Chapter

Tall Wooden Residential Buildings in Finland: What Are the Key Factors for Design and Implementation?

Lassi Tulonen, Markku Karjalainen and Hüseyin Emre Ilgın

Abstract

This chapter examines tall residential buildings using engineered wood products (EWPs) in Finland. As specified in the National Building Code of Finland, 'tall wooden building' is defined as a structure with more than 8-story. Currently, there are two wooden residential buildings, 14-story Lighthouse Joensuu (2019) with laminated veneer lumber (LVL) structure and 13-story HOAS Tuuliniitty (under construction) with cross laminated timber (CLT) structure, that fit the definition above. This study analyses the phenomena associated with the design and implementation processes of these remarkable buildings, the starting points for the projects as well as the prospects of tall wooden housing in Finland through the case study method and interviews with the key actors in the projects. These cases are mapped with extremely detailed information, comprising a valuable source both for designers, engineers as well as developers. As a result, the current state-of-the-art and the critical factors influencing the design and implementation of these challenging sustainable projects in Finland have been identified. It is believed that this chapter will aid and direct key stakeholders in the construction industry in the sound planning and development of tall wooden residential projects in Finland.

Keywords: Engineered wood products (EWPs), construction, tall residential building, Finland, architectural and structural design considerations

1. Introduction

Timber has typically been used for centuries in single and multi-residential construction projects around the world. Timber in the form of EWPs, such as CLT (manufactured from at least three layers of boards by gluing their surfaces together with an adhesive under pressure), has been available on small scale projects in Europe, particularly in Germany and Austria, since its invention in the early 1990s. Moreover, recent advances in EWP technology have overcome major challenges in material strength and fire safety, making these products competitive against concrete and steel for tall building design.

Increasing wood construction has been a governmental policy in Finland for nearly three decades, and wooden buildings are being promoted by public authorities through various supporting wood programs and legislative changes. The key to

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encouraging wood construction has been to increase the degree of processing of the wood industry, improve exports and enhance ecology locally [1].

In the 2010s, climate targets became the main driver of wooden construction. Technical solutions in this promising area have so far been perceived to develop mainly as state-supported housing so that public solutions and operating models developed through assisted residential construction gradually become established in self-sufficient housing [2].

Apartment building construction has been seen as an opportunity to boost wood utilization [3]. Approximately 70% of residential construction completed in Finland in the last five years has consisted of apartment buildings, many of which are still built with reinforced concrete. Although structural systems for industrial timber construction have been known in Finland for nearly thirty years, wooden apartments have gradually become widespread.

Fire regulations played a central role in spreading the factor contributing to the wooden structure. In 1997, the revised fire code version resulted in permission being granted for the construction of residential and office buildings with wooden frames and façades up to 4-story high, due to which momentarily growth started in the construction of wooden apartment buildings in Finland. In 2011, the building regulation was revised to allow the construction of wooden apartment buildings up to a maximum of 8-story under certain conditions [4].

Especially in recent years, the number of wooden flats has started to increase significantly, and wooden structures have also attracted a lot of attention. Multi-story wooden apartments, e.g. Lighthouse Joensuu also gained great international visibility. Especially in the media, there is a lot of focus on the height of wooden buildings, and the development and innovation of wooden structures are widely presented through tall buildings.

However, very few wooden apartment buildings have been implemented so far, and their share in all Finnish apartment production is still very small. In 2019, less than 32,000 apartment buildings were completed in Finland, of which less than 2% were in wooden apartment buildings [5]. However, as industrial manufacturing and design and construction know-how improves and costs drop, larger-scale wooden apartment construction is becoming increasingly common. In particular, the construction of low-rise wooden apartment buildings is beginning to settle down so well that industrial wood construction, especially for them, can no longer be considered purely experimental production [6, 7].

As apartment building with EWPs has begun to take root, critical views on new pilot projects have also emerged. For example, more than 8-story wooden apartment buildings can be considered as such, which require functional fire safety analysis and a special procedure for construction projects. Instead, less than 10-story wooden buildings and increased competition in established markets are more important for the construction sector [8].

Most residential apartment buildings in Finland have a maximum of 9-story. At the end of 2018, there were a bit more than 61,000 residential apartment buildings in Finland, of which only 236 were 10-story or higher [9]. Thus, of all apartment buildings in Finland, only 0.4% were relatively tall construction, which contributes to the question of whether there is a need or justification for the development of tall wooden apartment buildings, especially as subsidized housing production. On the other hand, although there are so far few apartment buildings in Finland, tall construction has also increased significantly in recent years [10].

The main purpose of this study was to reveal the current state of tall wooden apartment construction with EWPs in Finland. The research examined the architectural and structural considerations of tall wooden residential buildings in the Finnish context. To achieve this goal, this chapter scrutinized the design and implementation process as well as the architectural and structural features of the two wooden residential buildings (over 8-story), Lighthouse Joensuu (2019), and HOAS Tuuliniitty (under construction), in Finland.

The scope of the chapter was limited by using five main points to identify key factors for design and implementation in Finnish tall wooden residential construction: Literature survey, structural considerations of wooden apartment buildings, special features of tall building construction, case studies including general information together with architectural and structural design considerations, and finally, interviews.

By revealing the up-to-date status with key factors for the design and implementation of contemporary Finnish tall wooden residential practices, this research provides insights into the making of more technically and economically sound planning decisions for future tall wooden residential building designs. In this study, wood or timber refers to EWPs including CLT, laminated veneer lumber (LVL) (made by bonding together thin vertical softwood veneers with their grain parallel to the longitudinal axis of the section, under heat and pressure), and glue-laminated timber/glulam (GL) (made by gluing together several graded timber laminations with their grain parallel to the longitudinal axis of the section).

In this chapter, the three main research questions were: (i) What are the key factors for the design and implementation of tall wooden apartment buildings in Finland? (ii) What are the special features of tall residential buildings in Finland? (iii) What are the prospects for tall wooden apartment construction in Finland?

2. Literature survey

While wood construction research in Finland has increased in recent years, the use of EWPs in the construction industry has become progressively more common. However, particularly in the Finnish context, the peculiarities of the tall wooden apartment building have not been analyzed very extensively and studies have focused mainly on low-rise wooden construction. Previous research on tall wooden construction in Finland has primarily scrutinized individual wooden apartment buildings and so, no comparative study has been conducted between projects.

Among the above-mentioned studies, the research conducted at the Karelia University of Applied Sciences in Joensuu was particularly on the construction of tall wooden apartment buildings. This is mostly because currently, the only wooden apartment building with more than 8-story in Finland is Lighthouse Joensuu, which is also widely used as a case study. Several theses were published related to Lighthouse Joensuu construction process [11], the use of wood in tall construction in general [12], and more specifically individual technical and structural solutions. In addition to these studies, a collection of articles on Lighthouse Joensuu in tall urban construction was published [13].

On the other hand, the factors affecting the overall development of wooden apartment buildings were examined in several Finnish studies (e.g [14–18]).

2.1 Structural considerations of wooden apartment buildings

In Finland, wooden apartment buildings are currently implemented with three different structural systems: a volumetric modular system, a load-bearing large element system, and a post-beam system. The case studies examined in this chapter and the other tallest wooden apartments in Finland were applied with either large element or volumetric modular system solutions.

Wooden post-beam structures were considered a competitive structural system in Finland, especially in low-rise wooden apartment buildings with a maximum of 5-story

[19]. The structural system chosen affects the architectural design of the building, through the location of the load-bearing lines and the possible spans of the subfloors [20]. Steel fasteners or screw fasteners are usually used for joints in wooden structures. The method of fastening is influenced by the selection of the structural system.

Compared to reinforced concrete construction, the maximum spans of the subfloors of wooden apartment buildings are typically somewhat shorter and, depending on the construction method, spans of about 4-7meters can be cost-effectively achieved with wooden subfloors. The load-bearing structures and partitioning walls between apartments are also usually thicker than concrete structures, which is particularly due to fire and sound insulation requirements [21].

In addition to the above-mentioned structural systems, it is possible to use various combinations of structural systems or wood/timber-concrete hybrid structures. For example, the 14-story and 49 m high Treet (2015) wooden apartment building in Bergen (Norway) consists of a GL frame and volumetric modular system. The load-bearing structure of the building is an adhesive lattice resembling a bridge structure and two concrete subfloors on the fifth and tenth floors. Volumetric CLT modules make up four-story-high entities that are separate from the load-bearing frame and do not contribute to the total frame stiffening [22].

Currently, the 18-story and 85 m high Mjøstårnet (2019) in Brumunddal (Norway) (**Figure 1**) is the tallest wooden apartment building in the world, and the 24-story and 84 m high HoHo (2020) in Vienna (Austria) (**Figure 2**) is the

Figure 1.
Mjøstårnet (Norway, 2019) (source: Wikipedia).

Figure 2.
HoHo (Austria, 2020) (source: Wikipedia).

second tallest [23]. Mjøstårnet's structural system is like a massive post-beam grid as in the case of Treet, but the apartments were built with prefabricated walls and floor elements rather than a volumetric modular system. The partition walls are implemented as CLT structures and the facades as sandwich panels attached to the GL frame. The wall structures do not contribute to the structural stiffness of the building. The elevator shafts and staircases are implemented as a CLT structure. Subfloors are made of LVL up until the tenth floor. The upper floors have concrete subfloors to counter the swaying of the building caused by lateral forces [24].

HoHo was designed as a hybrid structure. In the middle of the building was a reinforced concrete stiffening staircase, the surrounding spaces of which were constituted by load-bearing CLT walls. The subfloors are wood-concrete joint-structures that are supported by the concrete stairwell and the exterior walls. In total, about 75% of the building was made of wood [25].

Other possible joint solutions are, for example, the steel corner joint used in the 10-story and 34 m high Dalston Works wooden block of flats in London (UK). The steel parts used to connect walls to the CLT-subfloors above and below the floor slab, are also connected through the subfloor. This solution transfers the upthrust caused by wind forces to the lower floors [26]. At the 8-story Bridport House in London, CLT wall and floor elements are connected through a comb joint that reduces compression of the floor slab [12].

In volumetric modular system construction, the building is assembled from prefabricated modules in the factory, which in apartment building construction form either individual apartments or parts of an apartment. These elements are connected at the construction site, for example with steel brackets, and they usually form the load-bearing and stiffening frame of the building as such. In Finland, most of the volumetric modular system construction is currently carried out with solid wood CLT elements, but the elements can also be implemented as a rigid structure.

In a solid wood volumetric modular system, the walls and the roofs are typically formed of CLT panels. The floor of this element, i.e. the load-bearing subfloor structure, can also be implemented with a CLT board, but recently the beam subfloor has been a more common solution, especially due to better sound insulation. For example, Puukuokka 1 in Jyväskylä was completed with CLT slab floors, but buildings 2 and 3 were made with beam floors. In volumetric modular system construction, the walls and mezzanines between the apartments consist of two adjacent or overlapping elements, which allows the wooden surface to be left visible inside the dwellings in some cases if sound insulation is implemented between the double structure. The CLT solid wood panel acts as load-bearing and bracing structure in the walls at the same time, but due to the way the volumetric modular system is installed, only one of the adjacent walls can be fixed so that it acts as a bracing wall [27]. Solid wood also performs as a vapor barrier, and in part also as warm and sound insulation.

Volumetric modular system construction imposes quite a few boundary conditions on architectural design. The element has certain maximum dimensions, which depend, among other things, on the manufacturer, transport, and lifting possibilities. The narrow rectangular shape of these elements limits the types of housing that can consist of the elements. On the other hand, the volumetric modular system technology allows for a more cost-effective implementation of recessed balconies than concrete construction, for example. The basic solutions in architectural design that affect the cost-effectiveness of such constructions are the size and shape of the element and their total number and frequency.

2.2 Special features of tall residential construction

In addition to wooden construction in Finland, interest in tall buildings has also increased over the past decade. This is largely related to the urbanization trend and the rapid population growth in the major cities [28]. In a Finnish urban structure, buildings that are already quite low can be considered tall construction. Tall construction definitions can vary by city in Finland, depending on how tall the current building stock is. The definition of tall buildings starting from 16-story in Helsinki is accepted as 12 in Tampere. In many smaller cities of Finland, construction of more than 8-story already stands out as a taller construction than the rest of the building stock. In the view of the authors of this study, a tall wooden building is assumed to be a building of more than 8-story height based on the National Building Code of Finland.

There are a total of about 50 buildings over 50 m in height in Finland [29]. At present, the tallest residential building in Finland is the 35-story and 132 m high Majakka in Helsinki (also known as Lighthouse, Redi Kalasatama 1) [23]. Other Finnish tallest apartment projects include the 26-story and 86 m high Cirrus (2006) in Helsinki, and the 24-story and 78 m high Niittyhuippu (2017) in Espoo. The tallest building project in Finland is the Trigoni Tower 1 with 51-story planned for Pasila, which will be 180 m high. In the 2010s, some rather tall student apartments with reinforced concrete have also been implemented, which were perhaps the best benchmark for the current tall wooden apartment building construction.

3. Research methods

The study was conducted through literature surveys, the case study method, and interviews with the key actors in the projects.

3.1 Case studies

In this section, two wooden residential buildings (over 8-story), Lighthouse Joensuu (**Figure 3**) and HOAS Tuuliniitty (**Figure 4**) were analyzed with exceptionally detailed information in terms of architectural and structural design considerations. Also, general information e.g. number of stories, floor area, frame system, fire consultant about case studies were provided in **Table 1** below.

In Lighthouse Joensuu project, in particular, the start-up of the entire project and wooden construction was strongly the goals set by the city's corporate management, according to which the builder acted, while HOAS Tuuliniitty was the builders' first wooden apartment building projects.

Lighthouse Joensuu and HOAS Tuuliniitty have were designed based on the existing town plan. Moreover, the Tuuliniitty is a special wood construction area,

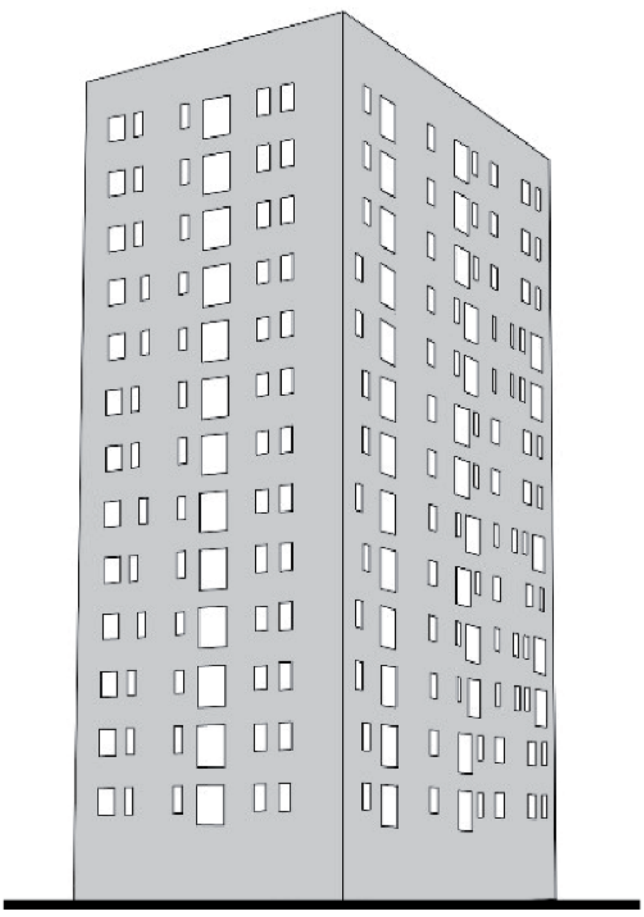

Figure 3.
Lighthouse Joensuu (Joensuu, 2019) (drawn by Emre ILGIN).

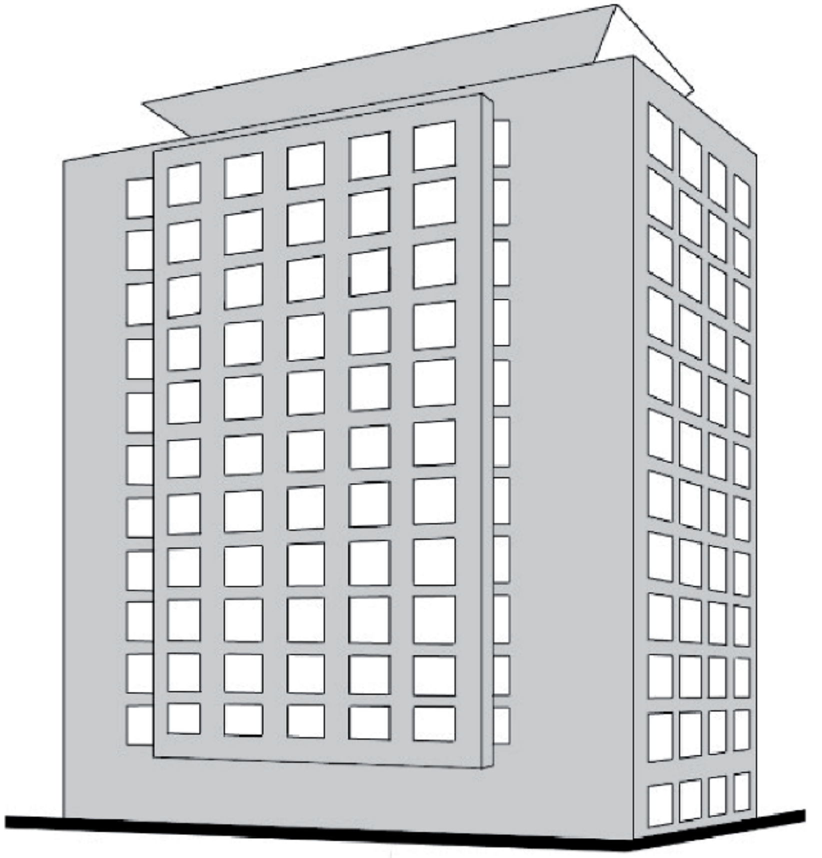

Figure 4.
HOAS Tuuliniitty (Tuuliniitty, under construction) (drawn by Emre ILGIN).

	Lighthouse Joensuu	HOAS Tuuliniitty
# of stories & height	14 & 48 m	13 & 42 m
Completion date	2019	2021
Floor area	4787 m^2	4787 m^2
Gross area	5934 m^2	7584 m^2
Residential area	3764 m^2	4433 m^2
Space efficiency	63%	58%
# of apartment & area (av.)	117 & 32 m^2	165 & 27 m^2
Duration of the project	38-month	
Duration of the construction	20-month	
Frame system	LVL/CLT large elements	CLT volumetric elements
Builder/client	Joensuun Elli opiskelija-asunnot Oy	Helsingin seudun opiskelija-asuntosäätiö HOAS
Architect	Arcadia Oy	Ark.tsto. Jukka Turtiainen (nowadays Arkkitehtipalvelu)
Structural designer	Joensuun Juva (nowadays A-Insinöörit)	A-Insinöörit
Wood supplier	Stora Enso	Elementti-Sampo
Contractor	Eero Reijonen	JVR Rakenne
Fire consultant	Markku Kauriala Oy	KK-Palokonsultti Oy

Table 1.
General information about Lighthouse Joensuu and HOAS Tuuliniitty.

the town plan of which defines wood as the mainframe and façade material for all new buildings.

3.1.1 Architectural design considerations

The architectural plan of the residential floors is largely based on the structural system selected (**Figure 5**). In HOAS Tuuliniity, most of the apartments are studios and all the space elements are located transversely to the building frame, which means that the frame depth of the buildings becomes quite large and almost all the apartments open in only one direction. The building has two staircases, one of which is an exit staircase outside the building envelope. The first floor is made of concrete construction and accommodates storage and common areas. Floors 2–13 are similar residential floors. Floor 13 is an attic floor not included in the building height, which houses the residents' club room and the sauna facility. The staircase and elevator shaft are implemented as separate space elements, which are located against the outer wall along the middle corridor. On the facades of the Tuuliniity, horizontal wood panel cladding is employed.

In Lighthouse Joensuu, the apartments are grouped around the staircase in the middle of the building (**Figure 6**). There are two compartmentalized staircases and an elevator that opens in both directions in the middle of the frame. All residential units are located on the periphery of the building, and the staircase is completely opaque. Most of the apartments are placed parallel to the staircase and the depths of the apartments are very narrow. Especially the studios consist of different models from the student units in Lighthouse Joensuu. Also, all interior surfaces are upholstered, and the wooden surface is invisible. The main reason for this is that the LVL panels used as the frame material are not esthetic surface material like CLT. The facades of the building are covered with fiber cement boards in three different shades of white and gray.

3.1.2 Structural design considerations

Lighthouse Joensuu is implemented with a large-element system, where the load-bearing walls are LVL-structured and floors are CLT-structured. In the foundation system of the building, steel pipe piles are used by anchoring to the rock. The lower

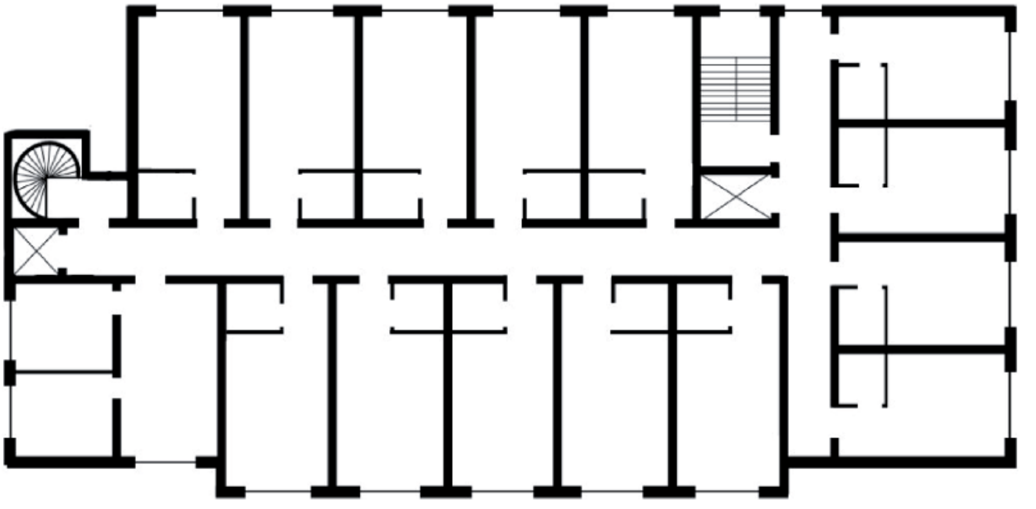

Figure 5.
HOAS Tuuliniity typical floor plan (drawn by Emre ILGIN).

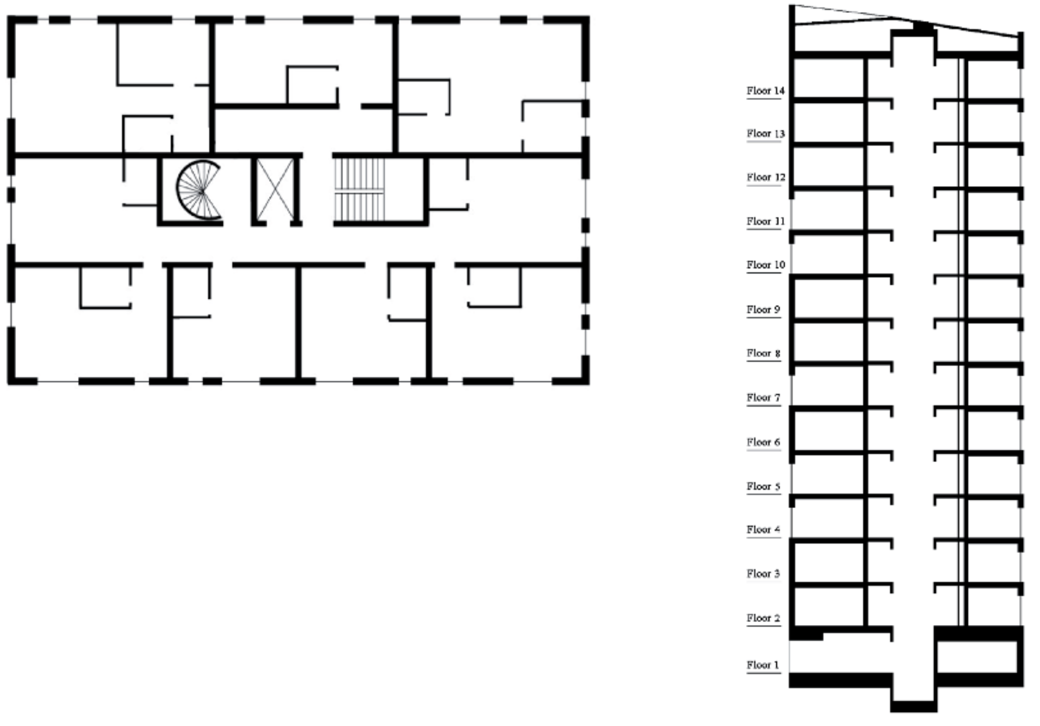

Figure 6.
Lighthouse Joensuu typical floor plan and section (drawn by Emre ILGIN).

floors have a concrete structure with 30 cm thick load-bearing reinforced concrete. Similarly, 20-30 cm thick concrete and 50 mm thick concrete subfloor are utilized on the first floor. A thicker intermediate floor slab increases the mass of the structure, which helps to control the lateral forces on a light wooden apartment building.

The thickness of the load-bearing walls decreases in the upper floors as the load decreases. In the three lowest wood-structured floors, the thickness of the load-bearing LVL board is 162 mm, the next seven floors, and the three top floors, 144 mm and 126 mm, respectively. The fire and sound insulation inside the apartments are made of 50 mm stone wool with double plasterboard on top.

The intermediate base subfloors of the staircases are made of solid wood elements connected by butt or half-point joints. The longer corridor has an LVL structure, and the shorter corridor and staircases have a CLT structure. The stairs are prefabricated elements made of CLT panels with the steps milled into the panel. Under the intermediate floor slab of the staircase, there is an LVL beam supported by the walls, to which the stair element is attached with screw connections.

The wet rooms are built on-site. The implementation of large-element construction did not allow the use of wet room elements, as the sound insulation on the lower surface of the subfloor structure had to be implemented before the construction of wet rooms.

HOAS Tuuliniitty is built from modular CLT elements. The load-bearing walls are constructed of CLT panels and the intermediate floor structure is built with LVL beam structure. Overlapping space elements are connected with dowel pins solder casting from inside the modular element. The partitions between the modular elements are load-bearing and the outer walls are mainly non-structural. Longitudinal bracing is mostly carried out by the walls of the central corridor and transverse bracing by the walls between apartments. The Tuuliniity is located near the sea, which causes the building to belong in terrain class 0. This affects the wind loads significantly compared to, for example, the Joensuu Lighthouse which belongs in terrain class 2.

The walls of the first floor are reinforced concrete elements and a cast 25 cm reinforced concrete slab. Similarly, on wooden floors, the intermediate floors of the staircase are made of reinforced concrete slabs. Reinforced concrete piles and a load-bearing lower base are employed in the foundation system. Wet rooms are implemented as pre-installed elements.

The load-bearing walls between the apartments consist of two 120 mm CLT panels with 30 mm of mineral wool as sound insulation between them. The apartments have stone wool insulation with a double gypsum board. There are sound insulation pads between the CLT frame and the studs of the insulation frame. The walls between the apartments and the staircase an otherwise similar structure, but there is only one CLT panel in the wall.

The ceilings of the apartment modules are 80 mm thick CLT panels that are kept exposed as a visible ceiling surface. The load-bearing floors have a 220 mm LVL-beam structure and a 100 mm layer of mineral wool as sound insulation. Beneath the beam structure, there is a double fire gypsum board and a 30 mm layer of mineral wool. On top of the beams, there is an 18 mm veneer, sound insulation layer, and a cast floor. In a tall building, a flexible frame structure would cause excessive swaying of the building, so instead of separating apartment modules with flexible insulation pads, the sound insulation is implemented as an acoustic inner shell inside the apartments. The intermediate floors of the central corridors are made of 250 mm thick reinforced concrete slabs that are connected to the surrounding CLT walls with steel.

3.2 Interviews

The semi-structured interview study (see Appendix) dealt with the specific issues through a realized case study and the general issues about tall wooden apartment building construction in Finland based on the views of different stakeholders as project partners on the success of the overall process and the roles of different actors in these challenging projects. Also, Lighthouse Joensuu and HOAS Tuuliniity, as well as other important apartments such as PuuMera, Puukuokka, DAS Kelo, were included in the survey. The 21 interviews highlighted the following key findings:

- The builder, structural designer, and architect/chief designer were deemed to have the most significant influence on the outcome of projects, and construction supervision municipal building control was the least important.

- According to interviews at HOAS Tuuliniity, the design process was architecturally oriented although the project was implemented with the same volume modular element supplier’s system. This was partly because the architectural office was responsible for the project’s BIM coordination. Tuuliniity did not happen either.

- Overall, it was estimated that the most important factor affecting the general result of the projects was the cost of wood construction. The projects tried to compensate for the construction cost, for example by simplifying the floor plan and the shape of the building. In volumetric modular system construction, in particular, costs are largely determined by the reproducibility of the total number of modules, so the cost savings have a significant impact on the overall architecture of the building.

- Architects estimated that wood construction, compared to the more conventional concrete building, has had the most significant impact on the shape and main dimensions of the building mass, as well as on the amount and schedule of design work. In particular, the design accuracy of wood construction and the frontloading of design work were emphasized. The architects interviewed also underlined the understanding of the structural system used and the boundary conditions it set right at the beginning of the design.

- The influence of wood construction on the facade and surface materials has been assessed by the architects more broadly concerning what type of building is considered a wooden apartment building. Non-architects' view, too, was quite often expressed that a wooden facade is not automatically related to wooden construction, but wood is seen mainly as a frame material. The use of wood as a visible surface material was also generally considered more essential indoors than in the facade of a building.

- No major problems were identified in the implementation of wooden apartment buildings with up to 8-story and they were believed to become more common as experience and cost competitiveness improve. However, according to interviews, it seems unlikely that tall wooden apartment buildings will proliferate much further unless the tall wooden building is strongly supported by public authorities.

- The builders of HOAS Tuuliniity and Lighthouse Joensuu stated that the solutions for tall timber construction in the projects were well suited for the construction of student housing. One of the major problems in the development of tall wooden structures was that the projects were one-off and the development of experience and building concepts through repetition has not materialized.

- Overall, the interviewees stated that there is little need for tall buildings in Finland, regardless of whether the buildings are made of wood or any other material. However, the construction of the first Finnish tall wooden apartments was considered an important factor in the credibility of wooden construction.

- While the focus of construction was found to be on buildings up to 8-story, the construction of taller buildings was seen as a tool to improve technical solutions and develop design expertise. The interviews also highlighted opportunities for Finnish wooden apartment buildings and relevant knowledge in foreign markets, so it might make sense to develop new tall wooden apartments even if there is no real demand for them in Finland.

4. Conclusions

The actual competitiveness factors of wood construction, such as the speed of construction or the possibilities of wood architecture, have not been very significant reasons for wood construction, but the projects have been chosen to be wood-based, mainly due to other objectives such as ecology or sustainable image of wood construction.

The implementation process for wooden apartment buildings is currently considerably different between buildings with a maximum of 8-story and taller.

8-story wooden apartment buildings are comparable to the low-rise wooden construction and similar structural solutions can be employed for low-rise construction.

The architectural design of a tall wooden building requires close interaction between the architect and the structural designer, where the structural designer also plays a major role in the architectural design in practice. With industrial prefabrication, the design process for tall wooden blocks of flats apartment buildings is more forward-looking frontloaded than conventional construction, which requires an open flow of information from all related parties and the ability to make solutions decisions early in the project. Additionally, the special technical design should not be done based on ready-made architectural plans, but solutions should be developed from the beginning in cooperation with all design fields.

Especially for projects up to 8-story high, it seems that different networks of developers, contractors, and wood suppliers are evolving, that develop their building concept and are widely responsible for the entire implementation chain of the building project.

Appendix: sample questions used in interviews

1. What would you give to the completed project and the implementation process?

   Finished building (1–5).

   construction/project management (1–5).

   construction (1–5).

   architectural/main design (1–5).

   permitting process and official activities (1–5).

   building components manufacturing process (1–5).

   Do you want to justify your answer or make suggestions for improvement?

2. How much influence do you think the following parties had on the outcome of the project?

   builder (1–5).

   principal designer/architect (1–5).

   structural designer (1–5).

   contractor (1–5).

   wood supplier (1–5).

   city planner (1–5).

   construction supervisor (1–5).

   Do you want to justify your answer or make suggestions for improvement?

3. How much impact do you think the following parties had on the cost of the project?

   builder (1–5).

   principal designer/architect (1–5).

   structural designer (1–5).

   contractor (1–5).

   wood supplier (1–5).

city planner (1–5).

construction supervisor (1–5).

Do you want to justify your answer or make suggestions for improvement?

4. How much influence do you think the following parties had on the project schedule?

builder (1–5).

principal designer/architect (1–5).

structural designer (1–5).

contractor (1–5).

wood supplier (1–5).

city planner (1–5).

construction supervisor (1–5).

Do you want to justify your answer or make suggestions for improvement?

(1) very low (2) quite low (3) neutral (4) quite significant (5) very significant.

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