

A Modern Solution for an Old Problem - Utilizing both CIPP and CFRP for Aerial Pipeline Rehabilitation

Amber Wagner, Ph.D., PE and Timothy Peterie

ABSTRACT

What happens when you determine one rehabilitation technology isn't sufficient enough? The internal or external rehabilitation of aerial piping can be a tricky concept when utilized as an either/or repair option, but when combined, these technologies can prove to complement one another and provide a fully structural repair solution not previously considered in our industry. For a municipality in North Texas, they are no stranger to this design challenge, but they had never considered the combination of these technologies until it was presented as one design solution procured under one contract. By consulting with their partners, they realized that this problem could be overcome by implementing both an internal and external repair solution. This paper will focus on two aerial pipes, 12-inch and 18-inch steel pipes, which were showing signs of severe deterioration. The design team determined that the pipes would be internally rehabilitated with cured-in-place pipe (CIPP) to eliminate internal corrosion; then, to provide additional protection due to environmental exposure and provide additional longitudinal strength, the use of carbon fiber reinforced polymer (CFRP) systems was designed to be applied to the exterior. This paper will discuss the City's struggle with this issue and the process that led to this unique repair option. The design procedures and the construction details will also be discussed and illustrated.

INTRODUCTION

During project development phases, there is typically an in-depth discussion of the pros and cons of different approaches to a design, construction and installation of a project. This was no different for a team of engineers at a municipality in Texas, who were trying to determine the best rehabilitation option for the City's aerial pipes, see Figure 1. There were several different options which were discussed:

1. **Reinforced CIPP Liner** – This option would not only protect the inside of the pipe from further corrosion, but also be able to withstand the internal and external loading conditions.
2. **Carbon Fiber Reinforced Polymer System** – Due the size of the piping systems, i.e. 12 and 18 inches, the system would need to be applied as an external repair. In the end, this option would protect the pipe from external corrosion and be designed to withstand the internal and external loading conditions.
3. **Replacement of Aerial Piping Section** – One way to ensure the piping system would be able to last another 50 years, was by replacing it with a brand-new section. This selection, however, would have resulted in significant costs and longer than allowed shut down times.
4. **Combined Non-Reinforced CIPP Liner and CFRP System** – This would allow the pipe to be not only protected on the inside and outside of the pipe, but also be designed to withstand all the internal and external loadings. Also, the use of the internal CIPP application would address the immediate concerns for leaks which the external CFRP could be planned and scheduled.

After reviewing all the different options, the City decided to use Option 4 for a variety of reasons:

- Allow for a minimized downtime of the pipe. The installation process for a reinforced CIPP liner is longer than for a non-reinforced standard felt CIPP system.
- The pipe could be protected both internally and externally.
- The rehabilitated pipeline would have an extended life up to 50 years.
- Due to access and the obstacles around the pipeline in question, removing and replacing it with a new pipe would come with logistical challenges, which would only add time and money to the project.

This paper will discuss further the design and installation practices for the CIPP and CFRP systems used to rehabilitate several aerial piping systems in Texas.



Figure 1. Example of Aerial Pipe to be Rehabbed

DESIGN PHILOSOPHY - CIPP

For the internal lining of this project, the standard felt and resin CIPP tube configuration (see Figure 2) was utilized. The design requirements for the CIPP portion were to provide internal corrosion protection and handle all the gravity loads of the host pipe. Since this is an aerial pipe, and there is no external (soil, water) loading to the pipe, the only real design requirement was based on the gravity head created by the change in elevation. Nevertheless, the industry standard for the design and installation of CIPP systems is the ASTM F1216 – Standard Practice for the Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube. By utilizing the Appendix X equations, the following design checks were required for the CIPP System:

- (1) Equation X1.1 – Hydraulic loading
- (2) Equation X1.2 – Withstanding ovality of the host pipe

- (3) Equation X1.3 – Buckling limitations
- (4) Equation X1.4 – Minimum Stiffness Requirements

For each of the equations mentioned above, the minimum thickness requirement can be attained and correlated to the installed CIPP thickness.

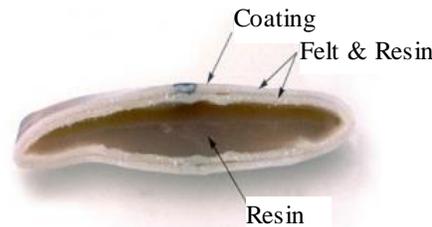


Figure 2: Sample Tube Construction for CIPP Liner

DESIGN PHILOSOPHY - CFRP

In contrast to the typical internal CFRP project, the design requirements for the CFRP system for the aerial piping systems was only required to provide strength going the length of the pipe, i.e. the longitudinal direction. All internal loads were to be taken by the CIPP system as discussed in more detail in the previous section. In addition, the CFRP system would help to provide additional protection to the existing host pipe by eliminating any new corrosion.

Since there is not a design standard that exactly addresses this design requirement, it was determined to design the CFRP system utilizing similar design methodologies described in the American Water Works Association (AWWA) design standard C305 [AWWA C305]. This design standard was developed specifically for strengthening Prestressed Concrete Cylinder Pipe (PCCP) using CFRP. Thoroughly reviewing and understanding the design methodology within the document strongly influenced the primary design considerations for this project. In the end, three different design checks were required for the CFRP System:

- (1) Deflection limitations due to moments spanning between supports,
- (2) Buckling of the CFRP liner due to temperature change, and
- (3) Debonding of the CFRP system due to shear demands at the termination locations.

Not only was it important to understand and identify the proper design requirements for the CFRP system, but it was also important to provide proper detailing for several components of the project: (1) saddle supports and (2) the exterior clamp used to stop previous leaking of the host pipe. Due to the height of the saddle supports (and project cost limitations), it was determined that the saddle supports could not be removed. This meant a special trim detailing was required at the saddle support locations to ensure the longitudinal forces were developed properly over the length of the pipe (see Figure 3). Even though the CIPP had already been installed and the risk of leak was non-existent, for ease of installation and keeping to the work schedule the clamp remained in place. The detail, shown in Figure 4, requires a ramp to be created with epoxy mortar to create a smooth transition for the CFRP system.

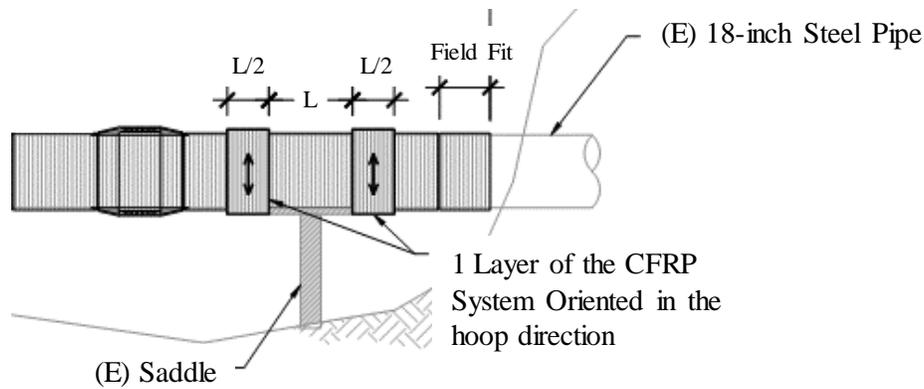


Figure 3: Special Detailing at Saddle Locations

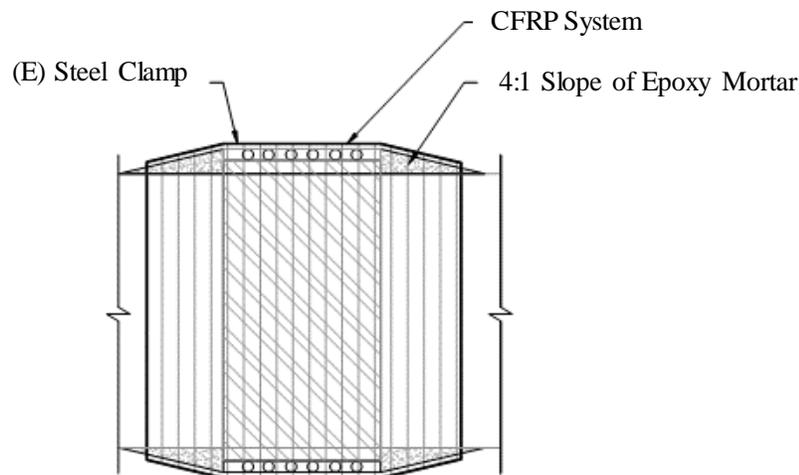


Figure 4: Special Detailing at Clamp Locations

PROJECT CONSTRUCTION – PHASE 1

For the construction of the CIPP liner, the following installation process was utilized:

1. Pipe is de-watered and cleaned in preparation for lining.
2. A pre-manufactured felt and resin tube was delivered to site. The tube is wet-out prior to delivery at a dedicated wet-out facility. This helps to ensure consistency in the wet-out process, as well as compliance with environmental methods.
3. The tube is then inverted using water pressure, see Figure 5a. The water pressure inverts the tube like a sock and propels it through the length of the pipe being rehabilitated.
4. The inversion water is then heated and used to cure the resin. This helps the product to “form in place” and creates a tight-fitting, jointless, and corrosion-resistant replacement pipe.
5. Finally, the rehabilitated pipe is inspected by closed-circuit TV, see Figure 5b.

In the end, the installation of the CIPP system took 1 day and was an overnight install.

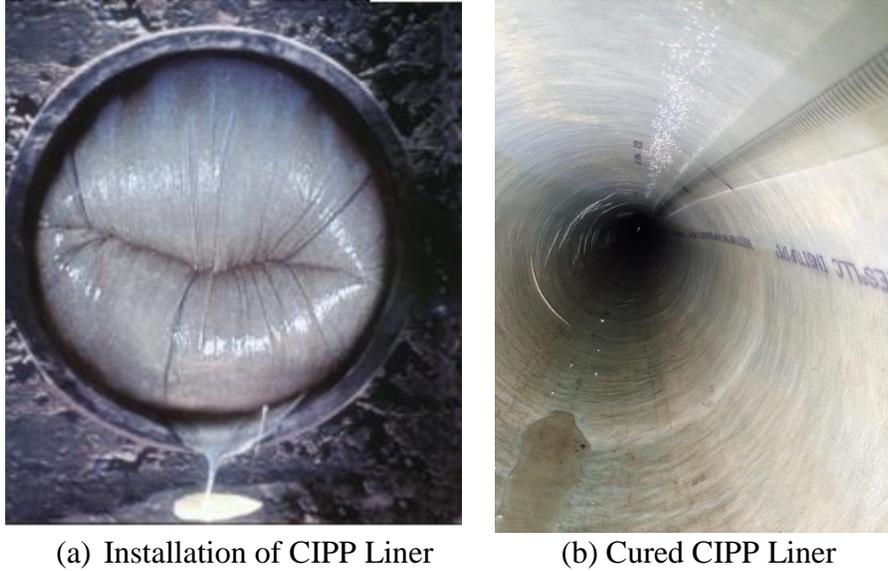


Figure 5. Installation of the CIPP Liner

PROJECT CONSTRUCTION – PHASE 2

Once the CIPP system was installed and properly cured, the next phase of construction was to install the CFRP system. Since this was an external repair over a creek, the installation was a bit different than the standard internal repairs:

1. The need for additional safety measures was reduced, only scaffolding was required.
2. Special scaffolding was required for the extent of the pipe to be repaired, see Figure 6.
3. Since, the repair occurred in a sensitive nature preserve, dust confinement and additional environmental measures were required.
4. The crew size required to complete the repair was less.
5. Installation time was quicker.
6. Difficult to increase cure time through heat unless confinement tents are utilized. For this project, ambient cure was enough.

For the actual installation of the CFRP system, the following installation procedure was utilized:

1. Exposed steel was prepared to SSPC SP-10 or near white metal finish.
2. A single layer of the GFRP system was applied to act as a dielectric barrier between the steel and CFRP system.
3. Apply a primer layer of thickened epoxy.
4. Apply the longitudinal layer and hoop layers as required, see Figure 7.
5. Allow system to cure for 72 hours before pipeline is put back into service.
6. Apply a top coat of acrylic paint for protection to the CFRP system.

In the end, the installation of the CFRP system took 5 days and the pipe was never out of service during the installation. .



Figure 6: Surface Preparation of Host Pipe



Figure 7: Installation of CFRP System

CONCLUSION

For the municipality in North Texas, the use of CIPP and CFRP to rehabilitate their aerial pipeline was a suitable choice for a variety of reasons. First of the installation sequence allowed for the pipeline to remain out of service for the least amount of time necessary. Second, the use of CIPP not only strengthened the pipe for the head gravity loads but provided internal corrosion protection to the host pipe. Finally, the CFRP system provided the additional longitudinal strength and

external corrosion protection, which a standard felt CIPP system can not sustain. In the end, the City was able to rehabilitate and protect their aerial pipe without significant bypassing costs and reduced downtime of their system, something that was necessary for the project to be deemed a success.

REFERENCES

AWWA (American Waste Water Association). (2017) *CFRP Renewal and Strengthening of PCCP*, ANSI/AWWA C305. First Edition. AWWA, New York, NY.

ASTM (American Society for Testing and Materials). (2016) *Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube*, ASTM F1216-16. Tenth Edition. ASTM International, West Conshohocken, PA.