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Information and Guidance Note

SPECIFICATION FOR POLYESTER INSITUFORM SEWER LININGS

FOREWORD

This is one of a number of specifications which have been prepared by WRc in order to assist engineers responsible for renovation of sewers. It covers Insituform sewer linings suitable for Type II designs as defined in the Sewerage Rehabilitation Manual published by WRc.

Insituform is manufactured by a process which involves impregnation of felt with liquid resin, installation in a sewer and production of the final cured product by internal heating.

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 = 1N/mm²

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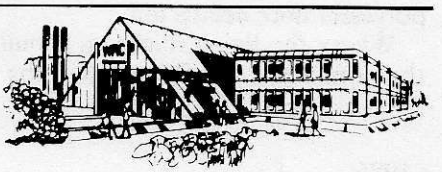

SPECIFICATION FOR POLYESTER INSITUFORM SEWER LININGS

1. SCOPE

This specification defines the requirements for construction, manufacture, materials, dimensional tolerances, testing, workmanship, inspection and certification of Insituform linings for the renovation of sewers where the lining is designed to act as a flexible pipeline.

This specification relates only to Insituform linings incorporating polyester resin.

2. MATERIALS

2.1 Resins

Isophthalic polyester resins to the requirements Types B or C of BS 3532: 1962 shall be used.

Alternative resins with proven equivalent or higher performance characteristics than isophthalic polyester resin should only be used where appropriate type test data is available and with the agreement of the purchaser.

The type of isophthalic resin shall be selected so that its properties are suitable for the mechanical and chemical properties required of the completed product. Resins may contain only those additives approved by and up to the limits defined by the resin manufacturer to control viscosity and pot life.

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

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

2.2 Lining bag

The lining bag shall consist of one or more layers of needle interlocked polyester felt. The felt layer, which will be adjacent to the sewage environment when the lining is installed, shall have an integral impermeable membrane to facilitate installation.

Non corroding mechanical strengthening tapes or strips may be interleaved between the layers of needle felt to control longitudinal stretching during installation.

3. CONSTRUCTION AND MANUFACTURE

The lining shall consist of an inner impermeable membrane, optional longitudinal strengthening tapes, and polyester fibre needle felt impregnated with polyester resin.

The lining bag shall be formed to the required dimensions by heat welding or stitching sheets of polyester fibre needle felt.

Where the lining thickness is built up using more than one layer of polyester felt, the joints in the felt shall be offset to prevent excessive local thickening of the completed lining.

The resin system and the lining thickness shall be selected to meet the chemical resistance and structural requirements for the lining.

The volume of resin used to impregnate the lining shall be between 0 and 15% greater than the nominal volume of the polyester felt.

The bag shall be vacuum impregnated with resin under controlled conditions.

Materials and working temperatures during impregnation shall not be less than 15°C.

4. DIMENSIONS

4.1 Perimeter

The manufacturer shall fabricate the lining so that when inverted it fits neatly against the existing sewer wall, or as otherwise agreed with the purchaser. The installed lining shall be generally free from wrinkles except where a specified degree of wrinkling is agreed between purchaser and manufacturer.

4.2 Length

The manufacturer shall provide the lining in lengths such that no joins are required between points of access to the sewer unless otherwise agreed with the purchaser. The manufacturer shall be responsible for making due allowance for longitudinal stretch in the lining during installation and providing such additional length as is required to suit the installation method.

4.3 Wall thickness

The wall thickness at all points shall be at least the minimum specified and may be up to 15% greater except where felt layers overlap in which case it may be in excess of this value.

5. PERFORMANCE REQUIREMENTS

Unless different requirements are specified by the purchaser, the lining shall meet the minimum requirements given in Table 1 when tested in accordance with those clauses indicated.

Table 1 – Lining Performance Requirements

Property	Minimum Requirement	Test Clause
Short term bending modulus	2200 MPa	6.2
50 Year flexural creep modulus	As agreed with the purchaser but not less than 620 MPa	6.3

6. TYPE TESTS

6.1 General

The tests given in 6.2 to 6.5 shall have been satisfactorily completed before linings can claim to have met this specification. All combinations of wall thickness, constituent materials, material proportions and curing method shall be tested. Should there be any modifications to these, the tests must be repeated.

The Quality Assurance Schedule of the quality system (see 7.1) may require type tests to be repeated at specified intervals.

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.

Samples used for testing should be flat and formed in moulds but otherwise must be manufactured and cured in an identical manner to the linings with which they are to be identified.

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

The initial tangent flexural modulus of elasticity, flexural stress and strain at failure shall be determined in accordance with the procedure described in BS 2782: Method 335A using a cross head displacement rate of 10mm/min.

Each test piece shall be tested with the impermeable membrane in contact with the load bearing supports.

The flexural properties of each test piece shall not be less than the following requirements:

Initial tangent flexural modulus	2600 MPa
Flexural stress at first break*	50 MPa
Flexural strain at first break*	1.0% to 2.5%

(*as indicated by the first discontinuity of the force/extension curve).

6.3 **Flexural creep modulus**

The lining material shall meet the requirement of Table 1, clause 5, when tested under aqueous conditions in accordance with the method described in Appendix B.

6.4 **Tensile properties**

The tensile strength, initial tangent modulus of elasticity and elongation at first break shall be determined in accordance with BS 2782: Method 1003 using Type II or Type III test pieces, a grip separation rate of 2mm/min, and either an optical or strain gauge extensometer.

The tensile properties of each test piece shall not be less than the following requirements:

Initial tangent tensile modulus	1700 MPa
Tensile stress at failure	25 MPa
Elongation at first break*	1.5%

(*as indicated by the first discontinuity of the force/extension curve).

Results from samples breaking within 10mm of the grips shall be discarded and the test repeated with the occurrence being recorded.

6.5 **Compressive properties**

The compressive strength shall be determined in accordance with BS 2782: Method 345A using Type IV test pieces and a cross head displacement of 0.5h mm/min where h is the height of the test sample in mm. The compressive strength shall not be less than 60MPa.

7. QUALITY CONTROL TESTS

7.1 **General**

The test requirements of 7.2 to 7.6 are necessary in order to demonstrate a continuing satisfactory level of production and installation quality in day to day production. The manufacturer shall establish a quality system to meet the requirements of BS 5750: Part 2 and be covered by a third party certification scheme acceptable to WRc Engineering.

Quality control tests shall be carried out by the manufacturer on each lining length after it has been installed and cured. If any of the tests are failed the purchaser shall be informed immediately.

7.2 **Samples for quality control tests**

7.2.1 For each lining length one sample shall be fabricated and cured in a clamped mould using the method detailed in Appendix C.

When curing of the lining has been completed the mould samples shall be removed and subjected to quality control testing. With the exception of the wall thickness requirement (7.4), if all tests are passed than no further quality control testing is required.

7.2.2 Where possible and by agreement between the manufacturer and purchaser, provision shall be made to suitably support the lining bag either at the ends or at intermediate manholes. In cases where disagreement or dispute exists over the results obtained from the clamped sample, these samples or samples cut from the installed lining (removed at the manufacturer's cost) shall be used for repeat testing as required in 7.6.2. For test purposes attention is drawn to the curvature limitations and orientation requirements of samples taken from linings.

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

7.2.3 Should there be any disagreement following testing performed on samples described in 7.2.2 then, at the manufacturer's discretion and cost, either:

(a) the creep modulus shall be validated against the manufacturer's creep data obtained for 6.3, using an abridged creep test, on material removed from the lining, or

(b) the lining shall be replaced.

7.3 **Visual examination**

After installation each lining shall be visually examined either by walk through survey or by CCTV. The installed lining shall have a smooth internal surface which shall be generally free from wrinkles except where a specified degree of wrinkling is agreed between the purchaser and the manufacturer.

7.4 **Wall thickness**

The minimum wall thickness shall be determined at a minimum of five locations on a cut section of the lining using a method of measurement accurate to the nearest 0.1mm. The minimum value shall meet the requirements of 4.3.

Samples from the clamped mould shall also meet the requirements of 4.3.

7.5 **Tensile properties**

The tensile strength, initial tangent modulus of elasticity and elongation at first break of at least five samples shall be determined in accordance with BS 2782: Method 1003 using Type II or Type III test

pieces, a grip separation rate of 2mm/min, and either an optical or strain gauge extensometer. The tensile properties shall not be less than the minimum requirements set down in 6.4.

The test is not applicable to curved lining samples.

7.6 Short term flexural (bending) properties

7.6.1 For normal quality control testing using clamped mould samples.

A minimum of five samples shall be tested by the method prescribed in 6.2 with the impermeable membrane of the sample in contact with the load bearing supports.

The samples shall comply with the requirements of 6.2.

7.6.2 For repeat testing referrred to in 7.2.2.

Where practicable and agreed betwen the manufacturer and the purchaser a minimum of five test pieces shall be prepared.

Wherever possible, samples for test purposes shall have a radius of curvature not less than 250mm and be taken from the hoop direction. However, for linings where hoop samples cannot meet the curvature requirements, samples may be taken from the longitudinal direction.

When tested by the method prescribed in 6.2 with the impermeable membrane in contact with the load bearing supports, the samples shall comply with the requirements of Table 1 clause 5.

8. CONTROL OF TEST CONDITIONS

8.1 Test conditions

Unless otherwise required by this specification the test measurements shall be conducted at a temperature of 23 ± 2°C.

8.2 Specimen conditioning

8.2.1 For type testing in air (or in any cases of disagreement) specimens shall be kept in air at 23 ± 2°C for not less than 88 hours prior to testing.

8.2.2 For quality control testing, specimens shall be kept in air at 23 ± 2°C for not less than 12 hours after they are considered to be cured.

8.3 Test specimen preparation

For mechanical tests, specimens shall be machined following the recommendations of BS 2782: Method 930A.

9. WORKMANSHIP, INSPECTION AND CERTIFICATION

9.1 Workmanship

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 accordance with the recommendations of their manufacturers.

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

The lining shall be transported to site under controlled environmental conditions.

The manufacturer shall decide when to transport the impregnated lining to the site and when to commence insertion with regard to weather conditions.

For sewers with running infiltration, a prelining may be installed prior to lining inversion to prevent the uncured resin from being washed out of the lining bag.

The lining shall preferably be inverted from upstream to downstream into the prepared sewer using cold water.

The manufacturer shall ensure that the pressure in the lining exceeds both the pressure due to the groundwater head given by the purchaser in the lining design sheet and any pressure due to sewage in laterals.

As soon as the lining has been fully inverted, the resin shall be cured by raising, maintaining and then lowering the internal water temperature in a predetermined manner to suit the resin system used.

The rate of temperature rise and fall during the heating and cooling shall not exceed 1°C/min. The curing water shall not be released until it reaches a temperature below 40°C.

NOTE (For guidance only) A well cured polyester Insituform lining would be expected to have a Barcol hardness of not less than 35 when tested in accordance with BS 2782: Method 1001. Lining samples should be abraded to remove the soft impermeable membrane and to produce a flat surface before testing.

9.2 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.

9.3 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, 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 D.

10. 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.

BS 2782 Methods of testing plastics.

Method 121A Determination of temperature of deflection under a bending stress of 1.8 MPa, of plastics and ebonite.

Method 335A Determination of flexural properties of rigid plastics.

Method 345E Determination of compressive properties by deformation at constant rate.

Method 432B Determination of the acid value of unsaturated polyester resins.

Method 432C Determination of the hydroxyl value of unsaturated polyester resins.

Method 620A Determination of density of solid plastics excluding cellular plastics (immersion method).

Method 930A Preparation of test specimens by machining.

Method 1003 Determination of tensile properties.

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

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

BS 5750 Quality Systems.
Part 2: Specification for manufacture and installation.

APPENDIX A – CONTRACT INFORMATION

This Appendix is included for guidance only and does not form a requirement of the specification.

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

(i) Responsibility for sewer surveys and the accuracy of information obtained.

(ii) Responsibility for structural designs.

(iii) Responsibility for sewer cleaning.

(iv) Responsibility and scheduling for installation and use of prelining tube.

(v) Limitations on installation programme.

(vi) Responsibility for dealing with sewer flows.

(vii) Details of resin systems to be used.

(viii) Required/acceptable lining shapes and wrinkles etc.

(ix) Lengths of lining units.

(x) Method of transporting, handling, installing and curing the linings.

(xi) Lateral reconnections.

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

B.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.

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

B.2 APPARATUS

The apparatus is shown schematically in Figure 1. 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:

B2.1 A pair of supports that:

(a) are parallel,

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

(c) do not deflect under experimental forces,

(d) do not impose significant longitudinal restraint on the 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.

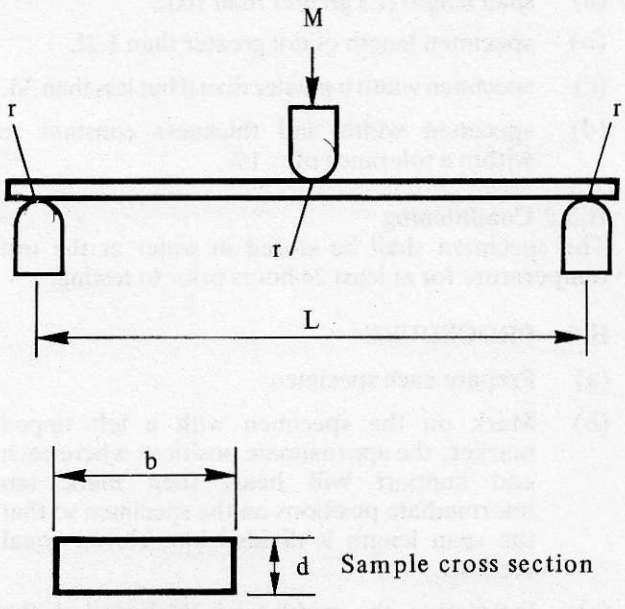

Figure 1 –
Schematic layout for three-point flexural creep tests

B.2.2 A means of applying to the specimen a force that:

(a) is constant,

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

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

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

B.2.3 A means of measuring the deflection of the specimen that:

(a) is 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 within ± 0.5%.

B.2.4 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.

B.3 TEST SPECIMENS

B.3.1 Preparation

For each of the minimum, maximum and an intermediate thickness manufactured, 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) 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%.

B.3.2 Conditioning

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

B.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.

(c) Determine the width and thickness of the specimen 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:

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

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 6.2.
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's longitudinal axis at right angles to the supports so that the 'inside surface' of the lining when in service will be in tension when the load is applied.

(i) Set and/or zero the deflection measuring device.

(j) Immediately after carrying out step (i), smoothly apply the mass M and commence timing the test.

(k) If continuous monitoring of deflection (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, 36, 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 $E_{(t)}$ for each value of $\delta_{(t)}$ at time t from:

$$E_{(t)} = \frac{2.45\,M\,L^3}{b\,d^3\,\delta_{(t)}} \text{ MPa} \qquad (2)$$

(m) Plot $\log_{10}$ creep modulus against $\log_{10}$ time. If for any reason the readings do not approximate to a smooth trace the test shall be abandoned, the occurrence recorded and the test repeated.

(n) The graph produced for each test specimen may appear to be a line which goes through a transition to an approximately straight line of greater slope. This being so, observe the position of the transition. After the transition or 50 hours (whichever is the later) regress the calculated values of $\log_{10}$ creep modulus on $\log_{10}$ time using the method of least squares and determine the extrapolated 50 year value of creep modulus E_L.

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

B.5 **REPORT**

For each specimen the test report shall include:

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

(b) Dimensions of the specimen,

(c) Method of specimen preparation,

(d) Graph or graphs of $\log_{10}$ flexural creep modulus versus $\log_{10}$ 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 C – METHOD FOR THE PRODUCTION OF CLAMPED MOULD SAMPLES

C.1 EQUIPMENT

The mould shall comprise a flat steel base plate and cover plate with threaded locating pegs at each corner. The approximate dimensions are given in Figure 2.

C.2 SAMPLE PREPARATION

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

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

Once the lining bag has been inverted, but before heating commences, the mould shall be suspended at the bottom of the inversion tube in the curing water.

The mould shall be withdrawn from the inversion tube after curing of the lining has been completed and despatched to a test laboratory.

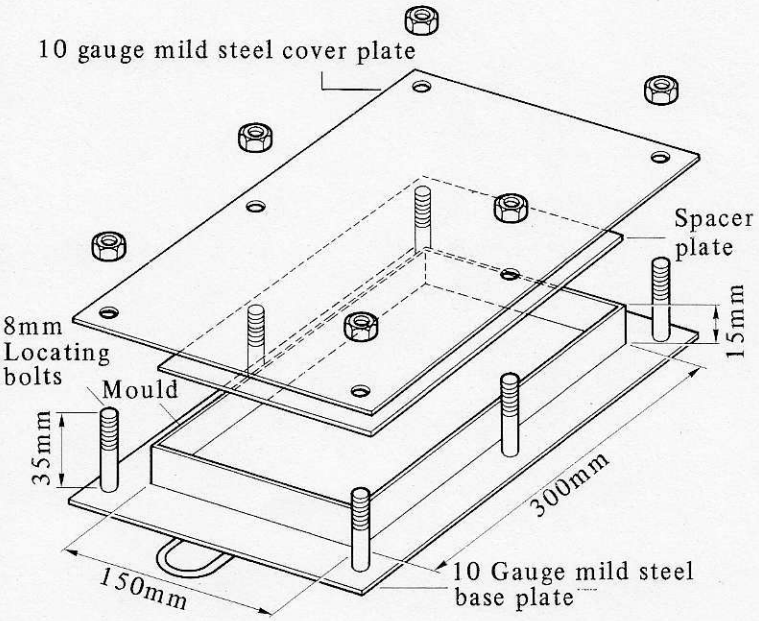

Figure 2 – Clamped mould

APPENDIX D – TYPICAL CERTIFICATE

CERTIFICATE

We, ... hereby certify that the Insituform sewer lining installed between ..... at ..... has a minimum wall thickness of ..... mm and has been manufactured and tested in accordance with the requirements of Information and Guidance Note No. 4-34-04; Issue 1, Specification for polyester Insituform sewer linings published by WRc Engineering.

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

*delete as applicable.

Signed .....

on behalf of .....

on .....