JUNCTION SEALING AND HOUSE SERVICE LINE REHABILITATION

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ABSTRACT

Programmes undertaken by Water Utilities to rehabilitate existing sewer catchments are typically designed to restore the structural integrity of deteriorated sewers and seal against infiltration and exfiltration.

Monitoring of the effectiveness of sewer rehabilitation programmes has shown that achieving infiltration / exfiltration reduction targets often requires more than just lining of deteriorated sewer mains. Four areas need to be comprehensively addressed:

1. The sewer main
2. The house service line
3. The junction between the sewer main and the house service line
4. The connection at the manhole

As a result of this, some Specifications now call for seals at lateral connections to have the same expected service life as the liner. Specifications from Australian Water Authorities have also been produced for lining of house service lines.

This Paper will detail advancements developed by Australian sewer rehabilitation Contractors to meet these new Specifications. This has required a high level of innovation, and has resulted in cost effective developments that are world leading.

KEYWORDS
Sewer, Rehabilitation, Infiltration, Sealing, Exfiltration

1 INTRODUCTION

Since the early 1980s rehabilitation of failing sewers has assumed increasing importance for Water Authorities and local Councils. Many sewers laid in the middle of last century are coming to the end of their useful life and cannot be dug up or replaced without prohibitive cost or unacceptable social disruption. Infiltration and exfiltration through cracked pipes or leaking joints etc can overload treatment plants or cause pollution of groundwater and local waterways. Thus the "trenchless technology" industry has developed, and continues to develop at an increasingly rapid pace.

Renewal of a deteriorated sewer by trenchless installation of a liner has for over 20 years been a cost effective alternative to conventional replacement. This form of rehabilitation minimises or eliminates excavation; therefore reinstatement costs and community disturbance are reduced.

Liners for deteriorated sewers are typically required to be "structural', meaning they must be designed to withstand all loads from soil, groundwater and traffic, as if the host pipe had no remaining strength. When installed, they must cause minimal reduction in internal diameter. Pressure testing identical to that required for new plastic pipelines is usually specified. An expected service life of 50 years is often stipulated.

The result is an "as new", pipeline, structurally designed by the same methods used to design conventionally installed plastic pipelines. The lined pipeline is expected to be water-tight and root-tight, thus eliminating blockages from roots and the possibility of infiltration and exfiltration.

While there are several different types of liners considered capable of meeting these requirements, it is universally acknowledged that each leaves a gap between the liner and the host pipe. Therefore, there exists the potential for infiltration / exfiltration and root infestation wherever the liner is cut to form junctions with house service lines.

Service laterals or house service lines are also an integral part of the sewerage system. While the Authority and the householder may share ownership of these particular assets, they have been identified as a significant source of infiltration that may overload treatment plants and contribute to downstream overflows. Studies by Sydney Water (Eyles et al.,2002) indicate that rehabilitation of house service lines must be addressed if infiltration / exfiltration reduction targets are to be met.

The worldwide Trenchless Technology industry has advanced rapidly over the past 2 decades. The Australian industry has not been left behind and has been responsible for several world-leading developments. In part this has been driven by the increasingly rigorous requirements of Australian Water Authorities. Now with the emphasis being firmly placed on achieving improved results by addressing lateral connection sealing and rehabilitation of house service lines, the Australian industry has again responded to the challenge.

2 EVIDENCE OF INFILTRATION THROUGH UNSEALED JUNCTIONS AND HOUSE SERVICE LINES

2.1 EXPERIENCE WITH UNSEALED JUNCTIONS

Several methods of trenchless installation of liners have proved to be effective in providing solutions to structural problems in deteriorated sewers. Cured-in-place liners, re-shaped thermoplastic liners and spirally wound liners are all well accepted. All these systems, if properly installed, provide an 'as new' pipe from access chamber to access chamber. However, the problem remains that all liners have a water path between the liner and the host pipe, causing points of infiltration and exfiltration at lateral connections and access chambers.

Previous claims from some lining suppliers that their particular liner provides a water-tight seal between the liner and host pipe, and thus do not require sealing at house service connections, have been comprehensively discredited.

That gaps are likely to exist can be considered to be due to a number of possible factors including:

- Shrinkage in liners that use heat during the installation process
- Tolerances in both liner and original host pipe manufacture
- Irregularities in the cross sectional shape of the deteriorated pipe

Laboratory testing confirming the likelihood of such gaps has been provided by at least 2 separate organisations. Baker et al. (1997) detailed testing carried out at the Trenchless Technology Centre, Louisiana Tech University involving lining above ground of new pipes with liners installed by experienced lining Company representatives who knew their installations would be tested for the existence of annular gaps.

This study confirmed that fluid would flow in the annulus for all types of liners even under laboratory conditions with total environmental control.

Larsen et al. (1996, 2000) details activity reports from North American agencies that "validate that the results from laboratory testing model the actual field installation behaviour" by referring to post installation inspections, performance evaluations and sealing programs from such agencies.

ASTM (American Society for Testing and Materials) has internationally accepted Specifications covering the design and installation of various types of liners, including the following that are applicable to different types of cured-in-place and fold-and-form liners: F 1606, F 1743, F 1867, F 1947, F 2019. Each of these Specifications carries a note that includes a statement similar to:

"...this practice (installation of the liner) should not be construed to provide a watertight seal at service connections. If total elimination of infiltration and inflow is desired, other means which are beyond the scope of this practice, may be necessary to seal service connections and to rehabilitate service lines and manholes."

2.2 EXPERIENCE WITH HOUSE SERVICE LINE INFILTRATION

Sydney Water commenced its "Clean Waterways Programme" in 1990 as an Infiltration/Inflow (I/I) investigation. Since that time it has extensively evaluated various approaches and has incorporated various advances in technology that have occurred since that time.

Defective sewers have been rehabilitated with various types of liners and grout sealing chemicals. In 1996 hydrophilic polyurethane applied with a packer was adopted as the preferred grouting sealing method. Around 1998 the lining Specification was amended to require sealing of the gap between the liner and host pipe at each lateral connection with hydrophilic polyurethane applied with a lateral sleeve grouting packer. Use of a lateral sleeve grouting packer means that the grout is applied under pressure to the defect and held at that pressure for its recommended curing time. The effectiveness of the seal can be immediately hydrostatically tested.

Evaluation showed that generally this grout could be considered to remain effective for a period of only 5 years. However, below the level of the water table indications are that the grout will have a considerably longer effective life.

In 2000 successful installation of lateral liners was demonstrated. Sydney Water now has a policy of full lining of deteriorated sewers, rather than grout sealing, when rehabilitation is required.

Effectiveness evaluation of Sydney Water' sewer rehabilitation programme was conducted on 6 catchments in 2002. This showed that, while there were dry weather improvements in system leakiness, choke rates and stormwater pollution, in wet weather there was no improvement in leakiness and the incidence of sewer overflows actually increased.

While some of this increase was attributed to the removal of roots during sewer rehabilitation, leading to flows arriving at overflow points more quickly, the main reason was considered to be additional flow entering from deteriorated house service lines. Eyles et al.(2002)) notes *"Soon after rain commences, the water level in the trench begins to rise. Any cracks or leaky joints in Sydney Water sewers allow water to enter the sewers. When Sydney Water sewers are rehabilitated the water level in the trench continues to rise until it finds the cracks in the private sewer. For this reason it is important to rehabilitate all sewers in identified mini-catchments, since flows can migrate to the next available crack or faulty joint.."*

The evaluation concluded that at least 40% of house service lines needed rehabilitation to achieve a reduction in wet weather ingress.

The results of similar programmes in other localities will vary depending on the actual local conditions. Compared to Sydney, for example, Melbourne and Adelaide sewers are buried under the road and are flatter and deeper while Perth is built on sand. Nevertheless, a similar phenomenon has been encountered in studies carried out in North America.

Rowe et al. (2003) mentions results of studies in several cities in the United States where wet weather (rainfall derived) infiltration and inflow into the sewer system was reduced by 25% to 75%, with the average being around 40%, after a programme of house service line rehabilitation was completed. It further cites an interesting study from a city in Pennsylvania where, while sewer main lining initially reduced infiltration by some 30%, flow from the unrehabilitated house service lines subsequently increased. The Pennsylvanian Authority now has a programme of rehabilitation for house service lines that they consider will reduce wet weather infiltration by over 60% when it is completed.

3 NEW OPTION FOR JUNCTION SEALING

In July 2001 Sydney Water released an updated revision to Engineering Product Specification (EPS) 201 "Linings for Circular Non Man-Entry Sewers." The principal revision was in the upgraded requirements for sealing at lateral connections. Clause 3.4 included *"...the Contractor shall seal both the gap between the lining and the host pipe at each junction and any cracks in the junction up to the first joint in the house service line. ... The sealing system shall be determined to satisfy the following minimum criteria:*

- *Material requirements to be the same as the liner (minimum requirements service life = 50 years etc)*
- *Provide a permanent water tight seal against infiltration, exfiltration and tree root ingress*
- *Smooth transitions that do not result in any accumulation or chokage"*

These requirements meant that the previous practice of sealing with hydrophilic polyurethane was no longer acceptable. It was also obvious that there was no system currently provided by Australian lining contractors that could comply with this Clause.

Interflow Pty Limited, one of the pre-qualified Contractors for the Sydney Water SewerFix Programme invested considerable dollars and expertise in developing an acceptable solution. The result is the L.C.R. (Lateral Connection Repair) - a one-piece, cured-in-place short form liner in a T configuration.

The L.C.R. provides a full-circle short liner in the lined host pipe, integrally connected to a full bore liner extending up the house service line beyond the first joint. It is composed of hoop stitched, highly elastic felt impregnated with silicate resin. It is installed using a lateral sleeve grouting packer from the sewer main, without the need for excavation.

The L.C.R. System Installation procedure is as follows:

1. The sewer should be cleaned prior to installation of the L.C.R. to remove fat and debris from the sewer main and the house service line (HSL). The HSL must be cleaned past the first joint up the house service sewer from the main.
2. The L.C.R. felt is prepared above ground by impregnating it with resin and securing it to the packer.
3. A camera is built into the packer so that installation can be viewed from the surface.
4. Air rods are attached to the back of the packer so that it can be pushed into the sewer main and later inflated when in place. A wire rope is also attached to the rear of the main packer to act as a safety line.
5. The packer is pushed up the sewer main using the air rods. When the lateral ball reaches the connection to be sealed, the lateral ball moves up the lateral.
6. The packer is then inflated to 140KPa and the packer is fully expanded.
7. The L.C.R. is allowed to cure for the recommended curing time (between 1.5 and 2 hours). After completion of curing the packer is slowly deflated.
8. A CCTV inspection of the L.C.R. is carried out to confirm the effectiveness of the installation.

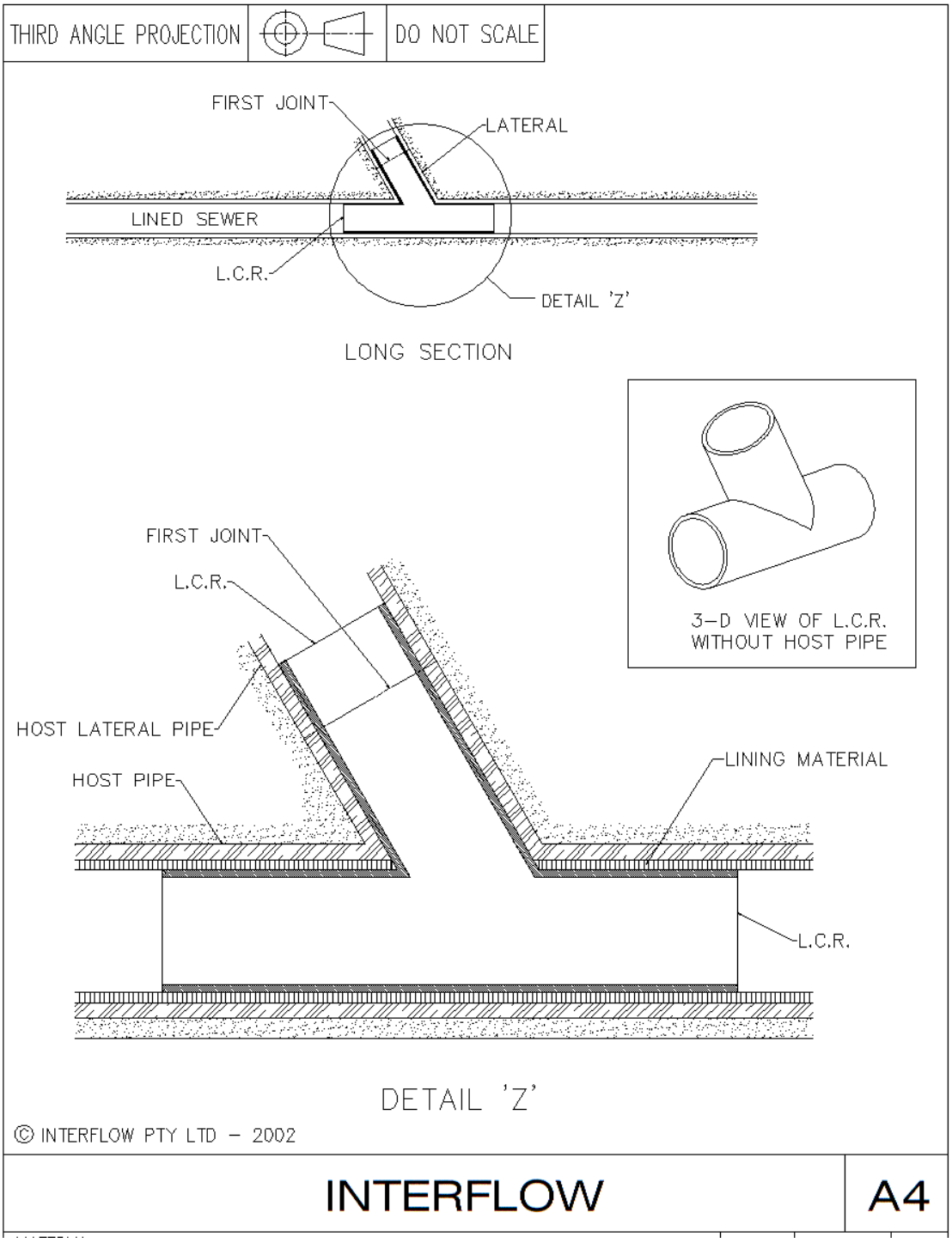
The L.C.R. installed by this method offers several inherent benefits:

- The lateral sleeve packer positively locates the L.C.R. and applies a high, uniform pressure to ensure it makes firm contact with the main liner and the house service line at the junction. It is held at this pressure while the resin cures.
- The L.C.R. is retained within the dimensions of the packer. This ensures that excess resin is not squeezed out the ends of the packer, to run down inside the liner. Instead …
- The pressure applied by the packer squeezes excess resin into cracks or gaps, including the gap between the liner and the host pipe. This means that the L.C.R. is mechanically held in place. Unlike the "top hat" collar or rim type seal, it does not solely rely on adhesion to hold it in position.
- Being a full circle cylindrical sleeve short form liner, it is self supporting and structurally stable. The cylindrical sleeve extends in the main line either side of the junction opening

Silicate resin is used with the L.C.R. This provides greater strength, adhesion and stability than the more commonly used, and cheaper, polyester resin. It cures in 1.5 to 2.0 hours at ambient temperature and has the added benefit over polyester in that styrenes are not emitted. Styrene is coming under increasing scrutiny from environmental authorities because of its known irritant factor and possible carcinogenic properties. These features are particularly relevant when working around householders.

Thus the L.C.R. provides a physical barrier against root intrusion and water flow – either infiltration or exfiltration. It comprises materials known to be suitable for use in sewer environments. It can be installed from existing manholes with no excavation. Thus it can be considered to comply with the rigorous requirements of latest Specification from Australian Water Authorities.

Figure 1: L.C.R. General Arrangement



4 LINERS FOR HOUSE SERVICE LINES

4.1 DEFINING THE PROBLEM

House service lines, or laterals, taking waste water from the house to the sewer main, have always presented a rehabilitation dilemma for Water Utilities.

House service lines are typically characterised by:

- small diameter, typically 100 or 150mm
- several tight radius bends in a short length of pipeline
- lack of convenient access at each end
- a wide range of configurations in a particular Authority's sewer system

Thus, the wide range of proven lining systems for sewer mains are not suitable for house service lines.

In addition, records of the location of house service lines are often not complete or accurate, and thus there is difficulty in locating them, particularly in older, densely populated areas of a city. They were often installed with minimal supervision, and so quality of installation can be variable.

Confusion often exists over who owns a house service line. Ownership is typically shared between an Authority and the householder, although confusion arises over liability for repairs and maintenance. Irrespective of ownership, it is the Authority who must bear the problems of infiltration from a deteriorated house service line through the extra volume of water that enters their sewer mains.

4.2 THE IMPORTANCE OF PROPER EVALUATION

The choice of rehabilitation solution for house service lines is often based on perception, rather than engineering evidence.

It is often assumed that if *some* of the house service lines are known to be deteriorated, then *all* should be rehabilitated. The cost resulting from making this assumption can no longer be justified, as existing closed circuit television technology allows fast, economical and non-disruptive inspection of house service lines.

Latest CCTV systems allow inspection of house service lines from the boundary trap/inspection opening. A small camera launched from the boundary trap and, if necessary, propelled through the pipe by jets of water, will provide a high quality record of the condition of the pipeline. Inspection systems are also available which launch the camera from the sewer main.

Several Water Authorities have realised major savings on sewer rehabilitation projects when proper inspection revealed that only a minority of the house service lines under consideration required structural rehabilitation.

It is now cost effective to survey all house service lines in order to establish exactly how many require renovation or replacement. This now allows Authorities to define the problem and then make an informed decision as to the most appropriate renovation technology – on an economic and social cost basis.

It is clearly evident that a 'look before you dig' policy can save thousands of dollars if inspection shows that only a small number of service lines are deteriorated. A rehabilitation system that allows 'no dig' reconnection may then lead to significant total cost savings. The availability of structural lining systems further increases the viability of this option. The extent of the problem must be identified in order to make the most economical and socially acceptable renovation choice.

4.3 LINERS

Installation of liners in house service lines is now an integral part of sewer rehabilitation contracts from major Australian water authorities. Systems are now available that can provide a structural liner in a deteriorated house service line from existing access points with minimal wrinkling at the tight bends often found in the pipelines.

The EPROS DrainPlus system offered by Interflow uses a highly elastic felt tube impregnated with epoxy resin. It is inverted into the house service line from the inspection opening. The process for installation is as follows:

- An access point (typically an inspection opening) is located at the surface. From here the deteriorated line is cleaned and inspected.
- The length of the house service line is measured and the positions of any incoming connections from upstream properties and vents are located and logged for future reference
- Incoming flows are assessed and if necessary diverted to avoid overflows
- The liner inversion drum and other installation equipment are positioned at the surface access point. The surrounding ground surface is covered with protective sheeting to avoid the potential of damage from epoxy resin spillage
- The liner tube is cut to length and the required amount of two-part epoxy is measured and mixed.
- The liner tube is then impregnated with epoxy resin and loaded into the inversion drum
- The liner is then inverted down the house service line to the junction of the sewer main using air pressure
- Once inverted, the epoxy impregnated liner is cured using hot water for the recommended curing time of approximately two hours
- Once cured, the liner end at the main is reopened using a robotic cutter. Incoming connections are also reopened using a robotic cutter.

Epoxy resin is used, as it is stronger, with better adhesive properties, and shrinks less than polyester or vinyl-ester resins. The strength properties are important in maximising the structural capacity of a fairly thin-walled liner. The elasticity of the felt and the adhesive properties mean that the liner can adhere tightly to the pipe wall, so minimising wrinkling at the tight bends habitually encountered in house service lines.

5 CONCLUSIONS

Investigations by Australian Water Authorities, in common with those around the world, have shown that sealing of house service lines and connections between house service lines and sewer mains is essential if infiltration and inflow into a sewer system are to be substantially reduced. Australian Authorities are now developing Specifications requiring sewer rehabilitation programmes to deliver completely sealed sewer and house service lines using techniques that will provide an expected service life greater than 50 years.

As at previous times in the history of the development of Trenchless Technology, the industry has responded to the challenge.

Systems are available to seal junction connections with a permanent physical barrier against roots and water ingress. House service lines can be structurally lined with high quality epoxy cured-in-place liners. Like liners for sewer mains, these can be installed without excavation using processes that cause minimal inconvenience to the community. There are cost benefits compared to excavation and replacement.

As these processes become a more accepted part of the industry, it can be expected that further developments will lead to greater improvements and efficiencies.

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