

Eurocode 3: Design of steel structures —

Part 1-1: General rules and rules for buildings

ICS 91.010.30; 91.080.10

National foreword

This British Standard is the UK implementation of EN 1993-1-1:2005+A1:2014, incorporating corrigenda February 2006 and April 2009. It supersedes BS EN 1993-1-1:2005, which is withdrawn.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags. Tags indicating changes to CEN text carry the number of the CEN corrigendum. For example, text altered by February 2006 corrigendum is indicated by AC1 AC1.

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.

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 BS EN 1993-1-1:2005+A1:2014 to be used in the UK the latest version of the NA to this Standard containing these NDPs should also be used. At the time of publication, it is NA+A1:2014 to BS EN 1993-1-1:2005+A1:2014.

BSI, as a member of CEN, is obliged to publish EN 1993-1-1:2005+A1:2014 as a British Standard. However, attention is drawn to the fact that during the development of this amendment to this European Standard, the UK committee voted against its approval.

The UK voted against its approval due to objections to the technical content of Annex C relating to the achievement of structural reliability. These objections have largely been addressed in the UK decisions on C.2.2 (3) and C.2.2 (4) in the NA+A1:2014 to BS EN 1993-1-1:2005+A1:2014.

The UK participation in its preparation was entrusted to Technical Committee CB/203, Design & execution of steel structures.

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

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.

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English version

**Eurocode 3: Design of steel structures - Part 1-1: General rules
and rules for buildings**

Eurocode 3: Calcul des structures en acier - Partie 1-1:
Règles générales et règles pour les bâtiments

Eurocode 3: Bemessung und Konstruktion von Stahlbauten
- Teil 1-1: Allgemeine Bemessungsregeln und Regeln für
den Hochbau

This European Standard was approved by CEN on 16 April 2004.

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 Central Secretariat 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 Central Secretariat has the same status as the official versions.

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

Management Centre: rue de Stassart, 36 B-1050 Brussels

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Foreword

This European Standard EN 1993, Eurocode 3: Design of steel structures, has been prepared by Technical Committee CEN/TC250 « Structural Eurocodes », the Secretariat of which is held by BSI. CEN/TC250 is responsible for all Structural Eurocodes.

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 2005, and conflicting National Standards shall be withdrawn at latest by March 2010.

This Eurocode supersedes ENV 1993-1-1.

According to the CEN-CENELEC Internal Regulations, the National Standard Organizations of the following countries are bound to implement these European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Foreword to amendment A1

This document (EN 1993-1-1:2005/A1:2014) 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 1993-1-1:2005 shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2015, and conflicting national standards shall be withdrawn at the latest by May 2015.

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

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, 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 harmonization of technical specifications.

Within this action programme, the Commission took the initiative to establish a set of harmonized 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

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).

Decisions dealing with European standards (e.g. the Council Directive 89/106/EEC on construction products – CPD – and Council Directives 93/37/EEC, 92/50/EEC and 89/440/EEC on public works and services and equivalent EFTA Directives initiated in pursuit of setting up the internal market).

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

EN 1990	Eurocode:	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 recognize 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 recognize 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 harmonized 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 harmonized 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) shall 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 shall :

- a) give concrete form to the essential requirements by harmonizing 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 harmonized 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 harmonized technical specifications (ENs and ETAs)

There is a need for consistency between the harmonized 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 1993-1

EN 1993 is intended to be used with Eurocodes EN 1990 – Basis of Structural Design, EN 1991 – Actions on structures and EN 1992 to EN 1999, when steel structures or steel components are referred to.

EN 1993-1 is the first of six parts of EN 1993 – Design of Steel Structures. It gives generic design rules intended to be used with the other parts EN 1993-2 to EN 1993-6. It also gives supplementary rules applicable only to buildings.

EN 1993-1 comprises twelve subparts EN 1993-1-1 to EN 1993-1-12 each addressing specific steel components, limit states or materials.

It 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 1993-1 is intended for use by

- committees drafting design related product, testing and execution standards,
- clients (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 1993-1-1

This standard gives values with notes indicating where national choices may have to be made. Therefore the National Standard implementing EN 1993-1 should have a National Annex containing all Nationally Determined Parameters to be used for the design $\boxed{AC_2}$ of steel structures and civil engineering works to be constructed $\boxed{AC_2}$ in the relevant country.

National choice is allowed in EN 1993-1-1 through the following clauses:

- 2.3.1(1)
- 3.1(2)
- 3.2.1(1)
- 3.2.2(1)
- 3.2.3(1)
- 3.2.3(3)B
- 3.2.4(1)B
- 5.2.1(3)
- 5.2.2(8)
- 5.3.2(3)
- 5.3.2(11)
- 5.3.4(3)
- 6.1(1)
- 6.1(1)B
- 6.3.2.2(2)
- 6.3.2.3(1)
- 6.3.2.3(2)
- 6.3.2.4(1)B
- 6.3.2.4(2)B
- 6.3.3(5)
- 6.3.4(1)
- 7.2.1(1)B
- 7.2.2(1)B
- 7.2.3(1)B
- BB.1.3(3)B
- $\boxed{A_1}$ – C.2.2(3)
- C.2.2(4) $\boxed{A_1}$

1 General

1.1 Scope

1.1.1 Scope of Eurocode 3

(1) Eurocode 3 applies to the design of buildings and civil engineering works in steel. 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) Eurocode 3 is concerned only with requirements for resistance, serviceability, durability and fire resistance of steel structures. Other requirements, e.g. concerning thermal or sound insulation, are not covered.

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

- EN 1990 “Basis of structural design”
- EN 1991 “Actions on structures”
- ENs, ETAGs and ETAs for construction products relevant for steel structures
-  – EN 1090-1, *Execution of steel structures and aluminium structures – Part 1: Requirements for conformity assessment of structural components*
- EN 1090-2, *Execution of steel structures and aluminium structures – Part 2: Technical requirements for steel structures* 
- EN 1992 to EN 1999 when steel structures or steel components are referred to

(4) Eurocode 3 is subdivided in various parts:

EN 1993-1 Design of Steel Structures : General rules and rules for buildings.

EN 1993-2 Design of Steel Structures : Steel bridges.

EN 1993-3 Design of Steel Structures : Towers, masts and chimneys.

EN 1993-4 Design of Steel Structures : Silos, tanks and pipelines.

EN 1993-5 Design of Steel Structures : Piling.

EN 1993-6 Design of Steel Structures : Crane supporting structures.

(5) EN 1993-2 to EN 1993-6 refer to the generic rules in EN 1993-1. The rules in parts EN 1993-2 to EN 1993-6 supplement the generic rules in EN 1993-1.

(6) EN 1993-1 “General rules and rules for buildings” comprises:

EN 1993-1-1 Design of Steel Structures : General rules and rules for buildings.

EN 1993-1-2 Design of Steel Structures : Structural fire design.

EN 1993-1-3 Design of Steel Structures :  Cold-formed members and sheeting .

EN 1993-1-4 Design of Steel Structures : Stainless steels.

EN 1993-1-5 Design of Steel Structures : Plated structural elements.

EN 1993-1-6 Design of Steel Structures : Strength and stability of shell structures.

EN 1993-1-7 Design of Steel Structures : Strength and stability of planar plated structures transversely loaded.

EN 1993-1-8 Design of Steel Structures : Design of joints.

EN 1993-1-9 Design of Steel Structures : Fatigue strength of steel structures.

EN 1993-1-10 Design of Steel Structures : Selection of steel for fracture toughness and through-thickness properties.

EN 1993-1-11 Design of Steel Structures : Design of structures with tension components made of steel.

EN 1993-1-12 Design of Steel Structures : Supplementary rules for high strength steel.

1.1.2 Scope of Part 1.1 of Eurocode 3

(1) EN 1993-1-1 gives basic design rules for steel structures with material thicknesses $t \geq 3$ mm. It also gives supplementary provisions for the structural design of steel buildings. These supplementary provisions are indicated by the letter “B” after the paragraph number, thus ()B.

NOTE [AC2] For cold formed members and sheeting, see EN 1993-1-3 [AC2].

(2) The following subjects are dealt with in EN 1993-1-1:

Section 1: General

Section 2: Basis of design

Section 3: Materials

Section 4: Durability

Section 5: Structural analysis

Section 6: Ultimate limit states

Section 7: Serviceability limit states

(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 low alloy structural steels.

(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.

1.2 Normative references

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 when 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 reference standards

EN 1090 Execution of steel structures – Technical requirements

EN ISO 12944 Paints and varnishes – Corrosion protection of steel structures by protective paint systems

[AC2] EN ISO 1461 [AC2] Hot dip galvanized coatings on fabricated iron and steel articles – specifications and test methods

1.2.2 Weldable structural steel reference standards

EN 10025-1:2004 Hot-rolled products of structural steels - Part 1: General delivery conditions.

EN 10025-2:2004 Hot-rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels.

EN 10025-3:2004 Hot-rolled products of structural steels - Part 3: Technical delivery conditions for normalized / normalized rolled weldable fine grain structural steels.

EN 10025-4:2004	Hot-rolled products of structural steels - Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain structural steels.
EN 10025-5:2004	Hot-rolled products of structural steels - Part 5: Technical delivery conditions for structural steels with improved atmospheric corrosion resistance.
EN 10025-6:2004	Hot-rolled products of structural steels - Part 6: Technical delivery conditions for flat products of high yield strength structural steels in the quenched and tempered condition.
EN 10164:1993	Steel products with improved deformation properties perpendicular to the surface of the product - Technical delivery conditions.
EN 10210-1:1994	Hot finished structural hollow sections of non-alloy and fine grain structural steels – Part 1: Technical delivery requirements.
EN 10219-1:1997	Cold formed hollow sections of structural steel - Part 1: Technical delivery requirements.

1.3 Assumptions

- (1) In addition to the general assumptions of EN 1990 the following assumptions apply:
- fabrication and erection complies with EN 1090

1.4 Distinction between principles and application rules

- (1) The rules in EN 1990 clause 1.4 apply.

1.5 Terms and definitions

- (1) The rules in EN 1990 clause 1.5 apply.
- (2) The following terms and definitions are used in EN 1993-1-1 with the following meanings:

1.5.1 frame

the whole or a portion of a structure, comprising an assembly of directly connected structural elements, 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 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 joints 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 in this plane, or between one such point and the end of the member

1.5.6

buckling length

system length of an otherwise similar member with pinned ends, which has the same χ_{AC2} critical buckling load χ_{AC2} as a given member or segment of member

1.5.7

shear lag effect

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

1.5.8

capacity design

design method for achieving the plastic deformation capacity of a member by providing additional strength in its connections and in other parts connected to it

1.5.9

uniform member

member with a constant cross-section along its whole length

1.6 Symbols

- (1) For the purpose of this standard the following symbols apply.
- (2) Additional symbols are defined where they first occur.

NOTE Symbols are ordered by appearance in EN 1993-1-1. Symbols may have various meanings.

Section 1

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)
b	width of a cross section
h	depth of a cross section
d	depth of straight portion of a web
t_w	web thickness
t_f	flange thickness
r	radius of root fillet
r_1	radius of root fillet
r_2	toe radius
t	thickness

Section 2

P_k	nominal value of the effect of prestressing imposed during erection
G_k	nominal value of the effect of permanent actions

$\langle AC2 \rangle X_k \langle AC2 \rangle$ 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

f_y yield strength
 f_u ultimate strength

$\langle AC2 \rangle R_{eH} \langle AC2 \rangle$ yield strength to product standards

R_m ultimate strength to product standards
 A_0 original cross-section area
 ϵ_y yield strain
 ϵ_u ultimate strain
 Z_{Ed} required design Z-value resulting from the magnitude of strains from restrained metal shrinkage under the weld beads.
 Z_{Rd} available design Z-value
 E modulus of elasticity
 G shear modulus
 ν Poisson's ratio in elastic stage
 α coefficient of linear thermal expansion

Section 5

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 stiffnesses

$\langle AC2 \rangle H_{Ed}$ total design horizontal load, including equivalent forces transferred by the storey (storey shear) $\langle AC2 \rangle$

$\langle AC2 \rangle V_{Ed}$ total design vertical load on the frame transferred by the storey (storey thrust) $\langle AC2 \rangle$

$\delta_{H,Ed}$ horizontal displacement at the top of the storey, relative to the bottom of the storey

h storey height

$\bar{\lambda}$ 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

h height of the structure

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
η_{init}	amplitude of elastic critical buckling mode
η_{cr}	shape of elastic critical buckling mode
$e_{0,d}$	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
α	imperfection factor
$EI \eta_{cr}''$	bending moment due to η_{cr} at the critical cross section

χ reduction factor for the relevant buckling curve

AC2 $\alpha_{ult,k}$ minimum load amplifier of the design loads to reach the characteristic resistance of the most critical cross section of the structural component considering its in plane behaviour without taking lateral or lateral torsional buckling into account however accounting for all effects due to in plane geometrical deformation and imperfections, global and local, where relevant **AC2**

α_{cr} minimum force amplifier to reach the **AC2** elastic critical buckling load **AC2**

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 $e_{0,d}$

ε strain

σ stress

$\sigma_{com,Ed}$ maximum design compressive stress in an element

ℓ length

AC2 ε factor depending on f_y **AC2**

c width or depth of a part of a cross section

α portion of a part of a cross section in compression

ψ stress or strain ratio

AC2 k_σ plate buckling factor **AC2**

d outer diameter of circular tubular sections

Section 6

γ_{M0} partial factor for resistance of cross-sections whatever the class is

γ_{M1} partial factor for resistance of members to instability assessed by member checks

γ_{M2} partial factor for resistance of cross-sections in tension to fracture

$\sigma_{x,Ed}$ design value of the local longitudinal stress

$\sigma_{z,Ed}$ design value of the local transverse stress

τ_{Ed} design value of the local shear stress

N_{Ed} design normal force

$M_{y,Ed}$ design bending moment, y-y axis

$M_{z,Ed}$ design bending moment, z-z axis

N_{Rd} design values of the resistance to normal forces

- $M_{y,Rd}$ design values of the resistance to bending moments, y-y axis
- $M_{z,Rd}$ 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_0 diameter of hole
- e_N shift of the centroid of the effective area A_{eff} relative to the centre of gravity of the gross cross section
- ΔM_{Ed} additional moment from shift of the centroid of the effective area A_{eff} relative to the centre of gravity of the gross cross section
- A_{eff} effective area of a cross section
- $N_{t,Rd}$ design values of the resistance to tension forces
- $N_{pl,Rd}$ design plastic resistance to normal forces of the gross cross-section
- $N_{u,Rd}$ design ultimate resistance to normal forces of the net cross-section at holes for fasteners
- A_{net} net area of a cross section
- $N_{net,Rd}$ design plastic resistance to normal forces of the net cross-section
- $N_{c,Rd}$ design resistance to normal forces of the cross-section for uniform compression
- $M_{c,Rd}$ design resistance for bending about one principal axis of a cross-section
- W_{pl} plastic section modulus
- $W_{el,min}$ minimum elastic section modulus
- $W_{eff,min}$ minimum effective section modulus
- A_f area of the tension flange
- $A_{f,net}$ net area of the tension flange
- V_{Ed} design shear force
- $V_{c,Rd}$ design shear resistance
- $\boxed{AC2}$ $V_{pl,Rd}$ design plastic shear resistance $\boxed{AC2}$
- A_v shear area
- η factor for shear area
- S first moment of area
- I second moment of area
- $\boxed{AC2}$ A cross-sectional area $\boxed{AC2}$
- A_w area of a web
- A_f area of one flange
- T_{Ed} design value of total torsional moments
- T_{Rd} design resistance to torsional moments
- $\boxed{AC2}$ $T_{t,Ed}$ design value of internal St. Venant torsional moment $\boxed{AC2}$
- $\boxed{AC2}$ $T_{w,Ed}$ design value of internal warping torsional moment $\boxed{AC2}$
- $\tau_{t,Ed}$ design shear stresses due to St. Venant torsion
- $\tau_{w,Ed}$ design shear stresses due to warping torsion
- $\sigma_{w,Ed}$ design direct stresses due to the bimoment B_{Ed}
- $\boxed{AC2}$ B_{Ed} design value of the bimoment $\boxed{AC2}$
- $V_{pl,T,Rd}$ reduced design plastic shear resistance making allowance for the presence of a torsional moment

- ρ reduction factor to determine reduced design values of the resistance to bending moments making allowance for the presence of shear forces
- $M_{V,Rd}$ reduced design values of the resistance to bending moments making allowance for the presence of shear forces
- $M_{N,Rd}$ reduced design values of the resistance to bending moments making allowance for the presence of normal forces
- n ratio of design normal force to design plastic resistance to normal forces of the gross cross-section
- a ratio of web area to gross area
- α parameter introducing the effect of biaxial bending
- β parameter introducing the effect of biaxial bending
- $e_{N,y}$ shift of the centroid of the effective area A_{eff} relative to the centre of gravity of the gross cross section (y-y axis)
- $e_{N,z}$ shift of the centroid of the effective area A_{eff} relative to the centre of gravity of the gross cross section (z-z axis)
- $W_{eff,min}$ minimum effective section modulus
- $N_{b,Rd}$ design buckling resistance of a compression member
- χ reduction factor for relevant buckling mode
- Φ value to determine the reduction factor χ
- a_0, a, b, c, d class indexes for 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
- λ_1 slenderness value to determine the relative slenderness
- $\bar{\lambda}_T$ relative slenderness for torsional or torsional-flexural buckling
- $N_{cr,TF}$ elastic torsional-flexural buckling force
- $N_{cr,T}$ elastic torsional buckling force
- $M_{b,Rd}$ 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
- $\bar{\lambda}_{LT,0}$ plateau length of the lateral torsional buckling curves $\overline{AC_2}$ for rolled and welded sections $\overline{AC_2}$
- β correction factor for the lateral torsional buckling curves $\overline{AC_2}$ for rolled and welded sections $\overline{AC_2}$
- $\chi_{LT,mod}$ modified reduction factor for lateral-torsional buckling
- f modification factor for χ_{LT}
- k_c correction factor for moment distribution
- ψ ratio of moments in segment
- L_c length between lateral restraints
- $\bar{\lambda}_f$ equivalent compression flange slenderness
- $\overline{AC_2} i_{f,z} \overline{AC_2}$ radius of gyration of compression flange about the minor axis of the section
- $I_{eff,f}$ effective second moment of area of compression flange about the minor axis of the section

$A_{\text{eff},f}$ effective area of compression flange

$A_{\text{eff},w,c}$ effective area of compressed part of web

$\bar{\lambda}_{c0}$ slenderness parameter

$k_{f\ell}$ modification factor

$\Delta M_{y,Ed}$ moments due to the shift of the centroidal y-y axis

$\Delta M_{z,Ed}$ moments due to the shift of the centroidal z-z axis

χ_y reduction factor due to flexural buckling (y-y axis)

χ_z reduction factor due to flexural buckling (z-z axis)

k_{yy} interaction factor

k_{yz} interaction factor

k_{zy} interaction factor

k_{zz} interaction factor

$\bar{\lambda}_{op}$ global non dimensional slenderness of a structural component for out-of-plane buckling

χ_{op} reduction factor for the non-dimensional slenderness $\bar{\lambda}_{op}$

$\alpha_{ult,k}$ minimum load amplifier of the design loads to reach the characteristic resistance of the most critical cross section

$\alpha_{cr,op}$ minimum amplifier for the in plane design loads to reach the elastic $\Delta M_{y,Ed}$ critical buckling load $\Delta M_{z,Ed}$ with regard to lateral or lateral torsional buckling

N_{Rk} characteristic value of resistance to compression

$M_{y,Rk}$ characteristic value of resistance to bending moments about y-y axis

$M_{z,Rk}$ characteristic value of resistance to bending moments about z-z axis

Q_m local force applied at each stabilized member at the plastic hinge locations

L_{stable} stable length of segment

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 $\Delta M_{y,Ed}$ maximum first order moment $\Delta M_{z,Ed}$ 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 or battens

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_b in plane second moment of area of a batten

μ efficiency factor

i_y radius of gyration (y-y axis)

Annex A

C_{my} equivalent uniform moment factor

C_{mz} equivalent uniform moment factor

C_{mLT} equivalent uniform moment factor

μ_y factor

μ_z factor

$N_{cr,y}$ elastic flexural buckling force about the y-y axis

$N_{cr,z}$ elastic flexural buckling force about the z-z axis

C_{yy} factor

C_{yz} factor

C_{zy} factor

C_{zz} factor

w_y factor

w_z factor

n_{pl} factor

$\bar{\lambda}_{max}$ maximum of $\bar{\lambda}_y$ and $\bar{\lambda}_z$

b_{LT} factor

c_{LT} factor

d_{LT} factor

e_{LT} factor

ψ_y ratio of end moments (y-y axis)

$C_{my,0}$ factor

$C_{mz,0}$ factor

a_{LT} factor

I_T St. Venant torsional constant

I_y second moment of area about y-y axis

AC2 C_1 ratio between the critical bending moment (largest value along the member) and the critical constant bending moment for a member with hinged supports **AC2**

$M_{i,Ed}(x)$ maximum first order moment

$|\delta_x|$ maximum member displacement along the member

Annex B

AC2 α_s factor; s = sagging **AC2**

AC2 α_h factor; h = hogging **AC2**

C_m equivalent uniform moment factor

Annex AB

γ_G partial factor for permanent loads

G_k characteristic value of permanent loads

γ_Q partial factor for variable loads

Q_k characteristic value of variable loads

Annex BB

$\bar{\lambda}_{\text{eff},v}$	effective slenderness ratio for buckling about v-v axis
$\bar{\lambda}_{\text{eff},y}$	effective slenderness ratio for buckling about y-y axis
$\bar{\lambda}_{\text{eff},z}$	effective slenderness ratio for buckling about z-z axis
L	system length
L_{cr}	buckling length
S	shear stiffness provided by sheeting
I_w	warping constant
$C_{9,k}$	rotational stiffness provided by stabilizing continuum and connections
K_v	factor for considering the type of analysis
K_9	factor for considering the moment distribution and the type of restraint
$C_{9R,k}$	rotational stiffness provided by the stabilizing continuum to the beam assuming a stiff connection to the member
$C_{9C,k}$	rotational stiffness of the connection between the beam and the stabilizing continuum
$C_{9D,k}$	rotational stiffness deduced from an analysis of the distortional deformations of the beam cross sections
L_m	stable length between adjacent lateral restraints
L_k	stable length between adjacent torsional restraints
L_s	stable length between a plastic hinge location and an adjacent torsional restraint
C_1	modification factor for moment distribution
C_m	modification factor for linear moment gradient
C_n	modification factor for non-linear moment gradient
a	distance between the centroid of the member with the plastic hinge and the centroid of the restraint members
B_0	factor
B_1	factor
B_2	factor
η	ratio of elastic critical values of axial forces $\langle AC_2 \rangle$
i_s	radius of gyration related to centroid of restraining member
β_t	ratio of the algebraically smaller end moment to the larger end moment
R_1	moment at a specific location of a member
R_2	moment at a specific location of a member
R_3	moment at a specific location of a member
R_4	moment at a specific location of a member
R_5	moment at a specific location of a member
R_E	maximum of R_1 or R_5
R_s	maximum value of bending moment anywhere in the length L_y
c	taper factor
h_h	additional depth of the haunch or taper
h_{max}	maximum depth of cross-section within the length L_y
h_{min}	minimum depth of cross-section within the length L_y

h_s vertical depth of the un-haunched section
 L_h length of haunch within the length L_y
 L_y length between restraints

1.7 Conventions for member axes

(1) 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 steel 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 yy axis)
 - v-v - minor principal axis (where this does not coincide with the zz axis)

(3) The symbols used for dimensions and axes of rolled steel sections are indicated in Figure 1.1.

(4) The convention used for subscripts that 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 but for sections such as angles are defined by the axes u-u and v-v.

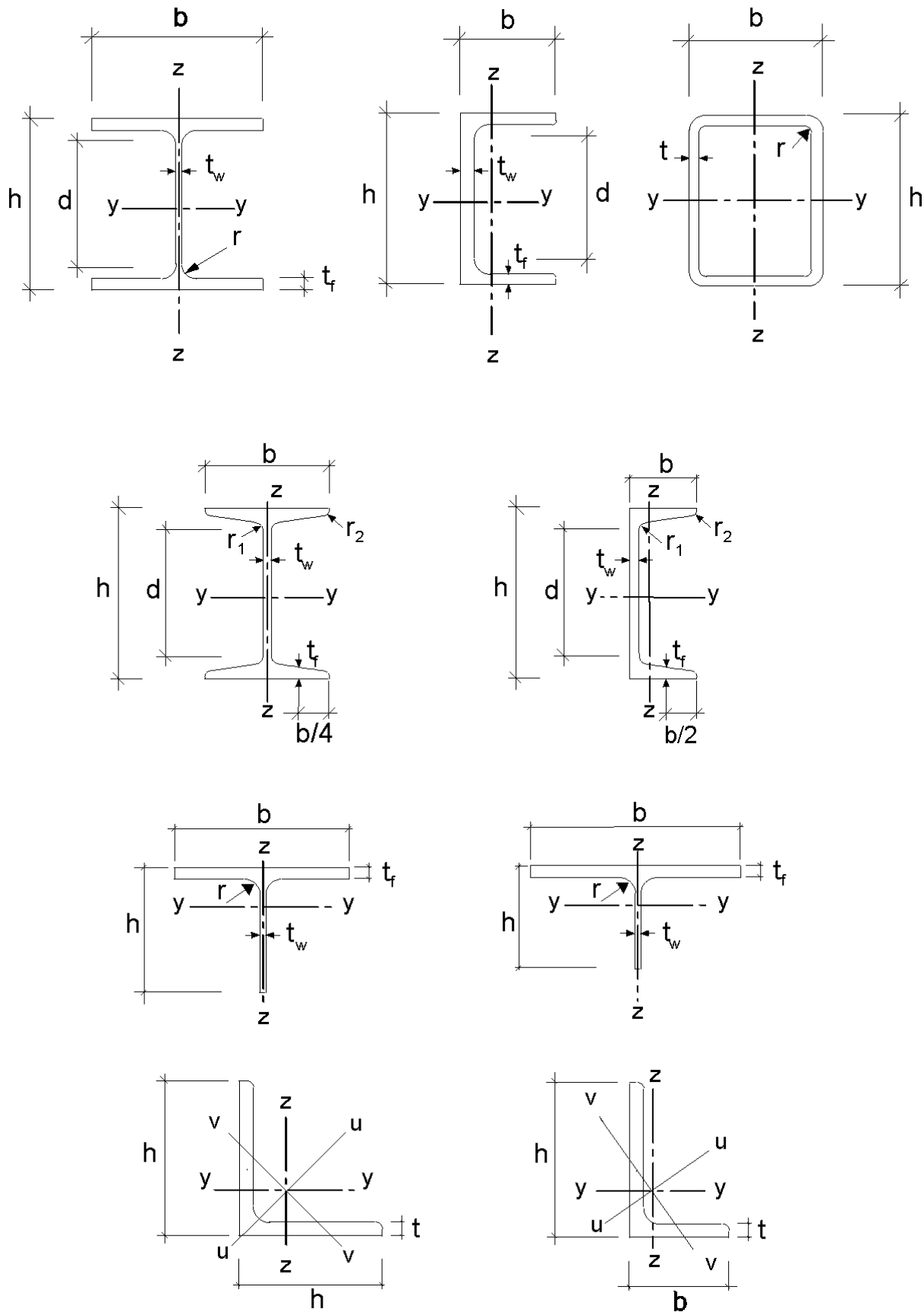


Figure 1.1: Dimensions and axes of sections

2 Basis of design

2.1 Requirements

2.1.1 Basic requirements

- ⌈AC1⌋ (1)P The design of steel structures shall be in accordance with the general rules given in EN 1990. ⌋AC1
- (2) The supplementary provisions for steel structures given in this section should also be applied.
- (3) The basic requirements of EN 1990 section 2 should 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 1993 should be applied.

2.1.2 Reliability management

- ⌈A1⌋ (1)P With respect to the application of EN 1090-1 and EN 1090-2, execution classes shall be selected in accordance with Annex C in this standard.
- (2) If different levels of reliability are required, these levels should preferably be achieved by an appropriate choice of quality management in design and execution, according to EN 1990 Annex B and Annex C and EN 1090. ⌋A1

2.1.3 Design working life, durability and robustness

2.1.3.1 General

- ⌈AC1⌋ (1)P Depending upon the type of action affecting durability and the design working life (see EN 1990) steel structures shall be ⌋AC1
- designed against corrosion by means of
 - suitable surface protection (see EN ISO 12944)
 - the use of weathering steel
 - the use of stainless steel (see EN 1993-1-4)
 - detailed for sufficient fatigue life (see EN 1993-1-9)
 - designed for wearing
 - designed for accidental actions (see EN 1991-1-7)
 - inspected and maintained.

2.1.3.2 Design working life for buildings

- ⌈AC1⌋ (1)P,B The design working life shall be taken as the period for which a building structure is expected to be used for its intended purpose. ⌋AC1
- (2)B For the specification of the intended design working life of a permanent building see Table 2.1 of EN 1990.
- (3)B For structural elements that cannot be designed for the total design life of the building, see 2.1.3.3(3)B.

2.1.3.3 Durability for buildings

- ⌈AC1⌋ (1)P,B To ensure durability, buildings and their components shall either be designed for environmental actions and fatigue if relevant or else protected from them. ⌋AC1

AC1 (2)P,B The effects of deterioration of material, corrosion or fatigue where relevant shall be taken into account by appropriate choice of material, see EN 1993-1-4 and EN 1993-1-10, and details, see EN 1993-1-9, or by structural redundancy and by the choice of an appropriate corrosion protection system. **AC1**

(3)B If a building includes components that need to be replaceable (e.g. bearings in zones of soil settlement), the possibility of their safe replacement should be verified as a transient design situation.

2.2 Principles of limit state design

(1) The resistance of cross-sections and members specified in this Eurocode 3 for the ultimate limit states as defined **AC2** in the clause 3.3 of EN 1990 are **AC2** based on tests in which the material exhibited sufficient ductility to apply simplified design models.

(2) The resistances specified in this Eurocode Part 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 steel structures should be taken from EN 1991. For the combination of actions and partial factors of actions see Annex A to EN 1990.

NOTE 1 The National Annex may define actions for particular regional or climatic or accidental situations.

NOTE 2B For proportional loading for incremental approach, see Annex AB.1.

NOTE 3B For simplified load arrangement, see Annex AB.2.

- (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 to 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 actions and grouped with other permanent actions **AC2** G_k to form a single action **AC2** $(G_k + P_k)$.
- (5) Fatigue actions not defined in EN 1991 should be determined according to Annex A of EN 1993-1-9.

2.3.2 Material and product properties

(1) Material properties for steels 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 values of material properties

AC1 (1)P For the design of steel structures characteristic values **AC2** X_k **AC2** or nominal values X_n of material properties shall be used as indicated in this Eurocode. **AC1**

2.4.2 Design values of geometrical data

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

(2) Design values of geometrical imperfections specified in this standard are equivalent geometric imperfections that take into account the effects of:

- geometrical imperfections of members as governed by geometrical tolerances in product standards or the execution standard;
- structural imperfections due to fabrication and erection;
- residual stresses;
- variation of the yield strength.

2.4.3 Design resistances

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

$$\boxed{\text{AC2}} R_d = \frac{R_k}{\gamma_M} = \frac{1}{\gamma_M} R_k (\eta_1 X_{k,1}; \eta_i X_{k,i}; a_d) \boxed{\text{AC2}} \quad (2.1)$$

where R_k is the characteristic value of the particular resistance determined with characteristic or nominal values for the material properties and dimensions

γ_M is the global partial factor for the particular resistance

NOTE For the definitions of η_1 , η_i , $X_{k,1}$, $X_{k,i}$ and 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 uplift 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

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

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 1993-1-9.

NOTE 3 For characteristic values of toughness resistance and safety elements for the toughness verification see EN 1993-1-10.

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

3 Materials

3.1 General

- (1) The nominal values of material properties given in this section should be adopted as characteristic values in design calculations.
- (2) This Part of EN 1993 covers the design of steel structures fabricated from steel material conforming to the steel grades listed in Table 3.1.

NOTE For other steel material and products see National Annex.

3.2 Structural steel

3.2.1 Material properties

- (1) The nominal values of the yield strength f_y and the ultimate strength f_u for structural steel should be obtained
- a) either by adopting the values $\boxed{\text{AC2}} f_y = R_{eH} \boxed{\text{AC2}}$ and $f_u = R_m$ direct from the product standard
- b) or by using the simplification given in Table 3.1

NOTE The National Annex may give the choice.

3.2.2 Ductility requirements

- (1) For steels a minimum ductility is required that should be expressed in terms of limits for:
- the ratio f_u / f_y of the specified minimum ultimate tensile strength f_u to the specified minimum yield strength f_y ;
 - the elongation at failure on a gauge length of $5,65 \sqrt{A_0}$ (where A_0 is the original cross-sectional area);
 - the ultimate strain ϵ_u , where ϵ_u corresponds to the ultimate strength f_u .

NOTE The limiting values of the ratio f_u / f_y , the elongation at failure and the ultimate strain ϵ_u may be defined in the National Annex. The following values are recommended:

- $f_u / f_y \geq 1,10$;
- elongation at failure not less than 15%;
- $\epsilon_u \geq 15\epsilon_y$, where ϵ_y is the yield strain ($\epsilon_y = f_y / E$).

- (2) Steel conforming with one of the steel grades listed in Table 3.1 should be accepted as satisfying these requirements.

3.2.3 Fracture toughness

- $\boxed{\text{AC1}}$ (1)P The material shall have sufficient fracture toughness to avoid brittle fracture of tension elements at the lowest service temperature expected to occur within the intended design life of the structure. $\boxed{\text{AC1}}$

NOTE The lowest service temperature to be adopted in design may be given in the National Annex.

- (2) No further check against brittle fracture need to be made if the conditions given in EN 1993-1-10 are satisfied for the lowest temperature.

(3)B For building components under compression a minimum toughness property should be selected.

NOTE B The National Annex may give information on the selection of toughness properties for members in compression. The use of Table 2.1 of EN 1993-1-10 for $\sigma_{Ed} = 0,25 f_y(t)$ is recommended.

(4) For selecting steels for members with hot dip galvanized coatings see [\[AC2\]](#) EN ISO 1461 [\[AC2\]](#).

Table 3.1: Nominal values of yield strength f_y and ultimate tensile strength f_u for hot rolled structural steel

Standard and steel grade	Nominal thickness of the element t [mm]			
	$t \leq 40$ mm		$40 \text{ mm} < t \leq 80$ mm	
	f_y [N/mm ²]	f_u [N/mm ²]	f_y [N/mm ²]	f_u [N/mm ²]
EN 10025-2				
S 235	235	360	215	360
S 275	275	430	255	410
S 355	355	[AC2] 490 [AC2]	335	470
S 450	440	550	410	550
EN 10025-3				
S 275 N/NL	275	390	255	370
S 355 N/NL	355	490	335	470
S 420 N/NL	420	520	390	520
S 460 N/NL	460	540	430	540
EN 10025-4				
S 275 M/ML	275	370	255	360
S 355 M/ML	355	470	335	450
S 420 M/ML	420	520	390	500
S 460 M/ML	460	540	430	530
EN 10025-5				
S 235 W	235	360	215	340
S 355 W	355	[AC2] 490 [AC2]	335	490
EN 10025-6				
S 460 Q/QL/QL1	460	570	440	550

Table 3.1 (continued): Nominal values of yield strength f_y and ultimate tensile strength f_u for structural hollow sections

Standard and steel grade	Nominal thickness of the element t [mm]			
	$t \leq 40$ mm		$40 \text{ mm} < t \leq 80$ mm	
	f_y [N/mm ²]	f_u [N/mm ²]	f_y [N/mm ²]	f_u [N/mm ²]
EN 10210-1				
S 235 H	235	360	215	340
S 275 H	275	430	255	410
S 355 H	355	510	335	490
S 275 NH/NLH	275	390	255	370
S 355 NH/NLH	355	490	335	470
AC2 S 420 NH/NLH AC2	420	540	390	520
S 460 NH/NLH	460	560	430	550
EN 10219-1				
S 235 H	235	360		
S 275 H	275	430		
S 355 H	355	510		
S 275 NH/NLH	275	370		
S 355 NH/NLH	355	470		
S 460 NH/NLH	460	550		
S 275 MH/MLH	275	360		
S 355 MH/MLH	355	470		
S 420 MH/MLH	420	500		
S 460 MH/MLH	460	530		

3.2.4 Through-thickness properties

(1) Where steel with improved through-thickness properties is necessary according to EN 1993-1-10, steel according to the required quality class in EN 10164 should be used.

NOTE 1 Guidance on the choice of through-thickness properties is given in EN 1993-1-10.

NOTE 2B Particular care should be given to welded beam to column connections and welded end plates with tension in the through-thickness direction.

NOTE 3B The National Annex may give the relevant allocation of target values Z_{Ed} according to 3.2(2) of EN 1993-1-10 to the quality class in EN 10164. The allocation in Table 3.2 is recommended for buildings:

Table 3.2: Choice of quality class according to EN 10164

Target value of Z_{Ed} according to EN 1993-1-10	Required value of Z_{Rd} expressed in terms of design Z -values according to EN 10164
$Z_{Ed} \leq 10$	—
$10 < Z_{Ed} \leq 20$	$Z 15$
$20 < Z_{Ed} \leq 30$	$Z 25$
$Z_{Ed} > 30$	$Z 35$