



**SLOVENSKI STANDARD**  
**oSIST prEN 1999-1-5:2021**  
**01-maj-2021**

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**Evrokod 9 - Projektiranje konstrukcij iz aluminijevih zlitin - 1-5. del: Lupinaste konstrukcije**

Eurocode 9 - Design of aluminium structures - Part 1-5: Shell structures

Eurocode 9: Bemessung und Konstruktion von Aluminiumtragwerken - Teil 1-5: Schalentragwerke

Eurocode 9 - Calcul des structures en aluminium - Partie 1-5 : Coques

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EUROPEAN STANDARD  
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**prEN 1999-1-5**

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Will supersede EN 1999-1-5:2007

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## Eurocode 9 - Design of aluminium structures - Part 1-5: Shell structures

Eurocode 9 - Calcul des structures en aluminium -  
Partie 1-5 : Coques

Eurocode 9: Bemessung und Konstruktion von  
Aluminiumtragwerken - Teil 1-5: Schalentragerwerke

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 250.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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COMITÉ EUROPÉEN DE NORMALISATION  
EUROPÄISCHES KOMITEE FÜR NORMUNG

**CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels**

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## European foreword

This document (prEN 1999-1-5:2021) 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 document is currently submitted to the CEN Enquiry.

This document will supersede EN 1999-1-5:2007.

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.

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## 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 >

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 Eurocode 9

EN 1999 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 – Basis of structural design.

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

EN 1999 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.

EN 1999 is subdivided in five parts:

- EN 1999-1-1 Design of Aluminium Structures: General structural rules.
- EN 1999-1-2 Design of Aluminium Structures: Structural fire design.
- EN 1999-1-3 Design of Aluminium Structures: Structures susceptible to fatigue.



- EN 1999-1-4 Design of Aluminium Structures: Cold-formed structural sheeting.
- EN 1999-1-5 Design of Aluminium Structures: Shell structures.

### 0.3 Introduction to EN 1999-1-5

EN 1999-1-5 applies to the structural design of aluminium structures, stiffened and unstiffened, that have the form of a shell of revolution or of a round panel in monocoque structures.

### 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 prEN 1999-1-5

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

The national standard implementing EN 1999-1-5 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 document is to be used.

When no national choice is made and no default is given in this document, 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 1999-1-5 through the following clauses:

- N/A

National choice is allowed in EN 1999-1-5 on the application of the following informative annexes:

Annex B (informative) Formulae for buckling analysis of tori-conical and tori-spherical shells.

**prEN 1999-1-5:2021 (E)****1 Scope****1.1 Scope of EN 1999-1-5**

(1) EN 1999-1-5 applies to the structural design of aluminium structures, stiffened and unstiffened, that have the form of a shell of revolution or of a round panel in monocoque structures.

(2) EN 1999-1-5 covers additional provisions to those given in the relevant parts of EN 1999 for design of aluminium structures.

NOTE Supplementary information for certain types of shells is given in EN 1993-1-6 and the relevant application parts which include:

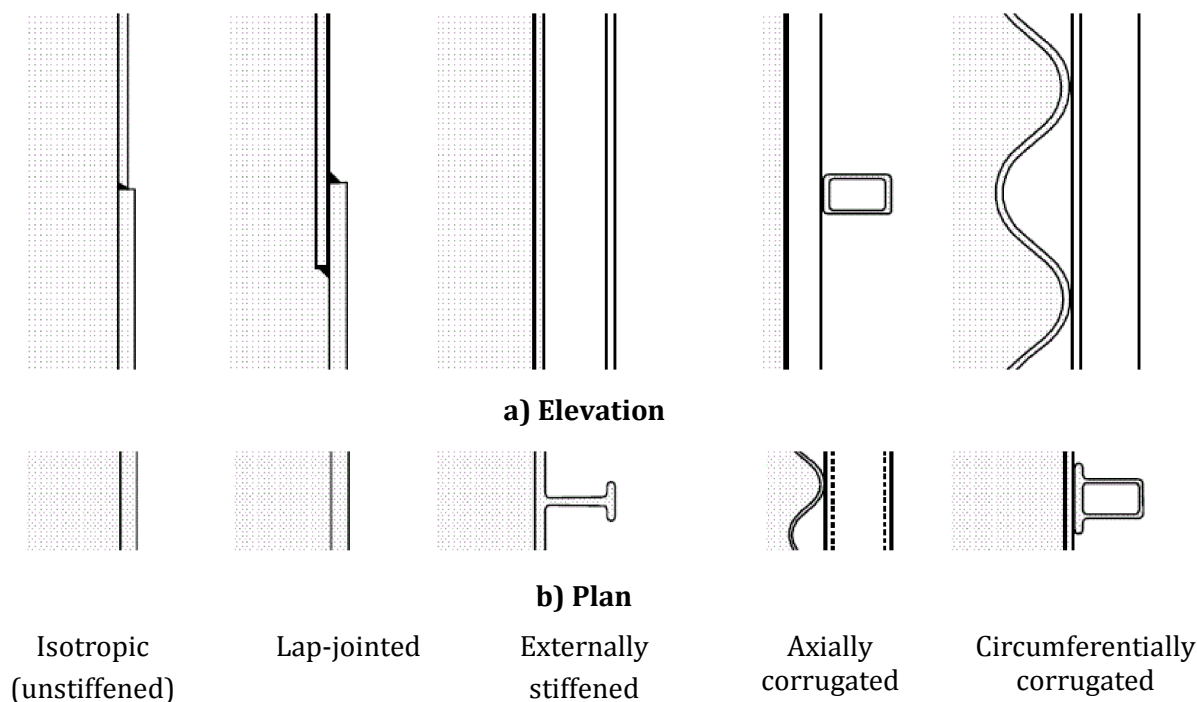
- Part 3-1 for towers and masts;
- Part 3-2 for chimneys;
- Part 4-1 for silos;
- Part 4-2 for tanks;
- Part 4-3 for pipelines.

(4) The provisions in EN 1999-1-5 apply to axisymmetric shells (cylinders, cones, spheres) and associated circular or annular plates, beam section rings and stringer stiffeners, where they form part of the complete structure.

(5) Single shell panels (cylindrical, conical or spherical) are not explicitly covered by EN 1999-1-5. However, the provisions can be applicable if the appropriate boundary conditions are duly taken into account.

(6) Types of shell walls covered in EN 1999-1-5 can be (see Figure 1.1):

- shell wall constructed from flat rolled sheet with adjacent plates connected with butt welds, termed 'isotropic';
- shell wall with lap joints formed by connecting adjacent plates with overlapping sections, termed lap-jointed;
- shell wall with stiffeners attached to the outside, termed 'externally stiffened' irrespective of the spacing of stiffeners;
- shell wall with the corrugations running up the meridian, termed 'axially corrugated';
- shell wall constructed from corrugated sheets with the corrugations running around the shell circumference, termed 'circumferentially corrugated'.



**Figure 1.1 — Illustration of cylindrical shell forms**

(7) The provisions of EN 1999-1-5 are intended to be applied within the temperature range defined in EN 1999-1-1. The maximum temperature is restricted so that the influence of creep can be neglected. For structures subject to elevated temperatures associated with fire see EN 1999-1-2.

(8) EN 1999-1-5 does not cover the aspect of leakage.

## 1.2 Assumptions

- (1) The general assumptions of EN 1990 apply.
- (2) The provisions of EN 1999-1-1 apply.
- (3) The design procedures are valid only when the requirements for execution in EN 1090-3 or other equivalent requirements are complied with.
- (4) For the design of new structures, prEN 1999 (all parts) 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.
- (5) EN 1999 (all parts) 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 1090-3: Execution of steel structures and aluminium structures - Part 3: Technical requirements for aluminium 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.

EN 1990, *Basis of structural design*

prEN 1999-1-1:2021, *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 1999-1-1 and the following apply.

#### 3.1.1 Structural forms and geometry

##### 3.1.1.1

##### **shell**

thin-walled body shaped as a curved surface with the thickness measured normal to the surface being small compared to the dimensions in the other directions

Note 1 to entry: A shell carries its loads mainly by membrane forces. The middle surface may have finite radius of curvature at each point or infinite curvature in one direction, e.g. cylindrical shell.

Note 2 to entry: In EN 1999-1-5, a shell is an aluminium structure or structural component formed from curved sheets or extrusions.

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##### 3.1.1.2

##### **shell of revolution**

shell composed of a number of parts, each of which is a complete axisymmetric shell

##### 3.1.1.3

##### **complete axisymmetric shell**

shell whose form is defined by a meridional generator line rotated around a single axis through 360°

Note 1 to entry: The shell can be of any length.

##### 3.1.1.4

##### **shell segment**

part of shell of revolution in the form of a defined shell geometry with a constant wall thickness

Note 1 to entry: Examples are a cylinder, a conical frustum, a spherical frustum, an annular plate or another form.

##### 3.1.1.5

##### **shell panel**

incomplete axisymmetric shell where the shell form is defined by a rotation of the generator about the axis through less than 360°

##### 3.1.1.6

##### **middle surface**

surface that lies midway between the inside and outside surfaces of a shell at every point

Note 1 to entry: If the shell is stiffened on only one surface, the reference middle surface is still taken as the middle surface of the curved shell plate. The middle surface is the reference surface for analysis, and can be discontinuous at changes of thickness or shell junctions, leading to eccentricities that are important to the shell response.

### 3.1.1.7

#### **junction**

point at which two or more shell segments meet

Note 1 to entry: It can include a stiffener or not: the point of attachment of a ring stiffener to the shell can be treated as a junction.

### 3.1.1.8

#### **stringer stiffener**

local stiffening member that follows the meridian of the shell, representing a generator of the shell of revolution

Note 1 to entry: It is provided to increase stability, or to assist with the introduction of local loads. It is not intended to provide a primary resistance for bending due to transverse loads.

### 3.1.1.9

#### **rib**

local member that provides a primary load carrying path for bending down the meridian of the shell, representing a generator of the shell of revolution

Note 1 to entry: It is used to transfer or distribute transverse loads by bending.

### 3.1.1.10

#### **ring stiffener**

local stiffening member that passes around the circumference of the shell of revolution at a given point on the meridian

Note 1 to entry: It is assumed to have no stiffness in the meridional plane of the shell. It is provided to increase the stability or to introduce axisymmetric local loads acting in the plane of the ring by a state of axisymmetric normal forces. It is not intended to provide primary resistance to bending.

### 3.1.1.11

#### **base ring**

structural member that passes around the circumference of the shell of revolution at the base and provides means of attachment of the shell to a foundation or other element

Note 1 to entry: It is needed to ensure that the assumed boundary conditions are achieved in practice.

## 3.1.2 Special definitions for buckling calculations

### 3.1.2.1

#### **critical buckling load**

smallest bifurcation or limit load determined assuming the idealised conditions of elastic material behaviour, perfect geometry, perfect load application, perfect support, material isotropy and absence of residual stresses (LBA analysis)

### 3.1.2.2

#### **critical buckling stress**

nominal membrane stress associated with the elastic critical buckling load

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## 3.1.2.13

**characteristic buckling stress**

nominal membrane stress associated with buckling in the presence of inelastic material behaviour and of geometrical and structural imperfections

## 3.1.2.4

**design buckling stress**

design value of the buckling stress, obtained by dividing the characteristic buckling stress by the partial factor for resistance

## 3.1.2.5

**key value of the stress**

value of stress in a non-uniform stress field that is used to characterise the stress magnitude in the buckling limit state assessment

## 3.1.2.6

**tolerance class**

class of requirements to geometrical tolerances for work execution

Note 1 to entry: Geometrical tolerances for work execution are built up from fabrication of components and execution of the components *in situ*.

## 3.2 Symbols

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

**Coordinate system (see Figure 3.1):**

$r$	radial coordinate, normal to the axis of revolution;
$x$	meridional coordinate;
$z$	axial coordinate;
$\theta$	circumferential coordinate;
$\phi$	meridional slope: angle between axis of revolution and normal to the meridian of the shell.

**Pressures:**

$p_n$	normal to the shell;
$p_x$	meridional surface loading parallel to the shell;
$p_\theta$	circumferential surface loading parallel to the shell;

**Line forces:**

- $P_n$  load per unit circumference normal to the shell;  
 $P_x$  load per unit circumference acting in the meridional direction;  
 $P_\theta$  load per unit circumference acting circumferentially on the shell;

**Membrane stress resultants (see Figure 3.2a):**

- $n_x$  meridional membrane stress resultant;  
 $n_\theta$  circumferential membrane stress resultant;  
 $n_{x\theta}$  membrane shear stress resultant;

**Bending stress resultants (see Figure 3.2b):**

- $m_x$  meridional bending moment per unit width;  
 $m_\theta$  circumferential bending moment per unit width;  
 $m_{x\theta}$  twisting shear moment per unit width;  
 $\theta_{xn}$  transverse shear force associated with meridional bending;  
 $\theta_{\theta n}$  transverse shear force associated with circumferential bending;

**Stresses:**

- $\sigma_x$  meridional stress; [standards.iteh.ai](https://standards.iteh.ai/catalog/standards/sist/d0322758-f6e4-4dc1-812b-075bbc5b1e72/osist-pr-en-1999-1-5-2021)  
 $\sigma_\theta$  circumferential stress; [oSIST prEN 1999-1-5:2021](https://standards.iteh.ai/catalog/standards/sist/d0322758-f6e4-4dc1-812b-075bbc5b1e72/osist-pr-en-1999-1-5-2021)  
 $\sigma_{eq}$  von Mises equivalent stress (can be negative in cyclic loading conditions);  
 $\tau, \tau_{x\theta}$  in-plane shear stress;  
 $\tau_{xn}, \tau_{\theta n}$  meridional, circumferential transverse shear stresses associated with bending;

**Displacements:**

- $u$  meridional displacement;  
 $v$  circumferential displacement;  
 $w$  displacement normal to the shell surface,  
 $\beta_\phi$  meridional rotation (see 7.2);

**Shell dimensions:**

- $d$  internal diameter of shell;  
 $L$  total length of shell;  
 $l$  length of shell segment;  
 $l_g$  gauge length for measurement of imperfections;  
 $l_{g,\theta}$  gauge length for measurement of imperfections in circumferential direction;  
 $l_{g,w}$  gauge length for measurement of imperfections across welds;  
 $l_R$  limited length of shell for buckling strength assessment;