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English Version

Eurocode 3 - Design of steel structures - Part 4-2: Tanks

Eurocode 3 - Calcul des structures en acier - Partie 4-2: Réservoirs

Eurocode 3: Bemessung und Konstruktion von Stahlbauten - Teil 4-2: Tankbauwerke

This draft amendment is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 250.

This draft amendment A1, if approved, will modify the European Standard EN 1993-4-2:2007. If this draft becomes an amendment, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for inclusion of this amendment into the relevant national standard without any alteration.

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European foreword

This document (EN 1993-4-2:2007/prA1:2016) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI.

This document is currently submitted to the CEN Enquiry.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

1 Modification to the Foreword

In the Foreword, in the section "National Annex for EN 1993-4-2", *in the 2nd paragraph, replace the whole list with the following one:*

"

- 2.2 (1)
- 2.2 (3)
- 2.9.2 (3)P
- 2.9.3 (2)
- 3.3 (3)
- 4.1.4 (3)".

2 Modifications to 1.1, Scope

Replace Paragraph (1) with the following one (including the present Footnote 1)):

"(1) Part 4-2 of Eurocode 3 provides principles and application rules for the structural design of vertical cylindrical, conical and pedestal above ground steel tanks for the storage of liquid products with the following characteristics:

a) tanks with capacity greater than 100 m^3 (100 000 litres);

b) tanks that have significant fabrication or assembly on site;

c) shop-fabricated tanks with conical bottoms, supported on skirts or columns;

d) tanks with characteristic internal pressures above the liquid surface not more negative than −0,1 bar and not greater than 0,5 bar[1)];

e) design metal temperatures limited to the ranges:

   1) tanks constructed using structural steel grades, $-50°C < T < +300°C$;

   2) tanks constructed using austenitic stainless steels, $-165°C < T < +300°C$;

   3) tanks constructed with special steel grades that have defined yield strengths up to higher temperatures, $-165°C <$ $T <$ the maximum defined temperature for the grade;

   4) tanks susceptible to failure by fatigue, $T < 150°C$;

f) in cylindrical ground-supported tanks, the maximum design liquid level not higher than the top of the cylindrical shell.".

Replace Paragraph (8) with the following one:

"(8) This Part 4-2 does not cover:

— tanks of rectangular planform;

— tanks with capacity below 100 m^3;

— tanks exposed to fire (refer to EN 1993-1-2);

1) All pressures are in bar gauge unless otherwise specified.

— tanks with dished ends and diameter less than 5 m;

— cylindrical tanks with an aspect ratio of height to diameter greater than 3.".

3 Modifications to 1.2, Normative references

Replace "EN 1990" *with* "EN 1990:2002".

In the list of the parts of EN 1993, replace "Part 1.6:" *with* "Part 1.6:2007:".

In the list of the parts of EN 1993, replace "Part 1.10:" *with* "Part 1.10:2005:".

In the list of the parts of EN 1993, replace "Part 4.1:" *with* "Part 4.1:2007:".

4 Modifications to 1.5, Terms and definitions

In 1.5.1, replace the last sentence with the following one: "In the tank construction industry, this term is also taken to have the special meaning of the vertical wall of a cylindrical tank, see 1.5.9.".

Delete Entry 1.5.3 and renumber the following numbered entries accordingly.

In 1.5.5 (new numbering 1.5.4), delete in the last sentence: "irrespective of whether the tank is circular or rectangular in plan".

Replace the content of Entry 1.5.6 (new numbering 1.5.5) with "This term is used to refer to the stress-free middle surface when a shell is subject to pure bending in any direction.".

In 1.5.8, (new numbering 1.5.7) replace the second sentence with: "In this standard it is assumed to be circular in plan.".

Replace the content of Entry 1.5.9 (new numbering 1.5.8) with: "The term shell is often used in the tank industry to refer to the vertical wall of a cylindrical tank. This usage is slightly confusing when compared with the general definition (see EN 1993-1-6) given in 1.5.1, it is quite widely used, so it is also used in this standard where appropriate. Where any confusion may arise, the term cylindrical wall is used instead.".

In 1.5.13 (new numbering 1.5.12), in the 1st sentence, delete "or flat plate elements".

In 1.5.13 (new numbering 1.5.12), in the 2nd sentence, delete "or box".

In 1.5.15 (new numbering 1.5.14), replace: "The shell-roof junction is the junction between the vertical wall and the roof. It is sometimes referred to as the eaves junction, though this usage is more common for solids storages." *with:* "The shell-roof junction, alternatively known as the top angle or eaves junction, is the junction between the vertical wall and the roof.".

In 1.5.17 (new numbering 1.5.16), in the first sentence, delete "or flat plate" *and* "or a vertical stiffener on a box".

In 1.5.18 (new numbering 1.5.17), delete the last sentence: "In a shell of revolution it is circular, but in rectangular structures is takes the rectangular form of the plan section.".

In 1.5.20 (new numbering 1.5.19), replace the first sentence with: "A ring girder or ring beam is a circumferential stiffener which has bending stiffness and strength in the plane of the circular section of a shell and also normal to that plane.".

In 1.5.20 (new numbering 1.5.19), delete in the second sentence: "or box structure".

In 1.5.23 (new numbering 1.5.22), replace: "An external tank structure to contain fluid that may escape by leakage or accident from the primary tank. This type of structure is used where the primary tank contains toxic or dangerous fluids." *with:* "An external tank structure to contain fluid that may escape by leakage or accident from the primary tank. This type of structure is usually used where the primary tank contains toxic or dangerous fluids. A catch basin also effectively reduces the requirement for an extensive area of fluid containment around the tank.".

5 Deletion of 1.7.2, Conventions for global tank structure axis system for rectangular tanks

Delete the whole Subclause 1.7.2, including Figure 1.2, and renumber Subclauses 1.7.3 and 1.7.4 as 1.7.2 and 1.7.3.

6 Modifications to 1.7.3 (new numbering 1.7.2), Conventions for structural element axes in both circular and rectangular tanks

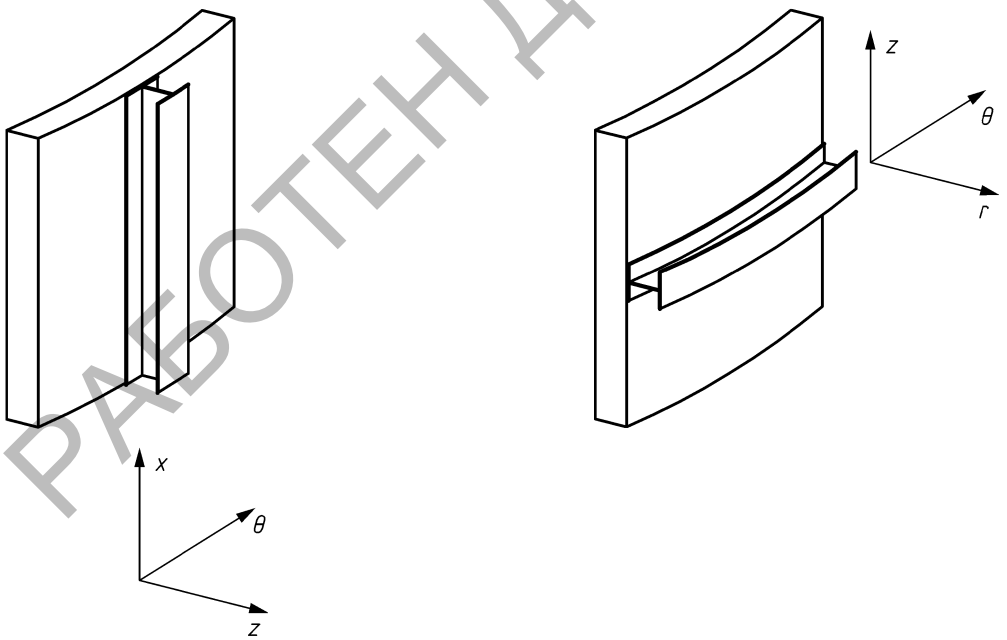
Replace the title of this subclause "Conventions for structural element axes in both circular and rectangular tanks" *with* "Conventions for structural element axes in circular tanks".

In Paragraph (1) replace "(see figures 1.3 and 1.4)" *with* "(see Figure 1.2)".

In Paragraph (2) replace "(see figure 1.3a)" *with* "(see Figure 1.2a)" *and delete* "(for both a shell and a box)".

Replace Figure 1.3 with the following new Figure 1.2:

"



a) Meridional stiffener **b) Circumferential stiffener**

Figure 1.2 — Local coordinate systems for meridional and circumferential stiffeners".

Delete Figure 1.4.

In Paragraph (3) replace "(see figure 1.4a)" *with* "(see Figure 1.2b)".

Delete Paragraph (4).

7 Modifications to 1.7.4 (new numbering 1.7.3), Conventions for stress resultants for circular tanks and rectangular tanks

Replace the title "Conventions for stress resultants for circular tanks and rectangular tanks" *with* "Conventions for stress resultants for circular tanks".

In Paragraph (1) replace the two references to Figure 1.5 with "Figure 1.3" *and delete:*

"n_y circumferential membrane stress resultant in rectangular boxes"

and

"σ_{my} circumferential membrane stress in rectangular boxes".

In Paragraph (2) replace the two references to Figure 1.5 with "Figure 1.3" *and delete:*

"m_y circumferential bending stress resultant in rectangular boxes"

and

"σ_{by} circumferential bending stress in rectangular boxes"

and

"σ_{siy}, σ_{soy} circumferential inner, outer surface stress in rectangular boxes

τ_{sixy}, τ_{soxy} inner, outer surface shear stress in rectangular boxes".

Renumber Figure 1.5 as Figure 1.3.

8 Modification to 2.2, Reliability differentiation

Replace Paragraphs (1) to (4)P with:

"(1) For reliability differentiation, see EN 1990.

NOTE The National Annex may define the Consequence Classes for tanks as a function of the location, type of stored fluid and loading, the structural form, size and operational aspects.

(2) Different levels of rigour should be used in the design of tank structures, depending on the Consequence Class chosen, the structural arrangement and the susceptibility to different failure modes.

(3) For this standard, three Consequence Classes are used, with requirements which produce designs with essentially equal risk in the design assessment and considering the expense and procedures necessary to reduce the risk of failure for different structures: Consequence Classes 1, 2 and 3.

NOTE The National Annex may choose appropriate values for the boundaries between the classes. Table 2.1 gives recommended values for the classification based on the size, structural form and stored contents into Consequence Classes when all other parameters result in medium consequences, see EN 1990:2002, B.3.1.

(4) The classification of flat-bottomed tanks that rest on the ground is based on the dimension *U*, which is related to the potential energy of the stored fluid.

$$U = \sqrt{DH} \tag{2.1}$$

where *D* is the tank diameter and *H* is the maximum depth of stored fluid (see Figure 2.1a)).

Table 2.1 a) — Recommended Consequence Class definitions depending on contents, size and structural form

Consequence Class	Design Situations
Consequence Class 3	a) Tanks storing liquids or liquefied gases with toxic or explosive potential; b) All flat-bottomed tanks used to store fluids at or near the top of a building; c) All pedestal tanks with centroidal height $H_g \geq H_{ga}$ (see Fig. 2.1b); d) Ground-supported water tanks with parameter U in the range $U > U_{3a}$; e) Ground-supported tanks storing water-polluting liquids with parameter U in the range $U > U_{3b}$; f) Ground-supported tanks storing flammable liquids with parameter U in the range $U > U_{3c}$. Emergency loadings should be taken into account for these structures where necessary, see A.2.14.
Consequence Class 2	a) All pedestal tanks not in Consequence Class 3; b) Ground-supported water tanks with parameter U in the range $U_{2a} < U \leq U_{3a}$; c) Ground-supported tanks storing water-polluting liquids with parameter U in the range $U_{2b} < U \leq U_{3b}$; d) Ground-supported tanks storing flammable liquids with parameter U in the range $U_{2c} < U \leq U_{3c}$.
Consequence Class 1	All other tanks within the scope of this standard.

NOTE 1 The recommended values for class boundaries are as follows:

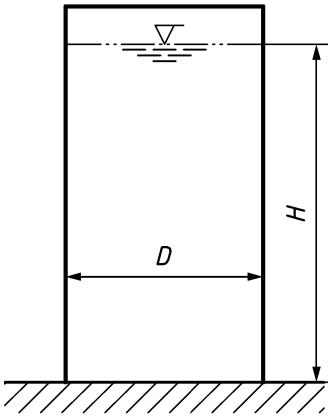
Table 2.1 b) — Recommended values for class boundaries

Class Boundary	Recommended Value
H_{ga}	30 m
U_{3a}	27 m
U_{3b}	24 m
U_{3c}	15 m
U_{2a}	18 m
U_{2b}	15 m
U_{2c}	10 m

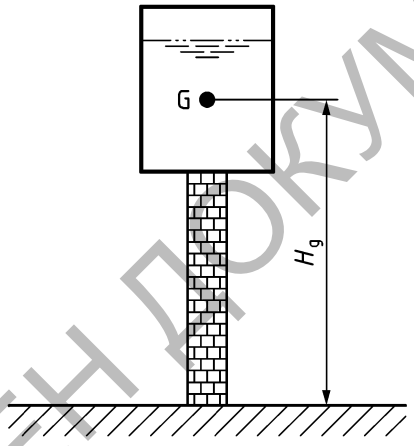
NOTE For the classification by Action Assessment Classes, see EN 1991-4.

(5) A higher Consequence Class than that required may always be adopted.

(6)PThe choice of relevant Consequence Class shall be agreed between the designer, the client and the relevant authority.



a) Basic geometry of ground-supported tank



b) Centroidal height of fluid in a pedestal tank

Figure 2.1 — Dimensions defined for Consequence Classes

".

9 Modifications to 2.7, Modelling of the tank for determining action effects

In Paragraph (2), replace "7.5" with "6.5" and delete "9.4".

In Paragraph (3), replace "5.3, 7.3 and 9.3" *with* "5.3 and 6.3".

10 Deletion of 2.10, Combinations of actions

Delete the whole Subclause 2.10 and renumber Subclause 2.11 as Subclause 2.10.

11 Modification to 3.5.1, General

Replace Paragraphs (1) and (2) with:

"(1) The toughness requirements should be determined for the reference temperature T_{ed} according to EN 1993-1-10.

(2) The minimum design metal temperature T_{MDMT} should be determined according to 3.5.2. The temperature T_{MDMT} should be used in place of (T_{md} + ΔT_r) in 2.2(5) of EN 1993-1-10:2005.".

12 Modification to 3.5.2, Minimum design metal temperature

Replace Paragraphs (1) and (2), including Table 3.1, with:

"(1) The minimum design metal temperature T_{MDMT} should be the lowest of the minimum temperature of the contents or those classified in Table 3.1.

(2) The lowest one day mean ambient temperature T_{LODMAT} should be taken as the lowest recorded temperature averaged over any 24 h period. Where insufficiently complete records are available, this average temperature may be taken as the mean of the maximum and minimum temperatures or an equivalent value.

Table 3.1: Minimum design metal temperature T_{MDMT} based on T_{LODMAT}

Lowest one day mean ambient temperature T_{LODMAT}	**Minimum design metal temperature** T_{MDMT}	
	10 years data	30 years data
$-10°C \leq T_{LODMAT}$	T_{LODMAT} +5°C	T_{LODMAT} +10°C
$-25°C \leq T_{LODMAT} \leq -10°C$	T_{LODMAT}	T_{LODMAT} +5°C
$T_{LODMAT} \leq -25°C$	T_{LODMAT} −5°C	T_{LODMAT}

".

13 Modifications to 4.1.3, Effects of corrosion

Replace the title of Subclause 4.1.3 with "Allowance for corrosion".

Replace Paragraphs (1) to (3) with:

"(1) The responsibility for corrosion losses in a tank lies entirely with the client, owner or end user.

(2) The life expectancy of the tank and its intended usage should be agreed between the client, the engineer and the relevant authority.

(3) The wall thickness reduction to account for the effects of corrosion should be agreed between the designer, the client and the relevant authority, taking account of the intended use, any internal lining, the nature of the liquid to be stored and the life expectancy of the tank.

Reference may be made to EN 12285-1:2003, Annex B, if applicable.

(4) Wall thickness losses and damage to internal structures due to corrosion should be considered in the design calculations.

(5) The extent of corrosion loss depends upon the stored liquid, the type of steel, the heat treatment, the life expectancy of the tank and any measures taken to protect the construction against corrosion.

(6) Where a suitable protection system, as approved by the relevant authority where appropriate, is provided to guarantee protection against corrosion (e.g. glass lining of the internal surface, cathodic protection etc.), no corrosion loss provision need be considered.

(7) Consideration should also be given to corrosion by the atmosphere above the level of the stored fluid, especially if it may contain steam.

NOTE The National Annex may choose appropriate values for corrosion losses for particular liquid in contact with defined tank wall materials for a defined life expectancy.

(8) Appropriate provision should be made for periodic inspection of the tank wall thickness, with reference made to its original design thickness at every level.".

14 Modification to 4.2.2.1, General

In Paragraph (3), replace "Section 11" *with* "Clause 7".

15 Deletion of 4.3, Analysis of the box structure of a rectangular tank

Delete Subclause 4.3 and renumber Subclause 4.4 as Subclause 4.3.

16 Modifications to 5.3, Resistance of the tank shell wall

Replace the title "Resistance of the tank shell wall" *with* "Resistance of the structural segments of the tank".

Add Paragraphs (4) and (5):

"(4) The design of conical hoppers should satisfy the requirements of EN 1993-4-1.

(5) The design of transition junctions at the bottom of a cylindrical wall and supporting ring girders should satisfy the requirements of EN 1993-4-1.".

17 Modification to 5.4.6.3, Design of shell man holes and shell nozzles of large size for LS1

In Paragraph (6), replace the definition of "t" underneath Formula (5.2):

"t is the shell plate thickness;"

with:

"t is the shell plate thickness required to resist only internal pressure from the stored fluid and overpressure;".

18 Modification to 5.4.7, Anchorage of the tank

Replace Paragraph (3):

"(3) Where the tank is supported on a rigid anchorage, and is subject to horizontal loads (e.g. wind, impact) the anchorage forces should be calculated according to shell theory.

NOTE It should be noted that these forces may be locally much higher than those found using beam theory. See clause (3) of section 5.4.7 of EN 1993-4-1."

with:

"(3) Where a uniformly supported anchored tank is subject to horizontal loads (e.g. wind) the anchorage forces should be calculated according to either linear shell bending theory or semi-membrane theory. They should not be calculated using beam theory.

It should be noted that these forces are locally much higher than those found using beam theory. See Paragraph (3) in 5.4.7 of EN 1993-4-1:2007.".

19 Deletion of Clause 6, Design of conical hoppers

Delete the whole Clause 6 and renumber Clause 7 as Clause 6 and its subclauses accordingly. (Renumber also Formula (7.1) as Formula (6.1).)

20 Modification to 7.1.2, Roof design

In Paragraph (2), replace "7.3 to 7.5" *with* "6.3 to 6.5".

21 Modification to 7.3, Resistance of circular roofs

In Paragraph (1), replace "7.4" *with* "6.4".

22 Modification to 7.4.3, Roof to shell junction (eaves junction)

In Paragraph (2), replace "11.1" *with* "7.1" *and* "11.2.5" *with* "7.2.5".

23 Deletion of Clause 8, Design of transition junctions at the bottom of the shell and supporting ring girders

Delete Clause 8.

24 Deletion of Clause 9, Design of rectangular and planar-sided tanks

Delete Clause 9.

25 Deletion of Clause 10, Requirements on fabrication, execution and erection with relation to design

Delete Clause 10.

26 Modification to Clause 11, Simplified design

Renumber Clause 11 as Clause 7 and renumber accordingly the subclauses, tables, figures and formulae contained in it.

27 Modification to 11.1, General

In paragraph (2), replace "2.9.2.2" *with* "2.9.2".

28 Modification to 11.2.1, Unstiffened roof shell butt welded or with double lap weld

In Paragraph (2), replace "section 7" *with* "Clause 6".

29 Modifications to 11.3.2, Stiffening rings

After Paragraph (14), add the two following paragraphs:

"(15) A rational method should be used to determine the required size of one or more intermediate ring stiffeners.

(16) It may be useful to apply the provisions of EN 1993-1-6:2007, 8.7 using the LBA-MNA method to obtain the elastic critical mode and critical buckling pressure and to estimate the plastic reference pressure for any proposed ring stiffening design.

NOTE It may be noted that a value of R_{cr} greater than 2 will typically fulfil the requirements of a more complete analysis.".

Renumber Paragraph (15) as Paragraph (17).

30 Modification to A.1, General

In Paragraph (2), delete "and the action combination rules according to 2.10".