

S. Johannes in Jerusalem Church: a disclosed mystery?

Analysis of constructive technology for the knowledge of the monument

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Abstract: The research aims to complete the store of knowledge on a monument of nearly a thousand years through the study and interpretation of ancient technological devices that have generated formal and unique characteristics. The absence of documents that has shrouded in mystery the evolutive history of the best preserved in Europe hosting complex along the Via Francigena has been bypassed by the research, which carried out to disclose the Templar's symbolism on one side and the oblivion of time from another. The object of the research is the small and elegant Romanesque church located in that complex. The search method based on direct observation, the direct survey of technological and structural devices, punctual measurements aimed at verifying the hypothesis and the reconstruction carried out in the field and not a reworking of data in post-production were distinctive characteristics of the study. We have achieved original and high contribution to knowledge results. In particular: the construction technique of the three cruises freestanding brick vault, unique in its kind as the result of handicraft manufacturers and therefore not categorized according to general patterns textbook; formal interpretation of a singular and unique denticular monofora that has so far left unsatisfied curiosity of scientists; detection of the method for tracing the monument and the proportional relationships used to its location in relation to the existing context; the explanation of the peculiar and irregular orientation of the church; assumptions about the likely dating of the monument, so far uncertain because of the lack of documents. These results allowed to fill those gaps that the studies conducted to date on the monument they left and provide useful tools for the enhancement of the monument and for a correct approach in case of any restoration.

Keywords: Templar symbolism, construction techniques, virtual simulation, 3D modelling

Introduction

This research starts from the necessity to complete the knowledge around the S. Johannes in Jerusalem Church (Fig. 1), in the monumental complex Castello della Magione (Poggibonsi, Tuscany) (Fig. 2), developed near a foothill path of Via Francigena in Valdelsa, on the banks of the river Staggia. The church, a jewel of Romanic architecture, characterized by unique and extremely fascinating elements, is an example of the cooperation between constructive models of different origin: the bell gable in the center of the main front and the single-lancet windows with their lunettes on the lintels are typical elements of Pisan Romanesque style of architecture (DE FILLA, 1986), while the apse, crowned with decorated brackets on which round arches are set, has a Lombard origin (FRATI, 1996). Element that characterize the church is the curious single-lancet window that adorns the entrance facade; unique in its kind, its shape and function have never been explained. Further particular device, later then the construction of the church, is a three groined brick

vault: the result of the constructive knowledge of the local artisans, it's a structure whose construction technique has never been studied previously. From its foundation until today, the church itself and the entire complex have suffered from a series of events led them to a progressive state of oblivion, stopped only by a recent restoration, completed in 1993, that has revived the entire complex, even though it resulted in an invasive intervention¹.

For the purpose of enhancement of the monument, the research aims to understand the totality of technological devices in an attempt to fill the lack of documentation: the analysis on the constructive technology becomes a tool to give a new interpretation to history, formation and project genesis of the church.



Fig. 1 – S. Johannes in Jerusalem Church (Copyright: Andrea Sichi, Carolina Rosini)

Search Method

The research was set on three levels of analysis: documental and historiographical analysis; direct survey of the monument; data's interpretation. By the first, we've clarified the historical events related to the complex, by consulting the archival sources and existing literature. It was clear that most of the formal properties of the church were not explained through a purely documentary survey; it became necessary a direct analysis phase, aimed to detection of the technological devices. General and detail measurement campaigns were

¹ Replacement of wooden structure of the roof of the church with a new reinforced concrete structure.

carried out; then a technological and structural survey on materials, construction techniques and all technological devices. This second type of analysis, based on the direct contact with the monument, guarantees the accuracy of all the data: other methodologies, such as indirect surveys with laser devices, won't allow to obtain the same precision. The knowledge on the monument can be only obtained through targeted and continuous measurements that guide us in the gradual discovery, in the study and in the interpretation of the devices of the monument. This aspect remains fundamental to understand the research and to set up similar projects for other monuments. The data collected were analyzed through a formal and technological comparison with similar examples in the area and in the technical literature; at the end, our hypothesis were verified on site and through 3D simulations.

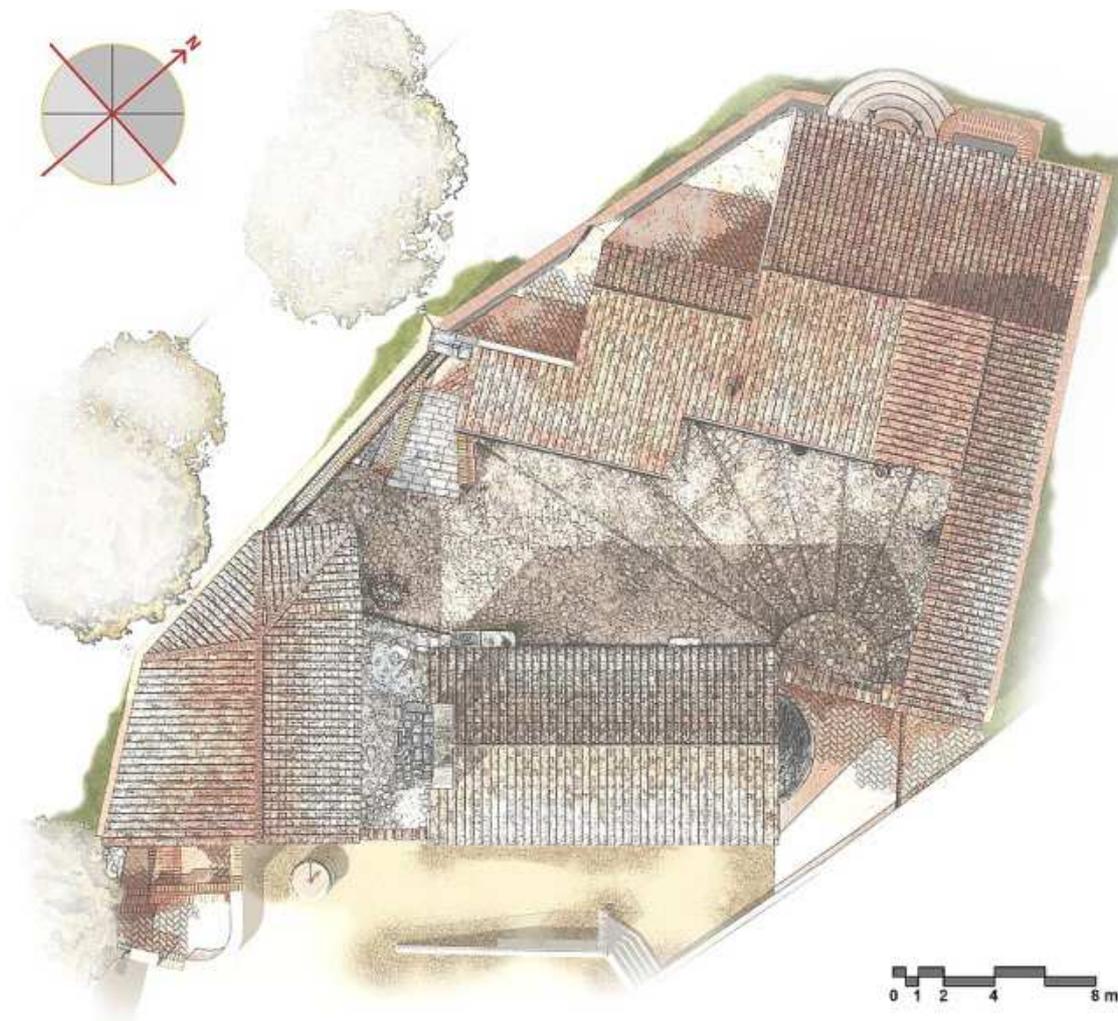


Fig. 2 – Castello della Magione, general plan (Copyright: Andrea Sichi, Carolina Rosini)

Search Results

For the first time, an analysis on the construction technology was carried out; by analyzing the devices, it has allowed us to understand the architectural evolution of the church, from its origins until the present day. The study of the masonry enabled us to distinguish the phases of construction and to identify the additions made to; was carried out a study on the roof of which have been identified evolutionary phases; an in-depth

analysis on the vault allowed to formulate the most likely technique used for its construction; the study of the passage of light from the single-lancet window of the entrance facade allowed to understand the function of its odd shape, the meaning of the anomalous orientation of the church, the tracking method, the relationships with the existing complex and, finally, to hypothesize the construction date.

The masonry

The church is characterized by rubble masonry with travertine facings; the wall thickness is 75 cm. The rows have varying heights and are regular along the whole length of the fronts; this regularity is interrupted only where interventions not coeval with the construction of the church have modified the original wall: the single-lancet window on the South-Est wall and the access doorway to presbytery on the North-West wall (Fig. 3). Moreover, according to a widespread constructional praxis, the corners are strengthened by implementation of larger ashlar that, consequently, alter the continuity of the rows (Fig. 4).

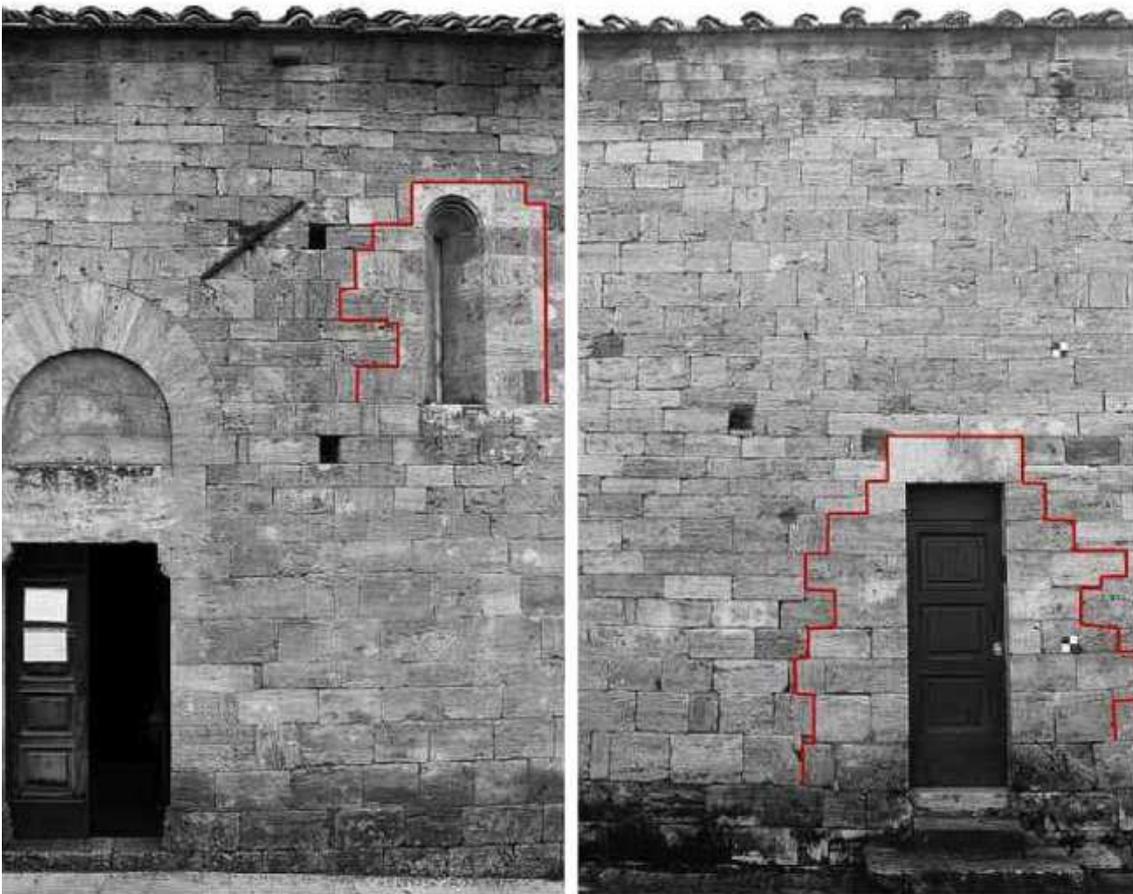


Fig. 3 – Discontinuity of the rows: later interventions (Copyright: Andrea Sichi, Carolina Rosini)

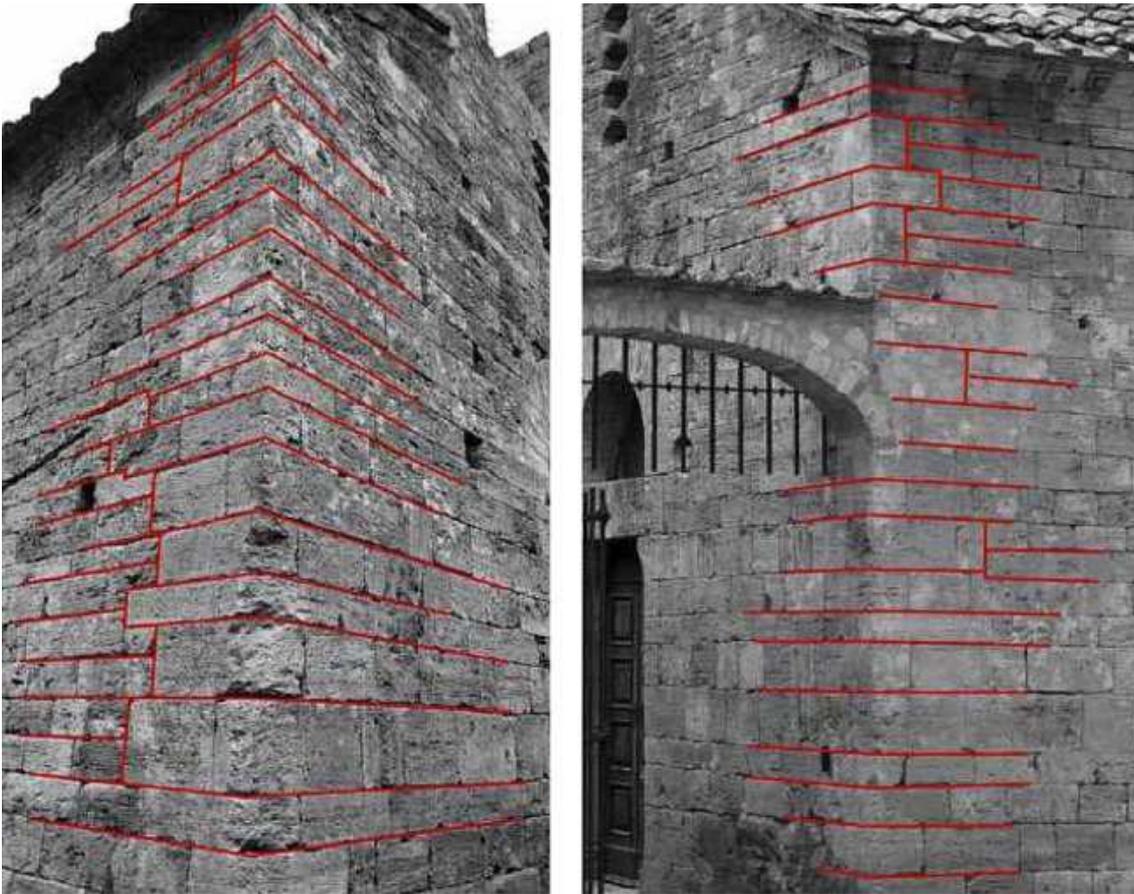


Fig. 4 – Discontinuity of the rows: corners (Copyright: Andrea Sichi, Carolina Rosini)

The variable height of the rows suggests a possible reuse of the ashlars. The travertine, in fact, does not have layers of sedimentation that, for other types of stones, determine the height of the quoins and, therefore, of the rows. This constructional fault, placed in relation to the type of masonry of the oldest part of the complex and to the presence, on the ground, of a trace of a wall which is interrupted just in correspondence of the left corner of the main front, allowed us to advance the hypothesis that the church was built using ashlars taken from a demolished masonry of the original complex.

Then have been identified and analyzed putlog holes; this has allowed to determine the stages of construction of the masonry and to evaluate any anomalies referable to later interventions.

Finally, we analyzed the construction technique of the archivolts, set on the lintel of the two access portals (Fig. 5).

These devices consist of a double pointed arch in the extrados and a round arch in the intrados. The centers of the arches are located on the skewback which is distanced of a row from the lintel; this formal solution is nothing but the result of constructive practice: in order to be removed at the end of construction, the centrings used for the construction of the arches had to be based on wedges which determined the need to insert an additional row, between the lintel and the skewback.

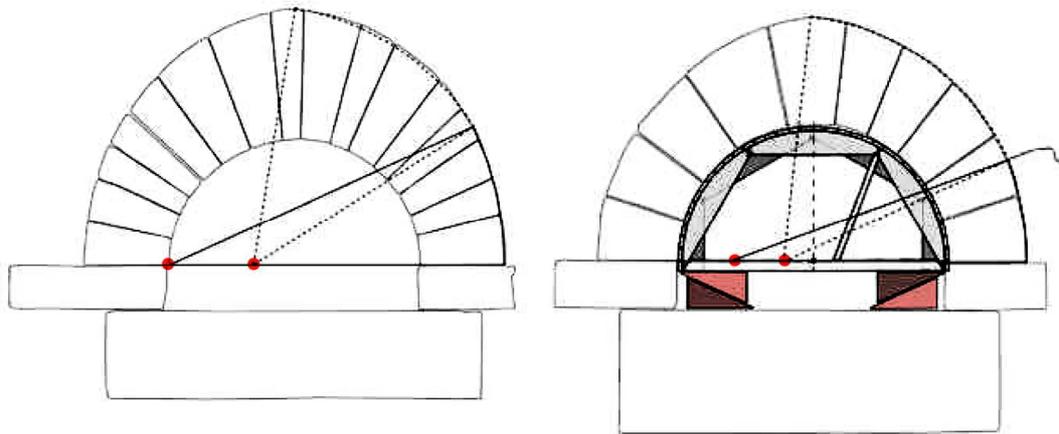


Fig. 5 – Archivolts: centers and hypothesis of centring (Copyright: Andrea Sichi, Carolina Rosini)

Evolutionary phases of the roofing system

Along the longitudinal sides, at the top of the masonry, there is a setback that was the plan where the first roofing solution was set (Fig. 6): a trusses system, common to minors religious architecture of Val d'Elsa. According to the dimensioning resulting from our analytical reconstruction, this structure consisted of two simple trusses, composed of tie beam, principal rafters and king post; these were enough to support the secondary frame.

For a savings in the long-term maintenance, the owners decided to replace trusses with, most likely, a Piedmont roofing (Fig. 6). By an analytical reconstruction, also for this second coverage we proceeded to the sizing of the elements. This structure, together with the vault, as will be explained later, caused a very strong thrust: that's why, at a later date, there was the implementation of two tie bars to reduce the pressure on the walls.

By the restoration of the monument, this roof was demolished and replaced with a new structure (Fig. 6): a reinforced concrete ridge beam and the secondary structure in precast joists for the support of hollow tiles; the joists are supported by two longitudinal curbs.

This intervention, very invasive, has altered the appearance of the church, changing the ridge line²; it has also caused an increase in seismic vulnerability of the monument³.

² The ridge line was originally lower than the level on which the belfry is set. The recent restoration has completely altered this configuration (source: surveys of Superintendence for the architectural and cultural heritage of Siena).

³ The denticular single-lancet window on the entrance front and the oculus on the apse's front have prevented the construction of a continuous curb: there are only two curbs on the longitudinal sides, set up on a brick superstructure. The lack of structural continuity and toothing with the masonry and the high concentration of mass increase the seismic vulnerability of the church.

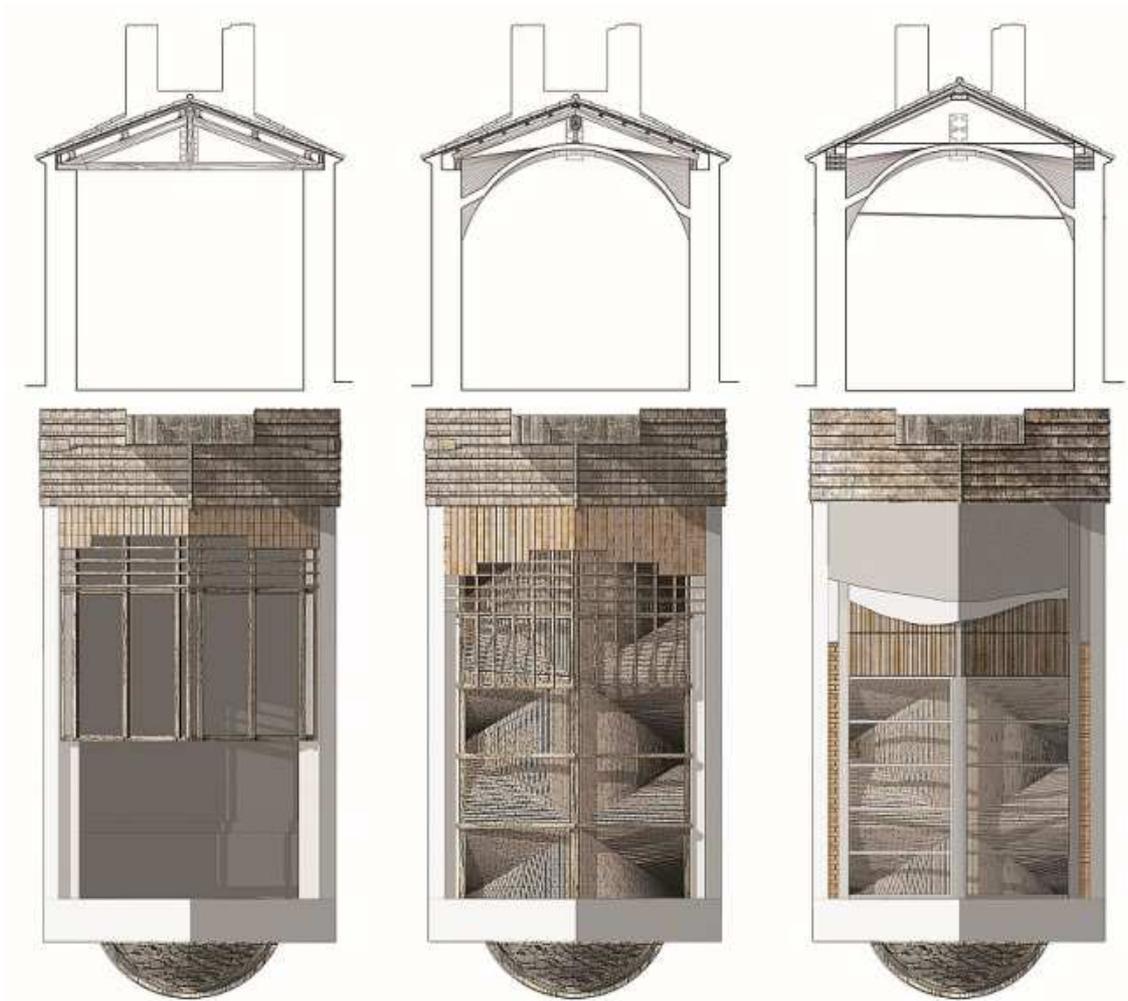


Fig. 6 – Comparison of the roofing solutions – Vertical section and top view – Left: first structure (trusses); middle: second structure (Piedmont roofing); right: existing structure (reinforced concrete structure) (Copyright: Andrea Sichi, Carolina Rosini)

The Vault

The three groined not ribbed brick vault consists of a longitudinal barrel intersected by rampant profile nails (Fig. 7); the bricks (29x15x6 cm) are laid on a side.

The thickness (15 cm) enables a starting point for analysis: bricks laid face-up would have generated a very light structure, an optimal requirement for a not accessible countertop device; instead, was chosen the brick laid on a side solution, strictly functional to a structural task.

Evidently, the original truss structure was exposed to fire and required too cumbersome maintenance tasks: it was decided to replace it with a Piedmont roofing. However, the 12 m distance between the walls would have caused an excessive inflection of the ridge beam. The vault would have reduced the span, providing a base for the new roof, by wooden supports fixed on the extrados; these cheap and light devices would have allowed to reduce the section of the ridge beam, costs and operations of maintenance and replacement.



Fig. 7 – The three groined vault of the church (Copyright: Andrea Sichi, Carolina Rosini)

Same time, the structure would have acted as a fire protection and would have prevented the material falls within the church.

The intervention, despite being a very rational solution to the problems related to maintenance of the roof structure, has completely altered the interior space of the church; then, as today the vault can be considered a unique structure in its kind, also thanks to what will be said about the construction technique, is in fact a profound alteration of the monument.

The vault has not a perfect geometry: the flying buttresses, directrices of the groins, show completely different profiles from each other; the spans have different geometries and the rows are arranged in an unusual way, as neither parallel to the directrices nor to the generatrices. Moreover, it shows changes in the alignment of the bricks and frequent laying errors. These are exactly the reasons that lead people to describe it as a device built in a hurry and by inexperienced bricklayers; on the contrary, these incongruities stimulated our research.

Comparing this vault to the vaulted systems known, we confirmed the strangeness of the apparatus. There are many examples of brick laying in the manuals, but the nails of the groined vaults are commonly laid in horizontal rows parallel to the generatrices of the curves, or in curved rows parallel to the directrices, or

herringbone (CAPOMOLLA, 1995). The corbels show from the outset an important angle that holds till the end of the setting.

The inclined rows, the continuous corrections, the perfect joints at the intrados, the small closed holes on the church walls⁴, the slight curvature of longitudinal rows of the barrel by a top view, different geometries for each span, all this has led us to hypothesize a building technique that does not require scaffoldings and ribs, provisional structures for support and geometrical definition (Fig. 8).

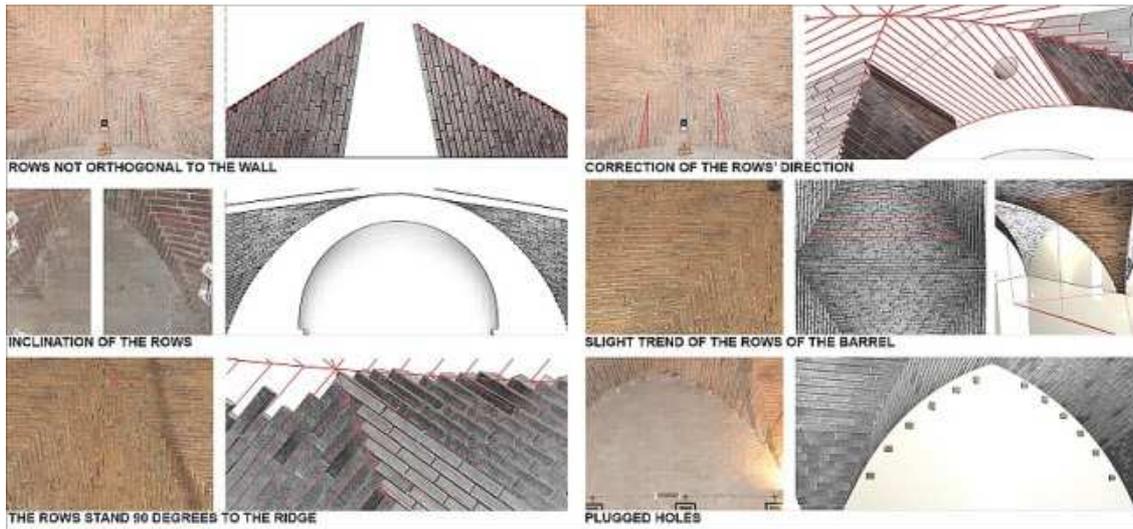


Fig. 8 – Vault details (Copyright: Andrea Sichi, Carolina Rosini)

The hypothesized self-supporting functioning would have enabled a reduction of construction time and costs. Scaffoldings should have been very massive to support the considerable weight of the vault; furthermore, the different geometry of the three spans would have resulted in the need to use three different centrings. It was necessary to solve the problem of supporting the vault during construction, as well as the problem of working without any visual reference; it was necessary to find an alternative method of construction.

Analyzing the data, we developed the technique that would have granted this solution (Fig. 9): first through a 3D simulation, afterward through a 1:10 scale model.

⁴ The holes on the internal sides of the church are interspersed at regular distances of about half arm (30 cm), approximately 10 cm from the intrados of the vault.

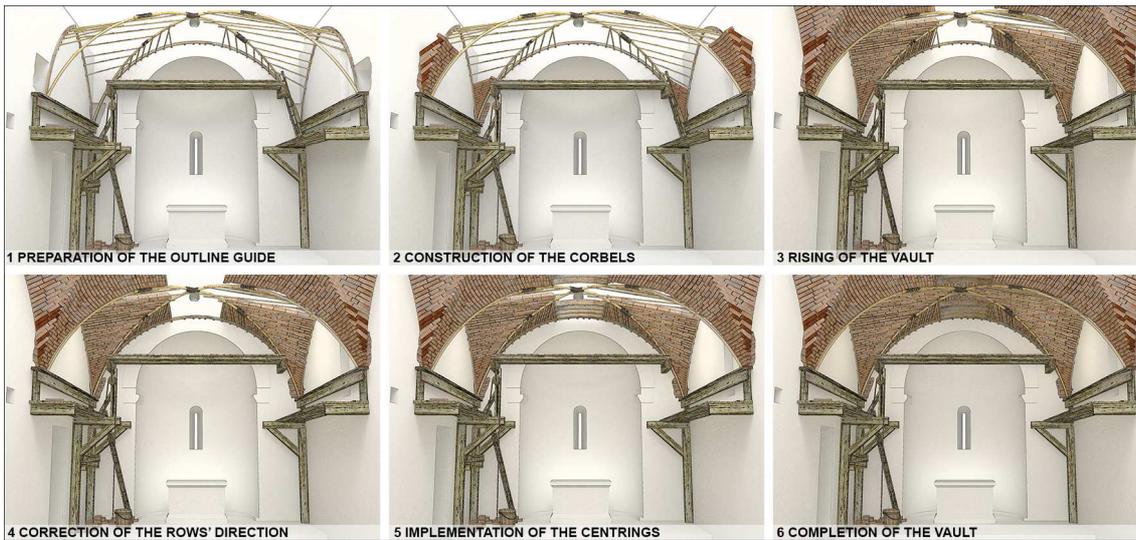


Fig. 9 – Construction phases of the vault (Copyright: Andrea Sichi, Carolina Rosini)

Drawn the arc profile geometry of the groins and barrel on the walls, they built arc profiles to define the ridges, for example with simple curved river reeds⁵. The remaining portions of the vault could be defined by using a system formed by reeds which inserted into the holes described earlier, would settle on the curved reeds of the ridges. This created a “wireframe” device that was used to define the geometry of the vault to be built, a reference to allow bricklayers to visualize the direction (the set-up) to give to the bricks.

This would not solve the problem of the self-supporting; to avoid a collapse during the construction was necessary an additional device: the inclination of the brick rows. Two corresponding rows, belonging respectively to the barrel and the groin, tilted and settled at a right angle on the ridge, trigger a push force that contrasts the sinking strain by driving it on the walls. To get the right inclination, the rows (the visual reference) had to be settled into a higher section on the crest than that of the start. The 90 degrees arrangement of these rows would have facilitated the laying of the bricks, decreasing the cutting phases. The inclination of the rows, reached a certain altitude, would not have been sufficient to eliminate the weight force and the portions not yet closed would begin to collapse. To complete the vault it was necessary to change technology: little wooden shapes, pushing on the opposite portions of masonry just built, would have allowed to complete the vault. First they would have guaranteed the support to the bricks (in this phase the bricks are laid forming arches one after another, clamped comb) and, furthermore, they would have pushed on the portions of masonry stabilizing them. That's why there are corrections of the longitudinal rows near the apse.

Ultimately, it's an artisan procedure, coming from the constructive experience of local bricklayers, adopted to solve this specific case, but easily reproducible, possibly with some variant, in similar buildings.

⁵ The ridges, defined by arches of circumference (the only traceable curve at that time) were lightweight structures, such as river reeds.

The denticular single-lancet window

The denticular single-lancet window is unique (Fig. 10), there are no other examples known and nobody has never clarified the reason of its shape and function: our analysis has led to original outcomes.



Fig. 10 – The single-lancet window of the main front (Copyright: Andrea Sichi, Carolina Rosini)

First, by the analysis of masonry follows that the window was designed together with the rest of the church: perfect tothing between the ashlar, no solution of continuity, identical cuts and processes in relation to the adjacent stones allow us to affirm that it is not a later work.

We found that the day is the 93rd, April 3, or 2 if it is a leap year. On this day, at approximately 2 pm, the projection's length is one arm⁶ and a precise point is detected: the intersection between the longitudinal axis and the step, normal to it, that separates the presbytery from assembly (Fig.11).

The point is simply the gnomonic projection generated by the appendage, located on the lintel of the window, to which no one had assigned a particular function so far. The architect not only wanted to find an area, but also a length and a point, on a precise day of the year⁷.

Discovered the function of the window, the study had to continue explaining the meaning of that point, the reason of the length of the projection (0,58 m, one arm) and the reason of the day 93.

⁶ The arm, 0,58 m, is the medieval builder's reference measurement.

⁷ There are many other examples of solar projections, which usually occur during the summer solstice or the spring equinox; but the particular shape of the projection that the window determines does not matches with projections of the usual solar devices.

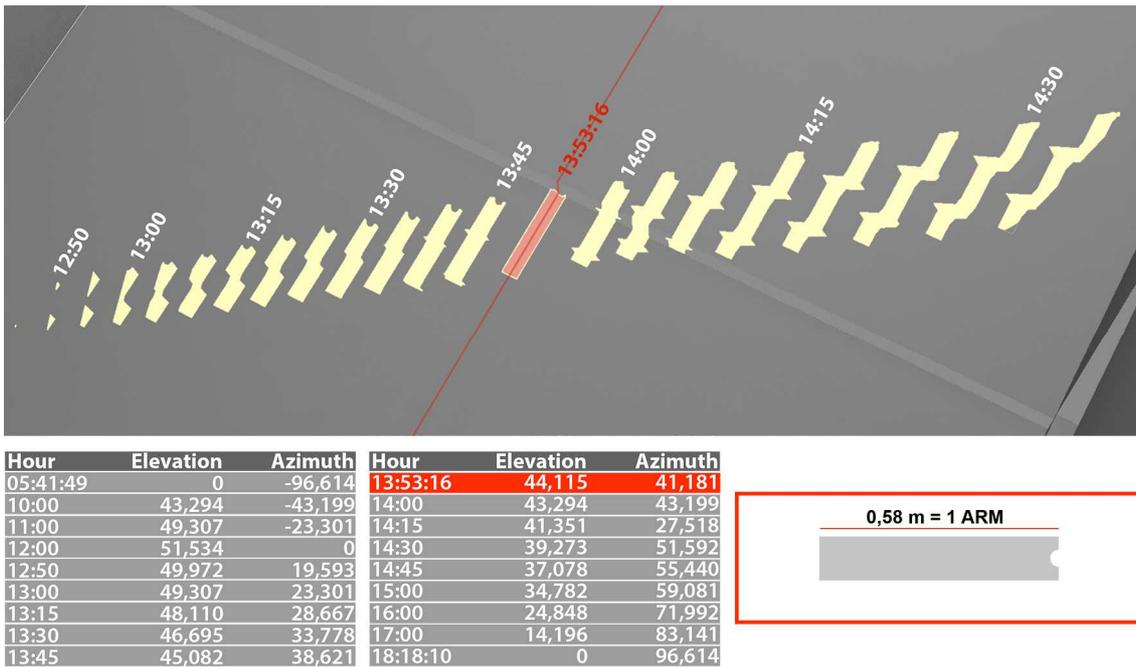


Fig. 11 – April 3rd: the shape of the light's projection during the day 93 (Copyright: Andrea Sichi, Carolina Rosini)

Looking at the plan of the complex, we can note that the distance of that point from the complex is 13.25 m; this measure coincides with the length of the long side of the church. Furthermore, that distance is exactly half of the complex (Fig. 12). Evidently with this trick the architects wanted to show how the church relates to the existing complex.

Starting from this point, considering half of 13.25 m and adding to this the projection length, 0.58 m, we get a measure equal to 7.20 m, exactly the size of the short exterior side of the church.

Using simple geometric rules related to the golden rectangle we developed the plan of the church, perfectly comparable to the survey.

historians date the foundation of the church¹⁰: it happened in year 1144 and 1155. In this way it is possible to reduce the time span of the church dating, from about a hundred years to just eleven.

It can be assumed that the architects wanted to combine Easter day with the consecration of the church, and with the end or the beginning of the building; but the study ends at this point, since the data in our possession do not let us to move on.

More 'suggestive' implications could be advanced, but they would be inconsistent with the nature of the research. However, the study provides a basis for a subsequent study and for further contributions.

Conclusions

The analysis of construction technology is a valuable contribution for the complete knowledge of monuments, because it permits to resolve critical factors that frequently inhibit full understanding of the cultural heritage, such as the lack of documents and the changes caused by time, nature and man.

The research aims to understand any technological and constructive device of the church; the interpretation of each device becomes the key to a full understanding of the monument: an operation focused on the enhancement of this architecture and its uniqueness.

The research provides useful tools for future restoration: not just a survey, not a simple 3D reconstruction, but a user manual which allows technically correct, respectful and conscious future interventions.

The work stands as a starting point for further contributions and becomes a method to be applied to the study of other monuments.

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¹⁰ Agostino Neri hypothesizes that the foundation of the church is shortly after 1000 (DE FILLA, 1986) and the intellectuals of the place, almost unanimous, they confirm the hypothesis, stating that the era of foundation has to be found between the XI and XII century.