

DIN EN 1999-1-1:2014-03 (E)

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

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 1991-1-1:2007/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	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	A₂ Single lap joints A₂	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 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 A_2 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