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Eurocode 1 - Actions on structures - Part 4: Silos and tanks

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

Eurocode 1 - Actions sur les structures - Partie 4 : Actions sur les silos et les réservoirs

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Eurocode 1 - Actions sur les structures - Partie 4 : Silos et réservoirs

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

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European foreword

This document (prEN 1991-4:2024) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI. CEN/TC 250 is responsible for all Structural Eurocodes and has been assigned responsibility for structural and geotechnical design matters by CEN.

This document is currently submitted to the CEN Enquiry.

This document will supersede EN 1991-4:2006 and AC:2012.

The first generation of EN Eurocodes was published between 2002 and 2007. This document forms part of the second generation of the Eurocodes, which have been prepared under Mandate M/515 issued to CEN by the European Commission and the European Free Trade Association.

The Eurocodes have been drafted to be used in conjunction with relevant execution, material, product and test standards, and to identify requirements for execution, materials, products and testing that are relied upon by the Eurocodes.

The Eurocodes recognize the responsibility of each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level through the use of National Annexes.

0 Introduction

0.1 Introduction to the Eurocodes

The Structural Eurocodes comprise the following standards generally consisting of a number of Parts:

- EN 1990 Eurocode — Basis of structural and geotechnical 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
- New parts are under development, e.g. Eurocode for design of structural glass

The Eurocodes are intended for use by designers, clients, manufacturers, constructors, relevant authorities (in exercising their duties in accordance with national or international regulations), educators, software developers, and committees drafting standards for related product, testing and execution standards.

NOTE Some aspects of design are most appropriately specified by relevant authorities or, where not specified, can be agreed on a project-specific basis between the relevant parties such as designers and clients. The Eurocodes identify such aspects making explicit reference to relevant authorities and relevant parties.

0.2 Introduction to the EN 1991 series

(1) The EN 1991 series specifies actions for the structural and geotechnical design of buildings, bridges and other civil engineering works, or parts thereof, including temporary structures, in conjunction with EN 1990 and the other Eurocodes.

(2) The EN 1991 series does not cover the specific requirements of actions for seismic regions. Provisions related to such requirements are given in the EN 1998 series, which complement and are consistent with the EN 1991 series.

(3) The EN 1991 series is also applicable to existing structures for:

— structural assessment,

— strengthening or repair,

— change of use.

NOTE In these cases additional or amended provisions can be necessary.

(4) The EN 1991 series is also applicable for the design of structures where materials or actions outside the scope of the other Eurocodes are involved.

NOTE In this case additional or amended provisions can be necessary.

0.3 Introduction to EN 1991-4

EN 1991-4 gives guidance for the evaluation of actions for the structural design of silos and tanks.

0.4 Verbal forms used in the Eurocodes

The verb “shall” expresses a requirement strictly to be followed and from which no deviation is permitted in order to comply with the Eurocodes.

The verb “should” expresses a highly recommended choice or course of action. Subject to national regulation and/or any relevant contractual provisions, alternative approaches could be used/adopted where technically justified.

The verb “may” expresses a course of action permissible within the limits of the Eurocodes.

The verb “can” expresses possibility and capability; it is used for statements of fact and clarification of concepts.

0.5 National annex for prEN 1991-4

National choice is allowed in this standard where explicitly stated within notes. National choice includes the selection of values for Nationally Determined Parameters (NDPs).

The national standard implementing prEN 1991-4 can have a National Annex containing all national choices to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

When no national choice is given, the default choice given in this standard is to be used.

When no national choice is made and no default is given in this standard, the choice can be specified by a relevant authority or, where not specified, agreed for a specific project by appropriate parties.

National choice is allowed in EN 1991-4 through notes to the following clauses:

1.1(4)	4.1(2)	5.5.16(2)	5.7(7)

National choice is allowed in EN 1991-4 on the application of the following informative annexes:

Annex A	Annex B	Annex F	Annex G

The National Annex can contain, directly or by reference, non-contradictory complementary information for ease of implementation, provided it does not alter any provisions of the Eurocodes.

1 Scope

1.1 Scope of EN 1991-4

(1) EN 1991-4 provides guidance for calculating actions for the structural design of silos and tanks.

NOTE 1 Silos are used for the storage of particulate solids: tanks are used for the storage of liquids.

NOTE 2 For limitations on rules for silos given in this document, see 1.3.

NOTE 3 For limitations on rules for tanks given in this document, see 1.4.

(2) EN 1991-4 includes some provisions for actions on silo and tank structures that are not only associated with the stored solids or liquids (e.g. the effects of thermal differentials) but substantially affected by them.

NOTE Liquid loads on tanks are very precisely defined. Many loads on silos are not known with great precision. This standard provides guidance for many practical situations for which very limited certain knowledge is available, and the information is derived from the limited experimental and analytical information available, coupled with conclusions drawn from failure investigations. The information is not based on a sound statistical treatment of experimental data.

(3) EN 1991-4 is intended for use with concrete, steel, aluminium, timber and FRP storage structures.

NOTE FRP is the standard acronym for fibre reinforced polymer materials.

(4) EN 1991-4 may be used for the structural assessment of existing construction, in developing the design of repairs and alterations or for assessing changes of use.

NOTE Where the structural appraisal of an existing structure is being considered, reference can be made to the National Annex and to the client concerning the relevance of the current standard.

1.2 Assumptions

(1) The assumptions of EN 1990 apply.

(2) EN 1991-4 is intended to be used in conjunction with EN 1990, with the other parts of EN 1991, EN 1992, EN 1993, EN 1995, EN 1997, EN 1998 and EN 1999 where relevant to the design of silos and tanks.

1.3 Limitations on silos

1.3.1 Geometrical limitations

(1) The following geometrical limitations apply to the design rules for silos covered by this document:

- the silo here defined is either an isolated structure or can be part of a battery of silos. For a silo battery, the term silo is used throughout this standard to refer to a single cell within the battery;
- the silo planform cross-section shapes are limited to those shown in Figure 1.1c.

NOTE 1 Minor variations to these shapes can be accepted provided the structural consequences of the resulting changes in pressure are expected to be considered. Further information concerning planform cross-section geometries is given in 7;

NOTE 2 Further information concerning planform cross-section geometries is given in Clause 7.

- the relevant overall height of the silo h_b (Figure 1.1a) is measured from the level of the equivalent surface of the stored solid (see 3.2.17) when the silo is filled to its maximum capacity, down to the apex of the cone of the hopper or to the flat base where there is no hopper;

NOTE For the evaluation of h_o to calculate h_b, see (2).

- the effective diameter d_c of the silo should be determined as indicated in Figure 1.1c;
- the following dimensional limitations on the overall height h_b and aspect ratio h_b/d_c apply (see Figure 1.1):

$$h_b/d_c < 10 \quad (1.1)$$

$$h_b < 100 \text{ m} \quad (1.2)$$

$$d_c < 60 \text{ m} \quad (1.3)$$

- the structural transition lies in a single horizontal plane (see Figure 1.1a);
- the relevant cylindrical section height of the silo h_c (Figure 1.1a) should be measured from the level of the equivalent surface of the stored solid (see 3.2.17) when the silo is filled to its maximum capacity, down to the structural transition (see Figure 1.1a) or to the flat base where there is no hopper;

(2) For a symmetrically filled circular silo of diameter d_c, h_0 should be determined as:

$$h_o = \frac{d_c}{6} \tan \phi_r \quad (1.4)$$

and for a symmetrically filled rectangular silo of characteristic dimension d_c, h_0 should be determined as:

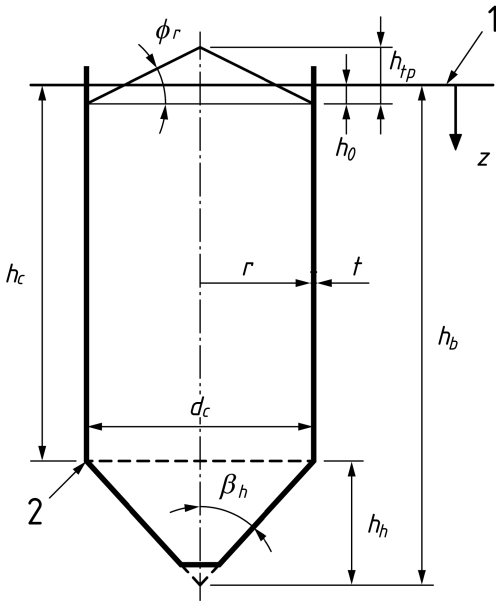
$$h_o = \frac{d_c}{4} \tan \phi_r \quad (1.5)$$

where:

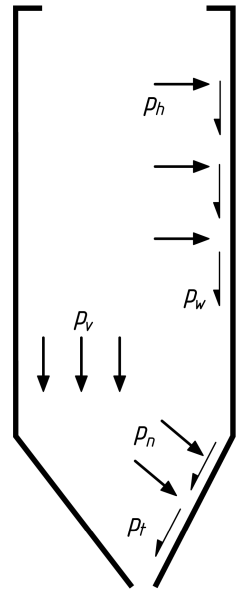
ϕ_r is the angle of repose of the solid (see Table C.1).

NOTE For solids that can become fluidised on filling, the value of ϕ_r can also be zero.

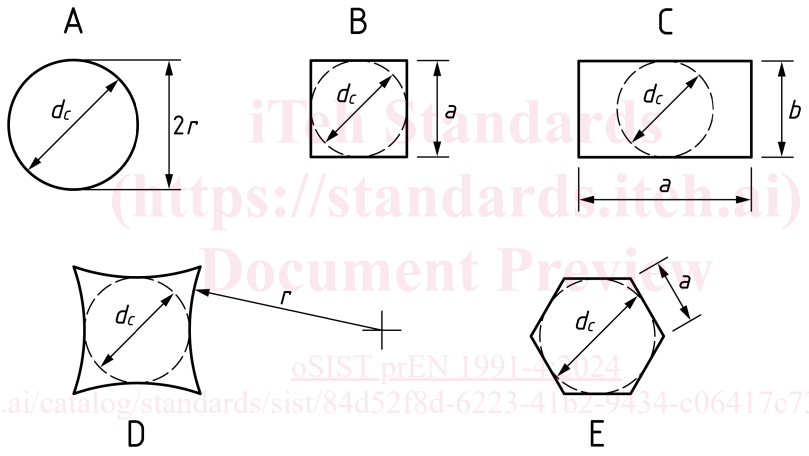
(3) The value of h_o for a powder may normally be taken as $h_o = 0$ because the solid is naturally aerated on deposition. Silo design for storing powders should allow for higher filling levels arising from this effect.



a) Geometry



b) Pressures and frictional tractions



c) Cross-section planform shapes and definition of d_c

Key

1	Equivalent surface
2	Transition
A	Circular
B	Square
C	Rectangular
D	Interstitial
E	Hexagonal

Figure 1.1 — Silo forms showing dimensions and pressure notation

(4) Only hoppers that are conical (i.e. axisymmetric), rectangular pyramidal, wedge-shaped (i.e. with vertical end walls) or oblique are covered by this standard. Other hopper shapes and hoppers with internal structures require special considerations.

(5) Silos with an oblique conical hopper used to achieve an eccentric outlet are covered by this standard.