

AN INTERDISCIPLINARY RESEARCH AND SITE AS A UNIVERSITY TEACHING LABORATORY: THE ‘CONTINUOUS WORKS’ OF THE BASILICA OF SAN LORENZO IN MILAN

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ABSTRACT

This paper illustrates the contribution of the survey of the famous Basilica of San Lorenzo in Milan (4th- 5th century) to interdisciplinary knowledge, between the project, the original construction and the structural transformation over time, dating some of the most important phases, from the beginning to the current state of the art, analyzed from several points of view, relating the history of document to the history of the material document of the structures.

Stratigraphic, chemical, and thermo-luminescence analyses, and so on, are related to the analysis of the 3D construction element evaluated in the multidimensional space. The Basilica of San Lorenzo presented many shadow zones in the documentation and in the knowledge of its long and difficult existence. This work on a structure of recognized complexity has generated a study that involves several disciplines, each bringing its own values and own approach, but whose common denominator is understanding the monument, careful to determine the validity and fully sharing the results, in the belief that input of several disciplines can generate a knowledge that is not merely the sum total, but added value that increases the knowledge itself, opening new perspectives in reading constructive age, geometrical, material and technological traditions during the centuries, but also making way for further developments in research and awaiting more answers.

The methodology adopted used an archaeological-stratigraphical analysis of the structure, with the important influence of archaeometric analysis, related to archive documents and the history of construction techniques, strictly connected to advanced survey technologies from the beginning and throughout the three-year-long research.

They supply the survey not only with measures but also a real time four dimensional space to relate analysis, extract information from the 3D interpretation of the elements, which seems immediately available as part of the new perspectives offered by laser scanner point clouds, but still hard to obtain on the road of modelling and deciphering the complex shapes of architecture and of its own ‘multiple ponds’ in the form of surfaces.

1. INTRODUCTION

“...The research describes an archetypical experience from several points of view: due to the highly-developed project which is the leitmotiv and deep reason; for rigorous methodologies of the researches carried on; for the challenge opened in the measuring with on of the most important monumental complex of Milan. The Basilica of San Lorenzo presented many shadow zones in the documentation and in the knowledge of its long and difficult existence. This work conducted on a structure of recognized complexity invites us to reap the results of a study faced in new way, where we gain value from different approaches, but balanced from the affinity in the philological reading of the monument, careful to determine the validity and the complete sharing of turns out to you caught up and the complete sharing of the results. The aims of conservation of a complex of primary importance in the occidental architectural history has open the way of a positive fecund season of searches to all field. They have as declared base, the adoption of an archaeological-stratigraphical analysis of the structure, with the strong influence of the archaeometric analysis, of new sophisticated survey technologies, related to archives documents and to the history of constructive techniques knowledge. A complex and continuous architectural structure which at the beginning of the third millennium represent a unique occasion of knowledge dedicated to young people in the form of a precious didactical university site and contributes to render

the tie more aware of the Basilica with the city of Milan and not only...”¹.

The contribute of the survey² to the different disciplines involved by the research, respect to the analysis of geometry and constructive techniques, faces to the polyhedral research aspects of the survey analysis of the complex system of the whole structure and of its own parts, managed in a unique reference system through the topographic network (Figure 1.) and processed in a multi-scale³ approach in function of the precision required, and in function the different level of scheme, pattern, details, geometric analysis and data modelling. A system which is only in appearance simple, whose actual shape and state of the art is the result of subsequently destruction and reconstruction, caused by

¹ ~~An extract from the Introduction of C. Di Francesco, Director of Regional Protection of Lombardy, in AA.VV., 2004, *La Costruzione della Basilica di San Lorenzo a Milano*, a cura di L. Fieni, Silvana Editoriale, Milano~~

² Monti, C., Brumana, R., Achille, C., Fregonese L., 2004. Per un moderno rilievo della Basilica di San Lorenzo, tra opera progetto e trasformazioni, pp. 225-243, in “La costruzione ...” op.cit.

³ Leibniz, G . W., 1720. *Monadologia*, “... 67. Any portion of matter can be perceived as a garden full of plants or as a pond full of fish. But any branch of the plant, any appendage of the animal, any drop of its essence is still a garden or a pond. ... 69. In the same way, nothing is left abandoned, sterile, or dead in the universe, there is no chaos, no confusion, except on the surface, perhaps as it would appear in a faraway pond, where one would see the confused movement of fish without distinguishing each individual fish.”

different external and internal events (earthquake, fires broken out in different dates, roof infiltration, disruption and so on) and by project choice superimposed and stratified on the original morphological geometry and wall structure. The result is perhaps a complex system of vaults, whose springing lines were found at numerous altimetric levels in the different ages, now read through the intrados and extrados profiles and levels, related to the 4 corner towers, inside a three-dimensional system of measures and of representation modelling, begun with the survey of the plan.

2. Survey and geometric analysis (the plan)

The front of the Basilica conceals a tetra-lobed shape, named for this reason 'clover-leaf', 'tetraconco' (here a system composed of four 'exedras', columned recesses semicircular in shape) developed on a central plan with the four towers positioned at the corner between the four apses of the external 'clover-leaf'. The 'clover-leaf' is composed by two concentric architectures, the internal and the external one. The internal one, with tracery in two orders (the ambulatory level floor order and the women's gallery), supports the dome superimposed atop the octagonal tambour: it's made up of a sequence of four columns or four octagonal pillars at the first order, and superimposed at the second order the same sequence, four smaller columns and four square pillars. The external one is built by a continuous circular wall.

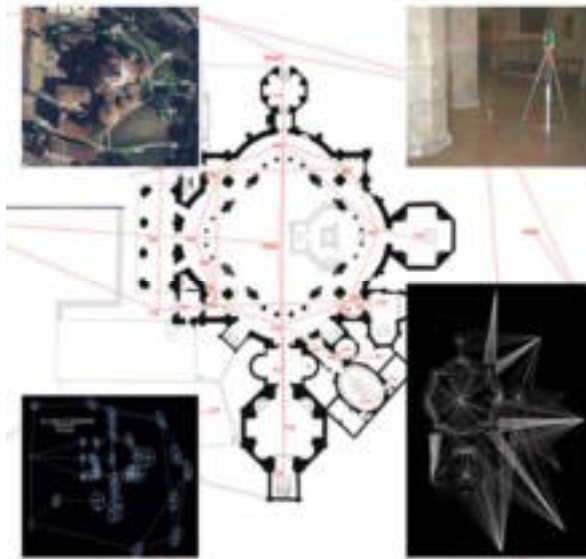


Figure 1. The topographic reference network, the stars of punctual survey taken from the different node-network and the final plan of the Basilica at the nominal scale 1:50 with 1:1 details acquired by direct measures

The four semicircular apses are separated by four pairs of pillars (Figure 2) with a 'V' shape (each corner versus is inside the internal of the Basilica). The pillar of each pair is connected to the other at the different level by arches. The pillar network belonged to the original construction, even if some of pillars were partially destroyed and reconstructed (half of XII due to fire), and in a second time they were reinforced in order to support the dome partially reconstructed in XII-XIII and the new one by M. Bassi (1557 post quem).

Each pillar has one face traced on circular section (Figure 2, detail I). One block was joined later for the new dome (Figure 2, detail II), as verified by the stratigraphic analysis. Geometric analysis on the base of the planimetric survey in

its parts has been conducted to study the construction and tracing criteria: particularly, the four exedras sector (continuous wall), each group of four pillars and column, and the pairs of pillars at the corner of each exedra (Figure 2). In the hypothesis that shape can be approximated to a circle, the result it has been obtained interpolating the surveyed points with different circles and then comparing the different fitted circles. The results related to measure-chronologic analysis, thermo-luminescence analysis and to carbon¹⁴ one's, allows to date all these groups distinguishing different step of reconstruction (i.e. the columns respect to the four octagonal pillar and so on). It's the case in which the simple apparent circle scheme, punctually read in function of the s.q.m. (mean square deviation) highlights, on one side, the high constructive tracing millimetre control (such as the circular arc section of the 'V' pillar at the upper right Figure 2) and at the other side the different period of reconstruction in case of bigger deviation.

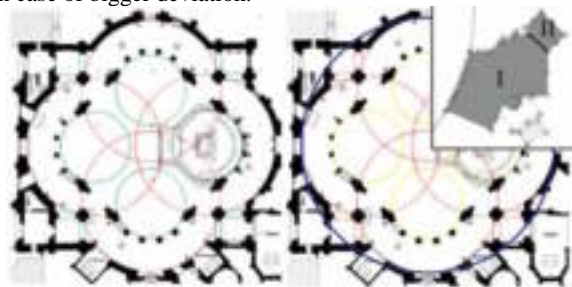


Figure 2. We can see (in green) and in the detail, how the interpolated circumference on the 'V' pillars is tangential to the four octagonal columns of the exedra of S. Aquilino (apse below) while the other three groups of four columns each depart from these interpolated circumferences on the pillars up to a maximum in the halfway point of circa 30 cm. The four circumferences (in red) interpolating the exedras of the clover-leaf are inscribed in a circumference tangential to the extrados of the sectors of the exedras (in blue).

We can achieve this knowledge of the form of the monument with survey, which must be represented as exactly as possible. There are mandatory procedures, logical and empirical rules; the procedures can be different from each other but not in an arbitrary way. The problem of measuring is central in the problem of the scientific understanding that bites into the real, and the problem of measurement can be framed as a continuing moment of analysis and synthesis of the perception, where the measurement of the dimensions is the analysis and the model is its synthesis, and both are difficult to separate because they are always present in concert. Measurement plays a precise role in the model. The nexus between the model and reality is a discontinuous set of contact and control points, i.e. measurements, within which a continuing coherence between the model and reality is interpolated.

In the case of the circumference the process is simple and basic: it starts with selection of a number of points, in a theoretical model (in this case it is the circle) and continues to a representative model obtained from a topographical survey of a number of points sufficient to interpret a theorized geometry.

The result has to be analyzed. The model can be enough. But it can be not enough to read the reality: in this case the theoretical model can be refined or changed in an iterative process, evolving more complex model.

3. Comparison of the altimetric levels and springing height: the distribution of openings, dating thresholds and open problems (survey of the towers)

A reading of the planimetry presents a central layout of the basilica complex, whose four corner towers are interconnecting at the ground floor, with the four exedras of the ambulatory. One might expect a similar planimetric layout at the upper levels.

But in walking along these levels, one notices that there are interruptions and important elements that deserve more attention. The towers present several masonry layers at various levels within the individual towers, for example, there are legible traces of past interventions and conversions that have changed the spatial distribution and layout over time. The objective of the survey is to set in relation this data, inside a single tower and show a relationship with the others, to form a cognitive support of georeferenced reference and to analyze the interdisciplinary nature (Figure 3). It would then be possible to draw a parallel between considerations or interpretations using this data "scattered" in the 3D space of the Basilica (Figure 4).

These forms of representation open up interesting scenarios to georeferencing of data due to the ability to connect investigations on the monument with the ability to handle all the information acquired on integrated models, georeferenced in the GIS form.



Figure 3. The various phases of construction (roman, late-ancient, medium age, modern age, and restoration) georeferenced thanks to interdisciplinary analyses (C14 samples, thermoluminescence, archaeometric, and so on) highlighted recovered bricks, dated the mortar between the bricks, etc

The survey was conducted tower by tower; the data was compared in particular in the external elevations (through rectified digital images) using internal survey, constructing vertical and horizontal sections, defining significant elements, levels and geometries. The survey of each tower is inserted into a single reference system, a network system, so that the data can be read in a diachronic and synchronous way (Figure 3). The project surveyed and highlighted elements such as the geometry of the arches, the springing geometry of the vaulted elements, the routes to the diverse levels between the towers and the parts of the Basilica, steps in the masonry apparatus, external and internal windows as well as the windows subsequently filled in or opened up in subsequent periods.

In this way, it was possible to draw several reasonable conclusions regarding the evolution of the building, the construction done to it, and the transformations that took place over time; in other cases, the survey was limited to a statement of metric and geometric aspects whose reason or tie with other aspects cannot be clear, leading to legitimate questions and queries that can be answered thanks to other

contributions or may represent a point of departure for speculative investigations.

The current distributive system and traces of the historic openings (NE, NW, and SW towers) shown in relationship to steps visible on the outside and inside.

One element highlighted and placed in comparison to the several surveyed steps is the level of the corresponding treadable floor of the current wooden floor slabs of the towers. At the level of the raised women's gallery, we can see traces of the springing line of the crossed domed vaults (keystone brick of the springing line at a height of 14.7 m). The survey of steps through the variations of thickness of the brick section, legible on the wall façade of the towers was found to be significant for the purposes of dating some phases and transforming subsequent phases.

The north-east, north-west and south-west towers present internal steps that correspond to the external steps quoted in the rectified images photoplanes; this suggests that originally, there was a floor slab on that floor (see Figure 4, bottom).

Also, the south-east tower presents on the internal east side a step that is located in correspondence with the external part (see the stringcourse) on the photoplane (Figure 4, up).

Observing the external and internal elevations of the other levels, we find that at a level of 20.04 m (north-west tower, south side), another external step is located in correspondence with the inside; at this level, we can presume that there was once a floor slab at that point.

The walls of the south-west, north-east and north-west towers - as underlined by L. Fieni⁴ - until the height of the first floor slab, all date back to the Roman era. The survey found traces of a series of arches and openings that had since been bricked over. The south-east tower is not included in these considerations since it was completely rebuilt in medieval times. In particular, the height of the intrados of these bricked-over arched openings is the same in all the towers (about 17.50m) and, inside of these, also on the two contiguous sides. By putting together the considerations above as regards the height of the floor slabs, we believe that there was an original design plan of the basilica that included the towers as an integral part of the monument; this theory is backed up by the fact that, observing the building fabric, we see that these arches are contemporary with the masonry and were not constructed in subsequent time periods (Fieni).

One theory that emerged regards the presence of a very ancient floor slab that connected all the towers directly to each other at the same height: the height of the extrados of the women's gallery in the late-ancient period must have been lower with respect to its current height (Figure 5). If we consider the planimetric distribution of the Basilica at a height of 16.9 meters, we see that the route, starting from the south-west tower, reaches the south-east tower but does not continue further to the north-east tower: one has to reverse and pass through the north-west tower. The layout does not have a coherent, logical design. Considering an imaginary distributive layout in the original route in the Roman era at a height of 15.30 meters (Figures 4 and 5), this becomes continuous and the system of the openings takes on a coherent configuration.

⁴The theory submitted by L. Fieni, op.cit., is that the construction of the Basilica of San Lorenzo was begun, dead Teodosio in 395, living Saint Ambrogio, as a mausoleum commissioned by General Stilicone, for himself, regent of the Teodosio's son, Onorio, successor to the imperial throne (395-408), when Milan was capital of the Empire, rather than as a church of Ambrosian Christianity. But when Stilicone died under uncertain circumstances (408), the remains of the martyr Lorenzo were buried (511-512 a.c.) there and the church dedicated to the saint, becoming a christianity church.

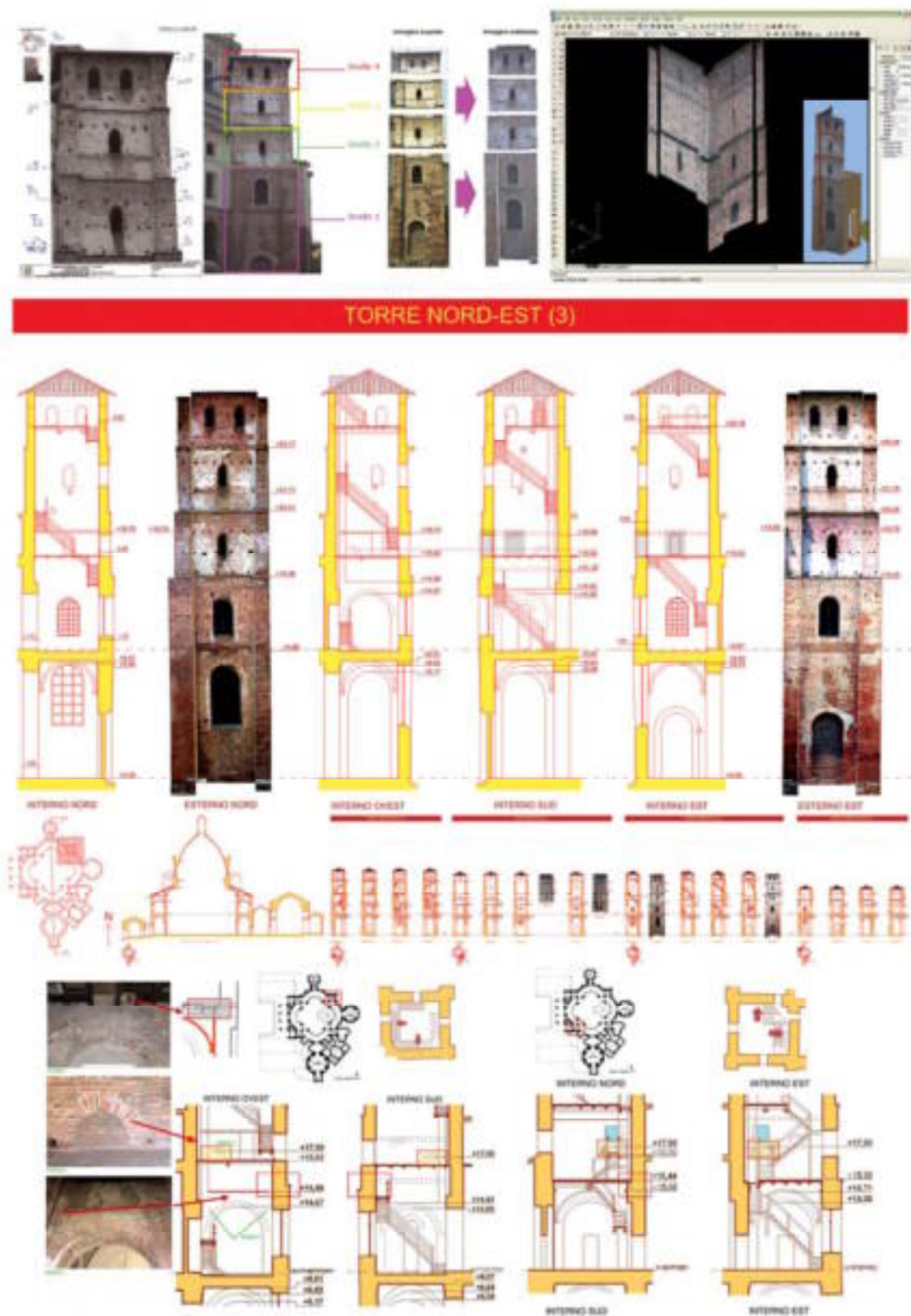


Figure 4. Synopsis sheet of comparison of the survey of the towers with the Basilica complex and comparison of the towers to each other. The sources and sections are developed and compared in their various orders of elevation, to highlight the systematic qualities, series, and abnormalities, that, in turn cross-referenced with data originating from different analysis, have made it possible to better approximate several theories of dating and transformations taking place over time

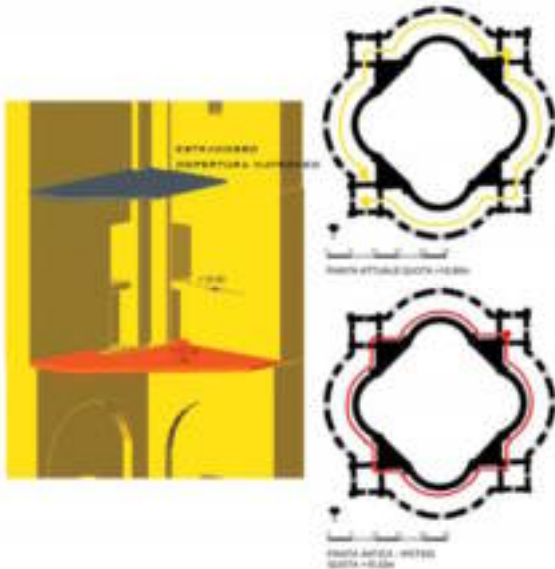


Figure 5. 3D Model relating to the south-west tower with the passages realized at two different heights, one above the other, respectively the older one at 15.32 meters (see Figure 4 below the SW tower) and the more recent at 16.90 m (see Figure 4 NE tower in correspondence to the internal north and east sides). At right, two planimetries with the old layout (theoretical) and the present day layout: connection layout between the towers through the possible passage above the extrados of the ceilings of the women's galleries in the two construction thresholds (the ceiling of the galleries was elevated by 2 meters for the reconstruction, dated to construction of the drum and the dome by M. Bassi,

4. Comparing the towers to the 4 dimensions of the Basilica ("the worlds" of an apparent chaos photographed by point clouds)

The appearance and reading of the historic drawings can add to our understanding of the complex in relation to the matters discovered in the survey of the towers, and brings questions by orienting new research and investigation (Figures 6-7).

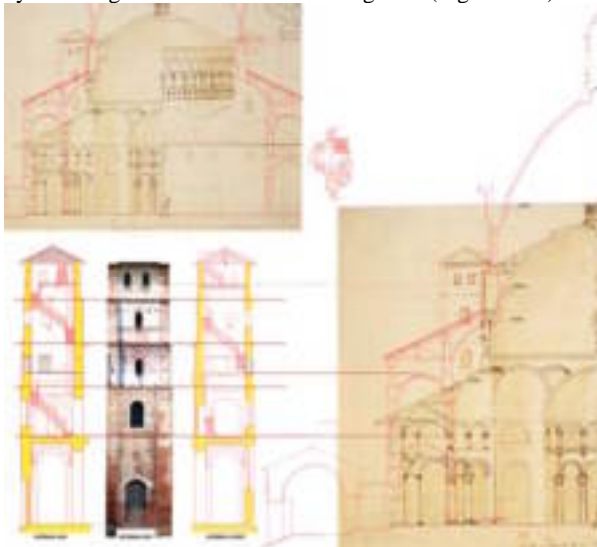


Fig. 6. The Basilica before the collapse of 1573 (design from Castello Sforzesco, Milan, Gabinetto dei disegni, Scuola B56) georeferenced on the state of art (the vertical section related to the altimetric level of the tower)



Figure 7. At the top left, identification layout of the towers for the ancient connection route (theoretical) in yellow and the current route in red, at the level of the extrados of the gallery. At the bottom, a 3D view of the nucleus of the Basilica in relation to the towers

The apparent chaos (Figure 7) photographed by the point clouds acquired by laser scanner CYRA 3500 needs to be deciphered through interpretive and representational models (Figures 8-9)

For example some historic drawings, such as in figure 6, depicting the Basilica of San Lorenzo before the collapse of 1537, report details and elements of the original layout that at first sight, may seem to be the result of reinterpretations and imaginary theories, far from a representation made on the basis of surveys, dimensional verifications, and geometric rectifications. Every consideration must be carefully considered. However, they can form theories and lead to new questions.

This representation leads back to the classic representations (the elevation of the Basilica from the outside, alongside the section and the internal cutaway). The tower demonstrates, seemingly erroneously, three orders of windows that look out outside starting from the top (there are five orders on the tower but the superelevation of the gallery hides the third order of windows, marked in grey in Figure 6); this leads to the assumption that the springing of the roof of the galleries was originally much lower.

Otherwise, under the assumption that the design has deformed some sections, the ambulatory-women's gallery "block" would be "pulled" upward: the height of the treadable surface of the gallery would be verified against the original.

An observer located virtually between the two towers at the height of the third order would have seen the external windows which, pursuant to the reconstruction of the higher women's gallery, no longer appear as windows.

The small sequential windows in the external side of the clover leaf, which today would be located in correspondence with the thickness of the vaults which support the women's gallery, were likely bricked over to give stability to the structure, since just above this, new external openings were made which appear today when passing along the women's galleries (Figures 7,8,9).



Figure 8. A preliminary raw elaboration of the model and the two ambulatories of the clover-leaf. An additional development seems to need to pass through generation of surfaces (for example, columns and vaulted surfaces) integrated by border line, rather than staying on lines of discontinuity

Conclusion: decoding models

The several open theories should be cross-referenced with other fact-finding investigations (thermography, specific multispectral analyses, ...) that can yield as much evidence as possible of the filled elements and with the extensive surveys of the vaulted roof of the ambulatory on the ground floor and at the level of the women's gallery.

With the appropriate processing, the surveys done recently with laser scanning technology may give important clues about the geometric and constructive genesis.

This objective conflicts with the geometric complexity of the building, which does not allow automatism in representational process and in data modelling procedures.

The data model of scattered points acquired by laser scanner technology represents the main theoretical and technical problem of the representation of the shape of the architecture, whose continuous shapes are characterized by discontinuity, in the sense that the material continuity in a point can assume different geometric shapes, including discontinuity (linear and non-linear edges).

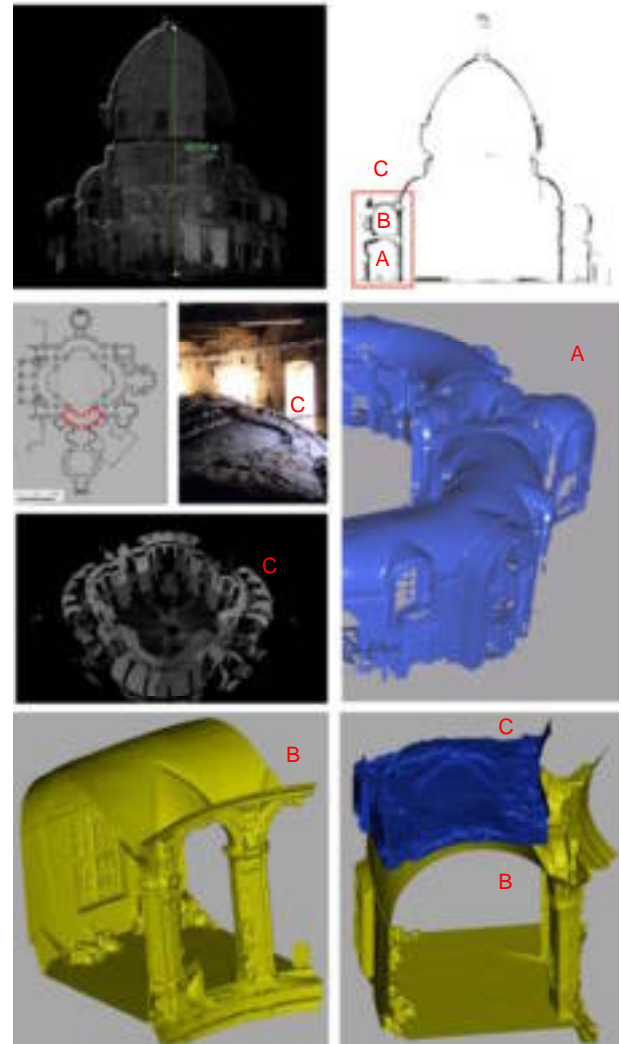


Figure 9. From composition of the point clouds to deciphering different construction systems. From the breakdown according to interpretational models until modelling and correlated recombination (the vaults system)

The best solution would seem to be an "intelligent" breakdown by construction elements (Figure 8-9), systematically assisted and guided by the geometric analysis, correlated with a construction and technological reading, validated in light of the contributions made by other disciplines.

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