Dansk standard

DS/EN 1993-1-6

1. udgave

2007-05-29

Eurocode 3 – Stålkonstruktioner – Del 1-6: Styrke og stabilitet af skalkonstruktioner

Eurocode 3 – Design of steel structures –
Part 1-6: Strength and Stability of Shell Structures

DANSK STANDARD
Danish Standards

Kollegievej 6
DK-2920 Charlottenlund
Tel: +45 39 96 61 01
Fax: +45 39 96 61 02
dansk.standard@ds.dk
www.ds.dk

DS/EN 1993-1-6

København
DS projekt: M215352
ICS: 91.080.10

Første del af denne publikations betegnelse er:
DS/EN, hvilket betyder, at det er en europæisk standard, der har status som dansk standard.

Denne publikations overensstemmelse er:
IDT med: EN 1993-1-6:2007.

DS-publikationen er på engelsk.

Denne publikation erstatter: DS/ENV 1993-1-6:2000.

DS-publikationstyper
Dansk Standard udgiver forskellige publikationstyper.
Typen på denne publikation fremgår af forsiden.

Der kan være tale om:

Dansk standard
- standard, der er udarbejdet på nationalt niveau, eller som er baseret på et andet lands nationale standard, eller
- standard, der er udarbejdet på internationalt og/eller europæisk niveau, og som har fået status som dansk standard

DS-information
- publikation, der er udarbejdet på nationalt niveau, og som ikke har opnået status som standard, eller
- publikation, der er udarbejdet på internationalt og/eller europæisk niveau, og som ikke har fået status som standard, fx en teknisk rapport, eller
- europæisk præstandard

DS-håndbog
- samling af standarder, eventuelt suppleret med informativt materiale

DS-hæfte
- publikation med informativt materiale

Til disse publikationstyper kan endvidere udgives
- tillæg og rettelsesblade

DS-publikationsform
Publikationstyperne udgives i forskellig form som henholdsvis
- fuldtekstpublikation (publikationen er trykt i sin helhed)
- godkendelsesblad (publikationen leveres i kopi med et trykt DS-omslag)
- elektronisk (publikationen leveres på et elektronisk medie)

DS-betegnelse
Alle DS-publikationers betegnelse begynder med DS efterfulgt af et eller flere præfikser og et nr., fx **DS 383**, **DS/EN 5414** osv. Hvis der efter nr. er angivet et **A** eller **Cor,** betyder det, enten at det er et **tillæg** eller et **rettelsesblad** til hovedstandarden, eller at det er indført i hovedstandarden.
DS-betegnelse angives på forsiden.

Overensstemmelse med anden publikation:
Overensstemmelse kan enten være IDT, EQV, NEQ eller MOD
- **IDT**: Når publikationen er identisk med en given publikation.
- **EQV**: Når publikationen teknisk er i overensstemmelse med en given publikation, men præsentationen er ændret.
- **NEQ**: Når publikationen teknisk eller præsentationsmæssigt ikke er i overensstemmelse med en given standard, men udarbejdet på baggrund af denne.
- **MOD**: Når publikationen er modificeret i forhold til en given publikation.

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 1993-1-6

February 2007

ICS 91.010.30; 91.080.10

Supersedes ENV 1993-1-6:1999

English Version

Eurocode 3 - Design of steel structures - Part 1-6: Strength and Stability of Shell Structures

Eurocode 3 - Calcul des structures en acier - Partie 1-6: Résistance et stabilité des structures en coque

Eurocode 3 - Bemessung und Konstruktion von Stahlbauten - Teil 1-6: Festigkeit und Stabilität von Schalen

This European Standard was approved by CEN on 12 June 2006.

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. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN Management Centre or to any CEN member.

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.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN 1993-1-6:2007: E

Contents **Page**

Foreword

This European Standard EN 1993-1-6, Eurocode 3: Design of steel structures: Part 1-6 Strength and stability of shell structures, has been prepared by Technical Committee CEN/TC250 « Structural Eurocodes », the Secretariat of which is held by BSI. CEN/TC250 is responsible for all Structural Eurocodes.

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 latest by March 2010.

This Eurocode supersedes ENV 1993-1-6.

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

National annex for EN 1993-1-6

This standard gives alternative procedures, values and recommendations with notes indicating where national choices may have to be made. Therefore the National Standard implementing EN 1993-1-6 should have a National Annex containing all Nationally Determined Parameters to be used for the design of steel structures to be constructed in the relevant country.

National choice is allowed in EN 1993-1-6 through:

- 3.1.(4)
- 4.1.4 (3)
- 5.2.4 (1)
- 6.3 (5)
- 7.3.1 (1)
- 7.3.2 (1)
- 8.4.2 (3)
- 8.4.3 (2)
- 8.4.3 (4)
- 8.4.4 (4)
- 8.4.5 (1)
- 8.5.2 (2)
- 8.5.2 (4)
- 8.7.2 (7)
- 8.7.2 (16)
- 8.7.2 (18) (2 times)
- 9.2.1 (2)P

1. General

1.1 Scope

(1) EN 1993-1-6 gives basic design rules for plated steel structures that have the form of a shell of revolution.

(2) This Standard is intended for use in conjunction with EN 1993-1-1, EN 1993-1-3, EN 1993-1-4, EN 1993-1-9 and the relevant application parts of EN 1993, 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.

(3) This Standard defines the characteristic and design values of the resistance of the structure.

(4) This Standard is concerned with the requirements for design against the ultimate limit states of:

plastic limit;
cyclic plasticity;
buckling;
fatigue.

(5) Overall equilibrium of the structure (sliding, uplifting, overturning) is not included in this Standard, but is treated in EN 1993-1-1. Special considerations for specific applications are included in the relevant application parts of EN 1993.

(6) The provisions in this Standard apply to axisymmetric shells and associated circular or annular plates and to beam section rings and stringer stiffeners where they form part of the complete structure. General procedures for computer calculations of all shell forms are covered. Detailed expressions for the hand calculation of unstiffened cylinders and cones are given in the Annexes.

(7) Cylindrical and conical panels are not explicitly covered by this Standard. However, the provisions can be applicable if the appropriate boundary conditions are duly taken into account.

(8) This Standard is intended for application to steel shell structures. Where no standard exists for shell structures made of other metals, the provisions of this standards may be applied provided that the appropriate material properties are duly taken into account.

(9) The provisions of this Standard are intended to be applied within the temperature range defined in the relevant EN 1993 application parts. The maximum temperature is restricted so that the influence of creep can be neglected if high temperature creep effects are not covered by the relevant application part.

(10) The provisions in this Standard apply to structures that satisfy the brittle fracture provisions given in EN 1993-1-10.

(11) The provisions of this Standard apply to structural design under actions that can be treated as quasi-static in nature.

(12) In this Standard, it is assumed that both wind loading and bulk solids flow can, in general, be treated as quasi-static actions.

(13) Dynamic effects should be taken into account according to the relevant application part of EN 1993, including the consequences for fatigue. However, the stress resultants arising from dynamic behaviour are treated in this part as quasi-static.

(14) The provisions in this Standard apply to structures that are constructed in accordance with EN 1090-2.

(15) This Standard does not cover the aspects of leakage.

(16) This Standard is intended for application to structures within the following limits:

design metal temperatures within the range −50°C to +300°C;
radius to thickness ratios within the range 20 to 5000.

NOTE: It should be noted that the stress design rules of this standard may be rather conservative if applied to some geometries and loading conditions for relatively thick-walled shells.

1.2 Normative references

(1) This European Standard 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 when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 1090-2	*Execution of steel structures and aluminium structures – Part 2: Technical requirements for steel structures;*
EN 1990	*Basis of structural design;*
EN 1991	*Eurocode 1: Actions on structures ;*
EN 1993	*Eurocode 3: Design of steel structures:*
Part 1.1:	*General rules and rules for buildings;*
Part 1.3:	*Cold formed thin gauged members and sheeting;*
Part 1.4:	*Stainless steels;*
Part 1.5:	*Plated structural elements;*
Part 1.9:	*Fatigue strength of steel structures;*
Part 1.10:	*Selection of steel for fracture toughness and through-thickness properties;*
Part 1.12:	*Additional rules for the extension of EN 1993 up to steel grades S 700*
Part 2:	*Steel bridges;*
Part 3.1:	*Towers and masts;*
Part 3.2:	*Chimneys;*
Part 4.1:	*Silos;*
Part 4.2:	*Tanks;*
Part 4.3:	*Pipelines;*
Part 5:	*Piling.*

1.3 Terms and definitions

The terms that are defined in EN 1990 for common use in the Structural Eurocodes apply to this Standard. Unless otherwise stated, the definitions given in ISO 8930 also apply in this Standard. Supplementary to EN 1993-1-1, for the purposes of this Standard, the following definitions apply:

1.3.1 Structural forms and geometry

1.3.1.1 shell

A structure or a structural component formed from a curved thin plate.

1.3.1.2 shell of revolution

A shell whose geometric form is defined by a middle surface that is formed by rotating a meridional generator line around a single axis through 2π radians. The shell can be of any length.

1.3.1.3 complete axisymmetric shell

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

1.3.1.4 shell segment

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

1.3.1.5 shell panel

An incomplete shell of revolution: 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. Where the shell is stiffened on either one or both surfaces, 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 at shell junctions, leading to eccentricities that may be important to the shell structural behaviour.

1.3.1.7 junction

The line at which two or more shell segments meet: it can include a stiffener. The circumferential line 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 to bending effects caused by 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 normally assumed to have no stiffness for deformations out of its own plane (meridional displacements of the shell) but is stiff for deformations in the plane of the ring. It is provided to increase the stability or to introduce local loads acting in the plane of the ring.

1.3.1.11 base ring

A structural member that passes around the circumference of the shell of revolution at the base and provides a means of attachment of the shell to a foundation or other structural member. It is needed to ensure that the assumed boundary conditions are achieved in practice.

1.3.1.12 ring beam or ring girder

A circumferential stiffener that has bending stiffness and strength both in the plane of the shell circular section and normal to that plane. It is a primary load carrying structural member, provided for the distribution of local loads into the shell.

1.3.2 Limit states

1.3.2.1 plastic limit

The ultimate limit state where the structure develops zones of yielding in a pattern such that its ability to resist increased loading is deemed to be exhausted. It is closely related to a small deflection theory plastic limit load or plastic collapse mechanism.

1.3.2.2 tensile rupture

The ultimate limit state where the shell plate experiences gross section failure due to tension.

1.3.2.3 cyclic plasticity

The ultimate limit state where repeated yielding is caused by cycles of loading and unloading, leading to a low cycle fatigue failure where the energy absorption capacity of the material is exhausted.

1.3.2.4 buckling

The ultimate limit state where the structure suddenly loses its stability under membrane compression and/or shear. It leads either to large displacements or to the structure being unable to carry the applied loads.

1.3.2.5 fatigue

The ultimate limit state where many cycles of loading cause cracks to develop in the shell plate that by further load cycles may lead to rupture.

1.3.3 Actions

1.3.3.1 axial load

Externally applied loading acting in the axial direction.

1.3.3.2 radial load

Externally applied loading acting normal to the surface of a cylindrical shell.

1.3.3.3 internal pressure

Component of the surface loading acting normal to the shell in the outward direction. Its magnitude can vary in both the meridional and circumferential directions (e.g. under solids loading in a silo).

1.3.3.4 external pressure

Component of the surface loading acting normal to the shell in the inward direction. Its magnitude can vary in both the meridional and circumferential directions (e.g. under wind).

1.3.3.5 hydrostatic pressure

Pressure varying linearly with the axial coordinate of the shell of revolution.

1.3.3.6 wall friction load

Meridional component of the surface loading acting on the shell wall due to friction connected with internal pressure (e.g. when solids are contained within the shell).

1.3.3.7 local load

Point applied force or distributed load acting on a limited part of the circumference of the shell and over a limited height.

1.3.3.8 patch load

Local distributed load acting normal to the shell.

1.3.3.9 suction

Uniform net external pressure due to the reduced internal pressure in a shell with openings or vents under wind action.

1.3.3.10 partial vacuum

Uniform net external pressure due to the removal of stored liquids or solids from within a container that is inadequately vented.

1.3.3.11 thermal action

Temperature variation either down the shell meridian, or around the shell circumference or through the shell thickness.