

DIN EN 1999-1-1



ICS 91.010.30; 91.080.10

Supersedes
DIN EN 1999-1-1:2010-05

**Eurocode 9: Design of aluminium structures –
Part 1-1: General structural rules;
English version EN 1999-1-1:2007 + A1:2009 + A2:2013,
English translation of DIN EN 1999-1-1:2014-03**

Eurocode 9: Bemessung und Konstruktion von Aluminiumtragwerken –
Teil 1-1: Allgemeine Bemessungsregeln;
Englische Fassung EN 1999-1-1:2007 + A1:2009 + A2:2013,
Englische Übersetzung von DIN EN 1999-1-1:2014-03

Eurocode 9: Calcul des structures en aluminium –
Partie 1-1: Règles générales;
Version anglaise EN 1999-1-1:2007 + A1:2009 + A2:2013,
Traduction anglaise de DIN EN 1999-1-1:2014-03

Document comprises 226 pages

Translation by DIN-Sprachendienst.

In case of doubt, the German-language original shall be considered authoritative.



A comma is used as the decimal marker.

National foreword

This document (EN 1999-1-1:2007 + A1:2009 + A2:2013) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes” (Secretariat: BSI, United Kingdom).

The responsible German body involved in its preparation was the *Normenausschuss Bauwesen* (Building and Civil Engineering Standards Committee), Working Committee NA 005-08-07 AA *Aluminiumkonstruktionen* (SpA zu CEN/TC 250/SC 9 + CEN/TC 135).

This standard includes Amendment A1:2009 approved by CEN on 12 March 2009 and Amendment A2:2013 approved by CEN on 8 August 2013.

The start and finish of text introduced or altered by amendment is indicated in the text by tags A1 A1 and A2 A2.

Amendments

This standard differs from DIN EN 1999-1-1:2010-05 as follows:

- a) Amendment A2:2013 has been incorporated;
- b) the standard has been editorially revised.

Previous editions

DIN 4113-1: 1980-05, DIN 4113: 1958x-02
DIN 4113-1/A1: 2002-09
DIN 4113-1/A1 Corrigendum 1: 2008-12
DIN 4113-2: 2002-09, DIN 4113: 1958-02
DIN 4113-2 Corrigendum 1: 2008-12
DIN V 4113-3: 2003-11
DIN V 4113-3 Corrigendum 1: 2008-12
DIN V ENV 1999-1-1: 2000-10
DIN EN 1999-1-1: 2010-05

English Version

**Eurocode 9: Design of aluminium structures –
Part 1-1: General structural rules**

Eurocode 9: Calcul des structures en aluminium –
Partie 1-1: Règles générales

Eurocode 9: Bemessung und Konstruktion
von Aluminiumtragwerken –
Teil 1-1: Allgemeine Bemessungsregeln

EN 1999-1-1:2007 was approved by CEN on 2006-09-18, Amendment A1:2009 on 2009-03-12 and Amendment A2:2013 on 2013-08-08.

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.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.



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

Management Centre: Avenue Marnix 17, B-1000 Brussels

Contents

Page

Foreword to EN 1999-1-1:2007.....	7
A1 Foreword to EN 1999-1-1:2007/A1:2009	7
A2 Foreword to EN 1999-1-1:2007/A2:2013	7
1 General	11
1.1 Scope	11
1.1.1 Scope of EN 1999	11
1.1.2 Scope of EN 1999-1-1	11
1.2 Normative references.....	12
1.2.1 General references	12
1.2.2 References on structural design	13
1.2.3 References on aluminium alloys.....	13
1.2.4 References on welding.....	15
1.2.5 Other references.....	15
1.3 Assumptions	15
1.4 Distinction between principles and application rules	16
1.5 Terms and definitions	16
1.6 Symbols	16
1.7 Conventions for member axes	27
1.8 Specification for execution of the work.....	27
2 Basis of design	29
2.1 Requirements	29
2.1.1 Basic requirements.....	29
2.1.2 Reliability management.....	29
2.1.3 Design working life, durability and robustness	29
2.2 Principles of limit state design.....	29
2.3 Basic variables	30
2.3.1 Actions and environmental influences.....	30
2.3.2 Material and product properties.....	30
2.4 Verification by the partial factor method.....	30
2.4.1 Design value of material properties	30
2.4.2 Design value of geometrical data.....	30
2.4.3 Design resistances.....	30
2.4.4 Verification of static equilibrium (EQU).....	31
2.5 Design assisted by testing	31
3 Materials.....	32
3.1 General.....	32
3.2 Structural aluminium	32
3.2.1 Range of materials	32
3.2.2 Material properties for wrought aluminium alloys	33
3.2.3 Material properties for cast aluminium alloys	37
3.2.4 Dimensions, mass and tolerances	38
3.2.5 Design values of material constants.....	38
3.3 Connecting devices	38
3.3.1 General.....	38
3.3.2 Bolts, nuts and washers.....	39
3.3.3 Rivets	41
3.3.4 Welding consumables.....	41
3.3.5 Adhesives.....	43
4 Durability	43

5	Structural analysis.....	44
5.1	Structural modelling for analysis.....	44
5.1.1	Structural modelling and basic assumptions	44
5.1.2	Joint modelling	44
5.1.3	Ground-structure interaction	44
5.2	Global analysis	44
5.2.1	Effects of deformed geometry of the structure	44
5.2.2	Structural stability of frames	45
5.3	Imperfections.....	46
5.3.1	Basis	46
5.3.2	Imperfections for global analysis of frames	46
5.3.3	Imperfection for analysis of bracing systems	51
5.3.4	Member imperfections	53
5.4	Methods of analysis.....	53
5.4.1	General	53
5.4.2	Elastic global analysis	53
5.4.3	Plastic global analysis	53
6	Ultimate limit states for members.....	54
6.1	Basis	54
6.1.1	General	54
6.1.2	Characteristic value of strength	54
6.1.3	Partial safety factors	54
6.1.4	Classification of cross-sections	54
6.1.5	Local buckling resistance	60
6.1.6	HAZ softening adjacent to welds	61
6.2	Resistance of cross-sections	64
6.2.1	General	64
6.2.2	Section properties	64
6.2.3	Tension	66
6.2.4	Compression	66
6.2.5	Bending moment	67
6.2.6	Shear	69
6.2.7	Torsion.....	70
6.2.8	Bending and shear	72
6.2.9	Bending and axial force.....	72
6.2.10	Bending, shear and axial force	74
6.2.11	Web bearing	74
6.3	Buckling resistance of members.....	74
6.3.1	Members in compression.....	74
6.3.2	Members in bending.....	79
6.3.3	Members in bending and axial compression	81
6.4	Uniform built-up members	85
6.4.1	General	85
6.4.2	Laced compression members	87
6.4.3	Battened compression members	89
6.4.4	Closely spaced built-up members.....	90
6.5	Un-stiffened plates under in-plane loading	91
6.5.1	General	91
6.5.2	Resistance under uniform compression.....	91
6.5.3	Resistance under in-plane moment.....	92
6.5.4	Resistance under transverse or longitudinal stress gradient	93
6.5.5	Resistance under shear	93
6.5.6	Resistance under combined action	94
6.6	Stiffened plates under in-plane loading	95
6.6.1	General	95

6.6.2	Stiffened plates under uniform compression	96
6.6.3	Stiffened plates under in-plane moment	98
6.6.4	Longitudinal stress gradient on multi-stiffened plates	99
6.6.5	Multi-stiffened plating in shear	99
6.6.6	Buckling load for orthotropic plates	99
6.7	Plate girders	102
6.7.1	General	102
6.7.2	Resistance of girders under in-plane bending	102
6.7.3	Resistance of girders with longitudinal web stiffeners	103
6.7.4	Resistance to shear	105
6.7.5	Resistance to transverse loads	109
6.7.6	Interaction	112
6.7.7	Flange induced buckling	113
6.7.8	Web stiffeners	114
6.8	Members with corrugated webs	115
6.8.1	Bending moment resistance	115
6.8.2	Shear force resistance	116
7	Serviceability Limit States	118
7.1	General	118
7.2	Serviceability limit states for buildings	118
7.2.1	Vertical deflections	118
7.2.2	Horizontal deflections	118
7.2.3	Dynamic effects	118
7.2.4	Calculation of elastic deflection	118
8	Design of joints	120
8.1	Basis of design	120
8.1.1	Introduction	120
8.1.2	Applied forces and moments	120
8.1.3	Resistance of joints	120
8.1.4	Design assumptions	121
8.1.5	Fabrication and execution	121
8.2	Intersections for bolted, riveted and welded joints	121
8.3	Joints loaded in shear subject to impact, vibration and/or load reversal	122
8.4	Classification of joints	122
8.5	Connections made with bolts, rivets and pins	122
8.5.1	Positioning of holes for bolts and rivets	122
8.5.2	Deductions for fastener holes	125
8.5.3	Categories of bolted connections	127
8.5.4	Distribution of forces between fasteners	129
8.5.5	Design resistances of bolts	130
8.5.6	Design resistance of rivets	132
8.5.7	Countersunk bolts and rivets	133
8.5.8	Hollow rivets and rivets with mandrel	133
8.5.9	High strength bolts in slip-resistant connections	133
8.5.10	Prying forces	135
8.5.11	Long joints	136
8.5.12	$\overline{A_2}$ Single lap joints $\overline{A_2}$	136
8.5.13	Fasteners through packings	136
8.5.14	Pin connections	137
8.6	Welded connections	140
8.6.1	General	140
8.6.2	Heat-affected zone (HAZ)	140
8.6.3	Design of welded connections	140
8.7	Hybrid connections	148

8.8	Adhesive bonded connections	148
8.9	Other joining methods	148
A1)	Annex A [informative] – Reliability differentiation	149
A.1	Introduction	149
A.2	Design provisions for reliability differentiation - Design supervision levels.....	149
A.3	Execution provisions for reliability differentiation – Execution classes	149
A.4	Governing factors for choice of execution class	149
A.5	Determination of execution class	150
A.6	Utilization grades	150
	Annex B [normative] - Equivalent T-stub in tension	152
B.1	General rules for evaluation of resistance.....	152
B.2	Individual bolt-row, bolt-groups and groups of bolt-rows.....	156
	Annex C [informative] - Materials selection	158
C.1	General	158
C.2	Wrought products	158
C.2.1	Wrought heat treatable alloys.....	158
C.2.2	Wrought non-heat treatable alloys.....	161
C.3	Cast products	162
C.3.1	General	162
C.3.2	Heat treatable casting alloys EN AC-42100, EN AC-42200, EN AC-43000 and.....	162
	EN AC-43300.....	162
C.3.3	Non-heat treatable casting alloys EN AC-44200 and EN AC-51300.....	162
C.3.4	Special design rules for castings.....	162
C.4	Connecting devices.....	164
C.4.1	Aluminium bolts.....	164
C.4.2	Aluminium rivets.....	164
	Annex D [informative] – Corrosion and surface protection.....	165
D.1	Corrosion of aluminium under various exposure conditions.....	165
D.2	Durability ratings of aluminium alloys.....	165
D.3	Corrosion protection.....	166
D.3.1	General	166
D.3.2	Overall corrosion protection of structural aluminium	166
D.3.3	Aluminium in contact with aluminium and other metals	167
D.3.4	Aluminium surfaces in contact with non-metallic materials	167
	Annex E [informative] - Analytical models for stress strain relationship.....	172
E.1	Scope	172
E.2	Analytical models	172
E.2.1	Piecewise linear models	172
E.2.2	Continuous models	174
E.3	Approximate evaluation of ε_u	178
	Annex F [informative] - Behaviour of cross-sections beyond the elastic limit.....	179
F.1	General	179
F.2	Definition of cross-section limit states	179
F.3	Classification of cross-sections according to limit states	179
F.4	Evaluation of ultimate axial load.....	180
F.5	Evaluation of ultimate bending moment	181
	Annex G [informative] - Rotation capacity.....	183
	Annex H [informative] - Plastic hinge method for continuous beams.....	185

Annex I [informative] - Lateral torsional buckling of beams and torsional or torsional-flexural buckling of compressed members	188
I.1 Elastic critical moment and slenderness	188
I.1.1 Basis.....	188
I.1.2 General formula for beams with uniform cross-sections symmetrical about the minor or major axis	188
I.1.3 Beams with uniform cross-sections symmetrical about major axis, centrally symmetric and doubly symmetric cross-sections	193
I.1.4 Cantilevers with uniform cross-sections symmetrical about the minor axis	194
I.2 Slenderness for lateral torsional buckling.....	196
I.3 Elastic critical axial force for torsional and torsional-flexural buckling	198
I.4 Slenderness for torsional and torsional-flexural buckling	199
Annex J [informative] - Properties of cross sections	204
J.1 Torsion constant I_t	204
J.2 Position of shear centre S	204
J.3 Warping constant I_w	204
J.4 Cross section constants for open thin-walled cross sections	208
J.5 Cross section constants for open cross section with branches.....	210
J.6 Torsion constant I_{A2} Deleted text I_{A2} of cross section with closed part	210
Annex K [informative] - Shear lag effects in member design.....	212
K.1 General.....	212
K.2 Effective width for elastic shear lag	212
K.2.1 Effective width factor for shear lag	212
K.2.2 Stress distribution for shear lag	213
K.2.3 In-plane load effects	214
K.3 Shear lag at ultimate limit states	215
Annex L [informative] - Classification of joints.....	216
L.1 General.....	216
L.2 Fully restoring connections.....	217
L.3 Partially restoring connections	217
L.4 Classification according to rigidity.....	217
L.5 Classification according to strength.....	218
L.6 Classification according to ductility	218
L.7 General design requirements for connections.....	218
L.8 Requirements for framing connections.....	218
L.8.1 General.....	218
L.8.2 Nominally pinned connections	219
L.8.3 Built-in connections.....	220
Annex M [informative] - Adhesive bonded connections	221
M.1 General.....	221
M.2 Adhesives	221
M.3 Design of adhesive bonded joints	222
M.3.1 General	222
M.3.2 Characteristic strength of adhesives.....	223
M.3.3 Design shear stress	223
M.4 Tests	223
 Bibliography.....	224

Foreword to EN 1999-1-1:2007

This European Standard (EN 1999-1-1:2007) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI.

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 November 2007, and conflicting national standards shall be withdrawn at the latest by March 2010.

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

This European Standard supersedes ENV 1999-1-1:1998.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard:

Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

A1 Foreword to EN 1999-1-1:2007/A1:2009

This document (EN 1999-1-1:2007/A1:2009) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI.

This Amendment to the European Standard EN 1999-1-1:2007 shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2010, and conflicting national standards shall be withdrawn at the latest by March 2010.

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

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom. **A1**

A2 Foreword to EN 1999-1-1:2007/A2:2013

This document (EN 1999-1-1:2007/A2:2013) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI.

This Amendment to the European Standard EN 1999-1-1:2007 shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2014, and conflicting national standards shall be withdrawn at the latest by December 2014.

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

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom. **A2**

Background of the Eurocode programme

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

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

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

In 1989, the Commission and the Member States of the EU and EFTA decided, on the basis of an agreement¹ between the Commission and CEN, to transfer the preparation and the publication of the Eurocodes to the CEN through a series of Mandates, in order to provide them with a future status of European Standard (EN). This links *de facto* the Eurocodes with the provisions of all the Council's Directives and/or Commission's Decisions dealing with European standards (e.g. the Council Directive 89/106/EEC on construction products – CPD – and Council Directives 93/37/EEC, 92/50/EEC and 89/440/EEC on public works and services and equivalent EFTA Directives initiated in pursuit of setting up the internal market).

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

EN 1990	Eurocode 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

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

Status and field of application of Eurocodes

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

- as a means to prove compliance of building and civil engineering works with the essential requirements of Council Directive 89/106/EEC, particularly Essential Requirement N°1 - Mechanical resistance and stability - and Essential Requirement N°2 - Safety in case of fire;
- as a basis for specifying contracts for construction works and related engineering services;
- as a framework for drawing up harmonised technical specifications for construction products (ENs and ETAs)

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).