SLOVENSKI STANDARD
SIST ENV 1992-4:2004

01-september-2004

Eurocode 2: Projektiranje betonskih konstrukcij ï 4. del: Zadrġevalniki tekoļ in

Eurocode 2: Design of concrete structures - Part 4: Liquid retaining and containment structures

Eurocode 2: Planung von Stahlbeton- und Spannbetontragwerken - Teil 4: Stütz- und Behälterbauwerke aus Beton

Eurocode 2: Calcul des structures en béton - Partie 4: Structures de soutenement et réservoirs

Ta slovenski standard je istoveten z: **ENV 1992-4:1998**

<u>**ICS:**</u>

91.010.30	Tehniļ ni vidiki	Technical aspects
91.080.40	Betonske konstrukcije	Concrete structures

SIST ENV 1992-4:2004 **en**

EUROPEAN PRESTANDARD

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Eurocode 2: Design of concrete structures - Part 4: Liquid retaining and containment structures

Eurocode 2: Calcul des structures en béton - Partie 4: Structures de soutènement et réservoirs

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This European Prestandard (ENV) was approved by CEN on 27 May 1997 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.

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

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

Ref. No. ENV 1992-4:1998 E

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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 harmonised technical specifications for products and for the methods of testing their performance are available, some of the Structural Eurocodes cover some of these aspects in informative Appendices.

Background of 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 alternatives 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 alloy structures

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

(9) This Part 4 of Eurocode 2 is being published 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 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/TC 250/SC 2 at the following address:

Deutsches Institut für Normung e.V. (DIN)
Burggrafenstrasse 6
D – 10787 Berlin
phone: (+49) 30 – 26 01 – 25 01
fax: (+49) 30 – 26 01 – 12 31

National Application Documents (NADs)

(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 assign definitive values to these safety elements.

(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 definitive values for the safety elements, referencing compatible supporting standards and providing national guidance on the 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 where the building or civil engineering works is located.

Matters specific to this prestandard

(16) The scope of Eurocode 2 is defined in 1.1.1 of ENV 1992-1-1 and the scope of this Part of Eurocode 2 is defined in 1.1.2. Other Additional Parts of Eurocode 2 which are already issued as ENV are indicated in 1.1.3 of ENV 1992-1-1; these cover additional technologies or applications, and complement and supplement this Part.

(17) In using this Prestandard in practice, particular regard should be paid to the underlying assumptions and conditions given in 1.3 of ENV 1992-1-1.

(18) The five chapters of this Prestandard are complemented by three Informative Appendices. These Appendices have been introduced to provide general information on material and structural behaviour which may be used in the absence of information specifically related to the actual materials used or actual conditions of service.

(19) As indicated in paragraph (14) of this Foreword, reference should be made to National Application Documents which will give details of compatible supporting standards to be used. For this Part of Eurocode 2, particular attention is drawn to the approved Prestandard ENV 206 (Concrete – performance, production, placing and compliance criteria).

For ENV 1992-4, the following additional sub-clauses apply.

(20) This Part 4 of Eurocode 2 complements ENV 1992-1-1 for the particular aspects of liquid retaining and structures for the containment of granular solids.

(21) The framework and structure of this Part 4 correspond to ENV 1992-1-1. However, Part 4 contains Principles and Application Rules which are specific to liquid retaining and containment structures.

(22) Where a particular sub-clause of ENV 1992-1-1 is not mentioned in this ENV 1992-4, that sub-clause of ENV 1992-1-1 applies as far as deemed appropriate in each case.

Some Principles and Application Rules of ENV 1992-1-1 are modified or replaced in this Part, in which case the modified versions supersede those in ENV 1992-1-1 for the design of liquid retaining or containment structures.

Where a Principle or Application Rule in ENV 1992-1-1 is modified or replaced, the new number is identified by the addition of 100 to the original number. Where a new Principle or Application Rule is added, it is identified by a number which follows the last number in the appropriate clause in ENV 1992-1-1 with 100 added to it.

A subject not covered by ENV 1992-1-1 is introduced in this Part by a new sub-clause. The sub-clause number for this follows the most appropriate clause number in ENV 1992-1-1.

(23) The numbering of equations, figures, footnotes and tables in this Part follow the same principles as the clause numbering as described in (22) above.

1 Introduction

1.1 Scope

Replacement of clause 1.1.2 in ENV 1992-1-1 by:

1.1.2 Scope of Part 4 of Eurocode 2

P(101) Part 4 of Eurocode 2 covers the design of structures constructed from plain or lightly reinforced concrete, reinforced concrete or prestressed concrete for the containment of liquids or granular solids and other liquid retaining structures.

P(102) Principles and Application Rules are given in this Part for the design of those elements of structure which directly support the stored liquids or materials (i.e. the walls of tanks, reservoirs or silos). Other elements which support these primary elements (for example, the tower structure which supports the tank in a water tower) should be designed according to the provisions of Part 1 except that the design actions arising from the retained material will be calculated according to the provisions of this Part.

P(103) This Part does not cover:

- Structures for the storage of materials at very low temperatures;
- Structures for the storage of materials at very high temperatures;
- Structures for the storage of hazardous materials the leakage of which could constitute a major health or safety risk;
- The selection and design of liners;
- design for resistance to fire. This is covered by Part 1-2 of Eurocode 2 or by national provisions;
- no-fines concrete and aerated concrete components, and those made with heavy aggregate or containing structural steel sections (see Eurocode 4 for composite steel-concrete structures);
- pressurised vessels;
- floating structures;
- Structures subjected to significant seismic actions (design for seismic actions is covered in Eurocode 8).

(104) Storage of materials of very low temperatures may be assumed where the temperature of the stored material is –20 °C or less. For the storage of liquid petroleum gas see EN 26502 Part 2.

(105) Storage of materials of very high temperatures may be assumed where the temperature of the stored material exceeds 200 °C.

(106) For the selection and design of liners, reference should be made to appropriate documents.

1.7 Special symbols used in Part 1 of Eurocode 2

Addition after 1.7.4:

1.7.5 Special symbols used in Part 4 of Eurocode 2

1.7.5.1 Latin upper case symbols

E_r effective modulus of elasticity of the stored material
L_c the crack length (m)
Q leakage rate in m^3/s
Q_o operating value of imposed load
Q_w imposed load from a retained liquid
R_{ax} factor defining the degree of external axial restraint provided by elements attached to the element considered
R_m factor defining the degree of moment restraint provided by elements attached to the element considered
T_1 temperature of material in contact with surface 1
T_2 temperature of material in contact with surface 2
T_m mean steady state temperature of a wall

1.7.5.2 Latin lower case symbols

f_{ctx} tensile strength, however defined

f_{ckT} characteristic compressive strength of the concrete modified to take account of temperature
h wall thickness in m
w_{eff} effective crack width (m)

1.7.5.3 Greek symbols

α_T a coefficient taking account of the moisture content of the concrete
α_1 resistance to heat flux at surface 1
α_2 resistance to heat flux at surface 2
γ_w partial safety factor on load due to retained liquid
Δp pressure difference across the element (N/mm^2)
ΔT_{ss} steady state temperature difference
ε_{av} average strain in the element
ε_{az} actual strain at level z
ε_{iz} imposed intrinsic strain at level z
ε_{Tr} transitional thermal strain
ε_{Th} free thermal strain in the concrete
λ_c conductivity of concrete
ρ_r density of the stored material in kN/m^3
υ_r Poisson's ratio of stored material
σ_z vertical stress in stored material in kN/m^2
η dynamic viscosity of liquid (kg/ms)

2 Basis of design

2.2 Definitions and classifications

2.2.2 Actions

2.2.2.3 Representative values of variable actions

Replacement of this sub-clause by:

P(101) The main representative value is the characteristic value, Q_k. The representative value corresponding to the specified quantity of the retained material which the structure is designed to hold should more properly be called the 'operating value', Q_o, but, for convenience, the symbol Q_k will be used for this operating value.

(102) In a liquid retaining structure where the maximum level of the liquid can be clearly defined and where the effective density of the liquid (allowing for any suspended solids) will not vary significantly, a lower safety factor, γ_w, than that in Table 2.2 of ENV 1992-1-1 may be used on the characteristic load due to the retained liquid, Q_w.

(103) If not stated otherwise, the values of ψ_0, ψ_1 and ψ_2 applied to the operating load should be taken as 1.0.

2.3 Design requirements

2.3.1 General

Addition after Principle P(4):

(105) The design situations to be considered should comply with ENV 1991-4, clause 3. For liquid retaining and containment structures made with concrete, the following design situations may be relevant:

- operating conditions implying patterns of discharge and filling;
- explosions due to powder;
- thermal effects caused, for example, by stored materials or environmental temperature;
- imposed deformations.

2.3.2 Ultimate limit states

2.3.2.2 Combinations of actions

Add a note below Table 2.1 in ENV 1992-1-1.

NOTE: Where γ_w is used for one of the variable actions, $\gamma_w Q_w$ is substituted for the corresponding value of $\gamma_Q Q_k$.

Replacement of Application Rules (5) to (8) by:

(105) Appropriate values for the characteristic actions and appropriate combinations of actions are given in Eurocode 1 Part 4: Actions in silos and tanks.

2.3.3 Partial safety factors for ultimate limit states

2.3.3.1 Partial safety factors for actions on structures

Replacement of Table 2.2 by:

Table 2.102: Partial safety factors for actions in containment structures for persistent and transient situations

	permanent actions γ_G	variable actions, general γ_Q	variable actions due to retained liquid γ_w	prestressing γ_p
Favourable effect	[1,0]*	**	**	*** [0.9] or [1.0]
Unfavourable effect	[1.35]*	[1.5]	[1.2][1)]	[1.2] or [1.0]

* see also paragraphs (3) in this clause in Part 1 and (109) below.
** see Eurocode 1; in normal circumstances, $\gamma_{Q,inf} = 0$
*** see relevant clauses
1) covering model uncertainties, see ENV 1991-1, clause 9 and Annex A.

Replacement of Application Rule (8) by:

(108) By adopting the γ values given in Table 2.102, the expression (2.7(a)) may be replaced by the following:

– for design situations with only one variable action $Q_{k,1}$ or Q_w:

$$\Sigma\gamma_{G,j}\, G_{k,j} + 1.5\, Q_{k,1} \text{ or } |\underline{1.2}|\, Q_w \qquad (2.108(a))$$

– for design situations with two or more variable actions:

$$\Sigma\gamma_{G,j}\, G_{k,j} + 1.35 \sum_{i\geq 1} Q_{k,i} + |\underline{1.2}|\, Q_w \qquad (2.108(b))$$

whichever gives the most unfavourable effect.

Equations (2.108(a)) and (2.108(b)) should be used only, if the conditions for the action Q_w in 2.2.2.3 (102) are met. Otherwise, the partial safety factor $\gamma_Q = 1.5$ should be applied to Q_w.

(109) Actions resulting from soil or water within soil are treated as permanent actions and should be obtained in accordance with Eurocode 7. Actions from retained materials in silos should be considered as variable actions.

(110) It should be noted that, where backfill is placed against the outside walls of a structure, it is required that the safety should be checked both with and without the soil present.

2.3.4 Serviceability limit states

Replacement of Application Rule (7) by:

(107) Where actions other than environmental actions (wind, snow, temperature etc.) are being considered, the rare combination may be simplified to the following expressions, which may also be used as a substitute for the frequent combination:

– design situations with only one variable action, $Q_{k,1}$

$$\Sigma G_{k,j}\, (+P) + Q_{k,1} \qquad (2.109(d))$$

– design situations with two or more variable actions, $Q_{k,i}$

$$\Sigma G_{k,j}\, (+P) + |\underline{1.0}| \cdot \Sigma\, Q_{k,i} \qquad (2.109(e))$$

whichever gives the more critical value.

Addition after Principle P(8):

(109) Acceptance criteria for liquid retaining structures could include maximum level of leakage.

2.5 Analysis

2.5.1 General provisions

2.5.1.1 General

Addition after Application Rule (6):

P(107) Account shall be taken of the effects of structure-soil interaction where these are significant.

Addition after 2.5.5:

2.5.6 Determination of the effects of temperature

2.5.6.1 General

(101) It will normally be adequate to use methods of analysis based on the assumption of elastic structural behaviour. However, allowance should be made for the effects of creep, shrinkage and cracking where these are likely to be significant.

(102) Rigorous analyses may be carried out using Equation (2.22) in 2.5.5.1 of ENV 1992-1-1. It should be noted that it will also be necessary to introduce compatibility and/or equilibrium conditions to obtain a solution (for example, in a fully restrained member of uniform section, $\varepsilon_{tot}(t,t_0)$, has to be equal to zero at all values of t).

(103) In many cases it will be sufficiently accurate to carry out an elastic analysis on the basis of an effective modulus of elasticity for the concrete which has been adjusted to make allowance for the effects of creep in accordance with Equation (2.24) in 2.5.5.1 (12) in ENV 1992-1-1.

(104) Where a member is subjected to different temperatures on opposite faces, the steady state temperature difference across the wall is given by Equation (2.125) below (see Figure 2.106):

$$\Delta T_{ss} = \frac{(h/\lambda_c)}{\alpha_1 + (h/\lambda_c) + \alpha_2}(T_2 - T_1) \tag{2.125}$$

where:

ΔT_{ss} steady state temperature difference

α_1 resistance to heat flux at surface 1. In the absence of specific data for the situation considered, the following values may be adopted for α_1:

0.005 m^2 °C/W for liquids
0.110 m^2 °C/W for granular materials
0.060 m^2 °C/W for ambient atmosphere (this may be significantly affected by wind).

α_2 resistance to heat flux at surface 2 (values as for α_1)

h wall thickness in m

λ_c conductivity of concrete which may be taken as 1.75 W/m°C in the absence of better data

T_1 temperature of material in contact with surface 1

T_2 temperature of material in contact with surface 2 numerically higher than T_1

The mean steady state temperature of the wall may be taken as:

$$T_m = T_1 + \left(0.5 + \frac{\lambda_c \alpha_1}{h}\right)\Delta T_{ss} \tag{2.126}$$

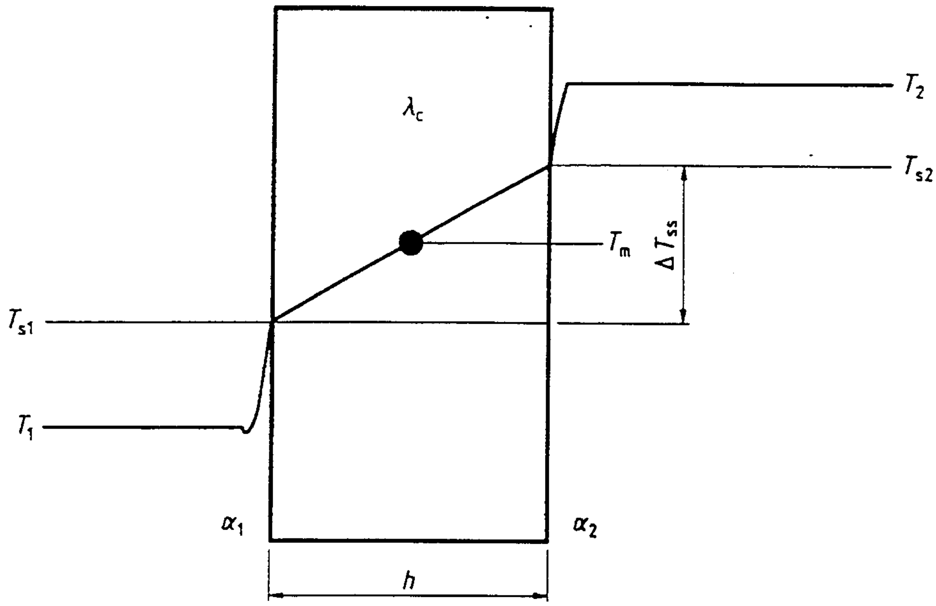

Figure 2.106: Steady state temperature state in a wall

In Figure 2.106:

$$\frac{T_2 - T_1}{(\alpha_1 + (h / \lambda_c) + \alpha_2)} = \frac{T_2 - T_{s2}}{\alpha_2} = \frac{\Delta T_{ss}}{(h / \lambda_c)} = \frac{T_{s1} - T_1}{\alpha_1} \tag{2.127}$$

(105) Where the mean temperatures in different, monolithically connected, elements of a structure are different, significant effects due to the restraint of some members by others in the structure may occur. Where significant, these should be taken into account.

(106) In silos, high temperature gradients may occur where the stored material is either self heating or is put into the silo at high temperature. In such circumstances calculation of the resulting temperature gradients and the consequent internal forces and moments will be necessary. Two situations may require consideration:

– high temperature gradients in the walls above the bulk material due to hot air in an almost empty silo;

– reduced wall temperature gradients due to heat insulating effects of the bulk material in an almost full silo.

(107) An increase in tensile forces and associated moments may also occur where a drop in the temperature outside the silo leads to the silo walls shrinking onto the retained material. These forces and moments may be calculated by estimating an effective modulus of elasticity for the retained material from the approximate relation:

$$E_r = \frac{3.09\ \rho_r^{1.5}\ \sigma_z}{(1 - \upsilon_r)} \tag{2.128}$$

where:

E_r effective modulus of elasticity of the stored material

ρ_r density of the stored material in kN/m^3

υ_r Poisson's ratio of stored material

σ_z vertical stress in the stored material in kN/m^2

3 Material properties

3.1 Concrete

3.1.2 Normal weight concrete

3.1.2.5.4 Coefficient of thermal expansion

Replacement of Principle P(1) by: