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# A Critical Review of Timber as a Structural Material

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## Abstract

The structure refers to the component of the building that maintains its stability. The beam, column, slab, and foundation are the major integral units of the structure. The major challenge while designing the structure for a building is to select materials for its units. Generally, reinforced cement concrete (RCC) is used worldwide in the current context. The search for the perfect material to replace RCC has been ongoing for decades. Timber can be the perfect material everyone has been searching for. It is made of wood, which is harvested from trees. This paper focuses on the process of installation and mechanical properties that make timber suitable for construction. Timber has ideal characteristics and mechanical properties that make it fit for the structure. Several mechanical properties have been tested in the lab, making timber a suitable replacement for existing RCC.

The timber has a compressive strength of 500 Kg/cm$^2$ to 700 Kg/cm$^2$, which makes it mechanically acceptable to use as a structural material. It also has other mechanical properties in acceptable ranges. The tensile strength of timber is 500 Kg/cm$^2$ to 2000 Kg/cm$^2$. It also has a favourable density of 300Kg/M$^3$ to 900Kg/M$^3$. Several problems occur with timber, too, which makes it questionable. But still, timber holds good credit. Major problems with timber, for example, low fire resistance, difficulty installing, and decay after contact with moisture, can be solved by applying the respective remedies. Overall, timber can be one of the best replacements for RCC in terms of suitability.

**Keywords:** *density, material, RCC, strength, structure, timber, wood*

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## Introduction

The use of sustainable materials in construction has been going on for decades. The demand for eco-friendly materials has also increased. Wood is considered as good for future generations and development. Wood grown on the earth is 100% renewable, extremely durable, and equally strong (Bhaskar et al., 2020). Timber is the term that represents processed wood that is ready to be used in construction. Most often, timber refers to trees that have been harvested that retain their bark or other characteristics for aesthetic purposes (Edward, 2022). Timber has high mechanical and aesthetic value, which makes it a suitable material for civil engineering constructions. High compressive strength, tensile strength, plasticity, durability, and minimal deflection are the factors that make timber a good construction material for civil engineering structures. Other pessimistic properties make timber questionable in terms of material for structural construction. Those properties include less fire resistance, less resistance against insects, inadequate water resistance, etc. However, these flaws can be reduced if the proper treatment of timber does not improve them. As the tree is exposed directly to the external environment, the moisture content of timber can be the major obstacle in using timber for structure. Many methods exist to remove moisture from timber, such as air, solvent, microwave, and supercritical $CO_2$ drying. According to Michael et al. (2017), convective or condensing kiln drying is the predominant technique used to eliminate moisture.

Similarly, other hindrances of timber can be overcome by several techniques. Timber as a building material contains all of the qualities and performs better when compared with most of the other common building materials. Timber is also a renewable building material that is flexible and easy to work with; it is a sustainable building material (Bhaskar et al., 2020).

### Statement of the Problems

Using timber in civil engineering constructions is not a new concept. The mechanically strong, sustainably durable, and economically effective timber has made it one of the best materials for the structure.

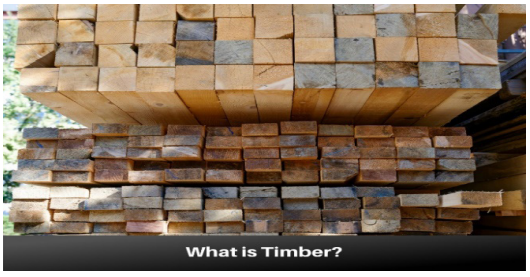


**Plate 1:** *Timbers (Rachel, 2023)*

Timber is used in construction for many purposes, such as making entrances (doors, windows), making aesthetic materials, etc. However, despite having excellent mechanical properties, timber has not been used much as a structural material. The availability of materials like steel, cement, and sand is low in remote areas, which badly hampers transportation costs. The construction is also less cost-efficient and less time-efficient, as reinforced cement concrete is being widely used, as it takes 28 days for concrete to gain its ultimate strength. The extremely high weight increases the self-weight stress in materials like steel, RCC, etc.

This paper aims to enlighten the strengths and weaknesses of timber to use as a structural material. The major focus of this paper is to conclude the suitability of timber in civil engineering construction.

### Objectives

The major objectives of this study are to study the mechanical properties of timber to check its suitability for construction, to analyze the methodology for the installation of timber structures, to perform a comparative study of the advantages and disadvantages of using timber as a structural material and to compare timber with Reinforced cement concrete (RCC) in terms of their mechanical properties.

### Significance of study

This paper aims to comprehensively analyse timber as a structural material based on its mechanical properties. This paper hopes to review the subject of the use of timber for other

aesthetic purposes where it can be used as an important load-bearing part of a building. The trend of using timber in construction is somehow outdated. Given its mechanical properties, timber is highly credited as a structural material. Timber is easily available; if not, it is easily transportable in most areas. Timber can be a very good material for constructing structural components like beams, columns, etc. The major aims of this paper are the analysis of mechanical properties, a review of the installation method, and a critical evaluation of merits and demerits.

## Literature Review

Edward (2022) highlighted a clear definition of timber and its uses. He also described the application of timber in civil engineering. This paper mainly focuses on the general use of timber in construction. While this paper describes the use of timber in civil engineering, it does not say much about the use of timber as a structural material.

Alyssa (2015) explained the criteria for selecting trees for timber extraction. This article focuses on the pre-study of any tree before extracting the timber. Not all types of trees can be used to extract timber, and selecting trees is the initial and one of the major steps in timber extraction.

Ali Sulaiha (2019) performed a fire test on wood to check its resistance to fire. Being highly suitable mechanically, timber has very low fire resistivity, which makes it questionable as a structural material. The effect of fire retardant on wood's natural ability is also well-tested in the paper.

Khademibami Laya (2022) analyzed the protection of wood from external agencies. Since wood is easily affected by an environmental factor, it needs to be well protected. The paper reviewed the development of studies on wood protection research.

Kumar Ajay (2020) majorly focused on using timber as a structural material. The suitability and sustainability of timber are also properly analyzed in this paper. A review of timber as a structural material is properly studied in the paper. The major concern of the paper was to review the application of timber in structural construction along with its sustainability.

Lundbäck Mikael (2021) described the extraction of round wood from the trees. There are several methods for the extraction of wood from a tree. This article highlighted two major methods for the extraction of round wood. The cut-to-length method and the tree-length method are explained very well in this article.

Ramage Michael H (2017) explained the use of timber in civil engineering constructions. This paper mainly focuses on using timber in small and large-scale constructions. The major conclusion of this paper was that timber is highly effective to use in buildings where the weight of the structure needs to be low. This paper also explains how timber structures can differ from steel and RCC structures.

Shanta (2024) highlighted the properties of timber. The major goal of this paper was to analyze the quality of timber. The qualities of good timber are also well studied in this paper. Not every timber can be used as a structural material. Timber should possess an adequate amount of mechanical strength, which is explained in this paper.

## Research Methodology

This paper is mainly based on the review of previous studies. Some of the details were obtained by observing them on-site. The data for the paper has been adopted from the existing reports of test experiments.

Papers regarding timber and its uses in construction have been reviewed. The installation process of timber structures has been analyzed by observing preexisting structures and reviewing the research. The mechanical properties of timber have been studied and analyzed to determine its suitability for construction. Merits and demerits of timber have been compared by observing the locality and studying several papers on the subject.

### Construction Method

Construction of the timber structure includes several steps in specific order.

**Selection of Tree**

It is the initial stage of the whole process. Trees are first selected to extract the timber later. Some important factors are to consider when selecting a tree for timber extraction. The tree should be old enough to gain enough ultimate strength yet not too old to lose its mechanical properties. The perfect age of a tree can provide the optimum strength to the structure. Depending on the size of the timbers, trees with decent straight stretches are needed (Alyssa, 2015). The straight trees have a high availability of quality timber, and even wastage is low in the straight trees. The process should also be economical and favourable to the budget as well as the manpower of the project. Hardwood trees should be selected as they possess the required mechanical properties in adequate amounts. There are also a lot of environmental factors to be considered. Trees should be selected in a manner that does not mess with the forest's ecosystem. The forest ecosystem should be strictly maintained.

**Plate 1:** *Trees (Berlyn & Everett, 2024)*

**Harvesting of Round Wood**

Demolished trees with branches removed and trunks cut to a length fit for transportation are generally called round wood (Michael et al., 2017). Almost 2 billion cubic meters of industrial round wood are harvested annually globally. Two of the most commonly used methods for Harvesting and extracting are cut-to-length (CTL) and tree-length (TL) (Mikael et al., 2021). Trees are cut and processed to the required length for transportation in the cut-to-length method. Additionally, this method is highly efficient as even a small amount of special wood can be separated and transported cost-effectively to the mill.

In the tree-length method, the harvesting equipment consists of a feller for felling the trees, a skidder for pulling the intact trunks to the roadside, and a processor for removing the limbs and cutting the tops of the trunks. Instead of the small units, the tree is transported as a whole. The tree-length method is less efficient and requires more machines than the cut-to-length method.

***Plate 3*:** *Harvesting of Round Wood (Jekinson, 2023)*

**Cutting and Shaping**

After Harvesting, the wood is ready to go into another process: cutting and shaping. Wood is cut into the required dimension and shaped into the required physique to be used as a structural unit. Manual tools like hand saws and power tools like table saws, miter saws, and band saws are used to cut the wood into desired dimensions. Similarly, shaping tools like routers, sanders, hand planes, and rasps are used to shape the wood (Danielle & Logan, 2023). Now, this cut and shaped wood can finally be called timber. The shape and dimension of timber may vary according to the load format and maximum load intensities in the building. Generally, the timber is cut into rectangle cross sections.

**Plate 4:** *Cutting of wood for timber (Nell, 2010)*

**Treatment**

Although timber has enough strength, it is treated

to boost its mechanical properties and increase durability for aesthetic purposes. The service period for wood and wooden products depends on the wood's natural durability, protection system, and design. If wood is properly processed and treated, it can last for a long time, and historic buildings, utility and artistic objects, and other wood products are some of the shreds of evidence (Laya & Gabrielly, 2022). Generally, Solignum paints, ASCU, Oil paints, Coal tar, etc., are preservatives for timber protection (Anupoju, 2021).

**Plate 5:** *Preservation of Timber (Anupoju, 2021)*

**Foundation Installation**

The type of foundation to be used depends upon several factors, such as ground type, size of structure, and type of wood used. Although the structural material does not determine the foundation type, strip foundations are the most commonly used foundation for timber-structured buildings. These consist of a concrete strip on a continuous level as a base for a linear construction. A three-course layer of bricks is now laid on top of the strip below floor level (Devenish, 2024). Other foundations like rafts, piled, and other shallow foundations are also used for the timber structure, depending on the type of building and location of the site.

**Joining and Finalization**

This step involves joining prepared timber beams and columns to make an integral structure. Timber beams and columns are joined by using several joints such as lap joints, butt joints, scarf joints, and so on. Scarf joints are used when the beams are required to be joined end to end. The ends of the wood are cut at the required angle to create a long, tapered joint, which is finally bolted together after gluing.

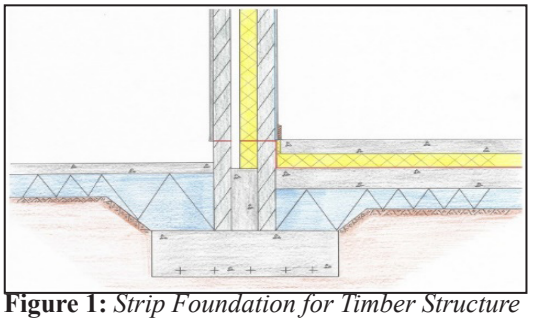

**Figure 1:** *Strip Foundation for Timber Structure (Colm, 2013)*

But joints are used when two pieces of wood have to be joined at a right angle. The ends of the wood are cut straight and joined using bolts or screws. Lap joints are mostly preferred when one beam overlaps the other. The ends of timber are cut at a certain angle to allow for the overlap, and the beams are then bolted together (Pastori Sofia, 2023).

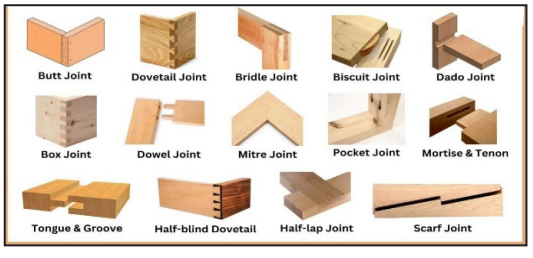


**Figure 2:** *Joints Used in the Timber Structures (Lyas, 2022)*

After the structural units are integrated, it is now time to finalize them. They are painted with different colors to give an excellent aesthetic appearance. Timber bears various mechanical properties that are important for its application in construction. These properties include strength, durability, and density. Strength indicates the timber's ability to withstand applied forces without breaking or deforming. Durability reflects its resistance to decay, insects, and other forms of deterioration. Density measures the mass of timber per unit volume, influencing its overall strength and weight-bearing capacity.

**Mechanical properties**

Timber has several mechanical properties that determine its suitability for construction.

**Compressive strength**

Compressive strength denotes the ability of a material or structural component to bear loads that reduce the size or dimensions of that material when applied. It plays a vital role in the overall stability of any engineering structure. The timber is placed between the two plates of a Universal testing machine (UTM), and a load is applied to opposing sides of the sample until it finally fractures. The loading rate is important since a loading rate that is too low has a higher potential to cause creep. In general, the compressive strength of any timber depends upon the tree, region, and year from which it is extracted. The compressive strength of timber is found to be 500 Kg/cm$^2$ to 700 Kg/cm$^2$ (Mou, 2024). Meanwhile, the compressive strength of RCC is 150 kg/cm$^2$ to 305 kg/cm$^2$ (Mishra, 2021)**.**


**Plate 6:** *Compressive Strength Test (Lan, 2017)*

**Tensile Strength**

Tensile strength is the amount of stress any material can handle until it stretches, deflects, and breaks. As its name insinuates, tensile strength is the material's resistance to tension caused by mechanical loads applied to the material itself. The material is usually tested using a universal testing machine (UTM) for its tensile strength. The machine holds a specimen material in place and applies the tensile stress needed to check its breaking point. The machine is connected to an extensometer, which measures changes in the material's dimension. The tensile strength of timber is 500 Kg/cm$^2$ to 2000 Kg/cm$^2$ (Mou, 2024). The tensile strength of RCC is 300 Kg/cm$^2$ to 500 Kg/cm$^2$ (Madhav, 2022).


**Plate 7:** *Tensile strength Test (Minghao, 2017)*

**Fire Resistance**

As timber is made of wood, it cannot entirely resist the fire. However, it can be made fire-resistant to some extent by applying several methods. The timber cannot completely be prevented from the fire, but it can be treated to reduce its possibility. There have been many tests regarding the fire resistivity of the timber structure. The room-corner test, cone calorimeter test, furnace test, single-burning item test (SBI), and limiting oxygen index (LOI) test are some of the tests that can inspect the fire resistivity of the timber (Sulaiha et al., 2019). RCC has a much higher resistance to fire than timber.

**Moisture Content**

The amount of water contained in a timber is known as the moisture content of the timber. It is one of the major factors in determining the suitability of timber to use as structural units. Generally, freshly cut wood has an average water content of 50%. The natural moisture content of timber depends upon several factors, such as the type of wood, the region it is harvested from, the climate of the area, and so on. A moisture meter is a device used to measure the moisture content on timber, and it is known to be the quickest and easiest method. The acceptable moisture levels of timber range from 9% to 14% for structural units like beams and columns (Larry, 2024). Acceptable moisture readings for concrete are usually 3.5% to 4.5% (Lee, 2023). Density

The ratio of mass to volume is known as density. Wood density is another crucial factor determining timber's structural value and strength. Wood density generally falls between 300Kg/M$^3$ to 900Kg/M$^3$. However, the wood

density depends on the tree from which it is harvested. Table 1 shows the variation of density in wood harvested from several trees. An increase in density increases the strength of timber to some extent.

**Plate 8:** *Moisture Meter (Chris, 2024)*

Meanwhile, increased density further inhibits wood's suitability for timber use after a certain point. The density of wood can be calculated by measuring its mass and volume (Taylor, 2017). The density of reinforced concrete is generally 2240Kg/$M^3$ to 2400Kg/$M^3$.

**Table 1**: *Variation in Wood Density from Different Trees*

| Tree of wood | Density (Kg/$M^3$) |
|---|---|
| Mango | 600-800 (Darial, 2024) |
| Oak | 593-897 (Jordan, 2020) |
| Cherry | 689-897 (Caldeira, 2024) |
| Walnut | 641-689 (Caldeira, 2024) |
| Maple | 625-753 (Caldeira, 2024) |
| Pine | 352-849 (Jordan, 2020) |

**Merits of Timber as a Structural Material**

Using timber as a structural material can be highly beneficial. There are a lot of merits to using timber as a structural material.

Installation of timber structures is a faster process. Timber does not have to wait longer to gain its ultimate strength; it gains its ultimate strength right after the installation. Timber is also highly cost-efficient compared to RCC and steel. Using timber can be cheaper in areas where trees are available in adequate amounts. Wastage of material is very low in a timber structure. The part of wood that remains after timber extraction can be used to make other products like frames for doors and windows, utensils, etc. Even wood powder can be used as fillers for other timber products. Having great aesthetic value is also another major advantage of timber. Since wood is a great insulator, it provides high insulation toward sound and heat. The insulation property of wood helps maintain internal temperature. The highest load provider to any structure is the material of the structure. The material provides a self-weight to the structural components, and the stress provided by the self-weight of a member is also high. Since timber is lightweight, self-weight stresses on the foundation are also low in a timber structure (Michael et al., 2017).

**Demerits of Timber as a Structural Material**

Despite holding excellent credit, timber also has some disadvantages.

Wood is highly flammable, so fire resistance is low in timber. Although the fire resistance of timber can be improved, it will never be completely fireproof. The formation of mold may appear if not appropriately treated. This problem appears due to poor workmanship; therefore, it can be improved simply with good workmanship. It can easily decay if it comes into contact with moisture. So, the use of timber in a rainy area is avoided. However, timber can be well treated to increase its resistance to moisture. The possibility of being eaten by termites is another demerit of timber. Since timber is not widely used in structures, the installation of timber structures requires skilled manpower. The unavailability of skilled manpower worldwide is another demerit of timber (Solarte & Couper, 2022).

Some of the demerits of timber are completely curable, whereas some can only be improved to some extent.

## Discussion

The installation method, mechanical properties, merits, and demerits are studied in this paper. The major issue this paper addresses is the suitability of timber in construction as a structural material. There is much existing research about the use of timber in construction, and timber has also been used in construction for years. However, the use of timber in structural components like beams and

columns is not very much seen. The installation of timber is found to be quite easier if done by skilled manpower, and mechanical properties are also in favourable ranges for bearing loads. There is also a lot of environmental research that does not support the use of wood in construction. However, timber can be the solution for places where other materials are unavailable, and trees are available in adequate amounts.

As supported by the study of Kumar Ajay (2020), timber can be the perfect material for the structure in most cases. Timber holds excellent mechanical properties and can be used as a load bearer. The result of this study is also somehow favoured by the study of Ramage Michael H. (2017), who analyzed the criterion where timber serves best as the structural material. Timber may not be very effective for larger buildings with a high serving period, but it can be an excellent material for temporary buildings. One of the few defects of timber is its low fire resistance, which is also well-studied in this paper and can be supported by the study of Ali Sulaiha (2019). However, timber can be treated to increase its fire resistance to an adequate extent, as this study supports. The initial steps of the installation of a structure are the selection of trees and the extraction of round wood; there are majorly two major methods for the extraction of round wood, which are well-studied in the studies by Alyssa (2015) and Lundbäck Mikael (2021).

## Conclusion

While using timber, there are a lot of points that need to be considered. The major consideration is the impact on the environment. While cutting down trees for timber extraction, we should consider the effect of the process on the environment. Another major recommendation is the good treatment of timber. Wood should be properly processed and checked for standard properties before being used in construction. The last and very important thing to note is the workmanship. The manpower working in this sector should be well-trained. Only after can we benefit from timber, which can act as the material for a structure. This research primarily aimed to analyze timber use, particularly as a structural material. With its excellent mechanical properties, the Timber can be used in construction differently as it is being used widely today. Timber can be used as a structural material instead of for constructing doors, windows, and so on, which can be done using other materials with weak mechanical properties. Another preprimary criterion this paper covers are the installation of the timber structure.

Timber is both an eco-friendly and sustainable replacement for concrete. It possesses excellent strength and high durability if appropriately treated. It has compressive and tensile strength superior to RCC. Regarding cost and maintenance, timber can be superior to RCC and steel if proper treatment is given. There are several disadvantages to using timber in structural units, too. Preparation of timber beams and columns takes less time than RCC as timber gains ultimate strength right after installation. Timber also has mechanical properties within the limit to be considered as material for the structural portion of any building. It has been being used for construction for a significant amount of time. Timber has widely distributed applications in the construction of residential buildings and larger temporary structures. The use of timber in huge superstructures is not preferred because of several factors, but it is observed to work as effectively as RCC and steel in small construction projects. If skilled manpower can be arranged and proper treatment can be provided, timber can be an excellent material for constructing structural units like beams and columns.

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