SLOVENSKI STANDARD
SIST EN 1999-1-5:2007

01-maj-2007

Nadomešča:
SIST ENV 1999-1-1:2002
SIST ENV 1999-2:2002

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: Schalen

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

Ta slovenski standard je istoveten z: EN 1999-1-5:2007

ICS:

91.010.30	Tehnični vidiki	Technical aspects
91.080.10	Kovinske konstrukcije	Metal structures

SIST EN 1999-1-5:2007 **en,fr,de**

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 1999-1-5

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English Version

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: Schalen

This European Standard was approved by CEN on 11 October 2006.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN Management Centre has the same status as the official versions.

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Foreword

This European Standard (EN 1999-1-5:2007) has been prepared by Technical Committee CEN/TC250 « Structural Eurocodes », the secretariat of which is held by BSI.

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of an identical text or by endorsement, at the latest by August 2007, and conflicting national standards shall be withdrawn at the latest by March 2010.

This European Standard supersedes ENV 1999-1-1:1998, ENV 1999-1-2:1998 and ENV 1999-2:1998.

CEN/TC 250 is responsible for all Structural Eurocodes.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard:

Austria, Bulgaria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italia, Latvia, Lithuania, Luxemburg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom

Background of the Eurocode programme

In 1975, the Commission of the European Community decided on an action programme in the field of construction, based on article 95 of the Treaty. The objective of the programme was the elimination of technical obstacles to trade and the harmonisation of technical specifications.

Within this action programme, the Commission took the initiative to establish a set of harmonised technical rules for the design of construction works, which, in a first stage, would serve as an alternative to the national rules in force in the Member States and, ultimately, would replace them.

For fifteen years, the Commission, with the help of a Steering Committee with Representatives of Member States, conducted the development of the Eurocodes programme, which led to the first generation of European codes in the 1980s.

In 1989, the Commission and the Member States of the EU and EFTA decided, on the basis of an agreement[1] between the Commission and CEN, to transfer the preparation and the publication of the Eurocodes to the CEN through a series of Mandates, in order to provide them with a future status of European Standard (EN). This links de facto the Eurocodes with the provisions of all the Council's Directives and/or Commission's Decisions dealing with European standards (e.g. the Council Directive 89/106/EEC on construction products - CPD - and Council Directives 93/37/EEC, 92/50/EEC and 89/440/EEC on public works and services and equivalent EFTA Directives initiated in pursuit of setting up the internal market).

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

EN 1990	Eurocode 0:	Basis of Structural Design
EN 1991	Eurocode 1:	Actions on structures
EN 1992	Eurocode 2:	Design of concrete structures
EN 1993	Eurocode 3:	Design of steel structures
EN 1994	Eurocode 4:	Design of composite steel and concrete structures
EN 1995	Eurocode 5:	Design of timber structures
EN 1996	Eurocode 6:	Design of masonry structures
EN 1997	Eurocode 7:	Geotechnical design
EN 1998	Eurocode 8:	Design of structures for earthquake resistance
EN 1999	Eurocode 9:	Design of aluminium structures

[1] Agreement between the Commission of the European Communities and the European Committee for Standardisation (CEN) concerning the work on EUROCODES for the design of building and civil engineering works (BC/CEN/03/89).

Eurocode standards recognise the responsibility of regulatory authorities in each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level where these continue to vary from State to State.

Status and field of application of Eurocodes

The Member States of the EU and EFTA recognise that Eurocodes serve as reference documents for the following purposes:

- as a means to prove compliance of building and civil engineering works with the essential requirements of Council Directive 89/106/EEC, particularly Essential Requirement No.1 – Mechanical resistance and stability, and Essential Requirement No 2 – Safety in case of fire
- as a basis for specifying contracts for the execution of construction works and related engineering services
- as a framework for drawing up harmonised technical specifications for construction products (En's and ETA's)

The Eurocodes, as far as they concern the construction works themselves, have a direct relationship with the Interpretative Documents[2] referred to in Article 12 of the CPD, although they are of a different nature from harmonised product standards[3]. Therefore, technical aspects arising from the Eurocodes work need to be adequately considered by CEN Technical Committees and/or EOTA Working Groups working on product standards with a view to achieving full compatibility of these technical specifications with the Eurocodes.

The Eurocode standards provide common structural design rules for everyday use for the design of whole structures and component products of both a traditional and an innovative nature. Unusual forms of construction or design conditions are not specifically covered and additional expert consideration will be required by the designer in such cases.

National standards implementing Eurocodes

The National Standards implementing Eurocodes will comprise the full text of the Eurocode (including any annexes), as published by CEN, which may be preceded by a National title page and National foreword, and may be followed by a National annex [informative].

The National Annex (informative) may only contain information on those parameters which are left open in the Eurocode for national choice, known as Nationally Determined Parameters, to be used for the design of buildings and civil engineering works to be constructed in the country concerned, i.e. :

– values for partial factors and/or classes where alternatives are given in the Eurocode;
– values to be used where a symbol only is given in the Eurocode;
– geographical and climatic data specific to the Member State, e.g. snow map;
– the procedure to be used where alternative procedures are given in the Eurocode;
– references to non-contradictory complementary information to assist the user to apply the Eurocode.

Links between Eurocodes and harmonised technical specifications (EN's and ETA's) for products

There is a need for consistency between the harmonised technical specifications for construction products and the technical rules for works[4]. Furthermore, all the information accompanying the CE Marking of the construction products, which refer to Eurocodes, shall clearly mention which Nationally Determined Parameters have been taken into account.

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[2] According to Art. 3.3 of the CPD, the essential requirements (ERs) shall be given concrete form in interpretative documents for the creation of the necessary links between the essential requirements and the mandates for harmonised ENs and ETAGs/ETAs.

[3] According to Art. 12 of the CPD the interpretative documents shall :

a) give concrete form to the essential requirements by harmonising the terminology and the technical bases and indicating classes or levels for each requirement where necessary ;
b) indicate methods of correlating these classes or levels of requirement with the technical specifications, e.g. methods of calculation and of proof, technical rules for project design, etc. ;
c) serve as a reference for the establishment of harmonised standards and guidelines for European technical approvals.

The Eurocodes, *de facto*, play a similar role in the field of the ER 1 and a part of ER 2.

[4] see Art.3.3 and Art.12 of the CPD, as well as clauses 4.2, 4.3.1, 4.3.2 and 5.2 of ID 1.

National Annex for EN 1999-1-5

This European Standard gives alternative procedures, values and recommendations for classes with notes indicating where national choices may have to be made. Therefore the National Standard implementing EN 1999-1-5 should have a National Annex containing all Nationally Determined Parameters to be used for the design of aluminium shell structures to be constructed in the relevant country.

National choice is allowed in EN 1999-1-5 through clauses:

- 2.1 (3)
- 2.1 (4)

1 General

1.1 Scope

1.1.1 Scope of EN 1999

(1)P EN 1999 applies to the design of buildings and civil engineering and structural works in 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.

(2)P 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.

(3) EN 1999 is intended to be used in conjunction with:

- EN 1990 Basis of structural design
- EN 1991 Actions on structures
- 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[5]
- EN 1090-3 Execution of steel structures and aluminium structures – Part 3: Technical requirements for aluminium structures[5]

(4) 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.

1.1.2 Scope of EN 1999-1-5

(1)P 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) The relevant parts of EN 1999 should be followed for specific application rules for structural design.

(3) Supplementary information for certain types of shells are 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 and beam section rings and stringer stiffeners where they form part of the complete structure.

5 To be published

(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, 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 the 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'.

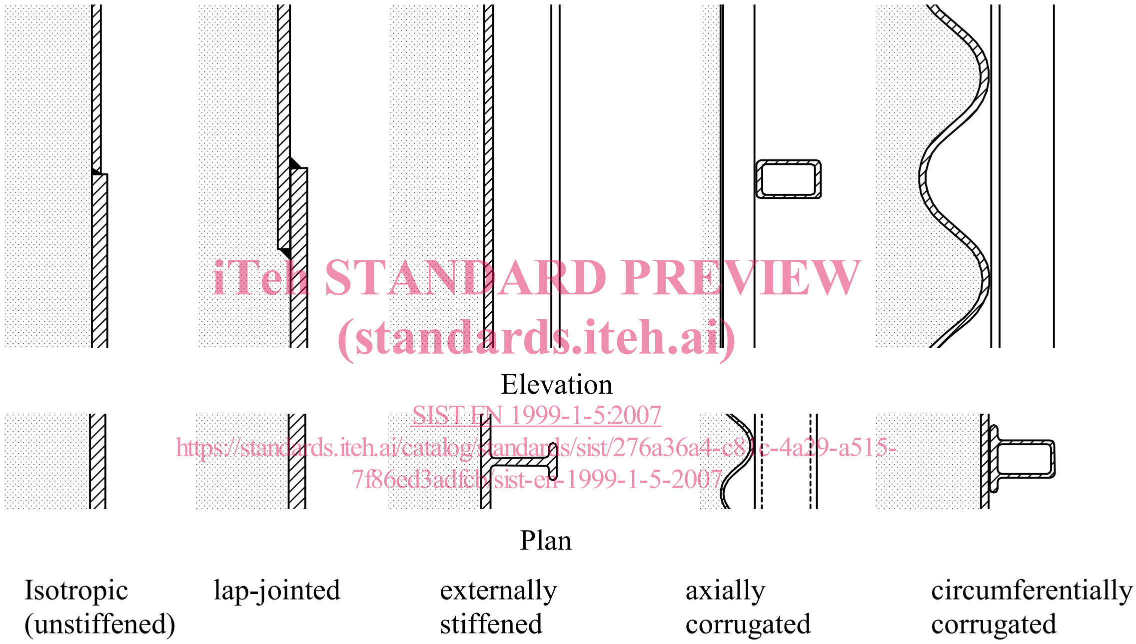

Figure 1.1 - Illustration of cylindrical shell forms

(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 aspects of leakage.

1.2 Normative references

(1) EN 1999-1-5 incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only if incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 1090-1 Execution of steel structures and aluminium structures – Part 1: Requirements for conformity assessment of structural components[5]

EN 1090-3 Execution of steel structures and aluminium structures – Part 3: Technical requirements for aluminium structures[5]

EN 1990 Basis of structural design
EN 1991 Actions on structures – All parts

EN 1993-1-6 Design of steel structures - Part 1-6: Shell structures
EN 1993-3-2 Design of steel structures - Part 3-2: Chimneys
EN 1993-4-1 Design of steel structures - Part 4-1: Silos
EN 1993-4-2 Design of steel structures - Part 4-2: Tanks
EN 1993-4-3 Design of steel structures - Part 4-3: Pipelines

EN 1999-1-1 Design of aluminium structures - Part 1-1: General rules
EN 1999-1-2 Design of aluminium structures - Part 1-2: Structural fire design
EN 1999-1-3 Design of aluminium structures - Part 1-3: Structures susceptible to fatigue
EN 1999-1-4 Design of aluminium structures - Part 1-4: Cold-formed structural sheeting

1.3 Terms and definitions

(1) Supplementary to EN 1999-1-1, for the purposes of this part, the following definitions apply:

1.3.1 Structural forms and geometry

1.3.1.1
shell
A 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. 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.
In EN 1999-1-5, a shell is a structure or a structural component formed from curved sheets or extrusions.

1.3.1.2
shell of revolution
A shell composed of a number of parts, each of which is a complete axisymmetric shell.

1.3.1.3
complete axisymmetric shell
A shell whose form is defined by a meridional generator line rotated around a single axis through 2π radians. The shell can be of any length.

1.3.1.4
shell segment
A part of shell of revolution in the form of a defined shell geometry with a constant wall thickness: a cylinder, conical frustum, spherical frustum, annular plate or other form.

1.3.1.5
shell panel
An incomplete axisymmetric shell: the shell form is defined by a rotation of the generator about the axis through less than 2π radians.

1.3.1.6
middle surface
The surface that lies midway between the inside and outside surfaces of the shell at every point. 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.

1.3.1.7
junction
The point at which two or more shell segments meet: it can include a stiffener or not: the point of attachment of a ring stiffener to the shell may be treated as a junction.

1.3.1.8
stringer stiffener
A local stiffening member that follows the meridian of the shell, representing a generator of the shell of revolution. It is provided to increase the 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.

1.3.1.9
rib
A 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. It is used to transfer or distribute transverse loads by bending.

1.3.1.10
ring stiffener
A local stiffening member that passes around the circumference of the shell of revolution at a given point on the meridian. 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 for bending.

1.3.1.11
base ring.
A 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. It is needed to ensure that the assumed boundary conditions are achieved in practice.

1.3.2 Special definitions for buckling calculations

1.3.2.1
critical buckling load
The 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).

1.3.2.2
critical buckling stress
The nominal membrane stress associated with the elastic critical buckling load.

1.3.2.3
characteristic buckling stress
The nominal membrane stress associated with buckling in the presence of inelastic material behaviour and of geometrical and structural imperfections.

1.3.2.4
design buckling stress
The design value of the buckling stress, obtained by dividing the characteristic buckling stress by the partial factor for resistance.

1.3.2.5
key value of the stress
The value of stress in a non-uniform stress field that is used to characterise the stress magnitude in the buckling limit state assessment.

1.3.2.6
tolerance class
The class of requirements to geometrical tolerances for work execution.

NOTE Geometrical tolerances for work execution are built up from fabrication of components and execution of the components at site.

1.4 Symbols

(1) In addition to the symbols defined in EN 1999-1-1, the following are used.

(2) Coordinate system (see Figure 1.2):

r radial coordinate, normal to the axis of revolution;
x meridional coordinate;
z axial coordinate;
θ circumferential coordinate;
ϕ meridional slope: angle between axis of revolution and normal to the meridian of the shell:

(3) Pressures:

p_n normal to the shell;
p_x meridional surface loading parallel to the shell;
p_θ circumferential surface loading parallel to the shell;

(4) Line forces:

P_n load per unit circumference normal to the shell;
P_x load per unit circumference acting in the meridional direction;
P_θ load per unit circumference acting circumferentially on the shell;

(5) Membrane stress resultants (see Figure 1.3a):

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

(6) Bending stress resultants (see Figure 1.3b):

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

(7) Stresses:

σ_x meridional stress;
σ_θ circumferential stress;
σ_{eq} von Mises equivalent stress (can be negative in cyclic loading conditions);
τ, $\tau_{x\theta}$ in-plane shear stress;
τ_{xn}, $\tau_{\theta n}$ meridional, circumferential transverse shear stresses associated with bending;

(8) Displacements:

u meridional displacement;
v circumferential displacement;
w displacement normal to the shell surface,
β_ϕ meridional rotation (see 5.3.3);

(9) 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;

r radius of the middle surface, normal to the axis of revolution;

t thickness of shell wall;

t_{max} maximum thickness of shell wall at a joint;

t_{min} minimum thickness of shell wall at a joint;

t_{ave} average thickness of shell wall at a joint;

β apex half angle of cone;

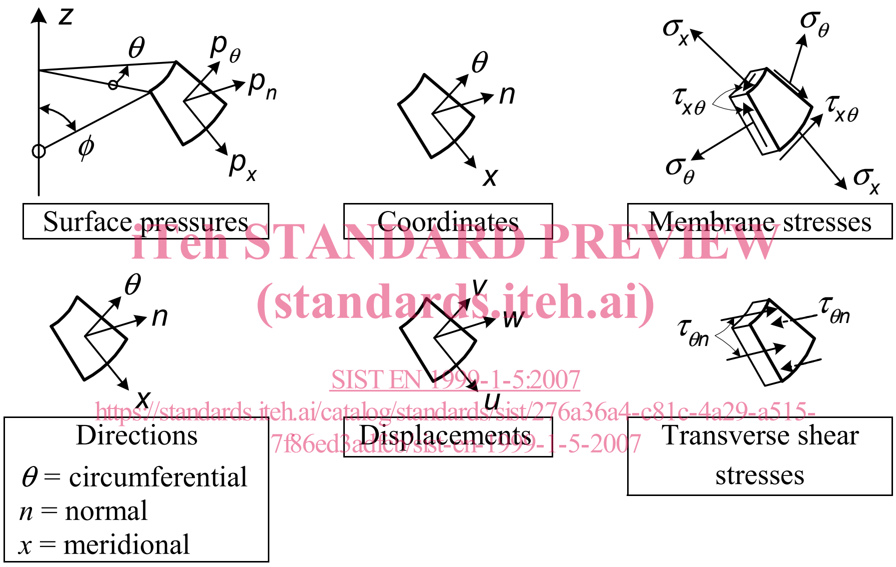

Figure 1.2 - Symbols in shells of revolutions

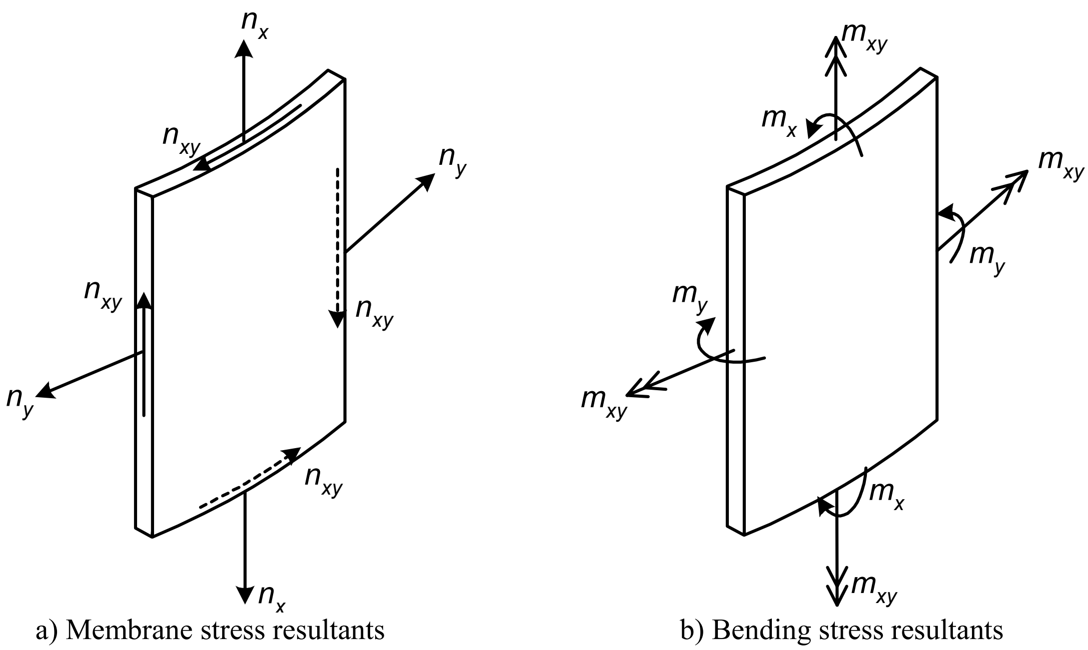

Figure 1.3 - Stress resultants in the shell wall (In this figure x is meridional and y is circumferential)