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Timber as a Future Material for Construction

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Abstract
Wood is known as one of the first construction materials for shelters for first people. İn the Middle Ages, the log and carcass construction system did have not major changes in the selection and detailing of materials. The Industrial Revolution brought about major changes in timber construction, as in all materials, and provided the opportunity for rapid and clean workmanship in material and processing. With new production, the durability and physical properties of wood have been improved by interventions made in some places to the organic structure of wood, and sometimes by the addition of additives. Although today in various parts of the world wood material production and wood construction continue using traditional methods and traditional timber materials, on the other hand, especially in the last fifty years, there have been radical changes in wood production and construction technology and structures. New wood materials with minimum structural weight are being designed and produced with minimum use of wood materials and components. New wood materials have like in the past economic, ecological, and sustainable characteristics (reachable, workable, good electric and thermo isolation, light and durable, easy to transport, easy to repair, combinable with other materials, has varicosity of structures, colors and different type of use.) New technologies have just strengthened this characteristic and added new ones. Accordingly, new materials have additional positive impacts like durability to fire, organic and chemical durability, durability to external impacts, and others. Rising challenges such as climate change, resource scarcity, and urbanization have increased the need for sustainable, high-performance building materials. Traditional wood, while renewable, has structural and durability limitations. Modern construction requires engineered wood products with enhanced mechanical properties, durability, and environmental benefits.

Keywords
timber, industrial wood, contemporary technology

1. Introduction

The development process of wooden structures, starting from the early ages and extending to today's construction systems; has been slow despite the fact that wood can be easily obtained from nature and easily applied during the construction phase. In the 19th century, with the influence of the Industrial Revolution, the use of new products in the construction sector with technological developments, especially the widespread use of stone and brick stacking systems, and the emergence and application of steel and reinforced concrete construction systems, the use of wood as a load-bearing material in structures has decreased. The development of wooden construction systems and their increased use as a load-bearing skeleton in structures coincides with the beginning of the 20th century. The needs arising from increasing and increasingly widespread industrialization and the withdrawal of steel, a valuable weapon raw material, from the construction area before World War I and during the war years brought about the necessity of using wood material in structures with different functions and more rationally. During this period, the mechanical and physical properties of wood material were investigated, studies were conducted on connection elements (nails, wedges, bolts, etc.), and materials and methods were developed that ensure the protection of wood against external effects.

As a result of numerous studies and investigations on wood in the modern era, by using newly discovered additives and modern technology, new progressive types of wood materials have been developed. Also, the wood construction technique has developed a lot and it has become possible to make even heavy load-bearing elements such as bridge beams from wood material. The introduction synthetic glue into wood construction as a bonding agent has revealed the possibility of constructing all kinds of structures (bridges, sports halls, etc.) with wood material. Considering the studies conducted on the protection of this material from external effects and fire, which have yielded positive results, it should not be assumed to be excessively optimistic to predict that the use of wood as a building material will become more widespread.

Although developments in reinforced concrete and steel construction caused wood to lose its popularity, wood has come back to the agenda with the development of industrial wood products and the desire to build environmentally friendly structures in building design approaches.

2. Industrial Wood

In general, a homogeneous and isotropic material formed by combining wood pieces, layers, lumber, chips and wood fibers with binding agents in various forms in a factory environment is called industrial wood. Industrial wood, which provides maximum utilization of trees, has superior structural and static properties compared to natural wood [1].

Industrial wood is a material that has been improved and developed in parallel with today's technological developments in terms of many unwanted features in the structure (such as fire resistance and deformation, etc.) compared to solid wood. The strength and hardness values of wood have been maximized in industrial wood. Thus, wood panels require less support elements, unlike the requirements of other materials.

They are resistant to buckling, bending and impacts. They do not show any dimensional deformation against buckling and shrinkage caused by heat changes and water vapor. Therefore, industrial wood is a good insulator against heat and water vapor. Especially since the wooden panels are large in size, the number of connection points will be reduced, thus minimizing sound, heat and vapor bridges. Since industrial wooden elements are factory-made products, their assembly is fast and the construction period is shortened. With industrial wooden elements, all kinds of system elements can be made in a wide variety of shapes and sections. The construction of wide-span and multi-story structures has become possible with the use of wooden structural elements.

The growing global challenges of climate change, resource depletion, and rapid urbanization have intensified the demand for construction materials that are sustainable, efficient, and high-performing. Although traditional wood has long been used in construction, it presents structural limitations that do not meet the complex demands of modern engineering. Today’s building industry requires advanced timber materials with improved mechanical strength, durability, and environmental performance. In this context, there is a critical need to explore, develop, and modernize new types and species of timber suitable for future construction. As a result, contemporary engineered wood products and innovative timber construction systems have emerged as promising alternatives, aligning with sustainability objectives and offering significant potential for future architectural and structural applications.

In recent years, interest in wood materials has become increasingly widespread. A growing body of literature offers comprehensive overviews of modern engineered wood products, focusing on their development, manufacturing processes, structural applications, and sustainability advantages. These studies also examine the historical evolution of timber construction, current technologies, and real-world architectural examples. Additionally, they evaluate the benefits and limitations of systems such as lamination and glulam.

This study provides a comparative analysis of modern timber systems such as Glulam, CLT, and LVL, alongside innovations like reinforced glulam and transparent wood. It examines contemporary techniques, technologies, and processes in timber construction, supported by case studies like the Avcılar Wedding Hall and Modvion wind turbine, demonstrating timber’s potential in sustainable, high-performance architecture. The research also explores future trends, including fire safety and “no-damage” design, aiming to define the evolving trajectory of timber construction with respect to sustainability, structural performance, and architectural innovation.

2.1. Lamination

Lamination technique can be explained as the process of bonding small-section wooden materials with each other by applying various methods in order to use raw material wood more economically by improving its mechanical and physical properties [2].

Lamination technique enables the production of large-sized, special-shaped and shaped wooden materials, and since it allows the use of small-sized wooden materials to create a whole wooden material, its use in wooden material applications is increasing day by day due to its economic nature.

Laminated wood technology was recognized by Otto Hetzer, a carpenter in Germany, and it began to be used widely in Switzerland and Germany between 1901 and 1906, and in all of Europe between 1907 and 1930. In the lamination technique, the use of pine and spruce trees, which are coniferous trees, is preferred due to their lightness and durability [2].

When the lamination technique is applied, gluing the fibers in the wood material parallel to each other eliminates possible strength loss and waste, and enables the production of high-strength wood material in large sizes. Thanks to advances such as economy and increase in mechanical load-bearing power in lamination technology, the use of wood material in the construction sector has increased visibly.

Thanks to the columns, beams, decks, and exterior elements produced with the lamination technique in factories, together with the connection elements and completely ready for application; wood structures have become economical, fast, durable and healthy. This use has become increasingly widespread worldwide and has enabled multi-story structures to be built entirely using wood materials, accelerating the growth of this sector.

2.1.1. Advantages of lamination

Lamination offers a range of advantages that make it a highly suitable and modern material for addressing the demands of contemporary construction. The following are some of its key benefits:

a. The dimensions of building materials to be produced from solid wood material are limited. However, it is possible to obtain larger products with the lamination system;

b. It provides the opportunity to work in the desired style and unlimited forms in both architecture and interior decoration;

c. In the design of structural elements, it is possible to make a difference in the cross-section area depending on the load. For example: in curved elements, a larger size can be applied where the load comes from (in the critical section);

d. Since it allows the use of very small-sized wood materials (minimum 20 cm) with the application of width and length combination loads, the loss rate is reduced;

In addition, solid material can be evaluated by cleaning it from its defects (knots, cracks, worm holes, fiber curl, rot, reaction wood, irrigation, etc.);

e. Since it allows the use of different thickness and color wood material in various layers on the same wood laminated element, more aesthetic formation can be provided;

f. Layered wood material works less than the same type of solid wood material (swelling-shrinking). The reason for this can be shown as the water-repellent feature of the glue used between the layers of wood material in lamination. As a result of this, layered wood material is more dimensionally stable than the same type of solid material;

g. It allows the creation of geometric structures such as domes, pyramids, vaults, etc. in wide and single-span structures;

h. Parts such as columns, beams, arches, trusses and purlins can be produced, and all the necessary details and metal accessories for their joining can be completed in the factory.

2.1.2. Disadvantages of lamination

However, despite its numerous advantages, lamination also presents certain disadvantages that warrant further investigation. It is essential to study how these drawbacks can be minimized, mitigated, or potentially transformed into positive outcomes. Below are some of the key disadvantages observed in lamination applications:

a. Preparing the wood for gluing and gluing it brings an additional labor cost on the final product. However, this is an acceptable situation compared to a solid wood material of the same dimensions;

b. The resistance of the laminated wood material also depends on the quality of the glue used in the width-length joining and bonding. The high prices of high-strength glues also bring additional costs;

c. For the production of laminated wood material, the special plan of the factory building, the need for special equipment, and the high need for qualified workers are also disadvantages;

d. The production of high-quality laminated wood material is possible by carefully and meticulously performing the processes carried out at all stages of production;
e. Large-sized curved carrier elements face great difficulties during transportation;
f. Since the laminated wood material must be dried to a certain moisture level, it requires a drying facility and additional labor costs [3].

2.2. Glulam

Glued-laminated timber, commonly referred to as glulam, is a structural timber product made by gluing together smaller pieces of wood. In TS EN 387 (2003), [4], it is defined as a structural element obtained by gluing wood lamellae, especially the fibers, together in parallel. Although all types of wood are generally suitable for production with this technique, from a practical point of view, softwoods, especially spruce and pine, are preferred due to the low ability to process hardwoods and to hold glue1. The layer length is between 1.5-5 m, and the layer thickness is applied as 40-50 mm in flat composite element production and 20-30 mm in curved element production. Elements can be produced in lengths of 16-20 m Glued-laminated timber is used in a wide variety of applications [5, 6].

In recent years, the use of glulam systems has become increasingly common in many different sectors in Turkey. These systems are now widely used in public spaces, various types of buildings such as residential housing, offices, hotels, restaurants, shopping malls, cultural and sports facilities, as well as in engineering structures like bridges and towers.

2.1.2. Avcilar Wedding Hall

The Avcılar Deniz Köşk Toplantı ve Davet Salonu (Figure 1), commonly known as the Avcılar Wedding Hall, is a prominent event venue located in the Denizköşkler neighborhood of Avcılar, Istanbul. The building features a modern architectural design with a transparent façade that opens up to the surrounding sea and greenery. Its distinctive wooden roof structure is inspired by natural elements, resembling ocean waves or floating clouds, creating an elegant and airy atmosphere.

Fig. 1. Glulam system. Openings of 108 metres. Avcilar Nikah Salonu (Naswood Archive)

The structure consists of an interwoven grid-like pattern of laminated timber beams. The beams create an elegant and continuous curved surface, offering a dynamic and modern architectural aesthetic. This type of structure demonstrates the high strength-to-weight ratio of glulam, which enables large spans and intricate curved designs. Such structures are commonly found in public spaces, such as exhibition halls, auditoriums, or large-scale pavilions, where aesthetics and structural integrity are critical.

2.1.3. Odunpazari modern museum

The Odunpazari Modern Museum (OMM) (Figure 2), located in Eskişehir, Türkiye, is an iconic example of contemporary architecture inspired by traditional design elements. It was designed by the Japanese architecture firm Kengo Kuma and Associates and completed in 2019. The museum is celebrated for its innovative use of wood and its connection to the surrounding urban and historical context.

Fig. 2. Glulam system. The Odunpazari Modern Museum (OMM) (NAARO)

The building features a visually striking façade made of horizontal, stacked glulam beams. These beams are spaced to create a pattern that allows light to penetrate while maintaining privacy and shading. The architectural design highlights the versatility and beauty of glulam as a material, showcasing its ability to combine natural warmth with modern construction techniques.

Glulam is prominently used for both structural and aesthetic purposes. The wooden beams exhibit uniformity and precision, reflecting the engineering benefits of glulam.

This structure is an excellent example of how glulam can be used innovatively in modern architecture, combining strength, sustainability, and beauty.

2.3. Reinforced Glulam

Reinforced glued-laminated timber (glulam) is an advanced material that combines the natural advantages of wood with the enhanced strength and durability provided by reinforcement. By integrating materials like steel, carbon fiber, or glass fiber-reinforced polymers (GFRP) into glulam, the structural performance of wood can be significantly improved. Reinforced glulam beams cost less because the use of reinforcement will reduce the need of a top grade laminate on the extreme tension face (less high grade material can be used); moreover, the volume of wood is reduced. Also, reinforced glulam beams have lower product variability, they are not affected by natural growth characteristics, and the manufacture of reinforcement is consistent and controlled. Reinforced glulam represents a significant innovation in structural materials, merging traditional wood construction with modern engineering advancements. Its versatility, strength, and sustainability make it a valuable material for future-focused construction projects [7].

2.4. Cross-Laminated Timber (CLT)

Cross-laminated timber (CLT) is an engineered wood product. This is a large and durable ready-made blocks made by cross-laminating wooden materials using strong adhesives. CLT become widespread in the construction sector due to their fast assembly, mechanical strength, and economy. Once the gluing phase is complete, the wood material is transferred to a press machine, where it undergoes horizontal and vertical compression. After the pressing process is finalized, the material is ready for use and can be sized to the desired dimensions [2].

Cross-laminated timber (CLT) is an innovative, sustainable construction material known for its strength, durability, and environmental benefits. Its versatility allows for broad applications across various sectors:

a) Residential Buildings: Used for walls, floors, roofs, and modular prefabricated homes;
b) Commercial Buildings: Ideal for multi-story offices, retail spaces, and hotels (Figure 3), due to its aesthetic appeal and fast assembly;
c) Public Buildings: Common in schools, community centers, museums, and cultural facilities, valued for its fire resistance, thermal insulation, and design flexibility;
d) High-Rise Buildings: Utilized in timber towers and tall structures combined with other engineered wood products;
e) Bridges: Applied in pedestrian and vehicular bridges for lightweight and durable designs.

Fig. 3. CLT system. Rixos hotel Tekirova (Naswood Archive)

Also CLT perfect for adding floors or expanding existing buildings due to its lightweight and structural integrity. CLT promotes sustainability, enables quick construction, provides excellent structural performance, and enhances aesthetic appeal.

2.5. Laminated Veneer Lumber (LVL)

Laminated Veneer Lumber (LVL) is a highly popular engineered wood product widely utilized in construction. It is created by bonding multiple thin layers of wood veneer, all oriented along the length of the final lumber. This overview highlights the key steps involved in its production, as well as the benefits and drawbacks of LVL compared to other structural engineered wood products.

The primary benefits of Laminated Veneer Lumber (LVL) are its consistent dimensions, shape versatility, exceptional strength-to-weight ratio, and cost-effectiveness. Unlike traditional lumber, its size is not constrained by the dimensions of the logs used, thanks to its unique manufacturing process. LVL is among the strongest wood-based construction materials for its density, offering reliable mechanical properties due to its uniform quality and minimal defects. Additionally, LVL can be customized into various shapes to suit specific applications and maximizes the efficient use of wood resources. On the other hand, LVL has a few drawbacks as a wood composite. The improvement of its strength properties through veneer densification during pressing is somewhat restricted. While its dimensional stability is superior to solid wood, improper storage in the warehouse can lead to defects like warping. Additionally, producing LVL requires a significant capital investment, yet its production costs remain relatively low. As a result, a high demand is essential for a profitable operation.

Laminated Veneer Lumber (LVL) is a strong, cost-effective engineered wood product with consistent dimensions and high versatility, making it ideal for construction.

2.5.1. Wooden wind turbine

Modvion, a Swedish company, pioneered the production of wooden wind turbine towers, and other countries such as Canada, Germany, and the United States have since adopted this approach. Wooden towers made from Laminated Veneer Lumber (LVL) offer higher strength per weight and cost compared to steel alternatives, with significant environmental benefits, including 90% lower emissions and carbon storage capacity, while also being lighter and easier to transport and assemble than steel towers. The tower is made of a tube made of laminated timber. The tower consists of modules that are assembled on 16-24 meter long cylinders at the wind turbine installation site. The cylinders are then stacked on top of each other like a traditional tower (Figure 4).

Wooden wind turbine towers, targeted at a height of 160 meters, offer increased energy production compared to steel towers, which are limited to 110 meters. Additionally, wooden towers can be transported as modules, reducing transportation costs, and can be produced in just 3 months, compared to a year for steel towers, while also providing advantages in terms of recycling and fire resistance.

3. Last Developments in Contemporary Wood

Contemporary wood production represents plenty of opportunities and offers a wide variety of different types of modern wood. The models of industrial wood described earlier, such as glulam and

CLT, are among the most popular and common types of contemporary wood. However, other types, like laminated strand lumber (LSL), parallel strand lumber (PSL), nail-laminated timber (NLT), dowel-laminated timber (DLT), and others, also deserve attention.

Fig. 4. Wooden Wind Turbine built with LVL Height 105 m. Sweden (Modvion Archive)

On the other hand, work and research are constantly being carried out to improve contemporary wood. These studies focus on enhancing resistance to decay, mold, deterioration, transformation, wind, fire, and other factors.

In recent years, new types of modern wood have emerged, such as thermowood, impregnated wood, and transparent wood. Some manufacturers now provide guarantees of up to 25 years for wood products. Production processes have become more stable, controlled, and certified, which means that products from the contemporary wood industry are becoming increasingly high-quality.

4. Conclusion

Wood obtained from nature has been used as a load-bearing element in structures with different functions throughout human history. However, due to limited wood processing techniques in the past, the qualities of the structures built and the openings they passed through remained limited. Over time, wooden products have also shown rapid development due to the development of both industrial technologies and the need for larger-volume structures.

Human expectations for living standards are rising at a time when deserts are expanding and supplies of resources like petroleum, potable water and food are shrinking, not to mention global warming and decreasing cultivatable land. Reliable estimates suggest that the global population reached nearly 7 billion in 2008 and is expected to peak at around 8 billion by 2040 [8]. It is evident that the current way of life will need significant changes to adapt to these challenges. Construction techniques and building materials will play a magnificent role in civil engineering such as different types of construction such as residential, commercial, public, and other types of buildings, such as bridges, towers, and so on, which will provide people with high standards and comfortable living spaces. Glulam, CLT, LVL, and other industrial modern timber with sustainable opportunities can meet these needs. Lumber stands out as a renewable and eco-friendly construction material, which can be harvested without destroying ecosystems. It offers advantages like prefabrication, reduced foundation requirements, and cost savings, especially for urban high-density and high-rise buildings.

Timber's low mass facilitates easy transport and assembly, improving efficiency and reducing on-site costs. It is particularly suitable for brownfield developments, where minimizing interference with surrounding structures is critical.

For timber buildings to be widely accepted, they must ensure near-zero risk of catastrophic failure. Recent studies demonstrate that "no-damage design" is feasible with proper methods, such as structural dumping and advanced construction techniques.

It is predictable that the future will be dominated by tall buildings with open structures, freeform designs, organic shapes, and sustainable construction methods. Timber buildings are expected to incorporate composite materials and prioritize preventing fire spread, minimizing sound transmission, and avoiding disproportionate structural damage. Timber structural systems will also enhance resilience against events such as earthquakes, strong winds, and accidental damage.

By combining traditional wooden construction techniques with modern innovations, it is essential to build eco-friendly wooden structures that preserve the environment. Additionally, the full potential of wood should be rediscovered and effectively utilized with the help of emerging technologies.

Through research and development efforts, advanced fire detection and protection systems have been created, alongside the discovery of new products and systems, paving the way for innovative configurations and advancements in timber construction. These developments show that wooden structures will regain their deserved value.

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