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Research Article

Evaluation in Environmental Effects of Timber and Reinforced Concrete Structures

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Abstract

The construction sector has an important share in terms of carbon emissions. A very intense carbon emission occurs in the process from the production of building materials to their use. For this reason, it is of great importance to conduct studies on the construction sector in the context of climate change and to make developments in this regard. In this study, it is aimed to present solution suggestions to prevent environmental problems by comparing timber structures with reinforced concrete structures within the scope of combating climate change. Within the scope of the study, to obtain more reliable data, two scenarios were considered where three different heights (one-story, five-story and twelve-story) buildings were built with exactly the same features, with timber and reinforced concrete structural systems, and the material consumptions under these conditions were analysed. Thus, the environmental effects of the materials in question were compared with their carbon emissions. In addition, the effects of on-site traffic and transportation in constructions to be made with two different structural systems were proportionally considered and consistent results were obtained. The findings reveal that there is a reduction in carbon emissions between 42.1% and 55.1% in timber structural systems at different heights in structures with identical features. In other words, it has been observed that constructing a building under exactly the same conditions using a wooden load-bearing system instead of reinforced concrete reduces carbon emissions by approximately 50%, offering an advantage.This results show that how important the use of timber structures is in the fight against climate change.

Anahtar Kelimeler
Ahşap Yapılar, Betonarme Yapılar, İklim Değişikliği, Karbon Ayak İzi, Sürdürülebilir İnşaat Malzemeleri

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Özet

İnşaat sektörü karbon salınımı açısından önemli paya sahiptir. Yapı malzemelerinin üretimlerinden kullanımına kadar geçen süreçte çok yoğun bir karbon emisyonu ortaya çıkmaktadır. Bu nedenle iklim değişikliği bağlamında inşaat sektörüne yönelik çalışmaların yapılarak bu konuda gelişmeler sağlanması büyük önem arz etmektedir. Bu çalışmada iklim değişikliği ile mücadele kapsamında ahşap yapılar ile betonarme yapıların karşılaştırılması yapılarak çevresel problemlerin önüne geçilmesi için çözüm önerilerinin ortaya konması amaçlanmıştır. Yapılan çalışma kapsamında daha sağlıklı verilerin elde edilebilmesi için üç farklı yükseklikteki (tek katlı, beş katlı on iki katlı) yapılar, birebir aynı özelliklerle, ahşap ve betonarme taşıyıcı sistemlerle inşa edildiği ikişer senaryo dikkate alınmış ve bu koşullardaki malzeme tüketimlerinin analizi yapılmıştır. Böylelikle söz konusu malzemelerin çevresel etkilerinin karbon emisyonları karşılaştırılmıştır. Buna ek olarak iki farklı taşıyıcı sistem ile yapılacak inşaatlardaki şantiye içi trafik ve nakliye gibi etkiler de orantısal olarak dikkate alınarak tutarlı sonuçlar elde edilmiştir. Elde edilen bulgular, birebir aynı özelliklerdeki yapılarda, farklı yüksekliklerde ahşap taşıyıcı sistemde karbon emisyonlarında %42.1 ile %55.1 arasında bir azalma olduğunu ortaya koymaktadır. Diğer bir ifadeyle birebir aynı şartlardaki yapının, betonarme yerine ahşap bir taşıyıcı sistemden oluşması durumundan %50 civarında karbon emisyonunun azaltarak ve avantaj sağladığı görülmektedir. Bu sonuçlar, iklim değişikliği ile mücadele kapsamında ahşap yapıların kullanımının ne kadar önemli olduğunu göstermektedir.

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1. Introduction

Among today's global problems, climate change continues to form environmental problems due to human-caused factors such as rapid urbanization, excessive fossil fuel consumption, and unconscious industrialization. This clearly demonstrates the need for improvements in the factors causing climate change. When evaluated in terms of carbon emissions, the construction sector has a significant share. This is because the entire process, from the production to the use of building materials, generates very high levels of carbon emissions. Therefore, conducting studies on the construction sector in the context of climate change and developing new perspectives to address these negative conditions is of great importance.

Climate change refers to a global problem resulting from both natural events and human-induced activities that cause permanent changes in the atmosphere, affecting climatic conditions such as temperature, wind, waves, currents, etc. A report published by the Intergovernmental Panel on Climate Change (IPCC) of the United Nations shows that the average temperature of our world has risen by 1.1 °C in the last hundred years [1]. The report also states that if necessary measures are not taken, irreversible effects may occur by 2100. Natural causes of climate change include volcanic activity, solar flares, and natural variations in the Earth's orbit. Regarding human-induced effects of climate change, the largest share is attributed to the use of fossil fuels [2]. The release of large amounts of carbon dioxide and other greenhouse gases into the atmosphere, particularly in sectors like construction, causes environmental damage during the production process of necessary materials. In addition, harmful gases produced by industrial and agricultural activities also damage the environment. On the other hand, the emission of greenhouse gases leads to an increase in atmospheric temperature, resulting in events such as melting glaciers, rising sea levels, and more frequent extreme weather events.

The construction industry, one of the largest sectors in the world, unfortunately leads the way in carbon emissions that cause climate change (see Fig. 1). Cement, in particular, is one of the most important sources of carbon emissions [3]. In addition, energy requirements such as heating, cooling and maintenance of constructed buildings are generally met through the consumption of fossil fuels, and these issues are among the factors that trigger climate change [4]. On the other hand, very high amounts of greenhouse gas emissions are also generated during the demolition or removal of structures. According to statistical data, it is seen that global carbon emissions are around 28% during the production of construction materials such as cement, iron and steel alone [5].

This study aims to demonstrate that timber structures are much more environmentally friendly than reinforced concrete structures, offering a way to reduce greenhouse gas emissions in the construction sector. In other words, the aim is to prevent environmental problems by proposing innovative solutions in the construction sector, which is significant in terms of carbon emissions. For this purpose, an analysis of the amounts of timber and reinforced concrete used in different construction types was conducted, and the resulting carbon emissions were examined and interpreted. In this context, it was considered important to examine structures of different heights rather than a single type [6]. Thus, it was aimed that the effects of reinforced concrete in the foundation system, which is seen as a necessity today, on the use of timber and reinforced concrete would not lead to misleading findings.

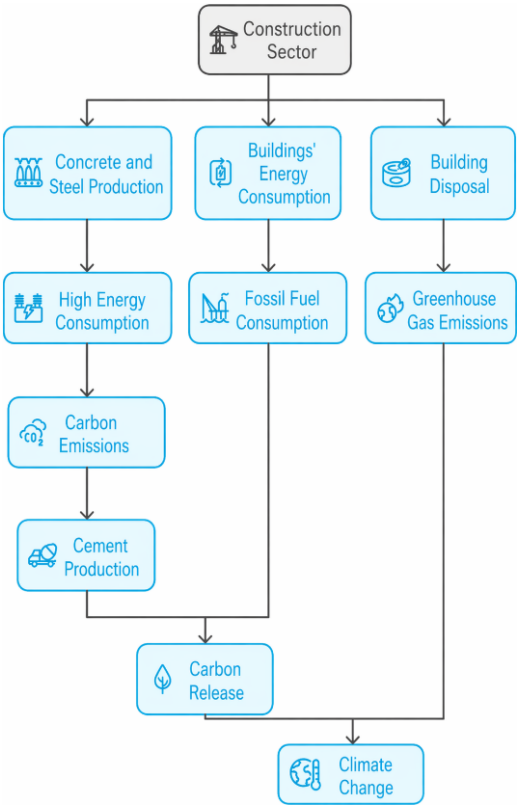

Figure 1. The impact of the construction industry on climate change.

2. Carbon Footprint and Environmental Impacts of the Construction Sector

The construction sector, one of the largest in Turkey and the world, drives a significant economic cycle and employment. However, according to data released in Türkiye, the construction sector, which has constant interactions with the environment, accounts for 30% of total waste [7]. As a result of research on climate change and greenhouse gas emissions, which currently occupy the world agenda, it is evident that greenhouse gas emissions from cement production alone account for approximately 7% of total emissions [8]. In both Türkiye and the world, the energy used by buildings for heating, cooling, and lighting, and the resulting greenhouse gas emissions, reach very significant levels (see Fig. 2). Today, many different methods are applied to reduce the environmental impact of the construction sector. Among these, while it is possible to reduce energy consumption through smart and energy-efficient buildings, the main problems are carbon emissions and waste generated during the construction and demolition phases of buildings [9].

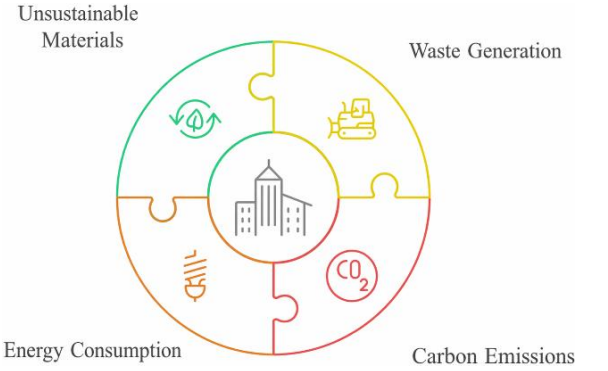

Figure 2. Environmental impacts of the construction industry [6].

In today's structures' construction, reinforced concrete structures, the most commonly used building materials, consume a significant amount of concrete and reinforcing steel. It is known that cement, a raw material for concrete, alone accounts for approximately 7% of global carbon emissions. According to data from a research company called *Carbon Brief*, steel production alone accounts for 11% of all carbon emissions, while studies by *Our World Data* suggest this rate is 7.2%. The fundamental reason for these discrepancies stems from the methods used in steel production. In 2019 alone, China produced 1.875 million tons of steel, releasing 3.375 million tons of carbon emissions into the environment [10]. According to the International Energy Agency (IEA), 1 ton of crude steel production results in 1.4 tons of CO_2 emissions, although this rate is estimated at 1.8 or even 3 in different sources. In particular, it is not difficult to imagine that, in the production of a large industrial country like China, these figures approach 3. Blast furnace (BF) is a production method that heats steel to very high temperatures. In electric arc furnaces, the process is carried out using energy generated by the contact of electrodes with the metal. In 2019, approximately 3.100 million tons of CO_2 were released during BF production, while this amount was around 500 million tons in the electric arc method (see Fig. 3). According to 2008 data, the construction sector accounted for 36% of Türkiye's total energy consumption. This rate is likely much higher today. In addition, very high amounts of greenhouse gas emissions are generated during the transportation of building materials to construction sites.

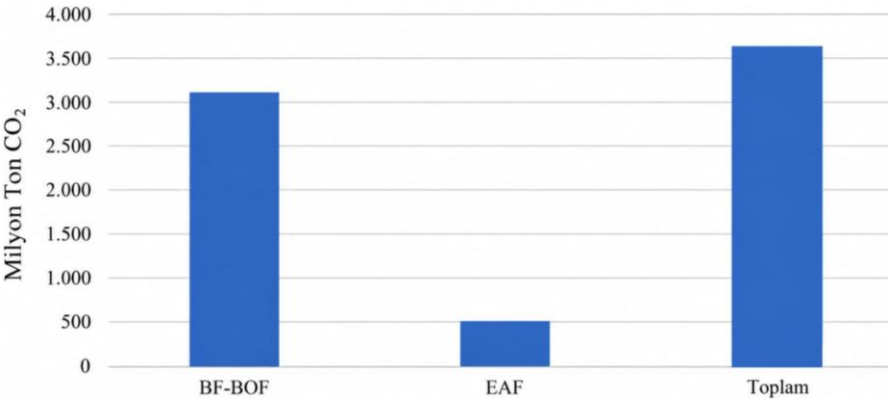

Figure 3. 2019 global steel industry CO_2 emissions report [8]

2.1. The Concept and Principles of Sustainable Construction

The concept of sustainable construction aims to conserve natural resources, achieve high energy efficiency, and reduce waste production. The principles of sustainable construction encompass all stages from the design and production of structures to their maintenance and demolition. At the beginning of sustainability is the longevity of the materials used and the fact that these materials require less repair and replacement. Therefore, care should be taken to design insulation

materials and heating and cooling systems in buildings to reduce water and energy consumption at multiple stages as can bee seen in Fig. 4.

2.2. Sustainable Building Materials

The use of sustainable building materials in construction plays an important role in reducing the carbon footprint due to their low environmental impact. The first product that comes to mind when considering sustainable building materials is wood. Wood stands out for its environmental impact due to its carbon-sequestration properties. In addition, the use of recycled steel has become widespread in construction. This has led to improvements in steel production techniques from scrap metal. This matter eliminates emission problems during the production phase.

3. A General Comparison of Timber and Reinforced Concrete Structures

When examining building permits issued in Türkiye in 2015, a total of 189.67 million m² of buildings were constructed, of which 180.54 million m² consisted of reinforced concrete structures. In contrast, the permit rate for timber structures was found to be below 1%. However, new trends in timber structures and advances in construction technologies are gradually increasing the use of timber structures [11].

When examining the structural properties of timber and reinforced concrete structures, it is observed that timber is a natural and renewable material, while reinforced concrete is an artificial and much heavier building material. In this respect, timber stands out with its strength-to-weight ratio, while reinforced concrete excels with its high compressive and tensile strength. Furthermore, timber is a much more flexible building material than reinforced concrete. Considering all these factors together, timber structures gain importance in terms of earthquake resistance performance. On the other hand, timber structures are much more advantageous than reinforced concrete structures in terms of sustainability and environmental impact. The main reason is wood's carbon sequestration properties and its environmental impact during cultivation. In contrast, reinforced concrete structures, composed of a combination of steel and cement, unfortunately have significant, harmful environmental impacts due to the very high carbon emissions they generate. Moreover, timber structures can be almost completely recycled and reused after reaching the end of their lifespan. Timber structures have certain economic disadvantages. The limited production of structural timber in our country is a major economic disadvantage. However, they also stand out due to their lightweight nature and the rapid construction process using prefabrication techniques. Regarding maintenance costs, timber requires much more careful attention and technological advancements during the construction phase to improve fire performance. Furthermore, it is difficult to find qualified craftsmen and/or apprentices to build traditional timber structures today.

In terms of earthquake resistance, timber structures have significant advantages over reinforced concrete structures due to their strength-to-weight ratio. While timber structures, due to their flexible nature, can withstand earthquake effects, they require some additional applications to improve fire resistance. However, thanks to technological advancements, very safe timber buildings can be produced following these applications. In conclusion, while timber structures stand out, particularly in terms of environmental impact and earthquake resistance, reinforced concrete structures are superior in terms of economic cost (see Fig. 5).

3.1. Life Cycle Analysis of Reinforced Concrete and Timber Structures

Life cycle analysis (LCA) is defined in the ISO 14040 and ISO 14044 standards as an evaluation method that examines the environmental impacts of a structure or product from the supply of raw materials to the end of its service life. Today, this method is also important for the construction sector, where environmental problems are rapidly increasing (see Fig. 6). In particular, over the last century, as concrete and steel dominated the construction sector, the use of alternative materials such as wood has decreased considerably. However, when the principles of sustainable construction are considered, life-cycle analysis shows that reinforced concrete structures have very high environmental impact values, primarily due to the high energy consumption and greenhouse gas emissions associated with cement [12]. In contrast, wood, as a renewable material, has a much lower carbon footprint [13]. The production process of cement used in the construction of reinforced concrete structures results in a significant amount of carbon dioxide with a high global warming potential. In addition, when evaluated in terms of acidification potential, it also causes the release of gases such as sulfur dioxide, which cause acid rain (see Fig. 7). On the other hand, the demolition of reinforced concrete structures also generates a large amount of construction waste, and therefore, its transportation increases the environmental impact due to fuel consumption and emissions [12]. Wood, the source of timber, offers carbon sequestration by absorbing carbon dioxide from the atmosphere during its growth. Furthermore, its lower energy and water consumption compared to reinforced concrete construction, and the fact that it produces recyclable and biodegradable waste, further enhance its environmental advantages. Considering all these factors together, timber structures are seen as more environmentally friendly.

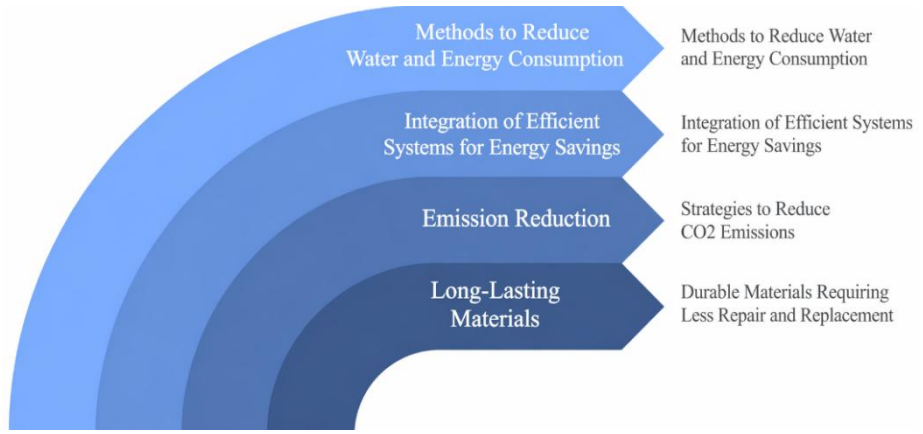

Figure 4. Principles of sustainable construction

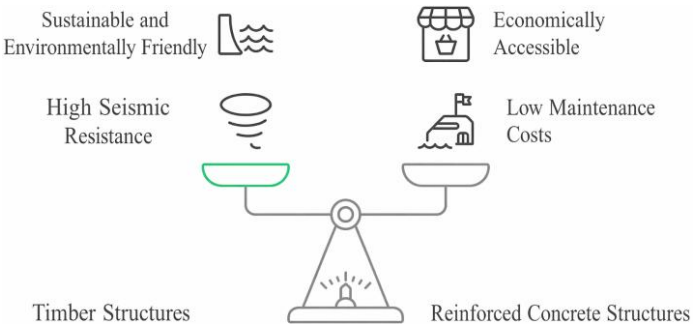

Figure 5. Comparison of timber and reinforced concrete structures

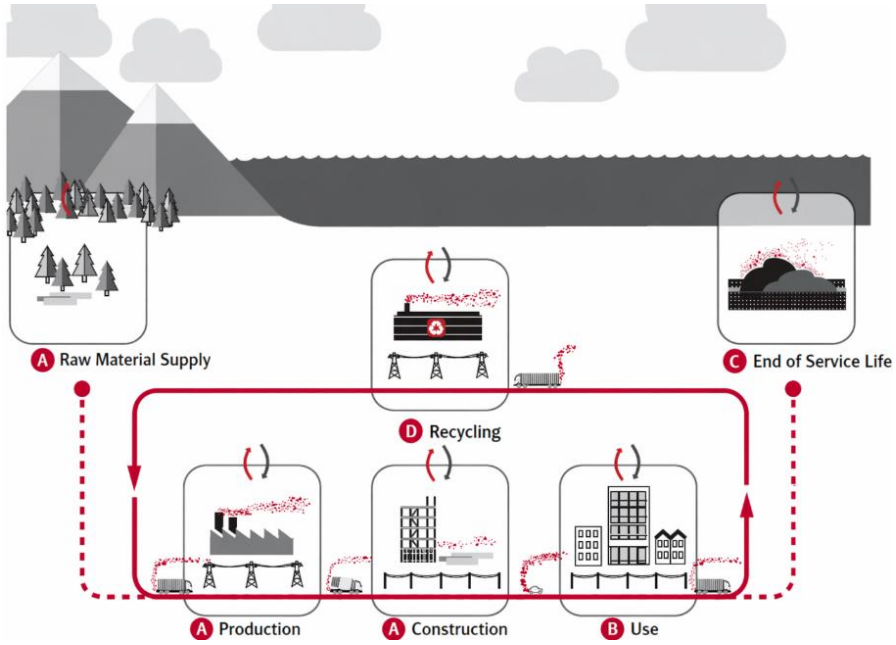

Figure 6. Life cycle stages [14]

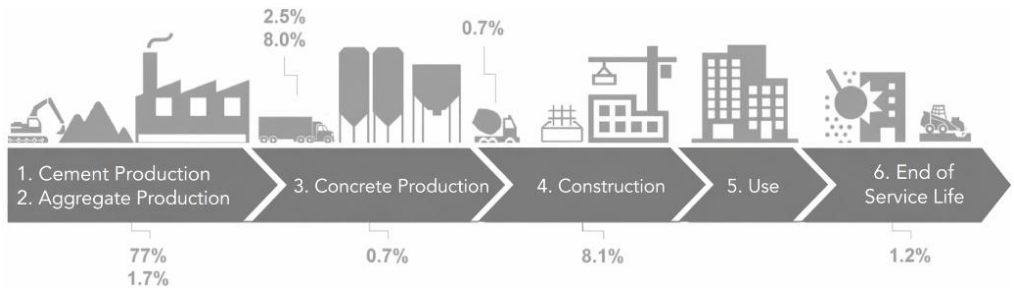

Figure 7. Life cycle stages of ready-mixed concrete and cement and CO_2 emission rates [14]

The United Nations Framework Convention on Climate Change (UNFCCC) was adopted at the Rio Summit on Environment and Development in 1992 to ensure international cooperation in combating climate change. The main objective of this convention is to stabilize atmospheric greenhouse gas concentrations before they reach dangerous levels and to enable humanity to achieve sustainable development goals in harmony with the environment. Today, 191 countries are implementing various strategies to reduce carbon emissions in line with UNFCCC policies. Türkiye became a party to this convention in 2004. One of the most significant impacts of the UNFCCC has been on the construction sector. To address this problem, the UNFCCC aims to promote the use of sustainable building materials and to reduce carbon footprints. Wood, a leading sustainable building material, is considered an important option for achieving UNFCCC goals due to its carbon storage capacity and its low energy consumption in production, as stated before. The World Conference on Timber Engineering (WCTE) brings together scientists, engineers, architects, and industry leaders to share innovative techniques for the design and use of timber structures. The carbon emission reduction effect of timber structures is one of the main agenda items of this conference. In short, this conference argues that the widespread use of timber structures contributes to achieving both environmental and economic sustainability goals.

3.2. Use of Timber Structures in Türkiye

As a result of the widespread use of concrete and steel structures in the early 20th century, traditional building and construction techniques were gradually abandoned. The disappearance of experienced labor in timber structures, especially the need for much greater knowledge in the design and construction of multi-story timber structures, has led to a much lower rate of timber construction. In addition, the production and supply of structural timber in Türkiye is much more limited than the availability of reinforced concrete structures. On the one hand, misconceptions about timber structures, such as their vulnerability to fire, susceptibility to biological deterioration, and the view that their widespread use is harmful to our forests, also create significant obstacles to their widespread use. Therefore, the very high economic costs of timber structures unfortunately limit their use in Türkiye. Today, these problems can be significantly reduced with fire protection technologies and calculations for timber structures.

3.3. Paris Climate Agreement

The Paris Climate Agreement, signed under the auspices of the United Nations in 2015, is the first binding agreement presenting a global action plan for climate change. The main goal of the agreement is to limit greenhouse gas emissions that cause global warming and to keep the temperature increase above pre-industrial levels to 1.5°C. Accordingly, Türkiye committed to reducing greenhouse gas emissions by 21% in 2015. This rate was increased to 41% in 2022. A zero-emission target was set for 2053. The construction sector plays a critical role in achieving the goals of the Paris Climate Agreement. Timber structures contribute to environmental sustainability goals through their carbon storage capacity and low emissions in their production processes. The Paris Agreement encourages countries to develop projects that will reduce carbon emissions in the construction sector through their National Contribution Declarations (NCDs).

4. Types of Structural Timber

Nowadays, thanks to technological advancements, the disadvantages of wood are beginning to be overcome. Today, wood can be safely used not only in low-rise buildings but also in very high-rise buildings. Different types of structural timber are preferred depending on the intended use of the buildings, the loads they will carry, and their height [6].

Solid wood is a type of structural timber obtained directly from the tree trunk in nature and used with minimal processing. Solid wood, especially produced from trees such as pine, oak, and fir, is limited by the natural height of the tree because it is a natural product. In addition, its strength varies depending on the direction of the fibers. Therefore, the use of solid wood is not very feasible in high-rise or wide-span structures. It can also be affected by humidity and temperature changes in terms of dimensional stability. In addition, since solid wood is a natural product, protection treatments should be applied with materials resistant to insects, fire, and moisture.

Glued laminated timber, also known as Glulam, is a type of structural timber produced by laying thin wooden planks, or lamellae, parallel to each other and then pressing them together with strong adhesives. Pine, spruce, and fir are the most commonly used woods in its production. Laminated timber has significantly higher strength than solid wood, a characteristic achieved because the lamellae fibers are aligned in the same direction. Furthermore, laminated timber does not have the length limitations found in solid wood and can be produced in much larger sizes. It also offers advantages in terms of resistance to humidity and temperature changes compared to solid wood [6]. On the other hand, this product, which is easier to process, also has high resistance to risks such as fire. Finally, laminated timber offers prefabrication possibilities, allowing it to be processed off-site and transported to the construction site, thus achieving much faster construction times.

Cross-laminated timber (CLT) consists of at least three layers of solid wood pieces positioned at right angles to each other. This results in high strength in both directions. Furthermore, cross-laminated timber is a highly innovative, sustainable, and high-performance structural timber product that enables much longer lengths in modern timber structures. CLT possesses high dimensional stability and is unaffected by humidity and temperature variations. It is also fire-resistant and can be used with large-section panels. A comparison of the differences in the production of structural timber is given in Table 1. It is worth noting here that the production of structural timber varies from country to country and depends on technological capabilities.

Table 1. Differences in obtaining structural timber

Quality	Structural Timber Forests	Normal Forests
Tree Species Selection	Tree species possessing properties such as high strength, durability, and dimensional stability are preferred. Coniferous trees (such as pine, spruce, fir, and Douglas fir) are generally used.	Various tree species can be found that serve different purposes. Biodiversity and ecosystem services are prioritized.
Planting and Maintenance	Trees are planted at specific intervals and in regular rows. The quality of the trees is improved through practices such as pruning, thinning, and fertilization.	Natural regeneration or fewer plantings are possible. Maintenance operations are less frequent, and more room is given to natural processes.
Harvest	Trees are systematically cut down when they reach a certain age or size.	Harvesting is planned according to different purposes and services (timber production, firewood, ecosystem, etc.).
Sustainability	Sustainable forest management principles are applied. Trees are planted in place of those cut down, protecting the long-term health of the forest.	While sustainability is important, the focus is on broader ecosystem services such as biodiversity, carbon sequestration, and water resource conservation.

5. Timber Building Regulations and Examples of Incentives for Timber Buildings in Türkiye

The design and construction of timber buildings in Türkiye are carried out according to the Regulation on the Design, Calculation and Construction Principles of Timber Buildings, published on March 24, 2024 and effective from January 1, 2025. Before this regulation came into force, regulations such as TS 647 Calculation and Construction Rules for Timber Buildings, Eurocode-5 and the 2019 Turkish Building Earthquake Regulation were used in the design and construction of timber buildings [15-17]. The Regulation on the Design, Calculation, and Construction Principles of Timber Buildings, aimed at comprehensive construction of timber buildings in Türkiye, establishes the principles to be followed in their design, calculations, and construction. In addition, this regulation also contains information on specific issues such as the selection of building materials, fire safety, earthquake resistance and energy efficiency.

In Türkiye, the *Promotion of Low-Cost, Energy-Efficient Timber Buildings in Türkiye* project, implemented in 2023 in collaboration with the United Nations Development Programme (UNDP) and the Ministry of Environment, Urbanization and Climate Change, encourages new timber construction applications, primarily cross-laminated timber technology. The initial phase aimed to construct six pilot timber building projects and to build a total of 0.58 million m^2 of timber structures within the first six years.

In Sweden, regulations implemented after 1997 have allowed the construction of 3~4 story timber structures. In addition, grant programs have been initiated on state lands, specifically for the construction of timber structures. Furthermore, civil engineers and architects have been enrolled in new training programs on timber structures. Moreover, public lands have been sold solely for the construction of timber structures. As a result of all these practices, approximately 90% of detached houses are now constructed with timber structural systems [18]. In Canada, since 2009, it has been mandatory for all government buildings to be constructed primarily of timber [19]. In addition, an incentive program launched in 2018 provides reimbursement for almost all extra costs arising from the use of wood. Thanks to this, over 400 multi-story wooden structures have been built since 2009 [20]. Looking at wood incentive programs in general, they have led to significant developments and gains across countries. In Sweden, the proportion of wood used in all buildings has risen to 15%, while in Finland it has reached 10% in just the first 5 years after the incentives. In the United Kingdom, the use of wood in detached houses rose from around 8% in 1998 to 28% in 2016. Similarly, in Germany, the proportion of timber buildings has increased from 2.7% to 14% in the last fifteen years. Finally, in Japan, the proportion of detached timber buildings, which was 42% in 1990, has risen to 80% in 2020 [21].

6. Comparison of Environmental Impacts of Timber and Reinforced Concrete Structures within the Scope of Sample Projects

To make consistent, accurate comparisons of timber and reinforced concrete structures regarding climate change, certain variables must first be held constant. First and foremost, the structure to be constructed must have the exact same architectural features and the same square footage. Furthermore, since almost all foundations of both timber and reinforced concrete structures are built with reinforced concrete, and the structures foundation varies proportionally with the floor height, the comparison will use more than one type of structure. Therefore, to achieve more consistent results, studies on the construction of single-story, 5-story, and 12-story structures with reinforced concrete and timber were evaluated, and the environmental damage caused by timber and reinforced concrete structures under the same conditions was determined using impact assessment methods based on their calculations.

Carbon footprint calculations measure greenhouse gas emissions from a product or material throughout its life cycle to determine the environmental damage it causes. This data is a sub-step of life cycle assessment and primarily focuses on its impact on climate change. These impacts mainly occur at different stages of the life cycle as can be seen in Fig. 8.

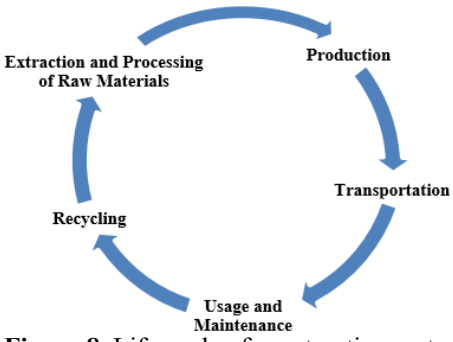

Figure 8. Life cycle of construction materials

6.1. Single-Story Building

In the article titled *A Comparison of Life Cycle Impact of Mass Timber and Concrete in Building Construction*, published in the World Journal of Civil Engineering and Architecture in 2022, the environmental impacts of timber and reinforced concrete structures were discussed [22]. When the nature of the building in question is considered, it is seen that it is 4.5 m high and has a usable area of approximately 120 m^2 (see Table 2). In addition, in the comparison, only the materials used in the load-bearing structural system such as columns, beams and foundation systems were taken into account, and parts such as walls and roofs were not included in the evaluation.

Figure 9. View of the single-story building selected as an example [22]

Table 2. Quantities for single-story timber and reinforced concrete buildings

Material Type	Reinforced Concrete Building	Timber Building
C25 Concrete (m^3)	6.27	6.27
C30 Concrete (m^3)	61.34	35.26
Reinforcement (ton)	5.8	0.41
Laminated Wood (m^3)	-	6.97
Total (m^2)	125	125

6.2. Five-Story Building

In the article titled A Lifecycle Assessment of a Low-Energy Mass-Timber Building and Mainstream Concrete Alternative in Central Chile published in the journal Sustainability in 2022, a lifecycle analysis of the use of solid timber and reinforced concrete materials in Chile was conducted [23]. In this research, a five-story, 1405 m^2 reinforced concrete building was compared with a solid timber building with similar characteristics. The material quantities used in this comparison are given in Table 3.

Table 3. Quantities for five-story timber and reinforced concrete buildings

Material Type	Reinforced Concrete Building	Timber Building
C10 Concrete (m^3)	28.3	24.6
C25 Concrete (m^3)	338.4	124.1
Reinforcement (ton)	23.4	3.1
Laminated Wood (m^3)	-	45
Cross-Laminated Wood (m^3)	-	212.6
Total (m^2)	1405	1405

Şekil 10. View of a 5-story timber and reinforced concrete building [23]

6.3. Twelve-Story Building

In the article Comparison of Building Construction and Life-Cycle Cost for a High-Rise Mass Timber Building with its Concrete Alternative published in the Forest Products Journal in 2020, life cycle analysis and cost comparison of concrete and mass timber building materials in high-rise buildings in Portland [24]. In the study, a twelve-story reinforced concrete building in Portland was compared with a timber building with equivalent characteristics (see Table 4).

Table 4. Quantities for twelve-story timber and reinforced concrete buildings

Material Type	Reinforced Concrete Building	Timber Building
Grade of unspecified concrete (m^3)	2027	1057
Reinforcement (ton)	192.3	91.6
Laminated Wood (m^3)	-	557
Cross-Laminated Wood (m^3)	-	1279
Total (m^2)	8360	8360

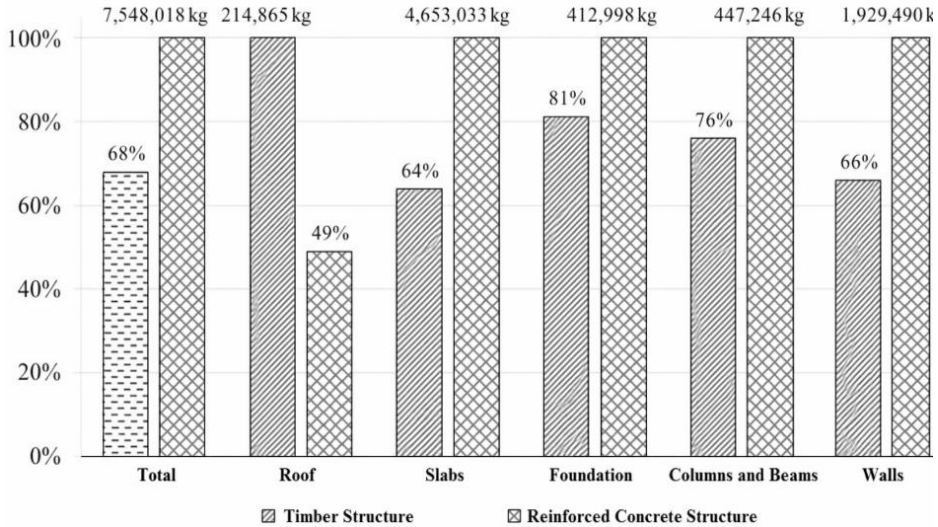

Figure 11. Weight comparison for the selected building as an example [24]

Considering the studies conducted, only the net carbon emissions during the production stages of the materials used were examined, and a comparison of the carbon footprints of reinforced concrete and timber structures was made. Looking at the research conducted to make this comparison, the results in Table 5 are obtained [25]. From this table, it is seen that the factor that significantly increases the carbon footprint of reinforced concrete structures is the use of reinforcement. Intensive energy consumption in steel production is the main cause of carbon emissions. In addition, some studies show that the carbon footprint of steel can reach up to 2750 kg CO_2/ton when it is produced directly from mining [26]. Furthermore, the most important part of the average carbon footprint value of 265 kg/ton of concrete is caused by the firing of clinker used in concrete production. The comparative analysis conducted by Hammond and Jones [26] for different concrete classes is presented in Table 6. Similarly, the results of the research on the carbon footprint of concrete used in England and Denmark are presented in Table 7. These charts show that carbon footprint values can vary significantly depending on the standards used in concrete production and the grade of concrete.

When the sample structures considered in this study are examined, taking into account the study by Dündar [25], the total carbon emissions of the materials used in the structural system of each structure during the production phase are presented in Table 8. In the calculation made in this table, 1 m^3 of concrete is taken as 2.4 tons, and 1 m^3 of structural timber is taken as 0.8 tons. Accordingly, the advantage calculation was performed using equation (1). As a result, across all three types of buildings, it is seen that when structural timber is preferred over reinforced concrete, structures with the same floor and m^2 release an average of 50% fewer carbon emissions in production alone.

$$Advantage\ (\%) = \frac{Reinforced\ Concrete\ Building\ Emissions - Timber\ Building\ Emissions}{Reinforced\ Concrete\ Building\ Emissions} \times 100 \quad (1)$$

Table 5. Net carbon emission in production for different types of materials

Material Type	Net Carbon Emissions in Production (kg/ton)
Grade of unspecified concrete	265
Reinforcement	694
Type of structural timber not specified	33

Table 6. Carbon footprint values for different concrete grades by Hammond and Jones

Material Type	Carbon Footprint (kg/m^3)
C25 Concrete	215
C40 Concrete	272
C60 Concrete	350
C80 Concrete	394

Table 7. Carbon footprint values of reinforced concrete used in the UK and Denmark

Material Type	Carbon Footprint (kgCO_2/m^3)
C35 reinforced concrete used in the UK	270
C35 reinforced concrete used in the Denmark	387

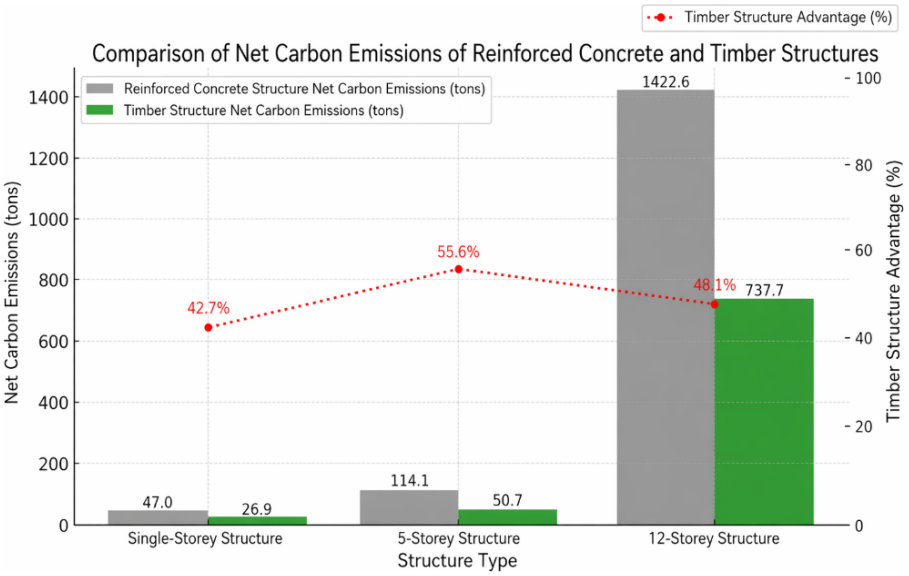

Figure 12. Comparison of net carbon emissions of reinforced concrete and timber buildings

Table 8. Net carbon emissions values in reinforced concrete-timber building and the advantage ratio of timber building

Number of Story in the Building	Reinforced Concrete Building Net Carbon Emission (kg)	Timber Building Net Carbon Emission (kg)	Advantage Rate of Timber Building (%)
Single-Story	47025	26927	42.7
5-Story	114051	50693	55.6
12-Story	1422628	737691	48.1

Transportation: In the report written about the 25-story Ascent Tower, built in Milwaukee in 2022 and holding the distinction of being the world's tallest timber structure, the characteristics of timber and reinforced concrete structures were compared [27]. This report shows that a timber structure of the same dimensions requires an average of 30% more transportation. Accordingly, the carbon released during transportation is 5% for reinforced concrete structures and 12% for timber structures.

Construction Site Traffic; it is stated that the on-site traffic in reinforced concrete structures is, on average 10.75 times higher than in timber structures [27]. The main reason is that the materials used in timber construction arrive at the construction site ready-made, so construction is faster. According to the same study, the ratio of on-site traffic to carbon released in production is 6.8% for reinforced concrete structures and 1% for timber structures.

After all analyses were evaluated, it was decided to convert the transportation and construction site traffic items into production emission types to present the results in a clearer, simpler way.

Single-Story Building; Findings obtained by converting transportation and construction site traffic items to production emission types are given in Table 9. This table shows that when transportation and on-site traffic effects are also taken into account, using wood materials in the structural system of the single-story example building results in 42.1% less carbon emissions.

Five-Story Building; The findings obtained by converting transportation and construction site traffic items into production emission types are given in Table 10. From this table, when transportation and on-site traffic effects are also taken into account, this ratio is seen to be 55.1% in the 5-story sample building.

Twelve-Story Building; The findings obtained by converting transportation and construction site traffic items into production emission types are given in Table 11. From this table, when transportation and on-site traffic effects are also taken into account, it is seen that timber buildings have a 47.8% advantage in carbon emission in the 12-story sample building. In short, all the findings given above are seen to be consistent with studies carried out in the technical literature [11]. This clearly demonstrates that timber structures play an important role in terms of environmental impacts.

Table 9. Net carbon emission values for a single-story timber and reinforced concrete building

Stages	Net Carbon Emissions in Reinforced Concrete Building (kg)	Net Carbon Emissions in Timber Building (kg)
Production and Raw Material	47.025	26.927
Transportation	2.351	3.231
On-worksite traffic	3.198	269
Total	52.574	30.427

Table 10. Net carbon emission values for a five-story timber and reinforced concrete building

Stages	Net Carbon Emissions in Reinforced Concrete Building (kg)	Net Carbon Emissions in Timber Building (kg)
Production and Raw Material	114.051	50.693
Transportation	5.702	6.083
On-worksite traffic	7.755	507
Total	127.508	57.283

Table 11. Net carbon emission values for a twelve-story timber and reinforced concrete building

Stages	Net Carbon Emissions in Reinforced Concrete Building (kg)	Net Carbon Emissions in Timber Building (kg)
Production and Raw Material	1.422.628	737.691
Transportation	71.131	88.523
On-worksite traffic	96.738	3.377
Total	1.590.497	829.591

7. Results and Recommendations

This article comparatively examines reinforced concrete and timber structures in terms of their impact on climate change. For this purpose, the carbon emissions resulting from the construction of three different building types with identical characteristics, using timber and reinforced concrete structural systems, were examined. The primary objective of examining three buildings with different heights in this study is to eliminate the possibility that the varying number of floors might create a dependent effect on the overall analysis of the foundation system requirements. The main conclusions and recommendations derived from this study are summarized below.

1) The obtained findings show that replacing a reinforced concrete structure with a timber structural system under identical conditions reduces carbon emissions by approximately 50%, providing a significant advantage. This demonstrates that timber structures are far more environmentally friendly than reinforced concrete structures. In other words, it clearly highlights the need to accelerate the transition to more environmentally friendly alternatives (timber structures) to reduce high carbon emissions in the construction sector. Furthermore, wood has carbon storage properties and is recyclable.

2) The findings of this study indicate that high-rise timber structures will become more popular worldwide in the near future, particularly due to the rapid increase in timber production potential and projects in developed countries. Therefore, it is clear that Türkiye, being rich in forests and naturally highly suitable for timber production, needs to make appropriate investments in this area.

3) The increasing use of timber structures offers significant advantages not only in environmental impact but also in seismic performance, thanks to their flexibility and light weight.

4) Educating the public about the benefits of sustainable construction techniques, especially timber structures, is crucial for the development of the sustainable construction sector. Therefore, it is recommended that undergraduate and postgraduate education and professional development programs related to sustainable construction techniques be organized at universities.

5) The transition of the construction sector to sustainable materials such as wood should be accelerated through legal regulations and incentives. For this purpose, it is recommended to utilize alternative options such as tax breaks, grant programs, and loan support that encourage the construction of timber structures.

6) For a sustainable construction sector, it is necessary to accelerate the production of environmentally friendly structural products through special investment incentives. In other words, technological advancements should focus on addressing the shortcomings of sustainable construction materials like wood, and new products should be developed to improve techniques, particularly in areas such as biodegradation, fire hazards, and atmospheric effects.

References

[1]. Calvin, K., Dasgupta, D., Krinner, G., Mukherji, A., Thorne, P. W., Trisos, C., Romero, J., Aldunce, P., Barrett, K., Blanco, G., Cheung, W. W. L., Connors, S., Denton, F., Diongue-Niang, A., Dodman, D., Garschagen, M., Geden, O., Hayward, B., Jones, C., … Orendain, D. J. (2023). *IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (P. Arias, M. Bustamante, I. Elgizouli, G. Flato, M. Howden, C. Méndez-Vallejo, J. J. Pereira, R. Pichs-Madruga, S. K. Rose, Y. Saheb, R. Sánchez Rodríguez, D. Ürge-Vorsatz, C. Xiao, N. Yassaa, J. Romero, J. Kim, E. F. Haites, Y. Jung, R. Stavins, … C. Péan, Eds.). Intergovernmental Panel on Climate Change (IPCC). https://doi.org/10.59327/IPCC/AR6-9789291691647

[2]. Tuğaç, Ç. (2022). İklim değişikliği krizi ve şehirler. *Çevre Şehir ve İklim Dergisi*, *1*(1), 38–60. https://dergipark.org.tr/tr/pub/csid/article/1102221

[3]. Gürsel, P. A., & Meral, Ç. (2012). Türkiye'de çimento üretiminin karşılaştırmalı yaşam döngüsü analizi. *2. Proje ve Yapım Yönetimi Kongresi*. https://www.researchgate.net/profile/Cagla-Meral-Akgul/publication/259199344_Turkiye'de_Cimento_Uretiminin_Karsilastirmali_Yasam_Dongusu_Analizi/links/00b4952a6df011a80a000000/Tuerkiyede-Cimento-Ueretiminin-Karsilastirmali-Yasam-Doenguesue-Analizi.pdf

[4]. Şen, Z. (2022). İklim değişikliği ve Türkiye. *Çevre Şehir ve İklim Dergisi*, *1*(1), 1-19. https://doi.org/10.1080/02626667.2016.1222533

[5]. Orhon, A. V, & Altın, M. (2012). Beton yapıların karbon ayak izi. *Sürdürülebilir Yapı Tasarımı Ulusal Konferansı*. 12-13 Kasım Dokuz Eylül Üniversitesi, Bornova-İzmir.

[6]. Yazıcıoğlu, H. (2025). *Ahşap yapılar ile betonarme yapıların çevresel etkilerinin değerlendirilmesi*. Karabük Üniversitesi, Lisansüstü Eğitim Enstitüsü, Karabük.

[7]. T.C. Çevre Şehircilik ve İklim Değişikliği Bakanlığı. (2020). Atık Yönetimi Yıllık Raporu.

[8]. IEA (International Energy Agency). (2021). *Tracking industry 2021 report*.

[9]. Öztürk Karadoğan, P., & Erdağ, A. (2022). The effects of construction waste on climate change: Is a more green construction industry possible? *Journal of Engineering Sciences and Design*, *10*(4), 1222-1231. https://doi.org/10.21923/jesd.1058358

[10]. Chen, C. X., Pierobon, F., Jones, S., Maples, I., Gong, Y., & Ganguly, I. (2021). Comparative life cycle assessment of mass timber and concrete residential buildings: A case study in China. *Sustainability*, *14*(1), 144. https://doi.org/10.3390/su14010144

[11]. Gün, B., & Anıktar, S. (2021). Çevre ve şehircilik uygulamalarında betonarme-ahşap yapı karşılaştırması. *İstanbul Sabahattin Zaim Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, *2*(3), 19–25. https://doi.org/10.47769/izufbed.801787

[12]. Al-Huthaifi, A. A. M. M., & Altan, M. F. (2021). Yapı sektöründe uygulanan yaşam döngüsü değerlendirmesinde karşılaşılan sorunlara çözüm önerileri. *MAS Journal of Applied Sciences*, *6*(1), 194-210. https://doi.org/10.52520/masjaps.47

[13]. Şirin, G., Aydemir, D., & Gündüz, G. (2024). Sürdürülebilirlik ve Ahşap Malzemede Yaşam Döngüsü Analizi Kullanımı. *Bartın Orman Fakültesi Dergisi*, *26*(3), 298-305. https://doi.org/10.24011/barofd.1345241

[14]. Türkiye Hazır Beton Birliği. (2021). *Hazır beton yaşam döngüsü rehberi*. https://www.thbbakademi.org/wp-content/uploads/2021/09/hazir-beton-yasam-dongusu-rehberi-v4010921.pdf

[15]. *TS 647-Ahşap yapıların hesap ve yapım kuralları*. (1979). Türk Standartları Enstitüsü, Ankara.

[16]. *TS EN 1995-1-1. Eurocode 5: Ahşap yapıların projelendirilmesi. Bölüm 1-1: Genel kurallar ve bina kuralları*. (2005). Türk Standartları Enstitüsü, Ankara.

[17]. TBDY. (2019). *Türkiye bina deprem yönetmeliği*. Afet ve Acil Durum Yönetimi Başkanlığı, Ankara.

[18]. Hurmekoski, E., Jonsson, R., & Nord, T. (2015). Context, drivers, and future potential for wood-frame multi-story construction in Europe. *Technological Forecasting and Social Change*, *99*, 181-196. https://doi.org/10.1016/j.techfore.2015.07.002

[19]. Bowyer, D. J. (2016). *Modern tall wood buildings: Opportunities for innovation*. https://www.dovetailinc.plscd.com/upload/tmp/1588011267.pdf

[20]. NRC (National Resources Canada). (2021). *The state of mass timber in Canada 2021*.

[21]. Şişman, M. E., & Balaban Ökten, B. (2023). Yapı sektöründe ahşap teşvik politikaları ve etkileri. *Bab Journal of Architecture and Design*, (Special Issue), 48–64. https://dergipark.org.tr/en/pub/babdergisi/article/1182570

[22]. Mofolasayo, A. (2022). A comparison of life cycle impact of mass timber and concrete in building construction. *World Journal of Civil Engineering and Architecture*, *1*(1), 47–72. https://doi.org/10.31586/wjcea.2022.449

[23]. Felmer, G., Morales-Vera, R., Astroza, R., González, I., Puettmann, M., & Wishnie, M. (2022). A lifecycle assessment of a low-energy mass-timber building and mainstream concrete alternative in central Chile. *Sustainability*, *14*(3), 1249. https://doi.org/10.3390/su14031249

[24]. Liang, S., Gu, H., Bergman, R., & Kelley, S. S. (2020). Comparative life-cycle assessment of a mass timber building and concrete alternative. *Wood and Fiber Science*, *52*(2), 217–229. https://doi.org/10.22382/wfs-2020-019

[25]. Dündar, T. (2019). *Bir yapı malzemesi olarak ahşap*. İstanbul Üniversitesi, Cerrahpaşa Orman Fakültesi Orman Endüstri Mühendisliği Ders Notları.

[26]. Hammond, G. P., & Jones, C. I. (2008). Embodied energy and carbon in construction materials. *Proceedings of the Institution of Civil Engineers - Energy*, *161*(2), 87–98. https://doi.org/10.1680/ener.2008.161.2.87

[27]. Fernandez, A., Komp, J., & Peronto, J. (2024). Timber rises. *Civil Engineering Magazine*, *94*(1), 64–71. https://doi.org/10.1061/ciegag.0001708