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Survey and analysis of the Fossanova abbey.

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The systematic study of Cistercian monastic complexes focuses on the Fossanova Abbey, presenting a unique challenge in Italian architecture. The lack of homogeneous and reliable documentation on the morphometric consistency of these structures, expressed through 2D and 3D models, has limited the completeness of historical-critical studies. By analyzing the floor plans and graphic materials, a significant discrepancy has been found compared to the actual structures, with regularization of axes and alignments that disregard vertical errors and offsets. To address this gap, an architectural survey methodology has been adopted, combining digital photogrammetry, 3D laser scanning, and other advanced technologies. This multidisciplinary approach enables the creation of reliable and coherent digital models that capture the formal, geometric, and chromatic aspects of the abbey, documenting diachronic changes and temporal stratification.

I. COMPLEX INTEGRATED SURVEY METHODOLOGIES

Typologically homogeneous and validatable documentation of the morphometric consistency of these objects expressed by means of 2D and 3D models. More generally, the lack of scientific survey, understood as the result of a complex methodological process aimed at achieving in-depth knowledge of the architectural object, makes the historical-critical study not always complete because it lacks a clarifying and often essential basis: the survey model.

The analysis of the plans and of the drawings present in the various historical studies highlights a significant discrepancy with respect to the reality of the structures investigated. Many of the historical plans obtained from detailed iconographic research show a regularization of the axes, angles and alignments, without considering the errors of verticality and the phase shifts which are instead relevant in architecture in general and in the structures analyzed in particular. This situation derives both from cultural factors and from operational limits in the acquisition of data, as well as from methodological choices that are not always clear in the creation of the final interpretative models.

The entire architectural survey process thus understood pursues a dual purpose: the first concerns the updating of the existing graphic documentation, building that graphic database necessary for interdisciplinary studies of a specialist nature; the second objective is, however, the systematic control of the state of art through representation. In this sense, the 2D models produced fit into the development process of the architectural product, documenting its diachronic changes and temporal stratification. This investigation methodology, accompanied by studies of a metric, proportional geometric and metrological nature, was tested on the Fossanova abbey. In this direction, the morphometric control through the massive survey of the structures becomes the essential tool of analysis.

The use of massive data processing methods, such as digital photogrammetry (Structure from Motion), integrated with technologically advanced acquisition tools, such as LIDAR (Light Detection and Ranging) systems and remotely piloted aircraft systems with high resolution digital cameras, is by now to be considered standard for the elaboration of 2D and 3D digital models, metrically reliable and consistent with the formal, geometric and chromatic aspects of the architectures analyzed (Fig. 1). Such a high availability of technologies and procedures makes the need to plan survey operations more and more evident, calibrating them according to the objectives to be pursued. Precisely in this sense, different and complementary acquisition strategies have been defined in relation to the level of detail to be achieved for each element: acquisitions of a general nature on the entire complex have been carried out using 3D laser scanners and drone Structure from Motion processes; in parallel, detailed architectural elements acquired through high-resolution photography were identified.

Fig. 1. Point cloud created by laser scanner of the abbey complex of Fossanova.

In this circumstance we can assert that the integrated survey can be understood as a reasoned and calibrated use of different autonomous survey methodologies, but also, with a broader meaning, integration of knowledge and knowledge between the different skills and sensitivities of the scholars involved in the study presented. At the basis of the research, to whose first results the present contribution contributes in a decisive way, there is the historical study aimed at highlighting the importance of the building of the Fossanova abbey, covering in the renewal of the medieval architecture of lower Lazio.

REPRESENTATIONS THROUGHOUT HISTORY

Although partial and often not responding to the criteria of reliability shared today, the existing iconographic documentation unquestionably provides a valuable support for reading the object, helping to build its image and to represent its historical evolution, both from an architectural point of view and the historical development of survey methodologies. The precious graphic documentation available on the Fossanova abbey was used as a comparison parameter for the elaboration of the 2D models generated starting from the survey operations carried out. Regarding Fossanova, the plan of the complex published in the 1890 by A.L. Frothingham, for example, shows the intended use of the spaces and provides the main information on the architectural solutions used for the roofing of the rooms (Fig. 2). A repertoire of constructive details in perspective completes the iconographic apparatus with suggestions referring to the architectural language used and representing the entire abbey complex defining its main structures. The elaborates are rather synthetic, few lines define the overall dimensions, the general proportions are not respected and the arrangement of the volumes is rectified. Nonetheless, the strong synthetic value of the drawings allows us to trace the most significant volumetric variations that have affected the complex over time. At the architectural scale, this approach to documentation makes a deeper reading inaccessible, aimed instead at understanding the architectural character and the consequent graphic formalization of the distinctive elements. In historical graphic production, this limitation is generally overcome by supplying the planimetry with perspective drawings of the most interesting construction details and architectural elements. In this context, the architectural survey operations have attempted to reproduce, just saying, this "multiscalar" approach to documentation. The floor plans and vertical sections of the entire complex and of the individual buildings were created on a scale from 1:100 to 1:50 for a correct reading of the geometric and proportional aspects; in addition, for each case study, the most representative detail elements were identified, rendered in plan, elevation and section at a scale from 1:20 to 1:5.

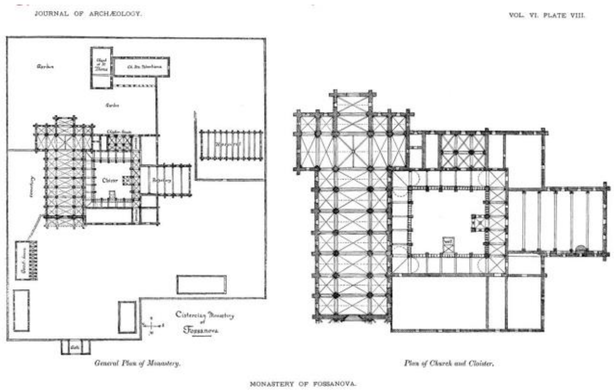

Fig. 2. Abbey complex of Fossanova. Floor plan by A. L. Frothingham, 1890.

II. THE SURVEY OF THE GENERAL STRUCTURE OF THE COMPLEX

The 3D acquisition, conducted with the aim of deepening the knowledge of this monastic complex, was based on a series of acquisition processes and techniques that are now widely used; in the particular case of the abbey complex of Fossanova - also taking as a reference the rules of the so-called "Bernardine plan", an attempt was made to set up an integrated survey procedure that could be reused in all case studies with similar characteristics, as befits any methodology. We have therefore tried to define a series of operations, independently of the subject, which lead to scientifically reliable results. The survey was therefore based on a first general campaign of massive terrestrial acquisition through 3D laser scanners, integrated by a subsequent aerial campaign with the use of drones. Of course, the two campaigns as described were characterized by the drafting of an accurate survey project that took into account both the logistics and the objectives to be pursued, in order to identify the best methodology and the most appropriate instrumentation to use, from a series of site inspections and from different stages of survey. The first campaign aimed at the acquisition of geometric and morphological data, in plan and elevation, of the ground floors and of the successive individual floors of the various parts making up the monastic structure, with particular attention to the connections to the ground, the passageways and the walls boundary between the parts. The second campaign naturally had as its objective the acquisition of all the roofs and all those parts that were inaccessible, or difficult to access, from the ground.

Both of these activities produced an enormous amount of data, in fact, regarding the church, the cloister and the Chapter House and with a large part of the acquisition of the exteriors, 80 scans were carried out from the ground.

The subsequent phases of recording and managing the data thus obtained allowed the elaboration of 3D numerical models, from which, as a first step, 2D models were extracted, such as general plans of the complex or plans of the single rooms making up the structure. The elaborations of the final 2D models have been set according to representation scales suitable for fully describing the various elements to be represented. Therefore, it was decided to represent the general plans of the monastic complexes through geometric models, on a scale of 1:200 and 1:100, in order to have a synthetic descriptive reading of the relationships between the different construction elements, the distribution rules, the metric, geometric and proportional relationships. Further insights, with consequent change of scale of representation, were entrusted to architectural models, on a 1:50 scale, from which it was possible to read the different construction characteristics from the masonry to the flooring, roofing systems, architectural orders, and maintenance status with characterizations and thematizations.

The contextual readings of the 2D planimetric and altimetric models have revealed a whole series of new information which, if well interpreted in the historical-critical reading phase, will be able to make various additions to the current readings.

III. The survey of architectural details

If, on the one hand, the numerical models of the entire complex provide the overall picture of the abbey architecture, on the other, such a vast repertoire of constructive solutions at the scale of detail reveals the need for an in-depth study both in terms of data acquisition and their processing.

In this sense it is possible to intercept a link of continuity between the consolidated tradition in the field of representation of this typology and the contemporary representation through 2D and 3D digital models. In the same way, in fact, attention to the scale of representation, conveyed through detailed perspective drawings associated with general plans, as previously mentioned, becomes the essential reference for setting up a multi-scalar approach to documentation using digital systems.

With a view to combining drawing, survey and historical instance, it was decided to conduct an acquisition campaign focused on the detailed survey of the architectural order.

To systematize the acquisition procedure and to propose an approach to the survey of the detail that can be repeated on typologically similar architectural complexes, the documentation concerned a selection of representative elements: the capitals and the bases of the bundled pillars, both of the naves of the church and of the Chapter House and the capitals of the cloister columns.

From a methodological point of view, the acquisitions were conducted through a detailed photographic campaign for digital photogrammetry applications. To ensure homogeneous photographic coverage of the object, the shots were taken by integrating the photographs from the ground with shots acquired using a telescopic rod and shots acquired with the aid of remotely piloted systems. This approach has made it possible to study the architectural object in its entirety with a constant and homogeneous level of reliability of the data. The 3D point clouds calculated from this very large photographic database have been integrated into the general numerical model of the entire complex.

After the data integration phase, the point clouds produced allowed the construction of adequately textured surface models to re-propose the digital copy of the investigated object.

These detailed 3D models constitute the metric basis for the elaboration of 2D representations, plans, elevations and sections, necessary for a critical analysis of the metrological and constructive characteristics.

The proposed line of investigation aims to build a reference abacus that can be archived and consulted by typology (Fig. 3). This informative tool expands the levels of global understanding of the abbeys by favoring conceptual connections and synthetic deductions based on a synoptic picture of the objects of study.

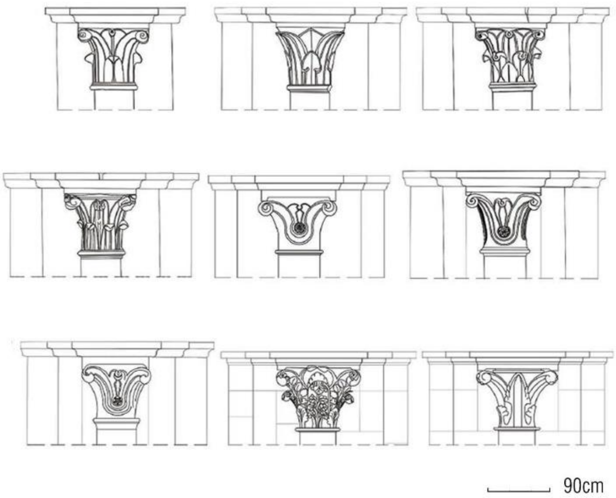

Fig. 3. Abbey complex of Fossanova. Abacus of the capitals of the central nave of the church.

IV. INTERPRETIVE ANALYSES

The 2D models of the Fossanova abbey complex (Fig. 4) have been the subject of a series of graphic analyses, in line with a work approach now consolidated within our Department, aimed at critical reading of the architectures represented.

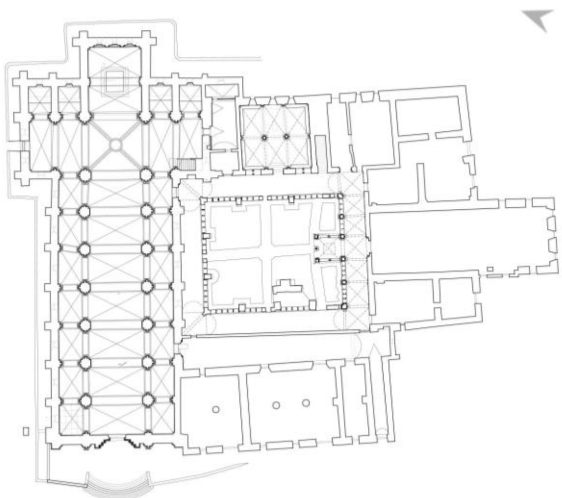

Fig. 4. Survey of the abbey complex. Partial plan of the Fossanova complex.

Fossanova abbey is characterized by a plan with three naves and seven bays with the main central one, a protruding transept with a choir and side chapels with a flat end. It was possible to estimate a length of approx. 65.70 m. (approx. 68.57 m including the thickness of the walls and approx. 69.70 m including the buttresses) and a width of approx. 19.50 m. (approx. 21.80 m. including the perimeter walls) measured inside. The transept has a length of approx. 29.20 m.; the main nave has a width of approx. 9.30m. and length of approx. 5.25 m., while the two lateral ones, smaller, have a width of approx. 3.95m.

From this we obtain a ratio between length and width equal to 3.38; the ratio between the main nave and the minor nave is approx. 2.37.

Some other interesting considerations can be highlighted, or rather graphically, in this analysis, such as some geometric characteristics of the abbey plant, substantially set on rectangular shape. In Fossanova it has been observed that the ratio between the main nave and the lateral nave is greater than 1:2 (as already expressed by the metric analysis), the bays of the main nave are characterized by a rectangular shape arranged horizontally, the same shape characterizes the two spans of the rectilinear choir, while the four spans of the transept have the same rectangular shape but with a vertical arrangement. The intersection between the nave and the transept, at the height of the presbytery, is characterized by a square figure (with the vertices coinciding with the center of the pillars) equal to twice the rectangular span of the main nave. The bays of the lateral naves and the rectilinear chapels adjacent to the choir are also rectangular in plan but with a longitudinal arrangement (Fig. 5).

The prevailing approach to rectangular figures prompted us to verify into some well-known geometric constructions already found in some medieval constructions. In fact, the constructions of the golden rectangle and similar rectangles were tested on the plan, all based on the ratio between the sides and the diagonal. The result, still under verification, if it excludes with some certainty the recourse to the "golden" construction, shows a decisive correspondence with that of similar rectangles. Indeed, by applying this construction to the transept, after inscribing it in a rectangle, its tripartition will be obtained, in which the smaller sides coincide with the pillars and, therefore, with the alignment in the central nave.

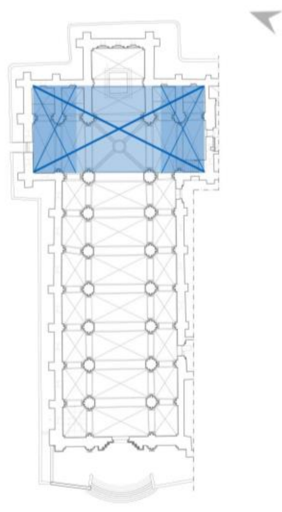

Fig. 5. Construction of similar rectangles on the plan: the rectangle of the lateral naves are similar to the rectangle of the transept, but in with longitudinal arrangement.

While maintaining a very cautious attitude, as highlighted by Tosco, this analysis had the purpose of verifying the correspondence between some historical units of measurement, identified in France in Burgundy and Lower Lazio between the 12th and 13th centuries and the main structures of the Complex of Fossanova. The identification of a unit of measurement, even if not sufficient, in fact constitutes a necessary element for its dating and the interpretation of some phases of the construction site that are not yet fully clarified.

Starting from the dating now accepted in the literature according to which Fossanova was begun in 1187, consecrated in 1208, some of the units of measurement most frequently used in this historical period have been taken into consideration.

Therefore, among others, four units of measurement widely used in the 13th century were identified, such as the Piede del Lazio approx. 0.33/0.34 m. (and its multiple the *Canna* equal to 7-10 *Piedi*), the *Braccio* or *Passetto* equal to 3 *Palmi Romani* ca. 0.67 m., the *Canna architettonica* equal to approx. 10 *Palmi Romani*. 2,234 m. of lower Lazio, and the Pass Commun, the *Pertica*, 7.68 m. of French origin.

From the first metrological readings it can be seen that the *Piede* and the *Canna architettonica* from Lazio adhere to both of the aforementioned structures in general dimensions, but also allow for the proportioning with great accuracy of some partial measures, such as the width and length of the spans.

V. Conclusions

From the above we deduce the usefulness, or rather the necessity, of having carried out an integrated survey of the abbey complex. The subsequent models, deriving from the modeling operations, thus become irreplaceable elements for the critical historical study of these religious structures. The conclusions presented in this contribution are, as mentioned, limited to the Fossanova plan. In reality, many other indications are emerging from the analyzes conducted on the other structures that make up the monastic complexes. Among the particular elements on which to prepare further checks are the misalignments, out of squares, rotations found between the church, the cloister, the Chapter House and some of the other service areas. In fact, we note a significant difference in alignment, a rotation of about 1°, between the longitudinal axis of the church and the functional and distributive group made up of the cloister and the Chapter House. Furthermore, in the church, one can also observe a series of evident "attachment points" between different construction phases such as the evident misalignment between the fifth and sixth bays of the minor left nave, corresponding on the outside to the passage from two to three levels in elevation. Clearly the above analyzes will be extended not only to the other rooms that make up the abbey complex but will have to take into consideration the elevations and vertical sections. Furthermore, from the comparison of the 2D models, in a sort of synchronic comparative reading, it will be possible to focus on the stylistic, linguistic, functional, constructive, distributive differences that characterize the two monuments. The final reading, realized thanks to the models presented here in minimal part, will undoubtedly lead to the achievement of a profound knowledge of these important complexes.

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