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# Integrated survey as a support for the restoration project of historic religious heritage

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*Abstract*

The restoration of historic religious architecture represents a very complex operation that requires a multidisciplinary approach and a deep respect for the history and identity of the site. In this context, architectural survey stands out as an essential tool, providing a solid knowledge base necessary to guide the restoration process. This paper, in its essence, has two simple goals. Firstly, to explore the role of architectural survey as an essential support in the restoration project. Secondly, to draw attention to a historical monument of secondary importance, which may not have national resonance but still deserves to be acknowledged. The topic of this research, conducted by several professors from different disciplinary areas of the Department of Engineering and Architecture of Parma University, is the in-depth study of the Beata Vergine del Carmine complex in Soragna (Parma, Italy). Partially abandoned for several years, it consists of the Church of Beata Vergine del Carmine and the former convent of San Rocco. In relation to the wider general research, this paper will present only the outcomes of the survey campaigns carried out on the various buildings of the complex with the purpose of obtaining support documentation for two different projects: the restoration of the former convent and the structural consolidation of the church.

*Keywords*
integrated survey, photogrammetry, architectural survey, TLS, cultural heritage.

Internal view of the Church of Beata Vergine del Carmine in Soragna (overlapping of a photograph and image of the point cloud obtained from the laser scanner survey). Graphic elaboration by the authors.



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## Introduction

The church of the Beata Vergine del Carmine, built by the Carmelite Fathers starting from 1661 and located near the more famous Rocca Meli Lupi of Soragna (Parma, Italy), represents one of the principal religious structures in the city. Next to the place of worship, on its eastern part, stands what was once intended to become the convent (fig. 1). Unlike the church, which was constructed in a relatively short time, the latter was never completed, probably due to lack of funds. Throughout its history, the complex underwent extensive transformations and accommodated different functions (convent, women's orphanage, elementary school). In fact, the current configuration of the complex only partially corresponds to the original layout.

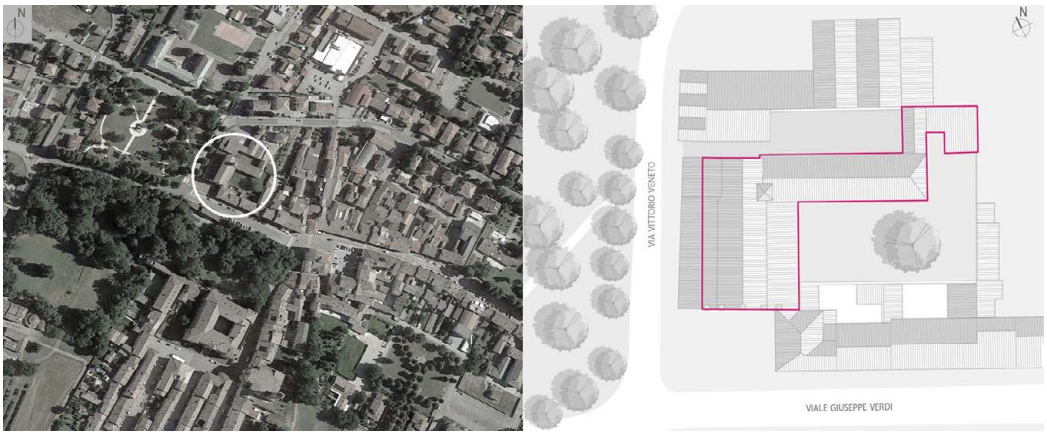


Fig. 1. Site plans with the indication of the surveyed buildings. Graphic elaboration by the authors.

Although the former convent has been widely lived by the citizens of Soragna for several years, today the structure is completely abandoned. Moreover, long periods of disuse and lack of maintenance have led to further deterioration of buildings, also aggravating their structurally unstable condition [Ottoni et al., 2020].
Since 2018, at the request of the Municipality of Soragna, a wider research was undertaken by several professors from different disciplinary areas of the Department of Engineering and Architecture of Parma University. The main purpose of this study was to investigate the complex in a deep way and provide the necessary information for the restoration and consolidation activities. To this aim, an accurate survey of the complex was necessary. In particular, two accurate survey campaigns, related to two different research agreements, were

Fig. 2. Views of the church (on the left: principal façade; on the right: internal nave). Photographs by the authors.

carried out. The first one focused on the former convent and aimed to document the complex from a geometrical point of view, with particular attention to the instability mechanism that were clearly evident within the structure. The second campaign concerned the church and aimed to provide information to use as support for the consolidation project. The data collected, once integrated, made it possible to document the entire complex as a unique structure and to provide fundamental information for future operations to be carried out.
In this paper, only the outcomes of the survey campaigns will be presented. It is noteworthy that the integrated survey of this architectural complex, although considered of minor importance, highlighted once again the role of the survey process as an essential support for the restoration project [Bertocci et al., 2023, Bevilacqua et al., 2017]. Finally, the presented study also seeks to draw attention to the importance of documenting abandoned heritage [Volzone et al. 2022].

## The church of Beata Vergine del Carmine and the former convent of San Rocco

The church of Beata Vergine del Carmine, finished at the end of the 17th century, is organized into three different naves (fig. 2). The central one, is a barrel-vaulted nave and is divided into five bays. The principal nave ends in a rectangular-plan chancel, also covered by a barrel vault, but featuring a pavilion head. Adjacent to the central space are two side naves, also divided into five bays on each side, covered by cross vaults. These side naves have a lower height compared to the central one, allowing space for eight windows that illuminate the church. At the northern end of the left nave is located the sacristy, while on the right side, connected to the principal structure of the former convent of San Rocco, stands the bell tower. Along the eastern side of the church, there is a portico covered with cross vaults that, through seven round arches, overlooks the main open space of the entire complex. This portico, surmounted by a second level housing two rooms, was intended to form one side of the convent cloister, which, however, was never completed (fig. 3).

Fig. 3. Views of the former convent (on the left: external view of the portico; on the right: internal view of the portico). Photographs by the authors.

As for the former convent, today it consists of a main rectangular building placed orthogonally to the church, joined by several smaller structures. The principal building has three floors and accommodates two stairwells: the first is located in the center of the building and connects only the ground floor with the second floor; the second, located near the apsidal area of the church, connects all the floors of the former convent and provides access to the bell tower. On the ground floor, a long corridor covered by a barrel vault runs alongside the southern wall of the building, connecting a series of rooms of various sizes. On the second floor, the corridor is located in the central part and ends with a door that provides access to the largest room in the complex, considered one of the most interesting and vulnerable

parts of the building. Additionally, connected to the main part of the former convent are two other smaller buildings of limited historical and architectural value.
The external aspect of the entire complex reflects the formal sobriety typical of Carmelite order buildings: they are extremely simple and unadorned. Even the main façade of the church, marked by five vertical pilasters, lacks significant decorative apparatus. Only several molded cornices characterize the interior of the church, as well as Baroque altars and a wooden organ, installed in the centuries subsequent to the structure construction.

## Architectural survey of the church

In order to provide support documentation for the consolidation project of the church, an accurate survey campaign was performed. In particular, an integrated and long-established survey methodology was adopted [Remondino 2011], based on the combined use of the main technologies available today (total station, laser scanner, and photogrammetry)[1]. Following the data collection phase, their digital processing was undertaken to document the morphological and geometric-dimensional features that characterize the church.
The first operation involved the establishment of a topographic network, to be used as the base for all surveys conducted with different techniques. It is important to stress that this phase required a detailed study of the site. The principal goal was to structure a rigid topographic network, which would then allow the surveys of non-communicating areas of the building to be connected (i.e. laser scanner survey of the church interior spaces with roof spaces). A total of 30 station points were identified, organized into several closed and concatenated networks (fig. 4). In particular, the stations were placed on the lower level of the church, outside the structure and in some internal rooms between the church and the roof space.
To make the network more stable, in addition to station points, targets strategically placed on the building were also surveyed. A total of 45 targets were placed (at the lower level of the church, outside the building, in the roof space). The use of special targets, which can also be identified by the laser scanner, facilitated the acquisition of all the measurements necessary for the proper co-registration of the surveys. Once the topographic survey was

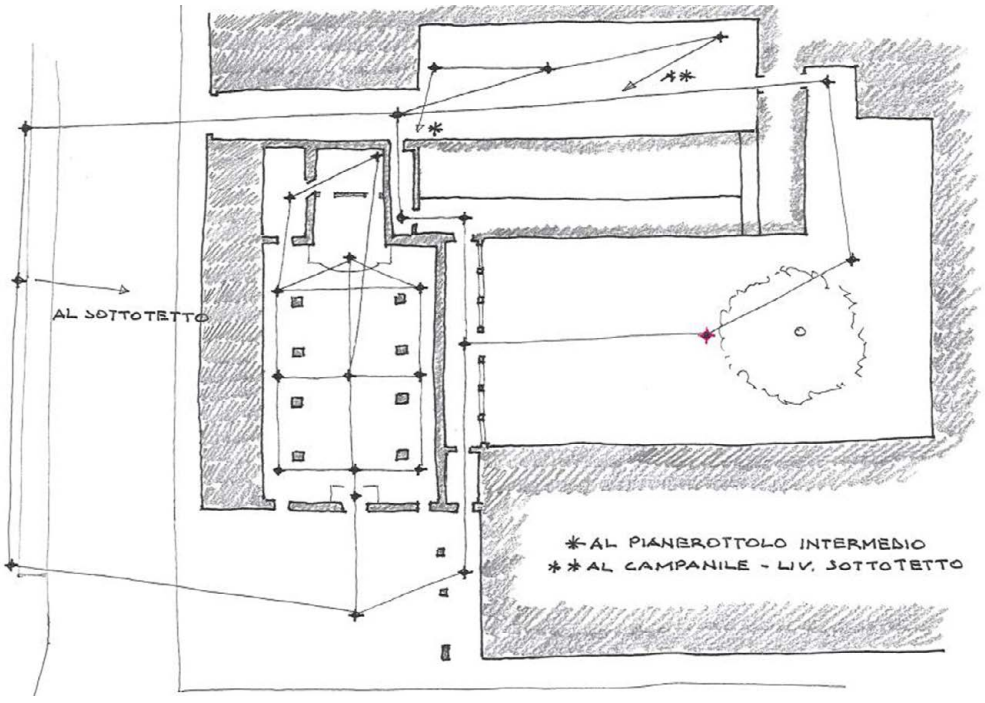


Fig. 4. Scheme of the planned topographic network. Graphic elaboration by the authors.

finished, compensation was applied, and it was possible to obtain a first point cloud made only and exclusively by the station points and targets.
Subsequently, it was possible to proceed with a laser scanner survey campaign. During this phase, only a few scans were taken at the station points used for the topographic survey. To minimize shadow areas as much as possible, most of scans were made at different strategically identified points. A total of 33 scans were performed (at the lower level of the church, outside the building, in the roof spaces), setting the resolution to 10x10 cm at a distance of 100 meters. Only for scans of the main facades, a higher resolution was employed (of 5x5 cm at a distance of 100 meters). Once the laser scanner survey campaign was finished, the 33 scans were co-registered through dedicated software (fig. 5). To this aim, the targets coordinates surveyed by the total station were used. The obtained point cloud was then exported in order to be used within the automatic drawing software.

Fig. 5. Point cloud of the church obtained from the laser scanner survey. Graphic elaboration by the authors.

A photogrammetric campaign was also performed to document the principal façade of the church and adjacent buildings. In total, 55 photographs were taken using full-frame camera. In particular, three horizontal swipes were captured, ensuring at least 60 percent overlap between frames. Additional detailed photographs were also acquired. All photographs were then post-processed in order to obtain a point cloud and a 3D mesh model, from which an orthophoto with a resolution of 1 mm/px was then obtained.
Considering the complexity of the structure and the purposes of the survey, it was decided to document the church through traditional two-dimensional survey drawings, at a 1:50 scale of representation (one floor plan, two vertical sections, four external elevations) (figs. 6, 7).
The survey campaign performed provided important information about the church and the most relevant data concern the out-of-plumbs mechanisms. In particular, it revealed that the bell tower slopes toward the former convent. This slope, in the approximately ten meters above the roof of the nave, reaches 22 centimeters. A similar issue also presents the two pinnacles that, on the façade, highlight the internal separation between the naves. Both of them are characterized by a strong out-of-plumb to the churchyard that, while not presenting imminent danger, will need to be carefully monitored over time.
Starting from the survey data, it was also possible to analyze some construction inaccuracies identified within the church. In particular, some eastern entablatures, column capitals and key points of the arches are higher (up to more than 30 centimeters) than on the western part. Considering the floor's perfect horizontal alignment, which may have been reconstructed

over time, and the absence of other instability signs, it's difficult to attribute this anomaly to ground subsidence. It's more plausible that construction issues arose during the initial phase or due to limited resources of the Carmelite fathers.

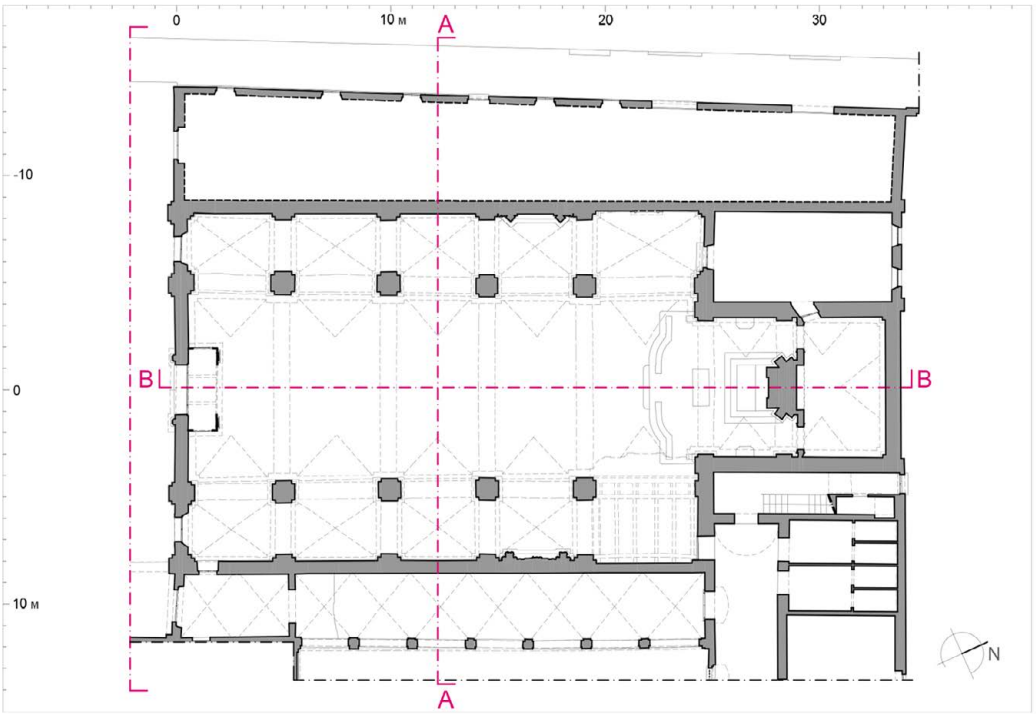


Fig. 6 - Ground floor plan of the church. Original scale of the drawing: scale 1:50. Graphic elaboration by the authors.

## Architectural survey of the former convent

The principal purpose of the survey conducted on the former convent was to document the complex from a geometrical point of view, with particular attention to the instability mechanism that were clearly evident within the structure.
Once again, the choice was made to work through integrated use of direct and indirect surveying methods, following almost the same workflow as for the church. The only difference is related to the choice to document some regular and small spaces using traditional survey methods.

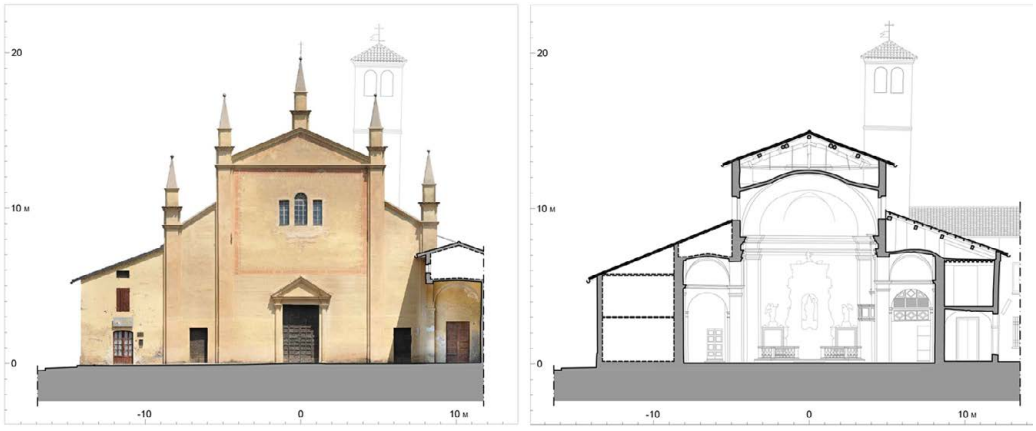


Fig. 7. South elevation of the church (on the left) and transversal section (on the right). Original scale of the drawings: scale 1:50. Graphic elaborations by the authors.

Starting from the previously mentioned existing topographic network, to which additional station points within the building were added, laser scanner survey was performed. In particular, 25 scans were taken at the same resolution used for the church. These scans were located within the following areas of the complex: at the ground level, on the first floor of the principal building and in the roof spaces. For the latter, this technique was particularly convenient because it allowed to accurately document extremely tight and difficult-to-access spaces. As previously mentioned, data regarding other areas of the structure were integrated using traditional surveying techniques.
Once the laser scanner survey campaign was finished, all the data were co-registered using dedicated software, obtaining a unique point cloud to use within the automatic drawing software (fig. 8). Considering the first mentioned purposes of the survey, it was decided to document the former convent through traditional two-dimensional survey drawings, at a 1:50 scale of representation. A total of nine drawings were elaborated: three floor plans and six vertical sections-elevations.

Fig. 8. Point cloud of tight and difficult-to-access roof spaces obtained from the laser scanner survey. Graphic elaboration by the authors.

In parallel to the laser scanner campaign, photogrammetric survey of the building's facades was also performed. The main challenge faced during this phase was related to the presence of extensive vegetation along South and East façade of the principal building. In both cases, it was not possible to document exhaustively the state of the walls. In order to generate orthophotos with an adequate resolution for the selected scale of representation, a scheme based on multiple swipes with an optical axis as perpendicular as possible to the walls was chosen. These strips were taken with a minimum overlap of 60% between consecutive photographs. For example, for the South façade of the principal building, around 50 frames were acquired from a distance of about 15 meters. Then, the acquired photographs were processed in order to obtain a point cloud and a 3D mesh model. It is worth nothing that in order to minimize errors, a vertical plane coincident with that used for the building's elevations was used for the generation of orthophotos. The illustrated *modus operandi* allowed to achieve the initially planned orthophotos resolution (of 1mm/px), then integrated with traditional survey drawings (figs. 9, 10). Thanks to the data collected by the survey campaign of the former convent, it was possible to analyze in detail several instability mechanisms of the most vulnerable portions of the complex, such as the principal building. For example, the survey clearly revealed how the barrel vault covering the main corridor present at ground level is characterized by widespread deformations along its development.

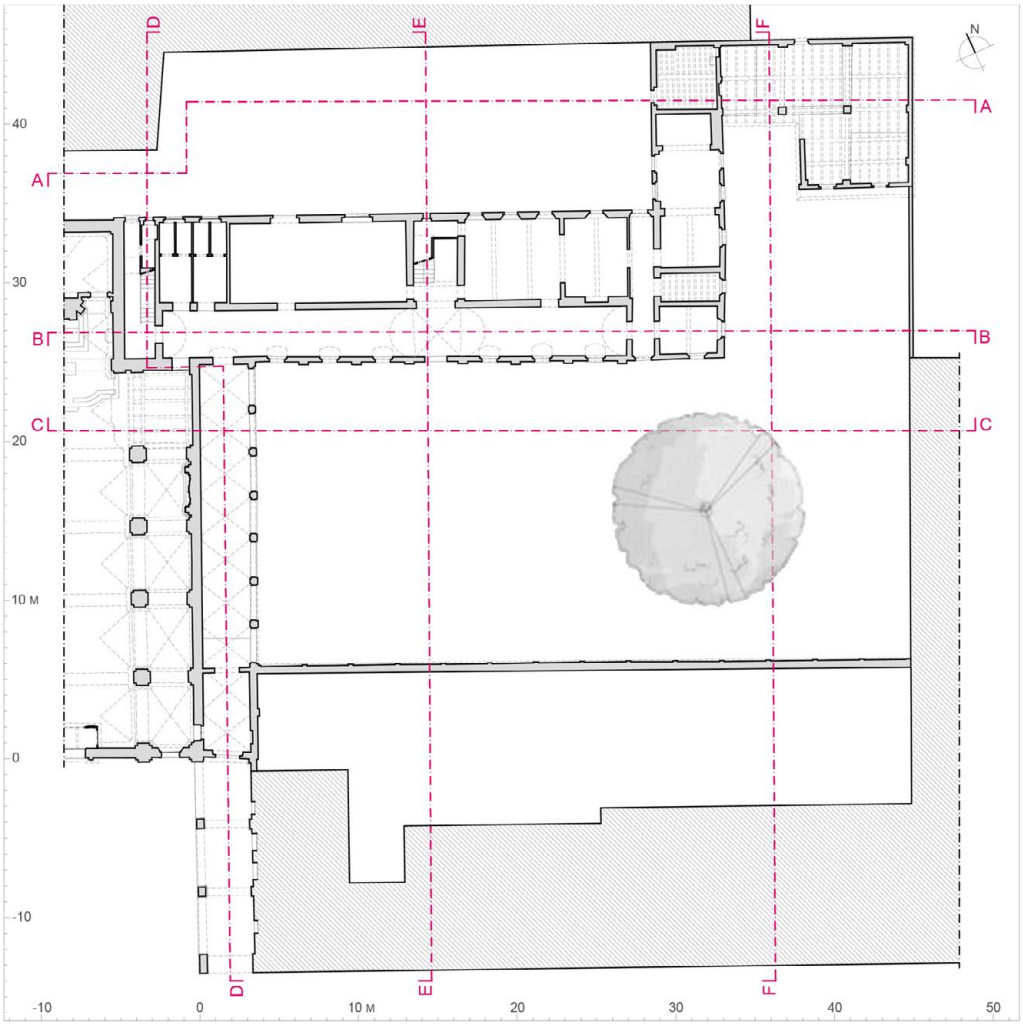


Fig. 9. Ground floor plan of the former convent. Original scale of the drawing: scale 1:50. Graphic elaboration by the authors.

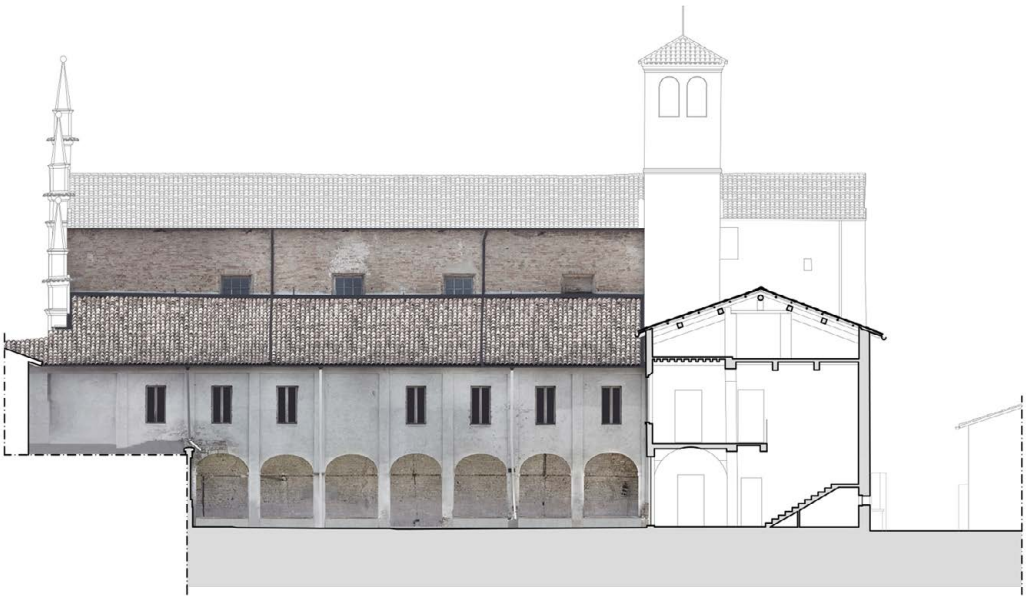

Fig. 10. Vertical section (EE) of the former convent. Original scale of the drawing: scale 1:50. Graphic elaboration by the authors.

Above the mentioned vault there is another critical situation, related to the south-east wall of the building. In order to analyze this part, additional vertical sections were made. These drawings, made it possible to quantify in each part of the wall the out-of-plumb phenomenon. The last noteworthy part in this context is related to several deformations of the cross vaults within the historical portico.

## Conclusions

The survey campaign carried out on the Church of Beata Vergine del Carmine and the former convent of San Rocco, in addition to making it possible to accurately document the entire complex in its entirety, provided important information on the instability mechanisms and structurally dangerous parts of the structure, essential for the professionals who will undertake the restoration project. It is also important to stress that a digitalization campaign such as the one carried out results fundamental for other studies and any kind of future operation.
In conclusion, the presented study has once again highlighted how an accurate survey campaign represents an essential phase in the complex process of knowledge of an architectural organism. Only by integrating the data collected with information from other surveys (historical, structural, and so on) will it be possible to identify design solutions suitable for the reuse of a historic complex that has been waiting too long for a new second life.

### Notes

[1] The following instruments were used for the survey campaign: topographic survey - Topcon Image station IS203; laser scanner survey - time-of-flight Leica ScanStation C10; photogrammetric survey – full-frame Nikon D3X DLSR (with a resolution of 6048x4032 pixels and equipped with 35 and 50 mm optic). PhD Arch. Andrea Maiocchi also participated in the survey campaign of the former convent.

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