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SPECIFICATION FOR LOCALISED SEWER REPAIRS USING CURED-IN-PLACE SYSTEMS WITH OR WITHOUT RE-ROUNDING

FOREWORD

This specification provides the materials performance and test requirements for local sewer repairs. Design guidance is also given. It was initially prepared by WRc plc in 1999 under the direction of Northumbrian Lyonnaise Technology and Research Centre Ltd, Severn Trent Water Ltd, Southern Water Services Ltd and Thames Water Utilities Ltd and further developed under the direction of the participants of the WRc Portfolio CP167 research project “long term testing of sewer repair and sealing techniques” who included Laing Utilities Limited, Severn Trent Water Limited, Southern Water Services Limited, Subterra Systems Division and Thames Water Utilities Limited.

This specification does not purport to include all the necessary provisions of a contract and users are responsible for its correct application. Compliance with this specification does not itself confer immunity from legal obligations.

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.

Reference to a European Standard, British Standard, Water Industry Specification or any other specification applies equally to any equivalent specification.

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

It has been assumed in the drafting of this specification that the execution of its provisions is entrusted to appropriately qualified and experienced people, for whose guidance it has been prepared.
Throughout this specification SI units are used, thus stress and modulus values are quoted in MPa (megapascals)*.

*1 MPa = 1 MN/m^2 = 1 N/mm^2

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1. SCOPE

1.1 This specification covers the following types of localised sewer renovation systems for making structural repairs: (i) CIPR (cured-in-place repair); (ii) re-rounding. Re-rounding is always used in conjunction either with a CIPR or a full length manhole to manhole lining. This specification does not cover the use of resin sealing systems which are injected under pressure using an inflatable packer or similar method. Dig-down local repairs and large diameter man-entry techniques are not covered by this specification.

1.2 The resin systems covered by this specification may use any appropriate method for curing.

1.3 There are practical limitations which restrict the range of defects for which local repairs can be used. Design guidance is provided in Appendix A.

1.4 The Supplier of the local repair is responsible for using appropriate installation techniques.

1.5 If materials meet the requirements of clause 4.4 then a minimum design life of 50 years should be ensured if the repairs are correctly installed.

2. DEFINITIONS

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

2.1 **Carrier material** - fibrous matrix (felt is typically used) which is filled with a resin system.

2.2 **Cured-in-place pipe (CIPP)** – lining with a flexible tube impregnated with a thermosetting resin which produces a pipe after resin cure.

2.3 **Cured-in-place repair (CIPR)** - short length of cured-in-place pipe (CIPP); also referred to as local linings and patch repairs.

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

2.5 **Declared Value** - design value of a CIPR material property which is declared in advance by the Supplier and substantiated by type testing.

2.6 **Design thickness** - the required wall thickness of the CIPR as determined by structural performance requirements, and limited by the requirements of hydraulic design.

2.7 **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.

2.8 **Inspector** – the competent person carrying out quality control inspection on behalf of the client.

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

2.10 **Local Repair** - general term that includes all short length sewer repair techniques.

2.11 **Local Lining** - short length of cured-in-place pipe (CIPP); also referred to as patch repairs and Cured-in-Place Repairs (CIPR).

2.12 **Mechanical prop** - technique for re-rounding partially collapsed sewers. The prop is installed using a re-rounder and is used in conjunction with CIPR or CIPP linings. Where the prop is a single sheet split longitudinally it is sometimes known as a ‘clip’.

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

2.14 **Nominal thickness** - one of a range of discrete lining wall thicknesses dictated by the materials used for construction. It is chosen so that the finished wall thickness of the CIPR within the sewer is not less than the design thickness.

2.15 **Packer** - a tube, usually made from rubber, that is inflated pneumatically to pressures typically between 0.03 and 0.15 MPa (0.3 and 1.5 bar).

2.16 **Patch Repair** - short length of cured-in-place pipe (CIPP); also referred to as local linings and Cured-in-Place Repairs (CIPR).

2.17 **Re-rounding** - use of techniques that can reshape pipes and displace ground, includes pneumatic packers and mechanical pipe bursters.

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

2.19 **Supplier** - the company responsible for providing the local repair system.

2.20 **Type Testing** - single set of detailed tests to demonstrate that the proposed repair technique can meet the declared values. Additional quality control tests are required for individual products**.**

3. QUALITY ASSURANCE

Suppliers shall operate a quality system relating to this specification in compliance with ISO 9001. This 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 third party certification body.

4. CURED-IN-PLACE REPAIRS (CIPR's)

This section covers the use of cured-in-place thermoset resin systems for the local repair of sewers. Guidance on the appropriate use of CIPR is given in Appendix A. If re-rounding is used then CIPR's are used in conjunction with mechanical props (see Section 5).

4.1 Requirement for leaktightness

4.1.1 The installed CIPR shall meet the leaktightness requirements of BS EN 1610 and the Civil Engineering Specification for the Water Industry, clause 5.7.7 in Sewers for Adoption 6th Edition, unless the Purchaser states otherwise.

4.1.2 Where applicable, the Supplier shall specify in their method statement the type of seal to be used with the CIPR.

4.2 Materials

4.2.1 Resin systems

General

4.2.1.1 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 that will be normally experienced during storage, transport and curing. These properties shall be selected to ensure that compliance with 4.3.2 and 4.4 is met across the whole temperature range.

NOTE: The Supplier should take into account changes in resin properties during storage when fabricating, installing or curing the resin system.

Storage

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

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

4.2.1.4 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.

Cured resins

4.2.1.5 Cured resins, as cast singly without reinforcement, shall conform to Clause 4.3 of BS EN 13566-4: 2002.

NOTE: For the purposes of testing local repairs in sewers, the maximum continuous service temperature is assumed to be 35°C.

4.2.2 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 CIPR required by clause 4.4.

4.2.3 Internal coating

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

4.3 Fabrication and installation

4.3.1 Fabrication

The resin system and the carrier material shall be combined to produce a resin impregnated lining. The volume of the resin used to impregnate the lining shall not be less than the volume of the pore space in the carrier material when compressed to its nominal thickness.

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

4.3.2 Dimensions

Shape

4.3.2.1 After installation the lining shall not be deformed from a circular shape (or other original shape) by more than 10% of the internal diameter (or relevant dimension) in rigid pipes (clay and concrete) or more than 20% in flexible pipes (plastics).

NOTE: See Appendix A for the structural requirements regarding the shape.

Thickness

4.3.2.2 The thickness of the lining shall be designed by the Supplier to provide the required installed thickness, taking into account installation methods.

NOTE: See design guidance in Appendix A.

4.3.2.3 Where the lining 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 CIPR.

4.3.2.4 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.

4.3.2.5 Multi-layered linings shall be manufactured so that there are no gaps between the layers which cause surface wrinkling.

Length

4.3.2.6 Where a complete pipe length requires a repair, the patch shall extend the full length of the pipe and overlap across the joints into the adjacent pipe barrels by a length of between 50 mm and 75 mm.

4.3.2.7 Where a repair is being made within a pipe length, it shall extend by a minimum length of 100 mm either side of the defect, except where it crosses a joint in which case 4.3.2.6 applies.

4.3.2.8 There is no maximum length; if multiple patches are used they shall overlap by a minimum length of 100 mm.

4.3.3 Installation

4.3.3.1 The Supplier shall specify the method of CIPR installation including:

- preparation of host pipe (state if re-rounding is to be used);
- equipment required;
- method of impregnating patch with resin;
- method of curing;
- records required and recording intervals (see clause 4.5.1).

4.3.3.2 When specifying the method of installation the Supplier shall take into account the following:

a) the installation pressure on the patch (typically applied via a packer) shall be high enough to resist any groundwater and so prevent deformation of the lining during curing due to groundwater head or pressure of sewage in laterals;

b) re-rounding (see definitions) of the existing sewer may be carried out prior to or while installing the CIPR;

c) the necessary measures to ensure that infiltration, inflows and standing water do not affect the lining during installation;

d) any conditions imposed on the installation by the Purchaser;

e) measures taken to ensure the local repair is leaktight (i.e. whether bonding or seals apply).

4.4 Type test requirements

4.4.1 General

4.4.1.1 The CIPR shall undergo type testing performed in accordance with 4.4.4 to 4.4.6 to substantiate Supplier's declared values and to demonstrate conformity with minimum required values as summarised in Table 4.1.

Note: BS EN 13566-4: 2002 specifies the strength of the cured-in-place pipes used for the renovation of sewers (complete lengths). Where this specification specifies the same properties then they conform to the European Standard.

Table 4.1 Summary of mandatory CIPR performance requirements

Property	Min. Requirement	Test Clause
Wall thickness	Design thickness (except as provided in clause 4.3.2)	N/a
Short-term flexural modulus E_0	Declared value but not less than 1500 MPa.	4.4.4
Flexural strain at first break ε_b	Declared value, but not less than 0.75%	4.4.4
Flexural stress at first break σ_b	Declared value, but not less than 25 MPa	4.4.4
50-year failure strain ε_{LF} in bending in acid environment (glass reinforced plastic only).	Declared value but not less than: 0.75% in type A fluid 0.45% in type B fluid	4.4.5

4.4.1.2 The CIPR is required to be leaktight and shall undergo type testing performed in accordance with 4.4.6 as summarised in Table 4.2.

Table 4.2 CIPR leaktightness performance requirement

Property	Maximum permitted	Test Clause
Leaktightness test	0.5 litres per metre of internal sewer diameter per patch repair	4.4.6

4.4.2 Sample Preparation

The test samples shall be obtained from either an actual or simulated CIPR installed in accordance with the method specified in 4.3.3.1.

4.4.3 Interpretation of Test Results

4.4.3.1 Except where specified otherwise, each of the type tests described in 4.4.4 and 4.4.5 shall be carried out on not less than five test pieces from each of two separately prepared CIPR samples.

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

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

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

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

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.

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

σ_y = Standard deviation of measured property or of y_L value estimated by regression analysis.

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

4.4.3.5 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.

4.4.4 Short Term Flexural (Bending) Properties

4.4.3.1 The testing shall conform to the requirements of Clause 4.3 of BS EN 13566-4: 2002.

4.4.3.2 The following properties shall be determined by type testing in accordance with BS EN ISO 178:1997 using a cross head displacement rate of 10 mm/min:

a) Short-term flexural modulus E_o.

b) Flexural stress at first break, σ_b.

c) Flexural strain at first break, ε_b.

4.4.3.3 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, ε_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 EN ISO 178:1997.

4.4.5 Long Term Failure Strain in Bending (Strain Corrosion Test)

4.4.5.1 To derive the Suppliers declared value, which shall then become the minimum requirement, the long-term failure strain ε_{LF} shall be determined by type testing in accordance with EN 1120.

4.4.5.2 The test fluids used shall be specified by the Purchaser, refer to Table 4.1.

4.4.6 Leaktightness Test

4.4.6.1 An external pressure test shall be conducted in accordance with the requirements of Appendix B. The peak test pressure shall be 0.5 bar (5 m head of water). A minimum of three repairs shall be tested.

4.4.6.2 The permissible rate of infiltration shall meet the requirements of the Civil Engineering Specification for the Water Industry, clause 5.7.7 in Sewers for Adoption 6th Edition, and is applicable to leakage in new pipelines in BS EN 1610 where the length of repair shall be taken as being one metre per patch. Therefore the leakage rate over a 30-minute period shall not exceed 0.5 litres per metre of internal sewer diameter per CIPR.

NOTE: the infiltration through one CIPR in a 0.300 metre diameter sewer shall not exceed 0.150 litres during a 30-minute period.

4.5 Quality control requirements

4.5.1 Site data recording and documentation

4.5.1.1 The curing time and packer pressure shall be stated for each type of repair and diameter.

4.5.1.2 A quality control inspection document should be produced for each CIPR containing the following information:

- Date
- Repair reference number
- Sewer diameter
- Resin batch number
- Hardener batch number
- Cleaning of host pipe
- Packer pressure
- Curing time

4.5.2 Frequency of Quality Control tests

In the event of a dispute, or at the Inspector's discretion (sampling may also be required as part of the auditing process), quality control samples shall be taken at the installation. Quality control (QC) tests shall be carried out on specially made samples.

4.5.3 Correlation of QC Testing to Type Testing

The method of sampling to be used for QC testing (see 4.5.4) shall also be simulated at the time of preparing type test samples, so that correlations can be established between relevant properties of the actual CIPR 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.

4.5.4 Samples for Quality Control Tests

4.5.4.1 Samples shall be fabricated and cured in a clamped mould. This sample shall be visually inspected for defects including air entrainment, fibre distribution and thickness. When curing of the CIPR has been completed, the sample shall be removed and subjected to the quality control testing.

4.5.4.2 In cases where disagreement or dispute exists over the results obtained from the sample, another sample cut from a CIPR shall be used for repeat testing as required in clause 4.5.7.

4.5.4.3 All samples shall be marked to indicate their place of origin and shall be stored for a minimum period of 12 months or until after the resolution of any disputes arising over sample results.

4.5.5 Wall Thickness

4.5.5.1 The wall thickness shall be checked on every sample. The measuring device shall be accurate to $\pm$0.1 mm.

4.5.5.2 The wall thickness at all points shall be not less than the specified design thickness.

4.5.6 Short Term Flexural (Bending) Properties

When tested in accordance with BS 2782[(6)]: Part 3: Method 335A using a cross head displacement rate of 10 mm/min, the 90% lower confidence limits of short term flexural modulus E_0, stress σ_b and strain ε_b shall be not less than the respective design values declared by the Supplier or the minimum values in Table 4.1.

4.5.7 Repeat Testing

Should any short-term tests performed on pipe wall samples fail to meet the specified short-term requirements, then either:

a) the short term flexural properties shall be validated on material removed from the CIPR, or;

b) other agreed remedial measures shall be undertaken.

4.6 Test conditions

4.6.1 In any case of dispute and unless specified otherwise in this specification, the test pieces shall be conditioned and tested at (23±2) ^{o}C.

4.6.2 For type testing, the test pieces shall be conditioned in air for not less than 48 hours immediately prior to testing.

4.6.3 For quality control testing, the test pieces shall be conditioned in air for not less than 12 hours and immediately prior to testing.

4.6.4 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.

4.6.5 All flexural tests shall be performed on test pieces cut from the full thickness of the CIPR wall with the inside surface of the CIPR in contact with the load bearing supports.

NOTE: This requirement takes precedence over the test piece thickness specification of BS 2782: Part 9.

4.7 Inspection and certification

4.7.1 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 CIPR and to all relevant test records.

4.7.2 Evidence of Cure

Evidence of adequate cure of the CIPR is provided by the combination of:

a) post installation CCTV inspection.

b) appearance and, in due course, mechanical testing of site samples.

4.7.3 Internal Inspection of CIPR

After installation and cure, the CIPR shall be visually inspected by CCTV, in accordance with the Model Contract for Sewer Condition Inspection, and photographs taken. A copy of the video recording (or DVD, CD-ROM, MP4 etc.) and the photographs shall be supplied to the Purchaser.

NOTE 1: Surveying sewers using CCTV gives an exaggerated impression of the size of all surface and shape 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 and shape irregularities other than by estimation from CCTV images but this should be available to resolve cases of dispute over acceptability (e.g. lightline surveys to measure dimensions).

4.7.4 Surface Appearance

4.7.4.1 The extent to which the CIPR is observed to introduce surface irregularities additional to those of the host sewer shall be limited either to the maximum sizes specified in Table 4.3, or 6 mm, whichever is greater.

NOTE: A feature of CIPR is that the lining generally conforms to the surface features of the host pipe.

4.7.4.2 The host sewer irregularity classifications in Table 4.3 are defined as follows:

- Classification A applies to situations where the host sewer is straight, has no displaced joints, minimal deformation and is of nominally constant internal perimeter.
- Classification B applies to situations where there are bends of 6 metre radius or greater, displaced joints of up to 10% of diameter, deformation is less than 10% or the perimeter varies by up to 5%.
- Classification 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.

4.7.4.3 The classification required shall be stated on the information given to the Supplier at the design stage.

4.7.4.4 Rotational twist of the patch repair shall be avoided.

Table 4.3 Maximum additional irregularity introduced by CIPR

Irregularity classification of host sewer	Allowable radial intrusion of CIPR 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	3	7
C	**	**	**	**

* where there is more than one radial intrusion then the effective irregularity is the sum of the individual longitudinal and circumferential irregularities.

Note: 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.

** to be agreed between Purchaser and Supplier.

4.7.5 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 CIPR 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.

5. LOCALISED SEWER RE-ROUNDING

5.1 Installation

5.1.1 Use of sewer re-rounding is limited to the types of locations shown in Appendix A. A mechanical prop, sometimes called a clip, shall always be installed when undertaking re-rounding, unless otherwise agreed with the Purchaser.

5.1.2 The installed outside diameter of the prop shall be no more than 5% larger than the sewer internal diameter, with the 5% increase limited to a maximum of 20 mm. After installation the mechanical prop shall conform to an essentially circular shape which is not deflected by more than 10% of its diameter and sufficient pressure shall be exerted by the re-rounder to maintain the required shape unless otherwise agreed with the Purchaser.

5.1.3 If the prop is required to 'lock' in position then it shall be shown by inspection, recorded on video or CD-ROM, that this has been achieved.

5.1.4 The prop and local defect shall in all cases be lined with a cured-in-place repair, which shall meet the requirements of Section 4, or a full length manhole to manhole lining.

5.2 Mechanical prop materials

The material to be used shall be agreed with the Purchaser (see Appendix A for design guidance).

5.3 Inspection and certification

5.3.1 A CCTV inspection, undertaken in accordance with the Model Contract for Sewer Inspection, of the mechanical prop shall be undertaken before a cured-in-place repair shall be installed in order to verify that it is correctly located. A recording shall be made and supplied to the Purchaser.

5.3.2 Inspection and certification of the cured-in-place repair shall meet the requirements of Section 4.

6. 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 2782-3: 1993	Method 335A Determination of flexural properties of rigid plastics
BS 2782-9: 1996	Method 930A Preparation of test specimens by machining

European Standards

EN 1120: 1996	Plastic piping systems – Glass-reinforced thermosetting plastics (GRP) pipes and fittings – Determination of the resistance to chemical attack from the inside of a section in a deflected condition
BS EN 1610: 1998	Construction and testing of drains and sewers
BS EN 13566-4: 2002	Plastics Piping Systems for Renovation of Underground Non-Pressure Drainage and Sewerage Networks – Part 4: Lining with cured-in-place pipes
BS EN ISO 178: 1997	Plastics -- Determination of flexural properties
BS EN ISO 9001: 2000	Quality Management Systems. Requirements. BSi

Other references

WRc plc: 2005	Model Contract Document for Sewer Condition Inspection
WRc plc: 2004	Civil Engineering Specification for the Water Industry (CESWI) 6th Edition
WRc plc: 2001	Sewerage Rehabilitation Manual
WRc plc: 1993	Materials Selection Manual for Sewers

APPENDIX A – DESIGN GUIDANCE

A.1 APPROPRIATE USE OF LOCAL REPAIR TECHNIQUES

Three types of localised structural repair can be made and their selection depends on the severity of the sewer defects:

1) **Re-rounding together with CIPR** - use for sewers in very poor condition which have suffered a significant loss of shape; and,

2) **CIPR** - use where the sewer shape provides support through arching but defects could cause future deterioration.

"**Re-rounding**" uses significant forces (high pressures in a pneumatic packer) that may be capable of causing ground displacement in addition to re-rounding the pipe. Ground displacement can cause vertical ground heave to occur which will then impose a load on the local repair as settlement occurs.

Detailed design guidance covering these three types of repair is provided below in Sections A.2 to A.4.

All local repairs should be leaktight. This is because most failure mechanisms causing sewer collapse or loss of sewer serviceability are associated with a lack of leaktightness because infiltration/exfiltration of water can occur and tree root ingress is possible.

The standard system of Internal Condition Grades (ICGs) for sewers as defined in the Sewerage Rehabilitation Manual are used in these notes. These are summarized in Table A.1 below.

Table A.1 Internal Condition Grades

ICG	Implication
1	Acceptable condition
2	Minimal collapse risk
3	Collapse unlikely in near future
4	Collapse likely in near future
5	Collapsed or collapse imminent

A.2 RE-ROUNDING

Re-rounding techniques are used to install props (also called 'clips') in sewers which are in very poor condition (ICG 4 or 5) and where there is significant deformation so that any reliable arching support has effectively been lost. The sewer should be lined shortly after re-rounding using a CIPR or full length sewer lining, otherwise further structural and serviceability problems are very likely to occur. There is no design limit to the diameter of sewer that can be re-rounded and this is governed by the practicalities of using the pipe bursting equipment. Although the possible range is approximately 100 mm to 600 mm diameter they are typically used in practice in the range 225 mm to 450 mm.

There are practical limits as to where re-rounding can be used because the prop must form an approximately circular shape before the lining is installed. If there is an excessively large void that could precipitate ground collapse or settlement after the sewer is repaired then a dig-down repair is required or the void has to be grouted up. Examples of defects that are suitable and not suitable for re-rounding are shown in Table A.2 below.

A number of different materials have been used for props, e.g. PVC-U and stainless steel. In order to determine if materials are suitable for use as a prop then the Materials Selection Manual for Sewers provides guidance on the use of different materials. Most props are made from relatively thin sheet material which have little strength or ring stiffness and should be considered as only holding the pipe debris temporarily in position until the complete lining repair is made.

A.3 CIPR DESIGN

A CIPR is used where a sewer is broken but is able to provide good arching support (most ICG 3 or 4s) and requires stabilising only to prevent further deterioration. Examples of typical cases for installing CIPRs are shown in Table A.3.

Leakage is prevented by a bond or a close fit between the lining and sewer wall or alternatively by the inclusion of a seal in the annulus between the lining and sewer wall. The specification allows for any satisfactory method to be used.

The ends of the lining should be positioned in sections of pipe which are in good condition. If this cannot be achieved then install more than one repair overlapping with the next. The maximum allowable wall thickness compatible with the hydraulic design should, if necessary, be included in the information provided by the Purchaser.

Table A.2 Typical re-rounding design cases

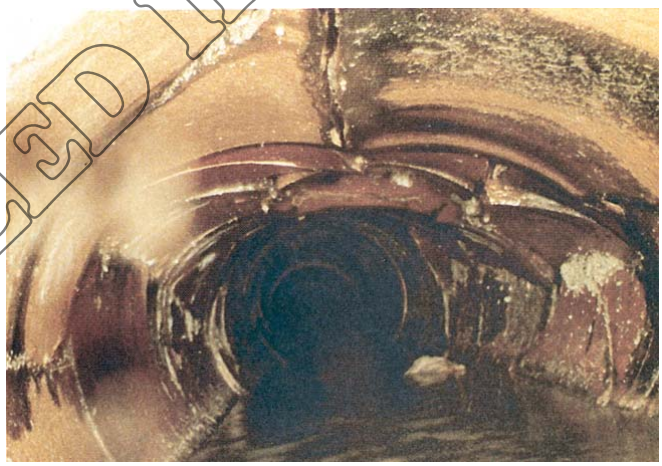
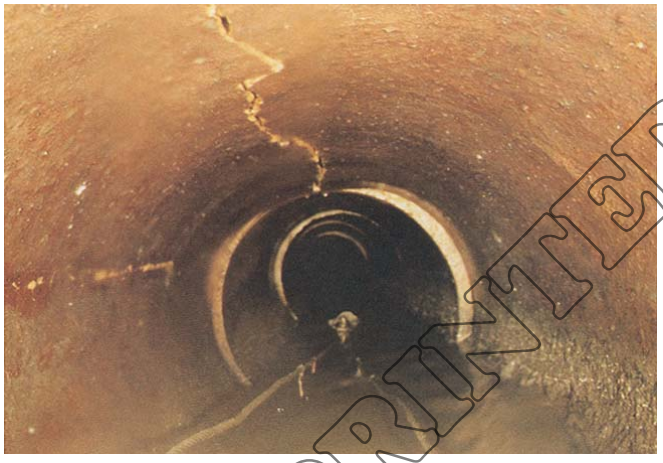
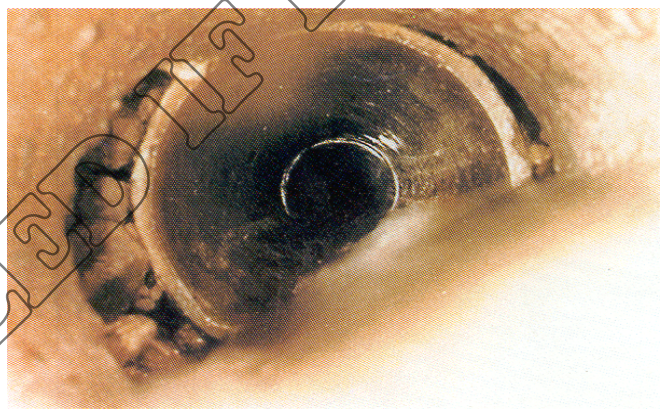
Complete overloading failure (ICG 5). Possibly caused by low cover under road, or a structure built over the sewer. Internal repair probably not possible because prop cannot maintain a circular shape before lining.	
Overloading failure, deformation >10% and multiple fracturing (ICG 5). Re-round and insert prop (followed by CIPR or full length lining).	
Circumferential fracture (ICG 4). Possibly caused by differential settlement or poor construction practices. Use re-rounding. If unsuccessful and lining would show excess wrinkling then use dig-down repair.	

Table A.3 Typical CIPR design cases

One pipe length suffering overloading failure, deformation between 5% and 10% with four point fracturing (ICG 4). Install CIPR of correct length.	
Circumferential break with hole (ICG 4). Possibly caused by third party damage or poor construction practices. Install short length CIPR.	

A.4 STRUCTURAL DESIGN – BACKGROUND INFORMATION

When local repairs are installed high levels of lateral ground support are present which provide the necessary support to the repair. Research carried out at WRc has shown that this support actually increases when re-rounding is carried out so no special design requirements are normally required if re-rounding is undertaken.

The pressure type test in Clause 4.4.6 of this specification caters for ground water pressures of up to 0.5 bar pressure (5 metres head). This test should ensure that, whatever method is used to keep the repair leaktight (e.g. bonding, hydrophilic seal or a close fit), it should demonstrate if there is a problem. If the sewer depths and possible ground water table pressures are greater than 5 metres head then additional design analysis to ensure buckling or de-bonding of the repair does not occur may be required.

APPENDIX B - LEAKTIGHTNESS TEST

B.1 SCOPE

B1.1 This test is used to assess the leaktightness of local sewer repair techniques. An external head is applied to a repaired clay pipe with a through-wall hole representing a defect and any infiltration through the repair is collected.

B.2 TEST RIG

B.2.1 A schematic of the test rig is shown in Figure B.1.

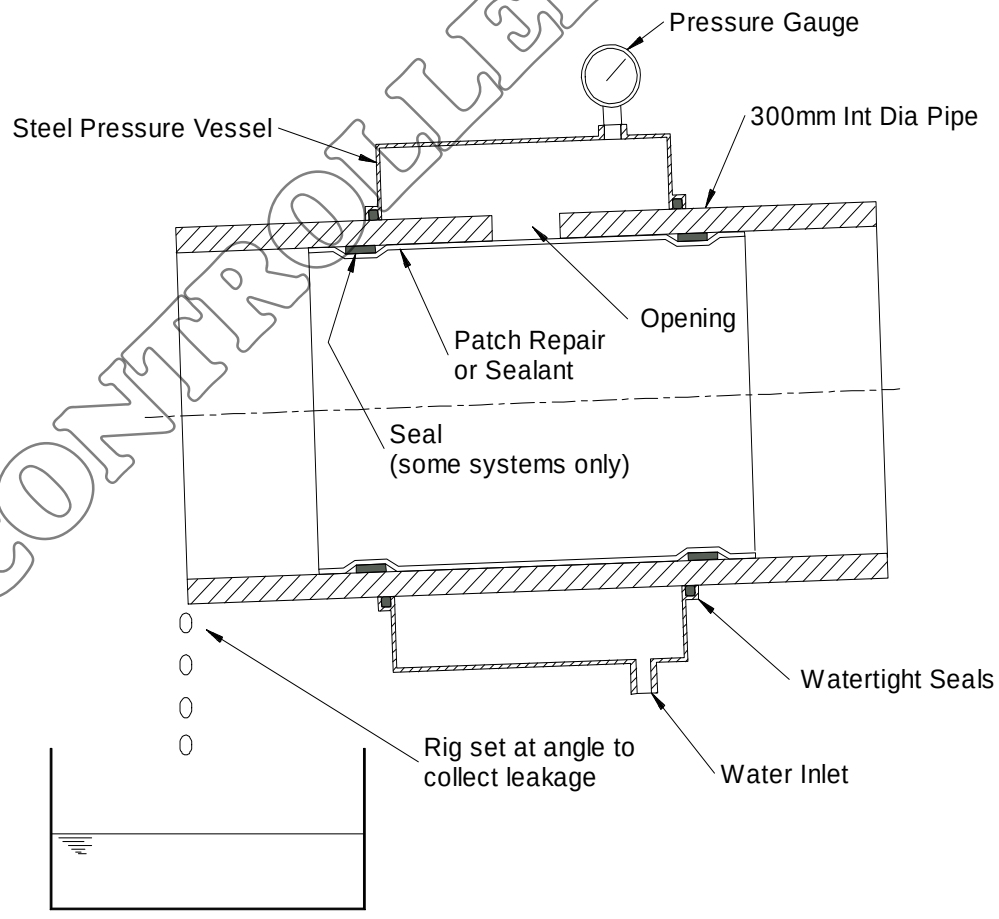


Figure B.1 Schematic of pressure testing rig

B.3 TEST SAMPLES

B.3.1 A 150 mm or 300 mm internal diameter sewer clay pipe has a 100 mm x 100 mm hole cut at mid-length. The repair shall be as close to 1 m in length as is reasonably practicable. The pipe can be reduced in length to ease handling, but shall exceed the length of the repair by a minimum length of 200 mm. The external surface of the clay pipes shall be coated with varnish to minimise the passage of test water through the clay pipe wall.

B.3.2 The repair shall be carried out using the same basic procedure that would be used on-site and the actual installation shall be witnessed by a representative from the testing body.

B.3.3 The 100x100 mm defect shall be positioned at the springing (i.e. the 3 o'clock or 9 o'clock position when looking along the pipe) during repair.

Note: otherwise a 'resin pool' may form if the defect is positioned at or near the crown during repair.

B.3.4 The test shall be undertaken in triplicate. During installation two repairs shall be undertaken with no hydrostatic head of water and one shall be undertaken against a 1m hydrostatic head of water with a flow rate into the pipe defect of 1 litre per minute.

B.3.5 Curing/setting of the repair and expansion of any water seals shall be completed before the section of pipe is tested.

B.4 TESTING PROCEDURE

B.4.1 This testing procedure is based on the requirements of the Civil Engineering Specification for the Water Industry, 6th edition[9] (equal to the leakage rate permitted in EN 1610[2]) for the permitted rates of infiltration into new sewers (see Clause 4.4.6).

B.4.2 The hydrostatic testing shall be undertaken over a 6-month period as follows:

- 4 weeks under cyclic pressure (i.e. 'wet' period), see below;
- 4 weeks with no hydrostatic pressure (i.e. 'damp' period);
- 4 weeks 'wet';
- 8 weeks 'damp', and;
- 4 weeks 'wet'.

Note: this wet/damp cycle is intended to simulate the seasonal changes in ground water level.

B.4.3 The hydrostatic pressure during the 'wet' period shall vary on a daily cycle via the following steps:

1) hydrostatic pressure is held at 1m head overnight;
2) hydrostatic pressure is increased to 2.5m head for one hour;
3) hydrostatic pressure is increased to 5m head for six hours;
4) hydrostatic pressure is decreased to 2.5m head for one hour;
5) hydrostatic pressure is decreased to 1m head, and;
6) to step 1.

Note: during the 'damp' period the hydrostatic rigs shall be drained, a stopper fitted in the lower end of the clay pipe and water poured into the pipe to keep the repair damp.

B.4.4 Any test water infiltrating via the repair shall be collected and measured so that the volume infiltrating during every 30 minute period can be calculated and recorded.

B.5 PASS/FAIL CRITERIA

B.5.1 The repair system is deemed to have passed the leaktightness test if all three tested repairs met the permitted infiltration rate defined in Clause 4.1

B.6 REPORT

B.6.1 The test report shall include:

a) Complete description and identification of the CIPP system;
b) Dimensions of the test piece;
c) Leakage measured;
d) The period of the test;
e) Whether the test was a 'PASS' or 'FAIL'; and
f) Any other relevant information.