

A Concrete Example

Carbon Fiber Repair for Thrust Restraint Upgrade of 84-in. PCCP

By Paul Acosta, Rasko Ojdrovic & Anna Pridmore

Tucson Water has been the City of Tucson's municipal water utility for more than 100 years. As a public water provider, Tucson Water serves approximately 710,000 residential, commercial and industrial customers within a 350-sq-mile service area. The water system is comprised of 4,500 miles of underground pipelines. A portion of the critical pipeline infrastructure consists of large diameter Pre-Stressed Concrete Cylinder Pipe (PCCP).

Since a major pipeline break event in 1999, Tucson Water has been actively identifying ways to deliver water while ensuring safe implementation of advanced technologies through active PCCP asset management. Through its Pipeline Protection Programs, Tucson has focused on creating an inventory of all pipeline assets, implementation of advanced inspection, monitoring and risk management practices along with procurement of necessary capital improvement funds.

Tucson's current best practices include, among others, live acoustic monitoring PCCP lines through a customized system utilizing installed Fiber Optic Cables. Specialized transient pressure sensors are installed on each of the PCCP lines to capture surges and water hammer events. This has served as an effective tool in aligning documented wire breaks. In conjunction with this, Tucson's Dynamic Risk Management program actively monitors all PCCP line data using advanced software which documents acoustic wire breaks, corrosion monitoring and transient pressure sensor data.

Through internal inspections, electromagnetic testing and state-of-the-art failure risk assessment, repairs and/or replacement of segment(s) are

predicated on the overall condition assessment program. This combination of asset management tools has created a comprehensive program which mitigates risk for the citizens of Tucson.

Using the asset management program, Tucson Water has prevented multiple catastrophic failures from occurring. Once distressed PCCP segment(s) are identified, Tucson utilizes segmental replacement and/or a range of structural repair methods which include external post-tensioning and internal application of carbon fiber reinforced polymer composite (CFRP) lining systems. For pipeline rehabilitation, CFRP composites involve the application of epoxy saturated sheets of carbon fiber and glass fiber composites typically on interior portions of the pipeline.

Unidirectional carbon fiber fabrics are relied on for structural integrity, whereas glass fabrics are most often used as the electrical isolator layer (on projects involving metallic pipelines or in the end termination details for PCCP) to separate the carbon fibers from direct contact with any metallic substrate being rehabilitated. Once cured, the CFRP system serves as the structural system and is designed to take all loads, internal and external, without relying on the host pipe for structural integrity.

A recent example of the asset management program success occurred in 2013 during a scheduled outage of a 66- to 96-in. PCCP line. During an internal visual inspection, Tucson Water crews identified a pipeline leak as water penetrating into the 84-in. PCCP wall from the outside.

A more thorough investigation revealed circumferential cracks in the



During an internal visual inspection in 2013, Tucson Water crews identified a pipeline leak as water penetrating into the 84-in. PCCP wall from the outside. Photo courtesy of Hector Posada, Tucson Water.

vicinity of elbows. The Tucson team concluded that more information was needed and their engineering partner, Simpson Gumpertz & Heger, performed a failure analysis based upon this. The study concluded that within a pipeline span of approximately 200 lf, encompassing two adjacent 45 degree bends, did not have adequate thrust restraint and the pipe was unable to resist the thrust forces acting on the bends.

Following repair options analysis, CFRP lining was selected to perform a repair scope of 165 lf of the 84-in. PCCP. CFRP was chosen because the pipe could be strengthened internally, requiring no excavation, and could be designed and installed rapidly. This allowed Tucson to place the pipeline back in service within the allotted outage window. The CFRP upgrade was completed on an emergency basis because the time required for a routine replacement made this option infeasible.

Given the short available time frame, and selection of CFRP as the repair methodology, design and construction activities had to commence simultane-

ously. A key aspect of design was that the longitudinal deficiencies within the 84-in. pipeline segment were found to be caused by inadequately installed thrust restraint. The longitudinal forces acting on the pipeline were not properly resisted and the pipe segments developed circumferential cracks at the pipe joints where sections were pulled apart by thrust forces.

The approved CFRP system design took into account the longitudinal weakness as the primary driver and, as such, the majority of the reinforcement utilized CFRP placed longitudinally. The use of unidirectional material allows for the design to be customized resisting specific loadings in each direction.

The CFRP installation took place over approximately two weeks, including the time required to cure the system. Prior to beginning the CFRP liner installation, the identified leaks had to be addressed. Each leak was welded and because the leak occurred in the joint region where the CFRP lining system terminated, welding of the joint was required to ensure leak-tightness of the overall system.

The first material to be installed as part of the CFRP system was a prime coat of epoxy followed by a layer of thickened epoxy and the first layer of longitudinal CFRP. Design varied, depending on the region within the pipeline, between a nominal thickness 0.24 in. and 0.50 in. of CFRP with the majority of the reinforcement in the longitudinal direction and a minimal amount of reinforcement in the hoop direction.

Given the weakened joints where the



The best practice for end detailing of CFRP systems includes a specially designed leak-tight connection through a tie-in at the steel cylinder portion of the PCCP. Photo courtesy of Hector Posada, Tucson Water.

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leaks occurred in the pipe, the joint repairs and CFRP system end termination details received focused attention during the design and installation phases. The best practice for end detailing of CFRP systems includes a specially designed leak-tight connection through a tie-in at the steel cylinder portion of the PCCP.

Following weld repairs, installation



The CFRP installation was completed successfully and safely by Structural Preservation Systems, LLC, using CFRP materials supplied by Structural Technologies, LLC, both Structural Group companies. Photo courtesy of Hector Posada, Tucson Water.

of the CFRP liner and end detailing, the proper cure time is essential prior to reloading the pipeline with water. As part of the Tucson project, the fiber optic cable was reinstalled in the repair region after the cure process was completed. The CFRP installation was completed successfully and safely by Structural Preservation Systems, LLC, using CFRP materials supplied by Structural Technologies, LLC, both Structural Group companies.

Through its proven asset management program, Tucson Water effectively manages its inventory of underground pipelines using significant experience combined with the latest inspection and repair technologies. The repair of the 84-in. PCCP segments using CFRP to address inadequate thrust restraint is an example of the program at work, starting with field communication regarding the leak through successful installation of the repair system designed to address the specific structural issues identified. Tucson Water's approach to asset management demonstrates to the

industry how potentially disruptive issues can be identified early and addressed successfully to ensure continuous delivery of water and keep customers satisfied.

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This article was developed for UIM from the ASCE paper, "Tucson Water's Strengthening Approach to Address Thrust Restraint for PCCP," by authors Paul Acosta and Anna Pridmore. The paper was recently presented in August at ASCE Pipelines 2014 in Portland. To view the full paper, visit www.asce.org.

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- C Wastewater ONLY Systems and/or Plants
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- H Legal Counsel/Firm
- I Other _____

Which title group best describes your job title?
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- C Council Member/Chairperson
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- F Executive/VP/Senior VP
- G Director/Manager/Gen Mgr/Project Manager/ Superintendent/Supervisor
- H CFO/Treasurer/Comptroller/Finance Director
- I Engineer (all) / Consultant / Estimator
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- L Energy Efficiency
- M Corrosion Control
- N Reuse/Recycle
- O Pipeline Assessment
- P Asset Management
- Q Other _____

What population does your water system serve? (check one)

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- C 5,001-20,000
- D 20,001-100,000
- E Greater than 100,000

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