Australian Experience with Spiral Wound Liners
For Large Diameter Sewer Pipelines

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INTRODUCTION

Since the early 1980s rehabilitation of failing sewers has assumed increasing importance for Water Authorities and local Councils. Many sewers laid several decades ago 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 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.

Several techniques have been developed to install structural liners from maintenance hole to maintenance hole without having to excavate and expose the old pipe. These liners effectively provide a new pipe with minimal reduction in cross sectional area. Cured-in-place, fold-and-form and spiral wound liners have all been extensively installed worldwide for many years.

In the past, Water Authorities have tended to shy away from the task of full structural rehabilitation of large diameter sewers until the risk of catastrophic failure became too great. The wide range of solutions for smaller diameter pipelines was simply not available for the larger sizes. Inherent difficulties included:

- Taking an important trunk main out of service while rehabilitation was carried out
- Bypass pumping of high flows
- Introduction of high flow surges from major pumping stations
- The risk of overflows during lining
- Costly excavation due to depths and locations
- Disruption to residents caused by working in built up areas.
- Risk to personnel from working inside a deteriorated pipeline

Overcoming these difficulties required the invention of products that satisfied the structural requirements, and the development of innovative construction practices that allowed these products to be installed.

The ingenuity necessary to meet these requirements has been matched by the willingness of Australian Water Agencies to allow, after thorough evaluation, the resulting innovative solutions to be incorporated on substantial pipeline rehabilitation projects.

This Paper presents details of major Australian projects where Australian developed spiral wound liners have been used in world-leading applications.

The end result has been the successful completion of projects requiring a partnering approach between the technology developer, the contractor and the Agency. This success has extended the possibilities for structural rehabilitation of these types of pipelines.

AUSTRALIAN LARGE DIAMETER LINER DEVELOPMENTS

One of several areas where the Australian Trenchless Technology industry leads the world is in the development and application of spiral would liners for structural lining of deteriorated sewers.

Liners are typically installed without excavation, using a winding machine placed in the base of an existing manhole. The liner is formed from a single, continuous strip of plastic with edges that lock together as it is wound by the winding machine. The plastic strip is profiled, with tees on the outer side, to provide a liner with a high stiffness to weight ratio. The side of the plastic strip that forms the inside of the liner is smooth, so minimising flow resistance.

Two Australian developments over the past few years have extended the capabilities of spiral wound liner technology to the structural rehabilitation of larger diameter sewer pipelines.

Rotaloc and Ribline can be designed as structural liners. In accordance with most pipeline rehabilitation Specifications, this means the liner must be designed as a flexible pipe capable of carrying all loads from soil, groundwater, traffic etc. Design must assume that the deteriorated host pipe has no remaining strength and is merely part of the soil system supporting the liner.

Rotaloc

A Rotaloc liner is formed as a profiled plastic strip is fed into a winding machine that rotates as it locks the edges together. The rotating winding machine, in effect, "crawls" forward down the line along the profile strip, locking the edges together.

The "arms" of the winding machine that hold the profile and lock its edges together are attached to hydraulic rams. These can move to alter the diameter at which the profile is wound to form a liner. By this method, it is possible to maximise the liner's diameter by adjusting it so it contacts the internal wall of the host pipe, while still remaining circular. When point deflections, stepped joints etc are encountered, the hydraulic arms reduce the liner diameter until the obstruction is passed. The liner then returns to the maximum diameter.

Fig 1: Rotaloc winding machine

The spiral lock of the Rotaloc PVC profile contains adhesives as well as an EPDM rubber seal. All sealants and adhesives are pre-applied as part of the plastic strip extrusion process. No sealants or additional sealing components need to be applied on site

Rotaloc liners can typically be used for pipelines with diameters from 900mm to 1,500mm.

Ribline

The stiffness of a liner (or pipe) varies with the cube of diameter. If the diameter doubles, then the moment of inertia of the pipe wall has to increase by a factor of eight if the pipe is to have the same stiffness. This means that for larger sized pipes, it becomes unfeasible to manufacture plastic liners that meet the stiffness requirements for structural design.

Ribline solves this situation by strengthening the liner wall with steel reinforcement.

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Fig 2: Cross section of the Ribline liner wall

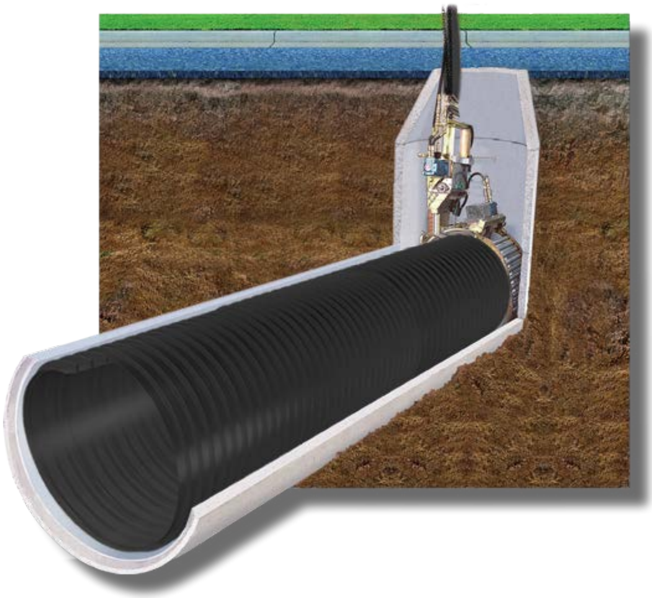

Fig 3: Schematic of the Ribline installation process

Ribline is a ribbed polyethylene liner with each rib reinforced with a strip of steel. A continuous strip of the steel reinforced polyethylene profile is wound in a helical formation by a winding machine which welds the edges of the strip together to form a pipe. The installation equipment can be dismantled to fit through an access chamber opening and to be reassembled at the base.

As welding is used to join adjacent strips of polyethylene profile to form a "pipe within a pipe", the liner formed has a constant diameter along its entire length. However, the configuration of the winding machine is such that it can be easily adapted to make the largest diameter that will fit into the deteriorated pipeline. Ribline is not restricted to a range of standard diameters.

PROJECT CASE STUDY: ROTALOC: Concord NSW: Limited working hours, bypass pumping, residential area

This Sydney Water Contract called for the rehabilitation of part of Sydney Water's Concord sewer sub-main, originally constructed in 1935. A 560m long section of 915mm diameter reinforced concrete pipeline required a structural liner, and 6 manholes required rehabilitation. The pipeline and manholes had all suffered deterioration due to hydrogen sulphide gas attack.

The rehabilitated section of sub-main receives flows from 3 sewage pumping stations (SPSs):

- SPS 90: This station pumped flow directly into the manhole at the upstream end of the deteriorated section. Sydney Water allocated a *six-hour* period from 9am to 3pm during which flow would be stored. Interflow, the liner installation contractor, was only permitted to enter the pipeline during this 6-hour period, although work external to the pipeline could extend before and after.

- SPS 91 – This pumping station discharged into a manhole approximately 100 metres from the start of the project through a 600mm rising main. These flows could not be shut off or diverted as they drained from all local systems. The only option was to bypass pump from SPS 91 to a sewer that discharges into downstream pumping station SPS 41.

Setting up of the bypass system involved two x 200mm pumps (one active and one standby) complete with 1,100 metres of 200mm diameter polyethylene delivery pipe with Victaulic couplings in 6 and 12 metre lengths. The temporary pipeline crossed environmentally sensitive parklands and a concrete stormwater channel. A temporary bridge was constructed across the channel to support the pipe.

- SPS 41 – This pumping station discharged into the manhole at the downstream end of the project. Sydney Water diverted it permanently for the duration of the works, with the stipulation that it should be capable of being restored to full operational use in storm conditions.

Fig 4: Rotaloc liner in a brick pipeline

Fig 5: Rotaloc lining through a manhole

The location in Concord West is an established residential area with quiet, wide, tree-lined roads. To avoid disruption to residents, noise and traffic control issues needed to be addressed.

Typically, Interflow was able to install some 80 metres of Rotaloc liner during the 6 hour time frame allowed for pipeline access. This lining could be completed in 3 hours of winding time. After setting up of the machine, winding was by remote control from above ground, where the machine operator monitored installation via CCTV cameras mounted on the Rotaloc machine. Man-entry to the deteriorated pipeline during liner installation was not necessary – an important safety consideration. The remainder of the time was taken up with setting up of the machine in the pipeline, removing it at completion of the day's lining work, then making the site safe prior to finishing work for the day.

Despite the bypass pumping and co-ordination with the pumping stations, there was always flow in the deteriorated pipeline during liner installation from local sewer reticulation systems.

As the deteriorated pipeline was gas attacked, the cross section of the pipe was an irregular shape. The Contract required Interflow to fill voids in the pipe external to the liner with cementitious grout. Prior to lining, 100mm diameter grout injection holes were drilled down from road level through the top of the pipe at 20 metre centres. Grout was then introduced through these injection holes after lining.

The project was completed on budget within 8 working weeks, more than 5 weeks ahead of schedule.

PROJECT CASE STUDY: RIBLINE – Coogee Diversion Sewer, NSW: Deep, 1830mm diameter pipeline

In late 2005, Interflow completed a project for Sydney Water to renew an underground 1.28 kilometre section of the 1,830mm diameter pipeline that transports sewer flow from much of eastern Sydney to the Malabar treatment plant.

The deteriorated section of pipe started below a residential area in Maroubra, a Sydney beachside suburb, continued beneath the Anzac Rifle Range before entering a large inlet structure just upstream of the Treatment Plant. Depths below ground ranged from 3.3 to 7 metres.

Detailed investigation and condition assessment showed that some 50 metres of this sewer had deteriorated to a stage where normal safety margins had been exceeded, and would soon be in a state where collapse would be a possibility. The remaining sections were in slightly better condition but problems could be expected to escalate to a critical stage within the next 5 years.

Design showed that adequate stiffness could be provided by a Ribline liner with an internal diameter of 1,700mm and wall height of 31mm. Survey showed that the actual internal diameter of the deteriorated host pipe was 1,830mm. Therefore, if the liner was centralised in the pipeline, the annulus around the outside of the liner would be 34mm.

Issues to be addressed included:

- Flow control so that:
  - Sewer services to the community could be maintained throughout the project
  - Liner installation could be safely undertaken
  - The liner would not be blocked in the event of a rapid flow increase such as sudden heavy rainfall
- Minimal excavation in built-up or contaminated areas. The depth of the pipeline, up to 7 metres, made excavation undesirable.
- Long distances between access chambers – up to 224 metres. The pipeline could not be accessed from above ground in between these chambers

Flow Control

Flow control, vital to the success and safety of the project, comprised two components:

- Bypass overpumping
- Controlled flow release.

Analysis by flow monitoring showed that work could take place during low flow periods at night, with an overpumping system to have the capacity to take the dry weather flow.

An overpumping arrangement was subsequently installed to take flow around the worksite in a single stage. Double stop-boards 1.5 metres apart were installed in a shaft upstream of the works. Flow stored behind the stop-boards was pumped through a total of 3,400m of PE pipe around the section being lined.

The stop-boards could be raised to enable some flow into the pipe section being lined. This aided installation as it allowed the liner to float as winding proceeded, so reducing friction at the winding head.

In the event of rainfall upstream of the site, equipment could be rapidly removed and the liner secured. The weir boards were designed so that they could be easily raised. This was necessary at the end of each shift to allow the pipeline to regain its full flow capacity but also allowed the contingency of removing the obstruction if necessary during the night shift liner installation.

Minimal Excavation in Contaminated Ground

While installation of Ribline did not require the large degree of excavation that would have been necessary with slip lining, the configuration of the manholes with the pipe offset, meant that the top of the manhole had to be removed to allow the winding machine to be placed in the pipeline.

Anzac Rifle range was originally an army base. Prior to that it was an uncontrolled landfill site. Asbestos and contaminated leachate are buried beneath the surface. Therefore strict safety controls were necessary for any excavation in that area.

The soil removed was treated as contaminated alluvial topsoil and securely transported off site in sealed containers and disposed of in accordance with Environmental Protection Authority guidelines. It was replaced with clean fill.

During the works, an exclusion zone was established around the site of the excavation. A specialist was appointed to monitor for signs of harmful gas given off by the soil in the exclusion zone.

Fig 6: Installing the Ribline liner inside the 1,830mm diameter deteriorated pipeline

Long Distances Between Access Chambers

Manufacture of the liner was done with some 300mm depth of water in the pipeline. Soon after winding of the liner began, it was observed that after some 10 metres of the liner had been manufactured, the end of the liner commenced floating. Torque readings at the winding machine barely increased as winding proceeded, because the buoyancy of the liner meant that additional weight was minimal.

So, it was decided to continue winding. Above ground, spools of profile were welded together to allow winding to be continuous. Thus, winding continued well past the proposed maximum of 30 metres.

The slope of the pipeline was not great, however after about 100 metres of continuous liner had been manufactured, flotation meant that the top of the liner began to scrape against the top of the sloping pipeline.

Buoyancy of the liner was controlled by use of a tractor tyre tube having about the same external diameter as the internal diameter of the liner. This was mounted in a specially fabricated holder, inserted in the leading end of the liner and inflated. The tractor tyre tube acted as a dam with water being placed behind it to add weight to the liner.

By controlling the amount of water held inside the liner, its buoyancy could be controlled, thus allowing the liner to be wound parallel to the slope of the host pipeline. Flotation minimised the additional weight.

Minimal Inconvenience

By delivering the liner to site on spools, minimal space was required compared to storing long lengths of large diameter pipe on site. Each spool held the equivalent of about 30 metres length of liner. The storage advantages this offered in a built up suburban area were obvious.

Project Implementation

Careful coordination was required between Sydney Water Operations Personnel, Interflow, and Interflow's sub-contractors to ensure the safety of all personnel during the works. Working in large diameter live sewers can be extremely dangerous, especially in this case where the section of pipeline being rehabilitated was receiving pumped flows from a wide area serviced by several pumping stations.

Consultation with residents was necessary prior to commencement of works. Local residents were advised by a leaflet drop at least 2 weeks prior to the commencement of work that directly affected them. The leaflet included details of the work methods and work times, as well as the expected benefits, and contact details for Interflow and Sydney Water representatives. Door knocks and advertising were also implemented as part of the Communication Strategy.

At the conclusion of the project the client, Sydney Water, expressed their satisfaction with the way it had been carried out, citing in particular:

- Meeting the structural design requirements
- No interruption of services to customers during the project
- Compliance with stringent Occupational Health and Safety and environmental standards
- Successful community relations management

CONCLUSIONS

The development of world leading spiral wound lining systems for large diameter sewer rehabilitation and the demonstration of their suitability on projects such as these have extended the range of options available to Authorities.

For large diameter sewers, Australian developed spiral wound liners have been proven to offer:

Structural design: Liners can be conservatively designed to renew fully deteriorated pipelines.

Installation in suburban areas without undue disruption: Installation uses existing access chambers without the need for excavation. Little pre-construction site establishment or reinstatement is necessary after the works are complete.

Installation can take place during limited time periods to meet Authority operating requirements.

The liner can still be installed if there is some flow in the pipeline, so the need for bypass pumping is minimised.

Traffic can still move around access chambers located in roadways. In cases where access for support vehicles is not available, winding can still be performed with the vehicles located remotely.

Installation around bends: Innovative methods have been developed to negotiate tight radius bends without compromising safety or the structural capabilities of the installed liner

High Level of Safety: As existing access chambers are used, there are no open pits requiring safety barriers. The access chamber covers are simply replaced at the end of the day's work.

Risk to installers is also reduced, as the need to work in the deteriorated pipeline is much reduced.

The success of these projects has lead to additional large diameter projects being awarded to spirally wound liners. Having been developed, and proven their suitability in Australia, they are continuing to gain acceptance around the world.