SLOVENSKI STANDARD
SIST ENV 1991-4:2004

01-september-2004

Eurocode 1: Osnove projektiranja in vplivi na konstrukcije – 4. del: Vplivi v silosih in zbiralnikih

Eurocode 1: Basis of design and actions on structures - Part 4: Actions in silos and tanks

Eurocode 1: Grundlagen der Tragwerksplannung und Einwirkungen auf Tragwerke - Teil 4: Einwirkungen auf Silos und Flüssigkeitsbehälter

Eurocode 1: Bases de calcul et actions sur les structures - Partie 4: Actions dans les silos et réservoirs

Ta slovenski standard je istoveten z: ENV 1991-4:1995

ICS:

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EUROPEAN PRESTANDARD

PRÉNORME EUROPÉENNE

EUROPÄISCHE VORNORM

ENV 1991-4

May 1995

ICS 91.040.00

Descriptors: civil engineering, structures, design, construction, buildings codes, computation, loads, silos, tanks:containers

English version

Eurocode 1: Basis of design and actions on structures - Part 4: Actions in silos and tanks

Eurocode 1: Bases de calcul et actions sur les structures - Partie 4: Actions dans les silos et réservoirs

Eurocode 1: Grundlagen der Tragwerksplannung und Einwirkungen auf Tragwerke - Teil 4: Einwirkungen auf Silos und Flüssigkeitsbehälter

This European Prestandard (ENV) was approved by CEN on 1993-06-30 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 an European Standard (EN).

CEN members are required to announce the existance 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, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

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

Ref. No. ENV 1991-4:1995 E

ENV 1991-4

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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 harmonized technical specifications for products and for methods of testing their performance are 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 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 of structures for earthquake resistance

EN 1999 Eurocode 9: Design of aluminium alloy structures

(8) Separate subcommittees have been formed by CEN/TC250 for the various Eurocodes listed above.

(9) This Part of ENV 1991 is being published as European Prestandard ENV 1991-4.

(10) This prestandard is intended for experimental application and for the submission of comments, and a future development is intended to cover greater eccentricities and silos with internal ties.

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

(12) Meanwhile feedback and comments on this prestandard should be sent to the secretariat of CEN/TC250/SC1 at the following address:

SNV / SIA (until end May 1995)
Selnaustrasse 16
CH-8039 ZÜRICH
SWITZERLAND

SIS (from June 1995)
Box 3295
S-103 66 STOCKHOLM
SWEDEN

or to your national standards organization.

National Application Documents (NAD's)

(13) In view of the responsibilities of 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 supporting European or International standards may not be available by the time this Prestandard is issued. It is therefore anticipated that a National Application Document (NAD) giving an 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 Organization.

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

(16) The scope of ENV 1991 is defined in clause 1.1.1 and the scope of this part of ENV 1991 is defined in 1.1.2. Additional parts of ENV 1991 which are planned are indicated in clause 1.1.3.

(17) This Part is complemented by a number of informative annexes.

Section 1 General

1.1 Scope

1.1.1 Scope of ENV 1991 - Eurocode 1

(1)P ENV 1991 provides general principles and actions for the structural design of buildings and civil engineering works including some geotechnical aspects and shall be used in conjunction with ENV 1992-1999.

(2) It may also be used as a basis for the design of structures not covered in ENV 1992-1999 and where other materials or other structural design actions are involved.

(3) ENV 1991 also covers structural design during execution and structural design for temporary structures. It relates to all circumstances in which a structure is required to give adequate performance.

(4) ENV 1991 is not directly intended for the structural appraisal of existing construction, in developing the design of repairs and alterations or, for assessing changes of use.

(5) ENV 1991 does not completely cover special design situations which require unusual reliability considerations such as nuclear structures for which specified design procedures should be used.

1.1.2 Scope of ENV 1991-4 Actions on silos and tanks

(1)P This part provides general principles and actions for the structural design of tanks and silos including some geotechnical aspects and shall be used in conjunction with ENV 1991-1:Basis of Design, other parts of ENV 1991 and ENV 1992-1999.

(2) This part may also be used as a basis for the design of structures not covered in ENV 1992-1999 and where other materials or other structural design actions are involved.

(3) The following limitations apply to the design rules for silos:

- The silo cross section shapes are limited to those shown in figure 1.2;
- Filling involves only negligible inertia effects and impact loads;
- The maximum particle diameter of the stored material is not greater than $0{,}3d_c$.

Note: When particles are large compared to the silo wall thickness the load shall be applied as single forces.

- The stored material is free-flowing;

- The eccentricity e_i of the stored material due to filling is less than $0{,}25d_c$ (figure 1.2);

- The eccentricity e_o of the centre of the outlet is less than $0{,}25d_c$;
  and no part of the outlet is at a distance greater than $0{,}3d_c$ from the centre plane of silos with plane flow or the centre line of other silos (figure 1.2).

- Where discharge devices are used (for example, feeders or internal flow tubes), material flow is smooth and central within the eccentricity limits given above.

- The transition is on a single horizontal plane.

- The following geometrical limitations apply:

  $h/d_c < 10$
  $h < 100$ m
  $d_c < 50$ m

- Each silo is designed for a defined range of particulate material properties.

(4) The design rules from tanks apply only to tanks storing liquids at normal atmospheric pressure.

(5) ENV 1991-4 shall be used in conjunction with ENV 1991-1 and other parts of ENV 1991.

1.1.3 Further Parts of ENV 1991

(1) Further parts of ENV 1991 which, at present, are being prepared or are planned are given in 1.2.

1.2 Normative references

This European Prestandard incorporates by dated or undated reference, provisions from other standards. These normative references are cited in the appropriate places in the text and publications listed hereafter.

ISO 3898 1987	Basis of design for structures Notations. General symbols

Note: The following European Prestandards which are published or in preparation are cited at the appropriate places in the text and publications listed hereafter.

ENV 1991-1	Eurocode 1: Basis of design and actions on structures Part 1 : Basis of design
ENV 1991-2-1	Eurocode 1: Basis of design and actions on structures

	Part 2.1: Densities, self-weight and imposed loads
ENV 1991-2-2	Eurocode 1: Basis of design and actions on structures Part 2.2: Actions on structures exposed to fire
ENV 1991-2-4	Eurocode 1: Basis of design and actions on structures Part 2.4 Wind loads
ENV 1991-2-5	Eurocode 1: Basis of design and actions on structures Part 2.5: Thermal actions
ENV 1991-2-6	Eurocode 1: Basis of design and actions on structures Part 2.6: Loads and deformations imposed during execution
ENV 1991-2-7	Eurocode 1: Basis of design and actions on structures Part 2.7: Accidental actions
ENV 1991-3	Eurocode 1: Basis of design and actions on structures Part 3: Traffic loads on bridges
ENV 1991-5	Eurocode 1: Basis of design and action on structures Part 5: Actions induced by cranes and machinery
ENV 1992	Eurocode 2: Design of concrete structures
ENV 1993	Eurocode 3: Design of steel structures
ENV 1994	Eurocode 4: Design of composite steel and concrete structures
ENV 1995	Eurocode 5: Design of timber structures
ENV 1996	Eurocode 6: Design of masonry structures
ENV 1997	Eurocode 7: Geotechnical design
ENV 1998	Eurocode 8: Earthquake resistant design of structures
ENV 1999	Eurocode 9: Design of aluminium alloy structures

1.3 Distinction between principles and application rules

(1) Depending on the character of the individual clauses, distinction is made in this part between principles and application rules.

(2) The principles comprise:

- general statements and definitions for which there is no alternative, as well as
- 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) The application rules are generally recognized rules which follow the principles and satisfy their requirements.

(5) It is permissible to use alternative rules different from the application rules given in this Eurocode, provided it is shown that the alternative rules accord with the relevant principles and have at least the same reliability.

(6) In this part the application rules are identified by a number in brackets eg. as this clause.

1.4 Definitions

For the purposes of this prestandard, a basic list of definitions is provided in ENV 1991-1, 'Basis of design' and the additional definitions given below are specific to this part.

1.4.1 equivalent surface: Level surface giving the same volume of stored material as the actual surface (figure 1.2).

1.4.2 flat bottom: A flat silo bottom or a silo bottom with inclined walls where $\alpha \leq 20°$.

1.4.3 flow pattern: The form of flowing material in the silo when flow is well established (figure 1.1). The silo is close to its maximum filling condition.

1.4.4 fluidised material: A stored material injected with air, which significantly changes the behaviour of the stored material.

1.4.5 free flowing material: A material with a low cohesion.

1.4.6 funnel flow (or **core flow**) (figure 1.1): A flow pattern in which a channel of flowing material develops within a confined zone above the outlet, and the material adjacent to the wall near the outlet remains stationary. The flow channel can intersect the vertical walled section or extend to the surface of the stored material.

1.4.7 homogenizing silo: A silo containing a fluidised material.

1.4.8 hopper: A silo bottom with inclined walls where $\alpha > 20°$.

1.4.9 internal flow (figure 1.1): A funnel flow pattern in which the flow channel extends to the surface of the stored material.

1.4.10 kick load: A local load that occurs at the transition during discharge.

1.4.11 low cohesion: A material sample has low cohesion if the cohesion is less than 4kPa when the sample is preconsolidated to 100kPa. (A method for determining cohesion is given in annex B).

1.4.12 mass flow: (figure 1.1). A flow pattern in which all the stored particles are mobilised during discharge.

1.4.13 patch load: A local load taken to act over a specified zone on any part of a silo wall.

1.4.14 plane flow: A flow profile in a rectangular or a square cross-section silo with a slot outlet. The slot is parallel with two of the silo walls and its length is equal to the length of these walls.

1.4.15 silo: Containment structure used to store particulate materials (i.e. bunkers, bins, and silos).

1.4.15.1 slender silo: A silo where $h/d_c \geq 1.5$

1.4.15.2 squat silo: A silo where $h/d_c < 1.5$

1.4.15.3 thin walled circular silo: A silo with a circular cross section, no stiffeners and where $d_c / t > 200$.

1.4.16 tank: Containment structure used to store liquids.

1.4.17 transition: The intersection of the hopper and the vertical walled section.

1.4.18 vertical walled section: The part of a silo or a tank with vertical walls.

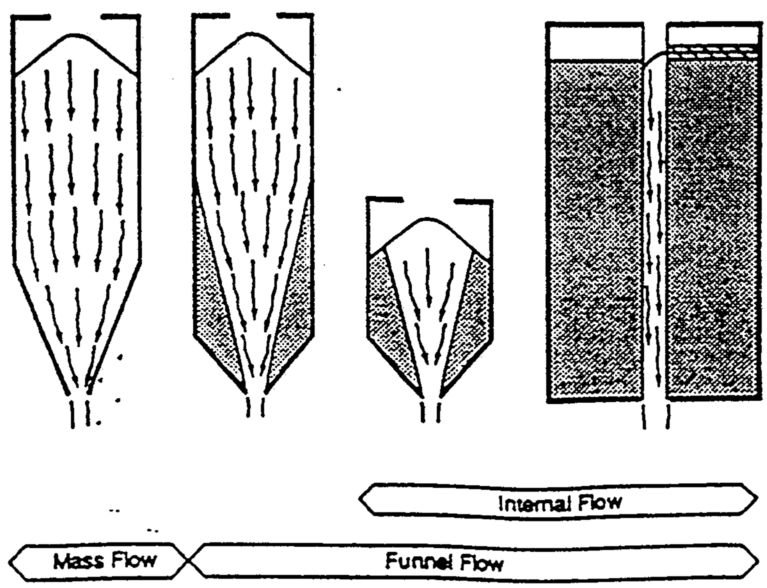

Figure 1.1: Flow patterns

1.5 Notations

(1) For the purpose of this prestandard, the following symbols apply.

Note: The notation used is based on ISO 3839:1987.

(2) A basic list of notations is provided in ENV 1991-1, 'Basis of design' and the additional notations below are specific to this Part.

Latin upper case letters

A	cross-sectional area of vertical walled section
C	wall load magnifier
C_0	maximum wall load magnifier
C_b	bottom load magnifier
C_h	horizontal load magnifier
C_w	wall frictional traction magnifier
C_z	Janssen coefficient
F_p	total horizontal force due to patch load on thin walled circular silo
K_s	design value of horizontal/vertical pressure ratio
$K_{s,m}$	mean value of horizonal/vertical pressure ratio
P_w	resulting vertical load per unit perimeter of the vertical walled section
U	internal perimeter of the vertical walled section

Latin lower case letters

d_c	characteristic cross-section dimension (figure 1.2)
e	the larger of e_i and e_o
e_i	eccentricity due to filling (figure 1.2)
e_o	eccentricity of the centre of the outlet (figure 1.2)
h	distance from outlet to equivalent surface (figure 1.2)

h_1, h_2 parameters used in the determination of vertical pressures in squat silos

l_h hopper wall length (figure 5.3)

p hydrostatic pressure

p_h horizontal pressure due to stored material

p_{he} horizontal pressure during discharge (figure 1.2)

$p_{he,s}$ horizontal pressure during discharge calcuated using the simplified method

p_{hf} horizontal pressure after filling

$p_{hf,s}$ horizontal pressure after filling calculated using the simplied method

p_{h0} horizontal pressure after filling at the base of the vertical walled section

p_n , p_{ni} pressure normal to inclined hopper wall, where i = 1, 2 and 3

p_p patch pressure

$p_{p,sq}$ patch pressure in sqat silos

p_{ps} patch pressure (thin walled circular silos)

p_s kick pressure

p_t hopper frictional traction (figure 1.2)

p_v vertical pressure due to stored material (figure 1.2)

p_{ve} vertical pressure during discharge

p_{vi} vertical pressure components used to determine the vertical pressure in squat silos, i = 1, 2, 3

p_{vf} vertical pressure after filling

$p_{vf,sq}$ vertical pressure after filling in squat silos

p_{v0} vertical pressure after filling at the base of the vertical walled section

p_w wall frictional pressure on the vertical section (figure 1.2)

p_{we} wall frictional pressure during discharge