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BSI Standards Publication

Structural design of buried pipelines under various conditions of loading

Part 4: Parameters for reliability of the design

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National foreword

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Structural design of buried pipelines under various conditions of loading - Part 4: Parameters for reliability of the design

Calcul de résistance mécanique des canalisations enterrées sous diverses conditions de charge - Partie 4 : Paramètres pour la fiabilité de la conception

Statische Berechnung von erdverlegten Rohrleitungen unter verschiedenen Belastungsbedingungen - Teil 4: Parameter für die Zuverlässigkeit der Auslegung

This Technical Report was approved by CEN on 13 April 2015. It has been drawn up by the Technical Committee CEN/TC 165.

EUROPEAN COMMITTEE FOR STANDARDIZATION
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CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

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European foreword

This document (CEN/TR 1295-4:2015) 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 document, EN 1295: “*Structural design of buried pipelines under various conditions of loading”,* consists of the following parts:

— Part 1: General requirements (EN);

— Part 2: Summary of nationally established methods of design (CEN/TR);

— Part 3: Common method (CEN/TR);

— Part 4: Parameters for reliability of the design (CEN/TR).

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.

While 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 that would fully reflect the various considerations identified in particular national methods, a multiple stage approach has been adopted for the development of a European Standard.

In accordance with this approach, a Joint Working Group, at its initial meeting, resolved "first to produce an EN 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".

EN 1295-1, "*Structural design of buried pipelines under various conditions of loading — Part 1: General requirements*" represents the implementation of the first part of that resolution, and CEN/TR 1295-2 "*Structural design of buried pipelines under various conditions of loading — Part 2: Summary of nationally established methods of design*" represents the full implementation of the first part of that resolution.

In 2003, CEN/TC 164 and CEN/TC 165 accepted a recommendation from JWG1 that the two structural design options should be published as CEN/TR 1295-3 "*Structural design of buried pipelines under various conditions of loading — Part 3: Common method*", because there was no prospect of the group reaching agreement on a "Common Method", and the human and financial resources needed to continue were, in any case, no longer available.

In 2011, CEN/TC 165 has decided to complete this approach to list the parameters for the reliability of the structural design of buried water and wastewater pressure pipelines, drains and sewers in relation with the installation conditions.

1 Scope

This Technical Report lists the parameters for the reliability of the structural design of buried water and wastewater pressure pipelines, drains and sewers.

The reliability of the design of buried pipelines is based on the selection of appropriate design parameters for a chosen design method. This document identifies the parameters appropriate to the chosen design method, which should all be clearly stated.

This Technical Report does not aim to specify the requirements for the structural design of water and wastewater pressure pipelines, drains and sewers. These requirements are defined in EN 1295-1.

This Technical Report does not apply for offshore laying, pipes supported on piles, no dig pipelines, or laid above ground. Supplementary considerations need to be taken into account for these specific installations.

Special situations (e.g. landslide, earthquake, fire) are outside the scope of this document.

Design parameters for calculation of longitudinal effects (including bending moments, shear forces and tensile forces resulting for example from non-uniform bedding and thermal movements and, in the case of pressure pipelines, from Poisson's contraction and thrust at change of direction or cross-section) are not covered in this document.

2 Normative references

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

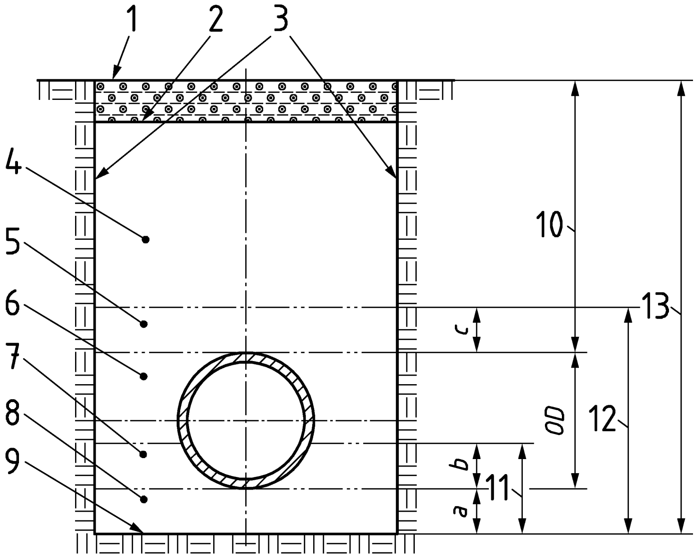
EN 1295-1, *Structural design of buried pipelines under various conditions of loading - Part 1: General requirements*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 Installation terms

Installation terms are given in Figure 1. The same terms apply for embankment installations and for trenches with sloping sides.



Key

1	surface	9	trench bottom
2	bottom of road or railway construction, if any	10	depth of cover
3	trench walls	11	depth of bedding
4	main backfill	12	depth of embedment
5	initial backfill	13	trench depth
6	sidefill	a	thickness of lower bedding
7	upper bedding	b	thickness of upper bedding
8	lower bedding	c	thickness of initial backfill

NOTE The terms in Figure 1 are the same as in EN 1610.

Figure 1 — Trench installation

3.1.1
compaction
deliberate densification of soil during the construction process

[SOURCE: EN 1295-1:1997, 3.1.1]

3.1.2
consolidation
time-dependent densification of soil by processes other than those deliberately applied during construction

[SOURCE: EN 1295-1:1997, 3.1.2]

3.1.3
embedment
arrangement and type(s) of material(s) around a buried pipeline which contribute to its structural performance

[SOURCE: EN 1295-1:1997, 3.1.3]

3.2 Design terms

3.2.1
allowable maximum operating pressure (PMA)
maximum pressure occurring from time to time, including surge, that a component is capable of withstanding in service

[SOURCE: EN 805:2000, 3.1.1]

3.2.2
allowable operating pressure (PFA)
maximum hydrostatic pressure that a component is capable of withstanding continuously in service

[SOURCE: EN 805:2000, 3.1.2]

3.2.3
allowable site test pressure (PEA)
maximum hydrostatic pressure that a newly installed component is capable of withstanding for a relatively short duration, in order to ensure the integrity and tightness of the pipeline

[SOURCE: EN 805:2000, 3.1.3]

3.2.4
bedding factor
ratio of the maximum design load for the pipe, when installed with a particular embedment, to the test load which produces the same maximum bending moment

[SOURCE: EN 1295-1:1997, 3.2.1]

3.2.5
design pressure (DP)
maximum operating internal pressure of the system or of the pressure zone fixed by the designer considering future developments but excluding surge

[SOURCE: EN 805:2000, 3.1.4]

3.2.6
limit states
states beyond which the structure no longer fulfils the relevant design criteria

[SOURCE: EN 1990:2002, 1.5.2.12]

3.2.7
load bearing capacity
load per unit length that a particular combination of pipe and embedment can sustain without exceeding a limit state

[SOURCE: EN 1295-1:1997, 3.2.3]

3.2.8
maximum design pressure (MDP)
maximum operating internal pressure of the system or of the pressure zone fixed by the designer considering future developments and including surge, where:

— MDP is designated MDPa when there is a fixed allowance for surge;

— MDP is designated MDPc when the surge is calculated

[SOURCE: EN 805:2000, 3.1.5]

3.2.9
serviceabilty limit states
states that correspond to conditions beyond which specified service requirements for a structure or structural member are no longer met

[SOURCE: EN 1990:2002, 1.5.2.14]

3.2.10
silo effect
effect whereby lateral earth pressure in trench backfill causes friction at the trench wall to carry part of the weight of the backfill

[SOURCE: EN 1295-1:1997, 3.2.5]

3.2.11
system test pressure (STP)
hydrostatic pressure applied to a newly laid pipeline in order to ensure its integrity and tightness

3.2.12
ultimate limit states
states associated with collapse or with other similar forms of structural failure

[SOURCE: EN 1990:2002, 1.5.2.13]

4 General requirements

All pipelines shall withstand the various loadings to which they are expected to be subjected, during construction and operation, without detriment to their function and to the environment.

The designer of the pipeline shall therefore specify the parameters for the structural design. These parameters shall be consistent with the requirements of the installation and the earthworks.

The structural designer shall state the chosen method for the design. The structural designer shall determine whether or not the pipeline comes within the scope of the chosen method of design including level of safety. The structural designer shall declare the selected parameters to ensure the reliability of the calculation.

Methods of design, when presented in the form of tables, charts or computer programmes, shall be deemed equivalent to a full calculation, provided that any simplification does not reduce the level of safety below that which would be obtained by a full design.

For the chosen design method, the designer shall use the whole method including the associated allowable limits on the results and shall assess that the chosen method is applicable for the project and shall express the resulting design safety.

Probable consequences of pipeline failure shall be identified prior to the structural design. The structural designer shall consider probable consequences of pipeline failure by establishing an acceptable level of safety consistent with the chosen design method.

At each stage of the design, the values of the selected parameters, including factors of safety, shall be in accordance with the chosen method and with site conditions, and shall be stated by the structural designer.

5 Declaration of the parameters

5.1 General

The designer shall state the chosen method by referring to a published document or by a detailed description of it.

The designer needs to clearly state the input data used and the analyses done.

The designer shall state the selected parameters, and at least refer to the following:

a) input data and characteristics:

   1) pipe parameters;

   2) external loads parameters:

      i) soil loads parameters,

      ii) traffic loads and construction loads parameters,

      iii) groundwater parameters;

   3) internal pressure parameters;

   4) pipes own weight parameters;

   5) weight of fluid parameters;

   6) subsidence parameters;

   7) temperature parameters;

b) parameters for limit state analysis;

c) safety parameters.

As stated in EN 1295-1:

— *Field and experimental studies of pipelines show variations in observed earth pressures and pipe deformations, stresses and strains. The main cause of these variations is the inevitable inconsistency of soil characteristics and construction practices. The magnitude of the variation can be reduced by good supervision, control measurement and by the use of fill materials, which are easily placed and treated, but some degree of variation is inevitable.*

— *Variations in pipe characteristics, such as strength or elasticity, also occur in practice.*

— *Appropriate allowance for these variations should be made at the design stage and be in accordance with one of the following design philosophies:*

1) *The design procedure shall aim to predict the mean values of loads, and shall compare these with the load bearing capacity of the pipeline based on mean values of pipe strength or stiffness (for example as derived by calculation), and on average earth pressure distribution assumptions.*

2) *The design procedure shall aim to predict the maximum possible (high fractile or upper bound) values of loads, and shall compare these with estimates of the load bearing capacity of the pipeline based on lower bound (or low fractile) values of pipe strength or stiffness (for example as established by testing), and on unfavourable earth pressure distribution assumptions.*

— *The factors of safety to be employed with designs following philosophy 2) will be lower than those used in 1), to achieve the same probability of failure.*

5.2 Input data and characteristics

5.2.1 Pipe parameters

Many different kinds of pipe materials are used for the production of components to construct buried pipelines for water and waste water systems. The pipes vary in weight, load bearing capacity and ductility. Next to that, many different types of jointing methods are used with the different pipe materials.

European or national standards can include dimensions, as well as material specific information needed for a structural design purpose.

When considering the pipe parameters to be taken into account, the designer shall at least refer to the following and shall state the selected parameters:

— pipe material;

— dimensions (diameter, wall thickness, shape);

— unit weight;

— material properties (E_{p}, σ_{ult});

  — short term;

  — long term;

— initial pipe out of roundness;

— pipe ring stiffness;

— Poisson's ratio;

— crushing strength.

5.2.2 External loads parameters

5.2.2.1 General

The external loads to be considered shall include:

— those due to the backfill;

— those due to the most severe surface surcharge or traffic load likely to occur;

— those due to any other causes, producing a loading of significant magnitude such as self-weight of the pipe and water weight, as appropriate;

— those due to groundwater;

— those due to trench construction.

As stated in EN 1295-1:

— *Of the various factors to be considered in the structural design process, some, such as pipe diameter and depth of cover, can be regarded as entirely under the control of the designer. Other factors, such as the methods adopted for trench excavation and for filling around and above the pipeline, are only under the control of the designer to the extent that they are specified in advance, and supervised during construction.*

— *The width of the trench can influence the extent to which the backfill load may be reduced by the silo effect; this effect is taken into account for certain applications.*

— *The width of the trench can also influence the quality of the lateral soil support at the sides of the pipes. This effect is variously covered in the design procedures, via the coefficient of lateral earth pressure, the bedding factor, the soil modulus, etc.*

— *The slope of the trench sides can affect the magnitude of the backfill load, and, if vertical trench sides are employed, consideration shall also be given to the method of support.*

— *If the trench supports are withdrawn after embedding and/or backfilling, voids are left which can cause loosening of the soil, reducing the quality of the embedment and the friction on which the silo effect relies, and also promote long term settlement.*

— *The presence of groundwater, and the use of measures such as ground water lowering to remove it during construction, can have important effects. The absence of groundwater assists in the compaction of backfill, but the subsequent return of ground water after completion of backfilling can cause movements of soil particles, possibly leading to increased loads and reduction of support to the sides of the pipe.*

Where appropriate, account shall be taken of the effects of time dependent influences. The design should take into consideration, the effect on trench conditions of any further planned works.

5.2.2.2 Soil loads parameters

Soil loads are normally considered as the weight of the soil column above the pipe and the reaction to the side and the bottom, this weight might be increased or decreased with the shear forces exerted by the adjacent soil.

As stated in EN 1295-1:

— *If the nature of the ground at the base of the trench is such that it will not itself provide adequate support, then, for all types of pipe, the thickness of lower bedding shall be designed to ensure adequate support along the length of the pipeline.*

— *Where pipes are installed in soft ground, the thickness of the lower bedding may need to be increased in order to prevent excessive settlement of the pipeline.*

— *The thickness of upper bedding should be such as to ensure that the bending moments in the pipe (as calculated directly or covered by the bedding factor) are acceptable.*

— *In the vicinity of the pipe, the placing and compaction of the fill material have very great influence on structural performance. They affect the distribution of soil pressure around the circumference of the pipe, and hence the response of the pipe. The amount of compaction applied initially during installation also affects the amount of settlement which will take place later, as a result of natural consolidation, or consolidation accelerated by traffic. Usually, the larger such settlements, the greater the load which will be transferred to the pipe.*

— *When the soil around the pipe is being compacted in order to improve its structural quality, some of the energy is diverted into the pipe (as strain energy of deformation) and some into the native soil. The extent to which the total compaction energy is so diverted depends upon the pipe-soil stiffness ratio and the type of native soil.*

— *Prediction of these effects is difficult and is further complicated by the sensitivity of some soils to moisture content. The use of soils which are easy to compact, and which have low sensitivity to moisture content, can therefore greatly reduce the magnitude of strains developed in pipes as a result of installation.*

When considering the soil parameters, the designer shall at least refer to the following and shall state the selected parameters:

— soil group Gs;

— type of soils:

  — native;

  — main backfill;

  — side fill;

  — bedding;

— level of compaction (e.g. very dense, dense, medium dense, loose, very loose):

  — native;

  — side fill;

  — bedding;

— soil density:

  — native;

  — main backfill in pipe zone;

- conventional evaluation of soil modulus on the basis of:
  - types of soils;
  - density levels;
  - water table;
  - cover depth;
- compaction classes for embedment;
- friction angle coefficient;
- Poisson's ratio.

When considering the soil loads parameters, the designer shall at least refer to the following and shall state the selected parameters:

- trench dimensions: width (B);
- depth of cover;
- embedment types;
- horizontal reaction angle for flexible pipe;
- support angle:
  - for rigid pipes;
  - for flexible pipes;
- horizontal pressure coefficient;
- cohesion;
- reductions to apply on soil parameters of the embedment:
  - due to trench width (B);
  - due to the native soil;
  - due to time effects;
  - due to removal of trench sheets.

5.2.2.3 Traffic loads and construction loads parameters

In Europe different types of axle loading exist. Care should be taken to take over some of the traffic loading regimes, because mostly they are taken from studies on bridges: here the damping and spreading effect is not covered, on the contrary they use high dynamic impact factors. It should be realized that traffic load further compacts the soil and changes the soil properties.

When considering the traffic loads parameters, the designer shall at least refer to the following and shall state the selected parameters:

— type of traffic, reference document;

— temporary loads during construction (e.g. vehicle, compaction);

— traffic loads after installation;

— method of traffic loads dissipation in soils;

— reduction for pavement;

— horizontal pressure due to traffic.

5.2.2.4 Groundwater parameters

The groundwater creates an external load by hydraulic pressure on the pipe and might change the properties of the soil.

When considering the groundwater parameters, the designer shall at least refer to the following and shall state the selected parameters:

— reductions to apply on soil parameters of the embedment due to groundwater;

— external hydrostatic pressure.

5.2.3 Internal pressure parameters

As stated in EN 1295-1:

— *Pipelines operating at internal pressures above or below atmospheric are subjected to loadings in excess of those at atmospheric pressure.*

— *The application of internal pressure not only introduces additional stresses and strains in the circumferential direction, but can also modify the deformation of flexible and semi-rigid pipes. In addition, pressure pipelines, containing changes of direction or other discontinuities, shall be designed for the longitudinal tensile loading, or the thrusts at the discontinuities.*

— *Special consideration shall be given to pipelines which will be subject to transient surge pressures. Both positive and negative transient pressures shall be considered, but it may not be appropriate for these to be taken in combination with the full vehicle surcharge load.*

— *The design shall take account of the design pressure, the maximum design pressure, and the system test pressure.*

— *Pressure pipelines shall also satisfy the design criteria which would apply if they were non-pressure pipelines, in order to ensure their satisfactory structural performance for the initial period between construction and the application of the internal water pressure, and subsequently when emptied for maintenance.*

— *Positive internal pressure assists pipes which are not rigid to resist any tendency to buckle, but since there can never be complete certainty that the pressure may not be removed at some time during the life of the pipeline, it is normal to design pipelines to resist buckling without this assistance.*

— *Pipelines subject to hydraulic transients may experience sub-atmospheric pressures, and, although these are usually of very short duration, they tend to increase the tendency to buckle.*

— *Proper account shall be taken of this possibility in the design of such pipelines, and it is preferable to rely on a conservative estimate of the sub-atmospheric pressure. When calculating stability, the sub-atmospheric pressure shall be added to the external pressure caused by sustained loading.*

When considering the internal pressure parameters, the designer shall at least refer to the following and shall state the selected parameters:

— for the pipeline:

  — design pressure DP;

  — maximum design pressure MDP;

  — system test pressure STP;

  — negative design pressure;

— for the pipes, allowable pressures:

  — allowable operating pressure PFA;

  — allowable maximum operating pressure PMA;

  — allowable site test pressure PEA.

5.2.4 Pipe own weight parameters

This type of loading becomes more important when bigger diameter pipes are considered. Next to the fact that it results in stresses and deformation of the pipe itself, it also loads the foundation of the pipe, which can lead to settlement differences along the pipeline.

When considering the pipe own weight parameters, the designer shall at least refer to the self–weight and shall state it.

5.2.5 Weight of fluid

This type of loading becomes more important when bigger diameter pipes are considered. Next to the fact that it results in stresses and deformation of the pipe itself, it also loads the foundation of the pipe, which can lead to settlement differences along the pipeline.

When considering the weight of fluid parameters, the designer shall at least refer to the water filling ratio (ratio between height of water and internal pipe diameter) and shall state it.

5.2.6 Subsidence (differential settlement) parameters

Pipe exerts pressure on its foundation, the pipe bed. The stiffness of the pipe bed may vary along the pipeline and hence result in differential settlement of the pipe. Increasing the height of cover, as a result of highway or dyke (re-) constructions, may have the same effect.

Settlement differences also occur when pipes are laid in mining areas, where differential settlement might occur. According to EN 1295-1, special attention shall be paid to the situation where a service pipe connects a rigid construction (chambers, houses, etc.) to a main pipe.

This document does not consider the parameters for settlement issues.

5.2.7 Temperature parameters

Fluids transported through the pipe can vary in temperature. The soil might also be prone to changes in temperature and as well as the fact that pipes might experience temperature differences before and after installation. The expansion (negative or positive) activates shear stresses between the soil and the pipe.

Pipes may be subjected to temperature changes due to any combination of the following:

— exposure during construction;

— temperature differences before and after installation;

— variations in the surrounding soil temperature in different seasons;

— variations of temperature of the fluid in the pipe.

The expansion or contraction arising will activate shear stresses between the soil and the pipe or stresses within the pipe wall. Pipeline should be end thrust resistant or allow the necessary displacement, before the soil balances the load. Where a pipe is restrained at its ends, the stresses arising from the thermal expansion or contraction should be considered to avoid buckling or rupture.

When considering the temperature parameters, the designer shall at least refer to the following and shall state the selected parameters:

— laying temperature;

— external service temperature;

— service temperature of the fluid.

5.3 Parameters for limit states analysis

The ultimate limit state for all types of pipe is reached when the pipe collapses or is subjected to other similar forms of structural failure.

Serviceability limit states for all types of pipe are reached when the pipe no longer fulfills the relevant design criteria. It can be dictated by effects either on the performance of pipelines (hydraulic, maintenance, settlements of backfill) or on their durability (for example leakage, deformation or cracking beyond allowable limits).

Additional considerations shall be made for pressure pipelines: internal pressures above or below atmospheric produce circumferential stresses and strains which act simultaneously with bending stresses and strains due to external loadings.

Design cases to be considered depending on pipe material and/or type and respective load intensities, can be one or more of the following:

— circumferential stresses resulting from combined loads;

— circumferential strains resulting from combined loads;

— separate analysis of circumferential stresses or strains.

Similar cases shall be considered for the longitudinal direction, when appropriate.

NOTE If the cross-section of the pipe is truly circular, circumferential stresses and strains due to internal pressure will be purely tensile or compressive, but if the pipe cross-section is not truly circular or has been deformed there will also be bending stresses and strains due to internal pressure.

When positive internal pressure is applied to a circular pipe which is not precisely circular, it tends to re-round the pipe, i.e. to reduce the out-of-circle deformations. The re-rounding process may have the beneficial effect of reducing the bending stresses and strains in the pipe wall. The extent to which the re-rounding process reduces pipe deformation depends on pipe property and on other various factors, such as the ratio of the internal pressure to the external pressure and the amount of consolidation of the soil which has taken place around the pipe. Thus, the beneficial effects of re-rounding are likely to be greater if the pressure is applied soon after backfilling, and less if there is a longer delay until the first pressurization.

Although the application of internal positive pressure will always produce some degree of re-rounding, the magnitude is difficult to predict. In addition, although pipe ovalization benefits from internal pressure, stresses and strains may not benefit to the same extent (e.g. when the deflected shape is not elliptical).

Additional serviceability limit states may apply to particular pipe materials, and reference shall be made to the relevant standards.

When considering the parameters for ultimate limit states analysis, the designer shall at least refer to Table 1 and shall state the selected parameters.

Table 1 — Parameters for ultimate limit states analysis

Types of verification	**Parameters**

Stress	— Shear stress
	— Amplification of stresses (e.g. for profiled pipes)
	— For calculation of 2nd order effects:
	  — Amplification of bending moment
	  — Amplification of displacements
	  — Evaluation of amplification factor
	— For time dependency analysis:
	  — Creep of the material
	  — Consolidation of the soil

Load bearing capacity	— For calculation of 2nd order effects:
	  — Amplification of bending moment
	  — Amplification of displacements
	  — Evaluation of amplification factor

Strain	— For calculation of 2nd order effects:
	  — Amplification of bending moment
	  — Amplification of displacements
	  — Evaluation of amplification factor
	— For time dependency analysis:
	  — Creep of the material
	  — Consolidation of the soil

Resistance to internal pressure	— Stress and strain resulting from simultaneous loads — Verification of pipes empty or under negative pressure — Effect of pressure on deformation — Effect of pressure on buckling resistance — Surge in relation with the pipe material — Re-rounding effect
Buckling	— Reduction of buckling resistance due to possible imperfections — Analysis of buckling taking into account: — Pipeline only or pipeline with its embedment

When considering the parameters for serviceability limit states analysis, the designer shall at least refer to Table 2 and shall state the selected parameters:

Table 2 — Parameters for serviceability limit states analysis

Types of verification	Parameters
Deflection	— For calculation of 2nd order effects: — Amplification of bending moment — Amplification of displacements — Evaluation of amplification factor — For temperature effect (longitudinal expansion): — Short-term — Long term — For time dependency analysis: — Creep of the material — Consolidation of the soil — Amplification of deflections depending on initial pipe out of roundness
Flotation	— Filling degree of the pipeline

5.4 Safety parameters

The safety analysis can be based on the following safety parameters:

— for actions (loads): partial factors;

— for verification:

  — partial factors on limit values;

  — acceptance criteria (e.g. maximum deflection for serviceability reason).

When considering the safety factors, the designer shall at least apply Table 3 and shall state the selected parameters:

Table 3 — Safety factors consideration

Actions	— For each verification: — Partial factors applicable to each type of actions (loads)
Verification	— Partial factors on limit value — Acceptance criteria

Annex A
(informative)

Checklist for parameters for reliability of the structural design of buried water and waste water pressure pipelines, drains and sewers

<table>
<tr><th colspan="2">General information on the project</th></tr>
<tr><td colspan="2">— Designer’s name/address
— Location of the installation
— Purpose of the pipeline installation
— Client
— Date
— Design method (EN, national standard, national rules…)
— Pipe material</td></tr>
<tr><th colspan="2">Checklist of the parameters for reliability of the structural design</th></tr>
<tr><td colspan="2">a) Input data and characteristics</td></tr>
<tr><td>1) Pipe parameters</td><td>— Pipe material
— Dimensions (diameter, wall thickness, shape)
— Unit weight
— Material properties (E_p, σ_{ult}):
    — Short-term
    — Long term
— Initial pipe out of roundness
— Pipe ring stiffness
— Poisson's ratio applied
— Crushing strength</td></tr>
<tr><td>2) External loads parameters</td><td>— Soil loads parameters
— Traffic loads and construction loads parameters
— Groundwater parameters</td></tr>
<tr><td>3) Internal pressure parameters</td><td>— For the pipeline:
    — Design Pressure DP
    — Maximum Design Pressure MDP
    — System Test Pressure STP
    — Negative design pressure
— For the pipes, allowable pressures:
    — Allowable operating pressure PFA
    — Allowable maximum operating pressure PMA
    — Allowable site test pressure PEA</td></tr>
<tr><td>4) Pipes own weight parameters</td><td>— Self-weight</td></tr>
</table>

5) Weight of fluid parameters	— Water filling ratio
6) Subsidence parameters	To be defined
7) Temperature parameters	— Laying temperature — External service temperature — Service temperature of the fluid
b) Parameters for limit state analysis	
ULS (Ultimate Limit State)	

1) Stress	— Shear stress
	— Amplification of stresses (e.g. for profiled pipes)
	— For calculation of 2nd order effects:
	    — Amplification of bending moment
	    — Amplification of displacements
	    — Evaluation of amplification factor
	— For time dependency analysis:
	    — Creep of the material
	    — Consolidation of the soil

2) Load bearing capacity	— For calculation of 2nd order effects:
	    — Amplification of bending moment
	    — Amplification of displacements
	    — Evaluation of amplification factor

3) Strain	— For calculation of 2nd order effects:
	    — Amplification of bending moment
	    — Amplification of displacements
	    — Evaluation of amplification factor
	— For time dependency analysis:
	    — Creep of the material
	    — Consolidation of the soil

4) Resistance to internal pressure	— Stress and strain resulting from simultaneous loads — Verification of pipes empty or under negative pressure — Effect of pressure on deformation — Effect of pressure on buckling resistance — Surge in relation with the pipe material — Re-rounding effect
5) Buckling	— Reduction of buckling resistance due to possible imperfections — Analysis of buckling taking into account: — Pipeline only or pipeline with its embedment
SLS (Service Limit State)	

6) Deflection	— For calculation of 2nd order effects:
	    — Amplification of bending moment
	    — Amplification of displacements

	— Evaluation of amplification factor — For temperature effect (longitudinal expansion): — Short-term — Long term — For time dependency analysis: — Creep of the material — Consolidation of the soil — Amplification of deflections depending on initial pipe out of roundness
7) Flotation	— Filling degree of the pipeline
c) Safety parameters	— Actions: for each verification: — Partial factors applicable to each type of actions (loads) — Verification: — Partial factors on limit values — Acceptance criteria (e.g. maximum deflection for serviceability reason)

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