Standard Specification

Sydney WATER

SS 201
Linings for Circular Non Man-Entry Pipes

Version 1

1 General

1.1 Intent

This specification defines the requirements for the rehabilitation of non-man-entry circular sewers by lining. This work may be required to protect the internal concrete surfaces from deterioration, restore structural integrity and/or hydraulic capacity, or prevent infiltration of groundwater and exfiltration of sewage.

1.2 Scope

This specification defines the requirements for the design, manufacture, installation, workmanship and testing of lining systems used to rehabilitate sewers. It also includes requirements for associated works including preparation of the sewer pipeline, identification and reinstatement of connections and adjustments and repairs to access chambers.

This specification covers both lining systems which are continuous between access chambers, and patch lining systems where the rehabilitation is undertaken locally around a defective section of the pipe.

The requirements of this specification are limited to non-man-entry linings installed in circular pipes with a diameter less than 900mm and which do not rely on the bond with the existing pipe for their structural capacity.

The design requirements contained in this specification only apply for gravity sewers. The other requirements detailed in this specification, apply to linings for both pressure and gravity sewers.

This specification is not applicable to linings which act solely as a protective coating or which are installed using spray techniques.

1.3 References

Document No	Title
AS/NZS 2566.1	Buried Flexible Pipes – Part 1: Structural Design
AS 1462.22	Methods of test for plastics pipes and fittings Method 22: Method for determination of pipe stiffness
AS 3571	Glass Filament Reinforced Thermosetting Plastic (GRP) Pipes Polyester Based – Water Supply, Sewerage and Drainage Applications
AS 3572	Plastics – Glass Filament Reinforced Plastics (GRP) Methods of Test
BS 1881	Testing Concrete Part 102: Method of determination of compressive strength of concrete cubes
BS 2782	Methods of Testing Plastics Method 335A: Determination of flexural properties of rigid plastics Method 1003: Determination of tensile properties.
WIS 4-34-04	Specification for Renovation of Gravity Sewers by Lining with Cured-in-Place Pipes
WIS 4-31-05	Specification for Solid Wall Concentric External Rib-reinforced uPVC Sewer Pipe
WIS 4-32-05	Specification for Polyethylene (PE) Pipes for Sewer Lining
ASTM D543	Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents
ASTM D638	Standard Test Method for Tensile Properties of Plastics

Document No	Title
ASTM D790	Test Methods for Flexural Properties of Reinforced Plastics and Electrical Insulating Material
ASTM D2412	Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading
ASTM D2583	Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor
ASTM D2240	Standard Test Method for Rubber Property – Durometer Hardness
ASTM F1216	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin Impregnated Tube
ASTM F1741	Standard Practice for Installation of Machine Spiral Wound Poly Vinyl Chloride (PVC) Liner Pipe for Rehabilitation of Existing Sewers and Conduits
ASTM F1743	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Cured-in-Place Thermosetting Resin Pipe (CIPP)
ASTM F1947	Standard Practice for Installation of Folded Poly Vinyl Chloride (PVC) Pipe into and Existing Sewers and Conduits
ASTM F2019	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Pulled in Place Installation of Glass Reinforced Plastic (GRP) Cured-in-Place Thermosetting Resin Pipe (CIPP)
AS 5100.2	Bridge Design – Design Loads
AS 3725	Design for Installation of Buried Concrete Pipes
WRC SRM	Water Research Centre, Sewerage Rehabilitation Manual
WSA 01-2004	Polyethylene Pipe Code
EPS 206	Lining of Lateral Connections
EPS 207	Junction Sealing for Circular Non-Man Entry Sewer Pipe
Bureau of Engineering, City of Los Angeles	A Guide to the Pickle Jar Test – Version September 18, 2009

1.4 Definitions

Term	Definition
Patch Lining	Lining used to repair a localised section of pipe between access chambers
Lateral Lining	A lining inserted in a house service line to rehabilitate a section of an incoming pipe upstream of the junction
Cured-in-Place Pipe Lining	Lining installed as a flexible resin impregnated hose which produce a lining after resin cure (often called Soft Lining system)
Slip Lining	Lining inserted into the existing pipeline as a single continuous pipe lining, or series of jointed sections, which form a new continuous pipe
Folded and Formed Lining	Lining inserted into the existing pipe with a temporarily reduced diameter which are subsequently reverted in-situ to their finished diameter (often called Reverted Slip Lining)
Wound Lining	Lining installed by the spiral winding of a profiled strip to form a continuous pipe (often called strip lining)
Reinforced Lining	Liner material that is reinforced by embedding stronger materials in the liner fabric in order to increase liner strength

Term	Definition
Defect	Any discontinuity, imperfection or inclusion arising from substandard materials, improper pipe preparation, or faulty manufacture, installation or workmanship which affects the required performance of the lining in terms of structural or hydraulic performance and water tightness
Inherent defect	A defect which commonly occurs with the lining system where it is neither possible nor commercially practicable to take action for their elimination because of the inherent nature of the system
Intact pipe condition	The existing sewer is in good condition and is capable carrying the externally imposed earth pressure loading. The liner is designed for hydrostatic loading caused by a water table located above the sewer.
Deteriorated pipe condition	The long term performance of the existing sewer is doubtful and the lining eventually bears the full load from the ground and traffic
Ovality	The difference between the mean outside diameter and minimum outside diameter in the same cross section of the lining
Design thickness	The minimum calculated wall thickness of the lining material required to provide a structurally adequate lining for its entire service life.
Normal thickness	The proposed finished wall thickness for the lining system when properly installed
Neat fit	The internal perimeter of the host pipe and the external perimeter of the of the liner at any section match exactly
UV light curing	Ultra-violet light trains used to heat cure CIPP liners
Laser profiling	A method used to measure the dimension of the pipe or lined pipe by using laser technology

1.5 Definitions

Term	Definition	Unit
C	Ovality correction factor (Refer Clause 2.2.2	-
D	Diameter at neutral axis of lining	m
d_{av}	Mean internal diameter of the existing pipe	m
d_{min}	Minimum internal diameter of the existing pipe	m
D_e	External diameter of barrel of existing pipe	m
D_f	Shape factor	-
E_b	Initial Ring bending modulus of elasticity of lining material	MPa
E_{bL}	Long term ring bending modulus of elasticity of lining material	MPa
E'	Effective soil modulus	MPa
F_S	Factor of safety	-
H	Depth of cover, vertical distance between the top of the pipe and the existing surface level	m
I	Moment of inertia of lining wall for ring bending	m^4/m
K_u	Buckling resistance enhancement factor	-
q_{all}	Critical buckling pressure for lining	kN/m^2
S_D	Initial ring bending stiffness of lining (per metre length)	N/m/m
S_{DL}	Long term ring bending stiffness of lining (per metre length)	N/m/m

Term	Definition	Unit
W_g	External dead loading	kN/m
W_q	External live loadings	kN/m
Δ_y	Predicted long term vertical deflection of lining	m
ν	Poisson's ratio	-
γ	Unit weight of soil	kN/m^3

2 Product

2.1 Material

The minimum required service life of the installed lining material is fifty [50] years.

The lining system shall be comprised of materials which are chemically and biologically resistant to internal exposure to sewage, sewage related gases and mild concentrations of industrial effluent for the service life of the lining.

Chemical resistance shall include:

a) 20% Sulphuric acid
b) 5% Sodium hydroxide
c) 5% Ammonium hydroxide
d) 1% Nitric acid
e) 1% Ferric chloride
f) 1% Sodium hypochlorite
g) 0.1% Soap
h) 0.1% Detergent (linear alkyl benzyl sulfonate)
i) Bacteriological (BOD @ 700 ppm or greater)

The method of testing shall be in accordance with the current version (September 2009) of “A Guide to the Pickle Jar Test” developed by the Bureau of Engineering, City Of Los Angeles, USA.

The lining shall also be resistant to external exposure to soil bacteria and any chemical attack which may be due to residues remaining on the pipe wall or materials in the surrounding ground.

If requested by the Principal, technical data confirming the chemical resistance of the lining material shall be forwarded by the Contractor.

The lining shall be comprised of materials which will not be subject to excessive shrinkage, thermal contraction, recovery or reversion affecting the shape or dimensions on the lining following installation. Residual stresses shall be released during installation process.

The lining material shall have satisfactory abrasion resistance to the migration of silt, sand and debris along the pipe. It shall be sufficiently robust not to be damaged by pipe cleaning equipment or cleaning process which may be required to remove any future blockage (debris, roots, etc.) following installation of the lining. The Contractor shall provide evidence that the liner will not be damaged as a result of normal cleaning and jetting process throughout its design life.

2.2 Design

2.2.1 General

2.2.1.1 Condition of Existing Pipe

The condition of the existing sewers at the end of the service life of the lining has been classified for design purposes as INTACT or DETERIORATED. These conditions have been defined in Clause 1.4.

The long term condition of the existing pipe for each length between access chambers to be lined shall be taken as given in the Sewer Rehabilitation Sheet appended to this specification. For patch linings, the long term condition of the existing pipe shall be taken as DETERIORATED.

For the case where the condition of the existing pipe is defined as INTACT, the design of the lining shall be carried out in accordance with Clause 2.2.2. When the existing pipe condition has been defined as DETERIORATED, the design of the lining shall be carried out in accordance with Clause 2.2.3.The work site shall be inspected prior to any work commencing.

2.2.1.2 Material

Where material properties under load vary with time, material properties of the lining at the end of the fifty (50) year service life shall be used in design calculations. The exception to this is design of the lining for loads applied only during installation, which may be based on short term material properties.

The two year values for ring-bending stiffness of the lining measured by testing may be used in calculations as representative values for the fifty (50) year buried pipe stiffness.

The material properties used in the design shall be consistent with the composition of the lining material. These shall be the same values as those nominated by the Contractor in the Schedule of Technical Data.

If requested by the Principal, the Contractor shall submit test data in accordance with Clause SL – 3.7 to substantiate the values for material properties nominated by the Contractor in the Schedule of Technical Data.

2.2.1.3 Design Assumption

For the purpose of structural design, it shall be assumed that in the long term there will be no bond existing between the original pipe and the lining.

2.2.1.4 Ring Bending Pipe Stiffness

The ring bending stiffness for homogeneous plain or solid wall liners may be determined using the equation (2) in section 2.2.2. For other type of liners e.g. structured wall, profiled wall or composites, the stiffness shall be established through testing.

The stiffness shall be tested for every variation of a given type of liner, and for all standard diameters. Only statistically validated results will be accepted.

Interpolation of stiffness for non-standard diameters may be permitted only if a relationship between the diameter and the stiffness for the given variety of the liner is established. Extrapolation of stiffness is not permitted.

2.2.1.5 Short Term Design Checks

Short term design checks shall be carried out for the lining material, either in its final or one of its intermediate states, to ensure the lining is stable and will not be overstressed during the installation and/or curing of the particular system.

Short term materials properties may be used to verify the suitability of installation and curing methods.

2.2.1.6 Design Calculations

The Contractor shall supply full details of their design calculations with their Tender. These calculations shall verify that the proposed nominal wall thickness of each lining given by the Contractor in the Schedule of Technical Data is greater than or equal to the design thickness.

Review of the Contractor’s design calculations shall not be construed as acceptance of the calculations. Responsibility of the design shall remain with the Contractor.

If requested by the Principal, the Contractor shall also provide a copy of the calculations for short term design checks.

All work on the preparation of the design calculations, including proof checking and review, shall be incorporated in the Contractor's Quality Assurance System.

2.2.1.7 Design Loadings

Vertical earth pressures shall comprise the full height of soil above the pipe without reductions for trench effects.

Each lining shall be designed to resist hydrostatic pressures from a water table located at the surface, unless nominated otherwise.

The live load, w_q, shall comprise traffic surcharge loadings. These loads shall be calculated in accordance Clause 4.7.2 of AS/ANZ 2566.1 based on SM1600 design loads specified in AS 5100.2, or Table B2 of AS 3725 for the following types of traffic loadings:

TYPE A	Main road	Maximum load case for SM1600 single lane or SM1600 dual lane
TYPE B	Light road	Maximum load case for SM1600 single lane
TYPE C	Field load	60% of light road loading

For each lining, the type of traffic load used for design shall be determined by the contractor based on existing traffic condition unless advised otherwise by the Principal.

The design loading on each of the linings shall be the maximum load produced from the combination of soil loadings and traffic surcharge loadings for the particular lining.

Each lining shall be designed to resist hydrostatic pressures from a water table located at the surface. Where approved by the Principal, the Contractor may undertake a geotechnical investigation to determine the actual long term ground water level for design purposes.

2.2.2 Design for INTACT Pipes

A lining within an INTACT pipe shall be designed to support the hydrostatic loads imposed externally from groundwater. The design shall be based on the buckling strength of the lining with account taken of the enhancement provided against a buckling mode of failure by the existing pipe.

Subject to limitations described in Clause 2.2.1.4, the following equation shall be used to determine the required stiffness of the lining.

$$q_{all} = \frac{24 \times K_n \times S_{DL} \times 10^{-3}}{(1 - v^2)} \times \frac{C}{FS} \qquad (1)$$

Where,

FS = 2

K = 7.0 when lining and pipe are in intimate contact or the annular gap is grouted

= 4.0 when the maximum gap between the outside of the lining and inside of the pipe exceeds 4mm.

$$S_{DL} = \frac{E_{bL} \times l \times 10^6}{D^3}$$

(2)

$$C = \left[\frac{1 - \frac{d_{av} - d_{min}}{d_{av}}}{\left(\left(1 + \frac{d_{av} - d_{min}}{d_{av}} \right)^2 \right)} \right]^3$$

(3)

The minimum ovality of the existing pipe shall be taken as 2% (C=0.84) for the lining of cast iron pipes and 5% (C=0.64) for all other pipes.

The linings shall also be designed for stresses induced from bending moments arising from the ovality of the out of round lining.

2.2.3 Design for DETERIORATED Pipes

A lining inside a DETERIORATED pipe shall ignore any contribution from the original pipe. The lining shall be designed as a flexible pipe and be capable of supporting all imposed loads in its own right.

The lining shall be designed in accordance with Section 5 of AS/ANZ 2566.1 to satisfy the critical performance criteria of deflection, strength and buckling.

The predicted long term vertical deflection shall be less than six per cent (6%) of the diameter of the lining when calculated in accordance with Clause 5.2. In calculating the dead load on the pipe the unit weight of soil, γ shall be taken as 20kN/m3. A value of soil modulus of E' = 2.0 MPa shall be used unless the Contractor proposes to fill possible voids outside the pipe. Where filling of voids is to be incorporated as part of the liner installation, a maximum value of E'=4.0 MPa may be used for deflection and buckling calculations.

For strength calculations, the long term flexural strain developed in the wall of the lining for any load or load combination shall not exceed the value nominated by the Contractor in the Schedule of Technical Data.

In addition to the requirements of Section 5 of AS/ANZ 2566.1 the lining shall be provided with a minimum ring bending stiffness to satisfy the local buckling requirements for an INTACT pipe in Clause 2.2.2.

2.3 Hydraulic Requirements

The lining system shall not reduce the diameter of the existing pipe by more than 10 per cent in lines 500mm and smaller, nor more than 5 per cent in lines greater than 500mm diameter.

The lining material shall be such that the reduction in the sewer's cross sectional area, is compensated by the reduction in flow resistance of the lining (i.e. improved surface smoothness) when calculated in accordance with Water Research Centre, Sewer Rehabilitation Manual 2001 (4th edition), Volume I, Appendix C.

Account shall be taken of the build-up of slime and any defects which may affect hydraulic performance.

2.4 Degree of Fit

The lining shall be designed and fabricated in a manner that, when installed, will neatly fit the internal wall and length of the pipe being lined. Where lining technology requires, suitable allowance shall be provided for longitudinal and circumferential stretching of the lining during installation.

A lining shall be considered to neatly fit if the gap left between the inside of the pipe and outside of the lining is less than maximum gap for the pipe diameter nominated by the Contractor in the Schedule of Technical Data for the particular lining system.

2.5 Retention of Structural Condition of Existing Sewer

No activity of the Contractor during preparation of the sewer section and installation of the liner shall adversely affect existing structural integrity of the sewer, unless otherwise agreed to by the Principal.

2.6 Manufacture of Lining

The manufacture of the lining shall be carried out in accordance with a specification purpose written for the particular system. This specification shall detail all labour, materials and equipment required to combine the various constituents to produce the lining ready for delivery to site.

The purpose written specification shall also include testing and inspection work carried out to verify the dimensions and quality of the manufactured lining. A copy of this specification shall be provided by the Contractor upon request by the Principal.

The Contractor shall be responsible for measuring the dimensions of the existing sewer in accordance with Clause 3.7.5 prior to fabrication, to ensure that neat fit is achieved in accordance with the requirements of Clause 2.4. The Contractor shall also be responsible for the measurement of the horizontal and vertical alignment at changes in direction and bends.

All work involved in the measurement, inspection and testing of the lining during manufacture shall be included in the Contractor's Quality Assurance System.

3 Execution

3.1 Preparation of Pipeline

The Contractor shall clean the pipelines as specified elsewhere in the Specification documents to ensure precise closed circuit television (CCTV) Inspections and installation of the lining system.

CCTV inspection shall be required prior to installation of liners to establish that the pipe is clean and ready to receive the liner.

The CCTV shall be run opposite to flow direction to ensure full view of any branch/house service line (HSL) joining-in at an acute angle.

The Contractor shall test and confirm before lining which junctions are live. Dyed water shall be run into the house service line and the running dyed water shall be evident on the pre-installation CCTV inspection.

The location of all live and dead junctions shall be recorded as part of the Contractor's Quality Assurance System.

Before installing the liner, the Contractor shall clear the junction at the property branch line and Principal's sewer of any roots, debris, silt etc. up as far as the branch of the junction to leave it clean and smooth edged and free of any obstruction.

3.2 Access Chambers

This clause only covers requirements associated with the adjustment of access chambers to facilitate lining and the sealing of the lining at the entry or exit points for the main line sewer. Requirements for repair of access chambers including grouting to reduce infiltration are covered elsewhere in the technical specifications.

Where an access chamber has to be altered by the Contractor, as part of these works, the Contractor shall notify the Principal of the change, prior to the work.

The Contractor shall reinstate all access chambers, to the satisfaction of the Principal, such that installed liners do not form irregularities around the edges of the liners at the access chambers. After installation of liners, the Contractor shall provide a channel in the access chamber free from any irregularities or differences in level which may cause accumulation of solids (i.e. debris, silt, rags, etc.) in the sewer or access chamber channel.

Where liners have been installed to one side of the access chamber, the access chamber channel shall be rendered to form smooth slope to the liner to prevent accumulation near the liner edge.

The Contractor shall seal the ends of the lining once they have been trimmed to match the face of the access chamber. The materials used and the method of sealing shall be determined by the Contractor. The minimum requirements of the seal are as follows:

- Material requirements in accordance with Clause 2.1
- Compatibility with composition of lining and access chamber
- Provide a permanent watertight seal against infiltration and exfiltration

If requested by the Principal, the Contract shall provide information such as chemical resistance data, method to ensure adequate curing of all sealing products and materials, particularly where the sealing shall be installed under water/live flow, accelerated aging tests, bond tests, full scale trials or hydrostatic testing to demonstrate the suitability of sealing system.

3.3 Delivery and Installation of Liner

3.3.1 General

The length to be lined shall generally be restricted to a single length between access chambers. Any lining installed over more than one length requires the prior approval of the Principal.

The Contractor shall clean the sewers immediately prior to lining. Flow in House Service Lines (HSLs) and the Principal's sewers should be isolated during the lining operation to ensure that no debris enters which may get trapped between the liner and the original pipe.

The Contractor shall make arrangements to ensure that HSLs are not in use during the lining operation.

Where the Contractor is also required to install a lateral lining in any house service lines off the Principal's sewer, lining work shall be sequenced to ensure the linings can be finished and sealed at lateral connections to satisfy the requirements of Clause 3.4. Lateral linings shall comply with EPS 206 "Standard Specification for Lining of Lateral Connections".

The Contractor shall install the lining in a continuous operation. The Contractor is solely responsible for the details of execution and suitability of methods and procedures used to satisfy the peculiar conditions of each segment. The installation procedure shall be executed to prevent both infiltration into, and migration through the annular space between the existing pipe and the lining. Welding of Polyethylene profiles or pipes shall be in accordance with WSA 01-2004.

The lining shall be initially cut to length in access chambers so monitoring of movements can be carried out in accordance with Clause 3.7.4.

If the liner is to be installed through bends, the Contractor shall demonstrate how the proposed liner will be able to negotiate bends without excessive wrinkling, deformation, unravelling of profiles, loss of cross section or stiffness.

A closed circuit television (CCTV) inspection shall be carried out after installation to establish that the lining has been installed in the desired manner and that all live laterals have been reconnected properly. The CCTV inspection shall be carried out as per the relevant specifications.

3.3.2 Curing

In case of heat curing, the Contractor shall ensure that the liner is heated at the prescribed temperature throughout its length for the required period. Temperature shall be monitored by installing temperature sensors along the length of the liner and recorded throughout the curing period. For UV cured system the light train shall be run centrally to ensure that the uniform curing throughout its perimeter.

It shall be ensured that there is no stress built in due to rapid cooling.

3.4 Reinstatement of Connections

The Contractor shall reinstate live junctions only. All cut-outs at junctions (connections) shall be sealed in accordance with EPS 207.

The Contractor shall allow sufficient time for any movement of the installed lining relative to the host pipe before finishing the cut outs. This shall include movements caused by shrinkage, thermal contraction, stress recovery, mechanical adjustment in material properties during curing, or any other action.

The cutting equipment shall be capable of reinstating the opening into the Principal's sewer for slope or square connections. The cutting tool shall leave a smooth bevelled

edge free of any protrusions. The cut shall be flush with the inside surface of the branch sewer line.

There shall be no discontinuity between the lining material at the cut hole and the branch sewer line. Each required opening shall have initial rough cut on the day of lining and be 100% completed after the lining has reached its final dimensions in terms of length and diameter.

The Contractor shall ensure that each hole cut by this equipment, or otherwise reinstated, will not inhibit flow into the Principal's sewer from the junction, cause any constrictions or be such that it will catch solid material and cause a choke.

If a lateral lining is to be installed in the house service line, the Contractor shall follow the specification EPS 206.

3.5 Finish (Hydraulic Acceptability)

The installed lining shall be continuous over its length and shall be free of any defect which is likely to affect the satisfactory hydraulic performance of the lined pipe or cause accumulation of solids. Where the Contractor has nominated inherent defects which are likely to affect hydraulic performance, these defects shall satisfy the accepted criteria negotiated with the Principal.

The finished lining shall be free of any leakage from the lined section of pipe to the surrounding ground or from the ground to the inside of the lined pipe.

Openings through the lining at junctions shall be finished so as not to inhibit the flow of sewage in the pipe.

3.6 Defects

The finished lining shall be free of all defects which affect hydraulic performance or structural adequacy. This shall include defects arising from substandard materials, faulty or inaccurate manufacture, inadequate pipe preparation, faulty installation or workmanship, or inadequate curing. The only exception is inherent defects, as defined in Clause 1.4, which shall satisfy the requirements of this clause.

For the Contractor's lining system, inherent defects shall be those nominated by the Contractor in the Schedule of Technical Data. The acceptance limit for each defect shall be those negotiated and/or agreed with the Principal.

If during the execution of the contract it becomes apparent that there are further inherent defects which have not been nominated by the Contractor, then, provided the Contractor can substantiate such defects satisfy the definition of "inherent defects" these may be accepted as such by the Principal. In this instance the Principal may nominate the acceptance limit for the defects in terms of its frequency and dimensions and this shall be binding on the Contractor.

Defects which are considered unacceptable in all liners include, but are not limited to the following:

- under strength finished lining materials
- foreign inclusions
- irregularity in lining caused by inadequate pipe preparation
- leakage through the lining
- inadequate material curing
- inadequate resin impregnation
- excessive resin loss during installation

- dry spots, bubbles, cracks or delamination
- pinholes
- leakage through welded, glued or mechanical locked joints
- poor quality cut outs
- inadequate seals at access chambers or laterals
- any other defect not nominated as inherent to the lining system
- non-compliance to clause 2.4

The following will be considered as unacceptable defects if they exceed the limits given in brackets below:

- inadequate lining thickness (finished thickness <90% of nominal lining thickness)
- excessive variation in thickness around the circumference of the lining (variation in minimum or maximum thickness > 20% of mean lining thickness)
- excessive longitudinal or circumferential variation in dimensions after completion of the cut-outs at access chambers or cut-outs (variation < 1mm in every 2m or 0.05% measured 14 days after installation) Refer Clause 3.7.4
- excessive longitudinal wrinkling of the lining in straight, non-defective portions of the host pipe (wrinkling > 2.5% of the nominal diameter of pipe).
- unravelling of liner profile
- transverse section rupture due to stress release

Defects which may be nominated as inherent for the proposed lining system may include, although not necessarily be limited to the following:

- bulges
- longitudinal or circumferential wrinkling
- excessive reduction in cross sectional area
- longitudinal or circumferential shrinkage

3.7 Grouting

To enhance buckling resistance, the contractor may fill the annulus between the host sewer and the liner with a cement based grout. The grouting method shall ensure the complete filling of the annulus without the liner deformation to provide uniform support to the liner and shall be subject to approval by the Principal.

The Contractor shall submit, at the Tender Stage, a work method statement detailing the proposed grouting procedures and grout composition.

The grout composition shall ensure that the following properties are attained:

- the grout shall not undergo any shrinkage
- the grout shall remain structurally sound over the long-term (minimum 50 year period)
- the grout composition shall have no adverse effect on the liner

The Contractor shall ensure that the liner is not subjected to any hydrostatic pressure from the grout and/or water table during the grouting phase that cannot be withstood by the liner. Short term design checks shall be carried out by the Contractor in accordance with Clause 2.2.1.5.

The Contractor shall maintain records of all grouting operations, which shall include (but not be limited to) the location of all grout injection points, volume of grout pumped, grouting pressures, commencement and completion times, and grout composition details. The Contractor shall submit one copy of this record to the Principal at the completion of each access chamber length.

3.8 Testing

3.8.1 General

The Contractor shall carry out testing on the lining material and its Constituents.

The Contractor shall give the Principal 7 days' notice of the date, time and place of all tests on the lining following manufacture and provide all facilities required.

All work on the testing of the lining constituents, manufacture of the lining, during and after installation shall be included in the Contractor's Quality Assurance System.

3.8.2 Pre-Installation Testing

If the Contractor is relying on local or overseas test data to justify the suitability of the lining system in terms of its physical and chemical properties, the Principal may request copies of such test results. These results shall be forwarded to the Principal prior to commencement of lining manufacture. Any property which cannot be verified by such test data shall be retested prior to installation.

Where the lining system is manufactured by a combination of a number of constituents which can be varied to suit the requirements of the Contract, the testing program shall include the testing of three prepared samples for the same series of tests (excluding leak tests) to those required for the installed liner.

All tests on the constituents of lining material and manufacture of the liners shall be in accordance with the relevant Australian or overseas standards.

3.8.3 Post Installation Testing

This clause lists the minimum requirements for testing which shall be carried out on installed lining. Each of the listed tests shall be carried out once for every twenty (20) linings installed.

Alternative overseas or Australian standards to those listed may be accepted by the Principal for testing purposes providing the contractor can demonstrate that the test method provides an accurate measure of the required physical property or aspect of installation quality.

3.8.3.1 Cured-in-Place Pipe Lining

- Gravity Pipe Leakage Test in accordance with ASTM F1216 carried out prior to cutting of laterals.
- Hardness in accordance with ASTM D2583
- Short Term Tensile Strength in accordance with ASTM D638 or BS 2782: Method 1003 (3 samples for each line being tested).
- Short Term Flexural Strength and Flexural Modulus in accordance with ASTM D790 or BS 2782: Method 335A (3 samples for each lining length) OR Short Term Ring Stiffness in accordance with AS 3572.10.

Samples for testing may be prepared using the procedure given in Appendix B of WIS 4-34-04.

3.8.3.2 Slip Lining

- Gravity Pipe Leakage Test in accordance with ASTM F1216 carried out prior to installation of cut-outs.
- Grout Cube Strength in accordance with BS 1881: Part 116 (three for each batch of grout with a maximum of six for any one length of lining).
- Grout Slump Test in accordance with BS 1881: Part 102 (one for each batch of grout).

These testing requirements assume the slip lining material is fully tested to confirm its tensile and flexural properties for each batch of pipes produced. It also assumes the pipes are not modified in any way by heat or temperature during installation.

3.8.3.3 Folded and Formed Lining

- Short Term Tensile strength in accordance with ASTM D638.
- Short Term Flexural Stiffness in accordance with ASTM 2412 or WIS 4-34-04 Appendix A OR Short Term Ring Stiffness in accordance with AS 3572.10.

Samples for these tests may be taken from excess sections extracted from near the bottom of one of the access chambers. Sections where samples are to be removed are to be insulated with sandbags or the like to simulate the temperature conditions of the lining in the pipe during reversion.

3.8.3.4 Wound Lining

- Gravity Pipe Leakage Test in accordance with ASTM F1216 prior to installation of cut-outs.
- Impact Test in accordance with WIS 4-31-05 with the impact weight contacting with the joint between strips.
- If applicable, Grout Cube and Slump tests as for slip linings.

Samples may be produced by extending the lining into the access chamber at the opposite end to the winding machine.

3.8.4 Monitoring of Longitudinal Shortening

Monitoring of longitudinal shortening shall be carried out and reported for nominated lining lengths installed. A minimum of one (1) out of every twenty (20) liner installed shall be checked.

Monitoring shall comprise the measurement of the longitudinal movement of both ends of the installed lining relative to a fixed point on the adjacent access chamber wall. Linings shall be cut with 100mm of additional length protruding into the access chamber. Fixed marks shall be placed on the liner and access chamber wall for measurement purposes so results are repeatable to accuracy of +/- 1mm.

Three series of measurements shall be made by the Contractor as follows:

- At completion of cut-outs, or at 24 hours for linings without cut-outs.
- Fourteen days.
- Ninety days.

Interim results of the monitoring shall be forwarded to the Principal after the fourteen day readings.

The lining shall be cut to its final length and if necessary resealed at the access chamber wall by the Contractor following acknowledgment by the Principal of the acceptance of the longitudinal monitoring results provided by the Contractor.

3.8.5 Monitoring of Internal Diameter

A profile measurement survey shall be carried out on existing pipes following cleaning, and prior to lining, to confirm internal diameter of the pipes. A similar survey shall be carried out on lined lines to assess the lining quality. Post lining surveys shall be carried after cut-out and junction seals are installed, as applicable.

The Contractor shall use methods laser profiling to assess the degree of fit (ref clause 2.4). Other survey method may be used where accuracy of measurements is at least equivalent to those by laser profiling.

Any length where the laser profiler surveyed diameter after the lining is less than determined based on a neat fit, when allowance is made for any localised defects at restrictions in the host pipe, shall be considered defective.

3.8.6 Failure During Post Installation Testing

A test result shall be deemed to have failed if the minimum values nominated by the Contractor in the “Schedule of Technical Data” are not achieved.

If only one sample has been extracted from a length of lining then failure of the sample shall be interpreted as indicating that the lining in question is defective.

The Contractor may repeat the tests which have failed from representative samples of the same lining length. These samples may be obtained from excavation and extraction from within the lined section of pipe or alternatively from spare samples prepared during lining installation. The lining will be accepted if the test results of two of the three samples extracted, and the average of the three results, exceed the nominated minimum values. Otherwise the lining shall be considered as defective. The Principal will direct the Contractor to undertake further testing of other lines to ensure compliance.

If three samples are extracted from a length of lining, testing will indicate the lining is acceptable when two of the three results and the average of the three results exceed the nominated minimum values.

The Principal, at his discretion, may take account of any reserve structural capacity of the lining under design loading, when assessing the acceptability of a lining with a test result(s) deemed to have failed.

3.8.7 Hydrostatic Testing

Unless stated otherwise in the Contract documents the Contractor shall carry out hydrostatic testing of all completed lines to confirm the watertightness of both the seals provided at lateral connections and liner ends and from grouting undertaken in the vicinity of access chambers. The hydrostatic testing shall be carried out in accordance with the requirements given elsewhere in the specification.

3.8.8 Test Records

Results of all tests shall be entered into a book and initialled as correct by the Contractor or his Representative present when the tests were made. This book shall be kept at the works and be open to inspection by the Principal or his nominated Representative.

3.9 Trial Excavations

The Contractor shall carry out trial excavations to confirm the quality of the finished lining. The excavations shall comprise 5% of the finished linings with at least one test for line of diameter greater than 375 mm.

The locations of the excavations will be advised by the Principal at the request of the Contractor. The Principal may elect to view the post installation CCTV tapes prior to nominating the excavation locations.

The minimum length of the lined pipe which is to be exposed for inspection and measurement is 1.2m unless agreed otherwise with the Principal. The Contractor shall give the Principal 2 working days prior notice of his intention to undertake any trial excavation work.

Once the outside of the original pipe is exposed saw cuts shall be made to remove the top half of the pipe in a single piece. At house service line connections the saw cut on each side shall extent past the collar of the junction. For soft linings and grouted linings, the saw cut shall pass through both the pipe and lining. For other linings the depth of saw cut shall be limited to the thickness of the original pipe. Following saw cutting the Contractor shall accurately record the following at four equally spaced cross sections in the length of the excavation:

- external and internal diameter of pipe
- external diameter of lining
- size of gap between lining and pipe at springing points
- thickness of lining at crown and springing points (grouted and soft linings)
- size and location of any defects (wrinkles, bulges, incomplete grouting, etc)

Requirements from the trial excavation shall be included in the Contractor's Quality Assurance System. Details of measurement made during the each trial excavation shall be forwarded to the Principal within 7 days.

Where the trial excavation indicates the finished lining does not comply with the requirements of the specification (i.e. neat fit, defects, grouting of laterals) the Principal may instruct the Contractor to carry out a further trial excavation within the same lining length. If this excavation confirms non-compliance of the lining for the entire pipe the lining may be deemed as defective.

Reinstatement shall comprise the repositioning of the removed top half of the pipe, the sealing of the saw cut surfaces, the wrapping of the pipe with steel bands and encasement with 150mm minimum thickness mass concrete extending at least 150mm past the upstream and downstream vertical saw cut.

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