Fire safety in timber buildings

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ABSTRACT

The very first European design guide for Fire safety in timber buildings has been developed. It presents information for architects, engineers, educators, regulatory authorities and building industry for the fire safe use of timber structures and wood products in buildings. It aims at providing the highest scientific knowledge with regard to fire safety on the European level. The guidance covers the use of design codes, such as Eurocode 5 Design of timber structures, European fire standards, practical guidance and examples for fire safe design and principles of performance based fire design. The design guide is focusing on structural fire protection by proving latest detailed guidance on load-bearing and separating functions of timber structures under standard fire exposure. New modelling not yet included in Eurocode 5 is presented. The guide includes information on the reaction to fire performance of wood products according to the European system. The importance of proper detailing in building design is stressed by practical solutions. Active measures of fire protection are presented as important means in fulfilling fire safety objectives.

KEYWORDS: FIRE RESISTANCE, REACTION TO FIRE, MULTI STOREY TIMBER BUILDINGS, PROPER DETAILING

1. INTRODUCTION

Timber has been a favoured construction material from the beginning of civilization because of its abundance, high stiffness and strength-to-weight ratios and the relative simplicity with which it can be adapted to use. These days, timber products have experienced a renaissance as their environmental credentials and an industry striving for continuously lower energy and less pollution appeal to consumers in a variety of sectors, from furniture to construction. The highest forest management standards ensure that there is a potential for a continuous and sustainable supply and use of timber as a building material in the future. It is therefore not surprising that timber structures are becoming an important element in sustainable and economic development, and have attracted worldwide attention in recent years.

New construction methods and new design tools have made timber framed houses an efficient construction method, offering good quality at affordable prices. Construction sites mainly employing timber products are recognized for their quiet and dry conditions, and the completed buildings offer user-friendly, healthy, natural living environments.
Globally, forests are an immense resource, accounting for about 30% of the Earth’s total land base. Europe has more than 1,000 million ha of forest spread over 44 countries, equivalent to 1.42 ha (more than two football pitches) per person. Recognizing the importance of wood, a naturally renewable building material is vital for meeting the challenges of climate change and ensuring a sustainable future. Forests play a key role in mitigating climate change as they absorb carbon dioxide from the atmosphere and store the carbon in trees and in the ground. Research shows that cultivating forests and utilizing their resources benefits the environment.

Figure 1 - Limnologen, eight storey residential buildings with timber structure in Växjö, Sweden. To the left, still under construction with a shield for weather protection. (Photo: Växjö University)

2. FIRE SAFETY IN TIMBER BUILDINGS

The combustibility of timber is one of the main reasons that too many building regulations and standards strongly restrict the use of timber as a building material. Fire safety is an important contribution to feeling safe, and an important criterion for the choice of materials for buildings. The main precondition for increased use of timber for buildings is adequate fire safety.

World-wide, several research projects on the fire behaviour of timber structures have been conducted over about the past two decades, aimed at providing basic data and information on the safe use of timber. Novel fire design concepts and models have been developed, based on extensive testing. The current improved knowledge in the area of fire design of timber structures, combined with technical measures, especially sprinkler and smoke detection systems, and well-equipped fire services, allow safe use of timber in a wide field of application. As a result, many countries have started to revise fire regulations, thus permitting greater use of timber.
Fire test and classification methods have recently been harmonised in Europe, but regulatory requirements applicable to building types and end users remain on national bases. Although these European standards exist on the technical level, fire safety is governed by national legislation, and is thus on the political level. National fire regulations will therefore remain, but the new European harmonisation of standards will hopefully also speed up the reform of national regulations.

Major differences between European countries have been identified, both in terms of the number of storeys permitted in timber structures, and of the types and/or amounts of visible wood surfaces in interior and exterior applications. Several countries have no specific regulations, or do not limit the number of storeys in timber buildings [1, 2]. However, eight storeys are often used as a practical and economic limit for the use of timber structures. This limit may be higher for facades, linings and floorings, since these applications may also be used in, for example, concrete structures.

![Map of timber structure restrictions](image)

- □ ≥ 5 storeys
- □ ≤ 2 storeys (incl. 0)
- □ 3-4 storeys
- □ No information

Figure 2 - Restrictions of the use of timber structures for higher buildings, set by national prescriptive regulations, have been eased in Europe over the last decades [1, 2].
3. ESSENTIAL REQUIREMENTS IN CONSTRUCTION PRODUCTS DIRECTIVE AND REGULATION

Building regulations are generally being altered towards functional or performance criteria, rather than being prescriptive. This development was accelerated by the Construction Products Directive (CPD), which was adopted in 1988. The CPD will be replaced by the Construction Products Regulation (CPR) in 2013. CPD contains six and CPR seven essential requirements, one of which is safety in the event of fire. The requirements on fire safety are that structures must be designed and built such that, in the case of fire:

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

The essential requirements are implemented and detailed in European standards within the standardisation body CEN and in European guidelines and technical approvals within EOTA European Organisation for Technical Approvals (will probably change name during 2013), see Figure 3.

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**Figure 3 - Systems for European fire standards and approvals for building products.**

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**Figure 4 - Design for both the initial and the fully developed fire in buildings is needed.**
4. EUROPEAN HARMONISATION

4.1. Harmonisation on structural design

As part of the European Union’s aim to remove technical barriers to trade, a set of European codes of practice in the field of civil and structural engineering has been published. These European design standards of components and structures for buildings, known as Eurocodes, will help to standardise design rules within Europe.

The Eurocodes have to be implemented by the national standard committees in all European countries. The national committees develop national annexes with specific rules and values to maintain the level of safety prevailing in the respective countries. The national annexes will be essential documents to enable Eurocodes to be used. The following appropriate information must be included:

- values or classes where alternatives are given in the Eurocode
- values to be used where only a symbol is given in the Eurocode
- specific data e.g. for material properties, wind or snow load
- the procedure to be used when alternative procedures are given in the Eurocode
- decision on the application of informative annexes.

The Eurocodes allow the calculation and verification of load-bearing capacity of components and structures for different materials, based on the semi-probabilistic design concept with partial safety coefficients. It is therefore also possible to design structures or components for desired behaviour in the case of fire, based on tabular values and simplified or general calculation methods, and to optimise the design of fire protection.

Application of the Eurocodes fire parts permits the integration of parametric temperature-time curves and natural fire curves to represent real fire scenarios as an alternative to the standard time/temperature curve in evaluating the fire resistance of components, which can be useful especially in evaluation of existing structures. However, the use of extended methods requires an increased level of expertise from the user. The Eurocodes will progressively replace the national design rules in all European countries.

4.2. Harmonisation of fire classification systems

4.2.1. Reaction-to-fire performance

A European classification system for the reaction-to-fire performance of building construction products has been introduced by the CPD. It is often called the Euroclass system, and consists of two sub-systems, one for construction products excluding flooring materials, i.e. mainly wall and ceiling surface linings, and another similar system for flooring materials. Both sub-systems have classes A to F, of which classes A1 and A2 are non-combustible products. The European system will replace the present national classification systems, which have created obstacles to trade. The European classification system for reaction-to-fire performance is based on a set of EN standards for test methods, EN 13823, EN ISO 11925-2 and EN ISO 9239-1 and for classification systems EN 13501-1. Three test methods are used for determining the classes of combustible building products. Methods EN ISO 1182 (non-combustibility) and EN ISO 1716 (calorific potential) are also used for classes A1 and A2.
4.2.2. Structural fire performance - Fire resistance

Fire resistance means that structural elements, e.g. wall elements, must withstand a fully developed fire and fulfil certain performance requirements. If the fire exposure is in accordance with the standard time-temperature curve, the performance requirements are load-bearing capacity (R), integrity (E) and insulation (I), see Figure 5. The standard fire curve describes a fully developed fire defined in EN 1363-1 and ISO 834-1 and is referred to in almost all national building codes. The building elements are expected to withstand the fire exposure for a specified period of time, e.g. 60 minutes. Timber structures can achieve high fire resistance, e.g. REI 60, REI 90 or even higher.

5. THE FIREINTIMBER PROJECT

The WoodWisdom-Net research project FireInTimber was conducted during 2007-2010 in close cooperation with 14 partners in nine countries. The key objective was to provide new possibilities for wood products in construction through proper fire design. The use of wood products is to be supported and stimulated by comprehensive and scientifically robust background data, which is presented in user-friendly and adapted tools for engineers and other stakeholders. The programme and its outcome are to facilitate and lead to simplified and quicker approval processes for wood products in buildings. This will increase the general public’s confidence and positive perception of and about wood products. The vision was to ensure that the wider use of wood in buildings will be associated with improved fire safety. The project also built a knowledge base by promoting core competence and multidisciplinary research. The transfer of new knowledge will be enhanced by networking between research and industry.

The FireInTimber project has resulted in new knowledge, especially for modelling of the load-bearing capacity of new types of timber structures. The project results are presented in about fifty scientific papers, reports and presentations at scientific and technical conferences. The main result for a greater audience is the technical guideline Fire safety in timber buildings [2]. It is the very first Europe-wide guideline on the fire safe use of wood in buildings. Short versions in several languages are also available [3, 4].
6. THE TECHNICAL GUIDELINE FOR EUROPE

The very first technical guideline on the European level for the fire safe use of timber structures and wood products in buildings aims at providing the highest scientific knowledge and covers the extended use of European design codes and standards, practical guidance and examples for fire safe design and principles of performance based design. The guideline presents information for architects, engineers, educators, regulatory authorities and building industry.

The guideline is focusing on structural fire design by providing the latest detailed guidance on separating and load-bearing functions of timber structures under standard fire exposure. Reference is made to the Fire Part of Eurocode 5 and, where new knowledge is available, to other references. Depending on national regulations, some of the new design methods may need agreement by the competent authority. This new information will be potential input to the next revision of the Fire Part of Eurocode 5.

The guideline also includes information on reaction to the fire performance of wood products according to the new European classification system. The importance of proper detailing in building design is stressed by practical examples. Active measures of fire protection and quality of construction workmanship and inspection are presented as important means for fulfilling the fire safety objectives.

The guideline comprises totally about 200 pages. Short summaries of the guideline chapters are presented below.

Chapter 1, **Timber buildings**, provides a short introduction to the established uses of timber buildings and the renaissance of timber structures in recent years as a result of the drive towards more sustainable construction solutions.

Chapter 2, **Fire safety in buildings**, gives an overview of the basic concepts of fire safety in buildings. It presents information on fire behaviour, fire loads, fire scenarios and fire safety objectives. Means of fulfilling the fire safety objectives are described for use in all buildings and as a basis for the design solutions in these guidelines.

Chapter 3, **European requirements**, presents an overview of the new European requirements for fire safety in buildings, based on the Construction Products Directive.
(CPD) and its essential requirements. These requirements are mandatory for all European countries. They include the classification systems for reaction to fire of building products, fire resistance of structural elements, external fire performance of roofs, fire protection ability of claddings and structural Eurocodes. Descriptions of how these requirements are applied to wood products and timber structures are given in the following chapters.

Chapter 4, **Wood products as linings, floorings, claddings and façades**, presents the reaction-to-fire performance of wood products according to the new European classification system. A wide range of products is included: wood-based panels, structural timber, glued laminated timber (glulam), solid wood panelling and wood flooring. A new system for the durability of the reaction-to-fire performance of wood products is explained and put into context, as well as the recently published K-class system for coverings with fire protection ability.

In addition to reaction-to-fire performance, some countries have extra requirements for façade claddings, for which at present no European harmonised solution exists. Best practice and state-of-the-art information on fire scenarios for facades are presented.

Chapter 5, **Separating structures**, presents the basic requirements, calculation methods based on component additive design and the Eurocode 5 design method. It also presents an improved design method from recent research as potential input for future revisions of Eurocode 5 and practical examples on how to use the method.

Chapter 6, **Load-bearing timber structures**, introduces the design methods for verification of the structural stability of timber structures in the event of fire, applying the classification for Criterion R for fire resistance (load-bearing function). Reference is made to Eurocode 5 with respect to charring and strength and stiffness parameters. Alternative design models are presented as well as new design methods for timber structures currently outside the scope of Eurocode 5, see Figure 7.

Chapter 7, **Timber connections**, provides an overview of the basic requirements for timber connections. The calculation methods in Eurocode 5 are complemented with state-of-the-art design methods, the result of recent research. Both timber-to-timber and steel-to-timber connections are included. The models are described and worked examples presented.

Figure 7 - New fire design models have been developed for the separating and load bearing capacity of innovative timber structures and verified by testing. The new models will be used as input for next revision of Eurocode 5.
Figure 8 - Proper detailing in timber structures is necessary to ensure that the fire resistance of structures is maintained. Fire stops are needed for joints, penetrations and installations.

Chapter 8, **Fire stops, service installations and detailing in timber structures**, deals with the need for adequate detailing in the building structure to prevent fire spread within the building elements to other parts of the building. Special attention is paid to basic principles, fire stops, element joints and building services installations. Several practical examples of detailing in timber structures are included.

Chapter 9, **Novel products and their implementation**, is aimed primarily at product developers. It describes guidelines for introducing novel structural materials and products. The basic performance requirements and potential solutions for insulating materials, encasing claddings and board materials, thin thermal barriers and fire-retardant wood products are included. The innovation process from idea to approved product ready for the market is outlined.

Chapter 10, **Active fire protection**, describes how such protection is used to achieve a more flexible fire safety design of buildings and an acceptable level of fire safety in large and/or complex buildings. The chapter introduces common active fire protection systems, including fire detection and alarm systems, fire suppression and smoke control systems. Sprinkler installation provides special benefits for increased use of wood in buildings, particularly where surfaces are to remain visible.

Chapter 11, **Performance-based design**, describes the basic principles of performance-based design, requirements and verification. Fire risk assessment principles are described in terms of objectives, fire safety engineering design, design fires, calculation/simulation methods and statistics. A case study of a probabilistic approach is also included.

Chapter 12, **Quality of construction workmanship and inspection**, describes the need for execution and control of workmanship to ensure that the planned fire safety precautions are built in. It also emphasises the need for fire safety at building sites, when not all fire safety measures are yet in place.
7. CONCLUSIONS

The European guideline presents information on wood products fulfilling the European fire classes and calculation tools for the fire resistance of timber structures, including new methods to be proposed for inclusion in the next revision of Eurocode 5.

The importance of proper detailing in building design is stressed by practical solutions. Active measures of fire protection are presented as important means in fulfilling fire safety objectives.

This information is useful for all types of buildings and in all European countries, especially for multi storey timber buildings.

A major remaining task is to create a system for harmonising the National building regulations. A promising tool is to use Fire Safety Engineering to replace or at least complement present prescriptive regulations.

8. ACKNOWLEDGMENTS

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9. REFERENCES


