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APPLICATION OF GLASS-REINFORCED PLASTIC TO SEWER REHABILITATION

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ABSTRACT: The nation's largest sewers -- which are often also some of the nation's *oldest* sewers -- have historically been difficult to repair. Because a single line can serve 100,000 customers or more, cities can hardly afford to shut them down for long. They're also generally too large to benefit from traditional nondisruptive methods of sewer repair. Aging manholes and non-circular shaped sewers pose similar kinds of repair and replacement challenges.

This paper introduces readers to a glass-reinforced plastic (GRP) technology, which uses fiber-reinforced, filled, thermoset resin to create products that address these common sewer problems and cites successful projects completed in Chicago, IL and Fort Wayne, IN using this GRP technology. This paper provides lessons and information that should prove particularly useful to planners and designers looking for alternative solutions when faced with the challenge of rehabilitating large or irregularly shaped sewers, and aging manholes.

Introduction

The 90-year-old concrete sewer beneath South Commercial Avenue and East 95th Street in Chicago has much in common with thousands of other aging, large and irregularly shaped sewers throughout North America and the world.

First, these aging sewers have little or no written history. When they experience structural problems, municipal owners typically have no design documents or other early records to reference when they wish to make large-scale repairs. Irregularities and other "surprises" are common.

Second, these sewers serve large numbers of people. In the case of Chicago's Commercial Avenue/East 95th Street Sewer, for example, more than 100,000 residents on the city's southeastern side depend on it, each and every day. The challenges associated with repairing or replacing these lines is complicated by the vast numbers of lives that may be disrupted in the process.

Finally, because of their large size or irregular shape, these sewers cannot be easily or economically repaired using traditional nondisruptive methods of sewer repair. Because municipal owners generally need more – not less – capacity, they are also reluctant to use repair methods that might further compromise the volume of sewage that can flow through these lines.

It was for sewers like these that glass reinforced plastic (GRP) technology has been developed.

This paper will briefly describe two such sewers and the repairs that were made to them using products created by GRP technology. It also describes additional applications for GRP technology – including sliplining and manhole rehabilitation.

To understand the significance of these applications, it will be helpful, first, to understand more about this technology and the unique manufacturing process used to create it.

GRP technology and its applicability to sewer rehabilitation

GRP technology enables engineers to create structural solutions for sewers of virtually any shape and size ranging from 54- to 144-inches-in-diameter or larger, as well as for deteriorated brick and concrete manholes.

Composed of thermoset resin, fillers and fiberglass reinforcement, products made with the GRP technology used in the two projects that are being presented were manufactured using MVI™ (Multiple Viscosity Infusion) technology. This is a proprietary, patent-pending manufacturing method of making GRP that makes it possible to create a "sandwich" composite that layers several different materials in a single production process. The resulting material, which is durable enough to extend the life of a sewer or manhole by 50 to 100 years, is typically just an inch or so thick – minimizing any loss in capacity.

Figure 1: Cross-section of GRP laminate.

The first sewer rehabilitation products made using GRP technology were GRP panels that can be pieced together to rehabilitate large sewers of virtually any shape, including round, square, oval, horseshoe, rectangular and egg-shaped lines. Because each panel is custom-made to fit the host sewer, these panels can also be manufactured to negotiate bends, and adapt to changes in sewer cross-section geometry and pipe size – all factors that can come into play with older sewers. They can also be adapted for sewers of any length, and the distance between shafts can be long, providing proper safety precautions are taken.

Because of the flexibility in composite design and wall thickness range, sewers rehabilitated with GRP panels can withstand high loadings. GRP's flexural strength and modulus values, in fact, are several times greater than that of cured-in-place-pipe. GRP panels, as a result, are a particularly good choice in deep and/or non-circular sewers with high groundwater and/or soil loadings.

Figure 2: GRP segment (2 panels) used in Fort Wayne.

The manufacturing process

The GRP panels used in the Chicago and Fort Wayne projects– like other products using GRP and MVI technology – were manufactured in a factory setting using a closed-mold manufacturing process.

Getting the correct measurements for the panel size and thickness is critical, and must be factored into the installation schedule. That's because closed molds can only be fabricated after the cross-section of the entire host sewer is determined. Because of the inconsistency in the size of many older sewers, as well as other unknown variables, video inspections of a deteriorated line may not, by themselves, provide sufficient information to determine these measurements. Rather, measurements are often best taken after a sewer has been cleaned of debris so that possible missing sections and other problem areas are revealed and can be accommodated in the panels' design.

Once panel dimensions were determined, factory personnel completed the mold and produced the panels. The molds themselves are constructed primarily of fiberglass and/or steel. The surfaces of the molds are sprayed with a gel coat, followed by layers of glass corrosion veil and glass fiber reinforcement.

The inner and outer molds are then assembled with a void space equal to the desired thickness of the panel. The void space is then filled with resin and a filler (typically sand) and the assembly is set aside to allow time for resin curing. Once cured, the panel is demolded and trimmed, and the manufacturing process is complete. Depending on the size and scope of the project, it can take from 6 to 8 weeks from the time the mold order is placed to the time when the finished panels begin arriving at the job site.


Figure 3: Panels in manufacturing facility

Once at the jobsite, the panels are lowered into a sewer and, using a man-entry procedure, fitted together inside a sewer to form a full segment in the shape of the original sewer. The annular space between the original sewer and the new panels is then filled with concrete grout to complete the installation.

In addition to the use of GRP panels as described above and in the case studies included later in this paper, new applications for GRP technology have been developed. They include manhole rehabilitation and sliplining.

Sliplining

The closed form MVI technology used to make GRP panels has also been applied to the development of a GRP sliplining product.


Figure 4: Non-circular slipline pipes

Sliplining, another process used to repair damaged sewer lines, has historically been performed using one of several different pipe materials, including circular GRP, polyvinylchloride (PVC), polyethylene (HDPE), fiberglass, clay and ductile iron. The slipline pipe, which is either pushed or pulled into place, is used to correct a variety of structural problems. This approach is best-suited for rehabilitating sewer segments that have only minor bends, a fairly regular cross-section and where a slight decrease in the inside diameter of the pipe segment can be accommodated.

Historically, sliplining has also been limited to pipes that are circular in shape. Noncircular pipes can be sliplined with a circular-shaped liner, but not without a relatively substantial loss in flow capacity. To date, custom made, non-circular slipline pipes have either been not available or not cost-effective.

These are problems that GRP sliplining is able to address. Unlike the GRP panels, which are pieced together to form a complete segment inside a sewer, the GRP sliplining product is custom-manufactured as a single, 360-degree pipe segment in the shape of the original sewer.

This product is expected to offer multiple advantages for municipal owners with medium to large non-circular sewers. The GRP sliplining product for non-circular sewers will often be able to be installed without bypass pumping or flow diversion. Because it conforms to the shape of the original pipe, it also results in minimal cross-section reduction. It also is safer than many solutions to install, requiring little or no worker entry into the sewer.

Best-suited for sewers with equivalent diameters ranging from 42- to 96-inches, GRP slipining pipes generally range from six to 12 feet in length, and can be pushed, one after another into a host pipe to a maximum length of approximately 1,000 feet.

Manhole rehabilitation

GRP technology has also been applied to the development of a full structural solution for deteriorating manholes constructed of concrete, brick or other similar materials.

Figure 5: GRP manhole insert

Like the other GRP products, the monolithic GRP manhole structures are comprised of thermoset resins, fillers and fiberglass reinforcement. Together, these materials form a high-strength composite that offers superior corrosion-resistance. Standard GRP manholes are supplied with an internal diameter of 42 inches, making them suitable for the rehabilitation of standard 48-inch-diameter manholes. The same materials and construction process can also be used to fabricate other manhole sizes.

The installation process for a GRP manhole is comparatively simple. Before it is installed, the existing ring/cover and corbel section of the original manhole are removed. The existing manhole requires no special surface preparation. After preparing the manhole invert and cut-outs for incoming and exiting piping, the new manhole is simply lowered into the old manhole and set in a quick-setting grout.

Following the reconnection of all existing lines to the new manhole, the small void between the old and new manhole is backfilled with a cementitious grout. The new manhole can then be backfilled following the placement of standard grade rings and a ring/cover.

Because the new manhole has no field joints, it helps ensure the elimination of infiltration and exfiltration. It is also able to withstand full external loading and to resist the attack of hydrogen sulfide and other common corrosive sewage byproducts.

GRP technology in practice: two case studies

Case Study #1: Commercial Avenue/East 95th Street Sewer Rehabilitation, Chicago, Illinois

By the time the large combined sewer at Commercial Avenue and East 95th Street in Chicago suffered a complete structural failure in 1999, the Chicago Department of Sewers (known now as the Department of Water Management) understood enough about its poor condition to construct a parallel 15-foot by 12-foot sewer to supplement it.

Still, engineers who inspected the collapsed pipe's condition came away astounded by the amount of debris that had accumulated inside. They also observed that the sewer had more irregularities than expected. While essentially circular in shape, the sewer's walls were frequently out of alignment, and the pipe's diameter changed abruptly from 9 feet to 10-½ feet, without the benefit of a manhole. In addition, the 9-foot sewer had a 45° bend at South Commercial Ave. and 94th Street, and a 90° bend at Commercial and 95th Street.

Because of the sewer's large size, irregularities and particularly poor condition, cured-in-place pipe and other rehabilitation methods commonly used on Chicago sewers were ruled out on this project. Instead, Department of Water Management officials researched alternative solutions. Their research led them to GRP technology**.** Under a contract awarded to Insituform Technologies, GRP panels manufactured using the MVI technology just described were used to rehabilitate 1,100 feet of 9-foot-diameter and 340 feet of 10 ½ -foot-diameter cast-in-place concrete sewer.

As sections of the sewers were cleaned and repaired, crew members took measurements to determine the GRP panel dimension requirements. In addition to the expected irregularities in line and grade, workers discovered through this process that some areas of the 9-foot-diameter sewer had experienced significant vertical deflection. At one point, for example, the 9-foot-diameter sewer measured 7 feet, 11 inches, top to bottom.

Once measurement information was plotted, engineers determined that 8-foot-diameter panels could be installed in the 9-foot sewer, and 9 ½-foot-diameter panels could be installed in the 10 ½-foot sewer. Even given this annular space allowance, the fit would be tight in some areas. Engineers also specified that the panels be manufactured in three different lengths -- 4 feet, 6 feet and 8 feet. The panel size used in a given segment would be dictated by the section's location and condition. When panels had to be transported through bends, for example, shorter sections would be used.

Once engineers determined the panel size and shape, they calculated the panel wall thicknesses to meet the parameters defined in the project contract documents. The panels were then manufactured in semi-circular shapes -- an upper and a lower panel that would later be joined together to form the 360° liner. In all, 620 panels would be pieced together to create the 8-foot diameter finished pipe that would be installed in the 9-foot diameter sewer. An additional 134 panels would be joined to create the 10 ½-foot-diameter sewer's lining.


Figure 6: Lowering equipment into shaft

After cleaning the sewer, workers created sandbag dams that would help divert the sewer's flow into the new parallel sewer. With some exceptions, flow of approximately 50 MGD was re-routed each day during the cleaning and rehabilitation process. Beginning in February 2003, crews methodically lowered individual panels down one of the two circular access shafts that had been dug during the cleaning process.

Individual panels were set in place and blocked into position using wooden blocks. Upper and lower panels were then fastened together by tongue and groove joints and secured with epoxy resin. Full segments were secured to adjoining segments by bonding the circumferential joints with epoxy. When weather permitted, about 50 feet of pipe, on average, were installed a day.


Figure 7: Transporting a panel in 9 ft. sewer

To re-establish service connections, crews cut the proper-sized hole in the panel wall, inserting a PVC stub pipe and sealing the PVC pipe to the panel face with epoxy. The PVC pipe was then trimmed flush. When the panels in a given reach had been installed, the annular space was filled with cementious grout.

Physical and managerial challenges drove the South Commercial Avenue / East 95th Sewer Rehabilitation Project from its beginning through to its end. Excellent coordination among the City, its contractor and the MWRDGC, however, all contributed to the project's successful completion. The City of Chicago expects to consider GRP technology on future projects of similar scope.

Case Study #2: Taylor Street Sewer Rehabilitation, Fort Wayne, IN

The Taylor Street combined sewer is a 100-year-old, 72-inch-diameter, two-ring brick sewer located under a busy multiple-lane road in Fort Wayne, Indiana. The sewer makes a 90° turn at the intersection of Taylor and Nelson Streets near downtown Fort Wayne.

Although crown cracks are not uncommon in large brick sewers, an assessment found that this particular line exhibited crown cracks with significant vertical deflection. In addition to mortar loss and a severe diagonal crack in the 90° bend, the sewer also had a 4-foot by 5-foot section of bricks missing.

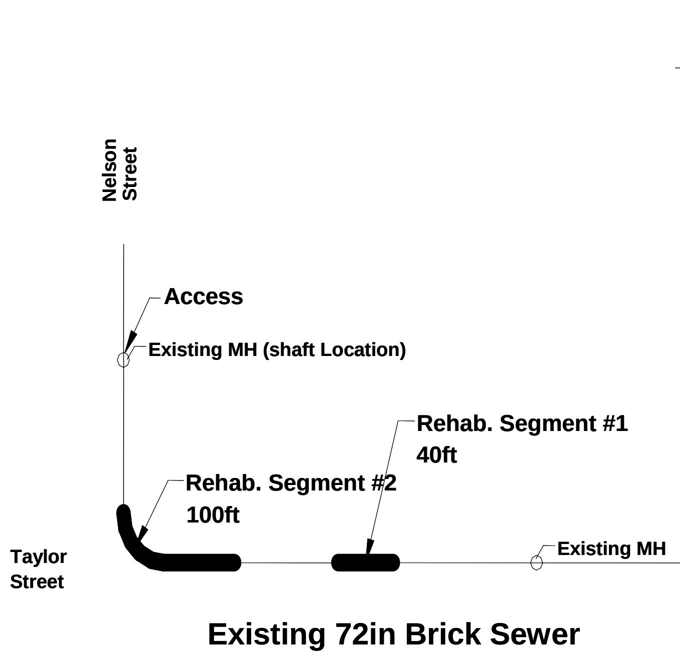

Figure 8: Site layout

Based on their assessment, engineers recommended rehabilitating approximately 140 feet of the sewer at two locations. After considering a variety of alternatives, GRP panel technology, was determined to be the only alternative to meet all the project's criteria; it would (1) restore the sewer's structural integrity, (2) maintain or increase flow capacity, (3) meet the project's budgetary requirements and (4) prevent excavation on Taylor Street.

To determine GRP panel dimensions, Affholder, the contractor, worked with the city and Greeley and Hansen, its engineering consultant, to determine the most appropriate cross-section for the installed GRP panels. After analyzing the sewer's calculated flow rates at different points before and after rehabilitation, the team chose 68.5-inch by 62-inch panels with a wall thickness of 0.83 inches. This size allowed for a minimum annular space of 1.5 inches in most locations and provided a post-rehabilitation flow rate equal to or greater than the flow rate in the original sewer.

Given the small size of the manhole entrance and the need to carry the panels around the 90° bend, a two-piece panel system was chosen; each 180° panel segment was two feet long and weighed approximately 150 lbs. The upper and lower panel sections would be connected by an axial joint of a tongue and groove configuration and attached to the adjacent segments with bell and spigot-designed circumferential joints. Both the axial and circumferential joints would be bonded together with epoxy.

After cleaning the sewer, the construction crew lowered the panels down a shaft at Nelson Street and then carried them through the sewer and around the 90° bend to the designated location under Taylor Street. Once the panels were set in place, they were bonded with epoxy. When the entire first 40-foot section was installed, workers grouted the annular space with a cementitious grout.

Figure 9: Lowering a panel into shaft

Workers then addressed the second part of the rehabilitation project: a 100-foot section of pipe beneath Taylor Street and the 90° bend at the Taylor Street/Nelson Street intersection. Seventeen trapezoidal-shaped panels had been custom manufactured that, when fitted together, formed a 90° bend. These panels had first been assembled on the manufacturing plant floor to verify the proper alignment.

After this section was installed, the contractor completed five lateral reinstatements, including one 30-inch connection in the 90° bend. Each lateral was then reinstated with an inserted PVC pipe set in place with epoxy. After the epoxy cured, the PVC pipe was cut flush with the inside surface of the panel and the annular space grouted.

Figure 10: Inspecting the 40 ft section

Under the terms of the contract, the project was to be completed in 120 calendar days. Fifty-six days after the “Notice to Proceed” order was given, panels began arriving on the jobsite. It then took 39 days to install the panels and reinstate the connecting sewers. Adding in shaft closure and site cleanup, the entire project was completed in about 113 days.

Conclusions

The Chicago and Fort Wayne projects are just two of many thousands of large and irregularly shaped sewers in this country. Because these sewers have historically been difficult to repair – and because of the limited number of affordable solutions available to them – municipal owners have frequently deferred major repairs on these sewers. Similarly, there are manholes across the country that have reached the end of their useful life and are in need of replacement.

While relatively new to this country, GRP technology shows great potential as an affordable alternative to municipal owners who face these problems. Already, the American Composites Manufacturers Association has recognized GRP's ability to expand sewer rehabilitation solutions, honoring it in its 2003 Awards for Composite Excellence competition. Given its ability to return structural integrity to large and irregularly shaped sewers and manholes, GRP technology gives municipal owners a new reason to consider addressing some of their most challenging sewer needs.