BRITISH STANDARD

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598 : 1995

Ductile iron pipes, fittings, accessories and their joints for sewerage applications —

Requirements and test methods

The European Standard EN 598 : 1994 has the status of a British Standard

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Committees responsible for this British Standard

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Adhesive Tape Manufacturers' Association
British Foundry Association
Ductile Iron Pipe Committee
Institute of British Foundrymen
Institution of Mechanical Engineers
Institution of Water and Environmental Management
Pipeline Protection Association
Society of British Water Industries
Water Companies Association
Water Research Centre
Water Services Association of England and Wales

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Contents

National foreword

This British Standard has been prepared under the direction of the Piping Systems Components Standards Policy Committee and is the English language version of EN 598 : 1994 *Ductile iron pipes, fittings, accessories and their joints for sewerage application - Requirements and test methods*, published by the European Committee for Standardization (CEN).

EN 598 was produced as a result of international discussion in which the UK took an active part.

Cross-references

International standard	Corresponding British Standard
EN 196-1 : 1989	BS EN 196 *Methods of testing cement* Part 1 : 1987 *Determination of strength*
EN 545 : 1994	BS EN 545 : 1995 *Ductile iron pipes, fittings, accessories and their joints for water pipelines*
EN 10002-1 : 1990	BS EN 10002 *Tensile testing of metallic materials* Part 1 : 1990 *Method of test at ambient temperature*
EN 29002 : 1987	BS 5750 *Quality systems* Part 2 : 1987 *Specification for production and installation*
EN 45012 : 1989	BS 7512 : 1989 *General criteria for certification bodies operating quality system certification*

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English version

Ductile iron pipes, fittings, accessories and their joints for sewerage applications - Requirements and test methods

Tuyaux, raccords et accessoires en fonte ductile et leurs assemblages pour l'assainissement - Prescriptions et méthodes d'essai

Rohre, Formstücke, Zubehörteile aus duktilem Gußeisen und ihre Verbindungen für die Abwasser-Entsorgung - Anforderungen und Prüfverfahren

This European Standard was approved by CEN on 1994-09-06. CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

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

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CEN

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Foreword

This European Standard was prepared by AHG2, Sewerage pipelines, of CEN/TC 203, Cast iron pipes, fittings and their joints, of which the secretariat is held by AFNOR.

It is one of a series of standards for cast iron products for pipelines for various applications.

This European Standard has been prepared under a Mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements or EC Directive(s).

It deals with the subjects covered by the International Standards ISO 7186, ISO 4179 and ISO 8179. The major differences are the presentation in one single standard and the addition of product performance specifications.

This standard is in conformity with the general requirements already established by CEN/TC 165 in the field of sewerage.

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 March 1995, and conflicting national standards shall be withdrawn at the latest by March 1995.

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

Contents

1 Scope

This European Standard specifies the requirements and associated test methods applicable to ductile iron pipes, fittings, accessories and their joints for the construction of drains and sewers outside buildings:

— Operating without pressure, or with positive or negative pressure.

— Installed below or above ground.

— For conveyance of surface water, domestic waste water and certain types of industrial effluents, either in separate systems or in mixed systems.

NOTE. In this standard, all pressures are relative pressures, expressed in bars (100 kPa = 1 bar).

This standard specifies products for gravity sewerage pipelines, for negative pressure pipelines and for pipelines operating at pressures which do not normally exceed 6 bar. For higher-pressure applications, special pipe thickness may be required by agreement between manufacturer and purchaser.

This standard specifies requirements for materials, dimensions and tolerances, mechanical properties and standard coatings of ductile iron pipes and fittings. It also gives performance requirements for all components including joints.

This standard covers pipes, fittings and accessories cast by any type of foundry process or manufactured by fabrication of cast components, as well as corresponding joints, of a size range extending from DN 100 to DN 2000 inclusive.

This standard applies to pipes, fittings and accessories which are:

— manufactured with socketed, flanged or spigot ends for jointing by means of various types of gaskets which are not within the scope of this standard;

— normally delivered externally and internally coated;

— suitable for fluid temperatures up to 50 °C excluding frost.

2 Normative references

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

EN 196-1 : 1989	*Methods of testing cement - Determination of strength*
prEN 476 : 1991	*General requirements for components used in discharge pipes, drains and sewers for gravity systems*
EN 545 : 1994	*Ductile iron pipes, fittings, accessories and their joints for water pipelines. Requirements and test methods*
EN 10002-1 : 1990	*Metallic materials - Tensile testing* Part 1: *Method of test (at ambient temperature)*
EN 29002 : 1987	*Quality systems - Model for quality assurance in production and installation*
EN 45012 : 1989	*General criteria for certification bodies operating quality system certification*
ISO 4633 : 1983	*Rubber seals - Joint rings for water supply, drainage and sewerage pipelines - Specification for materials*
ISO 6506 : 1981	*Metallic materials - Hardness tests - Brinell test*
ISO 6708 : 1980	*Pipe components - Definition of nominal size*
ISO 7268 : 1983	*Pipe components - Definition of nominal pressure*
ISO 7268/A1 1984	*Pipe components - Definition of nominal pressure - Amendment 1*
ISO 7483 : 1991	*Dimensions of gaskets for use with flanges to ISO 7005*

3 Definitions

For the purposes of this standard, the following definitions apply.

3.1 ductile iron

Cast iron used for pipes, fittings and accessories in which graphite is present substantially in spheroidal form.

3.2 pipe

Casting of uniform bore, straight in axis, having either socket, spigot or flanged ends, except for flanged-socket pieces, flanged-spigot pieces and collars which are classified as fittings.

3.3 fitting

Casting other than a pipe which allows pipeline deviation, change of direction or bore. In addition flanged-socket pieces, flanged-spigot pieces and collars are also classified as fittings.

3.4 accessory

Any casting other than a pipe or fitting which is used in a pipeline, e.g.

- inspection chambers (see **3.5**);
- manholes (see **3.6**);
- glands and bolts for mechanical flexible joints (see **3.15**);
- glands, bolts and locking rings for restrained flexible joints (see **3.16**);
- adjustable flanges and flanges to be welded or screwed-on.

3.5 inspection chamber

Component of a discharge system, of a drain or of a sewer providing access from the ground surface for inspection and maintenance equipment.

3.6 manhole

Component of a sewer of sufficient size to provide access from the ground surface for inspection and maintenance operations by personnel and equipment.

3.7 flange

Flat circular end of a pipe or fitting extending perpendicular to its axis, with bolt holes equally spaced on a circle.

NOTE. A flange may be fixed (e.g. integrally cast or welded-on) or adjustable; an adjustable flange comprises a ring, in one or several parts assembled together, which bears on an end joint hub and can be freely rotated around the pipe axis before jointing.

3.8 collar; coupling

Connecting piece used to join together the spigots of mating pipes or fittings.

3.9 spigot

Male end of a pipe or fitting.

3.10 socket

Female end of a pipe or fitting to make the connection with the spigot of the next component.

3.11 gasket

Sealing component of a joint.

3.12 joint

Connection between the ends of two pipes and/or fittings in which a gasket is used to effect a seal.

3.13 flexible joint

Joint which permits significant angular deflection both during and after installation and which can accept a slight offset of the centreline.

3.14 push-in flexible joint

Flexible joint assembled by pushing the spigot through the gasket in the socket of the mating component.

3.15 mechanical flexible joint

Flexible joint in which sealing is obtained by applying pressure to the gasket by mechanical means, e.g. a gland.

3.16 restrained flexible joint

Flexible joint in which a means is provided to prevent separation of the assembled joint.

3.17 flanged joint

Joint between two flanged ends.

3.18 nominal size DN

Numerical designation of size which is common to all components in a piping system. It is a convenient round number for reference purposes and is only loosely related to manufacturing dimensions. (See ISO 6708.)

3.19 nominal pressure PN

Numerical designation expressed by a number which is used for reference purposes. All components of the same nominal size DN designated by the same PN number have compatible mating dimensions. (See ISO 7268 and ISO 7268/A1.)

3.20 diametral stiffness of a pipe

Characteristic of a pipe which allows it to resist ovalization under loading when installed.

3.21 discharge system

System of pipes, fittings, accessories and joints used to collect and drain waste water and rainwater of a building; it comprises discharge pipes, stack ventilation pipes and rainwater downpipes, installed within the limits of a building or attached to the building.

3.22 drain

System of pipes, fittings, accessories and joints installed outside the limits of a building in order to connect the discharge system of this building to a sewer or a septic tank.

3.23 sewer

Pipeline designed to collect waste water and rainwater from buildings and surface water and to convey them to the point of disposal or treatment.

3.24 gravity sewer

Sewer operating normally under free flowing conditions.

3.25 pressure sewer; pumping sewer

Sewer (or section of a sewer) operating under positive pressure.

3.26 vacuum sewer

Sewer operating under negative pressure.

3.27 combined system

Sewerage system collecting together rainwater, surface water and waste water.

3.28 separate system

Sewerage system where are separately collected:

- rainwater and surface water;
- waste water.

3.29 batch

Quantity of castings from which a sample is taken for testing purposes during manufacture.

3.30 type test

Proof of design test which is done once and is repeated only after change of design.

3.31 length

Effective length of a pipe or fitting (see figure in **9.1**).

NOTE. For flanged pipes and fittings, the effective length L is equal to the overall length. For socketed pipes and fittings, the effective length L_{u} is equal to the overall length minus the spigot insertion depth as given in the manufacturer's catalogues.

3.32 ovality

Out of roundness of a pipe section; it is equal to

$$100 \left(\frac{A_1 - A_2}{A_1 + A_2} \right)$$

where:

A_1 is the maximum axis, in millimetres;

A_2 is the minimum axis, in millimetres.

4 Technical requirements

4.1 General

4.1.1 *Ductile iron pipes and fittings*

Nominal sizes, thicknesses, lengths and coatings are specified in clause **4**. When, by agreement between manufacturer and purchaser, pipes and fittings with different wall thicknesses, lengths and/or coatings and other types of fittings than those given in **9.2** and **9.3**, are supplied with reference to this standard, they shall comply with all the other requirements of this standard.

NOTE 1. Other types of fittings include tees and tapers with other combinations DN × dn, draining tees, etc.

The standardized nominal sizes, DN of pipes and fittings are as follows: 100, 125, 150, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1 000, 1 100, 1 200, 1 400, 1 500, 1 600, 1 800, 2 000.

NOTE 2. These DN values are DN/ID in the meaning of prEN 476.

The functional properties of ductile iron pipes and fittings shall be as given in clause **5**.

NOTE 3. When installed and operated under the conditions for which they are designed (see annexes A to C) ductile iron pipes, fittings, accessories and their joints maintain all their functional characteristics over their operating life, due to the constant material properties, to the stability of their cross section and to their design with high safety factors.

4.1.2 *Surface condition and repairs*

Pipes, fittings and accessories shall be free from defects and surface imperfections which could lead to non-compliance with clauses **4** and **5**.

When necessary, pipes and fittings may be repaired, for example by welding, in order to remove surface imperfections and localized defects which do not affect the entire wall thickness, provided that:

- the repairs are carried out according to a written procedure included in the manufacturer's quality assurance system;
- the repaired pipes and fittings shall comply with all the requirements of clauses **4** and **5**.

4.1.3 *Types of joints and interconnection*

4.1.3.1 *General*

Joint design and gasket shapes are outside the scope of this standard.

Rubber gasket materials shall comply with the requirements of ISO 4633. When materials other than rubber are necessary (e.g. for flanged joints), they shall comply with the appropriate EN standard or where no EN standard exists, the appropriate ISO standard.

4.1.3.2 *Flanged joints*

The dimensions and tolerances of the flanges of pipes and fittings shall comply with prEN 1092-2 and flange gaskets with ISO 7483. This ensures interconnection between all flanged components (pipes, fittings, valves, etc.) of the same PN and DN and adequate joint performance.

Although it does not affect interconnection, the manufacturer shall state in his catalogues whether his products are normally delivered with fixed flanges or adjustable flanges.

4.1.3.3 *Flexible joints*

Pipes and fittings with flexible joints shall comply with **4.2.1.1** for their spigot external diameters DE and their tolerances. This offers the possibility of interconnection between components equipped with different types of flexible joints. In addition, each type of flexible joint shall be designed to fulfil the performance requirements of clause **5**.

NOTE 1. For interconnection with certain types of joints operating within a tighter tolerance range on DE, the manufacturer's guidance should be followed as to the means of ensuring adequate joint performance at high pressures (e.g. measurement and selection of external diameter).

NOTE 2. For interconnection with existing pipelines which may have external diameters not in compliance with **4.2.1.1**, the manufacturer's guidance should be followed as to the appropriate means of interconnection (e.g. adaptors).

4.1.4 *Colour identification*

Pipes and fittings for sewers and drains shall be identified externally by one of the following colours: brown, red or grey.

NOTE. This is to allow easy identification of installed sewers and drains and to avoid mistaking with pipelines for water and gas supply.

4.2 Dimensional requirements

4.2.1 *Diameter*

4.2.1.1 *External diameter*

Subclause **9.1** specifies the values of the external diameter DE of the spigot ends of pipes and fittings and their maximum allowable tolerances, when measured using a circumferential tape in accordance with **6.1.1**.

NOTE 1. Certain types of flexible joints operate within a tighter range of tolerance (see **4.1.3.3**).

For DN ≤ 300, the external diameter of the pipe barrel measured with a circumferential tape shall be such as to allow the assembly of the joint over at least two thirds of the pipe length from the spigot end. For DN > 300, the same applies to a percentage of the pipes, when they need to be cut on site, after agreement between manufacturer and purchaser.

In addition, the ovality (see **3.32**) of the spigot end of pipes and fittings shall:

— remain within the tolerances on DE (see table 11) for DN 100 to DN 200;

— not exceed 1 % for DN 250 to DN 600 or 2 % for DN > 600.

NOTE 2. The manufacturer's guidance should be followed as to the necessity and means of ovality correction; certain types of flexible joints can accept the maximum ovality without a need for spigot re-rounding prior to jointing.

4.2.1.2 *Internal diameter*

The nominal values of the internal diameters of centrifugally cast pipes, expressed in millimetres, are equal to the numbers indicating their nominal size, DN, and the tolerances shall be as given in table 1 which apply to lined pipes.

NOTE 1. These tolerances apply to the pipe thicknesses given in table 11 and to the internal cement mortar lining thicknesses given in table 4. Where thicker iron and/or lining thicknesses are agreed between manufacturer and purchaser, these tolerances do not apply.

NOTE 2. Due to the manufacturing process of iron pipes and their internal linings, internal diameters with a maximum negative tolerance will only appear locally along the pipe length.

Compliance shall be demonstrated either by direct measurement according to **6.1.2** or by calculation from the measurements taken for pipe external diameter, iron wall thickness and lining thickness.

Table 1

DN	Tolerance[1] mm
100 to 1 000	− 10
1 100 to 2 000	− 0,01 DN

[1] A negative tolerance only is given.

4.2.2 *Wall thickness*

When measured in accordance with **6.1.3**, the minimum iron thicknesses of socket and spigot pipes shall be in conformity with those given in table 11; they are such that the diametral stiffnesses of pipes are not less than the values shown in table 10.

The minimum iron thicknesses of fittings shall be equal to or higher than those of pipes of the same DN.

4.2.3 *Length*

Socket and spigot pipes shall be supplied with the standardized lengths given in table 2.

Table 2

DN	Standardized length L_u [1] m
100 to 600	5 or 5,5 or 6
700 and 800	5,5 or 6 or 7
900 to 1 400	6 or 7 or 8,15
1 500 to 2 000	8,15

[1] See **3.31**.

In addition, pipes shall be designed to a length which shall be within ± 150 mm of the standardized length and shall be given in the manufacturer's catalogues.

Of the total number of socket and spigot pipes to be supplied in each diameter, the percentage of shorter pipes shall not exceed 10 %, in which case the length reduction shall be:

— up to 0,15 m for the pipes in which samples have been cut for testing (see **4.3**);

— up to half the standard length by increments of 0,5 m for DN < 700 and 0,1 m for DN ≥ 700.

When measured in accordance with **6.1.4** the length of pipes shall be within a manufacturing tolerance of ± 30 mm.

4.2.4 *Straightness of pipes*

Pipes shall be straight, with a maximum deviation of 0,125 % of their length.

The verification of this requirement is usually carried out by visual inspection, but in case of doubt or in dispute the deviation shall be measured in accordance with **6.2**.

4.2.5 *Flanged pipes*

The dimensions of flanged pipes shall comply with EN 545 and **4.2.2** of this standard.

4.2.6 *Fittings*

The usual types and sizes of fittings shall be those given in **9.2** and **9.3**; for lengths, see the manufacturer's catalogues.

Other fittings may be supplied as long as they comply with the other requirements of this standard (see **4.1.1**).

4.2.7 *Inspection chambers*

Inspection chambers (see **3.5**) shall be manufactured either as an integral item or by site assembly of a bottom part (inspection tee) and a vertical part.

Opening dimensions shall be as follows: 250 mm, 300 mm, 400 mm, 600 mm.

4.2.8 *Manholes*

Manholes (see **3.6**) shall comprise a vertical part of DN ≥ 800, a bottom plate, a top plate capable of receiving a frame and a manhole cover, and two or more inlets/outlets fixed to the vertical part.

The number and location of the inlets/outlets shall be agreed between the manufacturer and the purchaser and shall preserve the hydraulic continuity inside the manhole.

4.3 Material characteristics

4.3.1 *Tensile properties*

Pipes, fittings and accessories of ductile iron shall have the tensile properties given in table 3.

Table 3

Type of casting	Minimum tensile strength, R_m MPa	Minimum elongation after fracture, A %	
	DN 100 to DN 2 000	DN 100 to DN 1 000	DN 1 100 to DN 2 000
Pipes centrifugally cast	420	10	7
Pipes not centrifugally cast, fittings and accessories	420	5	5

NOTE. By agreement between manufacturer and purchaser, the 0,2 % proof stress ($R_{p0,2}$) may be measured. It shall be not less than:
- 270 MPa when $A \geq 12$ % for DN 100 to DN 1 000 or $A \geq 10$ % for DN > 1 000;
- 300 MPa in other cases.

During the manufacturing process the manufacturer shall carry out suitable tests in order to verify these tensile properties; these tests may be:

a) either a batch sampling system whereby samples are obtained from the pipe spigot or, for fittings, from samples cast separately or integrally with the castings concerned. Test bars shall be machined from these samples and tensile tested in accordance with **6.3**; or

b) a system of process control (e.g. by non-destructive testing) where a positive correlation can be demonstrated with the tensile properties specified in table 3. Testing verification procedures shall be based on the use of comparitor samples having known and verifiable properties. This system shall be supported by tensile testing in accordance with **6.3**.

4.3.2 *Hardness*

The hardness of the various components shall be such that they can be cut, drilled, tapped and/or machined with normal tools. In case of dispute, the hardness shall be measured by the Brinell hardness test in accordance with **6.4**.

The Brinell hardness shall not exceed 230 HB for pipes and 250 HB for fittings and accessories. For components manufactured by welding, a higher Brinell hardness is allowed in the heat affected zone of the weld.

4.4 Coatings and linings for pipes

4.4.1 *General*

Unless otherwise agreed between manufacturer and purchaser, all pipes shall be delivered with:

— an external coating of zinc with finishing layer in accordance with **4.4.2**;

— an internal lining of high alumina cement mortar in accordance with **4.4.3**;

— an epoxy-based coating on the end surfaces which can come into contact with the effluents (internal surface of the socket and external surface of the spigot).

Their field of use is given in annexes A and B.

By agreement between manufacturer and purchaser, the following coatings may also be supplied depending on external and internal conditions of use which may be different from those given in annexes A and B.

a) External coatings:

- zinc rich paint coating with finishing layer;
- thicker metallic zinc coating with finishing layer;
- polyethylene sleeving (as a supplement to the zinc coating with finishing layer);
- extruded polyethylene;
- extruded polypropylene;
- polyurethane;
- fibre cement mortar;
- adhesive tapes.

b) Internal coatings (linings):

- blast furnace cement mortar lining;
- polyurethane;
- polyethylene;
- epoxy resin.

These external and internal coatings shall comply with the corresponding EN standards or, where no EN standard exists, they shall comply with ISO standards or with national standards, or with an agreed technical specification.

4.4.2 *External coating of zinc with finishing layer*

4.4.2.1 *General*

The external coating of centrifugally cast ductile iron pipes shall comprise a layer of metallic zinc, covered by a finishing layer of a bituminous product or synthetic resin compatible with zinc. Both layers shall be works-applied by spraying with suitable spray-guns, the design of which is outside the scope of this standard.

The zinc is normally applied on oxide-surfaced pipes after heat treatment; at the manufacturer's option, it may also be applied on blast-cleaned pipes. Prior to application of the zinc, the pipe surface shall be dry and free from rust or non-adhering particles or foreign matter such as oil or grease.

4.4.2.2 *Coating characteristics*

The metallic zinc coating shall cover the external surface of the pipe and provide a dense, continuous, uniform layer. It shall be free from such defects as bare patches or lack of adhesion.

The uniformity of the coating shall be checked by visual inspection.

When measured in accordance with **6.5**, the mean mass of zinc per unit area shall be not less than 130 g/m^2 with a local minimum of 110 g/m^2.

4.4.2.3 *Repairs*

Damage to coatings where the area of total removal of metallic zinc has a width exceeding 5 mm and areas left uncoated (e.g. under test token, see **6.5**) shall be repaired.

Repairs shall be carried out either by:

a) metallic zinc spray complying with **4.4.2**; or

b) application of zinc-rich paint containing at least 90 % zinc by mass of dry film; the mean mass of applied paint shall be not less than 150 g/m^2.

4.4.2.4 *Finishing layer*

It shall uniformly cover the whole surface of the metallic zinc layer and be free from such defects as bare patches or lack of adhesion.

The uniformity of the finishing layer shall be checked by visual inspection.

When measured in accordance with **6.6**, the mean thickness of the finishing layer shall be not less than 70 μm and the local minimum thickness not less than 50 μm.

4.4.3 *Internal lining of high alumina cement mortar*

4.4.3.1 *General*

The cement mortar lining of ductile iron pipes shall constitute a dense, homogeneous layer covering the total internal surface of the pipe barrel.

It shall be works-applied by centrifugal spinning or by means of a centrifugal applicator head or by a combination of these methods. Smoothing with a trowel is permitted.

Prior to application of the lining, the metal surface shall be free from loose material and oil or grease.

The cement mortar mix shall comprise high alumina cement, sand and water; chloride-free admixtures may be used when necessary. The ratio by mass of sand to cement shall not exceed 3,5. At mixing stage, the ratio by mass of total water to cement depends on the manufacturing process and shall be determined such that the lining is in conformance with **4.4.3.2** and **4.4.3.3**; it shall not exceed 0,38 in the fresh lining immediately after application.

The sand shall have an appropriate grading; it shall not contain organic impurities, or fine clay particles in quantities which may affect the lining quality.

The water used in the mortar mix shall be potable water or water that has no harmful effect on the characteristics of the lining.

After application of the fresh lining, controlled curing shall be carried out so as to provide sufficient hydration to the cement.

4.4.3.2 *Strength of the lining*

When measured according to **6.7**, the compressive strength of the cement mortar lining after 28 days of curing shall be not less than 50 MPa.

NOTE. The compressive strength of the lining is directly related to other functional properties such as high density, good bond and low porosity.

4.4.3.3 *Thickness and surface condition*

The nominal thickness of the cement mortar lining and its tolerance shall be as given in table 4. When measured in accordance with **6.8**, the lining thickness shall be within the specified tolerance.

The surface of the cement mortar lining shall be uniform and smooth; trowel marks and protrusion of sand grains are acceptable, but there shall be no recesses or local defects which reduce the thickness to below the minimum value given in table 4.

If fine crazing and hairline cracks associated with cement rich surfaces appear in dry linings, there shall be no evidence of disbondment.

When shrinkage cracks inherent to cement-bound materials have developed in the dry linings, the crack width and the corresponding radial displacement shall not exceed the values given in table 4.

NOTE. Storage of pipes and fittings in a hot, dry environment can cause metal expansion and mortar shrinkage which may result in the dry lining developing areas of disbondment and shrinkage cracks. When the lining is re-exposed to water, it will swell by absorption of moisture and the cracks will eventually heal by an autogenous process.

Table 4

Dimensions in millimetres

DN	Thickness		Maximum crack width and radial displacement
	Nominal value	Tolerance[1)]	
100 to 300	3,5	− 1,5	0,6
350 to 600	5	− 2	0,7
700 to 1 200	6	− 2,5	0,8
1 400 to 2 000	9	− 3	0,8

[1)] A negative tolerance only is given.

NOTE. Pipe ends may have a chamfer of maximum length 20 mm.

4.4.3.4 *Repairs*

Repairs to areas of damaged linings shall be effected by the use of either cement mortar (see **4.4.3.1**) or a compatible polymer mortar; application may be by hand.

Prior to the application of the repair mortar, the damaged area shall be cut back to the sound lining or to the metal surface and all loose material shall be removed. After completion of the repair, the lining shall comply with **4.4.3.1**, **4.4.3.2** and **4.4.3.3**.

4.5 Coatings for fittings and accessories

4.5.1 *General*

Unless otherwise agreed between manufacturer and purchaser, fittings and accessories shall be delivered with an external and internal epoxy coating, conforming with **4.5.2**. Their field of use is given in annexes A and B.

By agreement between manufacturer and purchaser, the following coatings may also be supplied depending on external and internal conditions of use, which may be different to those given in annexes A and B:

a) External coatings:
- bituminous paint;
- zinc coating with finishing layer;
- polyethylene sleeving (as a supplement to the bituminous paint or to the zinc coating with finishing layer);
- adhesive tapes.

b) Internal coatings (linings):
- high alumina cement mortar lining (see **4.4.3**);
- blast furnace cement mortar lining;
- polyurethane.

These external and internal coatings shall comply with the corresponding EN standards or where no EN standard exists, they shall comply with ISO standards or with national standards, or with an agreed technical specification.

4.5.2 *Epoxy coating*

4.5.2.1 *General*

The coating material shall be either epoxy paint or epoxy powder.

Prior to application of the coating, the casting shall be suitably blast-cleaned in order to ensure a high, uniform level of bond between the coating and its substrate.

The coating shall be works-applied by dipping, by spraying or by brush with the equipment suitable for the paint or the powder.

4.5.2.2 *Characteristics of the coating*

The coating shall uniformly cover the whole surface of the casting; it shall have a smooth regular appearance and be free from defects which may affect its function. Sufficient curing time and temperature shall be provided in order to ensure a high degree of cross-linking of the epoxy resin.

The minimum coating thickness shall be such that the coating complies with **5.6**. When measured according to **6.6**, the coating thickness shall be not less than the minimum thickness given in the quality plan of the manufacturer.

4.6 Marking of pipes and fittings

All pipes and fittings shall be legibly and durably marked and shall bear at least the following information:

- the manufacturer's name or mark;
- the identification of the year of manufacture;
- the identification as ductile iron;
- the DN;
- the PN rating of flanges when applicable;
- the reference to this standard;
- the identification of third party certification when applicable.

The first five markings given above shall be cast-on or cold stamped; the two other markings can be applied by any method e.g. painting on the casting or attached to the packaging.

4.7 Leaktightness

4.7.1 *Systems design requirements*

Sewer systems constructed with ductile iron components in conformity with this standard shall be leaktight at the pressures given in table 5, depending on the way they are normally operated. This applies under all normal service conditions, including foreseable external loads and joint movements (angular, radial and axial).

Table 5

Type of operation	Internal pressure bar		External pressure bar
	continuous	occasional	continuous
Gravity	0 to 0,5	2	1
Positive pressure	6	9	1
Negative pressure	− 0,5	−0,8	1

4.7.2 *Leaktightness of pipeline components*

Pipes, fittings, inspection chambers and manholes shall be leaktight when used under the conditions for which they are designed (see **4.7.1**).

When tested in accordance with **6.9**, pipes and fittings for positive pressure applications shall exhibit no visible leakage, sweating or any other sign of failure.

When tested in accordance with **6.10**, pipes and fittings for negative pressure applications shall exhibit no visible leakage, sweating or any other sign of failure.

Pipes, fittings, inspection chambers and manholes for gravity applications shall comply with the performance requirements of **5.4**.

4.7.3 *Leaktightness of joints*

All joints shall be leaktight when used under the conditions for which they are designed (see **4.7.1**).

All joints shall comply with the performance requirements of **5.5**.

5 Performance requirements

5.1 General

The performance of all pipes, fittings, accessories and joints specified in clause **4** shall be in conformity with the requirements of **5.2** to **5.7**. This ensures their fitness for purpose in the field of sewerage in conformity with prEN 476.

There shall be at least one type test for each of the groupings given in table 6. One DN is representative of a grouping when the performances are based on the same design parameters throughout the size range. If a grouping covers products of different designs and/or manufactured by different processes, the grouping shall be sub-divided.

NOTE. If for a manufacturer a grouping contains only one DN, this DN may be considered as part of the adjacent grouping provided that it is of identical design and manufactured by the same process.

Table 6

Type tests	DN groupings			
Longitudinal bending of pipes (see **5.2**)	DN 100 to DN 200	—	—	—
Diametral stiffness of pipes (see **5.3**)	DN 100 to DN 250	DN 300 to DN 600	DN 700 to DN 1 000	DN 1 100 to DN 2 000
Joint tightness to positive internal pressure (see **5.5.2**)				
Joint tightness to negative internal pressure (see **5.5.2**)				
Joint tightness to positive external pressure (see **5.5.2**)				
Chemical resistance to effluents (see **5.6**)	DN 100 to DN 2 000			
Abrasion resistance (see **5.7**)				

5.2 Longitudinal bending of pipes

When tested according to **7.1**, pipes with an aspect ratio (length/diameter) equal to or greater than 25 shall comply with **5.2.1** and subsequently **5.2.2**.

5.2.1 ***Integrity under service conditions***

The pipes shall withstand the service bending moments given in table 9 without residual deflection and without visible damage to their external and internal coatings.

5.2.2 ***Bending resistance***

After the integrity test specified in **5.2.1**, the pipes shall withstand the proof bending moments given in table 9 without failure of the iron wall.

5.3 Diametral stiffness of pipes

When tested according to **7.2**, the pipes shall comply with the requirements of **5.3.1** and subsequently **5.3.2**.

5.3.1 ***Integrity under service conditions***

The diametral stiffness of the pipes shall be not less than the values specified in table 10, which means that they shall withstand the test loads given in table 10 with an ovalization not exceeding the allowable values.

In addition, there shall be no damage to the internal and external coatings which could affect their performance.

NOTE 1. As ductile iron pipes are intended to be used in the range of elastic deformations, they are not subjected to creep. Short-term and long-term values of the diametral stiffness are therefore identical.

NOTE 2. The allowable heights of cover of buried pipes, which depend largely on the diametral stiffness, are given in annex C.

5.3.2 ***Resistance to ovalisation***

After the integrity test of **5.3.1**, the pipes shall withstand double the allowable ovalizations given in table 10 without failure of the iron wall.

5.4 Leaktightness of components for gravity pipelines

When tested in accordance with **7.3**, pipes, fittings, inspection chambers and manholes shall exhibit no visible leakage, sweating or any other sign of failure.

5.5 Leaktightness of joints

5.5.1 ***General***

All joints shall be designed to be fully flexible; consequently, the allowable angular deflection declared by the manufacturer shall be not less than:

- 3°30′ for DN 100 to DN 300;
- 2°30′ for DN 350 to DN 600;
- 1°30′ for DN 700 to DN 2 000.

All joints shall be designed to provide sufficient axial movement; the allowable withdrawal shall be declared by the manufacturer.

NOTE. This permits the installed pipeline to accommodate ground movements and/or thermal effects without incurring additional stresses.

5.5.2 ***Test conditions***

All joint designs shall be type-tested under the most unfavourable, applicable conditions of tolerance and joint movement as given below:

a) Joint of maximum annulus (see **5.5.3.1**) aligned, withdrawn to the allowable value declared by the manufacturer, and subject to shear (see **5.5.3.3**);

b) Joint of maximum annulus (see **5.5.3.1**), deflected to the allowable value declared by the manufacturer (see **5.5.1**).

The joints shall exhibit no visible leakage when subjected to the following tests:

- test 1: positive internal hydrostatic pressure in accordance with **7.4**; the test pressure shall be 2 bar for joints intended for gravity or negative pressure pipelines and at least 11 bar for joints intended for all types of pipelines (including positive pressure pipelines);
- test 2: negative internal pressure of 0,9 bar below atmospheric pressure (approximately 0,1 bar absolute pressure), in accordance with **7.5**;
- test 3: positive external hydrostatic pressure of 2 bar, in accordance with **7.6** for joints intended for use deeper than 5 m below the water level (e.g. river, lake, aquifer).

5.5.3 ***Test parameters***

5.5.3.1 *Annulus*

All joints shall be type-tested at the extremes of manufacturing tolerance such that the annular gap between the sealing surfaces of the socket and of the spigot is equal to the maximum design value plus 0 %, minus 5 %. It is permissible to machine socket internal surfaces to achieve the required annulus for the type-test even though the resultant diameter can be slightly outside the normal manufacturing tolerance.

5.5.3.2 *Pipe thickness*

All joints shall be type-tested with a spigot having an average iron wall thickness (over a distance of 2 × DN in millimetres from the spigot end face) equal to the specified minimum value for the pipe for which the joint is designed plus 10 %, minus 0 %. It is permissible to machine the spigot end of the test pipe in the bore to achieve the required thickness.

5.5.3.3 *Shear*

All joints shall be type-tested with a resultant shear force across the joints of not less than 30 × DN in newtons, taking into account the weight of the pipe and of its contents and the geometry of the test assembly (see **7.4**).

5.5.4 ***Restrained flexible joints***

All restrained joints shall be designed to be at least semi-flexible; consequently, the allowable angular deflection declared by the manufacturer shall be not less than half of the value shown in **5.5.1**.

All restrained joint designs shall be type-tested in accordance with **7.4** to **7.6** following the requirements of **5.5.2** and **5.5.3**, except that:

- the withdrawal condition of **5.5.2**a) shall not apply;
- there shall be no external axial restraint in positive internal pressure tests so that the joint is subjected to the full end thrust.

During the positive internal pressure tests, the axial movement shall reach a stable value and cease.

NOTE. When the restraining mechanism and the sealing component of a restrained joint are independent, such a joint does not need to be subjected to test 2 and test 3 of **5.5.2** if the unrestrained version of the joint has passed these tests.

5.6 Chemical resistance to effluents

Long-term performance of pipes, fittings and joints shall be demonstrated by six-month exposure tests to an acid solution and to an alkaline solution according to **7.7**. Their field of use is given in annex B.

After six months of testing, the following conditions shall be met:

- thickness of the high alumina cement mortar lining shall be within 0,2 mm of the original thickness;
- there shall be no visible cracking, blistering or disbonding of the epoxy based coatings (fittings and pipe sockets);
- there shall be no visible cracking on the rubber gasket; its hardness, tensile strength and elongation shall remain in conformity with the specified values.

NOTE. All other combinations of coatings can be tested according to the same procedure; the values of pH can be modified in order to demonstrate long-term behaviour in different environments.

5.7 Abrasion resistance

When tested in accordance with **7.8**, the pipes shall not have an abrasion depth greater than 0,6 mm after 100 000 cycles.

6 Test methods

6.1 Dimensions

6.1.1 ***External diameter***

Socket and spigot pipes shall be measured at their spigot end by means of a circumferential tape or controlled by pass-fail gauges. The manufacturer's process control system shall specify the frequency of this test.

In addition, they shall be visually inspected for compliance with the spigot allowable ovality and, in case of doubt, the maximum and minimum spigot axes shall be measured by suitable equipment or controlled by pass-fail gauges.

6.1.2 ***Internal diameter***

The internal diameter of pipes shall be measured by means of suitable equipment. Two measurements shall be taken at right angles, at a cross section 200 mm or more from the end face. The mean value of these two measurements may then be calculated. The manufacturer's process control system shall specify the frequency of this test.

6.1.3 ***Wall thickness***

All centrifugally cast pipes shall be visually inspected for colour uniformity as they are extracted from the mould in order to detect iron wall thickness differences at an early stage.

The iron wall thickness shall be measured by suitable equipment, e.g. mechanical or ultrasonic, having a precision of ± 0,1 mm at regular intervals along the pipe barrel. The manufacturer's process control system shall specify the frequency of this test.

6.1.4 ***Length***

The length of socket and spigot pipes shall be measured by suitable equipment:

- on the first pipe cast from a new mould, for as-cast pipes;
- on the first pipe, for pipes which are systematically cut to a pre-set length.

6.2 Straightness of pipes

The pipe shall be rolled on two gantries or rotated around its axis on rollers, which in each case are separated by not less than two-thirds of the standardized pipe length.

The point of maximum deviation from the straight axis shall be determined and the deviation measured at that point.

6.3 Tensile testing

6.3.1 *Samples*

The thickness of the sample and the diameter of the test bar shall be as given in table 7.

6.3.1.1 *Centrifugally cast pipes*

A sample shall be cut from the spigot end of the pipe. This sample may be cut parallel with or perpendicular to the pipe axis, but in case of dispute the parallel with axis sample shall be used.

6.3.1.2 *Pipes not centrifugally cast, fittings and accessories*

At the manufacturer's option, samples shall be either cast integrally with the castings or cast separately. In the latter case they shall be cast from the same metal as that used for the castings. If the castings are subjected to heat treatment, the samples shall be subjected to the same heat treatment.

6.3.2 *Preparation of test bar*

A test bar shall be machined from each sample to be representative of the metal at the mid thickness of the sample, with a cylindrical part having the diameter given in table 7.

The test bar shall have a gauge length equal to at least five times the nominal test bar diameter. The ends of the test bar shall be such that they will fit the testing machine.

The surface roughness profile of the cylindrical part of the test bar shall be such that $R_z \leq 6{,}3$.

Two methods of measuring the tensile strength of the test bar may be used at the manufacturer's option:

Method A:

Machine the test bar to its nominal diameter ± 10 %, measure the actual diameter before the test with an accuracy of ± 0,01 mm and use this measured diameter to calculate the cross-sectional area and the tensile strength; or

Method B:

Machine the test bar to its nominal area S_o within a specified tolerance on diameter (see table 7) and use the nominal area to calculate the tensile strength.

6.3.3 *Apparatus and test method*

The testing machine shall have suitable holders or grips to suit the test bar ends so as to apply the test load axially. The testing machine shall have a force range suitable for testing the bars to failure whilst indicating the load applied.

The accuracy class of the testing machine shall be in accordance with clause **9** of EN 10002-1 : 1990. The rate of stressing shall be as constant as possible within the limits of 6 N/mm^2 to 30 N/mm^2 per second.

Table 7

Type of casting	**Test bar method A**	**Test bar method B**		
	Nominal diameter mm	**Nominal area S_o** mm^2	**Nominal diameter** mm	**Tolerance on diameter** mm
Centrifugally cast pipes with wall thickness in millimetres:				
less than 6	2,5	5,0	2,52	± 0,01
6 up to but not including 8	3,5	10,0	3,57	± 0,02
8 up to but not including 12	5,0	20,0	5,05	± 0,02
12 and over	6,0	30,0	6,18	± 0,03
Pipes not centrifugally cast, fittings and accessories:				
integrally cast samples	5,0	20,0	5,05	± 0,02
separately cast samples:				
sample thickness 12,5 mm for casting thickness less than 12 mm	6,0	30,0	6,18	± 0,03
sample thickness 25 mm for casting thickness 12 mm and over	12,0 or 14,0	-	-	-

The tensile strength shall be calculated by dividing the maximum force sustained by the test bar by the cross sectional area of the test bar before testing. The extended gauge length shall be measured after piecing together the two parts of the test bar after fracture. The elongation shall be calculated using the ratio of the extended gauge length to the original gauge length. Alternatively, the elongation may be measured directly by means of an extensometer.

6.3.4 *Test results*

Test results shall comply with table 3. If they do not comply, the manufacturer shall:

a) in the case where the metal does not achieve the required mechanical properties, investigate the reason and ensure that all castings in the batch are either re-heat treated or rejected. Castings which have been re-heat treated are then re-tested in accordance with **6.3**;

NOTE. The manufacturer may limit the amount of rejection by making tests until the rejected batch of castings is bracketed, in order of manufacture, by a successful test at each end of the interval in question.

b) in the case of a defect in the test bar, carry out a further test. If it passes, the batch is accepted; if not, the manufacturer has the option to proceed as in a) above.

6.3.5 *Test frequencies*

The frequency of testing is related to the system of production and quality control used by the manufacturer (see **4.3.1**). The maximum batch sizes shall be as given in table 8.

6.4 Brinell hardness

When Brinell hardness tests are carried out (see **4.3.2**), they shall be performed either on the casting in dispute or on a sample cut from the casting. The surface to be tested shall be suitably prepared by slight local grinding and the test shall be carried out in accordance with ISO 6506 using a steel ball of 2,5 mm or 5 mm or 10 mm diameter.

6.5 Zinc coating mass

A rectangular token of known weight per unit area shall be attached longitudinally along the axis of the pipe before passing it through the coating equipment. After coating and trimming, the size of the token shall be 500 mm × 50 mm. It shall be weighed on a scale having a precision of at least 0,01 g.

The mean mass M of zinc per unit area shall be determined from the mass difference before and after zinc coating.

$$M = C\frac{(M_2 - M_1)}{A}$$

where:

M	is the mean mass of zinc, in grammes per square metre;
M_1 and M_2	are the masses of the sample token, in grammes, before and after coating;
C	is the predetermined correction factor, taking account of the nature of the token and of the difference in surface roughness between the token and the iron pipe;
A	is the actual area of the trimmed token, in square metres.

NOTE 1. The value of C, generally lying between 1 and 1,2, is given in the relevant document of the manufacturer's quality assurance system.

The uniformity of the coating shall be checked by the visual inspection of the token; in the event of a lack of uniformity, 50 mm × 50 mm pieces shall be cut from the token in the lighter mass zones and the local minimum mass of zinc determined on each piece by mass difference.

NOTE 2. Alternatively the mass of zinc per unit area can be measured directly on the coated pipe by any method having proven correlation with the reference method described above, e.g. X-ray fluorescence or chemical analysis.

Table 8

Type of casting	DN	Maximum batch size	
		Batch sampling system	Process control system
Centrifugally cast pipes	100 to 300 350 to 600 700 to 1 000 1 100 to 2 000	200 pipes 100 pipes 50 pipes 25 pipes	1 200 pipes 600 pipes 300 pipes 150 pipes
Pipes not centrifugally cast, fittings and accessories	100 to 2 000	4 t[1)]	48 t[1)]

[1)] Weight of crude castings, excluding the risers.

6.6 Thickness of paint coatings

The dry film thickness of paint coatings shall be determined by either of the following methods:

a) directly on the casting by means of suitable gauges, e.g. magnetic, or by using a 'wet film' thickness gauge where a correlation between wet film thickness and dry film thickness can be demonstrated; or

b) indirectly on a token which is attached to the casting before coating and is used after coating to measure the dry film thickness by mechanical means, e.g. micrometer, or by a weight method similar to **6.5**.

For each casting to be controlled at least three measurements shall be taken (either on the casting or on the token). The mean thickness is the average of all the measurements taken and the local minimum thickness is the lowest value of all the measurements taken.

6.7 Compressive strength of the cement mortar lining

The compressive strength shall be the arithmetic mean of six compressive strength tests performed on three prism samples after 28 days of curing.

The compressive strength shall be determined by a type test according to EN 196-1, except that:

- the sand, the cement and the water used for the prism samples are identical with those used for the mortar before application of the lining;
- the sand/cement ratio used for the prism samples is equal to that used for the mortar before application of the lining;
- the water/cement ratio used for the prism samples is equal to that of the lining immediately after application to the pipe wall.

NOTE. This takes into account the influence of the centrifugal spinning process which allows expelling of the excess water.

6.8 Thickness of cement mortar lining

During manufacture, the thickness shall be measured on the freshly applied lining by a spear having a diameter of 1,5 mm or less and controlled on the finished hardened lining by means of a suitable gauge, e.g. magnetic.

The measurements shall be taken approximately 200 mm from the end face. The manufacturer's process control system shall specify the frequency of this test.

6.9 Works leaktightness test for pipes and fittings for positive pressure pipelines

6.9.1 ***General***

Pipes and fittings shall be tested in accordance with **6.9.2** or **6.9.3** respectively. The test shall be carried out on all pipes and fittings before the application of their external and internal coatings, except for the metallic zinc coating of pipes which may be applied before the test.

The test apparatus shall be suitable for applying the specified test pressures to the pipes and/or fittings. It shall be equipped with an industrial pressure gauge with an accuracy of ± 3 %.

6.9.2 ***Centrifugally cast pipes***

The internal hydrostatic pressure shall be raised steadily until it reaches a test pressure of at least 11 bar, which is maintained for a sufficient time to allow visual inspection of the pipe barrel. The total duration of the pressure cycle shall be not less than 15 s, including 10 s at test pressure.

6.9.3 ***Pipes not centrifugally cast and fittings***

At the manufacturer's option, they shall be submitted to a hydrostatic pressure test or to an air test, or to any other leaktightness test of equivalent performance.

When a hydrostatic pressure test is carried out, it shall be in the same way as for centrifugally cast pipes, (see **6.9.2**).

When an air test is carried out, it shall be with an internal pressure of at least 1 bar and a visual inspection time not less than 10 s; for leak detection, the castings shall be either uniformly coated on their external surface by a suitable foaming agent or submerged in water.

6.10 Works leaktightness test for pipes and fittings for negative pressure pipelines

All the pipes and fittings shall be subjected to an air test with an internal pressure of at least 1 bar and a visual inspection time not less than 10 s for fittings and 1 min for pipes. For leak detection, pipes and fittings shall be submerged in water or uniformly coated on their external surface by a suitable foaming agent.

7 Type tests

7.1 Longitudinal bending of pipes

The test shall be carried out on a pipe resting on two supports 4 m apart (see figure 1); the load shall be applied at mid-span by means of a loading block. The two supports and the loading block shall have a V shape of 120° and shall be covered with a sheet of elastomer having a thickness of 10 mm ± 5 mm and a hardness greater than or equal to 50 IRHD; their width shall not exceed 100 mm. Before the test, the pipe shall be immersed in water at ambient temperature for approximately 24 h.

In the first part of the test, the load shall be increased steadily until the pipe is subjected to the service bending moment given in table 9, which is kept constant for 10 min. The load shall then be released and the pipe visually inspected.

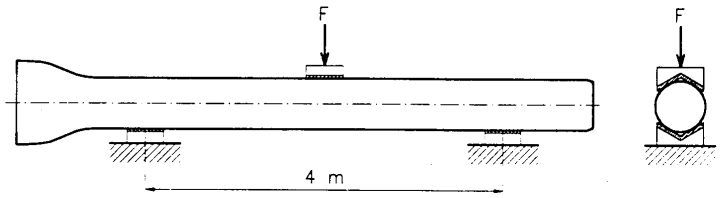

Figure 1

In the second part of the test, on the same pipe, the load is steadily increased until the pipe is subjected to the proof bending moment given in table 9. The rate of loading shall not exceed 2 kN/s. The proof load shall be applied for 1 min.

Table 9

DN	Service bending moments kN·m	Proof bending moments kN·m
100	6,5	11
125	9,5	16
150	13,5	23
200	26	44

NOTE. These bending moments, expressed in kilonewton metres, are achieved by application of loads F of the same numerical value, expressed in kilonewtons.

NOTE. The bending moments are calculated by the formula.

$M = 0{,}25 \times 10^{-6} R_f \times D^2 \times e$

where:

M is the bending moment, in kilonewton metres;
R_f is the allowable stress in the pipe wall, in megapascals;
D is the mean pipe diameter ($DE - e$), in millimetres;
DE is the nominal pipe external diameter, in millimetres;
e is the minimum pipe wall thickness, in millimetres.

The service bending moments are calculated with $R_f = 250$ MPa and the proof bending moments with $R_f = 420$ MPa.

7.2 Diametral stiffness of pipes

The test shall be carried out on a pipe section 500 mm ± 20 mm long, cut from the pipe barrel. The pipe section shall be placed on a support approximately 200 mm wide and 600 mm long, having a V shape with an angle between 170° and 180° (see figure 2). The load shall be applied at the pipe crown through a loading beam approximately 50 mm wide and 600 mm long. Both the V support and the loading beam shall be covered with a sheet of elastomer with a thickness of 10 mm ± 5 mm and a hardness greater than or equal to 50 IRHD. Before the test, the pipe section shall be immersed in water at ambient temperature for approximately 24 h.

The load shall be increased steadily until it reaches the test load corresponding to the minimum diametral stiffness given in table 10 and kept constant for 1 min. The vertical deflection of the pipe section shall be measured and the calculated ovalization shall not exceed the allowable value given in table 10. In addition, the pipe section shall be visually inspected in order to check that there is no damage to the external and internal coatings which can affect their function.

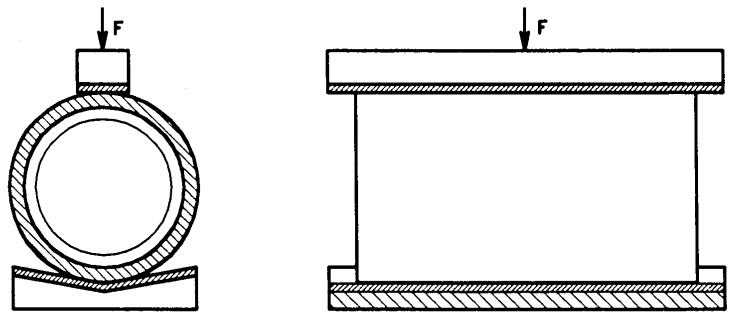

Figure 2

The load shall then be increased until the vertical deflection reaches twice the value previously measured. The load shall be kept constant for 1 min.

Table 10

DN	Minimum diametral stiffness S kN/m²	Test load F kN/m	Allowable pipe ovalization %
100	250	25,5	1,6
125	130	18,2	1,8
150	80	15,4	2,1
200	60	17,3	2,4
250	54	21,6	2,7
300	47	24,8	3,0
350	36	22,8	3,1
400	30	22,2	3,2
450	26	22,2	3,3
500	22	21,5	3,4
600	18	22,2	3,6
700	24	36,4	3,8
800	20	36,4	4,0
900	18	36,8	4,0
1 000	16	36,2	4,0
1 100	22	54,7	4,0
1 200	20	54,3	4,0
1 400	18	56,9	4,0
1 500	17	57,5	4,0
1 600	17	61,3	4,0
1 800	16	64,9	4,0
2 000	16	72,0	4,0

NOTE. The values for S have been calculated assuming a pipe wall thickness equal to the minimum thickness plus half the tolerance, in order to take account that there are only a few points with a thickness equal or close to the minimum thickness.

NOTE 1. The ovalization is 100 times the measured vertical deflection in millimetres (caused by the applied load) divided by the measured pipe external diameter in millimetres.

NOTE 2. The diametral stiffness, the vertical deflection and the applied load are linked by the following equation:

$$S = 0{,}019\,\frac{F}{Y}$$

where:

S is the diametral stiffness, in kilonewtons per square metre;

F is the applied load, in kilonewtons per metre length of pipe;

Y is the vertical deflection, in metres.

NOTE 3. The diametral stiffness S of a pipe is calculated by the formula

$$S = 1\,000\,\frac{E \times I}{D^3} = 1\,000 \times \frac{E}{12}\left(\frac{e}{D}\right)^3$$

where:

S is the diametral stiffness, in kilonewtons per square metre;

E is the modulus of elasticity of the material, in megapascals (170 000 MPa);

I is the second moment of area of the pipe wall per unit length, in millimetres to the third power;

e is the wall thickness of the pipe, in millimetres;

D is the mean diameter of the pipe ($DE - e$), in millimetres;

DE is the nominal pipe external diameter, in millimetres.

7.3 Leaktightness of components for gravity pipelines

Ductile iron pipes, fittings, inspection chambers and manholes, equipped with appropriate end restraints, shall be filled with water and suitably vented of air. The internal hydrostatic pressure shall then be raised to 2 bar and maintained constant for at least 2 h, during which a visual inspection for leak detection shall be carried out.

The test shall be carried out at ambient temperature on coated products.

NOTE. These type tests may be performed at the same time as those described in **7.4** for joints.

7.4 Leaktightness of joints to positive internal pressure

The test shall be carried out on an assembled joint comprising two pipe sections, each at least 1 m long (see figure 3).

The test apparatus shall be capable of providing suitable end and lateral restraints whether the joint is in the aligned position, or deflected, or subjected to a shear load. It shall be equipped with a pressure gauge with an accuracy of ± 3 %.

The vertical force W shall be applied to the spigot end by means of a V shaped block with an angle of 120°, located at approximately 0,5 × DN in millimetres or 200 mm from the socket face (whichever is the largest); the socket shall bear on a flat support. The vertical force W shall be such that the resultant shear force F across the joint is equal to the value specified in **5.5.3.3** taking into account the mass M of the pipe and its contents and the geometry of the test assembly.

$$W = \frac{F \times c - M\,(c - b)}{c - a}$$

where a, b and c are as shown in figure 3.

The test assembly shall be filled with water and suitably vented of air. The pressure shall be raised steadily until it reaches the test pressure given in **5.5.2**; the rate of pressure increase shall not exceed 1 bar per s. The test pressure shall be kept constant within ± 0,1 bar for at least 2 h during which the joint is thoroughly inspected every 15 min. All necessary safety precautions should be taken for the duration of the pressure test.

For a restrained joint, the test assembly, the test apparatus and the test procedure shall be identical except that there shall be no end restraint, so that the axial thrust is taken by the restrained joint under test. In addition, possible axial movement of the spigot shall be measured every 15 min.

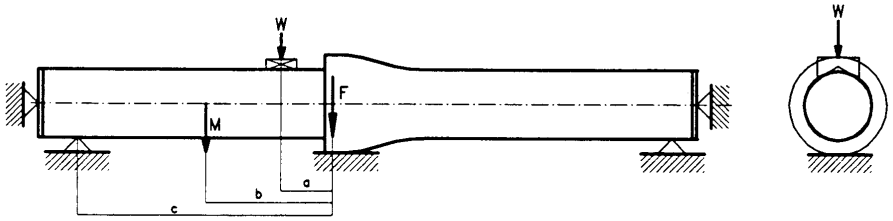

Figure 3

7.5 Leaktightness of joints to negative internal pressure

The test assembly and test apparatus shall be as given in **7.4**, with the pipe sections axially restrained to prevent them moving towards each other, or as given in **7.6**.

The test assembly shall be empty of water and shall be evacuated to a negative internal pressure of 0,9 bar (see **5.5.2**) and then isolated from the vacuum pump. The test assembly shall be left under vacuum for 2 h, at the end of which time the vacuum shall not have changed by more than 0,09 bar. The test shall begin at a temperature between 15 °C and 25 °C, which is then kept constant at ± 2 °C for the duration of the test.

For a restrained joint, the test assembly, the test apparatus and the test procedure shall be identical.

7.6 Leaktightness of joints to positive external pressure

The test assembly shall comprise two joints made with two pipe sockets welded together and one double-spigot piece (see figure 4); it creates an annular chamber which allows the testing of one joint to internal pressure and the other joint to external pressure.

The test assembly shall be subjected to a vertical force *W*, equal to the shear force *F* defined in **5.5.3.3**; one half of this load shall be applied to the spigot end on each side of the test assembly, by means of a V shaped block with an angle of 120°, located at approximately 0,5 × DN in millimetres or 200 mm from the ends of the sockets, whichever is the largest; the sockets shall bear on a flat support.

The test assembly shall then be filled with water and suitably vented of air. The pressure shall be steadily increased until it reaches the test pressure given in **5.5.2** and maintained constant within ± 0,1 bar for at least 2 h during which the internal side of the joint subjected to external pressure shall be thoroughly inspected every 15 min.

For a restrained joint, the test assembly, the test apparatus and the test procedure shall be identical.

7.7 Chemical resistance to effluents

Two type tests shall be carried out on test assemblies (see figure 5) comprising:

— a pipe section with high alumina cement mortar internal lining, including a socket with epoxy-based internal coating. Before test, the pipe section shall be immersed in water at ambient temperature for approximately 24 h;

— a spigot end of a fitting, epoxy coated;

— a rubber gasket.

The two test assemblies are positioned horizontally:

— the first one shall be filled to mid-height with a solution of sulfuric acid at pH 3;

— the second one shall be filled to mid-height with a solution of sodium hydroxide at pH 13.

The pH shall be monitored in both cases and the solution shall be renewed as soon as the pH has changed by more than 0,3 from the initial value. The test temperature shall be 18 °C ± 2 °C.

At the end of the six month test period, the test assemblies shall be dismantled; the necessary observations and measurements shall be carried out on the high alumina cement mortar lining, on the epoxy coatings and on the rubber gasket, to verify compliance with **5.6**.

7.8 Abrasion resistance

The test shall be carried out on a pipe sample 1 000 mm ± 10 mm long, closed at both ends after enclosing the test material; preferred sizes are DN 200 and DN 400.

Before test, the pipe section, with high alumina cement mortar lining, shall be immersed in water at ambient temperature for approximately 24 h.

The test material shall contain natural siliceous gravel to reach a level of 38 mm ± 2 mm above the invert with enough water to reach the same level. The gravel particle size shall be between 2 mm and 10 mm, with an average size of approximately 6 mm.

The pipe sample shall be fixed horizontally on a testing device capable of inclining the sample successively to an angle of plus 22,5° and minus 22,5° every 3 s to 5 s.

The pipe sample shall be examined after 100 000 cycles; the depth of abrasion shall be the average of 15 measurements taken every 50 mm along 700 mm of the pipe invert, excluding 150 mm at both ends.

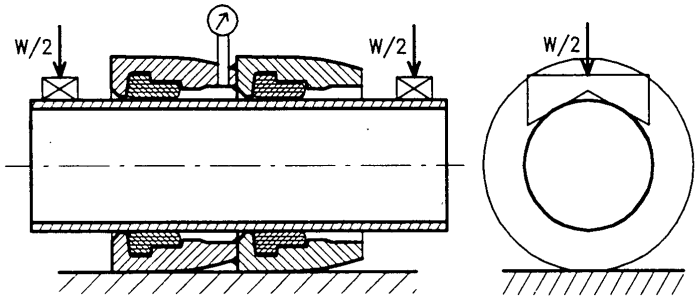

Figure 4

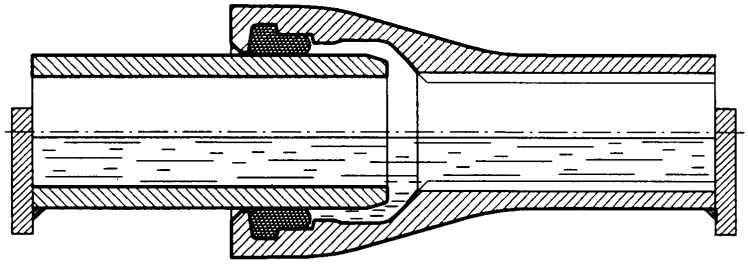

Figure 5

8 Quality assurance

8.1 General

The manufacturer shall demonstrate the conformity of his products with this standard by:

- carrying out performance type tests (see **8.2**); and
- controlling the manufacturing process (see **8.3**).

8.2 Type tests

The type tests specified in clauses **5** and **7** of this standard shall be carried out by the manufacturer or at his request, by a competent testing institute in order to demonstrate compliance with the requirements of this standard. Full reports of these type tests shall be retained by the manufacturer as evidence of compliance.

8.3 Quality assurance system

The manufacturer shall control the quality of his products during their manufacture by a system of process control in order to comply with the technical requirements of this standard. Wherever possible, statistical sampling techniques should be used.

Consequently, the manufacturer's quality assurance system shall comply with the requirements of EN 29002.

The manufacturer's quality assurance system should be approved by a third party certification body who is accredited in accordance with EN 45012.

9 Tables of dimensions

9.1 Socket and spigot pipes

The dimensions of socket and spigot pipes shall be as given in table 11. The values of L_u are given in table 2. For external and internal coatings see **4.4**.

NOTE. The values of DE and their tolerances, apply also to the spigot ends of fittings (see **4.2.1.1**).

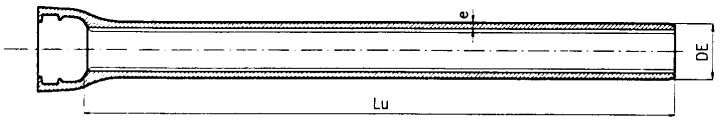

Figure 6

Table 11

DN	External diameter *DE* mm		Minimum iron thickness, *e* mm
	Nominal	Tolerance on diameter	
100	118	+ 1/ −2,8	2,5
125	144	+ 1/ −2,8	2,5
150	170	+ 1/ −2,9	2,5
200	222	+ 1/ −3,0	3,0
250	274	+ 1/ −3,1	3,5
300	326	+ 1/ −3,3	4,0
350	378	+ 1/ −3,4	4,3
400	429	+ 1/ −3,5	4,6
450	480	+ 1/ −3,6	4,9
500	532	+ 1/ −3,8	5,2
600	635	+ 1/ −4,0	5,8
700	738	+ 1/ −4,3	7,6
800	842	+ 1/ −4,5	8,3
900	945	+ 1/ −4,8	9,0
1 000	1 048	+ 1/ −5,0	9,7
1 100	1 152	+ 1/ −6,0	12,0
1 200	1 255	+ 1/ −5,8	12,8
1 400	1 462	+ 1/ −6,6	14,4
1 500	1 565	+ 1/ −7,0	15,1
1 600	1 668	+ 1/ −7,4	16,0
1 800	1 875	+ 1/ −8,2	17,6
2 000	2 082	+ 1/ −9,0	19,2

9.2 Fittings for gravity sewers

9.2.1 *Couplings*

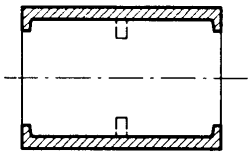

Figure 7

The standardized DN are all those from DN 100 to DN 1 200.

9.2.2 *Manhole connectors*

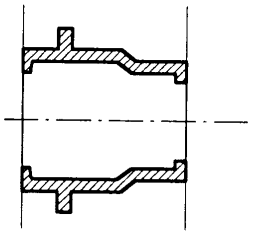

Figure 8

The standardized DN are all those from DN 150 to DN 1 200.

9.2.3 *Double socket bends*

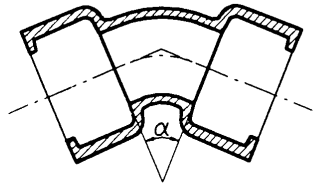

Figure 9

The standardized DN are all those from DN 100 to DN 2 000. The angles α of the bends shall be given in the manufacturer's catalogues.

9.2.4 *Angle branches*

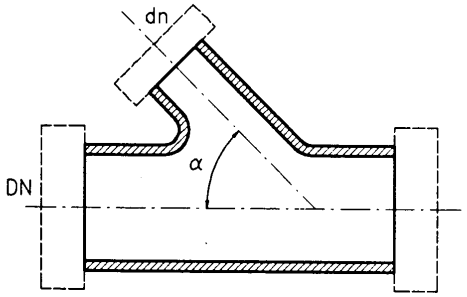

Figure 10

The standardized DN are all those from DN 150 to DN 500 for the body and from dn 100 to dn 250 for the branch. The various combinations DN × dn, the types of ends (socket or spigot) and the angle α of the branch shall be given in the manufacturer's catalogues.

9.2.5 *Connection branches*

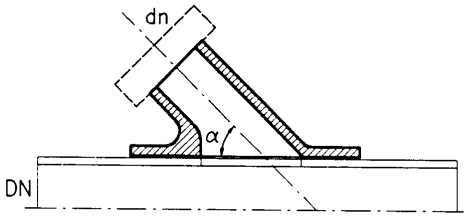

Figure 11

The standardized dn are all those from dn 150 to dn 250 for connection to pipes from DN 200 to DN 2 000. The type of end (socket or spigot) for connection with different pipe materials shall be given in the manufacturer's catalogues, as well as the angle of the branch and the shape of the hole to be cut in the pipe (circular, square or rectangular).

9.2.6 *Inspection tees*

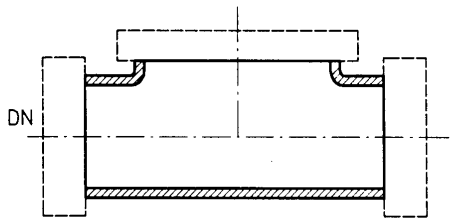

Figure 12

The standardized DN are all those from DN 100 to DN 400. The type of ends (socket or spigot) shall be given in the manufacturer's catalogues as well as the shape and dimensions of the access branch.

9.2.7 *Access traps*

Figure 13

The standardized DN are all those from DN 150 to DN 1 200. The shape and dimensions of the hole to be cut in the pipe shall be given in the manufacturer's catalogues, as well as the method of connection to the pipe.

9.3 Fittings for pressure sewers and vacuum sewers

The types and dimensions of fittings shall be those given in EN 545.

Annex A (informative)
Field of use, characteristics of soils

Ductile iron pipelines supplied with external coatings complying with **4.4.2** and **4.5.2** may be buried in contact with the majority of soils, except those:

- with a low resistivity, less than 1 500 ohms·cm above the water table or less than 2 500 Ω·cm below the water table;
- with a low pH, below pH 6;
- with contamination by certain wastes or organic or industrial effluents.

In such soils, and also in the occurrence of stray currents or corrosion cells due to external metallic structures, it is recommended that an additional protection is used (polyethylene sleeving) or other types of external coatings as appropriate (see **4.4.1** and **4.5.1**).

Annex B (informative)
Field of use, characteristics of effluents

Ductile iron pipelines supplied with the coatings complying with **4.4.3**, **4.5.2**, **5.6** and **5.7**, can be used to transport all types of surface water and domestic effluents and certain types of industrial effluents, provided that they are not exposed to values below pH 4 or greater than pH 12.

By agreement between manufacturer and purchaser, the use can be extended to special applications, after consideration of other parameters such as temperature, nature of the main aggressive substances, frequency of occurrence, etc.

Annex C (informative)
Calculation method for buried pipelines, permissible heights of cover

C.1 Calculation

C.1.1 *Calculation formula*

The method is based on an ovalization calculation according to the formula below:

$$\Delta = \frac{100K\,(P_e + P_t)}{8S + (f \times E')}$$

where:

- Δ is the pipe ovalization, (%);
- K is the bedding factor;
- P_e is the pressure from earth loading, in kilonewtons per square metre;
- P_t is the pressure from traffic loading, in kilonewtons per square metre;
- S is the pipe diametral stiffness, in kilonewtons per square metre; see values in table 10;
- f is the factor of lateral pressure (f = 0,061);
- E' is the modulus of soil reaction, in kilonewtons per square metre.

The ovalization calculated by means of this formula should not exceed the allowable ovalization shown in table 10. The allowable ovalization increases with DN while remaining well below the value that the internal cement mortar lining can withstand without damage; in addition, it provides a safety factor of 1,5 with respect to the elastic limit of ductile iron in bending (500 MPa minimum) by limiting the stress in the pipe wall at 330 MPa; finally, it is limited to 4 % for DN ≥ 800.

C.1.2 *Pressure from earth loading*

The pressure P_e, uniformly distributed at the top of the pipe over a distance equal to the external diameter, is calculated following the earth prism method by the formula below:

$$P_e = \gamma \times H$$

where:

- P_e is the pressure from earth loading, in kilonewtons per square metre;
- γ is the unit weight of backfill, in kilonewtons per cubic metre;
- H is the height of cover, in metres, that is the distance from the top of the pipe to the ground surface.

In the absence of other data, the unit weight of the soil is taken as being equal to 20 kN/m^3 in order to cover the vast majority of cases. If a preliminary geotechnical survey confirms that the actual unit weight of the backfill will be less than 20 kN/m^3, the actual value may be used for determining P_e. If, however, it appears that the actual value will be more than 20 kN/m^3, the actual value should be used.

C.1.3 *Pressure from traffic loading*

The pressure P_t, uniformly distributed at the top of the pipe over a distance equal to the external diameter, is calculated by means of the formula below:

$$P_t = 40\ \frac{\beta}{H}(1 - 2 \times 10^{-4}\ \mathrm{DN})$$

where:

- P_t is the pressure from traffic loading in kilonewtons per square metre;
- β is the traffic load factor.

This formula is not valid for $H < 0{,}3$ m.

Three types of traffic loading are to be considered:

- traffic areas with main roads, β = 1,5: this is the general case of all roads, except access roads;
- traffic areas with access roads, β = 0,75: roads
- where lorry traffic is prohibited;
- rural areas, β = 0,5: all other cases.

It should be noticed that all pipelines should be designed for $\beta = 0,5$ even where they are not expected to be exposed to traffic loading. In addition, pipelines laid in the verge and embankment of roads should be designed to withstand the full traffic loading expected on these roads. Finally, for pipelines which may be exposed to particularly high traffic loading, a factor $\beta = 2$ should be adopted.

C.1.4 *Bedding factor, K*

The bedding factor K, depends upon the soil pressure distribution at the top of the pipe (over a distance equal to the external diameter) and at the invert of the pipe (over a distance corresponding to the theoretical bedding angle 2α.

K normally varies from 0,11 for $2\alpha = 20°$ to 0,09 for $2\alpha = 120°$. The value of 20° corresponds to a pipe which is simply laid on the flat trench bottom, with no compaction effort.

C.1.5 *Factor of lateral pressure, f*

The factor of lateral pressure f, is equal to 0,061; this corresponds to a parabolic distribution of the lateral soil pressure over an angle of 100°, according to the IOWA-Spangler model.

C.1.6 *Modulus of soil reaction, E'*

The modulus of soil reaction E', depends upon the nature of soil used in the pipe zone and upon the laying conditions.

In a given situation, the modulus of reaction which is required can be determined by means of the formula below:

$$E' = \frac{4\,000K}{\delta \times f}\left[\frac{\beta}{H}(1 - 2 \times 10^{-4}\,\mathrm{DN}) + 0,5\,H\right] - \frac{8\,S}{f}$$

where:

E' is the modulus of soil reaction, in kilonewtons per square metre;

δ is the allowable ovalization, in %.

In table C.1, values of E' equal to 1 000 kN/m^2, 2 000 kN/m^2 and 5 000 kN/m^2 are taken as guidelines; they correspond to a compaction level which is respectively nil, low and good. The value $E' = 0$ has also been shown as the limit case for unfavourable laying conditions in poor soils (no compaction, water table above the pipe, trench shoring removed after backfilling or embankment conditions).

If a preliminary geotechnical survey allows the determination of the value of the modulus of soil reaction, this value should be taken into account in the calculations.

C.2 Heights of cover

Table C.1 gives the most pessimistic range of values of the allowable heights of cover for each group of diameters. These values can be used without any additional calculation; they are given in metres, with E' in kilonewtons per square metre.

For heights of cover outside the ranges given in table C.1 and for better laying conditions, a verification can be made using the formulae given in C.1.

Table C.1

DN	100 to 300	350 to 450	500 to 2 000
K (2 α)	0,110 (20°)	0,105 (45°)	0,103 (60°)
$\beta = 0,75$ $E' = 0$	0,3 – 5,0	0,5 – 3,0	0,5 – 2,0
$E' = 1\,000$	0,3 – 6,0	0,4 – 4,0	0,4 – 3,5
$E' = 2\,000$	0,3 – 6,5	0,3 – 5,0	0,3 – 4,5
$E' = 5\,000$	0,3 – 8,5	0,3 – 8,05	0,3 – 8,0
$\beta = 1,50$ $E' = 0$	0,6 – 5,0	[1]	[1]
$E' = 1\,000$	0,5 – 5,5	0,7 – 3,51	0,8 – 3,0
$E' = 2\,000$	0,5 – 6,5	0,6 – 5,0	0,6 – 4,5
$E' = 5\,000$	0,4 – 8,5	0,4 – 8,0	0,4 – 7,5

[1] Not recommended: only a specific calculation for each case can provide an adequate answer.

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National annex NA (informative)
Significant changes from BS 4772

NA.1 General

This British Standard is one of the three new application standards for ductile iron pipelines which have been developed by CEN, the other standards being BS EN 545 (water application) and BS EN 969 (gas supply). This standard replaces BS 4772 : 1988 in respect of sewerage applications, and with the publication of all three application standards as British Standards, BS 4772 will be withdrawn.

This annex has been written to identify the most significant changes from BS 4772 that have been adopted in BS EN 598 and it is not intended to contradict nor replace any of the clauses or provisions in BS EN 598.

NA.2 Internal coatings

In order to give adequate performance when operating under the wide range of effluent characteristics specified in annex B, this standard specifies special internal coatings not in the scope of BS 4772, e.g. high alumina cement mortar for pipes and epoxy coating for fittings. Type tests are specified for chemical resistance (see **5.6** and **7.7**) and abrasion resistance (see **5.7** and **7.8**).

NA.3 Surface imperfections

This standard requires that pipes, fittings and accessories have to be free from defects and surface imperfections which could result in non conformance to the technical requirements and performance requirements given in clauses **4** and **5** respectively. However, no quantitive guidance is given on the sizes or numbers of such surface imperfections. This is in contrast with BS 4772, which specified the maximum permissible depths of surface imperfections on ductile iron pipes and fittings.

The only surface defect, the repair of which is clearly unacceptable is one which penetrates the full wall thickness of the pipe (see **4.12**).

NA.4 Pipeline fittings

This standard introduces a special range of fittings for gravity sewers (see **9.2**), whilst for pressure sewers the types of fittings can be selected from BS EN 545.

NA.5 Polythylene sleeving

Where polyethylene (PE) sleeving is required for protection of buried ductile iron pipelines against external corrosion, it should be specified in accordance with BS 6076. Guidance on the handling and installation of PE sleeving is given in the Water Industry Information and Guidance Notes (IGN) 4-50-01 and 4-50-02.

NA.6 Performance requirements and type tests

An important development in this standard is the introduction of a range of performance requirements and associated type tests not previously specified in BS 4772 (see clauses **5** and **7**).

The most significant type test requirement concerns leaktightness of joints when tested under positive internal pressure, negative internal pressure and positive external pressure, with the joint subject to shear loading or angular deflection.

These joint leaktightness type performance requirements go significantly beyond the scope of BS 4772, which contains no specific joint performance requiremenrs other than those for welded or screwed flange joints.

It should be noted that the joint type performance qualification tests specified in this standard are of relatively short duration (2 h), when considered in relation to the likely design service life of pipelines constructed from such products. It is not expected that this would be a problem in respect of those joint types produced by European manufacturers over the past 10 years which have performed successfully in service.

Pipe strength capability is type tested under conditions of longitudinal bending and diametral stiffness.

Long-term performance of internal coating systems is demonstrated by type tests for chemical and abrasion resistance. Users should note that the standard does not specifically require the inspection of epoxy or polyurethane linings for holidays (through-thickness defects), which is normally carried out in

the UK as a quality control check on such surface coatings. All lining materials should conform to the relevant European Standards, where these exist; if these are not available, they should conform to ISO or national standards, or to a technical specification (e.g. WIS 4-52-01) agreed between the manufacturer and the user.

NA.7 Pipeline design

The design calculation method given in annex C has been derived from existing methods, as a simplified calculation procedure applicable to ductile iron pipeline installations.

Other calculation methods may also be used, at the discretion of the pipeline designer, in order to provide a similarly high degree of security for the pipeline during its operating life.

Work is currently being undertaken by CEN/TC 164 /165/JWG 1 to evaluate the principal calculation methods currently being used in the various European Union member states. Further design guidance will be given in the first edition of a European Standard currently being prepared by this JWG (Joint Working Group). The long term aim will be to provide harmonized calculation methods applicable to all of the major pipeline materials.

NA.8 Information to be supplied by the purchaser

The following information should be supplied by the purchaser in his enquiry and order:

a) For socket and spigot pipes, the quantity, size (DN), length (see table 2), and type of joint.

b) For flanged pipes, the quantity, size (DN), flange rating (PN), length (see **4.2.5**).

c) For fittings, the quantity, size (DN), type of fitting and type of joint ends (including flange rating where necessary).

d) Where required, the quantity of pipes > DN 300 required to be suitable for cutting on site (see **4.2.1.1**).

e) For pipes and fittings, identification of external and internal coatings which are required (see **4.1.1, 4.4.1** and **4.5.1**).

f) Whether guidance is needed for jointing new products with existing pipelines or with other types of joints (see **4.1.3.3**).

g) Operating conditions for pipelines required to operate at pressures exceeding 6 bar (see clause **1**).

h) Information on the details of inlets/outlets on manholes (see **4.2.8**).

i) Details of any special effluent characteristics (see annex B).

NA.9 Further information

For further information and guidance, reference can be made to the following:

a) UK Water Industry information and guidance notes[1)];

IGN 4-21-01 *Ductile iron pipes and fittings*

IGN 4-50-01 *Operational guidelines for the loose polyethylene sleeving of underground iron mains*

IGN 4-50-02 *Operational guidelines for the transportation, handling and laying of ductile iron pipes with factory applied polyethylene sleeves*

b) Ductile Iron Pipe Committee, 8th Floor, Bridge House, Smallbrook, Queensway, Birmingham, B5 4JP. Tel 0121 643 3377, Fax 0121 643 5064

c) The UK ductile iron pipe manufacturers.

[1)] These publications may be obtained from WRc plc, Frankland Road, Blagrove, Swindon, SN5 8YF. Tel 01793 511711, Fax 01793 511712.

List of references

See national foreword.

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