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Structural design of buried pipelines under various conditions of loading - Part 2: Summary of nationally established methods of design

Statische Berechnung von erdverlegten Rohrleitungen unter verschiedenen Belastungsbedingungen - Teil 2: Zusammenstellung national eingeführter Berechnungsverfahren

Calcul de résistance mécanique des canalisations enterrées sous diverses conditions de charge - Partie 2: Résumé des méthodes nationales de dimensionnement

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This Technical Report was approved by CEN on 28 February 2005. It has been drawn up by the Technical Committee CEN/TC 165.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Foreword

This Technical Report (CEN/TR 1295-2:2005) has been prepared by Technical Committee CEN/TC 165 “Wastewater engineering”, the secretariat of which is held by DIN.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This Technical Report was prepared by a Joint Working Group (JWG 1) of Technical Committees TC 164, Water supply, the secretariat of which is held by AFNOR, and TC 165, Waste water engineering, the secretariat of which is held by DIN.

This Technical Report is intended for use in conjunction with the series of product standards covering pipes of various materials for the water industry.

This Technical Report includes an Informative Annex A in which are included additional details about the nationally established methods of design declared, submitted by and used in member countries, and collated by the Joint Working Group.

Introduction

The structural design of buried pipelines constitutes a wide ranging and complex field of engineering, which has been the subject of extensive study and research, in many countries over a period of very many years.

Whilst many common features exist between the design methods which have been developed and established in the various member countries of CEN, there are also differences reflecting such matters as geological and climatic variations, as well as different installation and working practices.

In view of these differences, and of the time required to develop a common design method which would fully reflect the various considerations identified in particular national methods, a two stage approach has been adopted for the development of this document.

In accordance with this two stage approach, the Joint Working Group, at its initial meeting, resolved "first to produce a document giving guidance on the application of nationally established methods of structural design of buried pipelines under various conditions of loading, whilst working towards a common method of structural design". This document represents the full implementation of the first part of that resolution.

1 Scope

In addition to EN 1295-1, this Technical Report gives additional guidance when compared with EN 1295-1 on the application of the nationally established methods of design declared by and used in CEN member countries at the time of preparation of this document (see informative Annex A).

This Technical Report is an important source of design expertise, but it cannot include all possible special cases, in which extensions or restrictions to the basic design methods may apply.

Since in practice precise details of types of soil and installation conditions are not always available at the design stage, the choice of design assumptions is left to the judgement of the engineer. In this connection the document can only provide general indications and advice.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1295-1, *Structural design of buried pipelines under various conditions of loading — Part 1: General requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1295-1 apply.

4 Additional details about established methods

Annex A gives for several countries details about the established methods of design declared, submitted by and used in member countries.

Annex A
(informative)

Summary of Methods of different countries

A.1 Austria

A.1.1 General remarks

The Austrian Standard Őnorm B 5012:2005 is based on the "option 1" contained in CEN/TR 1295-3.

This "option 1" had been prepared by the TG1 of the CEN/TC164-165/JWG1 as a result of thorough study of the subject and long-lasting consultations carried out from 1992 onwards.

Although the design method described in "option 1" was mainly based on two recognised and well-tested "national methods", the German ATV-DVWK-A 127 and the (former) Austrian ÖNORM B 5012-1 and – 2, some new assumptions had to be incorporated in the re-drafted "option 1" in order to consider the most recent experience gained in this domain.

Therafter, it was of course also necessary to prove the correctness of the newly made assumptions by means of comprehensive field testing. This particular kind of testing was done during the period from 2000 to 2004. The tests results obtained were already incorporated in the ÖNORM B 5012 a revision of the former parts 1 and 2 of this standard.

Therefore the ÖNORM B 5012:2005 represents a calculation method which is based on the most recent experience in this field, but it still complies with the calculation principles elaborated by "JWG 1" regarding the "option 1" of CEN/TR 1295-3.

A.1.2 Differences between "option 1" and ÖNORM B 5012

The ÖNORM B 5012 differs in the following points from "option 1":

1) Two different applications of ÖNORM B 5012 enable to make

   i) calculations for pipe design and

   ii) back-calculations of failure situations

For the pipe design the soil moduli proposed in "option 1" (Table 4) shall be reduced by the factor 0,5, whereas for back-calculations the unchanged soil moduli from "option 1" should be used.

The purpose for this distinction is the following:

The results of calculations for the pipe design should be close to the 95 % fractile of the scattering design values, like deflection, stress or strain. Then the required safety or failure probability is assured by using the safety factors proposed in ÖNORM B 5012.

However, for back-calculations of failure situations the calculation results should be as close as possible to the mean value of the measured values.

2) Factor $f_{R,GW}$ is changed in ÖNORM B 5012 in comparison to "option 1" (compare equation 23 in "option 1" and ÖNORM B 5012).

3) The soil pressure ratios K_1 and K_2 are partly changed (compare Table 11 in "option 1" and ÖNORM B 5012).

4) The recommended support angles α_v are partly changed (compare Table 13 in "option 1" and ÖNORM B 5012).

5) In ÖNORM B 5012 the horizontal bedding stiffness S_{Bh} and factor ζ is calculated in a clearer and easier way than in "option 1" (compare 8.3.2 in "option 1" and ÖNORM B 5012).

6) The estimated values of relative initial ovalization $\delta_{v,io}$ in "option 1" are reduced in ÖNORM B 5012 by the factor 0,5 (compare Tables 19 and 20 in "option 1" with Table 18 and 19 in ÖNORM B 5012).

7) In ÖNORM B 5012 it is proposed to use the theory 2nd order calculation more consequently than in "option 1" (in ÖNORM for flexible pipes with deflections greater than 1 % in comparison to 5 % in "option 1").

A.1.3 Principles

Like "option 1", the ATV-DVWK-A 127 and the ÖNORM model the calculation system of ÖNORM B 5012 is based on the model of the embedded circular or non circular ring. The pipe-soil interaction is taken into account by the following interpretations:

1) In vertical direction: Using the shear-stiff beam model above the pipe for the calculation of the vertical loading due to the earth weight and uniformly distributed surcharge;

2) In horizontal direction: Using the compatibility condition of the horizontal pipe and soil movements taking into account all loads considered in the calculation (e.g. for the calculation of the horizontal bedding reaction pressures).

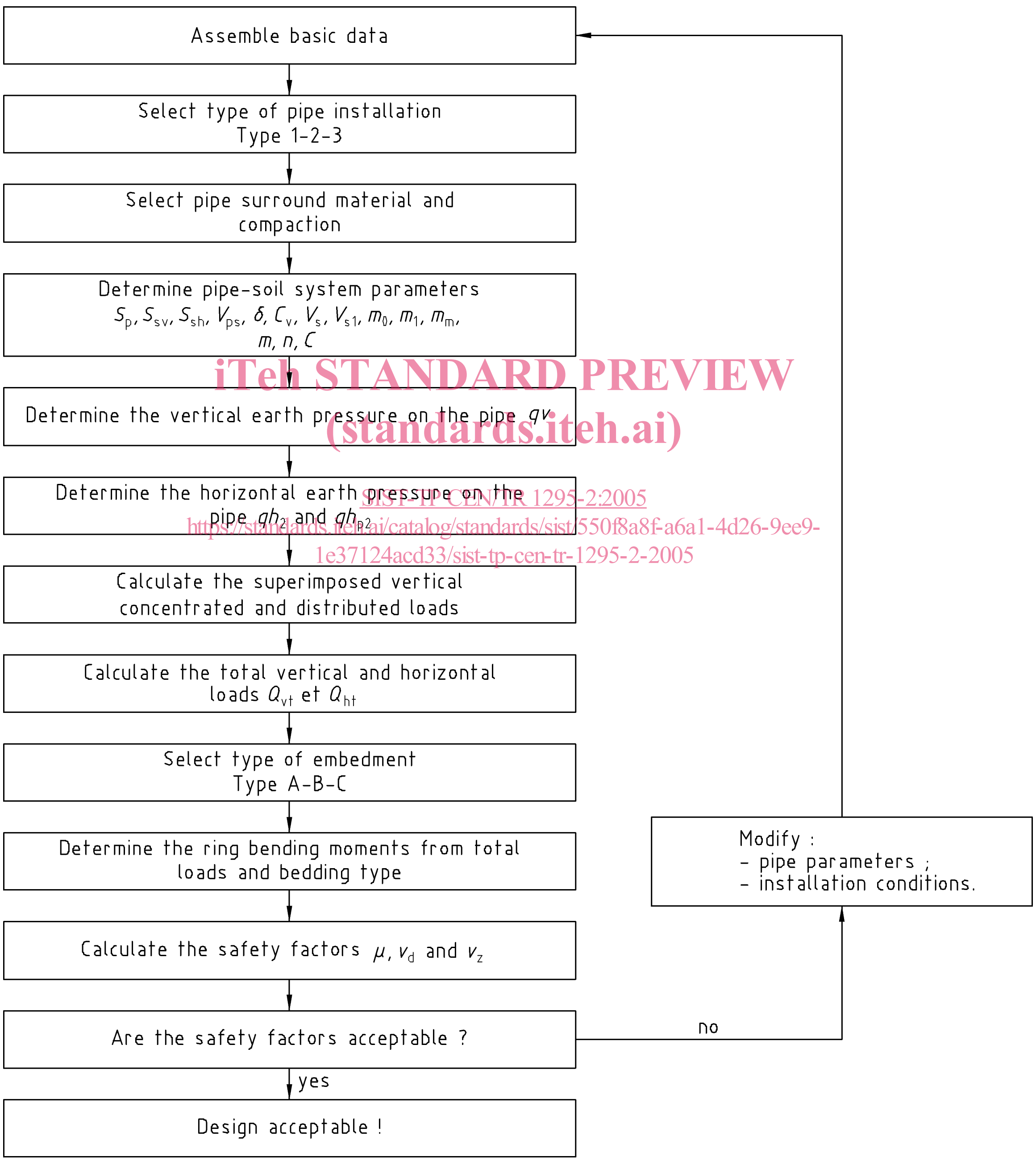
Further descriptions of details about the principles and the calculation method are stated in CEN/TR 1295-3.

A.2 Belgium

A.2.1 General

Calculation procedure of the ISO 2785: Directives for selection of asbestos-cement pipes subject to external loads with or without internal pressure.

A.2.2 Flowchart



A.2.3 Design, equations, tables and charts, symbols and abbreviations

A.2.3.1 Symbols and abbreviations

A width of uniform surcharge of small extent, in metres;

a distance between two wheels on a single axle of a truck, in metres;

B width of trench at the crown of the pipe, in metres;

B' distance of the spring-line of a pipe from the wall of the trench in which it is buried, in metres;

h distance between two wheels of two different axles of a truck, in metres;

c diagonal distance between two wheels of two different axles of a truck, in metres;

$C.C_{90}$ earth-load coefficient for a trench with vertical walls;

C_c load coefficient for superimposed concentrated moving loads;

C_d load coefficient for uniform surcharges of small extent;

C_n load coefficient for uniform surcharges of large extent;

C_v, C_{d1}, C_{v2}, C_{v3} coefficients of vertical deformation of pipe;

C_{h2}, C_{h3} coefficients of horizontal deformation of pipe;

d nominal or internal diameter of pipe, in millimetres;

D external diameter of pipe, in metres;

e base of natural logarithms;

E modulus of elasticity, in Newtons per square millimetre;

E_p modulus of elasticity of pipe, in Newtons per square millimetre;

E_s modulus of compression of soil, in Newtons per square millimetre;

E_t modulus of elasticity of road construction material, in Newtons per square millimetre;

E_1, E_2, E_3, E_4 moduli of compression of soil and backfill in various zones of the trench, in Newton per square millimetre;

H, H_1, H_2 heights of earth cover of a pipe, in metres;

H_e equivalent height of earth cover a pipe laid under a paved road, in metres;

HT heavy truck;

I modulus of inertia of the wall of the pipe per unit length, in cubic millimetres;

k factor of ring-bending moment;

k_{v1}, k_{h1}, k_{hp}, k_w factors of ring-bending moments due to vertical and horizontal loads, horizontal reaction pressure and water-load respectively;

K_1, K_2 coefficients of lateral earth pressure;

L length of uniform surcharge of small extent, in metres;

LT light truck;

m, m_0, m_1, m_m concentration factors of vertical earth pressure over the pipe;

M_e ultimate ring-bending moment of pipe when tested in accordance with ISO 881 or ISO 160, in Kilonewton metre per metre;

M_m maximum ring-bending moment in the wall of a buried, Kilonewton metre per metre;

M_1 the ring-bending moment that will fracture the pipe when combined with an internal hydraulic pressure p1;

M_2 the ultimate ring-bending moment when no internal pressure affects the pipe;

n concentration factor of lateral earth pressure on the sides of the pipe;

P_d intensity of distributed load, in kilonewtons per square metre;

P_j pipe projection ratio;

P_w hydraulic working pressure, in Megapascal;

P_1 the internal hydraulic pressure that will fracture the pipe when combined with a ring-bending moment M_1;

P_2 the internal hydraulic pressure that will burst a pipe which is not exposed to any external load;

P_e crushing load of a pipe when tested in accordance with ISO 881, in kilonewtons per 200 or 300 millimetre lengths of pipe;

P_v maximum wheel load of a truck, in kilonewtons;

P_{vc} vertical pressure on a pipe due to moving concentrated surcharge, in kilonewtons per square metre;

P_{vd} vertical pressure on a pipe due to moving distributed surcharge, in kilonewtons per square metre;

q_v, q_{v1}, q_{v2} vertical earth pressure on the pipe, in kilonewtons per square metre;

q_{vt} total vertical pressure due to earth and moving load on the pipe, in kilonewtons per square metre;

q_h, q_{h1}, q_{h2} horizontal earth pressure on the pipe, in kilonewtons per square metre;

q_{hp}, q_{hp1}, q_{hp2} horizontal soil reaction pressure on the pipe, in kilonewtons per square metre;

r mean radius of pipe, in metres;

s wall thickness of pipe, in metres;

s_p stiffness of pipe, in Newtons per square metre;

S_{sh} horizontal stiffness of soil backfill in the zone of the pipe, in Newtons per square millimetre;

S_{sv} vertical stiffness of pipe bedding, in Newtons per square millimetre;

t_1, t_2 thickness of layers in a road structure, in metres;

V_s, V_{s1} stiffness ratio;

V_{ps} pipe-soil system stiffness;

w, w_1, w_2 unit weight of backfill soil, in kilonewtons per cubic metre;

W crushing load per unit length of pipe when tested in accordance with ISO 160, in kilonewtons per metre;

x_1, x_2 , x_3 auxiliary parameter defined in the text;

α half the bedding angle of pipe;

β slope of the wall of the trench;

γ specific weight of water in kilonewtons per cubic metre;

δ deformation coefficient;

ξ correction factor;

η_d reduction factor of the resistance of the pipe to external load due to the action of internal pressure;

η_z reduction factor of the resistance of the pipe to internal pressure due to the action of external load;

ν_d safety factor against crushing of a pipe loaded externally without internal pressure;

ν_z safety factor against bursting of a pipe when a ring-bending moment is applied together with a internal hydraulic pressure;

ρ angle of internal friction of backfill soil;

ρ‘ angle of friction between the backfill soil and the wall of the trench;

ø impact factor.

A.2.3.2 Required basic data

— D, s, r, E_p pipe parameters ;

— B, H trench/embankment conditions;

— K_1, K_2 coefficients of lateral earth pressure, out of Table A.2;

— ρ angle of internal friction, out of soil investigation or Table A.1;

— p_j projection ratio;

— E_1 - E_2 - E_3 - E_4 soil conditions, out of soil investigation or Table A.1.

Table A.1 — Properties of soils for calculating earth-load

Group of soil	Types of soil[a]	Unit, weight, ω kN/m³	ρ degrees	Moduli of compression E_s[b] at following Proctor standard densities (%) achieved by self-consolidation compaction N/mm²					
				85	90	92	95	97	100
1	Non-cohesive	20	35	2,5	6	9	16	23	40
2	Slightly cohesive	20	30	1,2	3	4	8	11	20
3	Mixed cohesive	20	25	0,8	2	3	5	8	14
4	Cohesive	20	20	0,6	1,5	2	4	6	10

a The four types of soil are:

non-cohesive: gravel, sand;

slightly cohesive: binding non-uniform sand or gravel;

mixed cohesive: rock flour, weathered rock soils, clayey sand;

cohesive: clay, silt, loam.

b The moduli of compression E_s of the soils are measured by applying the CBR (California Bearing Ratio) method using a round plate of an area of 700 cm².

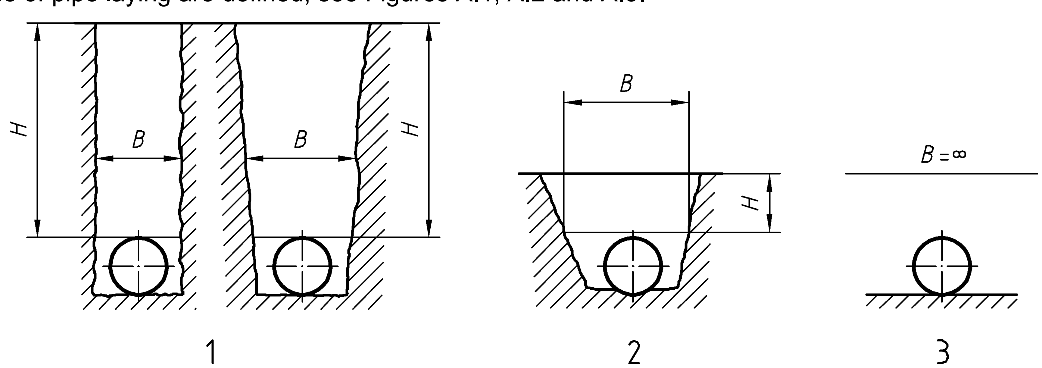
Table A.2 — Coefficients of lateral earth pressures

Group of soil	K_1	K_2
1	0,5	0,4
2	0,5	0,3
3	0,5	0,2
4	0,5	0,1

K_1 and K_2 shall always be considered simultaneously.

A.2.3.3 Selection of type of pipe laying

Three types of pipe laying are defined, see Figures A.1, A.2 and A.3.



key

1 Narrow trenches
2 Wide trench
3 Embankment conditions: positive projection

NOTE Type 1 covers trenches, wide trenches and positive projection embankment conditions.

Figure A.1 — Type 1 of laying