The largest reported FRP pipeline retrofit job completed to date in the world.

The features unique to the project, as well as the extent of the prep work required to assure a smooth surface free of the irregularities caused by the cast in place procedure; the significant changes in the vertical and horizontal alignment of the pipeline due to the mountainous topography and that required solutions to challenging engineering issues relative to the layout of the FRP lining; the training of local installation crews and the urgent need to minimize downtime of the power plant, made the successful completion of the project even more outstanding engineering achievement.

The fact that over one mile of a large diameter pipeline can be retrofitted to its original condition with minimum downtime and no excavation required, even under the unique challenges mentioned above, is a testament to the versatility and effectiveness of this FRP technology and the experience of the project team.

CONCLUSION

Costa Rica

Mo Ehsani, Ph.D., P.E., S.E. & Carlos Peña, M.S., P.E.

INTRODUCTION

The use of FRP structural linings to strengthen and/or rehabilitate existing pipelines is increasingly gaining widespread acceptance among power plant and utility facility managers. The versatility of the linings to conform to a wide range of diameters and lengths, their high strength properties, light weight, impermeability, thinness and fast rate of application/installation are some of the reasons why managers prefer FRP linings to other retrofit alternatives.

FRP linings typically consist of fabrics made with high strength fibers that are soaked in an adhesive resin, and are applied like wall paper to the interior or exterior of the pipe surface. Once the resin cures, the fabric turns into a very thin (about 0.05”) composite laminate. The density and orientation of the high-strength fibers, as well as the fiber type (usually comprised of bundles of very small diameter strands of materials such as glass, carbon, or Aramid) are parameters that the engineer can vary in order to create customized FRP linings that meet specific project criteria. A recent innovation in FRP lining technology is the PipeMedic™ product, which is a very thin plant-manufactured laminate that adheres to the pipe surface using only an epoxy paste. The greatest advantage of PipeMedic™ is that it eliminates the need for in-situ saturation of the fabric, thereby significantly increasing the speed and quality of the installation.

When applied to the inner surface of a pipeline, the FRP lining becomes a trenchless alternative; all labor, equipment and materials are introduced into the pipeline through service access points, thus avoiding the need for excavation. Since many major pipelines lie under freeways and urban or industrial developments, excavation is not possible without major disruptions to traffic, production, or other normal operations. The economic impact of the disruptions, coupled with the significant installation requirement to replace deteriorated pipelines, increase the relevance of trenchless retrofit options.

Although the use of FRP linings has focused on the rehabilitation of deteriorated pipelines that have been in service for decades, they can also be used to correct design and/or construction errors of new pipelines. Such was the case of the low-pressure pipeline at the “El Encanto” power plant outside San José, Costa Rica. This project included the installation of about 150,000 ft² (1575 m²) FRP lining, and is the largest reported FRP pipeline retrofit project to date. The design problems, and the FRP lining solution implemented to address them, are discussed herein.

This project has received Honorable Mention for the 2009 Trenchless Technology Project of the Year Awards.

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Figure 3: Seepage water draining into pipeline
Figure 4: Initial interior surface conditions of the pipeline
Figure 5: Prep work activities prior to installing FRP lining
Figure 6: Typical 2 ft. x 2 ft. access point
Figure 7(a): Epoxy paste of FRP lining material at one of the bottom half installation
Figure 7(b): Installation of FRP lining
Figure 7(c): Transitions between top and bottom half installation

SOLUTIONS TO THE PROBLEM

The application of FRP linings requires a certain amount of preliminary work to the pipe surface in order to maximize contact and bond strength between the substrate and the FRP. Therefore, pressure washing, as well as some patching and/or grinding must take place in the areas targeted for lining with FRP. In the case of the El Encanto pipeline, the amount of preliminary work was atypical large, since the cast in place construction process caused significantly more surface irregularities than those associated with the more traditional prestressed concrete pipe, such as Prestressed Concrete Cylinder Pipe (PCCP). Figure 4 shows the typical condition of the interior surface of the pipeline prior to initiating prep work activities. Evidence of cast in place procedures can be observed, such as construction joints, formwork fins, etc. The pipeline was pressure washed with 7,000 psi (482 bar) machines to remove any scour, sediment, and curing compounds, or water was observed draining through some of the longitudinal cracks (Figure 3). It was at this point that QuakeWrap’s Mexico (QWM) office was contacted for engineering consultation to repair the longitudinal cracks. A site visit was quickly arranged for one of QWM’s structural engineers. The engineer inspected the cracks, reviewed structural plans and available local engineering reports pertinent to the leak issues, and identified the main cause of the problem.

Moreover, the cracks generated multiple paths for humidity intrusion that reached the steel reinforcement, the additional hoop strength provided by the FRP effectively increased the useful life of the pipeline. It should be noted that the humidity barrier is effective against water leaking into and out of the pipe, due to seepage or internal pressure effects, respectively; however, the corrosion of the steel reinforcement will not be slowed significantly as a result of the humidity barrier, since seepage water will continue to provide the means for this process to continue. While nonstructural linings can also provide two way humidity barriers, nonstructural linings cannot account for the loss of structural integrity caused by the ongoing corrosion due to the presence of seepage water.

Moreover, the adhered FRP laminate was designed to achieve full deformation compatibility with the pipe as the pipe expands due to pressurization, and the bidirectional orientation of the high strength glass fibers in the fabric guarantees that existing and/or future cracks are intercepted in orthogonal directions providing superior crack control. Nonstructural linings, on the other hand, cannot serve as an effective crack control mechanism.

Finally, an epoxy top coat was applied as a cover for all the installed FRP. This coat provides resistance to the abrasion caused by sediment carried by the river water, and additional leak proofing by covering any thin holes remaining in the FRP lining. The coating has a concrete gray color, which facilitates quality control by providing a visual means of verifying that the entire light green-colored FRP lining is fully covered, and that any uncovered spots can be easily detected.

The time urgency associated with the power plant’s imminent start of operations cannot be overstated, and required the development of the entirety of the engineering design, specifications, installation shop drawings, as well as securing very large quantities of FRP fabrics and epoxy resins, pastes and top coats, on a very short schedule. QuakeWrap’s manufacturing plants were placed on accelerated production runs to meet rather tight deadlines, and part of the production was prepared for air cargo transport.

A technical team of two structural engineers and three field supervisors traveled from QWM to Costa Rica to oversee the project and train the local installation crews. A technical team fluent in Spanish was a must in order for the job to run smoothly.

INSTALLATION PROCEDURE

The 5,742 ft. long pipeline had four lateral access points at ft. to accommodate at maximum operational pressure. Each installation station consisted of four installation stations, with spacing ranging from 1,000 ft. to 1,500 ft. These 24" x 24" access points (Figure 6) were used to supply FRP materials, tools and equipment to four installation stations inside the pipeline.

The installation direction was opposite to the flow direction to prevent the joint in the FRP lining from being uplifted and detached by the water flow. Each installation station consisted of a 5-man crew inside the pipe applying the FRP lining to the pipeline’s interior walls, and another 5-man crew performing support activities such as transporting the rolls of lining material from the access point to the installation point, cutting and preparing the FRP rolls, etc.

Figure 7a illustrates the application of an epoxy paste to the top half of the pipeline; the main purpose of the paste is to prevent peeling due to the weight of the saturated FRP fabric, and to seal the surface to prevent excessive absorption by the dry concrete surface of the epoxy resin from the saturated FRP fabric. Figure 7b shows the installation of the first roll of FRP lining material at one of the