Relining Prestressed Concrete Cylinder Pipe, A Manufacturers Perspective

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Abstract

Prestressed Concrete Cylinder Pipe, PCCP, (AWWA C301), is a rigid, pressure pipe, designed to take advantage of the compressive strength and corrosion-inhibiting properties of portland cement concrete and the tensile strength of steel. Principally used for the transmission and distribution of water in municipal systems, it was widely accepted and installed throughout the US beginning in 1942. Numerous catastrophic failures across the nation have halted the use of PCCP by numerous water agencies throughout the US. Due to the large diameters and critical nature of these pipelines, the San Diego County Water Authority embarked on a twenty-year plan to reline or replace nearly 112 km (70 miles) of large diameter PCCP.
This paper describes the methods of manufacturing and installing the steel liner plates to reline existing PCCP. The project consists of relining sections of a 2438 mm (96in.) and 1753 mm (69in.) pipeline. This paper will describe the unique methods of collapsing the steel cans and the rapid installation requirements required by the owner. Cooperation between the agency, manufacturer, and contractor was essential for the completion of this project on slopes as great as 38 percent. The design and installation of this liner system allowed for a minimum reduction in hydraulic capacity.

Introduction

Pipeline 4 and 3 relining projects were originally installed in 1972 and 1958. They are located between Black Mountain Road to Miramar Hill, which is located 32 km (20 miles) north of San Diego. The terrain over the pipeline is a mixture of chaparral and residential urban. The relining project is owned, operated and designed by the San Diego County Water Authority. The project consists of lining four sections of PCCP pipe:

1. 4964 m (16,285 feet) of 2438 mm (96 inches), relined with a 2400mm(94.5 inches) steel liner plate,
2. 1219 m (4,000 feet) of 1676 mm (66 inches), relined with 1638 mm (64.5 inches) steel liner plate,
3. 3231 m (10,600 feet) of 1753 mm (69 inches), relined with 1714 mm (67.5 inches) steel liner plate,
4. 710 m (2,330 feet) of 1829 mm (72 inches), relined with 1791 mm (70.5 inches) steel liner plate.

Each pipe liner section was between 6m and 6.7m (20 and 22 feet) in length and each joint will match the existing joint along the pipeline. The original design included a total of thirteen different combinations of pipe diameter to wall thickness, ranging from 9.53 mm to 16.66 cm (0.375 inches to 0.656 inches). Each 6 m (20 foot) pipe section had twelve 25.4 mm (1inches) grout couplings and eight, 50.8 mm by 50.8 cm by 19.0 mm (2inches by 2 inches by 0.75 inches) spacers welded to the outside diameter of each can. Grout couplings were required for the pressure grouting of the annular space between the PCCP and the steel liner. The spacers provide an equalized annular space around the pipe liner to assist in grout flows. There were a total of over 1,600 individual joints, 24,408 grout couplings, 16,272 spacers, 556 grout rings, 533 mitered bells and 26 manways. Access to the pipeline was through eleven potential portal locations, which would require 134 m (440 feet) of 2438 mm (96 inches) ID, cement mortar lined and coated steel pipe. Portals were located to provide efficient and economical installation. Each portal was forty feet in length, the result of removing two existing pipe joints.

The Estimate

The project bid date was July 29, 2003 and has completion dates of April 9, 2004 for the Pipeline 4 reach, and September 1, 2004 for Pipeline 3 reach. Liquidated damages for each reach was $5000.00 per day. The contract work included environmental fencing and flagging, clearing and grubbing, dewatering, temporary erosion control, excavation, shoring and bracing, temporary sound walls, temporary fencing, cutting and demolition of existing prestressed concrete cylinder pipe, fabrication and installation of steel liner sections, fabrication and installation of replacement steel pipe sections, welding, grouting between the liner and the existing prestressed concrete cylinder pipe, placing field-applied cement mortar lining, installing cathodic protection systems, placing reinforcing steel and concrete encasements, replacing valves, backfill, disinfection of piping, access road restoration, hydroseeding, and any other appurtenant work.

Estimating a project of this size was very unique. First, there was literally no production pipe on the project. Each section of liner was an individual fabrication project. Liner projects had been installed in the past, but never to the size and scope of this project. The construction window for the installation of these liners was very short (four months for pipeline 4) due to water demands of SDCWA's customers during the busy spring and summer time periods. The design required steel sections to have a longitudinal split down the bottom, with a backup bar installed to accommodate a full internal fillet weld at the lap joint. A bell and spigot was required at each joint, and was manufactured with dimensional tolerances to match the existing "as built" drawings of the PCCP. Being as this was the first project of this size and complexity many of the estimating variables were substantially unknown. As an example the time and labor requirements for collapsing, banding, placing backup bars, welding and mitering ends, and the handling at each step of the process had never been performed to this scope. The efficiency and flexibility to adapt to multiple diameters and wall thickness made this multiple step operation a critical component to the final cost evaluation.

The Bid

Three material suppliers and six contractors combined to offer bids. The low bid was $20,870,000 the second low bid was $24,084,000 with the high bid submitted at $28,600,000. All of these bids came in under the Engineers estimate giving the owner good feed back that he was within budget forecasted for this complex project. The contract was awarded shortly after bid opening and immediately an excellent partnering relationship was established between the agency, contractor, and material supplier. Everyone recognized that this type of work had never been accomplished before and this project would be used as a learning tool to look for ways to improve efficiency, quality and scheduling for future projects.

Figure 1. Collapsing Jig

Manufacturing

Steel for the liner cans was ASTM A1018 grade 40, after a letter of intent was received from the contractor, steel was ordered immediately as part of our partnering efforts, as time was of the essence. Plates were ordered to exact dimensions longitudinally and to plus 76.2 mm (3 inches) in width. Couplings, plates for grout rings and spacers were also ordered. Prior to any fabrication, detailed drawings were prepared and submitted for approval. Each joint had to meet the existing pipe miter to a tolerance of 0.1 degrees, and was manufactured to a tolerance of within 3.17 cm (1/8-inch).

The manufacturing process consisted of:

- Squaring and cutting plate to exact dimensions
- Roll and tack the 3m(10 foot) cans

- Weld a 609.6mm(24 inch) seam at the bell end
- Fit and tack two 3m(10 foot) joints to a 6m(20 foot) section
- Miter the ends if required and bell the ends square to the miter
- Weld and test the circumferential weld
- Attach the couplings and spacers
- Cut the section longitudinally and weld back with an 38.1mm(1-1/2") offset
- Cut again longitudinally to create a 76.2cm(3") back up bar the entire length
- Collapse the cylinders to reduce the diameter by 304.8mm(1 foot)
- Install internal tack bars and external banding straps

All manufacturing processes and testing was performed under the inspection services of the San Diego County Water Authority.

Figure 2. Stored cylinders at jobsite

Transportation and Staging

Liner sections were loaded two per truck, bunked and strapped for the one hundred-mile trip to the project site. Due to the limited storage area at the portal locations, along a narrow right of way, daily deliveries were required to coordinate installation with section delivery.

Installation

The installation began in early December 2003. Pipe sections were loaded onto custom pipe carriers and transported into the existing pipe to the exact location for installation. It was extremely critical to align the top of pipe into the next section. Pipe were installed spigot into bells with the longitudinal seams off set 152 mm (6 inches) to the adjoining pipe, 76.2 mm (3 inches) either side of center line. A notch was cut into each spigot end's backup bar to facilitate the installation and provide for completed weld geometry at this location. Once the next section was aligned circumferentially and longitudinally, the carrier lifted the pipe to top center and a tack weld was installed at the top of the pipe to

secure it in place. The grout plugs were temporarily removed to expose the banding straps. The tack bars were then broken loose and banding straps cut until the section sprang open with a thunderous bang. Alignment clips and hydraulic jacks were then used to fit the section into the final location. The section was then tack welded along the entire length and circumference. The next section was then ready for placement. This process continued from 7:00 AM to 7:00 PM, Monday through. Friday.

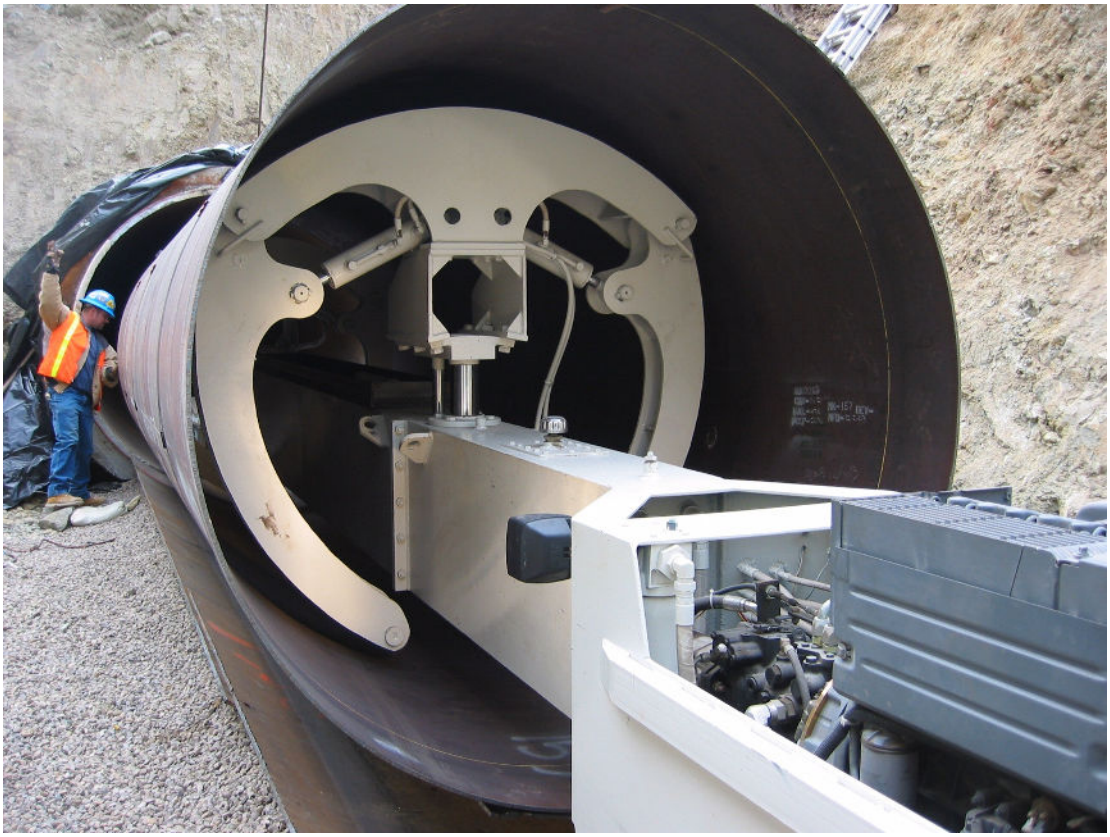

Figure 3. Pipe Carrier transporting liner piece into PCCP

Final welding of each individual section was completed behind the laying crews. Production was only delayed where grout rings were required. Grout rings were designed to isolate the hydraulic head behind the annular space between the PCCP and the steel liners. This limited the total pressure that could be developed during the grouting operation. Grades along the relining project were as great as 38 percent in some areas. This created some difficult challenges in transporting the pipe and maintaining a safe work environment for the employees. The grout rings were completely seal welded between the reline section and the existing PCCP joint rings. The grout rings had to be completely installed prior to the next joint installation. Grout ring locations were designed as close as 6 m (20 feet) apart in the steepest sections. Outlets from the pipeline were fitted with collars and connected to existing air vacuum valves, blowoffs, manways, and turnouts to create a water-tight connection.

The grouting operation began in mid January and proceeded throughout the process. Cement mortar lining operations followed the grouting operations and was the last stage of the relining process. The portals were then repaired with cement mortar lined and coated steel pipe.

Figure 4. Pipe carrier a portal

Summary

Deteriorating prestressed concrete cylinder pipe can be successfully relined with steel cylinders with minimal impact on hydraulics, rights of way, minimal environmental impacts, and without having to replace the pipeline. Cooperative partnering achieved through daily communications, was an essential component to ensure strategic timing of all phases of bidding, awarding, material acquisition, manufacturing, inspections and installation of long reaches of relined pipe during short shut down periods. Without these cooperative attitudes significant delays would have occurred as challenges surfaced during manufacture and installation. Specific issues that surfaced included, grout clearances, band locations, grout hole sizes and locations, spacer pad size and locations and tie-ins geometry at portals; all of which have been modified and will be included in future projects.