



## Fire safety concept for tall timber buildings

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### Summary

Based on the current knowledge in the field of fire design of timber structures this paper presents a generic fire safety concept for tall timber buildings. First, the paper gives an overview of fire safety concepts and presents experimental results on the fire performance of timber structures under natural fire conditions relevant for tall timber buildings. Then, the main differences between medium-rise and tall buildings with regard to the fire safety are discussed and the formulation of a generic fire safety concept for tall timber buildings is presented.

**Keywords:** tall timber buildings, fire behaviour of timber, full scale fire tests, sprinkler system, fire safety concept, fire regulations, fire performance based-design.

### 1. Introduction

Combustible building materials like timber burn on their surface, release energy, and thus contribute to fire propagation and the development of smoke in case of fire. The combustibility of wood is one of the main reasons that led most building codes to include strong limitations to the use of timber as a building material, in particular with regard to the number of storeys of timber buildings. For example, until 2005, new timber structures in Switzerland were mostly limited to low-rise buildings with not more than two storeys. The main precondition for the use of wood for tall timber buildings is adequate fire safety. Fire safety is an important contribution to feeling safe and comfortable and an important criterion for the choice of material for residential buildings. Currently better knowledge in the field of fire design of timber structures combined with technical measures, especially sprinkler and smoke detection systems, and nearby well equipped fire brigades allow safe use of timber in a wider field of application. As a result of the research projects, the Swiss fire regulations now allow the use of timber structures in multi-storey medium-rise residential buildings up to six storeys. Many other countries have also liberalized the use of timber for buildings or introduced fire regulations that permit the use of timber on the basis of performance. Even with the progresses of fire safety engineering as a new discipline integrating all aspects of fire safety (structural, technical, organizational) and its combination into the design of buildings, it is however unrealistic to suppose that fire authorities will permit the unlimited use of timber for tall buildings worldwide in the near future. Based on the current knowledge in the field of fire design of timber structures, the paper presents a generic fire safety concept for “future” tall timber buildings. As no modern buildings are constructed entirely using a single structural material, the term timber building concerns mixed constructions in which different materials are used, however with most of the volume and mass of the structure (wall and floors) constructed using timber or composite products.

### 2. Fire safety concept for tall timber buildings

The knowledge of the basic behaviour of fire, occupants and buildings during a fire is an important precondition for the development of a successful fire safety strategy. Fire safety has to be regarded as a basic requirement for buildings equal in importance to the load-bearing behaviour of the structure under normal conditions. The most efficient way to control the effects of fire is to establish a comprehensive fire safety strategy with adequate combination of measures to fulfill the fire safety objectives. Depending on the type of structure various combinations of technical and organizational measures are needed besides the traditional structural fire safety measures.

The basic safety objective for the standard requirements for medium-rise residential buildings is that the occupants can leave the building or can be evacuated by the fire brigades in case of fire. The limited height of the building plays an important role for fire brigade action. The regulations recognize that the fire safety objectives adopted for medium-rise residential buildings can be achieved with the given requirements despite the combustibility of the structural material used. Because of the height of tall buildings, the occupants located on the upper part of the building need more time to leave the building in case of fire. It takes also longer time for the fire brigade to reach and fight the fire. It may occur that some escape routes are blocked and the evacuation of the occupants by the alternative routes or by rescue teams is not possible. For these reasons, the fire safety concept adopted for tall buildings is based on the scenario that a number of occupants located in the upper part of the building cannot leave the building. Further it is assumed that the fire cannot be extinguished and continues until all combustible material in the fire compartment has burned. Based on this scenario tall buildings shall comply with fire requirements that are more rigorous than for medium-rise buildings. The requirements on building elements can be formulated as following:

- Separating building elements shall be designed in a way to sustain a full burn-out, thus preventing an uncontrolled fire spread to other parts of the building during the whole duration of the fire.
- Load-bearing building elements shall be designed in a way to prevent the structural collapse for a full burn-out without any intervention of the fire brigade.

Table 1 summarizes the main differences between medium-rise and tall buildings with regard to evacuation of people, fire spread and structural behaviour. It can be concluded that tall buildings should be designed in a way that the occupants can survive a full burn-out of the fire compartment while remaining in another part of the building. Based on this scenario and assuming that timber will not necessarily self extinguish, most building codes do not permit the use of combustible materials in tall buildings neither for the structure nor for the room linings.

*Table 1: Main differences in acceptable behaviour between medium-rise buildings and tall buildings in case of fire*

Type of building	Evacuation of people during fire	Fire spread to other parts of building	Building collapse
Medium-rise buildings	feasible	accepted after defined period of time	accepted after defined period of time
Tall buildings	aggravated, stay in safe place until burn-out	not accepted	not accepted

Is it still possible to design a tall building using timber as structural material?

A possibility to fulfill the requirements on building elements previously explained is to protect structural timber elements from ignition for the whole time of fire duration by non-combustible material. This means that in the room of fire origin a complete burn-out may occur (i.e. all combustible content has completely burned), however the structural and separating timber elements shall not start charring. This can be achieved by protecting the timber structure with a sufficient number of non-combustible claddings for example made of gypsum plasterboards. As the timber structure is enclosed by non-combustible claddings the term “building encapsulation” can be used in order to describe this requirement. Another possibility to fulfill the requirements on building elements previously explained may be the use of composite elements.

### 3. Conclusions

For tall buildings fire safety is important for design. The use of combustible materials is restricted or not permitted in most fire regulations. There is a fundamental difference between tall buildings and medium-rise buildings with regard to evacuation and fire resistance criteria as people in tall buildings can often not be evacuated by the fire brigade using external equipment. A total burn-out without loss of structural stability and some main compartmentation must be guaranteed by the building structure. For the use of timber this often leads to the protection of the timber by non-combustible material (encapsulation) or to mixed construction. A feasibility study showed that mixed timber-concrete tall buildings in combination with technical and organizational measures can be built to be as safe as typical traditional non-combustible tall buildings.