Rehabilitation of Non-Round Sewers Utilizing Profile Shaped Fiberglass Pipe

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ABSTRACT

Different shaped pipes have been used for centuries to help facilitate low flow velocities in sewer systems for centuries. These non-round sewer pipes were traditionally used in large cities where pipelines were utilized to carry sewer and storm water together. These pipes had the capability to maintain reasonable cleanout velocities for the sewer effluents during times of dry weather, but also had the capacity to carry storm water during significant rain events. These non-round sewer pipes are located all over the globe as part of the city's infrastructure and the performance of these pipelines are incredibly important to each municipality.

More specifically, many of the largest cities in the United States such as New York, Boston, Washington D.C., and Los Angeles have these types of sewer pipes in their systems. These pipes were traditionally constructed of unreinforced concrete and bricks or clay tiles. The majority of them were hand crafted manually by arguably some of the most skilled masonry laborers to create very specific profiles to achieve the necessary hydraulic conditions for these cities.

With many of these sewer lines being constructed in the early 1900's and with continued city expansion and developments, some of these sewers do not follow the public right-of-ways and even cross underneath existing building and residential housing. Because of the corrosive nature of a sanitary sewer environment, these sewers are now approaching the end of their service life and are in need of structural rehabilitation. With the constraints of public disturbance of digging and replacing the pipes, many city engineers are exploring new methods of restructuring with corrosion resistant materials. The difficult challenge that each engineer faces is to come up with a rehabilitation solutions to match the existing profiles as closely as possible, but the solution also has to have the structural integrity needed to hold up long term.

This paper will review a recent project installed in Los Angeles. The City of Los Angeles has utilized the slipline method of rehabilitation for their sewers for decades

with circular fiberglass pipes. It has only been recently where they have started to utilize profile fiberglass pipes for these non-round sewer rehabilitation projects.

This paper will review the physical property requirements required a profile shaped slipline product including the material testing procedures and results. The design approach for the physical properties was an important part of this project which was a driving factor behind the physical pipe properties. In addition, the construction means and methods will be discussed with the focus on the field variables during the installation.

PROJECT BACKGROUND

This project was created to rehabilitate 1,795 feet of the West Los Angeles Interceptor Sewer (WLAIS) between the intersections of Venice Boulevard and Kelton Avenue and Venice Avenue and Overland Boulevard. The sewer was a 60-inch semi-elliptical pipe with a clay tile liner.

Traffic Control was a major element of this project. The sewer to be rehabilitated being located under Venice Boulevard is under the jurisdiction of the California State Transportation Department. Four options were evaluated including open cut removal and replacement, cured-in-place or cast-in-place lining, sliplinig with a semi-elliptical pipe and the alternative of leaving the pipeline as-is. The recommended option chosen was to rehabilitate the pipe by slipline with a semi-elliptical pipe.

The WLASI was constructed in in the 1920’s and begins at the North Outfall SEWER (NOS) at Jefferson and the North Outfall Treatment Facility. The WLAIS extends to the northwest through various streets and easements to the intersection of Pico Boulevard and Granville Avenue. Portions of the WLAIS on Overland Avenue and on Barry Avenue were rehabilitated in the 1990’s, which left the portion of the WLAIS between Overland Avenue and Barry Avenue for future rehabilitation.

Inspection of this section of the WLAIS showed that the majority of the tiles had fallen off and the concrete behind the fallen tiles had experience severe corrosion. The sewer flowing through this section during the inspection showed levels of half to three quarters full under peak dry weather conditions. Based on a study done by the Bureau of Sanitation, relief of this sewer was not going to be needed until 2050 assuming that a semi-elliptical slipliner would minimize the loss of capacity following rehabilitation. The study concluded that this section of the system would have no impact on the hydraulic capacity of the sewer.

DESIGN CONSIDERATIONS

The first part of any rehabilitation project is understanding the system which needs to be rehabilitated. Many decaying sewer systems are identified early enough where the rehabilitation is limited to lining of the system to removed infiltration of groundwater and to increases flow characteristics. Unfortunately, some systems also require restructuring of the existing pipes system.

Regardless, there are certain things which need to be assessed and identified during the initial investigations. Below is a list of some things which are typically evaluated in the new system include the following:

- Level of vertical and/or horizontal deformation
- Detection of cracks in the wall channel
- Channel silting
- Location and condition of laterals
- Curve radii measurements
- Location of inlets
- Determination of the recess, the groundwater level and type of loads per channel

For this project, based on the evaluation of the system, the following detail was provided as a basis for the design and construction of this project.

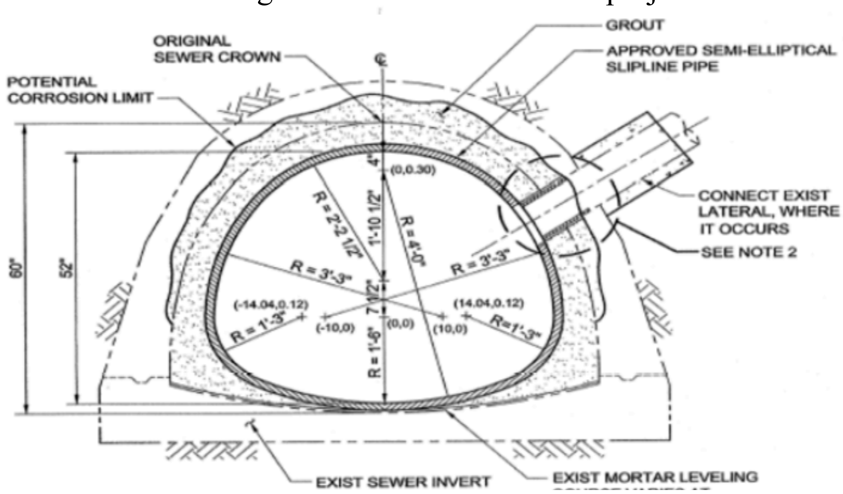

Figure 1: Existing Sewer to be Rehabilitated

Regardless, for sewer system to be rehabilitated investigation has to occur. For non-round pipelines, the existing channel dimensions are critical to the successful rehabilitation efforts because not only does it affect flow capacity, but it also affects the design of the product to be used for the reconstruction of the pipeline. The design and structural integrity of a non-round shape is more complex than designing a circular pipe due to the stress distribution when loads are applied creating deformation. A circular pipe has a very defined stress distribution when deflected, but and arching pipe has a much less predictable deformation when deflected. It is for this reason that the time and effort which goes in to the design and construction of these types of projects is much more significant and critical.

PRODUCT PHYSICAL PROPERTIES

The basic standard requirements for a fiberglass pipe material in a sanitary sewer environment are covered in various ASTM standards. For this project, the following standards were used as the basis for the performance requirements for the non-round fiberglass pipe product to be supplied.

- ASTM D3262 Gravity Sewer Fiberglass Pipe
- ASTM D4161 Joint Tightness Test
- ASTM D2412 Pipe Stiffness Test
- ASTM D3681 Strain Corrosion Test

These standards were utilized in creating testing protocol to ensure that the material properties of the non-round fiberglass pipe product would meet the design criteria for the project. The testing procedures and results required included the following standards:

- ASTM D2412 Pipe Stiffness
- ASTM D638 Axial Tensile Strength
- ASTM D695 Axial Compression Strength
- ASTM D638 Hoop Tensile Strength
- ASTM D790 Flexural Modulus
- Barcol Hardness
- Composition
- Joint Tightness

These basic tests are designed to verify the material properties and performance of the product to ensure that the product will perform as intended once installed. The first step in this process it to define the minimum performance requirement. This is done during the design phase of a project.

For this project, the primary solution for the rehabilitation of the non-round sewer was to utilize a fiberglass slipline product. This type of product was chosen due to the fact that these products are inherently corrosion resistance in sanitary sewer environments, but more importantly that can be shaped to practically any shape as show below.

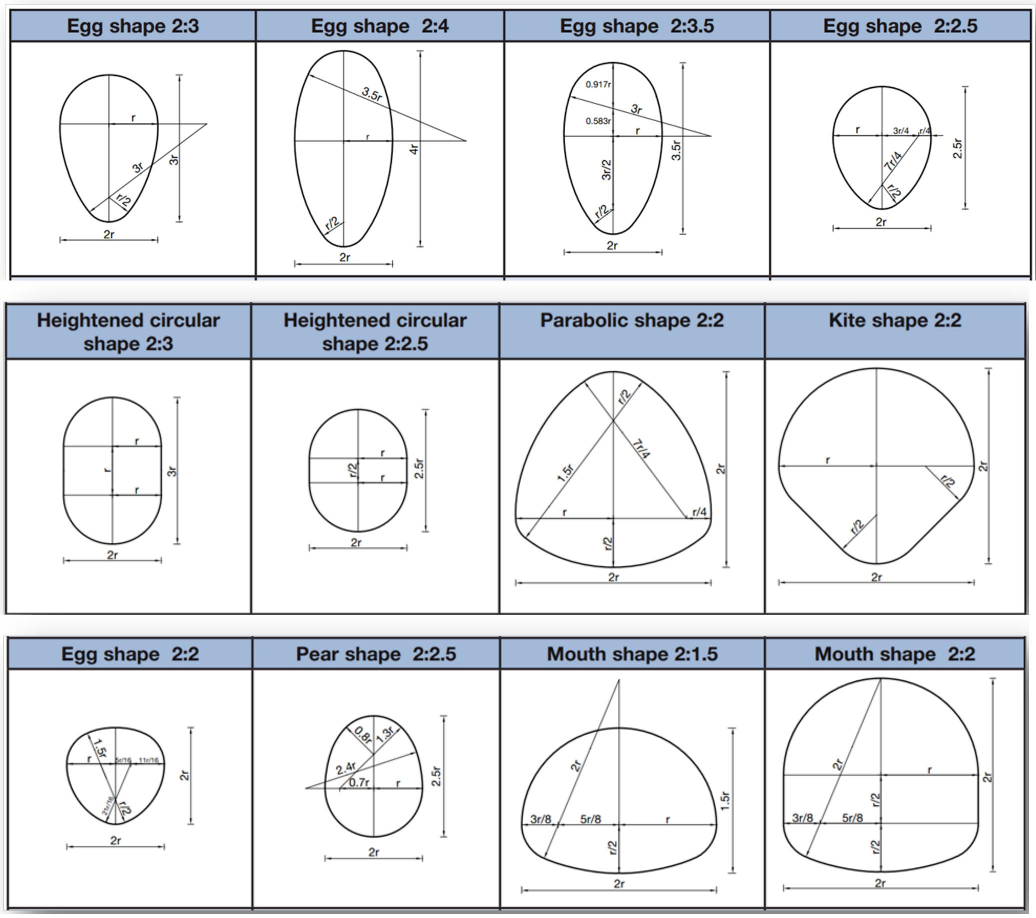

Figure 2: Sample Non-Round Fiberglass Pipe Shapes

The manufacturing flexibility of fiberglass into non-round shapes is extremely critical in being able to rehabilitate an existing profile shaped sewer so that the maximum capacity of flow may be maintained in the system. Just as important is the joint system for these non-round segments. These joint systems need to be able to resist infiltration, allow for articulation and have to be integral and low profile to the non-round fiberglass pipe segments in order to prevent from creating unnecessary annular space between the segments of pipe and the existing pipe. Below is an example of the typical joint system for non-round fiberglass pipes.

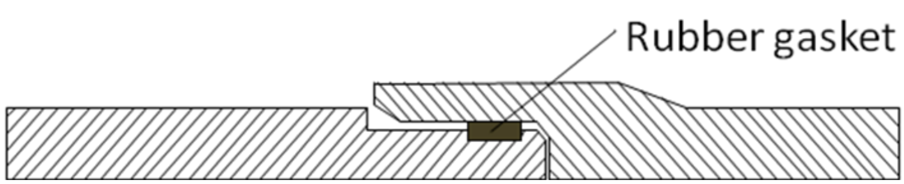

Figure 3: Integral Low Profile Gasketed Joint System

The next aspect of fiberglass pipe which makes it advantageous to use in non-round rehabilitation projects is that the products can be designed to have certain structural or physical properties due to the composite construction.

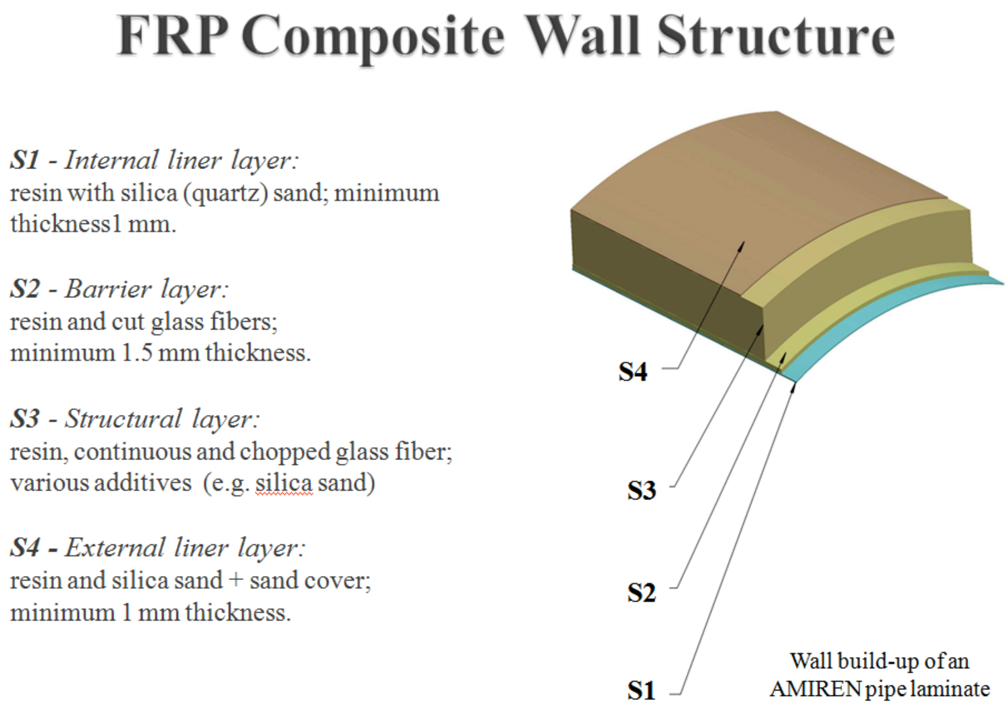

Figure 4: FRP Composite Wall Structure

The composition of the fiberglass laminate wall structure defines the physical properties of the finished product. This was one reason that the composition percentages of resin, sand and glass fibers were also part of the qualification process of the product.

For manufacturing of these shapes out of fiberglass, a mandrel is custom fabricated to match the profile of the existing non-round sewer pipe. Utilizing this manufacturing method, the pipe can be fabricated in practically any profile need to match the shape of the existing sewer pipe. The profile of the mandrel is sized to allow a gap between the host pipe and the new fiberglass slipline pipe.

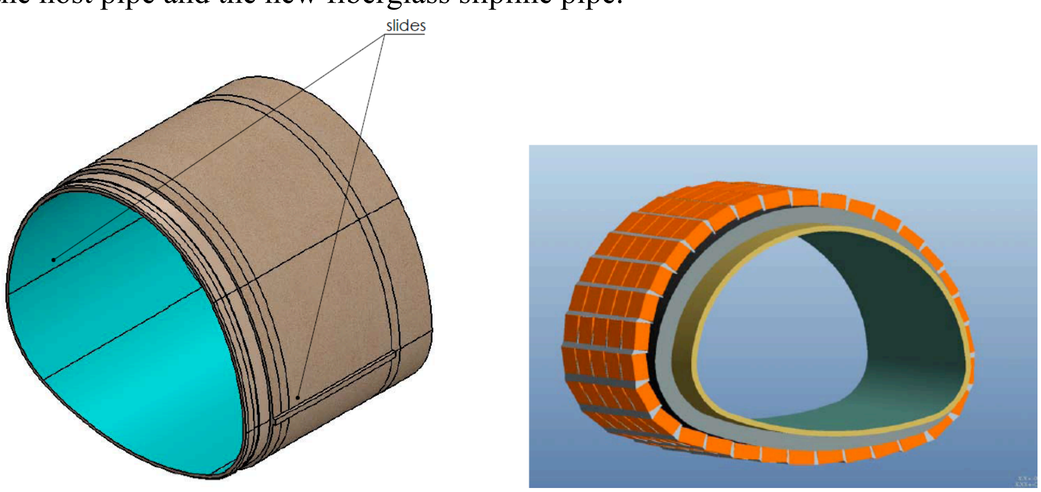

Figure 5: Non-Round FRP Pipe 3-D Profile and Post Installation Rendering

As part of this overall process, it is critical that the physical properties of the fiberglass pipe are verified through means of proof or qualification testing. For this project, prior to fabrication of the non-round fiberglass pipe for this project, samples were required to be produced and tested to show conformance to the original structural and performance requirements of the project. Below are the list of test and performance criteria require for the product prior to approval for production of the finished products to be shipped for this project.

No.	Test	Methodic	Minimum test requirement	Average test result
1	Profile deflection at 5%	ASTM D2412	24 psi	212.85 psi
2	Axial tensile strength Tensile modulus -axial Hoop tensile strength Tensile modulus -hoop	ASTM D638	3.600 psi(24.8 MPa) 171,015 psi (1180 MPa) 12.350 psi (85 MPa) 130,500 psi(900 MPa)	4,061 psi 195,800 psi 19725 psi 223,358 psi
3	Compressive strength	ASTM D 695	Axial – 11.500 psi (80 MPa) Hoop – none specifed	14,522 psi 17,690 psi
4	Flexural properties	ASTM D 790	Bending stress: 26.000 psi(180 MPa) Modulus: 1.160.000 psi (8000MPa)	33,222 psi 1,493,888 psi
5	Indentation hardness	ASTM D2583	Minimum 35	35.4
6	Composition	ISO 1172	Resin: 20 – 40% Glass: 10 – 30% Filler: 40 – 60%	29.5% 21% 49.5%
7	Joint tightness	Internal procedure/ASTM D4161 in part	pass	pass

Figure 6: Performance Test Results

As shown in the results from the testing, the fiberglass non-round pipe material and joint system passed with exceptional properties and performance. Below are a few pictures from the testing which was conducted on the finished product.

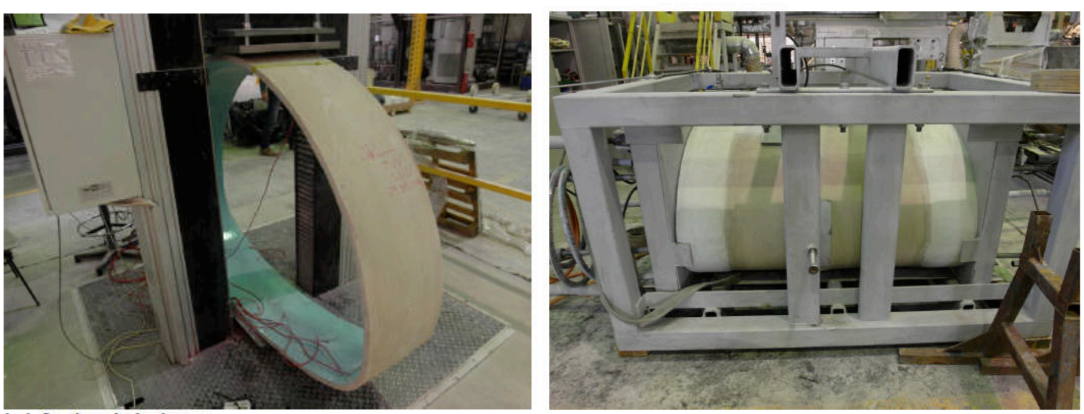

Figure 7: ASTM D2412 Pipe Stiffness Test and D4161 Joint Tightness Test

The testing of the product was conducted at the Flowtite/Amiren Fiberglass Pipe manufacturing facility in Poland and verified by a representative from the City of Los Angeles prior to the approval to release of production. With the approval, the product was then produced and shipped to Los Angeles where the contractor was

CONSTRUCTION

In July of 2015, the first containers of the non-round FRP slipline pipe arrived in Los Angeles from the Flowtite/Amiren Fiberglass Pipe manufacturing facility in Poland. Each container included for 4 segments of the FRP slipline pipe material. The material was removed from the containers by Colich and Sons, and stored at an off-site pipe yard. All 37 containers were received in approximately 30 days.

Permits from Caltrans were required for pit excavation and lane closures prior to construction. In addition, a 7 foot x 4 foot existing storm drain ran adjacent to the WLAIS on Kelton and Venice Boulevard. Excavation of the pits needed to accommodate the existing storm drain.

Installation of the FRP slipliner commenced in early September. Each pipe segment was transported by rubber tired construction equipment from the pipe storage area to the pit location which was approximately 1 to 2 miles away. The installation of the slipliner was able to be conducted during live flow condition. It took Colich and Sons less than 30 minutes to install a single segment of the slipliner pipe.

Figure 8: Installation of Non-Round FRP Slipline Segment

One of the biggest challenges was the curve section on the project. In order to install these sections on the project, the curve sections were excavated and each segment was place individually. The slipline pipe manufactured created bends using mitered sections of the pipe to fit the curved alignment. Manholes were also included in these section which were manufactured by the pipe manufacturer using the non-round slipline pipe material.

Figure 9: Installation Non-Round FRP Slipline Bend Segments and Manhole

Overall the project was able to be constructed on schedule and was a success for all parties. The time spent during the submittal, testing and coordination phase of this project was significant, but was well worth it. It is believed that this time spent going through every detail of the project and product submittal contributed to the success of this project.

REFERENCES

City of Los Angeles - Wastewater Conveyance Engineering Division (2010). "Pre-Design Report WLAIS Rehabilitation – Overton to Kelton W.O. SZC11522", Los Angeles, CA.