BRITISH STANDARD

BS EN 14636-1:2009

Plastics piping systems for non-pressure drainage and sewerage — Polyester resin concrete (PRC)

Part 1: Pipes and fittings with flexible joints

ICS 23.040.50; 93.030

British Standards

National foreword

This British Standard is the UK implementation of EN 14636-1:2009.

The UK participation in its preparation was entrusted to Technical Committee PRI/88/2, Plastics piping for pressure applications.

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

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

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 January 2010.

ISBN 978 0 580 53799 8

Amendments/corrigenda issued since publication

Date	Comments

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 14636-1

November 2009

ICS 23.040.50; 93.030

English Version

Plastics piping systems for non-pressure drainage and sewerage - Polyester resin concrete (PRC) - Part 1: Pipes and fittings with flexible joints

Systèmes de canalisations en plastique pour les branchements et les collecteurs d'assainissement sans pression - Béton de résine polyester (PRC) - Partie 1: Tubes et raccords avec assemblages flexibles

Kunststoff-Rohrleitungssysteme für drucklos betriebene Abwasserkanäle und -leitungen - Gefüllte Polyesterharzformstoffe (PRC) - Teil 1: Rohre und Formstücke mit flexiblen Verbindungen

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Contents

Page

Foreword

This document (EN 14636-1:2009) has been prepared by Technical Committee CEN/TC 155 “Plastics piping systems and ducting systems”, the secretariat of which is held by NEN.

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of an identical text or by endorsement, at the latest by May 2010, and conflicting national standards shall be withdrawn at the latest by August 2011.

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

This European Standard consists of the following Parts:

Plastics piping systems for non-pressure drainage and sewerage — Polyester resin concrete (PRC):

— *Part 1: Pipes and fittings with flexible joints;*

— *Part 2: Manholes and inspection chambers.*

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

1 Scope

This European Standard applies to pipes and fittings made from polyester resin concrete (PRC, see 3.1.23), intended to be used within a drain or sewer system operating without pressure. It applies to products for use in buried installations to be installed by open-trench techniques or pipe jacking.

It applies to pipes, fittings and their joints of nominal sizes from DN 150 to DN 3000 for circular cross-sections, from WN/HN 300/450 to WN/HN 1400/2100 for egg-shaped cross-sections and from DN 800 to DN 1800 for kite-shaped cross-sections.

The intended use of these products is for the conveyance of sewage, rainwater and surface water at temperatures up to 50 °C, without pressure or occasionally at a head of pressure up to 0,5 bar[1)], and installed in areas subjected to vehicle and/or pedestrian traffic.

NOTE 1 The attention of readers is drawn to applicable requirements contained in EN 476.

It specifies definitions, requirements and characteristics of pipes, fittings, joints, materials, test methods and marking.

The pipes are classified on the basis of the intended method of installation and cross-sectional shape.

NOTE 2 It is the responsibility of the purchaser or specifier to make the appropriate selections, taking into account their particular requirements and any relevant national regulations and installation practices or codes.

2 Normative references

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

EN 637, *Plastics piping systems — Glass-reinforced plastics components — Determination of the amounts of constituents using the gravimetric method*

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

EN 705, *Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes and fittings — Methods for regression analyses and their use*

EN 1119, *Plastics piping systems — Joints for glass-reinforced thermosetting plastics (GRP) pipes and fittings — Test methods for leaktightness and resistance to damage of non-thrust resistant flexible joints with elastomeric sealing elements*

EN 13121-1, *GRP tanks and vessels for use above ground — Part 1: Raw materials — Specification conditions and acceptance conditions*

EN ISO 75-2, *Plastics — Determination of temperature of deflection under load — Part 2: Plastics, ebonite and long-fibre-reinforced composites (ISO 75-2:2004)*

EN ISO 3126, *Plastics piping systems — Plastics components — Determination of dimensions (ISO 3126:2005)*

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1) 1 bar = 10^5 N/m^2 = 0,1 MPa

EN ISO 9001:2008, *Quality management systems — Requirements (ISO 9001:2008)*

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

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

3.1.1
adaptor
fitting that provides for connections to structures, pipes of other materials, or valves

3.1.2
angular deflection
δ
angle in degrees (°) between the axes of two adjacent pipes (see Figure 1 b) and c))

3.1.3
bend
fitting that provides for a change of alignment within a pipeline

3.1.4
branch
fitting comprising a pipe with one additional connecting pipe of equal or smaller nominal size, DN or WN/HN (see 3.1.13 or 3.1.14), to connect two pipelines

3.1.5
design service temperature
maximum sustained temperature in degrees Celsius (°C) at which the system is expected to operate

3.1.6
draw
D
longitudinal movement in millimetres (mm) of a joint (see Figure 1 a))

3.1.7
laying length of a bend
L
distance in metres (m) from one end of the bend, excluding the spigot insertion depth, L_i, of a socket end, where applicable, projected along the axis of that end of the bend to the point of intersection with the axis of the other end of the bend (see Figure 8)

3.1.8
laying length of a pipe
L
total length in metres (m) of a pipe, L_{tot} (see 3.1.20), minus, where applicable, the manufacturer's recommended spigot(s) insertion depth, L_i, in the socket. It is also known as the internal barrel length

3.1.9
fitting
component comprising an adaptor, bend or branch

3.1.10
flexible joint
joint that allows relative movement between the components being joined

3.1.11
minimum crushing load
$q_{cr,min}$
short-term load that a component is required to withstand during a crushing strength test, without failure (see 5.4.1.1, Equations (1) and (2)). It is expressed in kilonewtons per metre length (kN/m) or newtons per millimetre length (N/mm)

3.1.12
misalignment
M
amount by which the centrelines of adjacent pipes fail to coincide (see Figure 1 d))

3.1.13
nominal size DN
alphanumerical designation of size for a component with a circular or kite-shaped bore

NOTE 1 It is a convenient round number for reference purposes and is related to the internal diameter when expressed in millimetres.

NOTE 2 The designation for reference or marking purposes consists of the letters DN plus a number e.g. DN 600.

3.1.14
nominal size WN/HN
alphanumerical designation of size for a component with an egg-shaped bore

NOTE 1 It is a convenient round number for reference purposes and is related to the internal width and height (w_i and h_i, see Figures 3 and 6) when expressed in millimetres.

NOTE 2 The designation for reference or marking purposes consists of the letters WN/HN plus two numbers e.g. WH/HN 300/450.

3.1.15
non-pressure pipe or fitting
pipe or fitting not subject to an internal pressure greater than 0,5 bar

3.1.16
normal service conditions
conveyance of surface water, rainwater or sewage, in the temperature range from 2 °C to 50 °C, without pressure, for 50 years

3.1.17
rerating factor
multiplication factor that quantifies the relation between a mechanical, physical or chemical property at the service condition compared to the respective value at 23 °C and 50 % relative humidity (R.H.)

3.1.18
strength class
constant equal to the minimum short term crushing load of a component, $q_{cr,min}$, (see 3.1.11), divided by one thousandth of either its nominal size (DN) or nominal width (WN)

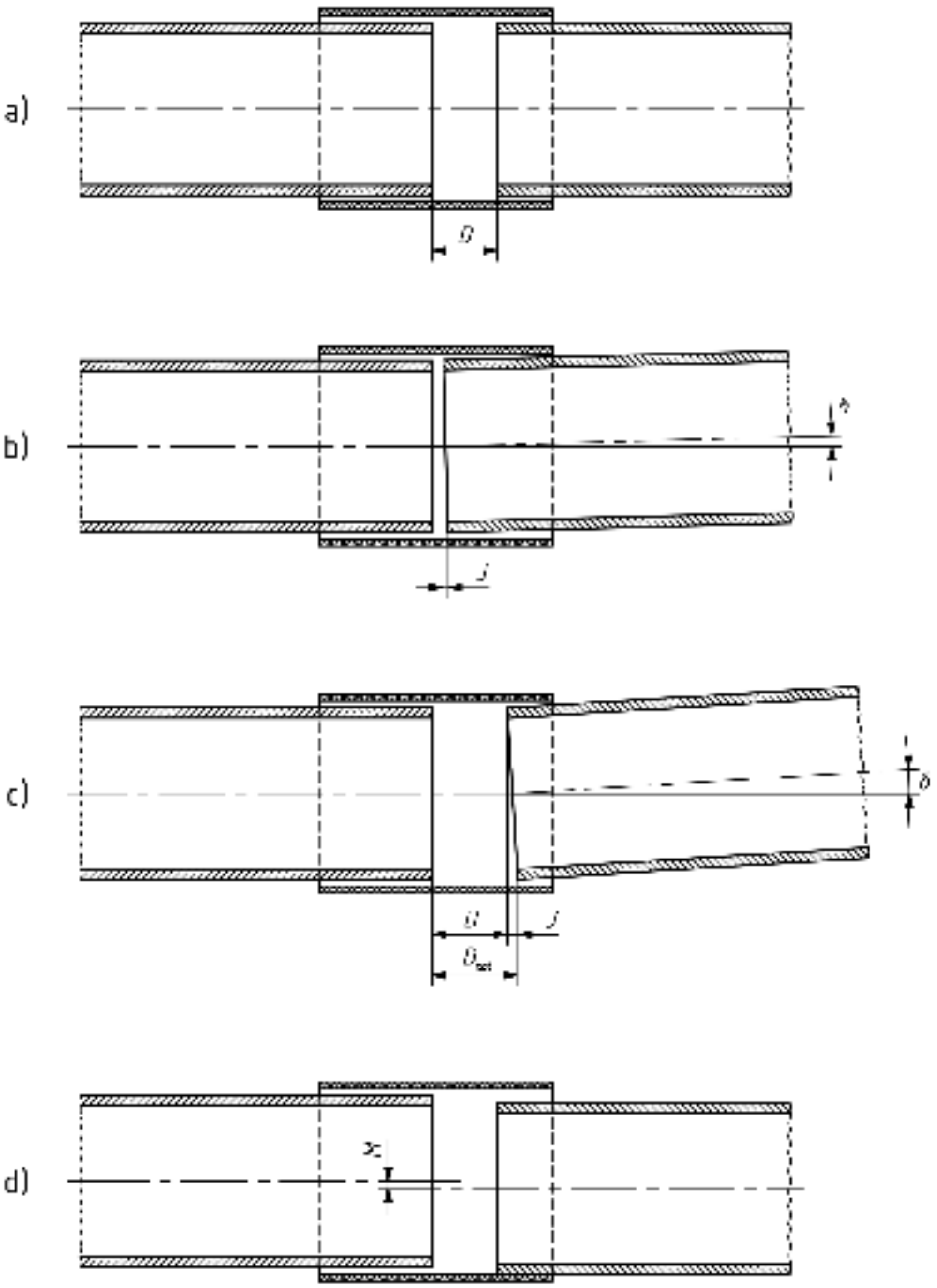
3.1.19
total draw
D_{tot}
sum of the draw, D, expressed in millimetres (mm), plus the additional longitudinal movement of joint components, J (see Figure 1 b) and c)), due to angular deflection, δ, (see 3.1.2 and Figure 1 b) and c))

3.1.20
total pipe length
L_{tot}
distance in millimetres (mm) between two planes normal to the pipe axis and passing through the extreme end points of the pipe (see Figures 2 to 7)

3.1.21
type tests
tests carried out in order to assess the fitness for purpose of a product or assembly of components to fulfil its or their function(s) in accordance with the product specification

3.1.22
crushing load (crushing strength)
q_{cr}
maximum short-term load that a component is able to withstand during a crushing strength test, expressed in kilonewtons per metre length (kN/m) or newtons per millimetre length (N/mm)

3.1.23
polyester resin concrete
PRC
material formed from mineral aggregates and fillers which are bound together using a polyester resin



Key

D draw

D_{tot} total draw

J longitudinal movement of the joint due to angular deflection

M misalignment

δ angular deflection

Figure 1 — Joint movements

3.2 Symbols and abbreviations

For the purposes of this document, the symbols given in Table 1 and abbreviations given in Table 2 apply.

Table 1 — Symbols

Symbol	Description	Unit	Where used
a_b	width of a bearing strip	millimetres	Annexes A, B and E
b	width of a sawn test piece	millimetres	5.4.1.2, Annexes B and E
B	laying length of a branch pipe	millimetres	6.3, Figure 9
B_B	nominal offset (body) length of a branch pipe	millimetres	6.3, Figure 9
B_i	spigot insertion depth of a branch pipe	millimetres	6.3, Figure 9
D	draw	millimetres	3.1.6, 3.1.19, Figure 1, 7.2.2
D_{max}	maximum draw	millimetres	4.4.2.2, 7.2.2, 7.2.4
D_{tot}	total draw	millimetres	3.1.19, Figure 1, 7.2.4
d_a	external diameter of a pipe	millimetres	5.3.1, Figure 2, 5.3.3 to 5.3.6, Figures 4 to 7, 6.2.1.1, 6.3.1.1
d_e	external diameter of a spigot	millimetres	5.3.4 to 5.3.6, Figures 5 to 7
d_i	internal diameter of a pipe with a circular or kite-shaped cross-section	millimetres	5.3.1, Figure 2, 5.3.3, Figure 4, 5.3.4, Figure 5, 5.3.6, Figure 7, Annexes A, B and E
e	wall thickness of a pipe with a circular or kite-shaped cross-section or wall thickness of a test piece taken from a pipe	millimetres	4.1.3, 5.3.1, Figure 2, 5.3.3, Figure 4, 5.3.4, Figure 5, 5.3.6, Figure 7, 6.2.1.1, 6.3.1.1, Annexes A, B and E
e_1	wall thickness at the springline of a pipe with egg-shaped cross-section	millimetres	5.3.2, Figure 3, 5.3.5, Figure 6, Annex A
e_2	wall thickness at top of pipe of a pipe with egg-shaped cross-section	millimetres	5.3.2, Figure 3, 5.3.5, Figure 6, Annexes A and B
e_3	pedestal height of a pipe with egg-shaped cross-section	millimetres	5.3.2, Figure 3
f_{corr}	correction factor for stress distribution	–	Annexes B and E
f_{low}	factor for lower load	–	Annex E
f_{up}	factor for upper load	–	Annex E
h_i	internal height of a pipe with egg-shaped cross-section	millimetres	3.1.14, 5.3.2, Figure 3, 5.3.5, Figure 6
J	longitudinal movement within a joint due to angular deflection, δ (see 3.1.2)	millimetres	3.1.19, Figure 1, 7.2.4
L	laying length of a pipe or a bend or laying length of the main pipe of a branch fitting	metres	3.1.7, 3.1.8, 4.4.2.2, 5.3.1 to 5.3.6, Figures 2 to 7, 5.3.7.1, 5.4.2.2, 5.5, Figure 8, 6.2.1.5, Figure 9, 6.3.1.4
l_a	lever arm length	metres	Annexes C and G
l_b	distance between the centres of the bearers	millimetres	Annexes B, C and E
L_B	nominal body length of the main pipe of a fitting	millimetres	6.2, Figure 8, 6.3, Figure 9
L_i	insertion depth of the spigot of a pipe or main pipe of a fitting	millimetres	3.1.7, 3.1.8, 5.3.1 to 5.3.6, Figures 2 to Figure 7, 6.2, Figure 8, 6.3, Figure 9
l_f	distance between the centres of the fulcrums	metres	Annex G
l_p	length of a test piece	millimetres	5.4.1.2, 7.2.4.6, Annexes A, B and E
l_s	support span	metres	Annex C
L_{tot}	total length of a pipe	millimetres	3.1.8, 3.1.20, Figures 2 to Figure 7, 5.3.1 to 5.3.6

Table 1 — *(continued)*

Symbol	Description	Unit	Where used
M	misalignment	millimetres	3.1.12, Figure 1
M_{BMR}	minimum longitudinal bending moment resistance	kilonewton metre	5.4.2, Annex C
M_3	calculated longitudinal bending moment resisted by the pipe when tested using three-point loading method	kilonewton metre	5.4.2.1, Annex C
M_4	calculated longitudinal bending moment resisted by the pipe when tested using four-point loading method	kilonewton metre	5.4.2.1, Annex C
N_{d}	specified shear load for joint misalignment test	newtons per millimetre of nominal size	7.2.4.2
P	test load applied by loading frame	newtons	Annexes A, B and E
P_{b}	total bending load applied	kilonewtons	Annex C
P_{calc}	calculated minimum test load	newtons	Annexes A and B
$P_{\text{calc,low}}$	calculated lower limit of cyclic load	newtons	5.4.4, Annex E
$P_{\text{calc,up}}$	calculated upper limit of cyclic load	newtons	5.4.4, Annex E
P_{cr}	load applied by loading frame at failure	newtons	Annex A
$P_{\text{eff,CK}}$	effective test load applied to a test piece with a circular or kite-shaped cross-section	newtons	Annex A
$P_{\text{eff},E}$	effective test load applied to a test piece with an egg-shaped cross-section	newtons	Annex A
P_{min}	minimum load to be applied by loading frame	newtons	Annexes A and B
q_{cr}	crushing load (or crushing strength) of a pipe calculated from the load applied to test piece at the moment of failure (collapse)	kilonewtons per metre or newtons per millimetre	3.1.22, Annexes A and B
$q_{\text{cr,min}}$	minimum crushing load	kilonewtons per metre or newtons per millimetre	3.1.11, 3.1.18, 5.4.1, Annexes A and B
r	radius of curvature	millimetres	6.2, Figure 8
t_{sq}	tolerance on diametrical squareness	millimetres per metre	5.3.1 to 5.3.6, Figures 2 to 7
T_{cube}	height, length and width of a cube sawn from a pipe wall	millimetres	5.4.3, Annex D
W^*	load due to own weight of the compression beam	newtons	Annexes A and B
W_{p}	load due to own weight of a test piece	newtons	Annex A
W_{pipe}	load due to own weight of a pipe	newtons per millimetre of length	Annex B
w_{i}	internal width of a pipe with an egg-shaped bore	millimetres	3.1.14, 5.3.2, Figure 3, 5.3.5, Figure 6, Annexes A and B
w_{p}	width of the pedestal of a pipe with an egg-shaped bore	millimetres	5.3.2, Figure 3

Table 1 — *(concluded)*

Symbol	Description	Unit	Where used
α_n	fitting angle	degrees	6.2, Figure 8, 6.3, Figure 9
δ	angular deflection of a joint	degrees	3.1.2, 3.1.19, Figure 1, 4.4.2.1, 7.2.3
Δ_{str}	deviation from straightness	millimetres per metre	5.3.1 to 5.3.6, Figures 2 to 7
σ_c	calculated compressive strength	newtons per square millimetre	5.4.3
σ_{fat}	calculated fatigue strength	newtons per square millimetre	Annex E
σ_{low}	lower limit of bending tensile stress	newtons per square millimetre	Annex E
σ_{rb}	calculated ring bending tensile stress or strength	newtons per square millimetre	Annexes A and B
$\sigma_{rb,min}$	minimum ring bending tensile stress	newtons per square millimetre	Annexes B and E
σ_{up}	upper limit of bending tensile stress	newtons per square millimetre	Annex E

Table 2 — Abbreviations

Symbol	Meaning	Where used
BMR	longitudinal bending moment resistance	5.4.2, 10.2.2, Annex C
DN	nominal size	1, 3.1.4, 3.1.13, 3.1.18, 5.2 to 5.5, Clause 6, 7.2.4, Annexes A to C
HN	nominal internal height of a pipe with egg-shaped cross-section	1, 3.1.4, 3.1.14, 5.2 to 5.5, 6.1, 6.4, Annex A
OC	classification for open-trench construction with circular bore	5.2 to 5.5 and 6.4, Annexes A and B
OE	classification for open-trench construction with egg-shaped bore.	5.2 to 5.5 and 6.4, Annexes A and B
OK	classification for open-trench construction with kite-shaped bore	5.2 to 5.5, and 6.4, Annexes A and B
PRC	polyester resin concrete	1, 3.1.23, 4.1.3, 4.1.6, 4.3.4, 5.2 to 5.5, 6.2.2, 6.3.2, 6.4, Clause 10, Annexes A to E
TC	classification for trenchless construction with circular bore	5.2 to 5.5, Annexes A and B
TE	classification for trenchless construction with egg-shaped bore	5.2 to 5.5, Annexes A and B
TK	classification for trenchless construction with kite-shaped bore	5.2 to 5.5, Annexes A and B
WN	nominal internal width of a pipe with egg-shaped cross-section	1, 3.1.4, 3.1.14, 3.1.18, 5.2 to 5.5, 6.1, 6.2, 6.4, 7.2.4, Annexes A to B

4 General requirements

4.1 Materials

4.1.1 General

The pipe or fitting shall be constructed using aggregates, polyester resin, with or without fillers and if applicable, additives necessary to impart specific properties to the resin.

4.1.2 Resin

The resin used in the pipe or fitting shall have a temperature of deflection of at least 70 °C, when tested in accordance with Method A of EN ISO 75-2 with the test specimen in the edgewise position. It shall also conform to the applicable requirements of EN 13121-1.

4.1.3 Aggregates and fillers

Aggregates and fillers shall not contain constituents in such quantities as may be detrimental to the curing, strength, leak-tightness or durability of the polyester resin concrete (PRC) (see 3.1.23). The size of particles in aggregates and fillers shall not exceed 1/3 of the smallest wall thickness, e, of the pipe or fitting.

4.1.4 Elastomers

Each elastomeric material(s) of the sealing component shall conform to EN 681-1. The sealing component shall be supplied by the pipe or fitting manufacturer either attached to the pipe or fitting or separately.

4.1.5 Metals

When exposed metal components are used, there shall not be evidence of corrosion of the components after the metallic item has been immersed for seven days at (23 ± 2) °C in an aqueous sodium chloride solution, 30 g/l, and then removed from the solution and visually examined for evidence of corrosion.

4.1.6 Minimum resin content

When tested in accordance with EN 637 the content of resin in the polyester resin concrete (PRC) (see 3.1.23) shall be not less than 7 % by mass of the sample.

4.2 Appearance

Both internal and external surfaces shall be free from irregularities that would impair the ability of the component to conform to the requirements of this European Standard. The edges of the pipe faces shall be free from cracks or burrs and the joint surfaces shall be free from irregularities that would preclude the formation of a leak-tight seal. The ends of a component shall be square to its longitudinal axis within the tolerance specified in Clause 5 and Table 4 to Table 9, as applicable.

4.3 Reference conditions for testing

4.3.1 Temperature

The mechanical, physical and chemical properties specified in this European Standard shall be determined at (23 ± 5) °C. For service temperatures over 35 °C and up to and including 50 °C, type tests shall be carried out at least at the purchaser's declared design service temperature (see 3.1.5) to establish rerating factors (see 3.1.17) for all long-term properties to be used in design.

4.3.2 Properties of water for testing

The water used for the tests referred to in this European Standard shall be tap water having a pH of (7 ± 2).

4.3.3 Loading conditions

The mechanical, physical and chemical properties specified in this European Standard shall be determined using circumferential and/or longitudinal loading conditions, as applicable.

4.3.4 Measurement of dimensions

The dimensions of the polyester resin concrete (PRC) components and the joints shall be determined at (23 ± 5) °C. Measurements shall be made in accordance with either EN ISO 3126 or using any method of sufficient accuracy to determine conformity or otherwise to the applicable limits. Routine measurements shall be determined at the prevailing temperature or if the manufacturer prefers at (23 ± 5) °C.

4.4 Joints

4.4.1 General

The manufacturer shall declare the length and the maximum external diameter or, for egg-shaped components, the maximum dimensions of the assembled joint, and the materials used, in documents at the time of the enquiry or delivery.

4.4.2 Flexibility of the jointing system

4.4.2.1 Maximum angular deflection

The manufacturer shall declare the maximum value of the angular deflection, δ, (see 3.1.2) for which each joint is designed, in documents at the time of the enquiry or delivery.

4.4.2.2 Maximum draw

The manufacturer shall declare the maximum draw, D_{max}, (see 3.1.6 and Figure 1) for which each joint is designed, in documents at the time of the enquiry or delivery. For flexible joints, the maximum draw, which includes temperature effects, shall not be less than 0,2 % of the laying length, L (see 3.1.8), of the longest pipe with which it is intended to be used.

4.4.3 Joint seals

Elastomeric joint seals shall be made from material conforming to EN 681-1. They shall be supplied by the pipe manufacturer and shall either be integrated into the unit or supplied separately. A sealing ring shall not have any detrimental effect on the properties of the components with which it is used and shall not cause the test assembly to fail the functional requirements of Clause 7.

4.4.4 Adhesives

When the components of a joint are to be connected using adhesives, the adhesives to be used shall be specified by the manufacturer of the joint, in documents at the time of the enquiry or delivery. The joint manufacturer shall ensure that the adhesives shall not have any detrimental effects on the components with which they are used and shall not cause the test assembly to fail the functional requirements of Clause 7.

5 Pipes

5.1 Classification

5.1.1 General

Pipes shall be classified (see Table 2 and Table 3) according to:

a) intended method of installation, i.e. whether open-trench construction or trenchless construction;

b) bore shape, i.e. whether circular, egg-shaped or kite-shaped.

5.1.2 Method of installation

Pipes intended to be installed using open-trench techniques shall be classified as such by the use of the letter "O" in their designation.

Pipes intended to be installed using trenchless techniques, such as jacking, shall be classified as such by the use of the letter "T" in their designation.

5.1.3 Bore shape

Pipes having a bore shape that is circular shall be classified by the use of the letter "C" in their designation.

Pipes having a bore shape that is egg-shaped shall be classified by the use of the letter "E" in their designation.

Pipes having a bore shape that is kite-shaped shall be classified by the use the letter "K" in their designation.

5.2 Designation

A pipe made to this European Standard shall be designated by adding the appropriate letters from 5.1.2 and 5.1.3 to the letters PRC, that indicate it is manufactured from polyester resin concrete. This procedure produces the designations shown in Table 3.

The nominal size (see 3.1.13 or 3.1.14) and strength class (see 3.1.18) shall also be designated. The strength class shall be taken from Table 10, Table 11 or Table 12, as applicable, relative to the pipe's nominal size, DN or WN/HN and designation (see Table 3).

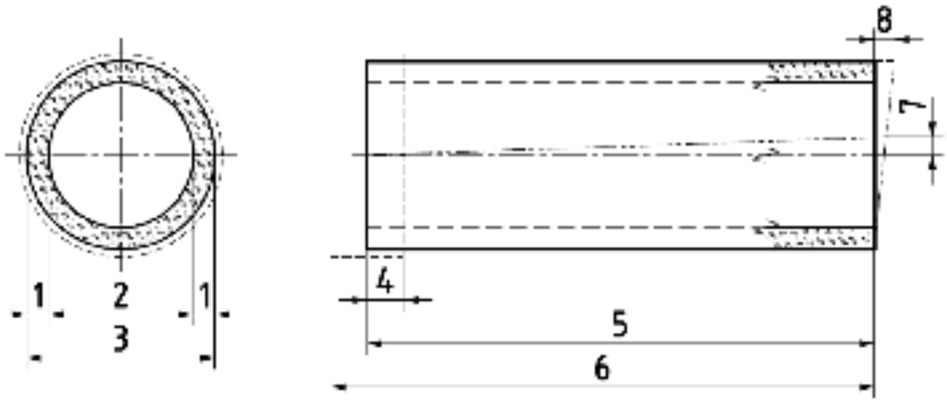
Table 3 — Designation of polyester resin concrete (PRC) pipes

Bore shape		**Designation of polyester resin concrete (PRC) pipes**	
		Open-trench construction (O)	Trenchless construction (T), such as pipe jacking
Circular	C	PRC-OC	PRC-TC
Egg-shaped	E	PRC-OE	PRC-TE
Kite-shaped	K	PRC-OK	PRC-TK

5.3 Geometrical characteristics

5.3.1 Polyester resin concrete (PRC) pipes with circular bore for installation in open trenches – PRC-OC

When measured in accordance with 4.3.4 the dimensions d_i, L, Δ_{str} and t_{sq} (see Figure 2) shall conform to the applicable values and tolerances according to Table 4 and 5.3.7. The dimensions, e, d_a, L_i, L_{tot} and their tolerances, shall be specified by the manufacturer in documents at the time of the enquiry or delivery.



Key

1 pipes wall thickness, e

2 internal diameter, d_i

3 external diameter, d_a

4 insertion depth of spigot, L_i

5 laying length, L

6 total length L_{tot}

7 deviation from straightness, Δ_{str}

8 tolerance on diametrical squareness, $t_{sq.}$

Figure 2 — Specified dimensions for pipes designated PRC-OC

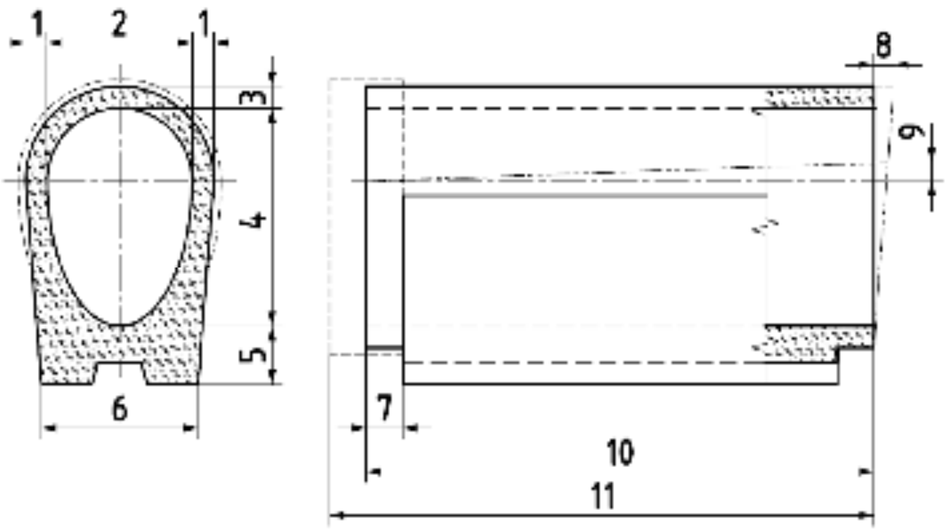
Table 4 — Dimensional requirements for pipes designated PRC-OC

Nominal size DN [a]	Inside diameter d_i mm	Inside diameter tolerance mm	Maximum deviation from straightness $\Delta_{str,max}$ mm/m	Maximum tolerance on diametrical squareness $t_{sq,max}$ mm/m
150 200 250 300	150 200 250 300	± 3	5	3
400	400	± 4	6	4
500	500	± 5		
600 700 800 900 1000	600 700 800 900 1000	± 6	7	5
1200 1400 1500 1600	1200 1400 1500 1600	± 10	8	6
1800 2000 2200 2400 2600 2800 3000	1800 2000 2200 2400 2600 2800 3000	± 12		7

[a] Applicable dimensions shall be interpolated between the nearest values in this table for other nominal sizes.

5.3.2 Polyester resin concrete (PRC) pipes with egg-shaped bore for installation in open trenches - PRC-OE

When measured in accordance with 4.3.4 the dimensions w_i, h_i, L, w_p, Δ_{str} and t_{sq} (see Figure 3) shall conform to the applicable values and tolerances according to Table 5 and 5.3.7. The dimensions, e_1, e_2, e_3, L_i, L_{tot} and their tolerances, shall be specified by the manufacturer in documents at the time of the enquiry or delivery.



Key

1 wall thickness at springline, e_1
2 internal width, w_i
3 wall thickness at top, e_2
4 internal height, h_i
5 height of pedestal, e_3
6 width of pedestal, w_p
7 insertion depth of a spigot, L_i
8 tolerance on diametrical squareness, t_{sq}
9 deviation from straightness, Δ_{str}
10 laying length, L
11 total length, L_{tot}

Figure 3 — Specified dimensions for pipes designated PRC-OE

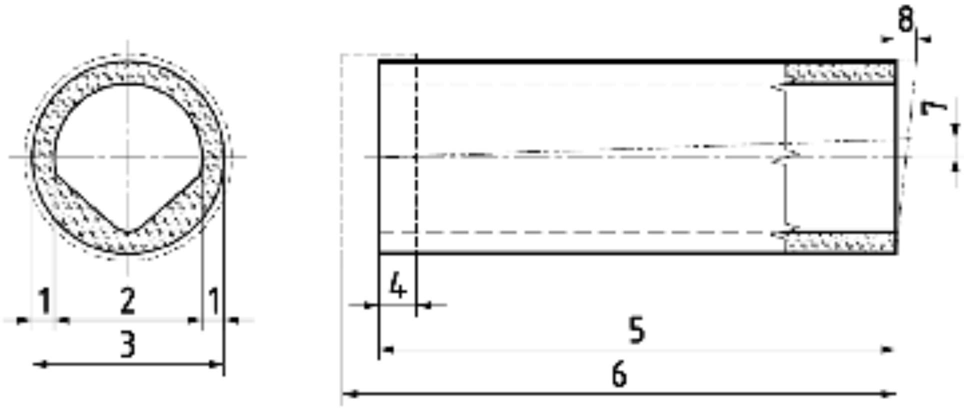
Table 5 — Dimensional requirements for pipes designated PRC-OE

Nominal size WN/HN [a]	Inside dimensions			Minimum pedestal width	Maximum deviation from straightness	Maximum tolerance on diametrical squareness
	w_i mm	h_i mm	tolerance mm	$w_{p,min}$ mm	$\Delta_{str,max}$ mm/m	$t_{sq,max}$ mm/m
300/450	300	450	± 3	180	5	3
400/600	400	600	± 4	240	6	4
500/750	500	750	± 5	300		
550/1000	550	1000		330	7	5
600/900	600	900		360		
700/1050	700	1050	± 6	420		6
700/1200	700	1200		420		
800/1200	800	1200		480		
850/1400	850	1400		510		
900/1350	900	1350		540		
1000/1500	1000	1500	± 10	600	8	
1200/1800	1200	1800		720		
1400/2100	1400	2100		840		

[a] Applicable dimensions shall be interpolated between the nearest values in this table for other nominal sizes.

5.3.3 Polyester resin concrete (PRC) pipes with kite-shaped cross-section for installation in open trenches - PRC-OK

When measured in accordance with 4.3.4 the dimensions d_i, L, Δ_{str} and t_{sq} (see Figure 4) shall conform to the applicable values and tolerances according to Table 6 and 5.3.7. The dimensions, e, d_a, L_i, L_{tot} and their tolerances, shall be specified by the manufacturer in documents at the time of the enquiry or delivery.



Key

1 wall thickness at springline, e
2 internal diameter at springline, d_i
3 external diameter, d_a
4 insertion depth of a spigot, L_i
5 laying length, L
6 total length, L_{tot}
7 deviation from straightness, Δ_{str}
8 tolerance on diametrical squareness, t_{sq}

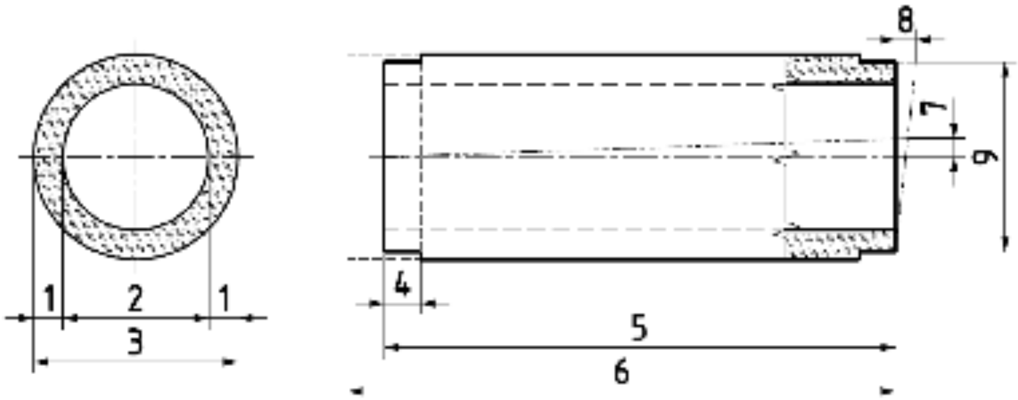
Figure 4 — Specified dimensions for pipes designated PRC-OK

Table 6 — Dimensional requirements for pipes designated PRC-OK

Nominal size DN [a]	Inside diameter		Maximum deviation from straightness	Maximum tolerance on diametrical squareness
	d_i mm	tolerance mm	$\Delta_{str,max}$ (mm/m)	$t_{sq,max}$ (mm/m)
800 900 1000	800 900 1000	± 6	7	5
1200 1400 1600 1800	1200 1400 1600 1800	±10	8	6
[a] Applicable dimensions shall be interpolated between the nearest values in this table for other nominal sizes.				

5.3.4 Polyester resin concrete (PRC) pipes with circular cross-section for installation using trenchless techniques - PRC-TC

When measured in accordance with 4.3.4 the dimensions d_a, L, Δ_{str} and t_{sq} (see Figure 5) shall conform to the applicable values and tolerances according to Table 7 and 5.3.7. The dimensions e, d_i, d_e, L_i, L_{tot} and their tolerances, shall be specified by the manufacturer in documents at the time of the enquiry or delivery.



Key

1 wall thickness at springline, e
2 internal diameter at springline, d_i
3 external diameter, d_a
4 insertion depth of a spigot, L_i
5 laying length, L
6 total length, L_{tot}
7 deviation from straightness, Δ_{str}
8 tolerance on diametrical squareness, t_{sq}
9 external diameter of a spigot, d_e

Figure 5 — Specified dimensions for pipes designated PRC-TC

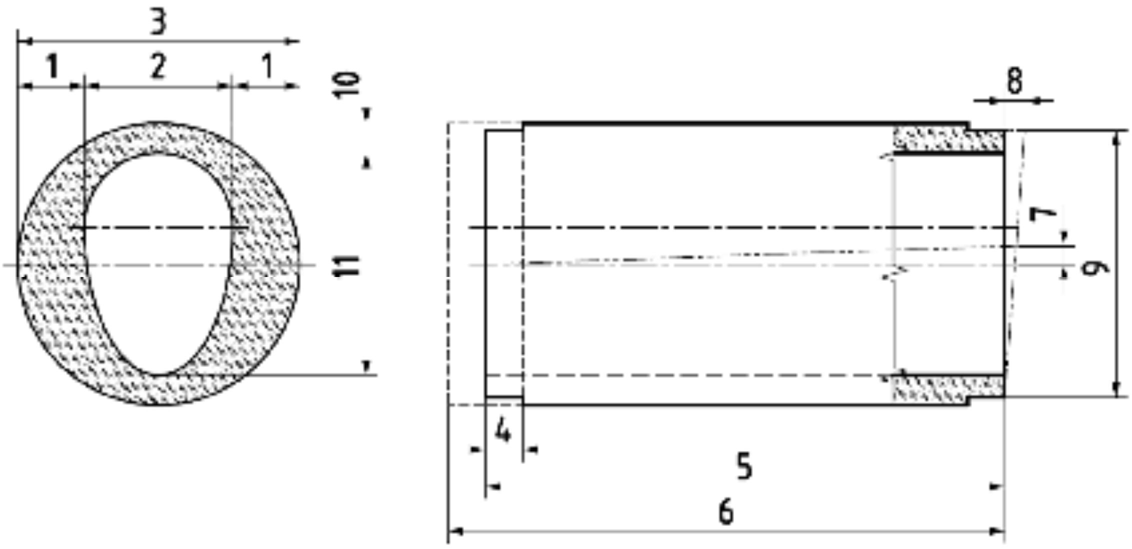
Table 7 — Dimensional requirements for pipes designated PRC-TC

Nominal size DN [a]	External diameter d_a mm	tolerance mm	Maximum deviation from straightness $\Delta_{str,max}$ (mm/m)	Maximum tolerance on diametrical squareness $t_{sq,max}$ (mm/m)
150	210	± 5	5	1,0
200	275			
250	360			
300	400			
400	550			
500	660			
600	760	± 6		
700	860			
800	960			
900	1100			
1000	1185			
1200	1485	± 7	10	1,5
1400	1720			
1500	1820			
1600	1940			
1800	2160			
2000	2400			
2200	2630	± 8	15	
2400	2870			
2500	2985			
2600	3100			

[a] Applicable dimensions shall be interpolated between the nearest values in this table for other nominal sizes.

5.3.5 Polyester resin concrete (PRC) pipes with egg-shaped internal cross-section and circular external cross-section for installation using trenchless techniques – PRC-TE

When measured in accordance with 4.3.4 the dimensions d_a, L, Δ_{str} and t_{sq} (see Figure 6) shall conform to the applicable values and tolerances according to Table 8 and 5.3.7. The dimensions d_e, e_1, e_2, h_i, L_i, L_{tot} and w_i and their tolerances, shall be specified by the manufacturer in documents at the time of the enquiry or delivery.



Key

1 wall thickness at springline, e_1
2 internal width at springline, w_i
3 external diameter, d_a
4 insertion depth of a spigot, L_i
5 laying length, L
6 total length, L_{tot}
7 deviation from straightness, Δ_{str}
8 tolerance on diametrical squareness, t_{sq}
9 external diameter of a spigot, d_e
10 wall thickness at top of pipe, e_2
11 internal height, h_i

Figure 6 — Specified dimensions for pipes designated PRC-TE

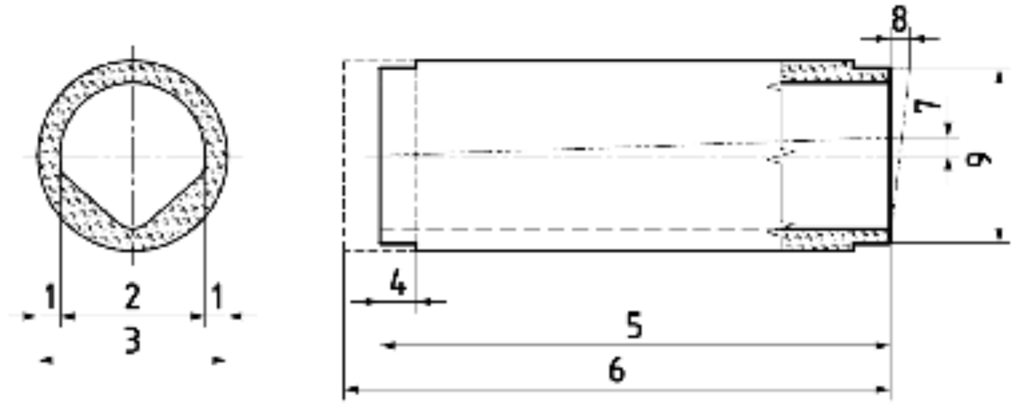
Table 8 — Dimensional requirements for pipes designated PRC-TE

Nominal width/height WN/HN [a]	External diameter		Maximum deviation from straightness	Maximum tolerance on diametrical squareness
	d_a mm	tolerance mm	$\Delta_{str,max}$ (mm/m)	$t_{sq,max}$ (mm/m)
300/450	660	± 5	5	1,0
400/600 500/750 600/900 550/1000	760 960 1100 1185	± 6		
700/1050 700/1200 800/1200 850/1400 900/1350 1000/1500 1200/1800	1310 1485 1485 1720 1720 1820 2160	± 7	10	1,5
1400/2100	2520	± 8		

[a] Applicable dimensions shall be interpolated between the nearest values in this table for other nominal sizes.

5.3.6 Polyester resin concrete (PRC) pipes with kite-shaped internal cross-section and circular external cross-section for installation using trenchless techniques - PRC-TK

When measured in accordance with 4.3.4 the dimensions d_a, L, Δ_{str} and t_{sq} (see Figure 7) shall conform to the applicable values and tolerances according to Table 9 and 5.3.7. The dimensions e, d_i, d_e, L_i, L_{tot} and their tolerances, shall be specified by the manufacturer in documents at the time of the enquiry or delivery.



Key

1 wall thickness at springline, e
2 internal diameter at springline, d_i
3 external diameter, d_a
4 insertion depth of a spigot, L_i
5 laying length, L
6 total length, L_{tot}
7 deviation from straightness, Δ_{str}
8 tolerance on diametrical squareness, t_{sq}
9 external diameter of a spigot, d_e

Figure 7 — Specified dimensions for pipes designated PRC-TK

Table 9 — Dimensional requirements for pipes designated PRC-TK

Nominal size DN [a]	External diameter		Maximum deviation from straightness	Maximum tolerance on diametrical squareness
	d_a mm	tolerance mm	$\Delta_{str,max}$ mm/m	$t_{sq,max}$ mm/m
800 900 1000	960 1100 1185	± 6	5	1,0
1200 1400 1500 1600 1800	1485 1720 1820 1940 2160	± 7	10	1,5

[a] Applicable dimensions shall be interpolated between the nearest values in this table for other nominal sizes.

5.3.7 Laying lengths (internal barrel lengths)

5.3.7.1 Pipes designated PRC-OC, PRC-OE and PRC-OK

The laying length, L, (see 3.1.8) shall be one of the following values:

- for DN ≤ 250: 2 m ± 10 mm;
- for DN > 250: 2 m ± 10 mm or 3 m ± 10 mm;
- for WN: 2 m ± 10 mm.

NOTE Laying lengths other than these can be supplied by agreement between the manufacturer and the purchaser using the same tolerance.

5.3.7.2 Pipes designated PRC-TC, PRC-TE and PRC-TK

The laying length shall be one of the following values:

- for DN or WN ≤ 400: 1 m ± 10 mm or 2 m ± 10 mm;
- for DN or WN > 400 and DN or WN ≤ 1000: 2 m ± 10 mm;
- for DN or WN > 1000: 3 m ± 10 mm.

NOTE Laying lengths other than these can be supplied by agreement between the manufacturer and the purchaser using the same tolerance.

5.4 Mechanical characteristics

5.4.1 Crushing strength

5.4.1.1 Requirements

A pipe shall withstand the applicable minimum crushing load, $q_{\text{cr,min}}$ (see 3.1.11) corresponding to its nominal size, designation and strength class (see 3.1.18) as given in Table 10, Table 11 or Table 12, as applicable.

The minimum crushing load, $q_{\text{cr,min}}$, is determined using Equation (1) or Equation (2), as applicable:

$$q_{\text{cr, min}} = \text{Strength class} \times [\text{DN}] \times 0{,}001 \quad (1)$$

$$q_{\text{cr, min}} = \text{Strength class} \times [\text{WN}] \times 0{,}001 \quad (2)$$

It is expressed in kilonewtons per metre length (kN/m) or newtons per millimetre length (N/mm).

Table 10 — Minimum strength classes for pipes designated PRC-OC or PRC-TC

Nominal size DN	Strength class	
	PRC-OC	PRC-TC
150 ≤ DN ≤ 500	140	160
600 ≤ DN ≤ 1000	120	140
1200 ≤ DN ≤ 3000	90	120

Table 11 — Minimum strength classes for pipes designated PRC-OE or PRC-TE

Nominal width/height WN/HN	Strength class	
	PRC-OE	PRC-TE
300/450 ≤ WN/HN ≤ 600/900	140	160
700/1050 ≤ WN/HN ≤ 1000/1500	120	140
1200/1800 ≤ WN/HN ≤ 1400/2100	90	120

Table 12 — Minimum strength classes for pipes designated PRC-OK or PRC-TK

Nominal size DN	Strength class	
	PRC-OK	PRC-TK
800 ≤ DN ≤ 1000	120	140
1200 ≤ DN ≤ 1800	90	120

The pipe shall be tested in accordance with Annex A, or, if a suitable apparatus is not available, in accordance with Annex B using test pieces sawn from a pipe.

NOTE For initial type tests (ITT) the preferred method is to test in accordance with Annex A.

5.4.1.2 Test pieces

When testing in accordance with Annex A the test piece shall be a length of pipe, with or without a socket, with a laying length of at least the applicable value in Table 13.

When testing in accordance with Annex B the test piece shall be a piece sawn from a pipe or a broken piece of a pipe. When testing pipes with kite-shaped or egg-shaped cross-section the test piece shall be taken from the top of the pipe. The test piece shall have parallel boundary surfaces. The length, l_p, in the circumferential direction, shall be about five times the wall thickness and its width, b in the longitudinal direction, about three times the wall thickness. The longitudinal sides of the test piece shall be perpendicular to the generated surface of the pipe. Three test pieces shall be taken from a pipe and the average of the results from the three tests is the test result.

Table 13 — Minimum length of a test piece

Nominal size DN	Nominal size WN/HN	Minimum length, l_p mm
DN < 300	WN/HN < 300/450	DN (or WN)
300 ≤ DN ≤ 1500	300/450 ≤ WN/HN ≤ 1000/1500	300
DN > 1500	WN/HN > 1000/1500	0,2 × DN (or WN)

5.4.2 Longitudinal bending moment resistance (BMR)

5.4.2.1 Requirements

Pipes with an external circular shape having laying lengths greater than six times their (vertical) internal diameter shall withstand the required longitudinal bending moment when tested with one of the methods described in Annex C. For pipes designated PRC-OC or PRC-TC having a nominal size (see 3.1.13) up to and including DN 400 and standard laying lengths as given under 5.3.7 the applicable minimum longitudinal bending moment resistance is specified in Table 14.

NOTE For initial type tests (ITT) the three point loading arrangement is the preferred method of test in accordance with Annex C, using test pieces in accordance with 5.4.2.2.

The test is continued until the test piece fails, whereupon the maximum load and the calculated bending moment M_3 or M_4, as applicable, shall be recorded.

Table 14 — Minimum longitudinal bending moment resistance, M_{BMR}

Nominal size DN	Minimum longitudinal bending moment resistance, M_{BMR} kNm	
	PRC-OC	PRC-TC
150	2,7	3,0
200	5,7	6,2
250	8,3	8,8
300	9,9	10,5
400	11,6	12,6

For pipes with non-standard laying lengths which are greater than given under 5.3.7 and also greater than six times their (vertical) internal diameter the appropriate value for M_{BMR} shall be agreed between manufacturer and purchaser based upon suitable calculation models.

5.4.2.2 Test pieces

The test piece shall be a whole pipe, with or without a socket, with a laying length, L, of at least 1,25 m or six times its internal diameter, whichever is the greater. If a whole pipe is shorter than six times its internal diameter then this test does not need to be performed.

Three test pieces of the same size, designation and strength class shall be used. The average of the results from the three tests is the test result.

5.4.3 Compressive strength of polyester resin concrete (PRC)

5.4.3.1 Requirements

The polyester resin concrete (PRC) used to manufacture PRC-TC, PRC-TE or PRC-TK pipes shall be tested in accordance with Annex D. When tested, the test pieces complying with 5.4.3.2 shall have a compressive strength, σ_c, not less than 80 N/mm^2.

5.4.3.2 Test pieces

The test piece shall be a cube of polyester resin concrete (PRC) sawn from a pipe, having height, length and width equal to T_{cube} (see Figure D.1 a)).

Three test pieces shall be used.

5.4.4 Fatigue strength under pulsating stress

5.4.4.1 Requirements

When tested in accordance with Annex E, all test pieces shall withstand at least 2×10^6 cycles, with the load cycling between $P_{\text{calc,low}}$ and $P_{\text{calc,up}}$ at a frequency not greater than 12 Hz, without failure.

5.4.4.2 Test pieces

The test piece shall be sawn from a pipe. The test piece is cut to produce a rectangular shape whose length, in the circumferential direction, is approximately five times the wall thickness and whose width, in the longitudinal direction, is approximately three times the wall thickness.

Three test pieces taken from the same pipe shall be used. The average of the results from the three tests is the test result.

5.4.5 Leak-tightness

5.4.5.1 Requirements

Pipes and their joints for applications covered by this European Standard are required to be leak-tight against internal and external pressure between 0 bar and 0,5 bar (see EN 476 [1]).

When tested in accordance with Annex F test pieces conforming to 5.4.5.2 shall withstand an internal pressure of 1 bar for 15 min without any signs of leaks, damp patches or droplets.

5.4.5.2 Test pieces

A test piece either consists of a complete pipe and its joint or two pieces of pipe and a joint. One test piece shall be used.

5.4.6 Long-term crushing strength under media attack

5.4.6.1 Requirements

This test is used to determine the percentage reduction in strength over 50 years. The manufacturer shall declare the result from this long-term type test in documents at the time of the enquiry or delivery. When tested in accordance with Annex G an extrapolated long-term crushing strength of a pipe (after 50 years under load), expressed as a percentage of initial strength, is determined. This value shall not be less than 50 % of the initial strength. This extrapolated value gives the load that pipes are capable of being subjected to, without failure, for 50 years, when exposed to acid or alkali solution, as described in Annex G.

The procedure described in Annex G may be used to take into account the influence of any particular solution on the long-term crushing strength of a pipe. In such cases the acceptable percentage value of strength reduction shall be agreed between the manufacturer of the polyester resin concrete (PRC) units and the purchaser.

5.4.6.2 Test pieces

A test piece consists of a pipe section having a minimum length conforming to the applicable requirements given in Table 13, with its ends cut plane and perpendicular to the longitudinal axis.

For a test series at least 18 test pieces shall be used.

5.5 Marking of pipes

Marking details shall be printed or formed directly on the pipe in such a way that the marking does not initiate cracks or other types of failure. If printing is used, the colouring of the printed information shall differ from the basic colouring of the product and such that the markings shall be readable without magnification.

The following marking shall be on the outside of each pipe of DN 500 or less, and in the case of pipes of DN 600 or greater shall be either on the inside or on the outside surface:

a) number of this European Standard;

b) strength class;

c) nominal size DN or WN/HN;

d) its classification, i.e. PRC-OC, PRC-OE, PRC-OK, PRC-TC, PRC-TE or PRC-TK;

e) laying length, L;

f) manufacturer's name or identification;

g) date or code of manufacture;

h) quality mark, if applicable.

6 Fittings

6.1 General

6.1.1 Designation of bends and branches

Bends and branches shall be designated according to 5.2 and Table 3 in respect of the following:

a) intended method of installation, i.e. open-trench construction, (O);

b) cross-sectional shape, i.e. whether circular (C), egg-shaped (E) or kite-shaped (K);

c) nominal size DN or WN/HN.

6.1.2 Method of installation

The method of installation for bends and branches to this European Standard is open-trench (O).

6.1.3 Cross-sectional shape

The cross-sectional shape (C, E or K) of the fitting shall be that of the straight length of pipe to which it is to be joined in the piping system and shall be one of the shapes specified in 5.1.3.

6.1.4 Nominal size DN or WN/HN

The nominal size DN or WN/HN of the fitting shall be that of the straight length of pipe to which it is to be joined in the piping system and shall be one of the nominal sizes given in 5.3.

6.2 Bends

6.2.1 Geometrical characteristics

6.2.1.1 General

The dimensions measured in accordance with 4.3.4 shall conform to the applicable values and tolerances according to 6.2.1. The dimensions e, d_a, L_i and their tolerances shall be specified by the manufacturer in documents at the time of the enquiry or delivery.

6.2.1.2 Diameter

The tolerance on the diameter of the bend at the spigot positions shall conform to the applicable requirements in 5.3.

6.2.1.3 Nominal fitting angle (α_n)

In the interests of rationalisation, the nominal fitting angle, α_n, which indicates the angular change in direction of the axis of the bend (see Figure 8) shall be one of the following preferred values, 15°, 30°, 45°, 60° or 90°. The deviation of the actual change in direction of a bend from the designated fitting angle shall not exceed 1° of the specified angle.

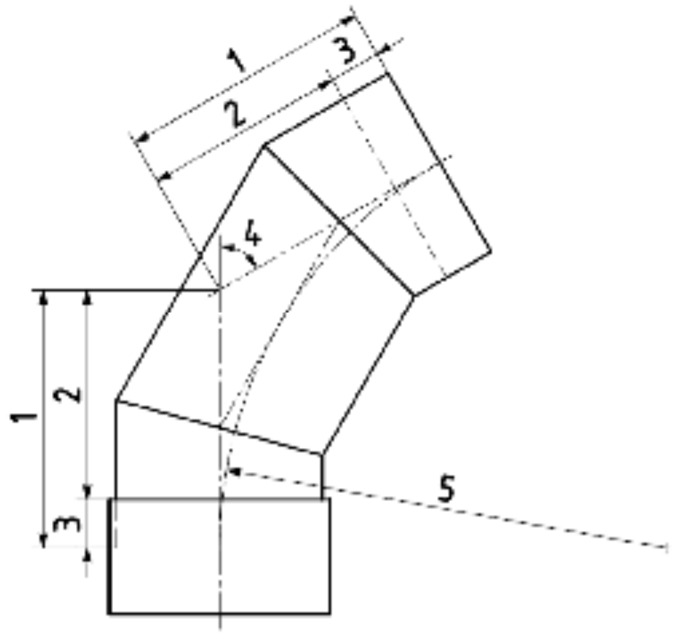
Fitting angles other than these may be supplied by agreement between the purchaser and the manufacturer.

6.2.1.4 Radius of curvature (r)

Bends made by fabrication from straight pipe (see Figure 8) shall not provide more than 30° angular change for each segment of the bend. The base of each segment shall have sufficient length adjacent to each joint to ensure that external wrapping or joining materials can be accommodated. The radius of curvature, r, shall be not less than the nominal size, DN or WN in millimetres, of the pipe.

The specified dimensions of the bends in this European Standard are based on a radius of curvature $r = 1{,}5 \times [DN]$ or $r = 1{,}5 \times [WN]$, in millimetres.

NOTE Radius of curvature other than those described can be supplied by agreement between the purchaser and the manufacturer.



Key

1 laying length, L

2 body length, L_B

3 insertion depth of spigot, L_i

4 fitting angle, α_n

5 radius of curvature, r

Figure 8 — Typical fabricated bend

6.2.1.5 Lengths

6.2.1.5.1 General

NOTE Lengths of individual bends are dependent upon the designated fitting angle, the radius of curvature, and the length of any linear extensions provided for jointing or other purposes.

6.2.1.5.2 Laying length

The laying length, L, of the bend (see 3.1.7) shall be the distance from one end of the bend, excluding the spigot insertion depth of a socket end where applicable, projected along the axis of that end of the bend to the point of intersection with the axis of the other end of the bend (see Figure 8).

For an end of a bend containing a spigot, the laying length, L, is the body length, L_B, plus the insertion depth of the joint, L_i (see Figure 8).

The permitted deviations on the declared or specified dimensions for laying length shall be ± (15 mm times the number of mitres of the bend).

6.2.1.5.3 Body length

The body length of the bend, L_B, shall be the distance from the point of intersection of the two axes of the bend to a point on either axis, equal to the laying length, L, minus an insertion depth, L_i. Nominal body lengths shall be taken from Table 15. The values in Table 15 are minimum lengths that are controlled by the fittings' geometry and may need to be increased to provide sufficient length for over-wraps at the mitres and joints.

Dimensions other than those given in Table 15 may be used by agreement between the purchaser and the manufacturer.

Table 15 — Nominal body length L_B for bends (see Figure 8)

DN	Nominal fitting angle, α_n			
	90°	60°	45°	≤ 30°
	Nominal body length [a], L_B (mm)			
150	230	135	95	65
200	440	390	390	380
250	710	400	380	380
300	690	380	380	380
400	720	630	255	380
500	1000	630	610	380
600	1000	610	590	380
700	1030	620	590	380
800	1590	620	590	380
900	1590	880	600	380
1000	1610	880	600	380

[a] The nominal body length, L_B, equals the minimum body length.

6.2.2 Mechanical characteristics

Bends shall be designed and manufactured in accordance with relevant design practices to have a mechanical performance equal to or greater than that of a straight polyester resin concrete (PRC) pipe of the same nominal size when installed in a piping system, and, if appropriate, supported by anchor blocks or encasements.

The manufacturer of the bend shall document the fitting design and manufacturing procedure.

6.2.3 Leak-tightness of installed bends

Where a specific site installation test is declared by the purchaser or is agreed between the manufacturer and the purchaser the bend and its joints shall be capable of withstanding that test following installation in the works.

NOTE When carrying out such tests care should be taken to ensure that bends are fully restrained to prevent movement.

6.3 Branches

6.3.1 Geometrical characteristics

6.3.1.1 General

The dimension measured in accordance with 4.3.4 shall conform to the applicable values and tolerances according to 6.3.1. The dimensions e, d_a, L_i, and their tolerances, shall be specified by the manufacturer in documents at the time of the enquiry or delivery.

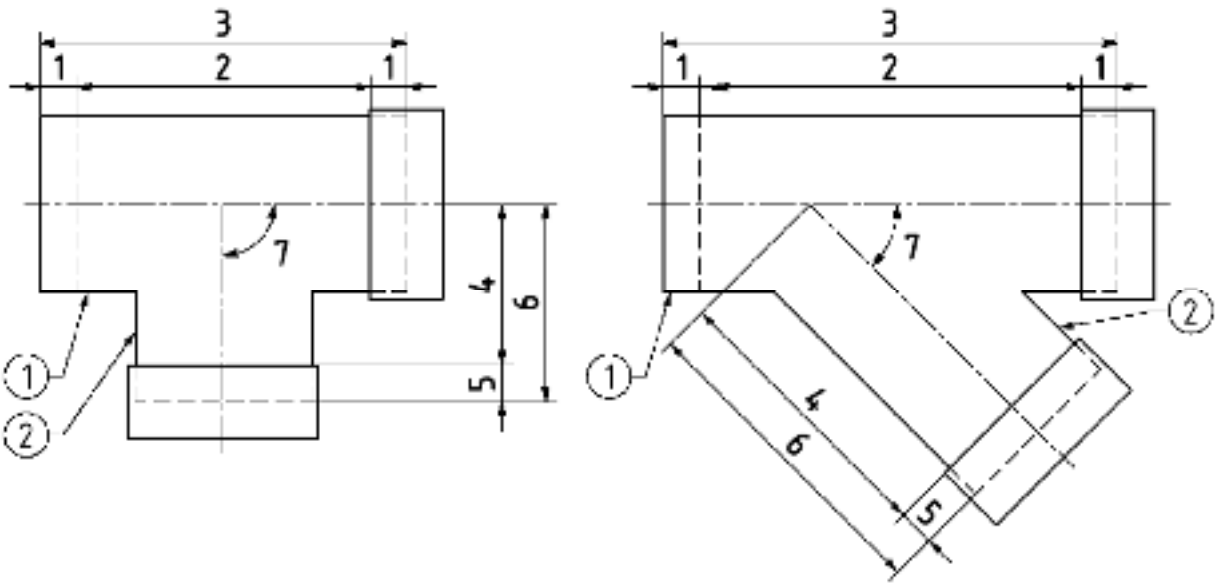
6.3.1.2 Diameter

The tolerance on the diameter of the main pipe or branch at the spigot positions shall conform to the applicable requirements in 5.3.

6.3.1.3 Nominal fitting angle

The nominal fitting angle, α_n, (see Figure 9) shall, in the interests of rationalisation, be one of the following preferred values, 45° or 90°. The deviation of the actual change in direction of a branch from the designated fitting angle shall not exceed 1° of the specified angle.

Fitting angles other than these may be supplied by agreement between the purchaser and the manufacturer.



a) Equal tee branch **b) Oblique branch**

Key

① main pipe
② branch pipe
1 insertion depth of main pipe spigot, L_i
2 nominal body length of main pipe, L_B
3 laying length of main pipe, L
4 nominal offset body length of branch pipe, B_B
5 insertion depth of the spigot of branch pipe, B_i
6 laying length of branch pipe, B
7 fitting angle, α_n

Figure 9 — Typical branches

6.3.1.4 Length

6.3.1.4.1 General

NOTE 1 Only tee branches are covered by dimensional requirements in this European Standard.

NOTE 2 Dimensions other than those specified can be used by agreement between the purchaser and the manufacturer.

6.3.1.4.2 Laying length

For a main pipe of a branch fitting , the laying length, L, is the body length, L_B, plus two spigot insertion depths of the joint, L_i (see Figure 9).

The laying length of the branch pipe, B (see Figure 9), is the distance from the end of the branch pipe excluding, where applicable, the spigot insertion depth of a socket end, to the point of intersection of the straight through axis of the main pipe of the fitting with the extended axis of the branch pipe. The laying length, B, of the branch pipe of equal tee branch fittings shall be 50 % of the main pipe body length, L_B.

6.3.1.4.3 Body length

The nominal body length, L_B (see Figure 9), of the main pipe of a branch fitting is equal to the laying length, L, minus two spigot insertion depths, L_i.

For equal tees the nominal body length, L_B, shall be as follows:

a) 500 mm for DN ≤ 200;

b) 1000 mm for 250 < DN ≤ 600;

c) 1500 mm for 700 < DN ≤ 1000.

6.3.1.4.4 Offset length

The nominal offset length, B_B (see Figure 9), of the branch pipe of a branch fitting is equal to the laying length, B, minus a spigot insertion depth, B_i.

6.3.1.4.5 Tolerances on length

The permissible deviations on the manufacturer's declared laying lengths, L and B, of the fitting shall be ± 25 mm or ± 1 % of the applicable laying length, whichever is the larger.

6.3.2 Mechanical characteristics

Branches shall be designed and manufactured in accordance with relevant design practices to have a mechanical performance equal to or greater than that of a straight polyester resin concrete (PRC) pipe of the same nominal size when installed in a piping system, and, if appropriate, supported by anchor blocks or encasements.

The manufacturer of the branch shall document the fitting design and manufacturing procedure.

6.3.3 Leak-tightness of installed branches

Where a specific site installation test is declared by the purchaser or is agreed between the manufacturer and the purchaser the branch and its joints shall be capable of withstanding that test following installation in the works.

NOTE When carrying out such tests care should be taken to ensure that branches are fully restrained to prevent movement.

6.4 Marking of fittings

Marking details shall be printed or formed directly on the fitting in such a way that the marking does not initiate cracks or other types of failure. If printing is used, the colouring of the printed information shall differ from the basic colouring of the product and such that the markings shall be readable without magnification.

The following marking shall be on the outside of each fitting:

a) number of this European Standard;

b) nominal size DN or WN/HN;

c) its classification, i.e. PRC-OC, PRC-OE or PRC-OK;

d) laying length(s);

e) fitting angle;

f) manufacturer's name or identification;

g) date or code of manufacture;

h) quality mark, if applicable.

7 Joint performance

7.1 General

NOTE Interchangeability between products from different suppliers can only be achieved with appropriate regard to the pipe and joint dimensions.

7.1.1 Materials

Materials used in joint assemblies shall be in accordance with the pipe and fitting manufacturer’s declared specification.

7.1.2 Dimensions

All dimensions of the tested joints, which may influence the joint's performance, shall be recorded.

7.2 Requirements

7.2.1 General

A joint made between pipes conforming to Clause 5 and/or fittings conforming to Clause 6 shall be designed so that its leak-tightness performance is equal to or better than the requirements of the piping system, but not necessarily of the components being joined.

For a particular design of joint, the properties described in 7.2.2 and 7.2.3 shall be declared by the manufacturer in documents at the time of the enquiry or delivery.

7.2.2 Draw

Flexible joints shall be capable of conforming to 7.2.4 when a draw, D (see 3.1.6 and Figure 1), including temperature effects, of not less than 0,2 % of the laying length of the longest pipe with which the joint is intended to be used or the manufacturer's declared maximum draw, D_{max}, (see 4.4.2.2) whichever is the greater, is applied.

7.2.3 Angular deflection

Flexible joints shall be capable of conforming to 7.2.4 when an angular deflection, δ (see 3.1.2 and Figure 1) not less than the manufacturers declared maximum values, is applied.

7.2.4 Leak-tightness

7.2.4.1 Leak-tightness when subject to internal pressure following assembly

When assembled in accordance with the pipe manufacturer's recommendations, the joint shall withstand without leakage an internal pressure of 0,75 bar for 15 min, and shall subsequently conform to 7.2.4.2 and 7.2.4.3.

7.2.4.2 Leak-tightness when simultaneously subject to misalignment and draw

When the joint is subjected to the manufacturers declared maximum draw, D_{max}, (see 7.2.2) and a total shear load, N_d , of 25 N per millimetre of the nominal size DN or WN, in millimetres, it shall not show any visible sign of damage to its components nor leak when tested by the appropriate method given in EN 1119 at the pressure and duration given in Table 16.

7.2.4.3 Leak-tightness when simultaneously subject to angular deflection and draw

When the joint is subject to an angular deflection in accordance with 7.2.3 and a total draw, D_{tot}, equal to the manufacturer's maximum draw, D_{max}, (see 7.2.2) plus the longitudinal movement, J, (see Figure 1) resulting from the applied angular deflection, it shall not show any visible signs of damage to its components nor leak when tested by the appropriate method given in EN 1119 at the pressure and duration given in Table 16.

7.2.4.4 Resistance to an external pressure differential

7.2.4.4.1 General

The assessment of a joint’s ability to resist external water pressure shall be made using either internal negative pressure or external water pressure.

7.2.4.4.2 Leak-tightness test when subject to negative pressure

When the joint is subjected to the declared maximum draw, D_{max}, (see 7.2.2) it shall not show any visible signs of damage to its components nor exhibit a change in pressure greater than 0,08 bar/h (0,008 MPa/h), when tested by the appropriate method given in EN 1119 at the pressure and duration given in Table 16.

7.2.4.4.3 Leak-tightness test when subject to external water pressure

When the joint is subjected to the declared maximum draw, D_{max}, (see 7.2.2) it shall not show any visible signs of damage to its components nor leak when tested using a test arrangement such as shown in Figure 10 at the pressure and duration given in Table 16.

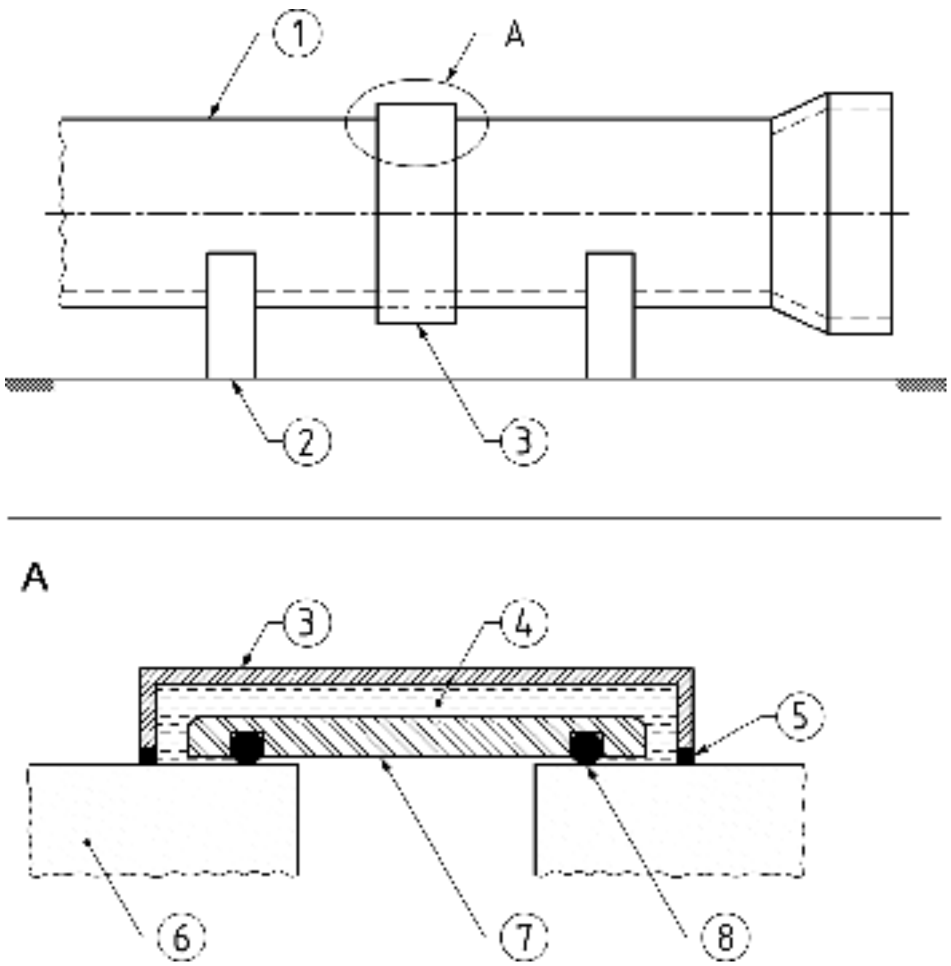
7.2.4.5 Number of test pieces

The number of joint assemblies to be tested for each test in 7.2.4 shall be one.

It is permitted to use the same assembly for more than one test.

7.2.4.6 Test pieces

A test piece shall comprise a joint and two pieces of pipe such that the total length of the test piece, l_P, is not less than is required to meet the requirements of the test method.



Key

A joint cross section

① pipe

② support for pipe

③ metal jacket

④ water under pressure

⑤ watertight seal

⑥ pipe wall

⑦ joint being tested

⑧ joint seal

Figure 10 — Typical test arrangement for resistance to an external pressure differential using external water pressure

Table 16 — Summary of test requirements for flexible joints

Joint position	Tests	Test pressure bar	Duration
Initial leakage	Initial pressure	0,75 [a]	15 min
Misalignment and draw	Positive static pressure	1	24 h
Angular deflection and draw	Initial pressure	0,75	15 min
	Positive static pressure	1	24 h
External pressure differential	Using negative pressure	–0,8 bar (–0,08 MPa)	1 h
	Using external water pressure	1	1 h

[a] Relative to atmospheric, i.e. approximately 0,75 bar (0,075 MPa) absolute.

8 Dangerous substances

Materials used in products shall not release any dangerous substances in excess of the maximum permitted levels specified in a relevant European Standard for the material or permitted in the national regulations of the member state of destination.

9 Manufacturer's installation recommendations

Where the performance of the product can be affected by the declared intended use and installation would require special considerations, the manufacturer shall supply such installation recommendation that would ensure the correct performance of the product.

10 Evaluation of conformity

10.1 General

The conformity of polyester resin concrete (PRC) pipe or fitting to the requirements of this European Standard and with the stated values (including classes) shall be demonstrated by:

— initial type testing;

— factory production control by the manufacturer, including product assessment.

For the purposes of testing, polyester resin concrete (PRC) pipe or fitting may be grouped into families, where it is considered that the results for one or more characteristics from any one product within the family are representative for that same characteristics. For all polyester resin concrete (PRC) pipe or fitting within that same family (a product may be in different families for different characteristics).

10.2 Initial type testing

10.2.1 General

An initial type test is the complete set of tests or other procedures, in respect of the characteristics to be assessed, determining the performance of samples of products representative of the product type.

Initial type testing shall be performed to show conformity with this European Standard for polyester resin concrete (PRC) pipes or fittings being put onto the market and

— at the beginning of the production of a new or modified polyester resin concrete (PRC) pipe or fitting design, the raw material or supplier of the components;

— at the beginning of a new or modified method of production.

In case of type testing of polyester resin concrete (PRC) pipes or fittings for which initial type testing in accordance with this European Standard was already performed, type testing may be reduced

— if it has been established that the performance characteristics compared with the already tested polyester resin concrete (PRC) pipe or fitting have not been affected, or

— in accordance with the rules for families and/or direct or extended application of test results.

Where components are used (e.g. seals) whose characteristics have already been determined, by the component manufacturer, on the basis of conformity with other technical specifications, these characteristics need not be reassessed provided that the components' performance or method of assessment remain the same and that the characteristics of the component are suitable for the intended end use of the finished product.

Products CE marked in accordance with appropriate harmonised European specifications may be presumed to have the performances stated with the CE marking, although this does not replace the responsibility of the manufacturer to ensure that the pipe/fitting as a whole is correct and its components have the necessary performance values to meet the design.

10.2.2 Characteristics

The following properties for pipes, fittings and their joints shall be subject to initial type testing:

a) crushing strength;

b) compressive strength of polyester resin concrete (PRC) (jacking pipes only);

c) longitudinal bending moment resistance (BMR) (pipes only);

d) geometrical characteristics;

e) leak-tightness;

f) fatigue strength under pulsating stress;

g) long-term crushing strength under media attack;

h) release of dangerous substances, may be assessed indirectly by controlling the content of the substance concerned.

10.2.3 Use of historical data

Tests previously performed on the same polyester resin concrete (PRC) pipes, fittings or joints in accordance with the provisions of this European Standard (same characteristic(s), test method, sampling procedure, system of attestation of conformity etc.) may be taken into account.

10.2.4 'Deemed to satisfy' provisions and use of reference tabulated data

In those cases where conformity with this European Standard is based on CWFT or conventionally accepted performance provisions, type testing shall be limited to the verification of whether the polyester resin concrete (PRC) pipes, fittings or their joints meet the requirements to use those values, classes or levels, unless better values, classes or levels are being claimed.

10.2.5 Treatment of calculated values and design

In those cases where conformity with this European Standard is based on calculations, type testing will be limited to the verification of the calculations made and that the resulting products correspond to the descriptions/ assumptions made in the design and/or calculations.

10.2.6 Sampling, testing and conformity criteria

10.2.6.1 Sampling

Initial type testing shall be performed on samples of polyester resin concrete (PRC) pipes and fittings of the same size, designation and strength class and on their joints which are representative of the manufactured product type.

10.2.6.2 Testing and conformity criteria

The number of polyester resin concrete (PRC) pipes, fittings and their joints to be tested (or assessed) are given in Table 17 and the link to the mandate with the characteristics to be assessed together with the means of verification, are given in Table 18.

Table 17 —Number of units and conformity criteria for initial type testing of polyester resin concrete (PRC) pipes, fittings and their joints

Characteristic	Requirement clause	Assessment method	Number of units	Conformity criteria
Pipes				
Crushing strength	5.4.1	Annex A	Three pipe pieces	5.4.1.1 [a]
Compressive strength of polyester resin concrete (PRC) (jacking pipes only)	5.4.3	Annex D	Three cubes cut from a pipe	5.4.3.1 [a]
Longitudinal bending moment resistance (BMR) (pipes only)	5.4.2	Annex C	Three pipes	5.4.2.1 [a]
Geometrical characteristics	5.3	4.3.4	Three pipes	5.3 [b]
Leak-tightness	5.4.5	Annex F	One pipe with joint or two pipes with a joint	5.4.5.1 [a]
Fatigue strength under pulsating stress	5.4.4	Annex E	Three pieces taken from a pipe	5.4.4.1 [a]
Long-term crushing strength under media attack	5.4.6	Annex G	18 pieces from pipes	5.4.6.1 [a]
Fittings [c]				
Geometrical characteristics	6.2.1 or 6.3.1	4.3.4	Three fittings	6.2.1 or 6.3.1 [b]
Joints				
Geometrical characteristics	4.4.1 and 7.1.2	4.3.4	Three joints	4.4.1 and 7.1.2 [b]
Leak-tightness	7.2	EN 1119	One joint and two pieces of pipe	7.2.4 [a]

a Manufacturer's limiting value (MLV) is the value stated by the manufacturer to be met or exceeded during testing, in documents at the time of the enquiry or delivery.

b Manufacturer's declared value (MDV) is the value declared by the manufacturer together with a declared tolerance, in documents at the time of the enquiry or delivery.

c Fittings made from pipes complying with this European Standard do not need to be tested separately for tightness, permeability, mechanical or chemical resistance characteristics as they are covered by the tests performed on pipes.

Table 18 — Type testing of polyester resin concrete (PRC) pipes, fittings and their joints

Characteristics from the mandate	Requirement clause of this European Standard	Testing relevant to [a]			Mandated level
		I	M	E	
Crushing strength [b]	5.4.1	+	+	+	None
Compressive strength of polyester resin concrete (PRC) (jacking pipes only)	5.4.3	+	+	+	None
Longitudinal bending strength (pipes only)	5.4.2	+	+	+	None
Dimensional tolerances - pipes - fittings - joints	 5.3 6.2.1 or 6.3.1 4.4.1 and 7.1.2	 + + +	 — — —	 + + +	None
Tightness (liquid) [b] - pipes - joints	 5.4.5 7.2	 + +	 — +	 + [c] +	None
Permeability [b] - pipes - Joints	 5.4.5 7.2	 + +	 — +	 + [c] +	None
Durability [b] - fatigue strength - long-term crushing strength	 5.4.4 5.4.6	 + +	 + +	 — —	None
Release of dangerous substances		+ [d]	+ [d]	—	None

a I Initial type test in case of new system;
M Change of material;
E Extension of the product range.
\+ Denotes testing for the characteristic-relevance-combination.

b Fittings made from pipes complying with this European Standard do not need to be tested separately for tightness, permeability, mechanical characteristics or durability as they are covered by the tests performed on pipes.

c Only in case of increased range of dimensions.

d Only to be performed if subject to regulatory requirements.

The results of all type tests shall be recorded and held by the manufacturer for at least 10 years after the last date of production of the product(s) to which they apply.

10.3 Factory production control (FPC)

10.3.1 General

The manufacturer shall establish, document and maintain an FPC system to ensure that the products placed on the market conform to the declared performance characteristics. The FPC system shall consist of written procedures (works' manual), regular inspections and tests and/or assessments and the use of the results to control raw and other incoming materials or components, equipment, the production process and the product. Records shall remain legible, readily identifiable and retrievable.

An FPC system conforming with the requirements of EN ISO 9001, and made specific to the requirements of this European Standard, shall be considered to satisfy the above requirements.

The results of inspections, tests or assessments requiring action shall be recorded, as shall any action taken. The action to be taken when control values or criteria are not met shall be recorded and retained for the period specified in the manufacturer's FPC procedures.

10.3.2 FPC requirements for all manufacturers

The manufacturer shall establish procedures to ensure that the production tolerances allow for polyester resin concrete (PRC) pipe, fitting and joints performances to be in conformity with the declared values, derived from initial type testing.

The characteristics, and the means of verification, are given in Table 19.

The manufacturer shall record the results of the tests specified above. These records shall at least include the following information:

— identification of the polyester resin concrete (PRC) pipe, fitting or joint tested;

— date of sampling and testing;

— test methods performed;

— test results.

Table 19 — Minimum frequency of testing for product testing and evaluation as part of FPC

Characteristic	Clause, indicating the relevant test method	Threshold value and/or tolerances	Minimum number of samples	Minimum frequency of tests [a]
Crushing strength [b]	5.4.1	Minimum crushing load corresponding to strength class given in tables under 5.4.1	Three pipe pieces (Test using Annex A or Annex B)	Every 200 pipes per nominal size
Compressive strength of polyester resin concrete (PRC) (jacking pipes only)	5.4.3	80 N/mm^2	Three cubes cut from a pipe	Every 200 pipes per nominal size
Geometrical characteristics - pipes - fittings - joints	 5.3 6.2.1 and 6.3.1 4.3.4	As given in 5.3, 6.2.1 or 6.3.1 or as declared by the manufacturer in documents at the time of the enquiry or delivery	Three pipes, fittings or joints	Once per week per nominal size
Leak-tightness [b] - pipes - joints	 5.4.5 7.2.4	1 bar over 15 min	One pipe with joint or two pipes with a joint	Every 200 pipes per nominal size

[a] If the manufacturer does not declare the performance (e.g. using the "No performance determined" option) for certain characteristics, the corresponding part of the test plan does not need to be performed.

[b] Fittings made from pipes complying with this European Standard do not need to be tested separately for tightness or mechanical characteristics as they are covered by the tests performed on pipes.

10.3.3 Manufacturer-specific FPC system requirements

10.3.3.1 Personnel

The responsibility, authority and the relationship between personnel that manages, performs or verifies work affecting product conformity, shall be defined. This applies in particular to personnel that need to initiate actions preventing product non-conformities from occurring, actions in case of non-conformities and to identify and register product conformity problems. Personnel performing work affecting product conformity shall be competent on the basis of appropriate education, training, skills and experience for which records shall be maintained.

10.3.3.2 Equipment

All weighing, measuring and testing equipment necessary to achieve, or produce evidence of, conformity shall be calibrated or verified and regularly inspected according to documented procedures, frequencies and criteria. Control of monitoring and measuring devices shall comply with the appropriate clause of EN ISO 9001:2008. All equipment used in the manufacturing process shall be regularly inspected and maintained to ensure use, wear or failure does not cause inconsistency in the manufacturing process.

Inspections and maintenance shall be carried out and recorded in accordance with the manufacturer’s written procedures and the records retained for the period defined in the manufacturer's FPC procedures.

10.3.3.3 Design process

The factory production control system shall document the various stages in the design of polyester resin concrete (PRC) pipe, fitting and joints; identify the checking procedure and those individuals responsible for all stages of design.

During the design process itself, a record shall be kept of all checks, their results, and any corrective actions taken. This record shall be sufficiently detailed and accurate to demonstrate that all stages of the design phase, and all checks, have been carried out satisfactorily. Compliance with EN ISO 9001:2008, 7.3 shall be deemed to satisfy the requirements of this sub-clause.

10.3.3.4 Raw materials and components

The specifications of all incoming raw materials and components shall be documented, as shall the inspection scheme for ensuring their conformity. The verification of conformity of the raw material with the specification shall be in accordance with EN ISO 9001:2008, 7.4.3.

In case supplied kit components are used, the attestation of conformity level of the component shall be at least that given in the appropriate harmonised technical specification for that component. If this is not the case, the inspection scheme shall be adequate to demonstrate their suitability.

10.3.3.5 In process control

The manufacturer shall plan and carry out production under controlled conditions. Compliance with EN ISO 9001:2008, 7.5.1 and 7.5.2 shall be deemed to satisfy the requirements of this sub-clause.

10.3.3.6 Traceability and marking

Individual [products, product batches or packages] shall be identifiable and traceable with regard to their production origin. The manufacturer shall have written procedures ensuring that processes related to affixing traceability codes and/or markings (see Clause 6) are inspected regularly. Compliance with EN ISO 9001:2008, 7.5.3 shall be deemed to satisfy the requirements of this sub-clause.

10.3.3.7 Non-conforming products

The manufacturer shall have written procedures which specify how non-conforming products shall be dealt with. Any such events shall be recorded as they occur and these records shall be kept for the period defined in the manufacturer’s written procedures. Compliance with EN ISO 9001:2008, 8.3 shall be deemed to satisfy the requirements of this sub-clause.

10.3.3.8 Corrective action

The manufacturer shall have documented procedures that instigate action to eliminate the cause of non-conformities in order to prevent recurrence. Compliance with EN ISO 9001:2008, 8.5.2 shall be deemed to satisfy the requirements of this sub-clause.

10.3.3.9 Handling storage and packaging

The manufacturer shall have procedures providing methods of product handling and shall provide suitable storage areas preventing damage or deterioration.

10.4 One-off products, pre-production products (e.g. prototypes) and products produced in very low quantities

10.4.1 General

Products produced as a one-off, prototypes assessed before full production is established, and products produced in very low quantities (less than 20 per year) are assessed as follows:

10.4.2 For initial type assessment

10.4.2.1 The FPC system of one-off products and products produced in very low quantities shall ensure that raw materials and/or components are sufficient for the production of the polyester resin concrete (PRC) pipes or fittings and their joints the provisions of Table 19 applying only where appropriate. The manufacturer shall maintain records allowing traceability of the product.

For prototypes where the intention is to move to series production, initial inspection of the factory and FPC shall be carried out before the production is already running and/or before the FPC is already in practice.

10.4.2.2 The following shall be assessed:

— FPC-documentation and

— factory.

In the initial assessment of the FPC and factory it shall be verified that:

a) all resources necessary for the achievement of the product characteristics required by this European Standard can be available and

b) FPC-procedures in accordance with the FPC-documentation can be implemented and followed in practice and

c) procedures are in place to demonstrate that the factory production processes can produce a component complying with the requirements of this European Standard and that the component can be the same as the initial type testing samples, for which compliance with this European Standard has been verified.

Annex A
(normative)

Determination of a pipe's crushing strength and ring bending tensile strength using a pipe test piece

A.1 Scope

This test determines the capacity of a pipe to resist an external load perpendicular to its axis along its length. The test is applicable to pipes of any nominal size having a circular, egg-shaped or kite-shaped cross-section.

According to 5.4.1 the test may be carried out on sawn test pieces in accordance with Annex B if a suitable apparatus is not available.

A.2 Principle

This test is used to show compliance with the minimum requirements for the crushing strength specified in 5.4.1 or to determine the ring bending tensile strength of polyester resin concrete (PRC) used to make a pipe. A test piece is subjected to a vertical load across its diameter for the whole of its length. To show compliance with the minimum crushing strength the load applied is the minimum crushing load, $q_{\text{cr,min}}$, specified in 5.4.1 times the length of the test piece. When it is required to determine the crushing strength of a pipe or the ring bending tensile strength of its polyester resin concrete (PRC) the load applied is increased until the test piece fails. Using the load applied, the length of the test piece and the applicable equations in this annex the minimum strengths are confirmed or the actual strengths are determined.

A.3 Apparatus

A.3.1 Loading frame

A machine capable of applying a compressive load to the test piece, which shall be a whole pipe or a pipe section having a length not less than that given in 5.4.1.2, at a steady rate between 400 N/s and 600 N/s until either the specified minimum crushing load is reached or the test piece fails.

The machine shall be sufficiently rigid so that the distribution of the load will not be affected by the deformation or yielding of any part and shall transmit the load, without shock, in a vertical plane through the longitudinal centre lines of the bearers and the test piece.

The load shall be applied in such a way that the combination of support and bearers is free to rotate in a vertical plane through the longitudinal centre lines of the top and bottom bearers.

The machine shall be equipped with a means of measuring, indicating and recording the total load applied to the test piece to an accuracy within ± 2 % of the load applied.

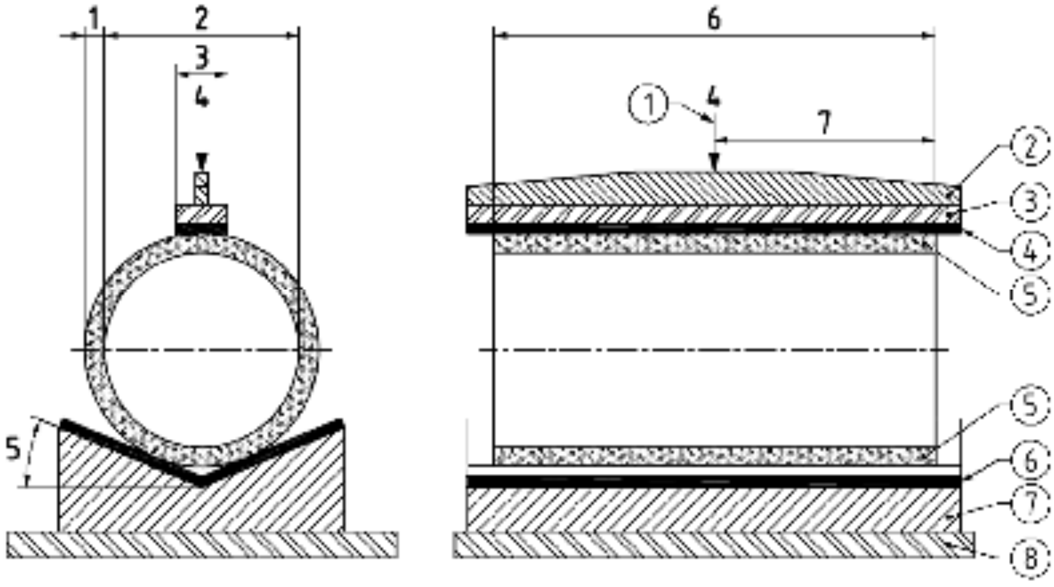
A.3.2 Bearers

The bearers shall be made of metal or suitable hardwood, which is straight and free from warping, twisting or knots. They may be continuous or segmented.

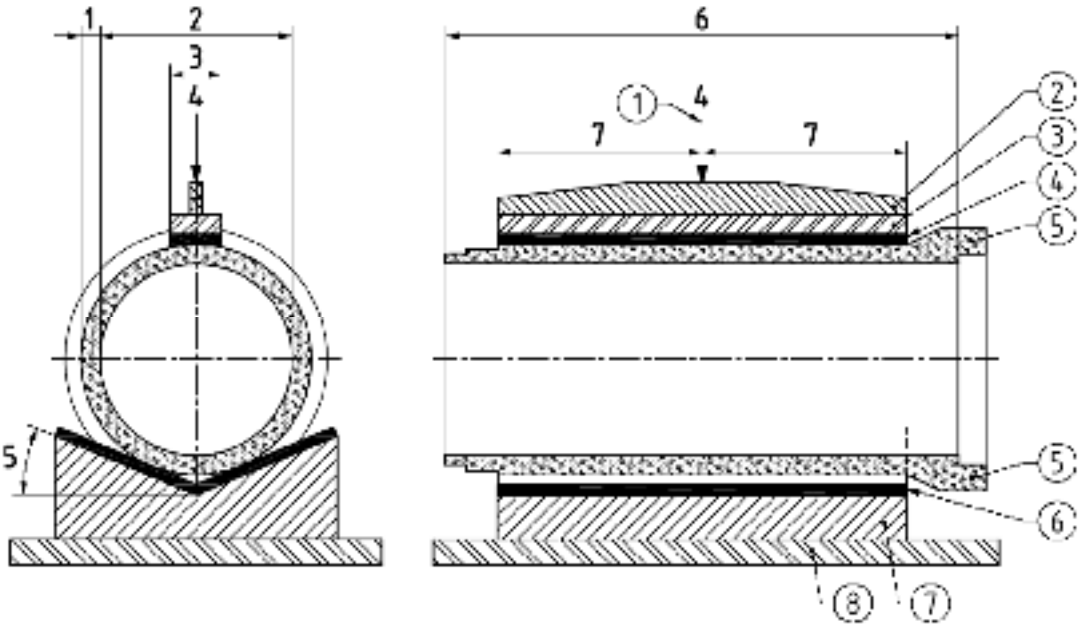
The bearers shall have a thickness that is not less than 25 mm and shall be placed centrally on their supports, shall be positioned centrally below the axis of load application and parallel to the pipe's longitudinal axis.

The load shall be applied through one top-bearing strip.

For pipes with an external circular shape the bottom bearer shall be formed as a V-shaped support with a slope of the surface between 0° and 15° and shall have a width that shall be not less than that required to support the test piece, or it shall consist of two bearing strips placed with their centres at a distance which subtends an angle of 30° at the centre of the pipe (see Figure A.1).



a) Cross-section for plain pipe **b) Longitudinal-section for plain pipe**



c) Cross-section for pipe with integral socket **d) Longitudinal-section for pipe with integral socket**

Key

① applied load, P
② compression edge
③ compression beam
④ elastomeric or felt facing top bearing strip
⑤ polyester resin concrete (PRC) test piece
⑥ elastomeric or felt facing bottom bearing strip
⑦ metal or knotless hardwood bearer
⑧ testing machine base plate

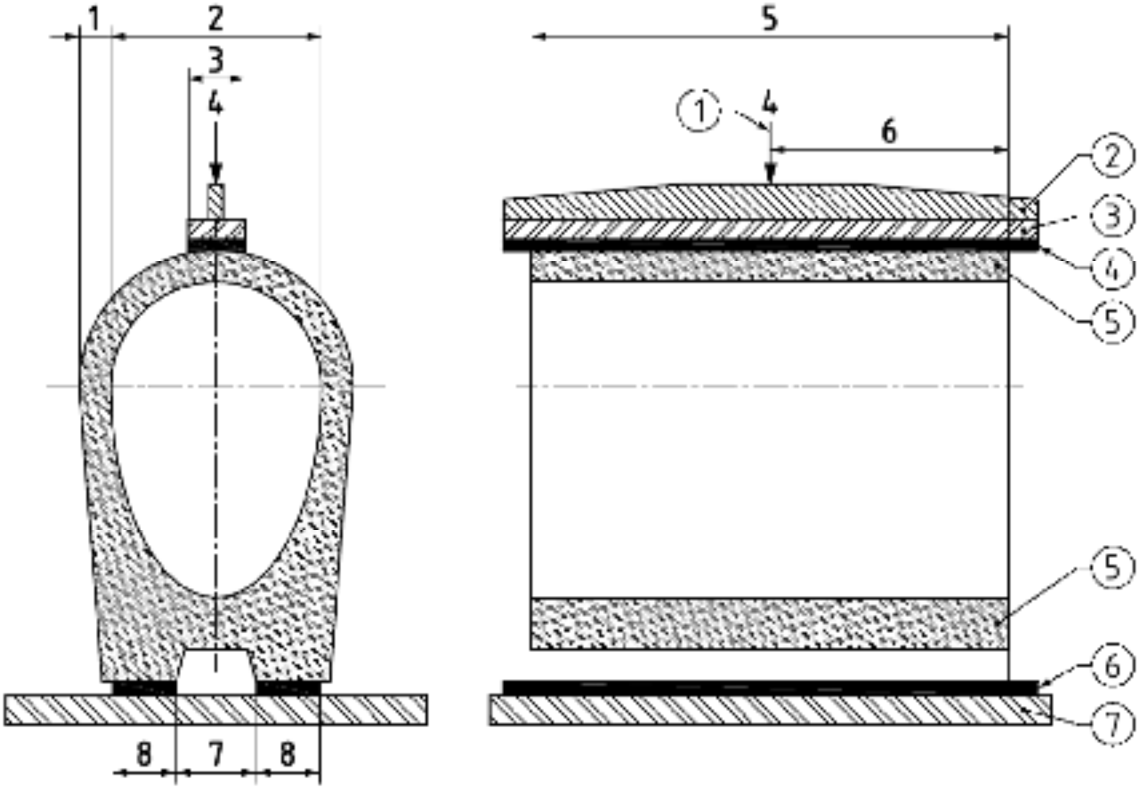
1 wall thickness of test piece, e
2 internal diameter of test piece, d_i
3 width of the bearing strip, a_b
4 axis of load application
5 angle of bearer surface, 0° to 15°
6 length of test piece, l_p
7 $0,5 \times l_p$

Figure A.1 — Typical arrangement for the crushing strength test on pipes with an external circular shape

Pipes with a base shall be supported by two bearing strips placed with their centres at a distance equal to 0,3 times the internal diameter, d_i or width, w_i, as appropriate to the shape of the bore (see Figure A.2).

The surfaces that are in contact with the test piece shall be either in the form of facings or of strips as shown in Figures A.1 or A.2. They shall be of an elastomeric material having a hardness of (55 ± 10) IRHD or when having facings of felt having a density of (0,3 ± 0,025) g/cm^3 and shall have a thickness of (20 ± 5) mm.

The width of a bearing strip, a_b, shall be not less than the width of its corresponding contact surface to the test piece but not greater than the applicable value in Table A.1.



a) Cross-section **b) Longitudinal-section**

Key

① applied load, P
② compression edge
③ compression beam
④ elastomeric or felt facing top bearing strip
⑤ polyester resin concrete (PRC) test piece
⑥ elastomeric or felt facing bottom bearing strips
⑦ testing machine base plate

1 wall thickness of test piece, e_1
2 internal width of test piece, w_i
3 width of the top bearing strip, a_b
4 axis of load application
5 length of test piece, l_p
6 $0,5 \times l_p$
7 distance $0,3 \times w_i$
8 width of the bottom bearing strip, a_b

Figure A.2 — Typical arrangement for the crushing strength test on pipes with a base

Table A.1 — Maximum width of bearing strips

Pipe nominal size DN or WN	Maximum width of bearing strips, a_b mm
(DN or WN) ≤ 400	50
400 < (DN or WN) ≤ 1200	100
1200 < (DN or WN) ≤ 2500	150
2500 < (DN or WN)	200

A.4 Test pieces

Three test pieces of the same size and designation shall be used.

The test piece shall be a whole pipe or a whole cross section of pipe having a length not less than that given in 5.4.1.2. The ends of the test piece shall be cut plane and perpendicular to the pipe axis.

A.5 Procedure

When testing a whole pipe then use the laying length as the length of the test piece when calculating loads and properties.

Place the test piece horizontally and centrally on the bottom bearer.

When testing to check conformity with the minimum crushing strength requirement calculate the minimum test load in accordance with A.6, by multiplying the minimum crushing load, $q_{cr,min}$, in newtons (N), specified in 5.4.1, by the length of the test piece in millimetres (mm).

Apply the load continuously at a rate of between 400 N/s and 600 N/s to the test piece until either the required test load, P_{min}, taking into account the load due to own weight of the compression beam W^*, is reached or failure occurs.

If failure occurs calculate the crushing strength of the pipe and ring bending tensile strength of its polyester resin concrete (PRC) in accordance with A.6 and record the results.

Record the test load applied and the appearance and dimensions of the test piece.

A.6 Calculations

A.6.1 Crushing strength

Calculate the minimum test load, P_{calc}, in newtons, using Equation (A.1) and the load to be applied using Equation (A.2) as follows:

$$P_{calc} = q_{cr,min} \times l_p \tag{A.1}$$

where

P_{calc} is the calculated minimum test load, in newtons (N);

l_p is the length of the test piece, in millimetres (mm);

$q_{cr,min}$ is the minimum crushing load, in newtons per millimetre length (N/mm). It is calculated using the applicable one of the following equations:

$q_{cr,min}$ = strength class × [DN] × 0,001, or

$q_{cr,min}$ = strength class × [WN] × 0,001

where

strength class is the dimensionless value given in Table A.2, Table A.3 or Table A.4, as applicable, for the nominal size of the pipe under consideration;

[DN] or [WN] is the applicable nominal internal size for the pipe under consideration, taken as a dimensionless value.

The minimum load, in newtons (N), to be applied, P_{min}, is:

$$P_{min} = P_{calc} - W^* \quad (A.2)$$

where

P_{min} is the minimum load to be applied, in newtons (N);

P_{calc} is the calculated minimum test load, in newtons (N);

W^* is the load due to own weight of the compression beam and if applicable of the compression edge, in newtons (N).

Table A.2 — Minimum strength classes for pipes designated PRC-OC or PRC-TC

Nominal size DN	Strength class	
	PRC-OC	PRC-TC
150 ≤ DN ≤ 500	140	160
600 ≤ DN ≤ 1000	120	140
1200 ≤ DN ≤ 3000	90	120

Table A.3 — Minimum strength classes for pipes designated PRC-OE or PRC-TE

Nominal width/height WN/HN	Strength class	
	PRC-OE	PRC-TE
300/450 ≤ DN ≤ 600/900	140	160
700/1050 ≤ DN ≤ 1000/1500	120	140
1200/1800 ≤ DN ≤ 1400/2100	90	120

Table A.4 — Minimum strength classes for pipes designated PRC-OK or PRC-TK

Nominal size DN	Strength class	
	PRC-OK	PRC-TK
800 ≤ DN ≤ 1000	120	140
1200 ≤ DN ≤ 1800	90	120

If failure occurs before the minimum load, P_{min}, is reached or the load applied is increased until failure occurs then calculate the crushing strength, q_{cr}, using Equation (A.3):

$$q_{cr} = \frac{P_{cr} + W^*}{l_p} \qquad \text{(A.3)}$$

where

- q_{cr} is the crushing strength, in newtons per millimetre of length (N/mm);
- P_{cr} is the load applied by the loading frame at failure, in newtons (N);
- W^* is the load due to own weight of the compression beam and if applicable of the compression edge, in newtons (N);
- l_p is the length of the test piece, in millimetres (mm).

A.6.2 Ring bending tensile strength of polyester resin concrete (PRC)

A.6.2.1 General

If the ring bending tensile strength of polyester resin concrete (PRC), σ_{rb}, is required for calculation purposes then its value can be determined using the applicable one of the following equation(s).

NOTE If failure occurs then the calculated ring bending tensile stress determined using Equations (A.5) or (A.6) is termed the ring bending tensile strength, σ_{rb}, If failure does not occur then the determined value is the ring bending tensile stress, σ_{rb}. For pipes with a circular or kite-shaped cross-section, i.e. types PRC-OC, PRC-TC, PRC-OK or PRC-TK:

$$\sigma_{rb} = \frac{P_{eff,CK}}{l_p} \times \frac{3 \times d_i + 5 \times e}{e^2} \qquad \text{(A.4)}$$

where

- σ_{rb} is the calculated ring bending tensile stress or strength, if failure occurred (see note below), in newtons per square millimetre (N/mm^2);
- d_i is the internal diameter of the test piece, in millimetres (mm);
- e is the wall thickness of a test piece having a circular or kite-shaped cross-section, in millimetres (mm);
- l_p is the length of the test piece, in millimetres (mm);
- $P_{eff,CK}$ is the effective test load applied to test pieces with circular or kite-shaped cross-section, in newtons (N). It is calculated using Equation (A.5):

$$P_{eff,CK} = 0,07 \times W_p + 0.3 \times \left(P + W^*\right) \qquad \text{(A.5)}$$

where

- W_p is the load of the test piece due to own weight, in newtons (N);
- P is the load applied, in newtons (N);
- W^* is the load due to own weight of the compression beam, in newtons (N);

A.6.2.2 For pipes with an egg-shaped cross-section, i.e. types PRC-OE or PRC-TE:

$$\sigma_{rb} = \frac{P_{eff,E}}{l_p} \times \frac{3 \times w_i + 5 \times e_2}{{e_2}^2} \qquad \text{(A.6)}$$

where

σ_{rb} is the calculated ring bending tensile stress or strength, if failure occurred (see note below), in newtons per square millimetre (N/mm^2);

w_i is the horizontal internal width of the test piece, in millimetres (mm);

e_2 is the wall thickness of the test piece at top of a pipe having an egg-shaped cross-section, in millimetres (mm);

l_p is the length of the test piece, in millimetres (mm);

$P_{eff,E}$ is the effective test load applied to test pieces with egg-shaped cross-section, in newtons (N). It is calculated using Equation (A.7):

$$P_{eff,E} = 0{,}06 \times W_p + 0{,}35 \times \left(P + W^*\right) \quad \text{(A.7)}$$

where

W_p is the load of the test piece due to own weight, in newtons (N);

P is the applied load, in newtons (N);

W^* is the load due to own weight of the compression beam and, if applicable, of the compression edge, in newtons (N).

A.7 Test report

The test report shall include the following information:

a) reference to this European Standard and this annex;

b) full identification of the pipe tested, including the cross-sectional shape, i.e. C, E or K;

c) number of test pieces;

d) dimensions of each test piece;

e) for each test piece whether it failed or not;

f) for each test piece subjected to the minimum strength test the actual load, P, and the minimum load for compliance, P_{min};

g) load due to own weight of the compression beam, W^*;

h) for each test piece the calculated value for minimum crushing load, $q_{cr,min}$, or the actual crushing strength, q_{cr}, as applicable;

i) for each test piece the load due to own weight of the test piece, W_p, if applicable;

j) for each test piece the calculated value of σ_{rb}, if applicable;

k) equipment details;

l) temperature during the test;

m) description of the test pieces after testing;

n) any factors that could have affected the results, such as any incidents or any operating details not specified in this European Standard;

o) date, time and place of testing.

Annex B
(normative)

Determination of a pipe's crushing strength or the ring bending tensile strength using test pieces sawn from a pipe

B.1 Scope

This annex gives a method for the determination of the capacity of a pipe to resist an external load perpendicular to its axis along its length using test pieces sawn from a pipe. The method is applicable to pipes having a circular, egg-shaped or kite-shaped cross-section of any nominal size. The method maybe used instead of the crushing strength test described in Annex A if a suitable apparatus, as described in Annex A, is not available.

B.2 Principle

This test determines the ring bending tensile strength or crushing strength of a polyester resin concrete (PRC) pipe using test pieces cut from a pipe rather than lengths of pipe as used in Annex A to determine the same properties. These properties are used to assess the capacity of the pipe to resist an external load along its length.

B.3 Apparatus

B.3.1 Loading frame

A machine capable of applying a compressive load to the test piece without shock or impact, until either the required minimum ring bending tensile strength is reached or the test piece is taken to failure. The load shall be applied at a steady rate so that the required load is reached within two to three minutes.

The machine shall be sufficiently rigid so that the distribution of the load will not be affected by the deformation or yielding of any part and shall transmit the load in a vertical plane through the longitudinal centre lines of the test piece.

The load shall be applied in such a way that the combination of support and bearers is free to rotate in a vertical plane through the longitudinal centre lines of the top and bottom bearers.

Free movement of one of the bottom bearing beams shall be ensured.

The machine shall be equipped with a means of measuring, indicating and recording the total load applied to the test piece to an accuracy within ± 2 % of the load applied.

B.3.2 Bearers and contact surfaces

The bearers shall be made of metal or a suitable hardwood, which is straight and free from warping, twisting or knots.

The bearers shall have a thickness that is not less than 25 mm.

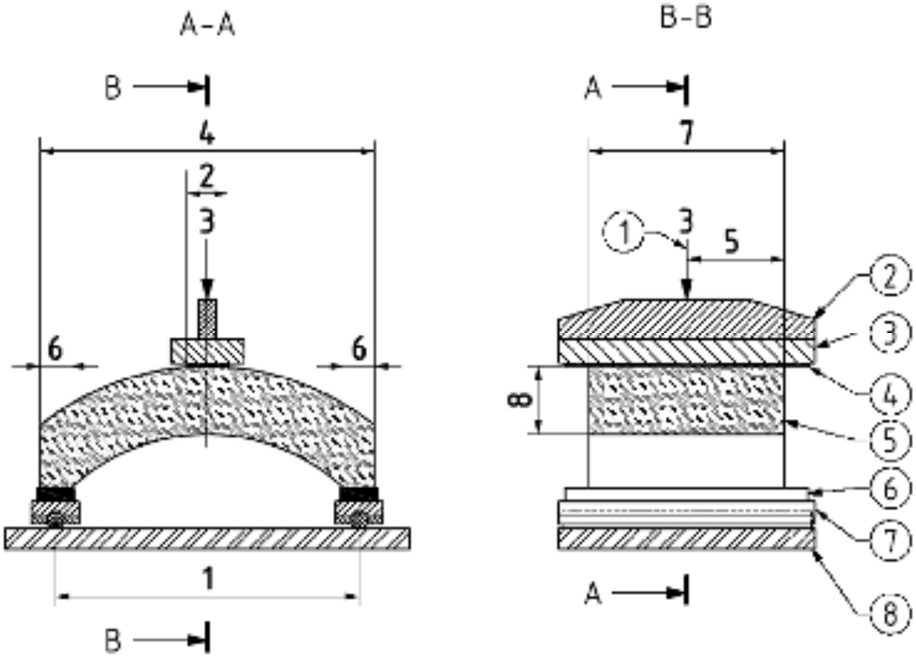
The load shall be applied through the top bearing-strip.

The surfaces that are in contact with the test piece shall be in the form of facings to the beams (see Figure B.1). They shall either be of an elastomeric material, having a hardness of (55 ± 10) IRHD or of felt having a density of (0,3 ± 0,025) g/cm^3. The facing of the top bearer shall have a thickness of 3 mm, and the bottom bearing beams facing shall have a thickness of (20 ± 5) mm.

The width of the top bearing strip, a_b, shall be 1/10 of the spacing between the centres of the bearing beams, l_b (see Figure B.1).

The bottom bearing beams shall be located centrally about the axis of load application on the bottom bearer.

Free movement of one of the bottom bearers shall be ensured.



a) Cross-section b) Longitudinal-section

Key

①	applied load, P	1	distance between bearers, l_b
②	compression edge	2	width of the top bearing strip, $0,1 \times l_b$
③	compression beam	3	axis of load application
④	elastomeric or felt facing 3 mm thick	4	length of test piece, l_p, = $5 \times e$
⑤	polyester resin concrete (PRC) test piece	5	location of applied load, $0,5 \times b$
⑥	elastomeric or felt facing 20 mm thick	6	width of the ground surface, $0,33 \times e$
⑦	metal roller bearer to provide movement	7	width of the test piece, $b = 3 \times e$
⑧	test machine base plate	8	wall thickness of test piece, e

Figure B.1 — Test arrangement when using test pieces taken from a pipe

B.4 Test piece

The test piece shall be sawn from a pipe or a broken piece of a pipe. When testing pipes with kite-shaped or egg-shaped cross-section the test pieces shall be taken from the top of the pipe.

The test piece shall have parallel boundary surfaces and its length, l_p, shall be about five times the wall thickness, e, and its width, b, about three times the wall thickness.

NOTE The dimensions quoted are indicative only.

The longitudinal sides of the test piece shall be perpendicular to the generated surface of the pipe.

B.5 Test procedure

B.5.1 Determination of minimum test load, P_{min}, to be applied

B.5.1.1 General

To verify conformity with the pipe's specified minimum crushing strength perform the calculations in this clause to determine the test load to be applied, P_{min}.

To determine the crushing strength of a pipe or the ring bending tensile strength of its polyester resin concrete (PRC) proceed as described in B.5.2. Otherwise, proceed with the applicable calculations in this clause.

B.5.1.2 Calculate the minimum crushing load, $q_{cr,min}$, in newtons per millimetre of pipe length (N/mm), using Equation (B.1a) or (B.1b), as applicable:

$$q_{cr,min} = \text{strength class} \times [DN] \times 0{,}001 \qquad \text{(B.1a)}$$

$$q_{cr,min} = \text{strength class} \times [WN] \times 0{,}001 \qquad \text{(B.1b)}$$

where

strength class	is the dimensionless value given in Table A.2, Table A.3, or Table A.4, as applicable, for the nominal size of the pipe under consideration;
[DN] or [WN]	is the applicable nominal internal size for the pipe under consideration, taken as a dimensionless value.

B.5.1.3 Calculate the minimum ring bending tensile stress, $\sigma_{rb,min}$, for circular and kite-shaped pipes, using Equation (B.2) or for egg-shaped pipes use Equation (B.3):

$$\sigma_{rb,min} = \frac{(q_{cr,min} + \frac{7}{30} \times W_{pipe}) \times 0{,}3(3 \times d_i + 5 \times e)}{e^2} \qquad \text{(B.2)}$$

$$\sigma_{rb,min} = \frac{(q_{cr,min} + \frac{6}{35} \times W_{pipe}) \times 0{,}35(3 \times w_i + 5 \times e_2)}{e_2^{\,2}} \qquad \text{(B.3)}$$

where

- $\sigma_{rb,min}$ is the minimum ring bending tensile stress, in newtons per square millimetre (N/mm^2);
- $q_{cr,min}$ is the minimum crushing load, in newtons per millimetre of pipe length (N/mm);
- d_i is the internal diameter of the pipe, in millimetres (mm);
- e is the wall thickness of the pipe, in millimetres (mm);
- e_2 is the wall thickness at the top of an egg-shaped cross-section pipe, in millimetres (mm);
- w_i is the horizontal internal width of the pipe with egg-shaped cross-section, in millimetres (mm);
- W_{pipe} is the load due to own weight of the pipe, in newtons per millimetre of pipe length (N/mm).

B.5.1.4 To verify conformity with the minimum crushing strength for a pipe calculate the minimum test load, P_{calc} in newtons (N), for the applicable shape of pipe using Equation (B.4) and the load to be applied by the loading frame to the test piece, P_{min}, using Equation (B.5):

$$P_{calc} = \frac{\sigma_{rb,min} \times 2 \times b \times e^2}{3 \times l_b \times f_{corr}} \tag{B.4}$$

$$P_{min} = P_{calc} - W^* \tag{B.5}$$

where

P_{calc} is the calculated minimum test load, in newtons (N);

P_{min} is the minimum test load to be applied to the test piece by the loading frame, in newtons (N);

W^* is the load due to own weight of the compression beam and, if applicable, of the compression edge, in newtons (N);

$\sigma_{rb,min}$ is the minimum ring bending tensile stress obtained from Equation (B.2) or (B.3) as applicable;

b is the width of the test piece, in millimetres (mm);

e is the wall thickness of the test piece, in millimetres (mm);

l_b is the distance between bearers, in millimetres (mm);

f_{corr} is the correction factor to allow for stress distribution in the curved beam, derived from Equation (B.6a) or (B.6b), as applicable:

$$f_{corr} = \frac{(3 \times d_i) + (5 \times e)}{(3 \times d_i) + (3 \times e)} \tag{B.6a}$$

$$f_{corr} = \frac{(3 \times w_i) + (5 \times e)}{(3 \times w_i) + (3 \times e)} \tag{B.6b}$$

where

e is the wall thickness of the test piece, in millimetres (mm);

d_i is the internal diameter of the original pipe, in millimetres (mm);

w_i is the horizontal internal width of the original pipe with egg-shaped cross-section, in millimetres (mm).

B.5.2 Load application

Place the test piece horizontally and centrally on the bottom bearing beams as shown in Figure B.1.

When checking conformity with the minimum crushing strength apply the load continuously at a steady rate so that the required load, P_{min}, is reached within 2 min to 3 min or the test piece fails. Record the load applied and the appearance and dimensions of the test piece.

When determining the crushing strength apply load continuously at a steady rate so that failure occurs within 2 min to 3 min. Record the maximum load applied and the appearance and dimensions of the test piece.

B.6 Calculations

B.6.1 Ring bending tensile strength

If the maximum load applied during the test causes the test piece to break then these calculation's value for σ_{rb} is the ring bending tensile strength of the pipe's polyester resin concrete (PRC). If however the maximum load applied does not cause the test piece to break then the calculated value for σ_{rb} is the ring bending tensile stress achieved during the test.

Calculate the ring bending tensile stress or strength of a pipe's polyester resin concrete (PRC), σ_{rb}, using Equation (B.7):

$$\sigma_{rb} = \frac{3 \times P}{2 \times b} \times \frac{l_b}{e^2} \times f_{corr} \tag{B.7}$$

where

- σ_{rb} is the calculated ring bending tensile stress or strength of the pipe's polyester resin concrete (PRC), in newtons per square millimetre (N/mm^2);
- f_{corr} is the correction factor to allow for the stress distribution in the curved beam, calculated using Equation (B.6a) or (B.6b) as applicable;
- P is the maximum load applied during the test, including $W*$, in newtons (N);
- l_b is the spacing between the centres of the bearing beams, in millimetres (mm);
- b is the width of the test piece, in millimetres (mm);
- e is the wall thickness of the test piece, in millimetres (mm).

B.6.2 Crushing strength

B.6.2.1 General

To assess conformity with the minimum crushing strength requirements perform the following calculation to determine the crushing load, q_{cr}, using the applicable Equation (B.8a) or (B.8b) and the ring bending tensile stress, σ_{rb}, determined in accordance with B.6.1. If failure of the test piece occurred during the test then use the ring bending tensile strength, σ_{rb}, determined in accordance with B.6.1, and the calculated value for q_{cr} is the crushing strength of the original pipe.

B.6.2.2 For pipes with a circular or kite-shaped cross-section, i.e. types PRC-OC, PRC-TC, PRC-OK or PRC-TK:

$$q_{cr} = \frac{\sigma_{rb}}{0{,}3} \times \frac{e^2}{3 \times d_i + 5 \times e} - \frac{7}{30} \times W_{pipe} \tag{B.8a}$$

where

- q_{cr} is the calculated crushing load or crushing strength, in newtons per millimetre of length (N/mm);
- σ_{rb} is the ring bending tensile stress or strength determined in accordance with B.6.1, in newtons per square millimetre (N/mm^2);
- d_i is the internal diameter of the original pipe, in millimetres (mm);
- e is the wall thickness of the original pipe, in millimetres (mm);
- W_{pipe} is the load due to own weight of the pipe, in newtons per millimetre of pipe length (N/mm).

B.6.2.3 For pipes with an egg-shaped cross-section, i.e. types PRC-OE or PRC-TE:

$$q_{\mathrm{cr}} = \frac{\sigma_{\mathrm{rb}}}{0{,}35} \times \frac{e^2}{3 \times w_{\mathrm{i}} + 5 \times e} - \frac{6}{35} \times W_{\mathrm{pipe}} \qquad \text{(B.8b)}$$

where

q_{cr} is the calculated crushing load or crushing strength, in newtons per millimetre of length (N/mm);

σ_{rb} is the ring bending tensile stress or strength determined in accordance with B.6.1, in newtons per square millimetre (N/mm^2);

w_{i} is the internal width of the original pipe with egg-shaped cross-section, in millimetres (mm);

e is the wall thickness of the original pipe at the top, in millimetres (mm);

W_{pipe} is the load due to own weight of the pipe, in newtons per millimetre of pipe length (N/mm).

B.7 Test report

The test report shall include the following information:

a) reference to this European Standard and this annex;

b) full identification of the pipe from which the test piece was obtained;

c) date, time and place of sampling;

d) number of test pieces made and tested and their identification numbers or codes;

e) dimensions of each test piece, if applicable its mass and calculated density;

f) for each test piece whether it failed or not;

g) for each test piece the minimum load to be applied to the test piece by the loading frame, P_{min}, if applicable;

h) for each test piece the maximum load applied during the test, P, including W^*;

i) for each test piece the value for σ_{b};

j) for each test piece the calculated value for f_{corr};

k) distance between the centres of the bearing beams, l_{b};

l) for each test piece the calculated value for q_{cr};

m) equipment details;

n) temperature during the test;

o) description of the test pieces after testing;

p) any factors that could have affected the results, such as any incidents or any operating details not specified in this European Standard;

q) date, time and place of testing.

Annex C
(normative)

Assessment of longitudinal bending moment resistance (BMR)

C.1 Scope

This test determines the capacity of a pipe to resist bending along its length when external loads are applied. The test is applicable to pipes of any nominal size having an external circular shape and laying lengths greater than six times their (vertical) internal diameter. Two test procedures are detailed using either a three-point or four-point loading arrangement.

C.2 Principle

This test is used to show compliance with the minimum requirements for the longitudinal bending moment resistance, specified in 5.4.2, of a pipe, by subjecting the test piece to a bending moment M_3 or M_4 from either a three-point or four-point loading arrangement. When testing using the three-point loading method, if the test piece fails in such a way as not to be “beam” failure (i.e. if crushing of an end occurs prior to the required test load being achieved) then the test has to be repeated using the four-point loading method.

C.3 Apparatus

C.3.1 Loading frame

A machine capable of applying a specified load to the test piece, at a steady rate between 6 kN and 9 kN per minute, through either two loading slings, when using a four-point loading arrangement or through a bearing block when using a three-point loading arrangement. The apparatus shall be substantially rigid throughout, so that the distribution of the load is not affected appreciably by the deformation or yielding of any part and shall transmit the load, without shock, to the test piece.

The machine shall be equipped with a means of measuring, indicating and recording the total load applied to the test piece to an accuracy within ± 2 % of the load applied.

C.3.2 Supports

C.3.2.1 General

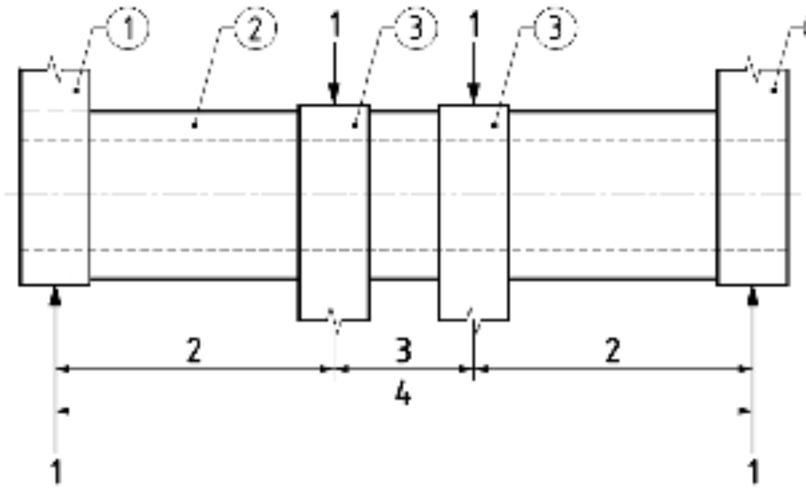
The arrangement of the supports shall be as shown in Figure C.1 or C.2 as applicable.

C.3.2.2 Slings

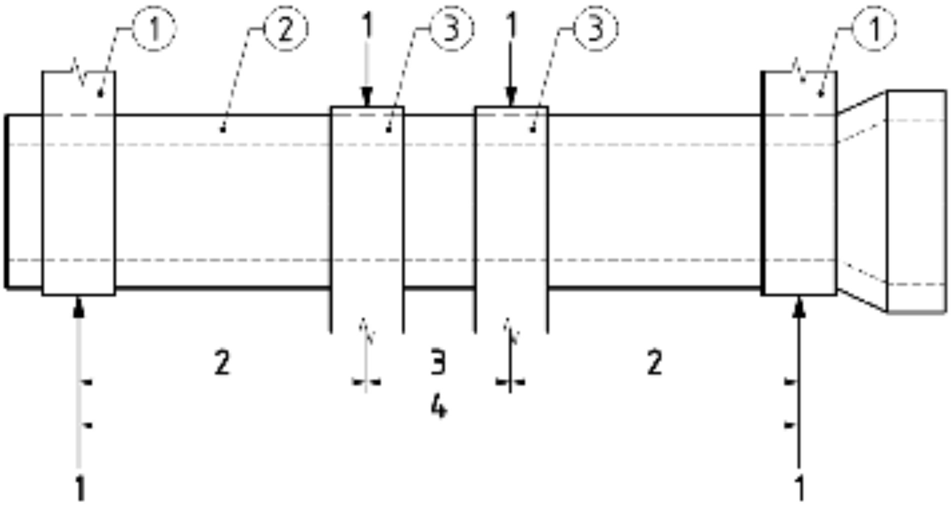
When using the four-point loading method the load shall be applied through slings having a width of 100 mm, and which are of sufficient strength. The slings shall be so designed that there is a contact angle of at least 120° around the test piece's circumference.

C.3.2.3 Bearing blocks

When using the three-point loading method the load shall be applied through blocks which are of sufficient strength, having a length of approximately 1,5 × DN and a width of (75 ± 5) mm. The block surface intended to be in contact with the test piece through at least 120° of its circumference shall match the test piece curvature and shall be lined with an elastomeric material having an IRHD of 55 ± 5 and a thickness of (20 ± 5) mm.



a) Test arrangement for a plain pipe



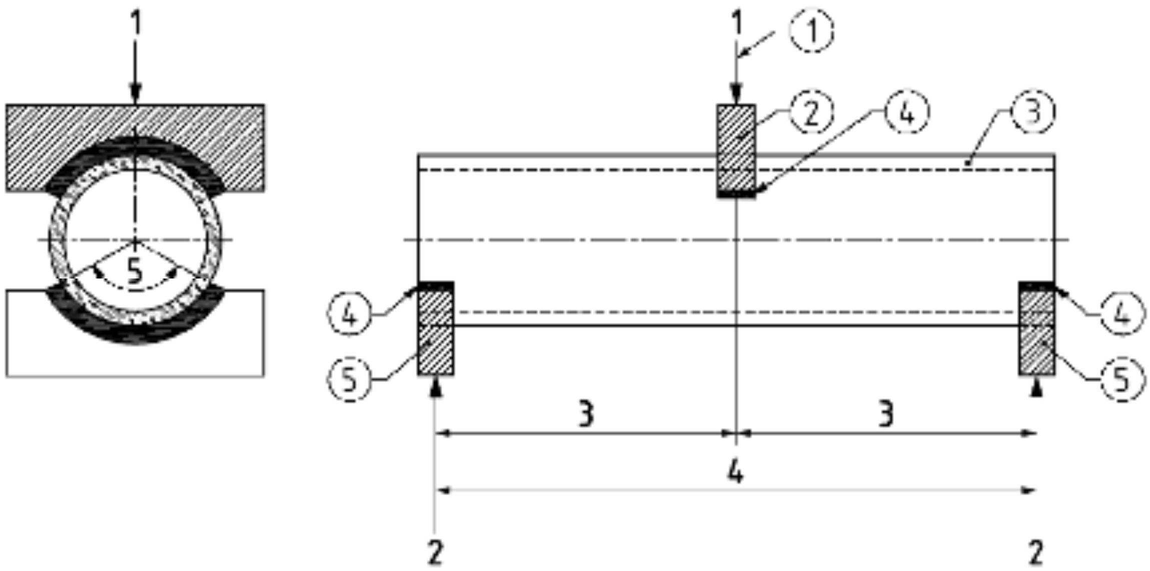
b) Test arrangement for a pipe with an integral socket

Key

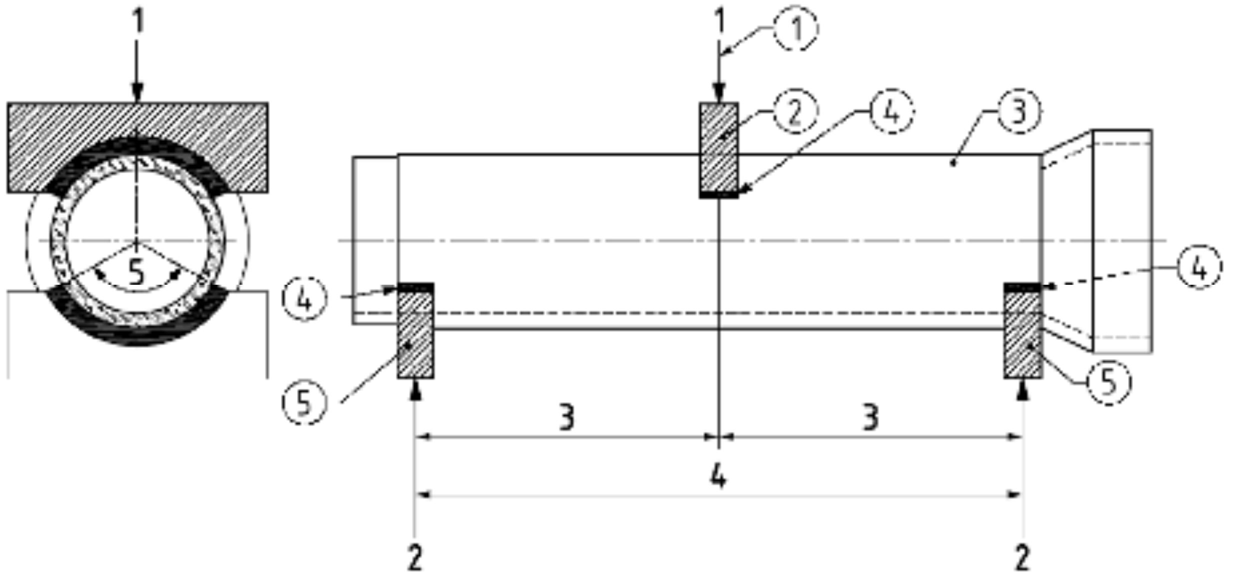
① supporting sling
② polyester resin concrete (PRC) test piece
③ loading sling

1 half the applied bending load, 0,5 × P_b
2 lever arm, l_a, 300 mm minimum
3 (300 ± 2) mm
4 supporting span, l_s, minimum [(6 × DN) – 100] mm

Figure C.1 — Arrangement for the four-point loading method



a) **Test arrangement for a plain pipe**



b) **Test arrangement for a pipe with an integral socket**

Key

① axis of load application
② load application bearer
③ polyester resin concrete (PRC) test piece
④ elastomeric material, (20 ± 5) mm thick
⑤ bottom bearing block, 1,5 DN high and (75 ± 5) mm wide

1 applied bending load, P_b
2 half the applied bending load, $0{,}5 \times P_b$
3 $0{,}5 \times l_b$
4 distance between centres of lower bearing blocks, l_b
5 120°

Figure C.2 — Arrangement for the three-point loading method

C.4 Procedure

C.4.1 General

Place the test piece in the loading frame and position it in the manner described C.4.2 or C.4.3, as appropriate. The test piece shall be a whole pipe or a short pipe with a length of at least either 1,0 m or six times its internal diameter, whichever is the greater.

NOTE When testing a whole pipe then use the laying length as the length of the test piece.

C.4.2 Four-point loading method

Support the test piece in a horizontal position on two slings complying with C.3.2.2 perpendicular to its longitudinal axis and symmetrical about the centre of its length. Place two loading slings on top of the test piece and symmetrical about the centre of the gap between the supporting slings. The distance between the centres of the loading slings shall be (300 ± 2) mm. For details of the arrangement see Figure C.1.

Attach the loading slings to the loading machine and apply the load as described under C.4.4.

C.4.3 Three-point loading method

This method is only usable when the mode of fracture is clearly “beam” failure (i.e. if no end crush occurs prior to the required test load being achieved). Should this not be the failure mode then this shall be recorded in the test report and the test repeated with another test piece but using the four-point loading method in accordance with C.4.2.

Support the test piece in a horizontal position on two bearing blocks complying with C.3.2.3, which shall be placed on a firm unyielding horizontal support. The distance between the centres of these bearing blocks shall be at least 0,15 m less than the length of the test piece and they shall be placed symmetrically about the centre of its length. Position the bearing block conforming to C.3.2.3, through which the load is to be applied, mid-way along the length of the test piece. For details of the arrangement see Figure C.2.

Using the loading machine, apply the load as described under C.4.4.

C.4.4 Load application

Apply the load continuously, at a rate of between 6 kN/min and 9 kN/min, to the test piece without sudden vibration or shock through the loading slings or the upper bearing block until the:

a) test piece fails, or

b) specified minimum longitudinal bending moment resistance, M_{BMR}, is reached, or

c) load is increased until the test piece fails.

Record the load applied and the appearance and dimensions of the test piece. Also record the spacing of the slings or the spacing of the bearing blocks.

C.5 Calculations

C.5.1 General

Calculate the longitudinal bending moment which the pipe resisted, M_3 or M_4, using the appropriate one of the following equations.

Compare the calculated value, M_3 or M_4, to the required longitudinal bending moment resistance, M_{BMR}, specified in 5.4.2.

C.5.2 When using the four-point loading method:

$$M_4 = P_b \times \frac{l_a}{2} \qquad \text{(C.1)}$$

where

M_4 is the calculated longitudinal bending moment resisted by the pipe when tested using four point loading, in kilonewton metres (kNm);

P_b is the total bending load applied, in kilonewtons (kN);

l_a is the lever arm length, i.e. 0,5 × (l_s – 0,3), in metres (m)

where

l_s is the support span, in metres (m);

C.5.3 When using the three-point loading method:

$$M_3 = P_b \times \frac{l_b}{4} \quad \text{(C.2)}$$

where

M_3 is the calculated longitudinal bending moment resisted by the pipe when tested using three point loading, in kilonewton metres (kNm);

P_b is the total bending load applied, in kilonewtons (kN);

l_b is the distance between the centres of the lower bearing blocks, in metres (m).

C.6 Test report

The test report shall include the following information:

a) reference to this European Standard and this annex;

b) full identification of the pipe tested, including the cross-sectional shape, i.e. C or K;

c) number of test pieces;

d) dimensions of each test piece;

e) whether the four-point or three-point loading method was used;

f) for each test piece the total bending load applied, P_b;

g) for each test piece the distance between the centres of the lower bearing blocks, l_b, if applicable;

h) for each test piece the lever arm length, l_a, the distance between the centres of the loading slings and the support span, l_s, if applicable;

i) for each test piece the calculated value for the bending moment resistance, M_3 or M_4;

j) for each test piece the specified minimum longitudinal bending moment resistance, M_{BMR};

k) for each test piece whether the failure was beam failure or not;

l) equipment details;

m) description of the test pieces after testing;

n) any factors that could have affected the results, such as any incidents or any operating details not specified in this European Standard;

o) date, time and place of testing.

Annex D
(normative)

Determination of the compressive strength of polyester resin concrete (PRC) using test pieces which are cut from a pipe

D.1 Scope

This annex describes a test method to determine the compressive strength of the polyester resin concrete (PRC) material used for the manufacture of pipes complying with this European Standard. The test is applicable to pipes having a circular, egg-shaped or kite-shaped cross-section of any nominal size. It includes requirements for cubes cut from pipes.

D.2 Principle

Test pieces are cubes cut from a pipe made from polyester resin concrete (PRC). The test pieces are crushed in accordance with the method described in this annex and from knowledge of the maximum load applied in newtons (N) and the dimensions of the test piece in millimetres (mm) the compressive strength is computed in newtons per square millimetre (N/mm^2). This property is used to show compliance with the minimum requirements specified in 5.4.3 and to calculate the capacity of the pipe to resist longitudinal loads in installation applications such as jacking.

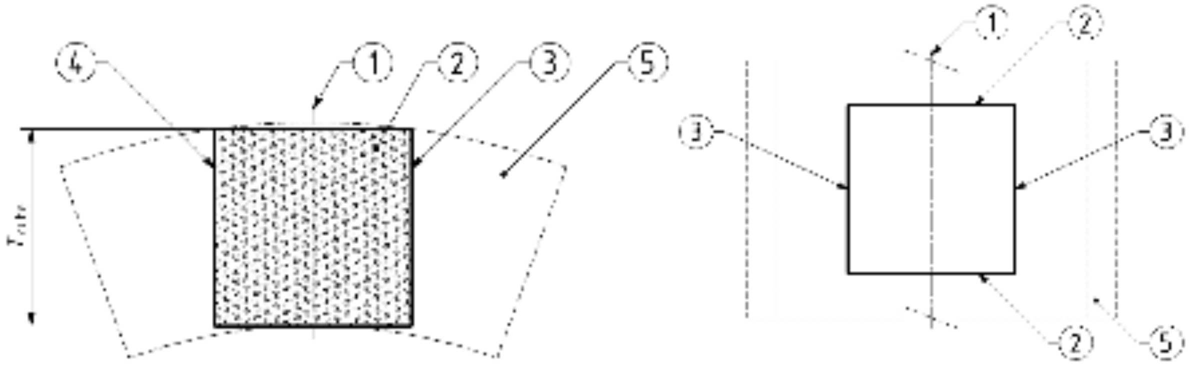
D.3 Apparatus

D.3.1 Masonry saw

A saw that is capable of cutting polyester resin concrete (PRC) test pieces to the form and accuracy required.

D.3.2 Measuring equipment

Equipment that is capable of determining the dimensions and the shape of test pieces to the accuracy that is required by the test method.

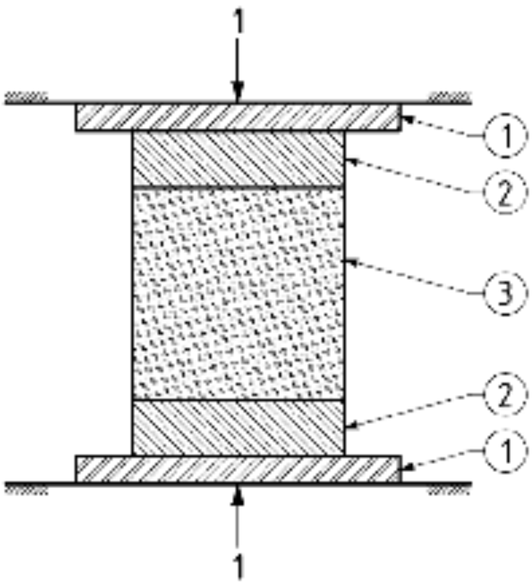


a) End view showing test piece in pipe wall **b) Plan view of test piece**

Key

① longitudinal axis of pipe
② test face of test piece
③ vertical face parallel to longitudinal axis
④ vertical face parallel to longitudinal axis
⑤ pipe wall
T_{cube} height, width and length of test piece

Figure D.1 — Details of test piece cut from a pipe



Key

① load application surface of loading frame
② 80 mm × 80 mm × 25 mm thick steel test platen
③ polyester resin concrete (PRC) test piece
1 load applied through centre line of loading frame

Figure D.2 — Test arrangement using test pieces cut from a pipe

D.3.3 Loading frame

A frame of sufficient rigidity so that the load will not be affected by the deformation or yielding of any part and shall transmit the load evenly to the test piece. The machine shall be capable of applying a compressive load at a controlled rate and without shock to a test piece and measuring, indicating and recording the maximum load applied. The indicated load shall be accurate to within ± 1 % of the indicated value.

D.3.4 Load application platens

Platens made of steel and having a thickness of at least 25 mm, through which the load is applied to the surfaces of the test piece. The load application surfaces shall be smooth and of a sufficient size to apply the load evenly over the test piece's upper and lower surfaces. The platens shall be 80 mm × 80 mm square.

D.4 Test pieces

Test pieces shall be obtained by cutting along planes which are parallel or perpendicular to the pipe's longitudinal axis. The width, height and length of the test piece shall be equal to T_{cube} in Figure D.1 a). The test piece's surfaces to be loaded shall be parallel and plane to within 0,2 mm. If the wall thickness of the pipe is such that the dimension T_{cube} is more than 80 mm then it is permissible to cut test pieces in the form of 80 mm cubes.

Before cutting test pieces inspect the polyester resin concrete (PRC) to ensure that it is free from damage.

D.5 Procedure

Ensure that all testing machine bearing surfaces are wiped clean and also the surfaces of the test piece which will be loaded in the test. The machines load application surfaces shall be larger than or equal to the test piece's loaded surface. Position a pair of platens as described in D.3.4 centrally in the machine. Centre the test piece in the machine (see Figure D.2).

Apply the load without shock at a rate between 10 N/mm^2 per minute and 20 N/mm^2 per minute. Continue until failure occurs and record the maximum load applied to the test piece. Inspect the test piece and note the nature of any unusual failure modes.

D.6 Calculations

Calculate the compressive strength by dividing the maximum load applied to the test piece, in newtons (N), by the cross-sectional area being loaded, in square millimetres (mm^2). Express the result to the nearest 0,5 N/mm^2.

D.7 Test report

The test report shall include the following information:

a) reference to this European Standard and this annex;

b) full identification of the pipe from which the test piece was obtained;

c) date, time and place of sampling;

d) number of test pieces made and tested and their identification numbers or code;

e) dimensions of each test piece and, if applicable, its mass and calculated density;

f) for each test piece whether or not it failed;

g) loaded area, maximum load at failure and calculated compressive strength;

h) appearance of the test piece after test;

i) details of test equipment;

j) temperature during test;

k) any factors that could have affected the results, such as any incidents or any operating details not specified in this European Standard;

l) date, time and place of testing.

Annex E
(normative)

Determination of the fatigue strength of a pipe under cyclic loading

E.1 Scope

This test assesses the capacity of a pipe to resist external cyclic loadings perpendicular to its axis along its length.

This test is applicable to pipes of any nominal size, having a circular, egg-shaped or kite-shaped cross-section.

The pipes are tested using test pieces which have been cut from them.

E.2 Principle

The test piece is subjected to a load cycling between an upper and lower limit, at a frequency not exceeding 12 Hz for a specified number of cycles, without failure.

The fatigue strength, σ_{fat}, is the difference between the upper limit of ring bending tensile stress σ_{up}, determined from the upper load, and the lower limit of ring bending tensile stress σ_{low}, determined from the lower load.

E.3 Apparatus

E.3.1 Loading frame

A machine capable of applying a cyclic compressive load to the test piece without shock or impact, until either the required minimum number of cycles is reached or the test piece fails. The cyclic load shall be applied between specified upper and lower limits at a frequency not exceeding 12 Hz.

The machine shall be sufficiently rigid so that the distribution of the load will not be affected by the deformation or yielding of any part and shall transmit the load in a vertical plane through the longitudinal centre lines of the test piece.

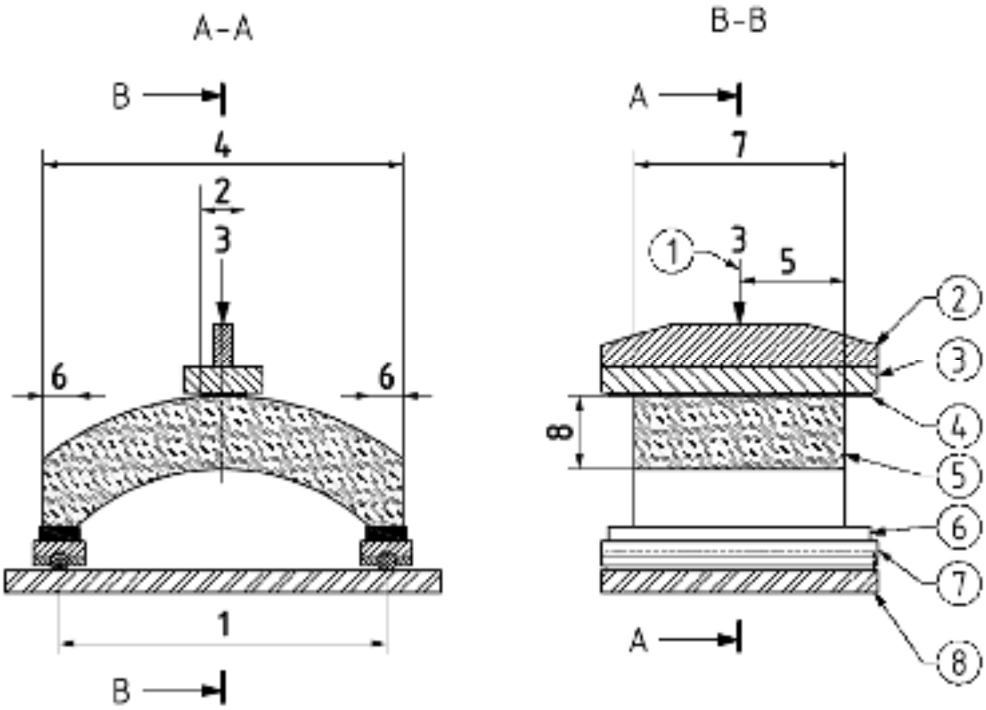
The load shall be applied in such a way that the combination of support and bearers is free to rotate in a vertical plane through the longitudinal centre lines of the top and bottom bearers.

Free movement of the bottom bearing beams shall be ensured.

The machine shall be equipped with a means of measuring, indicating and recording the upper and lower loads applied to the test piece accurate to within ± 2 % of the load applied. The machine shall also be equipped with a means of counting, indicating and recording the number of cycles completed.

E.3.2 Bearers and contact surfaces

The bearers shall be made of metal or a suitable hardwood, which is straight and free from warping, twisting or knots.



a) Cross-section

b) Longitudinal-section

Key

①	applied load, P	1	distance between bearers, l_b
②	compression edge	2	width of the top bearing strip, $a_b = 0,1 \times l_b$,
③	compression beam	3	axis of load application
④	elastomeric or felt facing 3 mm thick	4	length of test piece, $l_P = 5 \times e$
⑤	polyester resin concrete (PRC) test piece	5	location of applied load, $0,5 \times l_b$
⑥	elastomeric or felt facing 20 mm thick	6	width of the ground surface, $0,33 \times e$
⑦	metal roller bearer to provide movement	7	width of the test piece, $b = 3 \times e$
⑧	test machine base plate	8	wall thickness of test piece, e

Figure E.1 — Test arrangement for fatigue strength using test pieces cut from a pipe

The bearers shall have a thickness that is not less than 25 mm.

The load shall be applied through the compression beam.

The bottom bearing beams surfaces that are in contact with the test piece shall be in the form of facings to the beams (see Figure E.1). They shall either be of an elastomeric material, having a hardness of (55 ± 10) IRHD or of felt having a density of (0,3 ± 0,025) g/cm^3. The compression beam shall not have a facing, and the bottom bearing beams shall have a facing with a thickness of (20 ± 5) mm.

The bottom bearing beams shall be located centrally about the axis of load application on the bottom bearer.

Free movement of the bottom bearers shall be ensured.

E.4 Test pieces

The test piece shall be sawn from a pipe or a broken piece of a pipe. When testing pipes with kite-shaped or egg-shaped cross-section the test piece shall be taken from the top of the pipe.

The test piece shall have parallel boundary surfaces. Its length, l_p, shall be about five times the wall thickness, e, and its width, b, about three times the wall thickness. The longitudinal sides of the test piece shall be perpendicular to the generated surface of the pipe.

The test piece shall be ground at both ends so that the bearing strips, with a width of about one third of the wall thickness, form one single plane.

E.5 Procedure

Calculate the lower and upper loads to be applied to the test piece using Equations (E.1) or (E.2) as appropriate. Place the test piece horizontally and centrally on the bottom bearing beams. Set the machine to cycle between $P_{\text{calc,low}}$ and $P_{\text{calc,up}}$ and back to $P_{\text{calc,low}}$ at a frequency not exceeding 12 Hz.

NOTE The loads to be applied to the test piece include the loads due to own weight of the compression beam and the compression edge, if applicable.

Apply to the test piece at least 2×10^6 loading cycles which cycle between the calculated upper and lower load. The cycling test force shall be applied steadily until either the specified number of loading cycles is completed or the test piece fails. At the completion of the test record the number of cycles completed and the appearance and dimensions of the test piece.

E.6 Calculations

E.6.1 Upper and lower load

Calculate the upper and lower load to be applied, $P_{\text{calc,low}}$ and $P_{\text{calc,up}}$, using the appropriate one of the following equations:

$$P_{\text{calc,up}} = \sigma_{\text{rb,min}} \times \frac{2 \times b \times e^2}{3 \times l_\text{b} \times f_{\text{corr}}} \times f_{\text{up}} \quad \text{or} \tag{E.1}$$

$$P_{\text{calc,low}} = \sigma_{\text{rb,min}} \times \frac{2 \times b \times e^2}{3 \times l_\text{b} \times f_{\text{corr}}} \times f_{\text{low}} \tag{E.2}$$

where

$P_{\text{calc,up}}$, $P_{\text{calc,low}}$	are respectively the calculated upper or lower applied load, in newtons (N);
f_{up}, f_{low}	are respectively the factor for the upper (0,4) or the lower (0,1) load;
$\sigma_{\text{rb,min}}$	is the minimum ring bending tensile stress determined in accordance with Annex A or Annex B, in newtons per square millimetre (N/mm^2);
l_b	is the spacing between the centres of the bearing beams, in millimetres (mm);
b	is the width of the test piece, in millimetres (mm);
e	is the wall thickness of the test piece, in millimetres (mm);
f_{corr}	is the correction factor to allow for stress distribution in the curved beam, derived from Equation (E.3) or (E.4), as applicable:

$$f_{\text{corr}} = \frac{(3 \times d_\text{i}) + (5 \times e)}{(3 \times d_\text{i}) + (3 \times e)} \tag{E.3}$$

$$f_{\text{corr}} = \frac{(3 \times w_\text{i}) + (5 \times e)}{(3 \times w_\text{i}) + (3 \times e)} \tag{E.4}$$

where

d_i is the internal diameter of the original pipe, in millimetres (mm);

w_i is the horizontal internal width of pipe with egg-shaped cross-section, in millimetres (mm).

E.6.2 Fatigue strength

If the specified number of loading cycles is completed without failure calculate the fatigue strength using Equation (E.5):

$$\sigma_{fat} = \sigma_{up} - \sigma_{low} \tag{E.5}$$

where

σ_{fat} is the calculated fatigue strength, in newtons per square millimetre (N/mm²);

σ_{up} is the upper limit of the ring bending tensile stress determined from the upper load, in newtons per square millimetre (N/mm²) and is calculated using Equation (E.6);

$$\sigma_{up} = \sigma_{rb,min} \times f_{up} \tag{E.6}$$

where

$\sigma_{rb,min}$ is the minimum ring bending tensile stress determined in accordance with Annex A or Annex B, in newtons per square millimetre (N/mm²);

f_{up} is the factor for the upper (0,4) load;

σ_{low} is the lower limit of the ring bending tensile stress determined from the lower load, in newtons per square millimetre (N/mm²) and is calculated using Equation (E.7):

$$\sigma_{low} = \sigma_{rb,min} \times f_{low} \tag{E.7}$$

where

$\sigma_{rb,min}$ is the minimum ring bending tensile stress determined in accordance with Annex A or Annex B, in newtons per square millimetre (N/mm²);

f_{low} is the factor for the lower (0,1) load.

E.7 Test report

The test report shall include the following information:

a) reference to this European Standard and the this annex;

b) full identification of the pipe from which the test piece was obtained;

c) date, time and place of sampling;

d) number of test pieces made and tested and their identification numbers or codes;

e) dimensions of each test piece;

f) for each test piece the upper load, $P_{calc,up}$ and lower load, $P_{calc,low}$, applied;

g) for each test piece the calculated value for σ_{fat};

h) for each test piece the calculated value for f_{corr};

i) spacing between the centres of the bearing beams, l_b;

j) number of cycles completed by each test piece;

k) equipment details;

l) description of the test piece after testing;

m) any factors that could have affected the results, such as any incidents or any operating details not specified in this European Standard;

n) date, time and place of testing.

Annex F
(normative)

Assessment of the leak-tightness of a pipe and its joints under short term exposure to internal water pressure

F.1 Scope

This test method assesses whether or not a pipe and its joints are leak-tight under short-term internal water pressure. This test is applicable to pipes having a circular, egg-shaped or kite-shaped cross-section of any nominal size together with their joints.

WARNING: Attention is drawn to dangers associated with pressure and the need to apply all necessary precautions to prevent injury to the personnel near the test area.

F.2 Principle

A pipe is either installed in a test rig, which has platens that contain suitable joint profiles, or is joined to another pipe of the same classification. The thrust produced at the ends is transferred to the test rig and is not carried by the test piece. The test arrangement is filled with water, taking care to remove all air, and then pressurised to a specified pressure, which is maintained for 15 min. At the end of this time the test arrangement is inspected for signs of leakage or weeping. For the pipe and its joints to be considered leak-tight there shall not be any signs of leakage or weeping in either the joints or the pipe.

F.3 Apparatus

F.3.1 Test rig

Capable of holding the test arrangement for the duration of the test without transmitting loads to either the pipe or its joints.

F.3.2 End sealing devices

Suitable end sealing devices, such as end caps, internal stoppers or inflatable bags, that remain leak-tight for the duration of the test. Means shall be provided to prevent movement of the end sealing devices under pressure, and ensure that they do not transmit end thrust to the test piece.

F.3.3 Source of hydrostatic pressure

A source of hydrostatic pressure that is capable of controlling the test pressure to within ± 1 % of the specified value for the duration of the test.

F.4 Procedure

Either place the pipe in a test rig which has platens that contain suitable joint profiles or join two pipes or pipe sections with one flexible joint and clamp in a suitable test rig. If necessary seal the ends of the pipe using suitable end sealing devices.

Slowly fill the test arrangement with water, taking care to remove all air.

Using the source of hydrostatic pressure raise the test pressure, at a rate not exceeding 10 kPa (0,1 bar) in 1 s, until the specified test pressure is reached.

Maintain the test pressure within ± 2 % of the specified value for 15 min.

After 15 min inspect the outside of the pipe and the joints for signs of leakage, damp patches or water droplets. Record the result of the inspection.

F.5 Test report

The test report shall include the following information:

a) reference to this European Standard and this annex;

b) full identification of the pipe tested, including the cross-sectional shape, i.e. C, E or K;

c) joint details including dimensions and elastomeric seal details;

d) number of test pieces;

e) test pressure;

f) duration of the test or time to failure;

g) occurrence or absence of leakage;

h) equipment details;

i) any factors that could have affected the results, such as any incidents or any operating details not specified in this European Standard;

j) date, time and place of testing.

Annex G
(normative)

Determination of the long-term crushing strength of a pipe, including the effects of media attack, using the 50 years reference point

G.1 Scope

This test determines the capacity of a pipe to resist external long-term loadings perpendicular to its axis along its length, taking into account media attack. The test is applicable to pipes having a circular, egg-shaped or kite-shaped cross-section of any nominal size.

G.2 Principle

This test determines the long-term crushing strength of a pipe after being loaded for 50 years, by extrapolating the results of a long-term test series lasting at least 10 000 h. To take into account the influence of media attack the invert of the test piece, shall be exposed to one of the test solutions as described under G.5 and Figure G.1.

NOTE The method can be used to take into account the influence of any particular solution on the long-term crushing strength of a pipe.

The loadings for the test pieces shall be so selected that the times to failure are distributed over the test duration as described under G.6.

The short-term crushing strength of the pipe determined in accordance with Annex A is needed as a basis for the loading selection and also for the determination of the reduction factor.

If there is no value for the short-term crushing strength of the pipe to be tested then before starting the test series the pipe shall be tested with the method described in Annex A until failure occurs.

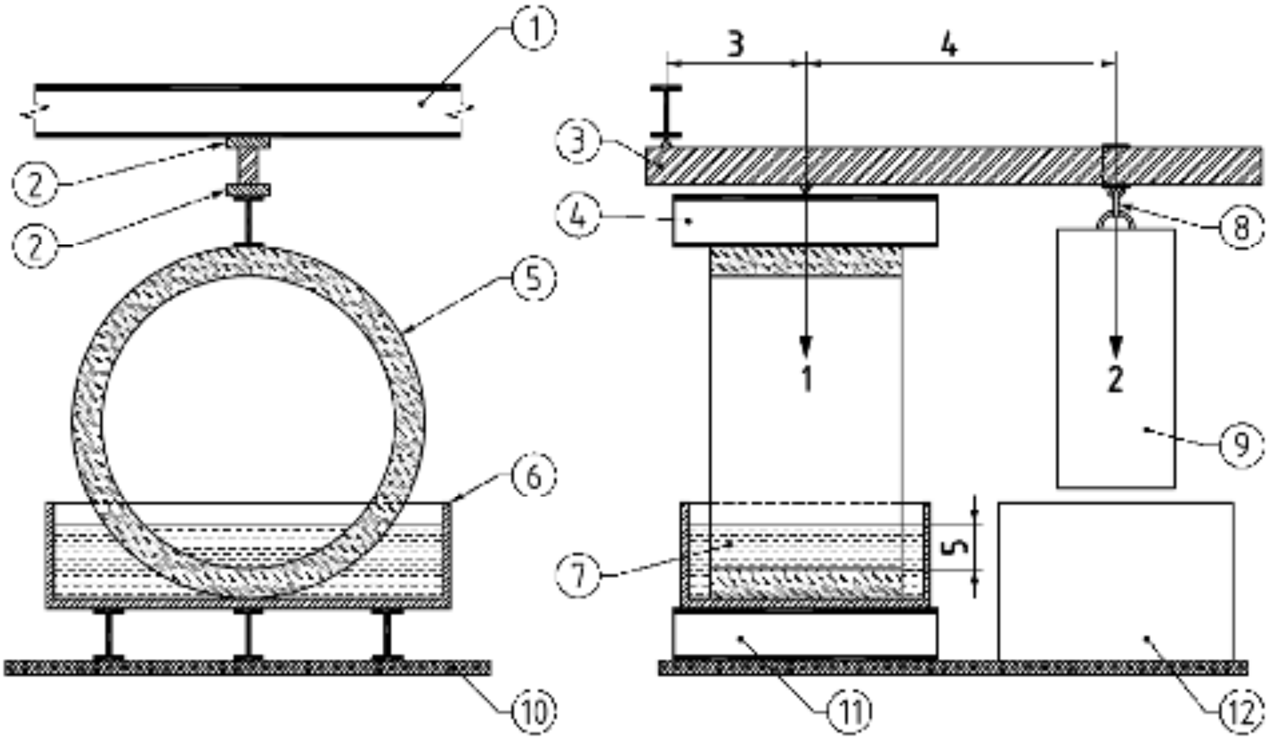
G.3 Apparatus

A machine capable of applying a compressive load permanently to the test piece, which shall be a pipe section having a minimum length as indicated in 5.4.1.2, until either the test has been carried out for not less than 10 000 h without failure or the test piece fails.

A typical arrangement of the test equipment is shown in Figure G.1. This apparatus consists of a rigid beam placed parallel to the floor, a rigid work-arm to introduce the load and with a means of attaching weights on one end, a rigid bearing beam parallel to the floor, rigid support beams, a container, if required, suitable for carrying the test solution, weights and a drop protection for the weights.

The surfaces in contact with the test piece shall be hard, flat, smooth and clean.

The components of the test apparatus shall be rigid enough to prevent any visible deformation during the test.



a) **Cross-section** b) **Longitudinal-section**

Key

①	rigid beam	⑩	bearing plate
②	fulcrum	⑪	supports
③	work arm	⑫	weight drop protection
④	compression beam	1	load applied to test piece
⑤	test piece	2	mass of weights
⑥	container (if required)	3	distance between fulcrums, l_f
⑦	test solution	4	lever arm, l_a
⑧	moveable weight hanger	5	minimum depth of test liquid at invert, 25 mm
⑨	weights		

Figure G.1 — Typical test arrangement for the long-term crushing strength test

G.4 Test pieces

The test pieces for the same test series shall come from pipes of the same type, nominal size and strength class.

The test pieces shall be pipe sections with a length not less than the requirements of 5.4.1.2. The ends of the test piece shall be cut plane and perpendicular to the pipe axis.

Two straight longitudinal lines, functioning as reference lines, are drawn on the pipe's inner or outer surface at 180° to each other.

At least 18 test pieces are required for one test series.

G.5 Test solutions

G.5.1 Acid test solution (1 N)

The acid test solution shall be a 0,5 mol/l sulfuric acid solution c(H_2SO_4) prepared by adding 28,5 ml of concentrated sulfuric acid (1,84 g/ml) to 971,5 ml of distilled water to produce 1 litre of test solution. The acid test solution shall be a 0,5 mol/l sulfuric acid solution c(H_2SO_4) prepared by adding 28,5 ml of concentrated sulfuric acid (1,84 g/ml) to 971,5 ml of distilled water to produce 1 litre of test solution.

G.5.2 Alkali test solution (pH 10)

The alkali test solution shall be a buffer solution of sodium carbonate (Na_2CO_3) and sodium bicarbonate ($NaHCO_3$) prepared by dissolving 2,640 g of sodium carbonate and 2,092 g of sodium bicarbonate in 800 ml of distilled water and then topping up to make 1 000 ml of test solution.

G.6 Procedure

Determine the short term crushing strength of a pipe of the same size and classification, in accordance with Annex A.

Place a test piece in the container, which is supported by rigid beams. Fill the container with the test solution to a level sufficient to cover the invert of the test piece to a minimum depth of 25 mm.

The concentration of the test solution shall be maintained throughout the test and if necessary corrected.

The test shall be carried out at a temperature maintained between (23 ± 5) °C for the duration of the test.

The load is introduced by concrete weights hanging from the work arms of the individual devices as shown in Figure G.1.

For the test series a minimum of 18 failure points is required to determine the regression graph. Select the range of loadings so that the times to failure are distributed between 0,1 h and over 10 000 h, and the distribution of these failure points shall conform to Table G.1.

For the duration of the test series check each test piece at least at the frequency stated in Table G.2.

The test on an individual test piece is deemed to have been completed when either the:

a) test piece fails, or

b) test has been carried out for no less than 10 000 h without failure.

Whenever a test piece fails the load applied and the time to failure shall be recorded.

Table G.1 — Failure point distribution

Test duration in hours	Minimum number of failure points
10 to 1 000 h	4
1 000 to 6 000 h	3
6 000 to 10 000 h	2
more than 10 000 h	1
NOTE The distribution of the other failure points is not specified.	

Table G.2 — Frequency of test piece inspections

Test duration in hours	Checking times
0 to 20 h	every hour
20 to 40 h	every 2 h
40 to 60 h	every 4 h
60 to 100 h	every 8 h
100 to 600 h	every 24 h
600 to 6 000 h	every 48 h
after 6 000 h	every week

G.7 Evaluation - Long-term (50 years) crushing strength

Determine the long-term crushing strength of a pipe being loaded for 50 years by making an extrapolation with the data from a test series using Method A in EN 705. The crushing strengths used in the analysis shall be expressed as a percentage of the initial strength. The test pieces, which have not failed after 10 000 h, may be included as failures to establish the regression line. If required the values can be represented in a double logarithm co-ordinate grid, with time to failure being entered on the X-axis and crushing strength expressed as a percentage of the initial strength entered on the y-axis.

G.8 Test report

The test report shall include the following information:

a) reference to this European Standard and this annex;

b) full identification of the pipe tested, including the cross-sectional shape i.e. C, E or K;

c) number of test pieces;

d) dimensions of each test piece;

e) length of the lever arm, la and distance between fulcrums, lf;

f) crushing load and time applied to failure for each test piece;

g) times of checking for each test piece;

h) control of composition and concentration of the test solution and the procedure used;

i) for each test series the short-term crushing strength;

j) for each test series the extrapolated long-term crushing strength (50 years);

k) equipment details;

l) temperature during the test;

m) description of the test pieces after testing;

n) any factors that could have affected the results, such as any incidents or any operating details not specified in this European Standard;

o) date, time and place of testing.

Bibliography

[1] EN 476, *General requirements for components used in discharge pipes, drains and sewers for gravity systems*

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