SLOVENSKI PREDSTANDARD

SIST ENV 1993-4-1

prva izdaja
julij 2001

Eurocode 3: Projektiranje jeklenih konstrukcij - Del 4-1: Silosi, rezervoarji in cevovodi - Silosi (prevzet ENV 1993-4-1:1999 z metodo platnice)

Eurocode 3: Design of steel structures - Part 4-1: Silos, tanks and pipelines – Silos

Eurocode 3: Calcul des structures en acier - Partie 4-1: Silos, réservoirs et canalisations - Silos

Eurocode 3: Bemessung und Konstruktion von Stahlbauten - Teil 4-1: Silos, Tankbauwerke und Rohrleitungen - Silos

Deskriptorji: jeklene konstrukcije, konstrukcijska jekla, silosi, projektiranje, računanje

ICS 65.040.20; 91.010.30; 91.080.10

Referenčna številka
SIST ENV 1993-4-1:2001 ((sl),en)

Nadaljevanje na straneh od II do V in od 1 do 98

NACIONALNI UVOD

Predstandard SIST ENV 1993-4-1 ((sl),en), Eurocode 3: Projektiranje jeklenih konstrukcij - Del 4-1: Silosi, rezervoarji in cevovodi - Silosi, prva izdaja, 2001, ima status slovenskega predstandarda in je z metodo platnice prevzet evropski predstandard ENV 1993-4-1 (en), Eurocode 3: Design of steel structures - Part 4-1: Silos, tanks and pipelines –Silos, September 1999.

NACIONALNI PREDGOVOR

Evropski predstandard ENV 1993-4-1:1999 je pripravil tehnični odbor Evropskega komiteja za standardizacijo CEN/TC 250 Konstrukcijski evrokodi.

Pripravo tega predstandarda sta CEN poverila Evropska komisija in Evropsko združenje za prosto trgovino.

Odločitev za prevzem tega predstandarda po metodi platnice je sprejela delovna skupina USM/TC KON/WG 3 Jeklene konstrukcije, ki je pripravila tudi nacionalni dokument za uporabo v Sloveniji, potrdil pa tehnični odbor USM/TC KON Konstrukcije.

Ta slovenski predstandard se lahko uporablja samo v skladu z nacionalnim dokumentom, ki je sestavni del SIST ENV 1993-4-1:2001.

Ta slovenski predstandard je dne 2000-12-04 odobril direktor USM.

Rok veljavnosti tega predstandarda je do izdaje evropskega standarda EN 1993-4-1.

ZVEZE S STANDARDI

S prevzemom tega evropskega predstandarda veljajo za omejeni namen referenčnih standardov vsi standardi, navedeni v izvirniku, razen tistih, ki so že sprejeti kot nacionalni standardi:

SIST ENV 1991-1:1998	((sl),en)	Eurocode 1: Osnove projektiranja in vplivi na konstrukcije - 1. del: Osnove projektiranja
SIST ENV 1991-2-1:1998	((sl),en)	Eurocode 1: Osnove projektiranja in vplivi na konstrukcije - Del 2-1: Vplivi na konstrukcije – Gostote, lastna teža in koristne obtežbe
SIST ENV 1991-2-3:1998	((sl),en)	Eurocode 1: Osnove projektiranja in vplivi na konstrukcije - Del 2-3: Vplivi na konstrukcije – Obtežbe snega
SIST ENV 1991-2-4:1998	((sl),en)	Eurocode 1: Osnove projektiranja in vplivi na konstrukcije - Del 2-4: Vplivi na konstrukcije – Vplivi vetra
SIST ENV 1993-1-1:1996	((sl),en)	Eurocode 3: Projektiranje jeklenih konstrukcij - Del 1-1: Splošna pravila in pravila za stavbe
SIST ENV 1993-1-1:1996/A1:1996	((sl),en)	Projektiranje jeklenih konstrukcij – Del 1-1: Splošna pravila in pravila za stavbe - Dodatka D in K
SIST ENV 1993-1-1:1996/A2:2001	((sl),en)	Projektiranje jeklenih konstrukcij – Del 1-1: Splošna pravila in pravila za stavbe - Dodatki G, H, J, N in Z
SIST ENV 1993-1-2:1999	((sl),en)	Projektiranje jeklenih konstrukcij – Del 1-2: Splošna pravila - Projektiranje požarnovarnih konstrukcij
SIST ENV 1993-1-3:2001	((sl),en)	Projektiranje jeklenih konstrukcij – Del 1-3: Splošna pravila - Dodatna pravila za hladnooblikovane tankostenske profile in pločevine

SIST ENV 1993-1-4:2001	((sl),en)	Projektiranje jeklenih konstrukcij – Del 1-4: Splošna pravila - Dodatna pravila za nerjavna jekla
SIST ENV 1993-1-5:2001	((sl),en)	Projektiranje jeklenih konstrukcij – Del 1-5: Splošna pravila - Dodatna pravila za ravninske pločevinaste konstrukcije (ortotropne plošče) brez prečne obremenitve
SIST ENV 1993-1-6:2001	((sl),en)	Projektiranje jeklenih konstrukcij – Del 1-6: Splošna pravila - Dodatna pravila za lupinaste konstrukcije
SIST ENV 1993-1-7:2001	((sl),en)	Projektiranje jeklenih konstrukcij – Del 1-7: Splošna pravila - Dodatna pravila za ravninske pločevinaste konstrukcije (ortotropne plošče), obremenjene s prečno obtežbo
SIST ENV 1993-2:2001	((sl),en)	Projektiranje jeklenih konstrukcij – 2. del: Jekleni mostovi
SIST ENV 1993-3-1:2001	((sl),en)	Projektiranje jeklenih konstrukcij – Del 3-1: Stolpi, jambori in dimniki - Stolpi in jambori
SIST ENV 1993-3-2:2001	((sl),en)	Projektiranje jeklenih konstrukcij – Del 3-2: Stolpi, jambori in dimniki – Dimniki
SIST ENV 1993-4-2:2001	((sl),en)	Projektiranje jeklenih konstrukcij – Del 4-2: Silosi, rezervoarji in cevovodi – Rezervoarji
SIST ENV 1993-4-3:2001	((sl),en)	Projektiranje jeklenih konstrukcij - Del 4-3: Silosi, rezervoarji in cevovodi - Cevovodi
SIST ENV 1993-5:2001	((sl),en)	Projektiranje jeklenih konstrukcij – 5. del: Piloti in zagatne stene
SIST ENV 1993-6:2001	((sl),en)	Projektiranje jeklenih konstrukcij – 6. del: Žerjavne proge

OPOMBI

- Povsod, kjer se v besedilu predstandarda uporablja izraz “evropski predstandard”, v SIST ENV 1993-4-1:2001 to pomeni “slovenski predstandard”.

- Nacionalni uvod in nacionalni predgovor nista sestavni del predstandarda.

VSEBINA **Stran**

Nacionalni dokument za uporabo v Sloveniji

Za vrednosti parametrov, podanih v okvirju (večinoma delni varnostni faktorji odpornosti ali zunanjih vplivov), se v SIST ENV 1993-4-1:2001 privzamejo priporočene vrednosti, podane v ENV 1993-4-1:1999.

EUROPEAN PRESTANDARD

PRÉNORME EUROPÉENNE

EUROPÄISCHE VORNORM

ENV 1993-4-1

September 1999

ICS 65.040.20; 91.010.30; 91.080.10

English version

Eurocode 3: Design of steel structures - Part 4-1: Silos, tanks and pipelines - Silos

Eurocode 3: Calcul des structures en acier - Partie 4-1: Silos, réservoirs et canalisations - Silos

Eurocode 3: Bemessung und Konstruktion von Stahlbauten - Teil 4-1: Silos, Tankbauwerke und Rohrleitungen - Silos

This European Prestandard (ENV) was approved by CEN on 25 December 1998 as a prospective standard for provisional application.

The period of validity of this ENV is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the ENV can be converted into a European Standard.

CEN members are required to announce the existence of this ENV in the same way as for an EN and to make the ENV available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force (in parallel to the ENV) until the final decision about the possible conversion of the ENV into an EN is reached.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

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

Central Secretariat: rue de Stassart, 36 B-1050 Brussels

Ref. No. ENV 1993-4-1:1999 E

Contents

Foreword

Objectives of the Eurocodes

(1) The "Structural Eurocodes" comprise a group of standards for the structural and geotechnical design of buildings and civil engineering works.

(2) They cover execution and control only to the extent that is necessary to indicate the quality of the construction products, and the standard of the workmanship, needed to comply with the assumptions of the design rules.

(3) Until the necessary set of harmonised technical specifications for products and for methods of testing their performance is available, some of the Structural Eurocodes cover some of these aspects in informative annexes.

Background to the Eurocode programme

(4) The Commission of the European Communities (CEC) initiated the work of establishing a set of harmonized technical rules for the design of building works and civil engineering works which would initially serve as an alternative to the different rules in force in the various Member States and would ultimately replace them. These technical rules became known as the 'Structural Eurocodes'.

(5) In 1990, after consulting their respective Member States, the CEC transferred the work of further development, issue and updating of the Structural Eurocodes to CEN, and the EFTA Secretariat agreed to support the CEN work.

(6) CEN Technical Committee CEN/TC 250 is responsible for all Structural Eurocodes.

Eurocode programme

(7) Work is in hand on the following Structural Eurocodes, each generally consisting of a number of parts:

EN 1991 Eurocode 1 Basis of design and 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 provisions for earthquake resistance of structures;

EN 1999 Eurocode 9 Design of aluminium structures.

(8) Separate sub-committees have been formed by CEN/TC 250 for the various Eurocodes listed above.

(9) This Part 4-1 of ENV 1993 is being published by CEN as a European Prestandard (ENV) with an initial life of three years.

(10) This Prestandard is intended for experimental application and for the submission of comments.

(11) After approximately two years CEN members will be invited to submit formal comments on this Prestandard to be taken into account in determining future actions.

(12) Meanwhile feedback and comments on this Prestandard should be sent to the Secretariat of Sub-committee CEN/TC 250/SC 3 at the following address:

BSI Standards
British Standards House
389 Chiswick High Road
London W4 4AL
England

or to your national standards organisation.

National Application Documents (NADs)

(13) In view of the responsibilities of the authorities in member countries for safety, health and other matters covered by the essential requirements of the Construction Products Directive (CPD), certain safety elements in this ENV have been assigned indicative values which are identified by ☐ ("boxed values"). The authorities in each member country are expected to review the "boxed values" and may substitute alternative definitive values for these safety elements for use in national application.

(14) Some of the necessary supporting European or International Standards might not be available by the time this Prestandard is issued. It is therefore anticipated that a National Application Document (NAD) giving any substitute definitive values for safety elements, referencing compatible supporting Standards and providing guidance on the national application of this Prestandard, will be issued by each member country or its Standards Organisation.

(15) It is intended that this Prestandard is used in conjunction with the NAD valid in the country in which the building or civil engineering work is located.

Matters specific to this Prestandard

(16) The list of parts of ENV 1993 that are currently envisaged is:

ENV 1993-1-1 General rules and rules for buildings;

ENV 1993-1-2 Supplementary rules for structural fire design;

ENV 1993-1-3 Supplementary rules for cold formed thin gauge members and sheeting;

ENV 1993-1-4 Supplementary rules for stainless steels;

ENV 1993-1-5 Supplementary rules for planar plated structures without transverse loading;

ENV 1993-1-6 Supplementary rules for the strength and stability of shell structures;

ENV 1993-1-7 Supplementary rules for the strength and stability of planar plated structures loaded transversely;

ENV 1993-2 Steel bridges;

ENV 1993-3-1 Towers and masts;

ENV 1993-3-2 Chimneys;

ENV 1993-4-1 Silos;

ENV 1993-4-2 Tanks;

ENV 1993-4-3 Pipelines;

ENV 1993-5 Piling;

ENV 1993-6 Crane supporting structures,

ENV 1993-7 Marine and maritime structures;

ENV 1993-8 Agricultural structures.

(17) Safety factors for 'product type' silos (factory production) can be specified by the appropriate authorities. When applied to 'product type' silos, the factors in 2.10 are for guidance purposes only. They are provided to show the likely levels needed to achieve consistent reliability with other designs.

1 General

1.1 Scope

(1)P Part 4.1 of Eurocode 3 provides principles and application rules for the structural design of steel silos of circular or rectangular plan-form, being free standing or supported.

(2)P This part is concerned only with the requirements for resistance and stability of steel silos. For other requirements (such as operational safety, functional performance, fabrication and erection, quality control, details like man-holes, flanges, filling devices, outlet gates and feeders etc.), see ENV....##

(3)P Provisions relating to special requirements of seismic design are provided in ENV 1998-4, which complements or adapts the provisions of Eurocode 3 specifically for this purpose.

(4) The design of supporting structures for the silo are dealt with in ENV 1993-1-1. The supporting structure is deemed to consist of all structural elements beneath the bottom flange of the lowest ring of the silo, see figure 1.1.

(5) Foundations in reinforced concrete for steel silos are dealt with in ENV 1992 and ENV 1997.

(6) Numerical values of the specific actions on steel silos to be taken into account in the design are given in ENV 1991-4 Actions in Silos and Tanks. Additional rules for silo actions are given in annex A to this Part 4.1 of Eurocode 3.

(7)P This Part 4.1 does not cover:
- resistance to fire;
- silos with internal subdivisions and internal structures;
- silos with capacity less than 10 tonnes;
- cases where special measures are necessary to limit the consequences of accidents.

(8) The circular planform silos covered by this Prestandard are restricted to axisymmetric structures, but the actions on them may be unsymmetrical, and their supports may induce forces in the silo that are not axisymmetrical.

1.2 Distinction between principles and application rules

(1)P Depending on the character of the individual paragraphs, a distinction is made in this Part between principles and application rules.

(2)P The principles comprise:
- general or definitive statements for which there is no alternative;
- requirements and analytical models for which no alternative is permitted unless specifically stated.

(3) The principles are identified by the letter P following the paragraph number.

(4)P The application rules are generally recognised rules that follow the principles and satisfy their requirements. Alternative design rules different from the application rules given in the Eurocode may be used, provided that it is shown that the alternative rule accords with the relevant principles and has at least the same reliability.

(5) In this Part the application rules are identified by a number in brackets, as in this paragraph.

1.3 Normative references

This European Prestandard incorporates, by dated and undated reference, provisions from other standards. 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 the European

Prestandard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

ENV 1090	*Execution of steel structures;*
ENV 1991	*Eurocode 1: Basis of design and actions on structures;*
Part 1:	*Basis of design;*
Part 2.1:	*Densities, self weight and imposed loads;*
Part 2.2:	*Actions on structures exposed to fire;*
Part 2.3:	*Snow loads;*
Part 2.4:	*Wind loads;*
Part 2.5:	*Thermal loads;*
Part 4:	*Actions on silos and tanks;*
ENV 1993	*Eurocode 3: Design of steel structures;*
Part 1.1:	*General rules and rules for buildings;*
Part 1.3:	*General rules - supplementary rules for cold formed thin gauge members and sheeting;*
Part 1.6:	*General rules - supplementary rules for the strength and stability of shell structures;*
Part 1.7:	*General rules - supplementary rules for planar plated structures loaded transversely;*
Part 4.2:	*Tanks;*
ENV 1997	*Eurocode 7: Geotechnical design;*
ENV 1998	*Eurocode 8: Design provisions for earthquake resistance of structures;*
Part 4:	*Silos, tanks and pipelines;*
EN 10025	*Hot rolled products of non-alloy structural steels - technical delivery conditions;*
EN 10113	*Hot rolled products in weldable fine grain structural steels;*
EN 10149	*Hot-rolled flat products made of high yield strength steels for cold forming;*
ISO 1000	*SI Units;*
ISO 3898	*Bases for design of structures - Notation - General symbols;*
ISO 4997	*Cold reduced steel sheet of structural quality;*
ISO 8930	*General principles on reliability for structures - List of equivalent terms.*

1.4 Definitions

(1) The terms that are defined in ENV 1991-1 for common use in the Structural Eurocodes and the definitions given in ISO 8930 apply to this Part 4.1 of ENV 1993, unless otherwise stated, but for the purposes of this Part 4.1 the following supplementary definitions are given:

1.4.1 shell. A structure formed from a curved thin plate.

1.4.2 axisymmetric shell. A shell structure whose geometry is defined by rotation of a meridional line about a central axis.

1.4.3 box. A structure formed from an assembly of flat plates into a three-dimensional enclosed form. For the purposes of this Prestandard, the box has dimensions that are generally comparable in all directions.

NOTE: There is no direction that can be compared with the span of a box girder bridge.

1.4.4 meridional direction. The tangent to the silo wall in a vertical plane at any point. It varies according to the structural element being considered. Alternatively, it is the vertical or inclined direction on the surface of the structure that a rain drop would take in sliding down the surface.

1.4.5 circumferential direction. The horizontal tangent to the silo wall at any point. It varies around the silo, lies in the horizontal plane and is tangential to the silo wall irrespective of whether the silo is circular or rectangular in plan.

1.4.6 middle surface. This term is used to refer to both the stress-free middle surface when a shell is in pure bending and the middle plane of a flat plate that forms part of a box.

1.4.7 separation of stiffeners. The centre to centre distance between the longitudinal axes of two adjacent parallel stiffeners.

1.5 S.I. units

(1)P S.I. units shall be used in accordance with ISO 1000.

(2) For calculations, the following consistent units are recommended:

– dimensions and thicknesses	:	m	mm
– unit weight	:	kN/m^3	N/mm^3
– forces and loads	:	kN	N
– line forces and line loads	:	kN/m	N/mm
– pressures and area distributed actions	:	kPa	MPa
– unit mass	:	kg/m^3	kg/mm^3
– acceleration	:	km/s^2	m/s^2
– membrane stress resultants	:	kN/m	N/mm
– bending stress resultants	:	kNm/m	Nmm/mm
– stresses and elastic moduli	:	kPa	MPa (=N/mm^2)

(3) Conversion factors
1 mbar = 100 N/m^2 = 0,1 kPa

1.6 Symbols used in Part 4.1 of Eurocode 3

The symbols used are based on ISO 3898: 1987.

1.6.1 Roman upper case letters

A	area of cross-section;
C	membrane stretching stiffness;
C	buckling coefficient;
D	bending flexural rigidity;
E	Young's modulus;
F	force;
G	shear modulus;
H	height of structure;
I	second moment of area of cross-section;
I_t	uniform torsion constant;
K	flexural stiffness of wall panel;
L	height of shell segment or stiffener;
M	bending moment;
N	axial force;
Q	fabrication tolerance quality of construction of a shell susceptible to buckling;
R_ϕ	local radius at the crest or trough of a corrugation.

1.6.2 Roman lower case letters

a	coefficient;
b	width of plate or stiffener;
d	crest to crest dimension of a corrugation;
e	eccentricity of force or stiffener;
f_y	design yield strength of steel;
f_u	ultimate strength of steel;
h	separation of flanges of ring girder;
j	equivalent harmonic of the design stress variation;
ℓ	effective length of shell in linear stress analysis;
ℓ	wavelength of a corrugation in corrugated sheeting;
ℓ	half wavelength of a potential buckle (height to be considered in calculation);
m	bending moment per unit width;
m_x	meridional bending moment per unit circumference;
m_y	circumferential bending moment per unit height of box;
m_θ	circumferential bending moment per unit height of shell;
m_{xy}	twisting shear moment per unit width of plate;
$m_{x\theta}$	twisting shear moment per unit width of shell;
n	membrane stress resultant;
n	number of discrete supports around silo circumference;
n_x	meridional membrane stress resultant per unit circumference;
n_y	circumferential membrane stress resultant per unit height of box;
n_θ	circumferential membrane stress resultant per unit height of shell;
n_{xy}	membrane shear stress resultant per unit width of plate;
$n_{x\theta}$	membrane shear stress resultant per unit width of shell;
p	pressure distributed loading;
p_n	pressure normal to shell (outward);
p_x	meridional surface loading parallel to shell (downward);
p_θ	circumferential surface loading parallel to shell (anticlockwise in plan);
q	transverse force per unit length acting on a tie;
r	radial coordinate in a circular plan-form silo;
r	radius of shell middle surface;
s	circumferential separation of stiffeners;
t	wall thickness;
t_x, t_y	equivalent wall thickness of corrugated sheet for stretching in the x, y directions;
w	imperfection amplitude;
w	radial deflection;
x	local meridional coordinate;
y	local circumferential coordinate;
z	global axial coordinate;
z	coordinate along the vertical axis of an axisymmetric silo (shell of revolution).

1.6.3 Greek letters

α	elastic buckling imperfection factor (knock-down factor);
α	coefficient of thermal expansion;
β	hopper apex half angle;
γ_F	partial factor for actions;
γ_M	partial factor for material strength;
δ	limiting deflection;
Δ	increment;
	reduction factor for flexural buckling;
	buckling stress reduction factor;
λ	shell meridional bending half-wavelength;
$\bar{\lambda}$	relative slenderness of a shell;
μ	wall friction coefficient;