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The History of Wood in Constructions Between Past and Present

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Abstract: Timber is one of the first materials used by man for construction. In the past, the problem of the durability of wood was not taken into account, which for this reason has had a progressive decline. But in recent years, these problems have been remedied with the new technologies that have led to the introduction of industrial production processes. The building systems of the past have not been abandoned, but rather optimized. Indeed, real innovation consists not so much in the invention of something new, but in the use of ancient techniques and materials, revisited in a contemporary way. This article offers an overview of the state of the art on wooden constructions. It starts from a historical-critical excursus on the first uses of wood and on the reasons why it has fallen into disuse over the centuries following the spread of more modern materials. The study continues by showing how the interest in the use of wood in the construction of buildings has grown strongly in recent years. The advantages of this natural material are therefore investigated and it is shown how the development of new technologies has managed to overcome the disadvantages associated with it. The properties of the wood material and the types of processing it undergoes are also shown. Finally, the article provides a review of the main construction systems used and their essential characteristics.

Key words: wood, innovation, prefabrication, heritage, technology

1. History

Building with the timber is perhaps the oldest "construction philosophy" that has developed on our planet. Wood is one of the best building materials found in nature. Thanks to its versatility and its structural features, it has always been used to create various types of structures. A recent study published in 2012 shows that the settlers of the early Neolithic period were able to build complex wooden constructions, already a thousand years before the invention of metal material processing tools. In particular, four water wells from the early Neolithic period were found that were excavated in eastern Germany and dated between 5469 and 5098 BC. These allowed us to have a more detailed view of the first wooden architecture [1]. Over time, various construction systems have been developed, among the oldest is the Blockbau system, a type of massive construction that has been widely used in the northern region, where there are a lot of woodlands from which to derive raw materials. Being self-made by the inhabitants themselves, these buildings had several problems. Our ancestors do not take into account the properties of wood which, being a living material, changes according to atmospheric conditions. Particularly, they did not consider the settling movements during the drying process and the withdrawal that happens if it is not appropriately opposed. Until the end of 1800, house construction with the Blockbau system was a practice throughout Europe, especially in the Alpine territories [2]. From the post-war period onwards, with the advent of reinforced concrete and steel, the wood had a progressive

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Fig. 1 Wooden frame.

a decline in its use. About Italian buildings, in past centuries, Italian people were among the best craftsmen of this material, which often integrated with other natural materials, such as stone. One just has to look at the beautiful historic villages that make up our country.

2. Prefabricated Wood

In recent years, the way and the technologies with which wood is processed and used had profoundly changed, thanks to the introduction of industrial production processes, which guarantee the quality of each component. The article "Prefabricated wood l-joists: an industry overview"' of 1920, presents the results of a survey carried out towards the end of 1987 and again at the beginning of 1989 to ten North American companies that produce over 95 percent of the total volume of wooden joists in North America. This provides us with a qualitative view of the emerging prefabricated wood industry. It turns out that wooden beams are highly efficient and light structural components. They are suitable for covering large lights and represent an attractive economic alternative to traditional solid wood. The engineering community has recognized the uniform rigidity, strength and lightweight of these prefabricated structural products. However, although the wooden joists were manufactured starting from 1920, they were not mass-produced until the late 1960s. Since then, the prefabricated industry has undergone great development [3]. So, we start talking about prefabricated houses, which have as further advantages: constructive speed, housing quality, excellent static requirements, and good ecological quality. For some experts, the history of prefabricated houses has its origins in the twelfth century, and the way of building was already very similar to the current one. It is a construction system composed of a load-bearing timber structure. The walls are filled with insulating materials and externally covered with panels. It is historically recognized that Leonardo da Vinci, in 1494, had already thought of a wooden prefabricated building to design a mobile home for Duchess Isabella Sforza's park. Particularly, the construction in series began in America, when the immigrants started to use prefabricated parts for faster construction of their houses. Already in 1833 an English carpenter, Herbert Mamming, sent huge crates with prefabricated modules to Australia by sea. Then in Austria, Wenzel Hartl presented the first single-family house, "Jagdhaus", built-in prefabricated on the occasion of the hunting exhibition of 1910 in Vienna. In Germany, on the occasion of the world exhibition in Stuttgart in 1927, architect Walter Gropius, founder of the "Bauhaus" movement, presented his first houses ready for editing. In 1925, still in Germany, the architect Konrad Wachsmann had already developed a system of prefabricated buildings. So together, Wachsmann and Gropius, founded in the United States one of the first factories for the production of wooden elements for construction. The Second World War and the economic crisis after the Great War slowed down the development of wooden constructions. In the post-war period, with the reconstruction and economic recovery, the need for new housing is growing. Especially in Germany and Austria, numerous small houses were built quickly. These had thin ten centimeters walls, so they turned out to be uncomfortable. These houses, although temporary, spread the idea, in Europe, that wooden constructions were synonymous with poor quality. Instead today the prefabricated in wood, enjoy an excellent prestige, thanks to the continuous research and the innumerable studies on this material [4].

3. Material Properties

In the last few years, wood has returned to the

attention of architectural culture thanks to the renewed interest in environmental well-being. Its features, its availability, and its workability have made it one of the most used materials for construction. In Italy, it is considered the most suitable material for some construction elements such as roofs, floors, and finishes. Instead, in Northern Europe, in China and wood-rich countries, it still constitutes the basis of construction. One of the great winning arguments of wood compared to materials deriving from exhaustible resources, such as oil or mineral deposits, is that being alive, it reproduces, grows and does not end. Moreover, the woodworking processes involve lower energy consumption than the one necessary for the production of other materials such as metals, concrete, synthetic materials and plastics. There are many woods of Italian production. Fir, chestnut, cypress, beech, larch and various types of pine are used for the structure. For furnishings, fixtures, and flooring, the following are also used: walnut, poplar, oak, maple, birch, and ash. The properties that make wood one of the most used materials are: lightness, workability, excellent mechanical strength, elasticity, renewability, the possibility of recycling and reuse. As regards the mechanical properties of wood, these are exhaustively illustrated in the 1999 article: “Mechanical properties of wood” [5]. If working in the direction of fibers, with the same thickness, it has a resistance similar to that of reinforced concrete and greater elasticity. In the event of a fire, the outermost layer will carbonize protecting the innermost parts from the flames. This is why large wooden beams have a greater heat resistance than metal joists, which bend and collapse when certain temperatures are reached (melting temperature of steel is 1350°C, whereas, during a fire, the temperature of flames goes from 1700°C to 2500°C). Entirely wood-built houses, widespread in central Europe, create an aesthetically warm and welcoming environment, but walls usually need additional insulation panels. Compared to brick, wood has no great sound-absorbing and thermal storage capacity. In the interior, it is certainly, one of the healthiest materials to use, if it is not treated with impregnating and harmful substances. Its hygroscopic capabilities make it a good natural air conditioner [6].

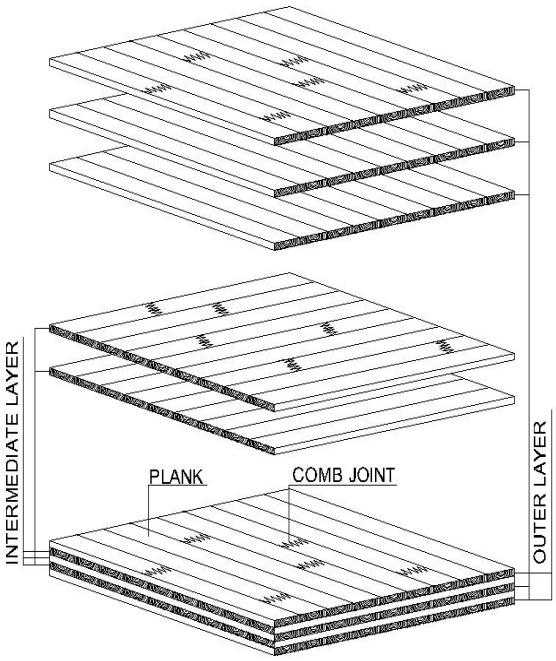

Fig. 2 X-LAM.

3.1 Wood Products

In addition to solid wood, which comes directly from the trunk of the tree, there are several derivatives. Among the most used, we have the plywood boards, made by gluing several thin layers of wood with staggered veins. Also, lamellar wood is obtained with procedures similar to plywood and is used for the construction of large structures and roofs. Instead, the chipboard panels are wood splinters and chips pressed and glued together. Then, there are medium density panels, widely used in carpentry due to their remarkable compactness and homogeneity features. These are composed of pressed and glued wood fibers to various thickness form panels. The quality of all these products is given, not only by timber itself but also by processing and glues used. In this regard, studies done on tannin-based adhesives reported in Ref. [7] are interesting.

3.2 X-LAM

Cross-laminated wood panels can have different denominations: X-LAM (Cross-Lam), CLT (Cross Laminated Timber), KLH (Kreuz Lagen Holz). It is a new generation construction material, with better properties than solid wood or laminated wood elements glued in one direction only. The X-LAM elements are composed of solid wood planks arranged in crossed layers, that is with alternating fiber direction, glued together under great pressure to form a single solid flat element, with load-bearing capacity in both directions. The panels are made with an odd number of layers, up to a maximum thickness of 60 cm. The relative orientation of the tables in the individual layers is 90° and the panel section is always symmetrical.

4. Construction Types

In technical literature, wooden structures are divided into light constructions and massive constructions. The subdivision depends, above all, on the supporting structure of the walls. Light constructions are characterized by reduced use of wood in favor of wide use of insulating materials. Therefore, they foresee the presence of slender elements in wood, interspersed with layers of insulators. Instead, massive constructions provide for wide use of the wooden material, which by itself allows obtaining remarkable thermal performances.

4.1 Massive Construction Systems

The main massive building systems are Blockbau, Brettstapekbauweise, Brettsperrholzbauweise.

4.1.1 Blockbau

Massive constructions are made almost exclusively of coniferous wood and are made up of elements that overlap horizontally and stuck together with wood carvings. massive walls, assembled in this way, perform both a supporting and a stiffening function.

4.1.2 Construction System with Parallel Table Packages (Brettstapekbauweise)

The packets of boards are solid floor type construction elements, with thickness coinciding with the width of the boards, and between 8 cm and 12 cm for the walls, and between 12 cm and 20 cm for the floors according to the spans and loads. The elements of table packs consist primarily of lamellas formed from the outer portion of the trunk. These are first dried and planed, then connected to each other by continuous riveting. The table packages can also be used, for greater than six meters span, in mixed wood-concrete structures. Deformable conjunction between the wood and the concrete is realized with a mechanical connection. Structures of this type can cover spans up to about 10 m.

4.1.3 Construction System with Plywood Boards (Brettsperrholzbauweise)

Plywood boards are solid, flat and multilayer elements with load-bearing function. The structure of the cross-section of the plywood board allows to obtain a load-bearing capacity in the two main directions of the plane with a single panel. The construction system with plywood boards has many possibilities of use: not only can floors, walls and roofing elements of large dimensions be made, but also slabs for stairs and balconies, architraves and columns. The minimum thickness of solid load-bearing elements should never be less than 75 mm. With 5-layer boards between 125 mm and 160 mm thick plywood boards, spans can be covered up to 5 m. Buildings made with elements of plywood boards require the addition of stiffening walls which, in combination with the floors, constitute a rigid three-dimensional structure. The number and position of the stiffening elements are mainly determined by the geometry of the building, the type of section and the horizontal loads.

4.2 Lightweight Building Systems

The main lightweight construction systems are Holzskelettbauweise, Fachwerkbau, Holzrahmenbau.

4.2.1 Construction System with Load-Bearing Wooden Frame (Holzskelettbauweise)

This construction system dates back to the early Neolithic when in addition to massive construction another type of construction was also developed, the piles. These consisted of vertically buried piles and connected them to each other through cross-beams. The walls between these piles were made with makeshift materials such as straw and clay. Modern load-bearing constructions, built from the late 1960s, have large lattices, thanks to the use of glued laminated wood. Columns and beams are arranged at large intervals to be able to insert facades and partition walls made at will. The secondary bearing elements can be beams, struts, or flat type elements. In buildings with load-bearing wooden frames, the facades and partition walls do not absorb any vertical force but can act as stiffening. The curtain walls can be made with construction systems at wills, such as wooden elements, glass constructions or even masonry. In this type of construction, the loads are absorbed almost exclusively by linear structural elements, and there is a clear separation between load-bearing and infill elements. The supporting structures are built according to a horizontal grid and often also according to a vertical one. This establishes the arrangement of the elements and the distribution of the spaces, thus defining the available free spans. In the load-bearing construction method, there are different types of constructions, which differ in the structure of the columns, the beams, and the connections.

4.2.2 Wooden Trellis Construction System (Fachwerkbau)

The peculiarities of lattice constructions are freedom in the architectural organization; the possibility of building multi-story buildings; connections made with joints and overlaps, without mechanical parts; relatively short lead times. For these reasons, lattice construction is economically competitive. In this type of construction, the transmission of vertical loads occurs directly through contact joints. Furthermore, the joints can be quite inexpensive because they are not very stressed since the wooden elements are at a small distance from each other.

4.2.3 Construction System with Wooden Frame (Holzrahmenbau)

Framed constructions are a type of slab construction system, for which the load-bearing elements are not separated from the stiffening and plugging ones. The walls are made as composite elements, consisting of a supporting framework with uprights and frames, covered by one or both sides with wood or plaster based materials, which connect uprights to the frames. Together, supporting structure and cladding panels form a single slab. Structures built in this way can be prefabricated in the factory and assembled on site. Wood-framed buildings are usually built floor by floor (“platform frame”). Occasionally, elements with a several floors height are also used (“balloon frame”).

Wood construction systems can also be combined with other ones. A combination used very frequently in multi-story dwellings provides, for example, construction of walls according to the framing construction system, while floors are made massively for more economical sound insulation [8].

5. Conclusions

The article presented here is intended to contribute to the dissemination of knowledge about a highly competitive material such as wood. Always present in western as well as eastern culture, wood is returning to the limelight showing its versatility of use that allows it to be used in the most varied fields. The renewed reputation of this material is also linked to its nature as a sustainable building material. A possible future scenario in woodworking will be the reduction of waste and therefore the reintegration of wood waste into the production cycle. This is to revive wood from the perspective of a closed-cycle economy, to preserve landscapes and avoid unnecessary waste, with a view to bio-economy and greater efficiency in the use of resources.

References

[1] Tegel, Willy et al. (Ed.), and Michael D. Petraglia, *Early Neolithic Water Wells Reveal the World's Oldest Wood Architecture*, Public Library of Science, 2012.

[2] Wood Lab, Storia del sistema costruttivo Blockbau, Novembre 27, 2014, available online at: https://www.woodlab.info/storia-del-legno/storia-del-sistema-costruttivo-blockbau/.

[3] Robert J. Leichti, Robert H. Falk and Theodore L. Laufenberg, Prefabricated woodl-joists: Anindustry overview, *Forest Products Journal* 40 (1990) (3).

[4] Studio Carturan, Le costruzioni in legno, *Studio Carturan Architecture & Engineering*, available online at: http://www.studiocarturan.com/edifici-in-legno/articolo/.

[5] W. Green, David Jerrold E. Winandy and David E. Kretschmann, *Mechanical Properties of Wood*.

[6] Corrado, Maurizio, *Oro, legno e terra*, Cesena: Macro Edizioni, 2006.

[7] A. Pizzi, H. Scharfetter and E. W. Kes, Adhesives and techniques open new possibilities for the wood processing industry, Springer-Verlag, 1981.

[8] Schickhofer Gerhard, Bernasconi Andrea and Traetta Gianluigi, *Costruzione di edifici di legno.*