D5.1 – Report on the needs to achieve improved fire protection as regards the implementation and development of the EN Eurocodes

Corresponding tasks and sub-tasks:

Sub-task 5.2 Needs for fire protection (sub-contracting)

Contents:

1. Summary

This document presents the deliverable D5.1 - Report on the needs to achieve improved fire protection as regards the implementation and development of the EN Eurocodes. The deliverable encompasses the results achieved during the three-year work on Sub-task 5.2 “Needs for fire protection” of the Administrative Arrangement with DG ENTR.

The deliverable consists of three self-contained papers, namely:

- Research needs to achieve improved fire design using the Eurocodes,
- Implementation and use of fire-parts of the Eurocodes, and
- Survey on the progress in the National implementation of the Eurocodes fire design Parts.

The paper “Research needs to achieve improved fire design using the Eurocodes” presents the research needs and priorities aiming at:

- further enhancement and/or expansion of the scope and of the basic approaches to fire safety design of the Eurocodes (pre-normative research needs);
- upgrading of the design rules of the different Eurocodes fire design Parts (co-normative research needs);
- expansion of fundamental knowledge on structural behaviour in fire (pre-normative research needs).

The objectives of the paper “Implementation and use of fire-parts of the Eurocodes” are:

- to introduce a certain ordering system for the various National regulatory requirements and associated technical rules which can be used as a scale for comparing the various National measures;
- to present a survey on the different National regulations and associated technical rules suitable for comparing the measures;
- to identify European rules and recommendations available and to conclude with recommendations for the further harmonisation of rules;
- to find out which issues could be subject of further research and development to establish the basis of decisions how to proceed in further harmonisation.

The paper “Survey on the progress in the National implementation of the Eurocodes fire design Parts” summarizes the results of the enquiry of all Member States (December 2007 – January 2008) on their needs related to the implementation of the fire design Eurocode parts with regard to:

- the progress in implementation of the Eurocodes fire design parts;
- specific and/or regulatory needs for adoption of National Standards implementing the Eurocodes fire design parts;
- research needs connected to the National implementation of the Eurocodes fire design parts;
- the advancement in the training and elaboration of guidelines and training materials on fire design.

The present deliverable has been prepared by the JRC in collaboration with the two ad-hock groups on fire design convened by the JRC and in consultation with DG ENTR, Member States and individual experts and organizations involved in fire design.

2. Introduction

The present deliverable is related to the Administrative Arrangement (AA) between DG ENTR and DG JRC regarding support to the implementation, harmonisation and further development of the Eurocodes. The deliverable is part of the activities that set as objective achieving increased protection of constructions against earthquakes and fire *(Safety objective).*

The deliverable presents the results achieved during the three-year work on Sub-task 5.2 “Needs for fire protection”. It was anticipated, during the project design phase of the Administrative Arrangement, that the JRC did not have appropriate expertise on the subject – fire safety engineering - and consequently it was foreseen only work to identify suitable European organizations/research institutions, independent from private and other interests and with appropriate expertise, to carry out the work on Needs for fire protection. During the first six-month review meeting with DG ENTR, the topic was discussed and it was concluded that the subject should be managed directly by the Commission without recourse to external sub-contracting. It was agreed that this topic will be addressed in the second and third years exclusively from the point of view of Eurocodes development and implementation.

The deliverable bases on the following activities and materials resulting from the work on the Administrative Arrangement with DG ENTR:

- Meeting with Mr. Giancarlo Bedotti, detached National Expert at DG ENTR, on 26 September 2005 at the JRC;
- Deliverable 5.2 “Proposal for a sub-contract on PR-needs for improved fire protection” presented in the end of Year 1;
- The Seminar and Working Meeting on Eurocodes Approach and Recent Advances in Fire Design within the Context of the Administrative Arrangement between JRC and DG ENTR, JRC/ELSA, Ispra, 11 July 2006;
- Deliverable 5.1 “Report on the progress of the work on identification of the needs for fire protection, presented in the end of Year 2;
- The working meeting on implementation and use of the Eurocodes in the field of fire design held in Ispra on 4 of June 2007 with key representatives of DG ENTR, CEN/TCs relevant to fire design, European Steel Technology Platform, European research institutions engaged in fire safety engineering, National Authorities, National Standardisation Bodies and Institutions involved in the Eurocodes National implementation in the Member States. At this meeting the progress and specific needs in the National implementation of the Eurocodes fire design parts in 8 Member States (Austria, Belgium, Finland, France, Germany, Portugal, Sweden and UK) have been presented and discussed.
- The survey on the progress in the National implementation of the Eurocodes fire design Parts (December 2007 - January 2008).

At the meeting on implementation and use of the Eurocodes in the field of fire design (4 June 2007) two ad-hoc-groups were formed in order to deal with:

- National implementation and use of the Eurocodes fire design parts,
- Research and standardisation needs for improved fire protection.

It was agreed that:

- Material justifying the needs to achieve improved fire design guidelines in the EU will be contributed by two ad-hoc-groups created at the Meeting, according to the adopted action plan.
- The variety of the needs in education and training on the Eurocodes fire design parts, and in further research in the Member States presented at the meeting naturally calls to enquire the National Fire Authorities of all Member States about the needs to achieve improved fire design using the Eurocodes. The ad-hoc group on National implementation and use of the Eurocodes will perform this enquiry jointly with the JRC;
- The JRC/ELSA will coordinate the work of the ad-hock groups and will provide documents exchange platform;
- CEN/TC127 will participate to the ad-hoc group on research and standardisation needs for improved fire protection;
- The ad-hoc groups will prepare by the end of January 2008 documents on the needs to achieve improved fire design using the Eurocodes.

An action plan for preparation of material on the needs to achieve improved fire design guidelines in the EU was adopted. To proceed with the envisaged enquiry of the Member States on their needs related to the implementation of the fire design Eurocode parts, a letter to the Eurocodes National Correspondents (ENC) Group has been prepared by the JRC and distributed at the ENC meeting on 22 November 2007 in Brussels. Member States were asked to present brief national reports (1-2 pages), prepared by the relevant National Authorities, focusing on:

- the progress in implementation of the Eurocodes fire design parts;
- specific problems, research and regulatory needs for adoption of National Standards implementing the Eurocodes fire design parts;
- advancement in training and elaboration of guidelines and training materials on fire design.

Twelve EU Member States and one EFTA Member State replied to the letter and sent National reports: Austria, Belgium, Bulgaria, Czech Republic, Finland, Germany, Italy, Lithuania, Netherlands, Poland, Portugal, Sweden and Norway. The reports received were analyzed by the two ad-hock groups and the conclusions were reflected in the prepared by them materials.

The present deliverable has been prepared by the JRC in collaboration with the two ad-hock groups on fire design convened by the JRC:

- The ad-hock group on national implementation and use of the Eurocodes fire design parts:

  Gerhard Sedlacek (chairman of the ad-hock group), CEN/TC250, RWTH Aachen, Gemany; Paulo Vila Real, University of Aveiro, Portugal; Hans Hartl, University Innsbruck, Austria; Jochen Fornather, Austrian Standards Institute, Austria; Saverio La Mendola, National Fire Brigade, Italy; Tom Lennon, BRE, UK; Ahmet Oztas JRC/Gaziantep University Turkey; Artur Pinto, JRC; Silvia Dimova, JRC.
- The ad-hock group on research needs for improved fire protection:

  Joel Kruppa (chairman of the ad-hock group), chairman CEN/TC250 Horizontal Group on fire design (HGF), CTICM, France; Gerald Newman , CEN/TC127; Paulo Vila Real, University of Aveiro, Portugal; Oliver Bahr, Leibniz University of Hannover, Germany; Peter Schaumann, Leibniz University of Hannover, Germany; Hans Hartl, University Innsbruck, Austria; Saverio La Mendola, National Fire

Brigade, Italy; Esko Mikkola, VTT, Finland; Ekkehard Richter, iBMB - TU Braunschweig, Germany; Tom Lennon, BRE, U.K.; Ahmet Oztas, JRC/Gaziantep University, Turkey; Artur Pinto, JRC; Silvia Dimova, JRC.

The materials were consulted with DG ENTR, Member States, and individual experts and organizations involved in fire design.

The deliverable consists of three self-contained papers, namely:

- Research needs to achieve improved fire design using the Eurocodes,
- Implementation and use of fire-parts of the Eurocodes, and
- Survey on the progress in the National implementation of the Eurocodes fire design Parts.

Research needs to achieve improved fire design using the Eurocodes

Contents

Executive Summary

The document presents the research needs and priorities aimed at achieving improved fire design by use of the Eurocodes. The identified research needs are aimed to:

- cover topics which are not presented in the current version of the Eurocodes fire design Parts,
- resolve aspects related to safety,
- further harmonize the National application of the fire design Parts by reducing the number of cases when National choices are permitted,
- expand the fundamental knowledge on structural behaviour in fire viewing at the future development of the Eurocodes.

The research needs presented are divided into following three groups:

A. Further enhancement and/or expansion of the scope and of the basic approaches to fire safety design of the Eurocodes (pre-normative research needs);

B. Upgrading of the design rules of the different Eurocodes fire design Parts (co-normative research needs).

C. Expansion of fundamental knowledge on structural behaviour in fire (pre-normative research needs).

The research needs are derived directly from the standardization needs for further development of the Eurocodes. In section 1 the research needs aimed to further enhance and/or expand the scope and the basic approaches of fire safety design in Eurocodes are presented. In sections 2-8 the research needs arising from the needs to upgrade the design rules in the different Eurocodes fire design Parts are considered. In section 9 the research priorities are presented in terms of necessary time span, effort and urgency to include the results of the research into the Eurocodes. The time span duration is given in terms of the number of years to complete the research; the effort gives an indication of the difficulty, as well as of the amount of human and financial resources necessary for the successful completion of the research; whereas the priority reflects the urgency of resolving standardization needs that would give a significant contribution towards improving the current versions of the Eurocodes. In section 9 possible strategies for financing the identified research needs are discussed centering on the actions to be undertaken at European level.

The document has been prepared by the ad-hock group on research needs for improved fire protection convened by the JRC/ELSA. It summarizes the materials elaborated by the members of the ad-hock group and the conclusions of:

- The Seminar and Working Meeting on Eurocodes Approach and Recent Advances in Fire Design within the Context of the Administrative Arrangement between JRC and DG ENTR, JRC/ELSA, Ispra, 11 July 2006;
- The working meeting on implementation and use of the Eurocodes in the field of fire design held in Ispra on 4 of June 2007 with key representatives of DG ENTR, CEN/TCs relevant to fire design, European Steel Technology Platform, European research institutions engaged in fire safety engineering, National Authorities, National Standardisation Bodies and Institutions involved in the Eurocodes National implementation in the Member States;
- The survey on the progress in the National implementation of the Eurocodes fire design Parts (December 2007 - January 2008).

Introduction

The Eurocodes provide common approach for the design of buildings and other civil engineering works which will provide appropriate safety levels across the European Union and will boost business in the construction sector by removing technical barriers to trade with construction products and services. Further research with regard to Eurocodes is essential to improve further the ratio “safety level reliability” / “cost of construction” and to preserve their statutes of the most up-to-date and comprehensive International Codes of Practice.

The European Commission in its Recommendation 2003/887/EC on the implementation and use of the Eurocodes encourages the Member States to undertake research to facilitate the integration into the Eurocodes of the latest developments in scientific and technological knowledge. The research is considered as a prerequisite for achieving an ongoing increased level of protection of buildings and civil works, specifically as regards the resistance of structures to earthquakes and fires.

The present document responds to the need to identify research priorities in order to achieve improved fire design by use of the Eurocodes. The research needs presented are aimed to:

- cover topics which are not presented in the current version of the Eurocodes fire design Parts,
- resolve aspects related to safety,
- further harmonize the National application of the fire design Parts by reducing the number of cases when National choices are permitted,
- expand the fundamental knowledge on structural behaviour in fire.

The research needs are derived directly from the standardization needs for further development of the Eurocodes. In section 1 the research needs aimed to further enhance and/or expand the scope and the basic approaches of fire safety design in Eurocodes are presented. In sections 2-8 the research needs arising from the needs to upgrade the design rules in the different Eurocodes fire design Parts are considered. The research priorities are presented in terms of necessary time span, effort and priority to include the results of the research into the Eurocodes. Possible strategies for financing the identified research needs are discussed centering on the actions to be undertaken at European level.

The document has been prepared by the ad-hock group on research needs for improved fire protection convened by the JRC/ELSA. The ad-hock group encompasses representatives of the main stakeholders as follows:

Joel Kruppa (chairman of the ad-hock group), chairman CEN/TC250 Horizontal Group on fire design (HGF), CTICM, France; Gerald Newman , CEN/TC127; Paulo Vila Real, University of Aveiro, Portugal; Oliver Bahr, Leibniz University of Hannover, Germany; Peter Schaumann, Leibniz University of Hannover, Germany; Hans Hartl, University Innsbruck, Austria; Saverio La Mendola, National Fire Brigade, Italy; Esko Mikkola, VTT, Finland; Ekkehard Richter, iBMB - TU Braunschweig, Germany; Tom Lennon, BRE, U.K.; Ahmet Oztas, JRC/Gaziantep University, Turkey; Artur Pinto, JRC; Silvia Dimova, JRC.

The document summarizes the materials elaborated by the members of the ad-hock group and the conclusions of:

- The Seminar and Working Meeting on Eurocodes Approach and Recent Advances in Fire Design within the Context of the Administrative Arrangement between JRC and DG ENTR, JRC/ELSA, Ispra, 11 July 2006;
- The working meeting on implementation and use of the Eurocodes in the field of fire design held in Ispra on 4 of June 2007 with key representatives of DG ENTR, CEN/TCs relevant to fire design, European Steel Technology Platform, European research institutions engaged in

fire safety engineering, National Authorities, National Standardisation Bodies and Institutions involved in the Eurocodes National implementation in the Member States;

- The survey on the progress in the National implementation of the Eurocodes fire design Parts (December 2007 - January 2008).

1. General needs for the Eurocodes fire design Parts

1-1 Partial safety factors

The recommended values of partial safety factors for material properties (thermal and mechanical) are equal to 1.0 in all fire design Parts. These values are in accordance with a decision taken in the CEN TC 250/HGF at the beginning of the 90s, making a parallel to a situation for fire testing for which, like in Germany, 2 tests on the same product are requested to issue a fire resistance rating. These safety factors need to be revisited with risk analysis methods to take into account the uncertainties in the material characteristics, in the calculation methods and in the execution, aiming at to refine their recommended values.

These partial safety factors should also reflect the level of sophistication at which the calculation methods for temperature development and mechanical stability at elevated temperature are used. For instance EN 1991-1-2 states that “for verifying standard fire resistance requirements, a member analysis is sufficient”, but there is no information regarding the use of member analysis with natural fires and the corresponding safety factors.

1-2 Assessment of the accuracy of simple calculation methods

When elaborating simple calculation methods it can be too expensive (as far as the cost of further works to be designed according to them is concerned) to choose the solution which encompasses all possible fire design situations. It is necessary to develop a risk analysis method for choosing the right "average" solution for which the cases not dealt with on the safe side will remain within an acceptable risk.

1-3 Extend the field of application to works other than buildings

The Eurocodes fire design Parts are covering only the case of buildings. Some other civil engineering works should be taken into consideration (e.g. bridges, for which, in certain situations, the behaviour in fire need to be assessed, or tunnels, for which some countries have requested very severe fires to be used for their design).

1-4 Extent of incorporation of fire safety engineering / fire risk analysis approach

Some clauses in EN 1991-1-2 and in fire design Parts of "material Eurocodes" have open the structural fire design to the fire safety engineering (FSE) approach, which is based on design fire scenarios. The extent of involvement of FSE is not yet sufficient; especially because the annex E of EN 1991-1-2 trying to establish links between active and passive fire protection measures is not adopted by many European countries. A better integration of the FSE approach into the framework of structural fire design needs to be considered and codified. This integration has to be performed in conjunction with a deep modification of annex E, based on new data and knowledge on fire growth, heat release rate, fire load densities, and a robust route for taking into account active fire protection measures, etc. This work could also cover better risk oriented requirements under standard fire situation to give room for improving current descriptive national regulations.

1-5 Further development and extension of assessment methods for passive fire protection systems

For the time being, when a load bearing structure (made in steel, aluminium, concrete, composite, or timber) needs to be protected against a rapid increase of temperature, the fire protection system to be used has to be experimentally evaluated according to one of the parts of ENV 13881 developed by CEN/TC127. These tests and assessments are very expensive and unable to meet all the needs for further advanced calculations. An improvement (and when necessary, development of new approaches) of these testing/assessment methods is needed.

1-6 Protection by plasterboards

Fire protection can be needed for load bearing structures to help them in fulfilling the requirements for fire resistance duration. In general, fire protection material (or system) is a trade mark developed by a manufacturer and that is why such materials or systems cannot be incorporated in a standard document but need to be, case by case, assessed according to a standard testing methodology as far as their efficiency in fire situation is concerned (see § 1.5). However, within EN 1995-1-2 information is provided for plasterboards used as fire protection material for timber structures. To have a uniform way of dealing with such fire protection whatever the load bearing material is (concrete, steel, timber, masonry, aluminium), it is necessary to verify if plasterboards can be considered as a generic material defined by the European standards. And if so, to investigate how to provide information for such fire protection material applied on concrete, steel, composite, aluminium structures and even on masonry.

1-7 "Composite" structures

In the structural Eurocodes the word "composite" is used for structural elements made of steel profile and concrete acting together. This concept can be extended to other combinations of materials in structural elements, such as timber-steel beams, solid or glued laminated timber in combination with timber based products or concrete, glazing panes providing bracing to beam-column structure, etc. The behaviour of such composite structures in fire situation needs to be investigated.1.8 Fibre Reinforced Polymer (FRP) structures

The use of FRP structures is increasing. To provide a full set of assessment methods for that materials, the behaviour of these structures need to be well understood, which is not the case for the time being. Research work should be performed in this area.

2. EN 1991-1-2 - Actions on structures: Exposure to fire

2-1 Modelling of fire development

Currently there are some restrictions in EN 1991-1-2, based on existing fire models and simulation tools. For example, the parametric fire curves given in annex A are too limited. To improve this situation, the use of computational fluid dynamics (CFD) or other fire simulation tools should be allowed in wider extent by defining the field of application and specifying the necessary professional requirements. The influence of the combustible surfaces on the fire scenario for building structures needs also to be addressed, for instance the contribution of surfaces of timber elements to internal and external fire exposures.

2-2 Influence of fire safety measures on the fire development

As already mentioned in §.1-4, the contents of annex E of EN 1991-1-2 has to be modified, as far as the concept is covered and improved regarding the latest available data and statistics. It is particularly important to take into account the influence of fire safety measures on the fire development and to define a better way to take into account the active fire measures, such as detection, smoke evacuation, sprinklers, etc.

3. EN 1992-1-2 – Design of concrete structures: General rules – Structural fire design

3-1 Thermal properties of various types of concrete

The thermal conductivity of concrete is currently a National Determined Parameter (NDP), since it was not possible to reach an agreement in the group dealing with fire safety within CEN/TC250 for a single set of values versus temperature. Even if it is realistic to have different figures for thermal properties of concrete in function of the type of agregats used, these properties cannot longer be considered as a NDP which may have different value when crossing the border of a Member State. Accurate figures need to be given.

3-2 Effect of creep at elevated temperature

Creep effect at elevated temperature can have an influence equivalent to that of the elongation. This is an important parameter for assessing the interaction between the structural members and for evaluating the level of stress in fire situation. A research project should cover different strengths of concrete ranging from normal to high.

3-3 High strength concrete and prestressed concrete

Most of the simple calculation methods given in EN 1992-1-2 are developed for normal strength reinforced concrete (concrete class up to C50). Since the nowadays trend is to use more and more pre-stressed concrete and high strength concrete, the structures made of high strength concrete (concrete class C55 to C90) need more precise rules. Now their fire design is completely open to national choices. The simple calculation models need to be checked and - if necessary - improved to get enough confidence that they accurately reflect the behaviour of structures made of pre-stressed and of high strength concrete.

3-4 Spalling conditions for mineral products

Spalling of concrete can have very strong effect when the thermal insulation of the reinforcement bars or of the pre-stressing bars is concerned. The rules given in the EN 1992-1-2 are not enough accurate, especially when high strength concrete and/or other fire severity than the standard fire is concerned.

3-5 Behaviour or structural assemblies under real fires, including cooling phase

Very limited knowledge, and consequently calculation methods, is available for the various kinds of connections between beams and columns, floors and walls, etc. in fire situation. This behaviour has large influence on determining the mode of failure of concrete structures and on the risk to which the occupants of the building and the fire fighters outside the building are subjected. Since the ultimate aim of structural fire design is to assess the behaviour of an entire building in a real fire situation, knowledge on the fire behaviour of any type of connections in different fire situation conditions has to be improved and calculation rules to be provided.

3-6 Model to evaluate stresses in tunnel concrete frames in fire

Basing on the catastrophic fires in road and rail tunnels, engineers have been asked to dimension tunnel structures even against high temperature loads. While standard procedures in the past have been based on experience, the now requested dimensioning requires sophisticated computer modelling.

In order to model the fire load case, it is essential to know the actual stresses caused by high temperature. Although the change of material properties is well known for either, concrete and reinforcement steel, the interaction and actual stresses have not been yet evaluated in detail. There is a need of enhancement of the calculation frame models evaluating the so-called equivalent temperatures in order to simulate the stresses caused by temperature within the structure.

3-7 Relationship between behaviour under standard fire conditions and real fire conditions

It is very expensive to test the fire behaviour of different kinds of separating concrete elements under various severities of fire for assessing for instance the integrity criterion (E) dealing with hot gas leakage. Relationships able to predict the behaviour of an element under well established real fire conditions from the performance of this element under standard fire condition need to be determined.

4. EN 1993-1-2 – Design of steel structures: General rules – Structural fire design

4-1 Effect of creep at elevated temperature

The stress-strain relationship of steel is assumed to be valid for heating up condition from 2 K/min to 50 K/min. In fact, creep effect can have an important influence at low rate of heating commensurate to the influence of elongation at elevated temperatures. Rules need to be developed to cover this situation.

4-2 Testing method for mechanical steel properties of steel grades

Since the performance of steel in fire situation can be influenced by percentage of carbon, molybdenum, etc., various grades of steel can be put on the market. It is needed to develop an accurate testing methodology providing to the designer the necessary mechanical characteristics, versus temperature up to 1200/1300 °C. This methodology needs also to cover the creep effects.

4-3 Instability at elevated temperature

Current EN 1993-1-2 is covering the case of instability of columns and beams only if they are at a uniform temperature for both the cross-section and along their length. This assumption does not correspond to the real situations. Some research works under progress deal with lateral torsional buckling and moment-axial force interaction of carbon and stainless steel. They need to be extended to cover all the mechanical situations, like class 4 cross-sections in all thermal situations (class 4 cross-sections are those in which local buckling will occur before the attainment of yield stress in one or more parts of the cross-section) and also to encompass cases where thermal gradient through cross-sections should have strong influence by developing additional internal forces. In addition, experiments have to be carried out to give the necessary confidence in the calculation methods to be elaborated.

4-4 Fire protected members and acceptable strains (acceptability of 2 % strain for fire insulation materials)

In the current version of the Eurocodes it is necessary to ensure the compatibility between the deformation of the structural element and the capability of the applied insulation material when dealing with real fires. This requirement makes necessary the use of advanced calculation methods, which is a burden for the everyday work in an engineering office. Simple calculation methods need to be developed to cover this compatibility verification.

4-5 Design of hybrid beams in case of fire

In the design of a welded beam, it can be appropriate to use different grades of steel for web and flanges. However, there is not enough knowledge on the possible behaviour of such elements at elevated temperatures. In addition, there is no simple calculation method for such kind of hybrid beams.

4-6 Behaviour or structural assemblages (concrete, steel, composite, timber) under real fires, including cooling phase

Some research projects on the behaviour of steel connections in fire situation were performed or are on-going. Since there are many situations to investigate, mainly due to the fact that a failure could occur in the cooling phase of a fire, this topic needs further investigation in order to provide the necessary knowledge and simple calculation methods to the designers.

4-7 Structural behaviour of steel and steel concrete composite beams with web opening

The heating conditions of such beams with fire protection materials are not sufficiently well known. Further research work is necessary to be able to develop simplified calculation method for heating up.

5. EN 1994-1-2 – Design of composite steel and concrete structures: General rules – Structural fire design

5-1 Design rules for composite floor systems

At least two kinds of composite floors are not addressed by the simple calculation methods of EN 1994-1-2. They are:

- slim-floor (or shelf-angle floor) for which the concrete slab acts also as a fire protection material for the whole height of steel beam (or part of it),
- unprotected steel beam and composite slab subjected to diaphragm effect to bear the applied load.

Even if there are already some calculation methods developed for dealing with these two kinds of structures, further investigations are necessary to develop accurate simple calculation methods.

5-2 Design rules for columns

Design rules for composite columns are either not all available (for instance no simple calculation method for concrete filled hollow column, no simple calculation method for fully steel section fully engulfed in concrete, no calculation method for hollow column made of stainless steel) or are rather complicated with a limited field of application (for instance a H column with concrete between flanges). Research should be carried out to provide the necessary information and simple calculation methods.

5-3 Behaviour or structural assemblies (concrete, steel, composite, timber) under real fires, including cooling phase

Similarly to the case of concrete structures, some research projects on the behaviour of composite connections in fire situation were performed or are on-going. Since there is a number of situations to investigate, mainly due to the fact that failure can occur in the cooling phase of a fire, this topic needs to continue to be investigated to provide the necessary knowledge and simple calculation methods to the designers.

6. EN 1995-1-2 – Design of timber structures: General – Structural fire design

6-1 Contribution of timber elements to fire development/ charring rate

Viewing at the fire action used for determining the load bearing capacity of structures, further information needs to be obtained and modelling approaches to be developed on such as the influence of fire retardants on the charring rate of timber, and long term performance**.**

6-2 Thermal properties / heat transfer into structural elements including connections

Determining the field of temperature in a timber element in fire situation, including the char and connections is still very difficult. Additional information is needed for the thermal properties of woods and of char. Modelling approaches have to be developed in this area to allow the development of more accurate simple calculation methods and the use of advanced calculation methods.

6-3 Load bearing capacity of timber and timber/steel joints depending on the fire scenario including the cooling phase

In the context of steel connectors in timber structures further research and development is needed, based on already existing test results.

There is still a lot of uncertainty on the behaviour of timber connections, mainly for the more resistant ones in the cooling phase of fire. Improvement of the knowledge in this area is needed.

6-4 Upgrading of calculation methods for wall and floor assemblies

Annex C "Load-bearing floor joists and wall studs" has to be improved regarding the following:

- definition of the modification factors for fire ($k_{mod,fi}$),
- application for structures of fire resistance class R90,
- use for partly insulated cavities.

These improvements will allow conversion of its status from Informative to Normative.

6-5 Development of tabulated data for the minimum size of columns and beams

To better help the designer, tabulated data giving the minimum size of columns and beams to reach acceptance according to fire resistance requirements have to be developed.

6-6 Determination of relationships between behaviour under standard fire conditions and real fire conditions

Similarly to the case of concrete structures, it is very expensive to test the fire behaviour of different kinds of separating elements under various severities of fire for assessing for instance the integrity criterion (E) dealing with hot gas leakage. Relationships able to predict the behaviour of an element under well established real fire conditions from the performance of this element under standard fire condition need to be determined.

7. EN 1996-1-2 – Design of masonry structures: General rules – Structural fire design

7-1 Tabulated data for the minimum thickness of walls

There are still too many uncertainties in the tabulated data of annex B for the minimum thickness of various kinds of masonry walls. A robust method for evaluating the fire resistance of such walls needs to be developed and used for a large population of masonry walls used in the EU Member States. This will lead to more accurate figures and better confidence in the given data.

7-2 Simple calculation method for assessment of fire resistance of masonry walls

The simple calculation method of annex C needs to use a constant "c" which should be obtained from strain-stress relationship at elevated temperature. The testing methodology has to be defined for assessing the constant "c" and used for a variety of units from the Member States. Afterwards the simple calculation method has to be fully verified by comparison with fire resistance test results obtained on loaded masonry walls.

7-3 Spalling conditions for mineral products for various fire severities

Spalling of masonry units can have very strong effect especially when hollow units are concerned. Rules need to be given in EN 1996-1-2 regarding the different types of masonry and different fire severities.

7-4 Determination of relationships between behaviour under standard fire conditions and real fire conditions

It is very expensive to test the fire behaviour of different kinds of separating masonry walls under various severities of fire for assessing the integrity criterion (E) dealing with hot gas leakage and the insulation criterion (I). Relationships able to predict the behaviour of an element under well established real fire conditions from the performance of this element under standard fire condition should be derived.

8. EN 1999-1-2 – Design of aluminium structures: Structural fire design

8-1 Assessment method for fire protection

There is no specific method in the ENV 13381 to deal with fire protection materials for aluminium alloys structures. Consequently the research needs mentioned within 1.5 have to be extended to cover this application.

8-2 Overall validation of simple calculation methods given in EN 1999-1-2

Simple calculation methods given in EN 1999-1-2 are mainly coming from those developed for steel structures. A very small number of these calculation methods were validated against fire resistance test results on aluminium alloys structures. This validation has to be performed for the whole set of calculation methods**.**

9. Research needs and priorities

The research needs presented in sections 1-8 address standardization needs arising from the state-of-the–art of the Eurocodes fire design Parts. They can be divided to the following groups:

A. Further enhancement and/or expansion of the scope and of the basic approaches of fire safety design;

B. Upgrading of the design rules of the different Eurocodes fire design Parts.

In the same time the fundamental knowledge for the structural behaviour in different fire situations needs to be further extended and systemized viewing at the future development of the Eurocodes. In this aspect a third group of research needs should be considered, namely:

C. Expansion of fundamental knowledge on structural behaviour in fire.

With regard to the relevance to the timeline of development of the Eurocodes fire design Parts these three main groups of research needs might be classified as follows:

- Group A: pre-normative research needs;
- Group B: co-normative research needs;
- Group C: pre-normative research needs.

The research priorities to carry out the research described in the previous sections are presented in Tables 1, 2 and 4 in terms of the necessary time span duration, effort and priority of including the results of the research into the EN Eurocodes. The time span duration is given in terms of the number of years to complete the research; the effort gives an indication of the difficulty, as well as the amount of human and financial resources necessary for the successful completion of the research; whereas the priority reflects the urgency of resolving standardization needs that would give a significant contribution towards improving the current versions of the Eurocodes.

9.1. Research needs for further enhancement and/or expansion of the scope and of the basic approaches of fire safety design

The topics considered in section 1 “General needs for the Eurocodes fire design Parts” aim at further enhancement and/or expansion of the scope and of the basic approaches of fire safety design, including aspects of safety. They are summarized in Table 1.

Table 1. Research needs Group A - enhancement and/or expansion of the scope and of the basic approaches

Research need	*Description*	Effort	Duration	Priority
1. Enhancement of basic approaches of fire safety design	Broader addressing the fire safety engineering approach, assessment of the accuracy of simple calculation methods in terms of acceptable risk.	High	Second generation of EN Eurocodes	Medium
2. Expansion of the scope of fire design Parts of the Eurocodes	A possible expansion should encompass: • construction works other than buildings (e.g. bridges and tunnels, which are currently designed under National regulations), • assessment methods for passive fire protection systems and plasterboards, • composite structural elements consisting of materials other than steel and concrete (e.g. timber-steel beams, timber – timber based materials, timber – concrete, glazing panes providing bracing to beam-column structure, etc.), • FRP materials	High	Second generation of EN Eurocodes	Medium
3. Enhancement of safety aspects	The recommended values for the partial safety factors for material properties (thermal and mechanical) need to be revisited by risk analysis methods.	Medium	Second generation of EN Eurocodes	Medium to high

9.2 Research needs for upgrading of the design rules of the different Eurocodes fire design Parts

According to the topics identified in sections 2-8, the research needs for the particular EN Eurocodes Parts for fire design encompass:

- material properties at elevated temperature, including spalling of mineral products and charring of combustible products;
- behaviour of structural elements, either load bearing elements (e.g. beams, columns, floor) or separating elements (e.g. wall, partition, ceiling);
- behaviour of structures and of sub-assemblies;
- modelling of fire loading.

These research needs are summarised in Table 2, where the quotation numbers of the research needs are shown in relevance with their presentation in sections 2-8.

Table 2. Research needs Group B - upgrading of the design rules

Eurocode fire design Part	Research needs			
	Material properties	**Behaviour of elements**	**Structures and sub-assemblies**	**Fire loading**
EN 1991				2-1 Modelling of fire development 2-2. Influence of fire safety measures on the fire development
EN 1992	3-1 Thermal properties of concrete 3-2 Effect of creep 3-4 Spalling conditions for mineral products	3-3 Calculation rules for elements of high strength concrete and pre-stressed concrete 3-7 Relationship between the behaviour under standard fire conditions and real fire conditions	3-5 Behaviour of structural assemblies under real fires 3-6 Model to evaluate stresses in tunnel concrete frame in fire	
EN 1993	4-1 Effect of creep 4-2 Testing method for mechanical steel properties of steel grades	4-3 Instability at elevated temperature 4-4 Fire protected members and acceptable strains 4-5 Design of hybrid beams in case of fire 4-7 Steel and steel concrete composite beams with web opening	4-6 Behaviour of structural assemblies under real fires	
EN 1994		5-1 Design rules for composite floor systems 5-2 Design rules for columns	5-3 Behaviour of structural assemblies under real fires	
EN 1995	6-2 Thermal properties/ heat transfer	6-3 Load bearing capacity of timber and timber/steel joints depending on of the fire scenario 6-5 Development of tabulated data for the minimum size of columns and beams 6-6 Relationship between the behaviour under standard fire and real fire conditions	6-4 Upgrading of calculation method for wall and floor assemblies	6-1 Contribution of timber elements to fire development/ charring rate
EN 1996	7-3 Spalling conditions for mineral products for various fire severities	7-1 Tabulated data for the necessary thickness of masonry walls 7-2 Simple calculation method for masonry walls 7-4 Relationship between the behaviour under standard fire and real fire conditions		
EN 1999	8-1 Assessment method for fire protection materials	8-2 Overall validation of the simple calculation methods given in EN 1999-1-2		

The estimated research effort, the duration of the projects and the priority of the four generalized research fields are presented in Table 3.

Table 3. Research needs Group B - research effort, priority and duration of projects

Research field	Fire design Part of Eurocode	Effort	Duration (years)	Priority
1. Material properties at elevated temperature, including spalling of mineral products and charring of combustible products	EN 1992, EN 1993, EN 1995, EN 1996, EN 1999	Medium	3-4	High
2. Behaviour of structural elements	EN 1992, EN 1993, EN 1994, EN 1995, EN 1999	High	3-4	High
3. Behaviour of entire structure and of sub-assemblies	EN 1992, EN 1993, EN 1994, EN 1995	Medium	3-4	Medium
4. Modelling of fire loading	EN 1991, EN 1999	Medium	3-4	Medium - high

9.3 Expansion of fundamental knowledge on structural behaviour in fire

The research needs, research effort, priority and duration of projects aimed to deepen and systemize the fundamental knowledge on the structural behaviour in fire are presented in Table 4.

Table 4. Research needs Group C - Expansion of fundamental knowledge on structural behaviour in fire

Research need	Description	Effort	Duration	Priority
1. Exposure to nominal fires	Behaviour of materials, elements and sub-assemblies when exposed to standard or other nominal fires	Medium	Second–third generation of EN Eurocodes	Medium
2. Exposure to real fires	Behaviour of materials, elements, assemblies and entire structures when exposed, totally or partially, to the action of real fires.	High	Second –third generation of EN Eurocodes	Medium

10. Possible strategies for financing the identified research needs

The research needs identified in the above sections may be funded at the National and/or European levels with the support and participation of Industry. In the cases when more synergy could be gained by action at the European level, funding should be sought from the European Institutions. In such cases the main source of funding would come from the European Commission, in particular:

- from DG RESEARCH through the Seventh Framework Programme (FP7), which finances research and development in Europe during seven years, from 1 January 2007 to 2013, and
- from DG ENTR for those topics where minimum safety to users and public, and realization of the Single Market (competitiveness) are of primary concern.

Under the Cooperation programme of FP7, Joint Technology Initiatives might be created on the basis of the work undertaken by the European Technology Platforms, where the scope of an RTD objective and the scale of the resources involved justify covering one or a small number of selected aspects of research in their field, combining private sector investment and national and European public funding. To progress with the research needed for improvement of the design guidelines for fire protection, it would be rational to explore the possibilities to create Focus Areas on fire safety in the European Construction Technology Platform and in the European Steel Technology Platform.

Aachen, 27.03.2008

Implementation and use of fire-parts of the Eurocodes

Gerhard Sedlacek, Chr. Heinemeyer

1. Objectives

(1) The fire parts of the Eurocodes provide unified technical rules for the design of structural fire resistance of buildings.

(2) The design for structural fire resistance is only a sector of measures needed to provide fire safety.

(3) The regulations in the various countries address the complete set of measures.

(4) There are differences from country to country in the way how these measures are addressed. These differences result mainly form long term traditions and different legal systems.

(5) The objectives of this report are:

- to introduce a certain ordering system for the various National regulatory requirements and associated technical rules which can be used as a scale for comparing the various National measures,
- to present a survey on the different National regulations and associated technical rules suitable for comparing the measures,
- to identify European rules and recommendations available and to conclude with recommendations for the further harmonisation of rules,
- to find out which issues could be subject of further research and development to establish the basis of decisions how to proceed in further harmonisation.

2. Aims of the harmonisation

(1) The purpose of the harmonisation of European rules and recommendations for fire design is the free marketing of construction products and engineering services.

(2) The regulatory situation aimed at by the harmonisation is characterized by the following three levels:

Level 1: Legal level defining protection aims:

This level is in general abstract and gives qualitative principles without defining rules how the protection aims could be reached. An example is the legal requirement to protect human lifes in case of fire.

Level 2: Level of administrative technical requirements:

These technical requirements are issued by the Regulatory Bodies; they are meant to reach the protection aims and are addressed to the various options in the design tools as the Eurocodes for the structural fire design. They give quantitative input data related to fire safety. An example is the technical requirement, that depending on the type of the building and its occupancy and the associated risk the building structure should withstand:

- a particular fire scenario with a certain energy release, and with
- a particular level of reliability with which the structure shall withstand the fire for a specified time.

Level 3: The level of design tools for designers.

These tools are prepared by Standard Bodies and give, as the Eurocodes do, the rules for fulfilling the legal protection aims by quantitative safety verifications using:

- the quantitative technical requirements of Level 2 and
- suitable engineering models for limit state verifications from the Eurocodes and
- properties of construction products and prefabricated components from the product specifications to be used in the engineering models.

(3) The rules in Level 1 and Level 2 are made by the Regulatory Bodies; they are safety-related and hence in the responsibility of Member States, so that they may differ from Member State to Member State.

However there is a unifying force for harmonisation of Level 1 and Level 2 rules across various countries, since the design rules of Level 3 (Eurocodes) are performance - based and intended to be implemented in Europe, and Level 1 - and Level 2 - rules shall address these unified rules and therefore should also be performance-based.

(4) The design rules in Level 3, i.e. the fire parts of the Eurocodes, are made by Standard-Committees; they are complete in conjunction with the level 2 requirements for daily use by practitioners. They should represent the „state of the art“ and as such are subject of continuous evolution.

Whereas the rules of level 1 and level 2 are stable for a long time, the rules in level 3 will be checked every 5 years to identify whether progress in research and development requires amendments and revisions.

(5) As a conclusion of the long-term character of the legal and administrative level 1- and level 2-rules and the short-term character of the technical level 3-rules these rules should be fully separated and not mixed.

(6) Unfortunately this requirement has not been followed by most of the existing regulatory systems, which represent a mixture of level 2- and level 3-instructions. They are based on long traditions that developed locally in different ways together with the development of National design rules and associated organisations of national professions.

(7) Hence there are differences in:

- the National legal requirements (level 1).
  The level 1-requirements are rather similar and differences seem to be small.
- The National administrative technical requirements (level 2).
  The National level 2-requirements differ in the depth of technical instructions. Partly they include technical stipulations that bypass rules of the Eurocodes; partly they do not use all options given by the Eurocodes.
- National peculiarities related to level 1 and level 2.
  These peculiarities refer to parameters for fire ignition and spread, as e.g. particular types of buildings, materials used, type of installations, habit of people, or to fire fighting, e.g. by the organisation and equipment of fire brigades and to the use of particular design procedures, e.g. compatible with the qualification of the design profession.
- National design rules.
  They depend on national administrative requirements, national peculiarities and the adaptability of results of research and development.

(8) These differences have been foreseen, when the fire parts of the Eurocodes were drafted, so that the Eurocodes include a great many of notes opening for National decisions on Nationally Determined Parameters and a set of “Informative Annexes” with technical rules that may be adopted, modified or substituted in the National Annexes.

(9) This flexibility in the draft of the fire-parts of the Eurocodes was meant to:

- achieve general acceptance without obstacles to early implementation,
- to initiate modifications of the National regulatory systems and of the organisations of professions to achieve a consistent system,
- to initiate drafting of National Annexes that could be checked to find ways of further research and development for further harmonisation.

3. Protection requirements (level 1) and derived administrative requirements (level 2)

(1) A common European protection requirement has been formulated in the Interpretative Document ID2 for the Essential Requirement No. 2 of the Construction Product Directive:

“ § 1.1 (3): Buildings have

- to remain load bearing resistant for a specific time period (this addresses public safety and life and health),
- to limit spread of fire and smoke in the building,
- to limit spread of fire to neighbouring buildings,
- to enable people to leave the building unhurt and being rescued (some regulations also address the rescue of animals),
- to consider safety of rescue team.”

(2) Comparisons of these requirements with the requirements in some countries may show that differences are small.

(3) From the administrative requirements (level 2) instructions for use following the concept of consequence classes to EN 1990 – Annex C would be expected.

EN 1991-1-7 gives an example for the categorisation of consequence classes in the Table A.1 of its informative Annex A “Design for consequences of localized failure in buildings from unspecified cause”, see Table 3-1

Table 3-1 – Categorisation of consequences classes

Table A.1 - Categorisation of consequences classes.

Consequence class	Example of categorisation of building type and occupancy
1	Single occupancy houses not exceeding 4 storeys. Agricultural buildings. Buildings into which people rarely go, provided no part of the building is closer to another building, or area where people do go, than a distance of $1^1/_2$ times the building height.
2a Lower Risk Group	5 storey single occupancy houses. Hotels not exceeding 4 storeys. Flats, apartments and other residential buildings not exceeding 4 storeys. Offices not exceeding 4 storeys. Industrial buildings not exceeding 3 storeys. Retailing premises not exceeding 3 storeys of less than 1 000 m^2 floor area in each storey. Single storey educational buildings All buildings not exceeding two storeys to which the public are admitted and which contain floor areas not exceeding 2000 m^2 at each storey.
2b Upper Risk Group	Hotels, flats, apartments and other residential buildings greater than 4 storeys but not exceeding 15 storeys. Educational buildings greater than single storey but not exceeding 15 storeys. Retailing premises greater than 3 storeys but not exceeding 15 storeys. Hospitals not exceeding 3 storeys. Offices greater than 4 storeys but not exceeding 15 storeys. All buildings to which the public are admitted and which contain floor areas exceeding 2000 m^2 but not exceeding 5000 m^2 at each storey. Car parking not exceeding 6 storeys.
3	All buildings defined above as Class 2 Lower and Upper Consequences Class that exceed the limits on area and number of storeys. All buildings to which members of the public are admitted in significant numbers. Stadia accommodating more than 5 000 spectators Buildings containing hazardous substances and /or processes

NOTE 1 For buildings intended for more than one type of use the "consequences class" should be that relating to the most onerous type.

NOTE 2 In determining the number of storeys basement storeys may be excluded provided such basement storeys fulfil the requirements of "Consequences Class 2b Upper Risk Group".

NOTE 3 Table A.1 is not exhaustive and can be adjusted

(4) The instructions should refer to such consequence classes and indicate parameters controlled by the risk of failure (β-values) of the structure or a part from it during a relevant time period. That time is controlled by the time for an alarm signal, the time that people react on a fire, the escape time, the mobilisation time of a fire brigade, the time needed for the fire brigade to rescue people and the time to start extinguishing the fire.

(5) The instructions should according to the formulation in the Interpretation Document ID2 in particular relate to:

"§ 3.2 (4): Fire resistance may be estimated considering:

- material fire scenarios,
- conventional fire scenarios,

§ 3.3: Requirements may be defined as

- performance requirement for the whole building

- performance requirement for members (e.g. by fire resistance classes)
- definition of critical conditions"

(6) More detailed informations on

- natural fire resistance,

  as on the combustibility of structural members
- prevention of fire spread

  as on the size of compartments
- enabling fire fighting

  as access routes and areas, supply with fire fighting devices
- escape routes

  as lengths and widths
- smoke exhaust

not covered in the Eurocodes will be subject of other future European Standards that deal with

- the determination of time for evacuation and rescue,
- the smoke management, so that smoke exhaust systems are designed such, that smokeless layers form for enabling evacuation and fire fighting (where applicable).

For the time being they are covered by non-conflicting supplementary National Standards addressed in the National Annexes. These National Annexes also address National peculiarities.

(7) A check of the various National regulatory systems and National Annexes prepared for the implementation of the Eurocodes in the Member States will give guidance for defining common protection requirements and derived administrative technical requirements, that permit to carry out a performance oriented design.

(8) So far the conclusions for research and further developments are

1. Inquires and studies of the National regulatory systems and National Annexes are needed to confirm the following:

   - Legal requirements (Level 1) are similar.

- Administrative technical requirements (Level 2) have been developed on historical basis (small scientific background). They are not performance-based, therefore give detailed technical instructions without taking into account of engineering models for numerical assessments. They consider however national peculiarities.
- National systems for qualifying and certifying experts for fire safety assessment and third party control are different and not yet fully adapted to all options for design given by the Eurocodes.

2. Depending on the outcome of these studies there is a need to develop a model for performance-based administrative technical requirements that could be adapted by Member States to comply with their socio-economic situation and national peculiarities.

   It is not possible, even in case of agreement to risk-classes, assessment methods, reliability and numerical values to abandon National Annexes fully due to National peculiarities.

   There is also a need to approximate the systems of qualifying and verifying experts for fire safety assessment, that is in balance with the depth of instructions from regulations.

4. Design rules in the fire parts of the Eurocodes (Level 3)

4.1 General aspects applicable to all Eurocodes

(1) The time of the preparation of national annexes to the fire parts of the Eurocodes has been used by Member States to check these parts in detail and to perform accompanying studies for either adopting the recommendations in the technical notes or the informative annexes or to modify or substitute them.

(2) As any National Annex constitutes a proposal for the further evolution of the fire-parts of the Eurocodes, Member States present these studies as justification notes for any deviation from the recommended values and thus are in line with the new approach, that any revision of a technical rule should be accompanied by a suitable background document.

(3) In this context it is criticized by Member States that appropriate background documents to the rules and recommendations given in the Eurocodes are missing, so that experts involved in the preparation of National Annexes must often guess. This concerns both large and small countries, but small countries in particular.

(4) Another item of general nature that is criticized is related to consistency questions:

1. Consistency between the properties of construction material including prefabricated components determined by classification-tests with the properties needed to calculate with the Eurocodes, e.g. with standard fire or natural fire curves.

   These properties should be such that they can be used for a reliable assessment of the structure (e.g. for construction material intended for fire protection as mineral wool or gypsum-based plates). This consistency would also lead to an improvement of the fire resistance classes.

   Construction products in this context also comprise equipments, e.g. elements of smoke and heating exhaust venting systems.

2. Consistency between the fire parts of the various Eurocodes e.g. for the description of strain hardening for steels in EC2, EC3 and EC4.

(5) In conclusion an important item of further research and development that encompasses the fire-parts of all Eurocodes is, to develop such background documents (any collection of publications addressing various rules in the Eurocodes is not sufficient) and to identify consistency problems and prepare solutions for them.

(6) In the following some reflections are given that relate to the criticism, questions and proposals to technical rules in the fire-parts of the various Eurocodes.

4.2 EN 1991-1-2

(1) A particular item of studies that are being performed concern the safety achievable with the description of fire actions in EN 1991-1-2.

(2) The safety concept of EN 1991-1-2 includes:

- Safety elements are applied to the size of fire load for which fire load densities for different occupancies of buildings based on Rates of Heat Release, are given.
- The design value of the fire load is reduced or increased by factors representing particular safety measures as:
  - automatic fire suppression,
  - automatic fire detection,
  - manual fire suppression,
  - danger of activation

due to the fact that the reliability of these measures is far higher than the reliability of structural integrity during a fire.

(3) Though the fire load densities are commonly accepted and active fire measured as detection and fire suppression are considered as a modern feature of fire design, the criticism relates to the following aspects:

- the reduction of fire load does not consider the physical mode of action of active fire measures,
- safety elements should not be applied to the fire load only but also to the development of heat release.

(4) Main features of an alternative approach taking account of this criticism would be:

- safety measures are considered in their mode of action
- object-specific boundary conditions may be directly taken into account, e.g.
  - distance to fire brigade
  - type of fire brigade
- partial factors are applied to the design effects
- partial factors consider
  - design target (ULS, smoke-management, SLS)
  - occupancy
  - evacuation (building height)
  - importance of building (e.g. parliament building, farm)

(5) Fig. 4-1 gives an example to compare the methods to develop natural fire-curves for an office building with $q_{fi,d}$ = 511 MJ/m^2:

Fire 1: No automatic fire detection, no alarm transmission

Fire 2: Automatic fire detection, alarm transmission

For Fire 1 and Fire 2: It takes 18 minutes from alarm to fire suppression by fire brigades.

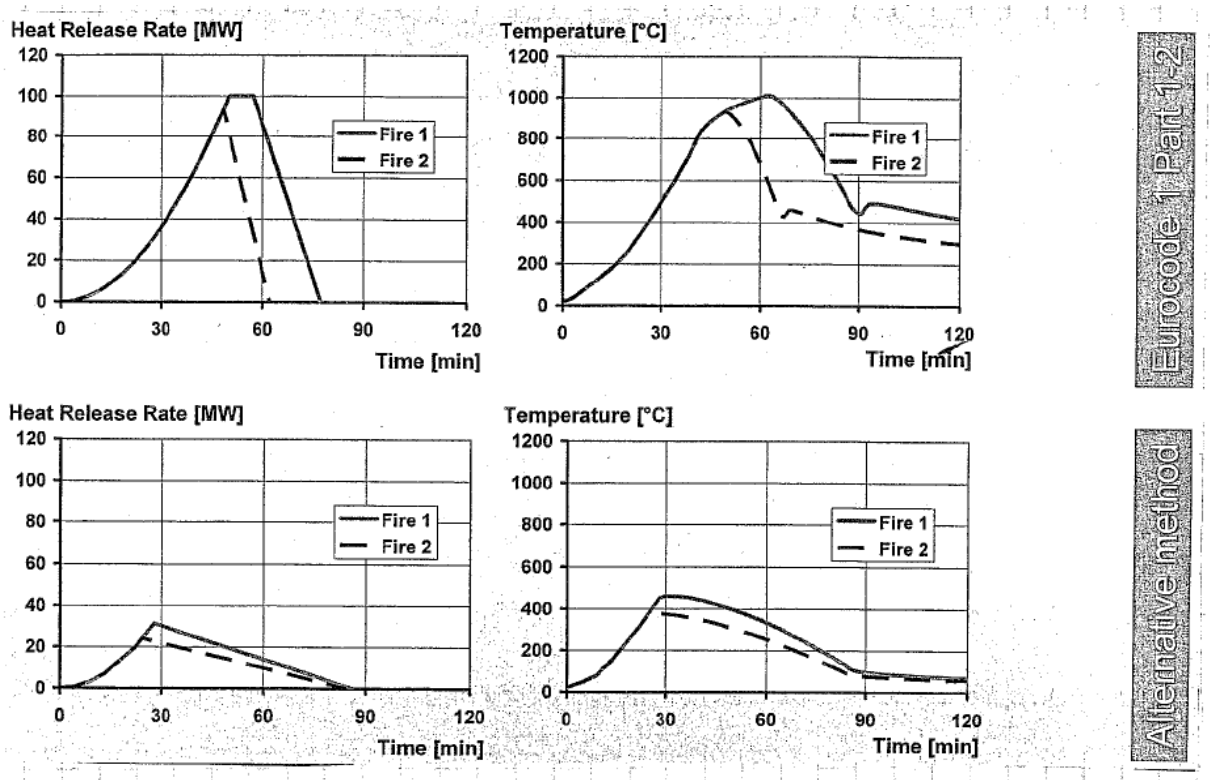

Fig. 4-1: Comparison of methods (EN 1991-1-2 and alternative method)

4.3 EN 1992-1-2 to EN 1999-1-2

(1) The fire parts of the Eurocodes provide 3 methods for the fire design

1. tabulated data
2. simple calculation methods
3. advanced calculation methods

where the method 1 is prepared for some materials, e.g. in EN 1992-1-2, whereas the methods 2 and 3 are prepared for all materials and type of construction.

(2) A particular emphasis in particular for the design of steel structures and composite structures is on method No. 3 to be implemented because it gives the most realistic procedure for safety and could be the basis for simplified more economical approaches.

(3) It is essential that method 3 (the “hot design” of structures) gets the same status as the “cold design” and that its use is not restricted to selected experts that anyway use any method suitable.

(4) Specific research and development needs for technical matters are related to

- consistency problems across the Eurocodes, see also “General”,
- satisfactory traceability and reproducibility of calculation in particular when using method 3,
- consistency of properties of structural products (e.g. protection materials, fire doors, etc.) determined from calculations with method 3 and determined from tests,
- consistency of properties of structural products as declared by the producers with the requirements for properties as needed when applying method 3 for structures,
- development of simplified approaches on the basis of method 3,
- filling of gaps as identified in practical use.

(5) For more details see “Survey on the progress in the National Implementation of the Eurocodes fire design Parts” prepared by the JRC.

Survey on the progress in the National implementation of the Eurocodes fire design Parts

Contents:

Executive Summary

The paper “Survey on the progress in the National implementation of the Eurocodes fire design Parts” is part of the report on the needs to achieve improved fire design using the Eurocodes, prepared by the Joint Research Centre (JRC) of the European Commission together with fire design experts in the frame of the activities on the Administrative Arrangement with DG ENTR on support to the implementation, harmonization and further development of the Eurocodes.

The document summarizes the results of the enquiry of all Member States (December 2007 – January 2008) on their needs related to the implementation of the fire design Eurocode parts with regard to:

- the progress in implementation of the Eurocodes fire design parts;
- specific and/or regulatory needs for adoption of National Standards implementing the Eurocodes fire design parts;
- research needs connected to the National implementation of the Eurocodes fire design parts;
- the advancement in the training and elaboration of guidelines and training materials on fire design.

The enquiry letter to the Eurocodes National Correspondents (ENC) Group, distributed at the ENC meeting on 22 November 2007 in Brussels in presented in Annex A.

Three National reports (Bulgaria, Finland and Netherlands) containing detailed proposals for research and/or further development of the Eurocodes fire design Parts are presented in Annex B, Annex C and Annex D of this document.

1. Introduction

This document is part of the report on the needs to achieve improved fire design using the Eurocodes, prepared by the Joint Research Centre (JRC) of the European Commission together with fire design experts in the frame of the activities on the Administrative Arrangement with DG ENTR on support to the implementation, harmonization and further development of the Eurocodes.

A meeting on implementation and use of the Eurocodes in the field of fire design was held on 4 June 2007 in Ispra (Italy), where were discussed:

- research and standardization needs in fire safety engineering related to performance-based fire design;
- the needs in the national implementation process of the Eurocodes fire design parts in eight Member States.

An action plan for preparation of material on the needs to achieve improved fire design guidelines in the EU was adopted, which envisaged an enquiry of all Member States on their needs related to the implementation of the fire design Eurocode parts. According to this decision a letter to the Eurocodes National Correspondents (ENC) Group has been prepared by the JRC (see Annex A) and distributed during the ENC meeting on 22 November 2007 in Brussels.

Member States were asked to present brief national reports (1-2 pages), prepared by the relevant National Authorities, focusing on:

- the progress in implementation of the Eurocodes fire design parts;
- specific problems, research and regulatory needs for adoption of National Standards implementing the Eurocodes fire design parts;
- advancement in training and elaboration of guidelines and training materials on fire design.

Twelve EU Member States and one EFTA Member State replied to the letter and sent National reports: Austria, Belgium, Bulgaria, Czech Republic, Finland, Germany, Italy, Lithuania, Netherlands, Poland, Portugal, Sweden and Norway.

The reports received are summarized in the present document and conclusions are drawn about the progress and needs in the National implementation of the Eurocodes fire design Parts. Three National reports (Bulgaria, Finland and Netherlands) containing detailed proposals for research and/or further development of the Eurocodes fire design Parts are presented in Annex B, Annex C and Annex D of this document.

2. Summary of the National reports

The National reports received are summarized in Table 1.

Table 1. Progress and needs in the National implementation of the Eurocodes fire design Parts

Country	Progress in implementation	Specific needs and regulatory issues	Research needs	Training
Austria	Published standards and NAs to: EN 1991-1-2, EN 1992-1-2, EN 1993-1-2, EN 1994-1-2, EN 1995-1-2, EN 1996-1-2 Under preparation: NA to EN 1999-1-2	To clarify the connection between the fire design of a structure according Eurocodes and the Fire classification of construction products and building elements according to EN 13501-2 (classification of results derived from tests).		In the last two years several training courses and seminars on fire design with Eurocodes have been carried out. More information (guidelines) would be helpful, especially having in mind that in 2010 the "old" Austrian classification system (F30, F60, F90 and F180) will be replaced by the "new" European system (REI).
Belgium	Finalized NAs to: EN 1991-1-2, EN 1992-1-2, EN 1993-1-2, EN 1994-1-2, EN 1995-1-2 NAs under preparation: EN 1996-1-2, EN 1999-1-2.	A Royal decree of 13 June 2007 is issued which modifies the Royal decree of 7 July 1994 fixing the Belgian fire regulation for new buildings. As soon as the Belgian National Annexes will be published by NBN as Belgian homologated standards (in Flemish and French, after a public inquiry), these standards are expected to be agreed officially by a decree of the Belgian Minister of the Interior, in execution of the Royal decree. A legal procedure is established by which the Eurocode parts "fire" will be agreed as calculation methods to support the classification by a certification body (accredited EN 45000) of the resistance to fire of building elements.		Training sessions (conferences) are periodically organized in Belgium, in Flemish and in French, since 2000 (approximately once a year).
Bulgaria	NAs under preparation: EN 1991-1-2, EN 1992-1-2, EN 1993-1-2, EN 1994-1-2, EN 1995-1-2, EN 1996-1-2,		Need to introduce analytical expressions for thermal properties of construction materials with fire protection ability (e.g. mineral wool and gypsum based plates) in order to carry out numerical thermal analysis of protected steel, composite and aluminum	University lecturing on rather specific structural fire design needs establishment of specialized departments which is hardly to be achieved in a short period due to lack of lecturers with the required qualification and fire design practice. For the moment lecturing on structural

Country	Progress in implementation	Specific needs and regulatory issues	Research needs	Training
	EN 1999-1-2		structures. Need for procedure to calculate the equivalent time of fire exposure for timber structures fire design, based on charring depth equality under the standard and a modelled natural fire exposure. A document on the research needs is attached as Annex B.	fire design is included in the programs of the University of Civil Engineering, Architecture and Geodesy (elective) and the University of Forestry (obligatory). Five books based on national and CEN standards on structural fire design, fire testing and post-fire investigation have been published recently.
Czech Republic	Published standards and NAs to EN 1991-1-2, EN 1992-1-2, EN 1993-1-2, EN 1994-1-2, EN 1995-1-2, EN 1996-1-2 Under preparation: NA to EN 1999-1-2	The Proceeding solution of project procedure on fire effects was processed by the new regulation „ Public Notice about the Technical Conditions of the Fire Protection".		Czech Technical University in Prague in co-operation with Ministry of Interior-General Directorate of Fire Rescue Service of the Czech Republic worked up a publication of „Calculation of Fire Resistance of Buildings". Czech Technical University in Prague is annually organizing seminars on the practical use of Eurocodes within the education of engineers. In the year 2007, 100 members of building fire prevention within Fire and Rescue Service of the Czech Republic were trained in case of the project construction procedure on fire effects.
Finland	Published standards and NAs to: EN 1991-1-2, EN 1992-1-2, EN 1993-1-2, EN 1994-1-2, EN 1995-1-2 Standards and NAs to: EN 1996-1-2, EN 1999-1-2	Consistency between different fire design parts needs improvement. For example strain hardening and maximum strains up to 2 % are allowed for structural steel in EN 1993-1-2 and EN 1994-1-2, see e.g. Annex A in EN 1994-1-2. However, According to EN 1992-1-2 strain hardening is not allowed to be taken into account for reinforcing steel. In addition strains up to 2 % are only allowed if it is checked that this steel strain can be achieved before other failure modes. The same level of checking and reliability should be required for all types of structures.	The list with the research needs is presented in the Finnish National report attached as Annex C.	Finnish Eurocodes Help Desk has been created to distribute information on the Eurocodes. All relevant information on the Eurocodes is given there. Web-pages are updated weekly. See www.eurocodes.fi Fire parts are presented in seminars on the Eurocodes for practicing engineers. Fire parts are also included in the education programmers of the

Country	Progress in implementation	Specific needs and regulatory issues	Research needs	Training
	will be published by the end of 2008.	Deformation criterion is the same in all fire parts, see e.g. principle rule (3)P and application rule (4) in clause 2.1.1 of EN 1992-1-2, but the wording is very unclear and hardly understandable even for fire specialists. More comments are given in the Finnish National report attached as Annex C.		universities. VTT has organized an E-learning course on fire safety engineering. There are also guidance booklets in preparation.
Germany	NAs prepared but not yet published: EN 1992-1-2, EN 1993-1-2, EN 1994-1-2, EN 1995-1-2. NAs under preparation: EN 1991-1-2, EN 1999-1-2.	There are some problems to be solved concerning National Annex of EN 1991-1-2. Germany is preparing a national solution in order to replace or correct the informative Annex E.	Currently research work is done on the safety concept, natural fires and the influence of active fire fighting measures on the developing of natural fires (Annex E of EN 1991-1-2). The research shows that the models presented in the Annex mentioned above are inconsistent.	Special trainings and seminars for planners and checking engineers are planned to be held in this year. There are also several publications in German concerning the background and the application of the fire parts of the Eurocodes. It is planned to implement the Eurocodes in Germany in 2010.
Italy	NAs approved: EN 1991-1-2, EN 1992-1-2, EN 1993-1-2, EN 1994-1-2 are, NAs under preparation: EN 1995-1-2, EN 1996-1-2, EN 1999-1-2	The already approved National Annexes have not yet been issued so for buildings including occupancies subject to National Fire Brigade's approval, the use of Eurocodes for structural members fire resistance verification (according to Ministerial Decree 16/02/2007) is exclusively allowed for EN 1992-1-2, EN 1993-1-2, EN 1994-1-2 and EN 1995-1-2, where, the recommended values of NDPs are adopted until the publication of the relevant National Annexes. Concerning all the other buildings, the issue of the revised text of the Ministerial Decree 14/09/2005: "Technical Standards for constructions" is expected.	The issue of the National Annex of EN 1996-1-2 has required a further experimental investigation whose duration, up till now, has not been decided.	There are no official training programmes or training materials available on Eurocodes.
Lithuania	Published standard and NA to: EN 1991-1-2 NAs to: EN 1992-1-2, EN 1993-1-2, EN 1994-1-2, 1995-1-2,	Growing quantity of CEN standards leads to contradiction between each other's (for example steel elements fire resistance determination principles in Eurocode 3. EN 1993-1-2 Design of Steel Structures. General Rules Structural Fire Design and EN 13381 part 1 to 4:" Test methods for determining the contribution to the fire resistance of structural members " are different); Each separate small country as we are doesn't have enough		Education on fire safety engineering discipline is available in Vilnius Gediminas technical university.

Country	Progress in implementation	Specific needs and regulatory issues	Research needs	Training
	EN 1996-1-2 are expected to be published in 2008, NA to: EN 1999-1-2 is expected to be published in 2009.	resources to establish national performance based codes (seems it's common case in Europe, as is presented in BeneFEU project); therefore we need some model standard with national annexes. There is a permanent need for consultations regarding the issues of application and implementation of European standards and it is very important to know where to apply to get the official explanations.		
Netherlands	no information given		The Netherlands have taken steps to promote the use of the natural fire concept through the development of a zone model described in their National Annex to EN 1991-1-2. The results are presented in a document attached as Annex D.	
Norway	no information given	In EN 1991-1-2 the use of Annex E is allowed on the condition that in Table E2 only a factor of 0,6 in case of Automatic Water Extinguishing System is used while all other factors in that table are 1,0. The principles of Annex E are also in the present standard, but with no values given for the various methods of fire fighting, just a recommendation that they should be taken at unity unless otherwise documented. The "New Approach" principles have been employed in Norway since many years, as a consequence the Norwegian Fire Regulations are dealing with the Fire Safety as it relates to all other matters than structural strength, while referring to Norwegian Standards for the structural design aspects. These general matters that are not part of the Eurocode system will have to be maintained until such time that the "Eurocode-concept" will be extended to cover "all 6-Essential Requirements" or at least also ER2.		
Poland	Published standards and NAs to: EN 1991-1-2, EN 1993-1-2		The following problems in the process of current implementation of fire design parts of the Eurocodes need additional	The training system on fire design is not yet in order and consists generally of incidental workshops prepared mainly for designers. Expected changes in

Country	Progress in implementation	Specific needs and regulatory issues	Research needs	Training
	Standards and NAs under preparation: EN 1992-1-2, EN 1994-1-2, EN 1995-1-2, EN 1996-1-2, EN 1999-1-2.		research program supported by the Commission: EN 1992-1-2: the data concerning hollow core slabs are not in agreement with test results. Also methods for assessment of fire protection may be doubtful. EN 1993-1-2: the mechanical properties of the steel differ from the former test results. EN 1995-1-2: the data concerning gypsum plasterboards cases may be doubtful. EN 1996-1-2: The tabulated data method given in the Normative Annex should be verified and developed (some of the values are doubtful, in many cells no values are given).	educational system should be introduced widely at technical universities construction faculties.
Portugal	NAs under preparation: EN 1991-1-2, EN 1992-1-2, EN 1993-1-2, EN 1994-1-2, EN 1995-1-2, EN 1996-1-2, EN 1999-1-2.	There is still a lack of knowledge to ensure that numerical simulations performed by using advanced calculation methods are accurate enough. This is the reason why the Portuguese National Annexes of the Eurocodes fire parts allow the use of such advanced calculation methods only by experts. The Portuguese designers should be trained for the use of such advanced tools as well as for the use of more general performance-based approaches for assessing the risk of collapse of an entire building under fire situation.		Several Universities and Institutions (Technical University of Lisboan, University of Aveiro, University of Coimbra, LNEC and University of Porto), have been teaching the subject in optional courses. Short courses on structural fire design have been organized. The relevant Portuguese Authorities are expected to organize training courses for the designers after the approval of the Portuguese versions of the Eurocodes and the National Annexes. The book on fire design of steel structures edited in 2003 should now be

Country	Progress in implementation	Specific needs and regulatory issues	Research needs	Training
				updated according the EN versions of the Eurocodes. A new version of the software Elefir, called Elefir-EN, for fire design of structural steel elements jointly developed by the University of Aveiro and the University of Liege will be ready in 2008.
Sweden	Implemented: EN 1991-1-2. Ready for notification: EN 1992-1-2 Ready for notification by the end of February 2008: EN 1993-1-2, EN 1994-1-2, EN 1995-1-2, EN 1999-1-2.	For EN 1991-1-2 there have been many discussions and more work and a revision of the NDPs for use in Sweden will be probably needed.		The training part has not yet started and will probably not start before second half of 2008.

3. Conclusions

On the basis of the National reports presented, the advance and needs of the EU and EFTA Member States can be summarized as follows:

1. Progress in implementation of the Eurocodes fire design parts:

- no problems with the progress in implementation of the Eurocodes fire design parts have been reported,
- no country has published yet the complete set of National Annexes on the Eurocodes fire design parts. This is normal, since the Date of availability of EN 1999-1-2 was February 2007. First complete sets of National Annexes are expected by the end of 2008.

2. Specific and/or regulatory needs for adoption of National Standards implementing the Eurocodes fire design parts: there are no regulatory or other country specific barriers to the implementation of the Eurocodes fire design parts. Some countries have solved already their specific problems as follows:

- Belgium: modification of the Royal decree fixing the Belgian fire regulation for new buildings; a legal procedure by which the Eurocode parts "fire" will be agreed as calculation methods to support the classification by a certification body on the resistance of building elements to fire.
- Czech Republic: new regulation „Public Notice about the Technical Conditions of the Fire Protection".
- Italy: the use of Eurocodes for structural members fire resistance verification (according to Ministerial Decree 16/02/2007) is exclusively allowed for EN 1992-1-2, EN 1993-1-2, EN 1994-1-2 and EN 1995-1-2, where, the recommended values of NDPs are adopted until the publication of the relevant National Annexes.
- Norway: the Fire Safety relates to all other matters than structural strength, while referring to Norwegian Standards for the structural design aspects. Since these general matters are no part of the Eurocode system, they should be maintained until the time when the "Eurocode-concept" will be extended to cover "all 6-Essential Requirements" or at least also ER2.
- Portugal: the Portuguese National Annexes of the Eurocodes fire parts allow use of advanced calculation methods only by experts.

3. Research needs connected to the National implementation of the Eurocodes fire design parts:

- research needs for the current national implementation of the Eurocodes
  - Germany: The research work on the safety concept, natural fires and the influence of active fire fighting measures on the developing of natural fires (Annex E of EN 1991-1-2) shows that the models presented are inconsistent. Germany is preparing a national solution in order to replace or correct the informative Annex E.
  - Italy: further experimental investigation needed for the issue of the National Annex to EN 1996-1-2.

  - Lithuania: consultations regarding the issues of application and implementation of European standards are needed and it is very important to know where to apply for official explanations.
  - Netherlands development of a zone model described in the National Annex to EN 1991-1-2.
- research needs for further improvement of Eurocodes fire design parts:
  - Bulgaria: analytical expressions for thermal properties of construction materials with fire protection ability are needed for numerical thermal analysis of protected steel, composite and aluminum structures.
  - Finland: Consistency between different fire design parts should be improved (e.g. strain hardening and maximum strains for steel in EN 1992-1-2, EN 1993-1-2 and EN 1994-1-2), deformation criterion in EN 1992-1-2 needs better definition. The needs for further research on the different Eurocodes Parts are considered in detail. The proposal is taken into account in the definition of the research needs to achieve improved fire design using the Eurocodes.
  - Poland: need of further verification of mechanical properties and other data in EN 1992-1-2, EN 1993-1-2, EN 1995-1-2 and EN 1996-1-2.

4. Advancement in the training and elaboration of guidelines and training materials on fire design:
   - while education programmes on structural fire design are available in the Universities, in almost half of the countries the training of designers has still not begun,
   - many countries have or are preparing books and guidelines on fire design using the Eurocodes,
   - E-learning courses on fire safety engineering would be very useful for training,
   - the results of DIFISEK+ (DIssemination of structural FIre Safety Engineering Knowledge throughout Europe) project are expected to contribute substantially the education and training and their visibility at EU level should be facilitated.

Annexes

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE
Institute for the Protection and the Security of the Citizen
European Laboratory for Structural Assessment

Ispra, 20 November 2007
G05/MG 19-20/11

To the Eurocodes National Correspondents Group

Subject: Needs of the Member States to achieve improved fire design using the Eurocodes

Dear Sir/Madame,

In the frame of the activities on the Administrative Arrangement with DG ENTERPRISE on support to the implementation, harmonization and further development of the Eurocodes, the Joint Research Centre (JRC) of the European Commission together with fire design experts is preparing report on the needs to achieve improved fire design using the Eurocodes.

A meeting on implementation and use of the Eurocodes in the field of fire design was held on 4th of June, 2007 in Ispra (Italy), where the needs in the national implementation process of the Eurocodes fire design parts in eight Member States were discussed. Research and standardization needs in fire safety engineering related to performance-based fire design were also addressed.

An action plan for preparation of material on the needs to achieve improved fire design guidelines in the EU was adopted. It will be contributed by two ad-hoc-groups created at the Meeting, which will concentrate on:

- national implementation and use of the Eurocodes fire design parts (convener: G. Sedlacek), and,
- research and standardization needs for improved fire protection (convener: J. Kruppa).

The minutes and the presentations at the Meeting are available for download at:

http://elsad.jrc.it/

folder ID: AF-132F

I-21020 Ispra (Varese) – Italy - Office: TP 480
Telephone: direct line secretariat (+39)0332-78-9989. Fax: (+39)0332-78-9049

e-mail: michel.geradin@jrc.it

The ad-hock group on national implementation and use of the Eurocodes fire design parts will deliver at the end of January 2008 a document on the needs of the Member States to achieve improved fire design using the Eurocodes. The document will subsequently be submitted to DG ENTR, DG RTD and to the relevant European Technology Platforms.

Our aim is to reflect in the document the needs of all Member States in the implementation and use of the Eurocodes fire design parts. To this purpose we are collecting brief national reports (1-2 pages), prepared by the relevant National Authorities. They should focus on:

- the progress in implementation of the Eurocodes fire design parts;
- specific problems, research and regulatory needs for adoption of National Standards implementing the Eurocodes fire design parts;
- advancement in training and elaboration of guidelines and training materials on fire design.

The reports should be sent to our colleague Dr. Silvia Dimova, e-mail silvia.dimova@jrc.it, by the end of December 2007.

Please convey this letter to your National Authorities responsible for the implementation of the Eurocodes fire design parts in order to facilitate the presentation of the needs of your Member State in the report.

Thank you in advance for the follow-up and collaboration.

Best regards,

Michel Géradin

Head, ELSA Unit

Republic of Bulgaria

a) Progress in implementation of the Eurocodes fire design parts.

For the moment in Bulgaria are introduced the fire design parts of:
- EN 1991;
- EN 1992;
- EN 1993;
- EN 1994;
- EN 1995;
- EN 1996.

b) specific problems, research and regulatory needs for adoption of National Standards implementing the Eurocodes fire design parts.

A specific national problem is the need to introduce analytical expressions for thermal properties of construction materials with fire protection ability (e.g. mineral wool and gypsum based plates) in order to carry out numerical thermal analysis of protected steel, composite and aluminum structures.

c) Advancement in training and elaboration of guidelines and training materials on fire design

University lecturing on the rather specific structural fire design needs establishment of specialized departments which is hardly to be achieved in a short period due to lack of lecturers with the required qualification and fire design practice.

For the moment lecturing on structural fire design is included in the programs of the University of Civil Engineering, Architecture and Geodesy (elective) and the University of Forestry (obligatory).

Existing training materials (books based on national and CEN standards) on structural fire design, fire testing and post-fire investigation, (author prof. K. Delev):
- Structural fire design according to the Eurocodes, 123 pages (1997);
- Fire resistance and fire protection of building structures, 185 pages (2000);
- Fire resistance testing of building structures, 136 pages (2002);
- Timber structures – design and evaluation for fire situation, 188 pages (2004),

Also a lot of articles/papers by Bulgarian scientists in the field are published in national and foreign magazines/proceedings.

Concerning the research and standardization needs for improved fire protection we dare present an idea for equivalent fire exposure for timber structure fire design, developed in Bulgaria (see the attached file with the paper “Equivalent fire exposure for timber structure design”).

MODERN BUILDING MATERIALS, STRUCTURES AND TECHNIQUES

May 19-21, 2004
The 8th International Conference
Faculty of civil Engineering,
Vilnius Gediminas Technical University
Saulėtekio al. 11, 10223 Vilnius-40, Lithuania
Tel.: +370 5 2745243; Fax.: +370 5 2745016; e-mail: stakon@konf.vtu.lt

EQUIVALENT FIRE EXPOSURE FOR TIMBER STRUCTURE DESIGN

Konstantin Delev

University of Forestry, 10 Climent Ohridski St., 1756 Sofia, Bulgaria,
E-mail: kdelev@ltu.bg; kdelev@abv.bg

Abstract. Required fire resistance periods for structural members are normalized for the ISO 834 standard temperature-time curve heating conditions. Structural fire design on the ground of parametrically modeled natural fire requires a comparison of the calculated (predicted|) fire resistance and the equivalent time of fire exposure regarded to ISO 834 curve.. The paper presents a procedure to calculate the equivalent time of fire exposure specifically for timber structure fire design, based on charring depth equality under the standard and a modeled natural fire exposure.

Keywords: compartment fire; charring depth; natural fire exposure

1. Introduction

The analysis of building structures for natural fire action grounds determination of the equivalent time of standard fire exposure in order to carry out a comparison between the normalized and the design fire resistance.

For the moment the prEN 1995-1-2 standard does not states a procedure to calculate the equivalent time of fire exposure, so the paper presents an attempt in this field.

From view-point of physics it is most grounded to calculate the equivalent time of fire exposure by the principle of temperature-time superposition of material damage.

An individual timber member with specified geometry, orientation in space and area of the exposed surface attains fire resistance under the standard or under a modeled natural fire action at the same charring depth (same dimensions of the effective cross-section), but at a different time. Thus for timber structure fire design or post-fire analysis the equivalent time of fire exposure can be expressed as the time period, necessary to attain under the standard exposure the same char depth as under natural fire action.

2. Calculation model

Charring depth $d_{char,s}$ for softwood under the standard exposure is taken as:

$$d_{char,s} = \beta_s . t \qquad (1)$$

where

β_s is the constant charring rate,

t - time period.

For a maximum design duration $t=3t_o$ of the charring process under a modeled natural fire exposure [4], the charring depth $d_{char,n}$ is calculated as:

$$d_{char,n}(3t_o) = 2.\beta_{\max,n}.t_o \qquad (2)$$

where

$\beta_{\max,n}$ is the maximum possible charring rate for an individual compartment;

t_o - duration of the natural fire heating phase.

The theoretic equivalent time of fire exposure $t_{e,d}$ is defined by the time period t, regarded since the beginning of the standard fire, when is satisfied the condition:

$$d_{char,s} = d_{char}(3t_o) \qquad (3)$$

Or after substitution of equations (1) and (2) into (3) and introducing $t=t_{e,d}$

$$\beta_s \, t_{e,d} = 2\beta_{\max,n} \, t_o \qquad (4)$$

And

$$t_{e,d} = 2\beta_{\max,n} \, t_o \,/\, \beta_s \qquad (5)$$

Accordingly to the requirements of the prEN 1995-1-2 standard, timber structure mechanical analysis for fire situation obligatory follows the restrictions $d_{char,n} \le 0,25b$ or $d_{char,n} \le 0,25h$ for $b \ge 13$ cm (b and h – width and depth of the cross-section). So the actual equivalent time of fire exposure usually is shorter than the theoretic.

The formula to calculate the actual equivalent time of fire exposure is:

$$t_{e,d} = d_{char,n}(t_{fi,d}) / \beta_s \qquad (6)$$

where $t_{fi,d}$ is the design fire resistance (natural fire exposure).

The verification for performance-based structural fire design is:

$$t_{fi,d} \supseteq t_{e,d} \qquad (7)$$

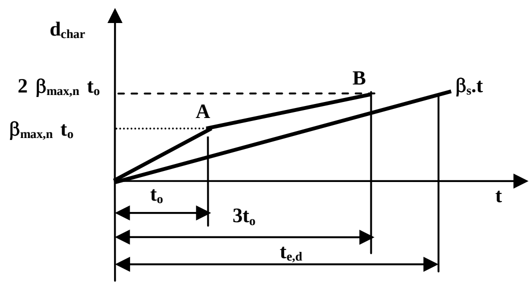

Fig. 1. Theoretic equivalent time of fire exposure for timber structure fire design. Point A – end of charring at constant rate; point B – end of charring (natural fire)

A purposely composed PC program is used to carry out technical calculations for performance-based structural fire design depending on the stress state and taking into account the equivalent time of fire exposure.

3. Conclusion

The proposed procedure is to be applied for:

- a) classification by fire rating (initial design or verification of existing unprotected or isolated by cellulose materials timber structures);
- b) calculation of the equivalent time of fire exposure in post-fire building investigation.

References

1. prEN 1995-1-2.
2. Delev K. Timber structures – design and assessment for fire situation. (Дървени строителни конструкции – проектиране и оценка за пожарно състояние). Sofia: ABC Technica, 2004, 188 p. (in Bulgarian).

9.1.2008

National Report: Finland

Subject: Needs of the Member States to achieve improved fire design using the Eurocodes (November 20th, 2007)

As the Finnish contribution to the abovementioned enquiry I will send this national report which is based on the work done by Mr. Esko Mikkola.

1. The progress in the implementation of the Eurocodes fire design parts

The first package of National Annexes came into force 1.11.2007 in Finland. See attached the summary of the Finnish implementation. Many normal buildings can be designed by using these 18 National Annexes. The 18 parts include also fire parts EN 1991-1-2; EN 1992-1-2; EN 1993-1-2; EN 1994-1-2 and EN 1995-1-2. Unofficial translations of the National Annexes of EN 1991-1-2; EN 1992-1-2 and EN 1994-1-2 are attached. I will send the translations of the other National Annexes in near future.

The rest of National Annexes will be elaborated during 2008. I will send unofficial English translations when they are ready.

According to our plan after April 2010, the only official way to design will be by using EN-Eurocodes. National design building codes will expire on the same date.

2. Specific problems, research and regulatory needs for adoption of National Standards implementing the Eurocodes fire design parts

Background documents have not been prepared for all fire design parts. This is causing difficulties in the preparation of National Annexes and will lead to different national interpretations. Background documents shall be elaborated for all parts and also for future amendments.

International harmonisation of requirements at European level is needed (for the moment are quite big differences in the fire requirements in various countries). The target should be that there is no need for NDPs and thus for National Annexes in any Eurocodes fire design parts. The clear programme for this target should be elaborated. The programme should be discussed at ENC and possibly at SCC meeting.

Some years ago so called BeneFEU-report was prepared for the Commission. This report presents many good ideas for future R&D-needs at European level. BeneFEU-report is general, not related to any material. But we consider that the first priority is to improve resistance to fire classification. Fire safety engineering belongs to CEN/TC 127.

Consistency between different fire design parts needs improvement. For example strain hardening and maximum strains up to 2 % are allowed for structural steel in EN 1993-1-2 and EN 1994-1-2, see e.g. Annex A in EN 1994-1-2. However, According to EN 1992-1-2 strain hardening is not allowed to be taken into account for reinforcing steel. In addition strains up to 2 % are only allowed if it is checked that this steel strain can be achieved before other failure modes. The same level of checking and reliability should be required for all types of structures.

Deformation criterion is the same in all fire parts, see e.g. principle rule (3)P and application rule (4) in clause 2.1.1 of EN 1992-1-2, but the wording is very unclear and hardly understandable even for fire specialists. Deformation as such is normally not critical for the load-bearing function of a single member, but it may have big influence due to interaction in the structure.

Actions on structures exposed to fire (EN 1991-1-2)

Problems

- Contents of Annex E

Reduction of fire load densities according to Annex E is not acceptable because it allows open interpretations. In addition background documentation is not available. Values given are not in line with new data and knowledge and all models need to be checked and justified.

Research needs

- Annex E needs to be revised based on the latest data and statistics
- Overall review to check concepts and formulas used

Generally, all fire models in EN 1991-1-2 should be checked and justified and their field of application should be defined more precisely. A more clear distinction between the most common way of design by using standard fire curve (resistance to fire classification) and parametric fire should be made.

Structural fire design - Concrete structures (EN 1992-1-2)

Problems

- Tabulated data method B for columns is not user friendly. Methods A and B should be combined to one method only.

Research needs

- High strength concrete structures need more precise rules. Now they are completely open for national choices.
- Differences between Class N and X for reinforcing steel properties are very small. The strength values in these classes should be checked and need of two classes evaluated. The two classes for prestressing steel, A and B, should be combined.

Structural fire design - Steel structures (EN 1993-1-2)

Comments, problems and needs:

- M-N interaction in case of fire, validity of the M-N-interaction rules given in EN 1993-1-1 also for fire.
    - Present rules for M-N-interaction given in EN 1993-1-2 are based on M-N-interaction rules given in ENV 1993-1-1 for normal temperature. The available test results should be re-analysed by using M-N-interaction rules given in EN 1993-1-1 in order to check if these M-N-interaction rules could be done also for elevated temperatures.
- Joints in fire.
    - Validity of the component method of EN 1993-1-8 also in the case of fire. It should be checked, if this model works also in the case of fire. Note: Some

European projects are already going on in this area. However more R&D-work is needed in the future.

- Adding of mechanical properties of some stainless steel grades at elevated temperatures.
    - For steel grades 1.4318, 1.4318 C850 and 1.4571 C850 the values at elevated temperatures are given in the publication "Euro Inox: Design Manual for Structural Stainless Steel, Third Edition, Brussel 2006." These values are based on European R&D-projects.
- Design of various hybrid profiles in case of fire. Hybrid profiles may consist of different steel grades (mild steel, stainless steel, fire resistance steel, etc.) in flanges and webs.
- Mechanical properties of steel grades S500….S700 at elevated temperatures. At the moment quite few public test results, if any, are available.
- Mechanical properties for weathering steels at elevated temperatures. However, the amount of tests results on the mechanical properties at elevated temperatures are quite limited for weathering steels.
- European standard for fire resistant steels is missing, but it would be very useful to have data on mechanical properties for various types of fire resistant steels.
- Into the clause 2.1.3 of EN 1993-1-2 detailed rules for parametric fire should be added as in other material related Eurocodes. These rules are not dependent on material.
- Some specific issues in cold-formed structures, like fire behaviour of joints, mechanical properties of high strength steels (S500…S700) at elevated temperatures
- Fire protected members and acceptable strains.
    - Fire protected members and the acceptable strains (the correct values of mechanical properties of steel at elevated temperatures for fire-protected steel structures (that is: applicability of 2 % strains (or some other lower strain limits) for various fire insulation materials)).
    - At the moment European standards (Eurocode 3 and related testing standards) do not give clear answer as to how large strain are allowed in fire insulation materials, if the test pieces pass the tests given in the standards.

Structural fire design - Composite steel and concrete structures (EN 1994-1-2)

Comments, problems and needs:

Further harmonization between Parts 1-1 and 1-2:
The fire part EN 1994-1-2 is not in harmony with EN 1994-1-1 and even with EN 1993-1-2 and 1992-1-2 in several aspects:

- Notations in EN 1994-1-2 are based on old background employed by ARBED (now ARCELOR), and they were not updated according to general principles agreed in the horizontal group 'Fire'. In the Finnish comments the harmonization was requested time and again, but without success. As an example, if a certain notation is employed in EN 1994-1-1 for strengths in normal temperature design, the similar values in EN 1994-1-2 should be notated similarly.

- In ENV 1994-1-1 certain types of the slim floor structures were excluded from scope, as it was not possible to get common rules for their design. In EN 1994-1-1 the scope was opened, but still there are no specific rules, but only general principles which can be interpreted to mean that slim floor structures are in the scope. However, in ENV 1994-1-2 slim floor structures are included in the scope, but only due to a single figure that illustrates a general principle of a slim floor member. The slim floor members are favored due to their inborn fire resistance, but this doesn't mean that there should not be any rules for the design.

In EN 1994-1-2 the figure of ENV 1994-1-2 referred to is further given as Fig. 1.4. Nothing more is given on the slim or shallow floor structures.

- EN 1994-1-2 includes bewildering set of clauses for the design of composite columns. It first gives an idea that all the types of the composite column are treated in the same way, i.e. that the design may be carried out using methods based on secant stiffness, which is OK and also the general principles in carrying out the design accordingly are given. However, in the subsequent clauses for various types of the column it is revealed that support for the general principles is not given for all types, and a totally different method is released for concrete filled steel hollow section columns in Annex H. Furthermore, the method of Annex H is known to be unconservative and unstable.
- Design rules for concrete filled stainless steel hollow section columns should be developed, but these should accord with the rules for the respective columns of normal structural steel hollow sections, which should be amended first.
- French research published in the CIDECT report "Improvement and Extension of the Simple Calculation Method for Fire Resistance of Unprotected Concrete Filled Hollow Columns" (CIDECT 15Q 12/03/1999) forms a good basis and should be considered when amending EN 1994-1-2. For the moment there is a situation where data from Annex G is used for concrete filled hollow section columns, when there are no specific data for them available.

Structural fire design - Timber structures (EN 1995-1-2)

Problems

- Calculation method of Annex C
  - Definition of $k_{mod,fi}$ factors
  - Use of R90 structures
  - Use for partly insulated cavities
- Calculation methods of Annex C and D should be consistent

Research and actions needed

- Solving problems given above
- Simple and easy to use calculation methods
- Methods for connections
- Quality differences of gypsum boards; effects to methods
- Development of the informative Annexes to reach acceptance on normative level
- Fire retardant treated timber/long term performance

Structural fire design – Masonry structures (EN 1996-1-2)

Problems

- Recommended values given in Normative Annex B are not always logical.
- Simplified calculation method given in informative Annex C is not correct (may be unsafe) for slender masonry walls.

Research and actions needed

- More fire tests for different kind of masonry walls based on new EN-standards
- National values of classes shall not be allowed as NDPs
- New simplified calculation method should be developed.

3. Advancement in training and elaborating of guidelines and training materials on fire design

Finnish Eurocodes Help Desk has been created to distribute information on the Eurocodes. All relevant information on the Eurocodes is given there. Web-pages are updated weekly. See www.eurocodes.fi

Fire parts are presented in seminars of the Eurocodes for practicing engineers. Fire parts are also included in the education programmers of the universities.

VTT has organized an E-learning course on fire safety engineering. See www.vtt.fi/proj/fise (mainly in Finnish)

- User name: fise-reader
- Password: June1906

There are also guidance booklets in preparation.

4. Concluding remarks

The main focus of the work should be on resistance to fire classification (REI) which also supports the CE-marking of construction products, not fire safety engineering. It also gives safe results and flexibility for later alternations in the buildings. According to our understanding calculations using the Eurocodes fire parts in order to show compliance with European resistance to fire classes are not fire safety engineering.

However, especially concerning steel and timber structures, the development of natural fire design methods and their more advanced inclusion in the design standards is of great importance. This does not belong to our first priorities.

It would be useful to collect a database on real fires, especially on cases where structures have collapsed or resisted fully developed fire. Analyzes of the practical fires by using fire safety engineering methods and also fire calculation methods of the Eurocodes would be beneficial. This would give valuable information for developing safe fire design methods.

Further development/extension of methods for all fire protection materials/products is needed.

Parametric fires are suitable for specific applications and high risk cases e.g. sport arenas and large commercial buildings.

There are some inconsistencies between different Eurocodes fire parts. These should be solved.

There is also a need for further harmonisation. I refer to the letter of Mr. Virtanen "Further development of the Eurocodes dated November 14th, 2007. The target should be that there is no need for NDPs and thus for National Annexes in any Eurocodes fire design parts. Today same interpretation of European fire classes is achieved by using fire testing but not by using calculations of the Eurocodes fire design parts. This is not acceptable on a long run.

The target of no National Annexes for fire design parts is very demanding and means a lot of work. The work programme needed should be elaborated and discussed at ENC and possibly at SCC meeting.

Matti J. Virtanen
Member of Eurocodes National Correspondents Group