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Eurokod 2: Dimensionering av betongkonstruktioner – Del 1-2: Allmänna regler – Brandteknisk dimensionering

Eurocode 2: Design of concrete structures – Part 1-2: General rules – Structural fire design

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 1992-1-2

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Supersedes ENV 1992-1-2:1995

English version

Eurocode 2: Design of concrete structures - Part 1-2: General rules - Structural fire design

Eurocode 2: Calcul des structures en béton - Partie 1-2: Règles générales - Calcul du comportement au feu

Eurocode 2: Planung von Stahlbeton- und Spannbetontragwerken - Teil 1-2: Allgemeine Regeln - Tragwerksbemessung für den Brandfall

This European Standard was approved by CEN on 8 July 2004.

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Contents List

Informative annexes

A Temperature profiles

B Simplified calculation methods

C Buckling of columns under fire conditions

D Calculation methods for shear, torsion and anchorage

E Simplified calculation method for beams and slabs

Foreword

This European Standard EN 1992-1-2 , “Design of concrete structures - Part 1-2 General rules - Structural fire design", has been prepared by Technical Committee CEN/TC250 ”Structural Eurocodes”, the Secretariat of which is held by BSI. CEN/TC250 is responsible for all Structural Eurocodes.

This European Standard shall be given the status of a National Standard, either by publication of an identical text or by endorsement, at the latest by June 2005, and conflicting National Standards shall be withdrawn at latest by March 2010.

This European standard supersedes ENV 1992-1-2: 1995.

According to the CEN-CENELEC Internal Regulations, the National Standard Organisations of the following countries are bound to implement these European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Background of the Eurocode programme

In 1975, the Commission of the European Community decided on an action programme in the field of construction, based on article 95 of the Treaty. The objective of the programme was the elimination of technical obstacles to trade and the harmonisation of technical specifications.

Within this action programme, the Commission took the initiative to establish a set of harmonised technical rules for the design of construction works which, in a first stage, would serve as an alternative to the national rules in force in the Member States and, ultimately, would replace them.

For fifteen years, the Commission, with the help of a Steering Committee with Representatives of Member States, conducted the development of the Eurocodes programme, which led to the first generation of European codes in the 1980s.

In 1989, the Commission and the Member States of the EU and EFTA decided, on the basis of an agreement[1] between the Commission and CEN, to transfer the preparation and the

[1] Agreement between the Commission of the European Communities and the European Committee for Standardisation (CEN) concerning the work on EUROCODES for the design of building and civil engineering works (BC/CEN/03/89).

publication of the Eurocodes to the CEN through a series of Mandates, in order to provide them with a future status of European Standard (EN). This links *de facto* the Eurocodes with the provisions of all the Council's Directives and/or Commission's Decisions dealing with European standards (e.g. the Council Directive 89/106/EEC on construction products - CPD - and Council Directives 93/37/EEC, 92/50/EEC and 89/440/EEC on public works and services and equivalent EFTA Directives initiated in pursuit of setting up the internal market).

The Structural Eurocode programme comprises the following standards generally consisting of a number of Parts:

EN 1990	Eurocode:	Basis of Structural Design
EN 1991	Eurocode 1:	Actions on structures
EN 1992	Eurocode 2:	Design of concrete structures
EN 1993	Eurocode 3:	Design of steel structures
EN 1994	Eurocode 4:	Design of composite steel and concrete structures
EN 1995	Eurocode 5:	Design of timber structures
EN 1996	Eurocode 6:	Design of masonry structures
EN 1997	Eurocode 7:	Geotechnical design
EN 1998	Eurocode 8:	Design of structures for earthquake resistance
EN 1999	Eurocode 9:	Design of aluminium structures

Eurocode standards recognise the responsibility of regulatory authorities in each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level where these continue to vary from State to State.

Status and field of application of Eurocodes

The Member States of the EU and EFTA recognise that Eurocodes serve as reference documents for the following purposes :

– as a means to prove compliance of building and civil engineering works with the essential requirements of Council Directive 89/106/EEC, particularly Essential Requirement N°1 – Mechanical resistance and stability – and Essential Requirement N°2 – Safety in case of fire ;

– as a basis for specifying contracts for construction works and related engineering services ;

– as a framework for drawing up harmonised technical specifications for construction products (ENs and ETAs)

The Eurocodes, as far as they concern the construction works themselves, have a direct relationship with the Interpretative Documents2 referred to in Article 12 of the CPD, although they are of a different nature from harmonised product standards3. Therefore, technical aspects arising from the Eurocodes work need to be adequately considered by CEN Technical

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[2] According to Art. 3.3 of the CPD, the essential requirements (ERs) shall be given concrete form in interpretative documents for the creation of the necessary links between the essential requirements and the mandates for harmonised ENs and ETAGs/ETAs.

[3] According to Art. 12 of the CPD the interpretative documents shall :

a) give concrete form to the essential requirements by harmonising the terminology and the technical bases and indicating classes or levels for each requirement where necessary ;

b) indicate methods of correlating these classes or levels of requirement with the technical specifications, e.g. methods of calculation and of proof, technical rules for project design, etc. ;

c) serve as a reference for the establishment of harmonised standards and guidelines for European technical approvals.

The Eurocodes, *de facto*, play a similar role in the field of the ER 1 and a part of ER 2.

Committees and/or EOTA Working Groups working on product standards with a view to achieving full compatibility of these technical specifications with the Eurocodes.

The Eurocode standards provide common structural design rules for everyday use for the design of whole structures and component products of both a traditional and an innovative nature. Unusual forms of construction or design conditions are not specifically covered and additional expert consideration will be required by the designer in such cases.

National Standards implementing Eurocodes

The National Standards implementing Eurocodes will comprise the full text of the Eurocode (including any annexes), as published by CEN, which may be preceded by a National title page and National foreword, and may be followed by a National Annex.

The National Annex may only contain information on those parameters which are left open in the Eurocode for national choice, known as Nationally Determined Parameters, to be used for the design of buildings and civil engineering works to be constructed in the country concerned, *i.e.* :

- values and/or classes where alternatives are given in the Eurocode,
- values to be used where a symbol only is given in the Eurocode,
- country specific data (geographical, climatic, etc.), *e.g.* snow map,
- the procedure to be used where alternative procedures are given in the Eurocode,
- decisions on the application of informative annexes,
- references to non-contradictory complementary information to assist the user to apply the Eurocode.

Links between Eurocodes and products harmonised technical specifications (ENs and ETAs)

There is a need for consistency between the harmonised technical specifications for construction products and the technical rules for works[4]. Furthermore, all the information accompanying the CE Marking of the construction products which refer to Eurocodes should clearly mention which Nationally Determined Parameters have been taken into account.

Additional information specific to EN 1992-1-2

EN 1992- 1-2 describes the Principles, requirements and rules for the structural design of buildings exposed to fire, including the following aspects.

Safety requirements

EN 1992-1-2 is intended for clients (e.g. for the formulation of their specific requirements), designers, contractors and relevant authorities.

The general objectives of fire protection are to limit risks with respect to the individual and society, neighbouring property, and where required, environment or directly exposed property, in the case of fire.

[4] see Art.3.3 and Art.12 of the CPD, as well as clauses 4.2, 4.3.1, 4.3.2 and 5.2 of ID 1.

Construction Products Directive 89/106/EEC gives the following essential requirement for the limitation of fire risks:

"The construction works must be designed and build in such a way, that in the event of an outbreak of fire
- the load bearing resistance of the construction can be assumed for a specified period of time
- the generation and spread of fire and smoke within the works are limited
- the spread of fire to neighbouring construction works is limited
- the occupants can leave the works or can be rescued by other means
- the safety of rescue teams is taken into consideration".

According to the Interpretative Document N° 2 "Safety in case of fire" the essential requirement may be observed by following various possibilities for fire safety strategies prevailing in the Member states like conventional fire scenarios (nominal fires) or “natural” (parametric) fire scenarios, including passive and/or active fire protection measures.

The fire parts of Structural Eurocodes deal with specific aspects of passive fire protection in terms of designing structures and parts thereof for adequate load bearing resistance and for limiting fire spread as relevant.

Required functions and levels of performance can be specified either in terms of nominal (standard) fire resistance rating, generally given in national fire regulations or by referring to fire safety engineering for assessing passive and active measures, see EN 1991-1-2.

Supplementary requirements concerning, for example:
- the possible installation and maintenance of sprinkler systems,
- conditions on occupancy of building or fire compartment,
- the use of approved insulation and coating materials, including their maintenance,

are not given in this document, because they are subject to specification by the competent authority.

Numerical values for partial factors and other reliability elements are given as recommended values that provide an acceptable level of reliability. They have been selected assuming that an appropriate level of workmanship and of quality management applies.

Design procedures

A full analytical procedure for structural fire design would take into account the behaviour of the structural system at elevated temperatures, the potential heat exposure and the beneficial effects of active and passive fire protection systems, together with the uncertainties associated with these three features and the importance of the structure (consequences of failure).

At the present time it is possible to undertake a procedure for determining adequate performance which incorporates some, if not all, of these parameters and to demonstrate that the structure, or its components, will give adequate performance in a real building fire. However, where the procedure is based on a nominal (standard) fire the classification system, which call for specific periods of fire resistance, takes into account (though not explicitly), the features and uncertainties described above.

Application of design procedures is illustrated in Figure 0.1. The prescriptive approach and the performance-based approach are identified. The prescriptive approach uses nominal fires to generate thermal actions. The performance-based approach, using fire safety engineering, refers to thermal actions based on physical and chemical parameters. Additional information for alternative methods in this standard is given in Table 0.1.

For design according to this part, EN 1991-1-2 is required for the determination of thermal and mechanical actions to the structure.

Design aids

Where simple calculation models are not available, the Eurocode fire parts give design solutions in terms of tabulated data (based on tests or advanced calculation models), which may be used within the specified limits of validity.

It is expected, that design aids based on the calculation models given in EN 1992-1-2, will be prepared by interested external organisations.

The main text of EN 1992-1-2, together with informative Annexes A, B, C, D and E, includes most of the principal concepts and rules necessary for structural fire design of concrete structures.

National Annex for EN 1992-1-2

This standard gives alternative procedures, values and recommendations for classes with notes indicating where national choices may have to be made. Therefore the National Standard implementing EN 1992-1-2 should have a National Annex containing the Eurocode all Nationally Determined Parameters to be used for the design of buildings, and where required and applicable, for civil engineering works to be constructed in the relevant country.

National choice is allowed in EN 1992-1-2 through clauses:

- 2.1.3 (2)
- 2.3 (2)P
- 3.2.3 (5)
- 3.2.4 (2)
- 3.3.3 (1)
- 4.1 (1)P
- 4.5.1 (2)
- 5.2 (3)
- 5.3.2 (2)
- 5.6.1 (1)
- 5.7.3 (2)
- 6.1 (5)
- 6.2 (2)
- 6.3.1 (1)
- 6.4.2.1 (3)
- 6.4.2.2 (2)

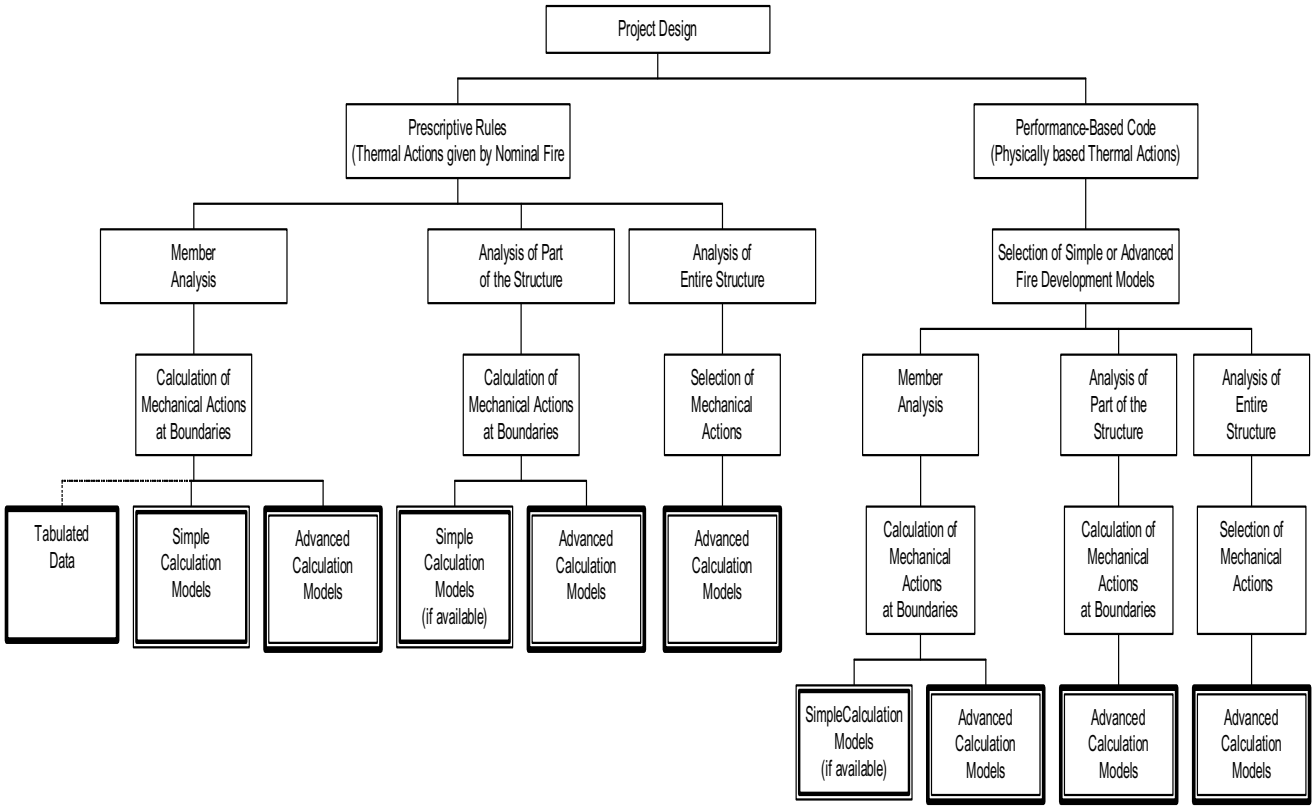

Figure 1 : Alternative design procedures

Table 0.1 Summary table showing alternative methods of verification for fire resistance

	Tabulated data	**Simplified calculation methods**	**Advanced calculation models**
Member analysis The member is considered as isolated. Indirect fire actions are not considered, except those resulting from thermal gradients	**YES** - Data given for standard fire only, 5..1(1) - In principle data could be developed for other fire curves	**YES** - standard fire and parametric fire, 4.2.1(1) - temperature profiles given for standard fire only, 4.2.2(1) - material models apply only to heating rates similar to standard fire, 4.2.4.1(2)	**YES**, 4.3.1(1)P Only the principles are given
Analysis of parts of the structure Analysis of parts of the structure Indirect fire actions within the sub-assembly are considered, but no time-dependent interaction with other parts of the structure.	**NO**	**YES** - standard fire and parametric fire, 4.2.1(1) - temperature profiles given for standard fire only, 4.2.2(1) - material models apply only to heating rates similar to standard fire, 4.2.4.1(2)	**YES** 4.3.1(1)P Only the principles are given
Global structural analysis Analysis of the entire structure. Indirect fire actions are considered throughout the structure	**NO**	**NO**	**YES** 4.3.1(1)P Only the principles are given

SECTION 1 GENERAL

1.1 Scope

1.1.1 Scope of Eurocode 2

(1)P Eurocode 2 applies to the design of buildings and civil engineering works in concrete. It complies with the principles and requirements for the safety and serviceability of structures, the basis of their design and verification that are given in EN 1990 – Basis of structural design.

(2)P Eurocode 2 is only concerned with requirements for resistance, serviceability, durability and fire resistance concrete structures. Other requirements, e.g. concerning thermal or sound insulation, are not considered.

(3)P Eurocode 2 is intended to be used in conjunction with:

- EN 1990 “Basis of structural design”
- EN 1991 “Actions on structures”
- hEN´s for construction products relevant for concrete structures
- ENV 13670-1 “Execution of concrete structures . Part 1: Common rules”
- EN 1998 “Design of structures for earthquake resistance”, when concrete structures are built in seismic regions

(4)P Eurocode 2 is subdivided in various parts:

- Part 1-1: General rules and rules for buildings
- Part 1-2: General rules – Structural fire design
- Part 2: Concrete bridges
- Part 3: Liquid retaining and containment structures

1.1.2 Scope of Part 1-2 of Eurocode 2

(1)P This Part 1-2 of EN 1992 deals with the design of concrete structures for the accidental situation of fire exposure and is intended to be used in conjunction with EN 1992-1-1 and EN 1991-1-2. This part 1-2 only identifies differences from, or supplements to, normal temperature design.

(2)P This Part 1-2 of EN 1992 deals only with passive methods of fire protection. Active methods are not covered.

(3)P This Part 1-2 of EN 1992 applies to concrete structures that are required to fulfil certain functions when exposed to fire, in terms of:

- avoiding premature collapse of the structure (load bearing function)
- limiting fire spread (flame, hot gases, excessive heat) beyond designated areas (separating function)

(4)P This Part 1-2 of EN 1992 gives principles and application rules (see EN 1991-1-2) for designing structures for specified requirements in respect of the aforementioned functions and the levels of performance.

(5)P This Part 1-2 of EN 1992 applies to structures, or parts of structures, that are within the scope of EN 1992-1-1 and are designed accordingly. However, it does not cover:

- structures with prestressing by external tendons
- shell structures

(6)P The methods given in this Part 1-2 of EN 1992 are applicable to normal weight concrete up to strength class C90/105 and for lightweight concrete up to strength class LC55/60. Additional and alternative rules for strength classes above C50/60 are given in section 6.

1.2 Normative references

The following normative documents contain provisions that, through reference in this text, constitute provisions of this European Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this European Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

EN 1363-2: Fire resistance tests – Part 2: Alternatives and additional procedures;

EN 1990: Eurocode: Basis of structural design;

EN 1991-1-2: Eurocode 1 - Actions on structures - Part 1-2: General actions - Actions on structures exposed to fire;

EN 1992-1-1: Eurocode 2. Design of concrete structures - Part 1.1: General rules and rules for buildings

EN 10080: Steel for the reinforcement of concrete - Weldable reinforcing steel - General

EN 10138-2: Prestressing steels - Part 2: Wire

EN 10138-3: Prestressing steels - Part 3: Strand

EN 10138-4: Prestressing steels - Part 4: Bar

1.3 Assumptions

The general assumptions given in EN 1990 and EN 1992-1-2 apply.

1.4 Distinction between principles and application rules

(1) The rules given in EN 1990 apply.

1.5 Definitions

For the purposes of this Part 1-2 of EN 1992, the definitions of EN 1990 and of EN 1991-1-2 apply with the additional definitions:

1.5.1 Critical temperature of reinforcement: The temperature of reinforcement at which failure of the member in fire situation *(Criterion R)* is expected to occur at a given steel stress level.

1.5.2 Fire wall: A wall separating two spaces (generally two buildings) that is designed for fire resistance and structural stability, and may include resistance to horizontal loading such that, in case of fire and failure of the structure on one side of the wall, fire spread beyond the wall is avoided.

1.5.3 Maximum stress level: For a given temperature, the stress level at which the stress-strain relationship of steel is truncated to provide a yield plateau.

1.5.4 Part of structure: isolated part of an entire structure with appropriate support and boundary conditions.

1.5.5 Protective layers: Any material or combination of materials applied to a structural member for the purpose of increasing its fire resistance.

1.5.6 Reduced cross section: Cross section of the member in structure fire design used in the reduced cross section method. It is obtained from the residual cross section by removing parts of the cross section with assumed zero strength and stiffness.

1.6 Symbols

1.6.1 Supplementary symbols to EN1992-1-1

(1)P The following supplementary symbols are used:

Latin upper case letters

$E_{d,fi}$ design effect of actions in the fire situation

E_d design effect of actions for normal temperature design

$R_{d,fi}$ design resistance in the fire situation; $R_{d,fi}(t)$ at a given time *t.*

R 30 or R 60,... fire resistance class for the load-bearing criterion for 30, or 60... minutes in standard fire exposure

E 30 or E 60,... fire resistance class for the integrity criterion for 30, or 60... minutes in standard fire exposure

I 30 or I 60,... fire resistance class for the insulation criterion for 30, or 60... minutes in standard fire exposure

T temperature [K] (cf θ temperature [^{o}C]);

X_k characteristic value of a strength or deformation property for normal temperature design

$X_{d,fi}$ design strength or deformation property in the fire situation

Latin lower case letters

a axis distance of reinforcing or prestressing steel from the nearest exposed surface

c_c specific heat of concrete [J/kgK]

$f_{ck}(\theta)$ characteristic value of compressive strength of concrete at temperature θ for a specified strain

$f_{ck,t}(\theta)$ characteristic value of tensile strength of concrete at temperature θ for a specified strain

$f_{pk}(\theta)$ characteristic value of strength of prestressing steel at temperature θ for a specified strain

$f_{sk}(\theta)$ characteristic strength of reinforcing steel at temperature θ for a specified strain

$k(\theta) = X_k(\theta)/X_k$ reduction factor for a strength or deformation property dependent on the material temperature θ

n = $N_{0Ed,fi} / (0,7(A_c f_{cd} + A_s f_{yd}))$ load level of a column at normal temperature conditions

t time of fire exposure (min)

Greek lower case letters

$\gamma_{M,fi}$ partial safety factor for a material in fire design

η_{fi} = $E_{d,fi}/E_d$ reduction factor for design load level in the fire situation

μ_{fi} = $N_{Ed,fi} / N_{Rd}$ degree of utilisation in fire situation

$\varepsilon_c(\theta)$ thermal strain of concrete

$\varepsilon_p(\theta)$ thermal strain of prestressing steel

$\varepsilon_s(\theta)$ thermal strain of reinforcing steel

$\varepsilon_{s,fi}$ strain of the reinforcing or prestressing steel at temperature θ

λ_c thermal conductivity of concrete [W/mK]

$\lambda_{0,fi}$ slenderness of the column under fire conditions

$\sigma_{c,fi}$ compressive stress of concrete in fire situation

$\sigma_{s,fi}$ steel stress in fire situation

θ temperature [°C]

θ_{cr} critical temperature [°C]

1.6.2 Supplementary to EN 1992-1-1, the following subscripts are used:

fi value relevant for the fire situation

t dependent on the time

θ dependent on the temperature

SECTION 2 BASIS OF DESIGN

2.1 Requirements

2.1.1 General

(1)P Where mechanical resistance in the case of fire is required, concrete structures shall be designed and constructed in such a way that they maintain their load bearing function during the relevant fire exposure.

(2)P Where compartmentation is required, the elements forming the boundaries of the fire compartment, including joints, shall be designed and constructed in such a way that they maintain their separating function during the relevant fire exposure. This shall ensure, where relevant, that:

- integrity failure does not occur, see EN 1991-1-2
- insulation failure does not occur, see EN 1991-1-2
- thermal radiation from the unexposed side is limited.

Note 1: See EN 1991-1-2 for the definitions.

Note 2: For concrete structures considered in this Part 1-2 thermal radiation criteria are not relevant.

(3)P Deformation criteria shall be applied where the means of protection, or the design criteria for separating elements, require consideration of the deformation of the load bearing structure.

(4) Consideration of the deformation of the load bearing structure is not necessary in the following cases, as relevant:

- the efficiency of the means of protection has been evaluated according to 4.7,
- the separating elements have to fulfil requirements according to nominal fire exposure.

2.1.2 Nominal fire exposure

(1)P For the standard fire exposure, members shall comply with criteria R, E and I as follows:

- separating only: integrity (criterion E) and, when requested, insulation (criterion I)
- load bearing only: mechanical resistance (criterion R)
- separating and load bearing: criteria R, E and, when requested I

(2) Criterion “R” is assumed to be satisfied where the load bearing function is maintained during the required time of fire exposure.

(3) Criterion “I” may be assumed to be satisfied where the average temperature rise over the whole of the non-exposed surface is limited to 140 K, and the maximum temperature rise at any point of that surface does not exceed 180 K

(4) With the external fire exposure curve the same criteria (R, E, I) should apply, however the reference to this specific curve should be identified by the letters "ef" (see EN 1991-1-2).

(5) With the hydrocarbon fire exposure curve the same criteria (R, E, I) should apply, however the reference to this specific curve should be identified by the letters "HC", see EN 1991-1-2

(6) Where a vertical separating element with or without load-bearing function has to comply with impact resistance requirement (criterion M), the element should resist a horizontal concentrated load as specified in EN 1363 Part 2.

2.1.3 Parametric fire exposure

(1) The load-bearing function should be maintained during the complete endurance of the fire including the decay phase, or a specified period of time.

(2) For the verification of the separating function the following applies, assuming that the normal temperature is 20°C:

- the average temperature rise of the unexposed side of the construction should be limited to 140 K and the maximum temperature rise of the unexposed side should not exceed 180 K during the heating phase until the maximum gas temperature in the fire compartment is reached;
- the average temperature rise of the unexposed side of the construction should be limited to $\Delta\theta_1$ and the maximum temperature rise of the unexposed side should not exceed $\Delta\theta_2$ during the decay phase.

Note: The values of $\Delta\theta_1$ and $\Delta\theta_2$ for use in a Country may be found in its National Annex. The recommended values are $\Delta\theta_1$ = 200 K and $\Delta\theta_2$ = 240 K.

2.2 Actions

(1)P The thermal and mechanical actions shall be taken from EN 1991-1-2.

(2) In addition to EN 1991-1-2, the emissivity related to the concrete surface should be taken as 0,7.

2.3 Design values of material properties

(1)P Design values of mechanical (strength and deformation) material properties $X_{d,fi}$ are defined as follows:

$$X_{d,fi} = k_\theta X_k / \gamma_{M,fi} \quad (2.1)$$

where:

X_k is the characteristic value of a strength or deformation property *(generally f_k or E_k)* for normal temperature design to EN 1992-1-1;

k_θ is the reduction factor for a strength or deformation property ($X_{k,\theta} / X_k$), dependent on the material temperature, see 3.2.;

$\gamma_{M,fi}$ is the partial safety factor for the relevant material property, for the fire situation.

(2)P Design values of thermal material properties $X_{d,fi}$ are defined as follows:

- if an increase of the property is favourable for safety:

$$X_{d,fi} = X_{k,\theta} / \gamma_{M,fi} \quad (2.2a)$$

- if an increase of the property is unfavourable for safety:

$$X_{d,fi} = \gamma_{M,fi} X_{k,\theta} \quad (2.2b)$$

where: