INTERNATIONAL STANDARD

ISO 25780

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Plastics piping systems for pressure and non-pressure water supply, irrigation, drainage or sewerage — Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin — Pipes with flexible joints intended to be installed using jacking techniques

Systèmes de canalisations en matières plastiques pour l'alimentation en eau avec ou sans pression, pour l'irrigation ou l'assainissement — Systèmes en matières plastiques thermodurcissables renforcés de verre (PRV) à base de résine de polyester non saturé (UP) — Tubes avec assemblages flexibles destinés à être installés par les techniques de poussée

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 25780 was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 6, *Reinforced plastics pipes and fittings for all applications*.

Plastics piping systems for pressure and non-pressure water supply, irrigation, drainage or sewerage — Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin — Pipes with flexible joints intended to be installed using jacking techniques

1 Scope

This International Standard specifies the properties of the piping system and its components made from glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP) for water supply, irrigation, drainage or sewerage systems with or without pressure.

This International Standard is applicable to GRP-UP piping systems, with flexible joints, intended to be installed using jacking techniques. It specifies the characteristics of pipes made from GRP-UP, with or without aggregates or fillers and also specifies the test parameters for the test methods referred to in this International Standard.

NOTE Pipes referred to in this International Standard are, because of their intended use, required to have a minimum nominal stiffness of at least SN 20000 (see 5.2.1).

This International Standard is applicable to pipes and joints with a size range from DN100 to DN4000 which are intended to be used for the conveyance of water or sewage at temperatures up to 50 °C, with or without pressure.

It covers requirements to prove the design of the joint and specifies type test performance requirements for the joints as a function of the declared nominal pressure rating of the pipeline system and the required joint deflection capability of the system.

GRP-fittings, used between pipe systems covered by this International Standard, shall be in accordance with ISO 10639 for water supply systems or ISO 10467 for drainage and sewerage systems, as applicable. In a pipe-work system, pipes of different nominal pressure and stiffness ratings may be used together.

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.

ISO 75-2:2004, *Plastics — Determination of temperature of deflection under load — Part 2: Plastics and ebonite*

ISO 604:2002, *Plastics — Determination of compressive properties*

ISO 2078, *Textile glass — Yarns — Designation*

ISO 3126, *Plastics piping systems — Plastics components — Determination of dimensions*

ISO 4633, *Rubber seals — Joint rings for water supply, drainage and sewerage pipelines — Specification for materials*

ISO 7685, *Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes — Determination of initial specific ring stiffness*

ISO 8639, *Glass-reinforced thermosetting plastics (GRP) pipes and fittings — Test methods for leaktightness of flexible joints*

ISO 10466, *Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes — Test method to prove the resistance to initial ring deflection*

ISO 10467, *Plastics piping systems for pressure and non-pressure drainage and sewerage — Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin*

ISO 10468, *Glass-reinforced thermosetting plastics (GRP) pipes — Determination of the long-term specific ring creep stiffness under wet conditions and calculation of the wet creep factor*

ISO 10471, *Glass-reinforced thermosetting plastics (GRP) pipes — Determination of the long-term ultimate bending strain and the long-term ultimate relative ring deflection under wet conditions*

ISO 10639, *Plastics piping systems for pressure and non-pressure water supply — Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin*

ISO 10928, *Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes and fittings — Methods for regression analysis and their use*

ISO 10952, *Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes and fittings — Determination of the resistance to chemical attack for the inside of a section in a deflected condition*

3 Terms and definitions

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

3.1
manufacturer's declared pipe outside diameter
d_{OD}
external diameter of the pipe barrel, excluding the spigot

NOTE Manufacturer's declared pipe outside diameter is expressed in millimetres (mm).

3.2
jacking diameter
d_{e}
calculated maximum outside diameter of the external profile of the pipe barrel at all cross-sections

$$d_{\mathrm{e}} = d_{\mathrm{OD}} + \Delta^{+} \quad (1)$$

where

Δ^{+} is the plus tolerance on the outside diameter;

d_{OD} is the manufacturer's declared outside diameter.

NOTE Jacking diameter, which is derived using the equation above, outside diameter and its tolerance are expressed in millimetres (mm).

3.3
mean diameter
d_m
diameter of the circle corresponding with the middle of the pipe wall cross-section

NOTE Mean diameter is derived using the following equation with the outside diameter and wall thickness expressed in millimetres (mm):

$$d_m = d_{OD} - e$$

where

e is the pipe's wall thickness;

d_{OD} is the manufacturer's declared outside diameter.

3.4
internal diameter
ID
d_i
external diameter minus twice the wall thickness, e

NOTE 1 Internal diameter is derived using the following equation

$$d_i = d_{OD} - 2 \times e$$

NOTE 2 Internal diameter, outside diameter and wall thickness are expressed in millimetres (mm).

3.5
spigot or groove diameter
d_g
external diameter of the spigot [see Figure 1 a) diameter], or in the groove of the spigot [see Figure 1 b) diameter, if applicable]

NOTE Spigot or groove diameter is expressed in millimetres (mm).

3.6
minimum cross-sectional area at the spigot
A_s
minimum area of the cross-section of the pipe at the spigot, or in the groove of the spigot, if applicable

NOTE Minimum cross-sectional area at the spigot is derived using the following equation and is expressed in square millimetres (mm^2)

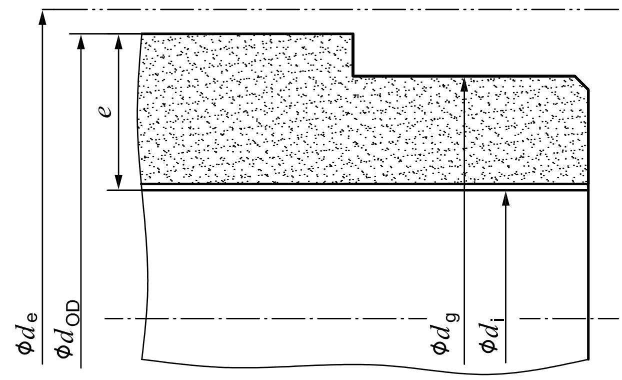
$$A_s = \pi\left[\left(0,5 \cdot d_g\right)^2 - \left(0,5 \cdot d_i\right)^2\right]$$

3.7
buried pipeline
pipeline which is subjected to the external pressure transmitted from soil loading, including traffic and superimposed loads and, possibly, the pressure of a head of water

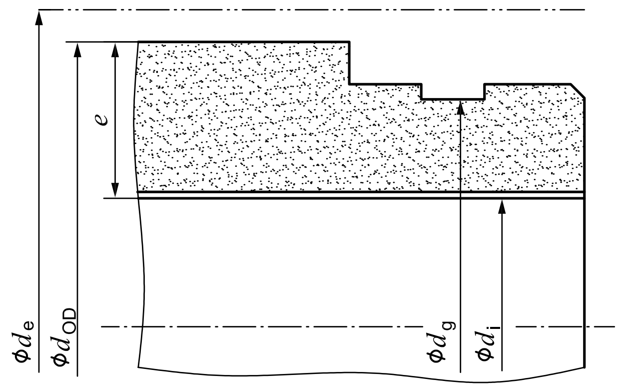
3.8
jacking
trenchless construction method which installs a pipeline by inserting pipes one by one under the ground by pressing with one or more hydraulic jacks, while the excavated ground is simultaneously evacuated from the cutting head

3.9
nominal length
numerical designation of a pipe length, which is numerically equal to the laying length (3.11), when expressed in metres (m) and rounded to the nearest whole number

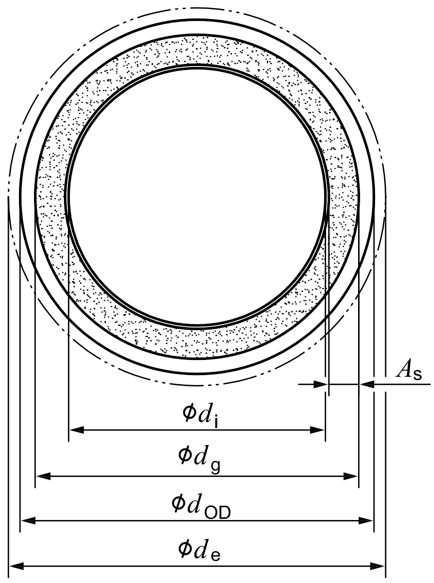
NOTE Nominal length is a dimensionless number rounded to the nearest whole number.



a) Section through a rebated un-grooved spigot



b) Section through a rebated grooved spigot



c) Cross-section through spigot

Key

d_{OD} outside diameter of pipe (see 3.1)

d_e jacking diameter (see 3.2)

d_i internal diameter of pipe (see 3.4)

d_g rebated spigot or groove diameter (see 3.5)

e wall thickness of pipe

A_s Minimum pipe cross-sectional area at spigot (see 3.6).

Figure 1 — Diameters referred to in these definitions

3.10
total length
distance between two planes normal to the pipe axis and passing through the extreme end points of the pipe

NOTE Total length is expressed in metres (m).

3.11
laying length
l
total length of a pipe minus, where applicable, the manufacturer's recommended insertion depth of the spigot(s) in the socket

NOTE Laying length is expressed in millimetres (mm).

3.12
specific initial longitudinal compressive stress at break (derived from a spool test-piece)
$\sigma_{b,s}$
compressive stress at break (3.46) of a spool test-piece, during a short-term compressive test with the test-piece loaded along its longitudinal axis, including, if applicable, spigots with rebates

NOTE When tested in accordance with Annex B, specific initial longitudinal compressive stress is expressed in megapascals (MPa).

3.13
minimum specific initial longitudinal compressive stress at break
$\sigma_{b,s,min}$
manufacturer's declared minimum value for the specific initial longitudinal compressive stress at break of the pipe

NOTE Minimum specific initial longitudinal compressive stress at break is expressed in megapascals (MPa).

3.14
initial longitudinal compressive stress at break (derived from rebated or un-rebated test-pieces)
$\sigma_{b,r}$
$\sigma_{b,u}$
compressive stress at break of the test-piece during a short-term compression test using either a rebated (r) or unrebated (u) test-piece

NOTE When tested in accordance with Annex A, the initial longitudinal compressive stress at break is expressed in megapascals (MPa).

3.15
sample de-rating factor
f_s
factor correcting for the relationship between compression test results obtained on full size pipes (spool test-pieces, 3.12) and results obtained using test-pieces with the same spigot geometry (3.14)

NOTE Sample derating factor is a dimensionless number.

3.16
de-rated initial longitudinal compressive stress at break
$\sigma_{b,d}$
calculated compressive stress obtained from the test results at break using either un-rebated or rebated test-pieces and the applicable de-rating factor

NOTE Derated initial longitudinal compressive stress at break is expressed in megapascals (MPa).

3.17
initial longitudinal compressive modulus
$E_{c,m}$
ratio of the applied stress to the resulting strain below the elastic limit, both measured concurrently during a short-term compression test

NOTE When tested in accordance with either Annex A or B, the initial longitudinal compressive modulus is expressed in megapascals (MPa).

3.18
ultimate longitudinal load
F_{ult}
calculated value of the concentric longitudinal load that the pipe withstands just before break

NOTE Ultimate longitudinal load is expressed in kilonewtons (kN).

3.19
longitudinal compressive (material) safety coefficient
γ
safety factor applied to the ultimate longitudinal load to determine the theoretical design jacking load $F_{j,\ calc}$ (3.21)

3.20
design jacking load
F_j
manufacturer's declared value of the longitudinal compressive load that a pipe can withstand during a jacking operation, taking into account the material safety coefficient, γ

NOTE Design jacking load is expressed in kilonewtons (kN).

3.21
theoretical design jacking load
$F_{j,\ calc}$
calculated value of the concentric longitudinal compressive load that the pipe can be expected to withstand during a jacking operation, taking into account the material safety coefficient, γ

NOTE Theoretical design jacking load is expressed in kilonewtons (kN).

3.22
permissible eccentric jacking force on the pipe
$F_{perm,\ p}$
calculated value of the permissible eccentric longitudinal load that the pipe can withstand during a jacking operation, taking into account the material safety coefficient, γ (3.19), and the estimated angular deflection, δ

NOTE Permissible eccentric jacking force on the pipe is expressed in kilonewtons (kN).

3.23
permissible eccentric jacking force on the system
$F_{perm,\ s}$
value declared by the pipe manufacturer of the permissible eccentric longitudinal force that the system can withstand during a jacking operation, taking into account the material safety coefficient, γ, and the estimated angular deflection, δ

NOTE Permissible eccentric jacking force on the system is expressed in kilonewtons (kN).

3.24
nominal stiffness
SN
S_N
alphanumerical designation for stiffness identification purposes (see 4.2.3), which has the same numerical value as the minimum initial specific ring stiffness value, when expressed in newtons per square metre (N/m^2)

NOTE Nominal stiffness is a dimensionless number used for identification or marking purposes consisting of the letters SN plus a number.

3.25
specific ring stiffness
S
physical characteristic of the pipe which is a measure of the resistance to ring deflection per metre length under external load

NOTE Specific ring stiffness is determined using the following equation and is expressed in newtons per square metre (N/m^2)

$$S = \frac{E \times I}{d_m{}^3}$$

where

E is the apparent modulus of elasticity, which can be derived from the result of the ring stiffness test, i.e. ISO 7685, expressed in newtons per square metre (N/m^2);

d_m is the mean diameter of the pipe (3.3), in metres (m);

I is the second moment of area in the longitudinal direction per metre length, in metres to the fourth power per metre, (m^4/m)

$$I = \frac{e^3}{12}$$

where e is the wall thickness, in metres (m).

3.26
initial specific ring stiffness
S_0
value of specific ring stiffness, S, obtained when tested in accordance with ISO 7685

NOTE Initial specific ring stiffness is expressed in newtons per square metre (N/m^2).

3.27
wet creep factor
$\alpha_{x,\text{creep,wet}}$
ratio of the long-term specific ring stiffness, $S_{x,\text{wet}}$ at x years, to the initial specific ring stiffness, S_0

NOTE When tested in accordance with ISO 10468, using sustained loading under wet conditions, the long-term specific ring stiffness, $S_{x,\text{wet}}$ is obtained and when this value is divided by the initial specific ring stiffness, S_0, the wet creep factor, $\alpha_{x,\text{creep,wet}}$, is obtained (see the following equation)

$$\alpha_{x,\text{creep,wet}} = \frac{S_{x,\text{wet}}}{S_0}$$

3.28
calculated long-term specific ring stiffness
$S_{x,\text{ wet}}$
calculated value of specific ring stiffness, S, at x years

NOTE Long-term specific ring stiffness is obtained using the following equation

$$S_{x,\text{ wet}} = S_0 \times \alpha_{x,\text{ wet}}$$

where

x is the elapsed time in years specified in this International Standard (see 4.6);

$\alpha_{x,\text{wet}}$ is the wet creep factor at x years;

S_0 is the initial specific ring stiffness.

3.29
pressure pipe
pipe having a nominal pressure (PN) (3.31) classification greater than 1 bar and which is intended to be used with the internal pressure equal to or less than its nominal pressure when expressed in bars

3.30
non-pressure pipe
pipe subjected to an internal pressure not greater than 1 bar

3.31
nominal pressure
PN
alphanumeric designation for pressure classification purposes, which has a numerical value equal to the resistance of a component of a piping system to internal pressure

NOTE Nominal pressure is a designation for reference or marking purposes that consists of the letters PN plus a number which is related to a component's pressure rating in bars.

3.32
normal service conditions
conveyance of water or sewage, in the temperature range 2 °C to 50 °C, with or without pressure, for 50 years

3.33
design service temperature
maximum sustained temperature, at which the system is expected to operate continuously

NOTE Design service temperature is expressed in degrees Celsius (°C).

3.34
rerating factor
R_{RF}
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 (RH)

3.35
relative ring deflection
y/d_{m}
ratio of the change in diameter of a pipe, y, in metres, to its mean diameter, d_{m}, in metres

NOTE Relative ring deflection is derived as a percentage, %, i.e.:

$$\left(\frac{y}{d_{\text{m}}}\right)\times 100$$

3.36
minimum initial relative specific ring deflection at 2 min **before bore cracking occurs**
$\left(y_{2,\text{bore}}/d_{\text{m}}\right)_{\text{min}}$
initial relative specific ring deflection at 2 min which a test-piece is required to exceed without bore cracking when tested in accordance with ISO 10466

NOTE Minimum initial relative specific ring deflection at 2 min before bore cracking occurs is expressed in % of mean diameter, i.e.:

$$\left(\frac{y_{2,\,\text{bore}}}{d_{\text{m}}}\right)_{\text{min}}\times 100$$

3.37
type test
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 this International Standard

3.38
flexible joint
joint which allows relative movement between components being joined

3.39
flush coupling
joint component with either an external diameter equal to the pipe's outside diameter or an inside diameter equal to the pipe's inside diameter

3.40
closed joint
joint condition where the pipe-ends, initially separated with a pressure transfer ring, are in close contact with each other without any gap around the whole circumference

3.41
open joint
joint condition where the pipe-ends are partly or totally not in close contact with each other thereby forming a gap

3.42
angular deflection
δ
angle between the axes of two adjacent pipes

NOTE Angular deflection (see Figure 2) is expressed in degrees (°).

3.43
draw
D
longitudinal movement of a joint

NOTE Draw (see Figure 2) is expressed in millimetres (mm).

3.44
total draw
T
sum of the draw, D, and the additional longitudinal movement, J, due to the presence of angular deflection

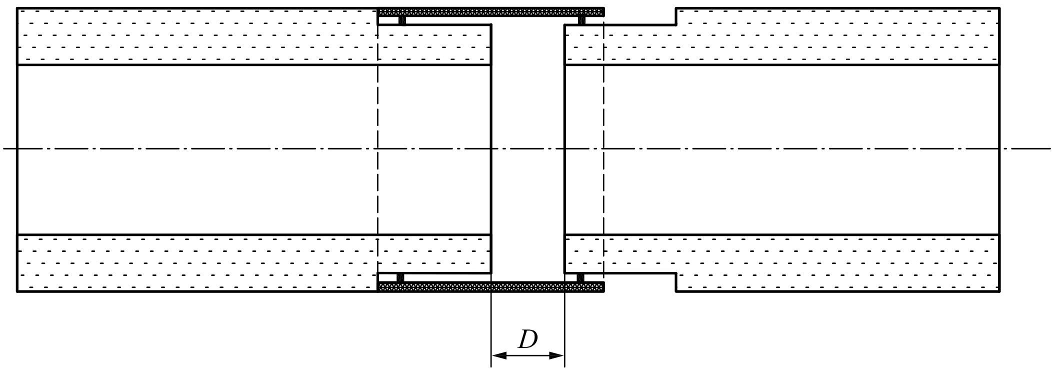
NOTE Total draw (see Figure 2) is expressed in millimetres (mm).

3.45
misalignment
M
amount by which the centrelines of adjacent pipes fail to coincide

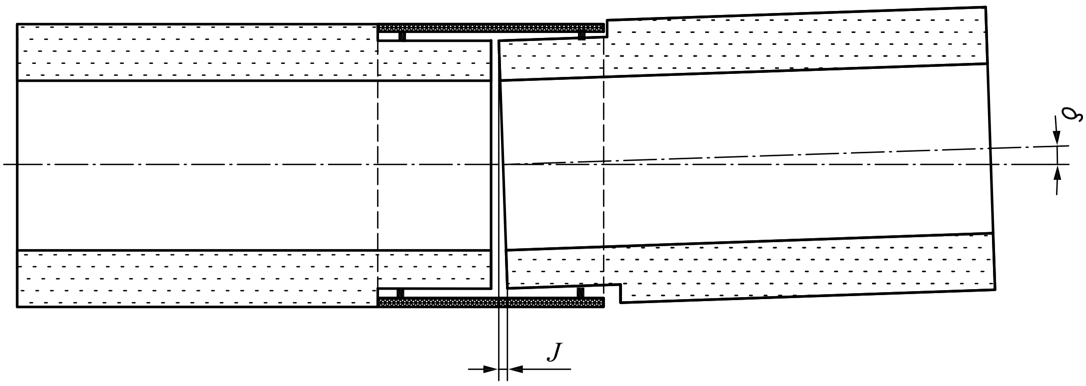
NOTE Misalignment (see Figure 2) is expressed in millimetres (mm).

3.46
break
condition where the test-piece can no longer carry the load to which it is being subjected

3.47
overcut
area between the bored wall formed in the native soil and the external surface of the pipe, created by the cutting head or shield of the jacking machine



a)



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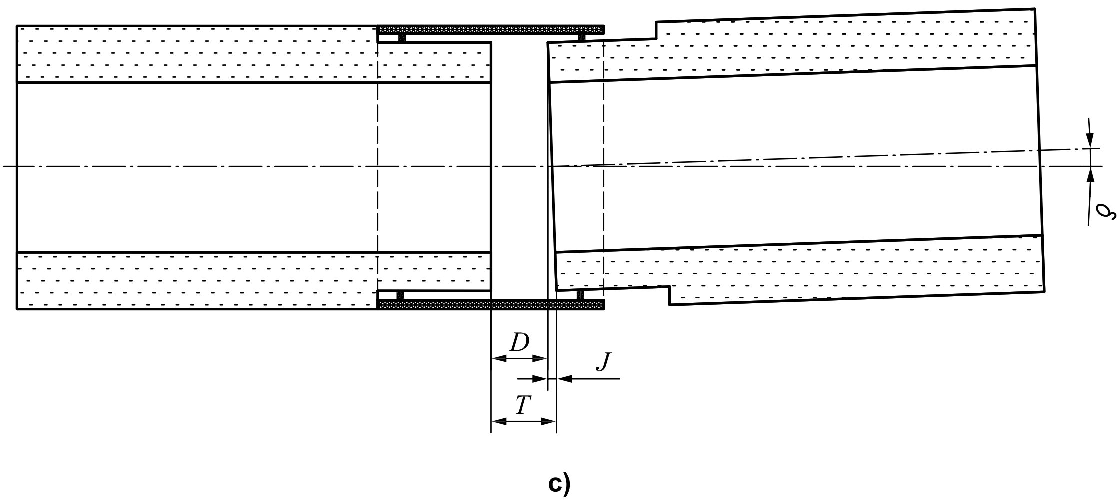
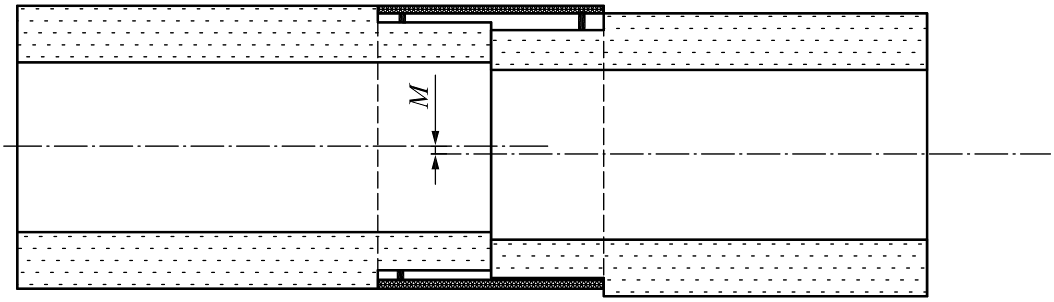


c)

Figure 2 — Joint movements (*continued*)



d)

Key

D draw

J longitudinal movement arising from angular deflection of the joint

δ angular deflection of the joint

T total draw

M misalignment

NOTE The joint in this figure is an example of a typical joint but is not intended to fix design. Other joints are available.

Figure 2 — Joint movements

4 Requirements

4.1 Classification

Pipes shall be identified according to the manufacturer's declared pipe outside diameter, d_{OD} (see 3.1), maximum jacking load (see 4.1.3), nominal stiffness (SN) (see 3.24), nominal pressure (PN) (see 3.31) and joint type (see 4.2.2).

Couplings for use on the outside of a pipe shall be identified according to the pipe jacking diameter, d_e, nominal pressure (PN) and joint type. Couplings for use on the inside of a pipe shall be identified according to the pipe's internal diameter, d_i (see 3.4), nominal pressure (PN) and joint type.

4.2 Pipe properties

4.2.1 Manufacturer's declared diameters

The outside diameter of GRP pipes conforming with this International Standard shall conform to the requirements given in Table 4 and be designated by the manufacturer's declared pipe outside diameter, d_{OD} (see 3.1). The manufacturer shall also declare the internal diameter, d_i (see 3.4).

4.2.2 Maximum jacking load

The manufacturer shall declare the maximum load that can be applied to the pipe during the jacking operation, in tonnes. The customer shall detail in his enquiry the maximum load that is required for the pipe to be capable of carrying during the jacking operation.

4.2.3 Nominal stiffness

For jacking applications, the pipe shall have a nominal stiffness (see 3.24) of at least SN 20000.

4.2.4 Nominal pressure

The nominal pressure (PN) (see 3.31) shall conform to one of those given in Table 1.

Where pressure ratings other than the nominal values in Table 1 are to be supplied, by agreement between the manufacturer and the purchaser, the pressure marking PN on the component shall be replaced by PNv, where v is the number equal to the component's nominal pressure.

4.2.5 Appearance

Both internal and external surfaces shall be free from irregularities, which would impair the ability of the component to conform to the requirements of this International Standard.

Table 1 — Nominal pressures (PN)

Nominal pressure (PN)	
1	(15)
(2,5)	16
(4)	(18)
6	(20)
(9)	25
10	32
(12)	
NOTE 1 Components marked PN1 are non-pressure components (see 3.30). NOTE 2 Values in parentheses are non-preferred nominal pressures.	

4.3 Materials

4.3.1 General

The pipe shall be constructed using chopped and/or continuous glass filaments, strands or roving, mats or fabric synthetic veils, polyester resin with or without fillers and, if applicable, additives necessary to impart specific properties to the resin. The pipe may also incorporate aggregates.

4.3.2 Reinforcement

The glass used for the manufacture of the reinforcement shall be classified as one of the following types in accordance with ISO 2078:

a) a type “E” glass, comprising primarily either oxides of silicon, aluminium and calcium (alumino-calcosilicate glass) or silicon, aluminium and boron (alumino-borosilicate glass);

b) a type “C” glass, comprising primarily oxides of silicon, sodium, potassium, calcium and boron (alkali calcium glass with an enhanced boron trioxide content) which is intended for applications requiring enhanced chemical resistance.

In either of these types of glass, small amounts of oxides of other metals will be present.

NOTE The descriptions for “C” glass and “E” glass are consistent with, but more specific than, those given in ISO 2078.

The reinforcement shall be made from continuously drawn filaments of a glass conforming to type E or type C, and shall have a surface treatment compatible with the resin to be used. It may be used in any form, e.g. as continuous or chopped filaments, strands or roving, mat or fabric.

4.3.3 Resin

The resin used in the structural layer (see 4.4.2) shall have a temperature of deflection of at least 70 °C when tested in accordance with method A of ISO 75-2:2004.

4.3.4 Aggregates and fillers

The size of particles in aggregates and fillers shall not exceed 1/5 of either total wall thickness of the pipe or fitting, or 2,5 mm, whichever is the lesser.

4.3.5 Elastomers

Each elastomeric material of the sealing component in contact with the fluid being conveyed shall conform to the applicable part of ISO 4633 or, if such material is not available, a similar standard that is acceptable to both the purchaser and supplier.

4.3.6 Metals

Where exposed metal components are used, there shall not be evidence of corrosion of the components after the fitting has been immersed in an aqueous sodium chloride solution, 30 g/l, for seven days at (23 ± 2) °C.

4.4 Pipe wall construction

4.4.1 Inner layer

The inner layer shall comprise one of the following:

a) a thermosetting resin layer with or without aggregates or fillers and with or without reinforcement of glass or synthetic filaments;

b) a thermoplastics liner.

The resin used in this inner layer need not conform to the temperature of deflection requirements given in 4.3.3.

4.4.2 Structural layer

The structural layer shall consist of glass reinforcement and a thermosetting resin, with or without aggregates or fillers.

4.4.3 Outer layer

The construction of the outer layer of the pipe shall take into account the environment in which the pipe is to be used. This layer shall be formed of a thermosetting resin with or without aggregates and fillers and with or without a reinforcement made of glass or synthetic filaments. The resin used in this outer layer need not conform to the temperature of deflection requirements in 4.3.3.

NOTE When selecting or specifying the pipe for use, ensure that the prevailing native soil conditions and the lubrication materials, such as bentonite gels, proposed for use by the pipe jacking contractor, are suitable and will not affect the performance of the pipe.

4.5 Reference conditions for testing

4.5.1 Temperature

The mechanical, physical and chemical properties specified in this International Standard shall, unless otherwise specified, be determined at (23 ± 5) °C.

For service temperatures over 35 °C, type tests (see 3.43) shall be carried out at least at the design service temperature (see 3.33) to establish rerating factors (see 3.34) for all long-term properties of relevance to the design of pipes.

4.5.2 Properties of water for testing

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

4.5.3 Loading conditions

Unless otherwise specified, the mechanical, physical and chemical properties specified in this International Standard shall be determined using circumferential and/or longitudinal loading conditions, as applicable.

4.5.4 Preconditioning

Unless otherwise specified, in case(s) of dispute, store the test-piece(s) in air at the test temperature specified in 4.5.1 for at least 24 h prior to testing.

4.5.5 Measurement of dimensions

In cases of dispute, determine the dimensions of GRP components at the temperature specified in 4.5.1. Make all measurements in accordance with ISO 3126 or using any other method of sufficient accuracy to determine conformity or nonconformity with the applicable limits. Make all routine measurements at the prevailing temperature or, if the manufacturer prefers, at the temperature specified in 4.5.1.

4.6 Elapsed time, x, for determination of long-term properties

The subscript x in, for example, $S_{x,\,\mathrm{wet}}$ (see 3.27 and 3.28) denotes the time at which the long-term property is to be determined. Unless otherwise specified, the long-term properties shall be determined at 50 years (438 000 h).

4.7 Joint properties

4.7.1 General

The manufacturer shall declare the length, LC, and the maximum external diameter, DEC, of the assembled joint.

4.7.2 Types of joint

The joint shall be classified as flexible (see 3.38). Use rebated spigots able to accommodate flush couplings (see 3.45). Rebated spigots may be grooved to house the elastomeric seals.

4.7.3 Flexibility of the jointing system

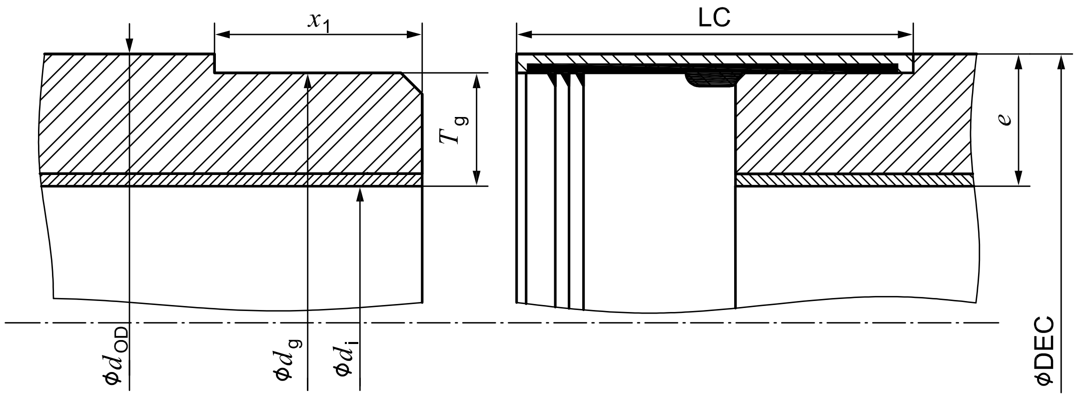
4.7.3.1 Allowable angular deflection

The manufacturer shall declare the maximum allowable angular deflection between adjacent pipes in the installed condition which shall not be less than the applicable value given in Table 2. The manufacturer shall also declare the maximum allowable angular deflection, δ (see 3.42), at which each joint is designed to operate when subjected to either internal or external pressure, as appropriate, and the value shall not be less than the applicable value in Table 2.

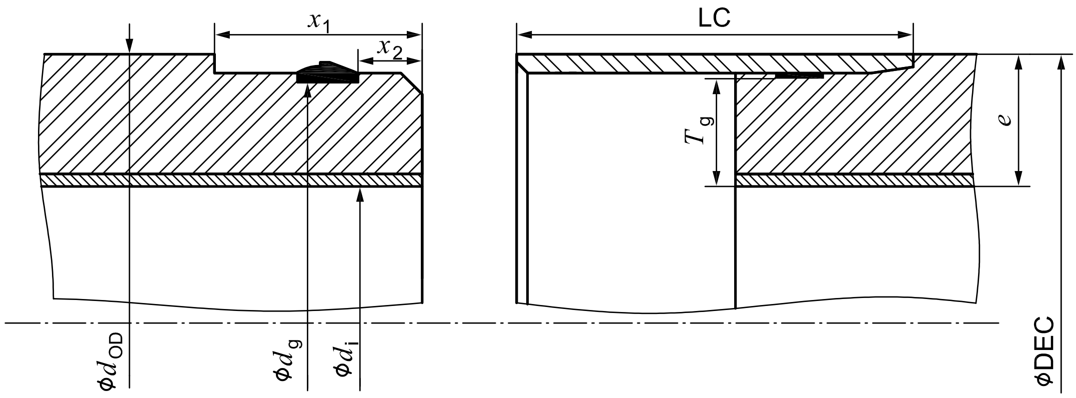
The manufacturer shall declare the maximum allowable angular deflection permitted during pipe jacking operations.

4.7.3.2 Allowable draw

The manufacturer shall declare the allowable draw, D (see 3.43), for which each joint is designed.



a) Example of a pipe connection using a rebated un-grooved spigot and flush coupling



b) Example of a pipe connection using a rebated grooved spigot and flush coupling

Key

d_{OD} external diameter (see 3.1)

d_i internal diameter (see 3.4)

d_g external diameter of the rebated spigot or in the groove, if applicable (see 3.5)

DEC external diameter of the flush coupling (see 3.39), expressed in millimetres (mm)

LC length of coupling, expressed in millimetres (mm)

x_1 rebated length, expressed in millimetres (mm)

x_2 distance of the groove to spigot end, expressed in millimetres (mm)

e pipe wall thickness (see 3.3)

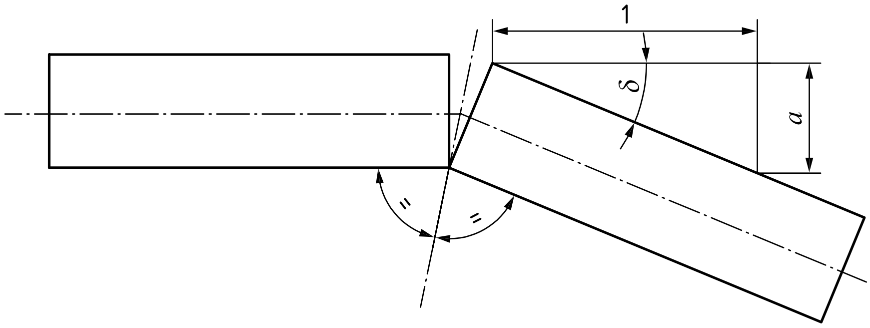
T_g thickness of the smallest section under the groove, expressed in millimetres (mm)

Figure 3 — Examples of a pipe connection

Table 2 — Maximum allowable installed deflection of pipe joints

External diameter d_{OD} mm	Maximum allowable installed deflection a mm/m	Maximum allowable installed deflection δ degrees
$d_{OD} \leq 200$	20	1,145 8
$200 < d_{OD} \leq 500$	15	0,859 4
$500 < d_{OD} \leq 1\,000$	10	0,572 9
$1\,000 < d_{OD}$	$a = 10 \times \frac{1\,000}{d_{OD}}$	Derive from value of a

Dimensions in metres



Key

δ Maximum angular deflection () in degrees (°).

a Maximum angular deflection in millimetres per metre (mm/m).

Figure 4 — Joint deflection

4.7.4 Sealing ring

The 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 performance requirements specified in Clause 7 of this International Standard.

4.7.5 Effect on water quality

When the pipes are intended to be used for the conveyance of water intended for human consumption, attention is drawn to the need for components to comply with any national regulations on the quality of drinking water in force at the location where the components are to be used.

5 Pipes

5.1 Geometrical characteristics

5.1.1 Jacking diameter

Pipes conforming with this International Standard have their diameter classified by their manufacturer's declared pipe outside diameter, d_{OD} (see 3.1). Because the outside diameter of a jacking pipe needs to be compatible with the jacking machinery, the actual outside diameter of a pipe conforming to this International Standard shall be agreed between the purchaser and the manufacturer.

The jacking diameter, d_e (see 3.2), is the calculated maximum outside diameter of the external profile of the pipe barrel at all cross-sections calculated using Equation (1):

$$d_e = d_{OD} + \Delta^+ \quad (1)$$

where

Δ^+ is the plus tolerance on the outside diameter;

d_{OD} is the manufacturer's declared pipe outside diameter.

The jacking diameter shall be compatible with the size of the hole bored by the pipe jacking machinery during installation.

NOTE 1 Jacking diameter, outside diameter and its tolerance are expressed in millimetres (mm).

NOTE 2 There is no additional tolerance on the agreed jacking diameter, d_e, derived from Equation (1) for any diameters.

5.1.2 Wall thickness

The manufacturer shall declare the minimum total wall thickness, e (see 3.3), and the minimum spigot thickness T_g (see Figure 3). The measured wall thickness at any point of pipe and spigot shall not be less than the manufacturer's stated values.

5.1.3 Nominal length

Unless otherwise agreed between the manufacturer and the purchaser, the nominal length (see 3.9) shall be one of the following values:

1, 2, 3, 4 or 6.

5.1.4 Laying length

The pipe shall be supplied in laying lengths, l (see 3.11), in accordance with the requirements given in the following paragraph. The tolerance on effective laying length is ±60 mm.

Of the total number of pipes supplied in each diameter, the manufacturer may supply up to 10 % in laying lengths shorter than the nominal length, unless a higher percentage of such pipes has been agreed between the manufacturer and purchaser. In all cases where the laying length of the pipe is not within 60 mm of the nominal length, the actual laying length of the pipe shall be marked on the pipe.

5.1.5 Straightness

For pipes with a laying length, l (see 3.11), up to 6 m, the deviation from straight of a surface line shall not exceed the values given in Table 3.

Table 3 — Maximum permissible deviation from straightness

Dimensions in millimetres

Manufacturer's declared outside diameter d_{OD}	Deviation from straightness, per pipe
$d_{OD} \leq 550$	5
$550 < d_{OD} \leq 960$	4
$960 < d_{OD}$	3

Straightness for pipes with a nominal length longer than 6 m shall be agreed between manufacturer and client.

Due to end effects, when checking a pipe's straightness, measure a length not less than the laying length, l (see 3.11), less 50 mm. Measure the deviation as the maximum distance between a calibrated lath, with the same length as the pipe, and the external or internal pipe surface.

5.1.6 Squareness of end faces

The deviation from squareness across a joint's external diameter, $d_{sq,\,d}$ (see Figure 5), shall not exceed the values given in Table 4.

Table 4 — Permissible deviation from squareness across a joint's external diameter

Dimensions in millimetres

Manufacturer's declared outside diameter d_{OD}	Deviation of squareness $d_{sq,d}$
$d_{OD} \leq 300$	0,5
$300 < d_{OD}$	1,0

The permissible deviation from squareness across a joint's wall thickness, $d_{sq,\,e}$ (see Figure 6), is −1° in relation to 90° for all pipe diameters and wall thicknesses.

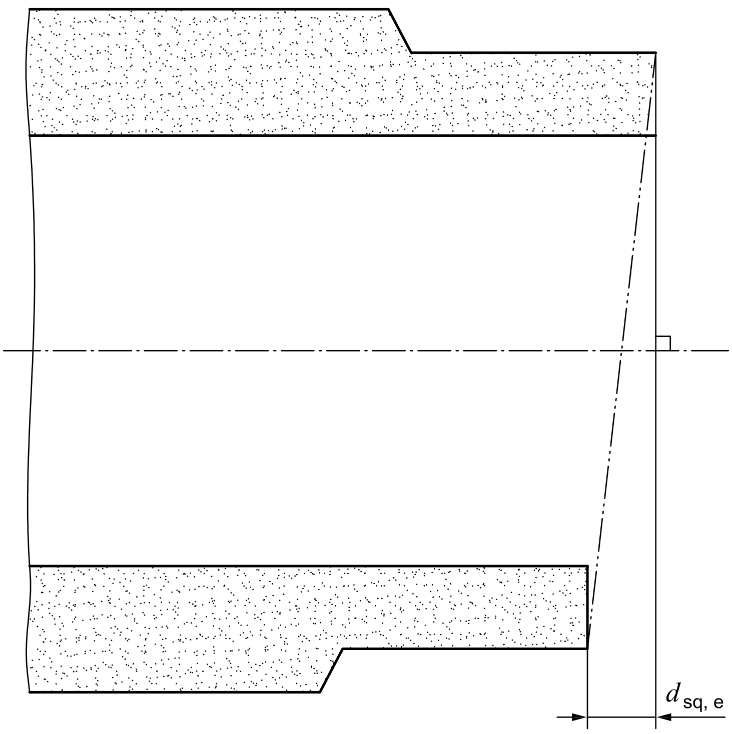


Figure 5 — Deviation from squareness across a joint's external diameter

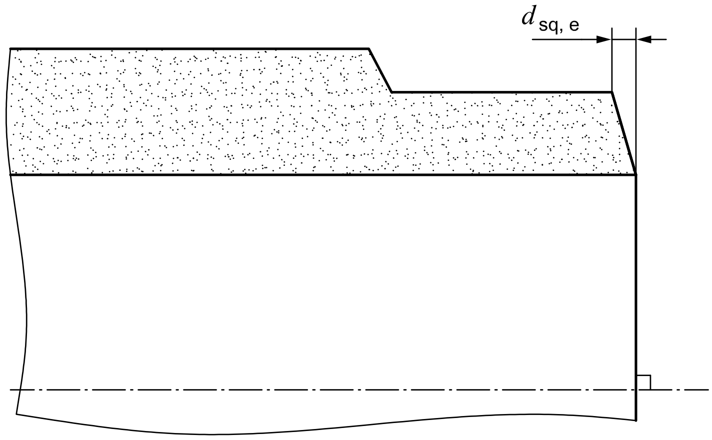


Figure 6 — Deviation from squareness across a joint's wall thickness

5.2 Mechanical characteristics

5.2.1 Initial specific ring stiffness

For jacking applications the pipe shall have a nominal stiffness of at least SN 20000.

NOTE Higher stiffnesses may be required for a particular application.

The manufacturer shall determine the initial specific ring stiffness by testing the product in accordance with test methods referred to in ISO 10467 or ISO 10639, as appropriate. Perform the test using a relative ring deflection (see 3.35) calculated using Equation (2).

$$\text{Relative deflection}\,(\%) = \frac{y}{d_\mathrm{m}} \times 100 = \frac{65}{\sqrt[3]{S_\mathrm{N}}} \pm 0{,}5 \qquad (2)$$

where

S_N is the nominal stiffness (see 3.24);

$\frac{y}{d_\mathrm{m}} \times 100$ is the relative deflection, in percent, for the initial specific ring stiffness test.

The value determined for the initial specific ring stiffness, S_0, shall not be less than the nominal stiffness expressed in N/m^2.

5.2.2 Long-term specific creep stiffness

The manufacturer shall determine the minimum long-term specific creep stiffness, $S_{x,\,\mathrm{creep,\,min}}$, by either testing the product in accordance with test methods referred to in ISO 10467 or ISO 10639 as appropriate or by similar testing of product complying with ISO 10467 or ISO 10639 having a wall structure that gives equivalent or higher strain in areas of similar material composition, when subjected to diametrical deflection.

The manufacturer shall determine the minimum long-term specific creep stiffness, $S_{x,\,\mathrm{creep,\,min}}$, of the pipe using Equation (3) that includes the creep factor, $\alpha_{x,\,\mathrm{wet,\,creep}}$, derived from tests performed on test-pieces having a wall structure that is the same as the pipe intended to be used in jacking installations.

$$S_{x,\,\mathrm{wet,\,creep,\,min}} = S_0 \times \alpha_{x,\,\mathrm{wet,\,creep}} \qquad (3)$$

where S_0 is the measured initial specific ring stiffness of the test-piece (see 3.26).

The value determined shall be declared by the manufacturer.

5.2.3 Initial resistance to failure in a deflected condition

The manufacturer shall determine the resistance to failure in a deflected condition by either testing the product in accordance with test methods referred to in ISO 10467 or ISO 10639, as appropriate, or by similar testing of products complying with ISO 10467 or ISO 10639 having a wall structure that gives equivalent or higher strain in areas of similar material composition, when subjected to diametrical deflection.

Calculate the required minimum initial relative specific ring deflection before bore cracking, $y_{2,\text{ bore}}/d_\text{m}$, using Equation (4).

$$\left(\frac{y_{2,\text{ bore}}}{d_\text{m}}\right)_\text{min} \times 100 = \frac{194}{\sqrt[3]{S_0}} \tag{4}$$

where

$(y_{2,\text{ bore}}/d_\text{m})_\text{min} \times 100$ is the required minimum 2 minute initial relative specific ring deflection calculated for the nominal stiffness of the test-piece, expressed in percent (%);

S_0 is the measured initial specific ring stiffness of the test-piece (see 3.26).

5.3 Resistance to strain corrosion

For pipes intended to be used for septic sewers or the conveyance of corrosive effluents, the manufacturer shall determine the resistance to strain corrosion by either testing the product in accordance with requirements and test methods referred to in ISO 10467 or by similar testing of products complying with ISO 10467 having a wall structure that gives equivalent or higher strain in areas of similar material composition, when subjected to diametrical deflection in a corrosive environment.

5.4 Longitudinal compressive strength

5.4.1 General

The manufacturer shall declare the minimum specific initial longitudinal compressive stress at break, $\sigma_\text{b,s,min}$ (see 3.13). Determine from routine quality control tests, performed in accordance with Annex A, the de-rated initial longitudinal compressive stress at break (see 3.16) of both the pipe barrel, $\sigma_\text{b,d,barrel}$, and the pipe spigot, $\sigma_\text{b,d,spigot}$, and declare the result.

The test results of the compressive properties obtained from grooved test-pieces or test-spools may be used to determine the compressive properties of pipes with non-grooved spigots.

5.4.2 Specific initial longitudinal compressive stress at break

For initial type test (ITT test) purposes, determine the specific initial longitudinal compressive stress at break, $\sigma_\text{b,s}$ (see 3.12), by central loading, using the procedure described in Annex B.

5.4.3 Test-piece de-rating factor, f_s

To calculate the test-piece de-rating factor, f_s, determine the initial longitudinal compressive stress at break, $\sigma_\text{b,r}$ (see 3.14), according to 5.4.4 on a sample of five rebated test-pieces made out of the same pipe and with the same spigot type as the test-piece for the specific longitudinal initial compressive stress at break, $\sigma_\text{b,s}$ (see 3.12). Calculate the test-piece de-rating factor, f_s, using Equation (5).

$$f_\text{s} = \frac{\text{Failure stress using pipe test-piece}}{\text{Failure stress using rebated test-piece}} = \frac{\sigma_\text{b, s}}{\sigma_\text{b, r}} \tag{5}$$

5.4.4 Initial longitudinal compressive stress at break

Determine the initial longitudinal compressive stress at break on both rebated $\sigma_{b,r}$ and un-rebated $\sigma_{b,u}$ test-pieces (see 3.14) using the method given in Annex A. The test-pieces shall conform to A.3.

Perform an ITT test on rebated test-pieces.

Routine quality control tests shall be performed on either rebated or un-rebated test-pieces.

5.4.5 Derated initial longitudinal compressive stress at break

5.4.5.1 General

Derated initial longitudinal compressive stress (see 3.16) values shall be calculated for all results obtained from routine quality control tests.

5.4.5.2 Pipe spigot strength

Calculate the derated compressive stress of the spigot, $\sigma_{b,\ d,\ spigot}$ by derating the un-rebated test-results using Equation (6).

$$\sigma_{b,d,spigot} = f_s \times \sigma_{b,u} \tag{6}$$

5.4.5.3 Pipe barrel strength

Calculate the derated compressive stress of the barrel, $\sigma_{b,\ d,\ barrel}$, by derating the un-rebated test-results using Equation (7).

$$\sigma_{b,d,barrel} = f_s \times \sigma_{b,u} \tag{7}$$

5.4.6 Requirements

5.4.6.1 Declared value

The specific initial longitudinal compressive stress at break, $\sigma_{b,\ s}$ (see 5.4.2), obtained from the ITT tests shall be higher than the declared minimum specific initial longitudinal compressive stress at break $\sigma_{b,\ s,\ min}$ (see 5.4.1).

5.4.6.2 Quality control

Both derated initial longitudinal compressive stresses at break $\sigma_{b,\ d,\ spigot}$ and $\sigma_{b,\ d,\ barrel}$ (see 5.4.5) of all quality control tests shall be higher than the minimum initial longitudinal compressive stress at break $\sigma_{b,\ s,\ min}$ (see 5.4.1).

5.5 Permissible jacking forces

5.5.1 General

Calculate the permissible jacking forces which can be applied to a pipe during the jacking operation, using the following procedure which is based on the methods described in Annex C.

NOTE The area, A_s, in the following equations is that of the joint surface in compression and not that of any pressure transfer ring (if used).

5.5.2 Ultimate longitudinal load, F_{ult}

The pipe's ultimate longitudinal load, F_{ult} (see 3.18), shall be calculated using Equation (8).

$$F_{\text{ult}} = \sigma_{\text{b,s,min}} \times A_{\text{s}} \tag{8}$$

where

$\sigma_{\text{b, s, min}}$ is the declared minimum specific initial compressive stress at break (see 5.4.1), expressed in megapascals (MPa);

A_{s} is the minimum pipe cross-sectional area at the spigot (see 3.6 and Figure 1), expressed in square millimetres (mm^2).

5.5.3 Manufacturer's declared jacking load for which a pipe is designed, $F_{\text{j,calc}}$, and the permissible eccentric jacking forces, $F_{\text{perm,p}}$ and $F_{\text{perm,s}}$

Using the appropriate procedures described below and in Annex C:

a) Calculate the theoretical design jacking load, $F_{\text{j, calc}}$ (see 3.21), which is the maximum load the pipe can withstand during a jacking operation, using Equation (9) which assumes that the jacking load is concentric and perpendicular to the joint faces (i.e. no deflection and all joint faces perfectly square).

$$F_{\text{j, calc}} = \frac{F_{\text{ult}}}{\gamma} \tag{9}$$

where

F_{ult} is the ultimate longitudinal load obtained from Equation (8), expressed in newtons (N);

γ is the material's safety factor in longitudinal compression.

The safety factor, γ, shall not be less than 1,75, unless specific agreement justifies the use of a lower value.

The manufacturer shall declare the jacking load for which each jacking pipe was designed [design jacking load, F_{j} (see 3.20)] and this load shall not be greater than the theoretical design jacking load ($F_{\text{j, calc}}$) derived from Equation (9).

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

b) Calculate the permissible eccentric jacking force on the pipe, $F_{\text{perm, p}}$ (see 3.22), using the estimated angular deflection, δ. The manufacturer shall declare the permissible eccentric jacking force on the pipe and the assumed angular deflection.

c) Calculate the permissible eccentric jacking force on the system, $F_{\text{perm, s}}$ (see 3.23), taking into account matters such as the following:

- the specified angular deflections during installation, the permissible jacking force on the pipe, $F_{\text{perm, p}}$, the effective eccentricity of the applied jacking force;
- the acceptable angular deflection in the coupling (see 4.7.3.1);
- the available overcut (see 3.47) in the curved bore.

The manufacturer shall declare the permissible eccentric jacking force on the system and the assumptions made in the calculations with regard to the above matters.

5.6 Specific initial longitudinal compressive modulus, $E_{c,m}$

Using the method described in Annex A, determine the specific initial longitudinal compressive modulus, $E_{c,m}$ (see 3.17), by performing ITT and quality control tests.

The manufacturer shall declare the value of $E_{c,m}$.

5.7 Resistance of pressure pipes to internal pressure

Pressure pipes (see 3.29) conforming to this International Standard are non-end-load-bearing as they are assembled using non-end-load-bearing joints (see 7.1).

The manufacturer shall determine the resistance of pressure pipes to internal pressure by either testing the product in accordance with test methods referred to in ISO 10467 or ISO 10639, as appropriate, or by similar testing of products complying with ISO 10467 or ISO 10639 having a wall structure that gives equivalent or higher strain in areas of similar material composition, when subjected to internal pressure.

6 Marking

Marking details shall be printed or formed directly on the pipe or coupling in such a way that the marking does not initiate cracks or other types of failure.

Marking on couplings is only required when delivered to the building site separately from the pipes.

If printing is used, the colour of the printed information shall differ from the basic colouring of the product and the printing shall be such that the marking is readable without magnification.

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

a) the number of this International Standard;

b) the manufacturer's declared pipe external diameter, d_{OD};

c) the nominal stiffness rating (SN);

d) the nominal pressure rating (PN);

e) permissible jacking load;

f) for pipes and couplings intended for the conveyance of surface water or sewage, the code-letter “C”;

g) for pipes and couplings intended for the conveyance of drinking water, the code-letter “P”;

h) the manufacturer's name or identification;

i) the date of manufacture, in plain text or code.

7 Joint performance

7.1 General requirements

Pipes conforming with this International Standard shall be joined using flexible non-end-load-bearing joints (see 3.38) with elastomeric seals.

Flexible joints shall be tested using test-pieces conforming to 7.6.2. To prove conformity to the requirements for performance under internal or external hydrostatic pressure detailed in 7.5, use the applicable method of test detailed in ISO 8639, in conjunction with specific conditions dependent upon the nominal pressure (PN) of the piping system in which the particular type of joint is to be used. Specific values of PN are given in 4.2.5.

7.2 Interchangeability

Where interchangeability between products from different suppliers is required, the purchaser shall ensure that the pipe and fitting dimensions are compatible with the components to be joined and that the performance of the joint conforms to the relevant performance requirements in Clause 7.

7.3 Geometrical characteristics

Use only flush couplings (see 3.39) in trenchless construction systems.

Record all dimensions which may influence the performance of the joints being tested (see Figures A.1 and B.1).

7.4 Design

7.4.1 Design requirements

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

7.4.2 Design parameters

For each design of joint, the maximum allowable values of the draw, D (see 3.43 and Figure 2), total draw, T (see 3.44 and Figure 2), and angular deflection, δ (see 3.42 and Figure 2), for which the joint has been designed to be used both during the jacking operation and in the installed condition, shall be declared by the manufacturer.

7.5 Performance requirements

7.5.1 General

A joint made for connecting pipes intended to be used in jacking techniques shall be designed to withstand the external forces and conditions applied during the installation operations; it shall also provide adequate sealing against both internal and external hydraulic forces which may occur during both the installation process and the subsequent operating life of the pipeline.

If the joint has been designed to be used with pressure transfer rings (packers), perform the tests on assemblies incorporating the pressure transfer ring (see also note to C.1 in Annex C).

Failure at the end closures during any of the following tests shall not constitute failure of the test.

7.5.2 Leak-tightness when subjected to an external pressure differential

When the joint is subjected to either the manufacturer's declared angular deflection, δ (see 7.4.2), or declared allowable draw, D (see 7.4.2), 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 ISO 8639 at the pressure given in Table 5.

7.5.3 Leak-tightness when subjected to internal positive pressure following assembly

When assembled in accordance with the pipe manufacturer's recommendations, the joint shall withstand without leakage an internal pressure of 1,5 × PN bar for 15 min, and shall subsequently conform to 7.5.2, 7.5.4, 7.5.5 and 7.5.6.

7.5.4 Leak-tightness when simultaneously subjected to angular deflection and draw

When the joint is subjected to the manufacturer's declared maximum allowable angular deflection in accordance with 7.4.2 and a total draw, T, equal to the manufacturer's declared maximum allowable draw, D (see 7.4.2), plus the longitudinal movement, J (see 3.44 and Figure 2), resulting from application of the manufacturer's declared allowable angular deflection, it shall not show any visible signs of damage to its components nor leak when tested by the appropriate method given in ISO 8639 at the pressure given in Table 5.

7.5.5 Leak-tightness when simultaneously subjected to misalignment and draw under static pressure

When the joint is subjected to the manufacturer's declared maximum allowable draw, D (see 7.4.2), and a total force, F, of 20 N per millimetre of the internal diameter, d_i, expressed in millimetres (see 3.4), it shall not show any visible sign of damage to its components nor leak when tested by the appropriate method given in ISO 8639 at the pressure given in Table 5.

7.5.6 Leak-tightness test when subjected to misalignment and draw under a positive cyclic pressure

When the joint is subjected to the manufacturer's declared maximum allowable draw, D (see 7.4.2), and a total force, F, of 20 N per millimetre of the internal diameter, d_i, expressed in millimetres (see 3.4), it shall not show any visible sign of damage to its components nor leak when tested by the appropriate method given in ISO 8639 at the positive cyclic pressure given in Table 5.

Table 5 — Summary of test requirements for flexible joints

Test condition	Pressure condition	Test pressure bar	Test duration
Initial leak-tightness test (ISO 8639:2000, 7.2)	Initial positive pressure	1,5 × PN	15 min
External pressure differential (ISO 8639:2000, 7.3)	Negative pressure [a]	– 0,8 bar (– 0,08 MPa)	1 h
Misalignment and draw under static pressure (ISO 8639:2000, 7.5)	Positive static pressure	2,0 × PN	24 h
Misalignment and draw under cyclic pressure (ISO 8639:2000, 7.6)	Positive cyclic pressure	Atmospheric to 1,5 × PN and back to atmospheric	10 cycles of 1,5 min to 3 min each
Angular deflection and draw (ISO 8639:2000, 7.4)	Initial pressure	1,5 × PN	15 min
	Positive static pressure	2,0 × PN	24 h

[a] Relative to atmospheric pressure, i.e. approximately 0,2 bar (0,02 MPa) absolute.

7.6 Test method additional information

7.6.1 Number of test-pieces for type test purposes

The number of joint assemblies to be tested for each test shall be one. However, the same assembly may be used for more than one of the tests.

7.6.2 Test-pieces

A test-piece shall comprise a joint and two pieces of pipe such that the effective laying length, l, is not less than the applicable value given in Table 15 of ISO 10467:2004 or ISO 10639:2004 or that which is required to meet the requirements of the test method.

If the joint has been designed to be used with pressure transfer rings (packers), perform the tests on an assembly comprising two pieces of pipe and a joint incorporating the pressure transfer ring (see also the note in C.1).

Annex A
(normative)

Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes — Determination of the longitudinal compressive properties of a pipe, using a sample of prism test-pieces cut from a ring from the pipe

A.1 Scope

This annex specifies the method for determining the initial longitudinal compressive properties of pipes measured on a sample of prism-shaped test-pieces having rectangular cross-sections produced from pieces cut from glass-reinforced thermosetting plastics (GRP) pipes intended for use in installations using trenchless construction techniques.

This method can be used for:

— rebated test-pieces to determine the test-piece de-rating factor, f_s;

— the determination of the specific initial longitudinal compressive modulus, $E_{c,m}$;

— the determination of the initial longitudinal compressive stress at break, $\sigma_{b,r}$ or $\sigma_{b,u}$;

— the determination of the initial longitudinal compressive modulus $E_{c,m}$.

A.2 General

A test-piece taken from the pipe wall is compressed, at a uniform rate of strain in the direction parallel to the longitudinal axis of the pipe, until failure occurs.

The procedure used shall conform to ISO 604:2002 and in addition include the following practices:

— the initial longitudinal compressive stress at break for rebated test-pieces, $\sigma_{b,r}$ or $\sigma_{b,u}$, for un-rebated test-pieces, is the average value of the results of compression tests on a sample of five test-pieces;

— the specific initial longitudinal compressive modulus, $E_{c,m}$, and the initial longitudinal compressive modulus, $E_{c,m}$, shall be measured on un-rebated test-pieces as specified in A.6.4.

NOTE The expression of compressive properties in terms of the minimum original cross-section is almost a universal practice. Under some circumstances the compressive properties have been expressed per unit of prevailing cross-section. These properties are called “true” compressive properties.

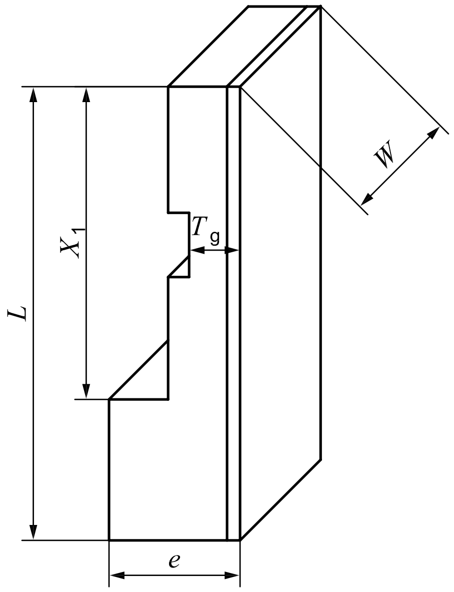
A.3 Test-pieces

A.3.1 General

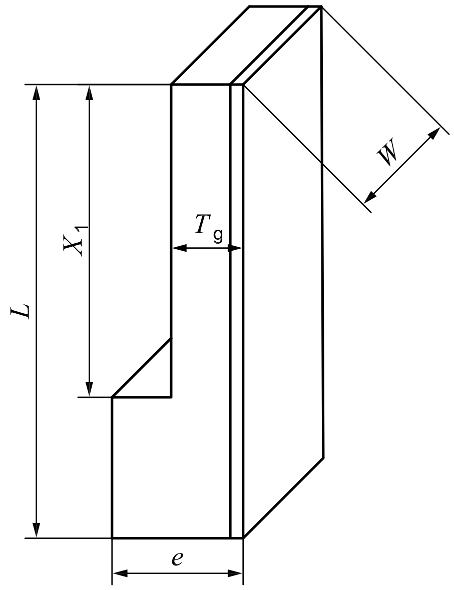
This clause replaces Clause 6 of ISO 604:2002.

A.3.2 Geometry

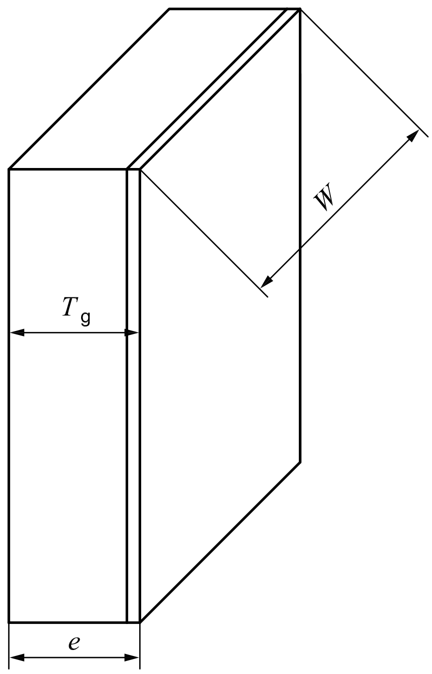
The method can be applied to both rebated and un-rebated test-pieces.



a) Rebated and grooved test-piece



b) Rebated test-piece



c) Un-rebated test-piece

Key

L height of test-piece, expressed in millimetres (mm)

X_1 rebated length, expressed in millimetres (mm)

e total wall thickness of pipe barrel, expressed in millimetres (mm)

T_g thickness of the pipe barrel at either the thinnest section of the rebate or under the groove, expressed in millimetres (mm)

W width of test-piece, expressed in millimetres (mm)

Figure A.1 — Geometry of prism test-pieces

A.3.3 Dimensions

A.3.3.1 Slenderness

Test-pieces shall be of such dimensions that their slenderness ratio, R_{SL}, calculated using Equation (A.1) is in the range from 5 to 16.

$$R_{\mathrm{SL}} = \frac{L}{r_G} = \frac{L}{0{,}289\left(T_{\mathrm{g}}\right)} \tag{A.1}$$

where

R_{SL} is the slenderness ratio;

r_G is the radius of gyration.

In the case of un-rebated test-pieces, $T_{\mathrm{g}} = e$ (see Figure A.1).

NOTE The slenderness ratio R_{SL} is the ratio of the length of a column of uniform cross-section to its least radius of gyration, r_G.

$$r_G = \sqrt{\frac{I}{A}} \tag{A.2}$$

where

$$I = \frac{W\left(T_{\mathrm{g}}\right)^3}{12} \tag{A.3}$$

$$A = W\left(T_{\mathrm{g}}\right) \tag{A.4}$$

Hence

$$r_G = 0{,}288\,7\left(T_{\mathrm{g}}\right) \tag{A.5}$$

where

I is the second moment of area in the longitudinal direction per millimetre of length, expressed in millimetres to the fourth power per millimetre ($\mathrm{mm}^4/\mathrm{mm}$);

A is the area of the smallest section under the groove, expressed in millimetres to the second power (mm^2);

W and T_{g} are dimensions, see Figure A.1.

A.3.3.2 Dimensions for rebated test-pieces

The length of the test-pieces, L, shall be not less than the value calculated using Equation (A.6) subject to the tolerances calculated using Equation (A.7).

$$L \geq (X_1 + 10) \pm 3\ \mathrm{mm} \tag{A.6}$$

$$\text{Tolerance limits: } 1{,}445\left(T_{\mathrm{g}}\right) \leq L \leq 4{,}624\left(T_{\mathrm{g}}\right) \tag{A.7}$$

The width of the test-pieces, W, shall not be less than the value calculated using Equation (A.8) subject to the tolerances calculated using Equation (A.9).

$$W \geq (40 \pm 2)\ \text{mm} \tag{A.8}$$

and

$$W \geq L / 4{,}624 \tag{A.9}$$

A.3.3.3 Recommended dimensions for un-rebated test-pieces

The length of the test-pieces, L, shall not be less than the applicable value given in Table A.1 depending on the pipe's wall thickness, e.

Table A.1 — Length of test-pieces

Wall thickness e mm	**Length of test-piece** L mm
14 to < 18	60 ± 3
18 to < 22	75 ± 3
22 to < 26	90 ± 3
26 or more	110 ± 3

The width of the test-pieces, W, shall be (40 ± 2) mm.

A.3.4 Production of the sample

Form the sample of test-pieces by cutting a pipe ring with height, L, into pieces complying with the applicable dimensions specified in A.3.3. Dimension L is parallel to the longitudinal axis of the pipe.

Rings for un-rebated test-pieces may be cut anywhere along the pipe length but preferably at the pipe end. Rings for rebated test-pieces shall be cut from the spigot end of the pipe. Ensure that pipe ring axes are parallel to the axis of the pipe.

When preparing the test-pieces, ensure that cut sides are parallel to each other and at right angles to the cut surfaces of the ring from which they are cut.

A.3.5 Number of test-pieces in the sample

A sample consists of five test-pieces made from the same pipe ring.

A.3.6 Conditioning

Unless otherwise specified, store the test-pieces for at least 0,5 h at the test temperature prior to testing.

In cases of dispute, condition test-pieces for 24 h at (23 ± 3) °C before testing, or subject them to a mutually agreed test conditioning schedule.

A.4 Test equipment

Test equipment shall conform to the applicable requirements of Clause 5 of ISO 604:2002.

A.5 Test procedure

A.5.1 General

The test procedure shall generally conform to the appropriate method specified in ISO 604:2002, except for the following requirements.

A.5.2 Measurements

For each test-piece, measure and record to an accuracy of ±0,2 mm all the external dimensions indicated in Figure A.1.

The measuring devices used shall comply with the applicable requirements of Clause 5 of ISO 604:2002.

A.5.3 Compressive loading

A compressive load, F, shall be applied to each test-piece as described in ISO 604:2002. The change of load, F, shall be recorded as a function of the change in length, ΔL, until fracture occurs when $F = F_{\mathrm{fr}}$ (see A.6.3).

A.5.4 Testing speed

Apply the compressive load using a cross-head movement speed between 0,8 mm/min and 6 mm/min. ISO 604:2002 sets indicative testing speed values of 1 mm/min for modulus measurement and 5 mm/min for strength measurement. As both of these compressive parameters are measured during the same test, and as experience does not indicate any fundamental influence from the test speed on the result, a testing speed between the values in ISO 604:2002, including tolerances, is appropriate for the test.

A.6 Calculation and expression of results

A.6.1 General

The procedures used for the calculation and expression of results shall conform to the applicable requirements of Clause 10 of ISO 604:2002, except for the properties determined in accordance with A.6.2, A.6.3 and A.6.4.

A.6.2 Initial mean cross-sectional area, A

Calculate the initial mean cross-sectional area, A, of the test-piece using Equation (A.10) or (A.11), as applicable.

For rebated test-pieces (see Figure 1):

$$A = W\left(T_{\mathrm{g}}\right) \tag{A.10}$$

For un-rebated test-pieces (see Figure 1):

$$A = W\left(e\right) \tag{A.11}$$

A.6.3 Initial longitudinal compressive stress at break

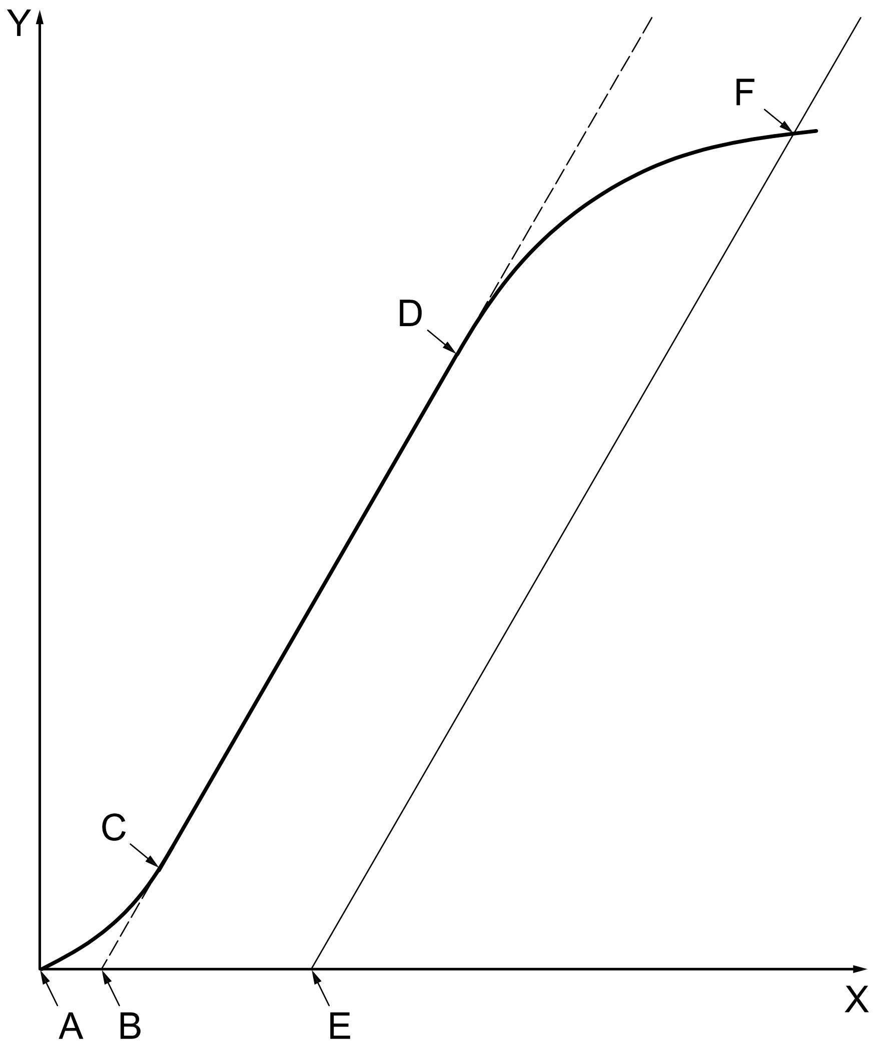
Calculate the longitudinal compressive stress at break of each individual test-piece by dividing the recorded load at fracture, F_{fr} (see A.5.3), by the respective initial mean cross-sectional area, A, determined in accordance with A.6.2.

Calculate the initial longitudinal compressive stress at break, $\sigma_{b,\,r}$ for rebated and $\sigma_{b,\,u}$ for un-rebated test-pieces, as the average value of the results of compression tests on a sample of test-pieces as specified in A.3.

A.6.4 Longitudinal compressive modulus, $E_{c,m}$

A.6.4.1 Toe region

In a typical stress-strain curve (Figure A.2) there is a toe region, AC, that does not represent a property of the material. It is an artefact caused by a take up of slack, and alignment or seating of the specimen. In order to obtain correct values of such parameters as modulus, strain, and offset yield point, this artefact must be compensated for to give the corrected zero point on the strain or extension axis.



Key

Y stress

X strain

A to F see A.6.4.2

NOTE Some chart recorders plot the mirror image of this graph.

Figure A.2 — Material with a Hookean region

A.6.4.2 Other regions

GRP exhibits a region of Hookean (linear) behaviour between C and D in Figure A.2. A continuation of the linear (CD) region of the curve is constructed through the zero-stress axis to B. This intersection is the corrected zero-strain point, ε_0, from which all extensions or strains must be measured, including the yield offset (BE), if applicable. The elastic modulus, $E_{\mathrm{c,m}}$, can be determined by dividing the stress at any point along the line CD (or its extension) by the strain at the same point (measured from Point B, which is defined as the point of zero-strain, ε_0).

A.6.4.3 Specific initial longitudinal compressive modulus, $E_{\mathrm{c,m}}$

Calculate the specific initial longitudinal compressive modulus, $E_{\mathrm{c,m}}$, and initial longitudinal compressive modulus, $E_{\mathrm{c,m}}$, by drawing a tangent to the initial linear portion of the load deformation curve, selecting any point (preferably the 0,25 % strain value) on this straight line portion, and dividing the compressive stress, $\sigma_{0,25\,\%}$, represented by this point by the corresponding strain. Measure from the point, ε_0, where the extended tangent line intersects the strain-axis as shown in Equation (A.12) (see also Annex C).

$$E_{\mathrm{c,m}} = \frac{\sigma_{0,25\,\%}}{0,002\,5 - \varepsilon_0} \tag{A.12}$$

A.6.5 Statistical parameters

Calculate the arithmetic mean of each set of five test results and, if required, the standard deviation and 95 % confidence interval of the mean value by the procedure given in ISO 2602.

A.7 Test report

The test report shall conform to Clause 12 of ISO 604:2002, and shall also make reference to this International Standard.

Annex B
(normative)

Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes — Determination of the compressive properties of pipes, using spool test-pieces

B.1 General

This annex specifies the method for determining the longitudinal compressive properties of pipes measured on spool test-pieces made of glass-reinforced thermosetting plastics (GRP). This test method is intended for initial type testing of pipes conforming with this International Standard, with rebated and, if applicable, grooved spigots, to determine the minimum specific initial longitudinal compressive stress at break, $\sigma_{b, s, min}$, and the test-piece de-rating factor, f_s.

B.2 Principle

A test-spool with rebated and, if applicable, grooved spigots at both ends, is compressed at a uniform rate of compressive strain in the direction parallel to the longitudinal axis of the pipe, until failure occurs.

The specific initial longitudinal compressive stress at break, $\sigma_{b, s}$, is calculated according to the procedures described in B.6.

B.3 Test-pieces

B.3.1 Geometry

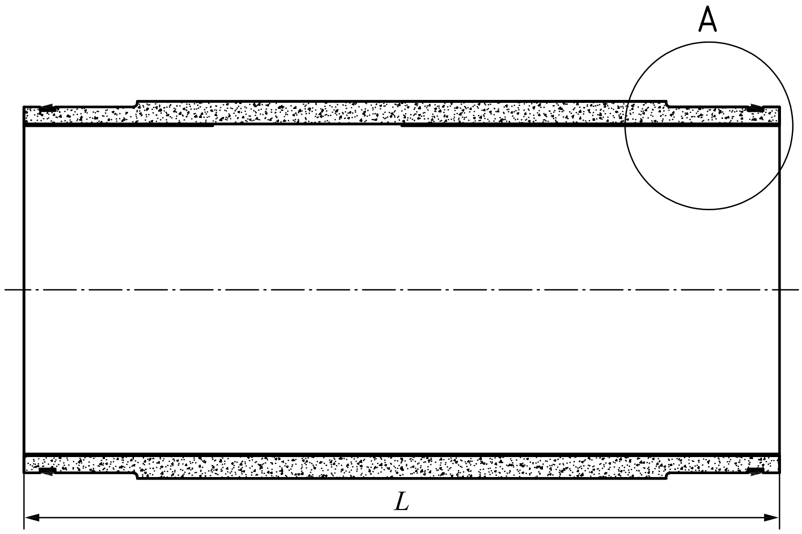
The general arrangement of a cylindrical test-spool is shown in Figure B.1. including rebates and, if applicable, grooves for sealing rings at both ends.

B.3.2 Length of test-spool

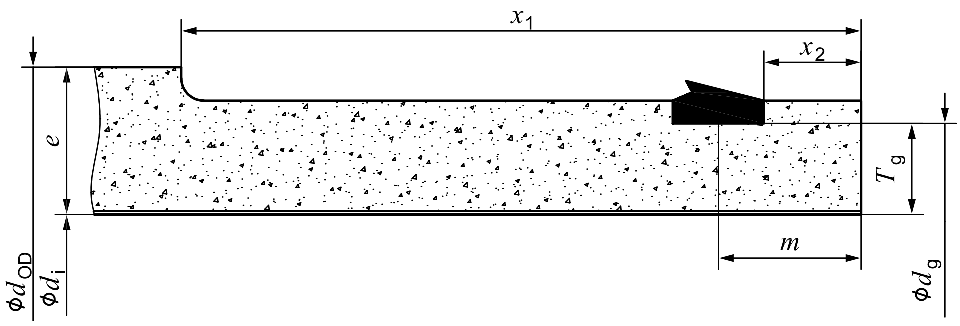
The length of the test-spool, L, shall be at least $(300 + 2 \times x_1) \pm 20$ mm.

B.3.3 Production of the test-spool

Production method and tolerances for the test-spool, including rebated spigots and grooves (if applicable), shall be the same as that used for the production of the related pipes.



a) Section through test-spool



b) Detail of spigot at A

Key

L length of the test-spool, expressed in millimetres (mm)

x_1 rebated length, expressed in millimetres (mm)

x_2 distance from the groove to the end of the spigot, expressed in millimetres (mm)

d_i internal diameter, expressed in millimetres (mm)

d_{OD} outside diameter, expressed in millimetres (mm)

d_g minimum outside diameter of the spigot at a distance, m, under the groove (if applicable) expressed in millimetres (mm)

e pipe wall thickness of the barrel, expressed in millimetres (mm)

T_g thickness of the thinnest section, under the groove (if applicable) expressed in millimetres (mm)

Figure B.1 — Geometry of test-spool

B.3.4 Number of test-pieces

When using this method for an ITT, three test-spools shall be tested.

B.3.5 Conditioning

Unless otherwise specified, store the test-spools for at least 0,5 h at the ambient temperature prevailing in the test facility, prior to testing.

In cases of dispute, condition test-spools for 24 h at (23 ± 3) °C prior to testing, or alternatively subject them to a mutually agreed test conditioning schedule.

B.4 Test equipment

B.4.1 Testing machine

B.4.1.1 General

The testing machine shall be a servo-hydraulic power-driven instrument capable of applying a longitudinal load, $F_{\mathrm{b,\,s}}$, to the test-piece that will cause it to fail in compression; it shall also be capable of maintaining the applicable rate of loading specified in B.5.4 up to failure.

B.4.1.2 Load application plates

The plates for applying the load to the test-spool shall be made of hardened steel and shall be so constructed that the load carried by the test-spool is axial and transmitted through surfaces which are flat and parallel to each other in a plane normal to the loading axis.

The plates shall each have a diameter which is larger than the outside diameter, d_{OD}, of the test-spool.

B.4.1.3 Load indicators

The testing machine shall be equipped with an indicator capable of indicating the compressive load applied to the test-spool. The mechanism shall be essentially free of inertia lag at the rate of loading specified in B.5.4 and indicate the load applied with an accuracy of ±1 % or better of the indicated value.

B.4.1.4 Recording equipment

The recording equipment consists of an automatic data logging system capable of recording the load applied, F, versus time, up to the moment of failure of the test-piece. When measurements of strain are also being taken, the automatic data logging system shall be capable of registering the strain versus the applied longitudinal load, F, up to the moment of failure.

B.4.2 Devices for measuring the dimensions of the test-spool

Use a micrometer or equivalent capable of reading to at least 0,01 mm, for measuring the spigot's wall thickness, inner surface layer thickness, depth of rebate and, if applicable, the groove, as indicated in Figure B.1.

Use a tape or other suitable device, reading to at least 1 mm, for measuring the length of the spool, L, diameters d_{OD}, d_{i} and d_{g} as indicated in Figure B.1.

B.5 Test procedure

B.5.1 Measurement of dimensions

Make measurements of the dimensions indicated in Figure B.1 in accordance with ISO 3126.

Measure and record the values of the diameters d_{OD}, d_{i} and d_{g} as well as the spool length L, as indicated in Figure B.1, to an accuracy of ±1 mm.

Measure and record the value of all other dimensions of the spigot indicated in Figure B.1 to an accuracy of ±0,2 mm.

B.5.2 Test temperature

Perform the test at one of the temperatures specified in B.3.5, preferably the same temperature used for conditioning.

B.5.3 Positioning of the test-spool in the test machine

Place a test-spool between the surfaces of the compression plates and align the centres of the compression plates. Position a wooden chipboard plate 6 mm thick at both ends between the test-spool and the compression plates. Ensure that the contact between the test-spool and the surfaces of the plates is as uniform as possible and that the surfaces of the compression plates are parallel to each other.

B.5.4 Application of load

Start the data recording equipment.

Apply the load to the test-spool at a compressive strain rate of ±2 mm/min until the test-spool is unable to sustain the applied load.

For the duration of the test, record, on a continuous time basis, the applied longitudinal compressive load, F_c, and the strain, ε.

Record the maximum compressive force at failure, F_c, in kilonewtons (kN) and, if applicable, the strain at failure, ε_b.

B.6 Calculation and expression of results

B.6.1 Initial mean cross-sectional area, A_s

Calculate the initial mean cross-sectional area, A_s, of the spigot using Equation (B.1), expressed in square millimetres (mm^2).

$$A_s = \pi\left[\left(0{,}5 \times d_g\right)^2 - \left(0{,}5 \times d_i\right)^2\right] \tag{B.1}$$

where

d_g is the external spigot or groove diameter (see Figure B.1), expressed in millimetres (mm);

d_i is the internal diameter of the pipe (see 3.4), expressed in millimetres (mm).

B.6.2 Specific initial longitudinal compressive stress at break, $\sigma_{b,\,s}$

Calculate the longitudinal compressive stress at break, σ_b, expressed in megapascals (MPa), for each of the three test-spools, using Equation (B.2).

$$\sigma_b = \frac{F_c \times 10^3}{A_s} \tag{B.2}$$

The specific initial longitudinal compressive stress at break, $\sigma_{b,\,s}$ (see 3.12), is the mean of the three values of σ_b minus two standard deviations [see Equation (B.3)].

$$\sigma_{b,s} = \text{mean } \sigma_b - \left[2\left(\text{highest } \sigma_b - \text{lowest } \sigma_b\right) \times 0{,}590\,8\right] \tag{B.3}$$

B.7 Test report

The test report shall include the following information:

a) a reference to this International Standard;

b) all details necessary for complete identification of the pipe(s) being tested, including type, source, manufacturer's code number and history;

c) the dimensions of all test-spools;

d) method of preparing the test-spool and any details of the manufacturing method used;

e) the number of test-spools tested;

f) the position in the pipe from where the test-spools were obtained;

g) the test equipment details, type and accuracy;

h) the rate of load application and rate of resulting strain;

i) the atmosphere used for conditioning and for testing, plus details of any special conditioning treatment, if applicable;

j) the individual test data and results;

k) the calculated test results;

l) any factors which may have affected the results, such as any incidents which may have occurred or any operating details not specified in this International Standard;

m) date and duration of the test.

Annex C
(normative)

Procedure for the calculation of the permissible jacking force on a GRP-(UP) pipe, $F_{perm,p}$

C.1 General

When a jacking load is applied axially to the rear pipe or any interjack pipe during installation, this load generates compressive stress within the cross-section of each pipe.

NOTE Pressure transfer rings are sometimes used at the interface between GRP and other materials such as interjack stations or a cutting head (shield). In GRP systems it is not recommended to use pressure transfer rings (or packers) between GRP joint faces.

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

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

The following subclauses, which are based on procedures described in ATV 161 (1990), describe how the permissible jacking force on the pipe, $F_{perm,p}$, for a specific angular deflection can be calculated.

C.2 Symbols and abbreviations

The symbols and abbreviations used in this annex have the following meanings (see also Figures C.1 to C.6):

γ the compressive (material) safety coefficient for the calculation of GRP pipes in a direction parallel to the longitudinal axis of the pipe (see 5.5.3);

δ angular deflection between adjacent pipes (see 4.7.3.1), expressed in degrees (°);

σ_{max} maximum stress in a specific loading situation occurring at the edge of the jacking face, expressed in newtons per square millimetre (N/mm^2);

σ_0 arithmetic mean value as the average compressive or tensile stress over the total spigot section, expressed in newtons per square millimetre (N/mm^2);

σ_{all} allowable stress, taking into account the (material) safety factor, γ, expressed in newtons per square millimetre (N/mm^2);

$\sigma_{b,\,s,\,min}$ minimum specific initial compressive stress at break, expressed in newtons per square millimetre (N/mm^2);

A_s minimum pipe cross-sectional area of the spigot, or in the groove of the spigot, if applicable (see 3.6), expressed in square millimetres (mm^2);

d_g spigot or groove diameter (see 3.5), expressed in millimetres (mm);

E_P axial compressive elastic modulus of the pipe, expressed in megapascals (MPa);

F_j manufacturer's declared jacking load for which a pipe was designed, expressed in kilonewtons (kN);

$F_{j,\,calc}$ theoretical design jacking load, expressed in kilonewtons (kN);

$F_{perm,\,p}$ permissible jacking load on the pipe, expressed in kilonewtons (kN);

F_{ult} ultimate longitudinal load;

d_i internal diameter, expressed in millimetres (mm);

l laying length of a jacking pipe, expressed in millimetres (mm);

Z diametrical extent of compression in the joint segments, expressed in millimetres (mm);

S_a stress eccentricity dependence is the dependence of the stress ratio, S_r, on the ratio Z/d_g (see Figure C.6) ;

S_r stress ratio, σ_{max}/σ_0.

C.3 Design criteria

C.3.1 Principles

The guidance in this annex is based on the procedures contained in ATV 161.

Calculation of the jacking forces, $F_{j,\,calc}$ and $F_{perm,\,p}$, relative to a particular pipe is dependent on the minimum specific initial compressive stress at break, $\sigma_{b,\,s,\,min}$, as declared by the manufacturer and verified on the basis of testing test-pieces in accordance with 5.4.4, and the minimum pipe cross-sectional area at the spigot, A_s, in accordance with 3.6.

The manufacturer shall declare the jacking load for which each jacking pipe was designed [design jacking load, F_j (see 3.20)] and this load shall be not greater than the theoretical design jacking load ($F_{j,\,calc}$).

The theoretical design jacking load, $F_{j,\,calc}$ (see 3.21) is calculated using Equation (C.1) which assumes that the jacking load is concentric and perpendicular to the joint faces, i.e. no deflection and all joint faces perfectly square.

$$F_{j,\,calc} = \frac{F_{ult}}{\gamma} \tag{C.1}$$

where

F_{ult} is the ultimate longitudinal load (see 5.5.2), expressed in kilonewtons (kN);

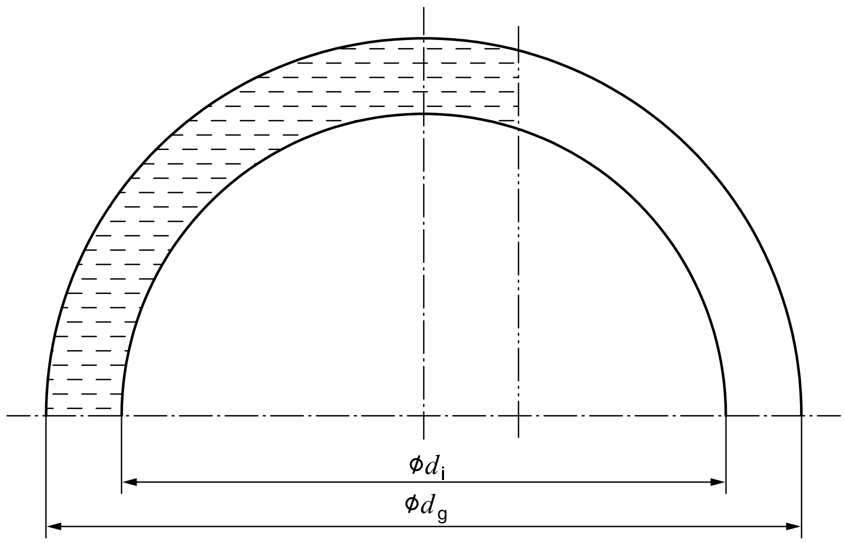
γ is the longitudinal compressive (material) safety factor.

The longitudinal compressive (material) safety factor, γ, shall not be less than 1,75, unless specific agreement justifies the use of a lower value.

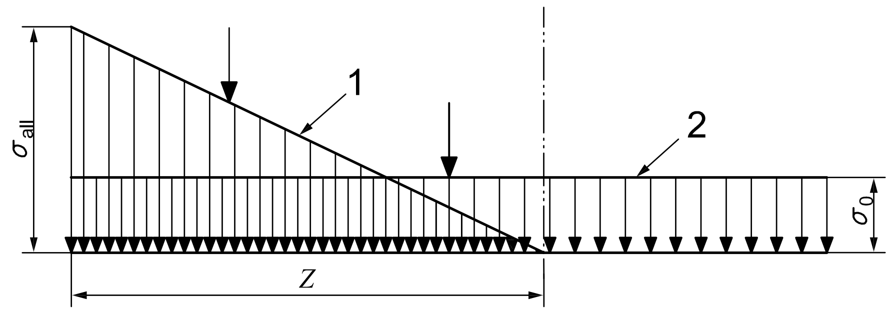
NOTE The design jacking load, as declared by the pipe manufacturer or calculated in accordance with this annex, does not include any safety factor to be used by the contractor, having regard to the jacking method and subsequent deflection of the pipes, the nature of ground and unforeseen conditions,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

In the “closed joint” situation (see 3.40) the permissible jacking force on the pipe, $F_{\text{perm, p}}$, shall not induce a stress which exceeds the allowable value calculated based on zero stress at one diameter extremity, increasing uniformly to the allowable stress, $\sigma_{\text{all}} = \sigma_{\text{b, s, min}} / \gamma$ at the opposite extremity.

In the “open joint” situation (see 3.41), with the permissible jacking force on the pipe, $F_{\text{perm, p}}$, acting more eccentrically, the maximum compressive stress occurring at the edge of the jacking face shall not exceed the maximum allowable stress, $\sigma_{\text{all}} = \sigma_{\text{b, s, min}} / \gamma$. The corresponding stress distribution across the joint is shown in Figure C.1. In this case the permissible jacking force on the pipe, $F_{\text{perm, p}}$, will be smaller than in the “closed joint” situation.



a) Compressed area



b) Stress diagram

Key

1 “open joint” situation

2 “closed joint” situation

σ_{all} allowable stress

σ_0 average compressive stress over total spigot section

Z diametrical extent of compression in the joint segments, expressed in millimetres

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

C.3.2 Permissible jacking force on the pipe, $F_{\text{perm, p}}$

The permissible jacking force on the pipe, $F_{\text{perm, p}}$ can be calculated using Equation (C.2), which takes into account a possible angular deflection:

$$F_{\text{perm, p}} = \frac{F_{\text{ult}}}{\gamma \times S_{\text{a}}} \tag{C.2}$$

where

$$F_{\text{ult}} = \frac{(d_{\text{g}} - d_{\text{i}})^2}{4} \times \pi \times \sigma_{\text{b, s, min}} \tag{C.3}$$

γ is the compressive material safety factor coefficient for GRP pipes, in a direction parallel to the longitudinal axis of the pipe;

S_{a} is the stress eccentricity dependence (SED), which is the dependence of the stress ratio, S_{r}, on the ratio Z/d_{g} (see Figure C.6);

S_{r} is the stress ratio, $\sigma_{\text{max}}/\sigma_0$;

$\sigma_{\text{b, s, min}}$ is the minimum specific initial compressive stress at break, expressed in newtons per square millimetre (N/mm^2);

$\frac{(d_{\text{g}} - d_{\text{i}})^2}{4} \times \pi$ is the minimum pipe cross-sectional area of the spigot, expressed in square millimetres (mm^2).

The factor, S_{a}, has to be at least 2 for the case of concentric jacking. In the case where an angular deflection is to be allowed for or is planned, S_{a} is obtained from Figure C.6 after calculating Z, in millimetres, using Equation (C.4) and then Z/d_{g}.

$$Z = \frac{\sigma_{\text{all}} \times l}{E_{\text{p}}} \times \frac{1}{\tan \delta} \tag{C.4}$$

The angular deflection is related to the elastic compression according to Equation (C.5).

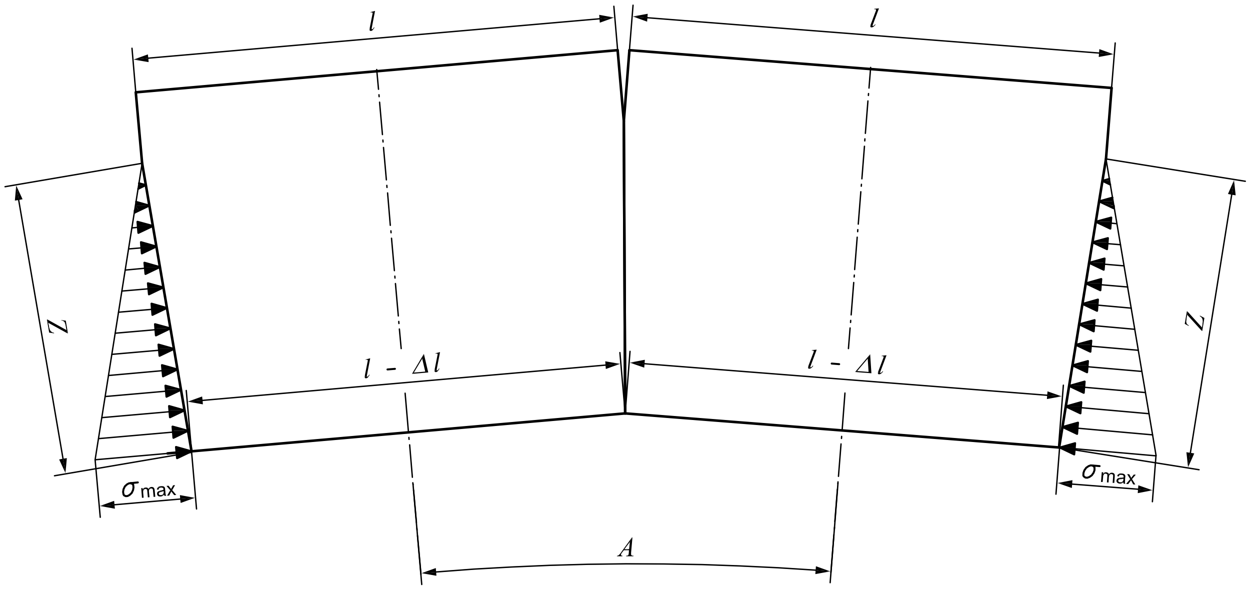
$$\tan\delta \approx 2\tan\frac{\delta}{2} = 2\frac{\frac{\Delta l}{2}}{Z} = \frac{\Delta l}{Z} \tag{C.5}$$

The elastic compressive strain at the circumference is expressed by Equation (C.6).

$$\frac{\Delta l}{l} = \varepsilon = \frac{\sigma}{E_{\text{p}}} \rightarrow \Delta l = \sigma \times \frac{l}{E_{\text{p}}} \tag{C.6}$$

Using Equations (C.5) and (C.6) gives the relation between angular deflection and the resulting stress, which is expressed by Equation (C.7).

$$\tan \delta = \frac{\sigma_{\text{all}}}{Z} \times \frac{l}{E_{\text{p}}} \tag{C.7}$$



Key

A compression angle in the pipe, δ, expressed in degrees (°)

Δl elastic compressive strain at the circumference of the jacking pipe, expressed in millimetres (mm)

σ_{max} maximum stress, expressed in newtons per square millimetre (N/mm^2)

Z diametrical extent of compression in the joint segments, expressed in millimetres (mm)

Figure C.2 — Angular deflection

The permissible jacking force on the pipe, $F_{perm,\,p}$, is calculated using Equation (C.8) for a determined angular deflection, δ, and is at the maximum value when $\sigma = \sigma_{all}$, using a factor of safety for GRP, γ, in accordance with C.3.1 and 5.5.3:

$$F_{perm,\,p} = \frac{\sigma_{b,\,s,\,min} \times A_s}{1\,000 \times \gamma \times S_a} \tag{C.8}$$

NOTE If a pressure transfer ring is used at the interface with other materials, such as interjack stations or a cutting head (shield), use Equation (C.9) instead of (C.7).

$$\tan \delta = \frac{\sigma}{Z} \times \left(\frac{l_p}{2 \times E_p} + \frac{a}{E_W} + \frac{l_{ext}}{2 \times E_{ext}} \right) \tag{C.9}$$

where

σ is the stress, expressed in newtons per square millimetre (N/mm^2);

Z is the diametrical extent of compression in the joint segments, expressed in millimetres (mm);

δ compression angle in the pipe, expressed in degrees (°);

l_p is the jacking pipe laying length, expressed in millimetres (mm);

E_P is the axial compressive elastic modulus of the pipe, expressed in megapascals (MPa);

a is the thickness of the pressure transfer ring (packer), expressed in millimetres (mm);

A_s is the minimum pipe cross-sectional area at spigot;

E_W is the compressive elastic modulus of the pressure transfer ring, expressed in megapascals (MPa);

l_{ext} is the length of the shield or interjack station, expressed in millimetres (mm);

E_{ext} is the compressive elastic modulus of the shield or interjack station, expressed in megapascals (MPa);

S_a is the stress eccentricity dependence, which is the dependence of the stress ratio, σ_{max}/σ_0, on the ratio Z/d_g. See Figure C.6;

S_r is the stress ratio, σ_{max}/σ_0.

C.3.2.1 Evaluation of joint gap and how it is related to eccentricity

In this subclause three joint gap conditions are considered which are defined by the ratio, Z/d_g, and, depending upon its value, the appropriate equation for the calculation of the stress ratio, σ_{max}/σ_0, is given. The stress ratio can also be derived using Figure C.6 from knowledge of the pipe's geometry and the ratio, Z/d_g. The examples in C.4 show how this evaluation is incorporated into assessment of required pipe properties.

In all cases the maximum stress should not exceed the allowable stress obtained from Equation (C.10).

$$\sigma_{all} = \frac{\sigma_{b, s, min}}{\gamma} \tag{C.10}$$

C.3.2.1.1 Closed joint condition

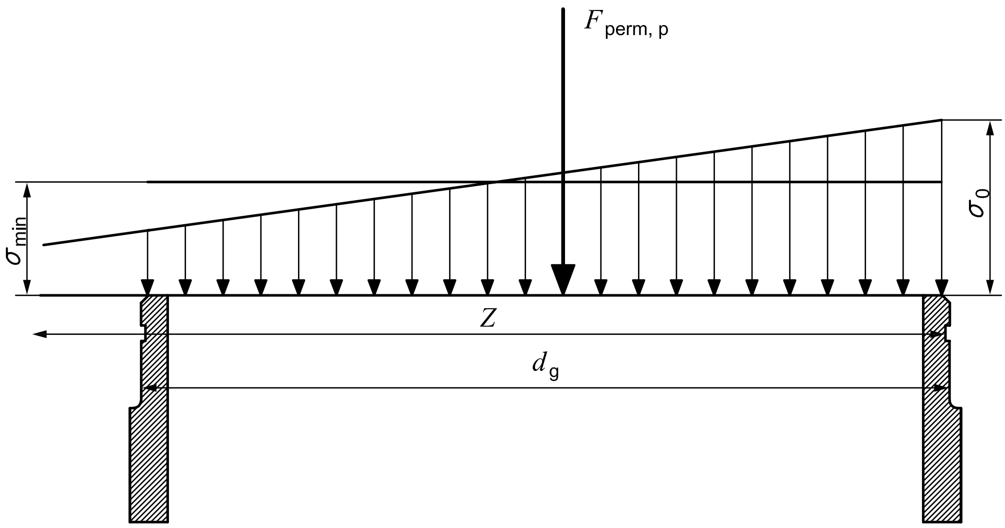


Figure C.3 — Closed joint

For this loading condition:

$$\frac{Z}{d_g} > 1 \tag{C.11}$$

and

$$S_a = \frac{\sigma}{\sigma_0} = \frac{\frac{Z}{d_g}}{\frac{Z}{d_g} - 0{,}5} \tag{C.12}$$

C.3.2.1.2 Maximum eccentricity by a closed joint

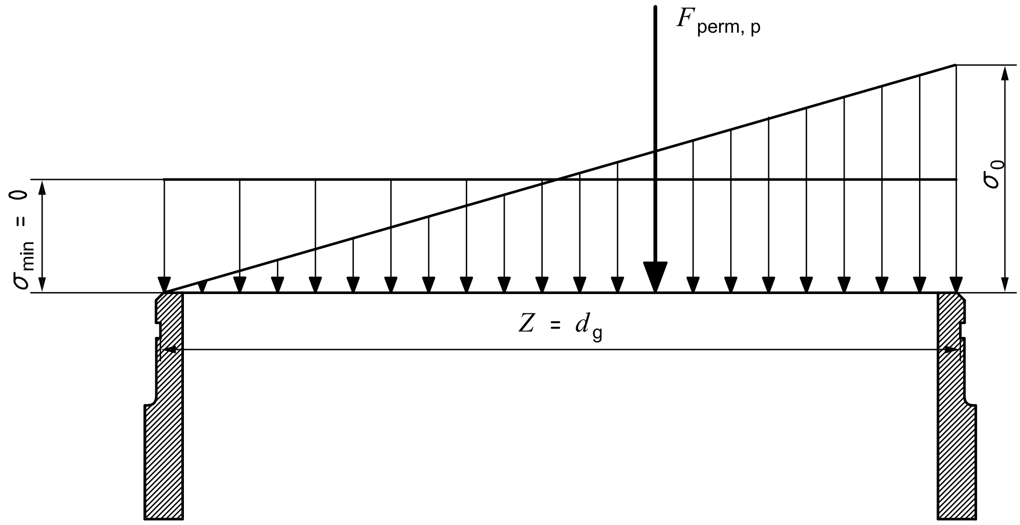


Figure C.4 — Closed joint — Maximum eccentricity

For this loading condition:

$$\frac{Z}{d_g} = 1 \tag{C.13}$$

and

$$S_a = \frac{\sigma}{\sigma_0} = 2 \tag{C.14}$$

C.3.2.1.3 Open joint

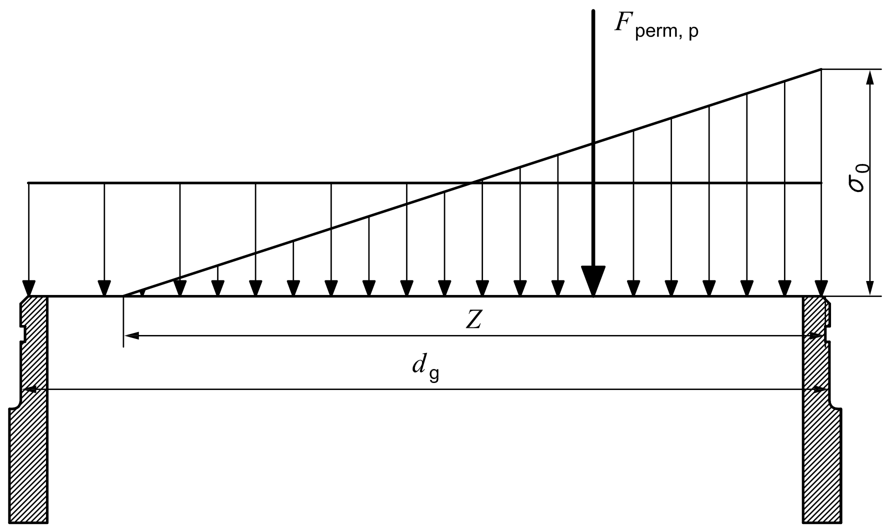


Figure C.5 — Open joint

For this loading condition:

$$\frac{Z}{d_g} < 1 \tag{C.15}$$

and

$$S_a = \frac{\sigma}{\sigma_0} = \int\left(\frac{Z}{d_g} \bigg/ \frac{d_i^*}{d_g}\right) \tag{C.16}$$

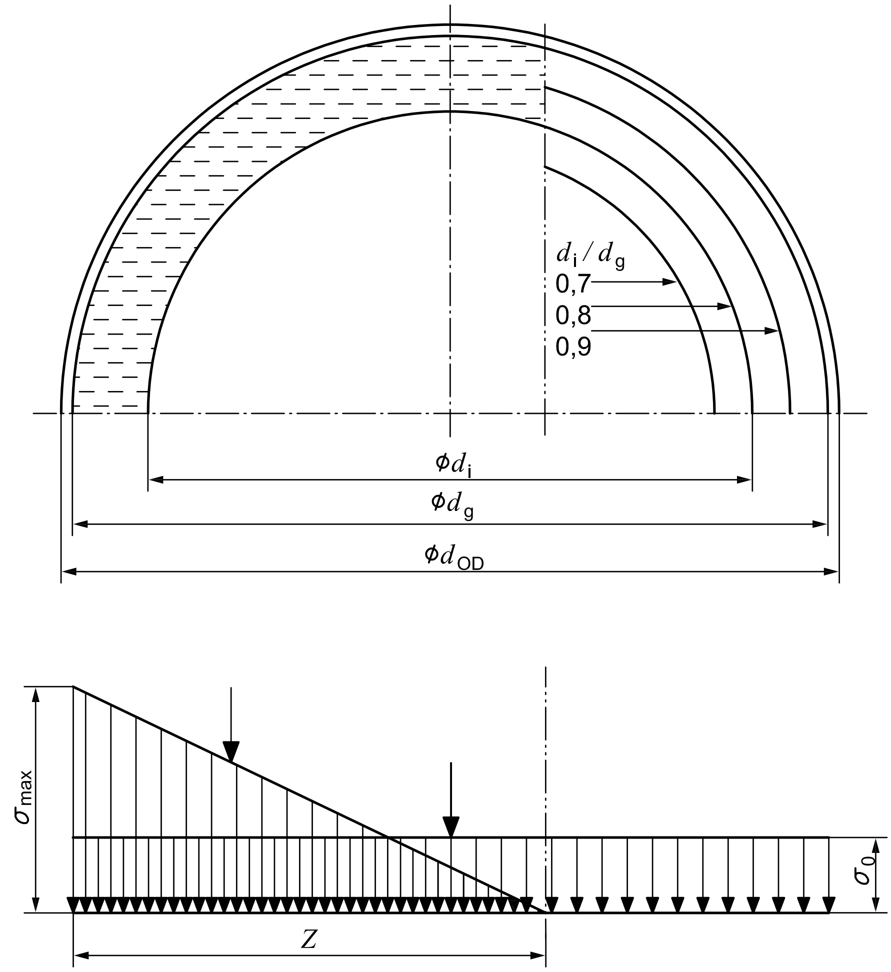


Figure C.6 — SED dependence of stress ratio σ/σ_0 on the ratio Z/d_g (*continued*)

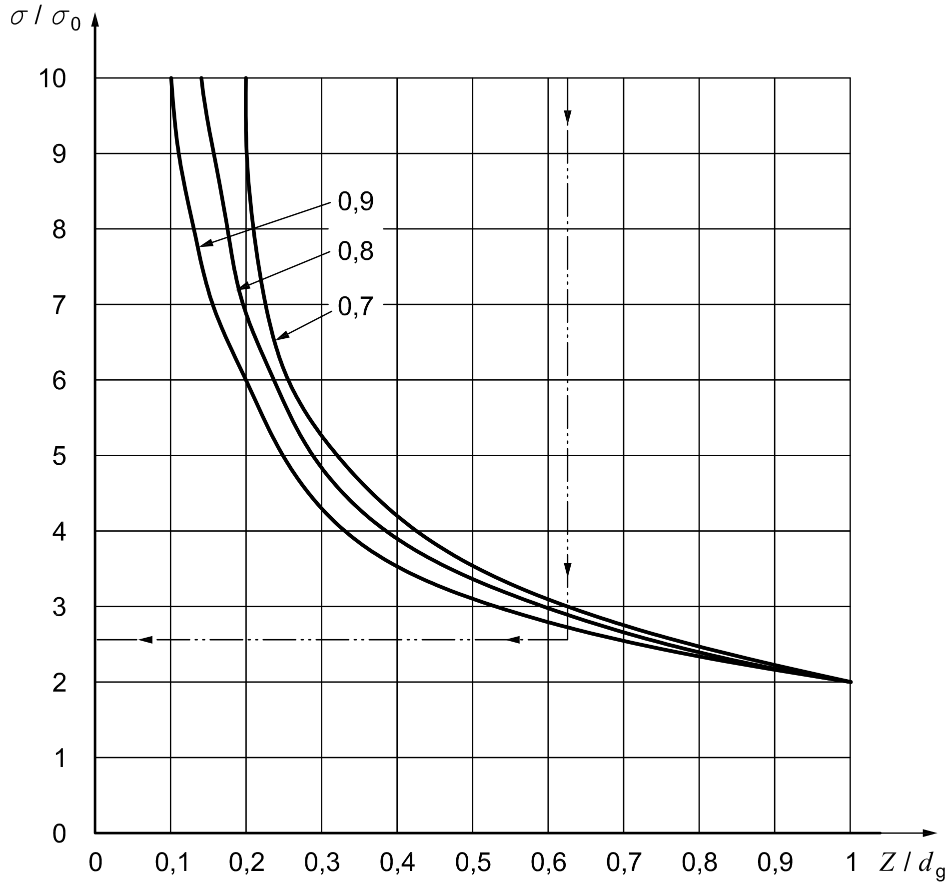


Figure C.6 — SED dependence of stress ratio σ/σ_0 on the ratio Z/d_g

C.4 Examples

C.4.1 Pipe properties assumed for these calculations

Pipe	d_{OD}	1 026 mm
	e	44 mm
	d_g	998,1 mm
Pipe laying length	l	6 000 mm
Longitudinal compressive modulus of elasticity	E_p	18 000 MPa

Declared minimum specific initial axial compressive stress at break $\sigma_{b,\, s,\, min}$ = 90 N/mm^2

C.4.2 Geometrical intermediate calculations

C.4.2.1 Determination of internal diameter (d_i)

Using Equation (C.17): $d_i = d_{OD} - 2 \times e$

$$d_i = 1\,026 - 2 \times 44 = 938 \text{ mm} \tag{C.17}$$

C.4.2.2 Determination of minimum cross-sectional area at spigot

Determination of the minimum cross-sectional area at spigot, A_s, using Equation (C.18).

$$\begin{aligned} A_s &= \pi\left[\left(0{,}5\,d_g\right)^2 - \left(0{,}5\,d_i\,^*\right)^2\right] \\ &= \pi\left[\left(0{,}5 \times 998{,}1\right)^2 - \left(0{,}5 \times 938\right)^2\right] \\ &= \pi\left[\left(249\ 051\right)^2 - \left(219\ 962\right)^2\right] = 91\,386\ \text{mm}^2 \end{aligned} \tag{C.18}$$

Determination of internal diameter divided by spigot or groove diameter.

d_i^*/d_g

$$d_i^*/d_g = 938\ /\ 998{,}1 = 0{,}94 \tag{C.19}$$

C.4.3 Determination of the ultimate longitudinal load, F_{ult}

The determination of the ultimate longitudinal load F_{ult} is carried out using Equation (C.20).

$$\begin{aligned} F_{ult} &= \frac{\sigma_{b,\,s,\,min} \times A_s}{1\ 000} \\ &= \frac{90 \times 91\ 386}{1\ 000} = 8\ 225\ \text{kN} \end{aligned} \tag{C.20}$$

C.4.4 Determination of the theoretical design jacking load, $F_{j,\,calc}$

The determination of the theoretical design jacking load $F_{j,\,calc}$ is carried out using Equation (C.21).

$$\begin{aligned} F_{j,\,calc} &= \frac{F_{ult}}{\gamma} \\ &= \frac{8\ 225}{1{,}75} = 4\ 700\ \text{kN} \end{aligned} \tag{C.21}$$

C.4.5 Determination of the permissible jacking load at maximum eccentricity for a closed joint

The determination of the permissible jacking load at maximum eccentricity for a closed joint $F_{perm,\,p}$ is carried out using Equation (C.22) and Equation (C.14) where the stress ratio, $S_r = \dfrac{\sigma}{\sigma_0} = 2$.

$$\begin{aligned} F_{perm,\,p} &= \frac{\sigma_{b,\,s,\,min} \times A_s}{1\ 000 \times \gamma \times S_a} \\ &= \frac{90 \times 91\ 386}{1\ 000 \times 1{,}75 \times 2} = 2\ 350\ \text{kN} \end{aligned} \tag{C.22}$$

C.4.6 Determination of the angular deflection at maximum eccentricity for closed joint

The determination of the angular deflection at maximum eccentricity for closed joint tan δ is carried out using Equation (C.23).

$$\tan\delta = \frac{\sigma_{\text{all}}}{Z} \times \frac{l}{E_{\text{p}}} \tag{C.23}$$

From Equation (C.24) $Z/d_{\text{g}} = 1$ and from Equation (C.25) $\sigma_{\text{all}} = \sigma_{\text{b, s, min}}/\gamma$

Therefore

$$Z = d_{\text{g}} = 998{,}1 \text{ mm} \tag{C.24}$$

and

$$\sigma_{\text{all}} = 90/1{,}75 = 51{,}43 \text{ N/mm}^2 \tag{C.25}$$

Hence $\tan\delta = \frac{51{,}43}{998{,}1} \times \frac{6\,000}{18\,000} = 0{,}017\,176$ therefore $\delta = 0{,}984\,01°$

NOTE Verify in this case the angular deflection capability of the coupling and the available over cut of the bore (see 5.5.2).

C.4.7 Calculation of the permissible jacking force on the pipe, $F_{\text{perm, p}}$, at 0,6° angular deflection

Assuming that the maximum stress is equal to the allowable stress.

Therefore $\sigma_{\text{max}} = \sigma_{\text{all}} = \sigma_{\text{b, s, min}}/\gamma$

Hence $\sigma_{\text{all}} = 90/1{,}75 = 51{,}43 \text{ N/mm}^2$

Transposing Equation (C.26) to obtain Z we have

$$Z = \frac{\sigma_{\text{all}}}{\tan\delta} \times \frac{l}{E_{\text{p}}} \tag{C.26}$$

Therefore $Z = \frac{51{,}43}{0{,}010\,472\,3} \times \frac{6\,000}{18\,000} = 1\,637 \text{ mm}$

$$\frac{Z}{d_{\text{g}}} = \frac{1\,637}{998{,}1} = 1{,}64 \tag{C.27}$$

Because this value is greater than 1, this is a closed joint condition.

Using Equation (C.12) we obtain the stress ratio.

$$S_{\mathrm{a}} = \frac{\sigma}{\sigma_0} = \frac{\dfrac{Z}{d_{\mathrm{g}}}}{\dfrac{Z}{d_{\mathrm{g}}} - 0{,}5}$$

$$= \frac{\sigma}{\sigma_0} = \frac{\dfrac{1\,637}{998{,}1}}{\dfrac{1\,637}{998{,}1} - 0{,}5} = 1{,}438\,7 \tag{C.28}$$

$F_{\mathrm{perm,p}}$ is obtained using Equation (C.29).

$$F_{\mathrm{perm,\,p}} = \frac{\sigma_{\mathrm{b,\,s,\,min}} \times A_{\mathrm{s}}}{1\,000 \times \gamma \times S_{\mathrm{a}}} \tag{C.29}$$

The permissible jacking force on the pipe, $F_{\mathrm{perm,\,p}}$, at 0,6° angular deflection is:

$$F_{\mathrm{perm,\,p}} = \frac{51{,}43 \times 91\,386}{1\,000 \times 1{,}438\,7} = 3\,267\ \mathrm{kN}$$

Bibliography

[1] ISO 2602, *Statistical interpretation of test results — Estimation of the mean — Confidence interval*

[2] EN 295-3, *Vitrified clay pipes and fittings and pipe joints for drains and sewers — Part 3: Test methods*

[3] ATV 161, *Static calculation of driven pipes* (1990)

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