

Eurocode 9: Design of aluminium structures —

Part 1-1: General structural rules

ICS 77.150.10; 91.010.30; 91.080.10

National foreword

This British Standard is the UK implementation of EN 1999-1-1:2007+A2:2013. It supersedes BS EN 1999-1-1:2007+A1:2009 which is withdrawn. Details of superseded British Standards are given in the table below.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to CEN text carry the number of the CEN amendment. For example, text altered by CEN amendment A1 is indicated by **A1** **A1**.

The structural Eurocodes are divided into packages by grouping Eurocodes for each of the main materials: concrete, steel, composite concrete and steel, timber, masonry and aluminium; this is to enable a common date of withdrawal (DOW) for all the relevant parts that are needed for a particular design. The conflicting national standards will be withdrawn at the end of the coexistence period, after all the EN Eurocodes of a package are available.

Following publication of the EN, there is a period allowed for national calibration during which the National Annex is issued, followed by a further coexistence period of a maximum three years. During the coexistence period Member States will be encouraged to adapt their national provisions to withdraw conflicting national rules before the end of the coexistence period in March 2010. At the end of this coexistence period, the national standard(s) will be withdrawn.

In the UK, the following national standards are superseded by the Eurocode 9 series. These standards will be withdrawn on a date to be announced.

Eurocode	Superseded British Standards
EN 1999-1-1	BS 8118-2:1991 DD ENV 1999-1-1:2000 BS 8118-1:1991 (partial)
EN 1999-1-2	DD ENV 1999-1-2:2000
EN 1999-1-3	DD ENV 1999-2:2000 BS 8118-1:1991 (partial)
EN 1999-1-4	BS 8118-1:1991 (partial)
EN 1999-1-5	None

The UK participation in its preparation was entrusted by Technical Committee B/525, Building and civil engineering structures, to Subcommittee B/525/9, Structural use of aluminium.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Where a normative part of this EN allows for a choice to be made at the national level, the range and possible choice will be given in the normative text, and a note will qualify it as a Nationally Determined Parameter (NDP). NDPs can be a specific value for a factor, a specific level or class, a particular method or a particular application rule if several are proposed in the EN.

To enable EN 1999-1-1 to be used in the UK, the NDPs will be published in a National Annex, which will be made available by BSI in due course, after public consultation has taken place.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Amendments/corrigenda issued since publication

Date	Comments
31 March 2010	Implementation of CEN amendment A1:2009
28 February 2014	Implementation of CEN amendment A2:2013
31 March 2014	Identifiers in running headers corrected

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English Version

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

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

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

This European Standard was approved by CEN on 18 September 2006.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN Management Centre has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
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Management Centre: rue de Stassart, 36 B-1050 Brussels

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Foreword

This European Standard (EN 1999-1-1:2007) has been prepared by Technical Committee CEN/TC250 « Structural Eurocodes », the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by November 2007, and conflicting national standards shall be withdrawn at the latest by March 2010.

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

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

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

Foreword to amendment A1

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

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

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

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

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

Background of the Eurocode programme

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

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

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

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

¹ Agreement between the Commission of the European Communities and the European Committee for Standardisation (CEN) concerning the work on EUROCODES for the design of building and civil engineering works (BC/CEN/03/89).

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

EN 1990	Eurocode 0:	Basis of structural design
EN 1991	Eurocode 1:	Actions on structures
EN 1992	Eurocode 2:	Design of concrete structures
EN 1993	Eurocode 3:	Design of steel structures
EN 1994	Eurocode 4:	Design of composite steel and concrete structures
EN 1995	Eurocode 5:	Design of timber structures
EN 1996	Eurocode 6:	Design of masonry structures
EN 1997	Eurocode 7:	Geotechnical design
EN 1998	Eurocode 8:	Design of structures for earthquake resistance
EN 1999	Eurocode 9:	Design of aluminium structures

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

Status and field of application of Eurocodes

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

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

The Eurocodes, as far as they concern the construction works themselves, have a direct relationship with the Interpretative Documents² referred to in Article 12 of the CPD, although they are of a different nature from harmonised product standard³. Therefore, technical aspects, arising from the Eurocodes work, need to be adequately considered by CEN Technical Committees and/or EOTA Working Groups working on product standards with a view to achieving a full compatibility of these technical specifications with the Eurocodes.

The Eurocode standards provide common structural design rules for everyday use for the design of whole structures and component products of both a traditional and an innovative nature. Unusual forms of construction or design conditions are not specifically covered and additional expert consideration will be required by the designer in such cases.

² According to Art. 3.3 of the CPD, the essential requirements (ERs) should be given concrete form in interpretative documents for the creation of the necessary links between the essential requirements and the mandates for hENs and ETAGs/ETAs.

³ According to Art. 12 of the CPD the interpretative documents should :

- a) give concrete form to the essential requirements by harmonising the terminology and the technical bases and indicating classes or levels for each requirement where necessary ;
- b) indicate methods of correlating these classes or levels of requirement with the technical specifications, e.g. methods of calculation and of proof, technical rules for project design, etc. ;
- c) serve as a reference for the establishment of harmonised standards and guidelines for European technical approvals.

The Eurocodes, *de facto*, play a similar role in the field of the ER 1 and a part of ER 2.

National Standards implementing Eurocodes

The National Standards implementing Eurocodes will comprise the full text of the Eurocode (including any annexes), as published by CEN, which may be preceded by a National title page and National foreword, and may be followed by a National annex (informative).

The National Annex (informative) may only contain information on those parameters which are left open in the Eurocode for national choice, known as Nationally Determined Parameters, to be used for the design of buildings and civil engineering works to be constructed in the country concerned, i.e. :

- values for partial factors and/or classes where alternatives are given in the Eurocode,
- values to be used where a symbol only is given in the Eurocode,
- geographical and climatic data specific to the Member State, e.g. snow map,
- the procedure to be used where alternative procedures are given in the Eurocode,
- references to non-contradictory complementary information to assist the user to apply the Eurocode.

Links between Eurocodes and product harmonised technical specifications (ENs and ETAs)

There is a need for consistency between the harmonised technical specifications for construction products and the technical rules for works⁴. Furthermore, all the information accompanying the CE Marking of the construction products which refer to Eurocodes should clearly mention which Nationally Determined Parameters have been taken into account.

Additional information specific to EN 1999-1-1

EN 1999 is intended to be used with Eurocodes EN 1990 – Basis of Structural Design, EN 1991 – Actions on structures and EN 1992 to EN 1999, where aluminium structures or aluminium components are referred to.

EN 1999-1-1 is the first part of 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.

The four other parts EN 1999-1-2 to EN 1999-1-5 are each addressing specific aluminium components, limit states or type of structures.

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

EN 1999-1-1 is intended for use by

- committees drafting design related product, testing and execution standards,
- owners of construction works (e.g. for the formulation of their specific requirements)
- designers and constructors
- relevant authorities

Numerical values for partial factors and other reliability parameters are recommended as basic values that provide an acceptable level of reliability. They have been selected assuming that an appropriate level of workmanship and quality management applies.

⁴ See Art.3.3 and Art.12 of the CPD, as well as clauses 4.2, 4.3.1, 4.3.2 and 5.2 of ID 1.

National annex for EN 1999-1-1

This standard gives alternative procedures, values and recommendations for classes with notes indicating where national choices may have to be made. Therefore the National Standard implementing EN 1999-1-1 should have a National Annex containing all Nationally Determined Parameters to be used for the design of aluminium structures to be constructed in the relevant country.

National choice is allowed in EN 1999-1-1 through clauses:

- 1.1.2(1)
- 2.1.2(3)
- 2.3.1(1)
- 3.2.1(1)
- 3.2.2(1)
- 3.2.2(2)
- 3.2.3.1(1)
- 3.3.2.1(3)
- 3.3.2.2(1)
- 5.2.1(3)
- 5.3.2(3)
- 5.3.4(3)
- 6.1.3(1)
- 6.2.1(5)
- 7.1(4)
- 7.2.1(1)
- 7.2.2(1)
- 7.2.3(1)
- 8.1.1(2)
- 8.9(3)
- A(6) (Table A.1)
- C.3.4.1(2)
- C.3.4.1(3)
- C.3.4.1(4)
- K.1(1)
- K.3(1)

1 General

1.1 Scope

1.1.1 Scope of EN 1999

(1)P EN 1999 applies to the design of buildings and civil engineering and structural works in aluminium. It complies with the principles and requirements for the safety and serviceability of structures, the basis of their design and verification that are given in EN 1990 – Basis of structural design.

(2) EN 1999 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.

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

- EN 1990 “Basis of structural design”
- EN 1991 “Actions on structures”
- European Standards for construction products relevant for aluminium structures
- prEN 1090-1: Execution of steel structures and aluminium structures – Part 1: Requirements for conformity assessment of structural components
- ~~EN~~ EN 1090-3~~A1~~: Execution of steel structures and aluminium structures – Part 3: Technical requirements for aluminium structures

(4) EN 1999 is subdivided in five parts:

EN 1999-1-1 Design of Aluminium Structures: General structural rules.

EN 1999-1-2 Design of Aluminium Structures: Structural fire design.

EN 1999-1-3 Design of Aluminium Structures: Structures susceptible to fatigue.

EN 1999-1-4 Design of Aluminium Structures: Cold-formed structural sheeting.

EN 1999-1-5 Design of Aluminium Structures: Shell structures.

1.1.2 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 ~~A1~~ (see section 3 and Annex C). ~~A1~~

NOTE Minimum material thickness may be defined in the National Annex. The following limits are recommended – if not otherwise explicitly stated in this standard:

- components with material thickness not less than 0,6 mm;
- welded components with material thickness not less than 1,5 mm;
- connections with:
 - steel bolts and pins with diameter not less than 5 mm;
 - aluminium bolts and pins with diameter not less than 8 mm;
 - rivets and thread forming screws with diameter not less than 4,2 mm

(2) The following subjects are dealt with in EN 1999-1-1:

Section 1: General

Section 2: Basis of design

Section 3: Materials

~~A1~~ footnote deleted ~~A1~~

Section 4: Durability

Section 5: Structural analysis

Section 6: Ultimate limit states for members

Section 7: Serviceability limit states

Section 8: Design of joints

Annex A Execution classes

Annex B Equivalent T-stub in tension

Annex C Materials selection

Annex D Corrosion and surface protection

Annex E Analytical models for stress strain relationship

Annex F Behaviour of cross section beyond elastic limit

Annex G Rotation capacity

Annex H Plastic hinge method for continuous beams

Annex I Lateral torsional buckling of beams and torsional or flexural-torsional buckling of compression members

Annex J Properties of cross sections

Annex K Shear lag effects in member design

Annex L Classification of connections

Annex M Adhesive bonded connections

- (3) Sections 1 to 2 provide additional clauses to those given in EN 1990 “Basis of structural design”.
- (4) Section 3 deals with material properties of products made of structural aluminium alloys.
- (5) Section 4 gives general rules for durability.
- (6) Section 5 refers to the structural analysis of structures, in which the members can be modelled with sufficient accuracy as line elements for global analysis.
- (7) Section 6 gives detailed rules for the design of cross sections and members.
- (8) Section 7 gives rules for serviceability.
- (9) Section 8 gives detail rules for connections subject to static loading: bolted, riveted, welded and adhesive bonded connections.

1.2 Normative references

(1) This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only if incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

1.2.1 General references

prEN 1090-1: Execution of steel structures and aluminium structures – Part 1: Requirements for conformity assessment of structural components

~~A1~~ EN 1090-3~~A1~~: Execution of steel structures and aluminium structures – Part 3: Technical requirements for aluminium structures

1.2.2 References on structural design

EN 1990 Basis of structural design

~~A1~~ footnote deleted ~~A1~~

EN 1991 Actions on structures – All parts

A1 Text deleted **A1**

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

1.2.3 References on aluminium alloys

A1 Text deleted **A1**

A2 1.2.3.1 Chemical composition and temper definition of wrought products and technical delivery conditions

EN 485-1 Aluminium and aluminium alloys - Sheet, strip and plate - Part 1: Technical conditions for inspection and delivery

EN 515 Aluminium and aluminium alloys - Wrought products - Temper designations

EN 573-3 Aluminium and aluminium alloys - Chemical composition and form of wrought products - Part 3: Chemical composition and form of products

EN 586-1 Aluminium and aluminium alloys - Forgings - Part 1: Technical conditions for inspection and delivery

EN 754-1 Aluminium and aluminium alloys - Cold drawn rod/bar and tube - Part 1: Technical conditions for inspection and delivery

EN 755-1 Aluminium and aluminium alloys - Extruded rod/bar, tube and profiles - Part 1: Technical conditions for inspection and delivery **A2**

A1 Text deleted **A1**

EN 28839 Fasteners - Mechanical properties of fasteners - Bolts, screws, studs and nuts made from non-ferrous metals

EN ISO 898-1 Mechanical properties of fasteners made of carbon steel and alloy steel - Part 1: Bolts, screws and studs

EN ISO 3506-1 Mechanical properties of corrosion-resistant stainless-steel fasteners - Part 1: Bolts, screws and studs

A1 1.2.3.2 Dimensions and mechanical properties

EN 485-2 Aluminium and aluminium alloys - Sheet, strip and plate - Part 2: Mechanical properties

EN 485-3 Aluminium and aluminium alloys - Sheet, strip and plate - Part 3: Tolerances on shape and dimensions for hot-rolled products

EN 485-4 Aluminium and aluminium alloys - Sheet, strip and plate - Part 4: Tolerances on shape and dimensions for cold-rolled products **A1**

 EN 508-2	Roofing products from metal sheet - Specifications for self supporting products of steel, aluminium or stainless steel - Part 2: Aluminium
EN 586-2	Aluminium and aluminium alloys - Forgings - Part 2: Mechanical properties and additional property requirements
EN 586-3	Aluminium and aluminium alloys - Forgings - Part 3: Tolerances on dimension and form
EN 754-2	Aluminium and aluminium alloys - Cold drawn rod/bar and tube - Part 2: Mechanical properties
EN 754-3	Aluminium and aluminium alloys - Cold drawn rod/bar and tube - Part 3: Round bars, tolerances on dimension and form
EN 754-4	Aluminium and aluminium alloys - Cold drawn rod/bar and tube - Part 4: Square bars, tolerances on dimension and form
EN 754-5	Aluminium and aluminium alloys - Cold drawn rod/bar and tube - Part 5: Rectangular bars, tolerances on dimension and form
EN 754-6	Aluminium and aluminium alloys - Cold drawn rod/bar and tube - Part 6: Hexagonal bars, tolerances on dimension and form
EN 754-7	Aluminium and aluminium alloys - Cold drawn rod/bar and tube - Part 7: Seamless tubes, tolerances on dimension and form
EN 754-8	Aluminium and aluminium alloys - Cold drawn rod/bar and tube - Part 8: Porthole tubes, tolerances on dimension and form
EN 755-2:2008	Aluminium and aluminium alloys - Extruded rod/bar, tube and profiles - Part 2: Mechanical properties
EN 755-3	Aluminium and aluminium alloys - Extruded rod/bar, tube and profiles- Part 3: Round bars, tolerances on dimension and form
EN 755-4	Aluminium and aluminium alloys - Extruded rod/bar, tube and profiles- Part 4: Square bars, tolerances on dimension and form
EN 755-5	Aluminium and aluminium alloys - Extruded rod/bar, tube and profiles- Part 5: Rectangular bars, tolerances on dimension and form
EN 755-6	Aluminium and aluminium alloys - Extruded rod/bar, tube and profiles- Part 6: Hexagonal bars, tolerances on dimension and form
EN 755-7	Aluminium and aluminium alloys - Extruded rod/bar, tube and profiles- Part 7: Seamless tubes, tolerances on dimension and form
EN 755-8	Aluminium and aluminium alloys - Extruded rod/bar, tube and profiles- Part 8: Porthole tubes, tolerances on dimension and form
EN 755-9	Aluminium and aluminium alloys - Extruded rod/bar, tube and profiles- Part 9: Profiles, tolerances on dimension and form 

 Text deleted 

1.2.3.3 Aluminium alloy castings

EN 1559-1	Founding - Technical conditions of delivery - Part 1: General
EN 1559-4	Founding - Technical conditions of delivery - Part 4: Additional requirements for aluminium alloy castings 

A1 EN 1371-1	Founding - Liquid penetrant inspection - Part 1: Sand, gravity die and low pressure die castings
EN 12681	Founding – Radiographic examination
EN 571-1	Non destructive testing - Penetrant testing - Part 1: General principles
EN 13068-1	Non-destructive testing - Radioscopic testing - Part 1: Quantitative measurement of imaging properties
EN 13068-2	Non-destructive testing - Radioscopic testing - Part 2: Check of long term stability of imaging devices
EN 13068-3	Non-destructive testing - Radioscopic testing - Part 3: General principles of radioscopic testing of metallic materials by X- and gamma rays
EN 444	Non-destructive testing - General principles for radiographic examination of metallic materials by X- and gamma-rays A1
A1 Text deleted A1	
A1 EN 1706	Aluminium and aluminium alloys - Castings - Chemical composition and mechanical properties A1

1.2.4 References on welding

A1 Text deleted **A1**

A1 EN 1011-4:2000	Welding – Recommendations for welding of metallic materials – Part 4: Arc welding of aluminium and aluminium alloys A1
A2 EN ISO 18273	Welding consumables – Wire electrodes, wires and rods for welding of aluminium and aluminium alloys – Classification (ISO 18273) A2

A1 Text deleted **A1**

1.2.5 Other references

A1 Text deleted **A1**

A2 EN ISO 6892	Metallic materials – Tensile testing (ISO 6892) (all parts) A2
A1 ISO 8930	General principles on reliability for structures - List of equivalent terms
ISO 11003-1	Adhesives -- Determination of shear behaviour of structural adhesives -- Part 1: Torsion test method using butt-bonded hollow cylinders
ISO 11003-2	Adhesives -- Determination of shear behaviour of structural adhesives -- Part 2: Tensile test method using thick adherents
prEN ISO 1302	Geometrical Product Specification (GPS) - Indication of surface texture in technical product documentation. A1

 EN ISO 4287	Geometrical Product Specifications (GSP) - Surface texture: Profile method - Terms, definitions and surface texture parameters
EN ISO 4288	Geometrical Product Specification (GPS) - Surface texture - Profile method: Rules and procedures for the assessment of surface texture. 

1.3 Assumptions

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

- execution complies with  EN 1090-3 

 - The aluminium products should comply with EN 573 and the product standards listed in 1.2.3. The mechanical properties should comply with the tabulated values in Parts 2 of the product standards listed in 1.2.3. 

1.4 Distinction between principles and application rules

(1) The rules in EN 1990 1.4 apply.

1.5 Terms and definitions

(1) The definitions in EN 1990 1.5 apply.

(2) The following terms are used in EN 1999-1-1 with the following definitions:

1.5.1

frame

the whole or a portion of a structure, comprising an assembly of directly connected structural members, designed to act together to resist load; this term refers to both moment-resisting frames and triangulated frames; it covers both plane frames and three-dimensional frames

1.5.2

sub-frame

a frame that forms part of a larger frame, but is to be treated as an isolated frame in a structural analysis

1.5.3

type of framing

terms used to distinguish between frames that are either:

- **semi-continuous**, in which the structural properties of the members and connections need explicit consideration in the global analysis
- **continuous**, in which only the structural properties of the members need be considered in the global analysis
- **simple**, in which the joints are not required to resist moments

1.5.4

global analysis

the determination of a consistent set of internal forces and moments in a structure, which are in equilibrium with a particular set of actions on the structure

1.5.5

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

1.5.6

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).

1.5.7**shear lag effect**

non uniform stress distribution in wide flanges due to shear deformations; it is taken into account by using a reduced “effective” flange width in safety assessments

1.5.8**capacity design**

design based on the plastic deformation capacity of a member and its connections providing additional strength in its connections and in other parts connected to the member.

1.6 Symbols

(1) For the purpose of this standard the following apply.

Additional symbols are defined where they first occur.

NOTE Symbols are ordered by appearance in EN 1999-1-1. Symbols may have various meanings.

Section 1 General

x - x	axis along a member
y - y	axis of a cross-section
z - z	axis of a cross-section
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)

Section 2 Basis of design

P_k	nominal value of the effect of prestressing imposed during erection
G_k	nominal value of the effect of permanent actions
X_k	characteristic values of material property
X_n	nominal values of material property
R_d	design value of resistance
R_k	characteristic value of resistance
γ_M	general partial factor
γ_{Mi}	particular partial factor
γ_{Mf}	partial factor for fatigue
η	conversion factor
a_d	design value of geometrical data

Section 3 Materials

f_o	characteristic value of 0,2 % proof strength
f_u	characteristic value of ultimate tensile strength
f_{oc}	characteristic value of 0,2 % proof strength of cast material
f_{uc}	characteristic value of ultimate tensile strength of cast material
A_{50}	elongation value measured with a constant reference length of 50 mm, see $\square_{A_2}$ EN ISO 6892 $\square_{A_2}$
$A = A_{5,65\sqrt{A_0}}$	elongation value measured with a reference length $5,65\sqrt{A_0}$, see EN 10 002
A_0	original cross-section area of test specimen
$f_{o,haz}$	0,2 % proof strength in heat affected zone, HAZ
$f_{u,haz}$	ultimate tensile strength in heat affected zone, HAZ
$\rho_{o,haz}$	$= f_{o,haz} / f_o$, 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
BC	buckling class

n_p	exponent in Ramberg-Osgood expression for plastic design
E	modulus of elasticity
G	shear modulus
ν	Poisson's ratio in elastic stage
α	coefficient of linear thermal expansion
ρ	unit mass

Section 5 Structural analysis

α_{cr}	factor by which the design loads would have to be increased to cause elastic instability in a global mode
F_{Ed}	design loading on the structure
F_{cr}	elastic critical buckling load for global instability mode based on initial elastic stiffness
H_{Ed}	design value of the horizontal reaction at the bottom of the storey to the horizontal loads and fictitious horizontal loads
V_{Ed}	total design vertical load on the structure on the bottom of the storey
$\delta_{H,Ed}$	horizontal displacement at the top of the storey, relative to the bottom of the storey
h	storey height, height of the structure
$\bar{\lambda}$	non dimensional slenderness
N_{Ed}	design value of the axial force
ϕ	global initial sway imperfection
ϕ_0	basic value for global initial sway imperfection
α_h	reduction factor for height h applicable to columns
α_m	reduction factor for the number of columns in a row
m	number of columns in a row
e_0	maximum amplitude of a member imperfection
L	member length
$e_{0,d}$	design value of maximum amplitude of an imperfection
M_{Rk}	characteristic moment resistance of the critical cross section
N_{Rk}	characteristic resistance to normal force of the critical cross section
q	equivalent force per unit length
δ_q	in-plane deflection of a bracing system
q_d	equivalent design force per unit length
M_{Ed}	design bending moment
k	factor for $e_{0,d}$

Section 6 Ultimate limit states for members

χ_{M1}	partial factor for resistance of cross-sections whatever the class is
χ_{M1}	partial factor for resistance of members to instability assessed by member checks
χ_{M2}	partial factor for resistance of cross-sections in tension to fracture
b	width of cross section part
f_{of}	is characteristic value of 0,2 % proof strength of the flange material f_{yk}
t	thickness of a cross-section part
β	width-to-thickness ratio b/t
η	coefficient to allow for stress gradient or reinforcement of cross section part
ψ	stress ratio
σ_{cr}	elastic critical stress for a reinforced cross section part
σ_{cr0}	elastic critical stress for an un-reinforced cross section part

R	radius of curvature to the mid-thickness of material
D	diameter to mid-thickness of tube material
$\beta_1, \beta_2, \beta_3$	limits for slenderness parameter
ε	$= \sqrt{250/f_0}$, coefficient
z_1	distance from neutral axis to most severely stressed fibre
z_2	distance from neutral axis to fibre under consideration
C_1, C_2	Constants
ρ_c	reduction factor for local buckling
b_{haz}	extent of HAZ
T_1	interpass temperature
α_2	factor for b_{haz}

6.2 Resistance of cross sections

$\sigma_{x,\text{Ed}}$	design value of the local longitudinal stress
$\sigma_{y,\text{Ed}}$	design value of the local transverse stress
τ_{Ed}	design value of the local shear stress
N_{Ed}	design normal force
$M_{y,\text{Ed}}$	design bending moment, y-y axis
$M_{z,\text{Ed}}$	design bending moment, z-z axis
N_{Rd}	design values of the resistance to normal forces
$M_{y,\text{Rd}}$	design values of the resistance to bending moments, y-y axis
$M_{z,\text{Rd}}$	design values of the resistance to bending moments, z-z axis
s	staggered pitch, the spacing of the centres of two consecutive holes in the chain measured parallel to the member axis
p	spacing of the centres of the same two holes measured perpendicular to the member axis
n	number of holes extending in any diagonal or zig-zag line progressively across the member or part of the member
d	diameter of hole
A_g	area of gross cross-section
A_{net}	net area of cross-section
A_{eff}	effective area of cross-section
$\text{A2} A_{u,\text{eff}}$	effective cross section area allowing for local buckling and HAZ softening of transverse welds A2
$N_{t,\text{Rd}}$	design values of the resistance to tension force
$N_{o,\text{Rd}}$	design value of resistance to general yielding of a member in tensions
$N_{u,\text{Rd}}$	design value of resistance to axial force of the net cross-section at holes for fasteners
$N_{c,\text{Rd}}$	design resistance to normal forces of the cross-section for uniform compression
M_{Rd}	design resistance for bending about one principal axis of a cross-section
$M_{u,\text{Rd}}$	design resistance for bending of the net cross-section at holes
$M_{o,\text{Rd}}$	design resistance for bending to general yielding
α	shape factor
W_{el}	elastic modulus of the gross section (see 6.2.5.2)
W_{net}	elastic modulus of the net section allowing for holes and HAZ softening, if welded
$\text{A2} W_{u,\text{eff}}$	section modulus allowing for local buckling and reduced thickness $\rho_{u,\text{haz}}t$ in HAZ softening of transverse welds A2
W_{pl}	plastic modulus of gross section

W_{eff}	effective elastic section modulus, obtained using a reduced thickness t_{eff} for the class 4 parts
$W_{\text{el,haz}}$	effective elastic modulus of the gross section, obtained using a reduced thickness $\rho_{\text{o,haz}}t$ for the HAZ material
$W_{\text{pl,haz}}$	effective plastic modulus of the gross section, obtained using a reduced thickness $\rho_{\text{o,haz}}t$ for the HAZ material
$W_{\text{eff,haz}}$	effective elastic section modulus, obtained using a reduced thickness $\rho_{\text{c}}t$ for the class 4 parts or a reduced thickness $\rho_{\text{o,haz}}t$ for the HAZ material, whichever is the smaller
$\alpha_{3,\text{u}}$	shape factor for class 3 cross section without welds
$\alpha_{3,\text{w}}$	shape factor for class 3 cross section with welds
V_{Ed}	design shear force
V_{Rd}	design shear resistance
A_{v}	shear area
η_{v}	factor for shear area
h_{w}	depth of a web between flanges
t_{w}	web thickness
A_{e}	the section area of an un-welded section, and the effective section area obtained by taking a reduced thickness $\rho_{\text{o,haz}}t$ for the HAZ material of a welded section
T_{Ed}	design value of torsional moment
T_{Rd}	design St.Venant torsion moment resistance
$W_{\text{T,pl}}$	plastic torsion modulus
$T_{\text{t,Ed}}$	design value of internal St. Venant torsional moment
$T_{\text{w,Ed}}$	design value of internal warping torsional moment
$\tau_{\text{t,Ed}}$	design shear stresses due to St. Venant torsion
$\tau_{\text{w,Ed}}$	design shear stresses due to warping torsion
$\sigma_{\text{w,Ed}}$	design direct stresses due to the bimoment B_{Ed}
B_{Ed}	bimoment
$V_{\text{T,Rd}}$	reduced design shear resistance making allowance for the presence of torsional moment
$f_{\text{o,V}}$	reduced design value of strength making allowance for the presence of shear force
$M_{\text{v,Rd}}$	reduced design value of the resistance to bending moment making allowance for the presence of shear force

6.3 Buckling resistance

N_{Rd}	resistance of axial compression force
$M_{\text{y,Rd}}$	bending moment resistance about y-y axis
$M_{\text{z,Rd}}$	bending moment resistance about z-z axis
$\eta_0, \gamma_0, \xi_0, \psi$	exponents in interaction formulae
ρ	reduction factor to determine reduced design value of the resistance to bending moment making allowance of the presence of shear force
$N_{\text{b,Rd}}$	design buckling resistance of a compression member
κ	factor to allow for the weakening effect of A2 longitudinal welding A2
χ	reduction factor for relevant buckling mode
ϕ	value to determine the reduction factor χ
α	imperfection factor
$\bar{\lambda}_0$	limit of the horizontal plateau of the buckling curves
N_{cr}	elastic critical force for the relevant buckling mode based on the gross cross sectional properties

i	radius of gyration about the relevant axis, determined using the properties of the gross cross-section
$\bar{\lambda}$	relative slenderness
$\bar{\lambda}_T$	relative slenderness for torsional or torsional-flexural buckling
N_{cr}	elastic torsional-flexural buckling force
k	buckling length factor
$M_{b,Rd}$	design buckling resistance moment
χ_{LT}	reduction factor for lateral-torsional buckling
ϕ_{LT}	value to determine the reduction factor χ_{LT}
α_{LT}	imperfection factor
$\bar{\lambda}_{LT}$	non dimensional slenderness for lateral torsional buckling
M_{cr}	elastic critical moment for lateral-torsional buckling
$\bar{\lambda}_{0,LT}$	plateau length of the lateral torsional buckling curve
$\eta_c, \gamma_c, \xi_{yc}, \xi_{zc}, \psi_c$	exponents in interaction formulae
$\omega_x, \omega_{x,LT}$	factors for the second order bending moments
$\omega_{x,haz}, \omega_{xLT,haz}$	factors for section with localized transverse weld
$\bar{\lambda}_{haz}, \bar{\lambda}_{haz,LT}$	relative slenderness parameters for section with localized weld
x_s	distance from section with localized weld to simple support or point of contra flexure of the deflection curve for elastic buckling from an axial force

6.4 Uniform built-up compression members

L_{ch}	buckling length of chord
h_0	distance of centrelines of chords of a built-up column
a	distance between restraints of chords
α	angle between axes of chord and lacings
i_{min}	minimum radius of gyration of single angles
A_{ch}	area of one chord of a built-up column
$N_{ch,Ed}$	design chord force in the middle of a built-up member
M_{Ed}^I	design value of the maximum moment in the middle of the built-up member
I_{eff}	effective second moment of area of the built-up member
S_v	shear stiffness of built-up member from the lacings or battened panel
n	number of planes of lacings
A_d	area of one diagonal of a built-up column
d	length of a diagonal of a built-up column
A_v	area of one post (or transverse element) of a built-up column
I_{ch}	in plane second moment of area of a chord
I_{bl}	in plane second moment of area of a batten
μ	efficiency factor
i_y, i_z	radius of gyration (y-y axis and z-z axis)

6.5 Un-stiffened plates under in-plane loading

ν_l	reduction factor for shear buckling
k_τ	buckling coefficient for shear buckling

6.6 Stiffened plates under in-plane loading

c	elastic support from plate
l_w	half wave-length in elastic buckling

χ	reduction factor for flexural buckling of sub-unit
I_{eff}	second moment of area of effective cross section of plating for in-plane bending
y_{st}	distance from centre of plating to centre of outermost stiffener
B_x	bending stiffness of orthotropic plate in section $x = \text{constant}$
B_y	bending stiffness of orthotropic plate in section $y = \text{constant}$
H	torsional stiffness of orthotropic plate
I_L	second moment of area of one stiffener and adjacent plating in the longitudinal direction
I_{XT}	torsional constant of one stiffener and adjacent plating in the longitudinal direction
a	half distance between stiffeners
t_1, t_2	thickness of layers in orthotropic plate
s	developed width of stiffeners and adjacent plate
$\tau_{\text{cr,g}}$	shear buckling stress for orthotropic plate
ϕ, η_h	factors

6.7 Plate girders

b_f	Flange width
h_w	web depth = clear distance between inside flanges
b_w	depth of straight portion of a web
t_w	web thickness
t_f	flange thickness
I_{st}	second moment of area of gross cross-section of stiffener and adjacent effective parts of the web plate
b_1, b_2	distances from stiffener to inside flanges (welds)
a_c	half wave length for elastic buckling of stiffener
ρ_v	factor for shear buckling resistance
η	factor for shear buckling resistance in plastic range
λ_w	slenderness parameter for shear buckling
$V_{w,Rd}$	shear resistance contribution from the web
$V_{f,Rd}$	shear resistance contribution from the flanges
$k_{\tau,\text{st}}$	contribution from the longitudinal stiffeners to the buckling coefficient k_τ
$k_{\tau 1}$	buckling coefficient for subpanel
c	factor in expression for $V_{f,Rd}$
$M_{f,Rd}$	design moment resistance of a cross section considering the flanges only
A_{f1}, A_{f2}	cross section area of top and bottom flange
F_{Ed}	design transverse force
F_{Rd}	design resistance to transverse force
L_{eff}	effective length for resistance to transverse force
l_y	effective loaded length for resistance to transverse force
χ_F	reduction factor for local buckling due to transverse force
s_s	length stiff bearing under transverse force
λ_F	slenderness parameter for local buckling due to transverse force
k_F	buckling factor for transverse force
γ_s	relative second moment of area of the stiffener closest to the loaded flange
I_{s1}	second moment of area of the stiffener closest to the loaded flange
m_1, m_2	parameters in formulae for effective loaded length

l_e	parameter in formulae for effective loaded length
$M_{N,Rd}$	reduced moment resistance due to presence of axial force
A_w	cross section area of web
A_{fc}	cross-section area of compression flange
k	factor for flange induced buckling
r	radius of curvature
h_f	distance between centres of flanges

6.8 Members with corrugated webs

b_1, b_2	flange widths
t_1, t_2	flange thicknesses
ρ_z	reduction factor due to transverse moments in the flanges
M_z	transverse bending moment in the flanges
$\rho_{c,g}$	reduction factor for global buckling
$\lambda_{c,g}$	slenderness parameter for global buckling
$\tau_{cr,g}$	shear buckling stress for global buckling
$\rho_{c,l}$	reduction factor for local buckling
$\lambda_{c,l}$	slenderness parameter for local buckling
$\tau_{cr,l}$	shear buckling stress for local buckling
$a_0, a_1, a_2, a_3, a_{max}$	widths of corrugations

Section 7 Serviceability limit state

I_{ser}	effective section moment of area for serviceability limit state
I_{eff}	section moment of area for the effective cross-section at the ultimate limit state
σ_{gr}	maximum compressive bending stress at the serviceability limit state based on the gross cross section

Section 8 Design of connections

$\gamma_{M3} \rightarrow \gamma_{M7}$	partial safety factors
γ_{Mw}	partial safety factor for resistance of welded connection
γ_{Mp}	partial safety factor for resistance of pin connection
γ_{Ma}	partial safety factor for resistance of adhesive bonded connection
γ_{Mser}	partial safety factor for serviceability limit state

[A1] Text deleted **[A1]**

$e_1 \rightarrow e_4$	edge distances
p, p_1, p_2	spacing between bolt holes
d	diameter of fastener
d_0	hole diameter
$V_{eff,1,Rd}$	design block tearing resistance for concentric loading
$V_{eff,2,Rd}$	design block tearing resistance for eccentric loading
A_{nt}	net area subject to tension
A_{nv}	net area subject to shear
A_1	area of part of angle outside the bolt hole
β_2, β_3	reduction factors for connections in angles

$F_{v,Ed}$	design shear force per bolt for the ultimate limit state
$F_{v,Ed,ser}$	design shear force per bolt for the serviceability limit state
$F_{v,Rd}$	design shear resistance per bolt
$F_{b,Rd}$	design bearing resistance per bolt
$F_{s,Rd,ser}$	design slip resistance per bolt at the serviceability limit state
$F_{s,Rd}$	design slip resistance per bolt at the ultimate limit state
$F_{t,Ed}$	design tensile force per bolt for the ultimate limit state
$F_{t,Rd}$	design tension resistance per bolt
$N_{net,Rd}$	design resistance of section at bolt holes
$B_{t,Rd}$	design tension resistance of a bolt-plate assembly
f_{ub}	characteristic ultimate strength of bolt material
f_{ur}	characteristic ultimate strength of rivet material
A_0	cross section area of the hole
A	gross cross section of a bolt
A_s	tensile stress area of a bolt
k_2	factor for tension resistance of a bolt
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;
t_p	thickness of the plate under the bolt head or the nut;
$F_{p,C}$	preloading force
μ	slip factor
n	number of friction interfaces
β_{Lf}	reduction factor for long joint
L_j	distance between the centres of the end fasteners in a long joint
β_p	reduction factor for fasteners passing through packings
a, b	plate thickness in a pin connection
c	gap between plates in a pin connection
f_w	characteristic strength of weld metal
$\sigma_{\perp}$	normal stress perpendicular to weld axis
$\sigma_{\parallel}$	normal stress parallel to weld axis
$\tau, \tau_{\parallel}$	shear stress parallel to weld axis
$\tau_{\perp}$	shear stress perpendicular to weld axis
γ_{Mw}	partial safety factor for welded joints
L_w	total length of longitudinal fillet weld
$L_{w,eff}$	effective length of longitudinal fillet weld
a	effective throat thickness
σ_{haz}	design normal stress in HAZ, perpendicular to the weld axis
τ_{haz}	design shear stress in HAZ
$f_{v,haz}$	characteristic shear strength in HAZ

Annex A Execution classes

U	utilization grade
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Annex B Equivalent T-stub in tension

$F_{u,Rd}$	tension resistance of a T-stub flange
B_u	tension resistance of a bolt-plate assembly
B_o	conventional bolt strength at elastic limit

A_s	stress area of bolt
$\sqrt{A_2} l_{\text{eff}} \sqrt{A_2}$	effective length
e_{min}	minimum edge distance
m	distance from weld toe to centre of bolt

Annex C Materials selection

$\sigma_{\text{eq,Ed}}$	equivalent design stress for castings
$\sigma_{x,\text{Ed}}$	design stress in x-axis direction for castings
$\sigma_{y,\text{Ed}}$	design stress in y-axis direction for castings
$\tau_{xy,\text{Ed}}$	design shear stress for castings
σ_{Rd}	design resistance for castings
$\gamma_{\text{Mo,c}}, \gamma_{\text{Mu,c}}$	partial factors for yields strength and ultimate strength castings respectively
$\gamma_{\text{M2,co}}, \gamma_{\text{M2,cu}}$	partial factors for yields strength and ultimate strength for bearing resistance of bolts, rivets in castings
$\gamma_{\text{Mp,co}}, \gamma_{\text{Mp,cu}}$	partial factors for yields strength and ultimate strength for bearing resistance of pins in castings

Annex E Analytical model for stress-strain relationship

The symbols are defined in the Annex

Annex F Behavior of cross-sections beyond elastic limit

α_0	geometrical shape factor
α_5, α_{10}	generalized shape factors corresponding to ultimate curvature values $\chi_u = 5\chi_{\text{el}}$ and $\chi_u = 10\chi_{\text{el}}$
$\alpha_{M,\text{red}}$	correction factor for welded class 1 cross section

Annex G Rotation capacity

χ_u	ultimate bending curvature
χ_{el}	elastic bending curvature ($= \chi_{0,2}$)
ξ	ductility factor
M_0	elastic bending moment corresponding to the attainment of the proof stress f_0
m, k	numerical parameters
R	rotation capacity
$\theta_p, \theta_{\text{el}}$	and θ_u , plastic rotation, elastic rotation and maximum plastic rotation corresponding to ultimate curvature χ_u

Annex H Plastic hinge method for continuous beams

η	parameter depending on geometrical shape factor and conventional available ductility of the material
α_ξ	shape factor α_5 or α_{10}
a, b, c	coefficients in expression for η

Annex I Lateral torsional buckling of beams and torsional or flexural-torsional buckling of compression members

I_t	torsion constant
I_w	warping constant
I_z	second moment of area of minor axis
k_z	end condition corresponding to restraints against lateral movement
k_w	end condition corresponding to rotation about the longitudinal axis
k_y	end condition corresponding to restraints against movement in plane of loading

κ_{wt}	non-dimensional torsion parameter
ζ_g	relative non-dimensional coordinate of the point of load application
ζ_j	relative non-dimensional cross section mono-symmetry parameter
μ_{cr}	relative non-dimensional critical moment
z_a	coordinate of the point of load application related to centroid
z_s	coordinate of the shear centre related to centroid
z_g	coordinate of the point of load application related to shear centre
z_j	mono-symmetry constant
c	depth of a lip
ψ_f	mono-symmetry factor
h_f	distance between centrelines of flanges
h_s	distance between shear centre of upper flange and shear centre of bottom flange
I_{fc}	second moment of area of the compression flange about the minor axis of the section
I_{ft}	second moment of area of the tension flange about the minor axis of the section
$\text{A2} \rangle C_1, C_2, C_3, C_{1,0}, C_{1,1} \text{A2} \rangle$	coefficients in formulae for relative non-dimensional critical moment
$N_{cr,y}, N_{cr,z}, N_{cr,T}$	elastic flexural buckling load (y-y and z-z axes) and torsional buckling load
i_s	polar radius of gyration
α_{yw}, α_{zw}	coefficients in equation for torsional and torsional-flexural buckling
k, λ_t	coefficients in formula for relative slenderness parameter $\bar{\lambda}_T$
λ_0, s, X	coefficients to calculate λ_t

Annex J Properties of cross sections

β, δ, γ	fillet or bulb factors
b_{sh}	width of flat cross section parts
α	fillet or bulb factor; angle between flat section parts adjacent to fillets or bulbs
D	diameter of circle inscribed in fillet or bulb

NOTE Notations for cross section constants $\text{A2} \rangle$ given in J.4 and J.6 $\text{A2} \rangle$ and are not repeated here

Annex K Shear lag effects in member design

b_{eff}	effective width for shear lag
β_s	effective width factor for shear lag
κ	notional width-to-length ratio for flange
A_{st}	area of all longitudinal stiffeners within half the flange width
$a_{st,1}$	relative area of stiffeners = area of stiffeners divided by centre to centre distance of stiffeners
s_e	loaded length in section between flange and web
$\text{A1} \rangle b_0$	width of outstand or half width of internal cross-section part
L_e	points of zero bending moment $\text{A1} \rangle$

Annex L Classification of joints

F	load, generalized force force
F_u	ultimate load, ultimate generalized force
v	generalized deformation
v_u	deformation corresponding to ultimate generalized force

Annex M Adhesive bonded connection

$f_{v,adh}$	characteristic shear strength values of adhesives
τ	average shear stress in the adhesive layer
γ_{Ma}	material factor for adhesive bonded joint

1.7 Conventions for member axes

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

- x-x - 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 dimensions and axes of aluminium sections are indicated in Figure 1.1.

(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.

1.8 Specification for execution of the work

(1) A specification for execution of the work should be prepared that contains 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](#) should apply, complete geometrical information and of materials to be used in members and joints, types and sizes of fasteners, weld requirements and requirements for execution of work. [EN 1090-3](#) contains a checklist for information to be provided.

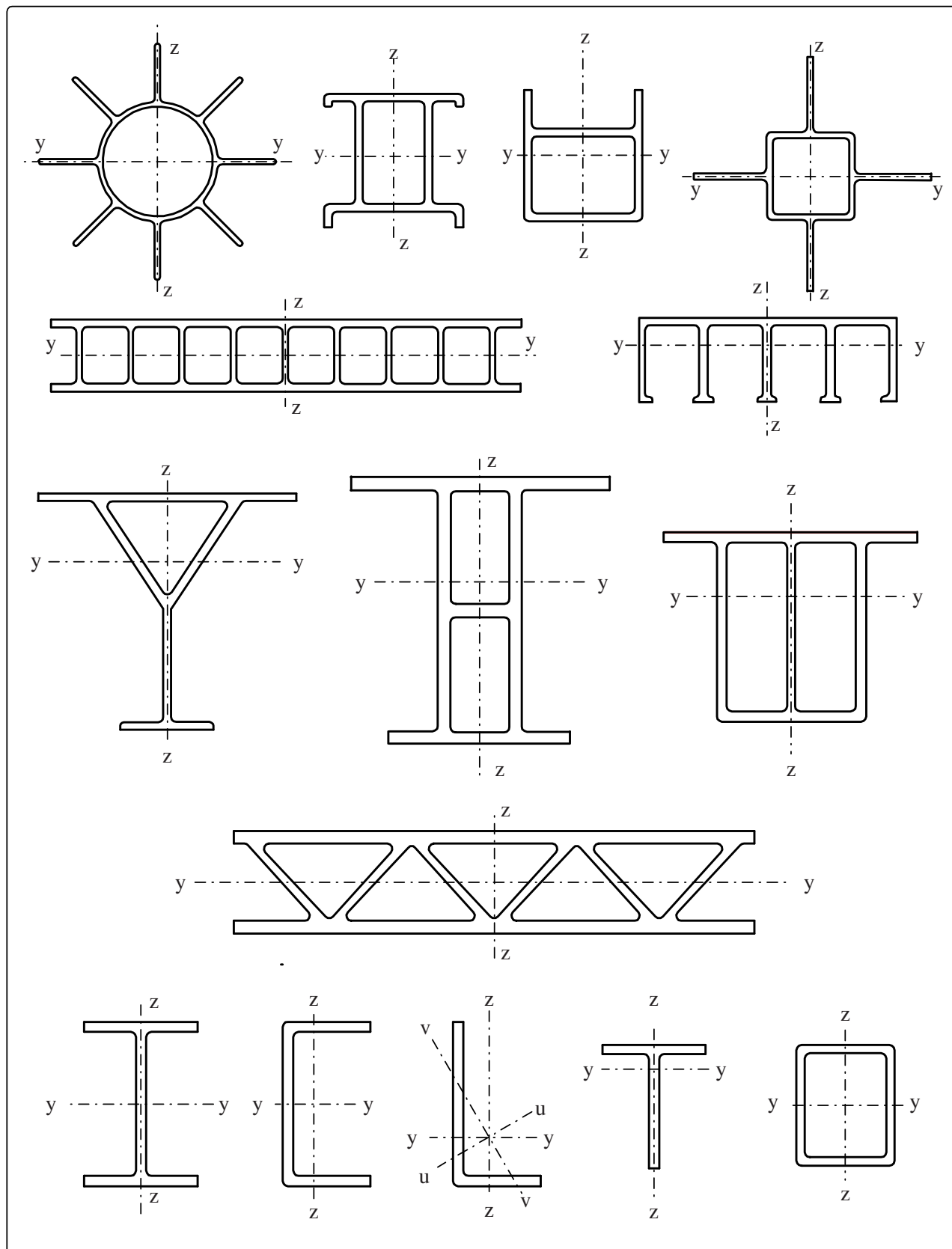


Figure 1.1 - Definition of axes for various cross-sections

2 Basis of design

2.1 Requirements

2.1.1 Basic requirements

- (1)P The design of aluminium structures shall be in accordance with the general rules given in EN 1990.
- (2)P The supplementary provisions for aluminium structures given in this section shall also be applied.
- (3)P The basic requirements of EN 1990 section 2 shall be deemed to be satisfied where limit state design is used in conjunction with the partial factor method and the load combinations given in EN 1990 together with the actions given in EN 1991.
- (4) The rules for resistances, serviceability and durability given in the various parts of EN 1999 should be applied.

2.1.2 Reliability management

- (1) Where different levels of reliability are required, these levels should be achieved by an appropriate choice of quality management in design and execution, according to EN 1990, **A1** EN 1090-3 **A1**.
- (2) Aluminium structures and components are classified in execution classes, see Annex A of this standard.
- (3) The execution should be carried out in accordance with prEN 1090-1 and **A1** EN 1090-3. The information, which EN 1090-3 **A1** requires to be included in the execution specification, should be provided.

NOTE Options allowed by prEN 1090 may be specified in a National Annex to EN 1999-1-1 to suit the reliability level required.

2.1.3 Design working life, durability and robustness

- (1) Depending on the type of action affecting durability and the design working life (see EN 1990) aluminium structures should as applicable be
- designed for corrosion (see Section 4)
 - designed for sufficient fatigue life (see EN 1999-1-3)
 - designed for wearing
 - designed for accidental actions (see EN 1991-1-7)
 - inspected and maintained.

NOTE 1 Recommendations for the design for corrosion are given in Annex C and Annex D

NOTE 2 Requirements for fatigue, see EN 1999-1-3

2.2 Principles of limit state design

- (1) The resistances of cross sections and members specified in this EN 1999-1-1 for the ultimate limit states as defined in EN 1990 are based on simplified design models of recognised experimental evidence.
- (2) The resistances specified in this EN 1999-1-1 may therefore be used where the conditions for materials in section 3 are met.

2.3 Basic variables

2.3.1 Actions and environmental influences

(1) Actions for the design of aluminium structures should be taken from EN 1991. For the combination of actions and partial factors of actions see Annex A to EN 1990

NOTE The National Annex may define actions for particular regional or climatic or accidental situations.

(2) The actions to be considered in the erection stage should be obtained from EN 1991-1-6.

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

(4) The effects of uneven settlements or imposed deformations or other forms of prestressing imposed during erection should be taken into account by their nominal value P_k as permanent action and grouped with other permanent actions G_k to a single action $(G_k + P_k)$.

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

2.3.2 Material and product properties

(1) Material properties for aluminium and other construction products and the geometrical data to be used for design should be those specified in the relevant ENs, ETAGs or ETAs unless otherwise indicated in this standard.

2.4 Verification by the partial factor method

2.4.1 Design value of material properties

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

2.4.2 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 [\[A1\]](#) EN 1090-3 [\[A1\]](#) and treated as nominal values.

(2) Design values of geometrical imperfections specified in this standard 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.

2.4.3 Design resistances

(1) For aluminium structures equation (6.6c) or equation (6.6d) of EN 1990 applies:

$$R_d = \frac{1}{\gamma_M} R_k (\eta_l X_{k1}; \eta_i X_{ki}; a_d) \quad (2.1)$$

where:

R_k is the characteristic value of 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 global partial factor for the particular resistance

NOTE For the definition of $\eta_l, \eta_i, X_{k1}, X_{ki}, a_d$ see EN 1990.

2.4.4 Verification of static equilibrium (EQU)

(1) The reliability format for the verification of static equilibrium in Table 1.2 (A) in Annex A of EN 1990 also applies to design situations equivalent to (EQU), e.g. for the design of holding down anchors or the verification of up lift of bearings of continuous beams.

2.5 Design assisted by testing

- (1) The resistances R_k in this standard have been determined using Annex D of EN 1990.
- (2) In recommending classes of constant partial factors γ_{Mi} the characteristic values R_k were obtained from

$$R_k = R_d \cdot \gamma_{Mi} \quad (2.2)$$

where:

R_d are design values according to Annex D of EN 1990

γ_{Mi} are recommended partial factors.

NOTE 1 The numerical values of the recommended partial factors γ_{Mi} have been determined such that R_k represents approximately the 5 %-fractile for an infinite number of tests.

NOTE 2 For characteristic values of fatigue strength and partial factors γ_{Mf} for fatigue see EN 1999-1-3.

- (3) Where resistances R_k for prefabricated products are determined by tests, the procedure referred in (2) should be followed.

3 Materials

3.1 General

(1) The material properties given in this section are specified as characteristic values. They are based on the minimum values given in the relevant product standard.

(2) Other material properties are given in the ENs listed in 1.2.1.

3.2 Structural aluminium

3.2.1 Range of materials

(1) This European standard covers the design of structures fabricated from aluminium alloy material listed in Table 3.1a for wrought alloys conforming to A_2 EN 573-3 and tempers listed in Tables 3.2a, 3.2b and 3.2c conforming to EN 515 A_2 . For the design of structures of cast aluminium alloys given in Table 3.1b, see 3.2.3.1.

NOTE Annex C gives further information for the design of structures of cast aluminium alloys.

Table 3.1a - Wrought aluminium alloys for structures

Alloy designation		Form of product	Durability rating ³⁾
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, 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, ST, PL, ET ²⁾ , EP ²⁾ , ER/B, DT	A
EN AW-5083	EN AW-Al Mg4,5Mn0,7	SH, ST, PL, ET ²⁾ , EP ²⁾ , ER/B, DT, FO	A ¹⁾
EN AW-5454	EN AW-Al Mg3Mn	SH, ST, PL, ET ²⁾ , EP ²⁾ , ER/B	A
EN AW-5754	EN AW-Al Mg3	SH, ST, PL, ET ²⁾ , EP ²⁾ , 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, 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, 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, ST, PL, ET, EP, ER/B, DT	C
EN AW-8011A	EN AW-AlFeSi	SH, ST, PL	B
Key:		SH - Sheet (EN 485) ST - Strip (EN 485) PL - Plate (EN 485) ET - Extruded Tube (EN 755) EP - Extruded Profiles (EN 755) ER/B - Extruded Rod and Bar (EN 755) DT - Drawn Tube (EN 754) FO - Forgings (EN 586) ¹⁾ See Annex C: C2.2.2(2) ²⁾ Only simple, solid (open) extruded sections or thick-walled tubes over a mandrel (seamless) ³⁾ See 4, Annex C and Annex D	

Table 3.1b - Cast aluminium alloys for structures

Alloy designation		Durability rating ¹⁾
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
1) see 4, Annex C and Annex D		

NOTE 1 For other aluminium alloys and temper than those listed, see the National Annex.

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

3.2.2 Material properties for wrought aluminium alloys

(1) Characteristic values of the 0,2% proof strength f_o and the ultimate tensile strength f_u for wrought aluminium alloys for a range of tempers and thicknesses are given in Table 3.2a for sheet, strip and plate products; Table 3.2b for extruded rod/bar, extruded tube and extruded profiles and drawn tube and Table 3.2c for forgings. The values in Table 3.2a, b and c, as well as in Table 3.3 and Table 3.4 (for aluminium fasteners only) are applicable for structures subject to service temperatures up to 80°C.

NOTE Product properties for electrically welded tubes according to EN 1592-1 to 4 for structural applications are not given in this standard. The National Annex may give rules for their application. Buckling class B is recommended.

(2) For service temperatures between 80°C and 100°C reduction of the strength should be taken in account.

NOTE 1 The National Annex may give rules for the reduction of the characteristic values to be applied. For temperatures between 80°C and 100°C the following procedure is recommended:

All characteristic aluminium resistance values ($f_o, f_u, f_{o,haz}$ and $f_{u,haz}$) may be reduced according to

$$X_{kT} = [1 - k_{100}(T - 80) / 20] X_k \quad (3.1)$$

where:

X_k is the characteristic value of a strength property of a material

X_{kT} is the characteristic strength value for 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 Buckling Class B is applicable for all aluminium alloys. For temperatures between 80°C and 100°C interpolation between Class A and Class B should be done.

NOTE 2 Between 80°C and 100°C the reduction of the strength values is recoverable, e.g. the materials regain its strength when the temperature is dropping down. For temperatures over 100°C also a reduction of the elastic modulus and additionally time depending, not recoverable reductions of strength should be considered.

(3) Characteristic values for the heat affected zone (0,2% proof strength $f_{o,haz}$ and ultimate tensile strength $f_{u,haz}$) are also given in Table 3.2a to 3.2c and also reduction factors (see 6.1.6), buckling class (used in 6.1.4 and 6.3.1) and exponent in Ramberg-Osgood expression for plastic resistance.

Table 3.2a - Characteristic values of 0,2% proof strength f_o , ultimate tensile strength f_u (unwelded and for HAZ), min elongation A , reduction factors $\rho_{o,haz}$ and $\rho_{u,haz}$ in HAZ, buckling class and exponent n_p for wrought aluminium alloys - Sheet, strip and plate

Alloy EN- AW	Temper ¹⁾	Thick- ness ¹⁾ mm	f_o ¹⁾	f_u	A_{50} ^{1) 6)}	$f_{o,haz}$ ²⁾	$f_{u,haz}$ ²⁾	HAZ-factor ²⁾		BC ⁴⁾	n_p 1), 5)
			N/mm ²		%	N/mm ²		$\rho_{o,haz}$ ¹⁾	$\rho_{u,haz}$		
3004	H14 H24/H34	≤ 6 3	180 170	220	1 3	75	155	0,42 0,44	0,70	B	23 18
	H16 H26/H36	≤ 4 3	200 190	240	1 3			0,38 0,39	0,65	B	25 20
3005	H14 H24	≤ 6 3	150 130	170	1 4	56	115	0,37 0,43	0,68	B	38 18
	H16 H26	≤ 4 3	175 160	195	1 3			0,32 0,35	0,59	B	43 24
3103	H14 H24	≤ 25 12,5	120 110	140	2 4	44	90	0,37 0,40	0,64	B	31 20
	H16 H26	≤ 4	145 135	160	1 2			0,30 0,33	0,56	B	48 28
5005/ 5005A	O/H111	≤ 50	35	100	15	35	100	1	1	B	5
	H12 H22/H32	≤ 12,5	95 80	125	2 4	44	100	0,46 0,55	0,80	B	18 11
	H14 H24/H34	≤ 12,5	120 110	145	2 3			0,37 0,40	0,69	B	25 17
5052	H12 H22/H32	≤ 40	160 130	210	4 5	80	170	0,50 0,62	0,81	B	17 10
	H14 H24/H34	≤ 25	180 150	230	3 4			0,44 0,53	0,74	B	19 11
5049	O / H111	≤ 100	80	190	12	80	190	1	1	B	6
	H14 H24/H34	≤ 25	190 160	240	3 6	100	190	0,53 0,63	0,79	B	20 12
5454	O/H111	≤ 80	85	215	12	85	215	1	1	B	5
	H14H24/H34	≤ 25	220 200	270	2 4	105	215	0,48 0,53	0,80	B	22 15
5754	O/H111	≤ 100	80	190	12	80	190	1	1	B	6
	H14H24/H34	≤ 25	190 160	240	3 6	100	190	0,53 0,63	0,79	B	20 12
5083	O/H111	≤ 50	125	275	11	125	275	1	1	B	6
		50 < t ≤ 80	115	270	14 ³⁾	115	270			B	
	H12H22/H32	≤ 40	250 215	305	3 5	155	275	0,62 0,72	0,90	B	22 14
	H14H24/H34	≤ 25	280 250	340	2 4			0,55 0,62	0,81	A	22 14
6061	T4 / T451	≤ 12,5	110	205	12	95	150	0,86	0,73	B	8
	T6 / T651	≤ 12,5	240	290	6	115	175	0,48	0,60	A	23
	T651	12,5 < t ≤ 80	240	290	6 ³⁾						
6082	T4 / T451	≤ 12,5	110	205	12	100	160	0,91	0,78	B	8
	T61/T6151	≤ 12,5	205	280	10			0,61	0,66	A	15
	T6151	12,5 < t ≤ 100	200	275	12 ³⁾			0,63	0,67	A	14
	T6/T651	≤ 6	260	310	6			0,48	0,60	A	25
		6 < t ≤ 12,5	255	300	9			0,49	0,62	A	27
	T651	12,5 < t ≤ 100	240	295	7 ³⁾			0,52	0,63	A	21
7020	T6	≤ 12,5	280	350	7	205	280	0,73	0,80	A	19
	T651	≤ 40			9 ³⁾						
8011A	H14 H24	≤ 12,5	110 100	125	2 3	37	85	0,34 0,37	0,68	B	37 22
	H16 H26	≤ 4	130 120	145	1 2			0,28 0,31	0,59		33 33

1) 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).

2) The HAZ-values are valid for MIG welding and thickness up to 15mm. For TIG welding strain hardening alloys (3xxx, 5xxx and 8011A) up to 6 mm the same values apply, but for TIG welding precipitation hardening alloys (6xxx and 7xxx) and thickness up to 6 mm the HAZ values have to be multiplied by a factor 0,8 and so the ρ -factors. For higher thickness – unless other data are available – the HAZ values and ρ -factors have to be further reduced by a factor 0,8 for the precipitation hardening alloys (6xxx and 7xxx) and by a factor 0,9 for the strain hardening alloys (3xxx, 5xxx and 8011A). These reductions do not apply in temper O.

3) Based on A ($= A_{5,65\sqrt{A_o}}$), not A_{50} .

4) BC = buckling class, see 6.1.4.4, 6.1.5 and 6.3.1.

5) n -value in Ramberg-Osgood expression for plastic analysis. It applies only in connection with the listed f_o -value.

6) The minimum elongation values indicated do not apply across the whole range of thickness given, but mostly to the thinner materials. In detail see EN 485-2.

Table 3.2b - Characteristic values of 0,2% proof strength f_0 and ultimate tensile strength f_u (unwelded and for HAZ), min elongation A , reduction factors $\rho_{0,haz}$ and $\rho_{u,haz}$ in HAZ, buckling class and exponent n_p for wrought aluminium alloys - Extruded profiles, extruded tube, extruded rod/bar and drawn tube

A1

Alloy EN- AW	Product form	Temper	Thick- ness t mm 1) 3)	f_0 1)	f_u 1)	A 5) 2)	$f_{0,haz}$ 4)	$f_{u,haz}$ 4)	HAZ-factor 4)		BC 6)	n_p 7)
				N/mm ²		%	N/mm ²		$\rho_{0,haz}$	$\rho_{u,haz}$		
5083	ET, EP,ER/B	O / H111, F, H112	$t \leq 200$	110	270	12	110	270	1	1	B	5
	DT	H12/22/32	$t \leq 10$	200	280	6	135	270	0,68	0,96	B	14
		H14/24/34	$t \leq 5$	235	300	4			0,57	0,90	A	18
5454	ET, EP,ER/B	O/H111 F/H112	$t \leq 25$	85	200	16	85	200	1	1	B	5
5754	ET, EP,ER/B	O/H111 F/H112	$t \leq 25$	80	180	14	80	180	1	1	B	6
	DT	H14/ H24/H34	$t \leq 10$	180	240	4	100	180	0,56	0,75	B	16
6060	EP,ET,ER/B	T5	$t \leq 5$	120	160	8	50	80	0,42	0,50	B	17
	EP		$5 < t \leq 25$	100	140	8			0,50	0,57	B	14
	ET,EP,ER/B	T6	$t \leq 15$	140	170	8	60	100	0,43	0,59	A	24
	DT		$t \leq 20$	160	215	12			0,38	0,47	A	16
	EP,ET,ER/B	T64	$t \leq 15$	120	180	12	60	100	0,50	0,56	A	12
	EP,ET,ER/B	T66	$t \leq 3$	160	215	8	65	110	0,41	0,51	A	16
	EP		$3 < t \leq 25$	150	195	8			0,43	0,56	A	18
6061	EP,ET,ER/B	T4	$t < 25$	110	180	15	95	150	0,86	0,83	B	8
	DT		$t \leq 20$	110	205	16				0,73	B	8
	EP,ET,ER/B	T6	$t < 25$	240	260	8	115	175	0,48	0,67	A	55
	DT		$t \leq 20$	240	290	10				0,60	A	23
6063	EP,ET,ER/B	T5	$t \leq 3$	130	175	8	60	100	0,46	0,57	B	16
	EP		$3 < t \leq 25$	110	160	7			0,55	0,63	B	13
	EP,ET,ER/B	T6	$t \leq 25$	160	195	8	65	110	0,41	0,56	A	24
	DT		$t \leq 20$	190	220	10			0,34	0,50	A	31
	EP,ET,ER/B	T66	$t \leq 10$	200	245	8	75	130	0,38	0,53	A	22
	EP		$10 < t \leq 25$	180	225	8			0,42	0,58	A	21
	DT		$t \leq 20$	195	230	10			0,38	0,57	A	28
6005A	EP/O, ER/B	T6	$t \leq 5$	225	270	8	115	165	0,51	0,61	A	25
			$5 < t \leq 10$	215	260	8			0,53	0,63	A	24
			$10 < t \leq 25$	200	250	8			0,58	0,66	A	20
	EP/H, ET	T6	$t \leq 5$	215	255	8			0,53	0,65	A	26
			$5 < t \leq 10$	200	250	8			0,58	0,66	A	20
6106	EP	T6	$t \leq 10$	200	250	8	95	160	0,48	0,64	A	20

A1

Table 3.2b - Continued

6082	EP,ET,ER/B	T4	$t \leq 25$	110	205	14	100	160	0,91	0,78	B	8
	EP	T5	$t \leq 5$	230	270	8	125	185	0,54	0,69	B	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	A	17
7020	EP,ET,ER/B	T6	$t \leq 15$	290	350	10	205	280	0,71	0,80	A	23
	EP,ET,ER/B	T6	$15 < t < 40$	275	350	10			0,75	0,80	A	19
	DT	T6	$t \leq 20$	280	350	10			0,73	0,80	A	18

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

1): Where values are quoted in **bold** greater thicknesses and/or higher mechanical properties may be permitted in some forms see ENs and prENs listed in **A2** 1.2.1.2 **A2**. 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 acc. to expression (6.13) and (6.14) with the same values for $f_{o,haz}$ and $f_{u,haz}$.

2): Where minimum elongation values are given in **bold**, higher minimum values may be given for some forms or thicknesses.

3): According to **A1** EN 755-2:2008 **A1**: following rule applies: "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 the manufacturer can support the value by an appropriate quality assurance certificate.

4) The HAZ-values are valid for MIG welding and thickness up to 15mm. For TIG welding strain hardening alloys **A1** (3xxx and 5xxx) **A1** up to 6 mm the same values apply, but for TIG welding precipitation hardening alloys (6xxx and 7xxx) and thickness up to 6 mm the HAZ values have to be multiplied by a factor 0,8 and so the ρ -factors. For higher thickness – unless other data are available – the HAZ values and ρ -factors have to be further reduced by a factor 0,8 for the precipitation hardening alloys (6xxx and 7xxx) alloys and by a factor 0,9 for strain hardening alloys (3xxx, 5xxx and 8011A). These reductions do not apply in temper O.

5) $A = A_{5,65} \sqrt{A_o}$

6) BC = buckling class, see 6.1.4.4, 6.1.5 and 6.3.1.

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

A1 Text deleted **A1**

Table 3.2c - Characteristic values of 0,2% proof strength f_o , 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	$f_{o,haz}^{1)}$	$f_{u,haz}^{1)}$	$A^{3)}$	Buckling class
				N/mm ²				%	
5754	H112	150	Longitudinal (L)	80	180	80	180	15	B
5083	H112	150	Longitudinal (L)	120	270	120	270	12	B
			Transverse (T)	110	260	110	260	10	B
6082	T6	100	Longitudinal (L)	260	310	125 ²⁾	185 ²⁾	6	A
			Transverse (T)	250	290			5	A

1) $\rho_{o,haz}$; $\rho_{u,haz}$ to be calculated according to expression (6.13) and (6.14)

2) For thicknesses over 15 mm (MIG-welding) or 6 mm (TIG-welding) see table 3.2.b footnote 4).

3) $A = A_{5,65} \sqrt{A_o}$

3.2.3 Material properties for cast aluminium alloys

3.2.3.1 General

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

NOTE 1 The design rules in this European standard are applicable for gravity cast products according to Table 3.3 if the additional and special rules and the quality provisions of Annex C, C.3.4 are followed.

NOTE 2 The National Annex may give rules for quality requirements for castings.

3.2.3.2 Characteristic values

A1 (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 are given in Table 3.3. The listed values are 70% of the values of EN 1706:1998, which are only valid for separately cast test specimens (see 6.3.3.2 of EN 1706:1998).

NOTE The listed values for A_{50} in Table 3.3 are 50 % of the elongation values of EN 1706:1998, which are only valid for separately cast test specimens (see 6.3.3.2 of EN 1706:1998) **A1**

Table 3.3 - Characteristic values of 0,2% proof strength f_o and ultimate tensile strength f_u for cast aluminium alloys – Gravity castings

Alloy	Casting process	Temper	f_o (f_{oc}) N/mm ²	f_u (f_{uc}) N/mm ²	A_{50} % ¹⁾
EN AC-42100	Permanent mould	T6	147	203	2,0
	Permanent mould	T64	126	175	4
EN AC-42200	Permanent mould	T6	168	224	1,5
	Permanent mould	T64	147	203	3
EN AC-43000	Permanent mould	F	63	126	1,25
EN AC-43300	Permanent mould	T6	147	203	2,0
	Sand cast	T6	133	161	1,0
	Permanent mould	T64	126	175	3
EN AC-44200	Permanent mould	F	56	119	3
	Sand cast	F	49	105	2,5
EN AC-51300	Permanent mould	F	70	126	2,0
	Sand cast	F	63	112	1,5
1) For elongation requirements for the design of cast components, see C.3.4.2(1).					

3.2.4 Dimensions, mass and tolerances

(1) The dimensions and tolerances of structural extruded products, sheet and plate products, drawn tube, wire and forgings, should conform with the ENs and prENs listed in 1.2.3.3.

(2) The dimensions and tolerances of structural cast products should conform with the ENs and prENs listed in 1.2.3.4.

3.2.5 Design values of material constants

(1) The material constants to be adopted in calculations for the aluminium alloys covered by this European Standard should be taken as follows:

- modulus of elasticity $E = 70\,000\text{ N/mm}^2$;
- shear modulus $G = 27\,000\text{ N/mm}^2$;
- Poisson's ratio $\nu = 0,3$;
- coefficient of linear thermal expansion $\alpha = 23 \times 10^{-6}\text{ per }^\circ\text{C}$;
- unit mass $\rho = 2\,700\text{ kg/m}^3$.

(2) For material properties in structures subject to elevated temperatures associated with fire see EN 1999-1-2.

3.3 Connecting devices

3.3.1 General

(1) Connecting devices should be suitable for their specific use.

(2) Suitable connecting devices include bolts, friction grip fasteners, solid rivets, special fasteners, welds and adhesives.

NOTE For adhesives, see Annex M

3.3.2 Bolts, nuts and washers

3.3.2.1 General

(1) Bolts, nuts and washers should conform with existing ENs, prENs and ISO Standards. For load bearing joints bolts and rivets according to Table 3.4 should be used.

(2) The minimum values of the 0,2% proof strength f_o and the ultimate strength f_u to be adopted as characteristic values in calculations, are given in Table 3.4.

(3) Aluminium bolts and rivets should be used only for connections of category A (bearing type, see Table 8.4).

NOTE 1 Presently no EN-standard, which covers all requirements for aluminium bolts, exists. The National Annex may give provisions for the use of aluminium bolts. Recommendations for the use of the bolts listed in Table 3.4 are given in Annex C.

NOTE 2 Presently no EN-standard, which covers all requirements for solid aluminium rivets, exists. Recommendations for the use of the solid rivets listed in Table 3.4 are given in Annex C.

(4) Selftapping and selfdrilling screws and blind rivets may be used for thin-walled structures. Rules are given in EN 1999-1-4.

Table 3.4 - Minimum values of 0,2 % proof strength f_o and ultimate strength f_u for bolts and solid rivets

Material	Type of fastener	Alloy Numerical designation: EN AW-	Alloy Chemical designation: EN AW-	Temper or grade	Dia-meter	f_o ⁷⁾ N/mm ²	f_u ⁷⁾ N/mm ²
Aluminium alloy	Solid Rivets ¹⁾	5019	AlMg5	H111	≤20	110	250
				H14,H34	≤18	210	300
		5754	AlMg3	H111	≤20	80	180
				H14/H34	≤18	180	240
		6082	AlSi1MgMn	T4	≤20	110	205
				T6	≤20	240	300
	Bolts ²⁾	5754	AlMg3	4)	≤10	230	270
		(AL1) ³⁾			10<d≤20	180	250
		5019	AlMg5	4)	≤14	205	310
		(AL2) ³⁾			14<d≤36	200	280
		6082	AlSi1MgMn	4)	≤6	250	320
		(AL3) ³⁾			14<d≤36	260	310
Steel	Bolts ⁵⁾			4.6	≤39	240	400
				5.6	≤39	300	500
				6.8	≤39	480	600
				8.8	≤39	640	800
				10.9	≤39	900	1000
Stainless Steel	Bolts ⁶⁾	A2, A4		50	≤39	210	500
		A2, A4		70	≤39	450	700
		A2, A4		80	≤39	600	800

1) see 3.3.2.1 (3) ~~A1~~ text deleted ~~A1~~
2) see 3.3.2.1 (3) ~~A1~~ text deleted ~~A1~~
3) Material designation according to EN 28839
4) No grade designation in EN 28839
5) Grade according to EN ISO 898-1
6) Designation and grade according to EN ISO 3506-1
7) The given values for solid rivets are the lesser values of EN 754 (drawn rods) or EN 1301 (drawn wire) of which solid rivets are manufactured by cold forming. For the 0,2-proof stress EN 1301 defines indeed only typical values, but the above given values can all be regarded as on the safe side. Anyway for the design of connections of category A (bearing mode) the ultimate strength value is the basis for the calculation of the bearing capacity of a bolt or a rivet.

3.3.2.2 Preloaded bolts

(1) Bolts of class 8.8 and 10.9 may be used as preloaded bolts with controlled tightening, provided they conform to the requirements for preloaded bolts in existing ENs, prENs and ISO Standards.

NOTE The National Annex may give rules for bolts not according to these standards, to be used for preloading application.

3.3.3 Rivets

(1) The material properties, dimensions and tolerances of aluminium alloy solid and hollow rivets should conform to ENs, prENs or ISO Standards (if and when they are available).

(2) The minimum guaranteed values of the 0,2% proof strength f_o and the ultimate strength f_u to be adopted as characteristic values in calculations, are given in Table 3.4.

3.3.4 Welding consumables

(1) All welding consumables should conform to ENs, prENs or ISO Standards (if available) listed in ~~A2~~ 1.2.4 ~~A2~~.

~~A2~~ text deleted ~~A2~~

(2) The selection of welding filler metal for the combination of alloys being joined should be made from prEN 1011-4 Table B.2 and B.3 in conjunction with the design requirements for the joint, see 8.6.3.1. Guidance on the selection of filler metal for the range of parent metals given in this European Standard is given in Tables 3.5 and 3.6.

Table 3.5 - Alloy grouping used in Table 3.6

Filler metal grouping	Alloys
Type 3	3103
Type 4	4043A, 4047A ¹⁾
Type 5	5056A, 5356 / 5356A, 5556A / 5556B, 5183 / 5183A
¹⁾ 4047A is specifically used to prevent weld metal cracking in joints. In most other cases, 4043A is preferable.	

Table 3.6 - Selection of filler metals (see Table 3.5 for alloy types)

Parent metal combination ¹⁾							
1st Part	2nd Part						
	Al-Si castings	Al-Mg castings	3xxx series alloys	5xxx- series alloys except 5083	5083	6xxx- series alloys	7020
7020	NR ²⁾	Type 5 Type 5 Type 5	Type 5 Type 5 Type 4	Type 5 Type 5 Type 5	5556A Type 5 5556A	Type 5 Type 5 Type 4	5556A Type 5 Type 4 ⁴⁾
6xxx-series alloys	Type 4 Type 4 Type 4	Type 5 Type 5 Type 5	Type 4 Type 4 Type 4	Type 5 Type 5 Type 5	Type 5 Type 5 Type 5	Type 5 Type 4 Type 4	
5083	NR ²⁾	Type 5 Type 5 Type 5	Type 5 Type 5 Type 5	Type 5 Type 5 Type 5	5556A Type 5 Type 5		
5xxx- series alloys except 5083	NR ²⁾	Type 5 Type 5 Type 5	Type 5 Type 5 Type 5	Type 5 ³⁾ Type 5			
3xxx series alloys	Type 4 Type 4 Type 4	Type 5 Type 5 Type 5	Type 3 Type 3 Type 3				
Al-Mg castings	NR ²⁾	Type 5 Type 5 Type 5					
Al-Si castings	Type 4 Type 4 Type 4						

¹⁾ In each box the filler metal for the maximum weld strength is shown in the top line; in the case of 6xxx series alloys and EN-AW 7020, this will be below the fully heat treated parent metal strength. The filler metal for maximum resistance to corrosion is shown in the middle line. The filler metal for avoidance of persistent weld cracking is shown on the bottom line.

²⁾ NR = Not recommended. The welding of alloys containing approximately 2% or more of Mg with Al-Si filler metal, or vice-versa is not recommended because sufficient Mg₂Si precipitate is formed at the fusion boundaries to embrittle the weld. Where unavoidable see prEN 1011-4.

³⁾ The corrosion behaviour of weld metal is likely to be better if its alloy content is close to that of the parent metal and not markedly higher. Thus for service in potentially corrosive environments it is preferable to weld EN-AW 5454 with 5454 filler metal. However, in some cases this may only be possible at the expense of weld soundness, so that a compromise will be necessary.

⁴⁾ Only in special cases due to the lower strength of the weld and elongation of the joint.

3.3.5 Adhesives

NOTE Recommendations for adhesive bonded connections are given in Annex M

4 Durability

(1) The basic requirements for durability are given in EN 1990.

NOTE For aluminium in contact with other material, recommendations are given in Annex D.

(2) Under normal atmospheric conditions, aluminium structures made of alloys listed in Tables 3.1a and 3.1.b can be used without the need for surface protection to avoid loss of load-bearing capacity.

NOTE Annex D gives information on corrosion resistance of aluminium and guidelines for surface protection of aluminium, as well as information on conditions for which a corrosion protection is recommended.

(3) Components susceptible to corrosion and subject to aggressive exposure, mechanical wear or fatigue should be designed such that inspection, maintenance and repair can be carried out satisfactorily during the design life. Access should be available for service inspection and maintenance.

(4) The requirements and means for execution of protective treatment undertaken off-site and on-site are given in [A1](#) EN 1090-3 [A1](#).

(5) The execution specification should describe the extent, type and execution procedure for a selected protective treatment.

5 Structural analysis

5.1 Structural modelling for analysis

5.1.1 Structural modelling and basic assumptions

- (1) Analysis should be based upon calculation models of the structure that are appropriate for the limit state under consideration.
- (2) The calculation model and basic assumptions for the calculations should reflect the structural behaviour at the relevant limit state with appropriate accuracy and reflect the anticipated type of behaviour of the cross sections, members, joints and bearings.

5.1.2 Joint modelling

- (1) The effects of the behaviour of the joints on the distribution of internal forces and moments within a structure, and on the overall deformations of the structure, may generally be neglected, but where such effects are significant (such as in the case of semi-continuous joints) they should be taken into account.
- (2) To identify whether the effects of joint behaviour on the analysis need be taken into account, a distinction may be made between three joint models as follows:
 - simple, in which the joint may be assumed not to transmit bending moments;
 - continuous, in which the stiffness and/or the resistance of the joint allow full continuity of the members to be assumed in the analysis;
 - semi-continuous, in which the behaviour of the joint needs to be taken into account in the analysis

NOTE Recommendations for the various types of joints are given in Annex L.

5.1.3 Ground-structure interaction

- (1) Account should be taken of the deformation characteristics of the supports where significant.

NOTE EN 1997 gives guidance for calculation of soil-structure interaction.

5.2 Global analysis

5.2.1 Effects of deformed geometry of the structure

- (1) The internal forces and moments may generally be determined using either:
 - first-order analysis, using the initial geometry of the structure or
 - second-order analysis, taking into account the influence of the deformation of the structure.
- (2)P The effects of the deformed geometry (second-order effects) shall be considered if they increase the action effects significantly or modify significantly the structural behaviour.
- (3) First order analysis may be used for the structure, if the increase of the relevant internal forces or moments or any other change of structural behaviour caused by deformations can be neglected. This condition may be assumed to be fulfilled, if the following criterion is satisfied:

$$\alpha_{cr} = \frac{F_{cr}}{F_{Ed}} \geq 10 \quad (5.1)$$

where:

α_{cr} is the factor by which the design loading would have to be increased to cause elastic instability in a global mode

F_{Ed} is the design loading on the structure

F_{cr} is the elastic critical buckling load for global instability mode based on initial elastic stiffness.

NOTE The national Annex may give a different criterion for the limit of α_{cr} for neglecting the influence of second order effects.

(4) The effects of shear lag and of local buckling on the stiffness should be taken into account if this significantly influences the global analysis.

NOTE Recommendations how to allow for shear lag are given in Annex K.

(5) The effects on the global analysis of the slip in bolt holes and similar deformations of connection devices like studs and anchor bolts on action effects should be taken into account, where relevant and significant.

5.2.2 Structural stability of frames

(1) If according to 5.2.1 the influence of the deformation of the structure has to be taken into account. (2) to (6) should be applied to consider these effects and to verify the structural stability.

(2) The verification of the stability of frames or their parts should be carried out considering imperfections and second order effects.

(3) According to the type of frame and the global analysis, second order effects and imperfections may be accounted for by one of the following methods:

- a) both totally by the global analysis,
- b) partially by the global analysis and partially through individual stability checks of members according to 6.3,
- c) for basic cases by individual stability checks of equivalent members according to 6.3 using appropriate buckling lengths according to the global buckling mode of the structure.

(4) Second order effects may be calculated by using an analysis appropriate to the structure (including step-by-step or other iterative procedures). For frames where the first sway buckling mode is predominant first order elastic analysis should be carried out with subsequent amplification of relevant action effects (e.g. bending moments) by appropriate factors.

(5) In accordance with 5.2.2(3) a) and b) the stability of individual members should be checked according to the following:

- a) If second order effects in individual members and relevant member imperfections (see 5.3.4) are totally accounted for in the global analysis of the structure, no individual stability check for the members according to 6.3 is necessary.
- b) If second order effects in individual members or certain individual member imperfections (e.g. member imperfections for flexural and/or lateral torsional buckling, see 5.3.4) are not totally accounted for in the global analysis, the individual stability of members should be checked according to the relevant criteria in 6.3 for the effects not included in the global analysis. This verification should take account of end moments and forces from the global analysis of the structure, including global second order effects and global imperfections (see 5.3.2) where relevant and may be based on a buckling length equal to the system length, see Figure 5.1 (d), (e), (f) and (g).

(6) Where the stability of a frame is assessed by a check with the equivalent column method according to 6.3 the buckling length values should be based on a global buckling mode of the frame accounting for the stiffness behaviour of members and joints, the presence of plastic hinges and the distribution of compressive forces under the design loads. In this case internal forces to be used in resistance checks are calculated according to first order theory without considering imperfections, see Figure 5.1 (a), (b) and (c).

5.3 Imperfections

5.3.1 Basis

(1)P Appropriate allowances shall be considered to cover the effects of imperfections, including residual stresses and geometrical imperfections such as lack of verticality, lack of straightness, lack of flatness, lack of fit and any unspecified eccentricities present in joints of the unloaded structure.

NOTE Geometrical imperfections $\bar{A}_1$ in accordance with the essential tolerances given in EN 1090-3 are considered in the resistance formulae, the buckling curves and the χ_M -values $\bar{A}_1$ in EN 1999.

(2) Equivalent geometric imperfections, see 5.3.2 and 5.3.3, should be used, with values which reflect the possible effects of all type of imperfections. In the equivalent column method according to 5.3.4 the effects are included in the resistance formulae for member design.

(3) The following imperfections should be taken into account:

- a) global imperfections for frames and bracing systems
- b) local imperfections for individual members

5.3.2 Imperfections for global analysis of frames

(1) The assumed shape of global imperfections and local imperfections may be derived from the elastic buckling mode of a structure in the plane of buckling considered.

(2) Both in and out of plane buckling including torsional buckling with symmetric and asymmetric buckling shapes should be taken into account in the most unfavourable direction and form.

(3) For frames sensitive to buckling in a sway mode the effect of imperfections should be allowed for in frame analysis by means of an equivalent imperfection in the form of an initial sway imperfection and individual bow imperfections of members. The imperfections may be determined from:

a) global initial sway imperfections, see Figure 5.1(d):

$$\phi = \phi_0 \alpha_h \alpha_m \quad (5.2)$$

where:

ϕ_0 is the basic value: $\phi_0 = 1/200$

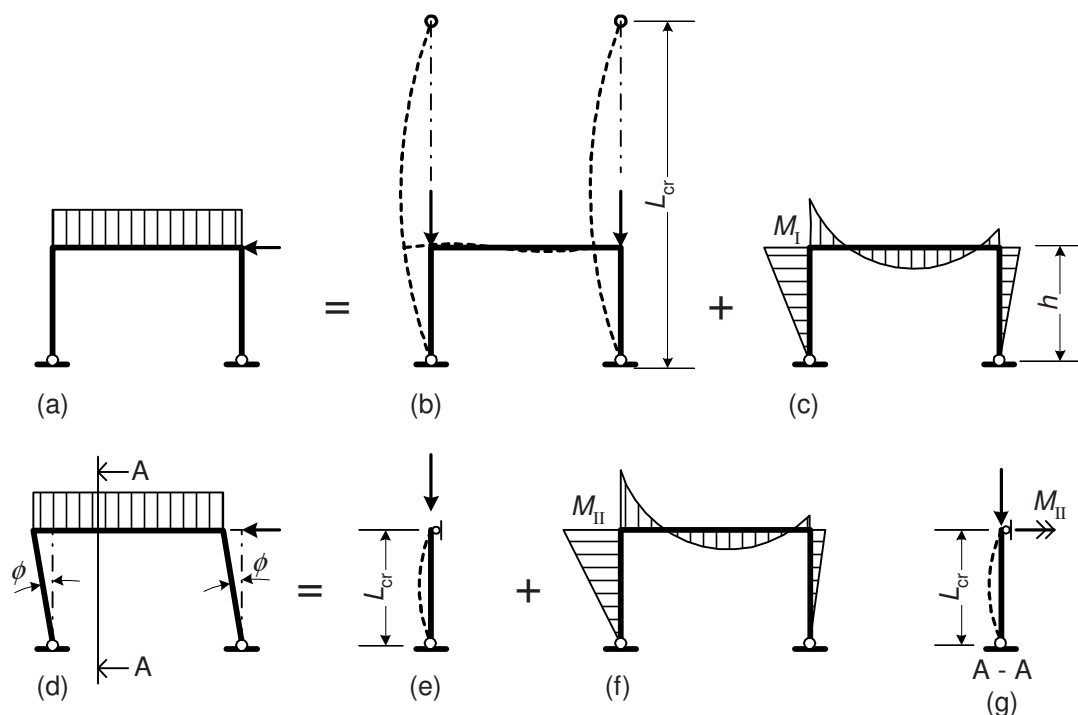
α_h is the reduction factor for height h applicable to columns:

$$\alpha_h = \frac{2}{\sqrt{h}} \text{ but } \frac{2}{3} \leq \alpha_h \leq 1,0$$

h is the height of the structure in meters

α_m is the reduction factor for the number of columns in a row: $\alpha_m = \sqrt{0,5 \left(1 + \frac{1}{m} \right)}$

m is the number of columns in a row including only those columns which carry a vertical load N_{Ed} not less than 50% of the average value of the column in the vertical plane considered.



The equivalent column method is illustrated by (a), (b) and (c), where (a) is system and load, (b) is equivalent column length and (c) is the first order moment.

The equivalent sway method is illustrated by (d), (e), (f) and (g), where (d) is system, load and displacement, (e) is initial local bow and buckling length for flexural buckling, (f) is second order moment including moment from sway imperfection and (g) is initial local bow and buckling length for lateral-torsional buckling.

Figure 5.1 - Equivalent buckling length and equivalent sway imperfections

b) relative initial local bow imperfections of members for flexural buckling

$$e_0 / L \quad (5.3)$$

where L is the member length

NOTE The values e_0/L may be chosen in the National Annex. Recommended values are given in Table 5.1.

Table 5.1 - Design values of initial bow imperfection e_0 / L

Buckling class acc. to Table 3.2	elastic analysis	plastic analysis
	e_0/L	e_0/L
A	1/300	1/250
B	1/200	1/150

(4) For building frames sway imperfections may be disregarded where

$$H_{Ed} \geq 0,15 V_{Ed} \quad (5.4)$$

where:

H_{Ed} is the design value of the horizontal force

V_{Ed} is design value of the vertical force.

(5) For the determination of horizontal forces to floor diaphragms the configuration of imperfections as given in Figure 5.2 should be applied, where ϕ is a sway imperfection obtained from expression (5.2) assuming a single storey with height h , see (3) a).

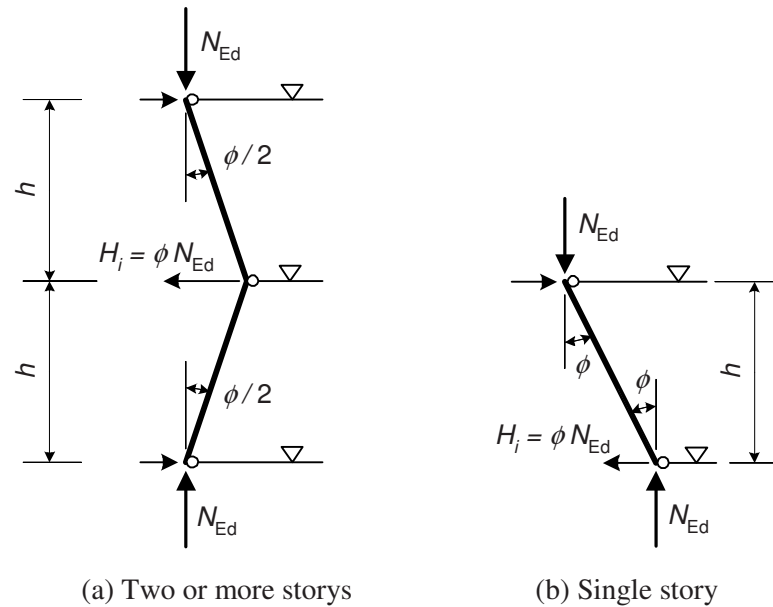


Figure 5.2 - Configuration of sway imperfections ϕ for horizontal forces on floor diaphragms

(6) When performing the global analysis for determining end forces and end moments to be used in member checks according to 6.3 local bow imperfections may be neglected. However, for frames sensitive to second order effects local bow imperfections of members additionally to global sway imperfections (see 5.2.1(3)) should be introduced in the structural analysis of the frame for each compressed member where the following conditions are met:

- at least one moment resistant joint at one member end

$$- \quad \bar{\lambda} > 0,5 \sqrt{\frac{A f_o}{N_{Ed}}} \quad (5.5)$$

where:

N_{Ed} is the design value of the compression force

$\bar{\lambda}$ is the in-plane relative slenderness calculated for the member considered as hinged at its ends

NOTE Local bow imperfections are taken into account in member checks, see 5.2.2 (3) and 5.3.4.

(7) The effects of initial sway imperfection and bow imperfections may be replaced by systems of equivalent horizontal forces, introduced for each column, see Figure 5.2 and Figure 5.3.

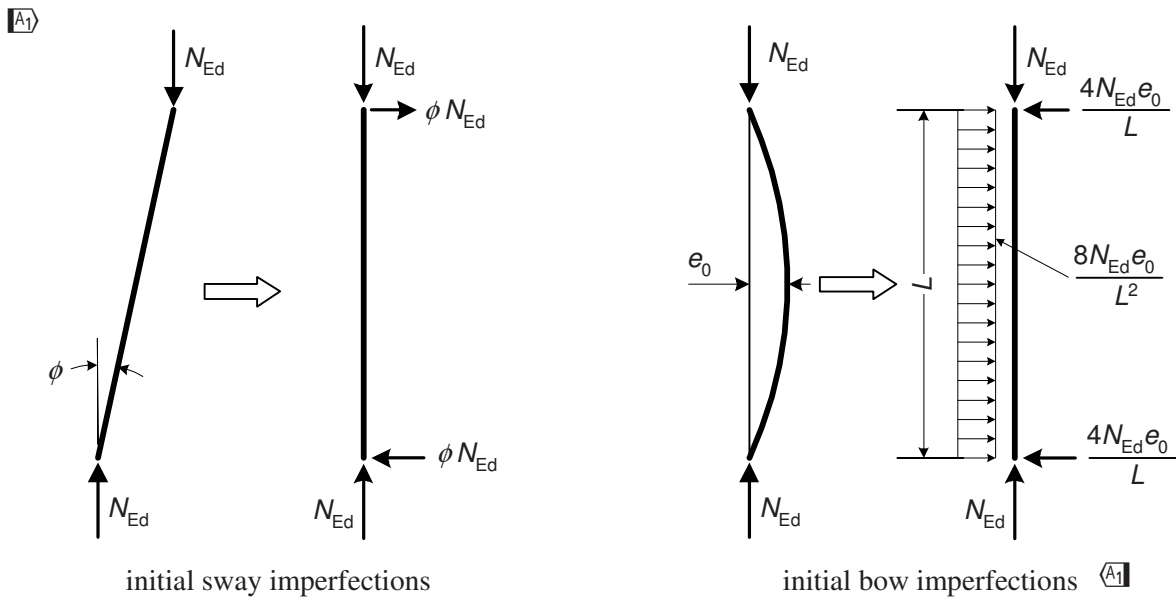


Figure 5.3 - Replacement of initial imperfections by equivalent horizontal forces

- (8) These initial sway imperfections should apply in all relevant horizontal directions, but need only be considered in one direction at a time.
- (9) Where, in multi-storey beam-and-column building frames, equivalent forces are used they should be applied at each floor and roof level.
- (10) The possible torsional effects on a structure caused by anti-symmetric sways at the two opposite faces, should also be considered, see Figure 5.4.

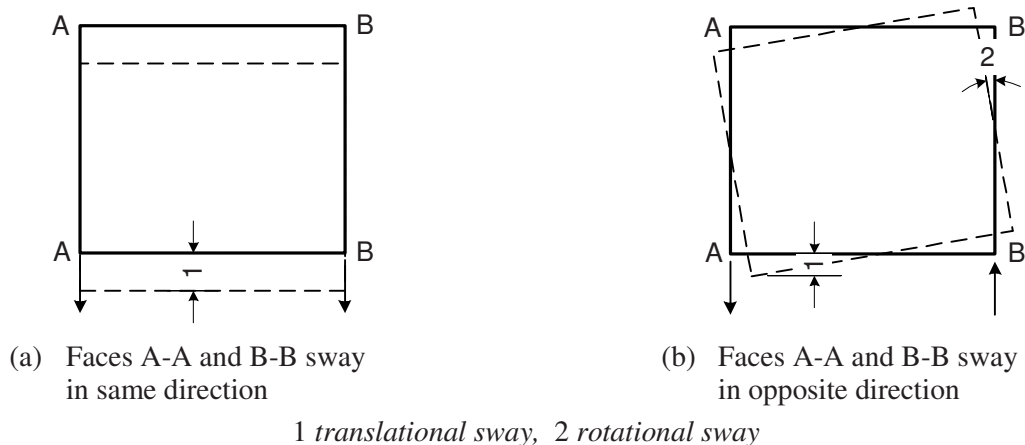


Figure 5.4 - Translational and torsional effects (plan view)

- (11) As an alternative to (3) and (6) the shape of the elastic critical buckling mode η_{cr} of the structure or of the verified member may be applied as a unique global and local imperfection. The equivalent geometrical imperfection may be expressed in the form:

$$\boxed{A1} \quad \eta_{init}(x) = e_0 \frac{N_{cr,m}}{EI_m |\eta_{cr,m}''|} \eta_{cr}(x) \quad (5.6) \quad \boxed{A1}$$

where:

$$\boxed{A1} \quad e_0 = \alpha (\bar{\lambda}_m - \bar{\lambda}_0) \frac{M_{Rk,m}}{N_{Rk,m}} \frac{1 - \frac{\chi \bar{\lambda}_m^2}{1 - \chi \bar{\lambda}_m^2}}{\gamma_{M1}} \quad \text{for } \bar{\lambda}_m > \bar{\lambda}_0$$