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Wood as a Housing material – Finnish Experiences of the Durability of Wooden Houses

Jari Heikkilä

Department of Architecture
University of Oulu, Finland e-mail: jari.heikkila@oulu.fi

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Abstract
Finland is a world leader in timber construction. Wooden houses in Finland have traditionally been single-family detached houses. Since the 1990s, Finland has made significant investments in timber construction and has tried to increase the use of wood also in apartment house construction. Finnish experiences of wooden houses have not only been positive. Serious moisture damage has been discovered in 82% of single-family houses built after the 1950s. The worst damage has been leaking of gently sloping roofs, floor damage caused by building too close to the ground, damage of wet areas and damage caused by pipe leaks. The large amount of damage demonstrates that wooden structures are susceptible to damage. However, the damage has resulted more from experiments and errors in ways of building than from the use of wood as a main building material. Before timber structures can become common in apartment house construction, it will be necessary to eliminate the damage and learn to build sound and lasting timber structures. When wood is structurally properly protected, it is a long-lasting and reliable material that creates beauty, warmth and cosiness in its surroundings.

1 Introduction

Finland is a world leader in timber construction. This is a due to the wealth of Finland's wood resources. Finland is the most forested country in Europe. Seventy-six per cent of its land area is covered by forest. Until recently the growth of Finnish forests has exceeded removal, and the annual utilisation of wood could clearly be increased. Increasing the use of wood creates new jobs and boosts Finland's exports and improves the economy. That is why since the 1990s Finland's state authorities have made significant investments in the development and research of timber construction. The purpose of these efforts has been to increase the use of wood in construction.

Wood is an excellent natural building material with deep traditions. The long history of timber construction demonstrates that wood can be used to build durable and lasting houses. However, wood also has its weak qualities. Therefore some people have expressed doubts about increasing timber

construction. The most serious misgivings concern the combustibility and long-term durability of wooden structures. In addition to fire, another significant risk of timber construction is moisture. Over 80% of the damage of all wooden houses is caused by moisture. As a result of the effect of long-term moisture, wooden structures become mouldy, rot and spoil. There are plenty of examples of this in the history of timber construction.

In order for timber construction to succeed and increase, it must be possible to build long-lasting and durable structures from wood. When using wood as a building material, we must know the physical and biological qualities of wood and the behaviour of wooden structures under various conditions. In construction, special attention must always be directed at protecting wood from moisture. Wood begins to be damaged when its moisture is 25-30% for an extended period of time. In this case the relative humidity of the surrounding is usually over 80%. Seventy-five per cent relative humidity of air can be considered the critical value for the moulding of wood. When the relative humidity of air exceeds 95%, wood begins to rot. Furthermore, in order for wood to become mouldy and to rot, the temperature must be between 0 and 55 °C. [1]. Mould spores and rot fungus require oxygen and nutrients to operate, and there are usually plenty of these in wood as well as the surrounding air.

It is evident from wooden houses and structures which have lasted hundreds of years that wood does last a long time if it is structurally protected. In order for wood to last a long time, its moisture level must be continuously kept under 20%. Wood is a demanding building material that requires careful planning, construction and maintenance.

2 Finland’s wooden building stock

Wood has always been a natural building material in Finland. Wood has been used in a varied manner in old buildings because no other building materials have been available, or they have been too expensive. Until the beginning of the 1900s, wood was almost the exclusive building material in Finland, used in residential buildings as well as outbuildings, in load-bearing as well as supplementary building elements.

Until to the mid-1800s, Finnish towns, too, were wooden towns. As a result of the large town fires of the 1800s, stone houses began to be favoured in the construction of towns. Gradually stone houses grew into multi-storey buildings and became larger than wooden houses. The way of building was controlled with fire safety regulations which allowed the use of wood only in low single- and two-storey houses. As a result, the use of wooden structures in Finland during the entire 1900s has been limited almost entirely to single-family detached houses.

New Finnish wooden houses are mainly one- or two-storey single-family houses. No comprehensive study of the condition and damage of wooden houses has ever been carried out in Finland. Instead a large amount of empirical information of single-family homes has been accumulated, and the most common types of damage and their causes can be determined from this information.

Before drawing conclusions about the durability of wooden houses and wooden structures based on these examples of damage, we must remember that wooden houses have been quite different in different periods. Knowledge of this background is required in order to be able to discuss this damage. One must know the ways of building commonly employed in different eras. Experiments have also been carried out in the history of wooden construction; feedback has been received and ways of building changed. This chain of efforts and errors must also be known. Next is a description of the typical way of building in Finland for various periods.

2.1 Log house tradition (-1940)

The traditional Finnish wooden house has been a log house in which the horizontal log has simultaneously been the bearing structure and the thermal insulation of the walls, and often the interior and external cladding as well. A significant step forward occurred when, in the 1700s, attention began to be directed towards the durability and thermal quality of houses. Ever since then, log houses have contained ventilated, timber-framed floors which were initially insulated with natural materials such as moss, and later with sawdust. The roof had a similar structure. We must remember that these houses did not originally have any wet areas or water pipes. The sauna and the washing room have, in traditional construction, always been located in separate outbuildings. Log houses have been wood-heated. Furnaces that generated powerful ventilation when heated were built into their rooms. Log houses, too, were built to be airtight. Therefore builders began to cover the walls with paperboard and wallpaper on the inside, and boarding on the outside. The log houses that remain today have proven to be lasting, provided that their roof has been kept in good condition. Damage has occurred in floor structures if there has been a lack of ventilation, if surface water has reached under the house, or if the ground has been exceptionally wet. This way of building prevailed in Finland until the early decades of the 1900s.

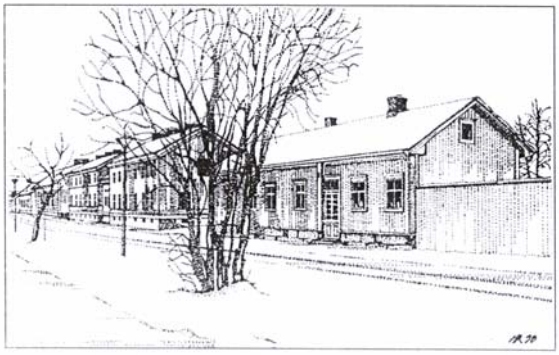

Figure 1: Log houses of wooden towns are one- or two-storey. Their roofs are steep and they have a high base.

2.2 Period of reconstruction (1940s and 1950s)

In the early 1900s, Finland was introduced to the American-style lightweight timber frame construction, which quickly displaced the log structure due to its affordability, speed in construction and superior insulating qualities. The insulation used in timber frame structures was sawdust and the airtightness was ensured by paperboard. The heyday of this structure was the period of reconstruction following the Second World War. The timber-framed veteran's homes of the 1940s and 1950s are one-

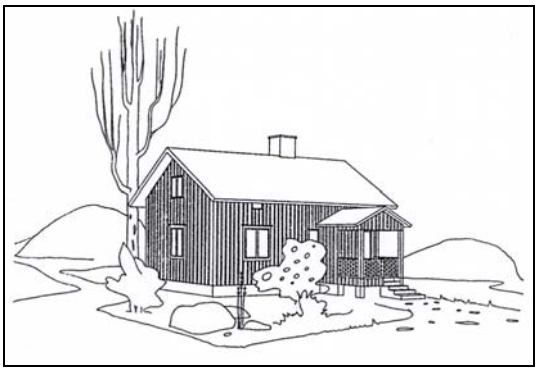

Figure 2: A house from the reconstruction period is one-and-a-half storey and its roof is steep. The house always has a cellar.

and-a-half storeys and have cellars. The houses are shaped like a cube and have steep roofs. Thanks to the cellar, the wooden floor structure is ventilated and clearly above ground level. The sauna and washing facilities were located in the stone-structured cellars. The wooden structures of these houses, too, are in good condition provided the roof had been maintained. However, an abundance of moisture problems have occurred in the cellars of these houses due to the poor waterproofness of the cellar walls.

2.3 Period of modernism (1960s and 1970s)

The way of building wooden houses underwent radical changes by the 1960s. When it was discovered that it was possible to build on a shallow foundation without danger of damage by frost, builders quit building cellars and began to make dwellings, including service spaces, in one storey. Architectural ideals also changed and houses began to be made low, accentuating the horizontal direction. Floors were built as concrete slabs on ground and were constructed as close to the ground as possible. As a result, the bottoms of timber-framed exterior walls were below ground, which has proven to be one of the worst mistakes in timber construction. This way of building has not been entirely eliminated even though its faultiness was proven 25 years ago. Designers of that period also wanted roofs to be as flat as possible. In the beginning of the 1970s new wooden houses became entirely flat-roofed, and eaves, which protected facades, were eliminated at the same time. In a short space of time, flat roofs proved to be a fateful mistake in Finland's harsh weather conditions.

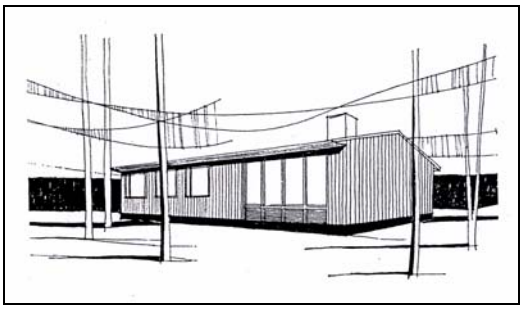

Figure 3: Wooden houses from the 1960 were built into one storey. The houses were made low and the roof gently sloped.

As cellars were not built in these houses, sauna and washing spaces were placed inside. This resulted in a significant increase in the moisture strain of dwellings and the placement of pipes inside of structures. This increase in the use of water occurred without developing the structural solutions of wet areas or boosting the ventilation of houses. Another fateful mistake was embedding water pipes into structures. Hidden pipes could leak for a long time before damage was noticed.

The moisture physics operational principle of wood structures changed in the 1960s when industrial mineral wool products replaced earlier wood-based insulation. With the use of mineral wool, which is a good thermal insulator and binds moisture poorly, a plastic foil was needed to ensure the airtightness and moistureproofness of the structure. The more impermeable wall solutions and poor ventilation led to problems with the indoor air quality of single-family homes.

The wooden houses of the 1960s and 1970s have proven to be very problematic. Some of the solutions used at that time were abandoned quickly. Most of the houses from that period have received new roofs and flat roofs have not been built on single-family homes thereafter. The flush mounting of water pipes was also discontinued and, ever since then, pipes have been installed inside casing pipes. As a

result of the problems with indoor air quality, later houses have usually been equipped with mechanical ventilation.

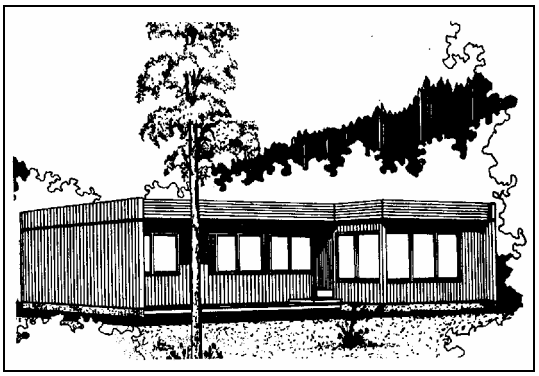

Figure 4: Wooden houses from the 1970s were made entirely flat-roofed.

2.4 A step backwards (1980-)

In the timber construction of the 1980s there was a return to tradition and a desire to avoid the problems that resulted from the structural experiments of the previous decades. Ever since the 1980s Finnish single-family homes have once again had sloped ridge roofs. New homes typically have efficient thermal insulation in the building envelope and are more airtight. The majority of homes are equipped with mechanical ventilation. Water pipes are mounted into casing pipes so that leaks can be detected and pipes can be replaced without damage to structures. Walls with stone material are often used in wet areas. Thus some of the problems typical of wooden houses of previous decades have been successfully avoided. One problem in even new houses is building too closely to the ground, which has continuously resulted in moisture damage in floors and the bottom edges of exterior walls.

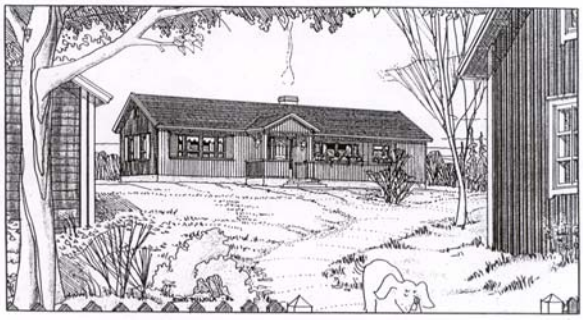

Figure 5: Lessons were learned from tradition in the construction of wooden houses in the 1980s. Once again houses have steep roofs.

2.5 Present situation

Wooden structures have retained their dominating position in the construction of single-family homes in Finland in the 21st century. Eighty-eight per cent of new Finnish houses were wooden houses in 2003 [2].

In the 1990s Finland's fire safety regulations were renewed to be in line with pan-European principles. The new fire safety regulations state that wood can also be used to build residential buildings of 3 - 4 storeys as well. The construction of wooden apartment buildings has been tested in Finland, but so far wooden apartment buildings have not achieved a breakthrough in housing construction.

3 Condition and typical moisture damage of Finnish wooden houses

The condition of Finnish wooden houses can be assessed on the basis of sample studies conducted. The amount of moisture damage in Finnish single-family homes is alarmingly great. A field study conducted in 1995 revealed that 82% of detached houses built after 1950 have serious moisture damage. An indication of the seriousness of the moisture damage is the fact that nearly 500,000 houses, or 55% of Finnish single-family homes, are in need of prompt repair. [3].

The study shows that there is moisture damage in wooden houses of all ages. However, moisture damage was clearly most prevalent in houses from the 1960s and 1970s, in which new types of materials and architectural solutions were used. Based on the studies, it appears as though something has been learned from the mistakes because the amount of moisture damage in houses built after the early 1980s has slightly decreased. [3]. Based on the study we can conclude that the danger of moisture damage in wooden buildings is always great.

When examining the moisture damage of wooden houses of different ages, it becomes evident that the damage is strongly linked to each way of building. The greatest moisture technical problem of houses from the 1950s is leaking of the stone-structured cellar walls. Other moisture damage is connected to the ageing of roofing and piping. The actual wooden structures are in good condition in these houses. The reason for this is the location of wooden structures high above ground level, steep roofs and protective eaves as well as the lack of proper wet areas inside the wooden frame. Houses from the 1960s contain an abundance of damage and it is located in all building elements. The majority of the damage is in the timber-framed roof structures due to leaks in the gently sloped roofs. Floor structures also contain plenty of damage. Other places with a lot of moisture damage include the floors and walls of wet areas, which have not been made waterproof. The worst moisture damage of houses from the 1970s is roof damage, and they result from leaks in the flat roofs. Another significant cluster of damage is the wall and floor damage of wet areas. Floor damage has also been caused by exterior surface water. As late as the 1970s it was still customary to embed pipes into floor structures, and piping damage continues to constitute a significant problem group. Moisture damage in roofs no longer occurs in wooden houses from the 1980s because adequately sloped roofs have been made on these houses. But damage to walls and floors are still common in wet areas. Also, floor damage caused by exterior surface water still occurs. [3].

When examining damage with respect to various building elements, it becomes evident that the types of damage in single-family homes built after the 1960s are related to the following four factors:

1) leaking of gently sloped roofs
2) damage to floor caused by building too closely to the ground
3) wet areas
4) pipe leaks.

More than 70% of flat roofs are damaged. Forty-two per cent of all houses have damage to wet areas. Of all damage to floor structures, 50% is caused by exterior surface water. Piping damage appears to correlate directly with the age of the pipes. [3]. In 1995 water leaks were discovered in 17,000 Finnish homes. [4].

The most significant reason behind moisture damage has been determined to be mistakes in work, material and design. Half (40-60%) of moisture damage is caused already in the construction phase. The ageing and deficient maintenance of building elements have also caused damage. Outright misuse also occurs.

The large amount of moisture damage suggests that wooden structures are especially problematic. In this respect, however, one must think critically. Moisture damage is linked more to ways of building and structural solutions than the use of wood as the main building material. The cellar walls of the houses from the 1950s are stone-structured and their problems with waterproofness are not related to wood. The roof leaks in the houses from the 1960s and 1970s are a result of overly flat inclination and waterproofing material that is of poor quality. Experience shows that damage has similarly occurred in the flat roofs of stone buildings. Neither can timber structures be considered the sole cause of moisture damage in wet areas. Moisture damage has also appeared in stone-structured wet areas that lack waterproofing. Pipe leaks result in the ageing of materials and pipes also leak in stone houses. Damage to floor structures is caused by exterior surface water and because of building too closely to the ground. The damaged floors have been concrete structures. Damage has also naturally occurred in the wooden structures that are in contact with the concrete. We can conclude from what has been stated above that the contribution of actual wooden material to the worst damage has been minor. This is also confirmed by the fact that during the equivalent period of time, serious moisture damage has been discovered in 60% of stone apartment buildings built in Finland [5].

4 Ways to avoid moisture damage

Over the past decade there has been continual and widespread public discourse in Finland about the quality of construction. The background behind these discussions is the large amount of moisture and mould damage as well as the resulting problems with indoor air quality. In addition to wooden single-family homes, apartment buildings and public and commercial buildings have suffered from serious moisture damage. On the other hand it must be noted that Finland is not alone with the problems of quality because in international assessments the quality of Finnish construction is considered fairly good. It has been stated in the discussions on quality that moisture damage can be avoided only through significant investments in building physical research and development. With research and development work it will be possible to create structural solutions that are more reliable and safe. This especially applies to timber construction, which is important to Finland's economy.

We have not yet got away from the moisture damage of wooden buildings even though information of sound solutions has been available for a long time. In spite of the attention drawn to the quality of construction, the same old mistakes are repeated in the construction of single-family homes. Sixty to eighty per cent of the risk of moisture damage in new wooden buildings is concentrated in floor structures and wet areas. For the most part, damage to roofs and pipes has been successfully held in check. Indeed, floor structures, the joint between the floor, foundation and exterior wall, and wet areas are the most difficult details of the moisture technical design of a wooden house. By working on the careful design, construction and maintenance of these structures, we can ensure durable and safe timber construction. [6].

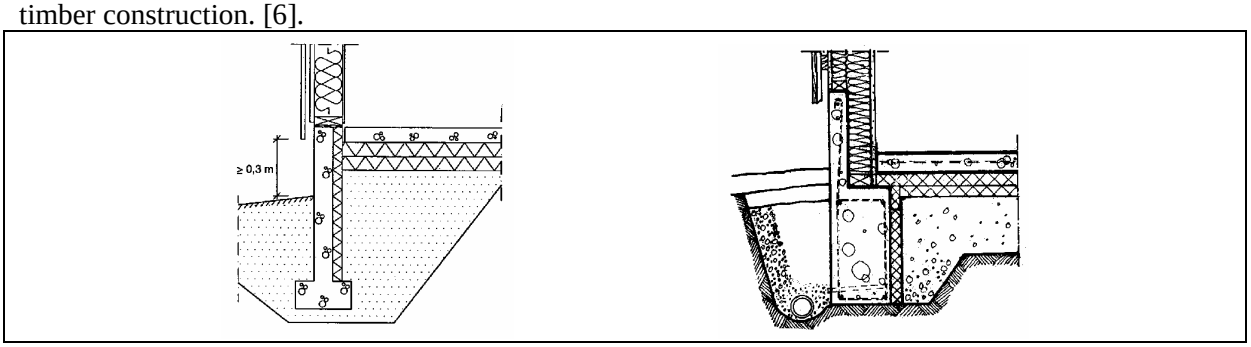

Figure 6: Left. A safe joint of the floor and the exterior wall.Right. A dangerous solution from the 1970s. The floor and the ground are on the same level.

The basic requirement of floor structures is to raise the floor area high enough above the surrounding ground. The moisture strain of the base floor and foundation can be reduced by inclining the ground surface sufficiently away from the building and making functioning subsurface drainage around the building. Wet areas should be built of stone structures where possible, even in wooden houses. Many of the problems of wet areas result from lightweight board structures and their warping caused by moisture. The floors as well as the walls of wet areas should be reliably waterproofed. Efficient ventilation must be arranged. With these fairly simple solutions it is possible to avoid the majority of the moisture problems of timber-framed detached houses. In addition, when buildings are made with a sufficiently inclined roof, and equipped with eaves that protect the façade, and have their water pipes mounted into pipe casing, a sound and risk-free way of building with wood has quite nearly been achieved.

As structural mistakes are successfully reduced, wood, the traditional Finnish building material, will be freed of the groundless misgivings directed at it. When its structures are properly protected, wood is a long-lasting and reliable material that creates beauty, warmth and cosiness in our housing environment.

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