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EXAMINATION OF MJØSTÅRNET STRUCTURE IN THE CONTEXT OF WOODEN BUILDINGS AND SUSTAINABLE ARCHITECTURE RE-UTILIZATION OF NATURAL MATERIALS

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ABSTRACT

This study examines the role of wood construction technologies in sustainable architecture and the re-evaluation of natural materials, using the Mjøstårnet building in Brumunddal, Norway, as a case study. Mjøstårnet is notable as the tallest wooden structure in the world, serving as a pioneering example in the use of sustainability and environmentally friendly building materials. The article evaluates various aspects, such as the potential of wooden materials to reduce carbon footprints, energy efficiency, the building's innovative engineering solutions, and the durability of wood. Furthermore, it investigates how Mjøstårnet has transformed into a sustainable design model by integrating traditional and contemporary wood construction techniques, effectively using local resources and architectural aesthetics. This examination discusses how wooden structures present a sustainable alternative in the modern construction industry and explores the future potential of natural materials.

Keywords:Sustainability, Wooden Structures, Building Materials, Sustainable Building Materials, Building Design That Reduces Environmental Impacts, Energy Efficient Buildings.

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Introduction

Although wooden structures have a long history in civil engineering and architecture, they have regained popularity with modern construction technologies. In addition to being a renewable material, wood is preferred by both engineers and architects for its high strength-to-weight ratio, durability, and aesthetic properties. Although the structural strength of wood varies depending on the direction of the fibers and the type of material, it can be increased to meet modern structural requirements, especially thanks to advanced production techniques such as laminated wood. In this context, the load-bearing system of wooden structures is shaped by using wooden components in its main elements, such as columns, beams, floors, and roofs. It is applied in many applications, from multi-story buildings to bridges. The lightness of wood also offers advantages in terms of seismic resistance and can be preferred as a safe material in earthquake zones. It is also a sustainable material that reduces carbon emissions. Minimizing environmental impacts makes wooden structures stand out in contemporary architecture. However, the natural disadvantages of wood should not be ignored. This material requires special measures to be protected against moisture, fire, and biological deterioration, and it requires a careful design and engineering approach to ensure the long life of the structures. When wooden structures' strength and usage areas are examined, the necessity for architectural and engineering disciplines to work with an integrated approach becomes clear.

Wooden structures, including Turkey, are important in traditional and modern architecture worldwide. The prominence of wood as a natural, sustainable, and aesthetic material has become even more important with the increase in environmental concerns in recent years. Particularly, efforts to reduce carbon emissions and increase energy efficiency have contributed to the revival of wooden structures in the construction industry. Wood stands out as an environmentally friendly material with features such as being a renewable resource, consuming less energy during production compared to other building materials, and being able to store carbon throughout its life cycle. Its use in large-scale projects such as multi-story wooden structures and bridges in Turkey and around the world indicates the durability of wood and how technological developments support it.

Multi-story wooden buildings like Mjøstårnet worldwide are a testament to the advanced state of modern wood technology and the engineering possibilities this material offers. In Turkey, traditional wooden structures like Safranbolu houses not only showcase the wide range of uses wood had in the past but also highlight its importance in terms of architectural and cultural heritage. These structures, with their enduring nature and aesthetic appeal, continue to attract attention and admiration.

The advantages offered by wooden structures, such as ease of construction due to their lightness, safety in earthquake zones, high thermal insulation and natural ventilation features, are significant. However, it's crucial to acknowledge the disadvantages of wood. Its sensitivity to fire, moisture and insects necessitates additional protection measures for the long life of the structure. Therefore, fire protection, moisture barriers and measures against biological degradation are not just important, but crucial in the design and construction of wooden structures. The correct use of wooden structures allows the construction of sustainable and aesthetic structures, overcoming the natural disadvantages of the material. Wooden structures around the world and in Turkey offer remarkable examples of combining traditional knowledge with modern engineering solutions.

Wooden structures' contributions to durability, aesthetic value, and sustainability have long been discussed and examined in both traditional and modern architecture. Academic studies on the historical importance of wood and its place in contemporary construction technologies provide detailed analyses of the material's advantages and disadvantages. For example, Buchanan (2000) highlighted the advantages of wood as an environmentally friendly material and examined its role in reducing the construction industry's carbon footprint. According to Buchanan, wooden structures consume less energy and emit less greenhouse gases into the atmosphere during construction than traditional concrete and steel structures. At the same time, wood is a renewable resource, making it a sustainable building material.

In Turkey, studies conducted by Eriç (2003) focused on the widespread use of wood in traditional Turkish architecture. They stated that examples such as Safranbolu houses reflect wood's durability and aesthetic value. While Eriç emphasized the importance of these structures in terms of cultural heritage, he also drew attention to wood's environmental and aesthetic contributions.

Modern wooden construction technologies have a promising future. Green building certification systems and the role of multi-story wooden structures in sustainability have been extensively studied. Espinoza and Buehlmann (2019) have explored the latest engineering techniques in the use of wood in multi-story structures, revealing that the potential for more durable and large-scale structures is within reach, thanks to new-generation wooden materials like CLT (Cross-Laminated Timber).

Wooden structures have an important place in both historical and contemporary architecture worldwide and in Turkey. Wood's advantages in terms of sustainability make it possible to reevaluate the material by combining it with modern construction techniques, which paves the way for the spread of more environmentally friendly buildings in the future.

Materıal And Method

It was carried out to evaluate wooden structures in the context of sustainability and examine the use of energy-efficient building materials in the construction sector. Data was collected and analyzed using literature review and case study methods.

The first stage of the research involved a comprehensive review of existing literature on the load-bearing systems of wooden structures, material properties, energy efficiency and sustainability. This review, which included academic articles, sectoral reports, conference proceedings and research on construction materials, aimed to highlight the advantages of wooden structures, particularly in terms of energy efficiency, environmentally friendly material use and structural durability. The thoroughness of this process, which evaluated critical properties such as wood's potential to reduce its carbon footprint, recyclability and fire resistance, instills confidence in the research's credibility. The analysis of studies on wooden structure examples in Turkey and around the world, as well as the investigation into the application areas of sustainable wooden structures, further solidifies the research's foundation.

In the second stage of the research, we undertook a comprehensive review of the Mjøstårnet structure in Brumunddal, Norway, a case study in the context of sustainable wooden construction technologies. This structure, known as the tallest wooden building in the world, is distinguished by its innovative architectural design and the use of wooden materials. Our review process was meticulous, examining Mjøstårnet's structural system, energy-efficient engineering solutions, and sustainability-oriented practices in detail.

Highly sustainable materials such as laminated timber (GLT) and cross-laminated timber (CLT) used in the construction of the Mjøstårnet structure and their structural advantages are discussed. The building's material choices that reduce environmental impacts and energy-saving applications were analyzed with the support of academic and sectoral resources. In addition, the carbon storage capacity of wooden structures and their effects on using renewable energy were among the important issues evaluated.

Visuals support the examination of the Mjøstårnet structure. Using the building's sections and plans, drawings of the ground floor, first floor, and east façade examined the functional and structural changes of each floor. These drawings visually revealed the functional and structural arrangements in the building and enabled more in-depth analysis. In addition, the building's energy-efficient systems and environmentally friendly materials were integrated into the research, supported by visuals.

The collected data was rigorously analyzed using qualitative research methods. The information obtained from the literature review played a pivotal role in the analysis, serving as a basis for comparison with the findings of existing research. This comparison allowed for a comprehensive evaluation of the environmental impacts, economic advantages, and energy efficiency potential of sustainable building materials. Additionally, the analysis of sample projects such as Mjøstårnet has further solidified the advantages of sustainable building materials and wooden structures in their application areas.

Results

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CLT panels consist of multi-layered wooden boards glued perpendicularly to each other. Since each plate is placed in a different direction, this layered structure increases the load-carrying capacity of the material in both longitudinal and transverse directions. This arrangement provides high strength by increasing the wood's natural bending and compressive strength. The compressive strength of CLT is approximately 20-30 MPa, which allows it to reach values close to the strength of concrete. The load-bearing capacity of these panels is calculated depending on the quality of the wood used and the number of layers.

Laminated wood, achieved by gluing thin layers of wood, is particularly adept at carrying heavy loads. The strength of the wood in the longitudinal direction, bolstered by the unidirectional placement of each layer, allows for the creation of structural members that can span long distances. GLT, in particular, is well-suited for use in column and beam systems, where its load-carrying capacity shines. The bending strength of these laminated wooden elements, typically falling within the range of 24-30 MPa, presents a compelling alternative to steel structural elements. At Mjøstårnet, the combination of these two materials allowed the structure to rise up to 85 meters high. GLT columns, which are the basic load-bearing system of the building, combine with CLT panels on each floor to effectively carry all the loads of the building. By taking into account the pressure and bending strength of each bearing element in the carrying capacity calculations, the building is ensured to function safely under different load conditions.

Various engineering approaches are used to calculate the load-bearing capacity of wooden structures. When determining the behavior of load-bearing elements under loading, regulations such as Eurocode 5 and American Wood Standards (ANSI/AWC) are complied with. These regulations detail the behavior of wooden structural elements under stresses such as pressure, bending, shear, and torsion.

The strength properties of the wooden materials used in the Mjøstårnet structure are important in structural engineering applications. This section presents the basic formulas used to calculate the load-bearing capacity of Cross Laminated Timber (CLT) and Laminated Timber (GLT) elements in Mjøstårnet.

1. Compressive Strength Calculations

Formula: $\sigma = F/A$

F: Load carried by the carrier element (N)

A: Cross-sectional area (m^2)

2. Flexural Strength Calculations

Formula: $M = (\sigma \cdot I) / y$

M: Bending moment ($N \cdot m$)

σ: Flexural strength (Pa)

I: Moment of inertia (m^4)

y: Distance of the farthest point from the neutral axis (m)

3. Shear Strength Calculations

Formula: $\tau = V/A$

τ: Shear strength (Pa)

V: Cutting force (N)

A: Cross-sectional area (m^2)

Wooden structures' fire resistance is a critical parameter for structural safety. Although wood is a flammable material, engineered wood elements can resist fire for a certain period of time. This durability is related to the wood's charring rate. During a fire, wood burns from its outer layers, and the inner layers are protected, allowing the building elements to maintain their carrying capacity for a certain period.

To increase fire resistance in the Mjøstårnet structure, CLT and GLT elements were protected with fire retardant coatings and partitioned with firewalls. Fire retardant coatings and barriers prevent fire from spreading to other parts of the structure. In addition, the structure's resistance time against fire scenarios is designed to be 90 minutes.

Mjøstårnet has been evaluated as a sustainable building in terms of its energy efficiency and environmental impacts. Wooden material has the feature of being a carbon-neutral building by storing carbon throughout its life. The wooden materials used in the construction of the building were procured from local sources, minimizing carbon emissions.

Additionally, the energy performance of the building has been optimized. Since wood is a natural insulator, heat loss within the building is kept to a minimum. In the energy performance calculations of the building, U-values (heat transmission coefficient) were kept at low levels, and the building achieved energy efficiency by reducing heat losses. The U-value of the wooden walls used in Mjøstårnet is calculated to be approximately 0.15 W/m²K, a factor that increases the energy efficiency of the building.

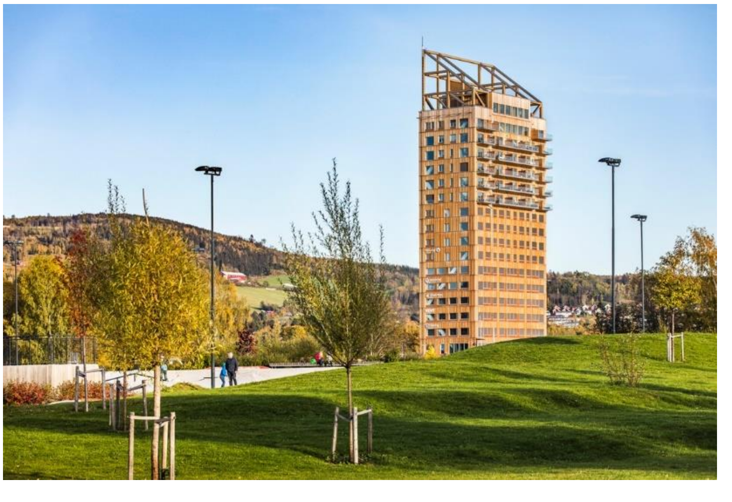

Figure 1. Mjøstårnet Structure, External View-1 (https://www.archdaily.com/934374/mjostarnet-the-tower-of-lake-mjosa-voll-arkitekter9 access date:05.10.2024)

Figure 2. Mjøstårnet Structure, External View-2 (https://www.archdaily.com/934374/mjostarnet-the-tower-of-lake-mjosa-voll-arkitekter9 access date:05.10.2024)

Figure 3. Ground Floor Plan (https://www.archdaily.com/934374/mjostarnet-the-tower-of-lake-mjosa-voll-arkitekter/5e5436fd6ee67e4e780000d1-mjostarnet-the-tower-of-lake-mjosa-voll-arkitekter-ground-floor-plan access date:05.10.2024)

Figure 4. Apartments Layout Plan (https://www.archdaily.com/934374/mjostarnet-the-tower-of-lake-mjosa-voll-arkitekter/5e5436c16ee67e4e780000d0-mjostarnet-the-tower-of-lake-mjosa-voll-arkitekter-apartments-layout-plan?next_project=no access date:05.10.2024)

Figure 5. Hotel Layout Plan (https://www.archdaily.com/934374/mjostarnet-the-tower-of-lake-mjosa-voll-arkitekter/5e54370b6ee67e943b000080-mjostarnet-the-tower-of-lake-mjosa-voll-arkitekter-hotel-layout-plan?next_project=no access date:05.10.2024)

Figure 6. Meeting Facilities Plan (https://www.archdaily.com/934374/mjostarnet-the-tower-of-lake-mjosa-voll-arkitekter/5e5437486ee67e4e780000d3-mjostarnet-the-tower-of-lake-mjosa-voll-arkitekter-office-layout-plan?next_project=no access date:05.10.2024)

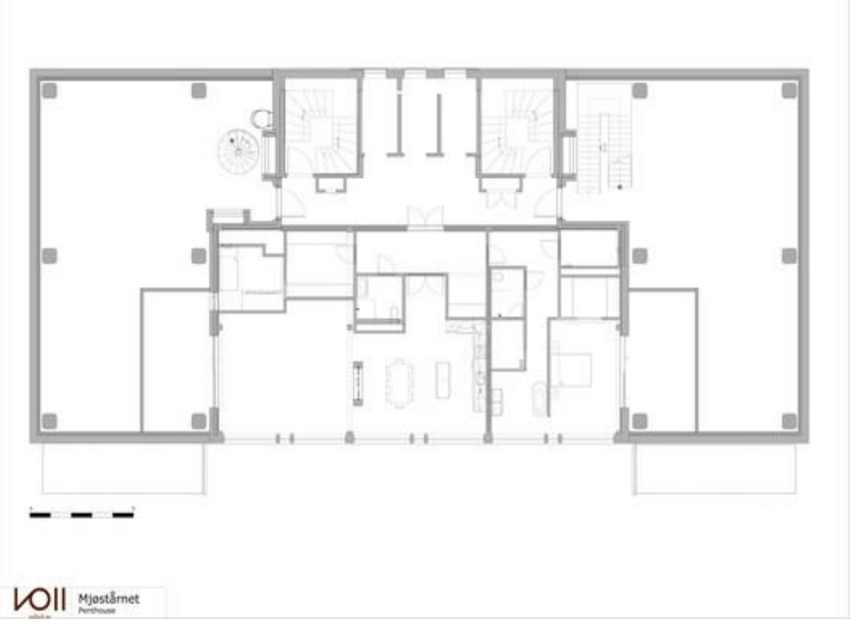

Figure 7. Penthouse Plan (https://www.archdaily.com/934374/mjostarnet-the-tower-of-lake-mjosa-voll-arkitekter/5e5437396ee67e943b000082-mjostarnet-the-tower-of-lake-mjosa-voll-arkitekter-meeting-facilities-plan?next_project=no access date:05.10.2024)

Figure 8. Event Room Plan (https://www.archdaily.com/934374/mjostarnet-the-tower-of-lake-mjosa-voll-arkitekter/5e5437636ee67e4e780000d4-mjostarnet-the-tower-of-lake-mjosa-voll-arkitekter-penthouse-floor-plan?next_project=no access date:05.10.2024)

Figure 9. Event Room Floor Plan (https://www.archdaily.com/934374/mjostarnet-the-tower-of-lake-mjosa-voll-arkitekter/5e5436d06ee67e943b00007d-mjostarnet-the-tower-of-lake-mjosa-voll-arkitekter-event-room-floor-plan?next_project=no9 access date:05.10.2024)

Conclusions

It examines the effects of the Mjøstårnet structure on the sustainability and energy efficiency of wood material use. In addition to being natural and renewable materials, wooden structures offer an important alternative in modern construction practices with their carrying capacity and mechanical strength properties. The Cross Laminated Timber (CLT) and Laminated Timber (GLT) systems used in Mjøstårnet's design clearly demonstrate the advantages provided by these materials.

The energy efficiency of the Mjøstårnet structure offers distinct advantages compared to conventional reinforced concrete structures. Thanks to sustainable design approaches at Mjøstårnet, it is aimed to significantly reduce annual energy consumption. The average annual energy consumption of the building is determined as approximately 80 kWh/m². Considering the carbon footprint, carbon emissions of building materials, and construction processes, it is estimated that wooden structures save approximately 100 tons of CO_2 per year in total with their carbon storage potential.

Comparison: The average annual energy consumption of a normal reinforced concrete structure varies between 150-200 kWh/m².

In this case, Mjøstårnet's energy savings can be calculated as follows:

Energy Saving=Reinforced Concrete Consumption−Wood Consumption

For example, compared to a reinforced concrete structure at 150 kWh/m²:

Energy Saving = 150kWh/m2 − 80kWh/m2 = 70kWh/m2

This savings is achieved in line with Mjøstårnet's sustainable construction approaches and energy efficiency targets.

The Mjøstårnet example demonstrates the potential of wooden materials in modern construction applications and offers an alternative that complies with the principles of sustainable architecture. The energy savings and environmental impacts of the structure reinforce the importance of wooden structures in the construction industry and provide inspiration for future projects.

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