Pesaro court registration number 3/2015 ISSN 2421-4574 (ONLINE)

Timber-Framed Structures and Standardized Elements of the 20th Century in Genova: Archaeological Analysis of Architecture and Written Sources

Daniela Pittaluga[1*], Juan Antonio Quiros Castillo[2],
1* – Dipartimento Architettura e Design (DAD),Università di Genova (UNIGE), Italy, daniela.pittaluga@unige.it
2 –Departamento de Geografia, Prehistoria y Arqueologia, area de Arqueologia, Universidad del Pais Vasco 2, Leioa, Bizkaia, Spain , quiros.castillo@ehu.eus

Abstract

Timber-framed structures exhibit a serial character, which over time has led to proper standardization and organization at an industrial level, encompassing both the production process and assembly. Historically, such buildings were not typical in Liguria. However, after the Universal Expositions of the late 19th and early 20th centuries, their popularity surged significantly alongside the growth of tourism. Indeed, between the end of the 19th century and the first half of the 20th century, numerous villas and country houses were constructed using timber-frame technology. As this technique became increasingly standardized, it was applied not only to the supporting structure but also to the infill. At this stage, Eternit panels were introduced, and various construction types were detailed in manuals produced by the Eternit company. These manuals also provided information on the most appropriate panels for each application. Research on these artifacts forms part of a broader university research program aimed at enhancing our understanding and techniques for the conservation of contemporary architecture.

Keywords: 20th Century, standardization, wooden-framed structures, architectural archeology

1. Introduction

This paper presents some results of scientific research carried out at the Dipartimento Architettura e Design (DAD), Università di Genova (UNIGE), Italy, on the tools and methods for knowledge and conservation of modern and contemporary architecture in *Progetti di Ricerca di Ateneo PRA* (University Research Projects) for which the writer is the scientific director: PRA201[illegible]-16 *Archeologia dell'Architettura e cantiere di restauro* (Archaeology of Architecture and the Restoration Site), PRA2018-19 *Conservazione e restauro: metodiche di analisi e strategie di monitoraggio e di manutenzione del patrimonio* (Conservation and Restoration: methods of analysis and strategies - monitoring/conservation of material and immaterial heritage), PRA2022-24 *L'archeologia dell'architettura per le strutture del XX e XXI secolo. Conoscenza per il restauro: studi teorici e esempi applicativi* (The Archaeology of Architecture for 20th- and 21st-century structures. Knowledge for restoration: theoretical studies and application examples) [1,2,3]. These research projects share the same purpose, i.e., to investigate recent architecture by means of the tools of architectural archeology in greater depth than hitherto and to grasp its distinctive features. The archeology of architecture involves the *in situ* analysis of materials and components through an approach adopted by archeologists during excavations to establish relationships of posteriority, anteriority, and contemporaneity among the parts under study.

Unlike excavation archeology, however, these observations are carried out on existing buildings, their elevations, plans, and volumes. These tools have long been utilized for historical architecture, with excellent results (see journals such as "*Archeologia dell'Architettura*" ed. All'Insegna del Giglio- Firenze, "*Arqueologia de la Arquitectura*" CSIC-Madrid). The current challenge is determining whether this methodology also applies to modern buildings. Indeed, many contemporary buildings undergo modifications after their construction [4]; such interventions are often due to

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transfer of ownership, changes in tastes, adaptations to regulations, and often also to repair damage due to the deterioration of materials and/or the structure [2]. Understanding the meaning and importance of the various layered traces allows us to intervene in these buildings more consciously and preserve their memory [5]. The restoration of the modern and contemporary heritage is already a necessity and will soon become urgent. Targeted interventions are therefore required. In this article, we will focus on wooden-framed structures with standardized elements. The article is structured in four sections: an introduction concerning the broader research into which this study fits; a brief explanation of the methodology used; the results, including data on Universal Expositions and their influence on traditional building, and the use of Eternit in timber-framed constructions (villas, chalets); conclusions.

2. Methods

The methodology followed is the same as that adopted in all research on the archeology of contemporary architecture. We start with some iconic timber architectures, on which a great deal of data is available, in order to analyze the various characterizing elements of these architectures. We also try to determine whether the tools currently available for studying the man-made environment (particularly the archeology of architecture) are sufficient or need to be modified. This research was therefore carried out in three phases: an initial phase of investigation of indirect sources (bibliographic sources, published and unpublished, archive documents, graphic representations, videos, and interviews); a second phase of data collection from direct sources (tools of the archeology of architecture) [5]; and a third phase of critical reflection concerning both the tools of knowledge and analysis and the impact of such knowledge as a concrete aid to more conscious conservation.

Comparisons were also made with archeological analyses of timber architecture from previous periods since the study of wooden artifacts, as opposed to traditional masonry constructions, presents some additional difficulties, owing to the ease of assembly/disassembly and the interchangeability and seriality of specific pieces. All this, therefore, requires special study expedients [6].

Furthermore, a comparison between the archeological analyses of timber structures of different periods (pre-industrial and 20th century) enables us to understand whether it is necessary to develop different study strategies and analyses on account of the peculiarities of the contemporary era (greater standardization of products and greater and more rapid diffusion of products, materials, and techniques) [1].

Indeed, it is very useful to carry out direct analyses of buildings, as the direct study of artifacts by means of the tools of the archeology of architecture is of fundamental importance not only in the case of all those minor constructions that lack historical documentation but also in cases where there is copious written documentation, as in this latter case it allows us to obtain complementary data and to achieve a better understanding of the artifacts themselves.

3. The first results of the research project

The results obtained enabled us to trace the gradual development of the building culture regarding timber structures in Liguria from the mid-19th century until almost the end of the 20th century. Concerning the use of wood as a building material, we observed an increasingly standardized use of structures in a geographic area without a strong tradition of wood technology. In some ways, however, it could be precisely this relative lack of a tradition of woodworking that prompted the adoption of new solutions. This aspect will be explored in greater depth in the later stages of the research. Another result obtained in this first phase concerned the tools with which to investigate these structures; more targeted and specific tools were developed for the analysis of the archeology of architecture in this type of construction.

3.1. Villas and chalets in Genoa in the first half of the 20th century.

Initial research in Liguria involved taking a census of timber-framed buildings erected between the 19th and 20th centuries [7] (Fig.1); 52 such buildings were identified, while other cases were surveyed later in the research [8]. The result was, in some ways, unexpected; indeed, historically, the use of wood as a building material was not particularly widespread in Liguria, and it was not expected that houses would be built entirely (or almost entirely) of wood in an area rich in stone. The research, therefore, looked for the reasons (if any) for this increased use of wood technology and any differences over time. Specific analyses were then conducted on a few cases of particular interest. In the present article, for the sake of brevity, the essential lines of this research are outlined through a few particularly significant examples (figs.1-9).

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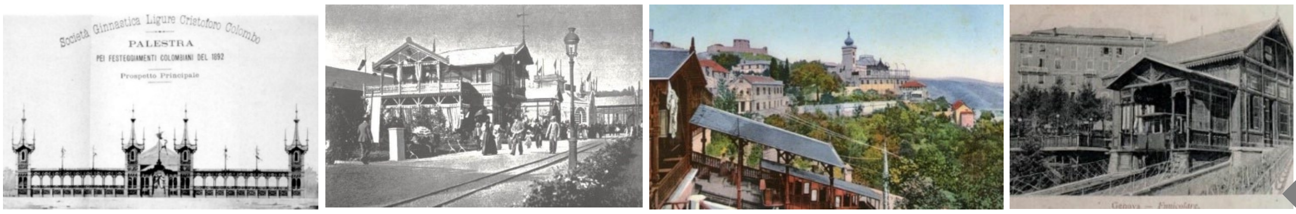

Fig. 1: 1a. R.Haupt, V.Storchi, Progetto della Palestra società ligure "C. Colombo"[C. Colombo Ligurian Society Gymnasium Project] in "Bollettino esposizione Italo-americana 1892" [Italian-American Exhibition Bulletin 1892]; 1b. Chalet Piaggio (source: [8]); 1c. Terminus of the Zecca-Righi Rack Railway (source: [7]); 1d. Terminus of the S. Anna Rack Railway (source:[7]).

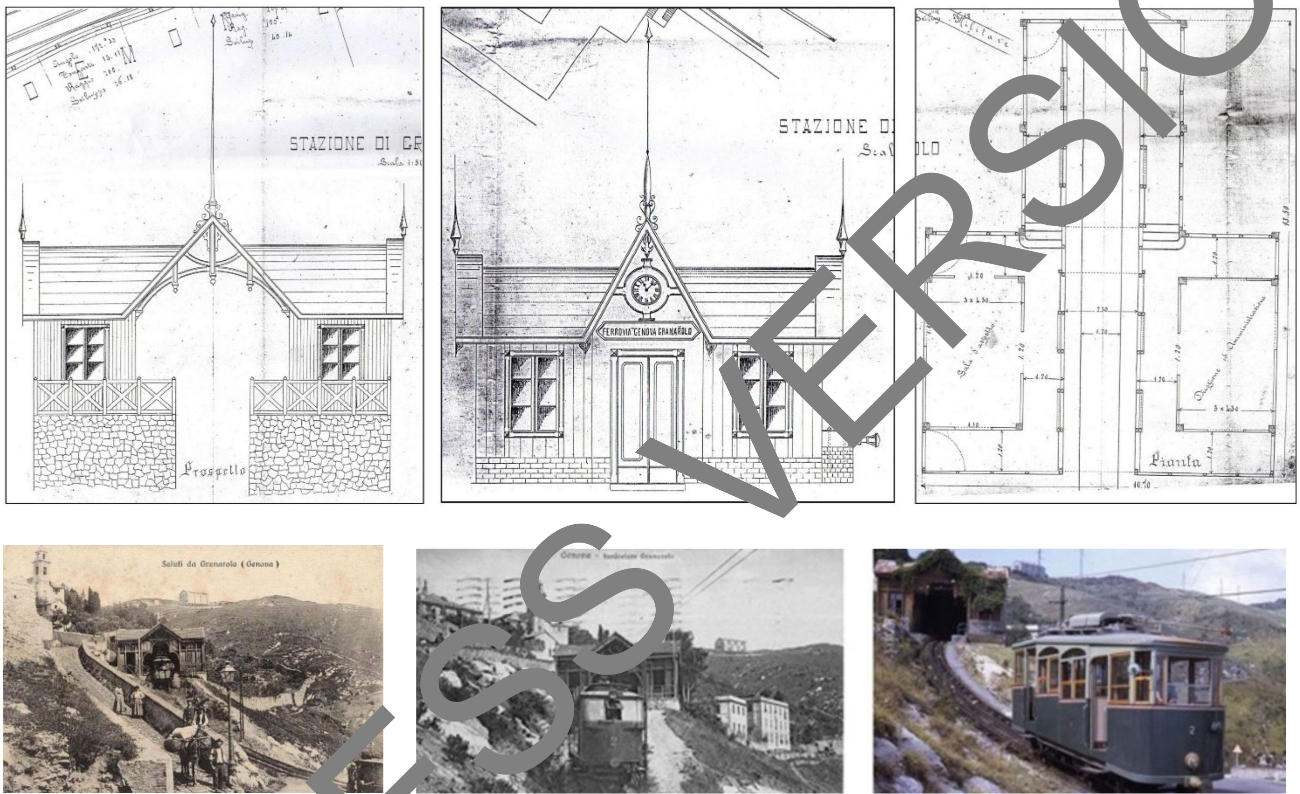

Fig. 2: 2a, 2b, 2c Terminus of the Granarolo Rack Railway design; 2d, 2e, 2f photos. In the early 1900s, the building was smaller and was covered by a double sloping roof; there were only three rooms, a waiting room, and an office for administration and management. (source: [7]).

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Pesaro court registration number 3/2015
ISSN 2421-4574 (ONLINE)

Fig. 3: Terminus of the Granarolo Rack Railway. In the early 1900s, the building was smaller and was covered by a double-sloping roof; there were only three rooms, a waiting room, and an office for administration and management. After the Second World War, the structure was significantly extended towards the hill behind. According to some hypotheses, the timber structure may have come from the Columbus Exhibition (CE) held in Genoa in 1892. The original plans for the station were found in the archives of the Azienda Municipalizzata Trasporti (AMT): a technical report dated 16 May 1893 states, «a chalet will be built for station use». Some details of the construction and similarities with artifacts displayed at the CE would seem to corroborate this hypothesis. Possible confirmation could come from the dendrochronological analysis of some original structural components. The load-bearing structure consists of uprights, secondary crosspieces, and "St. Andrew's crosses". These elements have a section of 20x20 cm. The joints are mostly interlocking, with lap joints or mortise and tenon joints. The smaller elements are joined with "wooden pins". Over the years, the framework has undergone various interventions, some of which were not carried out in the best way. Consequently, uneven stress has caused the main transom of the façade to incline. (source: [7])

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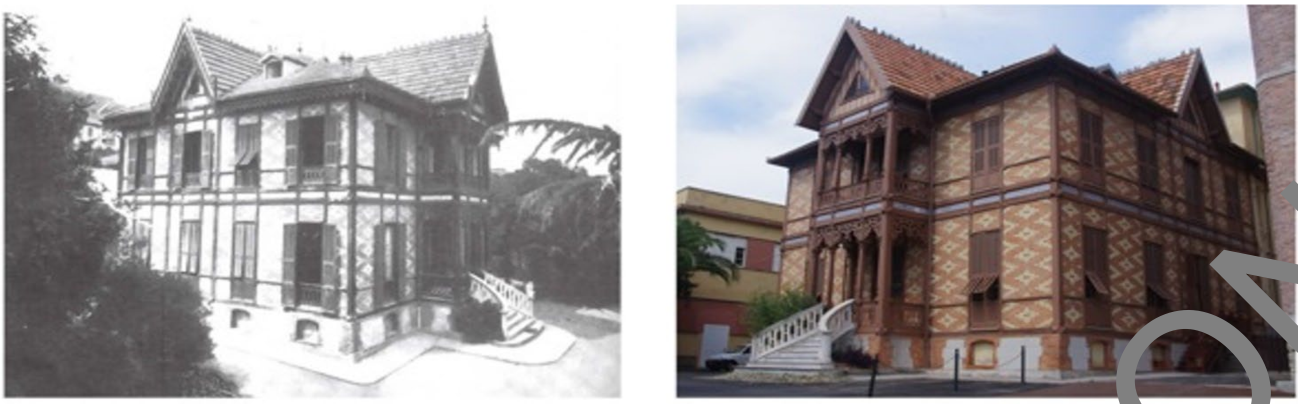
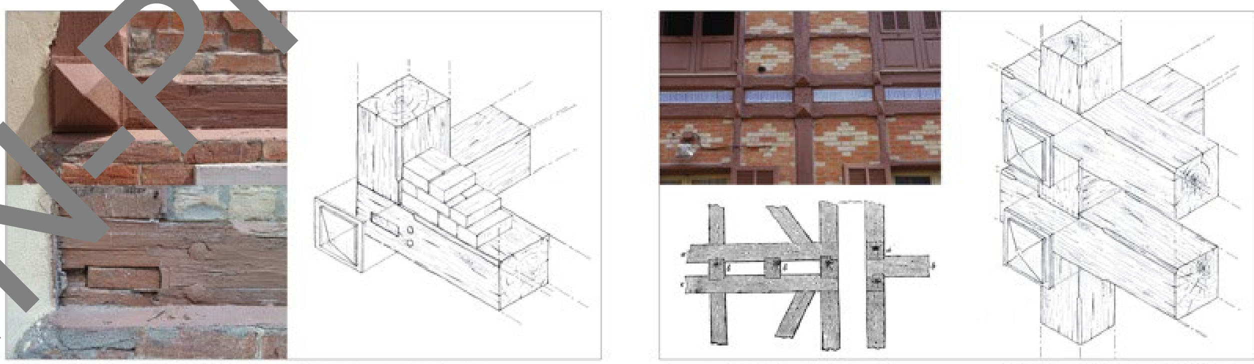


Villa Ida, ante anni '30 Canonica di Cristo Re, 2016

Fig.4: Villa Ida (or Canonica di Cristo Re). Villa Ida (1888) was built after a terrible earthquake. Designed by engineer Giovanni Sicardi. In 1933, it passed into the ownership of the Curia. This earthquake-proof structure turned out to be extremely effective: despite bombings and related air displacements in this area in 1943-'44, no damage was found to this structure. (source: [7])

Fig.5: Villa Ida. Non-destructive investigations to understand the structure: magnetometer survey and thermographic survey. (source: [7]).



Connessione d'angolo tra dormienti - montante Schizzo della connessione d'angolo, a cura di Linda Secondini Connessione tra telai - travi del solaio, basatata su "Costruzioni in legno", G. A. Breymann, 1851 Schizzo della connessione telai - travi del solaio a cura di Linda Secondini

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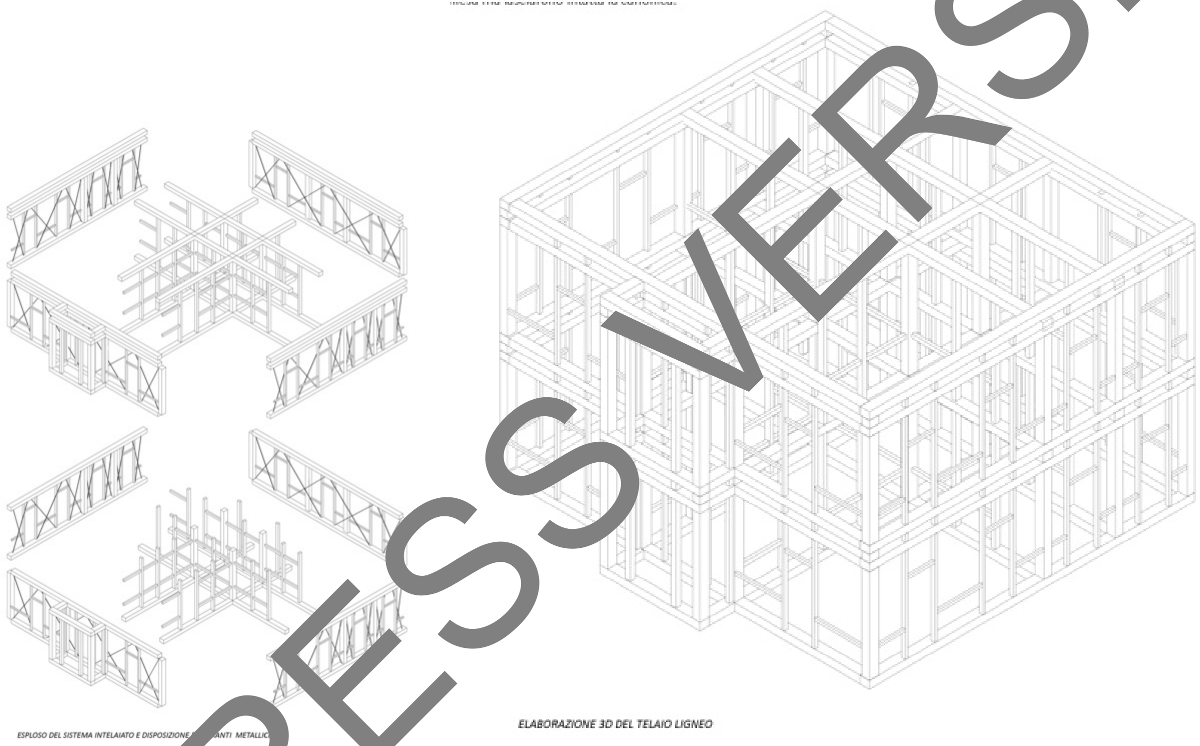

Fig.6: Villa Ida research: the load-bearing system consists of two overlapping frames in complete connection with each other; there are also iron tie rods between the different elements. The basement is made of stone masonry. The connections: the double-frame system is like that illustrated by Breymann in 1851. The connections are tenon and mortise (for orthogonal joints of the ground-beams) and overlapping connection with a "connecting rod" for in-line connections between ground-beams (photos by Silvia Gelvi, Linda Secondini, source: [7])

From the second half of the 19th century onwards, the idea of the holiday home as a place of escape immersed in nature became more popular. Among the various Italian holiday settlements of the early 20th century, those that developed in the Apennines near Genoa are of great interest. This consisted of a system of single-family villas with gardens in an area between the upper Val Polcevera and Valle Scrivia as far as Valle Stura on the border with the Province of Alessandria.
In many cases, precisely in these structures, a greater propensity can be seen for experimentation and using innovative materials and/or techniques, including wood. One such building is Villa Piaggio (figs. 7-9). Built in 1908 above Masone at the behest of the Piaggio family, the villa was designed by architect Riccardo Haupt (1864-1950), who was very active in Genoa then. Documents from indirect sources (bibliography, archive documents) were examined, and subsequently, through inspections, a fact sheet was compiled, and all the components of the "frame" system adopted in this villa were

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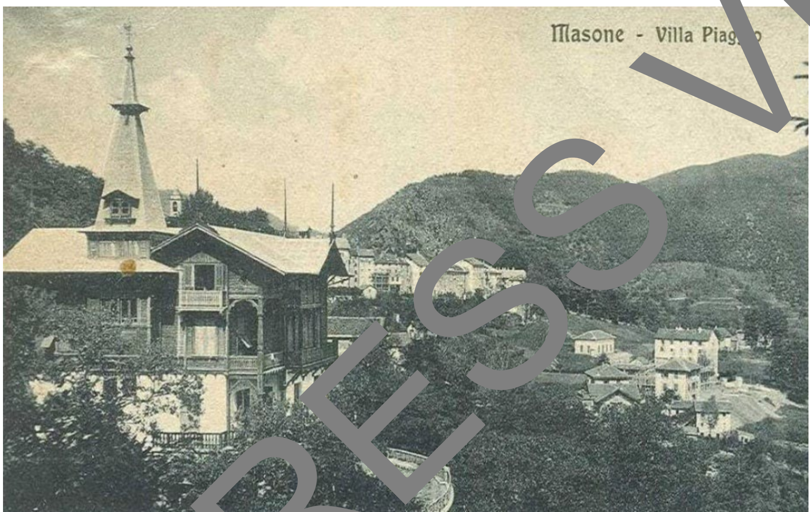
described with the aid of thermographic surveys of non-visible portions and the partial modifications made over time were highlighted [7, 9].

The building has three levels: the ground floor is made of masonry, and the two upper levels are made of wood. As was typical of the period of its construction, the villa displays eclectic features, with Art Nouveau and neo-Gothic styles being particularly evident in the turret. Haupt described his project as follows: «A Masone ho costruito la villa del senatore Rinaldo Piaggio, che consisteva in un grande chalet con base in pietra. Una parte in muratura intonacata di bianco e tutta la parte superiore in legno di pino, con verande e cuspide che ricordano lo chalet Piaggio [padiglione aziendale della famiglia Piaggio r.n.] della Mostra Colombiana e le torri della Palestra Ginnastica Ligure "C. Colombo" da me costruite nel 1892. (In Masone, I built Senator Rinaldo Piaggio's villa, which consisted of a large chalet with a stone base. Part of it in masonry plastered in white and the whole of the upper part in pitch-pine wood, with verandas and spire reminiscent of the Piaggio chalet [Piaggio family's company pavilion r.n.] in the Mostra Colombiana and the towers of the Palestra Ginnastica Ligure "C. Colombo" that I built in 1892) » [10; 11]. Haupt had also designed the buildings for the Piaggio factories in Sestri Ponente, which housed the shipyards and the railway carriage factory: «Per la ditta R. Piaggio & C. di Sestri Ponente, oltre agli uffici amministrativi e alla grande facciata, ho progettato anche un grande edificio per usi diversi con annessa portineria e la facciata su strada di un altro padiglione per la produzione di carrozze ferroviarie di lusso.

(For the firm R. Piaggio & C. in Sestri Ponente, in addition to the administrative offices and the large façade, I also designed a large building for various uses with an annexed factory porter's lodge and the street façade of another pavilion for the manufacture of luxury railway carriages)» [10; 11]. This case study testifies to an initial transition from timber constructions for exhibitions to a codified and standardized system used to build villas. This transition was made possible by architects such as Haupt, who transferred the experience they had acquired in ephemeral constructions to a more codified design method that could be reproduced with limited variations.



Figs.7, 8: Villa Piaggio researches. The villa was designed by R. Haupt in 1907. The load-bearing structure on the ground floor has exposed timber pillars and rafters. On the upper floor, there is a timber cladding with industrially processed elements. (source: Maraldi's archive)

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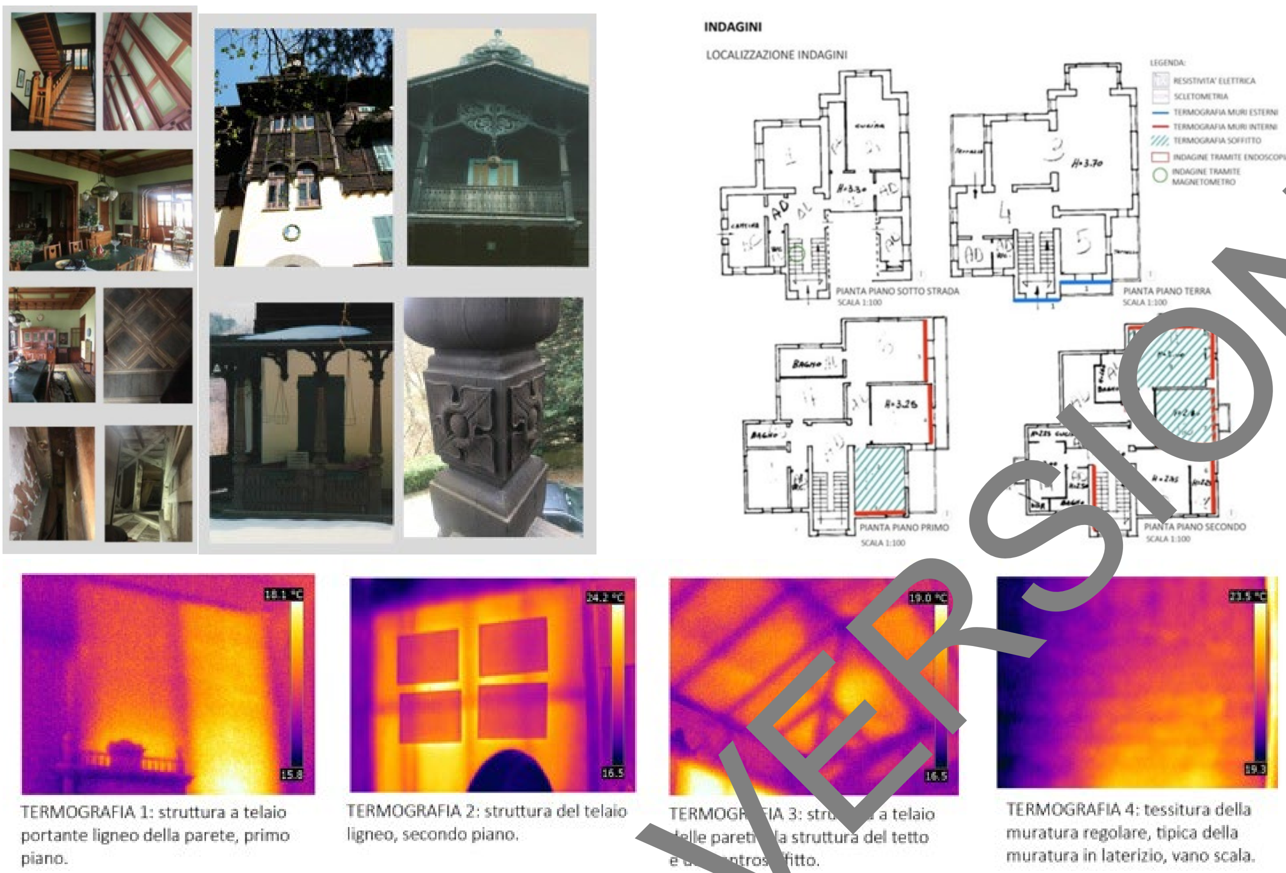

Fig, 9: An initial visual inspection was carried out on-site. Thermographic Survey: Conducted using a FLIR Thermocam TMB 400, this analysis revealed the timber-framed structure now concealed beneath the plaster. Endoscopic Analysis: Performed in the crawl space, this investigation confirmed and complemented the thermographic findings. Magnetometric Survey: Conducted in the stairwell, it revealed that the staircase is made of precast L-shaped steps in reinforced concrete and iron. These elements are likely among the earliest examples of precast reinforced concrete used in Liguria.(Photos by Chiara Marvaldi, source: [9])

The first decades of the 20th century constituted a special moment for Italy; the country was going through a phase of industrial take-off and, while lagging behind the great European nations, had great potential. New spaces were opening up for those with skills and initiative. Villino Eternit, in Via Giordano Bruno 19 (fig.10), fits into this context; it was inspired by the eclectic villa with a tower, which was popular around 1890-1930 [12].

Fig.10: Villino Eternit in via G. Bruno 19 (photos by Jacopo Baccani, source [12])

Its decorative features reveal various stylistic influences: geometry, rejection of the curved line (Hoffmann and Viennese secession), floral decorative elements, and naturalism. This villa was built at the behest of Cav. Ferruccio Gay, who, in 1920, asked the engineer Filippo Daneri to design a 'stately home'. Gay was a Roman engineer and the owner of the Ferruccio Gay company in Rome, which specialized in earthquake-proof housing systems. In those years, Gay also patented a prefabrication system consisting of a masonry base, a wooden cage, and sheet infill of a new and promising material:

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Eternit. In 1908, he had already designed and built a demountable timber house in Rome [13, 14]. This prototype, which is still visible, was proposed by F. Gay himself as a possible industrial solution (through the large-scale production of prefabricated earthquake-proof houses) to the massive demand for housing following the Messina and Reggio Calabria earthquakes. In this structure, unlike the one in Genoa, all the bolts are visible on the façade (wood/wood connections no longer being used). For the Villino Eternit, Gay specifically requested that it should be constructed according to "Cav. Ferruccio Gay's exclusive system". Gay also specified the characteristics that the building had to have and the materials to be used: «…t Questa costruzione è costituita da una base in muratura e da una sovrastante struttura in legno a giunti continui, rivestita internamente ed esternamente con pannelli di Eternit.(…this construction consists of a masonry base and an overlying wooden frame with continuous joints, covered inside and outside with Eternit panels...)». (document dated 7 July 1920, Genoa Municipal Historical Archives). The Municipality of Genoa, «…tenendo conto della novità dell'impianto (taking into account the novelty of the facility)», granted building permission. This building was still standing in 2015, being demolished only later in 2021. In 1984, however, it had undergone a major renovation and the removal of the Eternit material [13].

The history of this building is also very special in some respects. The local newspaper (the Secolo XIX), on 19 November 1918, stated that: «…nell'euforia della vittoria nella Grande Guerra, è stata indetta una lotteria di beneficenza a favore della Croce Rossa, con in palio nientemeno che una villetta nella pregiata zona di Albaro…(…in the euphoria of victory in the Great War, a charity lottery for the Red Cross has been announced, the prize being nothing less than a small villa in the highly prized Albaro area…)» [13]. The article does not go into technical specifications, simply mentioning «una struttura in legno e pannelli di amianto (a structure made of wood and asbestos panels)». However, why choose wood? This choice should not sound too strange, as wood was used in construction at the time much more often than is generally believed, for example, in the pavilions of the numerous exhibitions held in those years (in 1892, 1901, and 1914 in Genoa alone), minor rack railway stations, and "chalets" at the terminuses of the Sant'Anna, Righi (Fig.1) and Granarolo (Fig.2)[19]. Moreover, the subject of prefabrication was highly topical at the time. The use of asbestos panels can be explained on the one hand by the enterprising approach to experimentation that characterized Gay's entire work and on the other by his friendship with the industrialist Adolfo Pietro Mazza, who had founded the Italian trust company Eternit in Genoa in 1906. A year later, Mazza set up his factory in Casale Monferrato and later on, in 1917, patented his method of constructing fiber-cement pipes that would definitively establish the company. In the case of Villino Eternit, prefabrication reduced costs considerably, which made the building a suitable lottery prize. Once the materials and suppliers had been selected, all that remained was to find a competent architect. Interestingly, Paolo Vietti Violi, perhaps the most prolific Italian designer of sports facilities, was in Genoa for reasons of service during the First World War. Among the facilities he designed were the Capannelle (Rome), Cascine (Florence) and San Siro (Milan) racecourses. Indeed, his specialization was particularly congenial to him until the 1920s, when stadiums and racecourses were mostly built of wood. «Ecco allora che, in un'operazione un po' celebrativa, un po' d'immagine e un po' paternalistica, convergono una serie di nomi di prim'ordine: non ultimi, l'onnipresente Aedes e quell'"amministrazione Borzino", cioè l'assicuratore Emilio Borzino, ed Evan George Mackenzie, ex socio di Ausonia e poi presidente del Lloyd Italico. (Here, then, in a somewhat celebratory, somewhat image-driven, and somewhat paternalistic operation, a series of first-rate names converge: not least, the ubiquitous Aedes and that "Borzino administration", namely the insurer Emilio Borzino, and Evan George Mackenzie, the former partner of Ausonia and subsequently President of Lloyd Italico)» [13].

Here, a second transition can be identified: from wooden buildings to those made of wood and asbestos panels. Moreover, through the figure of the designer, experience was transferred from simpler standardized structures, such as those built in the post-earthquake emergency of the early 20th century, to the experience exploited in the construction of more sophisticated residences.

Given the success of Villino Eternit, in 1923, a small villa made of wood and Eternit artificial stone with the same characteristics was built on the same street by engineer Camuzzoni for Countess Ruspoli [7, pages 272-273].

A slightly different story is that of the chalet of the "Carlini Stadium", though the characteristics of its construction are similar. Built in 1912 by the Nafta company, an oil company that had contributed financially to the completion of the stadium, it was not opened until much later, in 1927, owing to various economic vicissitudes. In addition to the stadium, a service building called "the chalet" was erected. This originally housed a meeting room on the first floor and a bar/restaurant and reception room on the ground floor serving the stadium. It was used to host meetings and conferences. Now owned by Eni, it is currently a decommissioned building [7, page 276].

What unites all these buildings is the use of standardized timber components, designed for easy assembly, disassembly, and replication. Identical dimensions and details can be found in both refined architectural residences, often promoted in

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catalogs, and in prefabricated houses built to address post-disaster housing needs. The main point of differentiation lies in the level of refinement—such as a decorative joint concealing a bolt—that is more likely to be found in bourgeois cottages than in emergency housing.

3.2 Universal Expositions and Exhibitions in Genoa and their influence on traditional construction

After 1850, great changes occurred throughout Europe; France, followed by other nations, relaxed customs barriers and gradually liberalized international trade. Expositions, privileged settings in which to compare products from all over the world and the progress of engineering, became universal: London 1851, Paris 1889, Chicago 1893. From 1851 to 1889, the buildings erected for the Universal Expositions testified to the great progress in construction. For example, The Crystal Palace, which housed the Great Exhibition in London in 1851, was a revolutionary building made of wood, iron, and glass, the first large-scale testimony to the application of mass production and manufacturing. Even at that time, its architect, Joseph Paxton, had the foresight to divide the entire construction into a simple system of small prefabricated units (e.g., curved wooden frames for the glass, iron lattice girders, and so on).

Great exhibitions were also held in Genoa. The 1892 Italian-American Exhibition, organized to celebrate the 400th anniversary of the discovery of America, was a major local event supported by the Cristoforo Colombo Ligure Gymnastics Society (fig.1). Bisagno esplanade was the designated site of the exhibition, and architect Riccardo Haupt, together with Giovanni Battista Carpineti, Vittorio Storchi, and Mario Vallino, designed the main pavilions, including the Chalet by Rinaldo Piaggio & C from Sestri Ponente. Haupt was in charge of their construction and was responsible for the majority of the exhibition's wooden structures [10, page 53](fig.1).

Another impressive creation was the Società Ginnastica Ligure "C, Colombo" gymnastic stadium, designed by Haupt and the engineer Vittorio Storchi. The porticoed structure that delimited the inner square was composed of a continuous wooden truss. This architectural solution, which provided side tiers and a grandstand raised above the ground, was very similar to the two-story structure that had been built a few years earlier (1887) by Haupt inside Rinaldo Piaggio's industrial plant in Sestri Ponente. In 1901, architect Wenceslao Borzani [14] was commissioned to set up the 7th Regional Exhibition of Arts and Industries. Assisted by engineer Bregante, Borzani [14] created a series of phantasmagorical Art Nouveau constructions with fervid ingenuity. The experimentalism implemented by the young architect attested to his avant-garde style, his irreverent architectures being a veritable innovation in the Genoese environment, which was traditionally provincial and refractory to novelty. The façade of the entrance to the pavilion clearly drew inspiration from Art Nouveau's experiences of Franco-Belgian derivation in reference to the renewal of taste in international models that introduced Art Nouveau to Genoa. Numerous 'modern' artists were involved in decorating the pavilions.

The Genoese exhibition was a veritable temporary citadel of the materials used for the exhibition's pavilions [14, page 93]. In 1914, the Navy and Marine Hygiene Exposition was held in Genoa. Built by Gino Coppedè, the main buildings were the auditorium, the Pavilion of the Military Navy, those of the Merchant Navy, and those of the Hygiene and Navigation Companies. There were also buildings dedicated to the Italian-American Section; among these, the exotic Colonial Village had a great scenic impact: iconic historical architectures were reconstructed, including a medieval citadel, the Galata Tower, and the Caramanli Mosque of Tripoli. Everything was constructed of wood and plasterboard.

3.3 Framed structures

Timber-frame or post-and-beam construction has been a fundamental aspect of building technology across various historical periods. The dimensions and configurations of these structures have been shaped by factors such as material availability, socio-cultural influences, climatic conditions, and historical context [15]. The standardization of structural components developed gradually, with each country advancing at its own pace. By the 20th century, timber elements were routinely employed for both primary load-bearing frameworks and secondary infill systems (figs. 11, 12).

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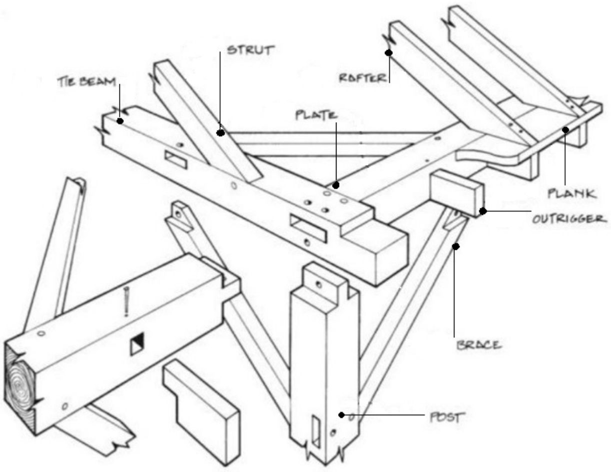

Fig.11: Detail of joints between wooden elements perpendicular to each other (reworked by source J.A. Sobon "Historic American Timbery Joinery", Timber Framers Guild ed., 2002)

Load-bearing structures were constructed using false struts or inclined braces, effectively reducing the horizontal thrust due to their steep angles. Floor structures played a key role in counteracting the lateral forces transmitted through the struts. In addition to horizontal and vertical members, diagonal braces were incorporated, which were crucial for structural stability, functioning as compression struts and enhancing the overall rigidity of the frame. One of the most critical and sensitive aspects of the structure was its connection to the ground, primarily due to the issue of rising damp. This was typically addressed through the use of masonry plinths, upon which the timber posts were seated. In some configurations, a timber sill beam (or ground beam) was laid atop the plinth, with the vertical posts connected to it using simple joinery techniques. Bracing elements within the rectangular frame contributed to node rigidity, where joints formed the key connection points. These bracing members were typically inclined at approximately 60° to the horizontal and were joined to the vertical posts. The nodes themselves constituted the fundamental structural units of the timber-framed system.

The integrity of the framed system depended on these nodes, which came in various types:

1. End-to-end connections of two horizontal members (used to span large distances);
2. Right-angle connections (T- or L-shaped) between primary and secondary elements at corners or floor intersections;
3. Vertical-to-horizontal joints, both in configurations with through-posts or through-beams;
4. Oblique connections linking pitched roof supports with diagonal bracing.

More complex nodes involved the intersection of three elements. Tongue-and-groove joints required shaping the connected pieces, which slightly reduced the structural cross-section. Common joint types included:

- Scarf joints (single or double, straight or oblique e.g. nibbed splice joint, nibbed scarf joint, tabled splice joint, stop-played scarf joint, tabled hooked joint, stop-played scarfed joint);
- Dovetail joints (full or half);
- Mortise and tenon joints—a classic method where a projecting tenon fits into a mortise slot in the adjoining member. These could be either blind mortises or through-tenons, often secured with wedges or wooden pegs.

Horizontal joints were often of the "protected" type, ensuring they remained flush and aligned by interlocking. Additional strength was provided by "through-bolts" or pegs [16].

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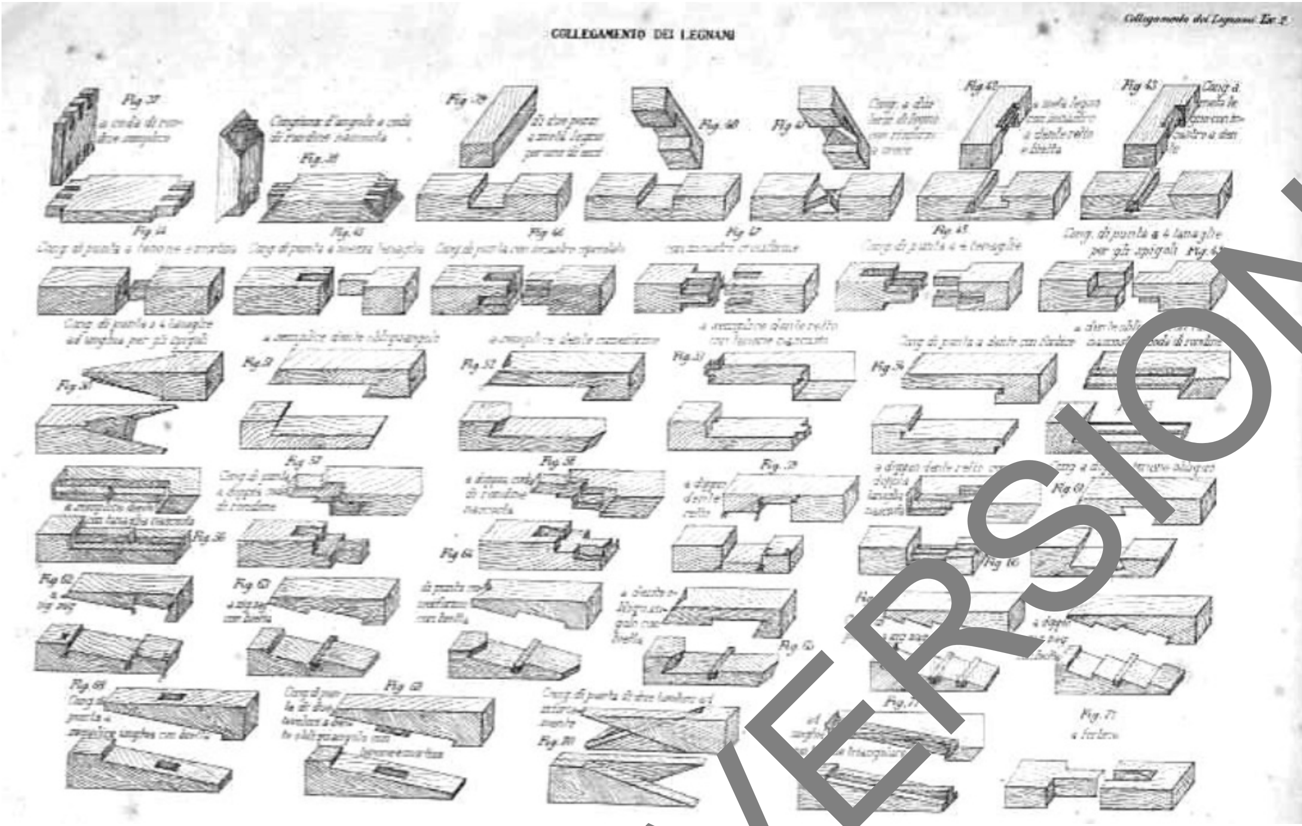

Fig. 12: Timber connection (source: [17])

The decoration of half-timbered façades varied greatly according to the construction area and the time available to finish the construction. Decorative value was generally provided by arranging the sloping elements, inserting other sloping elements without any real static utility, carving the elements with bas-reliefs, or painting the elements and the interstices. Attic floors had the function of chains, and at least one pillar was positioned at the ridge line. Art. 13 of *Norme tecniche ed igieniche obbligatorie per le riparazioni, ricostruzioni e nuove costruzioni degli edifici pubblici e privati nei comuni colpiti dal terremoto del 28 dicembre 1908 o da altri anteriori, R.D. 18 aprile 1909, n.193* (the First Earthquake-proof Standard issued by the Italian Government) specified that framed structures must have at least one of the following means of stiffening: a) rigid connections of the members at the points of intersection, diagonal connections or bracing, filling and cladding of structures such as to effectively resist deformations. According to Art. 14, by filling or cladding, the following structures were allowed in framed constructions: a) reinforced, caged or otherwise consolidated masonry, especially when it constitutes a means of stiffening; b) simple or double walls of natural or artificial slabs, of plastered metal mesh, of injected or coated wood planking, or of any other material that presents solidity, lightness and is immune as far as possible from the action of fire and atmospheric humidity: c) the masonry structures indicated in Art. 8 above (ordinary masonry) limited to the ground floor only. For insulated rural houses only, the use of double walls with wooden battens or wire mesh filled with light material, even if made of clay or other unfired substances, is permitted. According to Art. 15, «… Gli edifici a struttura in legno devono avere le centine montanti realizzate in un unico pezzo, almeno collegate in modo solido e robusto, o rinforzate nei giunti per evitare sezioni deboli…(…timber-framed buildings must have their upright ribs made in one piece, at least firmly and sturdily connected, or strengthened at the joints to avoid any weak sections...)» [18].

3.4 *The use of Eternit in framed constructions*

Eternit is a registered trademark for fiber cement, and the name of the company that produces it is owned by the Belgian company Etex. The history of asbestos cement or fiber cement began in 1901 when the Austrian industrialist Ludwig Hatschek patented the material that would later become known as Eternit. Hatschek granted licenses for his patent, one for each country concerned, and dealers were obliged to use the name Eternit in their companies and for their products. A year after the patent was granted, the industrialist Alois Steinmann acquired a production license and opened Schweizerische Eternitwerke A.G. in Niederurnen, Switzerland, in 1903. The new product aroused great expectations, and, indeed, by

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1911, production was running at full capacity. Products were also exported to Africa, Asia, and South America. In 1907, the first Italian factory was opened in Casale Monferrato, Piedmont. Another factory was subsequently opened in Cavagnolo (Turin). Eternit rapidly gained popularity, and in 1911, the production of Eternit panels and tiles took full advantage of the factory's production capacity. In 1928, the production of fiber cement pipes began; until the 1970s, these were standard components in the construction of aqueducts. A few years later, corrugated sheets appeared, which were often used for roofs and sheds. However, the shortage of raw materials during the First World War forced the company to look for alternatives. After the war, production was restarted, and sales rose to an all-time high in 1919. In the 1960s, medical research revealed that asbestos dust, generated by wear and tear on roofs and used as a base material for paving, caused asbestosis and a serious form of cancer, pleural mesothelioma. However, Eternit and Fibronit continued to produce artifacts until 1986. Since 1994, fiber cement has continued to be produced without asbestos as a reinforcing material. Instead of asbestos, organic, natural, and synthetic fibers have been used. In Italy, this material has been renamed 'ecological fiber cement': while retaining its original strength characteristics, it is not carcinogenic in production, use, or disposal phases. [6, page 134]. Issue N° 82 of AC magazine, published by S.A. [19], featured an article on the use of asbestos cement as a material that could be used to re-frame historic frame buildings in order to protect the exterior from weathering agents if the funds need to restore them were insufficient.

3.5 The catalog of demountable construction

In the early 1900s, the Eternit company published its catalog, "*Costruzioni smontabili*" (Demountable Constructions) (figs. 9-14), in which various types of demountable buildings were proposed [20]. These were timber-frame structures with Eternit panels as infill. The company proposed this combination of materials because «Eternit panels can be worked as easily as wood and with the same tools; they can be sawed, sheared, drilled, nailed» [20][7, page 135]. The dimensions of both the fiber-cement panels and the lattice structure were described in detail, as well as the loads that these elements could bear in the various types of buildings proposed in the catalog. For example, the catalog advertised flat panels of four different sizes (1.00x1.00, 1.20x1.20, 1.20x2.50, and 1.20x3.75 m). A curiosity: the publication also stated that: «Possono essere forniti anche pannelli in dimensioni inglesi, ovvero: piedi 4' 0'' x 4' 0" pari a 1,22x1,2 =1,44 mq, 4' 0''x 6' 0'' pari a 1,22x1,83= 2,23 mq, 4' 0''x 8' 0'' pari a 1,22 x 2,44 = 2,98 mq, 4' 0'' x 10' 0'' pari a 1,22x3,05=3,72 mq, e 4' 0''x12' 0" pari a 1,22x3,66 = 4,47 mq. (Panels in English sizes can also be supplied, namely: feet 4' 0" x 4' 0" equal to 1.22x1.2 =1.44 sq.m., 4' 0"x 6' 0" equal to 1.22x1.83= 2.23 sq.m, 4' 0"x 8'0" equal to 1.22 x 2.44 = 2.98 sq.m, 4' 0" x 10' 0" equal to 1.22x3.05=3.72 sq.m, and 4' 0"x12' 0" equal to 1.22x3.66 = 4.47 sq. m)» [19]. The standard thickness of panels for ceilings was 3.5-4 mm, and for cladding, 4.5-5mm; however, panels with thicknesses of 6, 7, 8, 10, 12, 14, 16, 18, and 20 mm were produced and, upon request, panels of intermediate or greater thicknesses. The manual then gave some general indications on the use of the panels in the different thicknesses. For example, panels of the minimum thickness (3.5-4 mm) were generally recommended for constructing ceilings, protecting wooden ceilings, and attics. They were particularly recommended as a protection against fire and the action of steam and moisture. The maximum recommended distance between supports was 60 cm. Thicknesses of 4.5 to 5 mm were generally used for cladding, to make ventilation and smoke ducts «... e per altri lavori (... and for other work)» [7]. The normal distance between supports in wall cladding «should be 40 cm». For the construction of the walls of pavilions, huts, garages, hangars, facilities for poultry, hen houses, rabbit hutches, kennels, plinths, door panels, shutter panels, furniture, cabinet tops, shelves, smoke hoods, and so on, the distance between supports «…può essere di 50-60 cm(…may be 50-60 cm)». Thicknesses from 10 to 12 mm were recommended for cladding and for wall constructions that were to resist relatively strong impacts and pressures, for exterior cladding, kitchen, and laboratory table tops, cladding of projection booths, furniture, sturdy plinths, supports for electrical appliances, meter boards, etc. The distance between supports «…può arrivare a 80 cm (… may be up to 80 cm)» (fig.13).

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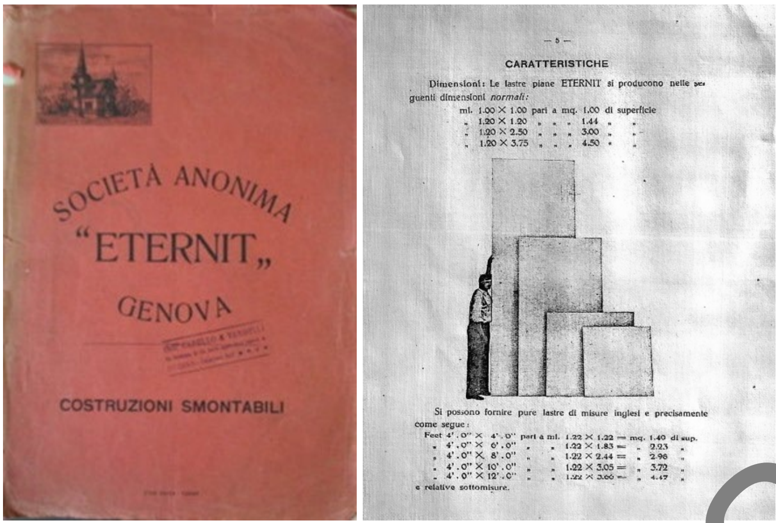

Figs. 13: Società anonima "Eternit" (1911), Strutture smontabili, Genova. [20] (photos by Lin[illegible] Secondini)

For the largest standard panel sizes produced in non-metric thicknesses (14 to 2[illegible] mm), the following applications were recommended: particularly sturdy plinths, chimney boards and components, window sills, cladding for transformer cabins, X-ray booths, power distribution panels, *"e altre applicazioni (and other applications)"* [20 p. 7].
The manual also included details about the manufacturing process: *"Produciamo pannelli "semicompressi", che sono sottoposti solo alla pressione esercitata dalle macchine di produzione e hanno una faccia liscia", e pannelli compressi, che "ancora freschi, subiscono un'ulteriore forte compressione idraulica e sono lisci su entrambi i lati. (We produce"* semi-compressed*" panels, which are subjected only to the pressure exerted by the production machines and have one smooth face,"* and compressed panels, which *"while still fresh, undergo an additional strong hydraulic compression and are smooth on both sides)"* [20, p. 7]. The compressed panels were manufactured in sizes up to 1.20 × 2.50 m.
Weight data were also provided, with a note specifying that the listed values should be increased by approximately 15% in the case of compressed panels (see Table 1).

Tab.1: Eternit panels: thickness and weight. Source: [20

thickness (cm)	3.5	4.5	[illegible]	7	8	10	12	14	16	18	20
weight (kg/m²)	6.70	8.50	9.[illegible]	11.5[illegible]	13.20	16.50	19.80	23.10	26.40	29.70	33

Additionally, data on bending resistance were provided. In particular, the manual included information on the breaking load of semi-compressed panels with a width of 1.20 meters, subjected to a uniformly distributed load and supported at two points. The published table [20, p. [illegible]] showed values for various distances between supports (e.g., 120, 100, 80 cm). For compressed panels, the allowable loads could be increased by approximately 30%. It was also noted that in the case of concentrated loads, failure could occur at approximately half the values indicated in the table.

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Tab.2: Eternit panels: thickness and distance between supports source:[20]

Distance between supports (cm.)	120	100	80	60	40	30
Surface (m^2)	1.44	1.20	0.90	0.72	0.48	0.30
thickness (mm.) 3.5-4	-	-	-	70	100	140
thickness (mm.) 4.5-5	-	-	.	110	165	220
thickness (mm.) 6	-	-	-	165	245	330
thickness (mm.) 7	-	-	160	215	320	430
thickness (mm.) 8	.	165	205	275	410	550
thickness (mm.) 10	-	250	310	415	620	830
thickness (mm.) 12	.	360	450	595	920	-
thickness (mm.) 14	425	510	635	850	-	-
thickness (mm.) 16	530	635	800	-	-	-
thickness (mm.) 18	670	800	1010	-	[illegible]	[illegible]
thickness (mm.) 20	830	1000	1249	-	[illegible]	-

The catalog proposed different types of constructions, each accompanied by a set of illustrative tables depicting typical plans, elevations, and sections, the types of panels to use and their installation mainly being deducible from the graphic representation (e.g. hospital pavilion, school pavilion, barrack for the hospital for officers or soldiers, hut for latrines, dormitory, gymnasium, family chalet, types of beach huts, buffets for railway stations, colonial house (bungalow), storage shed). Some information on the material used was also provided. It was made clear that the Eternit material was produced with slow-setting Portland cement and the best-quality asbestos fibers. «By virtue of these components and their special processing, Eternit is a material which, despite being light, is highly resistant to traction and bending, and is considerably elastic» [20. The manual's introduction specifies that: « I pannelli Eternit sono assolutamente incombustibili, di durata illimitata, insensibili all'azione degli agenti atmosferici in qualsiasi ambiente e in qualsiasi clima. Infatti, mentre gli agenti atmosferici disgregano muri e intonaci, ossidano i metalli e fanno marcire il legno, aumentano la resistenza dei pannelli Eternit. Questi pannelli, quindi, costituiscono quanto di meglio si possa utilizzare per la copertura di tetti e per cantine, sottotetti, soffitti, rivestimenti interni ed esterni, ecc. sia in edifici agricoli e industriali che in abitazioni residenziali, modeste o di lusso, in locali pubblici, ecc. (Eternit panels are absolutely non-combustible, of unlimited duration, insensitive to the action of atmospheric agents in any environment and in any climate. Indeed, while atmospheric agents disintegrate walls and plaster, oxidize metals, and rot wood, they increase the resistance of Eternit panels. These panels, therefore, constitute the best that can be used for covering roofs and for cellars, attics, ceilings, internal and external cladding, etc., both in agricultural and industrial buildings and in residential homes, whether modest or luxury, in public places etc.)» [20]. The "Country Cottage" (*Casa di Campagna*) was displayed at the Turin International Exhibition of 1911, where it was advertised as a Model of an Alpine Chalet. The removable structure is a useful solution in a mountain setting, where building materials are difficult to transport. The "Country Cottage" pavilion was then moved to Tripoli, as mentioned in the catalog, though this has not yet been verified. In the wake of the National and International Exhibitions, particularly that of Turin in 1911, a villa similar to the demountable buildings illustrated in the Eternit catalog was built in Genoa (see Ligurian cities and exhibitions). A few years later, Eternit used this type of structure in its pavilion at the *Fiera Campionaria* in Milan in 1[illegible].

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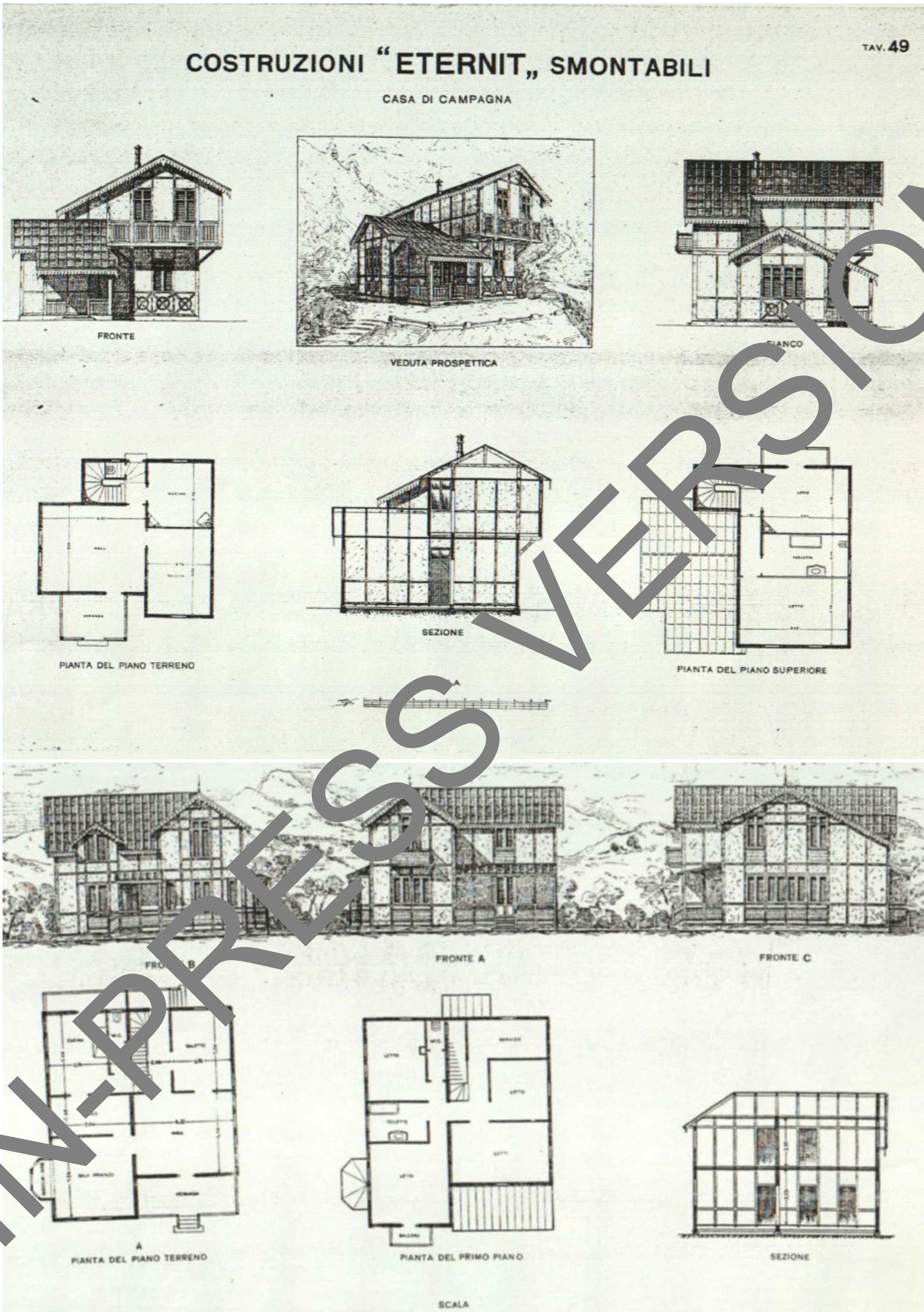

Fig.14: Dismantled constructions - Country Cottage [20]

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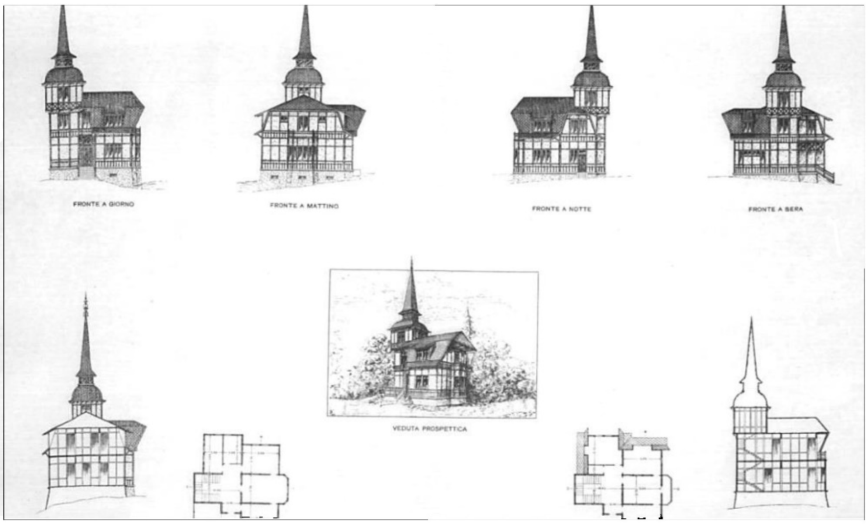

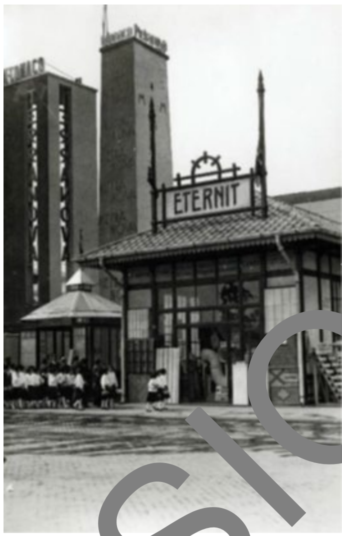

Fig. 15: Dismantled constructions- Villas [20], Fig. 16: "Chiosco di Eternit pietra artificiale S.A.", Milan Fiera Campionaria 1934, 12 April 1934 [7, page 139].

4. Conclusions

Based on the research presented here, several initial considerations can be drawn:

1. the influence of external factors on the construction and form of buildings;
2. the impact of aspects such as ease of assembly, material availability, standardization, and relatively low cost;
3. the differences between the archaeological interpretation of this type of architecture and traditional archaeological analyses of historical pre-industrial buildings [21].

Regarding the first point, the influence of aesthetic trends and approval processes has always been present; in fact, these processes have accelerated significantly over the past two centuries [22]. The increased accessibility to a wide range of forms and materials has further encouraged this cross-contamination. This dynamic complicates archaeological interpretation at a high level [23, 24, 25], requiring close attention to the socio-economic context—perhaps even more so than is typically necessary when analyzing pre-industrial structures.
One factor that can assist in identifying changes within a narrow chrono-typological framework is the set of regulatory requirements buildings must meet (e.g., seismic safety regulations, asbestos remediation policies, etc.). In the specific case of 20th-century framed constructions, as demonstrated, these buildings became more widespread following the Universal Expositions. This trend extended even into regions traditionally resistant to adopting timber-framed construction. Nonetheless, over time, forms, structures, and materials evolved—often driven by practical and health-related concerns.
Some questions remain unanswered and will be the subject of future investigations. For example, the modular use of Eternit panels seems to respond to a precise product integration strategy. The cases examined reveal a close relationship between what is described in the manuals and what is found in real constructions. In the case of the villas, however, it is not known whether the wood-Eternit panels were pre-assembled or not, nor how they were installed on site. Moreover, given the hazardous nature of the materials used, some observations were carried out from a distance and sometimes on surface-treated elements. However, the cases examined to date constitute a limited basis for study, which means that further investigation and comparison are needed. The other aspect is the issue of luxury holiday homes, homes for displaced persons, or other types of constructions for specific uses (e.g., maritime, transport, etc.). One question that arises is whether there are differences in materials, technologies, and/or costs. From the data in our possession, no particular differences emerge. Regarding the choice of materials (whether of higher quality or not) and the choice of the technological solutions to be adopted, it would seem that the figure of the architect or, in any case, of the designer is predominant; he or she may adopt similar technological solutions even in different contexts, albeit with inevitable adaptations. However, an in-depth study of this kind, which requires a considerably broader database, must be postponed. Concerning the possibility of analyzing these structures in the future, based on the experience gained, observations are being made on the construction details in order to identify standardized or prefabricated components, the degree of integration between the timber structure and panels, the joints between timber elements, and the types of fastenings (wood-wood, wood-metal elements, brackets, nails, bolts). While not everything is known, it is already possible to identify a sequence of variations which, through

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further investigations, will allow us to characterize timber-framed structures more precisely in the near future and to divide them into areas and periods.

5. Acknowledgments

Special thanks go to Arch. G. Stagno, who has devoted much of his time to studying historical timber buildings and Arch. L. Secondini, who determinedly investigated timber-framed structures and found the Eternit Manual. Thanks to C. Marvaldi, G. Mor, and R. Forte for the valuable advice.

6. Authors Contributions

The author of paragraphs 2 and 3 is D. Pittaluga. The authors of paragraphs 1 and 4 are D. Pittaluga and J.A. Quiros Castillo.

Conceptualization, methodology: D.P., Investigation: D.P., Funding acquisition, resources: D.P., Supervision: D.P., Writing original draft: D.P., J.A.Q.C., Writing-review & editing: D.P. Translations of documents and quotations from them are an elaboration of D.P.

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