

DIN EN 1999-1-1:2024-11 (E)

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

Contents	Page
European foreword	8
0 Introduction.....	10
1 Scope.....	13
2 Normative references.....	14
3 Terms, definitions and symbols	15
3.1 Terms and definitions.....	15
3.2 Symbols	17
3.3 Conventions for member axes.....	32
4 Basis of design.....	34
4.1 General rules	34
4.1.1 Basic requirements	34
4.1.2 Structural reliability.....	34
4.1.3 Design service life, durability and robustness.....	34
4.2 Principles of limit state design.....	35
4.3 Basic variables	35
4.3.1 Actions and environmental influences	35
4.3.2 Material and product properties.....	35
4.4 Verification by the partial factor method	35
4.4.1 Design value of material properties	35
4.4.2 Design value of geometrical data	35
4.4.3 Design resistances	35
4.5 Design assisted by testing.....	36
4.6 Execution requirements.....	36
5 Materials	37
5.1 General.....	37
5.2 Structural aluminium.....	37
5.2.1 Range of materials.....	37
5.2.2 Material properties for wrought and casting alloys.....	39
5.2.3 Material properties for cast aluminium alloys	46
5.2.4 Dimensions, mass and tolerances.....	47
5.2.5 Design values of material constants	47
5.3 Connecting devices.....	48
5.3.1 General.....	48
5.3.2 Bolts, nuts, washers and self-tapping and self-drilling screws	48
5.3.3 Rivets.....	50
5.3.4 Welding consumables	50
5.3.5 Adhesives.....	51
6 Durability.....	51
7 Structural analysis.....	52
7.1 Structural modelling for analysis	52
7.1.1 Structural modelling and basic assumptions	52
7.1.2 Joint modelling.....	52
7.1.3 Ground-structure interaction.....	52
7.2 Global analysis	52
7.2.1 Effects of deformed geometry of the structure	52

7.2.2	Structural stability of frames.....	53
7.3	Imperfections	54
7.3.1	General.....	54
7.3.2	Imperfections for global analysis of frames.....	54
7.3.3	Imperfection for analysis of bracing systems	61
7.3.4	Member imperfections	63
7.4	Methods of analysis.....	63
7.4.1	General	63
7.4.2	Elastic global analysis	64
7.4.3	Plastic global analysis	64
8	Ultimate limit states for members.....	64
8.1	Basis.....	64
8.1.1	General	64
8.1.2	Characteristic value of strength	64
8.1.3	Partial factors.....	65
8.1.4	Classification of cross-sections	65
8.1.5	Local buckling resistance in class 4 members	73
8.1.6	HAZ softening adjacent to welds	74
8.2	Resistance of cross-sections	77
8.2.1	General	77
8.2.2	Section properties.....	78
8.2.3	Tension.....	79
8.2.4	Compression.....	80
8.2.5	Bending moment.....	81
8.2.6	Shear.....	84
8.2.7	Torsion	85
8.2.8	Bending and shear.....	86
8.2.9	Bending and axial force	87
8.2.10	Bending, shear and axial force.....	88
8.2.11	Web bearing.....	88
8.3	Buckling resistance of members	89
8.3.1	Members in compression.....	89
8.3.2	Members in bending.....	95
8.3.3	Members in bending and axial compression	98
8.4	Simplified analysis of resistance.....	103
8.5	Uniform built-up members	104
8.5.1	General	104
8.5.2	Laced compression members.....	106
8.5.3	Battened compression members	108
8.5.4	Closely spaced built-up members.....	109
8.6	Un-stiffened plates under in-plane loading	110
8.6.1	General	110
8.6.2	Resistance under uniform compression	111
8.6.3	Resistance under in-plane moment.....	112
8.6.4	Resistance under transverse or longitudinal stress gradient.....	113
8.6.5	Shear resistance	113
8.6.6	Resistance under out-of-plane loading.....	114
8.6.7	Resistance under combined action	115
8.7	Stiffened plates under in-plane loading	116
8.7.1	General	116
8.7.2	Stiffened plates under uniform compression.....	117
8.7.3	Stiffened plates under in-plane moment	119
8.7.4	Longitudinal stress gradient on multi-stiffened plates	120
8.7.5	Multi-stiffened plate in shear	120
8.7.6	Buckling load for orthotropic plates	121
8.7.7	Out-of-plane loading.....	124
8.7.8	Resistance under combined loading.....	126

8.8	Plate girders.....	128
8.8.1	General.....	128
8.8.2	Resistance of plate girders under in-plane bending.....	128
8.8.3	Plate girders with longitudinal web stiffeners	129
8.8.4	Shear resistance	131
8.8.5	Resistance to transverse forces.....	136
8.8.6	Interaction.....	140
8.8.7	Flange induced buckling	141
8.8.8	Web stiffeners	142
8.9	Members with corrugated webs.....	143
8.9.1	General.....	143
8.9.2	Bending moment resistance	143
8.9.3	Shear force resistance.....	144
9	Serviceability limit states	146
9.1	General.....	146
9.2	Deformations and dynamic effects for buildings	146
10	Design of joints	147
10.1	Basis of design.....	147
10.1.1	Introduction.....	147
10.1.2	Applied forces and moments	147
10.1.3	Resistance of joints.....	148
10.1.4	Design assumptions	148
10.1.5	Fabrication and execution.....	148
10.2	Intersections for bolted, riveted and welded joints.....	149
10.3	Joints loaded in shear subject to impact, vibration and/or load reversal	149
10.4	Classification of joints	149
10.5	Connections made with bolts, rivets and pins.....	149
10.5.1	Positioning of holes for bolts and rivets.....	149
10.5.2	Deductions for fastener holes	152
10.5.3	Categories of bolted connections	155
10.5.4	Design resistances of bolts	157
10.5.5	Design resistance of rivets.....	159
10.5.6	Countersunk bolts and rivets	160
10.5.7	Self-tapping and self-drilling screws and blind rivets.....	160
10.5.8	Bolts in slip-resistant connections	161
10.5.9	Long joints	163
10.5.10	Single lap joints of flats with only one row of fasteners	163
10.5.11	Fasteners through packings	164
10.5.12	Pin connections	164
10.5.13	Aluminium connecting devices	166
10.6	Welded connections.....	167
10.6.1	General.....	167
10.6.2	Design of welded connections.....	168
10.7	Design of friction stir welds	183
10.8	Hybrid connections	184
10.9	Special joints.....	184
10.9.1	General.....	184
10.9.2	Bolt-channel joints	185
10.9.3	Screw grooves and screw ports	188
10.10	Equivalent T-stub in tension.....	188
10.10.1	General	188
10.10.2	Prying Forces in typical T-Stub Stand-alone Connection	189
10.10.3	General rules for resistance evaluation	191
10.10.4	Geometrical limitations.....	199

10.11	Column web in transverse tension and transverse compression	199
10.11.1	General.....	199
10.11.2	Column web in transverse tension	200
10.11.3	Column web in transverse compression.....	204
10.12	Adhesive bonded joints	206
10.13	Other joining methods.....	206
Annex A (normative) Quality requirements for execution.....		207
A.1	Use of this annex	207
A.2	Scope and field of application	207
A.3	General	207
A.4	Selection process for execution class	208
A.5	Evaluation of utilization grades	210
Annex B (informative) Finite Element Methods of analysis (FEM).....		211
B.1	Use of this Annex.....	211
B.2	Scope and field of application	211
B.3	Use of FEM for design	211
B.4	Modelling.....	212
B.5	Choice of software and documentation	212
B.6	Use of imperfections.....	212
B.7	Material properties.....	214
B.8	Loads	214
B.9	Limit state criteria.....	214
B.10	Partial factors.....	215
Annex C (informative) Materials selection.....		218
C.1	Use of this Annex.....	218
C.2	Scope and field of application	218
C.3	General	218
C.4	Wrought products	218
C.5	Cast products.....	222
Annex D (informative) Corrosion and surface protection		224
D.1	Use of this Annex.....	224
D.2	Scope and field of application	224
D.3	Corrosion of aluminium under various exposure conditions	224
D.4	Durability ratings of aluminium alloys.....	226
D.5	Corrosion protection.....	227
Annex E (normative) Castings		233
E.1	Use of this Annex.....	233
E.2	Scope and field of application	233
E.3	General design provisions for castings.....	233
Annex F (informative) Analytical models for stress-strain relationship		236
F.1	Use of this Annex.....	236
F.2	Scope and field of application	236
F.3	Analytical models	236
F.4	Approximate evaluation of $\epsilon_{uni,max}$	244
Annex G (informative) Geometrical properties of cross-sections.....		245
G.1	Use of this Annex.....	245
G.2	Scope and field of application	245
G.3	Torsion constant I_t	245
G.4	Torsion modulus W_t	246
G.5	Position of shear centre S	246
G.6	Warping constant I_w	246

G.7	Cross-section constants for open thin-walled cross-sections.....	249
G.8	Torsion constant of cross-section with closed part.....	252
G.9	Shear area.....	253
G.10	Plastic section modulus and interaction formula.....	254
Annex H (informative)	Behaviour of cross-sections beyond elastic limit.....	256
H.1	Use of this Annex.....	256
H.2	Scope and field of application.....	256
H.3	Definition of cross-section limit states.....	256
H.4	Classification of cross-sections to limit states.....	257
H.5	Boundary values of ultimate axial load.....	258
H.6	Boundary values of ultimate moment.....	259
H.7	Ultimate resistance.....	260
Annex I (informative)	Lateral-torsional buckling of beams and torsional or torsional-flexural buckling of compressed members.....	261
I.1	Use of this Annex.....	261
I.2	Scope and field of application.....	261
I.3	Elastic critical moment and slenderness.....	261
I.4	Slenderness for lateral-torsional buckling.....	271
I.5	Elastic critical axial force for torsional and torsional-flexural buckling.....	272
I.6	Slenderness for torsional and torsional-flexural buckling.....	275
Annex J (informative)	Shear lag effects in member design.....	279
J.1	Use of this Annex.....	279
J.2	Scope and field of application.....	279
J.3	Effective width for elastic shear lag.....	279
J.4	Shear lag at ultimate limit states.....	283
Annex K (informative)	Plastic hinge method for continuous beams.....	284
K.1	Use of this Annex.....	284
K.2	Scope and field of application.....	284
K.3	Determination of ultimate bending moment M_u	285
Annex L (informative)	Cross-sectional ductility and rotation capacity.....	287
L.1	Use of this Annex.....	287
L.2	Scope and field of application.....	287
L.3	Moment-curvature analysis of cross-section.....	288
L.4	Evaluation of rotation capacity.....	293
L.5	Empirical relations for ultimate resistance.....	294
L.6	Empirical relations for rotation capacity.....	295
Annex M (informative)	Classification of joints.....	297
M.1	Use of this Annex.....	297
M.2	Scope and field of application.....	297
M.3	General.....	297
M.4	Fully restoring joints.....	298
M.5	Partially restoring joints.....	298
M.6	Classification according to rigidity.....	298
M.7	Classification according to strength.....	298
M.8	Classification according to ductility.....	299
M.9	General design requirements for joints.....	301
M.10	Requirements for framing joints.....	301
Annex N (informative)	The use of the component method for joints.....	305
N.1	Use of this Annex.....	305
N.2	Scope and field of application.....	305
Annex O (informative)	Screw grooves and screw ports.....	306

O.1	Use of this Annex.....	306
O.2	Scope and field of application	306
O.3	Tensile resistance.....	307
O.4	Shear resistance	309
Annex P (informative)	Adhesive bonded joints.....	312
P.1	Use of this Annex.....	312
P.2	Scope and field of application	312
P.3	General	312
P.4	Adhesives.....	312
P.5	Design of adhesive bonded joints	313
P.6	Tests	315
Annex Q (informative)	Determining the extent of HAZ from hardness tests.....	316
Q.1	Use of this Annex.....	316
Q.2	Scope and field of application	316
Q.3	Determining the extent of HAZ from hardness tests	316
Annex R (informative)	Weld studs connected by arc stud welding with tip ignition	318
R.1	Use of this Annex.....	318
R.2	Scope and field of application	318
R.3	Construction	318
R.4	Design	319
Annex S (normative)	Aluminium bridges	321
S.1	Use of this Annex.....	321
S.2	Scope and field of application	321
S.3	Terms, definitions and symbols	321
S.4	Basis of design	321
S.5	Materials	322
S.6	Durability	322
S.7	Structural Analysis.....	323
S.8	Ultimate limit states	324
S.9	Serviceability limit states	325
S.10	Fatigue	326
S.11	Detailing.....	327
Annex T (informative)	Lattice spatial roof structures	340
T.1	Use of this Annex.....	340
T.2	Scope and field of application	340
T.3	General requirements.....	340
T.4	Double layer reticulated structures.....	340
T.5	Single-layer reticulated structures	348
Annex U (informative)	Composite Aluminium Concrete Beams.....	356
U.1	Use of this Annex.....	356
U.2	Scope and field of application	356
U.3	General and main problems	356
U.4	Calculation of Internal Forces	357
U.5	Ultimate limit states	358
U.6	Shear Connectors.....	364
Annex V (normative)	Modified Buckling Conditions	367
V.1	Use of this Annex.....	367
V.2	Scope and field of application	367
V.3	Design of flexural buckling for bow imperfections $L/500$.....	367
	Bibliography	369