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Eurocode 3: Design of steel structures - Part 1-2: General rules - Structural fire design

Eurocode 3: Bemessung und Konstruktion von Stahlbauten - Teil 1-2: Allgemeine Regeln - Tragwerksbemessung für den Brandfall

Eurocode 3 - Calcul des structures en acier - Partie 1-2 : Regles générales - Calcul du comportement au feu

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91.080.10	Kovinske konstrukcije	Metal structures

SIST EN 1993-1-2:2005 **en**

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Eurocode 3: Design of steel structures - Part 1-2: General rules - Structural fire design

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Eurocode 3: Bemessung und Konstruktion von Stahlbauten - Teil 1-2: Allgemeine Regeln - Tragwerksbemessung für den Brandfall

This European Standard was approved by CEN on 23 April 2004.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of 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.

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Contents

Page

Foreword

This European Standard EN 1993, Eurocode 3: Design of steel structures, 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of an identical text or by endorsement, at the latest by October 2005, and conflicting National Standards shall be withdrawn at latest by March 2010.

This Eurocode supersedes ENV 1993-1-2.

According to the CEN-CENELEC Internal Regulations, the National Standard Organizations 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 to 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 harmonization of technical specifications.

Within this action programme, the Commission took the initiative to establish a set of harmonized 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 publication of the Eurocodes to 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 0:	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

[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).

Eurocode standards recognize 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 recognize 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 harmonized 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 Documents[2] referred to in Article 12 of the CPD, although they are of a different nature from harmonized product standards[3]. Therefore, technical aspects arising from the Eurocodes work need to be adequately considered by CEN Technical 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.

It may contain

– decisions on the application of informative annexes,
– references to non-contradictory complementary information to assist the user to apply the Eurocode.

[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 harmonized 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 harmonizing 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 harmonized 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.

Links between Eurocodes and harmonized technical specifications (ENs and ETAs) for products

There is a need for consistency between the harmonized 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 1993-1-2

EN 1993-1-2 describes the principles, requirements and rules for the structural design of steel buildings exposed to fire, including the following aspects.

Safety requirements

EN 1993-1-2 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.

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.

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.

[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.

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 calls for specific periods of fire resistance, takes into account (though not explicitly), the features and uncertainties described above.

Application of this Part 1-2 is illustrated in Figure 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.

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 1993-1-2, will be prepared by interested external organizations.

The main text of EN 1993-1-2 together with normative Annexes includes most of the principal concepts and rules necessary for structural fire design of steel structures.

National Annex for EN 1993-1-2

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 1993-1-2 should have a National annex containing all Nationally Determined Parameters to be used for the design of steel structures to be constructed in the relevant country.

National choice is allowed in EN 1993-1-2 through paragraphs:

2.3 (1)
2.3 (2)
4.1 (2)
4.2.3.6 (1)
4.2.4 (2)

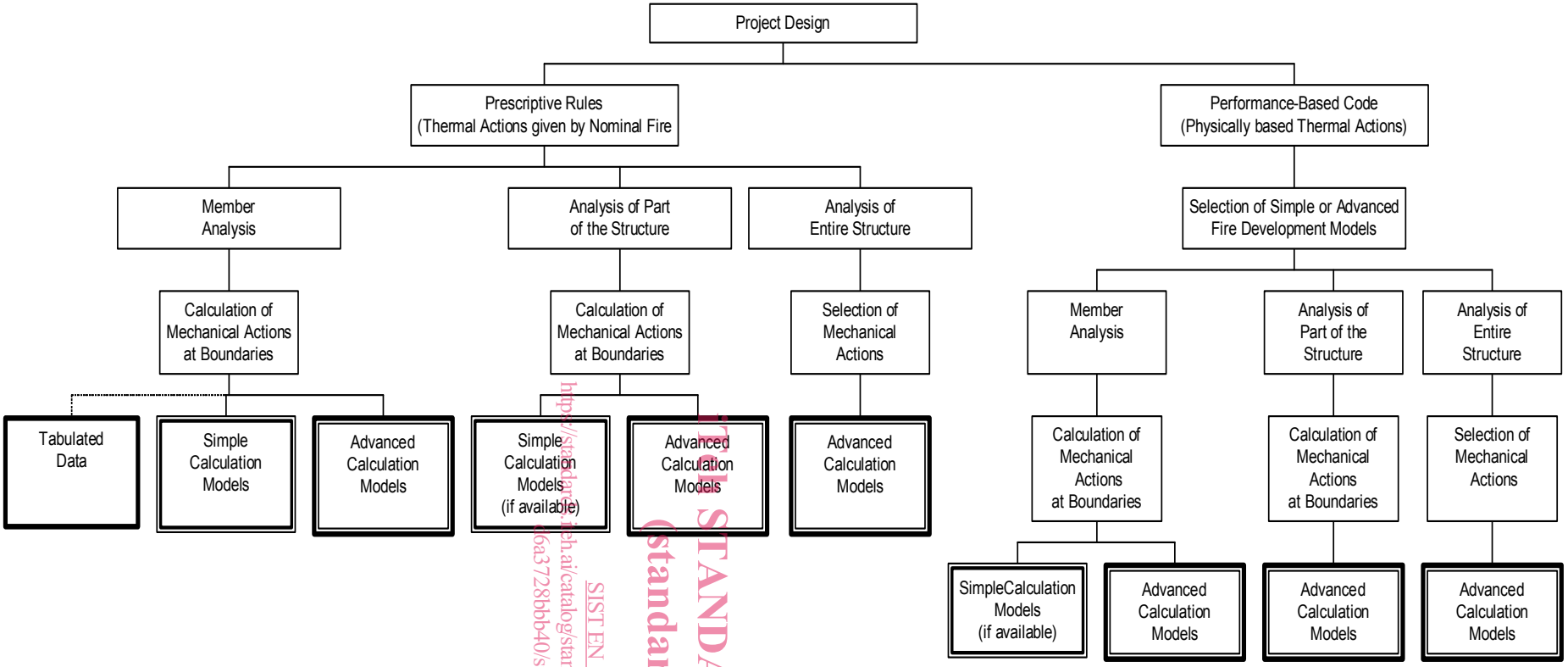

Figure 0.1: Design procedure

1. General

1.1 Scope

1.1.1 Scope of EN 1993

(1) EN 1993 applies to the design of buildings and civil engineering works in steel. 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) EN 1993 is only concerned with requirements for resistance, serviceability, durability and fire resistance of steel structures. Other requirements, e.g concerning thermal or sound insulation, are not considered.

(3) EN 1993 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 steel structures
- EN 1090 “Execution of steel structures”
- EN 1998 “Design of structures for earthquake resistance”, where steel structures are built in seismic regions

(4) EN 1993 is subdivided in six parts:

- EN 1993-1 Design of Steel Structures : Generic rules.
- EN 1993-2 Design of Steel Structures : Steel bridges.
- EN 1993-3 Design of Steel Structures : Towers, masts and chimneys.
- EN 1993-4 Design of Steel Structures : Silos, tanks and pipelines.
- EN 1993-5 Design of Steel Structures : Piling.
- EN 1993-6 Design of Steel Structures : Crane supporting structures.

1.1.2 Scope of EN 1993-1-2

(1) EN 1993-1-2 deals with the design of steel structures for the accidental situation of fire exposure and is intended to be used in conjunction with EN 1993-1-1 and EN 1991-1-2. EN 1993-1-2 only identifies differences from, or supplements to, normal temperature design.

(2) EN 1993-1-2 deals only with passive methods of fire protection.

(3) EN 1993-1-2 applies to steel structures that are required to fulfil this load bearing function if exposed to fire, in terms of avoiding premature collapse of the structure.

NOTE: This part does not include rules for separating elements.

(4) EN 1993-1-2 gives principles and application rules for designing structures for specified requirements in respect of the load bearing function and the levels of performance.

(5) EN 1993-1-2 applies to structures, or parts of structures, that are within the scope of EN 1993-1 and are designed accordingly.

(6) The methods given are applicable to structural steel grades S235, S275, S355, S420 and S460 of EN 10025 and all grades of EN 10210 and EN 10219.

(7) The methods given are also applicable to cold-formed steel members and sheeting within the scope of EN 1993-1-3.

(8) The methods given are applicable to any steel grade for which material properties at elevated temperatures are available, based on harmonized European standards.

(9) The methods given are also applicable stainless steel members and sheeting within the scope of EN 1993-1-4.

NOTE: For the fire resistance of composite steel and concrete structures, see EN 1994-1-2.

1.2 Normative references

(1) This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 10025	Hot rolled products of structural steels;
EN 10155	Structural steels with improved atmospheric corrosion resistance - Technical delivery conditions;
EN 10210	Hot finished structural hollow sections of non-alloy and fine grain structural steels:
Part 1:	*Technical delivery conditions*;
EN 10219	Cold formed welded structural hollow sections of non-alloy and fine grain structural steels:
Part 1:	*Technical delivery conditions*;
EN 1363	Fire resistance: General requirements;
EN 13501	Fire classification of construction products and building elements
Part 2	*Classification using data from fire resistance tests*
ENV 13381	Fire tests on elements of building construction:
Part 1:	*Test method for determining the contribution to the fire resistance of structural members: by horizontal protective membranes*;
Part 2	*Test method for determining the contribution to the fire resistance of structural members: by vertical protective membranes*;
Part 4:	*Test method for determining the contribution to the fire resistance of structural members: by applied protection to steel structural elements*;
EN 1990	Eurocode: Basis of structural design
EN 1991	Eurocode 1. Actions on structures:
Part 1-2:	*Actions on structures exposed to fire*;
EN 1993	Eurocode 3. Design of steel structures:
Part 1-1:	*General rules : General rules and rules for buildings*;
Part 1-3:	*General rules : Supplementary rules for cold formed steel members and sheeting*;
Part 1-4:	*General rules : Supplementary rules for stainless steels*
Part 1-8:	*General Rules: Design of joints*
EN 1994	Eurocode 4. Design of composite steel and concrete structures:
Part 1-2:	*General rules : Structural fire design*;
ISO 1000	SI units.

1.3 Assumptions

(1) In addition to the general assumptions of EN 1990 the following assumption applies:
- Any passive fire protection systems taken into account in the design should be adequately maintained.

1.4 Distinction between principles and application rules

(1) The rules given in clause 1.4 of EN1990 and EN1991-1-2 apply.

1.5 Terms and definitions

(1) The rules in EN 1990 clause 1.5 apply.

(2) The following terms and definitions are used in EN 1993-1-2 with the following meanings:

1.5.1 Special terms relating to design in general

1.5.1.1 Braced frame
A frame may be classified as braced if its sway resistance is supplied by a bracing system with a response to in-plane horizontal loads which is sufficiently stiff for it to be acceptably accurate to assume that all horizontal loads are resisted by the bracing system.

1.5.1.2 Part of structure
Isolated part of an entire structure with appropriate support and boundary conditions.

1.5.2 Terms relating to thermal actions

1.5.2.1 Standard temperature-time curve
A nominal curve, defined in EN 13501-2 for representing a model of a fully developed fire in a compartment.

1.5.3 Terms relating to material and products

1.5.3.1 Carbon steel
In this standard: steel grades according to in EN1993-1-1, except stainless steels

1.5.3.2 Fire protection material
Any material or combination of materials applied to a structural member for the purpose of increasing its fire resistance.

1.5.3.3 Stainless steel
All steels referred to in EN 1993-1-4.

1.5.4 Terms relating to heat transfer analysis

1.5.4.1 Configuration factor
The configuration factor for radiative heat transfer from surface A to surface B is defined as the fraction of diffusely radiated energy leaving surface A that is incident on surface B.

1.5.4.2 Convective heat transfer coefficient
Convective heat flux to the member related to the difference between the bulk temperature of gas bordering the relevant surface of the member and the temperature of that surface.

1.5.4.3 Emissivity
Equal to absorptivity of a surface, i.e. the ratio between the radiative heat absorbed by a given surface, and that of a black body surface.

1.5.4.4 Net heat flux
Energy per unit time and surface area definitely absorbed by members.

1.5.4.5 Section factor
For a steel member, the ratio between the exposed surface area and the volume of steel; for an enclosed member, the ratio between the internal surface area of the exposed encasement and the volume of steel.

1.5.4.6 Box value of section factor
Ratio between the exposed surface area of a notional bounding box to the section and the volume of steel.

1.5.5 Terms relating to mechanical behaviour analysis

1.5.5.1 Critical temperature of structural steel element
For a given load level, the temperature at which failure is expected to occur in a structural steel element for a uniform temperature distribution.

1.5.5.2 Effective yield strength
For a given temperature, the stress level at which the stress-strain relationship of steel is truncated to provide a yield plateau.

1.6 Symbols

(1) For the purpose of EN 1993-1-2, the following symbols apply:

Latin upper case letters

A_i	an elemental area of the cross-section with a temperature θ_i;
A_m	the surface area of a member per unit length;
A_m/V	the section factor for unprotected steel members;
C_i	the protection coefficient of member face i ;
A_p	the appropriate area of fire protection material per unit length of the member [m²];
E_a	the modulus of elasticity of steel for normal temperature design;
$E_{a,\theta}$	the slope of the linear elastic range for steel at elevated temperature θ_a ;
$E_{fi,d}$	the design effect of actions for the fire situation, determined in accordance with EN 1991-1-2, including the effects of thermal expansions and deformations;
$F_{b,Rd}$	the design bearing resistance of bolts;
$F_{b,t,Rd}$	the design bearing resistance of bolts in fire;
$F_{v,Rd}$	the design shear resistance of a bolt per shear plane calculated assuming that the shear plane passes through the threads of the bolt;
$F_{v,t,Rd}$	the fire design resistance of bolts loaded in shear;
$F_{w,Rd}$	the design resistance per unit length of a fillet weld;
$F_{w,t,Rd}$	the design resistance per unit length of a fillet weld in fire;
G_k	the characteristic value of a permanent action;
I_f	the radiative heat flux from an opening;
I_z	the radiative heat flux from a flame;
$I_{z,i}$	the radiative heat flux from a flame to a column face i;
L	the system length of a column in the relevant storey

$M_{b,fi,t,Rd}$ the design buckling resistance moment at time t

$M_{fi,t,Rd}$ the design moment resistance at time t

$M_{fi,\theta,Rd}$ the design moment resistance of the cross-section for a uniform temperature θ_a which is equal to the uniform temperature θ_a at time t in a cross-section which is not thermally influenced by the supports.;

M_{Rd} the plastic moment resistance of the gross cross-section $M_{pl,Rd}$ for normal temperature design; the elastic moment resistance of the gross cross-section $M_{el,Rd}$ for normal temperature design;

$N_{b,fi,t,Rd}$ the design buckling resistance at time t of a compression member

N_{Rd} the design resistance of the cross-section $N_{pl,Rd}$ for normal temperature design, according to EN 1993-1-1.

$N_{fi,\theta,Rd}$ the design resistance of a tension member a uniform temperature θ_a

$N_{fi,t,Rd}$ the design resistance at time t of a tension member with a non-uniform temperature distribution across the cross-section

$Q_{k,1}$ the principal variable load;

$R_{fi,d,t}$ the corresponding design resistance in the fire situation.

$R_{fi,d,0}$ the value of $R_{fi,d,t}$ for time $t = 0$;

T_f the temperature of a fire [K];

T_o the flame temperature at the opening [K];

T_x the flame temperature at the flame tip [813 K];

T_z the flame temperature [K];

$T_{z,1}$ the flame temperature [K] from annex B of EN 1991-1-2, level with the bottom of a beam;

$T_{z,2}$ the flame temperature [K] from annex B of EN 1991-1-2, level with the top of a beam;

V the volume of a member per unit length;

$V_{fi,t,Rd}$ the design shear resistance at time t

V_{Rd} the shear resistance of the gross cross-section for normal temperature design, according to EN 1993-1-1;

X_k the characteristic value of a strength or deformation property *(generally f_k or E_k)* for normal temperature design to EN 1993-1-1;

Latin lower case letters

a_z the absorptivity of flames;

c the specific heat;

c_a the specific heat of steel;

c_p the temperature independent specific heat of the fire protection material;

d_i the cross-sectional dimension of member face i;

d_p the thickness of fire protection material;

d_f the thickness of the fire protection material. ($d_f = 0$ for unprotected members.)

$f_{p,\theta}$ the proportional limit for steel at elevated temperature θ_a;