EMERGENCY SANITARY SEWER TRUNK REPAIR

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During the second week of December 2008, the city of Atlanta, GA, experienced a severe storm with a heavy downpour. During the storm, a portion of the 90 in. (2290 mm) sanitary sewer trunk burst and overflowed. The pipe had been repaired previously for the same reason. Upon immediate inspection, the control joint at the three o'clock position and cracks at the crown of the pipe appeared to emit the most overflowing liquid.

This 90 in. (2290 mm) sanitary sewer trunk line was built in the 1930s. The pipe's 8 in. (203 mm) thick walls were cast in place with nonreinforced concrete. Construction joints appear at the three and nine o'clock positions on the pipe. A portion of the pipe's circumference is embedded in the earth. The embedded portions of the pipe varied from 45 to 70%, depending on the pipe's relative elevation to the ground. The weight of the earth offered natural strengthening by placing various portions of the pipe underground in compression.

PIPE DAMAGE

Heavy storms resulted in a spike in the water flow through the pipes, causing additional circumferential stresses in the pipe. This resulted in cracks in the pipe. Emergency repairs were commissioned on Saturday, December 13, 2008. The overflowing water was a concern for the city, as it had the potential to cause damage to the community within the proximity of the sewer pipe.

The need for repairs to approximately 600 ft (183 m) of the existing 90 in. (2290 mm) concrete sanitary sewer trunk was identified. The repairs were critical, as this pipeline provides sewer service for thousands of homes and businesses in the area.

REPAIR STRATEGY

Three separate sections of pipe used three separate repair strategies. The first repair section, which measured approximately 160 ft (48.8 m), was repaired with the following procedure:

- To prepare the pipe's surface, a 3 to 4 in. (76 to 102 mm) deep section of previously placed concrete topping around the cracks was removed;
- Steel plates (0.25 x 12 in. [6 x 305 mm] wide x various lengths) were anchored on both sides of the cracks with 0.5 in. (13 mm) diameter stainless steel anchor bolts;
- Shear pins (3/8 in. [9.5 mm] threaded studs) were installed for adding bond strength between the new and old concrete; and
- A concrete cap was placed with embedded wire mesh.

The second section of pipe, measuring over 200 ft (61 m), was repaired by the method as stated in the first repair section, with the following two modifications:

- 3/8 in. (9.5 mm) screw anchors were used for shear strengthening; and

Fig. 1: Ninety in. (2290 mm) sewer pipe located in Atlanta, GA

Fig. 2: Use of steel plates followed by placement of fresh concrete

Fig. 3: Steel mesh was added prior to the concrete placement

Fig. 4: Application of the repair material

- Fiber mesh was added to the concrete.

The third section of pipe, measuring approximately 240 ft (73.2 m), had a longer section of the pipe, which was above grade compared to the other sections. This section of the pipe needed a comprehensive repair strategy.

The absence of structural information coupled with the time-sensitive nature of this project challenged the engineer to formulate repair strategies and evaluate the pros and cons.

SELECTION OF THE CARBON FIBER-REINFORCED POLYMER (CFRP) REPAIR STRATEGY OPTION

For the third section of the repair, a comparative assessment was done. This section was a more challenging repair because the majority of this section of the pipe was above grade and lacked the support of the earth present in the other sections. The recommendations made by the engineer that led to the selection of this method are summarized in Table 1.

DESIGN CONSIDERATIONS FOR STRENGTHENING WITH CFRP

The existing 90 in. (2290 mm) sanitary sewer pipe has an average flow of 29 to 41 million gal. (110 to 155 million L) per day with a peak flow of 93 million gal. (352 million L) per day. The estimated circumferential pressure exerted on the pipe flowing full without any additional head pressure or surcharge is approximately 2000 lb/ft (2976 kg/m). This flow cannot be bypassed or diverted at any time. Therefore, all repair work needed to be performed from the outside of the pipe. The job-site constraints made bringing in heavy equipment impossible, and sensitivity to the environmental ecosystem had to be taken into consideration.

The design engineer selected a unidirectional, 12 in. (305 mm) wide CFRP fabric to be installed using the dry layup method on the circumference of the pipe at 24 in. (610 mm) on center. This left a 12 in. (305 mm) wide open space between strips. Additional 3 ft (0.9 m) long strips were used in this space to "stitch" epoxy-filled cracks together. CFRP rod anchors were installed to provide additional bond strength.

PREPARATION

Any surface defects or pipe blemishes were repaired and smoothed out by using a low-shrinkage repair mortar. In instances where the application thickness and surface area were small, an epoxy was used.

TABLE 1: COMPARISON FOR DIFFERENT PIPE REPAIR METHODS

Fiber-reinforced polymer (FRP)	Similar to previously used method in first and second sections noted previously
1) Properly installed FRP will have much higher strength with external support uniformly distributed over the applied area, minimizing any local future cracking.	1) Marginal load-carrying capacity.
2) Upon completion of the repair, pipe repair would not be unsightly and ultraviolet (UV)-resistant color coating will be applied over the entire repair sections.	2) Because no concrete topping was considered for this repair segment with stainless steel plates, it would not be an aesthetic repair.
3) Installation would not be as intrusive as the other repair method.	3) More intrusive and damaging to the pipe, increasing the chance of future cracks (that is, drilling for anchor bolt installation).
4) After extensive negotiations with the contractor, the cost would be approximately $77,444.	4) Lower cost ($60,000).

Fig. 5: Route and seal with a swellable water stop

Fig. 6: Swellable water stop capped with an epoxy

Fig. 7: Dry layup technique used to install the fabric

Fig. 8: Multiple layers of CFRP installed

Fig. 9: Three-eighths in. (9.5 mm) CFRP rod installed in the groove

Fig. 10: The repaired pipe after being coated with a water-based acrylic coating

All large cracks were routed and sealed with a swelling water stop and covered with a high-modulus epoxy paste. Smaller cracks were routed and sealed with epoxy.

INSTALLATION OF CFRP

Upon completion of the necessary surface preparation, 12 in. (305 mm) wide CFRP fabric was installed on the entire exposed length of pipe. Where circumferential cracks were observed, the unidirectional CFRP fabric was installed longitudinally prior to installing the primary circumferential 12 in. (305 mm) wide CFRP fabric. To ensure complete bond, 3/8 in. (9.5 mm) carbon fiber rods were encapsulated with epoxy into reglets at the ends and on top of the 12 in. (305 mm) wide circumferentially oriented strips. All surfaces received two coats of an acrylic coating to protect the system from UV rays.

QUALITY CONTROL

Inspection and repairs were made to the air pockets, as directed by ACI 440.2R-08. This included direct tensile pulloff testing to ensure that adequate bond was achieved. During the course of the project, another heavy rain event occurred and a few additional weak spots were revealed, which were subsequently repaired.

REPAIR SUCCESS

Emergency repairs in and of themselves always pose some degree of difficulty. This project challenged the team to devise a durable and timely solution (refer to Table 2) that would keep the inhabitants of the adjacent community protected from any disruption or consequential damages. The comparison of the repair system for different sections of the pipe provided the city with the most optimal repair based on the requirements. The engineer did not opt to generalize the repair strategy—an aspect that can be easily overlooked in projects that are crunched for time. The repair strategy on this project may have opened the door to what may be a solution for many municipalities and towns across the country.

Atlanta Sanitary Sewer Trunk Pipe

OWNER
City of Atlanta
Atlanta, GA

PROJECT ENGINEER
Brown & Caldwell Engineering
Atlanta, GA

REPAIR CONTRACTOR
Engineered Restoration, Inc.
Lawrenceville, GA

MATERIAL SUPPLIER
Sika Corporation
Lyndhurst, NJ

TABLE 2: TIMELINE

Milestone	Section 1 and Section 2 Repairs	Section 3 Repairs
Damage reported to the city	12/11/08	12/11/08
Engineering assessment	12/13/08	1/13/09
Invitation for bids	12/15/08	1/15/09
Contract awarded	12/15/08	1/17/09
Mobilization	12/15/08	1/18/09
Project completion	1/14/09	3/31/09