Australian-made technology renews Sydney's oldest sewers

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Abstract: Like all large cities around the world, Sydney's major underground sewers are deteriorating through age and reaching the end of their service life. To succeed in its vision to be the lifestream of Sydney for generations to come, Sydney Water's active sewer renewals program needs to renew underground sewers beneath heavily populated and environmentally sensitive areas. One of Sydney Water's pipeline rehabilitation contractors, Interflow, recently applied world class spiral wound lining technology to renew two of these sewers without excavation or interrupting services. This Australian made technology is pushing the boundaries in non-disruptive underground sewer renewal previously considered too difficult or impossible. The projects carried out for Sydney Water and discussed in this paper have twice received the International Society for Trenchless Technology's award for international project of the year.

Keywords: Trenchless technology, sewer renewal, spiral wound lining technology

Introduction

Sydney Water is Australia's largest water utility, responsible for supplying water, wastewater, recycled water and some stormwater services to 4.8 million people in Sydney, Illawarra and the Blue Mountains. It is a statutory State owned corporation with 3,000 staff and an area of operations covering 12,700 km^2.

Sydney Water's sewer renewals program faces both environmental and social challenges such as potential leaks into groundwater or the environment, structural failures, and working with old sewers below some of the most densely populated parts of the city.

Sydney Water's program specifically requires rehabilitation methods that do not require excavation and which provide continuous sewer services. It has a history of producing demanding criteria to drive the industry to find world-leading solutions.

Interflow Pty Limited, one of Sydney Water's key sewer renewal delivery contractors, has twice received the international project of the year award from the International Society for Trenchless Technology's for projects using locally developed spiral wound lining technology.

Project 1: Lining of North Georges River Submain

The North Georges River Submain is a major part of Sydney Water's sewer network, serving a large and growing population in Sydney's south west. It is a pre-cast reinforced concrete pipeline with a nominal diameter of 2,515mm, constructed in a combination of trench and tunnel. The pipeline was constructed under a number of different projects with pipes supplied by a number of different pipe manufacturers over a period of a couple of decades, so there were variations in dimensions and construction methods.

Inspection found concrete deterioration due to H_2S attack, with exposed aggregate and exposed reinforcement in some sections. A decision was made to renew sections of the pipeline that were near the end of their service life and those which had only 5 to 10 years of service life remaining.

The client, Sydney Water, called for the pipeline renewal in a trenchless manner with:

- no disruption to the sewer system
- minimal impact on the environment, particularly the section of sewer passing under a nature reserve
- minimal disruption to the community as the sewer passed beneath houses and industrial complexes in suburban Sydney and also beneath high profile locations such as Bankstown Airport. It was essential that these residences and businesses could keep operating without disruption and without the adverse exposure to odours and noise.

Access to the sewer was mainly through maintenance holes with openings of only 600mm diameter, with a couple of larger chambers along the route. Distances between access points were up to 700 metres. While the depths at these access points varied between 3.5 metres and 5.5 metres, intermediate depths were up to 23 metres.

The liner needed to be structurally sound, capable of resisting applied loads, while providing an installed internal diameter of at least 2,400mm. The sewer needed to remain in operation during the project (without bypass pumping) and renewal should preferably be carried out without excavation.

Sydney Water awarded Interflow a contract to reline and renew sections of this pipeline totalling 5,438 metres in length. Interflow installed a Ribline spirally wound pipe with an internal diameter of 2.4 metres. The liner was installed continuously over distances of up to 706 metres, without the need to construct intermediate access.

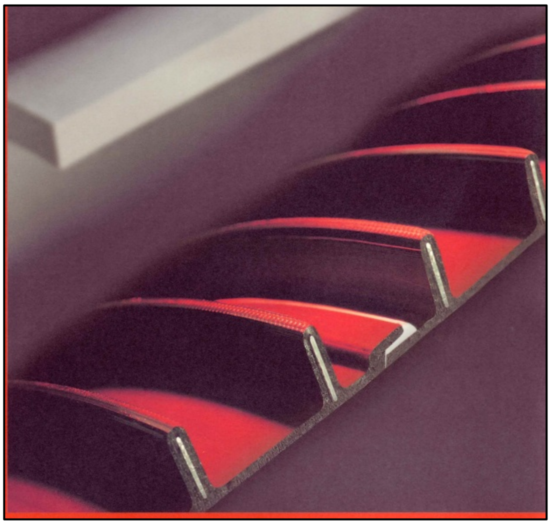

Figure 1: Ribline wall section with steel strip encased within the polyethylene ribs

Ribline is a spiral wound steel reinforced polyethylene liner installed by a winding machine placed in the base of a maintenance hole at the entrance to the pipeline. The liner consists of a continuous strip of ribbed polyethylene with each rib encasing a continuous strip of steel. The winding machine pulls the continuous strip from a spool above ground and winds it, welding the edges together to form a continuous barrel of liner.

The steel reinforcement gives the liner the structural stiffness to resist applied loads. It is a fixed diameter liner that is encased in cementitious grout after installation.

Before this project the practical limitation for the maximum length and size of pipe that could be produced using this spirally wound technique was governed by the torque of the winding machine and its ability to overcome the weight and frictional forces as the liner spirals along the inside of the host pipe. Attempting to install a 2,400mm diameter liner continuously over 706 metres between access points was well beyond the scope of what had previously been attempted.

Ribline can be installed in limited live sewer flow, typically up to a depth of 20% of the pipeline diameter. The flow allows the liner to float, so reducing friction as it is wound, and allowing longer continuous lengths of liner to be installed. As the liner floats horizontally, while the sewer slopes, eventually the liner comes in contact with the crown of the pipeline, which increases friction and limits the capacity to install a continuous length.

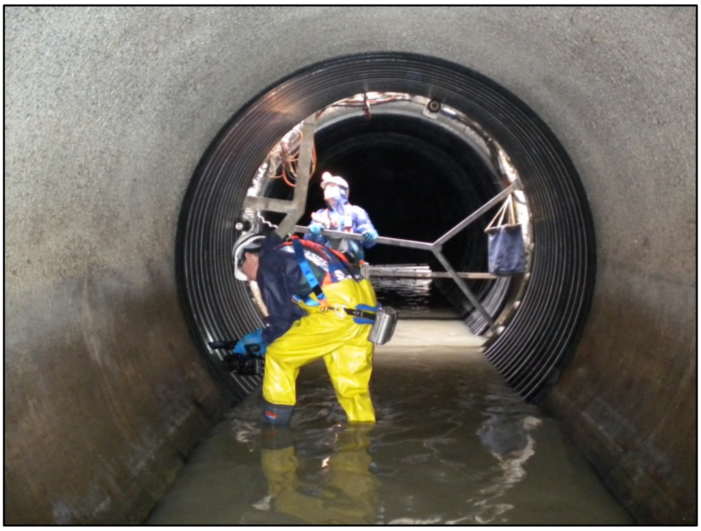

Figure 2: Installing the Ribline liner in live flow conditions

The key to meeting the challenge of continuously lining up to 706 metres of pipeline was in developing an innovative floatation control technique.

Using flow and buoyancy calculations, Interflow engineered a diversion device that enabled pipe buoyancy to be controlled, even in fluctuating flow conditions as the liner was wound into the pipeline. A method was developed to control the buoyancy of the liner by controlling the volume of flow allowed through the liner so it floated continuously at the same slope as the pipeline.

The device was adjusted so that the torque (frictional force) was kept at the optimum level. Using this method, a continuous length of liner of 706 metres weighing over 120 tonnes was able to be produced. The installation methodology meant that the torque levels on the winding machine remained low, indicating that the maximum possible length is longer still than the 706 metres achieved on this project.

Development of this installation methodology was essential to achieving the aims of this project and overcoming the constraints imposed. The alternative would have meant constructing intermediate access chambers and/or using conventional dig and replace methods. Given that the pipeline ran below high profile locations such as Sydney's Bankstown Airport, alongside residential properties, and below an established nature reserve and recreational park, this had the potential to cause community disruption, add considerable cost and cause unwanted environmental impact.

By challenging the Australian trenchless technology industry, Sydney Water was the catalyst to advance and expand existing technologies to rehabilitate deteriorated underground assets.

Project 2: Rehabilitation of Lidcombe, Auburn Granville (LAG) Sewer Mains

This project was one of the most challenging Interflow and Sydney Water have completed, and again required the development of world leading technology to meet all requirements.

This project involved the structural lining of some 1.2 kilometres of 900mm diameter reinforced concrete sewer, originally constructed in a tunnel around 1922. This project was challenging because:

- the liner must restore the long term load carrying capacity of the pipeline
- the rehabilitated sewer must not reduce flow capacity compared to the original sewer
- depths to invert are between 13 metres and 22 metres
- there is a significant bend along the pipeline
- the area has a high groundwater table
- there are long distances between access points of up to 200 metres
- the sewer has a high flow, which includes a high proportion of trade waste
- the pipeline route included both heavily populated and environmentally sensitive areas. It also passed deep under one of Sydney's busiest intersections, connecting the M4 Western Motorway and Silverwater Road.
- the sewer main is important as it services several upstream pumping stations, and it could not be taken out of service at any time during the work
- the methodology had to allow for the sewer to be brought back to its full flow capacity within three hours in the event of an emergency or wet weather event.

At the time of tendering, practical rehabilitation solutions that met all these requirements and challenges did not exist. Spiral wound liners were considered to have the greatest potential, although further development was required. The requirements for full return to service in 3 hours eliminated the possibility of CIPP lining.

Spiral wound liner installation does not block the pipeline. Flow can be allowed through a partially installed liner without compromising its integrity. In the event of sudden flow increase, the partially installed liner can be secured and all equipment removed from the sewer before restoring it to its full flow capacity. This can be accomplished well within the 3 hour time limit specified. When flow subsides, liner installation can recommence.

With the co-operation of Sydney Water and the support of technology partner Sekisui Rib Loc, Interflow was able to develop further innovations in spiral wound lining and grouting technology that allowed the project to be delivered successfully.

Innovations included:

- modifications to Expanda Pipe lining – both the liner and the installation process
- use of the newly developed Rotaloc bend profile – that allows continuous winding around bends
- development of a high flow, zero settling grout that could flow over 100 metres from a single access point

Figure 3: Route of the pipeline under a heavily developed area in western Sydney

Expanda Pipe is a spiral wound liner that is installed by a winding machine placed in the base of an access chamber. A continuous strip of PVC profile is fed from a spool above ground to the machine, which continuously winds it in a helix. This locks the edges together to form a liner which "corkscrews" its way up inside the deteriorated pipeline until it reaches the next access chamber. The liner is then mechanically expanded to firmly make contact with the existing host pipe.

Interflow, together with its partner Sekisui Rib Loc, developed a larger and thicker profile strip. By increasing the height of the tees and the thickness of the PVC, a strip was developed that provided the liner with more than double the stiffness of the largest previously available Expanda Pipe liner. It met the structural design requirements of this project.

This larger and heavier Expanda Pipe profile meant that higher capacity installation equipment was required. Development of a more powerful "Kubota" winding machine was carried out at Interflow's research and development facility.

Expanda Pipe requires a single strip of profile strip to be provided to line the full distance between access points. Access by a technician is required at each end. With this newly developed large size profile strip wound at 900mm diameter, a single spool only contains enough material to manufacture a liner for about 100 metres of pipe. This equates to only half the maximum distance required between access points on this project.

To complete this project, Interflow developed a method of remotely expanding the liner that did not require a technician to access and secure the line at the far end. The liner could be wound to about the midpoint of the line, then a newly developed process would hold the far end while expansion commenced. The liner was then wound from the other end and remotely expanded. The small gap between the two lengths of liner at the midpoint of the pipeline was sealed with a remotely installed fibreglass "patch." This world-first innovation meant that there was no need to dig a deep intermediate access chamber in a location where excavation would be extremely difficult.

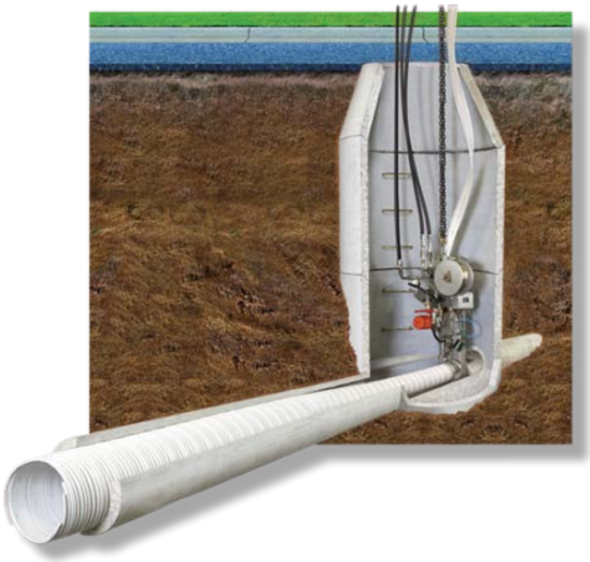

Figure 4: Expanda Pipe installation from existing access points

Another challenge was a limitation with spiral wound liners as they are typically only suitable for straight pipelines. They cannot be installed continuously around bends. Interflow had been researching a development that could partially overcome this limitation.

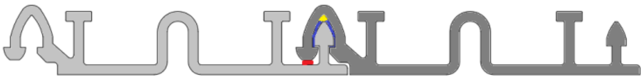

Figure 6: Rotaloc bend profile strip cross section with the "loop" that allows continuous lining around a bend

Rotaloc is a spiral wound liner that differs from Expanda Pipe in that the winding machine moves along inside the deteriorated pipe, progressively winding the liner tightly against the wall of the existing host pipe as it goes.

Interflow developed a Rotaloc profile strip with a U-shaped 'loop' in its cross section as shown in Figure 6. As the profile strip forms a liner around the bend, the loop opens slightly on the outside of the bend and closes slightly on the inside. Calculation and development trials showed that using this strip meant that the liner could accommodate the bends on this project.

Figure 5: Rotaloc installation in live flow conditions

Design for spiral wound lining of larger diameter sewers typically requires the liners to be encased in cementitious grout to enhance support and meet structural requirements. Grouting typically requires pumping from maintenance hole to maintenance hole in small diameter pipes where the grout quantities are small, or at injection intervals of 40 metres along the pipeline length in larger sizes or longer lengths. Intermediate injection requires entry by a technician.

For this project, approximately 20 cubic metres of grout were required per maintenance hole length and it was not possible for a technician to enter the pipe. Interflow needed to develop a grout material capable of being pumped rapidly, have low viscosity, and not exhibit water separation, bleed or shrinkage.

Interflow was successful in developing a material that was based on 75% flyash (a waste product from coal fired power stations) that flowed with a viscosity lower than previously available. Use of this grout allowed grout pumping from a single injection point over the long distances between access points on this project, with low pumping pressures. Once the grout had reached the downstream manhole, pumping ceased and the grout then set hard in less than 24 hours. This advancement significantly changed the way Interflow now grouts spiral wound liners.

Expanda Pipe and Rotaloc can be installed with some flow in the pipeline, so, if necessary, installation can be done at night during low flow periods without bypass pumping. Continual high flow on this project meant that this was not possible and a bypass system was needed to handle normal dry weather flow, although not the high flows that would apply in storm conditions.

Bypass pumping was complicated as the line was too deep to allow submersible pumps to bring the flow to the surface in one lift. A "pump-out pit" had to be constructed to allow the flow to be lifted in two stages.

The "pump-out pit" was constructed at a convenient location downstream of an existing maintenance hole, with excavation to the invert of the DN900 sewer. Double isolation was installed to allow lining work to be carried out downstream. The pit, with cast piles and walls comprising shotcrete over reinforcing mesh provided safe access for installation of the liner and the bypass pipework. It was a major civil engineering project in its own right.

New developments carried out to meet Sydney Water's requirements on this project have advanced the capability of the trenchless technology industry to meet the rehabilitation needs of deteriorated sewers in built up areas, which are common around the world.

Conclusions

Both projects were complex and demanding, requiring advances in spiral wound lining and associated technology to widen the possibilities for structural lining of deteriorated sewers worldwide.

By setting such demanding requirements on these projects, Sydney Water has driven the industry to rise to new challenges which were ultimately met with the development of world leading solutions. The renewal of these ageing and deteriorated sewers was made possible and their practical life was extended by over 50 years.

Both were deep pipelines that ran through environmentally sensitive areas with demanding community issues. Excavation was not really an option.

The work had to be carried out while the sewers remained in full service. At all times Interflow needed to be ready to remove all obstructions and return the sewers to their full flow capacity within the specified three hours.

Each of these projects has received world-wide recognition. Each has received the International Society for Trenchless Technology's annual "No Dig Award" for the most important project completed in the industry world-wide in that year.

These are Australian examples of the co-operation required to stimulate and implement innovation in the still developing trenchless technology industry to meet the needs of growing cities. These examples have implications for cities around the world.