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Information and Guidance Note

SPECIFICATION FOR GLASSFIBRE REINFORCED PLASTICS (GRP) SEWER LININGS

FOREWORD

This is one of a number of specifications which have been prepared by WRc in consultation with manufacturers and the Water Industry in order to assist engineers responsible for renovation of sewers. It specifies Glassfibre Reinforced Plastics (GRP) sewer linings suitable for Type I and Type II designs as defined in the Sewerage Rehabilitation Manual published by the Water Research Centre.

Type I design requires a bond between the lining and the grout, Type II design does not. Linings manufactured to this specification may be used for Type II applications, in which case a rough backing is not required.

Although BS 5480 has been used as the basis for this specification, and British Standard test methods are used wherever appropriate, this specification allows for the provision of any relevant shape of lining (in either one or two segments) and extends the provisions of BS 5480 to reflect the needs of sewerage renovation. However, for circular lining applications, particularly in the larger sizes, purchasers may be offered pipes manufactured to BS 5480; in this case it is the responsibility of the purchaser to satisfy himself that his particular requirements are met. In this context, particular attention is drawn to the strain corrosion requirements of this specification for normal non-septic sewage environments.

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

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 MPa = 1MN/m² = 1 N/mm²

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1 SCOPE

This specification defines the requirements for construction, materials, dimensional tolerances, joints, marking, testing, workmanship, inspection and certification of Glassfibre Reinforced Plastics (GRP) segmental or pipe linings for the renovation of sewers where the lining is designed either:

(i) to act with the existing sewer fabric and annulus grout to form a composite structure i.e. Type I design, or

(ii) as a flexible pipe with the annulus grout providing passive side support i.e. Type II design.

This specification relates only to GRP incorporating isophthalic, bisphenol A fumarate or terephthalic polyester resins, or vinyl ester resins (see 3.1 and Note), manufactured by either mechanised or hand lay-up processes.

It does not recognise hand lay-up GRP thick sandwich construction linings with a separate central core of density below that of the outer skins, or GRP incorporating epoxide resins.

2 DEFINITIONS

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

C glass — Glass reinforcing fibres formed from a low-soda borosilicate glass, regarded as chemical resistant, primarily used for overlay or surfacing mats.

E glass — Alumo-borosilicate glass with an alkali content of maximum one weight percent, when expressed as sodium oxide ($Na_2 0$).

Alumo-borosilicate glass — Glass which has as major ingredients beside silica and boron mainly aluminium trioxide plus other oxides. The alkali-oxide content is generally low.

E type glass — Alumino-calco-silicate glass with an alkali content of maximum one weight percent, when expressed as sodium oxide ($Na_2 0$).

Alumino-calco-silicate glass — Glass which has as major ingredients besides silica and calcium oxide mainly aluminium trioxide plus other oxides. The alkali-oxide content is generally low.

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 which may be either a single pipe lining unit or a combined 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).

Pipe Lining — Circular or non-circular sewer lining that has no longitudinal joints.

Polyester resin (unsaturated) A solution of polyester in a monomer (usually styrene) which, when subjected to the appropriate conditions (catalyst and accelerator), will cure (polymerise by crosslinking) to form a solid.

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 intented 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 their springings.

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

Total major axis length The distance between the crown and invert of a lining section.

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.

Type II design (Sewerage Rehabilitation Manual) This procedure is applicable to the design of pipe linings forming no reliable bond to the grout or old sewer. The design assumption is that the lining eventually bears the full load from the ground and traffic. The lining system is designed to act as a flexible pipe with the old sewer, annulus grout and soil providing the necessary support to maintain stability. The design concepts are applicable to both circular and non-circular linings.

Unit Axis For a pipe lining section, the unit axis is a line passing through the centroids of the two real end surfaces. For a segment, 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).

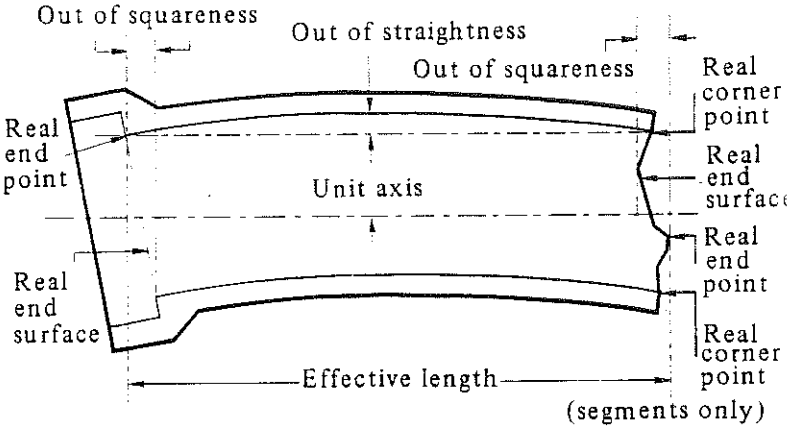

Figure 1 – Section through, or plan of, nominally straight lining unit (Diagrammatic only).
Lines marked thus – · – · – are either square or parallel to each other.

3 MATERIALS

3.1 Resins

The resins used in each layer of the lining shall be selected and applied so that they are suitable for the manufacturing process and so that the completed product shall have the required mechanical and chemical properties.

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. Additives, excluding thixotropes, are not permitted. 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. Resins "flexibilised" by the addition of plasticisers shall not be used.

Uncatalysed liquid polyester resins shall have an acid value of 20 or below when tested in accordance with BS2782: 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 121A, shall not be less than 20°C above the expected maximum service temperature of the lining.

NOTE Products containing resins of a similar chemically formulated type to those shown above but differing in some specified properties may be considered provided that

the lining manufacturer can demonstrate either 10 years proven service experience or relevant test data additional to that required by this specification.

3.2 Surface tissue
Surface tissue, where used, shall be manufactured from either C glass glassfibre, polyester fibres or acrylic fibres.

3.3 Glassfibre reinforcement
All glassfibre reinforcement shall have a surface treatment compatible with the lining manufacturing process and the resins with which it is to be laid. Glassfibre shall be E glass or E type glass in accordance with the requirements of one of the following standards: BS 3691, BS 3496, BS 3396, BS 3749. It shall contain not more than 0.2% moisture by weight as supplied; it shall be uncontaminated and protected to the point of use.

3.4 Aggregate
Aggregate when used as a part of the structural wall shall be clean, washed, high grade silica sand containing not less than 95% silica and of a size range between 0.05mm and 5mm with an upper limit of 20% of the glass reinforced wall thickness. Aggregate shall contain not more than 0.2% moisture by weight when tested in accordance with the method described in BS 812: Part 2.

3.5 Filler
Any filler shall consist of clean inert material (e.g. silica) with particle size below 0.05mm and shall be used only as a resin extender. Fillers shall be free from contaminants such as sodium chloride, calcium chloride or potassium chloride and contain not more than 0.2% moisture by weight when tested in accordance with the method described in BS 812: Part 2.

3.6 Dyes and pigments
Dyes or pigments shall not normally be included in the lining materials. 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

4.1 General
All sewer linings shall be manufactured with the following elements (see Figure 2):

(i) a resin rich liner to provide a durable, water resistant, smooth bore,

(ii) a glass reinforced wall,

(iii) a rough backing to provide a bond between the lining and annulus grout (necessary for Type I only).

NOTE 1 An optional non-slip invert coating may be provided additional to the resin rich liner.

NOTE 2 See Appendix B for various methods of manufacture.

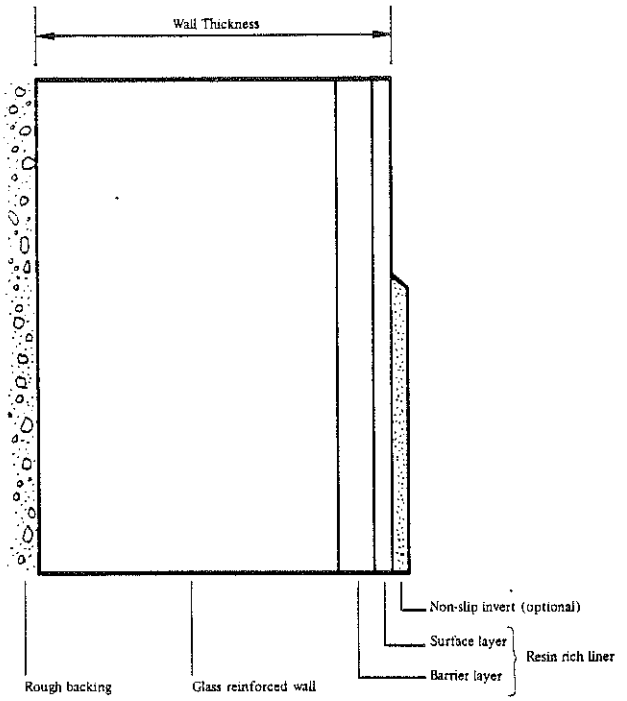

Figure 2 – Typical section through lining wall

4.2 Resin rich liner

4.2.1 General
Resin rich liners (see Figure 2) shall contain no filler or aggregate and shall have a maximum thickness of 3.0mm. They shall be designated as follows:

Type A: The minimum thickness shall be 0.25mm. (For use in normal non septic sewer environments with a pH $\geq$ 5.5.)

Type B: The minimum thickness shall be 1.5mm. (For use in septic, aggressive or uncertain sewer environments or where liable to change.)

Type C: The minimum thickness shall be 1.5mm. (For use in high temperature or specific effluent environments).

4.2.2 Surface layer
(Included in Types A, B and C liners). The thickness shall be a minimum of 0.25 and a maximum of 1mm. For filament winding and hand lay-up the surface layer shall consist of a suitable resin to which shall be added up to 10% by weight of surface tissue. Alternatively, and for manufacture by centrifugal casting, suitable unreinforced flexible resin shall be used compatible with any other resin in the system.

4.2.3 Barrier layer
(Included in Types B, C and possibly A). The barrier layer shall be fibre reinforced and shall be manufactured with 70%–80% resin content by weight. Reinforcement shall be in the form of E or E type glass chopped fibres, chopped strand mat or synthetic fibres. Where chopped strand mat reinforcement is used in this layer, only a styrene soluble powder bound mat shall be used.

NOTE 1 See 9.4.1 for strain corrosion tests to corroborate each type. The designations A, B and C have marking implications. See clause 13.

NOTE 2 When ordering sewer linings the thickness of the resin rich liner should be ascertained. In this context, consideration should be given to the abrasiveness of the effluent to be carried and any likely internal maintenance operations.

NOTE 3 In some processes it may not be possible to delineate the layers.

4.3 Glass reinforced wall
The structural wall shall be made up from resin impregnated layers of E or E type glassfibre and may include aggregate and filler and shall be finished with a continuous thin coating of resin before application of any rough backing.

4.4 Rough backing
If an additional application of material is required for Type I linings to pass the shear bond strength requirements of clause 8 it shall consist of an inert material uniformly distributed over the external surface and bonded using a suitable compatible resin.

4.5 Non slip invert
If a non slip invert coating is applied to the resin rich liner it shall be bonded to the cured lining unit using a suitable compatible resin.

NOTE Non slip inserts should be specified with care as they might compromise the durability or performance of the lining unit (see 10.9).

4.6 Edges and ends
At the edges and ends of all lining segments and sections the structural wall shall be sealed with a suitable compatible resin.

5 APPEARANCE AND SURFACE CONDITION

The internal surface of the lining shall be smooth. The surface shall be free from tackiness and defects such as protruding fibres, air voids, crazes, cracks, blisters or foreign matter that might impair the performance in service.

NOTE Some rectification or repair is permitted. See 10.7 and Table Appendix G.

6 DIMENSIONS

6.1 Section length
Lining sections shall be manufactured to within a tolerance of ±10mm of the nominal overall or effective lengths specified by or agreed with the purchaser provided that the sum of the lining section lengths are not less than the total length of sections required.

6.2 Effective length of segments
A pair of segments intended to fit together to form a lining section shall not differ in effective length by more than 3mm.

6.3 Cross section

6.3.1 Pipe linings
The tolerance on internal height and width shall be ± (4 + 0.002D)mm, where D(mm) is the nominal major axis of non-circular linings specified by or agreed with the purchaser, or ± 0.05% for circular linings.

6.3.2 Segments
The tolerance on the width between the longitudinal joints and the depth from the unit axis to the crown or invert of the lining shall be 1% or ± 5mm (whichever is the lesser) of the nominal value specified by or agreed with the purchaser.

6.4 Wall thickness
The wall thickness of the lining, excluding the rough backing if applied, but including the resin rich liner (see Figure 2), 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

6.5.1 Pipe lining units
The out-of-squareness at each end shall be compatible with the jointing system employed and shall be not more than 2mm + 0.005Ø or 10mm, whichever is the lesser, where Ø is the average of the maximum and minimum internal diameters measured in mm.

6.5.2 Segmental units
The out-of-squareness at each end shall be compatible with the jointing system involved and shall be not more than 2mm + 0.002W or 5mm, whichever is the lesser, where W is the average distance between the real end corner points at each end of the segment measured in mm.

6.6 Out-of-straightness
The out-of-straightness of a unit shall be no more than the lesser of 0.3% or 5mm of its effective length.

7 JOINTS

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

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 up to 1000mm size, 1° above that, and mismatch of the lining sections due to manufacturing tolerances. The joint detail shall be fit for the purpose intended such that grout infiltration during installation is minimised.

7.3 Sealing materials

7.3.1 Rings and strips

Elastomeric sealing rings and strips in joints 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 under 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	Clause covering test
Short term flexural (bending) modulus*	As agreed with purchaser and not less than 5000MPa (N/mm²).	9.2
Long term flexural (bending) modulus*	As agreed with purchaser and not less than 2500MPa (N/mm²).	9.3
Long term permissible flexural (bending) strain*	Greater than or equal to 0.5% where a test fluid of water is used or greater than or equal to 0.3% where a test fluid of acid is used.	9.4
Long term tensile strength*	As agreed with purchaser but not less than 12.0MPa (N/mm²).	9.5
Shear bond strength	1.0MPa (N/mm²).	9.6

* Property measured in the hoop direction.

9 TYPE TESTS

9.1 General

The tests given in 9.2 to 9.7 shall have been satisfactorily completed before linings can claim to have met this specification. The combinations of manufacturing process, glass types and configurations, aggregate, resin and curing system used during the manufacture of 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 tests shall be made available to the purchaser or his representative upon request.

Samples of all panels used for type testing shall be retained for inspection/comparison purposes by the purchaser or his representative.

9.2 Short term flexural (bending) modulus

The lining unit shall meet the requirements of Table 1, clause 8 when tested in the appropriate manner as follows:

9.2.1 Circular pipe lining units

The short term (or initial) pipe stiffness S, of at least five specimens for each diameter tested, shall be determined in accordance with the method described in Appendix J of BS 5480: Part 2: 1982. (Lining units representative of each stiffness range manufactured shall be tested.)

Calculate the short term bending modulus E_s from

$$E_s = \frac{12SD^3}{t^3} \times 10^{-6} \text{ MPa (N/mm}^2\text{)} \qquad (1)$$

where S is the short term pipe stiffness (N/m²),
D is the mean diameter of the lining excluding the rough backing (mm), and
t is the thickness of the lining wall excluding the rough backing (mm).

There shall be no evidence of structural damage of the test pieces after testing.

9.2.2 Segmental lining units or non circular pipe lining units

The short term flexural modulus shall be determined in accordance with the procedure described in BS2782: Method 1005 of coupons cut from the hoop direction and having a radius of curvature greater than 250mm (near the springings) and using a testing speed of 10mm/min.

NOTE When comparing lining units of a particular size but of different moduli and thickness, the value of E_s times t can be a useful guide to relative stiffness.

9.3 Long term flexural (bending) modulus

The lining unit shall meet the requirements of Table 1, clause 8 when tested in the appropriate manner as follows:

9.3.1 Circular pipe lining units

Determine $(\alpha\beta)_{50}$, the ageing and semi-permanent set factor in accordance with the method described in Appendix B of BS 5480: Part 2: 1982.

Calculate the long term flexural modulus, E_L from

$$E_L = (\alpha\beta)_{50} E_s \text{ MPa (N/mm}^2\text{)}. \qquad (2)$$

Where E_s is the short term flexural modulus in MPa as determined in 9.2.1.

9.3.2 Segmental lining units or non circular pipe lining units

Determine the long term flexural modulus, (which is equal to the creep modulus at 50 years) in accordance with Appendix C using coupons cut from the hoop direction and having a radius of curvature greater than 250mm.

9.4 Long term permissible bending strain (strain corrosion test)

9.4.1
The lining unit shall meet the requirements of Table 1, clause 8 when tested in accordance with the general principles of the method described in Appendix D of BS 5480: Part 2: 1982 and, unless otherwise specified for particular applications, using a test fluid of:-

A. potable tap water (pH $\geq$ 5.5), where the lining is intended for use in normal non septic sewer environments (Type A liner),

B. a reagent of 1.0N sulphuric acid, where the lining is intended for use in a septic or aggresive sewer environment (Type B liner),

C. other reagents or one of the above fluids at an elevated temperature, where the lining is intended for use in high temperature or specific effluents (Type C liner).

$\in_{LP}$ is the long term permissible strain, calculated from

$$\in_{LP} = 0.67 \in_{LF} \quad (3)$$

Where $\in_{LF}$ is the extrapolated value of failure strain at 50 years on a regression line of log $\in$ on log time.

The 95% lower confidence limit of failure strain at 100,000 hours shall not be less than 0.5%.

9.4.2
The type of failure and general condition of the resin rich liner after the tests shall be assessed and recorded. The information shall be available to the purchaser or his representative.

NOTE The test method is intended for circular pipe sections, but is applicable to any shape of lining unit provided that the mechanism for stressing the sample is adapted to suit the specimen geometry and strain gauges are suitably located.

9.5 Long term tensile strength
The long term hoop wall tensile strength of the lining units shall be determined in accordance with the method described in Appendix C of BS 5480: Part 2: 1982 and shall meet the requirements of Table 1, clause 8.

For non circular pipe lining or segment systems, it will be necessary to manufacture circular test samples with the identical materials, composition and laminate construction as the lining unit in order to perform the tests.

9.6 Shear bond strength (Type I only)
The lining unit shall be tested in accordance with the method described in Appendix D and shall attain the minimum requirement given in Table 1, clause 8.

A sample panel having a rough backing representative of those tested shall be retained for quality control comparisons.

9.7 Analysis of construction
A minimum of five samples from the full design wall thickness of each lining test unit (excluding any rough backing or non slip coating) shall be fully analysed in accordance with Appendix E and the results declared. The values shall form the control values for quality control purposes.

10 QUALITY CONTROL TESTS

10.1 General
The test requirements of 10.2 to 10.9 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 requirements of BS 5750: Part 2.

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

Where destructive tests are specified the remaining useful portion of a complying unit (trimmed square) may be offered for sale, appropriately marked "undersize".

10.2 Dimensions

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

10.2.2
Wall thickness and resin rich liner thickness shall be determined at a minimum of five locations in each test sample using a method of measurement accurate to the nearest 0.1mm, by measuring cut surfaces through the lining wall. The cut surfaces shall be smoothed sufficiently for the different layers to be delineated. The resin rich liner thickness shall be measured using a suitable optical (magnifying) technique. Each measurement shall comply with the requirements of clause 6. Generally the locations of cores shall include:-

(i) a point of minimum internal surface curvature,

(ii) a point towards the centre of the test sample,

(iii) points near each end of the test sample, but not at a joint.

NOTE Where the process does not produce distinct layer boundaries a relaxation in precision will be considered.

10.3 Resin cure
The surfaces shall not be tacky to the touch.

In case of dispute the inside surface of each test specimen shall be tested in accordance with the method described in BS 2782: Method 1001, at a minimum of five points, away from the invert, and shall have a hardness not less than the minimum declared by the manufacturer at the time of confirmation of the order, for the resin system used.

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 (9.6). If it is equivalent in respect of particle shape, size and surface distribution (or other bonding key) it shall be deemed to have adequate shear bond strength. If it differs appreciably it shall be rejected.

10.5 Short term bending modulus
Samples shall be tested by the method prescribed in 9.2.1 or 9.2.2 and shall comply with the requirements of Table 1, clause 8.

10.6 Analysis of construction
In any cases of disagreement, when tested by the method prescribed in 9.7 the disposition of the laminates or zones and the constituents within them shall correspond to those of the type tested liners. The percentage by mass of the constituents and the masses of glass per unit surface area shall not deviate from the declared control values by more than ± 10% (of each numerical value).

10.7 Appearance
The internal and external surfaces of each lining unit shall be examined visually for freedom from defects. Where practicable this shall occur prior to application of any rough backing or non-slip surface coating. Types of defect and final allowable limits are given in Table 2, Appendix G.

10.8 Initial longitudinal tensile test
When tested in accordance with one of the methods described in Appendices N and P of BS 5480: Part 2: 1982 linings shall have an initial ultimate resistance to longitudinal force per unit circumference or perimeter of not less than the following:

150kN/m for lining units up to and including 600mm nominal external diameter or total major axis length.

200kN/m for lining units above 600mm and up to and including 1200mm nominal diameter or total major axis length.

250kN/m for lining units above 1200mm up to and including 2400mm nominal diameter or total major axis length.

NOTE 1 The above requirements are intended to provide adequate strength for normal handling and insertion conditions only and are not intended to be used for design purposes.

NOTE 2 The requirements of BS 5480: Part 1 have been used in this clause.

10.9 Strain corrosion resistance
Where lining units are intended for use in a septic or aggressive sewer environment, where a non slip invert is applied or where the lining is intended for use in particular environments or with high temperature effluents, then one test piece shall be tested as required by 9.4.1 for each strain level at the 10, 100 and 1000 hour 95% failure strain confidence limit determined from the appropriate type tests. No fluid shall pass through the lining wall and there shall be no visible surface cracks or other evidence of surface degradation.

11 CONTROL OF TEST CONDITIONS

11.1 Test conditions
Unless otherwise required by this specification the test measurements shall be conducted at a temperature of 15 ± 10°C.

11.2 Specimen conditioning

11.2.1
For type testing in air (or in any cases of disagreement) specimens shall be kept in air at 15 ± 10°C for not less than 88 hours prior to testing.

11.2.2
For quality control testing specimens shall be kept in air at 15 ± 10°C for not less than 12 hours after they are considered to be cured.

NOTE The preferred temperature for conditioning and testing plastics materials is 23 ± 2°C.

11.3 Test specimen preparation
In cases of disagreement mechanical test specimens shall be machined following the recommendations of BS 2782: Method 930A.

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 manufacturers. Reinforcement materials shall be stored in dry conditions.

The lining manufacturer shall be familiar with the changes in viscosity, gel times, 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 limiting date in accordance with 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.

Materials and temperatures in the working environment shall not be less than 15°C. All laminating work shall be discontinued if the air temperature falls below 15°C or if the dew point is reached (condensation occurs), whichever is the higher.

NOTE A relaxation to 10°C (or the dew point) may be permitted if final cure is effected by applicaton of heat.

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 reinforcement, aggregates and fillers in the lining wall.

12.1.3
Where linings are being fabricated by hand, the requisite amounts of resin, catalyst and accelerator shall be measured out and thoroughly mixed in batches small enough to ensure utilisation within the pot life at the workshop temperature. The layers shall be consolidated with due care to avoid excessive pressure that could disturb the distribution of the layers and damage the reinforcement. Adjacent pieces of reinforcement shall be overlapped by not less than 50mm and their edges worked out to minimise the step. Such joints shall be staggered through the thickness of the wall. When directionally biased reinforcement is used, care shall be taken to ensure that the high strength direction is correctly aligned to give the designed balance of hoop and longitudinal strength.

Hand spraying of glass fibre is not acceptable.

12.1.4
The manufacturer shall ensure that good adhesion is obtained between successive layers of laminate either by correct time scheduling of the lay-up, or by removing the surface gloss of cured resin before further applications.

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 units 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 H.

13 MARKING

All lining units shall be indelibly 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 4-34-02. The marking of the number 4-34-02 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 "GRP TYPE IA", "GRP TYPE IB" or "GRP TYPE IC" "SEWER LINING" (depending on construction and use of appropriate test fluid) or "GRP TYPE IIA, B or C SEWER LINING", as appropriate.

14 PROTECTION OF LINING UNITS

Lining units shall be handled, stored and transported in such a way as to prevent damage before receipt by the purchaser.

15 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.

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 Specification for the grading of the forces applied by materials testing machines.

BS 1881 Methods for testing concrete.
Part 115 Specification for compression testing machines for concrete.

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

BS 2782 Methods 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 1005 Determination of flexural properties. Three point method.

BS 3396 Woven glassfibre fabrics for plastics reinforcement.

BS 3496 E glass fibre chopped strand mat for the reinforcement of polyester resin systems.

BS 3532 Unsaturated polyester resin systems for low pressure fibre reinforced plastics.

BS 3691 Glass fibre rovings for the reinforcement of polyester and of epoxide resin systems.

BS 3749 Woven roving fabric of E glass fibre for the reinforcement of polyester resin.

BS 3892 Pulverized-fuel ash.
Part 1 Specification for pulverized-fuel ash for use as a cementitious component in structural concrete.

BS 4551 Methods of testing mortars, screeds and plasters.

BS 4618 Recommendations for the presentation of plastics design data. Subsection 1.1.2: 1976 Creep in flexure at low strains.

BS 5480 Specifications for glass reinforced plastics (GRP) pipes and fittings for use for water supply or sewerage.
Part 1 Dimensions, materials and classification.
Part 2 Design and performance requirements.

BS 5750 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.

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

APPENDIX A – CONTRACT INFORMATION

A.1 GENERAL
This appendix is intended for guidance only on the exchange of information between purchaser and manufacturer likely to be required for each design situation before each party enters into a contract for the supply of lining materials.

A.2 INFORMATION TO BE PROVIDED BY PURCHASER
(i) Details of sewer environment (for selection of appropriate materials and determination of type test requirement for long term permissible bending strain),
(ii) Size and shape of sewer to be lined,
(iii) Design approach under consideration (Type I or Type II as defined by Sewerage Rehabilitation Manual),
(iv) Proposed grouting pressure and method.

A.3 DETAILS TO BE AGREED BETWEEN PURCHASER AND MANUFACTURER
(i) Segmental or pipe lining,
(ii) Shape and cross section dimensions,
(iii) Wall thickness (maximum overall and minimum structural),
(iv) Effective lengths and/or overall lengths,
(v) Joint details
(vi) Short term bending modulus,
(vii) Long term bending modulus,
(viii) Long term tensile strength.

A.4 INFORMATION TO BE PROVIDED BY MANUFACTURER
(i) Method of manufacture,
(ii) Name of supplier and designation of constituent materials,
(iii) Minimum hardness of cured resin (Barcol hardness),
(iv) Sketch of joint details,
(v) Written recommendations for the transport, handling and storage of all lining 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 SAMPLES
A representative sample (including a joint) having identical construction and thickness as the lining units under consideration should be made available for inspection by the purchaser upon request.

APPENDIX B – METHODS OF MANUFACTURE OF GLASS REINFORCED PLASTIC SEWER LININGS

This appendix is included for information only and does not form a mandatory part of the specification.

B.1 CONTACT MOULDING
In this process the resin and reinforcement ring is applied to mandrels by hand lay-up or by some form of mechanical application. The amount and type of glass put into the construction of the laminate can be varied to suit any specific mechanical design requirement. Rolling is generally employed to consolidate the resin and glass and to remove air. This process is done carefully so that the reinforcement is not disturbed and the glass fibre strands are not broken.

The lining is left on the mandrels until the resin has cured sufficiently to allow the pipe to be handled and the mandrel removed.

B.2 FILAMENT WINDING WITH CONTINUOUS ROVINGS

B2.1 Construction

B2.1.1 General
Filament wound GRP linings may be produced by winding specifically orientated resin impregnated glassfibre continuous rovings on a mandrel, and there are two basic construction methods for the structural thickness in current use, as follows:

(a) biaxial construction;
(b) helically wound construction.

In both types of construction, there is incorporated a resin rich liner comprising a surface layer and a barrier layer.

B2.1.2 Biaxial construction
This method of construction consists of applying circumferentially and longitudinally disposed glassfibres such that the corresponding circumferential and longitudinal strength and stiffness of the finished lining meets with design requirements.

This type of construction can be manufactured on any type of filament winding machine, either by a discontinuous process employing a series of mandrels or a proprietory continuous machine.

B2.1.3 Helically wound construction
In this method of construction the glass is not wound around the mandrel at right angles to the lining axis but a guide for the glass rovings is moved to and fro along the mandrel so that the fibres are in a helix around the pipe.

This type of liner may be produced only by a discontinuous process using conventional lathe type machines employing solid or collapsible mandrels.

B.3 REINFORCED PLASTICS MATRIX LINING
This type of lining is made in a similar manner to that described in B2.1.2, the difference being that special aggregate and filler are added in a predetermined sequence.

B.4 CENTRIFUGAL CASTING
This process manufactures pipes by applying resin, glassfibre and high purity silica sand to the inside of a rapidly rotating horizontal mould. The amount and position of the raw materials within the pipe wall is controlled to produce the requisite pipe stiffness. The amount and orientation of the glassfibre is controlled to produce the requisite circumferential and longitudinal design strengths.

APPENDIX C – METHOD FOR THE DETERMINATION OF FLEXURAL (BENDING) MODULUS UNDER AQUEOUS CONDITIONS

C.1 SCOPE
Method of test to determine 50 year flexural creep modulus of sewer lining material subjected to a constant flexural stress under aqueous conditions.

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

C.2 APPARATUS
The apparatus is shown schematically in Figure 3. It shall consist of the following equipment such that the specimen is maintained at 23 ± 2°C immersed in potable tap water of pH ≥ 5.5:

C2.1
A pair of supports that:

(a) are parallel,

(b) can be adjusted to give a variable span,

(c) do not deflect significantly under experimental forces,

(d) do not impose significant longitudinal restraint on the specimen,

(e) provide line contacts with the specimen without significant indentation,

(f) preferably have a radius r of less than 1.0% of the span length L.

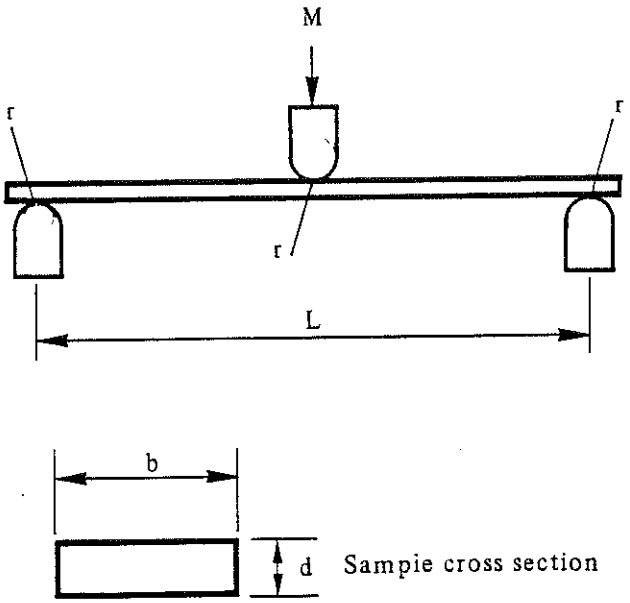

Figure 3 – Schematic layout for three-point flexural creep tests

C2.2
A means of applying to the specimen a force that:

(a) is constant,

(b) is midway between the supports (within a tolerance of ± 1% of the span),

(c) is uniform along a continuous line perpendicularly across the width of the specimen.

(d) is applied by a mass through a central loading member which shall preferably have a radius r of less than 1.0% of the span length L.

C2.3
A means of measuring the deflection of the specimen that:

(a) measures deflection as close as practicable to the line of application of the force,

(b) itself applies only an insignificant force to the specimen,

(c) is accurate to within ± 0.5%.

C2.4
A water bath or similar equipment that:

(a) maintains the sample immersed in water.

(b) maintains the water temperature at 23 ± 2°C,

(c) is adequately covered to avoid rapid loss of water due to evaporation.

C.3 TEST SPECIMENS

C3.1 Preparation
At least three specimens shall be prepared from the full thickness of lining wall to produce rectangular cross-sections (without rounded corners) and the following dimensional requirements:

(a) span length L preferably greater than 10d.

(b) specimen length of not greater than 1.2L,

(c) specimen width b greater than d but less than 3d,

(d) specimen width and thickness constant to within a tolerance of ± 1%.

C3.2 Conditioning
The specimen shall be stored in water at the test temperature for at least 24 hours prior to testing.

C.4 PROCEDURE

(a) Prepare each specimen.

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

(b) Determine the width and thickness at each of the ten lines to within an accuracy of ± 0.2% and calculate the arithmetic mean of the width and thickness measurements.

(d) Condition each specimen.

(e) set the span length L to approximately the required value.

(f) Measure the span length L mm (± 0.5%).

(g) Calculate the mass M, to be applied to the specimen to give the required flexural stress from:

$$M = \frac{bd^2S}{14.71\,L}\ kg \qquad (4)$$

Where b is the average width of the specimen (between the supports) (mm).
d is the average thickness of the specimen between the supports (mm).
S is the required flexural stress (MPa) and is equal to $0.0025E_s$, where
E_s is the initial tangent flexural modulus of elasticity determined for 9.2.2.
L is the distance between the supports or span length (mm).

The applied mass shall be accurate to within ± 0.1% of the calculated mass.

(h) Place the specimen in the apparatus with the specimen longitudinal axis at right angles to the supports so that the "inside surface" of the lining 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 (δ) 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 18 data points between 10 hours and 10,000 hours for each test specimen. The following nominal times are recommended: 1, 2, 3, 4, 12, 18, 24, 26, 48 minutes; 1, 2, 4, 6, 8, 10, 20, 40, 80, 100, 200, 400, 600, 1,000, 2,000, 4,000, 8,000, 10,000+ hours.

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

$$E_{(t)} = \frac{2.45\,M\,L^3}{b\,d^3\,\delta_{(t)}}\ MPa \qquad (5)$$

(m) Plot log creep modulus against log time. If the readings do not approximate to a smooth trace for any reason the test shall be abandoned, the occurrence recorded and the test repeated.

(n) If the graph produced for each test specimen appears to be a straight line, regress the calculated values of log creep modulus on log time using the method of least squares and determine the extrapolated 50 year value of creep modulus E_L.

(o) If the graph does not approximate to a straight line and continues to curve downwards, the procedure in (n) is invalid.

C.6 REPORT
For each specimen the test report shall include:

(a) Complete description and identification of the lining, including method of manufacture, times and temperatures involved, manufacturer, code and batch number of resin,

(b) Dimensions of the specimen,

(c) Method of specimen preparation,

(d) Graph or graphs of log deflection versus log time,

(e) Mass applied to the specimen,

(f) The calculated value of flexural creep modulus E_L at 50 years,

(g) The period of the test,

(h) Any other relevant information.

APPENDIX E – METHOD FOR THE DETERMINATION OF SHEAR BOND STRENGTH

D.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.

D.2 APPARATUS

(a) Compression testing machine accurate to grade 1.0 of BS 1610.

(b) Shear testing rig of the form shown in Figures 4, 5 and 6.

(c) Load spreading bar of the form shown in Figure 7.

D.3 MATERIALS

D3.1
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.

D3.2
At least three specimens approximately 150mm × 150mm shall be cut from the full thickness and different representative areas 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.

D.4 PREPARATION AND CONDITIONING

D4.1
The cut lining samples shall be immersed in water for at least 24 hours prior to testing.

D4.2
Each lining sample shall be placed in a 150mm cube mould with roughened "outside" surface facing upwards.

D4.3
The grout shall be mixed in a suitable grout mixer (neither hand mixing or the use of freefall concrete mixers shall be permitted).

D4.4
Grout shall be poured onto the linings in the moulds to a depth of 100 ± 5mm. Tamping is unnecessary.

D4.5
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.

D4.6
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.

D4.7
The shear bond samples shall be removed from their moulds with care and immersed in water at 20 ± 2°C until tested at 28 days after casting.

D.5 PROCEDURE AFTER PREPARATION

D5.1
The test specimen shall be clamped in the shear testing rig as shown in Figure 6 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.

D5.2
Force shall be applied without shock and increased continuously at a rate of approximately 0.5 MPa per minute until failure. The maximum force applied to the lining shall be recorded.

D5.3
A note shall be made of the failure mode, usually either grout or bond failure.

D.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 (mm^2).

D.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 0.1 MPa),

(c) the failure modes,

(d) the grout compressive strength results,

(e) the period of the test.

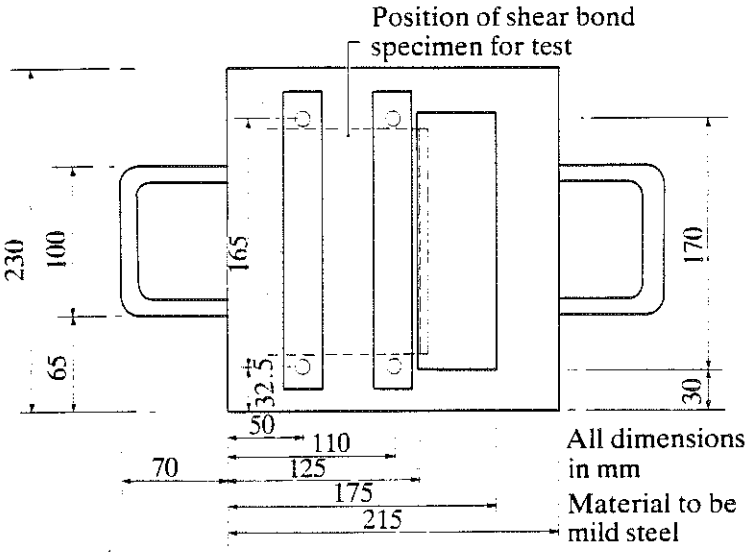

Figure 4 – Plan: shear bond rig

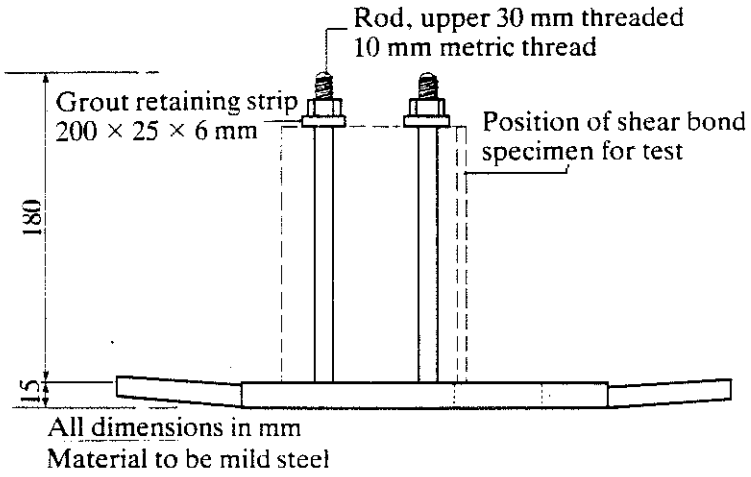

Figure 5 – Elevation: shear bond rig

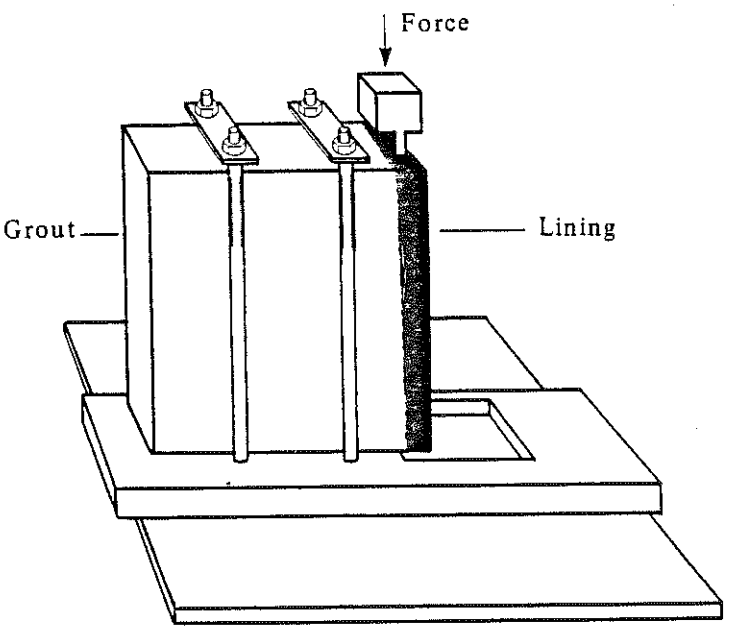

Figure 6 – Assembled shear bond apparatus

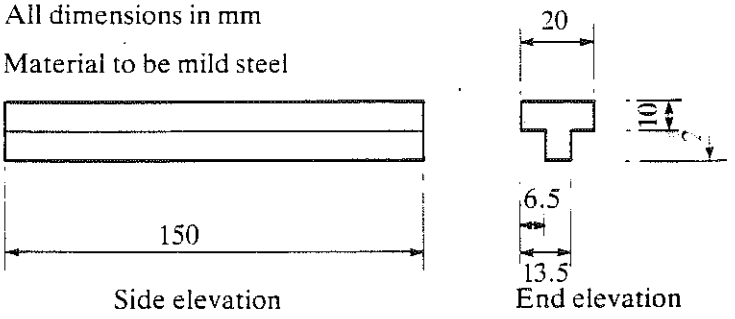

Figure 7 – Load spreading bar

APPENDIX E – METHOD FOR THE ANALYSIS OF CONSTRUCTION

E.1 SCOPE AND FIELD OF APPLICATION

This method specifies the apparatus and the procedure to be applied for the analysis of construction of a specimen cut from a GRP lining. It includes determination of resin, glass, aggregate and filler contents and determination of the quality, disposition and orientation of the constituent glass layers.

E.2 PRINCIPLE

A specimen of known size is heated to burn off the resin and the residue analysed by separating and weighing the constituents.

E.3 APPARATUS

(a) Crucible of a suitable material and dimensions.

(b) Oven capable of maintaining a temperature of 105 to 110°C.

(c) Electric muffle furnace capable of maintaining a temperature between 450 and 650°C with an accuracy of ± 20°C.

(d) Bunsen burner or an oven.

(e) Desiccator.

(f) Balance with an accuracy of 0.1 mg.

(g) Sieves of suitable mesh.

E.4 TEST PIECES

The test piece shall be a rectangle, not less than 400mm² in area and not narrower than 12mm, cut from a lining. It shall be square cut, have smooth edges and be free from dust. The number of test pieces shall be such that they are representative of the laminate.

E.5 CONDITIONING

No conditioning of the specimen is required.

E.6 PROCEDURE

E.6.1

Measure the axial and circumferential dimension of the test piece to the nearest 0.1mm. Calculate and record the area in mm² as A.

E.6.2
Heat the crucible in the furnace to 625 ± 20° for 15 minutes. Cool in the desiccator and weigh to the nearest 1 mg. Record the mass as M_1.

E.6.3
Heat the crucible and specimen in the oven to 100° to 105°C for 2 hours. Cool in the desiccator and weigh to the nearest 1 mg. Repeat by heating for 30 minutes periods until a constant weight within 1 mg is obtained. Record the total mass as M_2.

NOTE In the case of freshly manufactured lining known to be dry, E.6.3 may be omitted.

E.6.4
Heat the crucible and specimen in a bunsen flame or in an oven until the contents ignite. Maintain such a temperature that the specimen burns uniformly at a moderate rate until only ash and carbon remain when the burning ceases.

NOTE 1 Care must be taken in E.6.4 to prevent the combustion proceeding so rapidly that there is a mechanical loss of non-combustible residue, e.g. filler.

NOTE 2 Care should be taken in E.6.4 to avoid breathing of the vapours.

E.6.5
Heat the crucible and residue in the muffle furnace at 625 ± 20°C until all carbonaceous material has disappeared. Cool in the desiccator and weigh to the nearest 1 mg. Repeat E.6.5 until a constant weight within 1 mg is obtained. Record the total mass as M_3.

NOTE 1 The time taken for the carbonaceous residue to disappear is largely dependent on the test piece geometry. It can be 6 hours or more, but is usually much less.

NOTE 2 For glass reinforcements which are unstable at 625°C, a temperature between 500 and 600°C may be chosen. The chosen temperature must be kept constant to ± 20°C.

E.6.6
Separate the layers of glass by tweezers or spatula, noting the number of layers, the orientation and disposition.

E.6.7
Separate the aggregate if present by scraping, shaking or brushing from the glass and sieve to remove the filler, if present. Weigh the aggregate to the nearest 1mg and record the mass M_4. Collect the filler passing through the sieve and add to that obtained in E.6.8.

NOTE In the case of filled laminated especially those containing fillers of small particle size (including thixotropic agents), accurate analysis of the construction may prove to be difficult. This is due to the difficulty in separating such fillers from the other constituents and the risk of some filler being lost during combustion.

E.6.8
Sieve separately the various types and orientations of glass and record the masses as M_{5a}, M_{5b} etc. and the total mass of glass as M_5.

E.6.9
Add the filler obtained in E.6.8 to that obtained in E.6.7 and weigh the total to the nearest 1 mg. Record the mass as M_6.

E.6.10
If any synthetic fibre tissue is included in the construction of the laminate, estimate its mass from the area of the specimen and the known mass per unit area of the tissue used. Record the estimated mass as M_7.

E.7 CALCULATIONS

E.7.1
Total glass, percentage by mass = $\dfrac{M_5 \times 100}{M_2 - M_1}$ %

E.7.2
Individual laminate glass contents, percentage by mass = $\dfrac{M_{5a} \text{ or } M_{5b} \text{ etc.} \times 100}{M_2 - M_1}$ %

E.7.3
Resin, percentage by mass = $\dfrac{(M_2 - M_3 - M_7) \times 100}{M_2 - M_1}$ %

E.7.4
Aggregate, percentage by mass = $\dfrac{M_4 \times 100}{M_2 - M_1}$ %

E.7.5
Filler, percentage by mass = $\dfrac{M_6 \times 100}{M_2 - M_1}$ %

E.7.6
Synthetic tissue, estimated, percentage by mass = $\dfrac{M_7 \times 100}{M_2 - M_1}$ %

E.7.7
Total mass of glass per unit surface area of laminate = $\dfrac{M_5}{A}$

E.7.8
The individual masses of glass per unit surface area of laminate = $\dfrac{M_{5a}}{A}$, $\dfrac{M_{5b}}{A}$ etc.

E.8 REPORT
The test report shall include the following:

(a) Full identification of the lining tested.

(b) The dimension of the test piece.

(c) The temperature of the furnace.

(d) Whether preliminary drying (E.6.3) was carried out.

(e) The percentage by mass of the constituents of the laminate.

(f) The total mass of glass per unit surface area of laminate.

(g) The type, number of layers, disposition, orientation and individual percentage mass of the individual glass constituents.

(h) Observations in regard of any irregularities noted during the test such as excessively rapid combustion in E.6.4 or melting in E.6.5.

APPENDIX F – SAMPLING FREQUENCY FOR QUALITY CONTROL TESTS

F.1 ACCEPTABLE QUALITY LEVEL (AQL)

Quality control tests shall be carried out to achieve and AQL of 10% defectives at an inspection level of S-3 as described in BS 6001 using the double sampling plan (except where 100% testing is specified in this specification).

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 2.

Table 2 – 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				

F.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:

(a) 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 rejected.

(b) If the number of defectives in a sample is equal to or greater than the rejection number corresponding to that sample then the batch is rejected.

(c) 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.

(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.

F.3 SWITCHING RULES FOR SAMPLING 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 in 2 out of 5 or less successive batches are rejected using normal inspection.

(c) Tightened inspection shall be continued until five 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 BS 6001 Table VIII for exceptions).

(ii) The total number of defectives in all the samples tests from the proceeding 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 BS 6001 Table VIII.

(iii) The production is at a steady rate.

(iv) Reduced inspection is considered desirable by the independent inspector where a third party certification scheme acceptable to WRc Engineering is used, 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 a defective unit in any batch.

APPENDIX G –APPEARANCE CRITERIA

Table 3 – Types of defect and final allowable limits

DEFECT	DEFINITION	FINAL ALLOWABLE LIMITS		NUMBER AND SIZE OF DEFECTS ON SURFACE WHICH MAY BE REPAIRED PER LINING UNIT (Not more than 20% of units in a batch may be repaired for any one type of defect)
		EXTERNAL SURFACE	INTERNAL SURFACE	
Craze or crack	Craze or crack on surface usually star shaped, caused by sharp impact (or circumferential hairline cracks).	None	None	Only one and if less than 500mm diameter or 100mm length.
Delaminations and blisters	Separation in the laminate (due to any cause).	None to exceed 10mm in diameter and 0.5% of area to be affected.	None to exceed 3mm in diameter. Not more than 0.05% of unit area to be affected.	Only if none more than 400mm^2 in area and not more than 0.5% of surface area of lining unit affected.
Surface voids	Small air pockets or voids on the surface or directly beneath the surface mat.	None greater than 10mm in diameter and 0.5% of area to be affected.	None greater 1mm deep and/or 3mm diameter. Not more than 0.05% of lining unit area to be affected.	If less than 400mm^2 and if no more than 0.5% of surface area of lining unit affected.
Dry area	Area in laminate with glass or aggregate not wet out with resin.	None	None	Only one area not exceeding 2mm in depth and 2000mm^2 in area.
Foreign matter	Extraneous particles on inner surface.	N/A	None	Only one affected area up to 2mm depth and area up to 1000mm^2.
Pits	Shallow air inclusions on inner surface.	N/A	Not exceeding 1mm diameter and 0.5mm deep to maximum of 5% of linear surface.	All.
Missing surface tissue	Tissue/mat omitted.	Not if specified.	None	If less than 5% of surface area of lining unit affected.
Protruding fibres	Localised areas of fibre protruding from surface.	None	None	Maximum of three areas of less than 100mm^2 each.
Hand lay-up	Areas at the edge of hand lay-up that are not rolled down properly and that are rough.	None	None	Only if uncompacted areas removed by cutting out.
Ground areas	Area around lay-up which has been abraded but lay-up does not cover or has not been coated.	None (unless part of bond coat application process)	None	To maximum limits of repairs permitted by this table.
Wrinkles and indentations	Smooth irregularities on inner surface.	N/A	None greater than 3mm deep	If no deeper than the less of 6mm or 25% of lining wall thickness and not affecting more than 0.5% of surface area of lining unit.
Torn edges, end delaminations and end gouges	Tears and rips in cut edges of linings.	None	None	Only if non structural damage extending not more than 30mm in length.
Resin runs	Runs of resin on surface.	Minimal	None	All.
Score marks and scratches	Surface damage caused by sharp object.	None greater than 0.5mm deep. Not more than 100mm/m^2 of lining area.	None greater than 0.25mm deep. Not more than 100mm/m^2 of lining area.	If less than 1mm deep and less than 500mm per m^2 of lining area.
Surface tackiness	Permanently tacky surface normally due to inhibition of cure of surface layer of resin.	None	None	Reject unit.

N/A = not applicable

APPENDIX H –TYPICAL CERTIFICATE

CERTIFICATE

We, ... hereby certify that the Glassfibre Reinforced Plastics sewer linings manufactured on ..... and supplied to ..... on ..... have been manufactured and tested in accordance with the requirements of Information and Guidance Note No. 4-34-02; Issue 1 published by WRc Engineering to give:

(a) a minimum design wall thickness of ..... mm

(b) a maximum overall wall thickness of ..... mm

(c) a minimum short term stiffness of ..... N/m^2 (if a pipe lining unit)

(d) a minimum short term bending modulus of ..... MPa (N/mm^2)

(e) a minimum long term bending modulus of ..... MPa (N/mm^2)

(f) long term permissible strain of ..... %

(g) a minimum long term tensile strength of ..... MPa (N/mm^2)

(h) a nominal initial ultimate resistance to longitudinal force of ..... kN/m (state test method)

Our Company does/does not* have third party certification acceptable to WRc in respect of this specification and the lining units are/are not* marked with the number 4-34-02.

* Delete whichever is not applicable.

Signed .....

on behalf of .....

on .....