British Standard

BRITISH STANDARD

BS EN 1916:2002

Concrete pipes and fittings, unreinforced, steel fibre and reinforced

The European Standard EN 1916:2002 has the status of a British Standard

ICS 23.040.50; 93.030

British Standards

National foreword

This British Standard is the official English language version of EN 1916:2002.

EN 1916 is a candidate "harmonized" European Standard and fully takes into account the requirements of the European Commission mandate M131, *Pipes, tanks and ancillaries not in contact with water intended for human consumption*, given under the EU Construction Products Directive (89/106/EEC), and is intended to lead to CE marking. The date of applicability of EN 1916:2002 as a "harmonized" European Standard, i.e. the date after which this standard may be used for CE marking purposes, is subject to an announcement in the *Official Journal of the European Communities*.

BS EN 1916:2002 together with BS 5911-1:2002 supersede BS 5911-100:1988 and BS 5911-120:1989.

The Commission in consultation with Member States have agreed a transition period for the co-existence of "harmonized" European Standards and their corresponding national standard(s). It is intended that this period will comprise a period, usually nine months after the date of availability of the European Standard, during which any required changes to national regulations are to be made, followed by a further fifteen-month period for the implementation of CE marking. At the end of this co-existence period, the national standard(s) will be withdrawn. In the UK, the corresponding national standards, insofar as they specify pipes with nominal sizes not exceeding DN 1750, are:

— BS 5911-100:1988, *Precast concrete pipes, fittings and ancillary products — Specification for unreinforced and reinforced pipes and fittings with flexible joints;*

— BS 5911-120:1989, *Precast concrete pipes, fittings and ancillary products — Specification for reinforced jacking pipes;*

and based on this nominal transition period of twenty-four months, BS 5911-100:1988 and BS 5911-120:1989 will be withdrawn in October 2004 and replaced by BS EN 1916, the non-conflicting requirements having been revised.

NOTE This date is approximate. Users of this standard should contact BSI Customer Services for confirmation of withdrawal.

BS EN 1916 also supersedes DD 76-2:1983, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/505, Wastewater engineering, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

This British Standard, having been prepared under the direction of the Building and Civil Engineering Sector Policy and Strategy Committee, was published under the authority of the Standards Policy and Strategy Committee on 18 November 2002

Amendments issued since publication

Amd. No.	Date	Comments

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A list of organizations represented on this committee can be obtained on request to its secretary.

The foreword of EN 1916:2002 explains why, and under what circumstances, complementary requirements and associated test methods outside the scope of that standard will be needed at national level. BS EN 1916:2002 together with BS 5911-1:2002 supersede BS 5911-100:1982 and BS 5911-120:1994. Therefore, BS 5911-1:2002 is for use in conjunction with BS EN 1916:2002 and both come into effect simultaneously. In order not to create barriers to European trade, products under the scope of this British Standard should be specified as conforming to "BS EN 1916:2002 and BS 5911-1:2002 or equivalent".

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Search" facility of the *BSI Electronic Catalogue* or of British Standards Online.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii the EN title page, pages 2 to 90, an inside back cover and a back cover.

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 1916

October 2002

ICS 23.040.50; 93.030

English version

Concrete pipes and fittings, unreinforced, steel fibre and reinforced

Tuyaux et pièces complémentaires en béton non armé, béton fibré acier et béton armé

Rohre und Formstücke aus Beton, Stahlfaserbeton und Stahlbeton

This European Standard was approved by CEN on 18 August 2002.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

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

Management Centre: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN 1916:2002 E

Contents

Foreword

This document EN 1916:2002 has been prepared by Technical Committee CEN/TC 165 "Wastewater engineering", the secretariat of which is held by DIN.

It is a companion standard to EN 1917 “Concrete manholes and inspection chambers, unreinforced, steel fibre and reinforced”.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2003, and conflicting national standards shall be withdrawn at the latest by October 2004.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative annex ZA, which is an integral part of this document.

This European Standard includes eleven normative annexes and one informative annex. Annexes A, B, C, D, E, F, G, H, I, J and K are normative, annex ZA is informative.

When the text of this European Standard was approved, complete agreement could not be achieved for all requirements in the existing national specifications of CEN members and so it includes only those requirements and associated test methods for which a consensus could be reached. Consensus was achieved on the requirements for quality control.

NOTE For the time being, for specification purposes, complementary (i.e. non-conflicting) requirements and associated test methods outside the scope of this European Standard (see Table 1) will be needed at national level. In order not to create any barrier to trade, any call for conformity to complementary requirements should always be qualified by incorporating the words 'or equivalent' after the reference to them.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard specifies performance requirements as defined in Table 1 and describes test methods for precast concrete pipes and fittings, unreinforced, steel fibre and reinforced, with flexible joints (with seals either integrated in the units or supplied separately) and nominal sizes not exceeding DN 1 750 for units with a circular bore or WN/HN 1 200/1 800 for units with an egg-shaped bore, for which the main intended use is the conveyance of sewage, rainwater and surface water under gravity or occasionally at low head of pressure, in pipelines that are generally buried.

Provision is made for the evaluation of conformity of units to this European Standard.

Marking conditions are included.

Table 1 — Specified characteristics and exclusions

Characteristic	Exclusions
Materials	Specifications where relevant European Standards have not yet been published.
Concrete	Types and value(s) of minimum content of cement plus any pozzolanic or latent hydraulic addition, according to serviceability conditions.
Finish	Limitations on size of blemishes.
Geometrical characteristics	— nominal sizes; — internal dimensions with tolerances; — tolerances on the wall thickness; — tolerances on the internal barrel length; — deviation from straightness and from squareness of ends.
Joints and joint seals	— the choice of method from those listed in 4.3.4.2 for demonstrating the durability of joints; — provisions for interchangeability; — requirements for additional testing where watertightness of the joint assembly is dependent upon an internal pressure.
Crushing strength	Specific strength classes and corresponding minimum crushing loads.
Longitudinal bending moment resistance	None.
Watertightness	None.
Special requirements for steel fibre concrete pipes, reinforced concrete pipes, jacking pipes and pipes with inlet	— strength class exceeding class 165 for steel fibre and reinforced concrete units; — value(s) of minimum concrete cover for reinforced concrete units; — limitations on the spacing of reinforcement; — relationship between internal and external reinforcement cages; — requirements for weld testing of reinforcement cages; — tolerances on the external diameter of jacking pipes; — jacking pipe collars of materials other than weldable structural steel plate, stainless steel plate or reinforced plastics.
Marking	— symbols or letters for identifying the material of a unit; — symbols or letters for identifying serviceability conditions other than normal conditions as stated in 4.3.8.
NOTE Provisions for the following are also outside the scope of this European Standard: - units with nominal sizes greater than DN 1 750 or WN/HN 1 200/1 800; - units with a bore other than circular or egg-shaped; - lifting facilities; - resistance to high pressure jetting; - circumstances other than those stated; - any receiving inspection by, or on behalf of, the purchaser.	

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 681-1, *Elastomeric seals - Materials requirements for pipe joint seals used in water and drainage applications - Part 1: Vulcanized rubber.*

EN 10002-1, *Metallic materials - Tensile testing - Part 1: Method of test at ambient temperature.*

EN ISO 4287, *Geometrical product specification (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters (ISO 4287:1997).*

EN ISO 4288, *Geometrical product specifications (GPS) — Surface texture: Profile method — Rules and procedures for the assessment of surface texture (ISO 4288:1996).*

ISO 3384, *Rubber, vulcanized or thermoplastic - Determination of stress relaxation in compression at ambient and at elevated temperatures.*

ISO 4012, *Concrete - Determination of compressive strength of test specimens.*

ISO 10544, *Cold reduced steel wire for the reinforcement of concrete and the manufacture of welded fabric.*

3 Terms, definitions and symbols

3.1 Terms and definitions

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

3.1.1
pipe
hollow precast concrete unit of uniform bore throughout its internal barrel length, except in the vicinity of the joint profile, manufactured with or without base. Joints of units are preformed as spigot and socket and incorporate one or more joint seals

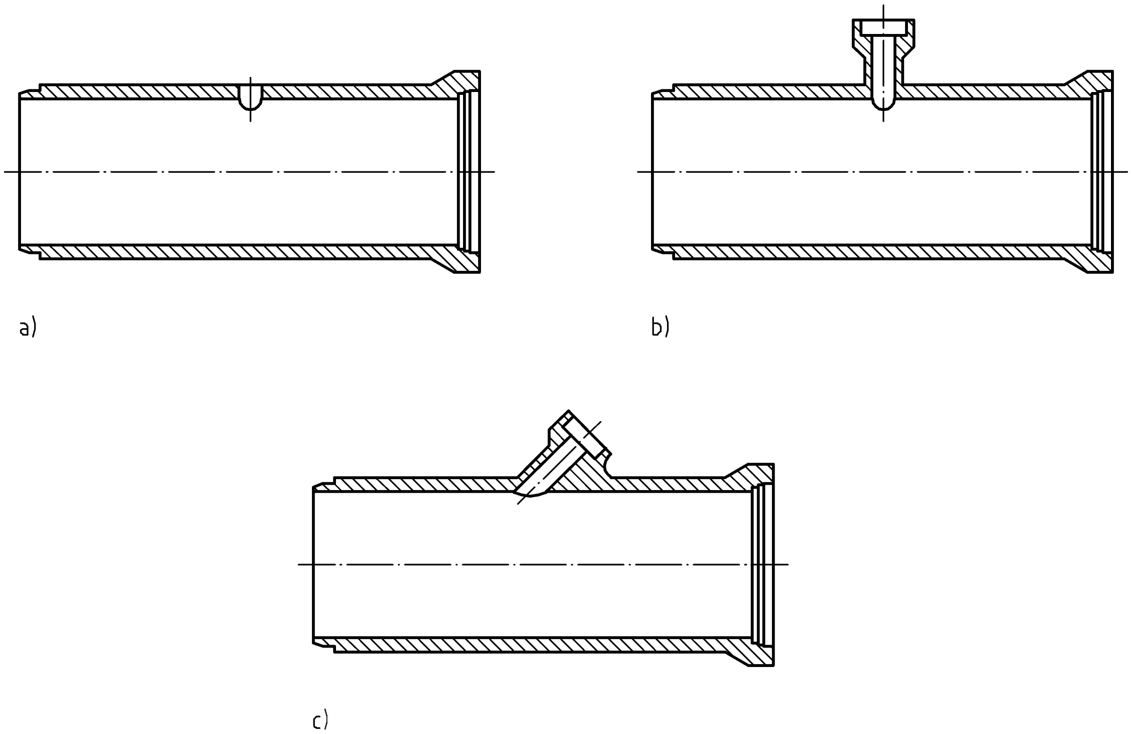
3.1.2
unreinforced concrete pipe
pipe that does not contain structural steel reinforcement or steel fibre strengthening

3.1.3
steel fibre concrete pipe
pipe that is structurally strengthened by steel fibres

3.1.4
reinforced concrete pipe
pipe that is structurally reinforced with one or more steel cages, suitably positioned to resist tensile stresses in the pipe wall

3.1.5
jacking pipe
unreinforced, steel fibre or reinforced concrete pipe, incorporating a flexible joint within the wall thickness, rebated or butt-ended with collar and which is intended for jacking

3.1.6
pipe with inlet
pipe as shown typically in Figure 1a, with one or more inlet-holes provided during or after manufacture



Key

a) Typical pipe with inlet

b) Typical junction with right-angled inlet

c) Typical junction with angled inlet

NOTE Types of joint other than those shown are available.

Figure 1 — Junctions and pipes with inlet

3.1.7
circular pipe
pipe whose barrel cross-section in a plane perpendicular to its longitudinal axis is described by two concentric circles

3.1.8
fitting
adaptor, bend, connecting pipe, junction or taper (reducer)

3.1.9
adaptor
fitting that provides for connections to structures, to pipes of other materials, or to valves

3.1.10
bend
fitting that provides for a change of alignment within a pipeline

3.1.11
connecting pipe
short pipe with plain, spigot or socket ends

3.1.12
junction
unit as shown typically in Figures 1b and 1c

3.1.13
taper (reducer)
fitting whose bore is reduced along its internal barrel length

3.1.14
unit
pipe or fitting

3.1.15
type
units of the same manufacturing process, cross-section and material (unreinforced, steel fibre or reinforced concrete)

3.1.16
nominal size
numerical designation of the size of a unit, which is a convenient integer approximately equal to the manufacturing dimension(s) in millimetres; for a circular unit it is the internal diameter (DN), for a unit with an egg-shaped bore it is the internal width/height (WN/HN)

3.1.17
internal barrel length
length between the base of the socket and the end of the spigot of a unit as shown in Figure 2

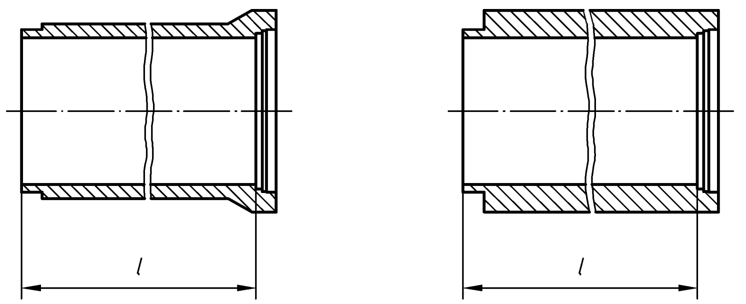


Figure 2 — Internal barrel length

3.1.18
integrated seal
seal incorporated into a unit during manufacture

3.1.19
strength class
minimum crushing load in kilonewtons per metre, divided by one thousandth of either a unit's nominal size (DN) or nominal width (WN)

3.1.20
minimum crushing load
load that a unit is required to withstand

3.1.21
ultimate (collapse) load
maximum load reached by the testing machine during a crushing test (i.e. when the load-recording facility does not show any further increase)

3.1.22
proof load
load that a steel fibre or reinforced concrete unit is required to withstand with a defined limit on cracking

3.1.23
concrete cover
actual thickness of concrete over any reinforcement

3.1.24
characteristic value
that value of a characteristic beyond which, with a 75 % confidence level, 5 % of the population of all possible measurements of the specified material may fall

NOTE A 75 % confidence level is recommended in ISO 12491.

3.1.25
inspection
process of measuring, examining, testing, gauging or otherwise comparing a unit with the applicable requirements

3.1.26
routine inspection
inspection by sampling at prescribed intervals in order to determine the acceptability of the items represented by the samples

3.1.27
continuous inspection
routine inspection according to a sampling plan which indicates the number of units from a specific process evaluated to have attained, and continue to be in, a state of control, and the associated acceptance criteria

3.1.28
sample
one or more units selected at random without regard to their quality

3.1.29
group
clearly identifiable collection of units, manufactured using the same process; units of different nominal sizes may be grouped together, provided that the ratio of largest to smallest nominal size is not greater than 2

3.1.30
specific process
manufacture of units of the same nominal size, strength class and type, essentially under the same conditions over any period of time

3.1.31
state of statistical control
state in which the variations among the observed sampling results can be attributed to a system of chance causes that does not appear to change with time

3.1.32
switching rules
rules that govern the decision to increase or decrease the severity of inspection

3.2 Symbols

Table 2 gives the meanings, units and references of symbols used in this European Standard.

Table 2 — Symbols

Symbol	Meaning	Unit	Reference
A_c	area of joint surface in compression	square metres	B.2, B.3.1, B.3.2, B.3.3, B.4.2
A_w	absorption of water by immersion	per cent	F.5
a_l	lever arm length	metres	D.3.2, D.4.1
a_s	distance between additional shear load and centre of joint seal	metres	E.5.3
b_t	effective tightened width	millimetres	4.3.4, A.1, A.2.5, A.2.6, A.2.7, A.3.2, A.3.3
C	constant equal to 0,013	kilonewtons per metre	4.3.6
d_e	external diameter of joint surface	metres	B.2, B.3.1, B.3.3, B.4.1, B.4.2
d'_e	diameter at front of rebated spigot	metres	B.3.1
d_i	internal diameter of joint surface	metres	B.2, B.3.1, B.3.3, B.4.1, B.4.2
d'_i	diameter of base of rebated spigot	metres	B.3.1
d_{so}	nominal internal diameter of socket	millimetres	4.3.4, A.1, A.2.5, A.2.7, A.3.2, A.3.3
d_{sos}	nominal internal diameter of socket at shear stop provision	millimetres	A.1, A.3.2, A.3.3
d_{sp}	nominal external diameter of spigot	millimetres	4.3.4, A.1, A.2.5, A.2.7, A.3.2, A.3.3
d_{sps}	nominal external diameter of spigot at shear stop provision	millimetres	A.1, A.3.2, A.3.3
E	modulus of elasticity	megapascals	A.1, A.3.2, A.3.3
e	load reduction (eccentricity) factor	-	B.2, B.3.3, B.4.2
F	measured tightening force	newtons	A.1, A.2.5, A.2.6, A.2.7
F'	jacking load applied on site	meganewtons	B.2, B.4.2
F_a	effective crushing test result	kilonewtons per metre	C.5, I.3.2, I.4.1
F_c	proof load	kilonewtons per metre	5.2.3, C.1, C.4.4, I.3.2, I.3.4, I.4.1
F_{cj}	maximum jacking load in closed joint situation	meganewtons	B.2, B.3.1, B.3.2, B.3.3, B.4.2
F_d	distributed unit force assumed to result from application of a specific shear load	newtons per millimetre	A.1, A.2.5, A.2.7
F_e	tightening force per unit length	newtons per millimetre	A.1, A.3.2, A.3.3
F_j	design jacking load	meganewtons	5.3.4, B.2, B.3.1, B.3.2, B.4.1, B.4.2
$F_{j\,max}$	maximum theoretical design jacking load	meganewtons	B.2, B.3.1, B.3.2, B.4.1, B.4.2
F_{oj}	maximum jacking load in open joint situation	meganewtons	B.2, B.3.1, B.3.3, B.4.2

Table 2 *(continued)*

Symbol	Meaning	Unit	Reference
F_n	minimum crushing load	kilonewtons per metre	4.3.5, 5.1.2, 5.2.3, C.1, C.4.4, I.1.1, I.3.2, I.4.1, I.4.2, K
F_s	shear load	kilonewtons	4.3.4, A.1, A.2.5, A.2.7, E.5.3, E.5.4
F_u	ultimate (collapse) load	kilonewtons per metre	5.1.2, C.1, C.4, I.1.1, I.3.2, I.3.4, I.4.1, I.4.2, K
f	mean pressure on test piece	megapascals	4.3.4, A.1, A.2.6, A.2.7, A.3.2, A.3.3
f_{bt}	bending tensile stress in concrete	megapascals	K
f_{ch}	characteristic bending tensile stress in concrete	megapascals	K
f_{ck}	characteristic concrete compressive strength	megapascals	5.3.2, B.2, B.3.1, B.3.2, B.3.3, B.4.1, B.4.2
f_{des}	design bending tensile stress in concrete	megapascals	K
G	test per group	-	H
h_j	nominal height of joint seal	millimetres	4.3.4, A.1, A.2.5, A.2.7, A.3.3
h_m	height of applied joint seal	millimetres	A.1, A.2.5, A.2.7, A.3.2, A.3.3
J	test per 500 produced per group, with a minimum of one per month	-	H
K	composite tolerance factor	-	A.1, A.3.2, A.3.3
k	acceptability constant	-	I.4.1, I.4.2, K
k_b	conversion factor for crushing test	-	C.5
l	internal barrel length	metres	3.1, 4.3.6, C.4.1, C.5
l_b	distance between bottom bearing strip centres	metres	D.3.3, D.4.2
l_l	distance between centres of adjacent joint seals	metres	E.5.3
l_s	support span	metres	D.3.2, D.4.1
l_t	length of test piece	millimetres	A.1, A.2.6, A.2.7
l_1	length of joint seal before application	millimetres	A.1, A.2.5, A.2.7, A.3.3
l_2	length of joint seal after application	millimetres	A.1, A.2.5, A.2.7, A.3.3
M	moment (BMR value)	kilonewtons metre	4.3.6, D.4.1, D.4.2
m_1	constant mass of immersed sample	kilograms	F.4.1, F.5
m_2	constant mass of dry sample	kilograms	F.4.2, F.5
N	test per type and nominal size	-	H
n	number of consecutive samples	-	I.4.1, I.4.2, K

Table 2 *(continued)*

Symbol	Meaning	Unit	Reference
P	measured crushing load	kilonewtons	C.4.1, C.5
P^*	effective self-weight of load bearer	kilonewtons	C.5
P_b	total applied bending load	kilonewtons	D.3.2, D.3.3, D.4.1, D.4.2
Q	quality statistic	-	I.4.2, K
R	routine inspection test	-	6.1, C.1
R_a	arithmetical mean deviation of surface finish	micrometres	A.1, A.2.3
R_s	additional shear load	kilonewtons	E.5.3
r	radius of bend	metres	4.3.3
r_m	mean radius of pipe	millimetres	K
S	test per type, nominal size and strength class	-	H
s	estimated standard deviation	-	I.4.1, I.4.2, K
T	initial type test	-	6.1, C.1
t	design wall thickness	millimetres	H, I.3.2
t_{act}	mean measured wall thickness at crown of pipe	millimetres	K
t_{min}	minimum permissible wall thickness at crown of pipe	millimetres	K
W	test per type, nominal size and same wall thickness	-	H
W_w	weight of pipe filled with water	kilonewtons	E.5.3
x	measured value	-	I.4.2, K
$\bar{x}$	arithmetic sample mean	-	I.4.1, I.4.2, K
Y	test per type, nominal size and strength class produced, per 1 000, with a minimum of one per type and year	-	H
z	diametrical extent of compression in joint segment	metres	B.2, B.3.1, B.3.3, B.4.2
α	angle subtended by a bend	degrees	4.3.3
β	included testing angle	degrees	C.4.1
Δd_{so}	tolerance from internal socket diameter	millimetres	A.2.5, A.2.7, A.3.2, A.3.3
Δd_{sos}	tolerance from internal diameter of socket at shear stop provision	millimetres	A.3.2, A.3.3
Δd_{sp}	tolerance from external spigot diameter	millimetres	A.2.5, A.2.7, A.3.2, A.3.3
Δd_{sps}	tolerance from external diameter of spigot at shear stop provision	millimetres	A.3.2, A.3.3
Δh_j	tolerance from height of joint seal	millimetres	A.2.5, A.2.7, A.3.2, A.3.3
$\Delta\delta_{min}$	change from minimum deformation δ_1 as a result of shear load	per cent	A.1, A.2.5, A.2.7

Table 2 *(continued)*

Symbol	Meaning	Unit	Reference
$\Delta\delta_{max}$	change from maximum deformation δ_2 as a result of shear load	per cent	A.1, A.2.5, A.2.7
δ_1	minimum deformation, ignoring shear load	per cent	4.3.4, A.1, A.2.5, A.2.7, A.3.2
δ_2	maximum deformation, ignoring shear load	per cent	4.3.4, A.1, A.2.5, A.2.6, A.2.7, A.3.2
δ_{max}	maximum deformation	per cent	4.3.4, A.1, A.2.5, A.2.6, A.3.2, A.3.3
δ_{min}	minimum deformation	per cent	A.1, A.2.5, A.2.6, A.2.7, A.3.2, A.3.3
ε	relative circumferential stretching of applied joint seal	-	A.1, A.2.5, A.2.7, A.3.3
σ	known standard deviation	-	I.4.1, I.4.2

4 General requirements

4.1 Materials

4.1.1 General

Materials under the scope of this European Standard shall be as listed in Table 3.

NOTE Where relevant European Standards have not yet been published, complementary requirements for the reference specifications of materials will be needed. These should take the form of national standards or, in the absence of these, regulations or provisions valid in the place of use of the units.

Table 3 — Materials under the scope of this European Standard

Material	Supplementary requirements to the reference specification
Cements	None.
Aggregates	Aggregates shall not contain harmful constituents in such quantities as may be detrimental to the setting, hardening, strength, watertightness or durability of the concrete, nor cause corrosion of any steel. It is permissible for the manufacturer to modify standard gradings to suit the manufacturing process.
Mixing water	Mixing water shall not contain harmful constituents in such quantities as may be detrimental to the setting, hardening, strength, watertightness or durability of the concrete, nor cause corrosion of any steel.[a]
Admixtures	Admixtures, when used, shall not impair the durability of the concrete, nor cause corrosion of any steel.
Additions	Additions, when used, shall not contain harmful constituents in such quantities as may be detrimental to the setting, hardening, strength, watertightness or durability of the concrete, nor cause corrosion of any steel.
Steel fibres	Steel fibres shall: - be manufactured from hard drawn steel wire and having a characteristic tensile strength of not less than 1 000 MPa (N/mm^2) when determined in accordance with EN 10002-1; - have a shape and/or surface texture that ensures their mechanical anchorage in the concrete.
Reinforcing steel	Reinforcing steel shall be weldable where welding is to be carried out. It is permissible for reinforcing steel to be plain, indented, profiled or ribbed. The same materials shall be used in the manufacture of any welded fabric. ISO 10544 shall be used in the absence of another reference specification for reinforcing steel.
Joint seals	See 4.1.2.
Jacking pipe collars (including welding, if ferrous)	See also 5.3.1.2.

[a] Drinking water from public supply is generally suitable for the manufacture of concrete.

4.1.2 Joint seals

Joint seals shall conform to EN 681-1 and to the durability requirements in 4.3.4. They shall be supplied by the pipe manufacturer either integrated in the unit or supplied separately.

4.2 Concrete

4.2.1 Concrete materials

Only materials as described in 4.1.1 shall be used.

4.2.2 Concrete quality

The concrete in any unit shall be dense, homogeneous and conform to the requirements of 4.2.3, 4.2.4 and 4.2.6.

4.2.3 Water content of concrete

4.2.3.1 General

Concrete shall have such a composition that the ratio of water to cement plus any pozzolanic or latent hydraulic addition in the fully compacted state is consistent with the serviceability conditions in 4.3.8.

4.2.3.2 Requirement for water/cement ratio

The ratio of water to cement plus any pozzolanic or latent hydraulic addition in the fully compacted state shall not be greater than 0,45.

4.2.4 Cement content of concrete

Concrete shall have such a composition that the minimum content of cement plus any pozzolanic or latent hydraulic addition in the fully compacted state is consistent with the serviceability conditions in 4.3.8.

4.2.5 Chloride content of concrete

4.2.5.1 General

The maximum amount of chloride ion in the concrete shall be evaluated by calculation.

4.2.5.2 Requirement for chloride content

The calculated chloride ion content of the concrete shall not exceed the relevant value given in Table 4.

Table 4 — Maximum chloride content of concrete

Type of concrete	Cl^- by mass of cement
Unreinforced	1,0 %
Steel fibre	0,4 %
Reinforced	0,4 %

4.2.6 Water absorption of concrete

4.2.6.1 General

The water absorption of the concrete shall be tested in accordance with 6.7.

4.2.6.2 Absorption requirement

The water absorption of the concrete shall not exceed 6 % by mass.

4.3 Units

4.3.1 General

Units shall conform to the following requirements at the time of delivery.

4.3.2 Finish

Functional surfaces of joint profiles shall be free from irregularities that would preclude a durable watertight assembly.

Crazing within the cement-rich layer, shrinkage or temperature hairline cracks with a surface width not exceeding 0,15 mm and, for reinforced concrete pipes, residual cracks caused by testing and having the same limiting surface width, are permissible. At the manufacturer's discretion it is permissible to soak a unit for a maximum of 28 hours before measuring any crack widths.

Units with cracks other than those described above do not conform to this European Standard.

After any final treatment, a unit shall conform to all relevant requirements of this European Standard.

4.3.3 Geometrical characteristics

4.3.3.1 Internal barrel length

The internal barrel length of a pipe shall conform to that stated in the factory documents.

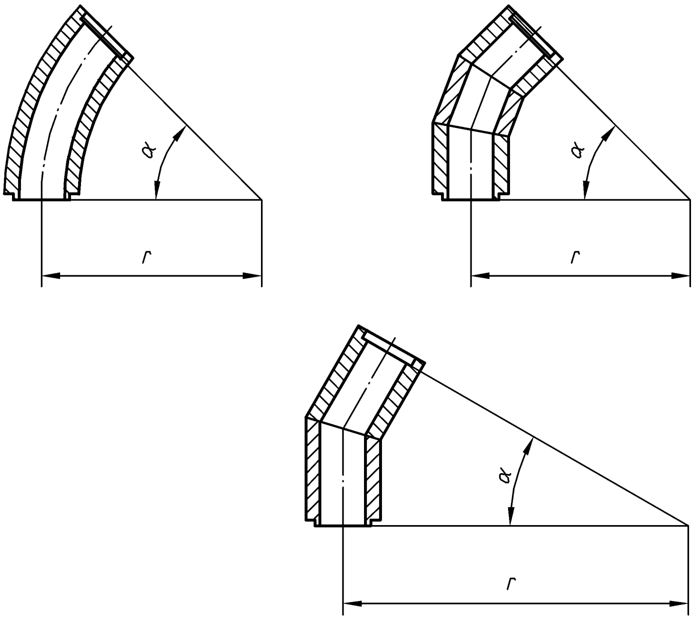
The internal barrel length of circular pipes up to and including DN 250 shall not exceed six times their external diameter, unless conforming to the requirements of 4.3.6.

4.3.3.2 Tolerances on joint assemblies

The profile of a joint shall conform to the corresponding design dimensions and tolerances stated in the factory documents. The tolerances stated for each joint profile and the maximum permissible tolerances on the seal(s) (which shall be not greater than that specified in EN 681-1) as stated in the factory documents shall be taken into account when calculating the relative deformation of the seal(s) in accordance with 4.3.4. The effect of any other dimensional tolerances that affect the functioning of the joint shall be taken into account, as appropriate.

4.3.3.3 Bends

Bends shall be manufactured as shown typically in Figure 3, either cast as one piece or fabricated from cut lengths of pipe conforming to this European Standard that have been bonded together with concrete or special mortar.



NOTE The illustrations show rebated joints. Spigot and socket joints are also available.

Figure 3 — Typical bends

4.3.4 Joints and joint seals

4.3.4.1 General

A joint shall comprise a spigot, socket (whether in-wall, as described in 5.3.1, or not) and joint seal(s) as described in the factory documents, be watertight according to 4.3.7 and shall be shown to conform to the following criteria, as appropriate, taking into account the most unfavourable combination of permitted tolerances.

A joint shall withstand the forces caused by the compression of the joint seal(s) when assembled and an internal hydrostatic pressure according to E.5.

Inlets or inlet-holes shall be provided with seals which satisfy the specification for the connecting component.

4.3.4.2 Durability of joints

4.3.4.2.1 General

A joint shall be shown to conform to the criteria in one of the following methods, taking into account the most unfavourable combination of permitted tolerances. Methods 1, 2 and 3 also take the shear load F_s into account, Method 4 does not.

NOTE 1 Methods 1, 2 and 3 are considered to be equivalent.

NOTE 2 Method 4 is only suitable where the ground and installation conditions are known to be such that the joint can safely be designed with no provision for shear load. In a European context, these conditions are likely to be rare.

<u>Method 1</u>

The minimum contact width b_t over which the seal is effective in an assembled joint, the mean pressure f across any zone of the seal involved in the sealing function and the maximum deformation δ_{max} shall be evaluated in accordance with annex A. The zone of the seal involved in the sealing function shall be stated in the factory documents.

Method 2

a) the maximum deformation δ_{max} of the joint seal (whether integrated or not) in an assembled joint shall be evaluated in accordance with annex A. The zone of the seal involved in the sealing function shall be stated in the factory documents.

b) the routine test for watertightness shall be as specified in E.5.4.

Method 3

In addition to the joint assembly test in E.5, a test in accordance with E.5.3 shall be carried out, immediately after which:

— the internal hydrostatic pressure shall be reduced to zero;

— at the manufacturer's discretion the infilling water shall be emptied;

— the shear load F_S shall continue to be applied for a further period of three calendar months, after first making any necessary adjustments to the loading arrangements in accordance with Figure E.1 as a result of emptying the infilling water;

— an internal hydrostatic pressure shall be re-applied in accordance with E.5.3 (after re-filling the unit if necessary and ensuring that the loading arrangements are in accordance with Figure E.1) and maintained for a period of 15 minutes, during which time the joint assembly shall be evaluated for conformity to 4.3.7, before reducing the internal pressure to zero;

— a record shall be made of whether the joint assembly conformed to the specified requirement.

Where pipes have different nominal sizes but identical joint profiles, an additional test as above relative to the largest size shall be accepted as representing all those sizes.

Method 4

The following shall be calculated in accordance with A.3 for an assembled joint:

— the minimum deformation δ_1 of the joint seal;

— the maximum deformation δ_2 of the joint seal;

— the minimum contact width b_t over which the seal is effective.

4.3.4.2.2 Limiting criteria

Method 1

When a joint conforming to the surface finish requirements of 4.3.2 for joint profiles is assembled, the seal shall be effective over a width b_t which is at least 50 % of the nominal radial annular space and the mean pressure f across any zone of the joint seal involved in the sealing function shall be not less than 0,15 Mpa (N/mm²). For integrated seals cast into the concrete the effective width and mean pressure shall be evaluated relative to the opposite face of the joint profile, but for all other seals both faces shall be considered. The relevant test method specified in A.2 shall apply.

NOTE 1 The "nominal radial annular space" is one half of the difference between the nominal internal diameter of the socket d_{so} and the nominal external diameter of the spigot d_{sp}.

NOTE 2 A joint assembly has to remain watertight throughout its working life and a significant factor in achieving this is that the physical characteristics of the installed seal are sustained at or above acceptable levels. In particular, stress relaxation of the rubber causes a decrease with time of the stress imposed on the seal by the constant strain, so initial values of limiting criteria have been set high enough to ensure continued performance throughout the joint's working life. In addition, the deformation of joint seals is limited to 65 % of their initial height, whether or not they have mechanical means for limiting such deformation.

Where pipes have different nominal sizes but identical joint profiles and joint seals, a test in accordance with A.2 relative to the largest size shall be accepted as representing all of those sizes.

As an alternative to testing a section of joint seal, and at the pipe manufacturer's discretion, it is permissible to calculate the foregoing limiting criteria for a seal within an assembled joint in accordance with A.3, provided that all of the following conditions are met:

— the seal has a circular or other convex cross-section;

— the seal has no enclosed void (at least in the zone involved in the sealing function);

— the seal is used in a joint having mechanical means for limiting deformation of the seal to a maximum of 65 % of its initial height.

Method 2

When a joint conforming to the surface finish requirements of 4.3.2 for joint profiles is assembled, the maximum deformation δ_{max} of the joint seal as evaluated according to annex A shall be limited to 65 % of its nominal height h_j.

Method 4

The seal shall have a circular or other convex cross-section and no enclosed void. When a joint conforming to the surface finish requirements of 4.3.2 for joint profiles is assembled, the following limiting criteria shall be met:

— the minimum deformation δ_1 shall be 25%;

— the maximum deformation δ_2 shall be 50%;

— the seal shall be effective over a width b_t of not less than 5 mm.

The foregoing criteria for a seal within an assembled joint shall be calculated in accordance with A.3.

4.3.5 Crushing strength

A pipe shall withstand the minimum crushing load F_n corresponding to its nominal size and strength class when tested in accordance with 6.4. For steel fibre and reinforced concrete pipes, see also 5.1.2 and 5.2.3 respectively.

4.3.6 Longitudinal bending moment resistance

4.3.6.1 General

The longitudinal bending moment resistance of a circular pipe up to and including DN 250 and having an internal barrel length greater than six times its external diameter shall be tested in accordance with 6.5.

4.3.6.2 Evaluation

The longitudinal bending moment resistance of a pipe shall be not less than that given by the following formula when tested as required by 4.3.6.1:

$$M = \mathrm{C} \times \mathrm{DN} \times l^2$$

where

M is the longitudinal bending moment resistance, in kilonewtons metre;

C is a constant equal to 0,013 kilonewtons per metre;

DN is the nominal size;

l is the internal barrel length, in metres.

NOTE Where the intended place of installation of a pipeline requires additional beam strength (e.g. a pipeline on piles), a specific structural design should be carried out.

4.3.7 Watertightness

When tested in accordance with 6.6 each unit or joint assembly shall not show any leakage or other visible defects during the test period; moisture adhering to the surface shall not constitute leakage. Units having a design wall thickness greater than 125 mm shall not be subjected to the hydrostatic test.

Where the same design of joint is used on pipes and fittings, at the manufacturer's discretion it is permissible to perform the tests for angular deflection and shear load (separately or combined) solely on pipes.

4.3.8 Serviceability

Units conforming to this European Standard are at least suitable for use in humid conditions and a slightly aggressive chemical environment (i.e. normal conditions for domestic sewage and treated industrial effluent, and for most soils and groundwaters). Special attention needs to be paid if more severe conditions are expected, primarily to the cement plus any pozzolanic or latent hydraulic addition in the concrete.

NOTE Definitions of "slightly aggressive" and more severe chemical environments can be found in national provisions for concrete.

4.3.9 Durability

The durability of installed units and their joints is specifically ensured by the following requirements:

— a maximum water/cement ratio of the concrete (see 4.2.3);

— a maximum chloride content of the concrete (see 4.2.5);

— a maximum water absorption of the concrete (see 4.2.6);

— conformity to the criteria in one of four methods for demonstrating the durability of joints (see 4.3.4.2);

— a minimum concrete cover in reinforced units (see 5.2.2);

— special requirements for jacking pipes (see 5.3.1.2 and 5.3.3).

5 Special requirements

Units shall conform to the following special requirements at the time of delivery.

5.1 Steel fibre concrete units

5.1.1 Steel fibre content

The amount of steel fibres introduced into the concrete shall be not less than that stated in the factory documents.

5.1.2 Crushing strength

A steel fibre concrete pipe shall conform to the following sequence of test requirements:

— it shall withstand a proof load of 0,67 F_n appropriate to its nominal size and strength class for one minute without showing any crack;

— the load shall be taken to ultimate (collapse) load F_u which shall be greater than F_n;

— after the sustained load has fallen to 95 % or less of the ultimate (collapse) load it shall be released, then reapplied to 0,67 F_n and supported for one minute.

5.2 Reinforced concrete units

5.2.1 Reinforcement

The reinforcement shall conform to 4.1.1 and the factory documents.

The reinforcement of pipes shall relate to the appropriate minimum crushing strength according to their nominal size and strength class. The minimum percentage of reinforcement, relative to the longitudinal cross-sectional area of the barrel, shall be 0,4 % for plain steel and 0,25 % for indented, profiled or ribbed steel.

It is permissible for one or more cages of reinforcement to be used, either helically wound or as concentric hoops, or fabricated from steel fabric, securely connected.

Elliptical or other non-circular reinforcement cages are permissible. In this case a durable indication on the crown of the unit and incorporating means of locating the reinforcement shall be provided, at least inside the unit.

Circumferential and longitudinal (if any) steel bars shall be assembled by welding or splicing in order to control spacing and the shape of the reinforcement cage(s). The circumferential reinforcement shall be spaced at regular distances throughout the length of the unit. The reinforcement cage(s) shall be maintained in the designed shape.

5.2.2 Concrete cover

The minimum concrete cover shall be consistent with the serviceability conditions described in 4.3.8.

5.2.3 Crushing strength

In addition to the requirement in 4.3.5 a reinforced concrete pipe shall also withstand a proof (crack) load F_c of 0,67 F_n when tested in accordance with 6.4, with any stabilized surface crack in the tensile zones of the concrete being not greater than 0,3 mm over a continuous length of 300 mm or more.

5.2.4 Conformity of proof (crack) load tested pipes

Reinforced concrete pipes tested only to proof (crack) load in accordance with 6.4 and meeting the requirements of 5.2.3 conform to this European Standard.

NOTE Taking the necessary installation conditions into consideration, the contractor could decide to use a reinforced concrete jacking pipe (see 5.3) subjected successfully to the proof (crack) load crushing test to complete a jacked pipeline.

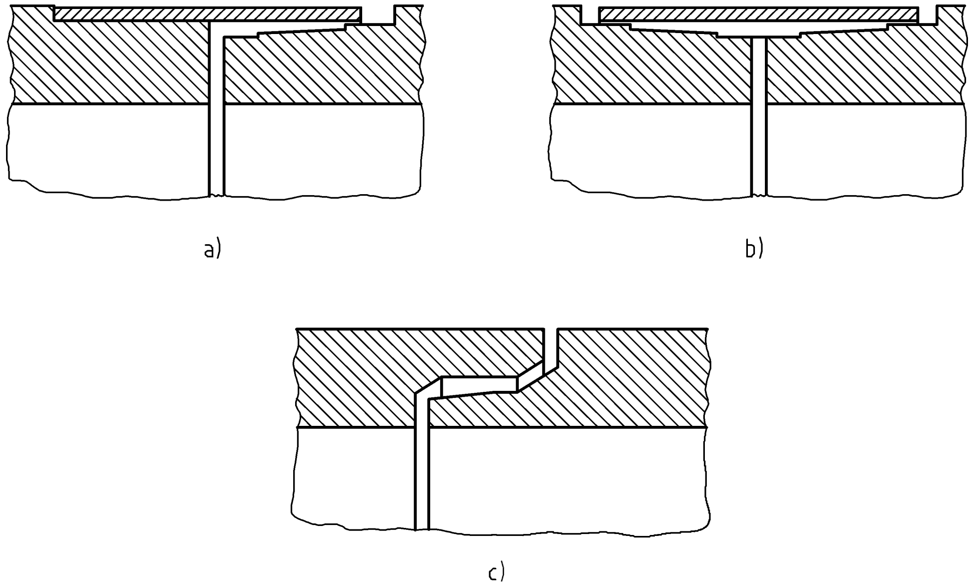
5.3 Jacking pipes

5.3.1 Joints

5.3.1.1 General

Joints of jacking pipes shall be in-wall flexible joints of either the collar or rebated type as shown typically in Figure 4. They shall be designed to include one or more joint seals. All joint surfaces which will transmit load during installation shall be plane and free from irregularities that could cause high local concentrations of stress.

NOTE The angle calculated from angular deflection (see E.5.2) is not necessarily that which can be accommodated during jacking operations. Consultation between contractor and manufacturer is recommended.



Key

a) Fixed collar

b) Loose collar

c) Rebated

NOTE The joint seals have been omitted, for clarity.

Figure 4 — Typical in-wall joints

5.3.1.2 Collars

Collars shall be manufactured from weldable structural steel plate, stainless steel plate or reinforced plastics.

NOTE Weldable structural steel plate collars can be susceptible to corrosion from the ground, groundwater or the effluent carried. If corrosion is expected by the specifier, the design of a joint incorporating this type of collar should provide for a secondary sealing gasket to be applied on site by the contractor, for example by means of an appropriate sealant.

5.3.2 Concrete strength

5.3.2.1 General

The characteristic compressive strength of the concrete f_{ck} in jacking pipes shall be verified on the basis of testing in accordance with 6.8. The verified value of this strength shall be not less than the manufacturer's declared design characteristic strength as stated in the factory documents.

5.3.2.2 Strength requirement

The design characteristic strength declared by the manufacturer in the factory documents shall be not less than 40 MPa (N/mm^2).

5.3.3 Concrete cover

For reinforced concrete jacking pipes the minimum concrete cover required by 5.2.2 shall be increased by 5 mm on external surfaces to be in permanent contact with the ground.

There shall be no steel within the concrete cover on joint surfaces which will transmit load during installation.

5.3.4 Jacking load

The manufacturer shall make available a statement of the jacking load for which each jacking pipe was designed (design jacking load F_j). This load shall be not greater than the maximum design load as determined by structural calculation in accordance with annex B.

The maximum stress resulting from the manufacturer's assumed installation parameters shall not exceed 60 % of his declared characteristic strength of the concrete (see annex B).

NOTE The design jacking load as declared by the manufacturer or calculated in accordance with annex B does not include any safety factor used by the contractor, having regard to the jacking method and subsequent deflection of the pipes, the nature of the ground and unforeseen conditions, or for the stress ratio across the jacking face (see Figure B.1).

5.4 Pipes with inlet

The design of the joint for a connection to a pipe with inlet shall ensure that conformity to 4.3.7 can be achieved. The bore of the inlet shall be free from burrs.

6 Test methods for finished products

6.1 General

6.2 to 6.8 inclusive shall apply to all units, unless stated otherwise in Table 5 for conformity evaluation.

Table 5 — Summary of test requirements

Clause	Requirement where specified	Pipes		Fittings				
		Pipe	Jacking pipe	Connecting pipe	Pipe with inlet	Junction	Taper (reducer), adaptor	Bend
4.2.6.1	Water absorption	T/R	T/R	T/R[a]	T/R[a]	T/R[a]	T/R[a]	T/R[a]
4.3.2	Visual inspection of finish	T/R	T/R	T/R	T/R	T/R	T/R	T/R
4.3.3	Geometrical characteristics: - units - joint profiles	 T/R T/R	 T/R T/R	 T/R[a] T/R[a]	 T/R[a] T/R[a]	 T/R[a] T/R[a]	 T/R[a] T/R[a]	 T/R[a] T/R[a]
4.3.4	Joints and joint seals[b]	T	T	T[c]	T[c]	T[c]	T[c]	T[c]
4.3.5	Crushing strength	T/R	T/R	T/R[a]	T/R	-	-	-
4.3.6.1	Longitudinal BMR	T[d]	T[d]	-	T[d]	-	-	-
4.3.7	Watertightness: - hydrostatic - joint assembly	 T/R[e] T/R	 T/R[e] T/R	 T/R[e] T/R[g]	 T/R[f] T/R[h]	 T/R[f] T/R[h]	 T/R T/R[h]	 T/R[g] T/R[h]
5.2.1, 5.2.2 and 5.3.3	Reinforcement and concrete cover	T/R	T/R	T/R[a]	T/R[a]	T/R[a]	T/R[a]	T/R[a]
5.3.2.1	Drilled core strength	-	T/R	-	-	-	-	-

T means initial type test;

R means routine inspection test;

[a] means not applicable to fittings fabricated from pipes or parts of pipes that conform to this European Standard;

[b] means that annex A is not applicable where Method 3 in 4.3.4.2 is adopted;

[c] means not applicable to fittings having the same design of joint as pipes;

[d] means not applicable to pipes > DN 250, nor to pipes ≤ DN 250 whose internal barrel length does not exceed six times their external diameter;

[e] means not applicable to units with a design wall thickness > 125 mm;

[f] means not applicable to units with main pipes > DN 800 or inlets > DN 300, for safety reasons;

[g] means not applicable to bends > DN 300, for safety reasons;

[h] means, at the manufacturer's discretion, not applicable to fittings having the same design of joint as pipes

6.2 Joint profiles

The critical dimensions of joint profiles and their respective tolerances shall be evaluated for conformity to the factory documents.

6.3 Reinforcement

A section shall be cut from an undamaged part of a reinforced concrete pipe that has been tested to collapse as required under a routine or initial type test, to enable both circumferential and any longitudinal reinforcement to be examined and the concrete cover evaluated for conformity to 5.2.1 and 5.2.2 or 5.3.3, as appropriate.

6.3.1 Placing and content of reinforcement

The spacing and content of circumferential bars shall be measured over a length of at least 1 metre and evaluated for conformity to the factory documents and 5.2.1. The distance of the circumferential reinforcement from the end of the spigot and of the socket shall also be evaluated for conformity to 5.2.1.

Longitudinal reinforcement (if any) shall be evaluated for conformity to the factory documents.

6.3.2 Concrete cover

The reinforcement shall be exposed, the concrete cover measured, and the minimum recorded to the nearest millimetre. The cover shall then be evaluated for conformity to 5.2.2 or 5.3.3, as appropriate.

6.4 Crushing strength(s)

Crushing strength(s) shall be determined in accordance with the relevant method(s) specified in annex C.

6.5 Longitudinal bending moment resistance

Longitudinal bending moment resistance shall be determined in accordance with one of the methods specified in annex D, the choice of method being at the manufacturer's discretion.

6.6 Watertightness

Watertightness of units, and of joint assemblies, shall be determined in accordance with the methods specified in annex E.

6.7 Water absorption

Water absorption shall be determined in accordance with the method specified in annex F.

6.8 Concrete strength in jacking pipes

Compressive strength of the concrete in jacking pipes shall be determined in accordance with ISO 4012 and the test carried out by drilling a sample at each third-point along the internal barrel length, then calculating the mean value of the two results.

The drilled cores shall have a height equal to their diameter ± 10 mm:

— when 100 mm ± 1 mm diameter cores are used, the result shall be applied without any conversion factor;

— when 50 mm ± 1 mm diameter cores are used, a conversion factor of 0,9 shall be applied to the results.

Linear interpolation for intermediate diameters of core is permissible.

7 Conformity evaluation

7.1 General

The manufacturer's quality assurance system shall be as specified in annex G.

NOTE 1 It is recommended that conformity to this European Standard should be demonstrated by means of product certification by an approved certification body complying with the requirements of EN 45011. However, attention is drawn to Table ZA.2 regarding the clauses to which the EU Commission's decision on the level of attestation of conformity applies for the purposes of CE marking, within the context of the Construction Products Directive (89/106). In order not to submit the manufacturer to a double procedure, the Commission has declared that the more severe procedure, if applied, can satisfy the less severe one reported and applying as described in ZA.2.

NOTE 2 When units are certified by an approved certification body (and in accordance with EN 45011) receiving inspection by, or on behalf of, the purchaser is not necessary, except for the marking.

7.2 Product evaluation procedures

7.2.1 General

The procedures are as follows:

1) initial type testing of units;

2) factory production control;

3) further testing of samples in accordance with a sampling plan prescribed in this European Standard.

7.2.2 Initial type testing

Initial type testing shall be undertaken to show conformity to this European Standard. Tests previously performed in accordance with the requirements of this standard (same product or specified product grouping, same characteristic(s), same method of sampling and same or more demanding test) may be taken into account. Initial type testing shall also be undertaken:

— at the start of production of a new type;

— whenever there is a significant change in design, type of material or method of manufacture.

The initial type test consists of taking samples (as indicated in Tables H.1 and H.2) from the production line and subjecting them to the relevant test(s). To satisfy the requirements of the initial type test, all samples shall conform to the requirements of this European Standard.

The results from initial type tests shall not be included for the purposes of routine inspection.

When the manufacturer's test equipment is officially calibrated, initial type testing shall normally be carried out with that equipment.

7.2.3 Factory production control

Factory production control shall be based on a quality assurance system as described in annex G.

7.2.4 Further testing of samples taken at the factory

Conformity to this European Standard shall be demonstrated by taking samples during initial type testing and at further routine inspection as described hereinafter. Tests shall be carried out on the samples at the minimum age declared by the manufacturer for conformity to this European Standard.

For routine crushing and watertightness (hydrostatic) tests, the manufacturer shall use continuous inspection for each type, nominal size and strength class of pipe in accordance with the provisions of annex I.

NOTE The manufacturer could choose to carry out routine air or vacuum testing to assist factory production control, in addition to the specified hydrostatic test.

7.2.5 Tasks for a certification body

Where conformity to this European Standard is to be demonstrated by means of product certification by an approved certification body, the tasks for that body shall be as specified in annex J.

8 Marking

Each unit or, where this is not practicable, each package of units, shall be marked indelibly and in a clearly visible manner. Identification of the unit(s) shall be made in such a way that no doubt is possible.

Marking shall include the following minimum information:

a) the manufacturer's name, trade mark or identification mark, and site of production;

b) the number of this European Standard, EN 1916;

c) the date of manufacture;

d) identification of material of unit;

e) identification of any third party certification body;

f) strength class (as confirmed by annex I);

g) identification of serviceability conditions other than normal;

h) identification of special use, where applicable;

i) the words "LESS SHEAR" if Method 4 has been used to demonstrate the durability of the joint.

NOTE Where the marking requirements of ZA.3 require the same information as this clause, the requirements of this clause are met.

Annex A
(normative)

Test and calculation methods for joint seals

A.1 Symbols

The symbols used in this annex have the following meanings:

b_t effective tightened width, in millimetres;

d_{so} nominal internal diameter of the socket, in millimetres;

d_{sp} nominal external diameter of the spigot, in millimetres;

d_{sos} nominal internal diameter of the socket at a mechanical means for limiting deformation (equal to d_{so}, if no such mechanical means in the socket), in millimetres;

d_{sps} nominal external diameter of the spigot at a mechanical means for limiting deformation (equal to d_{sp}, if no such mechanical means in the spigot), in millimetres;

E modulus of elasticity of the seal rubber, in megapascals;

F measured tightening force, in newtons;

F_d distributed unit force assumed to result from application of the specified shear load, in newtons per millimetre;

F_e tightening force per unit length, in newtons per millimetre;

F_s shear load, in kilonewtons;

f mean pressure on the test piece, in megapascals (newtons per square millimetre);

h_m height of the applied joint seal equal to $h_j/\sqrt{1+\varepsilon}$, in millimetres,

where h_j is the nominal height of the joint seal, in millimetres;

ε is the relative circumferential stretching of the applied joint seal equal to $(l_2 - l_1)/l_1$;

l_1 is the length of the joint seal before application, in millimetres;

l_2 is the length of the joint seal after application equal to $\pi(d_{sp} + h_j)$, in millimetres;

K composite tolerance factor;

l_t length of the test piece, in millimetres;

R_a arithmetic mean deviation of the surface finish, in micrometres;

δ_{max} maximum deformation, in per cent;

δ_{min} minimum deformation, in per cent;

δ_1 minimum deformation, ignoring the shear load, in per cent;

δ_2 maximum deformation, ignoring the shear load, in per cent;

$\Delta\delta_{max}$ change from the maximum deformation δ_2 as a result of the shear load, in per cent.

$\Delta\delta_{min}$ change from the minimum deformation δ_1 as a result of the shear load, in per cent.

A.2 Test methods

A.2.1 Applicability

In this annex "Method 1" and "Method 2" refer to those prescribed in 4.3.4.2. It is applicable as specified to all joint seals where the durability of the joint is to be demonstrated by Method 1 or Method 2. For integrated seals cast into the concrete the test relates to the opposite face of the joint profile, but for all other seals both faces shall be considered.

A.2.2 Principle

The purpose of these tests is to evaluate whether the effective tightened width and the mean pressure across any zone involved in the sealing function on a section of joint seal (Method 1), or its maximum deformation (Method 2), are within the relevant limits specified in 4.3.4.2.2. Before starting the procedure specific to a seal and joint profile, it is necessary to have available the specific force/deformation diagram for that joint assembly.

For the purposes of either test it shall be assumed that the shear load is distributed over a length of seal equal to the diameter or width of the joint, as appropriate to the shape of the bore, at the centre of the nominal radial annular space.

A.2.3 Apparatus

The apparatus for either test shall conform to that specified in ISO 3384, except that the compressive device plates shall be manufactured from any suitable robust material and, when measured in the disassembled condition, their flatness shall be accurate to 0,05 mm and their surface finish to 1,6 µm R_a as defined in EN ISO 4287, applied using the rules in EN ISO 4288. When the apparatus is assembled, the gap between the plates shall be accurate to ± 0,05 mm. Furthermore, the compression device shall be shaped in such a way that a test will reproduce the seal's function in the corresponding pipe joint assembly, including any shear stop provision and whether integrated or not in the unit.

Where the joint profile in the vicinity of the seal does not comprise two parallel lines, it shall be reproduced using profiled sections of the same material as, and in contact with, the compression device plates. The flatness and surface roughness criteria for the profiled sections shall be the same as those specified for the plates.

The apparatus shall have end plates to prevent the test piece from moving in a longitudinal direction during testing. The radial curve of the actual joint construction is not required to be taken into consideration. The end plates shall be lubricated with a silicone or fluorosilicone fluid as described in ISO 3384.

A.2.4 Preparation

The test piece for either test shall comprise a section of the relevant joint seal 100 mm ± 1 mm in length, or twice the nominal width of the seal, whichever is the greater. Any part of a seal outside the zone involved in the sealing function, together with any parts designed to be cast into concrete, may be removed from the test piece, which it is then permissible to support if necessary.

A.2.5 Procedures

A.2.5.1 Production of force/deformation diagram

The force/deformation diagram for the specific joint assembly shall be produced for either test using apparatus and a test piece conforming to A.2.3 and A.2.4 respectively at an ambient temperature of 20 ^{o}C ± 3 ^{o}C. The test piece shall first be deformed by 5 % and the required tightening force measured and recorded, then the procedure shall be repeated in successive increments of 5 % as foreseen in the design of the joint assembly, but not exceeding 65 %. During this stage of the procedure the deformation shall be applied at a rate not exceeding 25 millimetres per minute. The tightening force at each 5 % increment shall be measured after the test piece has stabilized for 10 seconds ± 2 seconds.

Where the apparatus provides for the simultaneous assessment of deformation and effective tightened width, it is permissible for these requirements to be carried out jointly with those of A.2.5.2.2.

A.2.5.2 Procedures specific to a seal and joint profile

A.2.5.2.1 Preliminaries

For Method 1 the values F_d, l_2, ε, h_m and δ_1 shall first be calculated from the following equations, using the width WN of egg-shaped pipes for d_{so} and d_{sp}:

$$F_d = F_s \times 1\,000 / [(d_{so} + d_{sp}) / 2];$$

$$h_m = h_j / \sqrt{1+\varepsilon}\ ;$$

where

$$\varepsilon = (l_2 - l_1)/ l_1, \text{ and}$$

$$l_2 = \pi\,(d_{sp} + h_j);$$

$$\delta_1 = \left[2h_m - d_{so} + d_{sp} - \sqrt{(2\Delta h_j)^2 + \Delta d_{so}^2 + \Delta d_{sp}^2}\right] \times 100/(2 \times h_m).$$

The specific force/deformation diagram shall then be used to determine the change in the minimum deformation $\Delta\delta_{min}$ caused by a unit force F_d, then the minimum deformation δ_{min} calculated from the following equation:

$$\delta_{min} = \delta_1 - \Delta\delta_{min}$$

For Method 2 the procedure shall be as for Method 1, except that δ_2 shall be calculated in lieu of δ_1 using the following equation:

$$\delta_2 = \left[2h_m - d_{so} + d_{sp} + \sqrt{(2\Delta h_j)^2 + \Delta d_{so}^2 + \Delta d_{sp}^2}\right] \times 100/(2 \times h_m).$$

The specific force/deformation diagram shall then be used to determine the change in the maximum deformation $\Delta\delta_{max}$ caused by a unit force F_d, then the maximum deformation δ_{max} calculated from the following equation:

$$\delta_{max} = \delta_2 - \Delta\delta_{max}$$

A.2.5.2.2 Evaluation of effective tightened width (Method 1)

The test piece shall be placed in the apparatus at an ambient temperature of 20 °C ± 3 °C, compressed to a deformation equal to δ_{min} and the relevant tightening force F and effective tightened width b_t measured and recorded.

Where it is not possible to measure the effective tightened width whilst the test piece is in the apparatus, provision shall be made for marks to be left on the compression device when the test piece is compressed (e.g. by inserting carbon paper). After reaching a deformation of δ_{min} the relevant tightening force shall be recorded and then released. The test piece shall then be removed and the effective tightened width measured and recorded from the marks left on the compression device.

A.2.6 Expression of results

A.2.6.1 Effective tightened width (Method 1)

The effective tightened width b_t is the width of rubber/compression device contact as measured in A.2.5.2.2.

A.2.6.2 Mean pressure (Method 1)

The mean pressure f across the zone of the seal involved in the sealing function shall be calculated using the equation:

$$f = F / (l_t \times b_t)$$

where

f I s the mean pressure, in megapascals (newtons per square millimetre);

F is the tightening force needed to cause a deformation δ_{min}, in newtons;

l_t is the length of the test piece, in millimetres;

b_t is the corresponding effective tightened width, in millimetres.

A.2.6.3 Maximum deformation (Method 2)

The maximum deformation δ_{max} is the value calculated in accordance with A.2.5.2.1.

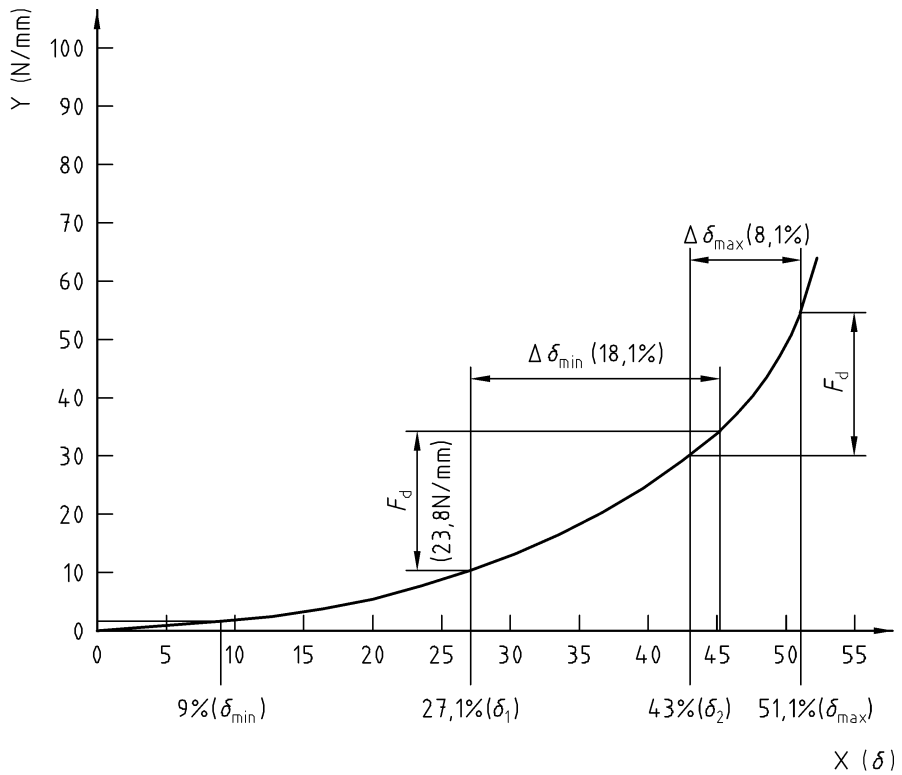
A.2.7 Examples

A.2.7.1 Method 1

An example of the procedures for evaluating the effective tightened width and the mean pressure across the zone of the seal involved in the sealing function is given in Table A.1. The associated specific force/deformation diagram for the assumed seal is shown in Figure A.1 and is for use only in connection with the example.

A.2.7.2 Method 2

An example of the procedures for evaluating the maximum deformation of the seal involved in the sealing function is given in Table A.2. The associated specific force/deformation diagram for the assumed seal is shown in Figure A.1 and is for use only in connection with the example.



Key

Y Force per unit length of seal

X Deformation

Figure A.1 — Specific force/deformation diagram assumed for the examples and the determination of $\Delta\delta_{min}$ (Method 1) or $\Delta\delta_{max}$ (Method 2)

Table A.1 — Procedures for evaluating the example (Method 1)

1) Assumptions			
DN	Nominal size		DN 1 000
d_{so}	Nominal diameter of socket		1 274,8 mm
d_{sp}	Nominal diameter of spigot		1 250,0 mm
Δd_{so}	Tolerance from socket diameter		± 1,2 mm
Δd_{sp}	Tolerance from spigot diameter		± 2,4 mm
F_s	Shear load (0,03 × DN) kN		30 kN
h_j	Nominal height of joint seal		20 mm
Δh_j	Tolerance from height of joint seal		± 0,7 mm
l_1	Length of joint seal before application		3 630 mm
2) Formulae and calculations			
F_d	$F_s \times 1\,000 / [(d_{so} + d_{sp})/2]$	$= 30 \times 1\,000 / [(1\,274{,}8 + 1\,250{,}0) / 2]$	23,8 N/mm
l_2	$\pi (d_{sp} + h_j)$	$= \pi (1\,250 + 20)$	3 990 mm
ε	$(l_2 - l_1) / l_1$	$= (3\,990 – 3\,630) / 3\,630$	0,10
h_m	$h_j / (1 + \varepsilon)^{0,5}$	$= 20 / (1 + 0{,}10)^{0,5}$	19,1 mm
δ_1	$\{2h_m - d_{so} + d_{sp} - [(2\Delta h_j)^2 + \Delta d_{so}^2 + \Delta d_{sp}^2]^{0,5}\} \times 100 / 2h_m$	$= \{2\times19{,}1 - 1274{,}8 + 1250{,}0 - [(2\times0{,}7)^2 + 1{,}2^2 + 2{,}4^2]^{0,5}\} \times 100 / (2\times19{,}1)$	27,1 %
δ_{min}	(i) determine $\Delta\delta_{min}$ from specific force/deformation diagram:		18,1 %
	(ii) $\delta_1 - \Delta\delta_{min}$	= 27,1 - 18,1	9,0 %
b_t	min. 50 % of $(d_{so} - d_{sp}) / 2$	≥ 0,5 × (1 274,8 – 1 250,0) / 2	≥ 6,2 mm
3) Test procedures and evaluation			
Test procedures:	a) compress test piece (length l_t = 100 mm) to give 9,0 % minimum deformation δ_{min};		
	b) record tightening force F;		200 N
	c) measure effective tightened width b_t;		10,5 mm
	d) calculate $F / (l_t \times b_t)$ to give mean pressure f.		0,19 MPa (N/mm²)
Requirements:	c) $b_t \geq 6{,}2$ mm;		Conforms
	d) $f \geq 0{,}15$ MPa (N/mm²).		Conforms

Table A.2 — Procedures for evaluating the example (Method 2)

1) Assumptions			
DN	Nominal size		DN 1 000
d_{so}	Nominal diameter of socket		1 274,8 mm
d_{sp}	Nominal diameter of spigot		1 250,0 mm
Δd_{so}	Tolerance from socket diameter		± 1,2 mm
Δd_{sp}	Tolerance from spigot diameter		± 2,4 mm
F_s	shear load (0,03 × DN) kN		30 kN
h_j	Nominal height of joint seal		20 mm
Δh_j	Tolerance from height of joint seal		± 0,7 mm
l_1	length of joint seal before application		3 630 mm
2) Formulae and calculations			
F_d	$F_s \times 1\,000 / [(d_{so} + d_{sp}) / 2]$	$= 30 \times 1\,000/[(1\,274{,}8 + 1\,250{,}0) / 2]$	23,8 N/mm
l_2	$\pi (d_{sp} + h_j)$	$= \pi (1\,250 + 20)$	3 990 mm
ε	$(l_2 - l_1) / l_1$	$= (3\,990 - 3\,630) / 3\,630$	0,10
h_m	$h_j / (1 + \varepsilon)^{0,5}$	$= 20 / (1 + 0{,}10)^{0,5}$	19,1 mm
δ_2	$\{2h_m - d_{so} + d_{sp} + [(2\Delta h_j)^2 + \Delta d_{so}^2 + \Delta d_{sp}^2]^{0,5}\} \times 100 / 2h_m$	$= \{2\times19{,}1 - 1\,274{,}8 + 1\,250{,}0 + [(2\times0{,}7)^2 + 1{,}2^2 + 2{,}4^2]^{0,5}\} \times 100 / (2\times19{,}1)$	43,0 %
δ_{max}	(i) determine $\Delta\delta_{max}$ from specific force/deformation diagram: (ii) $\delta_2 + \Delta\delta_{max}$	$= 43{,}0 + 8{,}1$	8,1 % 51,1 %
3) Evaluation			
Requirements: a) $\delta_{max} \leq 65$ %			Conforms

A.3 Calculation method

A.3.1 Applicability

The following calculation method is only permissible as an alternative to testing in accordance with A.2 where the seal has a circular or other convex cross-section, has no enclosed void (at least in the zone involved in the sealing function) and is used in a joint having mechanical means for limiting deformation of the seal to 65 % of its initial height. It is always applicable when Method 4 is being used to demonstrate the durability of a joint.

A.3.2 Basis

For Method 1 the effective tightened width b_t and the mean pressure f across any zone involved in the sealing function of a seal shall be calculated as follows, using the relevant width WN of egg-shaped pipes for values of d_{so}, d_{sp}, d_{sos} and d_{sps}:

$$\delta_{min} = [2h_m - d_{so} + d_{sp} - d_{sos} + d_{sps} - K] \times 100/(2h_m)$$

$$\delta_{max} = [2h_m - d_{so} + d_{sp} + d_{sos} - d_{sps} + K] \times 100/(2h_m)$$

where

K is the composite tolerance factor for the calculation method, in millimetres:

$$K = \sqrt{(2\Delta h_j)^2 + \Delta d_{so}^2 + \Delta d_{sp}^2 + \Delta d_{sos}^2 + \Delta d_{sps}^2}$$

where

Δd_{so} is the tolerance from the internal diameter of the socket, in millimetres;

Δd_{sp} is the tolerance from the external diameter of the spigot, in millimetres;

Δd_{sos} is the tolerance from the internal diameter of the socket at a mechanical means for limiting deformation (equal to Δd_{so} if no such mechanical means in the socket), in millimetres;

Δd_{sps} is the tolerance from the external diameter of the spigot at a mechanical means for limiting deformation (equal to Δd_{sp} if no such mechanical means in the spigot), in millimetres;

Δh_j is the tolerance from the height of the joint seal, in millimetres;

$$F_e = E \times h_m [1{,}25 (\delta_{min}/100)^{3/2} + 50 (\delta_{min} / 100)^6]$$

$$b_t = 0{,}5\, h_m [\pi / 2 - (1 - \delta_{min}/100)^2] / [1 - \delta_{min} / 100]$$

$$f = F_e / b_t$$

NOTE The formula for calculating the effective tightened width b_t is an empirical one and, although not valid for minimum deformations δ_{min} less than 5 %, in practice this is irrelevant.

Where a seal is manufactured on the basis of a fixed volume, Δh_j shall be assumed to be zero when calculating the composite tolerance factor K.

For Method 2 δ_{max} shall be calculated using the relevant parts of the above.

For Method 4 the minimum deformation δ_1, the maximum deformation δ_2 and the effective tightened width b_t shall be calculated as follows, using the relevant width WN of egg-shaped pipes for values of d_{so} and d_{sp}:

$$\delta_1 = \left[2h_m - d_{so} + d_{sp} - \sqrt{(2\Delta h_j)^2 + \Delta d_{so}^2 + \Delta d_{sp}^2}\right] \times 100/(2 \times h_m)$$

$$\delta_2 = \left[2h_m - d_{so} + d_{sp} + \sqrt{(2\Delta h_j)^2 + \Delta d_{so}^2 + \Delta d_{sp}^2}\right] \times 100/(2 \times h_m)$$

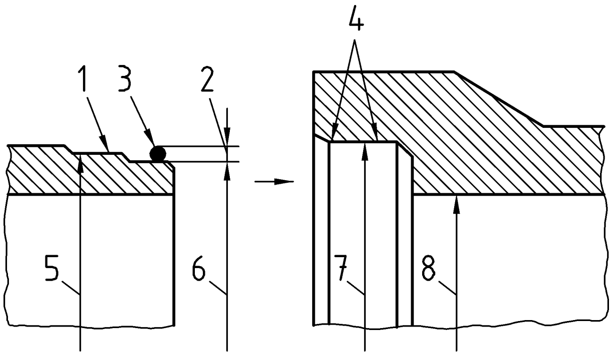
$$b_t = 0{,}5\, h_m\, [\pi / 2 - (1 - \delta_1 / 100)^2] / [1 - \delta_1 / 100]$$

A.3.3 Examples

A.3.3.1 Method 1

An example of the procedures for calculating the effective tightened width and the mean pressure across any zone of the seal involved in the sealing function is given in Table A.3. The basic assumptions for the example are shown diagrammatically in Figure A.2.

NOTE Although based on similar assumptions for the pipes, the values established for effective tightened width and mean pressure in the examples in Tables A.1 and A.3 should not be expected to correlate, because it is assumed in the former that there is no concrete shear stop.



Key

1 Concrete shear stop moulded into the spigot

2 Applied height h_m (19,1 mm)

3 'O' ring $h_j \pm \Delta h_j$ (20 mm ± 0,7 mm)

4 Socket parallel, therefore $d_{sos} = d_{so}$ and $\Delta d_{sos} = \Delta d_{so}$

5 $d_{sps} \pm \Delta d_{sps}$ (1 270,4 mm ± 2,0 mm)

6 $d_{sp} \pm \Delta d_{sp}$ (1 250,0 mm ± 2,0 mm)

7 $d_{so} \pm \Delta d_{so}$ (= $d_{sos} \pm \Delta d_{sos}$) (both 1 274,8 mm ± 1,0 mm)

8 DN 1 000

Figure A.2 — Basic assumptions for the example in Table A.2

A.3.3.2 Method 2

An example of the procedures for evaluating the maximum deformation of the seal involved in the sealing function is given in Table A.4. The associated specific force/deformation diagram for the assumed seal is shown in Figure A.1 and is for use only in connection with the example.

A.3.3.3 Method 4

An example of the procedures for calculating the minimum deformation, maximum deformation and effective tightened width of the seal is given in Table A.5. The basic assumptions for the example are essentially as shown diagrammatically in Figure A.2, except that the spigot has no concrete shear stop and the tolerances are adjusted accordingly.

Table A.3 — Procedures for calculating the example (Method 1)

1) Assumptions			
DN	Nominal size		DN 1 000
-	Joint with a concrete shear stop moulded into the spigot (i.e. $d_{sos} = d_{so}$ and Δd_{sos})		-
d_{so}	Nominal diameter of socket		1 274,8 mm
d_{sp}	Nominal diameter of spigot		1 250,0 mm
d_{sps}	Nominal diameter of spigot at concrete shear stop		1 270,4 mm
Δd_{so}	Tolerance from socket diameter		± 1,0 mm
Δd_{sp}	Tolerance from spigot diameter		± 2,0 mm
Δd_{sps}	Tolerance from shear stop diameter		± 2,0 mm
h_j	Nominal height of joint seal		20 mm
Δh_j	Tolerance from height of joint seal		± 0,7 mm
l_1	Length of joint seal before application		3 630 mm
E	Modulus of elasticity of seal rubber (40 IRHD)		1,50 MPa (N/mm²)
2) Formulae and calculations			
l_2	$\pi (d_{sp} + h_j)$	$= \pi (1\,250 + 20)$	3 990 mm
ε	$(l_2 - l_1) / l_1$	$= (3\,990 – 3\,630) / 3\,630$	0,10
h_m	$h_j / (1 + \varepsilon)^{0,5}$	$= 20/(1 + 0,10)^{0,5}$	19,1 mm
K	$[(2\Delta h_j)^2 + \Delta d_{so}^2 + \Delta d_{sp}^2 + \Delta d_{sos}^2 + \Delta d_{sps}^2]^{0,5}$	$= [(2 \times 0,7)^2 + 1,0^2 + 2,0^2 + 1,0^2 + 2,0^2]^{0,5}$	3,46 mm
δ_{min}	$[2h_m - d_{so} + d_{sp} - d_{sos} + d_{sps} - K] \times 100 / 2h_m$ $= [2 \times 19,1 – 1\,274,8 + 1\,250,0 - 1\,274,8 + 1\,270,4 - 3,46] \times 100 / (2 \times 19,1)$		14,5 %
δ_{max}	$[2h_m - d_{so} + d_{sp} + d_{sos} - d_{sps} + K] \times 100 / 2h_m$ $= [2 \times 19,1 – 1\,274,8 + 1\,250,0 + 1\,274,8 - 1\,270,4 + 3,46] \times 100 / (2 \times 19,1)$		55,7 %
F_e	$E \times h_m [1,25 (\delta_{min}/100)^{1,5} + 50(\delta_{min} / 100)^6]$ $= 1,50 \times 19,1[1,25 \times (14,5 / 100)^{1,5} + 50 \times (14,5 / 100)^6]$		1,99 N/mm
b_t	$0,5\, h_m [\pi / 2 - (1- \delta_{min} / 100)^2] / [1 - \delta_{min} / 100]$	$= 0,5 \times 19,1 [\pi/2 - (1 - 14,5 / 100)^2] / [1 - 14,5 / 100]$	9,4 mm
f	F_e / b_t	$= 1,99 / 9,4$	0,21 MPa (N/mm²)
b_t	min. 50 % of $(d_{so} - d_{sp}) / 2$	$\geq 0,50 \times (1\,274,8 – 1\,250,0) / 2$	≥ 6,2 mm
3) Evaluation			
Requirements:	a) $b_t \geq 6,2$ mm		Conforms
	b) $f \geq 0,15$ MPa (N/mm²)		Conforms
	c) $\delta_{max} \leq 65$ %		Conforms

Table A.4 — Procedures for calculating the example (Method 2)

1) Assumptions			
DN	Nominal size		DN 1 000
-	Joint with a concrete shear stop moulded into the spigot (i.e. $d_{sos} = d_{so}$ and $\Delta d_{sos} = \Delta d_{so}$)		-
d_{so}	Nominal diameter of socket		1 274,8 mm
d_{sp}	Nominal diameter of spigot		1 250,0 mm
d_{sps}	Nominal diameter of spigot at concrete shear stop		1 270,4 mm
Δd_{so}	Tolerance from socket diameter		± 1,0 mm
Δd_{sp}	Tolerance from spigot diameter		± 2,0 mm
Δd_{sps}	Tolerance from shear stop diameter		± 2,0 mm
h_j	Nominal height of joint seal		20 mm
Δh_j	Tolerance from height of joint seal		± 0,7 mm
l_1	Length of joint seal before application		3 630 mm
2) Formulae and calculations			
l_2	$\pi (d_{sp} + h_j)$	$= \pi (1\,250 + 20)$	3 990 mm
ε	$(l_2 - l_1) / l_1$	$= (3\,990 – 3\,630) / 3\,630$	0,10
h_m	$h_j / (1 + \varepsilon)^{0,5}$	$= 20 / (1 + 0,10)^{0,5}$	19,1 mm
K	$[(2\Delta h_j)^2 + \Delta d_{so}^2 + \Delta d_{sp}^2 + \Delta d_{sos}^2 + \Delta d_{sps}^2]^{0,5}$	$= [(2 \times 0,7)^2 + 1,0^2 + 2,0^2 + 1,0^2 + 2,0^2]^{0,5}$	3,46 mm
δ_{max}	$[2h_m - d_{so} + d_{sp} + d_{sos} - d_{sps} + K] \times 100 / 2h_m$ $= [2 \times 19,1 - 1\,274,8 + 1\,250,0 + 1\,274,8 - 1\,270,4 + 3,46] \times 100 / (2 \times 19,1)$		55,7 %
3) Evaluation			
Requirements: a) $\delta_{max} \leq 65$ %			Conforms

Table A.5 — Procedures for calculating the example (Method 4)

1) Assumptions			
DN	Nominal size		DN 1 000
d_{so}	Nominal diameter of socket		1 274,8 mm
d_{sp}	Nominal diameter of spigot		1 250,0 mm
Δd_{so}	Tolerance from socket diameter		± 0,8 mm
Δd_{sp}	Tolerance from spigot diameter		± 1,6 mm
h_j	Nominal height of joint seal		20 mm
Δh_j	Tolerance from height of joint seal		± 0,7 mm
l_1	Length of joint seal before application		3 630 mm
2) Formulae and calculations			
l_2	$\pi (d_{sp} + h_j)$	$= \pi (1\,250 + 20)$	3 990 mm
ε	$(l_2 - l_1) / l_1$	$= (3\,990 – 3\,630) / 3\,630$	0,10
h_m	$h_j / (1 + \varepsilon)^{0,5}$	$= 20 / (1 + 0,10)^{0,5}$	19,1 mm
δ_1	$\{2h_m - d_{so} + d_{sp} - [(2\,\Delta h_j)^2 + \Delta d_{so}^2 + \Delta d_{sp}^2]^{0,5}\} \times 100 / 2h_m$ $= \{2\times19,1 – 1\,274,8 + 1\,250,0 - [(2\times0,7)^2 + 0,8^2 + 1,6^2]^{0,5}\} \times100 / (2\times19,1)$		29,1 %
δ_2	$\{2h_m - d_{so} + d_{sp} + [(2\,\Delta h_j)^2 + \Delta d_{so}^2 + \Delta d_{sp}^2]^{0,5}\} \times 100 / 2h_m$ $= \{2\times19,1 – 1\,274,8 + 1\,250,0 + [(2\times0,7)^2 + 0,8^2 + 1,6^2]^{0,5}\} \times100 / (2\times19,1)$		41,0 %
b_t	$0,5\, h_m\, [\pi / 2 - (1- \delta_{min} / 100)^2] / [1 - \delta_{min} / 100]$ $= 0,5 \times 19,1\, [\pi/2 - (1 - 29,1 / 100)^2] / [1 - 29,1 / 100]$		14,4 mm
3) Evaluation			
Requirements:	a) $b_t \geq 5$ mm		Conforms
	b) $\delta_1 \geq 25$ %		Conforms
	c) $\delta_2 \leq 50$ %		Conforms

Annex B
(normative)

Structural calculations relative to pipe jacking

B.1 General

Jacking load is applied axially to the rear pipe or any interjack pipe during installation and this load generates compressive stresses within the cross-section of each pipe. The axial compressive load is normally transferred from one pipe to another by packers between the joint faces.

In the ideal situation leading to maximum theoretical design jacking load, if the longitudinal axes of two jointed pipes were perfectly aligned and the pipes had perfectly square jacking faces, the jacking load transferred from one pipe to another and the stresses in the pipe walls would be evenly distributed.

However, although in practice a straight pipeline is normally planned, control adjustments to line and level are always necessary and pipe jacking faces are rarely perfectly square, so this results in the jacking load being applied eccentrically from one pipe to another. This eccentricity also occurs when curved pipelines are planned.

In practice, application of the jacking load on the maximum cross-section can still be achieved with limited misalignment, providing the packer remains in contact with both pipe faces (the "closed joint" situation).

The following paragraphs specify how the maximum theoretical design jacking load and the maximum jacking load in the closed joint situation shall be calculated and give formulae for estimating that load in the situation where the packer does not remain in contact with both pipe faces (the "open joint" situation).

B.2 Symbols

The symbols used in this annex have the following meanings (see also Figures B.1 and B.2):

A_c area(s) of joint surface(s) in compression, in square metres;

d_e external diameter of the joint surface, in metres;

d_i internal diameter of the joint surface, in metres;

e load reduction (eccentricity) factor equal to F_{oj}/F_{cj};

F' jacking load applied on site, in meganewtons;

F_{cj} maximum jacking load in the "closed joint" situation, in meganewtons;

F_j design jacking load declared by the manufacturer, in meganewtons;

$F_{j\,max}$ maximum theoretical design jacking load, in meganewtons;

F_{oj} maximum jacking load in the "open joint" situation, in meganewtons;

f_{ck} characteristic concrete compressive strength, in megapascals (newtons per square millimetre);

z diametrical extent of compression in the joint segment, in metres.

B.3 Design criteria

B.3.1 Principles

Calculation of the jacking loads relative to a particular pipe is dependent on the design characteristic compressive strength of the concrete f_{ck} as declared by the manufacturer and verified on the basis of testing drilled cores in accordance with 6.8 (see 5.3.2.1), and the area of the joint surface in compression A_c.

The maximum theoretical design jacking load $F_{j\,max}$ shall be calculated by the manufacturer assuming that the jacking load is perpendicular to the joint design faces (no deflection and all jacking faces perfectly square) and applying a (material) safety factor of 1,67 to f_{ck} (f_{ck}/1,67 = 0,6 f_{ck}):

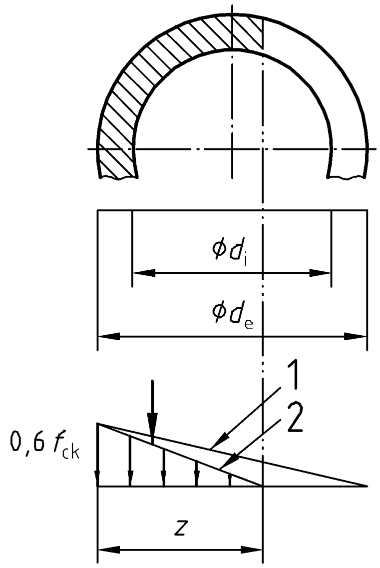
$$F_{j\,max} = 0{,}6\, f_{ck} \times A_c \quad (F_j \leq F_{j\,max})$$

In the "closed joint" situation the maximum jacking load F_{cj} shall not exceed the maximum value calculated based on zero stress at one diameter extremity, increasing uniformly to 60 % of f_{ck} at the opposite extremity:

$$F_{cj} = 0{,}5\, F_{j\,max} \quad \text{where } F_{cj} = 0{,}5\, F_j$$

In the "open joint" situation, with the jacking load acting more eccentrically, the maximum compressive stress occurring at the edge of the jacking face shall not exceed 60 % of f_{ck}. The corresponding stress distribution across the joint is shown in Figure B.1. In this case the maximum jacking load F_{oj} will be smaller than in the "closed joint" situation.

Compressed area



Stress diagram

Key

1 “Closed joint” situation

2 “Open joint” situation

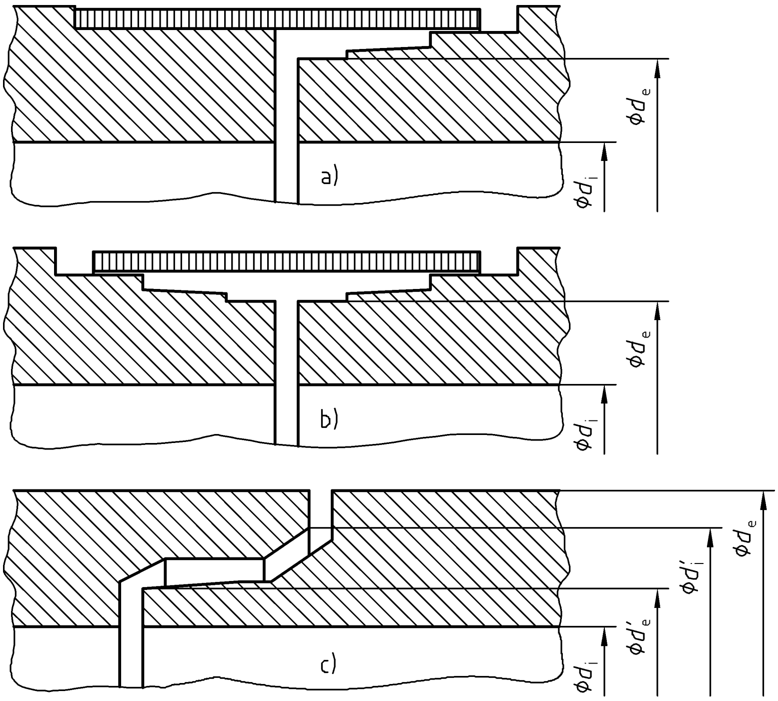
Figure B.1 — Compressed area and stress diagram for the deflected situation

Areas of joint surfaces in compression shall be based on a calculation with the smallest wall thicknesses in the joint area (see Figure B.2):

$$A_c = \left(d_e^2 - d_i^2\right) \times \pi/4$$ for collar joints

$$A_c = \left[\left(d_e^2 - d_i'^2\right) + \left(d_e'^2 - d_i^2\right)\right] \times \pi/4$$ for rebated joints

NOTE The area A_c is that of the joint surface in compression as shown in Figure B.2 and not that of any packer, which should not reduce the contact width by more than 20 % measured from each edge.



Key

a) Fixed collar

b) Loose collar

c) Rebated

Figure B.2 —Definition of diameters for different types of in-wall joints

B.3.2 "Closed joint" situation

In the "closed joint" situation there is no joint gap between two adjacent pipes, any deflection being taken up within the packer, and so the calculation of the maximum jacking load F_{cj} shall be in accordance with the following formula:

$F_{cj} \leq 0,5\ F_{j\ max}$ where $F_{cj} = 0,5\ F_i$

and $0,5\ F_{j\ max} = 0,3\ f_{ck} \times A_c$

B.3.3 "Open joint" situation

In the "open joint" situation two adjacent pipes will have a varying joint gap between the packer and the joint face and so in such a situation the calculation of the maximum jacking load shall be in accordance with the following formula:

$F_{oj} \leq 0{,}3\ e \times f_{ck} \times A_c$ where $F_{oj} = e \times F_{cj}$

and $e \leq 1$.

The value of *e* as a function of the joint surface diameters is shown diagrammatically in Figure B.3.

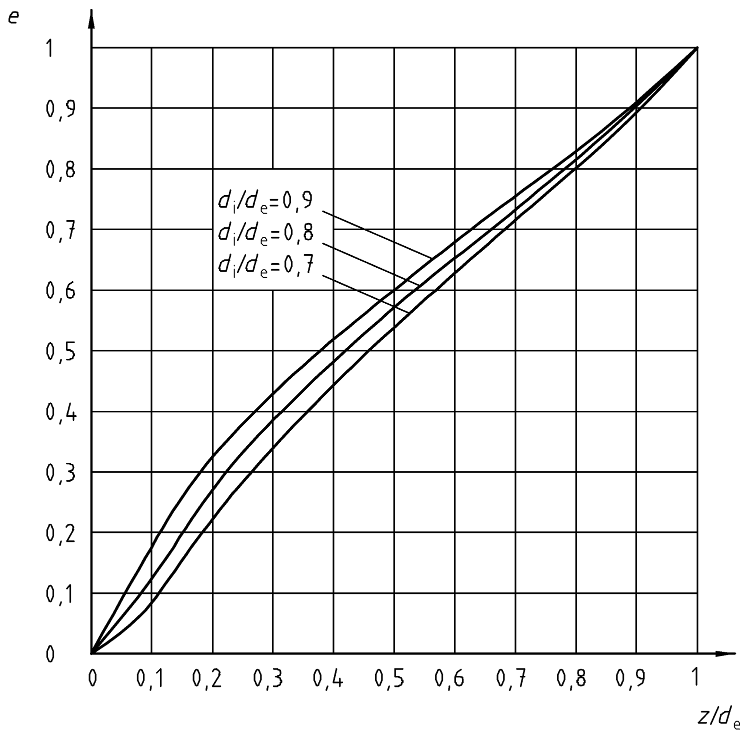


Figure B.3 — Load reduction (eccentricity) factor $e = F_{oj} / F_{cj}$ as a function of the joint surface diameters

NOTE The values of *e* in Figure B.3 have been calculated from the following formula:

$$e = e'/(\pi \times (1 - \xi^2) \times z/d_e)$$

where (with the angles in radians)

$$\xi = d_i / d_e$$

$$e' = \eta \times \left[\cos^{-1}(-\eta) - \xi^2 \times \cos^{-1}(-\eta/\lambda)\right] + \left[(2+\eta^2) \times \sqrt{1-\eta^2} - (2\xi^2 + \eta^2) \times \sqrt{\lambda^2 - \eta^2}\ \right] / 3$$

where

$$\eta = 2\ (z/d_e) - 1$$

and

$\lambda = \xi$ when $\xi \geq |\eta|$;

$\lambda = |\eta|$ when $\xi < |\eta|$.

B.4 Example

B.4.1 Assumptions for the calculation

Pipe:

d_i = 1,500 m

d_e = 1,735 m

d_i / d_e = 0,865

Concrete strength:

Declared characteristic compressive strength f_{ck} = 40 MPa (N/mm²)

Jacking load:

Declared design jacking load F_j = 14,3 MN.

NOTE F_j has to be less than or equal to $F_{j\ max}$. In this example the manufacturer has chosen to declare F_j equal $F_{j\ max}$ (see B.4.2).

B.4.2 Calculation

$A_c = (d_e^2 - d_i^2) \times \pi/4 = (1,735^2 - 1,500^2) \times \pi/4 = 0,597\ m^2$;

$F_{j\ max} = 0,6\ f_{ck} \times A_c = 0,6 \times 40 \times 0,597 = 14,3$ MN.

Closed joint situation:

$F_{cj} = 0,5\ F_j = 0,5 \times 14,3 = 7,2$ MN.

Open joint situation:

In this assumption, as given by the expected deflection (due to the jacking procedure) the effective diametrical extent of compression in the joint segment is:

$z = 0,5\ d_e$

and the load reduction (eccentricity) factor e can be determined from Figure B.1, where an intermediate graph between d_i / d_e = 0,8 and and d_i / d_e = 0,9 has to be considered:

e = 0,595.

In the assumed opened gap situation the maximum jacking load is:

$F_{oj} = e \times F_{cj} = 0,595 \times 7,2 = 4,3$ MN.

NOTE This maximum jacking load has to be greater than the applied jacking load on site F', which should include a safety factor determined by the contractor, having regard to his jacking method, the nature of the ground and unforeseen conditions; i.e. $F' < F_{oj}$.

Annex C
(normative)

Test method for crushing strength

C.1 Principle

The purpose of this test is to evaluate the relevant crushing strength of a pipe. For an initial type test and when using continuous inspection, see Table C.1. The reference test for crushing strength shall always be in accordance with this annex, whether an unreinforced concrete pipe has been inspected in accordance with annex K, or a reinforced pipe has been subjected to basic inspection (see I.1.1).

Table C.1 — Prescribed crushing strength tests

Crushing strength	Unreinforced concrete pipes (in accordance with annex I)		Steel fibre concrete pipes	Reinforced concrete pipes	
	Not using annex K option	Using annex K option		Regular inspection[a]	Basic inspection[a]
Proof, F_c = 0,67 F_n	-	-	T/R	T/R	-
Proof, F_c = 0,8 F_n	-	-	-	-	T/R
Ultimate (collapse), F_u	T/R	T/R	T/R	T/R	-
1,2 F_n	-	-	-	-	T/R
Minimum crushing, F_n	-	T/R	-	-	-
0,67 F_n re-applied	-	-	T/R	-	-

T Means initial type test;

R Means routine (continuous) inspection test;

[a] see I.1.1

C.2 Apparatus

The apparatus shall consist of a testing machine capable of applying the full test load without shock or impact and with an accuracy of 3 % of the specified test load. The testing machine shall be equipped with a load-recording facility.

C.3 Preparation

At the manufacturer's discretion it is permissible to soak the pipe for a maximum of 28 hours before testing.

C.4 Procedure

C.4.1 General

The pipe shall be positioned in the testing machine as shown in Figure C.1 or C.2 as appropriate and be supported and loaded through rigid bearers placed parallel to the pipe's longitudinal axis. The bearers may be continuous or segmented.

The centroid of the load shall be at a distance of l / 2 from the outside face of the socket and the load shall be distributed uniformly as shown in Figure C.1. At the manufacturer's discretion it is permissible for the loaded length of the pipe used in the test to extend over the socket. When using segmented bearers the loaded length shall be not less than 40 % of the internal barrel length.

For circular pipes the load shall be applied through one top bearer. The bottom bearer shall be formed as a V-shaped support with an included angle (β) of 150° ± 3° (see Figure C.2a) or, at the manufacturer's discretion, on two bearers placed with their centres at a distance which subtends an angle of 30° ± 3° at the centre of the pipe (see Figure C.2c). For circular pipes with nominal sizes greater than DN 1 200 it is permissible, at the manufacturer's discretion, instead of using a single top bearer alternatively to use a V-shaped one with an included angle (β) of 150° ± 3° (see Figure C.2b).

For pipes with base the load shall be applied through one top bearer and they shall be supported on two bottom bearers placed with their centres at a distance equal to 0,3 times the internal diameter or width, as appropriate to the shape of the bore (see Figure C.3). For circular pipes with nominal sizes greater than DN 1 200 it is permissible, at the manufacturer's discretion, for the load to be applied either through a V-shaped top bearer having an included angle (β) of 150° ± 3°; or through two top bearers whose centres are the same distance apart as the points of application for the V-shaped bearer, calculated on the basis of the actual pipe dimensions.

The elastomeric material for bearers shall have a mean hardness of 50 IRHD ± 5 IRHD with a thickness of 20 mm ± 5 mm.

Any bearing strips shall have a maximum width as decided by the manufacturer and in accordance with Table C.2, except for V-shaped bearers for which there is no limit.

At the manufacturer's discretion it is permissible for elastomeric bearing strips to be replaced by gypsum or sulfur, provided that their widths do not exceed the values given in Table C.2.

Table C.2 — Maximum width of bearing strips

Pipe diameter/width DN or WN	Maximum width mm
DN/WN ≤ 400	50
400 < DN/WN ≤ 1 200	100
1 200 < DN ≤ 1 750	150

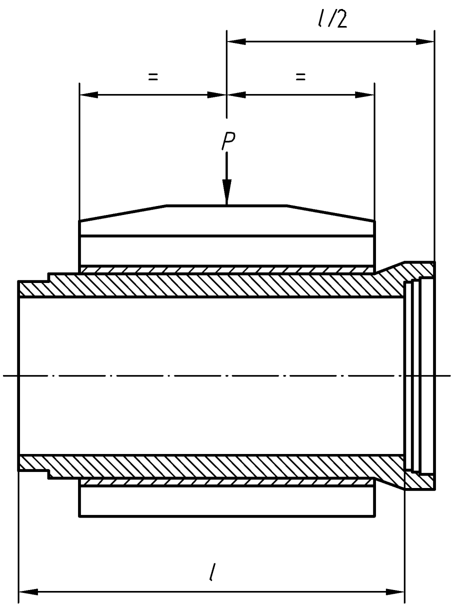


Figure C.1 — Upper and lower bearers for the crushing test

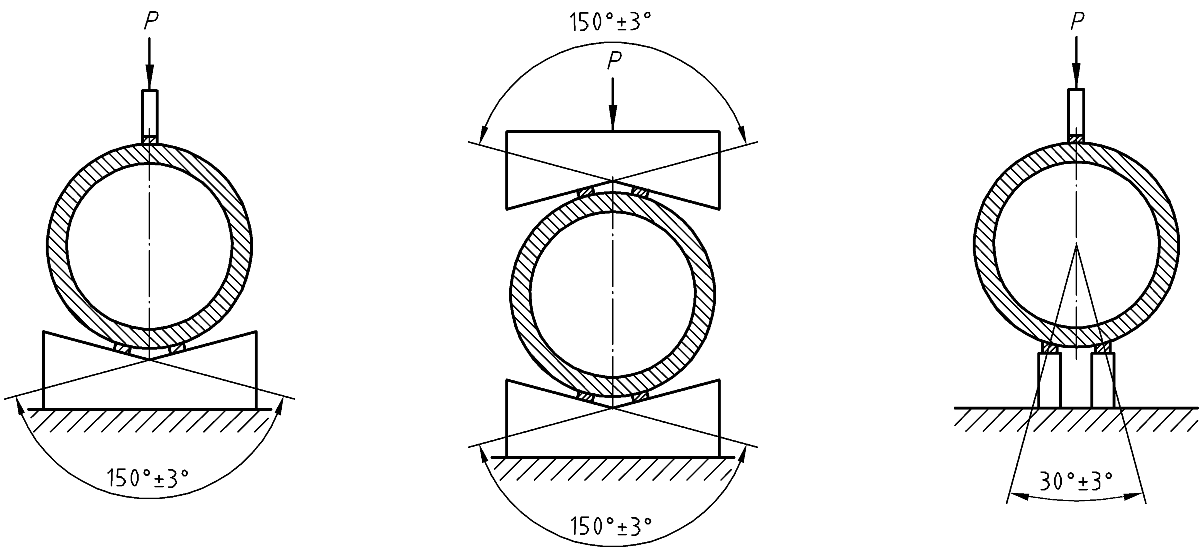


Figure C.2a

Figure C.2b
(not for pipes DN ≤ 1 200)

Figure C.2c

Figure C.2 — Typical arrangements for the crushing test on circular pipes

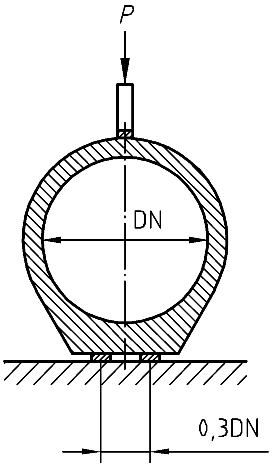


Figure C.3a

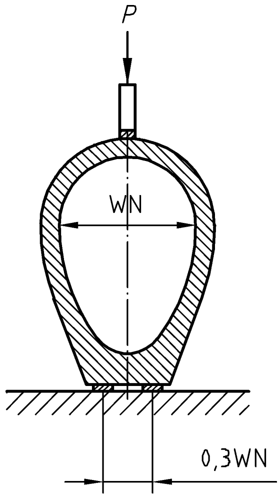


Figure C.3b

Figure C.3 - Crushing test arrangements for pipes with base and the load applied through one top bearer

The load shall be applied ensuring that loading is continuous up to the test load specified in C.4.2, C.4.3 or C.4.4 as appropriate. During application of the specified test load, it shall be increased at a rate between 20 kN/m and 25 kN/m per minute, but no adjustments in the controls of the testing machine shall be made while any pipe begins to deform rapidly prior to ultimate collapse.

C.4.2 Unreinforced concrete pipes

Where the manufacturer opts not to inspect crushing strength in accordance with annex K, the load shall be taken to the ultimate (collapse) load and a record made of that load. Where inspection is in accordance with annex K for a specific process, the load shall be taken to the minimum crushing load or the ultimate (collapse) load, as appropriate, and a record made of whether the pipe withstood the former, or the latter load, as the case may be.

C.4.3 Steel fibre concrete pipes

The load shall be taken to the specified proof load, held for one minute, and the pipe inspected for any crack. The result of that inspection shall be recorded. If no crack is found the load shall then be taken to the ultimate (collapse) load and a record made of that load. After the sustained load has fallen to 95 % (or less) of the recorded load it shall be released, re-applied to 0,67 times the specific minimum crushing load, held for one minute and a record made of whether the pipe withstood the reapplied load for that time.

C.4.4 Reinforced concrete pipes

The load shall be taken to the specified proof (crack) load and held. Any crack that occurs shall be measured on the surface, optically by a magnifier or equivalent, after three to five minutes and again at intervals of one to two minutes with the load held at the specified proof (crack) load in order to ensure that it has stabilized. The crack shall be judged to have stabilized when two of these consecutive measurements are the same. The results of each inspection shall be recorded. For the initial type test, and where required by Table I.1, the load shall then be increased to the ultimate (collapse) load F_u and a record made of that load.

Where the manufacturer opts for basic inspection of crushing strength for a specific process (see I.1.1), the load shall be increased only to 1,2 times the minimum crushing load F_n instead of the ultimate (collapse) load F_u and the proof (crack) load F_c shall be increased from 0,67 F_n (see 5.2.3) to 0,8 F_n.

C.5 Expression of results

The test result shall be expressed as the total load divided by the internal barrel length and shall be corrected according to the manufacturer's chosen and recorded testing arrangement to obtain the effective test result.

The effective test result F_a shall be obtained from the following formula:

$$F_a = k_b \times (P + P^*)/l$$

where

F_a is the effective test result, in kilonewtons per metre;

k_b is a conversion factor for the testing arrangement (see Table C.3);

P is the measured test load, in kilonewtons;

P^* is the effective self-weight of the load bearer(s), in kilonewtons;

l is the internal barrel length, in metres.

Table C.3 — Conversion factor k_b

Cross-section of pipe	Testing arrangement		Conversion factor k_b
	DN/WN ≤ 1 200	DN > 1 200	
Circular	Figure C.2a and C.2c	Figure C.2a and C.2c Figure C.2b	1,00 0,64
Circular with base	Figure C.3a	Figure C.3a Figure C.3a with a 150° V-shaped bearer (see NOTE 1)	1,00 To be calculated by the manufacturer (see NOTE 2)
Egg-shaped	Figure C.3b	-	1,00

NOTE 1 At the manufacturer's discretion, instead of a 150° V-shaped top bearer it is permissible to use two bearers, placed with their centres at a distance apart which is the same as the points of application of the V-shaped bearer.

NOTE 2 The conversion factor k_b for circular pipes with base loaded by a V-shaped bearer (or two bearers) is dependent on the distance between the points of application and, because the structure is three times statically indeterminate, a static calculation by the manufacturer will be needed for each case.

NOTE 3 A value of 1,00 for the conversion factor k_b is only correct if the base thickness is the same as the wall thickness around the rest of the pipe. If the base thickness is greater than the remaining wall thickness the structure is three times statically indeterminate and a static calculation by the manufacturer will be needed for each case.

Annex D
(normative)

Test method for longitudinal bending moment resistance

D.1 Principle

The purpose of this test is to evaluate the longitudinal bending moment resistance of circular pipes up to and including DN 250 having internal barrel lengths greater than six times their external diameter.

D.2 Apparatus

The apparatus shall be substantial and rigid throughout, so that the distribution of the load is not affected appreciably by the deformation or yielding of any part. The method of support and loading shall be as described in either D.3.2 or D.3.3. The apparatus shall be suitably calibrated and checked to enable the test load to be verified.

D.3 Procedure

D.3.1 General

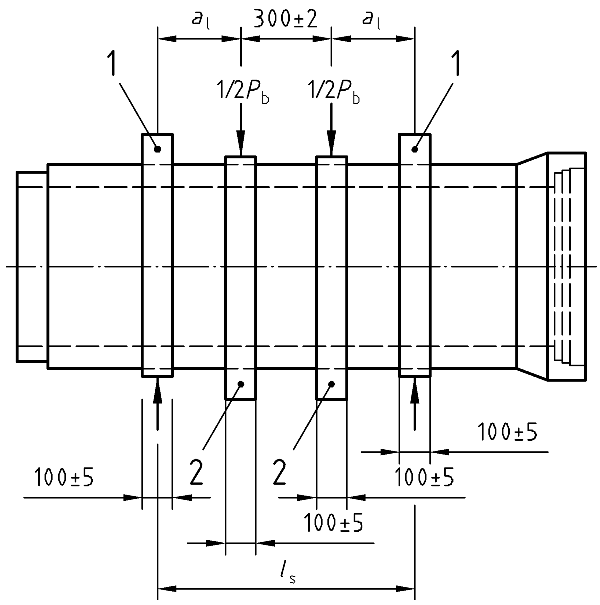
The test sample shall comprise a part of a circular pipe, with or without socket and having an internal barrel length greater than 1,25 m, or a whole such circular pipe. At the manufacturer's discretion it is permissible to soak the sample for a maximum of 28 hours before carrying out the test.

The load shall be applied to the sample without sudden vibration or shock and at a uniform rate of not less than 6 kN per minute and not more than 9 kN per minute.

D.3.2 Four-point loading procedure

The sample shall be supported horizontally with a lever arm of not less than 300 mm in an arrangement as shown in Figure D.1 and loaded accordingly. Each sling shall be so designed that there is a contact of at least 120° around the sample's circumference.

Dimensions in millimetres



Key

1 Supporting sling

2 Loading sling

The lever arm a_l shall be ≥ 300 mm

Figure D.1 — Loading and support arrangement (four-point)

D.3.3 Three-point loading procedure

NOTE This procedure is suitable only when the mode of fracture is clearly "beam" failure. If there is doubt (e.g. if end crush occurs) the procedure described in D.3.2 should be used.

The sample shall be supported horizontally in an arrangement as shown in Figure D.2 and loaded accordingly. The three bearing blocks shall be lined with elastomeric material having a mean hardness of 50 IRHD ± 5 IRHD, a thickness of 20 mm ± 5 mm and a width of 100 mm ± 5 mm, along a concave 120° arc, matched to the barrel.

Dimensions in millimetres

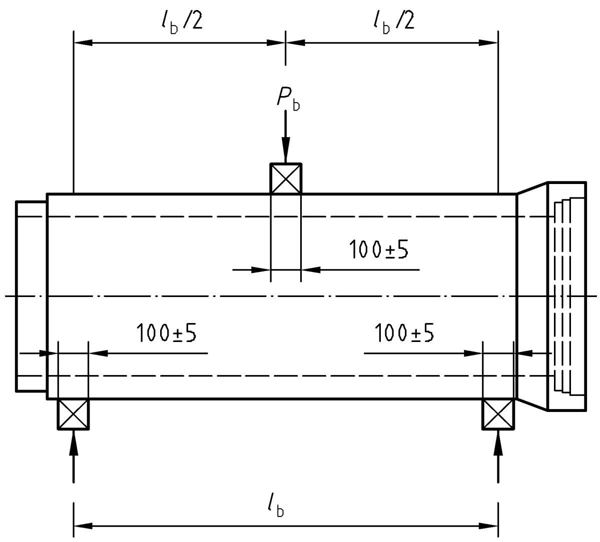


Figure D.2 — Loading and support arrangement (three-point)

D.4 Expression of results

D.4.1 Four-point loading procedure

The longitudinal bending moment resistance shall be calculated as:

$$M = P_b \times a_1 /2$$

where

M is the longitudinal bending moment resistance, in kilonewtons metre;

P_b is the total applied load, in kilonewtons;

a_1 is the lever arm length = 0,5 × (l_s - 0,3), in metres;

l_s is the support span, in metres.

D.4.2 Three-point loading procedure

The longitudinal bending moment resistance shall be calculated as:

$$M = P_b \times l_b /4$$

where

M is the bending moment resistance, in kilonewtons metre;

P_b is the total applied load, in kilonewtons;

l_b is the distance between the centres of the bottom bearing strips, in metres, and shall be as long as permitted by the sample.

Annex E
(normative)

Test methods for watertightness

E.1 Principle

The purpose of these tests is to evaluate whether units and joint assemblies remain watertight under specified internal hydrostatic pressure, in the case of joint assemblies when they are subject to angular deflection and/or shear load. The hydrostatic test is not applicable to units having a design wall thickness greater than 125 mm.

E.2 Apparatus

The apparatus for each test shall enable the unit(s) to be securely clamped, shall allow closure of the ends by an appropriate device and shall be capable of applying the specified internal hydrostatic test pressure for the requisite period of time. The pressure shall not exceed that specified by more than 10 % and shall not be less. For the joint assembly test the apparatus shall accommodate two units, flexibly jointed and supported in such a way that they can move in relation to each other to the specified limits.

E.3 Preparation

At the manufacturer's discretion it is permissible to soak the units for a maximum of 28 hours before testing and, prior to carrying out the test, he shall record whether this option was exercised. The external surface of units shall be sufficiently dry to let any possible tightness defects appear.

E.4 Procedure (hydrostatic test - routine and initial type tests)

Where the durability of joints is demonstrated by either Method 1 or Method 3 in 4.3.4.2, a single unit shall be clamped securely in the apparatus, its ends closed and then filled with water, taking care to ensure that all the air is removed. The internal hydrostatic pressure shall then be raised gradually to 50 kPa (0,5 bar or approximately 5 metre water column), measured from the centre-line of the unit, and maintained for a period of 15 minutes, during which time the unit shall be evaluated for conformity to 4.3.7, before reducing the internal pressure to zero.

E.5 Procedure (joint assembly test)

E.5.1 General

Two units shall be assembled in the apparatus with their joint seal(s) and closed at their ends, or (except where Method 2 in 4.3.4.2 is used) on the inside, isolating the joint to be tested. Where the manufacturer proposes to carry out routine measurements of joints (see Table H.2), the initial type test shall be carried out by assembling the units using the most unfavourable combination of permitted tolerances. In all other cases the spigot and socket to be jointed shall be selected at random from the two sampled units. Whilst filling the units with water, care shall be taken to ensure that all the air is removed.

E.5.2 Watertightness during angular deflection

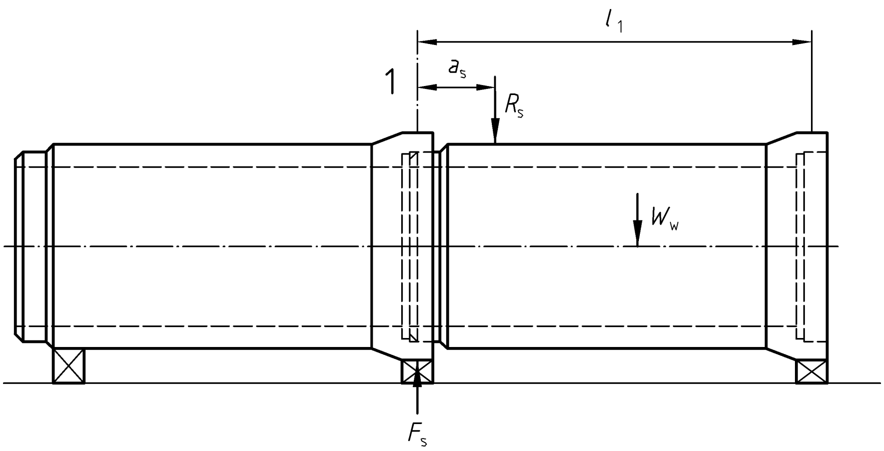
The units shall be deflected to an angular deflection of 12 500/DN (or 12 500/WN, as appropriate to the shape of the bore) in millimetres per metre or 50 millimetres per metre, whichever is the smaller, taking care to ensure that no structural damage is caused. In the case of egg-shaped units the deflection shall be in the vertical plane. During this operation the joint gap shall be prevented from closing at any point by, for example, interposing at the appropriate place a packing with a thickness equal to the mean value of the clearance stated in the factory documents.

NOTE The angle calculated from angular deflection is not necessarily that which can be accommodated during installation, especially jacking operations. Consultation between contractor and manufacturer is recommended.

An internal hydrostatic pressure of 50 kPa (0,5 bar or approximately 5 metre water column), measured from the centre-line of the units, shall then be applied and maintained for a period of 15 minutes, during which time the joint assembly shall be evaluated for conformity to 4.3.7, before reducing the internal pressure to zero.

E.5.3 Watertightness under shear load

The joint assembly shall be supported as shown in Figure E.1.



Key

1 Centre-line of joint seal

Figure E.1 — Shear load test

If an additional load R_s is required to generate a reaction equal to the shear load F_s (see Figure E.1) it shall be applied vertically as close as possible to the face of the socket at a rate of approximately 10 kN per minute. The value of R_s shall be calculated according to the following formula:

$$R_s = (F_s - W_w / 2) \times l_1 /(l_1 - a_s) \geq 0, \text{ in kilonewtons}$$

where

W_w is the weight of one unit filled with water, in kilonewtons

The load shall be transmitted by means of a V-shaped bearer with a minimum included angle of 120°, length 100 mm. At the manufacturer's discretion it is permissible to equip the bearer with a layer of elastomeric material having a maximum thickness of 20 mm and a mean hardness not less than 45 IRHD.

An internal hydrostatic test pressure of 50 kPa (0,5 bar or approximately 5 metre water column), measured from the centre-line of the units, and a shear load F_s in kilonewtons of 0,03 times DN or WN, as appropriate to the shape of the bore, shall then be applied and maintained for a period of 15 minutes, during which time the joint assembly shall be evaluated for conformity to 4.3.7, before reducing the internal pressure to zero.

E.5.4 Watertightness during angular deflection under shear load

As an alternative to testing separately for angular deflection and shear load in accordance with E.5.2 and E.5.3 respectively, at the manufacturer's discretion it is permissible to combine the two tests.

The combined test shall consist of a watertightness test during angular deflection in accordance with E.5.2 and at the same time a shear load test in accordance with E.5.3, except that the shear load F_s in kilonewtons shall be 0,01 times DN or WN, as appropriate to the shape of the bore. The angular deflection and shear load shall be applied in the same plane and in the same direction.

When the specified angular deflection is reached, the shear load procedure shall begin and the internal hydrostatic pressure then applied in accordance with E.5.2 and E.5.3.

This situation shall be maintained for the specified period, during which time the assembly shall be evaluated for conformity to 4.3.7, before reducing the internal pressure to zero.

E.6 Expression of results

A record shall be made of whether the unit(s) or joint assembly conformed to the specified requirement.

Annex F
(normative)

Test method for water absorption

F.1 Principle

The purpose of this test is to evaluate the water absorption of hardened concrete by immersion, which is defined as the difference between the mass of a given sample immersed in water and the mass of the same sample when dried, expressed in terms of the mass of the dry sample.

F.2 Sample

The sample shall have a mass of not less than 2 kg and not more than 4 kg when cut from a hardened unit.

F.3 Apparatus

The apparatus shall consist of a ventilated oven controlled at 105 °C ± 5 °C and scales sensitive to 0,05 % of the sample's mass.

F.4 Procedure

F.4.1 Determination of mass of immersed sample m_1

The sample shall be brought to a temperature of 20 °C ± 3 °C, then immersed in tap water at the same temperature until a constant mass has been reached. This shall be achieved in stages by successively immersing the sample at intervals of one hour to approximately 1/3 of the height, approximately 2/3 of the height and the total height, with a final water level of 20 mm above the top surface of the sample.

The constant mass m_1 shall be assumed to have been achieved when two weighings, 24 hours ± 1 hour apart, result in a difference in mass smaller than 0,1 % of the mean value of the mass of the immersed sample.

The surface of the sample shall be dried before each weighing, for example by a sponge (wet and squeezed) so as to remove all surface water.

F.4.2 Determination of mass of dried sample m_2

The sample shall be dried to a constant mass in a ventilated oven at a temperature of 105 °C ± 5 °C.

NOTE It is recommended to check that the capacity and ventilation of the oven are sufficient to dry the number of samples placed in it. Wet samples should not be placed in the oven before earlier samples have been completely dried.

After cooling the specimen to 20 °C ± 3 °C the mass m_2 shall be determined. The state of constant mass m_2 shall be assumed to have been reached when two weighings at least 24 hours apart result in a difference smaller than 0,1 % of the mean value of the mass of the dry sample.

F.5 Expression of results

The absorption of water by immersion A_w expressed in per cent to two decimal places, shall be obtained from the following expression and be recorded.

$$A_w = 100 \times (m_1 - m_2) / m_2$$

where

m_1 is the constant mass of immersed sample;

m_2 is the constant mass of dry sample.

Annex G
(normative)

Manufacturer's quality assurance system

G.1 Organization

G.1.1 Responsibility and authority

The responsibility, authority and the interrelation of all personnel who manage, perform and verify work affecting quality shall be defined, particularly for personnel who need the organizational freedom and authority to:

— initiate action to prevent the recurrence of defectives;

— identify and record any product quality problem.

G.1.2 Management representative for factory production control

The manufacturer shall appoint a person who, in addition to any other duties, shall have the appropriate authority, knowledge and experience of the production of units to be responsible for conducting and supervising factory production control procedures and for ensuring that the stated requirements are implemented and maintained.

G.1.3 Management review

The production control system adopted to satisfy the requirements of this annex shall be reviewed by the manufacturer's management at the intervals specified in the factory documents to ensure its continuing suitability and effectiveness. Records of such reviews shall be maintained.

G.1.4 Factory documents

Factory documents shall include the following specifications as appropriate:

— internal barrel lengths of pipes (4.3.3);

— description, dimensions, tolerances of joints and joint seals, plus zone of sealing function (4.3.3/4.3.4/6.2/H);

— steel fibre content (5.1.1);

— reinforcement (5.2.1/6.3.1/G.9);

— characteristic concrete compressive strength (5.3.2);

— clearance of joint gap (E.5.2);

— intervals for review of production control system (G.1.3);

— whether regular or basic inspection used for crushing strength of reinforced concrete pipes (I.1.1);

— bending tensile stresses (K);

— geometry of pipe cross-section (K).

G.2 Factory production control system

The manufacturer shall establish and maintain a documented factory production control system as a means of ensuring that units conform to the specified requirements. Particular attention shall be paid to the following aspects:

— the preparation of documented factory production control system procedures and instructions in accordance with the requirements of this European Standard;

— the effective implementation of the documented factory production control system procedures and instructions.

G.3 Inspection and testing

G.3.1 General

All necessary facilities, equipment and personnel shall be available to carry out the necessary inspections and tests. This requirement may also be fulfilled if, by means of a contract, the manufacturer or his agent employs a subcontractor (whilst retaining prime responsibility) having the necessary facilities, equipment and personnel. All test and measuring equipment shall be calibrated, inspected and maintained such that the conformity of units to the specified requirements can be demonstrated. Documentation and certificates for this equipment shall be made available. Equipment shall be used in a manner which ensures that measurement uncertainty is known and is consistent with its ability to measure the specified requirement.

G.3.2 Inspection and test status

Where appropriate, the inspection and test status of units shall be identified by means which indicate their conformity or nonconformity with regard to inspections and tests performed.

It is permissible to complete the marking of units during production, provided any certification mark and the EN number are deleted on defectives.

G.3.3 Testing

Testing shall be performed in accordance with the test methods specified in this European Standard.

G.3.4 Inspection and test records

The results of factory production control shall be recorded in a satisfactory manner. The log(s) shall contain a record of the description of the units, the date of manufacture, the testing method, the test results, the limits used and the signature of the person carrying out the inspection.

Where inspected units do not conform to this European Standard, or if there is an indication that they do not do so, a note shall be made in the manufacturer's log(s) as to the steps taken to deal with the situation (e.g. carrying out of a new test and/or measures to correct the specific process).

The manufacturer's log(s) shall be kept for at least five years.

G.3.5 Complaints

Details of all complaints received relating to the quality of units shall be recorded in a satisfactory manner. The log(s) shall contain a record of the description of the units, identification of the site, the date of manufacture, the nature of the complaint and the resultant action taken.

G.4 Action required in the case of defectives

G.4.1 Unsatisfactory results

If the result of a test on or inspection of a unit is unsatisfactory, the manufacturer shall immediately take the steps necessary to rectify the shortcoming. When the shortcoming has been rectified, the relevant test or inspection shall be repeated without delay, provided that this is technically possible and is necessary as evidence of rectification.

G.4.2 Defectives

Defectives (being units that do not conform to one or more requirements of this European Standard) shall be segregated and marked accordingly.

G.4.3 Purchaser information

Notification shall be made to purchasers if necessary for the purpose of avoiding any consequential damage, if units have been dispatched before the test results are available. If units have been delivered and the next determination of acceptability after their manufacture rejects production, the manufacturer shall notify each purchaser of units manufactured and delivered since the preceding determination that the conformity of those units cannot be ensured.

G.5 Handling, storage, packing and delivery of units

G.5.1 General

The manufacturer shall establish, document and maintain procedures where applicable for the handling, storage, packing and delivery of units.

G.5.2 Handling

The manufacturer shall use methods of handling that prevent damage or deterioration.

G.5.3 Storage

The manufacturer shall provide secure storage areas to prevent damage or deterioration of units before delivery.

G.5.4 Packing and marking

The manufacturer shall control packing, preservation and marking processes (including materials used) to the extent necessary to ensure conformity to this European Standard.

G.5.5 Traceability

Delivered units or groups of units shall be definitively identifiable and traceable with regard to their production data. For this purpose, the manufacturer shall establish and maintain the records required in the relevant technical specification, and shall mark the units or their delivery documents accordingly.

G.6 Training and personnel

The manufacturer shall establish and maintain procedures for the training of all personnel activities affecting quality. Personnel performing specific assigned tasks shall be qualified on the basis of appropriate education, training and/or experience as required. Appropriate training records shall be maintained.

G.7 Materials control

Numerical results and those requiring action from the inspections and tests specified in Tables G.1 to G.8 inclusive shall be recorded.

Table G.1 applies to all materials.

Table G.2 also applies to any materials:

— not certified by a third party complying with EN 45011;

— not produced under a quality assurance system according to EN ISO 9001 and certified by a third party complying with EN 45012;

— not produced by a supplier operating a quality scheme in accordance with this clause and audited by the manufacturer.

Table G.1 — Control for all materials

Material	Inspection/test	Purpose	Minimum frequency
All materials	Inspection of delivery ticket (and, where applicable, label on the container) showing conformity to the order (the order shall mention the specification(s))	To ascertain if consignment is as ordered and from the correct source	Each delivery

Table G.2 — Control for certain materials

Material	Inspection/test	Purpose	Minimum frequency
1. Cements	Producer shall verify conformity to specification(s)	To ensure conformity	Per 1 000 tonnes with a minimum of twice per month
2. Aggregates	Visual inspection of consignment	For comparison with normal appearance with respect to grading, shape and impurities/contamination	Each delivery Each source and grading
3.	Test by sieve analysis	To assess conformity to standard or agreed grading	1. First delivery from new source 2. In case of doubt following visual inspection 3. Once per week, more often as required by local or delivery conditions
4. Aggregates	Test for organic impurities or shell content	To assess the presence and quantity of impurities or contaminations	1. First delivery from new source 2. In case of doubt following visual inspection
5. Admixtures	Visual inspection of the admixture	For comparison with normal appearance	Each delivery
6.	Test for density	For comparison with normal density	Each delivery
7. Additions	Visual inspection of the addition	For comparison with normal appearance	Each delivery
8. Mixing water	Test by chemical analysis or in accordance with the reference specification	To ascertain that the water is free from harmful constituents	Only if the water is not taken from a public distribution system: 1. When new source is used for the first time 2. In any case of doubt 3. Every year 4. Three times per year where water is taken from a watercourse
9. Steel fibre	Producer shall verify conformity to specification(s)	To ensure conformity	Each delivery but not more than once per month
10. Reinforcing steel	Producer shall verify conformity to specification(s)	To ensure conformity	Each delivery but not more than once per month
11. Joint seals	Producer shall verify conformity to specification(s)	To ensure conformity	Each delivery but not more than once per month

G.8 Equipment control

For equipment control Table G.3 applies.

Table G.3 — Equipment control

Equipment	Inspection/test	Purpose	Minimum frequency
1. Storage	As appropriate	To prevent risk of contamination	Weekly
2. Weighing equipment	Visual inspection of performance	To ascertain that the weighing equipment is functioning correctly	Daily
3.	Test of weighing accuracy	To avoid inaccurate weighing	1. On installation 2. Twice per year 3. In any case of doubt
4. Admixture dispenser	Visual inspection of performance	To ascertain that the dispenser is in a clean condition and functions correctly	First batch of the day for each admixture
5.	Test of accuracy	To avoid inaccurate dispensing	1. On installation 2. Twice per year 3. In any case of doubt
6. Water metering equipment	Comparison of the actual amount dispensed with the reading of the meter	To avoid inaccurate dispensing	1. On installation 2. Twice per year 3. In any case of doubt
7. Volumetric batching system	Visual inspection	To ascertain that the batching equipment is functioning correctly	Daily
8.	Comparison of the actual mass of the batch constituents with the intended mass by a suitable method for volumetric batching system	To ascertain batching accuracy	1. On installation 2. Three-monthly intervals 3. In any case of doubt
9. Mixers	Visual inspection	To check the wear of the mixing equipment	Weekly
10. Moulds and pallets	Visual inspection	To check for cleanliness of the moulds and pallets	Daily
11.	Dimensional checks	To check for excessive wear	On installation or reinstallation of mould or renewal of equipment

G.9 Process control

For the control of concrete mix in accordance with the mix design, Table G.4 applies.

For the control of production, Table G.5 applies.

For the control of marking and storage, Table G.6 applies.

For the control of delivery, Table G.7 applies.

Table G.4 — Control of concrete mix

Process element	Inspection/test	Method	Minimum frequency
1. Concrete	Chloride content	By calculating chloride content	At start and each change of supply
2.	Correct mixing	Visual check	Daily for each mixer
3. Mix composition	Correct proportions	By verifying that correct recipe is used	Daily for each mixer

Table G.5 — Control of factory production

Process element	Inspection/test	Method	Minimum frequency
4. Production	Correct manufacturing process	By verifying conformity to factory documents	Daily
5. Reinforcement	Mean spacing and content of circumferential bars over internal barrel length and spacing from ends of spigot and socket	By verifying conformity to factory documents, to this EN and to design specification	Daily
6. Product	Significant dimension(s) according to specific process	Measurement	At start and daily

Table G.6 — Control of marking and storage

Process element	Inspection/test	Method	Minimum frequency
7. Marking	Marking of units	Visual check	Daily
8. Storage	Segregation of defectives	Visual check	Daily

Table G.7 — Control of delivery

Process element	Inspection/test	Method	Minimum frequency
9. Marking	Correct marking of units/documents	Visual check	Daily
10. Loading	Correct loading	Visual check	Daily

G.10 Control of laboratory equipment

For the control of laboratory equipment Table G.8 applies.

Table G.8 — Control of laboratory equipment

Equipment	Inspection/test	Method	Minimum frequency
1. Measuring equipment	Determination of dimensions	Calibration by reference to official standard	Once per year
2. Weighing equipment	Determination of mass	Calibration by reference to official standard	Once per year
3. Temperature measuring device	Determination of temperature	Calibration by reference to official standard	Once per year
4. Load test equipment	Determination of loading	Calibration by reference to official standard	Once per year
5. Watertightness equipment	Determination of pressure	Calibration by reference to official standard	Once per year

Annex H
(normative)

Sampling procedures for inspection of finished products

Table H.1 shall apply to the inspection of finished products where required by 6.1.

Table H.1 — Sampling procedures

Clause	Test when specified	Initial type test	Routine inspection
4.2.6.1	Water absorption	3 S	1 G/month
4.3.2	Visual inspection of finish	Every tested unit	Every tested unit
4.3.3	Geometrical characteristics: - units - joint profiles	 3 N See Table H.2	 3 Y See Table H.2
4.3.4	Joints and joint seals	Test, or calculation in specified circumstances	-
4.3.5	Crushing strength	3 S for unreinforced and steel fibre concrete 1 S for reinforced concrete	See Table I.1
4.3.6.1	Longitudinal bending moment resistance	2 S	-
4.3.7	Watertightness: Methods 1, 3 and 4 in 4.3.4.2 - hydrostatic ($t \leq 125$ mm) - joint assembly each type Method 2 in 4.3.4.2 - joint assembly each type	 3 W See Table H.2 See Table H.2	 See Table I.2 See Table H.2 See Table I.2
5.2.1	Reinforcement	1 N	Every reinforced concrete pipe that has been tested to collapse
5.2.2 and 5.3.3	Concrete cover	1 N using every pipe that has been type-tested to 5.2.3, or covermeter for other units	Every pipe that has been tested to 5.2.3 and, using covermeter, 2 N/day
5.3.2.1	Drilled core strength	1 N	J *)

G is test per group;

J is test per 500 produced per group, with a minimum of one per month;

N is test per type and nominal size;

S is test per type, nominal size and strength class;

W is test per type, nominal size and same wall thickness;

Y is test per type, nominal size and strength class produced per 1 000, with a minimum of one per type and year;

*) means that J is two cores from the same unit (see 6.8).

Table H.2 — Sampling procedures for joint assembly tests

Tests	
1) Angular deflection and 2) shear load, or 3) angular deflection and shear load combined.	
Initial type test	Routine inspection (where Method 1, 3 or 4 has been used in 4.3.4.2 to demonstrate the durability of joints)
Two pairs of units from the same group: - having the same seal profile section; - having the same joint profile that is effective when jointing.	One pair of units from the same group per 1 000 produced but not less than one test per year: - having the same seal profile section; - having the same joint profile that is effective when jointing; or, at the manufacturer's discretion, if the initial type test has been successfully carried out with the most unfavourable tolerances, it is permissible to verify only joint and joint seal profile dimensions at a frequency as stated in the factory documents, but not less than: - one unit per 25 produced for each nominal size and type; - one unit per day for each nominal size and type.

Annex I
(normative)

Sampling procedures for continuous inspection of crushing strength and watertightness (hydrostatic)

I.1 Inspection rates and interpretation of results

I.1.1 Inspection rates

Tightened inspection shall always be applied when assessing unreinforced and steel fibre concrete pipe crushing strength test results when inspecting on the basis of individual assessments (see I.4.1). When assessing any other test results, inspection rates shall be in three forms, of descending severity as follows.

— **tightened inspection**: This shall be applied, requirement by requirement, when a new production or a change in process occurs, or when the switching rules in I.2 apply.

— **normal inspection**: This shall be applied, requirement by requirement, according to the relevant rates when the specific process is under a state of control, or when the switching rules in I.2 apply.

— **reduced inspection**: A lower rate of sampling may be applied, requirement by requirement, when so permitted by the switching rules in I.2.

Inspection of the crushing strength of unreinforced concrete pipes is normally to the ultimate (collapse) load F_u. Alternatively, for a specific process and at the manufacturer's discretion, it is permissible for such inspection to be primarily to the minimum crushing load F_n in accordance with annex K.

At the manufacturer's discretion, inspection of the crushing strength of reinforced concrete pipes shall be at either the "regular" or "basic" level specified in Table I.1, the chosen level being stated in the factory documents.

I.1.2 Interpretation of results

The acceptability of routine tests and inspection shall be determined individually or statistically in accordance with the provisions of I.4.

I.2 Operating of switching rules

I.2.1 Tightened to normal inspection

Tightened inspection shall continue until five consecutive samples show conformity with the relevant requirement, at which time normal inspection may be instituted or reinstated.

I.2.2 Discontinuation of inspection

If 10 consecutive samples remain on tightened inspection, the provisions of these sampling procedures shall be discontinued pending action to improve the quality of the submitted products.

I.2.3 Normal to reduced inspection

It is permissible to introduce reduced inspection when normal inspection is in effect, provided that the following conditions are met:

- the last 10 samples have shown conformity with the relevant requirement; and
- production is in a state of control.

I.2.4 Reduced to normal inspection

When reduced inspection is in effect, normal inspection shall be reinstated if any of the following occur on original inspection (i.e. before any non-acceptance):

- production becomes irregular or is delayed;
- other conditions warrant the reinstatement of normal inspection.

I.2.5 Normal to tightened inspection

When normal inspection is in effect, tightened inspection shall be reinstated if two or more samples have shown nonconformity with the relevant requirement in any five consecutive tests of normal inspection.

I.3 Tightened, normal and reduced inspection

I.3.1 Tightened inspection

Tightened inspection corresponds to twice the sampling rate of normal inspection.

I.3.2 Normal inspection

Samples shall be selected and tested in accordance with the following:

- crushing strength:

  As defined in Table I.1.

- watertightness (hydrostatic):

  As defined in Table I.2, according to the method used in 4.3.4.2 to demonstrate the durability of joints;

I.3.3 Reduced inspection

Reduced inspection corresponds to half the sampling rate of normal inspection.

Table I.1 — Inspection of crushing strength

Pipe material	Symbol(s)	Frequency of testing sample[a] pipes of the same nominal size and strength class, produced using a specific machine or manufacturing facility (normal inspection)		
		Initially, or after a break of 18 calendar months or more	Overall[b]	
			Production per week[c]	Sampling rates
1	2	3	4	5
Unreinforced concrete (without using annex K option)	F_u	One at the start[d] of production	< 750 pipes	One per 500 pipes produced, but not less than four per year
			≥ 750 pipes	One per 750 pipes produced
Unreinforced concrete (using annex K option)	F_n	-	< 750 pipes	One per 500 pipes produced, but not less than four per year
			≥ 750 pipes	One per 750 pipes produced
	F_u	One at the start[d] of production	One for every five of those selected for F_n but not less than one every four weeks	
Steel fibre concrete	0,67 F_n + F_u + 0,67 F_n	One at the start[d] of production	< 750 pipes	One per 500 pipes produced, but not less than four per year
			≥ 750 pipes	One per 750 pipes produced
Reinforced concrete (regular inspection)	F_c = 0,67 F_n	One at the start[d] of production	< 250 pipes	One per 250 pipes produced, but not less than two per year
			250 ≤ pipes < 750	One per week[c]
			≥ 750 pipes	One per 750 pipes produced
	F_u	One at the start[d] of production	One for every 10 of those selected for F_c but not less than one per year	
Reinforced concrete (basic inspection)	F_c = 0,8 F_n	One at the start[d] of production	< 250 pipes	One per 500 pipes produced, but not less than two per year
			250 ≤ pipes < 750	One every two weeks
			≥ 750 pipes	One per 1 500 pipes produced
	1,2 F_n	One at the start[d] of production	One for every 10 of those selected for F_c but not less than one per year	

[a] One sample means one pipe;

[b] including the sample as per column 3;

[c] means five sequential days producing pipes of the same nominal size and strength class;

[d] means excluding initial type tests (see 7.2.2), but, since all samples have to be randomly selected (see 3.1.28), not necessarily the first pipe under routine production.

NOTE The relevant effective test result F_a is used for F_c, F_n and F_u as appropriate (see C.5).

Table I.2 — Inspection of watertightness; hydrostatic (Methods 1, 3 and 4) joint assembly (Method 2)

Design wall thickness (*t*) mm	Maximum production on consecutive working days before a sampling under normal inspection of each type, nominal size and same wall thickness[a]
$t \leq 40$	≤ 250
$40 < t \leq 100$	≤ 500
$100 < t \leq 125$	≤ 1 000
$125 < t$	-

[a] If a particular nominal size, type or design wall thickness has not been produced for a period of 60 consecutive working days, a sampling shall be carried out when production recommences, subject to at least one sampling per year.

I.3.4 Examples

Examples of the frequency of sampling for regular inspection of crushing strength in accordance with Table I.1 are given in Table I.3.

Table I.3 — Examples of sampling rates for inspection of crushing strength (regular inspection)

Specific machine or manufacturing facility	Pipe material	Nominal size and strength class	Action	Days producing cumulative numbers of pipes														
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Machine "A"	Unreinforced concrete	DN 300 Strength class 165	Pipes produced:	250	500	750	1 000	1 250	1 500	1 750	2 000	2 250	2 500	2 750	3 000	3 250	3 500	3 750
			Sample(s) taken:	1[1)] >>				< 1[2)] >			< 1[2)] >			< 1[2)] >			< 1[2)] >	
Machine "B"	Unreinforced concrete	DN 600 Strength class 135	Pipes produced:	100	200	300	400	500	600	700	800	900	1 000	1 100	1 200	1 300	1 400	1 500
			Sample(s) taken:	1[1)] >>							< 1[3)] >					< 1[3)] >		
Machine "C"	Unreinforced concrete	WN/HN 400/600 Strength class 135	Pipes produced:	100	200	300	400	500[4)]						600[4)]	700	800	900	1 000
			Sample(s) taken:	1[1)] >>												< 1[3)] >		
	Steel fibre concrete	DN 800 Strength class 110	Pipes produced:						100	200	300	400	500[5)]					
			Sample(s) taken:						1[1)] >>									
Machine "D"	Reinforced concrete	DN 600 Strength class 135	Pipes produced:	250	500	750	1 000	1 250	1 500	1 750	2 000	2 250	2 500	2 750	3 000	3 250	3 500	3 750
			Sample(s) taken (F_c):	1[1)] >>				< 1[6)] >			< 1[6)] >			< 1[6)] >			< 1[6)] >	
			Sample(s) taken (F_u):	1[1)] >>														
Machine "E"	Reinforced concrete	DN 1 200 Strength class 110	Pipes produced:	100	200	300	400	500	600	700	800	900	1 000	1 100	1 200	1 300	1 400	1 500
			Sample(s) taken (F_c):	1[1)] >>							< 1[7)] >					< 1[7)] >		
			Sample(s) taken (F_u):	1[1)] >>														
Machine "F"	Reinforced concrete	DN 1 500 Strength class 110	Pipes produced:	50	100	150	200	250[4)]						300[4)]	350	400	450	500
			Sample(s) taken (F_c):	1[1)] >>												< 1[8)] >		
			Sample(s) taken (F_u):	1[1)] >>														
		DN 1 600 Strength class 90	Pipes produced:						30	60	90	120	150[9)]					
			Sample(s) taken (F_c):						1[1)] >>									
			Sample(s) taken (F_u):						1[1)] >>									
Manufacturing facility "G"	Reinforced concrete jacking	DN 1600 Strength class 90	Pipes produced:	10	20	30												
			Sample(s) taken (F_c):	1[1)] >>														
			Sample(s) taken (F_u):	1[1)] >>														

1) see column 3 of Table I.1;
2) see columns 4 and 5 of Table I.1 for more than 750 unreinforced concrete pipes produced per week;
3) see columns 4 and 5 of Table I.1 for less than 750 unreinforced pipes produced per week;
4) sequential days' production;
5) less than 750 steel fibre concrete pipes produced in the week, so the sample at the start of production represents the one required (see columns 4 and 5 of Table I.1);
6) see columns 4 and 5 of Table I.1 for more than 750 reinforced concrete pipes produced per week;
7) see columns 4 and 5 of Table I.1 for between 250 and 750 reinforced concrete pipes produced per week;
8) 250 reinforced concrete pipes produced in the week, so the sample at the start of production represents the one required (see columns 4 and 5 of Table I.1);
9) see columns 4 and 5 of Table I.1 for less than 250 reinforced concrete pipes produced per week.

I.4 Acceptability determination

I.4.1 Inspection on the basis of individual assessments

I.4.1.1 Application

Inspection on the basis of individual assessments shall be applied to crushing strength and hydrostatic test results for all samples, except the ultimate (collapse) load test results for unreinforced and steel fibre concrete pipes satisfying the prerequisites for statistical assessment (see I.4.2.2).

I.4.1.2 Procedure

Every test result (F_a , F_c, F_n, F_u as appropriate for crushing strength) is compared with the relevant requirement of this European Standard.

The requirement for the ultimate (collapse) load F_u is:

$$F_u > F_n$$

where

F_n is the minimum crushing load.

The procedure for the ultimate (collapse) load F_u (excluding inspection of unreinforced pipes using the annex K option and basic inspection of reinforced pipes) is shown diagrammatically in Figure I.1.

The procedure for basic inspection of reinforced pipes is shown diagrammatically in Figure I.2.

I.4.1.3 Acceptance criteria

If the result is in conformity with the requirement in I.4.1.2, the corresponding production shall be accepted.

If a crushing strength or hydrostatic test result other than an ultimate (collapse) load test result is not in conformity with the requirement, a sample of two more pipes from the same production shall be tested. If both results of this second sample are in conformity, the corresponding production shall be accepted, with the exception of any defectives. If one or both results from this second sample are not in conformity, it shall be determined which part of the corresponding production is concerned and that part shall be rejected.

If an ultimate (collapse) load test result is not in conformity with that requirement, the following applies:

— if $F_u \geq 0{,}95\ F_n$ a sample of two more pipes from the same production shall be tested and acceptance shall be determined on the basis of statistical assessment (see I.4.2.4) of a set of both results of this second sample added to the nonconforming result;

— if $F_u < 0{,}95\ F_n$ the corresponding production shall be rejected.

If a test result on a reinforced pipe tested to 1,2 F_n under basic inspection is not in conformity with that requirement (i.e. the pipe collapses), the determination of acceptability shall be as above, except that the test result F_a shall be compared to 1,14 F_n (instead of 0,95 F_n) and 1,2 F_n used (instead of F_n) for determining the lower quality statistic Q (see I.4.2.4.2).

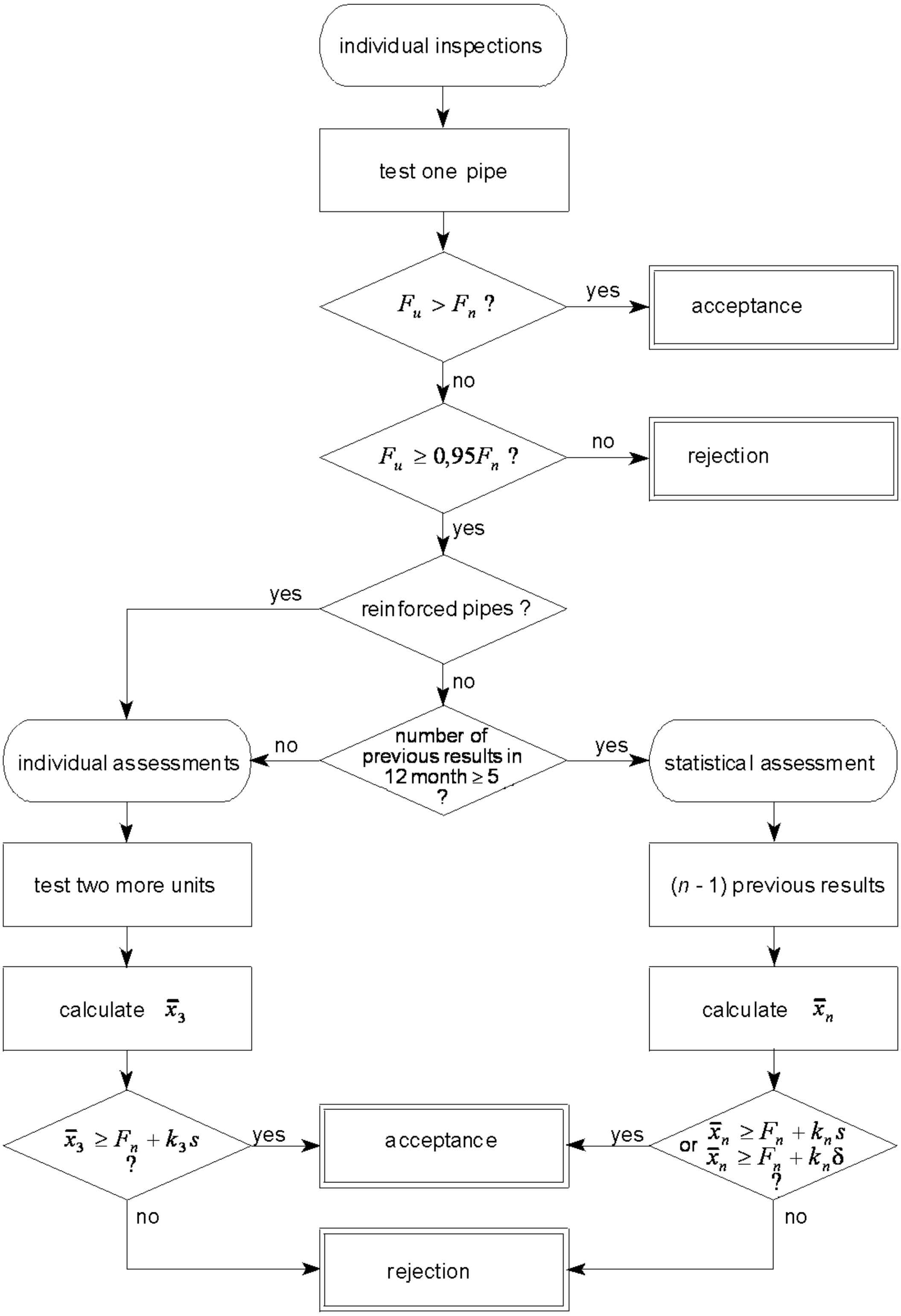


Figure I.1 — Flow chart for inspection of ultimate (collapse) load on the basis of individual assessments (excluding inspection of unreinforced pipes using the annex K option and basic inspection of reinforced pipes)

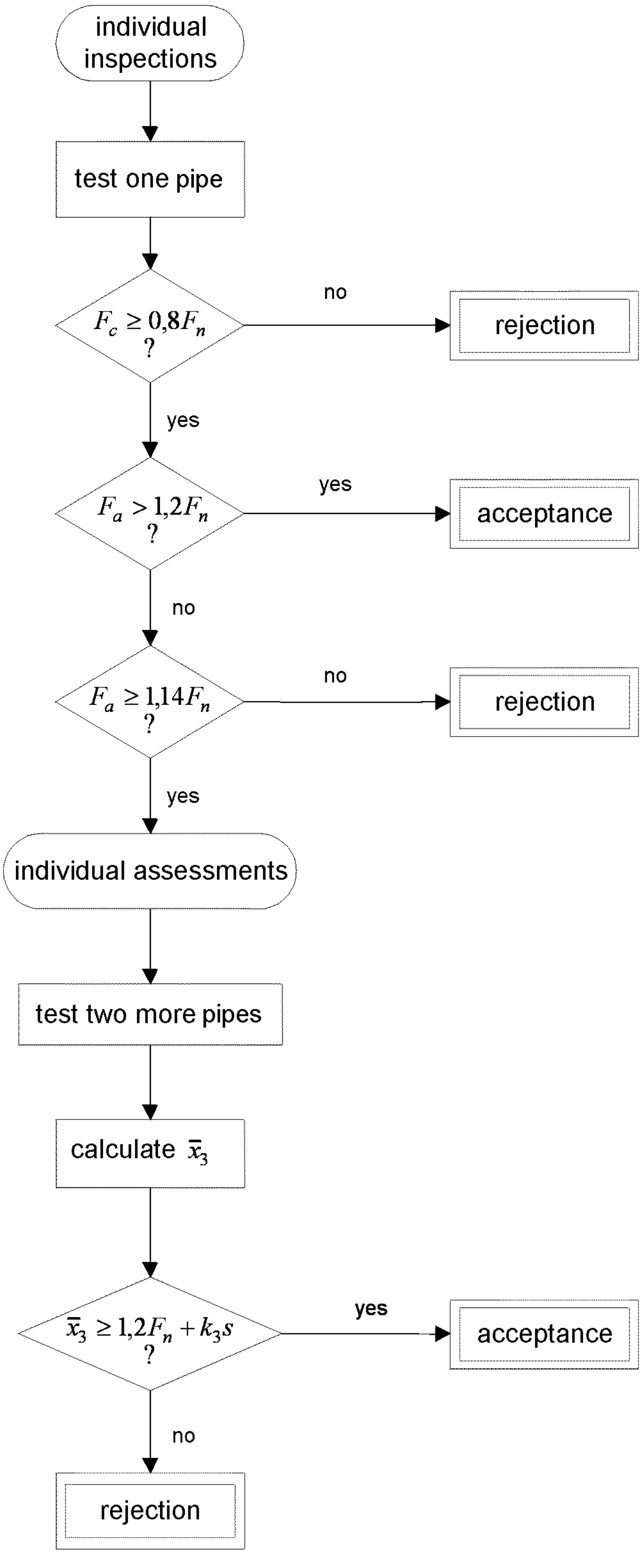


Figure I.2 — Flow chart for basic inspection of reinforced pipes on the basis of individual assessments

I.4.2 Inspection of crushing strength on the basis of statistical assessment

I.4.2.1 Application

Inspection of crushing strength on the basis of statistical assessment shall be applied to ultimate (collapse) load F_u test results for unreinforced and steel fibre concrete pipes satisfying the following prerequisites and whilst being applied, the specific process by which the samples are being manufactured shall be evaluated to have attained, and continue to be in, a state of statistical control.

I.4.2.2 Prerequisites

Inspection on the basis of statistical assessment shall be used when five consecutive crushing strength test results on samples from the same specific process conform to the requirements of this European Standard and can be deemed to be normally distributed.

Inspection on the basis of individual assessments (see I.4.1) shall be applied if the number of routine crushing strength test results obtained on samples from the same specific process is less than five per year, or if the test results are deemed not to be normally distributed.

I.4.2.3 Procedure

Inspection shall be carried out of a set of n consecutive routine crushing test results obtained on samples from the same specific process, where n is a fixed number chosen be the manufacturer and $3 \leq n \leq 15$. The first set shall consist of the three latest results conforming to the requirements of this European Standard.

As long as the number of available test results is less than n, the inspection shall be continued on the basis of consecutive sets, which shall be obtained by adding the new results to the existing set.

When the number of available test results exceeds n, progressive sets with n results shall be further used; obtained by deleting the oldest and adding the latest results.

After each change in manufacturing or testing parameters that may disturb the normal distribution of the test results, a new set shall be composed of results obtained after the change.

I.4.2.4 Acceptance criteria

I.4.2.4.1 General

Production shall be accepted if the test results conform:

— individually $F_u \geq 0{,}95\, F_n$

where

F_u is the ultimate (collapse) load, and

F_n is the minimum crushing load;

and

— statistically with I.4.2.4.2 or I.4.2.4.3.

If one or both are not in conformity, it shall be established which part of the corresponding production is concerned and that part shall be rejected.

I.4.2.4.2 Acceptability determination when standard deviation is unknown

Consider the measured value x of the ultimate (collapse) load F_u from the last n consecutive samples.

Calculate the mean value $\bar{x}$ and the standard deviation s of these n values.

Calculate the lower quality statistic Q for the lower specification limit:

$$Q = (\bar{x} - F_n)/s$$

where

F_n is the lower specification limit for the minimum crushing load,

then compare the quality statistic with the acceptability constant k obtained from the appropriate column in Table I.4. Interpolation for intermediate values of n is permissible.

Table I.4 — Acceptability constant[1)], standard deviation unknown

Number of samples n	Acceptability constant k		
	Tightened inspection	Normal inspection	Reduced inspection
3	1,12	0,958	0,765
4	1,17	1,01	0,814
5	1,24	1,07	0,874
7	1,33	1,15	0,955
10	1,41	1,23	1,03
15	1,47	1,30	1,09

For acceptance, the quality statistic for the lower specification limit shall be greater than or equal to the acceptability constant.

I.4.2.4.3 Acceptability determination when standard deviation is known

The procedure shall be the same as that specified in I.4.2.4.2 for unknown standard deviation, but the standard deviation σ used shall be determined on the basis of measured values of the ultimate (collapse) load F_u from at least 15 consecutive samples obtained during the last 12 months at the maximum, and shall be regularly verified. The acceptability constant k shall be obtained from the appropriate column in Table I.5. Interpolation for intermediate values of n is permissible.

[1)] Adapted from ISO 3951.

Table I.5 — Acceptability constant[1)], standard deviation known

Number of samples *n*	Acceptability constant k		
	Tightened inspection	Normal inspection	Reduced inspection
3	1,17	1,01	0,76
4	1,23	1,11	0,83
5	1,39	1,20	0,92
7	1,45	1,25	1,02
10	1,50	1,31	1,08
15	1,56	1,36	1,13

Annex J
(normative)

Tasks for a product certification body

J.1 Initial inspection of factory and factory production control

Initial inspection of the factory shall determine whether the prerequisites in annex G in terms of staff and equipment for continuous and orderly manufacture of units and for the factory production control are suitable.

All relevant facts of the initial inspection, especially the factory production control system operated by the manufacturer and the evaluation of the acceptability of the system, shall be documented in a report.

J.2 Evaluation and approval of initial type testing of units

Where a factory does not already have a certified production in accordance with this European Standard, in order to evaluate and approve the initial type testing, the certification body shall attend at tests on each standard requirement for each nominal size group.

Where a factory already has a certified production in accordance with this European Standard, in order to evaluate and approve the initial type testing of a new product or units coming from a new manufacturing facility, the certification body shall be notified by the manufacturer at least seven days before such products or units from such equipment are supplied.

J.3 Periodic surveillance, evaluation and approval of factory production control

The certification body's principal objective shall be to check whether the prerequisites in annex G for manufacturing and the agreed factory production control system are being maintained.

The certification body shall operate an inspection schedule such that all the relevant requirements in annex G are periodically inspected at a minimum frequency of twice a year.

The results from the manufacturer's production control shall be examined as part of a periodic inspection to ensure that the required routine testing has been carried out at the specified frequency and that proper actions have been taken, including those of calibration and maintenance of test equipment. Conformity to the requirements for marking shall also be checked.

The results of periodic inspections shall be documented in the records of the inspection.

J.4 Audit testing of samples taken at the factory

Since the basis of product certification is factory production control, the aim of audit testing shall be to check confidence in the results of such control and not to decide conformity or nonconformity of the units produced.

The audit testing shall be performed on units declared to conform to this European Standard. When the manufacturer's test equipment is standardized or calibrated, testing shall normally be carried out using this equipment.

Audit testing shall be carried out in such a way as to ensure that a representative range of nominal sizes and strength classes of units is tested during successive three-year periods.

J.5 Quality system

Where the manufacturer proposes to establish a certified quality system (e.g. in accordance with EN ISO 9001), it shall be verified and accepted by the approved product certification body prior to its application.

Annex K
(normative)

Procedure for unreinforced concrete pipes where routine (continuous) inspection of crushing strength is primarily to minimum crushing load

At the manufacturer's discretion it is permissible for routine (continuous) inspection of the crushing strength of unreinforced concrete pipes to be carried out for a specific process by testing primarily to the minimum crushing load F_n in accordance with the following procedure, providing:

— the pipes are circular pipes, or circular pipes with a base whose design thickness at the invert is the same as the design wall thickness at the crown;

— the test is carried out in accordance with the arrangement shown in Figures C.2a, C.2c or C.3a;

— a separate procedure is applied for pipes of the same nominal size, cross-section and strength class, produced using a specific machine or manufacturing facility;

— all aspects of the procedure are recorded in the factory documents.

NOTE For inspection of crushing strength on the basis of individual assessments, see I.4.1.

Step 1: From the start of production inspect crushing strength using tightened inspection (see I.1.1) by testing to ultimate (collapse) load F_u in accordance with Table I.1 for "Unreinforced concrete pipes (not using the annex K option)".

Step 2: Continue inspection until a set of n consecutive routine crushing test results is obtained on samples, where n is a fixed number chosen by the manufacturer using results not more than 12 months old and $5 \leq n \leq 15$.

Step 3: Calculate the bending tensile stress f_{bt} for each of the n pipes using the following formula:

$$f_{bt} = (6 \times F_u \times r_m) / (\pi \times t_{act}^2)$$

where

f_{bt} is the bending tensile stress in megapascals (newtons per square millimetre);

F_u is the ultimate (collapse) load in kilonewtons per metre;

r_m is the mean radius of the pipe in millimetres;

t_{act} is the mean measured wall thickness at the crown of the pipe, in millimetres.

Step 4: Calculate the characteristic value of the bending tensile stress f_{ch} from n results, then select a design bending tensile stress f_{des} not greater than the characteristic value f_{ch}.

Step 5: Calculate the bending tensile stress f_{bt} in the designed cross-section of the pipe using the following formula:

$$f_{bt} = (6 \times F_n \times r_m) / (\pi \times t_{min}^2)$$

where

f_{bt} is the bending tensile stress in megapascals (newtons per square millimetre);

F_n is the minimum crushing load in kilonewtons per metre;

r_m is the mean radius of the designed pipe in millimetres;

t_{min} is the minimum permissible wall thickness at the crown of the pipe, in millimetres.

If the bending tensile stress f_{bt} does not exceed the design bending tensile stress f_{des} the designed cross-section of the pipe is verified.

Step 6: After verifying the designed cross-section of the pipe, start routine (continuous) inspection in accordance with Table I.1 for "Unreinforced concrete pipes (using the annex K option)".

Step 7: Using the formula in Step 3, calculate the bending tensile stress f_{bt} in the concrete of the next pipe subjected to the ultimate (collapse) load F_u and substitute that result for the oldest one of the n results.

Step 8: Determine the acceptability as follows:

Consider the measured value x of the bending tensile stress at the ultimate (collapse) load F_u from the last n consecutive samples.

Calculate the mean value $\bar{x}$ and the standard deviation s of these n values.

Calculate the lower quality statistic Q for the lower specification limit:

$$Q = (\bar{x} - f_{des}) / s$$

where

f_{des} is the lower specification limit for the bending tensile stress,

then compare the quality statistic with the acceptability constant k obtained from the appropriate column in Table I.3. Interpolation for intermediate values of n is permissible.

For acceptance, the quality statistic for the lower specification limit shall be greater than or equal to the acceptability constant.

Step 9: If acceptability is determined, repeat Steps 7 and 8 for each subsequent test to the ultimate (collapse) load F_u, otherwise revert to Step 1.

Annex ZA
(informative)

Clauses of this European Standard addressing essential requirements or other provisions of EU Directives

ZA.1 Scope and relevant characteristics

This European Standard has been prepared under Mandate M/131 “Pipes, tanks and ancillaries not in contact with water for human consumption” given to CEN by the European Commission and the European Free Trade Association.

The clauses of this European Standard shown in this annex meet the requirements of the Mandate given under the EU Construction Products Directive (89/106/EEC).

Compliance with these clauses confers a presumption of fitness of the construction products covered by this annex for their intended uses herein; reference shall be made to the information accompanying the CE marking.

WARNING — Other requirements and other EU Directives, not affecting the fitness for intended use may be applicable to construction products falling within the scope of this European Standard.

NOTE In addition to any specific clauses relating to dangerous substances contained in this standard, there may be other requirements applicable to the products falling within its scope (e.g. transposed European legislation and national laws, regulations and administrative provisions). In order to meet the provisions of the EU Construction Products Directive, these requirements need also to be complied with, when and where they apply. *Note: an informative database of European and national provisions on dangerous substances is available at the Construction web site on EUROPA (CREATE, accessed through http://europa.eu.int/comm/enterprise/construction/internal/hygiende.htm).*

This annex has the same scope as clause 1 of this European Standard with regard to the products covered. It establishes the conditions for the CE marking of precast concrete pipes and fittings intended for the use indicated below and shows the relevant clauses applicable (see Table ZA.1).

Construction product(s): Precast concrete pipes and fittings, unreinforced, steel fibre and reinforced, with flexible joints.

Intended use(s): The conveyance of sewage, rainwater and surface water under gravity or occasionally at low head of pressure, in pipelines that are generally buried.

Table ZA.1 — Relevant clauses

Essential characteristics	Requirement clauses in this EN	Levels and/or classes	Notes
Dimensional tolerances relevant to joints	4.3.3.2 and 4.3.4.1	None	Maximum permissible tolerances expressed in mm are to be taken into account
Crushing strength	4.3.5, 5.3.2 and 5.3.4	None	Although minimum crushing load is expressed in kN/m, crushing strength is expressed by means of the corresponding strength class; for jacking pipes the characteristic compressive strength of the concrete is expressed in MPa (N/mm^2) and the design jacking load in MN
Longitudinal bending strength	4.3.6	None	Adequate for circular pipes ≤ DN 250 having an internal barrel length ≤ 6 times their external diameter; otherwise for such sizes, not less than a prescribed longitudinal bending moment resistance in kNm
Watertightness	4.3.7	None	Characteristic is demonstrated by no leakage or other visible defects during the test
Durability	4.3.9 and 5.3.1.2	None	Durability requirements are detailed and cross-referenced in 4.3.9

ZA.2 Procedure(s) for the attestation of conformity of precast concrete pipes and fittings

ZA.2.1 System of attestation of conformity

The system of attestation of conformity of precast concrete pipes and fittings indicated in Table ZA.1, as given in annex III of the Mandate, is shown in Table ZA.2 for the intended uses and relevant level(s) and classes.

Table ZA.2 — Attestation of conformity system

Product(s)	Intended use(s)	Level(s) or class(es)	Attestation of conformity system
Pipes; fittings and joints	In installations for the transport/disposal/storage of water not intended for human consumption	-	4
System 4: See Directive 89/106/EEC (CPD) Annex III.2.(ii), Third possibility			

The attestation of conformity of the precast concrete pipes, fittings and joints in Table ZA.1 shall be according to the evaluation of conformity procedures indicated in Table ZA.3 resulting from the application of the clauses of this European Standard indicated therein.

Table ZA.3 — Assignment of evaluation of conformity tasks

Tasks		Content of the task	Evaluation of conformity clauses to apply
Tasks for the manufacturer	Factory production control (FPC)	Parameters related to all characteristics of Table ZA.1 relevant for the intended use	7.2.3
	Initial type testing	All characteristics of Table ZA.1 relevant for the intended use	7.2.2

ZA.2.2 Declaration of conformity

When compliance with this annex is achieved, the manufacturer or his agent established in the European Economic Area (EEA), shall prepare and retain a declaration of conformity, which entitles the manufacturer to affix the CE marking. This declaration shall include:

— name and address of the manufacturer, or his authorized representative established in the EEA, and place of production;

— description of the product (type, identification, use, ...), and a copy of the information accompanying the CE marking;

— provisions to which the product conforms (e.g. annex ZA of this European Standard);

— particular conditions applicable to the use of the product (e.g. provisions for use under certain conditions etc.);

— name of, and position held by, the person empowered to sign the declaration on behalf of the manufacturer or his authorized representative.

The above mentioned declaration shall be presented in the official language or languages of the Member State in which the product is to be used.

ZA.3 CE marking

The manufacturer or his authorized representative established within the EEA is responsible for the affixing of the CE marking. The CE marking symbol shall be in accordance with Directive 93/68/EEC and shall be shown on the accompanying commercial documents (e.g. delivery note). It may also be shown on a label on at least one unit in any package or on any packaging. The following information shall accompany the CE marking symbol when on the label or package:

a) last two digits of the year of CE marking;

b) number of this standard (EN 1916);

c) the information required by clause 8, excluding c) and e).

The following characteristics shall accompany the above information on the commercial documents:

d) intended use;

e) crushing strength of pipes and fittings except where required by clause 8 - strength class; for jacking pipes, also the characteristic compressive strength of the concrete, in megapascals (newtons per square millimetre), and the design jacking load, in meganewtons;

f) longitudinal bending strength - dimensional adequacy or strength, in kilonewtons metre;

g) watertightness of pipes, fittings and joints - no leakage at an internal hydrostatic test pressure of 50 kPa (0,5 bar);

h) durability - serviceability conditions appropriate to intended use; normal or more severe conditions as stated;

i) durability of joints - method according to 4.3.4.2.

Figure ZA.1 gives examples of the information to be given on the commercial documents.

AnyCo Ltd, P.O.Box 21, B-1050
01

EN 1916:2002
Unreinforced precast concrete pipe for the conveyance of sewage, rainwater and surface water, in pipelines that are generally buried.
Watertightness: No leakage of joint or pipe at 50 kPa (0,5 bar) internally.
Crushing strength: Strength class 90.
Longitudinal bending strength: Dimensionally adequate.
Durability: Adequate for normal serviceability conditions.
Durability of joints: Demonstrated according to Method 1.

AnyCo Ltd, P.O. Box 21, B-1050
01

EN 1916:2002
Reinforced precast concrete jacking pipe for the conveyance of sewage, rainwater and surface water, in pipelines that are generally buried.
Watertightness: No leakage of joint or pipe at 50 kPa (0,5 bar) internally.
Crushing strength: Strength class 135, characteristic compressive strength of concrete ≥ 40 MPa (N/mm²) and design jacking load 15 MN.
Longitudinal bending strength: Dimensionally adequate.
Durability: Adequate for normal serviceability conditions.
Durability of joints: Demonstrated according to Method 2

Figure ZA.1 — Examples of CE marking information

In addition to any specific information relating to dangerous substances shown above, the product should also be accompanied, when and where required and in the appropriate form, by documentation listing any other legislation on dangerous substances for which compliance is claimed, together with any information required by that legislation. *Note: European legislation without national derogations need not be mentioned.*

Bibliography

EN 45011, *General requirements for bodies operating product certification systems (ISO/IEC guide 65:1996).*

EN 45012, *General requirements for bodies operating assessment and certification/ registration of quality systems (ISO/IEC guide 62:1996).*

EN ISO 9001, *Quality management systems – Requirements (ISO 9001:2000).*

ISO 3951, *Sampling procedures and charts for inspection by variables for percent nonconforming.*

ISO 12491, *Statistical methods for quality control of building materials and components.*

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