



BSI Standards Publication

Eurocode 9 — Design of aluminium structures

Part 1-1: General rules

National foreword

This British Standard is the UK implementation of EN 1999-1-1:2023. It supersedes BS EN 1999-1-1:2007+A2:2013, which will be withdrawn on 30 March 2028.

The UK participation in its preparation was entrusted to Technical Committee B/525/9, Structural use of aluminium.

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The first generation of EN Eurocodes was published between 2002 and 2007, with conflicting British Standards withdrawn in 2010.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UK adoptions of the first generation of EN Eurocodes will be withdrawn by BSI on 30 March 2028.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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Date

Text affected

English Version

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

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

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

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

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European foreword

This document (EN 1999-1-1:2023) 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 1999-1-1:2007.

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

- Reduction in the number of invitations for Nationally Determined Parameters;
- Introduction of a new material, alloy EN-AW 5383;
- Revision and improvement of the buckling curves;
- Addition of the case of out-of-plane loading on stiffened plating;
- New connection types: Friction Stir Welding, Bolt-Channels and Screw Grooves;
- Improvement and additional provisions for T-stub connection model in tension;
- Clarification of the distinction between buckling members with longitudinal welds and members with transverse welds;
- New provisions covering when the initial bow imperfection $L/1000$ for members is not fulfilled (Annex V);
- New Annex to determine the extent of HAZ from hardness tests (Annex Q);
- New Annex on weld studs connected by arc stud welding with tip ignition (Annex R);
- New Annex on bridges (Annex S);
- New Annex on lattice space roof structures (Annex T);
- New Annex on composite aluminium-concrete beams (Annex U).

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.

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 organizations 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.

0 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.

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.

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, EN 1998 and EN 1999.

Eurocode 9 is subdivided in 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;
- 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 1999-1-1

This document gives basic design rules for structures made of wrought aluminium alloys and limited guidance for cast alloys.

This document is the first of the five parts of EN 1999. It gives generic design rules that are intended to be used with the other parts EN 1999-1-2 to EN 1999-1-5.

EN 1999-1-1 can be used for design cases not covered by the Eurocodes (other structures, other actions, other materials) and serving as a reference document for other CEN TC's concerning structural matters.

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 1999-1-1

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

4.1.2(3)	4.4.3(2)	4.5(1)	5.2.1(1)
9.1(2)	9.2(2)	10.6.2.2(1)	A.3.2(1)
A.4(1)	A.4(3) – 2 choices	A.4(4)	A.5(1)
E.3.1(2)	E.3.1(3)	H.2(6)	O.2(2) – 2 choices
S.2(2)	S.4.1.2(3)	S.4.1.2(4)	S.6(3)
S.10.4(1)			

National choice is allowed in EN 1999-1-1 on the application of the following informative annexes:

Annex B	Annex C	Annex D	Annex F
Annex G	Annex H	Annex I	Annex J
Annex K	Annex L	Annex M	Annex N
Annex O	Annex P	Annex Q	Annex R
Annex T	Annex U		

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 1999-1-1

(1) EN 1999-1-1 gives basic design rules for structures made of wrought aluminium alloys and limited guidance for cast alloys (see Clause 5 and Annex C).

This document does not cover the following, unless otherwise explicitly stated in this document:

- components with material thickness less than 0,6 mm;
- welded components with material thickness less than 1,5 mm;
- connections with:
 - steel bolts and pins with diameter less than 5 mm;
 - aluminium bolts and pins with diameter less than 8 mm;
 - rivets and thread forming screws with diameter less than 3,9 mm.

1.2 Assumptions

(1) In addition to the general assumptions of EN 1990 the following assumptions apply:

- execution complies with EN 1090-3 and EN 1090-5;
- the mechanical properties comply with the product standards listed in 5.2.2.

(2) 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 1090-5, *Execution of steel structures and aluminium structures – Part 5: Technical requirements for cold-formed structural aluminium elements and cold-formed structures for roof, ceiling, floor and wall applications*.

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 1090-3, *Execution of steel structures and aluminium structures – Part 3: Technical requirements for aluminium structures*

EN 1090-5, *Execution of steel structures and aluminium structures – Part 5: Technical requirements for cold-formed structural aluminium elements and cold-formed structures for roof, ceiling, floor and wall applications*

EN 1990, *Eurocode — Basis of structural and geotechnical design*

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

EN 1993-1-8, *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 1999-1-2, *Eurocode 9 — Design of aluminium structures — Part 1-2: Structural fire design*

EN 1999-1-3, *Eurocode 9 — Design of aluminium structures — Part 1-3: Structures susceptible to fatigue*

EN 1999-1-4, *Eurocode 9 — Design of aluminium structures – Part 1.4: Cold-formed structural sheeting*

EN 1999-1-5, *Eurocode 9 — Design of aluminium structures — Part 1-5: Shell structures*

EN 10204, *Metallic products - Types of inspection documents*

EN 14399-1, *High-strength structural bolting assemblies for preloading — Part 1: General requirements*

EN 14399-3, *High-strength structural bolting assemblies for preloading — Part 3: System HR — Hexagon bolt and nut assemblies*

EN 14399-4, *High-strength structural bolting assemblies for preloading — Part 4: System HV — Hexagon bolt and nut assemblies*

EN 14399-5, *High-strength structural bolting assemblies for preloading — Part 5: Plain washers*

EN 14399-6, *High-strength structural bolting assemblies for preloading — Part 6: Plain chamfered washers*

EN 14399-8, *High-strength structural bolting assemblies for preloading — Part 8: System HV — Hexagon fit bolt and nut assemblies*

EN 15048-1, *Non-preloaded structural bolting assemblies — Part 1: General requirements*

EN ISO 3506-1, *Fasteners — Mechanical properties of corrosion-resistant stainless-steel fasteners — Part 1: Bolts, screws and studs with specified grades and property classes (ISO 3506-1)*

EN ISO 3506-2, *Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners — Part 2: Nuts with specified grades and property classes (ISO 3506-2)*

EN ISO 13918, *Welding — Studs and ceramic ferrules for arc stud welding (ISO 13918)*

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 the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1.1

frame

whole of or a portion of a structure, comprising an assembly of directly connected structural members, designed to act together to resist load

Note 1 to entry: This term refers to both moment-resisting frames and triangulated frames. It covers both plane frames and spatial frames.

3.1.2

connection

location at which two members are interconnected

Note 1 to entry: A “connection” is the system, which mechanically fastens a given member to the remaining part of the structure. It should be distinguished from the term “joint”, which usually means the system composed by the connection itself plus the corresponding interaction zone between the connected members (see Figure M.1).

3.1.3

joint

assembly of basic components that enables members to be connected together in such a way that the relevant internal forces and moment can be transferred between them

Note 1 to entry: A beam-to-column joint consists of a web panel and either one connection (single sided joint configuration) or two connections (double sided joint configuration).

Note 2 to entry: For distinction between joint and connection, see 3.1.3 and Figure M.1.

3.1.4

semi-continuous joint

joint in which the structural properties of the joint components need explicit consideration for its modelling in the global analysis

Note 1 to entry: The term continuous includes both strength and stiffness properties.

Note 2 to entry: The term continuous joint refers to continuous framing modelling.

3.1.5

continuous joint

joint in which only the structural properties of the members need be considered in the global analysis

Note 1 to entry: The term continuous includes both strength and stiffness properties.

Note 2 to entry: The term continuous joint refers to continuous framing modelling.

3.1.6

simple joint

joint that is not required to resist moments

3.1.7

global analysis

structural analysis of the entire structure

Note 1 to entry: Structural analyses are sometimes performed at more than one level using different models (e.g. global, member and local analyses). See definition of structural analysis in EN 1990.

3.1.8

system length

distance in a given plane between two adjacent points at which a member is braced against lateral displacement, or between one such point and the end of the member

3.1.9

buckling length

length of an equivalent uniform member with pinned ends, which has the same cross-section and the same elastic critical force as the verified uniform member (individual or as a component of a frame structure)

3.1.10

shear lag effect

non-uniform axial stress distribution in wide flanges due to shear deformations

Note 1 to entry: It is taken into account by using a reduced “effective” flange width.

3.1.11

capacity design

design method in which elements of the structural system are chosen and suitably designed and detailed for energy dissipation under severe deformations while all other structural elements are provided with sufficient strength so that the chosen means of energy dissipation can be maintained

Note 1 to entry: The design method is used, e.g. in design of structures for earthquake resistance.

3.1.12

open section

type of section prone to torsional or lateral-torsional buckling, e.g. I-, H-, U-, Z-, C-sections with low torsional stiffness

Note 1 to entry: The section can include small hollow parts, but still stability needs to be verified.

Note 2 to entry: The design provisions in this standard distinguish between open section, closed/hollow section and solid section, see Table 3.1.

3.1.13

closed/hollow section

type of section such as rectangular and square hollow sections (RHS, SHS), circular hollow sections (CHS) but also complicated hollow sections with outstands, i.e. sections with large torsional stiffness so that lateral-torsional buckling is not decisive

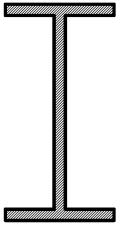
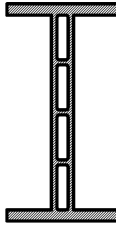
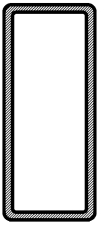
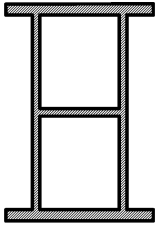
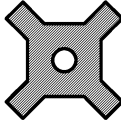
Note 1 to entry: The design provisions in this standard distinguish between open section, closed/hollow section and solid section, see Table 3.1.

3.1.14
solid section

type of section of rod or bar or other compact sections that may have small hollow parts and small compact outstand parts

Note 1 to entry: The design provisions in this standard distinguish between open section, closed/hollow section and solid section, see Table 3.1.

Table 3.1 — Designation in this standard and commercial designations of cross-sections ^a

EN 1999-1-1	Open		Closed/Hollow ^b	Solid	
Cross-section			 	 	 
EN 12258	Solid	Hollow	Hollow	Solid	Hollow
^a To avoid misunderstanding between the design engineer and the manufacturer/provider of extruded sections, one should be aware that according to EN 12258 (Aluminium – terms and definitions) differing terms for semi products are used. One distinguishes there between — Hollow section profile in which the cross-section completely encloses one or more voids; — Solid section profile in which the cross-section does not include any enclosed void. ^b The section may be considered as closed if the distance between the webs is larger than one third of the section height.					

3.1.15
high strength steel bolt assemblies

bolts of property class 8.8 or 10.9 with nuts and washers according to EN 14399-3 up to EN 14399-6 and EN 14399-8, in combination with EN 14399-1

3.2 Symbols

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

NOTE Additional symbols are defined where they occur.

Latin upper-case letters

- A

= $A_{5,65\sqrt{A_0}}$, elongation value measured with a reference length, $5,65 \sqrt{A_0}$, see EN ISO 6892
- A_{ch}

cross-sectional area of one chord of a built-up column
- A_d

area of one diagonal of a built-up column
- A_e

the full section area of an unwelded solid bar or circular tube, or the effective section area obtained by taking a reduced thickness, $\rho_{o,haz}t$ for the HAZ material of a welded section
- A_{eff}

effective cross-section area
- A_f

area of the tension flange

$A_{f,net}$	net area in the section with fastener holes
A_{f1}, A_{f2}	cross-section area of top and bottom flange
A_{fc}	cross-section area of compression flange
A_g	gross cross-section area
A_{net}	net cross-section area
A_s	tensile stress area of a bolt
A_{st}	area of all longitudinal stiffeners within half the flange width
$A_{st,eff}$	effective area of the stiffener column, see Figure 8.29(c)
$A_{u,eff}$	effective cross-section area allowing for local buckling and HAZ softening of transverse welds
A_V	shear area
A_v	area of one post (or transverse element) of a built-up column
A_w	cross-section area of web
A_0	cross-section area of the hole
A_1	area of part of angle outside the bolt hole
A_{50}	elongation value measured with a constant reference length of 50 mm, see EN ISO 6892
BC	buckling class
B_{Ed}	design value of bimoment
B_o	conventional bolt strength at elastic limit
$B_{p,Rd}$	design punching shear resistance per bolt
$B_{t,Rd}$	design tension resistance of a bolt-plate assembly
$B_{u,Rd}$	tension resistance of a bolt-plate assembly
B_x	bending stiffness of orthotropic plate in section $x = \text{constant}$
B_y	bending stiffness of orthotropic plate in section $y = \text{constant}$
C_o	reduction factor for $\rho_{o,haz}$, depending of the thickness, the filler material and the welding process
C_u	reduction factor for $\rho_{u,haz}$, depending of the thickness, the filler material and the welding process
C_1, C_2, C_3 $C_{1,0}, C_{1,1}$	factors
D	diameter of circle inscribed in fillet or bulb

D_m	diameter to mid-thickness of round tube
E	modulus of elasticity
E_k	characteristic value of action effect
E_s	secant modulus of elasticity
E_t	tangent modulus of elasticity
F	load, generalized force
$F_{o,Rd}$	design value of pull-out resistance
$F_{v,Rd}$	contact resistance against shear forces of the screw acting perpendicular to the channel
$F_{w,Rd}$	design weld resistance per length
$F_{b,Rd}$	design bearing resistance per bolt
F_{cr}	elastic critical buckling load for global instability mode based on initial elastic stiffness
F_e	elastic load, elastic generalized force
F_{Ed}	design load
$F_{p,A}$	preloading force
F_{Rd}	design resistance to transverse force
$F_{s,Rd}$	design slip resistance per bolt at the ultimate limit state
$F_{s,Rd,ser}$	design slip resistance per bolt at the serviceability limit state
$F_{t,Ed}$	design value of tensile force per bolt for the ultimate limit state
$F_{tt,Rd}$	design value of tensile resistance of the screw groove and port at the section through the tip of the screw
$F_{t,Rd}$	design tension resistance per bolt
$F_{tb,Rd}$	design tensile resistance of the fusion zone
$F_{tb,Rk}$	characteristic tensile resistance of the fusion zone
F_u	ultimate load, ultimate generalised force
$F_{u,Rd}$	tension resistance of a T-stub flange
$F_{v,Ed}$	design value of shear force per bolt for the ultimate limit state
$F_{v,Ed,ser}$	design value of shear force per bolt for the serviceability limit state
$F_{v,Rd}$	design shear resistance
$F_{vp,Rd}$	design value of shear resistance of the screw for loads within $-60^\circ \leq \theta \leq -120^\circ$ (opposite the opening of the groove)

G	shear modulus of elasticity
G_k	nominal value of the effect of permanent actions
H	torsional stiffness parameter of orthotropic plate
HAZ	heat affected zone
H_{Ed}	design value of the horizontal reaction at the bottom of the storey to the horizontal loads and fictitious horizontal loads
I_b	in-plane moment of inertia of a batten
I_{ch}	in-plane moment of inertia of a chord
I_{eff}	effective moment of inertia
I_{ep}	moment of inertia of the end-post section about the centre-line of the web
I_{fc}	moment of inertia of the compression flange about the minor axis of the section
I_{ft}	moment of inertia of the tension flange about the minor axis of the section
I_{gr}	moment of inertia of the gross cross-section
I_L	moment of inertia of one stiffener and adjacent plate in the longitudinal direction
I_s	moment of inertia about the minor axis
I_{ser}	moment of inertia for the effective cross-section for the serviceability limit state
I_{sl}	moment of inertia of the stiffener closest to the loaded flange
I_{st}	moment of inertia of gross cross-section of stiffener and adjacent effective part of the web about an axis through its centroid and parallel to the plane of the web
I_t	torsion constant
I_w	warping constant
I_{xT}	torsional constant of one stiffener and adjacent plate for torsion about x-x axis
L	member length
L_{cr}	buckling length in the buckling plane considered
$L_{b,e}$	bolt elongation length
L_b	length of the perimeter of the head of the bolt in contact with the side section of the channel in bolt-channel joints
L_e	embedded length in screw joints, which is the screw length with threads fully in the aluminium slot
L_{ch}	buckling length of chord
$L_{cr,z}$	buckling length for lateral-torsional buckling

L_{Ed}	design value of the component of the force, $F_{w,Ed}$, in the direction of the weld axis
L_{eff}	effective length for resistance to transverse force
L_j	distance between the centres of the end fasteners in a long joint
L_n	total screw length within the groove
L_o	original gauge length
L_p	screw point length
L_w	total length of longitudinal fillet weld
$L_{w,eff}$	effective length of longitudinal fillet weld
l_y	effective loaded length for resistance to transverse force
M_{cr}	elastic critical moment for lateral-torsional buckling
M_{Ed}^I	design value of the maximum moment in the middle of the built-up member
M_{Ed}^{II}	design value of the maximum moment in the middle of the built-up member with second order effects
$M_{b,Rd}$	design moment resistance for lateral-torsional buckling
M_{Ed}	design value of bending moment
$M_{f,Rd}$	design moment resistance of a cross-section consisting of the flanges only
$M_{N,Rd}$	reduced design moment resistance due to presence of axial force
M_o	elastic bending moment corresponding to the attainment of the proof stress, f_o
$M_{o,Rd}$	design resistance for bending moment to general yielding
M_{Rd}	design resistance for bending moment about one principal axis of a cross-section
M_{Rk}	characteristic moment resistance of the critical cross-section
$M_{u,Rd}$	design resistance for bending moment of the net cross-section at holes
$M_{V,Rd}$	reduced design bending resistance making allowance for the presence of shear force
$M_{y,Ed}$	design value of bending moment, y-y axis
$M_{y,Rd}$	design bending moment resistance about y-y axis
$M_{z,Ed}$	design value of bending moment, z-z axis
$M_{z,Rd}$	design bending moment resistance about z-z axis
$N_{u,Rd}$	design resistance for uniform compression in sections with transverse weld
$N_{b,Rd}$	design buckling resistance of a compression member or chord

$N_{c,Rd}$	design resistance for uniform compression of the cross-section
$N_{ch,Ed}$	design value of compression force in the chord at mid-length of the built-up member
N_{cr}	elastic critical force for the relevant buckling mode based on the gross cross-sectional properties
$N_{cr,y}, N_{cr,z}, N_{cr,T}$	elastic flexural buckling load (y-y and z-z axes) and torsional buckling load
N_{Ed}	design value of the axial force
$N_{net,Rd}$	design resistance of section at bolt holes
$N_{o,Rd}$	design resistance to general yielding of a member in tension
N_{Rd}	design resistance to normal force
N_{Rk}	characteristic resistance to normal force of the critical cross-section
$N_{t,Rd}$	design resistance to tension force
$N_{u,Rd}$	design resistance to axial force of the net cross-section at holes for fasteners
P_k	nominal value of the effect of prestressing imposed during erection
Q	prying force
R_d	design value of resistance
$R_{e,Ed}$	reaction at the end of the girder under design loading
R_{Ed}	design value of the resultant of the components of the force, $F_{w,Ed}$, in the weld seam cross-section
R_k	characteristic value of resistance
S	position of shear centre
S_v	shear stiffness of the lacings or battened panel of built-up member
T	highest temperature the structure is operating
T_{Ed}	design value of torsional moment
T_{Rd}	design St. Venant's torsion moment resistance
$T_{t,Ed}$	design value of internal St. Venant's torsional moment
$T_{w,Ed}$	design value of internal warping torsional moment
T_1	interpass temperature
U	utilization grade
$U(x_s)$	utilization grade in the section of the splice or connection

V_{Ed}	design value of the shear force
$V_{eff,1,Rd}$	design block tearing resistance for concentric loading
$V_{eff,2,Rd}$	design block tearing resistance for eccentric loading
$V_{f,Rd}$	design shear resistance contribution from the flanges
V_{Rd}	design shear resistance of cross-section
$V_{T,Rd}$	reduced design shear resistance making allowance for the presence of torsional moment
$V_{w,Rd}$	design shear resistance contribution from the web
W_{Ed}	total design loading on the adjacent span
W_{eff}	effective elastic section modulus, obtained using a reduced thickness, t_{eff} , or the class 4 parts
$W_{eff,haz}$	effective elastic section modulus, obtained using a reduced thickness, $\rho_c t$, for the class 4 parts or a reduced thickness, $\rho_{o,haz} t$, for the HAZ material, whichever is the smaller
W_{el}	elastic modulus of the gross cross-section (see 8.2.5.2)
$W_{el,haz}$	effective elastic modulus of the gross cross-section, obtained using a reduced thickness, $\rho_{o,haz} t$, for the HAZ material
W_{net}	elastic modulus of the net section allowing for holes and HAZ softening, if welded
W_{pl}	plastic modulus of gross cross-section
$W_{pl,haz}$	effective plastic modulus of the gross cross-section, obtained using a reduced thickness, $\rho_{o,haz} t$ for the HAZ material
$W_{T,pl}$	plastic torsion modulus
$W_{u,eff}$	section modulus allowing for local buckling and reduced thickness, $\rho_{u,haz} t$, in HAZ softening of transverse welds
X, Y	coefficients for calculation of relative slenderness for lateral-torsional buckling
X_k	characteristic value of a strength property of a material
X_{kT}	characteristic strength value for the material at temperature between 80 °C and 100 °C
X_n	nominal value of material property

Latin lower-case letters

a	effective throat thickness
a_c	half-wavelength for elastic buckling of stiffener
a_d	design value of geometrical data
a_{pen}	weld penetration

$a_{\text{pin}}, b_{\text{pin}}$	plate thickness in a pin connection
$a_{\text{st}}, b_{\text{st}}, c_{\text{st}}$	coefficients in formula for η_{st}
$a_{\text{st},1}$	relative area of stiffeners, area of stiffeners divided by centre to centre distance of stiffeners
$a_0, a_1, a_2, a_3, a_{\text{max}}$	widths of corrugations
b	width of cross-section part
b_{eff}	effective width for shear lag
b_f, b_1, b_2	flange widths
b_{haz}	extent of HAZ
b_{sh}	width of a flat cross-section part
b_w	distance between weld toes of flanges
b_0	width of outstand or half width of internal cross-section part
b_1	depth of the loaded sub-panel taken as the clear distance between the loaded flange and the stiffener
c	depth of the rib or lip
c_e	elastic support from plate
c_f	factor in formula for $V_{f,Rd}$
d	diameter of a fastener
d_b	nominal diameter of weld stud
d_{ch}	distance along a chord of a built-up member between two consecutive lacings or battens
d_m	mean of the across points and across flats dimensions of the bolt head or the nut or if washers are used the outer diameter of the washer, whichever is smaller
d_{sl}	internal diameter of a groove
d_0	diameter of hole
e	centre to centre distance between stiffeners
e_e	effective edge distance
e_{min}	minimum edge distance
e_w	weld spacing in intermittent welds
e_0	maximum amplitude of the initial bow imperfection
$e_{0,d}$	design value of maximum amplitude of the initial bow imperfection

e_1, e_4	edge distances
f_0	characteristic value of 0,2 % proof strength
$f_{0,haz}$	characteristic value of 0,2 % proof strength in heat affected zone, HAZ
$f_{0,V}$	reduced design strength making allowance for the presence of shear force
f_{oc}	characteristic value of 0,2 % proof strength of cast material
f_{of}	characteristic value of 0,2 % proof strength of flange material
f_{ow}	characteristic value of 0,2 % proof strength of web material
f_u	characteristic value of ultimate tensile strength
$f_{u,haz}$	characteristic value of ultimate tensile strength in heat affected zone, HAZ
f_{ub}	characteristic ultimate strength of bolt material or of the weld stud material
$f_{ub,haz}$	characteristic value of ultimate tensile strength in heat affected zone of the weld stud
f_{uc}	characteristic value of ultimate tensile strength of cast material
f_{ur}	characteristic ultimate strength of rivet material
$f_{v,adh}$	characteristic shear strength values of adhesives
f_{uw}	characteristic ultimate strength of web material
$f_{v,haz}$	characteristic shear strength in HAZ
f_w	characteristic strength of the weld metal
$f_{wv,d}$	design shear strength of the weld
g	distance from weld toe to centre of bolt
g_c	width of the opening of the channel in bolt channel joints
h	storey height, height of the structure
h_f	distance between centres of flanges
h_s	distance between shear centre of upper flange and shear centre of bottom flange
h_w	web depth = clear distance between flanges
h_0	distance between the centroids of chords of a built-up column
i	radius of gyration about the relevant axis, determined using the properties of the gross cross-section
i_{min}	minimum radius of gyration of one chord or one angle
i_s	polar radius of gyration

i_y, i_z, i_0	radius of gyration (y - y axis, z - z axis and 0 - 0 axis)
i_z	minor axis radius of gyration of the gross cross-section
k	buckling length factor
k_F	buckling factor for transverse force
k_g	coefficient which is depending on the shear strength of the threads in screw-groove joints
k_s	reduction factor for slip resistance of a preloaded bolt depending on connection configuration
k_w	end condition corresponding to rotation about the longitudinal axis
k_y	end condition corresponding to restraints against movement in-plane of loading
k_z	end condition corresponding to restraints against lateral movement
k_τ	buckling coefficient for shear buckling
$k_{\tau,st}$	contribution from the longitudinal stiffeners to the buckling coefficient
$k_{\tau 1}$	buckling coefficient for sub panel
k_1	coefficient for weld stud connectors
k_{100}	coefficient for reduction of a strength property of a material at temperature between 80 °C and 100 °C
k_2	factor for tension resistance of a bolt
k_3	coefficient for bolt-channel joints
l_e	parameter in formulae for effective loaded length
l_{eff}	effective length
l_s	length of a slotted hole
l_w	half wave-length in elastic buckling
m, k	numerical parameters
$m_{x,Rd}, m_{y,Rd}$	design bending moment resistances
m_1, m_2	parameters in formulae for effective loaded length
n	number of friction interfaces
n_p	exponent in Ramberg-Osgood formula for plastic design
p_{th}	threaded parts of the periphery inside the hole or groove
p, p_1, p_2	spacing between bolt holes
$q_{0,d}$	design value of equivalent force per length

r	radius of curvature
s	staggered pitch, the spacing of the centres of two consecutive holes in the chain measured parallel to the member axis
s_d	developed width of stiffeners and adjacent plate
s_e	loaded length in section between flange and web
s_s	length stiff bearing under transverse force
t	thickness of a cross-section part
t_e	deep penetration throat thickness, i.e. nominal or effective throat thickness to which a certain amount of fusion penetration is added
t_f	flange thickness
t_p	thickness of the plate under the bolt head or the nut
t_{pl}	mean value of adjacent material thickness
t_{sup}	thickness of the upper flanges of the channel in bolt channel joints
t_{sb}	minimum thickness of the side wall of the channel (t_{lat}) and thickness of the bottom wall of the channel (t_{inf}) in bolt channel joints
t_{sl}	thickness of wall of slot for screw groove joints, thickness of the groove
t_w	web thickness
t_1, t_2	thickness of layers or flanges
$u - u$	major principal axis (where this does not coincide with the y - y axis)
v	generalized deformation
$v - v$	minor principal axis (where this does not coincide with the z - z axis)
v_e	deformation corresponding to elastic generalized force
v_u	deformation corresponding to ultimate generalized force
v_1	reduction factor for shear buckling
$x_{s,haz}$	distance from the localised weld to a support or point of contra-flexure for the deflection curve for elastic buckling from axial force only
x_s	distance from the splice or end connection to the nearest point of contra-flexure for the deformation curve for elastic buckling
$y - y$	axis of a cross-section
y_{st}	distance from centre of stiffened plate to centre of outermost stiffener
$z - z$	axis of a cross-section
z_a	coordinate of the load application point related to centroid

z_g	coordinate of the load application point related to shear centre
z_j	mono-symmetry constant
z_s	coordinate of the shear centre related to centroid
z_1	distance from neutral axis to most severely stressed fibre (along the z-z axis)
z_2	distance from neutral axis to fibre under consideration (along the z-z axis)

Greek letters

$\alpha, \alpha_y, \alpha_z$	factor, shape factor
α_b	factors for bearing resistance of the connected parts
α_{cr}	factor by which the design loads would have to be increased to cause elastic instability in a global mode
α_h	reduction factor for height h applicable to columns
α_i	imperfection factor
α_{LT}	imperfection factor
α_m	reduction factor for the number of columns in a row
$\alpha_{M,j}$	correction factor for ultimate bending moment depending on the different behavioural classes of cross-sections
$\alpha_{M,red}$	correction factor for welded class 1 cross-section
$\alpha_{N,j}$	correction factor for ultimate axial load depending on the different behavioural classes of cross-sections
α_T	coefficient of linear thermal expansion
α_u	load magnification factor (to the ultimate limit state)
α_v	factor for shear resistance of a bolt
α_{yw}, α_{zw}	coefficients in formulae for torsional and torsional-flexural buckling
α_ξ	shape factor α_5 or α_{10}
α_0	geometrical shape factor
α_2	factor for b_{haz}
$\alpha_{3,u}$	shape factor for class 3 cross-section without welds
$\alpha_{3,w}$	shape factor for class 3 cross-section with welds
α_5, α_{10}	generalized shape factors corresponding to ultimate curvature values, $\chi_u = 5\chi_{el}$ and $\chi_u = 10\chi_{el}$
β	slenderness factor

β_{Lf}	reduction factor for long joint
β_p	reduction factor for fasteners passing through packings
β_s	effective width factor for shear lag
$\beta_1, \beta_2, \beta_3$	limits for slenderness factor
γ_M	partial factor for a material property, accounting for the uncertainties covered by γ_m and γ_{Rd} (see definitions in EN 1990)
γ_{M1}	partial factor for resistance of cross-sections and resistance of members to instability (based on f_o)
γ_{M2}	partial factor for resistance of cross-sections to fracture and resistance of joints
γ_{Ma}	partial factor for resistance of adhesive bonded connection
γ_{Mf}	partial factor for fatigue
$\gamma_{Mp,ser}$	partial factor for resistance of pin connection at serviceability limit state
γ_{Mp}	partial factor for resistance of pin connection for ultimate limit state
$\gamma_{Ms,ser}$	partial factor for slip resistance at serviceability limit state
γ_{Ms}	partial factor for slip resistance of connection for ultimate limit state
γ_{Mw}	partial factor for welded joints
$\delta_{H,Ed}$	horizontal displacement at the top of the storey, relative to the bottom of the storey
δ_q	in-plane deflection of a bracing system
ε	$\sqrt{250/f_o}$, f_o in N/mm ² , factor
ε_{true}	true strain
ε_u	characteristic value of elongation at rupture
ζ_g	relative coordinate of the point of load application
ζ_j	relative cross-section mono-symmetry parameter
η	coefficient to allow for stress gradient or stiffening of cross-section part
η_{ep}	correction factor depending on geometrical shape factor and conventional available ductility of the material
η_h	factor
η_{sb}	correction factor for shear buckling resistance in plastic range
η_v	correction factor for shear efficiency of area

η_V	V_{Ed} / V_{Rd}
$\eta_{y0}, \eta_{z0}, \beta_{z0}, \psi$	exponents in interaction formulae for bending and compression
$\eta_y, \eta_z, \beta_z, \psi_c$	exponents in interaction formulae for buckling due to bending and compression
η_{cr}	shape of the elastic critical buckling mode
θ	angle between axes of chord and lacings
$\theta_p, \theta_{el}, \theta_u$	plastic rotation, elastic rotation and maximum plastic rotation corresponding to ultimate curvature χ_u
κ	notional width-to-length ratio for flange
κ_{wt}	relative torsion parameter
$\bar{\lambda}$	relative slenderness
$\bar{\lambda}_{c,1}$	relative slenderness for local buckling
$\bar{\lambda}_{c,g}$	relative slenderness for global buckling
$\bar{\lambda}_F$	relative slenderness for local buckling due to transverse force
$\bar{\lambda}_{haz}, \bar{\lambda}_{haz,LT}$	relative slenderness for section with localized weld
$\bar{\lambda}_{LT}$	relative slenderness for lateral-torsional buckling
λ_t	coefficients in formula for relative slenderness, $\bar{\lambda}_T$
$\bar{\lambda}_T$	relative slenderness for torsional and/or torsional-flexural buckling
$\bar{\lambda}_w$	relative slenderness for shear buckling
λ_0	coefficients to calculate λ_t
$\bar{\lambda}_0$	length of the horizontal plateau of the buckling curves
$\bar{\lambda}_{0,LT}$	length of horizontal plateau of lateral-torsional buckling curves
μ	slip factor, efficiency factor
μ_{cr}	relative critical moment
ν	Poisson's ratio in elastic range
ξ	ductility factor
ρ	unit mass
$\rho_{c,1}$	reduction factor for local buckling
$\rho_{c,g}$	reduction factor for global buckling
ρ_c	reduction factor for local buckling
$\rho_{0,haz}$	$= f_{0,haz}/f_0$ ratio between 0,2 % proof strength in HAZ and in parent material

$\rho_{u,haz}$	$= f_{u,haz}/f_u$ ratio between ultimate strength in HAZ and in parent material
ρ_v	factor for shear buckling resistance
σ_{cr}	elastic critical stress for a stiffened cross-section part
σ_{cr0}	elastic critical stress for an un-stiffened cross-section part
$\sigma_{eq,Ed}$	equivalent design stress for castings
$\sigma_{haz,Ed}$	design value of normal stress in HAZ, perpendicular to the weld axis
σ_{Rd}	design resistance for castings
σ_{true}	true stress
$\sigma_{w,Ed}$	design value of normal stress due to the bimoment B_{Ed}
$\sigma_{x,Ed}$	design value of the local longitudinal normal stress at the point of consideration
$\sigma_{y,Ed}$	design value of the local transverse normal stress at the point of consideration
$\sigma_{\perp}$	normal stress perpendicular to weld axis
$\sigma_{ }$	normal stress parallel to weld axis
τ	average shear stress in the adhesive layer
$\tau_{ }$	shear stress parallel to weld axis
$\tau_{cr,1}$	shear buckling stress for local buckling
$\tau_{cr,g}$	shear buckling stress
τ_{Ed}	design value of the local shear stress
$\tau_{haz,Ed}$	design value of shear stress in HAZ
$\tau_{t,Ed}$	design value of shear stress due to St. Venant's torsion
$\tau_{w,Ed}$	design value of shear stress due to warping torsion
$\tau_{xy,Ed}$	design value of shear stress for castings
$\tau_{\perp}$	shear stress perpendicular to weld axis
φ	global initial sway imperfection
φ_0	basic value for global initial sway imperfection
ϕ	factor
ϕ_{LT}	value to determine the reduction factor, χ_{LT}
χ	reduction factor for relevant buckling mode
χ_{el}	elastic bending curvature ($= \chi_{0,2}$)

χ_F	reduction factor for local buckling due to transverse force
$\chi_{LT,haz}$	reduction factor for lateral-torsional buckling of the beam in a section with HAZ
χ_{LT}	reduction factor for lateral-torsional buckling of the beam
χ_u	ultimate bending curvature
ψ	stress ratio
ψ_f	mono-symmetry factor
$\omega_{x,haz}$	factors for section with localized transverse weld
$\omega_{x,LT,haz}$	
$\omega_x, \omega_{x,LT}$	factors for second order bending moments

NOTE 1 Notations for models for stress-strain relationship are given in Annex F.

NOTE 2 Notations for cross-section constants are given in Annex G, G.4, G.5 and G.6.

3.3 Conventions for member axes

(1) In general, the convention for member axes is:

x-x - axis along the member

y-y - axis of the cross-section

z-z - axis of the cross-section

(2) For aluminium members, the conventions used for cross-section axes are:

— generally:

y-y - cross-section axis parallel to the flanges

z-z - cross-section axis perpendicular to the flanges

— for angle sections:

y-y - axis parallel to the smaller leg

z-z - axis perpendicular to the smaller leg

— where necessary:

u-u - major principal axis (where this does not coincide with the y-y axis)

v-v - minor principal axis (where this does not coincide with the z-z axis)

(3) The symbols used for axes of aluminium sections are indicated in Figure 3.1.

(4) The convention used for subscripts, which indicate axes for moments is: "Use the axis about which the moment acts."

NOTE All rules in this Eurocode relate to principal axis properties, which are generally defined by the axes y - y and z - z for symmetrical sections and by the u - u and v - v axis for unsymmetrical section such as angles.

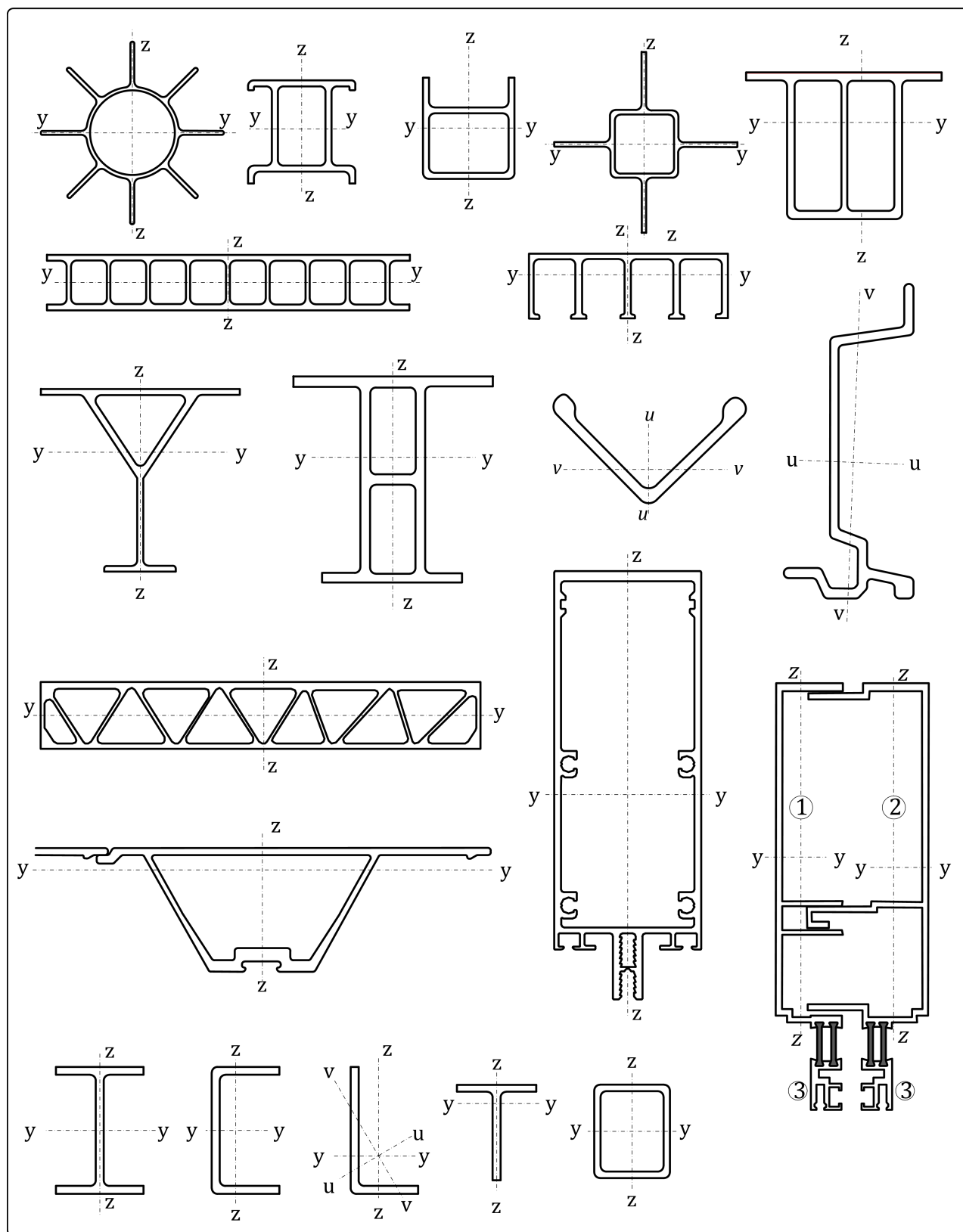


Figure 3.1 — Definition of axes for various cross-sections

4 Basis of design

4.1 General rules

4.1.1 Basic requirements

(1) The design of aluminium structures shall be in accordance with the general rules given in EN 1990 and the specific design provisions for aluminium structures given in this document (EN 1999-1-1).

(2) The design of aluminium structures shall be in accordance with EN 1999-1-2, EN 1999-1-3, EN 1999-1-4 and EN 1999-1-5 as appropriate.

(3) Aluminium structures designed according to EN 1999 (all parts) shall be executed according to EN 1090-3 and/or EN 1090-5.

(4) Supplemental requirements in Annex S to those given in the main part of this standard shall be applied for the structural design of bridges.

4.1.2 Structural reliability

(1) Where different levels of reliability are required, these levels should be achieved by an appropriate choice of quality management measures in design and execution, according to EN 1990, EN 1090-3, EN 1090-5 and Annex A.

(2) Aluminium structures and components should be classified by execution classes in accordance with Annex A.

(3) The execution should be carried out in accordance with EN 1090-1 and EN 1090-3. The information, which EN 1090-3 and EN 1090-5 require to be included in the execution specification, should be specified.

NOTE Options allowed by EN 1090-3 and EN 1090-5 can be given by the National Annex to suit the reliability levels required.

4.1.3 Design service life, durability and robustness

(1) Depending on the type of action affecting durability and the design service life (see EN 1990) aluminium structures should be

- designed for corrosion (see Clause 6);
- designed for sufficient fatigue life (see EN 1999-1-3);
- designed for wearing;
- designed for accidental actions (see EN 1991-1-7);
- specified for inspection and maintenance.

NOTE 1 Guidance on the design for corrosion is given in Annex C and Annex D.

NOTE 2 Requirements for fatigue are given in EN 1999-1-3.

4.2 Principles of limit state design

(1) The calculation methods for resistance specified in this document should be taken to apply to the ultimate limit states as defined in EN 1990 and are based on design models of recognised experimental evidence.

(2) The resistances specified in this document should be used for materials under the conditions given in Clause 5.

4.3 Basic variables

4.3.1 Actions and environmental influences

(1) Actions for the design of aluminium structures shall be in accordance with EN 1991 (all parts). For the combination of actions and partial factors of actions, see EN 1990.

(2) The actions to be considered during execution should be obtained from EN 1991-1-6.

(3) Where the effects of predicted absolute and differential settlements need be considered the best estimates of these imposed deformations should be used.

(4) The effects of uneven settlements, imposed deformations or other forms of prestressing imposed during execution should be taken into account by their characteristic value and combined with other actions in accordance with EN 1990.

(5) Fatigue loading not defined in EN 1991 should be determined in accordance with EN 1999-1-3.

4.3.2 Material and product properties

(1) Material properties for aluminium construction products shall be in accordance with Clause 5.

4.4 Verification by the partial factor method

4.4.1 Design value of material properties

(1) For the design of aluminium structures, characteristic values X_k or nominal values X_n of material properties shall be used as indicated in this Eurocode.

4.4.2 Design value of geometrical data

(1) Geometrical data for cross-sections and systems may be taken from product standards or drawings for the execution according to EN 1090-3 and EN 1090-5 and treated as nominal values.

(2) Design values of equivalent geometrical imperfections specified in this document comprise:

- the effects of geometrical imperfections of members as governed by geometrical tolerances in product standards or the execution standard;
- the effects of structural imperfections from fabrication and erection, residual stresses, variations of the yield strength and heat-affected zones.

4.4.3 Design resistances

(1) For aluminium structures, Formula (4.1) applies:

$$R_d = R_k / \gamma_M \quad (4.1)$$

where

R_k is the characteristic value of the resistance of a cross-section or member determined with characteristic or nominal values for the material properties and cross-sectional dimensions;

γ_M is the partial factor for the resistance.

NOTE For a more general formula for the design resistance, see EN 1990.

(2) The partial factors γ_M should be applied to members and joints.

NOTE 1 The values of γ_{Mi} are given in Table 4.1(NDP) unless the National Annex gives different values.

Table 4.1(NDP) — Partial factors for resistance for wrought aluminium alloys

Type of structure and failure	Partial factor	Recommended value
Resistance of cross-sections and resistance of members to instability, based on f_0 :	γ_{M1}	1,1
Resistance of cross-sections to fracture and resistance of joints in tension, shear and bearing, based on f_u :	γ_{M2}	1,25
Resistance of cross-sections to fracture and resistance of joints in tension, shear and bearing, based on f_w :	γ_{Mw}	1,25
Resistance of pin connections for ultimate limit state:	γ_{Mp}	1,25
Resistance of pin connections for serviceability limit state:	$\gamma_{Mp,ser}$	1,0
Slip resistance of connections for ultimate limit state:	γ_{Ms}	1,4
Slip resistance of connections for serviceability limit state:	$\gamma_{Ms,ser}$	1,0
Resistance of adhesive bonded connections	γ_{Ma}	$\geq 3,0$
Resistance in case of fire and fatigue	See EN 1999-1-2 and EN 1999-1-3	

NOTE 2 The values of γ_{M1} and γ_{M2} are also applicable for cold-formed aluminium structural sheeting and shells, see EN 1999-1-4 and EN 1999-1-5 respectively.

4.5 Design assisted by testing

(1) Values for resistances R_k or R_d may be determined using design assisted by testing methods.

NOTE 1 Guidance on design assisted by testing is given in Annex D of EN 1990:2023.

NOTE 2 The National Annex can give rules for testing.

4.6 Execution requirements

(1) A specification for execution of the work shall be prepared in order to include all necessary technical information to carry out the work. This information should include execution class(es), whether any non-normative tolerances in EN 1090-3 and/or EN 1090-5 should apply, complete information on geometry and information on materials to be used in members and joints, types and sizes of fasteners, weld requirements and requirements for execution of work.

NOTE EN 1090-3 contains a checklist for information to be provided.

5 Materials

5.1 General

(1) For design verification, the material properties given in this clause shall be adopted as characteristic values in the design calculations.

NOTE 1 The material properties in this clause are based on the nominal values given in the product standards as listed in 5.2.2 (1), 5.2.3 and 5.2.4. Nominal values are assumed as minimum guaranteed values.

NOTE 2 Other material properties can be found in the ENs listed in the Bibliography.

5.2 Structural aluminium

5.2.1 Range of materials

(1) This document covers the design of structures and components fabricated from aluminium alloy material listed in Table 5.1 for wrought alloys conforming to EN 573-3 with tempers listed in Tables 5.3, 5.4 and 5.7 conforming to EN 515 and welding filler metal listed in Table 5.10 conforming to EN ISO 18273. For the design of structural components of cast aluminium alloys, see 5.2.3.

NOTE 1 Additional aluminium alloys and tempers than those listed in Tables 5.1, 5.2 and 5.5 can be set by the National Annex, if set with detailed characteristic values and information for their use.

NOTE 2 For guidance on the selection of aluminium alloys, see Annex C.

NOTE 3 Annex E gives further provisions for the design of structural components of cast aluminium alloys.

Table 5.1 — Wrought aluminium alloys for structures

Alloy designation		Form of product	Durability rating
Numerical	Chemical symbols		
EN AW-3004	EN AW-AlMn1Mg1	SH, ST, PL	A
EN AW-3005	EN AW-AlMn1Mg0,5	SH, ST, PL	A
EN AW-3103	EN AW-Al Mn1	SH, (SHT), ST, PL, ET, EP, ER/B	A
EN AW-5005 / 5005A	EN AW-AlMg1(B) / (C)	SH, ST, PL	A
EN AW-5049	EN AW-AlMg2Mn0,8	SH, ST, PL	A
EN AW-5052	EN AW-Al Mg2,5	SH, (SHT), ST, PL, ET ^a , EP ^a , ER/B, DT	A
EN AW-5083	EN AW-Al Mg4,5Mn0,7	SH, (SHT), ST, PL, ET ^a , EP ^a , ER/B, DT, FO	A
EN AW-5383	EN AW-AlMg4,5Mn0,9	SH, ST, PL	A
EN AW-5454	EN AW-Al Mg3Mn	SH, ST, PL, ET ^a , EP ^a , ER/B	A
EN AW-5754	EN AW-Al Mg3	SH, (SHT), ST, PL, ET ^a , EP ^a , ER/B, DT, FO	A
EN AW-6060	EN AW-Al MgSi	ET, EP, ER/B,DT	B
EN AW-6061	EN AW-Al Mg1SiCu	SH, (SHT), ST, PL, ET, EP, ER/B,DT	B
EN AW-6063	EN AW-Al Mg0,7Si	ET, EP, ER/B,DT	B
EN AW-6005A	EN AW-Al SiMg(A)	ET, EP, ER/B	B
EN AW-6082	EN AW-Al Si1MgMn	SH, (SHT), ST, PL, ET, EP, ER/B, DT, FO	B
EN AW-6106	EN AW-AlMgSiMn	EP	B
EN AW-7020	EN AW-Al Zn4,5Mg1	SH, (SHT), ST, PL, ET, EP, ER/B, DT	C
EN AW-8011A	EN AW-AlFeSi	SH, ST, PL	B
Key SH Sheet according to EN 485 (all parts) ST Strip according to EN 485 (all parts) PL Plate according to EN 485 (all parts) ET Extruded Tube according to EN 755 (all parts) EP Extruded Profiles according to EN 755 (all parts) ER/B Extruded Rod and Bar according to EN 755(all parts) DT Drawn Tube according to EN 754 (all parts) FO Forgings according to EN 586 (all parts) (SHT) Tread plate according to EN 1386			
NOTE 1 EN 12258 (aluminium – terms and definitions) only distinguishes between two types of cross-sections: hollow and solid. The term solid has there a different meaning than in Eurocode terminology: it is any cross-section without hollow space, see Table 3.1.			
NOTE 2 For durability rating, see Clause 6, Annex C and Annex D. Especially for EN AW-5083 and EN AW-5383, see C.4.2.2(2).			
^a Only simple, solid extruded sections or thick-walled tubes over a mandrel (seamless).			

Table 5.2 — Cast aluminium alloys for structural components

Alloy designation		Durability rating ^a
Numerical	Chemical symbols	
EN AC-42100	EN AC-Al Si7Mg0,3	B
EN AC-42200	EN AC-Al Si7Mg0,6	B
EN AC-43000	EN AC-Al Si10Mg(a)	B
EN AC-43300	EN AC-AlSi9Mg	B
EN AC-44200	EN AC-Al Si12(a)	B
EN AC-51300	EN AC-Al Mg5	A
^a See Clause 6, Annex C and Annex D.		

5.2.2 Material properties for wrought and casting alloys

(1) The material properties should conform with the properties given in this clause and the following product standards:

- for aluminium wrought products EN 15088, EN 754-1 and -2, EN 755-1 and -2, EN 1301, EN 28839, EN 586-1 and -2, EN 485-1 and -2, EN 508-1 and -2, EN 1386;
- for aluminium casting alloy EN 1706, EN 1559-1 and EN 1559-4.

(2) Characteristic values of the 0,2 % proof strength f_0 and the ultimate tensile strength, f_u , for wrought aluminium alloys for a range of tempers and thicknesses given in Table 5.3 should be used for sheet, strip and plate products. Table 5.4 should be used for extruded rod/bar, extruded tube and extruded profiles and drawn tube and Table 5.7 for forgings.

(3) The values in Table 5.3 to 5.7, as well as in Table 5.8 and Table 5.9 (for aluminium fasteners only) apply to structures subject to service temperatures of up to 80 °C.

NOTE 1 There are no restrictions (temperature limits) for the use of aluminium at low temperatures.

NOTE 2 Product properties for electrically welded tubes according to EN 1592-1 to EN 1592-4 for structural applications are not given in this document.

(4) For service temperatures between 80 °C and 100 °C a reduction of the strength should be applied as follows:

All characteristic aluminium resistance values (f_0 , f_u , $f_{0,haz}$ and $f_{u,haz}$) should be reduced according to Formula (5.1):

$$X_{kT} = (1 - k_{100}(T - 80)/20) X_k \quad (5.1)$$

where

- X_k is the characteristic value of a strength property of a material;
- X_{kT} is the characteristic strength value for the same strength property of the material at temperature T between 80 °C and 100 °C;
- T is the highest temperature the structure is operating;
- k_{100} = 0,1 for strain hardening alloys (3xxx-alloys, 5xxx-alloys and EN AW-8011A);
- k_{100} = 0,2 for precipitation hardening material (6xxx-alloys and EN AW-7020).

At 100 °C generally all aluminium alloys should be classified as Buckling Class C. For temperatures between 80 °C and 100 °C interpolation between actual class for temperature below 80 °C and Class C should be done. Extrapolation is not valid.

For members exposed to temperature above 100 °C, the reductions of strength and elastic modulus should be considered and verified.

For members having been exposed to temperatures above 100 °C, a not recoverable reduction of strength should be considered and verified.

NOTE 1 For members having been exposed to temperatures between 80 °C and 100 °C the reduction of the strength values is recoverable, i.e. materials regain their strength when the temperature drops.

NOTE 2 Certain alloys are susceptible to intergranular and stress corrosion cracking at elevated temperatures (see e.g. C.4.2.2 for EN AW-5083).

(5) The characteristic values for the heat affected zone (0,2 % proof strength, $f_{o,haz}$, and ultimate tensile strength, $f_{u,haz}$), reduction factors (see 8.1.6), buckling class (used in 8.1.4 and 8.3.1) and exponent, n_p , in the Ramberg-Osgood Formula for plastic resistance should be taken from Tables 5.3 to 5.7.

Table 5.3 — Characteristic values of 0,2 % proof strength, f_o , and ultimate tensile strength, f_u , (unwelded and in HAZ), elongation values, A_{50} (A), reduction factors, $\rho_{o,haz}$, and $\rho_{u,haz}$, in HAZ, buckling class and exponent, n_p , for wrought aluminium alloys – sheets, strips and plates

Alloy EN AW	Temper ^a	Thick- ness mm ^a	f_o^a	f_u	A_{50} (A) a, c %	$f_{o,haz}^b$	$f_{u,haz}^b$	HAZ-factor ^b		BC ^d	$n_p^{a, e}$
			N/mm ²			N/mm ²		$\rho_{o,haz}^a$	$\rho_{u,haz}$		
3004	H14 H24/H34	≤ 6 3	180 170	220	3 4	75	155	0,42 0,44	0,70	A B	23 18
	H16 H26/H36	≤ 4 3	200 190	240	2 3			0,38 0,39	0,65	A	25 20
3005	H14 H24	≤ 6 3	150 130	170	3 4	56	115	0,37 0,43	0,68	A B	37 18
	H16 H26	≤ 4 3	175 160	195	2 3			0,32 0,35	0,59	A	43 24
3103	H14 H24	≤ 25 12,5	120 110	140	5 8	44	90	0,37 0,40	0,64	A	31 20
	H16 H26	≤ 8 4	145 135	160	2 3			0,30 0,33	0,56	A	48 28
5005/ 5005A	O/H111	≤ 50	35	100	24	35	100	1	1	C	5
	H12 H22/H32	≤ 12,5	95 80	125	7 10	44	100	0,46 0,55	0,80	B	18 11
	H14 H24/H34	≤ 12,5	120 110	145	5 8			0,37 0,40	0,69	A B	25 17
5052	H12 H22/H32	≤ 40	160 130	210	10 12	80	170	0,50 0,62	0,81	B	17 10
	H14 H24/H34	≤ 25	180 150	230	5 9			0,44 0,53	0,74	B	19 11
5049	O / H111	≤ 100	80	190	18	80	190	1	1	C	6
	H14 H24/H34	≤ 25	190 160	240	5 10	100	190	0,53 0,63	0,79	A B	20 12
5383	O/H111	≤ 50	145	290	16	145	290	1	1	C	7
		50 < t ≤ 80	135	285	(14)	135	285	1	1	C	6
		80 < t ≤ 120	130	275	(12)	130	275	1	1	C	6
	H116/H321	≤ 40	230	330	10	180	290	0,78	0,88	B	12
		40 < t ≤ 80	230	330	(10)	165	285	0,72	0,86	B	12
5454	O/H111	≤ 80	85	215	18	85	215	1	1	C	5
	H14 H24/H34	≤ 25	220 200	270	5 8	105	215	0,48 0,53	0,80	A B	22 15
5754	O/H111	≤ 100	80	190	18	80	190	1	1	C	6
	H12 H22/H32	≤ 40	170 130	220	9 10	100	190	0,59 0,77	0,86	B C	18 9
	H14 H24/H34	≤ 25	190 160	240	5 10	100	190	0,53 0,63	0,79	A B	20 12

Alloy EN AW	Tempera ^a	Thick- ness mm ^a	f_o^a	f_u	A50 (A) a, c	$f_{o,haz}^b$	$f_{u,haz}^b$	HAZ-factor ^b		BC ^d	$n_p^{a, e}$
			N/mm ²		%	N/mm ²		$\rho_{o,haz}^a$	$\rho_{u,haz}$		
5083	O/H111	≤ 6,3	125	275	15	125	275	1	1	C	6
		6,3 < t ≤ 80	115	270	14	115	270			C	
		80 < t ≤ 120	110	260	(12)	110	260			C	
	H12 H22/H32	≤ 40	250 215	305 ^f	7 10	155	275	0,62 0,72	0,90	A B	22 13
	H14 H24/H34	≤ 25	280 250	340	4 8			0,55 0,62	0,81	A B	22 14
6061	T4 / T451	≤ 80	110	205	18	95	150	0,86	0,73	C	8
	T6 / T651	≤ 12,5	240	290	9	115	175	0,48	0,60	A	23
		12,5 < t ≤ 80	240	290	(6)						
6082	T4 / T451	≤ 80	110	205	14	100	160	0,91	0,78	C	8
	T61/T6151	≤ 12,5	205	280	12	125	185	0,61	0,66	B	15
		12,5 < t ≤ 100	200	275	(10)			0,63	0,67	B	14
	T6/T651	≤ 6	260	310	9			0,48	0,60	A	25
		6 < t ≤ 12,5	255	300				0,49	0,62	A	27
		12,5 < t ≤ 100	240	295	(7)			0,52	0,63	A	21
7020	T6/T651	≤ 12,5	280	350	10	205	280	0,73	0,80	B	19
		12,5 < t ≤ 100			(8)						
8011A	H14 H24	≤ 12,5	110 100	125	5 7	37	85	0,34 0,37	0,68	A	37 22
	H16 H26	≤ 4	130 120	145	3 4			0,28 0,31	0,59		43 25

NOTE The following alloys/temperatures are available/standardized as sheet with rolled pattern (tread plate according to EN 1386) for thicknesses up to 20 mm, with values f_o and f_u as above, but with reduced elongation values (see EN 1386):

EN AW-3103 H24 (= H244 according to EN 1386)

EN AW-5052 H22, H24 (= H224, H244 according to EN 1386)

EN AW-5754 H22, H24 (= H224, H244 according to EN 1386)

EN AW-5083 O/H111 (=H114 according to EN 1386)

EN AW-6061 T4, T6 (=T4, T6 according to EN 1386)

EN AW-6082 T6, T61 (=T6, T61 according to EN 1386)

EN AW-7020 T6 (=T6 according to EN 1386)

^a If two (three) tempers are specified in one line, tempers separated by “|” have different technological values but separated by “/” have same values. (The tempers show differences for f_o , A and n_p .)

^b Depending on material thickness, filler metal and welding process (MIG or TIG) $\rho_{o,haz}$, $\rho_{u,haz}$ -values in the table should be multiplied by a reduction factor C_o or C_u respectively. For the different reduction factors see Tables 5.5 and 5.6.

^c The A_{50} -values in this column are the A_{50} -values for the thickness range 6 mm to 12,5 mm and therefore practically equivalent to the A -values of Table 5.4. For thicknesses outside this range other specific A_{50} - or A -values are valid, see EN 485-2. Values in italics are A_{50} -values for the thickness range of the material concerned beneath the range 6 mm to 12,5 mm. Values in brackets are the lowest A -values for material falling under the indicated thickness range in column 3.

^d BC = buckling class, see 8.1.4.4, 8.1.5 and 8.3.1.

^e n -value in Ramberg-Osgood Formula for plastic analysis. It applies only in connection with the listed f_o -value

^f 315 for H12

Table 5.4 — Characteristic values of 0,2 % proof strength, f_o , and ultimate tensile strength f_u (unwelded and in HAZ), minimum elongation, A , reduction factors, $\rho_{o,haz}$ and $\rho_{u,haz}$ in HAZ, buckling class and exponent, n_p , for wrought aluminium alloys – extruded profiles, extruded tubes, extruded rods/bars and drawn tubes

Alloy EN AW	Product form	Temper	Thick- ness, t, mm ^{a, c}	f _o ^a	f _u ^a	A ^{e, b}	f _{o,haz} ^d	f _{u,haz} ^d	HAZ-factor ^d		BC ^f	np ^g
				N/mm ²		%	N/mm ²		ρ _{o,haz}	ρ _{u,haz}		
5083	EP, ET, ER/B	O/H111 F/H112	t ≤ 200	110	270	12	110	270	1	1	C	5
	DT	H12/22/32	t ≤ 10	200	280	6	135	270	0,68	0,96	B	14
		H14/24/34	t ≤ 5	235	300	4			0,57	0,90	B	18
5454	EP, ET, ER/B	O/H111 F/H112	t ≤ 25	85	200	16	85	200	1	1	C	6
5754	EP, ET, ER/B	O/H111 F/H112	t ≤ 25	80	180	14	80	180	1	1	C	6
	DT	H14/ H24/H34	t ≤ 10	180	240	4	100	180	0,56	0,75	B	16
6060	EP, ET, ER/B	T5	t ≤ 5	120	160	8	50	80	0,42	0,50	B	17
	EP		5 < t ≤ 25	100	140	8			0,50	0,57	B	14
	EP,ET,ER/B	T6	t ≤ 15	140	170	8	60	100	0,43	0,59	A	24
	DT		t ≤ 20	160	215	12			0,38	0,47	B	16
	EP, ET, ER/B	T64	t ≤ 15	120	180	12	60	100	0,50	0,56	B	12
	EP, ET, ER/B	T66	t ≤ 5	160	215	8	65	110	0,41	0,51	B	16
	EP		5 < t ≤ 25	150	195	8			0,43	0,56	B	18
6061	EP, ET, ER/B	T4	t ≤ 25	110	180	15	95	150	0,86	0,83	C	10
	DT		t ≤ 20	110	205	16				0,73	C	8
	EP, ET, ER/B	T6	t ≤ 25	240	260	8	115	175	0,48	0,67	A	55
	DT		t ≤ 20	240	290	10				0,60	A	23
6063	EP, ET, ER/B	T5	t ≤ 10	130	175	8	60	100	0,46	0,57	B	16
	EP		10 < t ≤ 25	110	160	7			0,55	0,63	B	13
	EP, ET, ER/B	T6	t ≤ 25	160	195	8	65	110	0,41	0,56	A	24
	DT		t ≤ 20	190	220	10			0,34	0,50	A	31
	EP, ET, ER/B	T66	t ≤ 10	200	245	8	75	130	0,38	0,53	A	22
	EP		10 < t ≤ 25	180	225	8			0,42	0,58	A	21
	DT		t ≤ 20	195	230	10			0,38	0,57	A	28
6005A	EP/O, ER/B	T6	t ≤ 5	225	270	8	115	165	0,51	0,61	A	25
	EP/O		5 < t ≤ 10	215	260	8			0,53	0,63	A	24
			10 < t ≤ 25	200	250	8			0,58	0,66	A	20
	EP/H, ET	T6	t ≤ 5	215	255	8			0,53	0,65	A	26
			5 < t ≤ 10	200	250	8			0,58	0,66	A	20
6106	EP	T6	t ≤ 10	200	250	8	95	160	0,48	0,64	A	20

Alloy EN AW	Product form	Temper	Thick- ness, t, mm ^{a, c}	f_o^a	f_u^a	$A^{e, b}$	$f_{o, haz}^d$	$f_{u, haz}^d$	HAZ-factor ^d		BC ^f	n ^g
				N/mm ²		%	N/mm ²		$\rho_{o, haz}$	$\rho_{u, haz}$		
6082	EP, ET, ER/B	T4	$t \leq 25$	110	205	14	100	160	0,91	0,78	C	8
	EP	T5	$t \leq 5$	230	270	8	125	185	0,54	0,69	A	28
	EP, ET	T6	$t \leq 5$	250	290	8	125	185	0,50	0,64	A	32
			$5 < t \leq 15$	260	310	10			0,48	0,60	A	25
	ER/B	T6	$t \leq 20$	250	295	8			0,50	0,63	A	27
			$20 < t \leq 150$	260	310	8			0,48	0,60	A	25
	DT	T6	$t \leq 5$	255	310	8			0,49	0,60	A	22
			$5 < t \leq 20$	240	310	10			0,52	0,60	B	17
7020	EP, ET, ER/B	T6	$t \leq 15$	290	350	10	205	280	0,71	0,80	A	23
	EP, ER/B		$15 < t \leq 40$	275	340	10			0,75	0,80	B	20
	DT		$t \leq 20$	280	350	10			0,73	0,80	B	19

Key

EP Extruded profiles
 EP/H Extruded hollow profiles
 ER/B Extruded rod and bar
 EP/O Extruded open profiles
 ET Extruded tube
 DT Drawn tube

^a Where values are quoted in **bold** greater thicknesses and/or higher mechanical properties may be permitted in some forms, see EN 754-2:2016 (for drawn products) and EN 755-2:2016. In this case the $R_{p0,2}$ and R_m values can be taken as f_o and f_u . If using such higher values the corresponding HAZ-factors ρ have to be calculated according to Formula (8.15) and (8.16) with the same values for $f_{o, haz}$ and $f_{u, haz}$.

^b Where minimum elongation values are given in **bold**, higher minimum values may be given for some forms or thicknesses.

^c According to EN 755-2:2016: "If a profile cross-section is comprised of different thicknesses which fall in more than one set of specified mechanically property values, the lowest specified value should be considered as valid for the whole profile cross-section." Exception is possible and the highest value given may be used provided that the manufacturer can support the value by an appropriate quality assurance certificate.

^d Depending on material thickness, filler metal and welding process (MIG or TIG), $\rho_{o, haz}$, $\rho_{u, haz}$ -values in the table should be modified by a reduction factor C_o or C_u respectively. Where higher values of mechanical properties are used according to footnote a, the HAZ-factors, ρ , have to be modified.

^e $A = A_{5,65\sqrt{A_0}}$

^f BC = buckling class, see 8.1.4.4, 8.1.5 and 8.3.1.

^g n-value in Ramberg-Osgood Formula for plastic analysis. It applies only in connection with the listed f_o -value (= minimum standardized value).

Table 5.5 — Reduction factors for MIG Welding

1	2	3	4	5	6	7	8	9
2			Material thickness $t \leq 15$		Material thickness $15 < t^b \leq 30$		Material thickness $t^b > 30 (50)$	
3	Alloy^a EN AW	Weld metal (filler metal)^e	C_o	C_u	C_o	C_u	C_o	C_u
4	3004; 3005	4043A/5356/3103	1	1	---	---	---	---
5	3103	4043A/3103	1	1	0,9 ^d	1	---	---
6	5xxx except 5005,5005A	5356	1	1	1	1	0,9 ^d	1
7		4043A	n/a	n/a	n/a	n/a	n/a	n/a
8	5005,5005A	5356/4043A	1	1	---	---	---	---
9	6xxx	5356	1	1	1	1	0,8	0,8
10		4043A	1	1	1/0,8 ^c	1	0,8	0,8
11	7020	5356/4043A	1	1	1/0,8 ^c	1	0,8	0,8
12	8011	5356/4043A	1	1	---	---	---	---

Key

n/a not applicable

--- not relevant

^a Under the designation of aluminium alloy families 5xxx, 6xxx, only those alloys and tempers considered in this standard, are covered by column 2.

^b For material thicknesses between 15 mm and 30 mm or between 30 mm and 50 mm the reduction values to be applied may be determined by linear interpolation between the values of columns 4 and 6 or between columns 6 and 8 or columns 7 and 9 respectively.

^c This reduction factor 0,8 should only be applied for butt weld connections if the weld metal (filler metal) is an integral part of A_{eff} .

^d No reduction in temper O and H111.

^e For weld metal 4047A use values for 4043A, for weld metal type 5 materials listed in Table 5.10 use values for 5356.

Table 5.6 — Reduction factors for TIG Welding ^d

1	2	3	4	5	6	7
2			Material thickness $t \leq 6$		Material thickness $6 < t^b \leq 15$	
3	Alloy ^a EN AW-	Weld metal (filler metal)	C _O	C _U	C _O	C _U
4	3004; 3005	4043A/ 5356/3103	1	1	---	---
5	3103	4043A 3103	1	1	0,9 ^c	1
6	5xxx, except 5005, 5005A	5356	1	1	0,9 ^c	1
7		4043A	n/a	n/a	n/a	n/a
8	5005:5005A	5356/4043A	1	1	0,9 ^c	1
9	6xxx	5356/4043A	0,8	0,8	0,8	0,8
10	7020	5356/4043A	0,8	0,8	0,8	0,8
11	8011	5356/4043A	1	1	---	---
Key n/a not applicable --- not relevant						
^a For aluminium alloy families 5xxx and 6xxx, only those alloys and tempers considered in this document, are covered by column 2. ^b For material thicknesses between 6 mm and 15 mm, the reduction values to be applied may be determined by linear interpolation between the values of columns 4 and 6. ^c No reduction for strain hardening alloys in temper O and H111. ^d For weld metal 4047A use values for 4043A, for weld metal type 5 materials listed in Table 5.10 use values for 5356.						

Table 5.7 — Characteristic values of 0,2 % proof strength, f_o , and ultimate tensile strength, f_u , (unwelded and for HAZ), minimum elongation, A , and buckling class for wrought aluminium alloys – Forgings

Alloy EN AW	Temper	Thick- ness up to mm	Direction	f_o	f_u	$f_{o,haz}^a$	$f_{u,haz}^a$	A^c %	Buckling class
				N/mm ²					
5754	H112	150	Longitudinal (L)	80	180	80	180	15	C
5083	H112	150	Longitudinal (L)	120	270	120	270	12	C
			Transverse (T)	110	260	110	260	10	C
6082	T6	100	Longitudinal (L)	260	310	125 ^b	185 ^b	6	A
			Transverse (T)	250	290			5	A

^a $\rho_{o,haz}, \rho_{u,haz}$ to be calculated according to Formula (8.15) and (8.16).

^b For thicknesses over 15 mm (MIG-welding) or 6 mm (TIG-welding) see Table 5.4, footnote d.

^c $A = A_{5,65\sqrt{A_0}}$

5.2.3 Material properties for cast aluminium alloys

5.2.3.1 General

(1) EN 1999-1-1 is generally not applicable to castings.

(2) The design rules in this document are applicable for gravity casted products according to Table 5.8 if the additional and special rules and the quality provisions of Annex E are followed.

5.2.3.2 Characteristic values

(1) The characteristic values of the 0,2 % proof strength f_o and the ultimate tensile strength f_u for sand and permanent mould cast aluminium to be met by the caster or the foundry in each location of a cast piece given in Table 5.8 should be used.