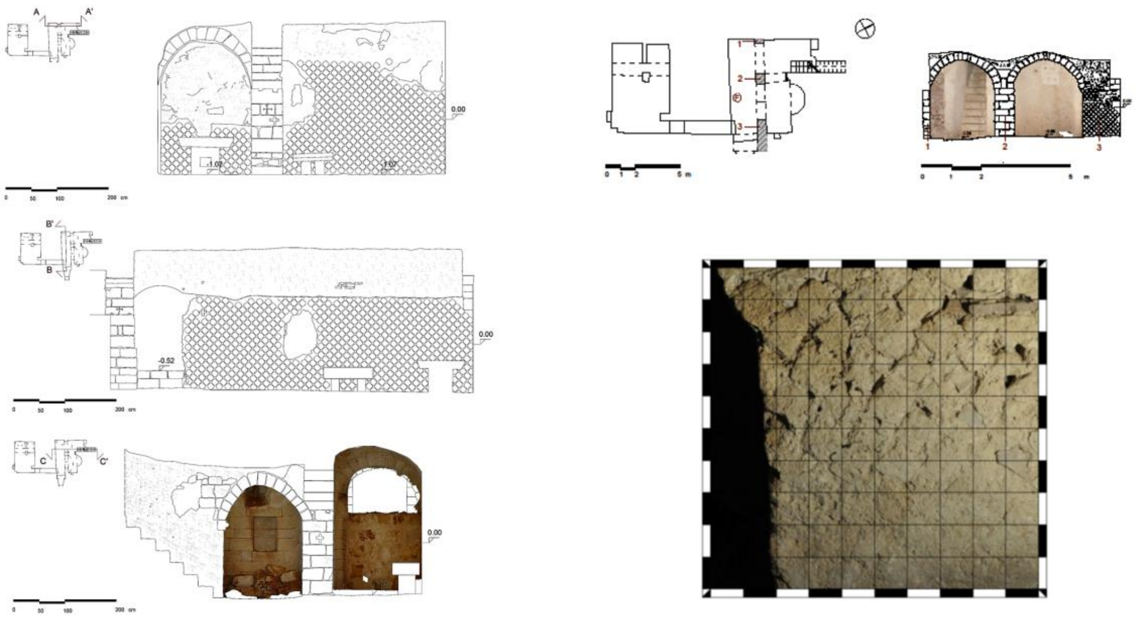
The comparison between the opus reticulatum of the base of the Castle and that of the submerged plinth of the Roman port of nearby Egnazia highlights the action of the sea on the tesserae in opus reticulatum. The water pulverized the cubilia into opus reticulatum, unlike the surviving cement mortar. Was this a wrong choice of building material? Unsuitable material for the construction of both the canals is found in Santo Stefano and the port of Egnazia. In Egnazia the opus reticulatum was used only in a few buildings: the cryptoporticus and the submerged piles of the port [13]. It is not excluded that one of the causes of the collapse of the port may have been the use of "tuff" for the opus reticulatum structures which over time, and with lack of maintenance, led to the loss of cohesion of the pilae. In Santo Stefano, therefore, the vulnerability of the underground environments depends on the alveolization of the opus reticulatum (Figure 11).

(**a**) (**b**)

Figure 11. (**a**) Santo Stefano cubilia in direct contact with the rock; (**b**) Egnazia cubilia of the submerged pilae. It can be observed how the Roman concrete has resisted the degradation, unlike the tuff cubilia which have partially disappeared.

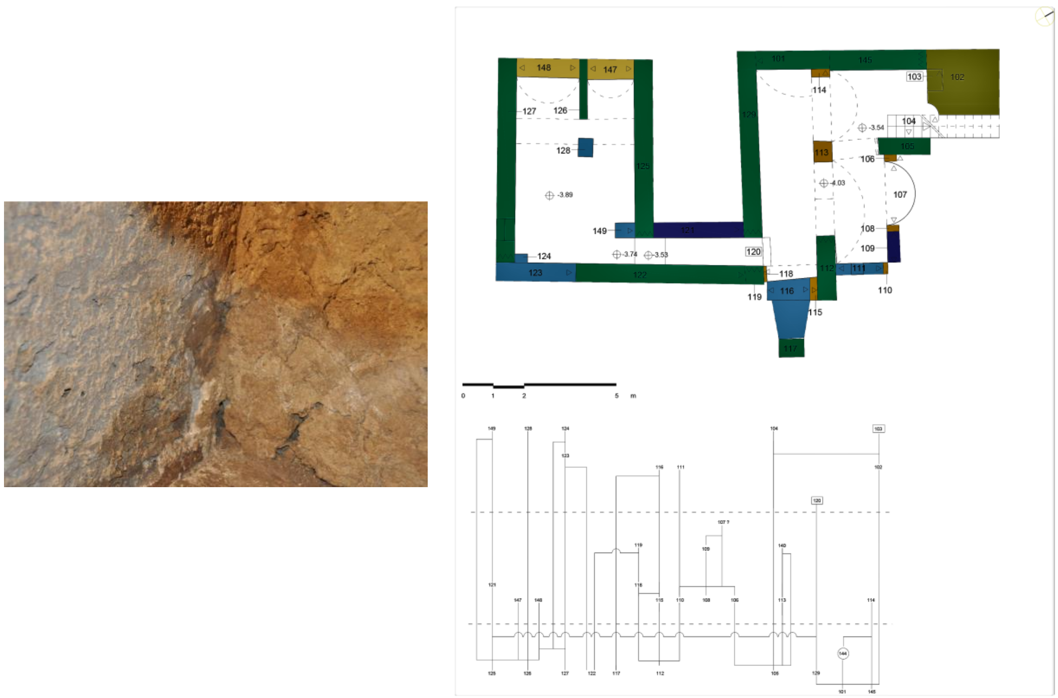
3.2.4. Stratigraphic Investigations

The investigation of the stratigraphic relationships of the walls of the crypt (summarized in the Herris diagram) and the morphological and constructive study of the masonry itself have yielded different construction phases, but also various construction sites relating to the same construction phases (Figures 12 and 13). The investigation aimed at identifying any joints and/or edges in the perimeter walls is interesting. The test carried out in the lower corner of walls AA'–BB' demonstrates the non-existence of the cantonal between the two walls in opus reticulatum (not recurrent in constructions in opus reticulatum). Between the 2nd and the 1st century BC, the ashlars placed on the masonry heads in opus incertum were progressively replaced by angular (cantonal) strips. The corners are not evident even in the rooms (b) where a masonry infill of rough stone blocks of various sizes with mortar joints is placed against the opus reticulatum wall. The lack of cornerstones was certainly the cause of vulnerability which, with the typological characteristics of the masonry, helped to define the criticality of the foundation environments (crypt).



(**a**) (**b**)

Figure 12. Investigations: (**a**) Investigations on the morpho-typological and constructive characters of the wall partitions such as AA′ and BB′; (**b**) Morpho-typological characters of the FF′ wall with description of the masonry sampling in material (mixed material with cubilia of the size 10 × 10, irregular stone blocks bordered by flakes and bricks, in correspondence with the arch tax a tessera in opus reticulatum).



(**a**) (**b**)

Figure 13. (**a**) Lower corner of walls AA′ and BB′ with lack of clamping; (**b**) Harris diagram on the different construction phases of the crypt.

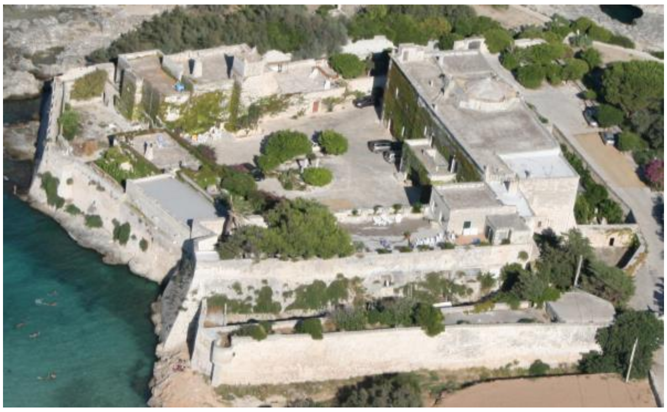
4. Analysis of the Church Blockade

In the Benedictine era the church of Santo Stefano, with a single nave, was divided into four bays: the fourth apse bay was erected, as shown by the studies presented here, above the crypt—which for a long time served as a place of worship—while the three bays of the longitudinal body were superimposed on the monks' lodgings. Already restored during the 13th century, it underwent mutilations and manipulations in the 19th century. On the terrace emerges the octagonal lantern with a pyramidal roof with eight slopes, incorporated into the residence and corresponding to the apsidal choir of the primitive Benedictine church. Two inscriptions: (1) in the Benedictine portal, repositioned in the 19th century; (2) on the eastern facade of the 18th-century building, describe the restorations by Abbot Riccardo (1236) and Abbot Matteo (1296). The introduction of the ribbed bays could refer to the latter intervention, which modifies the original layout, perhaps characterized by aligned domes as suggested by the surviving eight-pitched roof module (now incorporated into the 19th-century residence) probably aimed at lightening the roof above the perimeter and foundation walls [14] (Figure 14). From the studies carried out it emerges that between the end of the 15th and the beginning of the 16th century, the Abbey was transformed into a castle in analogy with the coastal fortifications of the territorial context. The church of the castle was considered an essential pre-existence also for its "defense" function on the south-west fronts of the port. The cannons positioned on the roof are visible in the 17th-century iconography. Scarp walls were added to the high south-west facades, which also closed off the entrance to the Benedictine portal. The new entrance to the place of worship opened into the internal courtyard (Figure 15). In 1757, twelve years after the Brindisi earthquake, the Balì Francone arrived in Santo Stefano and found the house of the Balì Marulli (1675) in a state of ruin. At the same time, he realized that the church "threatened to collapse". The hypotheses on the demolition, to rebuild it in a reduced form by the Balì Francone, have been replaced by a reinforcement project by means of a railing of the lower and upper rooms on the front of the internal courtyard with a residential function and reinforcement of the Church. The interventions of the 18th century, documented by unpublished sources [15], are then described in the cabreo of 1777 [16] (Figure 16). A stairway with a loggia led to the first floor apartment. The narrow and long rooms gave way on one side to the hanging garden and on the other to an "arch" that overlooked the southern bulwark. In the pre-diagnosis phase, the church block was investigated with thermographic investigations which highlighted the differences in the wall textures of the 18th and 19th centuries. With the end of the fiefdom of the Knights of Jerusalem, after 1813, Santo Stefano was purchased by private individuals [17]. Archival studies show that between 1845 and 1879 the church was mutilated in the first and fourth bays to expand the residential areas. The first span was replaced by a new lowered building block. The Benedictine portal was dismantled and repositioned on the new facade characterized by different wall structures. The fourth bay was incorporated into the 19th century house. The 18th-century alcove of the building was replaced by two rooms overlooking the moat.

(**a**)

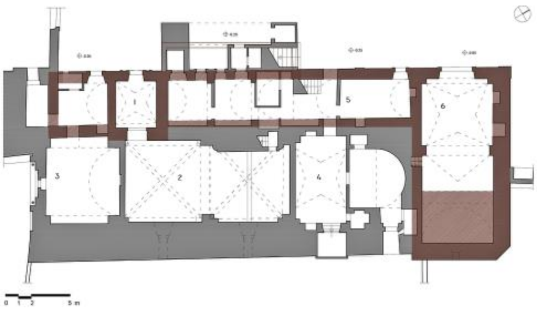
(**b**)

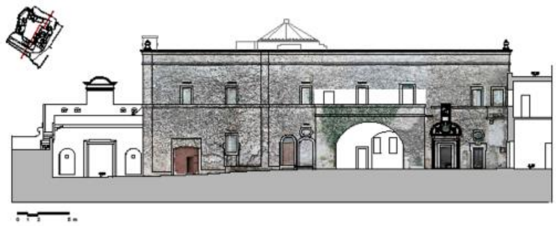
Figure 14. (**a**) Relief of the Benedictine portal; (**b**) View of the dome.



(**a**) (**b**)

Figure 15. Comparison between: (**a**) Cabreo di Santo Stefano from 1645; (**b**) Aerial view of the castle 2015.





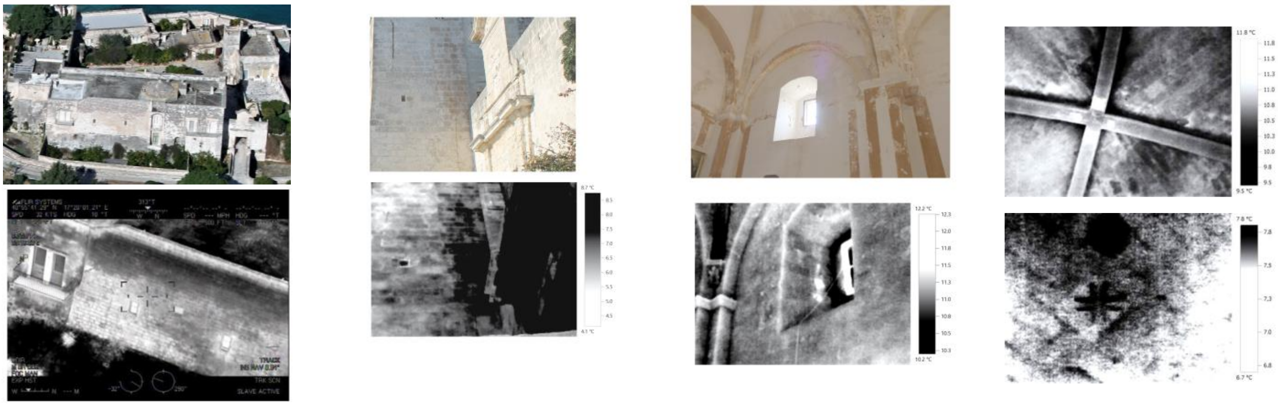
(**a**) (**b**)

Figure 16. (**a**) Survey of the ground floor of the ecclesiastical block, which highlights the 18th-century interventions commissioned by the Balì Francone; (**b**) Elevation of the facade of the 18th-century building with modifications from the 19th century.

4.1. Vulnerability Analysis of the Church Blockade

4.1.1. Thermographic Pre-Diagnosis

In the pre-diagnosis phase, low-altitude aerial shots were analyzed which gave different thermal responses between the 18th-century interventions compared to the previous and subsequent ones [18]. The thermographies, carried out on the eastern elevation, have highlighted two distinct sections of wall texture: the first, northern, corresponds to the 18th-century intervention; the second, southern, corresponds to the 19th-century renovations. In the 18th-century entrance room of the church, on the plastered vault we have highlighted ashlars that cannot be compared with those of the vaults of the internal bays (Figure 17).



(a) (b) (c) (d)

Figure 17. Thermographic investigations preparatory to the study of the church: (**a**) Aerial view in the visible and near infrared of the south facade; (**b**) Images in the visible and near infrared from the ground with Testo 883 thermal imaging cameras of the east facade; (**c**) Visible and near infrared image of the bricked-up window; (**d**) Near infrared image of the vault of the second span and the church entrance (the different wall structure of the two reconstructed vaults, the first rebuilt in the 19th century and the second in the 18th century, is highlighted).

4.1.2. Comparison

Comparison of the 1675 Cabreo with Phippe Hackert's 1790 painting reveals changes to the walls of the church. The southern wall of the cabreo has an enfilade of windows at the top. In 18th-century painting there are only two windows. The introduction, on the south facade, of a first chain with a plate terminal, different from the other two, added later, could refer to the 18th-century restorations. The chains are intended to prevent the perimeter walls from overturning and to guarantee the box-like behavior of the building in the presence of seismic events and refer to interventions aimed at maintaining the static equilibrium of the building.

4.1.3. The Brindisi Earthquake

The chains, little used in the area due to the absence of significant seismic events, refer to a single episode, that of the 1743 Brindisi earthquake (Figure 18). Historical accounts consider the earthquake of 20 February 1743 a seismic event of epicentral intensity I0 = IXdegree MCS and estimated magnitude M 7.1 [19]. The restoration works of Balì Francone refer to 1757, about 10 years after the earthquake. The first cast iron chain may have been inserted on this occasion.

(a) (b) (c)

Figure 18. (**a**) Cabreo from 1675 (**b**) painting by Phippe Hackert from 1790 (**c**) detail of the South facade today, with closed monafora.

4.1.4. The Stratigraphic Survey

The stratigraphic survey of the south facade has brought to light three distinct sections of masonry. The first, coming from the former first span of the church (houses on both levels) has a gabled back wall surmounted by a balcony. The wall structure is similar to that of the previous fourth span. The latter is characterized by a window with frames surmounted by a balcony with a mixtilinear profile (residential areas which include the apse choir), and finally the 19th-century loggia (of the new rooms). The central part of the wall, on the other hand, has ashlars of different sizes in the lower part (similar to those found on the ancient Porta della Tramontana) covered with a thin layer of plaster. In the interface area of the upper equipment, the key heads of three different chains can be seen. The upper ashlars, with concrete joints, are not comparable to those of the first two bays of the church or to the lower ones of the wall. The western facade, affected by the repositioning of the Benedictine portal, has an upper wall texture similar to the southern ones of the two former bays of the church (Figure 19).

(**a**) (**b**)

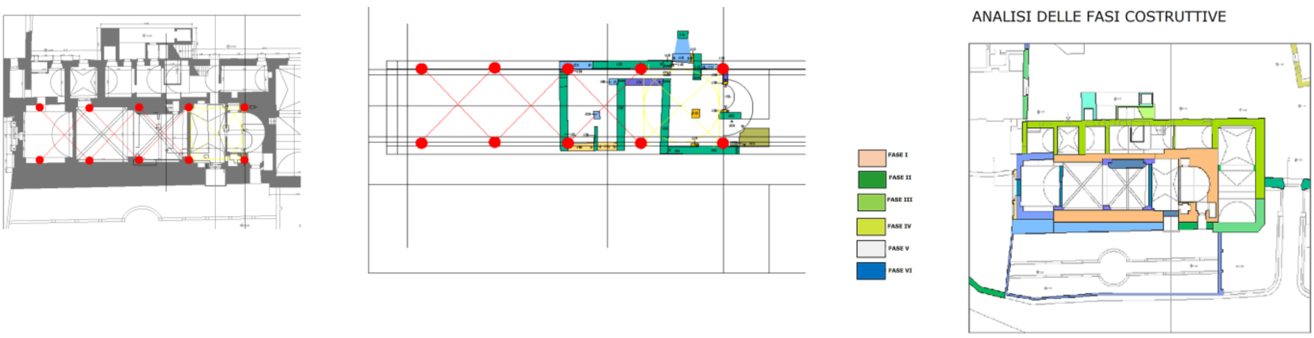
Figure 19. Stratigraphic analysis of the façade: (**a**) Western façade; (**b**) Southern façade.

4.1.5. The Church Today

The inside the church, divided by six pillars, four of which are partially incorporated in the 19th-century partitions, has an uneven spatial hierarchy. The tax planes and pitch of the roofs are characterized by a morphological and constructive irregularity of the roof plane where the differences between the two roofs are highlighted. The vaulted ceilings are reconstructed. This intervention is also confirmed by the repositioning of the ribs of the crosspieces where a non-relationship emerges between them and the original sculptures, reinserted in a non-homogeneous way on the tax planes. Thermography of the window of the altar span shows the infill of half a lancet window—also evident on the external wall but compensated by the repositioning of the ashlars (Figures 17c and 18c). The single lancet window had to be positioned in the central point of the wall corresponding to the wheelbase, as in fact the window reconstructed in the 19th century is positioned. Therefore, the punctiform and vertical structures appear to have been "moved" as documented by the investigations of the spans. As proof of the above, the 3D survey of the internal section of the church shows the support pillar with the discharge of the new roofs offset with respect to its center of gravity [20] (Figures 20 and 21).

(**a**) (**b**) (**c**)

Figure 20. 3D relief: (**a**) altar; (**b**) back wall; (**c**) southern perspective section.



(**a**) (**b**) (**c**)

Figure 21. (**a**) Study of the construction models of the spans; (**b**) Overlapping of the pillars in the base of the crypt; (**c**) Analysis of the construction phases of the block of the church.

5. Conclusions

At the conclusion of this study, the salient points of the state of conservation of the isolate are summarized. The ancient cisterns in opus reticulatum "reused" for the crypt with the lodgings of the monks, also in order to obtain a cavity between the rocky bank and the upper cult building as in many cathedrals on the sea in Puglia, have favored the problems of instability of the upper church. The Benedictines did not take into account either the porosity of the stone material of the opus reticulatum "tuff", or the lack of fixtures and cornerstones of the walls. The church, most probably already rebuilt in the Middle Ages with the removal of three domes, continued to have static problems. At the beginning of the modern age, scarp walls were added which on one side had a defensive function and on the other also served as support for the ancient building. The 18th-century restorations carried out shortly after the Brindisi earthquake (50 km away from Santo Stefano) could be attributable to seismic tremors which, with the vulnerability of the underground environments, caused their collapse. However, the 18th-century restoration was carried out on precarious foundations (the crypt). Could the first private individual who bought Santo Stefano Rocco Morelli find the arm of the church in a state of collapse thirty years after the end of the feud? This is possible and can be deduced from the total reconstruction of the first span. Why not place it in residential settings like the last one?

The surviving bays of the church are the result of horizontal and vertical reconstructions. The introduction of the new chains in the 19th century had the aim of avoiding an overturning of the vertical planes. In addition, the lack of correspondence between the central, upper masonry of the southern front with the other neighboring ones of the 19th-century interventions suggests that the 19th-century construction sites were divided into: reconstruction of the first span for residential environments; incorporation of the presbytery with the module above the apse in the house; and reconstruction of the upper wall of the church with relative vaults. A problem is that of guaranteeing the box-like behavior of the building, which has never been fully resolved by the studies carried out in the various seasons in which, from time to time, demolition and reconstruction interventions were carried out. Conservation requires a sustainable restoration project which generally concerns the safety of the structures by applying a seismic improvement by reinforcing the existing foundations, consolidating the vaults; use of environmentally friendly materials such as treatments that limit or block the damage caused by salt without altering the natural characteristics of the materials; and finally the recovery and conservation of the green areas of the castle.

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References

1. Conservazione Preventiva. Available online: https://www.iccrom.org/it/section/conservazione-preventiva (accessed on 9 October 2022).
2. Diceglie, A.; D'Amico, N. Preservation and rehabilitation of historic buildings and structures: Case studies. The restoration site of an house in Monopoli Largo Castello, N. 5. In Proceedings of the REHAB 2017 3rd International Conference on Preservation, Maintenance an Rehabilitation of Historical Buildings and Structures, Braga, Portugal, 14–16 June 2017.
3. Cagnana, A. *Archeology of Building Materials*; Publisher: Mantua, Italy, 2000.
4. D'Amelio, M.G.; Esposito, D. The Dismantling Site: The 'Stony Ground' along the Via Flaminia. Observations on the Recovery of Building Materials. In *On the Via Flaminia, The Mausoleum of Marco Nonio Ma-Crino*; Rossi, D., Ed.; Electa: Milan, Italy, 2012; pp. 331–343.
5. Bernard, J.-F.; Bernardi, P.; Esposito, D. *Reuse in Architecture: Recovery, Transformation, Use*; Collection de l'École Française de Rome, 418: Rome, Italy, 2008.
6. Diceglie, A. Problems of conservation of archaeological structures subject to variations in humidity. The Case Study of the Castle of Santo Stefano. In *Proceedings of the First International Scientific Conference "The Colors of Restoration"*; Nardini Editore: Florence, Italy, 2021; pp. 475–489.
7. Diceglie, A. *The Castle of Santo Stefano in Monopoli in Puglia*; Archeology for Architecture; Gangemi: Rome, Italy, 2018.
8. Egnazia. Available online: https://www.progettomusas.eu/arch_site/egnazia/ (accessed on 9 October 2022).
9. Diceglie, A. Cit. 2018. Available online: https://www.academia.edu/28570572/Tecniche_edilizie_nel_mondo_antico (accessed on 9 October 2022).
10. The Aerofotografico Center Laboratory Consortium of the University of Bari Aldo Moro Operational from 2000 to 2015 Mainly Dealt with Aerial Prospecting, Remote Sensing Surveys, Thermographic and Geophysical Surveys for the Knowledge of Urban Centers of Historical Artifacts and Archaeological Areas.
11. Bianchini, M. Building Techniques in the Ancient World, Rome. 2010.
12. D'Amico, N. Naples, State Archives, General Administration of the Amortization Fund and Public Property, Malta-Putignano-Cabreo di S. Stefano, b. 3540, f. 164, 1675, ff. 3v–4v. In Monumental Testimonies and Settlement Policy of the Bailiffs of Santo Stefano in the Light of Relations with Rhodes and Malta. Ph.D. Thesis, History of Comparative Art, Civilizations and Cultures of Mediterranean Countries, XXIV Cycle, University of Bari 'Aldo Moro', Bari, Italy, 2013.
13. Seymaour, L.M.; Maragagh, J.; Sabatini, P.; Di Tommaso, M.; Weaver, J.C.; Masic, A. Hot mixing: Mechanistic insights into the durability of ancient Roman concrete. *J. Sci. Adv.* **2023**, *9*, eadd1602.

14. Calò, M.M.S. Two Cathedrals in Molise: Termoli and Larino, Rome 1979; EAD, San Leonardo di Siponto «iuxta stratam peregrinorum», Galatina 2013 (Small Monographs of Puglia); EAD, Monte Sant'Angelo. The Monumental Complex of San Pietro, Santa Maria Maggiore and the Baptistery of San Giovanni, Galatina 2013 (Small Monographs of Puglia). 2013.
15. D'Amico, N. Valletta, National Library, AOM 6002, f. 11v, Summary of the Restorations of the Balì Francone in Santo Stefano. In Monumental Testimonies and Settlement Policy of the Balì of Santo Stefano in the Light of Relations with Rhodes and Malta. Ph.D. Thesis, History of Art Comparative, Civilizations and Cultures of Mediterranean Countries, XXIV Cycle, University of Bari 'Aldo Moro', Bari, Italy, 2013.
16. ASB (State Archives of Bari). *Fll. 48–53 Cabreo di Santo Stefano from 1777*; ASB: Bari, Italy, 1777.
17. ASB (State Archives of Bari). *Intendenza di Terra di Bari, State Property, 'Comparative Status of the Assets and Income Described in the Cabreo del Baliaggio di Fasano under the Title of St. Stephen of the Year 1777 for Notar D. Andrea Zac-caria of Ostuni', B. 29, Fasc. 431*; ASB: Bari, Italy, 1777.
18. AA. VV. The stratigraphic analysis of the elevated: Contributions to the knowledge of fortified architecture and to the restoration project, supplement of Medieval Archaeology, All' insignia of Giglio Florence 2006. In Proceedings of the 11th Congress of Archeology of Architecture of Udine 2006, Udine, Italy, 10–11 November 2006; Quendolo, A., Ed.; Giglio: Florence, Italy, 2006.
19. Available online: https://ingvterremoti.com/2020/08/17/la-sismicita-storica-del-salento-il-forte-tremoto-del-20-febebruary-del-1743/ (accessed on 9 October 2022).
20. Carocci, C.; Macca, V. Buildings' masonry work: Construction quality and seismic damage after 2016 Italy earthquake. In Proceedings of the HERITAGE 2020—7th International Conference on Heritage and Sustainable Development, Coimbra, Portugal, 8–10 July 2020; Amoêda, R., Lira, S., Pinheiro, C., Eds.; pp. 481–490.