North American Society for Trenchless Technology (NASTT)
NASTT's 2018 No-Dig Show

Palm Springs, California
March 25-29, 2018

Non-destructive Condition Assessment Technology for Asbestos Cement Pipes

Csaba Ékes, PhD, PGeo. – President, SewerVUE Technology Corp. – Burnaby, BC, Canada

1. ABSTRACT

Pipe Penetrating Radar (PPR) is the in-pipe application of ground penetrating radar (GPR), a non-destructive testing method that can detect defects and cavities inside and outside non-ferrous pipes. The advantage of PPR is the ability to map pipe wall thickness and deterioration, including voids outside the pipe, enabling accurate predictability of needed rehabilitation. This paper presents recent advancement of PPR technology together with selected case studies. A new, small diameter robotic system was developed for the condition assessment of asbestos cement (AC) water and sewer pipes, as well as other non-ferrous pipe materials.

The Asbestos Cement Pipe Scanner (ACPS) was deployed in a 250 mm diameter sewer main in Surrey, British Columbia. Analysis of the data revealed localized wall thinning and provided engineers with critical information to proceed with their rehabilitation plan.

The 4th Generation Surveyor robot was deployed on a condition assessment project in Melbourne, Australia. This involved surveying 600 mm, 750 mm, and 950 mm diameter reinforced concrete pipe (RCP), as well as 1050 mm brick-lined pipe, totaling 3521 m in inspection length.

PPR allows utility owners to accurately estimate the remaining lifetime of pipelines, and refine the timing of repairs.

2. INTRODUCTION

Pipe Penetrating Radar (PPR) is the in-pipe application of ground penetrating radar (GPR) technology. PPR is an advanced pipeline condition assessment method for non-ferrous water and wastewater infrastructure. In comparison to more common condition assessment methods like CCTV, PPR provides much more comprehensive data. While CCTV methods are effective for locating visible defects within pipes, they do not provide information about anything beyond the visible surface of the pipe. PPR collects quantitative data about wall corrosion and degradation, measure rebar cover in reinforced concrete pipe, and detect voids developing outside the pipe.

This paper will outline the benefits of PPR as a condition assessment method. Two recent projects will be used to highlight these benefits. The first project involves the deployment of PPR sensors on the newly-designed Asbestos Cement Pipe Scanner, surveying a length of 250 mm sewer main in Surrey, British Columbia, Canada. The second project involves PPR sensors mounted to the larger SewerVUE Surveyor robot that was used to survey a number of different pipelines in Melbourne, Australia.

3. OVERVIEW OF PIPE PENETRATING RADAR

PPR is the use of ground penetrating radar from the inside of a pipe. Typically, GPR is used to investigate the subsurface of the Earth by emitting electromagnetic waves and measuring the reflection. EM waves have two important properties where GPR is concerned: the waves travel at different speeds through different media, and amplitude of the reflections will be stronger based on how great the contrast between two different materials is. By measuring the time it takes for EM waves to reach a target and be reflected back to the sensor, and by measuring the strength of those reflections, a radargram image of the subsurface can be created (Daniels, 2004).

A GPR system consists of two antennas: a transmitter and a receiver. The transmitter emits EM waves, and the receiver records the reflections as a single trace. This trace is the A-scan. The measurement of the time lapse between wave transmission and measurement of the reflection is known as the two-way time. The A-scan process is repeated continuously across an entire survey line to build a profile (B-scan) along that line. This information is imaged as a display of two-way time vs. distance travelled. Amplitude of the measured reflections is expressed as either a wiggle trace or on a colour scale.

Different GPR systems transmit EM waves at different frequencies based on desired outcome. Lower frequencies will achieve deeper subsurface penetration, while higher frequencies will not penetrate as far, but can create a higher resolution image. High resolution GPR antennas (2.6 GHz – 500 MHz) typically achieve 600 mm – 3000 mm penetration. The general rule for GPR resolution is that the thinnest resolvable layer is ¼ of the wavelength used. For a 2.6 GHz antenna frequency in a concrete pipe, this is roughly 9 to 15 mm.

Pipe Penetrating Radar uses this technology to gather detailed data on the present condition of water and wastewater pipelines. By collecting GPR data from inside the pipe, PPR can provide information on remaining pipe wall thickness, rebar cover, or the presence and locations of voids developing on the outside of the pipe. (Ékes, et al., 2011) PPR is presently deployed on either of two platforms: the SewerVUE Surveyor robot, (Figure 1) or the ACPS. Where it is safe and feasible to do so, manned entry is an additional option. In the case of the Surveyor, two lines of PPR data are collected in one run, from any two clock positions between 9 o'clock and 3 o'clock. SewerVUE's current PPR antennae transmit at 1.6 GHz or 2.3 GHz. This setup results in signal penetration of up to 920 mm, with accuracy to 10 mm. The Surveyor also collects CCTV and LiDAR data to correlate with the PPR scans. The ACPS carries one or more PPR antennae, and is used to inspect smaller diameter pipelines (200 – 450 mm).

Figure 1 - The SewerVUE Surveyor robot on-site in Melbourne, Australia

Following completion of data collection comes data interpretation. PPR data interpretation is a critical step if meaningful information is to be drawn from the survey. SewerVUE uses proprietary software to apply different correction, filter, and gain functions to the PPR data. This processing enhances anomalies and allows for clearer interpretation of the results. Proper interpretation of PPR data is enhanced by the construction of a good three-dimensional display. Anomalies or points of interest are far easier to locate on a three-dimensional data set compared to a two-dimensional set. The final PPR data interpretation is superimposed over actual depth profiles versus distance.

4. PPR DEPLOYMENT PLATFORMS

To collect data for pipeline condition assessment, PPR sensors must be carried along the length of the pipe section that is to be surveyed, with the sensors remaining coupled to the walls for the duration of the survey. In large-diameter pipes, it is possible to collect PPR data via a man-entry operation. In smaller pipes, or in pipes where man-entry methods would be too unsafe, PPR sensors are mounted to one of two remotely operated vehicles: The Asbestos Cement Pipe Scanner, (Figure 2) or the SewerVUE Surveyor.

The ACPS is a prototype ROV used in AC pipes with diameters as small as 200 mm. The ACPS also features a CCTV camera, for visual correlation with the PPR results. The SewerVUE Surveyor is a tracked ROV. It was the first commercially available multi-sensor inspection robot to use both visual and quantitative technologies in underground pipeline condition assessment. It can be adjusted to scan pipes with diameters between 525 mm and 1500 mm. In addition to carrying two PPR sensors, the Surveyor also carries LiDAR and a CCTV camera that collects visuals for correlation with the sensor data.

Figure 2 - The Asbestos Cement Pipe Scanner

5. ASBESTOS CEMENT PIPE SCANNER – SURREY, BC

A significant portion of North America's water and wastewater infrastructure exists in the form of asbestos cement (AC) pipes. Between 1940 and 1970, over 900,000 km of AC pipe was laid in North American municipalities. The estimated useful life of AC pipe was about 50 years. Data has shown that an average of 60-70 years is more accurate. However, tens of thousands of kilometres of AC pipe in North America are reaching the end of this estimated lifetime (Hu, et al., 2013).

With such a large volume of AC pipe nearing the end of their useful life, predictive asset management becomes essential for municipalities. Waiting for catastrophic failure is neither desirable nor economical. Such failures can cause service disruption, environmental damage, and can be extremely costly to fix. However, replacing pipes too early is an inefficient use of resources.

AC pipes are vulnerable to deterioration by acidic, sulphate, and microbiological attack. They can also suffer deterioration due to corrosive groundwater. In the case of groundwater corrosion, traditional inspection methods such as CCTV cannot detect the presence of corrosion. To address this, more comprehensive measurements are required. The SewerVUE ACPS was developed with this challenge in mind (Figure 3).

Figure 3 - A SewerVUE technician places the ACPS into the Harbourgreene line.

The Harbourgreene line in Surrey, BC, Canada is an asbestos cement pipe that was installed in 1972. Currently there are no known corrosion issues; the initial inspection will serve as a baseline. The pipe is inspected regularly using traditional CCTV. The City has partnered with SewerVUE to conduct a high-frequency PPR survey to inspect sections of the Harbourgreene line in order to obtain structural condition information. This project's PPR survey was completed using high-frequency antennae while the pipe remained in service. 2D line data were collected on the invert of the pipe. The high antenna frequency provided good quality data and signal penetration to allow analysis to a depth of 300 mm from the inside pipe wall surface (Figure 4).

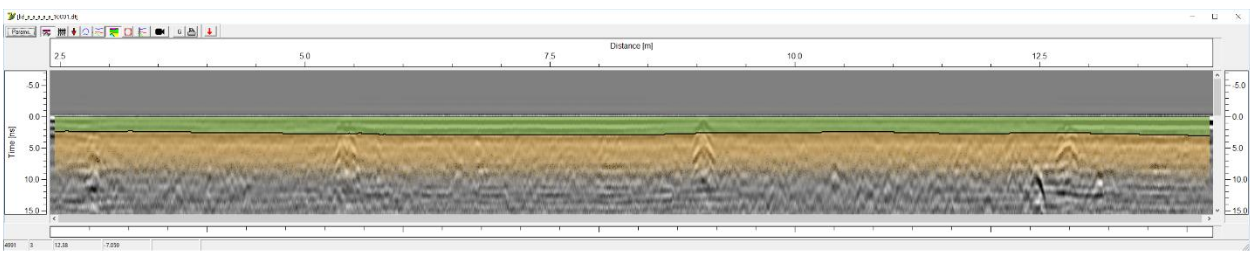

Figure 4 - PPR data collected from the Harbourgreene Line.

PPR inspection results are presented in "classic view" form with the interpretation overlaid on the processed PPR data. The distance shown on each profile is measured from the center of the manhole of deployment. Pipe wall thickness is represented by a continuous black line.

In Phase 1 of the project 60 m of PPR data were collected from the Harbourgreene line with supplementary CCTV using the ACPS. Wall thickness was interpreted to be in the 45 mm range with little variation over the inspected length. Interpreted results at the conclusion of Phase 1 concluded no significant structural issues on the inspected sections of the pipe.

6. SEWERVUE 4TH GENERATION SURVEYOR – MELBOURNE, AUSTRALIA

PPR can be used to gather quantitative data from any pipe made of non-ferrous material (concrete, RCP, AC, RP, PVC, HDPE, brick, etc.). In this case study, PPR was used to inspect a number of pipelines in Melbourne, Australia. Four lines were surveyed, with CCTV, LiDAR, and PPR data being collected. The utility owner had very little knowledge about the construction or current condition of these pipes.

A 1297 m section of the Mordialloc Main Sewer was inspected first. This section was reinforced concrete pipe, with a diameter of 750 mm. Access was from a single deployment point near the middle of the surveyed section. CCTV footage showed widespread surface damage that was consistent with chemical attack on the inner surfaces of the pipe wall. A small hole was located 33.4 m downstream from the access point. Some circumferential fracturing was also seen 41.5 m downstream. LiDAR results showed a small but consistent degree of deformation along the crown of the pipe. PPR data revealed average rebar cover in the line to be between 35 and 60 mm (Figure 5).

Figure 5 - PPR results from a 100 m section of the Mordialloc main in Melbourne, Australia

A section of the Hobsons Bay Main was surveyed next. This section was also 600 mm in diameter. From one access point, 572 m was surveyed in the upstream direction. The survey began 13.8 m from the access point, where the RCP section of the pipe started. This pipe also showed damage that appeared to be the result of chemical attack. PPR data showed the areas with thinner rebar cover, however rebar cover always exceeded 15 mm.

The Caulfield Intercepting Sewer is a 950 mm RCP line. The survey inspected a 1195 m section, using a single access point near the centre of the section. Generally, the survey showed the line to be in good condition. The most significant discovery from the inspection was a section where the pipe increased in diameter to 1100 mm, which was unknown to the utility owner. PPR data revealed an area 80-85 m downstream of the deployment site where the rebar was quite close to the pipe wall.

The Maribyrnong Main Sewer was the final inspected line (Figure 6). This line was built from RCP, and had a diameter of 760 mm. Two different sections of the line were inspected, in each case using an access point near the middle of the section. The inner pipe walls were covered in attached deposits, and the invert of the pipe had frequent patches of gravel and other sediment. CCTV footage from the survey showed significant surface damage, with sections of visible reinforcement. Much of the pipe wall was not visible due to the attached deposits. The PPR data from this section showed little rebar cover along the whole length of the survey.

Figure 6
- Map showing locations of both Maribyrnong main inspection areas.

7. SUMMARY AND CONCLUSION

Examples from the two projects outlined in this paper demonstrate the benefits of PPR in condition assessment projects. The nature of PPR data allows for the creation of accurate predictive models about the remaining useful life of pipes. This is especially true when PPR is supplemented with data from other condition assessment techniques, such as CCTV or LiDAR.

Data gathered from the ACPS survey in Surrey, BC, though only a baseline test, demonstrates that PPR is very useful in the assessment of small-diameter AC pipes. PPR has already been shown to be effective at gathering quantitative data from AC pipes, but this survey demonstrated that the technology could be adapted for smaller pipes, which represent a significant portion of the decaying AC pipe infrastructure in North America.

Information collected from the four sewer lines in Melbourne is a prime example of PPR as an effective asset management tool. In these cases, the utility owner had very little information about the current condition of the lines. Following the PPR survey, they could make informed decisions about which of the lines needed immediate attention, and which lines could afford to have maintenance deferred to a later date.

PPR is an invaluable tool for assessing the current condition of non-ferrous pipelines. Supplemented with data from other survey methods such as LiDAR and CCTV, PPR can be used to generate comprehensive data about the current conditions of pipe. This information forms a strong basis for creation of accurate predictive models that allow utility owners to make efficient asset management plans. The cost of a PPR survey pales in comparison to the costs that could be incurred if a line suffers catastrophic failure, or if a serviceable line is replaced too soon. Funding is often limited, so cost-effective asset management methods are essential for municipalities and other owners of underground pipeline infrastructure.

8. REFERENCES

Daniels, D. J., 2004. *Ground penetrating radar, Volume 1.* 2nd ed. s.l.:Institution of Electrical Engineers.

Ékes, C., Neducza, B. & Henrich, G. R., 2011. *GPR Goes Underground: Pipe Penetrating Radar.* Washington, DC, NASTT, pp. 1-10.

Hu, Y., Wang, D. & Chowdhury, R., 2013. *Long Term Performance of Asbestos Cement Pipe.* [Online]
Available at: http://www.waterrf.org/ExecutiveSummaryLibrary/4093_ProjectSummary.pdf
[Accessed November 2017].