VOL. 8, SPECIAL ISSUE (2022)

Remarkable historic timber roofs. Knowledge and conservation practice. PART 2 - Investigation, analysis, and interventions

TEMA
Technologies
Engineering
Materials
Architecture

Cover illustration: Auxiliary truss for the strengthening of the roof of San Giovanni Battista church, Borno, Brescia, Italy, 1771-81/2020. © Emanuele Zamperini (2020)

e-ISSN 2421-4574
DOI: 10.30682/tema08SI2

TEMA
Technologies
Engineering
Materials
Architecture

e-ISSN 2421-4574
ISBN online 979-12-5477-086-3
DOI: 10.30682/tema08SI2

Vol. 8, Special Issue (2022)

Remarkable historic timber roofs. Knowledge and conservation practice
Part 2 - Investigation, analysis, and interventions

Year 2022 (Issues per year: 2)

Cover illustration: Auxiliary truss for the strengthening of the roof of San Giovanni Battista church (architectural design by P. Castelnovi, structural design by E. Zamperini with the collaboration of G. Sacco), Borno, Brescia, Italy, 1771-81/2020 by E. Zamperini. © Emanuele Zamperini (2020)

Scientific Society Partner:
Ar.Tec. Associazione Scientifica per la Promozione dei Rapporti tra Architettura e Tecniche per l'Edilizia
c/o DICATECH - Dipartimento di Ingegneria Civile, Ambientale, del Territorio, Edile e di Chimica - Politecnico di Bari
Via Edoardo Orabona, 4
70125 Bari - Italy
Phone: +39 080 5963564
Email: info@artecweb.org - tema@artecweb.org

Media Partner:
Edicom Edizioni
Via I Maggio 117
34074 Monfalcone (GO) - Italy
Phone: +39 0481 484488

TEMA: Technologies Engineering Materials Architecture
Vol. 8, Special Issue part 2 (2022)
e-ISSN 2421-4574

THE ROOF STRUCTURE OF THE MEN'S ORATORY OF THE ALBERGO DEI POVERI IN GENOA

Marta Casanova, Stefano F. Musso, Stefano Podestà

TEMA Technologies Engineering Materials Architecture

e-ISSN 2421-4574

Vol. 8, Special Issue part 2 - (2022)

DOI: 10.30682/tema08SIq

Abstract

The Genoese roof structures are characterized by the originality of their construction and technological solutions compared to other cultural and geographical areas, including neighboring ones, and, in particular, by the unique connection with the underlying wall structures, by their thrusting nature and by the scarce or non-existent presence of trusses.
From the second half of the 16th century, in the roofs of large spaces such as churches and assembly halls, the wooden elements of the main roof structure are supported by solid brick pillars resting on arches or the ribs of the underlying vaulted structures.
This paper describes the building features, the state of preservation, and the restoration and consolidation project of the roof and the underlying vault with timber ribs and plastered reed mats on the intrados of the Men's Oratory of the Albergo dei Poveri in Genoa, one of the largest still preserved in the monumental complex and one of the most imposing among those still present in the city.

Keywords

Wooden structures, Timber structure vault, Consolidation project.

Marta Casanova*
DAD - Dipartimento Architettura e Design, Università degli Studi di Genova, Genova (Italy)

Stefano F. Musso
DAD - Dipartimento Architettura e Design, Università degli Studi di Genova, Genova (Italy)

Stefano Podestà
DICCA - Dipartimento di Ingegneria Civile, Chimica e Ambientale, Università degli Studi di Genova, Genova (Italy)

** Corresponding author:*
e-mail: marta.casanova@edu.unige.it

1. INTRODUCTION

The paper focuses on the description of a case study that is particularly significant in terms of its size and construction characteristics: the roof structure and wooden vault of the former Men's Oratory of the Albergo dei Poveri in Genoa. The contribution has the twofold aim of documenting the construction features and the state of preservation of one of the largest wooden vaults and the related roof structure, which have preserved the original conception in Genoa, and illustrating the definitive restoration and consolidation project. The study is contextualized and compared with the roof structures of all the monumental complexes referring to the Genoese building tradition. The state of decay, the collapse of a portion of the reed mat vault, and the structural analysis results have determined the need to prepare a structural consolidation intervention to ensure suitable safety standards in relation to the intended use of the Oratory.

2. THE ALBERGO DEI POVERI IN GENOA

The Albergo dei Poveri in Genoa is a monumental complex, raised from 1656 onwards to host the various charities present in the city; the leading supporter and financier of such a project was the Genoese nobleman Emanuele Brignole (1617-1678).

The ex-novo construction of a monumental building intended to house the poor had a strong political and social value. It first affirmed the importance for the

ruling classes of the time of finding a solution to the problem of the uncontrolled presence of the poor in the city and, at the same time, glimpsed the possibility of international political redemption for the Republic of Genoa [1].

The Regulation of the charitable institution was based on three rules – order, prayer, and work – which also influenced the unique organization of the vast complex. In fact, the project included a square plan with buildings arranged in a cross shape in the center of which stood the church and, under the dome, the high altar, the intended visual and symbolic center of the complex, visible from all the surrounding areas. However, the original project was not completed, and the construction was interrupted at the beginning of the XIX century so that the western wings were reduced to long corridors connecting the south and north fronts. The magnificence of the complex is attributable more to its immense size rather than to its decorations. These latter are concentrated solely in the entrance hall, the monumental staircases leading to the atrium and the first floor from which there is access to the ante-church and the church, and other reception rooms concentrated mainly in the southern building to the west.

In the XIX century, following social changes, the structure had become a hospice; at the time of the Second World War, it was classified as a Public Assistance and Charity Institution in accordance with Law 6970 of the 17th of July 1890. On the 4th of March 1912, the Ministry of Education declared the building a "valuable monument of art and history" in accordance with Law 185/1902 and Law 364/1909. The complex, owned by the "Emanuele Brignole" Personal Services Agency, was decommissioned at the end of the last century and then loaned to the University of Genoa for fifty years. In recent years, the University has partly restored the building and used three floors of the east wing to house classrooms, a library, and a book depository, as well as the former women's Oratory, i.e., the body of the central cross of buildings to the east of the church, as a lecture hall. In the southern building, part of the Law Faculty Library extends, and other classrooms and departmental offices can be found, in addition to the language center on the floor above the so-called ante-church.

The Laboratory of Analytical Methods for Restoration and the History of Buildings and the Specialization school in architectural and landscape heritage of the University of Genoa have been studying the state of conservation and possible uses of the unrecovered areas of the complex since 2013 [2–5]. The former men's Oratory, i.e., the building to the left of the church, towards the west, is abandoned and in a precarious state of preservation. Still, a project has now been approved for its restoration as the University's second lecture hall, to which this article refers with specific attention to the roof structures.

3. THE ROOF STRUCTURE OF THE ALBERGO DEI POVERI

Compared to other cultural and geographical areas, including neighboring ones, the roof structures in the Genoa area are characterized by their unique connection with the underlying wall structures, their thrusting nature, and the scarce or non-existent presence of trusses [6–9]. From the second half of the 16th century, a distinction was made between the roofs of large spaces, such as churches and assembly halls, and those of more important residential buildings. In the first case, the wooden elements of the main roof structure are carried by solid brick pillars resting on arches or the ribs of the underlying vaulted structures. In palace or villa architecture, on the other hand, the roofs (generally pavilion-shaped) are reminiscent of naval construction techniques, with resistant systems organized according to flat frames, with beams on props, where the diagonal struts are load-bearing elements, like the joists of the secondary beam level, on which the planking is fixed [6]. The diagonals of the pitch, in this way, do not load the edge of the wall box, which, due to the construction characteristics of the walls, is a point that tends to be weak, and the weight of the roof is conveyed onto the perimeter walls through the lame frames described above.

The choice of the wood species used in the roofing structures depends mainly on two factors: the availability in the woods of the territory of the Republic of Genoa and the workability with the tools available at the time. Generally speaking, larch or oak is used for the main

load-bearing structures (struts and purlins or beams) and chestnut for the secondary structures (rafters and planking) [10, 11]. Re-used elements from the demolition of ships and hulls of various kinds are not at all rare.

The Albergo dei Poveri offers examples of both types of traditional Genoese roofing identified in the literature [Fig. 1], as it includes both elongated buildings (dormitories, church, oratories, and corridors) and towers located in the corners and the central bodies. The prevailing typology in the arms of the central cross and the wings, i.e., the parts connecting the corner towers to the central ones, are characterized by pitched beams perpendicular to the external fronts, carried by pillars resting on solid brick arches fitted with iron tie-rods. Above the main frame, the rafters follow the slope of the pitch and rest on the dormant beam at the masonry; a fairly regular board is nailed to them, which supports the slate roofing (slate slabs, usually square in shape, 55 ÷ 61 cm wide and 4 ÷ 7 mm thick) fixed with lime mortar. In almost all rooms, there were self-supporting wooden ribbed vaults underneath the roof structures with pendants connected to the roof structures as a static reserve in case of deformation or subsidence.

Inside the Albergo dei Poveri, there are several variations of this basic structural scheme due to the different organization of the underlying masonry or pillars. The basic scheme is found in the arms of the central cross, with five or seven pillars, depending on the width of the underlying arch (9 m and 16.5 m, respectively). In the case of the roof of the central body at the church's nave, instead of having a succession of arches, the roof structure rests directly on the underlying barrel vault of solid brickwork [11].

During the Second World War, the Albergo dei Poveri suffered a great deal of damage, especially to the roof structures, due to the devastating effects of incendiary bombs. Many roof structures were thus rebuilt after the war by the Genio Civile (the roof of the Church or former Women's Oratory, the roof of the east wing with the southern tower, the roof of the eastern part of the north wing, and the advanced central portion of the main building to the south). The Genio interventions were carried out with reinforced concrete structures and prefabricated SACCAI-type beams, repeating the pre-existing structural scheme but using different materials. The roof structure of the former Men's Oratory, with its large trough vault with lunettes consisting of five solid brick arches and, between them, vault fields with wooden ribs and plastered reed mats on the intrados, is one of the largest still preserved in the monumental complex and one of the most imposing among those still present in the city.

Fig. 1. *Examples of the two types of roof structures present in the Albergo dei Poveri complex: (a) the roof structure of the west tower in the south wing of the complex; (b) the roof structure of the west side of the north wing.*

4. THE ROOF OF THE MEN'S ORATORY: GEOMETRIC AND CONSTRUCTION DESCRIPTION

The former Men's Oratory, which occupies the western arm of the central cross of buildings, is symmetrical in position to the former Women's Oratory in relation to the church but smaller in size (Fig. 2). In the original project of the Albergo dei Poveri, both Oratories were conceived in close connection with the church, as two of the thirteen points from which the guests of the structure could attend the Holy Mass, but, as mentioned, it was never completed. Therefore, the former Men's Oratory is shorter than the Women's.

The large room of the Oratory, 15.5 m wide and 25.6 m long, is connected on one side to the church, from which it is separated only by an imposing wooden and glass door, and on the opposite side to the west wing of the complex (Fig. 3). This wing is, in fact, reduced to a two-level corridor connecting the north wing to the south entrance building. The ground floor corridor is covered by solid brick cross vaults, while on the first floor, the pattern described above is repeated, and the cross vaults are made of wooden ribs and mats, anchored to solid brick transverse arches supporting the roof structures. In the large room of the former Oratory, the corridor of the upper floor opens up with a balcony that allows a view of the room below and the high altar of the church.

A pitched roof covers the Men's Oratory with a ridge in an east-west direction. The roof covering is made of slate laid with lime mortar *alla genovese*. Parallel to the eaves lines, there are two attic walls with barbicans. This part of the roof of the Albergo dei Poveri does not appear to have ever been replaced except for some localized consolidation work. The roof is structur-

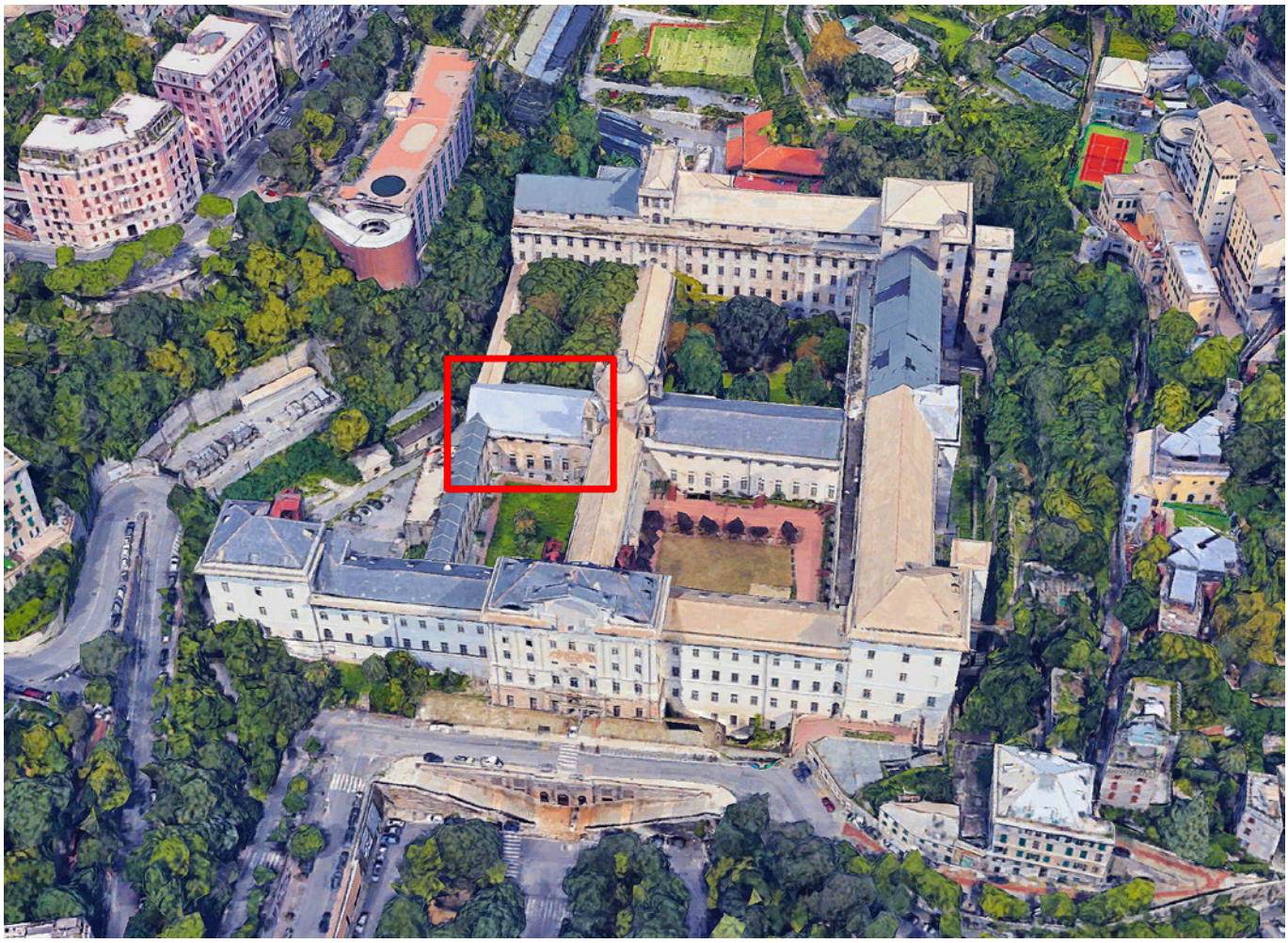

Fig. 2. *Location of the Men's Oratory in Genoa's Albergo dei Poveri complex.*

Fig. 3. *East and West views of the men's Oratory.*

ally composed of longitudinal beams (purlins) and the central ridge beam (circular section with a diameter of 30 cm) resting on the terminal masonry and five masonry arches with pillars at the purlins. The masonry arches are made of three-headed masonry 110 cm thick and 110 cm wide (Fig. 4). There are also wooden struts between the purlins to stiffen the system. Joists with a section of 7 cm x 10 cm are placed above the main frame, on which the planking rests and, above it, the covering. Connected to the roof by wooden pendants are the vault ribs to which the reed mat is attached. The wooden ribs have a cross-section of 5 cm by 13-15 cm (and are made up of two connected boards) with a center-to-center distance of approximately 41÷ 47 cm. Due to difficulties accessing the roof structure, it was impossible to identify the elements' wood species.

A barrel vault, with lunettes and a pavilion head towards the church, covers the large room of the former Oratory. The vault, as already mentioned, is made of five solid brick arches and, between them, fields made

Fig. 4. *The roof structure's current configuration; longitudinal and cross sections.*

of a structure of wooden ribs. These are connected to the roof rafters by wooden pendants, supporting a reed mat covered on the intrados with a thick layer of aerial lime mortar, with a white well-pressed lime surface finish; it has a maximum height from the internal floor of the Oratory of 15.7 m with a shutter at 9.5 m. Wooden vaults, their diffusion, construction techniques, and possible consolidation interventions have been the subject of several studies in Genoa [12, 13] and Italy [14–16]. Still, no interventions have been documented on structures of similar size to the former Oratory.

5. DIAGNOSTICS AND STATE OF PRESERVATION

In order to define the most appropriate restoration intervention for the parts of the vault with wooden structures and reed mat, it was necessary to carry out a preliminary cognitive and diagnostic phase of its peculiarities and criticalities [17].

A thermographic survey was then carried out to highlight the position of the individual constituent elements, hidden from view by the intrados, any anomalies, and particular signs (Fig. 5). A Laser Scanner survey and the

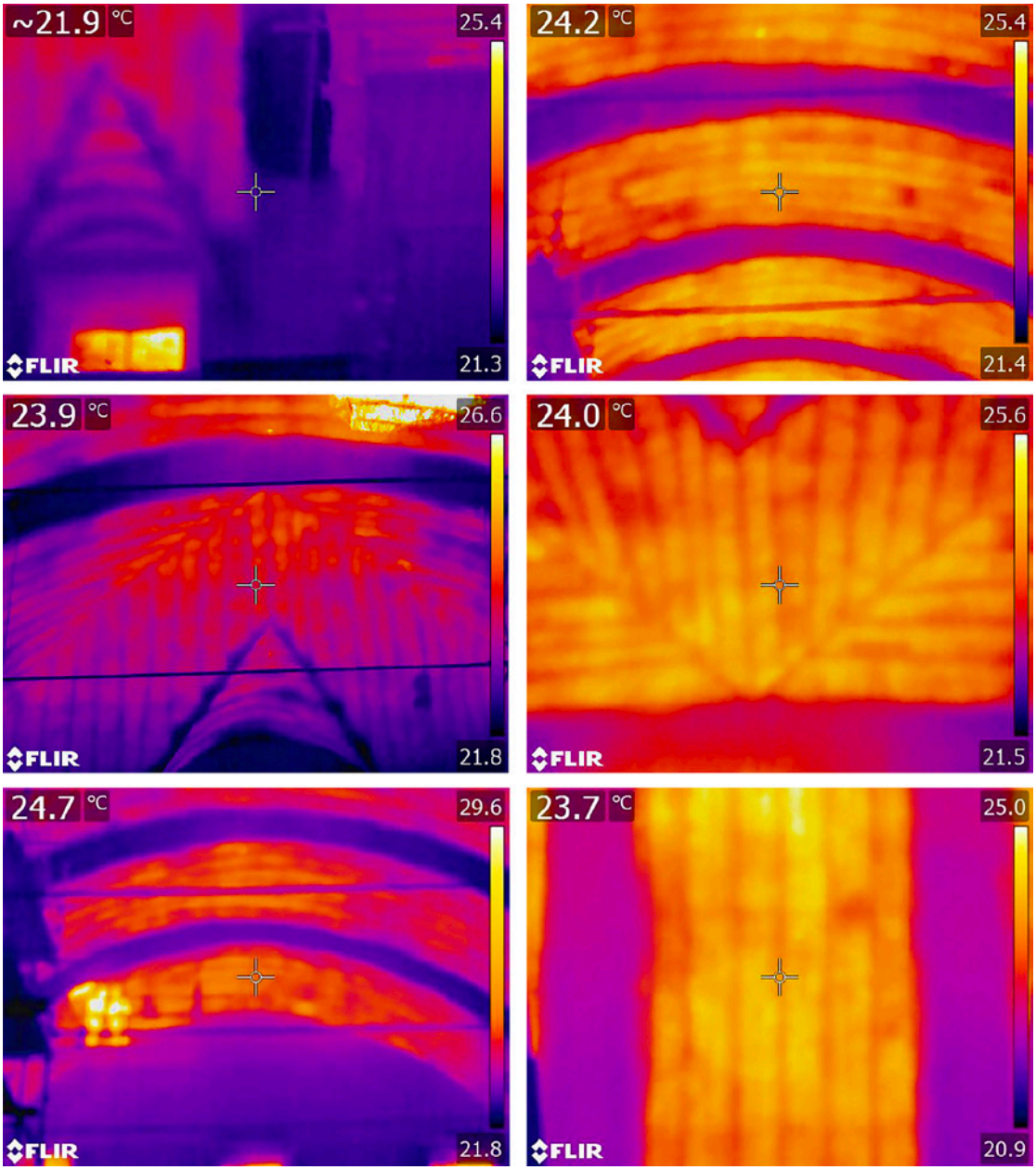

Fig. 5. *Thermographic images of the reed mat vault of the Men's Oratory. The masonry arches, the arrangement of the ribs of the barrel vault, the lunettes, and the pavilion terminal are visible.*

Fig. 6. *Longitudinal cracks in correspondence of the arches and partial lack of the wattle of the ceiling above a window on the south side.*

extraction of the main sections from the relative cloud of points also made it possible to verify the deformations of the vault with the probable partial detachment of the reed mat from the ribs above, in correspondence with the large transversal arches in solid brickwork.

Following the erection of two temporary tower scaffolds, three limited destructive tests were carried out on the southern part of the vault. The tests, complementary to the thermographic surveys and the survey, involved the destruction of small portions of plaster and reed mat to allow the vision of the roof structure and of the vault itself, necessary for the subsequent definition of the consolidation interventions.

In fact, the vault shows numerous cracks near the tie-rods, arranged transversely, parallel to the short side of the Oratory, in correspondence with the masonry arches (Fig. 6). The most cracked portions are, in particular, those along the pavilion head of the vault on the east side, where the central lunette meets the vault. Here, there are also two important bulges on the sides of the lunette, and the plaster is in the process of becoming detached, and on the lower right-hand side near the impost of the pavilion head, where there is also a deficiency affecting not only the layer of plaster but also the underlying supporting reed mat.

The second collapse of a portion of the vault (plaster and reed mat) occurred near the south wall, at the second southeast window, due to rainwater infiltration from the roof (Figs. 7 and 8). In the southeastern corner of the vault, there are drips and stains from infiltration. At the points of rainwater infiltration, especially along the south side of the vault, there are dirt drips and yellowish stains due to the release of tannin from the wooden ribs of the barrel vault. Along the north side of the vault, there are other whitish stains. Between the first two lunettes on the south side, the plaster of the vault has gaps and flaking parts; the paint layers are also subject to exfoliation at this point. In three small ceilings of the high windows on the south side, there are gaps in the plaster and rotting reed mat (Fig. 6). The plaster on the ceiling of the south door, which connects the gallery of the Oratory to the upper west corridor, is cracked, peeling, eroded, and peeling, and there is a gap that reveals the slate slabs underneath.

In addition, the vault observation through the collapsed portions and the assays revealed the presence of inconsistent material at the extrados, the inadequate connection between the ribs and the roof, and the lack of connection between the ribs and the reed mat.

Fig. 7. *Detail of the vault with the collapsed portion of wattle and plaster.*

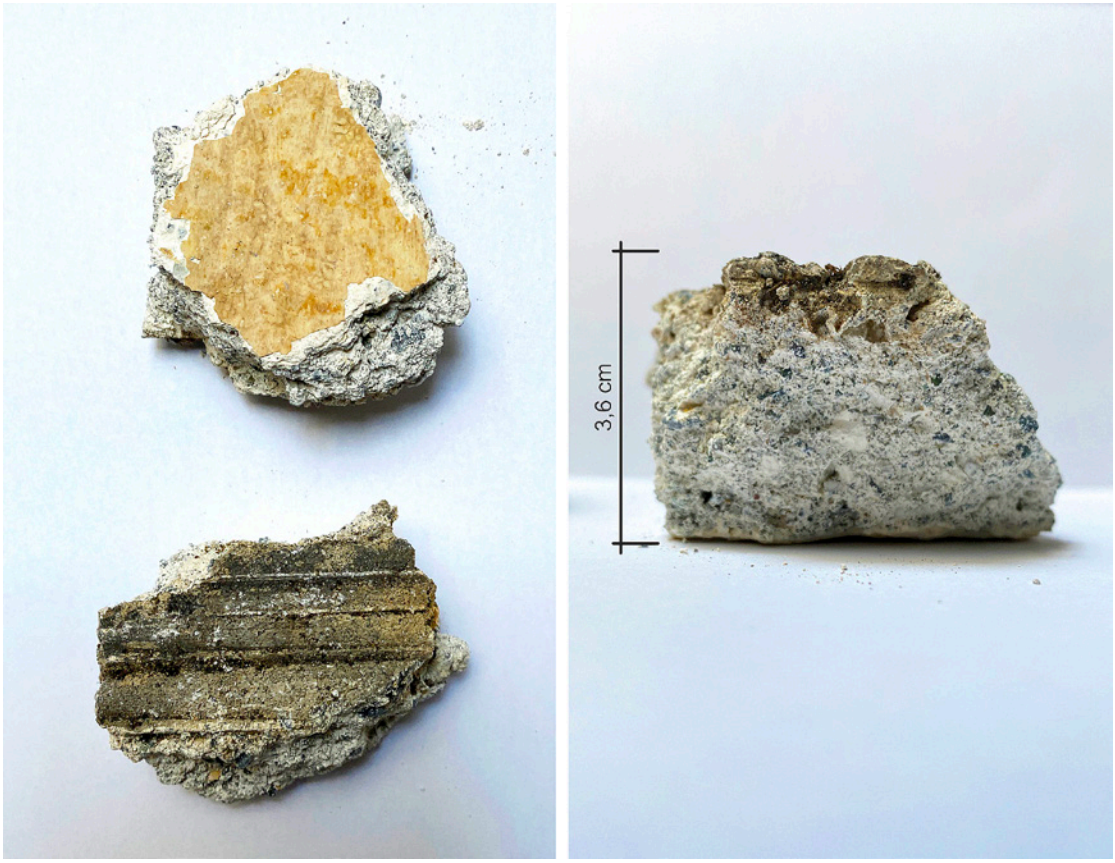

Fig. 8. *Detailed photo of a portion of plaster of the timber structure vault.*

Only limited parts of the roof structure could be inspected due to the difficulty of access (Fig. 9). The main phenomena of degradation are:

- wall disarticulation in correspondence with the connection of the wooden struts to the masonry;
- cracking due to shrinkage of the wooden struts;
- deterioration of the wooden elements (related to the level of humidity and biotic attacks);
- bending damage to some purlins;
- bending damage to several arches;
- loss of shape of the vault (buckling) in the areas between the masonry arches.

Fig. 9. *Cracks and rotting of the rafters.*

Fig. 10. *The collapsed area of the vault and masonry wattle and disjoining in the support area of the struts.*

Fig. 11. *Degradation of the ribs and presence of loose material on the vault.*

6. THE RESTORATION AND CONSOLIDATION PROJECT

The state of decay, the collapse of a portion of the reed mat vault, and the results of the structural analyses carried out have determined the need to prepare, first of all, a structural consolidation intervention capable of guaranteeing adequate safety standards in relation to the future use of the former Oratory. The conservation intervention proposed aims to combine the permanence of the material and forms of the monument-document, the effectiveness and technical efficiency of the new works in terms of durability, stability, usability, and safety of the artifact, as well as the fulfilment of basic requirements for the use of the environment in relation to the new use.

a. Intervention on the roof

The investigations carried out and described above have highlighted some deficiencies and vulnerabilities of the roofing system. Many wooden elements are also damaged due to the deterioration of the roofing, which has led to widespread rainwater infiltration into the attic. The masonry pillars resting on the arches supporting the roof beams are also particularly slender, and it was, therefore, considered necessary to stiffen the whole system in the transverse direction. The wooden strut supports of the pitch along the perimeter masonry are, in some cases, deficient, and this has led to their partial disconnection and the disarticulation of the masonry.

As for the perimeter masonry, the masonry will be split and stitched in the areas where the struts are supported, where the masonry has become disjointed, creating a lack of support. The masonry pillars above the arches will be stiffened by the insertion of steel frames made of cold-galvanized UPN120 profiles (S275 class steel) and anchored to the pillars using threaded through-bars (Fig. 12). The construction of the reticular system is necessary to inhibit any instability of the pillars and to avoid the loss of support of purlins on the pillars themselves, especially in the case of horizontal actions.

The purlins showing shrinkage cracks will be consolidated by inserting a hooping with metal straps in order to limit the degradation phenomenon in progress and ensure their structural functionality. The hooping will be carried out by adopting a system of 5 mm metal cables connected through a turnbuckle system consisting of two bolted hollow metal rods. To avoid damage to the wooden elements due to the stripping of the metal straps, they will be inserted in transparent PVC tubes. The maximum spacing between the single straps will be 50 cm to guarantee homogeneous reinforcement of the elements.

In addition, a flat reticular ring beam at the top will be constructed on top of the masonry, consisting of class S275 steel plates (60 mm wide and 5 mm thick) welded to form a reticulated grid. The steel plates will be embedded in a thin cast (less than 50 mm) made of hydraulic lime mortar and connected to the underlying wall employing anchor bolts made of threaded rods embedded in the masonry. The advantages of this flat metal reticulated ring beam are many: on the one hand, the negligible increase in mass and rigidity means that the seismic action at the top does not change, and on the other hand, the widespread connection of the roof with the top of the masonry (primary and secondary elements) prevents the occurrence of hammering mechanisms that can trigger overturning mechanisms in the attic strip. All wooden elements will be treated against woodborers and fungi. The existing planking, previously removed, will be replaced by a double planking with crossed metal strips, recovering the existing planks in a good state of preservation. The new package will consist of a double-crossed planking with a thickness of 30 mm + 20 mm screwed mutually and to the joists below. Pre-drilled steel strips of a limited thickness (2 mm) will be placed between the two layers of boards to create a regular criss-cross mesh with a spacing of about 1 m. This intervention will make it possible to connect the various elements, avoiding mutual disarticulation, without, however, determining critical points at an overall level or modifying the overall

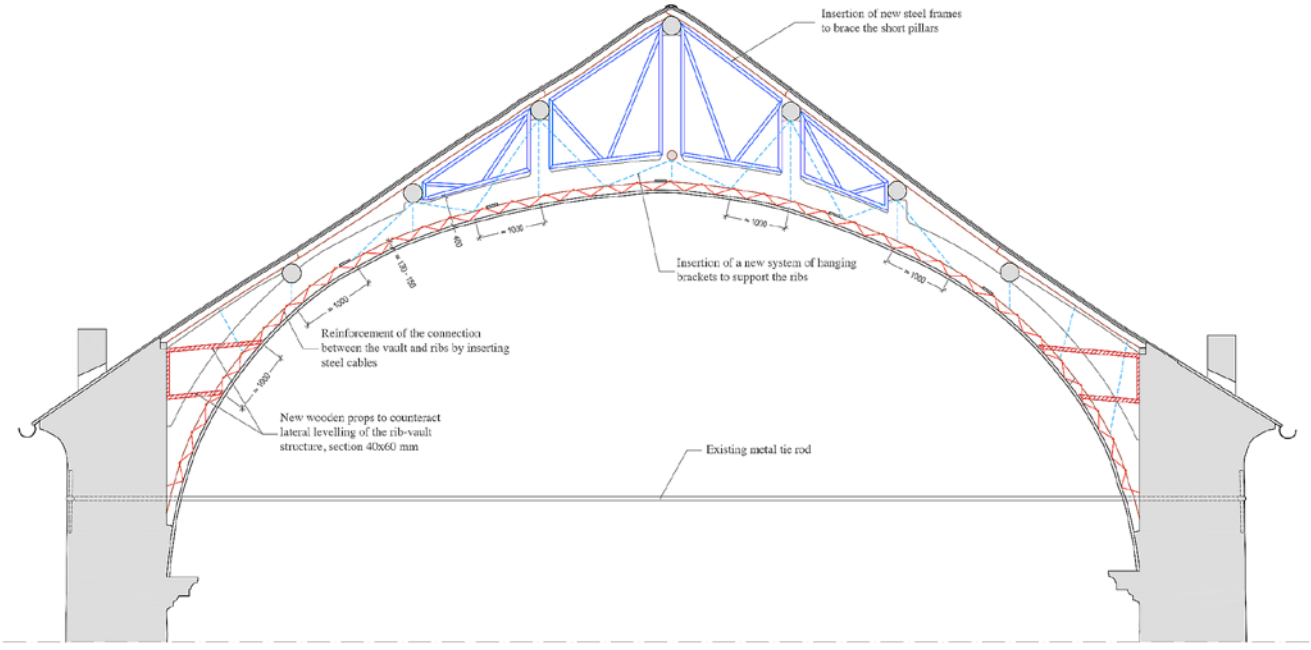

Fig. 12. *Cross-section in correspondence of an arch, consolidation project.*

response. The triple-layer slate roofing will be built with a waterproof sheath over the double planking to prevent infiltration, which in the past has undoubtedly contributed to the current state of deterioration. Openings will be provided in the side walls to allow ventilation of the attic and prevent the accumulation of moisture and condensation.

b. Interventions on the timber-structured vault

The shoring of the vault will precede the work on the vault itself through the creation of continuous ribs (rays of props) with deformable material (such as 10 mm thick polystyrene cakes) placed between the props and the vault since this operation is extremely delicate so as not to compromise the subsequent phases.

The evaluations carried out and described above have made it possible to define the following intervention for the conservation of the timber-structured vault:

- cleaning up the extrados of the vault from the materials currently present. This work will have to be carried out on the entire surface of the vault, allowing, once this preliminary phase has been completed, further verification of the diagnosis made, which has been limited to the accessible areas. Cleaning will be carried out by forced suction of the loose and powdery material deposited. The elimination of loose material on the vault is, in fact, a fundamental operation to permit subsequent consolidation work;
- consolidation of the ribs. The very advanced state of deterioration of many of the wooden elements making up the ribs led to the decision to place new 20 mm wooden boards alongside the damaged existing ribs, where necessary, on both sides, connected by 4 mm diameter screws;
- reconstruction of the collapsed portion of the vault. Reconstruction will be carried out by laying a stainless steel wire mesh plaster holder connected to the wooden ribs, on which a fiber-reinforced hydraulic lime mortar will be applied to reconstruct the portion of the collapsed vault;
- supplementary extrados casting. An extra casting of 10 mm or less will be made on the entire extrados surface of the reed mat of the vault (it is essential to limit the thickness to avoid overloading it). This intervention aims to integrate the irregularities and adequately encompass the portions of the reed mat currently exposed. This intervention will be carried out by infiltration from the extra-

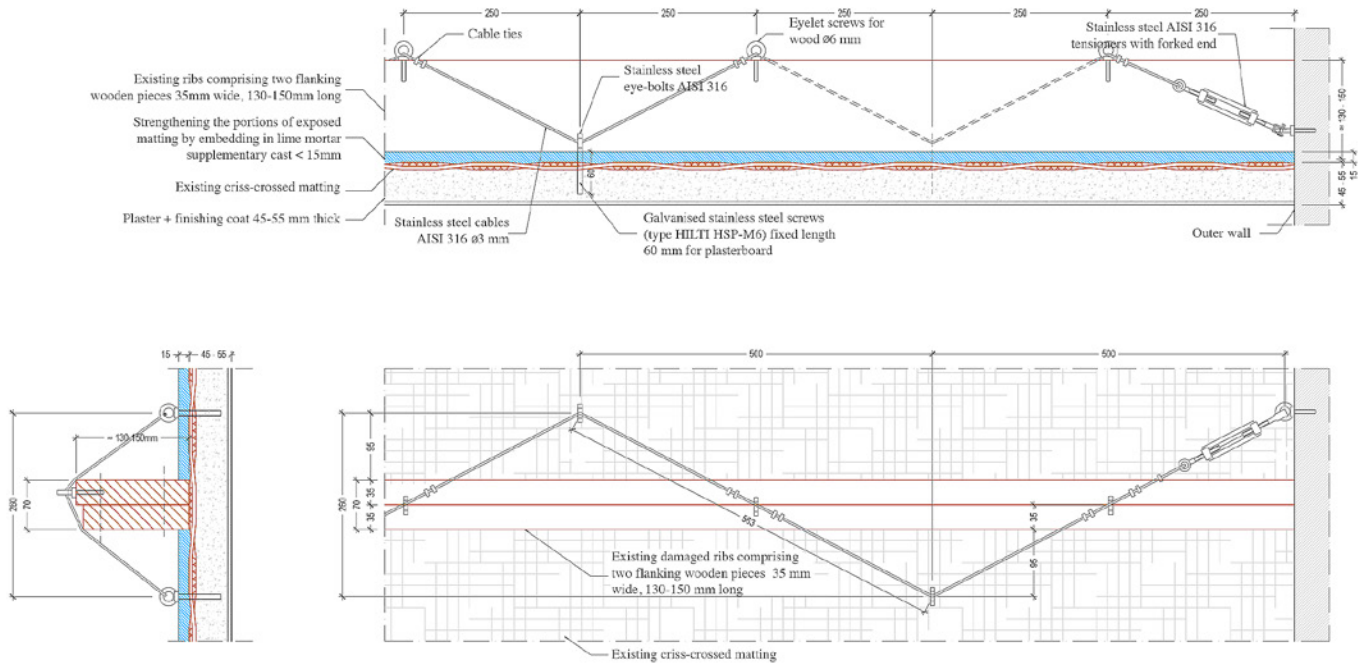

Fig. 13. *Detail of the connection between the vault and the ribs.*

dos in order to recover, as far as possible, the adherence between the underlying plaster and the structure. A cement-free hydraulic lime-based mortar (eco-pozzolan) will be used, with natural siliceous aggregates having a maximum diameter of 2 mm and a compressive strength greater than 15 MPa;

- restoration of the connection between the reed mat and ribs. The connection will be re-established by passing a 3 mm AISI 316 stainless steel stranded cable above the ribs, which will be passed through eyebolts that will be the ends of dowels inserted into the small casting made on top of the reed mat. The cables, continuous along the entire length of the vault, will be anchored to the perimeter walls of the building and tensioned through a tensioner. A tensile spring will be placed between the tensioner and the masonry to keep the cable taut, even in relation to any movements of the vault itself (Fig. 13);
- insertion of a new system of hangers. New hangers will be inserted with galvanized steel ropes (4 mm in diameter), connected to the top of the ribs by inserting wood screws with an upper eyelet (length of the threaded part between 5 cm and 7 cm). A metal element capable of elastic deformation (elastic spring with an elastic constant of 10 to 20 kN/m) is inserted between the tie rod attachment system and the tie rod itself. This new element connected to the turnbuckle will make it possible to dose the tension of the tie rod more appropriately, avoiding concentrations of localized stresses and allowing the vault to deform naturally according to the changes induced by variations in the boundary conditions (variations in humidity, temperature, etc.). Where necessary, it is possible to replace the existing tie rods. This operation must be carried out with the utmost caution, eliminating the existing element only after the new tie rod has been positioned and tensioned so as not to create undesirable deformation during the transitional phase. The presence of the tensile spring with a closed loop, placed between the steel cable and the tensioner, will ensure a more gradual tensioning of the steel cable itself, limiting the possibility of creating states of stress concentrated on the vault and allowing its natural adaptation to climatic conditions. The layout and quantity of hangers will be assessed on-site;
- treatment of wooden elements against woodborers and fungi. Cleaning and protective surface treatment of all exposed wooden elements. If insects are found inside the material, it will be necessary to proceed with punctual disinfestation;
- insertion of reinforcing elements in the areas where the vaults are deformed. At these points, two 40 mm x 60 mm section wooden elements will be inserted, anchored to the perimeter masonry by means of chemical anchors, and screwed to the ribs in such a way as to maintain the shape of the vault and avoid further deformation phenomena (Fig. 12);
- grouting the cracks in the soffit of the vault with mortar made of slaked lime and river sand that is compatible in color, size, and shape with the existing mortar and after stripping the cracks;
- surface consolidation of the plaster on the intrados with nanoclay suspension applied by brush until it is rejected after cleaning the surfaces.

The corniced ceilings of the windows on the upper level will be restored by replacing the damaged and rotting wooden beams/centers, and the portions of the vaulting where the layer of plaster and cornice is missing will be reconstructed by laying a stainless steel mesh plaster holder connected to the wooden ribs, on which hydraulic lime mortar will be applied.

7. CONCLUSIONS

The roof structure of the Men's Oratory is the largest preserved in the Albergo dei Poveri complex and one of the largest in the city of Genoa.

The seventeenth-century mixed structure with transversal masonry arches and a wooden frame made up of longitudinal beams and purlins with a wooden vaulted structure has never been replaced, except for some localized consolidation work.

The difficulties in accessing the extrados of the vault to inspect the construction characteristics and the state of conservation of both the roof structure and the wooden structure vault led to the choice of non-invasive diagnostic techniques (laser scanning and thermography) associated with the execution of three localized tests for the visual inspection of the attic. It will be necessary to carry out an in-depth diagnostic campaign during the construction phase in order to increase the level of knowledge of the structure of the vault, the roof, and above all, the level of deterioration of the individual elements before proceeding with the executive design and implementation of the works.

The project described makes it possible to maintain and restore the architectural elements without altering their structural function by repairing the gaps and improving the structural behavior by eliminating those sources of vulnerability that undermine the structural safety of the building.

Authors contribution

Section 1, 7: M. Casanova, S.F. Musso and S. Podestà; Section 2: S.F. Musso; Section 3, 4: M. Casanova; Section 5, 6: S. Podestà.

8. REFERENCES

[1] Molteni E (1995) L'Albergo dei Poveri di Genova. In: Guerra A, Molteni E, Nicoloso P, Il trionfo della miseria. Gli alberghi dei poveri di Genova, Palermo e Napoli. Electa, Milano, pp 17–78

[2] Franco G, Musso SF (2014) A "Comprehensive Sustainability". New design paradigms and methods for maintaining, conserving and managing monuments and traditional architecture. In: Bisconti G, Driussi G (a cura di) Quale sostenibilità per il restauro? Atti del Convegno di Studi, Bressanone 1-4 luglio. Arcadia Ricerche, Venezia, pp 53–64

[3] Franco G, Musso SF (2014) The "Albergo dei Poveri" in Genova: conserving and using in the uncertainty and in the provisional. In: Della Torre S (a cura di) ICT per il miglioramento del processo conservativo. Proceedings of the International Conference Preventive and Planned Conservation, Monza-Mantova, Italy, 5-9 May. Nardini Editore, Firenze, pp 51–62

[4] Franco G, Cartesegna M (2017) Miglioramento delle prestazioni energetiche degli edifici storici. Uno studio di fattibilità per il completo riuso dell'Albergo dei Poveri di Genova. In: Della Torre S (a cura di) Built Heritage Information Modelling/Management BHIMM. Edizioni Imready-Ingenio, Milano, pp 1–28

[5] Musso SF (2017) Architectural Restoration, I.C.T. and B.I.M. The "Albergo dei Poveri" in Genoa as a Case Study. In: Della Torre S (a cura di) Built Heritage Information Modelling/Management BHIMM. Edizioni Imready-Ingenio, Milano, pp 40–56

[6] Galliani GV (2001) Le strutture di copertura. In: Galliani GV, Franco G (a cura di) Una tecnologia per l'architettura costruita. Forme, strutture e materiali nell'edilizia genovese e ligure. Alinea, Firenze, pp 66–74

[7] Lanza S (2006) Le coperture. In: Galliani GV, Mor G, Beltrami G (a cura di) Manuale del Recupero di Genova Antica. DEI - Tipografia del Genio Civile, Roma, pp 115–148

[8] Montagni C (1993) Costruire in Liguria. Materiali e tecniche degli antichi maestri muratori. Sagep, Genova

[9] Galliani GV (1984) Tecnologia del costruire storico genovese. Sagep, Genova

[10] Acacia S, Casanova M (2017) Constructive Techniques in Historical Buildings. In: Franco G, Magrini A (eds) Historical Buildings and Energy. Springer, Cham, pp 101–132

[11] Acacia S, Casanova M (2015) Which will be its destiny? In: Proceedings of Shatis '15. 3rd International Conference on Structural Health Assessment of Timber Structures. Wroclaw, pp 139–149

[12] Resasco L (1994) Le volte a scheletro ligneo. Finzione, struttura e decorazione in architettura. Tesi di laurea magistrale in Architettura, Università degli Studi di Genova, sup. prof. Galliani GV, a.a. 1994/1995

[13] Corradi M, Filemio V (2005) Strutture lignee di sostegno delle volte in canniccio alla genovese. In: Tampone G (ed) Conservation of historic wooden structures: proceedings of the international conference, Florence, Italy, 22-27 February. Collegio degli Ingegneri della Toscana, Firenze, vol. 1, pp 81–85

[14] Russo V, Romano L, Marulo F (2020) Volte ad incannucciato nel cantiere storico napoletano. Risultati da una ricognizione in progress. Archeologia dell'Architettura XXV, pp 87–102

[15] Romano L (2021) Volte leggere. Saperi e magisteri costruttivi tra Napoli e l'Europa. Nardini Editore, Firenze

[16] Anessi A, Castellini P, Radaelli EO, Jurina L, Martarelli M (2020) Non-destructive consolidation assessment of historical camorcanna ceilings by scanning laser doppler vibrometry. Journal of Nondestructive Evaluation 39:56

[17] Costantino E, Curti E, Podestà S, Stagno G (2009) Le volte a centinatura in legno e camorcanna. La diagnosi dello stato di conservazione della volta dell'aula della Chiesa di San Rocco di Principe – Genova: il degrado invisibile dalla diagnosi all'intervento di conservazione. AIPnD - PnD Congresso, Roma, Italy, ottobre 15-17. eJNDT 2009-12