ASSESSING HISTORIC SEWERS: CASE STUDY OF THE ASSESSMENT OF THE HIGH AND LOW LEVEL INTERCEPTORS IN TORONTO[1]

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ABSTRACT

The importance and need for the inspection and condition assessment of large diameter sanitary sewers is becoming more and more apparent. High frequency Sonar technology, in conjunction with conventional CCTV, is proving to be a particularly effective diagnostic tool in assessing the condition of the wetted perimeter of these generally full-flowing types of sewers. This paper presents a case study involving the use of advanced technology in the assessment of the High Level and Low Level Interceptors in downtown Toronto. These two sewers, which are critical for the integrity of the Toronto collection system, are of particular interest since they are large (up to 2600 mm diameter), mostly constructed of triple ring brick, and were completed in 1910. Portions of the Low Level were constructed using new and then relatively unproven reinforced, precast concrete technology. The sewers were found to be in good condition and their inspection provides a unique opportunity to critique modern technology in the assessment of the durability of 90-year-old workmanship.

Keywords: trunk sewers, sanitation history, sewer maintenance, Sonar

1.0 INTRODUCTION

"*It is a realization of not so much the present needs of a city as her future requirements that leads to the undertaking of most civic improvements"*(Engineering Record, 1911). So begins a 1911 article about the construction of Toronto's "new" main drainage works. Little could the author, or the designers for that matter, imagine that ninety years later computers and highly sophisticated electronic equipment would be used to assess the current condition of those works. Advanced CCTV equipment combined with Sonar technology was used in 1996 and 1997 to inspect and assess the structural integrity of 14 km of the now historic High Level and Low Level Interceptor Sewers through the central core of Toronto. The majority of the sections inspected were installed in tunnel and represented plain concrete, reinforced concrete and brick lined construction. The results of the assessment show the sewers to be in fine condition. The sewers are in such good condition in fact, that it makes this author wonder what sort of technology will be used to inspect them at the end of the next century.

2.0 BACKGROUND

2.1 The High and Low Level Interceptors

As early as the 1880's Toronto was beginning to deal with a water pollution problem along its shores, particularly in Toronto Harbour. In those days the City's combined sewer system discharged raw sewage directly into the lake. Floating and decomposing material was becoming troublesome for the lakefront beaches and amusement parks and especially for the cottage properties on Toronto Island. Work was authorized in 1908 to deal with the growing problem. The new drainage works included the High Level and Low Level Interceptor Sewers, an 'electrically driven' pumping station for the Low Level sewer, a primary treatment system and a submerged outlet pipeline in Lake Ontario. The design and execution of the project was carried under the direction of the City Engineer, Mr. Charles H. Rust. Mr. A. Blanchard and Mr. W. Hollingworth were the design and resident engineers, respectively (Engineering Record, 1911).

The drainage of Toronto was from north to south following topography and the rectangular street grid. The pattern was such that the two sewers could be installed parallel to each other, and to the shoreline, and used to intercept drainage and direct it to the east. The High Level Interceptor was installed so that approximately two-thirds of the city could be intercepted and directed by gravity into the proposed treatment works without the need for pumping. The more southerly Low Level Interceptor collected the remaining third of the city and was directed to a pumping station at the site of the treatment works. Large triple barrel inverted siphons were constructed on each sewer in order to pass under the Don River.

The High Level Interceptor is approximately 13 km long and is circular in section except for the downstream 2 km which is a rectangular box. The sewer varies in size from 1000 mm to 2600 mm in diameter and is constructed of plain or reinforced concrete in the open cut areas and fully brick lined in the tunnel sections. In order to optimize the drainage area that could be serviced without pumping, in the order of 4.5 km of the Interceptor near the downstream end was constructed either on existing grade or was placed on fill in low laying areas (Canadian Engineer, 1911).

The Low Level Interceptor is approximately 8.5 km in length of which 3 km is egg-shaped brick in tunnel, 1.5 km circular brick in tunnel, and 4 km concrete pipe placed in open cut. Since this interceptor serves the lower laying portions of the city it required a lift of 7 m at the treatment works (Canadian Engineer, 1911).

2.2 The Inspection and Assessment Project

In the summers of 1996 and 1997 approximately 7.5 km of the High Level and 6.5 km of the Low Level Interceptors were inspected and assessed. In both cases the larger diameter downstream sections were inspected.

The inspection of these trunk sewers was carried out using advanced pan-and-tilt CCTV equipment and a Sonar device. The pan-and-tilt camera was particularly useful in the large

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diameter sewers since it enabled scrutiny of connections, joints and cracks, the interior of on-line chambers, and of various defects. Sonar is a relatively new and powerful diagnostic technology which is described later in this section.

The camera and Sonar equipment were floated through the sewers on a double pontoon rig. The sewers were inspected in sections from one manhole to the next one downstream. The rig was tethered to the surface vehicle where the control and monitoring equipment was housed. The simultaneously received video and Sonar images were continuously monitored and recorded on standard VHS video tapes. A written log of observed conditions and defects was prepared for each section of sewer according to the well-known, and standard, WRC condition codes. Subsequent to inspection, the video tapes and logs were reviewed and assessed. A condition grade was then assigned to each section of sewer, again based on the WRC method. These condition grades enabled decisions to be made regarding the need, if any, for remedial works or follow-up monitoring.

Sonar is a very useful tool for assessing the condition of large diameter sewers, particularly in areas of high flow. With conventional camera equipment only the portion of the sewer above the water line can be seen. As a result, in large sewers with high depths of flow a significant part of the pipe is not inspected. With Sonar however, images of the pipe wall below the water line can also be “seen”. Sonar scans the wall and produces cross-section images at a pre-determined frequency along the sewer.

In this case a Sonar device with a single, rotating transducer operating a 2 MHZ was employed. The Sonar equipment used is similar to conventional ‘side-scan’ sonar which has been specially adapted for use in a sewer environment. Since the transducer rotates as the rig floats through the sewer, the images retrieved actually reflect slightly ‘cork-screw’ shaped cross-sections. The transducer rotates once per second and assuming the rig travels along the sewer on average at 5 to 6 m/min then effectively one section is generated every 100 mm. This means that as a minimum missing or broken bricks (which traditionally are 4" (100 mm) wide) are not missed. Given the resolution of the Sonar, cracks as small as 5 mm could also be observed.

3.0 RESULTS AND FOLLOW-UP

3.1 Initial Findings

In general the sections of High Level Interceptor inspected were found to be in good to very good condition with several sites of light infiltration. The sewer invert was particularly clean with only light silt accumulation in a few isolated locations. The Low Level sewer was also generally in good condition but several locations of minor cracking and deterioration in the brick sections were observed which, in the long term, will require stabilization. The Low Level Interceptor was also very clean with only a few minor silt deposits (Andrews, 1996, 1997).

Both sewers pass directly through what is now one of the most highly developed downtown cores in North America. Toronto boasts one of the most extensive underground pedestrian tunnel networks anywhere. Little could the designers have imagined the extensive modifications that would be needed over the years to accommodate these tunnels, in addition to subways, foundations for skyscrapers, large diameter watermains, and numerous other utilities, bridges and roads. In every case the sewer has stood up well to these modifications and, where they exist, the transitions from old to new and back again have remained sound and stable.

At the end of the 1996 inspection work, however, several unanswered questions remained. Resolution or explanation of these issues was considered important since determination of what was actually constructed, and when, could have a significant impact on the results of assessment. Therefore, a brief historical research program was carried out in order to address the following points.

1. What appears to be a joint between the lower brick section and the upper concrete arch in the High Level Interceptor was in excellent condition with no sign of transverse movement. How was this joint made and what mechanism prevents slippage? With a flexible lower section and a relatively rigid upper section, one would have expected to observe some distortion at this joint.

2. Are the precast concrete pipe sections of the Low Level Interceptor original (ie constructed in 1910) or are they part of a subsequent reconstruction phase? If the precast sections are not original, then how old are they?

3.2 Historical Aspects

Initial research regarding the fundamental point of the latter question, that is, when was precast concrete sewer pipe first introduced into Canada, lead to some interesting findings regarding these sewers.

It was found that indeed precast concrete pipe was used in the original 1910 construction. The pipe was cast on site beside the trench. When sufficiently cured, the pipes were directly lowered into the trench and backfilled. These early precast pipes remain to this day in remarkably good condition. More incredibly though, throughout the entire length the bell and spigot joints were found to be in good condition with only occasional occurrences of light, active infiltration. Observed joint defects were far less frequent than observed in other similar, modern sewer pipes. The first conclusion of the historical research is that the observed precast pipe is as originally constructed in 1910 (Canadian Engineer, 1911).

Subsequent internal inspections confirmed that the joints were waterproofed using ‘puddle clay’. The interior spigot below the springline were intentionally left out of the precast pipe and the resulting void pack with clay. The interior surface was then covered with mortar. Presumably the joint above the springline was similarly packed prior to backfilling the trench. Such puddle clay was commonly used for waterproofing up to the end of the nineteenth century so its use here is not unusual.

On the High Level Interceptor sewer, contractors where given a choice of construction methods. In open cut either full brick lining could be used or a full, plain concrete section could be used. If a concrete section was used then the lower half was to be lined with a single ring of brick in order to protect the invert from scour. The contractors obviously selected this alternative and therefore, the observed joint between the concrete and the brick was in fact, not a joint. Rather, the invert bricks were recessed into the continuos concrete pipe wall. This explains the observation that there has been no lateral movement at the springline.

Historical research also confirmed that some portions of the concrete sewer were reinforced with ‘expanded’ metal sheets. This reinforcing steel was used in the flat slabs of the rectangular box section at the outlet of the sewer. It was also used in the circular sections which were installed in ‘embankment condition’ or in fill. At these locations the concrete was 12" (300 mm) thick at the crown, 17 ½" (445 mm) at the springlines and 12" (300 mm) in the invert (ie. 7 ½" below the brick lining). Reinforcing steel was placed in an elliptical shape located so as correspond to the tension zones of the concrete (ie. inside faces at the crown and invert and at the outside faces at the springlines) (Metcalf and Eddy, 1928). Again, these sections have been found to have stood up very well since constructed.

4.0 CONCLUSION

The inspected portions of the High Level and Low Level Interceptors were found to be in generally good condition with isolated areas of infiltration and minor cracking. The sewers were considered to be functioning in a satisfactory way and none of the findings suggested that the sewer wouldn't continue to give adequate service for many years to come.

The inspection methodology was found to be effective and the results particularly useful. The pan-and-tilt camera equipment provided good images of various defects and connections while the Sonar images provided useful information regarding the invert and condition of the brick linings underwater.

5.0 POSTSCRIPT

As previously noted, Charles Rust, Toronto's City Engineer, was responsible for the direction of the Main Drainage works. Today, Mr. Rust is regarded by historians of technology as a visionary in his adoption of new technology and, in particular, his use of photography to document construction. The City of Toronto Archives is blessed with an extensive collection of photographs produced by the City Engineer's Office during his tenure. Photography, especially non-studio work, was still in its infancy when Rust realized its potential benefits. As early as 1890, he developed a systematic approach to documenting municipal construction projects. Pre-construction, progress and post-works were all documented under Rust's program. No doubt he would be pleased, although perhaps not surprised, to see the advances made in construction photography and in particular the use of video cameras in remote places like his High Level and Low Level Interceptors.

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