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Information and Guidance Note

SPECIFICATION FOR SOLID WALL CONCENTRIC EXTERNAL RIB-REINFORCED uPVC SEWER PIPE

FOREWORD

This specification has been prepared by the Water Research Centre under the direction of the WAA Sewers and Water Mains Committee and in conjunction with the pipe manufacturers and the High Performance Pipe Association to define the properties for solid wall concentric external rib-reinforced uPVC sewer pipe suitable for the construction of sewers. It has been issued to satisfy the users' and manufacturers' requirement for a specification for this new type of uPVC sewer pipe.

Most of the test methods in this specification are based on draft International Standards. Further issues can be expected as these methods are refined, technical requirements varied, or if size ranges are extended.

A new manufacturing technology has allowed the production of uPVC pipes with a concentric rib-reinforced profile. The solid rib construction results in structurally effective use of the material and the design of the profile permits cutting and positive location of the sealing ring at any point along the pipe by connection to an integral socket (formed during the manufacturing process) or separate fitting.

A specification covering fittings suitable for use with solid wall concentric external rib-reinforced uPVC sewer pipe will be issued in the future as a separate document.

The nominal outside diameters which have been selected are based upon the BS 2045 Series of preferred numbers. The nominal bores have been selected to give a balance between optimum capacity and to be compatible with those of other materials which are in use in the market.

Pipes manufactured to this specification may be used in conjunction with pipes and fittings made to BS 4660 and to BS 5481 by the use of special fittings and adaptors.

Connections to clay and concrete pipes and fittings can be made by using adaptors.

Attention is drawn to the following publications:

(a) BS 5955: Part 6 and BS 8301 (which give guidance on storage, handling and installation).

(b) Sewers for adoption.

(c) Specification for highway works.

(d) WRc External Report No. ER 201E. The structural design of underground non-pressure uPVC pipelines.

(e) BS 8005 (see clause 10 – References).

uPVC pipe was originally designed and specified by pressure classification having initially been used primarily as pressure pipes. With the introduction of BS 4660 for drainage and BS 5481 for sewerage, pressure classification was replaced by pipe classes 41 and 34, for these applications, which were defined by the relative wall thickness, d/e (or SDR).

Rib-reinforced pipes are designated by the nominal size based upon inside diameter and nominal outside diameter. They are currently available with a nominal short term stiffness of $8kN/m^2$ (Class 8), equivalent to a conventional solid wall uPVC pipe of SDR 34.

Research conducted by WRc in their test pit facility and a field test site demonstrated that the rib-reinforced pipes and sockets manufactured to this specification performed totally satisfactorily under various soil/loading conditions, being generally superior to uPVC sewer pipe to BS 5481 with respect to handling and initial structural performance.

Requirements are specified for pipes for sewers intended for the disposal under atmospheric pressure of surface water, domestic effluent and such effluent as is permitted by the statutory authorities to be discharged into public sewers. Where it is proposed to use these pipes with untreated trade waste or with prolonged discharges at high temperatures, reference should be made to CP 312: Part 1 and/or the pipe manufacturer concerning the suitability of the product for such use.

Compliance with this specification does not itself confer immunity from legal obligations.

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

Purchasers are reminded that this specification requires that the manufacturer shall operate an acceptable quality system relating to the manufacture of pipe to this specification in compliance with BS 5750: Part 2 (ISO 9002), which ensures that products claiming to comply with this specification consistently meet the required level of

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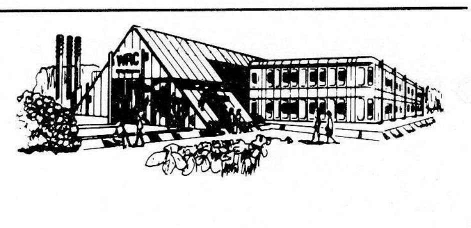

quality. Enquiries regarding the availability of third party certification should be addressed to WRc Engineering.

This specification calls for the use of substances and/or procedures that may be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

It has been assumed in the drafting of this specification that the execution of its provisions is entrusted to appropriately qualified and experienced people.

Information contained in this specification is given in good faith but neither the Water Authorities Association nor the Water Research Centre can accept any responsibility for actions taken as a result.

CONTENTS

1. SCOPE

This document specifies solid wall unplasticised polyvinyl chloride gravity sewer pipe having external concentric rib-reinforcements produced as an integral part of the pipe manufacture.

Nominal sizes (internal) of between 180 and 300 are specified (200 – 335mm nominal outside diameter). The requirements include dimensions, materials, appearance, type and quality control tests and marking.

2. SYMBOLS

The symbols associated with the pipe and socket dimensions are listed in Table 1. Pipe dimensions are indicated in Figure 1 and socket dimensions in Figure 2.

Table 1 – Dimensional symbols

Symbol	Significance
DE	Nominal outside diameter
NS	Nominal bore size
d_{em}	Mean outside diameter = DE $\pm$(0.003 $\times$ DE)
d_{ci}max	Maximum individual outside diameter = 1.012 $\times$ DE
D_o	Mean ring seat diameter
e_1	Minimum wall thickness $\geqslant$(0.0063 $\times$ DE)
T	Total profile height
P	Pitch
L_2	Total integral socket depth nominal
A	Effective integral socket depth – min = (0.1 $\times$ DE) + 30
B	Integral socket mouth – max = 0.1 $\times$ DE
D_i	Integral socket inside diameter
e_2	Integral socket minimum wall thickness

3. MATERIALS

3.1 Pipes

The material from which the pipes are produced shall consist substantially of polyvinyl chloride together with those additives that are needed for the manufacture and performance of pipe to this specification. Pigments may be added to achieve the colour required by 4.1.

3.2 Rework material

If rework material is added or used, it shall be clean and in accordance with 3.1, derived from pipe produced in accordance with this specification and reground under the supervision of the same manufacturer.

3.3 Elastomeric sealing rings

Sealing rings shall comply with the requirements of Type D of BS 2494: 1986.

4. APPEARANCE

4.1 Colour

The colour of the pipe shall be in the range 06D45 to 06D43 of BS 4901: 1976 (RAL 8023).

4.2 Surface Appearance

The internal and external surfaces of the pipe shall be clean, smooth and free from defects that would impair their performance.

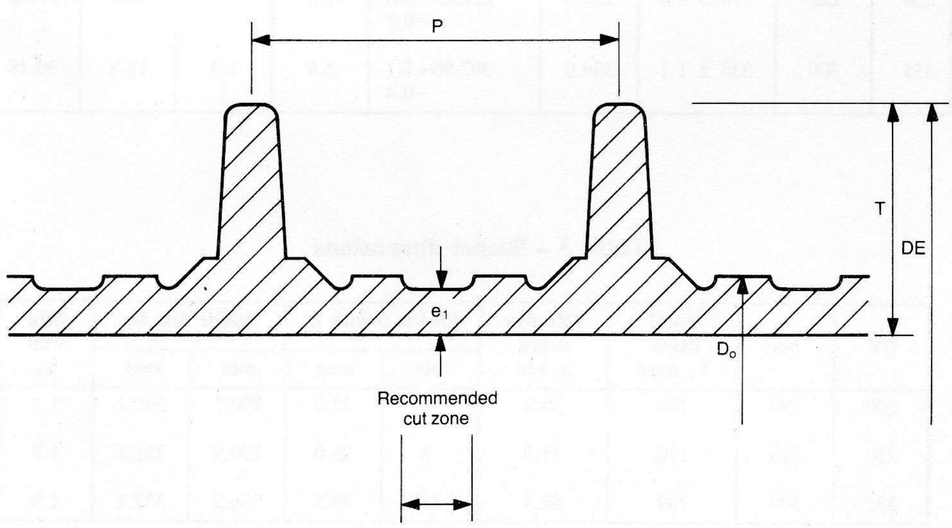

Figure 1 – Pipe wall profile

NOTE: The mould split lines and minor surface irregularities are controlled by the manufacturer's production process and quality assurance system and will not affect the performance of the product.

5. DIMENSIONS

5.1 Pipes

Pipe diameters and wall thicknesses shall comply with the dimensions given in Table 2. Where sockets are formed on the ends of pipes they shall conform to Table 3. The length of the designated part of the pipe spigot (illustrated in Figure 2) shall comply with the requirements of Table 3.

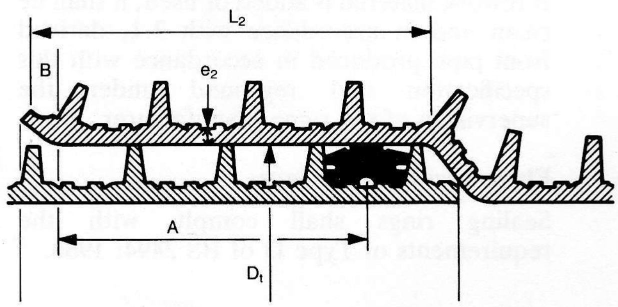

Figure 2 – Socket and spigot end with sealing ring located on the pipe

5.2 Tolerance on length

Lengths of pipes shall be not less than that specified.

NOTE: Preferred lengths are 3m or 6m.

5.3 Ends of Pipes

The ends of the pipes shall be cleanly cut square to the axis of the pipe and within the recommended cut zone shown in Figure 1.

6. QUALITY CONTROL TEST REQUIREMENTS

6.1 Impact resistance of pipes

The functional impact strength of the pipe shall be determined in accordance with Appendix A.

The impact strength B 50 shall be not less than 1.0m falling height.

6.2 Short term ring stiffness

The nominal short term ring stiffness shall not be less than 8.0kN/m^2 when tested in accordance with Appendix B.

6.3 Vicat softening temperature

When tested by the method described in BS 2782: Method 120B, the Vicat softening temperature of test pieces taken from pipes shall be not less than 79°C.

Table 2 – Dimensions of pipes

DE	NS	d_{em}	d_{ei} max	D_o	e_1 nom	e_1 min	T	P
200	180	200 ± 0.6	202.4	185.80+0.6 −0.2	2.0	1.6	9.8	16.93
250	225	250 ± 0.8	253.0	232.25+0.8 −0.3	2.3	1.9	12.2	19.05
335	300	335 ± 1.1	339.0	307.90+1.1 −0.4	2.9	2.3	17.8	30.48

Table 3 – Socket dimensions

DE	NS	Total depth L_2 nom	Effective depth A min	Socket mouth B min	Socket mouth B max	Inside dia. D_i min	Inside dia. D_i max	Min wall e_2
200	180	104	50.0	6	20.0	200.7	201.2	1.3
250	225	120	55.0	8	25.0	250.9	251.5	1.6
335	300	134	63.5	13	33.5	336.2	337.1	1.9

7. TYPE TEST REQUIREMENTS

7.1 Requirements for joint assemblies incorporating elastomeric sealing rings

7.1.1 Diameter distortion

When tested by the method described in Appendix C the joint shall show no visible leakage.

7.1.2 Angular deflection

When tested by the method described in Appendix C the joint shall show no visible leakage.

7.2 Long term ring stiffness

When tested in accordance with Appendix D the nominal two year stiffness ($STES_2$) shall be not less than $4.0 kN/m^2$. The nominal 50 year stiffness ($STES_{50}$) shall be not less than $3.0 kN/m^2$.

NOTE: In view of the ongoing discussions at ISO and other bodies, other methods of testing may be agreed between the manufacturers and the Water Industry.

7.3 Stress rupture requirement for pipes

When tested in accordance with the method described in BS 4728 (ISO 1167) the pipe shall meet the requirements of Table 4. Using the lowest measured value of e_1 determine the internal pressure using Formula (1):

$$P = \frac{20\sigma e_1}{d_i + e_1} \qquad (1)$$

Where: σ = circumferential stress to be introduced (MPa)
P = internal water pressure in the pipe (bar)
d_i = inside diameter of the pipe (m)
e_1 = minimum wall thickness of the pipe (m).

7.4 Flexibility requirement

When tested in accordance with Appendix E, no fracture or collapse shall occur.

For the purposes of this clause, fracture or collapse includes all features listed in E.9.

7.5 Long term strength and heat resistance of pipes

The strength of the pipe construction shall be tested by the BLT method described in Appendix F.

When testing pipes at least one socket shall be included.

The requirements are as follows:

(a) Maximum vertical deformation measured shall not exceed 8%.

(b) When tested for leak tightness no leakage may occur.

(c) Depths of cracks shall not exceed 20% of the inner wall thickness.

(d) When tested for straightness in the axial direction the distance between the rule and the pipe wall shall not have increased by more than 3mm.

(e) The radius at the bottom of the pipe shall be not less than 80% of the original radius.

8. MARKING

Each length of pipe shall be indelibly and legibly marked with the following:

(a) The manufacturer's identification.

(b) The number of this specification, i.e. No. 4-31-05, (only to be applied to complying pipe by manufacturers covered by a third party certification scheme acceptable to WRc).

(c) The nominal size/outside diameter.

(d) Identification of the shift, production line and date of manufacture. (Coding of this information is permitted provided that the meaning of the code is available to purchasers or their representatives on request.)

9. TESTING REQUIREMENTS

The implementation of the tests described in this specification are the responsibility of the manufacturer. All tests referred to in this clause relate to the methods described in this specification. The tests shall all be conducted under the following categories.

Table 4 – Internal pressure test requirements

	Circumferential stress (MPa)	Minimum test time (h)	Test temperature °C
Pipe in final state	10	1000	60

9.1 Type Tests

Type tests are intended to prove the suitability and performance of a new composition, a new compounding or processing technique, a design or size of pipe, joint or fitting as appropriate. Such tests are required when a significant change is made in polymer composition or method of manufacture.

9.2 Control Tests

Quality control tests shall be carried out during manufacture to prove the consistency of a production run of pipe.

9.3 Test Summary

A summary of type tests and quality control tests is given in Table 5.

10. REFERENCES

This specification makes reference to or should be read in conjunction with the latest edition of the following documents, including all addenda and revisions.

BS 2045 Preferred numbers.

BS 2494 Specification for elastomeric joint rings for pipework and pipelines.

BS 2782 Methods of testing plastics.
Method 120B Determination of the Vicat softening temperature of thermoplastics.

BS 4660 Specification for unplasticised PVC underground drain pipe and fittings.

BS 4728 Determination of the resistance to constant internal pressure of thermoplastics pipes.

BS 4901 Specification for plastics colours for building purposes.

BS 5481 Specification for unplasticized PVC pipe and fittings for gravity sewers.

BS 5750 Quality systems
Part 2 (ISO 9002) Specification for manufacture and installation.

BS 5955 Code of practice for plastics pipework (thermoplastics materials) Part 6 Code of practice for the installation of unplasticized PVC pipework for gravity drains and sewers.

BS 8005 Sewerage
Part 0 Introduction and guide data sources and documentation
Part 1 Guide to new sewer construction.

BS 8301 Code of practice for building drainage.

ISO 1167 Thermoplastics pipes for the transport of fluids – Determination of resistance to internal pressures.

WATER AUTHORITIES ASSOCIATION. Sewers for adoption.

DEPARTMENT OF TRANSPORT. Specification for highway works.

WATER RESEARCH CENTRE. The structural design of underground non-pressure uPVC pipelines. WRc Report ER 201E.

APPENDIX A – METHOD FOR THE DETERMINATION OF IMPACT RESISTANCE (B50 METHOD)

A.1 SCOPE

This appendix defines the test apparatus and method for testing the impact strength of plastics pipes by means of a tup (falling weight).

The required impact strength value is given in the specification text.

A.2 PRINCIPLE

The B50 failure level is determined by a falling weight test with a given mass of the tup dropped from various heights.

A.3 SIGNIFICANCE AND USE

The impact strength of plastic pipe relates to suitability for service and to quality of processing.

Table 5 – Definition of tests

Type test	Clause	Quality control test	Clause
Dimensions	5	Dimensions	5
Appearance	4	Appearance	4
Impact resistance	6.1	Impact resistance	6.1
Stress rupture requirements	7.3	Vicat softening point	6.3
Diameter distortion	7.1.1		
Angular deflection	7.1.2		
Short term ring stiffness	6.2	Short term ring stiffness	6.2
Long term ring stiffness	7.2		
Long term strength and heat resistance	7.5		
Marking	8	Marking	8
Flexibility	7.4		

Impact tests are used for quality control purposes and as an indication that products can withstand handling during installation or in service.

A.4 APPARATUS

A falling weight testing machine incorporating the following basic components (Figure 3) shall be used.

A4.1 Main frame rigidly fixed in the vertical position.

A4.2 Guide rails or drop tube, fixed to the main frame to accommodate the falling weight and allowing it to fall freely in the vertical plane.

A4.3 The falling weights (tups) of various masses up to 12.5kg, shall have hemispherical striking surface with a nose radius of 50mm.

A4.4 Test piece support, consisting of a 120° Vee-block of length at least 200mm, positioned so that point of the tup is in the axis of the Vee-block.

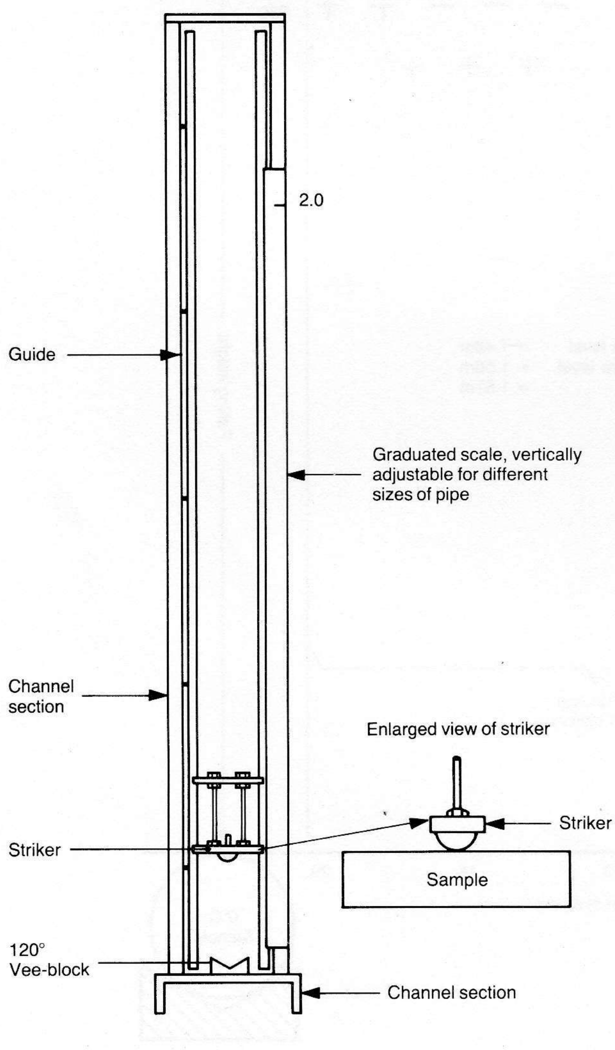

Figure 3 – Typical impact testing apparatus

A.5 TEST PIECES

The test pieces shall be cut from pipe selected at random from the series of pipe to be tested.

Length of the test pieces shall be not less than 200mm. The cut ends shall be square to the axis of the pipe, clean and free from damage.

A.6 CONDITIONING

Condition the test pieces in a liquid bath at a temperature of 0 ±1°C for at least 1 hour.

The test pieces shall be tested within 10 seconds of their removal from the conditioning bath. If this interval is exceeded, the test piece shall be returned to the bath for 5 minutes for reconditioning.

A.7 PROCEDURE

The mass of the falling weight appropriate to the pipe size shall be selected from Table 6. Impact each specimen only once.

Table 6 – Mass of the tup

Nominal outside diameter DE	Nominal size NS	Mass of the tup kg
200	180	9.00
250	225	12.50
335	300	12.50

A7.1 Preliminary test

The purpose of the preliminary test is to identify the optimum drop height to be used for the final test. (See Figure 4).

Select a height estimated to cause failure of some specimens. Start the test at an accepted height. If the specimen passes, test the next specimen at a height increased by 100mm. The test shall be continued until the first failure occurs. Record this dropping height and test result as the first test in the final test. If the first specimen fails, test the next specimen at a height decreased by 100mm, etc. Record the dropping height and the specimen that passes as the first test in the final test.

A7.2 Final test

A minimum of 20 specimens are required for the final test. Record the test results as dropping height as a function of number of the specimens that pass or fail.

Calculate the B50 failure level by the formula:

$$B50 = \frac{\bar{x}_f + \bar{x}_p}{2} \qquad (2)$$

Where $\bar{x}_f$ = average of the dropping heights when failure occurred

$\bar{x}_p$ = average of the dropping heights that specimens passed.

The test specimen is considered to have failed if any crack or split can be seen on the inner surface by the naked eye (or wearing spectacles if normally worn).

A.8 TEST REPORT

The test report shall include the following:

(a) A reference to this test method.
(b) Full identification of the pipe.
(c) Number of test pieces.
(d) The test temperature, in degrees Celsius.
(e) The mass of the tup.
(f) The total number of blows.
(g) B50 failure level.

NOTE: The wording of this Appendix is virtually identical to ISO/TC138/SCI/AHG LWP/N99 standard proposal.

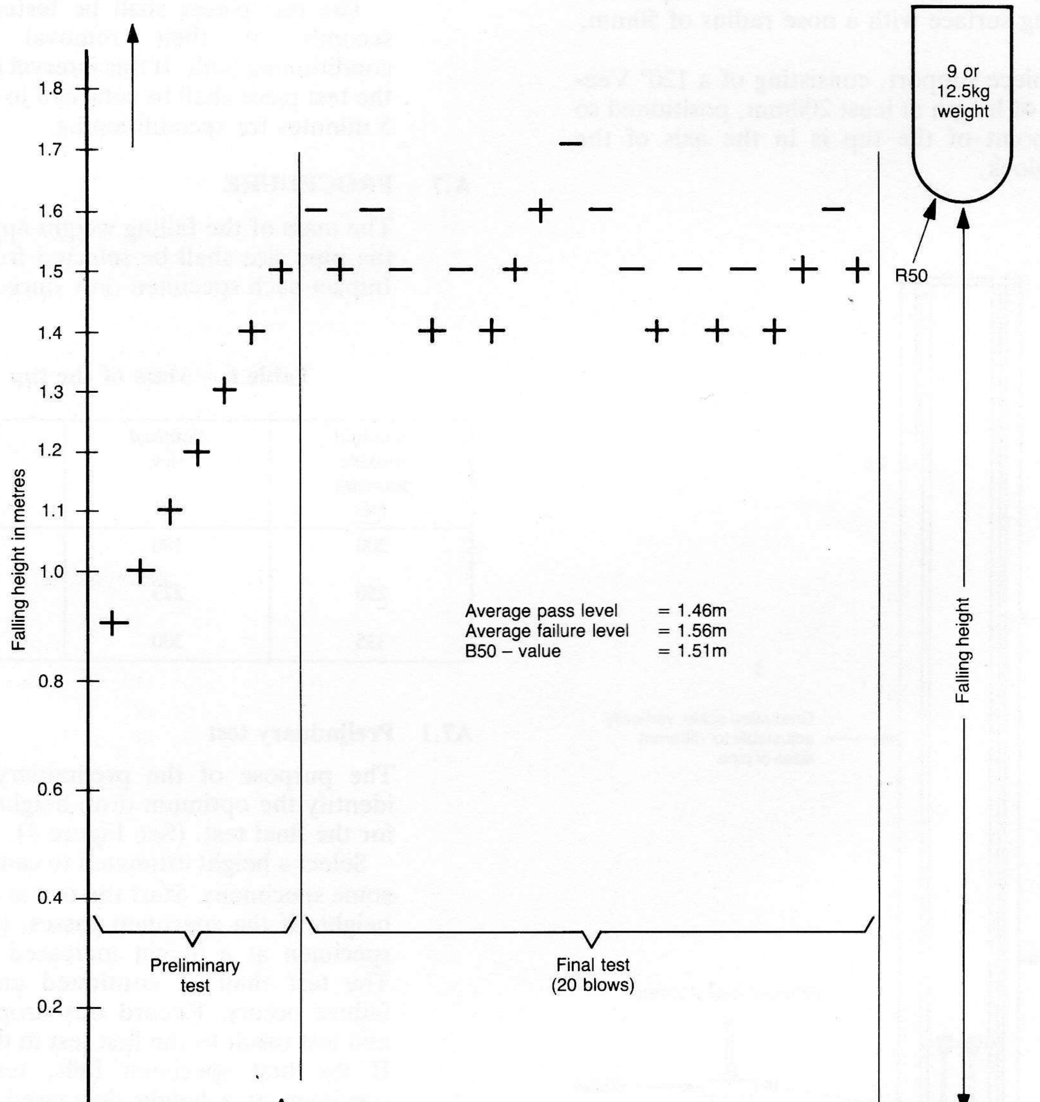

Figure 4 – Example of use of the impact resistance test, B50 method

APPENDIX B – METHOD FOR THE DETERMINATION OF SHORT TERM STIFFNESS (CONSTANT DEFLECTION RATE)

B.1 SCOPE AND FIELD OF APPLICATION

This appendix specifies a method of testing ring stiffness of plastic pipes of circular cross-section.

It uses the method of measuring the load and the deflection whilst deflecting the pipe at a constant deflection speed.

B.2 SYMBOLS

		Units
F	loading force	kN
l	length of the test specimen	m
S	short term ring stiffness	kN/m^2
d_i	inside diameter of pipe	m
γ	angle between the initial straight line portion and the horizontal axis in the load deflection plot	kN/m
δ	deflection	m
λ	deflection ratio $\left(\lambda = \frac{\delta}{d_i}\right)$	-

B.3 TEST PRINCIPLE

Test specimens are compressed between two parallel flat plates at a constant deflection speed.

A plot of load versus deflection is generated.

B.4 EQUIPMENT

B4.1 Testing machine

A properly calibrated compression testing machine of the constant rate of crosshead movement type shall be used to carry out the tests.

The rate of crosshead movement is defined in B7.5.

B4.2 Loading plates

The load shall be applied to the specimen through two parallel steel bearing plates. The plates shall be flat, smooth and clean.

The stiffness of the plates shall be sufficient to prevent bending or deformation during the tests.

The length of the plates shall at least be equal to the length of the test specimen. The width of the plates shall not be less than the width of the contact surface with the test specimen during the loading plus 25mm.

B4.3 Measurement of the deflection

The change in inside diameter in the direction of loading shall be measured with an accuracy of measurement better than 1% of the deflection.

Accuracy of measurement better than 0.1mm is not required.

B.5 TEST SPECIMENS

B5.1 Number of specimens

The pipe for which the short term ring stiffness is to be determined, shall be marked on its outside with a marking line over its full length.

Three test specimens ((a), (b) and (c)) shall be taken from this marked pipe.

B5.2 Length of specimens

The length of the specimens shall be (300 ± 10)mm.

The ends of the specimens shall be perpendicular to their axis.

Once cut to length, the length of each specimen shall be determined by taking the arithemic average of a number of equally spaced measurements around the perimeter as given in Table 7.

Table 7 – Number of length measurements

Inside diameter of pipe	Number of measurements
≤200mm	3
>200mm ≤500mm	4

B5.3 Inside diameter of specimens

The initial inside diameter of the three specimens shall be determined with a suitable instrument that has an accuracy of measurement better than 0.5%. The inside diameter is defined as the average of the maximum and minimum measured inside diameters.

B5.4 Age of specimens

The specimens shall be tested at least 24 hours after their manufacture. If a failure is recorded the pipe shall be bonded and a further test applied after the specimen has been conditioned as clause 6.

For type testing the age of the specimens shall be 21 ± 2 days.

B.6 CONDITIONING

The specimens shall be conditioned in air at 23 ± 2°C for at least 24 hours prior to type tests.

B.7 TEST PROCEDURE

B7.1 The test shall be carried out at (23 ±2)°C.

B7.2 If it can be determined in which position the test specimen has the lowest ring stiffness, the first specimen (a) shall be placed in this position and the two others ((b) and (c)) shall be rotated 60° and 120° respectively in relation to the first position.

Otherwise the first specimen is placed in such a way that the marking line is in contact with the upper parallel plate. The marking line of the second (b) specimen shall be turned 60° (marking line at two o'clock) and the marking line of the third specimen (c) shall be turned 120° (marking line) at four o'clock.

B7.3 Locate the specimen with its longitudinal axis parallel to the bearing plates and centre it laterally in the testing machine.

B7.4 Bring the upper plate into contact with the specimen with no more load than necessary to hold it in position.

B7.5 Compress the specimen at a constant speed as given in Table 8.

Table 8 – Compression test speed

Inside diameter of pipe	Deflection speed (mm/min)
>100mm ≤200mm	10 ± 20%
>200mm ≤400mm	20 ± 10%

B7.6 Record load deflection measurements continuously.

NOTE: The load versus deflection plot is typically a smooth curve. In some cases, for example when the curve is generated automatically, the zero point may be in error, see Figure 5.

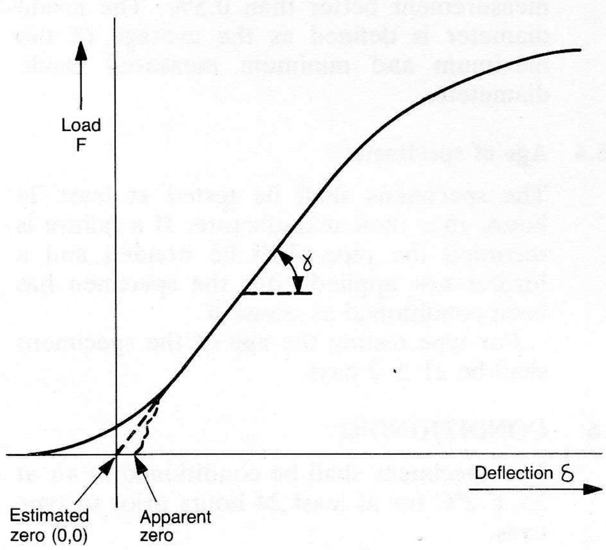

Figure 5 – Method of estimating the origin

In such cases, the initial straight line portion of the curve shall be extrapolated back and this intercept be used as the (0,0) point (origin).

B.8 DETERMINATION OF THE SHORT TERM RING STIFFNESS

The short term ring stiffness of the three specimens ((a), (b) and (c)) shall be calculated according to the formulae (3), (4) and (5):

$$S_a = 0.0186 \frac{F_a}{L_a.\delta_a} \quad (3)$$

$$S_b = 0.0186 \frac{F_b}{L_b.\delta_b} \quad (4)$$

$$S_c = 0.0186 \frac{F_c}{L_c.\delta_c} \quad (5)$$

Where F = the load that corresponds to a 5% pipe deflection ratio
L = the length of the test specimen
δ = the deflection that corresponds to a 5% deflection ratio
($\lambda = \delta/d_i = 0.05$)

The short term ring stiffness of the pipe is the arithmetical average of the three calculated values (Formula 6).

$$S = \frac{S_a + S_b + S_c}{3} \quad (6)$$

B.9 TEST REPORT

The report on this test shall include:

(a) complete identification of the plastic pipe (manufacturer, type of pipe, dimensions, production date, length of specimens L_a, L_b and L_c).

(b) testing temperature.

(c) date of test.

(d) if required, the load deflection plot of each specimen.

(e) if required, the angle γ from each deflection plot (see Figure 5).

(f) the values of the short term ring stiffness determined for the individual specimens (S_a, S_b and S_c).

(g) the value of S.

NOTE: The wording of this appendix is virtually identical to ISO/DP 9969, which in turn is based on ASTM D 2412 (1977) with some alterations e.g. definition of pipe stiffness, exclusion of 10% pipe stiffness, exclusion of different failures during the deflection, length of specimens and deflection speed.

APPENDIX C – METHOD FOR THE DETERMINATION OF JOINT LEAK TIGHTNESS WHILST UNDER ANGULAR AND/OR DIAMETRIC DISTORTION

C.1 APPARATUS

The apparatus shall be capable of simultaneous application of differential distortion, angular deflection and partial vacuum or constant water pressure. The ends of the pipes under test shall be sealed and the apparatus shall resist end thrust without otherwise supporting the pipes against the internal test pressure.

The apparatus is shown schematically in Figure 6, with the pipes installed including a socket containing an elastomeric sealing ring.

Both pipes shall be aligned and horizontal. The width of the socket loading plate is given in Table 9; other dimensions are shown in Figure 6.

Table 9 – Width of loading plate

Pipe nominal outside diameter	B (mm)
110 – 280	40
≥300	60

C.2 PROCEDURE

(a) Apply vertical loads through plates P_1 and P_2 to cause a deformation of 10% of the socket outside diameter and 15% of the pipe outside diameter respectively. The distorting loads shall remain in place throughout the test.

(b) Evacuate the pipes to a pressure of −45kPa (55kPa absolute). After 15 minutes the pressure shall not have risen to −35kPa (65kPa absolute).

(c) Release the vacuum and deflect the two pipes vertically through 2° relative to each other.

(d) Repeat step (b).

(e) Release the vacuum, realign the pipes and fill them with water.

(f) Increase the internal pressure to 5kPa and maintain it for 15 minutes.

(g) Lower the pressure to atmospheric and vertically deflect the pipes 2° relative to each other.

(h) Repeat step (f).

(i) Increase the pressure to 50kPa and maintain it for 15 minutes.

During the tests no leakage of water may occur.

C.3 REPORT

The test report shall include:

(a) Complete identification of the plastic pipe (manufacturer, type of pipe, dimensions, production data, length of specimens).

(b) Measured amount of pipe and socket deformation.

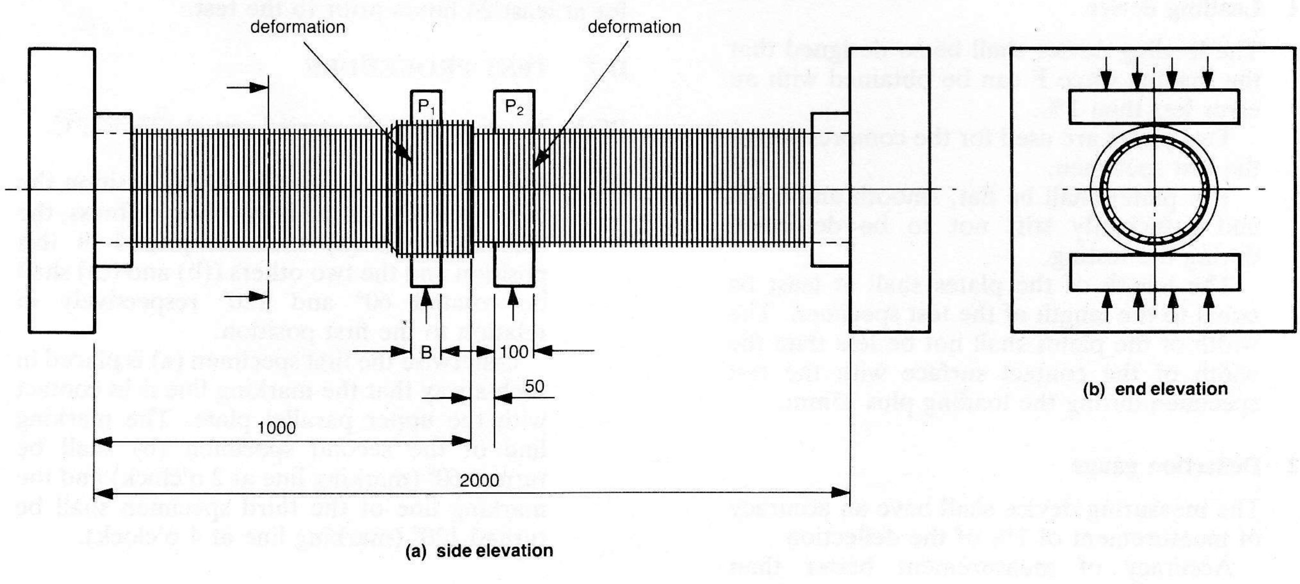

Figure 6 – Installation of pipes and fittings for leak tightness test

(c) Record of pressures at all stages.

(d) Record of pressures and leakage observation.

(e) Date of the test.

APPENDIX D – METHOD FOR THE DETERMINATION OF LONG TERM RING STIFFNESS

D.1 SCOPE AND FIELD OF APPLICATION

This appendix specifies a method of testing (2 year and 50 year) ring stiffness of plastic pipes.

D.2 DEFINITIONS

		Units
F	loading force	kN
F_o	pre-load	N
L	length of test specimen	m
Y_o	start deflection	m
Y_t	deflection at time t	m
Y_2	extrapolated 2 years deflection	m
Y_{50}	extrapolated 50 years deflection	m
STES	long term ring stiffness (the specific tangential end stiffness) ($STES_2$ = preliminary 2y stiffness) ($STES_{50}$ = projected 50y stiffness)	kN/m^2

D.3 TEST PRINCIPLE

Test specimens are placed between two flat parallel horizontal plates and a constant compression force is applied for at least 10,000 hours.

The deflection of the pipe is recorded so as to prepare a plot of pipe deflection against time.

D.4 EQUIPMENT

D4.1 Loading device

The loading device shall be so designed that the loading force F can be obtained with an error less than 1%.

Two plates are used for the compression of the test specimen.

The plates shall be flat, smooth and clean and sufficiently stiff not to be deformed during the testing.

The length of the plates shall at least be equal to the length of the test specimen. The width of the plates shall not be less than the width of the contact surface with the test specimen during the loading plus 25mm.

D4.2 Deflection gauge

The measuring device shall have an accuracy of measurement of 1% of the deflection.

Accuracy of measurement better than 0.1mm is not required.

D.5 TEST SPECIMENS

D5.1 Number of specimens

The pipe of which the long term ring stiffness is to be determined, shall be marked on its outside with a marking line over its full length.

Three test specimens ((a), (b) and (c)) are to be taken from this marked pipe.

D5.2 Length of specimens

The length of the specimens shall be 300 ±10mm.

Once cut to length, the length of each specimen shall be determined by taking the arithmetic average of 3 or 4 equally spaced measurements around the perimeter (see Table 10).

Table 10 – Length measurement

Inside diameter of pipe	Number of length measurements
≤200mm	3
>200 and ≤500mm	4

D5.3 Inside diameter of specimens

The inside diameter of the three specimens shall be determined with a suitable instrument that has an accuracy of measurement better than 0.5% (before submitting them to the pre-load F_o). The inside diameter is defined as the average of the maximum and minimum measured inside diameters.

D5.4 Age of specimens

For approval testing the age of the specimens shall be 21 ±2 days.

D.6 CONDITIONING

The specimens shall be conditioned in air at 23 ±2°C for at least 24 hours prior to the test.

D.7 TEST PROCEDURE

D7.1 The test shall be carried out at (23 ±2)°C.

D7.2 If it can be determined in which position the test specimen has the lowest ring stiffness, the first specimen (a) shall be placed in this position and the two others ((b) and (c)) shall be rotated 60° and 120° respectively in relation to the first position.

Otherwise the first specimen (a) is placed in such a way that the marking line is in contact with the upper parallel plate. The marking line of the second specimen (b) shall be turned 60° (marking line at 2 o'clock) and the marking line of the third specimen shall be turned 120° (marking line at 4 o'clock).

D7.3 Attach the deflection gauge after placing the test specimen in the loading device. Then the position of the test specimen shall be checked.

The loading plate is to be lowered until it touches the upper part of the test specimen.

Apply the pre-load (F_o) calculated from Formula (7) rounded to the nearest newton.

$$F_o = 75.d_i \text{ N} \quad (7)$$

Where d is in metres.

Then the deflection gauge is adjusted to zero and the test specimen is loaded with the loading force F in a period of 20 to 30 seconds.

The stopwatch that is used during the first hours of the test is started at the moment that the full load has been applied.

The loading force shall previously have been chosen such that a deflection ratio of (2 ±0.3)% is reached after 360 seconds (6 minutes).

D7.4 1,000 hours (nominal) assessment

Determine the start deflection (Y_o), 6 minutes after the application of the full load. Then determine the deflection after approximately 1, 4, 24, 168, 336, 504, 600, 696, 840 and 1,008 hours.

In this way a series of 11 deflection values is obtained for each specimen.

When the stiffness test is started on a Monday or Thursday, interference with weekends does not occur.

D7.5 10,000 hours assessment

Continue the test, obtaining at least four further deflection measurements at approximately 2000, 4000, 8000 and 10,000+ hours.

D.8 DETERMINATION OF THE STES

(a) 2 year projection

For each of the 3 test specimens plot the deflection against the logarithm of time in hours in a single logarithmic coordinate system (see Figure 7) and determine by linear regression the equation of the straight line:

$$Y_t = B + M \log t \quad (8)$$

through all 11 points, through the last 10 points, through the last 9 points ..... and through the last 4 points (see Table 11). The constants B and M and the coefficient of correlation R are determined from the following equations (using the methods of least squares):

$$M = \frac{N(\text{sum}(x_i y_i)) - (\text{sum}(y_i))(\text{sum}(x_i))}{N(\text{sum}(x_i^2)) - (\text{sum}(x_i))^2} \quad (9)$$

$$B = \frac{\text{sum}(y_i) - M(\text{sum}(x_i))}{N} \quad (10)$$

$$R = \left(\frac{M(N\,\text{sum}(x_i y_i) - (\text{sum}(x_i)\,\text{sum}(y_i))}{N\,\text{sum}(y_i^2) - (\text{sum}(y_i))^2}\right) \quad (11)$$

Where N = the number of points on the deflection curve used for the linear regression

t_i = the time for point i

x_i = $\log_{10}(t_i) = 0.4343 \log_e(t_i)$

y_i = total deflection in point i

R = coefficient of correlation (if R has a value between 0.99 and 1.00 the statement that different points are laying on a straight line is reliable).

For the different equations of $Y_t = B + M \log t$ calculate the extrapolated 2 years deflection Y_2 (t = 2 years = 17,250 hours), see Table 11.

The value that shall be chosen as "the" extrapolated 2 years deflection Y_2, for calculation of the STES of the specimen, is the highest calculated Y_2 that is accompanied with a coefficient of correlation R of 0.999 or the highest value between 0.990 and 0.999. Once having determined Y_2 the specific tangential end stiffness (STES) after 2 years of each of the 3 specimens is calculated with the following formulae:

$$STES_a = 0.0186 \times \frac{F_a}{L_a \times Y_{2a}} \text{ (kN/m}^2\text{)} \quad (12)$$

$$STES_b = 0.0186 \times \frac{F_b}{L_b \times Y_{2b}} \text{ (kN/m}^2\text{)} \quad (13)$$

$$STES_c = 0.0186 \times \frac{F_c}{L_c \times Y_{2c}} \text{ (kN/m}^2\text{)} \quad (14)$$

The STES of the pipe is then the arithmetical average of the three calculated values:

$$STES_2 = \frac{STES_a + STES_b + STES_c}{3} \quad (15)$$

Remark

Not less than 4 points shall be used to obtain the straight lines $Y_t = B + M \log t$.

Normally a correlation coefficient of over 0.99 is reached when the last 4 (5, 6 or even more) points are included in the regression analysis.

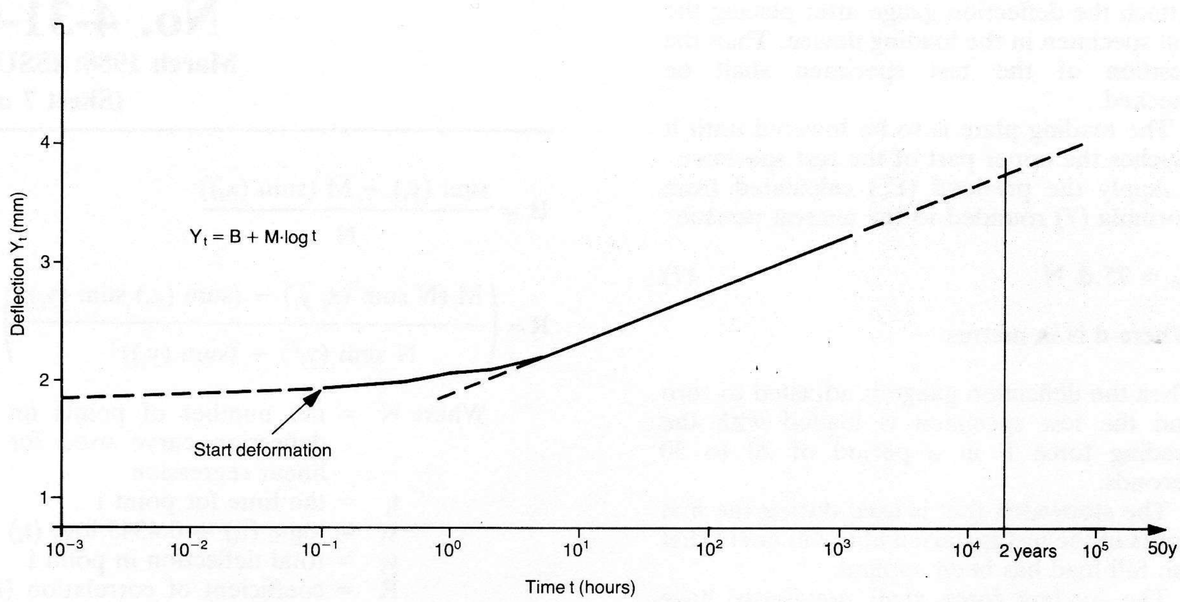

Figure 7 – Mean deflection/time plot

Table 11 – Data corresponding to Figure 7

Point No.	t (hours)	Y_t (mm)	Point* No.	M	B	R	Extrapolated 2 years deflection (mm)
1	0.001	1.85	1 – 17	0.242	2.254	0.936	3.3
2	0.01	1.90	2 – 17	0.272	2.213	0.953	3.4
3	0.02	1.91	3 – 17	0.272	2.180	0.961	3.4
4	0.05	1.93	4 – 17	0.316	2.137	0.970	3.5
5	0.1	1.95	5 – 17	0.343	2.088	0.978	3.5
6	0.5	2.02	6 – 17	0.378	2.021	0.990	3.6
7	1	2.08	7 – 17	0.397	1.979	0.993	3.7
8	2	2.11	8 – 17	0.419	1.930	0.997	3.7
9	4	2.19	9 – 17	0.434	1.895	0.998	3.7
10	8	2.29	10 – 17	0.448	1.863	0.999	3.8
11	25	2.48	11 – 17	0.462	1.827	0.999	3.8
12	51	2.61	12 – 17	0.467	1.814	0.999	3.8
13	115	2.78	13 – 17	0.463	1.824	0.999	3.8
14	187	2.88	14 – 17	0.463	1.826	0.999	3.8
15	400	3.03	15 – 17	0.473	1.795	0.999	3.8
16	700	3.14					
17	1003	3.22	* Points used for the linear regression.				

NOTES: (1) This temporary example uses data with 17 points instead of 11.

(2) The wording of this appendix is virtually identical to ISO/DP 9967, except that provisions for obtaining the $STES_{50}$ have been added.

In case that the use of even the last 4 points does not lead to a correlation coefficient higher than 0.990 in the regression analysis for any of the 3 specimens, the test on all 3 specimens shall be continued for another 8 days and a new deflection value after 1,200 hours (after the start of the test) shall be included in the calculations.

(b) 50 year projection

Use the same principles as (a) covering the data for the full 10,000 hours test period.

Determine Y_{50}, the highest calculated value of extrapolated calculated R of between 0.990 and 1.00.

The specific tangential end stiffness ($STES_{50}$) after 50 years is calculated using the following formula:

$$STES_{50} = 0.01863 \times \frac{F}{L \times Y_{50}} \quad (16)$$

D.9 TEST REPORT

The test report shall include:

(a) Complete identification of the plastic pipe (manufacturer, type of pipe, dimensions, production date, length of specimens L_a, L_b and L_c).

(b) The applied loading force.

(c) The testing temperature.

(d) The dates between which tests carried out.

(e) The mean deflection/time plot (linear deflection versus log time for each of the 3 specimens).

(f) The equation $Y_t = B + M \log t$ used for extrapolation of the 2 years deflection for each of the 3 specimens.

(g) The coefficient of correlation (2y) in each case.

(h) The points that have been used for the linear regression (2y).

(i) The values of F_a, F_b and F_c used.

(j) The calculated Y_{2a}, Y_{2b} and Y_{2c}.

(k) The calculated $STES_2$.

(l) The equation $Y_t = B + M \log t$ used for extrapolation of the 50 years deflection.

(m) The coefficient of correlation (50y) for each of the 3 specimens.

(n) The points that have been used for the linear regression (50y) in each case.

(o) The calculated Y_{50a}, Y_{50b} and Y_{50c}.

(p) The calculated $STES_{50}$.

APPENDIX E – METHOD FOR THE ASSESSMENT OF FLEXIBILITY OF A PIPE RING

E.1 INTRODUCTION

The knowledge on the behaviour of plastic pipes installed underground is mainly based on experience and on extensive investigations carried out with pipes that have smooth inside and outside surfaces (solid wall pipes) that are made of a limited number of plastic materials. When a new material or a new light weight design is introduced to be used in buried applications, a test method to study the behaviour of the pipe at large deflections is needed.

E.2 SCOPE AND FIELD OF APPLICATION

This appendix specifies a method of testing the behaviour of plastic pipes with circular cross section when subjected to a deflection of 30% of the original outside diameter.

It uses the method of measuring the load and the deflection while deflecting the pipe at a constant deflection speed.

E.3 SYMBOLS

		Units
F	loading force	kN
L	length of the test specimen	m
d_e	outside diameter of the pipe	m
δ	deflection	m
λ	deflection ratio $\left(\lambda = \frac{\delta}{d_e}\right)$	–

E.4 TEST PRINCIPLE

Test specimens are compressed between two parallel flat plates at a constant deflection speed. A plot of load versus deflection is generated. Eventual defects are observed.

E.5 EQUIPMENT

E5.1 Testing machine

A properly calibrated compression testing machine of the constant rate of crosshead movement type, shall be used to carry out the tests.

The rate of crosshead movement shall be (10 ±0.5)mm/min.

E5.2 Loading plates

The load shall be applied to the specimen through two parallel steel bearing plates. The plates shall be flat, smooth and clean.

The stiffness of the plates shall be sufficient such that no bending or deformation occurs during the tests.

The length of the plates shall at least be equal to the length of the test specimen. The width of the plates shall not be less than the width of the contact surface with the test specimen during the loading plus 25mm.

E5.3 Measurement of the deflection

The change in outside diameter in the direction of loading shall be measured with an accuracy of measurement better than 1% of the deflection.

Accuracy of measurement better than 0.1mm is not required.

E.6 TEST SPECIMENS

E6.1 Number of specimens

The pipe of which the deflection behaviour will be investigated will be marked on its outside with a marking line over its full length.

The test specimens are to be taken from this marked pipe.

E6.2 Length of specimens

The length of the specimens shall be (300 ±10)mm.

If the pipe design is such that a length of 300mm would not be representative because of lack of symmetry (e.g. corrugated pipes) the length of the specimen may be slightly different from 300mm.

The ends of the specimens shall be perpendicular to their axis.

E6.3 Outside diameter of specimens

The outside diameter of the three specimens shall be determined with diameter measuring tape or a suitable instrument that has an accuracy if measurement better than 0.5%.

E6.4 Age of specimens

The specimens shall be tested at least 24 hours after their manufacture.

For approval testing the age of the specimens shall be 21 ±2 days.

E.7 CONDITIONING

The specimens shall be conditioned in air of (23 ±2°C) for at least 24 hours prior to the test.

E.8 TEST PROCEDURE

E8.1 The test shall be carried out at (23 ±2)°C.

E8.2 If it can be determined in which position the test specimen has the lowest ring stiffness, the first specimen shall be in this position and the two others shall be rotated through 60° and 120° respectively in relation to the first position.

Otherwise the first specimen is placed in such a way that the marking line is in contact with the upper parallel plate. The marking line of the second specimen shall be turned through 60° (marking line at 2 o'clock) and the marking line of the third specimen shall be turned through 120° (marking line at 4 o'clock).

E8.3 Locate the specimen with its longitudinal axis parallel to the bearing plates and centre it laterally in the testing machine.

E8.4 Bring the upper plate in contact with the specimen with no more load than to hold it in position.

E8.5 Compress the specimen at a constant speed of (10 ±0.5)mm/min.

E8.6 Record load deflection measurements continously.

NOTE: The load versus deflection plot is typically a smooth curve. In some cases, for example when the curve is generated automatically, the zero point may be in error, see Figure 8.

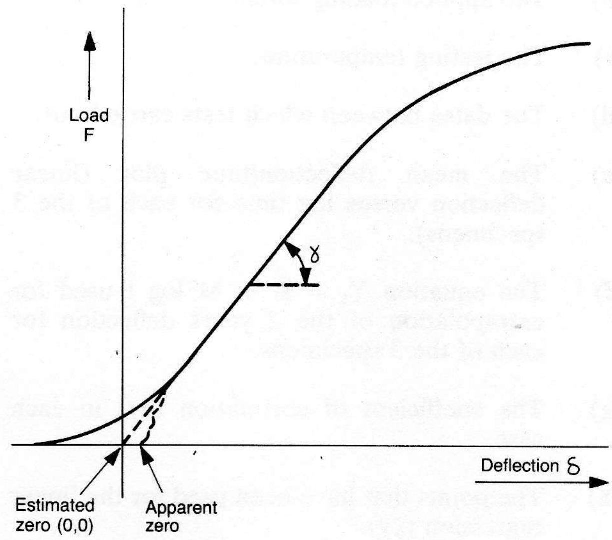

Figure 8 – Method of estimating the origin

In such cases, the initial straight line portion of the curve shall be extrapolated back and this intercept be used as the (0,0) point (origin).

Continue the test until a deflection ratio $\lambda = 0.3$ has been reached.

E.9 OBSERVATIONS

Observe and note the load and the deflection at the first evidence of each of the following significant events when they occur (if they occur):

- cracking or crazing of the inside wall or liner
- wall cracking
- wall delamination
- rupture
- buckling
- change in direction of curvature of the cross section of the specimen.

Record the type and the position of each event with respect to the corresponding load and deflection.

E.10 TEST REPORT

The report on this test shall include:

(a) Complete identification of the plastic pipe (manufacturer, type of pipe, dimensions, production date, length of specimens and weight per metre of the pipe).

(b) Testing temperature.

(c) Date of test.

(d) The load deflection plot of each specimen.

(e) The load and deflection at which any of the following events occurred:

- cracking or crazing of the inside wall or liner
- wall cracking
- wall delamination
- rupture
- buckling
- change in direction of curvature of the cross-section of the specimen

(f) Deflection and load at the maximum point (if a maximum occurred).

NOTE: This test may be carried out directly following the determination of the short term ring stiffness as described in Appendix C when that speed is constant.

APPENDIX F – METHOD OF TEST FOR THE RESISTANCE TO COMBINED TEMPERATURE AND EXTERNAL LOADING USING A BOX LOADING TEST (BLT)

F.1 SCOPE

This appendix specifies the testing apparatus and procedure for determining the functional properties of plastic pipes and sockets.

F.2 APPARATUS

F2.1 Aggregate-filled box, to accommodate a test assembly of pipe and fittings placed horizontally in the box so that a constant discharge of hot water can be passed through the assembly while it is subjected to a constant force acting through the aggregate.

The box shall have the dimensions shown in Table 12 (see also Figure 9) and shall be constructed and reinforced so that deflection of the box shall at no point exceed 3mm. If a wide box is used, it shall be lined to provide the appropriate width.

The pipeline shall run into and out of the box through apertures suitably sealed so as to impose no restraint on the assembly. The force shall be applied by means of suitable hydraulic equipment and transferred through a 450 × 300mm rigid plate with the 450 dimension being parallel to the assembly so that the applicable force is maintained to within ±1kN.

The aggregate shall have the following characteristics:

(a) It shall be 10mm single sized aggregate to BS 882: 1983.

(b) Its loose density shall not be less than 90% of its rodded density when measured in accordance with BS 812: Part 2: 1975.

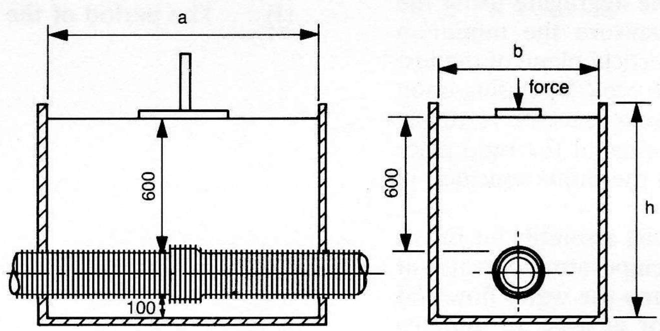

Figure 9 – Diagram of box loading test

Table 12 – Box dimensions and test conditions

Nominal pipe outside diameter DE	Inside box width a mm	Length of box b min mm	Inside height of h mm	Force F kN	Outlet water temperature T_1 °C
200	800	1500	900	50 ±2	50 ±2
250	900	1500	950	50 ±2	50 ±2
335	1000	1500	1035	55 ±2	50 ±2

(c) The particles shall be rounded or irregular in accordance with Figure 2 of BS 882: 1967 and their surface texture shall be glassy or smooth in accordance with Table 3 of BS 812: Part 3: 1975.

F2.2 Equipment suitable for determining and continuously recording the temperature of the water to an accuracy of at least 1°C.

F2.3 Tamping tool, with a flat foot 300mm square.

F2.4 Bore micrometer or equivalent, for measuring the internal vertical diameter in accordance with BS 2782: Method 1101A, in the test assembly.

F2.5 A rule of length $1.5d_e$.

F2.6 A gauge formed from a sector of a cylinder 10mm thick and of radius 0.8 × the original inside radius of the pipe.

F.2 PROCEDURE

Check that the test piece complies with the dimensional requirements of this specification. Lay and level a thoroughly compacted bed of aggregate, at least 100mm thick, in the box and place the test assembly on the aggregate. Attach the means of measurement of temperature to the inside of the pipe outlet at the crown and extending into the bore. Gently pour a volume of gravel equivalent to $0.3m^3$ per metre length of box evenly into the box from a height of 750mm via a funnel with a pouring opening diameter of approximately 50mm, and level it without agitation or tamping. Add further aggregate to achieve a total depth of 0.6m over the crown of the assembly. Lightly tamp the aggregate using the tamping tool. Locate and measure the minimum internal diameter, d_{i1}, in the vertical plane of the test piece. Apply the appropriate force (depending upon the size of the pipes) to the gravel surface vertically above the test assembly by means of the rigid plate and maintain the force within the limits specified in Table 12 throughout the test.

Pass hot water through the test assembly (as full as possible) for 192 hours. The temperature of water at the outlet shall be 50 ±2°C. Stop the water flow and allow the assembly to cool for at least 15 minutes before measuring the deflection.

Prior to removing the force on the plate, locate and measure the minimum internal diameter, d_{i2}, in the vertical plane of the test piece.

(If it is required to monitor the progress of deformation, measurements may be made 1, 3 and 24 hours after commencement of water flow and at 24 hourly intervals thereafter).

Plug the ends of the test assembly, fill with cold water and raise the water pressure steadily to between 0.35 and 0.5 bar over a period of not less than one minute and leave for 15 minutes.

Release the pressure, remove the force, empty the box, examine the joint areas for leakage, dismantle the test assembly and examine the fittings for weld line cracking.

Measure the straightness of the bottom of the test pieces on the outside by placing a straight ruler (F2.5) across the ribs parallel to the longitudinal axis and measuring the greatest gap.

Compare local deformation of the radius on the bottom of the inside with the gauge (F2.6) in the transverse direction.

F.3 CALCULATION OF RESULTS

Calculate the percentage deformation, Δ, of the internal diameter of the test piece using equation 17:

$$\Delta = 100\,(d_{i1} - d_{i2})/d_{i1} \qquad (17)$$

F.4 TEST REPORT

The report shall include the following:

(a) Identification of the components under test.

(b) Aggregate type.

(c) Force applied.

(d) Water temperature range.

(e) Any observations of signs of leakage at any of the joints.

(f) Any observations of weld line cracking including depth.

(g) The percentage deformation of the vertical internal diameter of the test piece.

(h) Deviation from straightness.

(i) Radius deviation.

(j) The period of the test.