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## SPECIFICATION FOR RENOVATION OF GRAVITY SEWERS BY LINING WITH CURED-IN-PLACE PIPES

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### FOREWORD

This document specifies the requirements for Cured In Place Pipes (CIPP) for the renovation of gravity sewers. Guidance is also provided for the purchaser of the renovation system on installation (Appendix D).

This specification has been prepared by WRc plc under the direction of the UK Water Industry Engineering and Operations Committee to assist engineers responsible for the renovation of sewers.

Designers are referred to the Sewerage Rehabilitation Manual for the determination of sizes, wall thickness requirements and design methods.

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

This 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 supplier shall operate a quality system relating to the manufacture of Cured-in-Place Pipes to this specification in compliance with BS EN ISO 9002, which should ensure that products claimed to comply with this specification meet the required level of quality. Enquiries regarding the availability of third party certification should be addressed to a NACCB or equivalent accredited third party certification body.

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 the technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

Information contained in this specification is given in good faith. Neither the UK Water Industry Research Ltd., The Water Services Association nor WRc plc can accept any responsibility for actions taken by others as a result.

Throughout this specification SI units are used, thus stress and modulus values are quoted in MPa (megapascals)\*.

$$*1\text{MPa} - 1\text{MN/m}^2 = 1\text{N/mm}^2$$

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## 1. SCOPE

This specification details the requirements of Cured In Place pipes designed for the renovation of gravity sewers.

The specification applies to Type II Sewer Lining Designs as defined in the Sewerage Rehabilitation Manual (third edition) for the renovation of sewers subject to a maximum surcharge pressure of 0.5 bar.

Additional requirements outside the scope of this specification may apply in sewers subject to surcharge pressures exceeding 0.5 bar.

## 2. DEFINITIONS

For the purposes of this specification, the following definitions apply:

**2.1 "Lining with Cured-in-Place Pipe (CIPP)"** - Sewer renovation technique consisting of the insertion of a flexible tube of carrier material impregnated with thermosetting resin which produces a structural pipe when cured.

**2.2 Carrier material** - Fibrous matrix which is filled by the resin system.

**2.3 Resin system** - A thermosetting resin including the curing agent(s) and any fillers or extenders.

**2.4 Liner** - a flexible tube or folded sheet, consisting of a combination of carrier material, liquid resin system, and any other coatings and/or reinforcements.

**2.5 Type II design** - A lining system designed to act as a flexible pipe with the host sewer and soil providing the necessary support to maintain stability. No bond is required between the CIPP and the host sewer.

**2.6 Supplier** - The company responsible for providing the CIPP.

**2.7 Curing** - The process of resin polymerisation, which may be initiated or accelerated by the use of heat or light.

**2.8 Diameter** - The internal diameter in the case of circular pipes or the diameter of a circular pipe of equal perimeter in the case of non circular pipes.

**2.9 Design thickness** - The required wall thickness of the CIPP as determined by structural design, and limited by the requirements of hydraulic design.

**2.10 Nominal thickness** - One of a range of discrete liner wall thicknesses dictated by the materials used for construction. It is chosen so that the finished wall thickness of the CIPP within the sewer is not less than the design thickness.

**2.11 Declared Value** - Design value of a CIPP property which is declared in advance by the supplier and substantiated by type testing.

**2.12 NACCB** - National Accreditation Council for Certification Bodies.

## 3. QUALITY ASSURANCE

Suppliers shall operate a quality system relating to this specification in compliance with BS EN ISO 9002.

## 4. MATERIALS

### 4.1 Resin system

#### 4.1.1 General

The resin system shall have a viscosity, thixotropy and pot life which comply with the requirements of the supplier's stated method of installation and transport. These properties shall be maintained over the whole temperature range during storage, transport and curing to ensure compliance with the stated CIPP dimensions, mechanical properties and chemical resistance required by clauses 6.3 and 7.

NOTE: The supplier should take into account changes in resin properties during storage when designing the manufacturing process.

**4.1.2 Resins**

- (a) Unsaturated polyester resin systems shall conform to the requirements of BS 3532: 1990.
- (b) Epoxy resins shall conform to the requirements of ASTM D1763-88.
- (c) Uncatalysed liquid polyester resins shall have an acid value of 24 or below, when tested in accordance with BS 2782: Part 4: Method 432B and a hydroxyl value of less than 30 when tested in accordance with BS2782: Part 4: Method 432C.
- (d) Alternative resin systems for which type test data are available to prove performance may be used subject to the agreement of the purchaser.

**4.1.3 Storage**

Resin stored in original, unopened containers shall not be used after the resin manufacturer's stated keeping period.

For resins delivered by tanker, the supplier shall obtain the remaining useful life of the resin from the resin manufacturer.

The supplier shall regularly inspect the tanks used for bulk storage for contamination. Records of the inspections shall be made and cleansing carried out where necessary.

**4.1.4 Cured resins**

Cured resins, as cast singly without reinforcement, shall conform to the following requirements.

- (a) The elongation at break shall be greater than 2.5% when tested in accordance with BS 2782: Part 3: Method 320C at a grip separation rate of 5mm/min. and using an optical or strain gauge extensometer.
- (b) The heat distortion temperature shall be not less than 20°C above the expected maximum continuous service temperature of the CIPP, when determined in accordance with BS 2782: Part 1: Method 121A.

NOTE: In domestic sewers, maximum continuous service temperatures are assumed to be 45°C and 35°C in diameters up to 200mm and greater than 200mm respectively.

**4.2 Carrier Material**

The carrier material shall consist of sheets or tubes of fibrous materials manufactured from synthetic or mineral fibre. The fibre, its finishes and any reinforcement material shall be compatible with the resin system. In combination with the resin system, the carrier material shall impart the mechanical properties and chemical resistance to the CIPP required by Clause 7.

**4.3 Internal Coating**

Any coating on the inside surface of the finished CIPP shall be bonded throughout to the CIPP surface. It shall also have no adverse effect on the resin system.

**5. LINER FABRICATION**

**5.1 Fabrication**

The resin system and the carrier material shall be combined to produce a resin impregnated liner.

NOTE: The fibres and the liquid resins should be evenly dispersed throughout the liner and be free from entrained air.

The volume of the resin used to impregnate the liner shall not be less than the volume of the pore space in the carrier material when compressed to its nominal thickness.

**5.2 Dimensions**

**5.2.1** The thickness of the liner shall be designed by the supplier to provide the required installed thickness, taking into account installation methods.

**5.2.2** Where the liner thickness is built up using more than one layer of carrier material, the joints in the carrier material shall be offset to prevent excessive local thickening of the completed CIPP.

**5.2.3** The manufactured length and thickness of the liner shall include allowances for the effects of any

longitudinal and circumferential stretch during installation.

NOTE: Reinforcement tapes or strips of compatible material may be incorporated in the liner to control longitudinal stretching during installation.

## 6. CIPP PRODUCTION

### 6.1 Transport and handling

The supplier shall specify the conditions under which the liner shall be transported to the site of installation. The conditions shall be chosen to prevent impairment of the performance of the CIPP.

### 6.2 Installation

The supplier shall specify the method of installation including:

- preparation of host pipe;
- equipment;
- method of curing;
- records required and recording intervals.

The supplier shall take into account:

- (a) the pressure in the liner necessary to prevent deformation of the liner due to groundwater head or pressure of sewage in laterals;
- (b) the necessary measures to ensure that infiltration, inflows and standing water do not affect the liner during installation;
- (c) any conditions imposed on the installation by the purchaser e.g. temperature for release of processing water.

Linings shall preferably be inserted and/or inflated from upstream to downstream in the prepared sewer.

### 6.3 Dimensions

#### 6.3.1 Perimeter

Unless otherwise authorised by the purchaser of the installed lining system, the CIPP shall be a close fit against the existing sewer wall.

#### 6.3.2 Length

Unless otherwise authorised, by the purchaser, the liner shall be installed in continuous lengths between points of access to the sewer.

#### 6.3.3 Wall Thickness

Except for local reductions associated with isolated discontinuities in the surface of the existing pipe or local thickening where layers of carrier material overlap, the wall thickness at all points shall be not less than the specified design thickness and may be up to 15% greater.

The maximum allowable wall thickness compatible with the hydraulic design shall be included in the information provided by the purchaser.

## 7. TYPE TEST REQUIREMENTS

### 7.1 General

Type testing shall be performed in accordance with 7.4 to 7.6 to substantiate supplier's declared values and to demonstrate conformity with minimum required values as summarised in Table 1.

### 7.2 Sample Preparation

The test samples shall be obtained from either an actual or simulated CIPP installed in accordance with the method specified by 6.2.

### 7.3 Interpretation of Test Results

Except where specified otherwise, each of the tests described in 7.4 to 7.6 shall be carried out on not less than five test pieces from each of two separately prepared CIPP.

Each test piece shall be tested with the inside surface of the CIPP in contact with the load bearing supports.

The measured properties of each individual test piece shall be reported, together with the mean and standard deviation for each property.

The maximum design value of any property that shall be declared for a given CIPP material shall be the lower 90% confidence value,  $y_L$  determined from the type test data as:

$$\bar{y}_L = \bar{y}_L - t_{v,0.95} \sigma_y$$

where

$\bar{y}_L$  = Mean measured value of property, or in the case of long term properties derived by regression analysis, the extrapolated value at 50 years or other design life.

$t_{v,0.95}$  = Percentage points of Student's  $t$  distribution at two sided 0.10 level of significance.

$\sigma_y$  = Standard deviation of measured property or of  $y_L$  value estimated by regression analysis.

NOTE: For properties determined by direct measurement,  $v = n - 1$ , where  $n$  is the number of individual test results. For long term properties determined by regression analysis with one independent variable (i.e. time),  $v = n - 2$ .

All combinations of constituent materials, material proportions and curing method in a representative range of wall thicknesses shall be tested. Should there be any significant modification to the material constituents, proportions or curing method, the tests shall be repeated.

**7.4 Short term flexural (bending) properties**

To derive the suppliers declared values, which shall then become the minimum requirements, the following properties shall be determined by type testing in accordance with BS 2782: Part 3: Method 335A using a cross head displacement rate of 10mm/min:

- (a) Short term flexural modulus  $E_0$ .
- (b) Flexural stress at first break  $\sigma_b$ , which shall not be less than 25 MPa.
- (c) Flexural strain at first break,  $\epsilon_b$ , which shall not be less than 0.75%.

The flexural stress and strain at first break shall be calculated from the same test data as used to derive the flexural modulus. The first break point is indicated by the first discontinuity of the force/extension curve. The datum for measurement of flexural strain at first break,  $\epsilon_b$ , shall be determined from the intersection with the zero stress axis of the line constructed to compute the flexural modulus in accordance with clause 9.2 of BS 2782: Part 3: Method 335A: 1993.

**7.5 Flexural creep modulus**

To derive the supplier's declared value, which shall then become the minimum requirement, the flexural creep modulus  $E_{50}$  shall be determined by type

testing under aqueous conditions in accordance with Appendix A.

When calculated as shown in Appendix A the flexural creep factor  $F_{50}$  shall not be less than 0.1.

**7.6 Long term failure strain in bending (strain corrosion test)**

To derive the supplier's declared value, which shall then become the minimum requirement, the long term failure strain  $\epsilon_{LF}$  shall be determined by type testing in accordance with clause F.8.1 Appendix F of BS 5480.

The test fluids used shall be those specified in clause 9.4.1 WIS 4-34-02: Issue 1. Where test fluid A (potable tap water) is used, the 50 year value of  $\epsilon_{LF}$  shall not be less than 0.75%. Where test fluid B (0.5M sulphuric acid) is used, the 50 year value of  $\epsilon_{LF}$  shall not be less than 0.45%.

CIPP containing fibres made from polyester only shall not be subjected to the strain corrosion test and the value  $\epsilon_{LF}$  shall be deemed to equate to  $\epsilon_b$ .

All materials shall comply with this clause by 1st July 1996. Prior to this glass fibre products may only be used if the inner and outer surfaces have a resin rich layer of at least 0.5mm thick as a protective coating.

**Table 1 - Summary of CIPP performance requirements**

Property	Min. Requirement	Test Clause
Short-term flexural modulus $E_0$	Declared value	7.4
50-year flexural modulus $E_{50}$	Declared value	7.5
50-year creep factor $F_{50}$	0.1	7.5
Flexural strain at first break $\epsilon_b$	Declared value but not less than 0.75%	7.4
Flexural stress at first break $\sigma_y$	Declared value but not less than 25 MPa	7.4
Wall thickness	Design thickness (except as provided in clause 6.3.3)	6.3.3
50-year failure strain $\epsilon_{LF}$ in bending in acid environment	Declared value but not less than: 0.75% in type A fluid 0.45% in type B fluid	7.6

## 8. QUALITY CONTROL REQUIREMENTS

### 8.1 General

Quality control (QC) tests shall be carried out on each installed CIPP or as otherwise agreed with the purchaser.

NOTE: The test requirements of clauses 8.4 to 8.6 are necessary to demonstrate continuing satisfactory level of production and installation quality in day to day production.

### 8.2 Correlation of QC testing to type testing

The method of sampling to be used for QC testing (see clause 8.3.1) shall also be simulated at the time of preparing type test samples, so that correlations can be established between relevant properties of the actual CIPP wall and measurements made on non-destructive QC samples. The factors used to convert QC sample values to equivalent pipe wall values of a given property shall be derived from the 90% lower confidence limit of the correlation established by type testing.

### 8.3 Samples for quality control tests

**8.3.1** For each CIPP length, one sample shall be fabricated and cured either in a clamped mould using the method detailed in Appendix B, or at the discretion of the supplier by supporting the lining tube at its ends or at intermediate manholes in a sleeve which confines the tube perimeter to that equivalent to the sewer being lined. This sample shall be visually inspected for defects including air entrainment, fibre distribution and thickness.

When curing of the CIPP has been completed, the mould or supported sample shall be removed and subjected to quality control testing. If all tests are passed then no further quality control testing shall be required on this CIPP, except for the separate verification of wall thickness, clause 8.4, where a clamped mould sample has been used.

**8.3.2** In cases where disagreement or dispute exists over the results obtained from either clamped or supported sample, samples cut from the CIPP (removed at the supplier's cost) shall be used for repeat testing as required in clause 8.7.

For test purposes attention is drawn to the curvature limitations and orientation requirements of samples taken from CIPP.

All cut-away material shall be marked to indicate its place of origin and shall be stored until the CIPP length has been tested and accepted as meeting the quality control test requirements.

NOTE: Wherever possible, flexural testing should be performed on test pieces cut with their longitudinal axes oriented perpendicular to the longitudinal axis of the CIPP. The aim is to measure the flexural properties in the hoop direction of the pipe. If this is not possible, or where the diameter of the CIPP is less than 250mm, test pieces oriented parallel to the longitudinal axis of the CIPP may be used provided that the test results are corrected for any systematic anisotropy of hoop and longitudinal properties of the CIPP composite.

### 8.4 Wall thickness

The wall thickness shall be determined at a minimum of five locations. The measuring device shall be accurate to  $\pm 0.1$ mm.

The wall thickness at all points shall be not less than the specified design thickness and may be up to 15% greater.

### 8.5 Short term flexural (bending) properties

When tested in accordance with BS 2782: Part 3: Method 335A using a cross head displacement rate of 10mm/min, the 90% confidence limit of short term flexural modulus  $E_0$ , stress  $\sigma_b$  and strain  $\epsilon_b$  shall be not less than the respective design value declared by the supplier.

### 8.6 Flexural creep modulus

The flexural creep modulus  $E_{50}$  shall be not less than the supplier's declared design value, when derived as:

$$E_{50} = (E_0 * F_{50})$$

where  $E_0$  is the QC sample value derived in accordance with clause 8.5 and  $F_{50}$ , the 50-year flexural creep factor, has been determined by type testing in accordance with clause 7.5.

### 8.7 Repeat Testing

Should any short term tests performed on pipe wall samples fail to meet the specified short term requirements, then at the supplier's discretion and cost, either:

- (a) the creep modulus shall be validated against the manufacturer's creep data obtained for clause 8.3, using an abridged creep test in accordance with Appendix A

(1000 hours or as otherwise agreed), on material removed from the CIPP, or;

- (b) other agreed remedial measures shall be undertaken.

## **9. TEST CONDITIONS**

**9.1** In any case of dispute and unless specified otherwise in this specification, the test pieces shall be conditioned and tested at  $(23\pm 2)^{\circ}\text{C}$ .

**9.2** Test pieces of CIPP in which the resin system is designed to cure at ambient temperature without the application of heat or other external source of energy shall be stored in air within  $-5^{\circ}\text{C}$  to  $+2^{\circ}\text{C}$  of the measured mean sewer ambient temperature from the time of sampling until ready for testing. Such test pieces shall be brought up to the test temperature not more than 24 hr., or less than 12 hr., prior to testing.

**9.3** For type testing, the specimens shall be conditioned in air for not less than 48 hr. immediately prior to testing.

**9.4** For quality control testing, the test pieces shall be conditioned in air for not less than 12 hr.

**9.5** The edges of test pieces shall be machined in accordance with BS 2782: Part 9: Method 930A. Care shall be taken to prevent damage to any protective coatings.

**9.6** All flexural tests shall be performed on specimens cut from the full thickness of the CIPP wall with the inside surface of the CIPP in contact with the load bearing supports.

NOTE: This requirement takes precedence over the test piece thickness specification of BS 2782.

## **10. INSPECTION AND CERTIFICATION**

### **10.1 Inspection at manufacture**

The purchaser or his appointed representative shall have access at all reasonable times to those parts of any works engaged on production and testing of the CIPP and to all relevant test records.

### **10.2 Site testing of cure**

Site testing, if required, shall be agreed between the purchaser and supplier prior to the commencement of any work.

NOTE: Evidence of adequate cure of the CIPP is provided by the combination of:

- (a) Boiler and wall sensor temperature records, (or equivalent in cases where cure is initiated other than by heat).
- (b) Post installation CCTV inspection.
- (c) Appearance and, in due course, mechanical testing of site samples.

If there are grounds for doubting that the CIPP has cured, and provision for site testing has been agreed, then one of the site tests described in Appendix D.10.2 could be used.

### **10.3 Reconnection to the sewer system**

Prior to the commencement of cutting any laterals a test shall be carried out to ensure that the sewer does not contain any gases in explosive concentrations.

The opening in the CIPP should be formed to restore the full opening dimensions of the lateral and shall have no irregularities, steps or burrs which could impede flows or cause snagging of fibrous matter either in the sewer or lateral.

NOTE: Side connections may be re-opened using either man-entry or robotic techniques as appropriate.

If the resin-fibre composite does not delaminate during the test to determine the flexural creep modulus (7.5) it is deemed to be durable. Where the resin-fibre composite does delaminate, then all cut surfaces shall be sealed with a compatible material.

### **10.4 Internal inspection of CIPP**

After installation and cure, the CIPP shall be visually inspected, either by a walk through survey or CCTV. The results shall be recorded on behalf of the purchaser.

NOTE 1: Surveying sewers using CCTV gives an exaggerated impression of the size of all surface

irregularities and this should be borne in mind when judging conformity to the specified requirements.

NOTE 2: It should not be necessary to routinely measure surface irregularities other than by estimation from CCTV images but this should be available to resolve cases of dispute over acceptability. Where direct measurement is not possible, surface irregularities may be measured radically using light ring or sonar.

### 10.5 Surface appearance

The extent to which the CIPP is observed to introduce surface irregularities to those of the host sewer shall be limited either to the maximum sizes specified in Table 2, or 6mm, whichever is greater.

NOTE: A feature of CIPP is that the lining will generally conform to the surface features of the host pipe.

The host sewer irregularity categories referred to in Table 2 are defined as follows.

Category A applies to situations where the host sewer is straight, has no stepped joints, minimal deformation and is of constant internal perimeter.

Category B applies to situations where there are bends of 6 metre radius or greater, stepped joints of up to 10% of diameter, deformation is less than 10% or the perimeter varies by up to 5%.

Category C applies to situations where the limits for category B are exceeded or where two or more of the conditions apply within a distance of one pipe diameter.

The category shall be stated on the information given to the supplier at the design stage.

**Table 2 - Maximum additional irregularity introduced by CIPP**

Irregularity Category of Host Sewer	Allowable Radial Intrusion of CIPP as % of Diameter			
	Longitudinal		Circumferential	
	4-8 o'clock	8-4 o'clock	4-8 o'clock	8-4 o'clock
A	2	5	2	2
B	5	10	5	10
C	*	*	*	*

\* To be agreed between purchaser and supplier

Longitudinal irregularities are those where the ridge alignment is within 45° of the longitudinal axis of the pipe. Circumferential irregularities are those where the ridge alignment exceeds 45° to the longitudinal axis of the pipe.

### 10.6 Rectification of lining defects

The method and extent of rectification of any defects in the CIPP are to be agreed between the supplier and the purchaser taking account of the factors given in Appendix D.10.6.

### 10.7 Certification

The supplier shall, on request, furnish the purchaser or purchaser's representative with copies of a signed certificate. This shall state that the construction and testing of the CIPP supplied comply with the requirements of this specification. It shall also give details of minimum performance parameters agreed with the purchaser. If required by the purchaser, the quality control test results or a suitable summary shall be provided with the certificate. A typical certificate is shown in Appendix C.

## 11. REFERENCES

This specification makes reference to the latest edition of the following publications (except where otherwise indicated) including all addenda and revisions.

### British Standards

BS 2782	Part 1	Method 121A Determination of temperature of deflection under a bending stress of 1.8 MPa, of plastics and ebonite.
	Part 3	Method 320C Determination of tensile strength, elongation and elastic modulus.
	Part 3	Method 335A Determination of flexural properties of rigid plastics.
	Part 4	Method 432B Determination of the acid value of unsaturated polyester resins.
	Part 4	Method 432C Determination of the hydroxyl value of unsaturated polyester resins.
	Part 9	Method 930A Preparation of test specimens by machining.
BS 3532: 1990		Method of specifying unsaturated polyester resin systems.



BS 4618 Recommendations for the presentation of plastics design data.

Subsection 1.1.2:1976. Creep in flexure at low strains.

BS 5480: 1990 Glass reinforced plastics (GRP) pipes, joints and fittings for use for water supply and sewerage.

BS EN ISO 9002 Quality Systems Model for quality assurance in production, installation and servicing.

#### **Water Industry Specifications**

WIS 4-34-02 Specification for glass fibre reinforced plastics (GRP) sewer linings. April 1986; Issue 1.

#### **Other references**

ASTM D1763-88 Specification for epoxy resins.

Civil Engineering Specification for the Water Industry (CESWI) published by WRc plc.

Sewerage Rehabilitation Manual published by WRc plc.

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## **APPENDIX A - METHOD FOR THE DETERMINATION OF FLEXURAL (BENDING) CREEP MODULUS UNDER AQUEOUS CONDITIONS**

### **A.1 SCOPE**

Method of test to determine 50 year flexural creep modulus of CIPP subjected to a constant flexural stress under aqueous conditions.

This method is based on BS 4618: Subsection 1.1.2: 1976.

### **A.2 APPARATUS**

The apparatus is shown schematically in Figure A1. It shall consist of the following equipment such that the test piece is maintained at  $23 \pm 2^\circ\text{C}$  immersed in potable tap water of  $\text{pH} \geq 5.5$ .

#### **A.2.1 A pair of supports that:**

- (a) are parallel;
- (b) can be adjusted to give a variable span;
- (c) do not deflect under experimental forces;
- (d) do not impose significant longitudinal restraint on the test piece;
- (e) provide line contacts with the test piece without significant indentation;
- (f) preferably have a radius  $r$  of less than 1.0% of the span length  $L$ .

#### **A.2.2 A means of applying to the test piece a force that:**

- (a) is constant;
- (b) is applied through a central loading member which shall preferably have a radius  $r$  of less than 1.0% of the span length  $L$ ;
- (c) is midway between the supports (within a tolerance of  $\pm 1\%$  of the span);

- (d) is uniform along a continuous line perpendicularly across the width of the test piece.

**A.2.3** A means of measuring the deflection of the test piece that:

- (a) is as close as practicable to the line of application of the force;
- (b) itself applies only an insignificant force to the test piece;
- (c) is accurate within  $\pm 0.5\%$ .

**A.2.4** A water bath or similar equipment that:

- (a) maintains the test piece immersed in water;
- (b) maintains the water temperature at  $23 \pm 2^\circ\text{C}$ ;
- (c) is adequately covered to avoid rapid loss of water due to evaporation.

### A.3 TEST SPECIMENS

#### A.3.1 Preparation

For each of the minimum, maximum and an intermediate thickness manufactured, at least three test pieces from each of the same two samples shall be cut from the full thickness of CIPP wall to produce rectangular cross sections (without rounded corners) and the following dimensional requirements:

- (a) span length (L) greater than 10d;
- (b) test piece length of not greater than 1.2L;
- (c) test piece width b greater than d but less than 3d;
- (d) test piece width and thickness constant to within a tolerance of  $\pm 1\%$ .

#### A.3.2 Conditioning

The test piece shall be stored in water at the test temperature for at least 24 hours prior to testing.

### A.4 PROCEDURE

- (a) Prepare each test piece.
- (b) Mark on the test piece with a felt tipped marker, the approximate positions where each end support will bear, then mark ten intermediate positions on the test piece so that the span length is divided into eleven equal sections.

- (c) Determine the width and thickness of the test piece at each of the ten lines to within an accuracy of  $\pm 0.2\%$  and calculate the arithmetic mean of the width and thickness measurements.

- (d) Condition each test piece.
- (e) Set the span length L to approximately the required value.
- (f) Measure the span length L mm ( $\pm 0.5\%$ ).
- (g) Calculate the mass M, to be applied to the test piece to give the required flexural stress from:

$$M = \frac{bd^2S}{14.71L} \text{ kg} \quad (1)$$

Where

b is the average width of the test piece between the supports (mm)

d is the average thickness of the test piece between the supports (mm)

S is the required flexural stress (MPa) and is equal to  $0.0025E_0$ , where

$E_0$  is the short term flexural modulus of elasticity determined for clause 7.4

L is the distance between the supports or span length (mm)

The applied mass shall be accurate to within  $\pm 0.1\%$  of the calculated mass.

- (h) Place the test piece in the apparatus with the test piece's longitudinal axis at right angles to the supports so that the 'inside surface' of the CIPP when in service will be in tension when the load is applied.
- (i) Set and/or zero the deflection measuring device.
- (j) Immediately after carrying out step (i), smoothly apply the mass M and commence timing the test.
- (k) If continuous monitoring of deflection ( $\delta$ ) is not employed, a series of readings shall be taken between approximately 1 minute and at least 10,000 hours. There shall be at least 10 data points between 10 hours and 10,000

hours for each test piece. The following nominal times are recommended: 1, 2, 3, 4, 12, 18, 24, 36, 48 minutes; 1, 2, 4, 6, 8, 10, 20, 40, 80, 100, 200, 400, 600, 1000, 2000, 4000, 8000, 10000 + hours.

- (l) Calculate the flexural creep modulus  $E_{(t)}$  for each value of  $\delta_{(t)}$  at time  $t$  from:

$$E_{(t)} = \frac{2.45 M L^3}{bd^3 \delta_{(t)}} \text{ MPa} \quad (2)$$

- (m) Plot  $\log_{10}$  creep modulus against  $\log_{10}$  time. If for any reason the readings do not approximate to a smooth trace the test shall be abandoned, the occurrence recorded and the test repeated.
- (n) The graph produced for each test piece may appear to be a line which goes through a transition to an approximately straight line of greater slope. This being so, observe the position of the transition. After the transition or 50 hours (whichever is the later) regress the calculated values of  $\log_{10}$  creep modulus on  $\log_{10}$  time using the method of least squares and determine the extrapolated 50 year value of creep modulus  $E_{50}$ .
- (o) If the appropriate part of the graph does not approximate to a straight line and continues to curve downwards, the procedure in (n) is invalid.
- (p) For each separately prepared sample, the 50-year flexural creep factor  $F_{50}$  shall be determined from the measured mean values of  $E_0$  and  $E_{50}$  as:

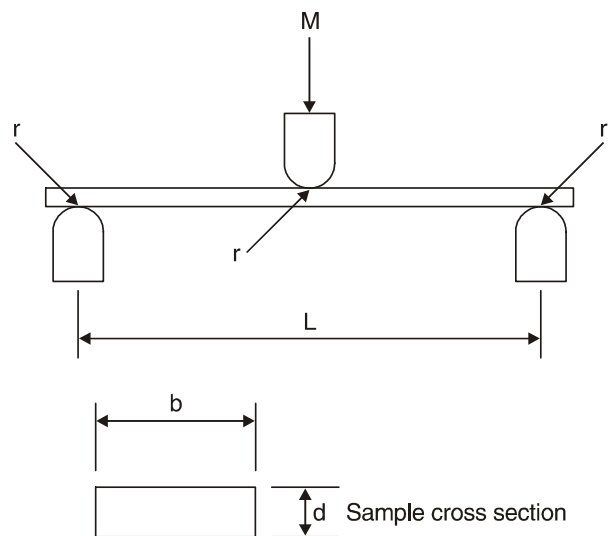
$$F_{50} = \frac{E_{50}}{E_0}$$

The value of  $F_{50}$  used in the interpretation of quality control test data (see clause 8.5) shall be the minimum value of  $F_{50}$  determined for any separately prepared sample subjected to type testing.

**A.5 REPORT**

For each test piece the test report shall include:

- (a) Complete description and identification of the CIPP, including method of manufacture, times and temperatures involved, supplier, code and batch number of resin.
- (b) Dimensions of the test piece.
- (c) Method of test piece preparation.
- (d) Graph or graphs of  $\log_{10}$  flexural creep modulus versus  $\log_{10}$  time.
- (e) Mass applied to the test piece.
- (f) The calculated value of flexural creep modulus  $E_{50}$  at 50 years.
- (g) The period of the test.
- (h) Any other relevant information.



**Figure A1 - Schematic layout for three-point flexural creep tests**

## APPENDIX B - METHOD FOR THE PRODUCTION OF CLAMPED MOULD SAMPLES

### B.1 EQUIPMENT

The mould shall comprise of a flat steel base plate and cover plate with threaded locating pegs at each corner. A typical mould design is illustrated in Figure B1.

The clamped mould dimensions shall be such that the sample size is sufficient to enable all quality control testing specified in clause 8 to be performed.

### B.2 SAMPLE PREPARATION

Remove a dry sample of the actual carrier material from the liner and cut it to fit inside the mould. The mould shall be marked to identify it with the liner. Lay a Melinex sheet on the base plate of the mould. Use some of the same batch of mixed resin which is used to impregnate the liner to impregnate the mould sample. Lay the impregnated carrier material, with any integral coating uppermost, on a sheet of Melinex. Place another sheet of Melinex on top of the sample and apply a vacuum to the mould. On removal from the vacuum, spacer plates shall be located in the mould to produce the required sample thickness when the mould is bolted down.

The mould shall be transported to site under the same conditions as the liner.

Once the liner has been installed, but before any heating commences, the mould shall be suspended within the liner at sewer level.

After completion of cure the mould shall be withdrawn from the CIPP and dispatched to a test laboratory.

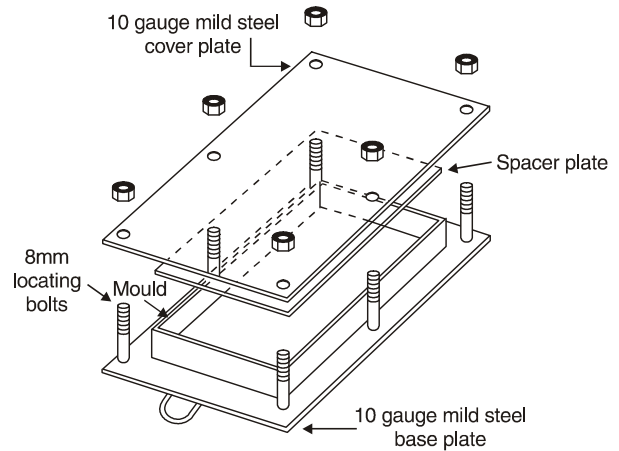


Figure B1 - Clamped mould

**APPENDIX C TYPICAL  
CERTIFICATE**

CERTIFICATE

We, ..... hereby certify that the Cured-in-Place sewer Pipe installed between ..... at ..... has properties indicated in the table and has been manufactured and tested in accordance with the requirements of Water Specification No. 4-34-04; Issue 2, Specification for renovation of gravity sewers by lining with Cured-in-Place pipes, published by WRc plc.

Our company \*has/does not have third party certification acceptable to WRc plc in respect of this specification.

\* delete as applicable

Date of installation \_\_\_\_\_  
Lining number \_\_\_\_\_

Nominal size \_\_\_\_\_ Manhole numbers \_\_\_\_\_

PROPERTY                      DECLARED VALUE

Short-term flexural modulus,  $E_0$

5-year flexural creep modulus,  $E_{50}$

Flexural strain at first break  $\epsilon_b$

Flexural stress at first break  $\sigma_b$

50-year failure strain  $\epsilon_{LF}$ :  
Type A fluid  
Type B fluid

Design Wall Thickness

Signed .....

on behalf of .....

on .....

## APPENDIX D - GUIDANCE NOTES

### D.1 SCOPE

This guidance note is offered as an aid to the use of WIS 4-34-04 and the section headings and clause numbers, with the exception of D.2, refer to the main body of the specification.

### D.2 CONTRACT INFORMATION

The following list includes some of the issues which should be resolved between a purchaser and supplier before entering into a contract for the provision of a CIPP lining system.

- (a) Responsibility for assessing and specifying design parameters. These might include external loads, design life, chemical environment, nature of effluent, etc.
- (b) Responsibility for sewer surveys and the accuracy of information obtained including location of laterals, lateral discharges, etc.
- (c) Responsibility for structural designs of CIPP.
- (d) Responsibility for any re-rounding of the host sewer.
- (e) Responsibility for sewer cleaning.
- (f) Responsibility and scheduling for the installation programme and the length of lining units.
- (g) Notification of any limitations on the installation programme.
- (h) Responsibility for dealing with sewer flows.
- (i) Details of resin systems used.
- (j) Required surface finish (clause 10.5).
- (k) Lateral reconnections.
- (l) Notification of any limitations on discharge temperature and quality of discharged process water (6.2 and D.6.2).
- (m) Responsibility for informing the public about substances potentially hazardous to health or potential odour nuisance.
- (n) Details and feasibility of site testing of cure should be agreed.

- (o) Requirements for public relations and notifications for work.

### D.3 QUALITY ASSURANCE

No comments.

### D.4 MATERIALS

No comments.

### D.5 LINER FABRICATION

The manufacturing process will differ between various proprietary systems. The factors of most concern are:

- Elimination of air from the resin during impregnation of the liner.
- Protection from heat and ultraviolet light during storage.
- Transportation.

The supplier should be able to provide details of methods and quality procedures.

### D.6 CIPP PRODUCTION

#### D.6.1 Installation

The purchaser should bring to the attention of the supplier any situations where the surcharge head at the laterals may exceed the level of the ground over the pipe being lined.

It is suggested that the temperature at the back of the lining be recorded approximately every 15 minutes during the heating cycle and at least every hour thereafter.

There are circumstances where releasing the curing water at 40°C may not be acceptable to the environment e.g. discharges into surface water systems which lead to waters containing fish. Any special circumstances of this sort should be drawn to the attention of the supplier by the purchaser at the design stage.

The supplier should provide details of methods and quality procedures.

## D.6.2 CIPP Dimensions

### D.6.2.1 Perimeter

Accurate measurement of the perimeter of the host sewer is essential for all lining systems of fixed circumference.

### D.6.2.2 Length

It is generally possible to line lengths which include several manholes with a single installation.

### D.6.2.3 Wall thickness

The design thickness should be determined from the external hydrostatic loading and/or other information provided by the purchaser in accordance with the Sewerage Rehabilitation Manual, using the material characteristics appropriate for a 50 year period or other agreed design life.

Some thinning of the CIPP is inevitable at points of discontinuity in the host sewer surface. Thinning at isolated points will not adversely effect the structural performance of the CIPP. The possible influence of extensive continuities should be considered at the design stage.

## D.7 TYPE TESTS REQUIREMENTS

The purpose of type testing is two fold:

- (a) to demonstrate the intrinsic suitability of CIPP materials and to establish characteristic values of material properties relevant to design;
- (b) to establish a correlation between long term material performance and short term properties suitable for routine quality control testing.

Repeat type testing is carried out at change of components, process or at regular intervals by a third party certification body.

The larger the number of samples the greater the relevance of the statistical analysis.

### D.7.1 Long term permissible bending strain (Strain corrosion test)

Environment B is a typical sewage environment within the UK. Consideration should be given to more severe conditions in cases where industrial exposure is anticipated.

## D.8 QUALITY CONTROL REQUIREMENTS

Testing for long term properties is inappropriate for routine quality control.

The clamp mould quality control sample shows that the resin, carrier materials and curing environment were capable of producing a CIPP to the required specification. It does not show that the CIPP has cured properly throughout its length. See clause 10.3.

## D.9 TEST CONDITIONS

No comments.

## D.10 INSPECTION AND CERTIFICATION

### D.10.1 Site testing of cure

One of the following site tests could be used:

- (a) After the liner has been cured but before any laterals have been cut a test pressure may be applied by the supplier to prove the cure is complete. In the case of gravity sewers this test should be at sub-atmospheric pressure (partial vacuum) equal in magnitude to the design load, less any external groundwater pressure or pressure of sewage in laterals acting at the time of test. The test shall be carried out as described in CESWI for the Testing of Pressure Pipelines.

NOTE: It is inadvisable to attempt this test if there is a risk that the head of sewage in the laterals temporarily sealed off by the CIPP could exceed ground level.

- (b) After the CIPP has been cured a hardness test may be applied to prove the cure.  
NOTE: A reliable quantitative site hardness test has yet to be developed.

- (c) After the CIPP has cured an ultrasonic test may be applied to prove the cure.

NOTE: A reliable quantitative site ultrasonic test has yet to be developed.

#### **D.10.2 Rectification of lining defects**

Where a localised area only is affected by surface irregularities, the influence if any of this area on overall hydraulic performance of the sewer should be carefully considered before undertaking remedial works. If remedial works are deemed essential, the risk of loss of leak-tightness will be reduced by cutting or grinding back intruding material no further than the maximum allowable dimensions as given in clause 10.5 Table 2. Careful consideration should also be given to the possible detrimental effects of surface irregularity removal on structural integrity of the CIPP.

Any cutting or grinding will remove the surface protective coating and expose the ends of fibres. Where there is concern over the durability of the materials when fibres are exposed, the cut area should be coated with a compatible durable material of suitable thickness.

Where the liner has failed to achieve a cure it may be possible to re-inflate it and initiate a cure.