The Modern Wooden Town Building Project – the standpoint of fire safety

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Abstract

In Finland the use of wood is increasing in multi-story apartment building construction and, along with the government's new housing policy guidelines, also in the construction of closely-spaced, low town-like single-family houses and small apartment buildings. Extensive use of wood façades in multi-story apartment buildings and closely-spaced wood milieus means issues related to fire safety need to be solved. Wood façades and roofs must not contribute to the spread of fire from one building to another or from one apartment to another. Wood houses over two stories high in Finland always require sprinklers and fire alarms. When a building is equipped with sprinklers, the fire-related requirements of the façades can be less strict, because it is not probable that the flames of an apartment fire will spread out of the window. In Finland eight metres is usually considered to be a sufficient fire safety gap between buildings. If the distance is shorter, fire safety can be increased, for example, by fitting façades and eaves with fire stops; by treating the wood façades with fireproof chemicals; by using fire barriers between the buildings and by planting leaf trees between the buildings.

1 Background: the status of timber construction in Finland

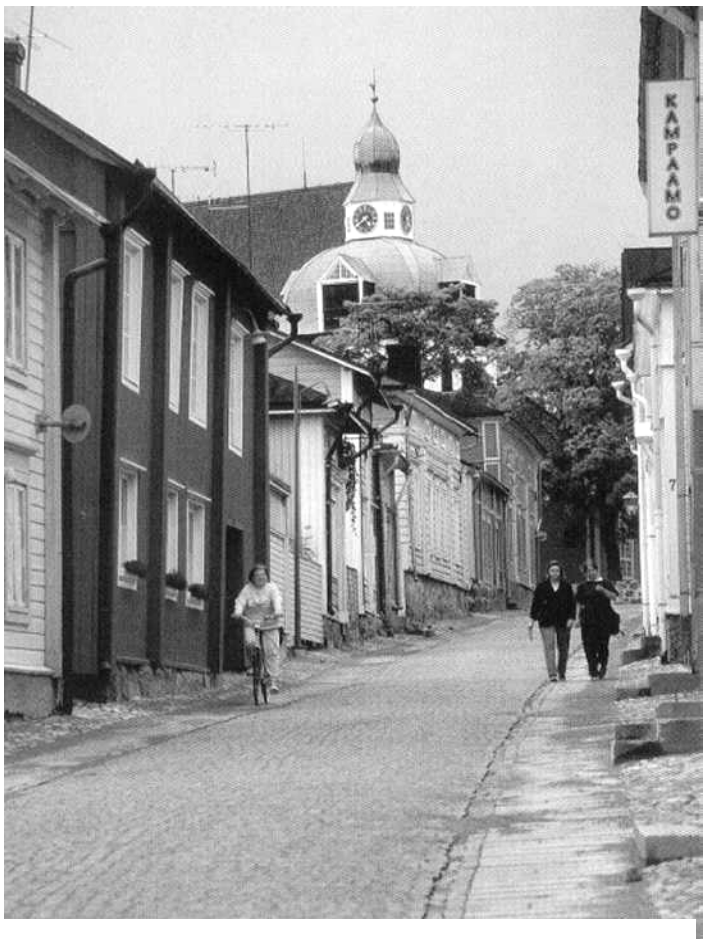

Figure 1: Old Finnish wooden town, Porvoo.

The history of construction and architecture in Finland has been composed of timber construction for a long time. All of Finland's towns have originally been wooden towns. About 40 wooden towns or parts of towns have been preserved in Finland. Today their milieus and scale are greatly valued.

Prior to today's new revival of timber construction (which began in the late 1990s), Finland experienced a strong wave of timber construction in the 1940s, in the post-war reconstruction period that lasted to the end of the 1950s. The 1960s and 1970s formed a period of strong urbanisation and construction of concrete multi-story apartment buildings in Finland. At the same time building codes were developed from the standpoint of fire safety to favour construction from stone. Today Finland has one of the highest concentrations of multi-story apartment buildings in western Europe: 44 % of Finns live in a multi-

story apartment building. About half of new housing production consists of multi-story apartment buildings. On the other hand, 98 % of leisure-time buildings and 90 % of all single-family homes are still made out of wood.

Figure 3: Typical Finnish concrete apartment building suburb in the 1970s.

Figure 2: Typical Finnish single-family home in the 1990s (architect Pekka Heikkinen).

A demand to permit the use of wood as the frame and façade material of 3 – 4-story buildings arose in the beginning of the 1990s. This pressure came from Finland's joining the EU and the compilation of uniform functional fire codes for the EU area. This has been a current issue in many Central European countries and in all the Scandinavian countries in recent years. Finland's wood product industry's goals of expanding the use of wood to multi-story apartment building and large-scale public sector construction have been particularly influential. Thus, there has been a demand for equal treatment of different construction materials in the fire code that is based on functional fire safety requirements.

Finland's fire code was finally revised on September 1, 1997, so that now it is permissible to construct 3 – 4-story residential and commercial buildings with timber frames and wood façades. By 2003 there were 12 sites with timber apartment buildings over two stories high in eight different localities in Finland, with a total of 27 buildings and 369 apartments. Questions regarding fire safety have been at the forefront in Finland's multi-story timber apartment building construction.

Based on extensive surveys of residents, there is more and more interest in timber construction in Finland. Residents also want wood to be used more in multi-story apartment building construction. Nevertheless, the most desired form of living is in a closely-spaced, low, single-family home-type residential milieu, which traditionally has consisted mainly of timber construction.

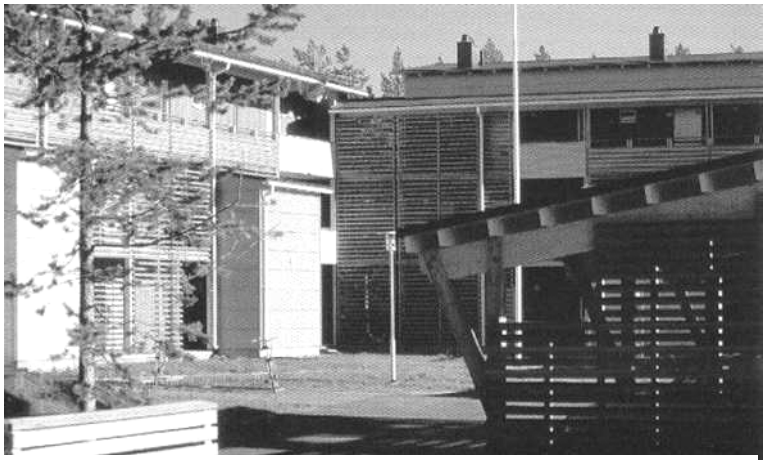

Figure 4: One of Finland's first multi-story timber apartment buildings, Asunto Oy Puukotka, was constructed under the supervision of the Wood Studio of the University of Oulu's Department of Architecture. The experimental site was completed in February 1997.

2 Nation-wide Modern Wooden Town project

2.1 Objectives of the project

Based on an initiative of the Wood Studio of the University of Oulu's Department of Architecture, a nation-wide *Modern Wooden Town* project was started in 1997 and will last until 2006. The main objective of the project is to employ timber construction in creating pleasant, exemplary new residential milieus in different areas of Finland. The Modern Wooden Town project has also responded to the recent goals of Finland's government housing policy, in which production of closely-spaced town-like areas of small apartment buildings and single-family houses and development of timber construction are the main concern. Design and implementation have employed closely-spaced, efficient timber construction to achieve cost-effectiveness and sustainable development. Furthermore, in the name of pleasant living, the main themes of the most recent wood milieu projects have been the use of wood in yard and environmental construction and in interior decorating. Thus, there has been an intentional shift in Finnish timber construction from technical designs and individual buildings to broader questions concerning milieus.

The Modern Wooden Town project has studied a new practice for guiding planning and construction as well as questions related to milieu creation in a wooden town environment, town block structure and scale, parking solutions, building types and living comfort. The project has also studied and tested the aesthetics, details, language of form, layout possibilities, long-term durability and particularly the fire safety of wood façades as a part of the wood milieu.

Figure 5: The nation-wide Modern Wooden Town project's first implementation was in Oulu. Altogether 45 2 – 3-story timber apartment buildings with a total floor area of 25,000 m^2 were constructed in the Puu-Linnanmaa construction area in 1998 – 2002. The area has 308 apartments and around 450 residents. The residential area was awarded Finland's 2003 Wood Award.

The Modern Wooden Town project currently includes over 30 timber construction area projects in different parts of Finland. The overall yield of the areas ranges from neighbourhoods of wooden single-family homes in rural municipalities to efficient town-like milieus consisting of multi-story timber apartment buildings. Completed wood milieu sites have received mostly positive feedback from residents, visitors and the media. General pressure to develop housing production and planning practice have been primary factors behind the creation of these new wood milieu sites.

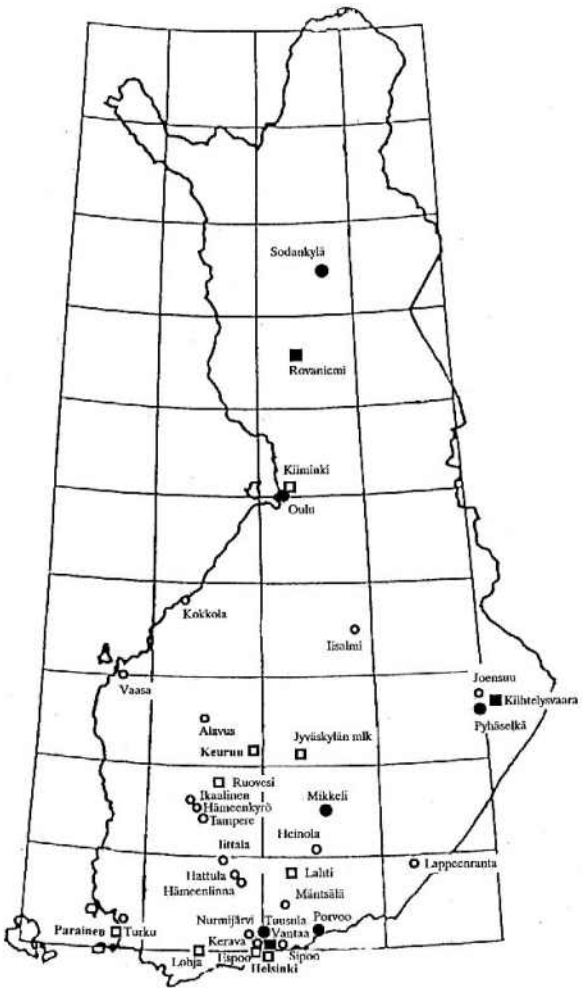

Figure 6: Modern Wooden Town partial projects in Finland.

2.2 Co-operative partners

The primary supporters of the Modern Wooden Town project have been the National Technology Agency of Finland (TEKES), the Ministry of the Environment and WoodFocus Oy, and since 1999 also the Ministry of Agriculture and Forestry and the Ministry of the Interior through basic funding of the nation-wide Wood Products Centre of Expertise network. The Wood Studio of the University of Oulu's Department of Architecture has acted as the nation-wide co-ordinator of the Modern Wooden Town project. The wood studios and urban planning laboratories of the Universities of Technology in Helsinki (TKK) and Tampere (TTY) have also been important participants in the Modern Wooden Town development project.

3 Fire safety of wood milieus

3.1 Background: fires and fire-related deaths in Finland

Every year there are about 10,000 fires in Finland. On average, 65 % of these are building fires. About half, or over 3,000 of these building fires occur in residential buildings. Around 100 people a year die in fires in Finland, with about 75 % of these deaths taking place in residential buildings. Over 75 % of fatal fires are caused by men and 71 % of those who died were intoxicated when the fire ignited. In every other case the fire was ignited by a lit cigarette.

In two-thirds of the cases the furniture inside the building, usually in the bedroom, caught fire. The most common reason for death is smoke poisoning. From the standpoint of the amount of damage cased by a fire, the critical response time of the fire department is considered to be eight minutes. In Finland the risk of dying in a fire is among the highest of the industrial countries. According to statistics, a fire risk profile in Finland is a man over 45 years old who is divorced, lives alone, is an alcoholic and smokes cigarettes. Studies have shown that the victim's behaviour contributes more to the occurrence of death in a fire than does the structural design of the site.

3.2 The nightmare of old wooden town fires

Town fires have been very common in Finnish history. It has been calculated that old Finnish wooden towns have been destroyed by fire every 30 or 40 years. After numerous town fires the streets of Finnish wooden towns were widened, it became mandatory to plant leaf trees along the streets, and construction of two-story wooden buildings was often prohibited. Because of the fires, most of Finland's wooden towns date back to only the 1800s, when by various means the town fires were made to end. In spite of this, nationally there are apparent signs that the Finns still have not got over their "nightmare of old wooden town fires".

Figure 7: The Oulu fire in 1822. Artist's interpretation.

An examination of Finnish wooden town fires indicates that roof material, in particular, has had a significant impact on the fire safety of wooden neighbourhoods. Beam, peat, shingle and board roofs were common in towns in the 1800s, whereupon town fires were able to spread in windy weather from roof to roof during the dry season (May - September), when the roofs were dry and not protected by a fire-retarding layer of snow. The risk of a fire was also increased by the fact that the buildings were usually heated with wood, whereupon firewood was stored on the lot. Also, fire protection equipment and organisations were quite lacking.

Figure 8: The newspaper KALEVA, 20.7.1998. ”Fire department’s plight. An extinguishing demonstration by Oulainen’s volunteer fire department using equipment from the 1920s entertained the public as the old pump caught fire in the middle of the demonstration. However, the fire department took the situation under control and finally put out the original fire.”

3.3 Fire safety requirements of Finnish multi-story timber apartment buildings

In accordance with Finland’s new fire code (September 1, 1997), the fire safety requirements of apartment buildings with a timber frame and wood façade are at a very high level:

- maximum height 4 stories, 14 metres
- 3 – 4-story timber buildings must be equipped with automatic extinguishing systems
- (= a sprinkler system in each apartment)
- each apartment must be equipped with fire alarms connected to the electrical power network
- insulation must be at least class A2-s1, d0
- at least class B-s1, d0 products must be used as the facing of interior walls and ceilings (except in the sauna).

So far, multi-story timber apartment buildings constructed in Finland have primarily had wood façades. In no way do Finns want to use materials that imitate wood in timber construction. When a building is equipped with sprinklers, the fire-related requirements of the façades can be less strict, because it is not probable that the flames of an apartment fire will spread out of the window. Instead, the most probable cause of a façade fire is a fire that ignites or is ignited on the outside of the building. In that case the focus of study is primarily on retarding the façade fire and keeping it under control and preventing it from spreading.

According to an extensive survey, residents also wished more wood would be used in the interior facings and cabinets of the apartments. Residents have a positive attitude toward sprinkler systems and fire alarms. As many as 87 % of the residents felt that due to the safety equipment, they live more safely in a timber multi-story apartment building than in a concrete building without a sprinkler system. Sprinkler systems eliminate the danger of a typical apartment fire and contain the spread of a fire from one apartment to another.

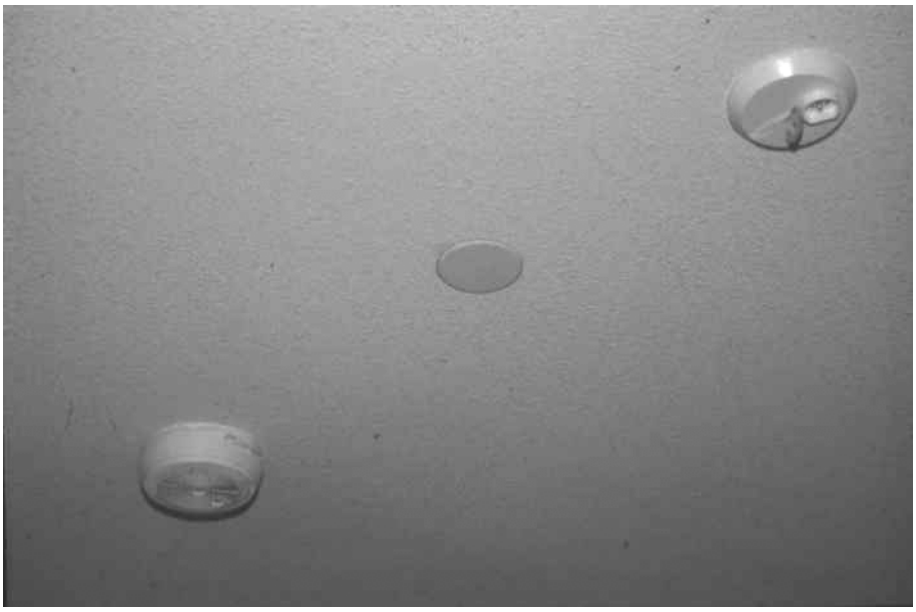

Figure 9: Finnish multi-story timber apartment buildings must be equipped with a light-duty sprinkler system and smoke detectors. The first fire occurred in a Finnish multi-story timber apartment building in Oulu in September 2003. A lit cigarette fell on a sofa, setting it and the apartment on fire. The sprinkler extinguished the fire already before the fire department arrived. The automatic extinguishing system saved the life of a woman sleeping in the apartment.

Many different solutions for preventing the spread of a wooden façade fire have been studied and tested in Finland during the last ten years. One tested solution involves fitting wooden façades with 200 mm wide fire stop projections at each floor. They are able to contain a minor façade fire for around 20 minutes. For aesthetic reasons such solutions have not, however, been very desirable. For this reason fire stops that are hidden inside the wall have been developed to ensure fire safety. Fire tests conducted in Finland have indicated that the spread of a façade fire can be limited effectively by partitioning the ventilation gap behind the facing in the horizontal direction and using horizontal ”chokes” in the ventilation gap that prevent a fire from spreading in the ventilation gap but do not hinder ventilation of the space behind the facing. The chokes may consist of perforated steel profiles or horizontal boarding that chokes the ventilation gap to 10 mm, for example, every 600 - 1200 mm. Most important is to prevent a chimney effect in a ventilation gap fire.

Figure 10: Testing fire stop projections at the Kuopio Rescue College in the summer **of 1998.**

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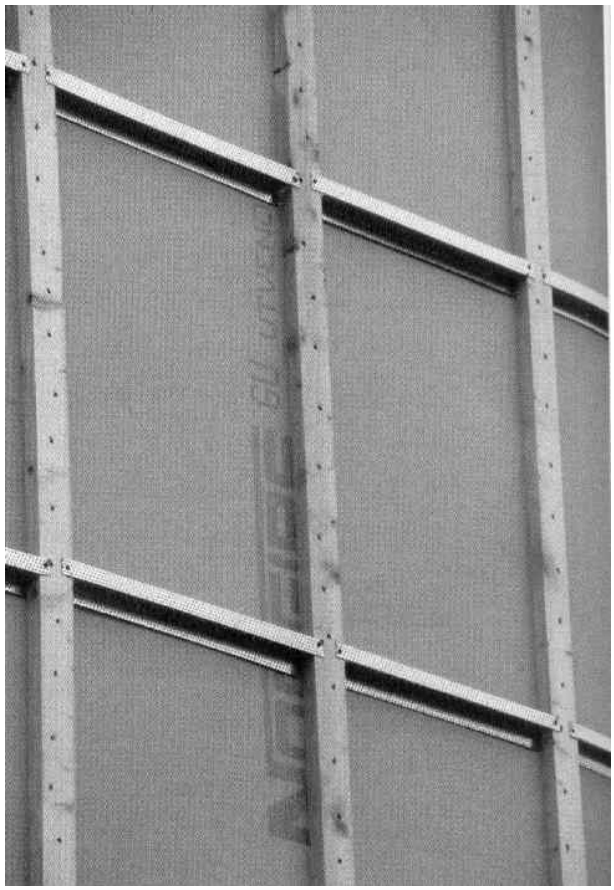


Figures 11 and 12. Horizontal perforated steel profile fire stops located in the ventilation gap retarded a façade fire very effectively in fire tests performed at the Kuopio Rescue College. The test wall in Figure 11 has burned for 1 hour and 40 minutes. This fire stop design has already been used in multi-story timber apartment buildings in Finland and Sweden.

On high façades and in closely-spaced wooden house milieus, special attention also has to be paid to the fire safety of eaves and attics. It is essential to prevent a fire from spreading into the attic. For this reason the ventilation gap of wood-faced façades must be separated from the attic space and each space should be ventilated separately. This can be achieved, for example, by arranging the layout of the building mass or by making the eaves airtight and ventilating the attic by means of ventilation pipes located on the roof.

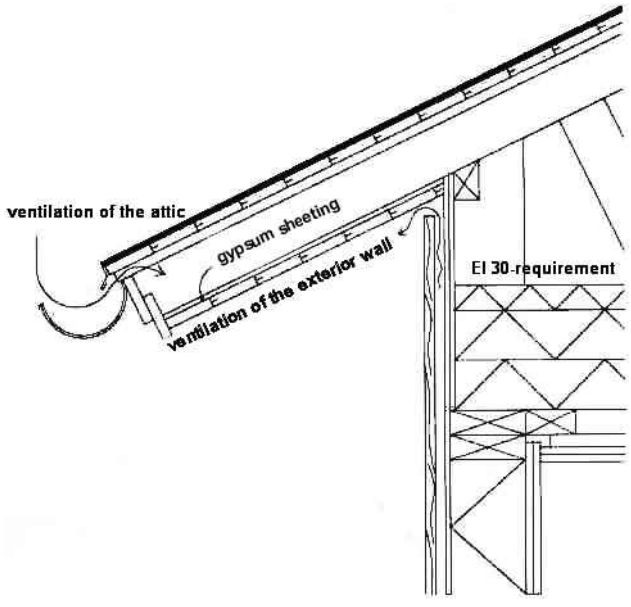


Figure 13: A tested fire-resistant eave structure. Ventilation of the exterior wall happens below the closed eave and ventilation of the attic takes place at the edge of the eave. Boarding alone is usually not sufficient on the bottom surface of the eave. The fire safety of the bottom surface of the eave and the exterior wall butting against the attic is improved by adding gypsum sheeting.

3.4 New applications for wood treated with fireproof material

The Finnish fire code adopted a new euro classification of construction materials on July 1, 2002. Because the classification of materials is more detailed, this may increase the possibilities of using wood products in construction. Products treated with fireproof materials will have particular utility value because they will permit freer, more extensive use wood as a facing material inside apartments, in stairways and on façades. Large-scale fire tests have indicated that even a single application of fireproofing significantly prevents a rise in the temperature of the wood, the spread of fire and spontaneous ignition in a fire. Based on the fire tests, treatment of wood with fireproofing material has been presented for the timber structures of attics and timber-framed intermediate floor cavities. With the help of fireproof chemicals, wood products can even be approved for class B-s1, d0. The important issue from the standpoint of fire safety is the long-term durability of fire resistance achieved with chemicals. This in particular has raised strong doubts among Finnish fire and construction supervision authorities.

3.5 Fire safety in a closely spaced wooden building milieu

In a closely-spaced residential area special attention must be paid to the area's fire safety. Regulations governing structural fire safety should be taken into consideration already during the planning phase. For example, in closely-spaced construction, changes in building, lot and possessory limits affect fire safety aspects even though the buildings themselves remain unchanged. Finland's fire code places limits on floor area, the number of stories, building height, the distance between buildings, façade material, usage, the number of inhabitants, window size and the fire-related properties of structures and surfaces.

In planning new Modern Wooden Town wood milieus the issue of area fire safety is continuously brought out. In designing multi-story timber apartment buildings and wood milieus it has become apparent that closely-spaced (< 8 m) buildings with wood façades would require more uniform and detailed practical nation-wide rules of the game.

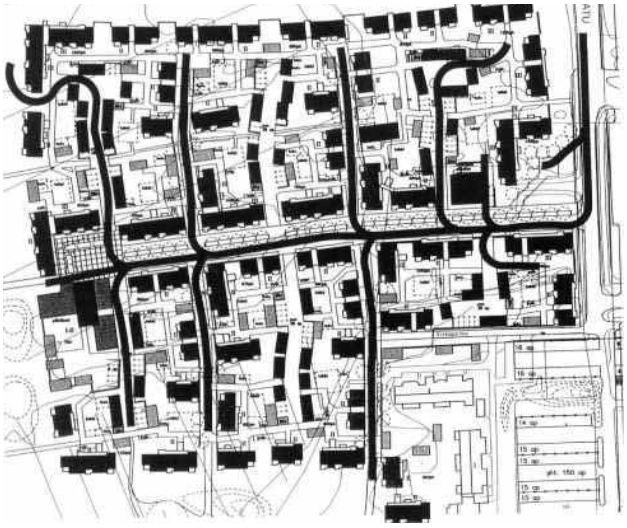
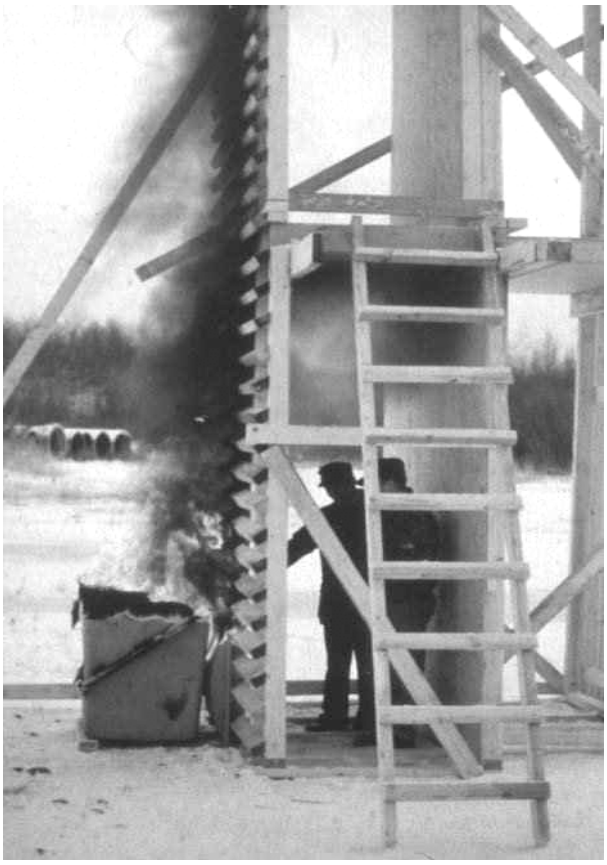


Figure 14. Rescue routes in Oulu's Puu-Linnanmaa area. The area's streets and alleys are much narrower than ordinary Finnish residential streets. The distance between buildings along the main street is 16 metres. The distance between residential buildings along the alleys is 8 metres. Rescue routes for all fire, rescue and emergency vehicles have been carefully planned in the Puu-Linnanmaa area together with fire and rescue authorities. The planning of rescue routes took into consideration the manoeuvring room required by today's Finnish fire fighting equipment. The area is planned so that for example, a ladder vehicle is able to access the balcony façades of all residential buildings over two stories high.The minimum width of routes used by fire vehicles is 3.5 metres and the minimum height is 4.0 metres. The turning radius of fire vehicles is 12 metres. A ladder vehicle weighs about 32 tons and an extinguishing vehicle weighs about 22 tons, for which reason special attention has been given to the load-bearing capacity of the rescue routes. The reach of the ladder vehicle is 24 metres when the top of the ladder is 15 metres high. Thus, the rescue route around a 3 – 4-story building can be situated about 20 – 25 metres from the building if the ladder vehicle is able to manoeuvre freely without being obstructed by trees, power lines, etc. If there are small areas not reachable by a ladder vehicle, special arrangements must be made to ensure emergency exits from such buildings. For example, balconies must be

equipped with folding or permanent ladders. The hose length of extinguishing vehicles is not a limiting factor, so the ***routes do not*** necessarily need to go around the buildings. However, smoke dispersing equipment and other heavy equipment are often needed in a fire fighting situation, for which reason fire vehicles must be able to get sufficiently close to all the façades of a building.

As far as fire-related aspects are concerned, buildings located on the same lot or construction site can be considered as one building, in which case normal fire partitioning is sufficient if the buildings belong to the same fire class and the resulting entity does not exceed the maximum floor area and number of inhabitants specified for one building in said class. Furthermore, in the plan of a uniform town block the fire barrier between separate residential buildings less than eight metres apart can be replaced with exterior wall partitioning. If the exterior wall is used as a partitioning wall, its asymmetrical structure and heat radiation and the effect of windows is be taken into consideration.

In Finland there are no limits on the floor area and number of residents in 3 – 4-story timber apartment buildings equipped with sprinkling systems. However, in more extensive areas of wood houses it is recommendable to primarily comply with the eight-metre minimum distance between residential buildings. If the buildings are constructed less than eight metres apart, attention must be paid to the operation of the fire department, and placement of windows, ventilation hatches, etc., on exterior walls, which may contribute to the spread of fire from one fire partition to another, should be avoided.



In planning yard layouts, attention should be given to the possible danger of vandalism. Because they are common sources of intentional or accidental ignition, waste containers and carports should not be located in the immediate vicinity of the walls of residential buildings. If an outbuilding or waste container shelter is located next to a residential building, structural methods should be used to prevent the spread of fire to the interior or structures. Fire hydrants can be situated along the streets to ensure access to sufficient extinguishing water.

Figure 15: Wood façade lattice fire test in Oulu in 1998. The fire was ignited using a 400 litre fibreglass waste container.

If the distance between wooden buildings is less than eight metres, fire safety can be improved by means of the following arrangements, for example:

- by adding an automatic extinguishing or fire alarm system into the apartments
- by fitting façades and eaves with fire stops
- by using fire barriers between buildings
- by treating wood façades with fireproof chemicals
- by equipping openings in exterior walls with fire doors and windows
- by situating fire hydrants along the streets
- by planting leaf trees between buildings.From the standpoint of an area's fire safety, it is also important that the roof structure of the buildings will not ignite easily in case there is a fire in the neighbouring building. In this sense, recommended roof materials are brick and sheet metal, for example.

3.6 Functional fire design and risk analysis as a developmental challenge

Numerical simulations of fires and other methods of calculation which can be used to estimate the fire safety of buildings have been developed considerably during the 1990s. Regulations have been renewed in many industrial countries, so that indicating the fire safety of buildings on the basis of product classification, which previously was the only available possibility, is now just one possibility among other methods. However, the rules of the game that govern application have been lacking, at least in Finland.

Functional planning of fire safety aims at limiting the risk caused by a fire. For this reason risk analysis is always a part of fire safety planning. The concept of "risk" is commonly understood as an indicator of the magnitude of a detrimental, damaging incident. The approvability of a plan is only based on the expected safety risk. In practice, evaluation of absolute risks is very difficult. Several computer applications have been developed for analysing the fire risks of buildings and the chain of events in a fire incident. However, the systems of different countries differ from each other, and a uniform international practice has not emerged yet.

As an example we can mention the difficulty of defining and verifying an acceptable risk: "The basis of design in the euro codes is that the maximum probability that the collapse of a single load-bearing structure will cause a serious accident within the life span of a building is 7.25×10^{-5}. Accidents that occur in conjunction with a fire are included within the scope of this probability, and a separate value for a risk that only takes fires into consideration is not given." Evaluation of safety risks is difficult for local authorities and to a great extent a matter of conscience. In practice, the demandingness of functional fire design means that it is always difficult to do away with old regulations and their logic when developing and compiling new regulations.

Drawing final conclusions concerning the fire-related designs and fire safety risks of wooden buildings is difficult because in a real fire people's behaviour in an accident and many other factors affect the ignition, development and spread of the fire. The behaviour of fire in a building can be simulated using various experimental situations. Modelling the spread of fire using available test methods is a complex task. No matter where or how fire tests are conducted, they can be criticised for not taking into sufficient consideration all the variables affecting a fire situation. As examples of variables that affect façade fires of wooden buildings we can mention the size of the initial fire, air temperature, humidity, raininess, wind direction, wind speed, the density, moisture and age of the wood façade's facing material, the thickness and surface treatment of the façade facing, the size of the ventilation gap, the windproofing material, the wall insulation material, etc.

Nevertheless, it is not possible to study all the correlations affecting the fire situation. In the end, not many of the above-mentioned variables can be influenced in an expedient way by means of regulations compiled by the authorities.

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