Wooden boards arches roofs in late nineteenth-century industrial architecture: conservation problems

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Abstract. The maintenance and preservation of wooden structures which are a significant part of historical building heritage requires suitable knowledge of both the material on which intervention is intended and the construction techniques used to build it. Understanding its structural design, characteristics, and construction specificities is crucial in order to correctly safeguard this aesthetical/cultural heritage of knowledge and values which in some cases has, unfortunately, been irremediably lost.
The present contribution will analyse several examples of wooden structures built using the system invented by Philibert de l'Orme in 1561. The case studies, all cited in the *New inventions for low cost building*, illustrate the different ways in which the construction system proposed by de l'Orme can be used.

Introduction

To acquire increased awareness regarding the need to safeguard the extensive heritage of wooden structures which are a significant part of historical building heritage requires suitable knowledge of both the material on which intervention is intended and the construction techniques used to build it. Assessment of timber structures is based on a multidisciplinary approach aimed at providing information about the mechanical properties and actual condition of timber members and the mechanical behaviour of joints. This information is essential for a reliable structural safety analysis which gives guidance to the conservation, replacement or strengthening work necessary to ensure an adequate safety level.

Understanding the structural design, characteristics, and construction specificities of timber members (floors, ceilings) built in the past is crucial in order to safeguard this aesthetical/cultural heritage of knowledge and values which in some cases has, unfortunately, been irremediably lost. In fact, timber elements were often considered as simple accessories in a building; their replacement was justified not only due to instability and/or degradation, but also because it was impossible for the wooden structures to positively respond to changes in structural and/or performance efficiency parameters elaborated for new structures built to satisfy different requirements.

Safety requirements and environmental, economic and cultural issues generate a growing need to maintain, upgrade and refurbish existing timber structures. However, the safeguard of this architectural/cultural heritage requires in-depth knowledge of this heritage in order to both safeguard and enhance it by advocating conservation rather than replacement, bearing in mind that architecture is a signature art and, therefore, "not reproducible without loosing its specific meaning which unequivocally lies in its material and in time". [1]

It is also important to emphasise that by helping to prefigure the future, structures built in the past can be used as valid reference during the ideation and design of new structures. In fact, even

Eugène Emmanuel Viollet-le-Duc stressed that the study and analysis of materials, building techniques, and structural design of the architecture of the past, makes it possible to acquire "valid practical indications for contemporary operational procedures" [2]. In fact, even if it is true that "the principles used by past artists nevertheless remain true and equivalent, and will never change as long as men are made of the same clay", knowledge of the past can help to indicate "the road towards progress" [3].

The wooden roofing system proposed by de l'Orme

In 1561 the French architect Philibert de l'Orme published a paper, entitled *New inventions for low cost building*, in which he describes a construction system to build roofs and floors using wooden boards which were shorter and thinner. The arches, used to support the beams of the roof or floors, were in fact built by assembling a double series of curved boards [4,5,6], placed on edge and "transversally perforated in the middle and at the ends, like a mortise and tenon joint" [7]. The arches were constructed by juxtaposing the boards with timber wedges rammed into the holes at each end.

All the arches in the system are joined and united using crossbeams (the crossbeams "can be as long as you like or depend on the length of wood you can find" [7]) placed perpendicularly to the boards and attached to the latter with wooden pins "which will be two and a half inches in width and one inch thick". The latter "must be well inserted with heavy blows of the hammer, in order to join the pieces so that they cannot fall apart, or move in any direction, with the greatest force possible" [7].

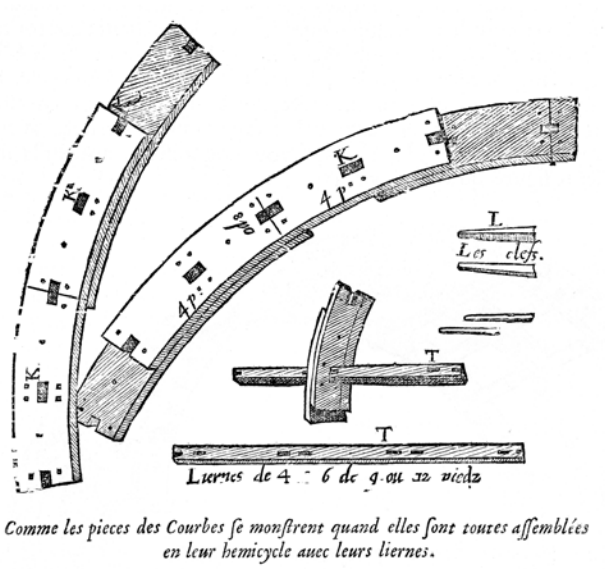

Figure 1 – De l'Orme method for the assembly of the boards (P. de l'Orme, New inventions for low cost building, Paris 1561).

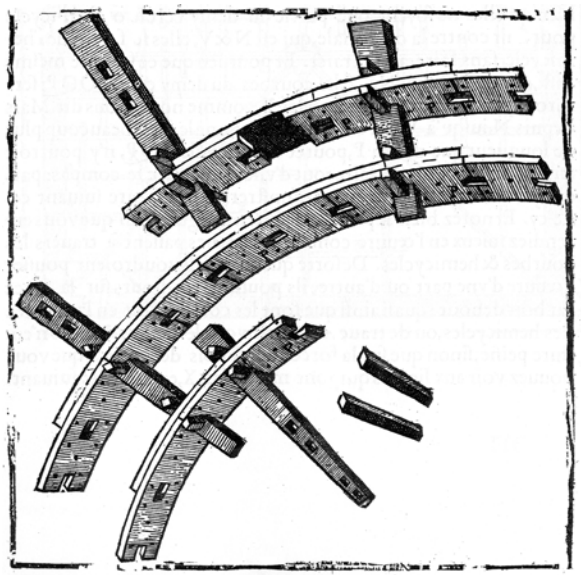

Figure 2 – Detail of the assembly method of the boards (P. de l'Orme, New inventions for low cost building, Paris 1561).

De L'Orme's invention has numerous advantages which he himself cites in the last chapter of his paper. The most important is the possibility to build structures covering large spans using smaller timber elements, assembled using metal pieces; these structures could easily be maintained by replacing the elements which, for any number of reasons, no longer performed their assigned task.

Furthermore, the lightness of such structure allows to reduce the weight burden on the perimeter walls that can, in this way, have a little thickness.

The system invented and promoted by de l'Orme was very popular in France; it was however forgotten until the end of the eighteenth century when in 1782 it was used to build the roof (a dome with a 40 m diameter, built only with de l'Orme arches) over the Halle au Blé in Paris. A few years later many architectural texts and treatises describing this construction system began to be published (for example, the *Theoretical and practical building treatise* by Jean-Baptiste Rondelet).

There are many examples of wooden structures which use de l'Orme's method and yet interpret it differently. For example, the roofs of several industrial buildings built in the second half of the eighteenth century in Italy and Spain; the latter are examined here in-depth to illustrate their similarities and differences. Knowledge about these buildings is crucial to influence the work performed not only to ensure successful long-term conservation while respecting their structural design, but also to suggest and possibly influence new design projects by exploiting what the past has taught us and what, in this case, is more topical than ever. "Knowledge and comprehension of the architecture of the past is crucial to achieve 'responsible' architectural design. Studying historically consolidated architectural building methods and techniques – or, on the contrary, ones which have fallen into oblivion – makes it possible to adopt an honest and, at the same time, mindful approach towards contemporary architecture which in turn inspires the expertise required to convey new forms" [8].

Arched wooden roofs made with boards

The former Trombetta wool mill. The structure of the wooden roof of the former Trombetta wool mill, built in the 1870s, has a series of arches, arranged on an interaxis, approximately three metres from one another. The structure was built during the refurbishment of the top floor of the building, originally with a flat roof, to create an area where the wool was stretched on tenters. De l'Orme himself also stressed that the use of the kind of roof he invented made it possible to exploit the space under the eaves which are "very comfortable for many things, unlike the ones normally found there", because "you can created beautiful rooms or halls underneath this kind of roof" [7].

Figure 3 – The former Trombetta wool mill, Biella. The roof of the wool mill before the construction of the arches. (Sella Archives, Biella).

Figure 4 – The former Trombetta wool mill, Biella. The wooden arch structure. (photo Mattone).

Figure 5 – The former Trombetta wool mill, Biella. Detail of the arches. (photo Mattone).

The arches were built by placing, side by side, three order of boards (a few centimetres thick and approximately two metres long), cut into semicircular pieces and placed on edge with staggered joints, and assembled with bolts and dovetail joints at the ends.

Unlike de l'Orme's system, in this case the arches are further away from one another; in addition, the structure has fewer transversal wooden crossbeams. The only function of the crossbeams, simply placed next to the boards, is to maintain the reciprocal distance between the arches. The entire system is made more stable by the use of reinforcements (almost posts) where the arches join the pitches of the roof. Wooden crossbeams were inserted when one of the arches warped; since they were attached to the arch and to one of the perimetral masonry pilasters, these crossbeams ensured structural solidity.

Figure 6 – The former Trombetta wool mill, Biella. Detail of the unstable arches. (photo Mattone).

The former Gallo wool mill. Another example of an arched timber roof is located in the former Gallo wool mill (now abandoned) built in the second half of the eighteenth century in Sagliano Micca (Biella). It has a series of arches built with a triple order of boards placed next to one another and fastened with screws, bolts and wooden connector plates; the roof rests on the rafters supported by the arches. Compared to de l'Orme's design, the arches are not attached to one another, however, this doesn't appear to have affected the stability of the structure which is still well preserved. The fact that this kind of construction system was inexpensive is one possible explanation why it was used to support a simple two-pitch roof; it was economical not only because it involved the use of smaller wooden boards, but because it was possible to exploit the space under the roof.

Figure 7 – The former Gallo wool mill, Sagliano Micca (Biella). The wooden arch structure. (photo Mattone).

Figure 8 – The former Gallo wool mill, Sagliano Micca (Biella). Detail of the assembly system of the boards. (photo Mattone).

The Obrera Mataronense Pavilion. Between 1883 and 1885 Anton Gaudì designed a pavilion (to be used as a bleaching hall) for the Obrera Mataronense Society. When designing this structure Gaudì probably used as reference both traditional Catalan architectures, such as the *drassana* in Barcelona and the novices' dormitory in the monastery of Santes Creus, and French models which he discovered when reading the treatises by Jean-Baptiste Rondelet and Armand Rose Emy, as well as the *Dictionary of French Architecture from 11th to 16th Century* by Viollet-le-Duc.

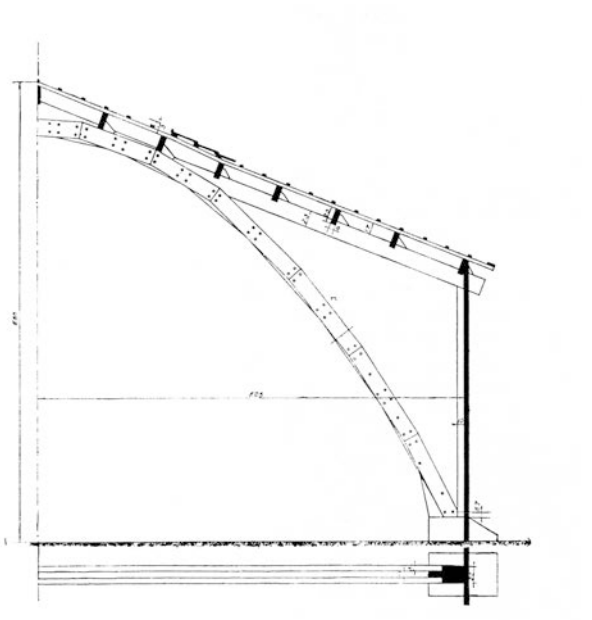

*Figure 9 – The Pavilion of the Societad Obrera Mataronense, Matarò, Spain. Detail of the wooden arch structure (*R. Pane, *Antoni Gaudì*, Comunità Editions, Milan, 1964*).*

Figure 10 – The Pavilion of the Societad Obrera Mataronense, Matarò, Spain. The wooden arch structure.

The pavilion, in fact, had a roof supported by twelve parabolic arches with a triple order of wooden boards (made with a strong pine-tree called "melis"). The boards were 22 cm wide and had a maximum length of 1.5 m; the external boards were 6 cm thick, while the internal boards were 10

cm thick; all the boards were assembled using bolts. Single pieces length varies in order to better comply with the parabolic bending. The rafters supporting the roof rested on the arch and on a springer, also wooden, which ensured that the arch did not move horizontally.

The use of a parabolic arc allows Gaudi to reduce the horizontal thrust at the support. The loads are in fact traced to the vertical or nearly allowing a reduction in the thickness of the perimetral walls. Nethertheless, the insertion of parabolic arcs is optimal when the loads are uniformly distributed on them. In the pavilion designed by Gaudì the load due to the roof is on the contrary concentrated almost near the top of the arch. This kind of load seems to ask for a different type of structure. The sequence of parabolic archs which characterize the pavilion of the Obrera Mataronense Society even if certainly gives it great formal intensity, however is not the optimal choice from the static point of view [9].

Conclusions

The maintenance and preservation of wooden structures which are a significant part of historical building heritage requires suitable knowledge of both the material on which intervention is intended and the construction techniques used to build it. Understanding its structural design, characteristics, and construction specificities is crucial in order to correctly safeguard this aesthetical/cultural heritage of knowledge and values which in some cases has, unfortunately, been irremediably lost.

Although the structural design and small elements of these roofs differ, their assembly and the techniques used to build them are the result of remarkable operational knowledge and construction expertise which should be studied in order to facilitate not only the work required to ensure “the working life, and permanence of signs that hand down a message”, but also to acquire the extensive knowledge which can gainfully guide the design of new constructions. As emphasised by Edoardo Benvenuto, “there can be no innovation that has not already been historically provided”[7] . Knowledge is therefore important not only to preserve the past, but also to design the future.

Nevertheless, this kind of result can only be achieved by preserving the documentary evidence and artefacts of buildings, their construction materials, and construction and structural specificities since the latter constitute valuable information and data which may be useful in new projects. In certain cases, however, the preservation of these structures may require replacement of degraded elements. This type of intervention, already suggested by de l'Orme, allows to preserve the structures without altering in any way the structural meaning of the building.

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