Chapter

Massive Wood Construction in Finland: Past, Present, and Future

Hüseyin Emre Ilgın and Markku Karjalainen

Abstract

Finland has a long history of massive wood construction such that the log construction technique has been used as a traditional method of Finnish residential construction for thousands of years, and the entire history of Finnish architecture is based on this technique. Today, almost all leisure buildings, for example, cottages in Finland are made of wood and mostly log construction. Also, today 90% of Finland's detached houses have timber frames, and a quarter of them are made from industrial glue logs. Apartment buildings began to be made of wood, especially cross-laminated timber (CLT) and laminated veneer lumber (LVL). The most common way of constructing wooden apartments is to use volumetric elements as compared to load-bearing large elements and post-beam systems. The increase in environmental awareness in Finland, as in many European countries today, strengthens the popularity of wood construction, and this brings the search for innovative and environmentally friendly engineered wood product solutions (e.g., dovetail massive wood board elements) as a future vision. The chapter aims to identify, combine, and consolidate information about massive wood construction in Finland from past, present, and future perspectives. This study will assist and guide Finnish key professionals in the design and implementation of timber buildings.

Keywords: timber/wood, construction, log construction, engineered wood products, sustainability, dovetail massive wooden board elements, Finland

1. Introduction

Finland has a long history of using massive wood in construction, starting with thousands of years of log building techniques [1]. Log, which was traditionally carved by hand from single trees, has been the main material of all types of buildings, for example, residences and religious buildings. In the early phases of industrialization, the log was used merely for the construction of sauna huts and summer cottages (**Figure 1**) [2–4]. Today's logs are produced industrially in factories, using sophisticated woodworking machines from glued laminated wood (**Figure 2**) [5]. Moreover, in the last 10 years, log construction doubled the share of all new prefabricated detached houses sold in Finland [6]. Overall, there is a swift development going on right now, where the use of log construction is growing, and neither the usage context of the logs nor the log itself is the same as in the past [7].

Figure 1.
Log cottage example from Finland (photo courtesy of Lotta Häkkänen).

Figure 2.
A modern log cottage example from Finland (photo courtesy of Lotta Häkkänen).

Finland has been experimenting with wood-frame multi-story construction since the mid-1990s due to industrialized prefabrication of engineered wood products (EWPs) such as CLT, and LVL [8], which allowed the use of wood in large-scale construction, for example, multi-story apartment buildings [9]. Furthermore, as timber construction research has increased in Finland in recent years, the use of EWPs in the construction sector has become gradually more prevalent (e.g., [10–12]). The most popular way of constructing wooden apartments is to use volumetric elements as compared to load-bearing large elements and post-beam systems [13]. Here, wooden multi-story refers to buildings more than 2-story with a wooden structural frame and, in some cases, with timber facade cladding [14, 15]. Moreover, the Finnish fire code was revised so that residential and office buildings with timber structures and facades could rise to 4-story and then 8-story in 1997 and 2011, respectively [16]. With the revision in 2018, it has become possible to design and construct housing and office buildings with timber structures and facades up to 8-story and, due to functional fire planning, wooden buildings higher than 8-story (e.g., apartments, dormitories, hotels, and offices) are also possible [17]. Currently, there are two wooden tall residential buildings (≥9-story), 14-story Lighthouse Joensuu (2019) with LVL (**Figure 3**), and 13-story HOAS Tuuliniitty (2021) with CLT (**Figure 4**).

In line with "Finnish National Energy and Climate Strategy" [18] and "Guidelines on State Aid for Climate, Environmental Protection and Energy 2022" [19], as a reflection of environmentally friendly approaches to reduce greenhouse gas emissions and carbon footprint on the construction industry, the use of wood has become more prevalent, especially by being encouraged by many government-supported

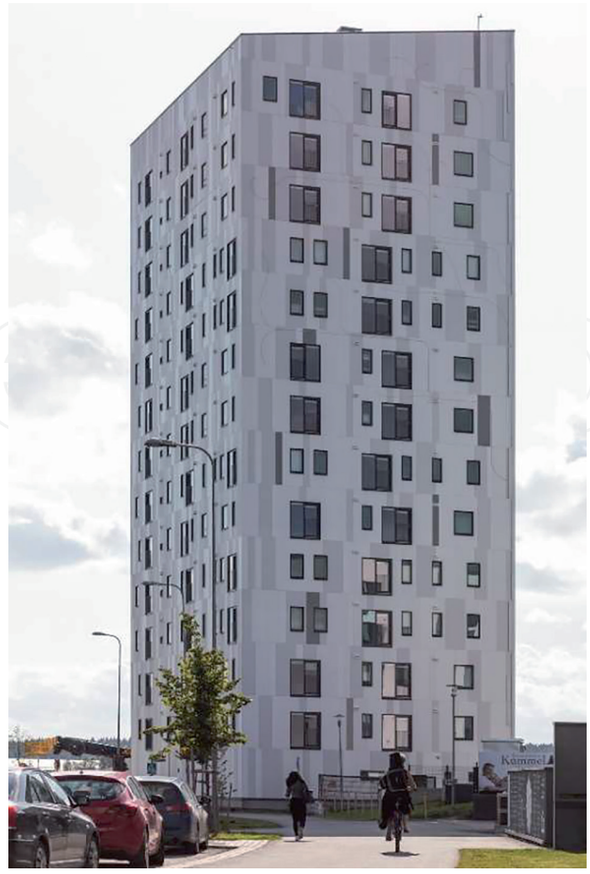

Figure 3.
Lighthouse Joensuu (photo courtesy of Arcadia).

Figure 4.
HOAS Tuuliniitty (photo by Miika Ullakko, courtesy of Arkkitehti toimisto Jukka Turti ainen/Arkkitehti palvelu Oy).

institutions, organizations, and regulations in Finland [20–28]. As a result, the search and trend towards innovative and "green" wood products such as adhesive- and metal fastener-free dovetail wood board elements (**Figure 5**) seem to shape the future of the Finnish construction industry [29, 30].

Overall, this chapter examines massive wood construction in Finland from past, present, and future perspectives. It is thought that this study will assist and guide key professionals in the design and implementation of timber buildings in Finland.

Figure 5.
Test specimen of adhesive- and metal fastener-free dovetail wood board element (photo by Hüseyin Emre Ilgın).

The chapter is structured as follows. The next section presents Finnish massive wood construction by detailing the history of log-based wood construction, the current state of the art, and finally the future of the Finnish wood construction industry. The last section provides our concluding remarks.

2. Massive wood construction in Finland

2.1 Past

The entire Finnish wooden building tradition is based on the use of logs (**Figure 6a**). The art of building logs has been developing in the northern coniferous region for more than a thousand years. The log structure is a traditional wooden construction method in which load-bearing walls are made of logs. In Finland, logs are usually arranged horizontally and joined by special corner joints (**Figure 6**) [31]. The horizontal log technique, which resulted in simple rectangular building volumes with scale uniformity relative to the length of the log, has been used in Finland for over a thousand years. Due to the always availability of trees, logs have become a natural building material in Finland.

In the first decades of the twentieth century, a new American-style lightweight timber-frame construction system began to be used in Finland [32] and log construction was the most used practice for residential buildings until the 1930s before the dominance of the American light frame in Finnish wooden construction industry [33].

In the 1930s, the Finnish forest, used for the paper and timber market, contributed to the industrialization of the country. In this period, when the international

Figure 6.
Log construction (a) earlier corner detail (photo courtesy of Lotta Häkkänen) and (b) modern corner detail (photo by Hüseyin Emre Ilgın).

style influenced Finnish architects, the Finnish wooden building tradition was heavily applied [34]. Rising labor costs spurred single-home builders to seek alternatives for industrial-scale housing solutions. The American-style urbanization and industrialization at the time gave architects like Alvar Aalto, designing numerous multi-dwelling accommodation facilities, enough inclination to explore possibilities including prefabricated solutions [35]. The focus of the construction was solely derived from natural resources, for example, the abundance of Finnish forests. Single houses were built utilizing massive wood logs harvested directly on the site [36].

In the 1940s, World War II led to a shortage of building materials and a demand for community and residential construction in a timely and cost-effective way. It's worth noting here that Alvar Aalto's approach relied on the use of prefabricated elements specifically to maximize Finland's use of forest resources, as a continuation of the framing system experiment Finland modeled on its previous American predecessor [34]. Nevertheless, despite heavy investments and the overall positive impact of the practice on Finland's architectural development, adverse weather conditions, and high labor costs resulted in low participation in this practice.

The arrival of wooden facades coincided with the end of World War II. The peculiarities of prefabrication during the war, especially due to the fast pace of construction, cemented the position of this private residential solution in Finnish construction history. Prefabrication provided an effective solution to the population boom, rapid urbanization, and migration from more rural areas to urban centers in Finland. Finnish log construction took on new vitality in the early 1950s, with the industrial production of log houses (**Figure 6b**). Due to their nail-free structure and good availability of timber, logs were again a beneficial building material, which was mostly used in single-family houses. On the other hand, with the emerging modernist movement internationally, concrete flourished on the construction scene in the late 1960s and became a generally common material for medium to large-scale building designs.

In the early 1990s, Finland started a piloting effort to explore the potential to return to wood construction, which was a background indicator of the relevance of Finnish buildings to traditional Finnish cultural values and the return to deindustrialization. However, although this effort was reflected in several pioneering projects that promoted the validity of wood as the next major building material, it later lost power due to the general economic fluctuation at the national level. Even though the economic boom of the late 1990s greatly boosted development in the construction industry, the American platform framing technique had a chance to enter the timber construction market as the forestry industry did not have a vision of collaborating particularly with architectural and structural designers to compete with concrete practices in Finland.

While the resulting pilot projects were successful, regulatory, and labor issues and logistical challenges combined with the disconnect between engineers and product manufacturers, the forestry industry's inability to provide the necessary technical assistance towards wood construction standards, and the lack of funding for further research and development, reduced the chance of wood to compete with the mature concrete industry [35].

The second wave of timber booms began in 2011 when an amendment to the Finnish fire code allowed wooden structures and facades to be used in projects, increasing the maximum allowable height of the building for wooden structures to 8-story.

2.2 Present

Regarding the log construction mentioned in the previous section, as is known, traditionally logs have been handcrafted from a single tree trunk, while modern logs are precise industrial products manufactured in plants by bonding together multiple parallels or cross lamellas of timber. As part of the global development of massive wooden construction, the use of industrial log construction has become more and more popular in Finland over the past decade (see **Figure 7**) [37] such that from just over 10% a decade ago, now about 30% of all new single-family homes have log structure [38].

Recent buildings using industrial logs show that this reputation also applies to larger construction, for example, school campuses (**Figure 8**). Additionally, in the early 2000s, due to the poor architectural quality of industrially produced log buildings, there were attitudes among designers and construction officials towards the use of logs in urban or suburban contexts, however, particularly in the last decade, the perception that log structures have an untapped potential for architectural expression has positively changed the perspective of professionals [39].

Wooden multi-story construction has been on the Finnish national policy agenda since the 1990s and there are high expectations for its potential market growth [40]. Additionally, in particular, due to the revision made in the Finnish fire code in 2018, it has been possible to design and construct residences, dormitories, hotels, nursing homes, offices with wooden structural systems up to 8-story, and buildings with more than 8-story, functional fire design analysis is applied in Finland.

Finland has the second-highest proportion of multi-story buildings in Europe after Spain, and about 47% of Finnish housing units are located in multi-story buildings [41]. However, the market share of timber multi-story apartments constructed was only 1% in 2010, and the share increased to 10% by 2015 [42]. By March of 2022, 130 two-story timber apartment buildings have been built in Finland, a total of 4150 apartments [43, 44].

Figure 7.
A four-story log apartment, Finland (photo by Hüseyin Emre Ilgın).

Figure 8.
Pudasjärvi log school campus, Finland (photo by Hüseyin Emre Ilgın).

The American platform-frame system, based on floor-by-floor stud frame construction, was mostly used for the construction of Finland's earliest residential buildings. Nowadays, in Finland, timber apartments are executed with three different structural solutions: a volumetric modular system, a load-bearing large element system, and a post-beam system, and among them, the most popular way of building wooden apartments is to use of volumetric modular element designs based on CLT [45]. On the other hand, these elements can also be applied as a rigid structure. Furthermore, timber-concrete composite board structures are primarily utilized on the intermediate floors due to their advantage in sound insulation.

Besides wooden construction in Finland, interest in high-rise construction has also risen over the past decade, which is mostly related to the urbanization trend in Finnish major cities as in other metropolises of the world [46–50]. In this sense, multi-story timber construction has been endorsed in Finland since the 1990s [51], and multi-story and tall buildings are considered the biggest opportunity for growth in wooden construction [52] with national policy support [53], as in the 14-story Lighthouse Joensuu (**Figure 3**) and 13-story HOAS Tuuliniitty (**Figure 4**), and the 8-story high Puukuokka 1.

On the other hand, due to the separation of the market by construction systems, difficulties arose when potential industry partners tried to enter the market, as the solution for each construction system was often different from the others. This challenge hindered the progress of the industry by discouraging potential competitors. Various strategies have been documented and introduced concerning the current market situation, both from a national programming perspective and as an internal review of possible policies.

Running various programs across the country to focus on the use of natural resources, from micro to macro scale, the Finnish government has been a supporter of the timber industry in general, putting wooden apartments on the national programming agenda. Alongside efforts to standardize construction systems, supporting activities in the industry have been undertaken by individual and government agencies.

Moreover, according to studies such as policy gap analysis of programs promoting the use of timber in construction in the Finnish context [54], the following are considered among the main obstacles and challenges: (i) demand for stricter fire safety measures compared to traditional building materials; (ii) lack of support from municipalities on tenures for new buildings; (iii) different practices and additional fee demands of insurance companies for timber structures; (iv) lack of knowledge about carbon footprint calculation methods, evaluation of operating and maintenance costs; (v) lack of suitable tools for implementing wood construction projects in BIM; (vi) training offer gap causing a shortage of available experts in the field; and (vii) skepticism about the durability of the material.

Overall, in the rapidly and constantly changing building construction industry, sustainable approaches often use specific materials and technologies to support architectural design. These strategies are also significantly influenced by the characteristics of the available market margin. Every major component in the market value chain must be scrutinized to give a healthy impetus to practical and profitable solutions in the industry. While Finland leads the way in joining the world race in environmentally-friendly applications, certain conditions in the Finnish construction sector tend to aggressively hinder progress. More specifically, the targeted level of using wood as the main building material in medium and large-scale projects has not been reached yet [35].

2.3 Future

As noted earlier, there is strong governmental support for timber construction in Finland, which is also defined in various national strategies and programs such as the Government Programme, the National Energy and Climate Strategy, the National Forest Programme, and the Finnish Bioeconomy Strategy, which aimed at increasing the share of long-term carbon storage products and applications. For example, The Wood Building Programme, which sets one of its goals as rising the market share of timber structures in public buildings to 30% in 2022 and 45% in 2025, has five focus areas: increasing the use of timber in urban development, endorsing the use of timber in public buildings, increasing the construction of large timber structures, reinforcing local skill bases, and encouraging exports [55].

In line with the government policy mentioned above, by focusing on the impact of business activities, for example, building construction industry, on climate and natural sources, ecological awareness has increased significantly in the last two decades and environmental degradation has been defined as a global problem (e.g., [56–58]). This important global rising awareness has led to the development of new and more environmentally friendly timber-based solutions, especially in the Finnish wood construction industry as the future vision. In this context, many research projects (e.g., the DoMWoB project/Dovetailed Massive Wood Board Elements for Multi-Story Buildings—see Acknowledgments and Funding) (**Figure 9**) [42, 59] are being carried out as in other EU countries (e.g., [60]).

In addition, as in other Scandinavian countries, the rise of wooden multi-story construction in Finland has become the most prominent new construction-related business opportunity in the emerging bio-economy. Similarly, the construction of tall timber buildings (≥9-story) seems to be gaining momentum, driven by decarbonization, forest management and timber life cycle, urbanization and densification, productivity in the construction industry, and benefits of using timber indoors [61, 62]. Moreover, in Finland, as part of the rise of the environmentally friendly building

Figure 9.
Manufacture of dovetail massive wood board element at Vocational College Lapland (Ammattiopisto Lappia), Kemi, Finland (photo by Hüseyin Emre Ilgın).

concept, the future of wooden construction can be shown as hybrid buildings, where other materials are used together and benefit most, either structural members (such as wood and steel or concrete combinations) or cross-section-based level (such as wood and plastic) [63]. As in the cases of the 25-story and 87 m high Ascent (Milwaukee, under construction), the 24-story and 84 m high HoHo (Vienna, 2020), and the 18-story and 58 m high Brock Commons Tallwood House (Vancouver, 2017), hybridization using a reinforced concrete core target better structural safety and performance, which becomes more and more important with increasing building height.

3. Conclusions

This study identifies, combines, and consolidates information about massive wood construction in Finland from past, present, and future perspectives. Finland has a long history of using massive wood in construction, starting with thousands of years of log building techniques. Wood-based solutions have traditionally held a strong position in Finland's construction industry and account for approx. 40% of all building materials. Today almost 90% of Finland's detached houses are timber-framed, and a quarter of them are made from industrial glue logs. Wood is also used on construction sites in structures, windows, doors, and finished surfaces, as well as in formwork construction, among other uses. Apartment buildings began to be made of wood, especially CLT and LVL mostly with volumetric elements. In addition, the possibilities of using wood have been expanded to include renovations and extensions of suburban concrete apartments. There are significant activities, initiatives, and legalization in support of wooden structures concerning current European regulations emphasizing the use of wood as a sustainable architectural building material for the future in Finland.

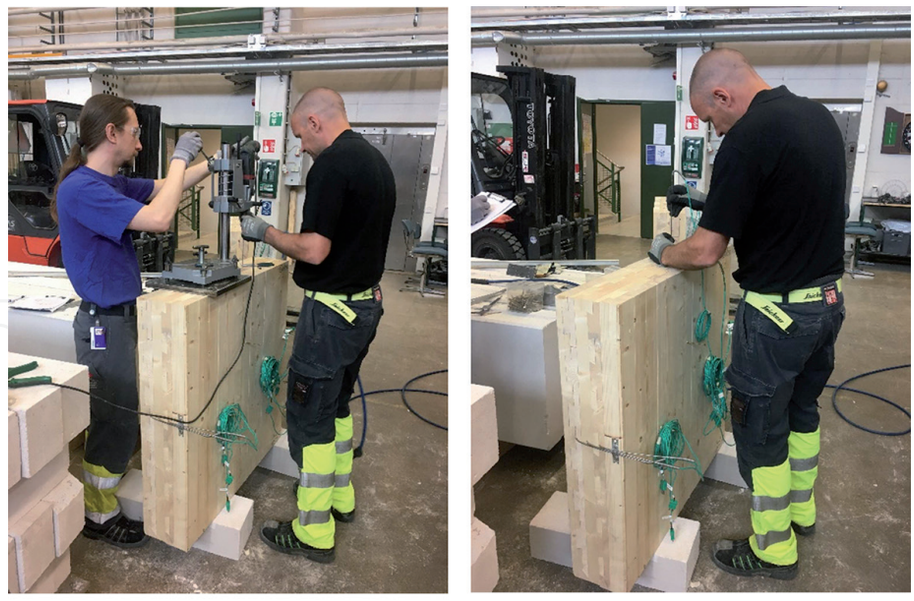

Figure 10.
Preparation of dovetail specimens for fire resistance test at Tampere University Fire Laboratory, Tampere, Finland. (a) Drilling and (b) thermocouple insertion (photos by Hüseyin Emre Ilgın).

Overall, the global economy engine naturally shifted the focus of Finnish construction technology to viable solutions, which means that concrete's low return on value hinders the use of one of the defining features of Finland's global image—the vast forest resources are not fully utilized internally as they should be. In this sense, because of environmental considerations, there is a rising interest in the use of timber and the advancement of wooden structural elements. This has led to a wide variety of EWPs used in advanced ways to replace conventional construction materials, for example, steel and reinforced concrete, and enhance the appeal of wood construction, thus leading to the quest for groundbreaking and environmentally friendly EWP solutions (e.g., dovetail massive wood board elements) (**Figure 10**) for the future of timber in Finland. Currently, although the uptake of for example dovetail massive wood board elements for industrial applications is very limited, with new projects to be developed, it can be used more in the construction of multi-story and even tall buildings. In order to contribute to environmentally friendly construction and low embodied energy and carbon buildings, more research is needed to develop innovative and sustainable EWPs that are nontoxic, low-cost, recyclable with well-designed structural features and life cycle assessments.

This study will assist and guide Finnish key professionals in the design and implementation of timber buildings, highlighting the status and future directions of massive timber construction.

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Author details

Hüseyin Emre Ilgın* and Markku Karjalainen
Tampere University, Tampere, Finland

*Address all correspondence to: emre.ilgin@tuni.fi

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