

Eurocode 2: Design of concrete structures —

**Part 1.2 General rules —
Structural fire design —**

**(together with United Kingdom
National Application Document)**

ICS 91.040; 91.080.40

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Committees responsible for this Draft for Development

The preparation of this Draft for Development was entrusted by Technical Committee B/525, Building and civil engineering structures, to Subcommittee B/525/2, Structural use of concrete, upon which the following bodies were represented:

- Association of Consulting Engineers
- British Cement Association
- British Precast Concrete Federation Ltd.
- Department of the Environment (Property and Buildings Directorate)
- Department of Transport (Highways Agency)
- Federation of Civil Engineering Contractors
- Institution of Civil Engineers
- Institution of Structural Engineers
- Steel Reinforcement Commission

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National foreword

This Draft for Development was prepared by Subcommittee B/525/2 and is the English language version of ENV 1992-1-2:1995 *Eurocode 2: Design of concrete structures — Part 1.2: General rules — Structural fire design*, as published by the European Committee for Standardization (CEN). This Draft for Development also includes the United Kingdom (UK) National Application Document (NAD) to be used with the ENV in the design of buildings to be constructed in the UK. ENV 1992-1-2 results from a programme of work sponsored by the European commission to make available a common set of rules for the structural and geotechnical design of building and civil engineering works.

This publication should not be regarded as a British Standard.

An ENV is made available for provisional application, but does not have the status of a European Standard. The aim is to use the experience gained to modify the ENV so that it can be adopted as a European Standard. The publication of this ENV and its National Application Document should be considered to supersede any reference to a British Standard in previous DD ENV Eurocodes concerning the subject covered by these documents.

The values for certain parameters in the ENV Eurocodes may be set by individual CEN Members so as to meet the requirements of national regulations. These parameters are designated by | _ | in the ENV.

During the ENV period of validity, reference should be made to the supporting documents listed in the National Application Document (NAD).

The purpose of the NAD is to provide essential information, particularly in relation to safety, to enable the ENV to be used for buildings constructed in the UK and the NAD takes precedence over corresponding provisions in the ENV.

The Building Regulations 1991, Approved Document A 1992, draws attention to the potential use of ENV Eurocodes as an alternative approach to Building Regulation compliance. ENV 1992-1-2 is considered to offer such an alternative approach, when used in conjunction with its NAD.

Users of this document are invited to comment on its technical content, ease of use and any ambiguities or anomalies. These comments will be taken into account when preparing the UK national response to CEN on the question of whether the ENV can be converted to an EN.

Comments should be sent in writing to the Secretary of Subcommittee B/525/2, BSI, 389 Chiswick High Road, London W4 4AL, quoting the document reference, the relevant clause and, where possible, a proposed revision, by 31 October 1996.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to x, the ENV title page, pages 2 to 63 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

National Application Document for use in the UK with ENV 1992-1-2:1995

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Introduction

This National Application Document (NAD) has been prepared by Subcommittee B/525/2. It has been developed from the following.

- a) A textual examination of ENV 1992-1-2.
- b) A parametric calibration against BS 8110, supporting standards and test data.
- c) Trial calculations.

1 Scope

This NAD provides information to enable ENV 1992-1-2 (hereafter referred to as EC2-1.2) to be used for the design of buildings to be constructed in the UK. It is assumed that it will be used in conjunction with DD ENV 1992-1-1, the NAD of which refers to BSI publications for values of actions. Since publication of ENV 1992-1-1 (hereafter referred to as EC2-1.1), ENVs for actions (Parts of Eurocode 1) have been published. Where appropriate this NAD refers to them. It should be borne in mind that designs should be consistent in their use of UK and CEN standards for all parameters.

2 Partial factors, combination factors and other values

- a) The values for combination coefficients (Ψ) should be those given in Table 1 of the NAD for EC2-1.1.
- b) The values for partial factors for normal temperature design should be those given in EC2-1.1 except where modified by the NAD for that code.

The values for partial factors for fire design should be those given in EC2-1.2. For thermal and mechanical actions reference should be made to ENV 1991-2-2 (hereafter referred to as EC1-2.2) and its NAD.

- c) Other values should be those given in EC2-1.1, except where modified by the NAD for that code, and in EC2-1.2 except for those given in Table 1 of this NAD.

Table 1 — Values to be used in referenced clauses instead of boxed values

Reference in EC2-1.2	Definition	UK values
4.2.3 (4)	Limit to fire resistance for distribution bars along sides of columns	120 min.
4.2.7.4 (2)	Minimum top reinforcement over span in column strip	10 %

3 Tabulated data

Tables 4.1 to 4.11 of EC2-1.2:1995 are replaced with Table N4.1 to Table N4.11 respectively as given below. All the tables in 4.2 of EC2-1.2:1995 have been reproduced, regardless of whether changes have been made, to avoid unnecessary cross referencing. Changes in values from those given in EC2-1.2 are shown in bold. These changes largely reflect the current values in BS 8110.

Table N4.1 — Minimum dimensions and axis distances for reinforced concrete columns; rectangular and circular section

Standard fire resistance	Minimum dimensions mm Column width $b_{\min}$ /axis distance a			
	Column exposed on more than one side			Exposed on one side
	$\mu_{fi} = 0.2$	$\mu_{fi} = 0.5$	$\mu_{fi} = 0.7$	$\mu_{fi} = 0.7$
1	2	3	4	5
R 30	150/10 ^a	150/10 ^a	150/10 ^a	100/10 ^a
R 60	150/10 ^a	180/10 ^a	200/10 ^a	120/10 ^a
R 90	180/10 ^a	210/10 ^a	240/35	140/10 ^a
R 120	200/40	250/40	280/40	160/45
R 180	240/50	320/50	360/50	200/60
R 240	300/50	400/50	450/50	300/60

^a Normally the cover required by ENV 1992-1-1 will control.

Table N4.2 — Minimum wall thickness of non load-bearing walls (partitions)

Standard fire resistance	Minimum wall thickness mm
1	2
EI 30	60
EI 60	80
EI 90	100
EI 120	120
EI 180	150
EI 240	175

Table N4.3 — Minimum dimensions and axis distances for load-bearing reinforced concrete walls

Standard fire resistance	Minimum dimensions mm			
	Wall thickness/axis distance for			
	$\mu_f = 0.35$		$\mu_f = 0.7$	
	Wall exposed on one side	Wall exposed on two sides	Wall exposed on one side	Wall exposed on two sides
1	2	3	4	5
REI 30	100/10 ^a	120/10 ^a	120/10 ^a	120/10 ^a
REI 60	110/10 ^a	120/10 ^a	130/10 ^a	140/10 ^a
REI 90	120/20 ^a	140/10 ^a	140/25	170/25
REI 120	150/25	160/25	160/35	220/35
REI 180	180/35	200/35	210/45	250/45
REI 240	230/45	250/45	270/55	300/55

^a Normally the cover required by ENV 1992-1-1 will control.

Table N4.4 — Minimum dimensions and axis distances for reinforced and prestressed concrete tensile members

Standard fire resistance	Minimum dimensions mm	
	Possible combinations of member width b_{min} /axis distance a	
1	2	3
R 30	80/25	200/10 ^a
R 60	120/40	300/25
R 90	150/55	400/45
R 120	200/65	500/45
R 180	240/80	600/60
R 240	280/90	700/70

NOTE For prestressed members the increase of axis distance according to 4.2.2(4) should be noted.

^a Normally the cover required by ENV 1992-1-1 will control.

Table N4.5 — Minimum dimensions and axis distances for simply supported beams made with reinforced and prestressed concrete

Standard fire resistance	Minimum dimensions mm				
	Possible combinations of a and $b_{\min}$ where a is the average axis distance and $b_{\min}$ is the width of beam				Web thickness b_w
1	2	3	4	5	6
R 30	$b_{\min}$ 80 a 25	120 15 ^a	160 10 ^a	200 10 ^a	80
R 60	$b_{\min}$ 120 a 40	160 35	200 30	300 25	100
R 90	$b_{\min}$ 150 a 55	200 45	250 40	400 35	100
R 120	$b_{\min}$ 200 a 65	240 55	300 50	500 45	120
R 180	$b_{\min}$ 240 a 80	300 70	400 65	600 60	140
R 240	$b_{\min}$ 280 a 90	350 80	500 75	500 70	160
$a_{sd} = a + 10$ mm (see note 2.)					
NOTE 1 For prestressed beams the increase of axis distance according to 4.2.2(4) of this Part 1-2 should be noted. NOTE 2 a_{sd} is the axis distance to the side of beam for the corner bars (tendon or wire) of beams with only one layer of reinforcement. For values of $b_{\min}$ greater than that given in column 4 no increase of a is required.					
^a Normally the cover required by ENV 1992-1-1 will control.					

Table N4.6 — Minimum dimensions and axis distances for continuous beams made with reinforced and prestressed concrete

Standard fire resistance	Minimum dimensions mm			
	Possible combinations of a and $b_{\min}$ where a is the average axis distance and $b_{\min}$ is the width of beam			Web thickness b_w
1	2	3	4	5
R 30	$b_{\min}$ 80 a 12 ^a	160 12 ^a	200 12 ^a	80
R 60	$b_{\min}$ 120 a 25	200 12 ^a	300 12 ^a	100
R 90	$b_{\min}$ 150 a 35	250 25	400 25	100
R 120	$b_{\min}$ 180 a 55	300 45	450 35	120
R 180	$b_{\min}$ 225 a 70	350 60	550 50	140
R 240	$b_{\min}$ 275 a 80	450 70	650 60	160
$a_{sd} = a + 10$ mm (see note 2.)				
NOTE 1 For prestressed beams the increase of axis distance according to 4.2.2(4) should be noted. NOTE 2 a_{sd} is the axis distance to the side of beam for the corner bars (tendon or wire) of beams with only one layer of reinforcement. For values of $b_{\min}$ greater than that given in column 3 no increase of a is required.				
^a Normally the cover required by ENV 1992-1-1 will control.				

Table N4.7 — Reinforced and prestressed concrete continuous I beams: increased beam width and web thickness for conditions according to Table N4.6

Standard fire resistance	Minimum beam width $b_{\min}$ and web thickness b_w mm
1	2
R 120	220
R 180	380
R 240	480

Table N4.8 — Minimum dimensions and axis distances for reinforced and prestressed concrete simply supported one-way and two-way slabs

Standard fire resistance	Minimum dimensions mm			
	Slab thickness h_s mm	Average axis-distance a		
		One way	Two way:	
			$l_y/l_x \leq 1.5$	$1.5 \leq l_y/l_x \leq 2$
1	2	3	4	5
REI 30	60	10 ^a	10 ^a	10 ^a
REI 60	80	20	10 ^a	15 ^a
REI 90	100	30	15 ^a	20
REI 120	120	40	20	25
REI 180	150	55	30	40
REI 240	175	65	40	50

NOTE 1 l_x and l_y are the spans of a two-way slab (two directions at right angles) where l_y is the longer span
 NOTE 2 The minimum cover of any bar should not be less than half of required average axis distance, a_m , defined in 4.2.2.
 NOTE 3 For prestressed slabs the increase of axis distance according to 4.2.2(4) should be noted.
 NOTE 4 The axis distance, a , in columns 4 and 5 for two way slabs relate to slabs supported at all four edges. Otherwise, they should be treated as one-way spanning slab.
^a Normally the cover required by ENV 1992-1-1 will control.

Table N4.9 — Minimum dimensions and axis distances for reinforced and prestressed concrete flat slabs

Standard fire resistance	Minimum dimensions mm	
	Slab thickness h_s	Axis-distance a
1	2	3
REI 30	75	10 ^a
REI 60	95	15 ^a
REI 90	110	25
REI 120	125	35
REI 180	150	45
REI 240	170	50

^a Normally the cover required by ENV 1992-1-1 will control.

Table N4.10 — Minimum dimensions and axis distance for two-way spanning, simply supported ribbed slabs in reinforced or prestressed concrete

Standard fire resistance	Minimum dimensions mm			
	Possible combinations of width of ribs $b_{\min}$ and axis distance a			Slab thickness h_s and axis distance a , in span
1	2	3	4	5
REI 30	$b_{\min} \geq 80$ $a \ 15^a$			$h_s \ 80$ $a \ 10^a$
REI 60	$b_{\min} \ 100$ $a \ 35$	120 25	≥ 200 15^a	$h_s \ 80$ $a \ 10^a$
REI 90	$b_{\min} \ 120$ $a \ 45$	160 40	≥ 250 30	$h_s \ 100$ $a \ 15^a$
REI 120	$b_{\min} \ 140$ $a \ 60$	190 55	≥ 300 40	$h_s \ 120$ $a \ 20$
REI 180	$b_{\min} \ 170$ $a \ 75$	260 75	≥ 410 60	$h_s \ 150$ $a \ 30$
REI 240	$b_{\min} \ 200$ $a \ 90$	350 75	≥ 500 70	$h_s \ 175$ $a \ 40$
$a_{sd} = a + 10 \text{ mm}$				
NOTE 1 For prestressed ribbed slabs, the axis-distance a should be increased in accordance with 4.2.2(4)				
NOTE 2 a_{sd} denotes the distance measured between the axis of the reinforcement and the lateral surface of the rib exposed to fire.				
^a Normally the cover required by ENV 1992-1-1 will control.				

Table N4.11 — Minimum dimensions and axis distances for two way spanning ribbed slabs in reinforced or prestressed concrete with at least one restrained edge

Standard fire resistance	Minimum dimensions mm			
	Possible combinations of width of ribs $b_{\min}$ and axis distance a			Slab thickness h_s and axis distance a , in span
1	2	3	4	5
REI 30	$b_{\min} \geq 80$ $a \ 10^a$			$h_s \ 80$ $a \ 10^a$
REI 60	$b_{\min} \ 100$ $a \ 25$	120 15^a	≥ 200 10^a	$h_s \ 80$ $a \ 10^a$
REI 90	$b_{\min} \ 120$ $a \ 35$	160 25	≥ 250 15^a	$h_s \ 100$ $a \ 15^a$
REI 120	$b_{\min} \ 140$ $a \ 45$	190 40	≥ 300 30	$h_s \ 120$ $a \ 20$
REI 180	$b_{\min} \ 175$ $a \ 60$	300 50	≥ 400 40	$h_s \ 150$ $a \ 30$
REI 240	$b_{\min} \ 200$ $a \ 70$	400 60	≥ 500 50	$h_s \ 175$ $a \ 40$
$a_{sd} = a + 10 \text{ mm}$				
NOTE 1 For prestressed ribbed slabs, the axis-distance a should be increased in accordance with 4.2.2(4).				
NOTE 2 a_{sd} denotes the distance measured between the axis of the reinforcement and the lateral surface of the rib exposed to fire.				
^a Normally the cover required by ENV 1992-1-1 will control.				

4 Reference standards

Supporting standards including materials specifications and standards for construction are listed in Table 2 of this NAD.

Table 2 — Reference in EC2 Part 1.2 to other codes and standards

Reference in EC2-1.2	Document referred to	Subject area	Status
Various	ENV 1992-1-1	Design of concrete structures. General rules and rules for buildings	Published 1991
Various	ENV 1991-2-1	Thermal and mechanical actions	Published 1995
1.1(1)P 2.4.3(4)	ENV 1991-2-2	Design for accidental situation of fire exposure	Published 1995
1.3(1)	ISO 834	Standards for fire tests	Published 1975
1.4.12	ENV 1991-1	Fundamental combination of actions	Published 1994
4.2.4.2(2)	ENV 1992-1-6	Minimum thickness of plain concrete walls	Published 1994

5 Additional recommendations

5.1 Chapter 4. Structural fire design

a) Clause 4.2.2(4)

Current British practice assumes a less conservative increase in axis distance, a , from that given in this clause. The second sentence onwards of this clause may be replaced with the following:

If no special check according to (4) is made in prestressed tensile members and beams the required axis distance, a , should be increased by:

10 mm for prestressing bars, corresponding to $\Theta_{cr} = 400\text{ }^{\circ}\text{C}$;

15 mm for prestressing wires and strands, corresponding to $\Theta_{cr} = 350\text{ }^{\circ}\text{C}$.

If no special check according to (4) is made in prestressed simply supported slabs (including simply supported ribbed slabs) the required axis distance, a , may be increased by 5 mm for prestressing bars, wires and strands.

If no special check according to (4) is made in prestressed continuous slabs (including continuous ribbed slabs) the required axis distance, a , should be increased by:

5 mm for prestressing bars;

10 mm for prestressing wires and strands.

b) Clause 4.2.2(14)

Current British practice assumes a less conservative increase in axis distance, a , from that given in this clause. The value of Δa_p in equation (4.6) may be assumed as follows:

$\Delta a_p = 5\text{ mm}$ for prestressing bars;

$= 15\text{ mm}$ for prestressing wires and strands.

c) Clause 4.2.7.1(4) — addition

The effective thickness, h_e , of hollow concrete slabs should be obtained by considering the total solid part of the cross-section area as follows:

$$h_e = h_1 \cdot \zeta^{0.7} \quad (4.12A)$$

where

h_1 is the total thickness of concrete slab (See Figure 4.7 of EC2-1.2);

ζ is the proportion of concrete cross section area to the total cross section area of concrete slab including voids.

ICS 91.040.00; 91.080.40

Descriptors: Buildings, concrete structure, design, computation, fire resistance

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 Prestandard (ENV) was approved by CEN on 1994-01-14 as a prospective standard for provisional application. The period of validity of this ENV is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the ENV can be converted into an European Standard (EN).

CEN members are required to announce the existence of this ENV in the same way as for an EN and to make the ENV available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force (in parallel to the ENV) until the final decision about the possible conversion of the ENV into an EN is reached.

CEN members are the national standards bodies of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

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Foreword

Objectives of the Eurocodes

(1) The “Structural Eurocodes” comprise a group of standards for the structural and geotechnical design of buildings and civil engineering works.

(2) They cover execution and control only to the extent that is necessary to indicate the quality of the construction products, and the standard of the workmanship needed to comply with the assumptions of the design rules.

(3) Until the necessary set of harmonized technical specifications for products and for the methods of testing their performance are available, some of the Structural Eurocodes cover some of these aspects in informative Annexes.

Background of the Eurocode program

(4) The Commission of the European Communities (CEC) initiated the work of establishing a set of harmonized technical rules for the design of building and civil engineering works which would initially serve as an alternative to the different rules in force in the various Member States and would ultimately replace them. These technical rules became known as the “Structural Eurocodes”.

(5) In 1990, after consulting their respective Member States, the CEC transferred the work of further development, issue and updating of the Structural Eurocodes to CEN, and the EFTA Secretariat agreed to support the CEN work.

(6) CEN Technical Committee CEN/TC250 is responsible for all Structural Eurocodes.

Eurocode program

(7) Work is in hand on the following Structural Eurocodes, each generally consisting of a number of parts:

EN 1991, Eurocode 1: Basis of design and 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 provisions for earthquake resistance of structures.

EN 1999, Eurocode 9: Design of aluminium alloy structures.

(8) Separate subcommittees have been formed by CEN/TC250 for the various Eurocodes listed above.

(9) This Part 1-2 of Eurocode 2 is being published as a European Prestandard (ENV) with an initial life of three years.

(10) This Prestandard is intended for experimental application and for the submission of comments.

(11) After approximately two years CEN members will be invited to submit formal comments to be taken into account in determining future actions.

(12) Meanwhile feedback and comments on this Prestandard should be sent to the Secretariat of CEN/TC250/SC2 at the following address:

Deutsches Institut für Normung e.V. (DIN)

Burggrafenstrasse 6

D-10787 Berlin

Phone:(+49) 30 2601 2501

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or to your national standards organisation

National Application Documents (NAD’S)

(13) In view of the responsibilities of authorities in member countries for safety, health and other matters covered by the essential requirements of the Construction Products Directive (CPD), certain safety elements in this ENV have been assigned indicative values which are identified by | _ | (“boxed values”). The authorities in each member country are expected to assign definitive values to these safety elements.

(14) Some of the supporting European or International Standards may not be available by the time this Prestandard is issued. It is therefore anticipated that a National Application Document (NAD) giving definitive values for safety elements, referencing compatible supporting standards and providing national guidance on the application of this Prestandard, will be issued by each member country or its Standards Organisation.

(15) It is intended that this Prestandard is used in conjunction with the NAD valid in the country where the building or civil engineering works is located.

Matters specific to this prestandard

(16) The scope of Eurocode 2 is defined in 1.1.1 of ENV 1992-1-1 and the scope of this Part of Eurocode 2 is defined in 1.1. Additional Parts of Eurocode 2 which are planned are indicated in 1.1.3 of ENV 1992-1-1; these will cover additional technologies or applications, and will complement and supplement this Part.

(17) In using this Prestandard in practice, particular regard should be paid to the underlying assumptions and conditions given in 1.3 of ENV 1992-1-1.

(18) The provisions of this Prestandard are based substantially on recent CEB and FIP documents.

(19) This Part 1-2 of Eurocode 2 complements ENV 1992-1-1 for the particular aspects of structural fire design of concrete structures. The provisions in this Part 1-2 have to be considered additionally to those in other Parts of ENV 1992.

(20) The framework and structure of this Part 1-2 do not correspond to ENV 1992-1-1.

(21) This Part 1-2 contains five sections and four informative Annexes. These Annexes have been introduced by moving some of the more detailed Application Rules, which are needed in particular cases, out of the main part of the text to aid its clarity.

(22) Required functions and levels of performance are generally specified by the National Authorities — mostly in terms of standard fire resistance rating. Where fire safety engineering for assessing passive and active measures is accepted, requirements by authorities will be less prescriptive and may allow for alternative strategies.

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1 General

1.1 Scope

(1)P ENV 1992-1-2 deals with the design of concrete structures for the accidental situation of fire exposure and shall be used in conjunction with ENV 1992-1-1 and ENV 1991-2-2. It provides additions to and identifies differences from the design of structures at normal temperatures.

(2)P Part 1-2 applies only to passive methods of fire protection. Active methods are not included.

(3)P Part 1-2 applies to structures which for reasons of general fire safety, are required to fulfil the following criteria when exposed to fire:

- avoid premature collapse of the structure (load-bearing function)
- limit fire spread (flames, hot gases, excessive heat) beyond designated areas (separation function)

(4)P Part 1-2 gives Principles and Application Rules (see 1.2 in ENV 1992-1-1) in respect to the design of structures to fulfil the criteria given in (3)P (e.g. in terms of required standard fire resistance).

(5)P Part 1-2 applies to those structures or parts of structures which are within the scope of Part 1-1, 1-3 to 1-6. However, it does not cover:

- structures with prestressing by external tendons
- shell structures.

(6) For structures using unbonded tendons reference should be made to 4.1(6) and 4.2.2(6).

1.2 Distinction between principles and application rules

(1) Depending on the character of the individual clauses, distinction is made in this Part between principles and application rules.

(2) The principles comprise:

- general statements and definitions for which there is no alternative, as well as
- requirements and analytical models for which no alternative is permitted unless specifically stated.

(3) The principles are identified by the letter P following the paragraph number.

(4) The application rules are generally recognized rules which follow the principles and satisfy their requirements.

(5) It is permissible to use alternative rules different from the application rules given in this Eurocode, provided it is shown that the alternative rules accord with the relevant principles and have at least the same reliability.

(6) In this Part the application rules are identified by a number in brackets eg. as this clause.

1.3 Normative references

(1) European standards for fire tests are under preparation. In National Application Documents reference may be made to national or International Standards. For structural members ISO 834 is generally used.

1.4 Definitions

1.4.1

critical temperature of reinforcement

the temperature at which failure is expected to occur in reinforcement at a given load level

1.4.2

design fire

a specified fire development assumed for design purposes

1.4.3

effects of actions E (as described in ENV 1992-1-1, 2.2.2.5)

the effects of actions (E) are responses (for example internal forces and moments, stresses, strains) of the structure to the actions

1.4.4

fire compartment

a space within a building extending over one or several floors which is enclosed by separating members such, that fire spread beyond the compartment is prevented during the relevant fire exposure

1.4.5

fire resistance

the ability of a structure or part of it to fulfil its required functions (load-bearing and/or separating function) for a specified fire exposure, for a specified period of time

1.4.6

global structural analysis (for fire)

the analysis of the entire structure, when either the entire structure or only parts of it are exposed to fire. Indirect fire actions are considered throughout the structure

1.4.7

indirect fire actions

thermal expansions or thermal deformations causing forces and moments

1.4.8

integrity criterion “E”

a criterion by which the ability of a separating member to prevent passage of flames and hot gases is assessed

1.4.9

load-bearing criterion “R”

a criterion by which the ability of a structure or a member to sustain specified actions during the relevant fire, is assessed

1.4.10

load-bearing function

the ability of a structure or member to sustain specified actions during the relevant fire

1.4.11

member analysis (for fire)

the thermal and mechanical analysis of a structural member exposed to fire in which the member is considered as isolated with appropriate support and boundary conditions. Indirect fire actions are not considered, apart from those resulting from thermal gradients

1.4.12

normal temperature design

ultimate limit state design for ambient temperatures according to ENV 1992-1-1 for the fundamental combination of actions (see ENV 1991-1)

1.4.13

protected members

members for which measures are taken to reduce the temperature rise in the member due to fire

1.4.14

separating function

the ability of a separating member to prevent fire spread by passage of flames or hot gases (integrity) or ignition beyond the exposed surface (thermal insulation) during the relevant fire

1.4.15

separating members

structural and non-structural members (walls or floors) forming the enclosure of a fire compartment

1.4.16**standard fire resistance**

the ability of a structure or part of it (usually only members) to fulfil required functions (load-bearing function and/or separating function) for exposure to heating according to the standard temperature-time curve, for a stated period of time

1.4.17**structural members**

the load-bearing members of a structure including bracings

1.4.18**sub-assembly analysis (for fire)**

the structural analysis of parts of the structure exposed to fire in which the respective part of the structure is considered as isolated with appropriate support and boundary conditions. Indirect fire actions within the sub-assembly are considered, but time-dependent interaction with other parts of the structure is not considered

NOTE 1 Where the effects of indirect fire actions within the sub-assembly are negligible, sub-assembly analysis is equivalent to member analysis.

NOTE 2 Where the effects of indirect fire actions between sub-assemblies are negligible, sub-assembly analysis is equivalent to global structural analysis.

1.4.19**support and boundary conditions**

description of restraints at supports and boundaries for structural modelling

1.4.20**temperature analysis**

the procedure to determine the temperature development in members on the basis of thermal actions and the thermal material properties of the members and of the protective layers, where relevant

1.4.21**temperature-time curves**

gas temperatures in the environment of member surfaces as a function of time. They may be either

- Nominal: Conventional curves, adopted for classification or verification of fire resistance, e.g. the standard temperature-time curve.
- Parametric: Determined on the basis of fire models and the specific physical parameters defining the conditions in the fire compartment.

1.4.22**thermal actions**

actions on the structure described by the net heat flux to the members

1.4.23**thermal insulation criterion “T”**

a criterion by which the ability of a separating member to prevent excessive transmission of heat is assessed

1.5 Symbols

The following symbols supplement those given in ENV 1992-1-1:

- $E_{d,fi}$ design effect of actions in the fire situation
- E_d design effect of actions for normal temperature design
- $R_{d,fi}$ design load bearing capacity (resistance) in the fire situation $R_{d,fi}(t)$ at a given time t .
- R 30 or R 60,... a member meeting the load-bearing criterion for 30, or 60... minutes in standard fire exposure
- E 30 or E 60,... a member meeting the integrity criterion for 30, or 60... minutes in standard fire exposure
- I 30 or I 60,... a member meeting the thermal insulation criterion for 30, or 60... minutes in standard fire exposure
- 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
- a axis distance of the steel from the nearest exposed surface
- c specific heat (characteristic value) [J/kgK]
- $f_{ck}(\Theta)$ characteristic value of compressive 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 to describe a strength or deformation property at temperature Θ
- t time of fire exposure (min)
- $Y_{M,fi}$ partial safety factor for a material in fire design
- $\eta_{fi} = E_{d,fi}/E_d$ ratio of design effect of actions in the fire situation to that in normal design
- $\epsilon_{s,fi}$ strain of the reinforcing or prestressing steel at temperature Θ .
- λ thermal conductivity (characteristic value) [W/mK]
- $\mu_{fi} = E_{d,fi}/R_{d,fi}(0)$ ratio of design effect of actions in the fire situation to the design resistance of the structural element at time $t = 0$
- $\sigma_{c,fi}$ 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 Units

(1) Temperature Θ in degrees Celsius (°C)

Temperature difference in kelvins (K)

Specific heat c in joule per kilogramme per kelvin (J/kgK)

Coefficient of thermal conductivity λ in watts per metre per kelvin (W/mK)

2 Basic principles

2.1 Performance requirements

(1)P Where structures are required to have mechanical resistance under fire conditions, they shall be designed and constructed in such a way that they maintain their load bearing function during the relevant fire exposure — Criterion “R”.

(2)P Where compartmentation is required, the members forming the compartment, including joints, shall be designed and constructed in such a way that they maintain their separating function during the relevant fire exposure, i.e.

- no integrity failure due to cracks, holes or other openings, which are large enough to cause fire penetration by hot gases or flame — Criterion “E”
- no insulation failure due to temperatures of the non-exposed surface exceeding ignition temperatures — Criterion “I”.

(3) Criterion “I” may be assumed to be met where the average temperature rise over the whole of the non-exposed surface during the standard fire exposure does not exceed 140K and the maximum temperature rise of that surface does not exceed 180K.

(4)P Members shall comply with criteria R, E and I as follows:

separating only: E and I

loadbearing only: R

separating and loadbearing: R, E and I

(5) When using general calculation methods (see 4.4) the deformation criteria should be used where separating members or protective measures are affected by the deformation of the load bearing structure. Reference should be made to the relevant product specifications.

2.2 Actions

(1)P Thermal and mechanical actions shall be obtained from ENV 1991-2-2.

(2) Where rules given in this Part 1-2 are only valid for the standard fire exposure, this is identified in the relevant clauses.

2.3 Design values of material properties

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

— thermal properties for thermal analysis

if an increase of the property is favourable for safety

$$X_{d,fi} = X_k(\Theta)/Y_{M,fi} \quad (2.1)$$

if an increase of the property is unfavourable for safety

$$X_{d,fi} = X_k(\Theta) Y_{M,fi} \quad (2.2)$$

— strength and deformation properties for structural analysis

$$\underline{X}_{d,fi} = k(\Theta) X_k/Y_{M,fi} \quad (2.3)$$

where

$X_k(\Theta)$ is the characteristic value of a material property in fire design, generally dependent on the material temperature

X_k is the characteristic value of a strength or deformation property (e.g. f_{ck} and f_{yk}) for normal temperature design to ENV 1992-1-1

$k(\Theta) = X_k(\Theta)/X_k$ is the reduction factor for a strength or deformation property dependent on the material temperature — see 3.2 and 3.3

$Y_{M,fi}$ is the partial safety factor for material property in fire design

(2) For thermal and mechanical properties of concrete and steel reinforcement the partial safety factor for fire design should be taken as