Power Generation Case Study: Feasibility of Carbon Fiber and Alternate Repair Methods

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Abstract

A coal fired Power Generation Facility in the Baltimore relies on a large diameter circulation pipeline stretching half a mile from the boiler to the cooling towers. The line was constructed with mainly 102” Prestressed Concrete Cylinder Pipe (PCCP) containing problematic class IV wire. The plant started experiencing breaks in the nineties with costly repairs and even more costly lost revenue. The plant engineers then devised a proactive inspection and preventive repair program that managed to mitigate breaks but still forced longer outages and costly repairs using post-tensioning loops or concrete encasements.

In 2007, a solution was presented which included the use of Fiber Reinforced Polymer, or Fiber Wrap. The advanced composite system was applied on the interior of the pipelines at this facility first in the fall of 2007. After that first successful experience, internal repairs utilizing Fiber Wrap became common practice for dealing with distressed pipes as they were detected year after year. The Power Generation facility went beyond the year to year approach and in 2009 decided to strengthen the

entire length under the switchyard to completely eliminate the chance that a break or a leak would shut down the entire plant.

The scope of work for this Project, completed in early 2010, was 55 sections, 20 ft long and 102" diameter to complete in 30 days. The project included a very short window for surface preparation of 10 days. The completion of the Fiber Wrap installation and top coating was reached on day 24 of the project, well ahead of a very challenging schedule. Alternative methods of mitigating this critical pipeline problem could have cost up to 5 times the Fiber Wrap option and would have caused major construction to take place under rail lines. The application of Fiber Wrap can be completed in 10-15% of the time required to replace pipelines of this nature.

For over a decade Fiber Wrap has been utilized to strengthen and renew pipelines in varying degrees of distress and degradation in the municipal water and power generation market. The process is viable when there is an inability to excavate and a trenchless method must be utilized. Fiber Wrap liners lend themselves well to trenchless rehabilitation where a fully structural solution is a requirement. The Fiber Wrap designs may consider various loading combinations from internal pressure to external loads such as vehicular traffic, or in some cases, train traffic.

The Fiber Wrap liner used as a segmental repair in combination with electromagnetic wire break testing for PCCP or Ultra Sonic(UT) testing for steel wall thickness loss may be a more economically feasible repair method when pipeline owners are working with limited rehabilitation budgets. The case study will present a clear contrast of various methods of pipeline repair considering the associated costs of down time, environmental impact, safety and capacity loss.

Using the Power Generation facility project as a detailed case study this paper will assist pipeline owners in determining if and when to consider the use of Fiber Wrap. It will present a concise and objective comparison and contrast to traditional pipeline upgrade meant to provide Conference attendees usable information to assist in making these critical operational and financial decisions.

1. Introduction to the Power Generation facility.

Because of the magnitude of the Power Generation Plant, a capacity of 1300 megawatt(MW) a year and a supply of power to much of the Baltimore area, any repairs or rehabilitation to take place would need to be both time sensitive and enduring. To make matters worse, in power generating plants such as this one, any unplanned shutdown can cost upwards of 1 million dollars a day.

Especially significant in this case, the facility has over 2,500 lineal feet of Pre-Stressed Concrete Cylinder Pipe (PCCP). Much of this line runs under an adjacent power grid not owned by the facility, as seen in Figure 1. If any failure did occur, Power Generation facility would be responsible for not only its own internal repairs, but also for the damage occurring at the power grid. As evidenced by the breaks in the pre-stressing strands in the nineties at this power plant, forced shutdowns and immediate repairs ensued that cost the plant millions in lost revenue, let alone in repair costs. While it is important to realize that these outages cannot be prevented, they can and should be planned for accordingly.

Figure 1. Power grid that lies on top of the PCCP line to be rehabilitated

After being hit by several costly shutdowns in the nineties, the Power Generation facility established a risk mitigation plan in its circulating water system to allow for a more proactive approach to pipeline repair. Regular inspections of the system using non-destructive technologies allowed for the power plant to see which pipelines were in distress and how best to allocate their money for potential repair.

While these efforts were large steps in the right direction, there still remained a question on whether or not the funding for repair could be better utilized. Initial solutions to the problems occurring within the pipeline were to simply replace the pipe, place post tensioning rings around the pipeline or to even encase the pipe in concrete. In all three cases, the pipeline would have to be dug up, thereby costing valuable time and potential revenue loss because of an extended outage. Although the Power Generation facility was prepared for the outage, there were still costs that could be reduced.

Image 2: Potential Solution – Pipeline Replacement

Inspecting the circulating water system on a regular basis and being proactive in solving potential pipeline problems was a critical first step forward for the Power Generation facility. All methods of pipeline repair and replacement, digging up the pipe, concrete encasement and post-tensioning hoops are great solutions to a distressed pipeline, but the real question is on whether or not these solutions provide the best value. If the pipeline is easily accessible – it can be dug up with little effort, and if large amounts of the pipeline are in distress, then this solution makes sense. However, if the pipeline runs under an adjacent power grid not owned by the power company (in this case), or even if the pipeline runs under a crowded urban street, there is really no means to replace the pipe or begin to dig it up. In these situations, the use of Fiber-Reinforced Polymers, Fibrwrap, is introduced.

2. Evaluation of Different Pipeline Repair Methods

While Fiber Wrap is certainly not the only method of pipeline rehabilitation that can be utilized, in the case of this Power Generation facility, it made the most sense. With the adjacent power grid not owned by the facility as well as railroad lines above sections of the pipeline, digging up the line was virtually impossible, eliminating a full replacement as an option. Similarly, post-tensioning repair, if possible is one in which the line can be kept in service as the pipe is dug up and externally strengthened. However, this method again requires the excavation of the pipeline, thereby eliminating this option as well.

Figure 2. Various solutions for damaged pipelines

Looking for a fully structural lining system, the Power Generation facility opted for a higher modulus composite system that would offer class IV lining capabilities as defined per American Water Works Association(AWWA) document M-28. While CIPP liners do have some structural capabilities, the design modulus used is typically not equivalent to that of higher strength Fiberglass Reinforced(FRP) systems and, if applied, can reduce the pipeline internal diameter by 6-12 inches. Again, Constellation Energy was looking for a viable option to strengthen their pipeline system and to maintain or increase their existing capacity. With a potential decrease of 6-12 inches, this would not be possible and Cured In Place Pipe(CIPP) was eliminated as a repair option. The fourth option of Sliplining is also an excellent repair technique, however, it again involved the digging up of some portion of the pipeline which would not be feasible. This method of repair makes sense in repairing large sections of pipeline at once, provided the repair is in a continuous and straight line. While all of these options are great repair techniques, the circumstances involved at this facility provided a substantial difficulty in moving forward, thereby making Fiber Wrap the most cost-effective solution.

3. Segmental Repairs using Fiber Wrap

In the fall of 2007, the Power Generation facility decided to move forward on a rehabilitation design that included Fiber Wrap. Initially, the Fiber Wrap was to be used as mainly a spot repair for the sections of the pipeline found to be distressed. Rather than dig up the pipe and spend large quantities of money in replacement, carbon fiber composite systems could be used to internally strengthen either problematic sections of pipe or entire lengths at a time. Both the applicators and the materials would enter the pipeline from various manholes or other access points and repair one spool, or roughly a 20 foot pipe section, at a time. With each successful installation and with time constraints never limiting the application, Fiber Wrap rapidly became a trusted rehabilitation technique and a valued construction material. From 2007 until 2010, more than 200 lineal feet of PCCP had been strengthened using Fiber Wrap systems. Upon realizing the potential for cost-effective repair that the Fiber Wrap presented, the Power Generation facility began to think of larger scale ways in which the material could be utilized.

4. FRP as a Permanent Long Term Repair

In 2010, the Power Generation facility decided that they would like to minimize the potential for a plant-wide shutdown and attempt to rehabilitate many sections of their circulating water line at once. In total, 1,100 lineal feet of the 102" diameter PCCP line was retrofitted using the Fiber Wrap systems. The goal in entering 2010 was to be proactive in renovating their infrastructure systems, setting aside money for thorough and continuous inspection, and if necessary, strengthen a circulating water system that could be in jeopardy. In completing the retrofit, the plant was looking to heavily minimize the chance of a break or a leak causing a plant-wide shutdown.

The details of the complete retrofit are what make this case study so interesting. With a very tight shutdown window of only 30 days, the Contractor was to de-water and enter the pipe, adequately prepare the surfaces of the pipe to ensure that a strong bond with the composites would be achieved and to fully adhere all the designed number of layers to the 1100 lineal feet of line requiring strengthening. So with these time constraints in mind and the realization of the overwhelming magnitude of the project, the Contractor began. To make the project more challenging was the fact that all surface preparation had to be completed within 10 days. In order to fully retrofit the pipeline and have the circulating water lines running again within 30 days from shutdown, completing the entire surface preparation in this time limit was a necessary first step.

Over a period of 24 days, the Contractor completed the full retrofit of 55 – 20' long sections of 102" diameter pipeline. With 10 days dedicated to the preparation of all surfaces, only 14 days were needed to complete 55 sections (surface preparation, Fiber Wrap layers and the top coat). The project was completed 6 days ahead of the very difficult work window and validated the idea that Fiber Wrap can be used as a cost-effective and time-efficient rehabilitation and strengthening material. In Figure 3, one can see the various stages of repair at the facility. The individual sections of pipe that are highlighted or boxed demonstrate the individual sectional repairs that took place from 2007 – 2010. The green sections of pipe highlighted all together represent the 55 sections, 1,100 lineal feet, of water circulating line rehabilitated.

5. Advantages of FRP – When to Use

While it is important to recognize the potential of Fiber Reinforced Polymers for the rehabilitation and strengthening of pipelines, it may be more critical to realize why it was a useful application at this power plant. The American Water Works Association document M-28 labels Class IV structural linings as "fully structural or structurally independent" linings that can be considered equivalent to pipeline replacement and are capable of resisting various dynamic loading cases (M-28 60). An example of the completed application can be seen in Figure 2.

Figure 3. Completed CFRP installation

Knowing this, we can begin to examine the types of applications in which Fiber Wrap makes sense. For pipelines, the applications are virtually limitless, consisting of PCCP, Reinforced Concrete Pipe, Steel, Aluminum and Ductile Iron Pipe. The Fiber Wrap itself can be designed for structural strengthening, leak protection, corrosion mitigation, pressure rating enhancement, and joint rebuilding.

When considering whether or not to design using Fiber Reinforced Polymers, there are several critical factors that need to be considered. The first of which, being access points, is very important in that this is a completely internal application. The labor and materials are to be transported within the pipeline and it is important that there are various access points for entry. Also important in ultimately deciding if Fiber Wrap is an option for repair is the cost and time period. Fiber Wrap is not a cheap material but depending on what your options are, it may end up being cost-competitive. In the case of this facility, a 30 day shutdown window coupled with the ground level power grid and railroad lines meant that the options weren't very extensive and Fiber Wrap actually represented a cost savings over the other repair methods. Other factors coming in to play in deciding if Fiber Wrap can be used is what kind of an effect will the application have? Is there a minimal project footprint? Are there any delays that would be caused in completing this application? All of these questions are discussed fully with clients and engineers prior to application to ensure a quality product will be installed.

Further advantages of the Fiber Reinforced Polymer systems are noted in a recent publication Opflow publication for the American Water Works. Besides being a fully trenchless repair technology that is so thin that any capacity losses are negligible, all system components contain virtually no volatile organic compounds and are NSF-61 approved for drinking water. The capability of sectional repairs rather than having to replace or retrofit full lengths of pipe also offer much in cost and time savings. While there are numerous capabilities of Fiber Wrap systems, it is important to realize that this is not a limitless system; it is, however, a great tool to have in your toolbox.

6. Creating an Asset Management Program

The Power Generation facility made large steps forward in the water transmission industry in the years leading up to 2010. Through a continued use and increasing trust in Fiber Reinforced Polymer systems, the energy supplier was able to save much time and money in potential lost revenue from a plant-wide shutdown. In the more recent years, an asset management program was initiated in order to mitigate potential risks of pipeline failures and allow for planned shutdowns for repairs.

With an asset management program established, the Power Generation facility made plans for continuous and thorough inspections to occur on a reoccurring basis. After inspecting the lines, if there were pipelines in obvious distress they could be focused on in a planned plant shutdown. In the case of the 1,100 lineal feet of pipeline to be repaired, not every section of the pipeline was determined to be in a critical state; however, by being proactive in repair and designing for a 50 year life cycle for each section, any fear of leaking and failure causing a plant-wide shutdown could be effectively dismissed. While the initial costs may have been higher than only replacing the distressed sections, the overall cost savings from preventing a failure are much higher.

While some water agencies opt for 3 or 5 year on-call contracts in which emergency situations can be handled immediately without the delay of a bid, this is another example of a successful planning program. In the coming years, there will be a stronger focus on establishing these asset management programs with money set aside for infrastructure needs, and we will see owners such as this Power Generation facility at the forefront of such achievements.

7. Conclusion

In what began as a few sectional repairs using a Fiber Wrap system on a year to year basis, the water circulating lines at this major Power Plant became an example of how successful a planned asset management program could be. After the first few installations at the power plant established a trust in the Fiber Reinforced Polymers and the construction procedure, the facility was able to plan and execute the rehabilitation of a good percentage of its water lines. And while the capabilities of Fiber Wrap are being heavily stressed, it should be noted that full material properties cannot be obtained without the proper installation and proper quality control techniques. Under such a tight time-frame of only 30 days it should be noted that this project could not have been completed without the quality control and quality assurance standards a highly experienced Contractor. With an established asset management program, high strength materials designed for a 50 year life cycle and a quality applicator, the Power Generation facility was able to proactively rehabilitate a large majority of its PCCP line, and mitigate the risk for failures in the future.

8. References

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