Universum Science Center in Gothenburg received the Swedish Wood Prize Award 2004.

FIRE SAFETY of timber buildings

The two main stages in building fires are the initial and the fully developed fire. Both are important for the fire safety in buildings and are used in most national building codes, but focus on different properties. National limitations for using timber in buildings in relation to these criteria are reviewed.

New possibilities to calculate the separating and load bearing performance of timber-frame structures are available. Proper detailing, wooden facade claddings, possibilities for active fire protection by residential sprinklers and new methods for risk assessment are also reviewed. All these aspects are included in a Nordic design guide.

1. European Harmonisation

In many countries the building regulations are being altered towards performance criteria. In Europe this development was speeded up by the Construction

Fire Safety

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Products Directive (CPD) adopted in 1988. The CPD gives six essential requirements, one of which is the Safety in the Case of Fire. The performance-based requirements are especially pronounced for the fire regulations that traditionally have been prescriptive. The CPD definition of the essential requirement on fire is: "The construction works must be designed and built in such way that in the event of a fire outbreak:

- the load-bearing capacity of the construction can be assumed for a specific period of time;
- the generation and spread of fire and smoke within the construction works are limited;
- the spread of fire to neighbouring construction works is limited;
- occupants can leave the construction works or be rescued by other means;
- the safety of rescue teams is taken into consideration."

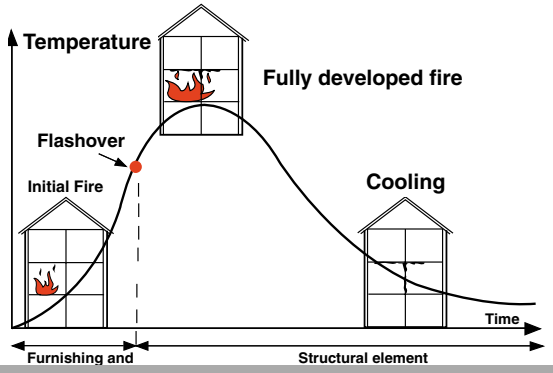
For fire safety in buildings, European standards deal mainly with harmonised methods for verification. These standards exist on the *technical level*, but fire safety is on the *political level* governed by national legislation. National authorities are still responsible for maintaining present national safety levels.

2. Two Stages in Building Fires

There are two different stages of a fire scenario to be considered in the fire safety design of buildings in relation to building materials and structures. These are the initial and the fully developed fire, see Figure 1 (page 58). In the initial fire, the building content e.g. furniture is of major importance both for the initiation of the fire and its development, but this is not regulated in building codes. Surface linings may also play a role in the initial fire, especially in escape routes. Limitations of their reaction to fire are required in most building codes. In

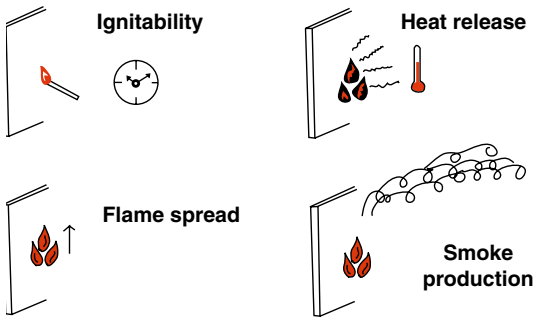
Five storey office building in timber construction in Skellefteå in northern Sweden. Wooden facades have been possible through the installation of fire rated windows

Figure 1



There are two main stages that are relevant for the fire safety in buildings in relation to building materials and structures. One is the initial fire in which the properties of surface linings may be important. The other is the fully developed fire in which the load bearing and separating structures are essential to limit the fire to the room or fire compartment of origin

Figure 2



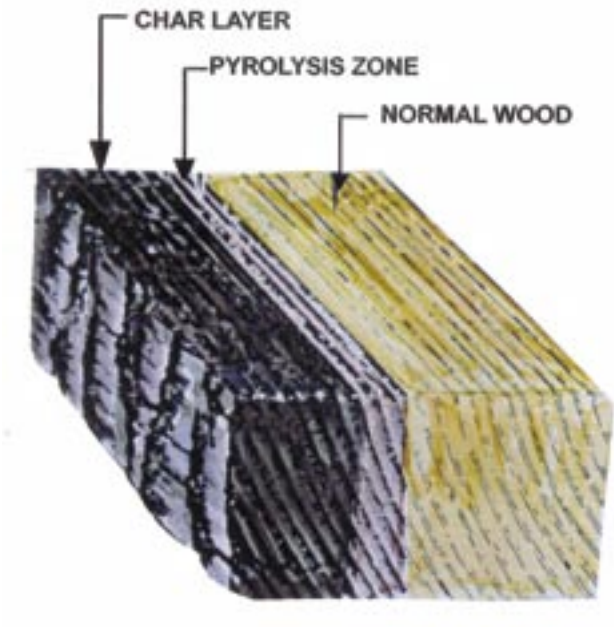
Reaction to fire properties of surface products such as wall and ceiling linings.

the fully developed fire, the performance of load bearing and separating structures is important in order to limit the fire to the room or fire compartment of origin. This is called the fire resistance of the building structure.

Generally speaking, wood structures can obtain high performance for fire resistance, while the properties of wood or wood-based linings in the initial fire may be less favourable and also more difficult to quantify.

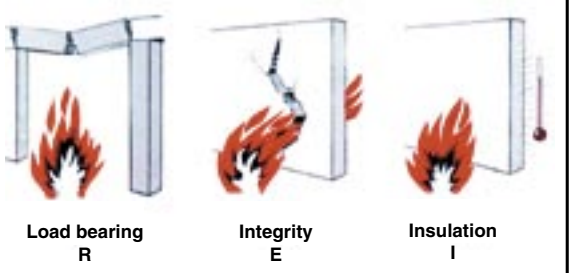
2.1 Reaction to Fire - Material Properties

Reaction to fire means the response from materials to an initial fire attack and includes properties like time to ignition, flame spread, heat release and smoke production, see Figure 2. These properties are relevant in the early fire development, which is the stage when wood products may contribute to fires. The use of combustible linings as wood panels in buildings is restricted in order to limit the rate of fire growth, but the contribution from



Wood products may burn and char from the surface, but normal wood remains below the pyrolysis zone for a long time. Good fire resistance may thus be obtained also for load-bearing structures.

Figure 3



Performance criteria for fire resistance. They are used together with a time value, e.g. REI 60 for an element that maintains its load bearing and separating functions in 60 minutes.

linings is often overemphasised in relation to the building content. However, some limitations are needed e.g. in escape routes. A new system with European classes has recently been adopted in the EU and will gradually replace the old national classification systems which have formed obstacles to trade. The new classes are of two types, one for all products excl. floorings, i.e. mainly wall and ceiling linings and one for floorings. Wood products fulfil usually main classes D and D_{fl} /7/.

2.2 Fire Resistance - Structural Fire Performance

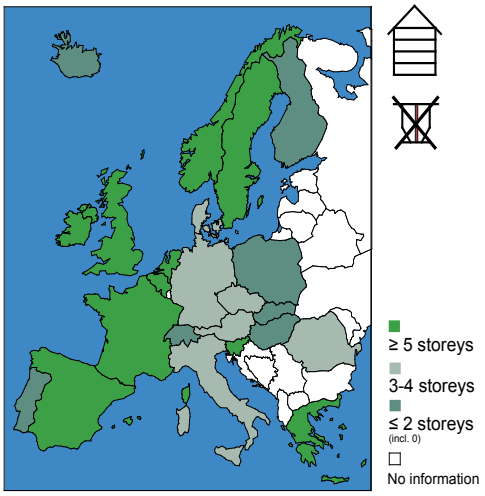
Fire resistance means that structural elements, e.g. wall elements, shall withstand a fully developed fire and fulfil requirements of insulation, integrity and/or load bearing capacity, see Figure 3. The fire exposure is usually according to the so-called standard time-temperature curve according to the international standard ISO 834 and referred to in almost all national building codes. New equivalent European standards have recently been adopted. They are more detailed and divided into different applications e.g. walls, floors etc.

Building elements have to withstand the standard fire exposure for a specified period of time, e.g. 60 minutes. Wood structures can obtain high fire resistance, e g REI 60, REI 90 or even higher.

3. National Limitations

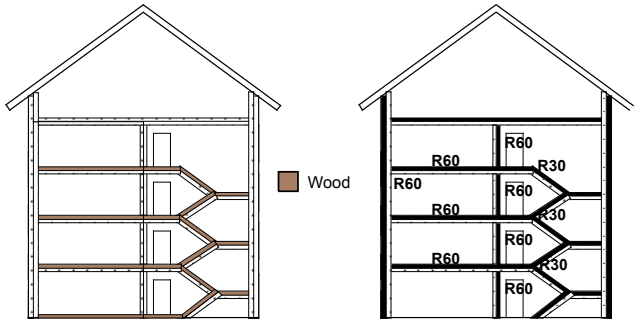
Even if the European harmonisation will reduce the obstacles to trade and facilitate a wider use of wood and timber products in buildings, there are still limitations since the national building codes are not harmonised due to the need to maintain present safety levels.

Figure 4



Number of storeys in timber-frame structure in residential buildings without sprinklers allowed in different European countries /5/.

Figure 5



Example (from Sweden) on the possibilities to use wood in unsprinkled 4-storey buildings. To the left: Visible wood surfaces on interior wall and ceiling linings and floorings. To the right: Load bearing timber structures /5/.

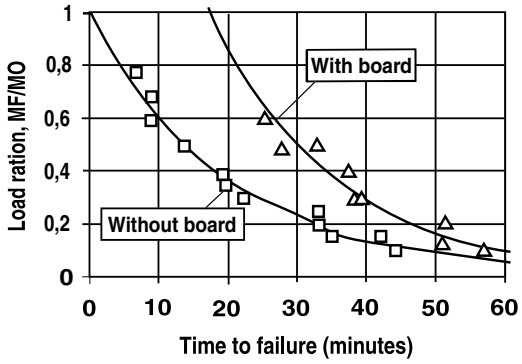
The present situation in Europe for multi-storey timber frame residential buildings has recently been reviewed /5/. Examples are given in Figures 4 and 5. A few non-European countries with a tradition in timber building have also been included. Several countries do not have any upper limit for the number of storeys in timber-frame, but timber frame is still not a real option e.g. in southern Europe.

The building codes have been changed in some countries during recent years, i.e. in Denmark, Finland, Ireland, Italy, Norway and Switzerland. Further changes are underway to allow for a wider use of wood in buildings.

4. New Design Possibilities

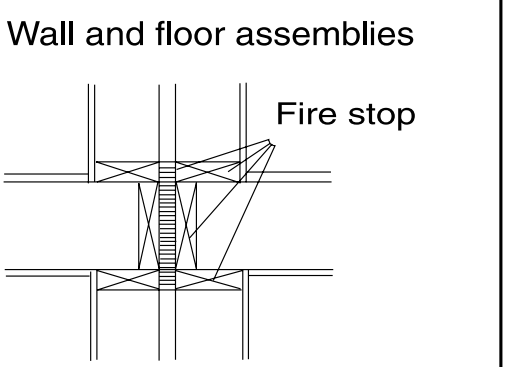
There are several new possibilities for a more advanced fire design of timber frame buildings. Models for load bearing and non-load bearing

Figure 6



The fire resistance is highly dependent on the applied load. Wood stud with and without protection from a board lining /3/.

Figure 7



Fire stops inside timber frame structures, e g at boundaries between different fire compartments, are essential for the fire performance. These fire stops can be made of wood, plywood or high density rockwool /8/.

structures are available. There are also possibilities for extended use of active fire protection e.g. residential sprinklers and for application of risk assessment methods.

4.1 Load Bearing Structures

The load-bearing capacity of a timber structure exposed to fire is often decisive for its fire resistance. The lower the applied load, the longer fire resistance is obtained. An example is given in Figure 6.

A model for the fire design of load-bearing light timber frame structures has recently been presented /3, 8/. It is based on the protection from boards, reduced cross sections in timber studs and reduced strength.

4.2 Separating Unloaded Walls

A component additive has been developed as a simple and practical method for calculating the fire resistance of non-loadbearing separating timber stud wall assemblies (partitions). The total fire resistance of a wall assembly is calculated as the sum of the contribution to the fire resistance from each layer of material. The method also takes into account where the layer of material is located in relation to the fire exposure.

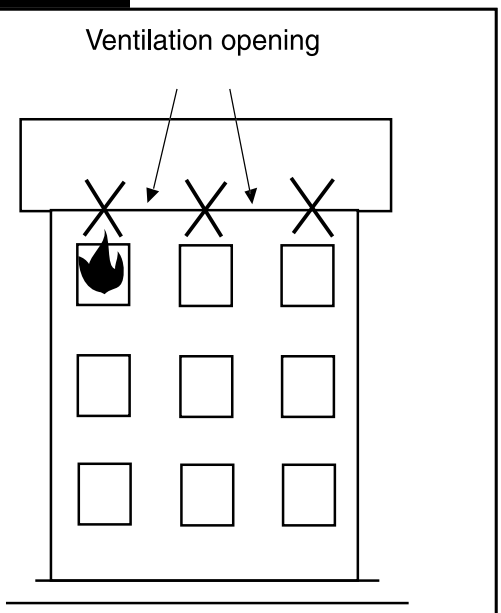
A modified version of the component additive method is included in Eurocode 5/8/.

4.3 Detailing

Proper detailing is essential in order not to jeopardise the passive fire protection achieved for the fire resistance of structural elements. Special attention should be paid to:

- fire stops
- roof ventilation
- fire separation in attics
- Most important is probably the use of fire stops to avoid creeping fires inside the structures. Such fires have occurred in many older timber frame buildings, but must be avoided especially in multi-storey buildings where the consequences of a fire getting out of control would be more disastrous. An example is given in Figure 7.

Figure 8



Ventilation at eaves should be avoided in order to stop the fire spread to the attic and the roof structure /8/

Secondly, in order to prevent the spread of the fire out of the windows to the attic, ventilation openings at the eaves of the roof should be avoided, see Figure 8. If roof ventilation is considered to be necessary, ventilation should be located in areas remote from direct flaming from windows or other technical design should be applied.

The third important detailing in the design of timber frame buildings is to use fire separating walls in attics. Fires in attics of timber frame buildings might be more severe than in concrete buildings. Therefore, as a simple mean to reduce the risk, it is recommended to divide the attic into sections, correspondingly to the fire compartmentation of the storey below.

4.4 Wooden facades

There are limitations in using wood as exterior facade cladding mainly due to the risk of upward flame spread. Partial wood up to about 50 % may fulfil the requirements, but the exact amount depends on the geometrical configuration of the wood in relation to the windows.

FRT (Fire retardant treated) wood products usually have higher reaction to fire classification and may be used both as interior linings and exterior claddings.

However, the durability at exterior and humid conditions may vary and have to be demonstrated for each single treatment. A new system with service classes for the durability of FRT wood products is being introduced /6/.

Wooden facades can also be used in sprinkled houses in many countries e.g. Finland and Sweden. This is logical since the risk for flames out of a window from a fully developed fire is eliminated.

4.5 Active Fire Protection – Sprinklers

Sprinklers are the most common means of active fire protection. They are frequently used in Northern America also in residential buildings independent of construction material. One of their main characteristics is to save lives.

Requirements on passive fire protection can be at least partly disregarded since fires will be extinguished in an early stage. This will promote the further use of wood products. However, the experience with residential sprinklers is still limited in Europe. Further development is going on mainly in UK and Sweden /4/.

Risk assessments - Alternative to code criteria

More cost-effective systems for fire safety design for timber frame buildings can be achieved by applying modern methods for risk assessments to achieve required levels of fire safety. Such approaches are underway in Australia and Canada. A new index method has recently been presented in the Nordic countries /2/. It is based on so called Delphi technique. For practical use, in total 17 parameters are evaluated, including active and passive fire protection and maintenance of a building.

The index method has been applied and used for several timber frame apartment buildings in four Nordic countries. It can be used directly for all multi-storey apartment buildings. To derive a fire risk index takes roughly one days work and demands that the user is an engineer or has some background in fire safety.

4.6 Nordic Design Guide

A Nordic project called Fire Safe Wooden Buildings with participation from all Nordic countries has recently been finalised. The aim was to promote the use of wood especially in multi-storey timber frame buildings and to provide fire safe design solutions. A Nordic design guide has been published /9/.

5. Conclusions

National responsibility for fire safety levels still limits the use of timber frame buildings. Technical solutions are available in some countries and there is a need for exchange of experience. There is also a need for further development and application of new technologies for fire safety engineering and performance based design. Some European wide activities have recently started10.

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