HISTORY OF CONSTRUCTION CULTURES

VOLUME 2

edited by
João Mascarenhas-Mateus
and **Ana Paula Pires**

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History of Construction Cultures

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Introduction: *History of Construction Cultures*

We are what we build and how we build; thus, the study of Construction History is now more than ever at the centre of current debates as to the shape of a sustainable future for humankind. Embracing that statement, the present work takes the title *History of Construction Cultures* and aims to celebrate and expand our understanding of the ways in which everyday building activities have been perceived and experienced in different cultures, times and places.

This two-volume publication brings together the communications that were presented at the 7ICCH – Seventh International Congress on Construction History, broadcast live from Lisbon, Portugal on 12–16 July 2021. The 7ICCH was organized by the Sociedade Portuguesa de Estudos de História da Construção (Portuguese Society for Construction History Studies – SPEHC); the Lisbon School of Architecture, University of Lisbon; its Research Centre (CIAUD); and the College of Social and Human Sciences of the NOVA University of Lisbon (NOVA FCSH).

This is the first time the International Congresses on Construction History (ICCH) Proceedings will be available in open access format in addition to the traditional printed and digital formats, embracing open science principles and increasing the societal impact of research. The work embodies and reflects the research done in different contexts worldwide in the sphere of Construction History with a view to advancing on the path opened by earlier International ICCH editions. The first edition of ICCH took place in Madrid in 2003. Since then, it has been a regular event organized at three-year intervals: Cambridge (2006), Cottbus (2009), Paris (2012), Chicago (2015) and Brussels (2018).

7ICCH focused on the many problems involved in the millennia-old human activity of building practiced in the most diverse cultures of the world, stimulating the cross-over with other disciplines. The response to this broad invitation materialized in 357 paper proposals. A thorough evaluation and selection process involving the International Scientific Committee resulted in the 206 papers of this work, authored by researchers from 37 countries: Australia, Austria, Belgium, Brazil, Bulgaria, Canada, China, Dominican Republic, Ecuador, Egypt, Estonia, France, Germany, India, Iran, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Peru, Poland, Portugal, Puerto Rico, Russia, Serbia, Spain, South Africa, Sweden, Switzerland, Thailand, United Arab Emirates, United Kingdom, United States of America, and Venezuela.

The study of construction cultures entails the analysis of the transformation of a community's knowledge capital expressed in the activity of construction. As such, Construction History is a broad field of knowledge that encompasses all of the actors involved in that activity, whether collective (contractors, materials producers and suppliers, schools, associations, and institutions) or individual (engineers, architects, entrepreneurs, craftsmen). In each given location and historical period, these actors have engaged in building using particular technologies, tools, machines and materials. They have followed specific rules and laws, and transferred knowledge on construction in specific ways. Their activity has had an economic value and belonged to a particular political context, and it has been organized following a set of social and cultural models.

This broad range of issues was debated during the Congress in general open sessions, as well as in special thematic sessions. Open sessions covered a wide variety of aspects related to Construction History. Thematic sessions were selected by the Scientific Committee after a call for proposals: they highlight themes of recent debate, approaches and directions, fostering transnational and interdisciplinary collaboration on promising and propitious subjects. The open sessions topics were:

- Cultural translation of construction cultures: Colonial building processes and autochthonous cultures; hybridization of construction cultures, local interpretation of imported cultures of building; adaptation of building processes to different material conditions;
- The discipline of Construction History: Epistemological issues, methodology; teaching; historiography; sources on Construction History;
- Building actors: Contractors, architects, engineers; master builders, craftspeople, trade unions and guilds; institutions and organizations;
- Building materials: Their history, extraction, transformation and manipulation (timber; earth, brick and tiles; iron and steel; binders; concrete and reinforced concrete; plaster and mortar; glass and glazing; composite materials);

- Building machines, tools and equipment: Simple machines, steam operated-machines, hand tools, pneumatic tools, scaffolding;
- Construction processes: Design, execution and protective operations related to durability and maintenance; organization of the construction site; prefabrication and industrialization; craftsmanship and workshops; foundations, superstructures, roofs, coatings, paint;
- Building services and techniques: Lighting; heating; ventilation; health and comfort;
- Structural theory and analysis: Stereotomy; modelling and simulation; structural theory and structural forms; applied sciences; relation between theory and practice;
- Political, social and economic aspects: Economics of construction; law and juridical aspects; politics and policies; hierarchy of actors; public works and territory management, marketing and propaganda;
- Knowledge transfer: Technical literature, rules and standards; building regulations; training and education; drawings; patents; scientific dissemination, innovations, experiments and events.

The thematic sessions selected were:

- Form with no formwork (vault construction with reduced formwork);
- Understanding the culture of building expertise in situations of uncertainty (Middle Ages-Modern times);
- Historical timber constructions between regional tradition and supra-regional influences;
- Historicizing material properties: Between technological and cultural history;
- South-South cooperation and non-alignment in the construction world 1950s–1980s;
- Construction cultures of the recent past: Building materials and building techniques 1950–2000;
- Hypar concrete shells: A structural, geometric and constructive revolution in the mid-20th century;
- Can engineering culture be improved by construction history?

Volume 1 begins with the open session “Cultural translation of construction cultures” and continues with all of the thematic sessions, each one preceded by an introductory text by the session chairs. The volume ends with the first part of the papers presented at the open sessions, organized chronologically. Volume 2 is dedicated to the remaining topics within the general themes, also in chronological order.

Four keynote speakers were chosen to present their most recent research results on different historical periods: Marco Fabbri on “Building in Ancient Rome: The fortifications of Pompeii”; Stefan Holzer “The role of temporary works on the medieval and early modern construction site”; Vitale Zanchettin “Raphael’s architecture: Buildings and materials” and Beatriz Mugayar Kühl “Railways in São Paulo (Brazil): Impacts on the construction culture and on the transformation of the territory”.

The editors and the organizers wish to express their immense gratitude to all members of the International Scientific Committee, who, despite the difficult context of the pandemic, worked intensively every time they were called on to give their rigorous evaluation of the different papers.

The 7ICCH was the first congress convened under the aegis of the International Federation of Construction History, founded in July 2018 in Brussels. Therefore, we are also very grateful to all the members of the Federation, composed of the presidents of the British, Spanish, Francophone, German, U.S. and Portuguese Societies and its Belgian co-opted member. A special thanks is due for all the expertise and experience that was passed on by our colleagues who have been organizing this unique and world significant event since 2003, and in particular to our predecessors from all the Belgian universities who organized 6ICCH.

The editors wish to extend their sincerest thanks to authors and co-authors for their support, patience, and efforts. This two-volume work would not exist but for the time, knowledge, and generosity they invested in the initiative.

Our sincere thanks also go out to Kate Major Patience, Terry Lee Little, Kevin Rose and Anne Samson for proofreading every paper included here, and to the team at Taylor & Francis (Netherlands), in particular Germaine Seijger and Leon Bijnsdorp.

Finally, we are grateful to all members of the Local Committee and to the institutions that have supported both the 7ICCH event and the publication of these proceedings.

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Calculation methods for reinforced concrete structures at the beginning of the 20th century: The Modernissimo Theater in Bologna

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ABSTRACT: Palazzo Ronzani represents a junction between local tradition and modernity as it collects different construction solutions: a reinforced concrete frame, unreinforced concrete masonry, and load-bearing masonry. The structural design followed the Hennebique system, but the archival documentation contains a limited number of documents about the structural design, and no structural calculation report to confirm the adoption of the system. The paper focuses on the study of its structural calculation, simulating the procedure that technicians must undertake in intervening on buildings dated to the beginning of the 20th century, with calculation and construction documentation often missing. The restoration site of the theater offered the opportunity to carry out specialized structural surveys, bringing to light the traditional stirrups and the huge smooth iron reinforcements. The theoretical simulation of the calculation procedure has highlighted the correspondence between the patent and the real situation, confirming the adoption of the system and its excellent structural performance.

1 INTRODUCTION

In Europe, the modernization process that characterized the season of scientific and technical innovations between the late 1800s and early 1900s was matched by profound parallel transformations of urban structures to adapt them to the new demanding framework.

This change also took place in medium-sized cities such as Bologna, an important administrative, economic, and cultural center within the Papal States in the first half of the 19th century.

Bologna continued to be a city with a predominantly agricultural economy, maintaining a mutual-dependence relationship with the neighboring countryside, being in a peripheral position from the centers of power and still confined within its multi-centenary city walls.

The Unification of Italy changed the geopolitical location of the city in the national context, involving Bologna in a new political, economic and social reality that transformed it into the crossroads of communications between the Po Valley cities and the rest of the peninsula.

The inclusion in the new national framework and a rapidly changing economic and commercial system led to a profound reshaping of the appearance of the city, influenced by foreign models of historical town renovation according to hygiene and decorum rules.

Bologna gradually welcomed these changes, but in a short time, the adaptation process of the historic center to the new functions caused traumatic interventions in the urban fabric and the built heritage. The 19th-century imprint on the city became increasingly evident, with urban modernization works that began in 1860 (Gottarelli 1978) and had their climax in the drafting of the 1889 Regulatory Plan, one of the first to be adopted in Italy.

The Plan made significant changes to the ancient city's urban fabric, starting with the demolition of the city walls and gates to eliminate the physical barrier between the central core and the outer villages, thus connecting the historic center to the outer expansion areas.

In the ancient center, the Plan provided for the widening of some existing avenues and the straightening of minor streets; it was also planned to realize a total of 50 km of new roads. These works were done by tearing down entire neighborhoods and thus destroying the city's appearance, previously characterized by a discreet and curvilinear road network, flanked by buildings with few floors, progressively replaced by higher buildings overlooking wide and straight streets (Gresleri & Massaretti 2001).

2 PALAZZO RONZANI IN BOLOGNA

2.1 *Stylistic features*

Since it was the first building to rise after the demolitions carried out in the historic city center, Palazzo Ronzani underwent a complicated design process due to opposition to large building construction in the old city. After a two-year debate and discussions, no project had yet been approved, while the demolitions had already begun.

The rich archival documentation made it possible to find the early design concept used to define the stylistic features and the planimetric distribution of the

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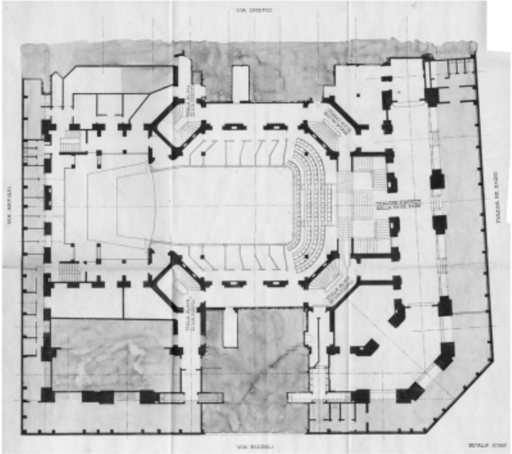

Figure 1. Plan of the first underground floor of Palazzo Ronzani (private collection).

building. The process leading to the final solution went through several intermediate projects by the architect, Gualtiero Pontoni, who gradually became less conservative regarding the historic building design until it became a big "business machine".

In 1912, the design reached its ultimate form, and the final solution was absolutely adherent to the 1889 Town Plan specifications: *"a remarkable example of the character that the new buildings of the center of Bologna should have, a character that is summarized in the word monumentality"* (Giovannetti 1912).

On an area of about 2000 m^2, the architect was able to design a theatre with 2000 seats located in the basement; shops, a café, and a restaurant on the ground floor; clubs, studios, and commercial storerooms in the intermediate and the first floors, and, finally, a hotel on the upper stories (Marchetti 1981). The works were entrusted to engineers Luigi Bernardi and Carlo Prati, and the structural design to the engineer Giuseppe Lambertini, who had more than a decade of experience in reinforced concrete construction.

At the opening of the Teatro Modernissimo, the two underground levels accommodated entertainment spaces (Sicari 2003); the entrance to the first underground floor, where the theater gallery was located, was via an internal staircase (Figure 1). On the second underground floor, four other stairs granted access to the parterre on either side of the hall (Figure 2).

The rectangular hall in the lower floor officially opened on 14 July 1921 and started hosting theatre performances and film screenings. However, a smaller hall, the Cinema Modernissimo, was already active in 1915. It was located on the ground floor and was equipped with 550 seats.

The building was characterized by some typical features of local building tradition and many references to new, foreign architectural styles. In Italy, at the beginning of the 20th century, the traditional historicist eclecticism was usually merged with the French and Spanish architectural styles in a sort of local Art Nouveau, the Liberty style. This building, strictly linked to the local tradition, was conceived with a portico since its first project, emphasizing the corner facades, especially at the intersection of the main streets. In the most visible corner, the top floor was surmounted by a magnificent Parisian belvedere, recalling the French construction tradition of highlighting the intersection of two main streets with an architectural elevation.

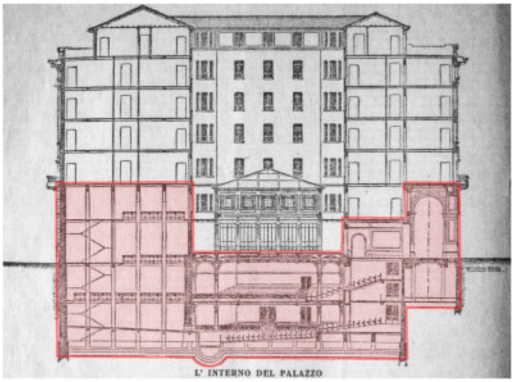

Figure 2. Longitudinal section of the hall of the Modernissimo Theater in the underground of Palazzo Ronzani. Highlighted in red are the volumes occupied by the theater stalls and galleries and all the vertical connection systems. (private collection).

Figure 3. Main facade of Palazzo Ronzani (private collection).

The external decorations were influenced by the Art Nouveau style, which refers to human figures in the plastic configuration and the alternating rhythmic sequence of the sweeping arches of the portico (Figure 3). Inside, the arch theme frames the wide opening between the gallery and the foyer of the underground hall so that direct daylight could reach the lower levels.

2.2 *Structural features*

At the lowest level of the building, the parterre insists on a smaller area than the upper floors. It is set on a grid foundation made of upturned concrete beams, which are surrounded by retaining walls on the perimeter

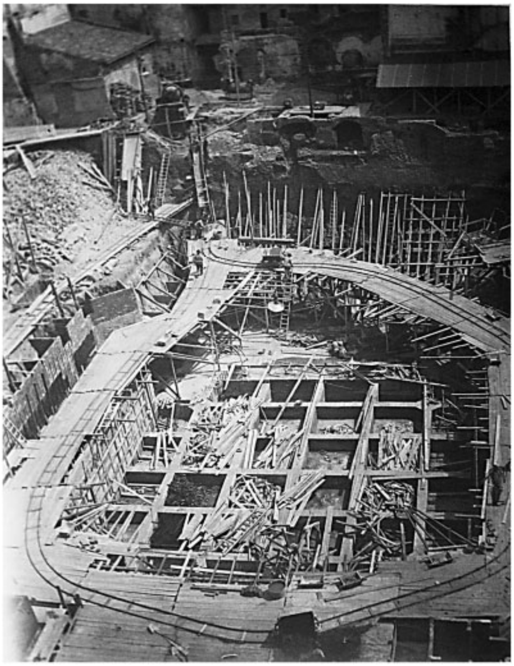

Figure 4. Construction phases of the foundation slab (private collection).

(Figure 4). These walls, made of one-meter-thick reinforced concrete with internal brick lining, were designed to insulate the inner spaces from the ground humidity.

The building core consists of a reinforced concrete frame, which allows the hall to have a clear span of 11 x 12 meters and a height of about 9 meters. Starting from the lowest level, a series of pillars (with cross-sections from 45 x 45 cm to 30 x 30 cm) and reinforced concrete beams support the gallery floor, made of slabs with a thickness of 15 cm. The pillars, beams, and slabs go over the back of the proscenium and are lengthened until reaching the mezzanine level (Mochi & Predari 2012).

The construction site images suggest a mixed technical solution for the two underground floors, which combines reinforced concrete with the widespread use of brick walls. Outside the central core of the theater, where a wide span was necessary, the construction technology has a more traditional character and consisted of 60-45-30 cm thick walls.

The slab covering the large theatrical space is a refined lattice of reinforced concrete beams, connected to the pillar structure and the two large portals at the ends of the hall, towards the proscenium and the access zone (Figure 5).

On the upper floors, the construction technology is more traditional, resorting to brick walls. Images of the first-floor construction phases clearly show the presence of traditional masonry structures behind the decorations. Furthermore, the internal distribution and the alignment of the openings, which are smaller in size than those of the floors below, refer to the typical structure of a load-bearing masonry building, with perimeter walls and a central spine wall.

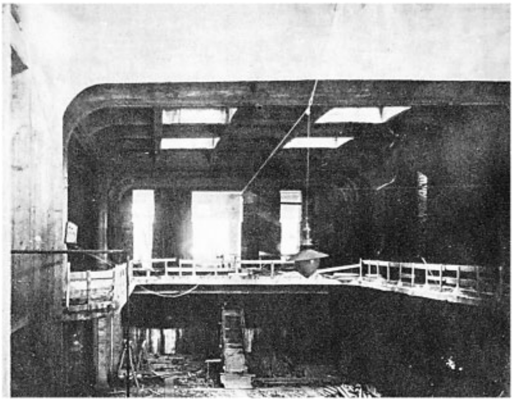

Figure 5. The slab of the theatrical hall from the proscenium (private collection).

3 THE HENNEBIQUE SYSTEM

3.1 *The use of the system in Palazzo Ronzani*

The primacy of “first application in Bologna of reinforced concrete in an entire building, according to the theory and practice of Hennebique” (Marchetti 1981) is bestowed to Palazzo Ronzani based on relatively recent sources. This information is not entirely correct since reinforced concrete was already used in Bologna to build entire residential and industrial construction frames for at least a decade; however, it was probably the first building dedicated to entertainment.

Further information regarding the structural analysis appears inconsistent since (Marchetti 1981) says that “one of the first treatise writers, Eng. Guidi was in charge of the structural calculation. Guidi, having found the groundwater layer a bit high in the terrain specimen, devised, to be sure, that the huge building should rise on ‘a monolithic waterproof floating box’ foundation, as he called it. Even the much criticized arches of the porch derive from static needs, as suggested by Guidi (...)”. The reference to Camillo Guidi as *“one of the first treatise writers”* is quite evident, having been the first Italian professor to teach and publish writings on the new material (Guidi 1914). However, it has not yet been possible to find any document that would prove the professor’s involvement in this project. Furthermore, at present, it seems that his role in the evolutionary process of reinforced concrete was only as a scientist and experimenter, never involved in real design practices, if not as a static tester.

An in-depth study of the archival material has made it possible to find only two documents referring to the structural design of the building: the structural layout plan of the slab-on-grade foundation (Figure 6), signed by Eng. Giuseppe Lambertini (and not by the alleged designer, Eng. Guidi) and the vertical section of the

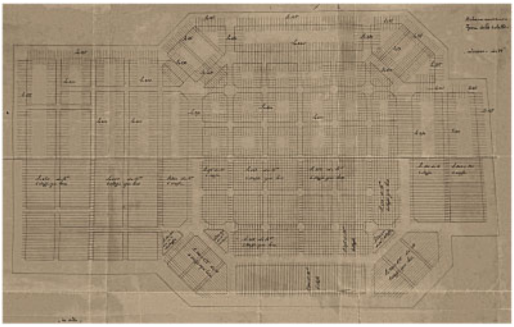

Figure 6. Structural layout plan of the foundation, with the signature of Eng. Lambertini (private collection).

underground walls in the basement. Two occurrences may not seem very substantial if compared to about 200 drawings available for the planimetric distribution, facade solutions, and artistic works; however, they are essential to definitively verify the adoption of the Hennebique system for the reinforced concrete structures, and, at the same time, establish who was directly involved in the structural analysis of this building.

Above all, the cross-section of the retaining walls highlights the characteristics of the Hennebique system: the rebars are placed only in the tension zone (in this case, the outer side of the wall, since it must withstand the ground thrust) and the typical shape of the stirrups, called *étriers*, consisting of small U-shaped folded metal plates, arranged in variable distances, according to the different shear stress value.

An ongoing project of re-functionalization of the spaces of the ancient theater aimed at transforming it into a cinema has followed specific design choices, trying to preserve the historical-artistic value of the building, as early 20th-century evidence of the construction techniques and decorative styles of local tradition. However, the project also provided the opportunity to carry out specialized, detailed investigations; these, on the one hand, made it possible to tackle the consolidation design fully and, on the other hand, allowed integrating the documentary-based notions and definitively recognize how the building site was one of the most extensive and advanced applications of the Hennebique system in Bologna.

3.2 *The Hennebique calculation method*

Starting from its first patent in 1892, the accurate description of the Hennebique system allows identifying its main features due to the characteristic properties of the two-component materials: the position of the reinforcements, the lightness, and high fire resistance of the structural elements depended on them.

In its final configuration, the Hennebique patent defined the construction of a monolithic spatial system through the composition of individual elements, i.e., to obtain complete frameworks consisting of a modular structural mesh. The system allowed the construction of foundation plinths or upturned beams, pillars, beams, slabs.

The pillars generally had a square, rectangular or polygonal section, with particular bevels at the edges; they were reinforced with four rods, with a diameter ranging between 8 and 50 mm, which were arranged near the vertices of the section. The beams were monolithically connected with the 8–16 cm thick slabs and constituted resistant structures with a T-beam, often oriented in the two orthogonal directions of the floor.

In the beams, the straight bars were placed near the tension zone and were alternated with bent bars obtained by raising both their extremities for a length equal to 1/3 of the length of the entire bar due to the inversion of the tensile stress between beam and column in the joint. Since the joint bending moment is lower than the maximum one in the midpoint, it was considered enough to bend one bar of every two alternately (Vacchelli 1900).

The calculation method used by the patent holders seems to have been developed by the Belgian engineer, Paul Christophe, from the Ponts et Chaussées institution, who was the technical consultant of the Hennebique organization (Billington 2020; Zorgno 1988). Christophe worked from 1892 onwards as a civil servant in the Belgian road and bridge building authority. At the start of his career in the civil service, he supervised the construction of several wide span bridges in Liège and was quickly promoted as the vice-secretary of the Central Committee for Public Works in Brussels; in 1898 he was entrusted with the experimental testing of bridges. One year later, he was dispatched to the international congress on reinforced concrete that Hennebique had organized on the occasion of the Paris World Exposition in 1900, for which he carried out careful preliminary studies (Kurrer 2008). Later that year, the journal, *Annales des Travaux publics de Belgique*, published his lengthy report, which shortly afterward appeared as the monograph, *Le béton armé et ses applications*, (Christophe 1902). The book was acknowledged "*as the best-known and the best compendium in this field*" and was translated into several languages, e.g. Russian (1903), and German (Hellebois & Espion 2013).

For a few years, the calculation method was not disclosed, but it soon became the reference for the first scientific studies and prescriptions of the first decade of the 20th century, given the widespread diffusion of the construction system.

The assumptions of the procedure were quite intuitive and straightforward: the compressed concrete – above the neutral axis, which was not barycentric but in an unknown position – and the reinforcements – placed only in the tense part of the section – both absorbed half of the bending moment. In this way, however, only the balancing of rotating and not of translating was satisfied, while the neutral axis position was independent of the overall height of the cross-section (Figure 7).

The method used no homogenization coefficient and considered the distribution of stresses as uniform in the compressed concrete and equal to the average

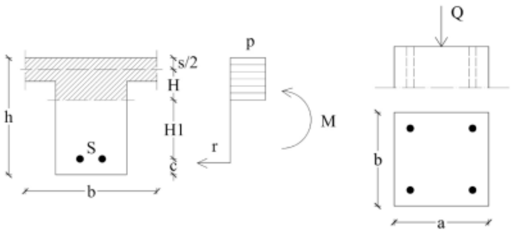

Figure 7. Design schemes for beams and pillars with the Hennebique method.

value of 25 kg/cm^2, while a value of 1000 kg/cm^2 was estimated for iron (Canevazzi 1902).

The first step of the calculation identified the position of the neutral axis thanks to the balancing of rotating equation for compressed concrete; in the case of a ribbed slab or T-beam, it was assumed that the whole slab, and only the slab, was subject to compression stress, neglecting the possible contribution of the compressed concrete part of the rib if the neutral axis passed in it (Donghi 1923). The equation was:

$$\frac{M}{2} = p \times b \times s \times H, \text{ so } 2H = \frac{M}{p \times b \times s} \tag{1}$$

Then, to derive the required area of the reinforcement S, it was sufficient to write the balancing of translating equation for the rebars:

$$\frac{M}{2} = r \times S \times H1, \text{ so } S = \frac{M}{2 \times H1 \times r} \tag{2}$$

where $p = 25$ kg/cm^2; $r = 1000$ kg/cm^2; $H1 = h - s/2 - H - c$.

The predominantly intuitive aspect of the procedure lay in the calculation of the pillars where, once the load action was assessed, a real calculation was not performed, but rather it was an estimation based on the section of the pillar and the strength of the concrete under compression.

The edge reinforcements had only the function of withstanding transverse actions. The bearing capacity of the pillars, subject to simple compression, was determined on the basis of the sum of the contributions of the concrete and the reinforcements, obtained as the product of the respective sections for the calculation stresses. The bearing capacity of the pillar, which had to be greater than the load action, was:

$$q_p = p \times a \times b + r \times S, \text{ so } S = \frac{(q_p - p \times a \times b)}{r} \tag{3}$$

where $p = 25$ kg/cm^2; $r = 1000$ kg/cm^2.

3.3 *The calculation method applied to the theatrical hall structures*

Knowing the system and the calculation method adopted in the original structural design was fundamental, given the lack of adequate technical support documentation. During the design phase aimed at the static strengthening of the structures, hypothesizing the positions and dimensions of the reinforcements as deriving from the Hennebique system turned out to be crucial to later verify their presence and consistency through appropriate surveys.

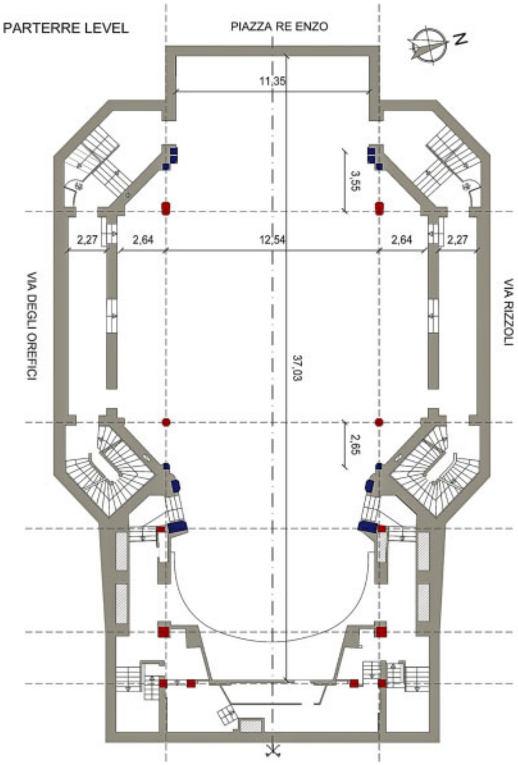

Figure 8. Types of vertical structures at the parterre level: in grey, masonry structures; reinforced concrete structures in red, unreinforced concrete structures in blue.

This structural re-design phase made it possible to simulate the rebar amount and arrangement in the reinforced concrete beams and pillars, precisely identifying the specific areas for the demolition tests, such as the concrete cover removals and bar diameter measurements. The overall diagnostic campaign consisted of 59 investigation spots, with 45 non-destructive tests and 14 destructive investigations. Without such simulation, the number of destructive tests would have been considerably higher and more widespread, harming the structural integrity of the concrete frame.

As already mentioned, the original structural scheme consisted of reinforced concrete beams and pillars, together with extensive brick walls and unreinforced concrete pillars, which were located where the material malleability allowed for the creation of decorative connections, leaving the structural function to the masonry structures.

In the first phase of the investigation, non-destructive tests were carried out using geo-radars to verify that the reinforcements were actually where the Hennebique system intended. SON-REB tests were

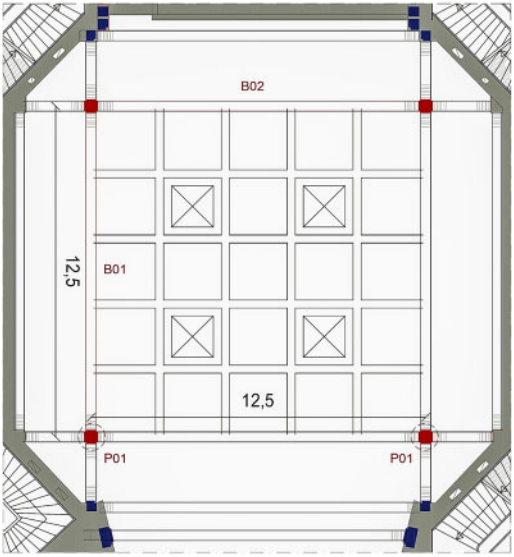

Figure 9. Location of the beams and the pillar subjected to the calculation procedure.

also carried out to determine the presence of flaws (micro-cracks, air bubbles, discontinuity, etc.), the compressive strength of the concrete, and in general, the material homogeneity.

Thanks to this first test campaign, it was possible to definitively demonstrate that the only pillars entirely made of reinforced concrete within the hall space are the four standing alone, placed at a distance of 12.5 m from each other. Originally these were all cross-shaped inscribed on a square base, but during the building's lifecycle, the two placed below the gallery bleachers, at the parterre level, have been doubled in the cross-section due to an extension of the theater gallery itself which required new supports. The additional reinforced concrete pillars are instead placed in the back of the proscenium, in the stage tower, and reached the mezzanine floor height, thus being over about 20 m high. All the slabs and beams are made of reinforced concrete (Figure 8).

As an example of the process followed, the calculation results for the two pillars remaining in their original shape at the gallery floor level (P01) and for one of the beams supporting the ground floor slab (B01) are presented (Figure 9). The latter is one of the edge beams supporting the smaller cross-section beam lattice covering the entire theater hall, where the *cafè chantant* was initially located

The preliminary non-destructive SON-REB investigations allowed detecting the spacing of the reinforcement bars and their position. In the P01 pillar, it was possible to identify the vertical bars positioning, in correspondence with the chamfered corners, their large diameter, and the relatively regular step of the stirrups, equal to 20–22 cm (Figure 10).

The B01 beam was inspected along the side parallel to its axis and showed the typical bent rebars pattern provided by Hennebique at about 1/3 from the edges. In addition, the number of bars and stirrups was identified, but their diameter could not be identified at this stage (Figure 11).

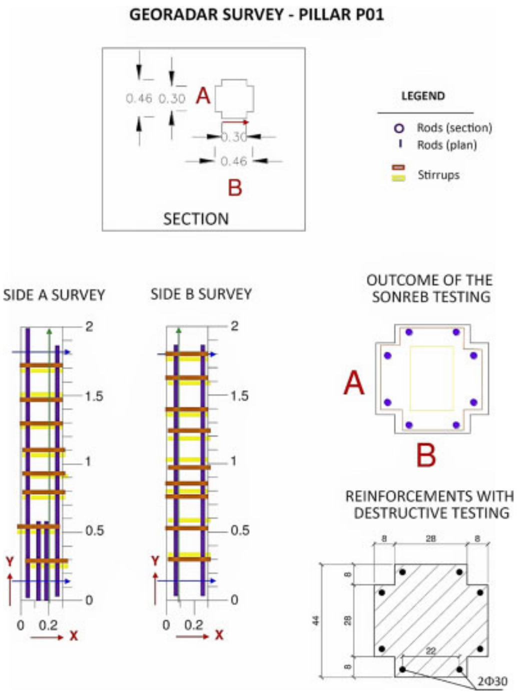

Figure 10. Destructive and non-destructive investigations on pillar P01.

While performing in-situ investigations, the theoretical calculation procedure was carried out. For P01 pillar, the application of the Hennebique calculation method according to the previous formula (3), considering a maximum cross-section of 44 x 44 cm, with 8 cm chamfer in each corner, and assuming a variable load equal to 300 kg/m^2 (a suitable value for the use of the upper floor as open to the public premises), allows obtaining a minimum rebar area S = 58 cm^2.

The on-site destructive tests have allowed detecting a longitudinal reinforcement made of 8Ø30 bars, whose area corresponds to 56.56 cm^2, indeed very close to the required minimum (Figure 12).

With regard to the beams, having a cross-section of a 48 cm base and 90 cm height, the adopted structural scheme provides a double symmetry in both directions for a total length of 12.50 m, so each of the four perimeter beams is intended to bear the same vertical load.

Performing the simplified calculation procedure proposed by Hennebique according to the previous formulas (1) and (2), the calculated value of 2H is equal to 65 cm, H1 is equal to 60 cm, and the minimum rebar area S is equal to 53.21 cm^2.

The destructive tests allowed detecting in the middle of the B01 beam a reinforcement composed of 2Ø32 + 3Ø40 bars, whose total area corresponds to

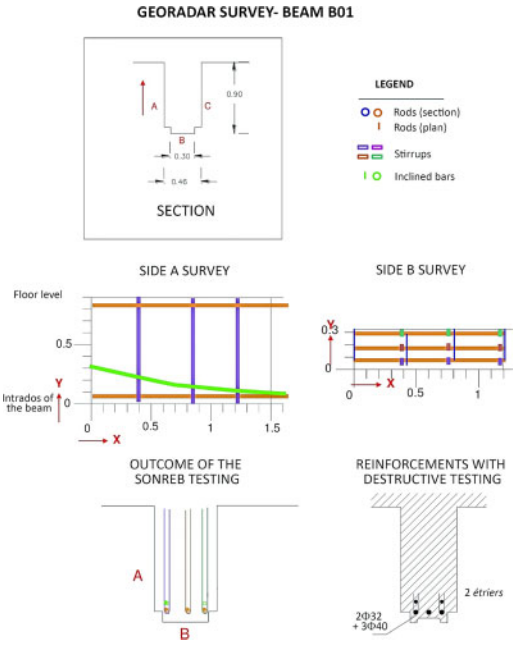

Figure 11. Destructive and non-destructive investigations on beam B01.

Figure 12. Reinforcements at the base of the pillar after the removal of the damaged concrete cover.

53.76 cm^2, indeed slightly higher than the required minimum (Figure 13).

Other destructive tests showed that approximately the same reinforcements had been placed in the other inspected beam on the same level, beam B02, where, however, there is a reinforcement equal to 4Ø42, corresponding to 55.39 cm^2.

Figure 13. Reinforcements of the perimeter beam after the removal of the damaged concrete cover.

4 CONCLUSIONS

Modern construction finds its founding reason in the gradual inclusion of the innovative technology of reinforced concrete in building practice. The history of modern construction has been exploring this field for more than 20 years now.

However, studies have mainly dealt with "exemplary" buildings, well-known to the scientific and technical community. Researchers have only recently started to pay specific attention to the so-called "minor" buildings.

Despite the many studies carried out, there are still many explorable areas of interest, both about the most hidden facets of what is already known and concerning those trends that are currently only hypothesized but not yet demonstrated.

In this context, Palazzo Ronzani becomes a significant reference point for both mentioned areas; it is an emblematic building for Bologna, with its figurative image with strong foreign influences, and the first building of the local "modernity". It can be considered one of the first buildings constructed in the city where reinforced concrete had been consciously used: the new material was actually positioned only where its potentiality allowed solving otherwise unsolvable construction space design problems.

The new material allowed engineers to obtain wide open spaces and fire-safe constructions, which are essential requirements for a theatre building. Where its use was strictly unnecessary, reinforced concrete still used to be combined with solid brick walls. In these cases, the structure was based on the traditional masonry construction, according to the local practice, or in unreinforced concrete.

The transition of traditional building to modern technique takes on specific features that are locally interpreted in the different, regional study contexts and cannot be generalized. Palazzo Ronzani is a non-secondary piece of this still open research, demonstrating how such a transition has not been instantaneous but has been only gradually implemented, at first constituting contamination of the tradition and then being able to fully establish itself.

Finally, Palazzo Ronani symbolizes one of the significant problems of our time, when contemporary technicians have to cope with listed, historic buildings, dated back to a period where there were no calculation standards at the national level.

The structural analysis simulated according to the Hennebique method is not a mere design exercise. However, it proved to be a very profitable activity since it allowed providing the technicians involved in the renovation project with a preliminary approach of investigation. Besides, it was possible to reduce the burden of the necessary on-site surveys and drastically decrease the number of destructive tests in favor of the non-destructive ones. In this case, the investigation method and the detailed knowledge on the building legitimately makes it possible to include Palazzo Ronzani, its history, design, and construction in the research field of international modern construction.

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