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Eurocode 9 - Design of aluminium structures - Part 1-2: Structural fire design

Eurocode 9 - Bemessung und Konstruktion von Aluminiumtragwerken - Teil 1 2: Tragwerksbemessung für den Brandfall

Eurocode 9 - Calcul des structures en aluminium - Partie 1-2: Calcul du comportement au feu

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Eurocode 9 - Design of aluminium structures - Part 1-2: Structural fire design

Eurocode 9 - Calcul des structures en aluminium -
Partie 1-2: Calcul du comportement au feu

Eurocode 9 - Bemessung und Konstruktion von
Aluminiumtragwerken - Teil 1 2:
Tragwerksbemessung für den Brandfall

This European Standard was approved by CEN on 2 January 2023.

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

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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EN 1999-1-2:2023 (E)**European foreword**

This document (EN 1999-1-2:2023) has been prepared by Technical Committee CEN/TC250 “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of an identical text or by endorsement, at the latest by September 2027, and conflicting national standards shall be withdrawn at the latest by March 2028.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 1999-1-2:2007.

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:

- Some reorganization of the text and its coherence with other Eurocodes;
- Improvement of figures;
- Update of symbols, alignment across the Eurocodes;
- Improved clarity and consistency.

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

The Eurocodes are intended for use by designers, clients, manufacturers, constructors, relevant authorities (in exercising their duties in accordance with national or international regulations), educators, software developers, and committees drafting standards for related product, testing and execution standards.

NOTE Some aspects of design are most appropriately specified by relevant authorities or, where not specified, can be agreed on a project-specific basis between relevant parties such as designers and clients. The Eurocodes identify such aspects making explicit reference to relevant authorities and relevant parties.

0.2 Introduction to EN 1999 (all parts)

EN 1999 (all parts) applies to the design of buildings and civil engineering and structural works made of aluminium. 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.

EN 1999 (all parts) is only concerned with requirements for resistance, serviceability, durability and fire resistance of aluminium structures. Other requirements, e.g. concerning thermal or sound insulation, are not considered.

EN 1999 (all parts) does not cover the special requirements of seismic design. Provisions related to such requirements are given in EN 1998, which complements, and is consistent with EN 1999.

Eurocode 9 is subdivided various parts:

- EN 1999-1-1 Design of Aluminium Structures — Part 1-1: General rules.
- EN 1999-1-2 Design of Aluminium Structures — Part 1-2: Structural fire design.
- EN 1999-1-3 Design of Aluminium Structures — Part 1-3: Structures susceptible to fatigue.

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- EN 1999-1-4 Design of Aluminium Structures — Part 1-4: Cold-formed structural sheeting.
- EN 1999-1-5 Design of Aluminium Structures — Part 1-5: Shell structures.

0.3 Introduction to EN 1999-1-2

This document describes the principles, requirements and rules for the structural design of aluminium buildings exposed to fire. The focus in EN 1999-1-2 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 1999-1-2

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 1999-1-2 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 1999-1-2 through the following clauses:

4.5(1)	7.2.1(1)	7.2.3(5)	7.2.4(4)
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National choice is allowed in EN 1999-1-2 on the application of the following informative annexes:

Annex A	Annex B
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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 1999-1-2

(1) This document deals with the design of aluminium structures for the accidental situation of fire exposure and is intended to be used in conjunction with EN 1999-1-1, EN 1999-1-3, EN 1999-1-4 and EN 1999-1-5. This document only identifies differences from, or supplements to, normal temperature design.

(2) This document applies to aluminium structures required to fulfil a load bearing function.

(3) This document gives principles and application rules for the design of structures for specified requirements in respect of the aforementioned function and the levels of performance.

(4) This document applies to structures, or parts of structures, that are within the scope of EN 1999-1-1 and are designed accordingly.

(5) The methods given in this document are applicable to the following aluminium alloys:

EN AW-3004 – H34 EN AW-5083 – O and H12 EN AW-6063 – T5 and T6

EN AW-5005 – O and H34 EN AW-5454 – O and H34 EN AW-6082 – T4 and T6

EN AW-5052 – H34 EN AW-6061 – T6

(6) The methods given in this document are applicable also to other aluminium alloy/tempers of EN 1999-1-1, provided that either all necessary information on properties at elevated temperatures are available or the simplified assumptions in 5.2.1 are applied.

1.2 Assumptions

(1) 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 active and passive fire protection systems taken into account in the design will be adequately maintained.

(2) For the design of new structures, EN 1999 is intended to be used, for direct application, together with EN 1990, EN 1991, EN 1992, EN 1993, EN 1994, EN 1995, EN 1997 and EN 1998.

(3) EN 1999 is intended to be used in conjunction with:

- European Standards for construction products relevant for aluminium structures
- EN 1090-1, *Execution of steel structures and aluminium structures - Part 1: Requirements for conformity assessment of structural components*
- EN 1090-3, *Execution of steel structures and aluminium structures - Part 3: Technical requirements for aluminium structures*

EN 1999-1-2:2023 (E)**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 1990, *Eurocode - Basis of structural design*

prEN 1991-1-2:2021,¹ *Eurocode 1 — Actions on structures - Part 1-2: General actions - Actions on structures exposed to fire*

EN 1999-1-1:2023, *Eurocode 9 — Design of aluminium structures - Part 1-1: General rules*

3 Terms, definitions and symbols**3.1 Terms and definitions**

For the purposes of this document, the terms and definitions given in EN 1990 and prEN 1991-1-2:2021 and the following apply.

3.1.1**part of structure**

isolated part of a structure with appropriate support and boundary conditions

3.1.2**fire protection material**

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

3.1.3**section factor**

ratio of the exposed surface area to the volume of aluminium or, in case of enclosed members, of the exposed encasement to the volume of aluminium

3.1.4**box value of section factor**

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

3.1.5**critical temperature of a structural aluminium member**

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

3.1.6**effective 0,2 % proof strength**

for a given temperature, the stress level at which the stress-strain relationship of aluminium gives a 0,2 % permanent strain

¹ Under preparation.

3.2 Symbols and abbreviations

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

Latin upper case letters:

A_i	an elemental area of the cross-section with a temperature θ_i
A_m	exposed surface area of a member per unit length
A_m/V	section factor of unprotected aluminium members
A_p	area of the inner surface of the fire protection material per unit length of the member
A_p/V	section factor for aluminium members insulated by fire protection material members
C_i	protection coefficient of member face i
E_{al}	modulus of elasticity of aluminium for normal temperature design
$E_{al,\theta}$	modulus of elasticity for aluminium at elevated temperature θ_{al}
E_d	design effect of actions at normal temperature, determined in accordance with EN 1990 and EN 1991-1-1
$E_{d,fi}$	design effect of actions for the fire situation, determined in accordance with prEN 1991 1-2:2021, including the effects of thermal expansions and deformations
I_f	radiative heat flux from an opening
I_z	radiative heat flux from a flame to the beam face
$I_{z,i}$	radiative heat flux from a flame to a column face
L	system length of a column in the relevant storey
L_H	horizontal projection of the flame (from the facade)
L_i	length along axis between the opening and the relevant point
L_L	flame height (from the upper part of the window)
L_x	distance from the opening measured along the flame axis
$M_{b,Rd}$	design buckling resistance moment for normal temperature design, according to EN 1999-1-1:2023
$M_{Ed,fi}$	design moment for the fire situation
$M_{b,Rd,fi,t}$	design buckling resistance moment in the fire situation at time t
$M_{Rd,fi,t}$	design moment resistance in the fire situation at time t of a cross-section with a non-uniform temperature distribution

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M_{Rd}	design moment resistance of the cross-section for normal temperature design, either $M_{c,Rd}$ or $M_{u,Rd}$
$N_{b,Rd}$	design buckling resistance of a compressed member for normal temperature design according to EN 1999-1-1:2023
$N_{Ed,fi}$	design axial force for the fire situation
$N_{b,Rd,fi,t}$	design buckling resistance in the fire situation at time t of a compressed member
$N_{Rd,fi,t}$	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_{al}
$R_{d,fi,t}$	design resistance in the fire situation at time t
T_f	temperature of fire
T_m	temperature of the aluminium 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 from Annex B of prEN 1991-1-2:2021, at the bottom of a beam
$T_{z,2}$	flame temperature from Annex B of prEN 1991-1-2:2021, at the top of a beam
V	volume of a member per unit length
V_{Rd}	design shear resistance of the net cross-section for normal temperature design, according to EN 1999-1-1:2023.
$V_{Ed,fi}$	design shear force for the fire situation
$V_{Rd,fi,t}$	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 1999-1-1:2023

Latin lower case letters:

a_z	absorptivity of flames
c_{al}	specific heat of aluminium
c_p	specific heat of the fire protection material
d_{eq}	effective cross-sectional dimension
d_f	flame thickness
d_i	cross-sectional dimension of member face i
d_p	thickness of fire protection material
$f_{0,\theta}$	effective 0,2 % proof strength at elevated temperature, θ_{al}
h_{eq}	equivalent height of the opening
$h_{net,d}$	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
k_θ	relative value of a strength or deformation property of aluminium at elevated temperature θ_{al}
$k_{0,\theta}$	strength reduction factor for the 0,2 % proof strength at the temperature θ_{al}
$k_{0,\theta,i}$	reduction factor for the effective 0,2 % proof strength at the temperature θ_i in the elemental area A_i .
$k_{0,\theta,max}$	the strength reduction factor for 0,2 % proof strength at the maximum aluminium temperature
k_{sh}	correction factor for the shadow effect
l	length at 20 °C; distance from an opening, measured along the flame axis
l_{fi}	buckling length of a column for the fire design situation
m	number of openings on side m
n	number of openings on side n
s	horizontal distance from the centreline of a column to a wall of a fire compartment
t	time in fire exposure
w_t	width of an opening
z_i	distance from the plastic neutral axis to the centroid of the elemental area A_i

EN 1999-1-2:2023 (E)**Greek lower-case letters**

α_c	heat transfer coefficient for convection
α_r	heat transfer coefficient for radiation
$\gamma_{M,fi}$	partial safety factor for the relevant material property for the fire situation
η_{fi}	reduction factor applied to E_d in order to obtain $E_{fi,d}$
θ	temperature in °C
θ_{al}	aluminium temperature
$\theta_{(t)}$	ambient gas temperature at time t
$\theta_{al(t)}$	aluminium temperature at time t
$\theta_{al,max(t)}$	maximum temperature of the cross section reached at time t
ε_f	emissivity of a flame; emissivity of an opening
ε_m	surface emissivity of the component
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
K	adaptation factor
λ_{al}	thermal conductivity of aluminium
λ_p	thermal conductivity of the fire protection material
μ_0	degree of utilization at time $t = 0$
ρ_{al}	density of aluminium
ρ_p	the density of the fire protection material
Σ	Stefan Boltzmann constant [$56,7 \times 10^{-12}$ kW/(m ² K ⁴)]
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
μ_0	degree of utilization at time $t = 0$
ρ_{al}	density of aluminium
ρ_p	the density of the fire protection material

4 Basis of design

4.1 General

- (1) Where mechanical resistance in the case of fire is required, aluminium structures shall be designed and constructed in such a way that they maintain their load bearing function during the relevant fire exposure.
- (2) Deformation criteria shall be applied where the means of protection require consideration of the deformation of the load bearing structure.
- (3) Consideration of the deformation of the loadbearing structure may be omitted, when the efficiency of the means of protection has been evaluated according to 5.2.2.
- (4) Deformation criteria shall be applied where the design criteria for separating elements require consideration of the deformation of the load bearing structure.
- (5) Consideration of the deformation of the load bearing structure may be neglected when the separating elements fulfil requirements of a nominal fire exposure, see 4.2.

4.2 Nominal fire exposure

- (1) For standard fire exposure, elements shall comply with one of the following functions or combinations of function defined in 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.
- (2) The loadbearing function is assumed to be satisfied when loadbearing capacity is maintained.
- (3) The separating function is assumed to be satisfied when integrity and, when requested, insulation is maintained.
- (4) 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.
- (5) 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.
- (6) When the external fire exposure curve is used, the same function shall apply, with the reference to this specific curve identified by the letters “ef”.

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 prEN 1991 1-2:2021.