



BSI Standards Publication

Eurocode 3 — Design of steel structures

Part 1-3: Cold-formed members and sheeting

National foreword

This British Standard is the UK implementation of EN 1993-1-3:2024. It supersedes BS EN 1993-1-3:2006, which will be withdrawn on 30 March 2028.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The first generation of EN Eurocodes was published between 2002 and 2007, with conflicting British Standards withdrawn in 2010.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UK adoptions of the first generation of EN Eurocodes will be withdrawn by BSI on 30 March 2028.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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Amendments/corrigenda issued since publication

Date	Text affected
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English Version

Eurocode 3 - Design of steel structures - Part 1-3: Cold-formed members and sheeting

Eurocode 3 - Calcul des structures en acier - Partie 1-3:
Règles générales - Profilés et plaques formés à froid

Eurocode 3 - Bemessung und Konstruktion von
Stahlbauten - Teil 1-3: Kaltgeformte Bauteile und
Profiltafeln

This European Standard was approved by CEN on 1 January 2024.

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COMITÉ EUROPÉEN DE NORMALISATION
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European foreword

This document (EN 1993-1-3:2024) 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 1993-1-3:2006 and its 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:

- Harmonization of wording according to the latest editions of EN 1993-1-1, EN 1993-1-5 and EN 1993-1-8;
- Nominal values of ultimate tensile strength (Table 5.1) adjusted to EN 1993-1-1 or the relevant product standards for harmonization (Clause 5);
- Minor specification added for the design of sinusoidal sheeting for clarification (7.6.5);
- Minor specification added for the design of trapezoidal sheeting in axial compression (8.1.3);
- Design of cross-sectional resistance to transverse forces of cross-sections with two or more unstiffened webs specified depending on the type of support (8.1.6.3);
- Design Formula for cross-sectional resistance of sections in combined axial force, bending moment, shear force and torsion reviewed for clarification (8.1.10);
- Minor specifications and explanations added for the buckling design of sections in combined compression and bending (8.2.5);
- Specifications of the design provisions in serviceability limit states (text converted into formulae) for clarification (Clause 9);
- Specifications for the design of trapezoidal sheeting with overlaps for clarification (11.3.4);

- Specifications for the bending moment resistance of liner trays for clarification (11.2.2);
- Specifications of the test set-up of single span tests for a clear uniform experimental test procedure (A.5.2);
- Specifications of the test set-up and assessment criteria of tests on sheeting (for walkability) for a clear uniform experimental test procedure (A.5.6);
- Special provisions for fasteners made of stainless steel in relation to corrosion environment deleted; general reference to EN 1993-1-4 included (Annex B).

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

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

0 Introduction

0.1 Introduction to the Eurocodes

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

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

The Eurocodes are intended for use by designers, clients, manufacturers, constructors, relevant authorities (in exercising their duties in accordance with national or international regulations), educators, soft-ware developers, and committees drafting standards for related product, testing and execution standards.

NOTE Some aspects of design are most appropriately specified by relevant authorities or, where not specified, can be agreed on a project-specific basis between relevant parties such as designers and clients. The Eurocodes identify such aspects making explicit reference to relevant authorities and relevant parties.

0.2 Introduction to EN 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: 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: Sandwich panels*.

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: 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: 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: Beams with large web openings*;

EN 1993-1-14, *Design of Steel Structures — Part 1-14: Design assisted by finite element analysis*.

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

All subsequent parts numbered EN 1993-2 to EN 1993-7 treat topics relevant for a specific structural type like 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.

0.3 Introduction to EN 1993-1-3

EN 1993-1-3 gives supplementary design rules for cold-formed steel members and sheeting. The focus in EN 1993-1-3 is on design methods and design rules for individual cold-formed members (beams, columns and beam-columns), sheeting and liner trays regarding resistance, stability and serviceability.

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 1993-1-3

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 1993-1-3 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 1993-1-3 through notes to the following clauses:

4.2(3)	4.2(4)	4.2(5)	5.2.1(3)
7.1(2)	7.2.1(6)	8.2.5(2)	10.3(3)
10.3(3)	10.3(3)	10.3(3)	12(1)
A.1(1)	A.9.4(3)		

National choice is allowed in EN 1993-1-3 on the application of the following informative annexes:

Annex B

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 1993-1-3

(1) This document provides rules for structural design of cold-formed steel members and sheeting.

(2) This document applies to cold-formed steel products made from coated or uncoated hot- or cold-rolled sheet or strip, which have been cold-formed by processes such as roll-forming or press-braking. It also covers sheeting and members which are curved during fabrication by continuous bending or roll-forming. Sheeting which has the curvature created by crushing the inner flanges is not included. This document is also applicable to the design of profiled steel sheeting for composite steel and concrete slabs at the construction stage, see EN 1994 (all parts). The execution of steel structures made of cold-formed steel members and sheeting is covered in EN 1090-4. Provisions for bolted connections are provided in EN 1090-2.

NOTE The rules in EN 1993-1-3 complement the rules in the other parts of EN 1993-1.

(3) Methods are also given for stressed-skin design, using steel sheeting as a structural diaphragm.

(4) This document does not apply to cold-formed circular and rectangular structural hollow sections supplied to EN 10219 (all parts), for which reference is made to EN 1993-1-1 and EN 1993-1-8.

(5) This document provides methods for design by calculation and for design assisted by testing. The methods for design by calculation apply only within the stated ranges of material properties and geometric proportions, for which sufficient experience and test evidence is available. These limitations do not apply to design assisted by testing.

1.2 Assumptions

(1) Unless specifically stated, EN 1990, EN 1991 (all parts) and EN 1993-1-1 apply.

(2) The design methods given in EN 1993-1-3 are applicable if:

- the execution quality is as specified in EN 1090-4, the execution quality of bolted connections is as specified in EN 1090-2, and
- the construction materials and products are as specified in the relevant parts of EN 1993 (all parts), or in the relevant material and product specifications.

(3) EN 1993 is intended to be used in conjunction with:

- the parts of EN 1992 to EN 1999 where steel structures or steel components are referred to within those documents;
- EN standards 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, *Eurocode — Basis of structural and geotechnical design*

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

EN 1993 (all parts), *Eurocode 3 — Design of steel structures*

EN 1993-1-1:2022, *Eurocode 3 — Design of steel structures — Part 1-1: General rules and rules for buildings*

EN 14509, *Self-supporting double skin metal faced insulating panels — Factory made products — Specifications*

EN ISO 7438, *Metallic materials — Bend test (ISO 7438)*

3 Terms, definitions and symbols

3.1 Terms and definitions

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

3.1.1 Material

3.1.1.1

basic material

flat steel sheet material used for cold-forming sections and profiled sheeting

3.1.1.2

basic yield strength

tensile yield strength of the basic material

3.1.1.3

nominal thickness

target average thickness after cold-forming specified by the steel supplier, inclusive of zinc and other metallic coating layers, but not including organic coatings

3.1.1.4

steel core thickness

nominal thickness minus zinc and other metallic coating layers

3.1.1.5

coil

storage system where a continuous plate is wound onto a drum

3.1.1.6

cold-forming

procedure of metal-forming executed near room temperature without the addition of heat

3.1.1.7**press-braking**

method of cold-forming using a brake press, where a metal sheet is bent between a punch and die

3.1.1.8**roll-forming**

metal-forming process involving the continuous bending of a steel sheet into a cross-section by forcing it through successive sets of rolls

3.1.1.9**galvanizing**

zinc coating for corrosion protection

3.1.1.10**harmonized product standard**

European Standard developed by a recognized European Standards Organization: CEN, CENELEC or ETSI, in response to a request from the European Commission to one of these organizations

3.1.2 Cold-formed steel members, sheeting and sandwich panels**3.1.2.1****member**

structural element with cross-sectional dimensions much smaller than its length

Note 1 to entry: Examples of typical cross-sectional shapes of cold-formed steel members are shown in Figure 3.1. Cross-sections of cold-formed steel members can either be unstiffened or incorporate longitudinal stiffeners in the webs, the flanges or both.

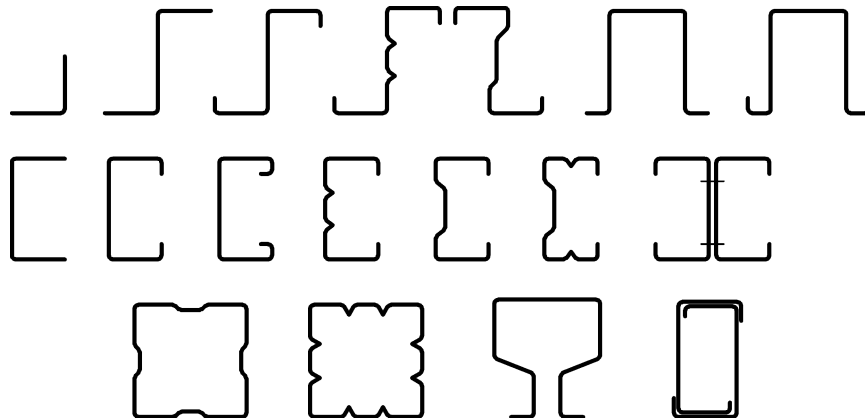


Figure 3.1 — Typical cross-sectional shapes of cold-formed members

3.1.2.2**sheeting**

structural element with a depth much smaller than its width and length, typically used as cladding or roofing or decking

Note 1 to entry: Examples of typical cross-sectional shapes of sheeting are shown in Figure 3.2. Cross-sections of sheeting can either be unstiffened or incorporate longitudinal stiffeners in the webs, the flanges or both.

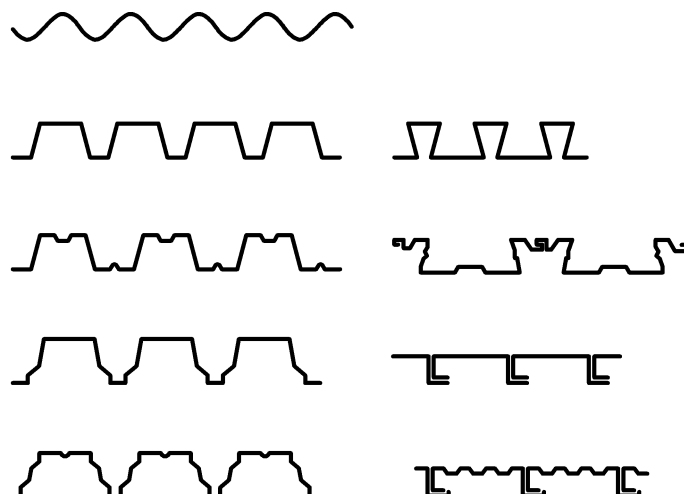


Figure 3.2 — Examples of cold-formed profiled sheeting and liner trays

3.1.2.3

liner tray

profiled sheet with large lipped edge stiffeners, suitable for interlocking with adjacent liner trays to form a plane of ribbed sheeting that is capable of supporting a parallel plane of profiled sheeting spanning perpendicular to the span of the liner trays

Note 1 to entry: Examples of typical cross-sectional shapes of liner trays are shown in Figure 3.2.

3.1.2.4

sandwich panel

cladding or roofing system consisting of a typically low-density core bonded to two outer skin layers

3.1.2.5

bend

rounded transition zone between flat plate elements

3.1.2.6

unstiffened elements

internal or outstand compression elements without stiffeners

3.1.2.7

stiffened elements

compression elements with intermediate or edge stiffeners

3.1.2.8

stiffener

within the context of EN 1993-1-3 the term 'stiffener' without further specification refers to a longitudinal stiffener, i.e. a single fold or succession of folds in the cross-section aimed at increasing the resistance against local buckling/distortional buckling

Note 1 to entry: Longitudinal stiffeners can either be edge stiffeners or intermediate stiffeners.

3.1.2.9

edge stiffener

longitudinal stiffener obtained by folding over the edge of a plate element with the aim of increasing the resistance against cross-sectional instability

Note 1 to entry: Typical edge stiffeners are shown in Figure 3.3.

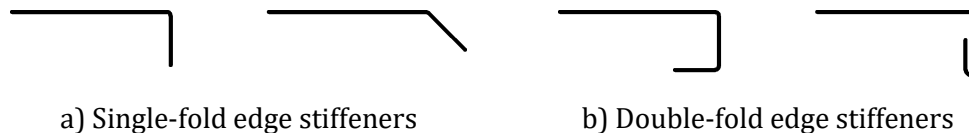


Figure 3.3 — Typical edge stiffeners

3.1.2.10

intermediate stiffener

longitudinal stiffener consisting of multiple bends within a plate element with the aim of increasing the resistance against cross-sectional instability

Note 1 to entry: Typical intermediate stiffeners are shown in Figure 3.4.

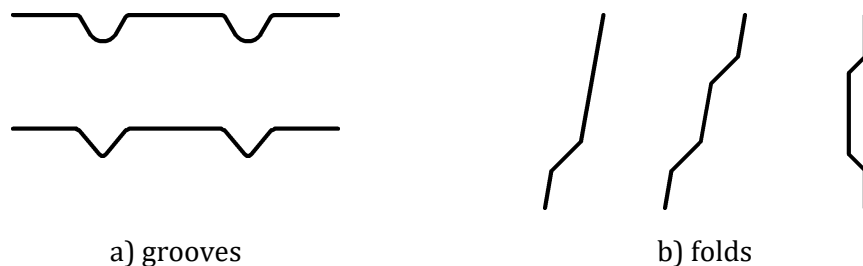


Figure 3.4 — Typical intermediate stiffeners

3.1.3 Stability modes

3.1.3.1

cross-sectional instability

instability where the cross-section as a whole does not undergo any translation or rotation; cross-sectional instabilities are usually categorized into local buckling and distortional buckling modes

3.1.3.2

local (plate) buckling

cross-sectional instability in which the constituent plates only undergo out-of-plane plate bending deformations and the corners of the cross-section remain in their original positions, defined as plate buckling according to EN 1993-1-5

3.1.3.3

distortional buckling

cross-sectional instability where some constituent plates undergo in-plane displacements in addition to out-of-plane displacements resulting from plate bending; in the particular case of lipped C- or Z-sections, distortional buckling may be interpreted as torsional-flexural buckling of the flange-lip assembly about the web-flange junction

3.1.3.4

global buckling

instability characterized by a translation and/or rotation of the cross-section with minimal change in its shape (i.e. excluding cross-sectional instability); global buckling modes include flexural, torsional, torsional-flexural and lateral-torsional modes

3.1.4 Cross-sectional analysis

3.1.4.1

design thickness

steel thickness used in design by calculation, according to 3.3.3(6) and 5.2.4

3.1.4.2

developed length

length measured along the midline of plate element(s) or a cross-section, including the lengths of any bends or stiffeners

3.1.4.3

gross cross-section

full cross-section without any deductions to account for local/distortional buckling or the presence of holes

3.1.4.4

effective cross-section

idealized cross-section accounting for the modified stress distribution in the local/distortional post-buckling range; the effective cross-section consists of portions of the plate elements adjacent to longitudinally supported edges which are assumed to carry stress, while the remainder of the cross-section is assumed to carry no stress

3.1.4.5

effective thickness

reduced thickness of a plate-stiffener assembly to account for the effects of distortional buckling

3.1.4.6

effective width

width or combined widths of a plate element, assumed to carry stress in the post-local buckling range, whilst the remainder of the plate element is assumed to carry no stress (see also: effective cross-section)

3.1.4.7

relative slenderness

normalized non-dimensional slenderness ratio

3.1.5 Cold-formed steel structures

3.1.5.1

support

location at which a member is able to transfer forces or moments to a foundation, or to another member or structural component

3.1.5.2**restraint**

full restriction of the lateral, rotational or warping deformation of a member or element, which increases its buckling resistance

3.1.5.3**partial restraint**

restriction of the lateral, rotational or warping deformation of a member or element, which increases its buckling resistance in a similar way to a spring support

3.1.5.4**residual bending moment resistance**

bending moment resistance remaining in the cross-section after reaching the maximum cross-sectional design bending moment resistance (i.e. on the descending branch of the moment-rotation curve)

3.1.5.5**diaphragm action**

structural behaviour primarily involving in-plane shear in sheeting

3.1.5.6**stressed-skin design**

design method that allows for the contribution made by diaphragm action to the stiffness and strength of a structure

3.1.5.7**anti-sag bar**

member providing lateral restraint to the free flange of a member

3.1.6 Joints**3.1.6.1****joint**

zone where two or more members are interconnected

3.1.6.2**connection**

set of basic components used to transfer forces and moments between two or more members or sheets at the location where they meet

3.1.6.3**basic component of a joint**

part of a joint that makes a contribution to one or more of its structural properties

3.1.6.4**connected element**

any member or sheeting that is joined to another member or sheeting

3.1.6.5

fastener

connection element: rivets, cartridge-fired pins, self-tapping/self-drilling screws, bolts or welds

3.1.6.6

fastening

local interaction of a fastener (rivets, cartridge-fired pins or self-tapping/self-drilling screws) with the surrounding material of the connected elements

3.1.6.7

blind rivet

rivet

mechanical fastener which establishes a connection by pulling a mandrel against its tubular body and plastically deforming it; it requires access to only one side of the connected elements for installation

3.1.6.8

cartridge-fired pins

fasteners similar to nails driven into the connected elements at high speed using a specially designed gun

3.1.6.9

self-drilling self-tapping screw

screw with a drill tip, which drills a hole and forms the female thread in a single operation as the screw is driven into the material

3.1.6.10

self-tapping screw

screw which produces its female thread in a predrilled hole as the screw is driven into the material

Note 1 to entry: Self-tapping screws are also referred to as screw in this document for simplification.

3.1.6.11

component I

connected element of fastening adjacent to the head of the fastener (or the swage head in the case of blind rivets)

3.1.6.12

component II

second connected element of a fastening, usually the supporting structure

3.2 Symbols

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

3.2.1 Latin upper-case symbols

A	area of the gross cross-section
A_{eff}	area of the effective cross-section, accounting for local and distortional buckling
A_i	area of the gross cross-section of element i
A_{net}	net cross-sectional area of a connected part
A_s	tensile stress area of a fastener
A_{sh}	area of the gross cross-section with sharp corners
A_{st}	area of the effective cross-section of the stiffener
$A_{\text{st,red}}$	reduced area of the effective cross-section of the stiffener due to distortional buckling
$A_{\text{st,a}}$	area of the effective cross-section of a single web stiffener in compression or of the web stiffener closer to the compression flange in webs with two stiffeners in trapezoidal sheeting
$A_{\text{st,a,red}}$	reduced area of the effective cross-section of a single web stiffener in compression or of the web stiffener closer to the compression flange in webs with two stiffeners in trapezoidal sheeting
$A_{\text{st,b}}$	area of the effective cross-section of the second web stiffener in compression in trapezoidal sheeting
$A_{\text{st,b,red}}$	reduced area of the effective cross-section of the second web stiffener in compression in trapezoidal sheeting
A_{st1}	area of the effective cross-section of the edge stiffener in flange 1
A_{st2}	area of the effective cross-section of the edge stiffener in flange 2
C	rotational spring stiffness
C_D	rotational spring stiffness which represents the partial torsional restraint provided to members by sheeting, liner trays or sandwich panels
$C_{D,A}$	rotational spring stiffness of the connection between the sheeting, sandwich panels or liner trays and the member
$C_{D,B}$	rotational spring stiffness resulting from the distortion of the cross-section of the member
$C_{D,C}$	rotational spring stiffness representing the flexural stiffness of the sheeting, liner trays or sandwich panels
$C_\theta, C_{\theta i}$	rotational spring stiffness of plane elements with edge or intermediate stiffeners
C_{100}	rotation coefficient representing the value of $C_{D,A}$ if the width of the member flange is equal to 100 mm
D	thickness of a sandwich panel
E	modulus of elasticity

E_C	modulus of elasticity of the core of a sandwich panel
$E_{C,c}$	compressive modulus of elasticity of the core of a sandwich panel
$E_{C,t}$	tensile modulus of elasticity of the core of a sandwich panel
$E_{C,t,\theta}$	modulus of elasticity of the core of a sandwich panel depending on the duration of loading
$F_{b,Rd}$	design value of the bearing resistance of a connection or fastening
$F_{bow,max}$	elastic force of a member in compression, determined with an initial bow according to the product specification
$F_{bow,test}$	elastic force of a member in compression, determined with an initial bow from test samples
F_{Ed}	design value of the transverse force
$F_{Ed,i}$	design value of the transverse forces resulting from an assumed load distribution of a point load or line load over the ribs of trapezoidal sheeting
$F_{e,Rd}$	design value of the end resistance of a spot weld
$F_{k,ol,Ed}$	design value of the shear force in a screw for fastening trapezoidal sheeting at overlaps
F_{lat}	test load in tests on torsionally restrained members
$F_{n,Rd}$	design value of the net-section resistance, determined for the relevant type of mechanical fastener or weld
$F_{o,Rd}$	design value of the pull-out resistance of a fastener
$F_{p,Rd}$	design value of the pull-through resistance of a fastener
$F_{rib,Ed}$	proportion of the design value of the load carried by a rib of trapezoidal sheeting for the purpose of verifying the resistance to transverse forces of the web
F_{str}	total test load in a strength test
F_{supp}	reaction force at the support of sheeting
$F_{t,Ed}$	design value of the tensile force in a fastener
$F_{t,Rd}$	design value of the tensile resistance of a fastener
$F_{t,Rk}$	characteristic value of the tensile resistance of a fastener
$F_{tb,Rd}$	design value of the tearing and bearing resistance of a spot weld
F_{unit}	unit load, acting at the centroid of the assembly consisting of the effective parts of the stiffener and the adjacent effective areas of the stiffened plate
$F_{v,Ed}$	design value of the shear force in a fastener
$F_{v,Rd}$	design value of the shear resistance of a fastener, determined for the relevant type of mechanical fastener or weld
$F_{v,Rk}$	characteristic value of the shear resistance of a fastener, determined for the relevant type of mechanical fastener or weld
$F_{w,Rd}$	design value of the resistance of a fillet or arc spot welded connection
F_{R1}, F_{R2}	transverse reaction forces in the plane of the flanges

G	shear modulus
I	moment of inertia of the gross cross-section
I'	moment of inertia of the gross cross-section related to the centroidal axes $y'-y'$ or $z'-z'$
I_{eff}	moment of inertia of the effective cross-section
I_{fic}	moment of inertia of a fictitious effective cross-section for serviceability limit state design
I_{fz}	moment of inertia of the gross cross-section of the free flange plus the contributing part of the web for bending about the z - z axis
$I_{\text{lt,a}}$	moment of inertia of the wide flange of a liner tray about its own centroidal axis parallel to the wide flange
I_{sh}	moment of inertia of the gross cross-section with sharp corners
I_{st}	moment of inertia of the cross-section of a stiffener
$I_{\text{st,a}}$	moment of inertia of the effective cross-section of a single web stiffener in compression or of the web stiffener closer to the compression flange in webs with two stiffeners in trapezoidal sheeting about its own centroidal axis parallel to the stiffened element
I_{T}	torsional constant of the gross cross-section
I_{w}	warping constant of the gross cross-section
$I_{\text{w,eff}}$	warping constant of the effective cross-section
$I_{\text{w,sh}}$	warping constant of the gross cross-section with sharp corners
$I(\sigma)_{\text{eff}}$	moment of inertia of the effective cross-section calculated for a maximum stress $\sigma \geq \sigma_{\text{gr}}$, used in serviceability limit state design
K	equivalent linear spring stiffness which represents the partial rotational restraint provided by sheeting, liner trays or sandwich panels in member design
K_{a}	stiffness parameter which accounts for the presence of a steel saddle washer when determining the rotational stiffness of trapezoidal sheeting
K_{A}	stiffness against lateral displacement of a member resulting from the rotational stiffness of the joint between the sheeting and the member;
K_{B}	stiffness against lateral displacement of a member resulting from the distortion of the cross-section of the member
K_{C}	stiffness against lateral displacement of a member resulting from the flexural stiffness of the sheeting
K_{fz}	spring stiffness of the compressed flanges of liner trays
$K_{\text{ol,f}}$	spring stiffness which represents the fasteners in the overlapping flanges of trapezoidal sheeting
$K_{\text{ol,w}}$	spring stiffness which represents the fasteners in the overlapping webs of trapezoidal sheeting
K_{st}	spring stiffness of a stiffener in a cold-formed steel section
$K_{\text{st,1}}$	spring stiffness of a stiffener in flange 1

K_1	category dependent coefficient for calculating the resistance to transverse forces
L	member length
L_a	distance between anti-sag bars or, if none are present, the span length of the member
L_{dia}	overall length of the steel diaphragm in the direction of the span of the sheeting
L_e	distance between a deflection measurement point and a sheeting support in a test
L_{lim}	maximum span length of sheeting which may be walked on by a single person
$L_{lim,test}$	maximum span length of sheeting which may be walked on by a single person, determined by testing
L_{span}	span length of profiled sheeting or sandwich panels
L_T	length of the member between torsional and/or warping restraints
L_{test}	test span
M	bending moment
$M_{c,Rd}$	design value of the bending moment resistance of a cross-section
$M_{c,Rk}$	characteristic value of the bending moment resistance of a cross-section
$M_{c,Rd,com}$	design value of the bending moment resistance of a cross-section using the section modulus for the compression side
$M_{c,Rd,ten}$	design value of the bending moment resistance of a cross-section using the section modulus for the tension side
M_d	design value of the bending moment resistance obtained from a test
$M_{d,lim}$	design value of the support moment resistance of sheeting obtained from a test and corresponding to an arbitrary chosen rotation limit θ_{lim}
M_{Ed}	design value of the bending moment
$M_{f,Rd}$	design value of the bending moment resistance of a cross-section consisting of the effective areas of the flanges only
$M_{fz,Ed}$	design value of the lateral bending moment in the free flange of a member
$M_{lt,c,Rd}$	design value of the bending moment resistance of a liner tray with the wide flange in compression
$M_{lt,t,Rd}$	design value of the bending moment resistance of a liner tray with the wide flange in tension
M_{mean}	mean value of the bending moment resistances resulting from tests
$M_{pl,Rd}$	design value of the plastic bending moment resistance of the cross-section consisting of the effective areas of the flanges and the gross area of the web
$M_{span,Ed}$	maximum design value of the bending moment in the span
$M_{supp,Ed}$	design value of the support moment
$M_{supp,Rd}$	design value of the bending moment resistance at the support

M_0	value of the bending moment used to calculate the resistance to combined bending moment and transverse forces
$M_{0,fz,Ed}$	design value of the initial lateral bending moment in the free flange of a member without any spring supports
$\widehat{M}_{c,Rd}$	design value of the bending moment resistance of curved sheeting without accounting for the arching effect
N	axial load
$N_{b,Rd}$	design value of the buckling resistance for flexural buckling
$N_{b,Rk,ref}$	characteristic value of the buckling resistance of the narrow flange of a liner tray calculated with the reference buckling length
$N_{b,Rk,1}$	characteristic value of the buckling resistance of the narrow flange of a liner tray calculated with the relevant buckling length
N_{cr}	elastic critical buckling load of a member
$N_{cr,i}$	minimum elastic critical buckling load of a member
$N_{cr,T}$	elastic critical buckling load for torsional buckling
$N_{cr,TF}$	elastic critical buckling load for torsional-flexural buckling
$N_{c,Rd}$	design value of the resistance of a cross-section for uniform compression
N_{Ed}	design value of the axial force
N_{Rd}	design value of the resistance of a cross-section to axial forces
$N_{t,Rd}$	design value of the tensile resistance
N_{test}	number of tests
P	midpoint of the corner between adjacent plane elements in a cold-formed steel section
R	radius of the corrugations in sinusoidal sheeting
R_{adj}	adjusted value of a resistance obtained from test results
$R_{adj,i}$	adjusted value of the resistance obtained from the i -th test specimen
$R_{adj,i,j}$	adjusted value of the resistance of specimen i of test series j
$R_{adj,m,j}$	mean value of the adjusted resistances of test series j
R_d	design value of the resistance obtained from testing
R_{eh}	value of the yield strength given by the product standard
R_k	characteristic value of a resistance obtained from testing
$R_{k,j}$	characteristic value of the resistance obtained from a test series j
R_m	value of the ultimate tensile strength given by the product standard
R_{obs}	value of a resistance obtained from testing
$R_{obs,min}$	minimum value of a resistance obtained from testing

$R_{p0,2}$	value of the 0,2 % proof stress given by the product standard
R_w	reaction force in the plane of the web
$R_{w,Rd}$	design value of the resistance of the web to transverse forces
R_0	value of the transverse force used to calculate the resistance to combined bending moment and transverse forces
S	contribution to the shear stiffness provided by the sheeting, liner trays or sandwich panels
S_{lt}	shear stiffness of a steel liner tray diaphragm per unit length
U_i	utilization ratio of a splice or joint
$V_{b,Rd}$	design value of the shear resistance of a cross-section in the plane of the web
V_{Ed}	design value of the shear force
$V_{supp,l,Ed}$	design value of the shear force adjacent to the support in sheeting with single overlaps
$V_{w,Rd}$	design value of the shear resistance of a cross-section perpendicular to the flanges
V_x	coefficient of variation
W	section modulus of a cross-section
W_{eff}	elastic section modulus of the effective cross-section, accounting for local and distortional buckling
W_{el}	elastic section modulus of the gross cross-section
W_{fz}	elastic section modulus of the cross-section consisting of the gross cross-section of the free flange of a member plus the contributing part of the web, for bending about the z-z axis
W_{pl}	plastic section modulus of the gross cross-section
$W_{pp,eff}$	partially plastic section modulus of the effective cross-section, based on a stress distribution which is bilinear in the tension zone but linear in the compression zone
X	point of intersection of midlines of adjacent plane elements in a cold-formed steel section

3.2.2 Latin lower-case symbols

a_{end}	distance from the internal edge of the end support to the end of sheeting (in end support tests)
a_f	distance from the fasteners in the flanges of sheeting to the web
a_{fp}	distance from the sheet-to-member fastener to the member web
a_{ol}	length of the overlap of trapezoidal sheeting
a_{per}	spacing between the centres of the perforations in sheeting
a_{pur}	distance between member
a_s	distance from the load q_{ed} to the shear centre (measured in the y-direction)
$a_{w,min}$	minimum distance from the centre of an arc spot weld to the nearest edge of an adjacent weld

$a-a$	centroidal axis of the stiffener parallel to the adjacent plane elements to be stiffened
b	overall width of the flange
b_a	width of the member flange
b_c	width of the compression zone, determined from a bilinear stress distribution
b_{cleat}	width of the cleat
b_{corr}	corrugation width of trapezoidal sheeting
$b_{corr,max}$	maximum allowable corrugation width of trapezoidal sheeting
b_{curl}	half the distance between webs in box and hat sections, or the width of the portion of the flange projecting from the web, required in flange curling calculations
b_{df}	developed width of a flange, measured along its midline, including any flange stiffeners
b_e	portion of a compression flange with two stiffeners in trapezoidal sheeting
b_{eff}	effective width of a plane element
b_{e1}	portion of the effective width of a plane element
b_{e2}	portion of the effective width of a plane element
b_{e0}	effective width of an outstand element
b_f	width of the flange, measured from the midline of the web
b_i	width of plane element i
$b_{i,e1}$	portion of the effective width of plane element i
$b_{i,e2}$	portion of the effective width of a plane element i
b_{K1}	distance from the web-to-flange junction to the centroid of the effective cross-section of the edge stiffener of flange 1
b_{K2}	distance from the web-to-flange junction to the centroid of the effective cross-section of the edge stiffener of flange 2
b_{lt}	overall width of the wide flange of liner trays
$b_{lt,eff}$	effective width of the wide flange of liner trays
b_m	portion of a compression flange with one stiffener in trapezoidal sheeting
b_{mod}	modified width of the member flange connected to the sheeting
b_p	notional flat width of plane elements
$b_{p,c}$	notional flat width of a single-fold edge stiffener (lip)
$b_{p,c1}, b_{pc2}$	notional flat widths of a double-fold edge stiffener
$b_{p,i}$	notional flat width of plane element i in a cross-section with sharp corners
b_{rib}	rib width of trapezoidal sheeting
b_{st}	width of a flange stiffener in trapezoidal sheeting, measured parallel to the centreline of the flange

$b_{st,d}$	developed width of a stiffener in trapezoidal sheeting, measured along the midline of the stiffener
$b_{st,mult}$	width of a compression flange with multiple stiffeners in trapezoidal sheeting, measured parallel to the centreline of the compressed flange
$b_{st,d,mult}$	developed width of a compression flange in trapezoidal sheeting with multiple stiffeners, measured along the midline of the stiffeners
b_{supp}	support width of sheeting in end support tests
b_{sw}	width of a sandwich panel
b_t	width of the tension zone, determined from a bilinear stress distribution
$b_{tot,i}$	portions of the flange width of trapezoidal sheeting
b_u	width of the flange of trapezoidal sheeting which is fastened to the supporting member
$b_{u,max}$	maximum allowable width of the flange of trapezoidal sheeting which is fixed to the supporting member
$\bar{b}$	relevant width of a plane element for local buckling analysis
$b-b$	centroidal axis of the stiffener perpendicular to the adjacent plane elements to be stiffened
c	width of the lip of a single-fold edge stiffener
c_{eff}	effective width of the lip of a single-fold edge stiffener
c_{eq}	equivalent width of the lip (of a single-fold edge stiffener) which is not perpendicular to the flange
c_k	distance between the two fasteners of a pair in sandwich panels
c_l	width of the lip measured from the midline of the flange
c_1	width of the internal plane element within a double-fold edge stiffener
$c_{1,eq}$	equivalent width of a double-fold edge stiffener which is not perpendicular to the flange
$c_{1,eff}$	total effective width of the internal plane element within a double-fold edge stiffener
$c_{1,e1}$	portion of the effective width of the internal plane element within a double-fold edge stiffener
$c_{1,e2}$	portion of the effective width of the internal plane element within a double-fold edge stiffener
$c_{1,l}$	width of the internal plane element within a double-fold edge stiffener, measured between the midlines of the adjacent elements
c_2	width of the outstand plane element within a double-fold edge stiffener
$c_{2,l}$	width of the outstand plane element within a double-fold edge stiffener, measured from the midline of the adjacent elements
$c_{2,eff}$	effective width of the outstand plane element within a double-fold edge stiffener
d	nominal diameter of a fastener, generally the outside diameter of the threads

d_{as}	visible diameter of an arc spot weld
d_p	effective peripheral diameter of an arc spot weld
d_{per}	diameter of the perforations in sheeting
d_s	interface diameter of a spot weld or arc spot weld
d_w	diameter of the washer or the head of the fastener
d_o	nominal diameter of a fastener hole
e	pitch of the sheeting-to-member fasteners
e_N	shift of the centroid of the effective cross-section relative to the centroid of the gross cross-section
e_f	eccentricity of fasteners in sheeting
$e_{lt,0}$	distance from the centroidal axis of the gross cross-section of liner trays to the centroidal axis of the narrow flanges
e_u	distance from the seam fasteners in the webs of liner trays to the wide flange
e_w	eccentricity of the folds in a web relative to the line connecting the end points of the web
e_0	bow imperfection
$e_{0,LT}$	bow imperfection for lateral-torsional buckling
e_1	end distance, measured from the centre of the fastener to the adjacent end of the connected part, in the direction of load transfer
e_2	edge distance, measured from the centre of the fastener to the adjacent edge of the connected part, in the direction perpendicular to the direction of load transfer
f_{bv}	shear strength accounting for shear buckling
f_{cc}	compressive strength of the core material of sandwich panels
f_{ct}	tensile strength of the core material of sandwich panels
f_u	ultimate tensile strength of the material; for connections with bolts or welds: the ultimate tensile strength of the material of the supporting member into which a bolt is fixed or onto which a weld is applied
f_{ub}	ultimate tensile strength of the fastener material
f_{uw}	ultimate tensile strength of the welding electrodes
$f_{u,I}$	for fastenings with rivets, screws or cartridge-fired pins: the ultimate tensile strength of component I directly underneath the head of the fastener (the swage head in the case of blind rivets)
$f_{u,II}$	for fastenings with rivets, screws or cartridge-fired pins: the ultimate tensile strength of component II (usually the supporting structure)
f_y	yield strength
f_{ya}	average yield strength, accounting for work hardening due to cold-forming
f_{yb}	basic yield strength

f_{ym}	average measured basic yield strength of a component in a test
$f_{yb,obs}$	experimentally measured basic yield strength
g_r	distance from the midpoint P of a corner of a cold-formed steel section to the point of intersection X of the midlines
g_s	distance from the loaded flange of a cold-formed steel section to the shear centre, measured in the z -direction
h	overall depth of the cross-section
h_a	portion of the depth of a stiffened web of trapezoidal sheeting
h_b	portion of the depth of a stiffened web of trapezoidal sheeting
h_c	distance from the neutral axis of the effective cross-section of trapezoidal sheeting to the centreline of the compression flange
h_d	developed depth of a web, measured along its midline, including any web stiffeners
$h_{lt,u}$	depth of the corrugations in the wide flange of liner trays
$h_{st,a}$	width of a single web stiffener in compression or of the web stiffener closer to the compression flange in webs with two stiffeners in trapezoidal sheeting
$h_{st,b}$	width of a second stiffener in webs with two stiffeners in trapezoidal sheeting
h_t	distance from the neutral axis of the effective cross-section of trapezoidal sheeting to the centreline of the tension flange
h_w	depth of the web between the midlines of the flanges
i_{fz}	radius of gyration of the free flange of a member
i	radius of gyration of the gross cross-section
i_{min}	minimum radius of gyration of the gross cross-section
i_0	polar radius of gyration of the gross cross-section relative to the shear centre
k_A	coefficient for calculating the rotational stiffness of the connection between sheeting and members in the case of gravity loading
k_{ba}	coefficient which accounts for the width of the member when calculating the rotational stiffness of the connection between sheeting and members
$k_{b,corr}$	coefficient which accounts for the corrugation width of trapezoidal sheeting when calculating the rotational stiffness of the connection between sheeting and members
k_{bu}	coefficient for calculating the rotational stiffness of the connection between sheeting and members in the case of uplift loading
k_{ce}	coefficient which accounts for the curved elements of the gross cross-section
k_{c1}	coefficient which depends on the core material of sandwich panels
k_{c2}	coefficient which depends on the core material of sandwich panels
k_{fp}	coefficient which depends on the forming process

k_h	coefficient for the conversion of torsion and lateral bending of members into an equivalent lateral load
k_{h0}	coefficient to determine the equivalent lateral load on the free flange of a member
$k_{i, sb}$	coefficients for calculating the resistance of a web to transverse forces
$k_{ld, i}$	coefficients which account for the dispersal of transverse forces in trapezoidal sheeting
k_{lf}	coefficient which accounts for the type of loading in the flanges of a cross-section
k_{ls}	coefficient which accounts for the loading on trapezoidal sheeting
k_n	coefficient used in the statistical evaluation of test results
k_{num}	coefficient which accounts for the number of bolts in the connection
k_{ol}	coefficient for calculating the spring stiffness of connections at overlaps of sheeting
k_{pur}	coefficient for calculating the rotational stiffness of a member
k_{ss}	coefficient which accounts for a member spring support
$k_{st, w}$	coefficient for calculating the resistance of a stiffened web to transverse forces
k_t	coefficient which accounts for the thickness of sheeting or members when calculating the bearing resistance of bolts
k_v	shear stiffness of a fastener of sandwich panels
k_α	stiffness coefficient for steel liner tray diaphragms
$k_{\theta f}$	coefficient which accounts for the partial rotational restraint of webs by the flanges in trapezoidal sheeting
$k_{\theta w}, k_{\theta w0}$	coefficients which account for the partial rotational restraint of the compression flange by the webs or other adjacent elements in trapezoidal sheeting
k_σ	buckling factor for plane elements subject to longitudinal stresses
k_τ	buckling factor for plane elements subject to shear
k_1	factor for sandwich panels
l_A	width of the sheeting in a test on torsionally restrained members
l_B	length of the beams in a test on torsionally restrained members
l_{bl}	effective bearing length
l_{cr}	buckling half-wavelength corresponding to the minimum buckling stress
$l_{cr, f}$	buckling half-wavelength of the stiffened compression flange in trapezoidal sheeting
$l_{cr, T}$	buckling length for torsional or flexural-torsional buckling of members
$l_{cr, LT}$	buckling length for lateral-torsional buckling of members
$l_{cr, y}, l_{cr, z}$	buckling lengths for flexural buckling of members
l_{end}	distance from the free end of a member to the position where the transverse force is applied
l_F	length over which transverse forces are introduced

l_{fz}	buckling length of the free flange of a member
l_{sb}	nominal length of stiff bearing
l_{spac}	spacing between transverse forces applied on opposite sides of the web
l_T	buckling length for torsional or flexural-torsional buckling, determined taking into account the degree of torsional and/or warping restraint present at each end of the length L_T
l_w	overall length of a fillet weld
$l_{w,e}$	effective length of an end fillet weld
$l_{w,s}$	effective length of a side fillet weld
$l_{w,as}$	length of an elongated arc spot weld
m	applied bending moment per unit width of sheeting or sandwich panel
n	number
n_c	number of corrugations between the longitudinal edge of a sheet and the corresponding edge of the next sheet
n_f	number of mechanical fasteners in one connection
n_{ce}	number of curved elements in a cold-formed steel cross-section
n_k	number of pairs of fasteners per sandwich panel and support
n_j	number of individual tests in test series j
n_p	number of whole corrugations with overlapping sheeting within the width n_c
n_{pe}	number of plane elements in a cold-formed steel cross-section
n_r	number of 90° bends with internal radius $r \leq 5t$ in the cross-section
n_s	number of sheets that are fixed to the supporting member by the same screw or pin;
n_w	number of spot welds in one connection
p	width of corrugations in sinusoidal sheeting
p_{ol}	spacing of fasteners in overlaps of trapezoidal sheeting
p_1	centre-to-centre spacing of fasteners in the direction of load transfer
$p_{1,lt}$	centre-to-centre spacing of fasteners in liner trays in the longitudinal direction
p_2	centre-to-centre spacing of fasteners in the direction perpendicular to the direction of load transfer
q	self-weight of the roof, including the self-weight of the profiled sheeting
q_{Ed}	uniformly distributed load acting on a member
$q_{h,Ed}$	equivalent lateral loading acting on the free flange of a member resulting from torsion and lateral bending
q_{pur}	load introduced by the sheeting into a member
q_s	shear force in a sheet-to-member fastener

q_t	tensile force in a sheet-to-member fastener
q_0	self-weight of the roof, including the self-weight of the profiled sheeting times the amplification factor a_{per}
r	internal bend radius
r_{beam}	radius of curvature of an arched beam
$r_{ce,j}$	internal bend radius of a curved element j
r_m	bend radius measured along the midlines of the cold-formed steel section
s	thread pitch of fasteners
s_a	portion of the slant height of a web of trapezoidal sheeting
s_b	portion of the slant height of a web of trapezoidal sheeting
s_c	portion of the slant height of a web of trapezoidal sheeting
s_d	total developed height of the web, measured along its midline, including any web stiffeners
$s_{eff,0}$	basic effective width of the web of trapezoidal sheeting
$s_{eff,i}$	portions of the effective width of the web of trapezoidal sheeting
$s_{eff,n}$	portion of the effective width of the web of trapezoidal sheeting next to the centroidal axis
s_n	portion of the slant height of a web of trapezoidal sheeting
s_p	slant height of the widest plane element in the web
s_{per}	slant height of the perforated part of a web of trapezoidal sheeting
s_{pF}	slant height of the plane web element nearest to the flange which is loaded by transverse forces
$s_{st,a}$	portion of a web stiffener of trapezoidal sheeting
$s_{st,b}$	portion of a web stiffener of trapezoidal sheeting
$s_{tot,i}$	sum of portions of the web heights of trapezoidal sheeting
s_w	slant height of the web, measured between the midlines of the flanges parallel to the web
s_x	standard deviation of test results
t	design thickness of the steel material
$t_{a,eq}$	equivalent thickness of perforated sheeting for the purpose of calculating the section properties of the gross cross-section
$t_{b,eq}$	equivalent thickness of perforated sheeting for the purpose of calculating the section properties of the effective cross-section
$t_{c,eq}$	equivalent thickness of perforated sheeting for the purpose of calculating the resistance of the web to transverse forces
t_{cleat}	thickness of the cleat
t_{cor}	nominal thickness minus the thickness of the zinc and other metallic coatings

$t_{\text{cor,obs}}$	experimentally measured core thickness
t_{eff}	effective thickness of a portion of an outstand element to account for local buckling
t_{eq}	equivalent thickness of the steel material
t_{F2}	nominal thickness of the inner face sheet of sandwich panels
$t_{\text{lt,eq}}$	equivalent thickness of the wide flange of a liner tray
t_{mc}	thickness of zinc and other metallic coatings
t_{nom}	nominal sheet thickness after cold-forming, inclusive of zinc and other metallic coatings, but not including any organic coatings
t_{obs}	experimentally measured thickness of the material
t_{red}	reduced design thickness of a stiffener to account for distortional buckling
t_{sheet}	thickness of steel sheeting
t_{supp}	design thickness of the flange of the supporting member
t_{w}	thickness of a steel washer
t_{I}	for fastenings with rivets, screws or cartridge-fired pins: the thickness of component I directly underneath the head of the fastener (the swage head in the case of blind rivets)
t_{II}	for fastenings with rivets, screws or cartridge-fired pins: the thickness of component II (usually the supporting structure)
t_1	for spot welds: the thickness of the thicker connected part
v_{curl}	maximum displacement of the flange towards the neutral axis as a result of curling
$v_{\text{lt,Ed}}$	design value of the shear flow in a steel liner tray diaphragm
$v_{\text{lt,Rd}}$	design value of the shear resistance of a steel liner tray diaphragm
$v_{\text{lt,Ed,ser}}$	shear flow in a steel liner tray diaphragm in the serviceability limit state
$v_{\text{lt,Rd,ser}}$	design value of the shear resistance of a steel liner tray diaphragm in the serviceability limit state
v_{st}	deflection of a stiffener due to a unit load F_{unit}
w	cover width of sinusoidal sheeting
x	distance in the x -direction along the member
x_{A}	distance in the x -direction from the cross-section under consideration to a simple support or a point of contraflexure
x_{B}	distance in the x -direction from the cross-section under consideration to a simple support or a point of contraflexure
$x_{\text{i,j}}$	normalized values of adjusted resistances obtained from tests
x_{s}	distance in the x -direction from the cross-section under consideration to a simple support or a point of contraflexure
x - x	axis along the member

y	distance in the y -direction measured from the neutral axis of the cross-section
y - y	principal axis of a cross-section
y' - y'	centroidal axis of a cross-section parallel to the flanges, or centroidal axis of sheeting parallel to the plane of the sheeting
y_o	y -coordinate of the shear centre relative to the centroid of the gross cross-section
z	distance in the z -direction measured from the neutral axis of the cross-section
z_c	distance in the z -direction from the compressive flange to the neutral axis of the cross-section
z_t	distance in the z -direction from the tension flange to the neutral axis of the cross-section
z_o	y -coordinate of the shear centre relative to the centroid of the gross cross-section
z - z	principal axis of a cross-section
z' - z'	centroidal axis of a cross-section parallel to the web, or centroidal axis of sheeting perpendicular to the plane of the sheeting

3.2.3 Greek upper-case symbols

Δ_{tol}	minus tolerance of the thickness in %, as specified by the product standard or the production specification document
ΔM_{Ed}	additional bending moment resulting from the shift of the centroid of the effective cross-section relative to the centroid of the gross cross-section

3.2.4 Greek lower-case symbols

α	exponent used in the adjustment of test results
α_b	coefficient for calculating the bearing resistance of bolts
α_l	exponent for calculating the bow imperfection
α_{per}	load amplification factor accounting for openings in sheeting
α_r	coefficient for calculating the bearing resistance of rivets
α_{sc}	coefficient for calculating the bearing resistance of self-tapping screws
α_T	coefficient of linear thermal expansion
α_y, α_z	exponents used in the member check for combined bending and compression
β	exponent used in the adjustment of test results
β_A	ratio of the area of the effective cross-sections to the area of the gross cross-section
β_{Lf}	reduction factor for long joints
β_i	exponent for calculating the bow imperfection
β_{lt}	correlation factor for calculating the buckling resistance of liner trays in bending
β_V	interaction factor for calculating the resistance to transverse forces

β_z	exponent used in the member check for combined bending and compression
γ_{M0}	partial factor for the resistance of cross-sections
γ_{M1}	partial factor for the resistance of members to global instability
γ_{M2}	partial factor for the resistance to fracture in tension
$\gamma_{M,ser}$	partial factor for serviceability limit state calculations
δ	deflection
δ_e	average deflection in an end support test on sheeting, measured at a given distance from the supports
δ_{el}	net deflection corresponding to a given load on the rising part of the test curve in an internal support test on sheeting
δ_{lat}	lateral displacement of the top flange of a member in a test on torsionally restrained members
δ_{lin}	fictitious net deflection, obtained assuming linear load-deflection behaviour in an internal support test on sheeting
δ_{pl}	net deflection corresponding to a given load on the falling part of the test curve in an internal support test on sheeting
δ_y, δ_z	exponents used in the member check for combined bending and compression
ε	material factor depending on the yield strength
ε_a	material factor depending on the average yield strength f_{ya}
ε_b	material factor depending on the basic yield strength f_{yb}
$\varepsilon_{mp,cf}$	maximum acceptable plastic strain for cold-formed structures
ζ	factor for calculating the reaction forces of simply supported members
η_i	coefficient for calculating the buckling length of the free flange of a member, depending on the loading and the number of anti-sag bars
η_k	adjustment coefficient accounting for a small number of test results
η_{sys}	conversion factor accounting for the differences in behaviour between test conditions and actual service conditions
θ	rotation
θ_{Ed}	plastic hinge rotation in the member over the support
θ_{lim}	rotation limit
κ_R	correction factor for the location and boundary conditions of a member
$\bar{\lambda}$	relative slenderness for calculating a bow imperfection of a member
$\bar{\lambda}_d$	relative slenderness for distortional buckling
$\bar{\lambda}_{d,red}$	reduced relative slenderness for distortional buckling
$\bar{\lambda}_e$	relative slenderness of a plane element for local or distortional buckling

$\bar{\lambda}_{e,0}$	limit value of the relative slenderness of a plane element for local or distortional buckling
$\bar{\lambda}_{fz}$	relative slenderness for flexural buckling of the free flange of a member
$\bar{\lambda}_p$	relative slenderness for local buckling of plane elements subject to longitudinal stresses
$\bar{\lambda}_{p,red}$	reduced relative slenderness for local buckling of plane elements subject to longitudinal stresses
$\bar{\lambda}_w$	relative web slenderness for local buckling of plane elements subject to shear
λ_1	reference slenderness to determine the relative slenderness
μ	factor which accounts for the utilization of the bending moment capacity
μ_F	load adjustment coefficient in strength tests
μ_R	resistance adjustment coefficient for test results
μ_{so}	factor which accounts for the increase in the bending moment resistance of sheeting with overlaps
ν	Poisson's ratio
ξ	factor for calculating the forces in member-to-sheeting fasteners
ρ	reduction factor for local buckling used to calculate the effective width of a plane element
σ	longitudinal stress
σ_a	mean stress in the flanges calculated on the basis of the gross cross-section
$\sigma_{com,Ed}$	maximum compressive stress in a plane element or stiffener
$\sigma_{com,Ed,n,red}$	reduced compressive stress in a plane element or stiffener calculated after a number of iterative cycles
$\sigma_{com,Ed,ser}$	compressive stress in a plane element under the serviceability limit state loading
σ_{cr}	elastic critical buckling stress of a cross-section, plane element or plate assembly
$\sigma_{cr,mod}$	modified elastic critical buckling stress of sheeting with both flange and web stiffeners
$\sigma_{cr,st}$	elastic critical buckling stress of the stiffener(s)
$\sigma_{cr,st,a}$	elastic critical buckling stress of a single web stiffener or the stiffener closer to the compression flange in webs with two stiffeners in trapezoidal sheeting
$\sigma_{eff,ser}$	maximum compressive bending stress in the serviceability limit state, based on the effective cross-section properties
$\sigma_{gr,ser}$	maximum compressive bending stress in the serviceability limit state, based on the gross cross-section properties
$\sigma_{max,Ed}$	design value of the maximum longitudinal stress
$\sigma_{M,Ed}$	design value of the longitudinal stress due to a bending moment
$\sigma_{N,Ed}$	design value of the longitudinal stress due to an axial force
$\sigma_{tot,Ed}$	design value of the total longitudinal stress resulting from all actions

$\sigma_{w,Ed}$	design value of the longitudinal stress due to warping torsion
σ_1, σ_2	values of a linear longitudinal stress profile at the longitudinal edges of a plane element
τ_{cr}	elastic critical shear buckling stress of a cross-section or plane element
$\tau_{t,Ed}$	design value of the shear stress due to uniform (St.-Venant) torsion
$\tau_{tot,Ed}$	design value of the total shear stress resulting from the design values of all actions, calculated on the basis of the gross cross-section
$\tau_{V,Ed}$	design value of the shear stress due to a transverse shear force
$\tau_{w,Ed}$	design value of the shear stress due to warping torsion
$\varphi_{\theta,t}$	parameter accounting for the duration of loading when determining the modulus of elasticity of the core of sandwich panels
ϕ	angle between two plane elements, typically the angle between the web and the flange of cold-formed sections or trapezoidal sheeting
ϕ_{fic}	angle between the stiffened web and the flange of the cold-formed section or sheeting relative to the line connecting the end points of the stiffened web;
ϕ_{fz}	parameter to determine the reduction factor for global buckling
ϕ_0	sway imperfection
χ	reduction factor to determine the buckling resistance according to the relevant buckling curve
χ_d	reduction factor to determine the distortional buckling resistance
$\chi_{d,n}$	reduction factor to determine the distortional buckling resistance, obtained after a number of iterative cycles
χ_{fz}	reduction factor for lateral-torsional buckling of members, equated to flexural buckling of the free flange
χ_y, χ_z	reduction factors for flexural buckling
χ_{TF}	reduction factor for torsional-flexural buckling
χ_{LT}	reduction factor for lateral-torsional buckling
ψ	ratio of the longitudinal stresses at the extremities of a plane element
$\omega_{x,y}, \omega_{x,z}, \omega_{x,LT}$	interpolation factors in the design stability check of members in combined bending and compression

3.3 Symbols for cross-sectional dimensions

(1) The overall dimensions of cold-formed steel members and sheeting, including the overall width b , the overall depth h , the internal bend radius r and other dimensions denoted by symbols without subscripts, are measured to the face of the material, as illustrated in Figure 3.5, unless stated otherwise.

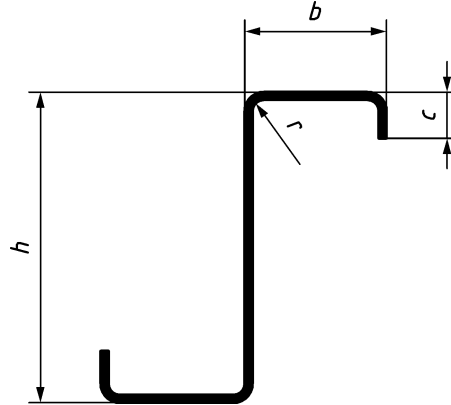


Figure 3.5 — Dimensions of typical cross-section

(2) The other cross-sectional dimensions of cold-formed steel members and sheeting, denoted by symbols with subscripts, such as b_f , h_w or s_w , are measured between the midlines of the plates or between the midpoints of the corners, unless stated otherwise.

(3) In the case of sloping elements, such as webs of trapezoidal sheets, the slant height s_w is measured parallel to the sloping line connecting the intersection points of the flanges and the web.

(4) The developed depth of a web h_d is measured along its midline, including any web stiffeners. An example is provided in Figure 11.5.

(5) The developed width of a flange b_{df} is measured along its midline, including any intermediate flange stiffeners. An example is provided in Figure 8.10.

(6) The thickness t is a design thickness of the steel as specified in 5.2.4(4), if not stated otherwise.

3.4 Symbols for member axes

(1) In general, the convention for the coordinate axes of member cross-sections is as laid out in EN 1993-1-1. In addition, Figure 3.6 specifies the axes conventions for cold-formed steel cross-sections which are not doubly symmetric.

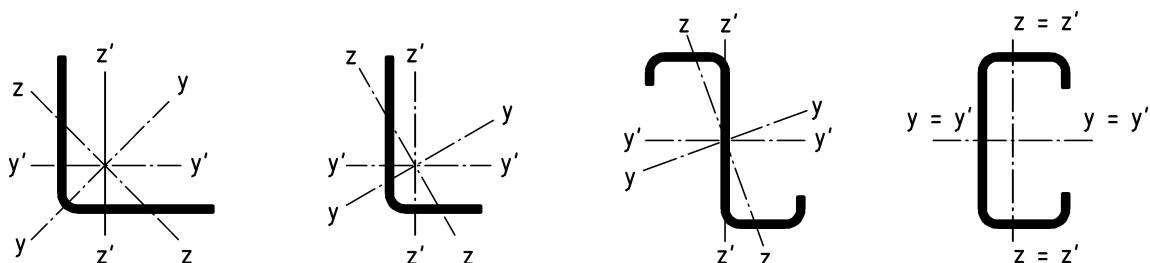


Figure 3.6 — Axes convention of typical cold-formed steel sections

(2) For cold-formed steel sections, profiled sheeting and liner trays the following axis convention is used:

- y - y major principal axis;
- z - z minor principal axis;
- y' - y' centroidal axis parallel to the flanges or parallel to the plane of the sheeting;
- z' - z' centroidal axis parallel to the web or perpendicular to the plane of the sheeting.

NOTE The design rules of this document generally relate to the section properties about the principal axes y - y and z - z . However, in some cases the bending axis is imposed by connected structural elements and does not coincide with one of the principal axes (see e.g. Clause 11).

4 Basis of design

4.1 Basic requirements

(1) The design of cold-formed steel members and sheeting 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 EN 1993-1-1.

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

4.2 Specific rules for cold-formed members and sheeting

(1) This document specifies design rules for cold-formed members and sheeting. For a general design approach based on Finite Element methods, see EN 1993-1-14.

(2) Appropriate partial factors shall be adopted for ultimate limit states and serviceability limit states.

(3) In ultimate limit state calculations, the partial factor γ_M shall be taken as follows:

- when calculating the resistance of cross-sections against yielding and cross-sectional instability, including local and distortional buckling: γ_{M0}
- when calculating the resistance of members and sheeting against global buckling: γ_{M1}
- when calculating the resistance of net sections at fastener holes and connections: γ_{M2} .

NOTE The partial factors γ_{Mi} for buildings are given below, unless the National Annex specifies different values:

- $\gamma_{M0} = 1,00$;
- $\gamma_{M1} = 1,00$;
- $\gamma_{M2} = 1,25$.

(4) In serviceability limit state calculations the partial factor $\gamma_{M,ser}$ shall be used.

NOTE The partial factor $\gamma_{M,ser}$ for buildings is given below, unless the National Annex specifies a different value:
 $\gamma_{M,ser} = 1,00$.

(5) In the design of structures, a distinction shall be made between various 'structural classes', based on the level of contribution of cold-formed steel members, sheeting or sandwich panels to the strength and stability of the overall structure or that of individual structural elements. These structural classes are associated with different requirements in the applicable product and execution standards for cold-formed steel members, sheeting and sandwich panels, and shall be determined as follows:

- Applications in which cold-formed steel members, sheeting or sandwich panels are designed to contribute to the overall strength and stability of a structure shall be classified as **Structural Class I**;

- Applications in which cold-formed steel members, sheeting or sandwich panels are designed to contribute to the strength and stability of individual structural elements shall be classified as **Structural Class II**;
- Sheeting or sandwich panels providing stabilizing support to purlins or side rails which are designed as part of the bracing system of the main structure (e.g. as compression members, struts, or tie beams) may be classified as Structural Class II.
- Applications in which cold-formed steel members, sheeting or sandwich panels are used as elements which only transfer loads to the structure shall be classified as **Structural Class III**. Sheeting and sandwich panels in Structural Class III can be further differentiated into 'structural' or 'non-structural' applications.

NOTE Permitted applications of non-structural cold-formed steel sheeting or non-structural sandwich panels in Structural Class III can be set by the National Annex.

EN 1090-4 and EN 1090-2 cover the requirements for execution of structural sheeting and cold-formed steel members. EN 14782 covers non-structural cold-formed sheeting in Structural Class III. EN 14509-1¹ covers non-structural sandwich panels in Structural Class III and EN 14509-2² covers structural sandwich panels in Structural Class II.

(6) The classification into structural classes is particularly relevant for sheeting and sandwich panels to establish their relation with the overall structure, as well as with their supporting members.

NOTE

Structural Class I: The designer of the structure assumes bracing of the structure by the sheeting.

Structural Class II: The designer of the members directly supporting the sheeting or sandwich panels assumes that the latter provide restraint with regard to global buckling or bending parallel to the plane of the sheeting or sandwich panel.

Structural Class III: The designer of the members directly supporting the sheeting or sandwich panels assumes that the latter do not provide restraint with regard to global buckling or bending parallel to the plane of the sheeting or sandwich panel.

Adequate communication is required between the designer of the members supporting sheeting or sandwich panels and the designer of the sheeting or sandwich panels, with respect to the assumed structural class and the corresponding implications according to the product standard.

(7) Additional requirements for structural applications are given in EN 1090-4, e.g. with respect to:

- communicating the structural class on layout drawings, as well as clearly posting it on the actual structure;
- providing a minimum number of fasteners between the sheeting or sandwich panels and the supporting member, as well as between the different sheets or sandwich panels;
- specifying the structural class in the design brief, as well as in the operations and maintenance manual.

(8) EN 1090-4 lists the factors affecting execution that shall be specified during design.

¹ Under preparation. Stage at the time of publication: prEN 14509-1.

² Under preparation. Stage at the time of publication: prEN 14509-2.

5 Materials

5.1 General

(1) All steels used for cold-formed steel members and profiled sheeting shall be suitable for cold-forming and, if relevant, for welding. Steels used for galvanized members and sheets should also be suitable for galvanizing.

Steels specified in Tables 5.1 and 5.2 with properties and chemical composition in compliance with the relevant standards shall be considered to fulfil these requirements. For other steels the suitability for cold-forming shall be demonstrated by a bend test in accordance with EN ISO 7438 or by an equivalent test. If steel materials other than those mentioned in Tables 5.1 and 5.2 are used, their properties (mechanical properties and weldability) shall be known and their mechanical properties shall conform to the conditions given in EN 1993-1-1:2022, 5.1(2).

Table 5.1 — Nominal values of basic yield strength f_{yb} and ultimate tensile strength f_u

Type of steel	Standard	Grade	f_{yb} [N/mm ²]	f_u [N/mm ²]
Hot-rolled products of non-alloy structural steels — Part 2: Technical delivery conditions for non-alloy structural steels	EN 10025-2	S 235	235	360
		S 275	275	390
		S 355	355	490
		S 460	460	540
Hot-rolled products of structural steels — Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels	EN 10025-3	S 275 N	275	370
		S 355 N	355	470
		S 420 N	420	520
		S 460 N	460	540
		S 275 NL	275	370
		S 355 NL	355	470
		S 420 NL	420	520
		S 460 NL	460	540
Hot-rolled products of structural steels — Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain structural steels	EN 10025-4	S 275 M	275	360
		S 355 M	355	450
		S 420 M	420	500
		S 460 M	460	530
		S 275 ML	275	360
		S 355 ML	355	450
		S 420 ML	420	500
		S 460 ML	460	530

(2) The nominal values of material properties given in 5.1 and 5.2 should be adopted as characteristic values in design calculations.

(3) This document covers the design of cold-formed steel members and profiled sheets fabricated from steel conforming to the requirements given in 5.2.1.

(4) The design values of the following material properties of steel should be taken as indicated in EN 1993-1-1:

— Modulus of elasticity: $E = 210\,000$ [N/mm²] (5.1)

— Elastic shear modulus: $G = \frac{E}{2(1 + \nu)}$ [N/mm²] (5.2)

— Poisson's ratio in the elastic range: $\nu = 0,3$ (5.3)

— coefficient of linear thermal expansion: $\alpha_T = 12 \cdot 10^{-6}$ [per Kelvin, valid for temperatures ≤ 100 °C] (5.4)

Table 5.2 — Nominal values of basic yield strength f_{yb} and ultimate tensile strength f_u

Type of steel	Standard	Grade	f_{yb} [N/mm ²]	f_u [N/mm ²]
Cold-reduced carbon steel sheet of structural quality	ISO 4997	CR 220 CR 250 CR 320	220 250 320	300 330 400
Hot-rolled flat products made of high yield strength steels for cold-forming — Part 2: Technical delivery conditions for thermomechanically rolled steels	EN 10149-2	S 315 MC S 355 MC S 420 MC S 460 MC S 500 MC S 550 MC S 600 MC S 650 MC S 700 MC	315 355 420 460 500 550 600 650 ^b 700 ^b	390 430 480 520 550 600 650 700 750
Hot-rolled flat products made of high yield strength steels for cold-forming — Part 3: Technical delivery conditions for normalized or normalized rolled steels	EN 10149-3	S 260 NC S 315 NC S 355 NC S 420 NC	240 ^a 295 ^a 355 ^a 400 ^a	350 ^a 410 ^a 450 ^a 510 ^a
Cold-rolled flat products made of high yield strength micro-alloyed steels for cold-forming	EN 10268	HC260LA HC300LA HC340LA HC380LA HC420LA	240 280 320 350 390	340 370 400 430 460
Continuously hot-dip coated steel flat products for cold-forming	EN 10346	S220GD+Z, +ZF, +ZA, +ZM, +AZ S250GD+ Z, +ZF, +ZA, +ZM, +AZ, +AS S280GD+ Z, +ZF, +ZA, +ZM, +AZ, +AS S320GD+ Z, +ZF, +ZA, +ZM, +AZ, +AS S350GD+ Z, +ZF, +ZA, +ZM, +AZ, +AS S390GD+Z, +ZF, +ZA, +ZM, +AZ S420GD+ Z, +ZF, +ZA, +ZM, +AZ S450GD+Z, +ZF, +ZA, +ZM, +AZ	220 250 280 320 350 390 420 480 450	300 330 360 390 420 460 480 510

Type of steel	Standard	Grade	f_{yb} [N/mm ²]	f_u [N/mm ²]
Continuously hot-dip coated steel flat products of steel with high proof stress for cold-forming	EN 10346	HX260LAD+Z, +ZF, +ZA, +ZM, +AZ, +AS	240 ^a	330 ^a
		HX300LAD+Z, +ZF, +ZA, +ZM, +AZ, +AS	280 ^a	360 ^a
		HX340LAD+Z, +ZF, +ZA, +ZM, +AZ, +AS	320 ^a	390 ^a
		HX380LAD+Z, +ZF, +ZA, +ZM, +AZ, +AS	360 ^a	420 ^a
		HX420LAD+Z, +ZF, +ZA, +ZM, +AZ, +AS	400 ^a	450 ^a
		HX460LAD+Z, +ZF, +ZA, +ZM, +AZ, +AS	435 ^a	475 ^a
		HX500LAD+Z, +ZF, +ZA, +ZM, +AZ, +AS	470 ^a	500 ^{a,c}
Continuously hot-dip coated steel flat products of low carbon steels for cold-forming	EN 10346	DX51D+Z, +ZF, +ZA, +ZM, +AZ, +AS	120 ^{a,c}	250 ^{a,c}
		DX52D+Z, +ZF, +ZA, +ZM, +AZ, +AS	120 ^{a,c}	250 ^{a,c}
		DX53D+Z, +ZF, +ZA, +ZM, +AZ, +AS	120 ^{ac}	250 ^{a,c}

^a The nominal values given in the respective product standard correspond to the transverse direction of the strip or sheet. The values given in the Table above correspond to properties in the longitudinal (rolling) direction.

^b For thicknesses > 8 mm the given yield strength shall be reduced by 20 N/mm².

^c The product standard does not specify minimum values of the yield strength or the ultimate tensile strength. For all steel grades a minimum yield strength of 120 N/mm² and a minimum ultimate tensile strength of 250 N/mm² may be assumed.

NOTE The materials in Table 5.1 conform to harmonized product standards, while the materials in Table 5.2 conform to EN or ISO product standards. This document is applicable to the materials listed in both Tables.

5.2 Structural steel

5.2.1 Properties of base material

(1) The nominal values of the basic yield strength f_{yb} or the ultimate tensile strength f_u should be obtained in one of the following ways:

- by adopting the values $f_{yb} = R_{eh}$ or $f_{yb} = R_{p0,2}$ and $f_u = R_m$ directly from product standards if they apply to the longitudinal direction;
- by using the values given in Table 5.1 and 5.2;
- from appropriate tests.

(2) If the characteristic values are determined from tests, such tests should be carried out in accordance with A.2.1.

(3) It may be assumed that the properties of steel in compression are the same as those in tension.

NOTE Information about whether the materials given in Table 5.1 and Table 5.2 can be used in a global plastic analysis can be provided by the National Annex.

(4) The material properties at elevated temperatures for fire design are given in EN 1993-1-2.

5.2.2 Material properties of cold-formed steel members and sheeting

(1) Where the yield strength is specified using the symbol f_y or f_{ya} , the average yield strength f_{ya} according to (2) or (3) may be used, if (4) to (5) apply.

In other cases, the basic yield strength f_{yb} should be used, see 5.2.1 (1).

(2) The average yield strength f_{ya} of a cross-section resulting from cold-forming may be determined from the results of full-scale tests.

(3) Alternatively, the average yield strength f_{ya} may be determined from Formula (5.5):

$$f_{ya} = f_{yb} + (f_u - f_{yb}) \frac{k_{fp} n_r t^2}{A} \quad \text{but} \quad f_{ya} \leq \frac{(f_u + f_{yb})}{2} \quad (5.5)$$

where

A is the area of the gross cross-section;

k_{fp} is a coefficient which depends on the forming process as follows:

- $k_{fp} = 7$ for roll-forming;
- $k_{fp} = 5$ for other forming methods;

n_r is the total number of 90° bends with an internal radius $r \leq 5t$ (fractions of a 90° bend should be counted as fractions of 1);

t is the design thickness of the steel material, as specified in 5.2.4(4).

(4) The average yield strength f_{ya} resulting from cold-forming may be used when determining:

- the resistance of a cross-section in uniform tension according to 8.1.2;
- the resistance of a cross-section in uniform compression, when $A_{eff} = A$, according to 8.1.3;
- the resistance of a cross-section with fully effective flanges in bending according to 8.1.4;
- the global buckling resistance of an axially loaded compression member with $A_{eff} = A$, according to 8.2.2 and 8.2.3.

(5) To determine the bending moment resistance of a cross-section with fully effective flanges, the cross-section may be subdivided into m nominal plane elements, such as webs or flanges. Formula (5.5) may then be used to obtain values of the increased yield strength $f_{y,i}$ separately for each plane element i ($i = 1 \dots m$), provided that the condition in Formula (5.6) is satisfied:

$$\frac{\sum_{i=1}^m A_i f_{y,i}}{\sum_{i=1}^m A_i} \leq f_{ya} \quad (5.6)$$

where

A_i is the area of the gross cross-section of element i ($i = 1 \dots m$). When calculating the increased yield strength $f_{y,i}$ using Formula (5.5), half of the bends adjacent to element i may be considered to be part of the area A_i .

(6) The average yield strength f_{ya} due to cold-forming should not be used for members which have been subjected to a heat treatment after forming and have been exposed to temperatures above 580°C for more than one hour.

NOTE For further information, see EN 1090-2.

(7) Special attention should be paid to the fact that some heat treatments (particularly annealing) might reduce the basic yield strength f_{yb} .

(8) For welding in cold-formed areas, see EN 1993-1-10.

5.2.3 Fracture toughness

(1) See EN 1993-1-1 and EN 1993-1-10.

5.2.4 Thickness and thickness tolerances

(1) The provisions for design by calculation given in this document are applicable to members and sheeting with $t_{\text{cor}} \geq 0,35$ mm.

(2) Thinner material may also be used, provided that the load carrying resistance is determined by design assisted by testing.

(3) EN 1090-4 specifies the minimum nominal steel thicknesses for various applications.

(4) A design thickness t based on the steel core thickness t_{cor} shall be used (rather than the nominal thickness t_{nom}), which should be determined using Formula (5.7) or (5.8):

$$t = t_{\text{cor}} \quad \text{if} \quad \Delta_{\text{tol}} \leq 5 \% \quad (5.7)$$

$$t = t_{\text{cor}} \frac{100 - \Delta_{\text{tol}}}{95} \quad \text{if} \quad \Delta_{\text{tol}} > 5 \% \quad (5.8)$$

where

$$t_{\text{cor}} = t_{\text{nom}} - t_{\text{mc}} \quad (5.9)$$

Δ_{tol} is the negative tolerance of the thickness in %, as specified by the product standard or the production specification document;

t_{nom} is the nominal sheet thickness, inclusive of zinc and other metallic coatings, but not including any organic coatings, see (6);

t_{cor} is the nominal thickness minus the thickness of the zinc and other metallic coatings;

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

For Z 275 galvanizing, the combined thickness of the coatings on both sides of the plate may be taken as $t_{\text{mc}} = 0,04$ mm.

(5) For continuously hot-dip metal coated members and sheeting supplied with negative tolerances less than or equal to the "special tolerances (S)" given in EN 10143, the design thickness according to Formula (5.7) may be used. If the negative tolerance is larger than the "special tolerance (S)" given in EN 10143, then the design thickness according to Formula (5.8) may be used.

(6) t_{nom} is the nominal sheet thickness after cold-forming. It may be taken as the value t_{nom} of the original sheet, if

- the cross-sectional area A before cold-forming (equal to the nominal sheet width times the nominal thickness) and the cross-sectional area A_{calc} after cold-forming (as calculated from the specified cross-sectional shape) do not differ by more than 2 %, or
- the design of the members is based on the basic yield strength f_{yb} .

Otherwise, the specified nominal thickness t_{nom} of the original sheet material should be reduced correspondingly.

NOTE 1 Alternatively, in the design calculations the thickness can be reduced locally at the bends until compliance with $A_{\text{calc}} \leq 1,02 A$ (where A is the nominal manufacturer sheet width times the nominal thickness).

NOTE 2 In the case of a design assisted by testing according to Clause 12, the effects addressed by these provisions are already implicitly taken into account, as the actual dimensions of the test specimens and the effects of the manufacturing process are indirectly included in the test results.

5.3 Connecting devices

5.3.1 Mechanical fasteners

5.3.1.1 Bolt assemblies

(1) Bolts, nuts and washers should conform to the requirements given in EN 1993-1-8.

5.3.1.2 Other types of mechanical fasteners

(1) Other types of mechanical fasteners, such as

- self-tapping screws, including thread-forming self-tapping screws, thread-cutting self-tapping screws or self-drilling self-tapping screws,
- cartridge-fired pins,
- blind rivets,
- clinching

may be used if they comply with the relevant European Product Standard or ETA, see also EN 1090-4.

(2) The characteristic value of the shear resistance $F_{v,Rk}$ and the characteristic value of the minimum tensile resistance $F_{t,Rk}$ of the mechanical fasteners may be taken from the EN Product Standard or ETA.

5.3.2 Welding consumables

(1) Welding consumables should conform to the requirements given in EN 1993-1-8.

6 Durability

(1) For basic durability requirements, see EN 1993-1-1.

(2) Special attention should be given to galvanic corrosion in cases where different metals are in contact with each other, see EN 1090-4.

(3) For the corrosion resistance of cold-formed steel products, see EN 1090-4. For the corrosion resistance of fasteners and the environmental class following EN ISO 12944-2, see Annex B. For hot-dip galvanized fasteners, see EN ISO 10684.

7 Structural analysis

7.1 Structural modelling for analysis

(1) Analysis shall be based upon calculation models of the structure that are appropriate for cold-formed steel structures and the limit state under consideration. The method used for the analysis shall be consistent with the design assumptions.

(2) Finite Element analyses to determine elastic critical buckling loads, to verify ultimate limit states or serviceability limit states, or to conduct numerical simulations should be carried out according to EN 1993-1-14.

NOTE For the purpose of Finite Element analysis, the maximum acceptable plastic strain for cold-formed structures is $\varepsilon_{mp,cf} = 5\%$, unless the National Annex specifies a different value.

(3) Where the effects of the behaviour of 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.

NOTE For the analysis of member systems with semi-continuity provided by overlaps or sleeves, see 11.1.3.3. For the analysis of sheeting with overlaps, see 11.3.4. For the analysis of adjustable pallet racking systems, see EN 15512.

7.2 Global analysis

7.2.1 Methods of global analysis for ultimate limit state design checks

(1) The method of global analysis (first- or second-order analysis with consideration of imperfections) should be compatible with the cross-section and member verification requirements in 8.1 and 8.2.

(2) The effects of local and distortional buckling on the stiffness of cold-formed members and structures shall be taken into account in the global analysis. These effects may be ignored in the global analysis when the effective cross-sectional area of each individual plane element, with or without stiffeners, is larger than 50 % of its gross sectional area.

(3) Second-order effects should be considered in the global elastic analysis of cold-formed steel structures in accordance with the provisions of EN 1993-1-1:2022, 7.2.1.

(4) Depending on the type of structure and the numerical modelling, imperfections and second-order effects should be considered using one of the following approaches:

- a) entirely in the global analysis;
- b) partially in the global analysis and partially by verification of the buckling resistance of individual members according to 8.2;
- c) by verification of the buckling resistance of “Equivalent Members” according to 8.2, using appropriate buckling lengths in accordance with the global buckling modes of the structure.

NOTE Appropriate methods of Finite Element based global analysis corresponding to the different methods given in a) to c) are provided in EN 1993-1-14.

(5) Ultimate limit state design checks may be carried out using the general methods of global analysis M0, M1, M2, M3, M4, M5 and EM, as specified in EN 1993-1-1:2022, 7.2.2 (4) to (9), considering also torsional and flexural-torsional buckling modes.

(6) The applicability of analysis methods to cold-formed structures and the corresponding ultimate limit state design checks required for cold-formed steel structures according to this document are indicated in Table 7.1. Methods M0-M4 are recommended for the design of cold-formed steel structures.

NOTE Limitations on the use of Method EM can be set by the National Annex.

(7) The cases where second-order effects due to lateral-torsional buckling may be neglected in the global analysis and the subsequent verifications to be carried out are defined in EN 1993-1-1:2022, 7.2.1 (6).

(8) Second-order effects due to torsional buckling or torsional-flexural buckling of members subject to compression should be taken into account. They may be neglected in the global analysis and the subsequent verifications where torsional buckling and torsional-flexural buckling are prevented or do not occur.

7.2.2 Imperfections

7.2.2.1 General

(1) The structural analysis should appropriately incorporate the effects of imperfections, including the residual stresses and geometric imperfections of cold-formed steel structures (such as a lack of verticality, lack of straightness, lack of flatness, lack of fit and load eccentricities) which are larger than the essential tolerances of cold-formed steel structures according to EN 1090-4.

(2) Equivalent geometric imperfections should be used with values which reflect the combined effects of all types of imperfections, unless these effects are included in the cross-sectional or buckling resistance checks for members, see Table 7.1.

(3) General information about imperfections is provided in EN 1993-1-1:2022, 7.3.1 (3)(4).

7.2.2.2 Sway imperfections

(1) Sway imperfections for the global analysis of frames should be taken from EN 1993-1-1:2022: 7.3.2, but using $\phi_0 = 1/200$ in all cases.

(2) The sway imperfection should apply in all relevant horizontal directions, but need only be considered in one direction at a time.

Table 7.1 — Methods of structural analysis applicable to ultimate limit state design checks of cold-formed steel structures and members

Method acc. To EN 1993-1-1: 2022, 7.2.2	Additional requirements for cold- formed steel sections	1 st /2 nd order effects for global analysis	Imperfections to be considered in the global analysis	Design check according to Clause 8.1 or 8.2
M0 7.2.2(4)	In-plane and out-of-plane buckling may be neglected	1 st order effects	None	8.1: Cross-sectional resistance
M1 7.2.2(5)	In-plane buckling may be neglected, Out-of-plane buckling (Flexural, torsional, torsional-flexural or lateral-torsional buckling) shall not be neglected	1 st order effects	None	8.1: Cross-sectional resistance and 8.2: Out-of-plane member buckling check
EM 7.2.2(9)	None	1 st order effects	None	8.1: Cross-sectional resistance and 8.2: In-plane and out-of-plane member buckling check acc. to 8.2 based on an appropriate buckling length of "Equivalent Members"

Method acc. To EN 1993-1-1: 2022, 7.2.2	Additional requirements for cold- formed steel sections	1 st /2 nd order effects for global analysis	Imperfections to be considered in the global analysis	Design check according to Clause 8.1 or 8.2
M2 7.2.2(6)	None	1 st order effects	Sway imperfections	8.1: Cross-sectional resistance and 8.2: In-plane and out-of-plane member buckling check
M3 7.2.2(7)a	None	2 nd order effects	Sway imperfections	8.1: Cross-sectional resistance using γ_{M1} and 8.2: In-plane and out-of-plane member buckling check
M4 7.2.2(7)b	None	2 nd order effects	Sway imperfections and in-plane member bow imperfections	8.1: Cross-sectional resistance using γ_{M1} and 8.2: Out-of-plane member buckling check
M5 7.2.2(8)	None	2 nd order effects	Sway imperfections and in-plane and out-of- plane member bow imperfections and torsional effects (torsional, torsional-flexural or lateral-torsional buckling modes)	8.1: Verification of the cross- sectional resistance using γ_{M1} or Stress verification e.g. based on FE-analysis acc. to EN 1993-1-14 using γ_{M1}

NOTE When applying the member buckling check according to 8.2.5(2) to (5) the verification of the cross-sectional resistance is included.

7.2.2.3 Equivalent bow imperfections of members

(1) For the purpose of carrying out a second-order analysis including member imperfections, the equivalent bow imperfections related to flexural buckling and torsional-flexural buckling e_0 may be determined from Formula (7.1):

$$e_0 = \frac{M_{c,Rd}}{N_{c,Rd}} \left(\frac{1}{\chi} - \frac{\bar{\lambda}^2}{\gamma_{M1}} \right) (1 - \chi^{\alpha_i})^{\frac{1}{\beta_i}} \quad (7.1)$$

where

χ is the reduction factor according to the relevant buckling curve, see 8.2.2;

$M_{c,Rd}$ is the design value of the bending moment resistance of the cross-section about the relevant axis according to 8.1.4;

$N_{c,Rd}$ is the design value of the resistance to axial forces according to 8.1.3;