The Rise of Wooden Skyscrapers

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Abstract

This paper was originally written for Mike Sjordsma ENSC 105w course *Process, Form, and Convention in Professional Genres*. The assignment asked students to write a persuasive paper addressed to a specific audience, intended to persuade them about any technology-related problem being faced in society today. The paper uses APA 7 citation style.

Skyscrapers worldwide predominantly rely on steel-reinforced concrete, presenting challenges such as a carbon-intensive manufacturing process. However, there is a material which addresses many of these problems, not currently being used to its fullest capability. Cross Laminated Timber, or CLT is a refined form of wood much lighter than reinforced concrete yet comparable in strength. The purpose of this paper is to advocate the construction of wooden skyscrapers above 12 stories in British Columbia because of the structural, affordability and environmental benefits they provide to urban environments. This paper will outline why CLT-construction is a viable solution to many of the problems cities face today along with addressing flammability and environmental arguments commonly cited with large scale timber construction.

Audience

This paper will be directed towards the zoning managers of the Building Officials' Association of BC who manage and regulate construction laws and code. They will be knowledgeable about general architecture zoning and construction facts.

Acknowledgments

I would like to acknowledge my friends Evan Feng and Vishnugupt Dixit along with WriteAway tutor, Suzanna for providing their feedback while proofreading. I would also like to thank my TA, Gustavo Silva, for spending extra time to critique my work and further guide me through my research.

Introduction

According to the International Energy Agency (IEA), the construction industry accounted for 39% of global carbon emissions in 2018. 11% of this was directly related to the production of concrete, steel, and glass in our modern-day skyscrapers (United Nations, 2019). For cities to become greener, engineering solutions need to be implemented to meet the goal of 2 degrees of temperature change set by the Paris Agreement in 2015 (United Nations, 2016).

One promising low-carbon solution is to instead use wood to construct larger buildings and skyscrapers above the current maximum in BC of 12 stories (Holmwood & Kilpatrick, 2019). With the advent of Cross Laminated Timber (CLT), a stronger refined type of wood, numerous benefits are provided, such as an increased seismic strength, cheaper initial cost, and a decreased climate impact. Despite perceived issues, namely the fire resistance of wood, mitigation strategies exist. Adapting BC's zoning codes to accommodate such construction is pivotal, offering a sustainable and climate-friendly alternative to the prevailing use of concrete and steel.

1. Why Wood as an Alternative

Constructed using steel reinforced concrete, skyscrapers today primarily combine the strengths of concrete with steel to create a durable material that can handle immense pressure. However, reinforced concrete still has the drawback of being highly resource and carbon-intensive. One alternative to concrete is constructing skyscrapers out of wood.

1.1 Problems with Current Concrete and Steel Construction

The main reason why current skyscrapers are so carbon-intensive is due to the production of concrete and steel. For example, during the manufacturing process of concrete, the cement used requires being heated in a kiln to over 1400 degrees Celsius (Lea, 2023). This alone per ton requires 3.2 Gigajoules of energy and 110 kilowatt hours of electricity (Mokhtar & Nasooti, 2020). While being heated, carbon dioxide is also released as a by-product during its oxidation process. Furthermore, during its transport, cement constantly needs to be flowing to stop hardening, thus requiring expensive cement trucks to transport it.

Similarly, the steel used in reinforced concrete also has high carbon emissions; 1.8 tons of carbon dioxide is emitted per ton of steel made (IEA, 2023). The iron ore used for steel requires a significant amount of energy to mine and emits considerable quantities of other pollutive gasses, such as nitrous oxide

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and sulfur dioxide (World Steel Association, 2019). This also excludes steel-based skyscrapers as a viable alternative for constructing greener skyscrapers. Overall, the pollutive energy intensive production of both concrete and steel production leaves a strong reason to look at other building material alternatives for a more climate friendly solution.

1.2 Cross Laminated Timber: A Refined Type of Wood

Currently, most buildings constructed with wood and timber in North America are under 6 stories. This includes single family homes, townhouses, and apartment complexes. This type of construction is commonly associated with being built with a cheap material, such as drywall, that often lacks structural integrity. However, with more recent developments, materials have evolved; timber-based skyscrapers are now currently being constructed around the world. Developed in Switzerland in the early 1990s, a much more refined type of wood called Cross Laminated Timber, or CLT is instead used. One example of a wooden skyscraper using CLT is Mjøstårnet in Norway (Block, 2019). Completed in 2019, it stands as a mixed-used apartment building at 84 meters and 18 floors. See Figure 1 below for a picture during construction.

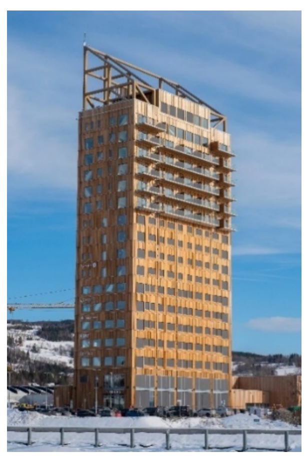

Figure 1: Mjøstårnet in Bergen, Norway
Source: (Block, 2019)

CLT, being a composite material, is much more durable than regular wood. It is manufactured with thin layers of wood stacked perpendicular to one another, as shown in Figure 2 (Karacabeyli, 2013). Those strips of wood are then

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glued together and coated with a weather-proof seal creating a material comparable in strength to concrete to be used for walls, floors, and support beams.

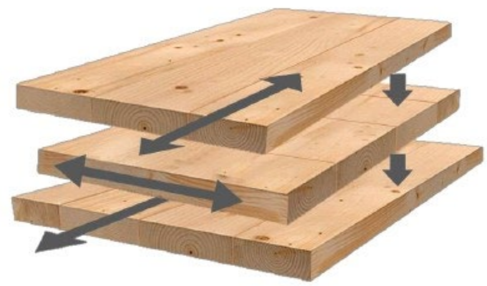

Figure 2: CLT Perpendicular Stacking
Source: (Fernanda et al., 2014)

Along with conventional metal braces and screws, the use of interlocking joints increases structural support in conjunction with glue when connecting segments. This helps connect different wall segments or beams at different angles and increases the overall strength. Figure 3 illustrates an example of such interlocking joints.

Figure 3: Interlocking Floor Joints
Source: (Mohammad, 2011)

2. Structure

Despite Cross Laminated Timber being comparable in strength to reinforced concrete, CLT is significantly lighter. CLT only weighs approximately 550 kg/m3 compared to steel reinforced concrete at 2500 kg/m3, depending on the kind of

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wood used (Jayalath et al., 2020; Kluziak, 2023). CLT therefore has a higher strength to weight ratio, meaning less mass is required to support itself (Lewis et al., 2016). With reinforced concrete, a significantly greater quantity of material is required just to support itself when adding additional floors. With CLT however, a higher strength to weight ratio means less material is required for the building, foundation, and additional floors, thus lowering the total resources and price for construction. Less material also increases the high-demand floor space in the lower floors of a building, thus furthering its floor space efficiency. This overall strength benefit gives CLT skyscrapers a structural advantage over reinforced concrete.

CLT Skyscrapers also have an advantage over reinforced concrete because of the seismic endurance wood offers. Currently, CLT beam reinforcements are often added to older brick buildings to increase their seismic protection (Brown et al., 2021). Due to being located near many fault lines, construction in BC needs to follow strict earthquake building regulations. Unlike with rigid reinforced concrete structures, CLT can bend and fluctuate more, allowing it to endure stronger earthquakes without cracking. This flexibility makes CLT buildings safer to reside in during stronger seismic events (Pan et al., 2023).

3. Fire Resistance

Often cited as a reason to avoid wood in the center of cities, historical events, such as the Great Chicago Fire influenced the attitude towards taller wooden construction. This event led to a shift away from wooden architecture in high-density cities where a fire would easily spread to neighbouring buildings (Schons, 2023). Building codes were then updated to require buildings to be built out of brick and concrete across North America, including in BC. A building's fire resistance is especially important as dry summers in BC led to increased wildfires. However, developments in CLT mitigate many of these past issues due to its denser structural design.

Unlike wood used in most construction, CLT exhibits better fire-resistant properties more comparable to concrete due to being a denser material and having a weather-proof coating. CLT tends to char, acting as a fire insulator for inner layers of wood (Asdrubali et al., 2017). This charring allows CLT to reach temperatures of about 400 Celsius before igniting. A study conducting a Fire Resistance Test with a slab of CLT indicated that the material integrity was maintained after a 30-minute test (Hull, 2008; Vairo et al., 2023). This can allow the building's occupants to safely evacuate the building with a significantly lower

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risk of collapse. However, the study further indicated the importance in considering the long-term loss of stiffness and strength of timber. Despite this, steel reinforced concrete is not flawless either. After being exposed to higher temperatures, concrete tends to crack, becoming more brittle, and steel also warps when being exposed to heat.

Additionally, another study indicates that CLT does have the ability to dissipate fires to stop burning without significant immediate structural damage (Crielaard et al., 2016). Adding more sprinkler systems, more advanced fire-proof coatings and additional layers of insulation can further assist with fire dissipation (Asdrubali et al., 2017).

Ultimately, similar to reinforced concrete buildings, assessments still need to be conducted before re-occupying a building after a fire. In the event of a fire, occupants in CLT skyscrapers will still have enough time to evacuate and in combination with other fire protection measures, the safety of the building's occupants will not be compromised.

4. Environmental Impact of CLT

Another widespread issue cited when using large quantities of wood in construction is the extra logging, loss of biodiversity and increase in CO2 that increased wood consumption would cause. However, according to a study in the field by the Potsdam Institute for Climate Impact Research, in a scenario where humans switch 90% of all buildings to using wood, about 100 Gigatons of carbon would still be saved compared to continuing to using concrete because the wood will continue to store the carbon that it sequestered (Mishra et al., 2022). While the land allocated for forest plantations would need to increase by 150 million hectares by 2100, the study further states this is possible to do with the land we have without impacting agricultural land usage (Mishra et al., 2022). When harvested from sustainable tree plantations, this ends up being a better option than the highly pollutive production of reinforced concrete.

To mitigate loss in biodiversity in the long term, what distinguishes wooden skyscrapers is the ability to recycle the wood used. Typically, at the end of a reinforced concrete building's lifespan, the steel is recycled but the concrete is not. This is due to the difficulty of isolating each ingredient used in cement. However, CLT is much more flexible allowing for much better recyclability. To test this, a group of researchers were able to fabricate CLT panels using discarded sleepers from railway tracks in Brazil without compromising on strength (Carrasco et al., 2023). Reusing wood obviates the need to harvest new wood

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from forests, further decreasing its carbon emissions and reducing any further losses in forest biodiversity.

5. Affordability

With newer building materials advancements, another concern that arises is the affordability of a solution. Developers still want to make a return on investment, meaning a green solution also needs to be an affordable solution.

5.1 Life Cycle Cost

Due to ever-rising land prices in urban centers, keeping the price of construction when building higher to accommodate growing cities is important. Despite its novelty, the total price of a CLT building is comparable to a reinforced concrete building. A life-cycle analysis conducted in Australia in 2020 states that a "CLT building has less initial cost than that of a RC [reinforced concrete] building, the savings ranging from 8-10%" (Jayalath et al., 2020, p. 15). However, the analysis further states that "during the operation phase, the CLT building was found to be 13-16% more expensive than the RC option." This is due to the increased maintenance cost of the CLT panels for things like the weather coating and fireproofing. Overall, the cost for a CLT building in a 50-year life-cycle is still 1-2% cheaper. Similar to reinforced concrete skyscrapers, the cost can change depending on where it is located and the climate of the region.

5.2 Initial Cost & Prefabrication

During the initial construction phase, reducing the price allows developers to feel more confident they will make a return on investment. The advantage with CLT is its flexibility to have prefabricated components during the construction process. Manufacturing separate wall and floor components offsite and then transporting them to the construction site for assembly significantly speeds up the time needed to build on site, thus decreasing labour costs.

Prefabrication cuts down on the labour costs because workers do not need to be working at the same site for long periods of time. Reinforced concrete requires a significant number of workers transporting cement and waiting for it to harden in place. Weather events can often cause delays when constructing skyscrapers. Prefabrication means that significant portions of the manufacturing can be done in a more controlled environment offsite. Long term price improvements could also be made if the wood is recycled, mitigating the spending of resources harvesting and refining new wood (Carrasco et al., 2023).

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6. Psychological Benefits

While there are many ecological and economic benefits to constructing skyscrapers out of wood, one hidden benefit is regarding the positive affect on the building's occupants psychologically. A major disadvantage to living in cities is the disconnection from nature. However, due to the busy lives people have, finding the time to visit parks outdoors can be difficult. Often, incorporating natural elements into a building can allow for its occupants to feel more connected to nature whilst living in denser urban environments. A study from UBC shows that a room constructed with 45% wood coverage decreases stress levels similar to being exposed to plants and nature (Fell, 2010). Along with its visual appeal, this subconscious effect also extends to the odor. Wooden construction has a scent more akin to nature and can lower a person's stress levels while indoors, unlike concrete and steel (Herz et al., 2004). Subconsciously, a decrease in stress levels can significantly increase an occupant's mental health, improve their mood and boost productivity.

Conclusion

Overall, wooden skyscrapers can have a bright future ahead and can be considered as a viable alternative to the traditional reinforced concrete-based skyscrapers if they were to be allowed in BC. The material they are primarily constructed out of, Cross Laminated Timber, significantly decreases the carbon emissions during the construction process and is also comparable in strength to reinforced concrete. Moreover, CLT's earthquake endurance, recyclability, affordability, and psychological benefits give wooden skyscrapers an advantage over reinforced concrete. While there is the drawback of its long-term fire resistance, the technology exists for it to be mitigated, making it a safe alternative. Allowing the construction of CLT based skyscrapers will help with the Province of BC's goals of becoming more sustainable and provide many benefits over current reinforced concrete Construction.

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