

Australian Standard™

Fibre-reinforced concrete pipes and fittings



This Australian Standard was prepared by Committee WS-008, Fibre Reinforced Concrete Pipes and Fittings. It was approved on behalf of the Council of Standards Australia on 3 June 2003 and published on 5 August 2003.

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This Standard was issued in draft form for comment as DR 02287.

Australian Standard™

Fibre-reinforced concrete pipes and fittings

Originated as AS 4139—1993.
Second edition 2003.

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Published by Standards Australia International Ltd
GPO Box 5420, Sydney, NSW 2001, Australia

ISBN 0 7337 5356 6

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PREFACE

This Standard was prepared by the Standards Australia Committee WS-008, Fibre-Reinforced Concrete Pipes and Fittings, to supersede AS 4139—1993, *Fibre-reinforced concrete pipes and fittings*, which is withdrawn.

The objective of this Standard is to provide manufacturers and purchasers with uniform requirements for fibre-reinforced concrete pipes and fittings.

The Standard has been written as a performance specification avoiding as far as possible any requirements that may restrict innovation in design. Pipe Classes 2, 3 and 4, specified in this Standard, correspond to the equivalent classes for steel-reinforced concrete pipe given in AS 4058, *Precast concrete pipes (pressure and non-pressure)*.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

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FOREWORD

Fibre-reinforced concrete pipe may be either rigid pipe or semi-rigid pipe.

Rigid pipe is assumed to be incapable of having sufficient deflection to gain support from the surrounding soil and must have sufficient ring bending strength to support the full soil prism load to maintain its integrity for its design life.

Semi-rigid pipe must have sufficient ring bending strength to initially support the full soil prism load, and sufficient deflection capability to deflect as its stiffness reduces with age, to obtain support from the surrounding soil to maintain its integrity for its design life.

A flexible pipe has insufficient ring bending strength to support the full soil prism load and relies on support from the surrounding soil to maintain its integrity for its full design life.

In common with other materials, fibre-reinforced concrete pipe may exhibit creep under sustained loading conditions. In order that this may be accommodated into the design of the product, the change is quantified by type-testing, either through the application of regression analysis or a stress relaxation methodology.

The minimum allowable test load for a pipe is determined by predicting the design life load that the pipe will be capable of withstanding in a saturated condition. A safety factor of 1.5 has been assumed for the purposes of design calculation. In addition, pipes satisfying the definition of being semi-rigid in this Standard have a further safety factor of 2 on long-term deflection.

The required design life and class of the pipe should be determined using informed engineering judgment of the conditions of installation and operation of the pipe.

This Standard has been developed with a focus on cellulose-reinforcing fibres. The Standard, however, covers a number of fibre types and does not restrict the method of pipe manufacture.

STANDARDS AUSTRALIA

Australian Standard Fibre-reinforced concrete pipes and fittings

1 SCOPE

This Standard specifies minimum requirements for pipes and fittings manufactured from fibre-reinforced concrete using standard curing, including autoclaving, for the conveyance of gravity water supply, and stormwater, waste water and sewage drainage.

Four classes of pipes are covered by this Standard, distinguished on the basis of long-term design load: Class 1, Class 2, Class 3, and Class 4. Other classes of pipe may be designed using the principles described in this Standard.

This Standard addresses the effect of creep under load by either, regression analysis of pipe materials (see Appendix H), or long-term stiffness prediction.

NOTES:

- 1 Fibre-reinforced concrete pipe is herein referred to as 'pipe'.
- 2 The load classes correspond with those of AS 4058.
- 3 This Standard does not cover the assessment of external service loads to which a pipe will be subjected to in a particular installation. Purchasers should, therefore, satisfy themselves that the class of pipe specified or selected on the basis of this Standard is suitable for its intended application. For buried pipes, reference to AS 3725 is required.
- 4 Guidance on the information to be supplied by the purchaser at the time of enquiry or order is given in Appendix A.
- 5 Appendix B provides concentration limits for commonly occurring soil/terrain constituents of the buried environment, but does not provide special requirements for pipes intended for use in environments aggressive to concrete. Where such applications are envisaged, the advice of the manufacturer should be sought.

2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS	
1199	Sampling procedures and tables for inspection by attributes
1379	Specification and supply of concrete
1399	Guide to AS 1199—Sampling procedures and tables for inspection by attributes
1478	Chemical admixtures for concrete, mortar and grout
1478.1	Part 1: Admixtures for concrete
1646	Elastomeric seals for waterworks purposes (all parts)
2193	Calibration and classification of force-measuring systems
2490	Sampling procedures and charts for inspection by variables for percent nonconforming (ISO 3951:1989)
2758	Aggregates and rock for engineering purposes
2758.1	Part 1: Concrete aggregates
3582	Supplementary cementitious materials for use with portland cement (all parts)
3725	Loads on buried concrete pipes

AS	
3972	Portland and blended cements
4058	Precast concrete pipes (pressure and non-pressure)
AS/NZS	
2566	Buried flexible pipelines.
2566.1	Part 1: Structural Design
3500	National Plumbing and Drainage Code
3500.0	Part 0: Glossary of terms
SAI/SNZ	
HB18.28	Guidelines for third-party certification and accreditation—General rules for a model third-party certification system for products
ISO	
2859	Sampling procedures for inspection by attributes
2859-1	Part 1: Sampling plans indexed by acceptance quality level (AQL) for lot-by-lot inspection
3951	Sampling procedures and charts for inspection by variables for percent nonconforming.
10928	Plastic piping systems — Glass-reinforced thermosetting plastic (GRP) pipes and fittings—Methods for regression analysis and their use.
ASTM	
C500	Standard Test Methods for Asbestos-Cement pipe
SABS	
0102	Selection of pipes for buried pipelines
0102-1	Part 1: General provisions

3 DEFINITIONS

For the purposes of this Standard, the definitions in AS/NZS 3500.0 and those below apply:

3.1 Joint deflection

The maximum angle (of deviation) between two adjoining pipes quoted by the manufacturer as being achievable without loss of joint integrity for an appropriate service condition.

3.2 Rigid pipe

A pipe with sufficient strength to carry the working load for its design life without significant deflection under loading.

3.3 Semi-rigid pipe

A pipe with sufficient strength to initially carry the working load, and with the capability to deflect under long-term loading, so that it is able to gain support from the soil in which it is embedded and maintain its integrity for its design life.

3.4 Nominal diameter

An alphanumeric designation of size, common to all components in a piping system. It is a convenient round number for reference purposes and is related to the internal diameter, in millimetres.

4 NOTATION

The following symbols are used in this Standard:

a	=	linear regression coefficient
A	=	water absorption, as a percentage of dry mass
b	=	linear regression coefficient
C	=	dry/wet strength factor, determined in accordance with Appendix G
C'_e	=	Spangler coefficient for rigid pipe installation design
DN	=	nominal size, in millimetres
d	=	design diameter, nominated by the manufacturer for a specified nominal pipe diameter, in millimetres
d_i	=	mean internal diameter, in millimetres
d_o	=	mean external diameter, in millimetres
E'	=	effective combined Spangler soil modulus, in megapascals
E'_Y	=	effective combined soil modulus for determining flexural stiffness ratio, in megapascals
E_{BS}	=	saturated pipe modulus of elasticity, in megapascals
E_{BS2}	=	predicted saturated pipe modulus of elasticity at 2 years, in megapascals
F	=	maximum force, indicated by the testing machine, in kilonewtons
F_b	=	bedding factor for rigid pipe installation design
F_{low}	=	lower force point, indicated by data acquisition, in kilonewtons
F_{max}	=	maximum force point, indicated by data acquisition, in kilonewtons
F_{upp}	=	upper force point, indicated by data acquisition, in kilonewtons
H	=	height of soil above the top of the pipe, in metres
I	=	moment of inertia of pipe, in millimetres to the fourth power
K	=	bedding constant for flexible pipe installation design
L	=	length of the test specimen, in millimetres
L_e	=	effective length of pipe, in millimetres
M_1	=	mass of saturated specimen, in grams
M_2	=	mass of oven-dried specimen, in grams
P_d	=	test load at failure for a dry specimen, in kilonewtons per metre
P_{dLC}	=	97.5% lower confidence limit of P_d , determined from not less than 30 test results, in kilonewtons per metre
P_R	=	relaxation initial load, in kilonewtons
P_{R2}	=	relaxation predicted load at 2 years, in kilonewtons
P_s	=	test load at failure for a saturated specimen, in kilonewtons per metre
P_{sLC}	=	97.5% lower confidence limit of P_s , determined from not less than 30 test results, in kilonewtons per metre
P_{ts}	=	sustained test load, causing creep failure of a saturated specimen, in kilonewtons per metre

P_{δ}	=	sustainable load, for a saturated specimen at 50 years (value calculated from the regression equation), in kilonewtons per metre
$P_{\delta LC}$	=	97.5% lower confidence limit of P_{δ} , in kilonewtons per metre
P_M	=	minimum dry test load at failure, in kilonewtons per metre
R	=	regression factor, determined from the analysis carried out in accordance with Appendix H
S_S	=	initial pipe saturated stiffness, in Newtons per metre per metre
S_{S2}	=	predicted pipe saturated stiffness at 2 years, in Newtons per metre per metre
T_c	=	long-term design load, equivalent to the crack test load in steel-reinforced concrete pipe of the same nominal diameter and load class as that of the test specimen, in kilonewtons per metre
t_f	=	time to failure of test specimen, subjected to sustained load testing, in hours
t	=	wall thickness of the pipe specimen, in millimetres
t_a	=	pipe average wall thickness, in millimetres
t_m	=	pipe minimum manufacturing wall thickness, in millimetres
w	=	soil density, in kilonewtons per cubic metre
w_g	=	soil prism pressure on the pipe, in kilopascals
W_g	=	soil dead load on pipe, in kilonewtons per metre
Y	=	pipe installation flexural stiffness ratio
$\frac{\Delta_{\max}}{d_i + t}$	=	pipe deflection to diameter ratio at maximum load in ring bending
$\frac{\Delta_y}{d_i + t}$	=	pipe deflection to diameter ratio
Δ_v	=	pipe vertical deformation between F_{low} and F_{max} , in millimetres
δ	=	Design life – 50 years (438 000 h)
$\varepsilon_{\max}$	=	strain at maximum load in ring bending
$\sigma_{\max}$	=	stress at maximum load in ring bending, in megapascals

5 CLASSIFICATION

Pipes shall be designated by their nominal size (DN), and classified according to their long-term design loads (T_c), given in Table 1.

NOTE: For further information see Appendix C.

TABLE 1
LONG-TERM DESIGN LOADS FOR PIPE (CLASSES 1 TO 4)

Nominal size DN	Long-term design load T_c kN/m			
	Class 1	Class 2	Class 3	Class 4
100	10	13	20	26
150	10	13	20	26
200	10	14	21	27
225	11	14	21	28
250	11	14	22	29
300	12	15	23	30
375	13	17	26	34
450	15	20	30	40
525	17	23	35	46
600	19	26	39	52
675	20	29	44	58
750	21	32	48	64
900	23	37	56	74
1050	25	42	63	84
1200	27	46	69	92

NOTE: Some diameters and load classes may not be available. The manufacturer should be consulted. The long-term design load is equivalent to the test crack load given in AS 4058.

6 MATERIALS

6.1 Concrete materials

6.1.1 Cement

Cement shall comply with AS 3972.

6.1.2 Supplementary cementitious materials

Supplementary cementitious materials shall comply with AS 3582 or AS 3972.

6.1.3 Aggregates

Aggregates, where used, shall comply with AS 2758.1 and with any additional requirements that may, according to that Standard, need to be separately specified for a particular usage or application of the pipes.

Lightweight aggregate and non-ferrous metallurgical slag shall not be used in concrete for pipes and fittings.

NOTE: Attention is drawn to the fact that AS 2758.1 includes a number of options, and cannot be used on its own as a specification for contract purposes. The particular option selected as appropriate to the intended usage of the pipes will, therefore, need to be separately referred to by the purchaser. When not specified by the purchaser, the manufacturer should select the appropriate options in accordance with AS 2758.1.

6.1.4 Water

Water added to the manufacturing process shall comply with the requirements of AS 1379.

6.1.5 Admixtures

Chemical admixtures shall comply with AS 1478.1. Chemical admixtures shall not contain nitrates, chlorides or other strongly ionized salts unless it can be shown that this does not adversely affect durability.

6.1.6 Fillers

Where fillers are added to the concrete mix in the manufacturing process, the filler shall be inorganic and shall be compatible with other materials in the mix, to ensure the performance requirements of Clause 11 are achieved.

6.1.7 Restriction on chemical content

The materials shall not contain acid-soluble chloride or sulfate salts in excess of the values given in Table 2.

TABLE 2
MAXIMUM VALUES OF ACID-SOLUBLE CHLORIDE ION
AND SULFATE ION CONTENT IN CONCRETE AS CAST

Condition	Maximum acid-soluble chloride ion content	Maximum acid-soluble sulfate ion content
	kg/m ³	% (by mass of cement)
Concrete cured other than by steam or autoclaving	0.8	5.0
Steam-cured concrete and autoclaved concrete	0.8	4.0

NOTE: For further information see Appendix B.

6.2 Reinforcement materials

Reinforcement may be any of the following materials:

- (a) Cellulose fibre.
- (b) Plastics fibre.
- (c) Glass filament.
- (d) Steel fibre.

No further restriction is placed on the choice of fibre-reinforcement materials given above, their combination, their proportion in the finished product, or the method of pipe manufacture, except that pipes manufactured using these materials shall comply with the requirements of this Standard. The manufacturer shall provide the purchaser with documented evidence that the fibres employed are compatible with the other materials in the pipes for the intended purpose of the pipes.

6.3 Joint materials

Elastomeric joint seals or joint bands shall comply with AS 1646. Other joint materials shall comply with the relevant Australian Standard or, where no such Standard exists, the appropriate current ISO, BSI or ASTM Standard.

NOTE: When placing an order for elastomeric joint seals or joint bands, the pipe manufacturer should supply the information required in AS 1646.

7 FITTINGS

Pipe fittings of fibre-reinforced concrete shall be fabricated from pipe complying with the requirements of this Standard using adhesives or fabrication techniques that can be demonstrated to be suitable for the intended application.

8 ELASTOMERIC SEAL JOINTS

Where elastomeric seal joints are employed, they shall provide a drip-tight seal. When tested in accordance with Appendix L, at the pressure specified in Clause 11.2, the joints shall provide a drip-tight seal at the manufacturer's maximum recommended angular deviation.

9 DEFECTS

9.1 Cracks

Pipes shall be free from fractures and cracks wider than 0.1 mm and deeper than 0.3 mm.

9.2 Delamination

Pipes shall be free from any visible delamination.

9.3 Dents and bulges

Dents on either inside or outside surfaces shall not exceed 3 mm depth; and bulges shall not exceed 3 mm in height on the inside surface of the pipe. Dents and bulges shall not extend laterally in any direction on the surface by more than 50 mm.

10 DIMENSIONS AND TOLERANCES

10.1 Internal diameter

The mean internal diameter of a pipe shall not differ from the design diameter (d) nominated by the manufacturer by more than the amount shown in Table 3. No individual internal diameter shall be less than the mean internal diameter (d_i) by more than $0.01d_i + 2$ mm, or 12 mm, whichever is the smaller.

The mean internal diameter (d_i) may be determined by taking two measurements mutually at right angles at 200 mm from each end. The mean internal diameter shall be taken as the mean of the four values. Alternatively, the mean internal diameter may be determined by measuring the average external diameter with a diameter tape and subtracting the mean of four measurements of wall thickness taken at equal intervals around the circumference.

For socket and spigot joints, the distance from the socket end shall be measured from the point at which the socket meets the barrel.

TABLE 3
PERMISSIBLE TOLERANCES ON DESIGN DIAMETER

Nominal size (DN) range	Tolerance on design diameter (d)
	mm
≤300	±3
>300, ≤600	±5
>600, ≤1200	±7

10.2 Wall thickness

The wall thickness shall be determined by direct measurement and shall not vary from the manufacturer's stated value (t_a), expressed in millimetres, by more than $\pm 0.1t_a$ mm.

10.3 Pipe length

The manufacturer shall supply the pipe in nominated effective lengths (L_e). The tolerance on the manufacturer's nominated effective length shall be ± 15 mm. The manufacturer shall provide information on the length of pipes.

10.4 Squareness of ends

The squareness of an end of a pipe shall be determined by measuring across three external end diameters at 60° to one another, as shown in Figure 1. The ends of the pipe shall be square relative to the internal surface as follows:

- For pipes ≤ 400 mm diameter, the tolerance on squareness shall be 2 mm.
- For pipes > 400 mm, the tolerance on end squareness shall be 1 mm/200 mm of the design diameter.

NOTE: When the ends of the pipe are machined whilst rotating in a standard lath process, it may not be necessary to include the squareness of ends in routine quality audit inspections.

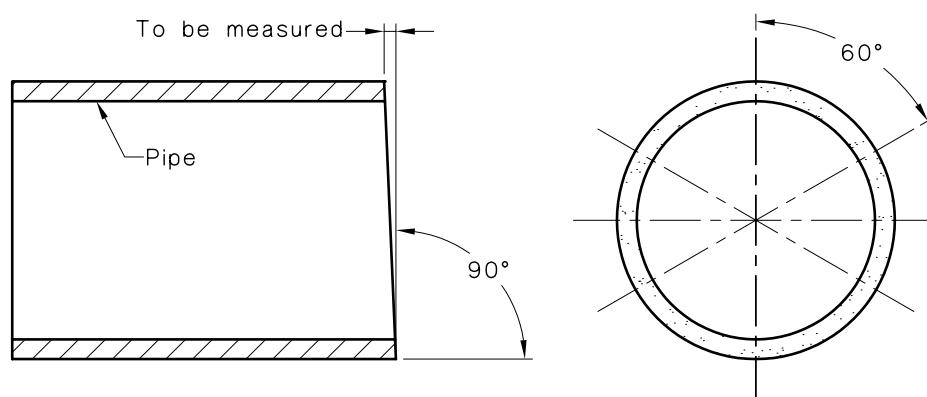


FIGURE 1 MEASUREMENT OF END SQUARENESS

10.5 Straightness

When a pipe is tested by means of a straightedge laid along the whole length of the pipe, the deviation from straight shall not exceed 8 mm/1000 mm distance from either end of the pipe, and the deviation from a straight line taken between any two points, 1 m apart, along the pipe barrel shall not exceed 3 mm.

11 PERFORMANCE REQUIREMENTS

11.1 Strength requirement

The minimum test failure load of a specimen in the dry condition shall be determined as follows:

- Rigid pipe (creep regression factor method)* When tested in accordance with Appendix E, the minimum test failure load of a dry specimen (P_M), in kN/m, shall not be less than the value calculated from the following equation:

$$P_M = 1.5CRT_c \quad \dots 11(1)$$

- Semi-rigid pipe (stress relaxation method)* When tested in accordance with Appendices E and F, and only if satisfying the conditions prescribed in Appendix D, the minimum test failure load of a dry specimen (P_M), in kilonewtons per metre, shall not be less than the value calculated as follows:

$$P_M = 1.5CT_c \text{ or } P_M = 2T_c \quad \dots 11(2)$$

whichever is the greater,

where (for both Equations 11(1) and 11(2))

P_M = minimum dry test load at failure, in kilonewtons per metre

- 1.5, 2 = factors of safety applied to the predicted load capacity
- C = a dry/wet strength factor, determined in accordance with Appendix G
- R = the load regression factor, determined in accordance with Appendix H
- T_c = as specified in Table 1

For the purpose of determining P_M , test samples used in the calculation of the C and R factors shall be taken from the same batch of pipes.

NOTE: For quality assurance purposes, the test specimens should be selected from batches of pipes of the same diameter, class and of consecutive manufacture.

11.2 Hydrostatic testing

Where required by the purchaser, pipes and joints shall withstand a test pressure of 250 kPa for 30 s or, alternatively, 90 kPa for 1 min plus 30 s for every 10 mm of wall thickness when tested in accordance with Appendix L. The number of specimens to be tested shall be specified by the purchaser. For the purpose of testing elastomeric joints, in accordance with Clause 8, the test pressure shall be 90 kPa.

11.3 Water absorption test

Pipes shall be tested for water absorption in accordance with Appendix K. The water absorption (A) of the test specimen shall not vary from the manufacturer's stated value by more than $\pm 0.1A$.

NOTE: The manufacturer should clearly state the water absorption value for the product in the product literature and any additional limits on the buried environment that may occur as a result of this stated value and the reinforcement materials used in the pipe (see Appendix B).

11.4 Flexural strength test

When tested in accordance with Appendix I, the nominal flexural strength of pipes of sizes DN 100 and DN 150, expressed as the minimum bending load at failure, shall be not less than the appropriate value given in Table 4.

NOTE: The flexural strength test is a performance test that relates to the ability of the pipe to withstand axial flexure in-service. The loads given in Table 4 do not represent the maximum service loads that could occur in service and apply to pipe lengths 3.6 m and longer.

TABLE 4
NOMINAL FLEXURAL STRENGTH

Nominal size DN	Class	Minimum applied bending load kN
100	1 & 2	1.8
100	3	2.4
100	4	2.8
150	1 & 2	5.2
150	3	6.6
150	4	7.9

12 MARKING

The following information shall be clearly and indelibly marked on the exterior surface of each pipe:

- The class of pipe as given in Table 1.
- Date and place of manufacture.
- Manufacturer's name or registered trademark.

- (d) The nominal size of the pipe.
- (e) The number of this standard, i.e., AS 4139.

The following information shall be clearly and indelibly marked on the interior surface of each pipe:

- (a) The class of pipe as given in Table 1.
- (b) Date of manufacture.
- (c) Manufacturer's name or registered trademark and code indicating fibre type.

NOTES:

- 1 Manufacturers making a statement of compliance with this Australian Standard on a product, packaging, or promotional material related to that product are advised to ensure that such compliance is capable of being verified.
- 2 Design principles used for determining the relationship between long-term and short-term performances of fibre-reinforced concrete pipe are outlined in Appendix C.
- 3 Methods of determining compliance with this Standard are given in Appendix N.
- 4 Guidance on the information to be supplied by the purchaser at the time of enquiry or order is given in Appendix A.

13 HANDLING AND STORAGE

13.1 General

Pipes shall be handled and, where necessary, stored in a manner such that—

- (a) they continue to be in a condition that complies with this Standard;
- (b) their shapes are not distorted so as to affect jointing, pressure tightness or water tightness; and
- (c) their surface and edge finishes are not damaged such that performance is affected.

13.2 Lifting holes

Where lifting holes are provided, they shall be cast with a tapered hole in the top centre of mass of the pipe, as per dimensions given in Table 5. The larger dimension in each case shall be perpendicular to the longitudinal axis of the pipe. The hole shall be positioned so that the pipe can be lifted without tilt or radial twisting.

A plug of concrete, or other suitable material, shall be provided to fit each hole.

TABLE 5
STANDARD LIFTING HOLES

Nominal size DN	Minimum hole size mm
≤525	40×30
>525, ≤750	70×30
>750, ≤1200	120×40

13.3 Lifting elements

Where lifting elements are provided, they shall comply with the requirements of the appropriate regulatory authority, and shall be installed in accordance with the supplier's recommendations.

APPENDIX A
PURCHASING RECOMMENDATIONS
(Informative)

A1 INFORMATION TO BE SUPPLIED BY THE PURCHASER

The purchaser should supply the following information at the time of calling tenders or quotations:

- (a) Nominal size (see Table 1).
- (b) The intended application.
- (c) The load class of pipe or installation conditions (see Table 1 and AS 3725).
- (d) Type of joint.
NOTE: Typical joint configurations are detailed in Appendix M.
- (e) Tests other than those required by Clause 11.1.
- (f) Any other special treatments or requirement.
- (g) Specific requirements concerning repair of defects, if applicable (see Clause 9.3).
- (h) A statement of information to be supplied by the manufacturer (see Paragraph A2).
- (i) The place and rate of delivery.

A2 INFORMATION TO BE SUPPLIED BY THE MANUFACTURER

In addition to information required by this Standard to be supplied, the manufacturer should, if requested by the purchaser, supply with the tender or quotation all or any of the following information:

- (a) The methods of manufacture and testing.
- (b) Drawings showing critical dimensions with tolerances thereon of the pipes and joints including the allowable deflection angles.
- (c) The type of fibre used in the pipe (see Clause 6.2).
- (d) Details of the joint system and the composition and dimensions of the rubber rings or joint material (see Clauses 6.3 and 8).
NOTE: Typical joint configurations are detailed in Appendix M.
- (e) The method of determination of the strength requirement (Clause 11.1(a) or 11.1(b)).
- (f) The values of *C* and *R* with test data establishing such values and the results of any screening evaluation performed.
- (g) Type of cement (see Clause 6.1.1).
- (h) Water absorption value (see Clause 11.3).
- (i) Diameter, wall thickness and length of the pipe (see Clauses 10.1 to 10.3).
- (j) A statement of compliance with this Standard.

APPENDIX B

GUIDE TO CONCENTRATION LIMITS APPLICABLE TO SOME CONSTITUENTS OF THE BURIED ENVIRONMENT

(Informative)

B1 SCOPE

The selection of a pipe should take into account the required design life of the infrastructure having consideration not only to the material being conveyed by the pipeline, but also the aggressiveness of the surrounding buried environment and the material and method of manufacture of the pipe. Pipelines are ideally placed to ensure their longevity in service. Soil moisture may provide continued curing and potential strength gain of the concrete matrix. Thermal stress effects are minimized by the relative constant temperature of the buried environment and drying shrinkage rarely takes place to any significant level in such installations.

B2 CONSTITUENT LIMITS

For the majority of buried concrete pipelines, the soil surrounding the installation is generally not overtly aggressive to concrete. Table B1 provides guidelines on chemical concentration limits for installed autoclaved concrete pipe only reinforced with cellulose fibre.

B3 REINFORCEMENT FIBRE

As of the publication of this Standard, the sole fibre-reinforced concrete pipe produced in Australia uses cellulose fibre and is autoclaved at elevated temperature and pressure. These pipes have been present in the Australian market since 1984 and their durability performance is generally well understood.

Pipes are known to have been manufactured in Germany for some years using a blend of poly vinyl alcohol fibres (PVA) and cellulose fibres in a water-cured cement matrix. In these pipes the PVA fibre is generally added to enhance the resistance of the pipe to repeated wetting and drying cycles as well as enhance the pipe strength. It is known that if cellulose fibres alone are used to form a pipe in an air-cured cement matrix particular attention is required to be paid to the durability of the pipe under repeated wetting and drying cycles.

Glass-fibre-reinforced cement building materials are well known in Australia. The reinforcing glass fibre in these materials is either e-glass with a resin coating, or alkali-resistant glass fibre (AR glass) with a resin coating. In a high pH wet environment, in the presence of calcium ions, glass fibre is known to be attacked by the calcium ions leading to ion substitution into the glass and degradation of the fibre. Pipes manufactured with glass fibre will need to be certified for their durability under extended wet conditions.

TABLE B1
MAXIMUM CONCENTRATION LIMITS FOR AUTOCLAVED PIPE REINFORCED
ONLY WITH CELLULOSE FIBRE

Constituent	Limits for autoclaved pipes reinforced only with cellulose fibre		
	Soil classification (see Note 1)		
	Clay/Stagnant	Medium	Sandy/Flowing
<i>Chloride</i> (max. p.p.m. Cl^-)			
Permanently submerged 500 mm below lowest seawater level	No Limit	No Limit	No Limit
Spray zone (500 mm above wave crest level)	No Limit	No Limit	No Limit
Splash zone (500 mm below lowest seawater level up to 500 mm above wave crest level)	(Note 2)	(Note 2)	(Note 2)
Buried in saline soils	No Limit	No Limit	No Limit
<i>Sulphate</i> (max. p.p.m. SO_4^{2-}) (Note 3)	(Note 4)	(Note 4)	(Note 4)
<i>Acidity</i> (Note 3)			
Acid (min. pH)	4.5	5.0	5.5
Exchangeable soil acid (max. mL of 0.1 M NaOH consumed by 100 g air-dried soil)	70	50	30
<i>Aggressive CO₂</i> (max. p.p.m.) (Note 3)	150	50	15
<i>Sewer</i>	(Note 5)	(Note 5)	(Note 5)

NOTES:

- The groupings used correspond to the classification system adopted by AS 1726.
 - Clay/Stagnant.....Practically impervious (clays).
 - Medium.....Poor Drainage (fine sands, organic and inorganic silt, mixtures of silt, sand and clay, stratified clay).
 - Sandy/Flowing.....Good drainage (gravels and sands).
- The splash zone is a very aggressive environment for steel- and fibre-reinforced concrete pipe. In applications where the pipe is partially submerged, or suspended above the water line, and could have the opportunity to dry out for long periods of time, specific site conditions should be carefully considered (see Clause 1, Note 5).
- In groundwater, or, of soil extract (2:1 water to soil by mass).
- Concentrations of sulphate ions, which may initiate micro-cracking within the concrete matrix, are unlikely to adversely affect autoclaved pipe provided the amount of un-combined Calcium Hydroxide in the pipe does not exceed 1.0% when tested in accordance with ASTM C500.
- This Table provides guidance on chemical concentration limits applying to cellulose-fibre-reinforced and autoclaved-cured concrete pipe only (see Clause 1, Note 5).
 Abrasion effects on concrete pipe are not covered and usually are not a concern in the majority of pipeline installations. The designer should, however, consider the effects of abrasion resulting from the conveyance of fluid materials within a buried installation. Design criteria that should be addressed include fluid velocities, mass flow volumes, type, shape and size of the abrasive material being transported. Under some circumstances, it may be prudent to increase the pipe wall thickness beyond the design requirement to account for such abrasive effects.