Pipeline Rehabilitation amidst Environmentally Sensitive Location

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Abstract

The District of Columbia Water and Sewer Authority (DC Water) was faced with repair of a degrading aerial sewer located in an environmentally sensitive area. The sewer is located over Klingle Creek in US National Park Service land. The sewer is an 18-in sanitary terra cotta line encased in 30-in wide by 30-in deep degrading concrete with support columns and footings position in the steam bed and banks. Significant erosion at the stream bed undermined the stream bed footings. This caused the design span to double and put the aerial sewer in jeopardy.

Mitigation options included realignment, replacement, renewal, and footing support updates. The importance of the sewer to accommodate public demand was not well supported by options requiring environmental impact reports or special permits, such as replacement, realignment, and stream bed alterations. Although initial project discussions considered realignment and replacement as viable options, DC Water recognized the urgency for an alternative that did not require extended planning and permitting.

The pipe owner contacted Analytical Engineering to provide an FRP (fiber reinforced polymer) repair alternative. Analytical recommend the use of the Tyfo CFRP (carbon fiber reinforced polymer) system for strengthening the exiting encased crossing while eliminating the need for stream bed supports and alterations. The use of the Tyfo CFRP system for external rehabilitation of the crossing also eliminated the need for

dewatering the pipeline, which provided significant cost and time savings to the owner. Additionally, the CFRP system is environmentally compliant with no impacts on high water flows contacting the crossing. The work was completed by Fibrwrap Construction with no spillage and no incidents which would have negatively affected the creek area. This renewal option not only solved the environmental issues and extended schedules required of other options, but was did so at a fraction of their costs.

1. Challenge

The aerial sewer crossing over Klingle Creek is located in North West Washington DC within the National Park Service land. The crossing was constructed in 1920 and over the past ninety years the condition of the crossing has progressively deteriorated. The condition of the crossing prior to repair is illustrated in Figure 1. The location of the crossing within land owned by the National Park Services causes substantial challenges for replacement or traditional repair options for the sewer due to the environmental considerations. To make matters worse, the only access road "Klingle Road" has been damaged and closed for 14 years due to the effects of a hurricane.

Figure 1. Original condition of the Klingle Creek aerial sewer

The crossing consists of an 18 inch pipeline which was encased in 30-in by 30-in concrete. The crossing is 40 ft in length and has four intermediate support piers along the length of the crossing as well as footings positioned on the banks of the creek. As shown in Figure 1, the original condition of the aerial sewer indicated substantial concrete cracking and spalling. Debris was blocking the stream creek, which altered the profile of the bank and had eroded the footings.

The soil adjacent to the two piers located within the path of the creek had undergone such extensive erosion that the piers were 100% suspended. One of the piers was suspended above the soil by approximately 24 inches, as shown in Figure 2 a. The other pier which was located within the path of the creek flow had separated from main structure on December 10, 2009 such that an approximately 6in gap exists between the pier and the aerial sewer crossing. This separation of the pier from the main structure occurred two days after bypass was started, so a potential spill was prevented, but the unrepaired aerial crossing provided substantial risk of failure. Because of the location within Klingle Creek of the National Park Services, any sewage spill would have resulted in steep fines and negative press.

a. Pier suspended approximately 24 in. b. Pier separated from the main structure

Figure 2. Deteriorated condition of the existing abutments

A field inspection performed by J.W. Marshall and Associates in January 2010 showed that the central two footings shown in Figure 2 had been completely removed and replaced with wooden temporary support structures as shown in Figure 3 (Marshall, 2010).

Figure 3. Temporary support structures observed at time of Jan 2010 inspection

2. Owner's Response by DC Water

DC Water examined various mitigation options included realignment, replacement, renewal, and footing support updates. The importance of the sewer to accommodate public demand was not well supported by options requiring environmental impact reports or special permits, such as replacement, realignment, and stream bed alterations. Although initial considerations strongly considered these as viable options, DC Water recognized the urgency for an alternative that did not require extended planning and permitting.

In response to these challenges, DC Water focused in on an innovative solution which involved the use of a structural carbon fiber composite for external strengthening of their crossing to address the rehabilitation of their aging structure. DC Water had previous experience with the carbon fiber wrap system for strengthening of their pipelines and felt confident with the durability of the system due to the material's history of over 25 years in rehabilitation applications for civil infrastructure. The carbon fiber wrap provided an ideal solution for repair and strengthening of the crossing because the system caused the least environmental impact due to its high strength, easy access considerations for installation, and low profile. The structural strengthening provided by the carbon fiber wrap also empowered DC Water to eliminate the two intermediate piers in the stream, thereby tripling the span distance for the crossing from 10 ft to approximately 30 ft.

3. Abutment Design by J.W. Marshall and Associates

An investigation of the footings indicated inadequate footing size and concerns regarding their capacity and stability of the footings to safely support the aerial sewer crossing (Marshall, 2010). Recommendations for action provided by J.W. Marshall to DC Water included foundation improvement,measures to increase the abutment size, and riprap placed around the footings to manage future erosion. These recommendations were implemented by DC Water and the capacity increase provided to the footings in conjunction with carbon fiber wrap strengthening provided to the concrete encased pipeline allowed for the permanent removal of two central footings which were previously located in the direct path of the creek.

4. Carbon Fiber Design and Engineering Solutions by Analytical Engineering

The minimum design considerations provided by DC Water included an increase of the clear span from 10 ft to approximately 30 ft, due to the removal of the two intermediate piers. The carbon fiber wrap strengthening was extended along the entire length of the crossing such that the total length of the repair was 46 ft. The system was designed for both live and dead loads and provided vertical and horizontal flexural improvement as well as shear improvement for the crossing. Vertical loads which were considered in the design included dead load of the 30-in by 30-in concrete encasement with full flow of sewage in the 18-in diameter pipe as well as a foot traffic load of 100 psf minimum. Lateral loads due to impact from floating

debris as well as storm flood water acting on the crossing up to the top of the encased sewer were also considered in the design (Bian, 2010). The design accounted for moments, shears, and allowable deflections in both the horizontal and vertical directions. In order to accomplish these strengthening objectives, Analytical Engineering provided a carbon fiber wrap design using Fyfe Company's Tyfo® Fibrwrap® System in to provide structural integrity in the longitudinal and circumferential direction for the crossing, as shown in Figure 4 and Figure 5.

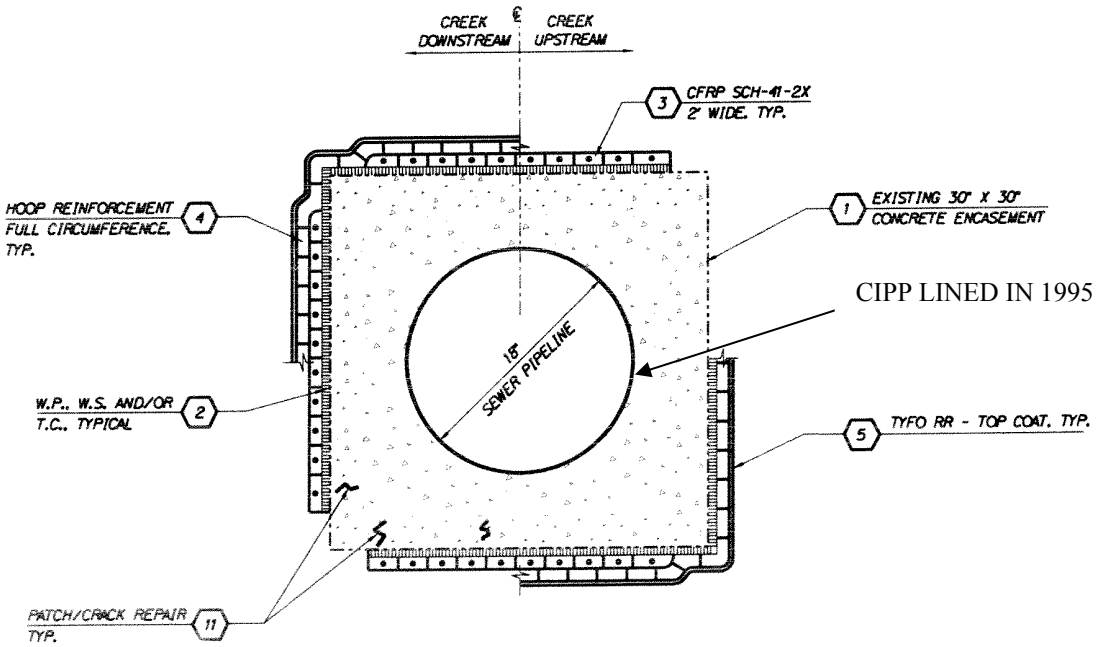

Figure 4. Typical Cross Section of Concrete Encasement (Analytical, 2010)

In addition to structural requirements, the external application of the carbon fiber wrap required that UV and fire protection be included as part of the design. Beyond this, NPS required, and needed to approve of, a textured sand stone like coating that blends into the environment. To accomplish this objective, Fyfe Company's Tyfo® RR was provided as a top coat for the carbon fiber wrap system. Due to the crossing's location within Klingle Creek of the NPS, aesthetics was also an important component of the project, therefore an owner selected grey pigment was applied to the Tyfo® RR in order to achieve a color and texture for the finish product which was comparable to sandstone (See Figure 10 for reference).

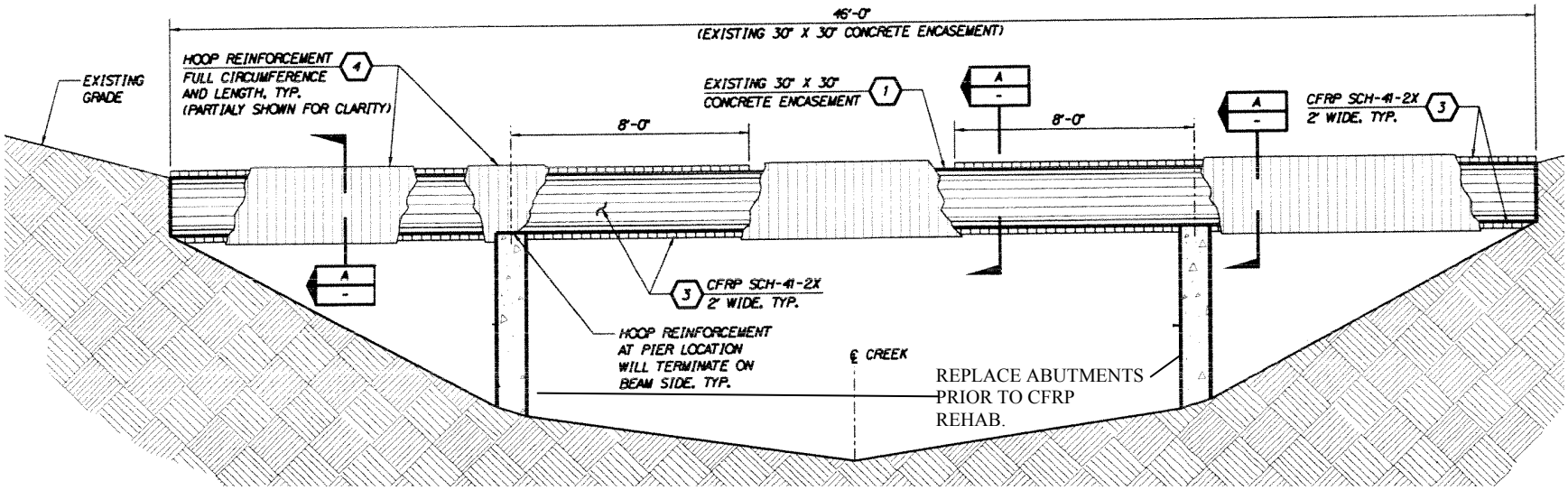

Figure 5. Profile of Existing 30-in x 30-in Concrete Encasement (Analytical, 2010)

5. CFRP Strengthening by Fibrwrap Construction, LLC

Prior to the executing the carbon fiber wrap portion of the scope of work, the repair of the footings and abutments recommended by J.W. Marshall and Associates were performed. While work was being performed on the crossing, the water from the creek was routed through bypass piping, as shown in Figure 6, to allow for a safe and dry construction site and to avoid potential for environmental contamination of the creek with construction debris.

Figure 6. Aerial sewer under construction with supporting scaffolding

In order to ensure adequate bond of the carbon fiber wrap system to the host structure, surface preparation was performed to all 360 degrees of the aerial sewer's surface along its entire length. The surface preparation included addressing issues such as spalling and cracking concrete, paint, and mildew as appropriate.

Once the surface preparation was completed, the carbon fiber fabric sheets were saturated with Tyfo® S epoxy resin system using the saturator machine shown in

Figure 7. The use of the saturator machine ensured full saturation of the carbon fiber wrap and allowed for tight quality control on the resin to fiber ratio provided for the carbon fiber composite system. Sheets of the Tyfo® Fibrwrap® carbon fabric were applied to the structure in the longitudinal and circumferential direction as shown in Figure 4 and Figure 5 in order to meet the project requirements.

Figure 7. Carbon fiber sheet, impregnated with Tyfo® S epoxy

Since the carbon fiber strengthening operation was performed in March during varying weather conditions, the work area was tented as shown in Figure 8 such that the work area could be temperature controlled to allow for optimum curing conditions for the carbon fiber wrap system. A final top coat of the Tyfo® RR was applied as a UV and fire protection coating as well as an aesthetically pleasing finish to fit in with the surrounding setting at Klingle Creek of NPS.

Figure 8. Tenting of project in order to provide environmental control

Once Fibrwrap Construction's carbon fiber strengthening work was complete, the site along the stream and at the embankment was restored per the National Park Service's requirements as shown in Figure 9. The completed restoration of the Klingle Creek aerial sewer is shown in Figure 10.

Figure 9. Environmental restoration of the surrounding area

Figure 10. Completed restoration of the Klingle Creek aerial sewer

6. Conclusion

The collaborative efforts provided by DC Water, J.W. Marshall and Associates, Analytical Engineering and Fibrwrap Construction resulted in an innovative rehabilitation project which is regarded as a significant success. Concerns regarding potential government fines and sanctions that would be caused by a sewer leak were alleviated through the structural strengthening and restoration of the sewer. The use of the carbon fiber wrap system allowed for an aesthetically pleasing solution which caused the least impact to the environmentally sensitive surroundings and provided a long term rehabilitation of the crossing.

References

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