Restoration of Large Diameter Prestressed Concrete Cylinder Pipelines

Water Flow, New Mexico

Submitted by QuakeWrap, Inc.

San Juan Generating Station, New Mexico

The San Juan Generating Station is located near the San Juan River, from which it get its water supply. The river water is stored in an artificial lake next to the station, where it is then transported to the coal-fired steam boiler units. The pressurized steam is then transported to the turbines that generate electricity. Once the steam leaves the turbines, some is allowed into the air, but most is allowed to condense back to water and taken to the cooling towers, where it travels back to the lake, thus completing one cycle of water use.

A network of underground steel and prestressed concrete cylinder pipelines (PCCP) is used to run the water cycle around the clock, so that the station is on the electrical grid all year. To allow maintenance service, programmed shutdowns of one of the four units take place, lasting usually about a month. During these maintenance periods, the pipes are dried out and inspected.

These pipes have a minimum 35-year service record and have begun to experience serious deterioration due to corrosion. In a way, this situation reflects the current state of most of the pipelines used by utility companies to provide water, wastewater, and electricity services to large metropolitan and industrial areas around the U.S. Pipeline bursts are not uncommon and can cause significant economic losses to a large region. Therefore, it is highly desirable that a long-term, maintenance-free solution be found for large diameter PCCP rehabilitation that can be implemented during short maintenance shutdown periods. Carbon fiber-reinforced polymer (CFRP) structural liners are now being considered to provide such a solution.

PCCP Deterioration and Inspection

The PCCP lines at the San Juan Generating Station are fabricated from individual 20 ft (6 m) segments with 10 ft (3 m) diameters. They are made with a steel cylinder core embedded in concrete that is prestressed with steel wires. With time, water found its way to the steel through cracks in the concrete, initiating the corrosion process. If the corrosion process is not mitigated, enough steel will be lost that the structural integrity of the PCCP will be compromised.

During maintenance shutdown periods, the PCCP is dried up and the integrity of the pipe is evaluated using sophisticated equipment that can detect hidden corrosion. Based on the degree of corrosion, 840 linear ft (256 m) of PCCP was targeted for urgent repair at the San Juan Generating Station.

The only access to pipe was through 30 in. (760 mm) diameter manholes

Materials were spaced out throughout the 840 ft (256 m) long section of pipe

PCCP Restoration Using CFRP Structural Liners

The structural retrofit needs for this project required designing the hoop strength of the CFRP liner to reestablish the 60 psi (414 kPa) design internal pressure and to provide longitudinal strength of at least 20% of the hoop strength. Typical CFRP liner designs usually call for multiple layers of fabric oriented in orthogonal directions to meet this design objective. Because multiple layered liners increase the installation time significantly, we decided to produce a custom-designed CFRP liner by varying the carbon fiber density in orthogonal directions within the fabric, so that only one layer was required to meet the design objective. Working closely with the fabric manufacturer, this fabric was produced and independent testing was conducted to demonstrate that the fabric met all the design requirements.

In this case, site preparation was straight forward and consistent with confined space environment work. Large industrial fans were installed over selected manholes to speed up the drying process and to provide air circulation. Hole watchers were installed over access and exit manholes and air monitors were placed inside the PCCP. Equipment and materials were lowered through the 30 in. (760 mm) diameter manholes and were stationed along the pipe. The saturating machine was redesigned to allow its reassembly inside the pipe.

Surface preparation consisted of sandblasting the inside of the PCCP to remove sediments, patching visible cracks and spalling, and smoothing (with grinders and patches) PCCP connections. Once prep work was completed, the CFRP installation scaffolding system, CFRP saturating machine, as well as all the epoxy resin buckets and CFRP fabric rolls, were lowered through the 30 in. (760 mm) diameter manholes. This required the redesign and fabrication of new equipment that could be disassembled, passed through the relatively narrow access, and reassembled inside the PCCP.

A surface primer was applied to the interior surface of the PCCP. The 50 in. (1270 mm) wide CFRP fabric was passed through the saturating machine and cut in 34 ft (10.4 m) lengths and pressed against the inside face of the PCCP with the aid of the specially-designed moving scaffolding system. The system and saturating machine layout allowed for a five-man crew to install approximately 1300 ft^2 (120 m^2) of liner per 8-hour work shift (about 40 linear ft [12 m] in a 10 ft [3 m] diameter pipe). Given the fact that the job had to be finished under a tight schedule dictated by the maintenance shutdown period, two daily shifts were run that allowed for the installation of about 2700 ft^2 (250 m^2) of liner per day (or 80 linear ft [24 m] in a 10 ft [3 m] diameter pipe).

The previous application rate allowed for an 840 ft (256 m) straight segment of pipe to be completed in about 2 weeks. Complex geometric transitions were encountered, however, such as an elbow turn of the 10 ft (3 m) diameter PCCP, as well as steel jacket transitions. The tight elbow section space did not allow for the use of the scaffolding system; and to avoid excessive overlaps and potentially large blisters and wrinkles in the liner, the CFRP strips were cut in variable width strips, following the complex tridimensional geometry of the elbow closely. Steel jacket segments were present in the PCCP due to previous repairs. Because a galvanic corrosion barrier is required between carbon and steel, a glass FRP (GFRP) fabric liner was placed over the jacket before installing the CFRP liner. Also, because the steel jackets were welded in place using individual plates, significant amounts of patching compound had to be used to smooth out the joints.

A final top coating of epoxy was applied for improved abrasion resistance and to minimize friction losses. Because the shutdown units could not be placed back into service without flooding the PCCP pipes, the CFRP liner had to be installed and fully cured within a 4-week period to avoid service delays. Therefore, the CFRP liner installation was in the critical path of the maintenance program. Even with the complex geometries encountered, the liner was installed in a 3-week period—1 week ahead of schedule.

Because large diameter PCCP pipes are currently used by many water, wastewater, and power utility companies, as well as other strategically important industries, and thousands of miles of these pipes have been in service for decades, ongoing corrosion deterioration may lead to significant disruption of water, electricity, and other important services to large metropolitan and industrial areas. This project proves that the use of CFRP liners is an efficient, cost-effective, long-term solution to PCCP pipe deterioration.

Prestressed Concrete Cylinder Pipelines

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Repair Contractor
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Material Supplier/Manufacturer
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Saturating machine reassembled inside the pipe

Installation of glass fabric on pipe

Application of final finish coating over installed FRP