Time and Material. Interdisciplinary Study for Dating St. Francesco Convent in Cagliari (XIII-XXI Century)

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This study concerns the Franciscan monastery, situated in the historic centre of Cagliari (Sardinia, Italy). It was founded in the 13th century, and transformed up to the present day. Its historical-stratigraphical complexity and the lack of data about its evolution led us to carry out an interdisciplinary inquiry. The investigation began with the use of a laser scanner survey aimed at defining a chronological hypothesis applied to the building which was based on reconstruction of historical maps, examination of masonry techniques and stratigraphic analyses. The dating obtained led to the choice of masonry samples to compare with other local and contemporary buildings where the chronology is well-known with the aim of confirming previous hypothesis. Analysis of the masonry samples allowed an understanding of their actual structure and composition, with reference to specific historical events. The mineralogical-petrographic characterization of building materials was essential. Plaster and mortar have been studied with instrumental techniques (OM, X-Ray diffraction) to analyze their components. The data obtained lead to a better knowledge of the Franciscan complex and this is essential for a restoration project respecting all its historical signs. The data is also very useful for dating other local buildings characterized by the same masonry techniques.

Introduction

This paper illustrates the results of an interdisciplinary methodology, developed by a team of researchers which involved restoration experts, surveyors and a petrographer, with the aim of obtaining a complete knowledge of the building analyzed. This case study is of the religious complex called San Francesco which is located in the historical quarter of Stampace in Cagliari. The building dates back to the 13th century and over the course of time it has been object of various transformations, alterations and collapses which have modified both its original size and structure with the use of different

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techniques, workers and materials. The documentation of the interventions that have occurred since the origin of the building is no longer available in the historical archives. The advanced state of decay has allowed stratigraphic investigations and a deep study of masonries, from a technical and material point of view.

The protocol used for the study of the complex followed five phases: 1. historical-architectural study; 2. 3D laser scanner survey to give graphic output data; 3. materials and degradation analyses; 4. stratigraphy and chronology of the architecture; 5. archaeometrical analysis of masonries, mortar and plaster. The systematisation of all collected data has been fundamental to the dating hypothesis concerning the building, as a necessary premise for the definition of a conservative restoration project, as well as for the dating of other coeval buildings situated in the same geographical context.

The Franciscan Convent

The San Francesco architectural complex was originally built as a church and a series of buildings used as a convent, surrounding a large cloister (see Figure 1).

As we said before, because of the succession of many events, it is now in an advanced state of decay. It only retains the ground floors of the eastern, southern and western parts which define the cloister area (see Figures 2a-b), and the west side, which originally housed the refectory (see Figure 2c). The northern part is the only one that has kept its upper level (see Figure 2d), although completely embedded in the newer buildings built in the late 19th century, consequent to the demolition of the church and the urban renewal of the area. Also, the southern part of the cloister is very compromised, having been partially demolished in order to open a new street in the middle of the 20th century.

The church, demolished in the late 1870's, due to its precarious structural condition, may have been built at the end of the 13th century.

The foundation date of the convent is not known, but some researchers ascribe it to the end of the 13th century, others to the period between the 13th and 16th century. From the 19th century on, the complex faced a sharp decline especially following the final closing of the convent, the insertion of

inappropriate functions and the abandonment of entire parts of it.

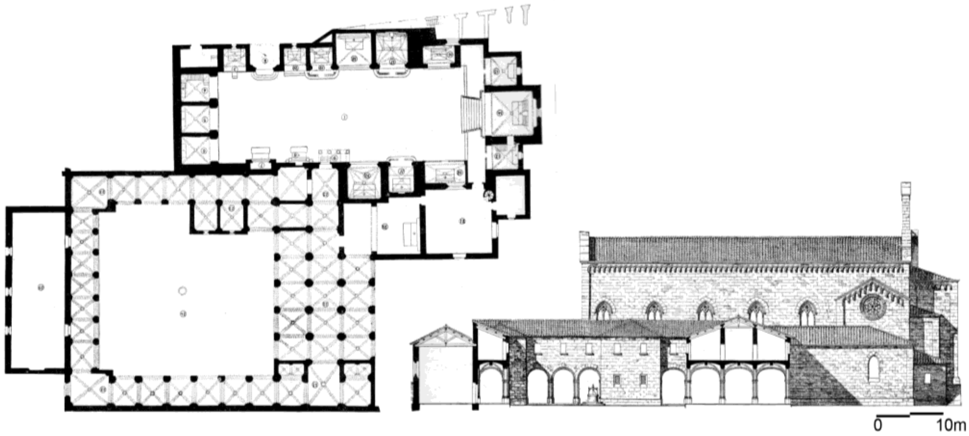

Figure 1. *The San Francesco Convent in an Illustration Published in Scano D., 1938.*

Figure 2. *The Cloister's Area (a-b-d) and the Inside of the Refectory (c) Source:* Author Aldo Vanini.

In addition, the surviving buildings were seriously damaged in the bombings of 1943, losing their respective upper levels.[1] Later in 1949 the southern side was knocked down. Nowadays this monument and its high historical, artistic and cultural value are irreversibly compromised.

The buildings that delimit the cloister on the north, south and west sides are characterized by a very simple decoration, with arches between the spans and crossed vaults with pendula (see Figure 3a). The west side is connected with the former refectory.

The east side presents numerous anomalies in comparison with other sides, consisting of a double row of crossed vaults, with different characteristics in

1. Caterina Giannattasio and Valentina Pintus, "Il Complesso Claustrale di San Francesco a Stampace in Cagliari. Archeologia dell'architettura per il progetto di restauro," in *Arkos* (2013): 51-72.

size and form. The two parts are connected by arches of different typologies (see Figure 3b).

The buildings facing the cloister show a floor plan articulated in square modules (see Figure 3c), with crossed vaults held up by finely decorated pillars and capitals (see Figure 3d), with some variants, caused by the subsequent stratifications which clearly compromised the original homogeneity of the architectural complex.

The spatial system was once characterized by a complete continuity between the modules. This was later lost in order to create separate rooms for functional purposes. This also entailed the closing of the colonnade towards the cloister, through the construction of exterior walls of different heights. The analysis of the vaults and arches system, supported by the drawing of synthetic graphical drafts, was particularly useful in making formal and stylistic assessments.

Figure 3. *The System of Vaults and Arches of San Francesco Convent*
Source: Author Valentina Pintus.

The mapping of the wall typologies and their representation was also very important as it supported, on the basis of dimensional-chronological assessments, the dating of the entire complex. In some cases the new results overturned the previous chronological theories, mainly centered on stylistic considerations, which ignored the modern phases that seriously affected the edifice.

The Methodology

The study of the architectural complex was based on direct analysis, supported by historical information, cartographic, iconographic and photographic documentation, analysis of decorative elements and stratigraphy considerations.[2] The masonries were studied analytically by placing in evidence samples chosen for the size of stone elements, their distribution, and details related to the composition of mortar and plaster taken from archaeometrical analyses. The complexity and volume of data required a database system to record and manage the information. It was based on thematic sheets for the masonry samples, reserving capacity for a close examination of plaster and mortar.

In detail, the stratigraphic method[3] was divided into three main phases: a) identification of stratigraphic units (masonry stratigraphic units - msu; surface stratigraphic units - ssu; negative stratigraphic units - nsu); b) definition of connections between the stratigraphic units in order to establish diachronic or synchronic relationships between the parts; c) construction of a relative chronology between the same units (see Figures 4-5).

Figure 4. *The West Facade: Stratigraphic Analysis of the Structures, Dating and Transformations Hypothesis*
Source: Authors Caterina Giannattasio and Valentina Pintus.

Actually, because of the lack of archival sources we could not obtain an absolute chronology, but on the basis of the relative one, it was possible to associate a temporal interval to each identified phase. Following this investigation, we were able to hypothesize that the complex was built in subsequent phases, some of them very close to each other.

To the first phase, around the 15th-16th century, can be ascribed the external module of the eastern side of the cloister, and in particular the six quadrangular spans with crossed vaults and the rectangular space to the north

2. Caterina Giannattasio et al., “The medieval San Francesco convent in Cagliari: from the architectural, material and historical-stratigraphical analysis to the information system,” in *International Journal of Heritage in the Digital Era* (2014): 413-429.

3. Silvia Beltramo, *Stratigrafia dell’architettura e ricerca storica* [Architecture stratigraphy and historical research] (Rome: Carocci, 2009).

and to the south. This hypothesis is supported by the fact that the spatial and stylistic features of the complex are similar to those found in the Dominican convent situated in the Villanova historic quarter of Cagliari.

That was dated, on the basis of unpublished archive documents, at the same period. Also, the area used as a refectory seems to belong to this time, as confirmed by the wall typologies identified in its longer sides.

In a second phase, corresponding to the middle 16th century, the cloister's space would have been completed with the building of the northern, western and southern sides, including the connecting corner spaces. The fact that the cloister was built at different times is confirmed by the use of modules of various sizes.

The proposed dates were confirmed by the presence of a homogeneous masonry typology, found in the same geographical area in structures of these ages. Further transformations concerned the refectory where the partition walls are transverse to the older walls, in the east-west direction, and seem to derive from the need for reducing and rationalizing the spaces.

During a third phase, between the end of the 16th and the first half of the 17th century, a deep transformation of the original configuration may have taken place. In effect, following the precepts of the Council of Trent, chapels would have been built next to the older eastern side, doubling its size towards the west, and closing the arches on the cloister permanently.

According to some archive documents, two more chapels were built at the same time on the opposite side, to the east, together with the new building to the south. Next to the northern, western and southern sides, buttresses were built in order to reinforce the existing load-bearing structures as well as to support the raising of a second floor which was added to the southern, northern and eastern sides. The two chapels overhanging from the northern front, and latterly the edifice at the centre of the same side, seem to have been built in a fourth and fifth phase which can be placed in a period between the 17th and 18th centuries. However the dates will be earlier than 1736 which was the date of one of the historical maps we studied which attests that it is the lateral prospect of the same building, which leans against one of the aforementioned buttresses thus proving it was built in a later phase to the buttresses.

Reading and reconstructing the historical cartography was also very useful for the definition of a sixth phase, which can be ascribed to the early years of the 19th century, to which the expansions along the southern front of the cloister (this no longer exists today, due to the aforementioned new road) can be referred.

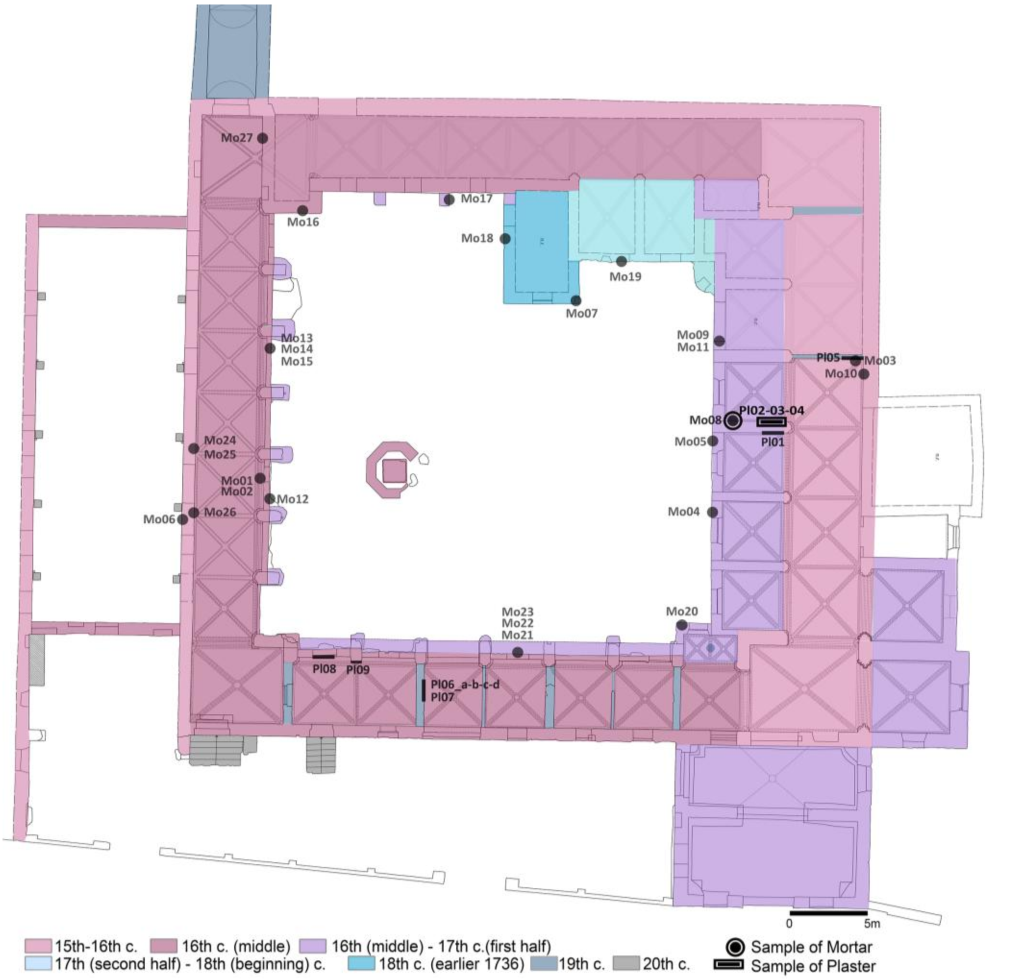

Figure 5. *The First Floor Plan of the Complex with Dating Hypothesis and Indication of Material Samples Analyzed*
Source: Authors Caterina Giannattasio and Valentina Pintus.

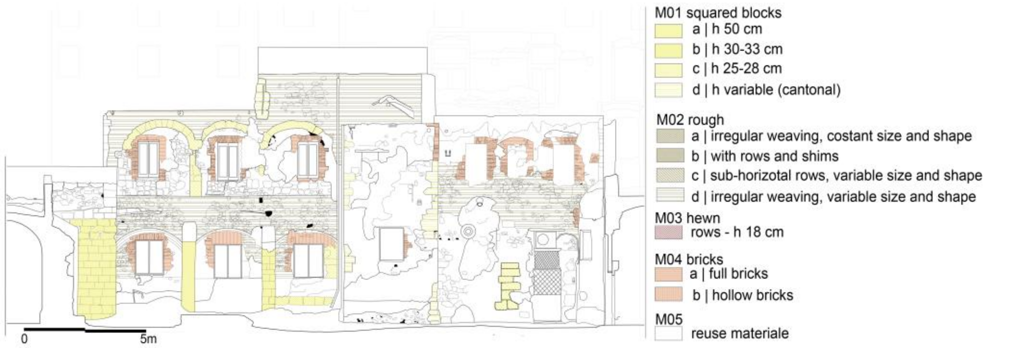

Figure 6. *The Northern Façade with Individuation of Masonry Typologies*
Source: Authors Caterina Giannattasio and Valentina Pintus.

In the middle of the 19th century, there were several devastating transformations, from the closing of the arches of the northern, southern and western sides of the cloister to the building of closing walls in the spaces on the southern side. The southern side was also seriously compromised by the opening of a driveway through one of the spans.

During the 20th century (seventh phase), and especially after the bombings of 1943, the structures on the second level of the southern and eastern sides collapsed. Furthermore, in consequence to the opening of a new driveway, the height of the floor level of the cloister space was lowered. The original floor is still visible in the foundations level.

Archaeometrical Issues

Masonries

The dating of the structures developed on the stratigraphic analysis has been confirmed by analysis of masonry techniques.

As is known, the adoption and continuing use of specific masonry techniques is influenced, not only by economic and cultural factors, but also, by local geological features and native materials with their mechanical and technological properties.

The materials used for the Franciscan complex masonry are local limestone rocks from the hills on which Cagliari is built, and commonly known as “pietra cantone” and “pietra forte”. The cloister is built almost entirely with squared ashlars and rubble masonry in “pietra cantone” with rare blocks of “pietra forte”.

With the help of the orthophoto analysis extracted from the laser scanner survey, it was possible to provide an analytical distribution of the kinds of material used. The “pietra cantone”, which is between cream and yellow in colour, is very soft and hygroscopic, so it is easily attacked by external forces. It is the most common stone investigated in the masonry.

Its physical-mechanical properties limited its use to walls coated with plaster. In fact, the damage of masonry is mainly caused by the loss of render and the elements of pietra cantone appear distressed by pulverisation and pitting. On the other hand, the “pietra forte”, employed for the masonries in large blocks, is an organogenic reef limestone that is very compact and generally white in colour. It is used for its excellent physical and mechanical properties in structural fascias and often to build portals, frames, columns and pilasters.

As we said before, the poor conservation status of the complex allowed an accurate analysis of large tracts of the walls, which were originally entirely plastered. The presence of the same masonry technique in different parts of the monument confirmed the diachronic relations in the stratigraphic study.

The structure of the complex is very heterogeneous and rich in signs of rearrangements - such as fillings and openings or demolitions and additions - which often interrupt the continuity of the original walls and interpretation is more difficult.

For the classification of masonry typologies we distinguished three main categories, depending on the form of the stones (see Figure 6): squared blocks (M01), rough (M02) or hewn (M03).

The typologies with square blocks are four (M01 abcd) and used in cantonals, buttresses, basements and walls. The masonries with rough stones are the most difficult to interpret and are divided into four subtypes (M02 abcd): rows with wedges, sub-horizontal rows, and two types irregular weaving, one of which shows stone elements of constant shape and size, the others of various sizes. With regard to the stones in hewn form, there is a single subtype (M03).

The comparison between the phases of construction of the Franciscan complex previously defined and the persistence of masonry types identified skips forward chronological hypotheses.

In particular it is clear that the masonry types M01-a-b-c e M02-a-d are placed at the phase attributable to the sixteenth century, while the type M02-c seems to be from the late 18th century, perhaps even the early 19th century. The type M01-D is connected to the phase dating from the 18th century, but prior to 1736.

Artificial Materials

The study, as described above, highlighted the need for further archaeometric information to establish the correlation between the proposed dating and the specific characteristics of masonry techniques, composed not only of stone elements but also of mortar and plaster. In this regard, the aims of the research are to link specific artificial material composition to precise dating, and also to create and progressively proceed to the implementation of a database.

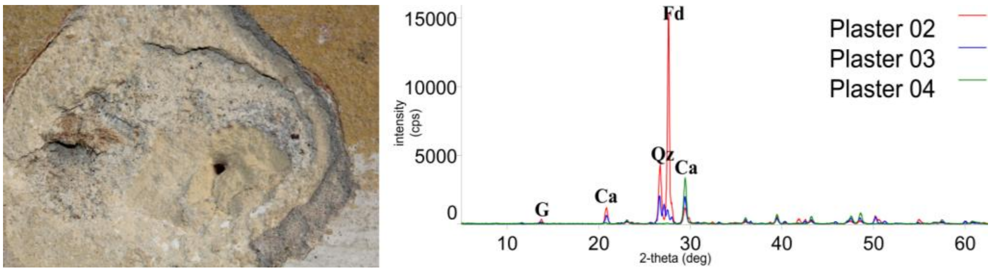

Figure 7. *Sampling of the Different Layers of Plaster in the East Side, Indoor. G: Gypsum; Ca: Calcite; Qz: Quartz; F: Feldspar*
Source: Authors Valentina Pintus and Silvana Maria Grillo.

For these reasons an extensive sampling (30 mortar, 20 plaster) was performed on different parts of the complex corresponding to different construction phases, according to the stratigraphic analysis.

Identification of the different typologies of mortar and plaster was carried out through polarized optical microscopy and X-ray powder diffraction.[4] The sampling was carried out using a lancet for the non-coherent materials and a micro-scalpel for the compact ones.

The samples of plaster 02-03-04 are successive layers in which Pl_04 is the one adhering to the masonry, Pl_02 is the outermost one, on which coating pictorial is still detectable and Pl_03 is the intermediate layer. The sample of mortar (Mo_08) was taken from the wall structure underlying these plasters, going deep in order to limit contamination.

The three samples of plaster show cream colours and different levels of cohesion, also, the Pl_02 is covered by an old red coloured paint. The layers show low mechanical resistance and adhesion to the substrate. The sample of mortar Mo_08 is soft and friable and shows a high level of degradation. It is completely incoherent.

The optical study of the aggregates and binder composition shows two types of plaster (1:pl_02-03 and 2:pl_04). Both of them consist of sandy aggregates made with a few fossil and lithic calcareous fragments with single crystal quartz grains and feldspars (see Figure 7). This composition, together with the granulometric and the morphometric characteristic of the aggregate grains are similar to those of the marine beach sand of the old city. The lime binder consists of micrite carbonates and sometimes shows a non-homogeneous texture due to the presence of lumps.

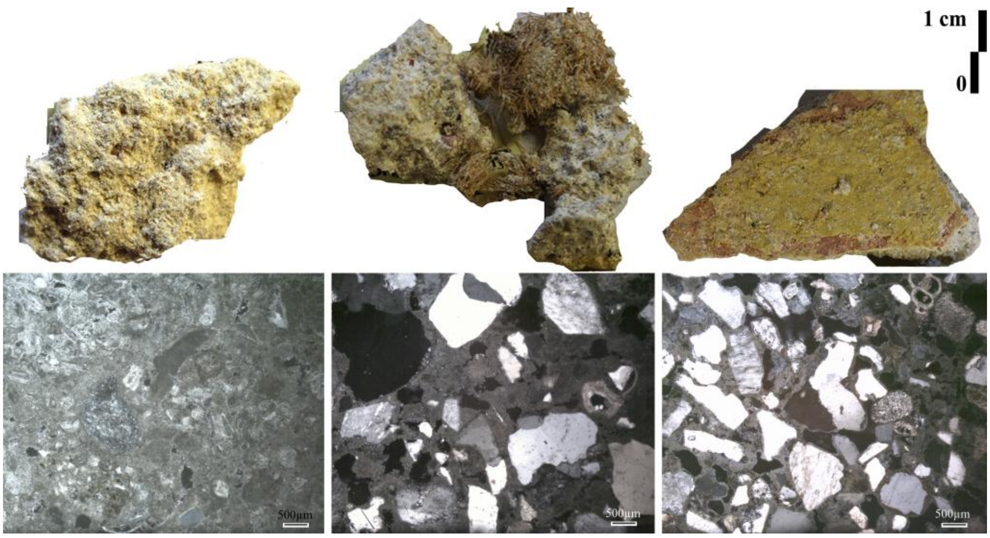

Figure 8. *Hand Samples of Plasters and Micro Photos of Correspondent Thin Sections*
Source: Authors Valentina Pintus and Silvana Maria Grillo.

4. Alick Leslie B. and John J. Hughes, "Binder microstructure in lime mortars: implication for the interpretation of analysis results," in *Quarterly Journal of Engineering Geology and Hydrogeology* (2002): 257-263.

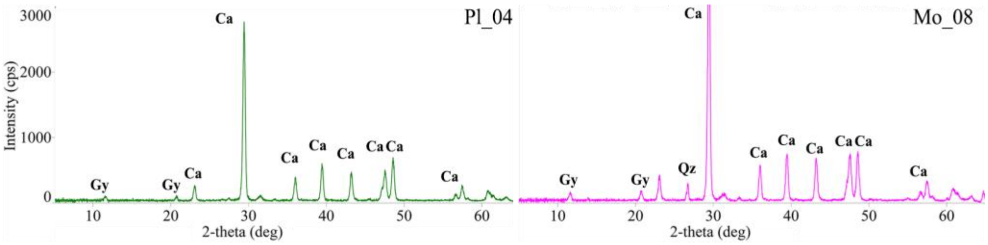

Figure 9. *X-ray Diffractions of Plaster 04 (on the Left), and of Mortar 08 (on the Right). G: Gypsum; Ca: Calcite; Qz: Quartz*

A rim of reaction with formation of cryptocrystalline carbonate and gypsum is often present around aggregate grains.

The Pl_04 has a higher binder/aggregate ratio than Pl_03 and Pl_02 (Figure 8).

A comparison between diffractograms and thin sections (see Figures 8 and 9) of the three plasters show that: samples Pl_2 and Pl_3 have the same mineralogical composition characterized by an aggregate of quartz, feldspar, and a few organic carbonates, and lime is used as the binder for all three samples.[5]

It is possible to say that plaster 02 and plaster 03 constitute two layers (arriccio and finishing) of the same plaster carried simultaneously in a single construction phase.

The plaster 04, adhering to the wall is, however, very different, as emerged in the diffractogram and in the thin section: in fact, it consists mainly of lime, with a very low percentage of aggregate. The mortar joint suffered degradation with loss of material between limestone ashlars. The strong damage is mainly caused by sulfation, as testified by the presence of gypsum. The total absence of ettringite and other calcium sulfoaluminates supports the idea that the original mortar was a lime mortar. The weathering observed is associated with diffusion through the pores of the mortar and stone and it is related mainly to the deposition of sea salt accumulated in the masonry.

According to the earlier analysis (stratigraphic and masonry types) it is possible to propose a dating for the mortar Mo_8 and plaster Pl_04 between the end of the 16th century and early 17th. The samples of plaster Pl_02 and Pl_03 can be dated to a successive constructive phase, which is not possible to define absolutely for the total lack of historical information.

Conclusions

This study highlights the characteristics of mortars and plasters of the San Francesco convent examined with reference to 15^{th}-18^{th} centuries.

This method allowed a better understanding of the monument and also an improvement of the knowledge of local historic masonries, identifying the

5. Tiziano Mannoni et al., "Ancient mortars and their binder," in *A showcase of the italian research in applied petrology. Special Issue of Periodico di Mineralogia* (2004): 259-268.

times that represent important references for dating buildings.

The dating of “minor buildings”, which were often the subject of improper treatment which disregarded their historical and cultural values, was considered.

Dating is an essential tool to protect and conserve. It is also used as a guide for good restoration work on existing buildings, based on conservative principles, for which the recognition of the various phases and specific technologies of historical materials is fundamental.

Acknowledgments

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