



BSI Standards Publication

Eurocode 3 — Design of steel structures

Part 1-2: Structural fire design

National foreword

This British Standard is the UK implementation of EN 1993-1-2:2024. It supersedes BS EN 1993-1-2:2005, which will be withdrawn on 30 March 2028.

The UK participation in its preparation was entrusted to Technical Committee CB/203, Design & execution of steel structures.

A list of organizations represented on this committee can be obtained on request to its committee manager.

National choice is allowed in this standard where explicitly stated within notes. The National Annex to this standard contains the national choices to be used for buildings and civil engineering works constructed in the UK.

The first generation of EN Eurocodes was published between 2002 and 2007, with conflicting British Standards withdrawn in 2010. This document forms part of the second generation of EN Eurocodes.

The second generation of EN Eurocodes is expected to be published between 2023 and 2026. These documents are being published as soon as they are available. This is being done to enable users to prepare for the transition from the first generation to second generation of EN Eurocodes.

UK adoptions of the first generation of EN Eurocodes will be withdrawn by BSI on 30 March 2028. Until that date, the first generation documents should be considered as the applicable standards for buildings and civil engineering works constructed in the UK unless otherwise specified by the relevant authority or in the specification for a particular project.

This standard is intended to be used with its National Annex and other referenced documents, including other second generation Eurocodes, as an interdependent suite of documents.

While the use of provisions in this standard in conjunction with first generation Eurocodes is not precluded, it should be undertaken with care and should only be done when users are satisfied that it will not result in a lower level of reliability than the minimum level set in the first generation Eurocodes and associated UK National Annexes.

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Amendments/corrigenda issued since publication

Date	Text affected
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English Version

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

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

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

This European Standard was approved by CEN on 1 January 2024.

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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 CEN-CENELEC Management Centre has the same status as the official versions.

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COMITÉ EUROPÉEN DE NORMALISATION
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Contents	Page
European foreword	4
Introduction	6
1 Scope	9
1.1 Scope of en 1993-1-2	9
1.2 Assumptions	9
2 Normative references	9
3 Terms, definitions and symbols	10
3.1 Terms and definitions.....	10
3.2 Symbols	11
4 Basis of design	16
4.1 General.....	16
4.2 Nominal fire exposure	16
4.3 Physically based fire exposure	17
4.4 Actions	17
4.5 Design values of material properties	17
4.6 Verification methods.....	17
4.7 Member analysis	18
4.8 Analysis of parts of the structure.....	18
4.9 Global structural analysis.....	18
5 Material properties.....	19
5.1 General.....	19
5.2 Thermal properties.....	19
5.3 Mechanical properties	21
6 Tabulated design data	26
6.1 General.....Error! Bookmark not defined.	
7 Simplified design methods.....	27
7.1 General.....	27
7.2 Classification of cross-sections	28
7.3 Effective width for class 4 cross-sections	28
7.4 Resistance.....	29
7.5 Critical temperature	41
7.6 Steel temperature development	42
8 Advanced design methods.....	48
8.1 General.....	48
8.2 Thermal analysis.....	48

8.3 Mechanical analysis..... 48

8.4 Validation of advanced design methods 49

Annex A (normative) Strain-hardening of steel at elevated temperatures 50

A.1 Use of this annex..... 50

A.2 Scope and field of application 50

A.3 Stress-strain relationships at elevated temperatures for structural steel..... 50

Annex B (normative) Heat transfer to external steelwork 52

B.1 Use of this annex..... 52

B.2 Scope and field of application 52

B.3 General 52

B.4 Column not engulfed in flame 56

B.5 Beam not engulfed in flame..... 61

B.6 Column engulfed in flame..... 65

B.7 Beam fully or partially engulfed in flame..... 68

Annex C (normative) Stainless steels 72

C.1 Use of this annex..... 72

C.2 Scope and field of application 72

C.3 Thermal properties 72

C.4 Mechanical properties of stainless steel..... 73

C.5 Simple calculation models 78

Annex D (normative) Joints 87

D.1 Use of this annex..... 87

D.2 Scope and field of application 87

D.3 Bolted joints 87

D.4 Design resistance of welds..... 89

D.5 Temperature of joints in fire..... 90

D.6 Welded steel tubular joints 90

Annex E (normative) Beams with large web openings 92

E.1 Use of this annex..... 92

E.2 Scope and field of application 92

E.3 Thermal response 92

E.4 Mechanical response..... 96

Bibliography 97

European foreword

This document (EN 1993-1-2:2024) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI. CEN/TC 250 is responsible for all Structural Eurocodes and has been assigned responsibility for structural and geotechnical design matters by CEN.

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 September 2027, and conflicting national standards shall be withdrawn at the latest by March 2028.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 1993-1-2:2005 and its corrigenda.

The first generation of EN Eurocodes was published between 2002 and 2007. This document forms part of the second generation of the Eurocodes, which have been prepared under Mandate M/515 issued to CEN by the European Commission and the European Free Trade Association.

The Eurocodes have been drafted to be used in conjunction with relevant execution, material, product and test standards, and to identify requirements for execution, materials, products and testing that are relied upon by the Eurocodes.

The Eurocodes recognize the responsibility of each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level through the use of National Annexes.

The main changes compared to the previous edition are listed below:

- reduction in number of National Choices (NDPs): NDPs have reduced from 5 to 4;
- enhanced ease of use;
- new structure harmonized with fire parts of other Eurocodes;
- high strength steels: Nominal fires are applicable to steel grades up to and including S700. Physically based thermal actions are applicable to steel grades up to and including S500;
- emissivity coefficient for hot-dip galvanized steel;
- existing buckling curve for LTB has been improved to take in to account the beneficial effect of non-uniform bending diagrams;
- Annex C for stainless steel member has been changed with a completely new content;
- Annex D has changed the calculation of the temperature of joints in fire;
- Annex D now includes welded steel tubular joints;
- former Annex E for Class 4 cross-sections was withdrawn. New design rules for class 4 cross-sections were included in EN 1993-1-2;
- new Annex E for beams with large web openings.

Any feedback and questions on this document should be directed to the users' national standards body. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.

Introduction

0.1 Introduction to the Eurocodes

The Structural Eurocodes comprise the following standards generally consisting of a number of parts:

- EN 1990 Eurocode: Basis of structural and geotechnical 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
- New parts are under development, e.g. Eurocode for design of structural glass

0.2 Introduction to EN 1993 (all parts)

EN 1993 (all parts) 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 and geotechnical design.

EN 1993 (all parts) is concerned only with requirements for resistance, serviceability, durability and fire resistance of steel structures. Other requirements, e.g. concerning thermal or sound insulation, are not covered.

EN 1993 is subdivided in various parts:

EN 1993-1, *Design of Steel Structures — Part 1: General rules and rules for buildings;*

EN 1993-2, *Design of Steel Structures — Part 2: Bridges;*

EN 1993-3, *Design of Steel Structures — Part 3: Towers, masts and chimneys;*

EN 1993-4, *Design of Steel Structures — Part 4: Silos and tanks;*

EN 1993-5, *Design of Steel Structures — Part 5: Piling;*

EN 1993-6, *Design of Steel Structures — Part 6: Crane supporting structures;*

EN 1993-7, *Design of steel structures — Part 7: Sandwich panels.*

EN 1993-1 in itself does not exist as a physical document, but comprises the following 14 separate parts, the basic part being EN 1993-1-1:

EN 1993-1-1, *Design of Steel Structures — Part 1-1: General rules and rules for buildings;*

EN 1993-1-2, *Design of Steel Structures — Part 1-2: Structural fire design;*

EN 1993-1-3, *Design of Steel Structures — Part 1-3: Cold-formed members and sheeting;*

NOTE Cold formed hollow sections supplied according to EN 10219 are covered in EN 1993-1-1.

EN 1993-1-4, *Design of Steel Structures — Part 1-4: Stainless steel structures*;

EN 1993-1-5, *Design of Steel Structures — Part 1-5: Plated structural elements*;

EN 1993-1-6, *Design of Steel Structures — Part 1-6: Strength and stability of shell structures*;

EN 1993-1-7, *Design of Steel Structures — Part 1-7: Plate assemblies with elements under transverse loads*;

EN 1993-1-8, *Design of Steel Structures — Part 1-8: Joints*;

EN 1993-1-9, *Design of Steel Structures — Part 1-9: Fatigue*;

EN 1993-1-10, *Design of Steel Structures — Part 1-10: Material toughness and through-thickness properties*;

EN 1993-1-11, *Design of Steel Structures — Part 1-11: Tension components*;

EN 1993-1-12, *Design of Steel Structures — Part 1-12: Additional rules for steel grades up to S960*;

EN 1993-1-13, *Design of Steel Structures — Part 1-13: Beams with large web openings*;

EN 1993-1-14, *Design of Steel Structures — Part 1-14: Design assisted by finite element analysis*.

All subsequent parts EN 1993-1-2 to EN 1993-1-14 treat general topics that are independent from the structural type like structural fire design, cold-formed members and sheeting, stainless steels, plated structural elements, etc.

All subsequent parts numbered EN 1993-2 to EN 1993-7 treat topics relevant for a specific structural type like steel bridges, towers, masts and chimneys, silos and tanks, piling, crane supporting structures, etc. EN 1993-2 to EN 1993-7 refer to the generic rules in EN 1993-1 and supplement, modify or supersede them, where relevant.

0.3 Introduction 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. The focus in EN 1993-1-2 is on design methods and design rules for individual members (beams, columns, beam-columns), joints and skeletal structures (frames) regarding resistance and stability under fire conditions.

0.4 Verbal forms used in the Eurocodes

The verb “shall” expresses a requirement strictly to be followed and from which no deviation is permitted in order to comply with the Eurocodes.

The verb “should” expresses a highly recommended choice or course of action. Subject to national regulation and/or any relevant contractual provisions, alternative approaches could be used/adopted where technically justified.

The verb “may” expresses a course of action permissible within the limits of the Eurocodes.

The verb “can” expresses possibility and capability; it is used for statements of fact and clarification of concepts.

0.5 National Annex for EN 1993-1-2

National choice is allowed in this standard where explicitly stated within notes. National choice includes the selection of values for Nationally Determined Parameters (NDPs).

The national standard implementing EN 1993-1-2 can have a National Annex containing all national choices to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

When no national choice is given, the default choice given in this standard is to be used.

When no national choice is made and no default is given in this standard, the choice can be specified by a relevant authority or, where not specified, agreed for a specific project by appropriate parties.

National choice is allowed in EN 1993-1-2 through notes to the following clauses:

4.5 (1) 4.7 (2) 7.5 (2) – 2 choices

National choice is allowed in EN 1993-1-2 on the application of the following informative annexes:

None

The National Annex can contain, directly or by reference, non-contradictory complementary information for ease of implementation, provided it does not alter any provisions of the Eurocodes.

1 Scope

1.1 Scope of EN 1993-1-2

- (1) This document provides rules for the design of steel structures for the accidental situation of fire exposure. This Part of EN 1993 only identifies differences from, or supplements to, normal temperature design.
- (2) This document applies to steel structures required to fulfil a loadbearing function.
- (3) This document does not include rules for separating function.
- (4) This document gives principles and application rules for the design of structures for specified requirements in respect of the aforementioned loadbearing function and the levels of performance.
- (5) This document applies to structures, or parts of structures, that are within the scope of EN 1993-1-1 and are designed accordingly.
- (6) This document is intended to be used in conjunction with EN 1991-1-2, EN 1993-1-1, EN 1993-1-3, EN 1993-1-4, EN 1993-1-5, EN 1993-1-6, EN 1993-1-7, EN 1993-1-8, EN 1993-1-11, EN 1993-1-13 or EN 1993-1-14.
- (7) In this document, carbon steel is meant when the term steel is used. Only in Annex C stainless steel is addressed.

1.2 Assumptions

- (1) Unless specifically stated, EN 1990, EN 1991(all parts) and EN 1993-1-1 apply.
- (2) The design methods given in this document are applicable if
 - the execution quality is as specified in EN 1090-2 and/or EN 1090-4, and
 - the construction materials and products used are as specified in EN 1993-1-1:2022, Table 5.1 and Table 5.2 and in EN 1993-1-3:2024, Table 5.1 and Table 5.2, or in the relevant material and product specifications.
- (3) In addition to the general assumptions of EN 1990 the following assumptions apply:
 - the choice of the relevant design fire scenario is made by appropriate qualified and experienced personnel, or is given by the relevant national regulation;
 - any fire protection measure taken into account in the design will be adequately maintained.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE See the Bibliography for a list of other documents cited that are not normative references, including those referenced as recommendations (i.e. through 'should' clauses) and permissions (i.e. through 'may' clauses).

EN 1090-2, *Execution of steel structures and aluminium structures - Part 2: Technical requirements for steel structures*

EN 1090-4, *Execution of steel structures and aluminium structures - Part 4: Technical requirements for cold-formed structural steel elements and cold-formed structures for roof, ceiling, floor and wall applications*

EN 1990:2023, *Eurocode - Basis of structural and geotechnical design*

EN 1991 (all parts), *Eurocode 1 - Actions on structures*

EN 1991-1-2:2024, *Eurocode 1: Actions on structures - Part 1-2: General actions - Actions on structures exposed to fire*

EN 1993-1-1:2022, *Eurocode 3 - Design of steel structures - Part 1-1: General rules and rules for buildings*

EN 1993-1-3:2024, *Eurocode 3 - Design of steel structures - Part 1-3: General rules - Supplementary rules for cold-formed members and sheeting*

EN 1993-1-4, *Eurocode 3 - Design of steel structures - Part 1-4: General rules - Supplementary rules for stainless steels*

EN 1993-1-5:2024, *Eurocode 3 - Design of steel structures - Part 1-5: Plated structural elements*

EN 1993-1-6, *Eurocode 3 - Design of steel structures - Part 1-6: Strength and Stability of Shell Structures*

EN 1993-1-7, *Eurocode 3 - Design of steel structures - Part 1-7: Plated structures subject to out of plane loading*

EN 1993-1-8:2024, *Eurocode 3: Design of steel structures - Part 1-8: Design of joints*

EN 1993-1-11, *Eurocode 3 - Design of steel structures - Part 1-11: Design of structures with tension components*

EN 1993-1-13:2024, *Eurocode 3 — Design of steel structures - Part 1-13: Beams with large web openings*

EN 1993-1-14, *Eurocode 3 — Design of steel structures - Part 1-14: Design assisted by finite element analysis*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1990, EN 1991-1-2 and the following apply.

3.1.1

box value of section factor

ratio between the exposed surface area of a notional bounding box to the section and the volume of steel

3.1.2

critical temperature of structural steel element

temperature for a given load level, at which failure is expected to occur in a structural steel element assuming a uniform temperature distribution

3.1.3

effective yield strength

stress level for a given temperature, at which the stress-strain relationship of steel is truncated to provide a yield plateau

3.1.4**fire protection material**

any material or combination of materials applied to a structural member for the purpose of increasing its fire resistance

3.1.5**part of structure**

isolated part of a structure with appropriate support and boundary conditions

3.1.6**section factor**

ratio between the exposed surface area and the volume of steel for a steel member, or ratio between the internal surface area of the exposed encasement and the volume of steel for an enclosed member

3.2 Symbols

For the purposes of this document, the following symbols apply.

3.2.1 Latin upper case letters

A_i	an elemental area of the cross-section with a temperature $\theta_{a,i}$;
A_m	surface area exposed to fire of a member per unit length;
A_m / V	section factor of unprotected steel members;
A_p	appropriate area of fire protection material per unit length of the member;
A_p / V	section factor for steel members insulated by fire protection material;
C_i	protection coefficient of member face i ;
E_a	modulus of elasticity of steel for normal temperature design;
$E_{a,\theta}$	slope of the linear elastic range for steel at elevated temperature θ_a ;
E_d	design effect of actions at normal temperature, determined in accordance with EN 1991-1-1;
$E_{d,fi}$	design effect of actions for the fire situation, determined in accordance with EN 1991-1-2, including the effects of thermal expansions and deformations;
$E_{p0,2,\theta}$	tangent modulus at $f_{p0,2,\theta}$;
$F_{b,Rd}$	design bearing resistance per bolt according to EN 1993-1-8;
$F_{b,Rd,fi,t}$	design bearing resistance per bolt in the fire situation at time t ;
$F_{v,Rd}$	design shear resistance per bolt per shear plane calculated assuming that the shear plane passes through the threads of the bolt according to EN 1993-1-8;
$F_{v,Rd,fi,t}$	design shear resistance per bolt per shear plane in the fire situation at time t ;
$F_{w,Rd}$	design resistance per unit length of a fillet weld according to EN 1993-1-8;
$F_{w,Rd,fi,t}$	design resistance per unit length of a fillet weld in the fire situation at time t ;
I_f	radiative heat flux from an opening;
I_z	radiative heat flux from a flame;
$I_{z,i}$	radiative heat flux from a flame to a column face i ;
L	system length of a column in the relevant storey;

L_i	length along axis between the opening and the relevant point;
M	number of openings on side m ;
$M_{b,Rd,fi,t}$	design buckling resistance moment in the fire situation at time t ;
$M_{c,Rd}$	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;
M_{cr}	elastic critical moment for lateral torsional buckling based on the gross cross-sectional properties, taking into account loading conditions, actual moment distribution and lateral restraints;
$M_{Rd,fi,t}$	design moment resistance in the fire situation at time t ;
$M_{Rd,fi,\theta}$	design moment resistance of the cross-section for a uniform temperature θ_a ;
N	number of openings on side n ;
$N_{b,Rd,fi,t}$	design buckling resistance in the fire situation at time t of a compression member;
N_{cr}	elastic critical axial force for the relevant buckling mode based on the gross cross-sectional properties, using the buckling length under fire conditions;
$N_{Rd,fi,t}$	design resistance in the fire situation at time t of a tension member with a non-uniform temperature distribution across the cross-section;
$N_{Rd,fi,\theta}$	design resistance of a tension member with a uniform temperature θ_a ;
$N_{t,Rd}$	design tension resistance of the cross-section for normal temperature design, according to EN 1993-1-1;
$R_{d,fi,t}$	design resistance in the fire situation at time t ;
$R_{d,fi,0}$	value of $R_{d,fi,t}$ for time $t = 0$;
T_f	temperature of fire;
T_m	temperature of the steel member;
T_o	flame temperature at the opening;
T_x	flame temperature at the flame tip;
T_z	flame temperature;
$T_{z,1}$	flame temperature [K] from Annex B of EN 1991-1-2:2024, level with the bottom of a beam;
$T_{z,2}$	flame temperature from Annex B of EN 1991-1-2:2024, level with the top of a beam;
V	volume of a member per unit length;
$V_{c,Rd}$	design value of the resistance to shear force for normal temperature design, according to EN 1993-1-1;
$V_{Rd,fi,t}$	design shear resistance in the fire situation at time t ;
X_k	characteristic value of a strength or deformation property (generally f_k or E_k) for normal temperature design to EN 1993-1-1).

3.2.2 Latin lower case letters

a_z	absorptivity of flames;
c_a	specific heat of steel;
c_p	specific heat of the fire protection material;
d	effective cross-sectional dimension;
d_i	cross-sectional dimension of member face i ;
d_p	thickness of fire protection material;
d_f	thickness of the fire protection material. ($d_f = 0$ for unprotected members.);
f	modification factor for $\chi_{LT,fi}$;
$f_{p,\theta}$	proportional limit for steel at elevated temperature θ_a ;
$f_{u,\theta}$	ultimate strength at elevated temperature, allowing for strain-hardening;
f_y	yield strength at 20 °C;
$f_{y,\theta}$	effective yield strength of steel at elevated temperature θ_a ;
$f_{y,i}$	nominal yield strength f_y for the elemental area A_i taken as positive on the compression side of the plastic neutral axis and negative on the tension side;
h_{eq}	equivalent height of the opening;
$\dot{h}_{net,d}$	design value of the net heat flux per unit area;
h_z	height of the top of the flame above the bottom of the beam;
i	column face indicator (1), (2), (3) or (4);
$k_{b,\theta}$	reduction factor determined for the appropriate bolt temperature;
k_c	correction factor for moment distribution;
$k_{E,\theta}$	reduction factor for the slope of the linear elastic range at the steel temperature θ_a reached at time t ;
$k_{E,\theta,com}$	reduction factor for the slope of the linear elastic range at the maximum steel temperature in the compression flange $\theta_{a,com}$ reached at time t ;
$k_{p0,2,\theta}$	reduction factor for the 0,2 % proof strength at the steel temperature θ_a reached at time t ;
k_{sh}	correction factor for the shadow effect;
$k_{u,\theta}$	reduction factor for the ultimate strength at the steel temperature θ_a reached at time t ;
k_θ	relative value of a strength or deformation property of steel at elevated temperature θ_a ;
$k_{w,\theta}$	strength reduction factor for welds at elevated temperature;
$k_{y,\theta}$	reduction factor for the yield strength at the steel temperature θ_a reached at time t ;
$k_{y,\theta,com}$	reduction factor for the yield strength of steel at the maximum temperature in the compression flange $\theta_{a,com}$ reached at time t ;
$k_{y,\theta,i}$	reduction factor for the yield strength of steel at temperature θ_i ;

$k_{y,\theta,\max}$	reduction factor for the yield strength of steel at the maximum steel temperature $\theta_{a,\max}$ reached at time t ;
$k_{y,\theta,\text{web}}$	reduction factor for the yield strength of steel at the steel temperature θ_{web} ;
k_y	interaction factor for buckling about y-y-axis;
k_z	interaction factor for buckling about z-z axis;
k_{LT}	interaction factor for lateral torsional buckling;
l	length at 20 °C ; a distance from an opening, measured along the flame axis;
l_{fi}	buckling length of a column for the fire design situation;
s	horizontal distance from the centreline of a column to a wall of a fire compartment;
t	time in fire exposure;
w_i	width of an opening;
z_i	distance from the plastic neutral axis to the centroid of the elemental area A_i .

3.2.3 Greek upper case letters

Δt	time interval;
Δl	temperature induced expansion;
$\Delta\theta_{a,t}$	increase of the steel uniform temperature distribution in a cross-section during the time interval Δt ;
$\Delta\theta_{g,t}$	increase of the ambient gas temperature during the time interval Δt .

3.2.4 Greek lower case letters

α	imperfection factor for flexural buckling;
α_c	convective heat transfer coefficient;
α_{LT}	imperfection factor for lateral-torsional buckling;
β_M	equivalent uniform moment factors;
γ_{M0}	partial factor for resistance of cross-sections at normal temperature;
γ_{M2}	partial factor at normal temperature;
$\gamma_{M,fi}$	partial factor for the relevant material property, for the fire situation;
ε	material parameter depending on f_y , at normal temperature;
ε_f	emissivity of a flame; the emissivity of an opening;
ε_{fi}	material parameter depending on f_y , for the fire situation;
ε_m	surface emissivity of the member;
ε_z	emissivity of a flame;
$\varepsilon_{z,m}$	total emissivity of the flames on side m;
$\varepsilon_{z,n}$	total emissivity of the flames on side n;
ε_θ	strain at the steel temperature θ_a ;
η_{fi}	reduction factor applied to E_d in order to obtain $E_{d,fi}$;
θ	temperature;

θ_a	steel temperature;
$\theta_{a,cr}$	critical temperature of steel;
$\theta_{g,t}$	ambient gas temperature at time t ;
θ_{web}	average temperature in the web of the section;
$\theta_{a,i}$	temperature in elemental area A_i ;
κ_1	adaptation factor for non-uniform temperature across the cross-section;
κ_2	adaptation factor for non-uniform temperature along the beam;
λ	thermal conductivity;
λ_i	flame thickness for an opening i ;
$\bar{\lambda}$	relative slenderness for flexural buckling;
$\bar{\lambda}_\theta$	relative slenderness for flexural buckling at the steel temperature θ_a ;
$\bar{\lambda}_{LT}$	relative slenderness for lateral torsional buckling;
$\bar{\lambda}_{LT,\theta,com}$	relative slenderness for lateral torsional buckling at the maximum temperature in the compression flange $\theta_{a,com}$;
$\bar{\lambda}_{p,\theta}$	relative slenderness for plate buckling of plane elements at the steel temperature θ_a ;
λ_p	thermal conductivity of the fire protection system;
λ_f	effective thermal conductivity of the fire protection material;
μ_0	degree of utilization at time $t = 0$;
σ	Stefan Boltzmann constant;
σ_θ	stress at the steel temperature θ_a ;
ρ_a	density of steel;
ρ_p	density of the fire protection material;
ϕ_f	overall configuration factor of the member for radiative heat transfer from the opening;
$\phi_{f,i}$	configuration factor of member face i for an opening;
ϕ_z	overall configuration factor of the member for radiative heat transfer from the flame;
$\phi_{z,i}$	configuration factor of member face i for a flame;
$\phi_{z,m}$	overall configuration factor of the column for heat from flames on side m ;
$\phi_{z,n}$	overall configuration factor of the column for heat from flames on side n ;
χ_{fi}	reduction factor for flexural buckling in the fire design situation;
$\chi_{LT,fi}$	reduction factor for lateral-torsional buckling in the fire design situation;
$\chi_{LT,fi,mod}$	modified reduction factor for lateral-torsional buckling;
$\chi_{min,fi}$	minimum value of $\chi_{y,fi}$ and $\chi_{z,fi}$;
$\chi_{y,fi}$	reduction factor for flexural buckling about the y-axis in the fire design situation;

$\chi_{z,fi}$ reduction factor for flexural buckling about the z-axis in the fire design situation.

4 Basis of design

4.1 General

(1) The structural fire design shall be in accordance with the general rules given in EN 1990 and EN 1991 (all parts) and the specific design provisions for steel structures given in EN 1993-1-1, EN 1993-1-3, EN 1993-1-4, EN 1993-1-5, EN 1993-1-6, EN 1993-1-7, EN 1993-1-8, EN 1993-1-11, EN 1993-1-13 or EN 1993-1-14.

(2) Steel structures designed according to this document shall be executed according to EN 1090-2 and/or EN 1090-4 with construction materials and products used as specified in the relevant parts of EN 1993, or in the relevant material and product specifications.

(3) Where mechanical resistance in the case of fire is required, steel structures shall be designed and constructed in such a way that they maintain their loadbearing function during the relevant fire exposure.

(4) Deformation criteria shall be applied where the means of fire protection require consideration of the deformation of the loadbearing structure.

(5) Consideration of the deformation of the loadbearing structure may be omitted when the efficiency of the means of protection has been evaluated according to 5.2.3.

(6) Deformation criteria shall be applied where the design criteria for separating elements require taking into account of the deformation of the loadbearing structure.

(7) Consideration of the deformation of the loadbearing structure may be omitted when the separating elements fulfil requirements of a nominal fire exposure.

(8) Steel structures designed in accordance with EN 1993-1-1 should be considered to have sufficient minimum robustness for the accidental fire design case. Where additional requirements are necessary the procedures of EN 1991-1-7:—¹, Annex A, apply.

4.2 Nominal fire exposure

(1) For standard fire exposure, elements shall comply with the following function defined in EN 1991-1-2 during the required time of fire exposure:

- loadbearing function: loadbearing capacity (R);
- separating function: integrity (E) and, when requested, insulation (I);
- separating and loadbearing functions: R, E and, when requested, I.

NOTE 1 The loadbearing function is assumed to be satisfied when loadbearing capacity is maintained.

NOTE 2 The separating function is assumed to be satisfied when integrity and, when requested, insulation are maintained.

NOTE 3 Integrity is assumed to be maintained when a separating element of building construction, exposed to fire on one side, prevents the passage through it of flames and hot gases and the occurrence of flames on the unexposed side.

¹ Under preparation. Stage at the time of publication: prEN 1993-1-7:2023.

NOTE 4 Insulation is assumed to be maintained when the average temperature rise over the whole of the unexposed surface is limited to 140 K, and the maximum temperature rise at any point of that surface does not exceed 180 K.

(2) With the hydrocarbon fire exposure curve the same loadbearing capacity (R) applies, however the reference to this specific curve shall be identified by the letters "HC".

4.3 Physically based fire exposure

(1) The loadbearing function shall be maintained during the complete duration of the fire, including the cooling phase or during a required period of time according to 4.4 (4) of EN 1991-1-2:2024.

4.4 Actions

(1) Thermal and mechanical actions shall be taken from EN 1991-1-2.

4.5 Design values of material properties

(1) Design values of mechanical (strength and stiffness) material properties for the fire situation $X_{d,fi}$ should be determined as follows:

$$X_{d,fi} = k_{\theta} X_k / \gamma_{M,fi} \quad (4.1)$$

where

- X_k is the characteristic value of a strength or stiffness property (generally f_k or E_k) for normal temperature design according to EN 1993-1-1;
- k_{θ} is the temperature-dependent reduction factor ($X_{k,\theta}/X_k$) for a strength or stiffness property, see 5.3;
- $\gamma_{M,fi}$ is the partial safety factor for the relevant mechanical material property for the fire situation.

NOTE The value of $\gamma_{M,fi}$ is 1,0 unless the National Annex gives a different value.

(2) The design values of thermal material properties for the fire situation should be taken equal to their characteristic values.

NOTE The characteristic values of thermal material properties correspond to mean values.

4.6 Verification methods

(1) The model of the structural system adopted for design shall reflect the performance of the structure in the fire situation.

(2) Mechanical resistance shall be verified for the required duration of fire exposure t according to Formula (4.2):

$$E_{d,fi} \leq R_{d,fi,t} \quad (4.2)$$

where

- $E_{d,fi}$ is the design effect of actions for the fire situation, determined in accordance with EN 1991-1-2, including effects of thermal expansions and deformations;
- $R_{d,fi,t}$ is the corresponding design resistance in the fire situation.

(3) The structural analysis for the fire situation should be carried out according to EN 1990:2023, 7.1.5.

NOTE For verifying resistance requirements based on the standard fire curve, unless otherwise specified, a member analysis is sufficient.

(4) If not specified in the relevant clauses, the verification methods given in this document may be applied for all types of fire exposure.

(5) The following design methods may be used in order to satisfy 4.6 (2):

- use of tabulated design data for specific types of members, see Clause 6;
- use of simplified design methods for specific types of members, see Clause 7;
- use of advanced design methods for the analysis of members, parts of the structure or the entire structure, see Clause 8.

(6) As an alternative to design by calculation, fire design may be based on the results of fire tests, or on fire tests in combination with calculations.

4.7 Member analysis

(1) The design effect of actions should be determined for time $t = 0$ using combination factors according to EN 1991-1-2:2024, 6.3.

(2) When $E_{d,fi}$ is obtained in accordance with 6.3.2(4) of EN 1991-1-2:2024, the safe-sided values of η_{fi} should be used.

NOTE: The value of η_{fi} is 0,65, except for imposed loads according to category E as given in EN 1990:2023 (areas susceptible to accumulation of goods, including access areas) where the value of η_{fi} is 0,7, unless the National Annex gives different values.

(3) The effects of thermal deformations resulting from thermal gradients across the cross-section shall be considered.

(4) The kinematic boundary conditions at supports and ends of members, applicable at time $t = 0$, may be assumed to remain unchanged throughout the fire exposure.

(5) Tabulated design data, simplified or advanced design methods given in this document may be used for verifying members under fire conditions.

4.8 Analysis of parts of the structure

(1) The effect of actions should be determined for time $t = 0$ using combination factors according to EN 1991-1-2:2024, 6.3.

(2) Within the part of the structure to be analysed, the relevant failure mode in fire, the temperature-dependent material properties and member stiffness, effects of thermal expansions and deformations (indirect fire actions) shall be taken into account.

(3) The part of the structure to be analysed should be specified on the basis of the potential thermal expansions and deformations such that their interaction with other parts of the structure can be approximated by time-independent support and boundary conditions during fire exposure.

(4) As an alternative to (1), the reactions at supports and internal forces and moments at the boundaries of the part of the structure may be obtained from structural analysis for normal temperature design as given in 4.7.

4.9 Global structural analysis

(1) A global structural analysis for the fire situation shall take into account:

- the relevant failure mode in fire exposure;
- the temperature-dependent material properties and member stiffness;

— effects of thermal expansions and deformations (indirect fire actions).

5 Material properties

5.1 General

(1) Unless given as design values, the values of material properties given in Clause 5 shall be treated as characteristic values.

(2) The mechanical properties of steel at normal temperature (20°C) shall be taken as those given in EN 1993-1-1 and EN 1993-1-3 for normal temperature design.

5.2 Thermal properties

5.2.1 Steel

5.2.1.1 Emissivity coefficient

(1) In addition to EN 1991-1-2:2024, 5.1(6), the values of surface emissivity, ε_m , related to different types of steel from Table 5.1 may be taken:

Table 5.1 — Values of surface emissivity ε_m

Type of steel	$\varepsilon_m (\leq 500^\circ\text{C})$	$\varepsilon_m (> 500^\circ\text{C})$
Steel	0,7	
HDG steel ^a	0,35	0,7
^a Steel that has been hot-dip galvanized according to EN ISO 1461 and with steel composition according to Category A or B of EN ISO 14713-2:2020, Table 1.		

5.2.1.2 Thermal conductivity

(1) The thermal conductivity of steel λ_a should be determined from the following:

— for $20^\circ\text{C} \leq \theta_a < 800^\circ\text{C}$:

$$\lambda_a = 54 - 3,33 \times 10^{-2} \theta_a \text{ W/(mK)} \quad (5.1)$$

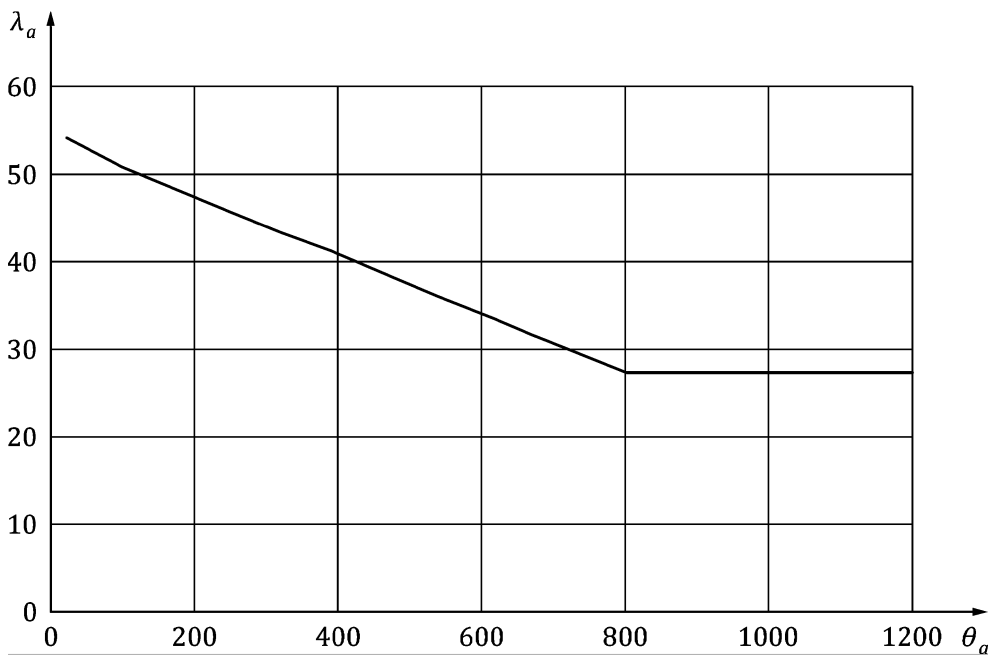
— for $800^\circ\text{C} \leq \theta_a \leq 1\,200^\circ\text{C}$:

$$\lambda_a = 27,3 \text{ W/(mK)} \quad (5.2)$$

where

θ_a is the steel temperature [$^\circ\text{C}$].

NOTE The variation of thermal conductivity with temperature is illustrated in Figure 5.1.



Key

λ_a thermal conductivity of steel in W/(mK)
 θ_a steel temperature in [°C]

Figure 5.1 — Thermal conductivity of steel as a function of temperature

5.2.1.3 Specific heat

(1) The specific heat of steel c_a should be determined from the following:

— for $20\text{ °C} \leq \theta_a < 600\text{ °C}$:

$$c_a = 425 + 7,73 \times 10^{-1} \theta_a - 1,69 \times 10^{-3} \theta_a^2 + 2,22 \times 10^{-6} \theta_a^3 \text{ J/(kgK)} \quad (5.3)$$

— for $600\text{ °C} \leq \theta_a < 735\text{ °C}$:

$$c_a = 666 + \frac{13002}{738 - \theta_a} \text{ J/(kgK)} \quad (5.4)$$

— for $735\text{ °C} \leq \theta_a < 900\text{ °C}$:

$$c_a = 545 + \frac{17820}{\theta_a - 731} \text{ J/(kgK)} \quad (5.5)$$

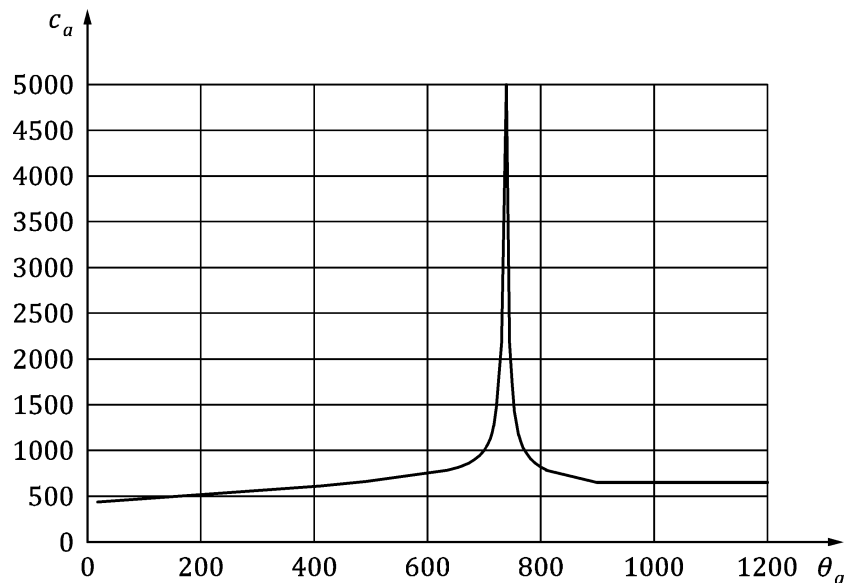
— for $900\text{ °C} \leq \theta_a \leq 1\,200\text{ °C}$:

$$c_a = 650 \text{ J/(kgK)} \quad (5.6)$$

where

θ_a is the steel temperature in [°C].

NOTE The variation of specific heat with temperature is illustrated in Figure 5.2.



Key

- c_a specific heat of steel in J/(kgK)
- θ_a steel temperature in [°C]

Figure 5.2 — Specific heat of steel as a function of temperature

5.2.1.4 Density

(1) The density of steel ρ_a may be considered to be independent of steel temperature. The following value may be taken:

$$\rho_a = 7\,850 \text{ kg/m}^3$$

5.2.2 Stainless steels

(1) The thermal properties of stainless steels should be taken from Annex C.

5.2.3 Fire protection materials

(1) The properties and performance of fire protection materials used in design should have been assessed using the test procedures given in the relevant parts of EN 13381 as appropriate.

5.3 Mechanical properties

5.3.1 Steel

5.3.1.1 Strength and stiffness properties

(1) For heating rates between 2 and 50 K/min, the strength and stiffness properties of steel at elevated temperatures should be obtained from the stress-strain relationship given in Table 5.2 and Figure 5.3.

(2) The relationship given in Table 5.2 and Figure 5.3 should be used to determine the resistance.

(3) Table 5.3 gives the reduction factors for the stress-strain relationship of steel at elevated temperatures shown in Table 5.2 and Figure 5.3. These reduction factors are defined as follows:

- effective yield strength, relative to yield strength at 20 °C: $k_{y,\theta} = f_{y,\theta} / f_y$
- proportional limit, relative to yield strength at 20 °C: $k_{p,\theta} = f_{p,\theta} / f_y$

— slope of linear elastic range, relative to slope at 20 °C: $k_{E,\theta} = E_{a,\theta} / E_a$

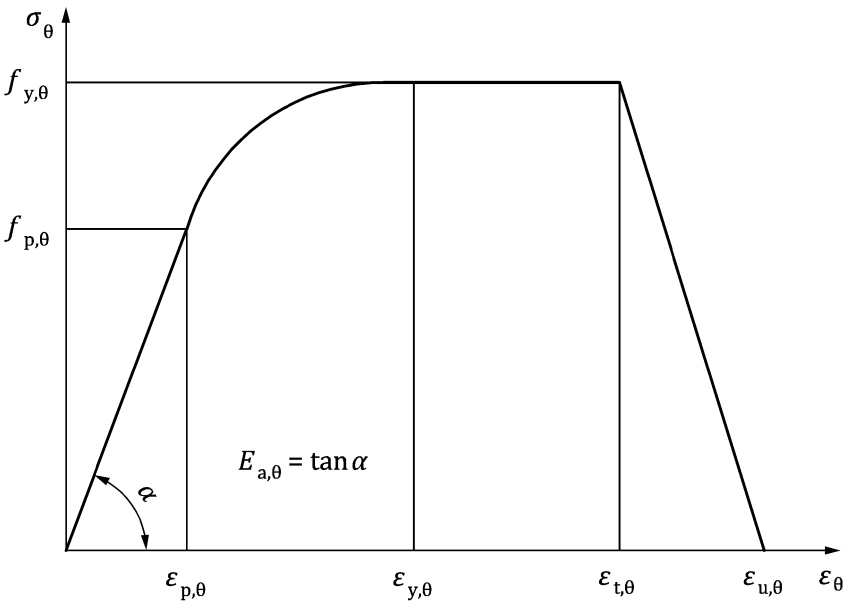
NOTE The variation of these reduction factors with temperature are illustrated in Figure 5.4.

(4) Alternatively, for temperatures below 400 °C, the stress-strain relationship specified in (1) may be extended by the strain-hardening option given in Annex A, provided local or member buckling does not lead to premature collapse.

(5) In case of thermal actions according to EN 1991-1-2:2024, 5.3 (physically based), the values specified in Figure 5.3 for the stress-strain relationship of structural steel up to and including S500 may be used as an approximation.

Table 5.2 — Stress-strain relationship for steel at elevated temperatures

Strain range	Stress σ_θ	Tangent modulus
$\varepsilon_\theta \leq \varepsilon_{p,\theta}$	$\varepsilon_\theta E_{a,\theta}$	$E_{a,\theta}$
$\varepsilon_{p,\theta} < \varepsilon_\theta < \varepsilon_{y,\theta}$	$f_{p,\theta} - c + (b/a) \left[a^2 - (\varepsilon_{y,\theta} - \varepsilon_\theta)^2 \right]^{0,5}$	$\frac{b(\varepsilon_{y,\theta} - \varepsilon_\theta)}{a \left[a^2 - (\varepsilon_{y,\theta} - \varepsilon_\theta)^2 \right]^{0,5}}$
$\varepsilon_{y,\theta} \leq \varepsilon_\theta \leq \varepsilon_{t,\theta}$	$f_{y,\theta}$	0
$\varepsilon_{t,\theta} < \varepsilon_\theta < \varepsilon_{u,\theta}$	$f_{y,\theta} \left[1 - (\varepsilon_\theta - \varepsilon_{t,\theta}) / (\varepsilon_{u,\theta} - \varepsilon_{t,\theta}) \right]$	-
$\varepsilon_\theta = \varepsilon_{u,\theta}$	0,00	-
Parameters	$\varepsilon_{p,\theta} = f_{p,\theta} / E_{a,\theta}$ $\varepsilon_{y,\theta} = 0,02$ $\varepsilon_{t,\theta} = 0,15$ $\varepsilon_{u,\theta} = 0,20$	
Functions	$a^2 = (\varepsilon_{y,\theta} - \varepsilon_{p,\theta})(\varepsilon_{y,\theta} - \varepsilon_{p,\theta} + c / E_{a,\theta})$ $b^2 = c(\varepsilon_{y,\theta} - \varepsilon_{p,\theta})E_{a,\theta} + c^2$ $c = \frac{(f_{y,\theta} - f_{p,\theta})^2}{(\varepsilon_{y,\theta} - \varepsilon_{p,\theta})E_{a,\theta} - 2(f_{y,\theta} - f_{p,\theta})}$	



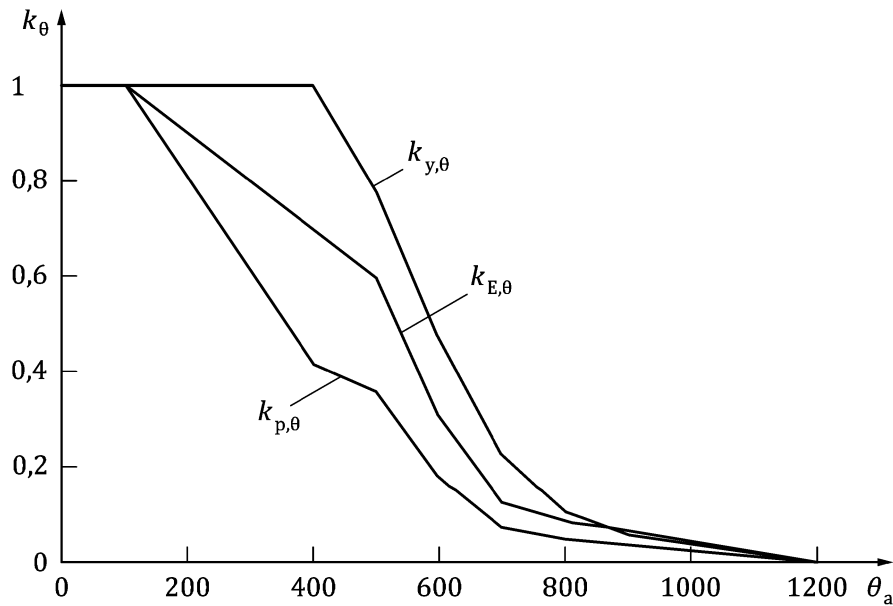
Key

- σ_θ stress
- ϵ_θ strain
- $f_{y,\theta}$ effective yield strength
- $f_{p,\theta}$ proportional limit
- $E_{a,\theta}$ slope of the linear elastic range
- $\epsilon_{p,\theta}$ strain at the proportional limit
- $\epsilon_{y,\theta}$ yield strain
- $\epsilon_{t,\theta}$ limiting strain for yield strength
- $\epsilon_{u,\theta}$ ultimate strain

Figure 5.3 — Stress-strain relationship for steel at elevated temperatures

Table 5.3 — Reduction factors for stress-strain relationship of steel at elevated temperatures

Steel Temperature θ_a	Reduction factors at temperature θ_a relative to the value of f_y or E_a at 20 °C		
	Reduction factor (relative to f_y) for the effective yield strength $k_{y,\theta} = f_{y,\theta} / f_y$	Reduction factor (relative to f_y) for the proportional limit $k_{p,\theta} = f_{p,\theta} / f_y$	Reduction factor (relative to E_a) for the slope of the linear elastic range $k_{E,\theta} = E_{a,\theta} / E_a$
20 °C	1,000	1,000	1,000
100 °C	1,000	1,000	1,000
200 °C	1,000	0,807	0,900
300 °C	1,000	0,613	0,800
400 °C	1,000	0,420	0,700
500 °C	0,780	0,360	0,600
600 °C	0,470	0,180	0,310
700 °C	0,230	0,075	0,130
800 °C	0,110	0,050	0,090
900 °C	0,060	0,0375	0,0675
1000 °C	0,040	0,0250	0,0450
1100 °C	0,020	0,0125	0,0225
1200 °C	0,000	0,0000	0,0000
NOTE For intermediate values of the steel temperature, linear interpolation can be used.			

**Key**

k_θ	reduction factor
θ_a	steel temperature in [°C]
$k_{y,\theta} = f_{y,\theta} / f_y$	reduction factor for the effective yield strength
$k_{E,\theta} = E_{a,\theta} / E_a$	reduction factor for the slope of linear elastic range
$k_{p,\theta} = f_{p,\theta} / f_y$	reduction factor for the proportional limit

Figure 5.4 — Reduction factors for the stress-strain relationship of steel at elevated temperatures

5.3.1.2 Thermal expansion

(1) The relative thermal expansion of steel $\Delta l / l$ should be determined from the following:

— for $20\text{ °C} \leq \theta_a < 750\text{ °C}$:

$$\Delta l / l = 1,2 \times 10^{-5} \theta_a + 0,4 \times 10^{-8} \theta_a^2 - 2,416 \times 10^{-4} \quad (5.7)$$

— for $750\text{ °C} \leq \theta_a \leq 860\text{ °C}$:

$$\Delta l / l = 1,1 \times 10^{-2} \quad (5.8)$$

— for $860\text{ °C} < \theta_a \leq 1\,200\text{ °C}$:

$$\Delta l / l = 2 \times 10^{-5} \theta_a - 6,2 \times 10^{-3} \quad (5.9)$$

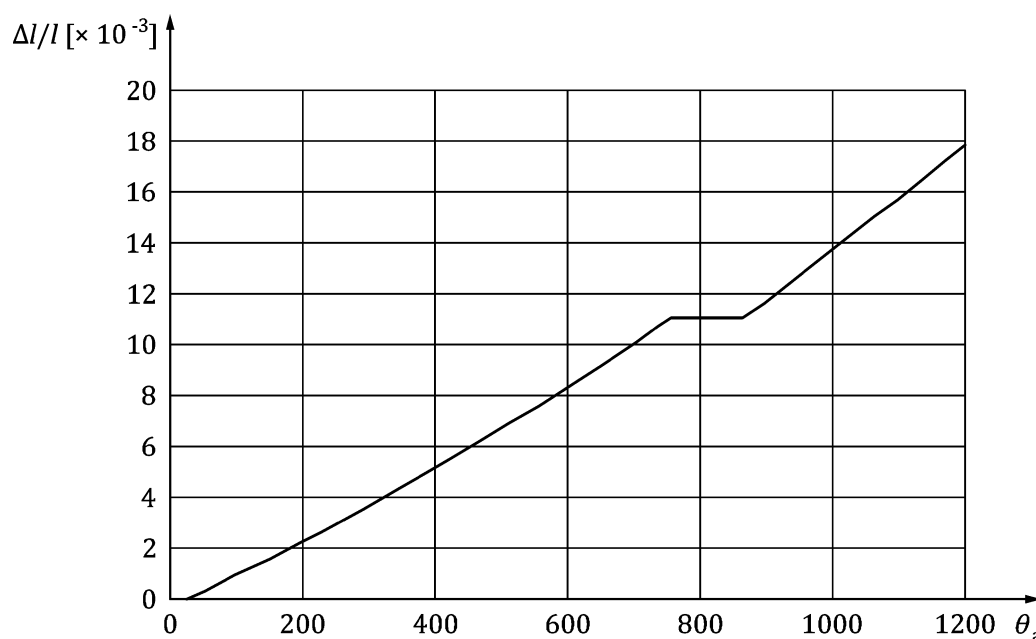
where

l is the length at 20 °C ;

Δl is the temperature induced expansion;

θ_a is the steel temperature [°C].

NOTE The variation of the relative thermal expansion with temperature is illustrated in Figure 5.5.



Key

$\Delta l / l$ relative thermal expansion

θ_a steel temperature in [°C]

Figure 5.5 — Relative thermal expansion of steel as a function of the temperature

5.3.2 Stainless steels

(1) The mechanical properties of stainless steels should be taken from Annex C.

6 Tabulated design data

(1) The tabulated design data refer to member analysis according to 4.7. They shall be used only for the standard fire exposure and without extrapolation outside their range of application.

NOTE 1: Tabulated data are derived from tests, calculation models or some combination of the two and can be presented either in the form of a table or an equation.

NOTE 2: Tabulated design data give safe-sided results compared to relevant tests or simplified or advanced design methods.

(2) The temperature distribution should be assumed to be the same along the length of the structural members.

(3) Tabulated design data may be used to obtain recognized design solutions generally in relation to member typology (dimensions) without recourse to any form of equilibrium equation.

NOTE: Tabulated design data are not provided in this document.

7 Simplified design methods

7.1 General

(1) The simplified design methods refer to member analysis according to 4.7. They shall be applied without extrapolation outside their range of application.

NOTE 1: Simplified design methods are based on global equilibrium equations, which are satisfied for a section or for a member.

NOTE 2: Solving the global equilibrium equation of a simplified design method results in the determination of a single quantity: e.g. a temperature in a section or part of it, a loadbearing capacity for a section or a member.

NOTE 3: Simplified design methods give safe-sided results compared to relevant tests or advanced design methods.

(2) The loadbearing function of a steel member shall be assumed to be maintained at a time t in a given fire if:

$$E_{d,fi} \leq R_{d,fi,t} \quad (7.1)$$

where

$E_{d,fi}$ is the design effect of actions for the fire design situation, according to EN 1991-1-2;

$R_{d,fi,t}$ is the corresponding design resistance of the steel member, for the fire design situation, at time t .

(3) The design resistance $R_{d,fi,t}$ at time t should be determined, usually in the hypothesis of a uniform temperature in the cross-section, by modifying the design resistance for normal temperature design to EN 1993-1-1, to take account of the mechanical properties of steel at elevated temperatures, see 7.4.

NOTE In 7.4 $R_{d,fi,t}$ becomes $M_{Rd,fi,t}$, $N_{Rd,fi,t}$ etc (separately or in combination) and the corresponding values of $M_{Ed,fi}$, $N_{Ed,fi}$ etc represent $E_{d,fi}$.

(4) If a non-uniform temperature distribution is used, the design resistance $R_{d,fi,t}$ may be determined based on the temperature distribution of the member.

(5) Alternatively to (3), by using a uniform temperature distribution, the verification may be carried out in the temperature domain, see 7.5.

(6) The fire resistance of a bolted or a welded joint may be assumed to be sufficient provided that the following conditions are satisfied:

- a) The thermal resistance $(d_f / \lambda_f)_c$ of the joint's fire protection is equal to or greater than the minimum value of thermal resistance $(d_f / \lambda_f)_m$ of fire protection applied to any of the jointed members;

where

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

λ_f is the effective thermal conductivity of the fire protection material.

- b) The degree of utilization of the joint is equal to or less than the maximum value of the degree of utilization of any of the connected members.

NOTE As a simplification, the comparison of the degree of utilization within the joints and joined members can be performed at normal temperature.

(7) As an alternative to the method given in 7.1 (6) the fire resistance of a joint may be determined using Annex D.