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DEALING WITH H_2S CORROSION IN THE GORDON TRUNK SEWER

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ABSTRACT: Since 2000 the City of London has been actively dealing with the effects of high levels of hydrogen sulphide in the Gordon Sanitary Trunk Sewer. Built in the late 1960s, the 5km concrete gravity sewer is fed by a 5km forcemain, and consists of pipe sizes ranging from 825mm to 1350mm. Contributing to the generation of hydrogen sulphide are upstream users that generate sewage with elevated BOD levels and poor hydraulics throughout the system. As a result, the City received complaints of odours; inspections revealed moderate to severe microbial induced corrosion throughout the sewer.

The City developed a strategy to ensure the long-term viability of the infrastructure: reduce H2S generation and odours, rehabilitate or replace damaged infrastructure, and remove hydraulic bottlenecks to allow for future growth without the replacement of the entire system.

Between 2004 and 2010, 14% of the system was replaced (some for capacity improvements), 38% of the system was rehabilitated via cured-in-place-pipe, a biofilter was constructed to reduce odours, and chemical addition at the pumping station began. Between 2011 and 2013 it is anticipated that an additional 9% will be replaced for capacity improvements and the remaining 39% will be rehabilitated via trenchless technologies. Hydrogen sulphide levels are monitored on a continuous basis.

This paper will give an overview of the various projects with the focus being the trenchless solutions implemented as part of the overall strategy. It will discuss lessons learned in dealing with H2S corrosion and how it has affected the City's requirements for new construction.

1. INTRODUCTION – THE GORDON TRUNK SEWER SYSTEM

The Gordon Trunk Sewer system is over 10 km long and carries sanitary flow from the southwest area of the City of London to the Greenway Pollution Control Centre. The pipe diameter ranges in size from 825mm to 1350mm. The sewer receives flow from laterals along its length and a forcemain at the upper end of the service area with flow rates up to 10MIGD. Upstream land uses include residential, commercial, industrial and food processing facilities. The sewer pipe gradient varies from 0.2 to 6 percent with several alignment changes and vertical drops creating turbulent hydraulics and contributing to the release of hydrogen sulphide gas and odours.

In response to odour complaints received from residents along the trunk sewer, the City of London initiated a study in 2000 to review the nature of the odours. The study identified serious microbiologically- induced corrosion issues in the Gordon Trunk Sewer. The corrosion was attributed to significant concentrations of hydrogen sulphide gas

detected along the sewer. After an extensive flow monitoring and air sampling program, significantly high levels of hydrogen sulphide were confirmed throughout the Gordon Trunk Sewer.

A comprehensive condition assessment program was initiated for the full length of the sewer system in 2002. The results were that large portions of the sewer condition were identified as being in WRc[1] condition 4 ("poor") or 5 ("bad" or "failed") due to severe corrosion. The remaining sections were in WRc condition 3, or "fair", with advanced signs of corrosion. As a result of these studies and investigations, a long term program for the rehabilitation and/or replacement of the trunk sewer was developed.

2. GORDON TRUNK SEWER SEWERSHED

The Gordon Trunk sanitary sewershed comprises a large drainage area to the Greenway Pollution Control Centre (GPCC). The land uses within the sewer service area are predominantly residential with neighbourhood commercial interspersed along the route except for the upstream portion. The upstream portion includes a mixture of industrial and food processing uses.

3. THE REHABILITATION STRATEGY

The rehabilitation strategy focused on three main areas: odour control, corrosion prevention and capacity issues.

For odour control, several measures were available to reduce odour levels and the inconvenience to the public. These included improved system hydraulics as well as odour reduction through the use of physical measures such as a biofilter and carbon filters within the maintenance structures.

Corrosion prevention could be addressed through improved system hydraulics particularly at those locations where the highest levels of H2S were measured as well as the repair (or replacement) of badly deteriorated pipe. New maintenance structures and realigned pipe transitions and turns at these junction structures could be used to improve system hydraulics. The badly deteriorated pipes would be replaced with "lined" pipe or "relined" in place using CIPP methods.

Capacity issues would be identified through system modeling which would address not only any land use changes not provided for in the original trunk sewer design, but also where system storage or pipe upsizing could have a positive impact on odour control and corrosion prevention .

An implementation plan was developed identifying a prioritized list of projects required to secure the function and operation of the Gordon Trunk Sewer.

4. TRENCHLESS REHABILITATION PROJECTS

With the Rehabilitation Strategy and implementation plan now in place, projects were initiated based on their priority. The following projects have implemented different methods and products, each with their own pros and cons.

4.1 Gordon Avenue – Commissioners Road to Highview Avenue

In 2002 the first project initiated provided for the replacement of severely corroded concrete pipe and maintenance holes on Gordon Avenue from Commissioners Road to Highview Avenue. Although not a trenchless project, it is included for comparison, and because it provided impetus to seek trenchless solutions. This project focused on the sewer section with the strongest sewer odours and poorest physical condition. To minimize the effects of hydrogen sulphide gas - related corrosion in the new sewer pipes, the City selected a lined concrete pipe supplied by Hanson Pipe and Precast located in Cambridge, Ontario. The pipe was precast with an Agru-liner, a high density polyethylene (HDPE) membrane liner cast within the barrel of the pipe. After installation of the pipe sections, all

[1] Water Research Council coding for sewer defects

joints had to be fused to provide the final level of protection, a time - consuming process. The same HDPE liner was also adapted for the new maintenance holes. Again, all liner joints in each maintenance hole had to be fused to ensure continuity. Though this was the first time the City had used sewer products with special liners, the project was completed without any serious issues. The City was satisfied that a suitable corrosion mitigation measure was now available for use with the future projects. Though the effectiveness of the Agru-liner protection had been demonstrated, a construction program post mortem identified the considerable time that had to be reserved for the final fusing of joints as an area for improvement. This task extended the sewer pumping and bypassing costs as well as the construction duration and local impacts.

4.2 Gordon/Langarth Trunk Sewers - Emery Street at Langarth Street

In 2007 another project was undertaken to replace a smaller trunk sewer that discharged into the Gordon Trunk Sewer.

The Langarth Trunk sewer services a portion of the "Old South" area of the City which is primarily residential. The existing sewer crossed a ravine via a pipe bridge and outletted to the Gordon Trunk sewer at a maintenance structure with poor hydraulics, allowing the release of H_2S gas. The ravine is considered part of "The Coves", a designated environmentally sensitive area (ESA). The pipe bridge consisted of concrete piers supporting a 450 mm diameter steel pipe. The steel pipe was badly corroded from the effects of the hydrogen sulphide gas that had migrated from the Gordon Trunk Sewer. The pipe loss was so severe that overflows of sewage to the ravine and into the Coves area was an imminent concern.

In addition to replacing the smaller Langarth trunk sewer, the substandard maintenance hole structure had to be replaced to address condition and improve hydraulics, and the sections of the Gordon trunk sewer on either side of the junction required rehabilitation. A cured-in-place pipe (CIPP) liner was selected for the pipe rehabilitation. This process would be faster than installing the Agru-liner lined pipes using conventional open cut methods as had been done in the previous project.

There was a considerable drop in elevation between the incoming and outgoing pipes in the original maintenance hole structure. A similar condition existed for the incoming Langarth Trunk sewer. The Gordon Trunk sewer also takes a ninety degree turn at this junction. The poor hydraulics increased the release of H2S gas at this location. To achieve the smoother flow, the original deteriorated structure was demolished and replaced with a new precast chamber.

To minimize future corrosion to the new maintenance hole, the use of Agru-liner was originally recommended. Concerned about the additional time required to fuse the Agru-liner joints in the maintenance hole and how to connect it to the CIPP, the Project Team decided to use a liquid additive available from ConShield Technologies Inc. for the precast maintenance hole sections. The decision was based on the successful use of the additive on other projects in North America. This additive was capable of preventing the acid producing bacteria from colonizing on concrete surfaces. By using this additive in the concrete mix design and manufacture of the precast concrete sections, the extra time required for fusing the Agru-liner membrane was eliminated from the installation schedule. The City has continued to monitor the performance of the finished product and has been very satisfied to date.

Sections of corroded pipe were taken from this project to be tested. The results were that the pipe kept strength up to 90D[2]. These results led the City to believe that although badly corroded the pipe retained enough strength to allow several years to carry out a rehabilitation strategy.

4.3 Gordon Avenue – Belmont Drive to Highview Avenue

With the announcement of stimulus funding, the rehabilitation plan for the Gordon Trunk sewer received a kick start in 2009. A Request for Proposal was issued for the CIPP rehabilitation of the section of sewer immediately upstream of the first rehabilitation contract undertaken in 2002. It included approximately 600 meters of 1200 mm and 1350

[2] 90D refers to D-load standards for concrete pipe. 90D is approximately equal to strength of 89kN/m^2. For comparison Class IV pipe is required to have 100D, or 95.8 kN/m^2

mm diameter pipe. Corrosion deterioration in this section of sewer was less severe and as a result did not require the rehabilitation of the cast-in-place maintenance holes.

4.4 Commissioners Road, Huxley Street, Base Line Road

While preparing the 2009 RFP the City updated the original sewer condition assessment data obtained in 2003. The CCTV inspections indicated that several sections of sewer along Commissioners Road to Huxley and then along Base Line Road showed more rapid deterioration than expected.

Complete corrosion of the reinforcing steel was observed. Based on the severity of the deterioration, an emergency repair project was initiated to reline approximately 465 meters of 900 mm diameter pipe using a CIPP liner. The maintenance holes were also badly deteriorated. Owing to the proximity of the maintenance holes to a major trunk watermain, structure replacement was not viable. Structure rehabilitation was selected. An epoxy based protection system developed by Saureisen was chosen for this project. The system comprised a multi layered application process to reinstate and then protect all the deteriorated surfaces. This product system is used extensively to protect wastewater collection systems and treatment plant structures from microbiologically induced corrosion. Seven structures were rehabilitated using this process.

The process was time consuming since the application environment for each product application had to be carefully controlled for optimum results. Many of the MHs were within traffic pavement areas extending the duration of the traffic control measures and the impact on the road network and driving public. The performance of the epoxy coating system will be monitored and evaluated for future use.

4.5 Southcrest Ravine

The 2010 phase of the Gordon Trunk Sewer rehabilitation was the CIPP lining of 770m of 900, 1050, and 1200mm concrete pipe in the top of bank area of a ravine. The project also required the rehabilitation of seventeen (17) maintenance holes. Bidding contractors were required to submit their proposed product for the maintenance hole rehab as part of the Request for Proposal. SpectraShield was the product specified in the winning RFP. The multi-layered liner system comes with a10 year warranty which was very appealing to City staff. The Silicone Modified Polyurea liner consists of a moisture barrier, surface, and corrosion barrier. Once the maintenance holes are properly prepared the application time is very reasonable. City staff were happy with the process and will continue to monitor the performance of the SpectraShield liner.

5. LESSONS LEARNED

As part of the Gordon Trunk Sewer rehabilitation program the City established a monitoring program to measure the performance of the various measures taken to control and minimize the H_2S induced corrosion.

During the original studies of the Gordon Trunk system only non-destructive measures were utilized to assess both condition and structural adequacy. The Gordon /Langarth project provided an excellent opportunity to examine the degree of corrosion and its effect on pipe strength. One length of 1200 mm concrete pipe was carefully removed in the field for examination and further testing. The City and Hanson Pipe and Precast, the supplier of the original concrete pipe, carried out a 3 edge bearing load test (to failure) at their pipe manufacturing facility in Cambridge, Ontario, on the section of corroded pipe salvaged.

Figure 1: Three edge bearing test on corroded 48" diameter specimen with 40 years of service.

Test results showed that the subject pipe had only lost approximately 10 percent of its load bearing capacity. This was welcome news since a number of sewer sections with WRc condition 4 ("poor") and 5 ("bad") ratings still remain within the system .Though catastrophic pipe collapses cannot be ignored, the test data seemed to suggest a lower probability of this occurring. However, a subsequent inspection of the system in 2009 revealed that the softened concrete continued to wash away and the rate of deterioration increased. Thus a rehabilitation plan was made a priority.

The existing maintenance hole, which was replaced, showed advanced concrete corrosion on all interior exposed surfaces. However, during removal, it was determined that both the design and the construction methods ,at the time the structures were constructed ,were generous in terms of design and safety factors resulting in wall thicknesses greater than required by today's standards. This observation was invaluable for the assessment of the remaining safe and useful life of other deteriorated structures remaining in the Gordon Trunk system.

Further monitoring is planned on the performance of concrete surfaces with the liquid additive from ConShield Technologies Inc. that mitigates microbiologically induced corrosion to the concrete. Site visits are carried out by the City to examine how well the additive is working to discourage bacterial growth. A close examination of the maintenance hole interior continues to show neither noticeable microbial growth nor corrosion on the concrete surfaces. The City will continue to monitor the performance of this structure.

To date, the Gordon Trunk Sewer projects have generated the following valuable observations and conclusions:

1. The use of an Agru-liner for concrete surfaces has proven effective though it has some construction limitations in terms of construction scheduling and increased sewer bypassing costs due to length of time under bypass.

2. Cured-in-place pipe (CIPP) liner solutions for deteriorated pipe have proven to be an effective means of improving the pipe and protecting it from the future effects of hydrogen sulphide induced corrosion.

3. The liquid additive for concrete from ConShield Technologies Inc. has performed well to date and appears to provide an effective means of corrosion control for maintenance structures which can be introduced during the casting process. It appears to be an excellent option for new or replacement infrastructure where H_2S generation is a concern.

4. The existing concrete pipe and maintenance hole structures which suffered severe corrosion were still able to provide useful service and appeared structurally more stable than expected. In the case of the concrete pipe, the severe corrosion only resulted in an approximate 10 percent loss in load carrying ability.
5. The epoxy based Sauereisen maintenance hole rehabilitation and protection system addressed the corrosion protection needs of the project but may have some limitations when considered in conjunction with other project cost elements such as traffic control, sewer bypassing and overall project schedule. The time needed is greatly affected by ambient temperatures and application equipment used by the contractor. These factors should be considered when using this product.

6. The SpectraShield was both time and cost effective. The structures will be inspected periodically to monitor performance.

The City will continue to monitor existing solutions and experiment with new techniques and measures to provide the most effective corrosion resistance for sewer pipes and appurtenances on the Gordon Trunk system.

6. OTHER INITIATIVES

Remediation work on the Gordon Trunk Sewer has taken place alongside other initiatives to reduce the levels of H_2S in the sewer and to reduce odour. As part of the Pollution Control Operations program City staff add ferric oxide and Bioxide at the Dingman Sanitary Pumping Station to help minimize the generation of H_2S. To address odour issues the City constructed a biofilter system alongside the sewer in 2005. A 5000cfm fan continuously draws air from the sewer and exhausts it through a porous natural media where aerobic bacteria break down the sulphide gases before releasing it to the environment.

Some of the Gordon Trunk sewer has or will be replaced to remove hydraulic bottlenecks and allow for more flow. The first phase of this work was completed in 2009 with the replacement of 420m of pipe. Remaining phases will replace an additional 445m of pipe. This represents almost 17% of the Gordon Trunk sewer.

7. CONCLUSIONS

For a trunk sewer this long and with a history of issues, no single solution could fit every location.

Considering multiple system criteria such as hydraulics, capacity, condition, and laterals, the City of London concluded that the Gordon Trunk Sewer Rehabilitation Program would be comprised of a number of smaller projects, each with their own set of unique criteria. By implementing innovative methods of replacement or rehabilitation, the City was able to ensure the continued service of this sewer in a fiscally responsible way while also evaluating new methods and innovative products.

It is the City's intent to complete the entire Gordon Trunk Sewer rehabilitation within the next several years.

8. REFERENCES

Andrews Infrastructure. (2003). Inspection and Condition Assessment Study Final Report. Ottawa, Canada.