Survey, documentary research and stratigraphic analyses of the gothic church of S. Eligio al Mercato in Naples

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Abstract
Digital techniques of survey are an essential tool in the field of the architectural restoration, for investigation of the stratigraphy of the structures, aiming at their chronological collocation in the right historical period. Their spread has been driven mainly by the reduction of the time needed for the survey step, the better reliability of the representation of the historicized artifacts, whose constituents do not have serial characteristics, and by the development of three-dimensional models, queried, which significantly reduce the level of discretization of the survey.
The study proposed in this paper is part of a larger research whose main aim is the construction and testing of a methodological research process that allows easy reading of the medieval buildings in Naples, particularly late medieval religious architecture in Naples. This procedure utilizes the drawing, the survey and the contribution from archival data in order to complete the work with historical information. In particular, the survey, conducted scientifically, allowed to bring out information (alignments, even the smallest variations, differences in wall thickness, anomalies and inaccuracies existing or fake, relations between the various parts of the building) otherwise not deductible.
We summarize here some of the findings related to the interesting case-study of the proto-Angevin church of S. Eligio al mercato, the first religious construction in Naples after the Angevin conquest of the kingdom. Once the artifact was surveyed with laser scanner, the data obtained were used as a database for the extrapolation of significant graphic restitution such as the materical survey of the buildings and the statistic elaboration of metrological data. In the end , these data were compared with the information that emerged from the documentary research, conducted at the Historical Archive of the Banco di Napoli and the Current Archive of the Superintendent of Architectural Heritage of Naples.
In this way it was possible to investigate the stratigraphic complexity of the artifact, confirming, once again, that the layers are not occasional and rare circumstances but instead a reality itself in the architecture and that the analysis of material consistency is essential for their identification and interpretation [1].
The research has led to significant acquisitions related to to historiographical construction phases (modernization, adaptation, restoration) of the church, with significant advances in knowledge.

The Church of S. Eligio al Mercato

The church of S. Eligio is located on the southwestern edge of the Market Square, the scene of memorable events in the history of Naples. The building has walls mainly made of Neapolitan yellow tuff.
The main entrance is located on the right side and is identified by the presence of a Gothic portal, one of the few surviving elements of the Angevin construction.
The interior is characterized by a longitudinal body with three aisles, which is followed by a quadrangular transect. The central nave, higher than the side aisles, has wooden trusses roofing while the aisles, each one made of four bays, are topped with groin vaults, with irregular plan.
During the transformations of the late sixteenth century, it was joined to the church, through the opening of round arches of piperno, and through another aisle, called in the literature "hospital aisle" probably an environment pertaining to the attached fourteenth hospital added to the religious foundation. All is terminating in a central polygonal apse, on which side there are two-span rectangular chapels , ended by pointed ogival vaults (figure 1).

Historical profile

S. Eligio al mercato is the first Neapolitan religious foundation of the Angevin dynasty, after Naples was made capital of the kingdom. It was built at the initiative of a brotherhood of laymen as charitable work intended to accommodate, in a first stage, poor and the sick people, mostly foreigners, which, especially if poor, came in town without assistance and a burial place.
Charles I of Anjou, on the request of the confraternity, donated the land intended to accommodate the new church on July 2th in 1270. In 1279 a second donation, made by the

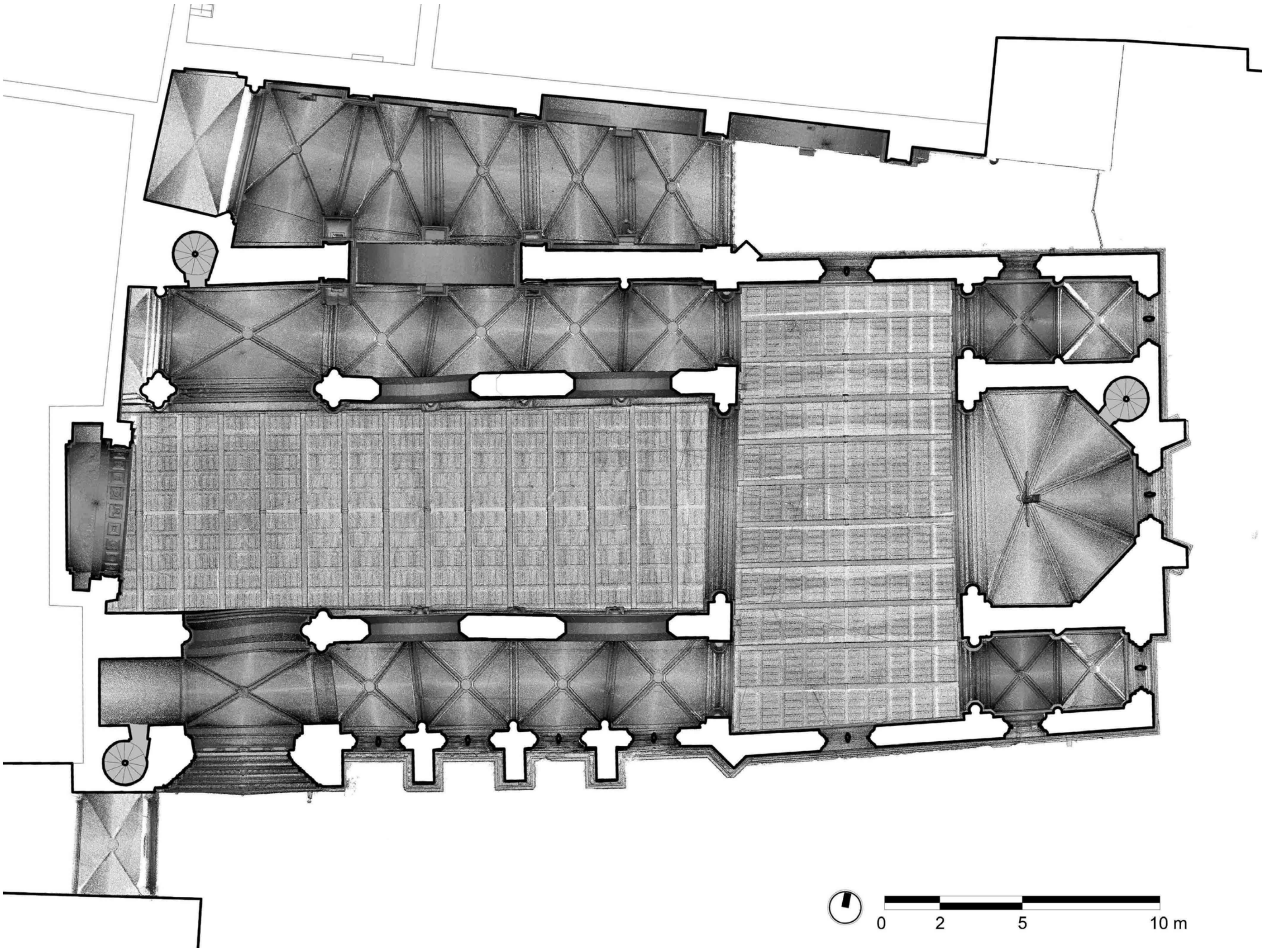

Figure 1 – Naples, church of S. Eligio, plan obtained by the post-processing of the point cloud.

same sovereign, approximately 861 m^2 of land (a band/strip wide 3 and long 41 canes) was placed in order to broaden the church and hospital.

The erection of the care complex underwent several interruptions, due, primarily, to the outbreak, in 1282, of the War of the Vespers, and also to many changes, funded by two donations of Charles II (one of 1302, the other 1304), for the expansion determined by the rapid growth of the hospital, and to the occurrence of instability and, finally, to repair the damage inflicted by the earthquakes of 1349 and 1456 [2].

Until 1546, the church and the hospital were managed exclusively by the brotherhood of laymen. From that date on, for the disposal of the Viceroy Pedro de Toledo, the administration of the church and the hospital was entrusted to three governors, then become five, one of royal appointment, the other elected by the people [3]. From the same year on in the hospital were also accepted women.

In 1592, as private donations (the main economic source the structure) were no longer sufficient to meet the changing needs of the building always in expansion, the governors of S. Eligio opened a public pawnshop.

In the early seventeenth century, the church was subject to further changes; in particular, it dates back to 1602 the payment of ten ducats for the design of a 'nova ecclesia facienda' by architect Francesco Grimaldi. Other works date back to the years 1619-20 by the master architect of the wall Giovanni Cola di Franco [4]. The fragmentary information related to these works, founded in the Historical Archive of the Bank of Naples, do not allow to reconstruct the work in detail, also because of the disappearance of the structures in the seventeenth century during the stylistic restoration.

Conspicuous and systematic are instead the news related to the restoration done in the eighteenth century. As part of the housing and urban renewal (promoted by the Bourbons from the mid-eighteenth century) of Naples, that in 1734 became the capital of the kingdom carolino, the Banco di S. Eligio commissioned, first to Luigi Vanvitelli, in 1766 to Ferdinando Fuga, the renewal of the complex and, in particular, of the church [5]. Archive documents show that in 1769 was opened a transaction account for the 'restoration' of the church. From the registers examined was deducted that several workers were under the supervision of Bartolomeo Vecchione. Just to name a few: the chief master Marino D'Acierno, the plasterer Pasquale Fucino, the marble worker Antonio Di Lucca, the carpenter Giovan Battista De Rosa, the smith Francesco Antonio Pellegrino, the gilder Giuseppe Porta and many more. The involvement of so many workers and the considerable amounts of money invested in the transaction (only for the works of marble were spent 5500 ducats) show that the renewals of the church in late eighteenth century, completed in 1774, were extended and systematic.

During the French decade, the pawnshop of S. Eligio was closed; in 1809, a commission was established for the management of the charity institutes in the city, disbanded six years later by Ferdinand IV.

After the Restoration, the literature of reference reports that the architect Orazio Angelini, in 1836-43, transformed the interior of the church, covering it entirely with stucco in classicist style [6]. However, the information founded in the State Archive of Naples attests the repair works in church, dating back to the period between 1842-43, were made under the direction of the architects Raffaele Cappelli, Domenico Mazzamauro and Giuseppe de Leva.

An air raid on March 1, 1943 caused extensive damage to the building. The documents and images related to the works made after the catastrophic event, kept in the Archives of the current Superintendent of the Architectural Heritage of Naples, in part already described in the literature [7], show that the repair of war damage, even for S. Eligio was an opportunity to conduct an extensive reconstruction, with the consequent elimination of baroque looking renewals.

Research objectives

The research aim to formalize the most appropriate working methods (in terms of equipment and technical specifications for data processing) for the survey of the Angevin monuments in order to derive stratigraphic data useful for the investigation of these construction. The survey, in fact, like the restoration, can not be considered a true science because it does not satisfy the Galilean method, cause for different solutions there are different situations and different results; however, the methodology implemented here can be considered scientific.

Before going on to describe this method it should be noted that the survey drawings used in the early stages of preliminary investigation were provided by the Regional Directorate for Cultural and Landscape Heritage of Campania, which are those made in 1992 on the occasion of the "Plan aimed at recovery and restoration of public monuments of the historical center of Naples" cured by the General Superintendent of the time, nominated after the earthquake in Campania and Basilicata.

The comparison between the surveys made in 1992 and those carried out with the use of laser scanners and those who exploit photogrammetry was not a simple exercise of metrics comparison for the search of precision (even if not less interesting) but an important opportunity to see in what ways the measurements produce information useful for the interpretations of the specific restorative practices and, finally, to understand when and how to make use of the two different methods, either separately or in combination, for the extrapolation of data useful for the next phase of preparation of the elaborate of stratigraphic investigation and reconstructive hypothesis.

Description of Methodology

The methodology used for this research consists of three basic steps: the preparation of the draft of the survey project, the acquisition of the metric data, the elaboration and interpretation of the data. In this method, based on laser scanner and photogrammetric survey, the planning phase of the operation, the preparatory moment before measurements in situ, is of particular importance. The use of these techniques in fact requires a specific survey project that indicates the location of the bases and of the target for the network of support and compensation, the definition of the steps of scanning and the resolution of each single range scan, the correct choice of the points of the station, in order to limit as much as possible shadow areas, the choice of passive sensors to be used and, above all, deciding which parts are better to be scanned with one or the other technology or with both. In the case presented here, it was decided to use laser scanner for all surfaces, both internal and external, in order to have a three-dimensional model of the entire structure from which it was easy to extract all the two-dimensional deliverables required for the next interpretation phase, and use the photogrammetric method only for the survey of the facades. The latter, in fact, provides a higher colorimetric quality, essential for the drawing of the survey of the materials. In the next phase of laser scanner survey, the instrument used was the FARO Focus 3D (figure 2) that guarantees, with the highest powerful setting and optimal environmental conditions, a range of about 120 meters, a speed of measure of 122,000 points per second, a maximum error of 2 mm at 25 linear meters of distance and an accuracy of a tenth of a millimeter. Moreover, it is able to take, thanks to an integrated CCD sensor, a number of pictures equal to 84 for each scan with a maximum resolution of 2 megapixels for single photo. They were carried out, in all, 49 scans, of which 28 external and 21 internal (figure 3), with varying resolutions between 1/8 and 1/2 of the maximum resolution (average distance of the scanning step 6 mm to 10 m), for an average span of 6 minutes each, including the acquisition of colorimetric data. (table 1).

Figure 2 – Data acquisition of external facades with laser scanner using spherical target.

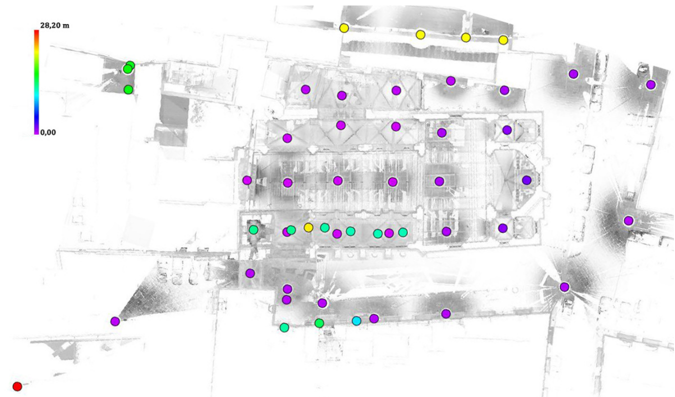

Figure 3 – Plan of all scanning stations.

During the acquisition step we made use of both checkerboard target, applied to the vertical surfaces, and spherical target as well, in order to facilitate the subsequent phase of post-processing of the data. In this way, they were included in each scan also the elements of reference useful to the union of the scans themselves: fifty paper plan targets (mark checkerboard) combined with six calibrated balls with a magnetic base (mark registration spheres) arranged at different heights above or near the building and in spots visible from several stations. The pre-alignment and registration of the scans were carried out with the FARO Scene 5.2 software. The results obtained gave acceptable values of error: an average error of overlap of individual scans of 3.4 mm and a standard deviation of 3.0 mm.

In order to compensate for the low resolution of the orthophotos obtained from laser scanner survey, photogrammetric shots have been taken using the Nikon D3100 and Nikon D3200 previously calibrated, and different lenses (18-55 mm, 18-105 mm, 10-20 mm shiftable and a 28 mm). In the shooting step, in addition to the usual parameters (focal plane, focal distance, aperture, average scale of the frame), was chosen the configuration of every single shot. In this specific case both a stereo and a multi-converging images configuration have been used. the first with axis parallel to each other and the latter when the surface to be surveyed is located at a very close distance from the shooting point.

After capturing, the frames have been processed with the software Photoscan of Agisoft to obtain a ortho images of the different facades. The software uses algorithms that allow to direct the frame even if acquired in a configuration not corresponding to the photogrammetric principles. The operations on the set and not through a web server, are completely automatic and the operator can set only certain parameters related to the quality of the final products (orientation and construction of the model). It does not provide explicit indication on the result or the orientation of the construction of the model, therefore the verification tests are based on comparison between reference models (in this case the survey obtained with the laser) or through qualitative observation. Every single facade was scaled using not a known measure, but instead using points acquired by laser scanner. In this way, the obtained cloud of points of the sigle facade by photogrammetry was both scaled and georeferenced according to the data obtained with the laser. In the end, by comparison between the graphics obtained from the three-dimensional survey and those obtained in 1992, it was possible to identify the major inconsistencies and integrate the data with new, more

Table 1 – Laser scanner settings.

	Setting	Resolution	Quality	Speed (pt./sec.)	Time	Number of scans
INTERNAL	Setting A	1/8	1 pt. each 12.3 mm a 10 m	122.000 (4X)	3’ 44”	19
	Setting B	1/5	1 pt. each 7.7 mm a 10 m	122.000 (4X)	6’ 31”	2
EXTERNAL	Setting A	1/8	1 pt. each 12.3 mm a 10 m	122.000 (4X)	3’ 44”	6
	Setting B	1/5	1 pt. each 7.7 mm a 10 m	122.000 (4X)	6’ 31”	12
	Setting C	1/4	1 pt. each 6.1 mm a 10 m	122.000 (4X)	9’ 06”	4
	Setting D	1/2	1 pt. each 3.0 mm a 10 m	122.000 (4X)	30’34”	5

comprehensive and more accurate measurements.

Results

A careful analysis of the related literature showed that the most significant gap in the study of medieval architecture in Naples is constituted by the lack of scientific surveys conducted according to the protocols of the restoration, that can't give information about the complex and stratified materials, and can't represent it and interpret it in different scales of detail like in our case.

Therefore a first result is the creation of a 'scientific' survey conducted using laser scanner technology and photogrammetry. By combining the two different methods of acquisition it was possible to realize a more rapid and accurate representation of the metric data and give specific data about the colors that has a quality suitable for the recognition of the stratigraphic units (figure 4).

As for our case study, the research carried out resulted in significant advances in the knowledge about the construction.

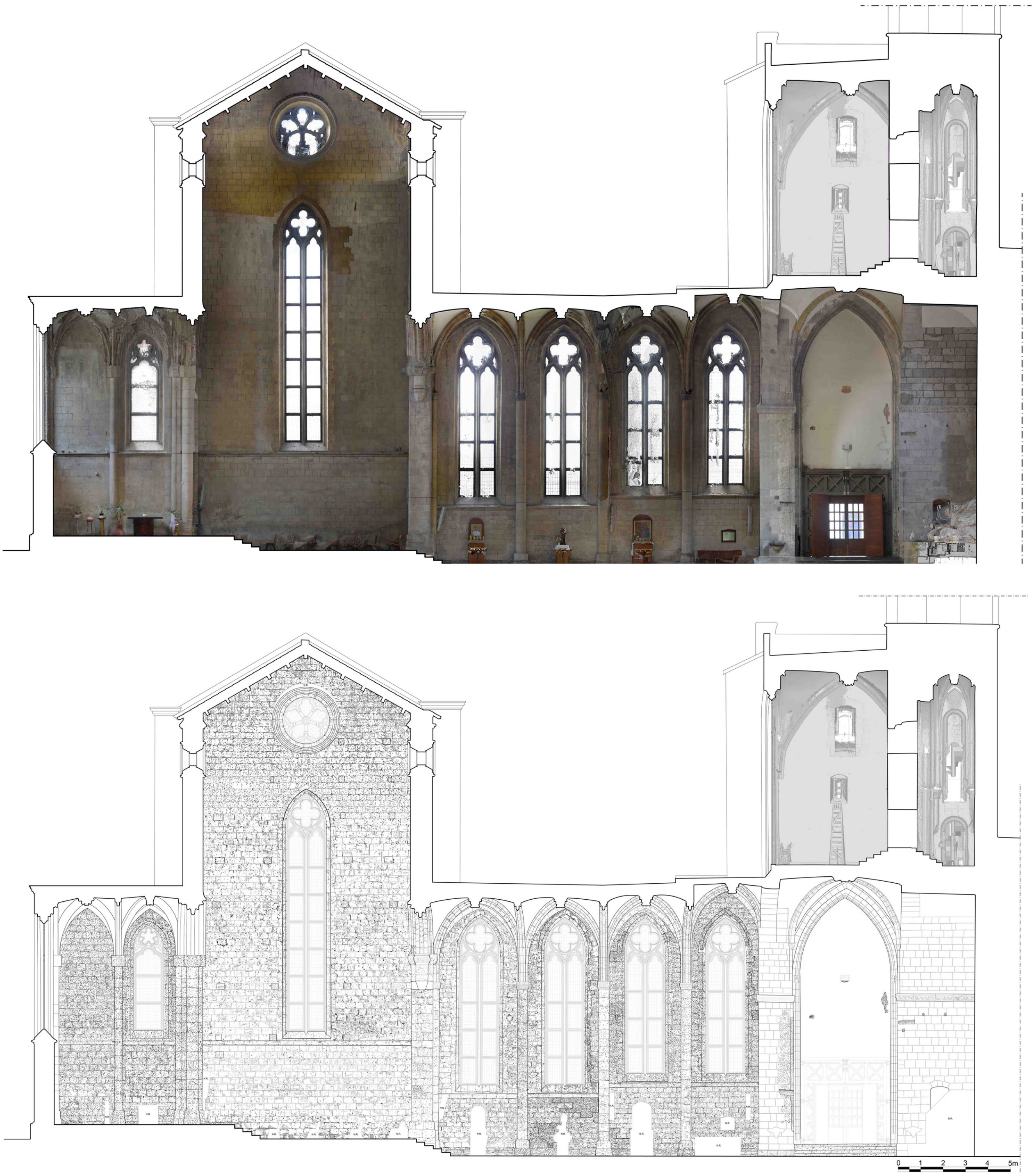

Figure 4 – Naples, church of S. Eligio, longitudinal section, ortophoto (top figure), materic survey (figure below).

In short, through the documentary research it was possible to provide a number of new data relating to the operations of restoration on the building from the eighteenth century. In particular, the information about the operations of the years 1769 to 1774, found in the Historical Archive of the Banco di Napoli, are the testimony of an extensive renovation commissioned by the Banco di S. Eligio to Ferdinando Fuga but directed by Bartolomeo Vecchione. Information on nineteenth-century restorations that regards mainly roofing, found at the State Archive of Naples, seem to deny the attribution of the operations of those years to Orazio Angelini, as reported by most of the relevant literature on the subject; in the end, the new information on the restoration work that affected the building since the war, are the result of research conducted in the Current and Photo archives of the Superintendence for Architectural Heritage of Naples. They made it possible to define, through the study of the drawings, the images and documents of those years, the extended works that interested the building after the work carried out to repair the damage caused by the catastrophic bombing of World War II. Works that have erased centuries of stratification (figures 5 and 6).

The data obtained from the documentary research, compared with the information that emerged from the surveys of materials and drawing plans, allowed to define an accurate set of information about the stratigraphic and a reliable dating. The interpretation of these data, made particularly difficult by the extensive post-war reconstruction, confirms the isolated survival of masonry attributable to the phase of Anjou, of pseudoisodomic type with blocks of yellow tuff, the presence in some parts of the eighteenth-century walls in *bozzette* masonry; almost everywhere it is possible to see the replacement or the reconstruction with blocks put in the first half of the twentieth century (figure 7).

Conclusions

Analyzing the first results achieved it was possible to identify, among the major advantages of digital reproduction, the acquisition of the complete three-dimensional geometry of the object, the storage of the model on digital media, the possibility to preserve the information in the time, the availability of a vast digital archive to be investigated at any time and the possibility to perform analysis directly on the three-dimensional replication. The upgrade compared with the traditional method of study (based on the availability of simple photos of the object or, at most, on wireframe three-dimensional models obtained by direct survey) is remarkable for the final accuracy and quantity of available information (figure 8).

Figures 5 and 6 – Naples, church of S. Eligio, extensive damage to the building after air raid on March 1, 1943 (picture right), repair of war damage (picture left).

Figure 7 – Naples, church of S. Eligio, chronology of structures.

Figure 8 – Point cloud 3D model.

The work here presented also opens the door to several possible developments and, at the same time, identifies a number of issues that require further study. We aim to extend the stratigraphic investigation to all other religious complexes of the Angevin period for which an important database is under realization. Moreover we aim to use the same methodological procedures to investigate even civil architecture of the same period. Through the materic survey of the buildings of different churches it will be possible to distinguish and recognize the few material evidence of the Angevin period for which future research could be directed to their metrological analysis, never performed in a systematic way, so as to achieve a better knowledge of medieval building techniques in Naples.

Aknowledgment

Part of this work is the result of a collaborative scientific work between the laboratories of Architectural Restoration of the Second University of Naples and of the University of Salerno, under the guidance of Prof. Luigi Guerriero, and laboratories of Architectural Survey of the University of Salerno, held by Prof. Salvatore Barba. Special thanks to the Laboratorio Modelli of the University of Salerno that had provided the laser scanner and software for the data processing and to the staff of the Historical Archive of the Banco di Napoli and of the Current and Photographic Archives of the Superintendent of Architectural Heritage of Naples for assistance in locating the relevant material.

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