



BSI Standards Publication

Eurocode 9 — Design of aluminium structures

Part 1-4: Cold-formed structural sheeting

National foreword

This British Standard is the UK implementation of EN 1999-1-4:2023. It supersedes BS EN 1999-1-4:2007+A1:2011, which will be withdrawn on 30 March 2028.

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

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

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

The first generation of EN Eurocodes was published between 2002 and 2007, with conflicting British Standards withdrawn in 2010.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

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

UK adoptions of the first generation of EN Eurocodes will be withdrawn by BSI on 30 March 2028.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

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

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

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Partie 1-4 : Tôles de structure formées à froid

Eurocode 9 - Bemessung und Konstruktion von
Aluminiumtragwerken - Teil 1-4: Kaltgeformte
Profiltafeln

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COMITÉ EUROPÉEN DE NORMALISATION
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European foreword

This document (EN 1999-1-4:2023) has been prepared by Technical Committee CEN/TC250 “Structural Eurocodes”, the secretariat of which is held by BSI. CEN/TC 250 is responsible for all Structural Eurocodes and has been assigned responsibility for structural and geotechnical design matters by CEN.

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

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

This document supersedes EN 1999-1-4:2007.

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

- Some reorganization of the text and its coherence with EN 1999-1-1 and the other Eurocodes;
- New general provisions for cold-formed profiles (i.e. not only profiled sheeting);
- New provisions for static overlapping system of sheeting with single or double overlap;
- New provisions for trapezoidal sheeting with side overlaps;
- Clarification of the behaviour of diaphragm at the end of a building;
- Improvement of wording.

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

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

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

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

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

0 Introduction

0.1 Introduction to the Eurocodes

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

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

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

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

0.2 Introduction to EN 1999 (all parts)

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

EN 1999 (all parts) is only concerned with requirements for resistance, serviceability, durability and fire resistance of aluminium structures. Other requirements, e.g. concerning thermal or sound insulation, are not considered.

EN 1999 (all parts) does not cover the special requirements of seismic design. Provisions related to such requirements are given in EN 1998, which complements, and is consistent with EN 1999.

Eurocode 9 is subdivided in various parts:

- EN 1999-1-1 Eurocode 9 — Design of Aluminium Structures — Part 1-1: General rules;
- EN 1999-1-2 Eurocode 9 — Design of Aluminium Structures — Part 1-2: Structural fire design;

- EN 1999-1-3 Eurocode 9 — Design of Aluminium Structures — Part 1-3: Structures susceptible to fatigue;
- EN 1999-1-4 Eurocode 9 — Design of Aluminium Structures — Part 1-4: Cold-formed structural sheeting;
- EN 1999-1-5 Eurocode 9 — Design of Aluminium Structures — Part 1-5: Shell structures.

0.3 Introduction to EN 1999-1-4

This document gives design requirements for cold-formed trapezoidal aluminium sheeting made from hot rolled or cold rolled sheet or strip.

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

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

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

0.5 National annex for EN 1999-1-4

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

The national standard implementing EN 1999-1-4 can have a National Annex containing all national choices to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

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

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

National choice is allowed in EN 1999-1-4 through the following clauses:

4(4)	5.1(3)	9.3(3)	A.4.4(3)
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National choice is allowed in EN 1999-1-4 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 1999-1-4

(1) EN 1999-1-4 gives design requirements for cold-formed trapezoidal aluminium sheeting. It applies to cold-formed aluminium products made from hot rolled or cold rolled sheet or strip that have been cold-formed by such processes as cold-rolled forming or press-breaking.

NOTE 1 The rules in this part complement the rules in other parts of EN 1999-1.

NOTE 2 The execution of aluminium structures made of cold-formed structures for roof, ceiling, floor and wall applications is covered in EN 1090-5.

(2) EN 1999-1-4 gives methods for stressed-skin design using aluminium sheeting as a structural diaphragm.

(3) EN 1999-1-4 does not apply to cold-formed aluminium profiles like C- and Z- profiles nor cold-formed and welded circular or rectangular hollow sections.

(4) EN 1999-1-4 gives methods for design by calculation and for design assisted by testing. The methods for the design by calculation apply only within stated ranges of material properties and geometrical properties for which sufficient experience and test evidence is available. These limitations do not apply to design by testing.

(5) EN 1999-1-4 does not cover load arrangement for loads during execution and maintenance.

1.2 Assumptions

(1) For the design of new structures, EN 1999 is intended to be used, for direct application, together with EN 1990, EN 1991, EN 1992, EN 1993, EN 1994, EN 1995, EN 1997 and EN 1998.

EN 1999 is intended to be used in conjunction with:

- European Standards for construction products relevant for aluminium structures;
- EN 1090-1, *Execution of steel structures and aluminium structures — Part 1: Requirements for conformity assessment of structural components*;
- EN 1090-5, *Execution of steel structures and aluminium structures — Part 5: Technical requirements for cold-formed structural aluminium elements and cold-formed structures for roof, ceiling, floor and wall applications*.

2 Normative references

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

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

EN 1990, *Eurocode — Basis of structural design*

EN 1999-1-1, *Eurocode 9 — Design of aluminium structures — Part 1-1: General rules*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1990, EN 1999-1-1 and the following apply.

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

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

3.1.1

base material

flat sheet aluminium material out of which profiled sheets are made by cold forming

3.1.2

proof strength of base material

0,2 % proof strength f_0 of the base material

3.1.3

diaphragm action

structural behaviour involving in-plane shear in the sheeting

3.1.4

partial restraint

restriction to some extent of the lateral or rotational displacement of a cross-section part, that increases its buckling resistance

3.1.5

restraint

full restriction of the lateral displacement or rotational movement of a plane cross-section part, that increases its buckling resistance

3.1.6

relative slenderness

normalised, material related slenderness ratio

3.1.7

stressed-skin design

design method that takes into account the contribution made by diaphragm action in the sheeting to the stiffness and strength of a structure

3.1.8

support

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

3.1.9

effective thickness

design value of the thickness to allow for local buckling of plane cross section part

3.1.10

reduced effective thickness

design value of the thickness to allow for distortional buckling of stiffeners in a second step of the calculation procedure for plane cross section parts, where local buckling is taken into account in the first step

3.2 Symbols

For the purposes of this document, the symbols given in EN 1999-1-1 and the following apply.

Latin upper-case letters

A_g	area of the gross cross-section
$A_{g,sh}$	value of A_g for a cross-section with sharp corners
$F_{n,Rd}$	net section design resistance
$F_{v,Rk}$	characteristic shear resistance
$F_{t,Rk}$	characteristic tension resistance
I_g	moment of inertia of the gross cross-section
$I_{g,sh}$	value of I_g for a cross-section with sharp corners
$R_{p0,2}$	0,2 % proof stress given by the product standard
R_m	ultimate tensile strength in material standard
S_f, S_w	spring stiffness of connection of sheeting
$V_{b,Rd}$	design value for shear resistance

Latin lower-case letters

a_{ol}	length of overlap of trapezoidal sheeting
a_{per}	spacing between the centres of the perforations in sheeting
b	overall width of the flange
b_{bu}	width of building
b_p	notional flat width of plane cross-section part
b_{rib}	pitch of the profile
d	diameter of the fastener
d_{per}	diameter of the perforations in sheeting
d_w	diameter of the washer or the sealing washer respectively or the head of the fastener
f_{bv}	shear buckling strength
$f_{u,min}$	minor ultimate tensile strength of connected parts
$f_{u,sup}$	ultimate tensile strength of the supporting component into which a screw is fixed
f_y	yield strength of supporting component of steel
h	overall height of the profile

h_a, h_b	distance from compression flange to grooves measured perpendicular to the flange
h_{bu}	height of the columns along the building
h_{sa}, h_{sb}	height of grooves in webs measured perpendicular to the web
h_w	height of profile
k	linear spring stiffness
k_f	coefficient for spring stiffness of connection of sheeting
k_{ol}	coefficient for calculating the spring stiffness of connections at overlaps of sheeting
k_σ	buckling coefficient for compression stress
k_τ	buckling coefficient for shear stress
l_a	effective bearing length
n	number of tests
n_c	number of pitches between the longitudinal edge of the sheeting to same edge of the next sheeting
n_p	number of whole pitches with double sheeting within the width n_c times the pitch
$q_{bv,Ed}$	vertical load per unit area acting on the roof (snow, self-weight and wind compression)
$q_{h,Ed}$	horizontal load per length acting along the roof diaphragm
r	internal bend radius
s_a, s_b	width of parts between grooves in webs
s_d	total developed slant height of the web
s_n	distance from neutral axis to nearest groove on the compression side of the web
s_p	slant height of the largest plane part in the web
s_{per}	slant height of the perforated portion of the web, centric in the web height
s_s	bearing length
s_{sa}, s_{sb}	width of grooves in webs
s_w	slant height of the web, between the midpoints of the web-to-flange corners
t	design thickness
t_{min}	thickness of the thinner connected part or sheet
t_{nom}	nominal thickness
t_{sup}	thickness of the supporting member in which the screw is fixed
v_h	maximum horizontal deformation of the roof diaphragm due to $q_{h,Ed}$
x_s	distance from the studied section to a hinged support or a point of counter flexure of the deflection curve for elastic buckling under an axial force only

Greek upper-case letters

θ rotation

Greek lower-case letters

γ_{M3} resistance of joints

$\bar{\lambda}_{lim}$ plateau length for plate buckling

$\bar{\lambda}_p$ plate relative slenderness

$\bar{\lambda}_s$ relative slenderness for stiffener

$\bar{\lambda}_w$ web relative slenderness

μ_{so} factor which accounts for the increase of bending moment resistance of sheeting with side overlaps

$\sigma_{com, Ed}$ the maximum compressive stress in a plane element or stiffener

$\sigma_{cr,sa}$ elastic buckling stress of stiffener

φ angle between two plane parts of a cross-section

ϕ slope of the web relative to the flanges

ψ stress relation factor

ω_x factor to allow for second order moment distribution due to axial force and deflection

3.3 Geometry and conventions

3.3.1 Cross-sectional shapes

- (1) Cold-formed sheets have, within the permitted tolerances, a constant nominal thickness over their entire length and have a uniform cross-section along their length.
- (2) The cross-sections of cold formed profiled sheets comprise a number of plane cross-section parts joined by curved parts.
- (3) Example of typical forms of cross-sections for cold formed profiled sheets are shown in Figure 3.1.
- (4) Cross-sections of cold formed sheets can either be unstiffened or incorporate longitudinal stiffeners in their webs or flanges, or in both.

3.3.2 Stiffener shapes

- (1) Typical shapes of stiffeners for cold formed sheets are shown in Figure 3.2.

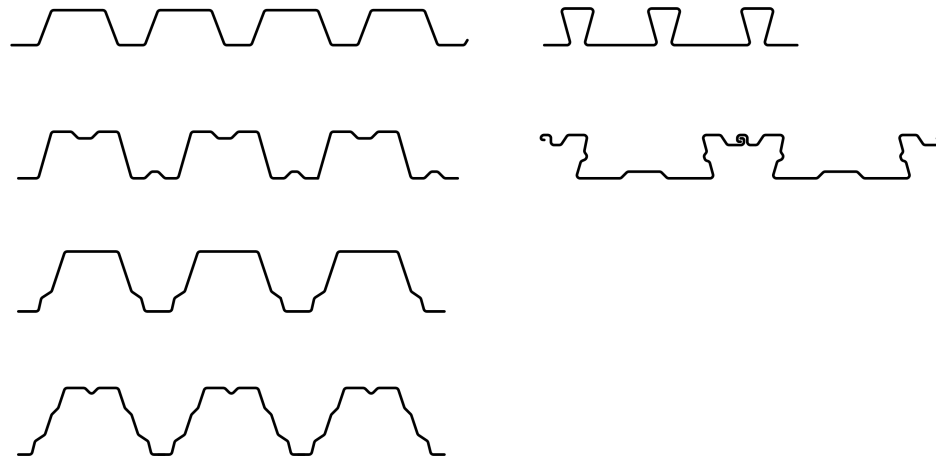


Figure 3.1 — Examples of cold-formed profiled sheeting

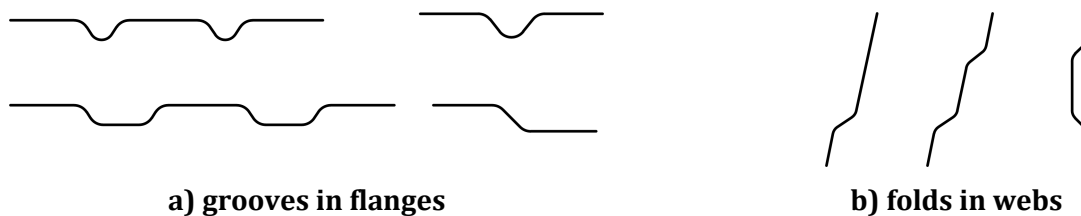


Figure 3.2 — Typical intermediate longitudinal stiffeners

3.3.3 Cross-sectional dimensions

- (1) Overall dimensions of cold-formed sheeting, including overall width b , overall height h , internal bend radius r and other external dimensions denoted by symbols without subscripts, are measured to the outer contour of the section, unless stated otherwise, see Figure 7.1.
- (2) Unless stated otherwise, the other cross-sectional dimensions of cold-formed sheeting, denoted by symbols with subscripts, such as b_p , h_w or s_w , are measured either to the midline of the material or the midpoint of the corner.
- (3) In the case of sloping webs of cold-formed profiled sheets, the slant height s is measured parallel to the slope.
- (4) The developed height of a web is measured along its midline, including any web stiffeners.
- (5) The developed width of a flange is measured along its midline, including any intermediate stiffeners.
- (6) The thickness t is an aluminium design thickness if not otherwise stated. See 5.2.2.

3.3.4 Convention for member axis

- (1) For profiled sheets the following axis convention is used in this standard:
 - y - y axis parallel to the plane of sheeting;
 - z - z axis perpendicular to the plane of sheeting.

4 Basis of design

(1) The design of cold-formed sheeting shall be in accordance with the general rules in EN 1990 and EN 1999-1-1.

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

(3) For verification by calculation at ultimate limit states the partial factor γ_M shall be taken as follows:

- resistance of cross-sections and members to instability: γ_{M1}
- resistance of cross-sections in tension to fracture: γ_{M2}
- resistance of joints: γ_{M3}

NOTE For the values of γ_{M1} and γ_{M2} , see EN 1999-1-1. For joints in cold-formed sheeting $\gamma_{M3} = \gamma_{M2}$.

(4) In the design of structures, a distinction should be made between various “structural classes”, based on the level of contribution of cold-formed aluminium members or sheeting 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 aluminium members and sheeting, and shall be determined as follows:

Structural Class I: Construction where cold-formed members or sheeting are designed to contribute to the overall strength and stability of a structure;

Structural Class II: Construction where cold-formed members or sheeting are designed to contribute to the strength and stability of individual structural elements;

Structural Class III: Construction where cold-formed members or sheeting are used as an element that only transfers loads to the structure. Sheeting and sandwich panels in Structural Class III can be differentiated in:

- structural or
- non-structural.

NOTE 1 Permitted application of non-structural cold-formed sheeting in Structural Class III can be set by the National Annex.

NOTE 2 EN 1090-1 and EN 1090-5 cover requirements for execution of structural sheeting and of cold-formed members. EN 14782 covers non-structural cold-formed sheeting for structural class III.

(5) Purlins designed as part of the bracing system of the main structure (e.g. compression members, struts, tie beams) may be stiffened by sheeting of Structural Class II.

(6) The categorization in Structural Classes should be made for sheeting in their relation to the overall structure and directly supporting members.

5 Materials

5.1 General

- (1) The methods for design by calculation given in this document should be used for the structural alloys in the tempers listed in Table 5.1.
- (2) For design by calculation given in this document, the 0,2 % proof strength, f_o , should be at least $f_o = 135 \text{ N/mm}^2$.
- (3) Aluminium sheet and strip used for cold-formed profile sheeting should be suitable for the specific cross section depending on cold forming and cold forming process.

NOTE Other aluminium materials and products can be given in the National Annex.

5.2 Structural aluminium alloys

5.2.1 Material properties

- (1) For design verification, the material properties given in this section should be considered as characteristic values.
- NOTE The characteristic values of 0,2 % proof strength f_o and tensile strength f_u have been obtained by adopting the values for minimum $R_{p0,2}$ and R_m from the relevant product standards.
- (2) It may be assumed that the properties in compression are the same as those in tension.
 - (3) If partially plastic moment resistance is utilized, the ratio of the characteristic ultimate tensile strength, f_u , to the characteristic 0,2 % proof strength, f_o , should be not less than 1,2.
 - (4) The material constants (modulus of elasticity, etc.) should be taken from EN 1999-1-1.

Table 5.1 — Characteristic values of 0,2 % proof strength, f_0 , ultimate tensile strength, f_u , and elongation A_{50} for sheet and strip for tempers with $f_0 \geq 135 \text{ N/mm}^2$ and thickness between 0,5 mm and 6 mm

Numerical designation EN AW-	Chemical designation EN AW-	Durability rating ^e	Temper ^{a, b, c}	Thickness up to mm	f_u R_m N/mm ²	f_0 $R_{p0,2}$ ^a N/mm ²	A_{50} % ^d
3003	AlMn1Cu	A	H16 H26	4,0	170	150 140	2 3
			H18	3,0	190	170	2
			H46	3,0	165	140	3
			H48	3,0	180	165	2-3
3004	AlMn1Mg1	A	H12 H22/H32	6,0	190	155 145	3-5 5-7
			H14 H24/H34	6 3	220	180 170	2-3 4
			H16 H26/H36	4 3	240	200 190	1-2 3
			H18 H28/H38	3 1,5	260	230 220	1-2 3
			H43	3	195	160	4-5
			H44	3	210	180	4
			H46	3	230	200	3
			H48	3	260	220	3
3005	AlMn1Mg0,5	A	H14	6,0	170	150	2-3
			H16	4	195	175	2
			H18 H28	3	220	200 190	2 2-3
			H44	3	165	135	3-4
			H46	3	185	160	2-3
			H48	3	210	180	2
3103	AlMn1	A	H16 H26	8 4	160	145 135	2 3
			H18	3	185	165	2
			H46	3	160	140	3
			H48	3	180	160	2-3
3105	AlMn0,5Mg0,5	A	H16 H26	3	175	160 150	2 3
			H18 H28	3 1,5	195	180 170	1 2
			H46	3	175	150	2-3
			H48	3	195	170	2
5005	AlMg1(B)	A	H16 H26/H36	4,0	165	145 135	2-3 3-4
			H18	3	185	165	2
			H46	3	165	135	3-4
			H48	3	185	160	2-3

Numerical designation EN AW-	Chemical designation EN AW-	Durability rating ^e	Temper ^{a, b, c}	Thickness up to mm	f_u R_m N/mm ²	f_o $R_{p0,2}$ ^a N/mm ²	A_{50} % ^d
5052	AlMg2,5	A	H12	6,0	210	160	5-8
			H14 H24/H34	6	230	180 150	3-4 5-7
			H16 H26/H36	6	250	210 180	3 4-6
			H18 H28/H38	3	270	240 210	2 3-4
			H44	3	230	150	5-6
			H46	3	250	180	4-5
			H48	3	270	210	3-4
5251	AlMg2Mn0,3	A	H12	6	190	150	4-8
			H14 H24/H34	6	210	170 140	2-4 5-8
			H16 H26/H36	4	230	200 170	2-3 4-7
			H18 H28/H38	3	255	230 200	2 3
			H46	3	210	165	4-5
			H48	3	250	215	3
6025-7072 alclad ^f	AlMg2,5SiMn Cu-AlZn1 alclad ^f	A	H32	5	180	135	2-4
			H34	5	210	165	2-3
			H36	5	220	185	2-4
			H42	3	180	135	3-4
			H46	3	220	185	3-4

^a The values for temper H1x, H2x, H3x according to EN 485-2:2016+A1:2018.

^b The values for temper H4x (coil coated sheet and strip) according to EN 1396:2015.

^c If two (three) tempers are specified in one line, tempers separated by "|" have different technological values, but separated by "/" have same values. (The tempers show differences only for f_o and A_{50} .)

^d A_{50} may depend on the thickness of material in the listed range, therefore sometimes also a A_{50} -range is given.

^e Durability rating, see EN 1999-1-1.

^f EN AW-6025-7072 alclad (EN AW-AlMg₂, 5SiMnCu-AlZn₁ alclad) is a composite material with core material EN AW-6025 and a cladding on both sides with EN AW-7072. For reasons of durability the cladding should have thickness of at least 4 % of the overall thickness of the material on each side. If the thickness of the cladding exceeds 5 %, fact should be considered in the structural calculations, i.e. only the core thickness of the composite sheet should be taken into account. For these reasons the minimum cladding thickness of 4 % and the minimum core thickness should be specified in the execution specification for the contractor to procure the corresponding constituent products with inspection certificate 3.1.

5.2.2 Thickness and geometrical tolerances

(1) The provisions for design by calculation given in this document may be used for alloy within the following ranges of nominal thickness, t_{nom} , of the sheeting exclusive of organic coatings:

$$t_{\text{nom}} \geq 0,5 \text{ mm}$$

(2) The nominal thickness, t_{nom} , should be used as design thickness, t , if a negative deviation is less than 5 %. Otherwise Formula (5.1) should be used:

$$t = t_{\text{nom}}(100 - |dev|)/95 \quad (5.1)$$

where

dev is the negative deviation in %.

NOTE Tolerances for roofing products are given in EN 508-2.

5.3 Mechanical fasteners

(1) The following types of mechanical fasteners may be used:

- self-tapping screws as thread-forming self-tapping screws, or self-drilling self-tapping screws according to standards listed in 10.3;
- blind rivets according to standards listed in 10.2.

(2) The characteristic shear resistance, $F_{v,Rk}$, and the characteristic tension resistance, $F_{t,Rk}$, of the mechanical fasteners should be calculated according to 10.2 and 10.3.

(3) For details concerning suitable self-tapping screws, and self-drilling screws and blind rivets, EN 1090-5 should be applied.

(4) Characteristic shear resistance and characteristic tension resistance of mechanical fasteners not covered in this document may be taken from ETA certifications.

6 Durability

(1) Basic durability requirements given in EN 1999-1-1 shall be followed.

(2) Special attention should be given to cases where different materials are intended to act compositely, if these materials are such that electrochemical phenomena might produce conditions leading to corrosion.

NOTE See Annex B for corrosion resistance of fasteners for the environmental corrosivity categories following EN ISO 9223.

(3) The environmental conditions prevailing from the time of manufacture, including those during transport and storage on site, should be taken into account.

7 Structural analysis

7.1 Influence of rounded corners

(1) In cross-sections with rounded corners, the notional flat widths, b_p , of the plane cross-section parts should be measured from the midpoints of the adjacent corner cross-section parts, as indicated in Figure 7.1.

(2) In cross-sections with rounded corners, the calculation of section properties should be based upon the actual geometry of the cross-section.

(3) Unless more appropriate methods are used to determine the section properties, the following approximate procedure may be used. If the internal radius $r \leq 10t$ and $r \leq 0,15b_p$, the influence of rounded corners on section properties may be neglected and the cross-section may be assumed to consist of plane cross-section parts with sharp corners.

(4) The influence of rounded corners on section properties may be taken into account by reducing the properties calculated for an otherwise similar cross-section with sharp corners, using the approximations of Formulae (7.1), (7.2) and (7.3):

$$A_g \approx A_{g,sh}(1-\delta) \quad (7.1)$$

$$I_g \approx I_{g,sh}(1-2\delta) \quad (7.2)$$

with

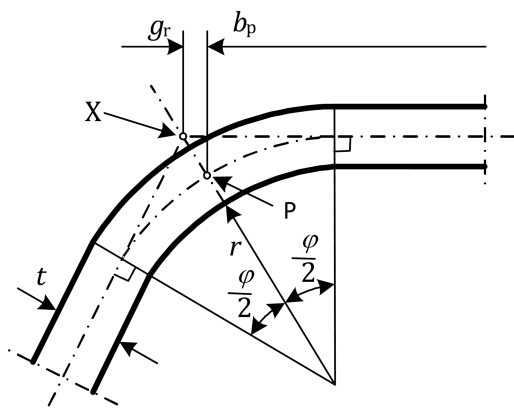
$$\delta = 0,43 \cdot \sum_{j=1}^n (r_j \phi_j / 90) / \sum_{i=1}^m b_{p,i} \quad (7.3)$$

where

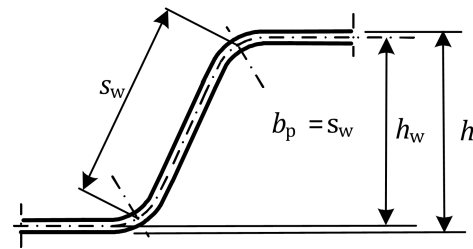
A_g	is the area of the gross cross-section;
$A_{g,sh}$	is the value of A_g for a cross-section with sharp corners;
$b_{p,i}$	is the notional flat width of plane cross-section part, i , for a cross-section with sharp corners;
I_g	is the moment of inertia of the gross cross-section;
$I_{g,sh}$	is the value of I_g for a cross-section with sharp corners;
ϕ	is the angle between two plane elements (in degrees);
m	is the number of plane cross-section parts;
n	is the number of curved cross-section parts without consideration of the curvature of stiffeners in webs and flanges;
r_j	is the internal radius of curved cross-section part.

(5) The reductions given by Formula (7.1) may also be applied in calculating the effective section properties A_{eff} and $I_{y,eff}$ according to 8.1, provided that the notional flat widths of the plane cross-section parts are measured to the points of intersection of their midlines.

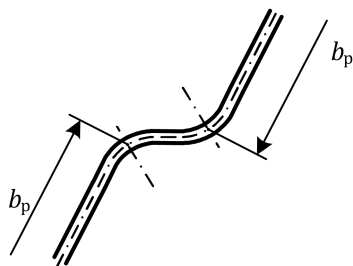
(6) Where the internal radius $r \geq 0,04t E/f_o$, then the bending moment resistance of the cross-section should be determined by tests.



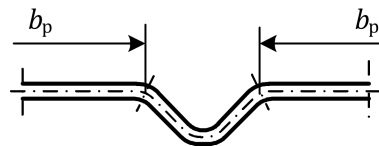
a) midpoint of corner or bend



b) notional flat width, b_p , for a web



c) notional flat width, b_p , of plane parts adjacent to fold



d) notional flat width, b_p , of flat parts adjacent to groove

Key

- X is the point of intersection of the midlines
- P is the midpoint of the corner
- $r_m = r + t/2$
- $g_r = r_m \left(\tan\left(\frac{\phi}{2}\right) - \sin\left(\frac{\phi}{2}\right) \right)$
- b_p is the plane part of the cross-section

Figure 7.1 — Notional widths of plane cross-section parts, b_p , taking into account corner radii

7.2 Geometrical proportions

(1) The provisions for design by calculation given in this document should not be applied to cross-sections outside the maximum width-to-thickness ratios b/t and s_w/t given below:

- for compressed flanges $b/t \leq 300$
- for webs $s_w/t \leq 0,5E/f_o$

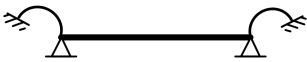
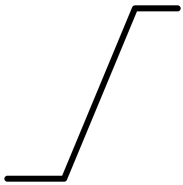
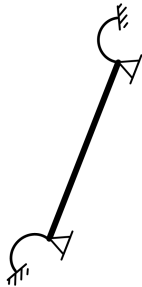
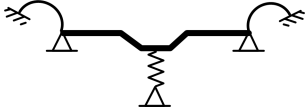
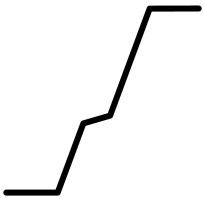
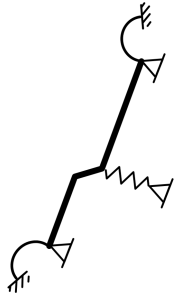
(2) The limits b/t and s_w/t given in (1) may be assumed to represent the field for which sufficient experience and verification by testing is available.

(3) Cross-sections with larger width-to-thickness ratios than those given in (1) may also be used, provided that their resistance at ultimate limit states and their behaviour at serviceability limit states are verified by testing and/or by calculations, where the results are confirmed by an appropriate number of tests.

7.3 Structural modelling for analysis

- (1) The parts of a cross-section may be modelled for analysis as indicated in Table 7.1.
- (2) The mutual influence of multiple stiffeners should be taken into account.

Table 7.1 — Modelling of parts of a cross-section

Type of cross-section part	Model
	
	
	
	

7.4 Flange curling

- (1) The effect on the load bearing resistance of curling (i.e. inward curvature towards the neutral plane) of a very wide flange in a profile subject to flexure, or of an initially curved profile subject to flexure in which the concave side is in compression, should be taken into account, unless such curling is less than 5 % of the depth of the profile cross-section.
- (2) If curling is larger than 5 % of the depth of the profile cross-section, then the reduction in load bearing resistance, for instance due to decrease in length of the lever arm for part of the wide flange, and to the possible effect of bending should be taken into account.

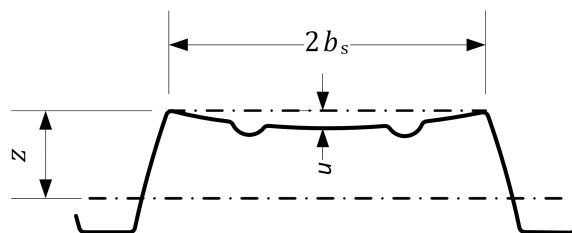


Figure 7.2 — Flange curling

(3) Calculation of the curling may be carried out as follows, for both compression and tensile flanges, both with and without stiffeners, but without closely spaced transverse stiffeners in flanges.

- For a profile, which is straight prior to application of loading (see Figure 7.2) Formulae (7.4) should be used:

$$u = \frac{2\sigma_a^2 b_s^4}{E^2 t^2 z} \quad (7.4)$$

- For an initially curved profile use Formula (7.5):

$$u = \frac{2\sigma_a b_s^4}{E t^2 r} \quad (7.5)$$

where

- u is the deflection of the flange towards the neutral axis (curling), see Figure 7.2;
- b_s is half the distance between the webs;
- z is the distance of flange under consideration from neutral axis;
- r is the radius of curvature of initially curved profile;
- σ_a is mean stress in the flange calculated with the gross area.

(4) If the stress is calculated for the effective cross-section, the mean stress is obtained by multiplying the stress for the effective cross-section by the ratio of the effective flange area to the gross flange area.

7.5 Local and distortional buckling

7.5.1 General

(1) The effects of local and distortional buckling should be taken into account in determining the resistance and stiffness of cold-formed sheeting.

(2) Local buckling effects may be considered by using effective cross-sectional properties, calculated on the basis of the effective thickness, see EN 1999-1-1.

(3) In determining resistance to local buckling, the 0,2 % proof strength, f_o , should be used.

NOTE 1 For effective cross-section properties for serviceability verifications, see 9.1(3).

NOTE 2 For the distortional buckling of cross-section parts with intermediate stiffeners, see 7.5.3.

7.5.2 Plane cross-section parts without stiffeners

- (1) The effective thickness, t_{eff} , of compression cross-section parts should be obtained as $t_{\text{eff}} = \rho \cdot t$, where ρ is a reduction factor taking local buckling into account
- (2) The notional flat width, b_p , of a plane cross-section part should be determined as specified in 7.1. In the case of plane cross-section parts in a sloping web, the appropriate slant height should be used.
- (3) The reduction factor, ρ , to determine t_{eff} should be based on the largest compressive stress, $\sigma_{\text{com,Ed}}$, in the relevant cross-section part (calculated on the basis of the effective cross-section), when the resistance of the cross-section is reached.
- (4) If $\sigma_{\text{com,Ed}} = f_o / \gamma_{M1}$ the reduction factor, ρ , should be obtained from Formulae (7.6), (7.7) and (7.8):

$$\text{if } \bar{\lambda}_p \leq \bar{\lambda}_{\text{lim}} : \rho = 1,0 \quad (7.6)$$

$$\text{if } \bar{\lambda}_p > \bar{\lambda}_{\text{lim}} : \rho = \alpha \left(1 - 0,22 / \bar{\lambda}_p \right) / \bar{\lambda}_p \quad (7.7)$$

in which the plate slenderness, $\bar{\lambda}_p$, is given by:

$$\bar{\lambda}_p = \sqrt{\frac{f_o}{\sigma_{\text{or}}}} = \frac{b_p}{t} \cdot \sqrt{\frac{12(1-\nu^2)f_o}{\pi^2 E k_\sigma}} \approx 1,052 \frac{b_p}{t} \sqrt{\frac{f_o}{E k_\sigma}} \quad (7.8)$$

where

k_σ is the relevant buckling factor from Table 7.3.

The parameters, $\bar{\lambda}_{\text{lim}}$ and α , should be taken from Table 7.2.

Table 7.2 — Parameters $\bar{\lambda}_{\text{lim}}$ and α

$\bar{\lambda}_{\text{lim}}$	α
0,517	0,90

- (5) If $\sigma_{\text{com,Ed}} < f_o / \gamma_{M1}$ the reduction factor, ρ , may be determined as follows:

Formulae (7.6) and (7.7) may be used, but with the plate slenderness, $\bar{\lambda}_p$, replaced by the reduced plate slenderness, $\bar{\lambda}_{p,\text{red}}$, given by Formula (7.9):

$$\bar{\lambda}_{p,\text{red}} = \bar{\lambda}_p \sqrt{\frac{\sigma_{\text{com,Ed}}}{f_o / \gamma_{M1}}} \quad (7.9)$$

NOTE For calculation of effective stiffness at serviceability limit states, see 9.1(3)

- (6) In determining the effective thickness of a flange cross-section part subject to stress gradient, the stress ratio, ψ , used in Table 7.3 may be based on the properties of the gross cross-section.

- (7) In determining the effective thickness of a web cross-section part, the stress ratio, ψ , used in Table 7.3 may be obtained using the effective area of the compression flange but the gross area of the web.