Restoring a corroded sewer

Robert Kelly & James Smolik describe the use of CCCP techniques to renew a concrete sewer that had suffered extensive hydrogen sulphide corrosion

WESTLAKE City, a suburb of Cleveland, Ohio, is primarily a residential community with light industrial and retail areas. It has a population of about 34,000, which doubles during the daytime. The city has its own engineering department, responsible for design, bidding, construction management and inspection.

In 2007, Westlake had a condition assessment performed of its primary sanitary interceptor sewer – a 6,400m pipe comprising part reinforced concrete and part poured-in-place concrete. Flowing to the regional wastewater-treatment plant, the 1960s constructed pipe conveys the city's entire sewage along the northern corporation boundaries.

Sewer projects are funded through bills collected at a flat rate of US$30.25 per quarter for residential dwellings, while that for commercial and industrial properties is usage-based. With diameters varying between 915-1,525mm, the sanitary interceptor has an average dry weather flow of 22.7ML/d and covers a sewer tributary area of 227km, which is owned and maintained by Westlake.

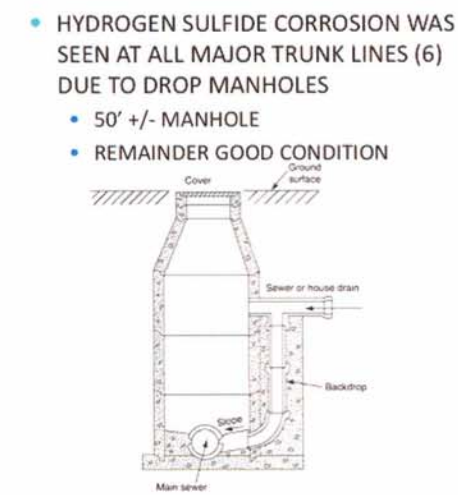
The condition assessment was performed after a sanitary interceptor failure at a neighbouring community in 2006, during which many basements were flooded with raw sewage. Only 18 years old, this interceptor was a reinforced-concrete pipe, similar to the one in Westlake. As a result of the calamity, which also involved a fatality, residents filed multiple lawsuits exceeding US$560,000, the majority of which have now been settled.

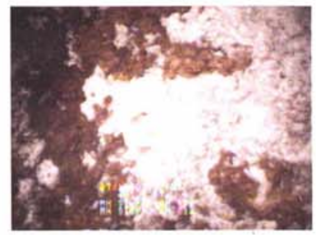
As no comprehensive assessment of the Westlake interceptor had been undertaken since its construction, the municipality hired URS Corp of Cleveland, Ohio, to perform an appraisal.

CONDITION ASSESSMENT

URS performed the CCTV inspection of the entire interceptor with ADS Environmental Services of Earth City, Missouri. This was accomplished with a crawler camera and a camera mounted on a pontoon boat for downstream locations with heavy flows. In addition, all 64 sanitary manholes along the interceptor were inspected.

The CCTV inspection was analysed by URS, and the condition assessment generated and organised in the following order:





CLAGUE ROAD

COLUMBIA ROAD

Typical manhole (left) with typical effects of corrosion (right)

> **"Due to budgetary constraints, rehabilitating the entire pipe from manhole to manhole was not an option since some sections were as long as 167m"**

- Operation and maintenance Issues (O&M)
  - a. Leaking joints contributing to infiltration;
  - b. Capacity-reducing obstructions; and
  - c. In-pipe debris.
- Structural defects
  - a. Cracks and fractures;
  - b. Microbiologically-induced corrosion (MIC); and
  - c. Open joints.
- Manhole inspection
  - a. Infiltration/inflow (i/i); and
  - b. Structural defects.

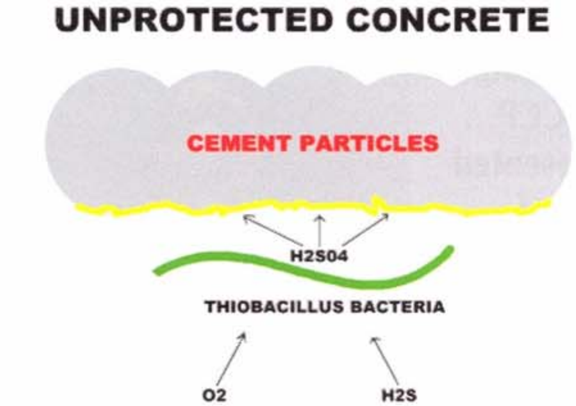
Assessments to prioritise defects relative to the pipe runs between manholes were carried out. This classified each run of pipe with respect to operational and maintenance issues, and structural defects. The locations of all defects were displayed in a GIS environment. Each pipe length, from manhole to manhole, was ranked for operation and maintenance, and structural condition. The system-ranking methodology allows for the values of each segment to be prioritised relative to the entire system's defects.

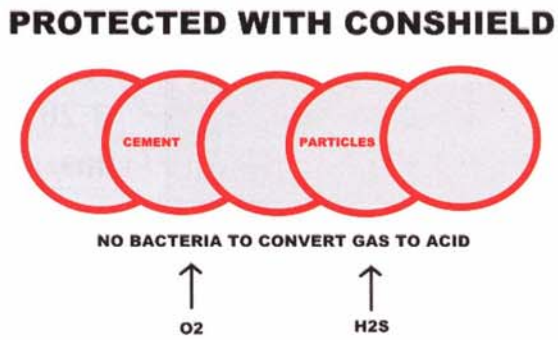
From the condition assessment in 2008, the greatest area of concern was microbiologically induced corrosion from hydrogen sulphide, which was prevalent throughout the entire system and concentrated at critical locations. These were at the connection points of the various trunk lines (458-610mm diameter) discharging into the sanitary interceptor.

At those connection points, drop manholes were located with at least a 3m vertical difference between the inverts of both pipes. Also, the downstream section of the interceptor had a large concentration of corrosion due to the proximity of the wastewater-treatment plant.

MICROBIOLOGICALLY INDUCED

Vertical-drop manholes of trunk lines cause severe turbulence in the interceptor, releasing large amounts of hydrogen sulphide gas, produced from anaerobic bacteria in the sewage. Over time, the effects of carbon dioxide and hydrogen sulphide lower the concrete pipe's surface pH to below seven, thereby providing an ideal environment for Thiobacillus





Left: corrosion process
Right: barrier protection

bacterial growth to thrive above the flow in the crown of the pipe.

New concrete pipe has a pH of 11; pH swabs were performed at various manholes during the manhole inspection. The majority of these pH levels were below seven, so the environment was ideal for bacteria. Since the capacity of the interceptor exceeds the average dry weather flow, a large amount of the interior surface of the pipe is left exposed above the flow line.

In the presence of oxygen, hydrogen sulphide gas reacts with the Thiobacillus bacteria in this region of the pipe, converting it into sulphuric acid through an aerobic-biological process. Sulphuric acid then attacks the concrete pipe, which can lead to structural failure.

At the majority of locations, corrosion from sulphuric acid was confined to within 7.5-15m either side of the manhole, with the remainder of the interceptor in good condition. This concentration resulted from trunk lines with drop connections.

The downstream section of the interceptor entering the treatment plant also had corrosion from sulphuric acid due to the changes in slope, the sewer's horizontal alignment and the wastewater-treatment plant itself.

DESIGN

Westlake's design philosophy was to permanently repair the deteriorated sections of pipe to prevent further corrosion at those locations. Controlling the hydrogen sulphide gas with temporary measures was therefore not an option. Also, as most of the interceptor is located in undeveloped areas, odour control was not an issue.

Due to budgetary constraints, rehabilitating the entire pipe from manhole to manhole was not an option since some sections were as long as 167m. A more target-based rehabilitation method was required.

As a possible solution, cured-in-place pipe (CIPP) was reviewed first. However, since the entire sewer run was not being repaired, partial liners for the deteriorated sections of that size diameter pipe were not feasible. The city then decided to perform the rehabilitation using centrifugally-cast concrete pipe (CCCP). a spray-applied cementitious coating with an anti-microbial agent called ConShield, made by AP/M Permaform.

Anti-microbial agents hinder the Thiobacillus bacterial growth on the interior surface of the pipe. This prevents the aerobic-biological process of hydrogen sulphide gas converting to sulphuric acid. The high compressive strength of the cementitious coating also improves the ring compression of the pipe.

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Westlake then formulated a rehabilitation project for the sanitary interceptor, associated manholes and the downstream sections of trunk lines. The project consisted of the following:

- Interceptor cleaning;
- Mineral deposit removal;
- Interceptor rehabilitation by the means of CCCP;
- Trunk line cleaning;
- Trunk line rehabilitation by the means of CCCP;
- Trunk line rehabilitation by the means of CIPP;
- Manhole rehabilitation by cementitious coating;
- Manhole grade ring area modifications; and
- Rehabilitation.

The project was awarded in 2009 to United Survey of Cleveland, Ohio, with Kevan Taylor of Spincrete as sub-contractor. Westlake funded the entire project through to completion in 2010, without federal or state assistance. Throughout the design stage, the tight budget was a key issue; only the corroded sections of pipe were rehabilitated.

The sections of interceptor scheduled for rehabilitation were cleaned by sub-contractor Brenford Environmental Services using a Sewer Hog jetter, capable of cleaning the line from manhole to manhole without bypass due to its $140kg/cm^2$ applied force and 1,325L nozzles.

Since domestic water was unavailable in some of the isolated cleaning locations, the jetter used sewage water pumped from the interceptor; an operation that also removed the silt and debris that had accumulated at manholes following the step-cleaning process.

The silt and debris were pumped through a high-speed decanting, separation and dewatering container that receives the slurry from the pump. Solids are captured while returning 99% debris-free grey water to the interceptor.

The interceptor rehabilitation was performed under full bypass conditions to provide a dry pipe for the work. Since the rehabilitation was undertaken at multiple locations, various bypass set-ups had to be established. Bypass pumping was based on wet weather flow, with the far downstream section of the interceptor having a pumping capacity of 45.4ML/d, and decreasing as work progressed upstream.

Since the majority of the work occurred in winter and early spring, precipitation levels were monitored closely as the city's sanitary interceptor experiences surcharging from infiltration/inflow. As the flow in the interceptor could increase five-fold during a major rain event, whenever the interceptor was under bypass there were pump watchmen on site to monitor the flow levels in the manholes.

Once a bypass was established, the sewer pipe was prepared for rehabilitation. Man entry was undertaken with compressed air and high-pressure water to clean the pipe of any organic matter and/or deteriorated pipe fragments. Compressed air was also used to dry →

Table 3: CCCP compressive strength results				
	1-day	2-day	3-day	28-day
Average break (psi)	3,160	4,865	6,246	8,037
(kg/cm²)	222	342	439	565

➔ the pipe surface prior to the cementitious coating operation. The surface of the pipe was then washed with a concentration of anti-microbial agent to kill any active Thiobacillus bacterial growth.

After the pipe had been prepared for rehabilitation, a pre-CCTV inspection was also performed to verify that the substrate could accept the cementitious coating. This factory blended mix, made by AP/M Permaform, comprises a high-strength, high-build, abrasion-resistant mortar that develops a hardened liner, which is dense and highly impermeable.

The mix was batched in a portable plant. As ConShield anti-microbial agent was batched within the mix as an admixture with water, it became an integrated component that bonded molecularly to the cement particles. The antimicrobial agent cannot wash off, delaminate or lose its effectiveness due to wear.

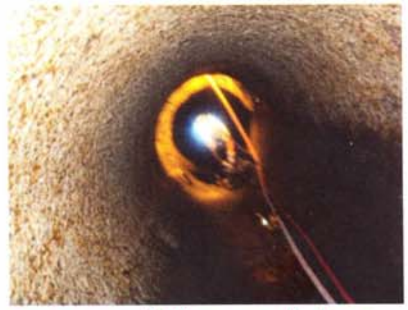
The CCCP coating was applied as a 12mm-thick layer on the surface of the prepared pipe by a

"Westlake rehabilitated 1,207m using CCCP... this, alone, represented a cost saving of US$1.6 million"

spin-caster; this was pulled through at a uniform rate using compressed air to apply the pumped, cementitious coating around the circumference of the pipe.

The process is similar to shotcrete application and waterline renewal. Some pipe showed corrosion beyond a depth of 38mm. Once the cementitious coating cured, an identification and curing coat was applied to the spun-cast surface prior to resuming active flow.

During the batching of the coating, cube samples were taken for quality control measures in accordance with ASTM C 109. In order to resume active flow in the rehabilitated sewer, samples had to withstand a compressive strength of 162kg/cm². For much of the time, this was achieved within 24 hours, which kept bypass pumping operation costs to a minimum (table 3).

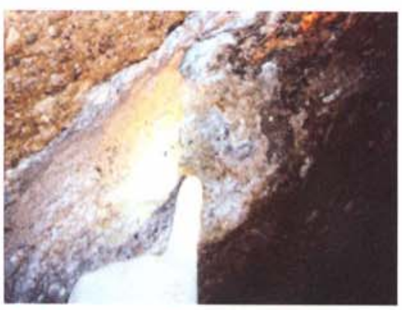


Operator controls Spincaster application rate

COST SAVINGS

Since Westlake specified CCCP, as opposed to cured-in-place pipe (CIPP), the work targeted only those areas of concern, with no rehabilitation undertaken for pipe sections that were in good condition. This kept construction costs to a minimum. The traditional approach would be to rehabilitate using CIPP for the entire sewer run. Indeed, the success of the project can be seen in the cost savings that Westlake realised with this targeted rehabilitation approach.

Westlake rehabilitated 1,207m using CCCP, but if CIPP had been used this would have necessitated the rehabilitation of 2,194m for the interceptor portion of the project. This, alone, represented a cost saving of US$1.6 million



Organic matter and deteriorated pipe

due to less pipe having to be rehabilitated in addition to the lower unit cost of CCCP (table 4).

Restoration of the area was kept to a minimum due to the lack of excavation using this true 'no-dig' approach. CIPP would have required the removal of all the cone sections of manholes at each location to insert the felt liner. Also, at some locations, the interceptor had size reductions within the sewer runs, which would have been a challenging and costly issue with CIPP.

This was a dramatic cost saving: the total project expense was US$1.6 million and the total savings were also US$1.6 million. If CIPP had been used, the project would have had to be divided into multiple lots over many years.

Table 4: cost savings for CCCP rehabilitation vs CIPP (CIPP US$ cost assumed)

Size of pipe	Distance (ft) (CCCP)	Distance (ft) (CIPP)	CCCP unit US$	CIPP unit US$	CCCP cost	CIPP cost
60in	562	2,119	280	420	157,360	889,980
60in	102	105	214	420	21,828	44,100
48in	75	952	258	336	19,350	319,872
42in	2,821	2,853	173	294	488,033	838,782
36in	401	1,184	241	252	96,641	298,368
Totals	**3,961**	**7,213**			**783,212**	**2,391,102**
Total savings						**1,607,890**

CONCLUSION

Completion of this project has extended the useful life of an important part of Westlake's infrastructure, and provided uninterrupted service to its residents for many years to come.

The use of an anti-microbial coating to hinder corrosion from sulphuric acid has been used vertically in manholes with great success, but, in this project, Westlake used the technology in a horizontal application. This provides communities across the US with a further tool for combatting hydrogen sulphide corrosion in concrete pipes – a problem that looks set to become all too common as infrastructure ages and community budgets decrease. The CCCP technique can also be said to be more sustainable than other methods as it uses reclaimed materials for the aggregate and contains no hazardous chemicals.

Robert Kelly, director of engineering, City of Westlake, Ohio; James Smolik, department of engineering, Westlake, Ohio. World Tunnelling *would like to thank the North American Society for Trenchless Technology (NASTT) for its kind permission to allow the publication of this paper, first presented at No-Dig Washington, March 2011*