PAPER 8

A CASE FOR TRENCHLESS TECHNOLOGY - MAHATMA GANDHI TRUNK SEWER REHABILITATION PHASE 2

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ABSTRACT

The project is a good example of a use case for Trenchless Technology (Cured in place Pipe) in comparison to open trench construction in an urban area with difficult site conditions. The project at the time of construction was the longest and largest diameter of cured in place pipe installed in Africa and was the winner of the 2021 award of excellence from the Southern African Society for Trenchless Technology. The existing 1350mm diameter concrete trunk sewer pipeline in Mahatma Gandhi Road Durban Central was constructed in 1954 (69 Years Old) has a total length of 1.8km and carries most of the city's central sewage catchment and is approximately 7.5m deep at its deepest point.

After an investigation the pipeline was found to be severely corroded, to an extent that it was close to collapse and required immediate attention. Scope of the project included rehabilitation of the existing 1350mm diameter sewer 1850m long using Cured in place pipe (CIPP) cured by UV light as the method of rehabilitation. In addition, 80m of 1250mm diameter HDPE was laid at depths of 6.0m using open trench construction required to complete the rehabilitation project in severe water logged conditions. Rehabilitation of 300mm diameter asbestos cement pipe using CIPP by Thermal Curing was also part of the project scope. The sewage catchment of the pipe required to be rehabilitated had incoming sewer pipes of 860,1050 and 1100mm diameters at various locations. The sewage from these incoming pipes were bypassed to facilitate the rehabilitation of the existing 1350mm diameter concrete pipe. The diversion of flows from different points along the 1350mm diameter pipeline presented a unique challenge due to the volumes of flow involved and the effect any diversion of flow will have on the rest of the sewer network in the area.

In addition, there were four smaller lateral incoming flows on the line which needed to be diverted. The liner was designed based on a fully deteriorated condition with onsite measurement of the ovalties along the pipeline. The liners thickness installed varied from a 10.8mm to 14.9mm using a reinforced UV cured liner supplied by CIPP liner supplier based in Germany. Numerous challenges were experienced in the installation mainly due to the weight of the liners (up to 15 tons) into a manhole access point inside a large diameter pipe.

The project demonstrated the capacity of rehabilitation of a sewer pipe in difficult conditions offers a resilient solution to infrastructure repair for projects now and in the future.

1. INTRODUCTION

This paper gives a contextual background, planning, design, and installation of a case for trenchless technology for rehabilitation of sewage pipelines in a built-up central business district metropolitan coastal city of South Africa using cured in place pipe liner for a1350mm diameter concrete pipe (which the paper primarily focuses on). The rehabilitation of a 300mm diameter asbestos cement pipe using the thermal method of curing is also discussed. The paper details why trenchless technology was considered due to the urban environment, significant number of underground services and the difficult in-situ ground conditions with a high-water table that made open trench construction comparatively more expensive, difficult and time consuming and discusses all elements of the project.

2. BACKGROUND- WHY TRENCHLESS WAS CONSIDERED

The existing 1350mm diameter concrete trunk sewer in Mahatma Gandhi Road which was constructed in 1954 has a total length of 1.8km and carries most of the central business district (CBD) sewage in Durban. Cracks and subsidence appeared on the road surface above the pipe, which eThekwini Water and Sanitation Unit suspected was due of the concrete sewer pipe and conducted closed circuit television (CCTV) of the 1350mm diameter pipeline. The pipeline was found to be severely corroded, to an extent that it is close to collapse and required immediate attention.

Work was started on Phase 1 of the project for a length of 640m, however, due to budget constraints, only 560m was completed. Phase 1 comprised the installation of a new 1250mm diameter Structured wall HDPE pipeline at a depth of 7.7m at its deepest point located well below sea level with the water table being 1.1m below the road surface. Phase 1 Construction was conducted using an open excavation method of construction, requiring sheet

FIGURE 1: *Corrosion inside existing 1350mm diameter concrete pipe*

FIGURE 2: *Phase 1 open trench construction with deep shoring and dewatering*

FIGURE 3: *Phase 1 open trench construction with high water table below sea level*

metal shoring and extensive dewatering to work at these depths. The new pipeline was constructed parallel to the old pipeline, enabling minimal disruption to the sewage flow in the existing pipe until the new pipe could be connected into the existing tie-in manholes. It was a slow process due to the ground conditions and it affected traffic and the surrounding business significantly during the 18-month construction duration.

Phase 2 of the project which is the subject of this paper was required to complete the work started in Phase 1 (80m of open trench method of construction), however using the lessons learnt from Phase 1 and to avoid major disruption to the public caused by open trench construction the alternative method of pipe rehabilitation was the preferred option.

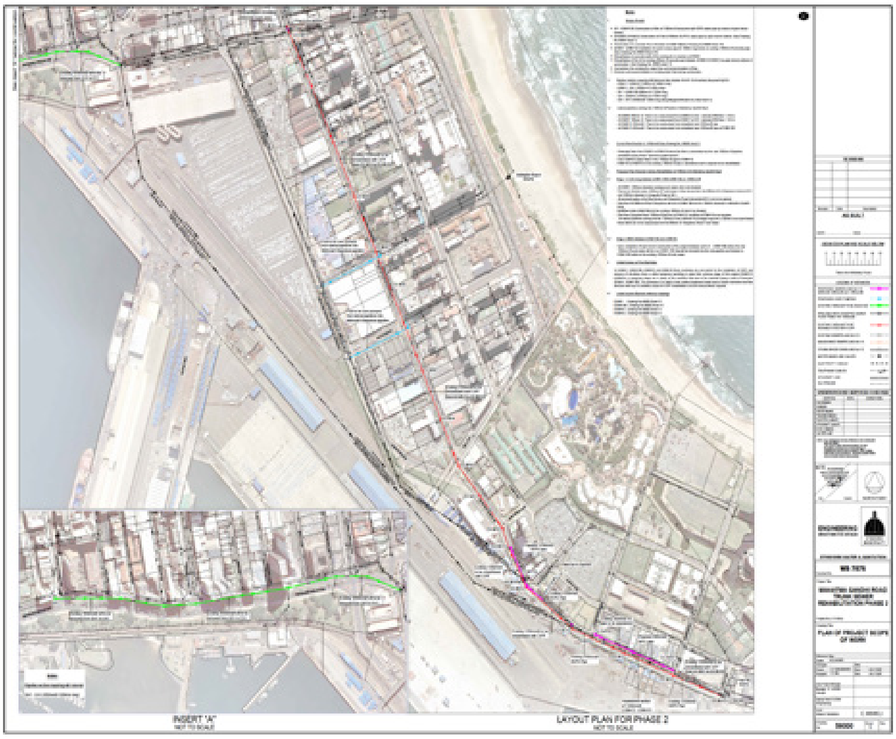


FIGURE 4: *Plan showing overall project scope of work*

3. SCOPE OF PHASE 2 OF THE PROJECT IS DETAILED BELOW:

- Installation of cured in place pipe liner for 1800m long inside an existing 1350mm Ø concrete pipe.
- Construction of 80m of 1250mm Ø structured wall HDPE sewer pipe by means of open trench method of construction to complete phase 1.
- Rehabilitation of 210m of 300mm Ø uPVC sewer pipe by cured in place liner (cured by hot water) method of construction in Mahatma Gandhi Road between Camperdown and Browns road
- Construction of a concrete Tie-in Chambers
- Diversion and accommodation of existing sewer flow during construction.
- Removal of detritus/silt material inside existing pipelines where required.
- Rehabilitation of concrete walls of the existing tie-in chamber at the intersection of Mahatma Gandhi Road and Bay Terrace.
- Rehabilitation of 9m of the existing 900mm Ø concrete pipe at the intersection of Mahatma Gandhi Road and Bay Terrace by open trench method of construction.
- Connections into existing live sewer lines and accommodation of flow.

4. WHAT IS A CURED IN PLACE PIPE LINER (CIPPL)?

Before getting into detail of the rehabilitation of the existing pipe by CIPPL the method of rehabilitation is briefly defined. CIPPL is the use of a fabric tube reinforced with glass fibers impregnated with polyester or epoxy resin. The tube is inserted into an existing pipeline and inflated by compressed air against the pipe wall, then cured either by hot water or steam (thermal cure) or by ultra-violet light to cure the resin to form a new pipe inside the existing pipe. The CIPPL creates a close fit pipe against the existing pipe which has structural strength that can be designed to take the loading of the pipe as if the host pipe was not there.

5. SELECTION OF CIPPL AS THE METHOD OF REHABILITATION

The prevailing conditions of the existing pipeline in a road reserve with many underground services, in close proximity to businesses, variance in trench depth of 5 to 7.7m and a high water table (below sea level) the replacement of the pipeline by conventional open trench methods of construction would cause serious disruption to the public and have a higher construction cost and duration (phase 1 construction time was 18 months for 540m) relative to rehabilitation of the pipeline by a trenchless method. The method of cured in place pipe was selected for the following main reasons:

- Installation would cause significantly less disruption to the public due to

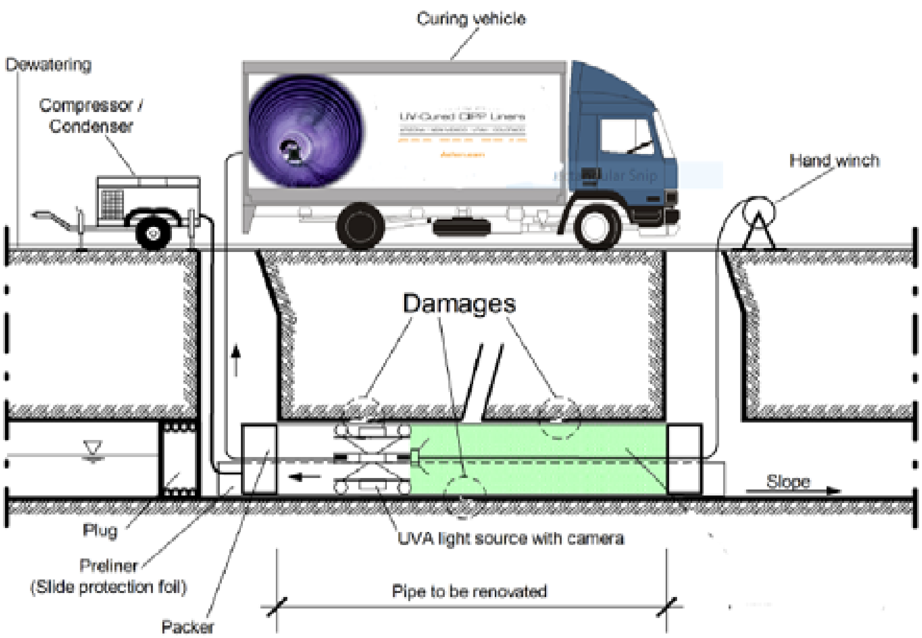


FIGURE 5: *Diagram showing the cured in pipe liner instillation process cured by UV light*

FIGURE 6: *Typical UV light train inside a pipe during curing*

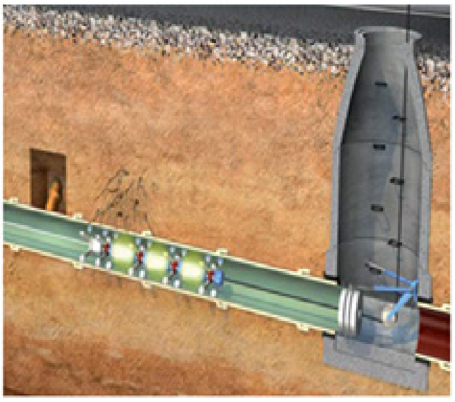


FIGURE 7: *Typical UV light train inside a pipe during curing*

FIGURE 8: *Cured in Placed liner cured by UV light on the project*

the method of installation requiring minimal to no open trench method of construction.

- The CIPP liner would cost less when compared to open trench construction for the equivalent length and be completed faster than open trench method of construction.
- The CIPP liner can meet the structural loading conditions required for the pipeline.
- The smooth inner surface of the CIPP will result in a low hydraulic roughness, ensuring better flow through the pipe.

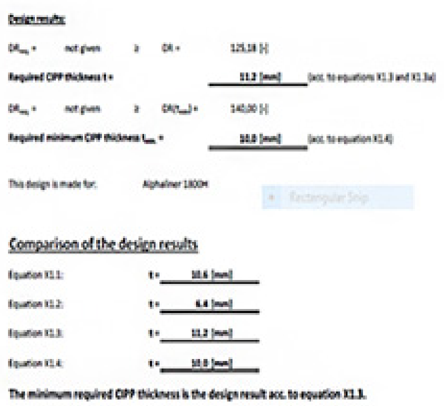
6. CURED IN PLACE PIPE – METHOD OF CURING

A cured in place pipe liner is cured by either circulated hot water or Steam (Thermal Methods) or by Ultraviolet Light (UV). The two types of curing have two different types of tube liner material. Thermal cured tube liners are needled polyester felt fibres material and a UV cured liner uses a glass fibre reinforced tube liner material. It must also be noted that this is an overall generalisation and installers/suppliers of CIPPL do have propriety combinations of liner with methods of curing for each installation, depending on prevailing conditions, the tube material is chosen for the method of curing.

For this project the method of ultraviolet curing a glass reinforced tube liner was the preferred liner curing combination for the following reasons (this specific project for a large 1350mm diameter pipe):

- The construction footprint is relatively smaller than the thermal method, thus causing less disruption to the public. During instillation one vehicle lane width was used.
- The liner strength and the flexural modulus of a UV cured liner is higher than thermal cured liner which was the essential criteria considering the pipe depth of 7m.
- Due to the large diameter of 1350mm a UV cured liner thickness will be thinner thus allowing for more pipe capacity and lesser weight for each liner which has a practical installation advantage.
- In terms of construction the UV liner has an advantage over thermal cured CIPP in that the installer can see the liner that has been pulled in place before it is cured thus ensuring better quality control.
- UV CIPP requires minimal energy and water consumption during curing process and refrigeration of the uncured liners is not required as per thermal cured CIPP.
- UV cure time is much faster than thermal cure.
- Cure time for a section of a liner occurs once a light train passes at a programmed speed opposed to thermal cure where the entire length must be brought up to temperature for cure to occur.
- UV cured liner can be installed during the day as opposed to a thermal cured liner that can be only installed in the night which presented a programme advantage.

FIGURE 9: *CIPPL Sample Design calculation sheet showing inputs for the design calculations*



Design results:

Required CIPP thickness t = 11.2 [mm] (acc. to equations X1.3 and X1.3a)

Required minimum CIPP thickness t_{min} = 10.0 [mm] (acc. to equation X1.4)

This design is made for: Alphaliner 1800H

Comparison of the design results

Equation X1.1: t = 10.6 [mm]

Equation X1.2: t = 6.4 [mm]

Equation X1.3: t = 11.2 [mm]

Equation X1.4: t = 10.0 [mm]

The minimum required CIPP thickness is the design result acc. to equation X1.3.

FIGURE 10: *CIPPL Sample Design calculation sheet showing different liner thickness output from equation parameters*

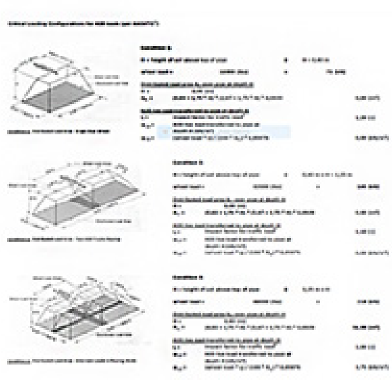


FIGURE 11: *CIPPL Sample Design calculation sheet*

FIGURE 12: *Onsite ovality measurement after flow diversion and pipe cleaing*

FIGURE 12: *Onsite ovality measurement after flow diversion and pipe cleaing*

FIGURE 14: *Onsite ovality measurement after flow diversion and pipe cleaing*

- UV cured liner has a significantly longer shelf life than a thermal cured liner which was essential for this project in terms of ordering of materials ahead of installation to match the installation program.

NB: As latter detailed in this paper there is use cases for both thermal and uv cured in place pipe. For this project for a smaller diameter of 300mm thermal cure was the preferred option due to cost and being practically reasonable to install. Thus, each pipe rehabilitation requires an assessment to select the preferred method of curing or rehabilitation method.

7. DESIGN OF CIPPL

The CCTV investigation of the existing pipeline indicated severe corrosion along the length of the pipeline, thus the proposed lining thickness was treated as fully deteriorated gravity pipe condition. This essentially means that the liner is designed to take all external and internal loads and not rely on the host pipe.

Thus, the CIPP required liner thickness was calculated using ASTM F1216 (Standard practice for rehabilitation of existing pipelines and conduits by the inversion and curing of a resin impregnated tube) Appendix X1.2.2(ASTM F1216) which details equations for the calculation of a liner thickness. The thickness calculated was then checked for each length of pipe between manholes for loading at invert, minimum thickness for ovality measured on site and for hydraulic, soil and live loads at the top of the pipe, which is generally the check that governs the required thickness. The ovality of the pipe was obtained by physical measurement on site and proved a critical critea in the design process for the determination of the appropriate thickness by a process of iteration for cost and liner thickness. Largest ovality observed from physical measurement was 5% and the liner thickness installed varied from 10.8mm to 14.9mm thick of glass reinforced UV cured liner imported from the supplier in Germany.

8. FLOW DIVERSION OF EXISTING FLOW FOR REHABILITATION

A major constraint of the project was the diversion of flow and the critical sequence of the flow diversion. The ordering of the liner from Germany was subject to onsite measurement before the liner could be ordered thus flow diversion and pipe cleaning where critical items on the critical path of the project. For the existing 1350mm diameter concrete pipe to be rehabilitated by CIPPL the existing flow was required to be diverted into the adjacent trunk sewer pipe, namely Shepstone Road Trunk Sewer (860mm diameter) and Quayside Road Trunk Sewer (1050mm diameter). An investigation of the sewage flow in the adjacent pipelines and the existing 1350mm diameter pipelines that was required to be rehabilitated was carried out using an ultrasonic level transducer located inside different manholes. The flow results indicated that the adjacent pipelines namely 860mm Ø down Shepstone road and the 1050mm Ø down Quayside road had sufficient reserve capacity to cater for the diverted flow of 410l/s peak flow from the existing 1350mm concrete pipe, subject to the removal of silt from these pipelines. Lateral pipelines were also diverted into these adjacent pipeline sequenced with cleaning the pipe, measurement and ordering the liner with a lead time to match the critical path for instillation.

9. CLEANING OF THE 1350MM DIAMETER CONCRETE PIPE

For the facilitation of the instillation of the CIPPL and creating additional capacity in the adjacent pipelines during the diversion of flow, detritus silt material was removed from the pipelines. The cumulative amount of silt that was removed during the project was 437m^3 which equated to approximately 20% of the volume of the pipe. Since the affected pipelines were not desilted for a long period of time, the silt in the pipe was compact and cementitious in consistency, thus difficult to remove which posed a challenge to the contractor during construction. The nearest waste management facility that would accept the silt material was the Dolphin Coast Waste Management facility which was 50km from the site.

10. INSTALLATION OF THE CURED IN PLACE LINER

Numerous challenges were experienced in the installation mainly due to the weight of the liners (up to 15 tonnes) and large diameter.The existing manhole shaft top slabs needed to be removed to facilitate the installation of the liner and limited space in these manholes made working conditions very difficult. In some cases sheetpiled shoring had to be deployed to get access to the manhole reducer slabs.Liners were winched into place and then blown up and cured in terms of the manufacturers strict protocols. A total of 17 liners were installed. To ensure additional quality control during construction specialist instillation technicians from the supplier, in Germany was part of all instillations.

Below is a brief general process for illustration purposes the method the contractor employed to install the cured in place liners inside the existing 1350mm diameter concrete pipe:

10.1 Preparation:

- All flow was diverted ensuring no water/liquid in the pipe, and the pipe was cleaned sufficiently to identify any obstructions/intrusions, which could obstruct or damage the liner.

10.2 Installation of CIPP Liner:

- The liner was transported to site by truck, still in its protective packaging (See figure 18).
- The liner was then inserted into the receiving manhole using a conveyor unit (see figure 17) with roller installed to guide the liner inside the

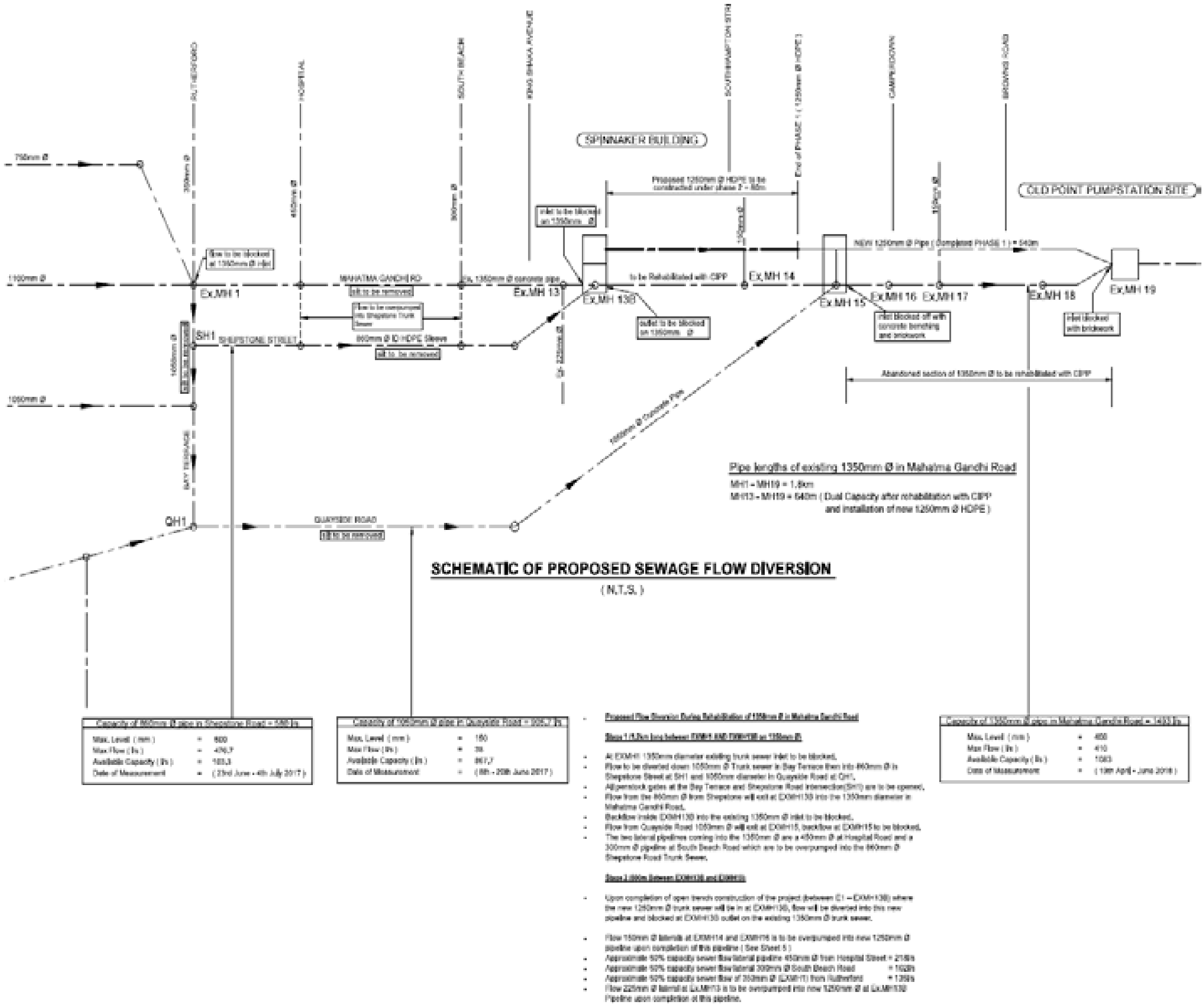


FIGURE 15: *Flow diversion schematic and sequence of flow diversion to facilitate rehabilitation.*

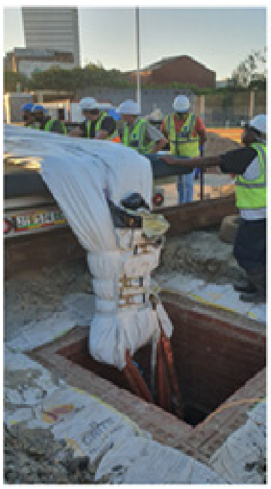


FIGURE 16: *CIPPL being inserted into a manhole*

FIGURE 17: *CIPPL being inserted into a manhole using a conveyor belt*

FIGURE 18: *CIPPL arriving on site in protective packaging*

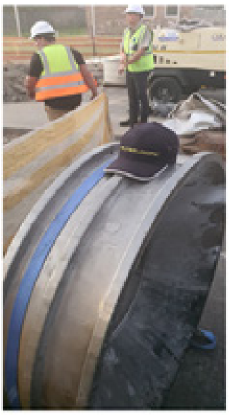


FIGURE 19: *Folding packer with strapping bands*

FIGURE 20: *Folding packer with pressure nozzles for inflating the liner*

FIGURE 21: *CIPPL liner being inflated after packer installed*

FIGURE 22: *UV Light train on site*

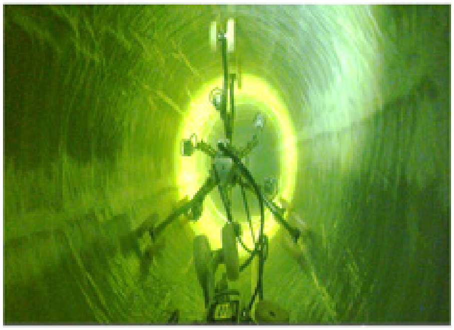


FIGURE 23: *UV Light train inside the pipe during curing*

FIGURE 24: *UV Rig used to control the curing of the UV Light train*

manhole and pulled into the pipe using the winch. The liner was pulled onto a mobile ramp to assist with fitting the strap around the packer in both manholes.

10.3 Packers:

- After instillation two strapping bands were placed around the ends of the liner. The folding packer (see figure 19 and 20) is then inserted into the liner end and the liner inflated slowly to position it (see figure 21).

10.4 Light Assisted Curing/hardening of Liner by Ultraviolet light:

- Once the liner is in position, the pressure is released, and the UV light source/train is inserted into the pipe (See figure 23).
- Once the light is activated it was then pulled through the liner at a nominal speed depending on the strength of the light source and as per manufacturers recommendations.
- During the hardening process the pressure, position and progress of UV light, the functioning of the UV tubes and reactive temperature where recorded.
- On completion of hardening the liner is cooled for a few minutes and the UV light source removed.
- Samples were then cut from the sections removed, labelled, and sent for testing to an approved materials laboratory in Germany.
- After curing process is complete CIPP CCTV was recorded and submitted to the engineer for the section that was lined.

10.5 Testing of the liner

After each liner was installed two samples (see figure 28) of the installed liner (labelled with unique verified QR codes) was taken to an independent lab in Germany to get tested for its properties to determine

FIGURE 25: *1350mm diameter pipe before rehabilitation*

FIGURE 26: *1350mm diameter pipe after rehabilitation with cured in place pipe liner*

FIGURE 27: *1350mm diameter pipe after rehabilitation with cured in place pipe liner*

FIGURE 28: *Sample of CIPP liner cut out for testing after curing*

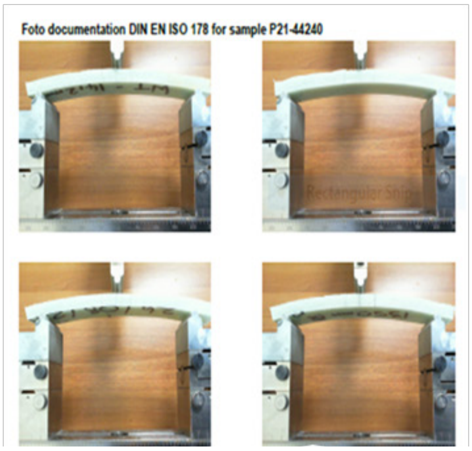
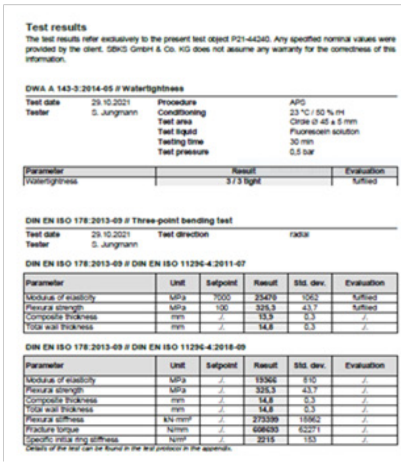


FIGURE 29: *CIPP liner sample undergoing flexural strength lab tests*



Test results

The test results refer exclusively to the present test object P21-44240. Any specified nominal values were provided by the client. SBKS GmbH & Co. KG does not assume any warranty for the correctness of this information.

DWA A 143-3:2014-05 // Watertightness

Test date	29.10.2021	Procedure	APS
Tester	S. Jungmann	Conditioning	23 °C / 50 % rH
		Test area	Circle Ø 45 ± 5 mm
		Test liquid	Fluorescein solution
		Testing time	30 min
		Test pressure	0,5 bar

Parameter	Result	Evaluation
Watertightness	3 / 3 tight	fulfilled

DIN EN ISO 178:2013-09 // Three-point bending test

Test date	29.10.2021	Test direction	radial
Tester	S. Jungmann		

DIN EN ISO 178:2013-09 // DIN EN ISO 11296-4:2011-07

Parameter	Unit	Setpoint	Result	Std. dev.	Evaluation
Modulus of elasticity	MPa	7000	23470	1062	fulfilled
Flexural strength	MPa	100	325,3	43,7	fulfilled
Composite thickness	mm	./.	13,9	0,3	./.
Total wall thickness	mm	./.	14,8	0,3	./.

DIN EN ISO 178:2013-09 // DIN EN ISO 11296-4:2018-09

Parameter	Unit	Setpoint	Result	Std. dev.	Evaluation
Modulus of elasticity	MPa	./.	15366	610	./.
Flexural strength	MPa	./.	325,3	43,7	./.
Composite thickness	mm	./.	14,8	0,3	./.
Total wall thickness	mm	./.	14,8	0,3	./.
Flexural stiffness	kN·mm²	./.	273399	15862	./.
Fracture torque	N·mm	./.	608630	62271	./.
Specific initial ring stiffness	N/m²	./.	2215	153	./.

Details of the test can be found in the test protocol in the appendix.

FIGURE 30: *Sample lab reslults of installed cured in place liner*

FIGURE 31: *CIPP liner arriving on site in refrigerated unit at night*

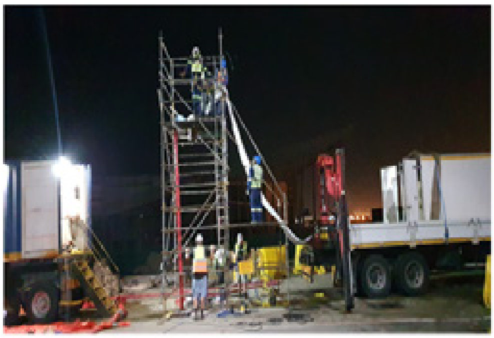


FIGURE 32: *CIPP liner being installed by the inversion process cured by hot water using a boiler*

FIGURE 33: *CIPP liner installed inside the existing 300mm diameter pipe*

if it complied with the document specification requirements. The tests conducted (see figure 29) by the laboratory was to determine the Short-term Flexural (Bending) Properties and wall thickness in accordance with applicable ASTM standard of the document specification.

11. EMPOWERING OF LOCAL CONTRACTORS

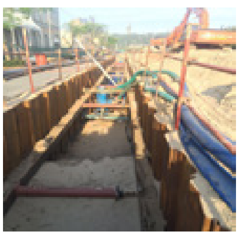
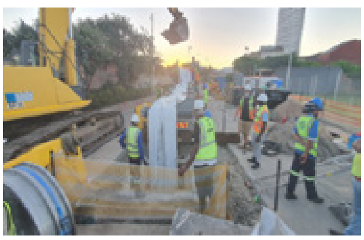
During the project 20% of the project scope was subcontracted to the local contractors and during construction the local contractors received training from the German supplier on the installation of cured in place pipe liner and they also were involved in the instillation of the CIPP liner.

12. CHALLENGES FACED DURING CONSTRUCTION

The project experienced many challenges during construction below a few are noted:

- Sharing the site with other contractors on different project raising issues of access which caused delays to the project.
- Business forum work stoppages
- Performance of local contractors
- Pumpstation downstream of the pipe required to be rehabilitated consistently was not working resulting in the pipeline filling which caused delays to the program.

TABLE 1: *Time and Cost Comparison of phase 1 and phase 2 of the project for the 1350mm diameter pipe.*

	Open Trench Construction (Phase 1)	Trenchless method CIPPL (Phase 2)	Difference between CIPP and Trenchless
Length completed	556m	1856m	
Duration of completion	20 months and 13 Days	15 Months 13 days	5 months
Cost of construction/per meter	R58 885,73	R43 117.74	R15 768/m (26.7%)
			

13. REHABILITATION OF 300MM Ø AC SEWER PIPELINE BY CIPP USING THERMAL CURING

An existing 300mm Ø AC sewer pipeline 210m long in Mahatma Gandhi Road between Browns Road and Camperdown Road was broken in places and needed to be replaced in sections and rehabilitated. Due to the proximity of an existing large diameter water main and other services the relatively cheaper cost of rehabilitation of the pipeline was selected. Sections of the pipe that was broken, point repair replacement was carried out by open trench construction.

Once the point repairs were complete and the sewage diverted by bypass pumping, the pipeline was rehabilitated by cured in place pipe liner cured by the thermal method of hot water. The liner was designed for fully deteriorated gravity pipe condition with the CIPP required liner thickness of 6mm selected, calculated using ASTM F1216 Appendix X1.2.2. The CIPP liner was fabricated in Cape Town transported to Durban and fully installed in one night.

CIPPL cost detailed in table 1 above includes the liner per meter, flow diversion, open trench at manholes for access of the liner and apportioned percentage P&G cost related to CIPPL scope.

14. CONCLUSIONS

The paper clearly shows how depending on the site conditions and myriad of constraints trenchless technology can be considered to a be a part of the engineer's solution "toolbox" to replace or rehabilitate sewage pipeline infrastructure. During the project as detailed in the paper the method of rehabilitation of cured in place pipe for a large diameter and a smaller diameter pipe using different methods of curing clearly shows two distinct use cases for both UV cured liners and thermal cured liners.

The paper demonstrates that during the project the selection of the method of rehabilitation/replacement of pipeline infrastructure considered many factors such as site conditions, location, cost, effect on the public, accommodation of existing sewage flow, available contractor experience for proposed rehabilitation method and local community participation which resulted in a relative cost and time saving compared to open trench construction.

The skill and experience of the contractor was critical to the successful completion of the project on time and within budget. Project programming and timeous implementation of the programme by the contractor was central to the project as sewage diversion, pipe cleaning, ordering of liners from Germany, cash flow constraints and instillation of the liner all had to have a well-timed sequential critical path to ensure the project success. With many technical and practical onsite challenges, the project was a great learning curve for future projects for all parties involved when implementing trenchless technology for pipeline rehabilitation.

15. Acknowledgments

I hereby acknowledge the valuable inputs of Mr. Rob Van Vuuren and Mr. Hannes Coetzee from CSV Construction / Tuboseal services Joint venture.