



Project Overview

REPAIR & STRENGTHENING OF PCCP CONCRETE PIPE WITH CARBON FRP

Name: San Juan Generating Station, PNM
Type: Industrial Facility
Location: Farmington, NM
Completed: October 2007

PROBLEM

Due to corrosion of reinforcing wires, several sections of 10-ft diameter Prestressed Concrete Cylinder Pipe (PCCP) in this coal burning plant required strengthening. Design requirements called for additional strength in both hoop and longitudinal directions. Access for the pipe was available only through a 30-inch diameter manhole. This required re-design and manufacturing of the equipment.

SOLUTION

A special PipeWrap™ Carbon fabric was developed for this project to achieve the strengthening requirements with a **single layer** of fabric – instead of **two layers** as the original design called for. Samples were constructed and tested to demonstrate the feasibility of the solution. 50-inch wide bands of fabric were applied in the hoop direction, with a single overlapping joint along the bottom of the pipe. There was a small steel section in the pipe; that was wrapped first with a layer of glass fabric (shown on the right) to avoid galvanic corrosion. The entire repaired section was coated with a layer of high chemical resistant coating.

Due to time limitation, two crews were employed. This allowed the project to be completed ahead of schedule.



Technical Highlights

- 700 linear feet of a 10-ft diameter PCCP were strengthened with Carbon FRP
- 27,000 ft² of a specially designed carbon fabric was used; this fabric allowed the pipe to be strengthened with only a single layer of fabric, compared to the previous phases at the same site that were done with two layers
- All equipment were re-designed and/or modified so that they could fit into the pipe through the 30-inch diameter manhole
- Strengthening was completed ahead of schedule



Credits

Engineering and Materials: QuakeWrap, Inc., Tucson, AZ
FRP Installation Subcontractor: FRP Construction, Tucson, AZ
Sales Team: Blome International, O'Fallon, MO
General Contractor: Riley Industrial Services, Farmington, NM

“The FRP Retrofit Experts”

— © 2007 QuakeWrap, Inc. | (520) 791-7000 —



Project Overview

CARBON FRP RETROFIT OF CONCRETE PIPES IN NUCLEAR POWER PLANT

Name: Nuclear Power Plant
Type: Industrial Facility
Location: Classified/ Confidential
Completed: September 1999

PROBLEM

A major Nuclear Power Plant in the U.S. uses 9-ft diameter Prestressed Cylindrical Concrete Pipes (PCCP) to carry water throughout the plant. Inadequate cover concrete caused corrosion of Prestressing cables in many pipes. Replacement of the pipes required significant downtime that was unacceptable to the plant operators.

To minimize downtime, excavation was not desirable, so a repair system had to be designed to repair the concrete pipes from the inside.



SOLUTION

QuakeWrap developed a very strong biaxial carbon fabric through the PipeWrap™ division. The FRP fabric was specially designed and manufactured for this project to allow repair of the pipes from inside in record time and to withstand the high internal design pressures.

The nuclear power plant set up field tests of the FRP retrofitted concrete pipe and the tests were stopped when the internal pressure exceeded the original design value. This proved that the FRP repair system could also be used as a strengthening procedure.



Technical Highlights

- Client is a major nuclear power plant in the United States
- 9-ft. diameter PCCP pipes were damaged by corrosion of prestressing cables
- 11,500 ft² of PipeWrap™ used
- Fabric specially designed for high 0/90° biaxial strength
- Applied QuakeBond™ corrosion-resistant resin for further protection



“The FRP Retrofit Experts”

Carbon Fiber Composites for Concrete Repair
UNIQUE FRP TECHNOLOGY
USED TO REPAIR AND STRENGTHEN
MUNICIPAL AQUEDUCT SYSTEM

Jay Thomas, Vice President

Structural Preservation Systems, Inc., Springfield, Virginia

One of the first-ever on-site application of FRP strengthening technology to water pipelines enabled the Providence Water Supply Board to repair rather than replace 50-year-old pipes in its aqueduct system. This presentation will discuss CFRP Strengthening systems for the structural upgrade of PCCP Aqueducts . Topic covered are material properties, design strategies, installation techniques and QC.

One of the worst nightmare scenarios for any municipal waterworks is the failure in its pipelines. If a blowout occurs, the cost of repairs is only the beginning. Add to this snarled traffic and disruption of neighborhoods — not to mention the community ill will generated by the protracted repair process — and it's easy to see why this is a scenario municipalities try to avoid at all possible cost.

The Providence Water Supply Board faced such a dilemma in 1998, when a major section of a 102"-diameter PCCP water line in Cranston, Rhode Island, failed completely. The ruptured precast concrete cylinder pipe failed due to corroded prestressing wires, which were the primary reinforcement in place to contain 120-psi water pressure as well as the overburden and live loads.

The Providence water line failure raised valid concerns that other sections of the aqueduct could also be prone to failure, since the pipes had originally been installed as long ago as 50 years. Ultrasonic (pulse echo) and acoustic (hammer sounding) testing identified other areas of potential concern where exterior delaminations could be occurring. Other forms of condition analysis techniques such as Eddy current testing have since been developed and accurately used on pipe testing.

An inspection of the entire water line system confirmed these suspicions. This inspection revealed vulnerabilities in twenty nonconsecutive 16-foot-long sections within a five-mile stretch of the pipeline. Strengthening these sections was deemed important to the long-term durability of the system. SPS, a national concrete repair contractor headquartered in Maryland was invited to propose on the repair and strengthening of the section

Designing a Better Repair Approach

Preventive aqueduct pipe repairs are often made by inserting a steel liner in sections, welding them together, then grouting the annular space between the new and old sections. But this approach requires long , continuous sections of repair to make it a viable option based on the fact that a significant degree of excavation, coupled with long periods of downtime is required. In the case of the Providence Aqueduct, the individual repairs were scattered along a five-mile stretch of line, which meant that the steel liner approach would be both costly and overly intrusive. For this reason, SPS believed that

the installation of a carbon fiber-reinforced polymer (FRP) sheet lining would be the fastest, least disruptive, and most cost-effective repair solution.

This carbon fiber strengthening design assumed that the existing prestressing wire was no longer effective. Thus, SPS designed a multi-ply system to carry the 125-psi internal service loads, the live and dead loads of the soil, plus additional safety factors. Layers were internally wrapped around the circumference of the pipe, as well as longitudinally. The design called for surface areas to be completely covered with carbon fiber – essentially creating a “pipe within a pipe.” In order to eliminate the possibility of water infiltrating behind the FRP system, thus bypassing the strengthening system and making it ineffective, a waterstop-type termination detail was designed for the end of each 16-foot section of pipe.

Testing the Design

Once the design was finalized, full-scale testing on three pipe sections was conducted by SPS to validate its effectiveness. Testing multiple sections as opposed to a single pipe section provided the chance to test a complete waterstop termination detail at both the spigot and bell ends of a pipe section. After the FRP liner was installed, the prestressing strands at the center of the strengthened section were cut so as to guarantee a full test of the FRP. The pipe assembly was sealed with large steel bulkheads and then filled with water. Next, the test pipe was pressurized at steadily increasing rates until failure – almost 300 psi, which is 2-1/2 times the service and surge pressures, and within 5% of the capacity of a new pipe.

Welcome to Winter in New England

The actual repairs began in January 2000, in typical New England winter weather conditions. The pipe sections to be strengthened were buried 10 to 15 feet underground, and some were situated miles apart from one another. Access points were limited and, predictably, not always near the areas to be repaired. Ladders were placed in the 30-inch diameter service holes to provide access to the repair areas, and a tripod and winch pulley system was used to raise and lower materials into the work area. Because of the confined work environment, special safety measures needed to be enacted.

Because the pipe sections had not been dry in years, high levels of humidity coupled with working temperatures required constant monitoring to ensure the required ambient conditions for the FRP installation. Blowers, dehumidifiers and heaters kept the relative humidity level between 40% and 50%, and the ambient temperature between 55° and 60° F.

A Meticulous Process

Before the FRP was applied, SPS conducted pull tests to verify the potential bond strength of the actual pipe surfaces. These tests revealed that failure occurred in the subsurface at an average of 300 psi — well over the 200 psi necessary for the carbon fiber application per the American Concrete Institute 440 (FRP) and manufacturer’s guidelines.

Next, high-pressure waterblasting removed sediment from the pipe’s interior to prepare the surface for the carbon fiber application. Scaffolding was erected to allow the technicians to reach the top of the pipe, and to prevent walking on the bottom. To

prepare the surface, an epoxy primer was applied, followed by a trowel-applied epoxy putty material to fill voids and level imperfections. The surfaces were now ready for the FRP installation.

Prior to installation, the FRP sheets were cut to a predetermined length in an above-ground staging area. Once the sheets were lowered into the work area, they were saturated with an epoxy saturant. Each layer of FRP sheet was then applied to the pipe's circumference in three sections, with a 4-inch overlap. Metal rib rollers were used to push out any air bubbles, and to press the FRP sheets into the saturant. A second layer of the saturant was then applied to form a complete fiber/laminate matrix.

This process was repeated for the subsequent layers of carbon fiber. Lastly, an epoxy topcoat approved for potable water applications was applied to protect the FRP and provide a safe, sealed passageway for the water.

Success on Many Levels

Using lightweight, flexible carbon fiber material for strengthening the Providence Aqueduct turned out to be an innovative, cost-effective solution. In fact, the total project cost came in on budget, and its success earned the International Concrete Repair Industry's ICRI Award of Excellence in the Water Systems Category.

The Providence Aqueduct project now serves as a model for water utilities facing similar repair situations, where a proactive condition survey and preventative repairs avoided disastrous failures or where excavation of pipes is neither cost-effective nor desirable. By using FRP, Providence Water Supply did not have to dig, replace, or line long pipe segments. This represents one of the first-time-ever on-site installation of FRP sheeting in potable water pipes for strengthening purposes. But based on the success of this project, FRP is likely to be adopted as a choice repair technique for future municipal waterworks projects throughout the United States involving isolated pipe section repairs.

Jay Thomas is Vice President of Sales for Structural Preservation Systems, Inc., the largest dedicated structural concrete repair contractor in the United States. He has 20 years of construction experience in commercial and industrial facilities on rehabilitation and maintenance projects involving structural repair, strengthening, and protection of concrete and steel. He can be reached at (410) 850-7000 or jthomas@structural.net.

Robert St. John is Project Manager for Structural Preservation Systems, Inc. A civil engineer with extensive experience on diverse concrete repair projects, he served as lead Project Manager on the Providence Aqueduct strengthening project. He can be reached at (410) 247-1800 or bstjohn@structural.net.