



BSI Standards Publication

Eurocode 3 — Design of steel structures

Part 1-1: General rules and rules for buildings

National foreword

This British Standard is the UK implementation of EN 1993-1-1:2022. It supersedes [BS EN 1993-1-1:2005+A1:2014](#), which will be withdrawn on 30 March 2028.

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 committee manager.

National choice is allowed in this standard where explicitly stated within notes. The National Annex to this standard contains the national choices to be used for buildings and civil engineering works constructed in the UK.

The first generation of EN Eurocodes was published between 2002 and 2007, with conflicting British Standards withdrawn in 2010. This document forms part of the second generation of EN Eurocodes.

The second generation of EN Eurocodes is expected to be published between 2023 and 2026. These documents are being published as soon as they are available. This is being done to enable users to prepare for the transition from the first generation to second generation of EN Eurocodes.

UK adoptions of the first generation of EN Eurocodes will be withdrawn by BSI on 30 March 2028. Until that date, the first generation documents should be considered as the applicable standards for buildings and civil engineering works constructed in the UK unless otherwise specified by the relevant authority or in the specification for a particular project.

This standard is intended to be used with its National Annex and other referenced documents, including other second generation Eurocodes, as an interdependent suite of documents.

While the use of provisions in this standard in conjunction with first generation Eurocodes is not precluded, it should be undertaken with care and should only be done when users are satisfied that it will not result in a lower level of reliability than the minimum level set in the first generation Eurocodes and associated UK National Annexes.

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Date

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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 24 July 2022.

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European foreword

This document (EN 1993-1-1:2022) has been prepared by Technical Committee CEN/TC 250 “Structural Codes”, the secretariat of which is held by BSI. CEN/TC 250 is responsible for all Structural Eurocodes and has been assigned responsibility for structural and geotechnical design matters by CEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2027 and conflicting national standards shall be withdrawn at the latest by March 2028.

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

This document supersedes EN 1993-1-1:2005 and its amendments and corrigenda.

The first generation of EN Eurocodes was published between 2002 and 2007. This document forms part of the second generation of the Eurocodes, which have been prepared under Mandate M/515 issued to CEN by the European Commission and the European Free Trade Association.

The Eurocodes have been drafted to be used in conjunction with relevant execution, material, product and test standards, and to identify requirements for execution, materials, products and testing that are relied upon by the Eurocodes.

The Eurocodes recognize the responsibility of each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level through the use of National Annexes.

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

- the scope of EN 1993-1-1 was extended to steel grades up to S700;
- the scope was extended to the design of elliptical hollow sections;
- the methods for the structural analysis were clarified and summarized in a flowchart;
- a new method for the design of semi-compact sections (Class 3) has been implemented;
- the effects of torsion on the resistance of cross-sections and members have been improved;
- a new method for the verification of beams to lateral torsional buckling has been introduced;
- the simplified method for lateral torsional buckling has been fully revised;
- the design of uniform members with mono-symmetric cross-sections was explicitly covered;
- a simplified design approach has been introduced for fatigue;
- an informative annex provides statistical data of material and dimensional properties as used for the calibration of the partial factors.

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

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

0 Introduction

0.1 Introduction to the Eurocodes

The Structural Eurocodes comprise the following standards generally consisting of a number of Parts:

- EN 1990 Eurocode: Basis of structural and geotechnical design
- EN 1991 Eurocode 1: Actions on structures
- EN 1992 Eurocode 2: Design of concrete structures
- EN 1993 Eurocode 3: Design of steel structures
- EN 1994 Eurocode 4: Design of composite steel and concrete structures
- EN 1995 Eurocode 5: Design of timber structures
- EN 1996 Eurocode 6: Design of masonry structures
- EN 1997 Eurocode 7: Geotechnical design
- EN 1998 Eurocode 8: Design of structures for earthquake resistance
- EN 1999 Eurocode 9: Design of aluminium structures
- New parts are under development, e.g. Eurocode for design of structural glass

0.2 Introduction to EN 1993 (all parts)

EN 1993 (all parts) 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 and geotechnical design.

EN 1993 (all parts) 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.

EN 1993 is subdivided in various parts:

EN 1993-1, *Design of steel structures — Part 1: General rules and rules for buildings*;

EN 1993-2, *Design of steel structures — Part 2: Steel bridges*;

EN 1993-3, *Design of steel structures — Part 3: Towers, masts and chimneys*;

EN 1993-4, *Design of steel structures — Part 4: Silos and tanks*;

EN 1993-5, *Design of steel structures — Part 5: Piling*;

EN 1993-6, *Design of steel structures — Part 6: Crane supporting structures*;

EN 1993-7, *Design of steel structures — Part 7: Design of sandwich panels* (under preparation).

EN 1993-1 in itself does not exist as a physical document, but comprises the following 14 separate parts, the basic part being EN 1993-1-1:

EN 1993-1-1, *Design of steel structures — Part 1-1: General rules and rules for buildings*;

EN 1993-1-2, *Design of steel structures — Part 1-2: Structural fire design*;

EN 1993-1-3, *Design of steel structures — Part 1-3: Cold-formed members and sheeting*;

NOTE Cold-formed hollow sections supplied according to EN 10219 (all parts) are covered in EN 1993-1-1.

EN 1993-1-4, *Design of steel structures — Part 1-4: Stainless steel structures*;

EN 1993-1-5, *Design of steel structures — Part 1-5: Plated structural elements*;

EN 1993-1-6, *Design of steel structures — Part 1-6: Strength and stability of shell structures*;

EN 1993-1-7, *Design of steel structures — Part 1-7: Plate assemblies with elements under transverse loads*;

EN 1993-1-8, *Design of steel structures — Part 1-8: Design of joints*;

EN 1993-1-9, *Design of steel structures — Part 1-9: Fatigue*;

EN 1993-1-10, *Design of steel structures — Part 1-10: Material toughness and through-thickness properties*;

EN 1993-1-11, *Design of steel structures — Part 1-11: Design of structures with tension components*;

EN 1993-1-12, *Design of steel structures — Part 1-12: Additional rules for steel grades up to S960*;

EN 1993-1-13, *Design of steel structures — Part 1-13: Rules for beams with large web openings*;

EN 1993-1-14, *Design of steel structures — Part 1-14: Design assisted by finite element analysis* (under preparation).

All parts numbered EN 1993-1-2 to EN 1993-1-14 treat general topics that are independent from the structural type such as structural fire design, cold-formed members and sheeting, stainless steels, plated structural elements, etc.

All parts numbered EN 1993-2 to EN 1993-7 treat topics relevant for a specific structural type such as steel bridges, towers, masts and chimneys, silos and tanks, piling, crane supporting structures, etc. EN 1993-2 to EN 1993-7 refer to the generic rules in EN 1993-1 and supplement, modify or supersede them, where relevant.

0.3 Introduction to EN 1993-1-1

EN 1993-1-1 gives general design rules for steel structures. It also includes supplementary design rules for steel buildings. The focus in EN 1993-1-1 is on design methods and design rules for individual members (beams, columns and beam-columns) and skeletal structures (frames) regarding resistance and stability.

0.4 Verbal forms used in the Eurocodes

The verb “shall” expresses a requirement strictly to be followed and from which no deviation is permitted in order to comply with the Eurocodes.

The verb “should” expresses a highly recommended choice or course of action. Subject to national regulation and/or any relevant contractual provisions, alternative approaches could be used/adopted where technically justified.

The verb “may” expresses a course of action permissible within the limits of the Eurocodes.

The verb “can” expresses possibility and capability; it is used for statements of fact and clarification of concepts.

0.5 National Annex for EN 1993-1-1

National choice is allowed in this standard where explicitly stated within notes. National choice includes the selection of values for Nationally Determined Parameters (NDPs).

The national standard implementing EN 1993-1-1 can have a National Annex containing all national choices to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

When no national choice is given, the default choice given in this standard is to be used.

When no national choice is made and no default is given in this standard, the choice can be specified by a relevant authority or, where not specified, agreed for a specific project by appropriate parties.

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

4.4.3 (2)	5.1 (1)	5.2.1 (1)	5.2.2 (1)
7.2.1 (4)	7.2.2 (9)	7.3.3.1 (1)	7.3.3.2 (1)
7.4.1(3)	8.1 (1)	8.2.8 (3)	8.3.2.3 (1)
8.3.3 (2)	8.3.4 (1)	9.2 (2)B	A.4 (2)
A.4 (3)	A.4 (5)		

National choice is allowed in EN 1993-1-1 on the application of the following informative annexes:

Annex E

The National Annex can contain, directly or by reference, non-contradictory complementary information for ease of implementation, provided it does not alter any provisions of the Eurocodes.

1 Scope

1.1 Scope of EN 1993-1-1

(1) EN 1993-1-1 gives basic design rules for steel structures.

(2) 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.

1.2 Assumptions

(1) The assumptions of EN 1990 apply to EN 1993-1-1.

(2) EN 1993 is intended to be used in conjunction with EN 1990, EN 1991 (all parts), the parts of EN 1992 to EN 1999 where steel structures or steel components are referred to within those documents, EN 1090-2, EN 1090-4 and ENs, EADs and ETAs for construction products relevant to steel structures.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE See the Bibliography for a list of other documents cited that are not normative references, including those referenced as recommendations (i.e. through ‘should’ clauses) and permissions (i.e. through ‘may’ clauses).

EN 1090-2, *Execution of steel structures and aluminium structures — Part 2: Technical requirements for steel structures*

EN 1090-4, *Execution of steel structures and aluminium structures — Part 4: Technical requirements for cold-formed structural steel elements and cold-formed structures for roof, ceiling, floor and wall applications*

EN 1990:—¹, *Eurocode — Basis of structural and geotechnical design*

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

EN 1993-1 (all parts), *Eurocode 3: Design of steel structures*

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in EN 1990 and the following terms, definitions and symbols apply.

3.1 Terms and definitions

3.1.1

frame

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

Note 1 to entry: This term refers to both moment-resisting frames and triangulated frames; it covers both plane frames and three-dimensional frames.

¹ Under preparation. Stage at the time of publication: FprEN 1990:2022.

3.1.2**sub-frame**

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

3.1.3**semi-continuous framing**

framing in which the structural properties of the members and joints need explicit consideration in the global analysis

3.1.4**continuous framing**

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

3.1.5**simple framing**

framing in which the joints are not designed to resist moments

3.1.6**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

3.1.7**buckling length**

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

3.1.8**equivalent member**

simply supported single span member of uniform cross-section with constant compressive axial force used for buckling verification

Note 1 to entry: Its length, cross-section and axial force are equal to the appropriate buckling length, cross-section and axial force at the investigated position in the structure.

3.1.9**shear lag effect**

non-uniform stress distribution in wide flanges due to shear deformation

3.1.10**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

3.1.11**uniform built-up member**

built-up member made of parallel chords with nominally constant cross-section along their whole length, connected by regularly spaced lacings or battens

3.1.12**uniform member**

member with a nominally constant cross-section along its whole length

3.1.13

fork end condition

support condition where the beam is supported vertically and/or laterally but free to rotate on plan

Note 1 to entry: More detailed explanations are given in prCEN/TR 1993-1-103², *Eurocode 3 – Design of steel structures – Part 1-103: Elastic critical buckling of members*.

3.2 Symbols and abbreviations

3.2.1 Latin upper-case symbols

A	cross-sectional area
A_c	area of the equivalent compression flange
A_{ch}	cross-sectional area of one chord of a built-up column
A_{dia}	cross-sectional area of one diagonal of a built-up column
A_{eff}	effective area of a cross-section
A_f	area of one flange
A_i	cross-sectional area for the calculation of the characteristic resistance to an axial force
A_{net}	net area of a cross-section
A_p	cross-sectional area of one post (or transverse element) of a built-up column
A_t	area of the tension flange
$A_{t,net}$	net area of the tension flange
A_v	shear area
A_w	area of a web
A_0	original cross-sectional area
B_{Ed}	design value of the bimoment
B_{Rd}	design value of the bimoment resistance
B_{Rk}	characteristic value of the bimoment resistance
C_D	rotational stiffness provided by stabilizing continuum and connections
$C_{D,A}$	rotational stiffness of the connection between the beam and the stabilizing continuum
$C_{D,B}$	rotational stiffness deduced from an analysis of the distortional deformations of the beam cross-sections
$C_{D,C}$	rotational stiffness provided by the stabilizing continuum to the beam assuming a stiff connection to the member
C_{my}, C_{mz}, C_{mLT}	equivalent uniform moment factors
E	modulus of elasticity

² Under preparation.

$EI \left \eta''_{cr,m} \right $	absolute value of the bending moment due to $\eta_{cr,m}$ at the critical cross-section m
$F_{cr,ns}$	minimum elastic critical flexural buckling load for either the in-plane or out-of-plane member (non-sway) buckling mode
$F_{cr,sw}$	minimum elastic critical in-plane flexural buckling load for a global (sway) buckling mode
F_d	design value of the loading on the structure
$F_{H,d}$	design value of the total horizontal load
$F_{V,d}$	design value of the total vertical load
$F_{z,Ed}$	design value of transverse force
$F_{z,Rd}$	design value of the resistance to transverse force
G	shear modulus
G_k	characteristic value of a permanent action
H	height of the structure
H_f	fictitious horizontal force
H_{st}	storey height
I	moment of inertia (second moment of area)
I_b	in-plane moment of inertia of a batten
I_{ch}	in-plane moment of inertia of a chord
I_{eff}	effective moment of inertia of a built-up member
I_T	torsion constant
I_w	warping constant
I_y, I_z	moment of inertia about y-y axis and z-z axis, respectively
$I_{z,fl}$	moment of inertia about z-z axis of one flange
I_1	equivalent moment of inertia of a battened built-up member
K_{st}	lateral rigidity of a storey
K_v	factor for considering the type of verification in evaluating torsional restraints
K_θ	factor for considering the moment distribution in evaluating torsional restraints
L	length (member length, span length, etc.)
L_c	length between two consecutive lateral restraints
L_{ch}	buckling length of chord in a built-up member
L_{cr}	buckling length
L_d	length of a diagonal in a built-up member
L_{st}	stable length of segment

$M_{b,Rd}$	design value of the buckling resistance of a member in bending
$M_{B,Rd}$	design value of the reduced cross-section resistance to bending moment making allowance for the presence of bimoment
$M_{B,V,Rd}$	design value of the reduced cross-section resistance to bending moment making allowance for the presence of shear force and bimoment
M_{cr}	elastic critical moment for lateral torsional buckling
$M_{c,Rd}$	design value of the bending moment resistance about one principal axis of a cross-section
M_{Ed}	design value of bending moment
M_{Ed}^I	design value of the maximum first order moment in the built-up member
$M_{el,Rd}$	design value of the elastic bending moment resistance
$M_{ep,Rd}$	design value of the elasto-plastic bending moment resistance
M_h	hogging moment at member ends
$M_{N,ep,Rd}$	design value of the elasto-plastic bending moment resistance making allowance for the presence of axial force
$M_{N,Rd}$	sign value of the reduced bending moment resistance making allowance for the presence of axial force
$M_{pl,Rd}$	design value of the plastic bending moment resistance
M_{Rk}	characteristic value of the bending moment resistance
$M_{Rk,m}$	characteristic value of the bending moment resistance of the critical cross-section m
M_s	sagging moment at mid-span of a member
$M_{V,Rd}$	design value of the reduced plastic bending moment resistance making allowance for the presence of shear force
$M_{y,Ed}$	design value of the bending moment about y-y axis
$M_{y,Rd}$	design value of the bending moment resistance about y-y axis
$M_{y,Rk}$	characteristic value of the bending moment resistance about y-y axis
$M_{z,Ed}$	design value of the bending moment about z-z axis
$M_{z,Rd}$	design value of the bending moment resistance about z-z axis
$M_{z,Rk}$	characteristic value of the bending moment resistance about z-z axis
M_0	free bending moment at mid-span (determined on an equivalent member with simply supported end conditions)
N	number of stress cycles during the design service life
$N_{b,Rd}$	design value of the buckling resistance of a member in compression
$N_{c,Rd}$	design value of the resistance to axial force of the cross-section for uniform compression
$N_{ch,Ed}$	design value of the axial force in a chord, in the middle of a built-up member

N_{cr}	elastic critical axial force for the relevant buckling mode based on the gross cross-sectional properties
$N_{cr,c,z}$	elastic critical axial force for flexural buckling of the equivalent compression flange
$N_{cr,m}$	elastic critical axial force at the cross-section m
$N_{cr,T}$	elastic critical axial force for torsional buckling
$N_{cr,TF}$	elastic critical axial force for torsional-flexural buckling
$N_{cr,V}$	effective critical axial force of a built-up member including the effect of its shear stiffness
$N_{cr,y}, N_{cr,z}$	elastic critical axial force for flexural buckling about y-y axis and z-z axis, respectively
N_{Ed}	design value of the compressive axial force
$N_{Ed,m}$	design value of the compressive axial force at the cross-section m
$N_{f,Ed}$	design axial force in the compressed flange of a stabilized member at a plastic hinge location
$N_{net,Rd}$	design value of the plastic resistance to axial force of the net cross-section
$N_{pl,Rd}$	design value of the plastic resistance to axial force of the gross cross-section
N_{Rd}	design value of the resistance to axial force
N_{Rk}	characteristic value of the resistance to axial force
$N_{Rk,m}$	characteristic value of the resistance to axial force at the cross-section m
$N_{t,Rd}$	design value of the resistance to tensile axial force
$N_{u,Rd}$	design value of the ultimate resistance to axial force of the net cross-section at holes for fasteners
P_k	characteristic value of a prestressing action imposed during erection
Q_m	local force applied at each stabilized member at the plastic hinge locations
R_{eH}	yield strength taken from the relevant product standard
R_d	design value of resistance
R_k	characteristic value of resistance
R_m	ultimate strength taken from the relevant product standard
S	static moment (first moment of area)
S_{Vb}	shear stiffness of a built-up member from the lacing or battened panel
S_v	shear stiffness provided by sheeting
T_{Ed}	design value of total internal torsional moment
$T_{t,Ed}$	design value of internal St. Venant torsional moment
T_{Rd}	design value of the resistance to torsional moment
$T_{w,Ed}$	design value of internal warping torsional moment

$V_{c,Rd}$	design value of the resistance to shear force
V_{Ed}	design value of the shear force
V_{Ed}^I	design value of the first order shear force in a built-up member
$V_{pl,Rd}$	design value of the plastic resistance to shear force
$V_{pl,T,Rd}$	design value of the reduced plastic shear resistance making allowance for the presence of a torsional moment
$W_{pl,B}$	plastic section modulus for the plastic resistance to bimoment
W_{eff}	effective section modulus
$W_{eff,y,min}$	minimum effective section modulus for bending about y-y axis
W_{el}	elastic section modulus
$W_{el,min}$	minimum elastic section modulus
$W_{el,y}, W_{el,z}$	elastic section modulus for bending about y-y axis and z-z axis, respectively
$W_{el,y,min}$	minimum elastic section modulus for bending about y-y axis
W_{ep}	elasto-plastic section modulus for Class 3 section
$W_{ep,y}, W_{ep,z}$	elasto-plastic section modulus for bending about y-y axis and z-z axis, respectively
W_{pl}	plastic section modulus
$W_{pl,y}, W_{pl,z}$	plastic section modulus for bending about y-y axis and z-z axis, respectively
X_d	design value of a basic variable
X_k	characteristic value of a basic variable
$X_{k,i}$	characteristic value of material property
$X_{k,th}$	target characteristic value of a basic variable
X_m	mean value of a basic variable
X_n	nominal value of a basic variable
X_{rep}	representative value of material properties
$X_{5\%}$	upper reference value
$X_{0,12\%}$	lower reference value
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

3.2.2 Latin lower-case symbols

a	ratio of web area to gross section area
a_d	design value of geometrical properties
a_f	ratio of section area of the smaller sides to gross section area for rectangular hollow sections
a_w	ratio of section area of the larger sides to gross section area for rectangular hollow sections
b	width of a cross-section
c	width or depth of a part of a cross-section
d	external diameter of a circular hollow section
d_{ch}	distance along a chord of a built-up member between two consecutive lacings or battens
d_e	equivalent diameter for circular and elliptical hollow sections
d_w	web depth between fillets or weld toes
d_z	distance of intermediate lateral supports from the shear centre of the cross-section
d_0	diameter of bolt hole
e_N	shift of the centroid of the effective area A_{eff} relative to the centroid of the gross cross-section
$e_{N,y}$	shift of the centroid of the effective area A_{eff} relative to the centroid of the gross cross-section, resulting in a bending moment about y-y axis
$e_{N,z}$	shift of the centroid of the effective area A_{eff} relative to the centroid of the gross cross-section, resulting in a bending moment about z-z axis
e_0	equivalent bow imperfection
$e_{0,LT}$	equivalent bow imperfection for lateral torsional buckling
$e_{0,m}$	equivalent bow imperfection at the critical cross-section m
f_m	factor that accounts for the effect of the bending moment distribution between discrete lateral restraints
f_y	yield strength
$f_{y,red}$	reduced yield strength
f_u	ultimate tensile strength
h	depth of a cross-section
h_w	depth of a web
h_0	distance between centroids of chords of a built-up column
i	radius of gyration about the relevant axis, determined using the properties of the gross cross-section
i_{min}	minimum radius of gyration of single angles
i_y, i_z	radius of gyration for bending about y-y axis and z-z axis respectively
i_p	polar radius of gyration

i_0	minimum radius of gyration of the cross-section of a star-battened built-up member
k	correction factor for ultimate resistance of the net cross-section
k_c	correction factor for moment distribution
k_{ij}	interaction factors (generic symbol for k_{yy} , k_{yz} , k_{zy} and k_{zz})
k_{sw}	amplification factor for taking into account second order sway effects due to vertical loads
k_w	interaction factor for uniform members in bending, axial compression and torsion covering the effect of bi-moment
k_{yy}, k_{yz} k_{zy}, k_{zz}	interaction factors for uniform members in bending and axial compression
k_{zw}	interaction factor for uniform members in bending, axial compression and torsion covering the effect of bending moment about z-z
k_α	interaction factor for uniform members in bending, axial compression and torsion covering the effect of bending moment about y-y
k_σ	plate buckling factor
k_0	limiting value for $\alpha_{cr,ns}$
ℓ_y	effective length for the resistance to transverse force
m	number of columns in a row or members to be restrained
n	ratio of design axial force to design plastic resistance to axial force of the gross cross-section
n_p	number of planes of lacing or batten
n_y	ratio of design axial force to design value of the buckling resistance of a member in compression for buckling about y-y axis
n_z	ratio of design axial force to design value of the buckling resistance of a member in compression for buckling about z-z axis
n_1	number of holes extending in any diagonal or zig-zag line progressively across the member or part of the member
n_2	number of holes in a section where the holes are not staggered.
p_2	spacing of the centres of the same two holes measured perpendicular to the member axis
q_d	equivalent design load per unit length
r	radius of root fillet
r_e	external corner radius of a rectangular hollow section
r_1	radius of root fillet
r_2	toe radius
s	staggered pitch, the spacing of the centres of two consecutive holes measured parallel to the member axis
s_s	length of stiff bearing
t	thickness

t_{cor}	core thickness (i.e. nominal thickness minus the thickness of the zinc and other metallic coatings)
t_{d}	design thickness
t_{f}	flange thickness
t_{mc}	thickness of metallic coating
t_{nom}	nominal sheet thickness
tol	minus tolerance of the thickness in % from the relevant EN or EN ISO, EAD or ETA
t_{w}	web thickness

3.2.3 Greek upper-case symbols

ΔA_{net}	section area to be deducted for a section to take into account the holes
Δ_f	horizontal displacement at the top of the storey due to H_f relative to the bottom of the storey
ΔM_{Ed}	additional moment from shift of the centroid of the effective area A_{eff} relative to the centroid of the gross cross-section
$\Delta M_{y,\text{Ed}}$	additional moment about y-y axis due to the shift of the centroid
$\Delta M_{z,\text{Ed}}$	additional moment about z-z axis due to the shift of the centroid
Φ	value to determine the reduction factor χ for flexural buckling
Φ_{LT}	value to determine the reduction factor χ_{LT} for lateral torsional buckling

3.2.4 Greek lower-case symbols

α	imperfection factor
α_{c}	portion of a part of a cross-section in compression
α_{cr}	factor by which the design value of the loading would have to be increased to cause elastic instability
$\alpha_{\text{cr,ns}}$	factor by which the design value of the loading would have to be increased to cause elastic instability in the in-plane or out-of-plane member (non-sway) buckling mode
$\alpha_{\text{cr,op}}$	minimum amplifier for the design value of the in-plane loading to reach the elastic critical buckling load with regard to lateral or lateral torsional buckling
$\alpha_{\text{cr,sw}}$	factor by which the design value of the loading would have to be increased to cause elastic instability in a global, in-plane (sway) mode
α_{h}	factor describing the moment diagram; h = hogging
α_{H}	reduction factor for height H applicable to columns
α_{LT}	imperfection factor for lateral torsional buckling
α_{m}	reduction factor for the number of columns in a row or members to be restrained
α_{R}	resistance-side weighting factor for calibration of partial factors
α_{s}	factor describing the moment diagram; s = sagging

α_T	coefficient of linear thermal expansion
α_{TF}	imperfection factor for torsional-flexural buckling
$\alpha_{ult,k}$	minimum load amplifier of the design loads to reach the characteristic resistance of the most critical cross-section
α_y	parameter introducing the effect of biaxial bending
α_z	parameter introducing the effect of biaxial bending
$\alpha_{\eta,m}$	imperfection factor α for the relevant buckling curve at the critical cross-section m
β	reference relative bow imperfection
β_c	modification factor of equivalent compression flange
$\beta_{ep,y}, \beta_{ep,z}$	interpolation factor for bending about y-y axis and z-z axis, respectively
β_{LT}	reference relative bow imperfection for lateral torsional buckling
γ_{Mi}	partial factor (generic symbol)
γ_{M0}	partial factor for resistance of cross-sections
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
γ_R	partial factor for the particular resistance
δ_q	in-plane deflection of a bracing system
ε	material parameter depending on f_y
ε_t	tensile strain
η	factor for shear area
$\eta_{cr}(x)$	shape of the relevant (first or higher) elastic critical buckling mode
η_i	conversion factor
$\eta_{init}(x)$	shape of the equivalent geometrical imperfection
θ	angle between axes of chord and lacing
$\bar{\lambda}$	relative slenderness
$\bar{\lambda}_{c,z}$	relative slenderness of the equivalent compression flange
$\bar{\lambda}_{c,z,mod}$	modified relative slenderness of the equivalent compression flange
$\bar{\lambda}_m$	relative slenderness related to the section m
$\bar{\lambda}_{LT}$	relative slenderness for lateral torsional buckling
$\bar{\lambda}_{LT,lim}$	limit of relative slenderness for susceptibility to lateral torsional buckling
$\bar{\lambda}_{LT,0}$	plateau length of the lateral torsional buckling curves

$\bar{\lambda}_{op}$	global relative slenderness of a structural component for out-of-plane buckling
$\bar{\lambda}_T$	relative slenderness for torsional buckling
$\bar{\lambda}_{TF}$	relative slenderness for torsional-flexural buckling
λ_1	reference slenderness to determine the relative slenderness
μ	efficiency factor in built-up members
ν	Poisson's ratio in elastic range
ρ	reduction factor to determine the design value of the reduced plastic bending moment resistance making allowance for the presence of shear forces
σ	stress
$\sigma_{com,Ed}$	maximum design value of compressive longitudinal stress
$\sigma_{eq,Ed}$	design value of equivalent longitudinal stress
$\sigma_{w,Ed}$	design value of the longitudinal stress due to bimoment B_{Ed}
$\sigma_{x,Ed}$	design value of the longitudinal stress
$\sigma_{z,Ed}$	design value of the transverse stress
τ_{Ed}	design value of the shear stress
$\tau_{t,Ed}$	design value of the shear stress due to St. Venant torsion
$\tau_{w,Ed}$	design value of the shear stress due to warping torsion
ϕ	initial sway imperfection
ϕ_0	basic value for initial sway imperfection
χ	reduction factor for relevant buckling mode
χ_{LT}	reduction factor for lateral torsional buckling
χ_{op}	reduction factor for the relative slenderness $\bar{\lambda}_{op}$
χ_T	reduction factor due to torsional buckling
χ_{TF}	reduction factor due to torsional-flexural buckling
χ_y	reduction factor due to flexural buckling about y-y axis
χ_z	reduction factor due to flexural buckling about z-z axis
ψ	ratio of end moments in a segment of beam, or stress ratio

3.3 Symbols 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 – cross-section axis parallel to the smaller leg

z-z – cross-section 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 rolled steel sections are indicated in Figure 3.1.

(4) The convention for subscripts indicating the axes for moments is: “Use the axis about which the moment acts.”

NOTE All rules in EN 1993 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.

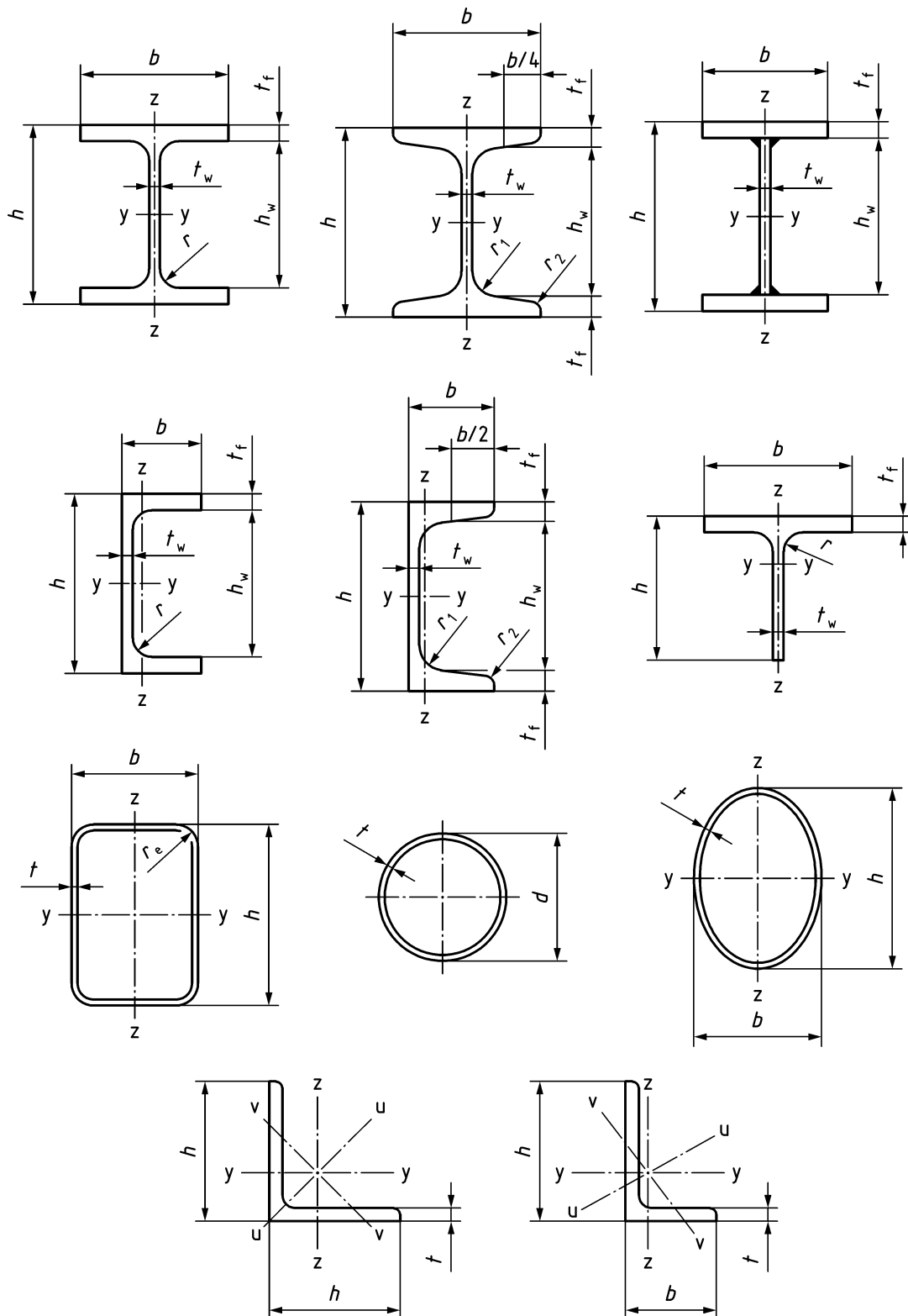


Figure 3.1 — Dimensions and axes of sections

4 Basis of design

4.1 General rules

4.1.1 Basic requirements

(1) The design of steel structures shall be in accordance with the general rules given in EN 1990 and EN 1991 (all parts) and the specific design provisions for steel structures given in the relevant parts of EN 1993-1 (all parts).

(2) Steel structures designed according to EN 1993 shall be executed according to EN 1090-2 and/or EN 1090-4 with construction materials and products used as specified in the relevant parts of EN 1993, or in the relevant material and product specifications.

4.1.2 Structural reliability

(1) To obtain the level of structural reliability of the completed works required according to EN 1990, an appropriate execution class shall be selected in accordance with Annex A for steel structures executed to EN 1090-2 and EN 1090-4.

(2) If different levels of reliability are required, they should be achieved by an appropriate choice of quality management measures in design and execution according to EN 1990, EN 1090-2 and EN 1090-4.

4.1.3 Robustness

(1) The provisions on robustness given in EN 1990:—, 4.4 should be followed.

(2) The general arrangement of the structure and the interaction and connection of its various parts should be such as to give appropriate robustness during construction and use.

4.1.4 Design service life for buildings

(1)B For the specification of the intended design service life of a permanent building, the provisions given in EN 1990 should be followed.

(2)B For structural elements that cannot be designed for the total design life of the building (e.g. components that need to be replaceable such as bearings), see Clause 6(5).

4.1.5 Durability

(1) Depending upon the type of action affecting the design service life (see EN 1990), steel structures shall be:

- designed for the effects of corrosion;
- designed for the effects of fatigue in accordance with Clause 10 and EN 1993-1-9;
- designed against brittle fracture in accordance with EN 1993-1-10;
- designed for wearing effects;
- designed for accidental actions (see EN 1991-1-7);
- inspected and maintained.

(2) Corrosion protection may be achieved by:

- suitable surface protection in accordance with EN ISO 12944 (all parts), EN ISO 1461;
- the use of weathering steel (see EN 10025-5);
- the use of stainless steel in accordance with EN 1993-1-4.

(3) For further consideration of durability, Clause 6 should be followed.

4.2 Principles of limit state design

(1) For steel structures, the ultimate limit state and serviceability limit state shall be considered for all aspects of the structure.

(2) For steel structures, all relevant design situations shall be considered, including relevant phases in the erection stage.

NOTE For the selection of design situations, see EN 1990.

4.3 Basic variables

4.3.1 Actions and environmental influences

(1) The characteristic values of actions for the design of steel structures, including any regional, climatic and accidental situations, shall be obtained from the relevant Parts of EN 1991.

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

(3) Where the effects of predicted absolute and differential settlements need to be considered, estimates of imposed deformations should be taken into account.

(4) The effects of uneven settlements, imposed deformations and forms of prestressing imposed during erection should be taken into account using the nominal value of the prestressing action P_k as a permanent action and grouping them with other permanent actions G_k to form a single action ($G_k + P_k$).

NOTE For more information on load combinations, see EN 1990 and for prestress, see EN 1993-1-11.

(5) Fatigue actions not defined in EN 1991 (all parts) should be determined in accordance with EN 1990:—, Clause 8 and the fatigue action effects in accordance with EN 1993-1-9.

4.3.2 Material, geometrical and product properties

(1) The material properties for steels and other construction products and the geometrical properties to be used for design should be those specified in the relevant EN and EN ISO product standards, or according to a transparent and reproducible assessment that complies with all the requirements of a European Assessment Document (EAD) or European Technical Assessment (ETA), unless otherwise indicated, see Clause 5.

(2) The nominal values of material properties should be adopted as characteristic values in design calculations.

(3) For structural analysis and design, the nominal values of dimensions may be used.

NOTE See EN 1990:—, 6.3(1).

4.4 Verification by the partial factor method

4.4.1 Design values of actions

(1) For the design of steel structures, combination of actions and partial factors of actions shall be derived from EN 1990:—, Annex A.

4.4.2 Design values of material properties

(1) For the design of steel structures, the design value for a material property shall be obtained by dividing its characteristic value X_k or nominal value X_n by the relevant partial factor for materials, γ_M .

NOTE Usually the partial factor is explicitly incorporated in the design rules.

4.4.3 Design values of geometrical properties

(1) Geometrical properties for cross-sections and systems may be taken from EN and EN ISO product standards, EADs, ETAs or component specifications for the execution to EN 1090 (all parts) and treated as nominal values.

(2) The dimensions of hot rolled profiles may be taken from EN 10365.

NOTE The standard EN 10365 does not give the fillet radius. However, it can be calculated from the section area and the other dimensions, unless the National Annex gives other provisions.

(3) Design values of geometrical imperfections specified in this document are equivalent geometrical imperfections that take into account the effects of:

- geometrical imperfections 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.

(4) The design rules should not be applied to steels with nominal material thicknesses t less than 3 mm, except as stated in (5).

(5) The design rules may be applied to components made of steels with nominal material thicknesses t less than 3 mm but higher than or equal to 1,5 mm provided that the design thickness t_d based on the steel core thickness t_{cor} is used instead of the nominal thickness t as follows:

$$t_d = t_{cor} \quad \text{if } tol \leq 5 \% \quad (4.1)$$

$$t_d = t_{cor} \frac{100 - tol}{95} \quad \text{if } tol > 5 \% \quad (4.2)$$

where

$$t_{cor} = t_{nom} - t_{mc}$$

tol is the minus tolerance of the thickness in % from the relevant EN or EN ISO, EAD or ETA;

t_{nom} is the nominal sheet thickness of the original sheet, inclusive of zinc and other metallic coating and not including organic coating;

t_{mc} is the thickness of the metallic coating.

4.4.4 Tolerances

(1) The dimensional and mass tolerances of rolled steel sections, structural hollow sections and plates should conform with the relevant EN or EN ISO product standard, EAD or ETA, unless more severe tolerances are specified by the relevant authority or agreed for a specific project by the relevant parties.

(2) The fabrication and erection tolerances of structural components should comply with EN 1090-2 and EN 1090-4.

4.4.5 Design resistances

(1) For steel structures, Formula (8.20) of EN 1990:— applies:

$$R_d = \frac{R_k}{\gamma_R} = \frac{R\{X_{\text{rep}}; a_d; \sum F_{\text{Ed}}\}}{\gamma_R} \quad (4.3)$$

where

F_{Ed} denotes the design values of actions, see 4.4.1;

$R\{\dots\}$ denotes the output of the resistance model;

R_k is the characteristic value of the particular resistance;

X_{rep} denotes the representative values of the material properties, defined as ηX_k . Unless defined differently for specific rules, the nominal values of the material properties as defined in 5.2.1 are used;

a_d denotes the design values of the geometrical properties, see 4.4.3;

γ_R is the partial factor for the particular resistance. In this document, γ_R will take the value of the appropriate partial factor γ_{M1} , see 8.1.

4.5 Design assisted by testing

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

NOTE Guidance on design assisted by testing is given in EN 1990:—, Annex D. More specific provisions can be given in other parts of EN 1993.

5 Materials

5.1 General

(1) For the design of steel structures according to this document the material for fabrication should conform to the grades in Table 5.1 and 5.2 and the following product standards: EN 10025 (all parts), EN 10149 (all parts), EN 10210 (all parts) and EN 10219 (all parts).

NOTE Other steel materials and products can be set by the National Annex.

(2) If other steel materials than those mentioned in (1) are used, their properties (mechanical properties and weldability) shall be known and their mechanical properties shall conform to the conditions given in 5.2.2, 5.2.3 and 5.2.4 when tested in accordance to the relevant EN, ISO or EN ISO testing standards.

5.2 Structural steel

5.2.1 Material properties

(1) The nominal values of the yield strength f_y and the ultimate tensile strength f_u for structural steel should be obtained:

- a) either by adopting the values $f_y = R_{eH}$ and $f_u = R_m$ (as lower bound of the given range) directly from the product standard;

- b) or by using the values given in Table 5.1 for steel conforming to EN 10025 (all parts), EN 10210 (all parts) and EN 10219 (all parts), and in Table 5.2 for steel conforming to EN 10149 (all parts), and considering the availability of the material in the thickness range according to the product standard.

NOTE 1 The choice of the approach can be set by the National Annex considering the effects on partial factors and their calibration according to Annex E and EN 1990. In case of option b), the partial factor γ_{M1} needs to be increased.

NOTE 2 Rules for the use of the steels according to Table 5.1 and Table 5.2 can be set by the National Annex.

Table 5.1 — Nominal values of yield strength f_y and ultimate tensile strength f_u for structural steels conforming to the following standards: EN 10025 (all parts), EN 10210 (all parts), and EN 10219 (all parts)

Steel grade ^a	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
S235	235	360	215	360
S275	275	390	245	370
S355	355	490	325	470
S420	420	510	390	490
S460	460	540	410	510
S500	500	580	450	580
S550	550	600	500	600
S600	600	650	550	650
S620	620	700	560	660
S650	650	700	-	-
S690	690	770	630	710
S700	700	750	-	-
^a Principal symbols in EN 10027-1.				

Table 5.2 — Nominal values of yield strength f_y and ultimate tensile strength f_u for hot rolled flat products for cold-forming, according to EN 10149-2 and EN 10149-3

Standards, Grades and quality	Nominal thickness of the element			
	t mm			
	$t \leq 8$ mm		$8 \text{ mm} < t \leq 20$ mm	
	f_y N/mm ²	f_u N/mm ²	f_y N/mm ²	f_u N/mm ²
EN 10149-2^a				
S315MC	315	390	315	390
S355MC	355	430	355	430
S420MC	420	480	420	480
S460MC	460	520	460	520
S500MC	500	550	500 ^b	550 ^b
S550MC	550	600	550 ^b	600 ^b
S600MC	600	650	600 ^b	650 ^b
S650MC	650	700	630 ^b	700 ^b
S700MC	700	750	680 ^b	750 ^b
EN 10149-3^a				
S260NC	260	370	260	370
S315NC	315	430	315	430
S355NC	355	470	355	470
S420NC	420	530	420	530
^a Verification of the impact energy in accordance with EN 10149-1:2013, Clause 11, option 5 should be specified. ^b $t \leq 16$ mm				

5.2.2 Ductility requirements

(1) A minimum ductility shall be provided and shall be expressed in terms of limiting values for:

- the ratio f_u/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).

NOTE The limiting values are given below unless the National Annex gives different limiting values:

a) For plastic global analysis

- $f_u / f_y \geq 1,10$;

— elongation at failure not less than 15 %.

b) For elastic global analysis

— $f_u / f_y \geq 1,05$;

— elongation at failure not less than 12 %.

(2) Steels conforming to any of the grades listed in Table 5.1 and Table 5.2 may be assumed to satisfy the minimum ductility requirements for elastic global analysis.

(3) Steels conforming to one of the grades up to and including S460 listed in Table 5.1 and Table 5.2 may be assumed to satisfy the minimum ductility requirements for plastic global analysis.

5.2.3 Fracture toughness

(1) Material shall have sufficient fracture toughness to avoid brittle fracture of elements within the intended design service life of the structure. Checking for fracture toughness is required under all loading conditions.

NOTE For steels intended to be hot dip galvanized, see EN ISO 1461.

(2) Further checks for brittle fracture may be omitted if the conditions given in EN 1993-1-10 are satisfied.

5.2.4 Through-thickness properties

(1) The target through-thickness properties of the material should be determined by calculating the required design Z-value Z_{Ed} for the material according to EN 1993-1-10.

(2) Where material with improved through-thickness properties is required ($Z_{Ed} > 10$), a material quality Class should be selected according to EN 10164, i.e. Z 15, Z 25 or Z 35.

(3) The selection of material quality Class should be in accordance with Table 5.3.

NOTE Through-thickness properties are relevant for plates loaded perpendicular to their plane, e.g. for welded beam to column connections and welded end plates with tension in the through-thickness direction.

Table 5.3 — Choice of quality Class according to EN 10164

Target design value Z_{Ed} according to EN 1993-1-10	Quality Class according to EN 10164 (Available design Z-value Z_{Rd})
$Z_{Ed} \leq 10$	—
$10 < Z_{Ed} \leq 20$	Z 15
$20 < Z_{Ed} \leq 30$	Z 25
$Z_{Ed} > 30$	Z 35

5.2.5 Values of other material properties

(1) The material properties to be adopted in calculations should be taken as the following mean values for steel:

- modulus of elasticity $E = 210\,000 \text{ N/mm}^2$
- shear modulus $G = \frac{E}{2(1+\nu)} \approx 81\,000 \text{ N/mm}^2$
- Poisson's ratio in elastic range $\nu = 0,3$
- coefficient of linear thermal expansion $\alpha_T = 12 \times 10^{-6} \text{ K}^{-1}$ (for $T \leq 100 \text{ °C}$)

(2) The material parameter ε is used in several expressions in EN 1993 (all parts). It is defined as follows:

$$\varepsilon = \sqrt{\frac{235}{f_y}} \quad (5.1)$$

where

f_y is the yield strength in N/mm^2 .

5.3 Connecting devices

(1) For fasteners and welding consumables, the provisions given in EN 1993-1-8 should apply.

5.4 Other prefabricated products in buildings

(1)B Any semi-finished or finished structural product used in the structural design of buildings shall comply with the relevant EN or EN ISO product standard, EAD or ETA.

6 Durability

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

(2) Execution of protective treatment shall comply with EN 1090-2.

NOTE EN 1090-2 lists the factors affecting execution that need to be specified during design.

(3) Parts susceptible to corrosion, mechanical wear or fatigue should be designed such that inspection, maintenance and repair can be carried out satisfactorily and access is available for in-service inspection and maintenance.

(4) For elements that cannot be inspected, an appropriate corrosion allowance should be included.

(5) If a structure includes components that need to be replaceable (e.g. bearings), the possibility of their safe replacement should be verified as a transient design situation.

(6)B Corrosion protection does not need to be applied to interior building structures, if the corrosivity category is C1 according to EN ISO 12944-2:2017.

7 Structural analysis

7.1 Structural modelling for analysis

7.1.1 Basic assumptions

(1) Analysis shall be based upon calculation models of the structure that are appropriate for the limit state under consideration. The method used for the analysis shall be consistent with the design assumptions. EN 1990:—, 7.1.1 applies.

7.1.2 Joint modelling

(1) Where 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, are significant (such as in the case of semi-continuous joints), they should be taken into account, see EN 1993-1-8.

(2) To identify whether the effects of joint moment-rotation behaviour need be taken into account in the analysis, a distinction may be made between three joint models as follows:

- simple joints, in which the joint may be assumed not to transmit bending moments;
- continuous joints, in which the joint may be assumed not to allow any relative rotation between connected members, and hence the joint behaviour has no effect on the analysis;
- semi-continuous joints, in which the joint should be assumed to allow relative rotation and bending moment transfer between connected members, and hence the behaviour of the joint needs to be taken into account in the analysis.

(3) For various types of joints the provisions given in EN 1993-1-8 should apply.

7.2 Global analysis

7.2.1 Consideration of second order effects

(1) The internal forces and moments may generally be determined using either:

- first-order analysis, using the undeformed geometry of the structure or
- second-order analysis, taking into account the influence of the deformation of the structure.

(2) The effects of the deformed geometry (second-order effects) should be considered if they increase the action effects significantly or modify significantly the structural behaviour.

(3) Second order analysis is not required if the conditions (7.1) and (7.2) are satisfied.

(4) If the condition in Formula (7.1) is satisfied, second order effects due to in-plane or out-of-plane member (non-sway) buckling may be neglected for the global analysis.

$$\alpha_{cr,ns} = \frac{F_{cr,ns}}{F_d} \geq k_0 \quad (7.1)$$

where

$F_{cr,ns}$ is the minimum elastic critical flexural buckling load for either the in-plane or out-of-plane member non-sway buckling mode. Torsional buckling, torsional-flexural and lateral torsional buckling are not considered;

F_d is the design value of the loading on the structure;

$\alpha_{cr,ns}$ is the factor by which the design value of the loading would have to be increased to cause elastic instability in the in-plane or out-of-plane member (non-sway) buckling mode.

NOTE 1 The value of k_0 is 25 unless the National Annex gives a different value.

NOTE 2 For frames, buckling modes can be classified as sway or non-sway, see Figure 7.1. Sway modes are characterized by significant relative displacements of the member ends, perpendicular to the undeformed member geometry.

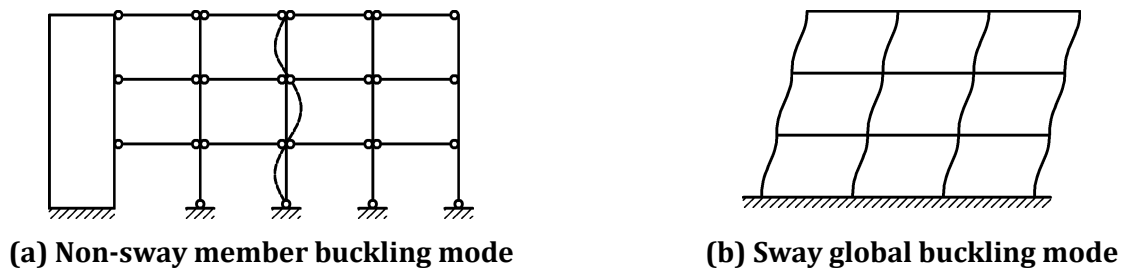


Figure 7.1 — Buckling modes of frames

NOTE 3 For the application of the condition in Formula (7.1) to plastic analysis, see 7.4.3.

(5) If the condition in Formula (7.2) is satisfied, second order effects due to in-plane sway buckling may be neglected for the global analysis and first order analysis may be used for the determination of the in-plane sway bending moments.

$$\alpha_{cr,sw} = \frac{F_{cr,sw}}{F_d} \geq 10 \quad (7.2)$$

where

$F_{cr,sw}$ is the minimum elastic critical in-plane flexural buckling load for a global sway buckling mode;

F_d is the design value of the loading on the structure;

$\alpha_{cr,sw}$ is the factor by which the design value of the loading would have to be increased to cause elastic instability in a global, in-plane (sway) mode.

NOTE 1 When the condition (7.2) is satisfied, the increase of the internal forces and moments due to sway second order effects is no more than 10 % of the internal forces and moments according to first order theory.

NOTE 2 For the application of the condition in Formula (7.2) to plastic analysis, see 7.4.3.

(6) Second order effects due to lateral torsional buckling may be neglected for the global analysis and the verifications in the following cases:

- for certain types of sections, e.g. structural hollow sections and equivalent welded box sections;
- when only weak-axis bending moments act on members with mono-symmetric or doubly symmetric sections;

- in case of sufficient restraint to the compression flange, see Annex D;
- when the limit slenderness for susceptibility to lateral torsional buckling of 8.3.2.3(1) is not exceeded.

(7) The effects of shear lag and plate buckling on the stiffness should be taken into account if they significantly influence the global analysis, see EN 1993-1-5.

(8) For rolled sections and welded sections with similar dimensions, the effects of shear lag and plate buckling on the stiffness may be neglected.

(9) The effects of the slip in bolt holes and similar deformations of connection devices like studs and anchor bolts should be taken into account if they significantly influence the global analysis.

(10)B Portal frames with rafter slopes not steeper than 1 : 2 (26°) and multi-storey beam-and-column type plane frames in buildings may be checked for in-plane, global (sway) mode failure with first order analysis if the condition in Formula (7.2) is satisfied for each storey. $\alpha_{cr,sw}$ may be calculated for a storey using Formula (7.3), see Figure 7.2, provided that the axial compression in the beams or rafters is not significant (see also (11)):

$$\alpha_{cr,sw} = \frac{K_{st} H_{st}}{\sum N_{Ed,i}} \quad (7.3)$$

where

K_{st} is the lateral rigidity of the storey. This may be calculated from a linear elastic analysis using Formula (7.4):

$$K_{st} = \frac{H_f}{\Delta_f} \quad (7.4)$$

H_f is a fictitious horizontal force applied at the top of the columns of the storey;

Δ_f is the horizontal displacement at the top of the storey due to H_f relative to the bottom of the storey;

$\sum N_{Ed,i}$ is the sum of axial forces in the columns within the storey under consideration;

H_{st} is the height of the storey.