LATERAL THINKING – THE KEY TO MEETING SEWER INFILTRATION REDUCTION TARGETS

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ABSTRACT

Programs undertaken by Water Utilities to rehabilitate existing sewer catchments are typically designed to restore the structural integrity of deteriorated sewers and / or reduce infiltration / exfiltration (I/E).

Monitoring of the effectiveness of sewer rehabilitation programs has shown that achieving I/E reduction targets often requires more than just lining of deteriorated sewer mains. Five areas need to be comprehensively addressed:

1. The sewer main
2. The house service line (lateral)
3. The junction between the sewer main and the lateral
4. The connection at the maintenance hole
5. The maintenance hole itself

For more than the past decade Water Authority projects for the rehabilitation of deteriorated sewers by lining have included requirements for sealing of lateral connections. In this time the technology has developed from the early days with solutions that were shown to offer insufficient working life, through to a couple of generations of development of solutions that were progressively more effective and more practical to install.

Rehabilitation of maintenance holes is featuring more prominently in rehabilitation programs as the effects of deteriorating structures comes to be better understood. Lining of house service lines has always been plagued by questions of ownership and responsibility, but there is now the recognition of the contribution they make to infiltration into a sewer system.

This paper details latest developments in these technologies and how they are being effectively employed.

KEYWORDS

House service line, lateral, infiltration reduction, rehabilitation, sealing

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. Wet weather inflow and infiltration through cracked pipes or leaking joints can overload sewerage networks, leading to surcharges and overflows into the environment. Treatment plants are forced to treat high levels of diluted sewage and will often be forced to go on overflow during wet weather periods.

The Trenchless Technology industry has continued its rapid pace of development to devise increasingly more effective solutions to these issues, using rehabilitation methods that further minimise or remove the need for expensive and disruptive excavation.

While there are several different types of sewer main liners on the World market considered capable of meeting structural lining requirements, the issue of the gap, or “annulus”, between the liner and the host pipe still remains. Therefore, there exists the potential for infiltration and root intrusion wherever the liner is cut to form junctions with house service lines, or where the liner ends at a maintenance hole.

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 acknowledged as a significant source of infiltration that may overload treatment plants and contribute to downstream overflows. Studies from around the world show that rehabilitation of house service lines must be addressed if infiltration reduction targets are to be met.

With various techniques for structural lining having been accepted for over two decades, development has concentrated on efficiencies to drive down installed costs. Addressing the peripheral requirements for lateral connection sealing, lining of house service lines and maintenance hole rehabilitation is not so advanced and effective solutions are still being developed.

As in other areas of Trenchless Technology, local suppliers are at the forefront of such developments and are producing solutions that are world leading.

2 TRENCHLESS OPTIONS TO REDUCE INFILTRATION

2.1 JUNCTIONS

2.1.1 SEALING BACKGROUND

Several lining methods have proven effective in providing solutions to structural problems in deteriorated sewers. Cured-in-place (CIP) liners, fold-and-form (FF) thermoplastic liners, and spirally wound liners are all well accepted throughout the world. All these systems, if properly installed, provide an 'as new' pipe from manhole to manhole. However, the problem of the water path between the liner and the host pipe still remains, creating points of infiltration and exfiltration at lateral connections and manholes.

The liner annulus exists for a number of reasons including:

- Shrinkage in liners using resin and / or thermal curing processes
- Tolerances in both liner and original host pipe manufacture
- Irregularities in the cross sectional shape of the deteriorated pipe
- Inherent design of the liner

This means that the potential exists for infiltration into the sewer through an unsealed gap when the liner is cut to reconnect a house service line. An analogy would be joining two pipes by butting them together without some form of separate seal being installed.

Until about 2001, the accepted material for sealing house connections into lined pipes and liner ends at manholes was hydrophilic polyurethane grout injected under pressure. While it provided an effective seal, it tended to deteriorate in an unacceptably short period of time.

Later, revised Water Authority Specifications started to be released with upgraded requirements for lateral junction sealing. One such Specification stated:

"...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:

- *The minimum required service life of the installed lining material is fifty [50] years*
- *Provide a permanent water tight seal against infiltration, exfiltration and tree root ingress*
- *Smooth transitions that do not result in any accumulation or chokage"*

Polyurethane grout was incapable of conforming to these requirements.

Interflow, along with other Contractors working in the sewer rehabilitation market, invested considerable time and money in developing a superior long-term solution. The result was a "T-seal" or "junction former" which is installed under a number of proprietary names using a felt / resin fitting cured under pressure. It is typically installed with an inflatable T-shaped packer.

These T-seal fittings provide a full-circle short-form cured-in-place liner in the lined host pipe, bonded to a full bore liner extending up the house service line. The liner is installed into junctions via the sewer main without the need for excavation.

These T-seals provide Clients with several inherent benefits including:

- The installation packer positively locates the short-form liner 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 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 T-Seal liner is mechanically held in place, as well as being bonded to the main and lateral.
- A physical barrier against roots and infiltration which can be easily assessed by means of a CCTV inspection. Hydrostatic junction testing is not required.
- A semi-structural seal which can also repair a structurally deteriorated connection which might otherwise have to be excavated and replaced.

Sealing with these cured-in-place fittings is now a part of major Water Authority Specifications for lining of deteriorated pipelines. Tens of thousands have been installed.

2.1.2 LATEST DEVELOPMENTS TO OVERCOME THE DEFICIENCIES IN JUNCTION SEALING SOLUTIONS

Throughout the 2000's several companies around the world developed and made available cured-in-place tees for sealing of lateral connections to lined pipelines. They were all essentially similar, comprising a felt tee, internally lined with a plastic film and impregnated with resin. They were installed by mounting on an inflatable packer and inserting into the sewer from the nearest manhole. The packer was pushed up the sewer to the location of the lateral connection, then the lateral bulb launched, or the lateral arm inverted up the house service line. The packer was inflated, holding the resin impregnated felt tee tightly against both the liner in the sewer main and the first section of the house service line.

After the resin had cured, the packer was deflated and removed. This left a cured-in-place tee spanning the junction connection and providing not only a seal, but a positive barrier against infiltration, exfiltration and root ingress.

This operation was not without its challenges.

Junction connections installed over 50 years ago were frequently of non-standard configuration. Often they were damaged or deteriorated in much the same manner as the deteriorated sewer main being lined. Getting the lateral bulb of the tee shaped packer into such a junction by remote control often proved impossible. The further up the house service line the branch of the tee was expected to extend, the more unlikely the process was to succeed.

Mixing of the resin was critical to successful curing. Resin needed to be properly mixed on site in small quantities for each tee. Curing was also critical, with the right temperature needing to be maintained for success. Improper resin mixing or curing could result in the fitting failing to bond to the liner wall, or moving within the liner, so damaging the seal. A further problem was the time to cure, which was typically about 2 hours, leading to problems with blocking of the sewer for that length of time.

These issues resulted in an unacceptably low success rate with junction seal installation. Often only about 50% of junctions could be successfully renovated. The remainder needed to be excavated and re-built, or left unsealed, leaving the risk of infiltration or root intrusion.

Latest developments from Interflow have resulted in a much improved product that now leads the world in this type of technology. Advances have been made in all the components that go to make up the fitting, as well as the installation process.

The components developed to offer superior properties are:

- **Resin:** A proprietary silicate resin blend has been specifically developed to suit this application. Instead of previously taking 2 hours to cure, this new resin achieves full cure in 45 minutes. It cures effectively in wet conditions and has high adherence to PVC, concrete and vitrified clay. The pot life of the resin is 20 minutes, meaning the ratio of pot life to cure time is world leading for this type of material

- **Felt tee**: The tee is now composed of PVC coated glass fibre felt. Together with the resin, it offers increased strength, toughness and impermeability. The fitting has greater stand-alone strength.

  Changes in the shape of each tee have also been made.

  If a typical uniform tee shaped fitting is loaded onto a packer and inflated, then high stresses develop at the throat of the tee where the junction connection is made as the inflating packer attempts to stretch it longitudinally and laterally to contact the wall of the main liner and the house service line. This can lead to bunching and folds forming at the "throat" which can result in an unacceptable restriction forming that inhibits flow from the house service line.

  Finite element analysis has been used to determine the optimum shape so that the entire body of the tee is subject to uniform stress as the packer inflates. This has resulted in a non-uniform tee shaped fitting that is mounted on the packer. Having this optimum starting shape means that the chance of wrinkling at the throat is eliminated, so increasing the chances of successful installation. A patented process has been developed to manufacture tees in the designated shapes.

  Application of this shape modification has led to installed junction seals having a smoother internal finish.

- **Packer**: A smaller, lightweight inflatable packer has been developed for easier handling, offering the ability to install the fitting in a wide range of non-standard junctions.

  The packer is made from materials with a lower coefficient of friction and a shape that reduces drag as it is pushed inside the liner.

  The packer has hollow cores along its length. This means that flow can be allowed through the packer when it is inflated, so installation does not block the pipeline.

These advances have resulted in:

  The capability to be installed in a wider range of junction types including non-standard junctions and in some cases "knock-in" connections. The success rate for installation has risen to be essentially 100%

- Faster installation, meaning more fittings can be installed in a day

As a result, overall costs have been reduced. The installed cost of each fitting has reduced due to easier installation and the capability of a crew to install more in a day. The overall project cost has reduced because of this lower installed cost and the higher success rate meaning fewer excavations.

2.2 HOUSE SERVICE LINES

Laterals taking waste water from the house to the sewer main, have always presented a rehabilitation dilemma for Water Utilities.

Lateral lines are typically characterised by:

- small diameter, typically 100mm 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 is not suitable for house service lines.

In addition, records of the location of laterals are often not complete or accurate, leading to 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 could be variable.

While there are often issues with ownership and liability, installation of liners in house service laterals is an integral part of sewer rehabilitation Contracts from some major 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 laterals.

The lateral lining system installed by Interflow uses a highly elastic felt tube impregnated with epoxy resin which is inverted into the house service line from the I/O and cured by circulating hot water through the liner for approximately 2 hours. Similar systems are installed by other Contractors using some variations on materials, inversion methods, and curing methods (which might involve the use of steam for curing).

Development is on-going with the aim of reducing installation time and improving overall efficiency.

2.3 MAINTENANCE HOLES / ACCESS CHAMBERS

Many of the reasons for rehabilitating maintenance holes are the same as those for rehabilitating sewer pipes; namely to repair/renew the structure, protect against gas attack, stop leaks and seal against infiltration.

Maintenance holes represent a significant proportion of a sewer network. In some configurations they can account for up to 30% of the total surface area of the sewer. Leaving the maintenance holes untreated leaves a large section of the sewer network exposed to deterioration.

A range of coatings is available, depending on the degree of rehabilitation required. The choice of which option to apply depends on the condition of the maintenance hole. Proper evaluation is therefore essential.

Maintenance holes have the advantage over most pipelines in that evaluation can be performed by man entry, rather than having to rely on remote CCTV. Man entry can be used to inspect and record the surface condition, including determining the depth of concrete lost to corrosion and the remaining wall thickness.

Once an evaluation has been made, a suitable rehabilitation program can be compiled using the expanded range of coating options now available. These include:

- Polyurea: a 3 – 5mm coating of polymer that is inert to sewer gas, hard wearing, flexible and capable of rapid application. It is used where the surface is in good condition and a coating is needed to provide protection against further deterioration

- Calcium aluminate cement: a corrosion resistant cementitious coating. When applied as a thin coating (12 – 15mm) it provides protection to the surface in all but the most acidic conditions. Thicker coatings can be applied to restore the strength of a concrete maintenance hole that has lost a proportion of its wall thickness.

- Epoxy mortar: has been used for over a decade as a re-build coating for maintenance holes. It is typically applied in thicknesses of 10mm to 20mm. Epoxy mortar has high strength, high corrosion resistance and high bond strength to concrete.

Experience has led to the recognition that proper surface preparation is vital to the successful application of any of these coatings. Preparation includes sealing against infiltration. Latest methods include injection of hydrophilic polyurethane to stop gushing infiltration while the coating is applied.

3 CONCLUSIONS

Australian and New Zealand Water Authorities, like their counterparts from around the world, have acknowledged for the past decade that sealing of lateral connections to lined sewers is necessary if infiltration, exfiltration and tree root ingress are to be avoided. Such sealing has been included in pipeline rehabilitation contracts over this time, with remotely installed cured-in-place tees being routinely specified.

Operating remotely in small diameter deteriorated sewers is inherently difficult. Latest developments have seen methods for installing cured-in-place tee seals improve, so raising the rate of successful installation. This has, in turn, led to reductions in installed cost.

Development is also on-going in other peripherals to main lining as acceptance grows that house service line sealing and rehabilitation of maintenance holes is also needed to ensure efficient long term operation of a sewer system.

The Trenchless Technology industry is responding to these needs, and as with other developments in the industry, advances are being made through cooperation and partnership between suppliers and Clients.

As the demand for trenchless solutions grows and the processes become an accepted part of the industry, it can be expected that further developments will lead to greater improvements, efficiencies, and cost savings.