Innovative Joint Proves Successful in Critical Slipline Project

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ABSTRACT

Ever-tightening budgets are forcing water system owners to rehabilitate their major water transmission mains with permanent solutions, a key approach in their asset management programs. Halifax Water was recently faced with a deteriorating Prestressed Concrete Cylinder Pipe (PCCP) water transmission main that needed rehabilitation or replacement. This transmission main is located under Kearney Lake Road, a main high traffic level corridor on the west side of Halifax. The use of Spirally Welded Steel Pipe (WSP) with a unique O-ring rubber-gasket joint, allowed Halifax Water to successfully rehabilitate 4,920 LF (1.5 km) of a 48-inch (1200 mm) host PCCP primary transmission main by sliplining. This fully structural lining system provided a *structurally independent* solution designed to last 100 years. This paper details the innovative use of polyurethane lined and coated Steel Pipe with the unique joint that eliminated liner pipe bells and ensured that maximum internal flow area was provided by the lining system.

OVERVIEW

Halifax, Nova Scotia, not unlike numerous other municipalities in North America, developed their water transmission system using Prestressed Concrete Cylinder Pipe (PCCP). Beginning in 1952, Halifax began the development of the Pockwock Water Supply system to support the growing industrial and cultural dynamics of metro Halifax. In 1977, the Pockwock Water Supply system was brought online to provide high quality water and service to the taxpayers of Halifax.

A primary water transmission main from one of the nine water supply plants operated by Halifax Water was constructed in 1977 along Kearney Lake Road, a major thoroughfare serving the west side of metro Halifax. This transmission main ranged in diameter from
30 inch (1050 mm) to 60 inch (1500mm). In the late 1980's and throughout the 1990's there were several major failures along the Kearney Lake Road transmission main.

Halifax Water began repairs on this pipeline through the use of conventional open cut pipe remove-and-replace methods. In 2001, construction began to twin approximately 5000 LF (1.5 km) of the pipeline along the areas that had failed over the last several years. This twining program was instituted because of growing concerns about the performance ability of this line over time.

SOLUTION ALTERNATIVES

In 2005, Halifax Water contracted with the Pressure Pipe Inspection Company (now owned by Pure Technologies) to use their Prestressed Concrete Cylinder Pipe PCCP assessment technology. The condition assessment program identified numerous prestressing wire breaks along the transmission main. These wire breaks created performance concerns and were repaired. Then in 2006 and 2007 respectively, two additional catastrophic failures occurred on this line. The latter failures demanded

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better management of this primary transmission main and its performance going forward. Resident safety and injury potential were also primary considerations in rehabilitating this main in an economical and timely fashion.

It was determined that one of the major contributors to the cause of these failures was the high use of road salts and the resultant high concentration of chlorides within the pipeline backfill all along the pipe's route. Several repair alternatives were evaluated. For each option analyzed, consideration was given to traffic disruption, overall resident inconvenience, total construction time required, and the cost of the technology. The area along Kearney Lake Road is primarily residential but also includes numerous commercial properties.

Carbon Fiber Reinforced Polymer (CFRP): In the past ten years, the internal structural repair of PCCP has been performed with carbon fiber composites in some municipalities in the United States. However, many of these municipalities utilize CFRP only as a temporary repair option until a more permanent solution is applied at a later time. There were also no known uses of CFRP in PCCP lines in Canada at the time. Halifax decided that the technology was still relatively new and needed further evaluation. Also, as an internally applied lining system, CFRP application would not address the high chloride concentrations within the surrounding backfill of the pipeline. To design a structurally independent CFRP system that would handle both internal pressure as well as full external soil loading in the event of complete loss of strength of the host pipe due to the external chloride conditions would be cost prohibitive.

Post-Tension Tendon Repair: The post-tension tendon repair of PCCP was developed by a French company specializing in the post-tension repair of highways and bridges. The repair method involves fully digging up the pipe section to be repaired and externally applying post-tensioning cables around the deficient pipe section to substitute for the strength lost by corroded prestressing wires. This heavily intrusive process would not provide much advantage over the remove-and-replace solution and would also be costly. There were also very limited known uses of the technology in PCCP systems in North America.

Line Replacement: Total replacement of the transmission main was also considered. The obvious high cost of completely replacing the line made this alternative unappealing due to budget constraints. To complicate things further, along the main pipeline route, a 16-inch (400 mm) ductile iron pipe feeder main had been installed in the same trench and would have to be abandoned and replaced as well if total replacement of the existing main was performed.

REHABILITATION SOLUTION

In 2008, CBCL Engineering, a local Halifax design consultant, and Robinson Consultants Inc. of Ottawa, Ontario, were contracted to develop a "permanent" rehabilitation solution that addressed all the concerns outlined above and also provided a 100 year service life for this critical transmission main. Their final selected approach was to slipline the existing PCCP with an AWWA C200 Spirally Welded Steel Pipe (WSP). This solution would provide the following advantages:

1. The sliplined Steel Pipe would provide a fully structural or *structurally independent* rehabilitation solution with a long-term (100 years) internal burst strength, when tested independently from the host pipe, equal to or greater than the Maximum Allowable Operating Pressure (MAOP) of the host pipe,
2. The sliplined Steel Pipe would be able to survive any dynamic loading or other short-term effects associated with a failure of the host PCCP due to the external effects of the high chloride concentration soils on the pipe,

3. The sliplined Steel Pipe itself would be fully protected from corrosion by the dielectric polyurethane internal lining and external coating system as well as a sacrificial-anode cathodic protection system as described in AWWA M27 (AWWA 2004a).

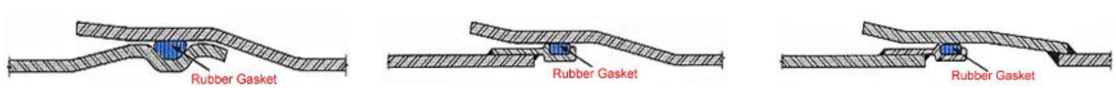
The first two capabilities of the Steel Pipe would place it into the Class IV Linings category as described in AWWA M28 (AWWA 2001).

PROJECT DETAILS

The project involved 4,920 LF (1.5 km) of 42-inch (1050 mm) diameter Steel Pipe sliplined into the existing 48-inch (1200 mm) diameter host Prestressed Concrete Cylinder Pipe PCCP. The project also included construction of the insertion and receiving pits, joint testing, grouting of the annular space, cathodic protection, connections to existing infrastructure, hydrostatic pressure testing, and disinfection. Tenders were scheduled to be received October 29, 2009 at 3:00 PM local time. Four tenders were received with the low tender at CAD $ 5,400,000 and the high tender at CAD $ 8,500,000.

Liner Pipe Details: The Steel Pipe to be sliplined into the Prestressed Concrete Cylinder Pipe PCCP was required to be manufactured in accordance with AWWA C200 (AWWA 2005). The Steel Pipe was dielectrically internally lined and externally coated with polyurethane in accordance with AWWA C222 (AWWA 2008). The 20-ft (6 m) long Steel Pipe liner sections were designed to a 200 psi (1,379 kPa) working pressure and a 250 psi (1,723 kPa) transient and test pressure utilizing AWWA C200 and the M-11 Design Guide (AWWA 2004b) recommendations. Designers also ensured that the resulting wall thickness of the Steel Pipe would be able to withstand grouting pressures.

Joint Details: The typical gasket-joint for Steel Pipe is manufactured in three configurations, the rolled-groove joint, the Carnegie joint with swedged bell, and the Carnegie joint with a welded-bell, Figs. 1a, 1b, and 1c, respectively. The rolled-groove joint is manufactured by first cold-forming a groove on the spigot-end of the pipe, into which an O-ring rubber gasket is seated. The gasket is therefore integral to the pipe. A swedged-bell is formed on the other end of a typical pipe section. Insertion of the spigot-with-gasket into the swedged bell of the adjoining pipe section forms a positive seal. The Carnegie joint with swedged bell is made by welding a pre-manufactured standard steel Carnegie ring section with gasket groove (joint ring) to the end of the spigot, then forming a swedged bell on the other end of the pipe. An O-ring gasket is then placed into the groove, before joint assembly. Finally, in the Carnegie joint with welded bell, pre-manufactured standard bell and spigot joint rings are welded to each end of a pipe section, resulting in a non-integral gasket joint system. All three configurations will provide appropriate water tight seals.



Figures 1a, 1b, 1c: Rolled Groove Joint, Carnegie with Swedged Bell Joint, Carnegie with Welded Bell Joint

On this project, if any of the three types of gasket-joints shown in Fig.1 were to be utilized, the internal flow area of the sliplining pipe would have to be lowered so that the larger outside diameter (OD) of the bell could be accommodated into the host PCCP line. To avoid this scenario and to enable the use of the largest possible internal diameter of the liner pipe, a unique joint was used, Fig. 2.

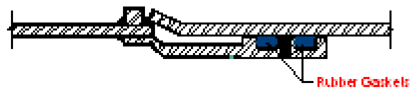


Figure 2: Innovative Joint for WSP Liner

The joints of the Steel Pipe liner sections were manufactured by welding a Carnegie double-gasket groove joint ring to the inside of one end of the pipe. The spigot ring was sized to perfectly match the interior of the main pipe body so that a swedged bell would not be required. Only a small flare was formed on the bell to allow for initial joint alignment during installation. The use of double gasket Carnegie joint rings, Fig. 2, allowed the integrity of each joint to be individually air-tested immediately upon installation into the host pipe and ensured that the OD of the Steel Pipe liner sections remained constant throughout the entire length of the pipeline. The maximum internal flow area was therefore successfully provided by the 42-inch Steel Pipe liner design.

The unique joint on each pipe section was manufactured and test stabbed at the Northwest Pipe Company manufacturing facility in Parkersburg, West Virginia.

Installation Process: To confirm the amount of pipe deflection, joint deflection and any other potential blockage in the line that might inhibit the slipline process, the contractor pulled a 20-ft (6 m) long, 42-inch (1050 mm) diameter steel pipe "test pipe" through the line prior to beginning the sliplining process. The host PCCP line was cleaned and some internal joint repairs were necessary to ensure smooth travel for the casing spacers.

Once the test pipe had been pulled through a section of the distressed PCCP line, the slipling process was begun. Each section of Steel Pipe liner was fitted with either three or four sets of casing spacers, depending on the length of the section being lined Fig 3.

Figure 3: Steel Pipe Liner Sections with Casing Spacers

The casing spacers centered the Steel Pipe in the PCCP and allowed the Steel Pipe liner to easily move through and articulate at any point in the host pipe that were over-deflected or had significant joint deflections. The casing spacers also provided a consistent annular space all the way around the liner pipe sections for grouting afterwards. In addition, they electrically isolated the new carrier pipe from the old PCCP which was part of the long term corrosion control plan. Each section of liner pipe was then placed into the insertion pit on the bed of the especially designed pipe jacking sled developed by the contractor. After the first liner pipe section was pushed into the host PCCP line, the next section was placed on the bed of the pipe jacking sled and pushed forward to engage the double gasketed O-ring joint. The gasketed joint was fitted with an integral pipe stop to assure joint alignment and fit up. The contractor performed an air test on each O-ring joint, using a threaded air test hole in the joint, and prior to pushing that segment up into the PCCP. This air test was performed to 55 psi (380 kPa) for 5 minutes to assure that each joint was airtight. All the joints in a run were then retested prior to any final connections being made.

In addition to the air-testing performed on each individual joint, every joint was also fitted with a continuous electrical bonding connection, Fig. 4, to assist in the corrosion control plan for the project developed by Brouco Services of Ottawa, Ontario. This joint bonding connection was made just prior to the engagement of the double gasketed O-ring liner pipe joint.

Figure 4: Joint Bonding for Electrical Continuity

This continuous process was repeated until the required number of liner sections were pushed into the host pipe up to the receiving pit. As much as 1000 ft (305 m) of liner pipe was pushed into the host pipe in a single straight run.

<u>Insertion and Receiving Pits</u>: Insertion/receiving pits were strategically placed along the pipeline route to allow for the longest and most efficient pipeline sections to be sliplined. Although the project design called for eighteen insertion/receiving pits, only sixteen pits were actually used. Two pits were eliminated because there were no bends in the PCCP line at those proposed locations as had been initially thought, and the Steel Pipe liner pipe sections were pushed straight through. Each pit was constructed to allow the use of 20 ft (6 m) lengths of Steel Pipe liner sections and minimize the number of joints within the pipeline.

The contractor made all the pipe pushes uphill with some grades up to 6 percent. They used a load cell on the hydraulic jacking sled to control the pushing force exerted on the pipe to assure that the Steel Pipe liner ends did not incur any damage to the pipe barrel and pipe ends.

<u>Reconnecting to Existing System</u>: The insertion/receiving pits also allowed the contractor to make new connections of the Steel Pipe liner sections to existing infrastructure such as valves, meters, and other appurtenances, prior to restoring the service of the transmission main. Mechanical couplings were used to make all the connections to new and existing pipe and other appurtenances. The use of mechanical couplings also minimized any field repair to the polyurethane lining and coating as a result of field welding. The insertion/receiving pits were also used as the primary form for the thrust restraint required at these locations. Typically a 20 MPa (2900 psi) concrete pour in multiple lifts was made to 12 inches (150 mm) around and over the pipe within the pit and to 48 inches (1200 m) when horizontal bends were present to provide the required restraint and provide additional corrosion control.

Grouting of Annular Space: The contractor was required to grout the interior annular space between the new Steel Pipe liner and the host PCCP line. The project specifications allowed the use of a liquid or foam grout providing a minimum compressive strength of 2 MPa (290 psi) and a maximum compressive strength of 5 MPa (725 psi). A minimum grout thickness of 2 inches (50 mm) between the Steel Pipe liner and the host PCCP was required.

After the insertion/receiving pits were excavated bore holes on the surface above the PCCP line were drilled and cased on 60 ft (18 m) centers allowing controlled gravity flow of the grout into the annular space. The bore holes were drilled through the top of the distressed PCCP to allow access to the annular space. The maximum allowable grout pressure during placement was 5 psi (34 kPa). The grout level within the annulus was monitored in the insertion/receiving pit at the downstream side of the push being grouted. The grout was also monitored through the vertical bore holes on the surface. The Steel Pipe liner was filled with water to prevent any over deflection due to unanticipated excessive grout pressures.

Cathodic Protection: In accordance with the project cathodic protection plan, test stations were installed along the pipeline route at 1000 LF (300 m) intervals. Eight magnesium anodes were installed in each insertion/receiving pit. The test stations will allow for future monitoring of the Steel Pipe performance going forward.

Field Hydrotesting: After all the Steel Pipe liner had been installed in the host pipe and reconnected to existing infrastructure, a successful hydro-static test of the entire pipeline was conducted at 250 psi (1724 kPa) for two hours. No leaks were found in the system.

CONCLUSION

After conducting an extensive search of existing rehabilitation technologies for the permanent repair of a structurally deficient 48-inch (1200 mm) diameter section along the Kearney Lake Road Prestressed Concrete Cylinder Pipe PCCP transmission main, Halifax Water selected 42-inch (1050 mm) spirally Welded Steel Pipe, manufactured to AWWA C200, to slipline the host pipe. The Steel Pipe liner pipe provided a fully structural or *structurally independent* system that would provide a service life of 100 years. A unique O-ring gasket joint was used with the Steel Pipe that eliminated pipe bells and accommodated the largest possible internal flow area. The joint configuration also allowed for joint-integrity testing prior to insertion into the host pipe. The 20 ft Steel Pipe liner sections were designed for 200 psi (1,379 kPa) working pressure and 250 psi (1,739 kPa) transient and test pressure utilizing AWWA C200 and the AWWA M-11 recommendations. Each liner pipe section was internally lined and externally coated with polyurethane per AWWA C222. Cathodic protection was also applied and test-stations were placed at 1000 ft (300 m) intervals. Every gasket-joint was bonded to ensure electrical continuity for the cathodic protection system. The contractor utilized a uniquely designed pipe jacking sled that allowed up to 1000 LF (300 m) of liner pipe to be inserted in a single straight run. Halifax Water as well as the design engineers were pleased with the successful outcome of the rehabilitation project and intend to utilize the same technology on future projects.

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