PILOT FIRST! INSPECTING PCCP WATER MAINS IN GREENSBORO

Authors: Jim Perotti, Brown and Caldwell
Melinda King, City of Greensboro

ABSTRACT: This paper will present the approach to and results of a pilot inspection of a 30-inch Prestressed Concrete Cylinder Pipe (PCCP) water main conducted for the City of Greensboro, NC (City).

The City opted to perform a pilot test after identifying a highly critical 36-inch PCCP water transmission main that needed a condition assessment. Before embarking on the full inspection program, the pilot test was initiated to evaluate the effectiveness of the inspection tools and adequately gauge the difficulty and the level of effort associated with this type of water main inspection.

The pilot inspection was performed on a shorter, less critical water main using the Pure Technologies (PURE) tools: PipeDiver and SmartBall. The pilot included the development of inspection procedures and recommendations for the future evaluation of PCCP water mains - including the City’s identified highly-critical 36-inch PCCP transmission main.

For the pilot inspection, the City performed all pipeline modifications, flow augmentation, and inspection support with their own staff. This paper will address the extensive preparation and efforts required for inspection of PCCP pressure pipe and will include a discussion of the different options for performing the work, including advantages and disadvantages of each.

The paper will also include a discussion on the technologies available for evaluation of PCCP pressure pipe and considerations when planning and implementing an inspection program. This paper will be of interest to water and sewer utilities that desire to plan, design, and implement an asset management program that includes PCCP pressure pipe evaluation, an evaluation of alternative inspection technologies, the pre-planning required to implement alternative technologies, and interpretation of inspection data.

KEY WORDS: PCCP Water Main, Condition Assessment, In-line inspection, Acoustic Inspection.

INTRODUCTION

The City of Greensboro (City) provides water, wastewater and stormwater services for the City. The City’s water system includes two water treatment plants and delivers approximately 32 million gallons of water per day. The water distribution system is made up of various pipe materials including PVC, CIP, DIP, and PCCP. The City currently has approximately 20 miles of PCCP pressure pipe in the ground.

The City’s Bryan Park Water Main (WM) is a highly critical 36-inch PCCP transmission main from the Townsend Water Treatment Plant. The main had a failure at a joint along Bryan Park Road in November 2011. The City repaired the failed portion of pipe and decided to conduct a condition assessment of the entire Bryan Park water transmission main. The Bryan Park WM cannot be taken out of service to perform condition assessment and any service disruption of this main would impact a large portion of the community including several large commercial water users in that area.

This would be the first detailed inspection of this kind on a PCCP WM that the City has ever conducted. Due to the criticality and risk involved with the Bryan Park WM, the City decided to first perform a pilot inspection on a less critical PCCP water main of similar size. The City selected the Bridge Point WM for the pilot inspection. The Bridge Point WM is a 2,000-foot, 30-inch diameter PCCP WM located on the east side of the city. It serves only a few residential customers and has the added benefit of being able to...
be isolated and depressurized for the inspections. Like the Bryan Park WM, the Bridge Point WM also had a joint failure in the past.

**PCCP Water Mains**

The type of PCCP in this project is lined cylinder pipe and is made up of a concrete core, a steel cylinder, steel pre-stressing wires, and an external cement mortar coating (see Figure 1). The pipe has a gasketed joint which is filled with a field applied cementitious mortar on the interior and exterior of the joint to help protect the steel from exposure to water and corrosion. For high pressure applications such as water mains, the primary modes of failure for PCCP are loss of integrity of the pre-stressing wires or deterioration at the pipe joint. The condition assessment approach for this pilot inspection will focus on gathering data related to both modes of failure.

![Figure 1. Prestressed Concrete Cylinder Pipe – Lined Cylinder Pipe (Hanson)](image)

**METHODOLOGY**

The City started the preparation and planning to conduct field inspection of the pilot water main by first reviewing the PCCP inspection technologies.

**PCCP Inspection Technologies**

There are a limited number of inspection tools that provide data on the PCCP pre-stressing wires. The remote field eddy current with transformer coupled (RFEC/TC) tools provide information on the current condition of the pre-stressed wire in the pipe. In other words, it can identify where there are broken wires. The wire is the primary structural element in the pipe and is vulnerable to corrosion and to hydrogen embrittlement. The PipeDiver from Pure Technologies is an internal, in-line tool which uses RFEC/TC technology to identify pre-stressed wire break zones along the entire length of a PCCP main.
The PipeScanner from Pure Technologies is an externally mounted tool which uses the same electromagnetic technology as PURE’s in-line inspection tools to check the integrity of the pre-stressed wires in PCCP. The top half of the pipe must be exposed so that the tool can be rolled along the crown of the pipe. The tool collects data on the pre-stressed wires with indications of where wire breaks have occurred and the extent of the wire break zone. The tool will collect data over the entire length of exposed pipe, so the greater the length of exposed pipe, the more data is collected. Typically, at least one to three pipe sections are exposed.

There are some limitations to these electromagnetic technologies. For example, the tool cannot detect wire breaks in close proximity to a joint due to the amount of additional steel in the pipe at those locations which impacts the electromagnetic signal. It does not detect mortar loss or mortar cracking regardless of its location. The tool also only detects pre-stressing wires which have broken. Wires which are exposed or corroded but otherwise still capable of conducting the electromagnetic signal are not identified with this technology.

Pilot Inspection Planning

The selected pilot inspection plan approach included both the free swimming acoustic technology, SmartBall, and the free swimming remote field eddy current/transformer coupled (RFEC/TC) tool, PipeDiver, both by PURE. The SmartBall inspection was conducted prior to the insertion of the PipeDiver tool to detect if leaks and pockets of trapped gas are present within the length of pipe at the time of inspection. The SmartBall also provided a proving run for the larger PipeDiver tool. PipeDiver inspection was performed next to locate broken pre-stressing wires in the structure of the PCCP.

Joint inspections were also performed as part of this inspection project to assess the condition of the external pipe mortar at the pipe joints. Joint inspection locations were selected to get a representative sampling of the joints throughout the length of the water main.

The inspection planning and preparation work included the following items:

- Gathering information including record information, system data, and institutional knowledge
- Develop a tool insertion plan and details
- Develop a flow management plan to augment/throttle flow as required to maintain proper velocity
- Develop a tool tracking plan
- Pre-inspection flushing
- Verify valve function
- Notifications
- Pipe dewatering (where applicable)

The inspection planning included evaluation of the flow conditions and development of a flow management plan. A minimum flow velocity of 1 foot per second (fps) is typically required to propel these free-swimming tools through the water main. Based on the City’s water system model, the typical flows in the Bridge Point WM range from 0.3 MGD to 1.1 MGD, which results in velocities of only 0.1 fps to 0.3 fps. Therefore, flow augmentation would be required to perform the inspections. Using the City’s existing system model, it was determined that 1 fps velocity could be achieved by opening three downstream hydrants along Cedar Park Road and pulling more flow through the Bridge Point WM. Prior to inspection, a trial was performed while monitoring the flow velocity in the WM at the extraction location. Using this proposed flow management plan, velocities were measured between 1 and 1.5 fps during the inspection.
Inspection Civil Support

Civil construction support is needed to accommodate the PCCP inspections. The specific required work items and details to support the inspection are identified during the planning and review phase. However, the following are the typical work items required to accommodate a PCCP WM inspection:

- **Excavate and Construct WM Access** - If the WM has existing access points of the size required (minimum 12-inch flanged connection) and in the necessary locations, construction of new access points may not be required. However, in most cases, one or more of the access points will require a new tap in the pipe. The number and location of access points will be determined during the inspection planning phase. Wherever possible, the inspection will be conducted in a single insertion requiring pipe access at the beginning and the end of the inspection run. However, depending on the configuration and layout of the WM, inspection may require more than one insertion (i.e. three or more access points into the pipe).

- **Joint Inspection Excavations** – Expose the joints at selected locations to provide an adequate sampling along the WM.

- **Traffic Control** - If the access points are located on or near a roadway, traffic control will be required for the installation of the access points and the inspection process itself. This work would also include any permitting necessary.

- **Provide Connections During the Inspection** - The inspection will require lifting and connecting the insertion and retrieval stacks to the WM via flanged fittings (see Figures 2 and 3). This work includes dewatering the excavation as necessary.

- **Valves and Pump Operation** – The free-swimming tools use the flow in the WM to propel the device through the pipeline which requires a coordinated operation of the system to ensure proper timing and velocities.

- **Other Miscellaneous Inspection Support** - Disinfection, flow augmentation, public notification, temporary water supply (if necessary), etc.

- **Pipe Connection Restoration** - Where new taps/access points are constructed, the City may desire to maintain permanent access to the new tap via a manhole or above ground connection, or to simply close and backfill the connection.

The inspection civil support work can be accomplished a number of different ways. The three typical approaches used are:

- Utility’s crews perform the work
- Civil contractor – contracted directly with the Utility
- Civil contractor – contracted under the engineer’s contract

Each can be a viable option depending on the desires, resources, and availability of the utility owner. The owner may also select which individual tasks to perform themselves and which to contract out. For example, many owners choose to perform their own valve and pump operations, public notifications, or permitting while the civil contractor performs the remaining construction work and the engineer handles the coordination between the City, contractor, and inspection crews. Some owners also provide materials (i.e. tapping sleeves, valves, spool pieces, etc.) that the owner has in stock to reduce the cost of the civil contract or to expedite the project.
Inspection support for the Bridge Point WM pilot inspection was performed entirely by City crews which provided them direct control over all the work affecting the City's water system and allowed them to become familiar with the inspection process for future inspections.

**Inspection Preparation Work – Access Points**

Prior to the inspection, City staff installed 16-inch tapping sleeves and valves to provide access at the insertion and extraction sites. The excavations remained open to provide access to the valves and risers during the inspection. Refer to the following photos (Figures 2 and 3) for details of the insertion and retrieval configurations. The 16-inch pipe coupons and pre-stressing wires from the taps were collected by the City and provided for use in the pipe evaluation.

![Figure 2. Insertion Configuration](image1)

![Figure 3. Extraction Configuration](image2)

**In-line Pipe Inspections**

On the morning of the inspection, Acoustic Surface Mounted Sensors (SMS) were installed on the pipe at the insertion and extraction sites to track the progress of the SmartBall. The PipeDiver was tracked along the entire inspection length at the ground surface using a portable locator.

Prior to the SmartBall insertion, the City connected the extraction net stack to the reducer at the extraction site (See Figure 3). PURE staff lowered the net into the flow and verified proper placement using a camera attached to the net. The SmartBall was dropped into the riser at the insertion stack and was tracked using the SMS sensors at the insertion and extraction sites during the inspection. The actual inspection ran approximately 36 minutes.

The PipeDiver can be inserted with the WM in service (pressurized) or the main out of service (not pressurized). The Bridge Point WM was inserted with the main out of service. Upon completion of the
SmartBall inspection, the City crew closed the inline valves to isolate the Bridge Point WM. The City drained the WM until the water level was below the insertion tap. Once drained, the PipeDiver tool was inserted by hand into the pipe. The WM was filled from the extraction end to prevent the tool from moving downstream prior to the WM being filled.

Once completely filled, the flow was restored to the WM and the inspection began. As the tool reached the extraction site, flow was reduced and stopped to bring the tool to the extraction point. PipeDiver was retrieved manually by PURE staff and data was downloaded from the memory for evaluation. A pressure transient monitor was installed at the extraction location to collect pressure data to be used for the condition evaluation of the pipe.

**PCCP Joint Inspections**

The data that is collected from the PipeDiver inspection provides good, detailed information on wire breaks which is one of the main failure modes of PCCP. However, deterioration of the mortar at the pipe joints is another common mechanism of failure of PCCP. The pipe’s external mortar helps protect the steel in the joint and prestressing wires in the pipe wall from moisture and corrosion. There has already been one pipe joint leak/failure on the Bridge Point WM. It was located near the upstream (north) end of the WM. As part of the pilot inspection, BC conducted external inspections of six (6) pipe joints, including one near the previous failure location, to confirm the condition of the mortar and help identify what, if any, chronic issues are evident.

The joint inspection involved exposing the selected joints and examining the exterior to determine:

- Existence of the mortar coating (diaper) at the joint
- Identify defects in the joint mortar (i.e. softening, delaminating, cracking, broken, leaks, etc.)
- Corrosion of steel in joint (if exposed)
- Check external mortar on pipe adjacent to the joint

**RESULTS**

**In-line Inspection Results**

There were no leaks or gas pockets detected in the Bridge Point WM during the SmartBall inspection. The reporting for the PipeDiver inspection looks at each individual pipe stick along the entire inspection length. For this WM, 16-foot pipe lengths were found resulting in 110 PCCP pipe sticks. The inspection revealed five areas of wire break zones in four of the 110 pipe sticks. The number of wire breaks per zone ranged between 5 to 10.

Structural analysis of the pipe was performed for the current external and internal loads. The analysis used the wire size, wire spacing, steel cylinder thickness, and concrete thickness measured from the coupons collected during the pipe taps. Other assumptions included a 5-foot depth of cover and a total internal pressure of 140 psi as confirmed by the transient pressure data collected.

The pipe performance curve developed as part of the analysis is shown in Figure 4. At the assumed pressure of 140 psi, the yield limit of these pipe sticks will be reached when the pipe has a wire break zone containing 24 broken wires. This condition still affords a factor of safety against rupture at the ultimate strength of both the wire and cylinder. Based on the analysis, the range of wire breaks found (10 or less) are considered to be a low level of distress.
Joint Inspection Results

A total of six (6) PCCP pipe joints were exposed and inspected along the Bridge Point WM. The results were documented using a field form and photos.

Joint numbers 1 through 4 are located near the downstream (south) end of the WM. In general, the mortar at the joints in this area appears to be in good condition. The small isolated defects observed were repaired with mortar by the City crew prior to backfilling the sites.

Joint number 5 is located near the upstream (north) end of the WM. The mortar at the joint has failed exposing the steel in the joint to the soil and moisture. Corrosion of the steel in the joint will eventually lead to a leak/failure of the pipe. The exterior mortar on the pipe wall (approximately 1 to 1.5 feet from the joint) was also failing. The exterior mortar along the entire circumference in this area was delaminated or falling off of the pipe and the prestressing wires were exposed in two locations. Where visible, the prestressing wires appeared to still be intact with minor corrosion. Mortar failure can be caused by a variety of reasons including: damage to the pipe during installation; defect during manufacturing; excessive loading of the pipe at the joint causing stress on the pipe adjacent to the bell; or broken wires causing the mortar above to come loose. There is some concern that this damage may be chronic in this portion of the force main. Joint number 5 is within one or two joints from the section of WM that the City had replaced with DIP due to a pipe joint leak/failure, therefore the conditions observed are likely not isolated to this particular joint. See Figure 5 for an example of the specific defects identified during the inspection of joint number 5.
Joint number 6 is located near the middle of the WM. The mortar at the joint is almost completely missing. (See figure 6)
RECOMMENDATION

Based on the inspection information collected to date, no rehabilitation beyond the mortar repairs at the uncovered joints is currently recommended for the Bridge Point WM. However, the following actions are recommended to complete the pilot inspection and continued maintenance:

- **Joint Inspections.** Based on the results of the joint inspections, there are significant concerns that the mortar damage at or near the joint found in the upstream portion of the WM may be a chronic issue. The proximity of joint number 5 to the previously repaired joint failure is an indication that this damage may not be an isolated occurrence, however there is no documented information on the specific type or extent of mortar damage found during the previous joint failure. The damage found near the upstream end at joint number 5 is significant and presents a higher risk of catastrophic failure. Where multiple wire strands and/or the steel cylinder are compromised through the mortar defects it is at higher risk that, when a wire finally fails, the remaining damaged wires will fail in rapid succession.

Since only one joint has been uncovered and inspected in the upstream area of the water main, we recommended exposing the next three pipe joints downstream of joint number 5 to verify if this is an isolated or a consistent problem. If similar mortar damage/failure is found at the nearby joints then the overall pipeline may be compromised. In that case, the overall approach for the WM will be discussed with the City. Continuing to expose and repair all the joints along the water main one by one will not be cost effective. The rehabilitation options, cost, and water main criticality should be considered in determining the best course of action for addressing the pipeline defects. In its current configuration the water main location and relatively low number of service connections likely contributes to a lower consequence of failure which should be considered in the approach. If the configuration of the water main changes (i.e. if the City proceeds with extending the water main across I-40) the approach would need to be reevaluated.

- **Periodic Electromagnetic Data Collection.** The electromagnetic data collected during the pilot inspection provides detailed information on the current amount of broken prestressing wires in the pipe. However, this is only a "snapshot" of the current condition related to wire breaks. This single inspection does not provide information on the rate in which the wire breaks are occurring. Periodic re-inspection of the Bridge Point WM would be needed to determine the rate of deterioration. However, a longer re-evaluation schedule may be warranted for the Bridge Point WM based on its low criticality. As part of the City’s asset management program, a risk prioritization of all the City’s WMs should be performed to help determine the appropriate frequency of inspection of this particular main based upon criticality.

- **Update City GIS.** We recommended that the City incorporate the WM modifications (taps) into their current GIS data in an effort to maintain current, accurate data for their future planning and maintenance.

CONCLUSIONS

The results of the pilot WM inspection identified a low level of distress as related to broken prestressing wires. The inspection did, however, identify a potential chronic issue related to the pipe joints in at least a portion of the Bridge Point WM, specifically the area near the previous joint failure.

The Bridge Point WM inspection was conducted as a pilot to familiarize the City with the process, procedures, requirements and resulting data associated with a PCCP WM inspection. As part of the pilot inspection project we developed a recommended approach for the future PCCP WM assessments including a discussion of modifications to the procedures used for the pilot to improve the process, inspection support requirements, options for providing the inspection support services, and general guidance on estimating assessment costs for planning level budgets. Based on the findings of the pilot inspection and the previous joint failure on Bryan Park WM the overall approach will be similar to the pilot inspection however particular focus will be placed on evaluating the condition of the joints in the Bryan
Another key difference from the pilot inspection will be that the Bryan Park WM will be inspected under live flow conditions and cannot be isolated and depressurized.

REFERENCES
