

Information and Guidance Note

SPECIFICATION FOR PRECAST GUNITE SEWER LININGS

FOREWORD

This is one of a number of specifications which have been prepared by WRc Engineering in order to assist engineers responsible for renovation of sewers. This publication covers precast gunite sewer linings suitable for Type I design 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 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 a contract is entered into for the supply of precast gunite linings is included in Appendix A.

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.

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.

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 values are quoted in MPa (megapascals)*

*1 MPa = 1MN/m² = 1N/mm²

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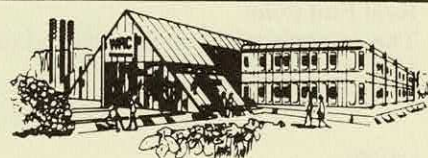
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1. SCOPE

This specification defines the requirements for construction, materials, dimensional tolerances, joints, testing, workmanship, and inspection of precast guniting 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:-

Guniting

Sprayed concrete with a maximum aggregate size less than 10mm.

Dry Process

A mixture of cement and aggregates, weight or volume batched, thoroughly mixed dry and fed into a purpose made machine wherein the mixture is pressurised, metered into a dry airstream and conveyed through pipes to a nozzle at which **water** is injected to the mix which is then projected without interruption into place.

Wet Process

A mixture of cement and aggregate, weight or volume batched and mixed with water in a purpose made machine or in a mixer truck prior to being conveyed through a hose or pipe to a nozzle, where **air** is injected and the mix projected without interruption into place.

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 sewer lining which may be either a single pipe lining unit or a combined pair of segmental lining units.

Major Axis Length

The distance between the crown and invert of a lining section or the distance between the springing whichever is the larger.

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.

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

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).

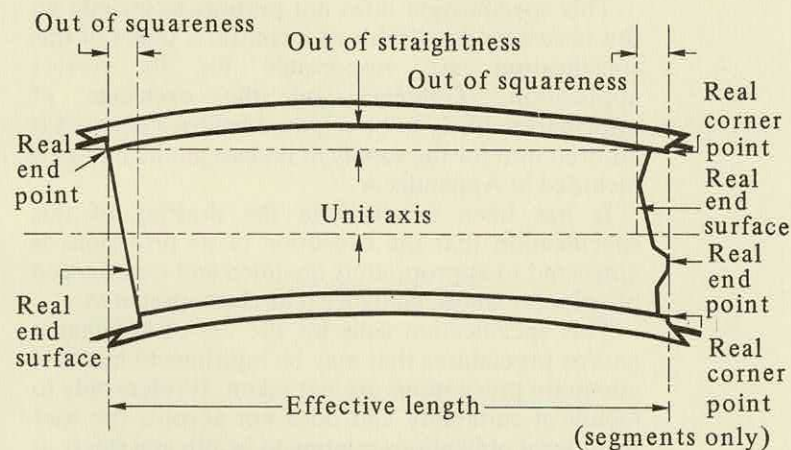


Figure 1 – Section through or plan of a nominal straight lining unit (Diagrammatic only)

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

3. MATERIALS

3.1 Cement

The cement shall be ordinary or rapid hardening Portland cement complying with the requirements of BS 12 or sulphate resisting Portland cement complying with the requirements of BS 4027.

The type of cement used shall be selected by the manufacturer to provide the lining with the required mechanical and chemical properties.

Each consignment of cement shall be identified, stored in dry conditions, protected against deterioration and used in order of manufacture.

3.2 Aggregates

Aggregates shall consist of materials complying with the requirements of BS 882 and shall be from a source approved by the purchaser.

The aggregate size shall not exceed 10mm and comply with the fine aggregate grading in Table 5 BS 882: 1983.

The limiting values of the mechanical properties of the aggregate shall be either a minimum 10% fines value of 100 kN or a maximum aggregate impact value of 30% when determined in accordance with BS 812: Part 3.

The chloride ion content of aggregate when determined in accordance with BS 812 Part 4 shall not exceed 0.06% by mass of the aggregate for 95% of the test results with no individual result greater than 0.08%.

Aggregates shall be handled and stored to minimise segregation and avoid contamination.

3.3 Water

Water used in the mix shall be of potable quality and be free from harmful matter.

Where tests are required they shall be conducted in accordance with BS 3148.

3.4 Admixtures

Admixtures complying with the requirement of BS 5075: Part 1 may be used with the approval of the purchaser and their suitability verified by trial mixes. Combinations of admixtures in one mix should not be undertaken without the approval of the purchaser and consultation of the admixture manufacturers. The manufacturer shall provide for the approval of the purchaser the amount of the admixture to be added to the concrete mix, the method of use including the chemical names of the main active ingredients in the admixture and the reason why the use of the admixture is being proposed. The detrimental effects, if any, of under-dosage or over-dosage shall be established particularly in relation to durability throughout the service life of the Works. The information scheduled in clause 7 of BS 5075: Part 1: 1982 shall be provided.

All admixtures shall be used strictly in accordance with the manufacturer's instructions. Admixtures shall be incorporated using a dispensing system sufficiently accurate to deliver within $\pm 5\%$ of the approved dosage rate.

No admixture containing calcium chloride shall be used.

3.5 Pulverised-fuel ash

Where pulverised-fuel ash (PFA) is used it shall comply with BS 3892: Part 1 and the total sulphate content (expressed as sulphuric anhydride SO_3) of the mix shall not exceed 4% by weight of the cement. The sulphate content shall be calculated from the sulphate content of the cement, aggregate (where applicable) and PFA as determined by tests carried out in accordance with BS 4550: Part 2 and BS 3892: Part 1.

PFA shall not be used in conjunction with sulphate resisting Portland cement.

3.6 Reinforcement

The reinforcement shall be plain round mild steel (rods or bars) to the requirements of one of the following British Standards:

BS 4449, BS 4461, BS 4482 or BS 4483.

All reinforcement shall be free from any coating, loose rust, scale, oil, grease or other deleterious matter.

4. CONSTRUCTION AND MANUFACTURE

4.1 General

Sewer lining segments shall be precast above ground

on formers shaped to give the required geometry.

The precast segments shall contain sufficient mild steel reinforcement to enable the segments to be handled and installed without damage to their structure. Each segment shall have reinforcement protruding from within the wall thickness to facilitate jointing to adjacent segments within the sewer.

4.2 Mix design

4.2.1 Cement content

The cement content of the mix shall not be less than 340kg/m^3 and not greater than 550kg/m^3 .

4.2.2 Aggregate content

The cement/aggregate ratio should not be less than 0.25:1 or greater than 0.33:1.

4.2.3 Water content

The water/cement ratio of the mix shall not exceed 0.45:1.

4.2.4 Chloride ion content

The total chloride ion content of the mix expressed as a percentage chloride ion by weight of cement shall not exceed 0.35% for 95% of test results with no result greater than 0.5%.

4.3 Manufacture

4.3.1 General

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. All raw materials shall be stored and used in compliance with the recommendations of their manufacturers.

All operators shall be approved by the purchaser.

Prior to commencement of spraying, the manufacturer shall certify to the purchaser that the foreman, nozzle men and delivery equipment operatives have completed satisfactory work in similar capacities elsewhere. Where required by the purchaser the operators shall spray preconstruction panels (see clause 4.3.11) which shall be approved by the purchaser before the operators are employed on the Works. Such panels may also be used by the purchaser to assess the competence of operators or trainees for whom such certification is not available.

4.3.2 Formers

Formers shall be timber or steel and shall be evenly coated with an approved release agent. Contact of release agent and reinforcement shall be avoided.

4.3.3 Reinforcement

Reinforcement shall be firmly fixed to give the minimum cover defined in 4.3.7, and in accordance with the clearances and gaps required by the contract or specified by the purchaser.

Unless otherwise agreed with the purchaser reinforcement should protrude from the edges of the sprayed concrete by not less than 100mm to facilitate jointing of individual lining segments.

4.3.4 Batching

Weigh batching shall be employed unless volume batching is approved by the purchaser. Batch weights of aggregate shall where necessary be adjusted to allow for the moisture content.

4.3.5 Mixing

All constituents shall be uniformly dispersed throughout the mix. No frozen materials shall be used.

Ordinary Portland cement shall not be mixed with sulphate resisting Portland cement (SRPC).

PFA shall not be used with SRPC.

4.3.6 Spraying

No concrete shall be mixed or sprayed in air temperatures less than 5°C.

No concrete shall be sprayed on to frozen surfaces. Freshly sprayed concrete shall be protected from rain, water, direct sunlight and drying winds and the ambient temperature shall not fall below 5°C until the units are cured.

The concrete shall be applied so that it neither sags or slumps.

Reinforcement shall be completely surrounded by concrete except that which protrudes from the edges of the lining unit.

During starting or stopping of the spraying operation or whenever spraying is irregular the nozzle shall be directed away from the work until uniform flow is attained.

Rebound material shall not be worked into the construction or reused.

4.3.7 Cover to reinforcement

The thickness of concrete cover to reinforcement shall not be less than 20mm on the inside face of the segment and not less than 10mm on the outside face.

4.3.8 Surface finish

The internal surface of the lining unit shall have a Type B finish as defined in 6.10.3 of BS 8110: Part 1: 1985.

4.3.9 Curing

Units shall be protected from direct sunlight and kept in a humid frost free atmosphere for a minimum of 7 days whilst curing. Membrane curing shall not be used.

Units may be stripped from their moulds in accordance with 6.9.3.2 of BS 8110: Part 1: 1985.

4.3.10 Plant

Delivery equipment should be capable of delivering a continuous even flow of uniformly mixed material to the nozzle.

The water supply at the nozzle shall be maintained at a uniform pressure in the case of the dry process.

In both wet and dry processes, the supply of compressed air shall be uninterrupted and sufficient to maintain adequate nozzle velocity.

Accuracy of weigh batching equipment shall be within $\pm 3\%$ of the quantity of cement or aggregates being measured.

4.3.11 Preconstruction test panels

Preconstruction testing, where required, shall be carried out using plant identical to that proposed for

the Works and shall be undertaken in such time before commencement of the Works to allow approval by the purchaser.

Trial mixes of each mix design proposed shall be produced by the contractor. For each mix design or for each type of plant test panels of minimum size 750mm \times 750mm shall be sprayed with the appropriate reinforcement and unit thickness as detailed by the purchaser.

Preconstruction test panels shall be tested in accordance with 7.2 to 7.4

5. DIMENSIONS

5.1 Section lengths

Lining sections shall be provided to the overall effective lengths specified by or agreed with the purchaser to within a tolerance of ± 10 mm.

5.2 Effective length

The difference in effective length of a pair of segments intended to fit together to form a lining section shall not exceed 10mm.

5.3 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 ± 5 mm of that specified by or agreed with the purchaser, whichever is the smaller.

5.4 Wall thickness

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

5.5 Out-of-squareness

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

5.5 Out-of-straightness

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

6. JOINTS

Edges and ends of lining units shall be chamfered as shown in Figure 2 to facilitate the insitu construction of joints whilst avoiding rebound traps.

When installed the protruding reinforcement shall overlap by at least 50mm.

Longitudinal joints between lining units shall be at the springings.

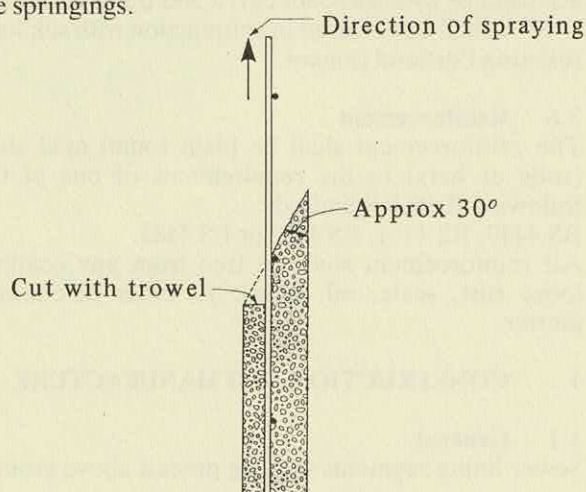


Figure 2 – Joint detail

7.1 General

The requirements given in 7.2 to 7.4 shall be met before compliance to this specification can be claimed and whenever a change in process technique or introduction of a new or modified compound has occurred. The Quality Assurance Schedule of the quality system (see 8.1) may require type tests to be repeated at specified intervals in addition to any required under 4.3.11.

Unless otherwise specified, the test samples shall be taken from a batch from which the product has complied with all other requirements of this specification.

All tests are the responsibility of the manufacturer. Details and results for type tests relevant to each material composition and manufacturing process shall be made available to the purchaser or his representative on request.

7.2 Compressive strength

Core samples taken from a precast unit shall have an equivalent 150mm in situ cube compressive strength of at least 40MPa (N/mm²) at 28 days when tested in accordance with the method detailed in Appendix B.

7.3 Concrete density

The concrete density of the core samples taken for strength testing shall be determined in accordance with the method detailed in Appendix B. The 95% lower confidence limit of the results shall form the minimum requirement for quality control purposes.

7.4 Shear bond strength

The lining unit shall be tested in accordance with the method described in Appendix C and shall attain a minimum shear bond strength of 1.0MPa (N/mm²).

Samples with external surface finish representative of those tested shall be retained for quality control comparison purposes.

8. QUALITY CONTROL TESTS

8.1 General

The test requirements of 8.2 to 8.6 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 D.

8.2 Dimensions

The overall length, effective length, cross section, out-of-squareness and out-of-straightness shall be determined using a method of measurement accurate to the nearest mm and comply with the requirements of clause 5.

Wall thickness shall be determined by measuring cut sections through the lining wall at a minimum of five locations for each test sample using a method of measurement accurate to the nearest 0.1mm. Similarly the cover from both surfaces to the reinforcement shall be determined and comply with 4.3.7. Generally the location of the cut surfaces shall include:

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

8.3 Compressive strength

At least five cores shall be cut from the finished lining unit at positions indicated in 8.2(i), (ii) and (iii) (or by the purchaser) and tested in accordance with Appendix B.

The average 150mm equivalent cube compressive strength shall not be less than 40MPa (N/mm²) at 28 days and the difference between individual results shall be less than 20% of the mean value. This requirement is deemed to be satisfied (and product may be released) if the 10 day compressive strengths are no less than those obtained for 7.2 on product satisfying the 28 day requirement.

8.4 Density

The density of at least five cores taken from the finished lining unit shall be determined in accordance with Appendix B.

The density shall not be less than the 95% lower confidence value declared from type testing.

8.5 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 (7.3).

If it is equivalent in respect of surface roughness, 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.

8.6 Appearance

Lining units shall have the general physical appearance of a dense well compacted concrete. There shall be no significant air voids, foreign matter or cracks.

The internal finish shall be smooth and comply with 4.3.8.

9. INSPECTION AND CERTIFICATION

9.1 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 areas used for manufacture and testing and to all relevant test records.

9.2 Certification

The manufacturer shall, upon request, furnish the purchaser or purchaser's representative with copies of a signed certificate for each size and classification of lining stating that the construction and testing of the lining 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 E.

10. MARKING

All lining units shall be marked on the inside face.

No method of marking shall prejudice the performance of the lining when in service.

The marking shall give the following information:

- (a) The manufacturer's name, initials or identification mark.
- (b) The number 4-12-05. The marking of the number 4-12-05 on products produced to this specification may only be applied by manufacturers covered by a third party certification scheme acceptable to WRc.
- (c) The letters "OPC", "RHPC" or "SRPC" to indicate the type of cement used.
- (d) The batch and date of manufacture. Coding of this information is permitted provided that the meaning of the code is available on request.

11. 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 WRc.

Specification for Sprayed Concrete, published by the Concrete Society.

- BS 12 Specification for ordinary and rapid hardening Portland cement.
- BS 812 Methods for sampling and testing of mineral aggregates, sands and fillers.
Part 3 Mechanical properties
Part 4 Chemical properties
- BS 882 Specification for aggregates from natural sources for concrete.
- 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
Part 114 Methods for determination of density of hardened concrete
Part 115 Specification for compression testing machines for concrete
Part 120 Method for determination of the compressive strength of concrete cores.
- BS 3148 Methods of test for water for making concrete (including notes on the suitability of the water).
- BS 3892 Pulverized-fuel ash.
Part 1 Specification for pulverised-fuel ash for use as a cementitious component in structural concrete.
- BS 4027 Specification for sulphate resisting Portland cement.
- BS 4449 Specification for hot rolled steel bars for the reinforcement of concrete.
- BS 4461 Specification for cold worked steel bars for the reinforcement of concrete.
- BS 4482 Hard drawn mild steel wires for the reinforcement of concrete.
- BS 4483 Steel fabric for the reinforcement of concrete.

BS 4550 Methods of testing cement.
Part 2 Chemical tests

BS 4551 Methods of testing mortars, screeds and plasters.

BS 5075 Concrete admixtures
Part 1 Specification for accelerating admixtures, retarding admixtures and water-reducing admixtures.

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.

BS 8110 Structural use of concrete
Part 1 Code of practice for design and construction.

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. It does not form a mandatory requirement of this specification.

A.2 Information to be provided by purchaser

- (a) Details of sewer environment (for selection of appropriate materials),
- (b) Size and shape of sewer to be lined,
- (c) Compressive strength of gunite (if greater than 40MPa (N/mm²) required),
- (d) Proposed grouting pressure and method.

A.3 Details to be agreed between purchaser and manufacturer

- (a) Shape and cross section dimensions,
- (b) Wall thickness (maximum overall and minimum structural),
- (c) Lengths of segments,
- (d) Joint details.

A.4 Information to be provided by manufacturer

- (a) Method of manufacture,
- (b) Constituent materials and proportions.
- (c) 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 having identical composition and thickness as the lining units under consideration should be submitted to the purchaser upon request.

B.1 Cut at least five 100mm or preferably 150mm cores from the lining panel at right angles to the surface approximately 48 hours after its production in accordance with the procedure in BS 1881: Part 120.

Cores shall not be taken within 125mm of the edges of the panel. The position of the cores shall be indicated either by the purchaser or in accordance with 8.2.

B.2 All cores shall be labelled to identify them with the panels from which they were taken.

B.3 Cores shall be inspected before testing and any defects such as lack of compaction, dry patches, voidage or aggregate pockets shall be recorded using the methods described in 4.4 of BS 1881: Part 120: 1983.

B.4 Measure the dimensions of the core and the depth of cover to reinforcement (if present) from both surfaces.

B.5 Prior to capping for compressive strength testing determine the volume (V) m^3 of the trimmed cores using the water immersion procedure in clause 7 of BS 1881: Part 114: 1983.

B.6 If the cores contain no reinforcement the saturated concrete density shall be determined in accordance with BS 1881: Part 114.

B.7 Cap the cores in accordance with BS 1881: Part 120 taking care to prevent air being trapped in the capping material and between the core and the capping material.

B.8 If the saturated density of the capping material is not known to within $\pm 1\%$ its density should be determined by fabricating samples and testing to BS 1881: Part 114.

B.9 Determine the volume of the capped cores (V_c) m^3 using the water immersion procedure in clause 7 of BS 1881: Part 114: 1983.

B.10 Immerse the capped cores in water at $20 \pm 2^\circ C$ for the required period of time.

B.11 Test as follows:

One core after 5 days from spraying (for monitoring product consistency).

One core after 10 days from spraying.

Three cores after 28 days from spraying.

Immediately prior to compressive testing weigh the capped core in air (in the soaked surface dry condition) to determine its mass M (kg).

If the core contains reinforcing steel it shall be extracted after the core compressive test and its mass determined in kg. The volume of the reinforcing steel shall be determined in m^3 by the displacement of the meniscus in a measuring cylinder of water.

B.12 Calculate the saturated density of the sprayed concrete (D) from the following equation:

$$D = \frac{M - D_c (V_c - V) - M_s}{V - V_s} \text{ kg/m}^3$$

Where: D = Density of sprayed concrete

D_c = Density of the capping material (kg/m^3)

M = Mass of the wet capped core (kg)

M_s = Mass of the steel reinforcement core:
zero if non present (kg)

V = Volume of the uncapped core (m^3)

V_s = Volume of the steel reinforcement: zero if
none present (m^3)

B.13 Compressive strength tests shall be conducted in accordance with BS 1881: Part 120 and the estimated in situ cube strength calculated.

B.14 The test report shall include:

- (a) Identification of the samples.
- (b) Date of drilling, capping, testing.
- (c) Storage period and conditions.
- (d) Presence of reinforcement.
- (e) Quality of core.
- (f) Core dimensions, maximum and minimum depth of cover to reinforcement.
- (g) Capping method and length after preparation.
- (h) Maximum load at fail.
- (i) Measured compressive strength and estimated in situ strength at 5, 10 and 28 days.
- (j) Type of failure.
- (k) Density of capping material.
- (l) Density of sprayed concrete.

APPENDIX C – METHOD FOR THE DETERMINATION OF SHEAR BOND STRENGTH

C.1 Scope

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

C.2 Apparatus

- (a) Compression testing machine accurate to grade 1.0 of BS 1610: 1985 (see BS 1881: Part 115).
- (b) Shear testing rig of the form shown in Figures 3, 4 and 5.
- (c) Load spreading bar of the form shown in Figure 6.

C.3 Materials

C3.1 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 0.40:1.

C3.2 At least three specimens approximately 150mm \times 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.

C.4 Preparation and conditioning

C4.1 The cut lining samples shall be immersed in water for at least 24 hours prior to testing.

C4.2 The lining samples shall be placed in 150mm cube moulds with roughened "outside" surface facing upwards.

C4.3 The grout shall be mixed in a suitable grout mixer (neither hand mixing nor the use of freefall concrete mixers shall be permitted).

C4.4 Grout shall be poured onto the linings in the moulds to a depth of 100 ± 5 mm.

C4.5 From each batch of grout cast, 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.

C4.6 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.

C4.7 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.

C.5 Procedure after preparation

C5.1 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.

C5.2 Force shall be applied without shock and increased continuously at a rate of approximately 0.5MPa (N/mm^2) per minute until failure. The maximum force applied to the lining shall be recorded.

C5.3 A note shall be made of the failure mode, usually either grout or bond failure.

C.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).

C.7 Report

The report shall include the following:

- The identification of the lining and the grout mix,
- The individual shear strength results and the mean value (to 0.1MPa (N/mm^2)),
- The failure modes,
- The grout compressive strength results,
- The period of the test.

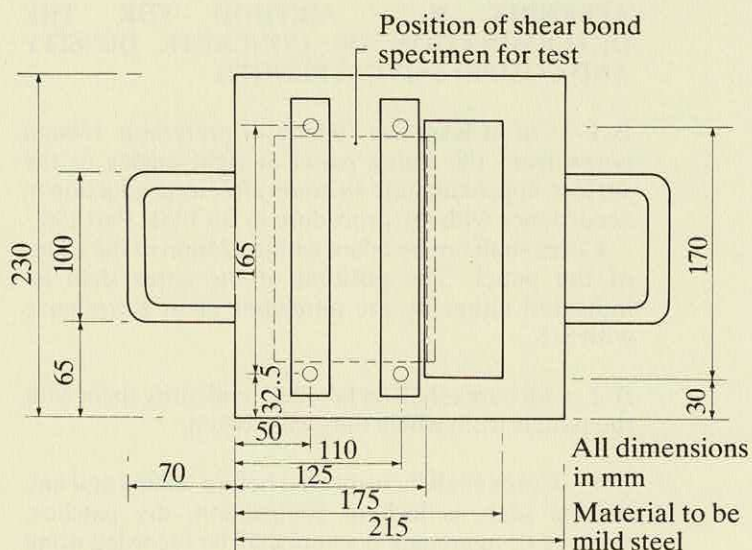


Figure 3 – Plan: shear bond rig

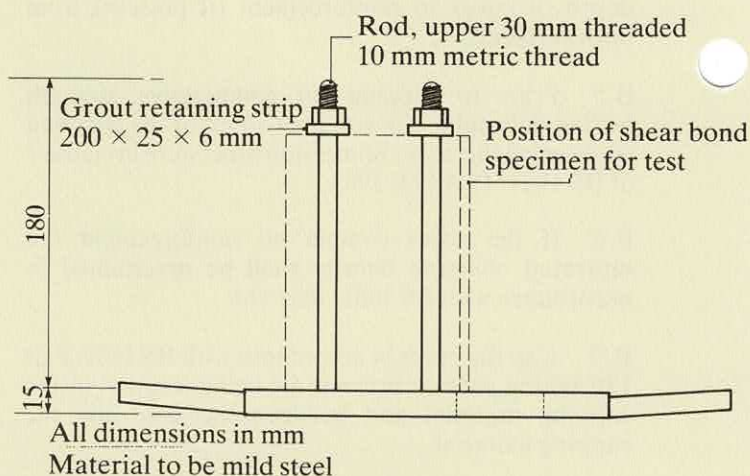


Figure 4 – Elevation: shear bond rig

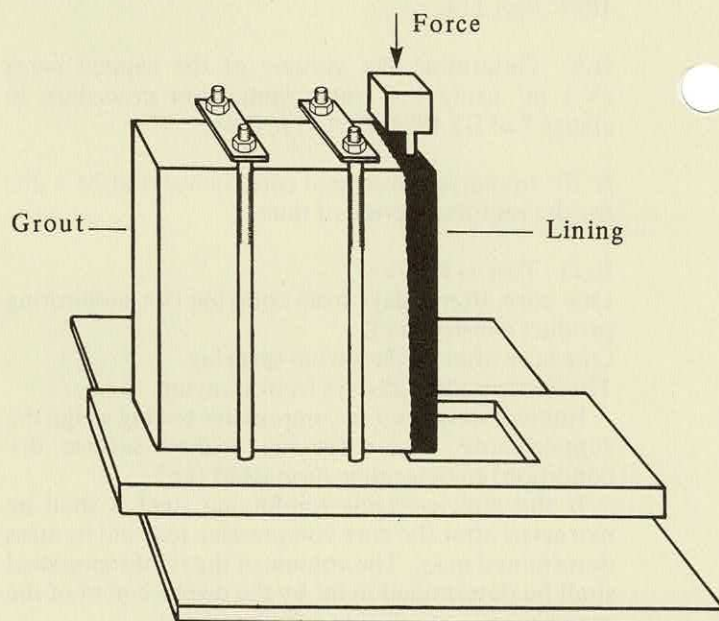


Figure 5 – Assembled shear bond apparatus

All dimensions in mm

Material to be mild steel

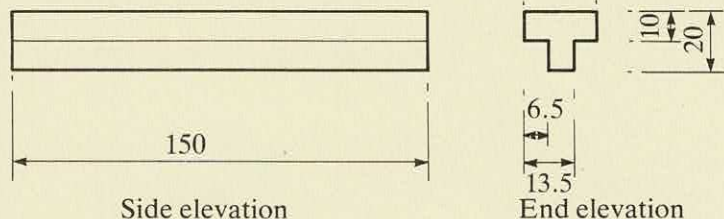


Figure 6 – Load spreading bar

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 (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				

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

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:

(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 accepted.

(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.

D.3 Switching rules for sampling frequency variation

The switching rules between the different inspection levels are described in BS 6000 and BS 6001 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 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 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 BS 6001 Table VIII.

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 is 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 a defective unit in any batch.

APPENDIX E – TYPICAL CERTIFICATE

CERTIFICATE

We, hereby certify that the Gunitite sewer linings manufactured on and supplied to on have a minimum wall thickness of mm and have been manufactured and tested in accordance with the requirements of Information and Guidance Note No. 4-12-05; Issue 1, Specification for Precast Gunitite Sewer Linings, published by WRc Engineering.

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 4-12-05.

*Delete as applicable.

Signed:

On behalf of

on