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BROOKS BRIDGE WATERLINE REHABILITATION

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ABSTRACT: The Brooks Bridge Water Main was installed in 2001 to convey potable water across a bay to Okaloosa Island, a popular tourist destination in the Florida Panhandle. The high-density polyethylene (HDPE), subaqueous main was taken offline in 2006 after the Okaloosa County Water and Sewer Department discovered that it was leaking into an adjacent fiber optic conduit. Video investigations indicated that the overall water main is in very good condition, but a welded pipe joint is torn approximately 750 feet along the 1,400 feet segment. The location of the leak is approximately 100 feet below the water surface of the bay and approximately 70 feet below the bottom. The purpose of this project was to evaluate various alternatives for repairing or replacing the main and to recommend and implement the most feasible and cost-effective solution. The five methods evaluated included sliplining, close fit lining, pipe bursting, total replacement, and a local repair using stainless steel sleeves. All the methods were evaluated and assessed based on ease of implementation, long-term reliability, effects on pipe capacity, and cost. The local repair approach was selected, but several obstacles need to be overcome to install the sleeves successfully, namely providing access to launch and guide the video and installation equipment; removing the sand slurry in the pipe and preventing it from reentering while the sleeve is being installed; and maintaining water supply to the island and surrounding areas.

1. INTRODUCTION

The Water and Sewer Department of Okaloosa County, Florida, installed the Brooks Bridge Water Main in 2001 to replace an older water main that provided potable water to the residents and businesses on Okaloosa Island, a tourist community just east of Fort Walton Beach, Florida. The older 16-inch ductile iron water main, which was suspended along the side of Brooks Bridge, was exhibiting signs of deterioration and was vulnerable to hurricanes. The new main was installed as a subaqueous horizontal directional drill (HDD) that extends from the mainland to the island as it crosses under the Santa Rosa Sound. At each end of the crossing, the new water main reconnects to the distribution system. Figure 1 shows the general area of the crossing and the Brooks Bridge.

Figure 1. General area where the Brooks Bridge Water Main crosses the Santa Rosa Sound , perspective from the island looking toward the mainland.

During a routine inspection, the local phone company discovered that water was entering a fiber optic junction box located on the island. The phone company and the Water and Sewer Department later confirmed that the water was potable and was being conveyed under pressure to the box via a subaqueous conduit connected to the box. They surmised that the water main sustained a leak at a location below the Sound and was entering the fiber optic conduit, which also must have been compromised. The cause of the opening is unknown, but could have been the result of an external force on the pipe after it was installed, such as a drilling auger, or an HDPE joint that was improperly fused during the original construction. The main was taken offline in 2006 and the original water main was placed back into service until the subaqueous main can be repaired.

The details of the pipe, which were derived from the plan and profile as-built drawings[1], are summarized in Table 1.

Table 1. Details of Brooks Bridge Water Main

Item	Details
Material	High Density Polyethylene (HDPE)
Nominal Diameter	18” (Ductile iron pipe size)
Internal Diameter	15.7”
Installation Method	Horizontal Directional Drill (uncased)
Dimension Ratio (DR)	11
Approximate Length	1,400’
Approximate External Pressure at Bottom of Crossing	90 psi
Operating Pressure (at bank)	50-60 psi
Approximate Depth Below Water Level (lowest point)	100’
Approximate Depth Below Bottom of Sound (lowest point)	75’

[1] Source: Polyengineering of Florida, Inc., Fort Walton Beach, Florida.

In October 2007, the Water and Sewer Department retained CH2M HILL to provide engineering services to support the department's assessment of methods for repairing the water main and the procurement of contractor(s) to make the repairs.

2. INITIAL WATER MAIN ASSESSMENT

In late September of 2007, the Water and Sewer Department hired a contractor to assist them in inspecting the main using a closed circuit television (CCTV). An earlier attempt by the Water and Sewer Department to videotape the main was unsuccessful because of the sand that had accumulated and packed down in the "belly" of the pipe. Therefore, the sand in the main needed to be thoroughly flushed without entering the downstream distribution system. The Water and Sewer Department installed a fabricated diffuser on the downstream end of the pipe in order to discharge and distribute the wash water along the streets, which had to be closed off (Figure 2). Additionally, they fabricated a wye fitting with a specially configured flanged plate to launch the camera and allow the pipe to be flushed and pressurized while the camera was operating (Figures 3 and 4). Footage from the camera confirmed that the pipe was torn at a location approximately 750 feet into the main (about the lowest point under the sound). The tear, which ranged from approximately ¼ inch to 1 inch wide, extended from the 3 o'clock position to the 9 o'clock position. The collected data were used to develop a list of feasible alternatives for correcting the problem.

Figure 2. Installation of diffuser to flush the water main.

Figure 3. Fabricated wye fitting for launching the video camera.

Figure 4. Fabricated plate for wye fitting to allow the camera to operate during flushing.

3. SELECTION OF REPAIR METHOD

Screening of Repair/Replacement Alternatives

Five alternatives for repairing the main were screened as part of this project, including pipe bursting, total replacement, slip lining, close fit lining, and a local repair using stainless steel sleeves. Pipe bursting the existing pipe and pulling in a new pipe was not considered feasible because of the density of other utilities (e.g., fiber optic) in the pipe corridor. Some of the utilities may be immediately adjacent to the water main, as indicated by the potable water entering the fiber optic conduit.

Although installing another subaqueous water main at another location and abandoning the existing main was briefly reviewed, it was not evaluated in detail because of the relatively high costs, the difficulty and timing of finding another suitable pipe corridor, the cost of extending the connections to the water systems on each side of the sound, and the viability of repairing the existing main.

The three remaining repair methods were selected for further evaluation, as described below and summarized in Table 2.

Slip Lining

In the slip lining process, a smaller diameter pipe is inserted into the existing damaged pipe by either pulling or pushing continuous or short-length pipes, frequently HDPE pipe. The existing pipe, or host pipe, is used as a “tunnel” for installing a new pipe. The new liner pipe is typically designed to take the full internal and external loads independent of the existing pipe. To provide additional strength, the annular space between the lining and the original pipe is sometimes filled with a flowable grout.

The advantage of this method is that it will result in a new main without having to obtain another pipe route and perform a new HDD. The disadvantage of this method, however, is that the flow capacity of the liner pipe will be much less than the existing pipe. For this application, it appears that a 14-inch (nominal) HDPE could be used as a liner pipe. This would reduce the internal diameter from 15.7 inches to approximately 12 inches. Assuming that the pressure drop across this segment will need to remain approximately the same after slip lining, the capacity of the main will decrease by nearly 50 percent. In addition, the change in slope along the profile of the pipe as well as the vertical deflection due to external loads will need to be confirmed to ensure that a liner pipe could be inserted completely through the host pipe.

This method will require additional pipe fittings at each end of the pipe where the new pipe transitions to the existing ductile iron pipe. The estimated cost for slip lining will be approximately $150,000.

Fold and Form Lining

Fold and form lining, or sometimes referred to as modified cross section lining, is similar to slip lining except that the liner pipe has a thinner wall. This allows the liner to be folded using specialized equipment prior to installation, thereby temporarily reducing the cross sectional area by up to 40 percent. The liner pipe is inserted into the host pipe, then heated and pressurized to conform to the shape and size of the host pipe. The liner can be made of either polyvinyl chloride (PVC) or HDPE.

Because the fold and form liner is thinner and molds to the internal diameter of the host pipe, there is much less reduction in flow capacity than slip lining. Also, in host pipes having relatively large deflections and bends, the fold and form liner can be installed easier than the slip lined pipe.

Unlike the slip lining process, the liner primarily relies on the host pipe for structural support under pressure. The lined pipe should be able to withstand the anticipated internal pressures; however, the liner may not withstand net external pressures for extended periods unless the damaged areas of the host pipe are sealed. Therefore, this method will require that the openings be grouted after the pipe is flushed and prior to the installation of the lining. Any grout used on the main will need to be National Sanitation Foundation (NSF) approved.

The long-term effectiveness of the grout seal is questionable and difficult to project because of the limited data available for this type of application. However, as long as the main remains online and under pressure, the internal pressure should more than offset the external pressure acting on the liner. Therefore, even if the grout seal eventually fails, the liner should remain in tact. Also, discussions with subcontractors specializing in the installation of fold and form liners indicate that the liner should maintain its structural integrity for up to 90 days even if the pipe needs to be drained and a net external pressure imparted on the liner. The estimated cost for this method is approximately $500,000.

Local Repair

This method involves the installation of a mechanical sleeve placed inside the pipe and over the damaged area. The sleeve evaluated as part of this project is typically prefabricated to meet the specific conditions of the pipe and damaged area. The sleeves are typically about 2 to 3 feet long. The sleeve core is made of stainless steel with an internal locking mechanism. The outside gasket is saturated with an epoxy resin that is mechanically pressed against the host pipe when the sleeve is expanded. The compressed sleeve and external gasket are placed around a plug and transported to the damaged area. Once in position, the plug is expanded and the sleeve is locked into place.

In order for the sleeve to properly lock and form a tight seal around the interior of the pipe, the damaged area of the Brooks Bridge Water Main will need to be free of accumulated sand, the circumferential pipe deflection of the pipe (ovality) needs to be less than 10 degrees, and the weld beads at the joints need to be less than 3/8" deep.

The advantage of this approach is that because the extent of the repair will be focused at the damaged area, the material and installation costs should be significantly lower than the other alternatives. The estimated cost of this method is expected to be less than $100,000.

Selected Alternative

Based on this assessment, CH2M HILL recommended that the Water and Sewer Department further pursue the point repair method to repair the damaged area of the Brooks Bridge Water Main. The localized point repair is the least expensive alternative, will not affect the existing capacity, and will take advantage of the fact that the remainder of the pipe is in very good condition.

Table 2. Assessment of Repair Methods For The Brooks Bridge Water Main

Repair Method	Advantages	Disadvantages	Order Of Magnitude Cost
Slip Lining	New pipe is installed without having to obtain a new route and install new pipe. Provides the most reliable, long-term service of the repair methods. Many contractors can perform this work	May be difficult to install, depending on the pipe ovality and angles of inclination. Reduces capacity by about 50% of the existing capacity.	$200,000
Fold and Form Lining	The entire main will be lined and sealed. Easier than slip lining to insert liner. Will have little impact on the capacity of the main.	The damaged area will need to be temporarily sealed with grout to clean the pipe and install the liner. Most expensive repair method. The long-term effectiveness of grouting the opening is questionable; therefore, ability to take water main out of service in the future is limited. Specialized work resulting in limited contractors to perform the work.	$500,000
Local Repair	Takes advantage of the fact the rest of the main is in very good condition. Least costly repair method. The work may be able to be performed while the water main is full. Minimal lead-time for order material.	Specialized work resulting in limited contractors to perform the work. The work will need to proceed in phases to verify the suitability of the sleeve.	$100,000

Note: The costs do not include those incurred by the Water and Sewer Department to prepare the site and assist with the initial assessments and installations.

4. IMPLEMENTATION

Phase 1 – Confirm Selection of Alternative and Develop Strategy

Phase 1 of the implementation plan included selecting and procuring the services of a contractor to install the sleeve; performing a more detailed assessment of the damaged pipe and overall condition of the pipe; and developing a strategy for performing the work in the implementation phase, Phase 2. Given the uniqueness of the project and the inherent risks associated with the installation, the Water and Sewer Department had difficulty finding a contractor in the region that was willing and had the expertise to perform the work. The Water and Sewer Department was ultimately successful in procuring the services of a pipe inspection and cleaning contractor that was also certified and licensed to install this type of sleeve. Like many of the contactors contacted, this contractor had performed many successful point repairs, but none was performed under these types of conditions.

In April 2008, the contractor videotaped the pipe to perform a more detailed assessment of the damaged area and the overall pipe, to confirm that the sleeve is indeed suitable for this application, and to obtain the data required to fabricate the sleeve. For this assessment, the area of the damaged pipe was videotaped both prior to and following the hydraulic flushing. Photos of the damaged area are shown in Figure 5. It was interesting to note that only a small amount of sand had accumulated in the area of the pipe opening since the previous flushing, which occurred approximately seven months prior. In addition, after the water main was repressurized and flushed, it was noted that several hours had passed before the sand slurry began to re-enter the pipe. It appears that when the pipe is pressurized, an air cavity is formed outside of the tear that temporarily resists the sand slurry from re-entering the pipe.

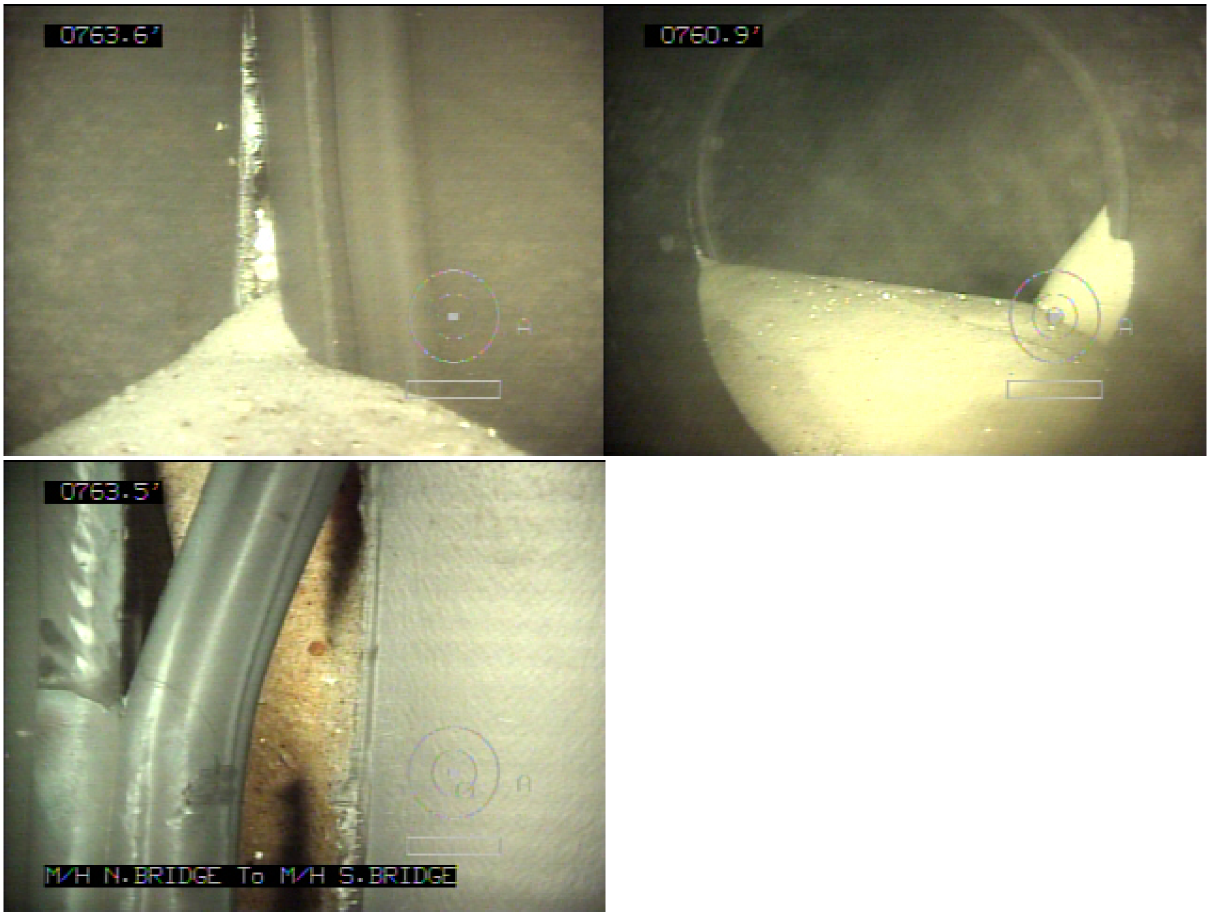

Figure 5. Photos of the damaged area of the water main.

Based on this assessment, the following installation criteria, constraints and obstacles were identified:

- The HDPE bead weld at the pipe tear would probably prevent the sleeve from fully expanding and sealing uniformly along the inside of the pipe.
- The water available for flushing the pipe is limited because the Water and Sewer Department must maintain an adequate level in the nearby elevated storage tank.
- The ovality of the pipe at that depth appeared to be minimal, but the extent could not be confirmed.
- A camera would need to be launched from the mainland side of the pipe, but the sleeve packer would need to be launched from the other end of the pipe segment, on the island side. The piping on the island side would need to be modified so the diffuser could be readily disconnected from the main and a straight segment of the pipe for launching the packer could be installed.
- Once launched, the sleeve would need to be in position within 15 to 20 minutes so the epoxy resin placed on the sleeve did not set up prematurely.
- Once flushed, the sleeve would need to be installed within about 2 to 3 hours to avoid reentry of the sand slurry.

- Cables with larger diameters and longer lengths than what is normally used for the packer winch would be required to accommodate the long run and resulting loads.
- A rope would need to be "flushed" through the pipe from the mainland side to the island side for attaching a cable to the packer at the time of installation.
- The Water and Sewer Department, engineers, contractor, and sleeve manufacturer would have to work closely as a team and share the responsibilities and risks in order for the repair to be successful.

Phase 2 – Install Sleeves
Despite the challenges and risks identified in Phase 1, and the burden that would be placed on the Water and Sewer Department's resources to prepare for and assist with the installation, the Water and Sewer Department decided to purchase the sleeves and proceed with Phase 2 of the implementation. The supplier of the sleeve reviewed the video recordings and, in collaboration with the installation contractor, recommended installing three sleeves to seal the opening. Because of the depth of the HDPE weld bead, the plan was to install one sleeve on each side of the bead, then install a third sleeve over the other two sleeves, tear, and the weld bead. The third sleeve would be fabricated with a diameter slightly less than the other two sleeves. This configuration would provide a uniform surface for the primary sleeve to seat. For this application, the supplier fabricated double-sleeve, variable diameter, stainless steel sleeves because of the relatively high system pressures and the uncertainty of the internal diameter at the tear. Figure 6 shows a generic photo of the sleeve positioned on the packer and being prepared with the exterior felt and epoxy resin. Figure 7 shows a photograph of the sleeve after it has been expanded and locked in place.

Figure 6. The pipe sleeve and packer being prepared with the epoxy-saturated felt liner (Source: Link Pipe, Inc.)

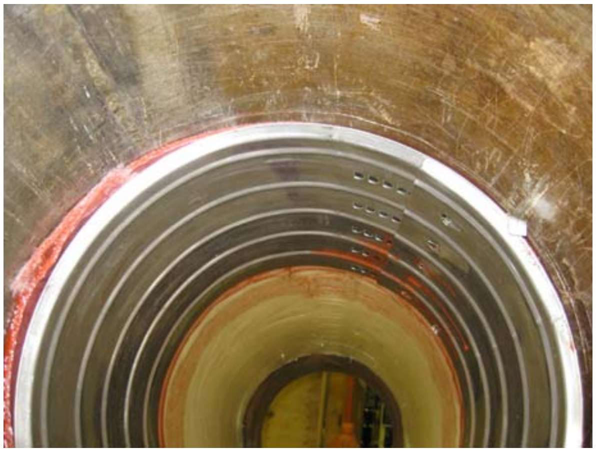

Figure 7. Photograph of the pipe sleeve after installation (Source: Link Pipe, Inc).

The plan for installing the sleeve included the following steps:

1. Flush and videotape the pipe from the mainland side. The camera would remain at the repair location.
2. Remove the existing pipe fittings and a 10-foot segment of the pipe on the island side in order to accommodate the launching of the packer and sleeve.
3. Load the sleeve on the packer, apply a grout over the felt, and wrap the sleeve. Launch the packer and install the sleeve on the mainland side of the tear.
4. Return the packer, and repeat the preparation and installation of the remaining two sleeves.
5. Replace the pipe segment and return the water main to service.

On July 29, 2008, the project team, which included representatives from the County, CH2M HILL, the subcontractor, and the supplier, convened onsite to begin the installation process. The pipe was flushed and the camera was placed into position from the mainland side. The crew of the subcontractor was in position with the motorized winch on both sides of the pipe to shuttle the packer and sleeve into position. No sand was observed entering the pipe after the initial flush.

The Water and Sewer Department immediately proceeded with removing the flushing diffuser, the existing tee, and the 10-foot segment of pipe on the island side of the pipe segment (Figure 8). Unfortunately, the bolts securing the mechanical joints of the existing pipe and fittings were severely corroded and very difficult to remove. In addition, a large thrust block encapsulating the tee was encountered, which significantly slowed the progress. By the time the provisions were made for launching the packer, it appeared that the air cavity surrounding the tear collapsed and the sand slurry rapidly entered the pipe and filled the bottom fourth of the pipe. This occurred approximately 5 hours after the pipe was flushed.

Figure 8. The Water and Sewer Department prepare island side of main for launching the sleeve.

It was decided to temporarily install the previously prepared 10-foot spool piece into the open section so that the pipe could be flushed again, this time in the direction of the mainland through a fire hydrant (Figure 9. The video indicated that the repressurizing and reflushing of the pipe did not prevent the sand from continually entering the pipe as it had done during the Phase 1 assessment. There was enough sand in the pipe around the damaged area that the sleeves could not be installed properly. Therefore, after a total of approximately 12 hours of preparation, the operation was suspended for the day.

Figure 9. Temporary spool piece on island that will be removed for launching the sleeve in the future.

The next morning the team reconvened, the Water and Sewer Department flushed the pipe in the direction of the mainland, and the camera was again positioned at the tear. Unfortunately, the sand slurry could not be prevented from filling the pipe at the location of the tear, so the installation of the sleeve was postponed until an unspecified later date.

5. PATH FORWARD

Before another attempt is made, a more reliable method will be required to prevent the sand slurry from entering the pipe at the opening while the three sleeves are installed. The length of time that the sand slurry is held back after a flushing is too unpredictable. Two scenarios will be closely investigated to accomplish this. One would include injecting a hydrophilic grout directly into the torn joint to temporarily seal the opening prior to installing the sleeves. The disadvantage of this approach would be trying to procure the services of an experienced grout contractor that would be willing to perform a relatively small amount of work under these types of conditions. In addition, there exists some risk that the grouting process could cause additional damage to the area of the tear and prevent the sleeves from being installed properly without additional preparation of the joint.

The other scenario would be to configure the pipe on the island to allow the sleeve to be installed while the system is under pressure. If an internal pressure greater than the external pressure can be maintained at the opening, the sand should be prevented from entering the pipe. The difficulty will be to launch, pressurize the pipe, position the packer, and expand the sleeve within the set up time of the epoxy. These steps will have to be accomplished for all three sleeves.

6. CONCLUSION

Although the initial attempt at installing the sleeves was not successful, a significant amount of valuable information and experience were obtained to facilitate a future attempt. If the County had not been slowed by the unforeseen conditions encountered while removing the existing pipe and tee, it appeared there probably would have been sufficient time to install the sleeves.

However, a more reliable method will be required to prevent the sand slurry from entering the pipe during installation of the three sleeves. Two scenarios that show promise involve injecting a temporary hydrophilic grout directly into the torn joint to seal the tear or configuring the pipe on the island to allow installation while the system is pressurized. Each method will require further investigation.