# WOOD AND CONCRETE AS A BUILDING MATERIALS

Behavior of building a material

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The history of building materials can be traced back to the earliest endeavors of humankind to create shelter. This scholarly investigation centers on wood and concrete as prominent building materials in the context of Finland. While concrete has been widely employed as a construction material across many regions worldwide and remains the most prevalent choice, recent concerns regarding environmental impact and extreme weather conditions have prompted a search for more ecologically sound alternatives in residential and other building projects. Consequently, there is a pressing need to encourage stakeholders to consider alternative building materials that not only match concrete in terms of cost but also present viable competition in the realms of sustainability, maintenance, constructability, and client satisfaction. In this regard, wood has been identified as the primary alternative material to compete with concrete within the Finnish construction sector.

This research critically examines both concrete and wood materials, exploring their characteristics, merits, and drawbacks, with a comprehensive evaluation of which material proves superior when considering all pertinent factors such as structural integrity, economic feasibility, environmental impact, and energy considerations. The culmination of diverse investigations provides compelling evidence that wood stands as a superior building material for small and medium-sized structures. Based on these findings, coupled with Finland's ambitious target of achieving climate neutrality by 2035, it is strongly recommended that low-rise, wood-based buildings play a pivotal role in helping the country attain its set objectives. This recommendation takes into account the advantages and disadvantages associated with both wood and concrete constructions..

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# 1 INTRODUCTION

Materials for buildings have existed as long as man has attempted to build a shelter for himself. As such, one can firmly say building materials are as old as time immemorial. However, as civilization and knowledge expanded, so did the skills, knowledge, and understanding of building materials. As a result, man attempted to transit from the Stone Age to the Computer Age, which had additional effects on development, the use of new construction materials, as well as modern technology (Osore 2019). Undoubtedly, building materials and design developments in the construction sector have become a recurring phenomenon. These changes have led to the use of modern materials in building construction (Osore 2019). Buildings used enormous amounts of materials, energy, and other resources, which continued to have an adverse effect on the environment because of their overreliance on these materials. Throughout the construction process, from the beginning to the end or final phase, the construction engineers, builders, or project managers must consider the sustainability, and weather conditions of the building, to determine the type of building materials to ensure the maximum safety of the end-users. As such, the materials must meet international and national accepted standards.

Today, wood and concrete remain among the most used and accepted materials for building construction, even though several other building materials exist. This is given to the fact that these materials have unique qualities. For instance, wood is a natural, renewable material that emits very little carbon dioxide into the environment and stores carbon throughout its lifespan (Abimaje and Baba 2014; Ede et al. 2015; Osore 2019). Also, wood is easy to work with, lightweight, and adaptable (Abimaje and Baba 2014). On the other hand, concrete is given credit for its superior qualities of strength, durability, workability, and the capacity to be shaped into various structural shapes (Ede et al. 2015; Al-Menhosh, 2017). Several efforts are being made among professionals to use the best possible building materials, both in terms of environmental consideration and other related consideration issues such as weather conditions, and sustainability, which is now a global concern (Ede et al. 2015; Al-Menhosh, 2017; Osore 2019). This is because most building materials have their own peculiar challenges in terms of durability, cost, acceptability, and negative impact on the environment. It is on account of this that this current study investigates wood and concrete as building materials in Finland.

## 1.1 Background of Study

Wood as a building material has been as old as mankind has been civilized. In fact, wood is widely used as a building material not only for houses back then, but also for the construction of boats used in expeditions. Today, wood is still widely used in the construction of boats and buildings in most parts of the world. The use of wood in the construction of the frames of the majority of household dwellings is also prevalent. Hence, it is nearly impossible to construct a building without the use of wood, at least in some form. This is so because even when a structure is made using other materials, such as concrete, wood will still be used in some areas of the construction, such as the creation of internal door frames, roofing, or even outside cladding. The construction of huts, cabins, houses, and bridges in rural parts of the world, particularly in low- and middle-income countries, was mostly done using logs of wood. This shows that the use of wood as a building material has a long history. Its use is even prominent because wood is natural, most construction engineers believed that wood is vital materials of construction. In all, wood is a good building material. This is why most of the commercial and industrial buildings, residential houses all use wood as a structural building material. Though wood is not without some limitations as a construction material, however, some experts believe that concrete is an alternative for building materials.

However, the use of concrete as a building material is credited to the fact that it is durable and has strength (Ede et al., 2015; Al-Menhosh, 2017). As such, concrete plays a vital role in the building construction sector. Concrete is described as a mixture of water, cement or binder, and aggregates (Salain, 2021). It is a structural material used in buildings that is made of aggregate, or hard, chemically inert particle material (often sand and gravel), plus cement and water. It is a mixture of particles that are tightly linked together and an industrial material that mimics the characteristics of rock. Concrete has a resistance that is quite powerful. It is the most popular building material (Ede et al., 2015; Osore, 2019; Salain, 2021). This is partly due to its versatility in shaping; it provides flexibility in structural form.

The chemical composition of concrete admixtures is also incorporated in most modern concrete constituents (Al-Menhosh, 2017). The binder phase for concrete is supposed to be Portland cement, while the aggregates phase consists of coarse and fine aggregates (Ede et al. 2015; Osore 2019). Concrete's superior attributes of strength, durability, workability, and ability to be molded into diverse structural shapes make it the material of choice for a variety of purposes in the construction industry. It is used in more applications than all other construction materials combined, including buildings, highways, concrete bridges, tunnels, tanks, infrastructure, and sewage systems (Abimaje and Baba, 2014; Ede et al., 2015; Salain, 2021). Nonetheless, the early disintegration of concrete structures in harsh conditions has sparked scholarly arguments about the ideal building material.

As a result, the challenges of selecting one building material over another have been a source of much concern and debate in the construction industry, as clients, architects, and design engineers all have their own preferred choice, which is most likely based on material availability, ease of erection building, material cost, aesthetics, and technical knowledge, to name a few. Environmental and sustainability considerations are becoming increasingly relevant in the choice of building materials in recent years (Ede et al., 2015; Osore, 2019; Salain, 2021). In Finland and many parts of the world, two fundamental building materials are used as building materials. Although wood is more commonly used for less critical structural parts, and buildings, concrete is one of the materials used for concrete block walls. Concrete is more often used in developing countries (Ede et al. 2015; Osore 2019), however, wood is rarely used save for temporary constructions, low-value structures, and in remote areas across in both developed and developing countries. Scholarly debates rage over which of these two building materials, wood and concrete, is superior in terms of current weather and global environmental concerns (i.e., climate change, global warming, and the greenhouse effect). It is on account of this, that this study investigates wood and concrete as building materials in Finland.

## 1.2 Statement of Problem

Building structures is an essential part of any human civilization and building types have evolved over time. These building structures are unique to each country and location, considering a variety of elements such as climate and material availability (Spisakova and Mackova, 2015), with no single aspect being crucial. Traditional buildings were often built with locally available materials such as wood, natural stone, and bricks (either clay or mud bricks) (Dutu et al. 2018). All these materials are subjected to a variety of environmental conditions, which alter their structure and integrity (Fierascu et al. 2020). Wood and concrete remained the most used building and construction materials in the world, despite some known limitations. The question of which of these building materials is the most environmentally friendly and sustainable, particularly in extreme environmental and weather conditions. From this perspective, a much-needed comparison between concrete and wood in structural, economic, environmental, and energy terms is provided to assist designers in making the decision between the two.

This is necessary because proper technical knowledge on building material is required for sustainable structural buildings and designs. It is important to point out that wood is a natural and traditional building material. As a result, substantial knowledge, and information about its importance as a construction material, its characteristics, and its influence on structural design and behavior has been studied over the years in sophisticated nations; nonetheless, it is not a favored alternative for key structural elements in Finland. A comprehensive understanding of the physical properties of wood and concrete can help in the construction of safe structures, which is why this research is necessary. Also, these building materials necessitate the assembly of various components during the construction process. Most developing nations rely heavily on fossil fuels for energy generation in these processes. As a result, greenhouse gases such as carbon dioxide, Sulphur dioxide, and methane are released into the atmosphere, depleting the ozone layer and triggering global warming and, by extension, climate change. Putting everything into perspective and knowing and comprehending how these building materials are essential for constructions workers, as well as project managers. Hence, the purpose of this study is to critically examine the behavior of wood and concrete as building materials with a view to the advantages and disadvantages of each in terms of their structural, economic, environmental, and energy stances.

## 1.3 Justification for the Study

According to the International Energy Agency (2023), the building industry sector is now responsible for around 40% of the world's greenhouse gas (GHG) emissions, which significantly contributes to climate change. It is necessary to make efforts to lessen this impact, not only by increasing the service life energy efficiency of buildings but also by utilizing materials with low embodied carbon emissions (Bribian et al. 2011). This second aspect is crucial since it has been suggested that proper material selection for building and construction projects might cut overall carbon emissions by as much as 50%. (Chen et al., 2020). This is because of some building material's capacity to store carbon in completed goods and to replace functionally comparable materials with a greater carbon footprint, such as wood, concrete and steel, has a huge potential to become a sustainable future option. Even the possibility has been raised that the widespread use of wood-based building materials in the construction of mid-rise, multi-story structures might assist the construction industry in becoming a carbon sink rather than a source (Churkina et al. 2020).

In Finland, the average annual increment of stem wood is currently approximately 107 million m3, whereas the annual harvesting (which in recent decades has reached up to 87 million m3) is less than this amount (Markus, 2018). The maximum sustainable felling potential of Finland's forests for the ten-year period 2015–2024 was assessed by the Natural Resource Institute of Finland to be 84 million m3 of round-wood per year (Luke 2018). Statistics on round-wood harvesting show that, on average, 86% of this potential is exploited, with the majority being processed locally at commercial facilities. These processed goods, including sawn-wood, wood-based panels, pulp, and paper, are mostly shipped to overseas markets. For instance, since 2017, about 75% of sawn-wood and more than 95% of paper and paper-based products have been exported, making up one-fifth of Finland's total exports of commodities (Luke 2018). However, while the demand for domestic wood may increase, a lack of understanding about and the unknown cost structure of wood construction, due to inconclusive prior research (Talvitie et al. 2021), may affect this target. Finland's ambitious goal of having 45% of new buildings constructed from wood by 2025 (Finland Nordic Council of Ministers, 2023) might influence exports.

Currently, it is understood that ineffective information dissemination, a small number of industry operators, and ineffective legislative measures are the main obstacles to the use of wood as a sustainable building material (Franzini et al., 2018). Nonetheless, Finland consistently promotes the use of wood in building through a variety of programs and revised legislative requirements as it works to become carbon neutral by 2035, with certain towns having even more ambitious goals. The Adoption of the "Wood Building Program, 2016–2021" was a recent development in this area (Finland Ministry of Environment, 2023). This initiative aims to encourage the wise use of forest resources while encouraging industrial wood building and increasing long-term carbon storage in timber structures. Less than 3% of wood is now used in the construction of residential complexes (Talvitie et al., 2021). Residential single-family homes and terraced dwellings, which are primarily made of wood, stand in stark contrast to this. Thus, a bigger emphasis should be placed on the long-lasting use of wood in the structural systems of multi-story residential structures to assist in reaching carbon neutrality requirements. By evaluating the possible contribution of carbon hand printing of wood as a building material in connection to the Finnish low-carbon construction effort, this objective should be promoted (Kuittinen and Hakkinen, 2022). Yet, because wood is not as well-known as a construction material, Finland's construction sector has been reticent to engage in wood construction (Makinattila 2022).

It is a complicated matter to use wood sustainably to slow down climate change. The procedures involved in using wood in multi-story structures are extensive and consider the material's whole life cycle. These operations include work done in the forest, logistics and the supply chain, manufacture, and usage in construction. While there has been a lot of attention paid to studies into wood structures and life cycle assessment (LCA) during the past ten years (Gustavsson et al., 2010; Cindy et al., 2019), however, the focus has been on environmental factors, with various comparisons of wood and concrete buildings having been done (Sandanayake et al., 2018; Chen et al., 2020). It is on account of this study that we investigate wood and concrete as building materials in Finland, with the hope of making some recommendations based the findings if wood-based buildings can help Finland achieve the goal of becoming carbon neutral by 2035.

## 1.4 Objective of Study

The purpose of this study is to evaluate wood and concrete as a building material, with a view to understanding their behavior in terms of their structural, economic, environmental and energy stance.

This study has the following research questions.

1. What are the advantages and disadvantages of wood and concrete in terms of their structural, economic, environmental and energy stance?
2. Which of these is a better building material putting all factors (structural, economic, environmental and energy stance) into consideration?
3. What are the factors that limits the use of wood as a building material in Finland?

# 2 LITERATURE REVIEW

## 2.1 Wood

Wimmers (2017) explained that, in truth, wood is one of the oldest building materials, and as such, it is not an invention. This is because the use of wood has been around since many thousands of years ago, and wood has been used to construct buildings on practically every continent and in almost every civilization. In the past, wood was frequently used to construct massive buildings like bridges, towers, and temples (Hurmekoski, 2017; Wimmers, 2017). Wood is an organic material that is generated by a vast variety of woody plants and has a wide range of qualities. It is a fiber-based, rigid material that is derived from plants. Wood is often used interchangeably with timber. Wood is a natural material with differences in strength, elasticity, and other attributes that can arise because of variations in fiber angle, the existence of flaws, or even the proportion of moisture present in the wood (Rocha et al., 2018). Wood is well recognized for its orthotropic features, which result in differing mechanical properties for the three orthogonal directions considered (tangential, longitudinal, and radial) (Costa et al., 2020; Mascia et al., 2020). Since the earliest hominids, wood has been a valuable resource for making tools, shelters, and weapons. The main components of wood have a hierarchical structure; as such, wood is made up of cellulose, hemicellulose, and lignin (Broda and Hill, 2021).

There are two major types of wood: hardwood and softwood (Hurmekoski, 2017; Osore, 2019; Fierascu et al., 2020). Angiosperm or broad-leaved trees such as Iroko, Mahogany, and Danta (*Khaya ivorensis*) produce hardwood (Jamala et al., 2013). Other sources of wood include the *Triplochiton scleroxylon, Nauclea diderichii*, and *Nesogordonia papaverifera* (Jamala et al., 2013). While the sources of softwood are coniferous trees with needle-like leaves, Scots pine, Norway spruce, as well as Douglas fir (Jamala et al., 2013). For centuries, wood has been a key source of building material, particularly in the construction of buildings and bridges. Wood is a natural and renewable resource (Nilsson and Rowell 2012; Osore 2019). It has a high strength-to-weight ratio and is simple to deal with, making it particularly helpful in situations where only basic technology and methods are available (Hurmekoski, 2017). Wood was the most common construction material until the latter part of the nineteenth century (Nilsson and Rowell, 2012; Osore, 2019).

### 2.1.1 Advantages and Qualities of Wood as a Building Material

According to Wimmers (2017), wood has considerable potential as a building material, partly because it is strong and lightweight, environmentally friendly, and can be used in prefabricated buildings. However, only modifications to construction codes will allow wood to compete with steel and concrete. Hence, the advantages of wood as a building material still outweigh those of other building materials, based on the quality and advantages that wood possesses that other related materials may lack because of both environmental and weather conditions (Wimmers, 2017; Hurmekoski, 2017; Broda and Hill, 2021; Loffer, 2022). Hence, wood as a building material has some qualities that make it preferable as a building material. The qualities include, among others, tensile strength, sound absorption, availability, electrical and heat resistance, workability and versatility, environmental sustainability, flexibility of space arrangement, dry construction, industrial production, comparative cost effectiveness, and physical and aesthetic qualities (Loffer, 2022). The advantages and qualities of wood are described below:

**Tensile Strength:** Though wood is a lightweight building material, it exceeds even steel in terms of breaking length (or self-support length). It can better sustain its own weight while allowing for wider areas and fewer essential supports in some architectural designs (Walley and Rogers, 2022). According to Rocha et al. (2018) wood has varied in its strength, elasticity as well as other attributes. As a result of these tensile strength, it makes wood a good material for building and construction of other related projects.

**Electrical and Heat Resistance:** When dried to typical moisture content levels of 7%–12% for most wood species, wood has a natural barrier to electrical conduction (Loffer, 2022). In fact, this conductivity serves as the foundation for one type of moisture measurement system. Heat also has little effect on its strength and size. This gives the final structure stability and safety implications in the event of a fire. To estimate wood moisture content, electrical resistance-based techniques need wood species, modification, and treatment intensity-specific resistance (Brischke and Lampen 2014). Below the fibre saturation threshold, the accuracy of estimating wood moisture content by electrical resistance is 5% for native timber and 10–20% for modified timber, but it drops above the fibre saturation point (Brischke and Lampen 2014).

**Sound Absorption:** Wood is perfect for reducing echo in living or working environments because of its acoustic qualities, rather than reflecting or enhancing sound, wood is a poorer absorber of sound. This may greatly lower noise levels, providing added comfort. Wood and wood-based materials are commonly employed as interior finishes in structures partly because of its sound absorption (the reduction of the amount of sound generated in a space within that room) properties. As such, Smardzewski et al. (2015) posited that woods are good sound absorbers in such places.

**Availability and Acceptability**: Another advantage of wood is that it is renewable and readily availability. It may be obtained from nearby vendors and delivered to the location using even modest vehicles. In most cultures, work is seen as a beautiful construction material, and Finland is no different.

**Physical and Aesthetic Qualities:** Wood is a desirable frame material because of its excellent strength to weight ratio. Some species have a high level of rot resistance. Compared to other construction materials, wood withstands humidity with less structural change. It is incredibly resilient, and a variety of treatments are available to preserve and accentuate the material's inherent beauty. Its durability is enhanced by these sealants and protective coatings. If properly constructed and secured, wood may survive for hundreds of years with little upkeep (Singh et al 2016; Broda and Hill, 2021). Due to the charring process, which creates an insulating coating that shields the material's inner core, wood is more fire resistant than naked steel. In the event of a fire, heavy timber structure is more resistant to damage of transiently high temperatures, providing for a longer evacuation time.

**Workability and Versatility**: Wood is easily molded using basic hand tools. It can be chiseled, planted, and sliced. Since wood may be readily secured or connected using nails, screws, bolts, and other connectors, there are various ways to link wood to other wood or to other materials. With inorganic materials like concrete or steel, there are numerous design possibilities that are not feasible. By choosing timber with the suitable density, compressive and tensile strength, colour, texture, and fire resistance, the design performance needed by a specific construction application may be more easily matched (Singh et al., 2016; Rocha et al., 2018; Broda and Hill, 2021; Walley and Rogers, 2022).

**Environmental Sustainability:** Environmental sustainability recognizes that human activity and environmental health have always been linked, and that environmental health has necessitated social, political, and economic drivers. The renewability and biodegradability of wood are arguably the most significant environmental advantages (Brada and Hill, 2021). Low energy is used in the production process, and air emissions are safe (Broda and Hill, 2021). Whether it's hot or chilly outside, wood is a great insulator. An example of a building that uses the least amount of energy is the traditional "log house" (Al-Menhosh, 2017; Osore, 2019).

**Flexibility of Space Arrangement:** The wood is partitioned in such a way that there is a simple shift to alter layout in response to changing functional demands.

**Industrial Production:** Particularly well suited for mass manufacturing is wood. As such, it may buy standard-sized building materials, including skirting, doors, windows, wall-building boards, floors, ceilings, and roof tiles.

**Comparative Cost Effectiveness:** The quantity of local millers and the accessibility of high-quality wood locally reduce the reliance of timber production on imports. Prices are comparatively steady since the erratic foreign exchange market has less of an impact on them. Because of this, lumber is more affordable than other materials with a high import percentage.

### 2.1.2 The Behavior of Wood as a Sustainable Building Material

Wood is a complicated composite material that combines mechanical, chemical, and biological qualities in a superb way (Teischinger, 2016; Raposo et al., 2017; Wimmers, 2017; Huang et al., 2020). Wood is a dynamic medium as a result. It has personality and peculiarities like all that biological stuff, and as a result, it reacts to its surroundings and evolves through time. Wood should be handled with consideration and a certain level of care due to its "personality." This is partially since wood is a hygroscopic substance, meaning it prefers to release moisture into a dry atmosphere before achieving equilibrium between the two. According to Haung et al. (2020), wood has viscoelastic properties since it is composed of cellulose, hemicelluloses, and lignin. Due to the thermal-softening impact on wood during the densification process, heat and moisture may be employed to modify the mechanical behavior of wood similarly to other synthetic polymers. For every 3% change in the wood's moisture content, there is a 1%-dimensional change. As maple is one of the toughest of the hard woods, the action and changes are more pronounced. This is more applicable to hard wood than soft wood. At a specific temperature, air can contain a certain quantity of moisture. Relative humidity expresses how much of this maximum is really held by the air. Warm air may store far more moisture than cold air. For example, if we take a sample of air at 32 degrees Fahrenheit with 100% relative humidity and heat it to 75 degrees Fahrenheit, the relative humidity will drop to 20%. As a result, heating the air significantly lowers the relative humidity. Hence, it is easy to see how fluctuations in relative humidity might harm wood based on the ideas stated above.

Sustainable development is defined as "filling the demands of the present without compromising the ability of the future generations to satisfy their own needs" in this report (Holmberg and Sandbrook, 2019). This suggests that environmentally friendly construction materials are those that have minimal adverse effects on the environment. It also refers to using resources that are accessible to the current generation without denying them the resources they will need to live well in the future. The purpose of the idea, which is to achieve social, environmental, and economic goals by using construction materials while considering safety, health, efficiency, and productive existence in harmony with nature, is inherent in this description. Sustainability is crucial in all its ecological, economic, and social facets. Improved weather and climate, clean air, the preservation of biological variety, the safeguarding of soil and food crops, carbon sequestration, the provision of job opportunities (poverty alleviation), and the provision of recreational facilities are all part of this. Okereke (2006) states that a sustainable material should have the following qualities: a) it should be readily and affordably available, preferably locally; b) it should meet national standards for durability and upkeep; c) it should be environmentally friendly and pose no health risks; and d) it should be versatile in use, meaning it could be put to a variety of uses (as walling materials, flooring, etc.). These characteristics of wood are self-evident. Apart from its warmth, wood produces a welcome environment and also mixes seamlessly with nature, producing a real appeal that most other materials lack. Wood is another natural commodity that degrades after its life cycle with minimal environmental impact. The strength and longevity of wood may be seen in numerous heritage structures across the world. Wooden structures need less energy to construct and run, reducing our dependency on fossil fuels. Wood can be recycled and regenerated indefinitely, and few other materials can match its unique mix of virtues, including strength, affordability, and environmental sustainability.

## 2.2 Concept of Concrete

Concrete is the most popular and widely used building material in the world today. Concrete is defined as a composite material composed of several easily accessible elements (aggregates, sand, cement, and water) (Ede et al. 2015; Tantawi, 2015; Al-Menhosh, 2017). Alam and Ahmad (2020) described concrete as an artificial stone made from a mixture of binding materials and inert materials mixed with water. It is a versatile building material that can be quickly blended to fit a wide range of demands and molded into almost any shape. The use of concrete as a building and construction material has a long history. Concrete is the most widely used building material in the world because it is cheaper, readily available, has a long lifespan, and can withstand harsh weather conditions (Ede et al. 2015; Tantawi, 2015; Al-Menhosh, 2017; Obolewicz and Wdoowska, 2020). It has a wide range of commercial uses and variants (Obolewicz and Wdoowska, 2020). Concrete's technical features, which are governed by its fundamental characteristics, dictate the material's kind and use. These include, first, compressive strength, water absorption, and frost resistance, as well as aggregate particle size (Obolewicz, 2018). Concrete is a fragile substance because it has high compressive strength but low tensile strength. For concrete to bear tensile pressures, it must thus be reinforced (Tantawi, 2015). Typically, steel is used for this reinforcement. This is achieved by the composite made by mixing cement, fine and coarse material, water, and any other additives, chemicals, or fibers (Ede et al. 2015; Tantawi, 2015; Al-Menhosh, 2017). Yet it was used in antiquity as a combination of rock pieces and a mineral binder and was perfect for creating the most renowned constructions from that period. It is important to add that when using building materials, there are several factors to consider, partly because the building's safety is primarily attributable to the superior quality of the materials used to build it. The fundamental requirements, limitations, and specifications for concrete used for both monolithic projects and prefabricated pieces are covered in the European standard PN-EN 206 (Obolewicz and Wdoowska, 2020). Several emerging nations throughout the world are currently making significant efforts to enhance their infrastructure, including motorways, power projects, and industrial complexes among many others. So far, concrete has been used in these infrastructural developments. Concrete performs the correct function and is used in huge quantities in the construction of buildings and other structures to satisfy the demands of globalization (Kandekar et al. 2012). This is why concrete is such a good and safe building materials.

### 2.2.1 Advantages and Qualities of Concrete as a Building Material

Concrete has several knowledge qualities which makes it a fine building material. The concrete use of energy is efficient, and this is critical for mitigating the worldwide consequences of climate change. As such, concrete performs better in terms of energy efficiency than any other principal construction material when considered over the course of a building's entire life cycle. Concrete's thermal inertia enables it to absorb excess heat or cold, store it, and then release it back into the air (heat in the winter and coolness in the summer) as part of a planned thermal strategy. That may:

**Energy Efficiency**: Concrete is an excellent insulator, making it an excellent choice for controlling temperatures in both hot and cold conditions (Obolewicz and Wdoowska, 2020). Since it has fewer holes for air to pass through, it requires less energy to keep a structure warm or cold. Because of its low permeability, concrete may help sustain temperatures even when there is no heat or power, which is why it is commonly used for shelters. When comparing light and heavyweight buildings, concrete cuts heating energy consumption by 2–15%, with an average 10% savings in Northern European climate conditions (Hietamaki et al., 2003; Jacob, 2007). Also, when combined with natural ventilation, this can reduce the energy needed for cooling by up to 50% (Hietamaki et al., 2003; Jacob, 2007).

More so, concrete is admixtures of sand, cement, water, coarse aggregates (gravel or crushed stone), and these admixtures are the ingredients make concrete an inorganic, adaptable, and a strong building material. Its special qualities offer a cosy and secure atmosphere for living and working (Ede et al. 2015; Tantawi, 2015; Al-Menhosh, 2017). Owing to its large thermal mass, concrete regulates fast temperature changes that would otherwise require the deployment of pricey, energy-intensive air conditioners, creating a stable indoor atmosphere. As such, concrete is fully non-toxic and helps to maintain healthy indoor air quality and a comfortable living space since it is an inert, stable substance (Ede et al. 2015; Tantawi, 2015; Al-Menhosh, 2017).

**Durability:** According to Hansson et al. (2012), durability refers to a structure's ability to provide the needed performance over the course of its planned service life while being subject to deterioration processes. The capacity of a building to withstand deterioration, corrosion, and other harm over time is referred to as its durability (Kaewunruen et al., 2018). In other words, the longevity of a construction increases with its level of durability (Kaewunruen et al., 2018). Any structure will be exposed to a multitude of climatic conditions during its lifetime, such as shifting temperatures and wind speeds (Djamil, 2017). Hence, it is crucial to take durability into consideration to meet performance demands throughout the service's life. Most concrete structures are made to survive at least 30 years in use, but many last much longer before needing to be repaired or replaced. Buildings composed of concrete are so strong and long-lasting that they are seldom torn down due to deterioration. Instead, they grow outdated and are good candidates for destruction to make way for new buildings (Ede et al. 2015; Al-Menhosh, 2017; Obolewicz, 2018). High humidity and rain have little effect on concrete's resistance to deterioration and abrasion. Moisture can only attack joints since it contains very little organic material that might rust or decay. An annual joint maintenance program guarantees a concrete structure's moisture resistance (Al-Menhosh, 2017; Obolewicz, 2018). In places prone to severe weather, concrete is the ideal material to build homes.

A concrete building is naturally sustainable due to its durability and recyclable nature (Djamil, 2017). After being crushed, concrete may be recycled and used as aggregate for roads instead of gravel obtained from natural sources. It is possible to reuse even precast concrete components in their original shape. The concrete industry developed this method to protect natural resources while minimizing the environmental consequences of waste disposal and the extraction, manufacturing, and transportation of new materials (Al-Menhosh, 2017; Obolewicz, 2018). In terms of cost-effectiveness, the use of concrete in building structures aids in the creation of "affordable homes" by reducing energy usage (Al-Menhosh, 2017; Obolewicz, 2018). In a nutshell, concrete durability may be attained by preserving its distinctive performance while fending off weathering and any other outside degrading elements (Djamil, 2017).

**Low Maintenance**: The low operating and maintenance costs of a building make up the largest share of its overall life-cycle costs. Construction materials with maintenance and upkeep requirements have very high long-term expenses (Djamil, 2017). The concrete industry works to reduce its impact on the environment. Progress is still being made in reducing emissions by using improved methods for making cement and concrete, expanding the use of alternative fuels and raw materials, and recycling trash that would otherwise wind up in landfills.

**Safety and Security:** Excellent vibration and sound dampening characteristics exist in concrete. It absorbs sounds of all frequencies, low and high. It also has benefits in terms of safety and security because of its size and density. Concrete gives total fire protection, including saving life, property, and the environment in the case of a fire since it does not burn.

**Fire Resistance:** Because of its well-known high fire resistance, it acts as a great fire barrier, providing inhabitants with safe escape routes and safeguarding the safety of firefighters. Also, after a fire, it is easier to repair than to rebuild, which speeds up and lowers the cost of a company's rehabilitation. People need to be able to rely on structures that hold up under adverse conditions.

**Resistance to Fungus and Other Insects or Explosions:** Concrete is resistant to fungus and insect assault, explosions, break-ins and break-outs, high temperatures, and natural disasters.

**Cost:** Concrete is linked to affordable building and construction materials, as well as minimal upkeep expenses (Stanaszek-Tomal, 2020). However, building a new concrete home is more expensive up front than building one with a wood or steel structure. Since steel prices rise and fall while concrete prices remain mostly consistent, the cost differential has a tendency to change. On average, a concrete house will cost between 4 and 8% more than one made of steel or wood. That modest proportion might add up to a hefty price tag when you're already talking about hundreds of thousands of euros. But, over time, homeowners who live in concrete experience a significant decrease in energy expenses. There is a consensus that homes built of concrete reduce monthly energy bills for homeowners by 20 to 25 percent. In other words, upgrading to concrete is financially advantageous. As concrete homes are substantially less prone to damage of all kinds, insurance prices for them are also significantly reduced.

**Construction Speed:** Although the time of construction for a concrete building varies depending on the kind of concrete, it is often faster than structural steel and equivalent to wood frame construction. The procedure requires more time than pouring and building a concrete slab since steel must be manufactured and shipped off-site. With a cast-in-place concrete strategy, contractors can use a two-day cycle. With this quick cycle, employees may finish up to 20,000 square feet of flooring in 48 hours.

**Versatility:** When combined, concrete is extremely pliable and may adopt a variety of additions, appearances, surface textures, and forms. Every year, new varieties of concrete are created, including mixtures with high-performing properties for particular uses. Concrete can be tailored to meet even the most unusual requirements and used in specialized projects. Moreover, concrete may solidify at room temperature because it doesn't require any particular setup circumstances. Concrete is a suitable choice for environments with these requirements, such as underwater construction and high-heat manufacturing, because of properties like moisture and high-temperature resistance.

### 2.2.2 Factors that Limits Concrete as a Building Material

Like many building materials, concrete also has some limitations as a building material. Some of these factors that limit concrete as a building material are highlighted below:

**Concrete is a quasi-brittle material:** Brittle, quasi-brittle, and ductile failure are the three primary forms of material failure. Glass and mild steel are typical examples of brittle and ductile failures, respectively. Brittle materials break as soon as stress begins to build up or when tensile strength is attained. Contrary to these materials, concrete displays a phenomenon known as strain softening. These materials are referred to as "quasi-brittle materials." Concrete is a brittle and quasi-brittle material, and it deforms very little before failing. The warnings will be stronger when the deformation is smaller. In addition, concrete has weak fracture toughness (Ede et al. 2015; Al-Menhosh, 2017). This is the main reason why concrete and steel are used together to support tension and compression stresses, respectively. Reinforced concrete is, therefore, second-generation concrete. The structure is made more stable by the concrete (Tantawi, 2015; Al-Menhosh, 2017).

**Low Tensile Strength**: Concrete has different compression and tensile strengths (Stanaszek-Tomal, 2020). In actuality, concrete's tensile strength is just 10% as strong as its compressive strength. To boost the tensile strength of concrete, fibers and other polymers are added.

**Concrete has Low Toughness**: toughness is a material's capacity to absorb impact energy. It is the region under the curve of load displacement. Concrete's much lower toughness as compared to steel is another drawback. Concrete is just 1% to 2% as tough as steel. Better toughness is provided by fiber-reinforced concrete.

**Concrete has Low Specific Strength**: This is defined as the strength-to-density ratio. Standard-grade concrete has a specific strength of 20, which is half that of steel. Specific strength is controlled by decreasing density and increasing strength. Concrete's drawbacks are lessened by lightweight and highly durable concrete (Djamil, 2017).

**Formwork**: Because unfinished concrete is liquid, formwork is required. It needs formwork to be molded into a shape and to sustain its own weight. Wood, steel, or plastic can be used for shuttering. The cost of installing and acquiring the formwork is high. Installation takes a lot of time and effort. These constraints of concrete are solved by recasting and prefabrication processes.

**Long Curing Time**: After casting and curing, concrete reaches the desired compressive strength in 28 days. A month of good ambient temperature regulation is necessary for full-strength growth. Another drawback of concrete is this. Steam curing, microwave curing, or the use of admixture all shorten the curing duration**.**

## 2.3 Life Cycle Assessment

Jolliet et al. (2016) explained that life cycle assessment (LCA), is a method for assessing a material’s or product's overall environmental effect at each stage of its life, including the procurement of raw materials, manufacturing in a facility, transportation, retail sale, use at home or at work, and finally its disposal (figure 1).

Hence, the global finite resources and their quick depletion have drawn the attention of world leaders, material producers, landscape architects, and architects in the housing and building industry to the problem of sustainability.

In order to ensure sustainability and recycling of the finite resources, the LCA introduced to address issues of carbon footprint analysis, and eco-labelling, which will help determine the level of negative effects of buildings based on their design, production, usage, deconstruction, and destruction processes.

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The construction sector was not left behind in this noble cause for global change. More so, this tool is primarily used to compare distinct goods, systems, or processes, as well as the various stages of a product's life cycle. According to the International Organization for Standardization (ISO) guidelines and the Society of Environmental Toxicology and Chemistry (SETAC), an LCA is defined by its goal and scope definition, inventory analysis, effect assessment, and result interpretation (Jolliet et al. 2016).


Figure 2.1: LCA process of Wood and Concrete (Yildiz et al.,2020)

### 2.3.1 The Four Stages of LCA

These four phases are defined as follows (see Figure 2.2): Goal and Scope, Inventory Analysis, Impact Assessment, and Interpretation. These four, stages that is, goal and scope formulation, inventory analysis, impact assessment, and outcome interpretation are all included in the life cycle assessment process can be used make valuable additions to several decision-making processes (Yildiz et al., 2020)

**Goal and Scope definition***:* The problem is discussed, and the study's objectives and scope are specified. At this step, several critical aspects are determined: the system's function, the functional unit on which the emissions and extractions will be based, and the system boundaries. The basic situation and the options are well discussed.

**Inventory Analysis:** In this stage of the analysis, the harmful emissions to air, water, and soil are measured in conjunction with the extraction of renewable and nonrenewable raw materials**.** Here, it is also decided how many resources are needed for the system (that is, building) to work. It involves quantifying the material consumption, energy use, environmental discharges, and waste related with each life cycle step by gathering, verifying, and combining input and output data.

**Impact Assessment:** This stage examines the effects of the emissions that have been inventoried on the environment. It is the process of converting the raw data into probable effects on human health and the environment using impact categories, category indicators, characterization models, equivalence factors, and weighting values for the environment.

**Interpretation:** As part of an iterative process, this crucial step is carried out during the first three phases to evaluate the outcomes considering the project's objectives. If findings are to be used externally for comparison statements, they must be confirmed by a third-party critical review panel of interested parties (e.g., claims that product X has lower or higher environmental impacts than product Y). The study's findings must show significant effects and offer suggestions for lowering resource use and environmental costs. Here, the results that have been acquired up to this point are interpreted, and the uncertainties are assessed. Sensitivity studies and uncertainty propagation may be used to identify the essential parameters and improvement alternatives, and a critical analysis can be used to assess the impact of the chosen limits and hypotheses. Also, it is possible to contrast the environmental effects with the economic or social effects.

Finally, it is important to note that these four stages of LCA are rigorous and in-depth assessments that practically analyze every aspect of the product life cycle, and they are not as obvious as they are simplified in this thesis. Hence, the LCA was used to assess wood and concrete as building materials in terms of their life cycles and their impact on the environment in terms of sustainability.

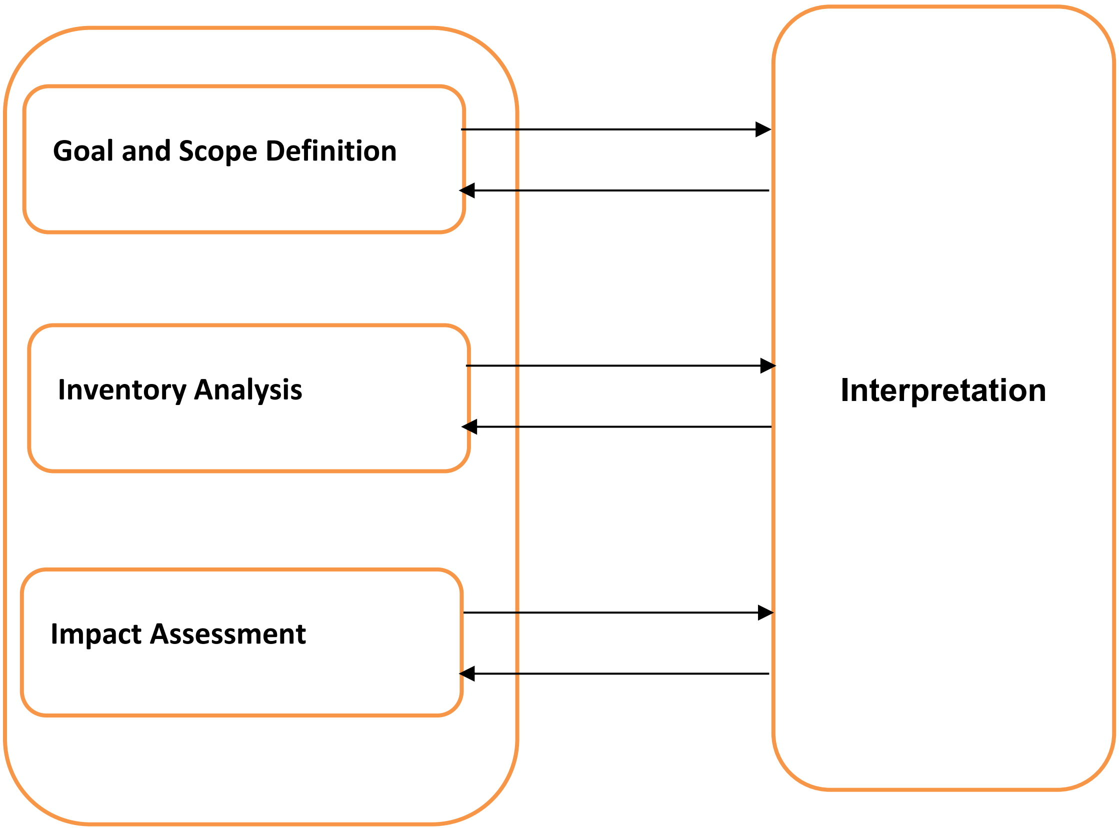


Figure 2.1: The four (4) Stages of LCA Iterative (Jolliet et al., 2016)

### 2.3.2 LCA of Wood and Concrete as Building Materials

The system boundaries of LCA studies are named according to which stage they start and end. It is called obtaining the raw material (cradle), ending the use of the product (grave), and the stage where the raw material is shipped to the factory (gate) (Simonen, 2014). A procedure called life cycle impact assessment (LCIA) is used to calculate a product's total raw material and energy consumption, as well as its airborne, waterborne, solid waste, and other emissions (Yildiz et al. 2020). Like concrete, wood may be used as a building material. Throughout their lives, trees absorb carbon from the atmosphere, and this carbon is largely found in wood. This has the benefit that using wood may be seen as a technique for storing carbon from the atmosphere in the anthroposphere. LCAs investigations have conclusively show that wood-based structures have lower $CO_2$ equivalent emissions than other building types (Dodoo et al., 2009; Cabeza et al., 2014; Knauf, 2016; Pealoza et al., 2018). This is partly due to the material characteristics of wood; fewer materials are needed to provide an equivalent level of thermal isolation.

After being used, it is believed that wood-based constructions would be burned for heat and energy, which has low carbon emissions. Yet, using chemical compounds to finish, stop a fire from spreading, and hold the wood together has other negative environmental implications. Hence, wood-based constructions must undergo considerable repair work if there is a fire within the building compared to concrete structures. Wooden buildings have a restricted range of options for façade materials, upkeep, and the number of levels. The maximum height and, thus, the maximum number of stories that a wooden building may sustain are likewise constrained. This excludes wood as a material option for residential high-rise buildings, which has larger implications for the residential regions' climatic effect (Norman et al., 2006).

Concrete, on the other is admixture of cement, water, and aggregates. As such, steel is frequently used to strengthen it. Often, cement is the source of the most $CO_2$-equivalent emissions. As a result, changing the cement to other material ratio can have a significant impact on the concrete. Moreover, there are a variety of uses for cement. There are several types of cement, ranging from pure cement (CEM I), which is essentially made entirely of Portland cement, to fly ash combined with Portland cement (CEM II), to slag cement (CEM III), which incorporates waste products from other industries with Portland cement. Slag is harder to deal with in practise since it has higher material properties but takes longer to set. Concrete's inherent time-dependent processes, such as the calcination and carbonation balance, have an influence on $CO_2$ equivalent emissions. Carbon dioxide, which is chemically bonded in the raw material, is released during the calcination process of making cement. Typically, calcination is responsible for 50% of cement's carbon dioxide emissions. If the heat and power used in manufacturing produce fewer emissions than usual, calcination could account for more than half of the total.

People used building structures for living, working, learning, and social interaction, which reflects our culture and level of development. Strong bonds are developed between the city and the location of the buildings, as well as their form, height, attractiveness, and a variety of other factors, such as the material from which they are built or coated. Although the presence and attractiveness of the outer coverings assist the structure visually, removing the covering poses major dangers. Rain, wind, sunshine, biological forms, and air pollution are all factors that the materials used to build the facade are exposed to. As such, rain-covered facades go through a constant cycle of soaking and drying, and this process takes longer on facades that get less sunlight. The construction material's lifespan is shortened by the water in it, which causes various expansions at levels above and below the frost line (Yildiz et al. 2020). Similarly, wind must be considered in facade designs, especially for high-rise structures (Iousef et al., 2019).

In addition, both construction materials and biological beings are susceptible to harm from ultraviolet light due to their chemical makeup. Building materials used for facades that are exposed to biological forces might exhibit inflorescence. Together with the harm from natural disasters like earthquakes, floods, and fire, building materials' shorter lifespans owing to the aforementioned factors have serious negative effects on both the economy and the environment.

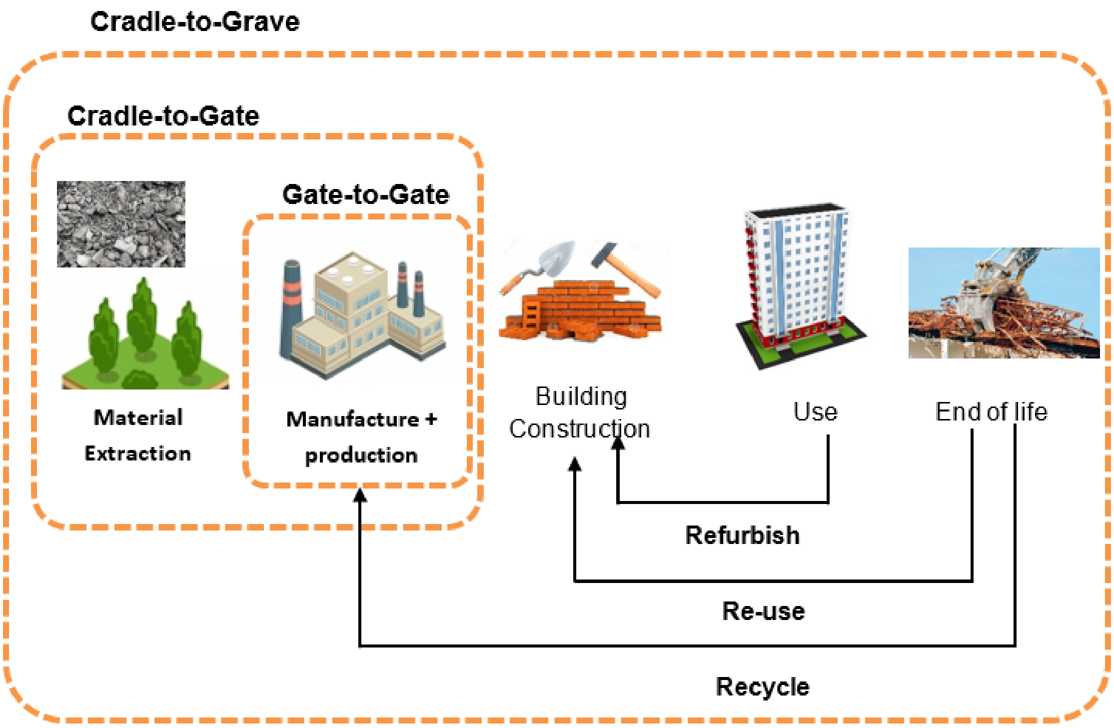


Figure 2.3: Simplified life cycle system boundaries of a building (Yildiz et al., 2020)

More so, building materials' physical, chemical, and biological environments can have a variety of adverse impacts (Kobeticova and Cerny, 2017). Several studies have developed methods of evaluating construction materials that have been created by several researchers (Seto 2015; Ferrandez-Garcia et al. 2016; Ingrao et al. 2018; Ylmaz 2018; Yildiz et al. 2020). Despite this, it turns out that it is difficult to compare the LCAs of the various types of building materials. More so, either wood or concrete is partly dependent on the climate as well as where the building is situated. The reasons for this include the choice of a functional unit, such as a commercial building or a building material; the choice of various LCA boundaries, such as cradle-to-grave or cradle-to-cradle; and the inclusion of regional factors, such as location, climate, and technology, because of studies conducted in various countries. As a result, Yildiz et al. (2020) asserted that a high recycling rate of materials with a significant environmental impact during the manufacturing stage can make the country where the building is built more sustainable in terms of recycling capability, ratio, and prevalence. From a different perspective, building materials' service lives have an impact on the life cycle's economic and environmental sustainability.

## 2.4 Summary of Literature Review

Both wood and concrete are unique building materials that have been used extensively for years in various parts of the world, particularly in Finland. Both building materials have positive and negative aspects in terms of advantages and disadvantages. This study has extensively discussed types of wood as a building material, the concept of wood, the benefits of wood as a building material, and the disadvantages of wood as a building material. Similarly, concrete was also reviewed extensively while highlighting the advantages and disadvantages. The life cycle assessment of wood and concrete was performed. Based on the findings, it is important to note that both building materials can be recycled from cradle to grave. Both building materials have some form of recycling tendency. As such, they are environmentally sustainable. The next chapters will present the methods by which both building materials are produced (see figure 2.3).

# 3 RAW MATERIALS AND METHODOLOGY

## 3.1 Introduction

This chapter describes the materials and procedures used in the manufacture of wood and concrete. The structural behavior of wood and concrete composites as well as the specifics of all wood and concrete ingredients, such as cement, grout, and aggregates, are thoroughly described. This chapter also discusses the construction of wood-based structures and concrete structures.

## 3.2 Raw Materials

Trees serve as the primary raw material for wood, while aggregates, cement, water, and admixtures are essential components for concrete construction.

Figure 3.1: Timber structure (Corches, 2019)

### 3.2.1 Manufacturing of Wood as building material

The following steps are involved in the processing of wood: felling of trees, wood seasoning, wood conversion, and wood preservation.

**Felling of Trees:** Felling is just chopping down trees that can be used for engineering projects. The tree should be felled after it has reached maturity. Only then does it have more heart wood than sap wood. Trees should be cut down when they are between 50 and 100 years old. The ideal time to cut down trees is in the middle of the winter in flat regions and in the middle of the summer in steep places. Initially, a cut is made near the base of the trunk on the side of the tree where it is anticipated to fall (see figure 3.2). The incision should be made beyond the tree's center of gravity. After which, a skilled or trained personnel is expected to make a parallel incision that is positioned just across from the initial cut. Then, secure the treetop with four ropes, one on each side. Pull the rope on the side with the initial cut, then loosen the rope on the other side. Swing the tree slowly with the other two ropes. The tree then begins to split along the wounds before falling softly to the earth. The branches are removed, the bark scraped off, and they are trimmed to the necessary lengths.

**Wood Seasoning:** The term "seasoning" refers to the process of removing moisture from wood. Up to 50% of a recently felled tree's dry weight is made up of water. Both free and bound moisture are present in the wood. Wood has free moisture in the form of water vapor, whereas bound moisture is found in cell walls. Free moisture is the first to evaporate when anything is left to season, and this point is referred to as the fibre saturation point. The lumber will shrink upon drying after the fiber saturation point, which is nothing more than bound moisture evaporating. There are two ways to season wood, notably natural and artificial seasoning.

**Wood Conversion:** Cutting wood into the necessary portions is the process of converting it. Power tools can be used for this. For the profitable conversion of wood, skilled individuals should be needed. There are several ways to convert wood, or saw it namely, quarter sawing, ordinary sawing, tangential sawing, and radial sawing (see figures 3.3a-3.3b, and 3.4a-3.4d).

**Ordinary Sawing:** It is the most popular and simple sawing technique. The timber piece is cut through at an angle that is perpendicular to the yearly rings. In this instance, there is very little waste timber. The acquired planks don't all have the same strength. Whereas the interior section of the planks includes heart wood, which shrinks less, the outer planks contain sap wood, which shrinks more.

**Tangential Sawing:** This kind of Sawing involves making cuts that are perpendicular to yearly rings and that come together at right angles. When the yearly rings are quite distinct from one another, this strategy works well.

**Quarter Sawing:** The cuts are produced at a straight angle to one another while using a quarter saw. This is appropriate when there are no obvious medullary rays in the wood.

**Radial Sawing:** The incisions in this kind of sawing are done radially, parallel to the medullary rays. The most lumber is wasted with this procedure.

**Wood Preservation:** The final step in the processing of wood is preservation, which is done to make wood more durable and more resistant to things like fungus and insect infestations.

For this reason, a variety of techniques are employed to preserve wood, including the application of coal tar, oil paints, alkaline copper quaternary (ACQ), polymeric betaine, borates, copper azole, and so lignum paints, among many others.

Figure 3.2: Felling of a Tree (Skadill, 2010)

Fig 3.3a: Wood Seasoning ( The constructor, n.d.)

Fig 3.3b: Wood Seasoning (AUTODESK Instructables, n.d.)

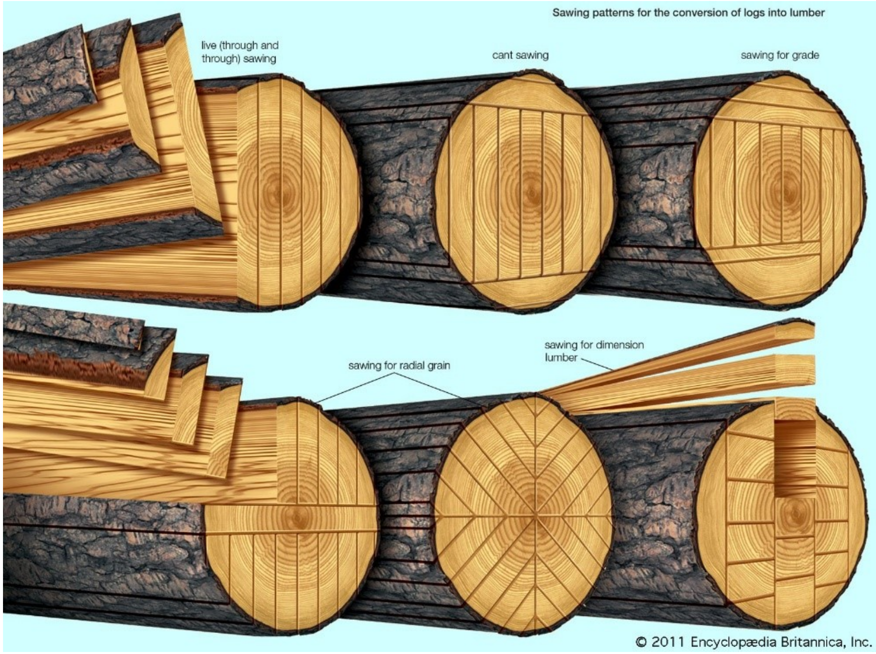


Fig 3.4: Log sawing patterns (Britannica, n.d.)

### 3.2.2 Major Advantages and Disadvantages of Wood

**Advantages of Wood**

1. Wood-based buildings are affordable, that are less expensive compared to concrete.
2. Wood-based buildings are lightweight, and easy to work with
3. Wood is a renewable resource, as such, it is readily available, presenting promising opportunities)
4. Wood is biodegradable.
5. Wood is versatile and can be used for a variety of construction projects.

**Disadvantages of Wood**

1. Wood-based structures are quick in structural depreciation.
2. Wood-based structures are expensive to maintenance cost.
3. Wood-based buildings are susceptible to moisture and mold.
4. Wood-based buildings are susceptible to fire.

5. Wood-based buildings are less effective soundproofing materials.
6. Wood-based buildings are prone to noise and cracking floor.
7. Wood-based structures are affected by water, termites, and can rot over time.

#### 3.2.1.1 Concrete Composite and Admixture

Cement, sand, aggregate, and water make up concrete. Admixtures are anything else that is added to concrete before or during mixing to change the characteristics to our specifications. Admixtures provide benefits to concrete, such as better workability, accelerated or delayed setting time, reduced water-to-cement ratio, and so on. Concrete is a heterogeneous mixture made up of Portland cement, water, and aggregate (rock, sand, or gravel), and sometimes with other components or admixtures. When combined with water and aggregates, cement, which is most frequently in powder form, serves as a binding agent. This mixture, also known as concrete mix, will be poured and solidified into the robust substance that is used to build concrete and other related materials.

Figure 3.5: Concrete Building Construction (Design Buildings 2020)

**Portland Cement:** Contains around 7–14% concrete (Fahl, 2009). The objective of cement is to hold the concrete together. Portland cement is classified into five categories by the American Society for Testing and Materials (ASTM).

1. **Type I Cement:** This is regarded as the standard Portland cement, and it is the most commonly used type of cement. It is used if there is a minimal exposure of sulphate.
2. **Type II Cements:** used for concrete that may be exposed to a low sulphate content such as soils that contain a low concentration of sulfate.
3. **Type III Cements:** used for applications that require strength at an early age.
4. **Type IV Cements:** used for applications that require a fast-setting time, such as in dams and places that require large amounts of concrete.
5. **Type V Cements:** these are the high sulphate-resistant Portland cements, they are used in applications where concrete is exposed to a high concentration of sulphate, such as sewer water.

**Aggregate:** This made up about 75% of the concrete volume. Aggregates can be sand, crushed rock, recycled concrete rubble (Tantawi, 2015), or other materials.

**Water:** The higher the water content in concrete, the greater its workability, because water thins the concrete. When water is introduced to concrete, it undergoes a hydration process and then hardens. The pH of water should be between 6 and 8. If salt is present in the water used for reinforced concrete, it can cause the reinforcing steel material to corrode.

**Additives:** Several additives are used to improve the workability of concrete. They are added in amounts that do not exceed 2% of the cement composition, which is normally 1-2%. It should be remembered that as the additive amount grows, so does the concrete strength. There are several kinds of additives.

#### 3.2.2.2 Properties of Hardened Concrete

**Compressive Strength of Concrete:** The compressive strength of hardened concrete (fc’) at 28 days is one of the most used measures for evaluating concrete performance. A concrete specimen can be broken in a compression-testing machine to perform this test. A normal cube specimen of 150 mm by 150 mm by 3 or a typical cylindrical concrete specimen of 150 mm by 300 mm can be used. The strength of a cylinder is around 80% that of a cube. Other tests that may be performed to determine the compressive strength of in-place concrete include the hammer test and the coring test, although the coring test is more expensive to execute. However, the testing is not within the purview of this research project.

**Tensile Strength of Concrete:** Concrete's tensile strength is far lower than its compressive strength. It is typically insignificant in reinforced concrete design, but in rare circumstances it must be considered.

**Elasticity of Concrete:** Concrete's elasticity is essentially stable at low stress levels but begins to decrease at greater stress levels when matrix cracking develops. Concrete has an extremely low coefficient of thermal expansion, which therefore decreases as it ages. Due to shrinkage and strain, all concrete structures will fracture to some extent.

**Creep and Shrinkage of Concrete:** Creep in concrete is defined as a change in the form of a structure caused by a long-term load. Creep occurs as the cement concentration of the concrete mixture increases. As a result, one popular way for reducing creep in concrete is to use roller-compacted concrete (Fahl, 2009), which requires less water and cement than typical concrete mixes. There are several techniques for minimizing shrinkage in concrete, such as employing shrinkage compensating concrete, reinforced concrete, or a shrinkage-reduction chemical additive (Li 2011). Structures must account for creep and shrinkage throughout the design phase.

**Concrete Reinforcement:** Although concrete can endure significant compressive loads, its tensile strength is limited in comparison to its compressive strength. Tensile reinforcement is thus necessary. Steel bars or steel wires are used to reinforce concrete to improve its tensile strength. In general, concrete carries compressive and shear stresses in buildings, whereas reinforcing steel carries tensile loads (Li 2011).

#### 3.2.2.3 Major Advantages and Disadvantages of Concrete

**Advantages of Concrete**

1. Concrete components are easily accessible.
2. Concrete is easy to work with and can be shaped into any shape needed.
3. Concrete may be conveniently transferred from the mixing location to another casting location before the initial setting occurs.
4. Concrete can be injected or sprayed into fissures and tunnel linings.
5. Any building may be built using steel as reinforcement.
6. The monolithic nature of concrete improves the look and rigidity of the construction.
7. The great compressive strength of concrete makes a concrete construction more cost-effective than a steel structure.

**Disadvantages of Concrete**

1. The tensile strength of concrete is minimal. As a result, concrete must be strengthened to prevent fractures.
2. If there is a substantial temperature variation in the area, expansion joints must be included in lengthy buildings.
3. Concrete may crack due to drying shrinkage and moisture expansion. Hence, building joints is necessary to avoid these sorts of fractures.
4. If soluble salt is present in concrete, it may cause efflorescence when exposed to moisture.
5. In the presence of alkalis, sulphates, and other contaminants, conventional Portland cement concrete becomes integrated.
6. Persistent loads cause structural creep.

## 3.3 Summary of the Chapter Three

Time and again, both wood and concrete have proven to be useful and good building materials. This is evident in the several structures that have been put together using either wood, concrete, or both. This chapter presents how wood is processed before it becomes a building material. The process is not as brief as discussed in this study; it is a long one that involves several workers in the different stages of the wood's processing. Given the structural strength of concrete and its components, concrete is most used on high-rise buildings and skyscrapers. The admixture of the composition of concrete often varies; however, no matter the differences in functionality and use of concrete, the composition must be cement, aggregates, and water. Though the concentration of each component may vary based on the type and kind of structure, all in all, concrete remains a very reliable building material. Table 1 summarise the most important findings.

Table 1 – Advantages, Timber versus Concrete

| **Advantages** | **Wood** | **Concrete** |
|---|---|---|
| Structural | Wood-based buildings are lightweight, and easy to work with, and has tensile strength | Flexibility and versatile Compressive strength<br>Cost-effective than a steel structure. Durability<br>Low Maintenance |
| Economic | Affordable, less expensive, Comparative Cost, Effectiveness, Workability and readily available | Material are readily available and accessible. |
| Environmental | Biodegradable, Physical and Aesthetic Qualities, Environmental Sustainability, | Safety and Security, Fire Resistance, Resistance to fungus and and other Insects |
| Energy efficiency | Renewable, Sound Absorption, Electrical and Heat Resistance | High thermal mass, Thermal stability, Conserves energy, and produce a better indoor environment for building |

# 4 RESULTS AND DISCUSSION

This study investigated wood and concrete as building materials, with a view to understanding their behavior in terms of structural, economic, environmental and energy efficiencies. Based on the investigations from various studies both quantitative and qualitative findings are discussed as follow:

## 4.1 Timber versus concrete as a building material

Several studies have investigated both the advantages and disadvantages of wood and concrete. The advantages and disadvantages were often based on durability, strength, climate changes, environmental concerns, $CO_2$ emissions, and many others. However, to better appreciate the distinctive differences in the two material sources, it is important to discuss them in light of some key themes, such as building strength, durability, sustainability, environmental concerns, climate change and weather conditions, energy efficiency, and cost efficiency, among others.

In general, wooden structures are not as safe as concrete buildings. Wood is vulnerable to external threats like fire, wind, insects, moisture, and mold—all of which can result in structural damage and safety risks. While concrete is a durable and strong material, it also presents some safety risks (Obolewicz, 2018). For example, if a concrete structure collapses at a job site or once the building is occupied, the falling concrete could seriously injure anyone who is nearby. Also, working with concrete may predispose workers to safety risks and health issues, as working with dry or wet concrete may expose workers to irritation of the eyes, skin, nose, and throat. Furthermore, exposure to silica, a main ingredient in dry concrete, can cause far more severe health issues, including lung cancer.

Concrete as a building material is flexible and has tremendous strength which made it a good building or construction material (Ede et al. 2015; Al-Menhosh, 2017; Obolewicz, 2018). Concrete is pliable enough to be shaped into any shape even though it is hard when dried. This gives it the dimensional stability needed for both inside installations and outdoor buildings, and it also promotes creativity. Further strengthening the structure through time, concrete tends to grow stronger. Wood is less thick than other materials, making it less robust. Another benefit of concrete is that it can be shaped to any required strength and cast on site, making it a cost-effective material. Moreover, it can endure gusts of up to 250 mph. Concrete homes are excellent for areas exposed to tornadoes and hurricanes since they also have deeper foundations. This is while concrete is the favorite for high-rise building.

Furthermore, wood is less expensive than concrete, but it ages more quickly and requires more frequent maintenance and repairs. As a result, concrete has a lifespan that is two to three times longer than that of most other construction materials, but wood degrades fast, especially if it is not maintained frequently. Moreover, termites love timber constructions and buildings with wooden frames, and wood typically has insect and moisture issues. Wood, being an organic material, also draws microorganisms like mold and mildew, which negatively affects the interior climate in confined places. Contrarily, concrete resists the growth of both termites and mold, which slows down the rate of disintegration over time (Hansson et al. 2012; Djamil, 2017; Kaewunruen et al., 2018). Wooden buildings are extremely susceptible to water damage; even a little rain can cause leaks from tiny gaps. Contrarily, concrete is more moisture resistant and absorbs water, causing less harm to the overall structure. Similarly, unlike wood, which fuels fire, concrete is fire resistant. Overall, the resistance of concrete results in less maintenance expense over the course of the project.

There were many ways to create the frame during the modelling of the wood frame structure, offering the designer a wide range of alternatives. As a result, changes to designs and to the construction process are readily made. This contrasts with concrete structures, whose designs and detailing must strictly adhere to a laid-down regulation since changes to the works on site can be highly expensive (Singh et al., 2016; Broda and Hill, 2021). Because of the difference in density between wood and concrete, wooden constructions have a terrible reputation for being loud. For someone who lives near a busy street, some gaps or leaks in the building create channels for noise to move through. In addition, wood expands and contracts when the environment changes, which can cause doors and cupboards to shrink or expand inside their frames. Contrarily, concrete provides a solid, airtight, and soundproof answer to each of these issues.

### 4.1.1 Environmental consideration of Wood and Concrete as Building Materials

This is one of the major challenges around the globe, and as such, in almost every sector, the need to consider environmental concerns before embarking on any project becomes necessary because of the possible negative impact of environmentally unfriendly practices. In comparison, wood is a natural, sustainable, and environmentally friendly building material. Wood can store carbon dioxide up to 2.432 metric tons (it is believed to be equal to the carbon dioxide generated by about 500 cars). Concrete, on the other hand, is thought to contribute to environmental pollution due to the cement component. Though concrete is excellent at absorbing and retaining heat, it will increase a building's energy efficiency and reduce heat, ventilation, and air conditioning (HVAC) costs. This finding is consistent with several previous reports on wood or concrete as building materials (Al-Menhosh, 2017; Osore, 2019; Brada and Hill, 2021).

### 4.1.2 Energy efficiency of Wood and Concrete as Building Materials

Unlike wood, concrete homes are less likely to suffer leaks. Sheathing and insulation are two features that can create breaches in wooden walls and allow air to enter. Due to the molecular structure of concrete, there is little likelihood that air will pass through its airtight and unbroken construction. This keeps cold air contained inside buildings and prevents heat from entering. It is crucial to note that contemporary concrete homes also feature tighter sealing and insulations, such as polystyrene panels and foil-backed bats. In summary, concrete structures tend to have fewer hot or cold spots, and their compact design inhibits the transfer of heat through the walls. Hence, concrete is a great material for building energy-efficient structures since it offers year-round low heating and cooling costs. Also, according to the findings of the research and studies, timber-built structures are more ecologically friendly than concrete ones. This is primarily because wood has a negative effect on carbon emissions and actively contributes to the storage of atmospheric $CO_2$, which lowers global warming. Energy savings are also extremely.

### 4.1.3 Economic Aspects of Wood and Concrete as Building Materials

Concrete has been shown in several studies to be appropriate for multi-housing projects, as such is much more expensive in term of building, however, it is cheaper to maintenance when compared to wood-based buildings. Ede et al. (2015) reported that cost analyses of the two models, the wood model has a greater advantage over the concrete model. This is largely because of how these types of buildings are constructed, how simple it is to obtain the materials used in construction, and how these buildings are built. In simpler terms, rapid erection of buildings could result in a huge financial gain, particularly if such buildings are low-rise buildings. However, this contradicts an earlier report by Ahmed and Arocho (2021), that conducted a comparative study on wood and concrete on the same type and size of buildings and found wood to be about 6.8% more costly compared to concrete building. It is important to add that there are several factors and preference for cost analysis as the type of wood, or concrete will also be a contributing factor to the cost of buildings. But in general, it is strongly believed that concrete buildings are more expensive when compared to other building materials including wood (Alam et al. 2022).

## 4.2 Factors limiting the use of wood as building material in Finland

No building material is without difficulties, yet the restrictions posed by these materials only apply to the degree of knowledge, creativity, and technology that is now available. Materials need to be researched scientifically and evaluated. New material possibilities and uses are emerging because of technological innovation. Wood has the obvious problem of being flammable; nonetheless, its capacity to insulate against heat is vastly underappreciated. Hence, some of the challenges, or limitation for wood as building materials include among others.

1. **Weathering and decay:** weathering and rotting are other factors that have an impact on wood. While excessive moisture and a fungal attack on wood result in wood degradation, chemical and light interactions cause weathering (Teischinger, 2016). Though these weathering effects can be minimised by applying coatings to the surface of wood. However, the coating choice is made

based on the intended outcomes. Coatings are classified into two types: those that form a thin layer or coating on the surface of the wood and those that permeate the wood and provide protection without leaving any coating. All coatings' protective advantages, meanwhile, also rely on regular coating maintenance. All coatings must be periodically renewed because none will endure forever.

2. **Fire:** The greatest challenge to wood as a structural material has been fire. Studies have shown that wood as a building material is the only material that insulates itself after the initial charring. Fire has been the most difficult obstacle for wood as a construction material. According to studies, wood is the only construction material that insulates itself after the initial charring. According to studies, when wood burns, it is temporarily protected by its own charring, which generates an insulating charcoal layer that slows the spread of fire. This indicates that a well-built wood building will continue to be capable of supporting the weight for which it was designed, even if exposed to fire for a suitable period for escape. However, the greatest control in wood structures, as in other buildings, is prevention in the first place, as well as the use of fire-rated wood in areas prone to fire outbreaks.
3. **Termite Infestation:** Although termite management is crucial, the possibility of termites invading a home is independent of the type of frame that was used during construction. Simple adherence to certain fundamental maintenance concepts is all that is required. In addressing these problems, the suggested procedures include suppression, site management, soil barriers, and foundation selection.
    a. **Suppression**: This method requires the methodical identification and elimination of colonies, the examination of wood products to treat an infested region, the burning of infested wood, and the heat treatment of salvaged wood.
    b. **Site Management**: site management is another method for reducing termite infestations. This may be accomplished by properly disposing of building waste, pegs, and concrete formwork, as opposed to burying them.
    c. **Chemical and Soil Barriers**: The use of environmentally friendly pesticides helps reduce termite infestations. Because they are too heavy

for the termites to move and the space between them is too narrow for them to get through, sharp sand placed along the foundation footing has been shown to be a very effective barrier.

d. **Slab and Foundation Details**: It is possible to construct foundation walls and slabs to prevent them from entering the structure. Termites will be driven to the surface, where they may be easily spotted thanks to the concrete cap detailing on the foundation. Foundations without a concrete covering enable termites to bore easily and covertly

# 5 CONCLUSION AND RECOMMENDATIONS

The findings indicate that concrete is heavier and stronger than wood. A smaller foundation is required for wood construction because of its reduced weight, which has an economic benefit. Wood's reduced weight is especially advantageous in subsoil conditions that are unfavorable and prone to differential movement. When comparing costs, the wood-based buildings have an edge over the concrete model since it seems more reasonable. From a design and constructability standpoint, the modelling of a wood frame building provides many alternatives, which makes it simpler than designing and building something out of concrete. Buildings built of lumber are more ecologically friendly than those made of concrete, according to analyses of their energy efficiency and environmental effects. The findings based on various investigations show conclusive evidence that wood is a superior building material for small and medium-sized structures. Based on these findings, as well as Finland's goal of becoming climate neutral by 2035, It is strongly suggested that low-rise wood-based buildings will help the country achieve its set goals, looking at the advantages and disadvantages associated with both wood and concrete buildings.

## 5.1 Recommendations

Based on the findings in this study, the following recommendations were made:

1. There is a need for good technical knowledge of wood to use it as a building material, given that there are several types and kinds of wood.

2. There is a need for knowledge of the functions of the structural unit and the specific properties of wood in relation to the functions of the structural unit.
3. Wood is also suggested because of its physical and aesthetic appeal, use, adaptability for space arrangement, dry construction, industrial production, and comparative cost-effectiveness.
4. It is required to provide wood with various preventative treatments to prevent biodegradation of wood members, potential failure, and collapse of wood-based structures. They might contain information on seasoning and the use of chemical preservatives. To lessen instances of dimensional instability and deformation of wood structural members while in use, thorough seasoning of the wood should be done.
5. There is a stronger need to use wood preservatives that are environmentally friendly to not defeat the purpose for which wood is used as a building material. This is because many of the preservatives are environmentally unfriendly.

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