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PART 1 - Construction history and survey of historic timber roofs

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Cover illustration: Lattice roof trusses in the nave of Jät church, Småland, Sweden, 1225–1226 by Robin Gullbrandsson. © Robin Gullbrandsson (2022)

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EDITORIAL

REMARKABLE HISTORIC TIMBER ROOFS. KNOWLEDGE AND CONSERVATION PRACTICE

Part 1 - Construction history and survey of historic timber roofs

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The culture of timber structures dates back to the origins of construction and extends its branches to the industrial era when the culture of metal structures gradually replaced it. This phenomenon crossed all of Europe, developing particularities in different geographical areas and simultaneously becoming characteristic of other parts of the world. The function of covering and protecting buildings with timber elements, in particular large spaces such as theatre halls, church naves, or warehouses, has been implemented using construction types of considerable invention even more than static analysis. The outcomes are often unique in their kind and based on the wisdom and competence of engineers, architects, and master carpenters, who made their advancements following cultural, technical-scientific, and socio-economic factors.

Today these timber structures represent a fragile heritage threatened by natural and anthropic actions, and they are mainly the subject of fragmentary and episodic research activities, often dictated by the occurrence of fires, collapses, damage, or imminent dangers. Nevertheless, the study of historic timber roof elements has reached good dissemination within the scientific community, considering its relevance for the more general issues of use, conservation, and safety of the built heritage. The conservation of valuable carpentry works for their safety poses interesting challenges since operating on artifacts built in the context of extinct or radically evolved technical cultures is never trivial. Their modifications over time, their state of conservation, and their interaction with the rest of the buildings are often unknown and not easily predictable.

This special issue has the ambitious goal of helping to outline the current international panorama of research on historic timber roof structures, especially those with great span or peculiar technical relevance. The collection of papers is divided into two volumes: the first is focused on the history of timber roof construction, and the second is on the investigation, analysis, and intervention for roof preservation.

This introductory contribution is written to comment on construction history. The studies are developed by researchers from different countries and disciplines. Some declare in their career to work in the field of Construction History; others belong to other sectors such as Historic Building Conservation, Building Survey, or Historic Building Structures. As it is well known, in the Italian academic context, the distinction between sectors in the field of civil engineering and architecture (ICAR) is relevant, and it favors the isolation of research and discourages the integration of different working methods. As mentioned on the website of the Construction History Society, “Construction history is not blind to the importance of conservation and repair work, but it is focused on establishing and studying the history of building construction and not on how buildings should be repaired”. In any case, understanding construction history is vital for all those involved in the maintenance and repair of historic structures. Therefore, the first aim of this collection is to fill the gap among different methodologies and approaches.

Most of the studies presented here are based on bibliographic and/or archival research, illustrating innovative approaches to knowledge and documentation. These studies may rely on historical treatises and handbooks, reminding us that the dissemination of knowledge in Italy and Europe passed through treatises and handbooks or the transfer of expertise among architects, engineers, and master carpenters. From this perspective, the historical-typological profile of notable timber roofs, with a focus on structural concepts, construction details, and joints, is fascinating.

Some studies go directly to the origin of wooden trusses. According to Nicola Ruggieri, indirect evidence of roof carpentry organized as a truss system seem to have been found in the Mediterranean basin, at least from the Iron Age. However, these are isolated cases that probably did not have a decisive influence on the evolution of the roofs in the immediately following eras. Full awareness of the potential and systematization of the truss system occurred in the Roman scope, and only in Late Antiquity did such an organization of the roof structure start to be notably widespread, especially in the basilicas. In the conceptualization process of trusses, a considerable contribution is to be recognized to the Etruscan and Phrygian civilizations. The author gives us examples and evidence to support his statements on lost timber artifacts of ancient times.

In the German area, a research project has been focused on reconstructing the lost wooden structures of a more recent past; this is the case of Clemens Knobling, whose aim is to reconstruct the destroyed Munich roofs on the basis of archival sources and archaeological research on the remains of buildings. The results show a great variety of structures, constantly reflecting the current developments in roof construction. Among them, there are also quite experimental solutions. The results are presented as detailed scale models. Italian influences are often evident in these roofs. As Knobling reminds us, every region has peculiarities in building construction, and, in fact, there have been systematic studies on roofs within cities and regions, like in Basel, with the work of Thomas Lutz and Gerhard Wesselkamp, or in Thüringen and Sachsen-Anhalt with Thomas Eißing’s work.

Belgium also has a remarkable heritage of historic timber roofs traced back to the 12th century. Louis Vandenabeele notes that this country’s interest in historic timber roofs grew during the 19th century with the Gothic revival movement and the construction of national identities. New light was shed on medieval timber structures in European countries through publications by architects such as Augustus W. N. Pugin or the Brandon brothers in the United Kingdom, Eugène E. Viollet-le-Duc in France, and Friedrich Ostendorf in Germany. In Belgium, the architect Pierre F. Langerock compiled several volumes on important Flemish buildings in the 1880s, with particular attention to roofs. This comparative typological analysis is an essential aspect of the research on timber structures.

The open roof structures – that is, open to the interior and without tiebeams – of Norwegian stave churches were studied in the mid-19th century and attained interest even outside Scandinavia, as Robin Gullbrandsson remembers. The development of buildings archaeology and the advent of dendrochronology in the 1970s and 1980s got a foothold even in Scandinavia, giving birth to new methods and raising questions in the research on medieval churches, often revising earlier stylistic datings. Wood construction, more than any construction element, show peculiar solutions to specific problems; this is due to the flexibility of the structural system, its adaptation to building transformation, and its properness to substitution. The accurate study of wood is fascinating because it needs attention and a deep look into detailing, for example, carpenter marks. Scarce attention to detail has led to inadequate and inaccurate interventions. Gullbrandsson reminds us that people can properly maintain and preserve only what they know.

Some studies show the transformation of timber roofs over time, including partial or complete replacement or integration with elements made of different materials. This is the case of the Bruntál Tower (Czech Republic) analyzed by Lucie Augustinkova, an example of a polyfunctional half-timbered tower modified in the 16th and 17th centuries. Very similarly, some studies in Italy give a critical description of significant projects due to the complexity of the technical-construction choices or the importance of the building.

Original solutions are investigated by Enrico Genova and Giovanni Fatta in the residence of the princes of Butera in Palermo. These include timber trusses of the roof, partitions and ceilings on the second story of the examined part of the building, and metal and timber elements used to hang partitions and ceilings from the overlaying trusses. The restoration works offered the opportunity to enlarge the documentation: surveyed buildings can be conceived as a comprehensive repository of information about Sicilian timber structures and their technology from the 18th to early 20th century. In particular, the use of suspended building components such as floors or partitions was not marginal in the architectural heritage of Sicily, although recurring solutions have not been clearly defined yet. It is feasible to think that these solutions were found to cope with Sicily's scarcity of wooden elements.

Similar insights on suspended ceilings, with a similar approach to one in Palermo, are also offered by Arianna Tosini in Rome. In this case, the research is not only supported by a detailed survey but also by the reading of early 19th century texts by Jean-Baptiste Rondelet and Giuseppe Valadier, illustrating two different criteria for creating coffered ceilings: in the first one, the coffered ceilings are directly connected to the roof trusses, providing for the lining of the tie beams; in the second one, the coffered panels are nailed to wooden frames hanging from purlins placed over the tie beams.

The study aimed to highlight the importance of these building techniques of the coffered ceilings in the churches of Rome. So far, this topic has not been explicitly addressed. In fact, according to the author, there is a lack of a detailed illustration of the different structures built and a broad picture of the different construction typologies, while studies of ceilings in the field of art are highly developed. Studies usually focus on the diffusion and the evolution of forms over time, starting from the second half of the fifteenth century to the early twentieth century. Preserving the structure of the coffered panels and the richly decorative and chromatic quality repeatedly required interventions, even of considerable extension, to prevent collapses, replace damaged parts, and restore various surfaces. However, the lack of knowledge on the topic and the scarce consideration of the ancient wooden carpentry, especially when used above the extrados of the ceilings, led to inappropriate interventions, up to the complete replacement of the ancient technological system.

Daniela Pittaluga stresses how studies on timber structures should be complete, obtained thanks to indirect sources (archive and bibliographic research) and direct ones: archaeological analyses (stratigraphic, mensiochronological, mineralogical-petrographic, and wall textures), thermographic and ultrasonic analyses. Specifically, she wanted to show the entire path of the analysis conducted in one church in Liguria and list the individual steps by which it was possible to draw, in the end, a weighted conclusion. Tiziano Mannoni used to say that it is not the quantity of data collected that makes history but the critical analysis of those concerning the problems. In this regard, this research highlights the extent to which critical analyses help arrive at a fruitful conclusion. The result of the study was also to discover wooden vaulted roofs that have elements in common in the same region.

According to Angelo Landi and Emanuele Zamperini, the constant comparison of the bibliographic and archival data with that of the real and present consistency of an important church in Cremona, Italy, its construction techniques, wood species, and decay not only allowed to understand and interpret the construction and maintenance acts, framing them in the more general social and economic context of the time, but also made it possible to expand its history beyond the boundaries of the original construction, although split into two phases, towards the numerous, and sometimes minute, maintenance works during four-hundred years of service life.

Finally, the history of roof construction is traceable between memory and innovation. The memory has to do with roofs because structures often lose their original configuration, and the initial concept is forgotten when elements are deeply renovated. Roofs usually consist of statically undetermined structures, and they are the result of the expertise of the master builders of their time; newly renovated configurations may follow the principles of the Science of Construction. New restored solutions come from the loss of confidence in the old construction or from the belief that the new science and the new building practice bring a consistent improvement in structural safety. Perhaps, this merely derives from the total lack of knowledge of the old techniques, in other words, from memory loss.

The presented studies are based on accurate research on historical documents and surveys, considering the conservation state and the structural behavior of the original structures. Detailed surveys are also the basis for the rehabilitation of the roofs. With the term "memory", we stress the importance of building tradition, expressed through the choice of wood, the knowledge of how to join the pieces, and the experience gained in thinking about the element arrangements and the installation sequence. The studies trace the life of roofing systems, from their conception to their current configuration, through the alternation of the memory of the construction tradition and technological innovation. When technical innovation goes beyond the construction tradition, in a certain sense, it modifies the extent of knowledge. The word tradition brings with it the terms "*tradere*", or "betray", which represent the process of transferring knowledge over time, accompanied by a continuous renewal, a continuous rethinking of the same things. Today, in fact, not all the steps in the design and execution process of roofs are known. The direct observation and the geometric survey of these structures are perhaps not sufficient to complete all the knowledge; we could probably approach the understanding of historical techniques by trying to reconstruct the original objects, using the materials available at the time as far as possible. Of course, if we wanted to redo those objects today as they were and where they were, we would be forced to use the tools offered by our current technology, which suppose greater precision in processing and greater control of the quality of materials, ending up with different products. In fact, today, we are prone to reduce work-related risks and increase the perception of safety – or objective safety – during the life of each construction. In any case, the construction tradition is an essential aspect of the restoration field. According to Paolo Marconi, more than twenty years after the 1972 Charter, modern technologies applied to ancient structures have revealed their limits in many cases.

For this reason, some recent trends push towards the recovery of a pre-modern tradition in architectural restoration, reactivating past techniques. In Italy, a revision of the ministerial charter of 1972, especially for architectural monuments and historical sites, promotes an approach to restoration based on teaching traditional techniques, combining resources in local raw materials, environmental factors, and cultural traditions. The aim is to re-evaluate a type of intervention that consists in the alliance between properly collected and disseminated historical knowledge and professional and entrepreneurial forces (from the associations of builders to craft associations) in order to re-propose a vision of the physiological mutation of architecture that confirms the philologically active role of restoration, guaranteeing the significance of the artifact and a conscious continuity. The life of these structures through centuries testifies to this continuous process of memory transfer and transposition and continuous translation of knowledge through maintenance, renovation, and reconstruction operations.

TECHNIQUE AT THE SERVICE OF A NEW LITURGICAL MODEL: THE TIMBER ROOF OF THE CHURCH OF SAINTS MARCELLINO AND PIETRO IN CREMONA

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At the turn of the 17th century, the Jesuit order settled in the city of Cremona, where, thanks to the support of Bishop Speciano and some notable families, it started the construction of the church of Saints Marcellino and Pietro (1606-1620), the Schools and the College. The church model of the aisleless rectangular hall – large enough to accommodate a large number of faithful – forced the fathers to resort to unusual solutions for the area of Cremona, which, over the centuries, also led to instability and structural problems. The careful archival and bibliographic research made it possible to investigate the wooden roof with wide-span "Palladian" trusses (about 15.20 m), directing the diagnostic analyses, identifying the peculiarities of the technical solutions adopted, in a continuous comparison between indirect sources and *in situ* investigations. The construction events of the trusses and secondary framing were investigated over a long period of time, to include the succession of minute maintenance and repairs, also carried out in the last two centuries; the complexity and stratification of works carried out in phases and singular interventions, linked to the chronological succession of events, is the basis for the interpretation of the current state of the structure, therefore for a restoration intervention aimed at protecting the building palimpsest.

Keywords

Church of Saints Marcellino and Pietro in Cremona, Historical timber trusses, Palladian trusses, History of construction, Timber shipping.

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1. INTRODUCTION

At the turn of the 17th century, the signs of an economic and social crisis manifested in the city of Cremona, involving above all the merchant class and aristocratic families: following the plague of 1630, the city's population was reduced from about 46400 inhabitants in 1621 to only 13900 in 1660; therefore a long period of stagnation and cultural isolation begins, also as the result of the transition to an economy based mainly on agricultural income [1].

However, the harbinger of this crisis had already begun to appear in the 16th century; many noble families extinguished, and wealth flowed to a few individuals; Habsburg rule did not calm the political instability and, at the same time, numerous heretical communities settle and sprout, even among the noble class.

In this context, the reforms advocated by the Council of Trent, the influence of Cardinal Carlo Borromeo, and the appointment as bishop of Cremona of the Cremonese Cesare Speciano determined the conditions for the settlement of the Jesuits in the city of Cremona; a new religious congregation which was attributed the role of stemming heresy by preaching and educating the future ruling classes. As in other cities, the Jesuits settled in a central position of the city, where they initiated an impressive building program aimed at the construction of a capacious church, a school, and a college with dormitories and a library.

2. THE CONSTRUCTION OF THE CHURCH, GENERAL MODELS, AND LOCAL WORKERS

It is well known that the Council's "reform decrees" directly concerned the figurative arts but not architecture which, however, adapted itself to the radical change in liturgical functions and catechesis: the new buildings were conformed to re-evaluation of the salvific value of the sacraments (facilitating preaching and the centrality of the Eucharistic rite), the community of the faithful were gathered in aisleless churches, focused towards the main altar and the pulpit [2]. Even the newly built Jesuit churches found inspiration in architectural models – albeit not rigidly applied – identifiable in a rectangular hall with the altar at the end and shallow chapels communicating with each other on the sides of the nave [3, 4]. The Jesuit strategy in the architectural field – under the aegis of the *consiliarius aedificiorum* (and in particular of Father Giovanni Tristano, 1568 to 1575, and of Father Giovanni De Rosis, 1575 to 1610) – was also linked to the criteria of practicality, functionality, and economy, in accordance with the pauperism that characterized the first settlements.

From these architectural models also derived construction techniques that were new or derived from other existent building types: the first churches were often covered by articulated wooden ceilings, more rarely by brick vaults, the walls presented an austere architectural vocabulary, and the roofs had to cover the large span of the single nave. However, these recommendations were put into practice in different ways in the numerous provinces of the Order, where the materials available, the workers, and local building practices influenced the construction of churches and colleges.

In the ecclesiastical province of Milan – which includes the suffragan diocese of Cremona – the significant reforms implemented by Cardinal Carlo Borromeo also had a translation in the architectural field: the *Instructiones fabricae et suppellectilis ecclesiasticae* had great importance in initiating and orienting the restoration and construction of new religious complexes, defining stringent and highly detailed

Fig. 1. *On the left: orthophoto of the main façade. (Image source: courtesy of R.T.C. di Colturato&Pedrini). On the right: the interior of the church. (Photo by Angelo Giuseppe Landi).*

rules [5, 6]. Bishop Speciano was a trusted friend of Borromeo and a staunch – also economic – supporter of the Jesuit settlement; he was well acquainted with the *Instructiones fabricae*, and it is likely that he applied many indications in the project of the Jesuit complex, in which he played a pivotal role: in several documents the explicit will of the bishop to build a grandiose church is reported, a sign of the Counter-Reformation in the city. In fact, Speciano seeked to identify the site of the church and the college, necessarily located in a central, easily identifiable area, close to the places most frequented by the faithful. The studies conducted so far on the church have contextualized the settlement of the Jesuits in the city of Cremona and have documented, as far as possible, the construction of the church, with a specific interest in the early stages [7–10]: the building donated by Margherita Torri in January 1594, constituted the first step in a building program that affected the entire surrounding block, with the gradual acquisition of neighboring houses. Speciano also undertook to raise funds necessary for the purchase of the buildings, their demolition, and the construction of a new grandiose church, the schools, and a college: the hereditary bequests of the noble families (among which those of Margherita Torri Ferrari, of the Mainoldi, Fondulo and Fossa families) and a significant part of the inheritance of the bishop Speciano himself (who died in 1607) contributed to the costs for the construction of the church – dedicated to saints Marcellino and Pietro – which started between 1602 and 1603 [9]. The local aristocratic class worked to stem the spread of heretical movements and, at the same time, invested huge resources in a new religious order responsible for the education of future generations of the new ruling class.

The purchase of the houses located on the southern and eastern border of the church of San Michele Nuovo and the confirmation of the bequests allowed the Jesuits to start the demolition of the church and some adjoining buildings, as well as the start of the construction site, documented by the specifications of the works stipulated on October 30th, 1602 [10]: Francesco Laurenzi was commissioned by the Fathers to build the new church, in accordance with the project of the engineer Angelo Nani, following the best rules of art. The new building is structured on a single hall system (about 15 m x 37 m), a pseudo-Latin cross of imposing dimensions, with a pseudo-transept, side chapels, a large presbytery, and the slender bell tower. Originally the interior was probably austere, decorated, and punctuated by a succession of monumental pilasters surmounted by a plain entablature; the large windows above the entablature collect the light from protected loggias, guaranteeing filtered lighting in the interior space.

The church was built starting from the presbytery, demolishing all the pre-existing structures (whose materials were carefully stacked and, at least in part, reused) and building the new structures from the foundations: the construction from scratch of the building perhaps also implied a sign of symbolic value, of a Church to be re-founded on the austere solidity of the religious Order. The conditions agreed to in the specifications were quite precise; they required complex operations, the use of high-quality materials, mostly lime-based mortars instead of traditional earth ones, and «mature and well-experienced» workmanship for the most delicate processes (e.g., for lime processing).

The same principle is also reiterated for roofs, which had to have the correct slope of the pitches, trusses worked by competent carpenters, flat bricks under the monk and nun tiles (of adequate thickness), and the only requirement that «no beam rests on or touches the vault». Little or nothing is known about the materials used, in particular the woods that were supplied directly by the Jesuits to the construction site: the character of the commissioner, whose relationships and interests went beyond the confines of the Cremona area, today pose some critical issues in identifying the origin of the workers and materials used in the construction site.

The specifications predict a long and complex construction process, consisting of at least two building phases, the first involving the construction of the presbytery and the "transept", completed in 1607, whose project was still subject to revision by Father De Rosis, of the Roman *council aedificiorum*, in July 1603 [11]: in fact, the construction of a church of this size must have seemed excessive to the Jesuit fathers themselves if in March 1604 – when the foundations were already laid – they asked for permission to reduce the nave, denied by Father General Acquaviva. The construction continued briskly, also thanks to the inheritance of Bishop Speciano, who left most of his fortune to the Jesuit order [12]. The first portion was completed a year later, with a blessing by the

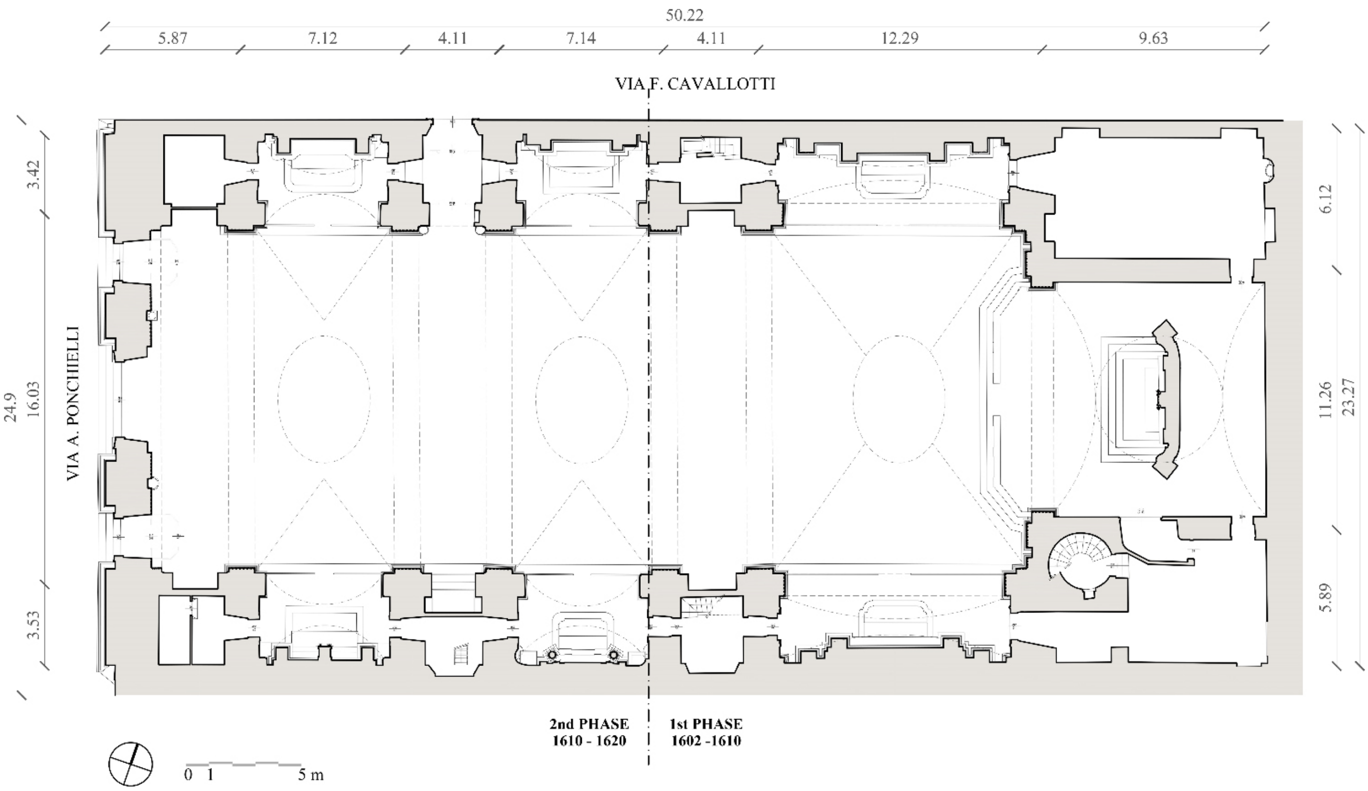

Fig. 2. *Plan of the church of the Saints Marcellino and Pietro with the projection of the vaults: a brick vault separates the large (about 15 m wide) Latin cross liturgical hall with a pseudo-transept from the attic space and the wooden roof. (Image source: geometrical survey, courtesy of R.T.C. di Colturato & Pedrini).*

bishop Paolo Sfondrati and although there is no description, it can be assumed that it was finished and suitable for placing the relics granted in 1611. Even today, the toothing on the vertical wall structures is clearly visible, while the large vault was certainly missing if, in December 1609, Father Acquaviva asked the local Jesuits for clarification on whether or not they intended to build it [13].

The analyses carried out in situ made it possible to establish that instead, the wooden Palladian or queen post trusses – a technological solution suitable for covering the wide span of the liturgical room, equal to about 15 meters (corresponding to about 31 Cremonese arms, being each arm equal to 0.483 m) – had already been placed on site. The vaults, however, were undoubtedly built before the start of the second building phase: the large cracks on the walls and the vaults themselves are compatible with the instability that occurred on an incomplete structure, in which the thrusts could not yet be fully countered.

After an interruption the duration of which is still unknown, the construction of the church resumed with the conclusion of the nave, without interrupting the use of the church, documented by expenses for the altars (in particular that of the Transfiguration) and the purchase of an organ. Margherita Torre expresses the will that her funeral be held at the church, while the bells of the nearby church of S. Nicolò «and that of the Jesuits» must ring, implicitly attesting to the presence at least of a bell, perhaps waiting to finish the bell tower [14]. The interruptions of such large-scale construction sites are well documented in the history of architecture; the unfinished aisles were closed with provisional wooden structures, mainly composed of boards, sometimes decorated with paintings.

On July 7th, 1620, the church was consecrated by Bishop Giovanni Battista Brivio [8]: it is very likely that this ceremony took place in a building still lacking in finishes, partially occupied by building works, but certainly sheltered by the entire wooden roof and probably also by the brick vault. The tympanum to be placed at the top of the main façade was never completed, while in 1622, Alessandro Macchi and Ippolito Tonsis financed the construction of the altars of two chapels and the related decorations in a church that still had a marked pauperistic character.

It was not possible to clarify whether the second phase of the construction site was completed by the same workers employed by Laurenzi and whether the procurement of materials is attributable to the same commercial channels: the investigation conducted on the roofs shows significant differences, not in the general structural system, but in some construction details.

Other finishes were progressively completed, always using the conspicuous bequests of Speciano and Margherita Torre. However, the economic resources converged towards the continuation of the building program, aimed at the erection of the Schools and the College, respectively on the southern and eastern sides of the church. In the period 1628-1629, the school project was discussed between the Roman *consiliarius* and the provincial father, opting for the entrance adjacent to that of the church, «as the founder [Bishop Speciano] liked» [15].

The appearance of the plague epidemic in 1630 determined the rapid decline of the city's economic system and a profound crisis for the following decades [16]. The city building activity was substantially canceled, and numerous construction sites were suspended or not started, resulting in a decline in real estate prices; however, raw materials prices dropped as they could be recovered from demolitions. Thus, the considerable economic resources of the Jesuits could guarantee the construction of the contiguous schools at sustainable costs and represented the opportunity to definitively finish the decorative arrangement of the interiors, with stucco moldings, between 1651 and 1652.

After the completion of the interiors, a long period of – discontinuous and poorly documented – maintenance begins and, from the 19th century, of abandonment. In 1777 a storm caused «serious damage» to the church of Saints Marcellino and Pietro [17]; after the suppression of religious orders, there was a risk of profane use (military riding hall). In 1817 the *Fabbriceria* of the parish church of S. Agostino – of which the church was a subsidiary – reported damage to the roof of the church of San Marcellino, in particular in the parts bordering the bell tower from which bricks fell; the following year, the parish vicar requested restoration work on the roof and the facade, whose marbles were by then in a very precarious condition [18]. However, the most significant intervention, albeit limited only to some parts of the roof, consisted of the strengthening that took place in 1841: three trusses needed to be reinforced with struts, modifications to some members, and insertion of metal straps, for a total amount of 700 Austrian lire [19].

Despite the directions in the specifications, the wooden tie-beams of the trusses are in contact with the extrados of the nave vault; a succession of longitudinal beams, placed on the tie-beams in a central position, seem to support the vault, to which they are connected by means of metal straps. The instability at the vault and the detachment of the plaster were also attributed to this system: in 1862, a restoration work designed by engineer Guarneri filled up the cracks, made the extrados buttresses up to a third of the height of the vault, and restored the detached plaster on the intrados [20].

The reconstruction of the eaves was attested in 1897, on both sides towards the road: the gutters and all the protruding parts of the wooden eaves were replaced [21]. Although with a certain discontinuity in the archival documentation, in the following years and up to the recent past, maintenance interventions and, more often, revision of the roof covering are attested.

3. METHODS

The historical-archival research conducted by the authors aims to develop further insights into the construction phase of the church, already partly outlined in the recent bibliography, and to integrate it with the history of uses and, above all, of the maintenance carried out up to the present. Even if incomplete and discontinuous due to the state of conservation of the archives (the Jesuit archive is quite incomplete, and that of the Fabbriceria di S. Agostino is discontinuous), this information constitutes a fundamental basis for supporting the interpretation of the data collected *in situ*, through direct observation of the building. However, historical knowledge also plays an essential role in drafting a restoration project that recognizes the value of the building as an architectural palimpsest, on which the numerous stories that have interested it have left their traces.

The analysis of the roof structures is, therefore, part of a continuous comparison process between written sources and material traces: a process of identification of construction phases, traces of woodworking, replacements, additions, strengthening, carried out giving diachronic restitution, based on absolute – when possible – or relative dating. This leads to the possibility of attributing materials and construction techniques to the different historical contexts that generated them, identifying the duration or intervals of deterioration manifestation in the structures and architectural finishes, of verifying the results of previous interventions.

4. THE CHURCH ROOF

From a constructional point of view, the church roof can be divided into four parts:

- the hip roof of the presbytery, with a truss, two half-principal rafters, hip rafters, and purlins supporting the joists;
- the gable roof of the nave (its span greater than that of the presbytery), with nine trusses that support the purlins on which the joists are placed;
- the roofs of the two bands on the sides of the nave – consisting of the side chapels and the pseudo-transept – with rafters, purlins, and joists.

Although – on a general level – the same structural organization was maintained in the two construction phases, differences can be identified both in the nave and lateral roofs. The peculiarities connected with the two construction phases of the church are accompanied by others due to the maintenance, renovation, and strengthening of the roof over the centuries.

4.1. THE ROOF OF THE PRESBYTERY

A single truss (T1) is on the roof of the presbytery; its span is significantly minor to that of the nave (about 11 m compared to about 15.15÷15.20 m in the nave). The truss support: on its west side, towards the nave, the ridge beam and four purlins (two for each pitch); on the east, two half-principal rafters, two hip rafters, and four purlins (also in this case, two per pitch). Transversely to the hip rafters, two diagonal, horizontal beams reinforced with struts are intended to support the rafters by vertical posts. Above this structure, there are the joists placed at a distance of about 60 cm, which support the laths on which the roof tiles are placed.

Fig. 3. *Closed joint king post truss in the attic above the presbytery of the church. (Photo by Emanuele Zamperini).*

The roof of the presbytery has been significantly reashed: it indeed underwent at least one significant maintenance intervention, of which, however, no documentary trace has been found; however, it can be dated to the period between the 1920s and 1950s, in which the parish archives show some gaps. The reinforcement works of the southern joint of the truss and the construction of the hip rafters certainly belong to this period; in both cases, thick boards connected with bolts and thin iron strips were used. The replacement of some purlins and joists probably dates back to this same period. These works most likely involved dismantling the entire roof frame and its repositioning with significant changes. The substitution of laths for flat bricks as the supporting element of the roof tiles has allowed a reduction in loads and the overcoming of the dimensional constraints imposed by the bricks; in the presbytery, in fact, the joists are placed at a distance of about 60 cm, unlike what happens in the nave in which the length of the "one arm long flat bricks" – used for the construction of the roof deck – is about 48 cm, equal to a Cremonese arm, as mentioned by Capra in his treatise written shortly after the construction of the church [22].

The truss is a king post closed joint truss [23] with struts; the joint between the king post and the tie-beam is a half dovetail tenon and mortice joint fixed with a wedge. The truss members are all made of oak timber; the boards used to reinforce the southern rafter/tie-beam joint are of spruce; part of the purlins are made of oak, part of spruce – and in this case, protected with the application of a tar-based paint – as one of the half principal rafters and some of the joists; the remaining joists – probably those preserved from the original construction – are some of oak and others of poplar. The laths – probably also made of spruce – are all treated with the same tar-based paint.

The two hip rafters deserve a separate discussion; they are not made of solid wood but with thick boards of painted spruce wood: two external boards are continuous along the entire length, and a third is present only in the middle part, where the bending stresses are greater; at the ends, to distance and connect the sideboards, there are laths inclined at 45° with respect to the axis of the beam, placed at 30÷50 cm from each other.

4.2. THE ROOF OF THE CHAPELS

The roof structure of the side chapels is simpler, consisting of rafters (generally placed in correspondence with the trusses of the nave, but some are probably added later

Fig. 4. *Roof of the band on the northern side of the nave; it is possible to see the extrados of the barrel vault of the pseudo transept. (Photo by Emanuele Zamperini).*

and placed between those) which support a single purlin placed in the middle of the pitch on which the joists rest. The rafters and the purlins are almost all made of oak timber, but some of them – probably even these still original – are made of larch, and others of spruce, which are probably recently replaced or added. The joists are mainly made of oak and discontinuous in correspondence with the purlin, but there are some made of poplar and some others of spruce which are recently added and usually continuous on the two spans. In this part of the roof, no significant differences are visible between the two construction phases of the church.

4.3. THE ROOF OF THE NAVE

The most remarkable part of the roof is, without a doubt, that of the nave; this applies both to the greater complexity of the structure – connected to the presence of trusses whose span is more than 15 m – and to the articulation of the construction events, and the presence of interesting traces related to timber transport and trade.

The structure is made of nine trusses (T2-T10), supported by masonry corbels or engaged pillars protruding from the longitudinal walls; the trusses – together with the wall above the arch that separates the nave from the presbytery and with that of the façade – support ten bays of purlins. All the bays have the same span, with the exception of the second from the presbytery (between T2 and T3), wider due to the greater height of the groin vault of the pseudo-transept, which would have interfered with the tie-beams of the trusses. There are three purlins per pitch plus the ridge beam, which are all discontinuous at the trusses; above each of the walls between the nave and the chapels, there are two other purlins. Almost all the purlins are made of oak wood, but some – even in this case obviously replaced in maintenance works or placed side by side with the pre-existing ones – are of spruce wood. In the organization of the joists (almost all of oak, except for a very few of poplar and some, recently made, of spruce), there is a clear difference between the first and second construction phase: in the bays of the first phase, the joists of the upper part of the pitches

Fig. 5. *Plan of the roof structure. (Geometrical survey: Courtesy of R.T.C. di Colturato & Pedrini). In purple the king post truss of the roof of the presbytery (T1); in red the Palladian trusses of the first phase in which the queen posts rest on the tie-beam (T3-T5); in orange the Palladian trusses of the second phase in which the queen posts are linked to the tie-beam with tenon-mortice joints (T6-T8); in pink the Palladian truss reworked probably in the first decades of the 19th century with queen posts detatched from the tie-beam (T9); in yellow the Palladian trusses reworked in 1841 with queen posts detatched from the tie-beam (T2 and T10).*

are continuous from the ridge beam to the second purlin of each pitch, while the other has a single span, from a purlin to the adjacent; instead, in the bays of the second phase, almost all the purlin have a single span. An exception to this general system occurs in the second bay of the first phase, in which the joists of the lower part of the north pitch are also continuous on three supports and are all made of spruce, like the underlying purlin; this – together with the traces of woodworking – suggests a recent replacement. Among the oak joists, there are some – perhaps coming from the houses demolished to build the church – that show evident signs of previous uses as floor joists due to the presence of notches intended to accommodate the laths covering the joints between the boards, and the *bussole*, thin inclined or concave boards placed between the joists to close the space above the girders.

As already stated, above the nave joists, there is a layer of flat bricks, whose dimensions determine the center distance between the joists, equal to about 48 cm. The only exception is the two bays adjacent to the penultimate truss (T9), probably rehashed in the early decades of the 19th century, as we will see later; in these bays, the joists are placed at a greater distance between centers – about 60 cm as in the presbytery – and support a recently made planking of machined spruce boards. The discrepancy between the period of intervention on the truss and the presumed date of construction of the planking leads to the hypothesis that when the truss was modified, the flat bricks were replaced with laths and that in a more recent intervention, the laths were replaced with the boards.

4.4. THE RELATIONSHIP BETWEEN THE ROOF AND THE MASONRY STRUCTURES

As already mentioned, contrary to what was prescribed by the specifications of the construction contract, all the tie-beams of the trusses (except the replaced one, which will be discussed later) are in contact with the crown of the vault, which, indeed, was shaped to house them. However, the interaction between trusses and vaults does not end in that contact; in fact, there are also some metal hangers that hang the ribs of the groin vault at the intersection between the nave and pseudo-transept, probably installed during the construction phase to prevent asymmetrical deformations in the vault when its centering was lowered. Another construction aspect already mentioned is the presence along the axis of the nave of a sequence of timber beams that rest on the tie-beams of the trusses and are bound to the vault by metal hangers; the dimensional variety of timber beams and metal hangers, and the fact that many of them show evident signs of previous use – contrary to what can be seen in the roof purlins, which are all rather regular – could lead one to believe that it is a consolidation system put in place later (perhaps even in emergency conditions) to limit the deformations of the vault. The lack of signs of the anchoring points of the metal elements to the intrados of the vault would, however, lead to place the realization of this intervention in the time lapse between the construction of the vault and its plastering. Alternatively, the irregularity of the timber used could be justified by the fact that the construction system was built at the same time as the vault but was initially considered just a temporary device, only necessary when lowering the centering and intended to be subsequently removed, but that this removal never took place, perhaps because the builders had noted the poor stability of the vault. The considerable thrust and lack of stability of the vaults are also manifested by the distancing of the longitudinal walls of the nave, evidenced by the vertical lesions present at the connection between them and the corbels or engaged pillars that support the trusses.

5. THE NAVE TRUSSES

The nine trusses of the nave roof are all “Palladian” or queen post trusses. Also in the case of the trusses, differences can be noted between the first and second phases, to which are added others connected to the reinforcement interventions carried out over the years. Observing the trusses that have not undergone significant alterations, it can be seen that: in those of the first phase (T3-T4-T5), the queen posts rest on the tie-beam, which in its midpoint is hung from the king post by means of a long metal bracket; in the unmodified trusses of the second phase (T6-T7-T8), instead, we see that the queen posts are joined to the tie-beam through tensile-resistant connections, made with a half dovetail tenon and mortise closed joint. In addition, the king post – always connected to the straining beam with a closed joint – has struts in the trusses of the first phase, while they are absent in those of the second phase.

The apparently modest different relationship between the queen posts and the tie-beam denounces a different structural conception. The quadrilateral formed by tie-beam, lower rafters, and straining beam inside the Palladian truss is a statically underdetermined structure, which – if loaded asymmetrically – undergoes large displacements. The role of the queen posts is, therefore, fundamental: they fix the distance between the lower rafter/straining beam joint and the underlying tie-beam; thus, they prevent the structure from becoming a mechanism by exploiting the flexural stiffness of the tie-beam.

However, from this point of view, the trusses of the two phases behave differently. In the trusses of the second phase, the queen posts are connected to the tie-beam with a joint capable of resisting both compression and traction; therefore, in case of asymmetrical loads, one of them will press against the tie-beam, and the other will lift it, subdividing the force necessary to stabilize the structure between two points, in one of which it would also reduce the bending of the tie-beam induced by its own weight and by the other loads applied to it. In the trusses of the first phase, instead, the queen posts simply rest on the tie-beam, and this ensures that in case of asymmetrical deformation, only one of them comes into action, pressing on the tie-beam and increasing the stresses induced in it by the other loads.

As already written, three of the trusses of the nave (T2, T9, and T10) underwent significant modifications and, therefore, now present a different structural configuration. As regards two of them (T2 and T10), it is possible to date the interventions with certainty, thanks to the archive documentation.

Fig. 6. *Unmodified truss of the first phase: T3 truss seen from the north-east. (Photo by Emanuele Zamperini).*

Fig. 7. *Unmodified truss of the second phase: T8 truss seen from the north-west. (Photo by Emanuele Zamperini).*

In January 1841, following a winter characterized by heavy snow, roof reinforcement works were started by the master builder Angelo Fontana; eng. Luigi Ghisolfi – a member of the *Fabbriceria* of the parish of S. Agostino – drafted a first report [19], in which he stated that the load imposed by the queen posts on the tie-beam would have caused the trusses to burden the vaults, causing them to crack. In his report, he also indicated the work to be carried out urgently and the other necessary – but postponable – improvements. A subsequent and more detailed appraisal is sent to the *Fabbriceria* by Eng. Benini on March 30th [24]: to eliminate the load of the trusses tie-beams on the vaults, in the T2 and T10 trusses, the queen posts are equipped with two struts each and are shortened so that they are no longer in contact with the tie-beam, but can support it by adding of metal straps; furthermore, the T4 and T10 trusses are equipped with struts that support the tie-beam, thrusting on the walls. In the T10 truss, some elements are also replaced (rafter, lower rafter, and king post), partially charred – such as some of the preserved elements and some purlins – having been struck by lightning; probably, this is the one that struck the church 64 years earlier – on August 19th, 1777 – right in that part of the roof, during a violent storm described in detail in a publication of the time [25]. Among the works described in the appraisal, there is also the shoring of the roof near the two trusses on which the most invasive interventions were planned, which therefore did not require the dismantling of the secondary framing and the roofing.

In describing the deferrable works, Benini instead stated that the insertion of the new struts and the cutting of the queen posts had to be performed on six more trusses [24]; this note is useful to define an *ante quem* term for the reinforcement of the T9 truss. There are nine trusses in the nave, and on two of them, the queen posts had just been shortened; the fact that the report provided that only six of them still needed to be modified suggests that at that time, the intervention on the T9 had already been carried out.

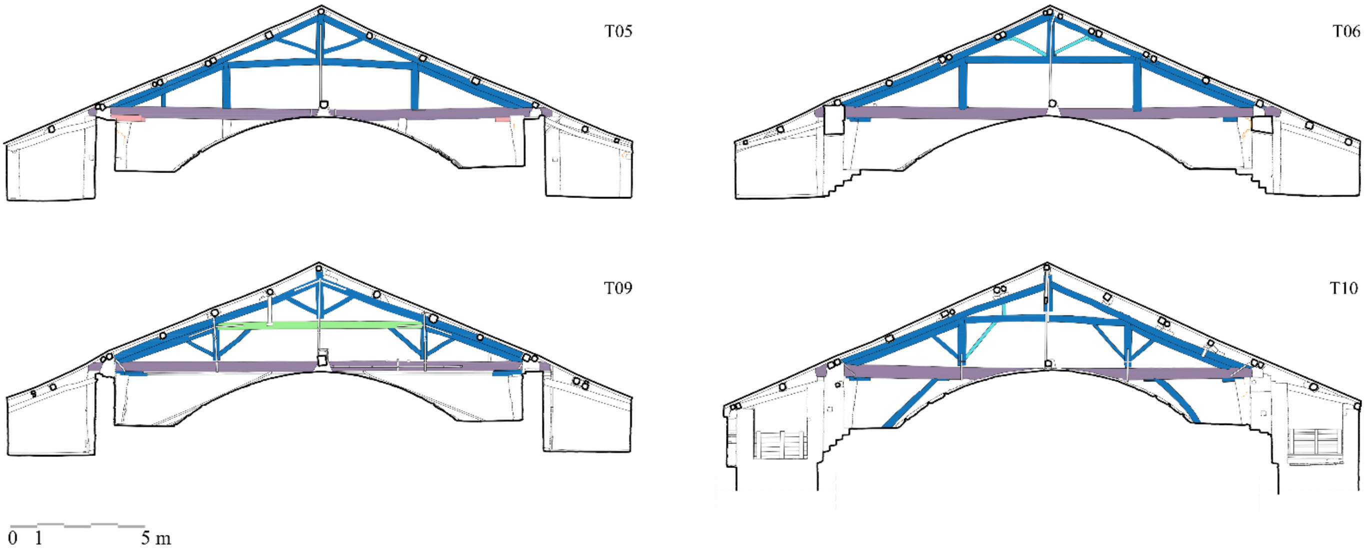

Fig. 8. *Survey of the trusses of the nave: on the top left, T5; on the top right, T6; on the bottom left, T9; on the bottom right, T10. (Geometrical survey: Courtesy of R.T.C. di Colturato & Pedrini). The colours represent the wood species of each truss member: purple for larch; blue for oak; light blue for poplar; green for ash; pink for chestnut.*

The T9 truss underwent the most radical modifications, perhaps after the breakage of heavy damage to its tie-beam, which has been, in fact, substituted. The new tie-beam is made of two pieces connected with a keyed and nibbed scarf joint, reinforced with lateral plates and through bolts, and it is placed at a slightly higher level than that of the other trusses in order to place the wrought iron horizontal tie-rod, to which other two in-

Fig. 9. *Modified truss of the first phase: T2 truss seen from the south-east. (Photo by Emanuele Zamperini).*

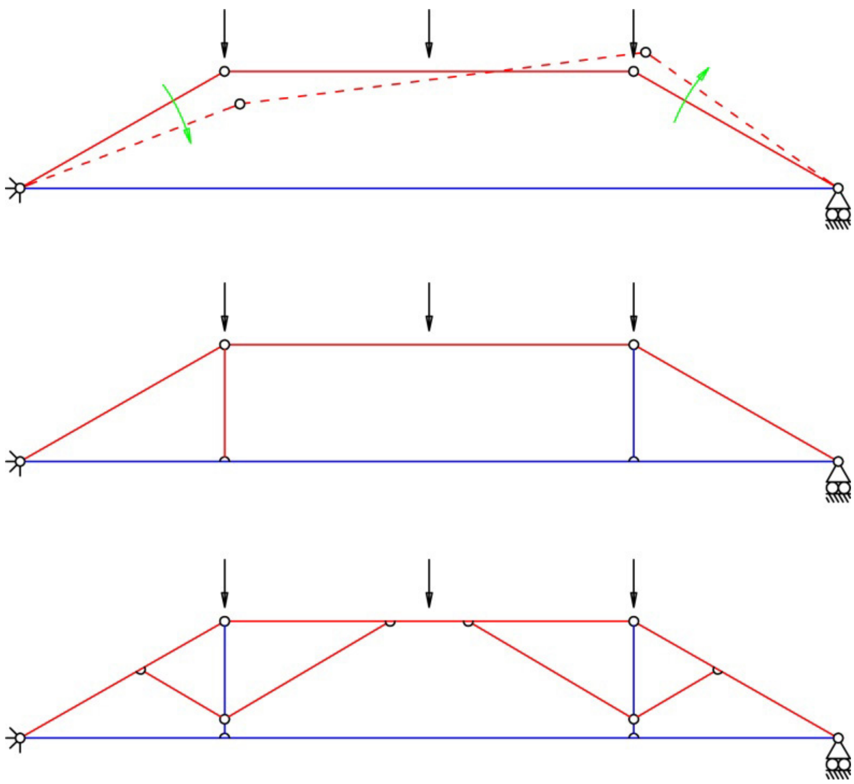

Fig. 10. *Schemes of the structural behavior of the trapezoidal structure inside the Palladian truss (in red, the compressed members; in blue the stretched ones): on the top, the structure without queen posts; in the middle, the structure with the queen posts; on the bottom, the structure with queen posts and two struts for each of them. (Drawing by Emanuele Zamperini).*

clined ties are fixed to reduce the thrust of the vault, but maybe also to lift and detach the truss from the vault. In this intervention, the truss was completely reconfigured, giving the rafters a lower slope (to have the ridge at the same height despite the tie-beam being at a higher level) and putting in place two struts to each of the three posts, which are detached from the tie-beam and straining-beam. The ironware used to reinforce the scarf joint, the tie-beam/rafter joints, and the straps that hang the tie-beam from the three posts seem to date back to the early decades of the 19th century [26] due to the coexistence of tightening systems with metal wedges and with screw bolts with square nuts, as well as for the fact that the straps are articulated with rings of the type that make up chains. In this case, the works were certainly carried out by dismantling the structure of the two spans adjacent to the truss, which are, in fact – as already described – made differently.

The interventions carried out on the three most rehashed trusses show a detailed understanding of their static behavior. The shortening of the queen posts and their detachment from the tie-beam makes the internal trapezoidal structure statically underdetermined; the simple addition of the straps would allow making the truss statically determined again; however, they only allow traction forces and therefore – like the simple supports of the queen posts in the trusses of the first phase – a unilateral constraint that concentrates in a single point all the actions intended to stabilize the trapezoidal structure. The addition of the struts to all the queen posts – blocking the amplitude of the angle between the lower rafters and the straining beam – instead constitutes a different system of stabilization of the structure, more effective, as it does not use the flexural stiffness of the truss tie-beam, which is rather poor given its remarkable span.

5.1. THE TIMBER USED FOR THE TRUSSES AND ITS ORIGIN

For the construction of the trusses, mainly oak and larch timber were used; however, there are some elements of other wood species. The tie-beams are all made of larch wood, both the original ones and that of the T9 truss, which has been replaced and is made of two elements.

The other elements are in the vast majority of oak, with some exceptions: the southern rafter of T2, the three posts and the two rafters of the T3, the two rafters of the T4, which are made of larch; the straining beam of the T6 and T9 which seem to be made of ash timber; the struts added to the king post of the T6, as well as various cleats and other secondary elements, which are made of poplar. The cantilevers placed under the supports of the trusses on the masonry deserve a different discourse: in the trusses from T2 to T5, these are reused chestnut elements, characterized by the presence of painted candelabra decorations, generally on the lower face; in all other cases, they are of oak wood.

Writing about the uses of wood from trees that grow in the Cremona area, Capra mainly mentions oak as a suitable wood for making beams and joists and poplar only for joists; with regard to chestnut – although he estimates its quality equal to that of oak – he mentions only the use for the construction of barrels and other containers, while for the ash he proposes the use only for work tools or weapon shafts [22]. As for the uses of wood obtained from trees that did not grow in the Cremona area but could be found on the market (such as all conifers), Capra instead refers to the treatise by Vincenzo Scamozzi, some decades prior to his work, and substantially coeval with the construction of the church. Writing about larch, Scamozzi affirms that «it is admirably suitable for making beams and roofing» [27].

In most cases, floors and roofs in the Cremona area – and more generally in the lower Lombard plain – contemporary to or earlier than the Church of San Marcellino confirm Capra's indications, as they are made almost entirely of oak or poplar wood; the presence of tie-beams made with larch wood is, therefore, an unusual fact, perhaps unique for the period. The reasons for this choice are to be linked to the remarkable span covered by the trusses, for which the woods of the Cremonese plain were probably no longer able to supply timber of a suitable size [28] due to the progressive exhaustion connected to excessive consumption, slow growth of oaks, and replacement of lowland forests with cultivated land.

Up to now, it has not been possible to find archival documentation relating to the origin of the wood used; however, the oak wood is probably of local origin; on the other hand, identifying the origin of the larch wood is more complex. Scamozzi cites the cities of the Po valley as a possible destination for larch wood coming both from the middle part of the Alps («these mountains of ours and [...] those of Grisons, and Switzerland») as well as from the eastern part that separates Italy from the Austrian regions. In the first case, timber could reach the cities directly from the mountains through the left tributaries of the Po (Ticino, Adda, Oglio, and Mincio) and then through the Po itself; instead, in the second case, it was transported through Adige, Brenta and Piave to Venice and from there led to the Lombard cities going up the Po. There is little information on the trade and transport of timber in the central part of the Alps [28, 29]. On the contrary, many studies have been carried out relating to the Veneto area, deepening technical, economic, and social aspects [30–38]. After a first phase practiced with very different techniques, depending on the specific orographic conditions of the forest, the transport of the timber started with the free-floating in the upper parts of the river courses, narrower and characterized by greater impetuosity and irregularity of the waters, to pass then to the transport in the form of rafts in the great Lombard lakes and the river sections in the plains, which are broader and more easily navigable; in Lombardy, however, transport by boat was often preferred to transport in the form of rafts [29]. These transport phases correspond to particular operations that leave traces that can also remain on the timber in place: to avoid confusion or theft of the free-floating timber; the logs were marked with special marks, different for each merchant [39]; the floating of the timber in the form of rafts, on the other hand, involved assembling them by making holes in the trunks and tying them by means of unstrung branches [40].

The original tie-beams of the church's trusses – and also some of the other elements of larch wood – keep both holes that testify to its transport in the form of a raft and transportation marks. The survey of these marks and their comparison with the repertories of marks relating to the eastern Dolomites [39], the only ones published so far with a certain systematicity, while showing strong similarities, did not allow for recognizing exact correspondences and therefore to identify with certainty the timbers provenance.

Fig. 11. *Trading mark on the west side of the tie-beam of the T7 truss. (Photo by Emanuele Zamperini).*

On the western face of the southern part of the tie-beam of the T9 truss – as already written probably dating back to an intervention of the early 19th century – it is possible to read the word "NOGAI" engraved with a scratch awl or a knife. A quick toponymic research has made it possible to identify a place with this name in the morainic amphitheater of Sebino in Franciacorta [41], a short distance from the Oglio river, which may have been used for the transport of timber up to a short distance from Cremona, also through its derivations of the Naviglio Civico and Naviglio Pallavicino.

6. CONCLUSIONS

The article summarizes the historical-constructional study of a remarkable example of a timber roof built in the Lombardy area in the 17th century, addressing it from the point of view of the history of the institutions that determined its construction and maintenance and of the construction history and technique. The singularity of the size of the covered space in the context of the city of Cremona makes it unique (not only for the time in which it was built), both in terms of the construction techniques used and for the need to procure non-local timber.

The constant comparison of the bibliographic and archival data with that of the real and present consistency of the artifact, its construction techniques, wood species, and decay has allowed the understanding and interpretation of the construction and maintenance acts, framing them in the more general social and economic context of the time and not only: the investigation made it possible to define a construction history that was not confined only to the construction site, albeit developed in two phases, but also to the numerous, and sometimes minute, maintenance works that involved the roof, over a period of four centuries.

The collection and interpretation of the data derived by the survey and knowledge of the building throughout its existence is an essential basis for further investigations (analytical checks on the state of conservation of the wood, analysis and assessment of the structures, definition of an overall structural model…) aimed at a coherent conservation project, for the purpose of the building protection and a controlled structural improvement.

Authors contribution

The bibliographic and documentary research, the direct study of the artifact, and the general conception of the article were made by the two authors jointly; the writing of paragraphs 1, 2, and 3 were carried out by Angelo Giuseppe Landi, of paragraphs 4 and 5 by Emanuele Zamperini; the conclusions were written jointly by the two authors. Emanuele Zamperini did the translation of the article.

8. REFERENCES

[1] Muto G (2006) La città, lo Stato, l'impero. In: Politi G (a cura di) Storia di Cremona - L'età degli Asburgo di Spagna (1535-1707). Bolis, Azzano San Paolo, pp 12–57

[2] Sale G (2001) Pauperismo architettonico e architettura gesuitica. Jaca Book, Milano

[3] Patetta L (1989) Le chiese della Compagnia di Gesù: complessità e sviluppi. In: Id. Storia e tipologia. Cinque saggi sull'architettura del passato. Clup, Milano, pp 159–201

[4] Balestreri I (1997) Scritti di padri gesuiti in materia d'architettura. In: Balestrieri I, Coscarella C, Patetta L, Zocchi D (a cura di) I Gesuiti e l'architettura. La produzione in Italia dal XVI al XVIII secolo. Edizioni S. Fedele, Milano, pp 46–58

[5] Castiglioni C, Marcora C (a cura di) (1952) Arte sacra: de fabrica Ecclesiae. Milano

[6] Sénécal R (2000), Carlo Borromeo's Instructiones fabricae et supellectilis ecclesiasticae and its origins in the Rome of his time. Papers of the British School at Rome 68:241–267

[7] AA.VV. (1975) Itinerari d'arte in provincia di Cremona: un quindicennio di interventi a favore del patrimonio artistico della provincia. Amministrazione provinciale. Cremona, pp 78–87

[8] Bonometti P (1991) La chiesa dei SS. Marcellino e Pietro a Cremona. Camera di Commercio Industria Artigianato Agricoltura, Cremona

[9] Foglia A (1996) Il Collegio dei Gesuiti dei Santi Pietro e Marcellino e il Collegio della Beata Vergine (o delle "Gesuitesse") di Cremona. In: Colmuto Zanella G (a cura di) L'architettura del collegio tra XVI e XVIII secolo in area lombarda. Guerini e Associati, Milano, pp 139–158

[10] Foglia A (2006) Le istituzioni ecclesiastiche e la vita religiosa. In: Politi G (a cura di) Storia di Cremona - L'età degli Asburgo di Spagna (1535-1707). Bolis, Azzano San Paolo, pp 288–333

[11] ARSI, Med. 22/II, c. 410r

[12] ASCr, AN, Giulio Prezagni, filza 2385, 21 agosto 1607

[13] ARSI, Med. 22, f. 381r, 14 dicembre 1609

[14] ASMi, Fondo Religione, p.a., b. 4357, 8 gennaio 1619

[15] ARSI, Med. 25/II, f. 629v, 29 giugno 1629

[16] Jean G (2000) La casa da nobile a Cremona: caratteri delle dimore aristocratiche in età moderna. Electa, Milano

[17] ASMi, Atti di governo, Fondo Culto, p.a., b. 1698, 1777

[18] ASMi, AG, Culto, p.m., b. 1043

[19] ASDCr, APSA, Atti evasi, fasc. 1841-1846, 26 gennaio 1841

[20] ASDCr, Atti 1800-1830, 16 gennaio 1862

[21] ASDCr, APSA, Conto consuntivo, fasc. 1897

[22] Capra (1678) La nuova architettura famigliare. Monti, Bologna

[23] Zamperini E (2015) Timber trusses in Italy: the progressive prevailing of open-joint over closed-joint trusses. In: Bowen B, Friedman D, Leslie T, Ochsendorf J (eds) Proceedings of the fifth International Congress on Construction History. Volume 3. Construction History Society of America, Chicago, pp 629–636

[24] ASDCr, APSA, Atti evasi, fasc. 1841-1846, 30 marzo 1841

[25] Aglio G (1777) Rapporto veridico dei due orribili temporali insorti in Cremona la notte del dì 19 Agosto 1777. Francesco Gaetano Ferrari, Cremona

[26] Zamperini E (2019) Capriate e tetti di legno. Evoluzione tecnologica e tipologica delle strutture lignee di copertura in Italia (1800-1950). CLU, Pavia

[27] Scamozzi V (1615) L'idea dell'architettura universale. Parte seconda. Venezia

[28] Dellavedova P (2008) Conoscenza delle pratiche costruttive storiche degli edifici in area lombarda: le strutture lignee di copertura. In: Pracchi V (a cura di) Pratiche costruttive storiche: manufatti in stucco e strutture lignee di copertura in edifici lombardi. Nodo Libri, Como, pp 93–149

[29] Mazzocchi L (1879) Trasporto dei legnami. In: Id. Trattato su le costruzioni in legno. Vallardi, Milano, pp 9–10

[30] Zamboni FC (1925) La navigazione sull'Adige in rapporto al commercio Veronese. Officine Grafiche C. Ferrari, Venezia

[31] Canali G (1939) I trasporti sull'Adige da Bronzolo a Verona e gli spedizionieri di Sacco. Tipografia Terme, Roma

[32] Perco D (a cura di) (1988) Zattere, zattieri e menadàs. La fluitazione del legname lungo il Piave. Feltre, Castaldi

[33] Caniato G (a cura di) (1993) La via del fiume dalle Dolomiti a Venezia. CIERRE, Verona

[34] Agnoletti M (1998) Segherie e foreste nel Trentino dal medioevo ai giorni nostri. Museo degli Usi e Costumi della Gente Trentina, San Michele all'Adige

[35] Lazzarini A (2006) La trasformazione di un bosco. Il Cansiglio, Venezia e i nuovi usi del legno. Istituto Storico Bellunese della Resistenza e dell'Età Contemporanea, Belluno

[36] Occhi K (2006) Boschi e mercanti. Traffici di legname tra la contea di Tirolo e la Repubblica di Venezia (secoli XVI-XVII). Il Mulino, Bologna

[37] Bianco F, Burgos A, Ferigo G (2008) Aplis. Una storia dell'economia alpina in Carnia. Consorzio Boschi Carnici, Tolmezzo

[38] Asche R, Bettega G, Pistoia U (2010) Un fiume di legno. Fluitazione del legname dal Trentino a Venezia. Priuli & Verlucca, Scarmagno

[39] Pais Becher G, Martella A (1988) Segni nelle Dolomiti Orientali. Comunità Montana Centro Cadore, Calalzo di Cadore

[40] Šebesta G (1993) Struttura – evoluzione della zattera. In: Caniato G (a cura di) La via del fiume dalle Dolomiti a Venezia. CIERRE, Verona, pp 183–207

[41] Cacciamali G B (1907) Studio sull'Anfiteatro morenico sebino. In: Commentari dell'Ateneo di Scienze, Lettere ed Arti in Brescia per l'anno 1907. Apollonio, Brescia, pp 32–79