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SPECIFICATION FOR POLYESTER RESIN CONCRETE (PRC) SEWER LININGS

FOREWORD

This is one of a number of specifications which have been prepared by WRc in order to assist engineers responsible for renovation of sewers. It covers Polyester Resin Concrete (PRC) sewer linings suitable for Type I designs as defined in the Sewerage Rehabilitation Manual published by the Water Research Centre.

Designers are referred to the Sewerage Rehabilitation Manual for the determination of sizes and minimum wall thickness.

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. Guidance on the exchange of information likely to be required before entering into a contract for the supply of linings is given in Appendix A.

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, for whose guidance it has been prepared.

Attention is drawn to the policy of the Water Industry to purchase products produced to an acceptable Quality Assurance and Third Party Certification Scheme.

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

The specification defines the requirements for construction, materials, dimensions, joints, marking, testing, workmanship, inspection and certification of Polyester Resin Concrete (PRC) segmental linings for the renovation of sewers where the lining is designed to act with the existing sewer fabric and annulus grout to form a composite structure i.e. Type I design.

2. DEFINITIONS

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

Effective Length of Unit

The distance between planes normal to the unit axis and passing through the real end points of the lining unit.

Lining Section

A discrete length of circumferentially continuous sewer lining made up from a joined matching pair of segmental lining units.

Out of Squareness of Unit End

The maximum distance between the real end surface and a plane normal to the unit axis and passing through the real end point (see Figure 1).

Out of Straightness

The maximum radial distance between the lining inner surface and any line parallel to the unit axis touching the lining inner surface (see Figure 1).

Real Corner Points

The two points at each end of a lining segment at which the real end surface meets the lines along which the inner surface of the lining is intended to be jointed longitudinally to the adjacent lining segment (see Figure 1).

Real End Point

The extreme point on the real end surface (see Figure 1).

Real End Surface

A surface joining the points against which the inner surface of the lining is intended to be jointed to the next lining section (see Figure 1).

Segmental Lining

Circular or non-circular sewer lining that is made up from pairs of upper and lower segments, which are jointed longitudinally at or near their springings.

Springings

The highest point at each side of an installed lining where the tangent to the internal surface is vertical.

Type I design (Sewerage Rehabilitation Manual)

The renovated sewer is considered to be acting as a composite section, consisting of the old sewer wall, grout and lining. It is assumed in the design that these three components are bonded together and that the grout is stiff and strong enough to transfer stress to the lining.

Unit Axis

The unit axis is a line passing through the mid points of lines joining the real corner points at each end of the segment (see Figure 1).

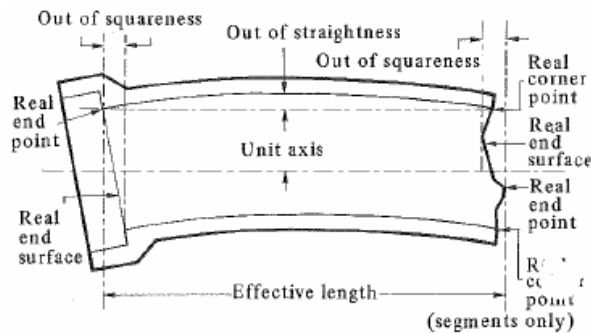


Figure 1 - Section through or plan of, nominally straight lining unit (Diagrammatic only)

Lines marked thus - - - - - are either square or parallel to each other

3. MATERIALS**3.1 Resins**

The resin shall be selected so that its properties are suitable for the manufacturing process and so that the completed product shall have the required mechanical and chemical properties.

The resin content of the structural wall shall be not less than 10% by weight.

Only isophthalic, bisphenol A fumarate or terephthalic polyester resins meeting the requirements of Type B or C of BS 3532: 1962 or vinyl-ester resins shall be used. Fire retardants shall not be incorporated unless specifically required. The catalysation and hardening processes shall be in accord with the resin manufacturer's instructions.

Cured resins, as cast singly without reinforcement, shall have an elongation at break greater than 2.5% when tested in accordance with BS 2782 Method 320C at a grip separation rate of 5mm/min and using an optical or strain gauge extensometer. Uncatalysed liquid polyester resins shall have an acid value of 20 or below when tested in accordance with BS 2782: Method 432B and a hydroxyl value of less than 30 when tested in accordance with BS 2782: Method 432C.

In addition to the requirements of BS 3532, the heat distortion temperature of the unreinforced fully cured resin, when determined in accordance with BS 2782: Method 121 A, shall not be less than 20°C above the expected maximum service temperature of the lining.

3.2 Plasticisers and curing agents

The minimum quantity of plasticisers and curing agents may be incorporated in the mix to provide the required product properties and to suit the manufacturing process.

3.3 Aggregate

Aggregate shall be clean, washed natural silica in the size range 3 to 5 mm. The maximum particle size used in any unit shall be not more than 20% of the design wall thickness of the finished product at its narrowest point. Aggregate shall contain not more than 0.2% moisture by weight when tested in accordance with the method described in BS 812: Part 2.

3.4 Filler

Any filler shall consist of clean inert material (e.g. ground silica) with nominal particle size of 10µm. Fillers shall be free from contaminants such as sodium chloride, calcium chloride or potassium chloride and shall contain not more than 0.2% moisture by weight when tested in accordance with the method described in BS 812: Part 2.

3.5 Dyes and pigments

No dyes or pigments may be included in the lining units. Painting or any other obscuration of the surfaces shall be limited to any marking or other process required by this specification.

NOTE Colouration for the purposes of resin mix control may be permitted and only when approved by the resin supplier.

4. CONSTRUCTION

The structural wall of each unit shall be manufactured by casting and compacting a uniformly blended mixture of aggregate, filler, resin, plasticisers and curing agents, either directly into a mould or into sheets and then rolled whilst still pliable into the required shape. A rough backing shall be incorporated to provide a bond between the unit and

the annulus grout when installed. This may be produced by a covering of inert material uniformly distributed over, and resin bonded to, the external surface of each unit.

NOTE An optional non-slip invert coating may be provided on the internal surface by bonding inert material to the cured lining unit using a suitable compatible resin.

5. APPEARANCE AND SURFACE CONDITION

The internal surface of the lining shall be smooth and essentially free from defects such as air voids, crazes, cracks, blisters or foreign matter that might impair the performance in service. Neither internal nor external surfaces shall be tacky. The walls of all lining units shall be free from cracks or breakages.

6. DIMENSIONS

6.1 Section length

Lining sections shall be provided to the overall or effective lengths specified by or agreed with the purchaser to within a tolerance of $\pm 10\text{mm}$.

6.2 Effective length of segments

The difference in effective length of a pair of segments intended to fit together to form a lining section shall not exceed 3mm.

6.3 Cross section

The width between the longitudinal joints and the depth from the unit axis to the crown or invert of the lining shall be within 1% or 5mm of that specified by or agreed with the purchaser whichever is the smaller.

6.4 Wall thickness

The design wall thickness of the lining (excluding the rough backing) shall be at least the minimum specified by or agreed with the purchaser.

The maximum overall wall thickness shall be not greater than that specified by or agreed with the purchaser.

6.5 Out of squareness

The out of squareness at each end shall be not more than $2\text{mm} + 0.003L$ or 5mm, whichever is the lesser,

where L is the average distance between the real corner points at each end of the segment measured in mm.

6.6 Out of straightness

The out of squareness of a unit shall be no more than 0.3% of its effective length.

7. JOINTS

7.1 Longitudinal joints

Longitudinal joints between lining segments shall be at or near the springings. The joints may be flexible or rigid and shall be capable of taking up mismatch of the linings due to manufacturing tolerances on squareness and dimensions. The joint detail shall be such that grout infiltration is minimised during installation.

7.2 Circumferential joints

Circumferential joints between lining sections may be flexible or rigid. The joints shall be capable of taking up an angular displacement of 1° in the vertical plane, 2° in the horizontal plane, and mismatch of the lining sections due to manufacturing tolerance. The joint detail shall be such that grout infiltration is minimised during installation.

7.3 Sealing materials

7.3.1 Rings and strips

Elastomeric sealing rings and strips in flexible joint shall be used in accordance with their manufacturer's recommendations for the particular application, and shall be manufactured from a biodeterioration resistant elastomer meeting the Type D requirements of BS 2494: 1986. Where the lining is to be used to convey deleterious trade effluents a biodeterioration resistant elastomer suitable for use in those conditions shall be used.

NOTE See also Information and Guidance Note No. 4-40-01.

7.3.2 Compounds

Rigid setting or flexible compounds used to caulk or seal the gap between lining units shall be resistant to the sewer environment for which they are intended, and shall be suitable for installation within a confined space taking safety aspects into consideration.

8. PERFORMANCE REQUIREMENTS

The lining shall meet the minimum requirements given in Table 1 when tested in accordance with those clauses indicated. These parameters will be used for the structural design of the lining system.

Table 1 - Lining Performance Requirements

Property	Minimum requirement (MPa)	Clause covering test
Flexural strength	14.0	9.4
Tensile strength	8.0	9.2
Shear bond strength	1.0	9.3

9. TYPE TESTS

9.1 General

The tests given in 9.2 to 9.5 shall have been satisfactorily completed before linings can claim to have met this specification. All combinations of manufacturing process, composition and any other components used during the manufacture of the linings offered shall be tested. Should there be any modifications to these, the tests must be repeated. The Quality Assurance Schedule of the quality system (see 10.1.) may require type tests to be repeated at specified intervals.

All tests are the responsibility of the manufacturer. All details and results of the tests shall be made available to the purchaser or his representative upon request. Samples of panels used for type testing shall be retained or made available for inspection/ comparison purposes by the purchaser or his representative.

9.2 Tensile properties

The tensile strength and initial tangent modulus of elasticity shall be determined in accordance with BS 2782: Method 1003 and using either an optical or strain gauge extensometer (but at a grip separation rate of 1mm/mmute). In the case of Type II or Type III test pieces, the results for any breaking within 10mm

of the grips shall be discarded, the test repeated and the occurrence recorded.

A minimum of five coupons shall be taken from each test unit including areas nearest to and furthest from the point of entry of the material into the mould during production. Each test piece shall attain the minimum tensile strengths given in Table 1 and shall have a minimum initial tangent modulus of elasticity of 1500MPa. (Either the thickness of the rough backing shall be discounted or it shall be ground off.)

9.3 Shear bond strength

A test unit shall be tested in accordance with the method described in Appendix B and shall attain the minimum requirements given in Table 1, clause 8.

9.4 Flexural strength

A minimum of five test coupons shall be taken from the same test unit.

Each test coupon shall be tested in accordance with the method described in Appendix C and shall attain the minimum requirement given in Table 1, clause 8.

9.5 Loss on ignition

Three test coupons shall be taken from the full wall thickness of the same lining unit excluding any bond coat.

Each test coupon shall be tested by the method described in BS 2782: Method 1002 except that the test pieces shall be of at least 40mm x 40mm and of full wall thickness and the loss on ignition (expressed as a percentage weight loss) shall be calculated and declared. The percentage weight loss values shall be greater than 10%. The values declared shall form the control values for quality control purposes.

10. QUALITY CONTROL TESTS

10.1 General

The test requirements of 10.2 to 10.7 are necessary in order to demonstrate a continuing satisfactory level of production quality in day to day production. The manufacturer shall establish a quality system to meet the recommendations of BS 5750: Part 2.

The required sampling frequency for quality control tests is given in Appendix D.

10.2 Dimensions

10.2.1 The overall length, effective length, cross section, out-of-squareness and out-of-straightness of each test sample shall be determined using a method of measurement accurate to the nearest millimeter and shall comply with the requirements of clause 6.

10.2.2 Wall thickness, excluding the rough backing, shall be determined at least five locations in each test sample using a method of measurement accurate to the nearest 0.1mm. Each measurement shall comply with the requirements of 6.4. Generally the locations shall include:

- i) a point of minimum internal surface curvature,
- ii) a point near the centre of the test sample,
- iii) points near each end of the test sample.

NOTE It may be necessary to cut through the lining wall to satisfy this clause.

10.3 Resin cure

The inside surface of each test specimen shall be tested in accordance with BS 2782: Method 1001 at a minimum of five points and the hardness values shall be greater than 35 and not less than the minimum hardness declared by the manufacturer at the time of confirmation of the order for the resin system used. Care must be exercised to ensure hardness readings are not taken from exposed aggregate particles. The surfaces shall not be tacky to the touch.

10.4 Shear bond strength

In the absence of a suitable objective test method each test unit shall be compared visually with a panel retained from the type tests (clause 9.3). If it is equivalent in particle shape, size and surface distribution it shall be deemed to have adequate shear bond strength. If it differs appreciably it shall be rejected.

10.5 Unit weight

Each test unit shall be weighed to within an accuracy of 0.1kg and shall be within $\pm 10\%$ of the mean weight for its size and shape as declared by the manufacturer at the commencement of a contract for the supply of linings.

10.6 Loss on ignition

A coupon of the structural wall shall be tested as prescribed in 9.5 and the percentage weight loss on ignition shall be greater than 10% and not less than 0.975 times the mean value obtained from the type tests.

10.7 Flexural strength

A minimum of five coupons shall be taken from each test unit and tested in accordance with the method described in Appendix C. The flexural strength at failure shall be greater than 14.0 MPa.

11. CONTROL OF TEST CONDITIONS

11.1 Test temperature

Unless otherwise required by this specification the test measurements shall be conducted at a standard laboratory temperature of $23 \pm 2^\circ\text{C}$.

11.2 Specimen conditioning

11.2.1 For type testing (or in any cases of disagreement) specimens shall be kept in air at $23 \pm 2^\circ\text{C}$ for not less than 88 hours prior to testing.

11.2.2 For quality control testing specimens shall be kept in air at $23 \pm 2^\circ\text{C}$ for not less than 12 hours after they are considered to be cured.

12. WORKMANSHIP, INSPECTION AND CERTIFICATION

12.1 Workmanship

12.1.1 All raw materials shall be tested at a frequency sufficient to ensure consistency and compliance with this specification.

The manufacturer shall adequately supervise all stages of production and keep records of the raw material batches used and products made each work shift or day.

Manufacture shall be under environmental conditions compatible with producing satisfactory linings and raw materials shall be stored and used in compliance with the recommendations of their manufacturer.

The lining manufacturer shall be familiar with the change in viscosity, gel time, etc., which may occur during storage of the resin, and make appropriate allowances in the lining manufacturing process. Resin stored in original unopened containers shall not be used after the resin manufacturer's stated keeping period required by clause 4 of BS 3532: 1962. The guidance of the resin manufacturer shall be sought on the useful life of resin delivered by tanker. Tanks

used for bulk storage of polyester resin must be inspected regularly and checked for contaminants.

12.1.2 Where linings are being fabricated by repeatable machine controlled processes, sufficient control shall be maintained of the mechanisms for metering and mixing resins, catalysts and accelerators, and emplacing the mixed resin together with aggregate and fillers in the lining wall, to ensure that the construction of the lining complies with the quality control requirements specified.

12.2 Inspection

In addition to the manufacturer's own inspection and supervision, the purchaser or his appointed inspecting authority shall have access at all reasonable times to those parts of the manufacturer's works engaged on production and testing of linings for the purchaser and to all relevant test records.

12.3 Certification

The manufacturer shall, on request, furnish the purchaser or purchaser's representative, with copies of a signed certificate for each size and classification of lining unit stating that the construction and testing of lining units supplied comply with the requirements of this specification and giving 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 D.

13. MARKING

All lining units shall be permanently marked at each end on the inside face. No method of marking shall prejudice the performance of the lining in service. The marking shall give the following information.

(a) the manufacturer's name, initials or identification mark,

(b) the number 4-34-05. The marking of the number 4-34-05 on products produced to this specification may only be applied by manufacturers covered by a third party certification scheme acceptable to WRc.

(c) 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 on request.

(d) the words "PRC TYPE 1 SEWER LINING".

14. REFERENCES

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

Sewerage Rehabilitation Manual published by the Water Research Centre.

WAA Sewers and Water Mains Committee Information and Guidance Note No 4-40-01 "Rubber Sealing Rings".

BS 12 Specification for ordinary and rapid hardening Portland cement.

BS 812 Methods of sampling and testing of mineral aggregates, sands and fillers.
Part 2 Physical Properties.

BS 1610 Materials testing machines and force verification equipment.
Part 1. Grading of the forces applied by materials testing machines.

BS 1881 Methods of testing concrete
Method 115 Specification for compression testing machines for concrete.

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

BS 2782 Method of testing plastics.
Method 121A Determination of temperature of deflection under a bending stress of 1.8MPa, of plastics and ebonite.
Method 432B Determination of the acid value of unsaturated polyester resins.
Method 432C Determination of the hydroxyl value of unsaturated polyester resins.
Method 930A Preparation of test specimens by machining.
Method 1001 Measurement of hardness by means of a Barcol impressor.
Method 1002 Determination of loss on ignition.
Method 1003 Determination of tensile properties.

- BS 3532 Unsaturated polyester resin systems for low pressure fibre reinforced plastics.
- BS 3892 Pulverised-fuel ash.
Part 1 Specification for pulverised-fuel ash for use as a cementitious component in structural concrete.
- BS4551 Methods of testing mortars, screeds and plasters.
- BS5750 Quality Systems.
Part 2 Specification for manufacture and installation.
- BS 6000 Guide to the use of BS 6001. Sampling procedures and tables for inspection by attributes.
- BS 6001 Sampling procedures and tables for inspection by attributes.

- iv) Joint details.

A.4 Information to be provided by manufacturer

- i) Method of manufacture,
- ii) Name of supplier, designation of constituent materials and proportions,
- iii) Sketch of joint details,
- iv) Unit weight per size and shape of unit,
- v) Written recommendations for the transport, handling and storage of all fining units.
- vi) Whether products will be covered by a third party certification scheme acceptable to WRc Engineering.

NOTE It is intended to resource and promote quality assurance certification so that schemes acceptable to WRc will become available for all lining materials and systems.

A.5 Representative sample

A representative sample (including a joint) having identical construction, thickness and composition to the lining units under construction should be made available for inspection by the purchaser upon request.

APPENDIX A - CONTRACT INFORMATION

A.1 General

This appendix is intended for guidance only on the exchange of information between purchaser and exchange of information between purchaser and situation before each party enters into a contract for the supply of lining materials. It does not form a mandatory requirement of this specification.

A.2 Information to be provided by purchaser

- i) Details of sewer environment (for selection of appropriate materials),
- ii) Size and shape of sewer to be lined,
- iii) Design approach under consideration (Type I as defined by Sewerage Rehabilitation Manual).
- iv) Proposed grouting pressure and method.

A.3 Details to be agreed between purchaser and manufacturer

- i) Shape and cross section dimensions,
- ii) Wall thickness (maximum overall and minimum structural),
- iii) Effective lengths and/or overall lengths,

APPENDIX B - METHOD FOR THE DETERMINATION OF SHEAR BOND STRENGTH

B.1 Scope

A method of test to determine shear bond strength between cementitious grout and sewer lining by measurement of the shear strength of the bond.

B.2 Apparatus

- (a) Compression testing machine accurate to grade 1.0 of BS 1610: Part 1: 1985 (see BS 1881: Part 115).
- (b) Shear testing rig of the form shown in Figures 2, 3 and 4.
- (c) Load spreading bar of the form shown in Figure 5.

B.3 Materials

B.3.1 Cementitious grout of the same composition as that to be used during the renovation contract for which shear bond values are required, shall be used.

If the testing is not applicable to any specific combination of lining and grout, the grout shall comprise 4 parts pulverized-fuel ash (BS 3892: Part 1) to 1 part ordinary Portland cement (BS 12) by weight with a water/solids ratio of 0.40.

B.3.2 At least two specimens approximately 150mm x 150mm shall be cut from the full thickness of the lining unit. (Care should be taken that the sample dimensions do not exceed 150mm). The radius of curvature of each sample should not be less than 400mm. A hardboard or wooden template 150mm wide with convex curved edge of radius 400mm may be used to check the suitability of different parts of egg shaped units.

B.4 Preparation and conditioning

B.4.1 The cut lining samples shall be immersed in water for at least 24 hours prior to testing.

B.4.2 The lining sample shall be placed in a 150mm cube mould with roughened 'outside' surface facing upwards.

B.4.3 The grout shall be mixed in a suitable grout mixer (neither hand mixing or the use of freefall concrete mixers shall be permitted).

B.4.4 Grout shall be poured onto the linings in the moulds to a depth of 100 ± 5 mm.

B.4.5 From each batch of grout used, three 70.7mm or 100mm cubes shall be prepared and compressive strength at 28 days determined in accordance with clause 15 of BS 4551: 1980 to correlate grout strength to shear bond strength.

B.4.6 Shear bond moulds shall be covered with damp sacking or plastic sheeting to prevent evaporation and left free from vibration on a horizontal surface for between 5 and 7 days.

B.4.7 The shear bond samples shall be removed from their moulds with care and immersed in water at $20 \pm 2^\circ\text{C}$ until tested at 28 days after casting.

B.5 Procedure after preparation

B.5.1 The test specimen shall be clamped in the shear testing rig as shown in Figure 4 such that the compressive force can be applied to the lining at the grout/lining interface via the load spreading bar. When testing curved linings care should be taken to apply load in the longitudinal and not transverse direction.

B.5.2 Force shall be applied without shock and increased continuously at a rate of approximately 0.5MPa (N/mm²) per minute until failure. The maximum force applied to the lining shall be recorded.

B.5.3 A note shall be made of the failure mode, usually either grout or bond failure.

B.6 Calculation

The shear bond strength (MPa) of each specimen shall be calculated by dividing the maximum force (N) sustained by the measured lining surface area (mm²).

B.7 Report

The report shall include the following:

- (a) the identification of the lining and the grout mix,
- (b) the individual shear strength results and the mean value (to 0.1MPa),
- (c) the failure modes,
- (d) the grout compressive strength results,
- (e) the period of the test.

- vi) are at least as wide as the specimen,
- vii) are of 6mm minimum diameter.

(b) the applied force is transmitted uniformly to two line contacts on the upper face of the specimen by two loading bars on a beam which:

- i) are parallel to the specimen supports,
- ii) can be adjusted to give a minor span equal to a third of the major span,
- iii) do not deflect significantly with respect to the beam centre, under experimental forces,
- iv) do not impose significant longitudinal restraint on the specimen,
- v) provide line contacts with the specimen,
- vi) are positioned symmetrically about the mid point of the span,
- vii) are at least as wide as the specimen,
- viii) do not apply a significant load from their self weight,
- ix) are of 6mm minimum diameter.

C.3.3 Chart recorder, of the multirange type, capable of continuous recording.

C.3.4 Silicon carbide saw, or other suitable equipment.

C.3.5 Absorbent cloth or paper.

C.4 Test specimens

C.4.1 General

Specimens shall have an internal radius of curvature greater than 500mm and shall be cut such that their longitudinal axes are in the circumferential direction of the sewer lining unit.

Where this condition is not practicable, test specimens shall be cut from the flat test boards, identical in composition, manufacturing process, curing and thickness to the finished product.

C.4.2 Preparation

C.4.2.1 Prepare a minimum of five coupons from a cured lining unit or test board described in C.4.1 using a silicon saw or other suitable equipment with water cooling in either case. (It is advisable to prepare spare test coupons to replace ones that break outside the central one third during testing).

C.4.2.2 Prepare each specimen of full wall thickness to have a width of 50 ± 2 mm and a length of between 25mm and 50mm greater than the major span dimension for the appropriate specimen thickness as

given in Table 2. Specimens shall be rectangular in cross section with parallel sides which are perpendicular to the mould or machine face of the specimen, and marked to identify the mould or machine faces. Where a rough backing has been applied to the external surface of the lining unit, this shall be ground smooth in the areas where the load bars will bear.

C.5 Procedure

C.5.1 Condition the specimens.

C.5.2 Set the major and minor spans of the bending test jig to the appropriate values for the specimen thickness given in Table 2, and align the loading rollers and supports so that the axes of the cylindrical surfaces are parallel (see Figure 6). Record the major span (L).

C.5.3 Adjust the testing machine so that its crosshead speed is within the limits appropriate to the specimen thickness given in Table 2.

C.5.4 Apply the force to failure at constant crosshead speed, while continuously recording the load/deflection curve.

C.5.5 Record the force at failure (P).

C.5.6 Measure and record the specimen thickness to nearest 0.05mm at a minimum of five points at or near the failure location taking care not to choose places where the specimen may have been expanded during the test.

Thickness measurements shall not include the rough backing.

Calculate the arithmetic mean (d) of the thickness measurements.

C.5.7 Measure and record the specimen width (b) to the nearest 0.1mm at or near the failure location taking care not to choose places where the specimen may have been expanded during the test.

C.5.8 Disregard the results from any specimen that breaks outside the minor span and repeat the procedure with another specimen. Record the occurrence of such cases.

C.6 Calculation and expression of results

For each specimen calculate and record the flexural strength F from:

$$F = \frac{PL}{bd^2} \text{ MPa} \quad (1)$$

where:

P is the maximum force (N),

L is the major span (mm),

b is the specimen width (mm),

d is the arithmetic mean of five specimen thickness measurements (mm).

Table 2 - Major and minor span lengths and crosshead speeds for various coupon thicknesses

Nominal coupon thicknesses (mm)	Major span L (mm)	Minor span l (mm)	Crosshead speed minimum to maximum (mm/min)
Up to 6.7	135	45	1.5-3.0
6.8 to 10.0	200	66.7	1.5-3.0
10.1 to 12.5	250	83.3	1.5-3.0
12.6 to 15.0	300	100	3.0-5.0
15.1 to 17.5	350	116.7	3.0-5.0
17.6 to 20.0	400	133.3	3.0-5.0
20.1 to 22.5	450	150	4.5-7.0
22.6 to 25.0	500	166.7	4.5-7.0
25.1 to 27.5	550	183.3	4.5-7.0
27.6 to 40.0	600	200	4.5-7.0

C.7 Report

The test report shall include:

- Product or test board identification,
- Details of specimen preparation,
- Radius of curvature of specimen,
- Date of the test,
- Number of test units or boards tested and number of specimens tested from each test unit or board,
- Individual values of flexural strength,
- The specimens that broke outside the minor span.
- Any other relevant information, e.g. visual appearance of aggregate distribution.

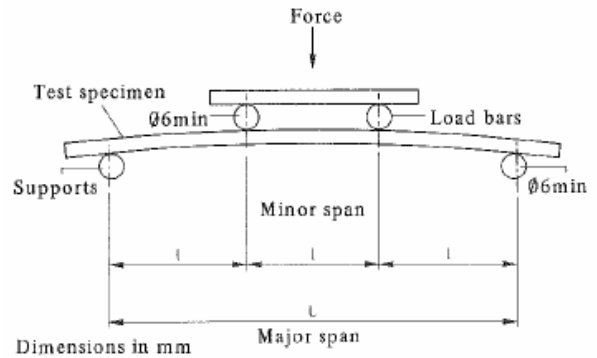


Figure 6 – Position of specimen in bending test rig

APPENDIX D - SAMPLING FREQUENCY FOR QUALITY CONTROL TESTS

D.1 Acceptable Quality Level (AQL)

Quality control tests shall be carried out to achieve an AQL of 10% defectives at an inspection level of S-3 as described in BS 6001 using the double sampling plan.

This inspection level covers production batches up to and including 150 units of one size and classification, and specifies sampling requirements and acceptance/rejection levels as summarised in Table 3.

D.2 Defectives

A test unit failing a quality control test is defined as having a defect. A test unit having one or more defects is defined as a defective. All defective test units shall be rejected and the acceptability of the batch from which they were drawn shall be determined as follows:-

- If the number of defectives in a sample is less than or equal to the acceptance number corresponding to that sample then the batch is accepted.
- If the number of defectives in a sample is greater than or equal to the rejection number corresponding to that sample then the batch is rejected.
- If the number of defectives in a first sample from a batch is between the acceptance and rejection numbers corresponding to that sample, then a

second sample is tested except in the case of reduced inspection.

Table 3 – Summary of sampling plans for inspection level S-3 giving acceptance/rejection numbers

Batch size	Sample	Normal inspection				Tightened inspection				Reduced inspection			
		Sample size	Cumulative sample size	Ac	Re	Sample size	Cumulative sample size	Ac	Re	Sample size	Cumulative sample size	Ac	Re
Up to 150 units	First	3	3	0	2	5	5	0	2	2	2	0	2
	Second	3	6	1	2	5	10	1	2				

NOTE: Ac is the acceptance number and Re is the rejection number.

(d) If the number of defectives in a sample at reduced inspection is between the acceptance and rejection numbers corresponding to that sample, then the batch is accepted, but the sampling level for further batches shall be at normal level.

D.3 Switching rules for sample frequency variation

The switching rules between the different inspection levels are described in BS 6001 and BS 6000 and may be summarised as follows:-

- (a) Normal inspection shall be used at the start of inspection for any one size and classification of production unit.
- (b) Tightened inspection shall be used if 2 out of 5 or less successive batches are rejected on normal inspection.
- (c) Tightened inspection shall be continued until 5 successive batches have been accepted on tightened inspection, when normal inspection shall be restored.
- (d) Reduced inspection may be used at the discretion of the manufacturer provided that:-
 - i) The preceding 10 batches have been on normal inspection and none has been rejected (see Table VIII of BS 6001: 1972 for exceptions).
 - ii) The total number of defectives in all the sample tests from the preceding 10 batches (or such other number of batches as was used for condition (i) above) is equal to or less than the applicable number given in Table VIII of BS 6001: 1972.
 - iii) The production is at a steady rate.

iv) Reduced inspection is considered acceptable by the independent inspector where a third party certification scheme accepted by WRc Engineering in operation, or reduced inspection is agreed to by the purchaser in writing.

(e) Any batch resubmitted for inspection shall be inspected at tightened inspection level and the result shall not be taken into consideration for the switching rules.

The manufacturer shall not knowingly supply any defective unit in any batch.

APPENDIX D - TYPICAL CERTIFICATE

CERTIFICATE

Wehereby certify that the polyester resin concrete sewer linings manufactured on and supplied to onhave been manufactured and tested in accordance with the requirements of Information and Guidance Note No. 4-34-05: Issue 1 published by WRc Engineering to give a minimum structural thickness of mm and a maximum overall wall thickness of mm.

Our company has/does not have* third party certification acceptable to WRc in respect of this specification and therefore the lining units are/are not* marked with the number 4-34-05.

*delete as applicable.

Signed

on behalf of

on