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CONSTRUCTION AND BUILDING PERFORMANCE

BUILDING AND DESIGN TECHNOLOGIES

CONSERVATION PRINCIPLES AND STRUCTURAL PERFORMANCE OF MODERN HERITAGE: THE CHURCH OF SAN GIOVANNI IN BOSCO IN BOLOGNA

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Abstract

The knowledge of the design and construction practice of peculiar works that belong to the Modern heritage is an essential prerequisite for its conscious conservation.

In the transition phase between Modern Italian construction and the beginning of prefabrication in the late 1960s, a significant episode is the construction of the church of San Giovanni Bosco in Bologna between 1963 and 1969, one of the most recent, and the last Bolognese work, by the architect Giuseppe Vaccaro.

On the one hand, the church presents some technical features that confirm the construction practice consolidated during the Twentieth century in Italy, identifiable as a mixed construction. On the other, innovative elements were introduced to integrate three different structural technologies, such as load-bearing masonry walls, reinforced concrete frames and steel trusses.

The paper proposes the repertoire of the construction techniques of the church, which represents a condition of uniqueness within the local building heritage. This complexity and the particular combination of different load-bearing materials make the structural components invisible, being an obstacle for assessing the structural performance of the existing building according to traditional methods.

Keywords

Modern heritage, Giuseppe Vaccaro, San Giovanni Bosco, Reinforced concrete construction, Building conservation.

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1. INTRODUCTION

In their triple typological, construction and material nature, the architectural values that characterize historical heritage determine reasons and decisions related to its protection. Italian cultural heritage also includes buildings designed and built in the Twentieth century using the construction system of the reinforced concrete frame, which spread in the peninsula between the 1920s and the 1960s. In this period, this technical solution has established itself with certain gradualness and continuity, starting from its initial collaboration in masonry works until the achievement of its own structural autonomy [1]. These construction types, initially mixed then entirely framed, fully fall into the urban and architectural works to be safeguarded, posing the problem of combining the demands of conservation and protection with their structural safety. In fact, these buildings date back before the 1970s, when a specific reference regulatory framework on structural safety was lacking in

Italy, and regulatory requirements were very different from the current ones.

The conservation of these artefacts requires a careful process of knowledge acquisition, which includes studying the historical regulatory framework and calculation methods, identifying proper technological and construction archival references, and analyzing construction deficiencies and the ongoing degradation. Only on the basis of this knowledge, it is possible to determine reliable criteria for assessing the structural performance of Modern buildings. Nevertheless, the absence of construction solutions and details that current regulations consider fundamental to guarantee the safety of reinforced concrete structures, which cause a high level of vulnerability in terms of structural quality, usually determines the inapplicability of the verification protocols proposed at the regulatory level.

A further consideration then concerns the criteria for choosing the intervention. When is there the need to preserve the material integrity of the building in the face of structural safety?

Intervening on a Twentieth-century reinforced concrete building may require an approach falling within the context of Building Restoration. On the one hand, this means drawing the primary motivations from the aim to preserve the building's identity and historical memory and the desire to confirm its construction logic. On the other hand, the restoration path requires a solid knowledge process to recognize the technical peculiarities of the artefact and set up specific methodologies to synthesize them in new calculation models instead of standardized ones. Therefore, given the large number of historical reinforced concrete buildings and their high cultural value, the conservation of Modern heritage is a very present issue that poses problems not only of a technical nature.

This contribution aims to illustrate the complexities that emerge in restoration processes while combining both the protection of historical built assets and their structural safety, especially when the uniqueness of construction solutions and the lack of proper archival documents prevent technicians from following the traditional knowledge process and performance assessment practice.

The presented case study is the church of San Giovanni Bosco in Bologna [2], one of the most recent works by the well-known architect Giuseppe Vaccaro [3], designed and built between 1963 and 1969. The relationship between the design features and the construction elements describes in an emblematic way the state of architectural research, realization practice and material culture of the time, explaining the productive, economic and social processes at the basis of the conception and execution of this architecture. The study of the vast repertoire of technical solutions adopted in the building is proposed as a moment of critical understanding of the technical culture of the 1960s, as well as a prerequisite for an aware process of protection and conservation of the church.

2. THE HISTORY OF THE PROJECT

2.1. DESIGN PREMISE

The parish church dedicated to San Giovanni Bosco [4, 5], located in the eastern outskirts of the city of Bologna, represents one of the most recent works by Giuseppe Vaccaro [6], as well as "one of his most significant works, in perfect coherence with his past production, in the characteristic breath of his temperament as an artist" [5]. The church's construction was undertaken between 1964 and 1968 as a part of the Bolognese movement for modern sacred architecture led by Cardinal Giacomo Lercaro. Within this initiative, the city was enriched with fifty new churches involving personalities of great cultural depth, including national architects such as Luigi Figini, Giò Ponti, Giovanni Michelucci, Giuseppe Vaccaro, and international ones like Le Corbusier, Alvar Aalto, and Kenzo Tange.

In 1957, the idea of establishing a new parish church in the eastern area of Bologna took shape, entrusting its construction to the Salesians, who accepted the proposal with enthusiasm. The only condition was that, next to the new church, schools, workshops and green courtyards had to be built to establish a new driving force urban centre. The preliminary project was assigned to engineer Carlo Tornelli, who outlined the church, the annexed buildings and the sports field. Subsequently, the church's project, the fulcrum of the entire Salesian complex, was entrusted in 1963 to the architect Giuseppe Vaccaro, a well-known designer, to increase its cultural value. The architect already had extensive experience in the design of ecclesiastical buildings; his works include the Collegiate Church of Santa Maria Assunta in Portomaggiore (1946-1960), the Cuore Immacolato di Maria church in the Ina Casa district of Borgo Panigale in Bologna (in collaboration with Pierluigi Nervi between 1951 and 1957) and church of San Gregorio Barbarigo, in the north-eastern area of the EUR district in Rome (1968-1971) [7].

Vaccaro's design idea differed considerably from the first draft of the engineer Tornelli, as he operated according to the criteria of modern sacred architecture and outside any traditional scheme. His temple was defined as "one of the most beautiful and functional of all the new churches in Europe" as well as a "jewel of architecture and a powerful instrument for souls" [8] (Fig. 1).

2.2. THE BUILDING

The church looks like a majestic building, designed as an attractive pole in a newly expanding district; actually, it is totally incorporated within a context characterized by buildings dating back between the 1950s and 1970s, with an almost similar height, and which hide at sight the massive volume, visible only from close range (Fig. 2).

The typological layout is a large hall that refers to the centripetal spatiality of a central plan church, thanks to the advanced position of the presbytery with respect to the back wall. The originality in the treatment of internal surfaces resides in the deformation of classical spatiality. According to a formal mechanism, the arbitrary folding action of the perimeter walls generates, in the plan, more or less deep niches that enclose the liturgical poles, the weekday chapels, the penitential chapels, the minor altars and the baptismal font, separating them from the assembly space.

Externally, geometry and proportion are the permeating characteristics of the entire project; the approach to the design of large volumes translates into a very pure geometry of prismatic elements having different heights that give monumentality to the building. The gradualness of the elevations gives harmony and grandeur to the forms while leaving separated three clearly visual elements: the metal roof, the glass facade and the brick curtains, protagonists of the internal and external spatiality of the church. Instead of relying on the preciousness of marble and freestone, Vaccaro covered his volumes with simple bricks in the typical custom of recalling the

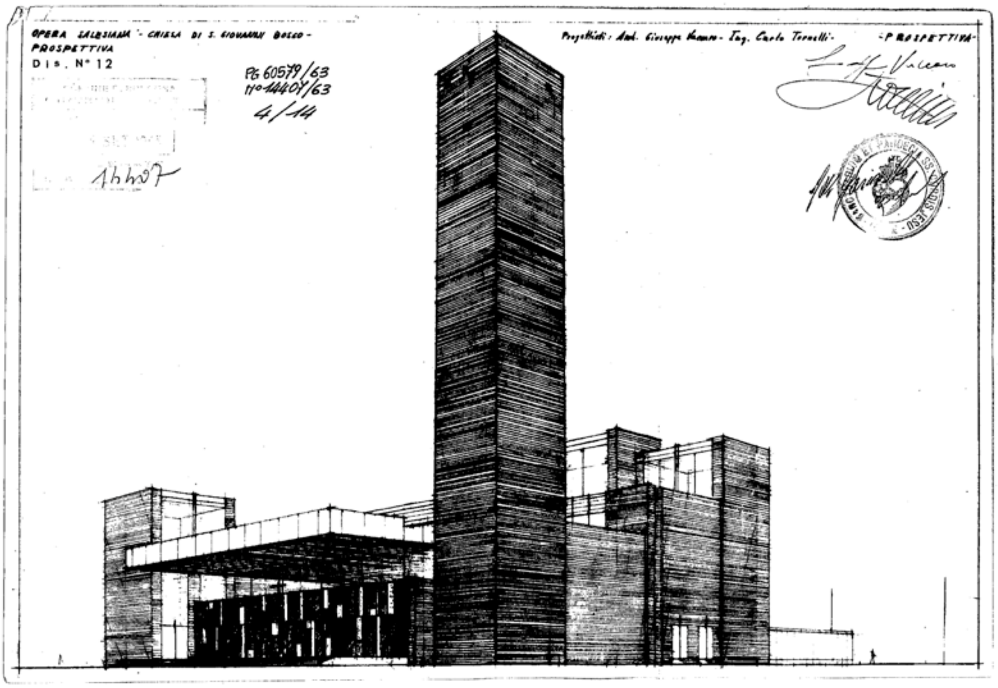

Fig. 1. *Perspective representation of the Don Bosco church by the architect Giuseppe Vaccaro and the engineer Carlo Tornelli [9].*

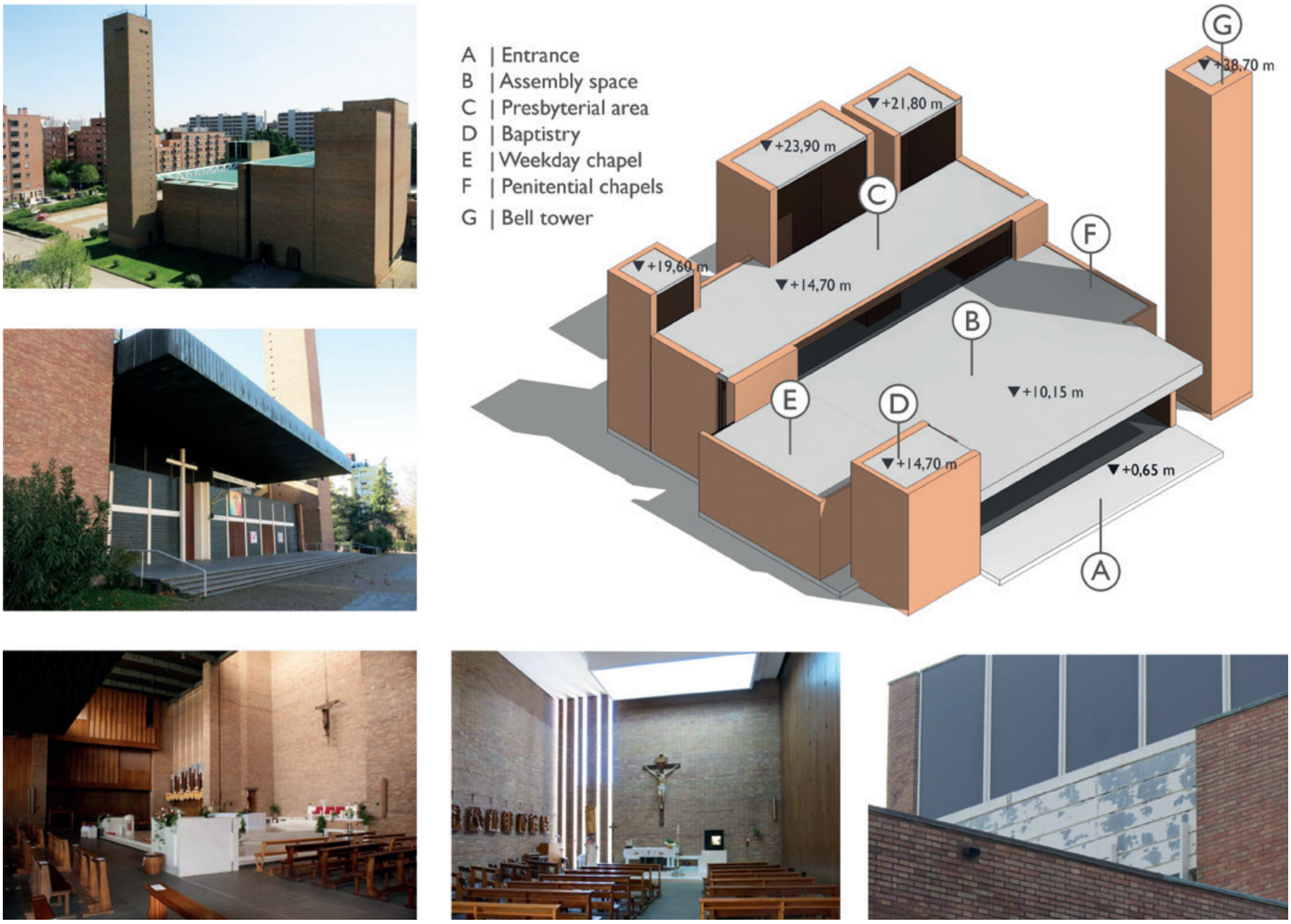

Fig. 2. *Top left: aerial view and entrance façade of the building. Bottom: internal views and materials degradation © 2015, Giorgia Predari. Top right: functional layout © 2022, Author's graphic elaboration.*

characteristics of the local construction tradition in his Bolognese works.

The entrance, raised by four steps in Serizzo granite from Valmasino, is strongly emphasized by the large copper-clad projection that covers and shelters the churchyard. The glass blocks on the main facade generate a dematerialization of the elevation and give a greater sense of openness and permeability in the search to create a church open to all the observants. Even internally, the walls are all treated with exposed brick, without openings and windows; the diffused light comes from vertical slits along the sides, in the ceiling and from the large glass wall at the entrance. The interior space is enriched on the roof intrados by a succession of copper lamellae, which is emphasized by the zenith light from carvings in the overlying roof.

The conclusion of the slatted ceiling denotes the passage between the area reserved for the observants and the beginning of the presbyteral area, where the altar stands out. On the left, there is the tall and slender baptistery and the weekday chapel, with a rectangular shape and divided from the main hall by a large movable wooden wall. The light effects coming from the wall at the back of the altar are particular, as characterized by the alternation of glass bands and solid brick bands, emphasized by the simple white false ceiling.

3. THE CONSTRUCTION FEATURES

Construction works began on the first part of the building complex, intended to accommodate parish services and associations, a temporary church and an oratory. They took place at the end of 1961 under the direction of the Giorgio Lenzi Construction Company. In January 1963, the agreement for the concession of the new parish to the Salesians was drawn up. During the following month,

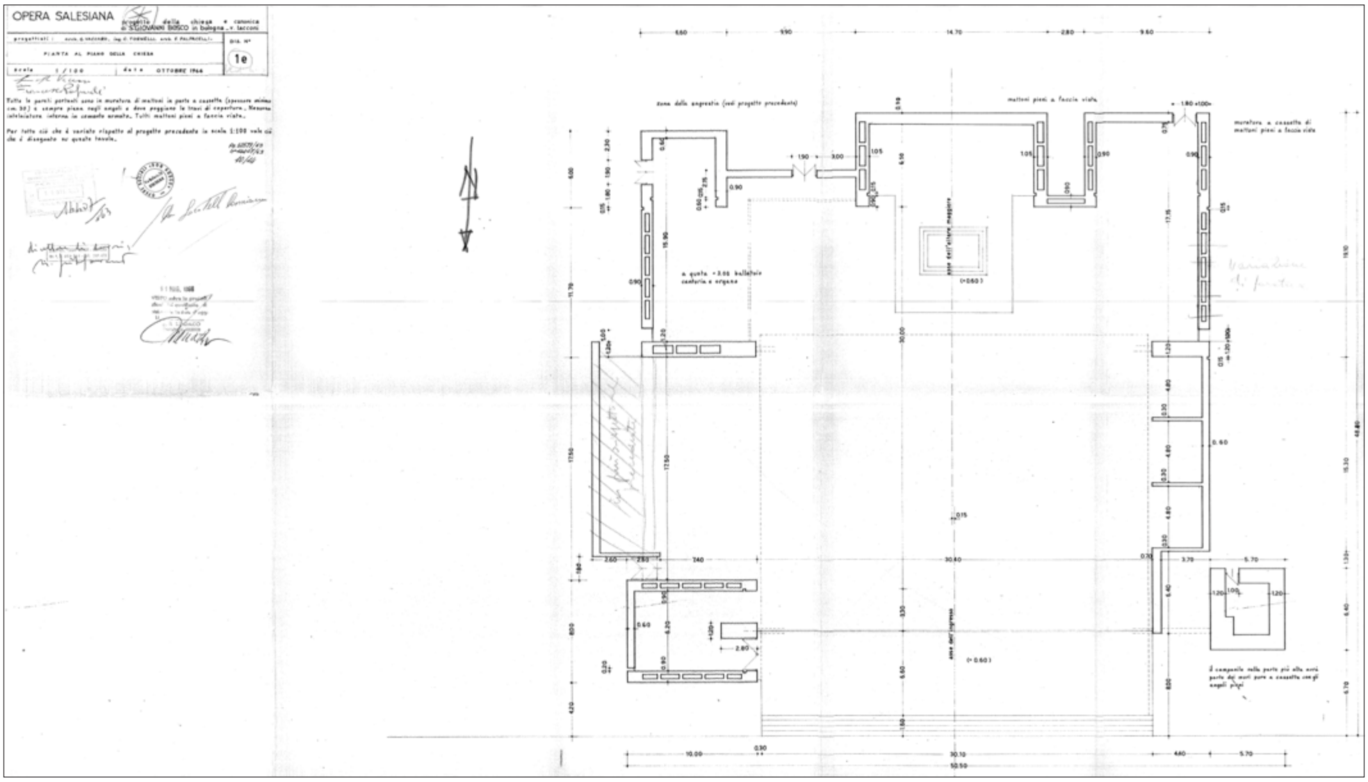

Fig. 3. *Ground floor layout included in the architectural drawings, 1963 [9].*

the excavations works for the foundation began, presumably on the basis of the project already designed by engineer Tornelli. In the meantime, the architect Vaccaro was developing a new project for the church, departing from the engineer's original design (Fig. 3).

In January 1964, Cardinal Lercaro laid the first stone, and the structure began to reach the ground level in June 1965. First of all, the bell tower around 38 meters high was built, providing support for the roof's large reticular structures. Then, the pillars and basement walls were erected, and the massive external walls were finally built. The laying of the metal roof trusses began in 1966; then, the works were completed in 1968 (Fig. 4) [8].

Fig. 4. *The church during the last phases of the construction works.*

3.1. THE ELEVATION

Identifying the adopted technical solutions is a complex activity due to their variety, the scarcity of documentary-archival material, and the fact that the brick curtains do not make their construction nature visible.

As regards the wall elevation, the drawings dating back to the 1964 architectural layout indicate that "all the load-bearing walls are in brick masonry, partly in cavity walls (minimum thickness 30 cm) and always solid walls at the corners and where the roof trusses rest. No internal framework of reinforced concrete. All solid exposed bricks" [10]. However, this indication is not evident in the construction site images, where reinforced concrete pillars are clearly visible, particularly in the southern area.

A specific study on the wall thicknesses identified different stratigraphic solutions concerning the respective heights (Fig. 5). All the bricks have the typical dimensions of the Bolognese brick, which is 13.5×28.0×5.5 cm, with holes in a percentage lower than 45%, as can be deduced from the site photographs. The wall texture refers to the cross-bond type formed by alternating bricks arranged as headers and stretchers.

The combination between thicknesses and heights of the wall volumes made it possible to hypothesize the coexistence of two different main construction techniques in the elevation structures (Fig. 6). The first, used for the volumes having a greater height (the three southern ones and the baptistery), consists of a reinforced concrete frame structure completely incorporated into the masonry, with variable-sized pillars and reinforced concrete walls in correspondence with the supports of the metal trusses. The second, used for the

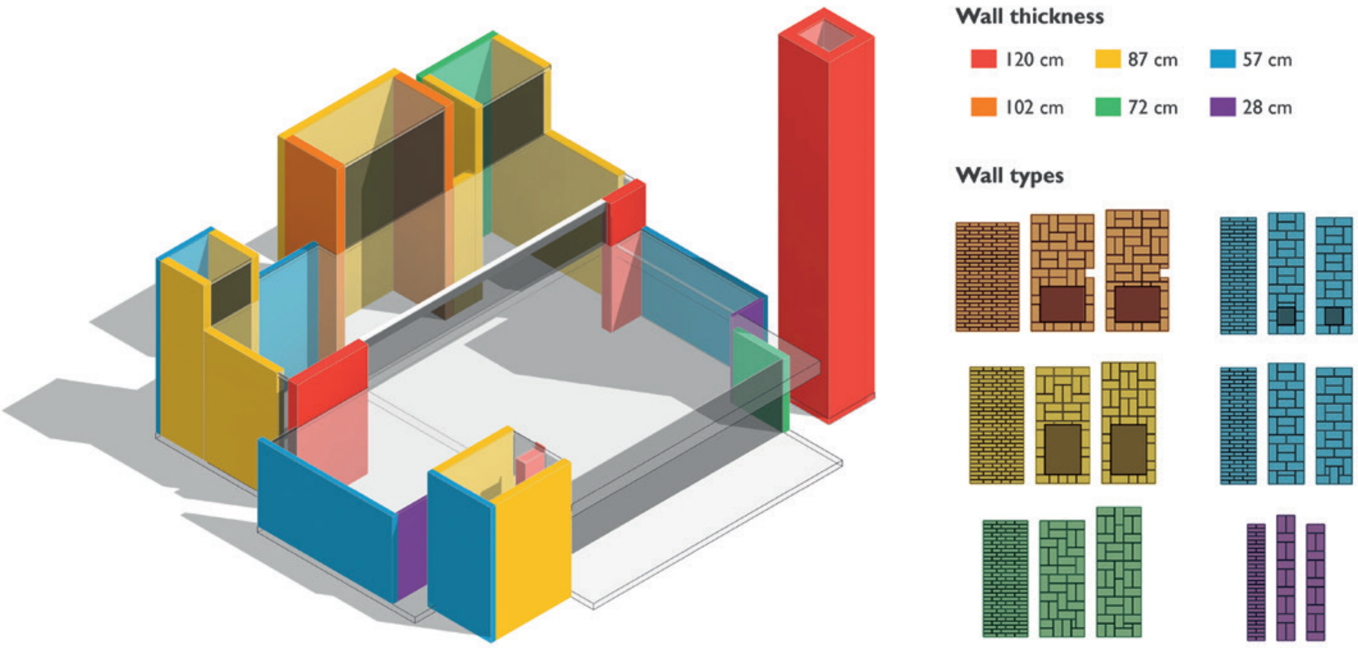

Fig. 5. *Identification of wall types.*

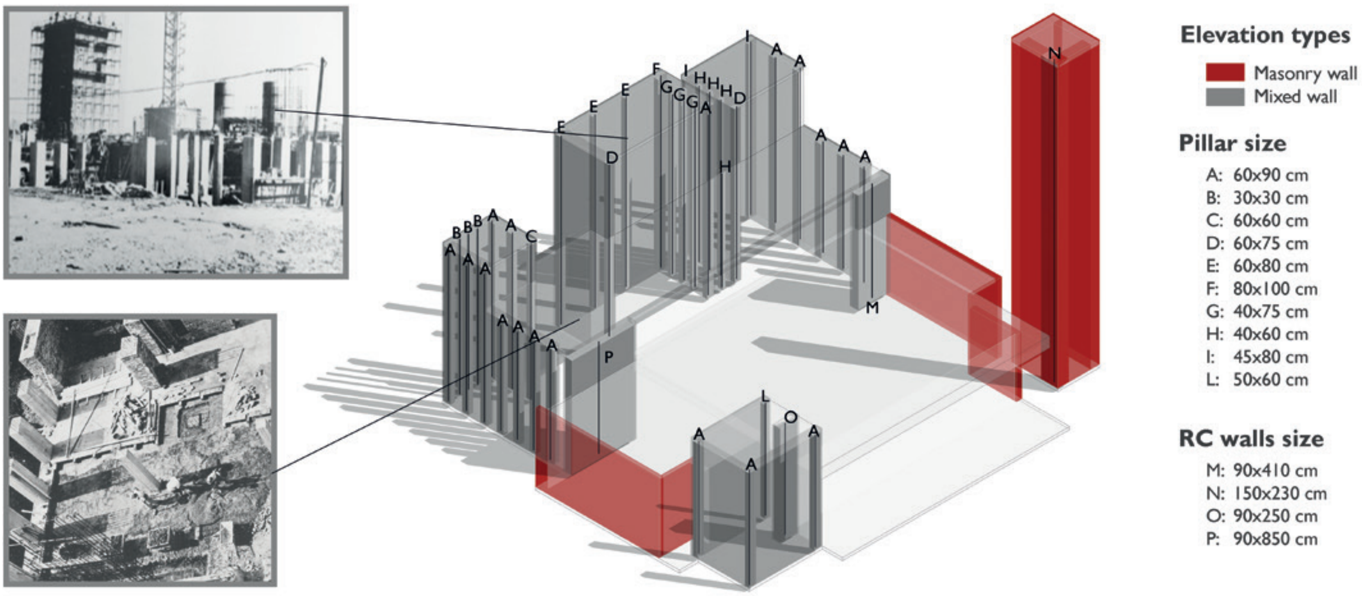

Fig. 6. *On the left, photographic documentation of the construction site: initial construction of the bell tower, raising the pillars in the southern area © 1971, G. Roversi [8]. On the right: identification of the hypothetical elevation structures.*

bell tower and the lower central volumes, consists of a load-bearing masonry structure.

The considerable heights of the volumes in the presbytery area, combined with the absence of cracks, suggest the presence of a dense pillars framework in these areas. In fact, these volumes have heights of 23.90 m, 21.80 m and 19.60 m, too high for load-bearing masonry structures without intermediate floors; in addition, the type of roof – with the use of only two main trusses about 30 m long to support the secondary frames – is not suitable for being supported by a solid wall system.

If the presence of pillars is well documented for the southern areas, it is not near the access to the church. Here, the presence of simple load-bearing walls would be possible. Firstly by observing the architectural representation with solid fills in the elevation structures; then, by deducing the compatibility of the thicknesses of the walls (60 cm for the longitudinal walls and 30 cm for the transverse ones) and the height of the wall structures (equal to 10.75 m); finally, due to the presence of transverse walls arranged in order to increase the stability of the perimeter walls, in particular in the area of the penitential chapels.

3.2. THE ROOF STRUCTURE

From a formal point of view, the construction element that most characterizes the building is the roof, whose structural organization reflects what Vaccaro had already defined in his architectural project. The main framework is made up of two steel trusses designed to support the large roof ceiling, resting on reinforced concrete walls on the sides of the church. One of them is close to the main facade and externally visible. It is a Monier-type truss made with C-shaped profiles for the upper and bottom chord, IPE profiles for the vertical members, and two solid profiles with a rectangular section for the diagonal members (Fig. 7). At the bottom chord, plates are welded perpendicularly to the plane of the truss to connect it to the secondary framework. The second main beam, placed at a higher level than the façade truss, is made of a solid steel beam with transverse triangular stiffeners.

The secondary framework is also made of steel lattice beams of the Monier type. They are realized by L-shaped coupled profiles for both the chords and the diagonal members; the vertical members are rectangular section profiles. The upper chord is inclined towards the main façade truss to give a slope to the pitches; the horizontal bracing systems are anchored to it. The connection between the main framework and the secondary one allows a part of the latter to overhang above the churchyard (Fig. 4).

Above these trusses, there is a third framework consisting of profiles with a wooden plank fixed on them and, above them, there is a corrugated copper sheet. Instead, the side volumes roofs are made with simple HEA-type

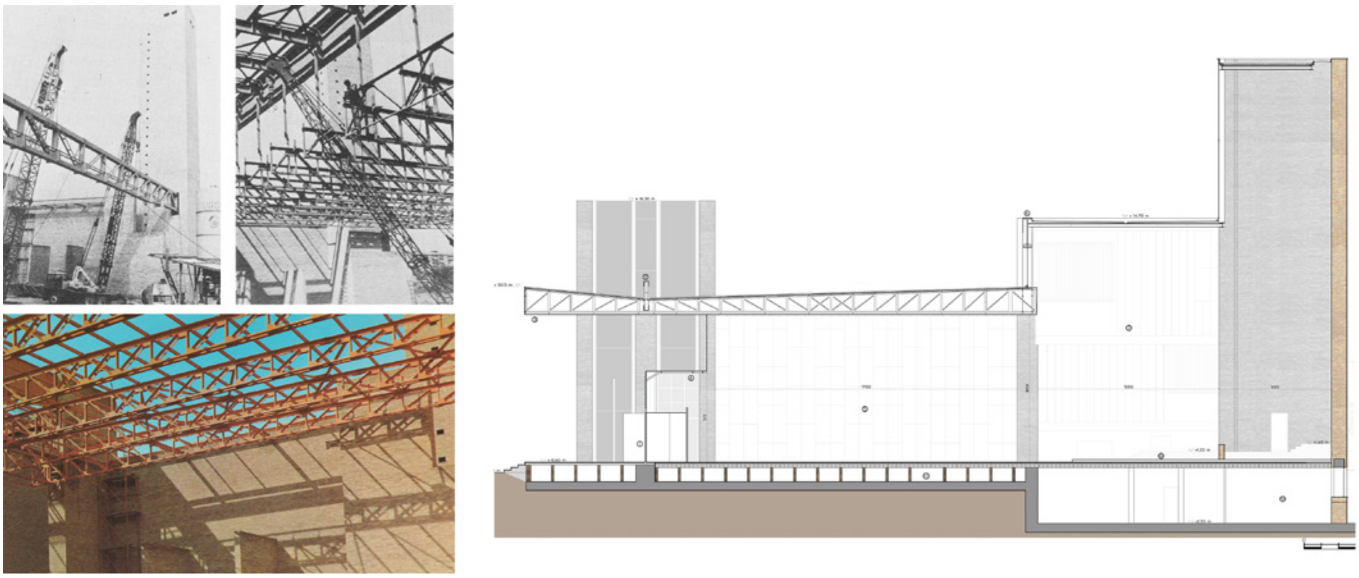

Fig. 7. *On the left, photographic documentation of the construction site: installation of the roof and assembly of the main facade © 1971, G. Roversi [8]. On the right: section of the building © 2015, L. Vecchio.*

steel profiles for the main beams and IPE-type for the secondary beams, placed at a center distance of about one meter. Also, there is a wooden plank and a corrugated cover sheet above this framework.

3.3. FINISHES

In addition to the roof, steel is also used on the main façade. Here, a robust steel framework left exposed and painted white supports a glass brick façade system made of overlapping glass lamellae. An emerald light filters inside through it, giving brightness to the interiors. In the main façade, there are two sizeable central pivot doors with steel structure and wood finish and a further sliding door as high as the front itself, which, once closed, remain perfectly in line with the façade.

Copper is the primary material for most of the other finishes: the covering of the entrance canopy, the corrugated sheets in the roof, the false ceiling of the hall and also the two side doors, slightly protruding from the edge of the façade.

4. SCENARIOS FOR ASSESSING THE STRUCTURAL PERFORMANCE

From a structural point of view, the survey operations did not reveal the presence of cracks, further corroborating the hypothesis of a reinforced concrete structure hidden behind the curtain wall, at least in the highest volumes. However, it is not known how extensive this is, how close the spacing between the pillars is, and what the actual structural sections are, since it was impossible to find the original drawings of the structural design. Even if it has been possible to find some indications of construction features relating to the architectural design, nothing is available regarding the structuring of the church. On-site diagnostic investigations and destructive tests [11, 12] would allow the identification of the material characteristics in terms of their strength, which are necessary for a detailed assessment of the structural performance, but at the expense of the integrity of the building. In this case, the investigations must deal with the building protection constraint, with construction solutions concealing the load-bearing structures under brick curtains, which constitute the formal solution for treating the façades.

The case study arises as a recurring problem in the performance assessment of existing buildings. Unfortunately, not finding sufficient technical information to carry out structural modelling, albeit approximate, is common. This difficulty is because, before 1971, it was not necessary to approve the final structural plans of designed buildings or because these have been lost.

About 75% of existing buildings were built before the entry into force of seismic regulations at the national level. Most of these buildings with reinforced concrete structures usually date back to the post-war thirty years and have therefore reached and exceeded their conventional service life. This could lead to problems of degradation and decay of the mechanical properties of the structural elements. Among this percentage, numerous constructions – such as the Church of San Giovanni Bosco – are considered of interest as cultural assets due to their architectural and historical value. Being protected assets, they have particularities both for assessing seismic vulnerability and, above all, for identifying any seismic improvement interventions. Therefore, how to proceed to assess the safety level of the building complex, at least partially?

An initial assessment could be performed using non-destructive methods, which would allow evaluating the onset of the phenomenon responsible for most of the structural damage following an extreme seismic event, i.e. the phenomenon of double resonance. It occurs when the value of the fundamental resonant frequency of the foundation soil is similar to the building's one. By comparing the vibrational frequency value of the foundation soil with the one of the structure, the possibility of the onset of the resonance phenomenon can be highlighted.

In recent years, the use of devices initially designed for the dynamic characterization of soils has spread [13–15]. These are digital tromometers increasingly used for the operational modal analysis of structures in terms of frequencies, modal forms and damping. The investigation measures the background noise that crosses the subsoil and the building structures on the surface to determine and estimate the structure's natural frequencies, the corresponding modal deformations both vertically and torsionally, and the associated damping values. If the percentage difference in the resonance frequency of building and soil is ≤50%, there will be seismic amplification effects due to double resonance. If the percentage difference in the resonance frequency of building and soil is >50%, local seismic amplification effects due to double resonance can be reasonably excluded.

This technique is totally non-invasive and very fast. It can be applied anywhere and does not require any drilling, laying cables, or external energization other than the environmental noise that exists everywhere. However, it is not sufficient to characterize the complexity of the site seismic effects and the absolute value of the seismic amplification. In current literature, the measurement of the frequency of an existing building through experimental measurements allows confirming the reliability of the dynamic model of the structure when not all the structural conditions are known [16].

In the present case study, the realization of a structural model would be too approximate to refine its reliability only with this investigation; therefore, this measurement should be assumed to detect the distance between the frequency of the soil and the resonant frequency of the building in order to exclude possible double resonance effects.

In addition, some unknowns remain regarding the reliability of the result, which should be carefully evaluated. From an empirical point of view, the resonant frequency of a building is governed mainly by height; in this case, the building has different heights of the volumes that compose it, with the total absence of intermediate floors. Furthermore, as evidenced, it is presumably a mixed structure with reinforced concrete pillar and solid curtain walls in some parts, and other parts in load-bearing masonry. The method has proved reliable for multi-storey reinforced concrete frame buildings, but for masonry buildings, the reliability of the measurements must be further demonstrated.

5. CONCLUSIONS

The church of San Giovanni Bosco in Bologna, designed by the architect Giuseppe Vaccaro in the 1960s, stands as a significant example of the late Modern Bolognese construction, and more generally of the Italian one, being built in a period of transition between the introduction of prefabrication systems and artisanal production processes focused on the technique of mixed construction in masonry and reinforced concrete.

The technical measures aimed at emphasizing the architectural design's forms and spatiality consist of confirming a consolidated construction practice during the Twentieth century in Italy. We refer to the integration between local brick walls and the dense framework of reinforced concrete walls and pillars hidden inside, necessary to meet particular static requirements and avoid too heavy and slender load-bearing walls. These coexist with innovative components, such as pre-assembled elements in the roofing system, not directly belonging to the figuration of the masonry or mixed construction.

The construction concept has taken consolidated technical solutions as its basis. Nevertheless, new technical solutions allowed to satisfy the special formal and functional requirements linked to the use and the complexity of a liturgical building, aimed at being a means of promoting the extensive cultural program advanced by the Bolognese Church to encourage the participation of the observants and create new centers of urban aggregation in the post-war suburbs.

A process of critical analysis, totally non-invasive and non-destructive, was based on the integration of careful visual investigations in situ, observation of construction site documentation, the study of design evolution, historical-archival research. It allowed highlighting the vast construction repertoire of the building with sufficient completeness, firstly dividing it into different parts and then re-composing its overall structure by identifying the relationships between the various structural components. This knowledge process, together with the definition of the genetic vulnerabilities of the building and the underlying causes of its degradation phenomena, constitutes an essential first step for its sustainable conservation, intended as the transmission of its cultural, social, artistic and architectural values to future generations, in full respect of its dual figurative-formal and historical-material nature.

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