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Demonstration of an Innovative Large-Diameter Sewer Rehabilitation Technology in Houston, Texas

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1. ABSTRACT

While sewer renewal technologies currently being used for the repair, replacement and/or rehabilitation of deteriorating wastewater collection systems are generally effective, there is still room for improvement of existing technologies and for the development of new technologies. Many utilities are seeking innovative rehabilitation technologies, particularly for large-diameter pipes; however information about these emerging technologies is not always readily available. As part of the U.S. Environmental Protection Agency (USEPA)'s Aging Water Infrastructure Program, a field demonstration program of innovative rehabilitation technologies was initiated with the purpose of: (1) gathering reliable performance and cost data for new technologies; and (2) making the capabilities of these technologies better known to the industry. This paper describes the demonstration of an innovative, spray-applied, fiber-reinforced geopolymer mortar for rehabilitating a 60-in. reinforced concrete pipe approximately 25 ft deep in Houston, TX. The demonstration section was 165 ft of severely deteriorated pipe that terminated at a wastewater treatment plant (WWTP). Unique aspects of this project included: (a) the use of an innovative and emerging large-diameter structural rehabilitation technology on a severely deteriorated pipe located beneath a large open stormwater channel; (b) an independent, third-party assessment of the technology; and (c) difficult flow control issues at the WWTP.

2. INTRODUCTION

As trenchless technologies have continued to develop and improve over the past 40 years, the average rate of system renewal is still not adequate to keep up with the increasing needs of utilities. To meet these needs, many wastewater utilities are seeking innovative trenchless technologies to repair larger portions of their systems. However, information on emerging technologies is not always easy to obtain. The need for independently verified information on emerging technologies has been a focus of U.S. Environmental Protection Agency (U.S. EPA). Therefore, the U.S. EPA created an innovative technology demonstration program to demonstrate and evaluate the performance of emerging technologies under actual field conditions (Matthews et al., 2013). The field demonstration of innovative rehabilitation technologies was intended to make the capability of these technologies better known to utilities. The benefits include (U.S. EPA, 2012a; 2012b):

A. Benefits to Utilities

- Reduced risk of experimenting with new technologies and new materials on their own
- Increased awareness of innovative and emerging technologies and their capabilities
- Understanding of technology environmental impact and social cost
- Identification of design and quality assurance/quality control (QA/QC) issues

B. Benefits to Technology Developers

- Opportunity to advance technology development and commercialization
- Opportunity to accelerate the adoption of new technologies in the U.S.
- Opportunity to better understand the needs of utilities

C. Benefits to Consultants

- Opportunity to compare performance and cost of similar products in a consistent manner
- Access to standards and specifications for new technologies
- Education of best practices on pre- and post-installation procedures and testing

D. Benefits to Contractors

- Identification of successfully implemented QA/QC protocols
- Identification of successfully implemented installation procedures including surface preparations
- Understanding of regulations related to the use of new renewal technologies

This paper summarizes the results from the first of two innovative technology demonstrations and focuses on the application of a cementitious geopolymer spray-on lining called GeoSpray™ for a large-diameter (i.e., 60-in.) gravity driven sanitary sewer main.

2. TECHNOLOGY DESCRIPTION

The use of cementitious geopolymer spray-on lining has shown potential as a cost-effective means of rehabilitation for gravity sanitary and storm sewer mains. Cementitious linings can be applied to gravity sewers, but the corrosive environment makes the application of ordinary cement and concrete materials prone to deterioration (U.S. EPA, 2010). To combat the corrosive environment, innovative geopolymer materials have been developed, which have improved corrosive characteristics and have high material strengths.

The GeoSpray™ material is a high-strength, fiber reinforced geopolymer mortar that can be spray applied to structural thicknesses (Figure 1). GeoSpray™ forms a crystalline structural solution for a high resistance to acids and surface durability. It cures fast, providing shortened bypass time, which allows the pipe to be reestablished quickly. It is resistant to environmental factors such as heat and cold through batch temperature control. It can adhere to both organic and inorganic materials (e.g., properly prepared cement and brick surfaces) and can be used for filling voids and patching.

Figure 1. Corrugated Metal Pipe Before (left) and After (right) being Rehabilitated with GeoSpray™

The lining is designed for use in storm and sanitary sewer pipe rehabilitation applications in diameter ranges of 30 to 200 in. (750 to 5,000 mm). The renewal length will vary depending on the pipe diameter and required thickness and is typically between 100 to 300 ft (30 to 100 m) per day for a 1.5-in. thick lining. Bends of any degree are feasible, but straight runs are preferred. Laterals are plugged prior to lining and do not require reconnection, only the removal of the plugs. The lining is typically sprayed at a minimum thickness of 1.5-in. (38 mm) for structural repairs. Typically a 0.5-in. (12 mm) thickness would be applied if a lining is designed for additional corrosion protection of a structurally sound pipe. The work time is 60-90 minutes at 80°F. This demonstration allowed for an independent evaluation of some of the main benefits claimed and limitations cited by the manufacturer (Milliken, 2013a):

A. <u>Main Benefits Claimed</u>

- High flexural, bond, and ultimate strength
- 60 to 90 minute work time
- Low permeability
- Adheres to virtually any surface (i.e., brick, rock, concrete, corrugated metal, and cast iron)
- Surface does not need to be dry

B. <u>Main Limitations Cited</u>

- Requires a surface free of all dirt, grit, roots, grease, sludge, and debris
- Temporary stoppage of flow or bypass may be required
- Cannot be placed when the temperature is 37°F and falling without additional measures to maintain temperature above that threshold
- Materials contain highly alkali cement and chemicals that may cause eye and skin sensitization

The GeoSpray™ material is composed of a proprietary micro-fiber reinforced, dense geopolymer mortar. The dark gray mortar has a dry unit weight of 127.7 pounds per cubic foot (pcf) and a wet unit weight of 139.3 pcf. The largest particle size is 0.3 mm. A 100-lb bag is added to 18 lbs of water which yields 0.86 ft^3 or:

- 6.88 ft^2 at a thickness of 1.5-in.
- 10.32 ft^2 at a thickness of 1-in.
- 20.64 ft^2 at a thickness of 0.5-in.

Physical properties for GeoSpray™ that were evaluated under this project are shown in Table 1.

Table 1. Physical Properties of GeoSpray™ (Milliken, 2013b)

Property	Standard	Duration	Minimum Value
Compressive Strength	ASTM C39/C109	1 Day 28 Days	2,500 psi 8,000 psi
Flexural Strength	ASTM C293 (C78)	7 Days 28 Days	650 psi (1,200 psi) 800 psi (1,300 psi)
Modulus of Elasticity	ASTM C469	1 Day 28 Days	3,000 ksi 6,840 ksi
Set Time	ASTM C807	Initial Set Final Set	120 minutes 300 minutes
Sulfate Resistance (% expansion)	ASTM C1012	6 weeks	0.011%

3. TECHNOLOGY DEMONSTRATION

The field demonstration took place during the week of April 22nd, 2013 and the work was performed by IPR out of Texas. The bypass piping was laid out in the weeks before the demonstration and included three 16-in. high density polyethylene (HDPE) bypass pipes which converged into two pipes (Figure 2, left). Three large pumps ran continually to divert the flow from the 60-in. collection main to the wastewater treatment plant (WWTP) as this main fed directly into the WWTP. The bypass piping had to run parallel to an open channel before crossing the channel on a bridge and then heading to the WWTP (Figure 2, right).

Figure 2. Three Pipe Bypass Pipe Converging to Two (left) and Laying Parallel to an Open Channel

The 60-in reinforced concrete pipe (RCP), which was approximately 160-ft long, was severely deteriorated with rebar exposed and several infiltration locations gushing water prior to lining (Figure 3). Prior to spraying, the infiltration had to be stopped using a chemical grout material.

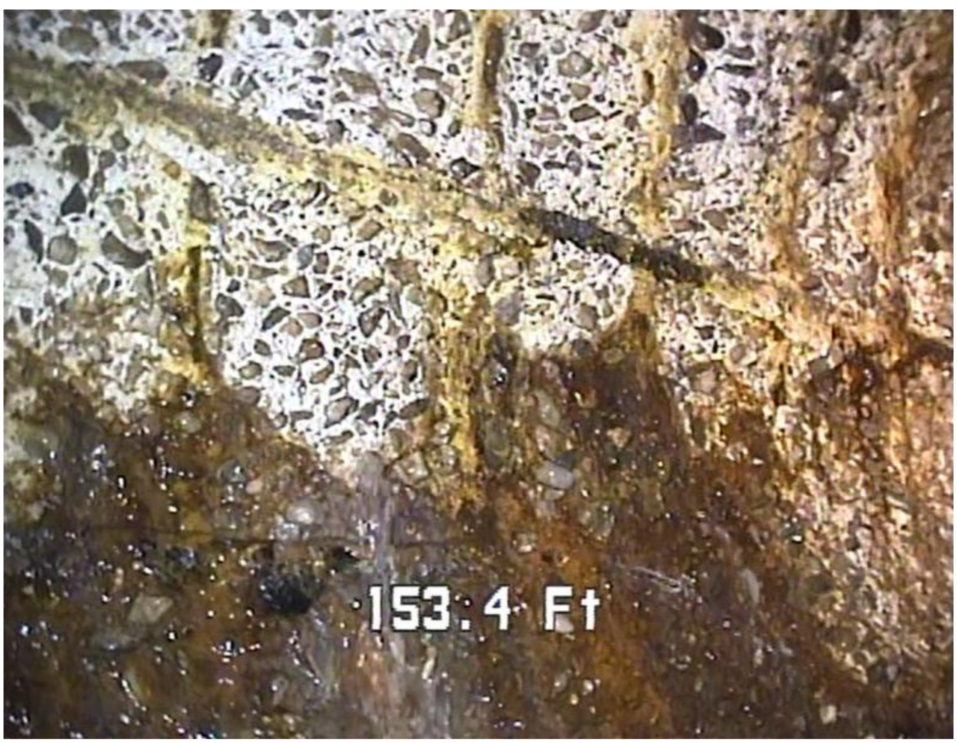

Figure 3. Typical Condition of the Host Pipe Prior to Lining

There were some flow control issues at the WWTP that were out of the control of the contractor that delayed the start of spraying. The WWTP operator could not control the flows for nearly a week. Once all the infiltration was removed and the WWTP gained control of its flow, the pipe was sprayed. The material was loaded into a hopper near the entry manhole, which is connected to a mixer that combines the dry material and water (Figure 4). The prepared material was then pumped to a spray head used to apply the material then smoothed by hand with a trowel.

Figure 4. Hopper (left) and Mixer (right) used for Preparing the Material

Prior to spraying, samples were collected from the spray nozzle (Figure 5). This included five cylinders for compressive strength via ASTM C39 (2009), five beams for flexural testing via ASTM C78 (2010), three cylinders for modulus of elasticity via ASTM C469 (2002), and a small cylinder for set time via ASTM C191 (2008). The samples were collected during a light rain and it was suspected that this additional moisture negatively impacted the test results.

Figure 5. Collecting Fresh Material from the Nozzle (left) and Preparing Samples (right)

The actual spraying operation took a total of four days and was conducted over a period of 11 days. Table 2 summarizes the spraying. A 2-in. coating was sprayed along the entire 160 ft section over the course of three days, and then an additional 1-in. coating was sprayed the entire length of the pipe on the final day. The post-lining inspection showed the pipe to be infiltration free, with no signs of steel reinforcement or cracking (Figure 6).

Table 2. Summary of Spraying

Date	Duration (mins)	Material (lbs)	Distance (ft)	Thickness (in.)
Saturday, 4/27/13	80	6,000	30	2
Tuesday, 4/30/13	190	12,000	70	2
Wednesday, 5/1/13	160	12,000	60	2
Tuesday, 5/7/13	300	18,000	160	1

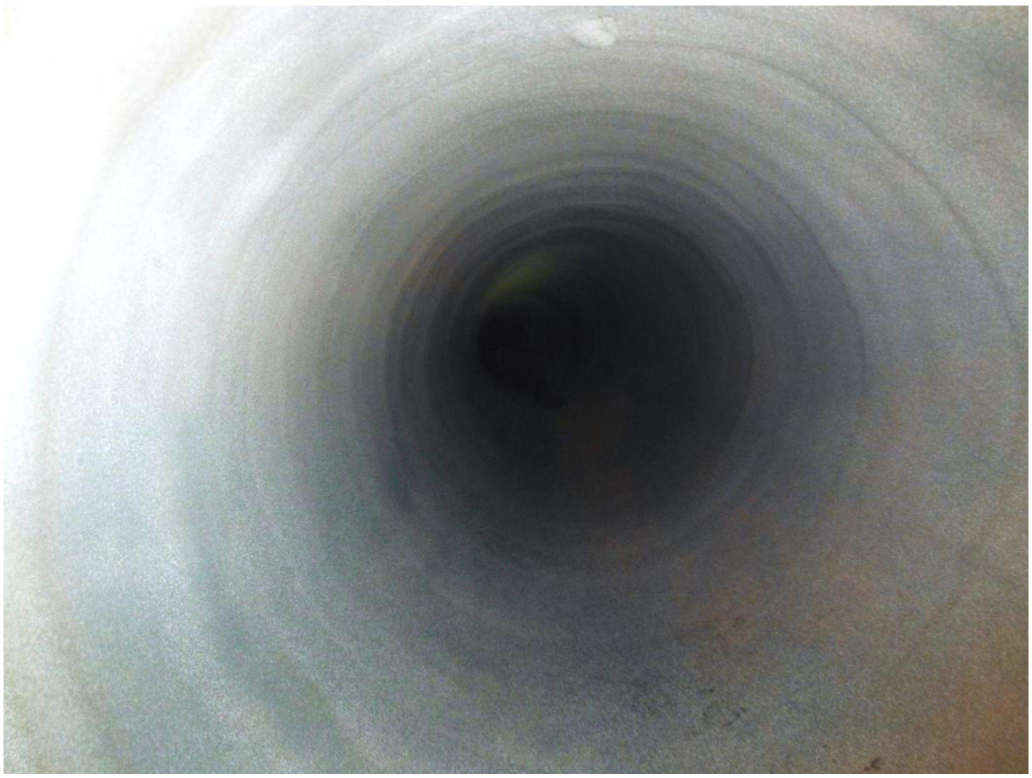

Figure 6. Post-Lining Inspection of Lined Pipe

4. TECHNOLOGY EVALUATION

This lining process is considered traditional, but the material used is classified as innovative in terms of maturity. The material is suitable for use in corrosive sewers due to its design to prevent microbial induced corrosion. The actual lining process is not a complex procedure; therefore, it is conceivable that contractors and/or wastewater utility personnel could be trained to install this product. The contractor's crew included a foreman to control the mixer, two laborers on the surface, and three laborers in the pipe (one spraying the material on the pipe wall and two troweling the material smooth). The quality assurance person responsible for collecting test samples and performing tests should be American Concrete Institute (ACI) certified and have experience in following ASTM procedures in handling, storing, and transporting the samples.

The initial results of the laboratory evaluation are shown in Table 3. The samples tested slightly under the manufacture-stated claims. It is believed this is attributed to the rain experienced during sample collection and preparation. It is also believed that the rain had no impact on the material sprayed in the pipe as the mixer was covered during the installation and the water ration was closely monitored during all spraying activities. Additionally, the material is designed for spraying; therefore pouring in the field without a shaker table can create voids, which might also impact this testing.

Table 3. Testing Results of the Material

Property	Standard	Duration	Test Value	Manufacturer Values
Compressive Strength	ASTM C109	28 Days	7,881 psi	8,000 psi (ASTM C39)
Flexural Strength	ASTM C78	28 Days	641 psi	800 psi (ASTM C293)
Modulus of Elasticity	ASTM C469	28 Day	6,500 ksi	6,840 ksi
Set Time (Final)	ASTM C191	Final Set	75 minutes	300 minutes (ASTM C807)
Sulfate Resistance	ASTM C1012	6 weeks	In Progress	

5. CONCLUSION

This demonstration resulted in the successful installation of an innovative, spray-applied, fiber-reinforced geopolymer mortar to rehabilitate a 60-in. RCP that was 160-ft long and 25-ft deep in Houston, TX. The host pipe was severely deteriorated with reinforcing steel exposed and missing and several locations of heavy infiltration. The independent evaluation of the technology showed it is a technically viable structural alternative to traditional repair and replacement methods.

6. DISCLAIMER

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